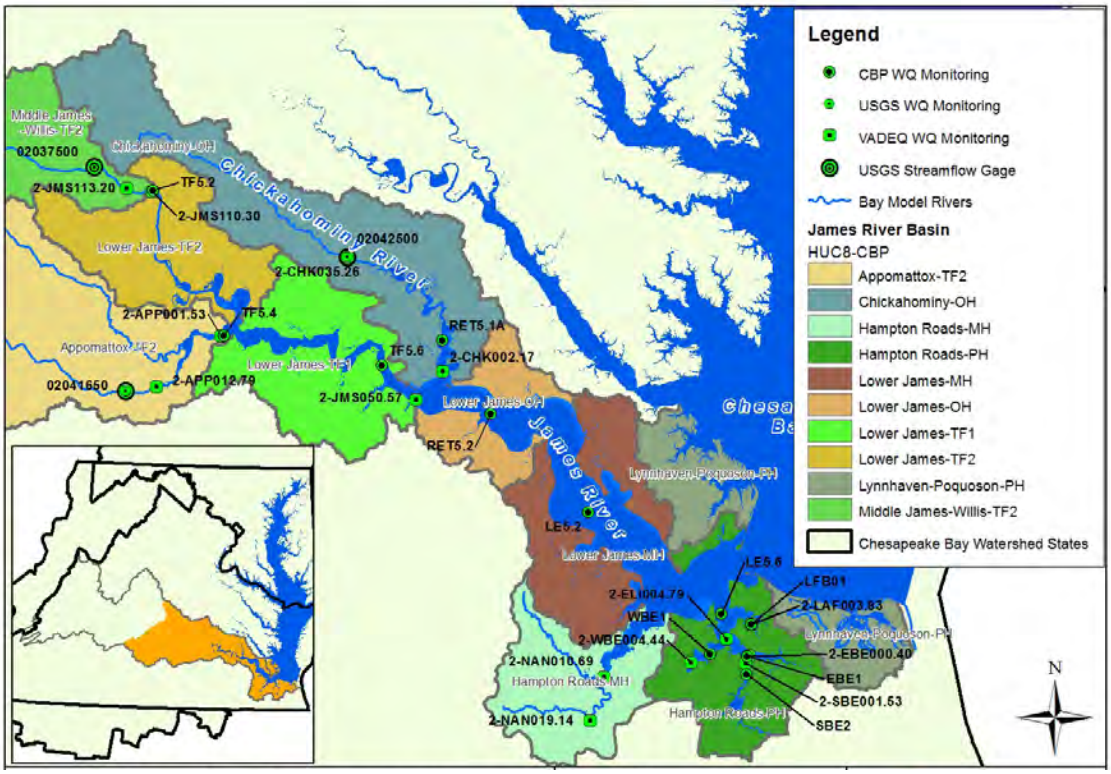

Modeling Support for the James River Chlorophyll Study

Task 2 – Empirical Data Analysis Report

Prepared for:
Commonwealth of Virginia
Department of Environment Quality

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Executive Summary

Long term river flow, water quality, and phytoplankton data from the James River were analyzed to characterize conditions in the James River basin as part of the "Modeling Support of the James River Chlorophyll Study". Over the period 1985-2010 TN and TP fall line loads at Cartersville, VA have decreased significantly with a more rapid decline in TP (Figure E1).

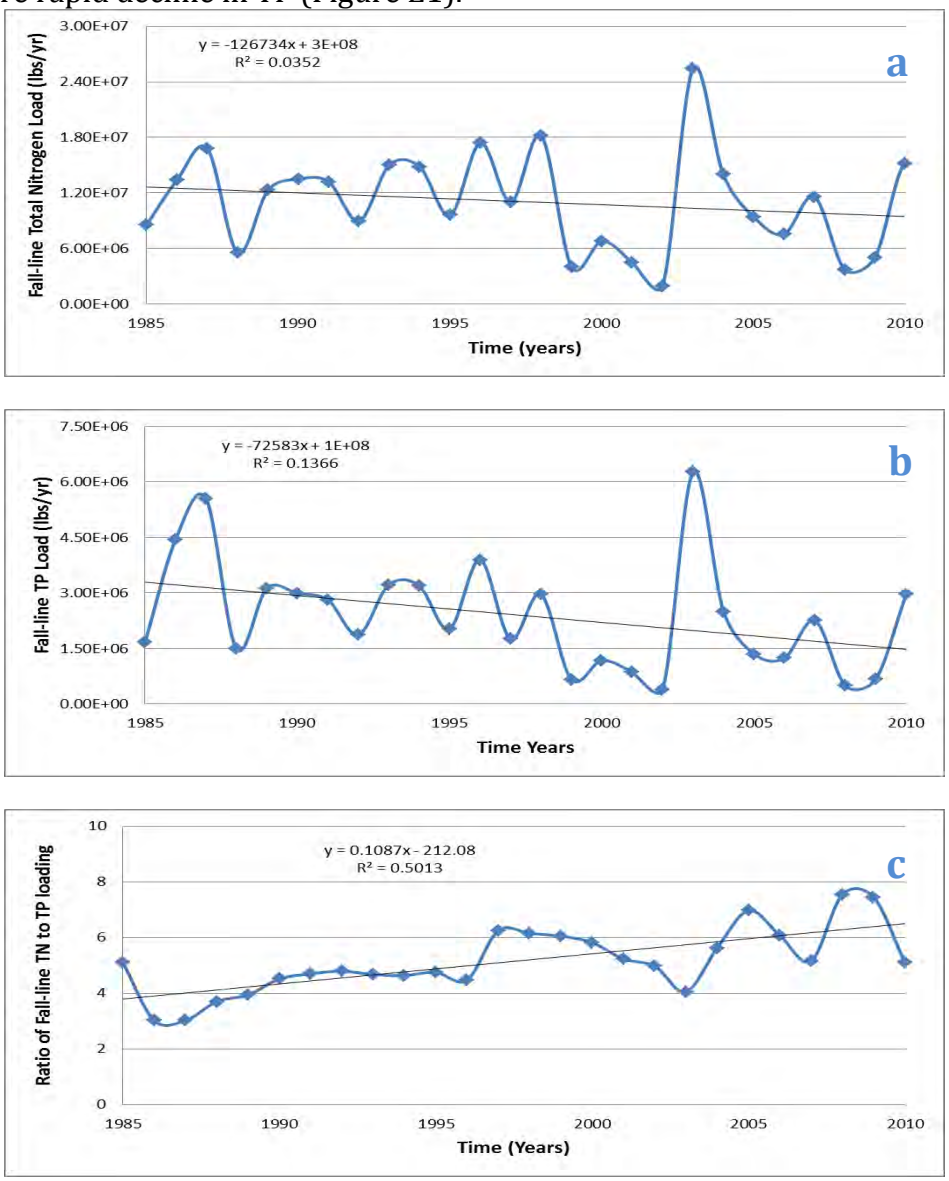


Figure E1 - Trends in James River Fall-line Nutrient Loads.

Trends in nutrient concentration were calculated at four stations in the tidal fresh, mesohaline, polyhaline, and the Elizabeth River (Figure E2). The time period for the trend calculation was shortened to 1995-2010 due to analysis changes in 1994 that may have resulted in a step trend. There were no significant trends in TN in the area of the James with the exception of a declining trend in the Elizabeth River. TP concentrations declined significantly in the tidal fresh, mesohaline, and polyhaline

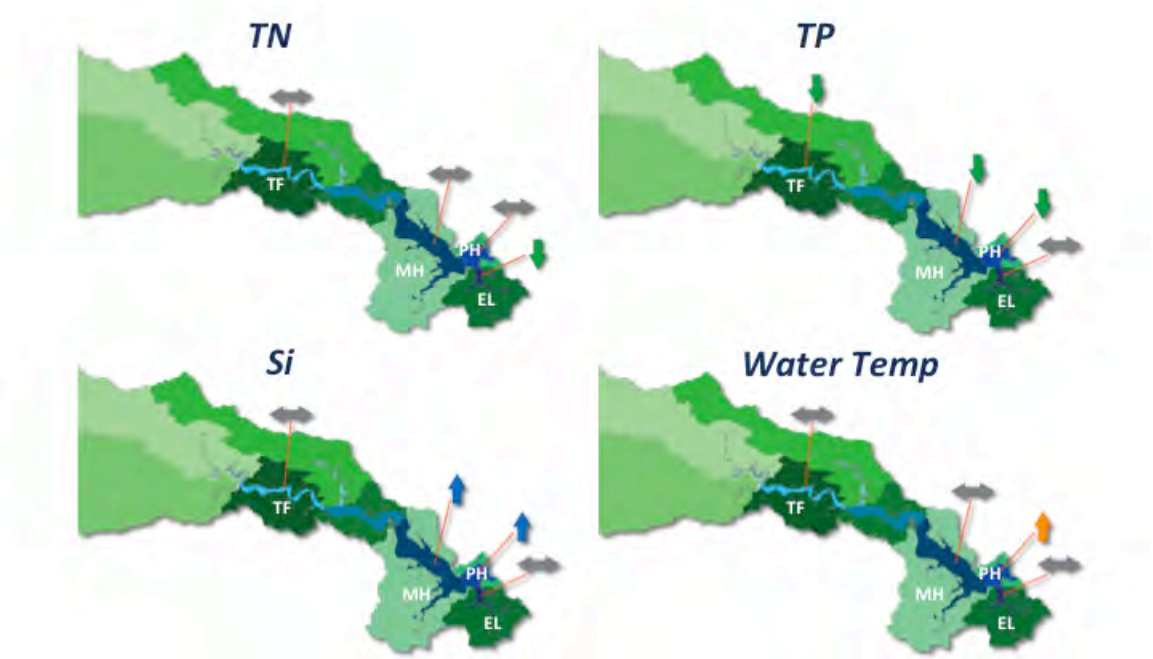


Figure E2 – Long-term trends (1995-2010) of TN, TP, Si, and Water Temperature in the tidal fresh, mesohaline, polyhaline, and Elizabeth River sections of the James River. Arrow direction indicates trend direction.

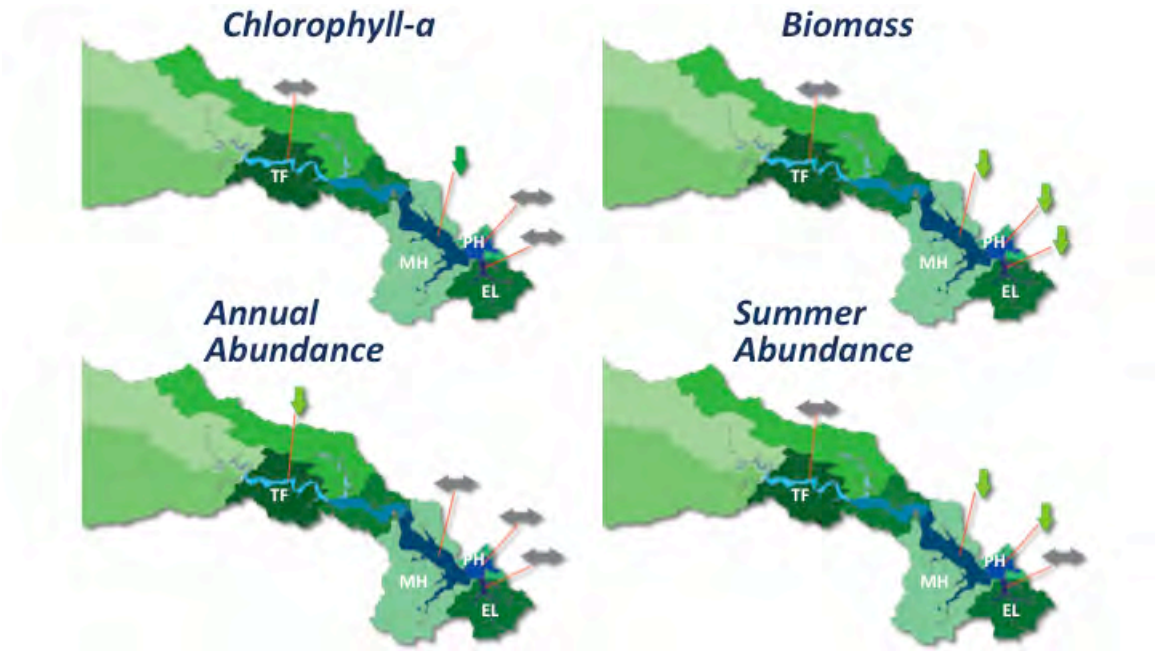


Figure E3 – Long-term trends (1995-2010) of chlorophyll-a, biomass, annual abundance, and summer abundance in the tidal fresh, mesohaline, polyhaline, and Elizabeth River sections of the James River. Arrow direction indicates trend direction.

and remained unchanged in the Elizabeth. Chlorophyll-a declined in the mesohaline while dissolved silica increased in the mesohaline and polyhaline. There was an increasing trend in water temperature in the polyhaline.

The phytoplankton data were analyzed for changes in abundance and carbon biomass over time (1995-2010) in the same tidal regions that the water quality data was analyzed (Figure E3). There was a decline in phytoplankton abundance in the Tidal Fresh and declines in summer abundance in the mesohaline and polyhaline. Phytoplankton biomass declined in the mesohaline, polyhaline, and Elizabeth.

The tidal water quality data were next analyzed for seasonal and spatial correlations between chlorophyll-a and the nutrient and physical parameters (Figure E4). In the Tidal Fresh, chlorophyll-a is strongly correlated with freshwater flow and temperature and is not strongly correlated to TN or TP. In the mesohaline portion of the estuary, chlorophyll-a does not appear to be strongly correlated to any physical or nutrient variables. In the polyhaline portion of the estuary, chlorophyll-a appears to be weakly correlated to TN or TP.

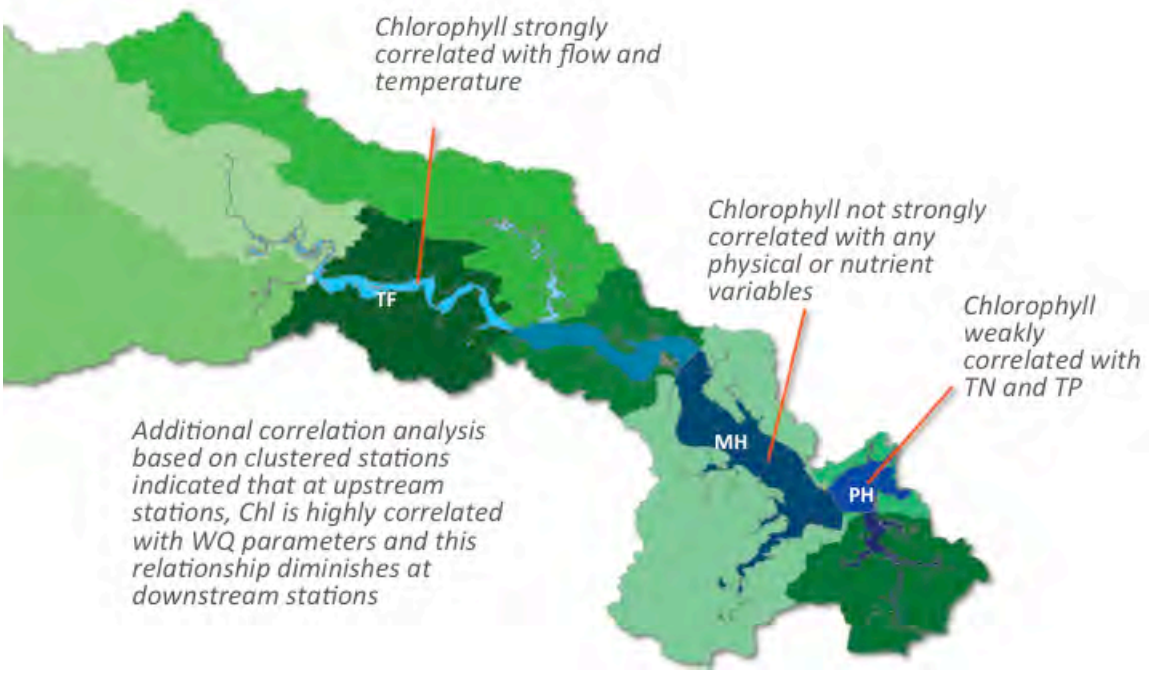


Figure E4 – Results from correlation analyses investigating the relationship between chlorophyll-a and nutrient and physical parameters.

In a separate correlation analysis, the tidal monitoring stations were first grouped using cluster analysis. In general, it was found that the ensemble chlorophyll-a data monitored at upstream stations are highly predictable using locally measured water quality parameters, while the variability of chlorophyll-a at downstream are less controlled by local water quality conditions.

A regression analysis was conducted on data from stations TF5.5, RET5.2, LE5.5, and SBE5 (Figure E5). The purpose was to determine if the observed data would lend themselves to predicting chlorophyll-a biomass using an empirical modeling approach. In all cases the regression models performed poorly in predicting the raw chlorophyll-a data. These results suggest that the construction of an empirical-based model to predict chlorophyll-a concentrations in the tidal James River may be limited to seasonal averages only and that a deterministic model will have to be developed that will be able to the simulate the within season and year-to-year variability. The latter framework will likely be more responsive to predicting changes in chlorophyll-a in response to changes in nutrient inputs, than the empirically-based model. The Project Team will, however, evaluate the predictive accuracy of both modeling approaches as called for in the original scope of work.

Figure E5 – Results from a regression analysis to determine if the water quality data could be used to predict the raw chlorophyll-a data.

A flow and nutrient budget for the tidal James River was developed using available stream flow and water quality monitoring data as well as Chesapeake Bay Model output (Figures E6 & E7). Flow and nutrient loads were calculated for the five segments of the James River (TF1, TF2, OH, MH, and PH). In general, nutrient loads increase with contributing drainage area. The major exception is the Hampton Roads-PH drainage (Elizabeth River), which has the smallest drainage area but a significant load contribution from permitted facilities. Its load contribution is greater than Hampton Roads-MH (Nansemond River) and Chickahominy-OH for all constituents.

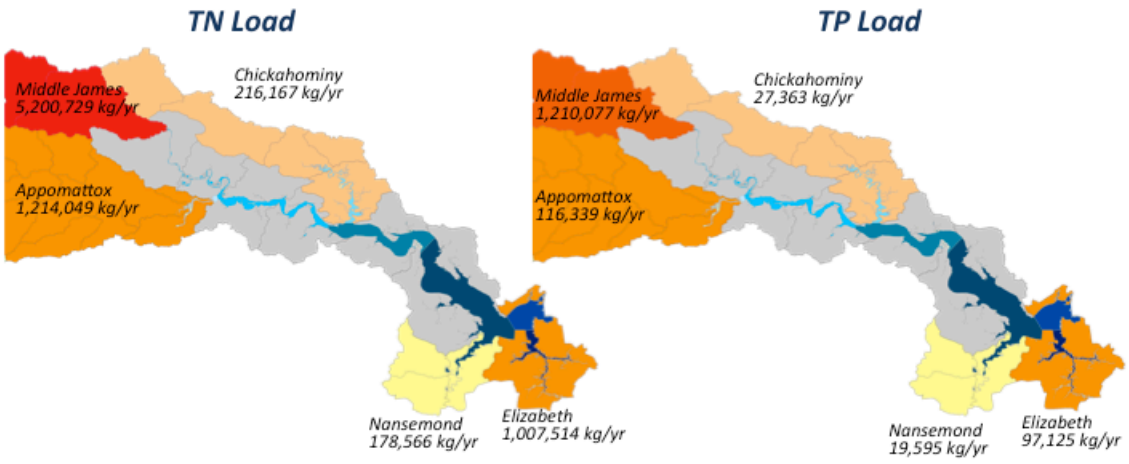


Figure E6 – TN and TP total annual loads by sub-watershed of the lower James River.

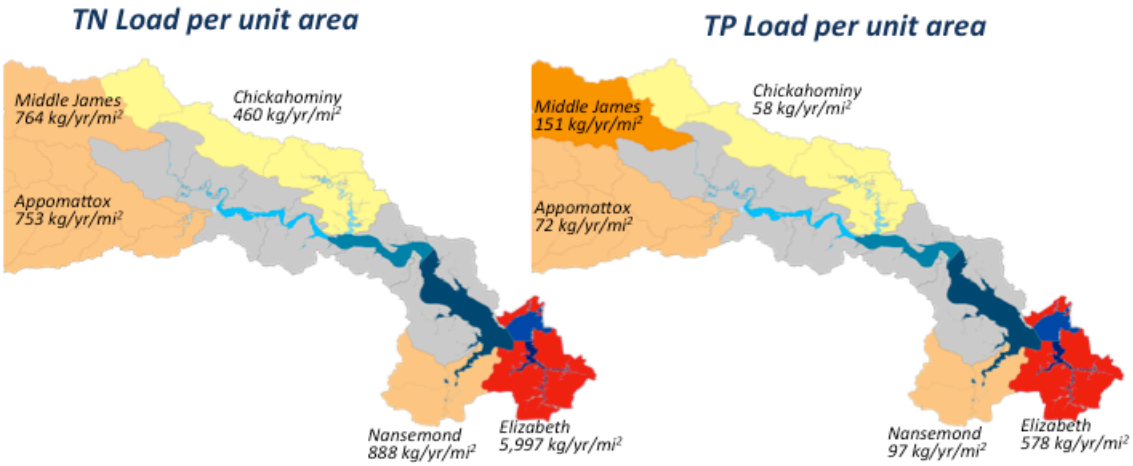


Figure E7 – TN and TP total annual loads per unit area by sub-watershed of the lower James River.

A critical condition for chlorophyll-a in the tidal James River was assessed to inform future model application. The statistical analysis was consistent with that previously conducted by EPA for Chesapeake Bay TMDL development but used more recent data. As with the previous analysis, the updated analysis showed a very weak relationship between flow and chlorophyll-a, water quality criteria exceedance, regardless of location. Additional analysis focusing on the relationship between flow and chlorophyll *a* concentrations showed moderately better relationships that varied by location throughout the tidal James.

We attempted to calculate a biological reference curve for the tidal fresh portion of the James. Doing so would inform the development of chlorophyll-a criteria and provide an alternative to the current narrative criteria. Similar to the findings of the USEPA Chesapeake Bay Program Office, we were not able to develop a biological reference curve for chlorophyll-a for either the freshwater or the marine portion of the tidal James River. Rather, it is proposed that the USEPA-approved Cumulative

Frequency Distribution (CFD) approach be utilized for assessing attainment of water quality standards.

Background

In December 2010, EPA developed the Chesapeake Bay Total Maximum Daily Load (TMDL) for Nitrogen, Phosphorus and Sediment (EPA, 2010). The TMDL was based on "Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll-a for the Chesapeake Bay and Its Tidal Tributaries" (EPA, 2003, 2007). Jurisdictional Watershed Implementation Plans (WIPs), which were developed in addition to the TMDL, were designed to ensure that all pollution control measures needed to fully restore the Bay and its tidal rivers would be in place by 2025, with at least 60 percent of the actions completed by 2017. When the restoration goal is met and the criteria are achieved, the Bay will be removed from EPA's list of "impaired" waters.

The Virginia State Water Control Board has held on to a key decision about standards for the state's largest Bay tributary—the James River. It noted that nutrient reductions for most of the Bay watershed are driven primarily by the dissolved oxygen and water clarity standards, which establish the minimum amounts to support the fish, shellfish, SAV, and other organisms that live in the Bay. In the James River, however, no low dissolved oxygen problems are apparent and water clarity problems are generally caused by suspended sediments.

Local governments and wastewater treatment plant operators are concerned that newly established chlorophyll-a criteria (Table 1) would require significant additional nitrogen and phosphorus reductions. They contend that EPA and DEQ have not yet demonstrated clear environmental benefits resulting from chlorophyll-a criteria and standards revisions to justify such expensive reductions. While dissolved oxygen and water clarity criteria are based on well-documented research, (USEPA 2003, 2007), the chlorophyll-a criteria have proven more problematic. This is due to the fact that the link between nutrient loading and phytoplankton biomass and especially HABs, is difficult to establish. Physical factors, such as temperature, residence time, turbidity, salinity, stratification, and wind-induced mixing, can play a major role in determining phytoplankton growth dynamics. In addition, "top down" grazing effects may influence phytoplankton community composition and biomass. In 2011 the General Assembly authorized funding administered by DEQ for conducting additional riverine-estuarine water quality monitoring, targeted field studies and enhanced watershed, hydrodynamic and water quality monitoring. The funds also support a Scientific Advisory Panel (SAP), comprised of scientists and modelers, to provide advice as to the best scientific basis for the new chlorophyll-a standard, especially its linkages to HABs, and to ensure that the standards are appropriately protective of water quality and aquatic life. Based on the results of

the new riverine-estuarine monitoring, watershed and water quality modeling and with input from the SAP, the VADEQ may revise the chlorophyll-a standards and may revise the TMDL Waste Loads Allocations (WLAs) and effluent limits for James River dischargers.

The first step in the watershed, hydrodynamic and water quality modeling task was to provide a review of the available water quality data. Specifically, a data analyses was conducted to understand the underlying processes driving phytoplankton blooms; correlations between algal blooms and environment variables such as rainfall, salinity, available light and nutrients; ambient factors limiting algal blooms; and critical conditions for algal blooms. The major components of the data analyses included the following tasks:

- Analyze seasonal and spatial distributions of phytoplankton, nutrients and associated environmental variables in relation to chlorophyll-a concentrations;
- Examine correlations among chlorophyll-a, nutrients, temperature, salinity, suspended solids (turbidity), and light attenuation;
- Determine limiting factors for algal blooms such as those related to nutrients, temperature, light availability, salinity, and residence time;
- Determine chlorophyll-a exceedances for the observation period; and
- Identify major algal species in different regions of the James River and its estuary.

Table 1 – James River chlorophyll-a criteria

Designated Use	Chesapeake Bay Program Segment	Salinity (abbreviation)	Segment Description	Temporal Chlorophyll-a Criteria (µg/L)	
				Mar 1–May 31	Jul 1–Sep 30
Open Water	JMSTF1	Fresh (F)	Tidal fresh James River, below Hopewell, VA	15	23
	JMSTF2	Fresh (F)	Tidal fresh James River, above Hopewell, VA	10	15
	JMSOH	Oligohaline (OH)	Tidal oligohaline James River	15	22
	JMSMH	Mesohaline (MH)	Tidal mesohaline James River	12	10
	JMSPH	Polyhaline (PH)	Tidal polyhaline James River	12	10

Subtask 2.1 – Data review and methodology Selection

Monitoring Data Summary

Chlorophyll and Water Quality Data

The initial time period selected for data analysis and water quality modeling focused on the years 1991 through 2000. This was meant to be consistent with the EPA directive to evaluate all eight 3-year periods to assess attainment of chlorophyll-a water quality standards in the tidal James River, since a critical 3-year assessment period could not be identified. The time period was further expanded to include the time period 2007-2010, since there is more information available from expanded monitoring and field studies during this time frame which could be used to better understand HAB bloom dynamics and to develop and calibrate the HAB models. However, for our data analysis, rather than to just look at the years 1991-2000 and 2007-2010, it was decided to include all of the available water quality data for the period 1991 through 2010. While the analyses of time-series trends presented here (and in the appendices to this report) illustrate the available water quality data for this twenty-year period, the data included in the trend analysis were limited to the period 1995-2010. This is based on a discussion presented in Dauer et al. (2012), which indicated that laboratory methodologies for nutrients changed in 1994. Initially the revised nutrient methodologies on James River water quality samples were carried out in the Virginia Institute of Marine Science (VIMS) laboratories, before the Virginia DEQ began conducting the analyses in their labs in 1995. Therefore, in order to account for the method change and to eliminate any effects due to the brief change in laboratories, our trend analysis was limited to the post-method changes, i.e., 1995-2010.

Watershed and Flow Data

Available water quality and stream flow monitoring data were collected, summarized, and reviewed to support the development of the watershed nutrient loading and critical condition analysis. Data were available from three primary sources; the United States Geological Survey (USGS), DEQ, and CBP. USGS data included both stream flow and water quality data, while monitoring data available from DEQ and CBP consisted of water quality observations only.

The focus area of the nutrient budget and critical condition analysis is the tidal portion of the James River, below the City of Richmond. Review of the available monitoring data were, therefore, for the nutrient budget and critical condition analysis, reduced to monitoring locations at the tidal boundaries and in critical open water segments of the James River. In addition, the CBP James River segment definitions provided in Table 1 as well as HUC-8 descriptions of the local drainage provided a framework for organizing the available data. Figure 1 shows the focus area for this study.

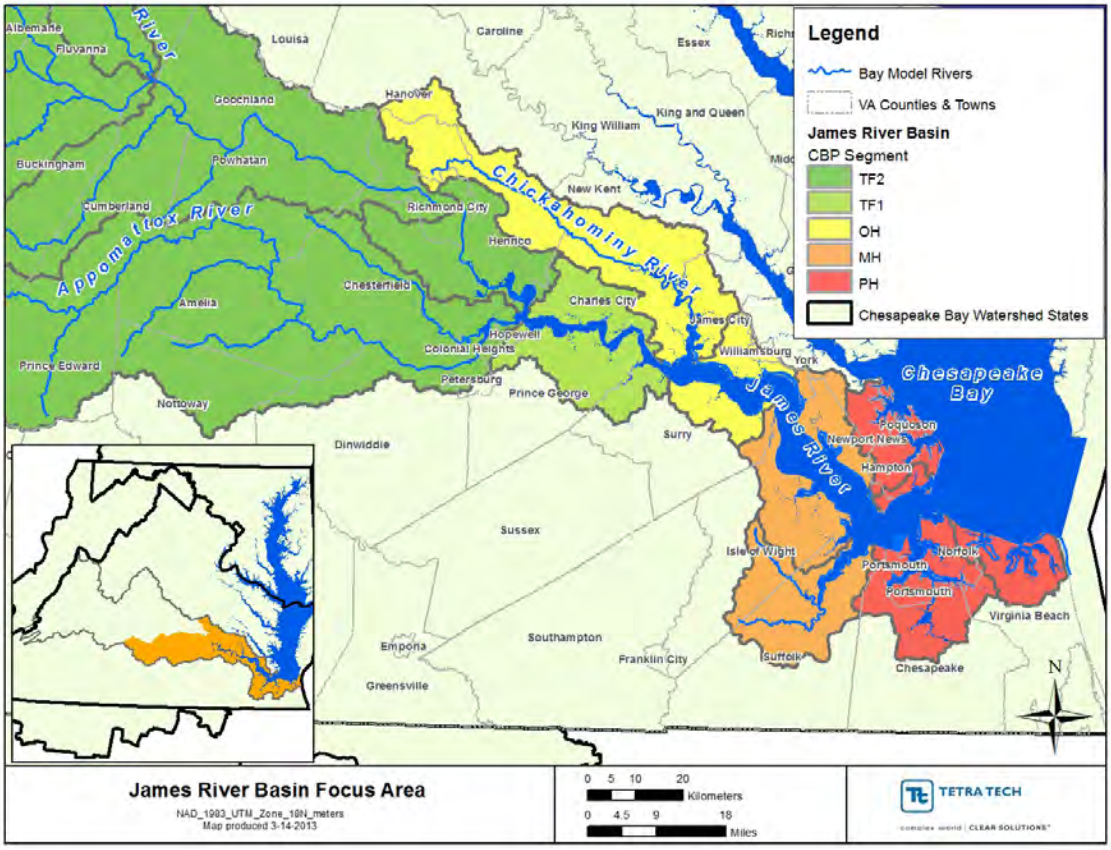


Figure 1. James River Basin focus area.

While the number of stream flow stations in the focus area included only four locations, thousands of DEQ monitoring stations have available data, as well as multiple CBP and USGS monitoring locations. To make the selection of monitoring stations used in the analysis more manageable, select parameters were identified and summarized by station. A station within a HUC-8 CBP segment composite area was selected for each parameter if it had the longest period of record and the greatest number of samples, with emphases also placed on the availability of more recent data (2010–present). Figure 2 depicts the selected locations and Table 2 provides data summaries for each. The three selected stream flow monitoring stations (USGS 02037500, 02041650, and 02042500) set the period of analysis on the basis of their period of records, beginning in 1984 in correspondence with the simulation start date of the Chesapeake Bay Model (U.S. EPA 2010) and ending for the most recent sampling date (10/24/2012).

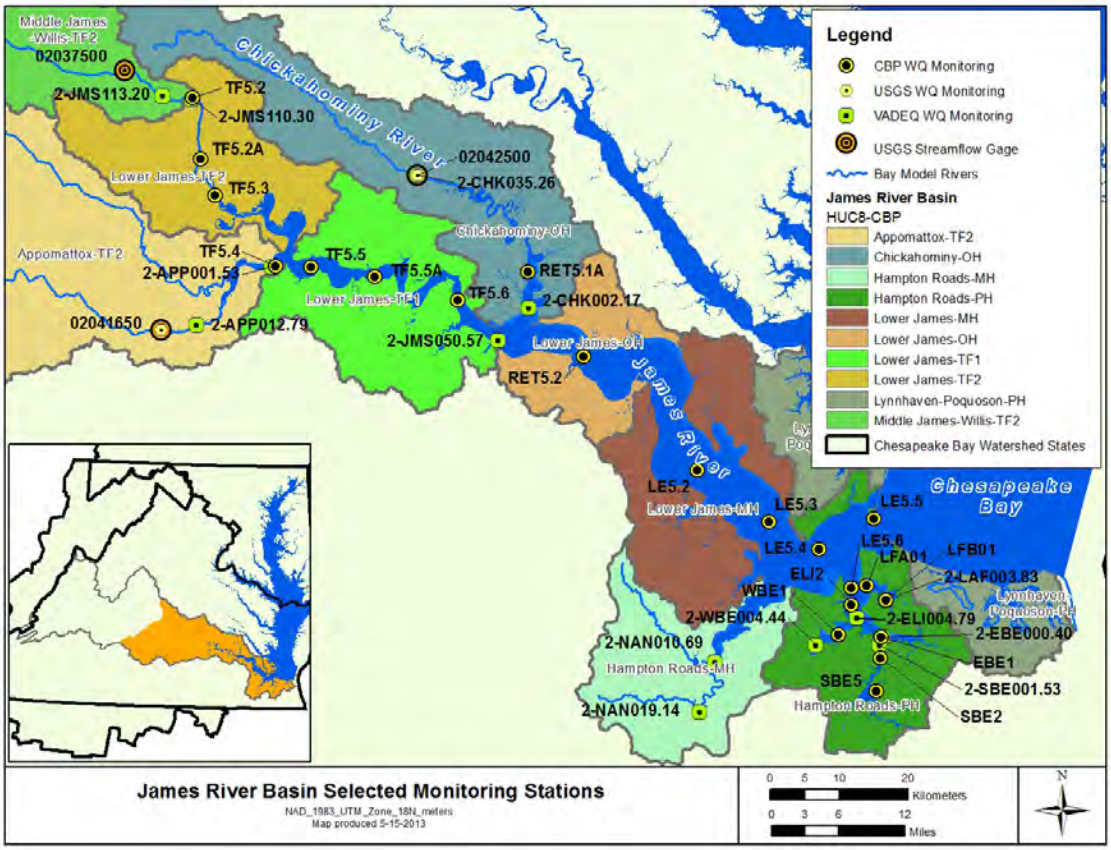


Figure 2. – James River Basin selected monitoring stations

Table 2. Monitoring station summary for selected stations

HUC8-CBP Seg	Station ID	Sample Dates	Sample Count												
			Chl *a*	S. Solid	TSS	TP	Ortho	Ortho F.	TN	NH_3	NO_2	NO_3	NO_X	NO_X F.	Org. N
Appom.-TF2	TF5.4	7/12/84-9/20/12	440	663	0	782	0	804	900	0	0	0	0	926	882
	2-APP001.53	1/14/80-12/4/12	168	788	0	469	0	913	0	154	154	154	0	413	0
	2-APP012.79	1/14/80-12/17/12	1	322	0	313	130	130	59	258	258	258	2	0	0
	02041650	1/17/80-2/5/13	172	761	381	540	14	819	536	73	14	14	29	833	391
Chick.-OH	RET5.1A	4/18/88-9/20/12	387	677	0	634	0	677	815	0	0	0	0	856	878
	2-CHK002.17	1/29/80-12/10/12	30	315	0	308	96	160	57	265	256	256	9	0	0
	2-CHK035.26	4/26/84-12/5/12	0	156	0	158	0	12	146	158	12	12	146	0	0
	02042500	1/18/80-2/5/13	10	117	143	170	23	200	170	35	1	1	35	200	52
Hampton Roads-MH	2-NAN010.69	6/14/83-6/5/02	6	130	0	119	41	89	0	121	132	132	0	0	0
	2-NAN019.14	1/29/80-12/27/12	68	320	0	297	126	133	59	256	261	262	0	0	0
Hampton Roads-PH	EBE1	2/27/89-9/26/12	522	555	0	559	0	556	526	0	0	0	0	561	524
	LE5.6	9/25/84-9/25/12	451	669	0	770	0	795	905	0	0	0	0	922	778
	LFB01	1/22/98-9/25/12	184	375	0	333	0	371	358	0	0	0	0	371	448
	SBE2	2/28/89-9/26/12	522	556	0	559	0	571	540	0	0	0	0	572	543
	WBE1	2/27/89-9/25/12	521	556	0	545	0	563	526	0	0	0	0	566	567
	2-EBE000.40	1/7/80-12/13/12	41	246	0	124	39	208	0	158	168	169	0	78	0
	2-ELI004.79	1/22/98-12/18/12	197	389	0	18	0	382	0	2	0	0	0	382	0
	2-LAF003.83	1/22/98-12/18/12	203	399	0	18	0	390	0	0	0	0	0	390	0
	2-SBE001.53	1/7/80-5/19/10	1	190	0	130	39	136	0	163	175	175	0	1	0
	2-WBE004.44	1/22/98-12/18/12	195	386	0	33	14	374	0	13	14	14	0	375	0
Lower James-MH	LE5.2	9/25/84-9/6/12	439	668	0	765	0	800	917	0	0	0	0	949	891
Lower James-OH	RET5.2	7/12/84-9/6/12	438	658	0	785	0	805	980	0	0	0	0	989	1001
Lower James-TF1	TF5.6	7/12/84-9/20/12	443	677	0	786	0	818	883	0	0	0	0	913	881
	2-JMS050.57	5/19/80-12/4/12	0	186	0	219	145	35	65	164	157	157	7	0	0
Middle James-Willis-TF2	TF5.2	7/12/84-9/20/12	433	337	0	390	0	409	595	0	0	0	0	564	574
	2-JMS110.30	1/23/80-12/4/12	172	487	0	315	15	541	0	167	167	166	2	218	0
	2-JMS113.20	5/17/06-12/4/12	124	154	0	154	0	125	149	27	0	0	27	127	0

Data Review

Long-Term Trends in Water Quality

Before beginning the analyses of seasonal and spatial correlations in water quality, it was decided to look at long-term trends in riverine and estuarine water quality. Four stations for which both water quality and phytoplankton species

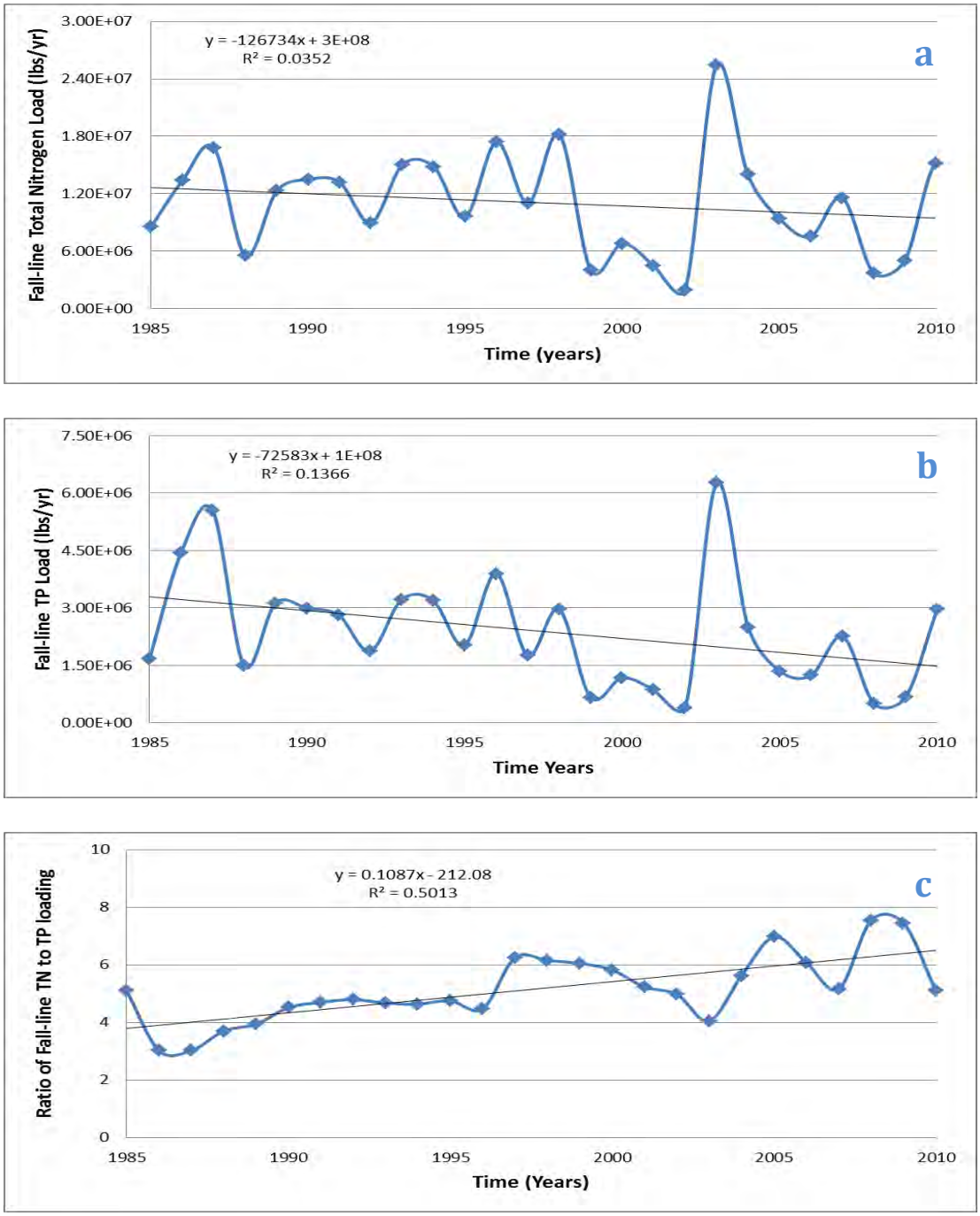


Figure 3. - Trends in James River Fall-line Nutrient Loads

composition and biomass data were available (Marshall and Egerton, pers.comm.) were selected.. The available stations included one in the upper freshwater section of the James River Estuary (TF5.5), one in the mesohaline section of the estuary (RET5.2), one in the polyhaline portion of the estuary (LE5.5) and one in the Elizabeth River (SBE5). We first downloaded James River fall-line (Cartersville, VA) loading information as estimated by the U.S. Geological Survey's River Input Monitoring program (http://va.water.usgs.gov/chesbay/RIMP/index.html). An analysis of these data suggests that both total nitrogen (Figure 3a) and total phosphorus (Figure 3b) have declined over the past 25 years, with a more rapid decline in total phosphorus (TP) as compared to total nitrogen (TN). This has resulted in an increase in the ratio of TN/TP from around 3-4 in the mid- to late 1980's to current levels of between 5 and almost 8 in the mid- to late 2000's (Figure 3c). We were interested to see if this change in the N:P ratio might have resulted in a change in algal species composition. This will be discussed below in this section.

The trend analysis considered the period 1995-2010 for the reasons provided above. In conducting our trend analysis, we decided to take into account the effects of seasonality. Seasonality comes into play in the following ways:

1) There are seasonal differences in freshwater inflows into the river, with the winter/spring period typically having higher inflows as compared to the summer and early fall, which tend to be characterized by lower freshwater inflows. This seasonality may affect the concentrations of TN and TP via dilution and may affect phytoplankton biomass (as indicated by chlorophyll-a) via increased residence time during the summer months.
2) Temperature also varies seasonally with higher temperature during the summer months. The higher temperatures usually are associated with higher rates of primary production and thus could affect phytoplankton biomass. Therefore, this potential seasonal variation must be compensated for to better discern the trend in the water quality variables. Otherwise, little power may be available to detect trends that are truly present within the data. A parametric approach was chosen to address seasonality in the data; that is, a multiple regression using periodic functions:

$$\boldsymbol{Y = \beta_0 + \beta_1 \sin(2\pi T) + \beta_2 \cos(2\pi T) + \beta_3 \sin(4\pi T) + \beta_4 \cos(4\pi T) + \beta_5 \sin(6\pi T) + \beta_6 \cos(6\pi T) + \beta_9 T + \varepsilon}$$

Where

Y	**=**	**dependent water quality variable,**
β_n	**=**	**the regression coefficients,**
T	**=**	**time, and**
ε	**=**	**residuals.**

Normally, it is possible to get by with using only one or two paired sine/cosine terms, but it was found that a slightly better power in the analysis for a few water quality variables was obtained by using three sine/cosine pairs. Therefore, three paired sine/cosine terms were used for all variables.

Statistical Note: On the plots and text which follow we present some statistical information, including:

- The slope of the trend line or the rate of change of the variable of interest over time. If the slope is positive, then the water quality variable is increasing over time; if the slope is negative, then the water quality variable is decreasing over time,
- Standard error or standard deviation of the slope of the trend line,
- t-statistic is the slope of the trend line divided by the standard error. Generally for large samples (>100), if t is greater than 1.7 then the slope of the trend line is statistically significant and different than zero at a 95% confidence level,
- p-value, in our case, is a measure of the chance that the slope of the trend line is observed by pure chance. In other words, if we obtain a p-value of 0.05, it means that there is a 5% chance that the slope of the trend line estimated via the regression analysis doesn't actually exist.
- Correlation coefficient (r) of the trend line. The r^2 value or coefficient of determination is a measure of the fraction of the variation in the data that is explained by the slope of the trend line.

Station TF5.5

Results for the upstream freshwater station, TF5.5, suggest that TN declined over the 16-year period between 1995 and 2010 (Figure 4). However, the standard error of the trend-line is fairly large relative to the estimate (and results in a t-score of 0.88). This suggests that the trend-line is not appreciably different from zero. In the case of TP, however, the trend analysis indicates that there is a statistically significant decline in TP (t-score = -3.9, $p<0.0001$) of approximately .038 mg P/L between 1995 and 2010(Figure 4). Similar to TN, the trend analysis for chlorophyll-a biomass results in a low t-score of -0.42, indicating no statistically significant change in phytoplankton biomass. While the long-term trend of dissolved silica (Si) indicated a strong seasonal cycle, with peak values in the winter and minimum values in the summer (Figure 5), the t-score of -1.07 ($p=0.14$) indicated a moderate decreasing trend in Si concentrations over the 16-year period of analysis. Consistent with the increasing trend of the ratio of TN to TP in the fall-line loadings, the trend analysis indicated a statistically significant ($p<0.0001$) trend in the ratio of water column TN:TP. Interestingly, the water column ratios show a seasonal signal and are about a factor of two greater than the fall-line loading TN:TP ratios. Water column temperature shows a very strong seasonal signal, as might be expected, but does not indicate a long-term change in water temperature.

Station RET5.2

Moving downstream to the mesohaline portion of the estuary, a trend analysis was conducted for station RET5.2 (Figure 6). Similar to the upstream TF5.5 station, the trend analysis did not indicate a statistically significant trend in TN, but did find a statistically significant declining trend ($p = 0.029$) of 0.014 mg P/L over the 16-year interval for water column TP. Chlorophyll-a also showed a statistically significant ($p=0.008$) decline of about 4 ug/L over the 16-year period. The trend analysis for Si (Figure 7) indicates a statistically significant trend ($p=0.058$) over the 16-year period. Further analysis suggests that this trend is the result of higher concentrations of Si during the summer months, rather than a year-round increase. This might suggest less utilization of Si during the summer months by the diatom community or perhaps a decline in diatom abundance. This will be explored further later in this section. The trend analysis does not show the same increasing trend in the ratio of TN:TP as was observed at the upstream TF5.5 station. Also, there is no statistically significant trend in water column temperature.

Station LE5.5

The next station considered was LE5.5, located in the polyhaline portion of the estuary. As with the stations located upstream of LE5.5, the trend analysis did not show any trend for TN (Figure 8). There was a statistically significant ($p<0.0001$) decline in TP of about 0.01 mg/L (Figure 8), which represents a decline of 15-20 percent. There was a statistically significant trend ($p=0.065$) of increasing chlorophyll-a for this station. Also the trend analysis showed a statistically significant ($p=0.028$) increase in Si (Figure 9). However, as was the case for the RET5.2 station, most of this can be attributed to increases in summer Si. The TN:TP ratio also showed a statistically significant ($p<0.0001$) increasing trend over the 16-year period. Interestingly, the trend analysis indicated a statistically significant increase in water temperature ($p=0.02$) (Figure 9). Further investigation suggests that perhaps this is due to increased water column temperature in the winter months, rather than a year-round change in temperature.

Station SBE5

Finally moving into the Elizabeth River, a trend analysis was conducted for station SBE5, which is located in the southern branch of the river. Unlike the other stations in the mainstem James River Estuary, station SBE5 indicated a statistically significant ($p=0.005$) decline in TN (Figure 10) over the 16-year period of about 0.22 mg N/L. The trend analysis also indicated a decline in TP (Figure 10), with a $p=0.146$. The trend analysis did not indicate any long-term trend for chlorophyll. However, the data do suggest that perhaps summer maxima are declining over time (Figure 10). There were not sufficient data for Si to perform a trend analysis. The data and the trend analysis suggest a decline in the TN:TP ratio (Figure 11). However, the trend line was not statistically significant. Table 3 presents a summary of the statistical results from the trend analysis for Stations TF5.5, RET5.2, LE5.5, and SBE5, including the correlation coefficient for the long-term trend line.

Long term trends in species compositions and abundance

The next step in the trend analysis was to see if there have been any long term shifts in phytoplankton species composition and abundance. Information for this analysis was kindly provided by Drs. Harold Marshall and Todd Egerton of Old Dominion University (pers. comm.). A formal trend analysis on the data was not conducted for phytoplankton species composition and abundance, given that the number of yearly samples has declined from 10-11 per year in the early portion of the data set to 7-8 per year. However the analysis on the phytoplankton community was conducted looking at both phytoplankton abundance (#/L) and looking at estimates of phytoplankton carbon biomass. (Note: while picoplankton often dominated the phytoplankton community based on cell counts, the available data did not provide estimates of picoplankton carbon biomass.)

Station TF5.5

Starting at the upstream end of the James River Estuary at station TF5.5, and based on a qualitative assessment, there appears to be a very slight decline in overall phytoplankton abundance (Figure 12). This is reflected in the summer maxima cell counts. Picoplankton tend to dominate the phytoplankton community, particularly during the summer months and occasionally into the mid- and late fall. There also appears to be a slight decrease in the numbers of diatoms, based on their percentage contribution to the overall plankton abundance. The decline in the overall diatom percentage of the total plankton cell counts appears to being made up by increases in chlorophytes and perhaps cyanobacteria, the latter more readily observed in the summer months. The carbon biomass estimates (Figure 13), indicate that there were some elevated levels of phytoplankton biomass between 1999 and 2003, while post-2003 appears to be consistent with the early and mid-1990's. Carbon biomass also supports an apparent decline in diatoms. Coincident with the decline in the diatom community, it appears as though chlorophytes and cyanobacteria have increased over this 16 year period.

Station RET5.2

Moving downstream in the mesohaline portion of the estuary, at station RET5.2, there is some indication that phytoplankton abundances have declined very slightly, but inconsistencies in sampling frequency preclude a formal trend analysis (Figure 14). It also appears, based on cell counts, as if the phytoplankton community structure has changed over time. By examining the annually averaged data, one can observe a small increase in diatom abundance during the early to mid-1990's followed by a gradual decline in the mid- to late-2000's. A reverse pattern was observed in the picoplankton abundance. Overall, the cyanobacteria and chlorophyte communities do not show any consistent pattern. Based on estimates of phytoplankton carbon biomass, there appears to be a long-term change in the phytoplankton carbon, particularly post-1995 (Figure 15). It is not apparent if the decline is related to any one algal group, as there does not appear to be any real change in the compostion of the plankton communities. There is considerable inter-annual variation, with the diatoms and chlorophytes tending to dominate in each

year, but no real long-term trend in the relative contributions of specific algal groups to the carbon pool emerged.

Table 3 - Summary of the statistical results from the trend analysis for Stations TF5.5, RET5.2, LE5.5, and SBE5, including the correlation coefficient for the long-term trend line.

Variable	TF5.5	RET5.2	LE5.5-W	SBE5
Total Nitrogen (TN)				
Trend line (mg N/L-yr)	-0.0036	-0.0028	-0.0001	-0.0136
Standard error of trend line	0.0041	0.0040	0.0011	0.0052
t-score	-0,883	-0.694	-0.079	-2.585
p	0.189	0.244	0.469	0.005
Correlation coefficient (R)	0.062	0.044	0.005	0.184
Total Phosphorus (TP)				
Trend line (mg N/L-yr)	-0.0024	-0.0009	-0.0007	-0.0004
Standard error of trend line	0.0006	0.0004	0.0002	0.0004
t-score	-3.880	-1.900	-3.723	-1.057
p	<0.0001	0.029	<0.0001	0.146
Correlation coefficient (R)	0.269	0.140	0.199	0.054
Chlorophyll-a (Chl-a)				
Trend line (mg N/L-yr)	-0.1187	-0.2665	0.1554	-0.0361
Standard error of trend line	0.2847	0.1096	0.1024	0.1014
t-score	-0.417	-2.431	1.517	-0.356
p	0.339	0.008	0.065	0.361
Correlation coefficient (R)	0.024	0.154	0.097	0.025
Silica (Si)				
Trend line (mg N/L-yr)	-0.0260	0.0280	0.0114	No Data
Standard error of trend line	0.0242	0.0177	0.0059	
t-score	-1.074	1.579	1.929	
p	0.142	0.058	0.028	
Correlation coefficient (R)	0.069	0.102	0.126	
TN/TP				
Trend line (mg N/L-yr)	0.2360	-0.0124	0.2318	-0.0602
Standard error of trend line	0.0601	0.0540	0.0370	0.1065
t-score	3.930	-0.229	6.270	-0.565
p	<0.0001	0.410	<0.0001	0.286
Correlation coefficient (R)	0.268	0.016	0.275	0.030
Water Temperature				
Trend line (mg N/L-yr)	0.0228	-0.0001	0.0601	0.0074
Standard error of trend line	0.0316	0.0270	0.0206	0.0353
t-score	0.722	-0.002	2.918	0.210
p	0.236	0.499	0.002	0.417
Correlation coefficient (R)	0.012	0.0	0.036	0.005

Station LE5.5

Station LE5.5, located in the polyhaline portion of the estuary, also seems to show a decline in the peak abundances of phytoplankton during the summer months (Figure 16). The cell abundances at this station are dominated by the picoplankton, which represent almost 100 percent of the phytoplankton community, except during the winter/spring period, which is dominated by diatoms (generally between 40 and 80 percent). The diatom composition at this station reveals periods of both increasing and decreasing percentages, but no long-term trend is evident. Estimated carbon biomass also indicates a decline post-2005, perhaps decreasing by a factor of 2 to 3 (Figure 17). While there is considerable within year variability, based on yearly averages, carbon biomass is generally dominated by diatoms (50-80 percent) and dinoflagellates (15-30 percent), followed by chlorophytes and euglenophytes (not shown).

Station SBE5

Finally, looking at station SBE5, located in the southern branch of the Elizabeth River, there does not appear to be a long-term trend in total phytoplankton cell abundance (Figure 18). There is, however, a marked decline in the winter cell counts of diatoms, from between 20 to 40 percent in the 1990's to less than 10 percent in the late 2000's. This decline has been accompanied by an increase in the picoplankton community. The estimated phytoplankton carbon also shows a similar post-2005 decline as was observed at stations RET5.2 and LE5.5 (Figure 19). However, the decline in the diatom community is not as evident when considering phytoplankton carbon. A yearly-averaged minimum in the percentage (~40%) of estimated carbon biomass is observed in 2008, but by 2010, the percentage has increased to levels (~60%) that were observed in the 1990's. The diatoms do show year-to-year and within year variability, but still tend to comprise between 40 to 70 percent of the phytoplankton carbon. They are followed by dinoflagellates (0-35 percent) with cryptophytes contributing between 10 and 20 percent of the phytoplankton carbon, depending upon the year. Other contributors include euglenophytes and chlorophytes (not shown).

Seasonal and Spatial Water Quality Correlations

The first in a series of analyses performed was to consider the inter-relationships and correlations between chlorophyll-a (chl-a) and other environmental and water quality variables. Initial assessment involved cross-plotting the raw data for each of the variables under-consideration. An example of this is presented in Figure 20 for available data for station TF5.5, using data from all months. While one can see a general decreasing trend in chlorophyll-a as freshwater flow increases (leftmost panel
upper row) and perhaps a decreasing trend in nitrate+nitrite (NO_2+NO_3) with decreasing flow (fourth panel from left in upper row), the large scatter in the data tends to cloud the correlations. Therefore, it was decided to "bin" the data using the independent (or x-axis) physical (flow, temperature) or water quality (ex. total nitrogen (TN), total phosphorus (TP), etc.). Binning the data involves averaging the

dependent (or y-axis) data within fixed intervals or ranges of the independent (or x-axis) data. For each interval or bin the average and standard-deviation of the dependent data were computed and plotted at the min-point of the x-axis bin. Using this procedure helps to better illustrate the relationship or trend in the water quality variables vs. the physical and other water quality variables.

Station TF5.5

For example, again looking at the data for all months for station TF5.5, the correlation between low flow and elevated chlorophyll-a levels in the tidal fresh station (TF5.5) of the James River is easier to see in Figure 21 as compared to Figure 20. There are also weak trends of decreasing concentrations of TN and TP vs. increasing river flow. The data show virtually no correlation between dissolved inorganic nitrogen (DIN the sum of ammonium (NH_4) and nitrate+nitrite (NO_s+NO_3)) and river flow, nor in orthophosphate (PO_4 or DIP) and river flow, except at very low flows. There is a strong correlation between dissolved silica (Si) and river flow with concentrations decreasing rapidly at flows below about 8000 cfs. There is a slight decreasing trend in the ratio of TN to TP with increasing flow, perhaps due to the resuspension of particle bound phosphorus at high flows. The data also suggest, in this portion of the river, that phosphorus may be a potentially limiting nutrient. This is based on assuming a Redfield ratio of 7 mg N/mg P and noting that the averages of the TN/TP ratios are all above the Redfield ratio of 7 mg N/mg P and most are above 10 mg N/mg P.

Total organic carbon (TOC) appears to be independent of flow as does total suspended solids (TSS), except for the highest flow, but this is likely due to a limited number of samples available at high flows. Secchi depth (or the depth of light penetration into the water column) appears to be very weakly correlated to flow, with only a very slight increase in secchi disk depth with increasing flow. Water temperature is very strongly correlated with flow, which is not surprising, given that high flows usually occur in the mid- to late-winter and early spring and low flows usually occur during the summer months and early fall when water temperatures are highest. However, as indicated by the standard deviations about the mean there is quite a bit of variability within this correlation.

Chlorophyll-a appears to be correlated to both TN and TP in this portion of the river, with increasing chlorophyll-a concentrations associated with increasing concentrations of TN and TP. However, it is important to note that there is considerable variability in these correlations given the large standard deviations about the binned means. Chlorophyll-a is also strongly correlated to water column temperature with increasing chlorophyll-a levels associated with increasing water temperature. Again there is considerable variability in this correlation. It is difficult to make a definite statement about a relationship between chlorophyll-a and TSS perhaps due to data limitations. Chlorophyll-a appears to increase with increasing TSS below concentrations of about 40-45 mg/L of TSS, but this relationship disappears above a TSS concentration of ~50 mg/L. There does not appear to be a

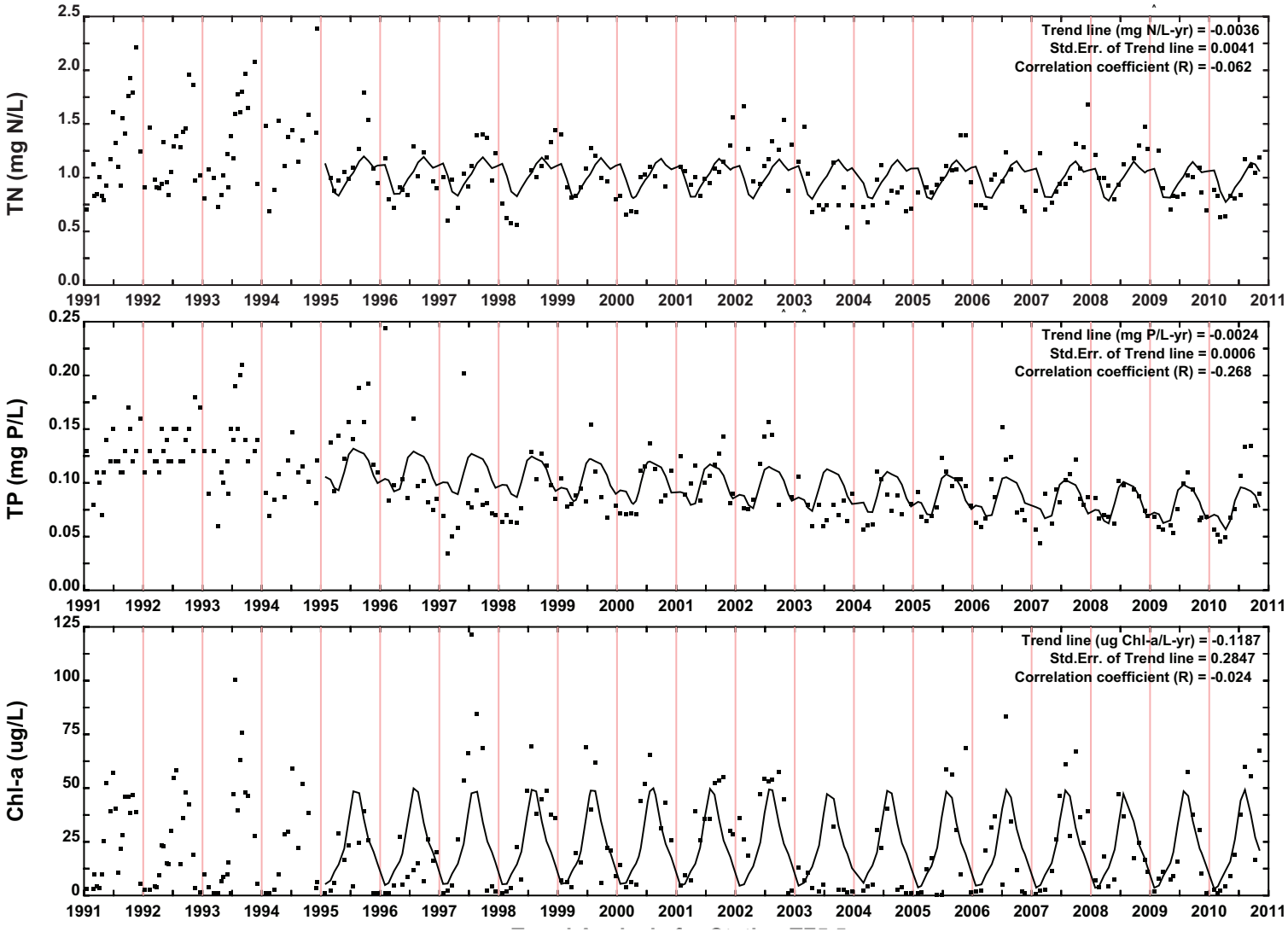


Figure 4. Trend Analysis for TN, TP, and Chlorophyll-a for Station TF5.5

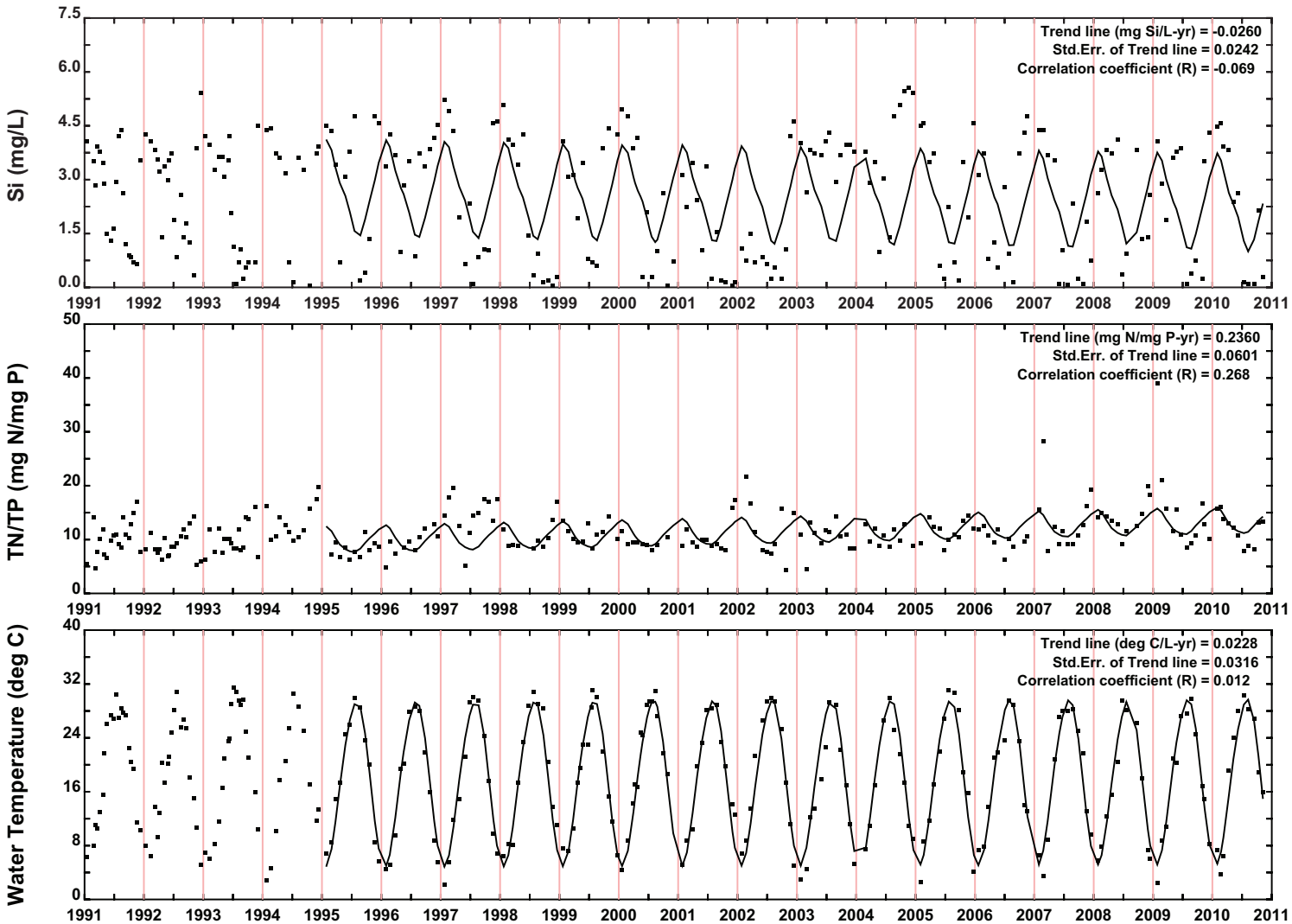


Figure 5. ***Trend Analysis for Silica, TN:TP Ratio, and Water Temperature for Station TF5.5***

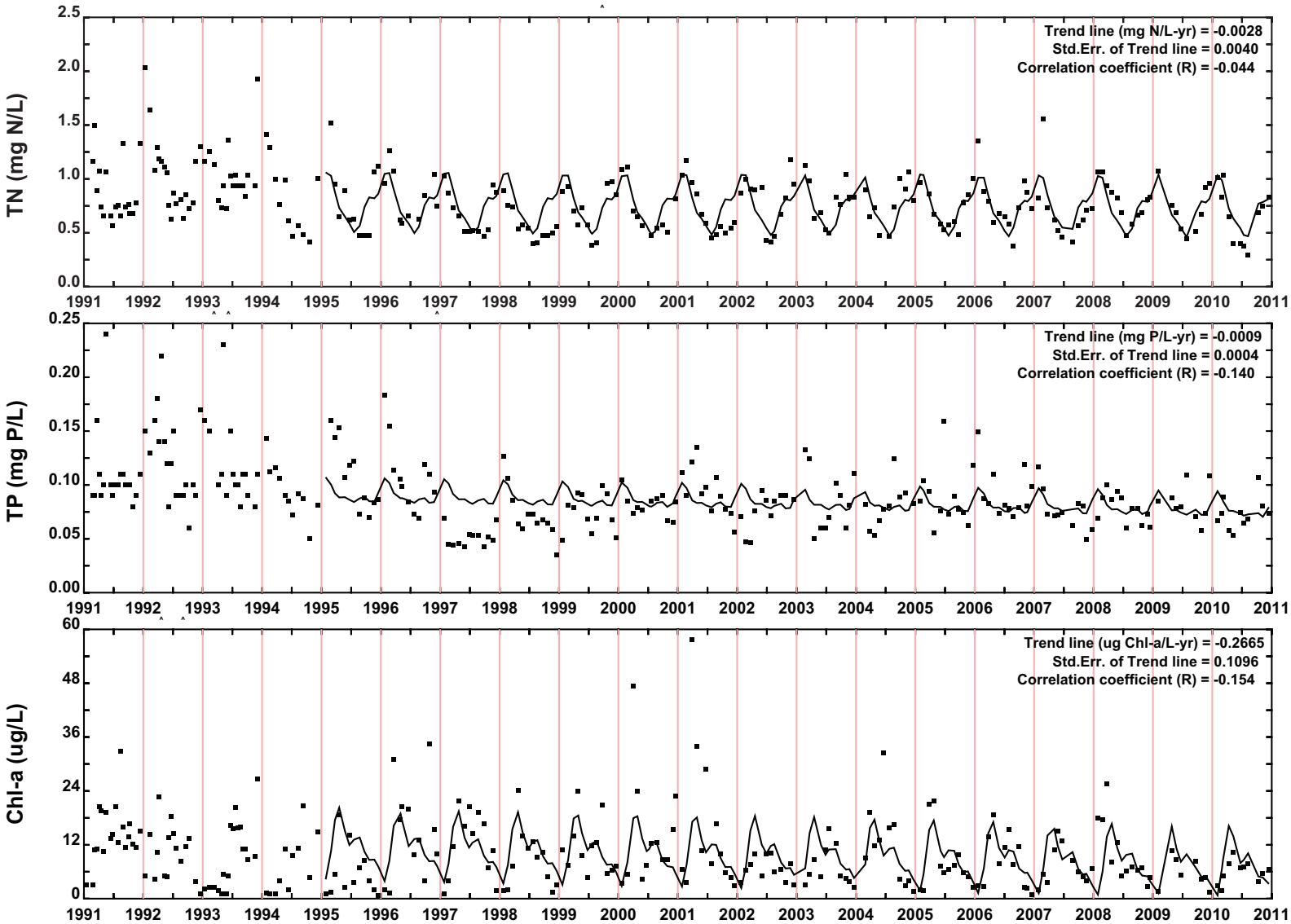


Figure 6. Trend Analysis for TN, TP, and Chlorophyll-a for Station RET5.2

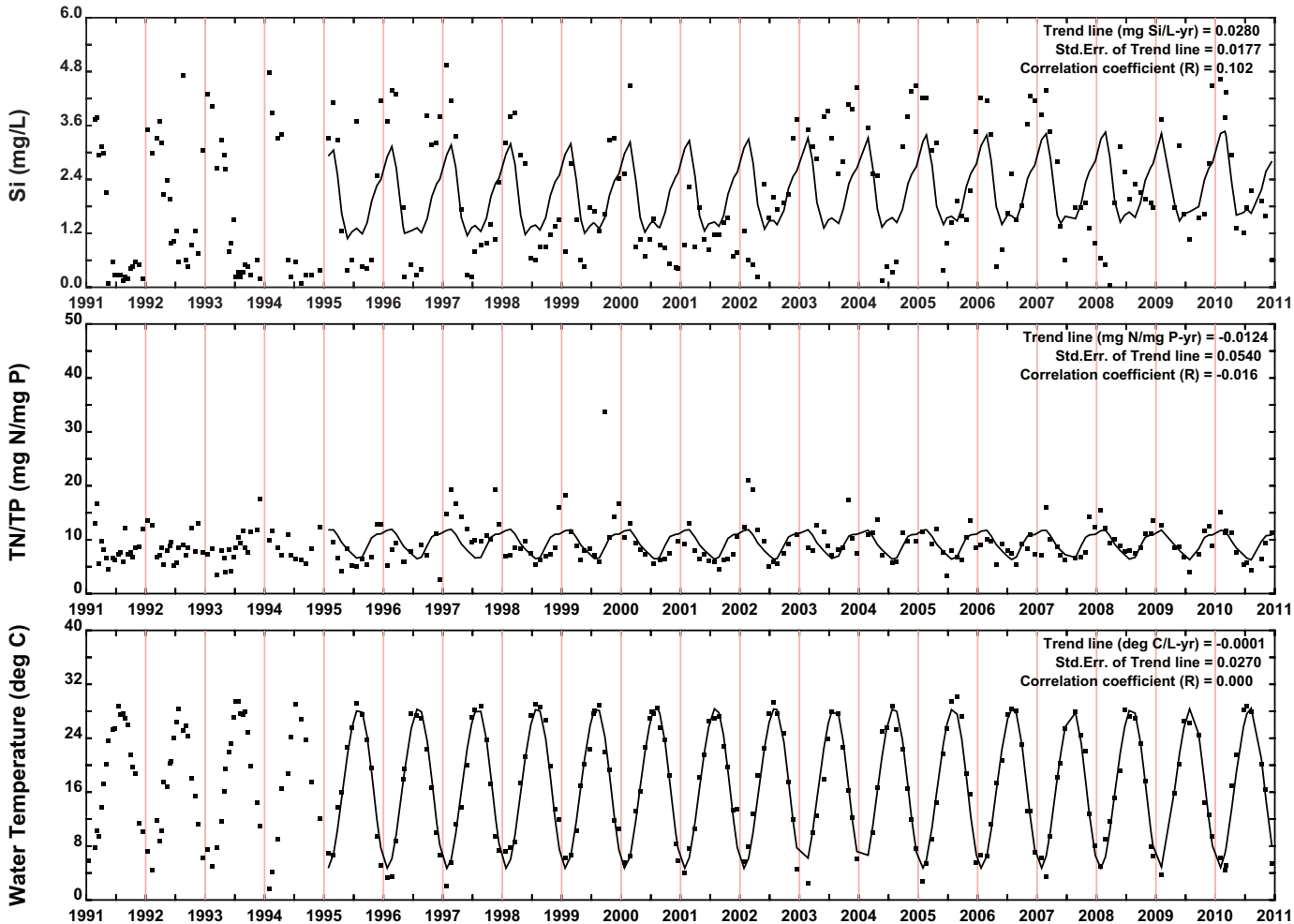


Figure 7. Trend Analysis for Silica, TN:TP Ratio, and Water Temperature for Station RET5.2

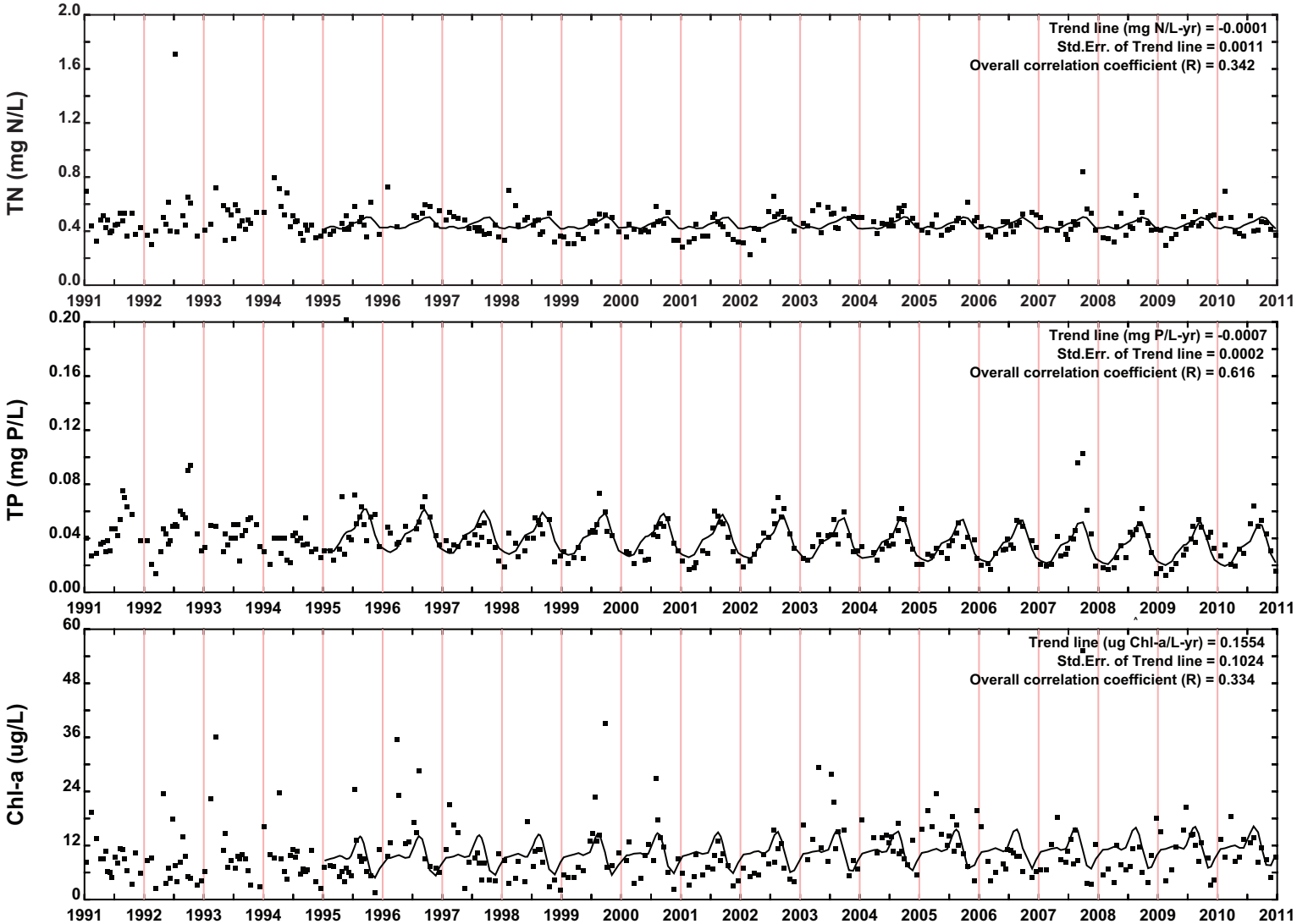


Figure 8. Trend Analysis for TN, TP, and Chlorophyll-a for Station LE5.5-W

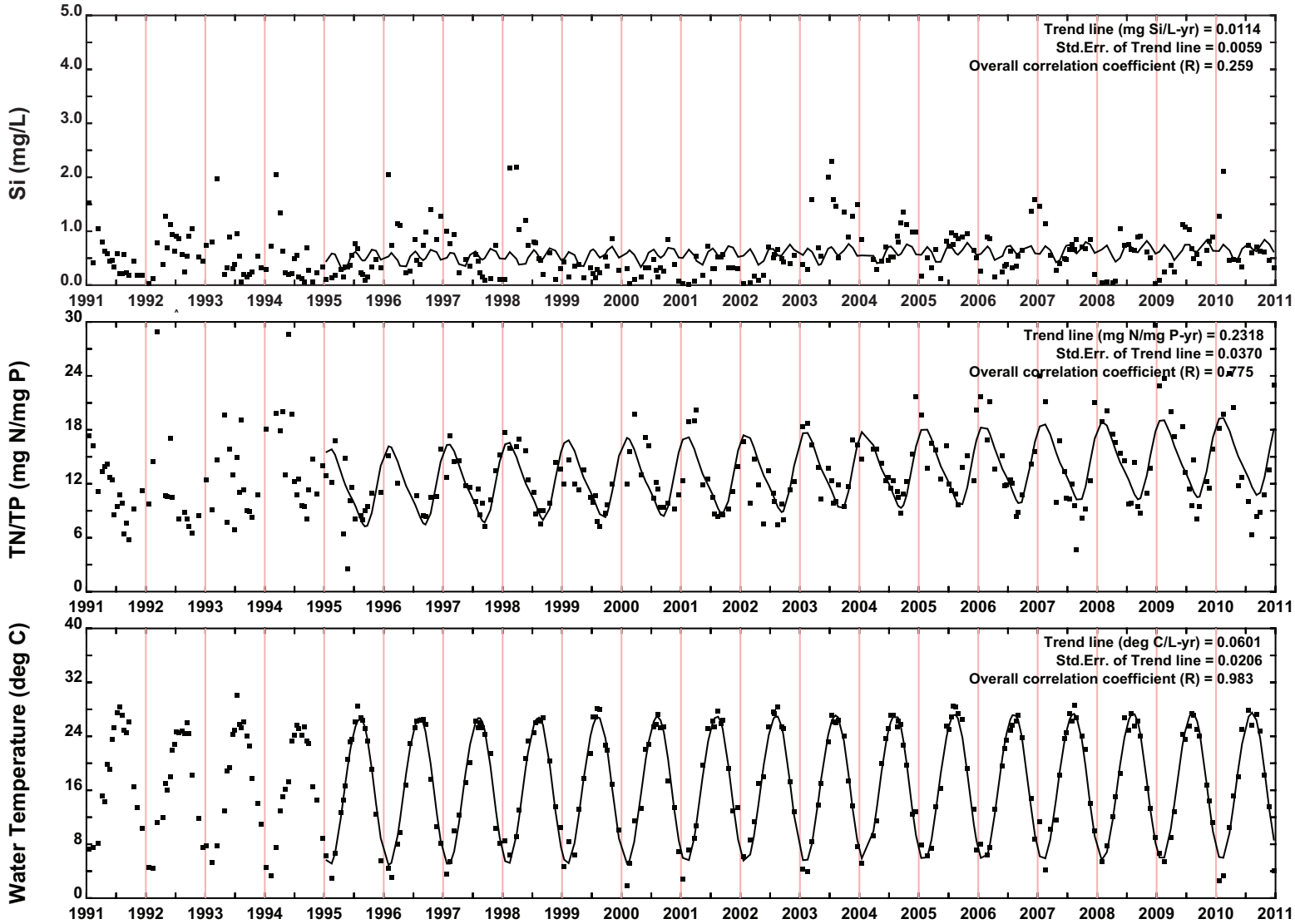


Figure 9. Trend Analysis for Silica, TN:TP Ratio, and Water Temperature for Station LE5.5-W

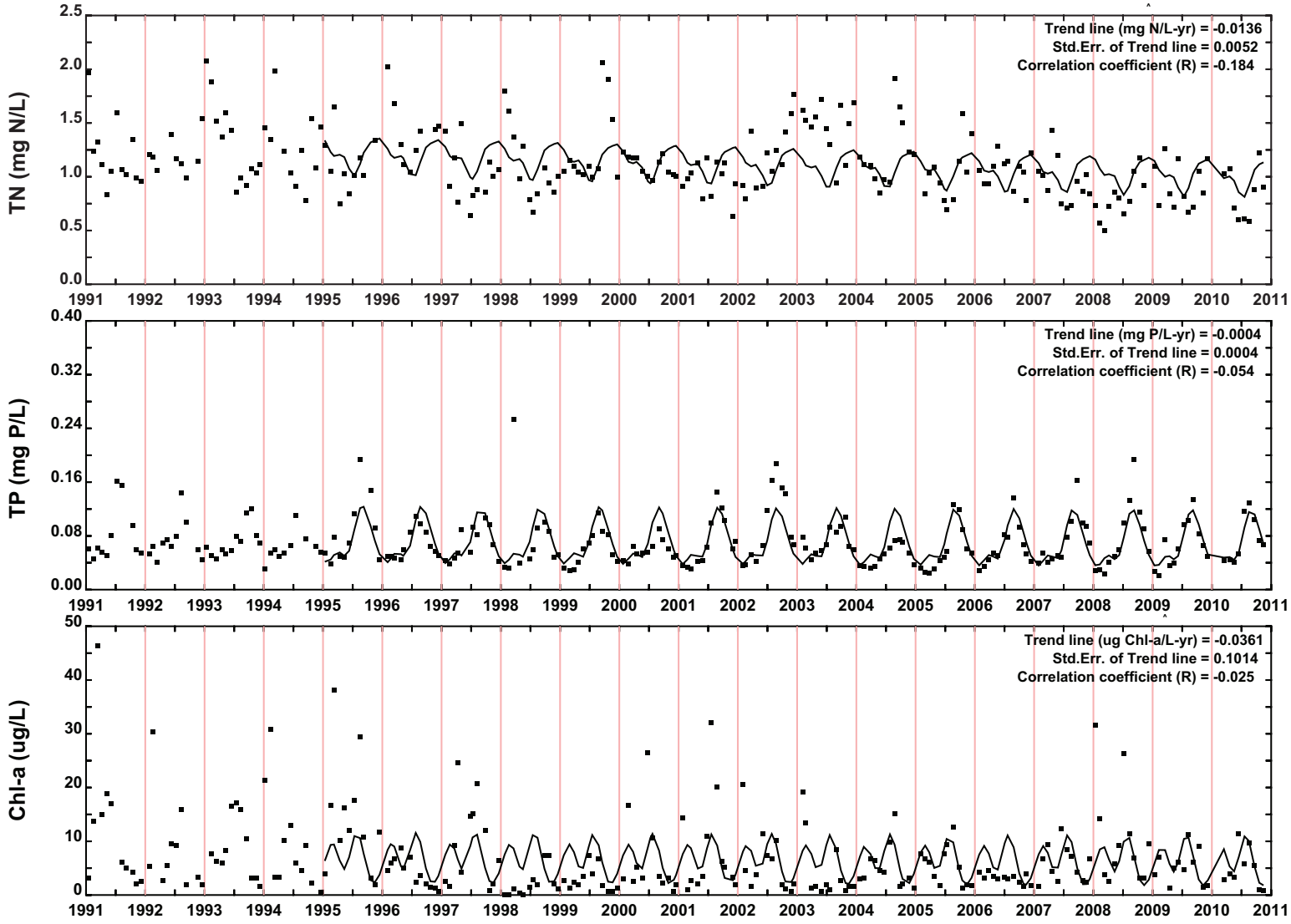


Figure 10. Trend Analysis for TN, TP, and Chlorophyll-a for Station SBE5

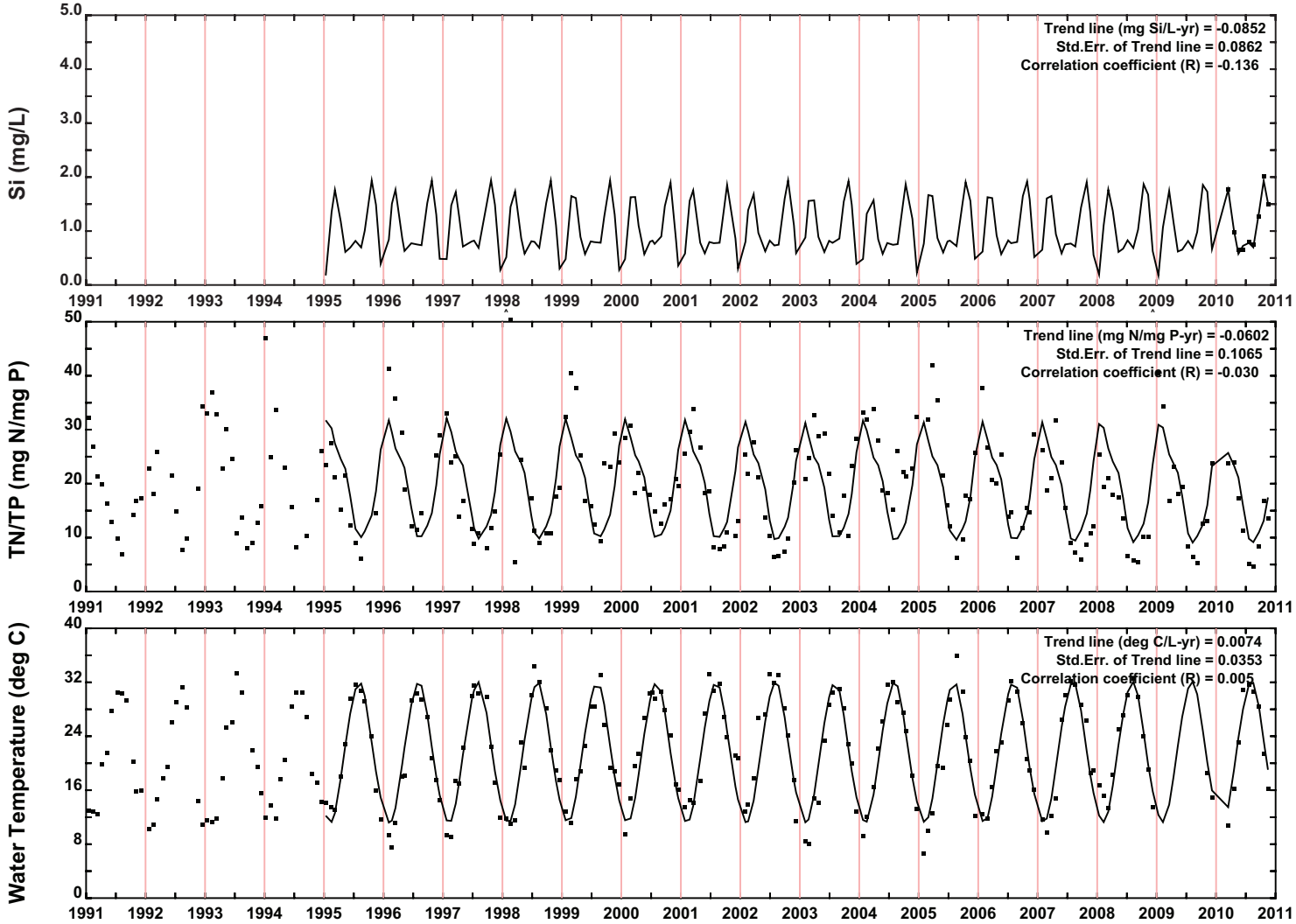


Figure 11. Trend Analysis for Silica, TN:TP Ratio, and Water Temperature for Station SBE5

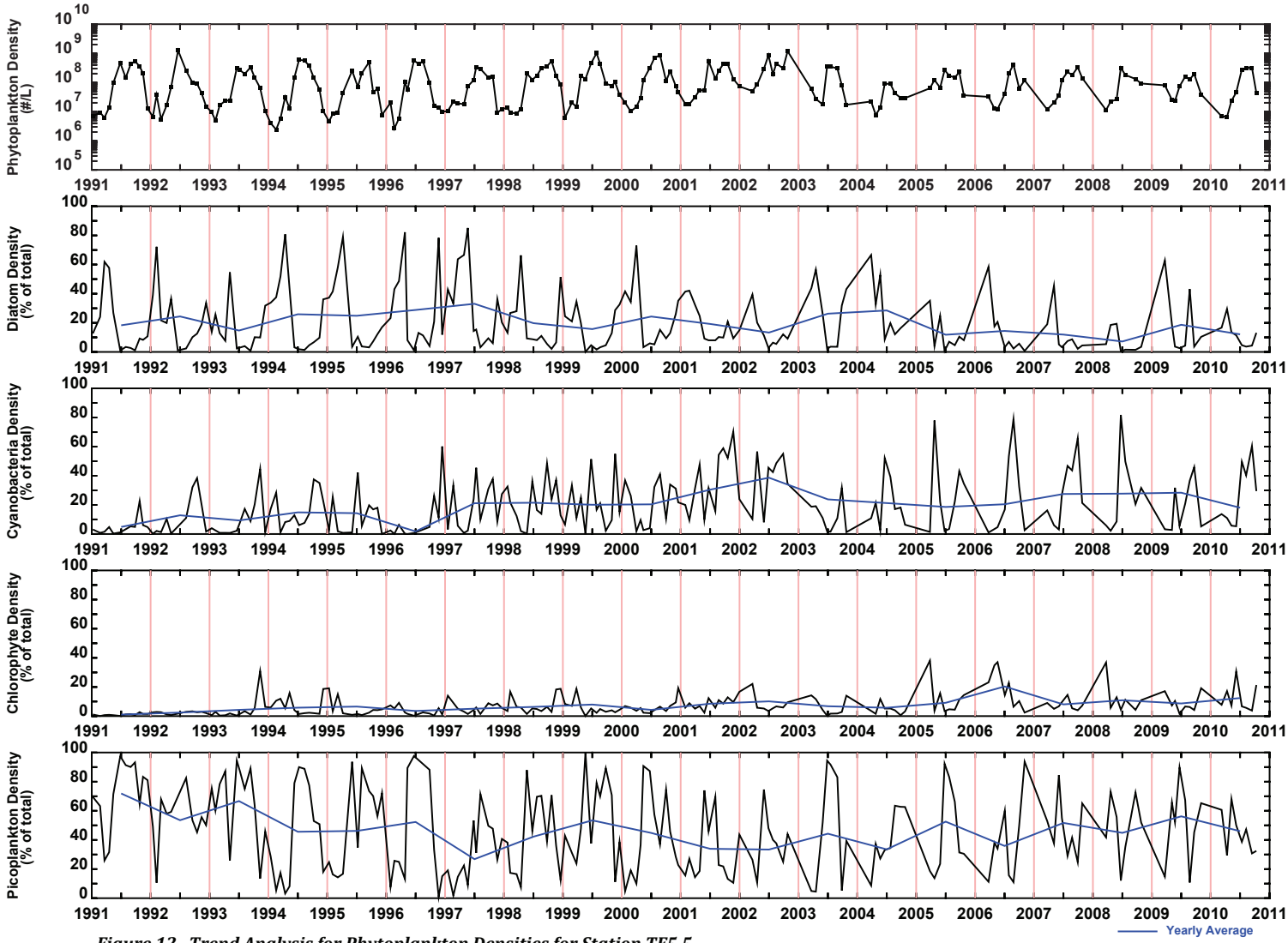


Figure 12. Trend Analysis for Phytoplankton Densities for Station TF5.5

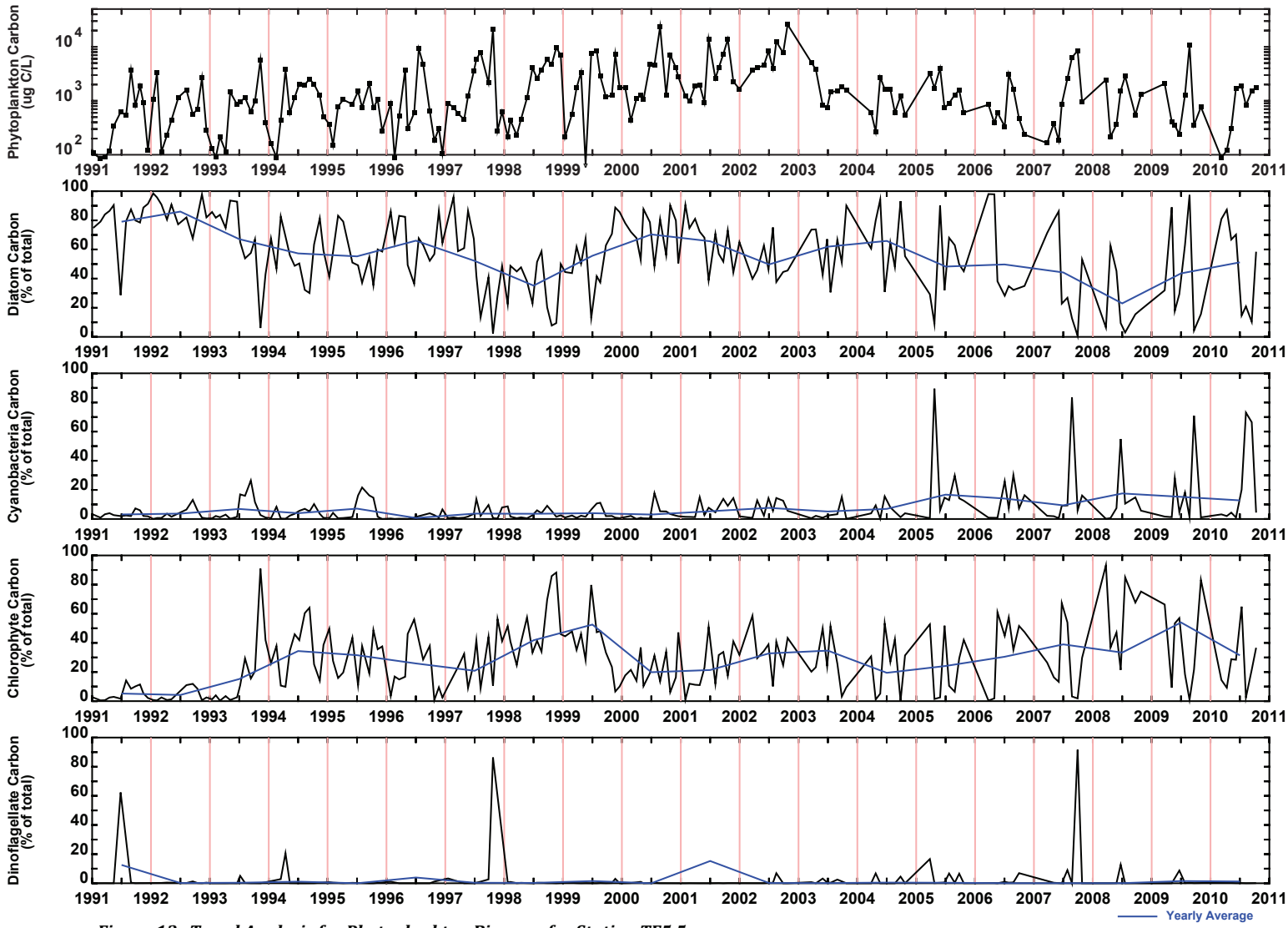


Figure 13. Trend Analysis for Phytoplankton Biomass for Station TF5.5

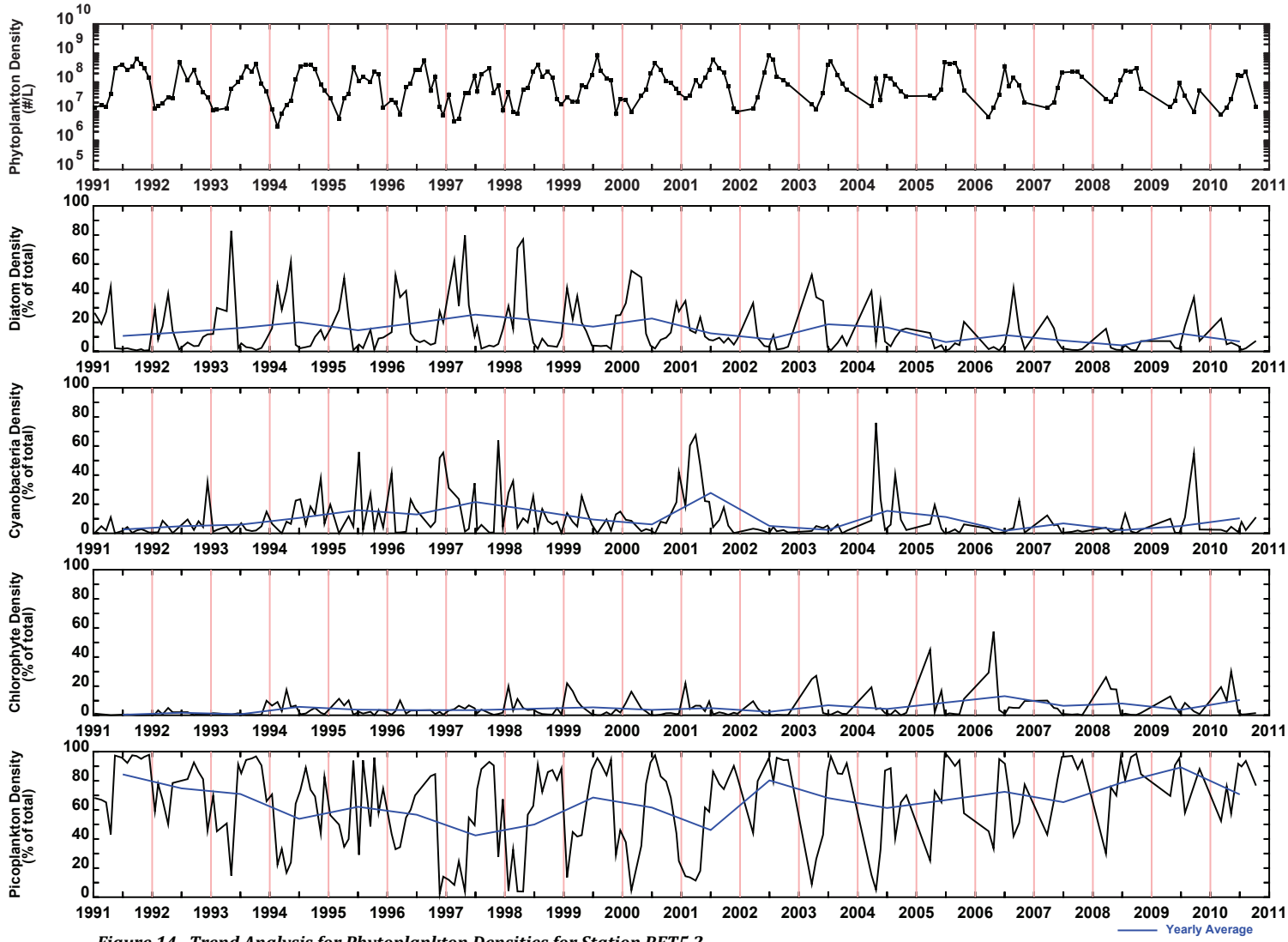


Figure 14. Trend Analysis for Phytoplankton Densities for Station RET5.2

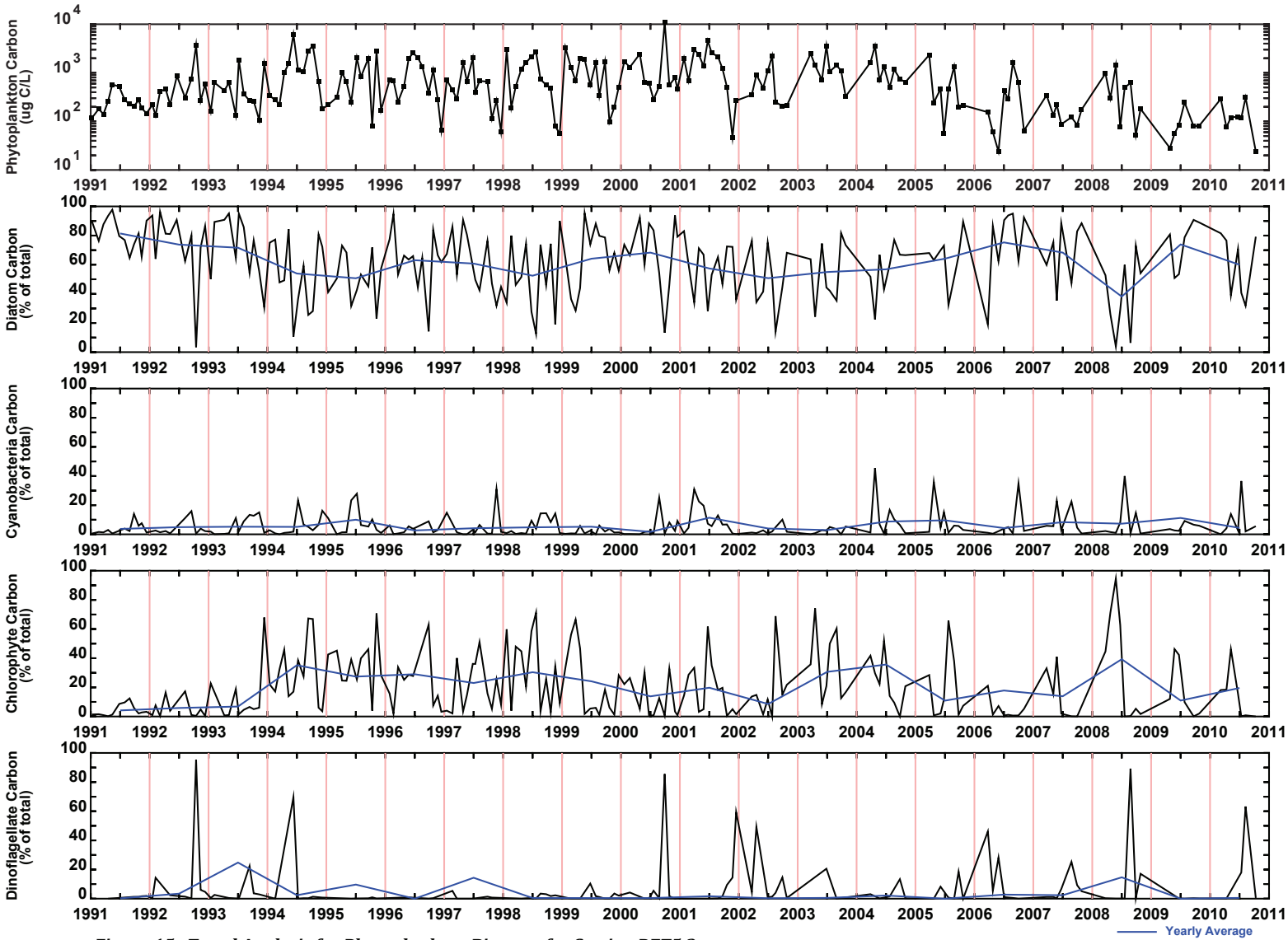


Figure 15. Trend Analysis for Phytoplankton Biomass for Station RET5.2

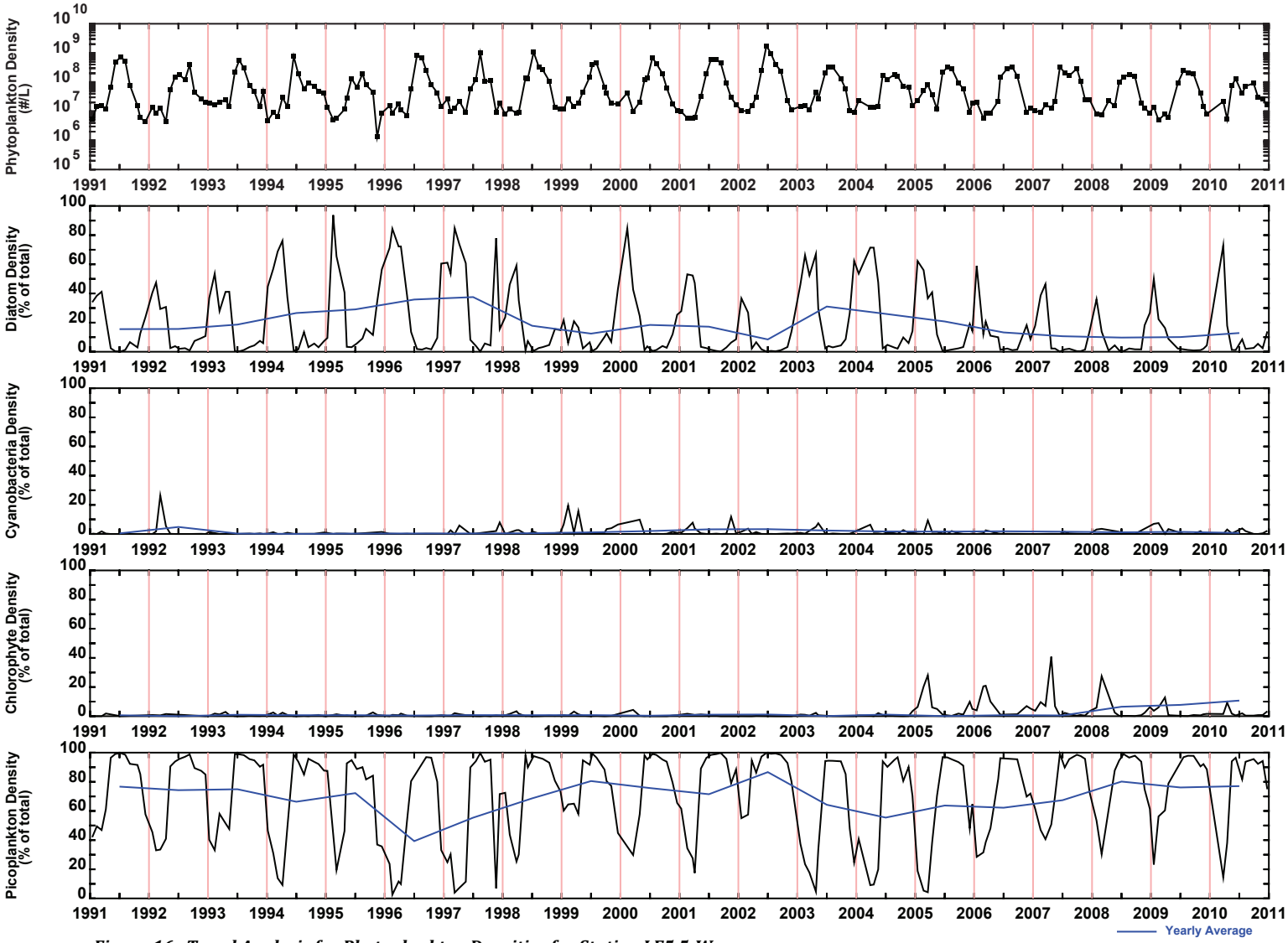


Figure 16. Trend Analysis for Phytoplankton Densities for Station LE5.5-W

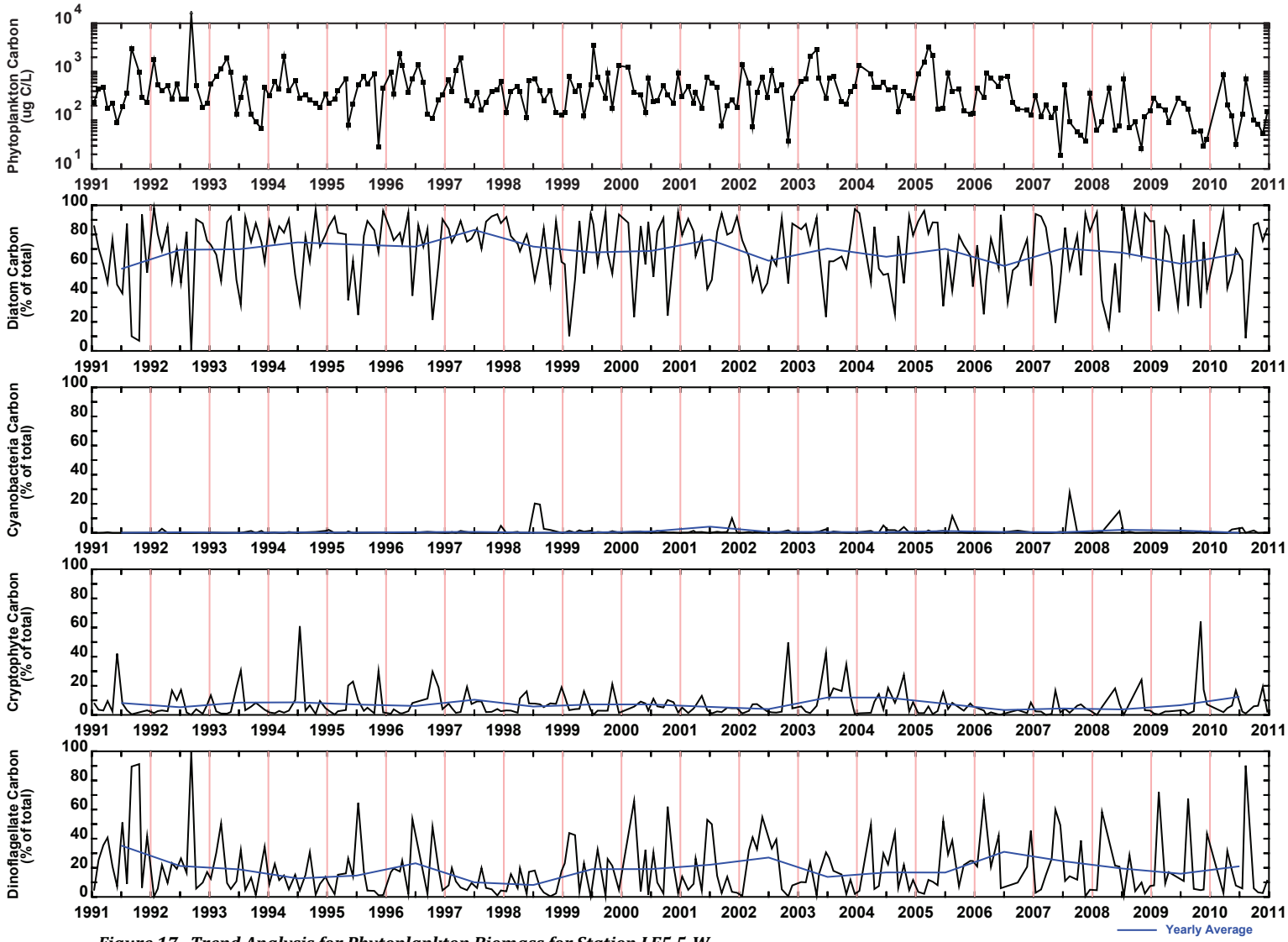


Figure 17. Trend Analysis for Phytoplankton Biomass for Station LE5.5-W

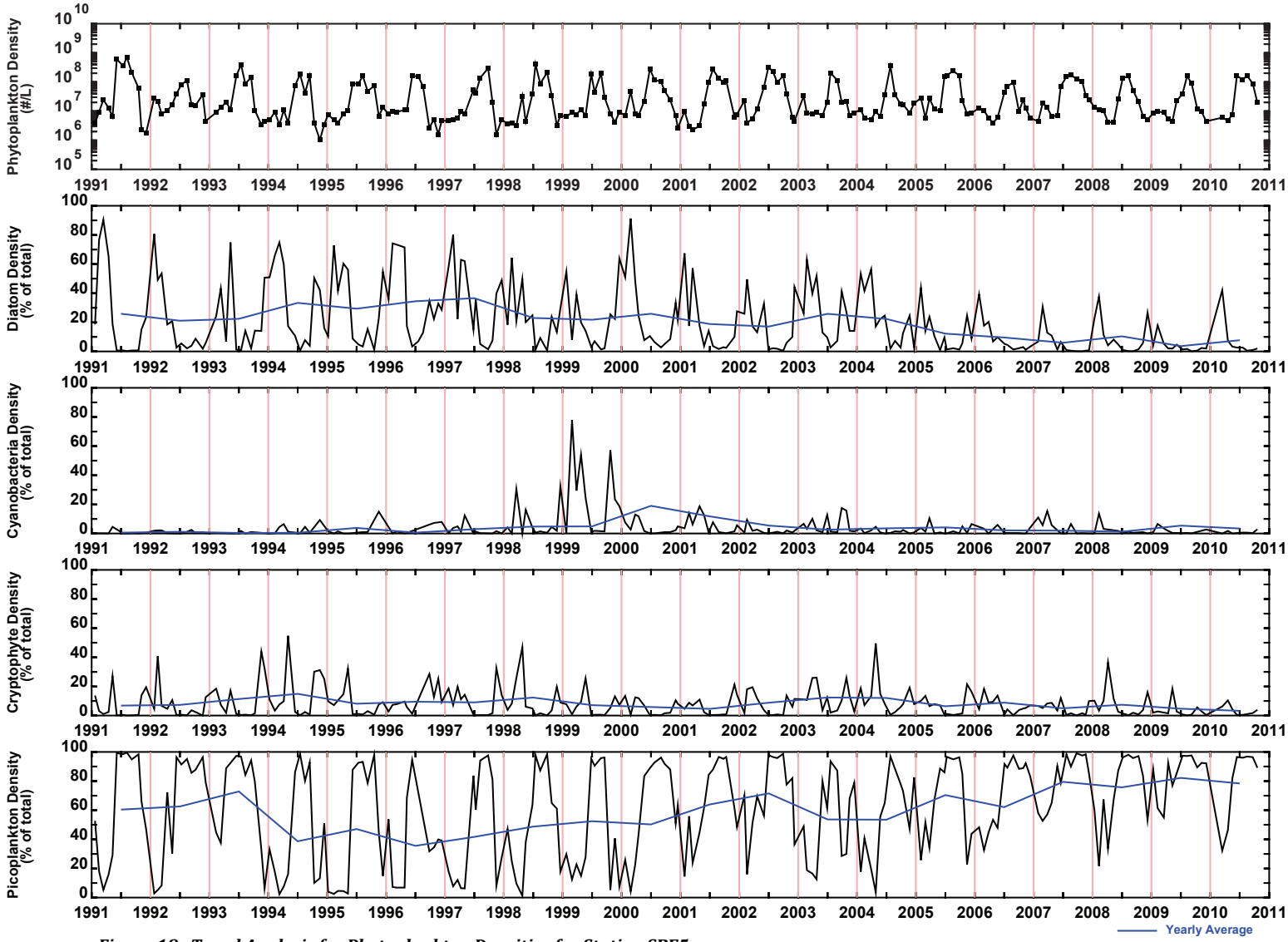


Figure 18. Trend Analysis for Phytoplankton Densities for Station SBE5

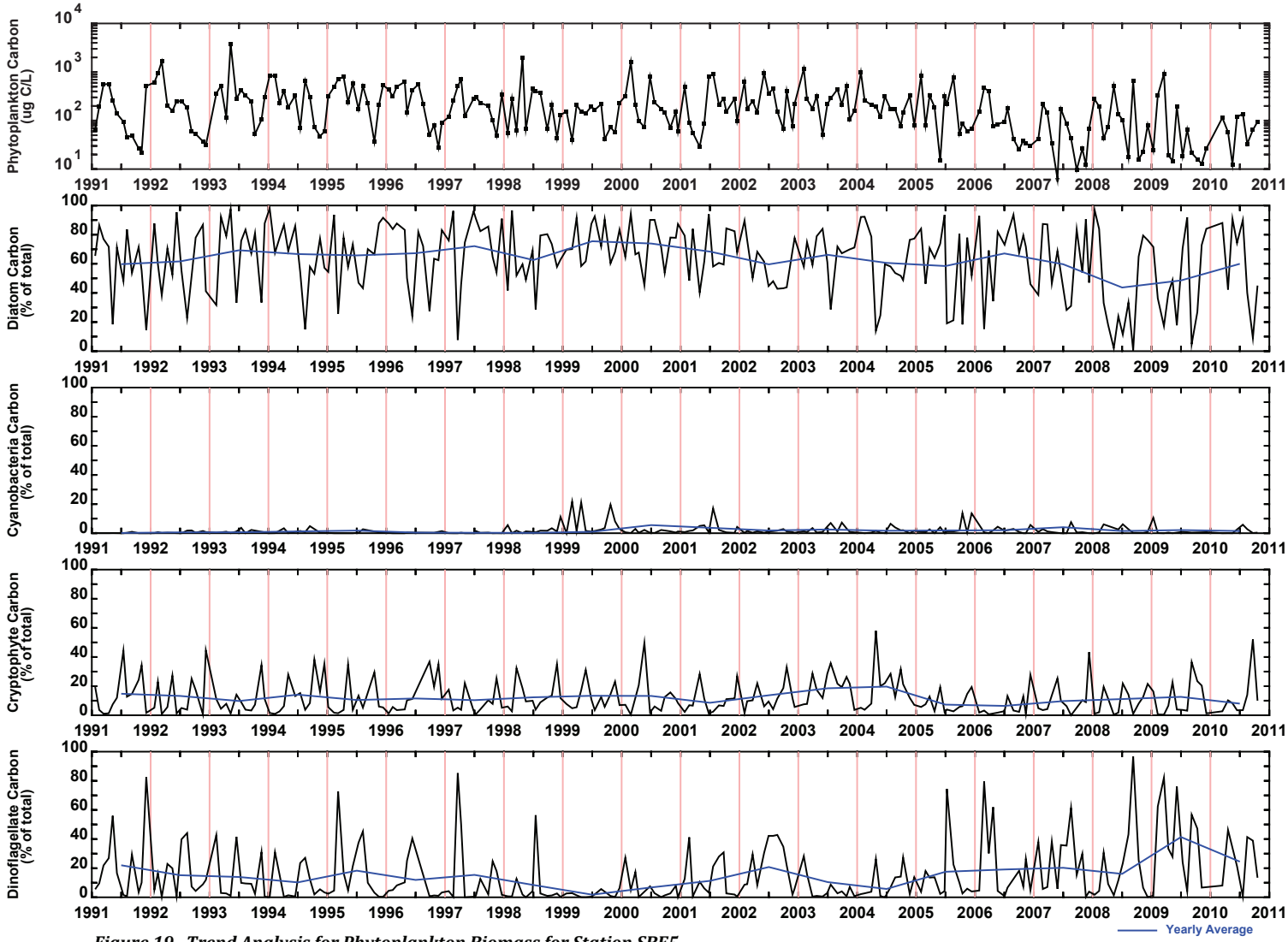


Figure 19. Trend Analysis for Phytoplankton Biomass for Station SBE5

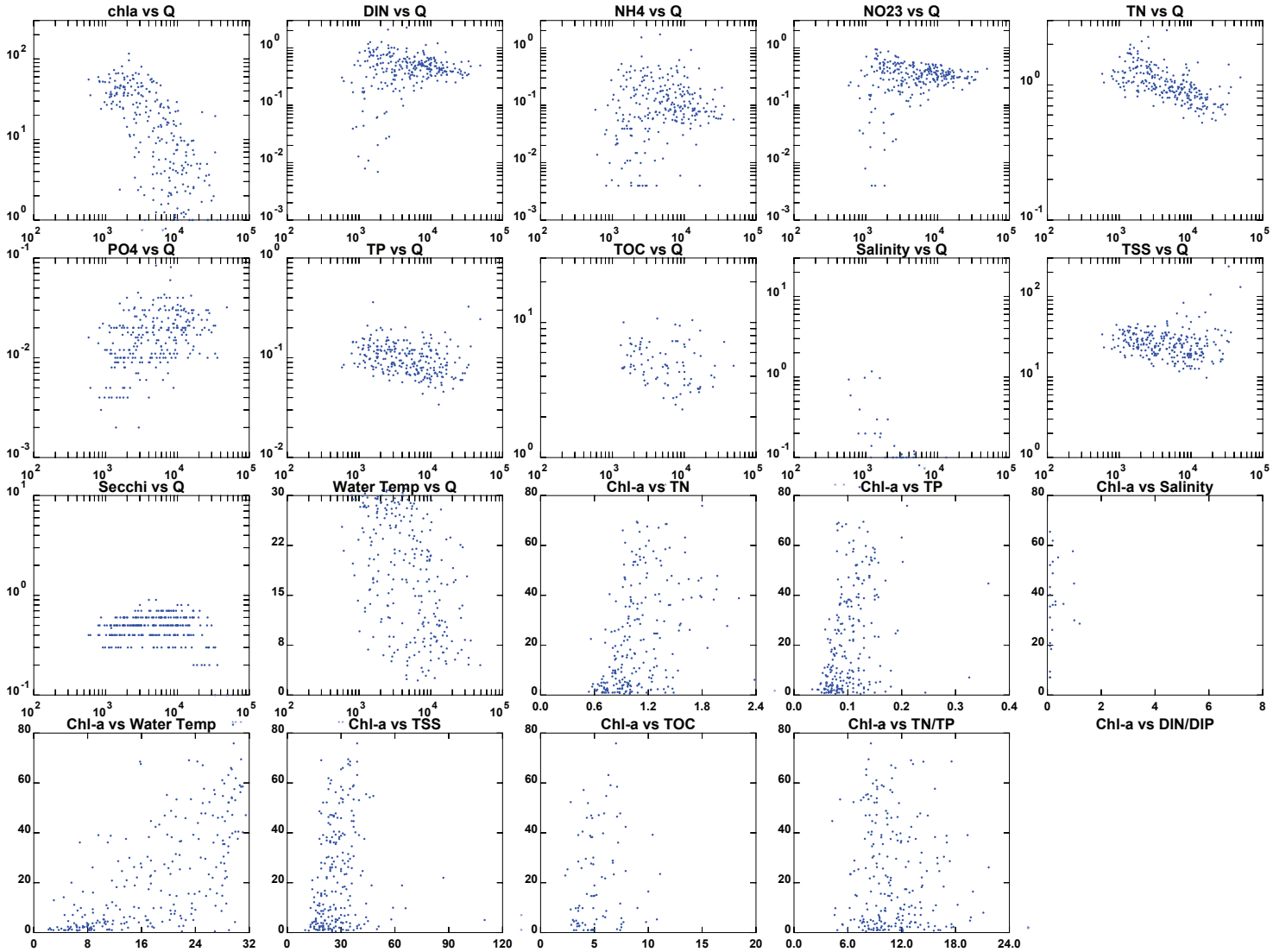


Figure 20. Correlation Analysis of Raw Data for Station TF5.5

relationship between chlorophyll-a and TOC, nor is there a correlation between chlorophyll-a and the ratios of TN/TP nor DIN/DIP.

The data were also analyzed on a seasonal basis, considering spring and summer data only. Consistent with the definition of spring and summer used by the VADEQ for establishing seasonal chlorophyll-a standards for the James River; spring is defined as March 1 through May 31, while summer is defined as July 1 through September 30. There are several interesting differences between the spring (Figure 22) and summer (Figure 23) data sets. While there are still strong correlations between chlorophyll-a and flow, the maximum binned chlorophyll-a averages are about 30 ug/L for the spring vs. 50-60 ug/L for the summer, about a factor of two higher. Some of this difference is due to longer residence times in this portion of the estuary in the summer, which corresponds to lower freshwater inflows. Binned averages for TN and TP are also lower in the spring as compared to the summer. Average DIN and PO4 concentrations are quite similar and appear to be at concentrations above which would strongly limit algal growth (10 ug N/L and 1 ug P/L, respectively). Interestingly, minimum averages of dissolved silica (Si) appear lower in the summer as compared to the spring, suggesting additional uptake and utilization by summer diatoms. Although the concentrations of TSS appear quite similar in the spring and summer, secchi depths are slightly lower in the summer as compare to the spring; probably reflecting the influence of increased concentrations of chlorophyll-a in the summer period. Interesting as well, is that there appears to be a good correlation between the concentrations of chlorophyll-a and TN and TP in the spring and for chlorophyll-a and TN in the summer, while the correlation between chlorophyll-a and TP is not as strong in the summer. Both seasons, however, continue to indicate that phosphorus is the more potentially limiting nutrient, as indicated by the ratios of TN to TP.

Station RET5.2

Moving downstream to station RET5.2, located in the mesohaline portion of the James River estuary, there does not appear to be a strong relationship between chlorophyll-a and river flow either on an annual (Figure 24), spring (Figure 25) or summer (Figure 26) timeframe. Chlorophyll-a levels do appear to be slightly higher in the spring (binned averages ~10-15 ug/L) as compared to the summer (binned averages ~5-10 ug/L). Concentrations of DIN are lower in the summer at this station when compared to the upstream tidal fresh station (TF5.5), while concentrations of PO_4 are slightly higher, perhaps indicating that nitrogen is becoming the more limiting nutrient in this section of the river. This is not as strongly reflected in the ratios of TN/TP during the summer months. While, the ratios are lower than observed at TF5.5, they are still slightly above 7, which would still favor a limitation by nitrogen as compared to phosphorus. It should be recognized however that the literature suggests that there is some range in this value. Total suspended solids are elevated in the spring (binned averages ranging from ~25-50 mg/L) when compared to the summer (~20-30 mg/L), which results in slightly lower values of secchi disk depth in the spring as compared to the summer. There is some suggestion of a correlation between chlorophyll-a and TP,

but not TN, in the spring. However, during the summer months, chlorophyll-a concentrations do not appear to be correlated to either TP or TN.

Station LE5.2

Station LE5.2 is located in the polyhaline portion of the estuary. On an annual basis, the data do not show a strong correlation between chlorophyll-a biomass and freshwater inflow (Figure 27), but do tend to increase a little at intermediate flows (2,000 to 10,000 cubic feet per second (cfs)). Both DIN and TN increase at flow above ~5,000 cfs. This is in contrast to PO_4, which shows a decrease in concentration with increasing flow, but the decrease levels off for flows about 2,500 cfs. TP is fairly independent of flow. Similar to DIN, Si demonstrates an increase in concentration above flows of 2,500 cfs. The ratio of TN:TP shows an increasing trend with increased flows, as does TSS. Corresponding to the increased levels of TSS, the secchi disk depth decreases with increasing flow. At this station, there appears to be a fairly strong relationship between chlorophyll-a and TN and to a lesser degree with TP. Interestingly, chlorophyll-a appears to be inversely correlated to temperature, with the higher chlorophyll-a concentrations observed at the lower temperatures. However, as shown by the standard deviations about the binned data, there is considerable variability in this relationship. On an annual basis, there does not appear to be a relationship between chlorophyll-a and the ratio of TN:TP. Similar observations can be made for the spring (Figure 28) and summer (Figure 29) data sets. The one noteworthy observation concerns the ratio of TN:TP, which for the summer period indicates that nitrogen may be becoming the more limiting nutrient, as the TN:TP ratio is below 7 under low flows.

Station LE5.5

Station LE5.5, is also located in the polyhaline portion of the estuary, at the confluence of the river and Chesapeake Bay. On an annual basis, the data do not show a strong correlation between chlorophyll-a biomass and freshwater inflow (Figure 30). Binned chlorophyll-a concentrations are averaging about 10 ug/L. DIN does appear to increase about flows of ~10,000 cfs, while TN appears to be relatively independent of flow. Both PO_4 and TP data show minimum values between 5,000 and 10,000 cfs. Silica, similar to DIN, shows an increasing trend at flows above 10,000 cfs. The ratio of TN:TP appears to be slightly correlated to flow, with the TN:TP ratio increasing with increasing flow. TSS and secchi depth appear to be independent of flow. There does appear to be a correlation between phytoplankton chlorophyll-a and TN, but not for TP nor salinity nor temperature. Chlorophyll-a also appears to be independent of the TN:TP ratio. In general, the same comments that were made for the annual data also apply to both the spring (Figure 31) and summer (Figure 32) periods. The only major difference is that for the summer period, the TN:TP ratio appears to be independent of flow and the ratios are lower in the summer as compared to the spring.

In general, this data analysis (with additional supporting plots presented in Appendix A) suggests that in the upper freshwater portions of the James River

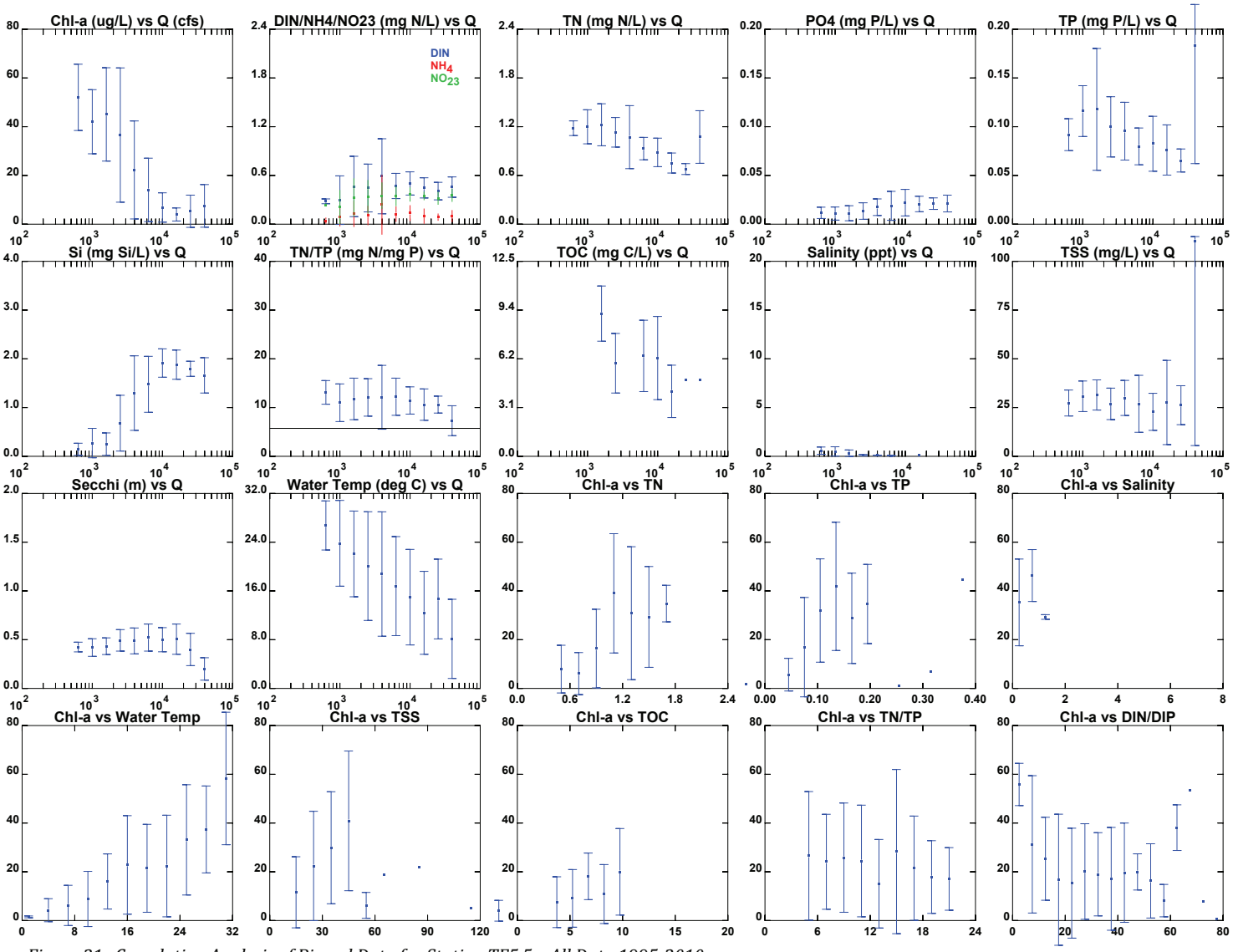


Figure 21. Correlation Analysis of Binned Data for Station TF5.5 – All Data 1995-2010

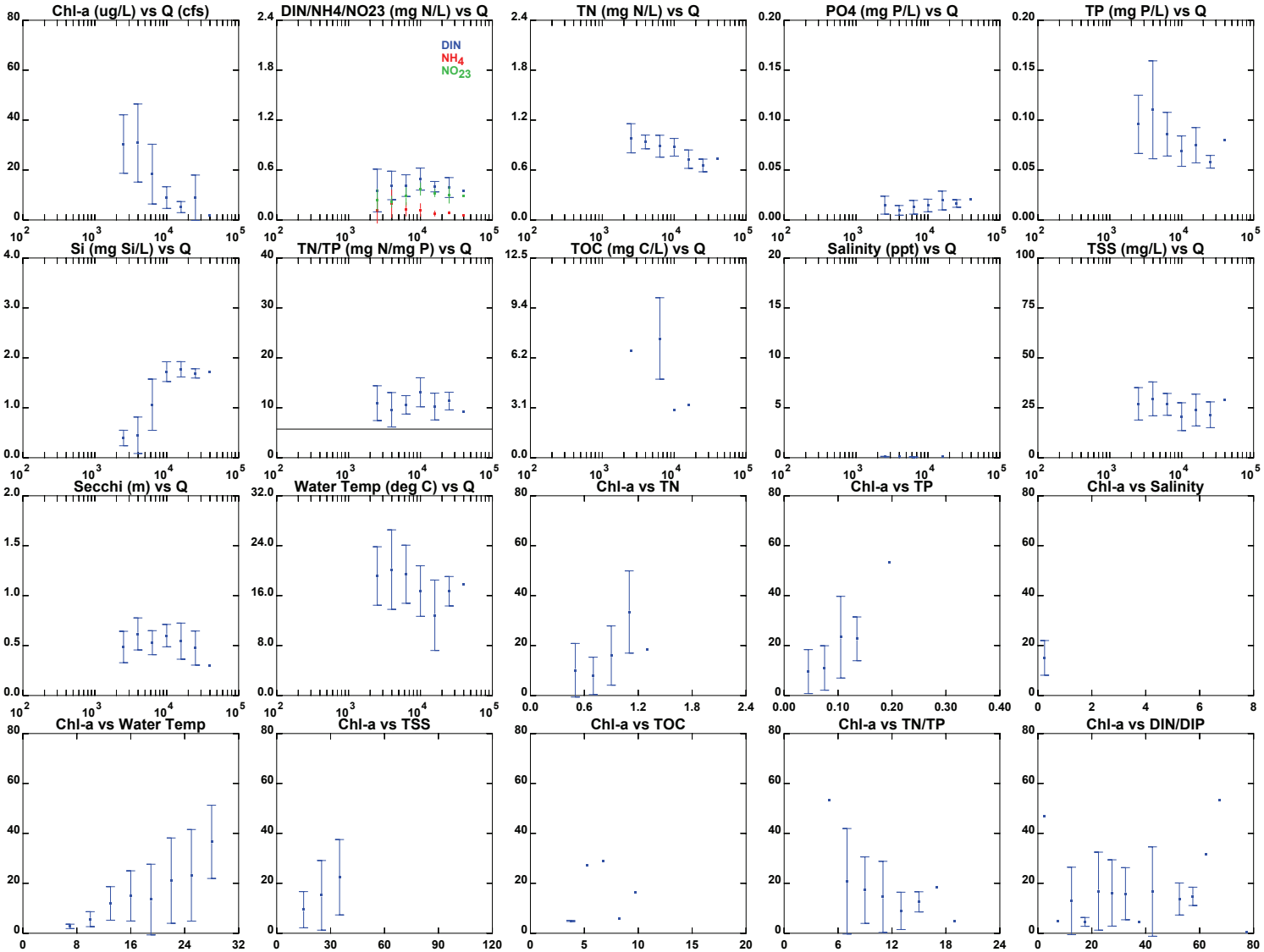


Figure 22. Correlation Analysis of Binned Data for Station TF5.5 – Spring Data Only 1995-2010

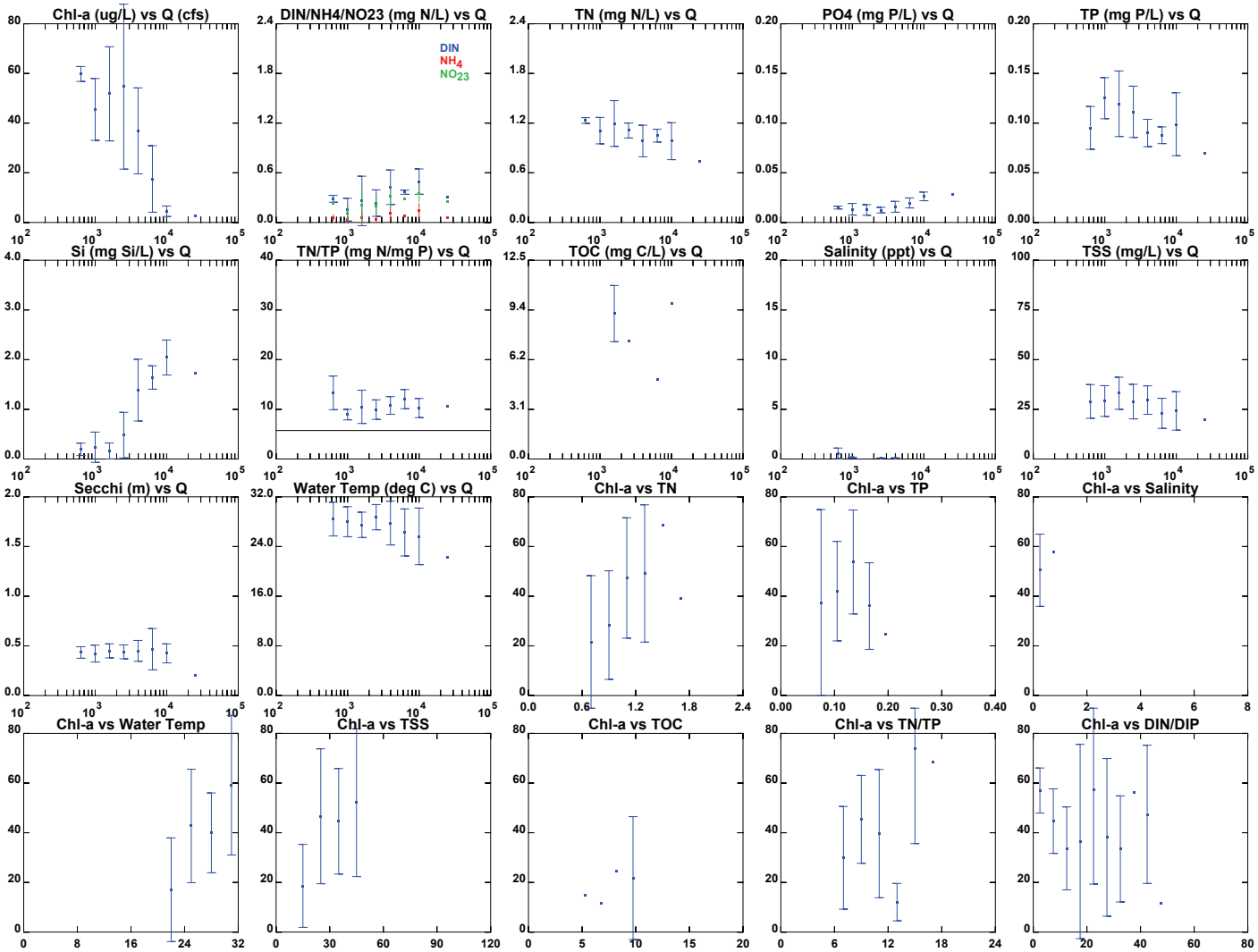


Figure 23. Correlation Analysis of Binned Data for Station TF5.5 – Summer Data Only 1995-2010

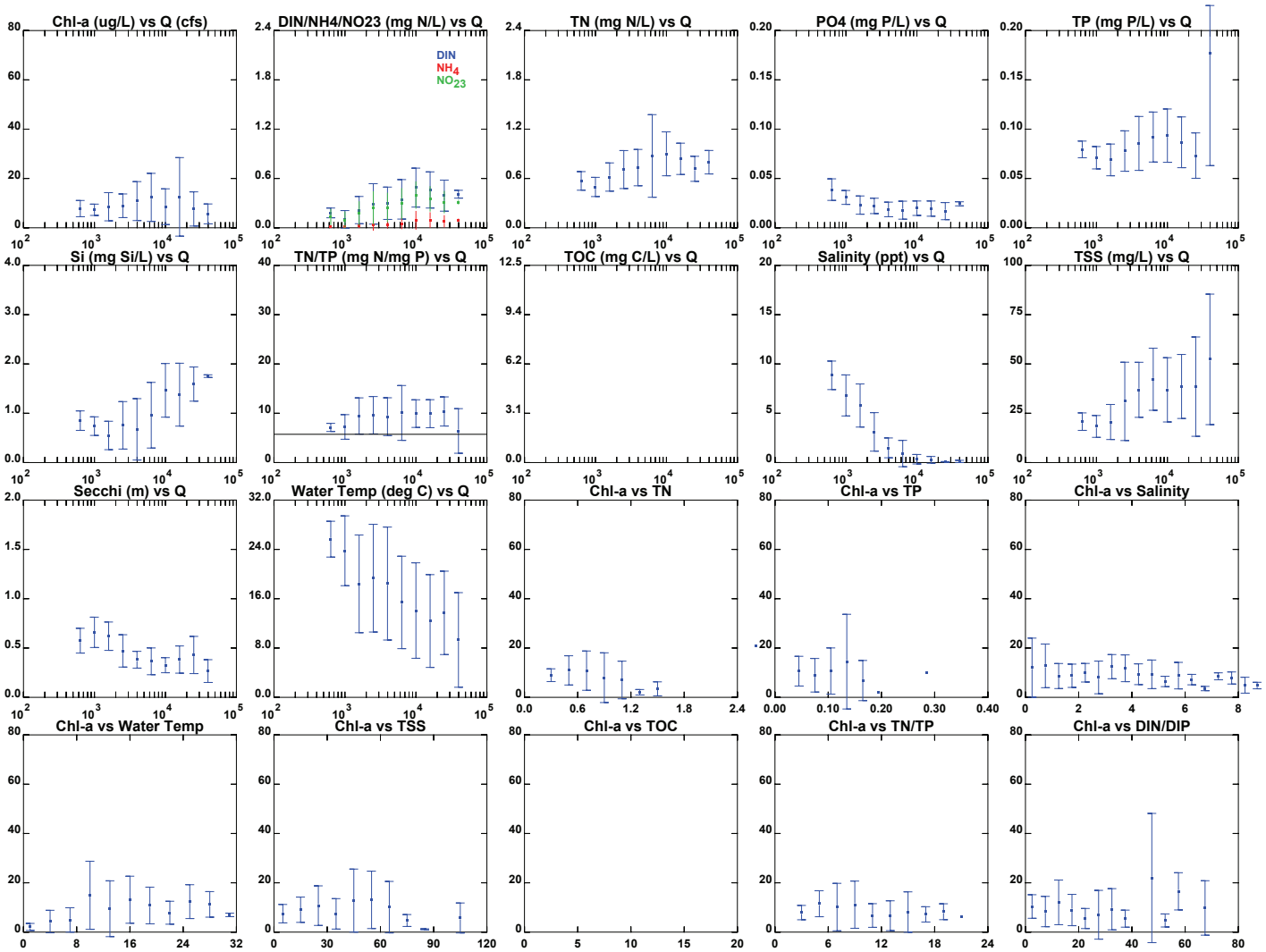


Figure 24. Correlation Analysis of Binned Data for Station RET5.2 – All Data 1995-2010

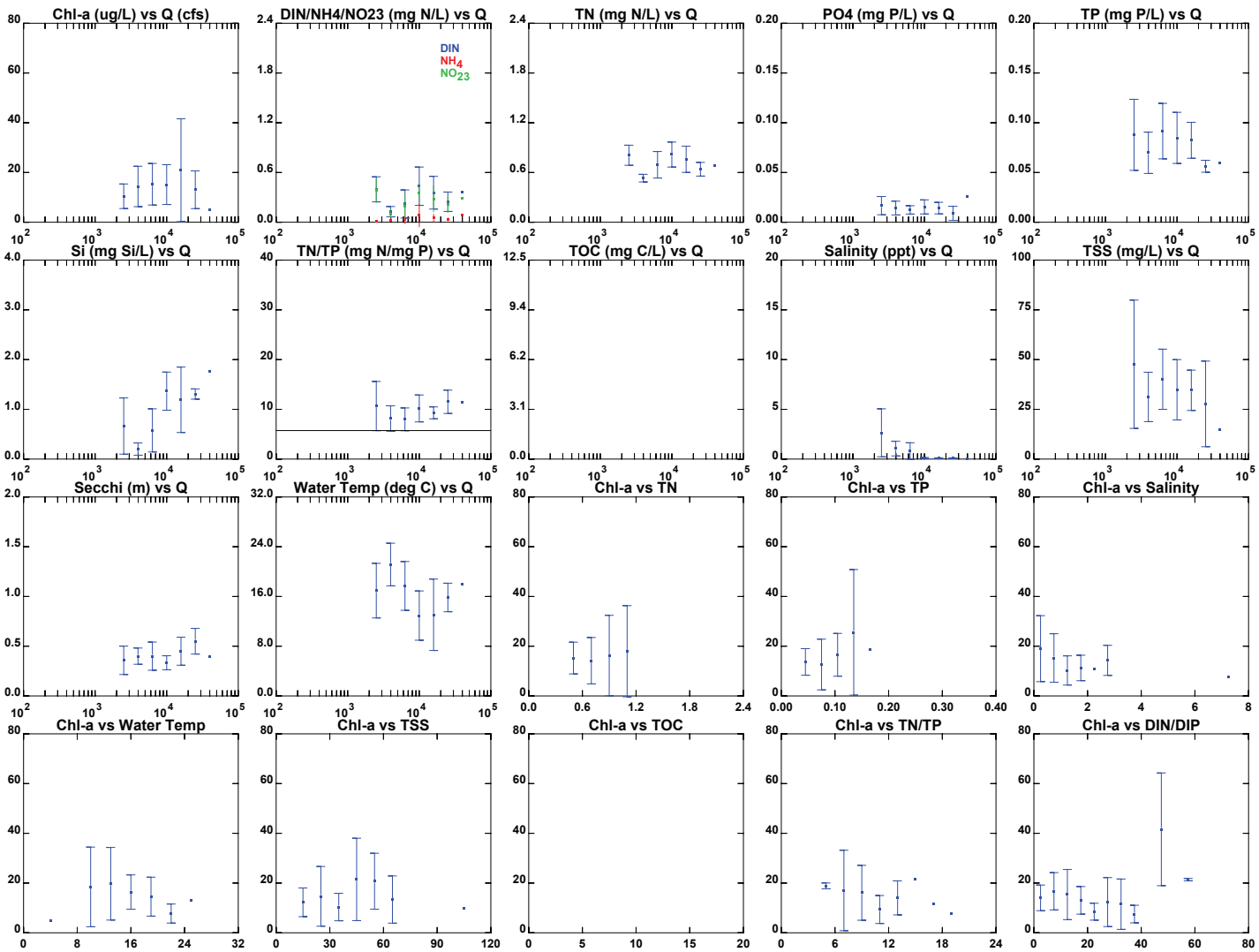


Figure 25. Correlation Analysis of Binned Data for Station RET5.2 – Spring Data Only 1995-2010

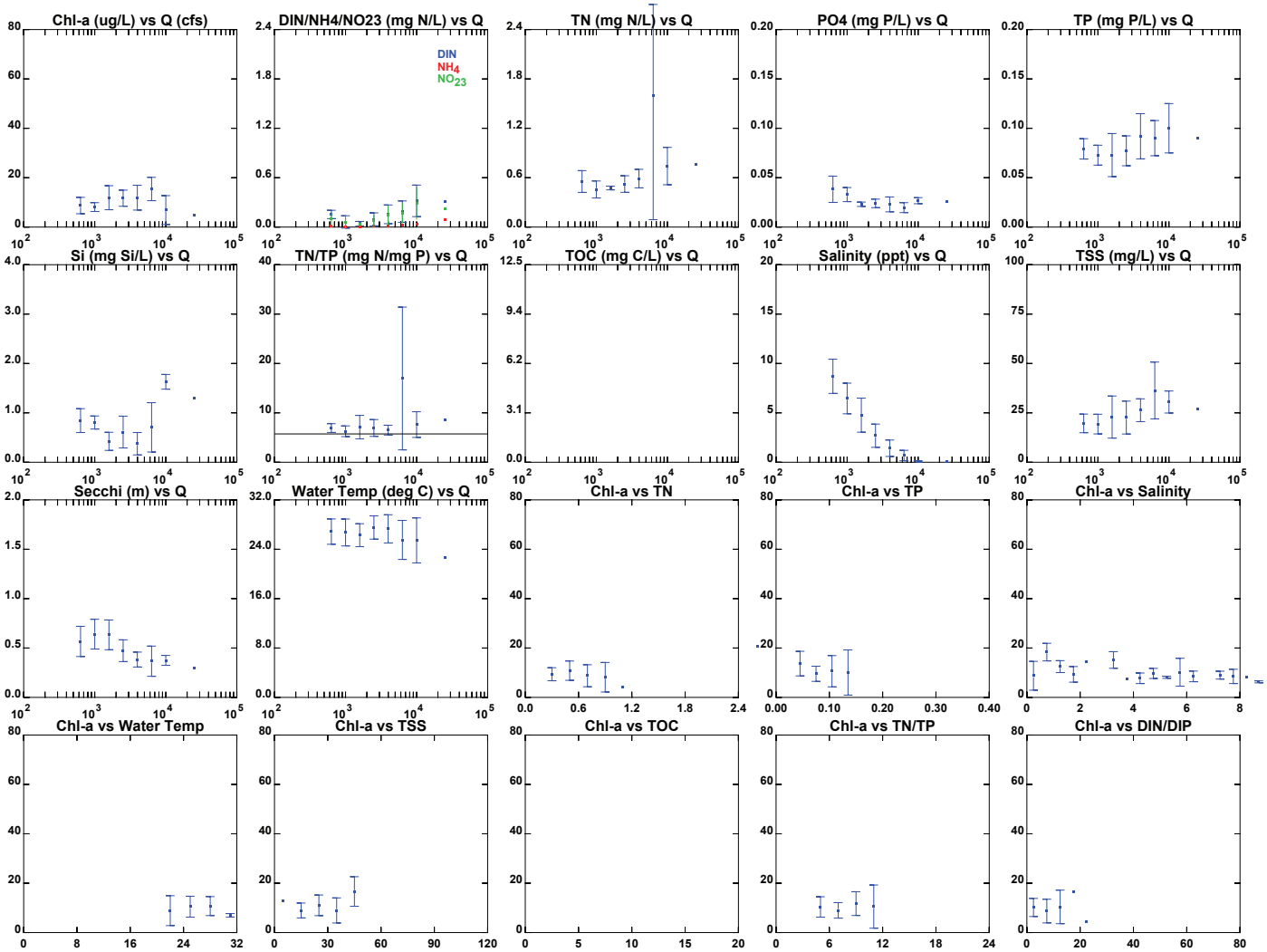


Figure 26. Correlation Analysis of Binned Data for Station RET5.2 – Summer Data Only 1995-2010

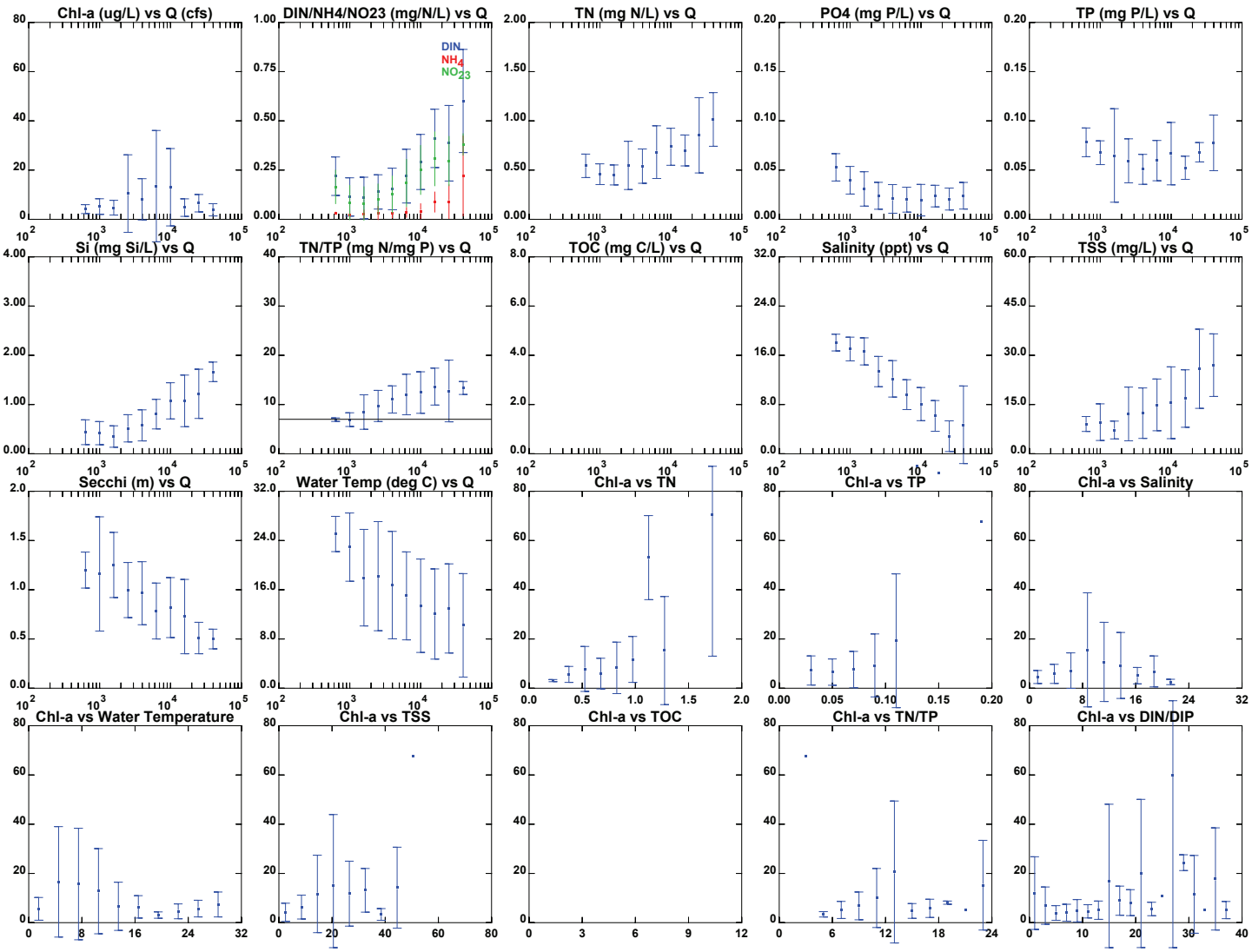


Figure 27. Correlation Analysis of Binned Data for Station LE5.2 – All Data 1995-2010

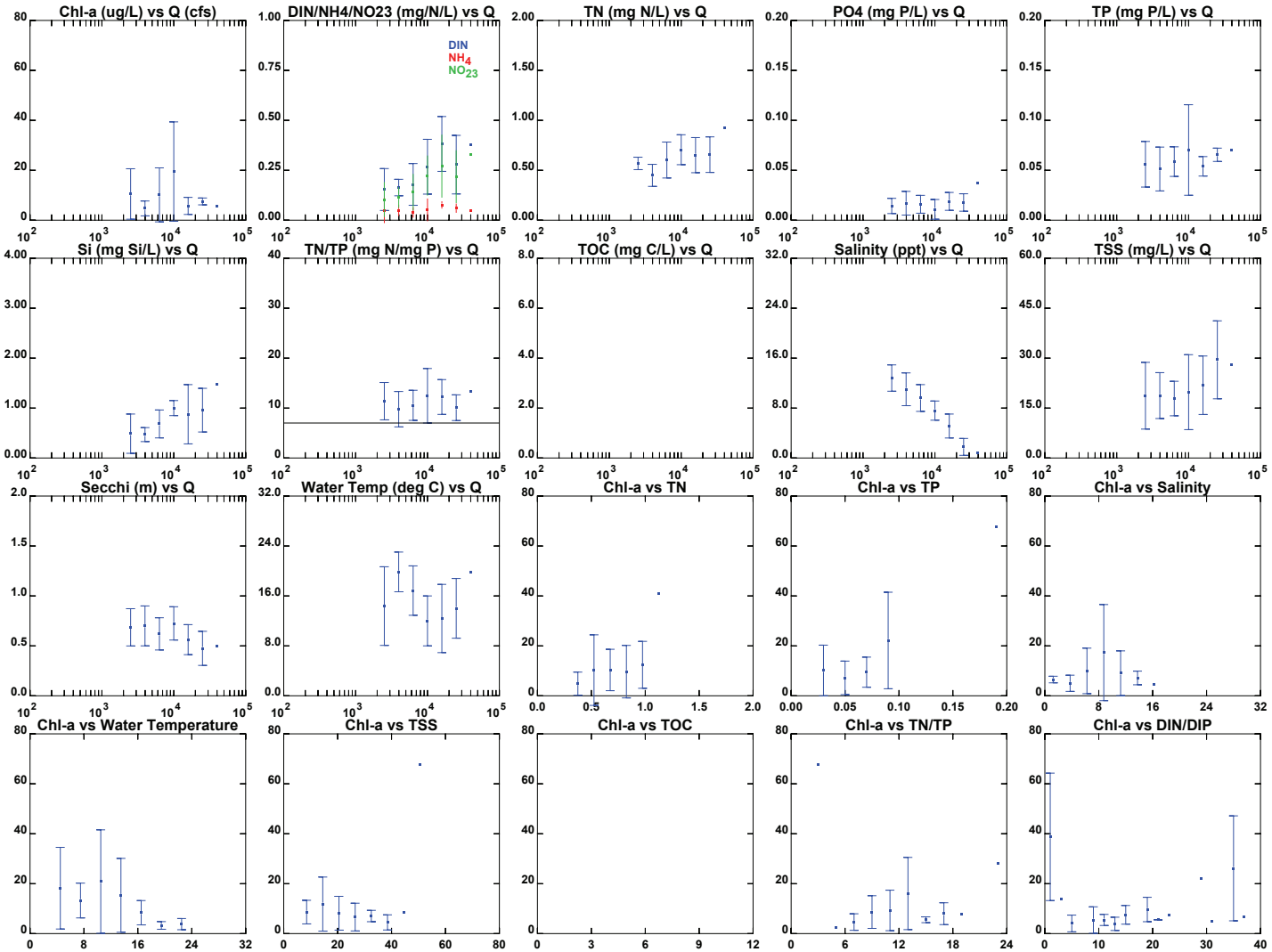


Figure 28. Correlation Analysis of Binned Data for Station LE5.2 – Spring Data Only 1995-2010

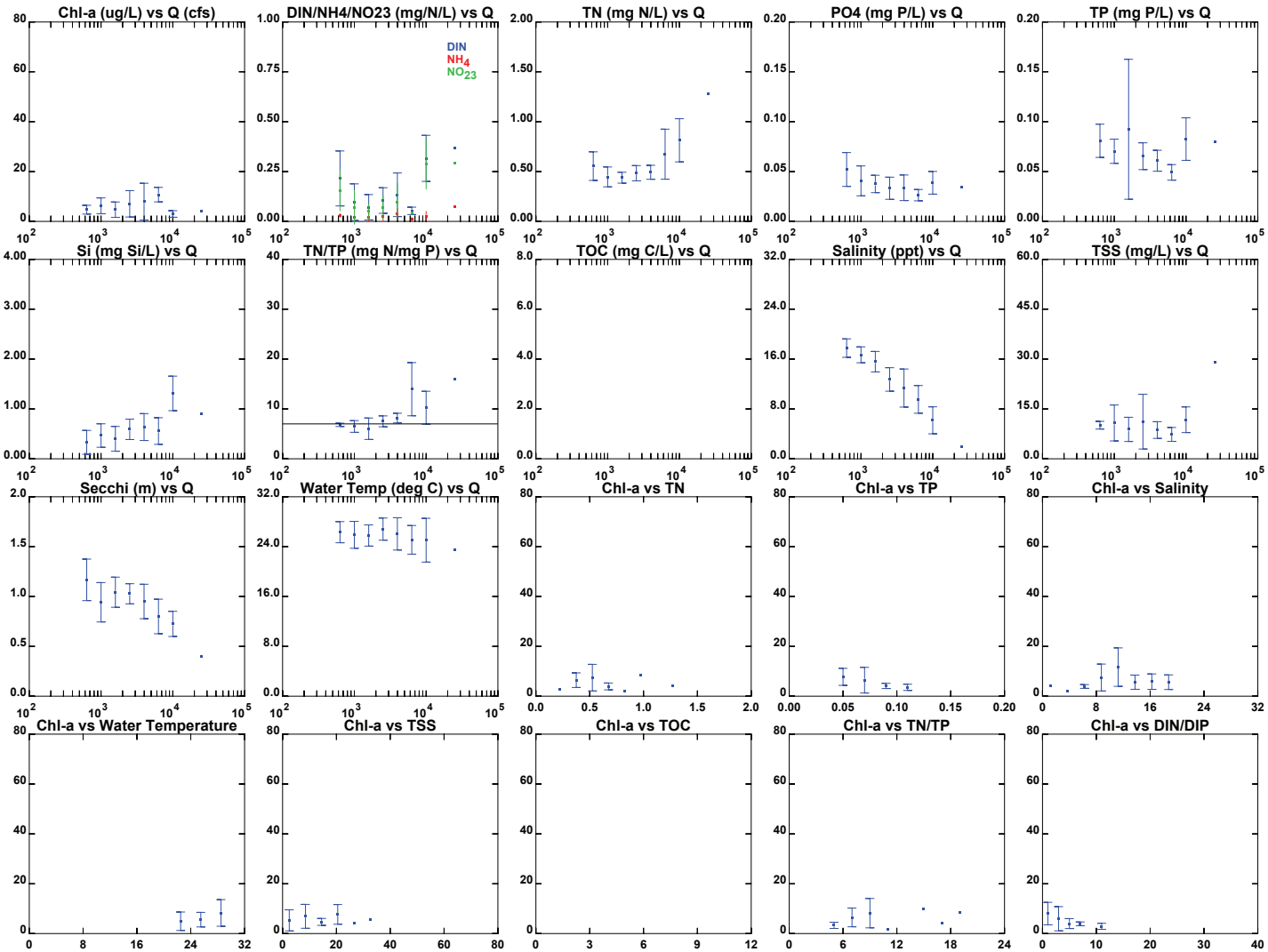


Figure 29. Correlation Analysis of Binned Data for Station LE5.2 – Summer Data Only 1995-2010

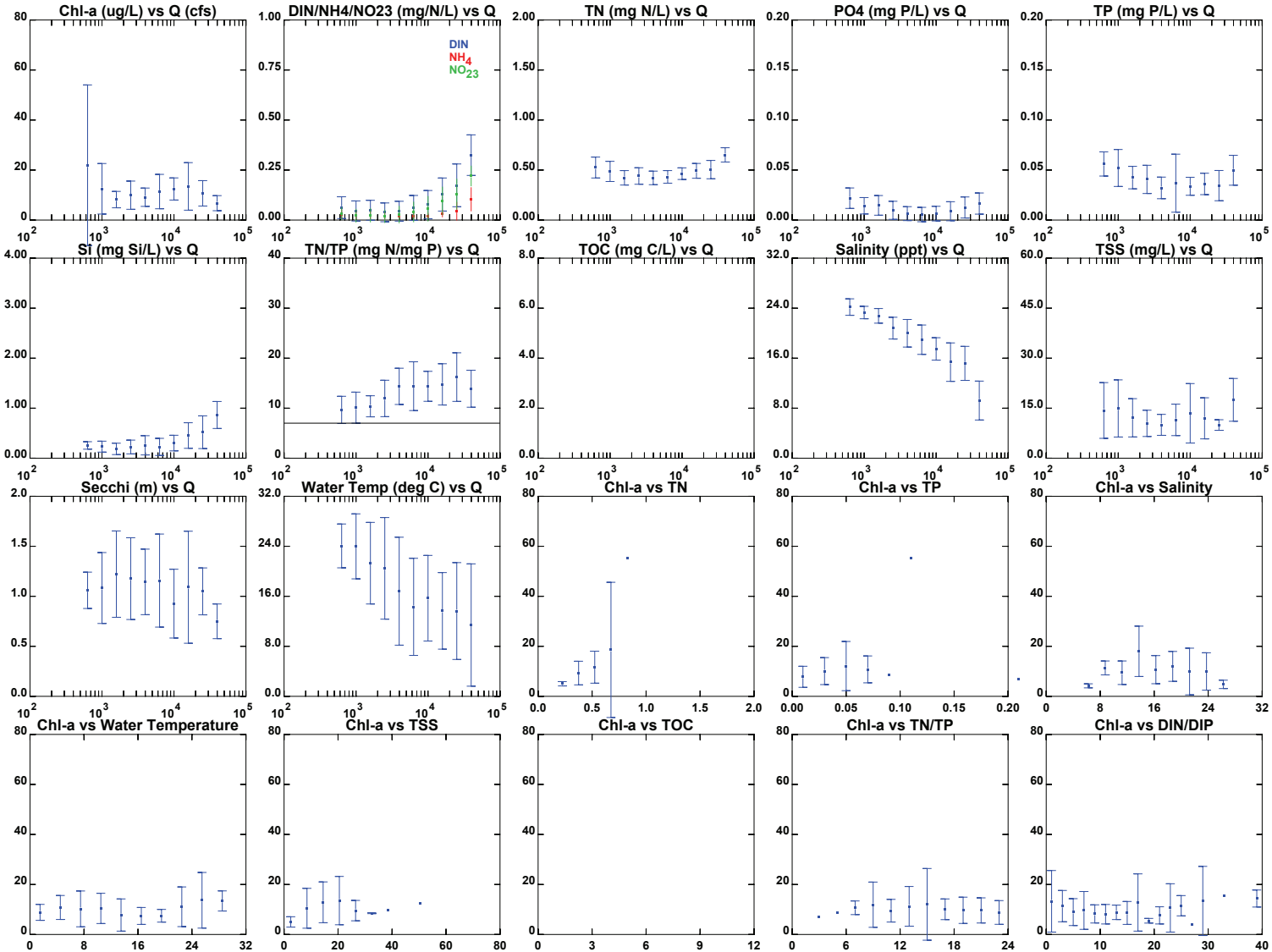


Figure 30. Correlation Analysis of Binned Data for Station LE5.5-W – All Data 1995-2010

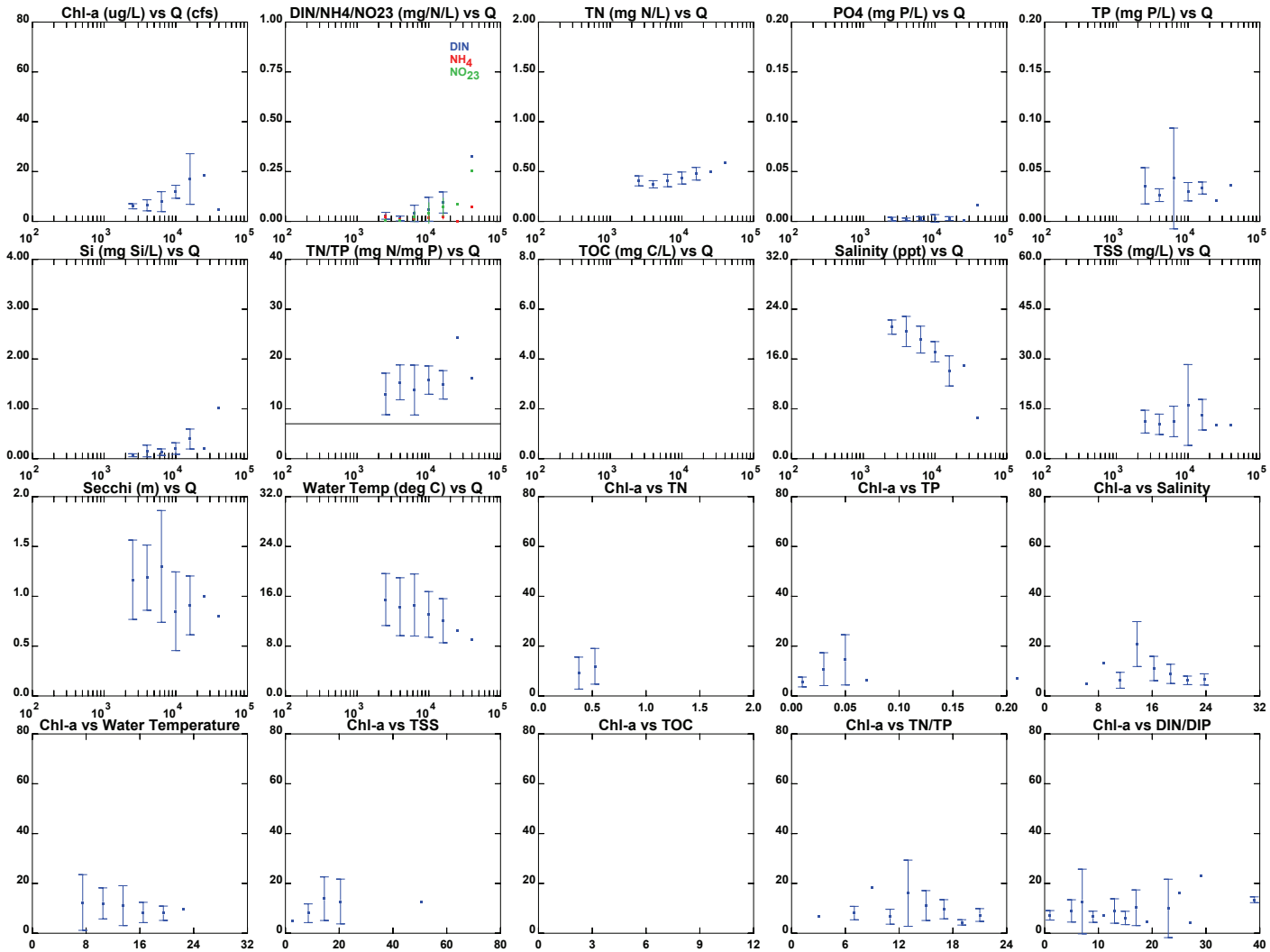


Figure 31. Correlation Analysis of Binned Data for Station LE5.5-W – Spring Data Only 1995-2010

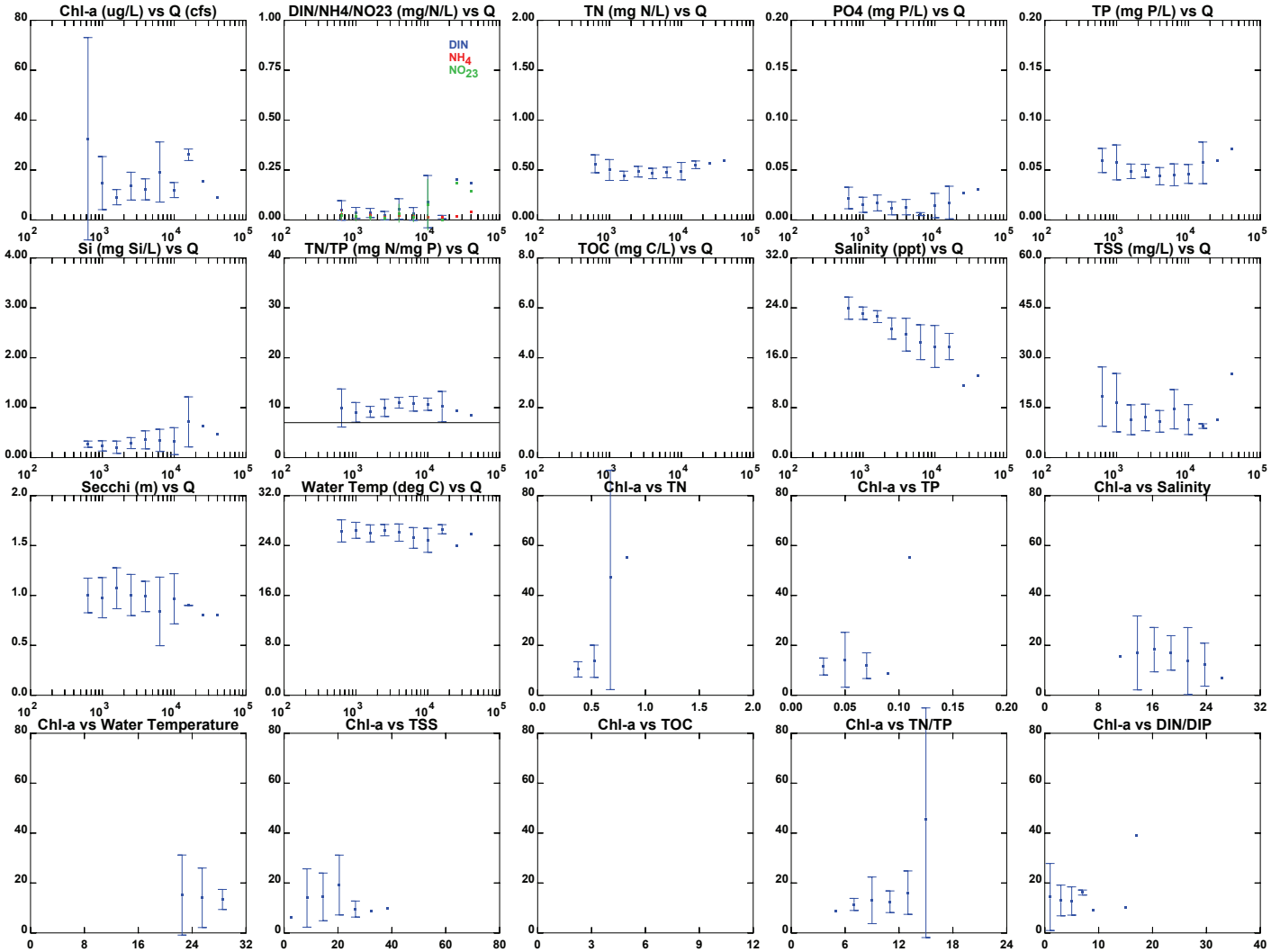


Figure 32. Correlation Analysis of Binned Data for Station LE5.5-W – Summer Data Only 1995-2010

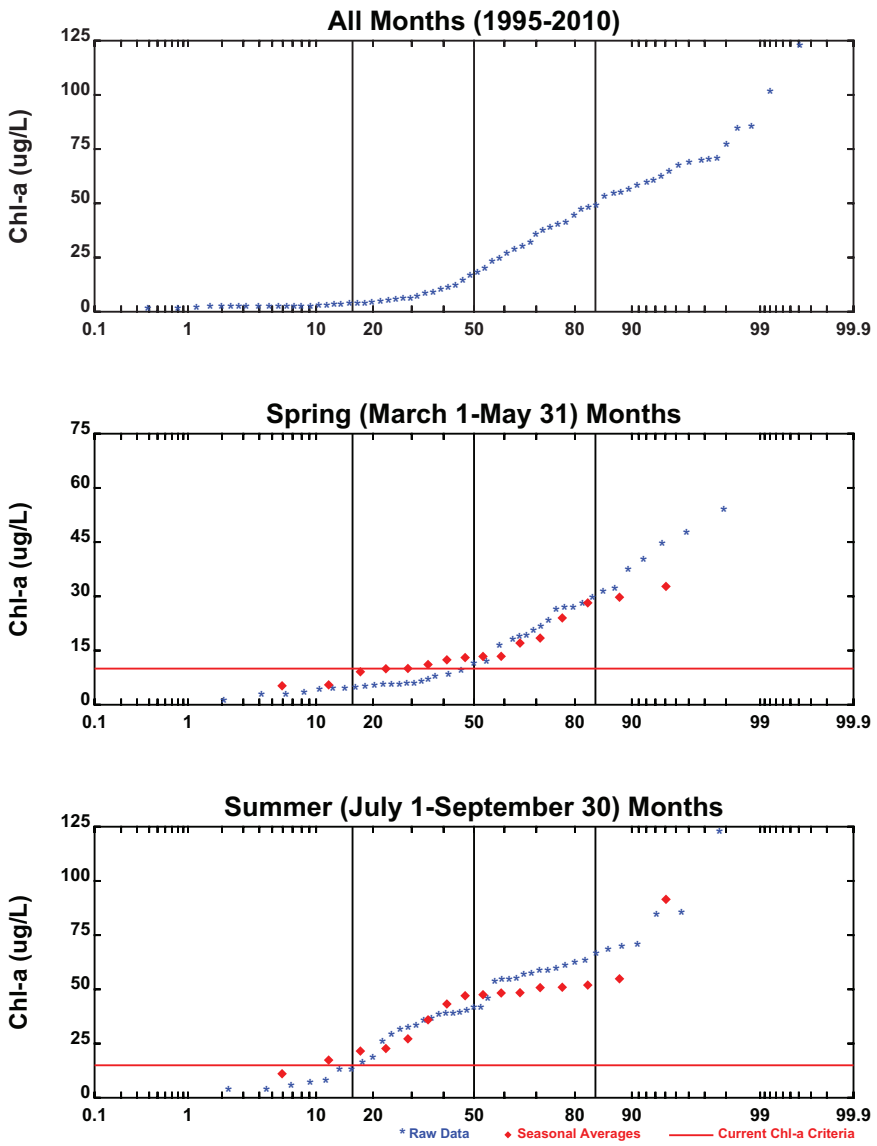


Figure 33. Cumulative Distribution Functions for Annual Chlorophyll-a Concentrations and Compliance with Current Spring and Summer Chlorophyll-a Criteria for Station TF5.5

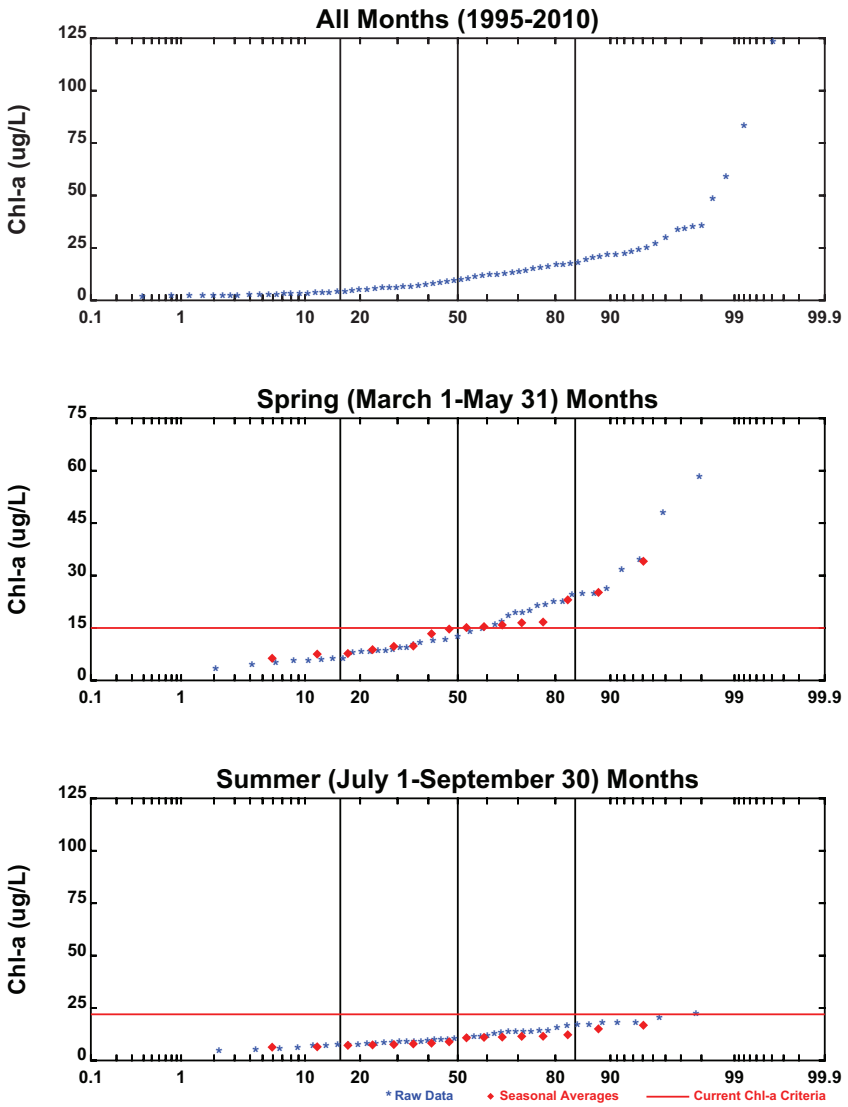


Figure 34. Cumulative Distribution Functions for Annual Chlorophyll-a Concentrations and Compliance with Current Spring and Summer Chlorophyll-a Criteria for Station RET5.2

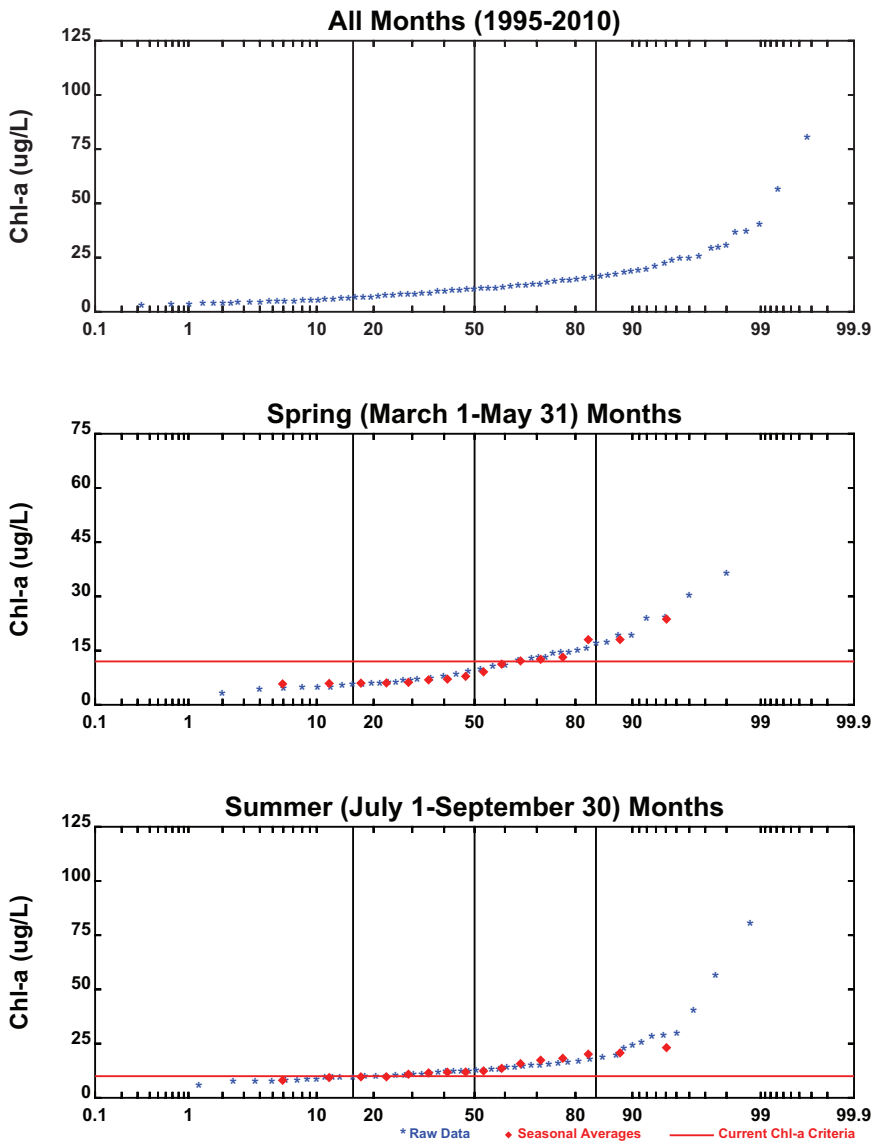


Figure 35. Cumulative Distribution Functions for Annual Chlorophyll-a Concentrations and Compliance with Current Spring and Summer Chlorophyll-a Criteria for Station LE5.5-W

Estuary, chlorophyll-a is strongly correlated with freshwater flow and temperature and, with perhaps the exception of stations TF5.4 and TF5.5, is not strongly correlated to TN nor TP. In the mesohaline portion of the estuary, chlorophyll-a does not appear to be strongly correlated to any physical or nutrient variables. In the polyhaline portion of the estuary, chlorophyll-a appears to be weakly correlated to TN or TP and perhaps temperature, depending upon the station and season being considered.

Present Compliance with Existing Standards

The chlorophyll-a data were reviewed to evaluate the frequency that the observed data exceeded the current chlorophyll-a standards. Cumulative frequency distributions (including the one standard-deviation around the median, represented by vertical bars) of the available chlorophyll-a concentrations (blue asterisks) were generated on an annual basis and then for the spring (March 1 through May 31) and summer (July 1 through September 30) periods. In addition, the data were seasonally averaged (red diamonds) so that compliance with the current criteria could be evaluated. Starting at the upstream freshwater station (TF5.5), the observations show that, on an annual basis, chlorophyll-a concentrations are greater than 18 ug/L more than 50% of the time (Figure 33) and are greater than 40 ug/L about 20% of the time. The existing spring chlorophyll-a criteria of 10 ug/L would have been exceeded in 9 of the 16 years, although the "raw" or non-seasonally-averaged data were above the current criteria only about 50% of the time. The summer criteria of 15 ug/L would have been exceeded in 15 of the 16 years, while the "raw" data exceeded the criteria about 85% of the time during the 1995-2010 period. With the exception of a few high values in the spring, chlorophyll-a concentrations are generally lower in the mesohaline portion of the river. On an annual basis data from station RET5.2 (Figure 34) indicate that chlorophyll-a concentrations are less than 10 ug/L about 50% of the time and less than 18 ug/L about 85% of the time. The spring criteria of 15 ug/L would have been violated in 8 out of 16 years and the "raw" data were above the criteria about 45% of the time. The summer criteria of 22 ug/L would not have been violated during the 1995-2010 period. Chlorophyll-a concentrations are also low in the polyhaline portion of the estuary, as compared to the tidal freshwater portion of the estuary. Data from station LE5.5-W (Figure 35) indicate that chlorophyll-a concentrations are less than 10 ug/L about 50% of the time and less than 15 ug/L about 85% of the time. For the historical data record from 1995 through 2010, the data indicate that the polyhaline criteria of 12 ug/L for the spring season would have been exceeded in 5 of the 16 years, while the summer criteria of 10 ug/L would have been exceeded in 12 of the 16 years.

Correlation analysis based on clustering

In an additional attempt to characterize chlorophyll-a dynamics over the 1991-2010 time periods, a cluster analysis was used to divide the chlorophyll-a monitoring stations into similar groups and then principal component analysis, bivariate linear regression and multiple-regression to study Chlorophyll-a as a function of water quality parameters (flow, water temperature, secchi depth, TSS, TN, and TP) was

conducted within these groups. The correlation matrices and the multivariate table are listed in Appendix B and will be frequently cited.

The ensemble water quality data in the James River varies along its length and through time. The chlorophyll-maximum shifts upstream between February and July, as shown in Figure 36. The seasonal cycles at these maxima is illustrated in Figure 37. Generally, in the summer months at the upstream station, the correlation of chlorophyll-a with temperature is quite high (r=0.82), while further downstream at station LE5.2, one can observe an inverse correlation of chlorophyll-a with temperature. Since there are differences in space and time across a number of variables, a cluster analysis was used to systematically identify similarities and differences between the stations.

Cluster Analysis

A cluster analysis was performed on the James River data using the average distance function of the variables (a measure of similarity or dissimilarity in the correlation matrix). It separated and grouped the stations spatially, indicating significant similarities and differences in water quality parameters in the upper, middle and lower sections of the James River (see Figure 38). Cluster analyses for the Elizabeth/Lafayette river systems found a similar pattern corresponding to a spatial upstream and downstream grouping (see slide 29-31 in Appendix B).. The James and Elizabeth River clustering identified 7 groups as follows:

Group 1: Upper tidal fresh James -- TF5.2, TF5.2A, and TF5.3
Group 2: Lower tidal fresh James, Summer Peak -- TF5.4, TF5.5, TF5.5A;
Group 3: Mesohaline James Spring peak – LE5.2;
Group 4: Lower mesohaline and polyhaline James - LE5.3, LE5.4, LE5.5, and LE5.6;
Group 5: Elizabeth River upstream - SBE5 and SBE2;
Group 6: Polyhaline Elizabeth River downstream ELI2 and LFA01;
Group 7: Lafayette River, LFB01.

Group 1 corresponds to the upper tidal fresh, group 2 to the lower tidal fresh, group 3 to the mesohaline, and groups 4, 5, 6, and 7 to the lower mesohaline and polyhaline portions of the James River. Among them, two regions: (a) TF4, TF5 and TF5A and (b) LE5.2 in the James are clearly distinct from other stations and each other in the James. In the Elizabeth River, it was found that the upper Lafayette station LFB01 is clearly distinct from the rest of the Elizabeth river stations. Given the close proximity of LFB01 to the City of Norfolk, this distinction corresponds to the spatial distribution of the observed water quality variables. Based on the cluster analysis, the stations within the same spatial group possess similar water quality properties; therefore, in the subsequent system analyses, it is not necessary to conduct analysis for each station; rather, it is sufficient to either pool the data or to select a representative station from the group to characterize the response of that group.

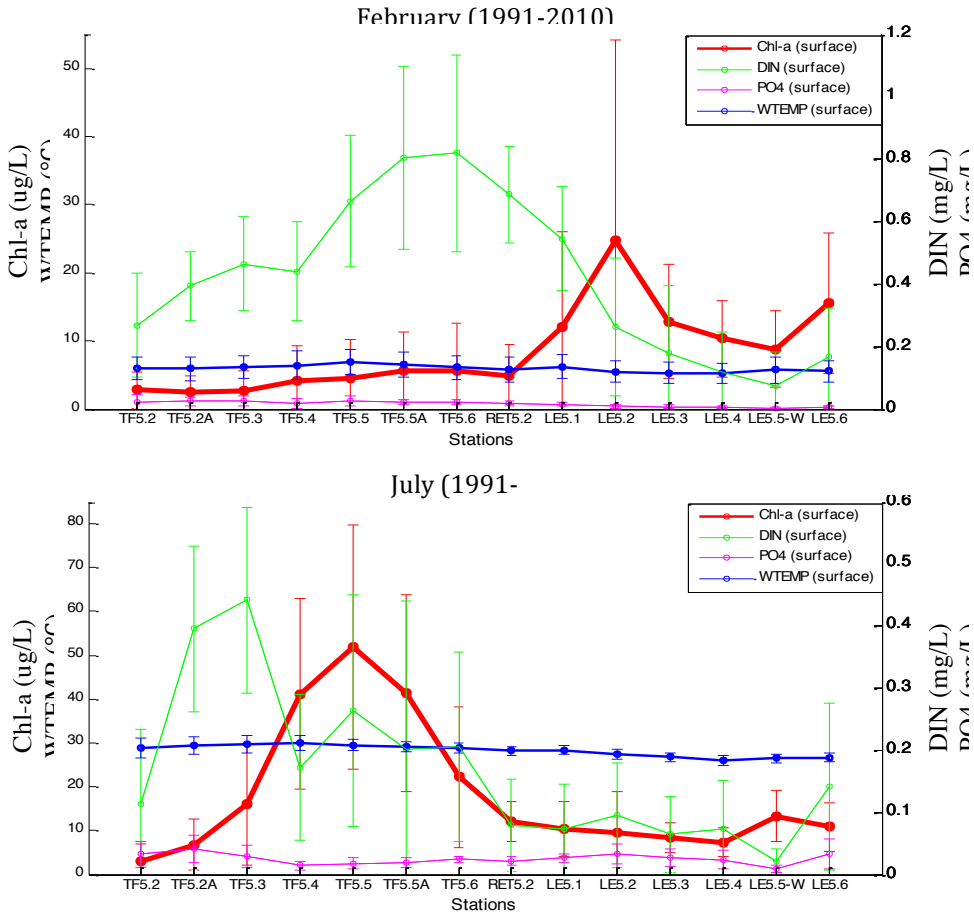


Figure 36: James River spatial variability of monthly averaged Chl-a, DIN, PO4, and water temperature for February (top panel) and July (bottom panel), 1991-2010. Note the February Chl-a maximum is

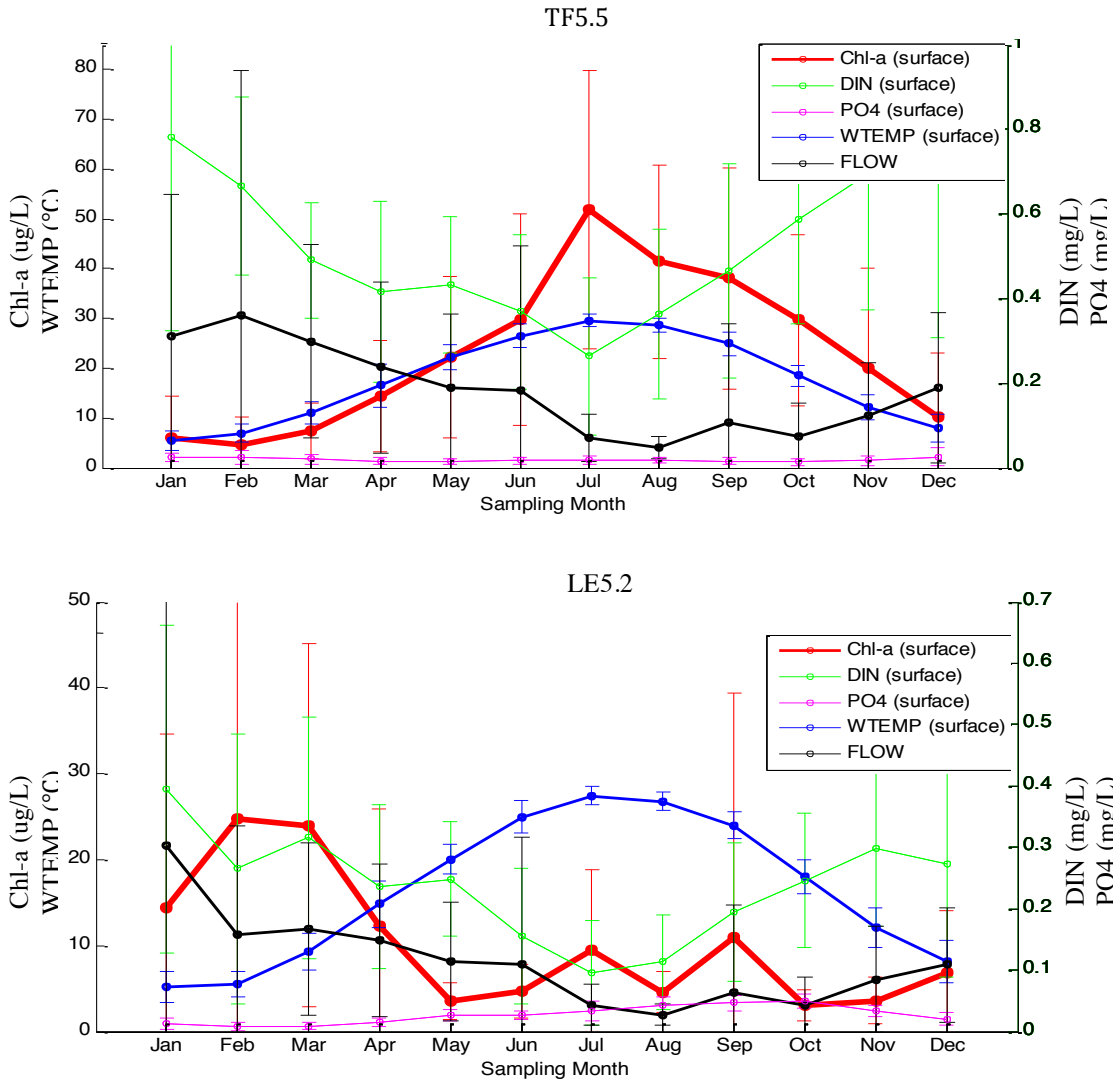


Figure 37: Seasonal cycles in water quality data at the locations of the Chl-a maximums. Top panel: TF5.5 July maximum; Bottom panel LE5.2 February maximum. Note the high correlation of Chl-a with temperature in the upper panel, while the correlation is opposite in the lower panel. (The flow are normalized and scaled with max. Chl-a).

Bivariate linear regression analysis

(a) For group 1, using the ensemble average data, chlorophyll-a was highly correlated with water temperature and inversely correlated with flow. The correlation of chlorophyll-a with temperature and flow is: 0.79 and 0.48 for 1995-2010, 0.62 and 0.40 for 1995-2000, and 0.69 and 0.30 for 2001-2010 (see slide 9, Appendix B). However, when the raw data were used, the correlation of chlorophyll-a with water temperature and flow dropped dramatically to 0.25 and <0.05 (left panel of slide 7 in Appendix B). This

suggested that the cross-correlations between daily chlorophyll-a and daily temperature were weaker than the cross-correlation conducted from the 5-15 year ensemble average of chlorophyll and temperature. A similar conclusion can be drawn for the cross-correlation between chlorophyll-a and flow data. This indicates that the short-term dynamics in this region tend to appreciably depart from the long-term ensemble mean and make it difficult to make short predictions using the long-term monitoring data. It also suggests that the region is more susceptible to higher frequency fluctuations specifically inter-annual variations.

(b) In group 2, using ensemble data stations TF4, TF5 and TF5A in the lower tidal fresh James, it was found that chlorophyll-a is highly correlated with temperature and inversely correlated with flow. The correlation of chlorophyll-a with temperature and flow is: 0.89 and 0.71 for 1995-2010, 0.78 and 0.79 for 1995-2000, and 0.87 and 0.46 for 2001-2010, respectively. When the raw data in 1995-2010 were used, the correlation between chlorophyll-a with temperature and flow became 0.44 and 0.33. The drop of r^2 from using ensemble data to raw data was obvious, but the drop was not as dramatic as that for group 1. This indicates that the dynamics in this region are more associated with the long-term average such as seasonality and less affected by inter-annual fluctuations when compared with group 1. One important point is that for both groups 1 and 2, which are located in the tidal fresh James, chlorophyll-a is negatively correlated with flow. One plausible explanation is that the influence of flushing rate exceeds the effect of phytoplankton growth rates and biomass accumulation. In both groups 1 and 2, the correlation of TSS (or secchi depth) with chlorophyll-a was not high, 0.11 for both the groups, suggesting that phytoplankton growth was not strongly controlled by the light limitation. However, Lung (1986) indicated that turbidity may have controlled phytoplankton growth during 1980s in the lower tidal fresh James. Recent bioassay experiments by Wood et al. (2013) indicated weak dependence on light. Therefore, the limiting factor for phytoplankton growth rate may have changed since the 1980s.

(c) Further downstream from the tidal fresh James, group 3(LE5.2) and group 4 (LE5.3, LE5.4 and LE5.6) are located in the lower mesohaline, and polyhaline James. In this region, it was found that chlorophyll-a is positively correlated with the flow. This is significant and intriguing because in groups 1 and 2, chlorophyll-a is inversely correlated with flow. Borsuk et al. (2004) reported the confounding effect of flow in the upper Neuse River in that it can play a role in flushing the phytoplankton, depressing the algae population, during relatively large freshwater inflows and, at the same time, deliver nutrients to fuel algal growth. This seemingly contradicting role of flow is illustrated in Figure 39. The figure shows the dual roles of flow – on one hand, the effects of flow velocities, turbidity and salinity can reduce the algal population (right panel); on the other hand, flow also plays a key role in delivering nutrients, which fuels the algal population (left panel). The inverse relationship between chlorophyll-a and flow suggests that the flushing

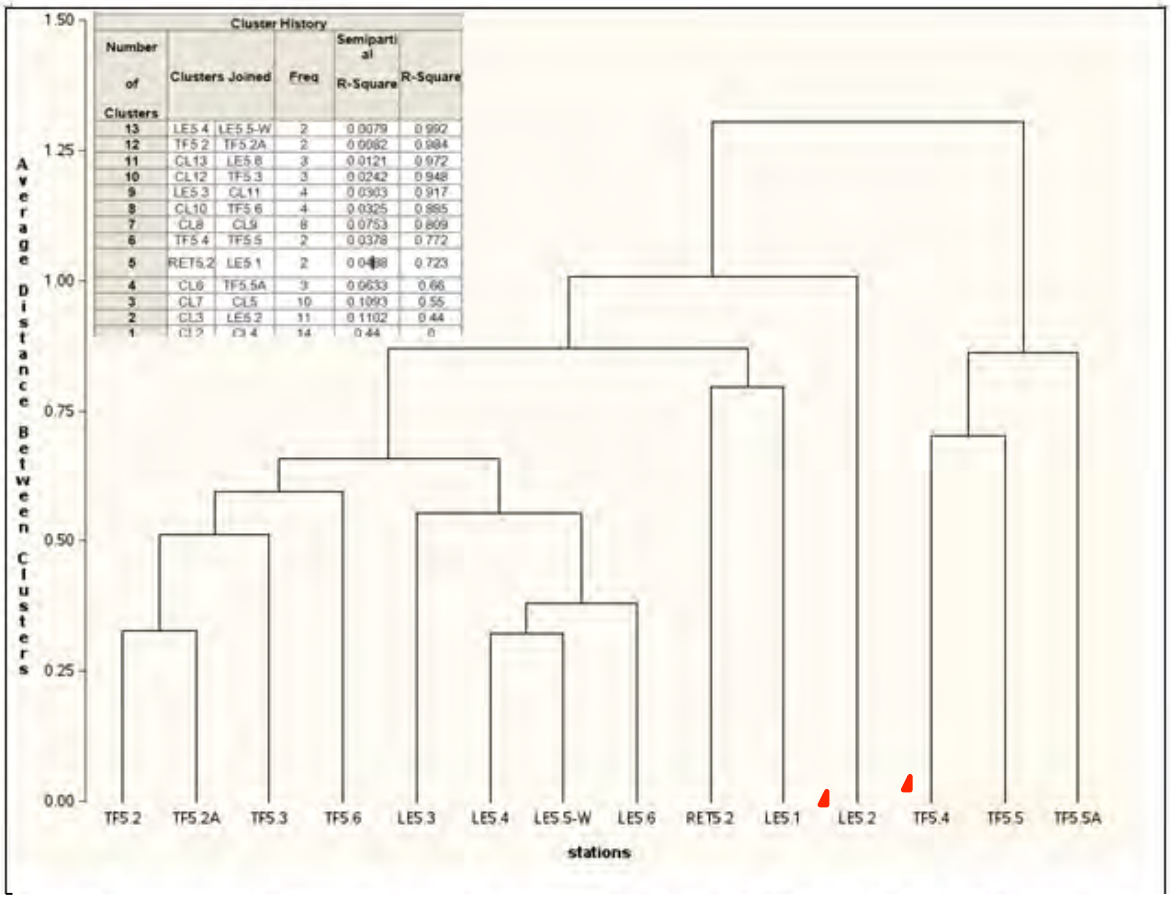


Figure 38 - Average Distance Cluster analysis of the James River Water Quality stations. Note that the first cluster identified on the right hand side, the TF5.4, TF5.5, and TF5.5A group, corresponds to the stations near the summer turbidity maximum.

effect outweighs the delivery of nutrients in the tidal fresh region (groups 1 and 2). The positive relationship between chlorophyll-a and flow in the mesohaline and polyhaline (groups 3 and 4), on the other hand, suggests that delivery of nutrients overwhelms the effect of flow, turbidity and salinity. Thus, as part of the modeling effort, the ability of the model to separate the different zones by simulating salinity intrusion and turbidity maximum becomes critically important. Salinity in the mesohaline is inversely correlated with flow (r^2=0.63) as salinity transitions from salt water to fresh water. Given the phytoplankton population in different parts of the James is controlled by different mechanisms and flows change over time, it is foreseen that the TMDL control strategy is "dynamic" in both space and time.

Multivariate regression analysis

The multivariate regression analyses are used in this section which considers the relationship between chlorophyll and multiple independent variables simultaneously.

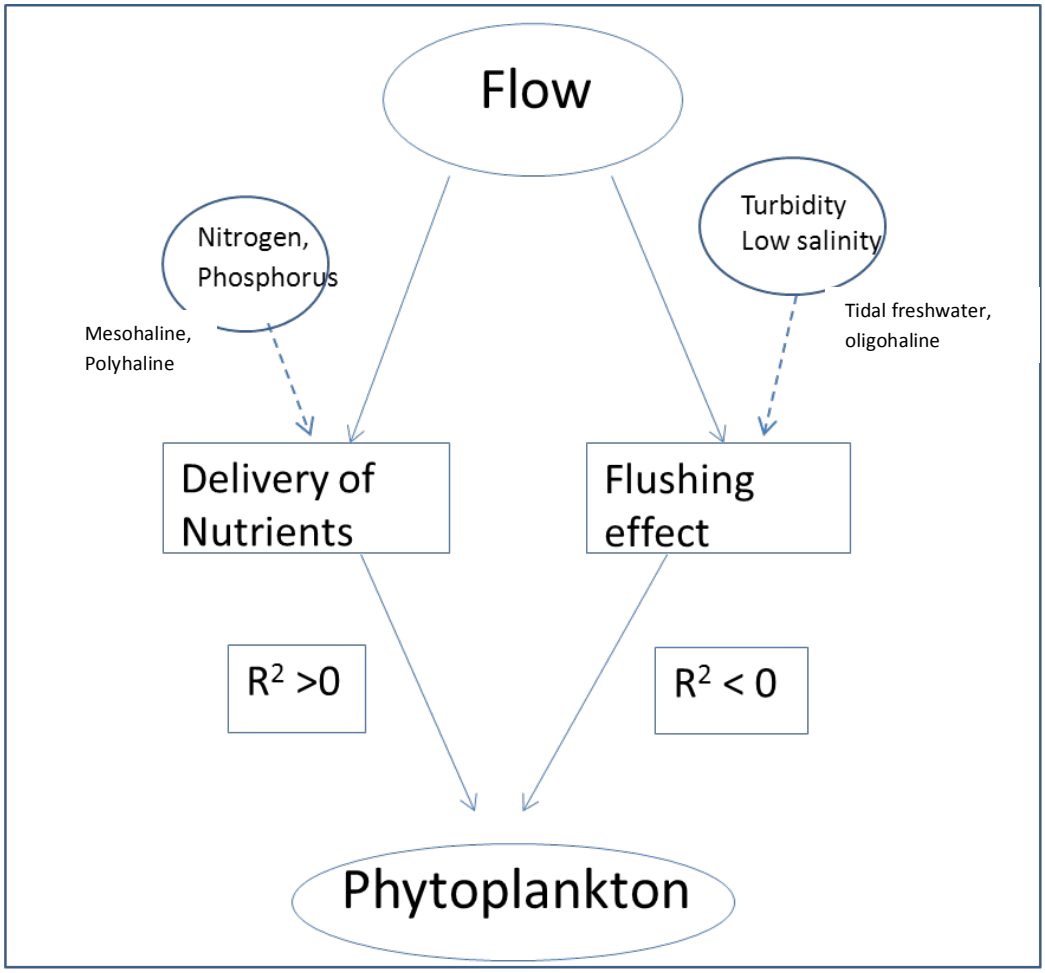


Figure 39: The flow has confounding effects on the phytoplankton. For the tidal freshwater, zone, the flushing effect accompanied by turbidity, and low salinity can dominate (right). For the mesolaline zone, the delivery of nutrients becomes dominate.

Multivariate regression analysis:

The multivariate regression analyses in this section considers the relationship between chlorophyll-a and multiple independent variables at the same time, versus the previous analysis that just looked at chlorophyll-a relative to single variables.

(a) The summer chlorophyll-a maximum occurs at stations TF4, TF5, and TF5A (group 2), which are located in the lower tidal fresh region of the James. The Pearson correlation matrix (slide 14 Appendix B) indicates that chlorophyll-a

is correlated with several individual variables including water temperature (r=0.94), flow (r=-0.84), TP (r=0.76), TN (r=0.87), Secchi depth (r=-0.25), and TSS (r=-0.25), in one to one correlations. A multivariate regression statistical model considers multiple independent water quality parameters using:

$$Ln\ (CHLA) = a + b_i x_i + \varepsilon$$

This statistical analysis encompasses multiple independent variables. The sum of squares symbol R^2 is used to represent the square of the correlation coefficient. The model was applied to group 2 and the sum of squares is R^2=0.66 for the 1995-2010 period, R^2=0.58 for the 1995-2000 and R^2=0.85 for the 2001-2010 period. This indicates the model can explain 66% and 85% of the variability for 1995-2010 and 2001-2010 respectively. The multivariate regression coefficient as well as partial regression coefficients for 1991-2010 are shown in Figure 40. Among the most significant variables are: water temperature (0.43), Secchi (0.39), flow (-0.34). It also shows that TN and TP have a less significant standardized slope of 0.26 and 0.12 respectively. Between TN and TP, nitrogen, on average, is more likely to be the limiting nutrient. However, it is a well-known fact that the TN to TP ratio tends to increase during high flow and decrease during low flow periods. Thus there are periods, particullarly low flow periods, when TN and TP are co-limiting, which is consistent with the Wood et al. (2013) bioassay experiments. Figure 41 shows the TN/TP and DIN/DIP time series in which it can be seen that the ranges vary significantly, affected by flow, seasons, and storm events. To discern all these effects, the WRTDS (Weighted Regression on Time, Discharge, and Season) method developed by Hirsch and Archfield (2010) may be needed.

(b) For the mesohaline station LE5.2 (group 3), where the chlorophyll-a maximum is located, the standardized slopes of TN and TP from the multivariate regression have a larger contribution: TN (=0.55) and TP (=-0.34) indicating that the mesohaline James is more strongly nitrogen limited. The multivariate predictability for LE5.2 , though, was not as good; the R^2 is only 0.13-0.30. It is interesting to note that adding DIN as a variable in a step-wise statistical procedure can improve the R^2 for the linear regression model by 0.20 and 0.40 for the mesohaline James and the Elizabeth and Lafayette Rivers, respectively. These are very significant improvements in the predictability of chlorophyll. Gudimov, et al. (2012) have used both TN and DIN as the index variables (measurements) for the latent variable nitrogen in the study of lake eutrophication in Canada.

(c) At the downstream stations in the lower mesohaline and polyhaline regions of the James, which includes stations LE5.3, LE5.4, LE5.5 and LE5.6, the multivariate linear regression for chlorophyll-a was not highly correlated

with the independent water quality variables (R^2= 0.20). A possible reason for this may be due to influence from the adjacent Chesapeake Bay. The highest correlation of chlorophyll-a is with salinity (R^2= -0.33) followed by flow (R^2= 0.24), and Secchi depth (R^2=-0.20). The inverse relationship between chlorophyll-a and Secchi depth suggests a self-shading effect by the phytoplankton.

Elizabeth and Lafayette River Special Study

The Elizabeth and Lafayette Rivers were clustered into three groups: group 5 (the upstream Elizabeth River stations SBE5 and SBE2), group 6 (the downstream polyhaline Elizabeth River with stations ELI2, LFA01) and group 7 (the Lafayette River group with station LFB01). The Deep Creek Spillway located downstream of the Dismal Swamp is the only major river inflow into the southern branch of Elizabeth River. The annual mean discharge of the Deep Creek Spillway is about 100 cfs with occasional high flows, which do not follow a seasonal pattern.

(a) The upstream portion of the Elizabeth, group5, consisting of stations SBE5 and SBE2, has the strongest bivariate relationship between chlorophyll-a and TSS. The multivariate regression model indicates that TSS, secchi, and salinity are the most significant predictors; but with the overall R^2 ranging between 0.28 -0.32, much of the variability in chlorophyll-a in the upstream portion of the Elizabeth is unexplained by these factors.

(b) The polyhaline downstream portion of the Elizabeth, group 6, consisted of stations EL12 and LFA01. For EL12, the strongest bivariate relationship is between chlorophyll-a and secchi depth (-0.35). Going from the Elizabeth River into the Lafayette River, an increase in the correlation of TN and chlorophyll-a was observed. For LFA01, the strongest bivariate relationship is between chlorophyll and TN (0.37). The multivariate regression gives the largest standardized slope for Secchi (-0.60) followed by water temperature (-0.29) and salinity (0.14). The overall R^2 for the multivariate regression though is 0.21, which indicates a low predictability. As pointed out in the last section, however, when DIN is added as an additional variable, the R^2 jumps from 0.21 to 0.68, which is a very significant improvement, with DIN and TN having the largest standardized slopes of -0.88 and 0.52 respectively.

(c) The upstream portion of the Lafayette River, represented by station LFB01, is distinctly different from other stations in the Elizabeth River based on the cluster analysis. For this group, the bivariate linear regression showed that TP (R^2 =0.81) and TN (R^2=0.65) have the two highest correlation scores. Using the multivariate regression, the R^2 was 0.54, and TN, TP and Secchi depth have standardized slopes of 0.35, 0.32, and -0.46 (slide 63, Appendix B). Additionally, the principle component analysis (top of slide 64, Appendix

B) shows that clear patterns stand out as factors 1 and factor 2, which combined can explain 72% of the total variance. Factor 1, consisting of turbidity, TN, TP, and temperature, has a Pearson correlation coefficient of 0.62 with chlorophyll-a. Factor 2, consisting of salinity has a correlation coefficient of -0.18 (bottom slide 64, Appendix B). Factor 1 shows a high r for TP (0.77), TN (0.70), secchi depth (-0.82), TSS (0.81) and water temperature (0.82) , suggesting a relationship with locally high nutrients and turbidity characteristic of urban runoff from Norfolk metropolitan area. Factor 2, salinity, is inversely correlated with chlorophyll, suggesting nutrient discharge is associated with freshwater from the city. Synthesizing both factors 1 and 2 suggests that the local inputs of nutrients in the Upper Lafayette River from the City of Norfolk is a likely cause of recurring high chlorophyll-a and harmful algal blooms in the region, which is consistent with the study by Mulholland et al. (2009). Additional field and laboratory analysis are needed, though, to further elucidate and confirm the exact mechanism.

(d) From Charette and Buesseler (2004), the submarine groundwater discharge (SGD) in the Lafayette River was determined to be 200 m^3/day, which is among the highest SGD in the Elizabeth River basin. Nitrate and phosphorus surface concentrations were also considered elevated. The degree to which the SGD and elevated nitrate and phosphorus concentrations contribute to Elizabeth River water quality is unknown, but it is included here for future reference.

An ensemble statistical analysis was conducted using James River monitoring data from 1995-2010. The data was divided into 1995-2010, 1995-2000, 2001-2010 periods. It was found that the ensemble chlorophyll-a data at upstream stations in group 1 and group2 located in the tidal fresh James are better correlated with the locally measured water quality parameters. While the variability of chlorophyll-a at downstream stations such as group 3 and group 4, located in the mesohaline and polyhaline, are less controlled by local water quality conditions. When the raw data (rather than the ensemble data) were used, the prediction skill score dropped significantly.

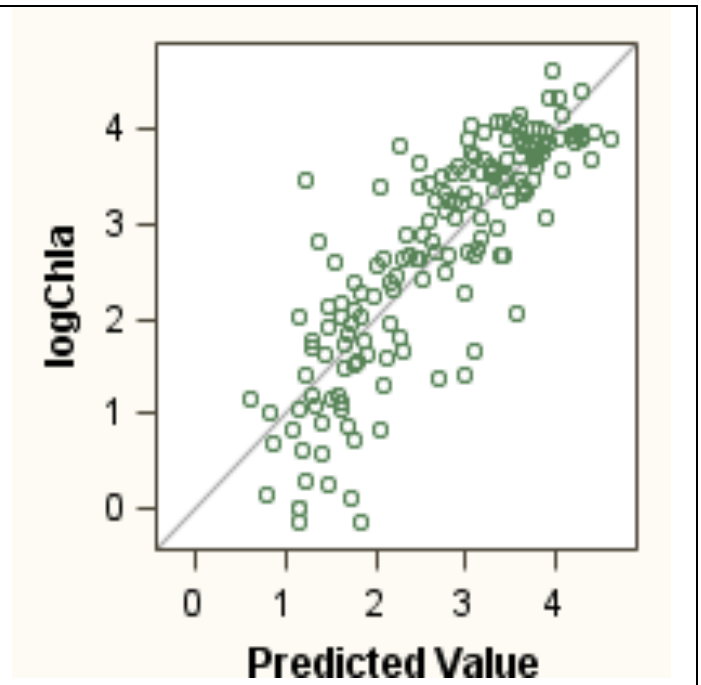
It was found that flow has a confounding role – on the one hand, it flushes the algal population out of the system and, on the other hand, delivers a nutrient load to fuel algal growth. From tidal fresh to polyhaline stations, both the chlorophyll:flow relationship and the nutrient:flow relationship change from negative to positive, suggesting there is a dynamic shift between tidal fresh and polyhaline zones. The chlorophyll-a and water quality variables have a better correlation with the tidal fresh stations compared to those in the lower mesohaline and polyhaline. In the

Elizabeth and Lafayette River, the relationship was unexplainable for most of the stations except in LLFB01. Located in the upstream area of the Lafayette, the multi-regression results for LFB01 were relatively high: R^2 (0.54) with standard slopes for TN (0.35), TP (0.31), and Secchi (-0.46), indicating nutrient inputs from the Norfolk metropolitan area.

Station group (Lower tidal fresh, location of summer peak: TF5.4 TF5.5 TF5.5A) (1995~2010)

R^2=0.66
N=106 samples

(2001-2010)
R^2=0.85
N=61 samples



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	-0.09815	1.48263	-0.07	0.9475	0
logFlow	1	-0.36097	0.0982	-3.68	0.0005	-0.33621
WTEMP	1	0.05873	0.0102	5.76	<.0001	0.42917
TP	1	4.98124	3.38126	1.47	0.1465	0.11543
SECCHI	1	4.45925	0.87991	5.07	<.0001	0.38683
TSS	1	0.03151	0.00978	3.22	0.0022	0.25188
TN	1	1.35295	0.45993	2.94	0.0048	0.25851

Figure 40: The results of multivariate regression linear statistical model for tidal fresh stations. The figure and regression table is for 200111991-2010.

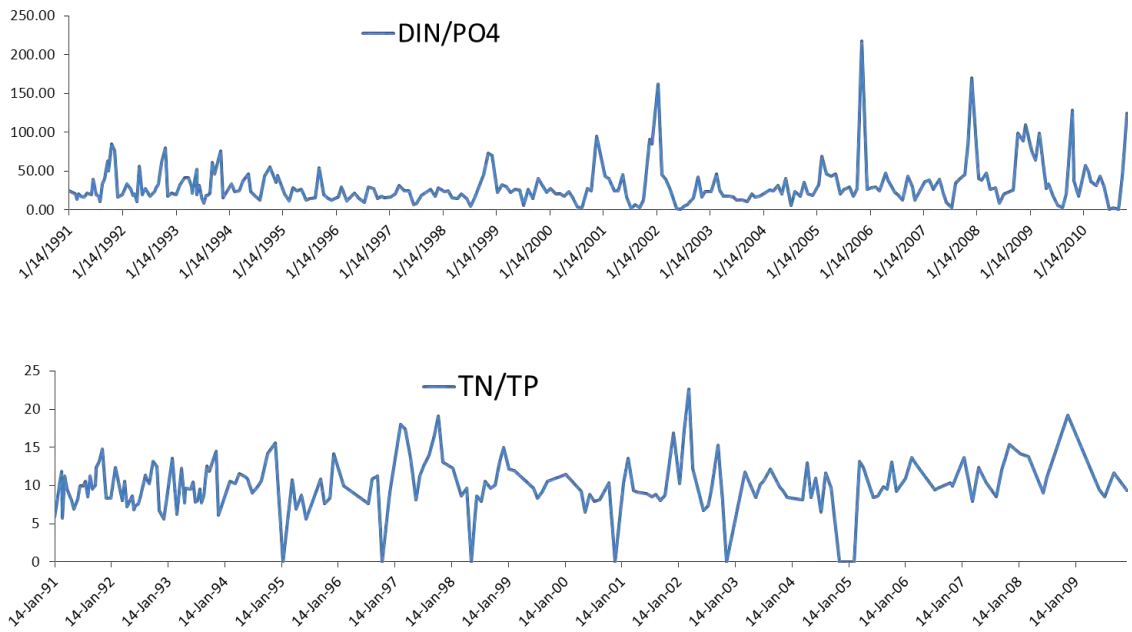


Figure 41- Time series of DIN/DIP and TN/TP plotted at tidal fresh station TF5.5 from 1991-2010.

Additional Regression Analyses

Additional regression analyses were performed on the four stations with long-term phytoplankton cell count and biomass data: TF5.5, RET5.2, LE5.5, and SBE5. A series of regression analyses were conducted for each station, starting with using the "raw" or individual data points and then using "binned" or monthly-averaged data from 1995-2010. The purpose was to determine if the observed data would lend themselves to predicting chlorophyll-a biomass using an empirical modeling approach. The regressions were performed using the observed chlorophyll-a data and $\log_e$ transformed chlorophyll-a data. Interestingly, when performing univariate regressions (e.g., chlorophyll-a vs. TN or chlorophyll-a vs. temperature) there was not a significant difference between the untransformed data and the transformed ($\log_e$) regressions. However, when performing multivariate regressions, the $\log_e$ transformed regressions provided greater predictive power (i.e., higher correlation scores). Therefore, we shall present the $\log_e$ transformed results (the untransformed regression results can be found in the appendices). Figure 42 presents the regression analysis results for chlorophyll-a versus TN for station TF5.5. The upper left panel presents the results for the "raw–transformed" data. Although the regression analysis indicates that the slope is significant ($p<0.001$), the correlation coefficient is only 0.36, which only explains about 13% of the variation in the data. Applying the slope and intercept from the regression analysis to the TN to predict the $\log_e$ chlorophyll-a and then transforming the predictions back to arithmetic space (panel upper right), indicates that the regression is a poor

predictor of chlorophyll-a, with only a few predicted chlorophyll-a concentrations above 45 ug/L versus a significant portion of the observed data being about 45 ug/L. Next a regression was performed using the "binned" or monthly-averaged data. As can be seen from the panel on the lower left, the regression slope is a poor predictor of chlorophyll-a from monthly-averaged TN (p=0.16). This is also observed when applying the estimated slope and intercept to the monthly-averaged TN to estimate monthly-averaged chlorophyll-a (lower center panel). Applying the regression slope and intercept, as estimated from the monthly-averaged data, to the raw TN data, the regression also fails to do a good job of predicting the observed raw chlorophyll-a data (lower right panel).

A similar analysis was conducted for TP (Figure 43) for station TF5.5. The results are very similar to those obtained from the TN regression analysis. The computed slope for the raw chlorophyll-a versus TP (upper left panel), was significant (P<0.001), but the correlation coefficient was low (~0.3) and explained less than 10% of the observed variation between chlorophyll-a and TP. Predicted chlorophyll, as estimated from TP and the regression slope and intercept, compares poorly to the observed chlorophyll-a data (upper right panel). Although the regression results obtained from the monthly-averaged data are more favorable than obtained for TN, i.e., the slope is significant (p<0.001) and the correlation coefficient is 0.73, which explains about 53% of the data (lower left panel) and does a reasonably good job of predicting the monthly-averaged chlorophyll-a (lower middle panel), using the computed slope and intercept and the raw TP, the regression model performs poorly, when predicting the raw chlorophyll-a data (lower right panel). Although using the slope and intercept from the monthly-averaged regression appears to perform better than the slope and intercept from the raw data, i.e., the predictions are better centered around the 1:1 line, the regression model significantly over-predicts chlorophyll-a for observed chlorophyll-a concentrations less than 60 ug/L.

Next, the regression analyses were performed for water temperature (Figure 44). The regression slope was statistically significant (p<0.001) and explained about 43 percent of the variation between chlorophyll-a and water temperature (upper left panel), but overall was a poor predictor of chlorophyll-a (upper right panel). Similar to TP, the regression results obtained from using the monthly-averaged chlorophyll-a and water temperature were statistically significant with the regression model being able to explain about 85% of the variation in the data (lower left panel) and also providing a good prediction of the monthly chlorophyll-a (lower middle panel). However, when applied to the raw data, the regression model again proved to be a poor predictor of chlorophyll-a biomass (lower right panel). Similar results were also obtained from a regression of chlorophyll-a against a $\log_{10}$ transformed 10-day averaged freshwater flow – Q_{10} (Figure 45). While the regression slope for the $\log_{10}$ transformed Q_{10} was significant (p<0.001) and explained about 46% of the variation in the data, it performed poorly when predicting the high concentrations of chlorophyll-a observed in the data. Using the slope and intercept estimated from the monthly-averaged data appears to perform

better at predicting the raw chlorophyll-a data, but one can observe considerable variation around the 1:1 line. For example, for observed chlorophyll-a concentrations of between 45 and 55 ug/L, the predictions range from about 12 ug/L to about 125 ug/L. Each of the regression models performed poorly when attempting to predict the raw chlorophyll-a biomass.

The next step in the regression analysis was to perform a multiple linear regression on the raw data. In this case chlorophyll-a was regressed against TN, TP, water temperature and the $\log_{10}$ transformed 10-day averaged freshwater flow (Q_{10}). The initial regression analysis was performed on the raw data (left-hand panel Figure 46) and while the multi-variable regression model was able to explain about 54% of the observed variation in the chlorophyll-a data, overall it was a poor predictor of chlorophyll, failing to reproduce the observed chlorophyll-a data in excess of ~50 ug/L (left-hand panel). Performing a similar analysis on $\log_e$ transformed chlorophyll, provided a small increase in the correlation coefficient, which explained about 63% of the observed variation in the data. However, as can be seen (right-hand panel) there is still a large degree of variation around the 1:1 prediction line. Finally, multiple linear regression analyses were performed using the "binned" or monthly-averaged data (Figures 47 and 48). While the multiple linear regression models performed well on both the normal and $\log_e$ transformed chlorophyll-a data, explaining greater than 90% of the observed variation in the monthly-averaged chlorophyll-a data (left-hand panels), when the regression slopes and intercept were then applied to the raw TN, TP, water temperature and $\log_{10}$ Q_{10} data to predict chlorophyll, the models did not perform as well (right-hand panels).

When these regression analyses were applied to data from Stations RET5.2, LE5.5, and SBE5 (results presented in Appendix A), the overall findings were quite similar. In some cases the monthly-averaged regression models appeared to provide a reasonable prediction of monthly-averaged chlorophyll-a data, but in all cases they performed poorly in predicting the raw chlorophyll-a data. These results suggest that the construction of an empirically-based model to predict chlorophyll-a concentrations in the tidal James River is not feasible. This is likely due to the fact that phytoplankton biomass, as represented by chlorophyll-a, is determined by the complex interactions of TN, TP, temperature, freshwater flow (and other water quality variables, such as light attenuation, wind-mixing, etc.), and cannot be captured in simple univariate or multivariate linear regression models. Rather, it will be necessary, to construct a process-based or deterministic model to provide water quality managers with a tool with which to predict chlorophyll-a response to nutrient management scenarios. The output, specifically chlorophyll-a biomass, from the deterministic model may then be used together with an empirically-based chlorophyll-HAB model to predict the frequency, duration and spatial extent of HABs in the freshwater and marine waters of the James River.

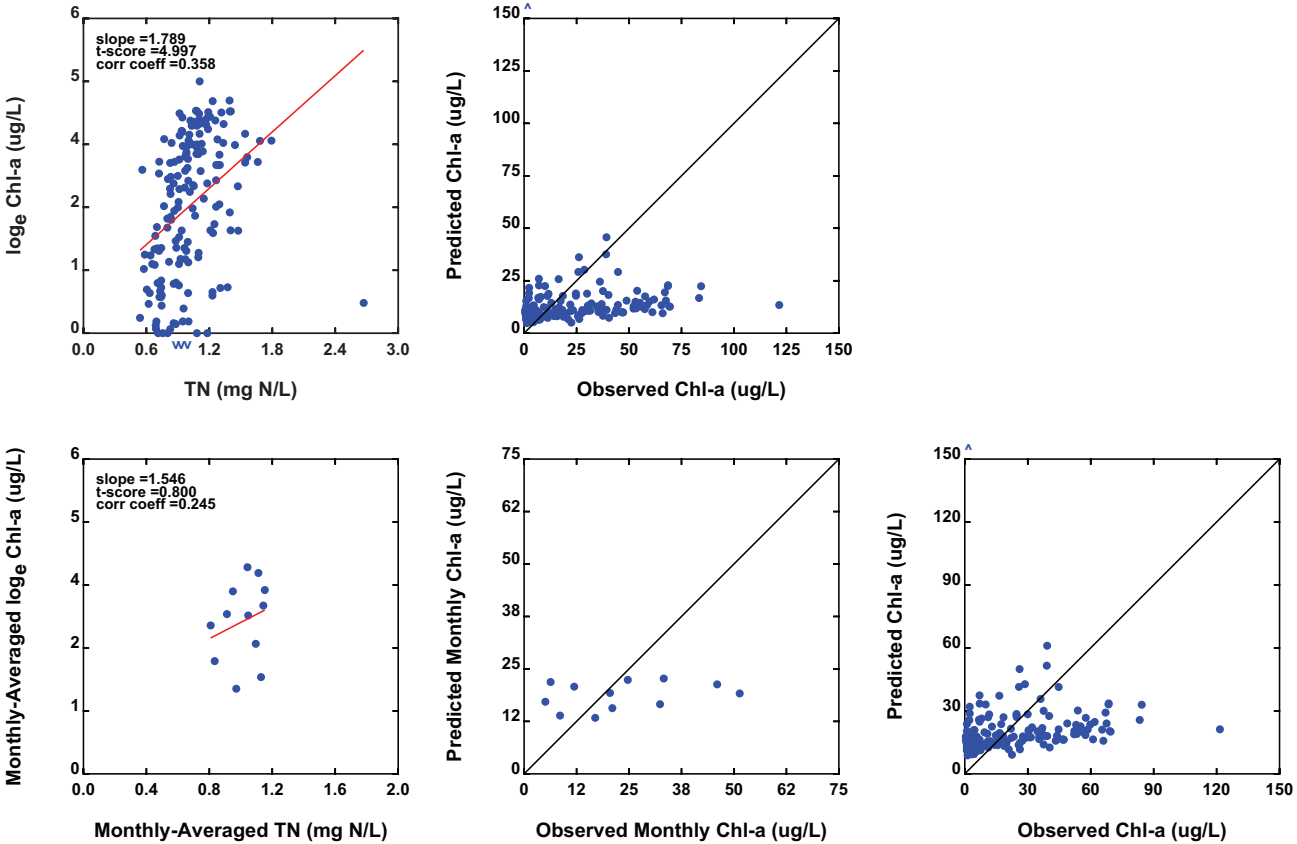


Figure 42. Regression Analysis Results for Chlorophyll-a versus TN for Station TF5.5

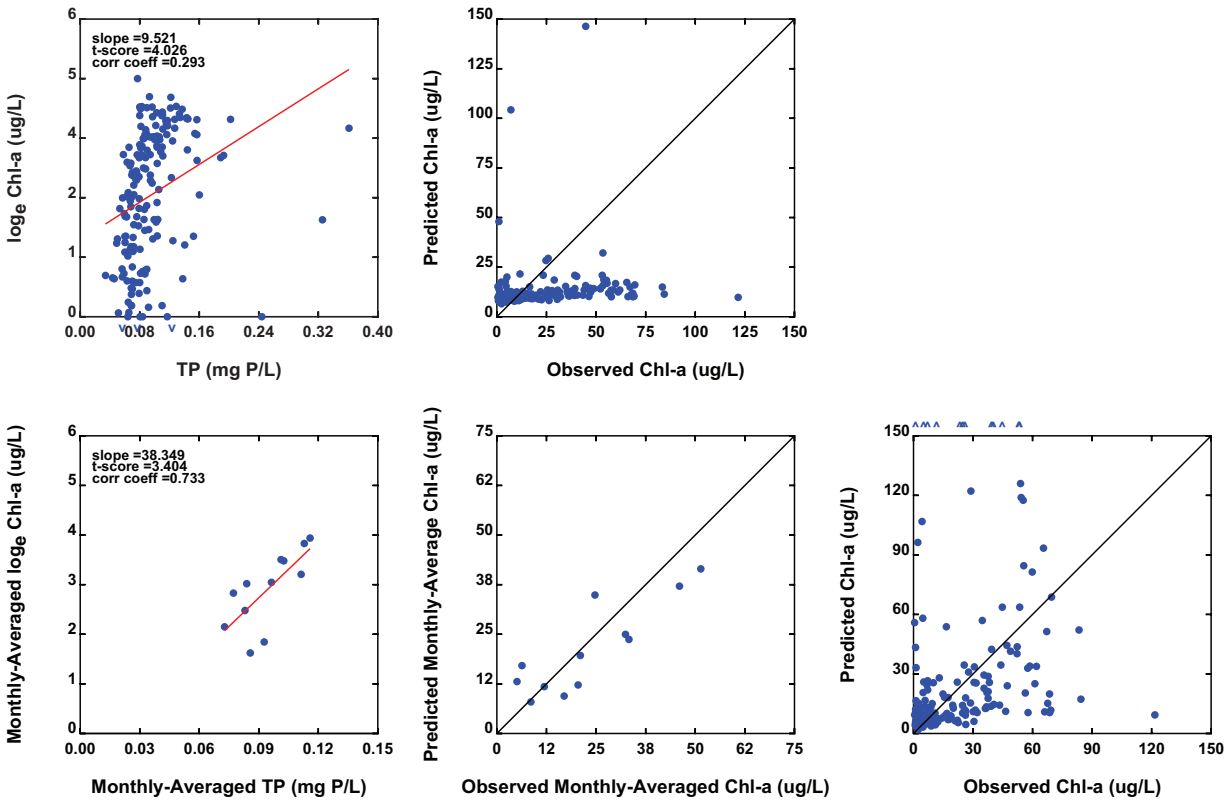


Figure 43. Regression Analysis Results for Chlorophyll-a versus TP for Station TF5.5

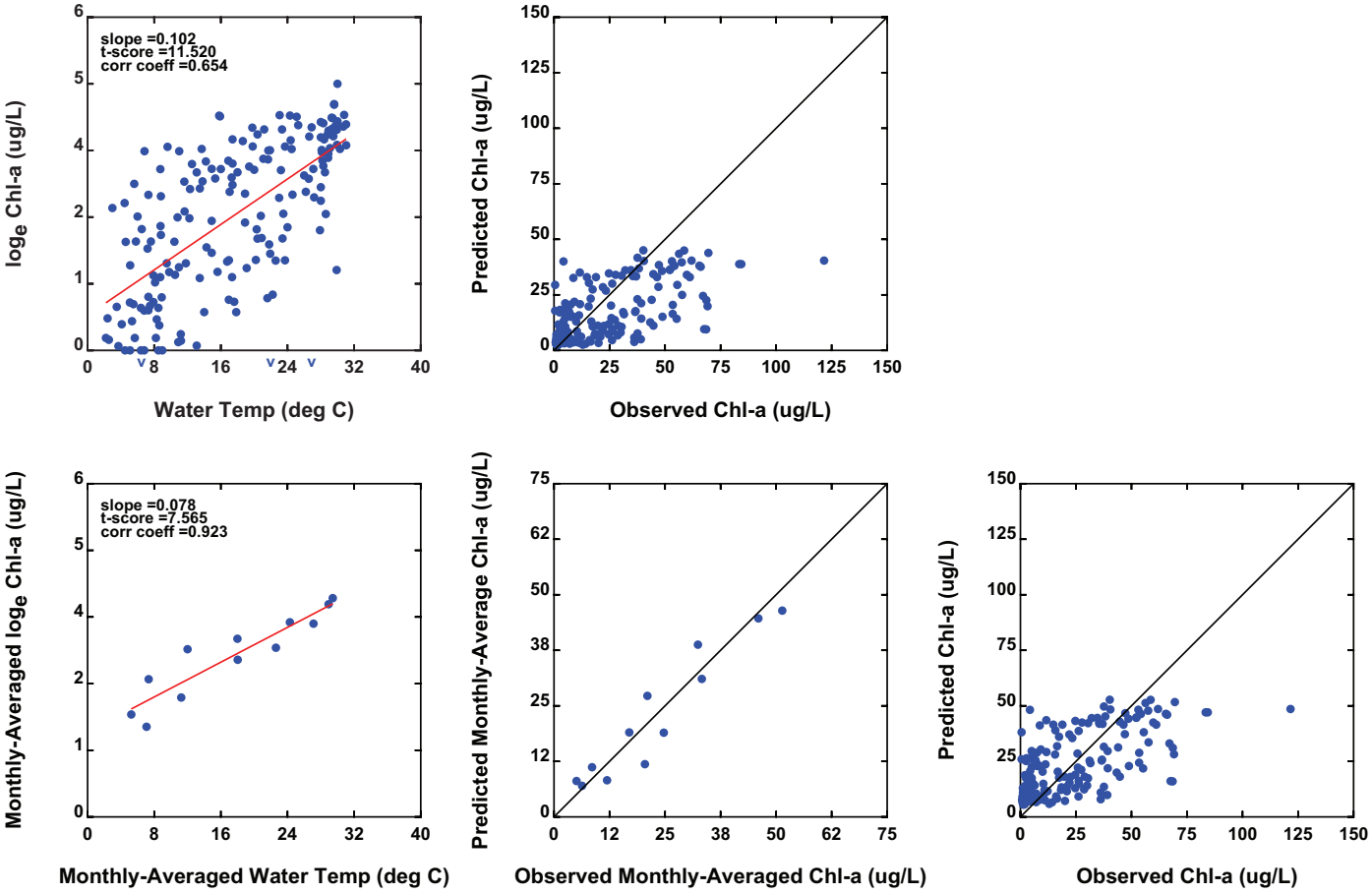


Figure 44. Regression Analysis Results for Chlorophyll-a versus Water Temperature (WTEMP) for Station TF5.5

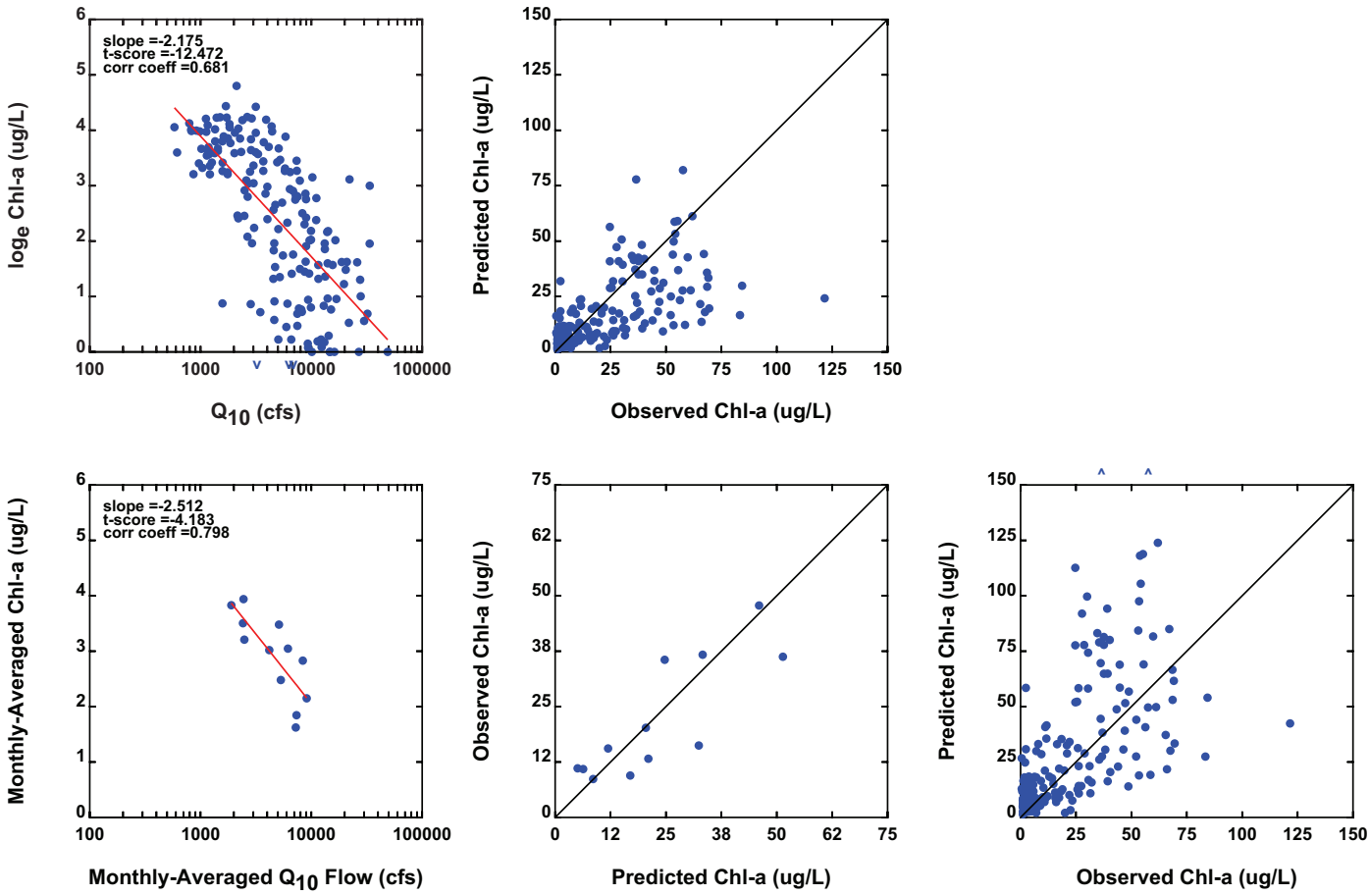


Figure 45. Regression Analysis Results for Chlorophyll-a versus Log10 Transformed 10-day Averaged Freshwater Flow (Q10) for Station TF5.5

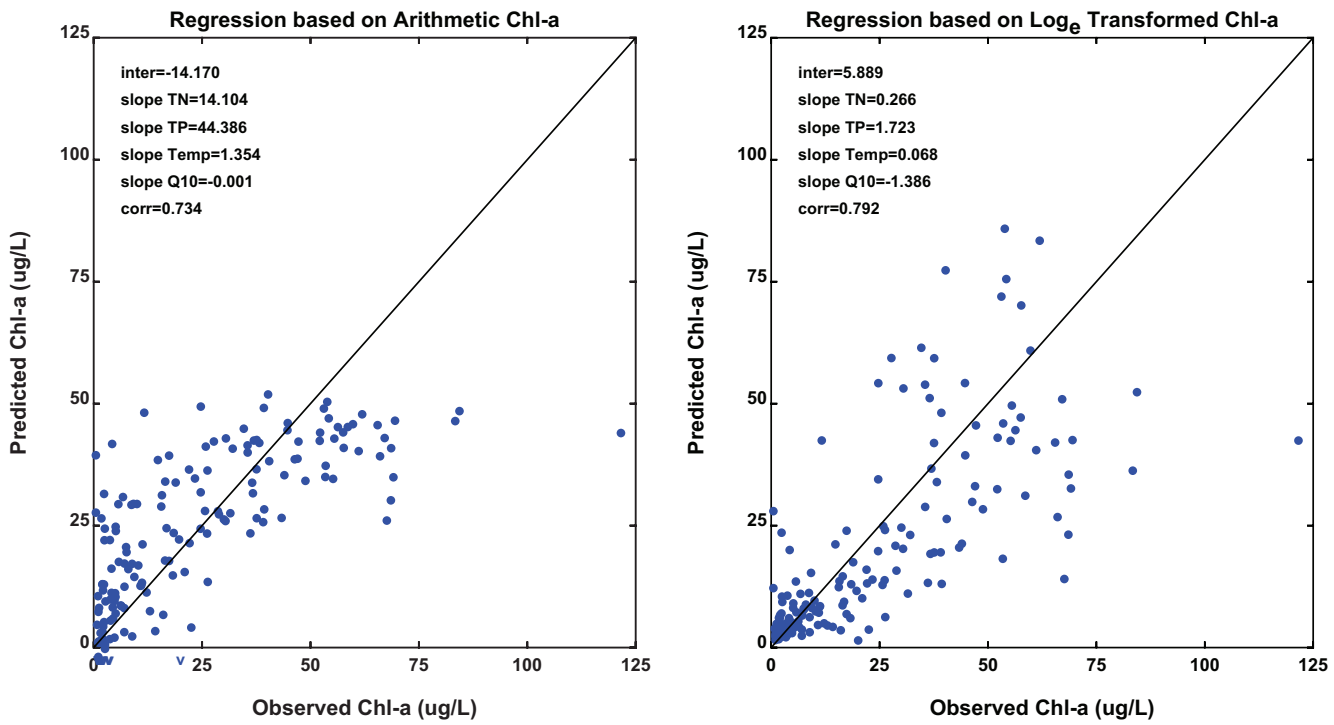


Figure 46. Multiple Linear Regression Analysis Results for Chlorophyll-a versus TN, TP, WTEMP, and Q10 for Station TF5.5 – Raw Data

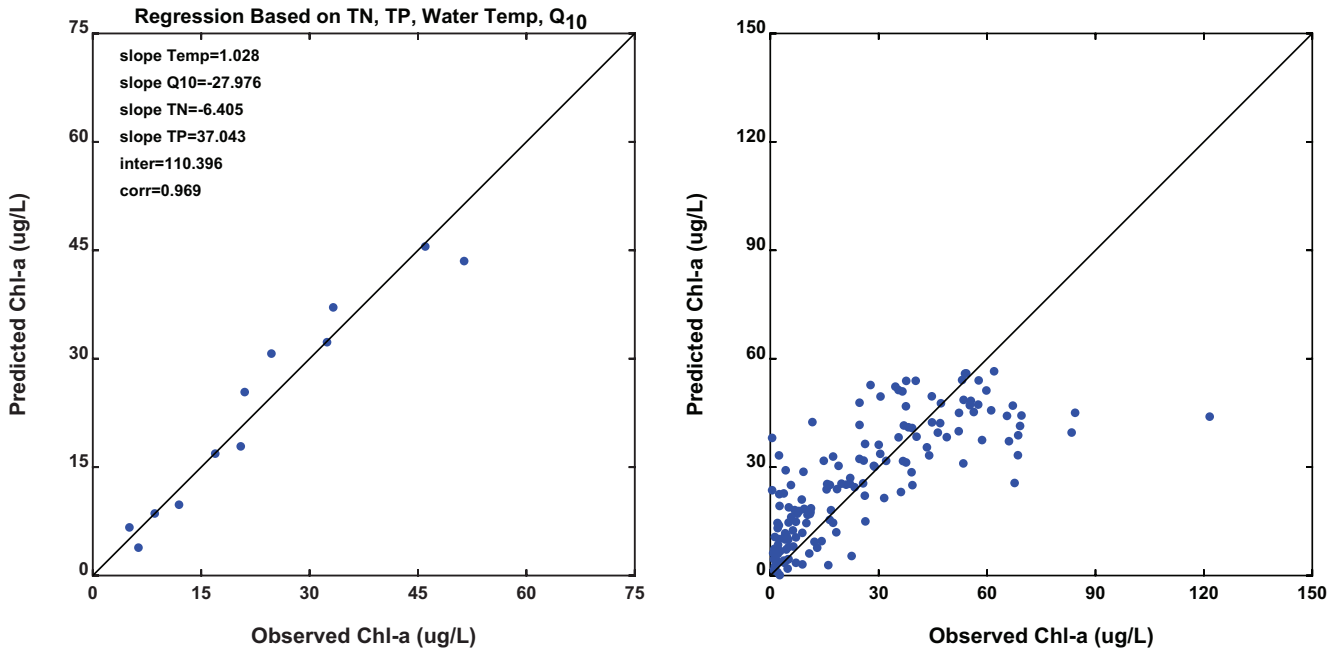


Figure 47. Multiple Linear Regression Analysis Results for Chlorophyll-a versus TN, TP, WTEMP, and Q10 for Station TF5.5 – Monthly-Averaged Data

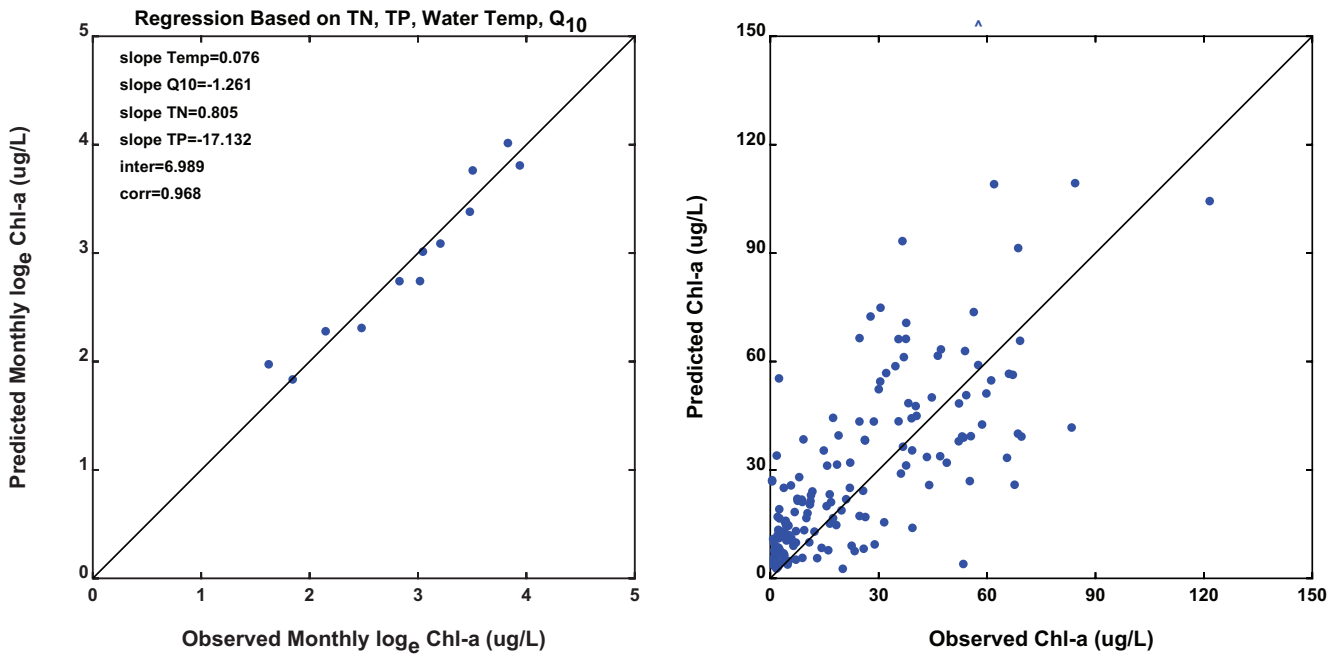


Figure 48. Multiple Linear Regression Analysis Results for Chlorophyll-a versus TN, TP, WTEMP, and Q10 for Station TF5.5 – Monthly-Averaged Data Derived Coefficients Applied to Raw Data

Subtask 2.2– Flow and Nutrient Budget

A flow and nutrient budget for the tidal James River was developed using available stream flow and water quality monitoring data as well as Chesapeake Bay Model (U.S. EPA 2010b) output. Budgets were first calculated on the basis of coincident flow and water quality data. Coincident data were sorted into flow percentile categories, in 10 percent increments. Loads were then calculated for each category. The percentile loads were aggregated and then used to develop annual and seasonal budgets. Budgets are representative of the time period from 1985 to 2012, to coincide with the simulation start date of the Chesapeake Bay Model and ending when data are no longer available (as outlined in Table 1). Budgets were then calculated based on Chesapeake Bay Model results and reflect the time period from 1985 to 2005, coinciding with the start and end simulation dates of the model.

Assessment Locations

Upland pollutant loads from the James River watershed are the drivers of the nutrient budget. As a result, the loading analysis focused on loading at five locations that represent significant upland drainage areas to the tidal James River. These areas include:

- Middle James-Willis-TF2
- Appomattox-TF2
- Chickahominy-OH
- Hampton Roads-MH
- Hampton Roads-PH

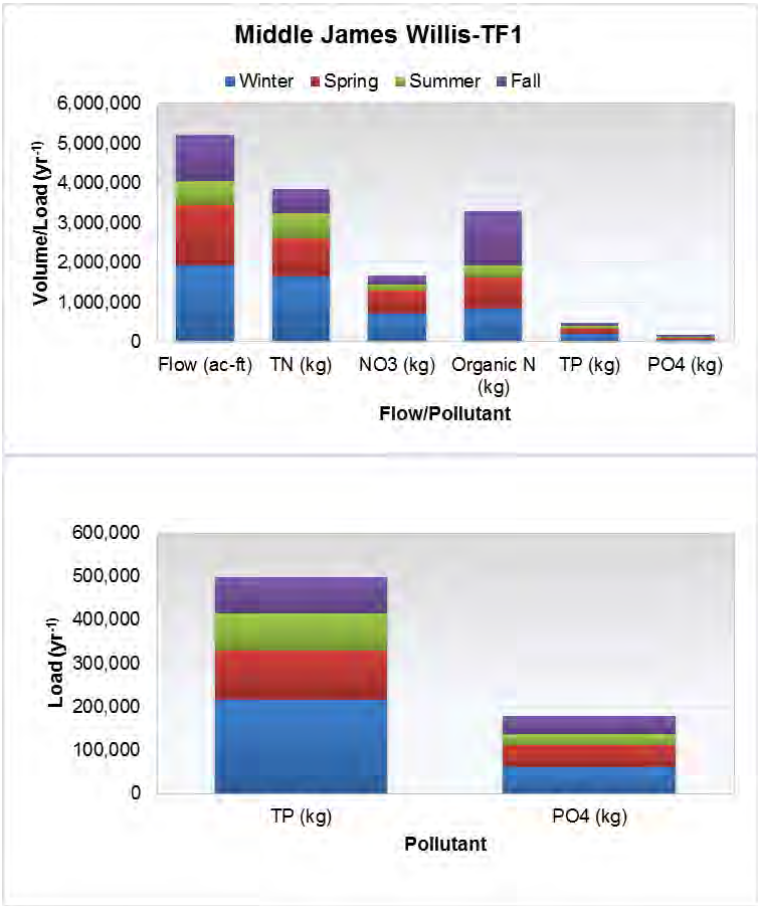
These areas represent the majority of upland area contributing pollutant loads to the tidal James River. Not included are the lateral direct drainage areas to the Lower James. These areas will be evaluated at a later date as data permit. The Middle James, Appomattox, and Chickahominy drainages include a USGS flow monitoring gage at or near the location of confluence with the tidal James. Monitored flows were adjusted on an area percentage basis to account for watershed area not draining to the gage. For the two Hampton Road locations (MH and PH representing the Elizabeth and Nansemond Rivers, respectively) no observed monitoring records are available. To estimate stream flow inputs and direct runoff from these areas, output from the Chesapeake Bay Model (U.S. EPA 2010b) was used. Corresponding water quality data were used from the selected water quality monitoring locations for all areas. For the two Hamptons Road locations this is limited to data through 2005 because the Bay Model simulation period ends at this date. In addition, modeled flows and pollutant loads were examined at each location and compared to the observed data for coincident dates.

The nutrient budgets presented in the following sections characterize average annual loads of observed total nitrogen (TN), nitrate (NO_3), total organic nitrogen (Org N), total phosphorus (TP), and dissolved ortho-phosphate (Ortho P or PO_4). Comparative modeled loads are presented for the same constituents, excluding NO_3 and PO_4 because the Chesapeake Bay model does not directly simulate these

pollutants. Bay model output for NO_x and PO_{4x}, representing the various forms of nitrogen oxides and phosphates, respectively, are used as surrogates for comparison purposes.

Middle James-Willis-TF2

Figure 49 presents a seasonal analysis for observed flow and pollutant loads at the outlet of the Middle James-Willis-TF2 segment, with total phosphorus and PO_4 presented in separate plots for clarity. In general, pollutant loads track with river outflows, with the highest occurrences in the winter for all parameters except organic nitrogen, which has the highest loads in the fall. Loads are lowest for all parameters in the summer when flows are at their lowest. Following the flow trend, spring loads are generally greater than fall loads, again with an exception for organic nitrogen.



.Figure 49. Observed seasonal flow and pollutant loads for Middle James-Willis-TF2.

Table 4 presents a comparison of the observed and modeled average annual loads of the selected constituents for the Middle James-Willis-TF2 segment. The loads presented only include observed data collected during the Chesapeake Bay Model simulation period (1985–2005). Note that no organic N observations are available for the modeling time period at this location, thus no comparison was made.

Table 4. Average annual flow and loads for select nutrient constituents for Middle James-Willis-TF2

Constituent	Source	Winter	Spring	Summer	Fall	Total
TN (kg/yr)	Modeled	2,416,221	1,208,485	1,003,204	1,077,379	5,705,289
	Observed	2,991,969	1,185,679	1,387,126	985,529	6,550,302
TP (kg/yr)	Modeled	411,138	246,470	205,243	200,465	1,063,316
	Observed	493,950	152,141	242,228	163,425	1,051,744
NO_3 (kg/yr)*	Modeled	507,460	268,200	192,522	197,942	1,166,125
	Observed	903,847	529,530	201,895	411,163	2,046,436
PO_4 (kg/yr)*	Modeled	88,064	66,844	47,363	68,462	270,732
	Observed	108,897	81,067	50,078	68,256	308,298
Org N (kg/yr)	Modeled	--	--	--	--	--
	Observed	--	--	--	--	--

***Modeled NO_x andPO_{4x} loads are used as surrogates for NO_3 and PO_4, respectively, for comparison to observed loads**

Appomattox-TF2

Figure 50 presents a seasonal analysis for observed flow and pollutant loads at the outlet of the Appomattox-TF2 segment, with total phosphorus and PO_4 also presented in a separate plot for clarity. All pollutant loads track with river outflows, with the highest occurrences in the winter for all parameters. Loads are lowest for all parameters in the summer when flows are at their lowest. Following the flow trend, spring loads are very similar to fall loads with greater loads in the spring for NO_3, organic N, and PO_4, but slightly smaller loads for TN and TP

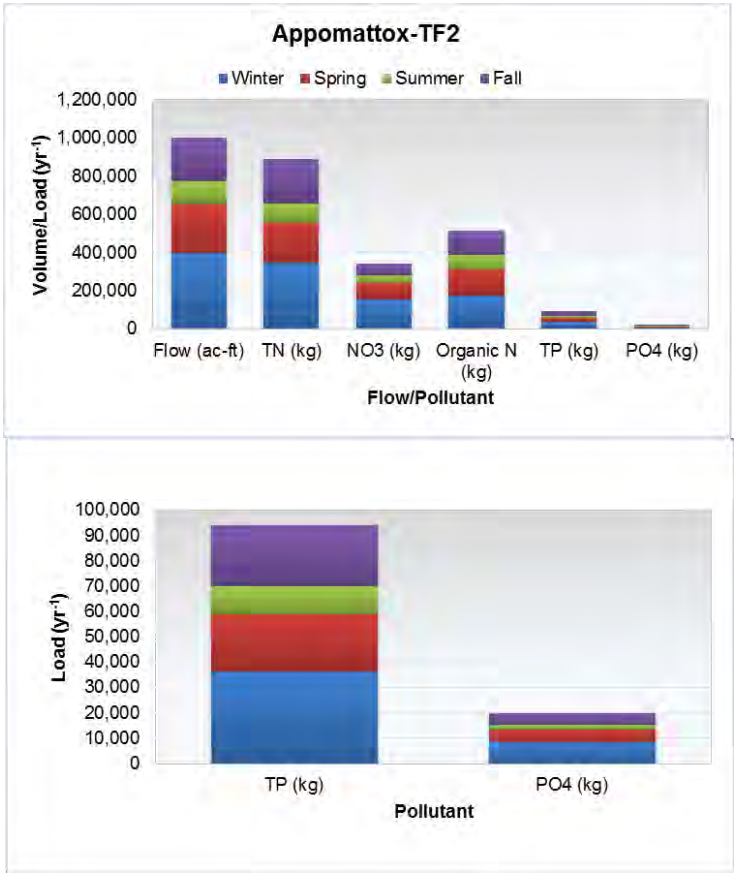


Figure 50 Observed seasonal flow and pollutant loads for Appomattox-TF2.

Table 5 presents a comparison of the observed and modeled average annual loads of the selected pollutants for the Appomattox-TF2 segment over the Chesapeake Bay Model simulation time period (1985–2005).

Table 5. Average annual flow and loads for select nutrient constituents for Appomattox-TF2

Pollutant	Source	Winter	Spring	Summer	Fall	Total
TN (kg/yr)	Modeled	479,839	272,251	187,143	280,732	1,219,965
	Observed	426,399	244,761	125,275	236,240	1,032,674
TP (kg/yr)	Modeled	35,208	31,844	26,847	27,116	121,016
	Observed	50,243	28,331	15,663	28,968	123,205
NO_3 (kg/yr)*	Modeled	212,360	87,279	70,146	103,054	472,838
	Observed	141,458	55,220	30,251	81,193	308,122
PO_4 (kg/yr)*	Modeled	12,233	9,279	8,968	9,549	40,029
	Observed	12,812	7,161	3,716	7,276	30,964
Org N (kg/yr)	Modeled	200,723	137,031	97,192	146,273	581,219
	Observed	232,907	171,116	102,564	143,658	650,244

*Modeled NO_x andPO_{4x} loads are used as surrogates for NO_3 and PO_4, respectively, for comparison to observed loads.

Chickahominy-OH

Figure 51 presents a seasonal analysis for observed flow and pollutant loads at the outlet of the Chickahominy-OH segment, with total phosphorus and PO_4 also presented in a separate plot for clarity. All pollutant loads track with river outflows, with the highest occurrences in the winter for all parameters. Loads are lowest for all parameters in the summer when flows are at their lowest. Following the flow trend, spring loads are very similar to fall loads with greater loads in the spring for TP and organic N, but slightly smaller loads for TN, NO_3, and PO_4.

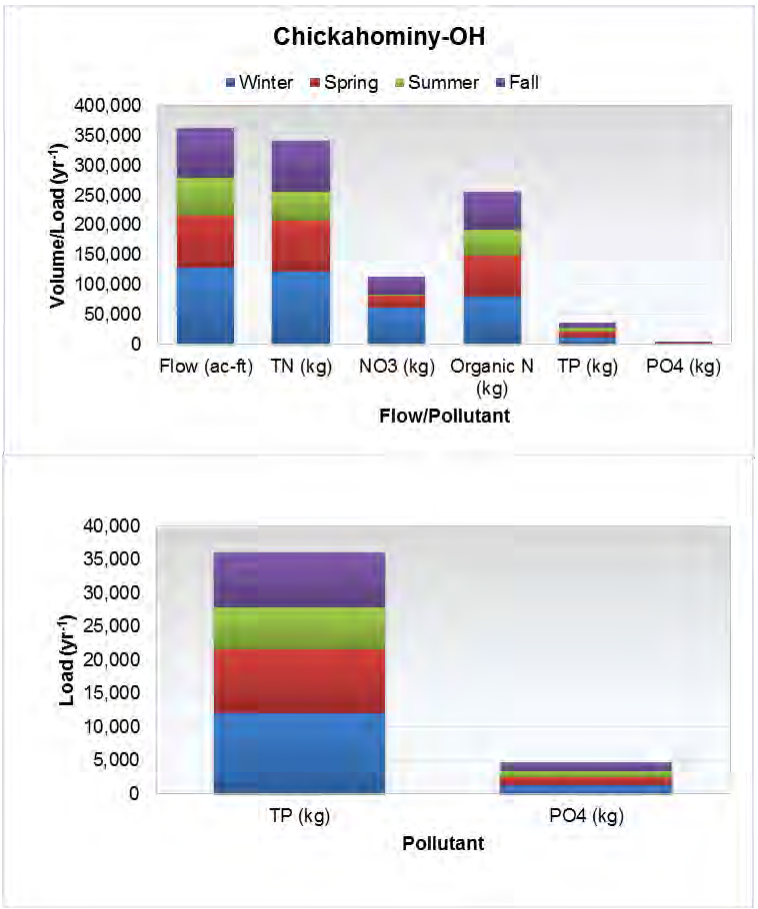


Figure 51 - Observed seasonal flow and pollutant loads for Chickahominy-OH.

Table 6 presents a comparison of the observed and modeled average annual loads of the selected pollutants for the Chickahominy-OH segment over the Chesapeake Bay Model simulation time period (1985–2005).

Table 6. Average annual flow and loads for select nutrient constituents for Chickahominy-OH

Pollutant	Source	Winter	Spring	Summer	Fall	Total
TN (kg/yr)	Modeled	69,983	49,753	35,585	30,162	185,483
	Observed	75,074	52,229	34,711	43,386	205,400
TP (kg/yr)	Modeled	6,356	8,662	8,235	3,864	27,116
	Observed	8,328	6,357	5,133	4,115	23,932
NO_3 (kg/yr)*	Modeled	30,357	15,166	9,900	13,562	68,985
	Observed	18,327	7,555	3,086	9,011	37,978
PO_4 (kg/yr)*	Modeled	4,075	5,534	6,523	3,437	19,569
	Observed	1,071	988	761	821	3,641
Org N (kg/yr)	Modeled	36,286	32,640	25,289	15,704	109,919
	Observed	50,526	42,383	31,508	32,020	156,437

*Modeled NO_x andPO_{4x} loads are used as surrogates for NO_3 and PO_4, respectively, for comparison to observed loads.

Hampton Roads-MH

Figure 52 presents a seasonal analysis for modeled flow and pollutant loads at the outlet of the Hampton Roads-MH segment, representing the Nansemond River

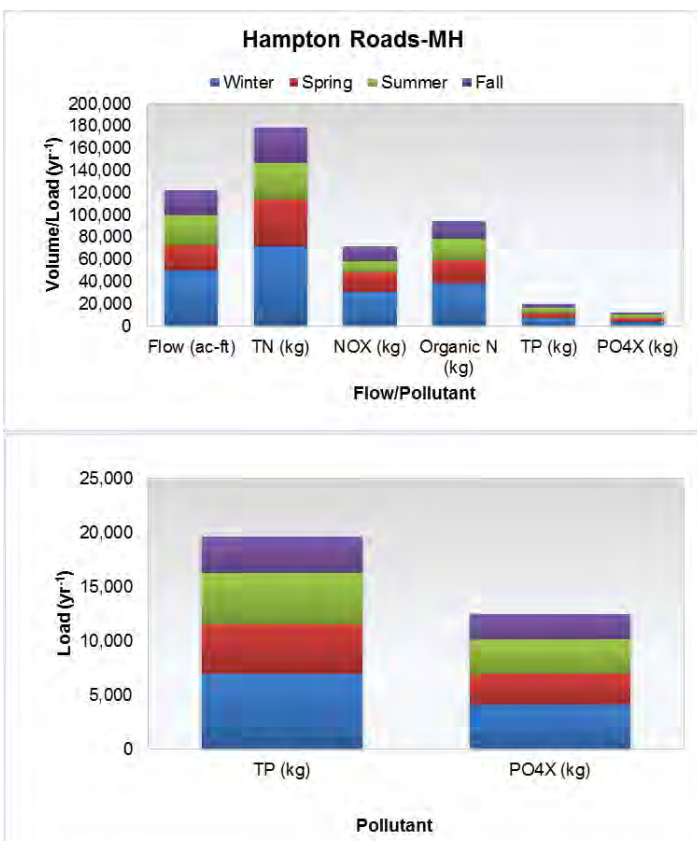


Figure 52 - Modeled seasonal flow and pollutant loads for Hampton Roads-MH

drainage, with total phosphorus and PO_4 also presented in separate plots for clarity. The seasonal signature for this location is unlike what is observed for the three upstream locations. This area shows slightly higher summer flows than in spring or fall, though the volumes for these three seasons are very similar. Winter is still the wettest season and, as for the other locations, exhibits the highest pollutant loads. Fall generally exhibits the lowest pollutant loads, including for TN, organic N, TP and PO_4^{3-}. Comparing spring and summer, the larger load changes with pollutant where spring shows higher TN, NO_3, and organic N loads, but higher TP and PO_4^{3-} are seen in the summer. The seasonal flow and pollutant loading signatures for this area are likely affected by point sources and reservoirs located in the watershed.

Table 7 presents a comparison of the observed and modeled average annual loads of the selected pollutants for the Hampton Roads-MH segment over the Chesapeake Bay Model simulation time period (1985–2005). Only modeled flows are available for this watershed. Observed loads are estimated using modeled flows and observed monitoring data. These should be used with caution given the tidal nature of the monitoring location. Modeled loads of NO_x and PO_{4x} are used as surrogates for NO_3 and PO_4, respectively, as the Chesapeake Bay model did not explicitly simulate the latter.

Table 7 - Average annual flow and loads for select nutrient constituents for Hampton Roads-MH

Pollutant	Source	Winter	Spring	Summer	Fall	Total
TN (kg/yr)	Modeled	14,527	9,278	15,877	20,734	60,416
	Observed	11,725	1,965	12,253	13,916	39,859
TP (kg/yr)	Modeled	5,389	2,037	1,247	1,919	10,591
	Observed	9,006	2,661	2,637	2,977	17,282
NO_3 (kg/yr)*	Modeled	--	--	--	--	--
	Observed	--	--	--	--	--
PO_4 (kg/yr)*	Modeled	2,605	981	1,096	1,209	5,890
	Observed	3,936	1,272	1,699	1,218	8,124
Org N (kg/yr)	Modeled	--	--	--	--	--
	Observed	--	--	--	--	--

*Modeled NO_x andPO_{4x} loads are used as surrogates for NO_3 and PO_4, respectively, for comparison to observed loads.

Hampton Roads-PH

Figure 53 presents a seasonal analysis for modeled flow and pollutant loads at the outlet of the Hampton Roads-PH segment, representing the Elizabeth River drainage, with total phosphorus and PO_4 presented in a separate plot for clarity. The seasonal signature for this location is similar to what was described for the Hampton Roads-MH segment. Again, this area shows higher summer flows than in

spring or fall. Winter is still the wettest season, but summer flows are only 8 percent lower than for the winter. Also the spring and summer show the highest loads for certain pollutants including TP and PO_{4x} in the summer and NO_x in the spring. Winter has the highest loads for the other constituents (TN and organic N). Fall generally shows the lowest pollutant loads, though loads higher than in spring are seen for organic N, TP, and PO_{4x}. Seasonal flows and pollutant loads for this area are likely affected by permitted facilities in the watershed.

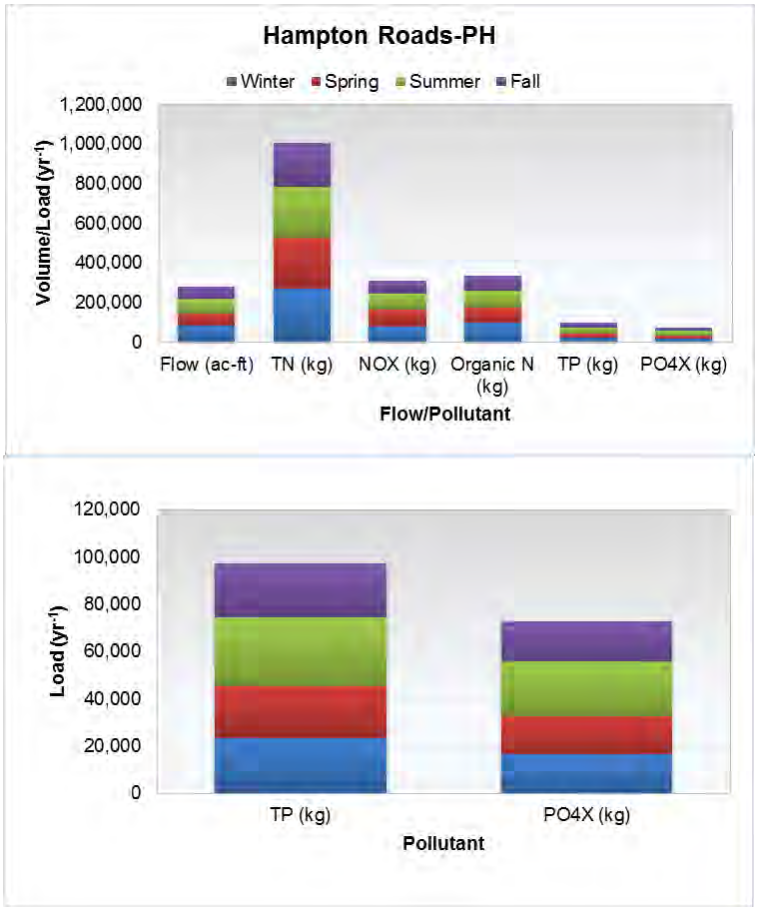


Figure 53 - Modeled seasonal flow and pollutant loads for Hampton Roads-PH.

Table 8 presents a comparison of the observed and modeled average annual loads of the selected pollutants for the Hampton Roads-PH segment over the Chesapeake Bay Model simulation time period (1985–2005). Again, only modeled flows are available for this watershed. Observed loads are estimated using modeled flows and observed monitoring data. These should be used with caution, particularly when compared to modeled loads, given the tidal nature of the monitoring location and permitted facility contributions represented by the modeled loads. Modeled loads of NO_x and PO_{4x} are used as surrogates for NO_3 and PO_4, respectively, as the Chesapeake Bay model did not explicitly simulate the latter.

Table 8. Average annual flow and loads for select nutrient constituents for Hampton Roads-PH

Pollutant	Source	Winter	Spring	Summer	Fall	Total
TN (kg/yr)	Modeled	239,520	216,365	266,537	214,714	937,135
	Observed	55,227	38,422	75,199	44,055	212,903
TP (kg/yr)	Modeled	19,239	19,653	26,177	17,662	82,730
	Observed	5,065	4,152	9,626	4,009	22,851
NO_3 (kg/yr)*	Modeled	72,324	72,715	79,470	64,420	288,928
	Observed	8,949	5,095	12,869	11,294	38,207
PO_4 (kg/yr)*	Modeled	13,182	14,115	19,209	12,523	59,029
	Observed	925	1,033	5,256	2,318	9,532
Org N (kg/yr)	Modeled	76,356	52,323	84,469	60,252	273,401
	Observed	40,478	26,717	46,563	24,842	138,599

*Modeled NO_x andPO_{4x} loads are used as surrogates for NO_3 and PO_4, respectively, for comparison to observed loads.

Nutrient Budget Summary

A summary of the nutrient loads to the tidal James River based on the Chesapeake Bay Model results is presented in Table 9. The contributing areas assessed include 90 percent of the watershed. The remaining un-assessed areas represent direct lateral flows to the Lower James. In general, nutrient loads increase with contributing drainage area. The major exception is the Hampton Roads-PH drainage (Elizabeth River), which has the smallest drainage area but a significant load contribution. Its load contribution is greater than Hampton Roads-MH (Nansemond River) and Chickahominy-OH for all constituents.

The Elizabeth River and its tributary, the Lafayette River, have been identified as algae bloom hotspots (Marshall and Egerton 2013) and are likely influenced by the high nutrient loads delivered to open water in these areas. This conclusion is reinforced if unit-area flows and loads are examined for each segment as shown in Table 10. The Hampton Roads-PH segment exhibits the greatest unit area loading for all nutrients, largely due to permitted facility contributions and high unit-area flows caused by the large fraction of urban impervious area in the drainage. It should be noted that these model results are currently being confirmed given the magnitude of variability when compared to other drainage areas.

Table 9 - Summary of flow and nutrient loads to the tidal James River[1]

HUC8-CBP Seg	Drainage Description	Drainage Area (mi^2)	Flow (ac-ft/yr)	Average Annual Load (kg/yr)				
				TN	TP	NO_x	Organic N	PO_{4x}
Middle James-Willis-TF1	James River above Richmond, VA	6,803	5,498,103	5,200,729	1,029,412	1,210,077	3,668,970	256,273
Appomattox-TF2	Appomattox River	1,612	1,041,983	1,214,049	116,339	483,926	559,754	42,620
Chickahominy-OH	Chickahominy River	470	359,017	216,167	27,363	76,945	128,392	18,742
Hampton Roads-MH	Nansemond River	201	122,613	178,566	19,595	71,870	94,948	12,441
Hampton Roads-PH	Elizabeth River	168	282,399	1,007,514	97,125	311,000	336,028	72,701
Total		9,254	7,304,115	7,817,025	1,289,834	2,153,818	4,788,092	402,777

[1]Flows and loads from direct local drainages are not included in the summary.

Table 10. Summary of unit area flow and nutrient loads to the tidal James River[1]

HUC8-CBP Seg	Drainage Description	Unit Area Flow (ac-ft/yr·mi^2)	Unit Area Average Annual Load (kg/yr·mi^2)				
			TN	TP	NO_x	Organic N	PO_{4x}
Middle James-Willis-TF1	James River above Richmond, VA	808	764	151	178	539	38
Appomattox-TF2	Appomattox River	646	753	72	300	347	26
Chickahominy-OH	Chickahominy River	764	460	58	164	273	40
Hampton Roads-MH	Nansemond River	610	888	97	358	472	62
Hampton Roads-PH	Elizabeth River	1,681	5,997	578	1,851	2,000	433

[1]Flows and loads from direct local drainages are not included in the summary.

Subtask 2.3 - Critical Condition Analysis

Critical condition analysis is conducted to identify conditions suitable as a basis for TMDL development. Attainment of applicable water quality criteria during the critical condition implies a general attainment of criteria during all conditions. Therefore, identifying critical conditions in the tidal James River will help inform future model application including selecting an appropriate model simulation time period. A critical condition for chlorophyll-*a* in the tidal James River was assessed previously as part of the development of the Chesapeake Bay TMDLs (U.S. EPA 2010a). This work is built on previous analysis done by Malcolm Pirnie (Bell 2009). In light of new data collected, DEQ seeks to revisit this analysis.

The previous critical condition analysis assumed that freshwater inputs during the winter-spring drive chlorophyll *a* criteria exceedances in the tidal James. Thus, the average daily inflow from January through May was calculated for each year and for a sliding 3-year period within a 75-year period of record (1935–2009). The sliding 3-year period is consistent with critical condition analysis conducted by EPA for

dissolved oxygen in the Chesapeake Bay (U.S. EPA 2010a), as well as assessment periods evaluated. The return period of these flows was determined and compared to chlorophyll *a* exceedances over the Bay Model simulation time period (1984–2004) to determine if there was a statistical correlation between flow magnitude and water quality. Results of the analysis found no strong correlation. Later work done by Malcolm Pirnie (Bell and Hunley 2009) using multi-variable regression techniques to account for the various factors that contribute to algae blooms also failed to identify a statistically significant critical condition.

The availability of more recent water quality and flow data prompted a reassessment of the critical condition in the James River watershed. Data collected through 2012 (Table 1) was used to investigate what conditions may be driving chlorophyll-a criteria exceedances in the tidal James. Two veins of investigation were approached using the new data. A statistical approach re-visited the methods used in previous analysis to correlate ambient conditions with water quality violations, while a graphical approach used summaries of paired data to visually assess the relationship between water quality watershed conditions.

Statistical Approach

Correlation of flow conditions and chlorophyll-a water quality criteria exceedances was assessed for five locations in the James River watershed. These locations and the water quality and flow data assigned to them are shown in Table 11. The data analysis methods built upon previous methods and used a 3-year sliding average of flow return periods over 1984–2012, which were compared to chlorophyll-a exceedance averages over the same periods. This approach was founded on the previously documented relationship between winter-spring inflows and summer hypoxia in the mainstem Bay.

Table 11. James River segments, flow, and water quality data used for critical condition correlation analysis

HUC8-CBP Segment	USGS Stream-flow Station	Water Quality Station
Appomattox-TF2	02041650	TF5.4
Middle James-Willis-TF2	02037500	TF5.2
Lower James-TF1	Sum of 02037500; 02041650	TF5.6
Lower James-MH	Sum of 02037500; 02041650; 02042500	LE5.2
Lower James-OH	Sum of 02037500; 02041650; 02042500	RET5.2

The non-parametric Kendall-Tau statistic and single-variable linear regression were used to determine the strength of the relationship between chlorophyll-a water quality criteria exceedances and the flow return period. Analysis was performed on

data grouped by segment and season, with the seasons defined as in Virginia's James River chlorophyll-a standards:

- Spring (March-May)
- Summer (July-September)

The correlation analysis was accompanied by a hypothesis test to determine if the correlation was significant at the 95-percent confidence level (α=0.05). Results are presented in the following sections.

Statistical Approach Results

The combined results of the statistical analysis are interpreted below for each segment-season combination. The Kendall-Tau correlation score can range from -1 to 1. The closer the absolute value of a score is to 1 the stronger the correlation, while the sign of the score indicates a positive or inverse relationship. An inverse relationship would indicate a higher number of water quality criteria exceedances during low-flow conditions. None of the segment-seasons showed a particularly strong correlation between chlorophyll *a* exceedances and stream flow return period. That is not to say that there is no correlation between stream flow and chlorophyll *a* concentrations in general, as discussed in Subtask 2.1. Only that a weak association is observed for flow and water quality criteria exceedance. Also, the flow return periods differ by season with one of the driest summers (1992–1994) being associated with the wettest springs. This is generally indicative of a representative annual rainfall budget where rainfall can be shifted from one season to the next along the margins. A general increase in exceedances is seen for this period at most locations, but it does not represent the time of most exceedance at any location.

Spring

The Kendall Tau rank correlation coefficients presented in Table 12 indicate weak correlations during the spring season between chlorophyll-a and stream flow return periods for the five James River segments examined. Appomattox-TF2 and Lower James-OH show the highest scores, both indicating an inverse relationship. All other segments show a positive relationship with scores less than or equal to 0.10. The Appomattox-TF2 and Lower James-OH are also the only segments with r^2 values greater than zero and no segment came close to showing a statistically significant relationship between chlorophyll-a exceedances and stream flow return period (α=0.05).

The spring relationship between flow return periods and chlorophyll-a exceedance for running three year averages are shown for the analyzed segments in Figure 54 through Figure 58. The flow return periods for segments are very similar with 1992-1994 showing the highest return period, representing the wettest 3-yr average and 1999-2001 showing the shortest return period. The timing of exceedances varies noticeably between the five segments, though the Lower James-TF1 and OH show the most similar pattern with comparatively large percentages of exceedances preceding and following the highest flow return period. The Appomattox-TF2

segment generally shows exceedances throughout the monitoring period, while the Middle James-TF2 only shows exceedances in 2000-2003 and 2007–2012.

Table 12. Correlation results for the spring season

HUC8-CBP Segment	Kendall Tau Score	r^2	p-value
Appomattox-TF2	-0.13	0.08	0.36
Middle James-Willis-TF2	0.07	0.00	0.82
Lower James-TF1	0.08	0.00	0.58
Lower James-OH	-0.16	0.12	0.27
Lower James-MH	0.10	0.00	0.51

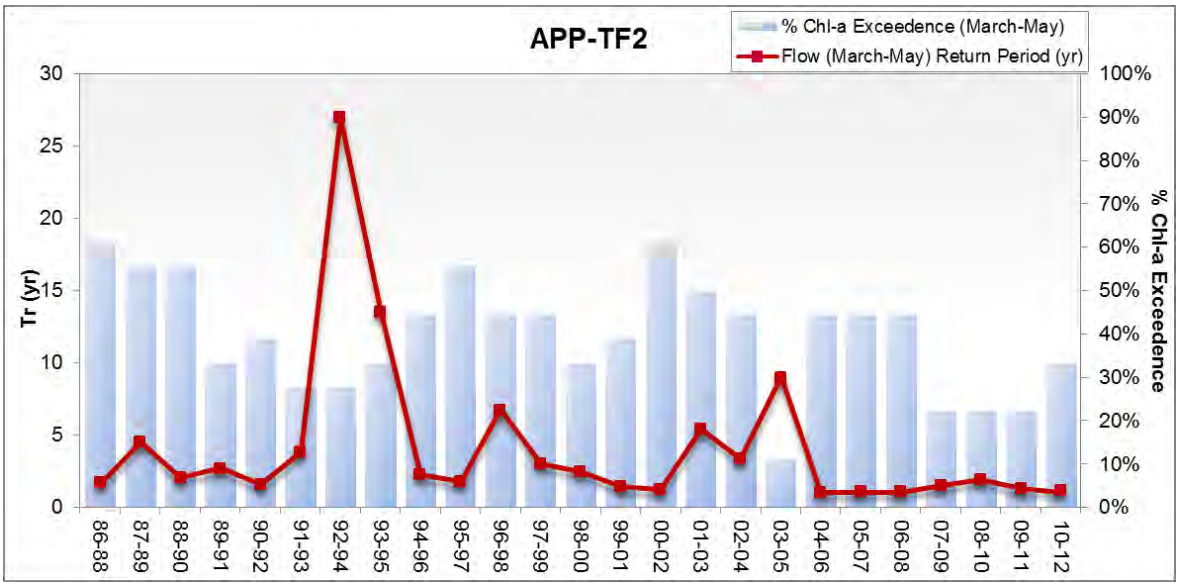


Figure 54 - 3-yr average flow return periods and chlorophyll-a percent exceedances at Appomattox-TF2 during spring.

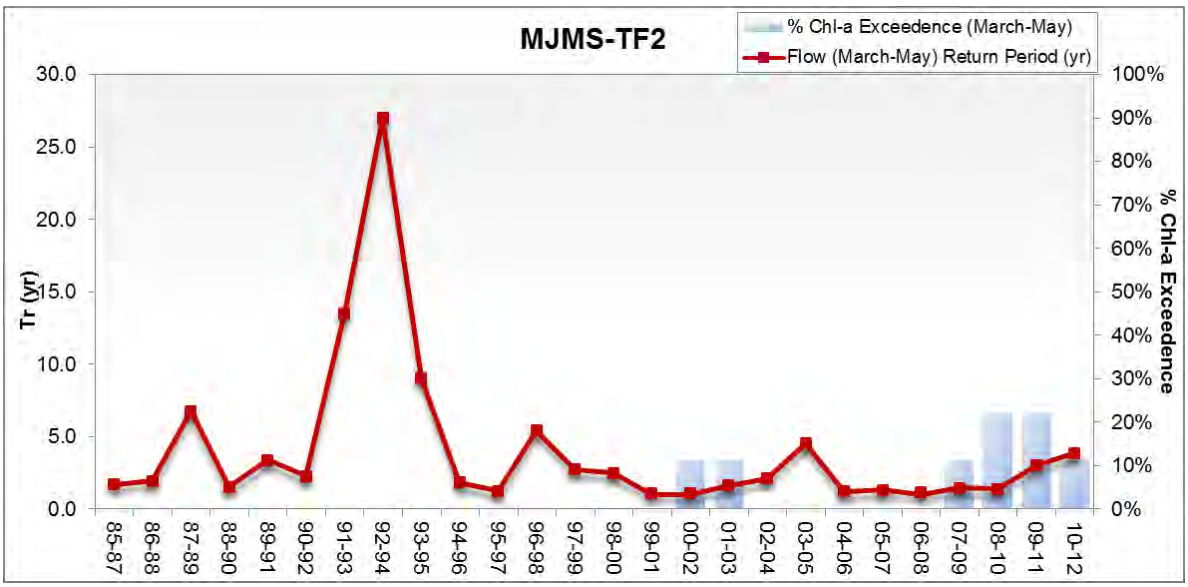


Figure 55 - 3-yr average flow return periods and chlorophyll-a percent exceedances at Middle Jmes-Willis-TF2 during spring.

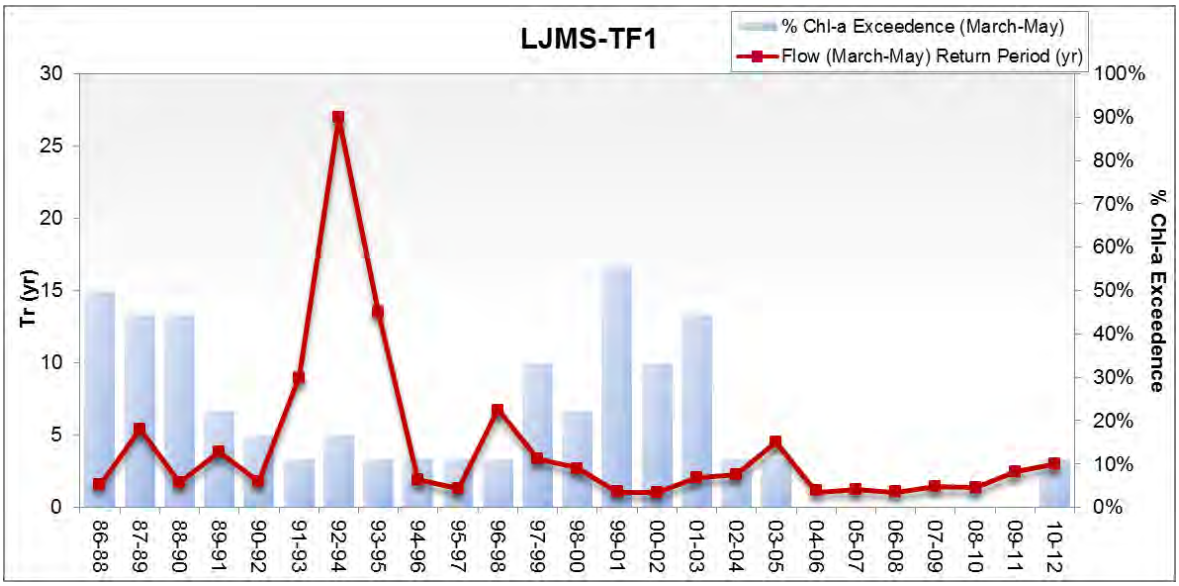


Figure 56 -. 3-yr average flow return periods and chlorophyll-a percent exceedances at Lower James-TF1 during spring.

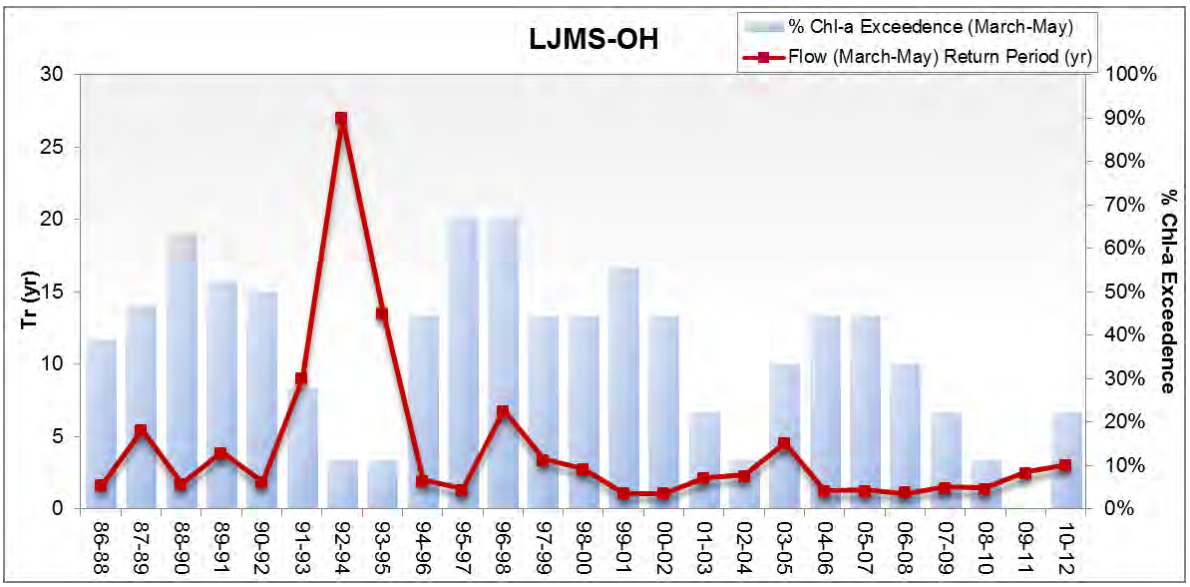


Figure 57 -3-yr average flow return periods and chlorophylla percent exceedances at Lower James-OH during spring.

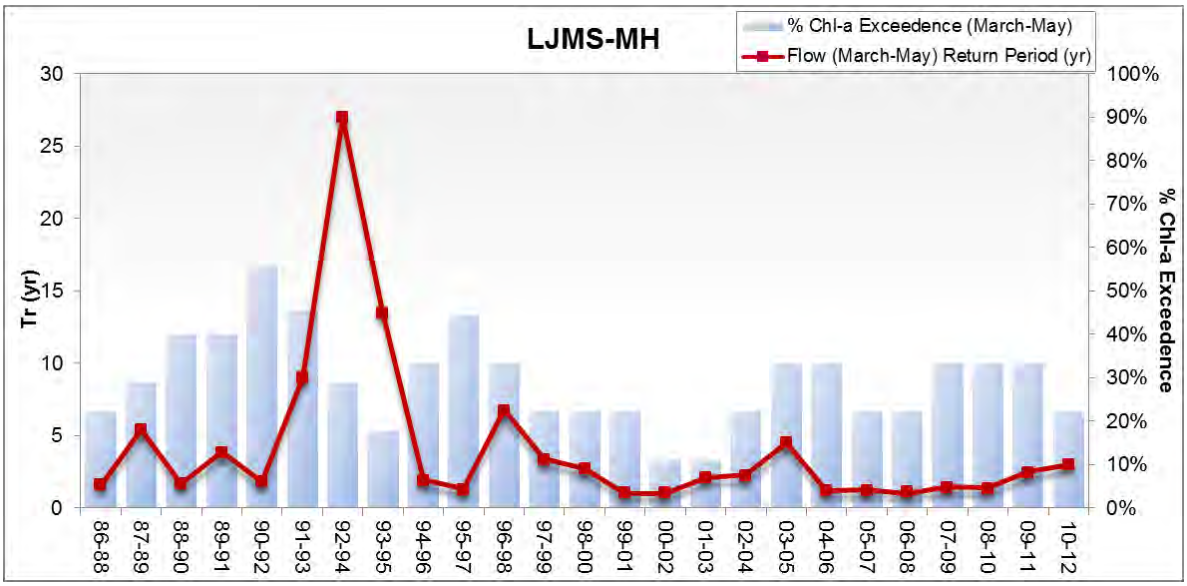


Figure 58 - 3-yr average flow return periods and chlorophyll-a percent exceedances at Lower James-MH during spring.

Summer

The Kendall Tau rank correlation coefficients presented in Table 13 indicate generally weak correlations during the summer season between chlorophyll-a and stream flow return periods for the five James River segments examined. Summer correlations are generally stronger than for spring, however, with Appomattox-TF2 and Middle James-TF2 showing close to or at moderate scores (>0.33). Appomattox-TF2 also shows a statistically significant relationship with a p-value less than 0.05. The negative sign of the Tau score indicates that it is an inverse relationship, with lower flow return periods (dry periods) correlated with higher water quality criteria exceedances. As with the spring season the remaining

segments do not show a statistically significant relationship between chlorophyll-a exceedances and stream flow return period. Also of note is that the sign of the Tau scores for the Lower James-OH and MH switched from the spring season. Because the scores are so low, however, it is difficult to draw any conclusions from the change.

Table 13 - Correlation results for the summer season

HUC8-CBP Segment	Kendall Tau Score	r^2	p-value
Appomattox-TF2	-0.31	0.13	0.03
Middle James-Willis-TF2	0.36	0.61	0.08
Lower James-TF1	0.00	0.15	1.00
Lower James-OH	0.08	0.02	0.57
Lower James-MH	-0.19	0.1	0.17

The summer relationship between flow return periods and chlorophyll-a exceedance for running three year averages are shown for the analyzed segments in Figure 59 through Figure 63. The flow return periods for segments are very similar with 2003–2005 showing the highest return period, representing the wettest 3-yr average and 1991-1993 showing the shortest return period. As noted previously, the highest and lowest return periods for the summer are essentially reversed for the spring season indicating the vast majority of rainfall occurring in one season during those time periods.

The timing of exceedances between the five segments varies even more during the summer than was observed for the spring season. Again the Appomattox-TF2 segment generally shows exceedances throughout the monitoring period, but for the summer season the exceedances are much more severe often approaching or equaling 100 percent. This reinforces the negative Tau score for this segment, which indicates lower flows being associated with higher chlorophyll-a exceedances. The Lower James-TF1 shows the next most frequent exceedances, while the other segments only show sporadic exceedances at low percentages for the comparison period. Like for the spring season, there is no clear visible relationship between flow return period and water quality criteria exceedance.

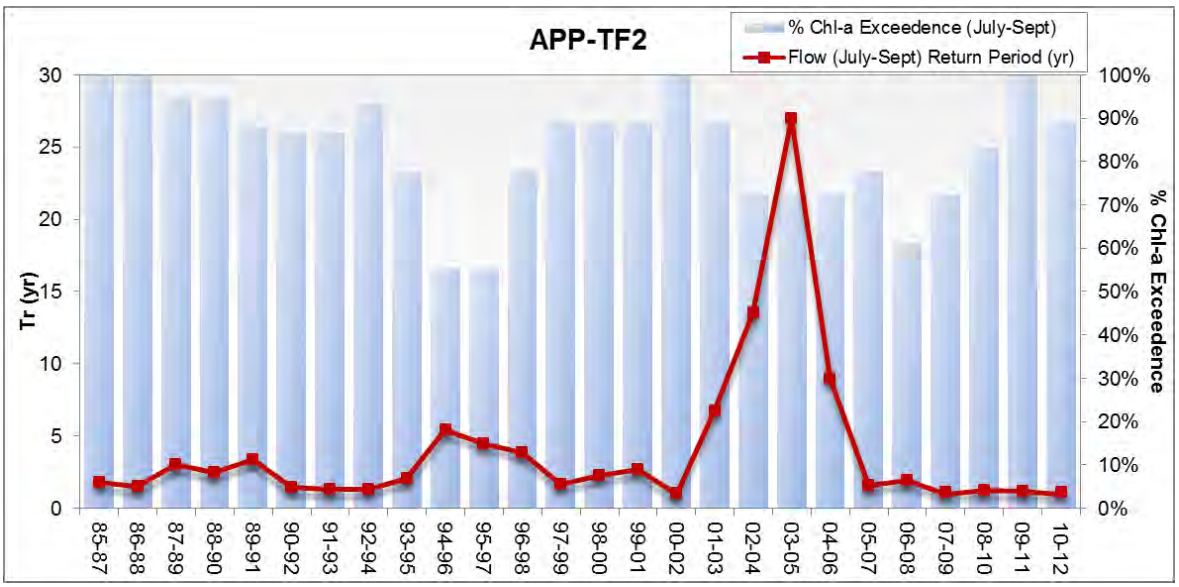


Figure 59.- 3-yr average flow return periods and chlorophyll-a percent exceedances at Lower Appomattox-TF2 during summer.

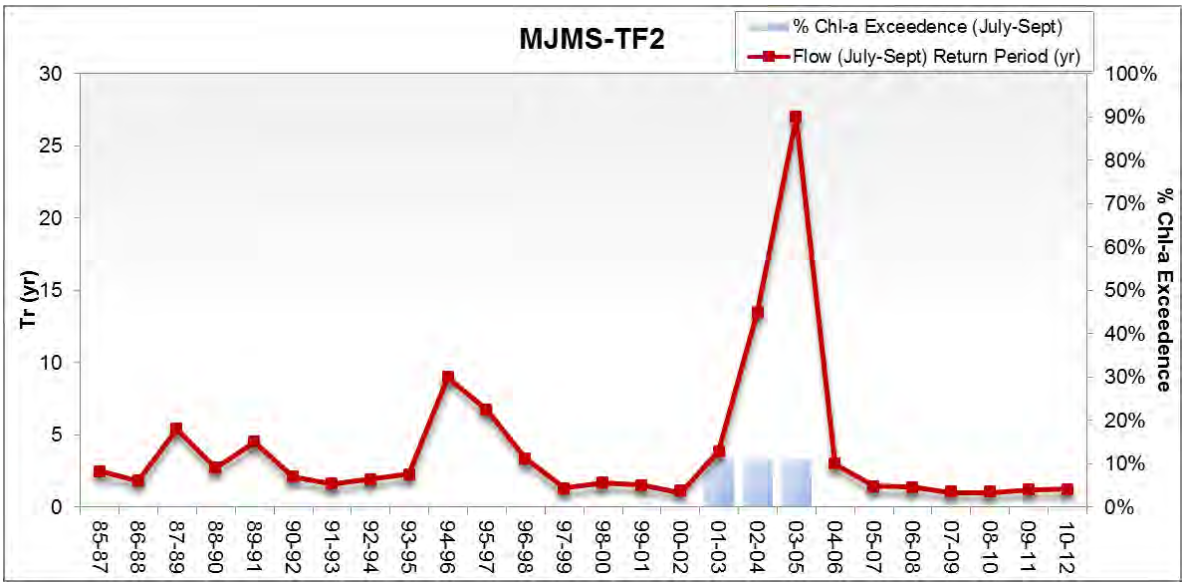


Figure 60 - 3-yr average flow return periods and chlorophyll-a percent exceedances at Middle James-TF2 during summer.

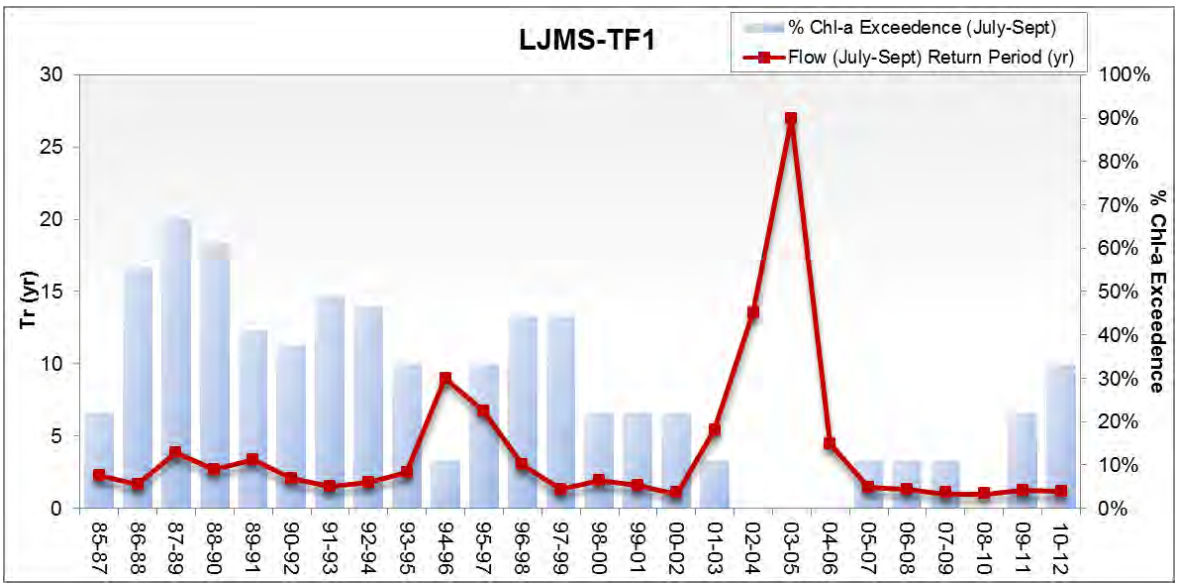


Figure 61 - 3-yr average flow return periods and chlorophyll-a percent exceedances at Middle James-Willis-MH during summer.

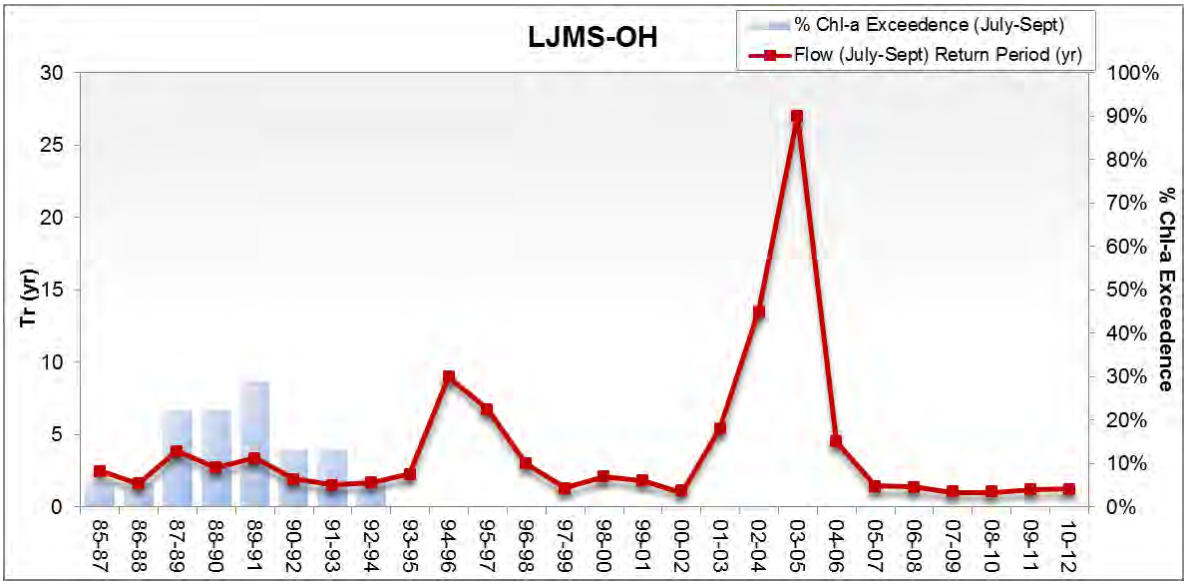


Figure 62- 3-yr average flow return periods and chlorophyll-a percent exceedances at Lower James-OH during summer.

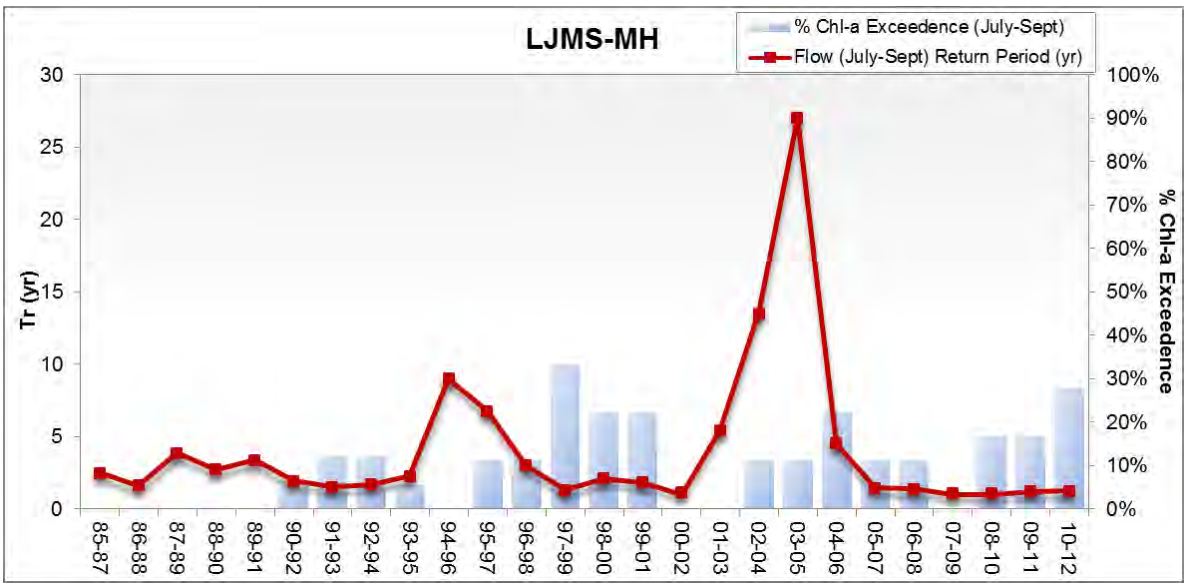


Figure 63 -3-yr average flow return periods and chlorophyll-a percent exceedances at Lower James-MH during summer.

Water Quality Concentration Analysis

To further explore the statistical approach, the analytical methods were replicated to determine if using average chlorophyll *a* concentrations, as opposed to water quality criteria exceedance, would strengthen the return flow correlation results. Sliding 3-year averages and the 1984-2012 time period were again used for this analysis. In addition to examining concentrations, alternative time period "slices" were examined to determine whether flows in one time period were driving water quality conditions in another. For example, do winter flows (January–March) drive summer water quality (July-September)? The temporal comparisons made in the supplemental correlation analysis included:

- March–May return flows : March–May chlorophyll *a* concentrations
- July–September return flows : July–September chlorophyll *a* concentrations
- Winter return flows : Winter chlorophyll *a* concentrations
- Spring return flows : Spring chlorophyll *a* concentrations
- Summer return flows : Summer chlorophyll *a* concentrations
- Fall return flows : Fall chlorophyll *a* concentrations
- Spring–Summer return flows : Mar–May chlorophyll *a* concentrations
- Spring–Summer return flows : July–September chlorophyll *a* concentrations
- Winter–Spring return flows : Mar–May chlorophyll *a* concentrations
- Winter–Spring return flows : July–September chlorophyll *a* concentrations

In addition, correlation analysis was performed for the Lower James-PH segment using the same USGS stream-flow data as Lower James-MH and water quality monitoring station LE5.4. A summary of the locations and temporal comparison that showed statistically significant correlation at the 95-percent confidence level

(α=0.05) is presented in Table 14. Locations with close to significant (α≤0.10) are also presented to help identify trends in the results.

Table 14 – Supplemental flow return period-average chlorophyll a concentration correlation results for selected scenarios

HUC8-CBP Segment	Flow Time Period	Concentration Time Period	Kendall Tau Score	r^2	p-value	95% Confidence Interval	Flow Return Period	Avg. Chlorophyll a Conc. (µg/L)
Appomattox-TF2	Fall	Fall	-0.508	0.28	0.00	Stat. sig	1.50	37.26
	Jul-Sep	Jul-Sep	-0.268	0.22	0.06	Not sig	1.66	52.54
	Spring-Summer	Jul-Sep	-0.243	0.14	0.09	Not sig	1.59	52.54
	Summer	Summer	-0.268	0.22	0.06	Not sig	1.66	52.54
	Winter	Winter	-0.422	0.20	0.00	Stat. sig	1.41	9.31
Middle James-Willis-TF2	Fall	Fall	0.436	0.58	0.04	Stat. sig	14.79	1.10
	Jul-Sep	Jul-Sep	0.451	0.59	0.03	Stat. sig	14.79	2.94
	Spring-Summer	Jul-Sep	0.407	0.06	0.05	Stat. sig	15.30	2.94
	Summer	Summer	0.451	0.59	0.03	Stat. sig	14.79	2.94
	Winter	Winter	-0.462	0.18	0.03	Stat. sig	1.39	4.94
Lower James-TF1	Fall	Fall	-0.372	0.23	0.01	Stat. sig	1.51	14.71
	Winter	Winter	-0.440	0.06	0.00	Stat. sig	2.21	14.93
Lower James-OH	Fall	Fall	-0.348	0.16	0.01	Stat. sig	1.58	19.28
	Winter	Winter	-0.415	0.10	0.00	Stat. sig	1.21	16.48
	Winter-Spring	Jul-Sep	0.354	0.04	0.01	Stat. sig	6.48	21.62
Lower James-MH	Mar-May	Mar-May	0.255	0.02	0.07	Not sig	4.85	23.30
	Spring	Spring	0.348	0.05	0.01	Stat. sig	3.62	10.32
	Winter-Spring	Mar-May	0.255	0.00	0.07	Not sig	2.98	23.30
Lower James-PH	Jul-Sep	Jul-Sep	-0.397	0.02	0.00	Stat. sig	1.10	16.17
	Spring	Spring	0.274	0.19	0.05	Not sig	11.23	10.81
	Spring-Summer	Jul-Sep	-0.348	0.03	0.01	Stat. sig	1.38	16.17
	Spring-Summer	Mar-May	0.415	0.16	0.00	Stat. sig	3.09	16.45
	Summer	Summer	-0.397	0.02	0.00	Stat. sig	1.10	16.17
	Winter	Winter	-0.292	0.13	0.04	Stat. sig	1.38	27.30
	Winter-Spring	Jul-Sep	-0.243	0.03	0.09	Not sig	1.33	16.17

Some general observations of the supplementary analysis include:

- Correlative concentration results are similar to the exceedance results for the same comparison time periods (March–May and July–September).
    - Both comparisons show no statistically significant correlation for March–May, while p-values for locations showing statistical significance for exceedance data are very similar to those using average concentration data

(Appomattox-TF2: p-value=0.03 for exceedance vs. p-value=0.06 for concentration; Lower James-TF2: p-value=0.08 for exceedance vs. p-value=0.03 for concentration).
    - All Kendall Tau scores have the same sign between the two analyses, indicating the same trend direction.
- Average chlorophyll *a* concentrations at Appomattox-TF2 show consistent negative correlation with return flow period indicating that lower flows are associated with higher concentrations. This relationship is observed for five of the comparison time periods as presented in Table 13. That the highest chlorophyll *a* concentrations are observed in the summer (see Appendix C) at this location is consistent with the correlation trend. The average return period for comparisons showing statistically significant or near-significant correlation is 1.56 years.
- Average chlorophyll *a* concentrations at Middle James-Willis-TF2 show statistically significant correlation with return flow period for five of the comparison time periods as presented in Table 13, for of which were positive. The average chlorophyll *a* concentration for the statistically significant comparisons is 2.48 µg/L, however, which is well below the applicable water quality criteria indicating that chlorophyll *a* water quality is not necessarily a concern at this location.
- Average chlorophyll *a* concentrations at Lower James- TF1 are always negatively correlated with return flow period. This relationship is observed for two of the comparison time periods (Fall : Fall and Winter : Winter) with an average return period of 1.56 years for the statistically significant comparison time periods. That the highest chlorophyll *a* concentrations are observed in the summer at this location (see Appendix C)is consistent with the correlation trend.
- Average chlorophyll *a* concentrations at Lower James-OH show both negative and positive correlation with return flow period. Positive correlation is observed for the Winter–Spring : July–September comparison period, while negative correlation is observed for the Fall : Fall and Winter : Winter comparison time periods. The flow return period for the positively correlated time period is 6.48 years and 1.40 years for the negatively correlated time period. Seasonal average chlorophyll *a* concentrations reflect the correlation analysis showing peak concentrations in spring and summer (see Appendix C).
- Average chlorophyll *a* concentrations at Lower James- MH are always positively correlated with return flow period. This relationship is observed for three of the comparison time periods (March–May : March–May, Spring : Spring, and Winter–Spring : March–May) with an average return period of 3.82 years for the statistically significant comparison time periods. That the highest chlorophyll *a* concentrations are observed in the late winter-early spring at this location is consistent with the correlation trend.
- Average chlorophyll *a* concentrations at Lower James-PH show both negative and positive correlation with return flow period. Positive correlation is observed for the Spring : Spring and Spring–Summer : March–May comparison period, while negative correlation is observed for five comparison time periods as presented in Table 13.

The flow return period for the positively correlated time period is 7.16 years and 1.26 years for the negatively correlated time period. Seasonal average chlorophyll *a* concentrations partially reflect the correlation analysis showing peak concentrations in the winter and spring at this location (see Appendix C). There does not appear to be a significant increase in average chlorophyll *a* concentrations during the low-flow seasons of summer and fall. This could be an artifact of small but consistent changes in concentration associated with lower flows.

Graphical Approach

Key water quality and flow monitoring data were paired with coincident chlorophyll-a sampling to examine the potential for association and temporal trends, in order to supplement the statistical analysis. The five locations included in the statistical analysis, as well as the Hampton Roads-PH and Chickahominy-OH segments were evaluated for this graphical analysis. The water quality parameters outlined in Table 1 as well as flow data were included in the paired graphical analysis from which constituents were chosen on the basis of whether there were sufficient coincident data to examine trends. Sufficient data typically consisted of 30 or more paired observations. Table 15 lists the analysis locations and the water quality parameters that had sufficient data to perform the analysis.

Table 15. Water quality parameters evaluated as part of the graphical trend analysis

Comparison Parameter	HUC8-CBP Segment Sample Counts						
	Appomattox-TF2	Chickahominy-OH	Hampton Roads-PH	Lower James-MH	Lower James-OH	Lower James-TF1	Middle James-Willis-TF2
Flow	375	326	300	372	373	380	153
Suspended solids (S. Solids)	299	322	243	316	316	325	154
Total phosphorus (TP)	366	311	294	362	364	370	139
Ortho-phosphorus (Ortho)	--	--	--	--	--	143	--
Ortho-phosphorus dissolved (Ortho F)	344	325	294	368	371	380	154
Total nitrogen (TN)	361	309	292	358	364	366	143
Ammonia (NH_3)	35	64	--	--	--	151	--
Nitrite (NO_2)	--	63	--	--	--	144	--
Nitrate (NO_3)	35	63	--	--	--	144	--
Nitrite + nitrate dissolved (NO_x F)	375	325	299	371	372	379	154
Organic nitrogen (Org N)	359	309	269	336	352	360	31

Graphical Approach Results

Paired data were compared in two ways. First, paired data were grouped into percentile ranges and compared as shown on the left in Figure 64. Within each

percentile range, weighted concentrations are calculated on the basis of the quantity (flow) or concentration (water quality) of the constituent being compared with chlorophyll-a. The other analysis looks at seasonal trends for the paired data as show in the same Figure to the right. Graphical trends are presented for all seven locations and available monitoring data are generally distributed evenly amongst the analysis intervals (percentile and season). Graphical analyses for all constituents and data summaries for the evaluated locations are presented in Appendix C.

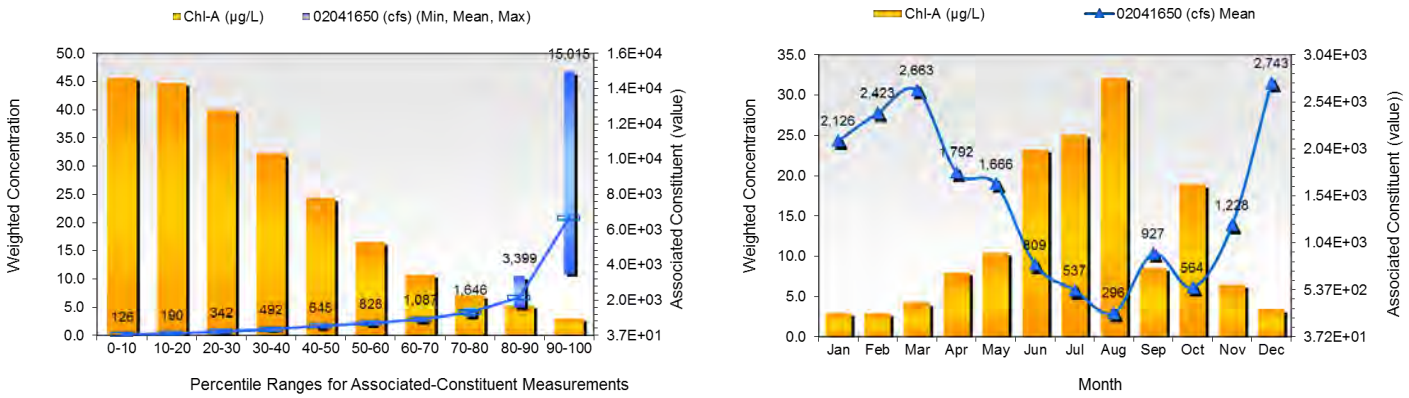


Figure 64 - Graphical trends example for stream flow associated chlorophyll-a concentrations in the Appomattox-TF2 segment.

Critical Analysis Summary

The statistical analysis showed a very weak relationship between flow and chlorophyll *a* criteria exceedances, regardless of location. The only location to show a statistically significant correlation between flow and chlorophyll *a* exceedance was the Appomattox-TF2 segment, which had a negative linear correlation (p=0.03) with stream flow during the summer season. The Middle James-Willis-TF2s segment also showed a moderately strong positive Tau test score (0.36), indicating positive correlation with stream flow. Chlorophyll *a* concentrations at this location are consistently low; however, indicating it is not necessarily an area of water quality concern.

Additional statistical analysis using paired flow return period and average chlorophyll *a* concentrations showed statistically significant relationships for various time period "slice" comparisons, differing by assessment location. General trends showed a negative correlation at Appomattox-TF2 and Lower James-TF1, a general positive correlation at Middle James-Willis-TF2 and Lower James- MH, and both positive and negative correlation at Lower James-OH and Lower James-PH.

The graphical analysis presented in Appendix C also indicates significant variability in the association of flow and chlorophyll *a* throughout the James River, mirroring the trends identified in the Task 2.1 Section and the average flow-concentration statistical analysis presented in this section. Flow is negatively associated with

chlorophyll *a* concentrations at three locations (Appomattox-TF2, Chickahominy-OH, and Lower James-TF1), positively associated at three locations (Hampton Roads-PH, Lower James-MH, and Middle James Willis-TF2), and shows no apparent association at Lower James-OH. As discussed in the Task 2.1 Section this variability throughout the river is due to differences in channel geometry, residence time, pollutant inputs, water clarity, salinity, mixing, and other factors that vary along the length of the James River and its tributaries.

Contrary to what is observed for stream flow, the relationship between chlorophyll a concentrations and the examined nutrient constituents is consistent across locations. In general, increased concentrations of total nitrogen and total phosphorus are associated with increases in chlorophyll *a* concentrations. At the same time, bioavailable nutrients (NH_3, NO_3, and NO_2) generally decrease with increased chlorophyll *a* concentrations, suggesting algal uptake. Because the occurrence of algal blooms is influenced by a variety of factors, associating a critical time period for the entire tidal James River with just one variable (flow) is likely not justified (Malcolm Pirnie 2009a). As a result it is recommended that all eight three year periods in the 1991–2000 hydrologic period be evaluated to assess attainment of the chlorophyll *a* water quality standards. This is consistent with the 2010 EPA conclusion made for chlorophyll *a* critical conditions in the Chesapeake Bay (U.S. EPA 2010a).

Subtask 2.4 – Biological Reference Curve

Defining a chlorophyll biological reference curve for the James River is not as easy as developing such a curve for dissolved oxygen. For dissolved oxygen, one can consider the relationships between dissolved oxygen and benthic diversity and/or abundance, fish presence/absence, or fish and/or larval survival. While there have been some special studies in the James River and nearby Chesapeake Bay that show the effects of specific phytoplankton species on aquatic life (e.g., Glibert et al., 2007, Mulholland et al., 2009) and much information is available in the literature concerning *Microcystis aeruginosa*, a toxin- producing cyanobacteria species commonly found in the upper tidal freshwater James River, large data sets were not readily available with which to determine or classify the health of relevant species of interest in the James River estuary as they are influenced by chlorophyll-a. Therefore, at this point, we propose to utilize a combination of the Cumulative Frequency Distribution (CFD) approach, allowing approximately 10 percent "allowable" exceedance in time and space (Figure 65), recommended by the USEPA (2003, 2007) and empirical relationships between chlorophyll-a and the presence of HABS.

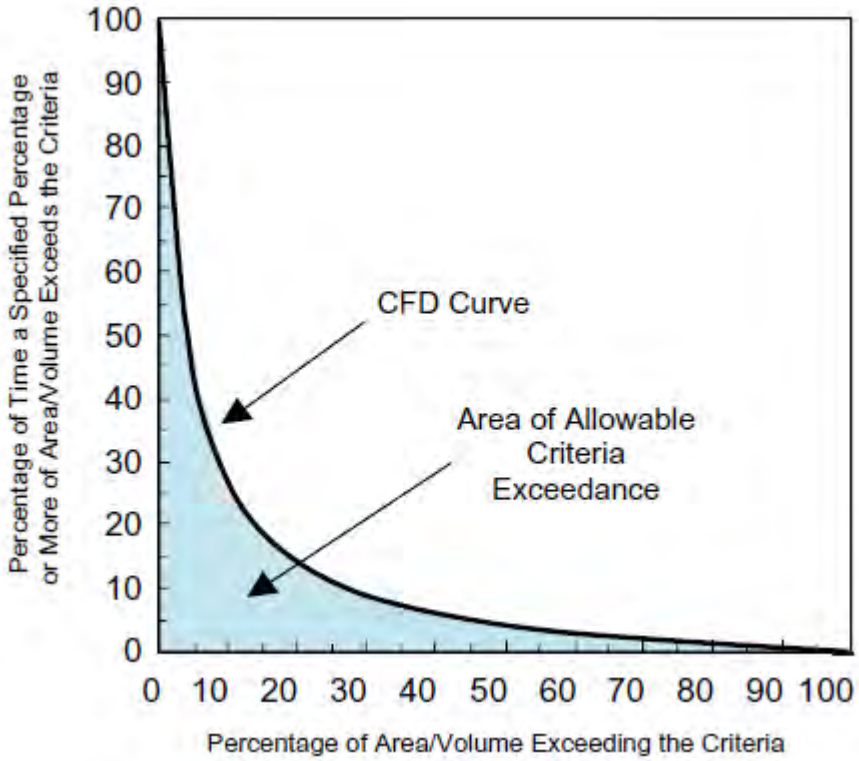


Figure 65 – Cumulative frequency distribution curve in the shape of a hyperbolic curve that represents approximately 10 percent allowable exceedances equally distributed between space and time.

The computational results from the deterministic water quality model can be used to develop the CFD curves, since the water quality model will have very high spatial (on the order of 500x500 meters) and temporal (daily) resolution.

We have performed a limited literature review of relevant data from Chesapeake Bay and its tidal tributaries, including the James River, as well as conducting our own preliminary data analyses, to look at relationships between chlorophyll-a and the occurrences of HABs. The analysis started in the upper freshwater portion of the James River, where blooms of the toxin producing cyanobacteria, *Microcystis aeruginosa*, are usually observed in mid- to late summer (Marshall et al., 2008, Wood et al., 2013). Analysis of data in the upper tidal freshwater James River by Bukaveckas (pers. comm.), indicated that as the levels of chlorophyll-a increased so did the likelihood of *M. aeruginosa* blooms (Figure 66).

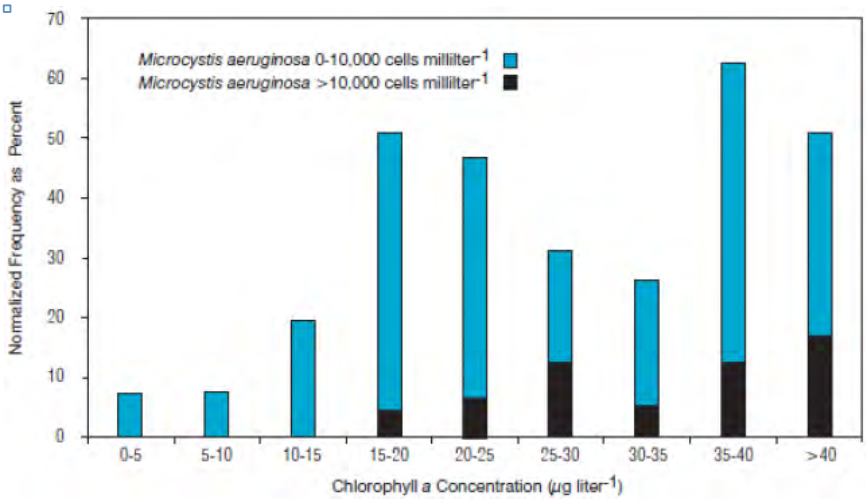


Figure 66 - Likelihood of the presence of Microcystis as a function of total chlorophyll-a

The analysis considered the likelihood of the presence of *M. aeruginosa* as a function not only of chlorophyll-a, but other environmental (freshwater inflow and temperature) and water quality variables as well (TN, TP, and the ratio of TN:TP). Data from the period between March and November were considered and were binned to see if the relationships would become clearer. Water quality data from stations TF5.4, TF5.5 and TF5.5A, the three stations that tend to show the highest chlorophyll-a concentrations, were grouped and the analysis conducted with *M. aeruginosa* cell count information from station TF5.5. As was observed by Bukaveckas et al. (pers. comm.) a strong relationship exists between *M. aeruginosa* cell count and chlorophyll-a (Figure 67). With increasing chlorophyll-a concentrations the frequency of occurrence of *M. aeruginosa* increases, such that for concentrations of chlorophyll-a above 35 ug/L, *M. aeruginosa* are observed in greater than 70% of the samples.

M. aeruginosa cell counts are also strongly correlated to the concentration of TN (Figure 68), with the frequency of observation of *M. aeruginosa* increasing with increases in TN. In fact, for concentrations of TN greater than 1.75 mg N/L, the frequency of *M. aeruginosa* observations was 100 percent, and 50 percent of the time the cell counts were greater than 10,000 cells/ML. There is a mixed signal on the correlation of *M. aeruginosa* and TP (Figure 69). The data suggest that the highest frequency of observations of *M. aeruginosa* (35-65%) occurs in the mid-range of TP concentrations of greater than 0.10 mg P/L and less than 0.175 mg/L. There did not seem to be a strong correlation between the frequency of occurrence of *M. aeruginosa* and the ratio of TN:TP (Figure 70).

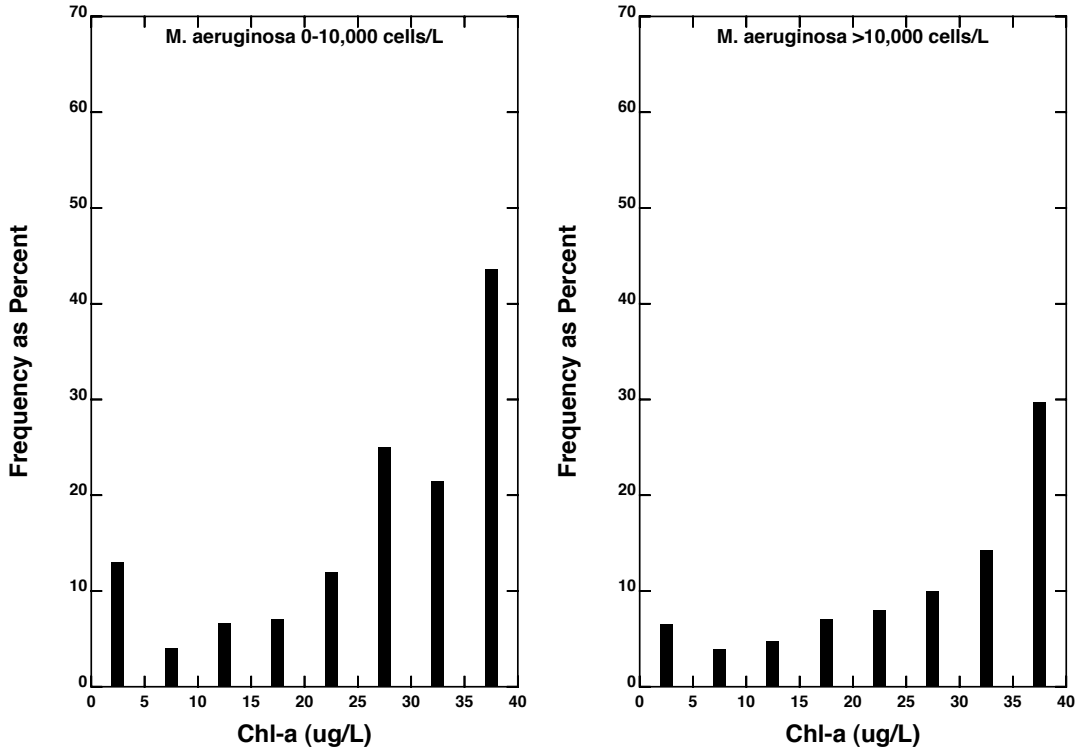


Figure 67 – Frequency (as a percent) of the occurrence of Mycrocystis aeruginosa as a function of Chlorophyll-a for stations TF5.4, TF5.5, and TF5.5A.

Generally, there was a good correlation between water temperature and *M. aeruginosa* cell counts, with the exception of some anomalous data at water temperatures below 4° C (Figure 71). Generally, the frequency of occurrence of *M. aeruginosa* increased with increasing temperature. However, the greatest increases in frequency of occurrence were within the 0-10,000 cells/mL range, rather than the greater than 10,000 cells/mL range. It is possible that the unusual observations of *M. aeruginosa* at temperatures less than 4° C might be related to resuspension of *M. aeruginosa* cells from the sediment bed during high flow events in the late winter and early spring. The correlation between *M. aeruginosa* cell counts and the 10-day averaged flow was marginal

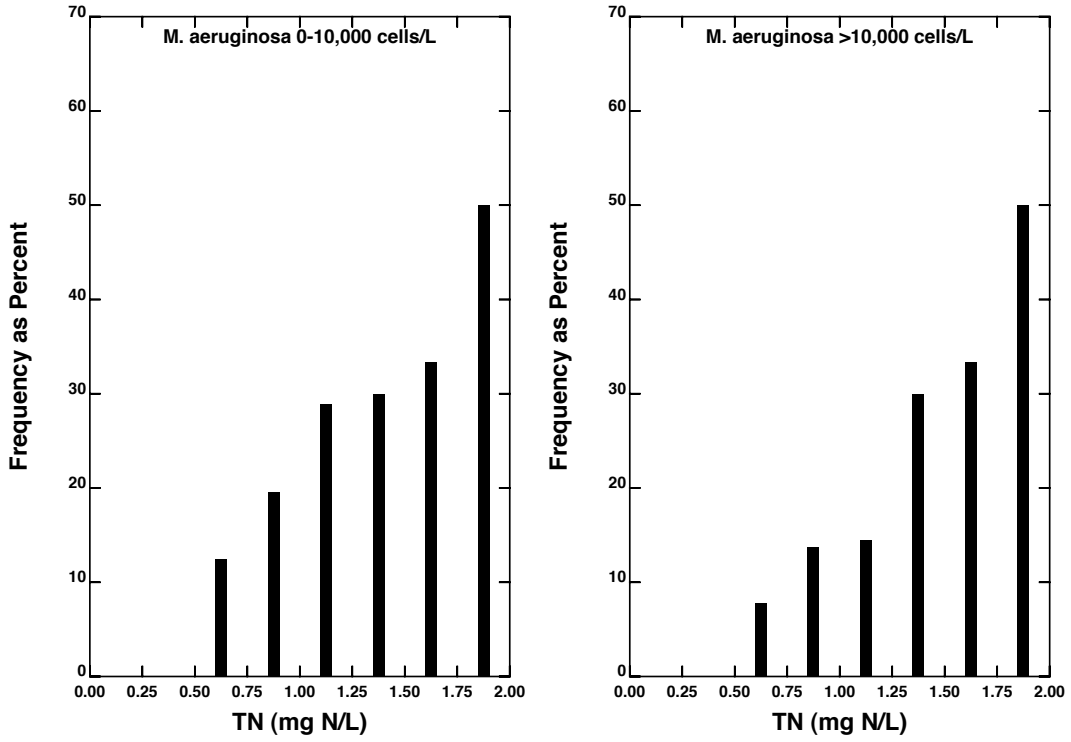


Figure 68 – Frequency (as a percent) of the occurrence of Mycrocystis aeruginosa as a function of TN for stations TF5.4, TF5.5, and TF5.5A.

(Figure 72). There appeared to be a correlation between cell counts greater than 10,000 cells/mL and flow, with the percentage of samples greater than 10,000 cells/mL decreasing from about 20% at flows less than 8,000 cfs to less than 10% at flows above 10,000 cfs. It appears then that the best chance for developing a biological reference curve for the upper tidal freshwater portion of the James River could be based on a correlation between *M. aeruginosa* and chlorophyll-a, perhaps in conjunction with TN.

As reported in the Chesapeake Bay criteria document (USEPA, 2003), based on laboratory analyses (Wickfors and Smolowitz 1995; Luckenbach et al. 1993 a threshold density of 3,000 cells/mL for *Prorocentrum minimum* was shown to have effects on larval growth, poor development of the digestive system and development into pedi-veligers and new set spat of the Eastern oyster (*Crassostrea* virginica). The USEPA analysis found that chlorophyll-a concentrations greater than 5 ug/L could generate bloom densities (>3,000 cells/mL densities) that might impair oyster larvae and that the likelihood of bloom level events tended to increase with increasing chlorophyll-a levels (Figure 73).

Recently, Todd Egerton and Harold Marshall (pers. comm.) presented some 2012 data from the lower James and the Elizabeth and Lafayette Rivers that indicated potential relationships between HAB (*Cochlodinium polykrikoides and Heterocapsa triquetra*) biomass and chlorophyll-a (Figure 74). As more data become available it is likely that we will be able to develop strong empirical relationships between HABs (both freshwater and marine) that can be used in conjunction with the deterministic water quality model and the CFD approach to provide VADEQ with a tool with which to guide the development of new chlorophyll-a criteria.

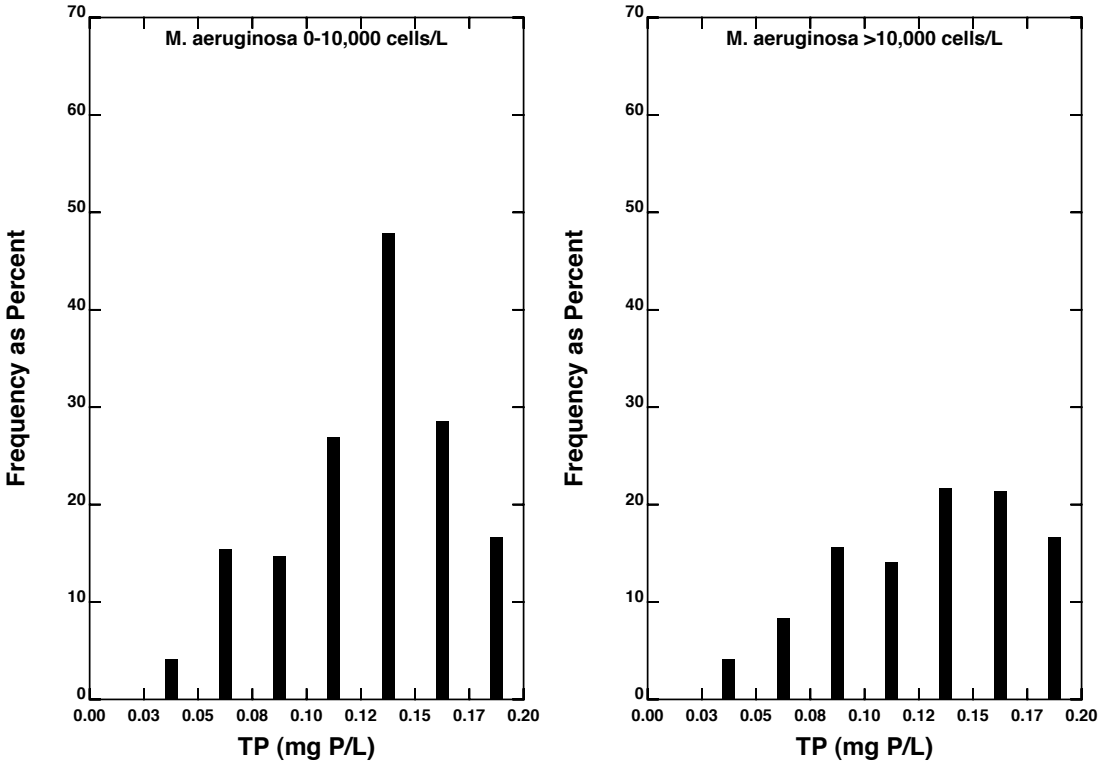


Figure 68. Frequency (as a Percent) of the Occurrence of Microcystis-aeruginosa as a Function of TP for Stations TF5.4, TF5.5 and TF5.5A

Figure 69 – Frequency (as a percent) of the occurrence of Mycrocystis aeruginosa as a function of TP for stations TF5.4, TF5.5, and TF5.5A.

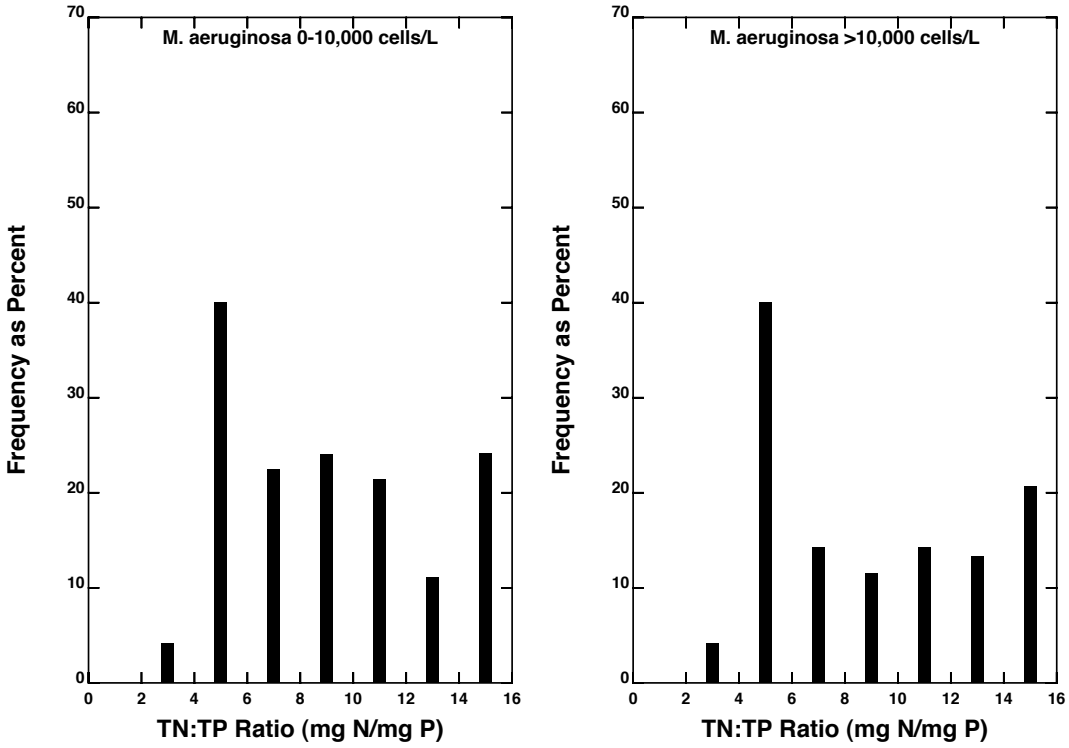


Figure 69. Frequency (as a Percent) of the Occurrence of Microcystis-aeruginosa as a Function of the Ratio of TN:TP for Stations TF5.4, TF5.5 and TF5.5A

Figure 70 – Frequency (as a percent) of the occurrence of Mycrocystis aeruginosa as a function of the ratio TN:TP for stations TF5.4, TF5.5, and TF5.5A.

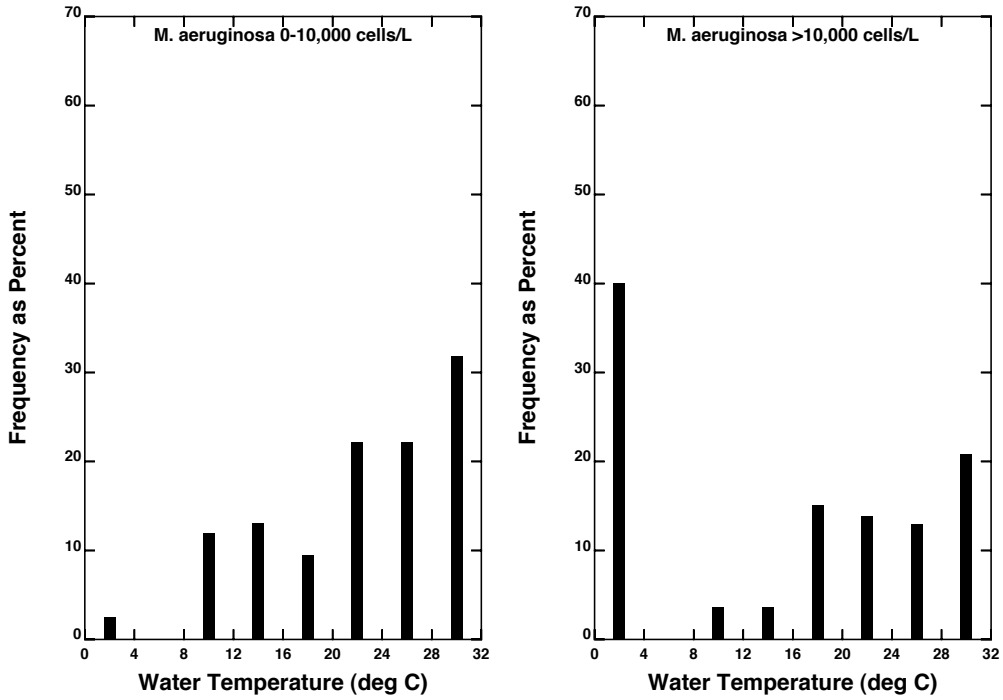


Figure 70. Frequency (as a Percent) of the Occurrence of Microcystis-aeruginosa as a Function of Water Temperature for Stations TF5.4, TF5.5 and TF5.5A

Figure 71 – Frequency (as a percent) of the occurrence of Mycrocystis aeruginosa as a function of water temperature for stations TF5.4, TF5.5, and TF5.5A.

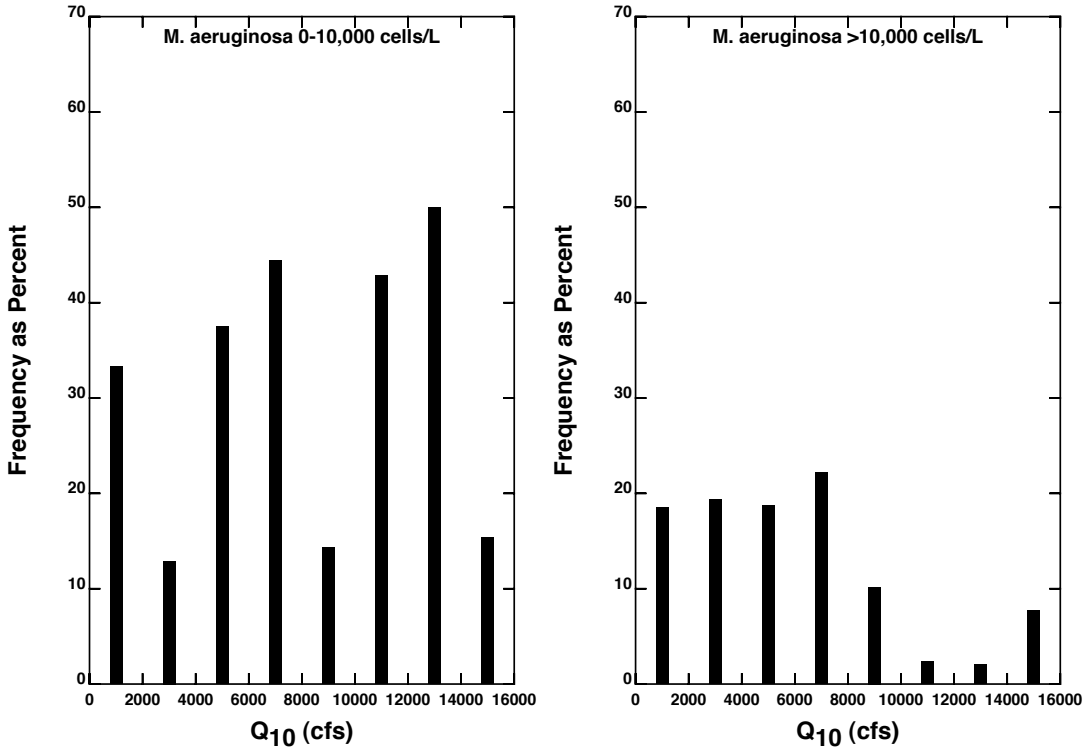


Figure 71. Frequency (as a Percent) of the Occurrence of Microcystis-aeruginosa as a Function of 10-day Averaged Freshwater Flow (Q10) for Stations TF5.4, TF5.5 and TF5.5A

Figure 72 – Frequency (as a percent) of the occurrence of Mycrocystis aeruginosa as a function of 10-day averaged freshwater flow (Q10) for stations TF5.4, TF5.5, and TF5.5A.

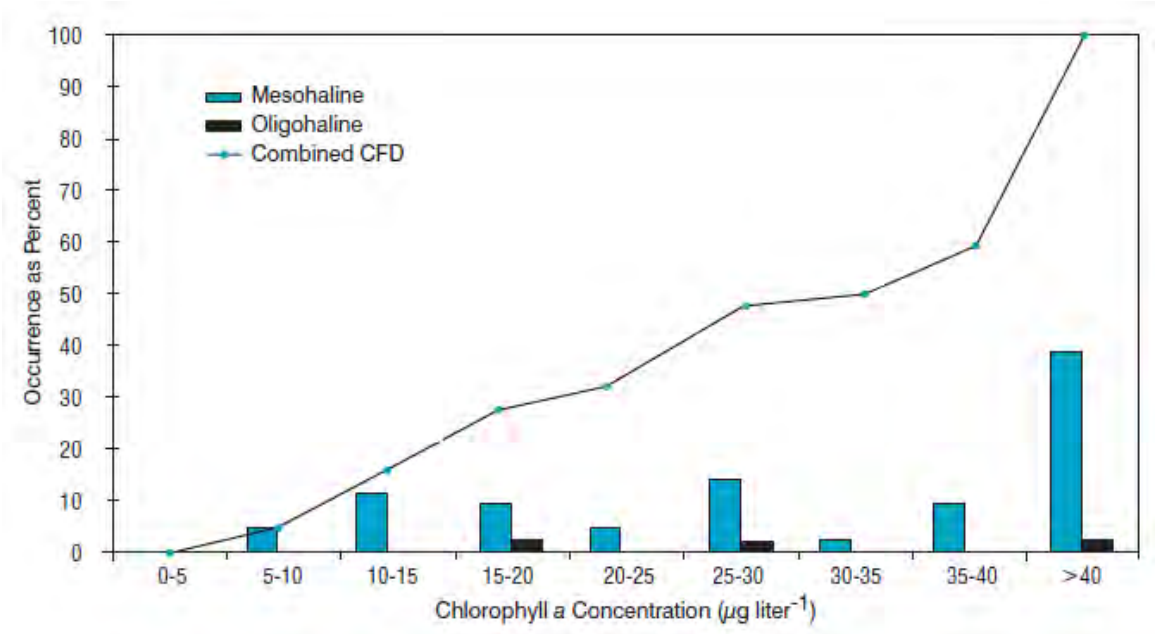


Figure 73 – Occurrences of P. minimum abundances above the 3,000 cells/mL threshold as a function of chlorophyll-a. (USEPA, 2003)

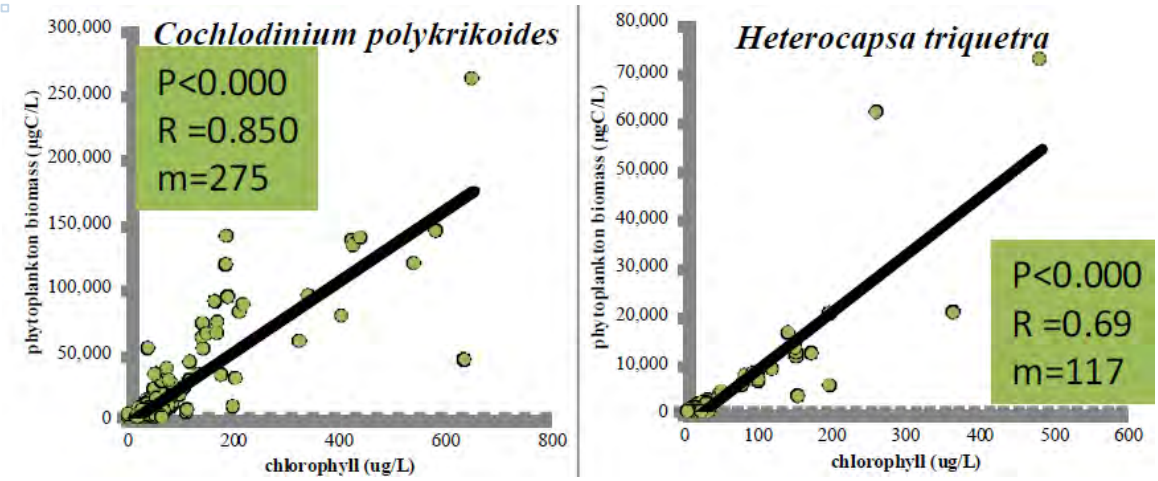


Figure 74 – Relationships between C. polykrikoides biomass and chlorophyll-a and between H. triquetra biomass and chlorophyll-a for the lower James River and the Elizabeth and Lafayette Rivers

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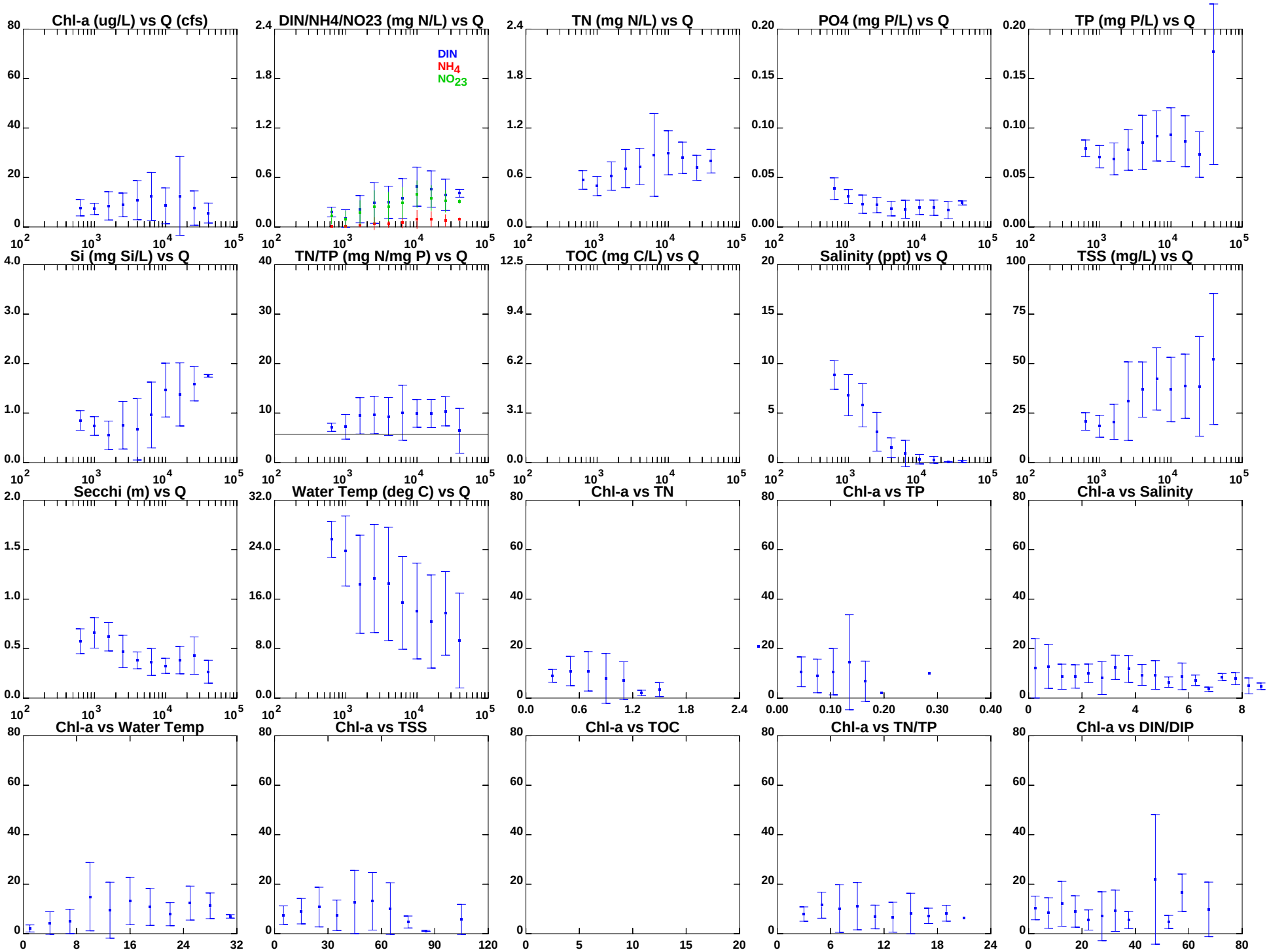
Appendix A:

Additional Long-term Water Quality Data Analysis



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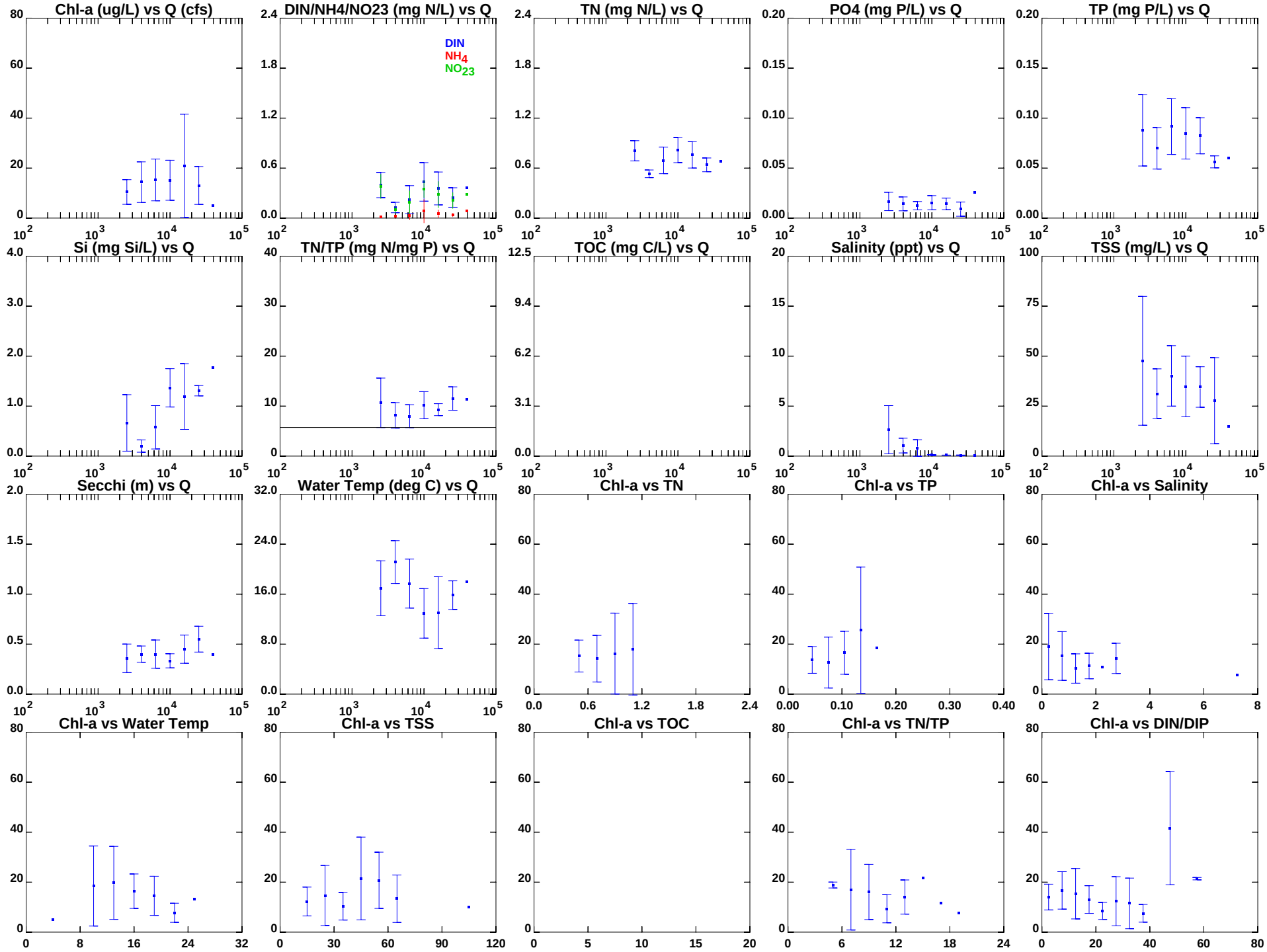

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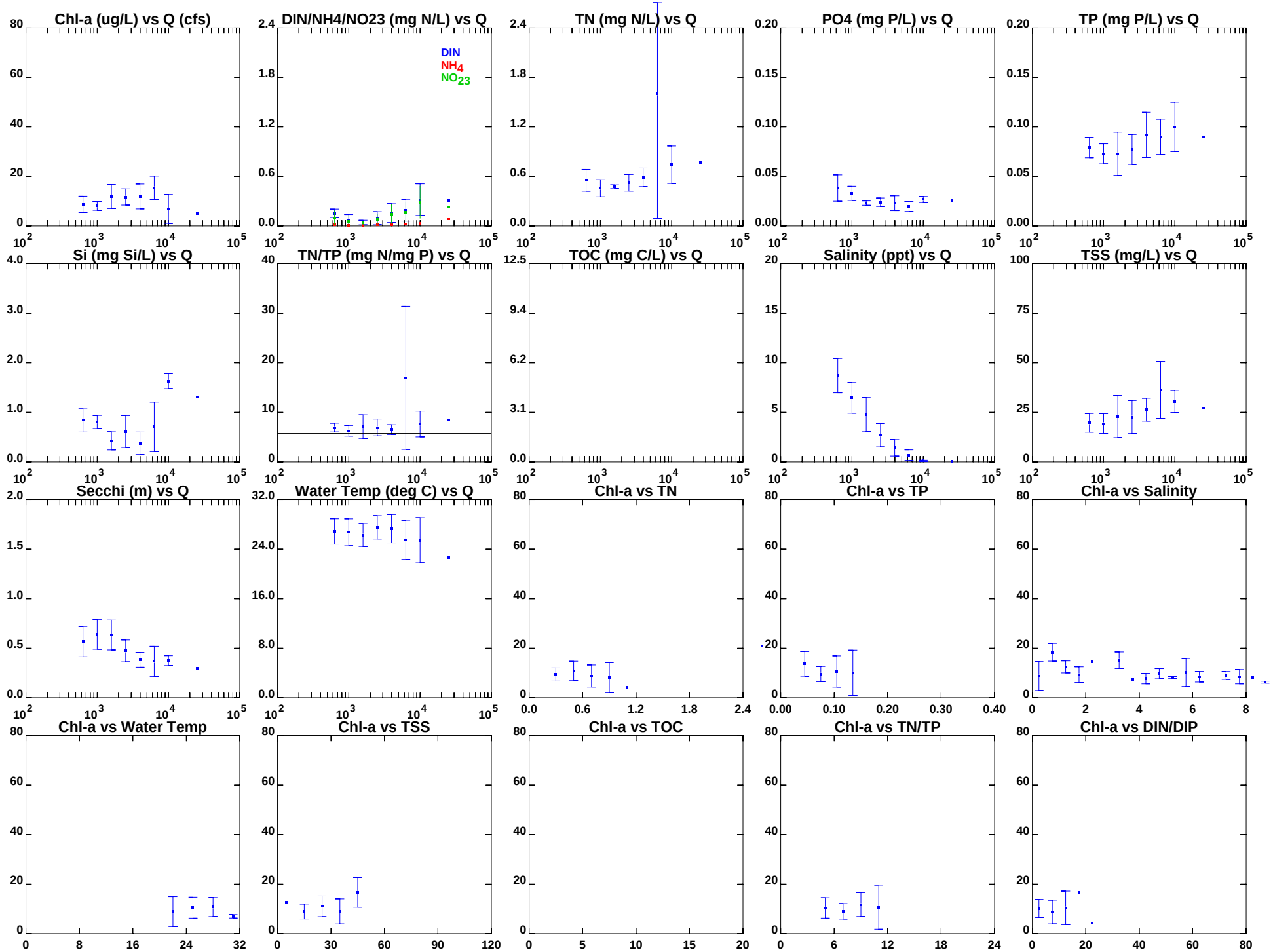

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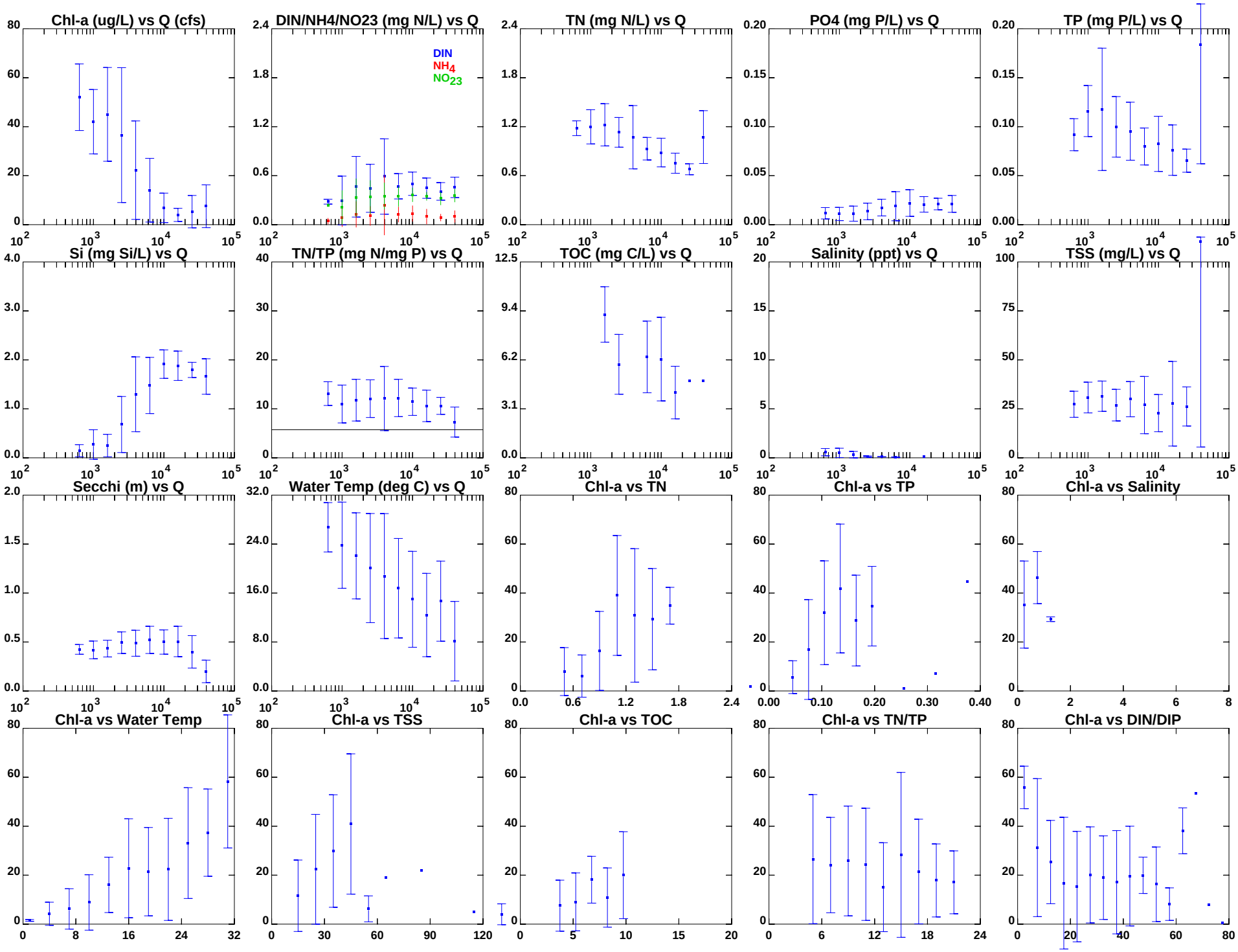

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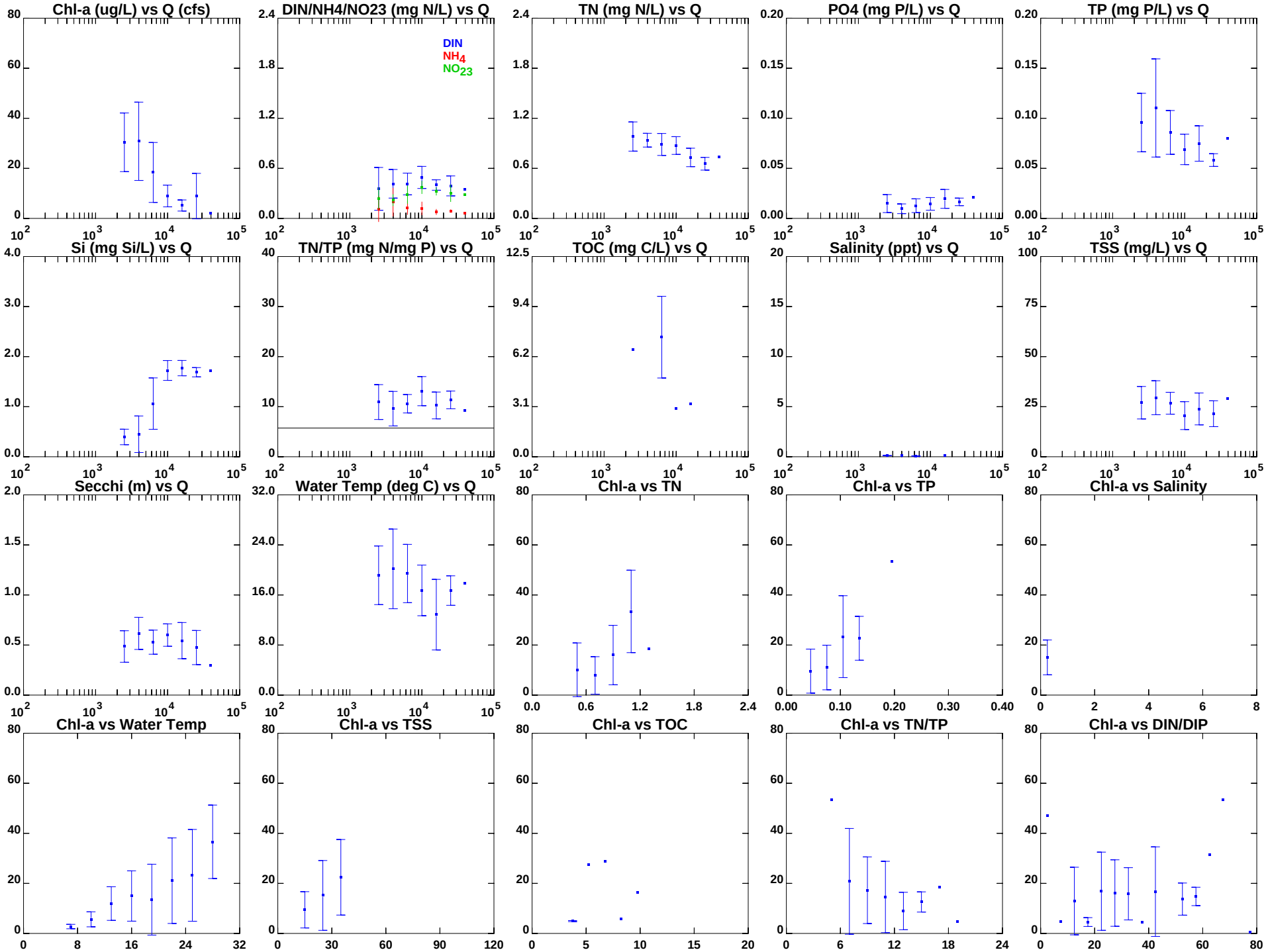

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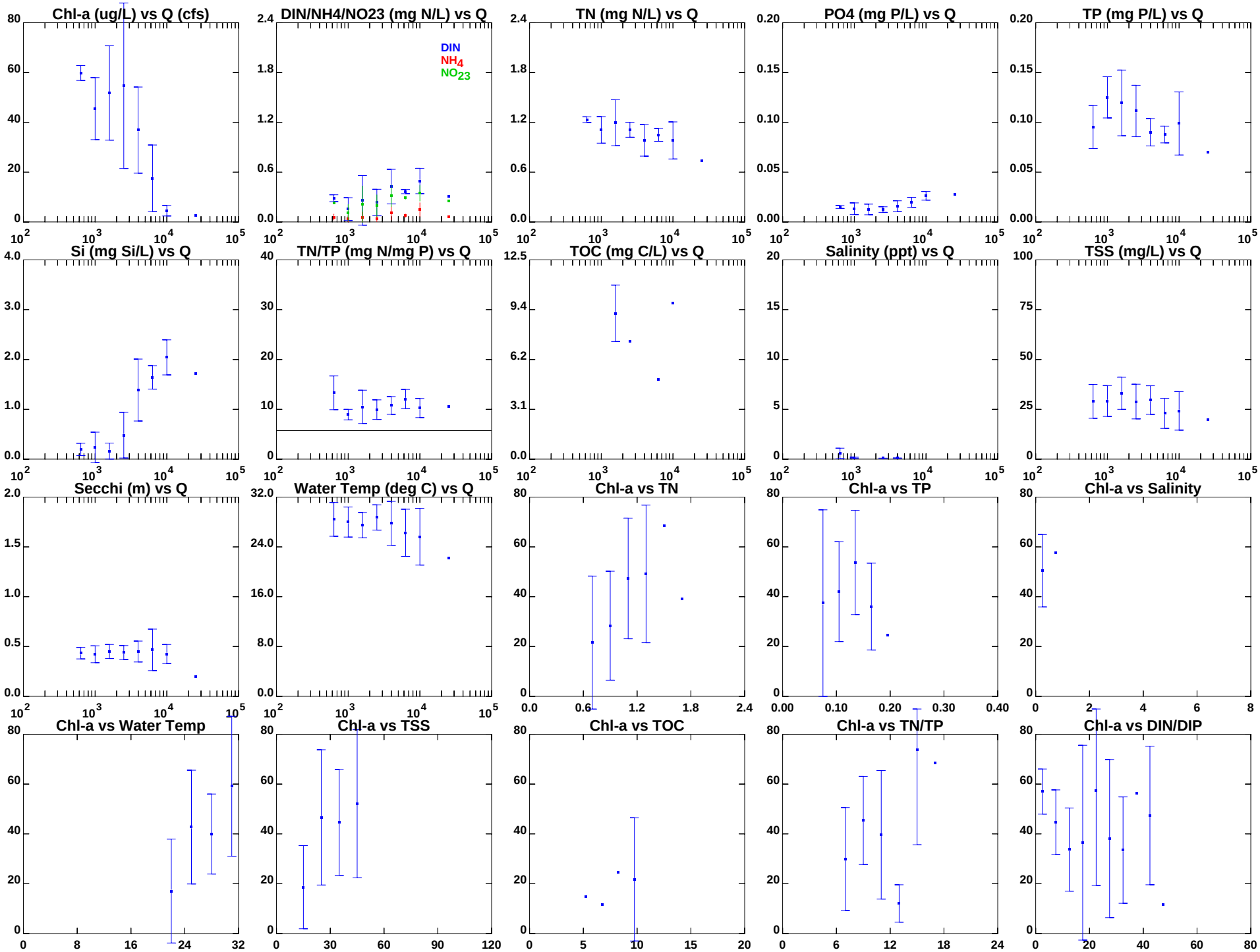

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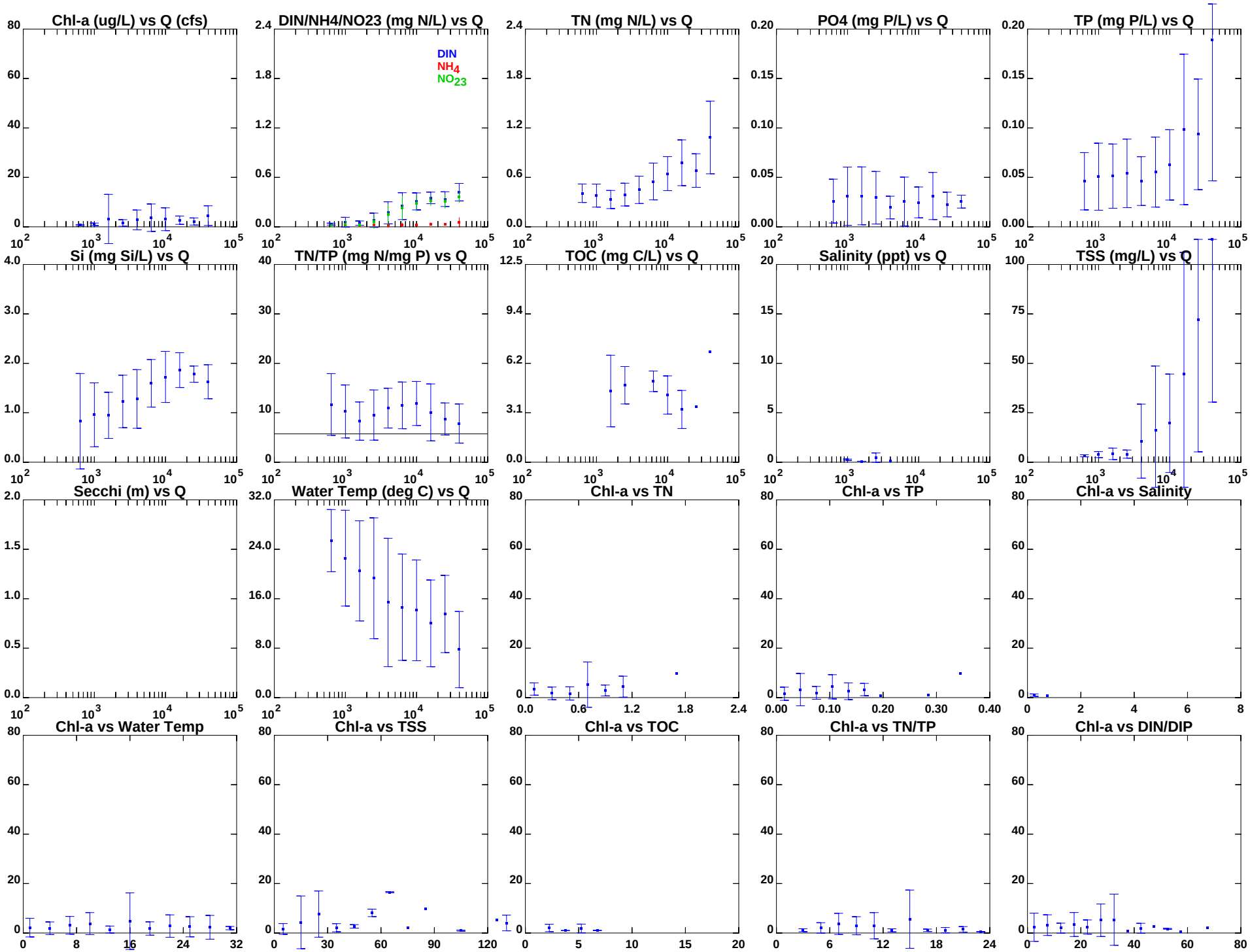

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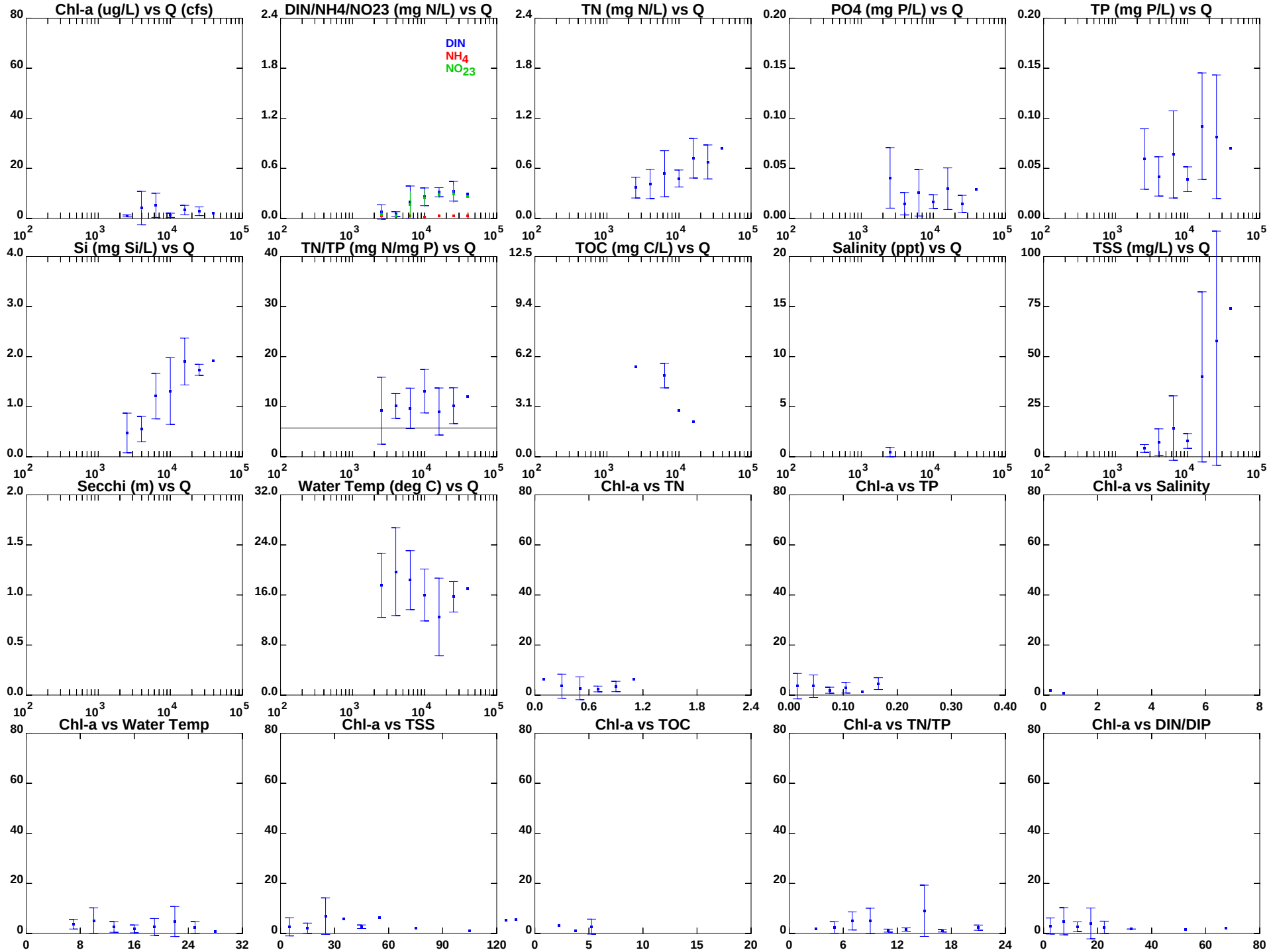

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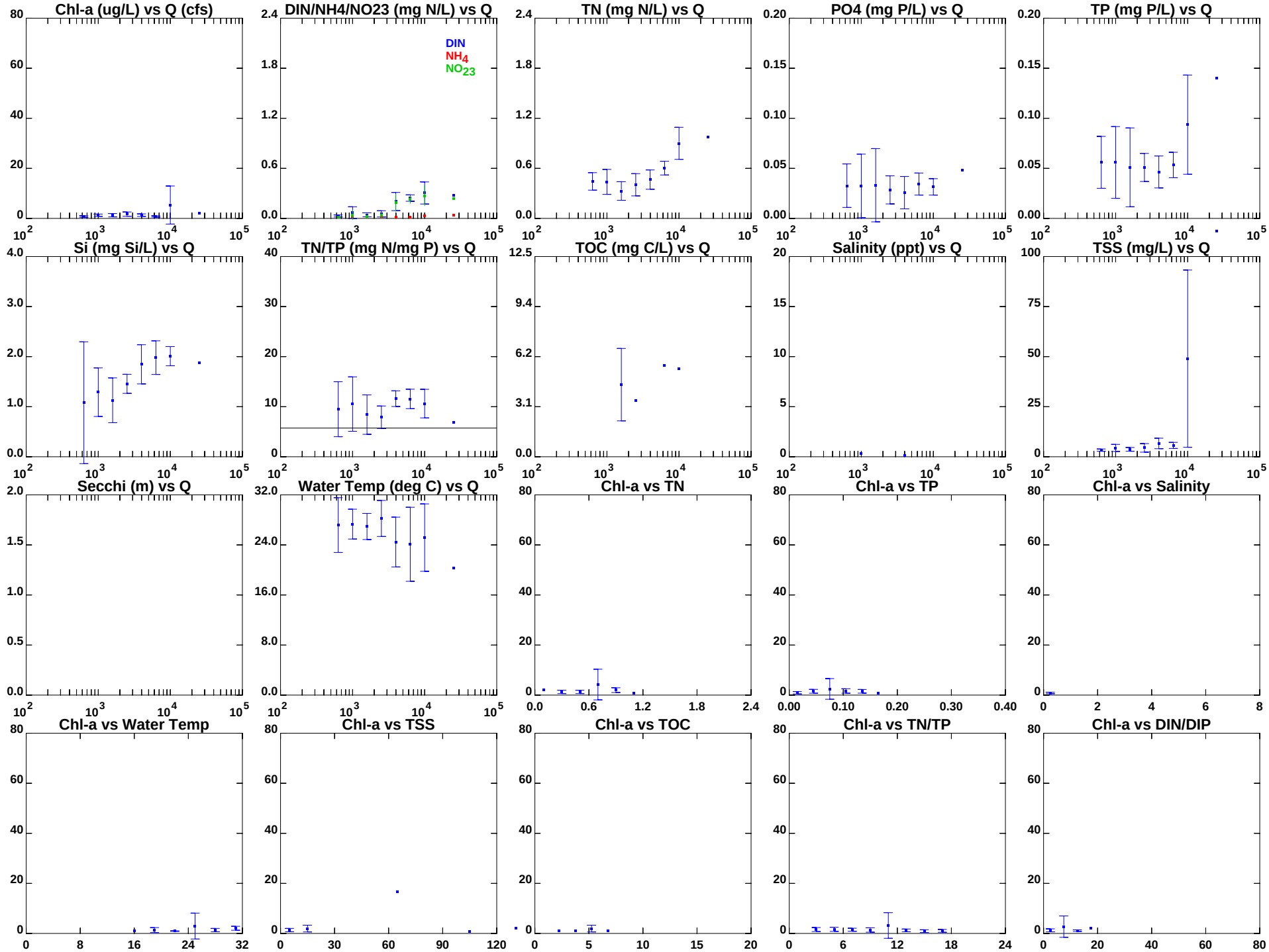

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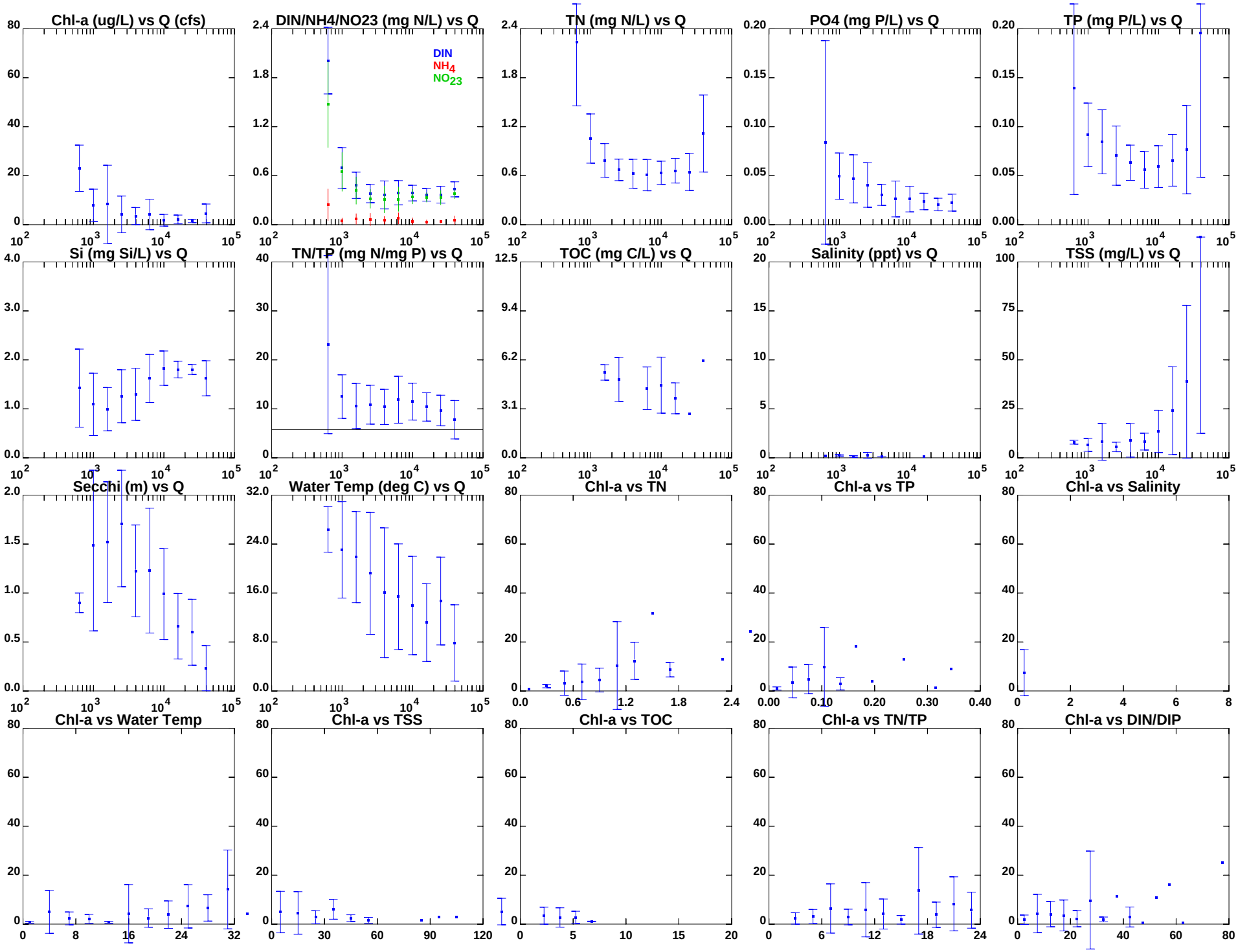

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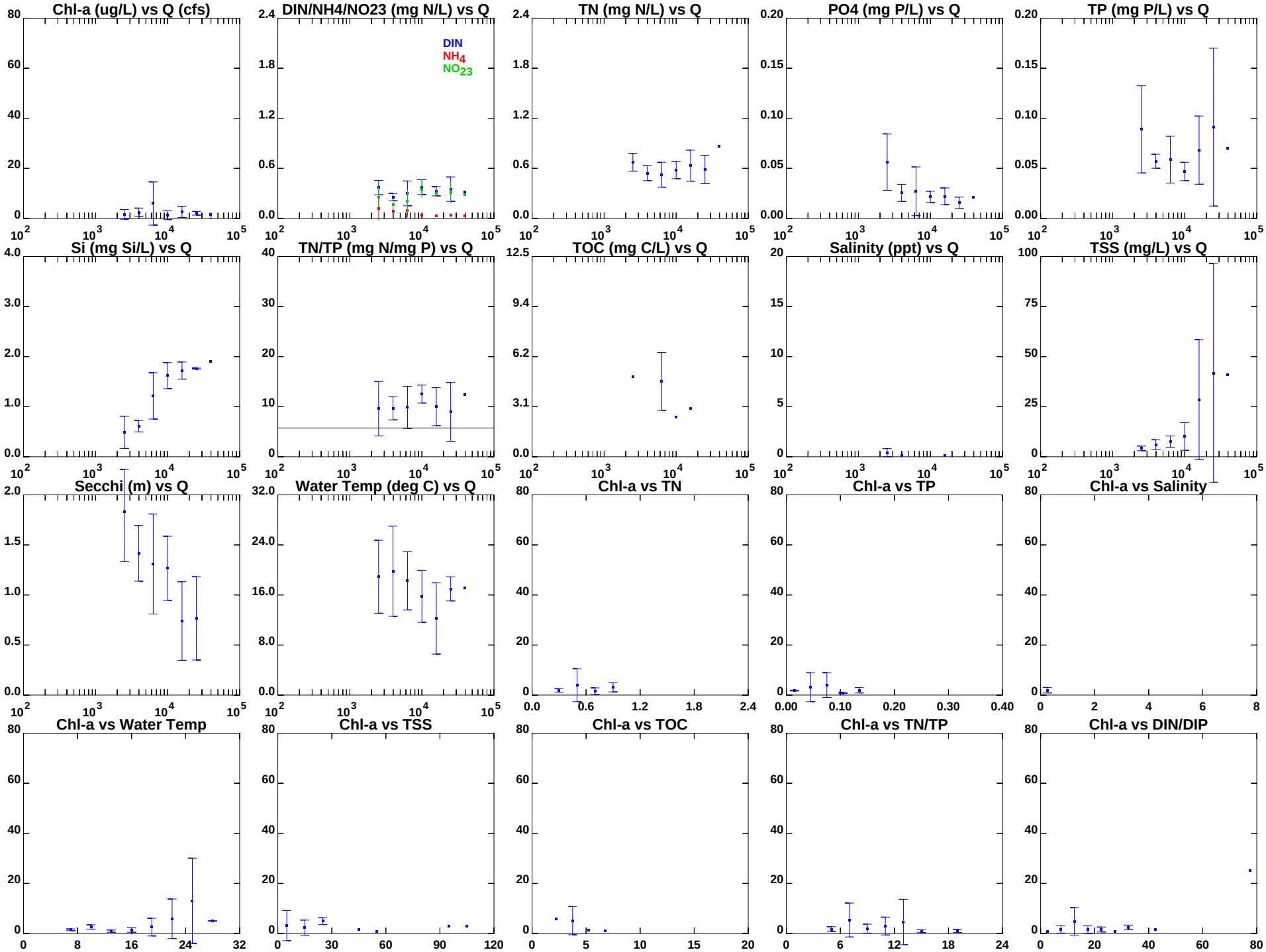

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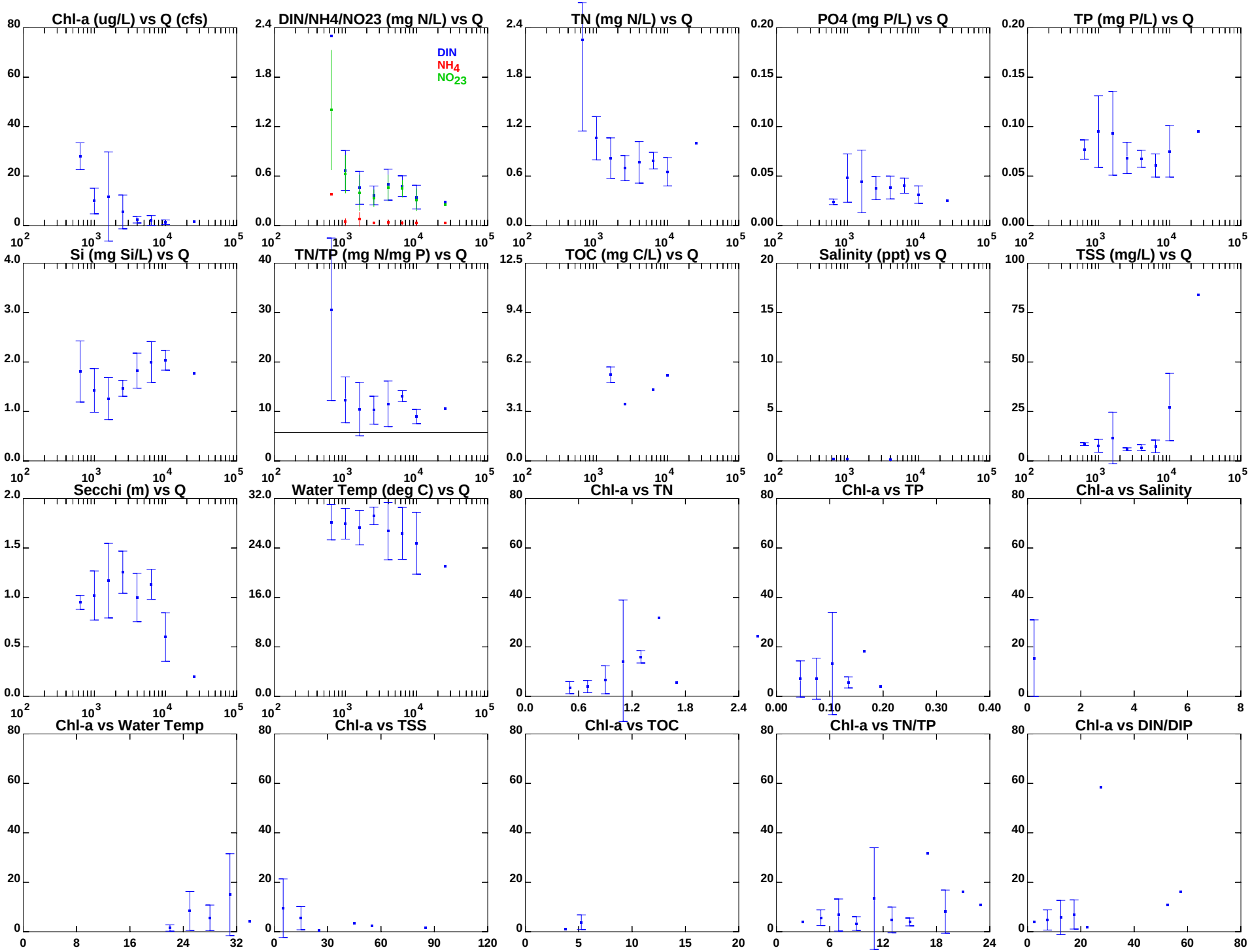

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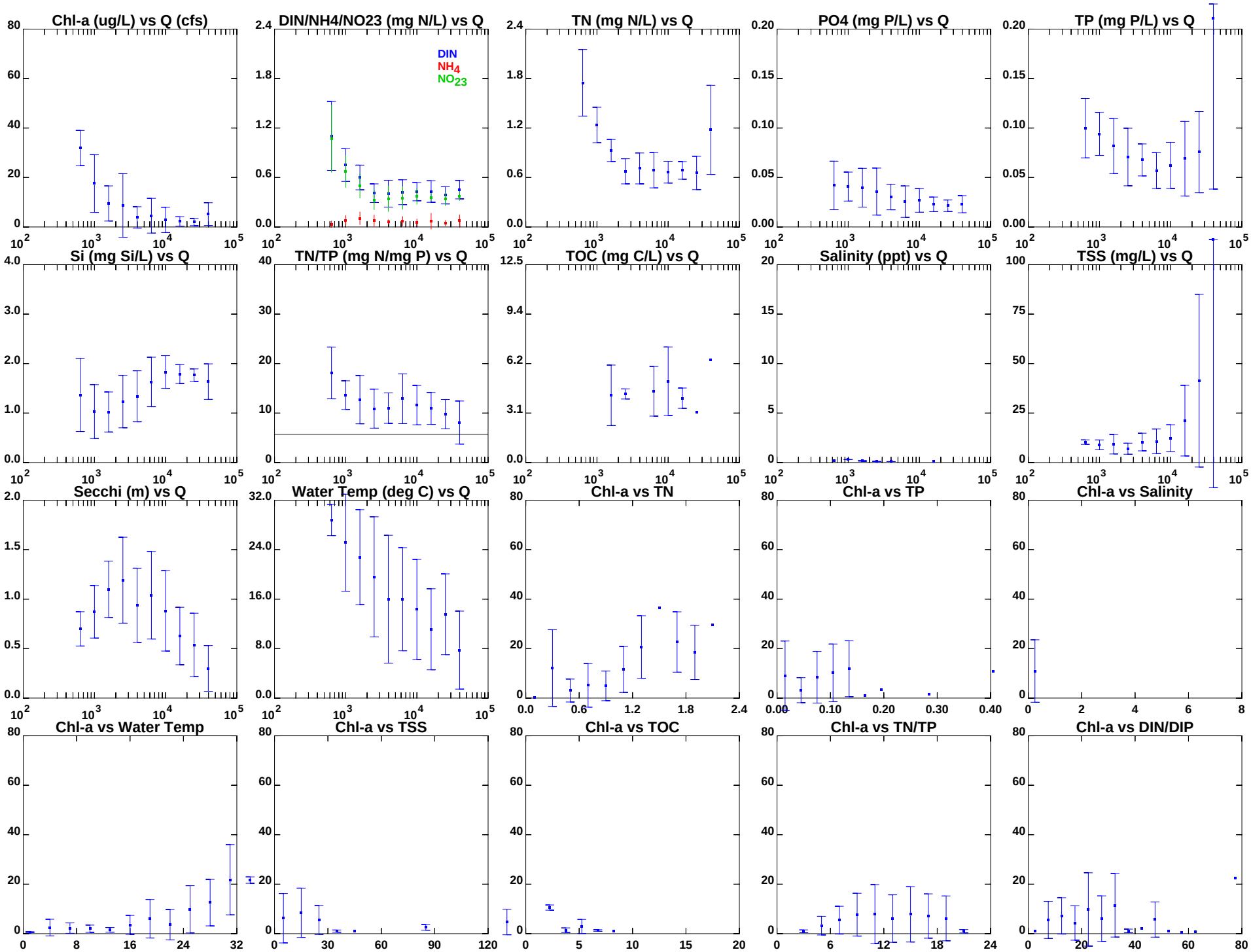

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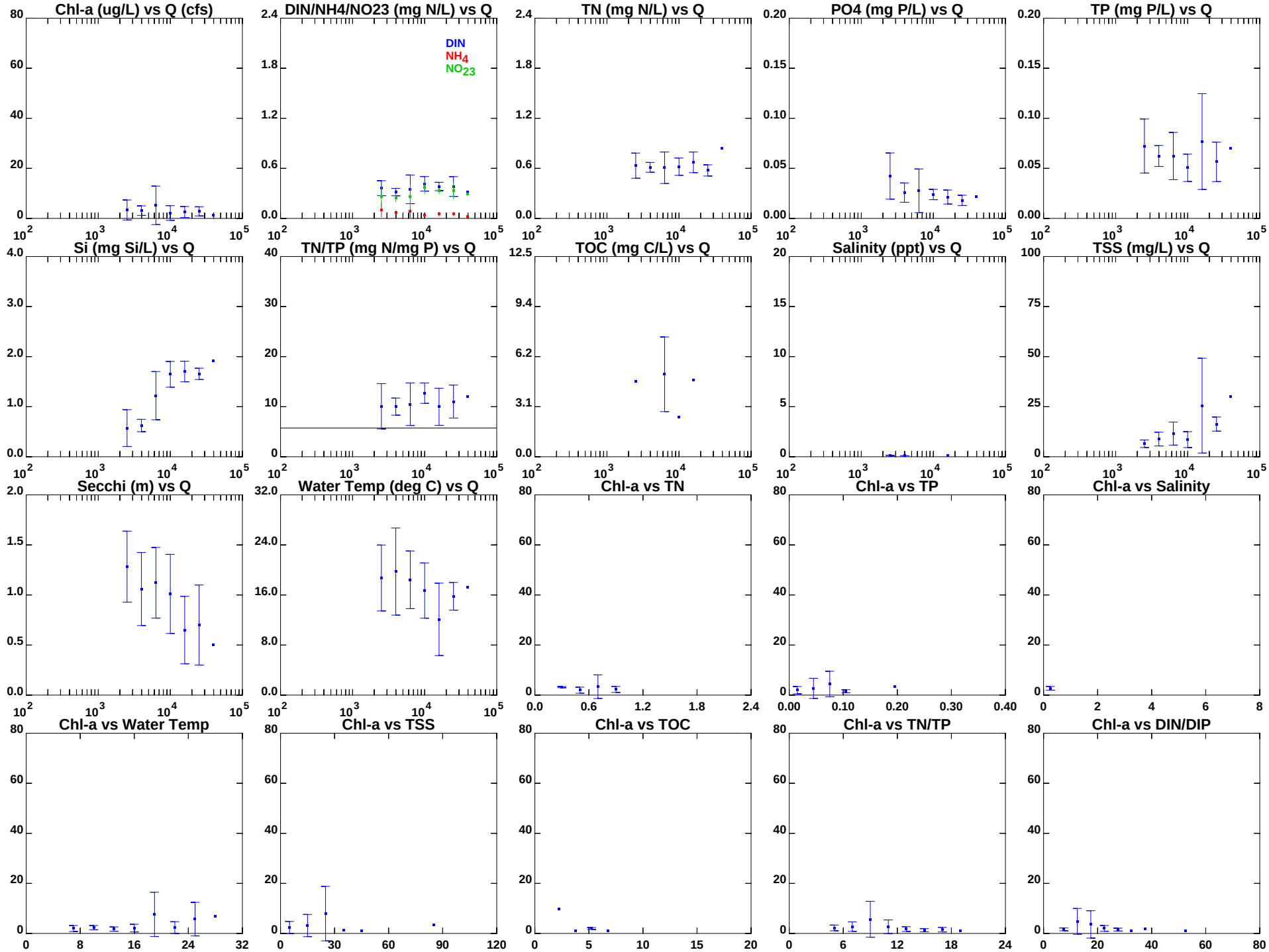

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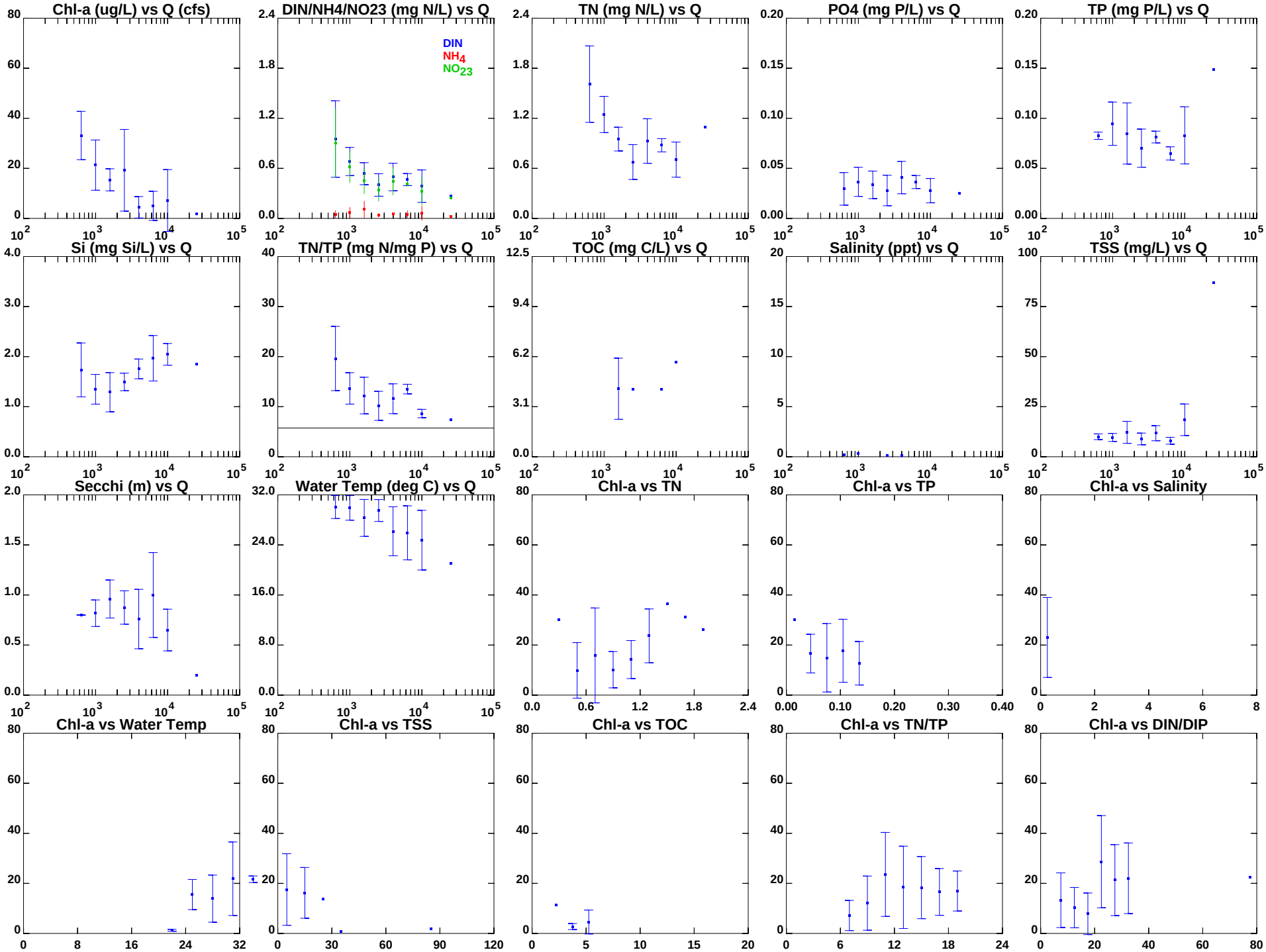

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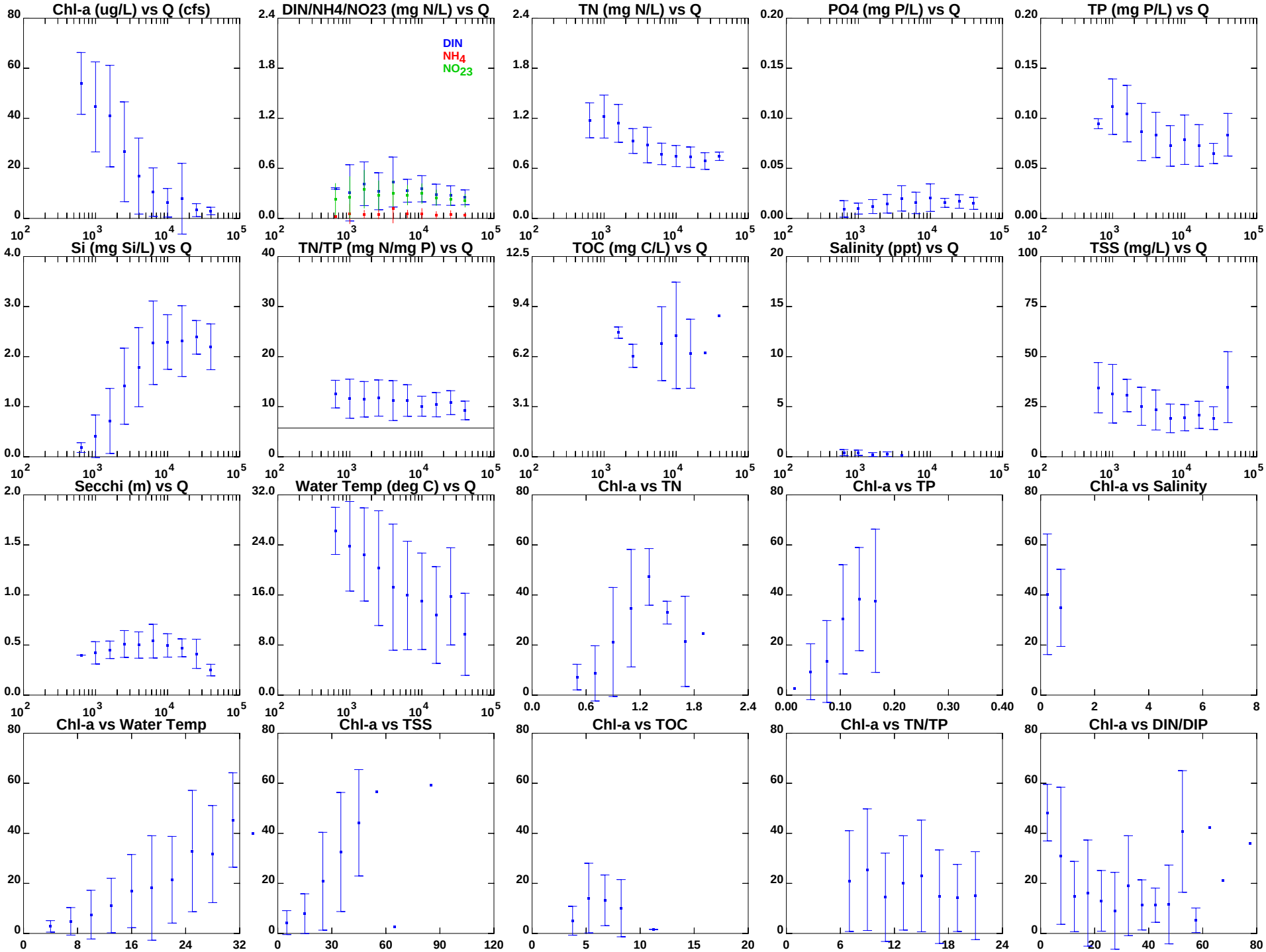

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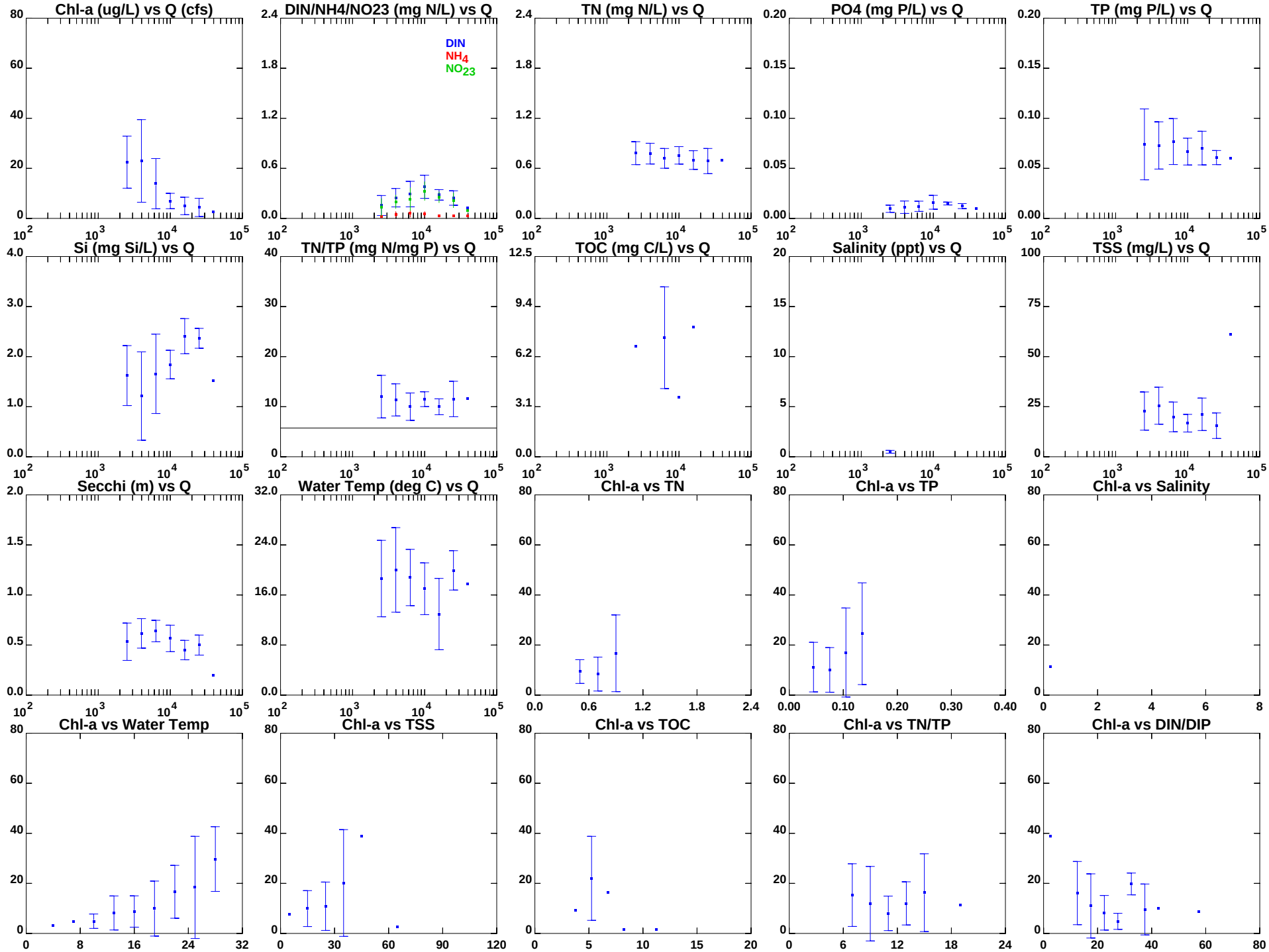

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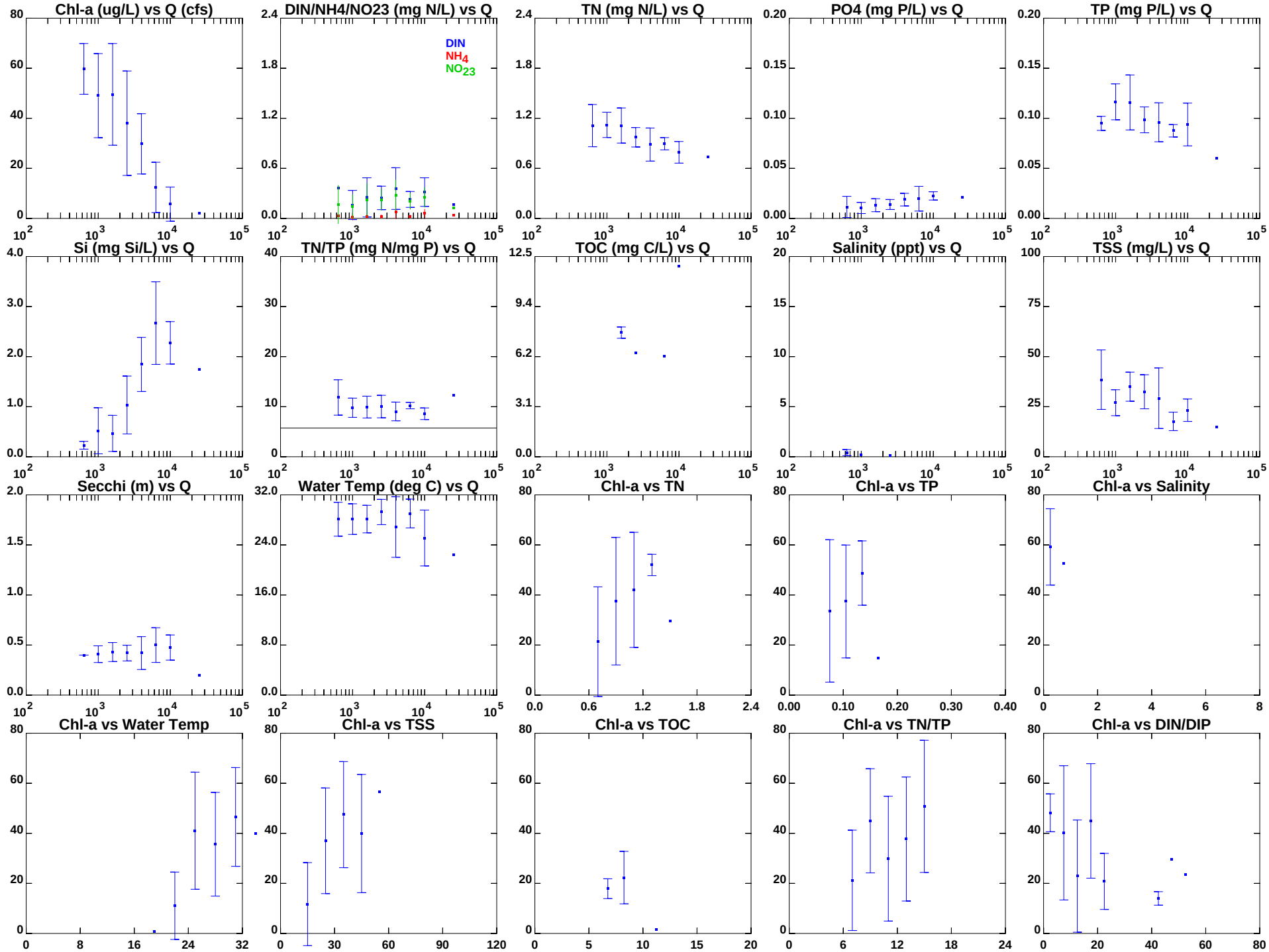

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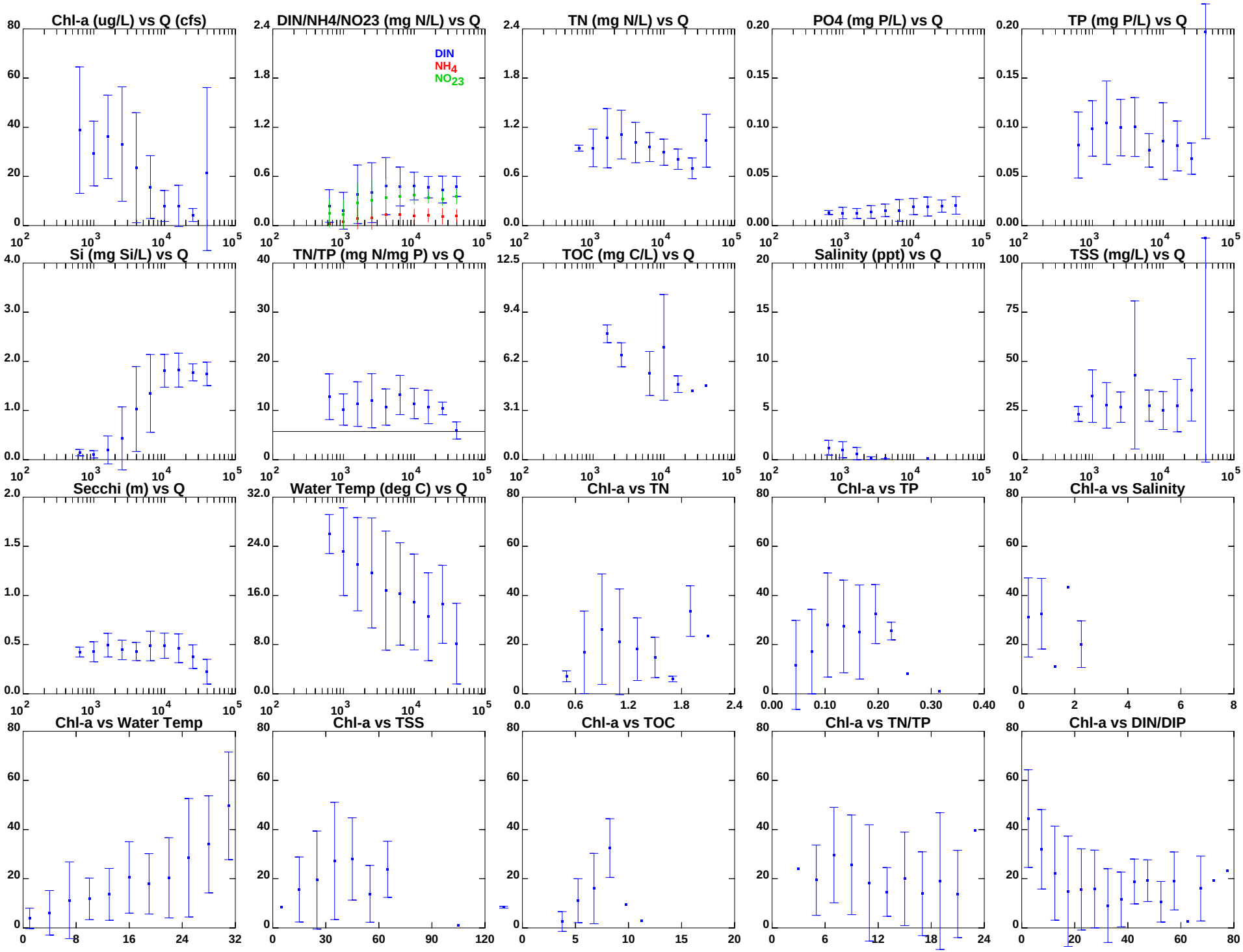

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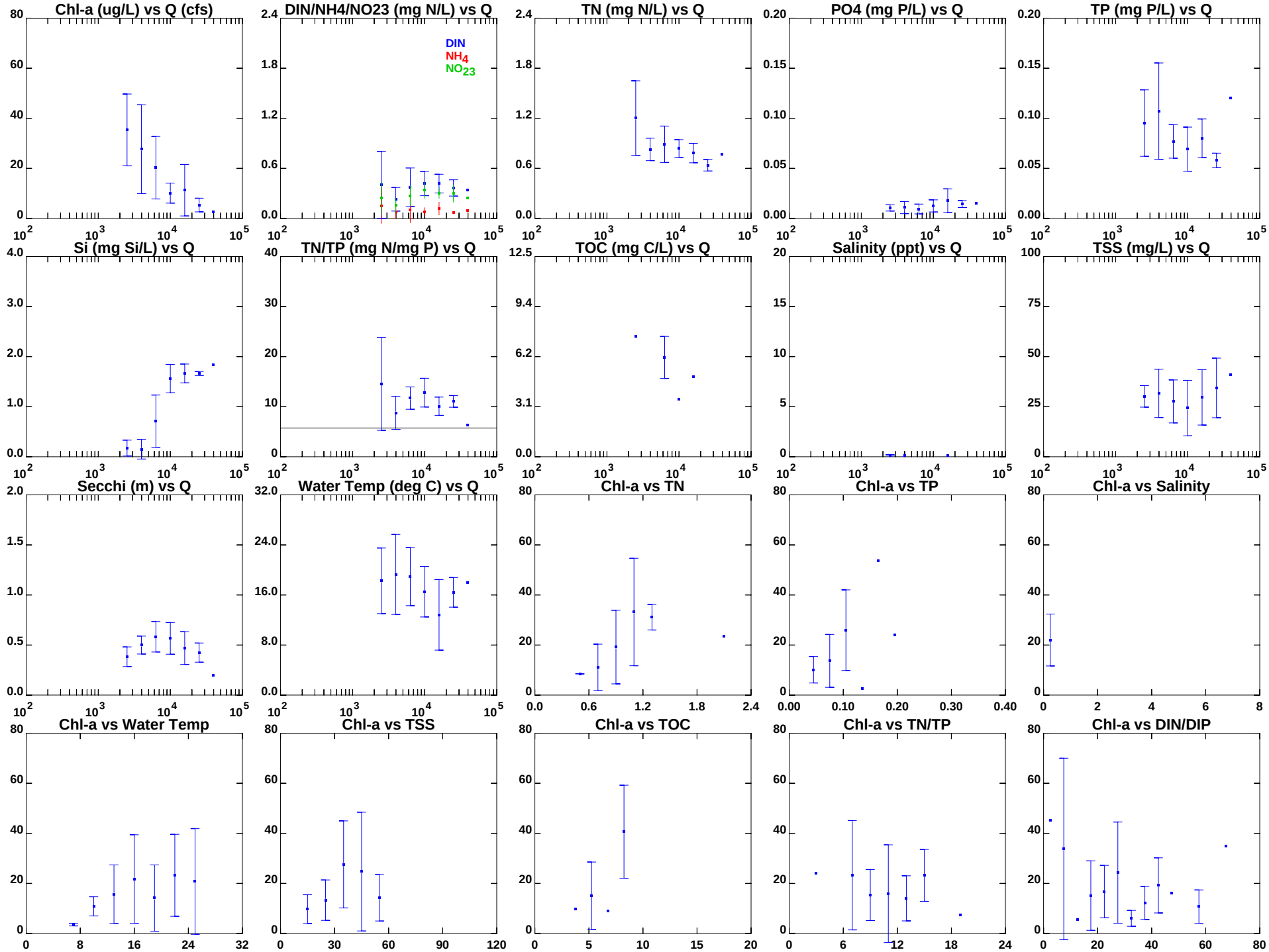

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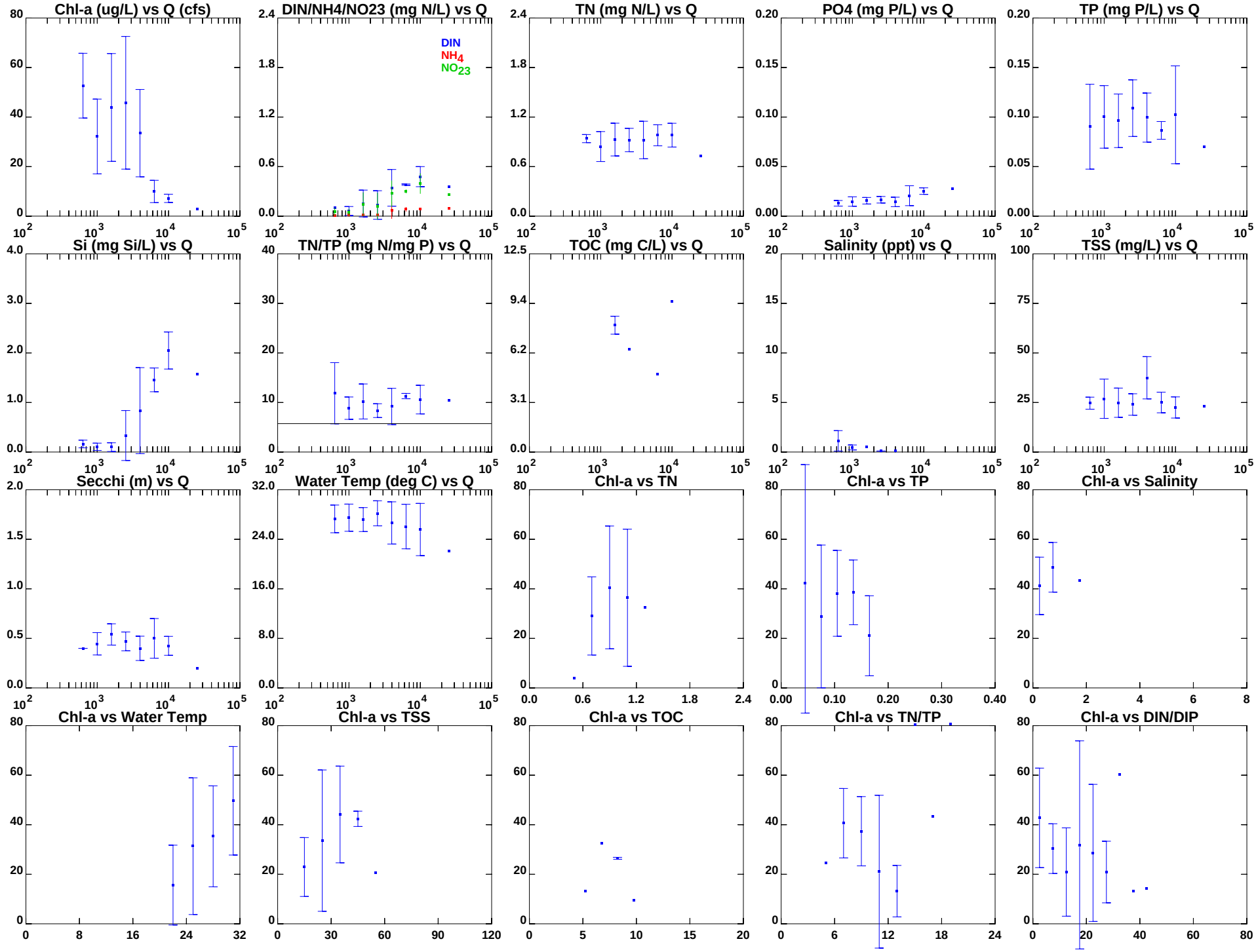

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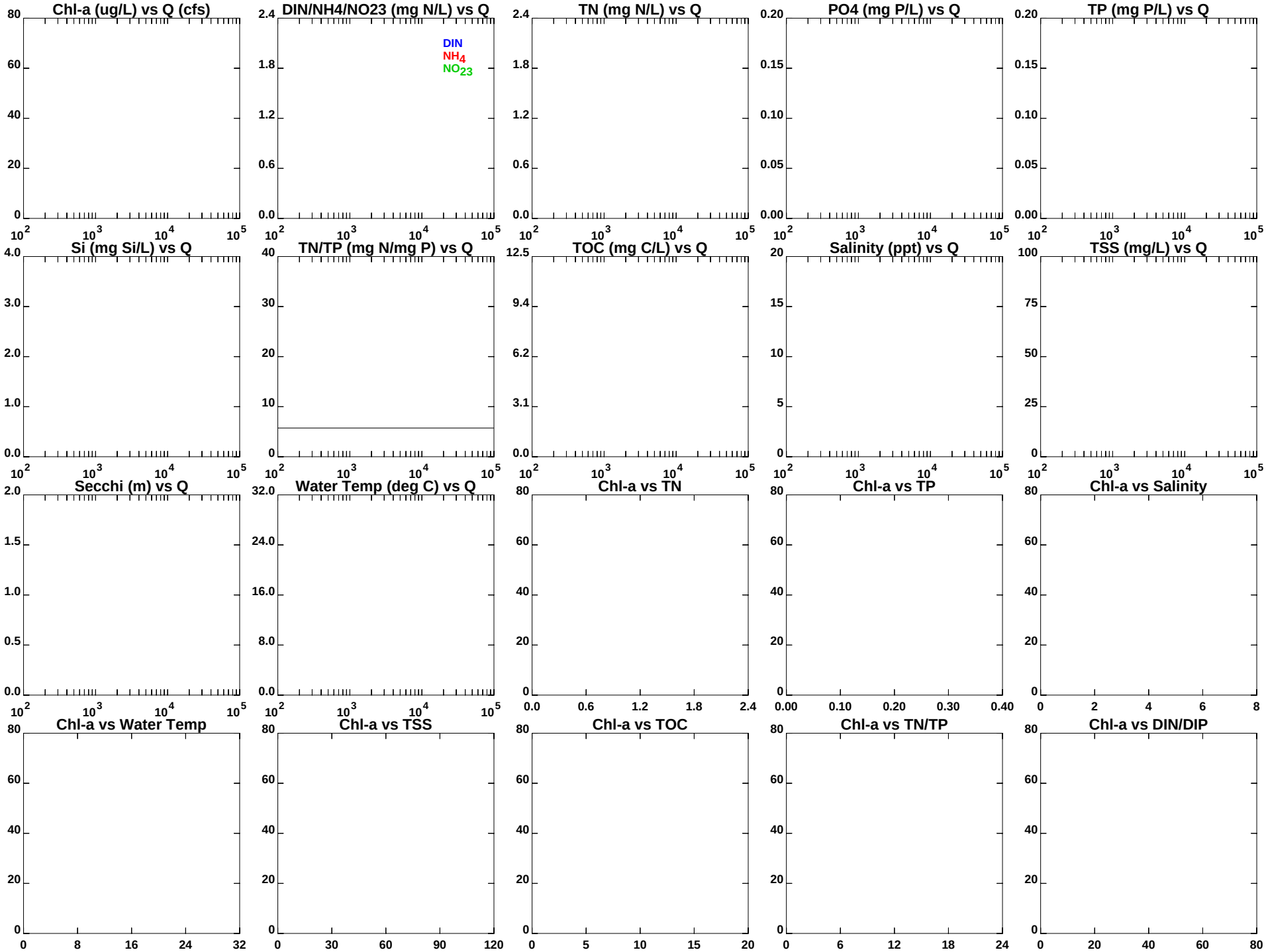

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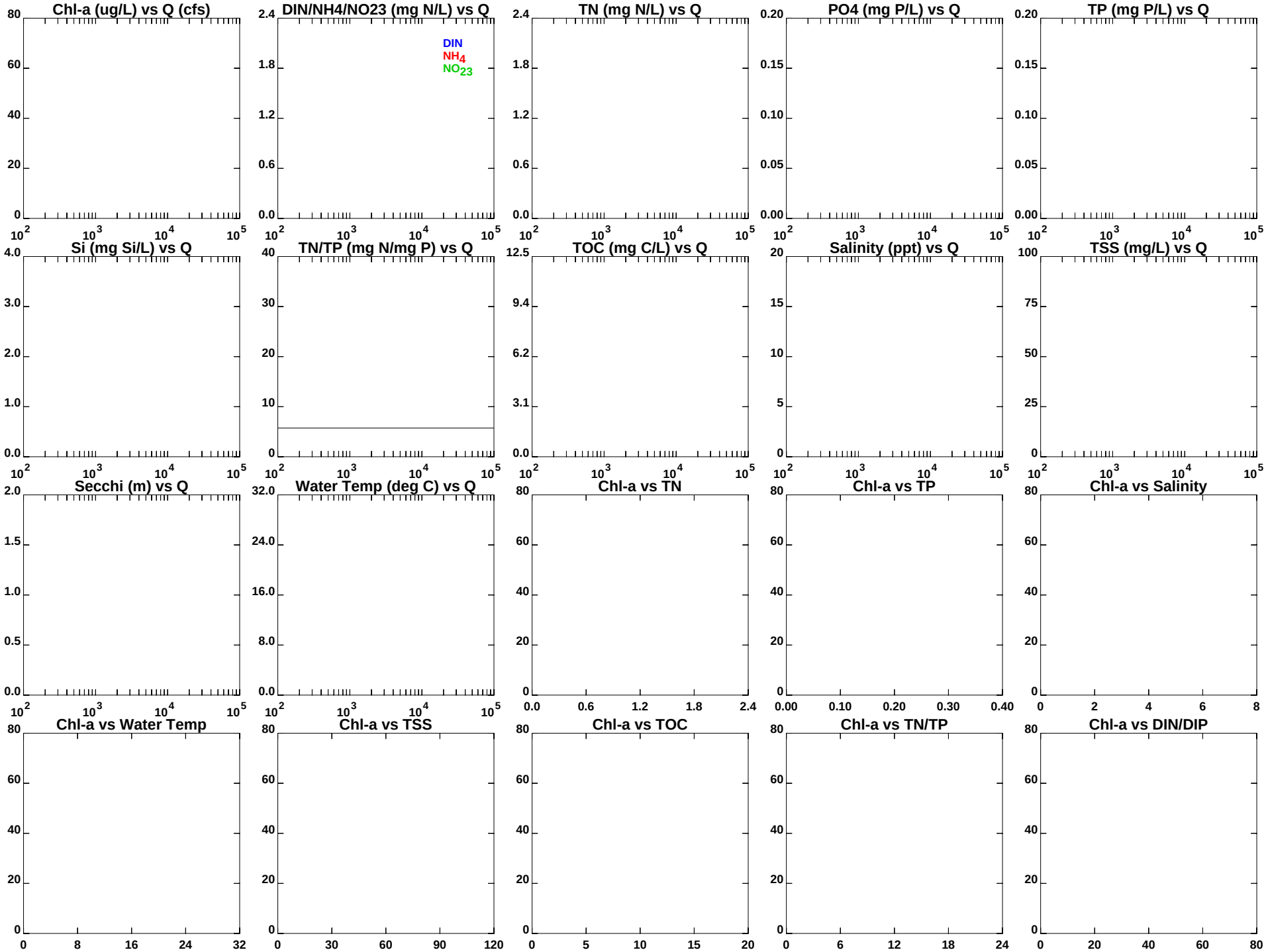

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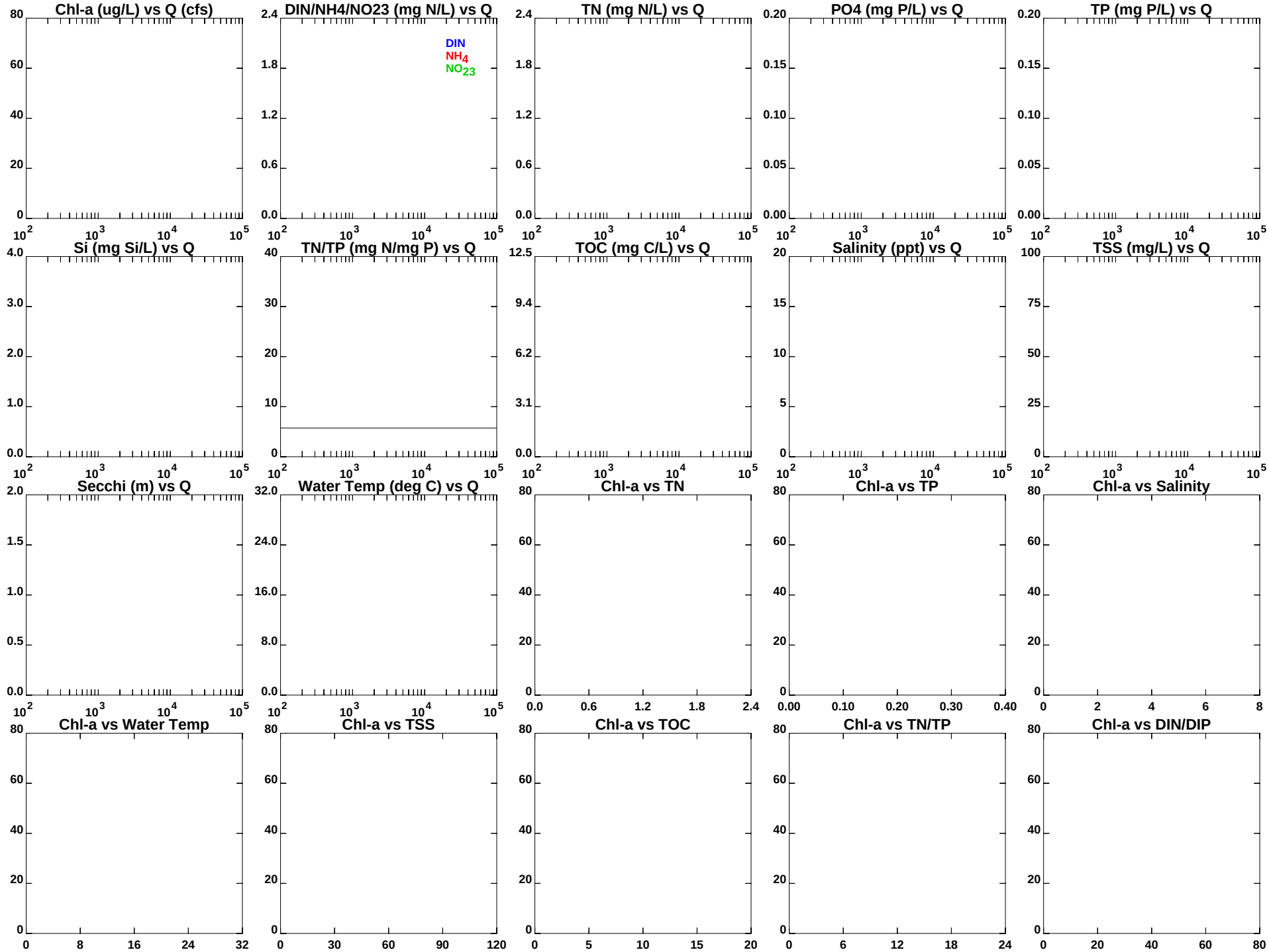

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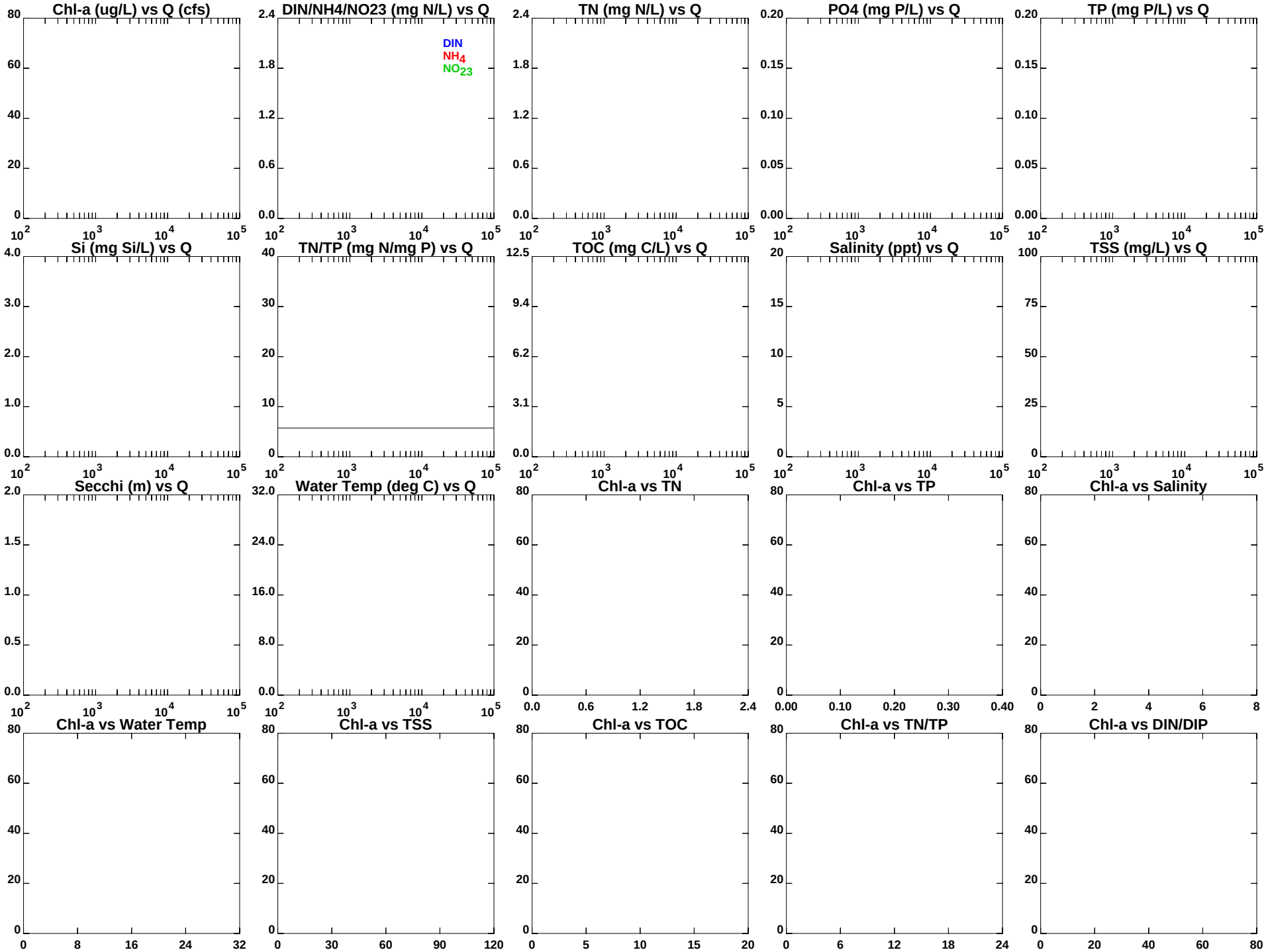

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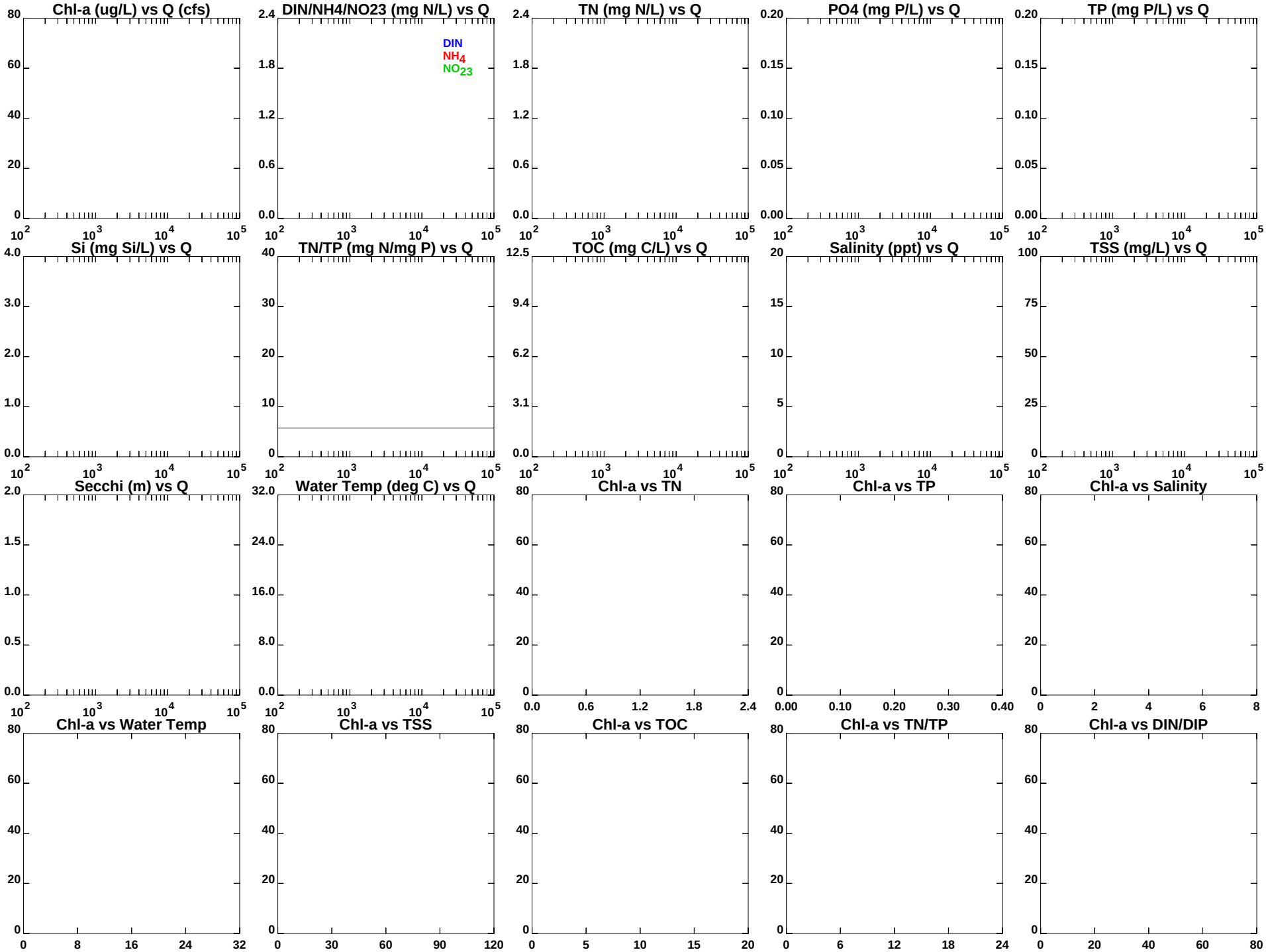

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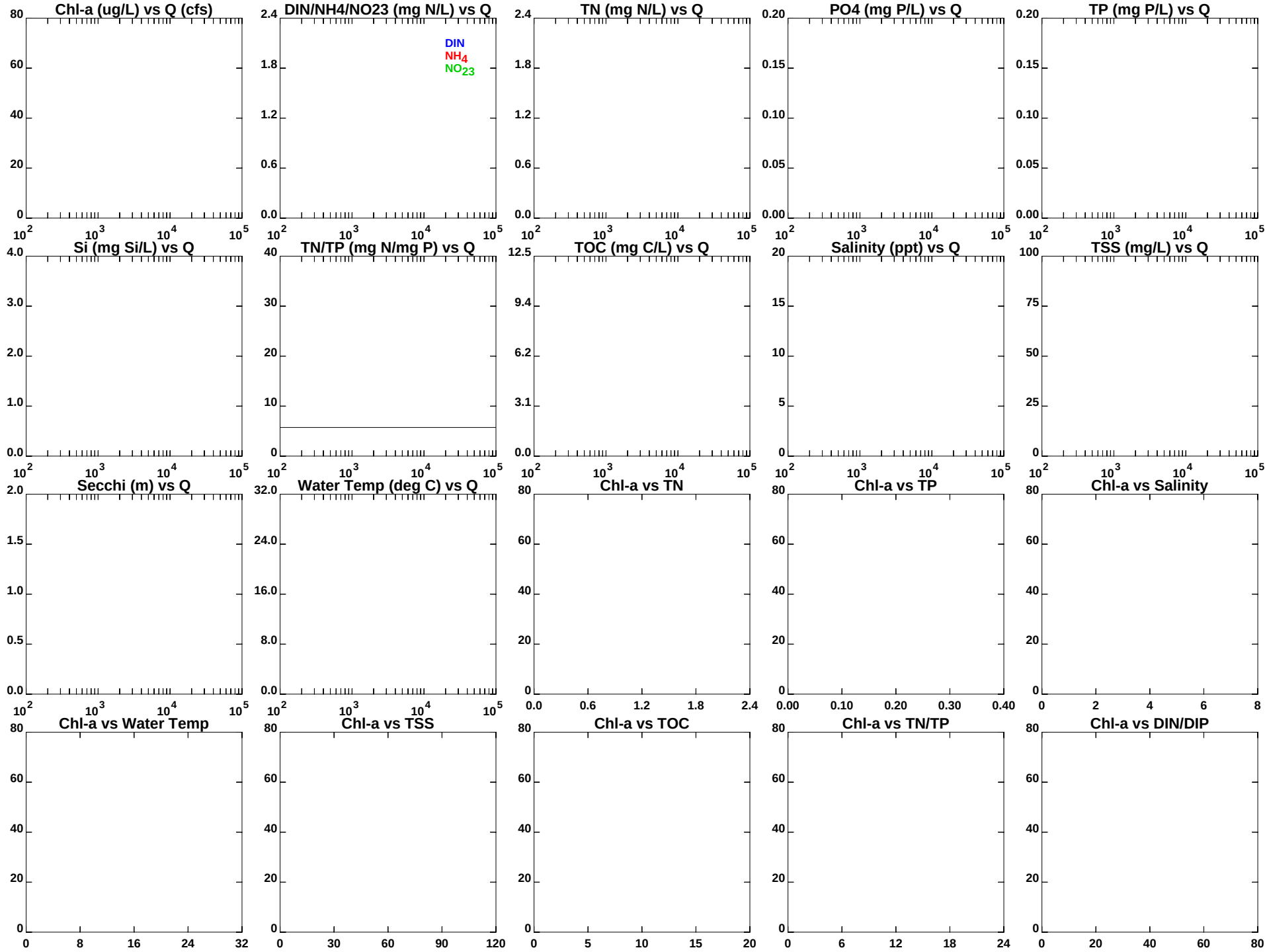

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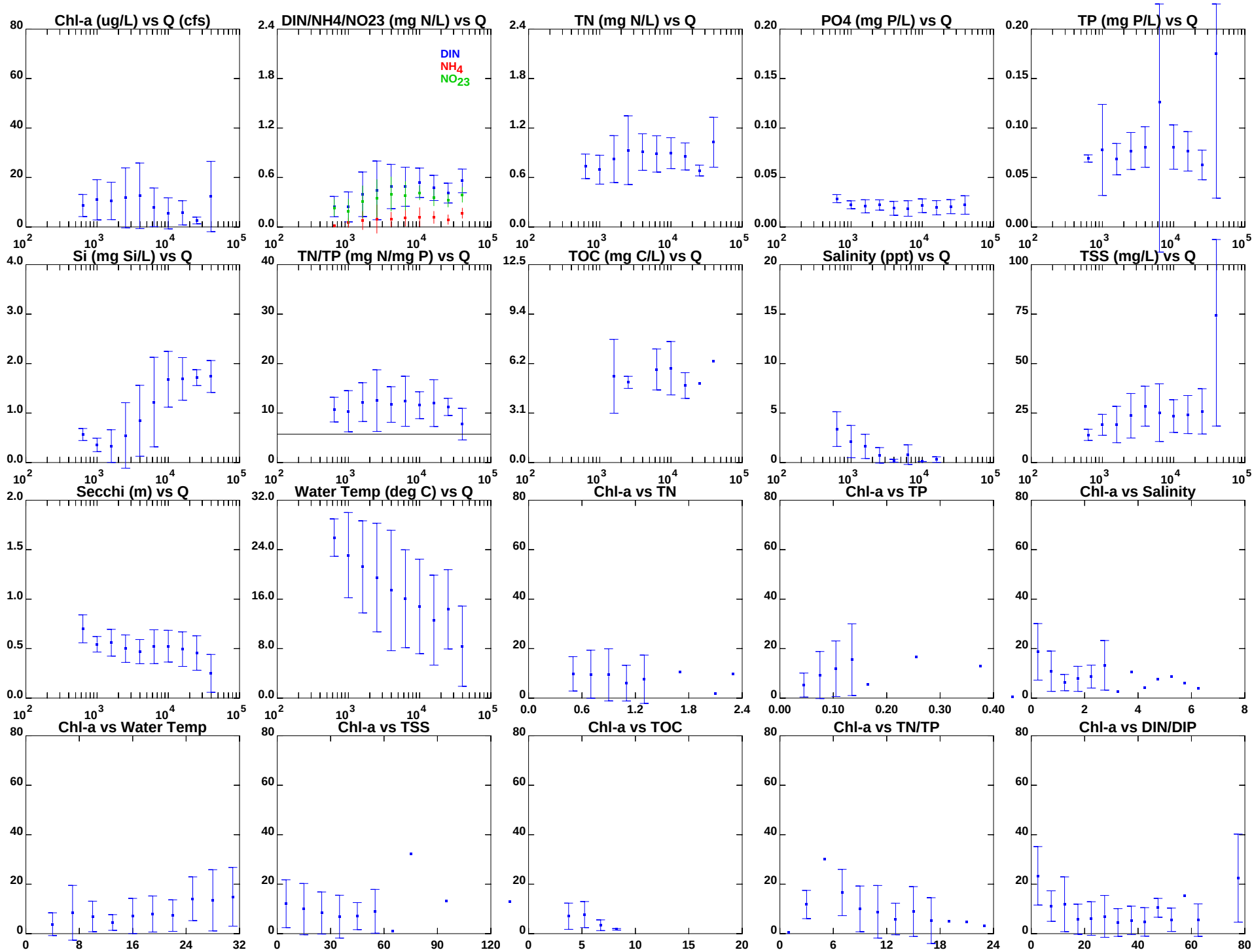

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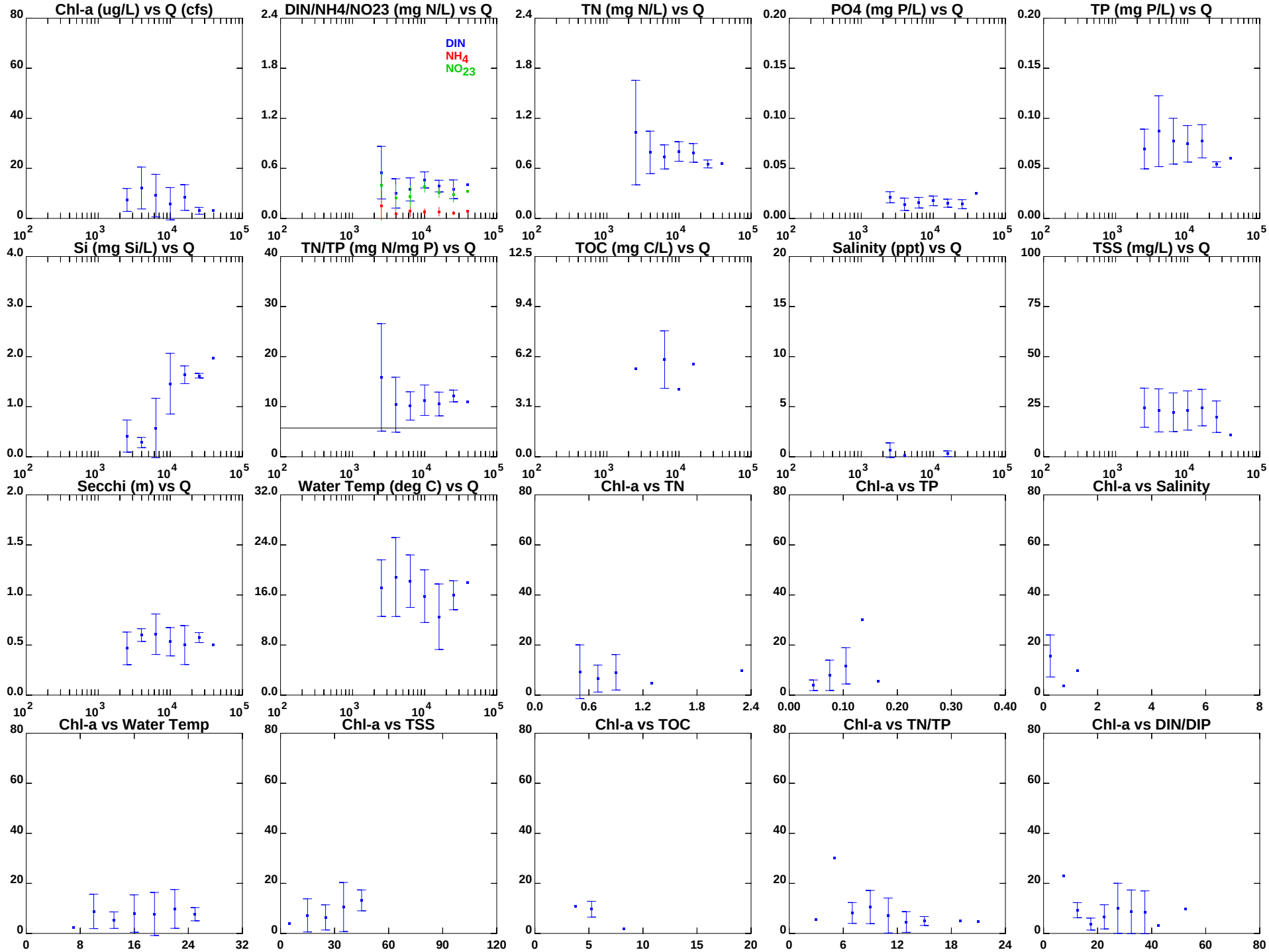

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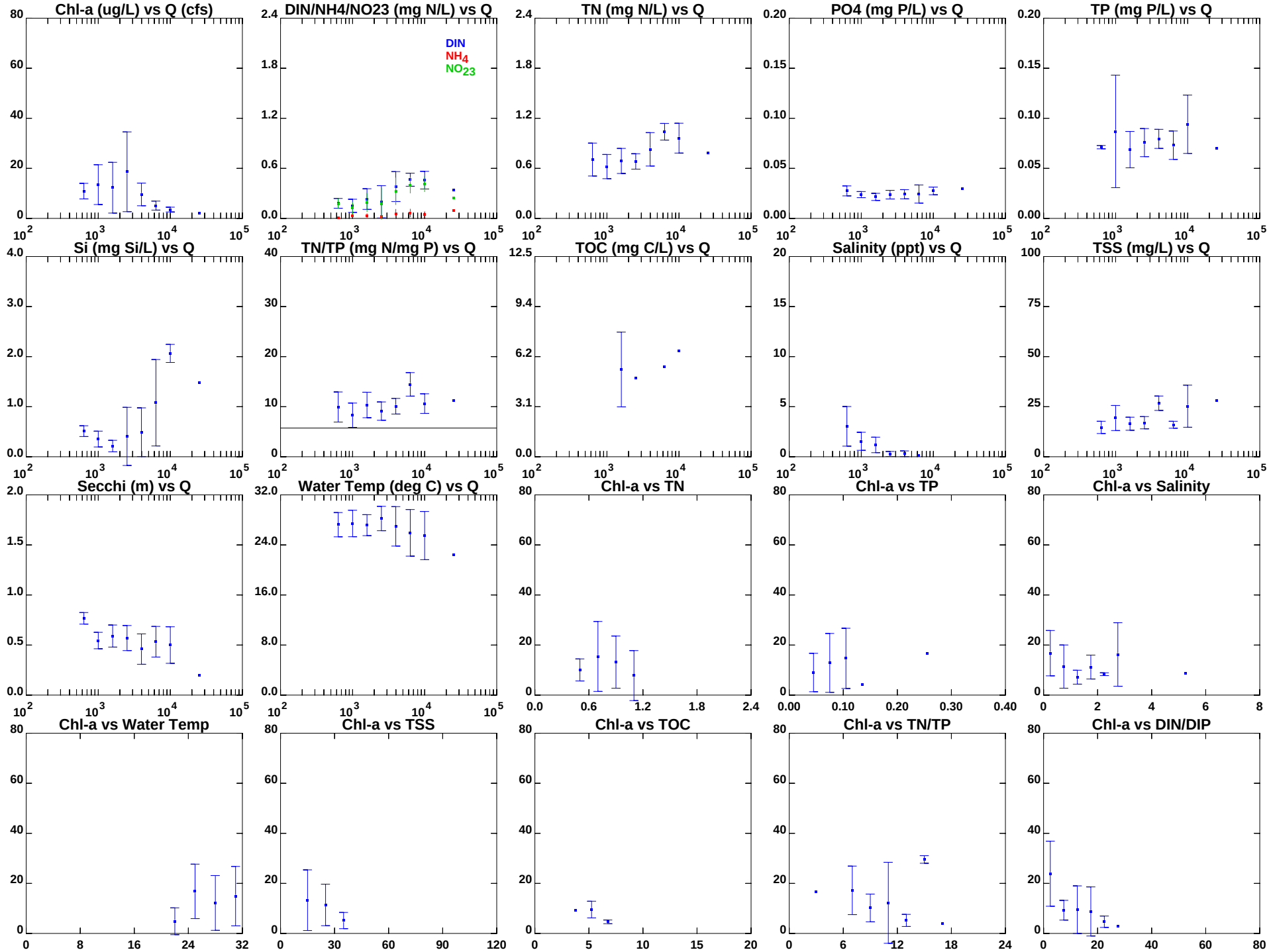

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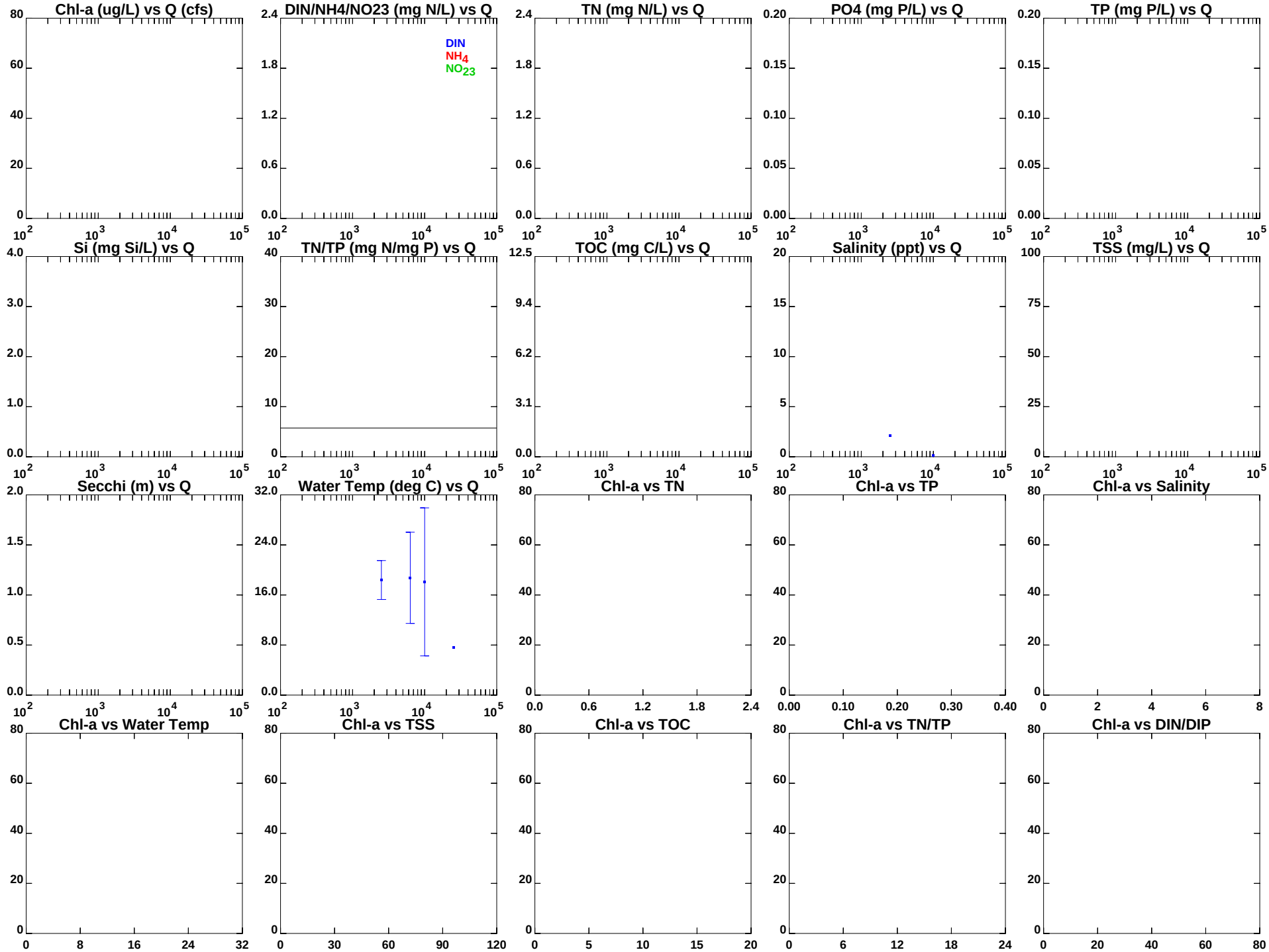

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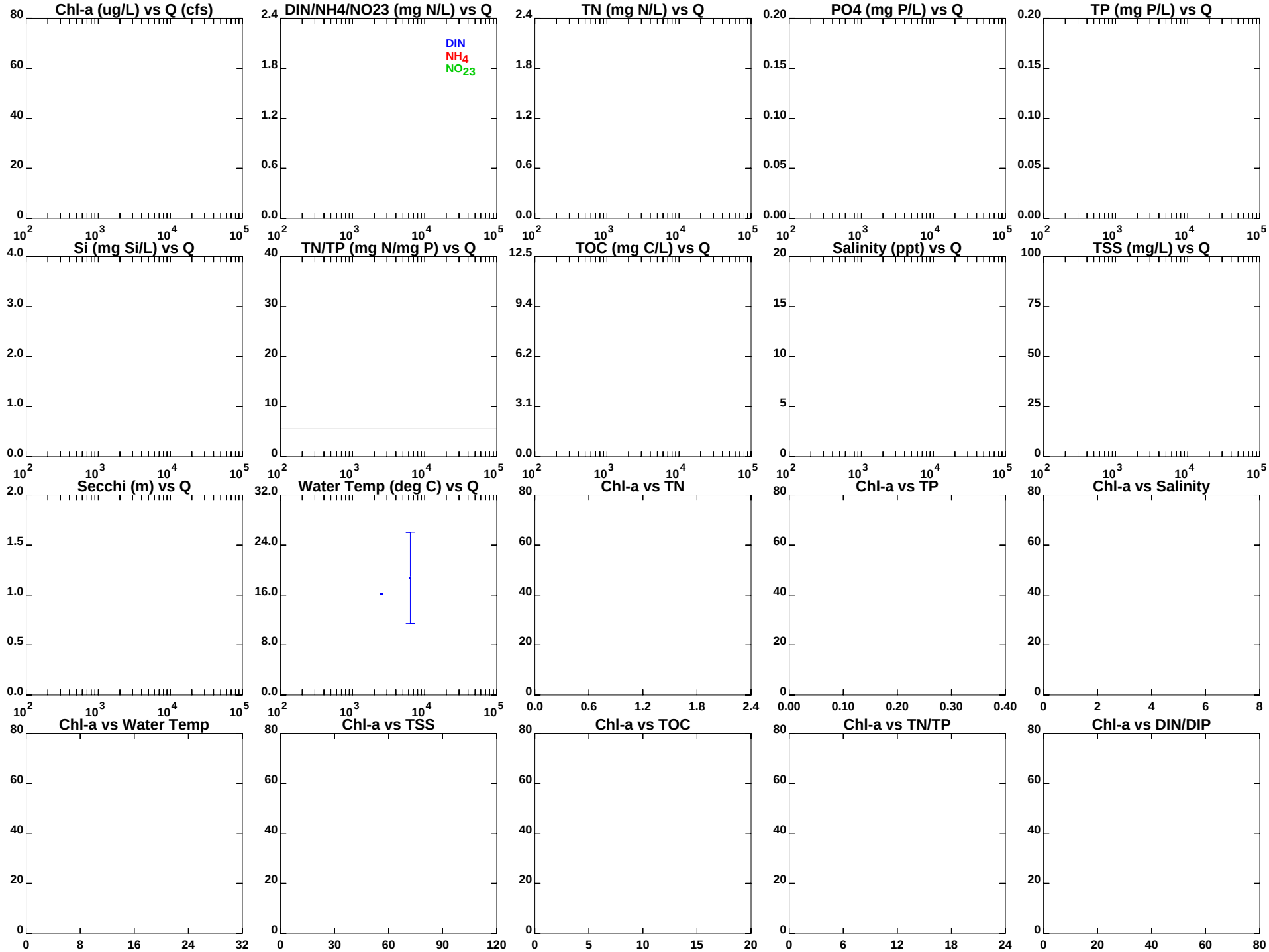

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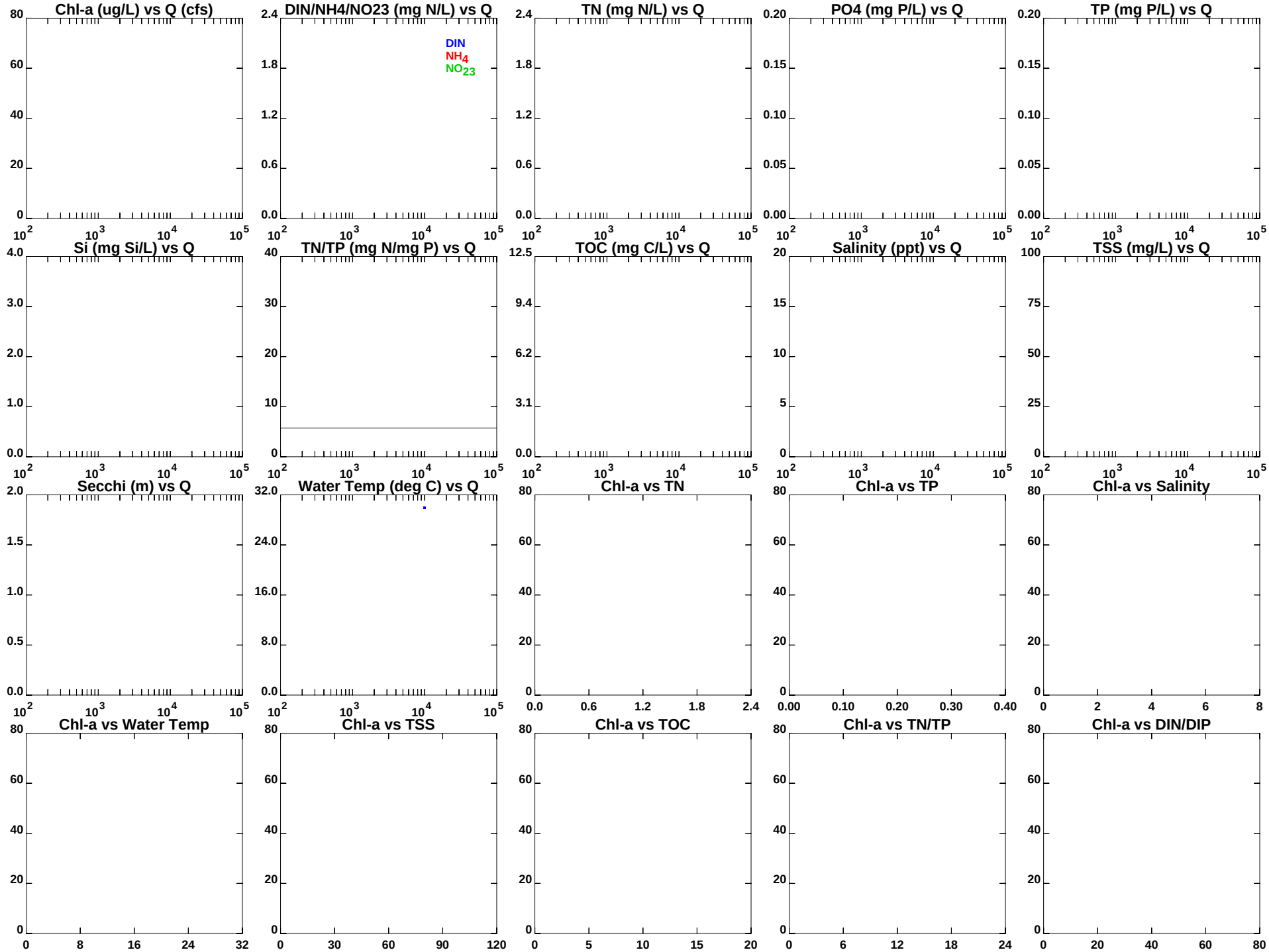

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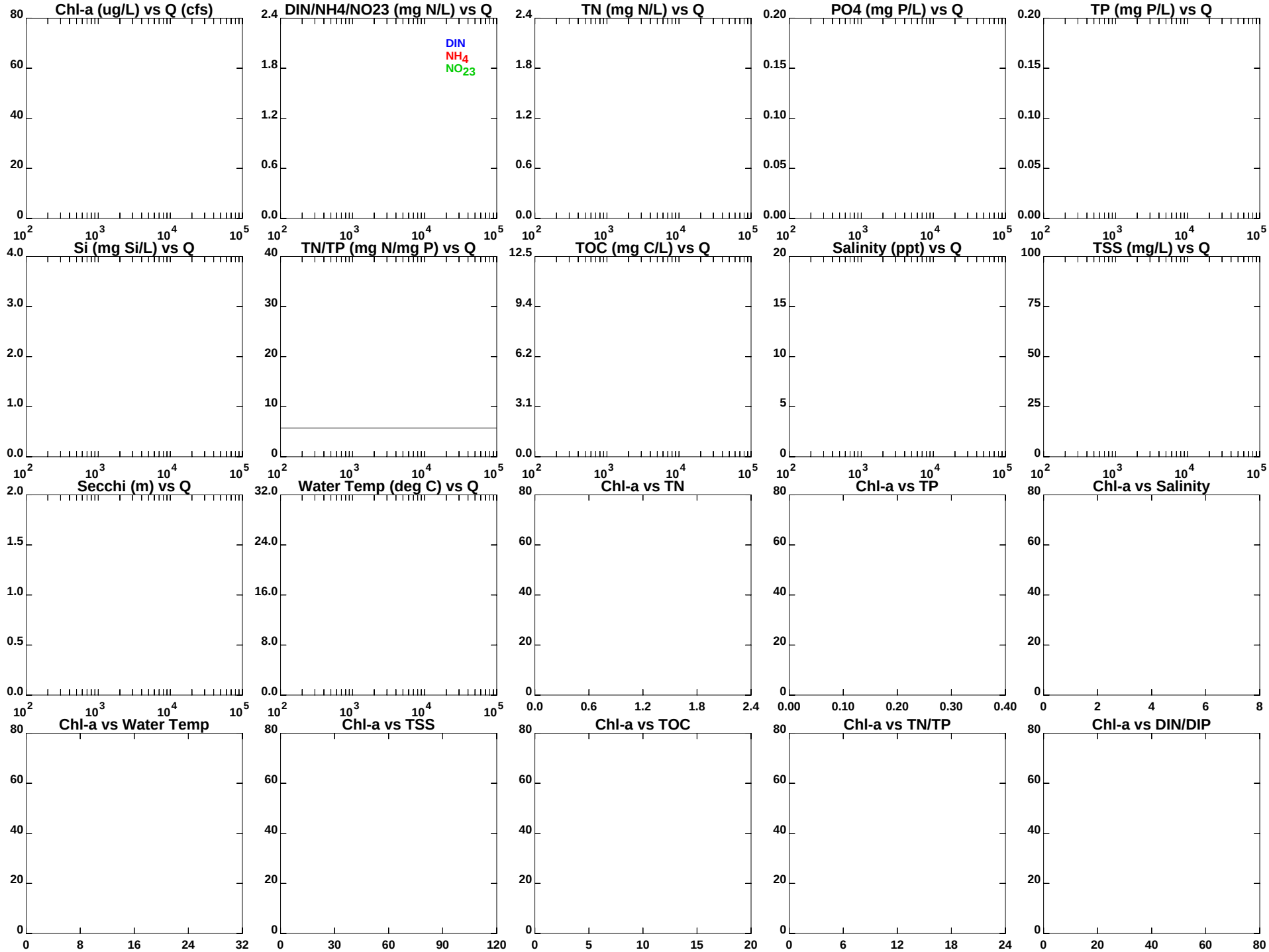

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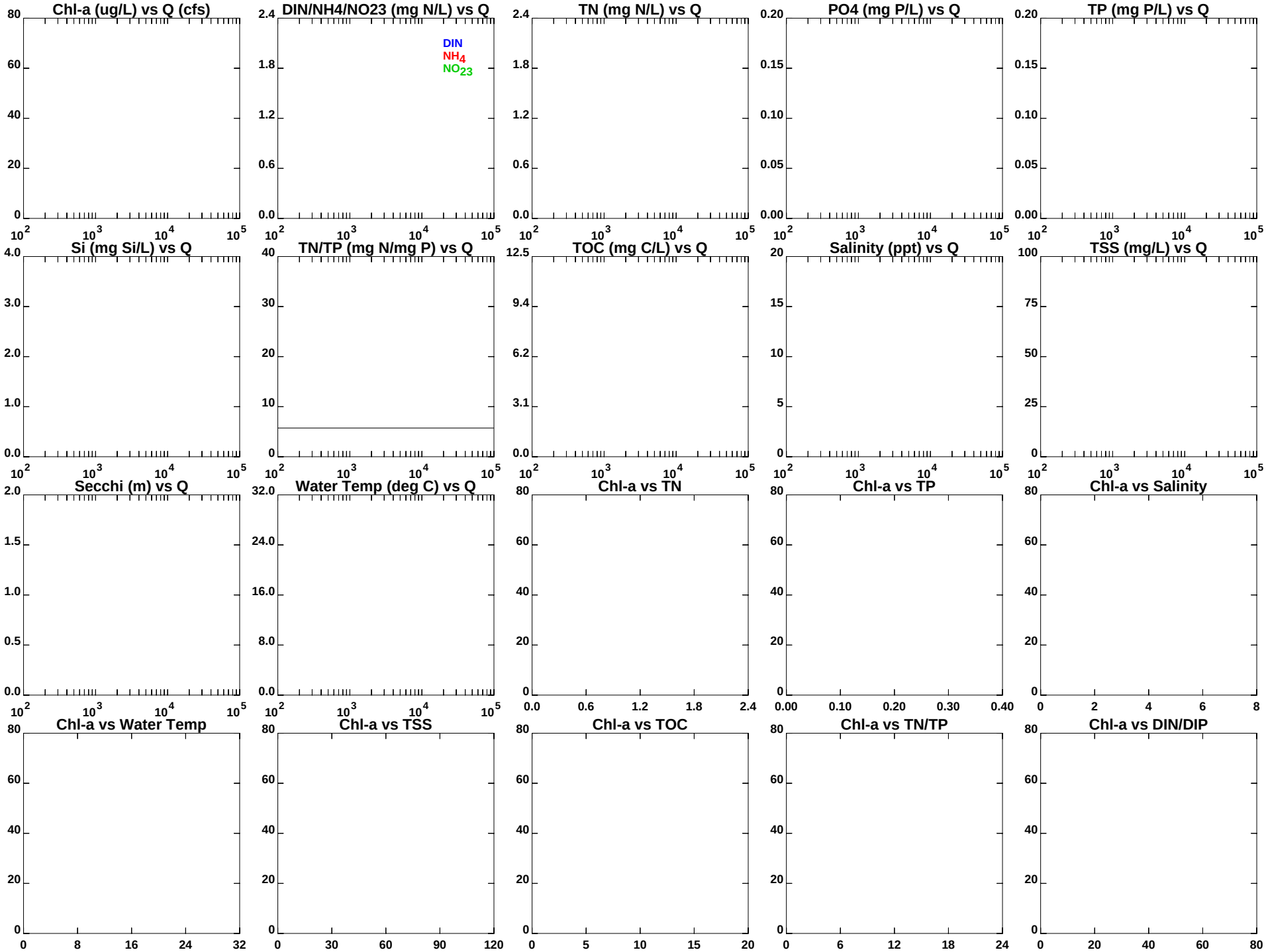

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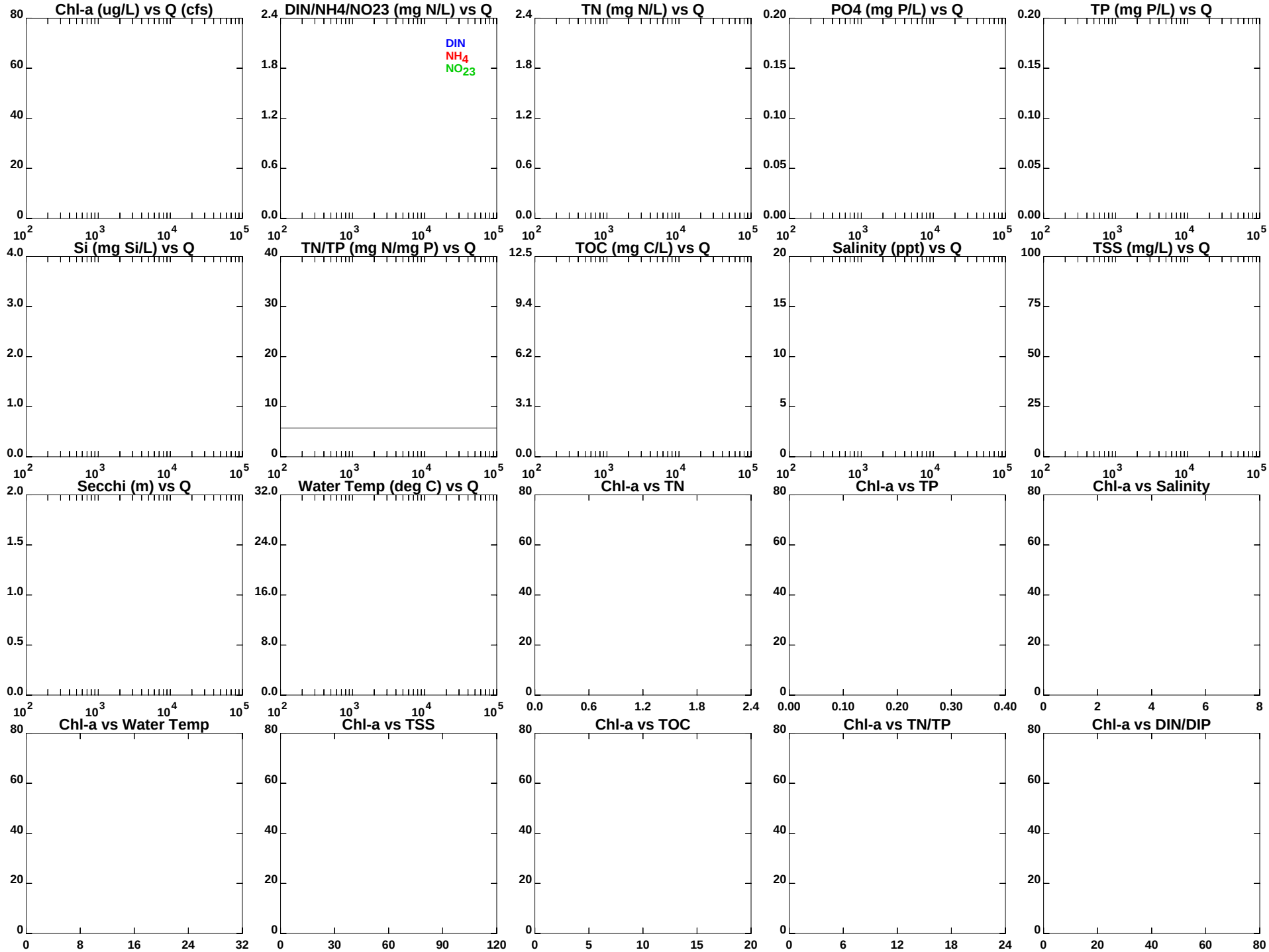

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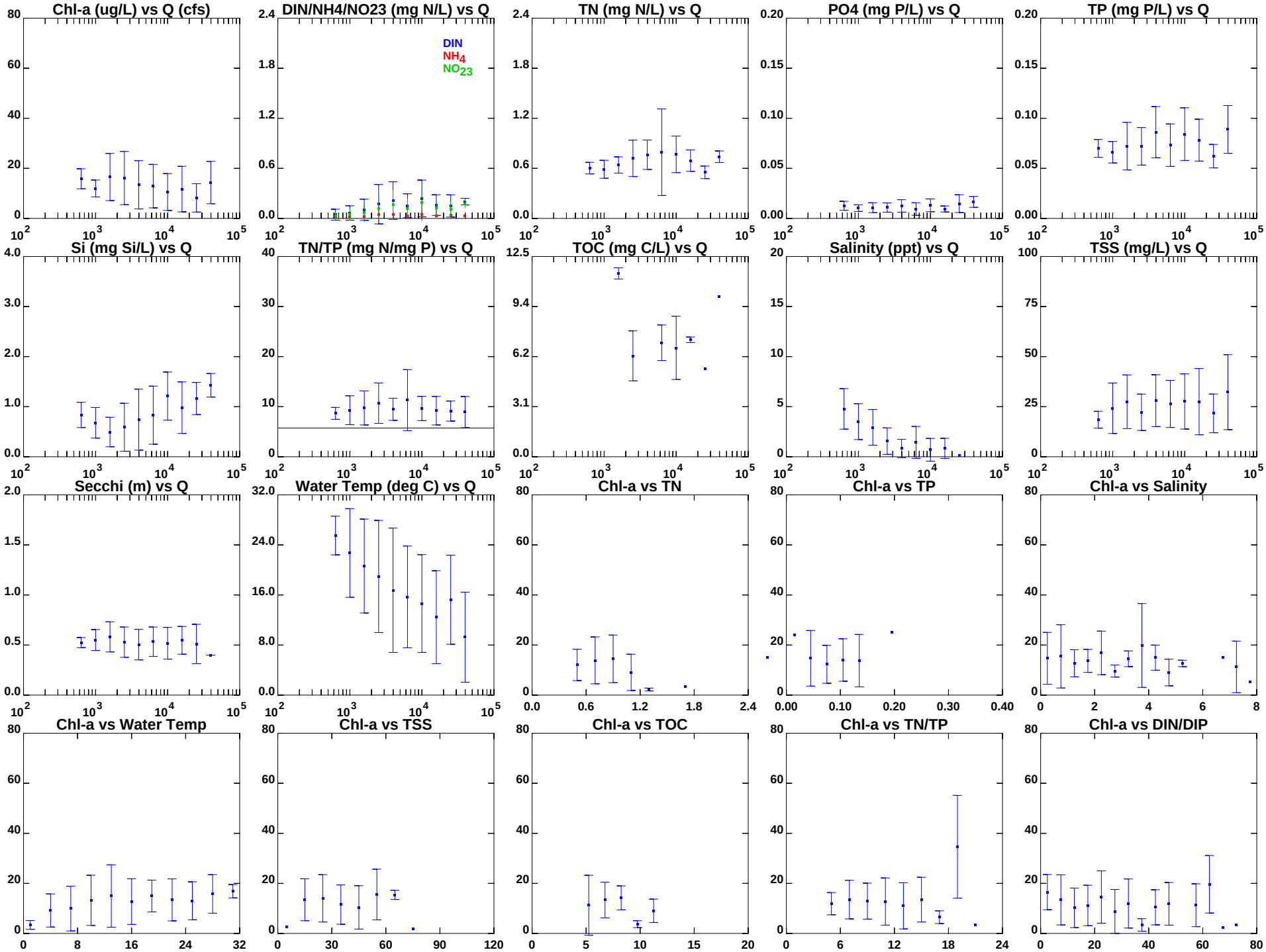

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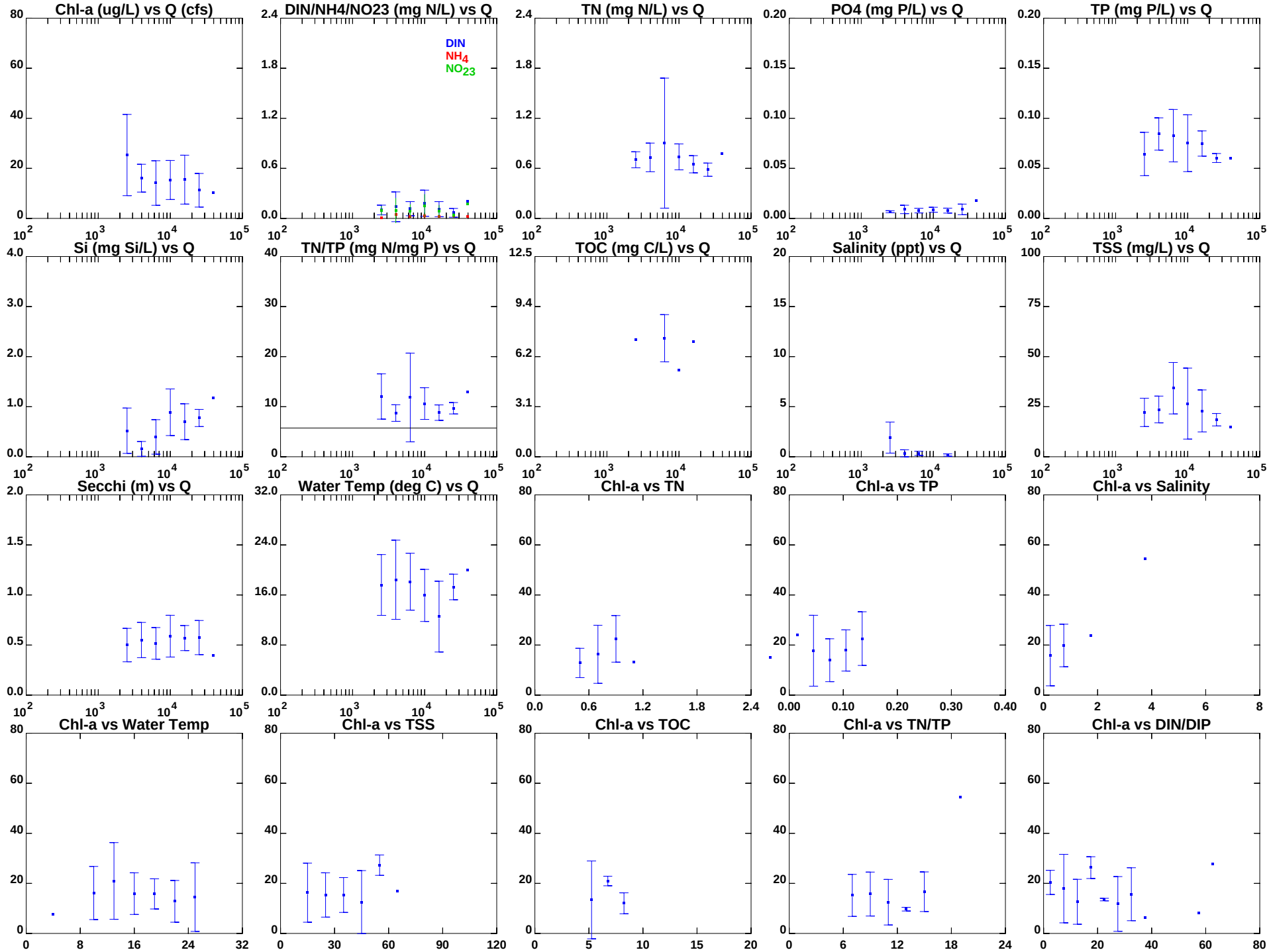

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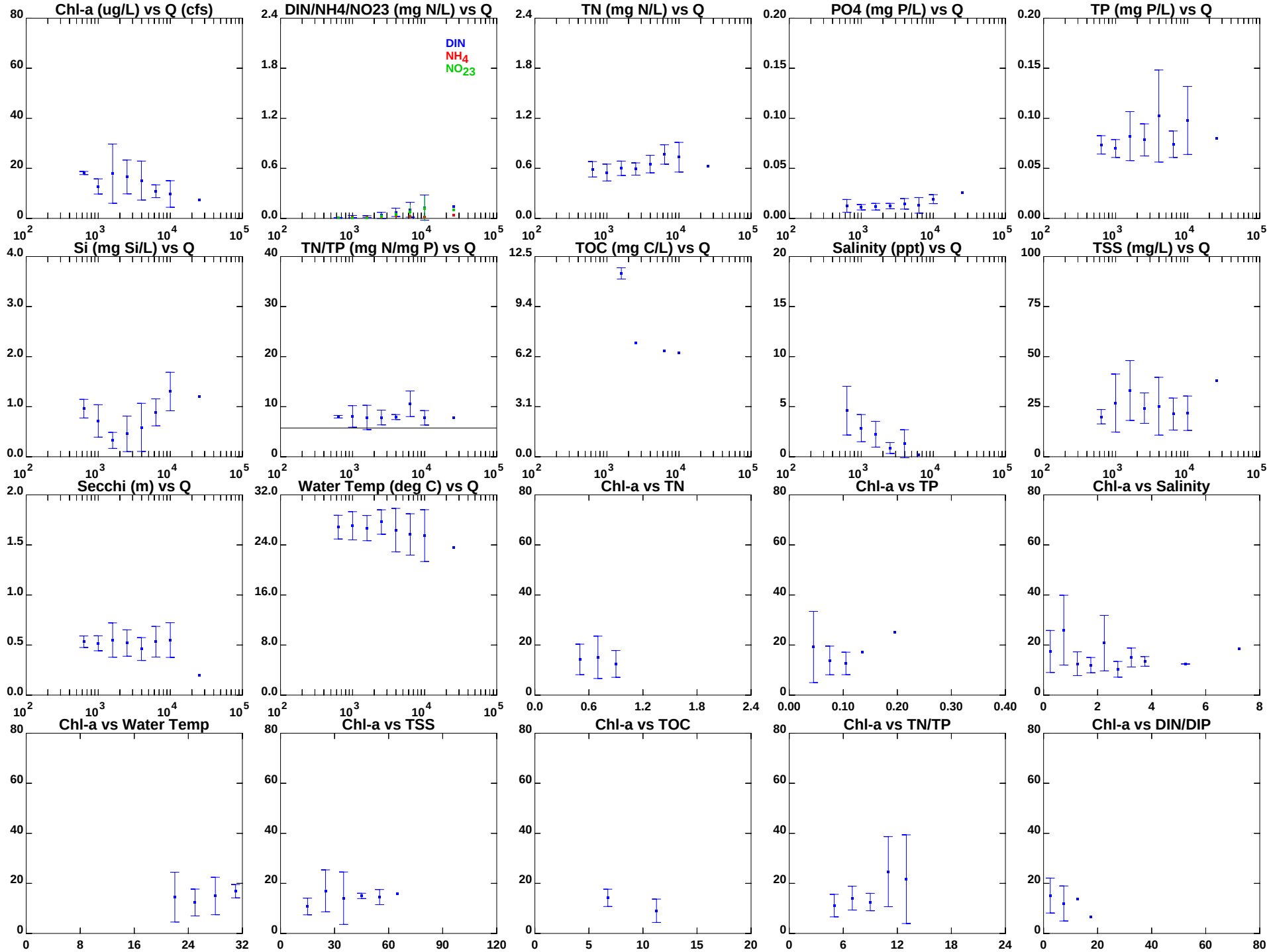

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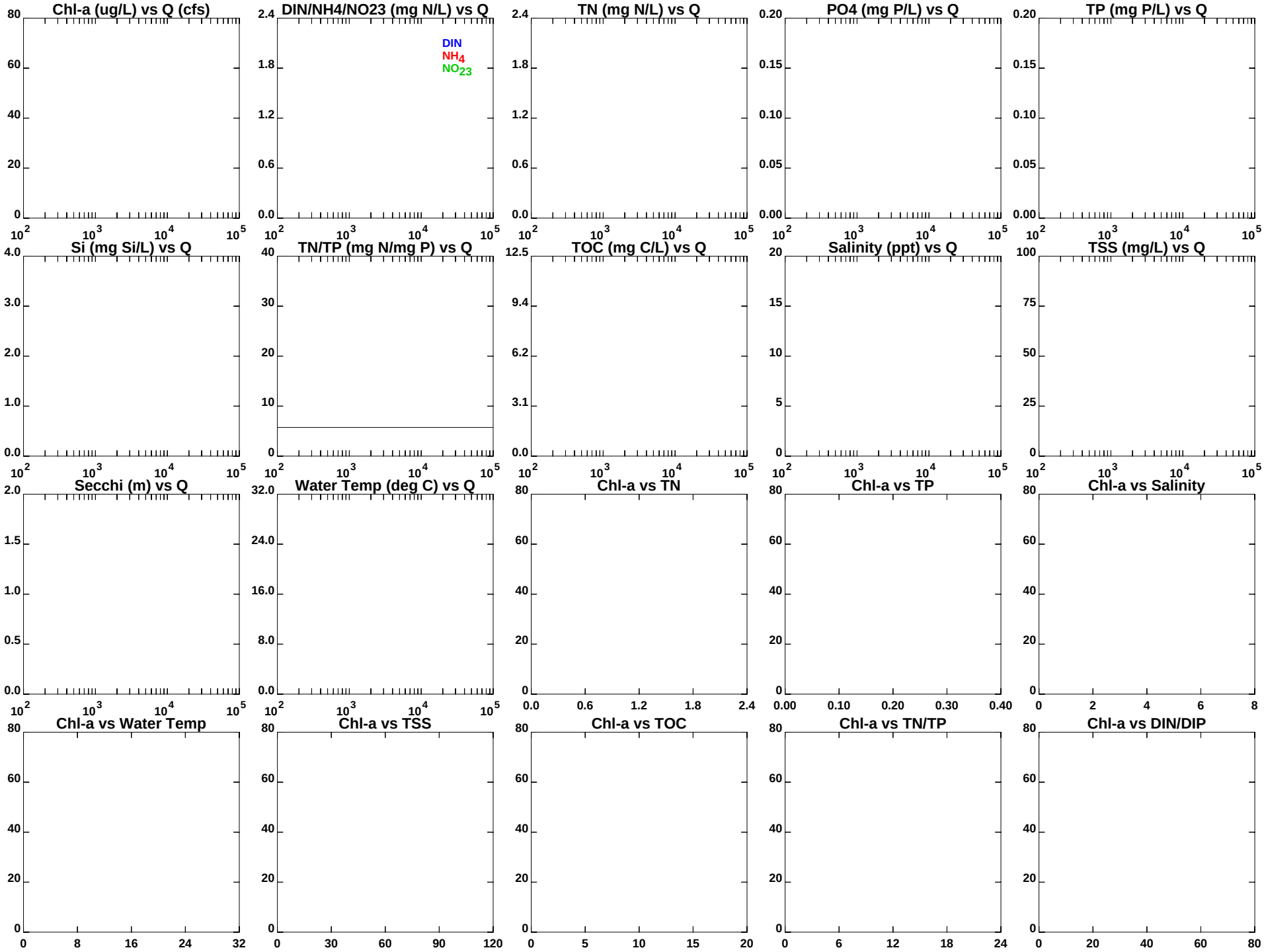

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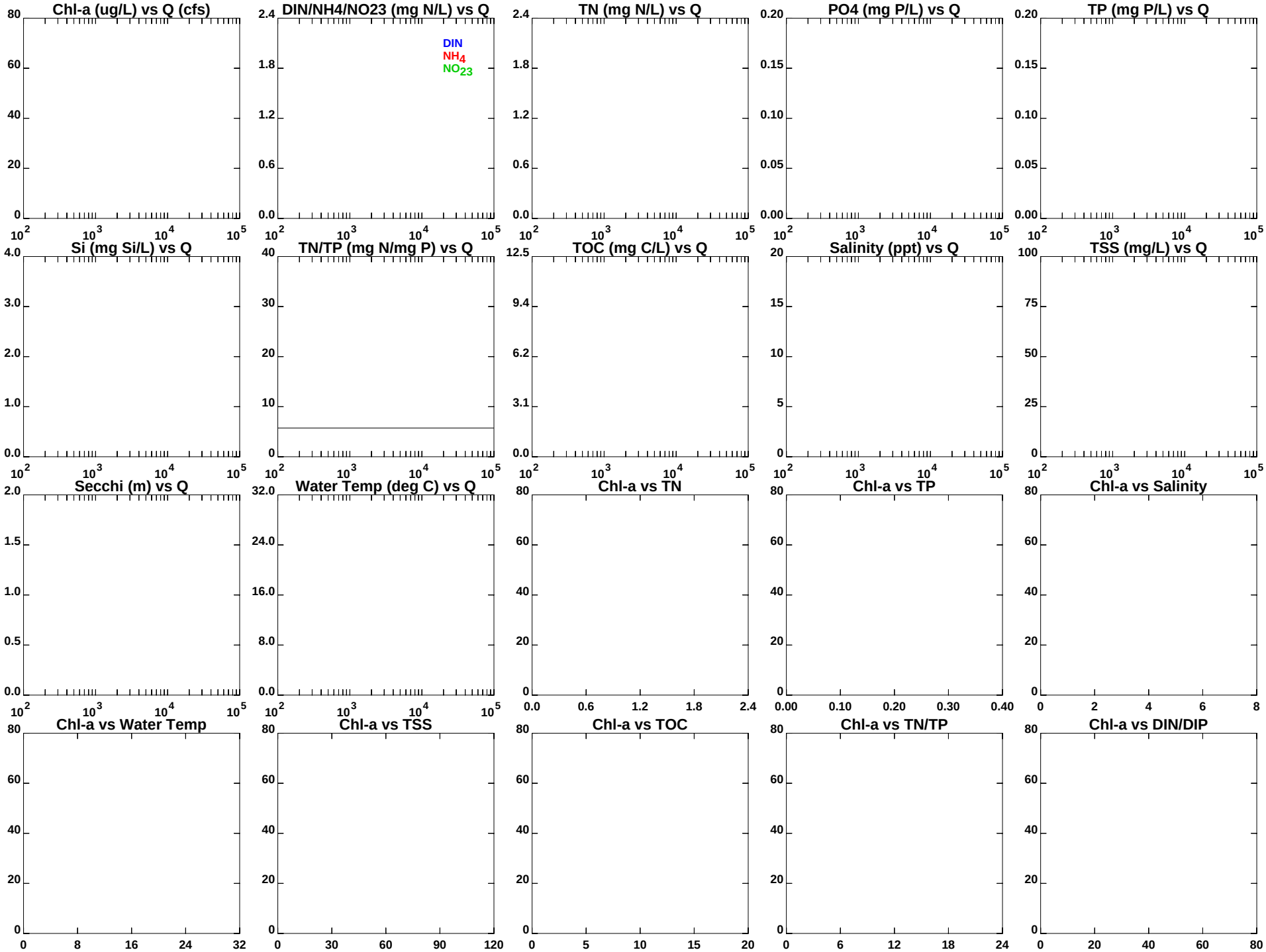
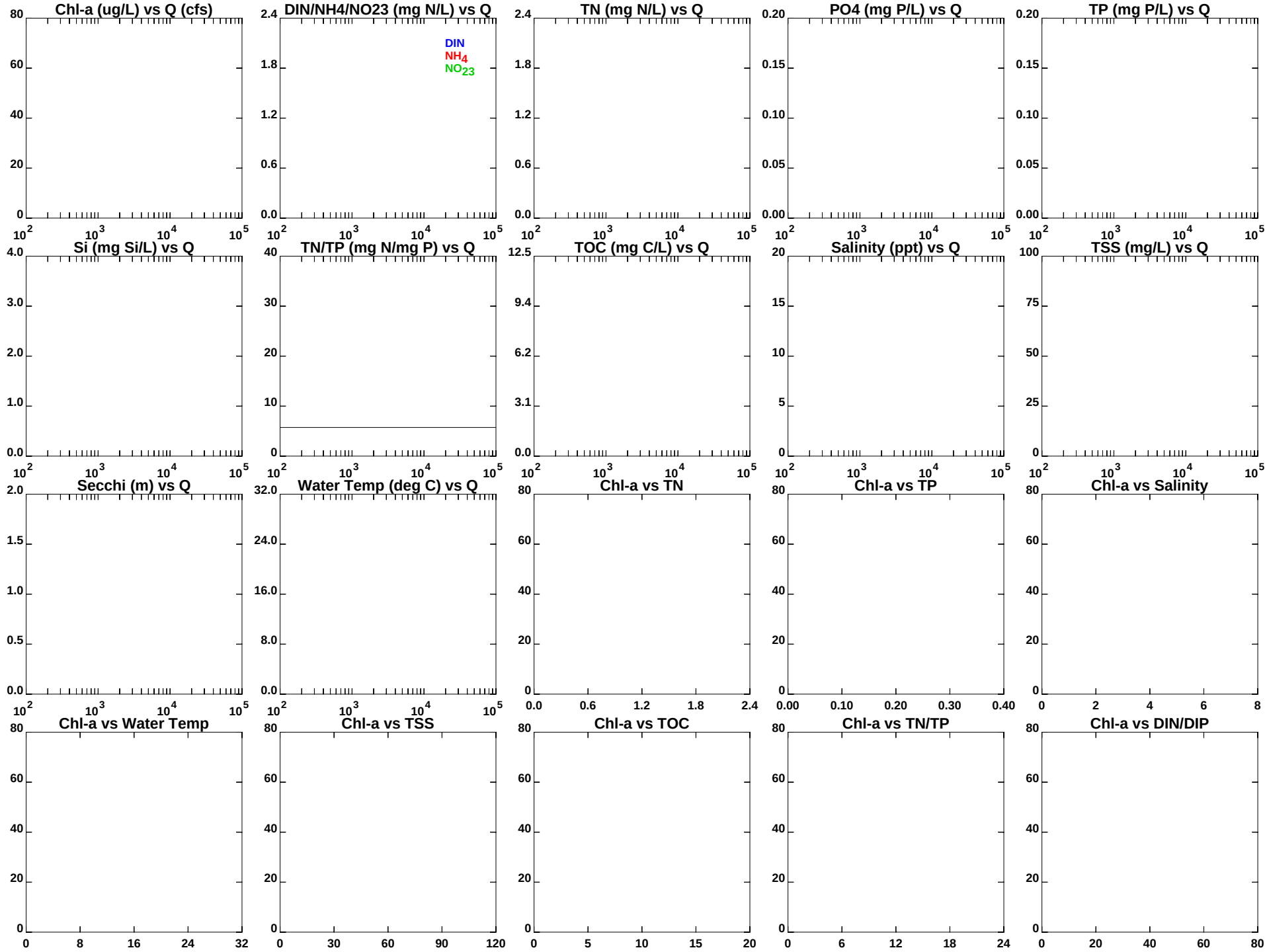


1995-2010: Spring data only for Station = RET5.2N



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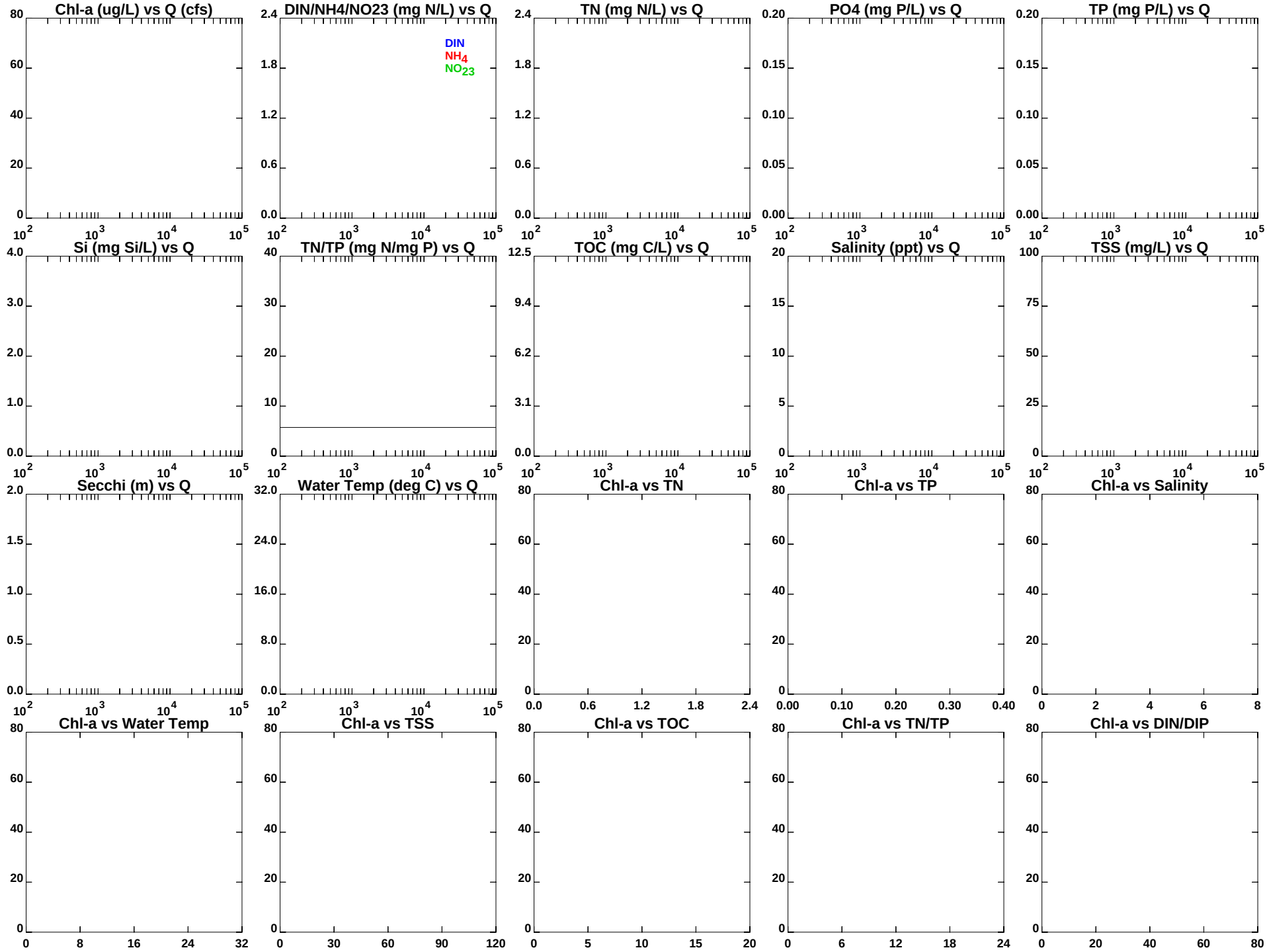

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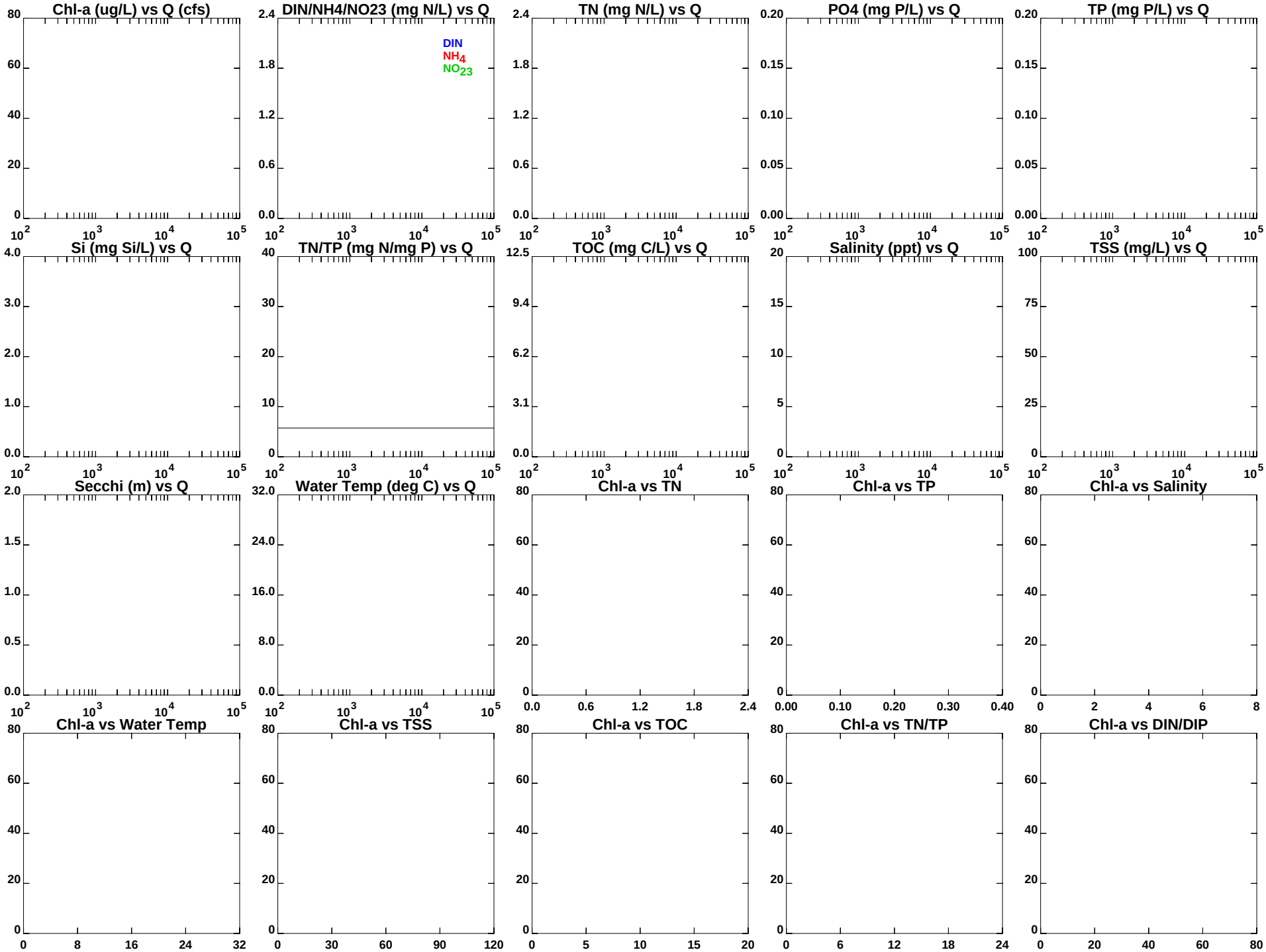

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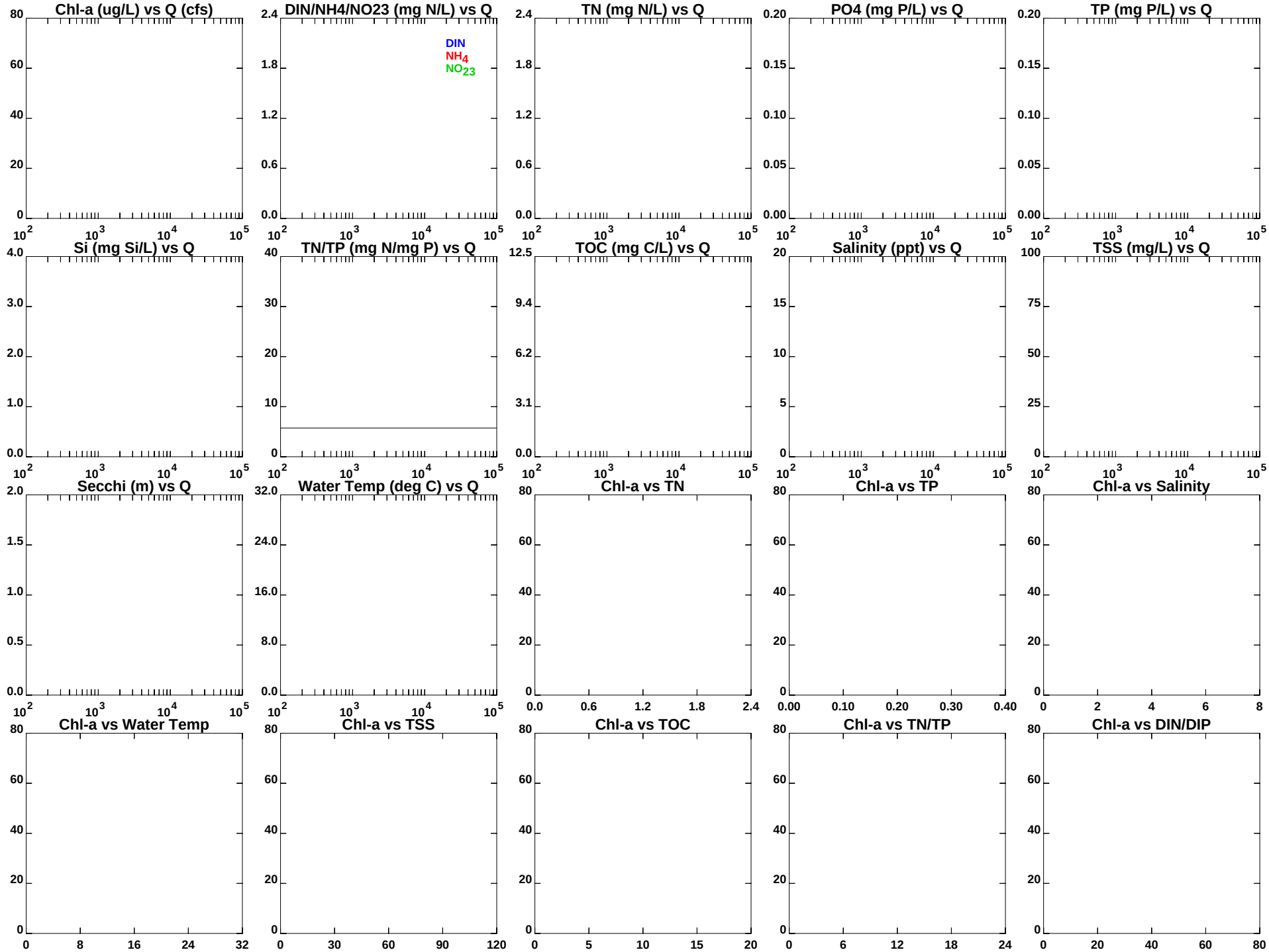

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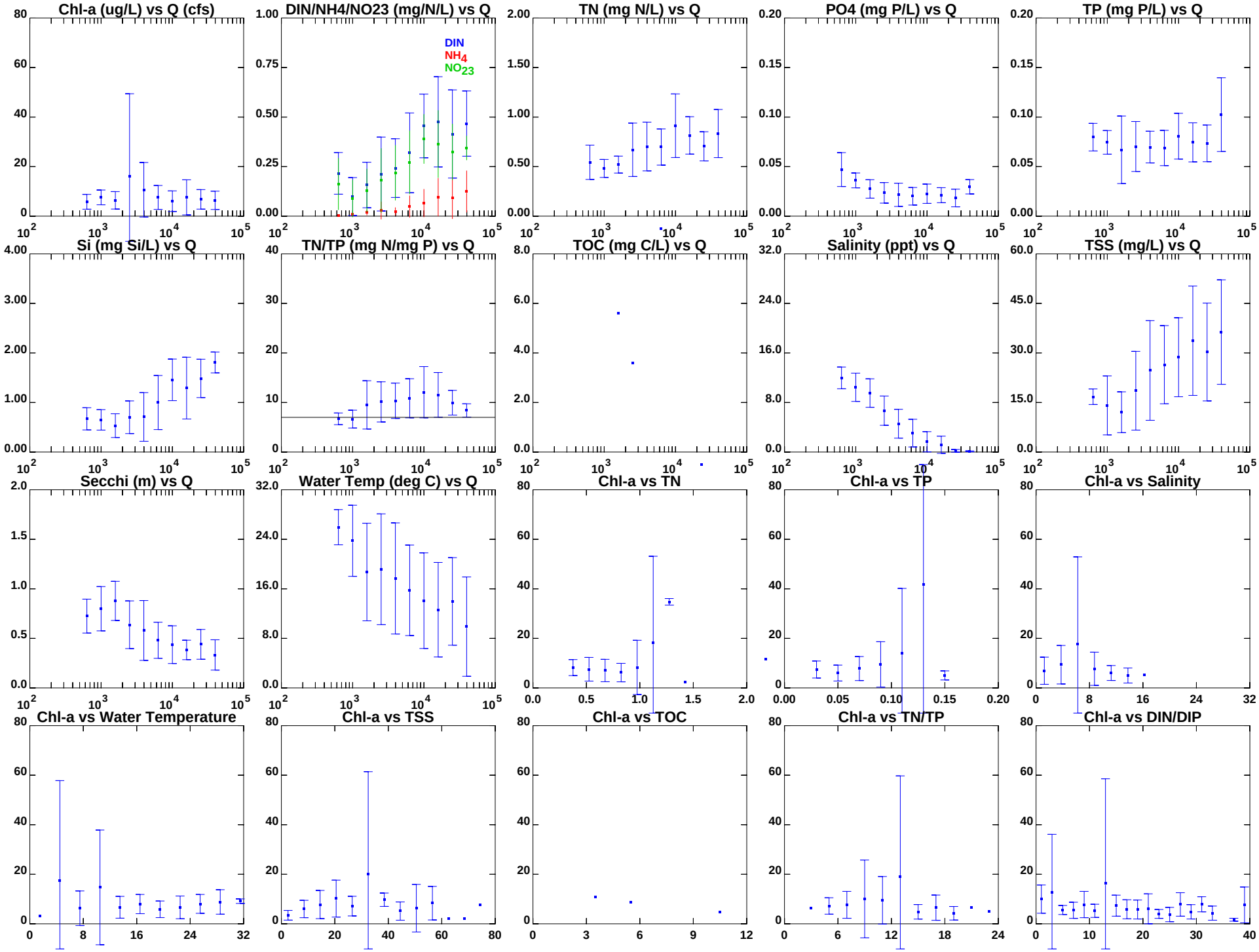

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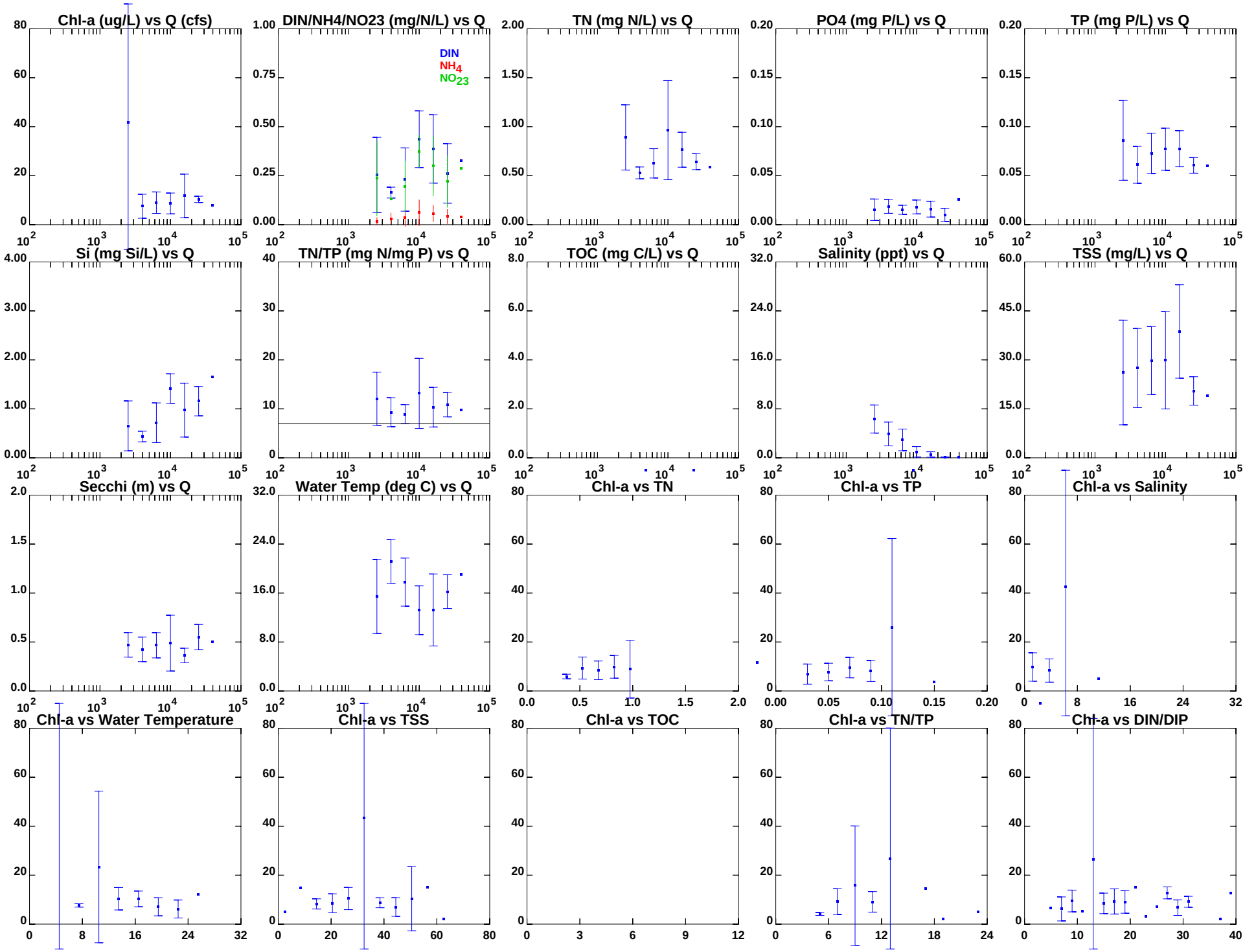

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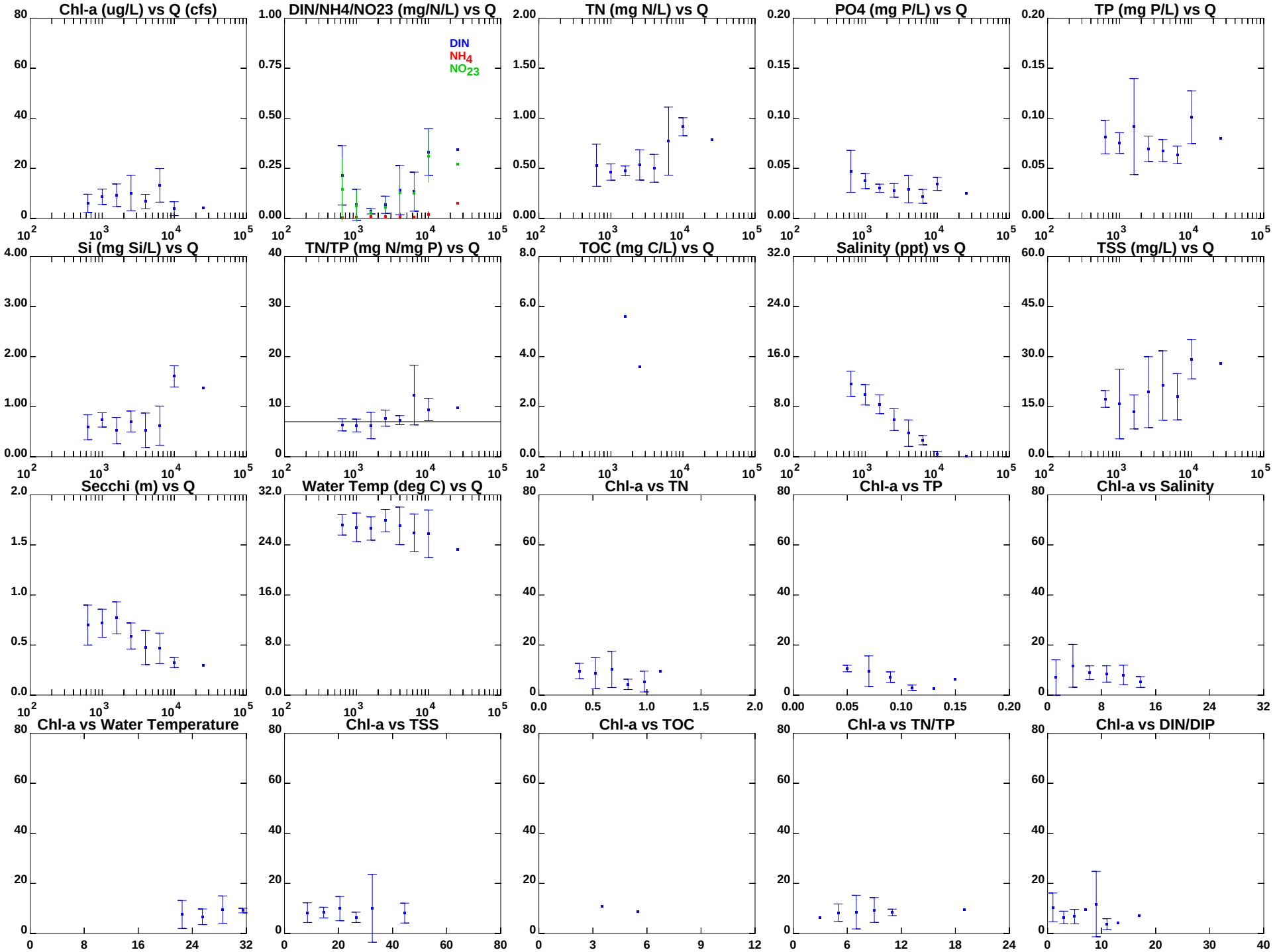

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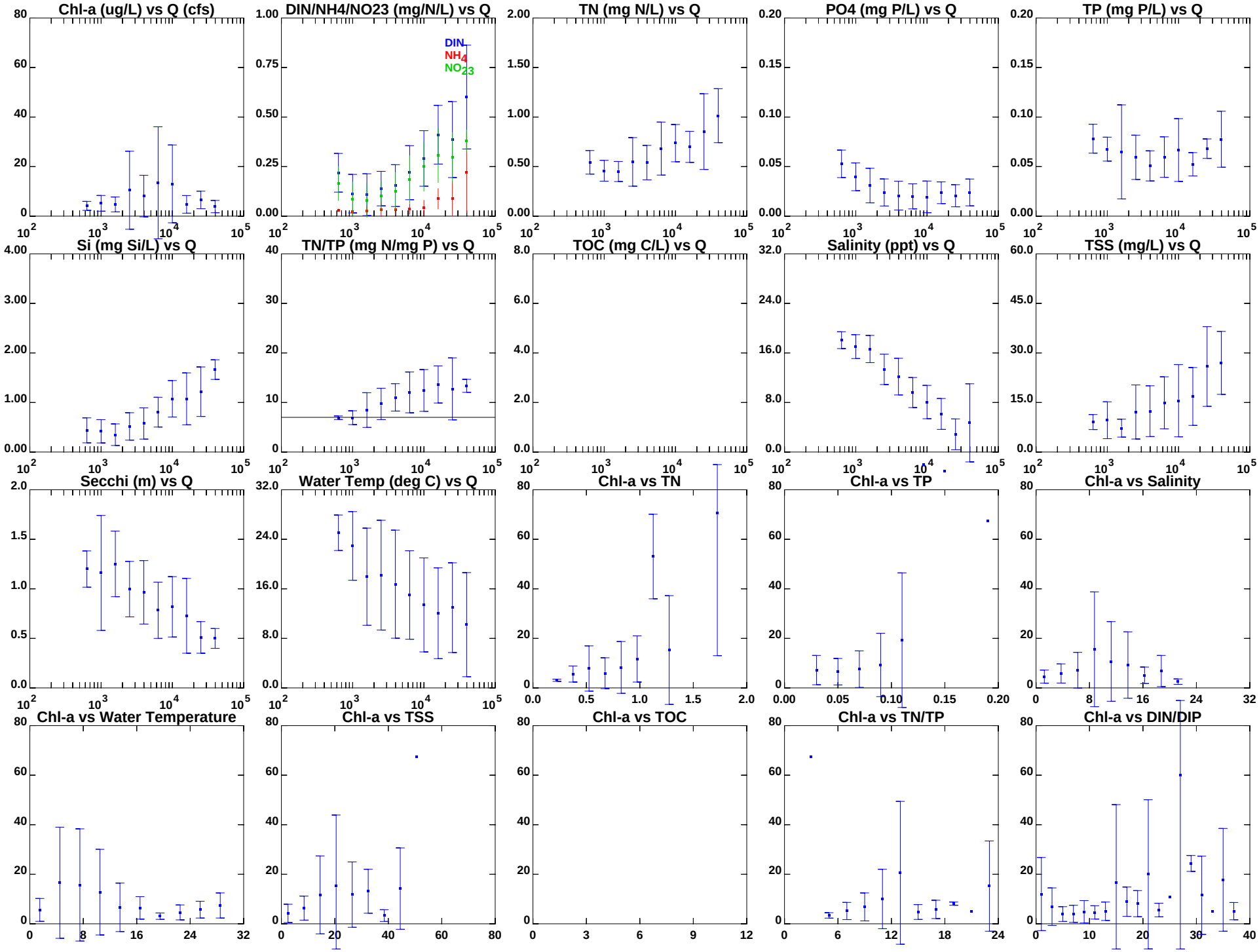

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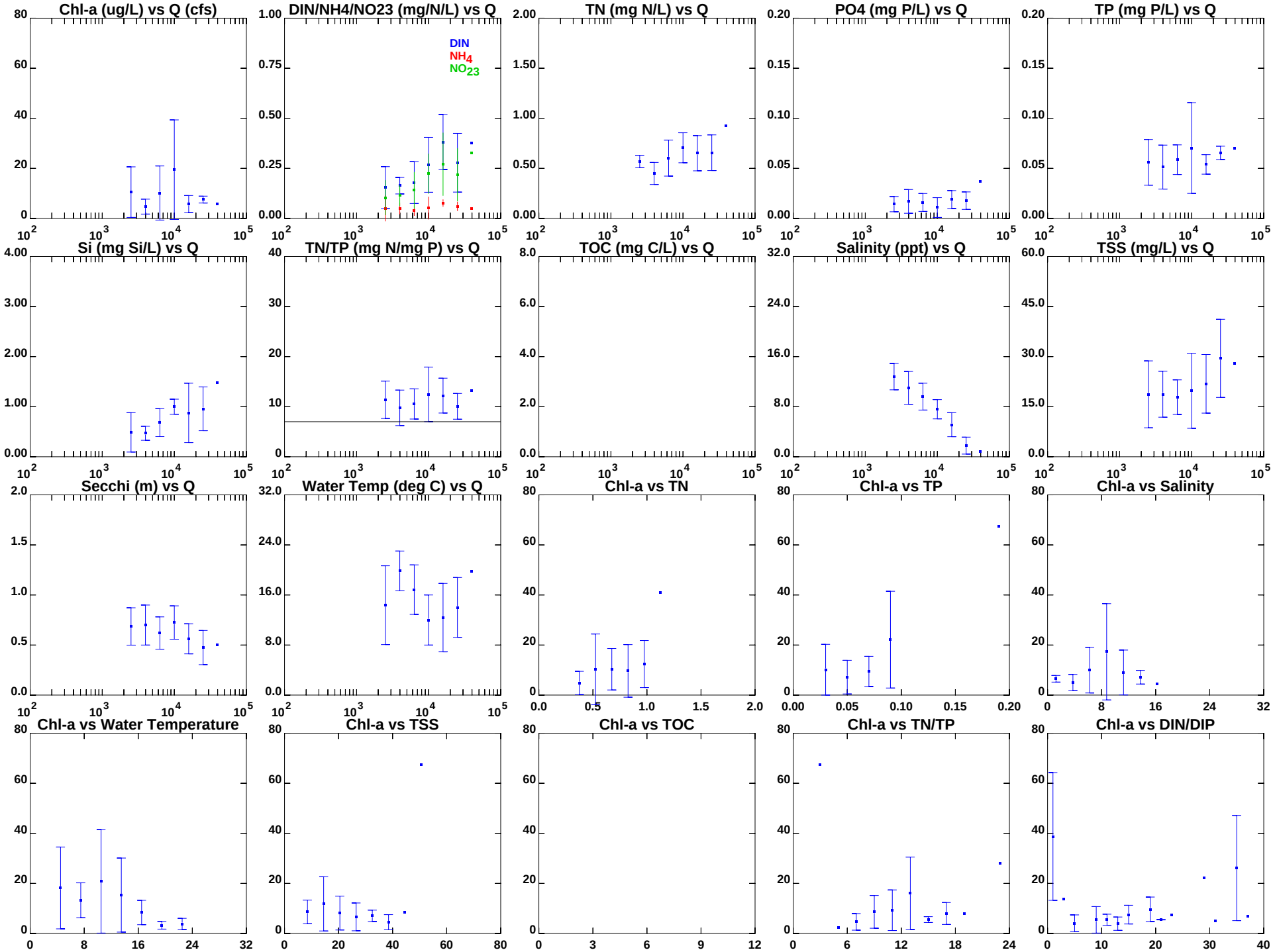

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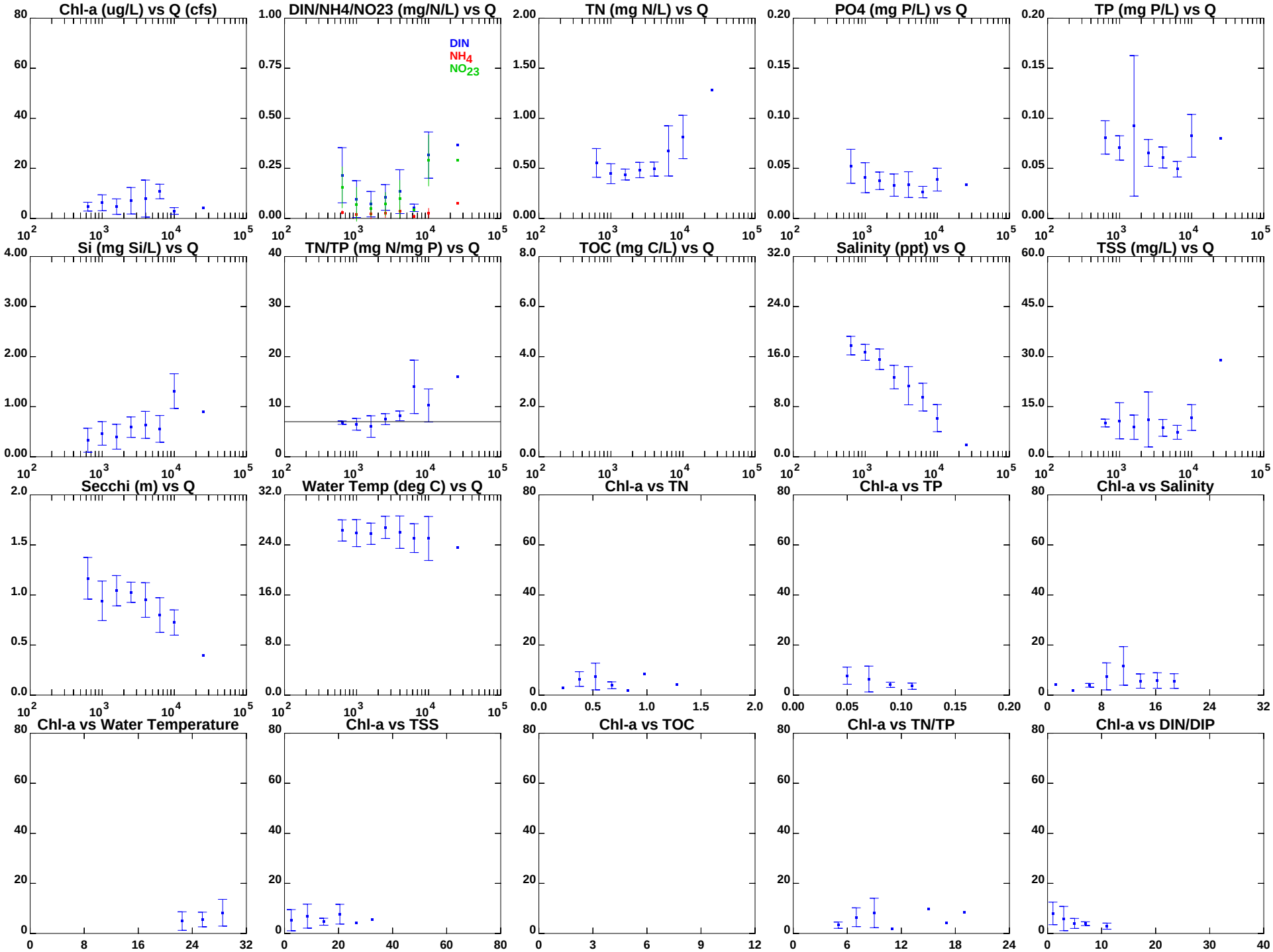

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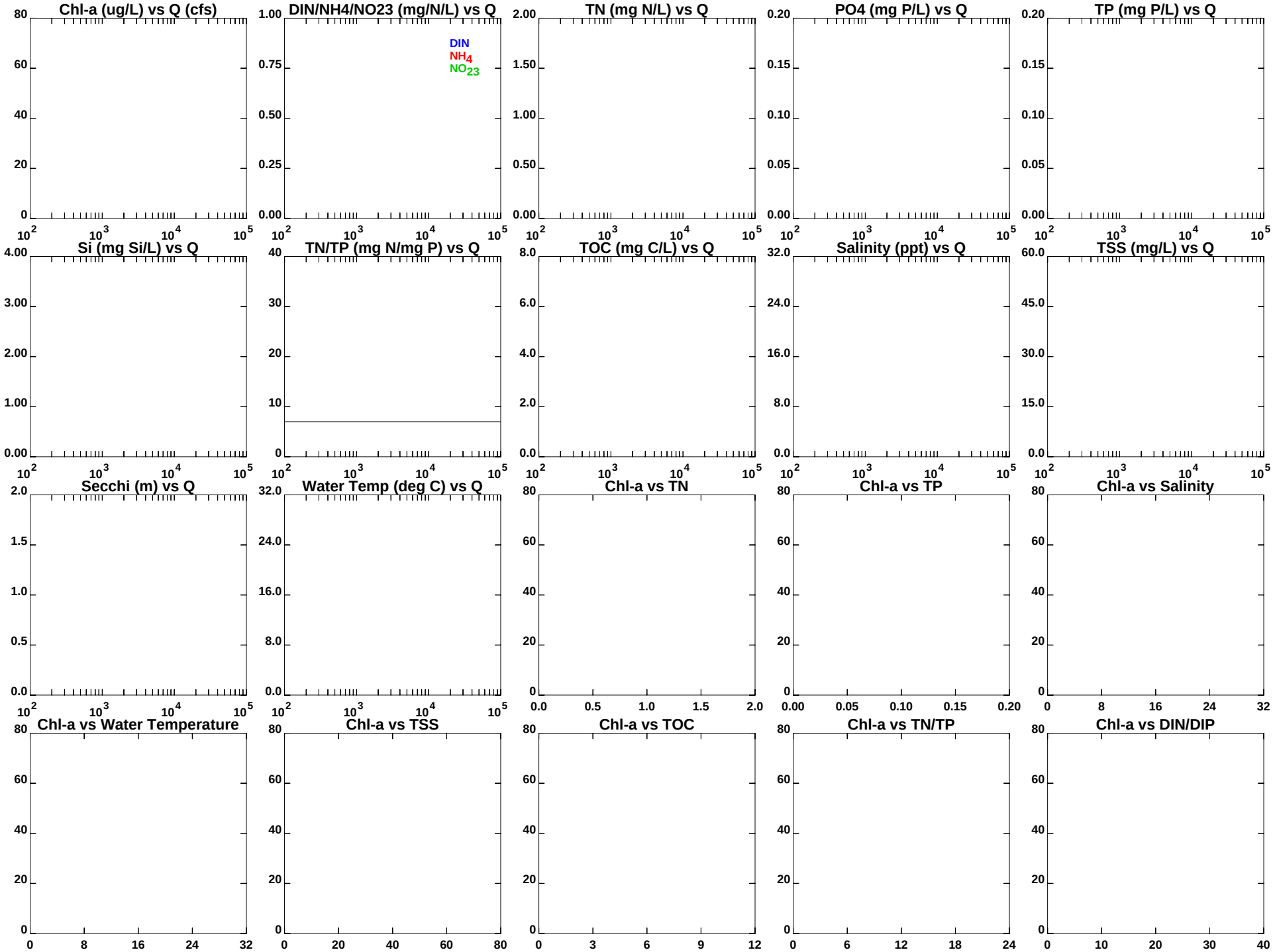

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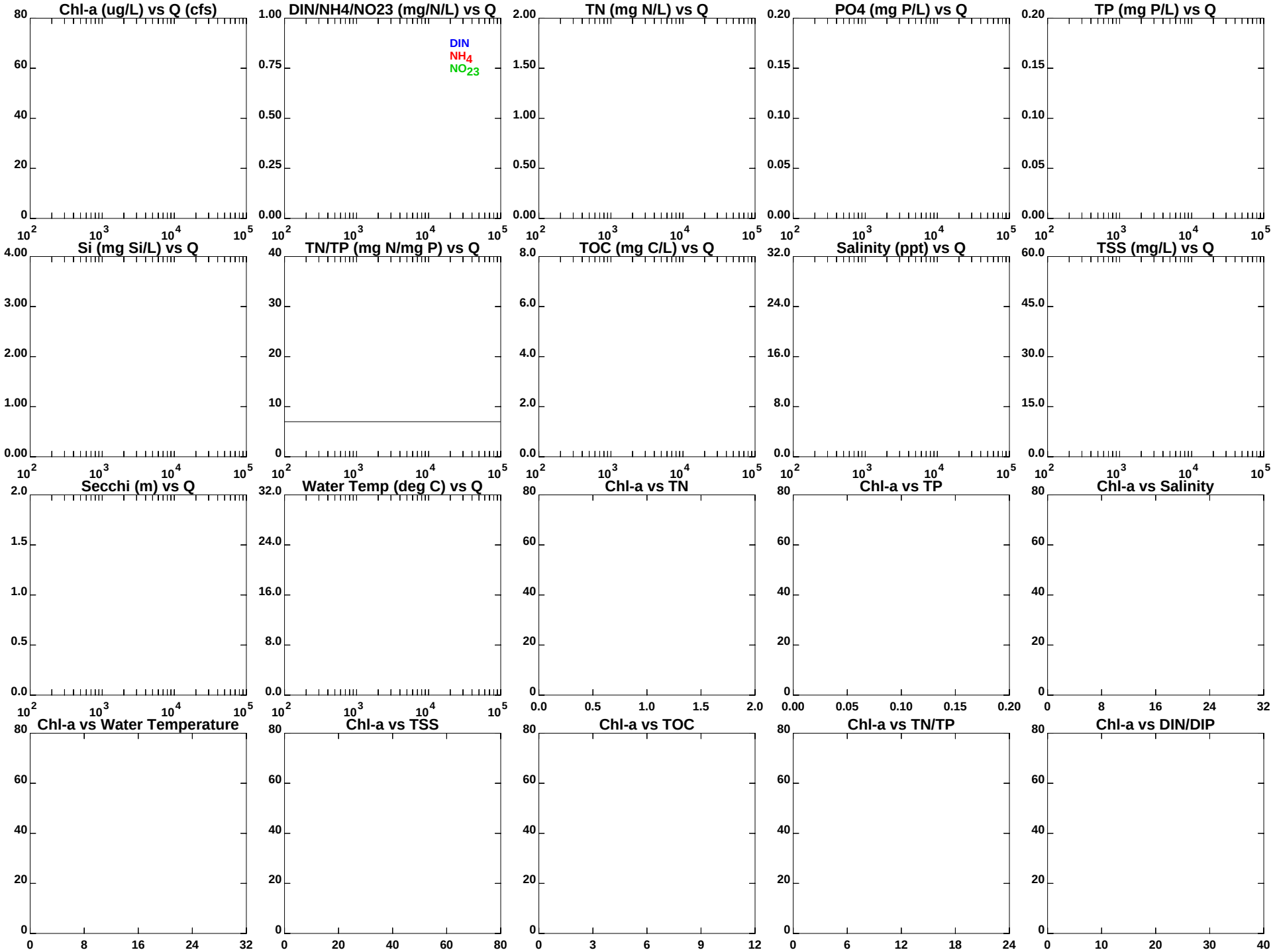

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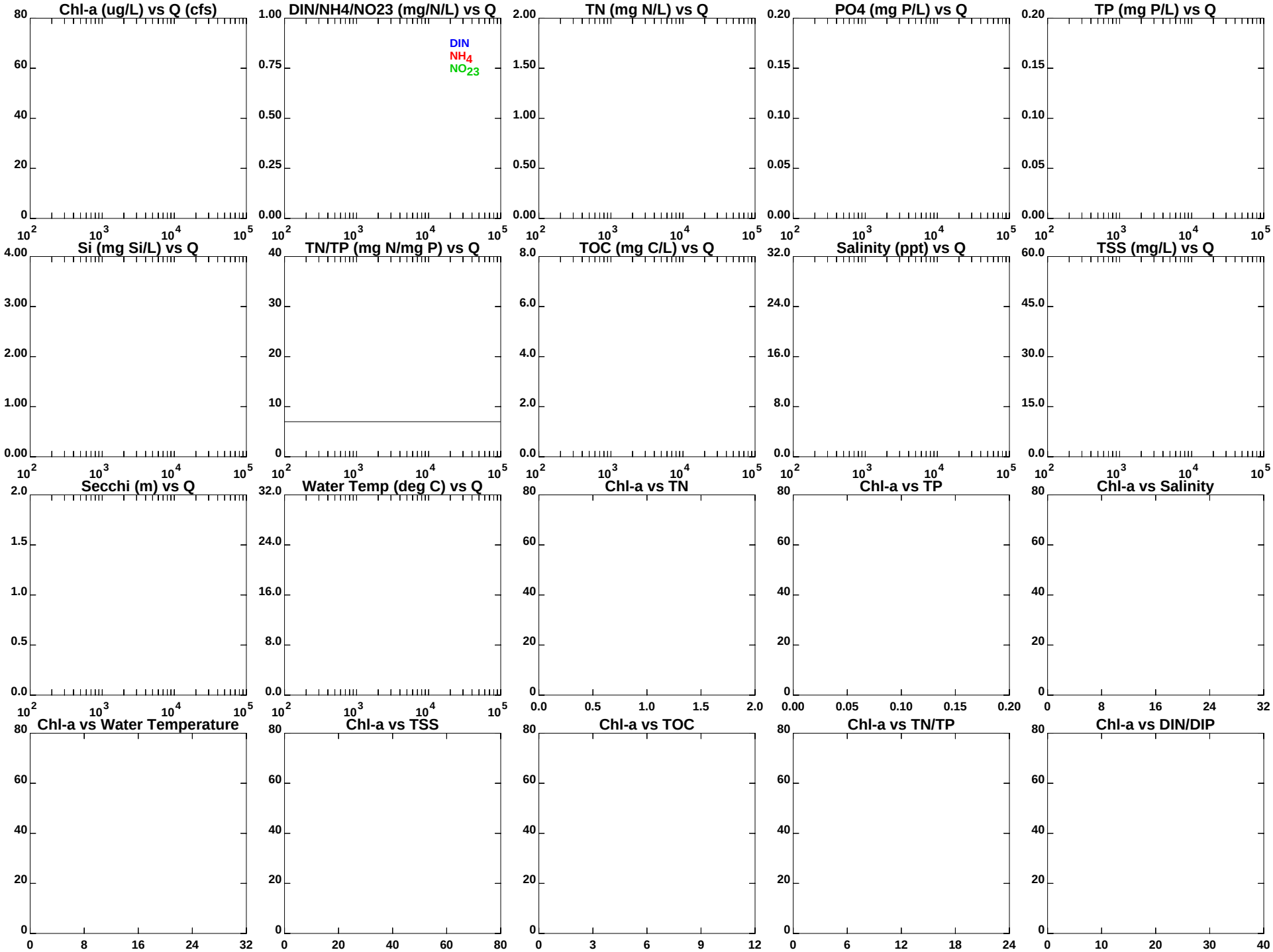

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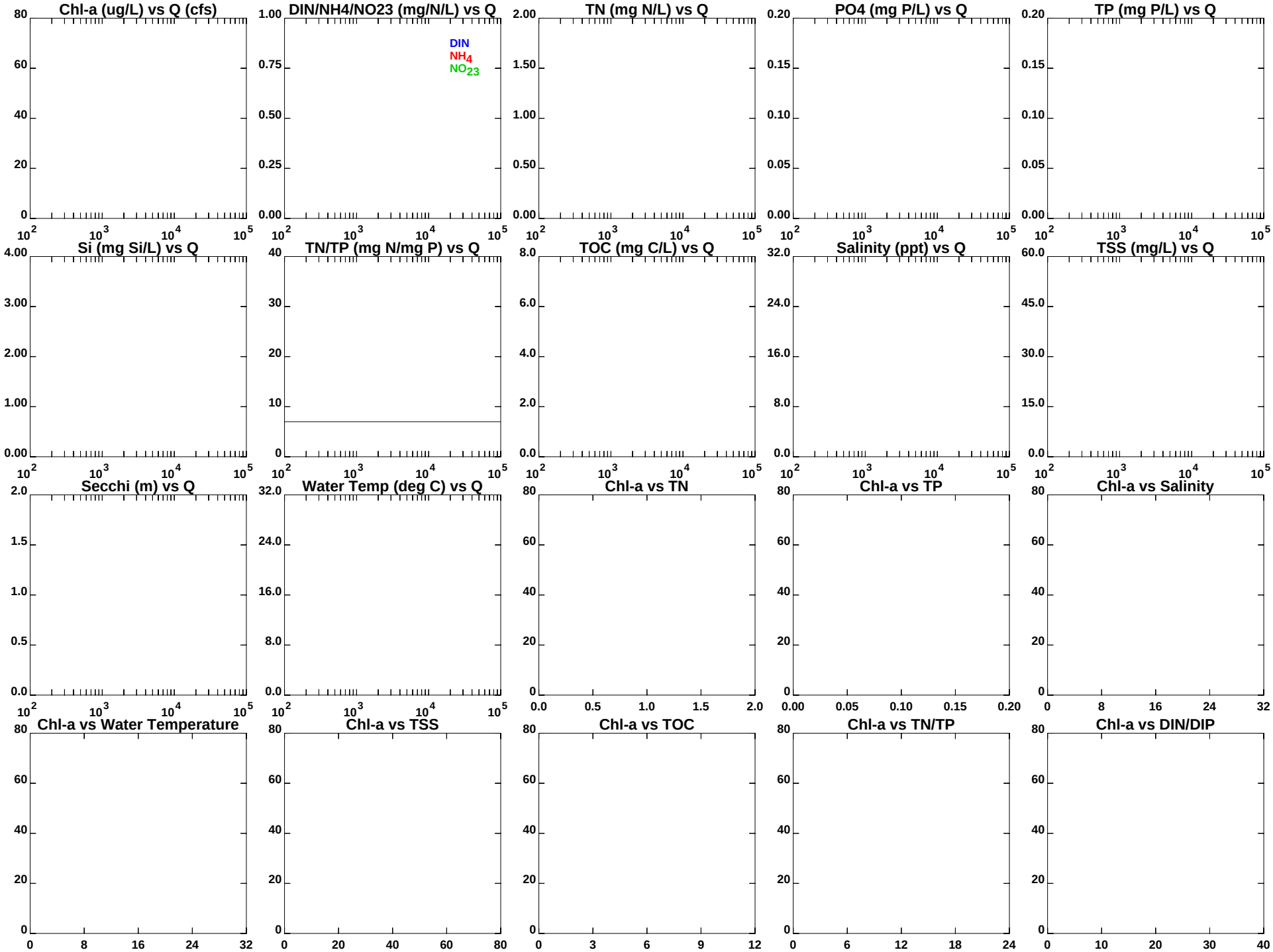

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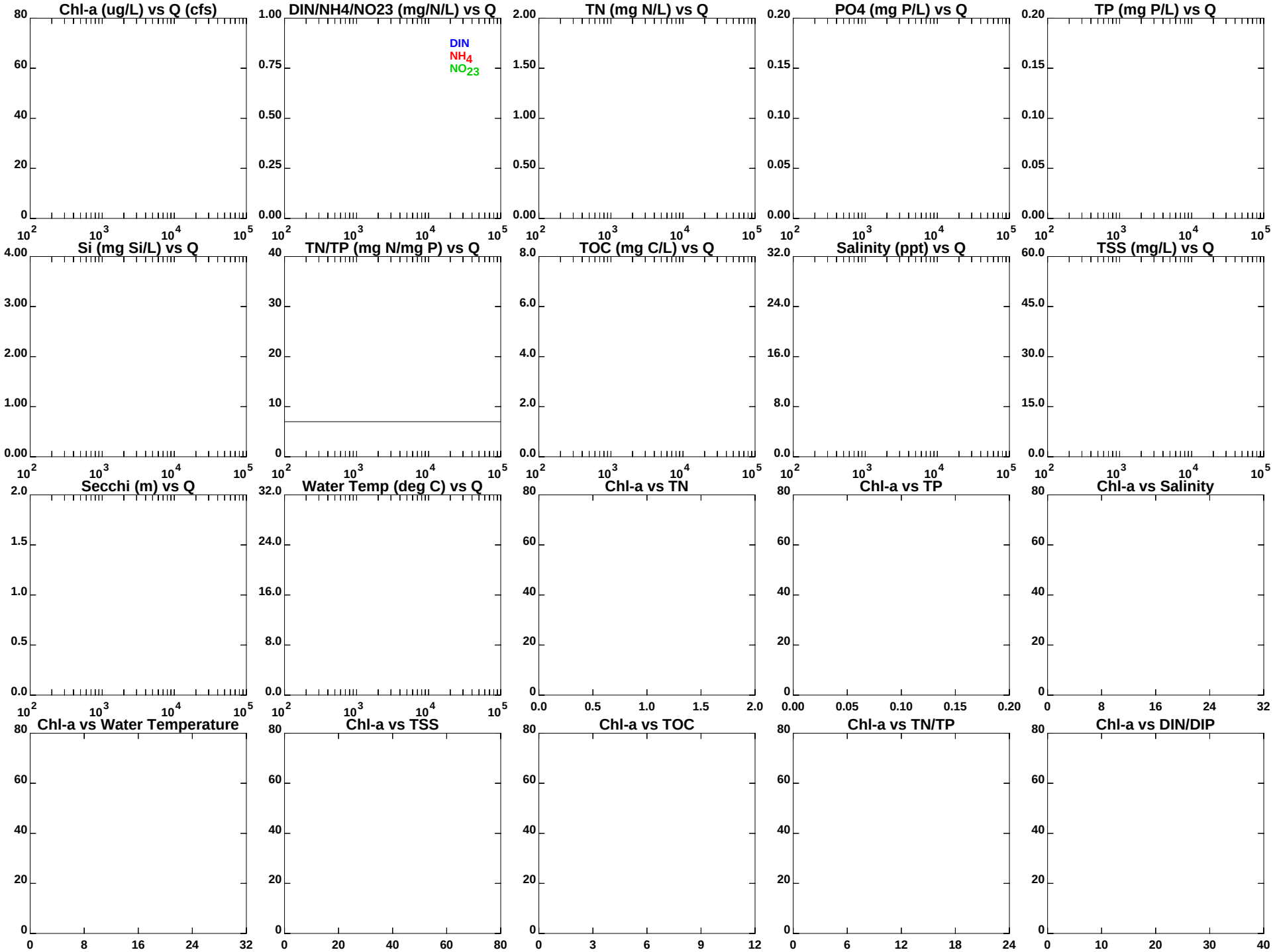

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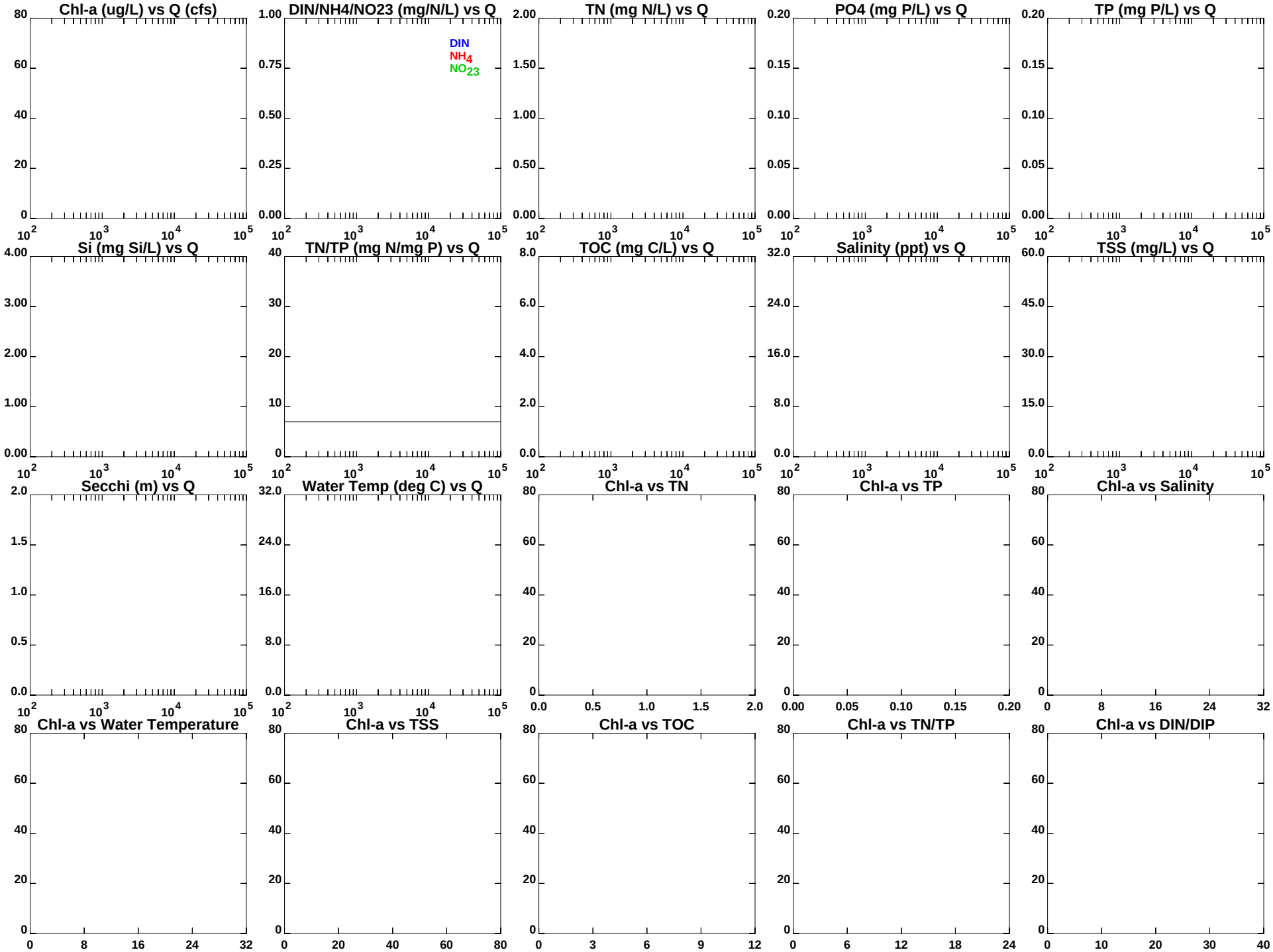

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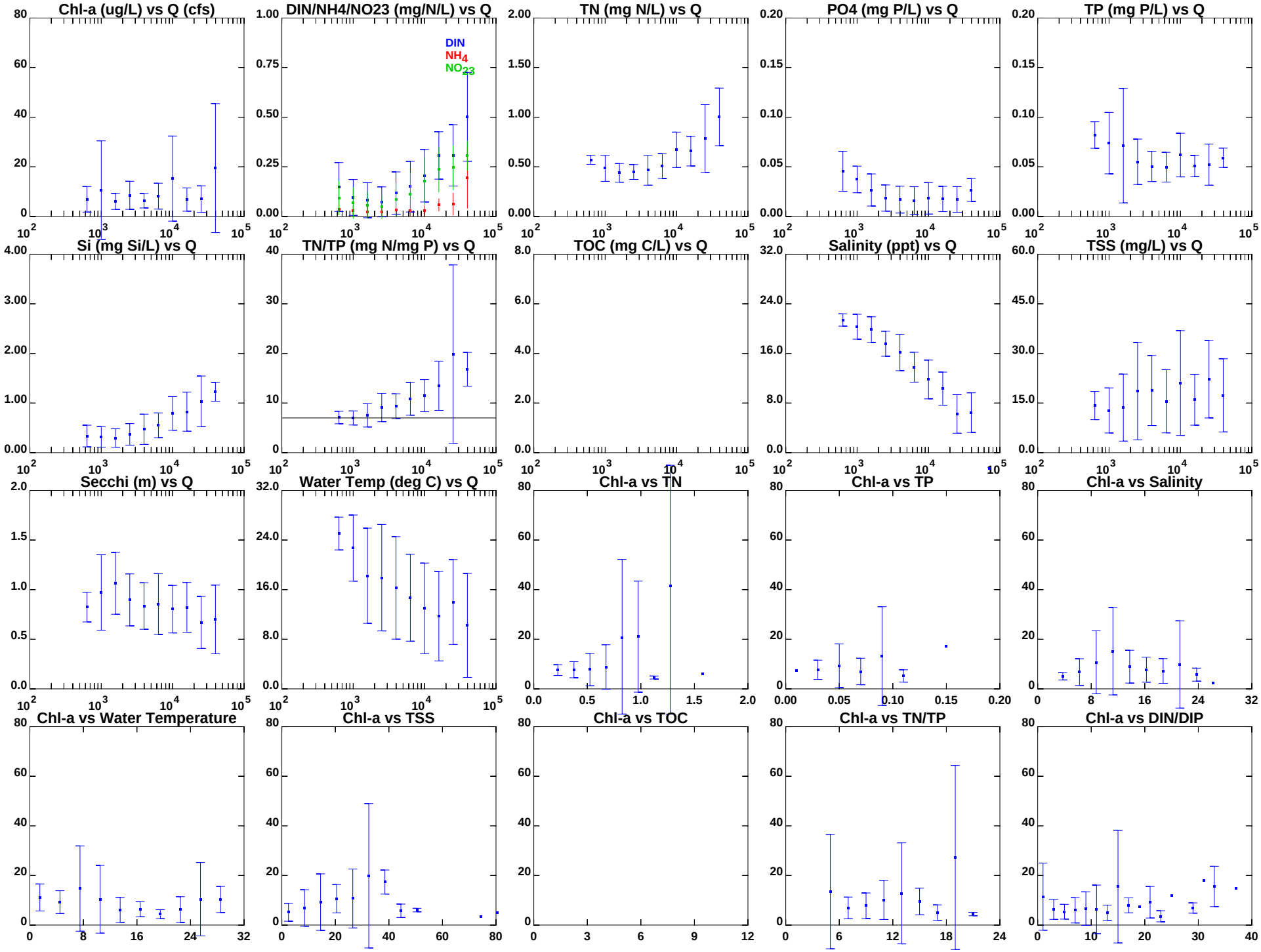

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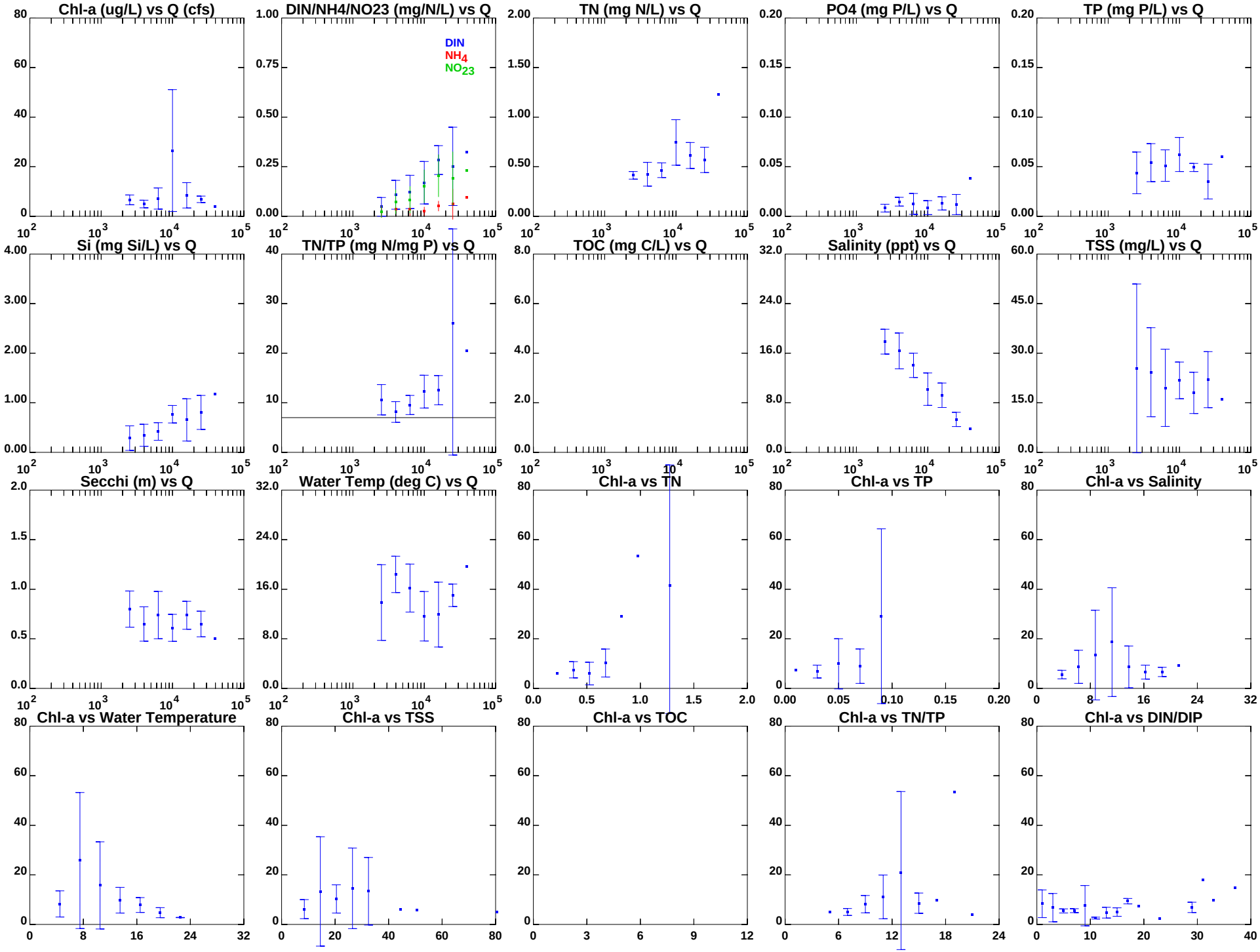

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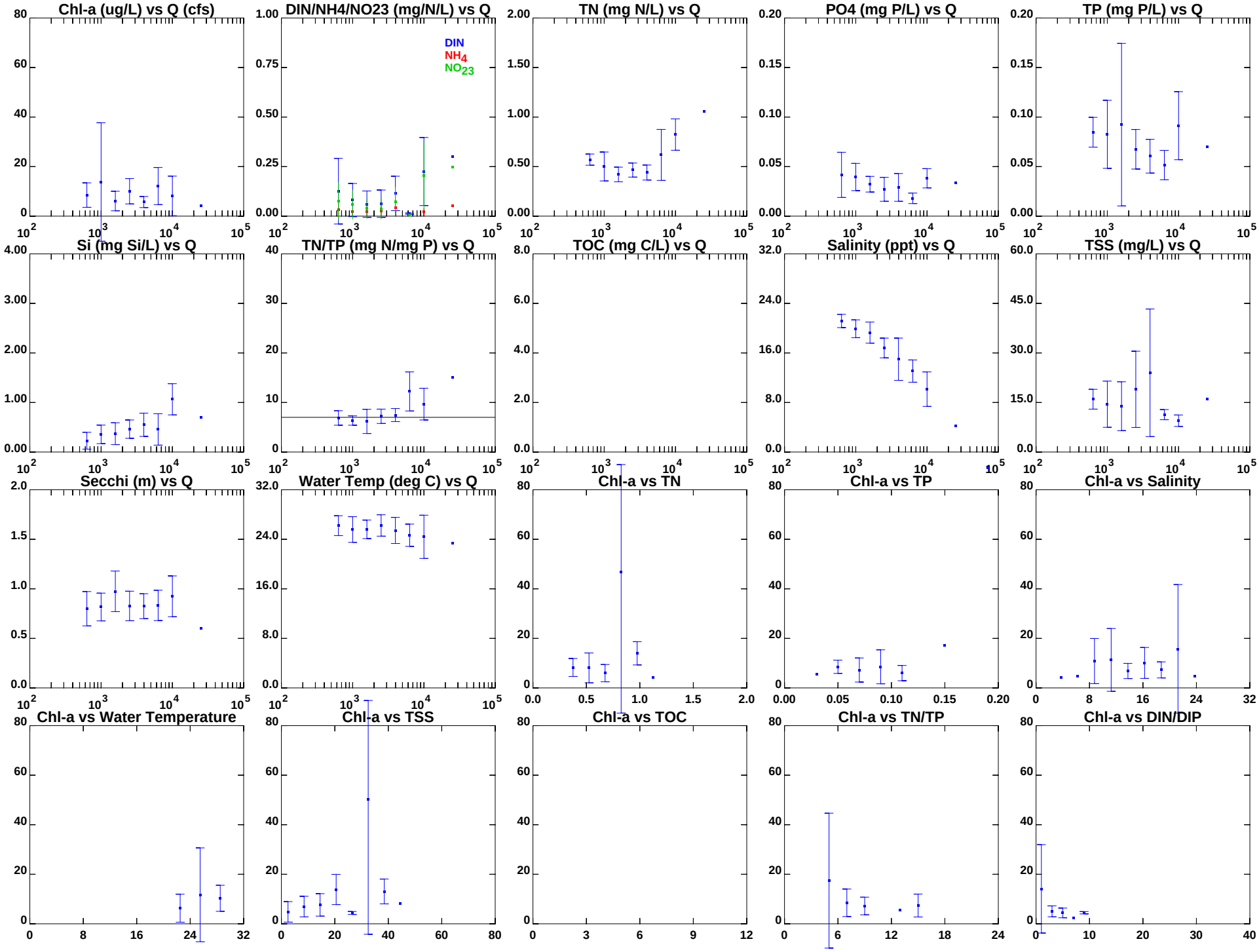

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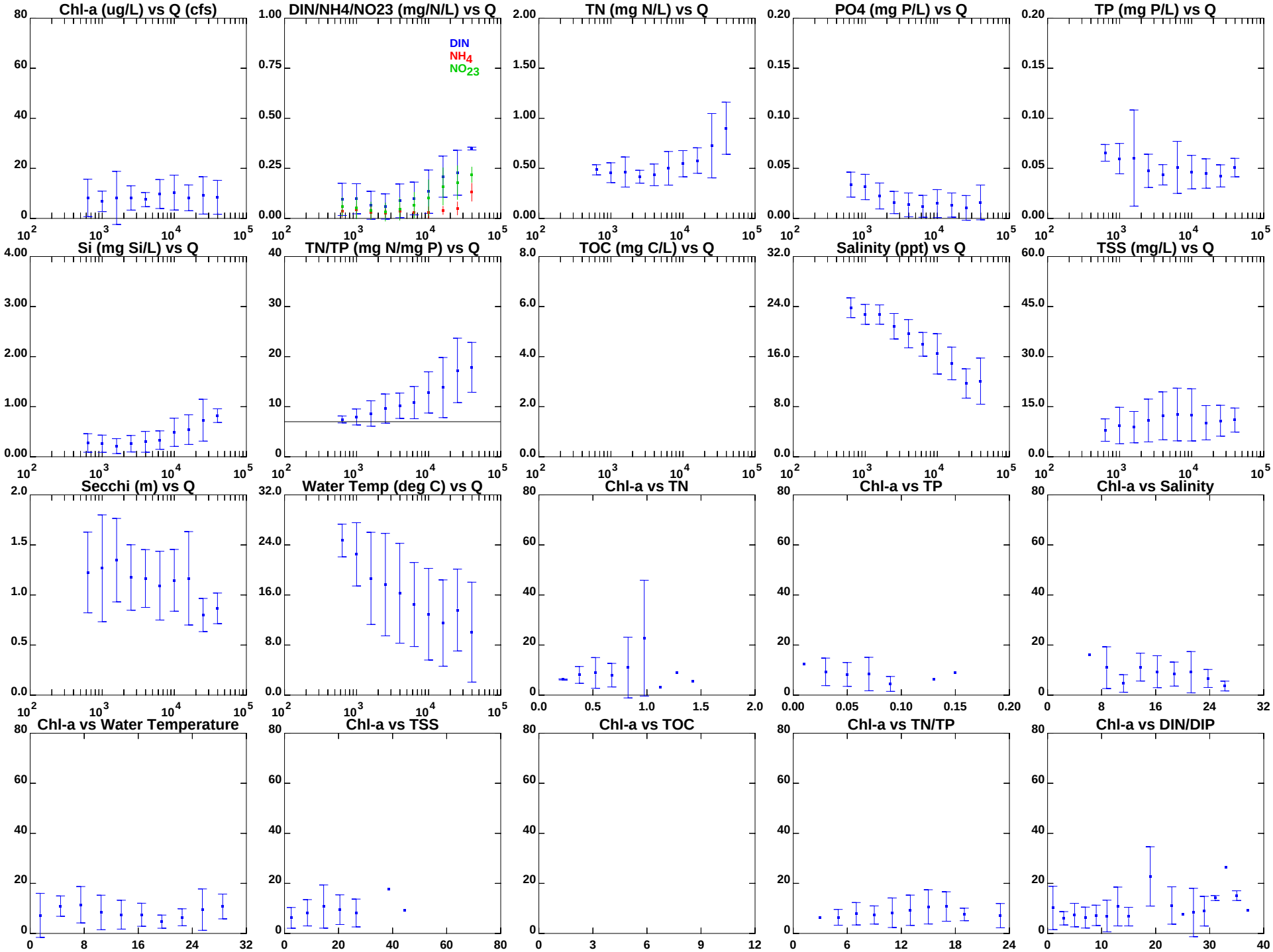

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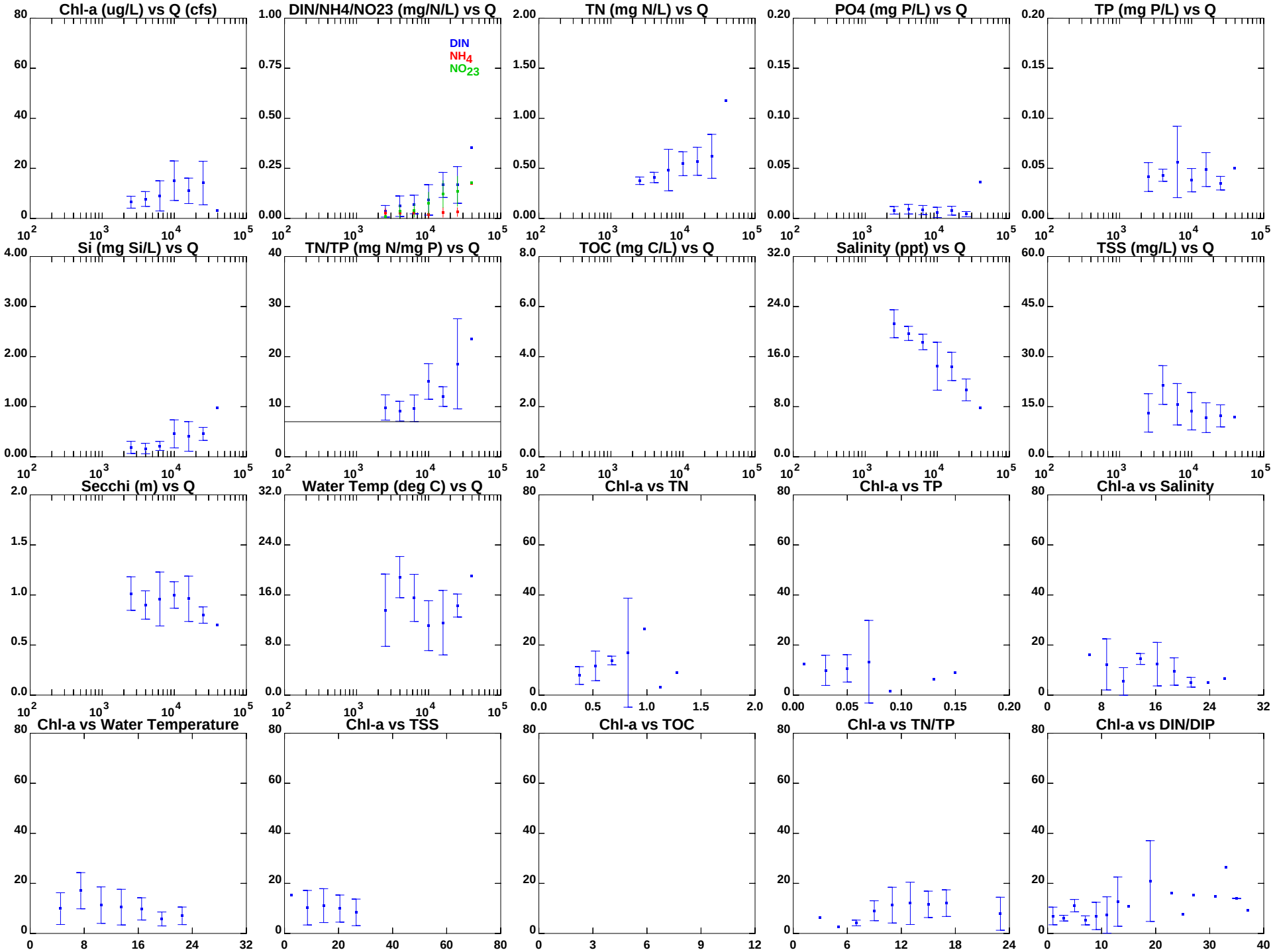

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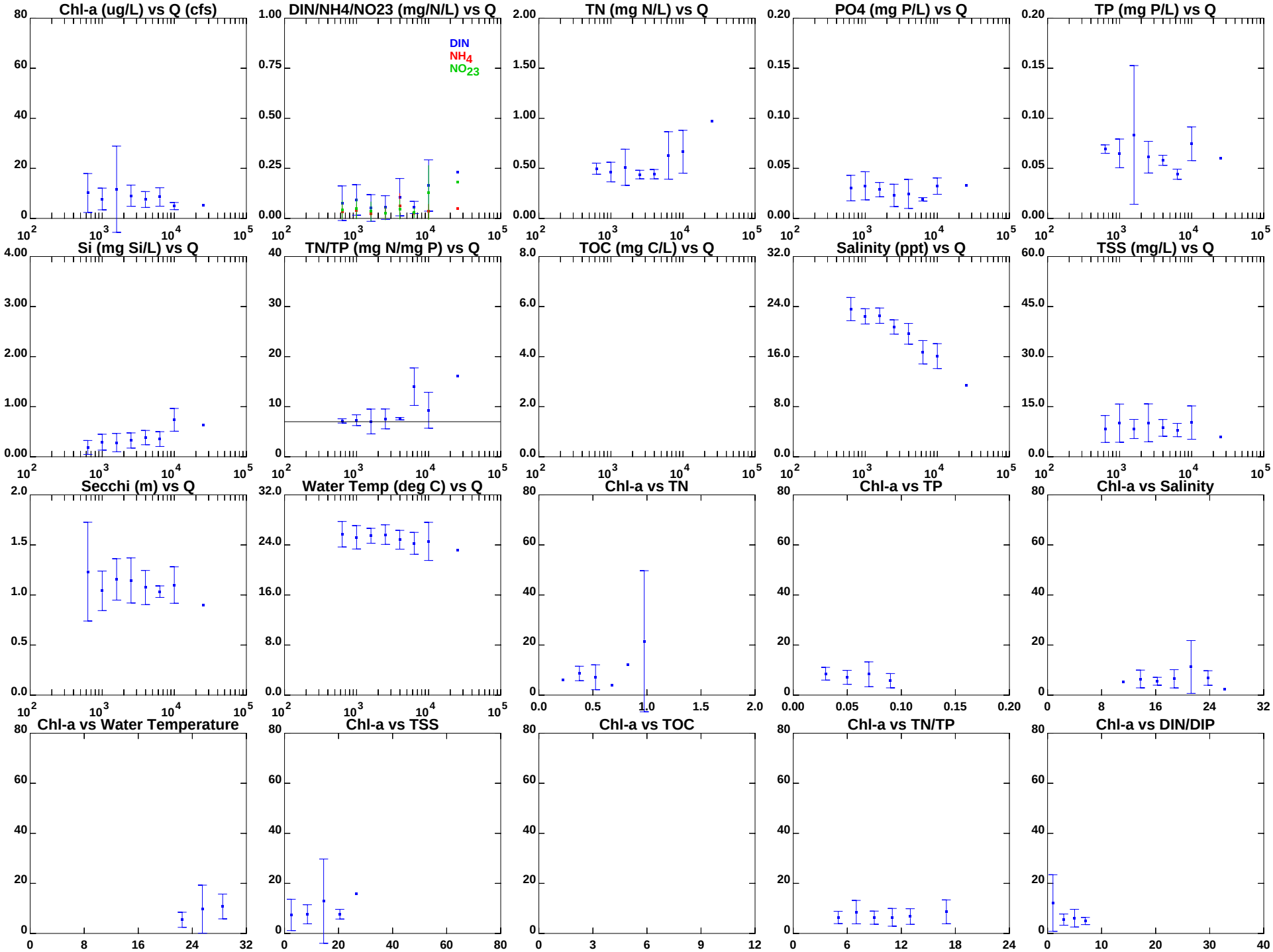

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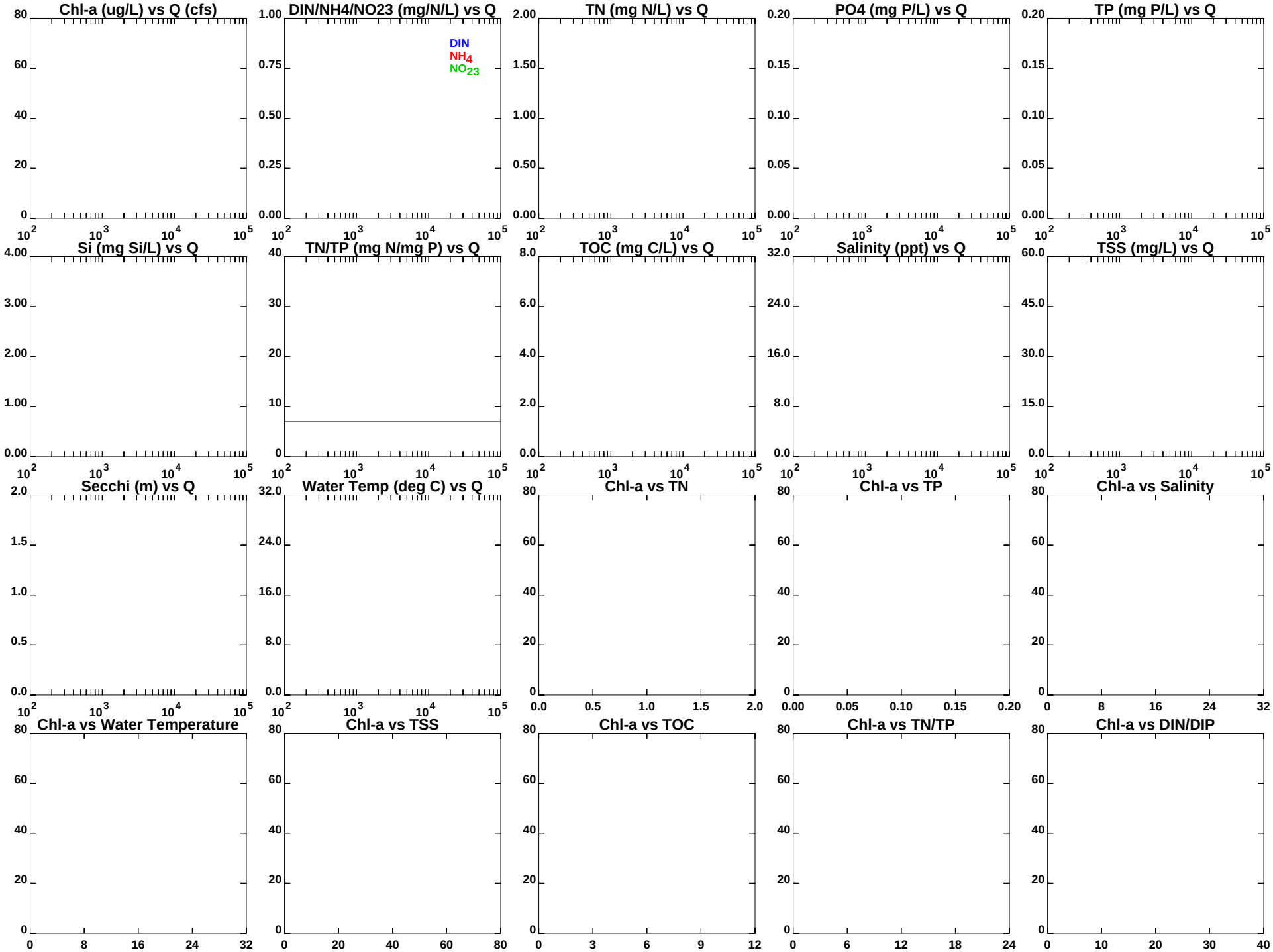

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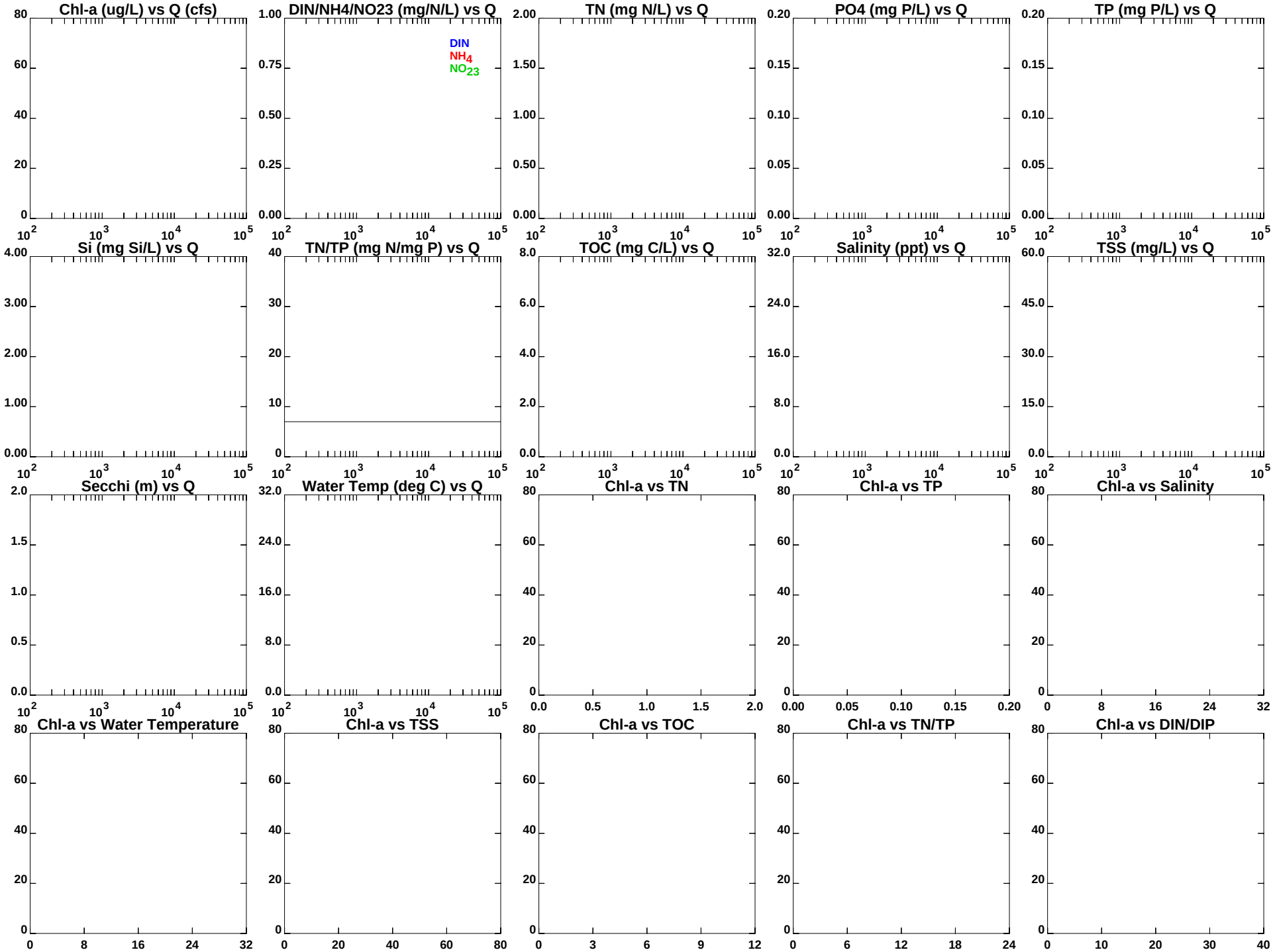

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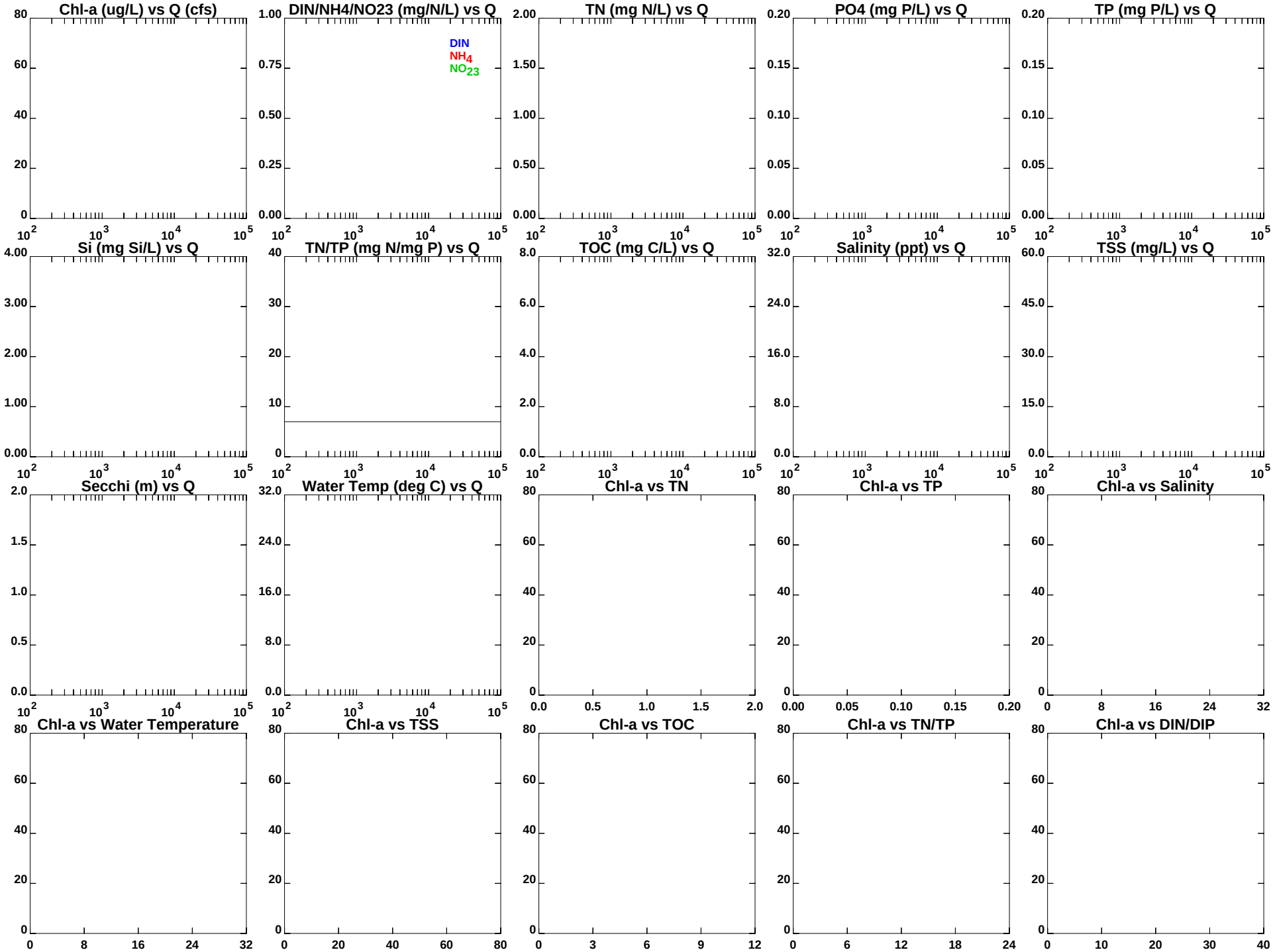

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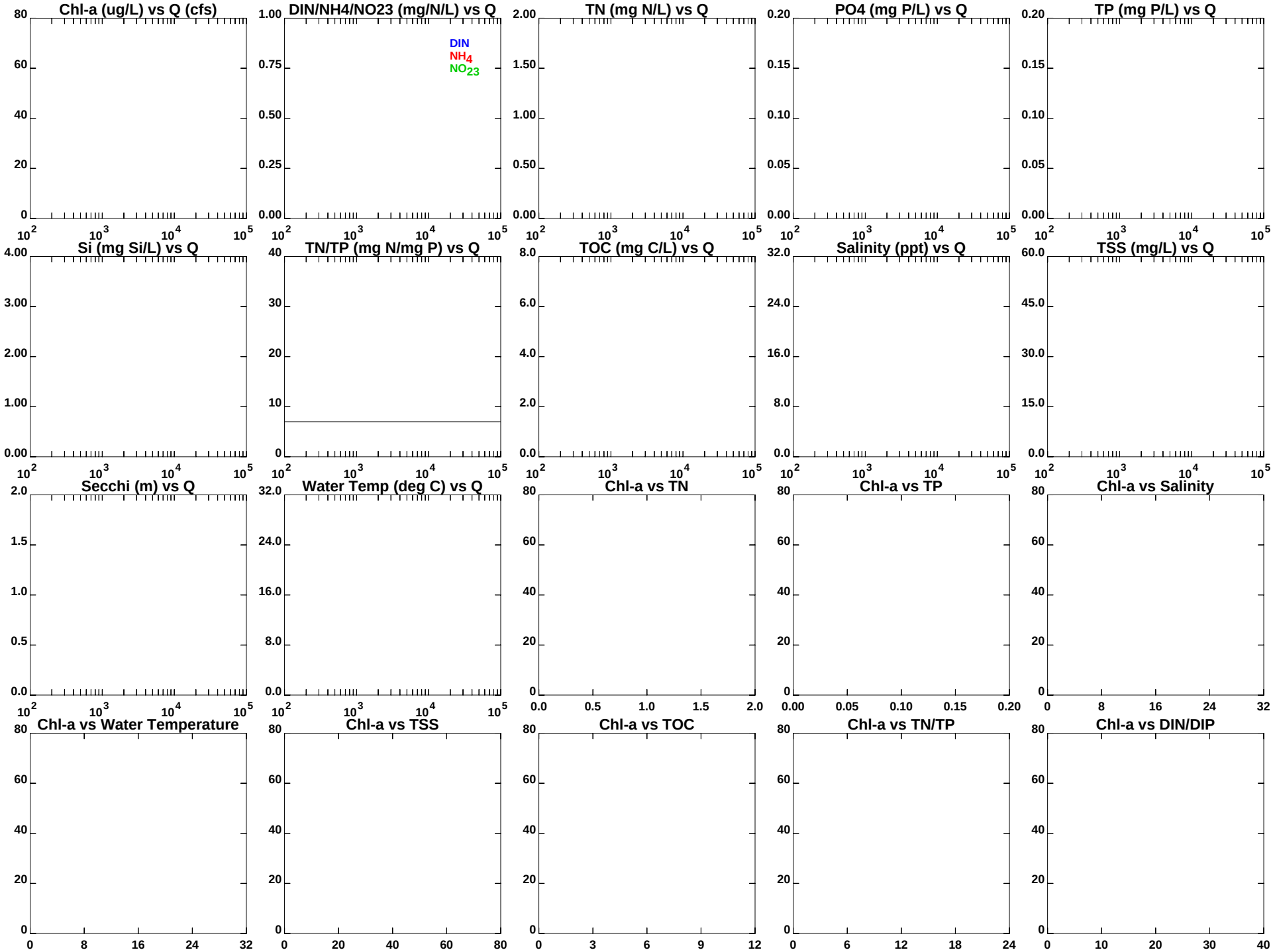

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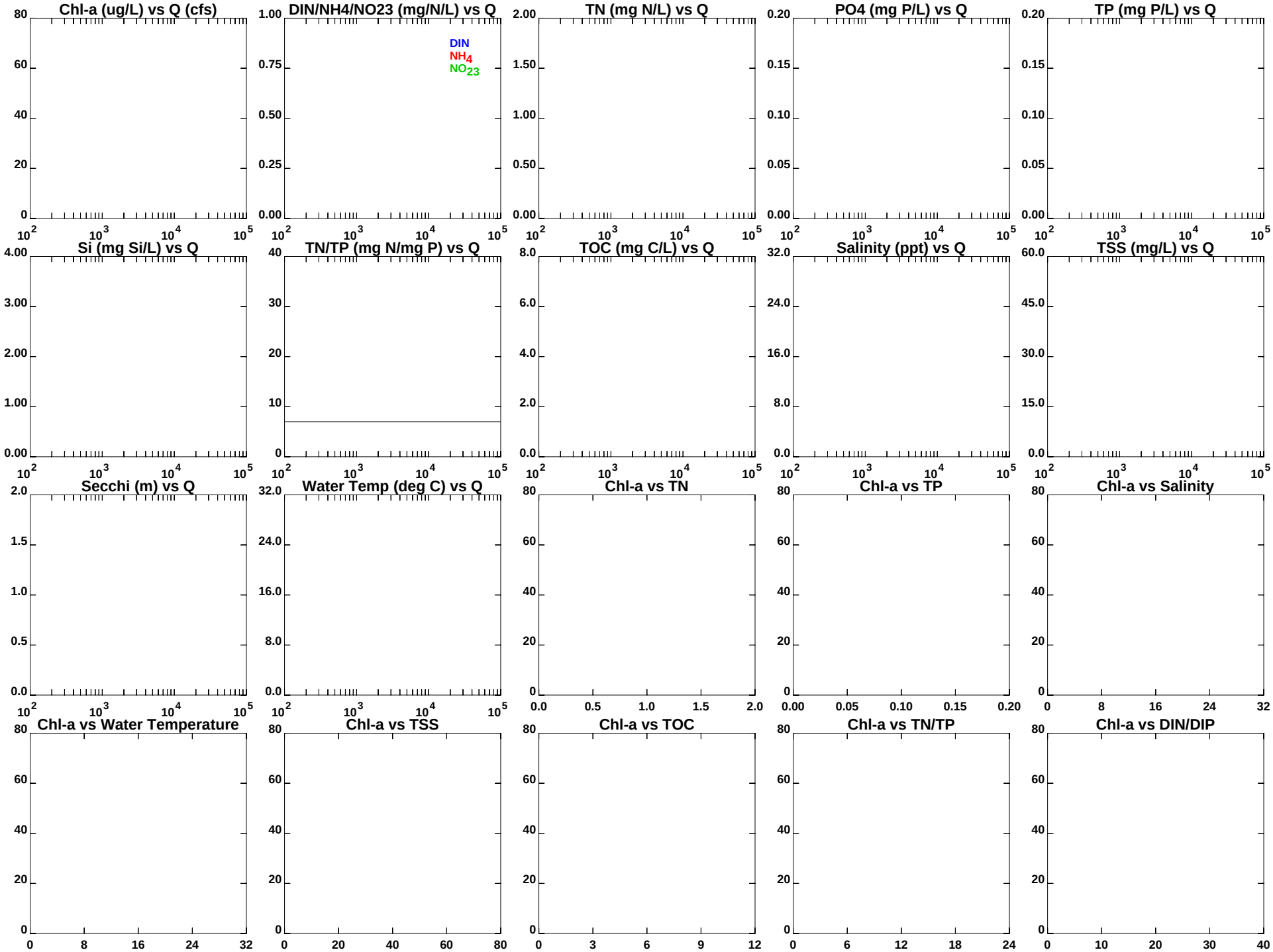

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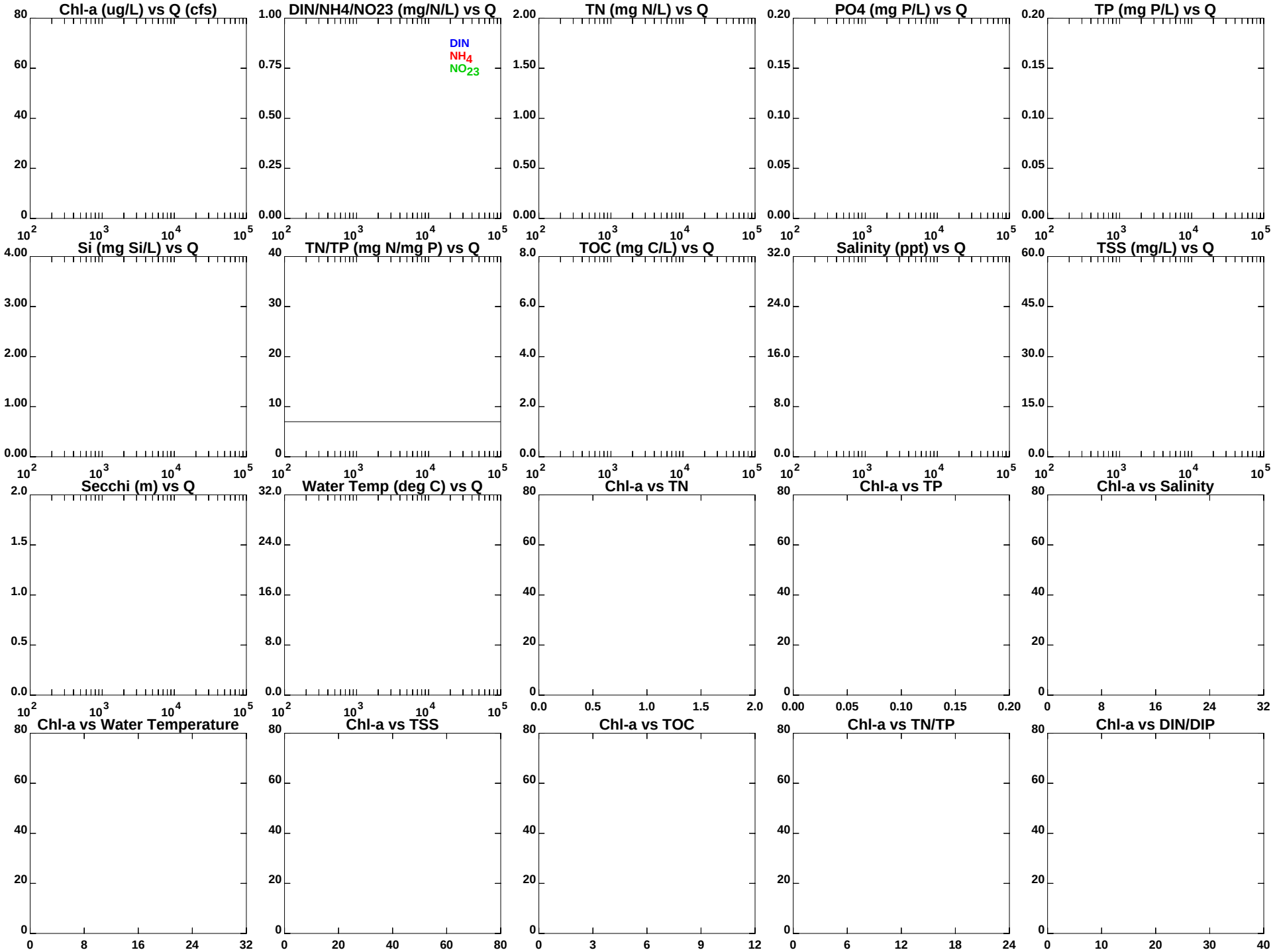

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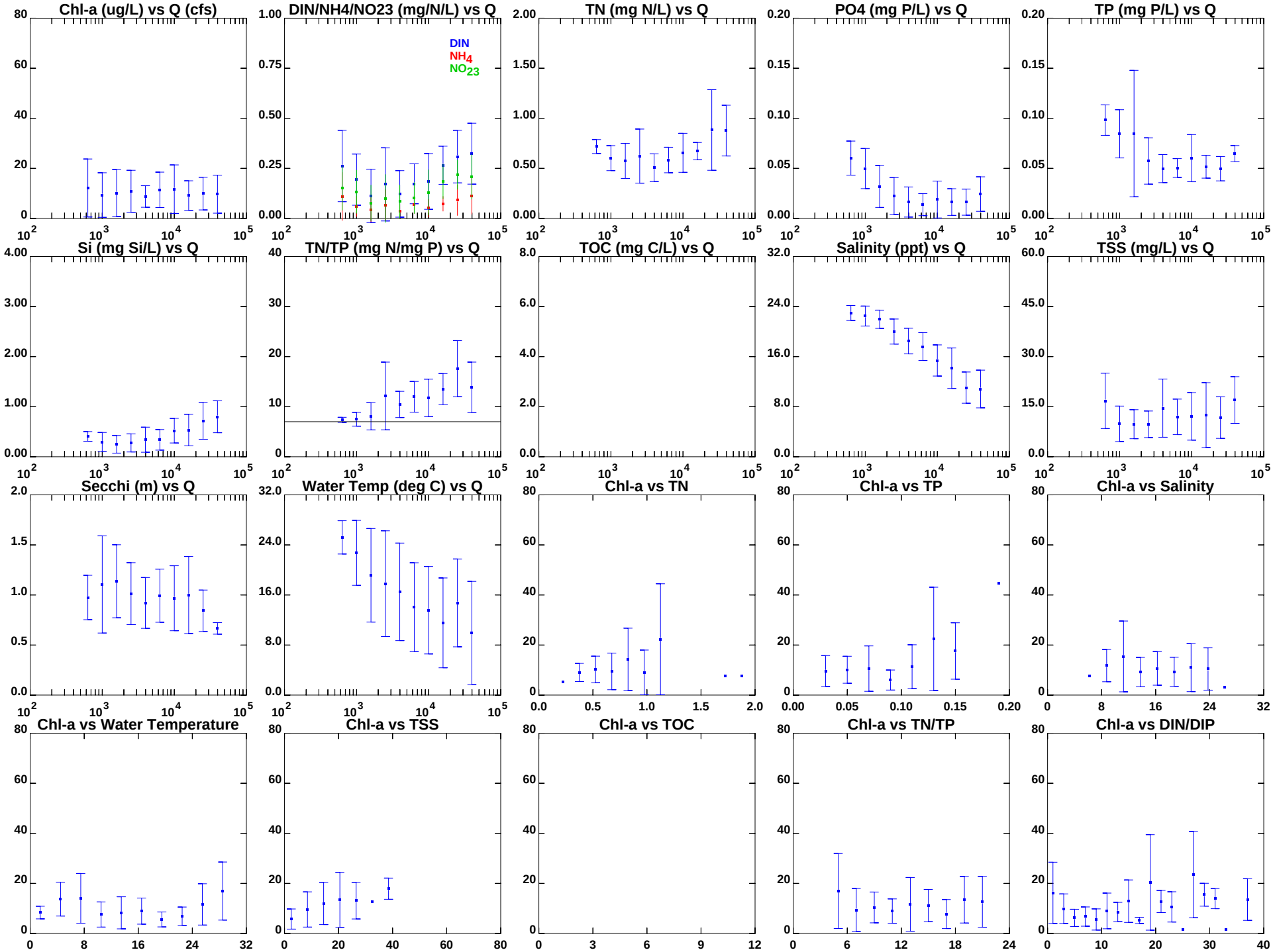

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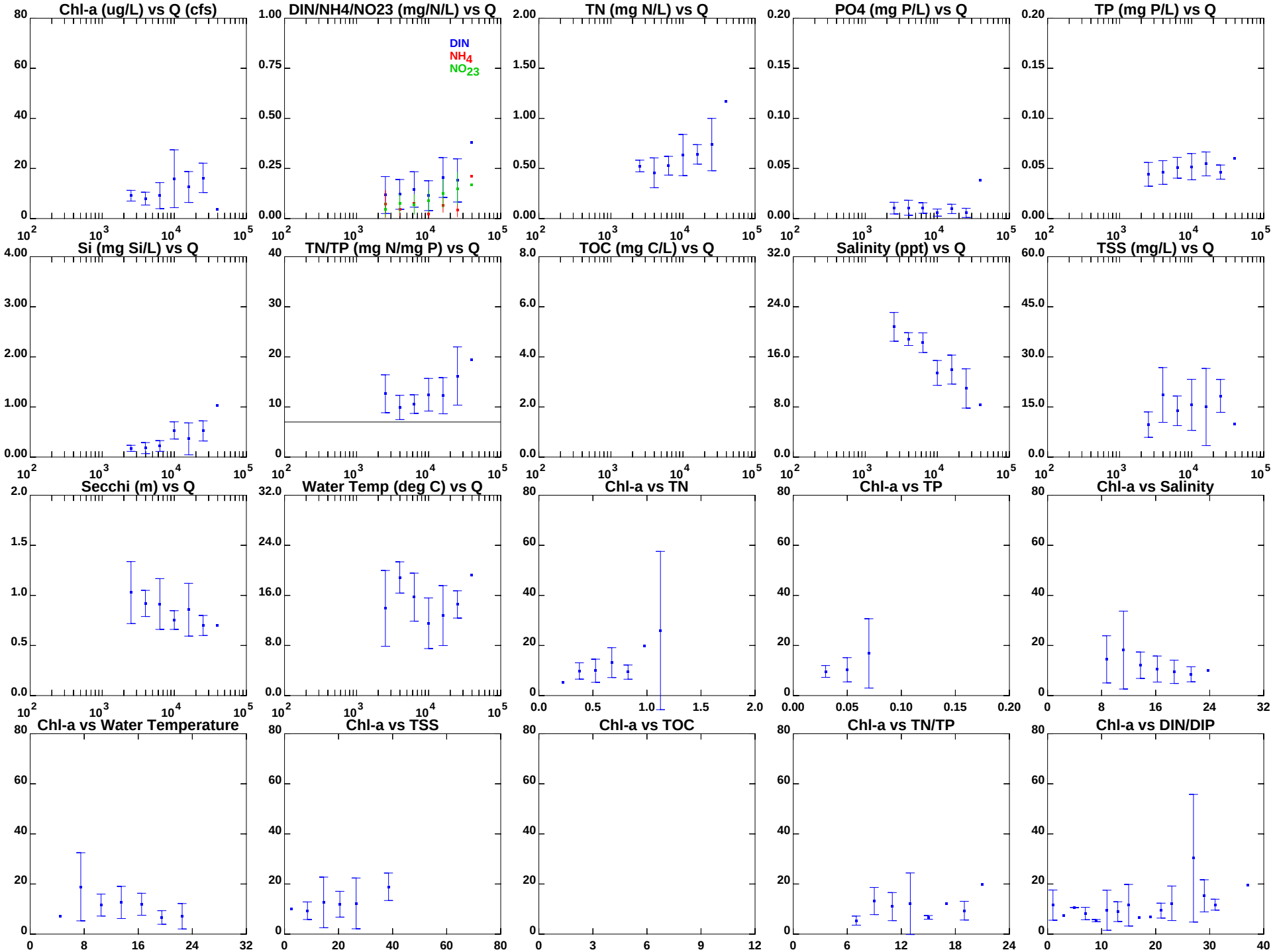

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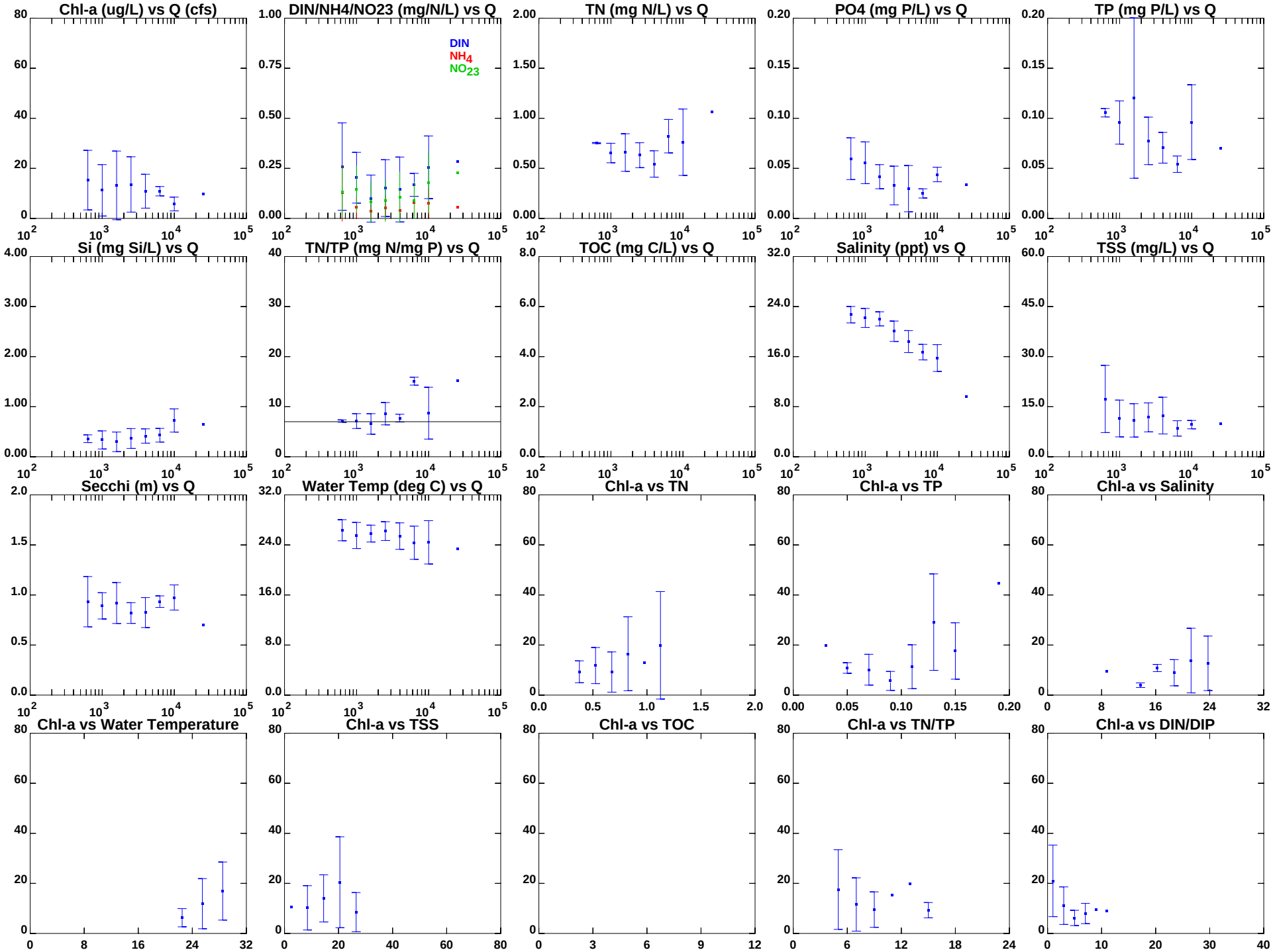

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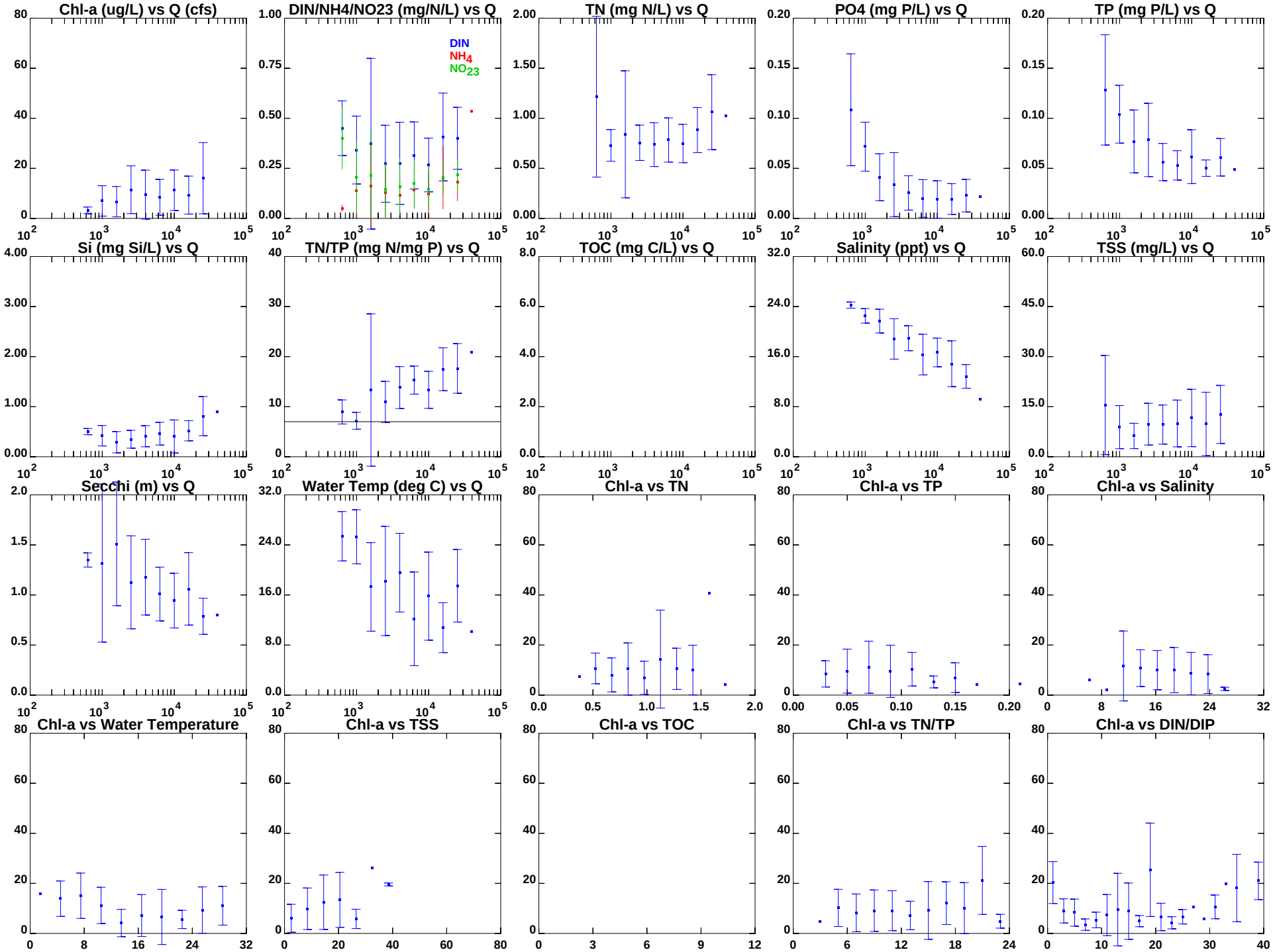

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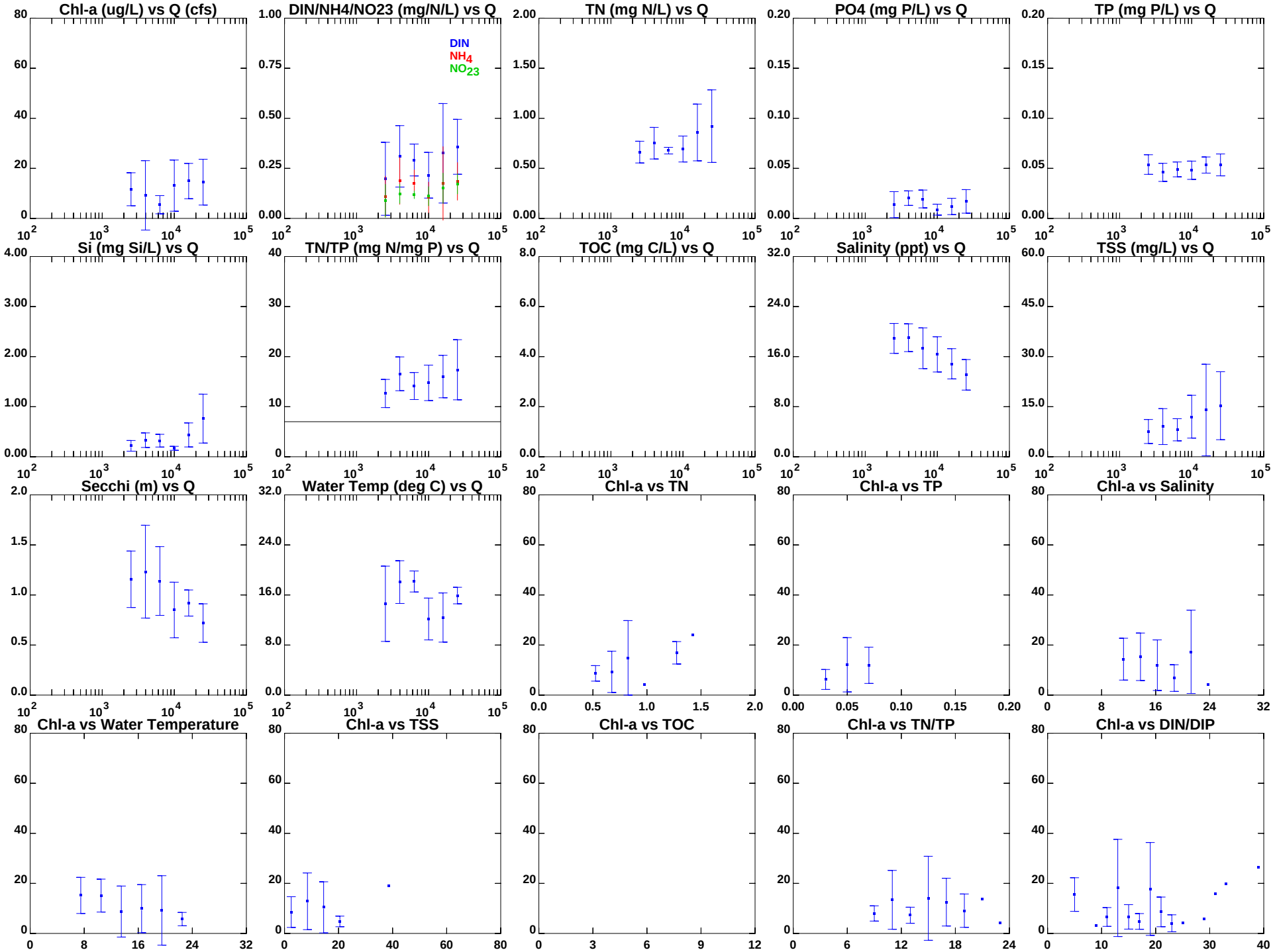

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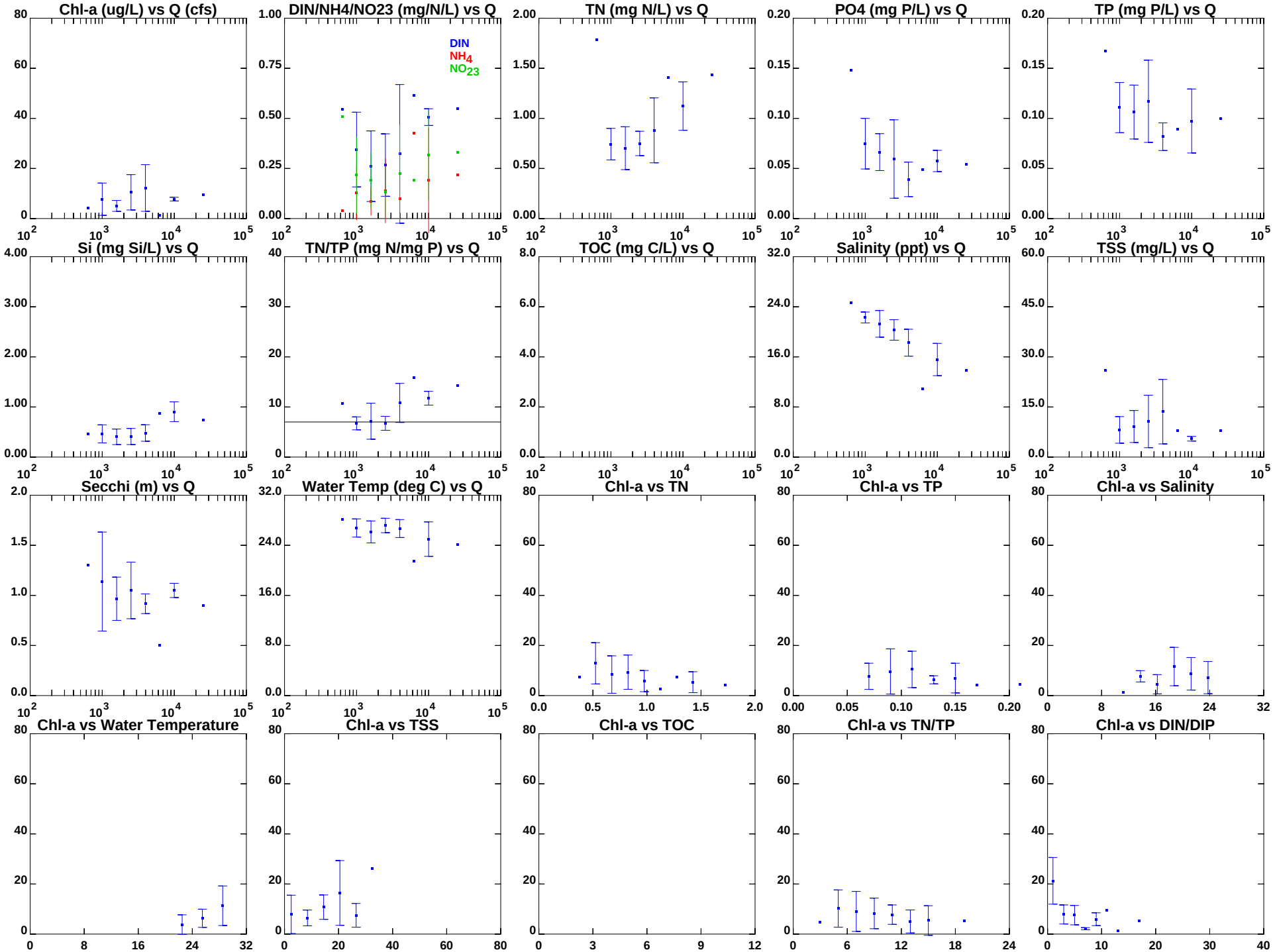

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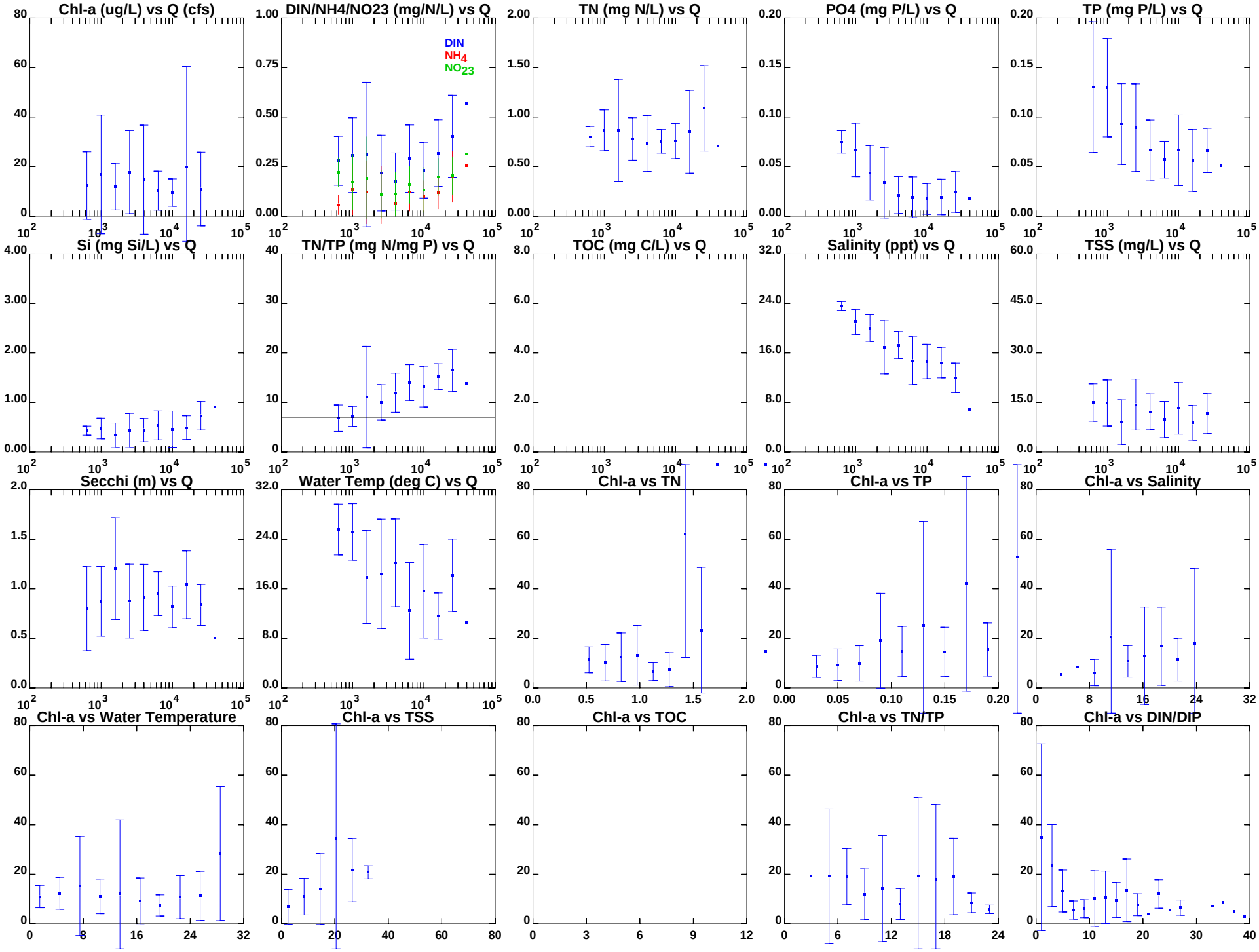

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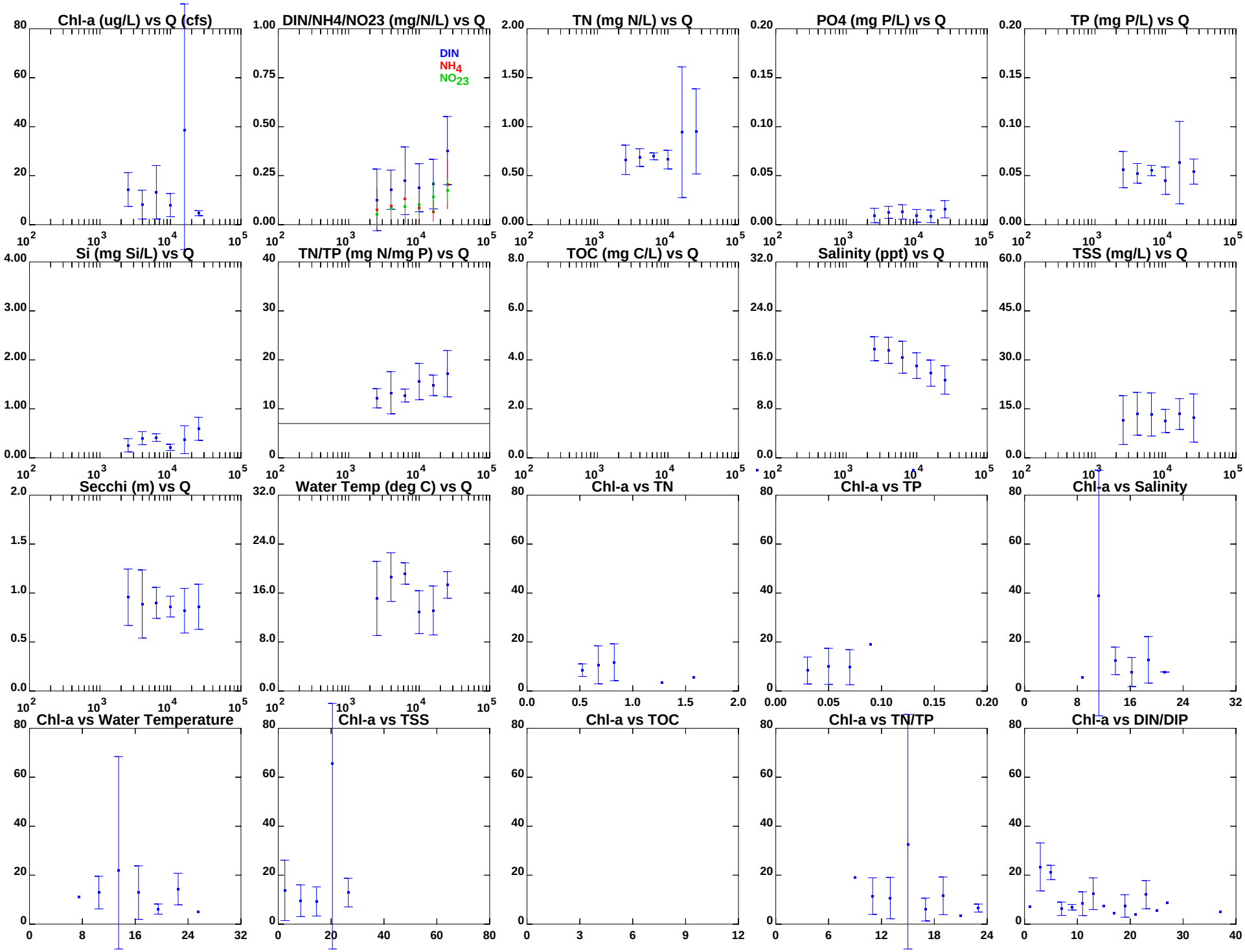

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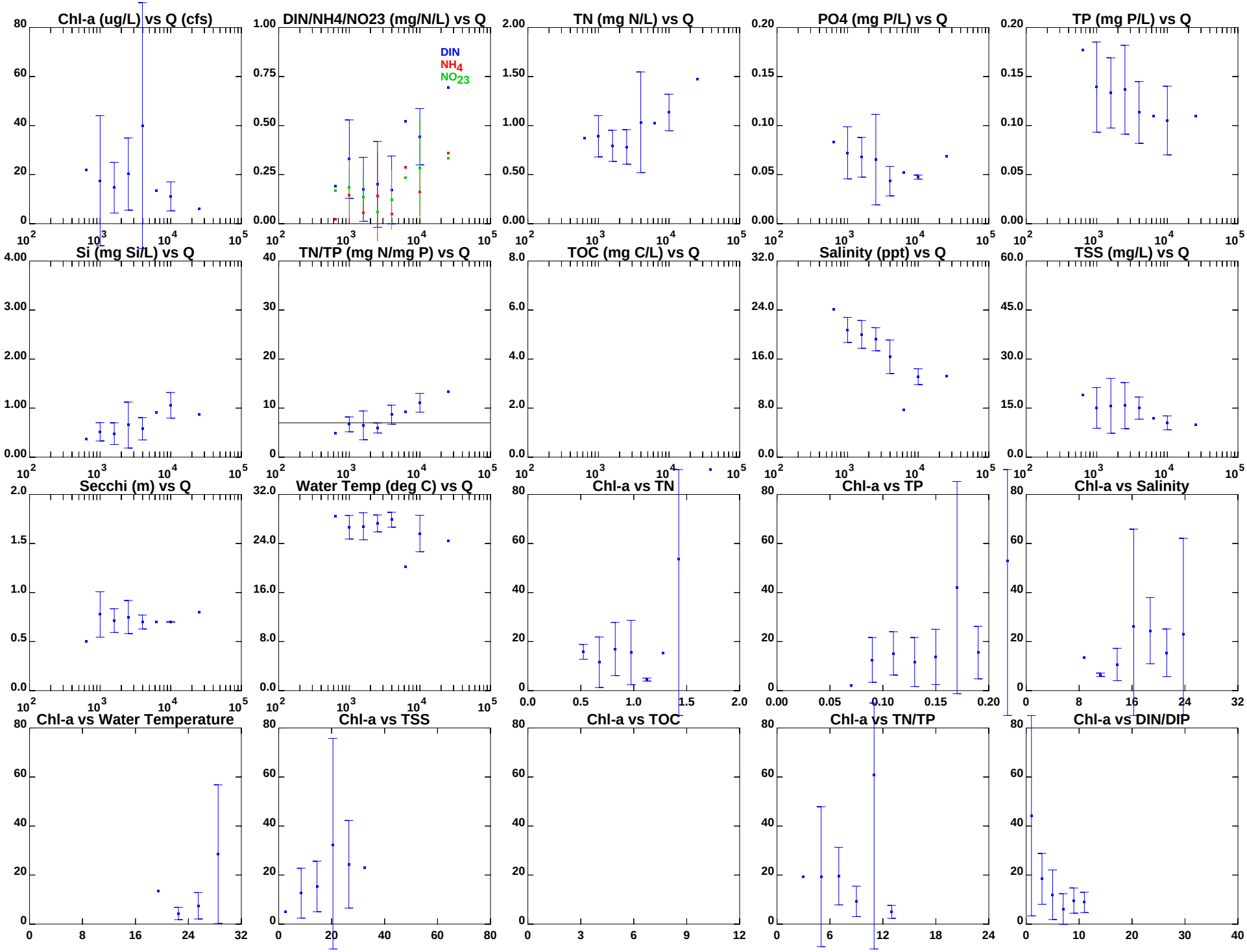

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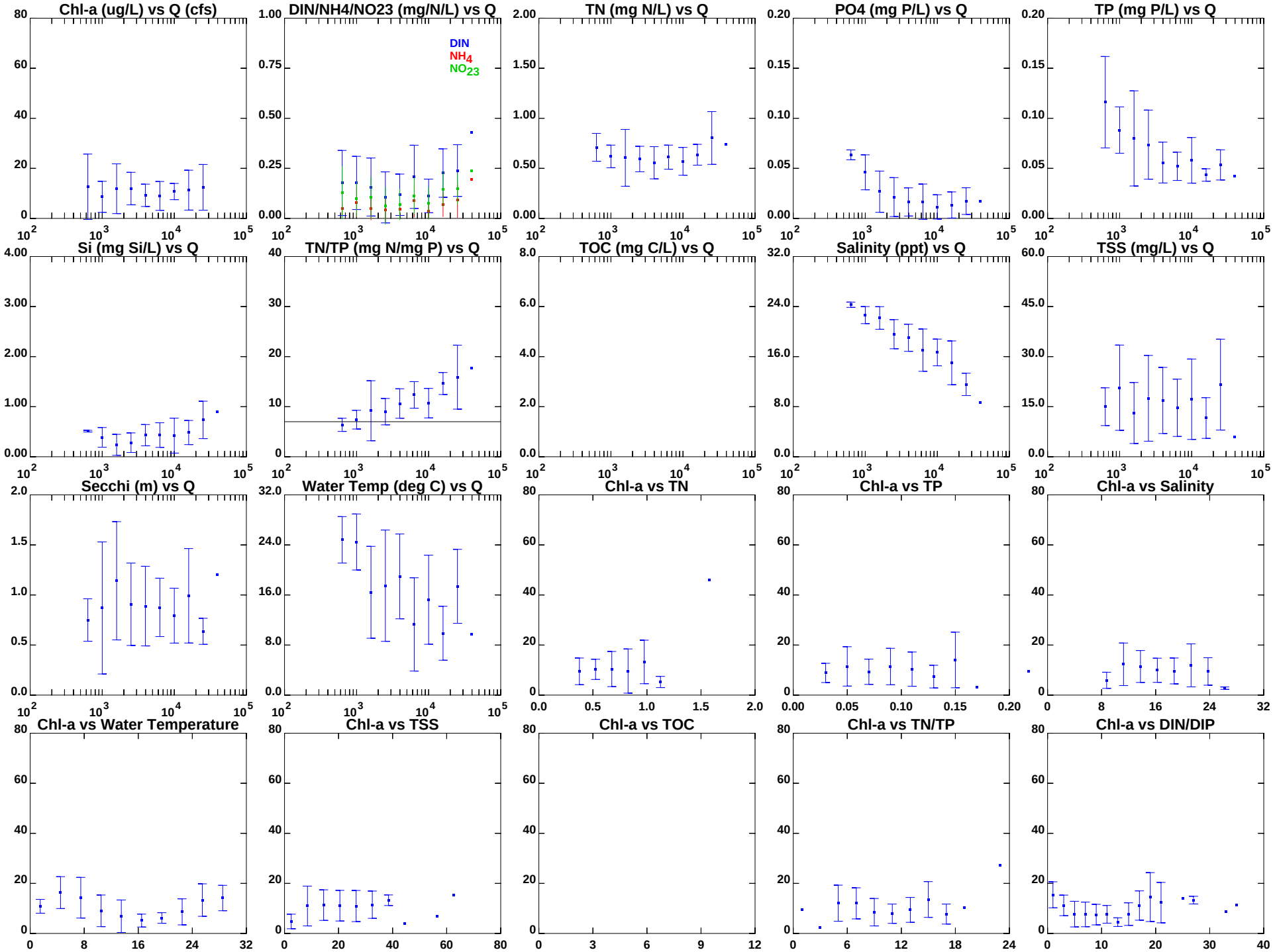

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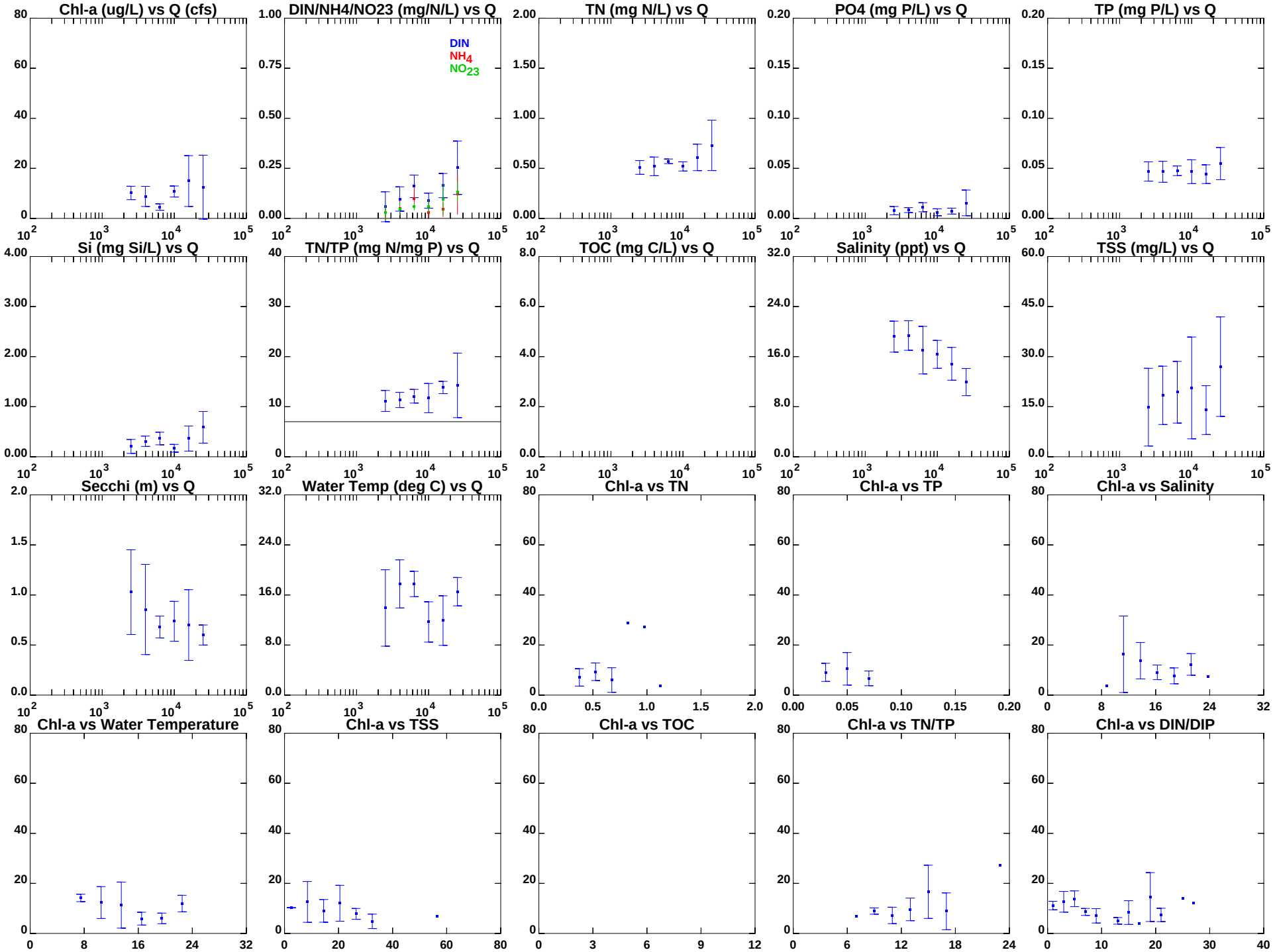

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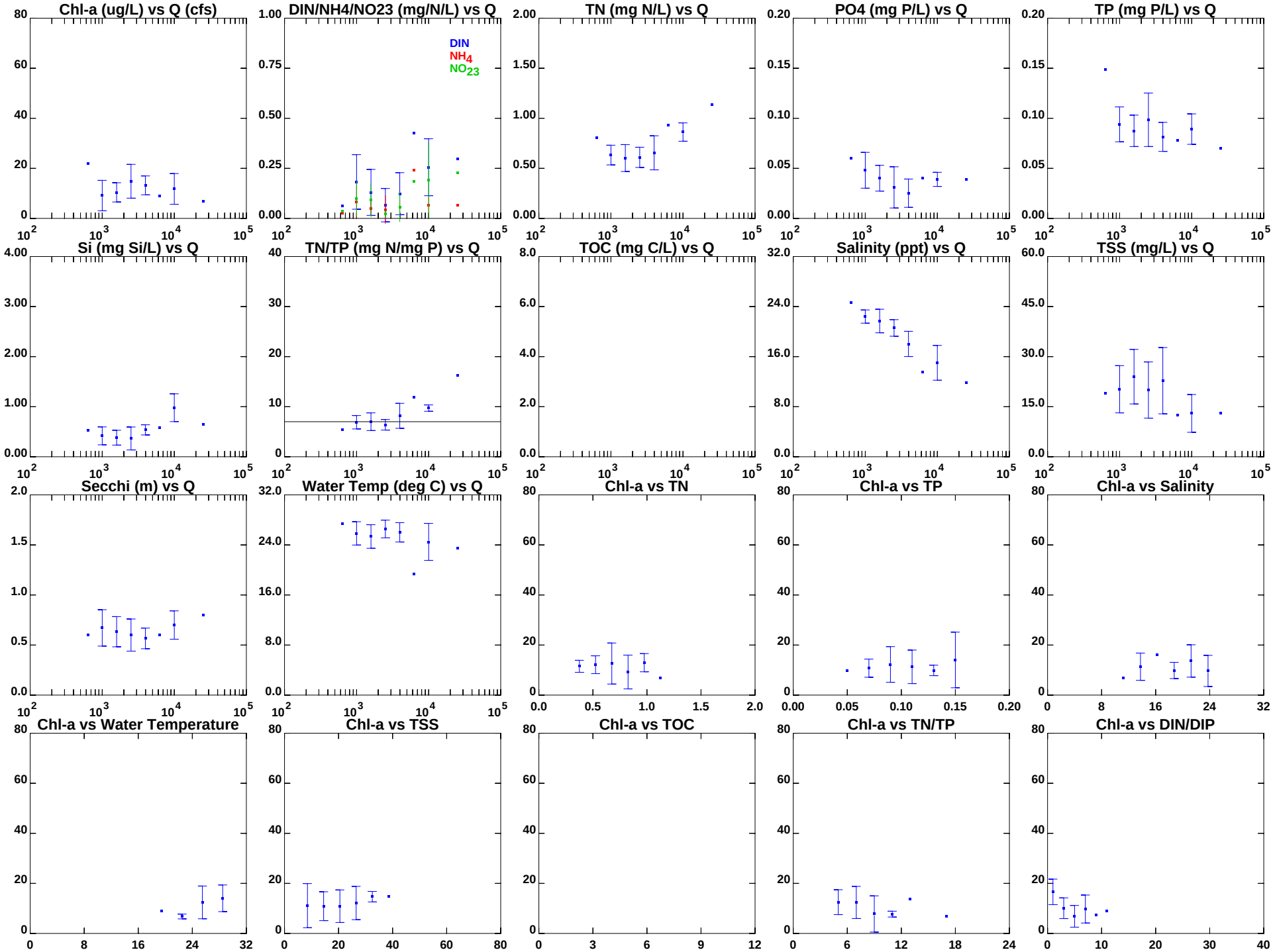
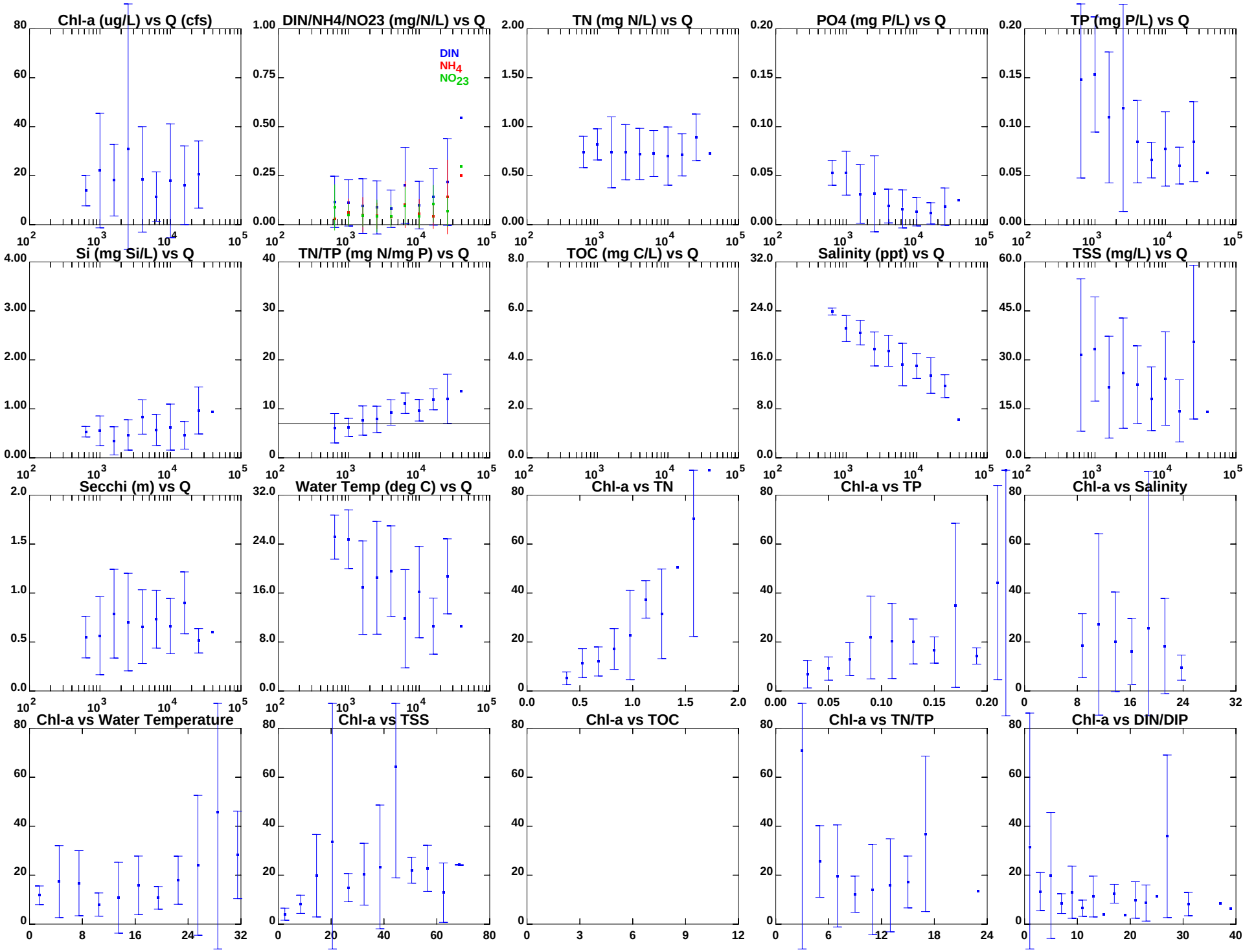
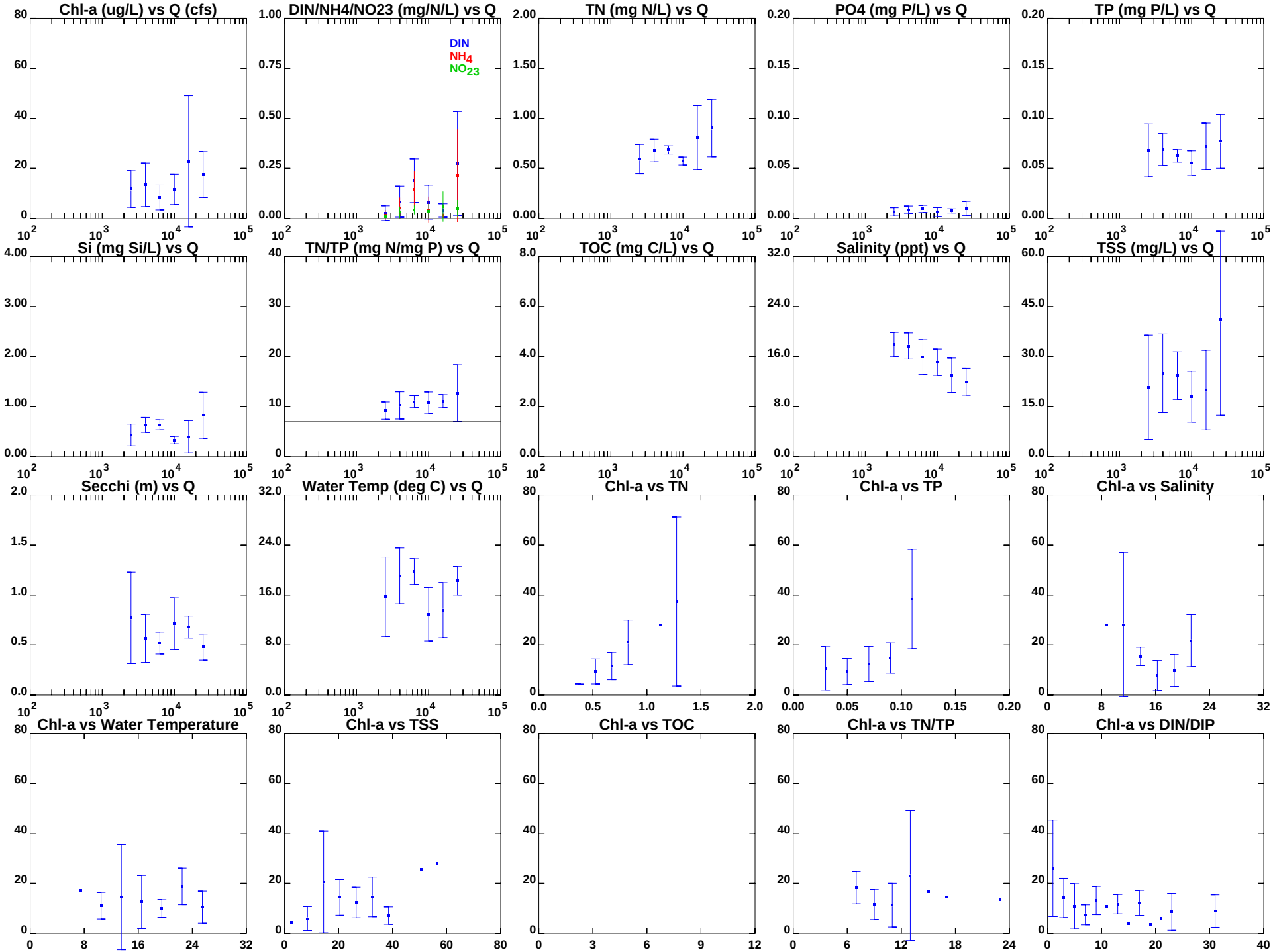


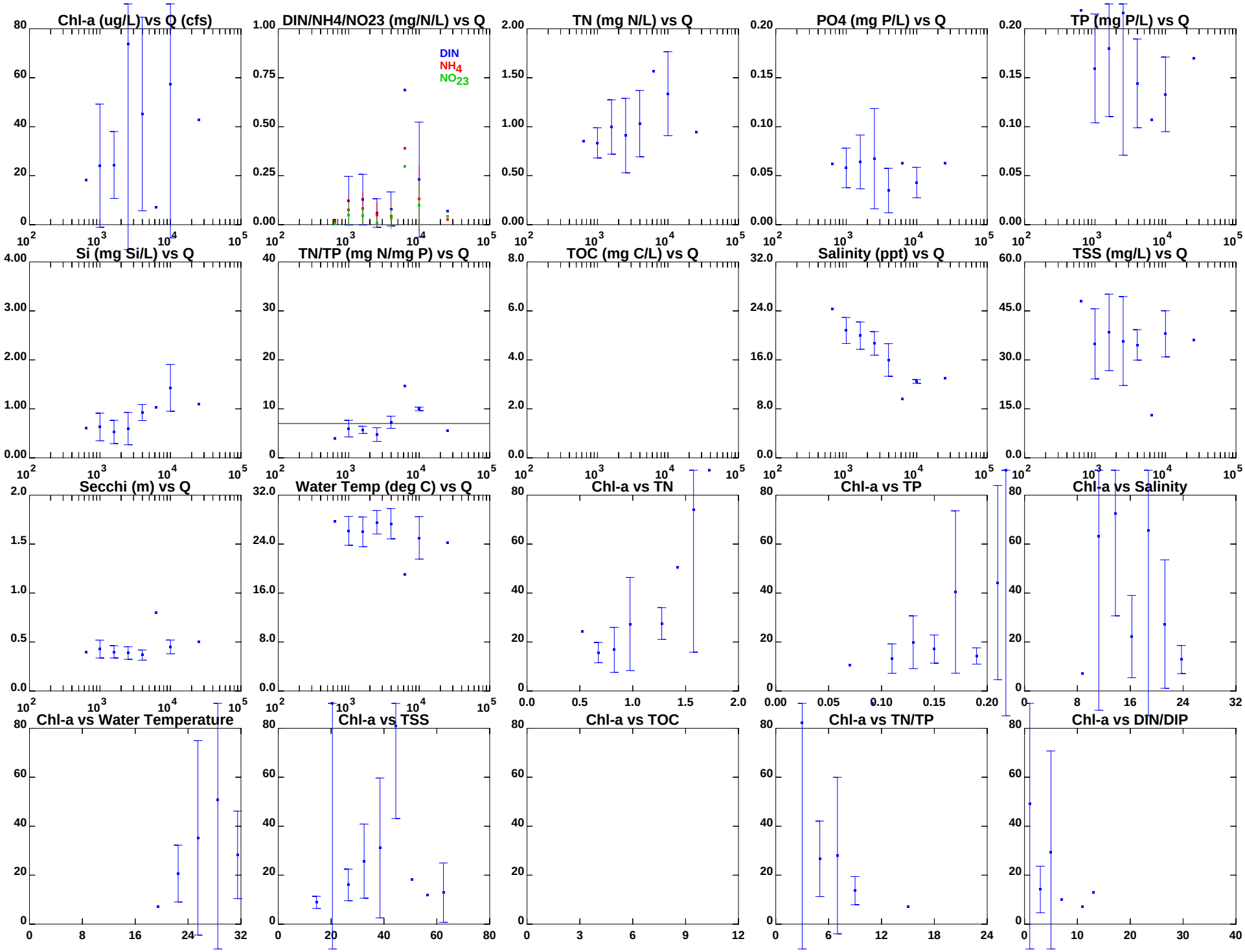
1995-2010: Summer data only for Station = LFA01



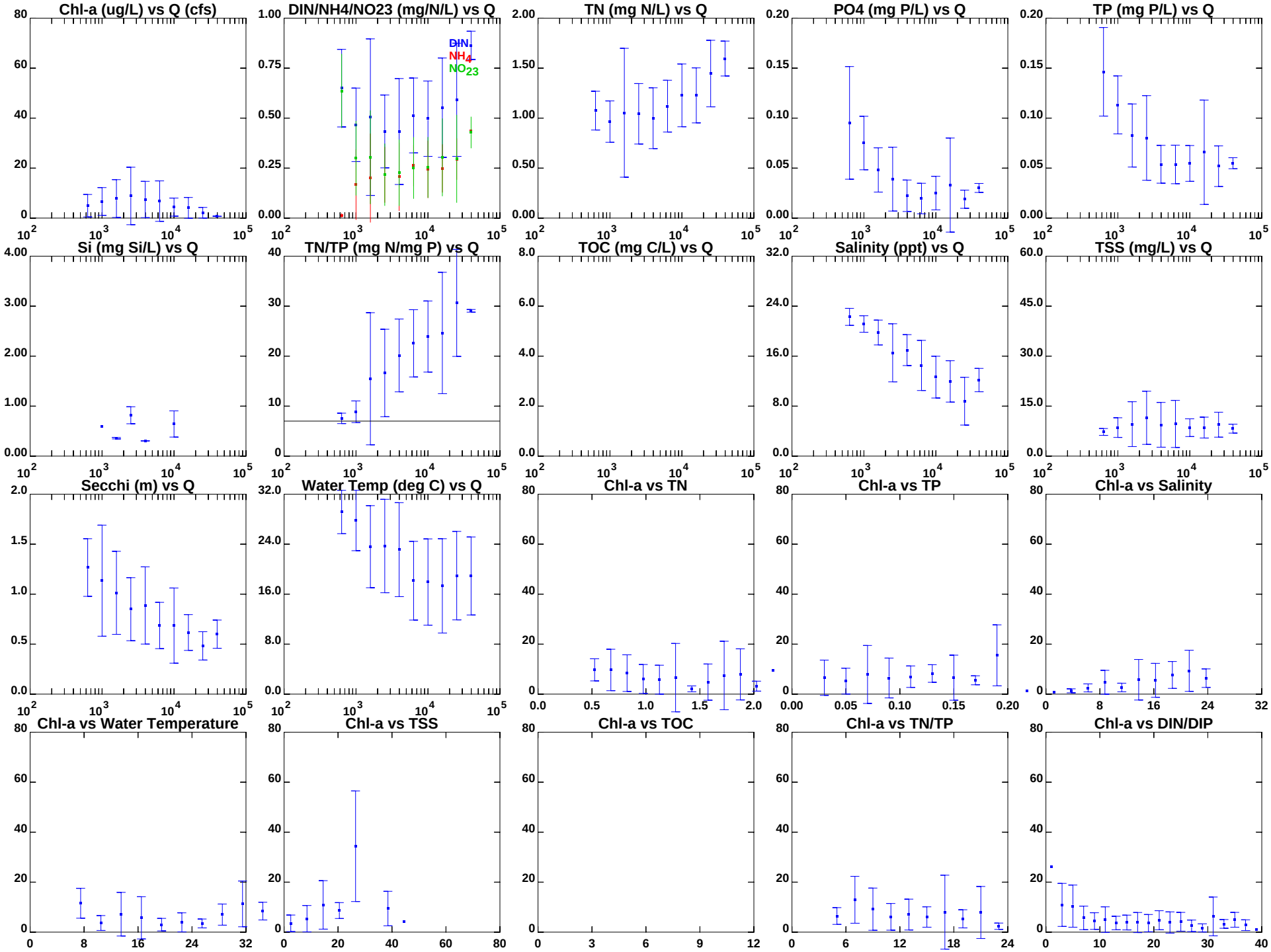
1995-2010: Annual data for Station = LFB01



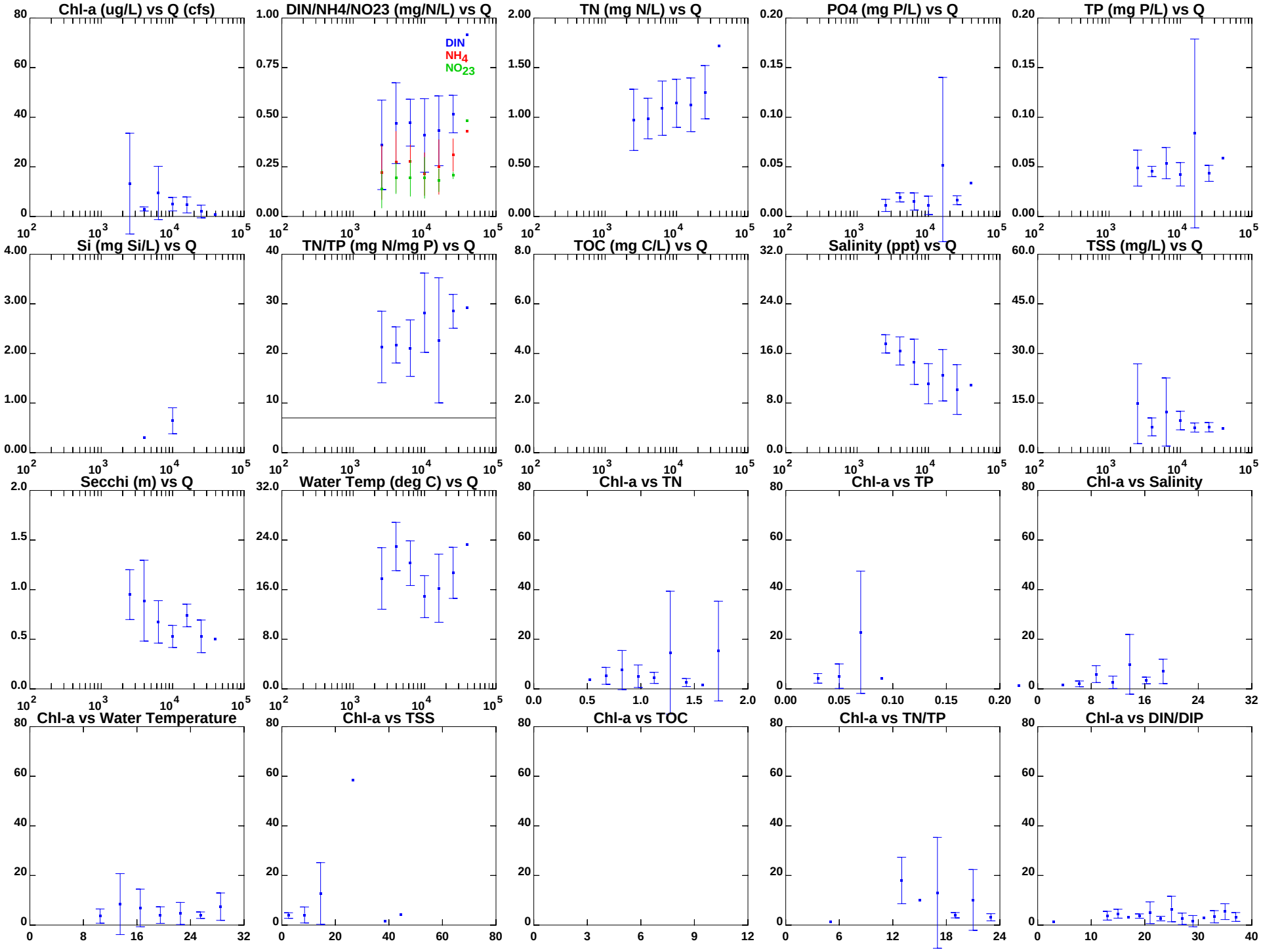
1995-2010: Spring data only for Station = LFB01



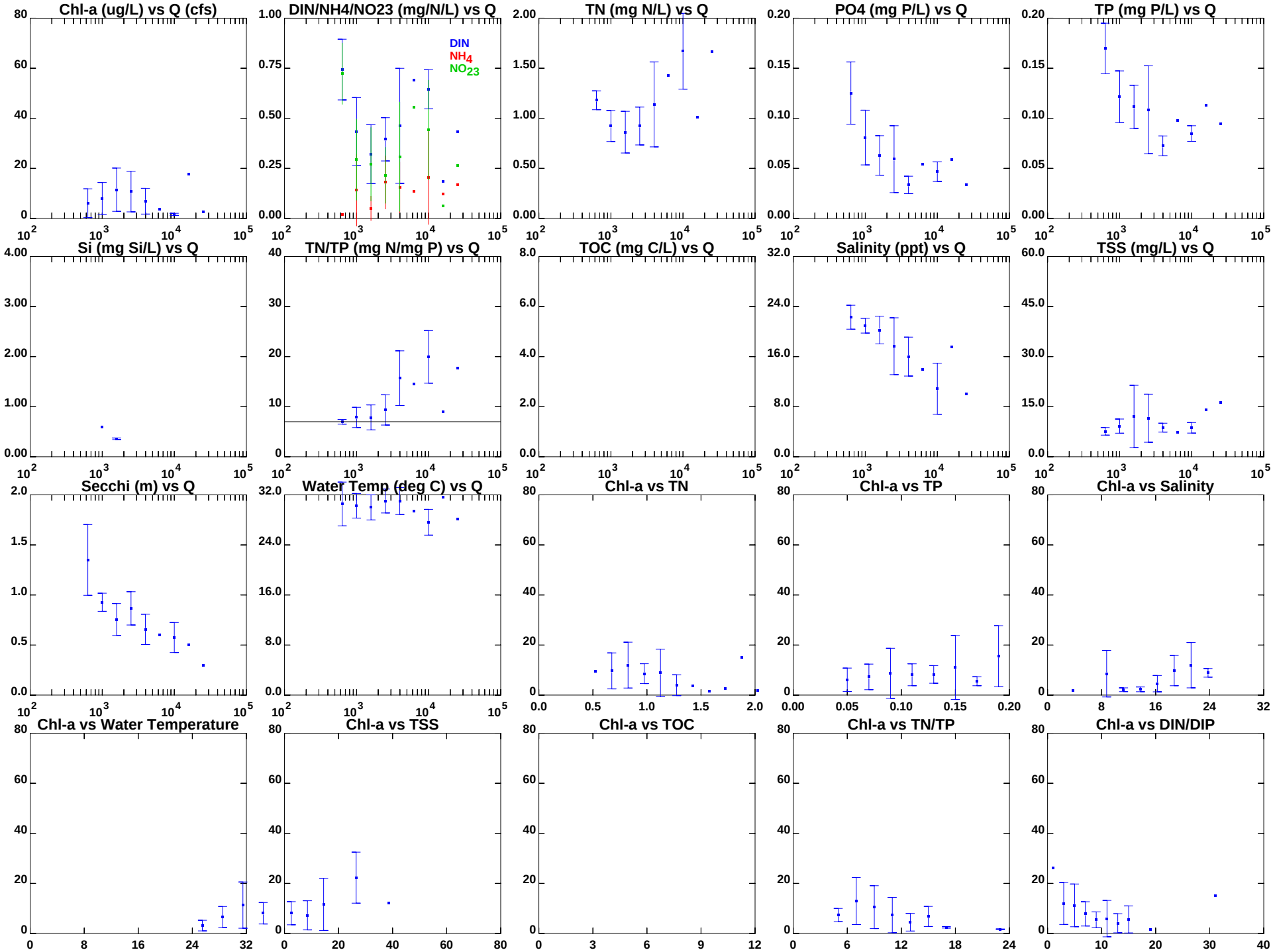
1995-2010: Summer data only for Station = LFB01



1995-2010: Annual data for Station = SBE5



1995-2010: Spring data only for Station = SBE5



1995-2010: Summer data only for Station = SBE5

Appendix B:

Analysis of James River water quality data

James River: PCA and Cluster Analysis

In all of the three time periods, the Cluster Analysis generally identifies two main groups:

TF5.4, TF5.5 and TF5.5A (location of summer Chl-a peak);

The others including LE5.2 (spring Chl-a peak);

Besides, LE5.1 is distinctive from others during the 2001~2010 period

The subsequent analysis is mainly based on:

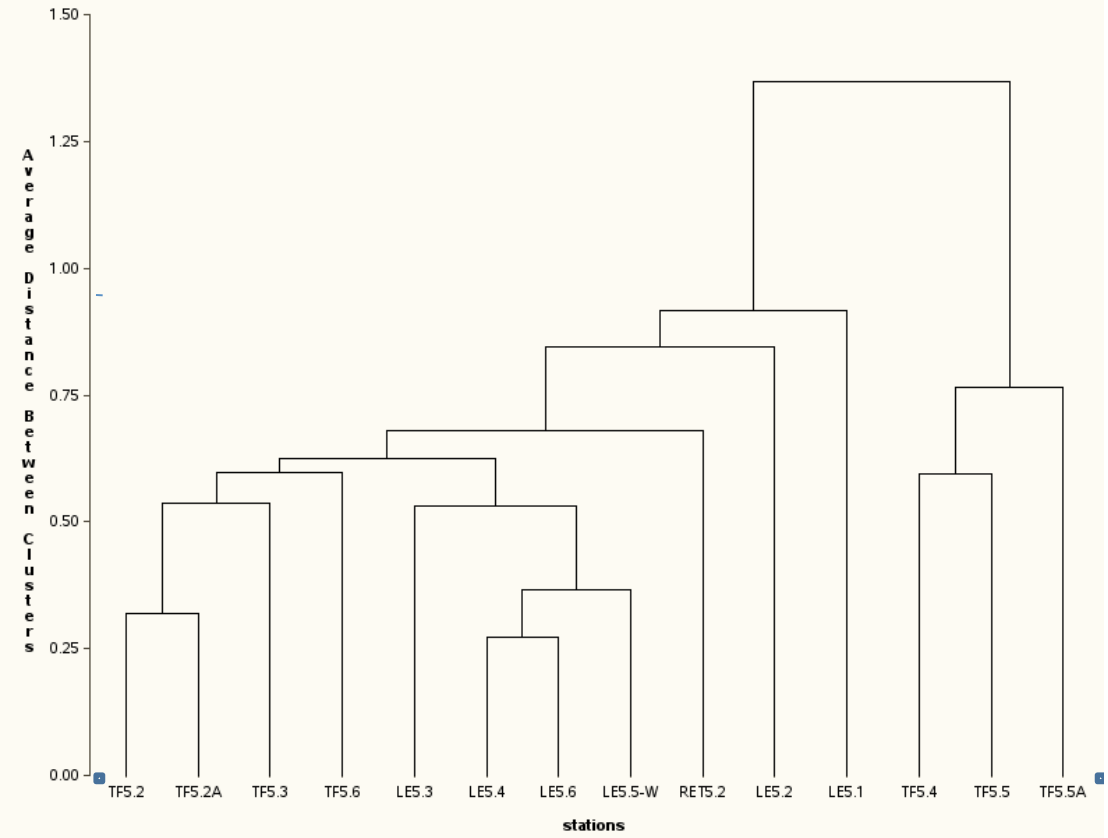
TF5.4, TF5.5 and TF5.5A (location of summer Chl-a peak)

LE5.2 (spring Chl-a peak)

LE5.1 (at the near upstream of spring Chl-a peak)

James River: Cluster Analysis (1995~2010)

Number of Clusters	Cluster History: Clusters Joined		Freq	Semipartial R-Square	R-Square
13	LE5.4	LE5.6	2	0.0057	0.994
12	TF5.2	TF5.2A	2	0.0078	0.987
11	CL13	LE5.5-W	3	0.0118	0.975
10	LE5.3	CL11	4	0.0282	0.947
9	CL12	TF5.3	3	0.0268	0.92
8	TF5.4	TF5.5	2	0.0273	0.892
7	CL9	TF5.6	4	0.0327	0.86
6	CL7	CL10	8	0.0634	0.796
5	CL6	RET5.2	9	0.0438	0.753
4	CL8	TF5.5A	3	0.051	0.702
3	CL5	LE5.2	10	0.0771	0.624
2	CL3	LE5.1	11	0.0904	0.534
1	CL2	CL4	14	0.534	0

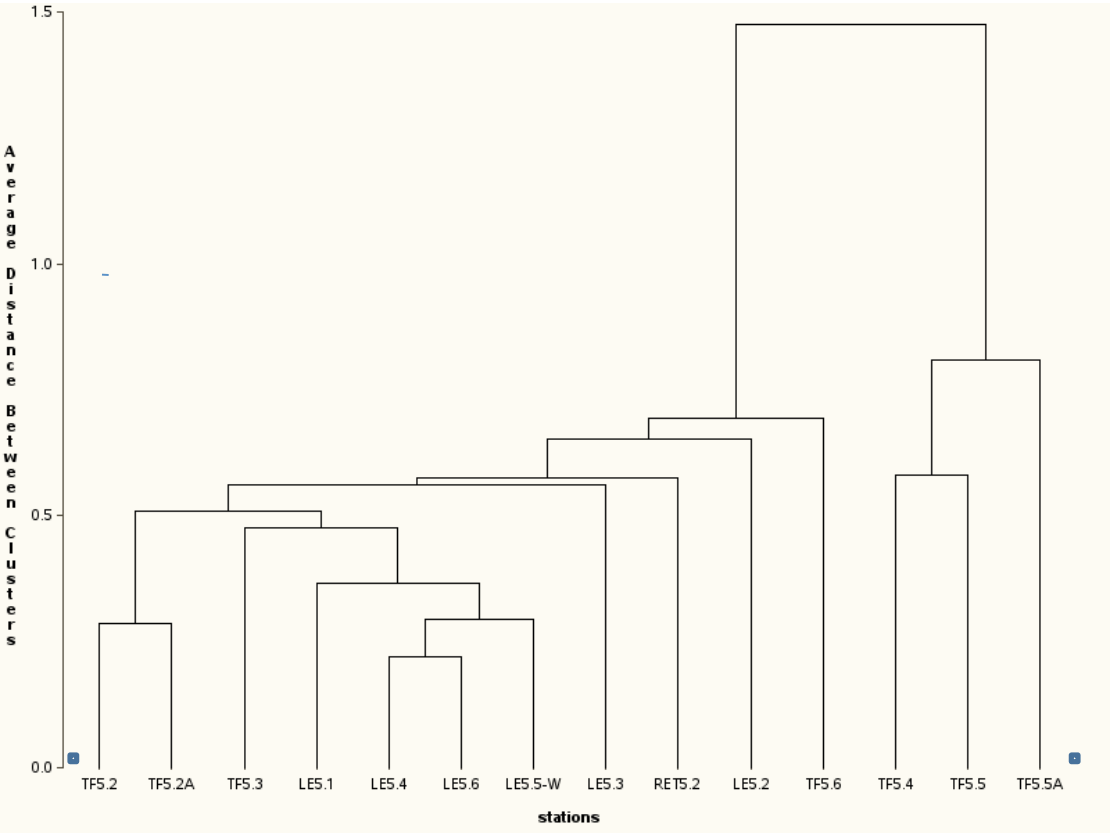


14 stations;
176 samples per station

James River: Cluster Analysis (1995~2000)

Cluster History

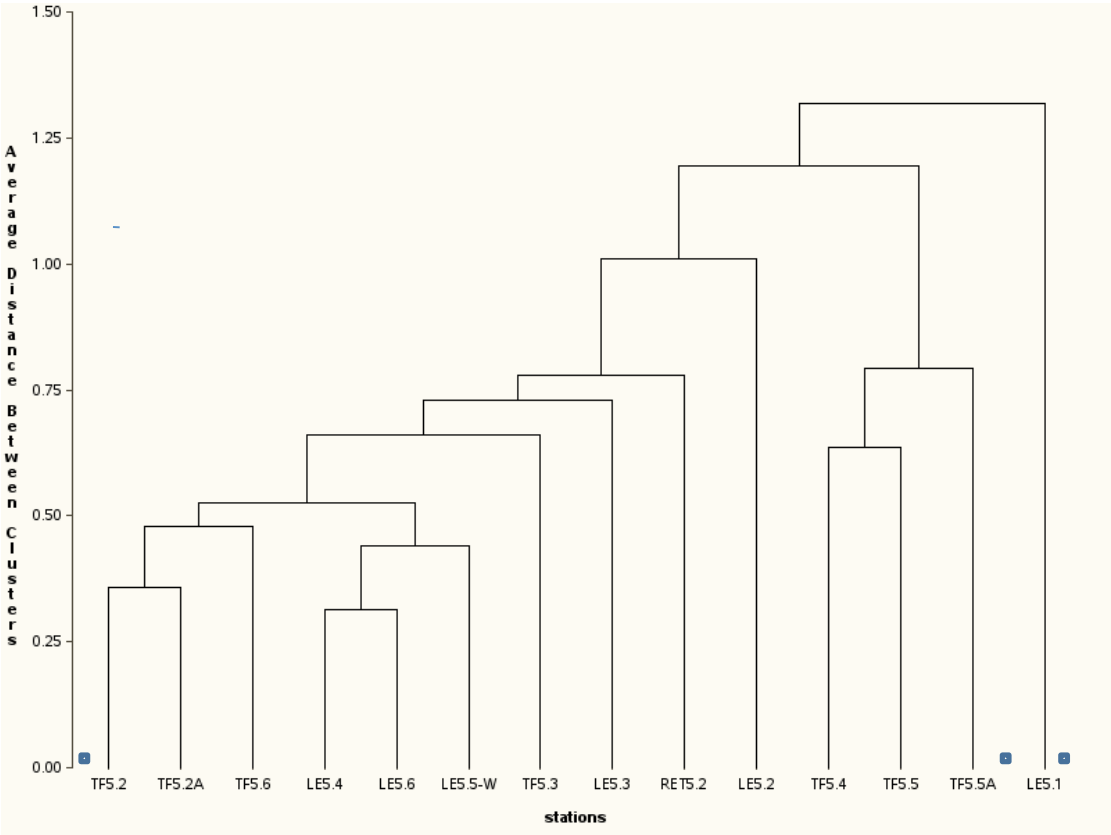
Number of Clusters	Clusters Joined		Freq	Semipartial R-Square	R-Square
13	LE5.4	LE5.6	2	0.0038	0.996
12	TF5.2	TF5.2A	2	0.0063	0.99
11	CL13	LE5.5-W	3	0.0077	0.982
10	LE5.1	CL11	4	0.0126	0.97
9	TF5.3	CL10	5	0.0231	0.947
8	CL12	CL9	7	0.0387	0.908
7	CL8	LE5.3	8	0.0308	0.877
6	CL7	RET5.2	9	0.0316	0.845
5	TF5.4	TF5.5	2	0.026	0.819
4	CL6	LE5.2	10	0.0433	0.776
3	CL4	TF5.6	11	0.0493	0.727
2	CL5	TF5.5A	3	0.0583	0.669
1	CL3	CL2	14	0.6686	0



14 stations;
71 samples per station

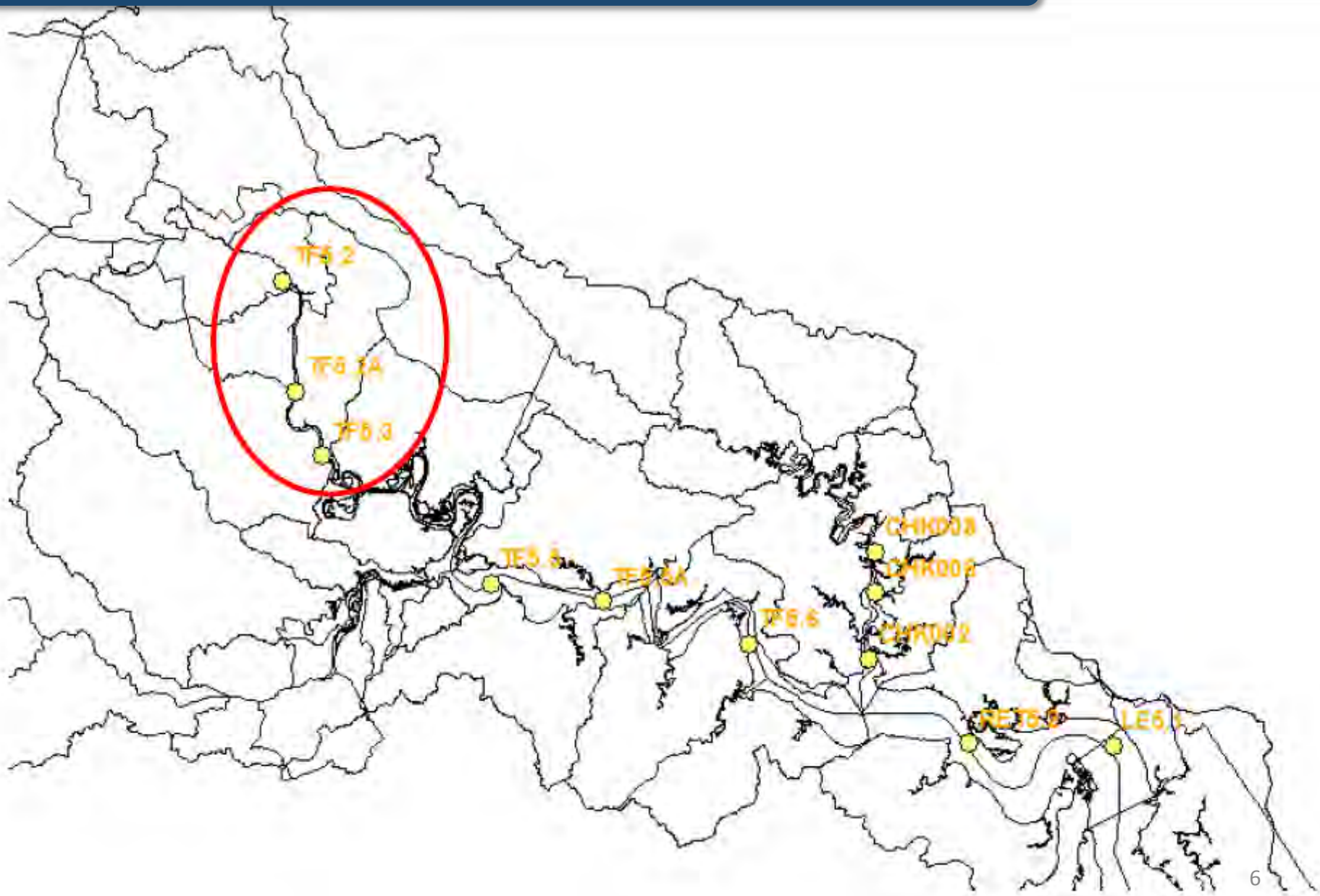
James River: Cluster Analysis (2001~2010)

Number of Clusters	Cluster History: Clusters Joined		Freq	Semipartial R-Square	R-Square
13	LE5.4	LE5.6	2	0.0076	0.992
12	TF5.2	TF5.2A	2	0.0099	0.983
11	CL13	LE5.5-W	3	0.0175	0.965
10	CL12	TF5.6	3	0.0202	0.945
9	CL10	CL11	6	0.0362	0.909
8	TF5.4	TF5.5	2	0.0312	0.877
7	CL9	TF5.3	7	0.0443	0.833
6	CL7	LE5.3	8	0.0549	0.778
5	CL6	RET5.2	9	0.062	0.716
4	CL8	TF5.5A	3	0.054	0.662
3	CL5	LE5.2	10	0.1162	0.546
2	CL3	CL4	13	0.3558	0.19
1	CL2	LE5.1	14	0.1904	0



14 stations;
105 samples per station

Station group (upstream: TF5.2, TF5.2A, TF5.3)



Station group (upstream: TF5.2, TF5.2A, TF5.3)

Summary of regression analysis between Chl-a and each water quality parameter

Raw Data

Monthly (ensemble average, 1995~2010)

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2	samples
WTEMP	0.25	119
SALINITY	<0.05	102
SECCHI	0.06	113
TSS	<0.05	119
TP	<0.05	117
TN	0.13	115
FLOW	<0.05	120
FLOW5	0.08	120
FLOW10	0.09	120
FLOW20	0.11	120
FLOW30	0.08	120
FLOW40	0.07	120

Parameters	R^2
WTEMP	0.79
SALINITY	<0.05
TSS	0.11
TP	0.13
TN	0.29
FLOW	0.48

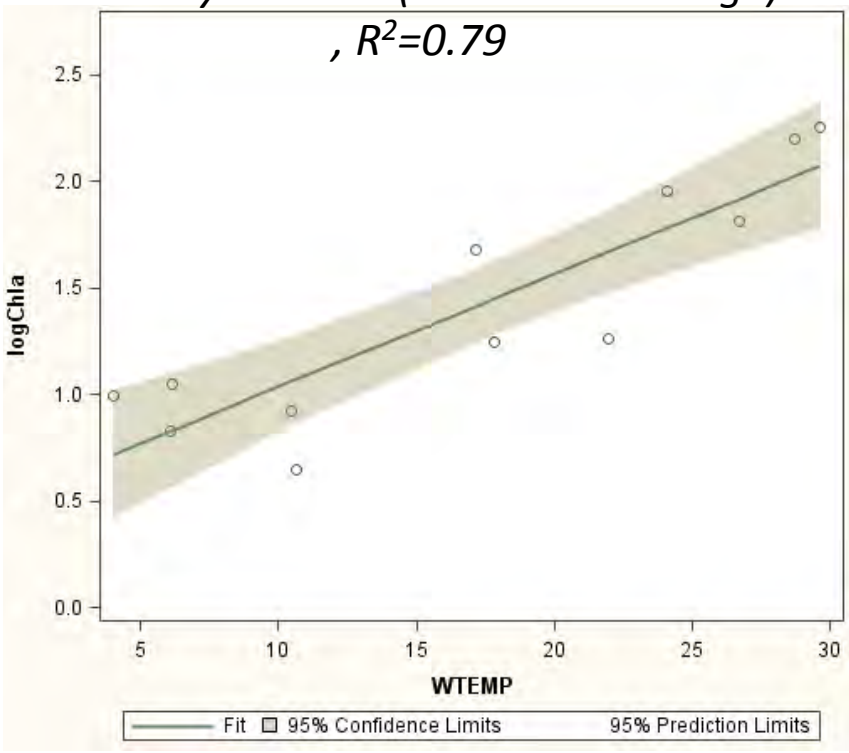
12 samples per parameter

Selective regression plots are presented in next slide

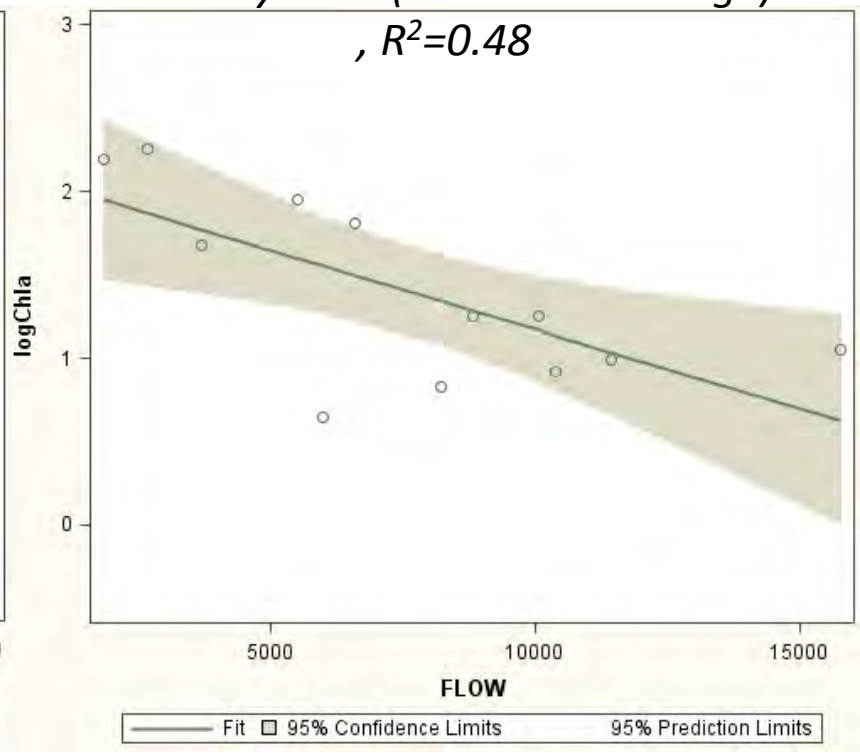
Station group (upstream: TF5.2, TF5.2A, TF5.3)

Regression plots between Chl-a and each water quality parameter 1995~2010 , (only those with high correlation)

Monthly WTEMP (ensemble average) , R^2=0.79



Monthly Flow (ensemble average) , R^2=0.48



Station group (upstream: TF5.2, TF5.2A, TF5.3)

Summary of regression analysis between Chl-a and each water quality parameter, monthly ensemble average, 3 periods

Statistical Model:

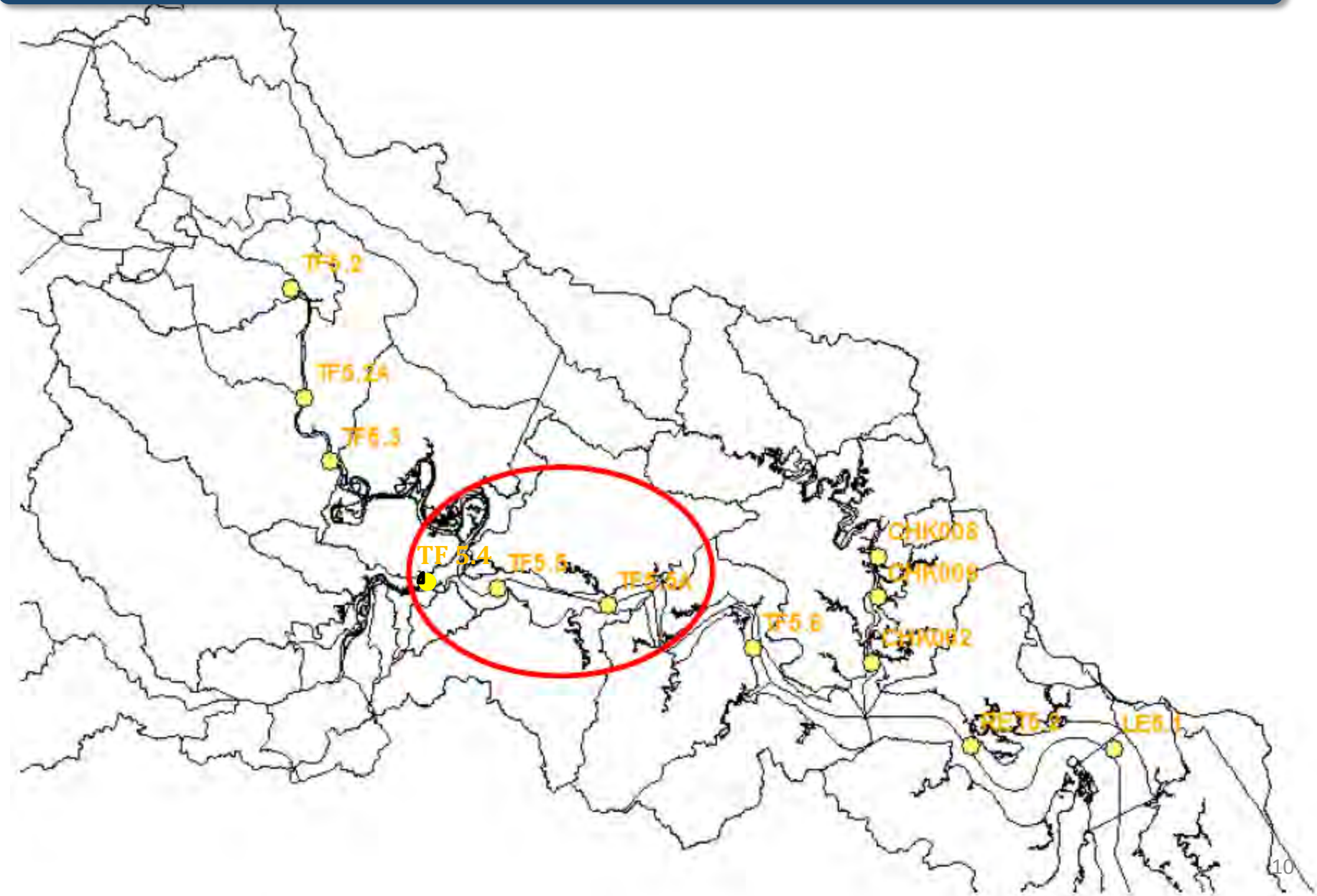
$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2 (1995~2010)	R^2 (1995~2000)	R^2 (2001~2010)
WTEMP	0.79	0.62	0.69
SALINITY	<0.05	0.11	<0.05
TSS	0.11	0.17	<0.05
TP	0.13	0.04	0.38
TN	0.29	<0.05	0.26
FLOW	0.48	0.40	0.30

12 samples per period per parameter

Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)



Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)

Summary of regression analysis between Chl-a and each parameter

Raw Data

Parameters	R^2	samples
WTEMP	0.44	116
SALINITY	0.06	105
SECCHI	<0.05	113
TSS	0.10	117
TP	0.18	115
TN	0.19	113
FLOW	0.33	118
FLOW5	0.38	118
FLOW10	0.37	118
FLOW20	0.36	118
FLOW30	0.31	118
FLOW40	0.28	118

Monthly (ensemble average, 1995~2010)

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

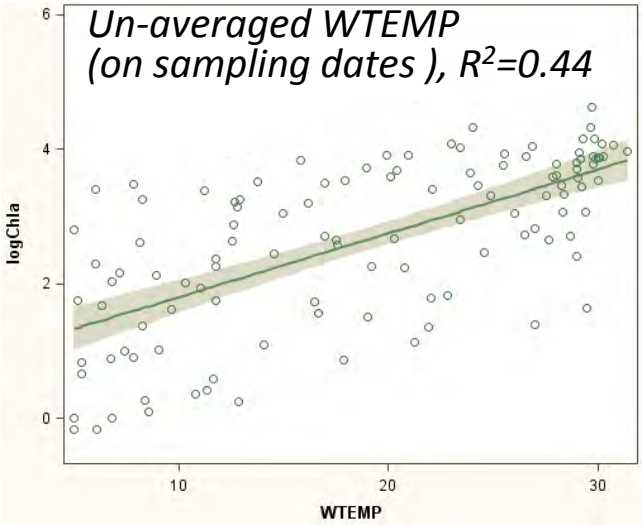
Parameters	R^2
WTEMP	0.89
SALINITY	<0.05
SECCHI	0.07
TSS	0.06
TP	0.59
TN	<0.05
FLOW	0.71

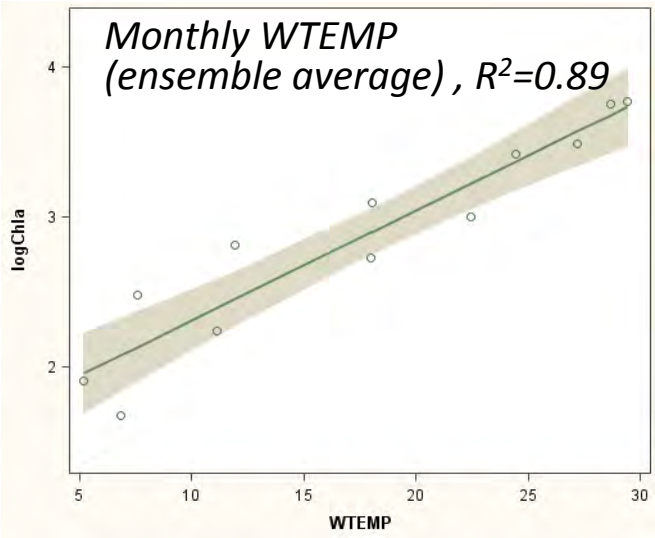
12 samples per parameter

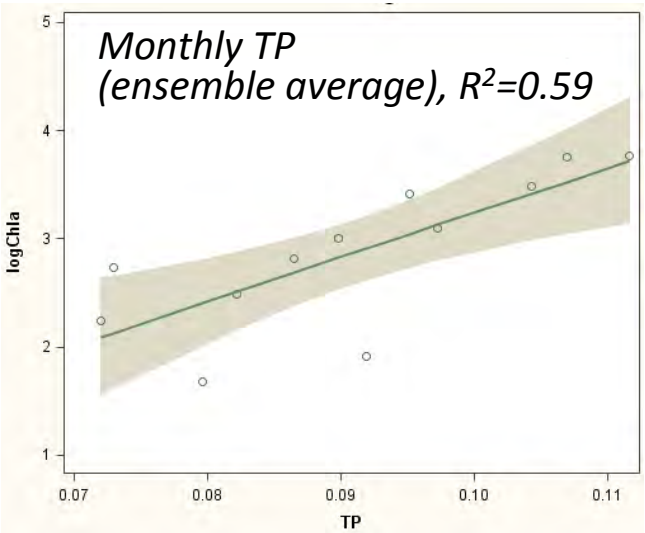
Selective regression plots are presented in next slide

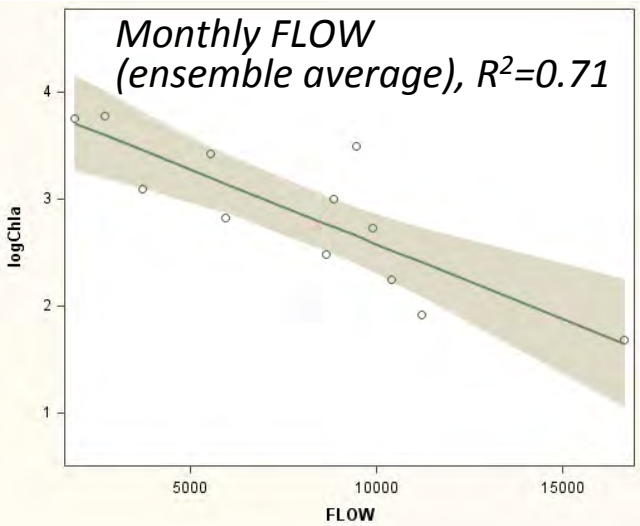
Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)

Selective regression plots between Chl-a and each water quality parameter 1995~2010 , (only those with high correlation)









Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)

Summary of regression analysis between Chl-a and each water quality parameter, monthly ensemble average, 3 periods

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2 (1995~2010)	R^2 (1995~2000)	R^2 (2001~2010)
WTEMP	0.89	0.78	0.87
SALINITY	<0.05	0.12	<0.05
SECCHI	0.07	<0.05	0.11
TSS	0.06	<0.05	<0.05
TP	0.59	0.44	0.59
TN	<0.05	0.28	0.06
FLOW	0.71	0.79	0.46

12 samples per period per parameter

Comments: similar among different periods

Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)

Correlation Matrix, Monthly ensemble average, 3 periods, 12 data points (12 months) per period per parameter

Pearson Correlation Coefficients, N = 12

Prob > |r| under H0: Rho=0

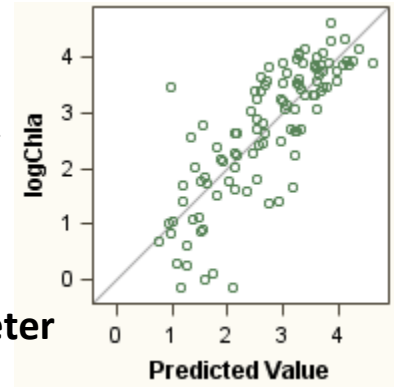
	time periods	logChl-a	FLOW	WTEMP	SALINITY	TP	SECCHI	TSS	TN
logChl-a	1995~2010	1							
	1995~2000	1							
	2001~2010	1							
FLOW	1995~2010	-0.84361	1						
	1995~2000	-0.88832	1						
	2001~2010	-0.68059	1						
WTEMP	1995~2010	0.94415	-0.66996	1					
	1995~2000	0.88401	-0.73211	1					
	2001~2010	0.93365	-0.506	1					
SALINITY	1995~2010	0.12978	-0.4397	-0.13336	1				
	1995~2000	0.34156	-0.55233	0.03174	1				
	2001~2010	0.02549	-0.28376	-0.14344	1				
TP	1995~2010	0.76768	-0.6711	0.72455	0.04342	1			
	1995~2000	0.66313	-0.55444	0.70927	0.22619	1			
	2001~2010	0.77014	-0.56879	0.6469	0.16872	1			
SECCHI	1995~2010	-0.25757	0.30061	-0.11175	-0.37236	-0.64092	1		
	1995~2000	0.01329	0.00266	0.06751	-0.22923	-0.5322	1		
	2001~2010	-0.32444	0.30087	-0.17227	-0.46214	-0.69381	1		
TSS	1995~2010	-0.24827	0.37226	-0.1692	-0.14451	0.34318	-0.60966	1	
	1995~2000	-0.12359	0.18911	-0.08908	-0.03252	0.54404	-0.68587	1	
	2001~2010	-0.20443	0.4756	-0.19096	0.04276	0.34262	-0.47294	1	
TN	1995~2010	0.08666	-0.37553	-0.12131	0.68102	0.44503	-0.83373	0.42099	1
	1995~2000	0.52638	-0.69279	0.35587	0.47025	0.57644	-0.47712	0.24782	1
	2001~2010	-0.24082	-0.14105	-0.46498	0.59556	0.30366	-0.66595	0.48335	1

Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)

Multiple Regression Statistical Model:

$$\log(CHLA) = a + b_i x_i + \varepsilon$$

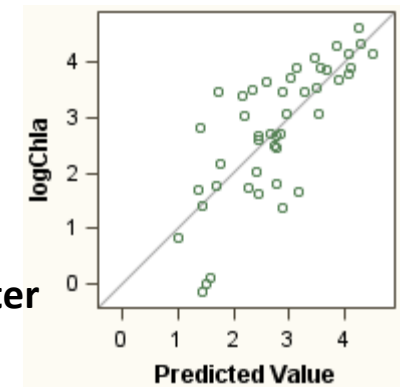
(1995~2010)
R^2=0.66
106 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	4.0866	1.43263	2.85	0.0053	0
logFlow	1	-0.51365	0.10721	-4.79	<.0001	-0.44119
WTEMP	1	0.05681	0.01095	5.19	<.0001	0.41219
TP	1	-2.76794	3.28671	-0.84	0.4017	-0.06775
SECCHI	1	1.3752	0.76857	1.79	0.0766	0.12441
TSS	1	0.02852	0.01106	2.58	0.0114	0.1999
TN	1	0.59089	0.50941	1.16	0.2489	0.10584

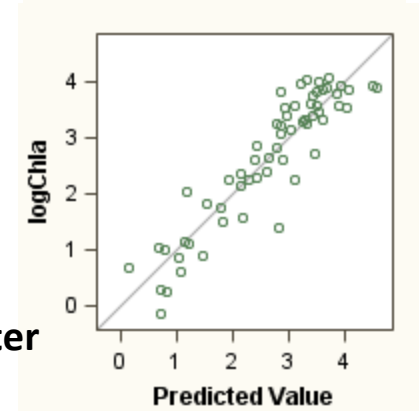
(1995~2000)
R^2=0.58
45 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	5.42774	2.50325	2.17	0.0365	0
logFlow	1	-0.43084	0.21093	-2.04	0.0481	-0.32666
WTEMP	1	0.0723	0.02003	3.61	0.0009	0.52102
TP	1	-7.14211	5.4267	-1.32	0.196	-0.18549
SECCHI	1	-1.27529	1.43487	-0.89	0.3797	-0.10232
TSS	1	0.04659	0.02362	1.97	0.0559	0.25686
TN	1	-0.44438	0.98635	-0.45	0.6549	-0.07245

(2001~2010)
R^2=0.85
61 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	-0.09815	1.48263	-0.07	0.9475	0
logFlow	1	-0.36097	0.0982	-3.68	0.0005	-0.33621
WTEMP	1	0.05873	0.0102	5.76	<.0001	0.42917
TP	1	4.98124	3.38126	1.47	0.1465	0.11543
SECCHI	1	4.45925	0.87991	5.07	<.0001	0.38683
TSS	1	0.03151	0.00978	3.22	0.0022	0.25188
TN	1	1.35295	0.45993	2.94	0.0048	0.25851

Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)

PCA (identifying the patterns among water quality parameters)

On sampling dates (1995~2010)

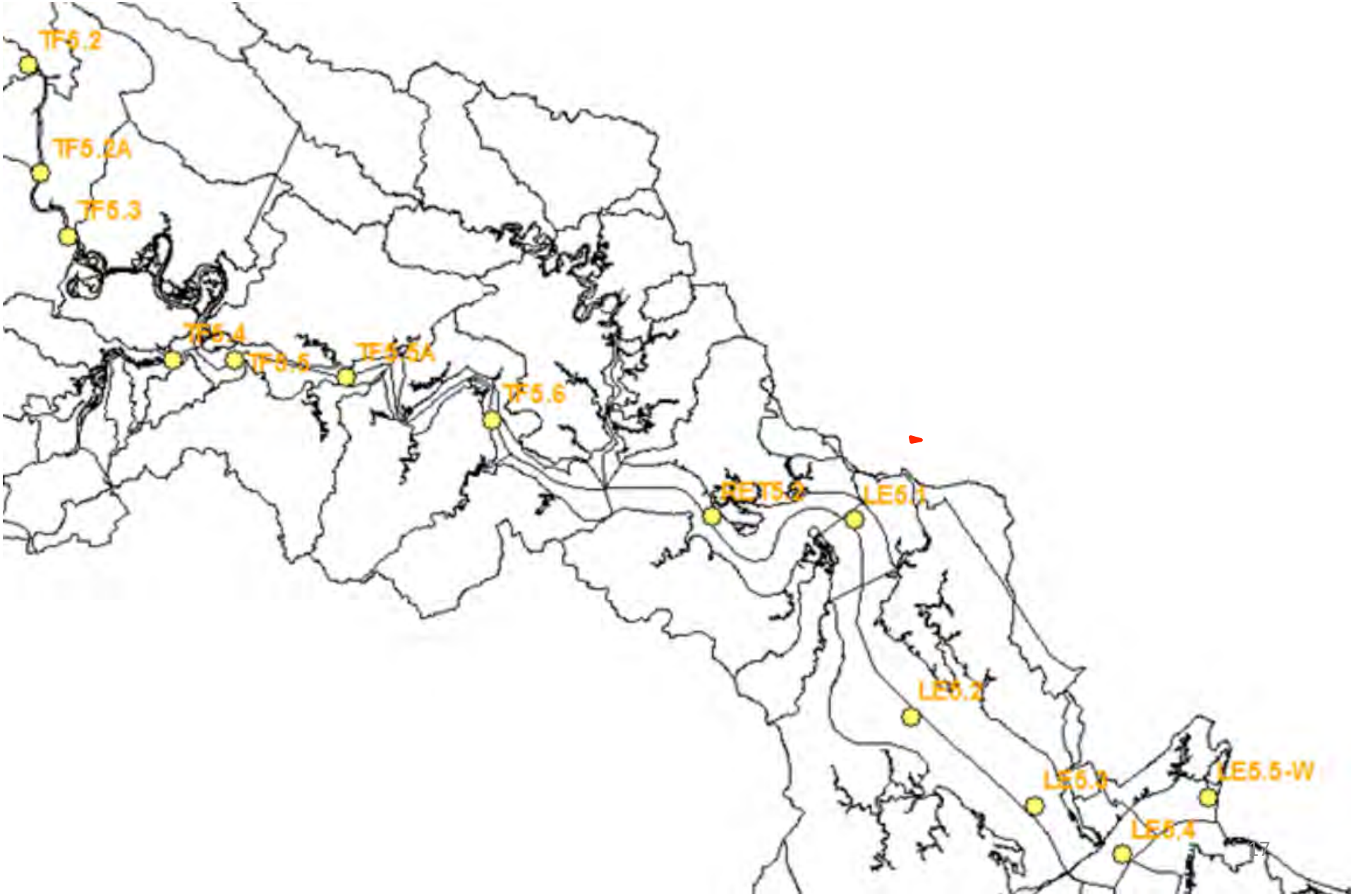
	Rotated Factor Pattern					
	Factor1		Factor2		Factor3	
TN	85	*	17		24	
TP	29		47	*	63	*
SECCHI	-3		-86	*	5	
TSS	22		79	*	21	
WTEMP	-14		10		87	*
FLOW	-56	*	34		-64	*
SALINITY	80	*	15		-15	

Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.4 are flagged by an '*'.

No obvious patterns

99 samples per parameter

Station group (downstream, location of spring peak: LE5.1, LE5.2)



Station group (downstream, location of spring peak: LE5.1, LE5.2)

Summary of regression analysis between Chl-a and each water quality parameter

Raw Data

Monthly (ensemble average, 1995~2010)

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2	Samples
WTEMP	<0.05	118
SALINITY	<0.05	118
SECCHI	0.05	117
TSS	0.05	117
TP	<0.05	112
TN	0.05	110
FLOW	<0.05	118
FLOW5	<0.05	118
FLOW10	<0.05	118
FLOW20	<0.05	118
FLOW30	<0.05	118
FLOW40	<0.05	118

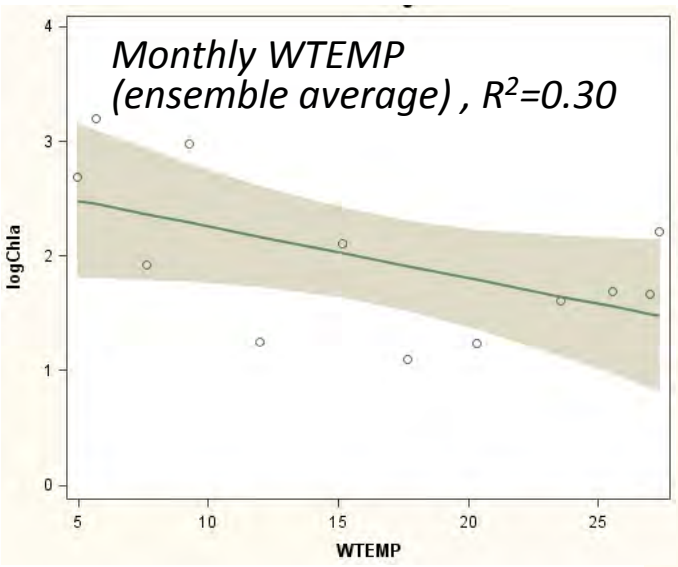
Parameters	R^2
WTEMP	0.30
SALINITY	0.27
SECCHI	0.20
TSS	0.40
TP	<0.05
TN	0.56
FLOW	0.28

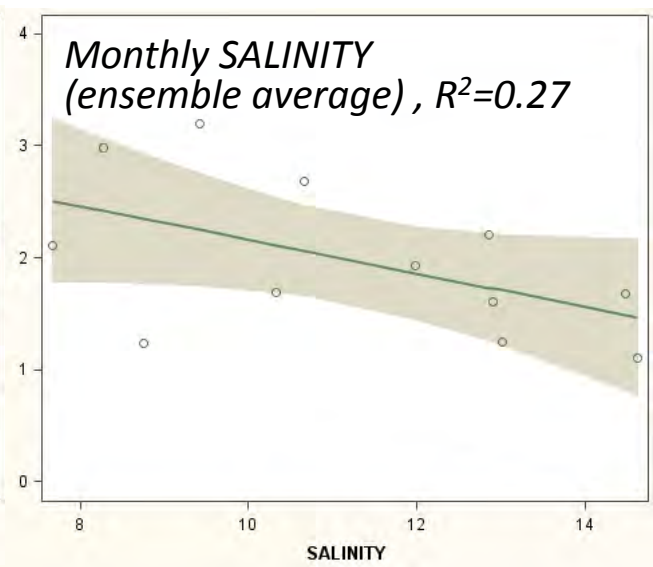
12 samples per parameter

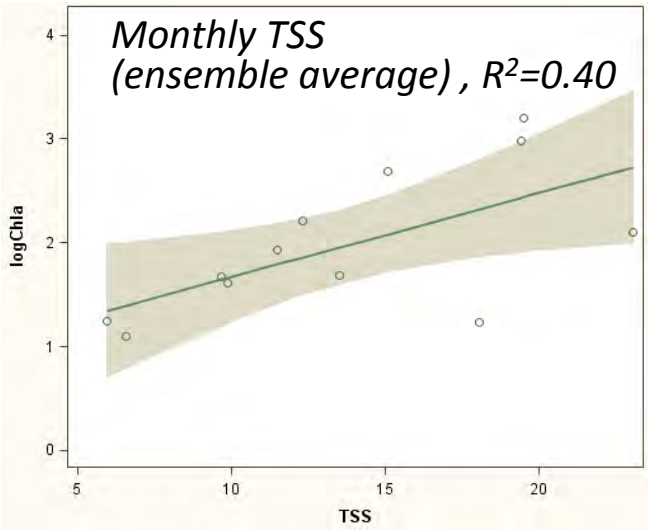
Selective regression plots are presented in next slide

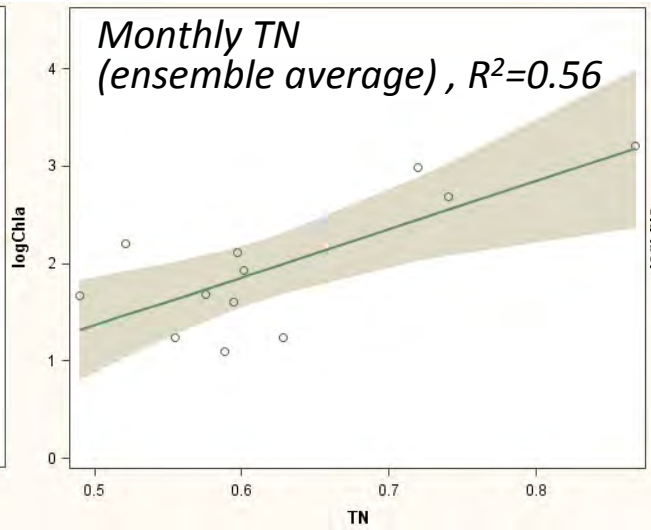
Station group (downstream, location of spring peak: LE5.1, LE5.2)

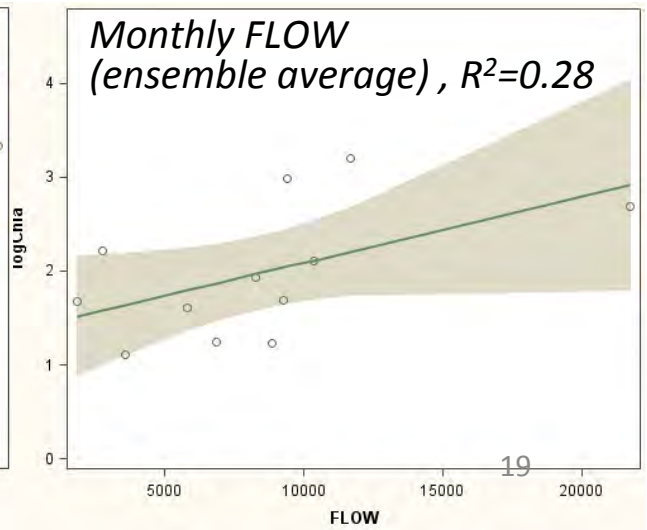
Selective regression plots between Chl-a and each water quality parameter 1995~2010











Station group (downstream, location of spring peak: LE5.1, LE5.2)

Summary of regression analysis between Chl-a and each water quality parameter, monthly ensemble average

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2 (1995~2010)	R^2 (1995~2000)	R^2 (2001~2010)
WTEMP	0.30	0.10	0.30
SALINITY	0.27	0.33	0.10
SECCHI	0.20	0.22	0.09
TSS	0.40	0.35	0.31
TP	<0.05	0.58	<0.05
TN	0.56	0.48	0.31
FLOW	0.28	0.07	0.13

12 samples per period per parameter

Comments: similar among different periods

Station group (downstream, location of spring peak: LE5.1, LE5.2)

Correlation Matrix, Monthly ensemble average, 3 periods, 12 data points (12 months) per period per parameter

Pearson Correlation Coefficients, N = 12

Prob > |r| under H0: Rho=0

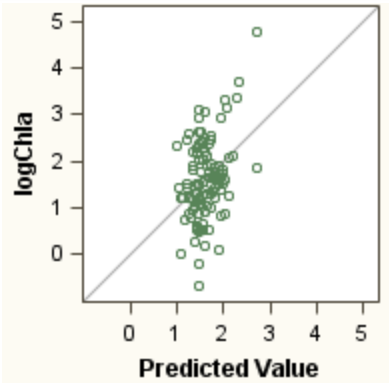
	time periods	logChl-a	FLOW	WTEMP	SALINITY	TP	SECCHI	TSS	TN
logChl-a	1995~2010	1							
	1995~2000	1							
	2001~2010	1							
FLOW	1995~2010	0.53282	1						
	1995~2000	0.26499	1						
	2001~2010	0.35689	1						
WTEMP	1995~2010	-0.54657	-0.69291	1					
	1995~2000	-0.31154	-0.73116	1					
	2001~2010	-0.54451	-0.5179	1					
SALINITY	1995~2010	-0.52086	-0.57528	0.39459	1				
	1995~2000	-0.57102	-0.63557	0.31611	1				
	2001~2010	-0.32106	-0.47412	0.36794	1				
TP	1995~2010	0.14266	-0.44358	0.50214	0.25994	1			
	1995~2000	0.76047	-0.12789	0.26555	-0.49619	1			
	2001~2010	-0.07507	-0.57795	0.53685	0.65913	1			
SECCHI	1995~2010	-0.44845	-0.29056	-0.06831	0.77948	-0.16769	1		
	1995~2000	-0.46519	-0.49758	0.05167	0.88944	-0.48683	1		
	2001~2010	-0.30709	-0.0667	-0.18915	0.62692	0.0117	1		
TSS	1995~2010	0.63552	0.4924	-0.30916	-0.93355	-0.03522	-0.89239	1	
	1995~2000	0.59441	0.54068	-0.32806	-0.85985	0.43275	-0.84973	1	
	2001~2010	0.55445	0.43862	-0.26403	-0.83065	-0.29629	-0.86429	1	
TN	1995~2010	0.74749	0.66614	-0.81651	-0.45573	-0.13847	-0.14053	0.42068	1
	1995~2000	0.69467	0.79334	-0.81749	-0.63285	0.18361	-0.37575	0.59136	1
	2001~2010	0.55362	0.41797	-0.70632	-0.21351	-0.20092	0.0661	0.26494	1

Station group (downstream, location of spring peak: LE5.1, LE5.2)

Multiple Regression Statistical Model:

$$\log(CHLA) = a + b_i x_i + \varepsilon$$

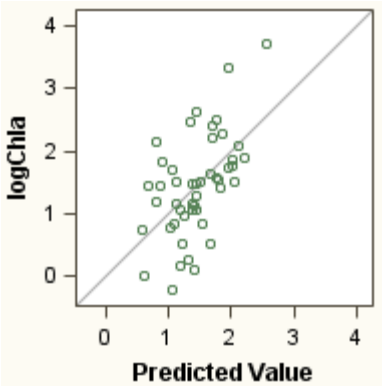
(1995~2010)
R^2=0.13
105 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	2.09609	2.1116	0.99	0.3233	0
logFlow	1	-0.13719	0.18984	-0.72	0.4716	-0.15756
WTEMP	1	0.00575	0.01438	0.4	0.6899	0.05336
SALINITY	1	0.02945	0.03774	0.78	0.4371	0.17262
TP	1	-7.90723	5.94594	-1.33	0.1867	-0.17367
SECCHI	1	-0.4415	0.39535	-1.12	0.2669	-0.18473
TSS	1	0.02074	0.01618	1.28	0.2032	0.1805
TN	1	1.39193	0.52184	2.67	0.009	0.37224

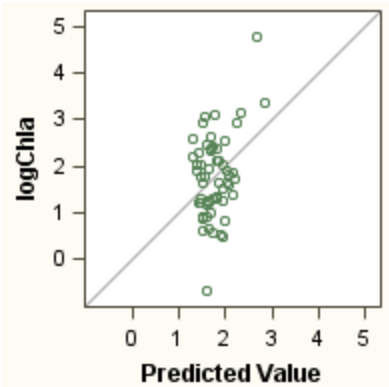
(1995~2000)
R^2=0.30
47 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	1.17866	2.92926	0.4	0.6896	0
logFlow	1	-0.15997	0.24497	-0.65	0.5176	-0.17765
WTEMP	1	0.04139	0.02304	1.8	0.0802	0.41864
SALINITY	1	0.06383	0.04691	1.36	0.1814	0.36247
TP	1	-14.4799	7.96699	-1.82	0.0768	-0.3479
SECCHI	1	-0.74885	0.53276	-1.41	0.1678	-0.34231
TSS	1	0.01424	0.02007	0.71	0.4823	0.14701
TN	1	2.61513	1.07046	2.44	0.0192	0.55287

(2001~2010)
R^2=0.13
58 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	0.63299	3.28644	0.19	0.848	0
logflow	1	0.0589	0.30274	0.19	0.8465	0.07105
WTEMP	1	-0.01058	0.02006	-0.53	0.6003	-0.09465
SALINITY	1	0.04352	0.06216	0.7	0.4872	0.26759
TP	1	-2.61814	8.80402	-0.3	0.7674	-0.05484
SECCHI	1	-0.33491	0.61766	-0.54	0.5901	-0.13501
TSS	1	0.0303	0.02581	1.17	0.2459	0.23269
TN	1	0.68888	0.67023	1.03	0.309	0.20332

Station group (downstream, location of spring peak: LE5.1 LE5.2,)

PCA (identifying the patterns among water quality parameters)

On sampling dates (1995~2010)

Rotated Factor Pattern		
	Factor1	Factor2
TN	-68*	-7
TP	-20	74*
SECCHI	83*	-19
TSS	-74*	16
WTEMP	22	80*
FLOW	-75*	-37
SALINITY	87*	12

Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.4 are flagged by an '*'.

2 main factors explaining 62% of the variance.

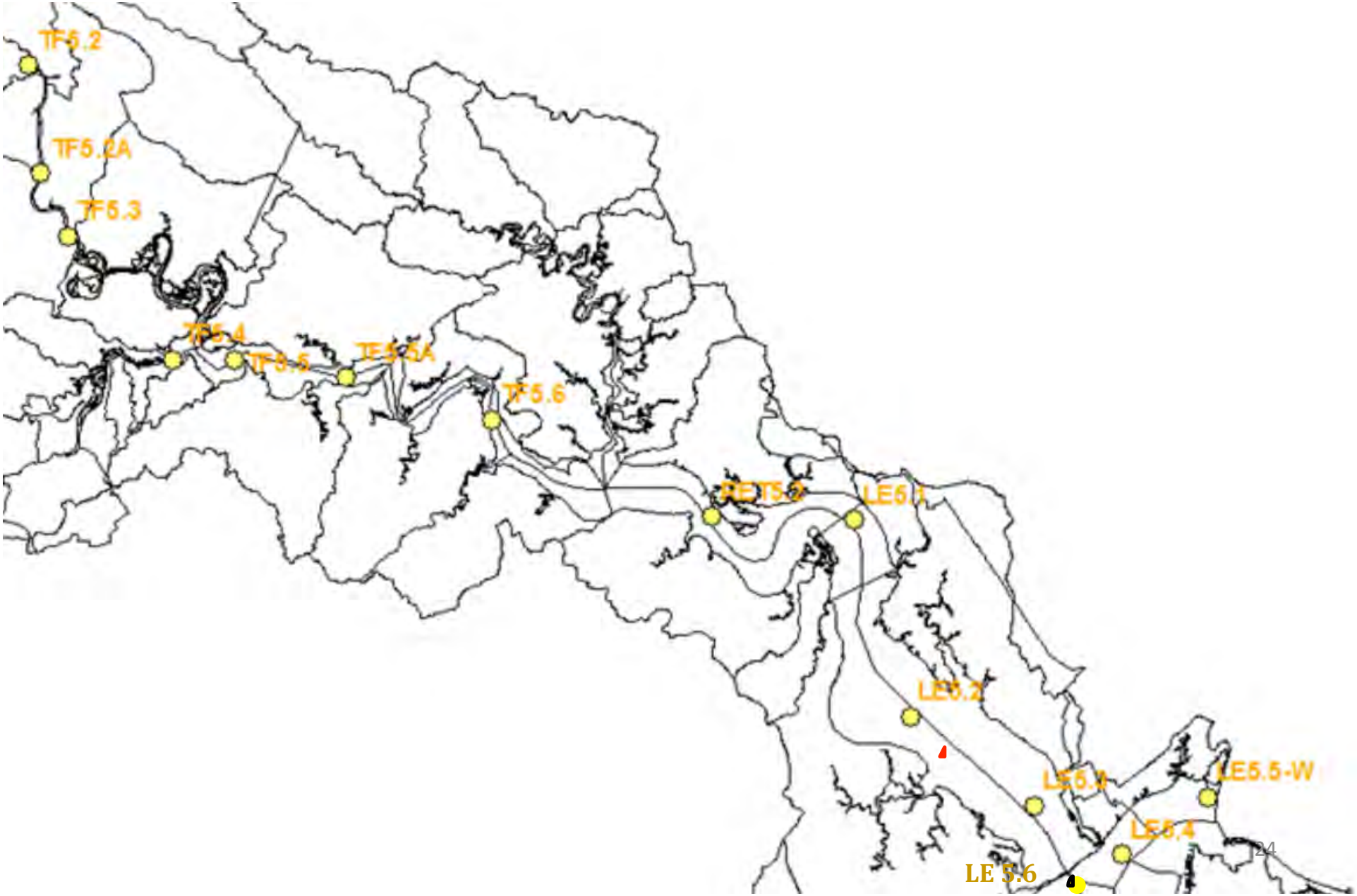
Possible interpretation:
Factor 1: Salinity , Flow and turbidity dominated, TN also has some effects
Factor 2: Temperature and TP dominated

108 samples per parameter

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations			
	logChl-a	Factor1	Factor2
logChl-a	1	-0.19732	0.08436
		0.0436	0.3922
	118	105	105
Factor1	-0.19732	1	0
	0.0436		1
	105	108	108
Factor2	0.08436	0	1
	0.3922	1	
	105	108	108

Correlations between principle components and Chl-a are all weak

Station group 4 (downstream: LE5.3, LE5.4, LE5.6)



Station group 4 (downstream: LE5.3, LE5.4, LE5.6)

Summary of regression analysis between Chl-a and each water quality parameter

Raw Data

Monthly (yearly average, 1995~2010)

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2	Samples
WTEMP	<0.05	120
SALINITY	<0.05	120
SECCHI	0.20	119
TSS	0.08	119
TP	<0.05	116
TN	<0.05	115
FLOW	<0.05	120
FLOW5	<0.05	120
FLOW10	<0.05	120
FLOW20	<0.05	120
FLOW30	<0.05	120
FLOW40	<0.05	120

Parameters	R^2
WTEMP	<0.05
SALINITY	0.13
SECCHI	0.21
TSS	0.15
TP	<0.05
TN	0.21
FLOW	0.08

12 samples per parameter

Station group 4 (downstream: LE5.3, LE5.4, LE5.6)

Summary of regression analysis between Chl-a and each water quality parameter, monthly ensemble average

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2 (1995~2010)	R^2 (1995~2000)	R^2 (2001~2010)
WTEMP	<0.05	0.15	<0.05
SALINITY	0.13	0.25	<0.05
SECCHI	0.21	0.13	0.22
TSS	0.15	<0.05	0.22
TP	<0.05	<0.05	<0.05
TN	0.21	0.06	0.28
FLOW	0.08	<0.05	<0.05

12 samples per period per parameter

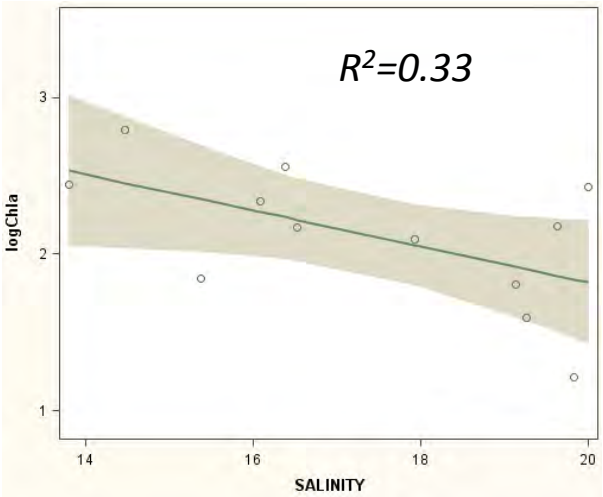
The parameters that have large differences among the 3 periods are presented in next slide

Station group 4 (downstream: LE5.3, LE5.4, LE5.6)

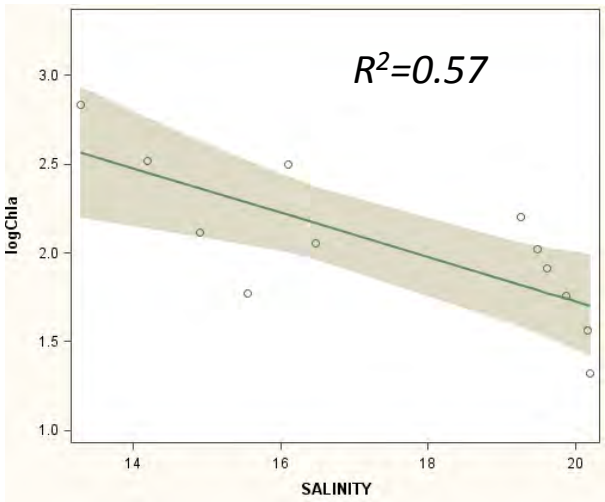
Selective regression plots between Chl-a and each water quality parameter :

Monthly SALINITY (ensemble average)

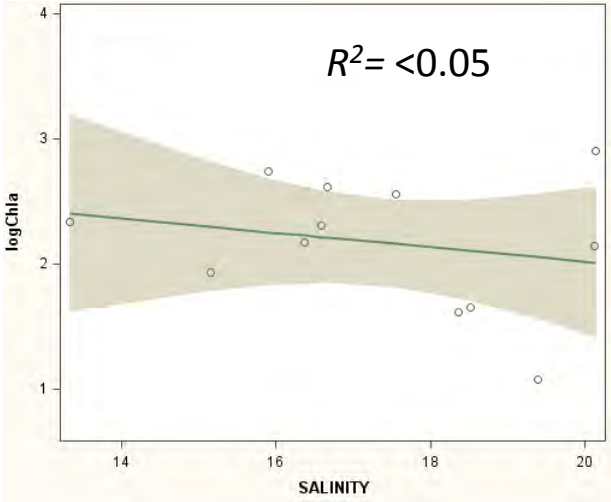
1995~2010



1995~2000



2001~2010



Elizabeth River: Cluster Analysis

Comments:

>>In all of the three time periods, Cluster Analysis identifies three main groups:
Upstream, downstream and one station on Lafayette river (LFB01)

>>The subsequent analysis is mainly based on these 3 groups, since some stations have missing data, the subsequent analysis is focused on the stations with at least 13 years of data:

upstream – SBE5, SBE2
downstream – ELI2, LFA01
Lafayette river – LFB01

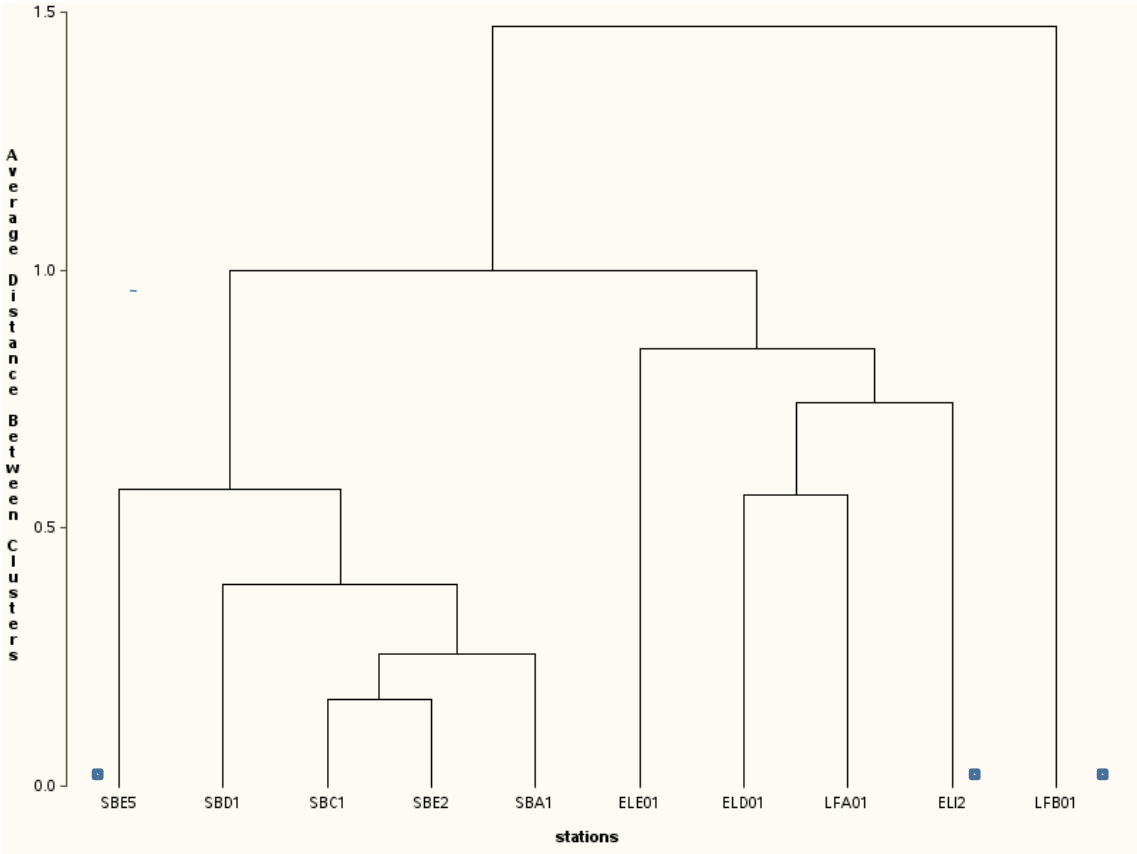
>>LFA01 is not distinguished from the stations from Elizabeth River, probably because it is near the mouth of Lafayette river and close to Elizabeth River.

>>flow discharge data for Elizabeth River is from Deep Creek spillway:
1991~1998: monthly average dataset; 1999~2010: daily average dataset.
For the "on sampling dates" analysis during 1991~1998, monthly average flow discharge is used as an approximation of the flow discharge on each water quality sampling date (usually 1 water quality sample per month)

Elizabeth River: Cluster Analysis (1995~2010)

Cluster History

Number of Clusters	Clusters Joined		Freq	Semipartial R-Square	R-Square
9	SBC1	SBE2	2	0.0031	0.997
8	CL9	SBA1	3	0.0086	0.988
7	SBD1	CL8	4	0.0224	0.966
6	ELD01	LFA01	2	0.0354	0.93
5	SBE5	CL7	5	0.0518	0.879
4	CL6	ELI2	3	0.0698	0.809
3	ELE01	CL4	4	0.0932	0.716
2	CL5	CL3	9	0.3459	0.37
1	CL2	LFB01	10	0.3698	0

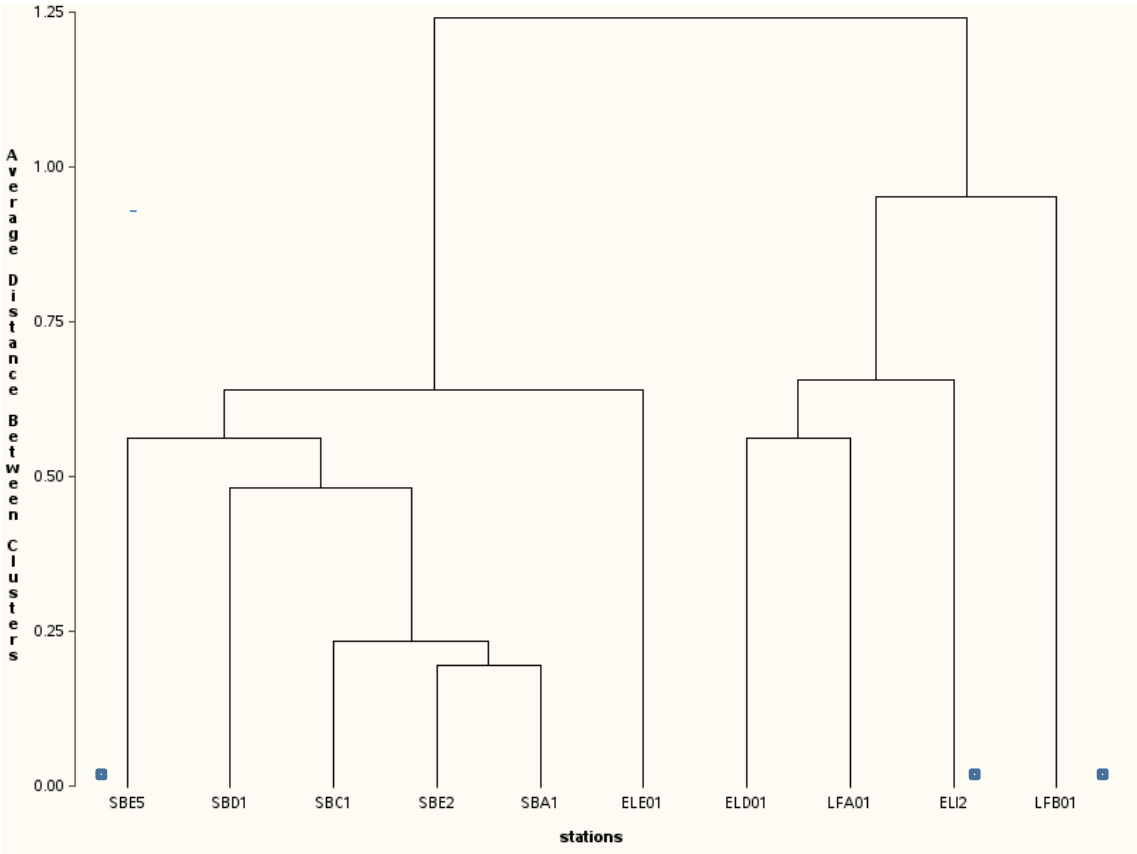


10 stations;
36 samples per station

Elizabeth River: Cluster Analysis (1995~2000)

Cluster History

Number of Clusters	Clusters Joined		Freq	Semipartial R-Square	R-Square
9	SBC1	SBE2	2	0.0031	0.997
8	CL9	SBA1	3	0.0086	0.988
7	SBD1	CL8	4	0.0224	0.966
6	ELD01	LFA01	2	0.0354	0.93
5	SBE5	CL7	5	0.0518	0.879
4	CL6	ELI2	3	0.0698	0.809
3	ELE01	CL4	4	0.0932	0.716
2	CL5	CL3	9	0.3459	0.37
1	CL2	LFB01	10	0.3698	0

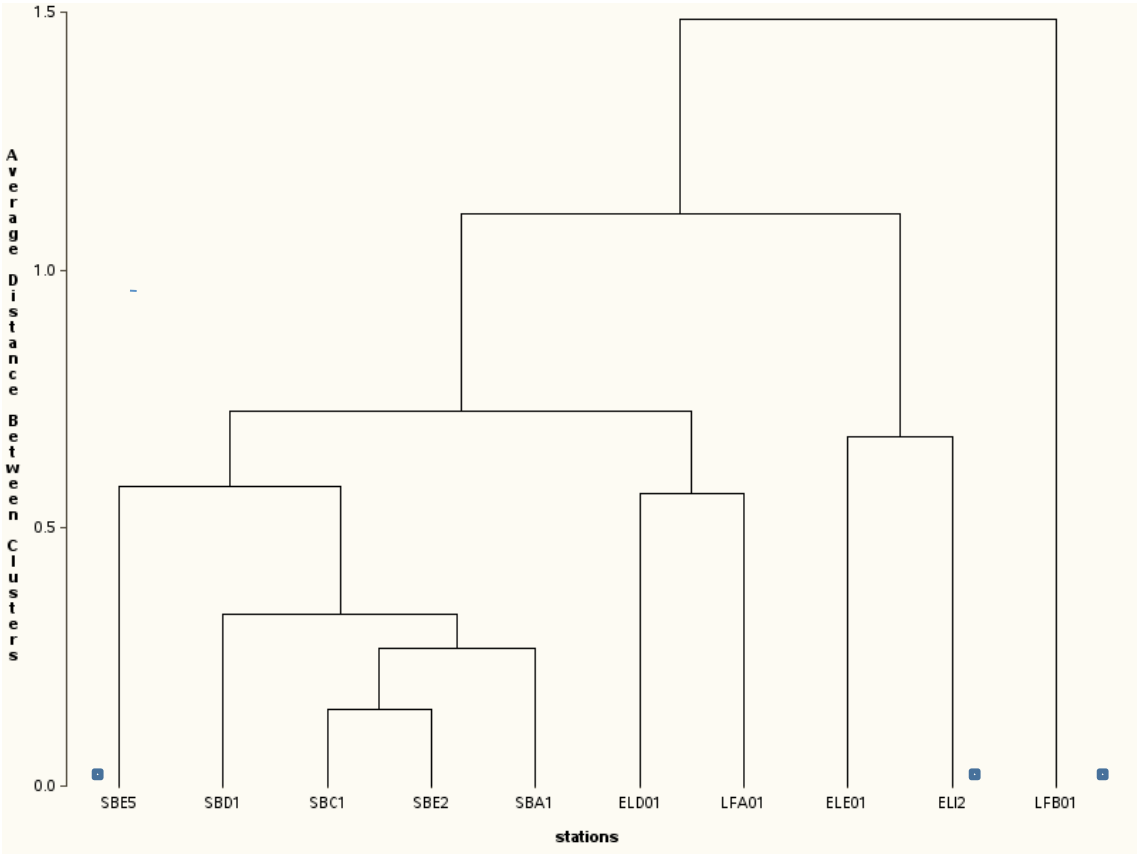


10 stations;
19 samples per station

Elizabeth River: Cluster Analysis (2001~2010)

Cluster History

Number of Clusters	Clusters Joined		Freq	Semipartial R-Square	R-Square
9	SBC1	SBE2	2	0.0024	0.998
8	CL9	SBA1	3	0.0097	0.988
7	SBD1	CL8	4	0.0155	0.972
6	ELD01	LFA01	2	0.0356	0.937
5	SBE5	CL7	5	0.0544	0.882
4	ELE01	ELI2	2	0.051	0.831
3	CL5	CL6	7	0.1183	0.713
2	CL3	CL4	9	0.3326	0.38
1	CL2	LFB01	10	0.3805	0



10 stations;
17 samples per station

Elizabeth River SBE5

Elizabeth River SBE5

Summary of regression analysis between Chl-a and each water quality parameter

Raw Data

Monthly (ensemble average, 1995~2010)

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2	samples
WTEMP	0.07	179
SALINITY	0.18	179
SECCHI	<0.05	178
TSS	0.08	189
TP	<0.05	187
TN	0.07	183
FLOW	<0.05	189

12 samples per parameter

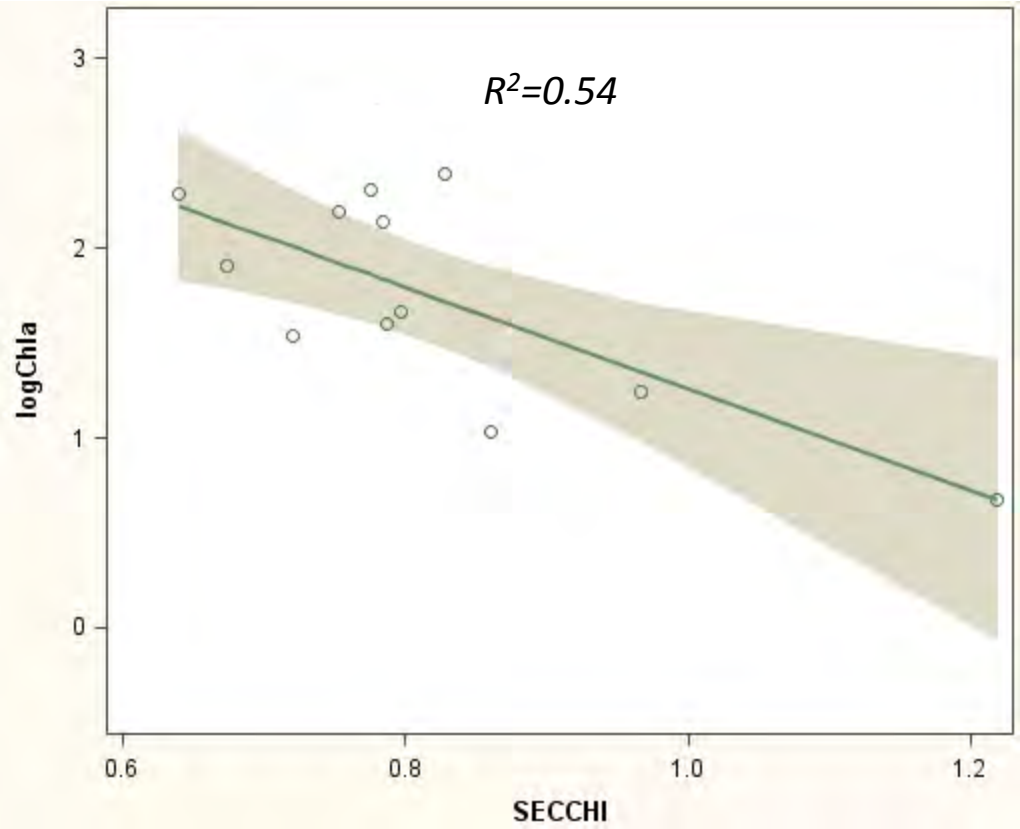
Parameters	R^2
WTEMP	0.06
SALINITY	<0.05
SECCHI	0.54
TSS	0.38
TP	<0.05
TN	0.24
FLOW	<0.05

12 samples per parameter

Elizabeth River SBE5

Selective regression plots between Chl-a and each water quality parameter 1995~2010 , (only those with high correlation)

Monthly SECCHI
(ensemble average)



Elizabeth River SBE5

Summary of regression analysis between Chl-a and each water quality parameter
Monthly ensemble average, 3 periods

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2 (1995~2010)	R^2 (1995~2000)	R^2 (2001~2010)
WTEMP	0.06	0.23	<0.05
SALINITY	<0.05	<0.05	<0.05
SECCHI	0.54	0.40	0.55
TSS	0.38	0.38	0.33
TP	<0.05	0.11	<0.05
TN	0.24	0.20	0.27
FLOW	<0.05	<0.05	<0.05

12 samples per period per parameter

Comments: similar among different periods

Elizabeth River SBE5

Correlation Matrix, Monthly ensemble average, 3 periods , 12 data points (12 months) per period per parameter

Pearson Correlation Coefficients, N = 12

Prob > |r| under H0: Rho=0

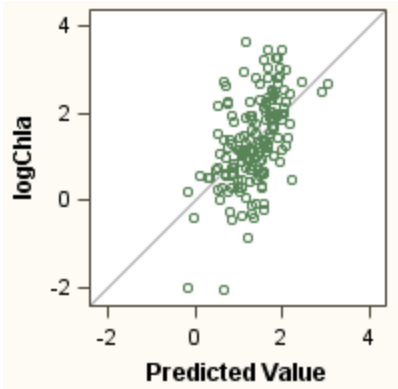
	time periods	logChl-a	FLOW	WTEMP	SALINITY	TP	SECCHI	TSS	TN
logChl-a	**1995~2010**	1							
	1995~2000	1							
	2001~2010	1							
FLOW	**1995~2010**	0.05208	1						
	1995~2000	-0.00373	1						
	2001~2010	-0.0111	1						
WTEMP	**1995~2010**	0.23671	-0.83643	1					
	1995~2000	0.47834	-0.64082	1					
	2001~2010	0.11884	-0.88641	1					
SALINITY	**1995~2010**	-0.04579	-0.88805	0.76107	1				
	1995~2000	-0.16027	-0.89633	0.5984	1				
	2001~2010	0.20259	-0.80618	0.75526	1				
TP	**1995~2010**	0.07923	-0.57225	0.79234	0.68147	1			
	1995~2000	0.33095	-0.19411	0.71955	0.22027	1			
	2001~2010	0.00685	-0.75676	0.78425	0.80618	1			
SECCHI	**1995~2010**	-0.7371	-0.34526	-0.02964	0.48474	0.11251	1		
	1995~2000	-0.63324	-0.4413	-0.08605	0.64342	-0.11994	1		
	2001~2010	-0.74397	-0.24999	0.01909	0.24704	0.21499	1		
TSS	**1995~2010**	0.61416	-0.32247	0.6128	0.10175	0.32003	-0.63061	1	
	1995~2000	0.61976	-0.36308	0.69117	0.14357	0.35346	-0.55599	1	
	2001~2010	0.57358	-0.14777	0.35304	-0.02696	0.12413	-0.63677	1	
TN	**1995~2010**	-0.4944	0.4754	-0.60001	-0.31931	-0.20969	0.24943	-0.49052	1
	1995~2000	-0.4439	0.76607	-0.67552	-0.68082	-0.10092	-0.13053	-0.44528	1
	2001~2010	-0.51511	0.40787	-0.3456	-0.3506	-0.06905	0.26985	-0.27604	1

Elizabeth River SBE5 Multiple regression (On sampling dates)

Multiple Regression Statistical Model:

$$\log(CHLA) = a + b_i x_i + \varepsilon$$

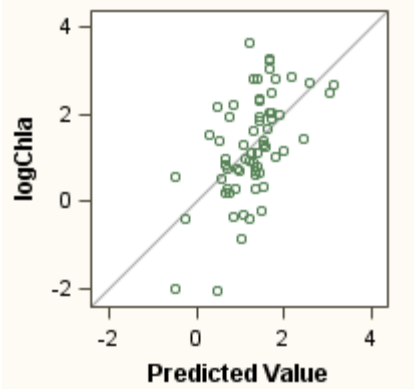
(1995~2010)
R^2=0.28
170 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	0.1465	0.59549	0.25	0.806	0
FLOW	1	-0.00034	0.000746	-0.46	0.6488	-0.05363
WTEMP	1	0.0049	0.01237	0.4	0.6922	0.03621
SALINITY	1	0.10379	0.02899	3.58	0.0005	0.47783
TP	1	-1.20643	2.36365	-0.51	0.6105	-0.04274
SECCHI	1	-0.64531	0.2293	-2.81	0.0055	-0.2529
TSS	1	0.034	0.012	2.83	0.0052	0.1991
TN	1	-0.19164	0.22276	-0.86	0.3909	-0.07095

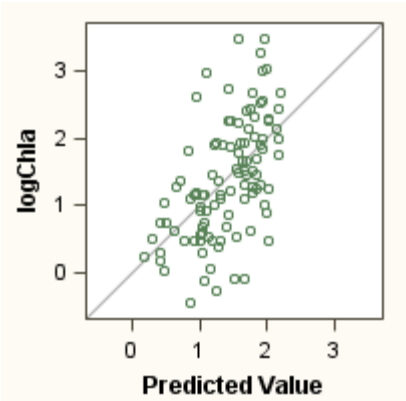
(1995~2000)
R^2=0.32
64 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	1.10477	1.31167	0.84	0.4032	0
FLOW	1	-0.00131	0.00126	-1.04	0.3014	-0.21534
WTEMP	1	0.00163	0.02339	0.07	0.9446	0.01008
SALINITY	1	0.05941	0.05169	1.15	0.2553	0.23717
TP	1	2.7657	4.46104	0.62	0.5378	0.07619
SECCHI	1	-0.76186	0.48243	-1.58	0.1199	-0.22991
TSS	1	0.03775	0.01804	2.09	0.0409	0.24661
TN	1	-0.50224	0.65879	-0.76	0.449	-0.12953

(2001~2010)
R^2=0.31
106 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	-1.27318	0.73656	-1.73	0.087	0
FLOW	1	0.0019	0.00108	1.77	0.0804	0.28291
WTEMP	1	0.01924	0.01468	1.31	0.1932	0.16462
SALINITY	1	0.18239	0.03817	4.78	<.0001	0.93047
TP	1	-6.43103	2.94713	-2.18	0.0315	-0.27413
SECCHI	1	-0.73553	0.24756	-2.97	0.0037	-0.34702
TSS	1	0.01636	0.01957	0.84	0.4053	0.07636
TN	1	-0.004	0.21555	-0.02	0.9852	-0.00186

Elizabeth River SBE5

PCA (identifying the patterns among water quality parameters)

On sampling dates (1995~2010)

Rotated Factor Pattern		
	Factor1	Factor2
FLOW	-85*	-21
TN	-67*	-5
TP	17	73*
SALINITY	89*	24
SECCHI	76*	-18
WTEMP	33	80*
TSS	-25	58*

Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.4 are flagged by an '*'.

2 main factors explaining 63% of the variance.

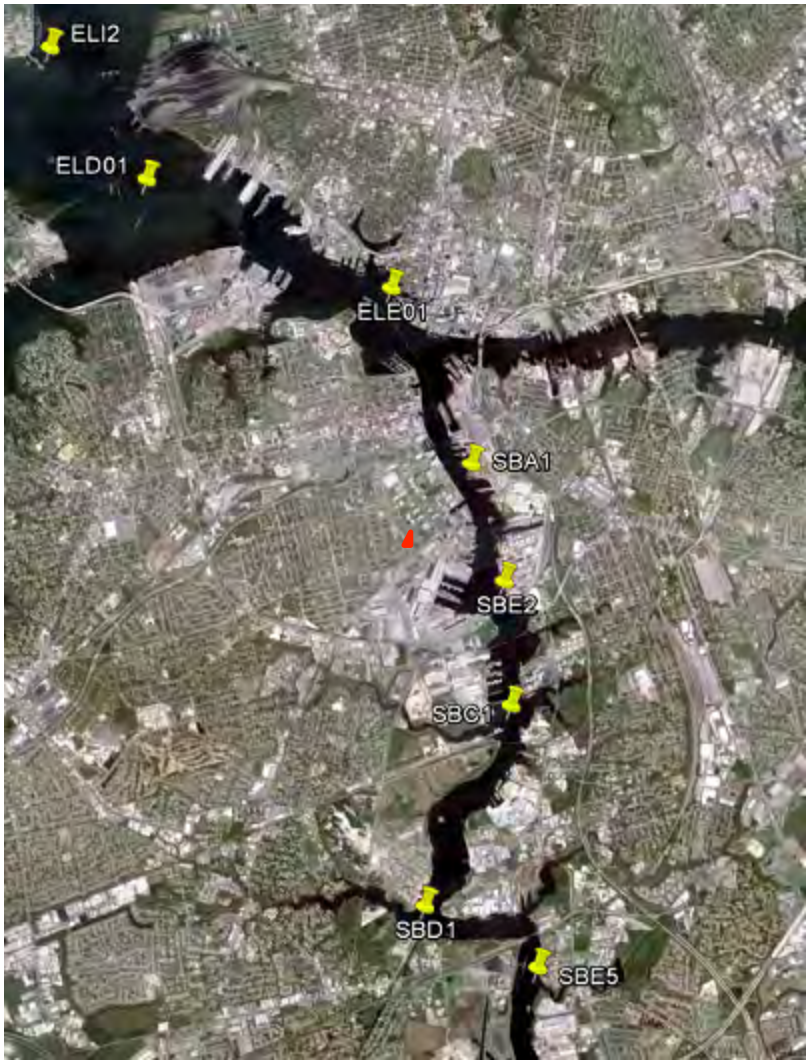
Possible interpretation:
Factor 1: Flow, Salinity and turbidity dominated, TN also has some effects
Factor 2: Temperature and TP dominated, turbidity also has some effects

170 samples per parameter

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations			
	logChl-a	Factor1	Factor2
logChl-a	1	0.28282	0.29003
		0.0002	0.0001
	189	170	170
Factor1	0.28282	1	0
	0.0002		1
	170	170	170
Factor2	0.29003	0	1
	0.0001	1	
	170	170	170

Correlations between principle components and Chl-a are all weak

Elizabeth River SBE2



Elizabeth River SBE2

Summary of regression analysis between Chl-a and each water quality parameter

Raw Data

Monthly (ensemble average, 1995~2010)

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2	Samples
WTEMP	<0.05	177
SALINITY	<0.05	177
SECCHI	<0.05	176
TSS	0.11	186
TP	<0.05	184
TN	<0.05	180
FLOW	<0.05	187

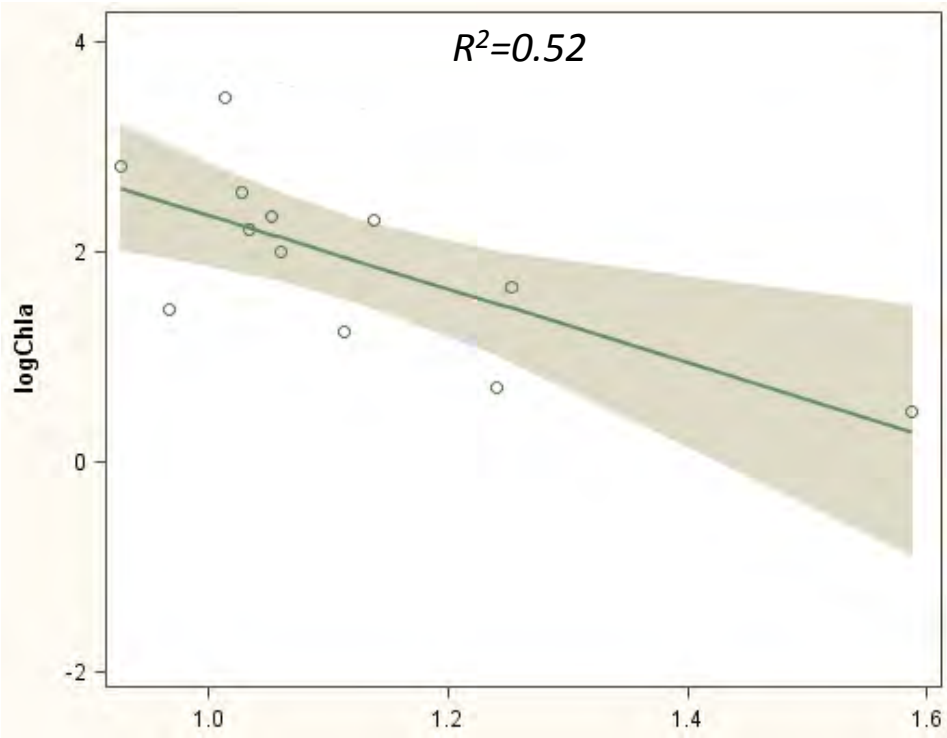
Parameters	R^2
WTEMP	<0.05
SALINITY	<0.05
SECCHI	0.52
TSS	0.49
TP	<0.05
TN	<0.05
FLOW	0.06

12 samples per parameter

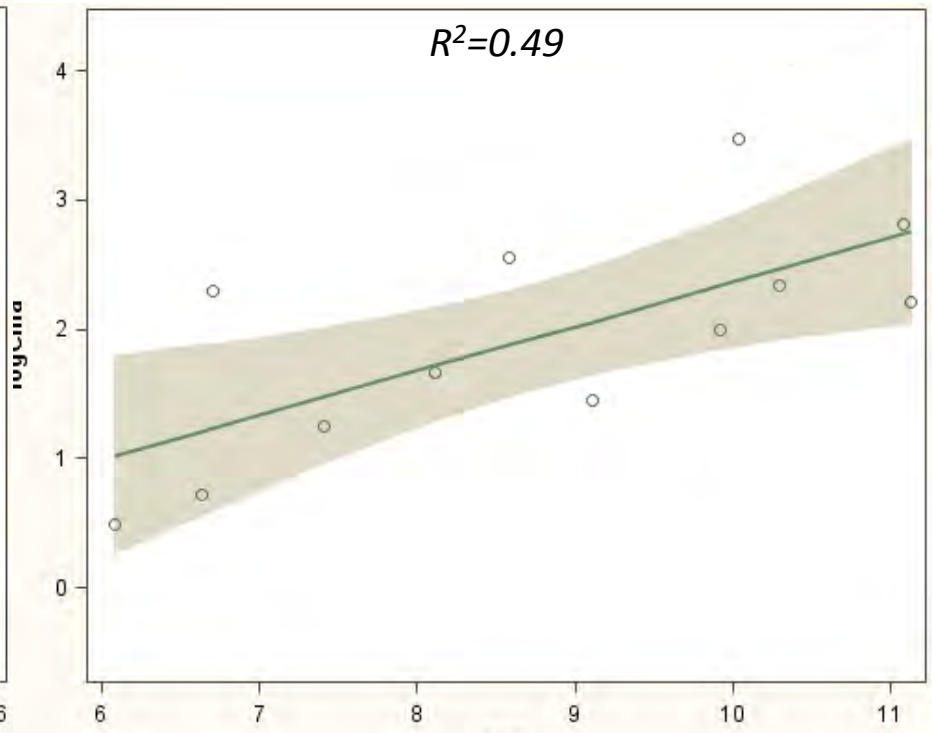
Elizabeth River SBE2

Selective regression plots between Chl-a and each water quality parameter 1995~2010 , (only those with high correlation)

Monthly SECCHI
(ensemble average)



Monthly TSS
(ensemble average)



Elizabeth River SBE2

Summary of regression analysis between Chl-a and each water quality parameter, monthly ensemble average

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2 (1995~2010)	R^2 (1995~2000)	R^2 (2001~2010)
WTEMP	<0.05	<0.05	<0.05
SALINITY	<0.05	0.28	<0.05
SECCHI	0.52	0.37	0.57
TSS	0.49	0.66	0.60
TP	<0.05	<0.05	<0.05
TN	<0.05	<0.05	0.07
FLOW	0.06	0.08	<0.05

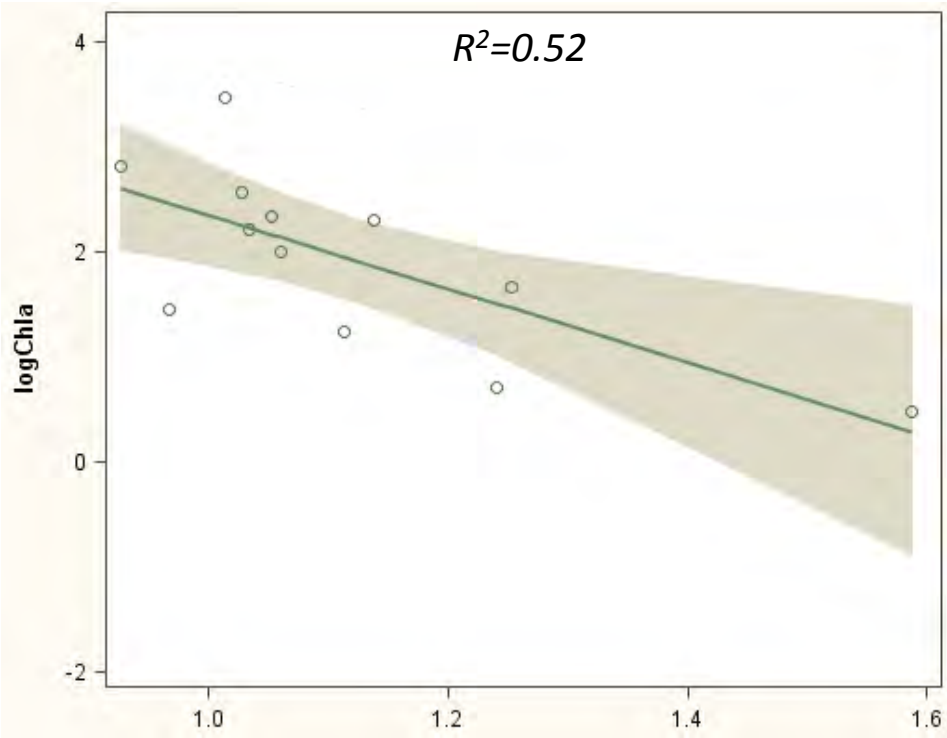
12 samples per period per parameter

The parameters that have large differences among the 3 periods are presented in next slide

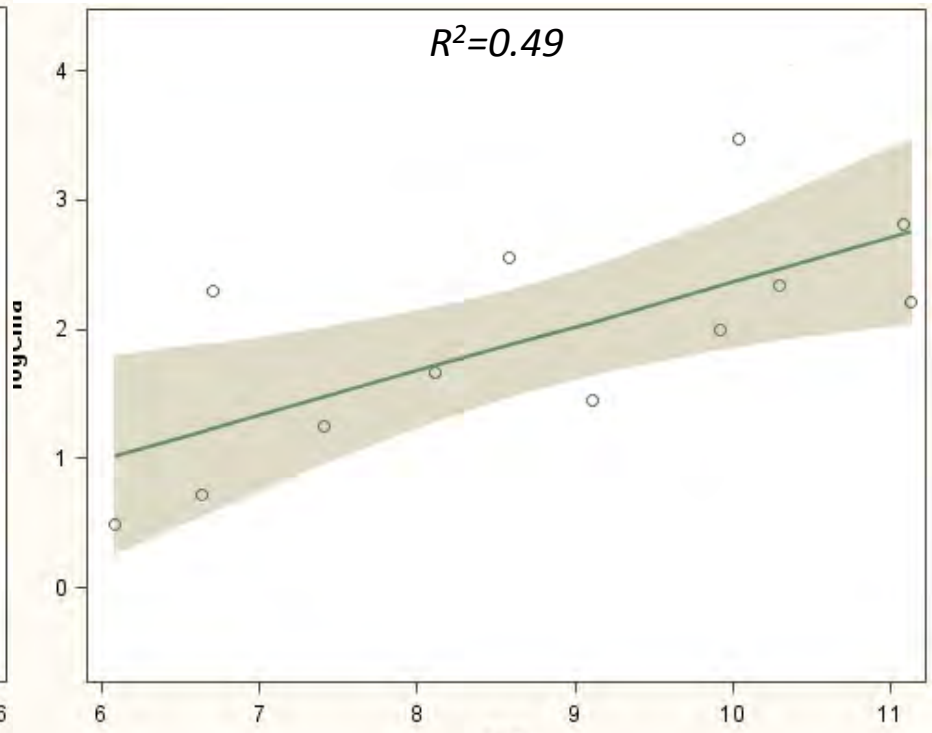
Elizabeth River SBE2

Selective regression plots between Chl-a and each water quality parameter 1995~2010 , (only those with high correlation)

Monthly SECCHI
(ensemble average)



Monthly TSS
(ensemble average)



Elizabeth River SBE2

Correlation Matrix, Monthly ensemble average, 3 periods , 12 data points (12 months) per period per parameter

Pearson Correlation Coefficients, N = 12

Prob > |r| under H0: Rho=0

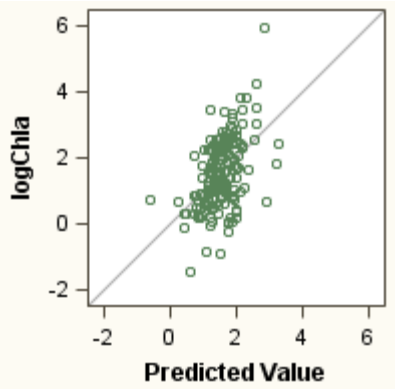
	time periods	logChl-a	FLOW	WTEMP	SALINITY	TP	SECCHI	TSS	TN
logChl-a	1995~2010	1							
	1995~2000	1							
	2001~2010	1							
FLOW	1995~2010	0.25387	1						
	1995~2000	0.28337	1						
	2001~2010	0.16563	1						
WTEMP	1995~2010	0.00164	-0.8234	1					
	1995~2000	-0.11116	-0.61946	1					
	2001~2010	0.03288	-0.88178	1					
SALINITY	1995~2010	-0.12824	-0.82133	0.701	1				
	1995~2000	-0.52741	-0.8527	0.55523	1				
	2001~2010	0.16997	-0.79029	0.71481	1				
TP	1995~2010	-0.03759	-0.53239	0.79096	0.72899	1			
	1995~2000	-0.21264	-0.25354	0.79623	0.385	1			
	2001~2010	0.05346	-0.7142	0.77576	0.83152	1			
SECCHI	1995~2010	-0.71847	-0.19941	-0.15187	0.36104	0.05299	1		
	1995~2000	-0.61106	-0.244	-0.28774	0.48861	-0.26509	1		
	2001~2010	-0.75269	-0.22757	0.0007	0.22374	0.20433	1		
TSS	1995~2010	0.70233	0.02407	0.24286	-0.24313	-0.09102	-0.75579	1	
	1995~2000	0.80961	-0.02508	0.10091	-0.34962	-0.11048	-0.62567	1	
	2001~2010	0.77201	-0.10007	0.36816	0.14674	0.22268	-0.68284	1	
TN	1995~2010	-0.19136	0.58832	-0.54716	-0.26125	-0.12452	0.22472	-0.38426	1
	1995~2000	0.06628	0.92712	-0.61613	-0.74645	-0.2016	-0.04543	-0.23198	1
	2001~2010	-0.26633	0.38524	-0.28275	-0.14299	0.03611	0.27953	-0.27303	1

Elizabeth River SBE2 Multiple regression (On sampling dates)

Multiple Regression Statistical Model:

$$\log(CHLA) = a + b_i x_i + \varepsilon$$

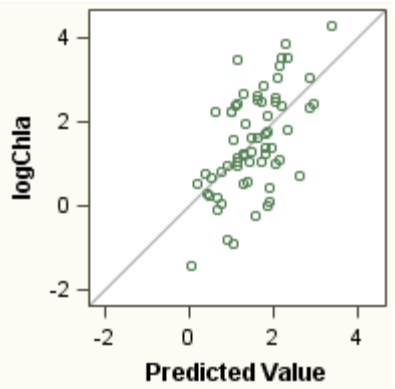
(1995~2010)
R^2=0.25
168 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	0.76005	0.74706	1.02	0.3105	0
FLOW	1	-0.00097	0.000758	-1.28	0.2041	-0.13939
WTEMP	1	-0.02521	0.01344	-1.88	0.0625	-0.17707
SALINITY	1	0.09489	0.03667	2.59	0.0106	0.31822
TP	1	-0.97431	3.0025	-0.32	0.746	-0.0314
SECCHI	1	-0.79185	0.196	-4.04	<.0001	-0.3547
TSS	1	0.05752	0.01342	4.29	<.0001	0.30819
TN	1	0.08694	0.20977	0.41	0.6791	0.03248

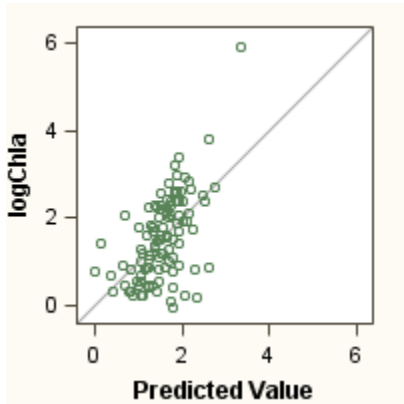
(1995~2000)
R^2=0.33
64 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	-0.40544	1.64266	-0.25	0.806	0
FLOW	1	-0.00123	0.00115	-1.07	0.2898	-0.18646
WTEMP	1	-0.03782	0.026	-1.45	0.1514	-0.23545
SALINITY	1	0.1345	0.06959	1.93	0.0583	0.38521
TP	1	8.58374	8.26017	1.04	0.3032	0.16769
SECCHI	1	-1.26808	0.42729	-2.97	0.0044	-0.40678
TSS	1	0.04994	0.01839	2.72	0.0088	0.31217
TN	1	0.62451	0.72121	0.87	0.3902	0.1518

(2001~2010)
R^2=0.32
104 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	1.02599	0.85157	1.2	0.2312	0
FLOW	1	-0.00155	0.00105	-1.48	0.143	-0.20989
WTEMP	1	-0.02417	0.01524	-1.59	0.1161	-0.18593
SALINITY	1	0.06479	0.04377	1.48	0.1421	0.23973
TP	1	-4.4348	3.05038	-1.45	0.1492	-0.18046
SECCHI	1	-0.57256	0.21028	-2.72	0.0077	-0.29996
TSS	1	0.11334	0.02635	4.3	<.0001	0.40739
TN	1	0.07858	0.19926	0.39	0.6942	0.03654

Elizabeth River SBE2

PCA (identifying the patterns among water quality parameters)

On sampling dates (1995~2010)

	Rotated Factor Pattern		
	Factor1	Factor2	Factor3
FLOW	80*	-30	19
TN	79*	18	-21
TP	1	92*	-1
SALINITY	-75*	39	-33
SECCHI	-46*	4	-70*
WTEMP	-20	83*	10
TSS	-11	10	81*

Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.4 are flagged by an '*'.

No obvious patterns

169 samples per parameter

Elizabeth River ELI2

Elizabeth River ELI2

Summary of regression analysis between Chl-a and each water quality parameter

Raw Data

Monthly (ensemble average, 1995~2010)

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2	Samples
WTEMP	<0.05	180
SALINITY	<0.05	180
SECCHI	0.10	180
TSS	<0.05	190
TP	<0.05	183
TN	<0.05	177
FLOW	<0.05	190

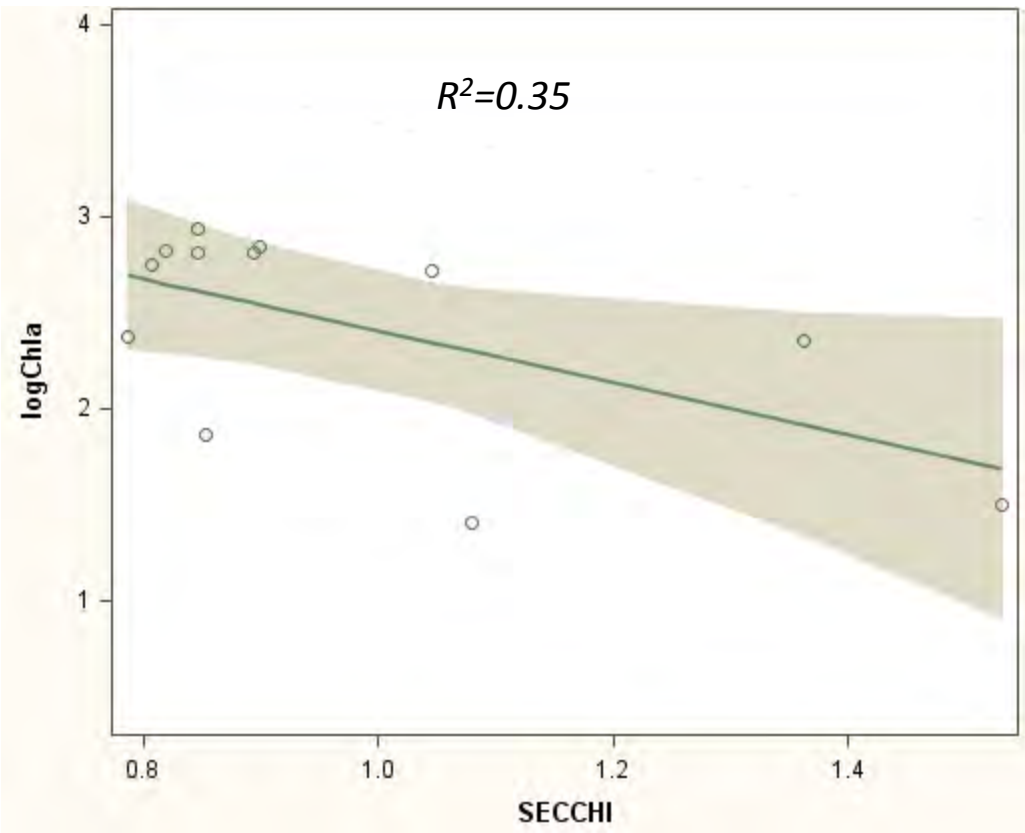
Parameters	R^2
WTEMP	<0.05
SALINITY	0.08
SECCHI	0.35
TSS	0.29
TP	<0.05
TN	<0.05
FLOW	<0.05

12 samples per parameter

Elizabeth River ELI2

Selective regression plots between Chl-a and each water quality parameter 1995~2010 , (only those with high correlation)

Monthly SECCHI
(ensemble average)



Elizabeth River ELI2

Summary of regression analysis between Chl-a and each water quality parameter

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2 (1995~2010)	R^2 (1995~2000)	R^2 (2001~2010)
WTEMP	<0.05	<0.05	<0.05
SALINITY	0.08	0.09	<0.05
SECCHI	0.35	0.32	0.34
TSS	0.29	0.25	0.23
TP	<0.05	<0.05	0.08
TN	<0.05	0.17	0.14
FLOW	<0.05	<0.05	0.08

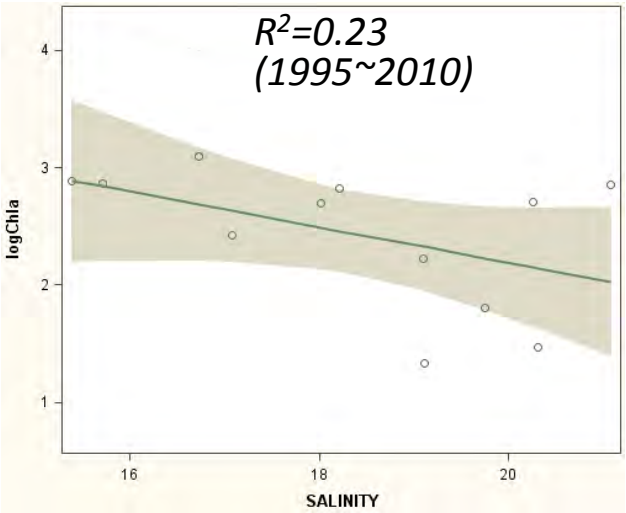
12 samples per period per parameter

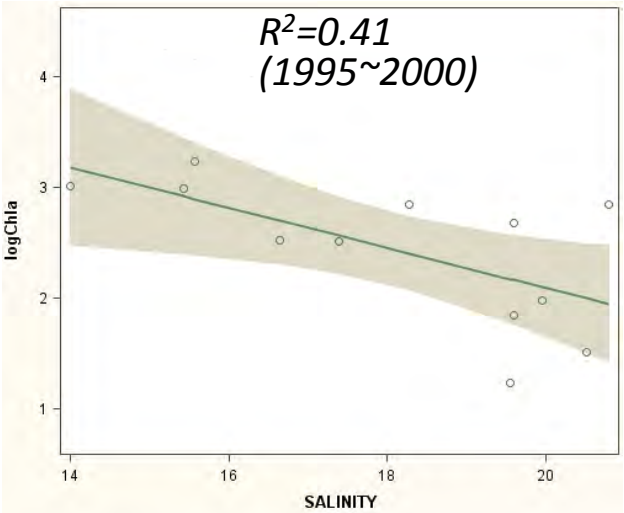
The parameters that have large differences among the 3 periods are presented in next slide

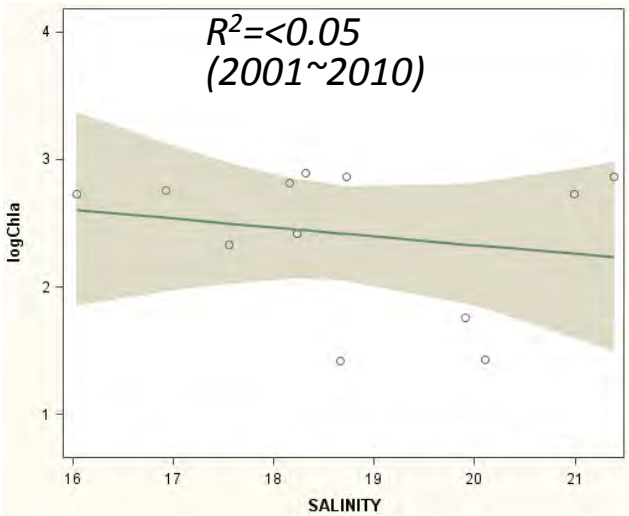
Elizabeth River ELI2

Selective regression plots between Chl-a and each water quality parameter :

Monthly SALINITY
(ensemble average)







Elizabeth River ELI2

Correlation Matrix, Monthly ensemble average, 3 periods, 12 data points (12 months) per period per parameter

Pearson Correlation Coefficients, N = 12

Prob > |r| under H0: Rho=0

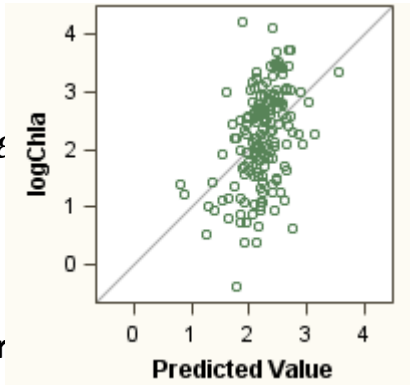
	time periods	logChl-a	FLOW	WTEMP	SALINITY	TP	SECCHI	TSS	TN
logChl-a	1995~2010	1							
	1995~2000	1							
	2001~2010	1							
FLOW	1995~2010	0.19007	1						
	1995~2000	-0.0578	1						
	2001~2010	0.4027	1						
WTEMP	1995~2010	-0.03103	-0.8203	1					
	1995~2000	0.18661	-0.62996	1					
	2001~2010	-0.15765	-0.88105	1					
SALINITY	1995~2010	-0.27482	-0.74832	0.6024	1				
	1995~2000	-0.29475	-0.77314	0.55857	1				
	2001~2010	-0.19644	-0.68217	0.52394	1				
TP	1995~2010	-0.18602	-0.49161	0.77507	0.67398	1			
	1995~2000	0.00912	-0.24869	0.77354	0.50236	1			
	2001~2010	-0.27938	-0.64874	0.76722	0.63539	1			
SECCHI	1995~2010	-0.58891	-0.06524	-0.35633	0.33364	-0.23053	1		
	1995~2000	-0.56427	-0.2337	-0.36305	0.49101	-0.38078	1		
	2001~2010	-0.58559	0.07069	-0.33845	0.20874	-0.16985	1		
TSS	1995~2010	0.54087	-0.0722	0.34168	-0.26063	0.24103	-0.82137	1	
	1995~2000	0.49951	-0.18534	0.45936	-0.1193	0.19809	-0.66552	1	
	2001~2010	0.47616	0.15691	0.17977	-0.33751	0.21933	-0.65499	1	
TN	1995~2010	-0.12282	0.11791	0.14893	0.39582	0.64886	0.04425	-0.02373	1
	1995~2000	0.41817	0.27893	0.1039	-0.08242	0.43815	-0.38113	0.06093	1
	2001~2010	-0.37549	-0.04708	0.151	0.24122	0.61832	0.22001	-0.03875	1

Elizabeth River ELI2 Multiple regression (On sampling dates)

Multiple Regression Statistical Model:

$$\log(CHLA) = a + b_i x_i + \varepsilon$$

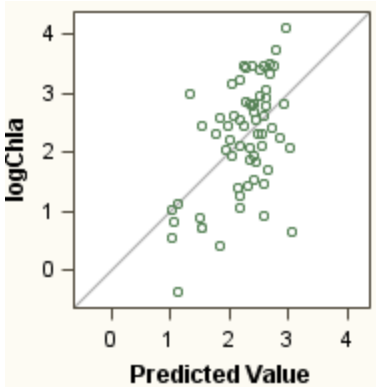
(1995~2010)
R^2=0.19
169 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	2.31224	0.55883	4.14	<.0001	0
FLOW	1	-0.00101	0.000534	-1.88	0.0616	-0.18971
WTEMP	1	-0.00829	0.01026	-0.81	0.4203	-0.07776
SALINITY	1	0.0236	0.02501	0.94	0.3469	0.09924
TP	1	-6.57767	3.28783	-2	0.0471	-0.22178
SECCHI	1	-0.68126	0.16909	-4.03	<.0001	-0.35205
TSS	1	0.01658	0.00756	2.19	0.0299	0.1811
TN	1	0.86171	0.39112	2.2	0.029	0.19493

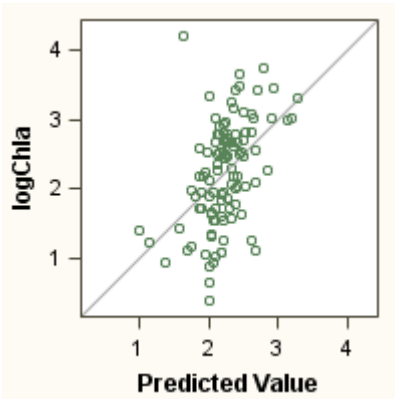
(1995~2000)
R^2=0.28
64 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	1.77954	1.13193	1.57	0.1216	0
FLOW	1	-0.00173	0.000793	-2.19	0.0329	-0.35538
WTEMP	1	-0.00975	0.01729	-0.56	0.5749	-0.08307
SALINITY	1	0.05287	0.04872	1.09	0.2825	0.18985
TP	1	-5.49039	7.44303	-0.74	0.4638	-0.13751
SECCHI	1	-0.91116	0.32667	-2.79	0.0072	-0.38859
TSS	1	0.01233	0.01108	1.11	0.2705	0.14618
TN	1	1.27519	0.90322	1.41	0.1635	0.23157

(2001~2010)
R^2=0.22
105 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	2.03729	0.65902	3.09	0.0026	0
FLOW	1	0.000491	0.000778	0.63	0.5294	0.08298
WTEMP	1	-0.00427	0.01272	-0.34	0.7377	-0.0433
SALINITY	1	0.02612	0.0289	0.9	0.3683	0.12243
TP	1	-7.2473	3.66055	-1.98	0.0506	-0.29199
SECCHI	1	-0.5294	0.19349	-2.74	0.0074	-0.3078
TSS	1	0.02314	0.01214	1.91	0.0596	0.21159
TN	1	0.63468	0.41291	1.54	0.1275	0.16615

Elizabeth River ELI2

PCA (identifying the patterns among water quality parameters)

On sampling dates (1995~2010)

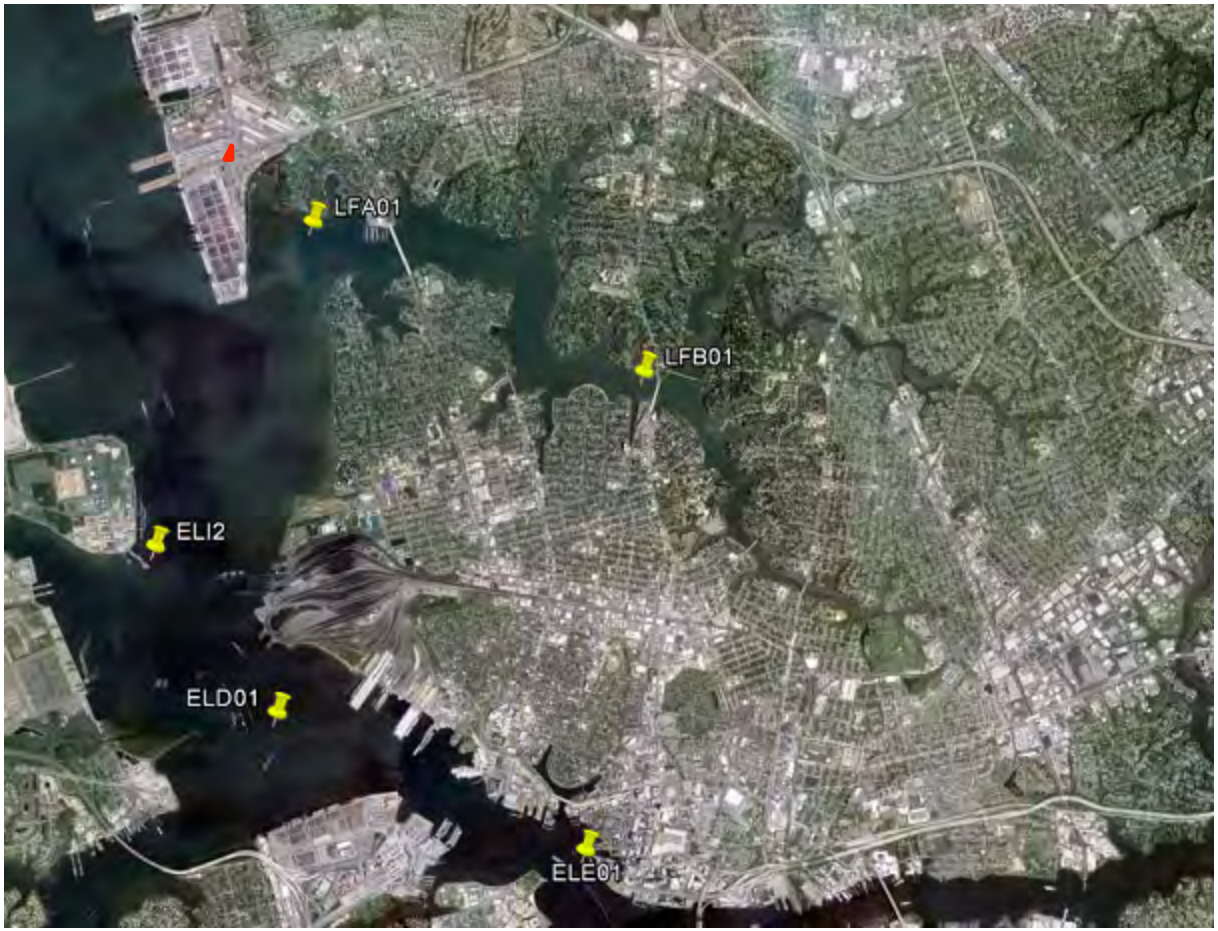
Rotated Factor Pattern			
	Factor1	Factor2	Factor3
FLOW	-87*	11	7
TN	-40	81*	-10
TP	37	79*	27
SALINITY	84*	8	-19
SECCHI	27	-21	-77*
WTEMP	57*	52*	23
TSS	6	-2	85*

Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.4 are flagged by an '*'.

No obvious patterns

169 samples per parameter

Lafayette River LFA01



Lafayette River LFA01

Summary of regression analysis between Chl-a and each water quality parameter

Raw Data

Parameters	R^2	Samples
WTEMP	<0.05	143
SALINITY	<0.05	143
SECCHI	0.15	143
TSS	<0.05	142
TP	<0.05	139
TN	<0.05	140

Monthly (ensemble average, 1998~2010)

Parameters	R^2
WTEMP	<0.05
SALINITY	<0.05
SECCHI	<0.05
TSS	<0.05
TP	<0.05
TN	0.37

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

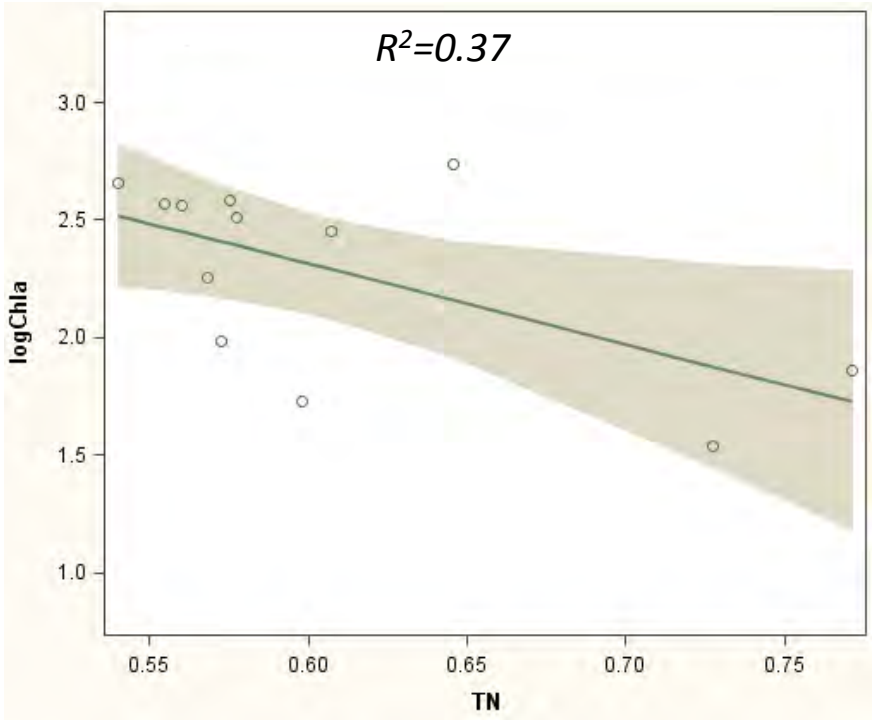
(Linear regression, log transform on Chl-a)

12 samples per parameter

Lafayette River LFA01

Selective regression plots between Chl-a and each water quality parameter 1991~2010 , (only those with high correlation)

Monthly TN
(ensemble average)



Lafayette River LFA01

Correlation Matrix, Monthly ensemble average, 1998~2010, 12 data points (12 months) per period per parameter

Pearson Correlation Coefficients, N = 12

Prob > |r| under H0: Rho=0

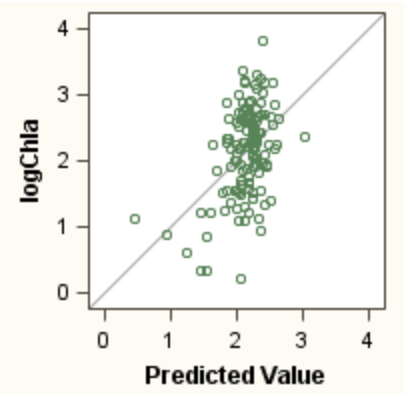
	logChl-a	WTEMP	SALINITY	TP	SECCHI	TSS	TN
logChl-a	1	-0.0451	0.01503	-0.06749	-0.21924	0.21833	-0.60722
WTEMP	-0.0451	1	0.45922	0.73838	-0.72892	0.68376	0.33595
SALINITY	0.01503	0.45922	1	0.73658	0.09471	-0.08787	0.39961
TP	-0.06749	0.73838	0.73658	1	-0.36608	0.19579	0.68695
SECCHI	-0.21924	-0.72892	0.09471	-0.36608	1	-0.85115	-0.08792
TSS	0.21833	0.68376	-0.08787	0.19579	-0.85115	1	-0.17805
TN	-0.60722	0.33595	0.39961	0.68695	-0.08792	-0.17805	1

Lafayette River LFA01 Multiple regression (On sampling dates)

Multiple Regression
Statistical Model:

$$\log(CHLA) = a + b_i x_i + \varepsilon$$

(1998~2010)
R^2=0.21
135 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	2.99354	0.4455	6.72	<.0001	0
WTEMP	1	-0.02439	0.00881	-2.77	0.0065	-0.28785
SALINITY	1	0.02578	0.01791	1.44	0.1525	0.14201
TP	1	0.2688	2.04841	0.13	0.8958	0.01257
SECCHI	1	-0.91692	0.18107	-5.06	<.0001	-0.59918
TSS	1	-0.00576	0.00749	-0.77	0.4429	-0.08105
TN	1	-0.03088	0.34621	-0.09	0.9291	-0.00809

Lafayette River LFA01

PCA (identifying the patterns among water quality parameters)

On sampling dates (1998~2010)

Rotated Factor Pattern			
	Factor1	Factor2	Factor3
TN	1	18	92*
TP	7	85*	21
SALINITY	-17	66*	-60*
SECCHI	-88*	-3	-25
TSS	88*	11	-13
WTEMP	51*	68*	2

Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.4 are flagged by an '*'.

No obvious patterns.

130 samples per parameter

Lafayette River LFB01

Lafayette River LFB01

Summary of regression analysis between Chl-a and each water quality parameter

Raw Data

Monthly (ensemble average, 1998~2010)

Statistical Model:

$$\log(CHLA) = a + bx + \varepsilon$$

(Linear regression, log transform on Chl-a)

Parameters	R^2	Sample
WTEMP	0.13	143
SALINITY	<0.05	142
SECCHI	0.28	143
TSS	0.17	142
TP	0.34	138
TN	0.39	137

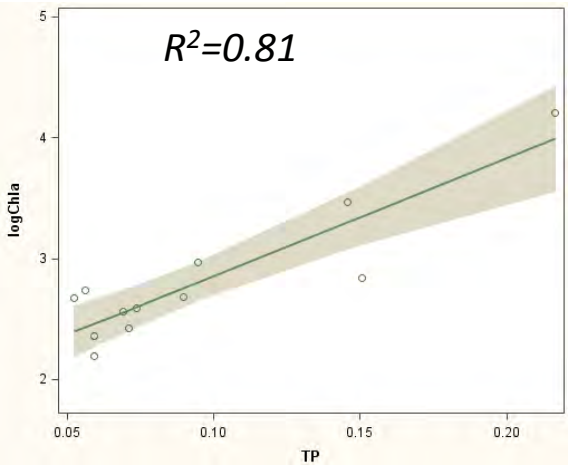
Parameters	R^2
WTEMP	0.48
SALINITY	0.33
SECCHI	0.36
TSS	0.47
TP	0.81
TN	0.65

12 samples per parameter

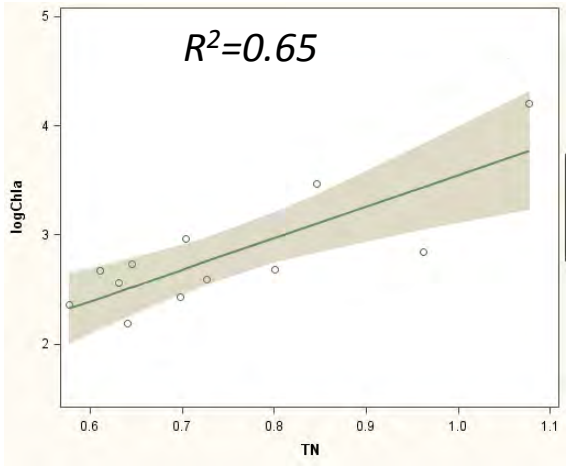
Lafayette River LFB01

Selective regression plots between Chl-a and each water quality parameter 1998~2010 , (only those with high correlation)

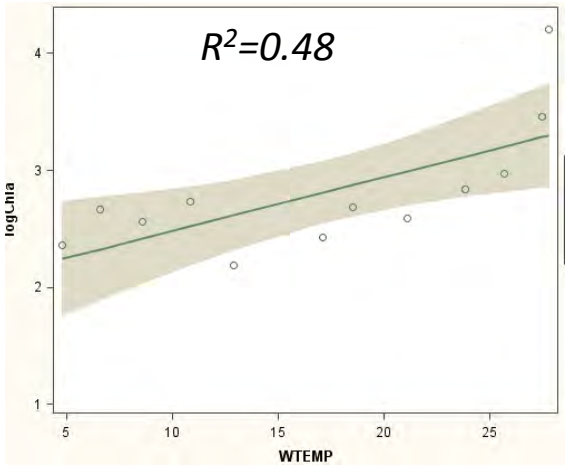
Monthly TP (ensemble average)



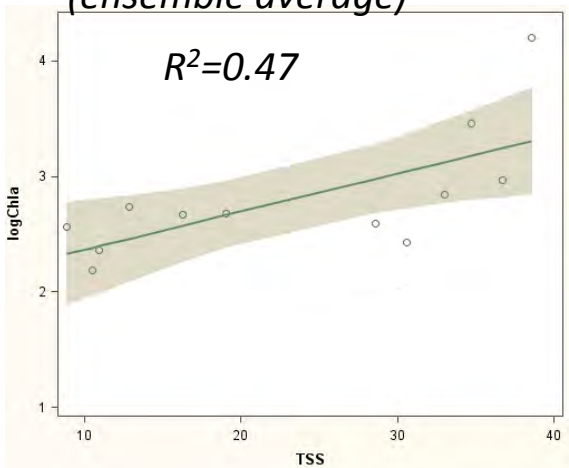
Monthly TN (ensemble average)



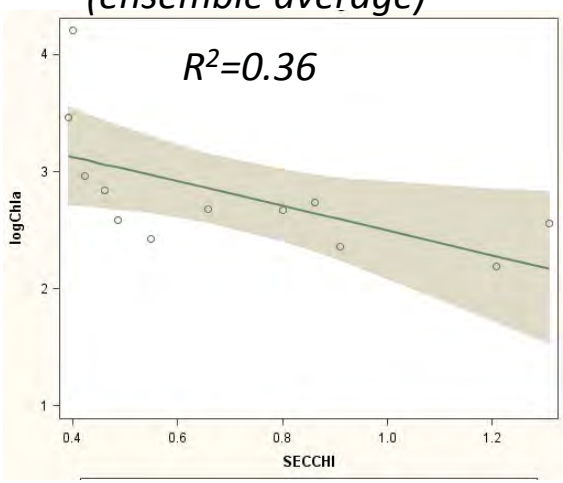
Monthly WTEMP (ensemble average)



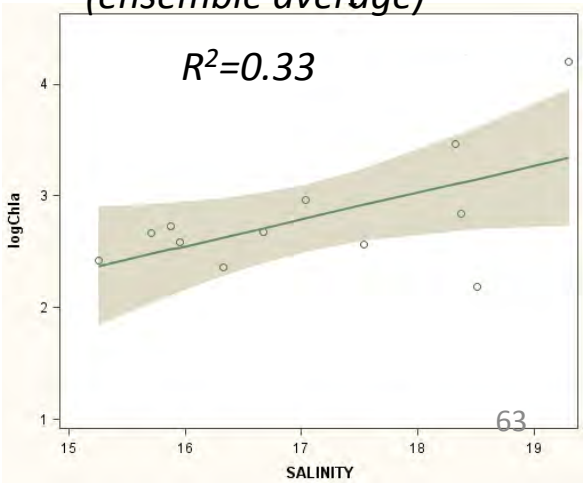
Monthly TSS (ensemble average)



Monthly SECCHI (ensemble average)



Monthly SALINITY (ensemble average)



Lafayette River LFB01

Correlation Matrix, Monthly ensemble average, 1998~2010, 12 data points (12 months) per period per parameter

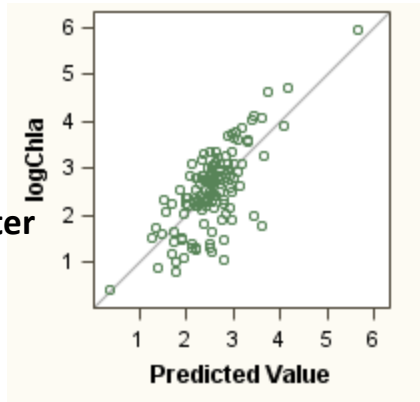
Pearson Correlation Coefficients, N = 12 Prob > |r| under H0: Rho=0							
	logChl-a	**WTEMP**	**SALINITY**	**TP**	**SECCHI**	**TSS**	**TN**
logChl-a	1	0.6935	0.57692	0.89789	-0.60406	0.68286	0.80712
WTEMP	0.6935	1	0.51172	0.78589	-0.8107	0.91568	0.81177
SALINITY	0.57692	0.51172	1	0.74312	-0.06453	0.29869	0.66081
TP	0.89789	0.78589	0.74312	1	-0.62065	0.74259	0.95829
SECCHI	-0.60406	-0.8107	-0.06453	-0.62065	1	-0.92357	-0.66064
TSS	0.68286	0.91568	0.29869	0.74259	-0.92357	1	0.74368
TN	0.80712	0.81177	0.66081	0.95829	-0.66064	0.74368	1

Lafayette River LFB01 Multiple regression (On sampling dates)

Multiple Regression
Statistical Model:

$$\log(CHLA) = a + b_i x_i + \varepsilon$$

(1998~2010)
R^2=0.54
131 samples per parameter



Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
Intercept	1	2.57508	0.44232	5.82	<.0001	0
WTEMP	1	-0.02037	0.00972	-2.1	0.0382	-0.19788
SALINITY	1	-0.00028	0.0172	-0.02	0.9869	-0.00125
TP	1	4.14604	1.31161	3.16	0.002	0.31673
SECCHI	1	-1.0461	0.22658	-4.62	<.0001	-0.46325
TSS	1	-0.007	0.00661	-1.06	0.2919	-0.10986
TN	1	1.09309	0.29024	3.77	0.0003	0.34974

Lafayette River LFB01

PCA (identifying the patterns among water quality parameters)

On sampling dates (1998~2010)

Rotated Factor Pattern	Factor1	Factor2
TP	77*	26
TN	70*	-33
SECCHI	-82*	17
TSS	81*	3
WTEMP	82*	29
SALINITY	4	97*

Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.4 are flagged by an '*'.

2 main factors explaining 72% of the variance

Factor 1: Turbidity, temperature and nutrient dominated
Factor 2: salinity dominated

138 samples per parameter

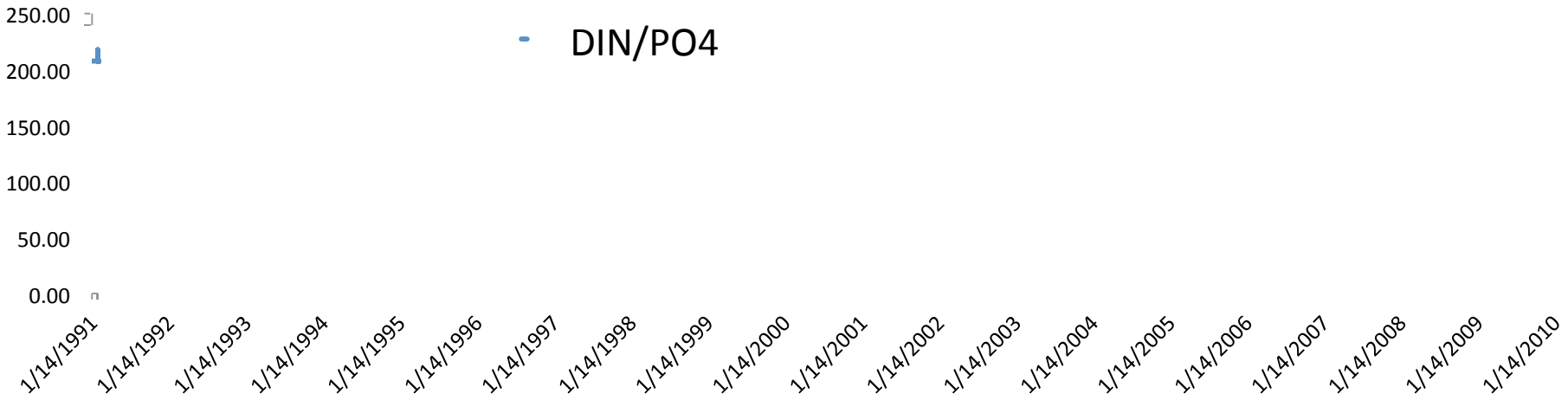
Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations	logChl-a	Factor1	Factor2
logChl-a	1	0.61896	-0.18298
		<.0001	0.0364
	144	131	131
Factor1	0.61896	1	0
	<.0001		1
	131	138	138
Factor2	-0.18298	0	1
	0.0364	1	
	131	138	138

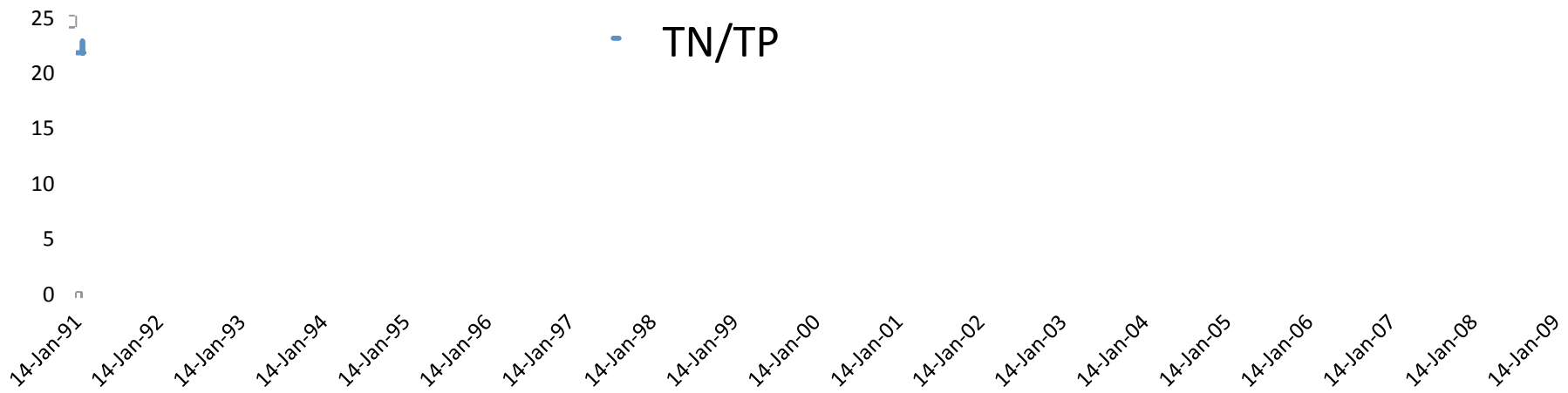
Factor 1 has positive correlation with Chl-a: high water temperature, high nutrient concentrations and high turbidity condition leads to high Chl-a concentration. The R^2 is not very high though.

Factor 2's correlation is weak

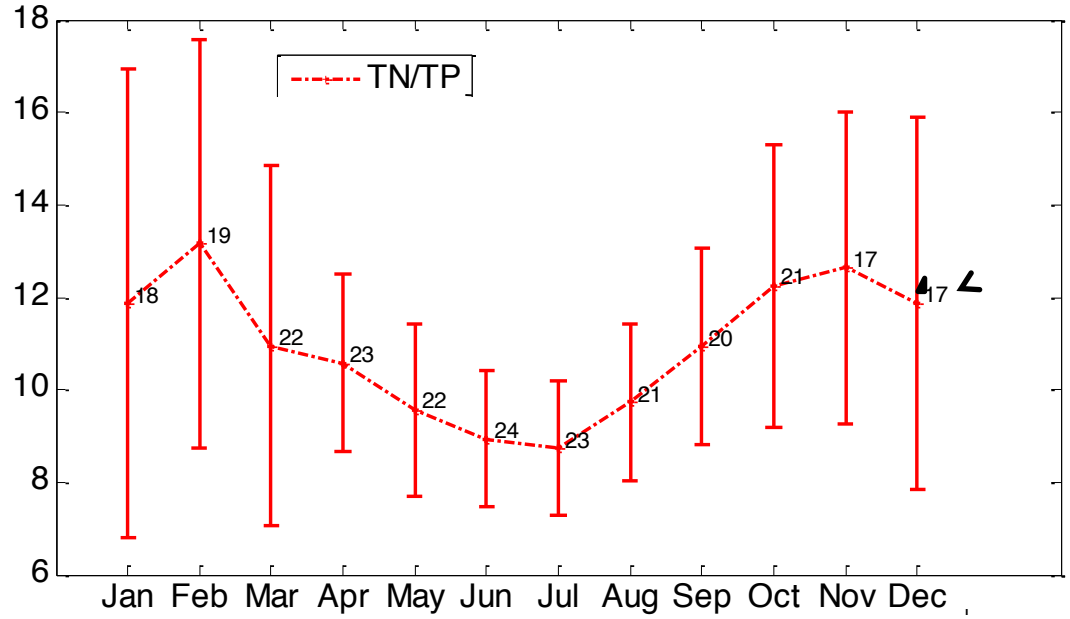
- Additional Pots of TN/TP and DIN/DIP in mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A

Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)



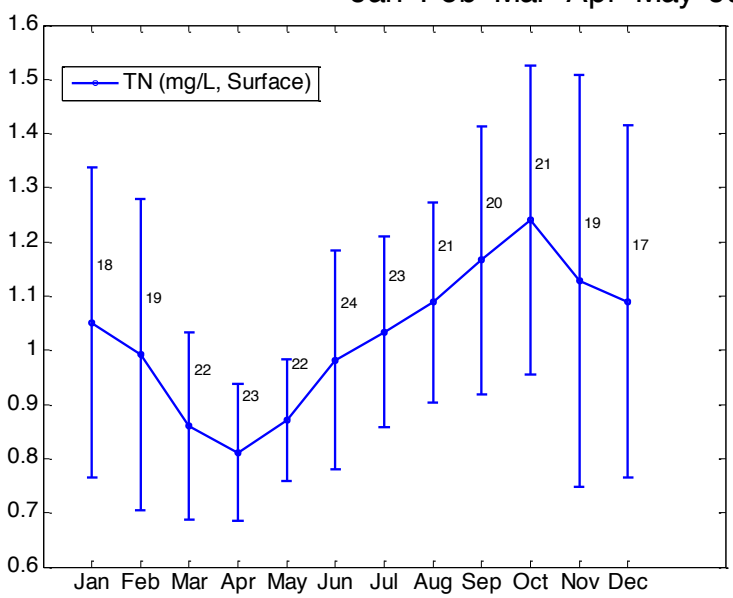


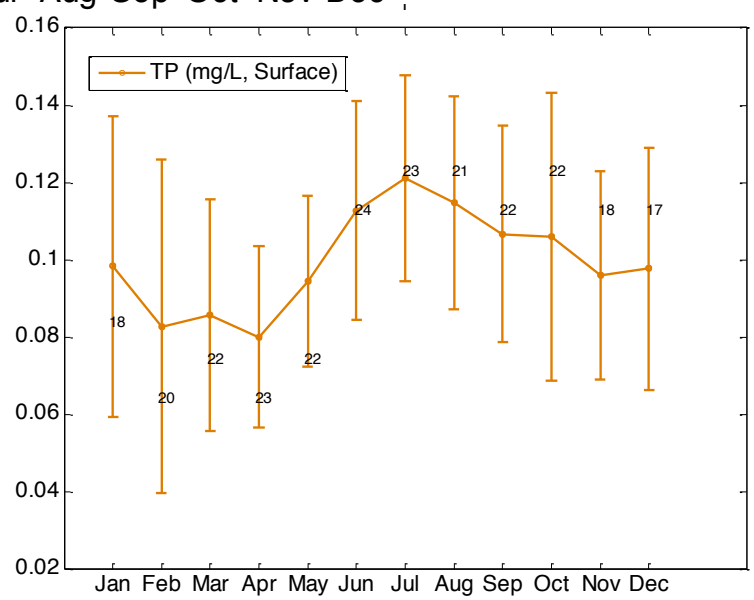
Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)



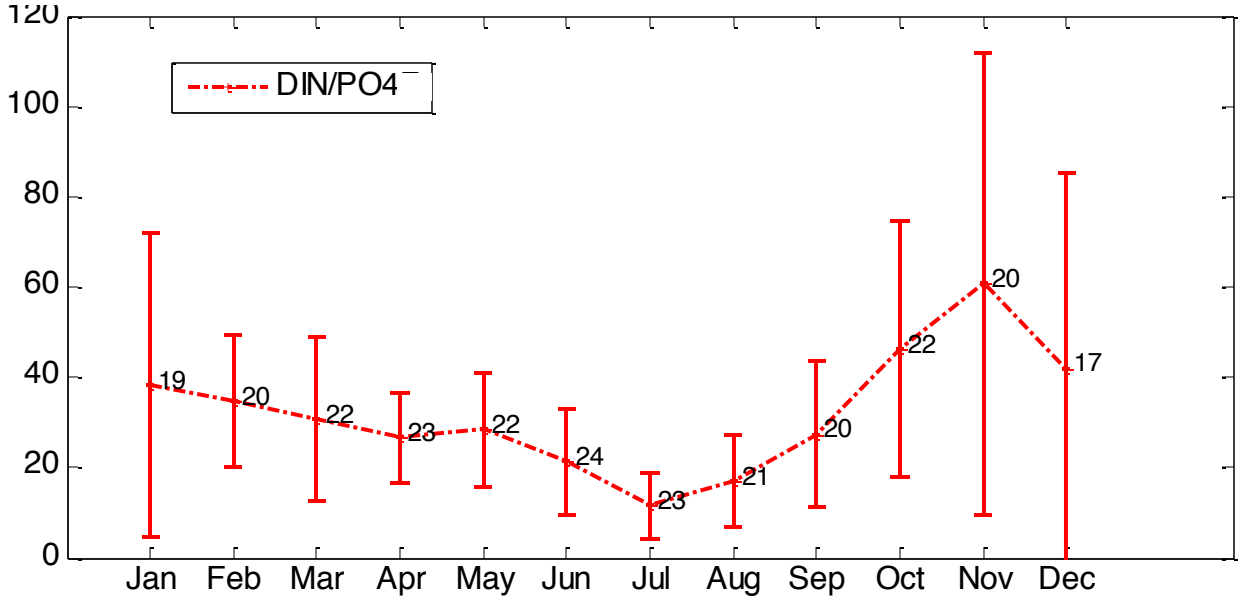
Number of samples

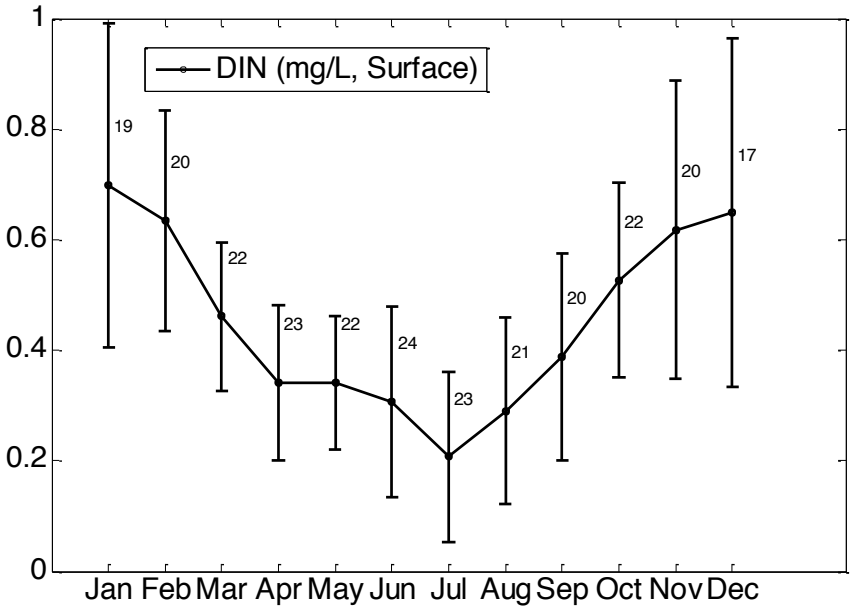
Standard deviations

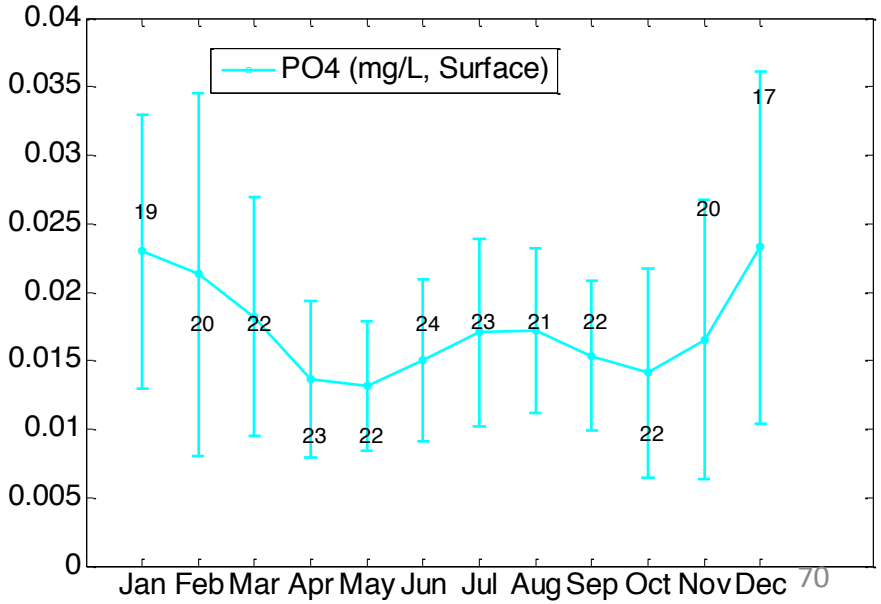




Station group (mid-stream, location of summer peak: TF5.4 TF5.5 TF5.5A)







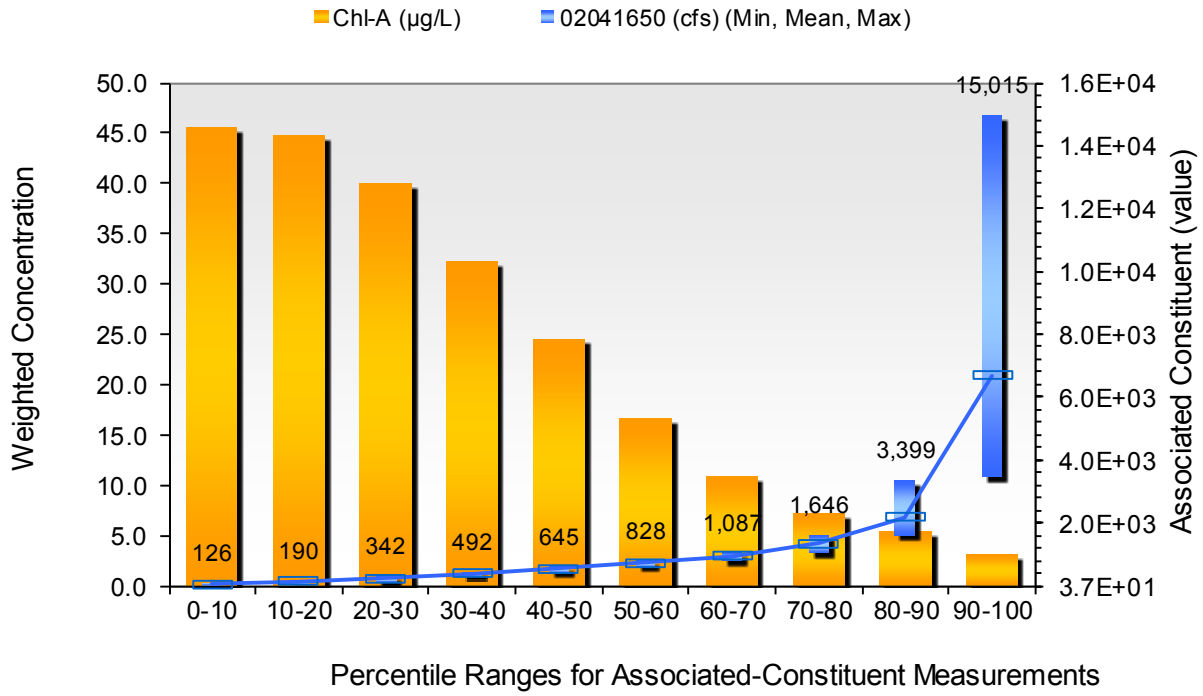
Appendix C
Graphical Analysis of Water Quality and Stream Flow Data

Appomattox-TF2

Constituent-Associated Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 9/20/2012 (375 Observations)

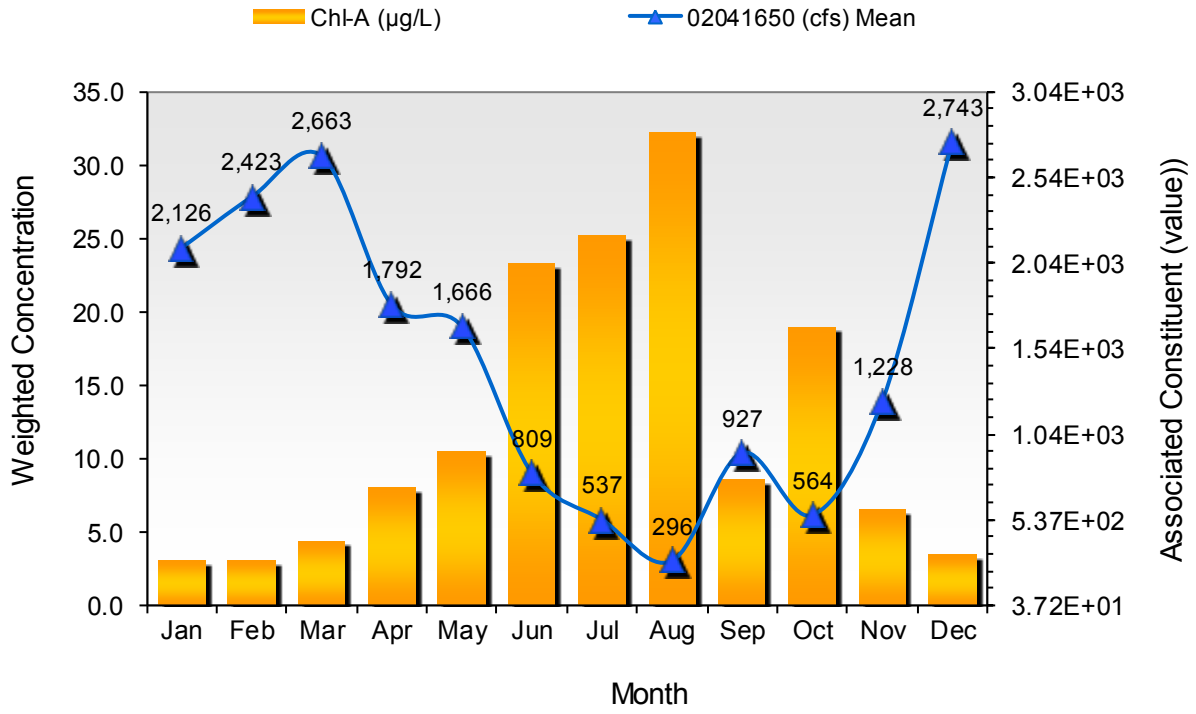
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	91.702	37.237	126.13	45.645	1.34	73.43
10-20	37	162	129.73	189.79	44.833	11.2	116.3
20-30	38	254.53	190.99	342.34	40.037	9.595	76.5
30-40	37	410.48	344.74	492.49	32.311	0.91	122.16
40-50	37	577.06	493.69	645.04	24.425	2.5	67.89
50-60	38	754.29	653.45	827.62	16.574	1	58.78
60-70	37	965.24	844.44	1087.1	10.838	0.5	48.11
70-80	38	1374.7	1101.5	1645.6	7.2054	0.5	28.5
80-90	37	2212.1	1657.6	3399.4	5.4534	1	24.5
90-100	37	6730.2	3519.5	15015	3.1076	0.85	10.22



Seasonal Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 9/20/2012 (375 Observations)

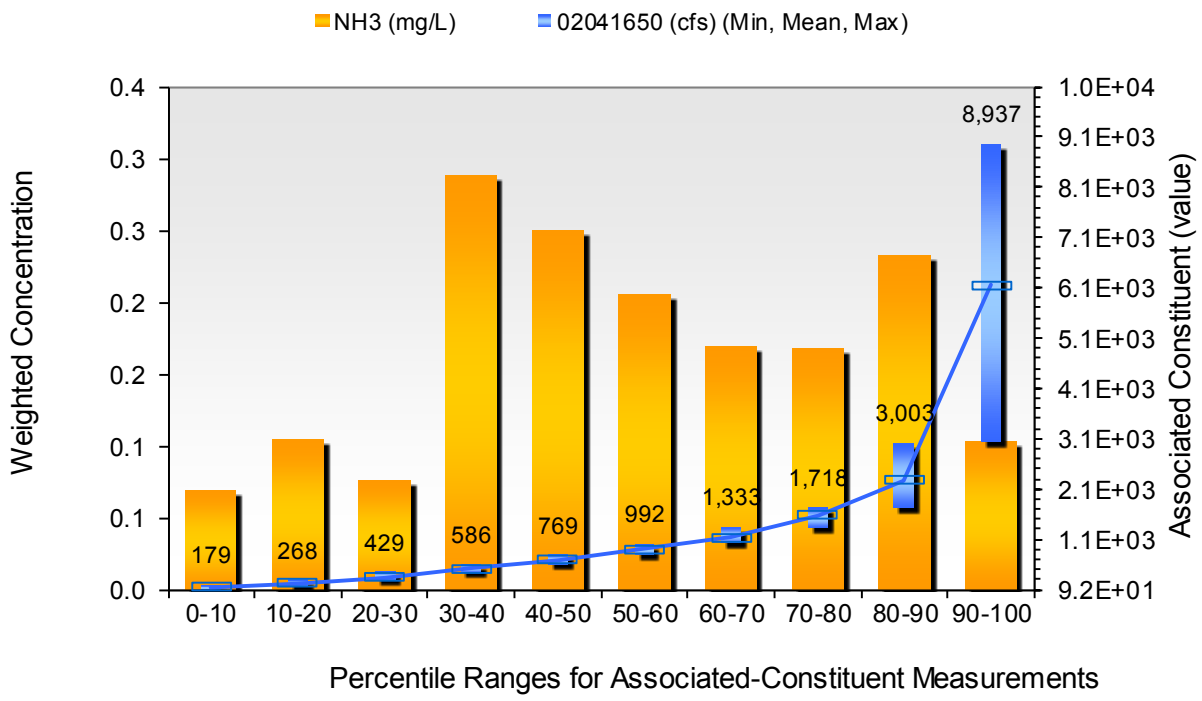
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	25	2126.1	353.15	7699.6	3.0226	0.5	13.17
February	26	2423.4	290.69	9741.7	3.0083	1	24.67
March	34	2662.7	444.44	13333	4.3205	1	23.03
April	31	1792.1	496.09	7807.8	8.0218	1.4	58.78
May	34	1666.2	213.81	22342	10.511	0.5	122.16
June	37	808.57	78.078	5429.4	23.261	5.57	74.95
July	34	536.69	45.646	5441.4	25.148	1.6	76.5
August	34	296.24	37.237	875.67	32.173	7.2	70.47
September	35	926.57	42.042	15015	8.5481	0.87	75.5
October	35	563.6	49.249	2906.9	18.97	0.98	76.48
November	27	1227.5	69.669	8156.1	6.5195	0.85	116.3
December	23	2742.6	104.5	11567	3.4202	0.91	36.19



Constituent-Associated Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: NH3 (mg/L)
Data from: 1/30/1985 to 2/1/1994 (97 Observations)

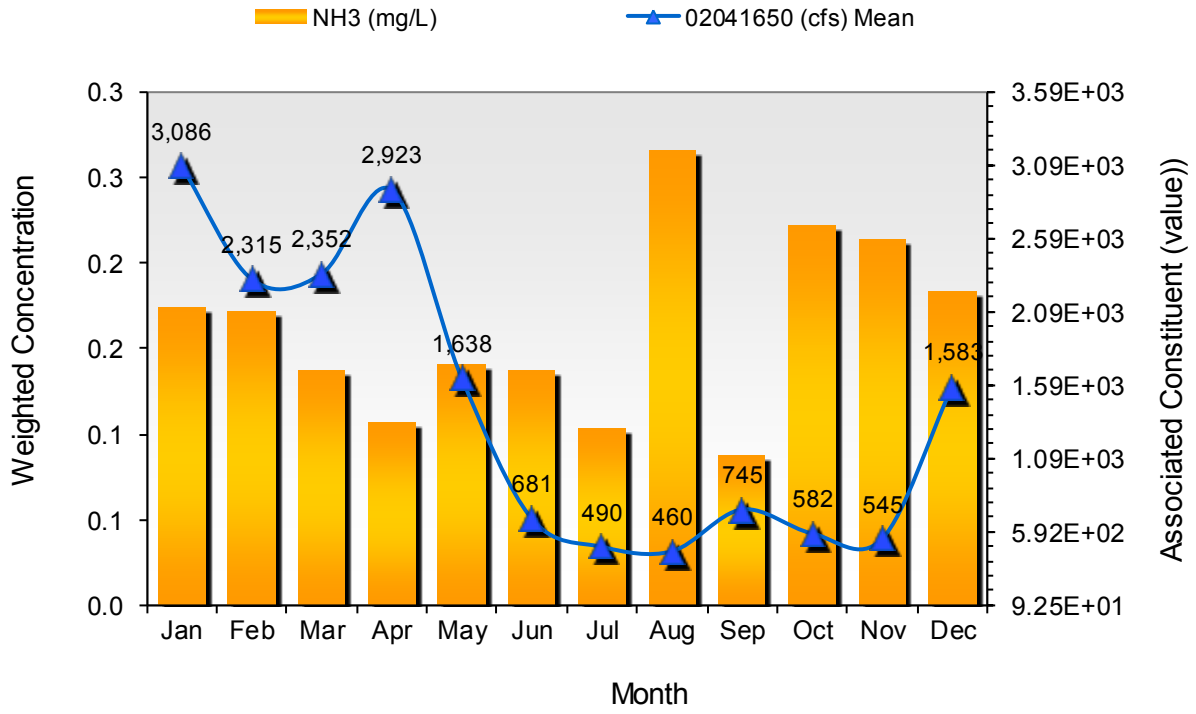
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	10	140.3	92.492	178.98	0.069264	0.04	0.12
10-20	10	210.93	180.18	267.87	0.10411	0.02	0.3
20-30	9	336.07	278.68	428.83	0.076259	0.04	0.15
30-40	10	500.42	436.03	586.18	0.28766	0.04	0.9
40-50	9	686.68	606.6	768.76	0.24986	0.04	0.61
50-60	10	902.34	806	992.19	0.20499	0.09	0.4
60-70	10	1118.9	1000.6	1333.3	0.16897	0.07	0.3
70-80	9	1568.2	1345.3	1717.7	0.16788	0.1	0.31
80-90	10	2264.2	1729.7	3003	0.23289	0.1	0.69
90-100	9	6152.8	3015	8936.9	0.10279	0.07	0.2



Seasonal Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: NH3 (mg/L)
Data from: 1/30/1985 to 2/1/1994 (97 Observations)

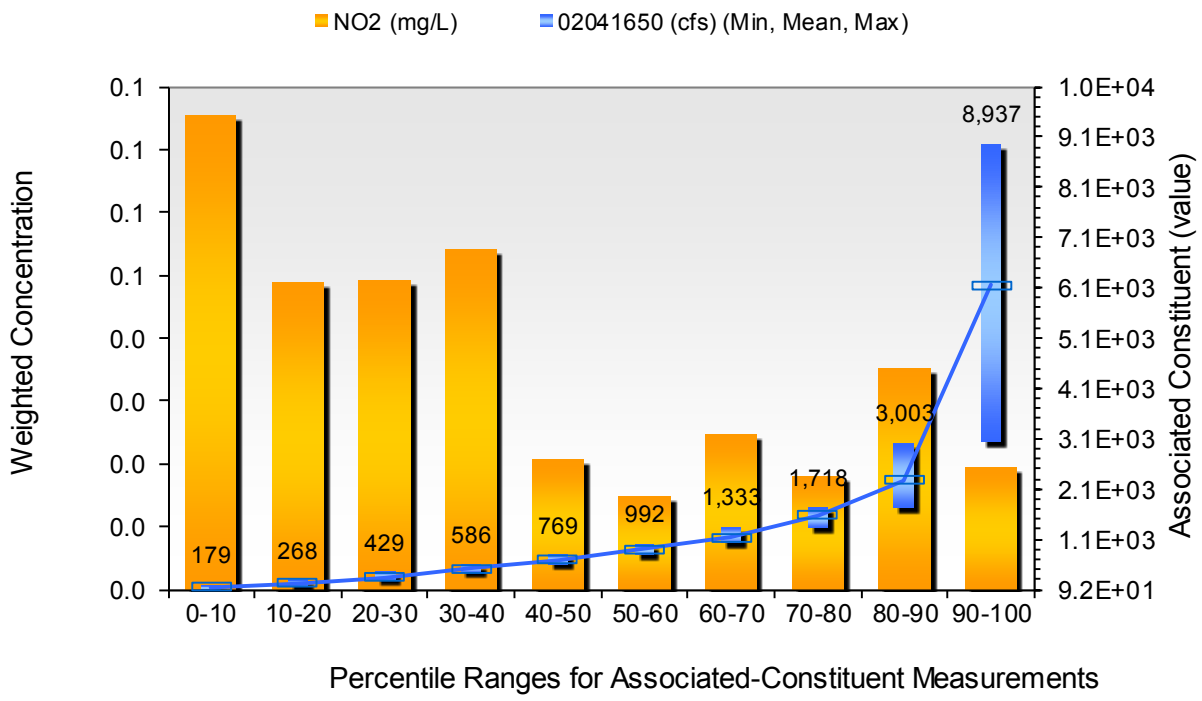
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	8	3085.6	494.89	8780.7	0.17446	0.07	0.69
February	9	2315.2	428.83	6462.4	0.17128	0.1	0.4
March	8	2352.4	806	8216.2	0.13741	0.09	0.31
April	9	2923.2	586.18	14655	0.10728	0.04	0.2
May	9	1638.4	326.72	8936.9	0.14028	0.04	0.9
June	7	681.42	267.87	1537.5	0.13661	0.04	0.3
July	9	489.95	92.492	1633.6	0.10333	0.04	0.3
August	7	459.89	105.7	1729.7	0.26614	0.04	0.4
September	7	744.57	126.13	3063	0.087195	0.02	0.1
October	9	581.51	130.93	2102.1	0.22122	0.04	0.3
November	7	545	163.36	944.14	0.21353	0.04	0.5
December	8	1583.2	443.24	5225.2	0.18381	0.09	0.61



Constituent-Associated Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: NO2 (mg/L)
Data from: 1/30/1985 to 2/1/1994 (97 Observations)

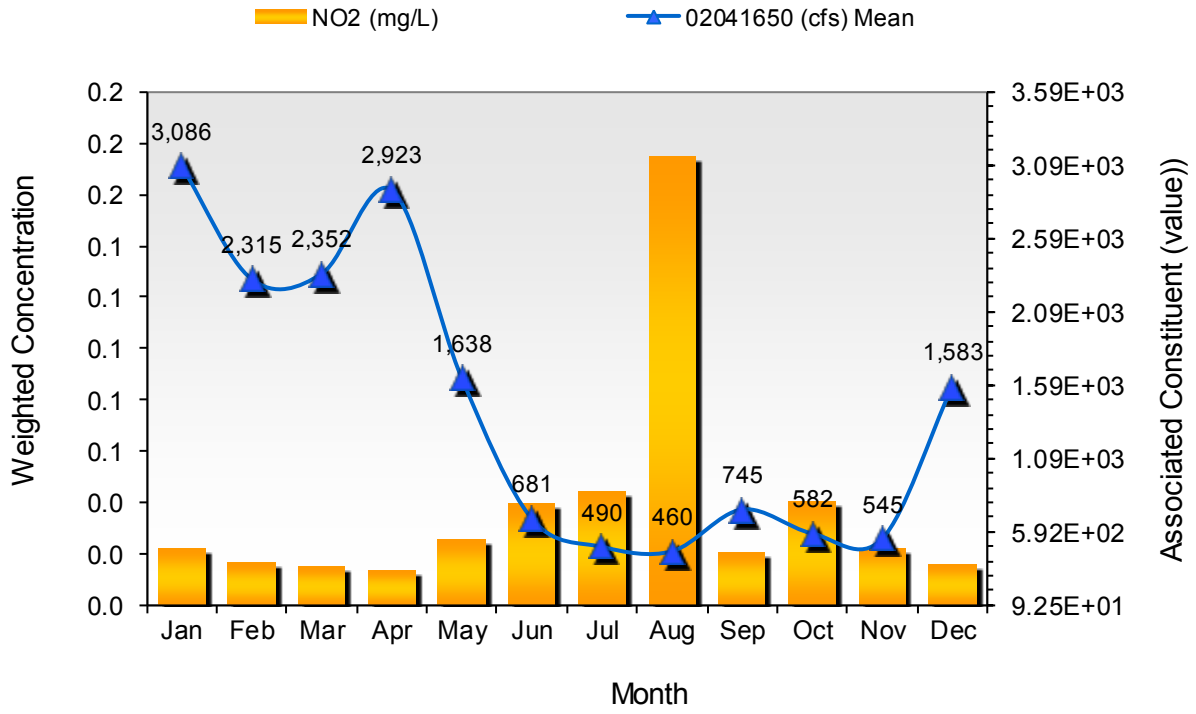
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	10	140.3	92.492	178.98	0.075317	0.02	0.16
10-20	10	210.93	180.18	267.87	0.048656	0.01	0.14
20-30	9	336.07	278.68	428.83	0.049079	0.01	0.14
30-40	10	500.42	436.03	586.18	0.054054	0.01	0.15
40-50	9	686.68	606.6	768.76	0.020573	0.01	0.06
50-60	10	902.34	806	992.19	0.014977	0.01	0.02
60-70	10	1118.9	1000.6	1333.3	0.024574	0.01	0.1
70-80	9	1568.2	1345.3	1717.7	0.017864	0.01	0.03
80-90	10	2264.2	1729.7	3003	0.035225	0.01	0.25
90-100	9	6152.8	3015	8936.9	0.019501	0.01	0.03



Seasonal Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: NO2 (mg/L)
Data from: 1/30/1985 to 2/1/1994 (97 Observations)

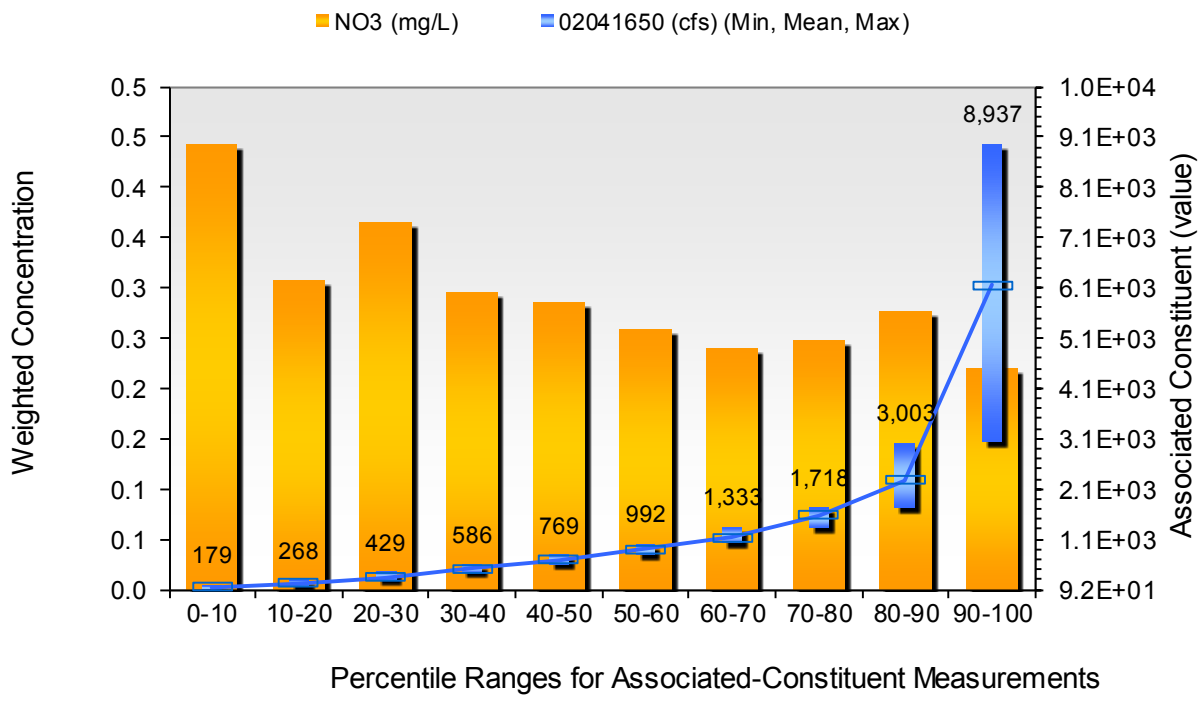
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	8	3085.6	494.89	8780.7	0.021967	0.01	0.03
February	9	2315.2	428.83	6462.4	0.016454	0.01	0.03
March	8	2352.4	806	8216.2	0.014794	0.01	0.02
April	9	2923.2	586.18	14655	0.013505	0.01	0.05
May	9	1638.4	326.72	8936.9	0.025464	0.01	0.1
June	7	681.42	267.87	1537.5	0.039708	0.01	0.14
July	9	489.95	92.492	1633.6	0.044062	0.01	0.15
August	7	459.89	105.7	1729.7	0.17456	0.05	0.25
September	7	744.57	126.13	3063	0.019982	0.01	0.16
October	9	581.51	130.93	2102.1	0.040601	0.02	0.11
November	7	545	163.36	944.14	0.022031	0.01	0.08
December	8	1583.2	443.24	5225.2	0.015794	0.01	0.02



Constituent-Associated Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: NO3 (mg/L)
Data from: 1/30/1985 to 2/1/1994 (97 Observations)

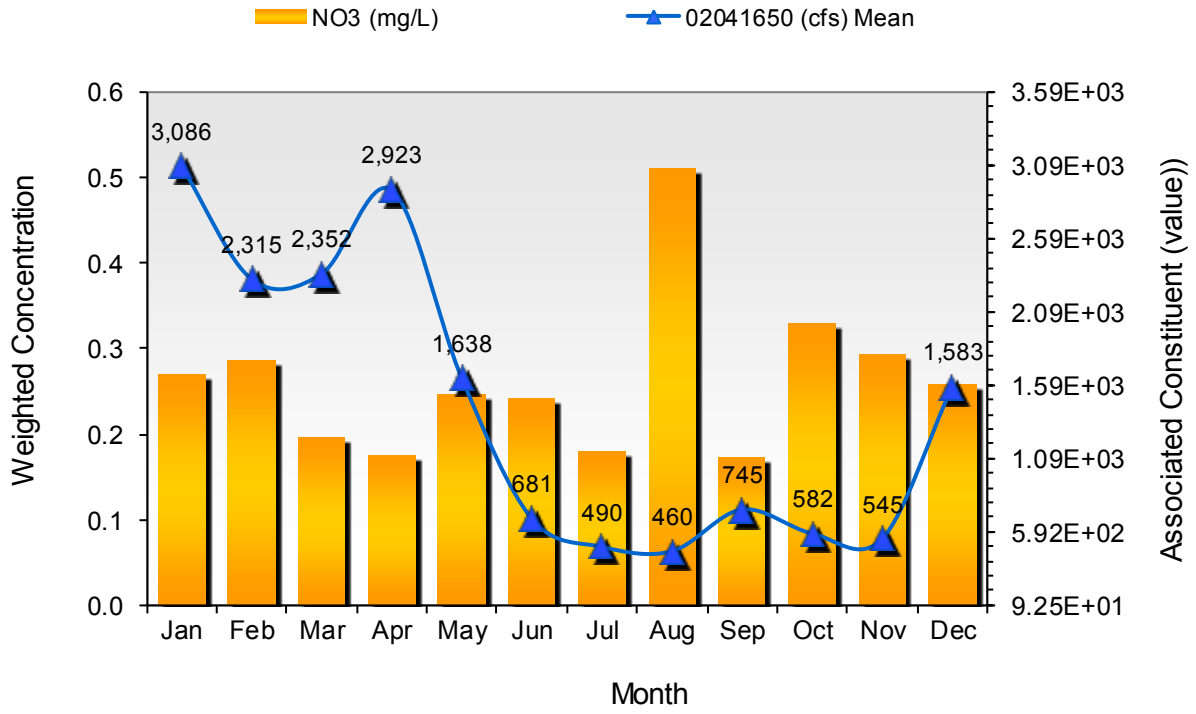
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	10	140.3	92.492	178.98	0.44195	0.04	1.54
10-20	10	210.93	180.18	267.87	0.30693	0.04	1.23
20-30	9	336.07	278.68	428.83	0.36419	0.17	0.54
30-40	10	500.42	436.03	586.18	0.29558	0.04	0.45
40-50	9	686.68	606.6	768.76	0.28577	0.12	0.52
50-60	10	902.34	806	992.19	0.25835	0.13	0.44
60-70	10	1118.9	1000.6	1333.3	0.23919	0.08	0.36
70-80	9	1568.2	1345.3	1717.7	0.24698	0.13	0.41
80-90	10	2264.2	1729.7	3003	0.27695	0.15	0.65
90-100	9	6152.8	3015	8936.9	0.22075	0.06	0.34



Seasonal Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: NO3 (mg/L)
Data from: 1/30/1985 to 2/1/1994 (97 Observations)

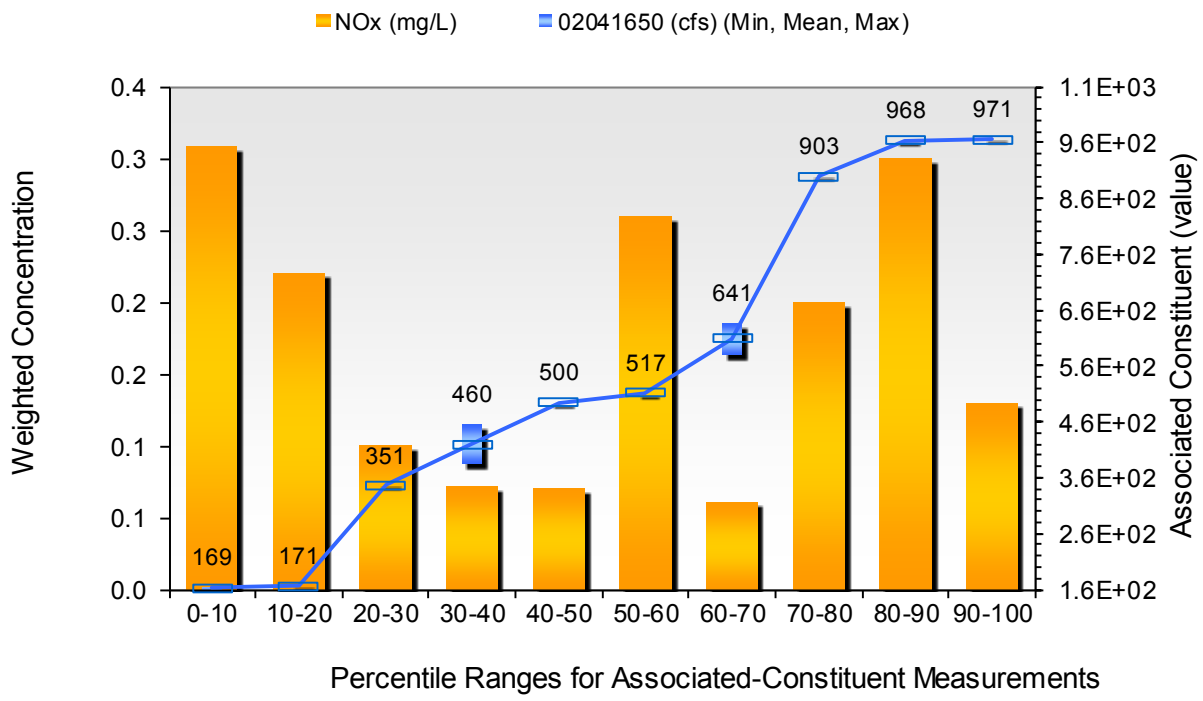
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	8	3085.6	494.89	8780.7	0.26885	0.2	0.44
February	9	2315.2	428.83	6462.4	0.28606	0.21	0.47
March	8	2352.4	806	8216.2	0.19469	0.13	0.4
April	9	2923.2	586.18	14655	0.17533	0.04	0.26
May	9	1638.4	326.72	8936.9	0.24571	0.13	0.46
June	7	681.42	267.87	1537.5	0.24228	0.08	0.35
July	9	489.95	92.492	1633.6	0.18018	0.04	0.48
August	7	459.89	105.7	1729.7	0.51005	0.23	0.65
September	7	744.57	126.13	3063	0.17296	0.06	1.54
October	9	581.51	130.93	2102.1	0.32873	0.21	1.23
November	7	545	163.36	944.14	0.29322	0.16	0.52
December	8	1583.2	443.24	5225.2	0.25773	0.13	0.41



Constituent-Associated Trend Assessment

Location: 02041650
Comparison Parameter: 02041650 (cfs)
Pollutant: NOx (mg/L)
Data from: 11/20/1990 to 11/19/1992 (14 Observations)

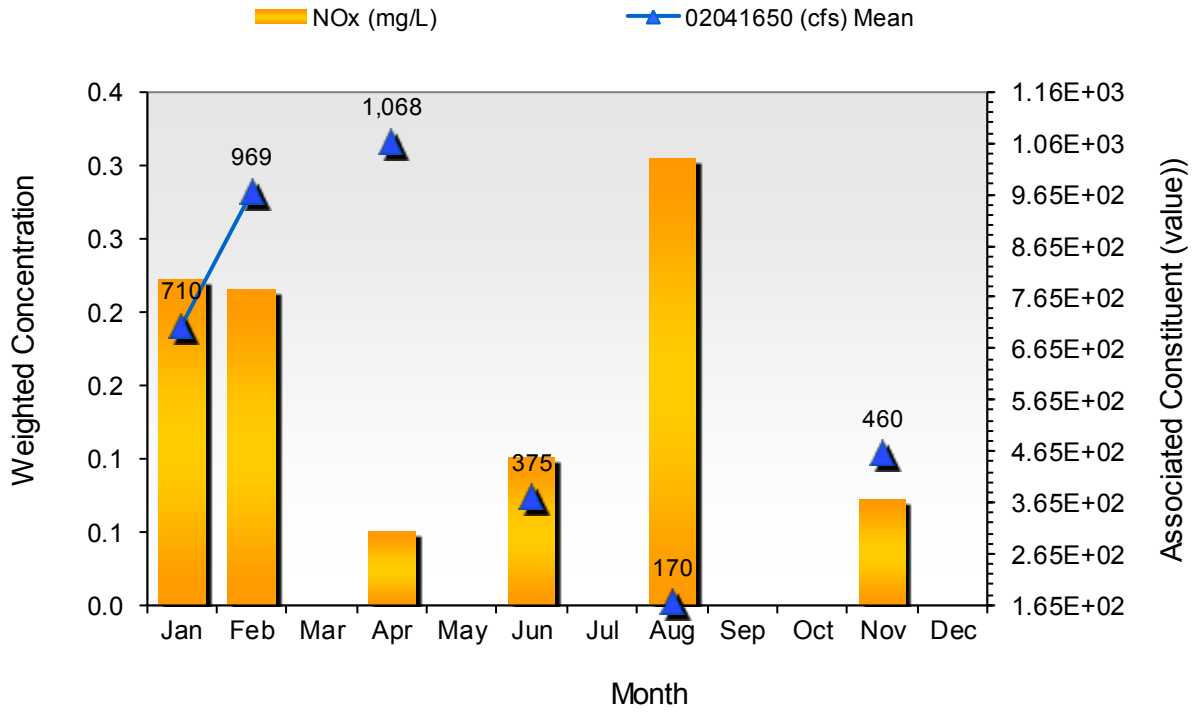
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	2	166.97	164.56	169.37	0.30869	0.225	0.39
10-20	1	170.57	170.57	170.57	0.22	0.22	0.22
20-30	1	350.75	350.75	350.75	0.1	0.1	0.1
30-40	2	424.62	389.19	460.06	0.071669	0.05	0.09
40-50	1	499.7	499.7	499.7	0.07	0.07	0.07
50-60	1	516.51	516.51	516.51	0.26	0.26	0.26
60-70	2	613.81	586.18	641.44	0.06045	0.05	0.07
70-80	1	903.3	903.3	903.3	0.2	0.2	0.2
80-90	1	968.16	968.16	968.16	0.3	0.3	0.3
90-100	1	970.56	970.56	970.56	0.13	0.13	0.13



Seasonal Trend Assessment

Location: 02041650
Comparison Parameter: 02041650 (cfs)
Pollutant: NOx (mg/L)
Data from: 11/20/1990 to 11/19/1992 (14 Observations)

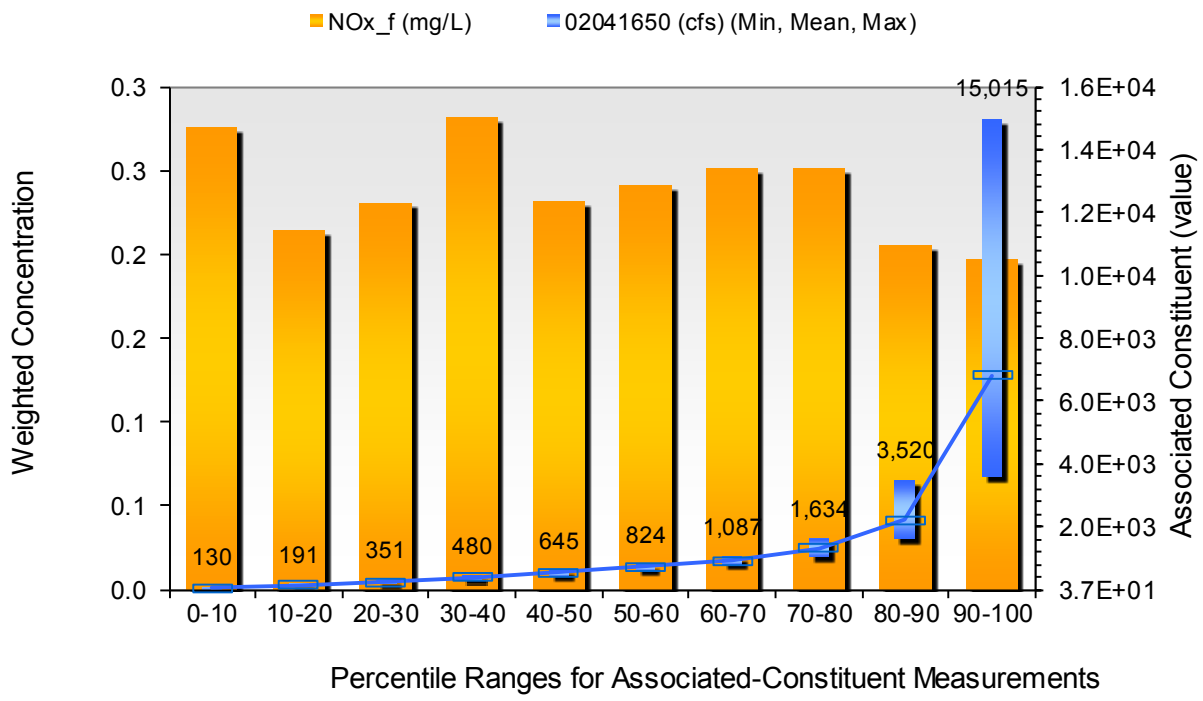
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	709.9	516.51	903.3	0.22183	0.2	0.26
February	2	969.36	968.16	970.56	0.21489	0.13	0.3
March	0	No Data	No Data	No Data	No Data	No Data	No Data
April	2	1067.9	586.18	1549.5	0.05	0.05	0.05
May	0	No Data	No Data	No Data	No Data	No Data	No Data
June	3	374.77	164.56	499.7	0.10087	0.07	0.225
July	0	No Data	No Data	No Data	No Data	No Data	No Data
August	2	169.97	169.37	170.57	0.3047	0.22	0.39
September	0	No Data	No Data	No Data	No Data	No Data	No Data
October	0	No Data	No Data	No Data	No Data	No Data	No Data
November	3	460.46	350.75	641.44	0.071983	0.05	0.1
December	0	No Data	No Data	No Data	No Data	No Data	No Data



Constituent-Associated Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/4/1985 to 9/20/2012 (386 Observations)

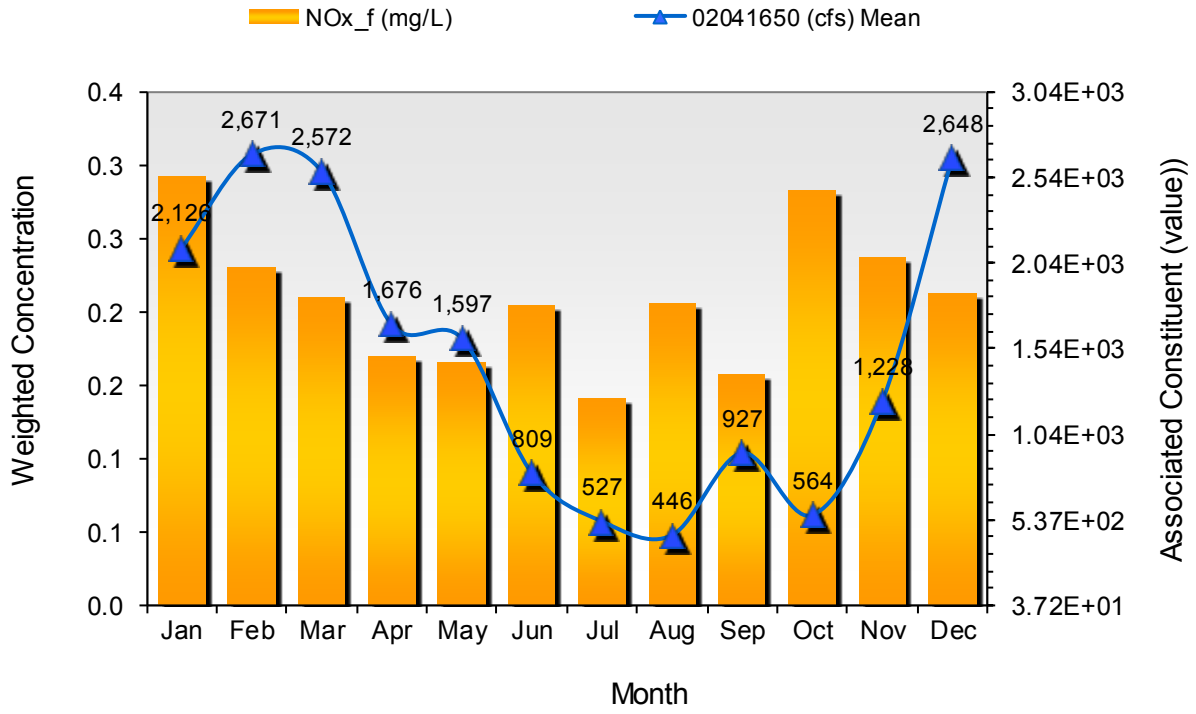
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	39	92.677	37.237	129.73	0.27582	0	0.695
10-20	38	164.31	133.33	190.99	0.21411	0	0.864
20-30	39	260.94	192.19	350.75	0.23108	0	0.7
30-40	38	413.34	350.75	480.48	0.28134	0	1.51
40-50	39	569.7	490.09	645.04	0.23115	0	0.7
50-60	38	749.48	645.04	824.02	0.24059	0	0.738
60-70	39	959.97	827.62	1087.1	0.25142	0	0.542
70-80	38	1362.2	1101.5	1633.6	0.25082	0	0.5085
80-90	39	2231.1	1645.6	3519.5	0.20528	0	0.4195
90-100	38	6845.8	3591.6	15015	0.19685	0	0.39



Seasonal Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/4/1985 to 9/20/2012 (386 Observations)

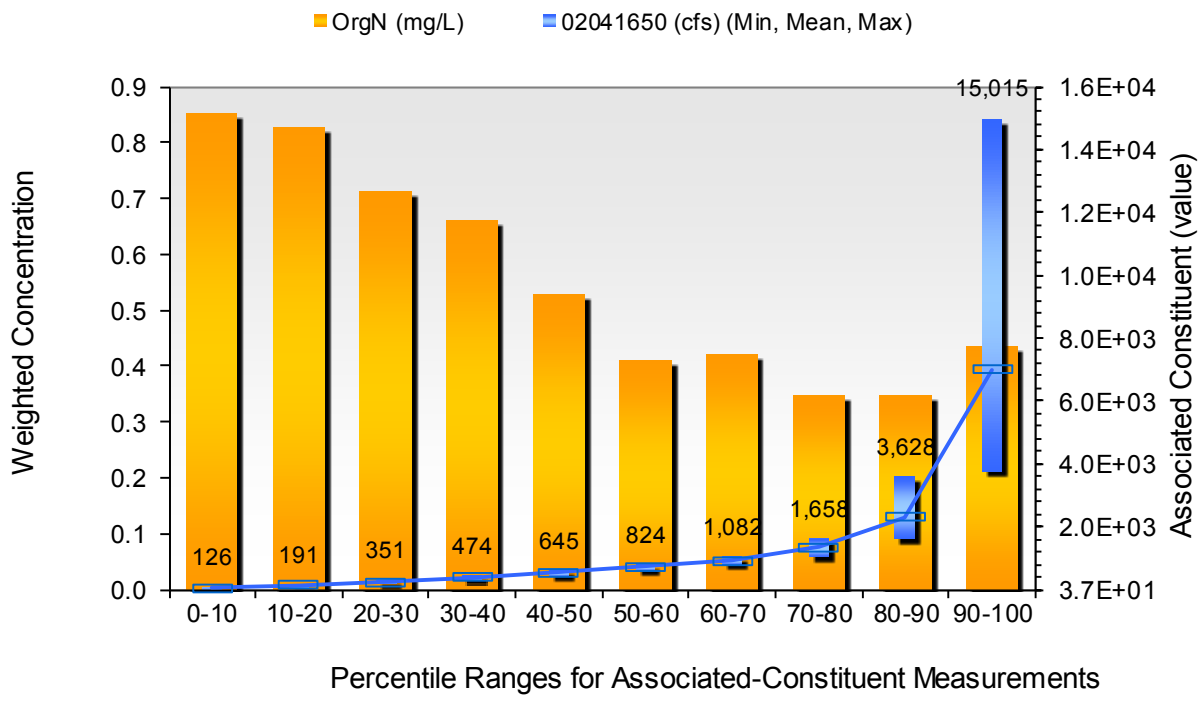
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	25	2126.1	353.15	7699.6	0.29201	0	0.738
February	27	2670.9	290.69	9741.7	0.23072	0	0.4775
March	36	2572.2	444.44	13333	0.20931	0	0.542
April	34	1676.4	452.85	7807.8	0.16913	0	0.45
May	36	1596.5	213.81	22342	0.16531	0	0.378
June	37	808.57	78.078	5429.4	0.20502	0	0.425
July	35	526.74	45.646	5441.4	0.14168	0	0.3775
August	35	445.99	37.237	5537.5	0.2053	0	0.6
September	35	926.57	42.042	15015	0.15759	0	0.7
October	35	563.6	49.249	2906.9	0.2826	0	1.51
November	27	1227.5	69.669	8156.1	0.23684	0	0.7
December	24	2647.6	104.5	11567	0.21306	0	0.864



Constituent-Associated Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (370 Observations)

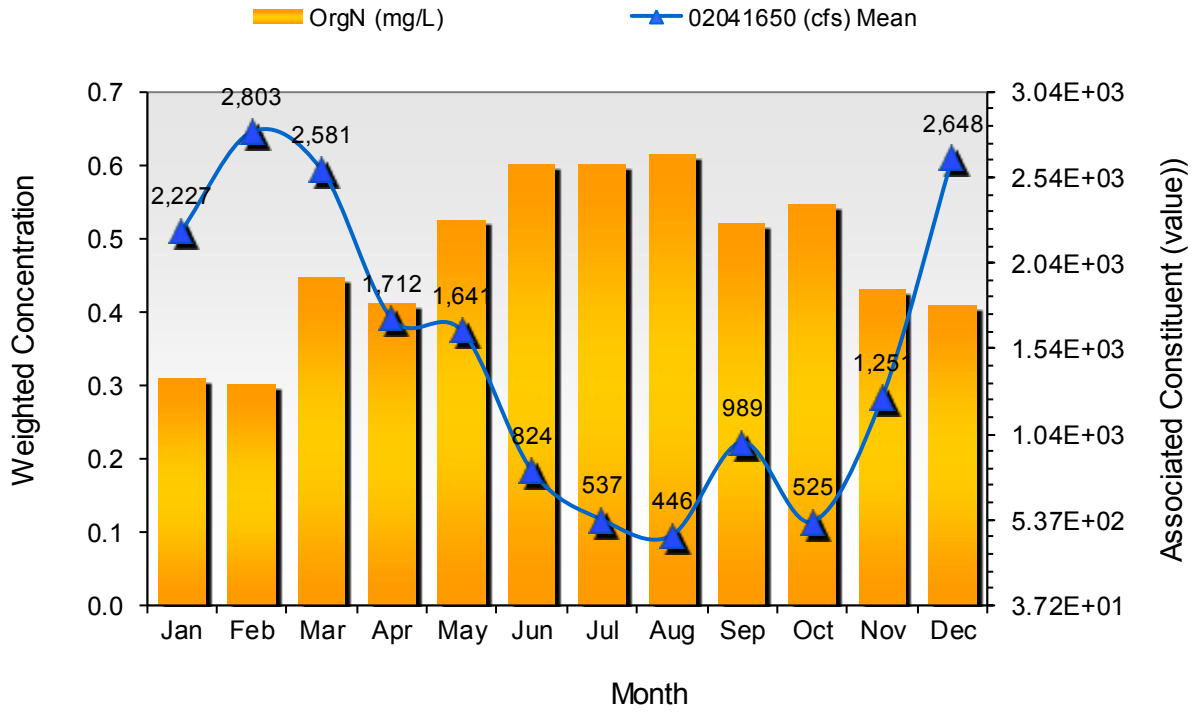
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	37	90.901	37.237	126.13	0.84962	0	1.35
10-20	37	163.49	129.73	190.99	0.82546	0	1.35
20-30	37	259.72	192.19	350.75	0.71203	0	1.28
30-40	37	411.52	350.75	474.47	0.6612	0	1.2583
40-50	37	572.68	490.09	645.04	0.52857	0	1.105
50-60	37	752.3	653.45	824.02	0.41065	0	0.92
60-70	37	960.11	844.44	1082.3	0.41978	0	0.925
70-80	37	1383.5	1087.1	1657.6	0.34897	0	0.592
80-90	37	2345.2	1669.7	3627.6	0.34606	0	0.7186
90-100	36	7025.6	3783.8	15015	0.43513	0	0.78



Seasonal Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (370 Observations)

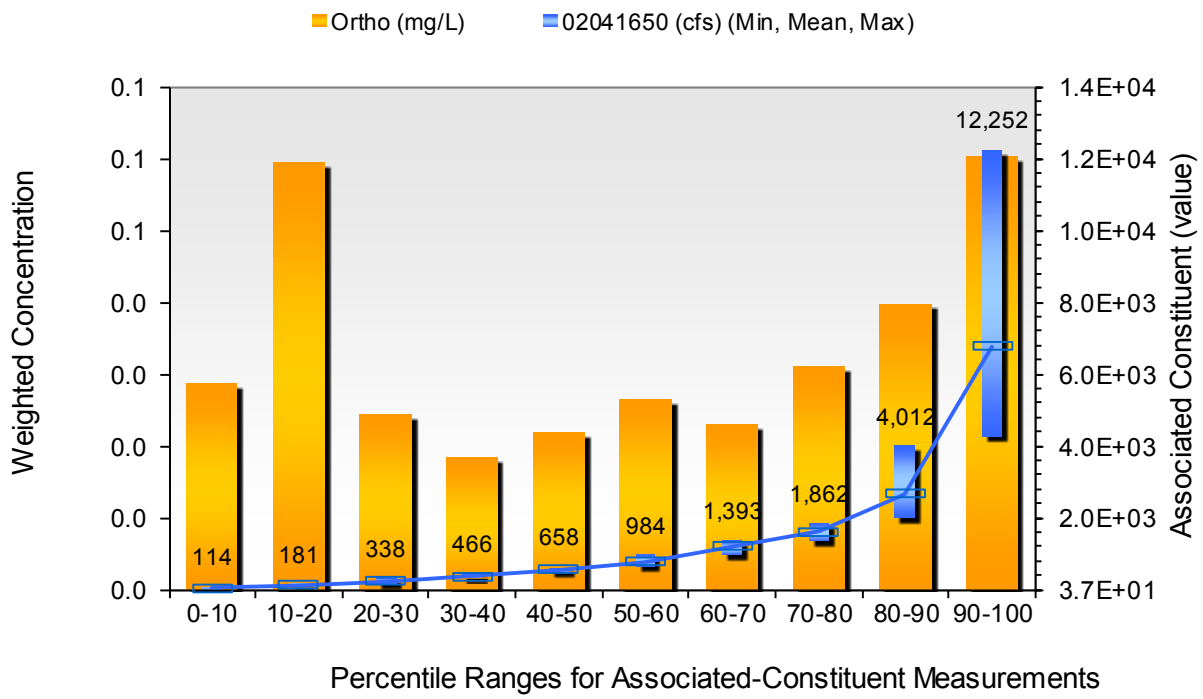
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	2227.4	353.15	7699.6	0.30893	0	0.595
February	25	2803.4	290.69	9741.7	0.30031	0	0.5655
March	35	2580.5	444.44	13333	0.44794	0	0.74
April	33	1712.1	452.85	7807.8	0.41173	0	0.78
May	34	1640.9	213.81	22342	0.52485	0	1.2583
June	36	823.55	78.078	5429.4	0.60011	0	1.309
July	34	536.86	45.646	5441.4	0.60085	0	1.35
August	35	445.99	37.237	5537.5	0.61526	0	1.35
September	31	989.4	42.042	15015	0.52023	0	1.315
October	34	525.06	49.249	2906.9	0.54714	0	1.1807
November	26	1250.9	69.669	8156.1	0.43162	0	0.79167
December	24	2647.6	104.5	11567	0.40937	0	0.925



Constituent-Associated Trend Assessment

Location: 2-APP012.79
Comparison Parameter: 02041650 (cfs)
Pollutant: Ortho (mg/L)
Data from: 12/27/1990 to 6/5/2003 (130 Observations)

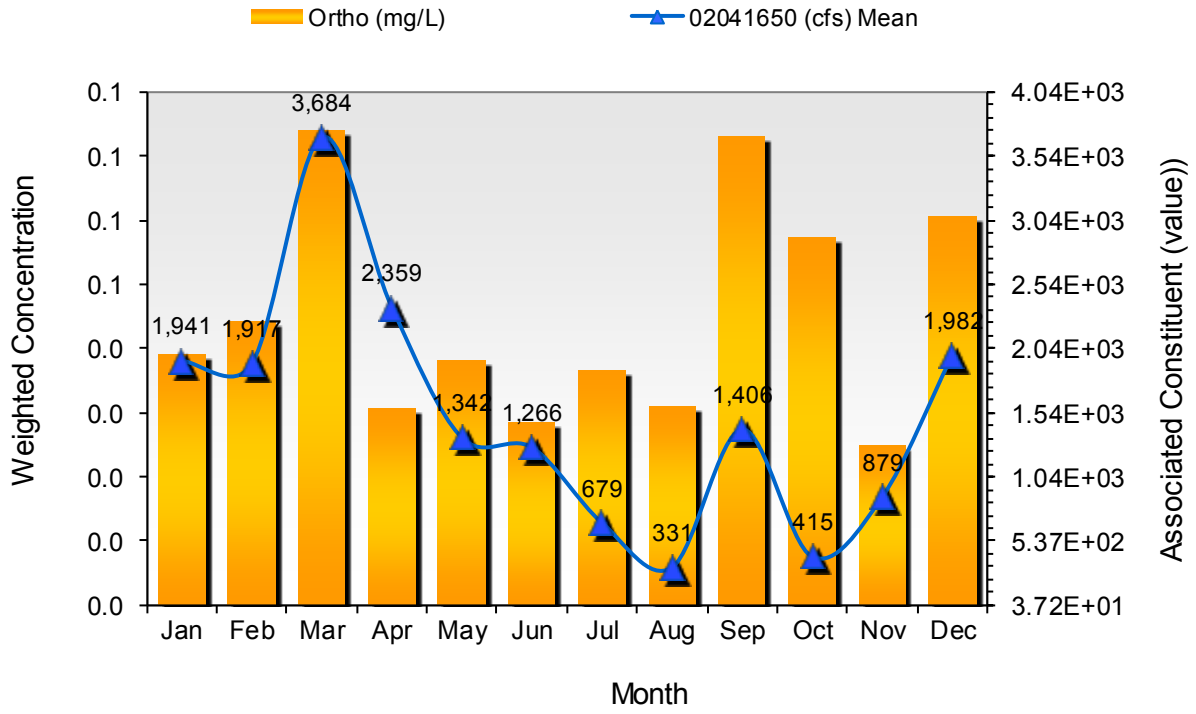
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	13	80.388	37.237	114.11	0.02854	0.01	0.06
10-20	13	147.84	120.12	181.38	0.059394	0.01	0.53
20-30	13	257.61	188.59	337.54	0.024319	0.01	0.05
30-40	13	400.74	338.74	466.06	0.018476	0.01	0.04
40-50	13	582.67	505.7	658.25	0.021973	0.01	0.04
50-60	13	802.21	672.67	983.78	0.026555	0.01	0.04
60-70	13	1226.7	1004.2	1393.4	0.022933	0.01	0.05
70-80	13	1634.5	1405.4	1861.8	0.031051	0.01	0.06
80-90	13	2693.4	2054	4012	0.039756	0.01	0.06
90-100	12	6810.8	4312.3	12252	0.060319	0.03	0.09



Seasonal Trend Assessment

Location: 2-APP012.79
Comparison Parameter: 02041650 (cfs)
Pollutant: Ortho (mg/L)
Data from: 12/27/1990 to 6/5/2003 (130 Observations)

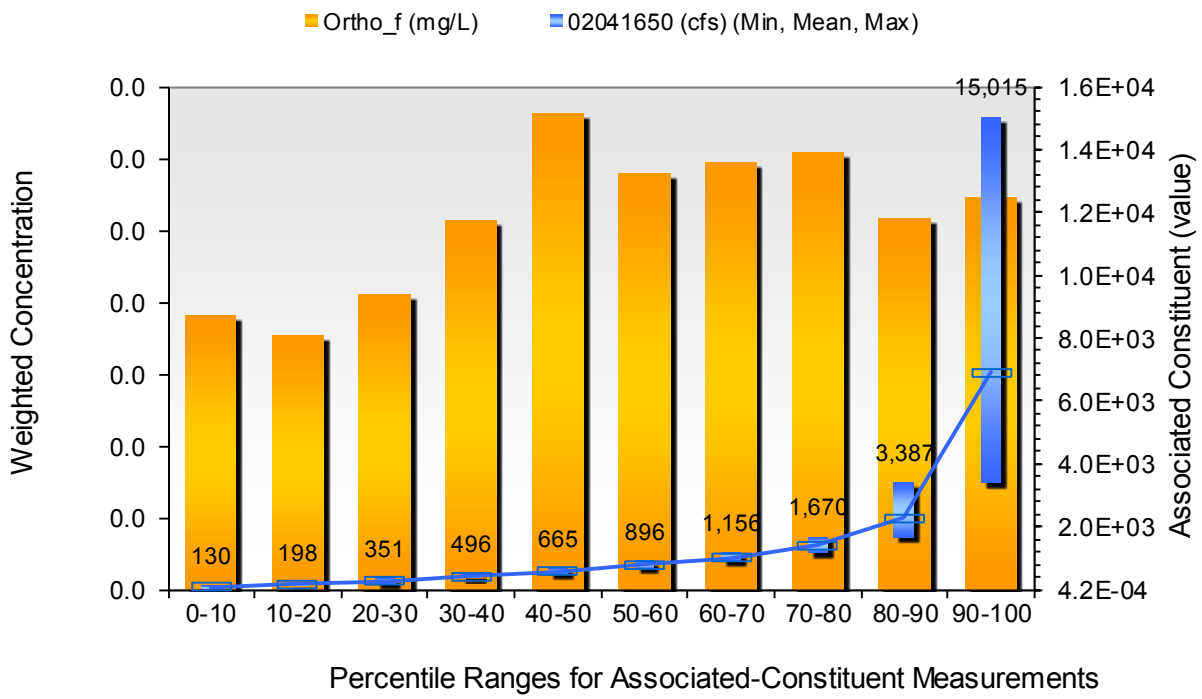
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	10	1940.9	742.34	4012	0.03908	0.01	0.06
February	11	1917.1	385.58	7711.7	0.044206	0.02	0.06
March	11	3683.8	299.1	15856	0.073799	0.01	0.11
April	12	2358.9	593.39	7999.9	0.030803	0.01	0.04
May	10	1342.3	338.74	5994	0.038089	0.01	0.06
June	10	1266.2	171.77	3435.4	0.028475	0.01	0.04
July	10	678.79	99.699	4720.7	0.03654	0.01	0.06
August	11	331.09	37.237	1004.2	0.030937	0.02	0.06
September	11	1405.8	79.279	12252	0.073061	0.01	0.08
October	11	414.85	37.237	2738.7	0.05731	0.01	0.53
November	11	878.95	69.669	4312.3	0.024673	0.01	0.04
December	12	1982.3	360.36	7603.5	0.060578	0.01	0.09



Constituent-Associated Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 1/30/1985 to 10/23/2012 (419 Observations)

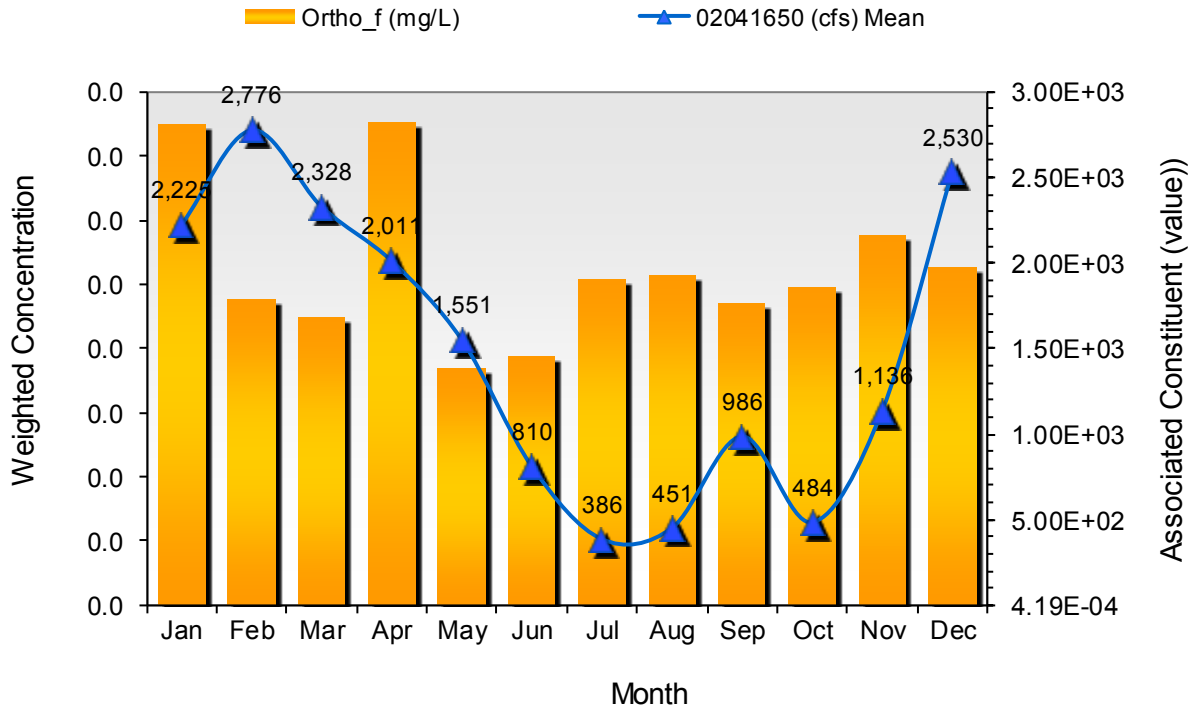
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	42	91.262	0.000419	129.73	0.019082	0.002	0.085
10-20	42	166.57	130.93	198.2	0.017677	0.0025	0.07
20-30	42	267.24	205.4	350.75	0.020578	0.002	0.1
30-40	42	424.34	353.15	496.09	0.02569	0.0045	0.12
40-50	41	580.85	497.29	665.46	0.033063	0.0025	0.185
50-60	42	784.72	682.28	896.09	0.028891	0.0045	0.09
60-70	42	1002.2	896.09	1155.5	0.029785	0.007	0.13
70-80	42	1414.8	1171.2	1669.7	0.030453	0.002	0.08
80-90	42	2258.5	1681.7	3387.4	0.025826	0.007	0.08
90-100	41	6911.3	3399.4	15015	0.027327	0.008	0.11



Seasonal Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 1/30/1985 to 10/23/2012 (419 Observations)

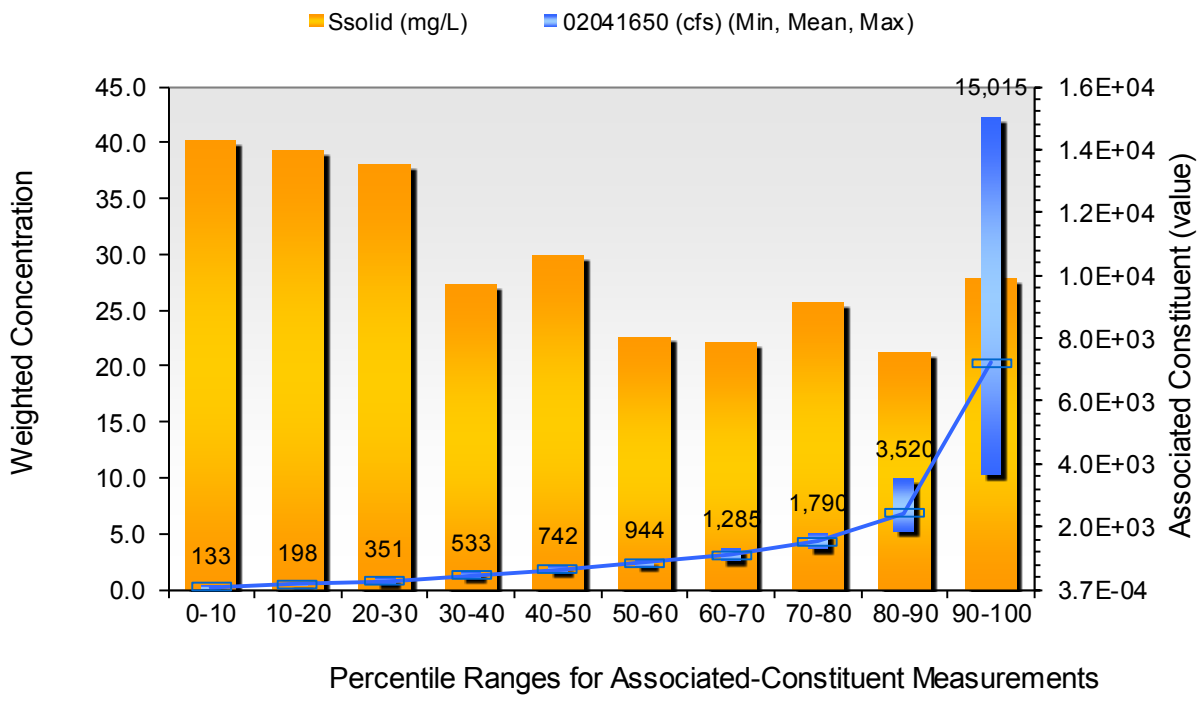
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	31	2225.3	353.15	8780.7	0.037375	0.0045	0.13
February	32	2776.1	290.69	9741.7	0.023853	0.002	0.09
March	38	2327.9	444.44	13333	0.022399	0.0055	0.09
April	38	2011	452.85	14655	0.03761	0.0045	0.11
May	37	1550.5	213.81	22342	0.018368	0.0025	0.1
June	36	810	78.078	5429.4	0.019327	0.003	0.07
July	38	385.65	45.646	1957.9	0.025323	0.003	0.06
August	35	451.41	37.237	5537.5	0.025685	0.0025	0.085
September	36	986.05	42.042	15015	0.023468	0.003	0.07
October	39	484.39	0.000419	2906.9	0.024832	0.002	0.07
November	32	1135.7	69.669	8156.1	0.028842	0.002	0.185
December	27	2530.1	104.5	11567	0.026299	0.005	0.12



Constituent-Associated Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: Ssolid (mg/L)
Data from: 1/30/1985 to 10/23/2012 (368 Observations)

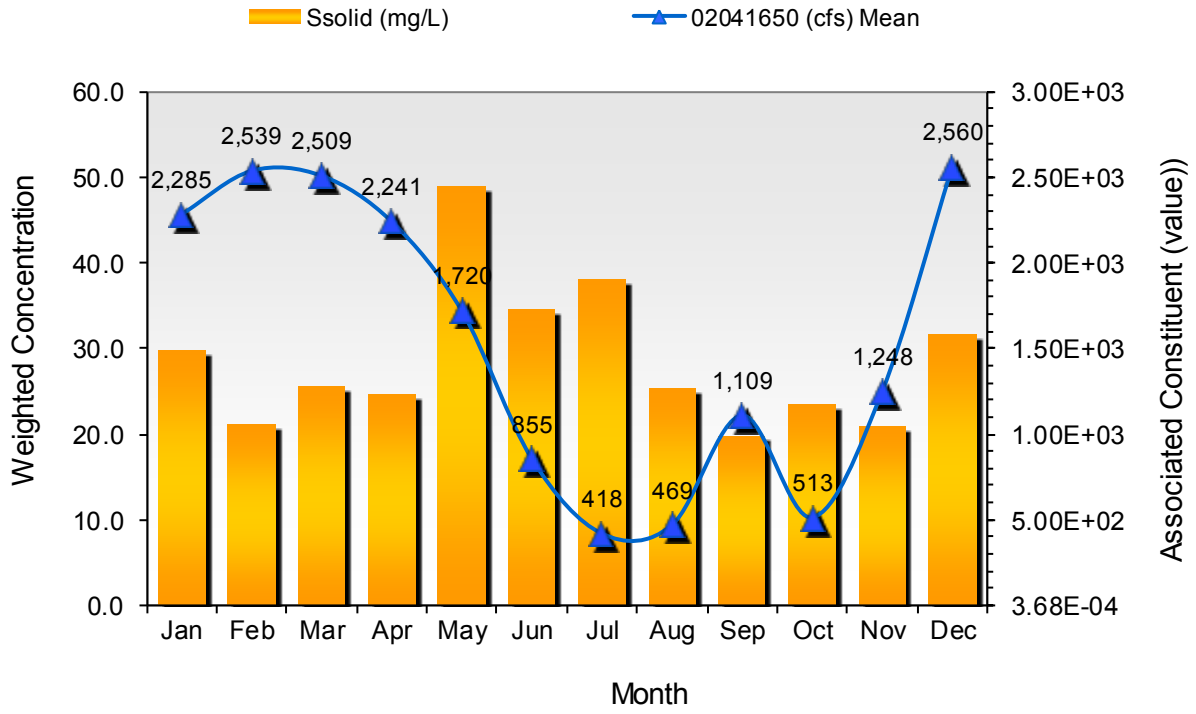
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	37	90.479	0.000368	133.33	40.171	18	138.5
10-20	37	168.46	134.53	198.2	39.287	21	132.5
20-30	37	268.61	205.4	350.75	37.978	17	94.5
30-40	36	448.41	353.15	533.33	27.276	3	74.5
40-50	37	628.71	538.13	742.34	29.825	5	66.5
50-60	37	839.28	742.34	944.14	22.64	8	73
60-70	36	1082.2	953.75	1285.3	22.049	3	43.5
70-80	37	1541.1	1309.3	1789.8	25.758	7	98
80-90	37	2416	1861.8	3519.5	21.186	10	51
90-100	36	7215.5	3627.6	15015	27.87	7.5	68



Seasonal Trend Assessment

Location: 2-APP001.53
Comparison Parameter: 02041650 (cfs)
Pollutant: Ssolid (mg/L)
Data from: 1/30/1985 to 10/23/2012 (368 Observations)

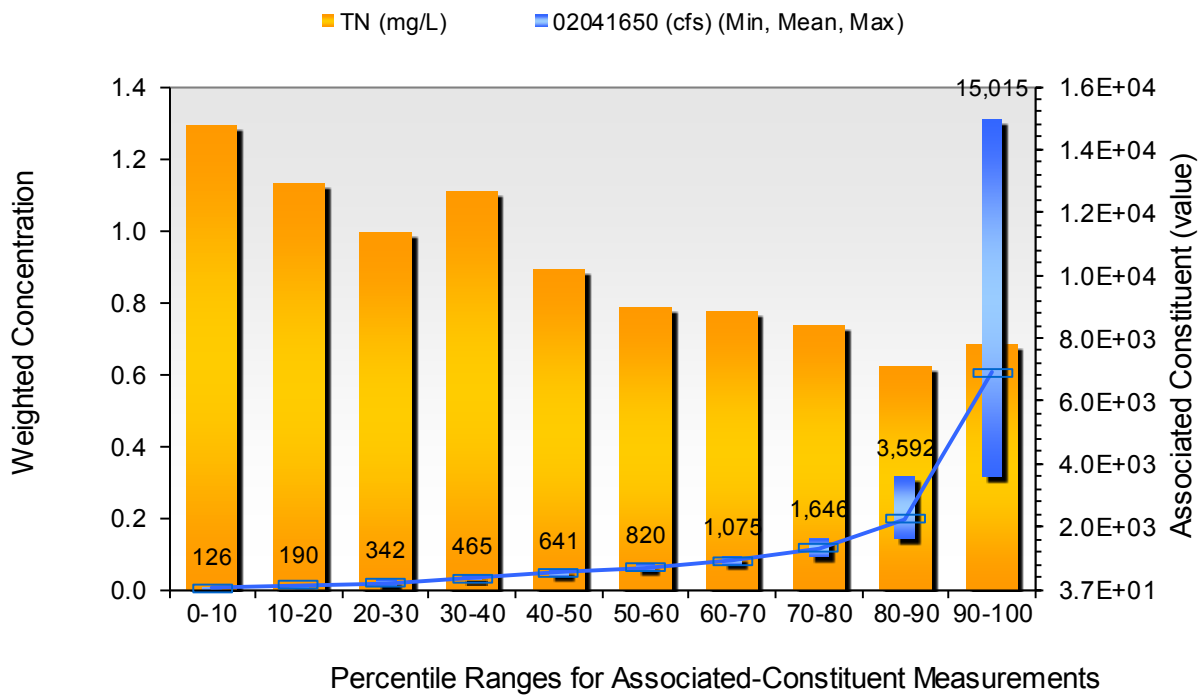
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	29	2284.5	353.15	8780.7	29.784	9	51
February	31	2538.6	290.69	9741.7	21.24	7.5	38.5
March	33	2509.3	444.44	13333	25.564	11	98
April	32	2241.1	452.85	14655	24.527	10.5	46.5
May	31	1719.7	213.81	22342	48.879	13	76.5
June	32	854.76	78.078	5429.4	34.661	3	138.5
July	33	418.2	45.646	1957.9	38.188	3	94.5
August	31	468.58	37.237	5537.5	25.224	9	73
September	31	1109.1	42.042	15015	19.711	13	89.5
October	33	512.62	0.000368	2906.9	23.458	7	86
November	27	1247.9	69.669	8156.1	20.964	5	54.5
December	25	2560	104.5	11567	31.494	8	68



Constituent-Associated Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (372 Observations)

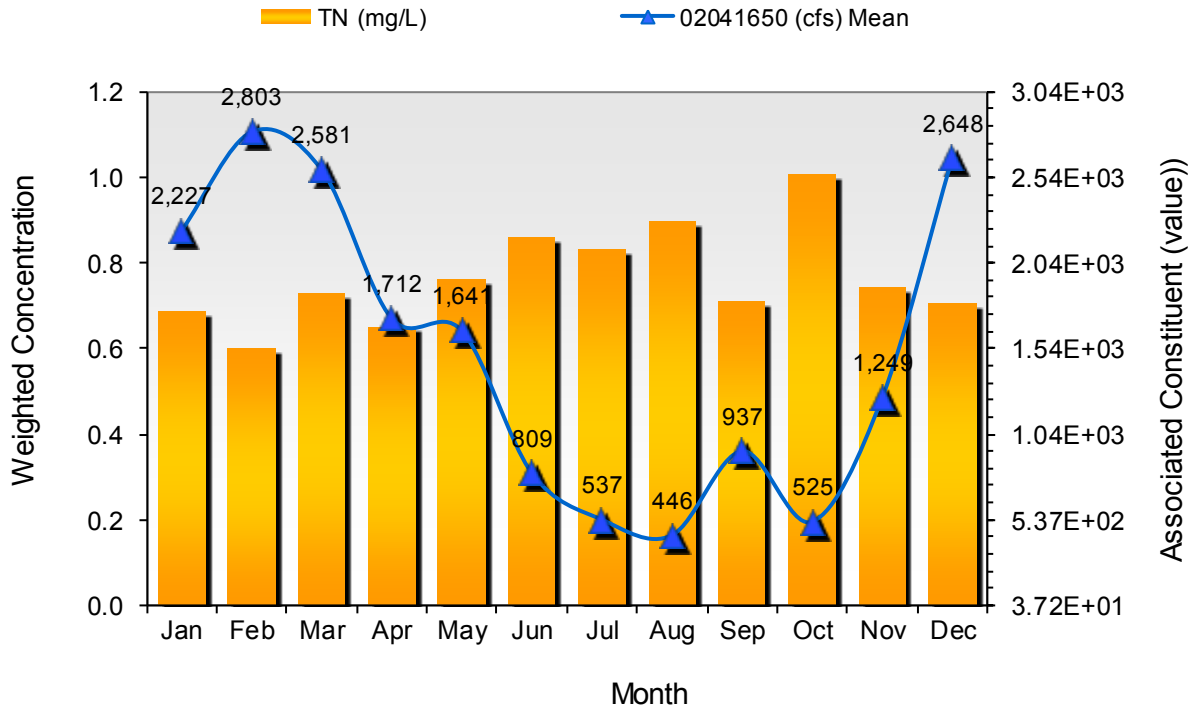
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	91.702	37.237	126.13	1.2923	0	1.842
10-20	37	162.16	129.73	189.79	1.1296	0	2.01
20-30	37	253.35	190.99	342.34	0.9968	0	1.6378
30-40	37	404.7	344.74	464.86	1.1082	0	2.61
40-50	37	563.42	473.27	641.44	0.89157	0	1.55
50-60	37	742.73	645.04	820.41	0.78472	0	1.38
60-70	37	946.09	820.41	1075.1	0.7737	0	1.4825
70-80	37	1361.8	1081.1	1645.6	0.73556	0	1.2
80-90	37	2292	1657.6	3591.6	0.62175	0	1.095
90-100	37	6933.8	3627.6	15015	0.67894	0	1.0525



Seasonal Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (372 Observations)

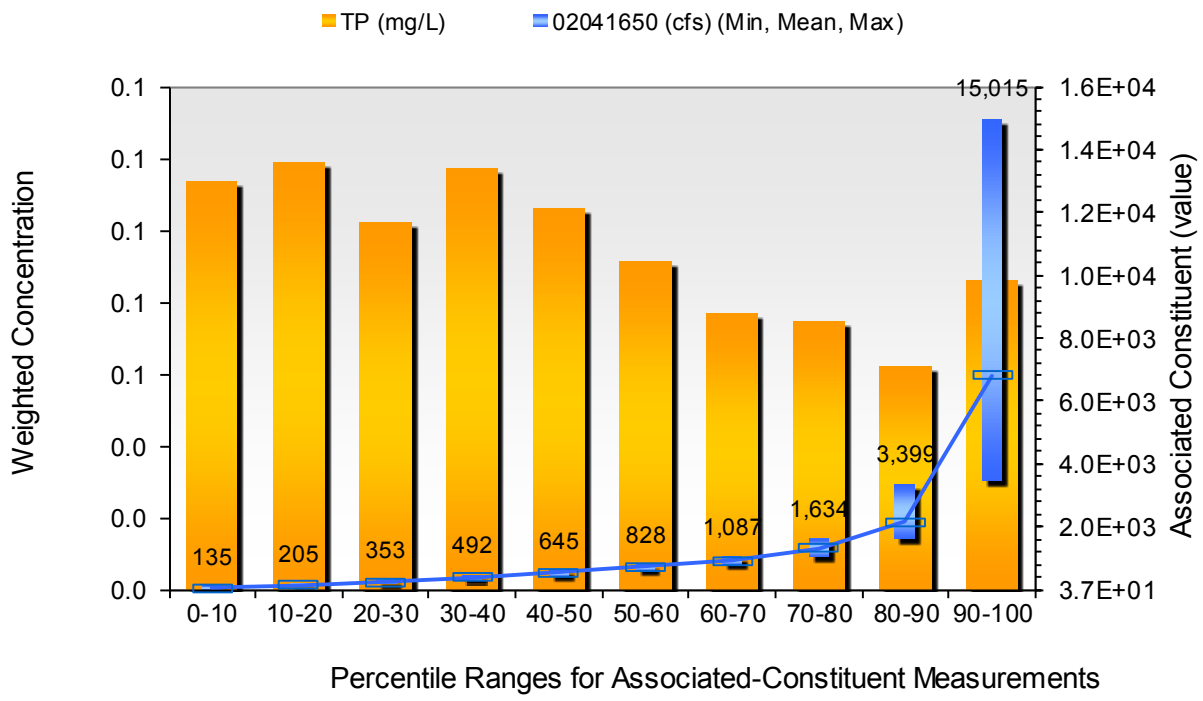
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	2227.4	353.15	7699.6	0.68655	0	1.635
February	25	2803.4	290.69	9741.7	0.59766	0	1.2775
March	35	2580.5	444.44	13333	0.73	0	1.1725
April	33	1712.1	452.85	7807.8	0.64833	0	1.0525
May	34	1640.9	213.81	22342	0.76056	0	1.4475
June	37	808.57	78.078	5429.4	0.85869	0	1.49
July	34	536.86	45.646	5441.4	0.82997	0	1.76
August	35	445.99	37.237	5537.5	0.89595	0	2.01
September	33	937.4	42.042	15015	0.71081	0	1.72
October	34	525.06	49.249	2906.9	1.0074	0	2.61
November	25	1248.6	69.669	8156.1	0.74475	0	2.14
December	24	2647.6	104.5	11567	0.7081	0	1.8305



Constituent-Associated Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 4/12/2012 (377 Observations)

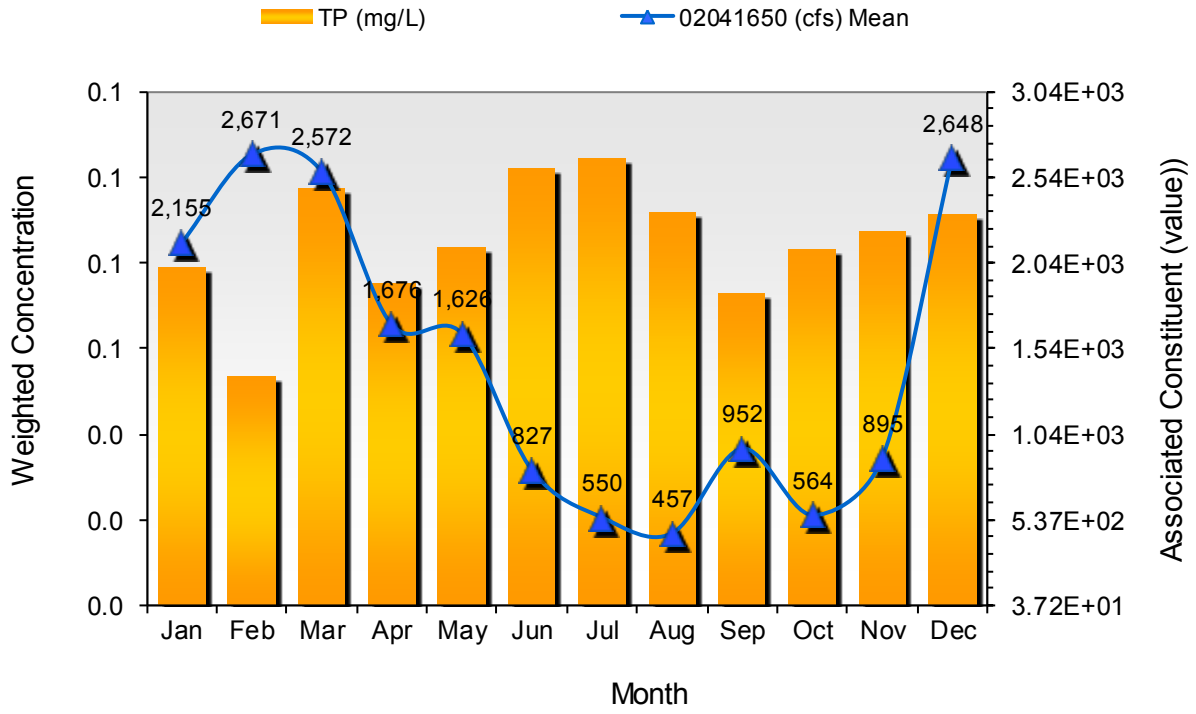
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	95.811	37.237	134.53	0.11326	0	0.2349
10-20	38	169.53	136.94	205.4	0.11897	0	0.295
20-30	37	272.41	211.41	353.15	0.10207	0	0.18
30-40	38	420.67	356.75	492.49	0.11703	0	0.24
40-50	37	576.25	493.69	645.04	0.10604	0	0.31
50-60	38	754.29	653.45	827.62	0.091619	0	0.53
60-70	38	963.45	844.44	1087.1	0.076608	0	0.125
70-80	37	1360	1101.5	1633.6	0.074679	0	0.1128
80-90	38	2197.2	1645.6	3399.4	0.062324	0	0.165
90-100	37	6835.1	3519.5	15015	0.085906	0	0.19



Seasonal Trend Assessment

Location: TF5.4
Comparison Parameter: 02041650 (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 4/12/2012 (377 Observations)

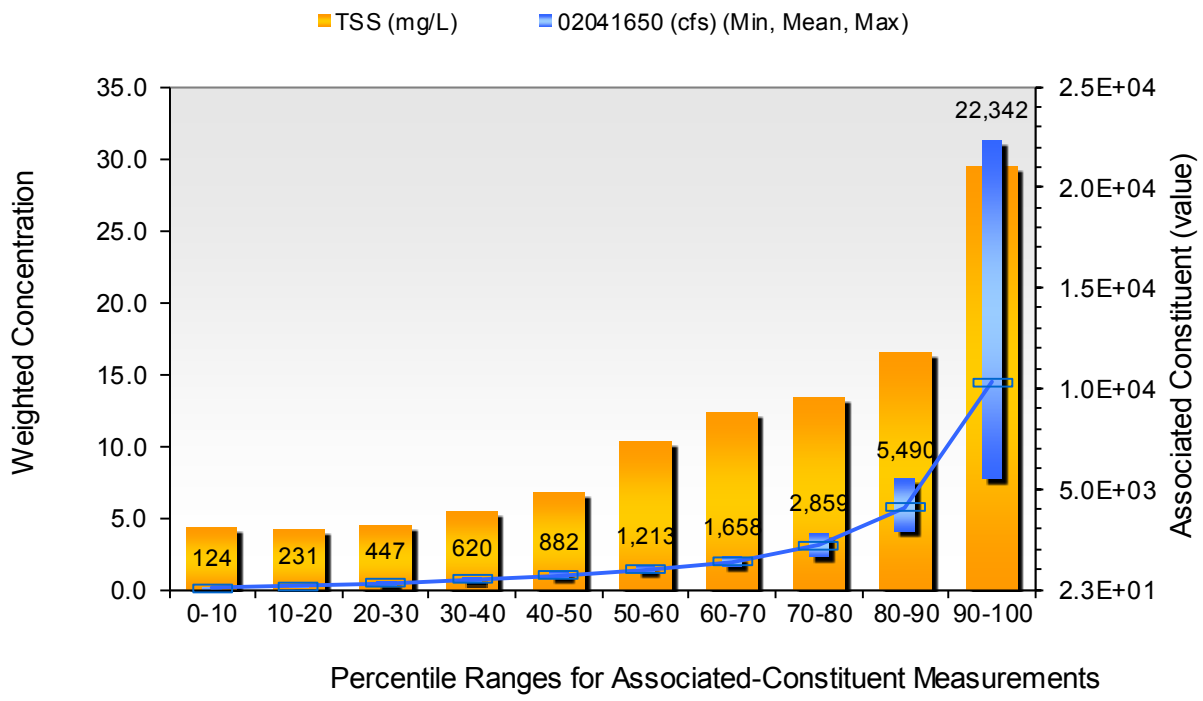
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	24	2154.6	353.15	7699.6	0.078713	0	0.135
February	27	2670.9	290.69	9741.7	0.053256	0	0.1447
March	36	2572.2	444.44	13333	0.097652	0	0.53
April	34	1676.4	452.85	7807.8	0.075303	0	0.145
May	35	1626.1	213.81	22342	0.083584	0	0.195
June	36	826.79	78.078	5429.4	0.10189	0	0.295
July	33	550.22	45.646	5441.4	0.10458	0	0.215
August	34	456.98	37.237	5537.5	0.091878	0	0.185
September	34	951.66	42.042	15015	0.072709	0	0.1905
October	35	563.6	49.249	2906.9	0.083127	0	0.18
November	25	895.22	69.669	8156.1	0.087308	0	0.31
December	24	2647.6	104.5	11567	0.091665	0	0.215



Constituent-Associated Trend Assessment

Location: 02041650
Comparison Parameter: 02041650 (cfs)
Pollutant: TSS (mg/L)
Data from: 1/24/1985 to 10/3/2012 (346 Observations)

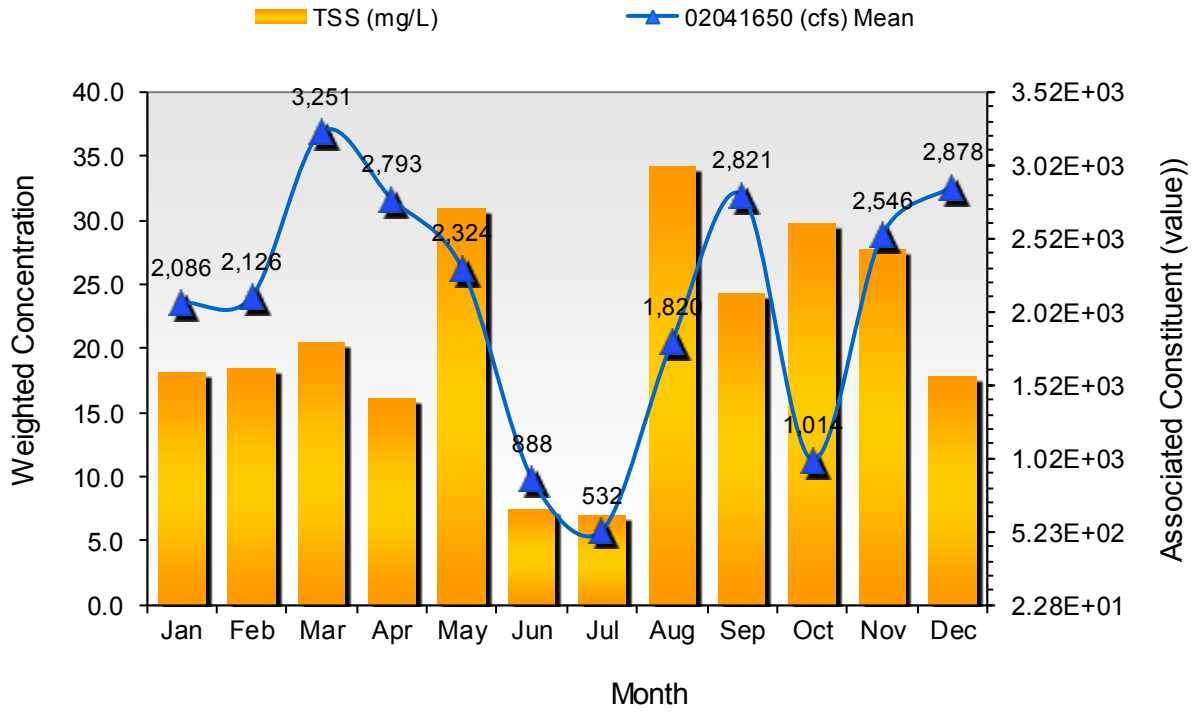
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	35	74.234	22.823	123.72	4.2672	0.5	23
10-20	34	180.36	127.33	230.63	4.191	1	11
20-30	35	342.1	236.64	446.84	4.4256	2	11
30-40	34	532.91	448.05	619.82	5.4396	2	12
40-50	35	725.59	623.42	881.68	6.7098	2	17
50-60	34	1036.2	890.08	1213.2	10.293	3	40
60-70	35	1420.8	1225.2	1657.6	12.328	4	69
70-80	34	2220.4	1669.7	2858.8	13.325	6	36
80-90	35	4121.8	2906.9	5489.5	16.533	1	72
90-100	34	10351	5537.5	22342	29.426	11	55



Seasonal Trend Assessment

Location: 02041650
Comparison Parameter: 02041650 (cfs)
Pollutant: TSS (mg/L)
Data from: 1/24/1985 to 10/3/2012 (346 Observations)

Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	31	2086.3	110.51	10126	18.192	2	34
February	33	2126.4	290.69	9525.5	18.511	3	69
March	40	3251.4	386.78	12012	20.51	3	72
April	33	2793.1	332.73	11664	16.073	3	31
May	28	2324	203	22342	30.98	3	55
June	34	887.93	72.072	3555.5	7.4772	1	11
July	22	531.91	45.645	3423.4	7.0239	2	23
August	30	1819.7	22.823	23784	34.165	2	51
September	23	2820.8	34.835	19219	24.226	1	34
October	19	1013.9	43.243	13093	29.632	0.5	41
November	32	2545.6	45.645	15736	27.768	1	42
December	21	2878.1	72.072	9453.4	17.817	1	35

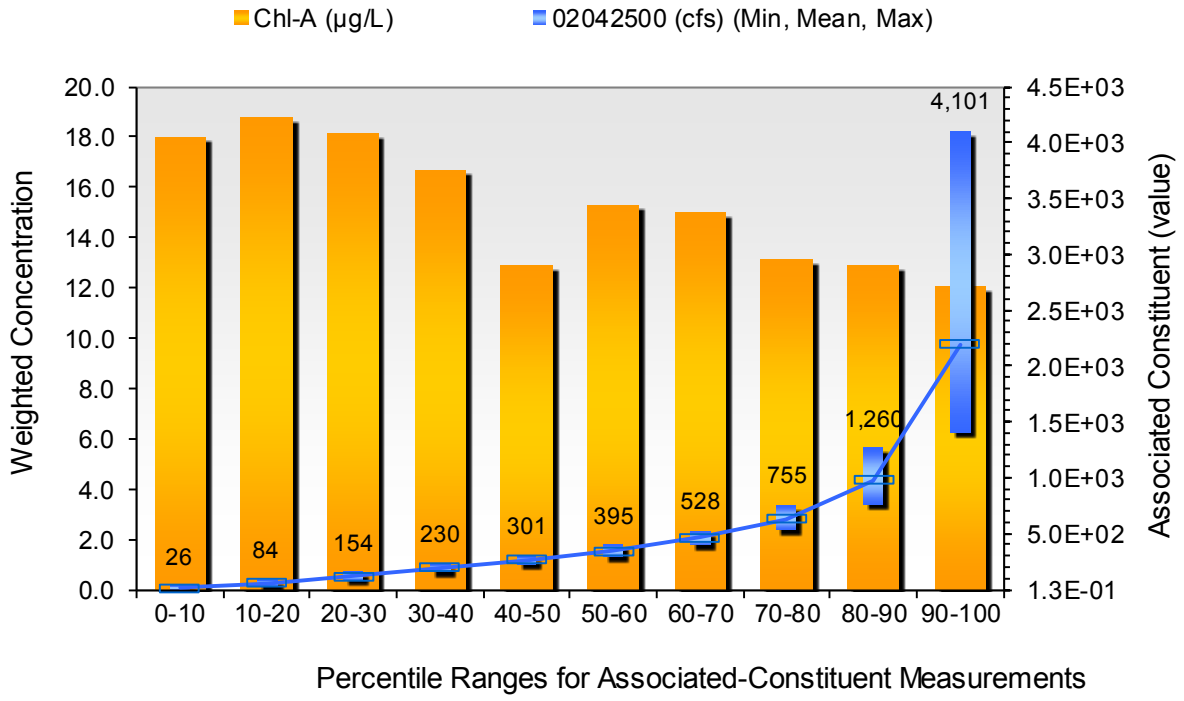


Chickahominy-OH

Constituent-Associated Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: Chl-A (µg/L)
Data from: 4/18/1988 to 9/20/2012 (326 Observations)

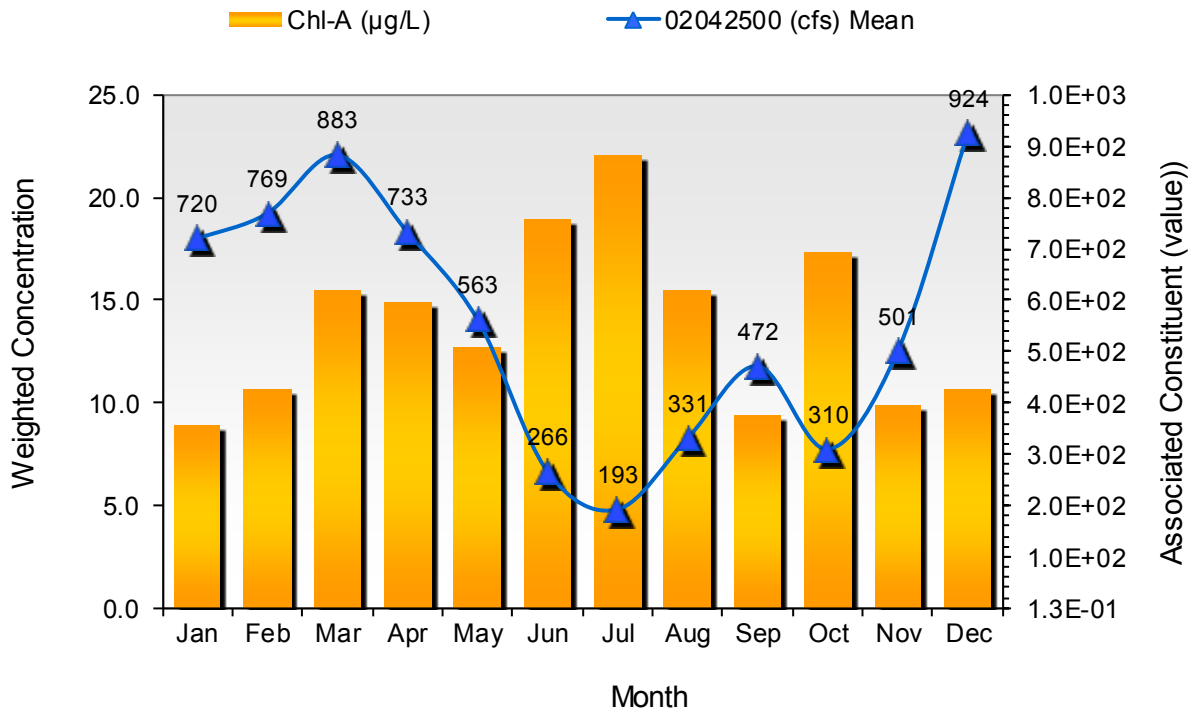
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	33	10.187	0.13129	26.215	17.961	5.75	41.5
10-20	32	55.181	28.088	84.263	18.781	0.5	64.74
20-30	33	117.97	86.135	153.55	18.111	3.99	35.76
30-40	32	195.09	157.29	230.32	16.698	1	44.28
40-50	33	265.67	230.32	301.47	12.875	1.64	26.6
50-60	32	346.3	303.35	395.1	15.323	1	54.61
60-70	33	463.13	406.33	528.05	14.985	1	32.5
70-80	32	631.85	531.79	754.62	13.127	0.5	40.42
80-90	33	977.79	760.24	1260.2	12.86	0.87	47.85
90-100	32	2196.5	1400.6	4100.8	12.019	1.8	35.5



Seasonal Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: Chl-A (µg/L)
Data from: 4/18/1988 to 9/20/2012 (326 Observations)

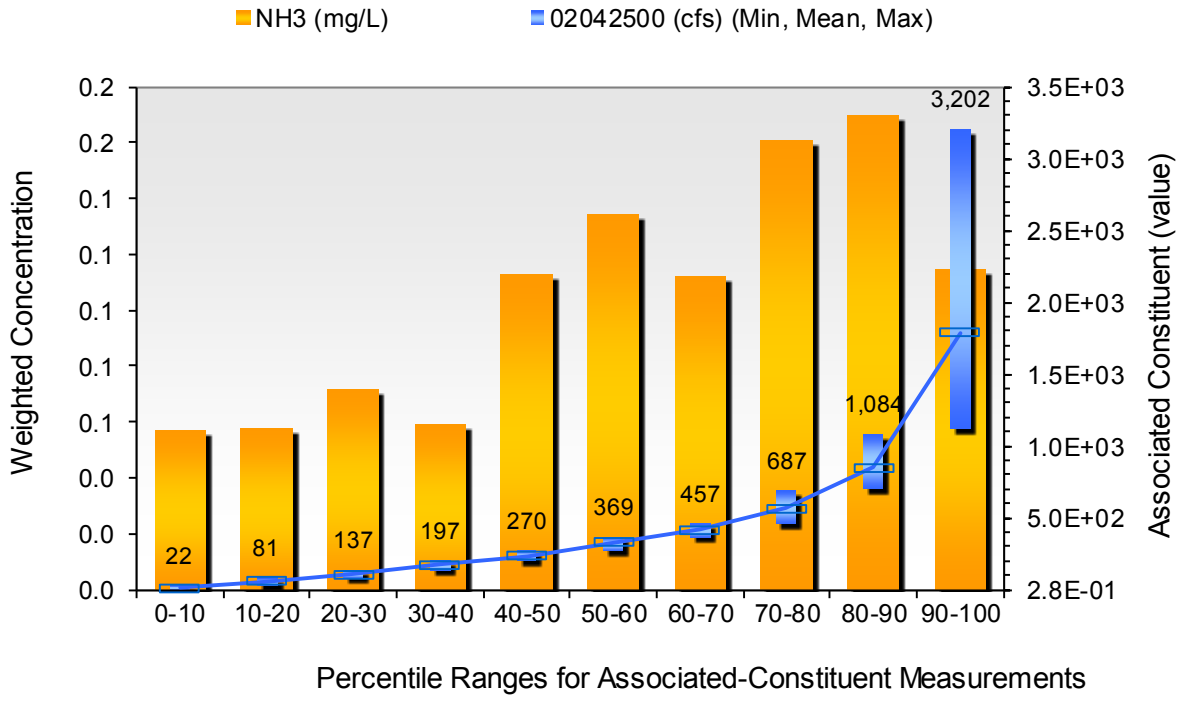
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	719.94	207.85	2303.2	8.8895	1	28.7
February	24	769.21	119.84	3333.1	10.646	1.5	35.76
March	28	882.75	132.95	2902.4	15.433	2.3	54.61
April	30	732.78	102.99	2359.4	14.871	2.7	29.8
May	29	562.72	39.323	4100.8	12.697	0.5	32.5
June	31	266.26	5.805	969.96	18.97	0.5	36.47
July	29	192.55	0.13129	797.69	22.033	8.79	64.74
August	29	331.06	0.73049	2059.8	15.52	4.19	44.28
September	30	471.84	0.28103	4550.2	9.3625	5.32	33.64
October	29	309.53	7.8647	1593.5	17.34	2.53	40.42
November	25	500.93	24.343	3089.6	9.8712	0.87	41.33
December	19	924.23	101.12	3408	10.678	2.5	27.8



Constituent-Associated Trend Assessment

Location: 2-CHK002.17
Comparison Parameter: 02042500 (cfs)
Pollutant: NH3 (mg/L)
Data from: 1/7/1985 to 12/5/2006 (206 Observations)

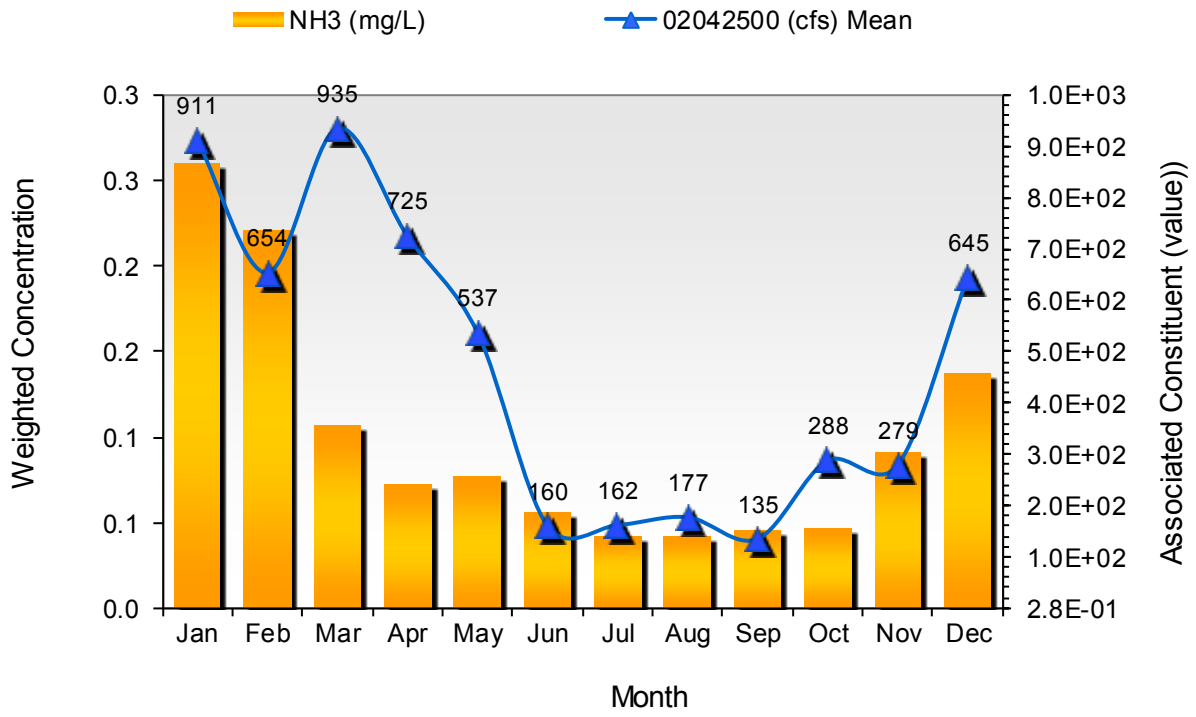
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	21	10.372	0.28107	22.47	0.057125	0.04	0.1
10-20	20	58.516	29.96	80.518	0.057872	0.04	0.1
20-30	21	104.68	82.39	136.69	0.071695	0.04	0.27
30-40	20	169.27	136.69	196.61	0.058899	0.04	0.21
40-50	21	234.42	200.36	269.64	0.11267	0.04	0.41
50-60	20	327.5	277.13	368.88	0.1338	0.04	0.6
60-70	21	415.61	370.76	456.89	0.11197	0.04	0.6
70-80	20	561.38	458.76	687.21	0.16032	0.04	0.69
80-90	21	848.34	698.45	1084.2	0.1694	0.04	0.6
90-100	20	1788.5	1121.6	3202	0.11481	0.04	0.3



Seasonal Trend Assessment

Location: 2-CHK002.17
Comparison Parameter: 02042500 (cfs)
Pollutant: NH3 (mg/L)
Data from: 1/7/1985 to 12/5/2006 (206 Observations)

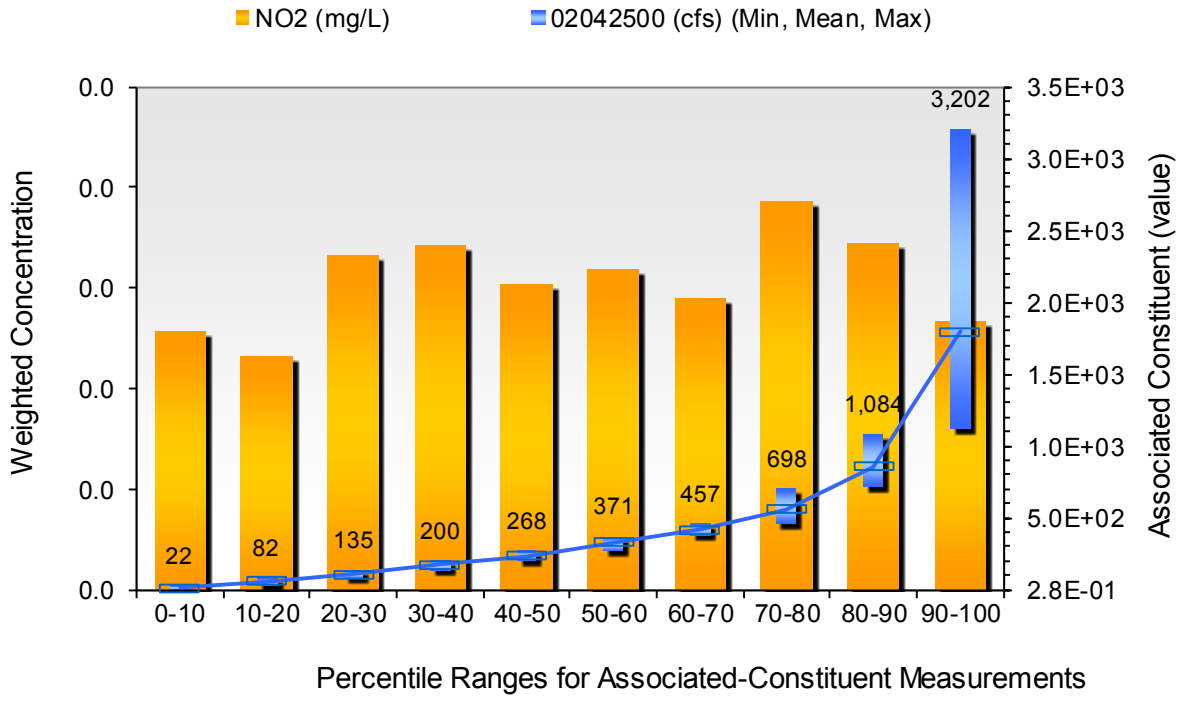
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	17	911.36	211.59	3520.3	0.26017	0.04	0.69
February	18	653.71	121.71	1793.9	0.22012	0.04	0.6
March	17	935.04	269.64	3070.9	0.10669	0.04	0.39
April	18	725.18	164.78	2190.8	0.072294	0.04	0.2
May	15	537.16	74.9	3202	0.077332	0.04	0.19
June	21	160.45	6.3667	432.55	0.05655	0.04	0.11
July	16	162.05	0.28107	520.56	0.041824	0.04	0.1
August	17	177.41	1.442	1084.2	0.042023	0.04	0.1
September	17	135.21	0.37464	447.53	0.045465	0.04	0.1
October	18	287.96	5.6177	1378.2	0.047088	0.04	0.1
November	16	279	22.47	1284.5	0.090231	0.04	0.3
December	16	644.73	61.793	1715.2	0.13703	0.04	0.4



Constituent-Associated Trend Assessment

Location: 2-CHK002.17
Comparison Parameter: 02042500 (cfs)
Pollutant: NO2 (mg/L)
Data from: 1/7/1985 to 3/6/2003 (197 Observations)

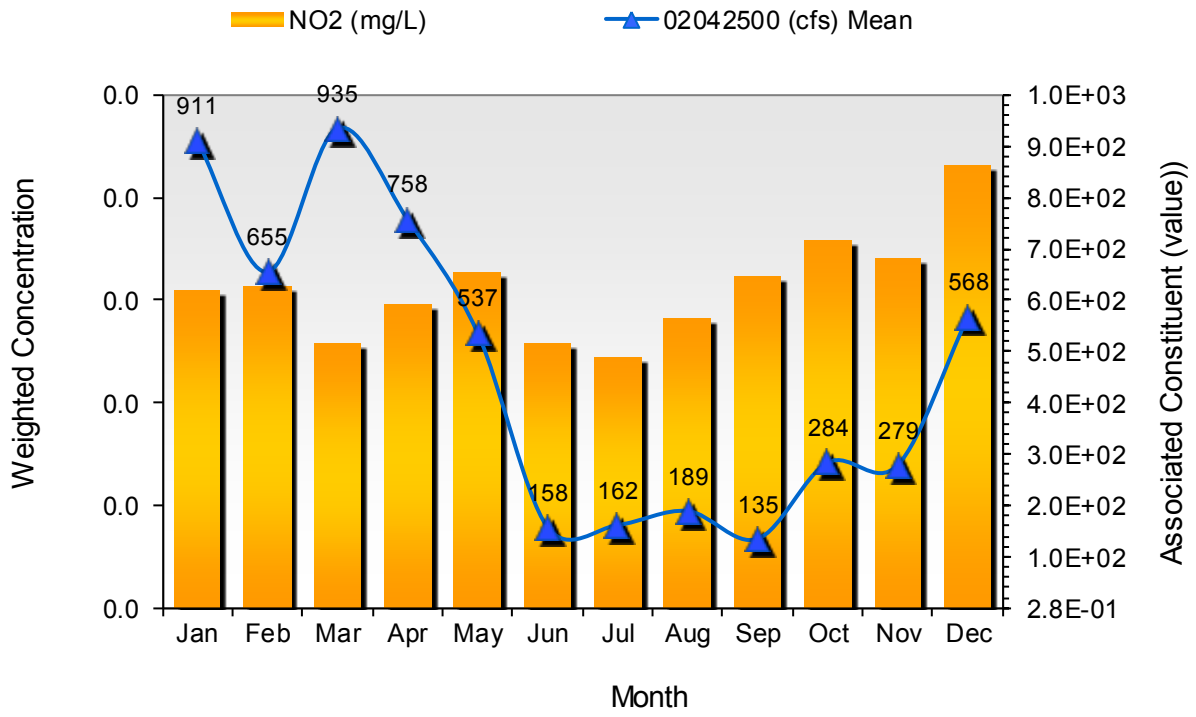
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	20	10.61	0.28107	22.47	0.012833	0.01	0.04
10-20	20	59.078	29.96	82.39	0.011585	0.01	0.05
20-30	19	104.17	86.135	134.82	0.016613	0.01	0.05
30-40	20	169.46	136.69	200.36	0.017094	0.01	0.06
40-50	19	234.36	200.36	267.77	0.015168	0.01	0.06
50-60	20	326.66	269.64	370.76	0.015913	0.01	0.05
60-70	20	417.85	372.63	456.89	0.014457	0.01	0.03
70-80	19	560.37	458.76	698.45	0.019302	0.01	0.06
80-90	20	855.83	719.04	1084.2	0.017194	0.01	0.04
90-100	19	1792.4	1121.6	3202	0.013289	0.01	0.03



Seasonal Trend Assessment

Location: 2-CHK002.17
Comparison Parameter: 02042500 (cfs)
Pollutant: NO2 (mg/L)
Data from: 1/7/1985 to 3/6/2003 (197 Observations)

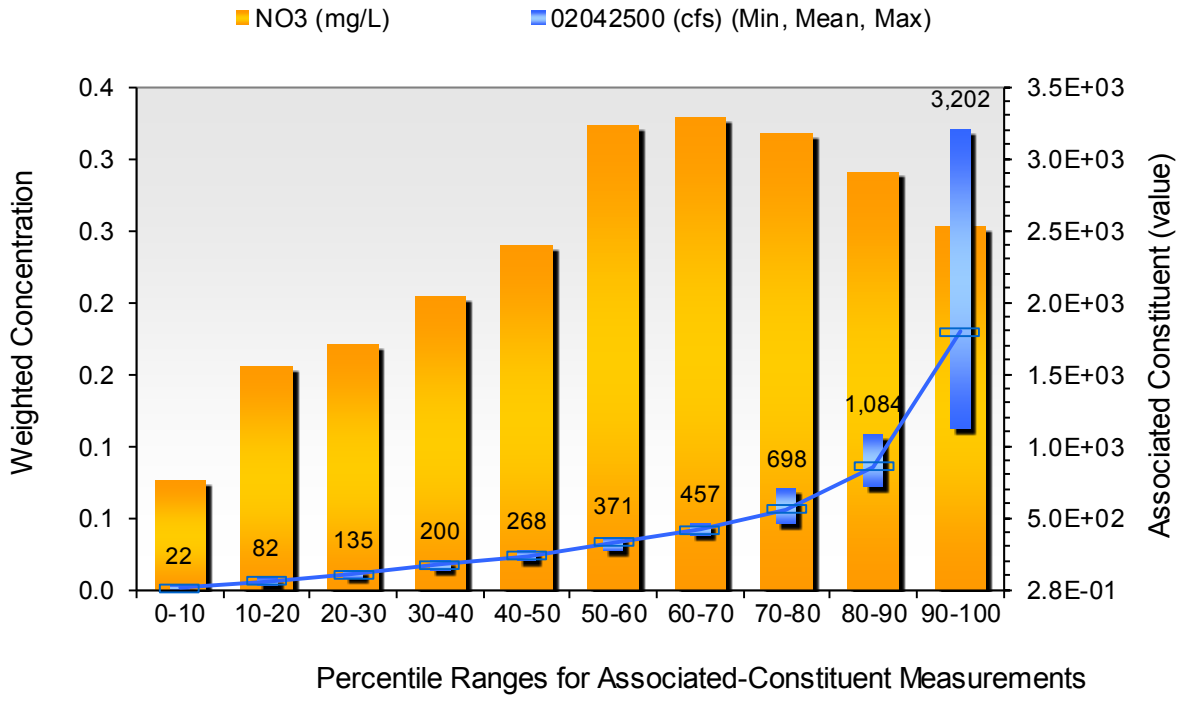
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	17	911.36	211.59	3520.3	0.015487	0.01	0.04
February	17	655.27	121.71	1793.9	0.015668	0.01	0.03
March	17	935.04	269.64	3070.9	0.012832	0.01	0.02
April	17	758.15	183.51	2190.8	0.014826	0.01	0.04
May	15	537.16	74.9	3202	0.01637	0.01	0.02
June	19	157.82	6.3667	432.55	0.01286	0.01	0.05
July	16	162.05	0.28107	520.56	0.012196	0.01	0.02
August	15	189.46	1.442	1084.2	0.014131	0.01	0.06
September	17	135.21	0.37464	447.53	0.016174	0.01	0.05
October	17	283.86	5.6177	1378.2	0.017898	0.01	0.05
November	16	279	22.47	1284.5	0.017013	0.01	0.04
December	14	567.77	61.793	1318.2	0.021517	0.01	0.06



Constituent-Associated Trend Assessment

Location: 2-CHK002.17
Comparison Parameter: 02042500 (cfs)
Pollutant: NO3 (mg/L)
Data from: 1/7/1985 to 3/6/2003 (197 Observations)

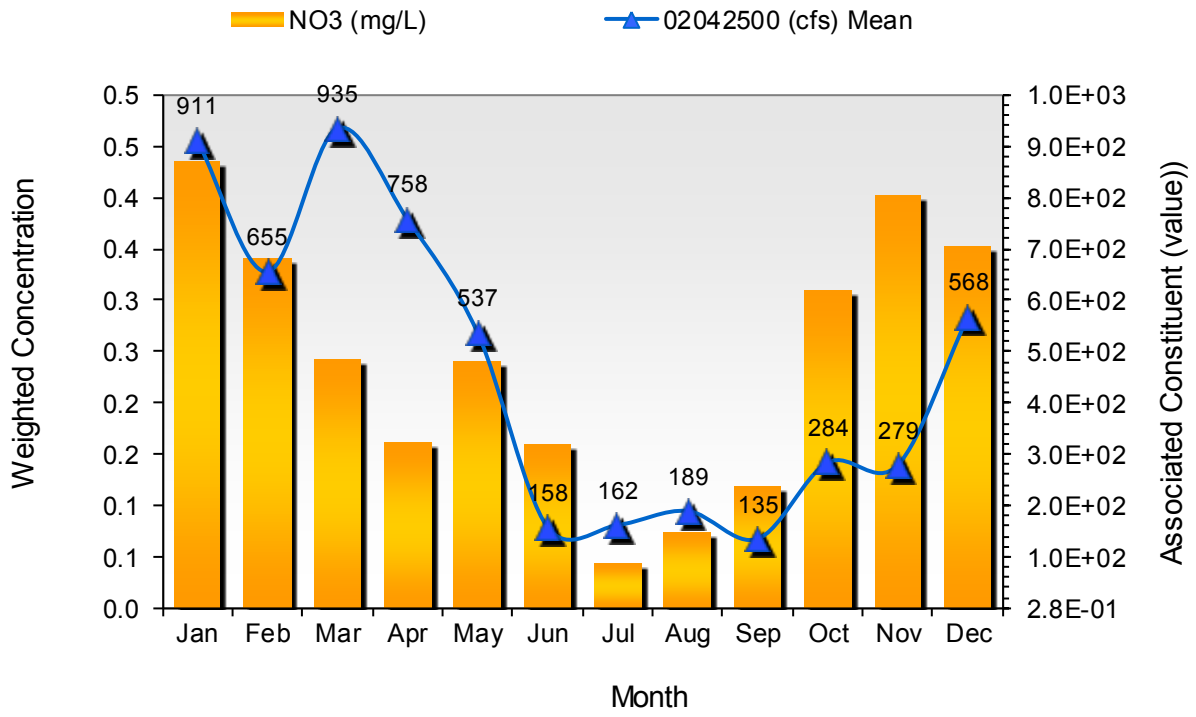
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	20	10.61	0.28107	22.47	0.076039	0.04	0.25
10-20	20	59.078	29.96	82.39	0.15594	0.04	0.59
20-30	19	104.17	86.135	134.82	0.1699	0.04	0.47
30-40	20	169.46	136.69	200.36	0.20422	0.04	0.84
40-50	19	234.36	200.36	267.77	0.23963	0.04	0.71
50-60	20	326.66	269.64	370.76	0.32281	0.04	0.73
60-70	20	417.85	372.63	456.89	0.32783	0.04	1.17
70-80	19	560.37	458.76	698.45	0.3169	0.04	0.64
80-90	20	855.83	719.04	1084.2	0.2905	0.04	0.58
90-100	19	1792.4	1121.6	3202	0.25218	0.04	0.54



Seasonal Trend Assessment

Location: 2-CHK002.17
Comparison Parameter: 02042500 (cfs)
Pollutant: NO3 (mg/L)
Data from: 1/7/1985 to 3/6/2003 (197 Observations)

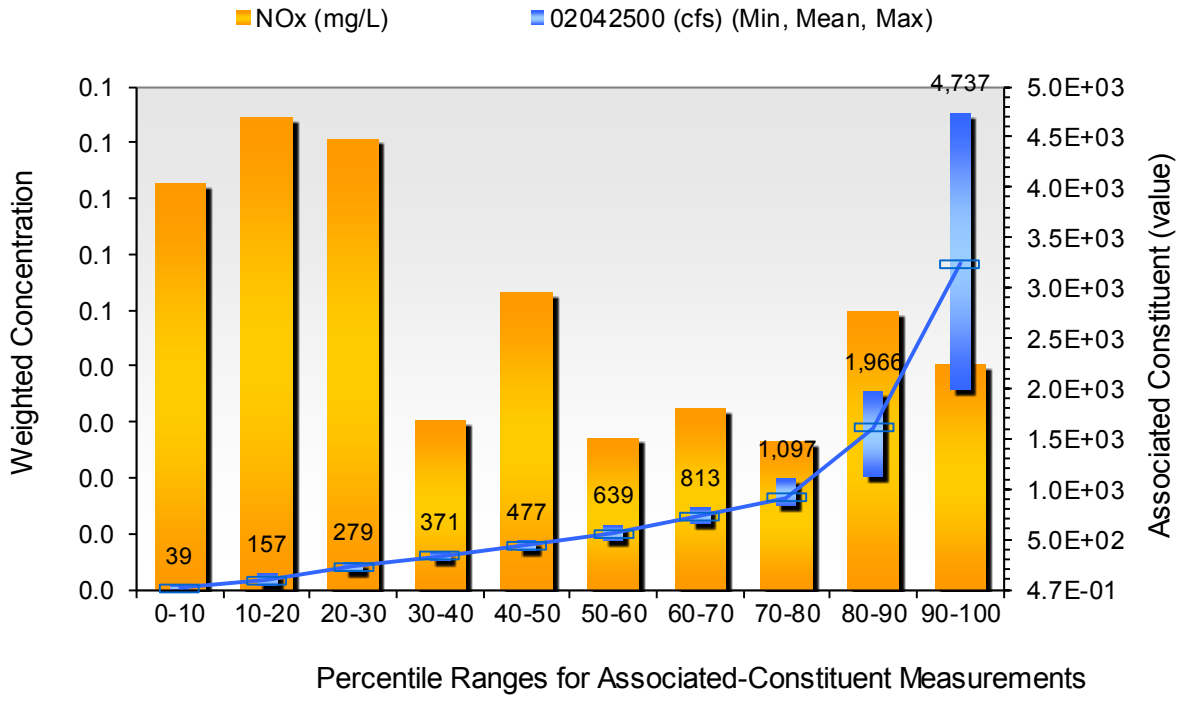
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	17	911.36	211.59	3520.3	0.43527	0.23333	0.64
February	17	655.27	121.71	1793.9	0.33987	0.21	0.71
March	17	935.04	269.64	3070.9	0.24208	0.09	0.49
April	17	758.15	183.51	2190.8	0.15992	0.04	0.43
May	15	537.16	74.9	3202	0.23909	0.04	0.34
June	19	157.82	6.3667	432.55	0.15969	0.04	0.55
July	16	162.05	0.28107	520.56	0.043561	0.04	0.25
August	15	189.46	1.442	1084.2	0.074028	0.04	0.42
September	17	135.21	0.37464	447.53	0.11834	0.04	0.35
October	17	283.86	5.6177	1378.2	0.30983	0.04	0.59
November	16	279	22.47	1284.5	0.40241	0.04	0.73
December	14	567.77	61.793	1318.2	0.35119	0.13	1.17



Constituent-Associated Trend Assessment

Location: 2-CHK035.26
Comparison Parameter: 02042500 (cfs)
Pollutant: NOx (mg/L)
Data from: 3/9/2007 to 10/3/2012 (112 Observations)

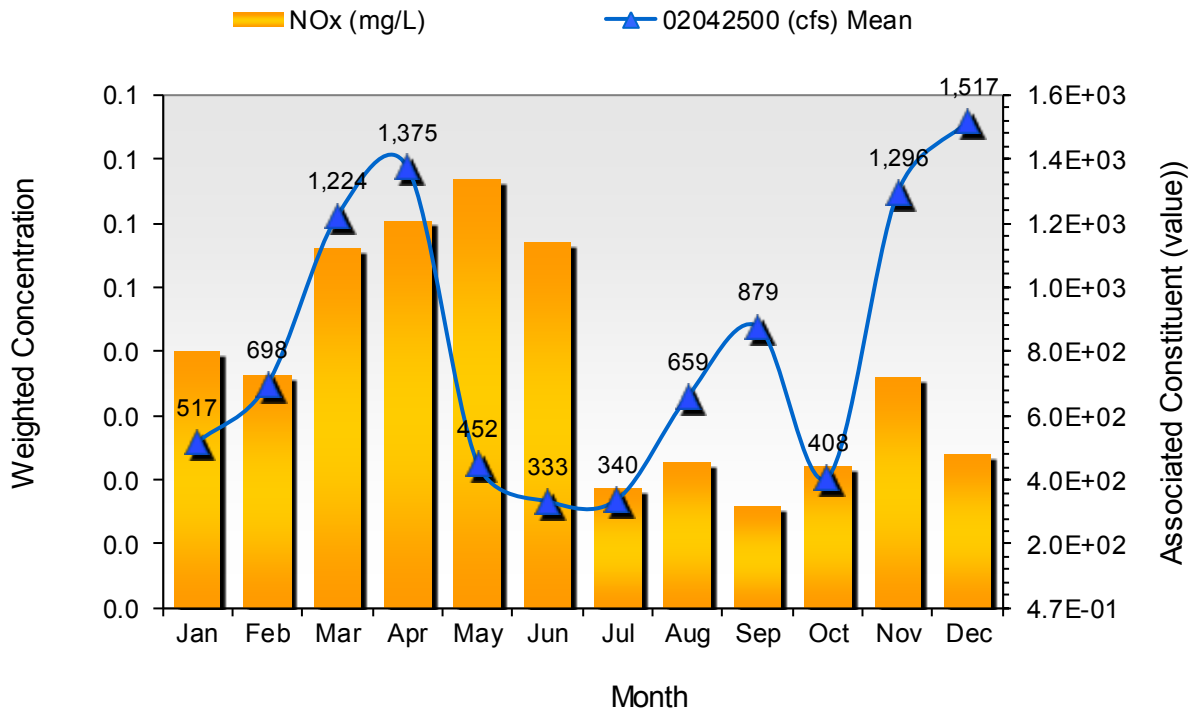
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	12	14.929	0.4682	39.323	0.072744	0.008	0.14
10-20	11	93.966	41.195	157.29	0.08433	0.04	0.27
20-30	11	227.77	166.65	279	0.080583	0.03	0.14
30-40	11	330.41	280.88	370.76	0.030144	0.008	0.06
40-50	11	437.32	387.61	477.49	0.053169	0.02	0.09
50-60	11	555.28	490.6	638.53	0.02702	0.01	0.07
60-70	11	730.96	655.38	812.67	0.032352	0.01	0.08
70-80	11	912.76	829.52	1097.3	0.02635	0.01	0.06
80-90	11	1609.7	1114.1	1966.1	0.049845	0.01	0.18
90-100	11	3241.1	1984.9	4737.4	0.040289	0.01	0.1



Seasonal Trend Assessment

Location: 2-CHK035.26
Comparison Parameter: 02042500 (cfs)
Pollutant: NOx (mg/L)
Data from: 3/9/2007 to 10/3/2012 (112 Observations)

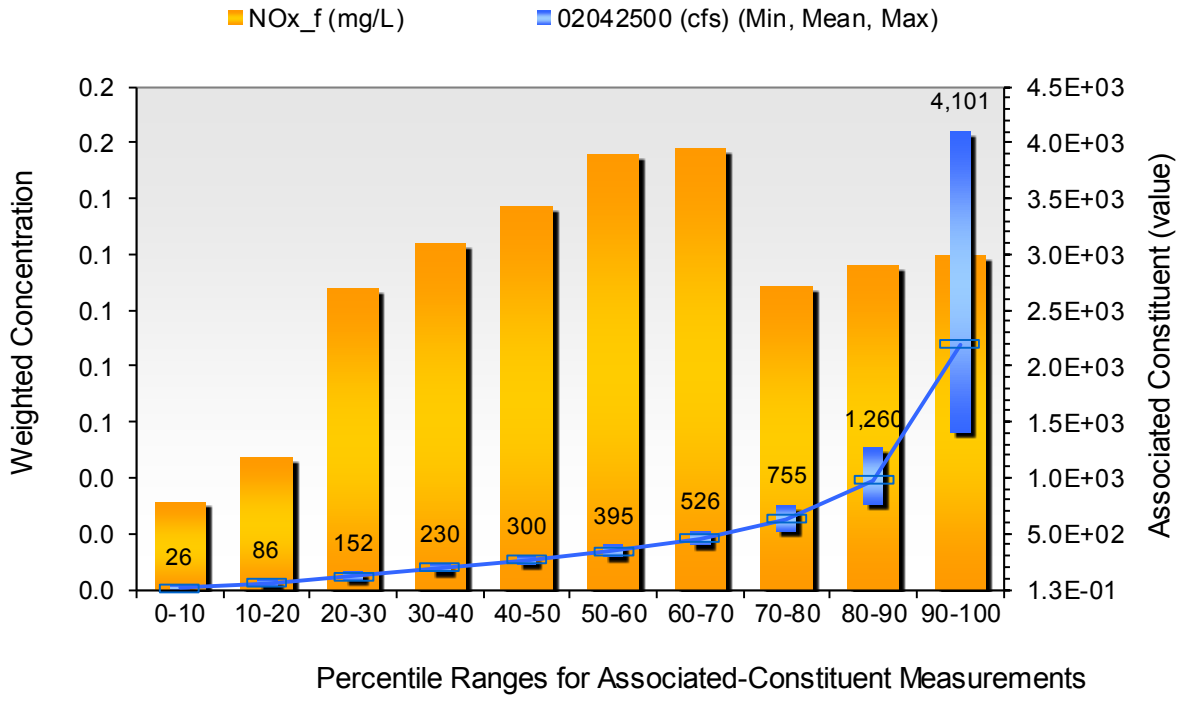
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	9	517.44	234.06	893.19	0.039859	0.02	0.08
February	7	697.91	174.14	1157.2	0.036282	0.02	0.06
March	18	1223.9	280.88	4231.9	0.056031	0.01	0.18
April	11	1374.8	247.17	4737.4	0.06027	0.01	0.10667
May	9	451.69	157.29	1097.3	0.066951	0.01	0.15
June	8	333.07	20.598	1537.3	0.056894	0.04	0.27
July	8	340.08	1.7228	1026.1	0.018755	0.008	0.095
August	9	659.48	6.1793	2902.4	0.022783	0.008	0.13
September	9	879.34	0.4682	3838.6	0.015901	0.01	0.09
October	8	407.65	14.231	866.97	0.021913	0.01	0.04
November	8	1295.8	76.773	6048.2	0.035863	0.01	0.05
December	8	1517.2	119.84	3164.5	0.023957	0.01	0.04



Constituent-Associated Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: NOx_f (mg/L)
Data from: 4/18/1988 to 9/20/2012 (329 Observations)

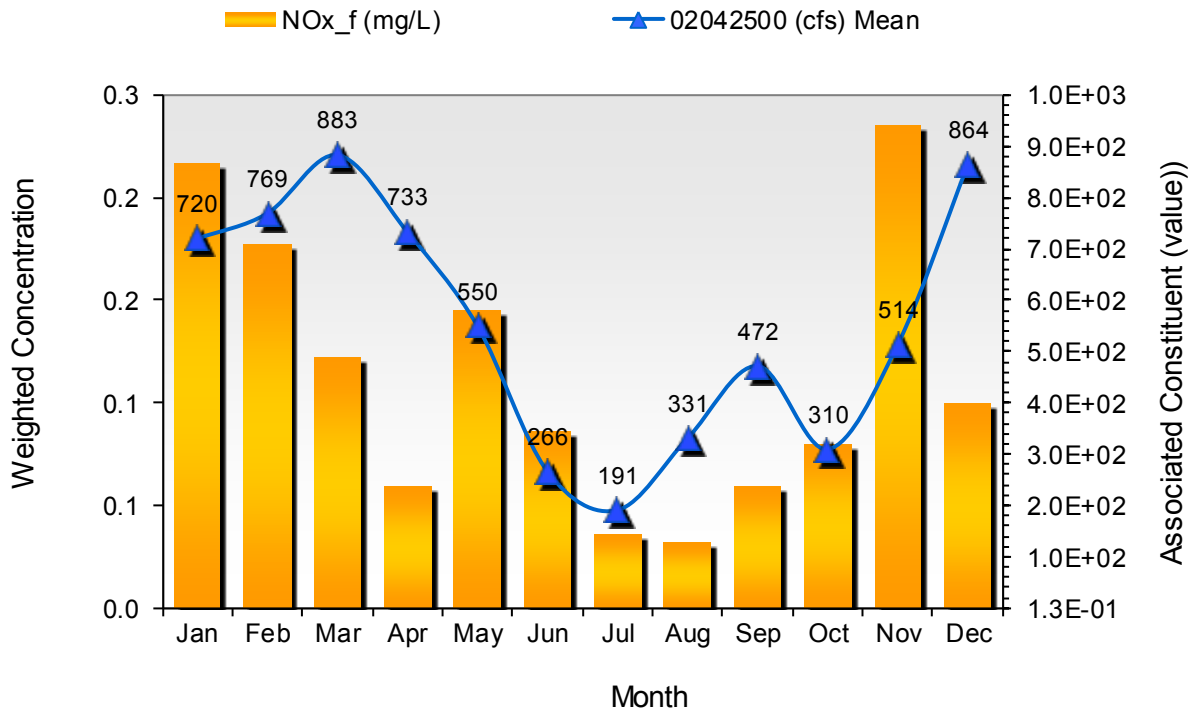
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	33	10.187	0.13129	26.215	0.031237	0	0.185
10-20	33	56.119	28.088	86.135	0.04757	0	0.4905
20-30	33	119.39	89.88	151.67	0.10796	0	1
30-40	33	193.1	153.55	230.32	0.12378	0	0.705
40-50	32	264.55	230.32	299.6	0.13694	0	0.6575
50-60	33	344.94	301.47	395.1	0.1555	0	0.575
60-70	33	460.47	406.33	526.18	0.15757	0	0.545
70-80	33	628.71	528.05	754.62	0.10847	0	0.3955
80-90	33	977.79	760.24	1260.2	0.11576	0	0.374
90-100	32	2196.5	1400.6	4100.8	0.11952	0	0.4165



Seasonal Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: NOx_f (mg/L)
Data from: 4/18/1988 to 9/20/2012 (329 Observations)

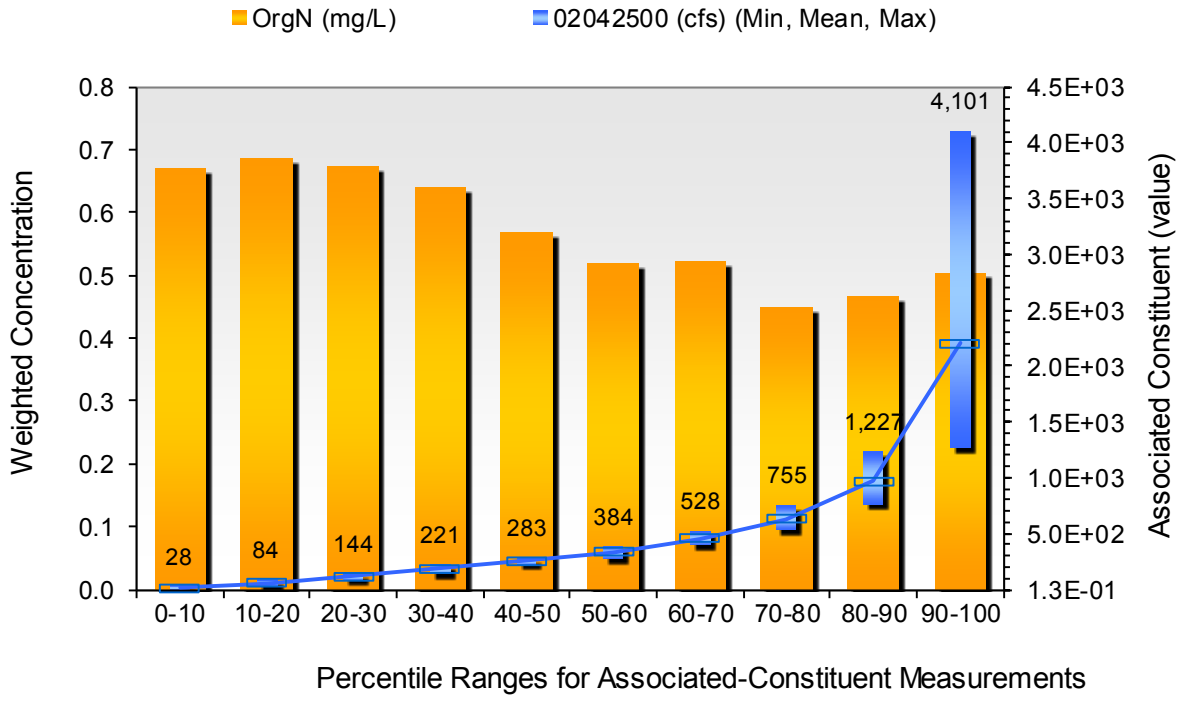
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	719.94	207.85	2303.2	0.21607	0	0.6165
February	24	769.21	119.84	3333.1	0.17692	0	0.6575
March	28	882.75	132.95	2902.4	0.12174	0	0.577
April	30	732.78	102.99	2359.4	0.059503	0	0.3355
May	30	549.77	39.323	4100.8	0.14483	0	0.465
June	31	266.26	5.805	969.96	0.085919	0	0.3875
July	30	191.18	0.13129	797.69	0.035982	0	0.28
August	29	331.06	0.73049	2059.8	0.031779	0	0.1245
September	30	471.84	0.28103	4550.2	0.059309	0	0.185
October	29	309.53	7.8647	1593.5	0.079427	0	0.2975
November	24	513.54	24.343	3089.6	0.23471	0	0.545
December	21	863.58	101.12	3408	0.099675	0	1



Constituent-Associated Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: OrgN (mg/L)
Data from: 4/18/1988 to 9/20/2012 (313 Observations)

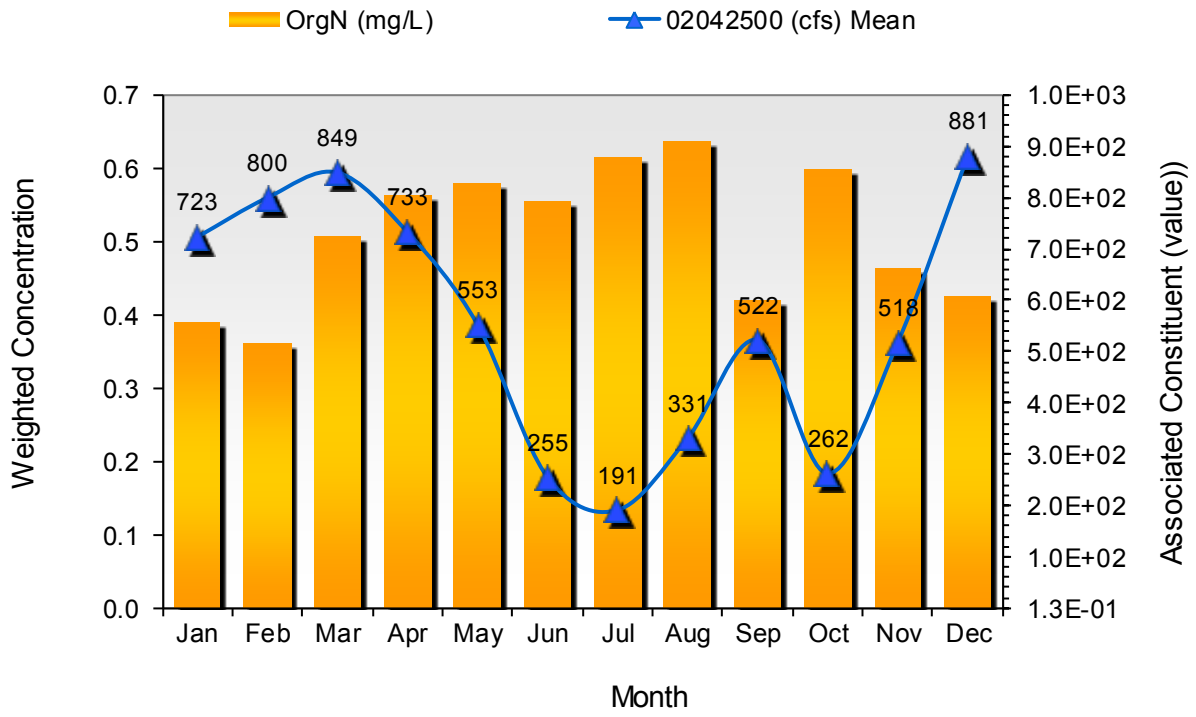
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	32	11.122	0.13128	28.088	0.67117	0	1.37
10-20	31	56.055	29.96	84.263	0.68432	0	1.2233
20-30	31	115.55	86.135	144.18	0.67189	0	1.62
30-40	31	183.63	144.18	220.96	0.6404	0	1.5
40-50	31	253.82	220.96	282.75	0.56938	0	0.9
50-60	32	333.19	282.75	383.86	0.51924	0	0.775
60-70	31	453.39	393.23	528.05	0.52297	0	0.97
70-80	31	633.03	531.79	754.62	0.44843	0	0.925
80-90	31	970.87	760.24	1226.5	0.4669	0	0.832
90-100	31	2198.4	1260.2	4100.8	0.50466	0	0.895



Seasonal Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: OrgN (mg/L)
Data from: 4/18/1988 to 9/20/2012 (313 Observations)

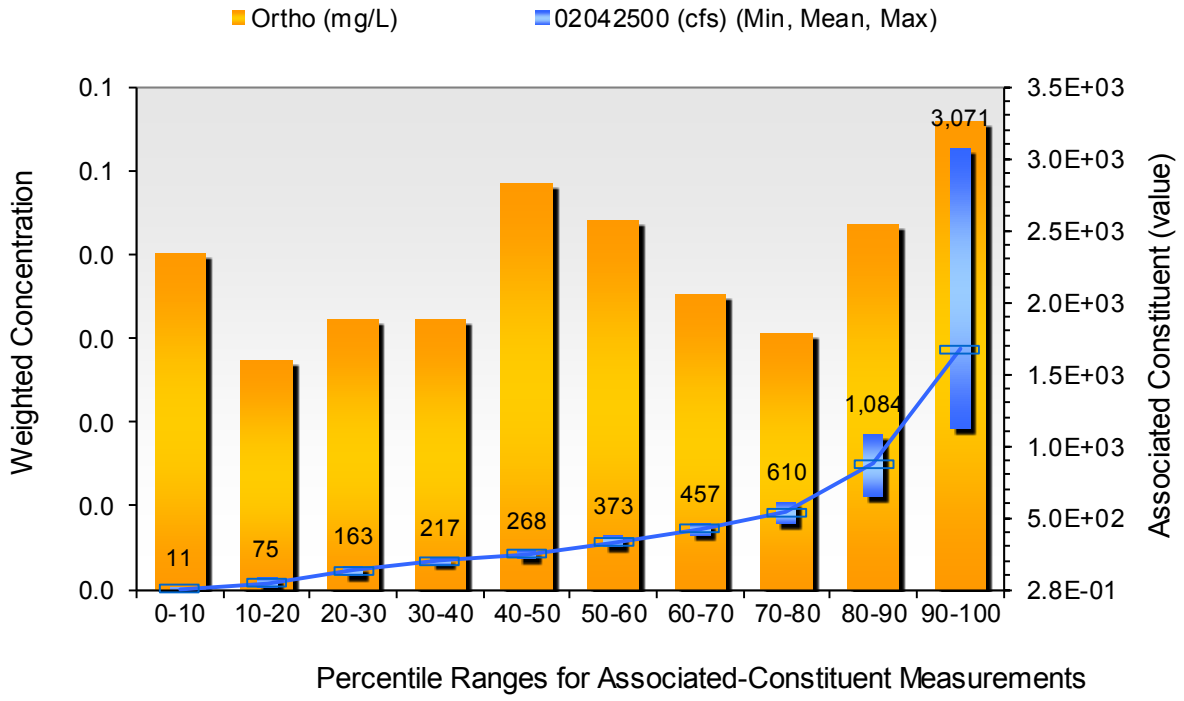
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	21	723.15	207.85	2303.2	0.39097	0	0.785
February	22	799.65	119.84	3333.1	0.35997	0	0.735
March	27	848.66	132.95	2902.4	0.50719	0	0.895
April	30	732.78	102.99	2359.4	0.56178	0	1.5
May	29	552.84	39.323	4100.8	0.57834	0	0.88367
June	30	255.29	5.805	969.96	0.55539	0	0.98
July	30	191.18	0.13128	797.69	0.61452	0	1.2233
August	29	331.06	0.73049	2059.8	0.63615	0	1.62
September	26	522.37	3.3708	4550.2	0.42041	0	1.22
October	27	262.34	7.8647	1026.1	0.59794	0	1.37
November	22	517.83	24.343	3089.6	0.46228	0	0.86
December	20	880.73	101.12	3408	0.42469	0	0.96



Constituent-Associated Trend Assessment

Location: 2-CHK002.17
Comparison Parameter: 02042500 (cfs)
Pollutant: Ortho (mg/L)
Data from: 7/19/1994 to 3/6/2003 (94 Observations)

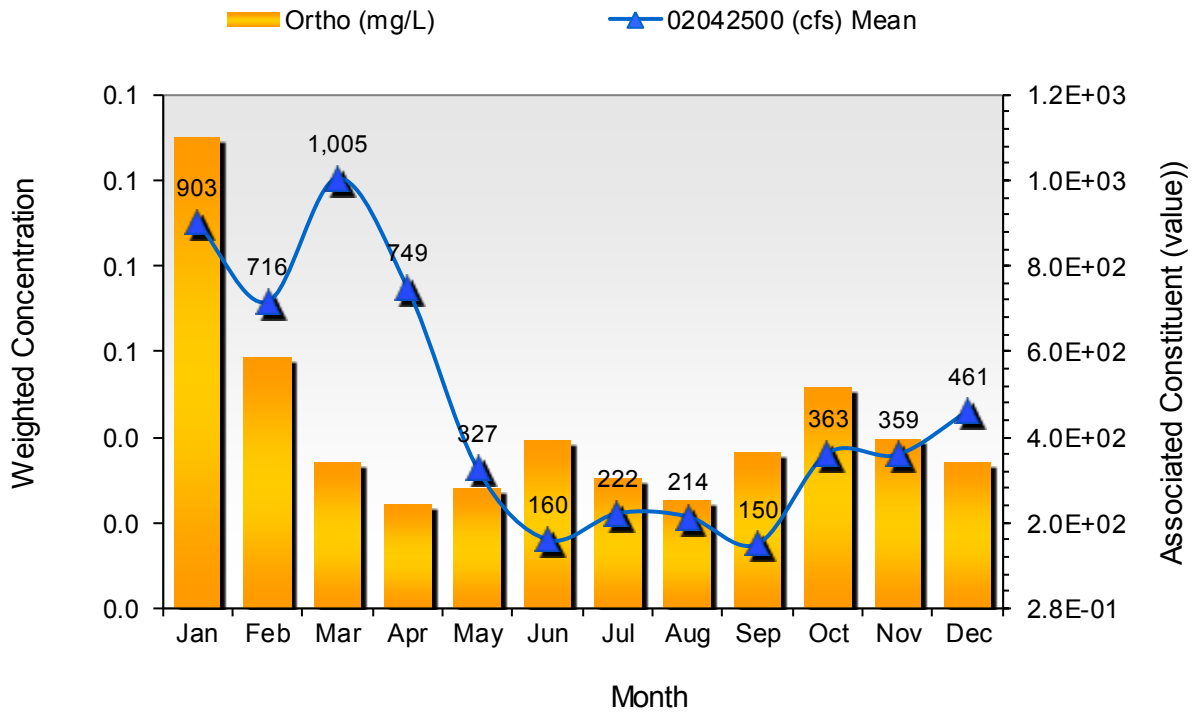
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	10	5.4902	0.28097	11.235	0.040034	0.02	0.05
10-20	9	42.548	13.108	74.9	0.027311	0.01	0.06
20-30	9	134.2	97.37	162.91	0.03214	0.01	0.06
30-40	10	196.24	170.4	217.21	0.032271	0.01	0.05
40-50	9	244.05	222.83	267.77	0.04844	0.03	0.08
50-60	9	328.52	293.98	372.63	0.043908	0.02	0.11
60-70	10	423	378.25	456.89	0.035135	0.02	0.06
70-80	9	537.2	458.76	610.44	0.030608	0.01	0.05
80-90	9	873.01	646.02	1084.2	0.043449	0.02	0.09
90-100	9	1675.1	1121.6	3070.9	0.055886	0.02	0.26



Seasonal Trend Assessment

Location: 2-CHK002.17
Comparison Parameter: 02042500 (cfs)
Pollutant: Ortho (mg/L)
Data from: 7/19/1994 to 3/6/2003 (94 Observations)

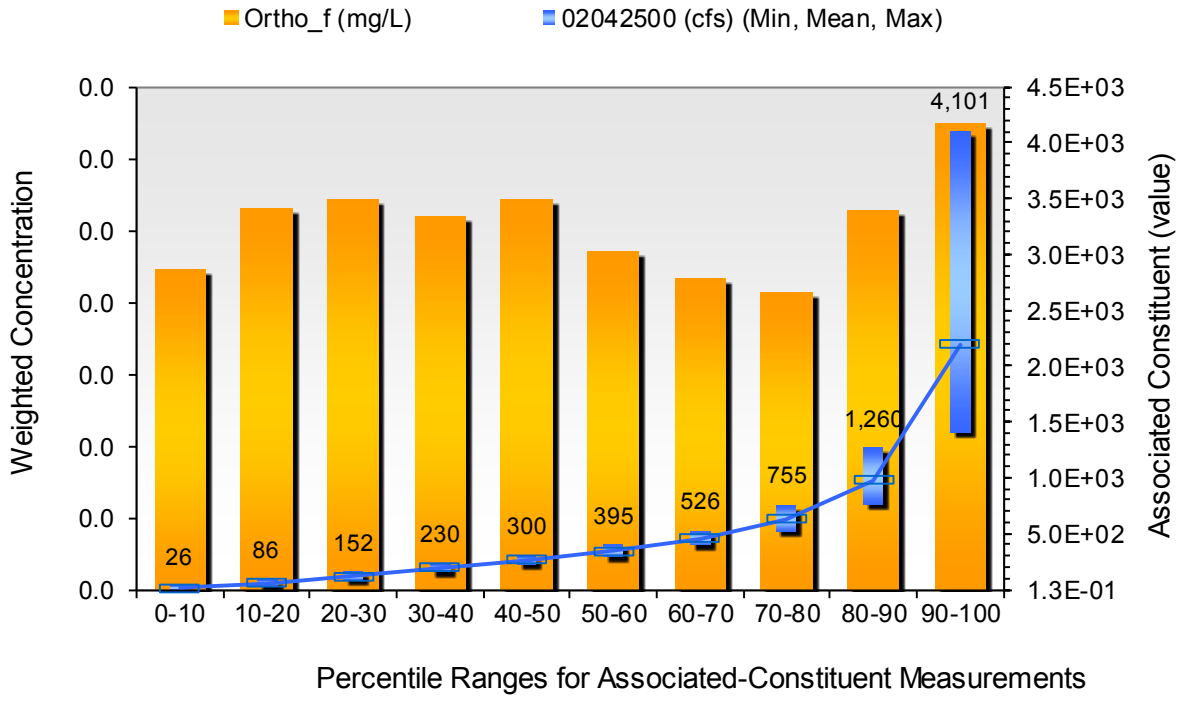
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	8	902.55	211.59	3520.3	0.11009	0.033333	0.26
February	8	716.23	136.69	1793.9	0.058431	0.02	0.09
March	8	1005.1	299.6	3070.9	0.034127	0.02	0.11
April	8	749.24	217.21	1735.8	0.024408	0.02	0.04
May	6	326.75	74.9	578.61	0.028176	0.01	0.05
June	8	160.19	6.3666	293.98	0.039117	0.02	0.06
July	8	221.93	0.28097	520.56	0.030431	0.01	0.04
August	8	214.49	1.4419	1084.2	0.025181	0.02	0.05
September	8	150.22	0.37454	370.76	0.036313	0.03	0.05
October	8	362.59	5.6176	1378.2	0.051632	0.01	0.08
November	9	359.11	22.47	1284.5	0.039594	0.01	0.06
December	7	460.9	61.793	1121.6	0.033848	0.02	0.05



Constituent-Associated Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 4/18/1988 to 9/20/2012 (329 Observations)

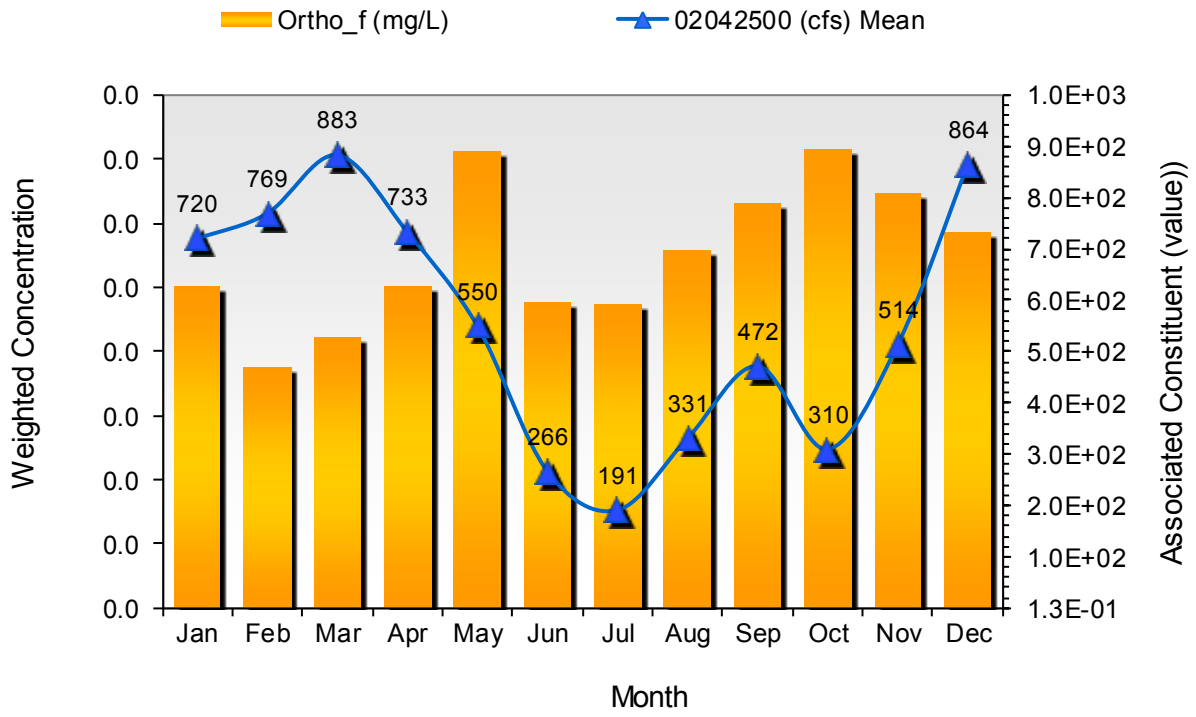
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	33	10.187	0.13129	26.215	0.0089207	0	0.02
10-20	33	56.119	28.088	86.135	0.010604	0	0.02
20-30	33	119.39	89.88	151.67	0.010877	0	0.055
30-40	33	193.1	153.55	230.32	0.010364	0	0.03
40-50	32	264.55	230.32	299.6	0.010842	0	0.0275
50-60	33	344.94	301.47	395.1	0.0094093	0	0.021
60-70	33	460.47	406.33	526.18	0.0086662	0	0.0215
70-80	33	628.71	528.05	754.62	0.0082902	0	0.03
80-90	33	977.79	760.24	1260.2	0.010546	0	0.034
90-100	32	2196.5	1400.6	4100.8	0.012978	0	0.0285



Seasonal Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 4/18/1988 to 9/20/2012 (329 Observations)

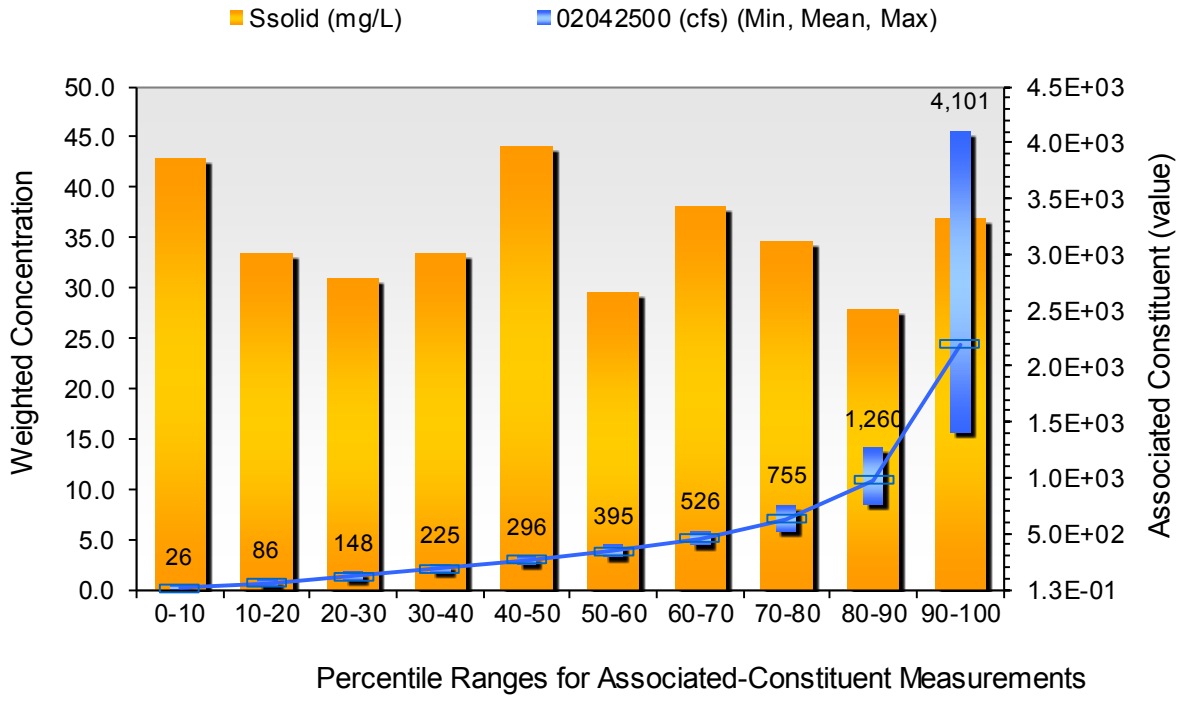
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	719.94	207.85	2303.2	0.010013	0	0.03
February	24	769.21	119.84	3333.1	0.0074764	0	0.03
March	28	882.75	132.95	2902.4	0.0084495	0	0.025
April	30	732.78	102.99	2359.4	0.010047	0	0.02
May	30	549.77	39.323	4100.8	0.01425	0	0.03
June	31	266.26	5.805	969.96	0.0095549	0	0.02
July	30	191.18	0.13129	797.69	0.0094694	0	0.0205
August	29	331.06	0.73049	2059.8	0.011162	0	0.0165
September	30	471.84	0.28103	4550.2	0.012627	0	0.024
October	29	309.53	7.8647	1593.5	0.014277	0	0.034
November	24	513.54	24.343	3089.6	0.012915	0	0.055
December	21	863.58	101.12	3408	0.011667	0	0.0285



Constituent-Associated Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: Ssolid (mg/L)
Data from: 4/18/1988 to 9/20/2012 (327 Observations)

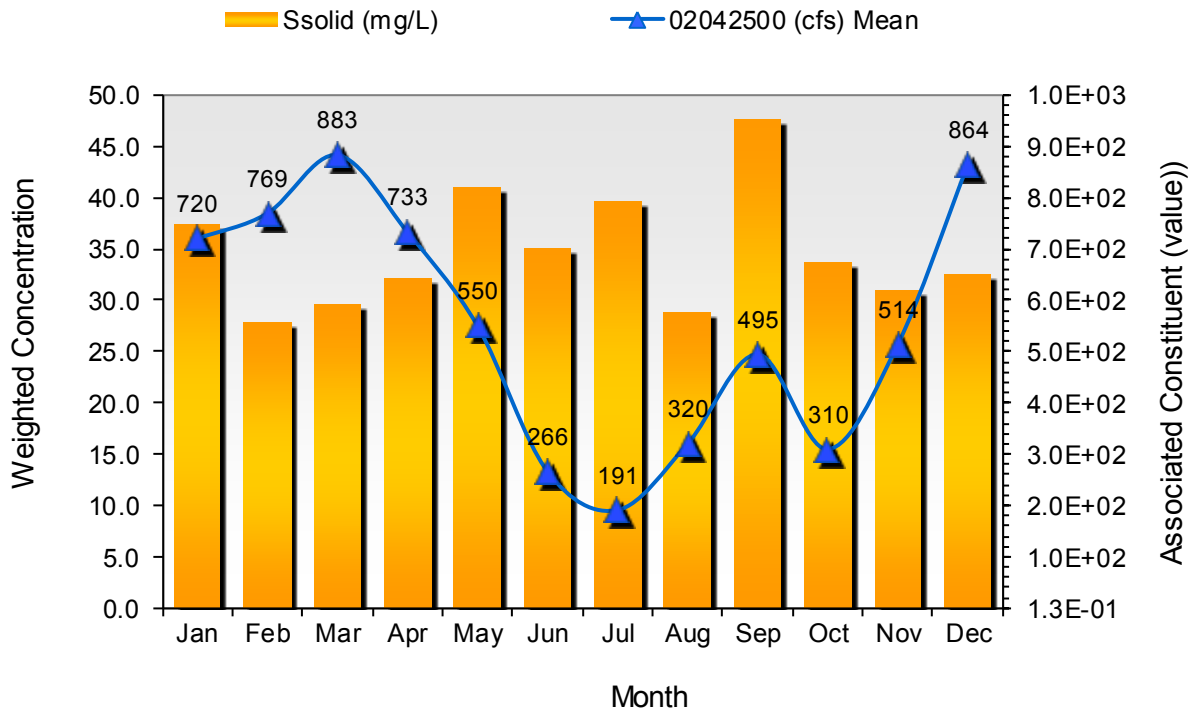
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	33	10.232	0.13128	26.215	42.913	13.5	199
10-20	33	56.119	28.088	86.135	33.379	10	87
20-30	32	118.38	89.88	147.93	30.848	9	98.5
30-40	33	190.71	151.67	224.7	33.387	8.5	95
40-50	32	262.39	230.32	295.86	44.11	15	104
50-60	33	344.88	299.6	395.1	29.447	10	117
60-70	33	460.47	406.33	526.18	37.982	13.5	100.5
70-80	32	631.5	528.05	754.62	34.598	11	82
80-90	33	977.79	760.24	1260.2	27.751	12	71.5
90-100	32	2196.5	1400.6	4100.8	36.873	11	81



Seasonal Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: Ssolid (mg/L)
Data from: 4/18/1988 to 9/20/2012 (327 Observations)

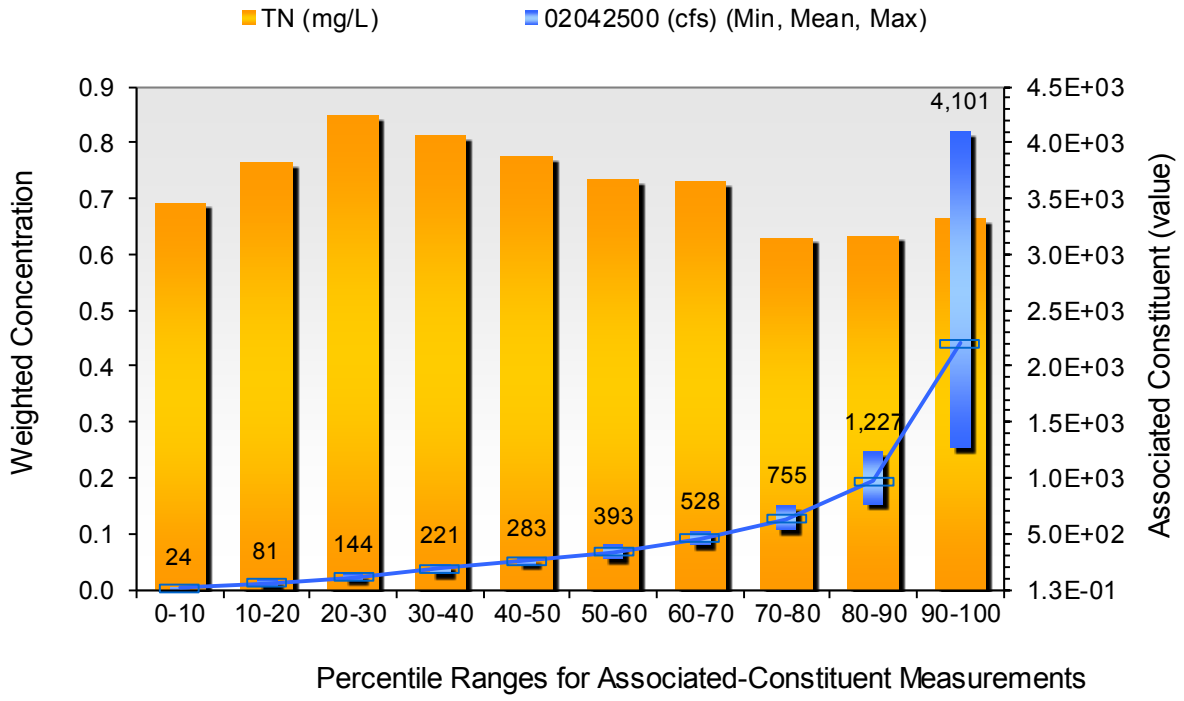
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	719.94	207.85	2303.2	37.299	10.5	75
February	24	769.21	119.84	3333.1	27.838	13.5	99.5
March	28	882.75	132.95	2902.4	29.535	11	86
April	30	732.78	102.99	2359.4	32.047	10	117
May	29	550.13	39.323	4100.8	41.026	8.5	104
June	31	266.26	5.805	969.96	34.968	12.5	92
July	30	191.18	0.13128	797.69	39.604	13	85.5
August	30	320.3	0.73049	2059.8	28.915	9	98.5
September	28	494.54	0.28103	4550.2	47.617	13.5	114.5
October	29	309.53	7.8647	1593.5	33.66	10	199
November	24	513.54	24.343	3089.6	30.888	10	100.5
December	21	863.58	101.12	3408	32.457	9.75	72.5



Constituent-Associated Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: TN (mg/L)
Data from: 4/18/1988 to 7/19/2012 (313 Observations)

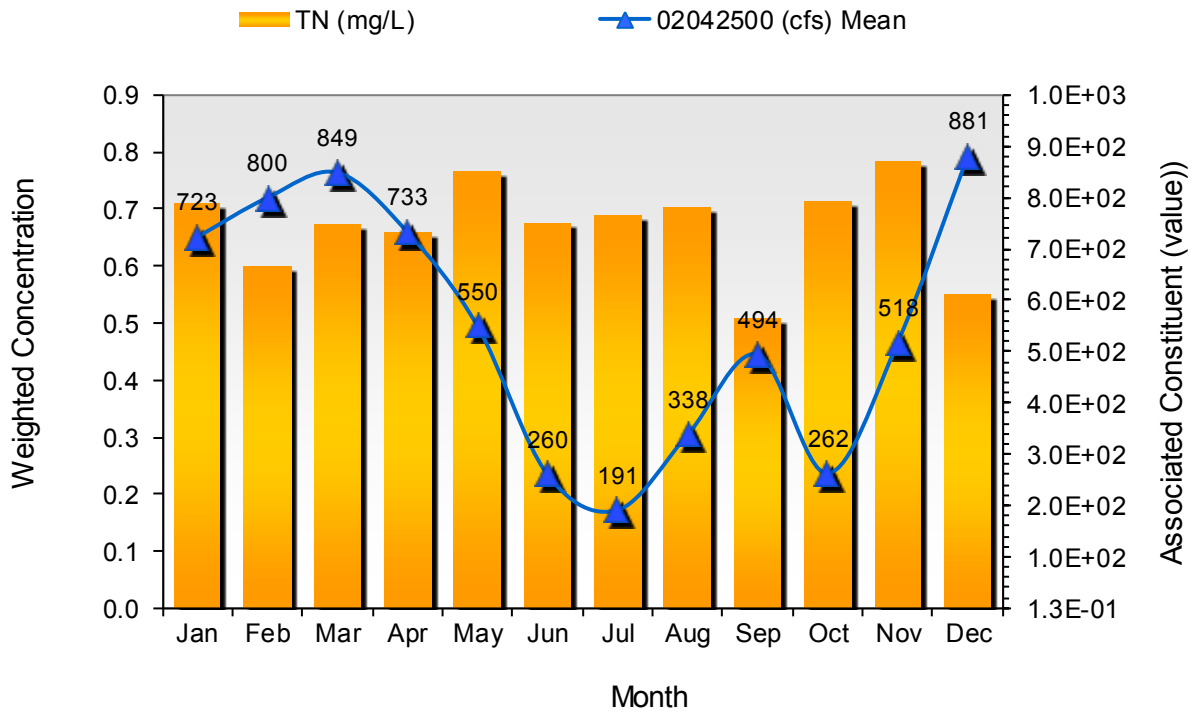
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	32	9.6857	0.13128	24.343	0.69169	0	1.4375
10-20	31	52.43	26.215	80.518	0.76389	0	1.44
20-30	31	112.71	82.39	144.18	0.84835	0	2.1
30-40	31	183.63	144.18	220.96	0.81244	0	2
40-50	31	255.2	220.96	282.75	0.7733	0	1.3775
50-60	32	336.64	284.62	393.23	0.73431	0	1.395
60-70	31	455.56	395.1	528.05	0.73108	0	1.2638
70-80	31	633.03	531.79	754.62	0.62842	0	1.04
80-90	31	970.87	760.24	1226.5	0.631	0	1.3025
90-100	31	2198.4	1260.2	4100.8	0.66329	0	1.0475



Seasonal Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: TN (mg/L)
Data from: 4/18/1988 to 7/19/2012 (313 Observations)

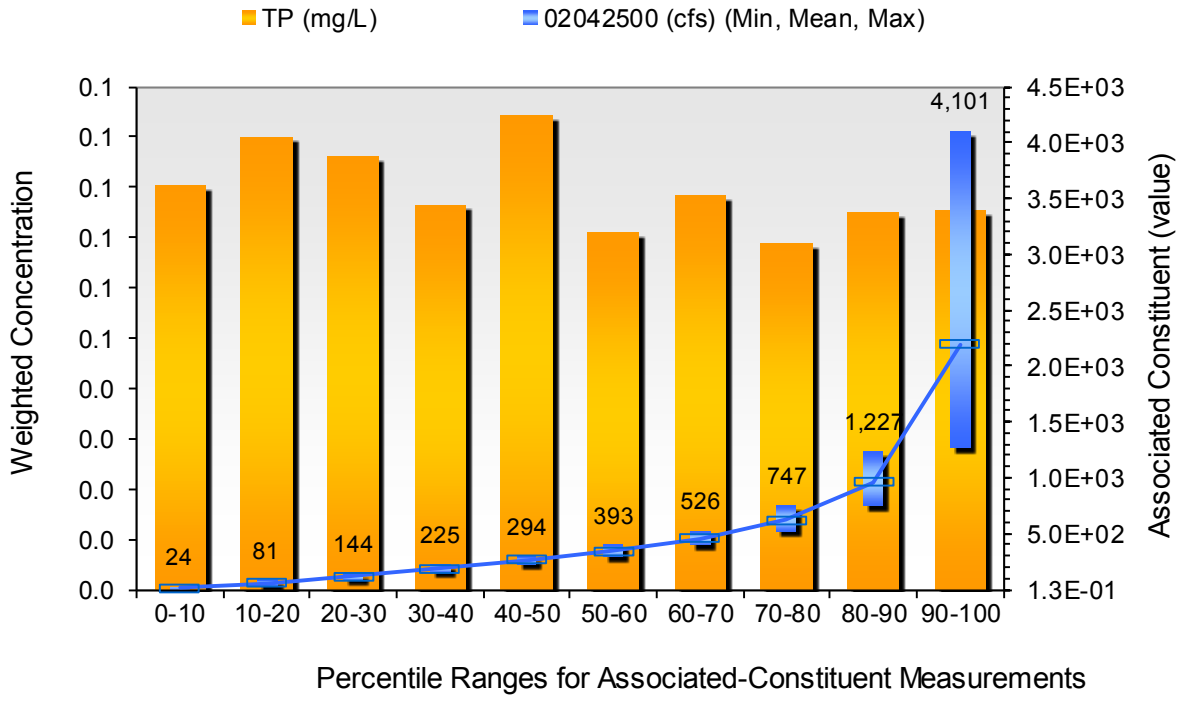
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	21	723.15	207.85	2303.2	0.71171	0	1.3825
February	22	799.65	119.84	3333.1	0.59934	0	1.7625
March	27	848.66	132.95	2902.4	0.67114	0	1.3025
April	30	732.78	102.99	2359.4	0.65816	0	2
May	30	549.77	39.323	4100.8	0.76415	0	1.065
June	29	260.22	5.805	969.96	0.67571	0	1.185
July	30	191.18	0.13128	797.69	0.68825	0	1.44
August	28	337.8	0.73049	2059.8	0.70427	0	1.6875
September	27	494.45	0.28103	4550.2	0.50839	0	1.2875
October	27	262.34	7.8647	1026.1	0.71374	0	1.4375
November	22	517.83	24.343	3089.6	0.78129	0	1.2638
December	20	880.73	101.12	3408	0.54902	0	2.1



Constituent-Associated Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: TP (mg/L)
Data from: 4/18/1988 to 2/7/2012 (315 Observations)

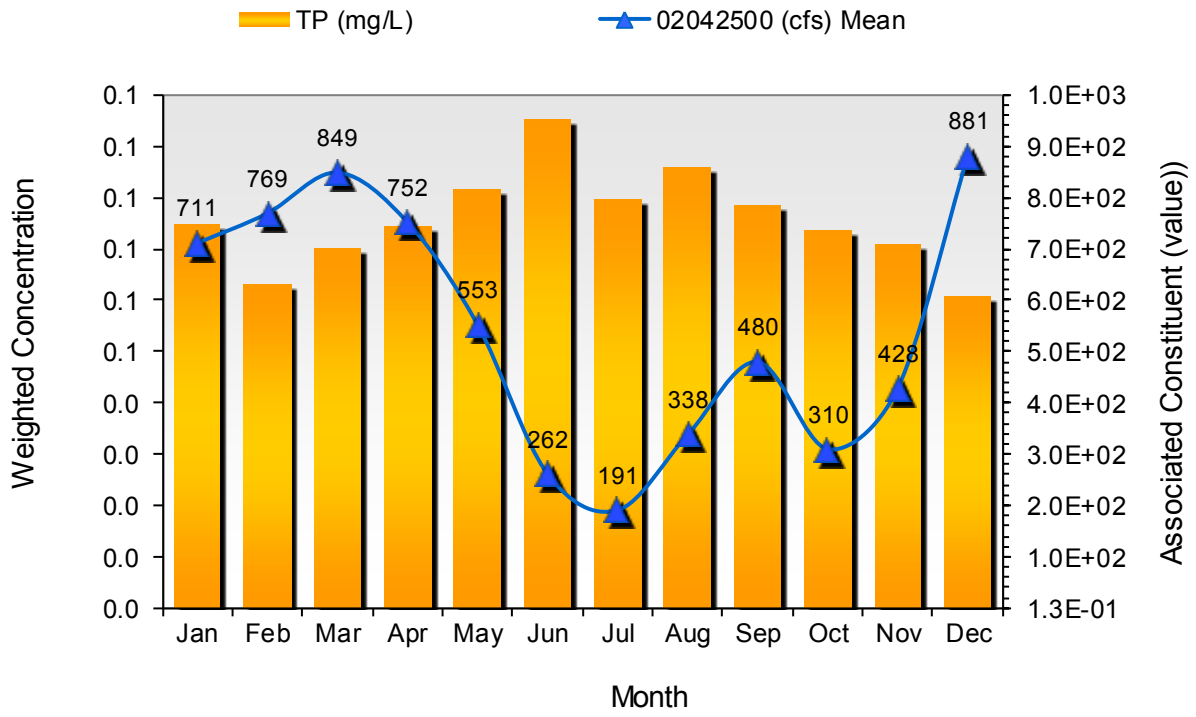
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	32	9.6857	0.13128	24.343	0.080423	0	0.2049
10-20	31	52.43	26.215	80.518	0.089839	0	0.1902
20-30	32	113.7	82.39	144.18	0.085969	0	0.2
30-40	31	188.64	147.93	224.7	0.07638	0	0.1437
40-50	31	260.82	224.7	293.98	0.094082	0	0.195
50-60	32	340.27	295.86	393.23	0.070926	0	0.1825
60-70	31	453.93	395.1	526.18	0.078254	0	0.14615
70-80	32	623.96	526.18	747.13	0.06876	0	0.1414
80-90	31	959.33	754.62	1226.5	0.074963	0	0.2016
90-100	31	2191.4	1260.2	4100.8	0.075215	0	0.17975



Seasonal Trend Assessment

Location: RET5.1A
Comparison Parameter: 02042500 (cfs)
Pollutant: TP (mg/L)
Data from: 4/18/1988 to 2/7/2012 (315 Observations)

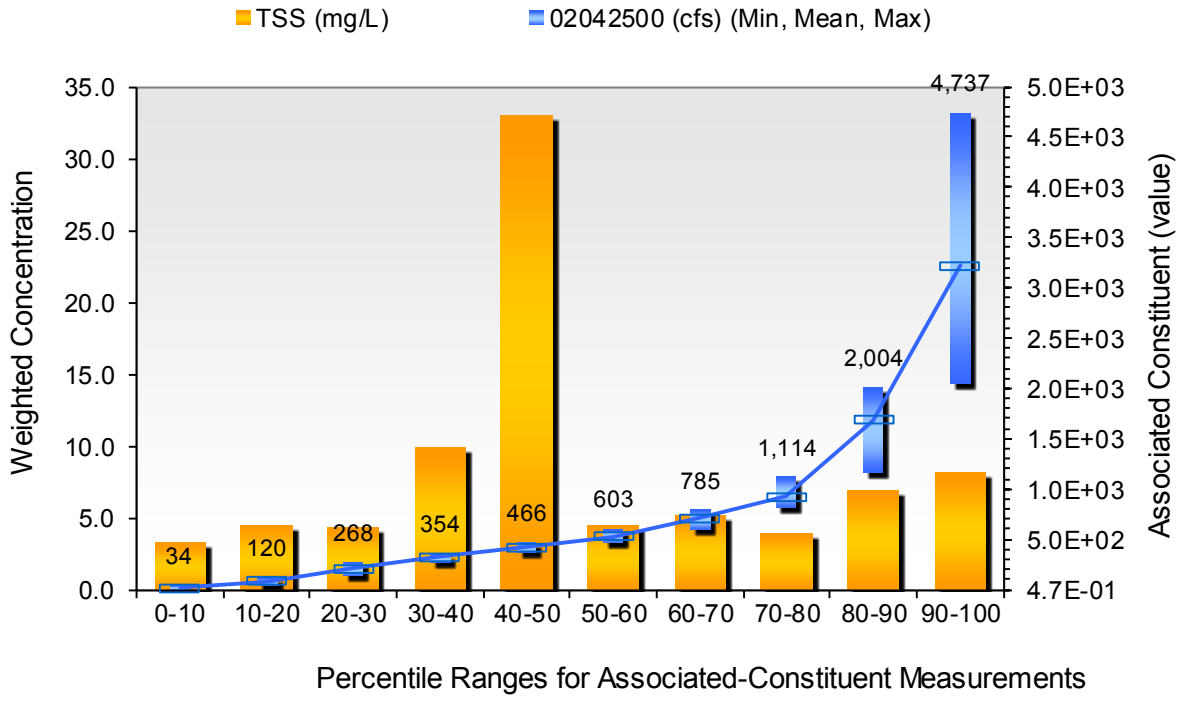
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	22	711.3	207.85	2303.2	0.074654	0	0.1261
February	24	769.21	119.84	3333.1	0.063099	0	0.2016
March	27	848.66	132.95	2902.4	0.069834	0	0.14615
April	29	752.1	102.99	2359.4	0.074249	0	0.185
May	29	552.84	39.323	4100.8	0.081452	0	0.141
June	29	261.71	5.805	969.96	0.095038	0	0.1965
July	29	191	0.13128	797.69	0.079829	0	0.1902
August	28	337.8	0.73049	2059.8	0.085972	0	0.2049
September	29	479.85	0.28103	4550.2	0.078666	0	0.1825
October	28	309.88	7.8647	1593.5	0.073351	0	0.15745
November	21	428.45	24.343	3089.6	0.070888	0	0.10785
December	20	880.73	101.12	3408	0.06088	0	0.135



Constituent-Associated Trend Assessment

Location: 02042500
Comparison Parameter: 02042500 (cfs)
Pollutant: TSS (mg/L)
Data from: 4/12/1988 to 10/3/2012 (135 Observations)

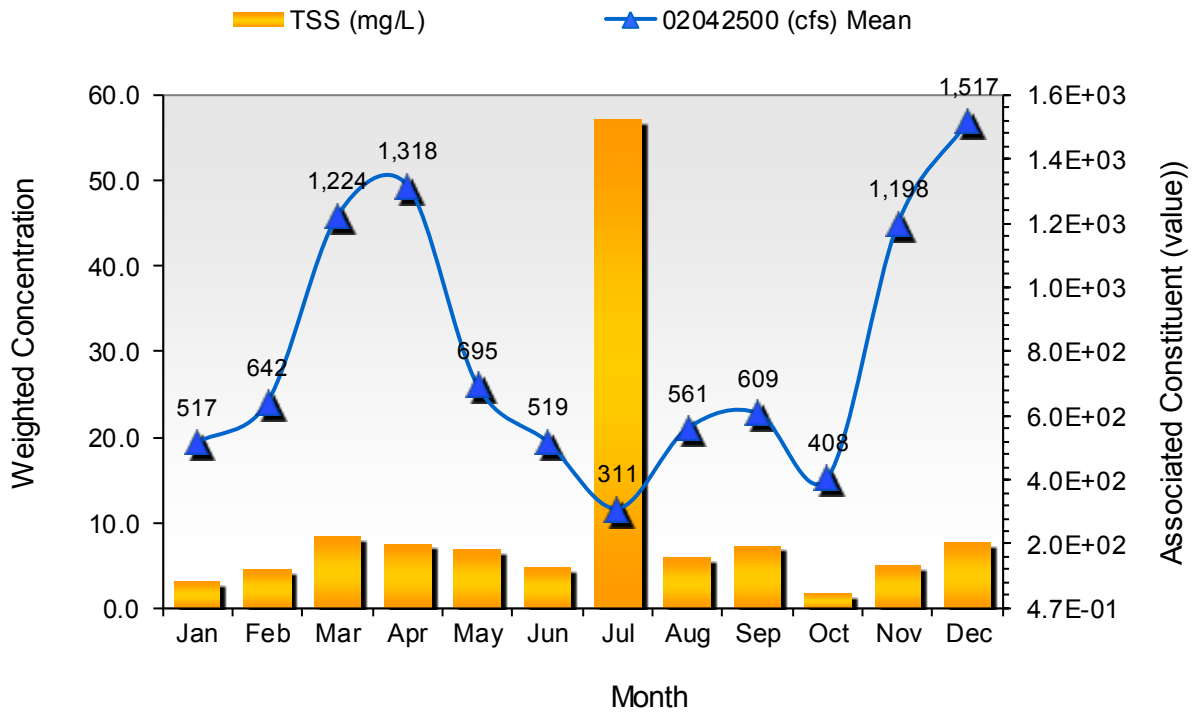
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	14	17.21	0.46822	33.705	3.2632	1	4
10-20	13	82.39	39.323	119.84	4.3934	2	9
20-30	14	207.58	127.33	267.77	4.3112	1	8
30-40	13	323.37	279	353.9	9.8494	2	90
40-50	13	419.15	370.76	466.25	32.958	1	400
50-60	14	526.17	468.13	602.95	4.4715	2	9
60-70	13	705.36	604.82	784.58	5.0783	0.7	20
70-80	14	922.21	812.67	1114.1	3.8855	0.6	8
80-90	13	1686.3	1157.2	2003.6	6.892	3	13
90-100	13	3220.7	2041	4737.4	8.1699	3	16



Seasonal Trend Assessment

Location: 02042500
Comparison Parameter: 02042500 (cfs)
Pollutant: TSS (mg/L)
Data from: 4/12/1988 to 10/3/2012 (135 Observations)

Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	9	517.44	234.06	893.19	3.1411	1	6
February	8	641.8	174.14	1157.2	4.581	2	8
March	20	1223.5	280.88	4231.9	8.525	3	90
April	16	1318.1	247.17	4737.4	7.5073	2	20
May	12	694.86	157.29	3202	6.7456	1	19
June	10	518.87	20.598	2490.4	4.6059	2	6
July	9	311.03	1.7228	1026.1	56.984	1	400
August	11	560.85	6.1793	2902.4	5.8346	2	8
September	15	608.62	0.46822	3838.6	7.2039	2	15
October	8	407.65	14.231	866.97	1.645	0.6	9
November	9	1198	76.773	6048.2	4.8546	2	7
December	8	1517.2	119.84	3164.5	7.7378	0.7	12

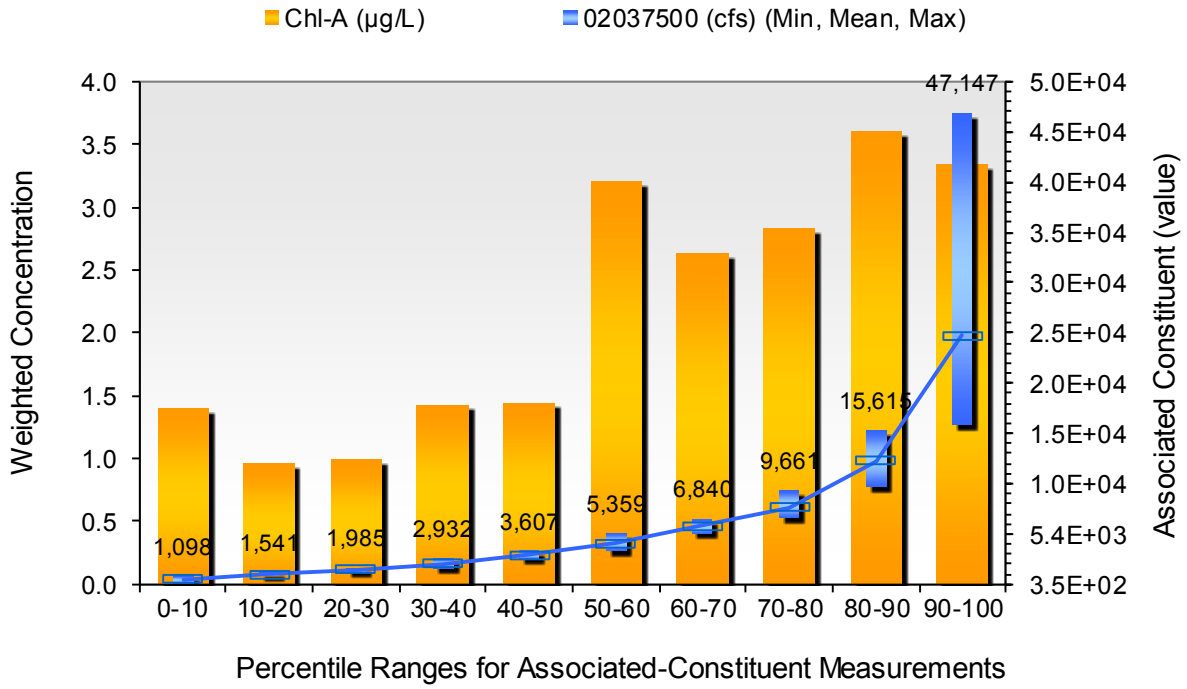


Middle James Willis-TF2

Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/22/1999 to 9/20/2012 (153 Observations)

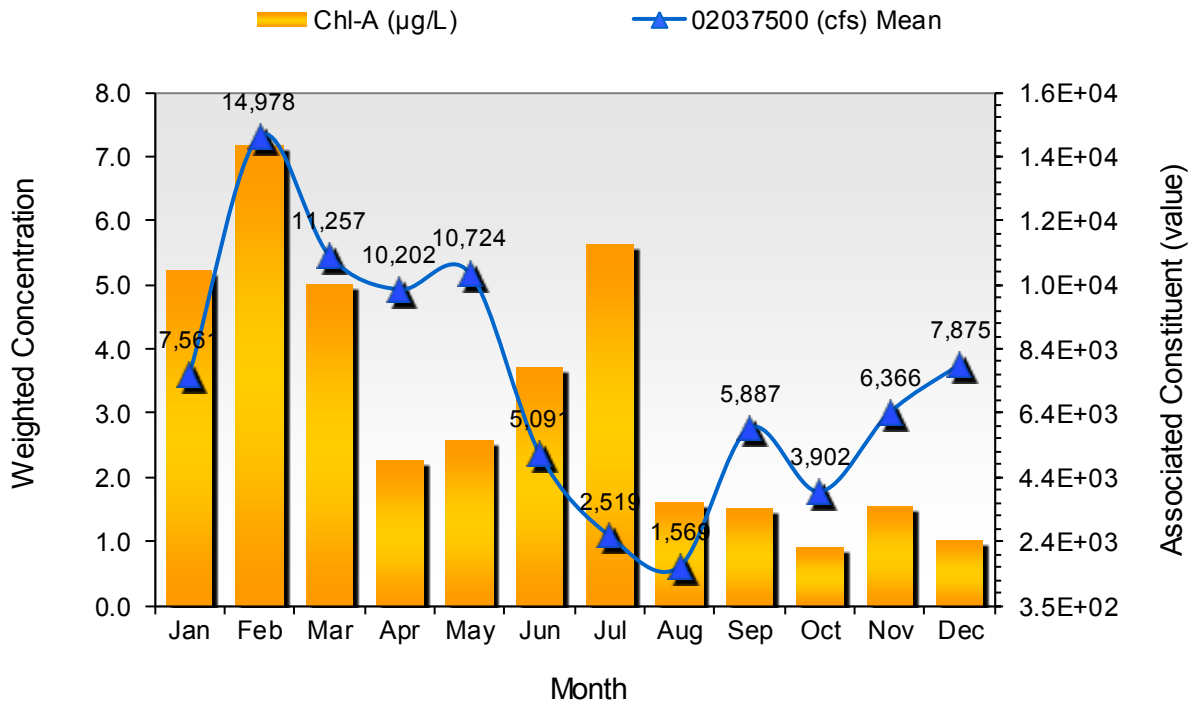
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	16	815.557	354.606	1098.07	1.38741	0	6.18
10-20	15	1315.67	1138.37	1541.33	0.969837	0.11	1.62
20-30	15	1778.4	1571.55	1984.59	0.993185	0.5	2.9
30-40	15	2444.63	1984.59	2931.55	1.41983	0.37	7.12
40-50	15	3263.99	2951.7	3606.51	1.43377	0.5	5.77
50-60	16	4470.99	3737.47	5359.39	3.20524	0.5	16.3
60-70	15	6171.36	5389.61	6840.28	2.63597	0.5	26.5
70-80	15	7998.79	6900.72	9661.01	2.82464	0.5	17.76
80-90	15	12653	10074	15614.8	3.5963	0.66	16.68
90-100	15	25070.9	16219.2	47146.5	3.34311	0.64	16.39



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/22/1999 to 9/20/2012 (153 Observations)

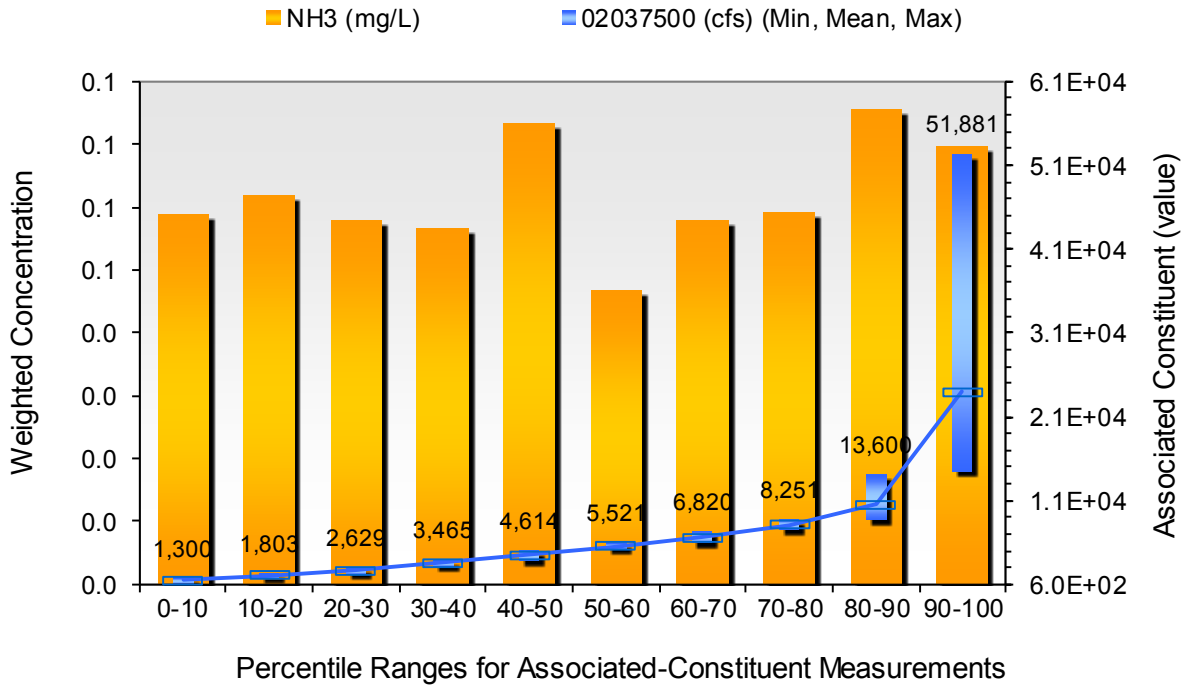
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	12	7561.41	1762.96	22162.9	5.21232	0.5	16.39
February	12	14978.4	1541.33	106785	7.15541	0.5	9.83
March	13	11256.6	3183.4	35460.6	5.01472	0.85	17.76
April	13	10201.9	3314.36	24782.1	2.25238	0.5	11.43
May	13	10724.2	1803.25	34251.8	2.57304	0.5	16.3
June	12	5090.75	664.887	20752.5	3.70596	0.11	26.5
July	14	2518.58	784.768	10074	5.6074	0.5	16.68
August	14	1569.32	354.606	4694.5	1.60464	0	6.18
September	14	5886.98	623.583	47146.5	1.52555	0.41	2.06
October	13	3901.83	679.998	15614.8	0.898016	0.5	1.25
November	13	6366.02	1098.07	19946.6	1.53823	0.37	2.76
December	10	7874.88	1339.85	26494.7	1.00814	0.5	1.98



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NH3 (mg/L)
Data from: 1/29/1985 to 6/21/2006 (111 Observations)

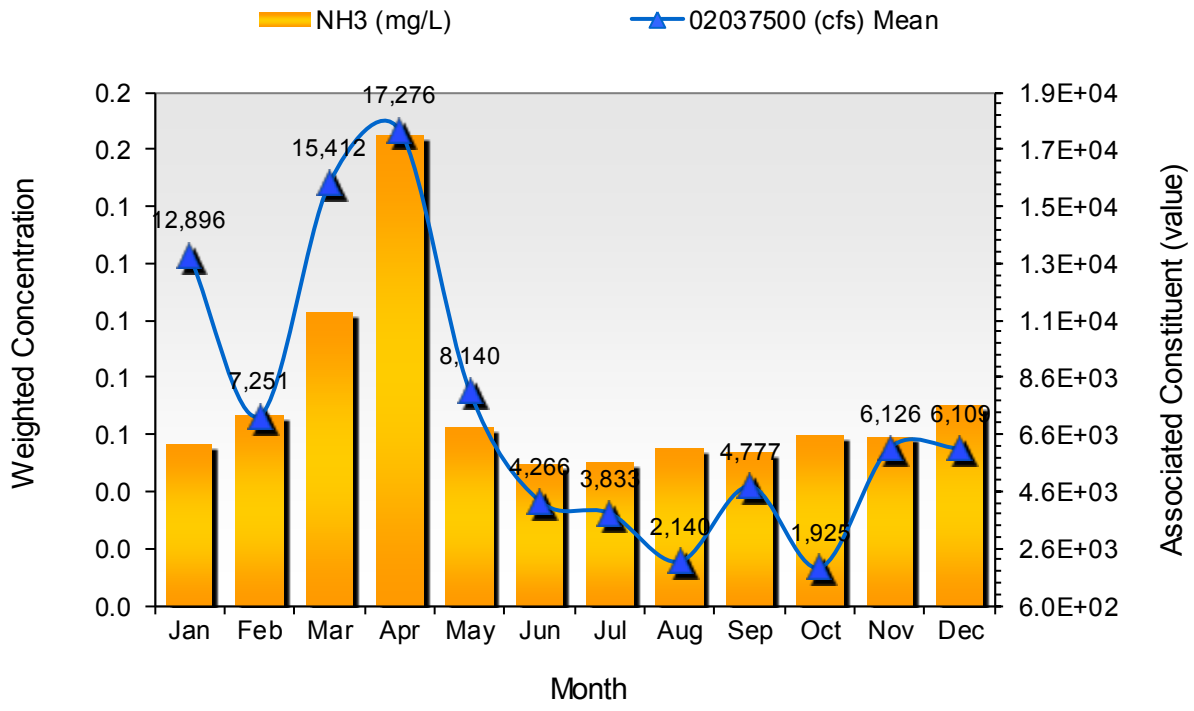
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	11	1130.4	601.42	1299.55	0.0587734	0.01	0.1
10-20	11	1653.97	1319.7	1803.25	0.0617276	0.04	0.1
20-30	11	2244.68	1833.48	2629.33	0.057805	0.04	0.1
30-40	11	3197.14	2810.66	3465.47	0.0566886	0.04	0.1
40-50	11	4107.46	3515.84	4613.91	0.0733289	0.04	0.1
50-60	11	5170.73	4765.02	5520.58	0.0466419	0.04	0.1
60-70	11	6158.9	5611.24	6820.13	0.0579613	0.04	0.1
70-80	11	7664.52	7061.91	8250.64	0.0591457	0.04	0.1
80-90	11	10135.4	8250.64	13600	0.0753917	0.04	0.1
90-100	11	23518.3	14103.7	51881.3	0.0695405	0.04	0.2



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NH3 (mg/L)
Data from: 1/29/1985 to 6/21/2006 (111 Observations)

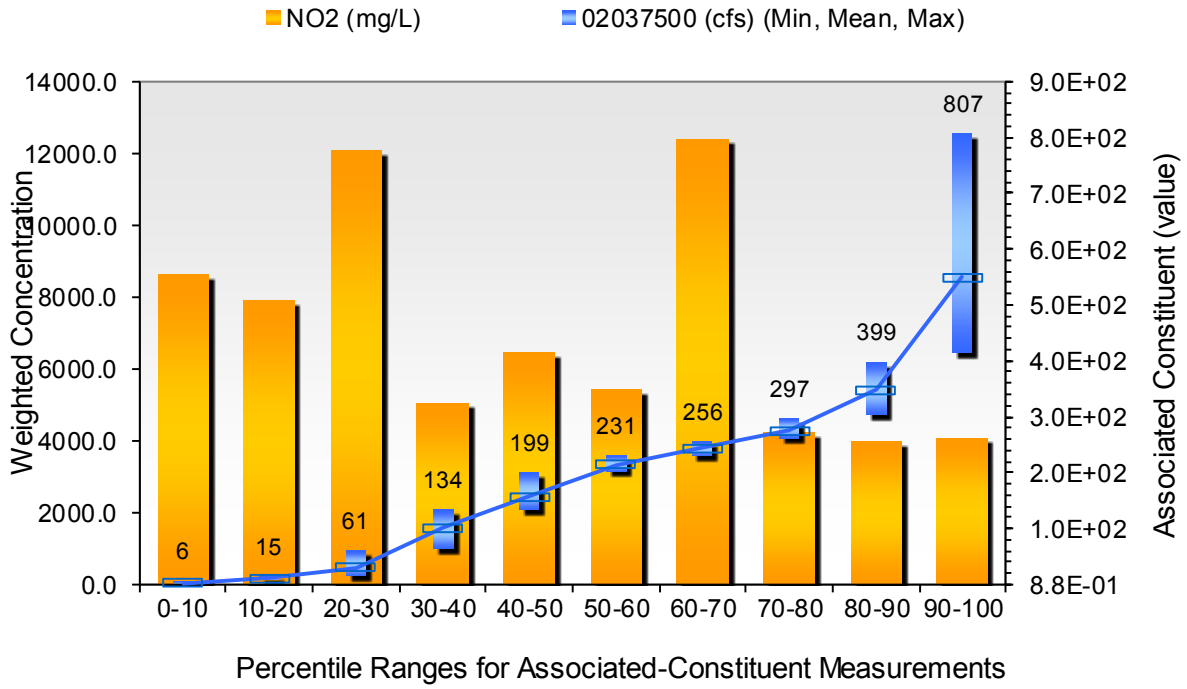
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	9	12895.9	3082.66	51881.3	0.0565281	0.04	0.1
February	8	7250.79	2810.66	10174.8	0.066801	0.04	0.1
March	7	15411.8	5691.84	29114	0.102965	0.04	0.2
April	8	17275.7	3969.17	78073.8	0.164911	0.04	0.25
May	11	8139.83	3364.73	15917	0.0628015	0.04	0.1
June	11	4265.9	1319.7	8250.64	0.0493195	0.04	0.1
July	10	3833.17	1712.59	5923.54	0.0498581	0.04	0.1
August	9	2139.84	601.42	3163.25	0.0551708	0.04	0.1
September	12	4777.28	896.59	31531.8	0.0536629	0.01	0.1
October	9	1925.26	1188.74	5147.84	0.0598488	0.04	0.1
November	9	6126.14	1672.29	16118.5	0.0591851	0.04	0.1
December	8	6108.65	3828.14	9983.38	0.0704947	0.04	0.1



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NO2 (mg/L)
Data from: 1/29/1985 to 6/21/2006 (110 Observations)

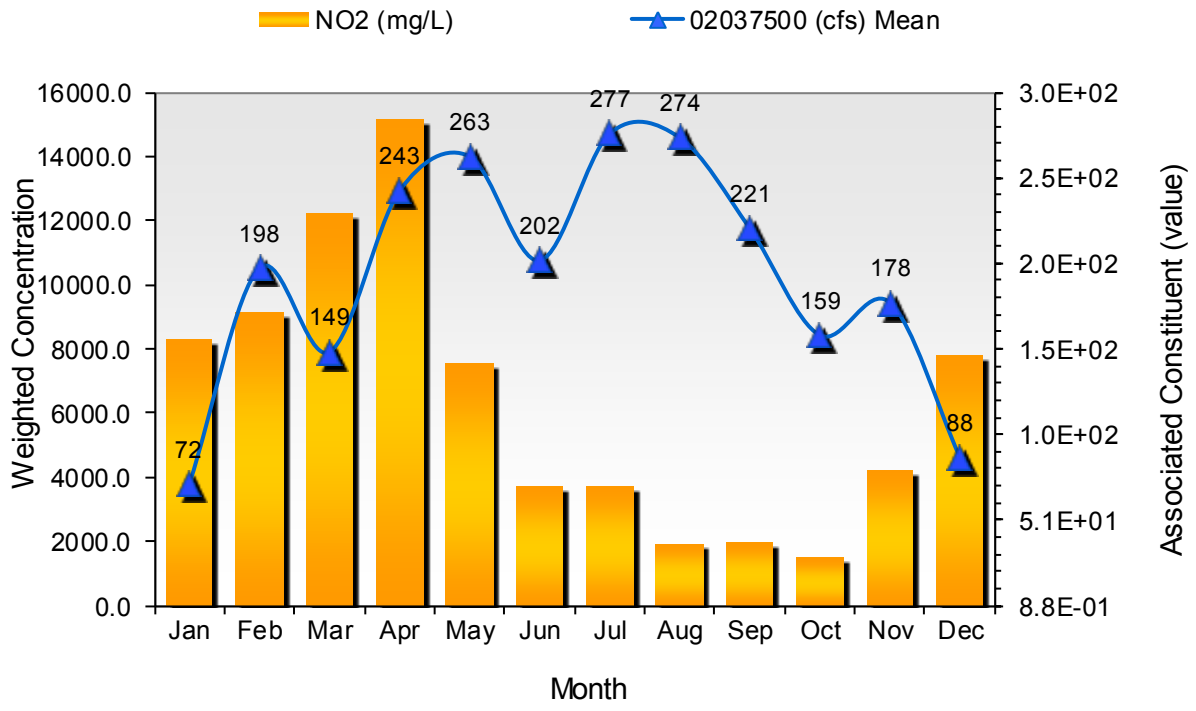
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	11	3.36569	0.876505	6.34671	8614.68	1690	51500
10-20	11	12.1255	8.05926	15.1112	7888.73	1230	19500
20-30	11	30.2222	16.1185	61.4517	12049.9	5280	31300
30-40	11	101.839	63.4665	133.985	5055.38	1220	13500
40-50	11	157.705	133.985	199.466	6430.89	1260	22500
50-60	11	214.028	203.496	230.696	5420.34	896	15000
60-70	11	244.433	231.703	255.881	12390.8	1290	77500
70-80	11	275.754	261.925	297.184	4214.95	1180	8190
80-90	11	349.478	303.229	398.932	3948.36	1230	9910
90-100	10	549.338	417.065	806.931	4047.2	597	10100



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NO2 (mg/L)
Data from: 1/29/1985 to 6/21/2006 (110 Observations)

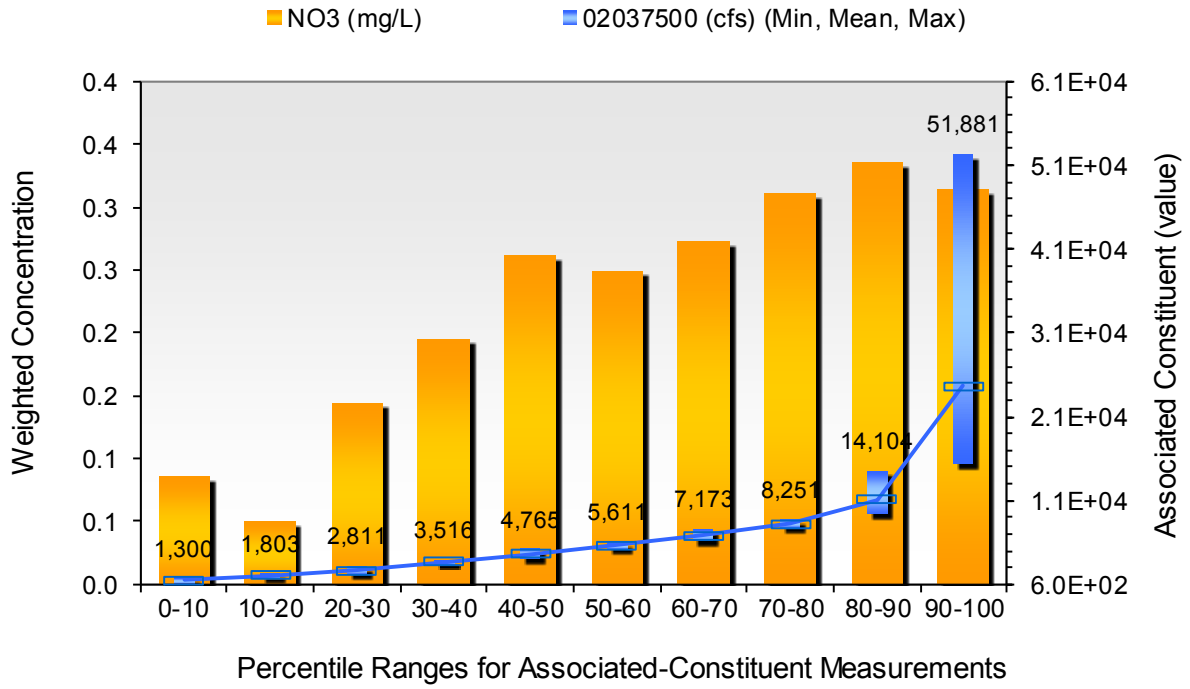
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	9	71.9265	0.88658	210.548	8265.25	3060	51500
February	9	198.011	13.0963	469.45	9139.75	2790	22500
March	7	149.053	5.74223	453.332	12206.1	5650	28900
April	8	243.2	6.34671	806.931	15115.6	3940	77500
May	11	263.354	3.12297	914.723	7529.95	3340	15800
June	10	202.478	9.97336	727.346	3719.36	1310	8190
July	9	276.589	144.059	469.45	3728.64	1700	5880
August	9	274.339	5.94375	503.702	1916.83	597	3140
September	12	221.369	1.91413	426.132	1956.86	890	31300
October	9	158.834	5.03707	392.888	1461.22	1180	5110
November	9	177.952	1.81338	417.065	4171.86	1660	16000
December	8	87.5775	0.876505	309.273	7811.93	3800	9910



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NO3 (mg/L)
Data from: 1/29/1985 to 6/21/2006 (111 Observations)

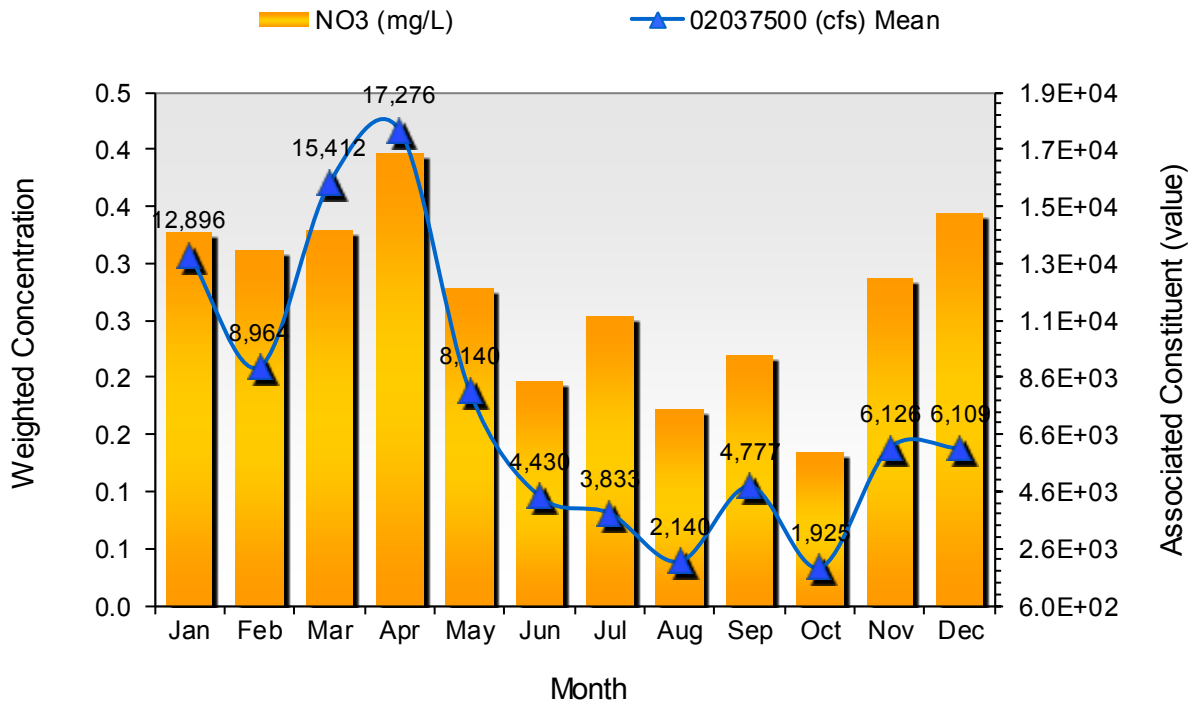
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	11	1130.4	601.42	1299.55	0.0856623	0.04	0.48
10-20	11	1653.97	1319.7	1803.25	0.0492027	0.04	0.08
20-30	11	2261.17	1833.48	2810.66	0.143937	0.04	0.46
30-40	11	3261.24	3082.66	3515.84	0.195782	0.04	0.41
40-50	11	4221.02	3677.03	4765.02	0.262068	0.05	0.48
50-60	11	5247.66	4825.47	5611.24	0.249127	0.11	0.45
60-70	12	6364.28	5691.84	7172.72	0.272229	0.01	0.44
70-80	10	7832.57	7303.68	8250.64	0.310606	0.18	0.47
80-90	11	10667.5	8935.68	14103.7	0.336217	0.06	0.45
90-100	11	24296.8	15111.1	51881.3	0.313931	0.21	0.46



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NO3 (mg/L)
Data from: 1/29/1985 to 6/21/2006 (111 Observations)

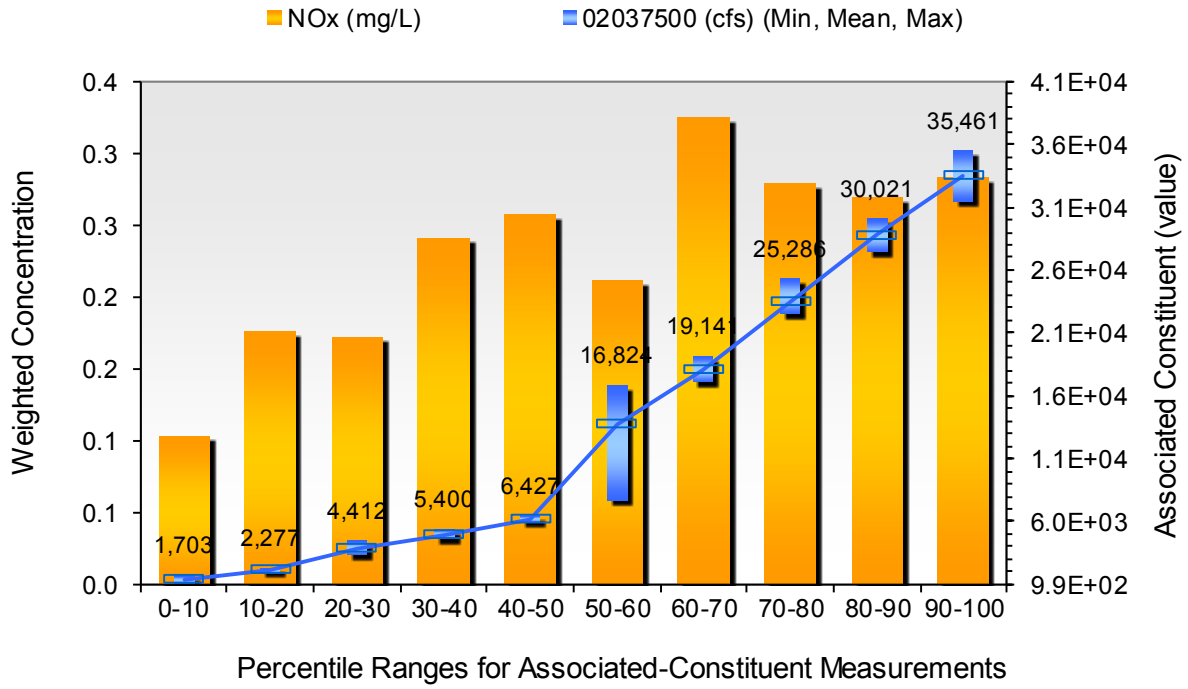
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	9	12895.9	3082.66	51881.3	0.327308	0.27	0.46
February	9	8963.66	2810.66	22666.6	0.310937	0.06	0.47
March	7	15411.8	5691.84	29114	0.32855	0.05	0.46
April	8	17275.7	3969.17	78073.8	0.396722	0.05	0.51
May	11	8139.83	3364.73	15917	0.277681	0.01	0.44
June	10	4429.56	1319.7	8250.64	0.195995	0.04	0.41
July	10	3833.17	1712.59	5923.54	0.253456	0.04	0.45
August	9	2139.84	601.42	3163.25	0.172624	0.04	0.46
September	12	4777.28	896.59	31531.8	0.218576	0.04	0.48
October	9	1925.26	1188.74	5147.84	0.133721	0.04	0.27
November	9	6126.14	1672.29	16118.5	0.287415	0.04	0.48
December	8	6108.65	3828.14	9983.38	0.343346	0.26	0.42



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NOx (mg/L)
Data from: 5/17/2006 to 6/20/2007 (25 Observations)

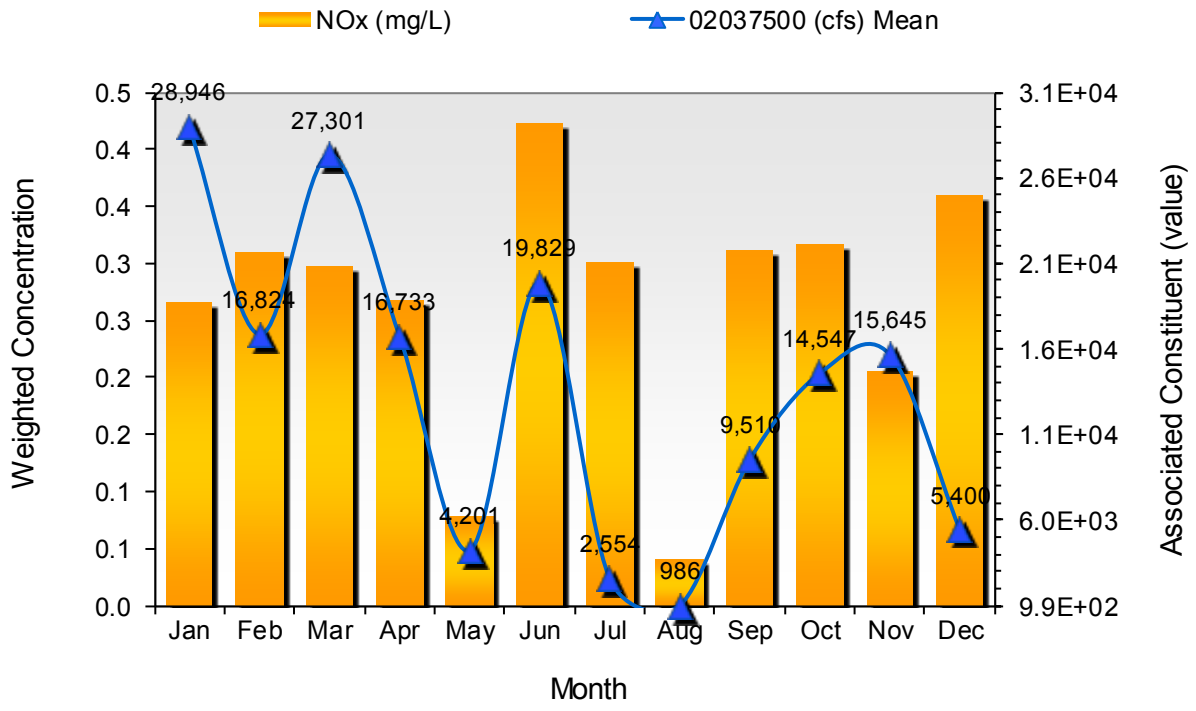
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	1363.02	986.249	1702.51	0.103119	0.04	0.2
10-20	2	2135.7	1994.66	2276.73	0.176038	0.12	0.24
20-30	3	3828.14	3405.03	4412.43	0.171825	0.04	0.42
30-40	2	4961.47	4523.25	5399.69	0.241482	0.1	0.36
40-50	2	6195.54	5963.83	6427.24	0.256683	0.21	0.3
50-60	3	13764.5	7646.2	16823.7	0.211852	0.11	0.31
60-70	2	18082.9	17025.1	19140.7	0.325292	0.32	0.33
70-80	3	23472.5	22465.1	25285.9	0.278913	0.25	0.32
80-90	2	28761.4	27502.1	30020.7	0.269562	0.26	0.28
90-100	2	33496.2	31531.8	35460.6	0.282353	0.28	0.285



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NOx (mg/L)
Data from: 5/17/2006 to 6/20/2007 (25 Observations)

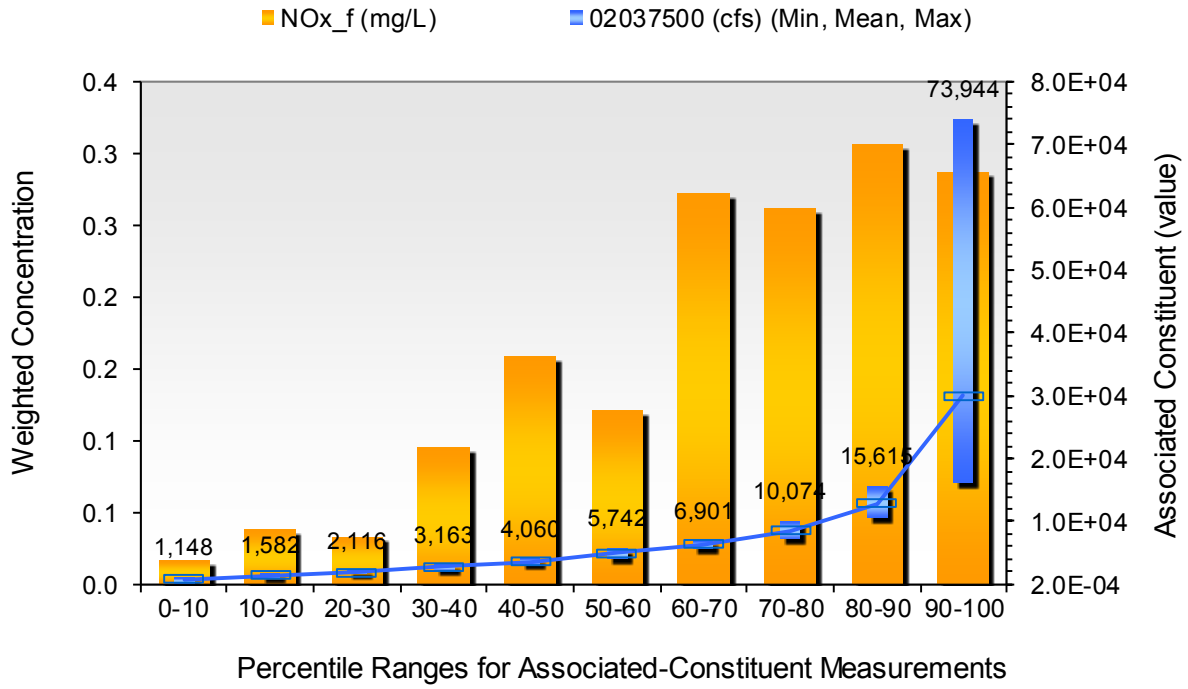
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	3	28946.1	25285.9	31531.8	0.266166	0.25	0.285
February	1	16823.7	16823.7	16823.7	0.31	0.31	0.31
March	2	27300.7	19140.7	35460.6	0.297528	0.28	0.33
April	2	16733	5963.83	27502.1	0.267526	0.21	0.28
May	3	4200.88	3666.95	4523.25	0.0789928	0.04	0.1
June	3	19829.1	1400.29	55810.2	0.422103	0.12	0.44
July	2	2553.77	1702.51	3405.03	0.3	0.06	0.42
August	1	986.249	986.249	986.249	0.04	0.04	0.04
September	2	9509.9	1994.66	17025.1	0.31161	0.24	0.32
October	2	14546.9	6427.24	22666.6	0.315582	0.3	0.32
November	3	15645	7646.2	22465.1	0.204503	0.11	0.27
December	1	5399.69	5399.69	5399.69	0.36	0.36	0.36



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/20/1996 to 10/23/2012 (196 Observations)

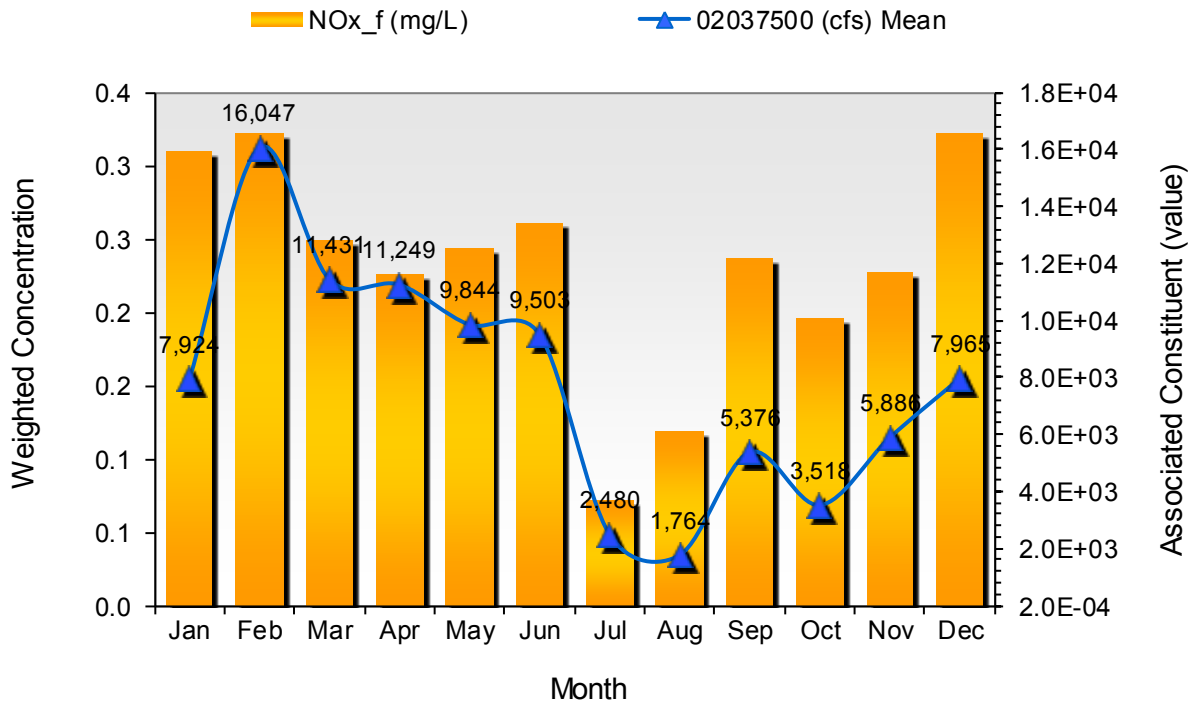
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	20	824.208	0.000196	1148.44	0.0169724	0.004	0.046
10-20	19	1374.31	1158.52	1581.63	0.0386485	0.005	0.215
20-30	20	1879.31	1581.63	2115.55	0.0324099	0	0.203
30-40	19	2748.09	2236.44	3163.25	0.0948478	0	0.427
40-50	20	3559.16	3163.25	4059.84	0.158349	0.014	0.387
50-60	20	4935.27	4100.14	5742.21	0.120713	0.004	0.354
60-70	19	6380.58	5782.5	6900.72	0.272123	0	0.531
70-80	19	8456.9	7082.05	10074	0.261475	0.026	0.45
80-90	20	12784	10477	15614.8	0.30637	0.21	0.439
90-100	19	30052.5	16219.2	73943.5	0.286994	0.19	0.445



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/20/1996 to 10/23/2012 (196 Observations)

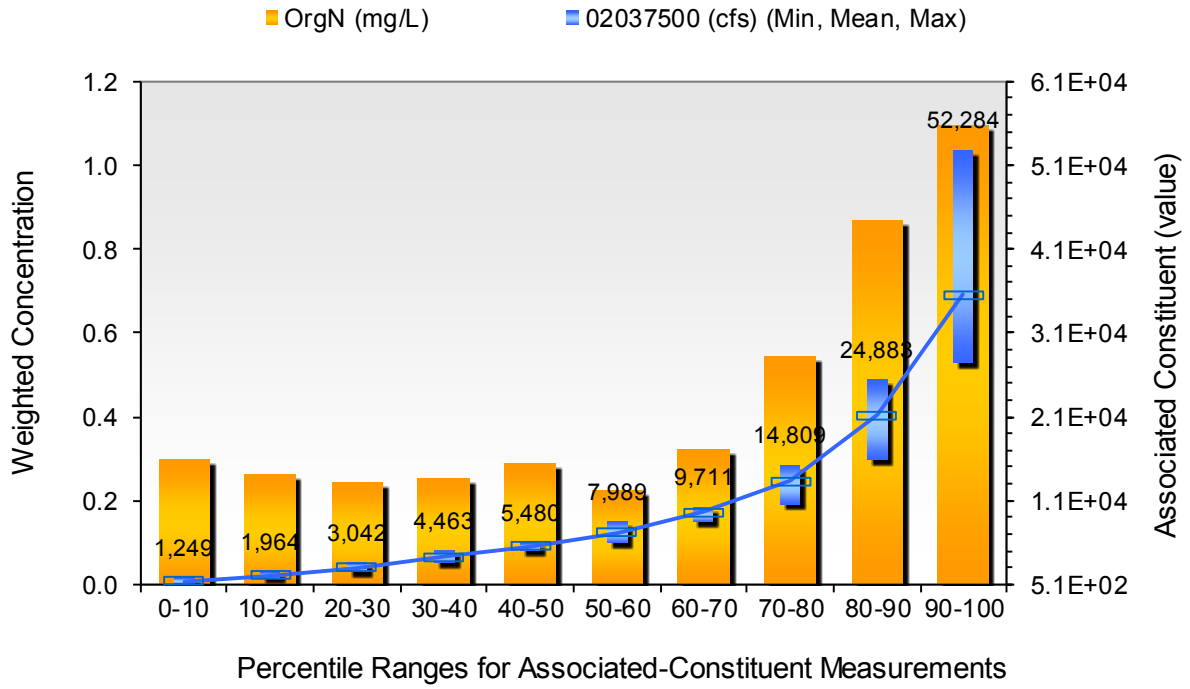
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	15	7923.57	1762.96	22162.9	0.30894	0.013	0.444
February	17	16047.4	1541.33	106785	0.32198	0.004	0.45
March	17	11431.1	3183.4	35460.6	0.24841	0.013	0.442
April	17	11248.6	3314.36	42713.9	0.225636	0	0.439
May	17	9843.53	1803.25	34251.8	0.242631	0.004	0.445
June	16	9502.97	664.887	73943.5	0.260927	0	0.502
July	17	2480.05	784.768	10074	0.0720158	0	0.354
August	17	1764.08	354.606	4694.5	0.119491	0.008	0.26
September	17	5375.51	623.583	47146.5	0.236526	0.004	0.378
October	17	3517.68	0.000196	15614.8	0.195836	0.004	0.427
November	16	5886.39	1098.07	19946.6	0.227407	0.007	0.313
December	13	7964.69	1339.85	26494.7	0.321362	0.005	0.531



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: OrgN (mg/L)
Data from: 7/23/2007 to 9/5/2012 (89 Observations)

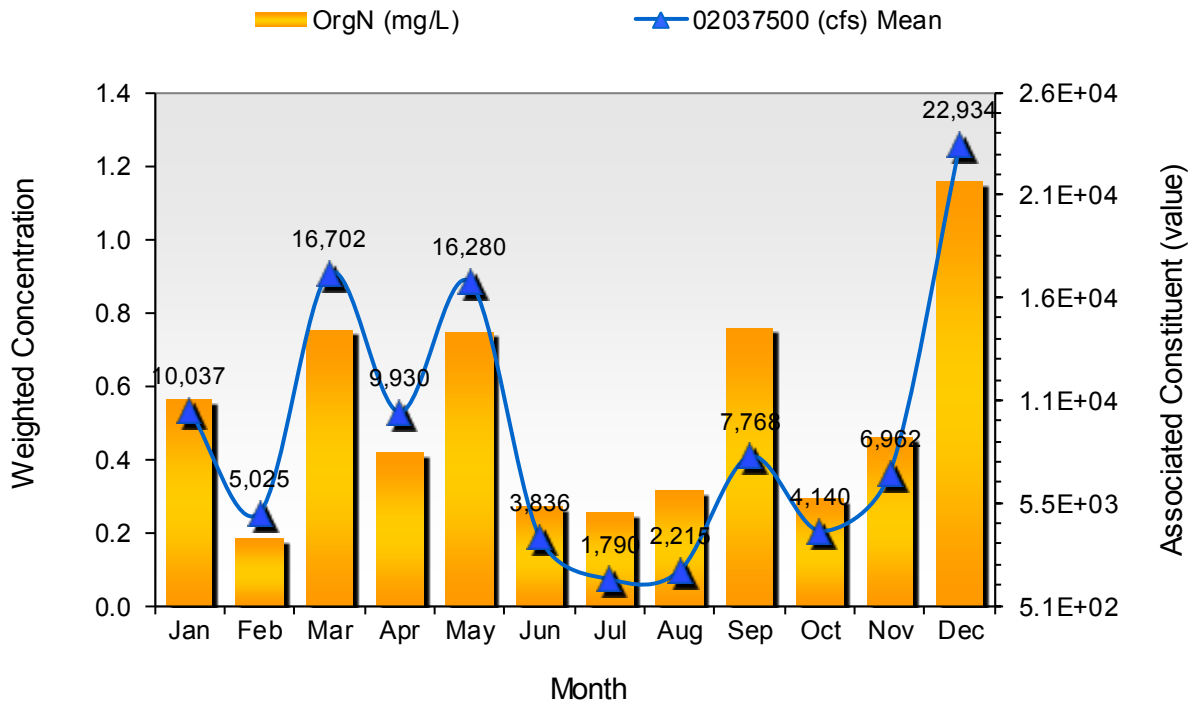
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	9	917.074	513.776	1249.18	0.295982	0.2085	0.363
10-20	9	1533.49	1319.7	1964.44	0.260274	0.1875	0.431
20-30	9	2474.86	1984.59	3042.36	0.241043	0.1725	0.315
30-40	9	3785.6	3143.1	4462.8	0.250444	0.1375	0.337
40-50	8	5094.95	4553.47	5480.28	0.28659	0.226	0.418
50-60	9	6707.07	5530.65	7988.72	0.222678	0.017	0.368
60-70	9	9061.04	8029.01	9711.38	0.320184	0.0455	0.6
70-80	9	12794	9973.3	14808.8	0.545451	0.19	1.102
80-90	9	20663	15514	24882.9	0.869662	0.369	1.427
90-100	8	35007.3	27099.2	52284.3	1.09677	0.468	2.272



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: OrgN (mg/L)
Data from: 7/23/2007 to 9/5/2012 (89 Observations)

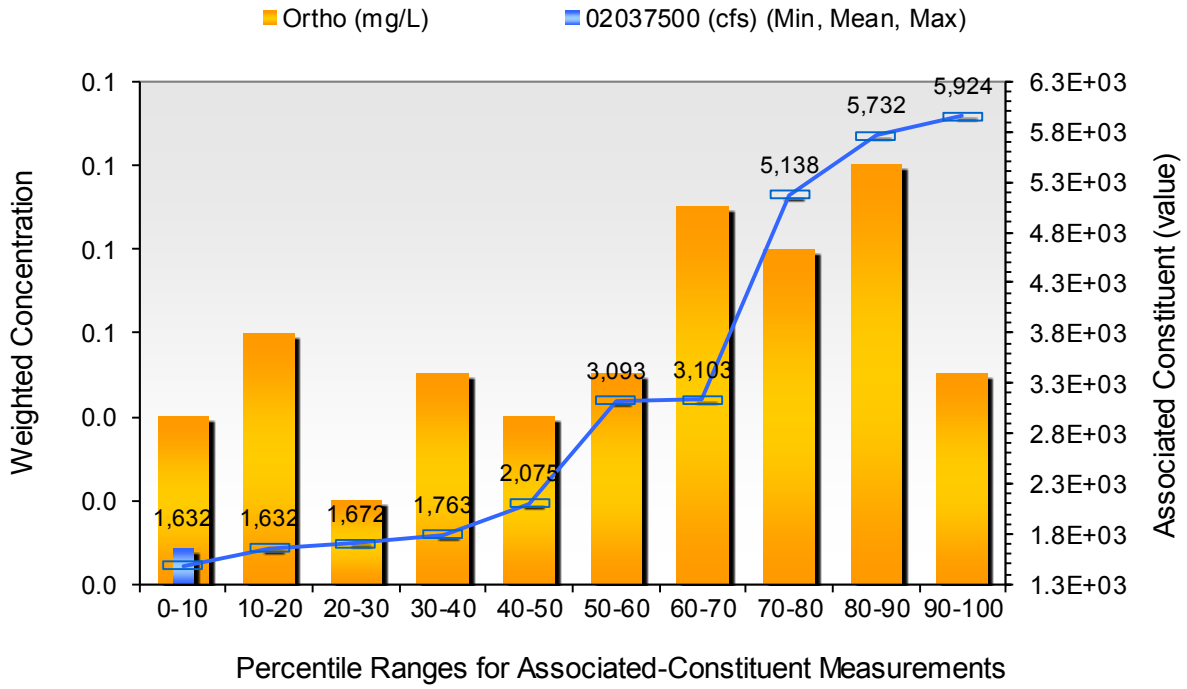
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	6	10037.1	2377.47	27099.2	0.564058	0.1375	0.865
February	5	5024.93	2800.58	8029.01	0.18149	0.11	0.281
March	11	16701.8	5359.39	44728.8	0.75156	0.0455	1.471
April	6	9929.65	5752.28	17528.8	0.416356	0.185	0.786
May	8	16279.7	4100.14	27099.2	0.74785	0.225	1.102
June	4	3835.69	1964.44	5480.28	0.271661	0.227	0.308
July	5	1789.55	888.531	2538.66	0.25495	0.208	0.315
August	6	2214.61	513.776	7676.42	0.314654	0.256	0.431
September	11	7767.64	655.82	29516.9	0.754405	0.25	1.042
October	8	4139.8	679.998	9650.93	0.290367	0.1875	0.342
November	9	6962.28	1319.7	18737.7	0.459029	0.017	0.761
December	10	22933.6	1339.85	64776.1	1.15557	0.1725	2.272



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: Ortho (mg/L)
Data from: 7/28/1994 to 6/21/2006 (12 Observations)

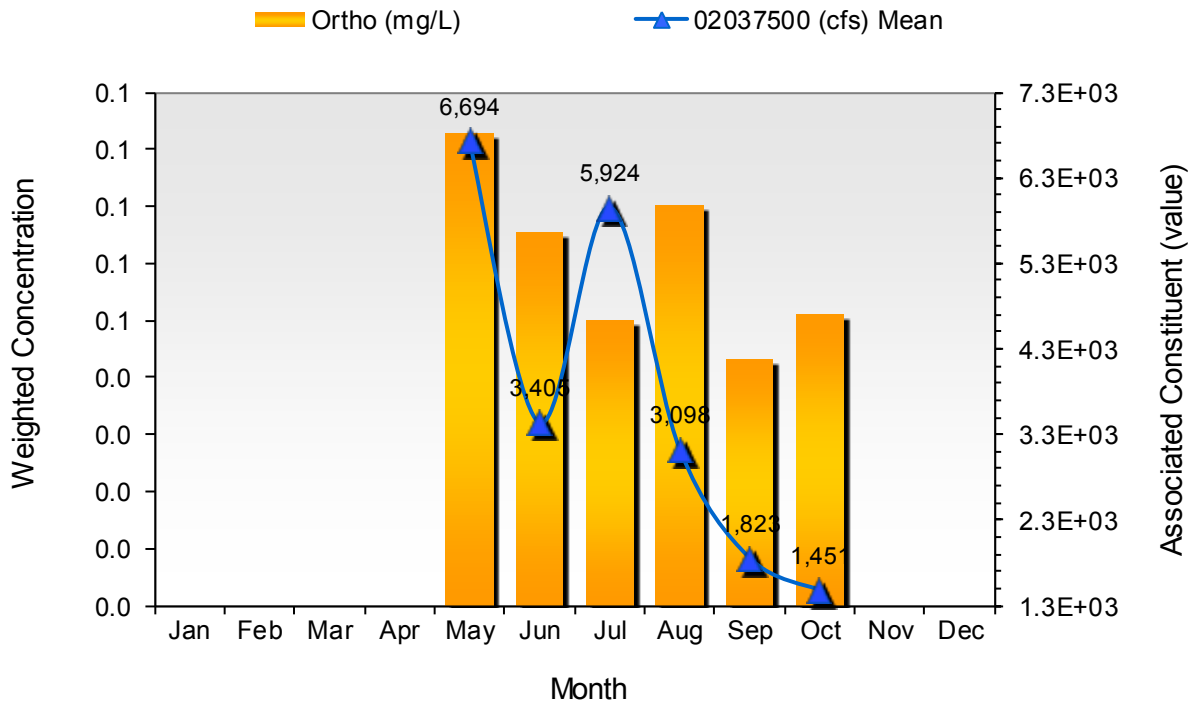
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	2	1450.66	1269.33	1632	0.04	0.04	0.04
10-20	1	1632	1632	1632	0.06	0.06	0.06
20-30	1	1672.29	1672.29	1672.29	0.02	0.02	0.02
30-40	1	1762.96	1762.96	1762.96	0.05	0.05	0.05
40-50	1	2075.25	2075.25	2075.25	0.04	0.04	0.04
50-60	1	3092.73	3092.73	3092.73	0.05	0.05	0.05
60-70	1	3102.81	3102.81	3102.81	0.09	0.09	0.09
70-80	1	5137.76	5137.76	5137.76	0.08	0.08	0.08
80-90	1	5732.13	5732.13	5732.13	0.1	0.1	0.1
90-100	1	5923.54	5923.54	5923.54	0.05	0.05	0.05



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: Ortho (mg/L)
Data from: 7/28/1994 to 6/21/2006 (12 Observations)

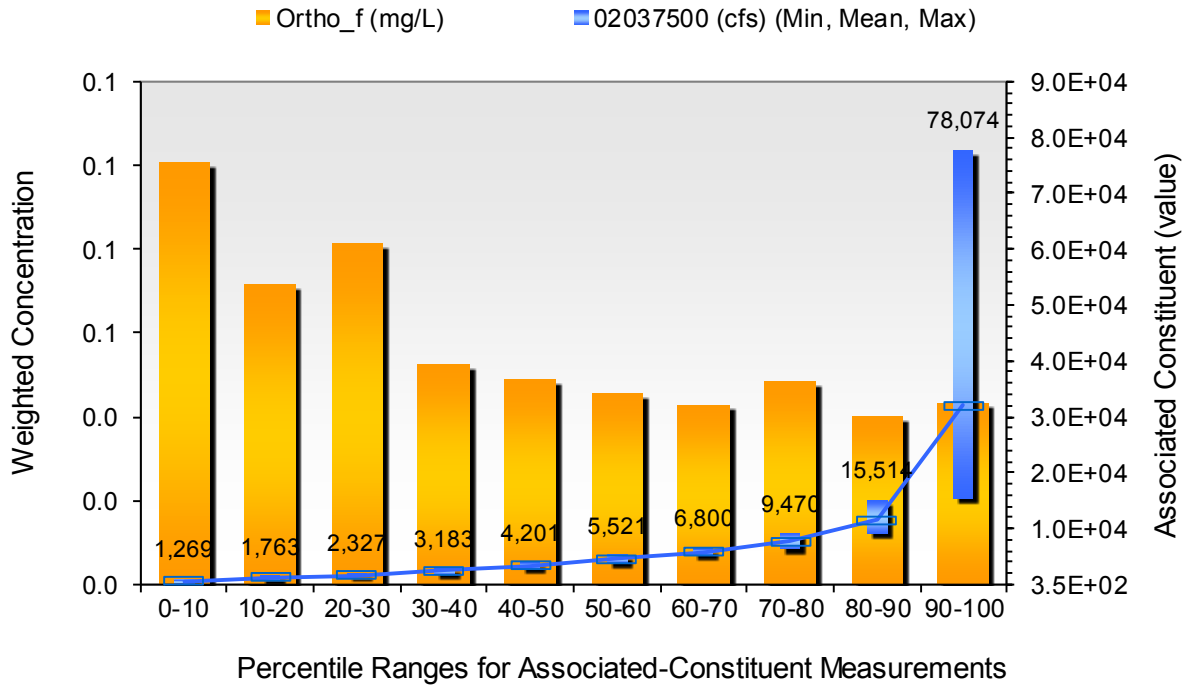
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	0	No Data	No Data	No Data	No Data	No Data	No Data
February	0	No Data	No Data	No Data	No Data	No Data	No Data
March	0	No Data	No Data	No Data	No Data	No Data	No Data
April	0	No Data	No Data	No Data	No Data	No Data	No Data
May	2	6694.2	5732.13	7656.27	0.0828442	0.07	0.1
June	2	3405.03	1672.29	5137.76	0.0652663	0.02	0.08
July	1	5923.54	5923.54	5923.54	0.05	0.05	0.05
August	2	3097.77	3092.73	3102.81	0.0700325	0.05	0.09
September	3	1823.4	1632	2075.25	0.0432228	0.04	0.05
October	2	1450.66	1269.33	1632	0.05125	0.04	0.06
November	0	No Data	No Data	No Data	No Data	No Data	No Data
December	0	No Data	No Data	No Data	No Data	No Data	No Data



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 1/29/1985 to 8/18/2009 (391 Observations)

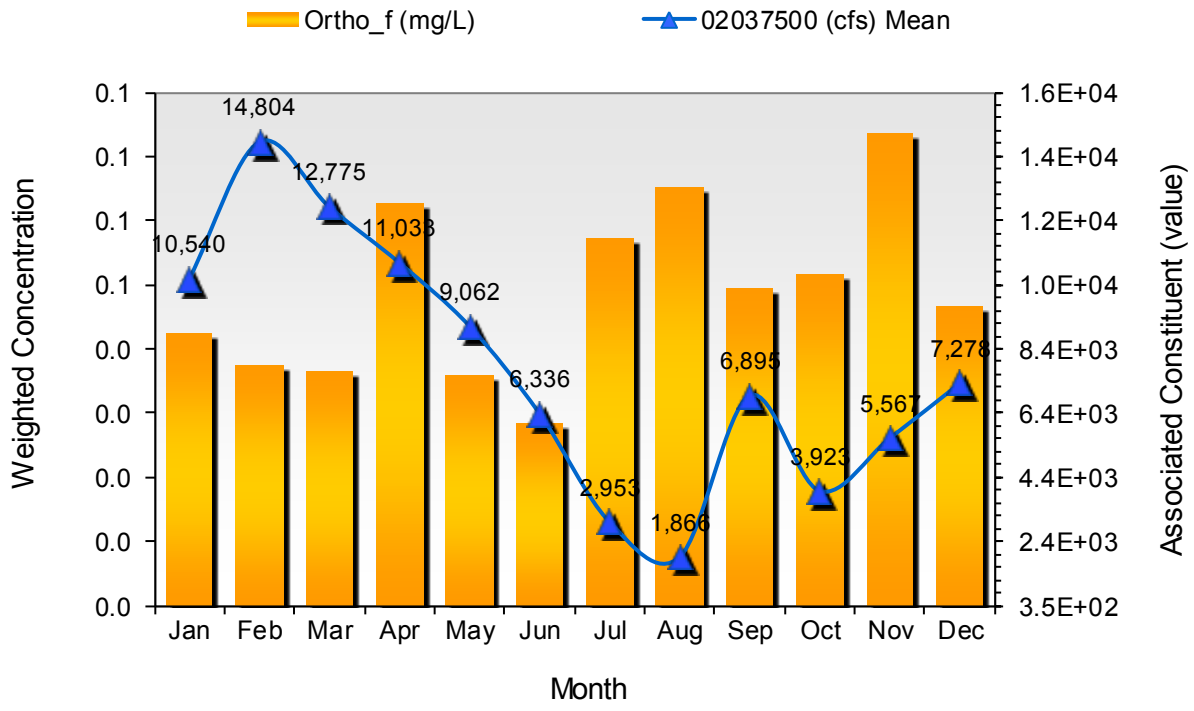
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	39	974.703	354.607	1269.33	0.100736	0.005	0.28
10-20	39	1514.46	1279.4	1762.96	0.0715596	0.006	0.3
20-30	39	1990.01	1762.96	2327.1	0.0814646	0.003	0.46
30-40	39	2755.9	2327.1	3183.4	0.0524376	0.003	0.27
40-50	39	3673.15	3183.4	4200.88	0.0489229	0.004	0.32
50-60	39	4886.17	4200.88	5520.58	0.0453806	0	0.33
60-70	39	6135.35	5550.8	6799.98	0.042766	0.003	0.14
70-80	39	8012.22	6799.98	9469.6	0.0482327	0.004	0.35
80-90	39	11860	9661.01	15514	0.0401709	0.007	0.11
90-100	39	32379	15614.8	78073.8	0.0434563	0.01	0.19



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 1/29/1985 to 8/18/2009 (391 Observations)

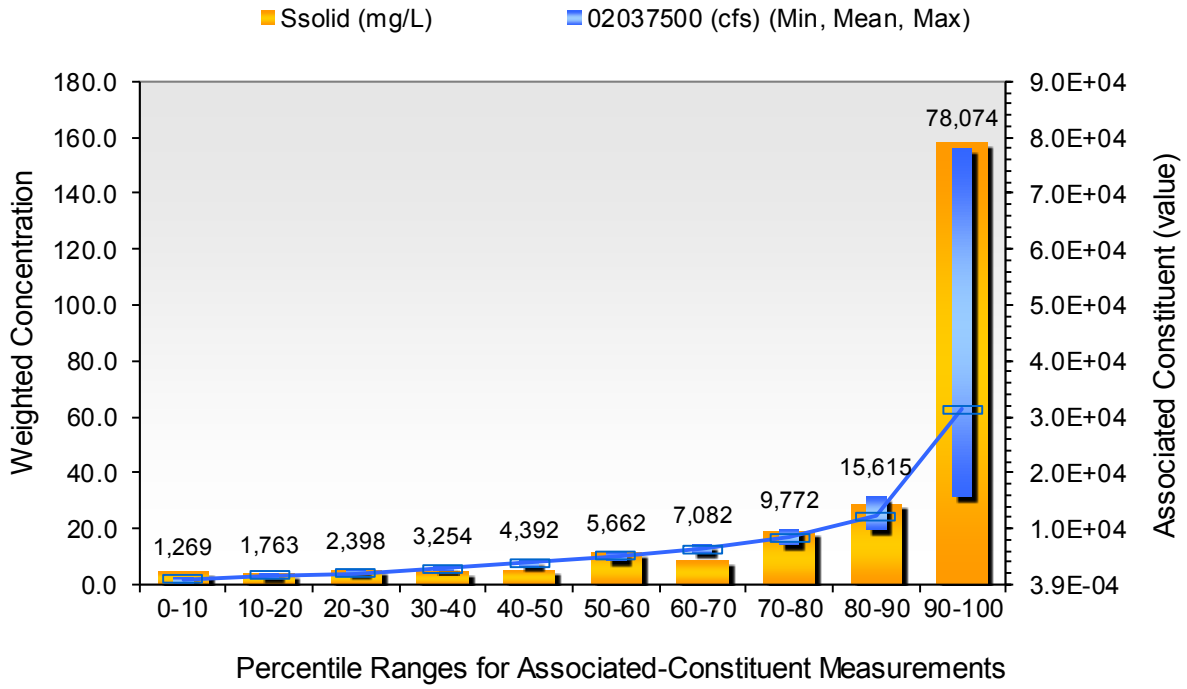
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	27	10540.4	1762.96	51881.3	0.042197	0.003	0.15
February	29	14804.3	1541.33	106785	0.0372628	0.003	0.14
March	36	12775	3183.4	45131.7	0.0365825	0.004	0.12
April	36	11033.3	3163.25	78073.8	0.062567	0	0.19
May	34	9062.49	1803.25	40900.6	0.0357035	0.004	0.12
June	37	6335.78	664.887	73943.5	0.028449	0.005	0.11
July	34	2952.55	784.768	10074	0.0571998	0.009	0.33
August	34	1866.07	354.607	4694.5	0.0650407	0.008	0.25
September	34	6895.48	623.584	76462	0.0494334	0.005	0.3
October	35	3923.44	679.998	49967.3	0.0514917	0.006	0.28
November	29	5567.47	1098.07	19946.6	0.073416	0.003	0.46
December	26	7277.72	1339.85	26494.7	0.0466748	0.006	0.18



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: Ssolid (mg/L)
Data from: 1/29/1985 to 10/23/2012 (387 Observations)

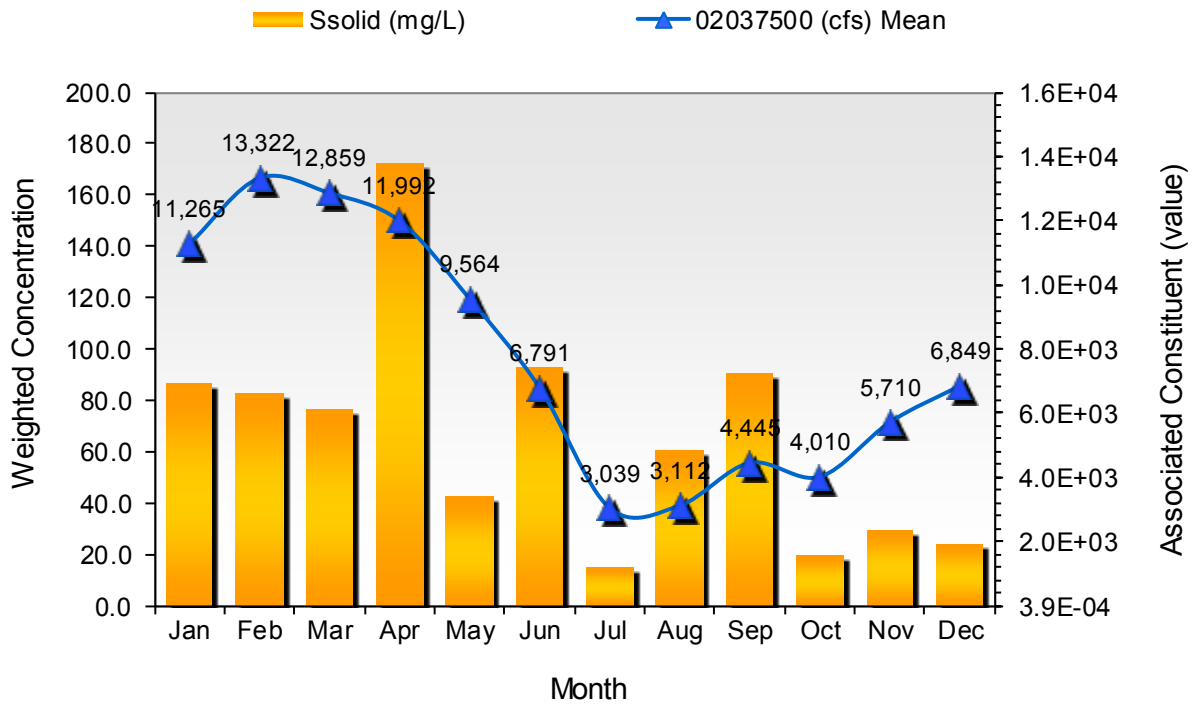
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	39	971.603	0.000387	1269.33	4.30335	1	10
10-20	39	1528.41	1299.55	1762.96	3.61428	1	8
20-30	38	2026.47	1762.96	2397.62	5.19466	1	16
30-40	39	2860	2407.7	3253.92	4.46154	1	10
40-50	38	3795.26	3263.99	4392.28	5.36194	2	12
50-60	39	5096.95	4402.36	5661.61	11.616	1	181
60-70	39	6312.55	5691.84	7082.05	8.58771	2	30
70-80	38	8320.9	7152.57	9771.82	18.8882	3	77
80-90	39	12180.8	9812.12	15614.8	28.4039	2	99
90-100	38	31258.7	15917	78073.8	158.091	25	718



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: Ssolid (mg/L)
Data from: 1/29/1985 to 10/23/2012 (387 Observations)

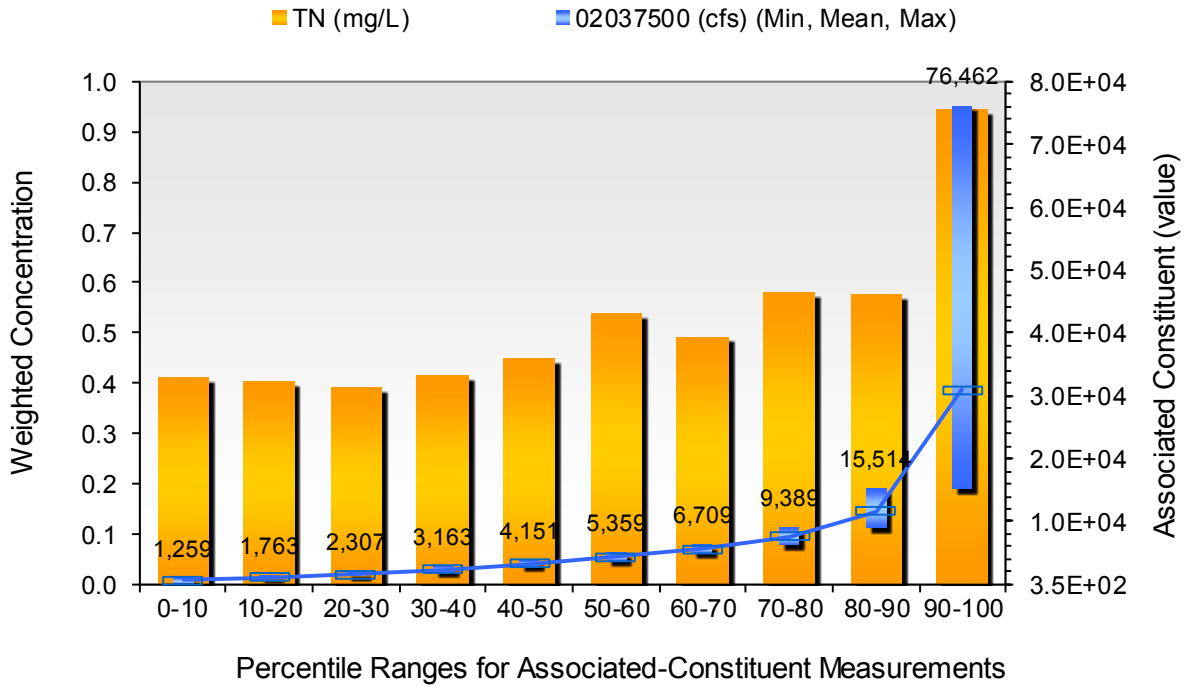
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	28	11264.9	1762.96	51881.3	86.4547	2	247
February	31	13322.1	1541.33	106785	82.6916	2	181
March	34	12859.2	3183.4	44728.8	76.2253	2	325
April	33	11991.8	3163.25	78073.8	171.923	1	718
May	34	9564.12	1803.25	40900.6	42.1772	3	104
June	34	6791.39	664.887	73943.5	92.6834	3	257
July	35	3039.22	784.768	10074	14.5499	3	69
August	34	3112.11	354.607	40699.1	60.6126	1	148
September	36	4445.12	623.584	47146.5	90.2924	1	169
October	35	4010.36	0.000387	49967.3	19.2691	1	37
November	28	5709.82	1098.07	19946.6	29.2184	1	108
December	25	6848.74	1339.85	26494.7	23.8638	1	90



Constituent-Associated Trend Assessment

Location: TF5.2
Comparison Parameter: 02037500 (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (374 Observations)

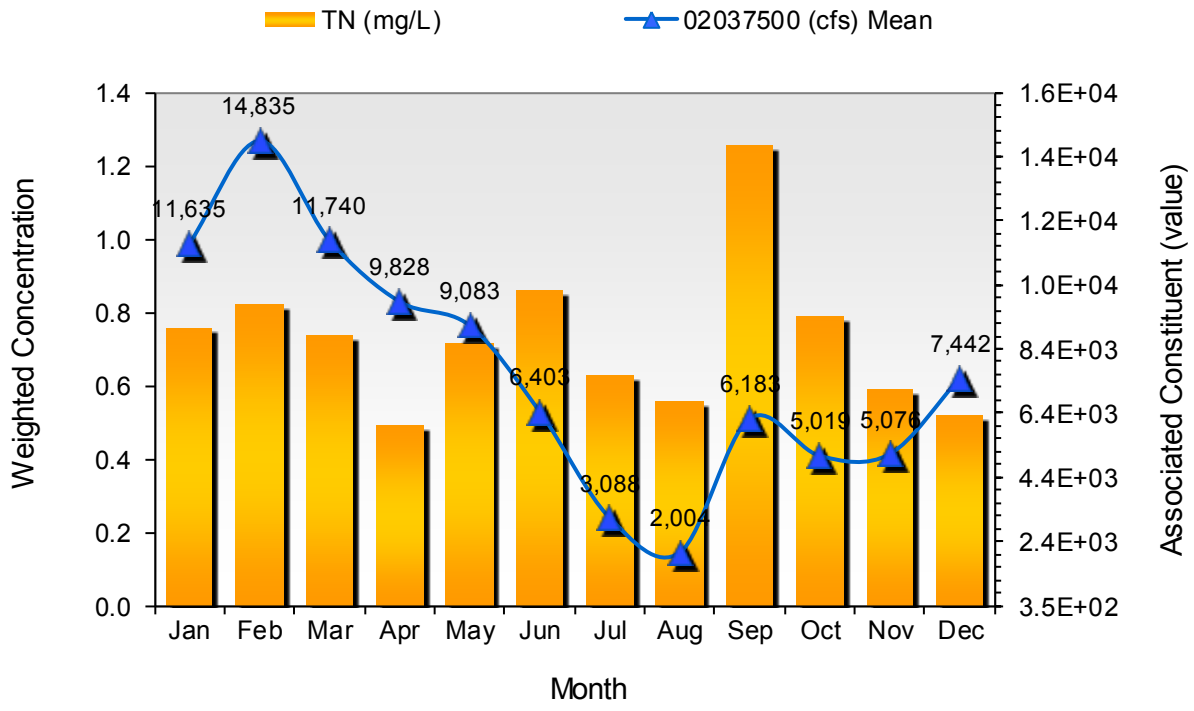
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	978.641	354.607	1259.26	0.409368	0	1.45
10-20	37	1502.39	1259.26	1762.96	0.404428	0	1.6375
20-30	37	1978.6	1762.96	2306.96	0.392254	0	1.24
30-40	38	2731.13	2327.1	3163.25	0.416027	0	1.2075
40-50	37	3628.02	3183.4	4150.51	0.447901	0	1.1075
50-60	37	4732.62	4190.8	5359.39	0.537971	0	1.1875
60-70	38	5953.76	5379.54	6709.31	0.490338	0	1.66
70-80	37	7939.98	6709.31	9389.01	0.580039	0	1.4975
80-90	37	12031.7	9439.38	15514	0.576176	0	1.37
90-100	37	31221.4	15614.8	76462	0.945116	0	2.0675



Seasonal Trend Assessment

Location: TF5.2
Comparison Parameter: 02037500 (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (374 Observations)

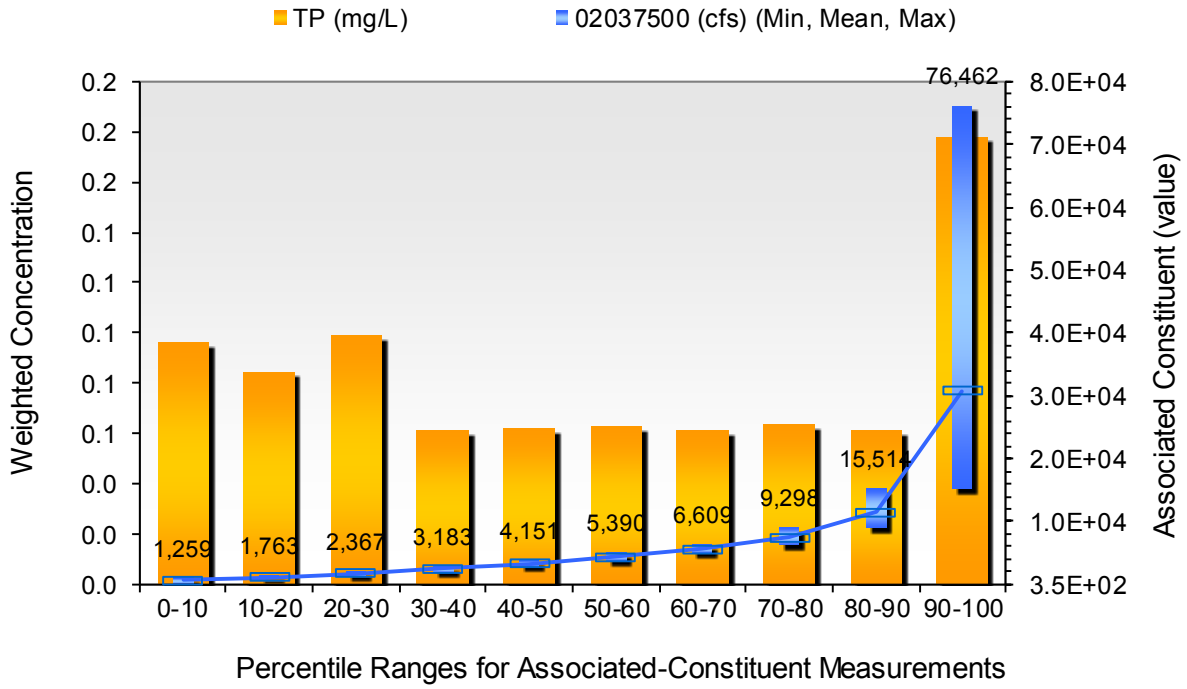
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	24	11634.7	1762.96	51881.3	0.754272	0	1.2275
February	26	14834.8	1541.33	106785	0.818963	0	1.693
March	35	11739.7	3183.4	45131.7	0.732969	0	1.7575
April	35	9827.66	3314.36	42713.9	0.491861	0	1.145
May	35	9083.05	1803.25	40900.6	0.710831	0	1.4975
June	36	6402.92	664.887	73943.5	0.857618	0	1.584
July	34	3087.75	846.22	10275.5	0.624326	0	1.66
August	35	2003.96	354.607	5842.95	0.556502	0	1.24
September	33	6182.96	623.584	76462	1.25514	0	2.0675
October	34	5019.27	679.998	49967.3	0.789038	0	1.2275
November	26	5075.77	1098.07	19946.6	0.586864	0	1.0075
December	21	7442.32	1339.85	26494.7	0.518598	0	0.9675



Constituent-Associated Trend Assessment

Location: TF5.2
Comparison Parameter: 02037500 (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 4/12/2012 (372 Observations)

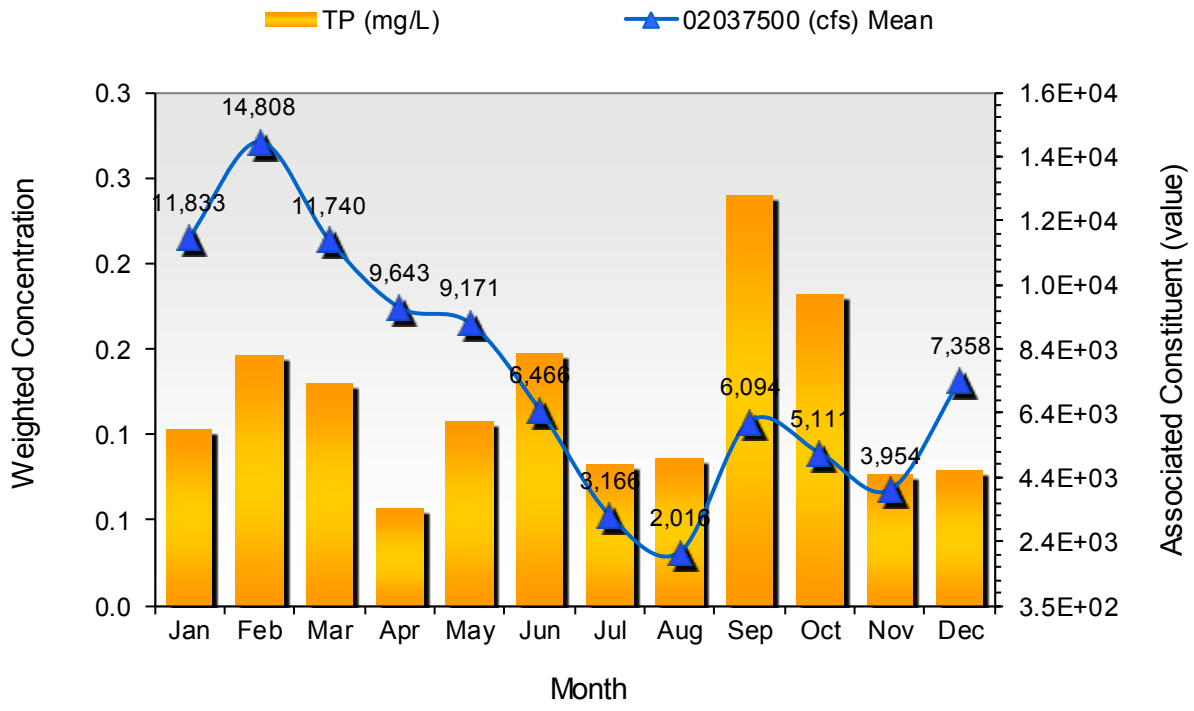
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	978.641	354.607	1259.26	0.0958245	0	0.31
10-20	37	1507.84	1259.26	1762.96	0.0840726	0	0.47
20-30	37	2014.54	1773.03	2367.4	0.0993998	0	0.5
30-40	37	2788.6	2377.47	3183.4	0.0614826	0	0.24
40-50	37	3634.01	3183.4	4150.51	0.0622581	0	0.16
50-60	37	4781.9	4190.8	5389.61	0.0630652	0	0.22
60-70	37	5950.22	5389.61	6608.57	0.0612378	0	0.16
70-80	37	7821.81	6699.24	9298.34	0.0638896	0	0.146
80-90	37	11749.1	9389.01	15514	0.061615	0	0.17
90-100	37	31101.6	15514	76462	0.177916	0	0.48



Seasonal Trend Assessment

Location: TF5.2
Comparison Parameter: 02037500 (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 4/12/2012 (372 Observations)

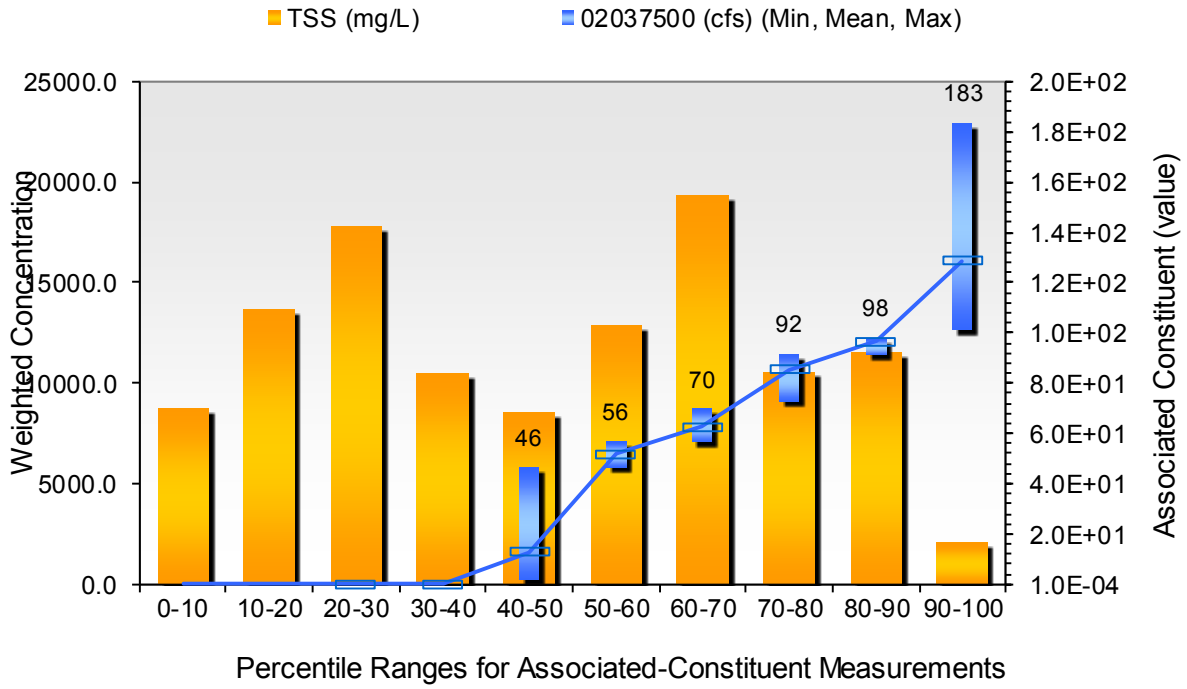
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	11832.6	1762.96	51881.3	0.102931	0	0.32
February	26	14808.1	1541.33	106785	0.145934	0	0.3475
March	35	11739.7	3183.4	45131.7	0.12961	0	0.48
April	36	9642.54	3163.25	42713.9	0.05722	0	0.17
May	35	9170.83	1803.25	40900.6	0.107365	0	0.3
June	36	6465.89	664.887	73943.5	0.147109	0	0.3314
July	32	3165.83	846.22	10275.5	0.0817127	0	0.2
August	34	2016.38	354.607	5842.95	0.0856402	0	0.27
September	34	6094.44	623.584	76462	0.240127	0	0.47
October	34	5110.83	679.998	49967.3	0.182425	0	0.37
November	24	3954.06	1098.07	13600	0.0765371	0	0.5
December	23	7357.99	1339.85	26494.7	0.0782821	0	0.23



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: TSS (mg/L)
Data from: 10/10/2006 to 9/5/2012 (78 Observations)

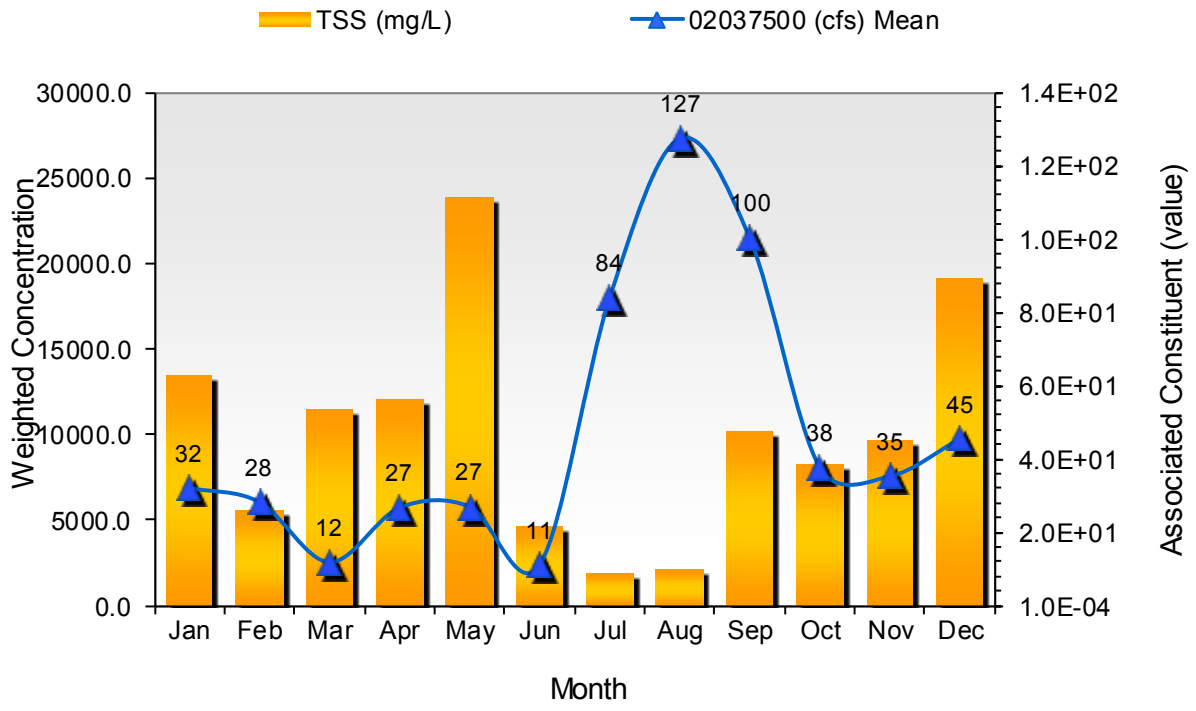
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	8	0.0000435	0.00004	0.000047	8708.79	2740	33700
10-20	8	0.000052	0.000048	0.000059	13621.1	3120	44400
20-30	8	0.0000635	0.00006	0.000067	17838.9	2610	64300
30-40	7	0.000071	0.000068	0.000074	10491.9	4500	30500
40-50	8	12.7689	1.71259	46.3406	8506.22	4680	35200
50-60	8	51.7554	46.3406	56.4147	12882.6	1930	24700
60-70	7	62.603	56.4147	69.5109	19329.9	3140	51900
70-80	8	85.2516	72.5331	91.6738	10545.9	1580	21800
80-90	8	96.459	91.6738	97.7183	11485.2	1350	29300
90-100	7	128.66	101.748	183.348	2068.41	510	4430



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: 02037500 (cfs)
Pollutant: TSS (mg/L)
Data from: 10/10/2006 to 9/5/2012 (78 Observations)

Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	8	32.0355	0.000047	72.5331	13472.4	3140	31300
February	4	28.2074	0.000048	60.4443	5560.36	2780	7970
March	8	11.7993	0.000049	46.3406	11453.8	5320	44400
April	6	26.6459	0.000052	56.4147	11998.3	5710	27300
May	4	26.9481	0.000053	55.4073	23825.2	9990	24700
June	4	11.0815	0.000054	44.3258	4680	3120	4720
July	4	83.8665	49.3628	111.822	1880.6	1350	2520
August	5	127.336	97.7183	183.348	2119.62	510	7620
September	6	100.237	0.000059	183.348	10190.6	1160	29300
October	8	37.6518	0.00004	111.822	8179.13	1050	27900
November	11	35.2226	0.000043	110.814	9558.29	2740	22300
December	10	45.434	0.000045	85.6294	19089.3	2030	64300

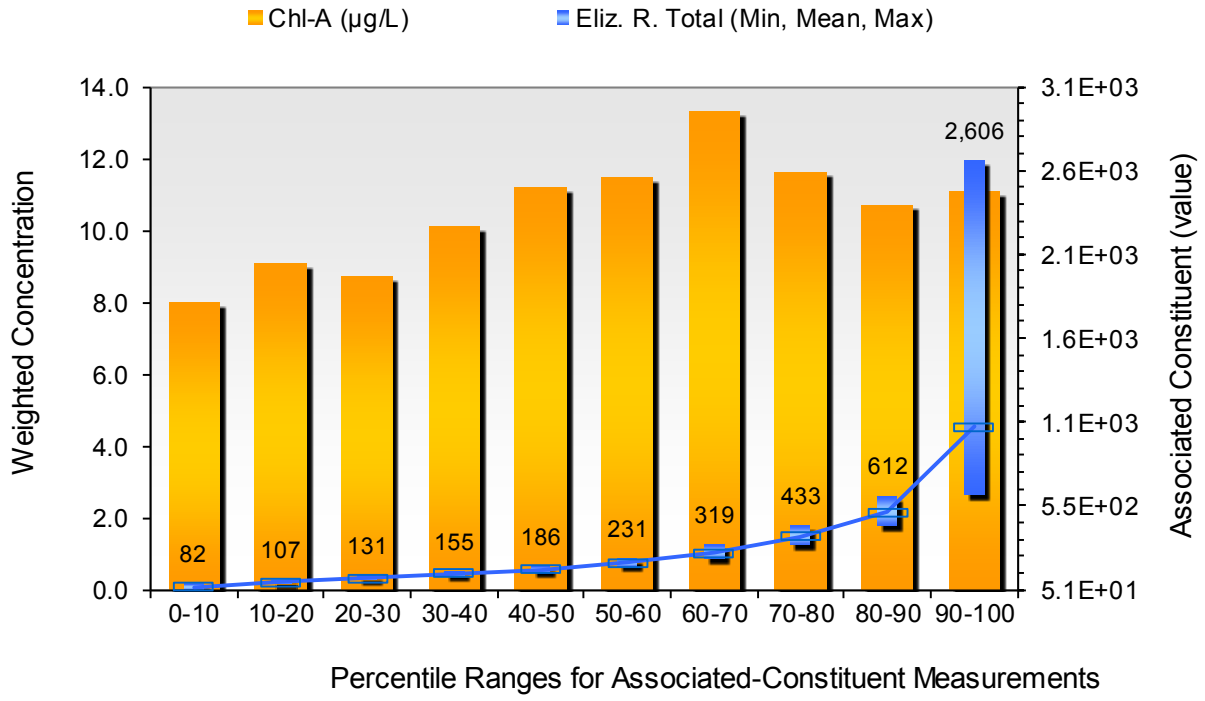


Hampton Roads-PH

Constituent-Associated Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 12/19/2005 (300 Observations)

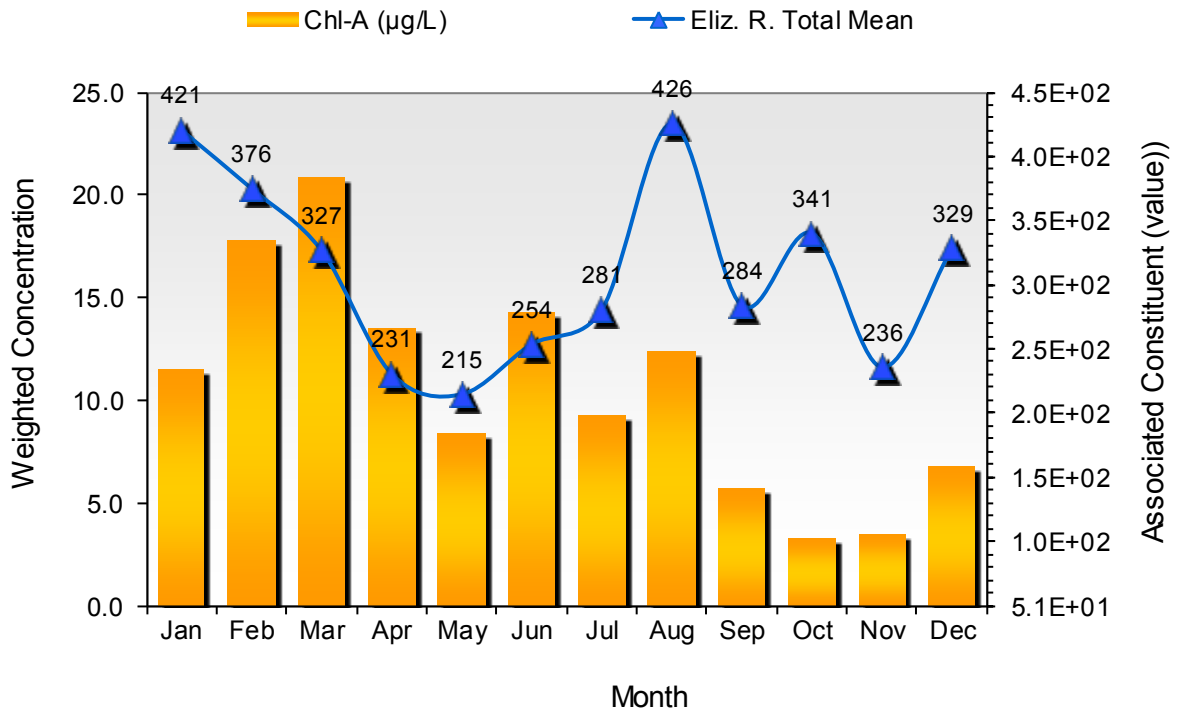
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	30	67.545	50.756	82.358	8.0192	2.6	20.93
10-20	30	96.802	83.104	107.47	9.0567	2.6	18.84
20-30	30	118.55	107.5	131.36	8.6908	2.6835	34.02
30-40	30	143.68	131.73	154.75	10.131	2	41.53
40-50	30	170.58	154.91	186.46	11.203	2.15	66.5
50-60	30	207.99	188.87	230.82	11.443	1	29.21
60-70	30	270.76	233.45	319.49	13.274	0.5	80.52
70-80	30	366.12	322.73	432.63	11.6	2.6	64.6
80-90	30	509.17	437.17	611.6	10.678	1	45.57
90-100	29	1019.5	622.57	2605.6	11.086	0.5	43.84



Seasonal Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 12/19/2005 (300 Observations)

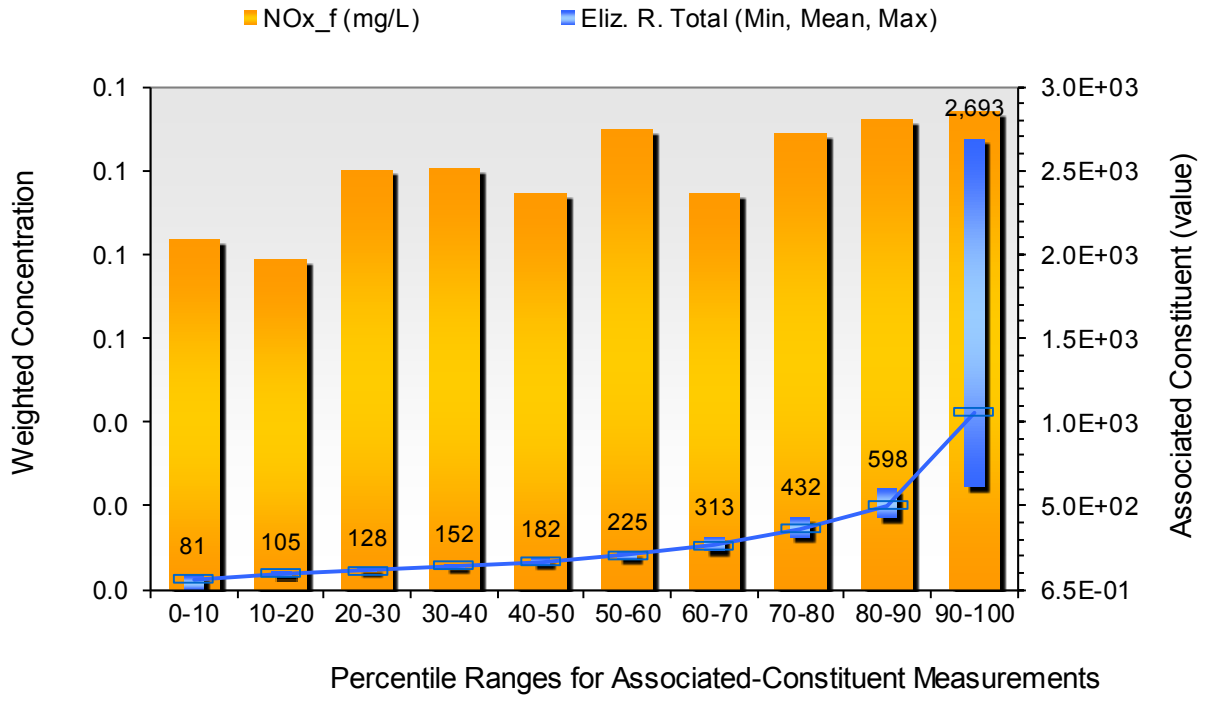
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	16	421.29	103.31	1111.2	11.506	1	23.7
February	18	375.68	97.007	1139.9	17.756	1	80.52
March	26	327.4	127.56	763.69	20.874	3.1	66.5
April	27	231.3	94.398	636.48	13.478	2.6	29.87
May	29	215.3	61.842	509.26	8.4078	1	29.21
June	30	254.34	52.608	1427.7	14.328	5.5	28.52
July	28	281.03	69.663	1023.9	9.3035	3.1	26
August	29	426.12	54.749	3221.6	12.356	2	43.84
September	28	284.48	54.316	1849.8	5.6489	3.1	27.4
October	28	340.86	50.756	2605.6	3.3107	0.5	9.42
November	22	236.49	58.446	923.64	3.4581	0.5	10.4
December	19	329	118.47	961.23	6.7337	2.5	21.93



Constituent-Associated Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: NOx_f (mg/L)
Data from: 9/25/1984 to 12/19/2005 (314 Observations)

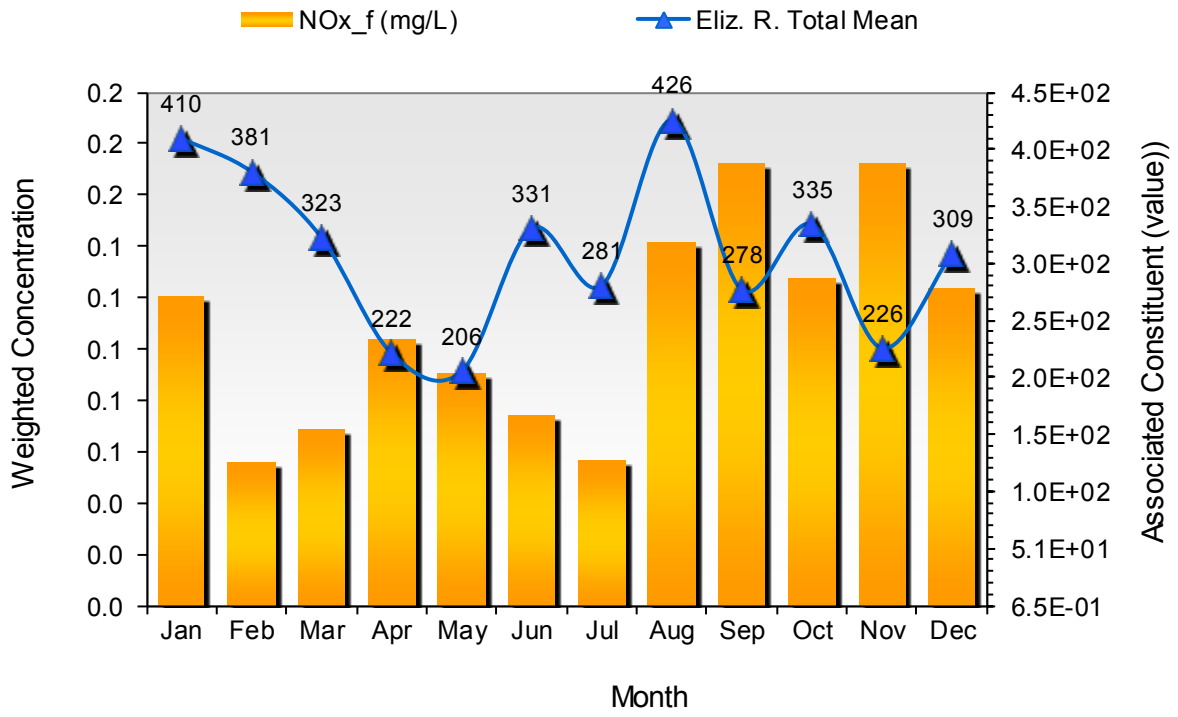
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	32	63.71	0.64721	80.847	0.083433	0	0.26
10-20	31	94.448	81.369	104.77	0.078685	0	0.235
20-30	31	116.01	105.91	128.45	0.10014	0	0.39
30-40	32	141.25	130.05	152.04	0.10058	0	0.245
40-50	31	167.3	152.88	181.69	0.094503	0	0.265
50-60	31	204.29	182.78	225.23	0.10996	0	0.49
60-70	32	265.5	229.39	313.02	0.094748	0	0.4025
70-80	31	361.18	318.35	431.82	0.1089	0	0.45833
80-90	31	502.34	432.63	598.14	0.11228	0	0.395
90-100	31	1060.3	611.6	2692.6	0.114	0	0.355



Seasonal Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: NOx_f (mg/L)
Data from: 9/25/1984 to 12/19/2005 (314 Observations)

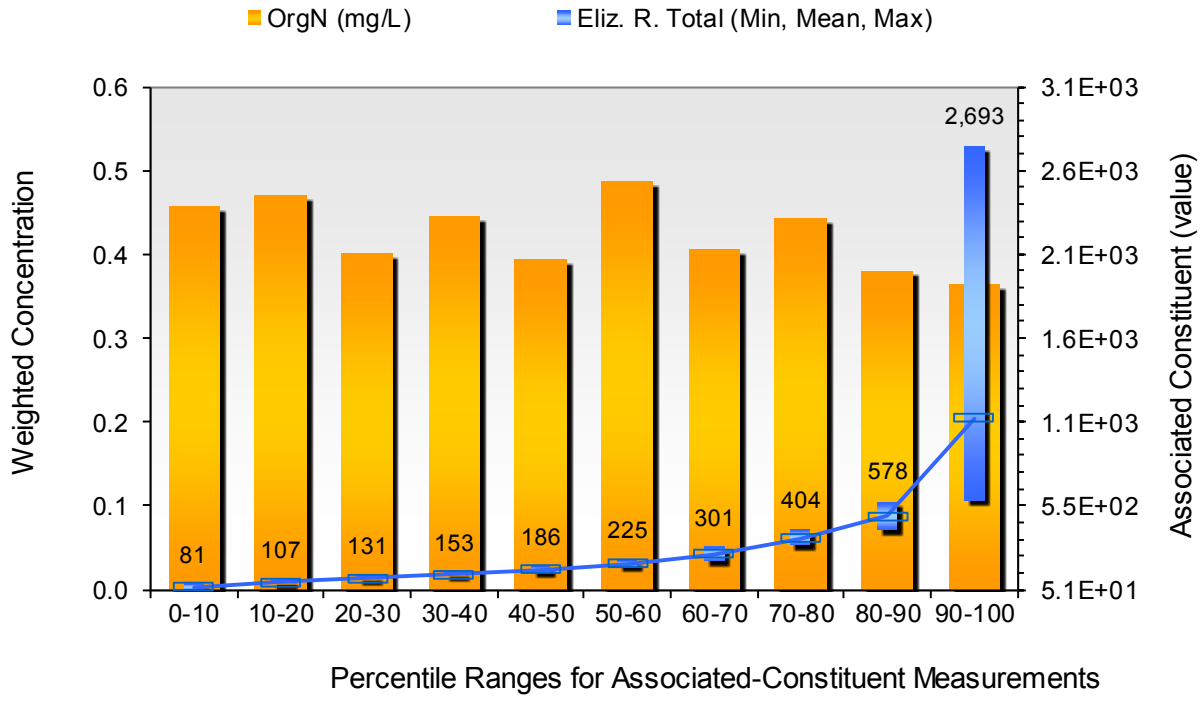
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	17	410.17	103.31	1111.2	0.12045	0	0.45833
February	19	380.98	97.007	1139.9	0.05562	0	0.2275
March	28	323.27	127.56	763.69	0.068678	0	0.19167
April	29	221.78	75.289	636.48	0.10358	0	0.25
May	31	205.93	59.422	509.26	0.090452	0	0.245
June	30	331.14	52.608	2692.6	0.074197	0	0.49
July	28	281.03	69.663	1023.9	0.056309	0	0.215
August	29	426.12	54.749	3221.6	0.1415	0	0.355
September	30	277.5	41.279	1849.8	0.17251	0	0.39
October	29	334.68	50.756	2605.6	0.12718	0	0.4025
November	23	226.23	0.64721	923.64	0.17226	0	0.335
December	21	308.84	99.038	961.23	0.12359	0	0.395



Constituent-Associated Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 12/19/2005 (281 Observations)

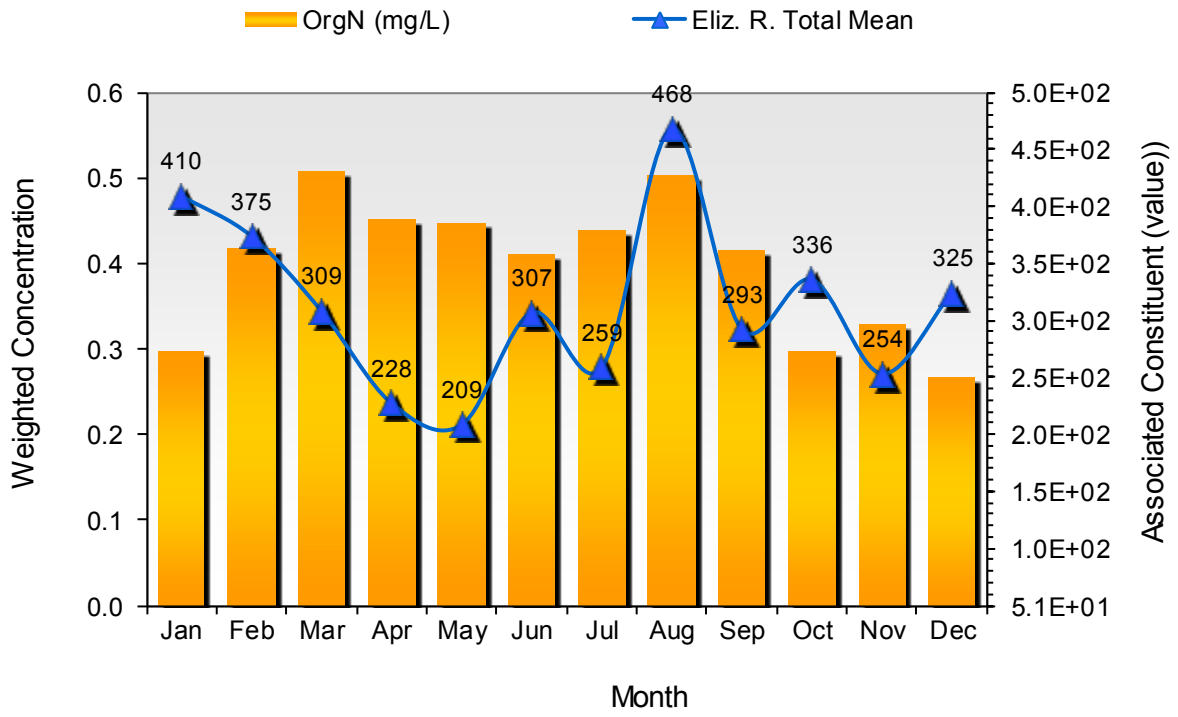
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	28	66.594	50.756	81.369	0.45695	0	0.98
10-20	28	96.046	81.37	107.47	0.47067	0	0.9
20-30	28	118.74	107.5	131.36	0.40119	0	0.8
30-40	28	143.42	131.73	153.1	0.44446	0	0.895
40-50	28	169.02	154.75	186.46	0.39472	0	0.96
50-60	28	206.41	188.87	225.23	0.48616	0	1.216
60-70	28	261.68	229.39	300.65	0.40483	0	0.92
70-80	28	355.84	312.08	404.14	0.44212	0	1.2
80-90	28	488.73	412.81	577.65	0.37901	0	0.94833
90-100	28	1070.1	588.91	2692.6	0.36306	0	0.82188



Seasonal Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 12/19/2005 (281 Observations)

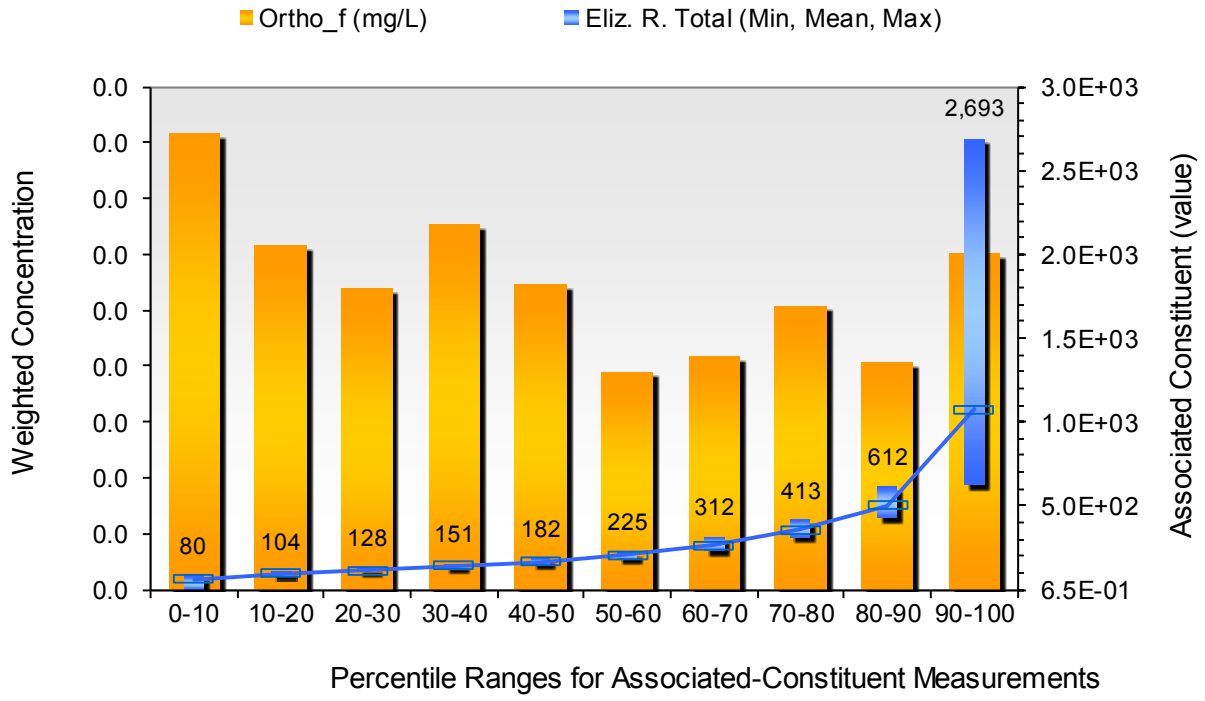
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	15	409.8	103.31	1111.2	0.29643	0	0.59
February	18	374.53	97.007	1139.9	0.41622	0	0.96
March	25	308.91	127.56	763.69	0.50791	0	1.2
April	27	228.03	75.289	636.48	0.45237	0	0.775
May	30	209.12	59.422	509.26	0.44607	0	0.75
June	27	307.44	52.608	2692.6	0.41047	0	1.216
July	25	259.41	69.663	1023.9	0.43801	0	0.98
August	25	468.45	54.748	3221.6	0.50242	0	0.895
September	26	293.11	54.316	1849.8	0.4137	0	0.91667
October	25	336.48	50.756	2605.6	0.29537	0	0.89
November	19	253.93	58.446	923.64	0.32953	0	0.76
December	19	324.7	99.038	961.23	0.26665	0	0.616



Constituent-Associated Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: Ortho_f (mg/L)
Data from: 9/25/1984 to 12/19/2005 (309 Observations)

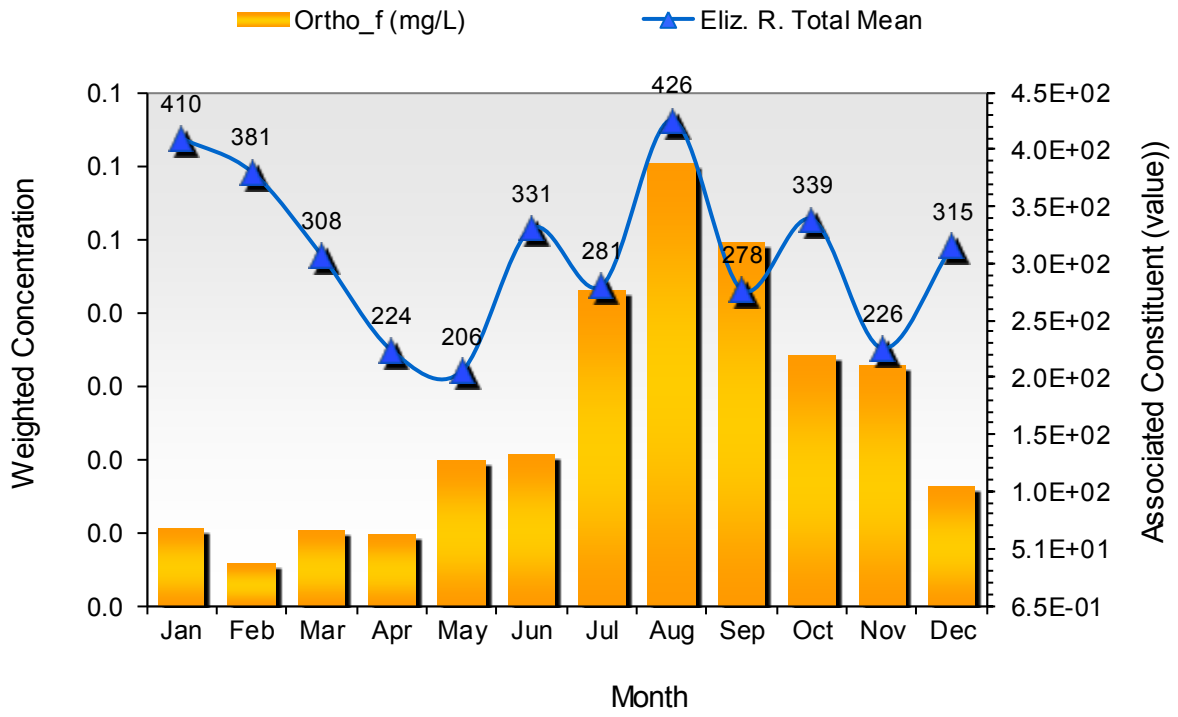
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	31	63.157	0.64721	80.072	0.040756	0	0.0875
10-20	31	93.676	80.847	103.51	0.03082	0	0.08
20-30	31	115.24	104.77	128.31	0.026925	0	0.08
30-40	31	140.18	128.45	150.88	0.032598	0	0.085
40-50	30	165.87	152.04	181.59	0.027343	0	0.09
50-60	31	203.38	181.69	225.23	0.019387	0	0.06
60-70	31	263.96	229.39	312.08	0.020935	0	0.09
70-80	31	357.35	313.02	412.81	0.025346	0	0.105
80-90	31	502.17	431.82	611.6	0.020375	0	0.0755
90-100	30	1075.3	622.57	2692.6	0.03005	0	0.095



Seasonal Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: Ortho_f (mg/L)
Data from: 9/25/1984 to 12/19/2005 (309 Observations)

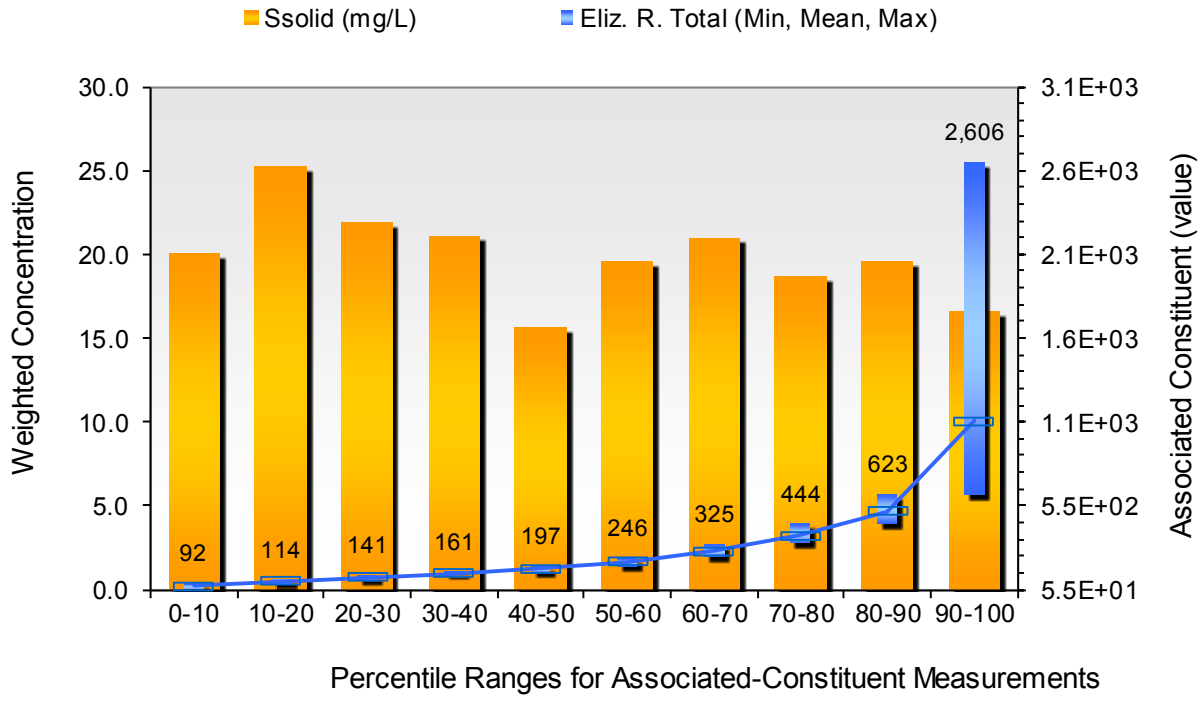
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	17	410.17	103.31	1111.2	0.010453	0	0.04
February	19	380.98	97.007	1139.9	0.0056446	0	0.02
March	26	307.8	127.56	763.69	0.010328	0	0.04
April	28	224.31	75.289	636.48	0.0097725	0	0.035
May	31	205.93	59.422	509.26	0.019647	0	0.05
June	30	331.14	52.608	2692.6	0.020472	0	0.085
July	28	281.03	69.663	1023.9	0.042849	0	0.095
August	29	426.12	54.749	3221.6	0.060385	0	0.09
September	30	277.5	41.279	1849.8	0.049416	0	0.105
October	28	339.13	50.756	2605.6	0.034163	0	0.0755
November	23	226.23	0.64721	923.64	0.032786	0	0.07
December	20	315.25	99.038	961.23	0.016103	0	0.04



Constituent-Associated Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: Ssolid (mg/L)
Data from: 11/12/1985 to 12/19/2005 (246 Observations)

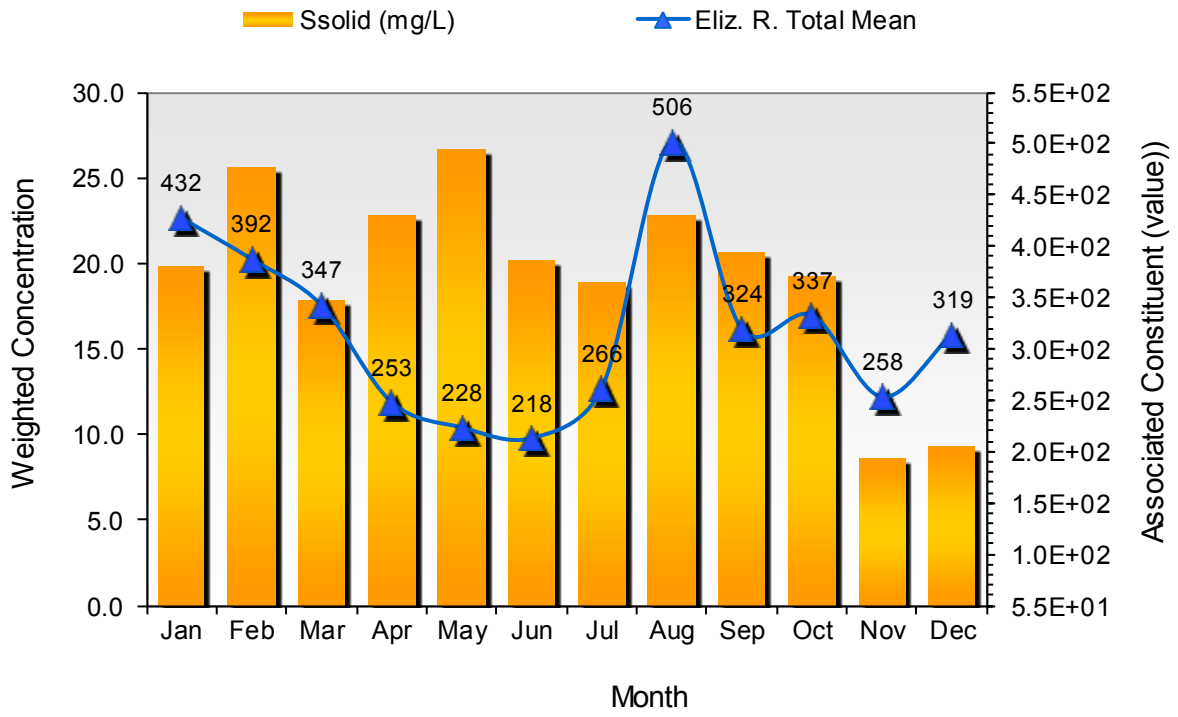
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	25	75.386	54.748	92.205	20.037	3.5	58.5
10-20	24	103.59	92.531	113.62	25.253	4.5	48
20-30	25	127.38	113.96	141.14	21.922	4.5	66.5
30-40	24	150.63	141.79	161.48	21.127	7	61
40-50	25	180.32	162.28	196.91	15.595	5	55
50-60	24	220.16	198.55	245.66	19.612	6	76.5
60-70	25	285.87	250.66	325.47	20.959	6.5	59.5
70-80	24	375.04	329.55	443.68	18.633	7	47
80-90	25	519.75	446.13	622.57	19.575	4.5	63
90-100	24	1057.2	625.04	2605.6	16.508	4.5	40



Seasonal Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: Ssolid (mg/L)
Data from: 11/12/1985 to 12/19/2005 (246 Observations)

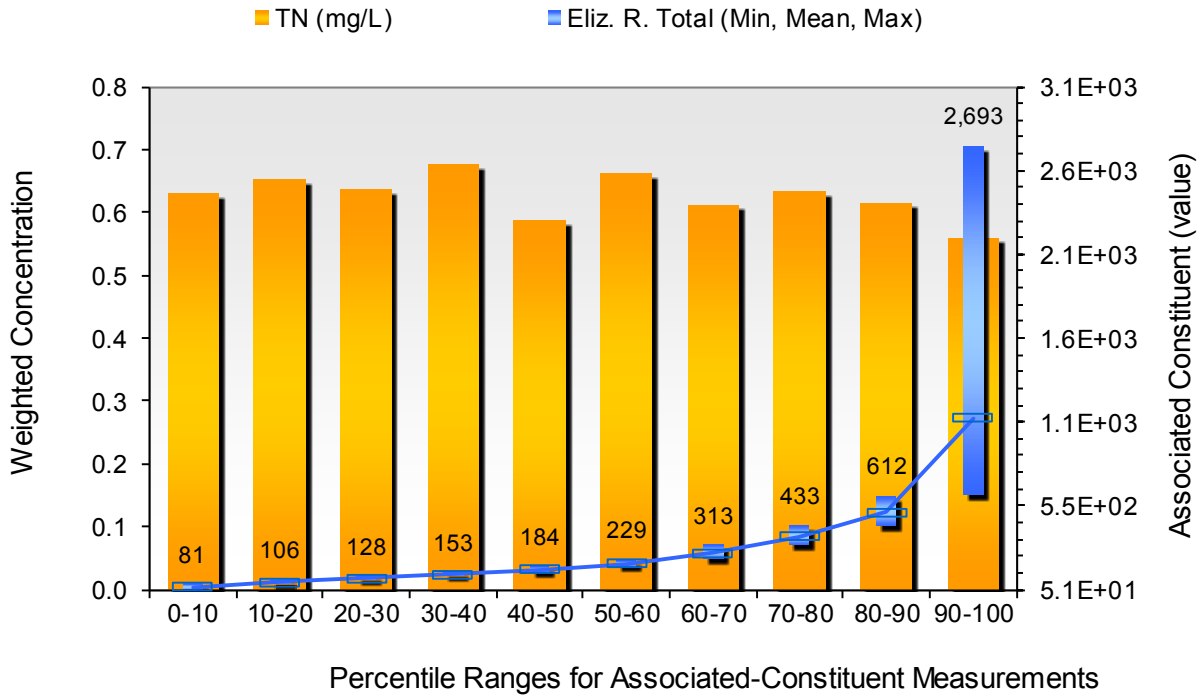
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	15	432.28	179.91	1111.2	19.822	6	47
February	16	392.29	97.007	1139.9	25.647	6.5	59.5
March	20	347.38	132.49	763.69	17.862	6	43.5
April	22	252.86	100.07	636.48	22.807	4.5	76.5
May	21	228.17	89.948	509.26	26.607	11.5	61
June	23	217.73	54.944	1071.3	20.167	8	58.5
July	23	266.12	69.663	1023.9	18.867	11	28
August	23	506.48	54.748	3221.6	22.836	5	45.5
September	23	324.23	65.613	1849.8	20.627	9	47
October	23	337.46	63.636	2605.6	19.237	6.5	66.5
November	19	258.06	58.446	923.64	8.5236	3.5	22
December	18	318.71	99.038	961.23	9.2274	4.5	22



Constituent-Associated Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 12/19/2005 (304 Observations)

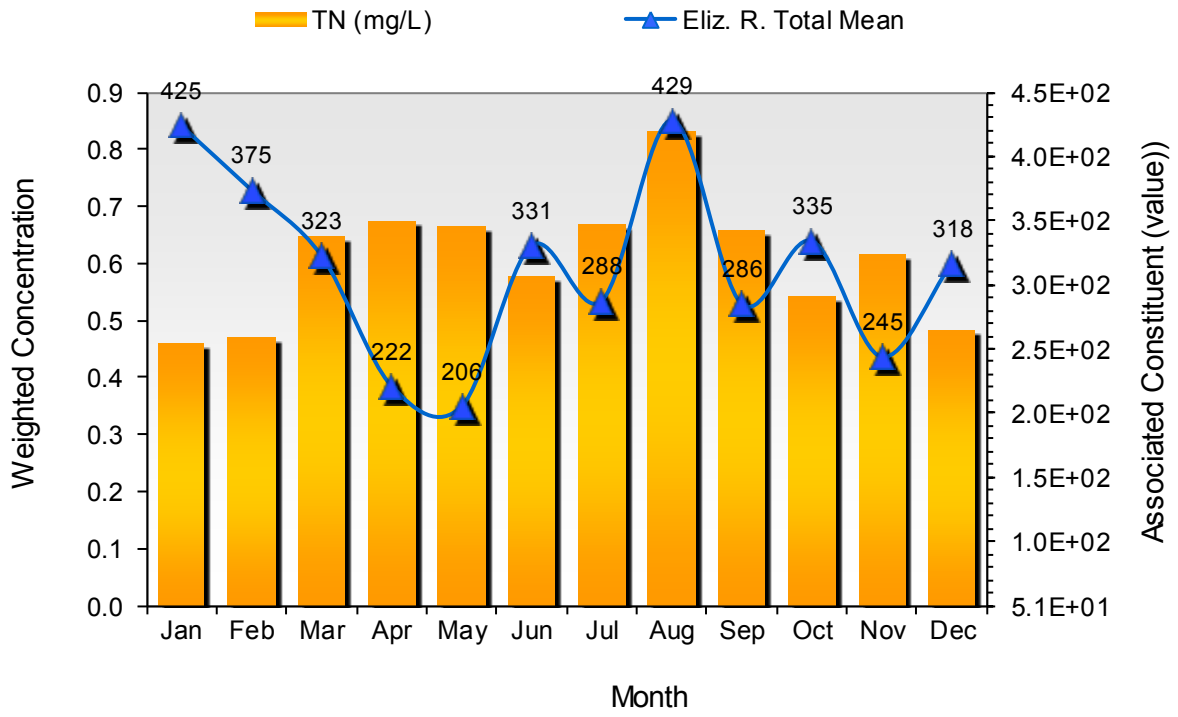
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	31	67.038	50.756	81.369	0.62969	0	1.3105
10-20	30	95.562	81.37	105.91	0.65127	0	1.175
20-30	30	116.34	106.92	128.45	0.63588	0	1.225
30-40	31	142.11	130.05	152.88	0.67787	0	1.2117
40-50	30	167.99	153.1	184.16	0.58645	0	1.13
50-60	30	206.51	186.46	229.39	0.6621	0	1.54
60-70	31	266.66	230.82	313.02	0.61051	0	1.1
70-80	30	364.84	318.35	432.63	0.63185	0	1.465
80-90	30	508.49	437.17	611.6	0.61398	0	1.0417
90-100	30	1075.3	622.57	2692.6	0.55931	0	1.205



Seasonal Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 12/19/2005 (304 Observations)

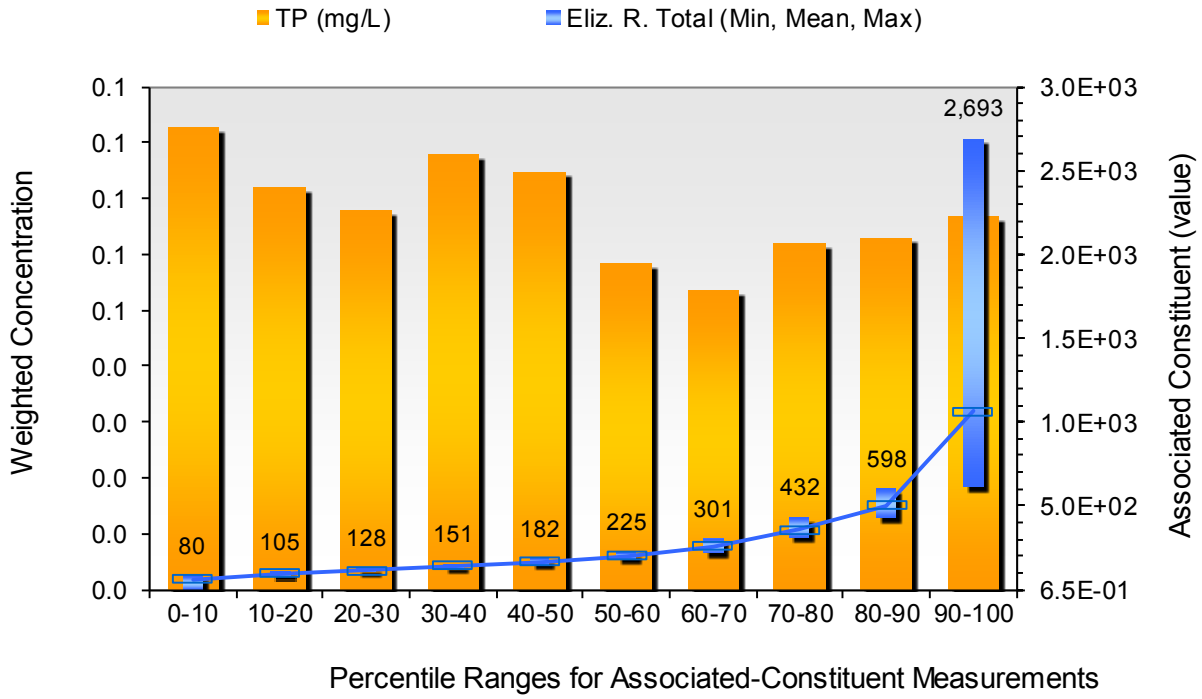
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	16	424.56	103.31	1111.2	0.45937	0	1.0583
February	18	374.53	97.007	1139.9	0.47061	0	1.13
March	28	323.27	127.56	763.69	0.64795	0	1.465
April	29	221.78	75.289	636.48	0.67388	0	1.1
May	31	205.93	59.422	509.26	0.66433	0	1.045
June	30	331.14	52.608	2692.6	0.57594	0	1.54
July	27	288.27	69.663	1023.9	0.6685	0	1.3105
August	28	428.82	54.749	3221.6	0.82964	0	1.2117
September	29	285.65	54.316	1849.8	0.65541	0	1.21
October	28	334.73	50.756	2605.6	0.54226	0	1.15
November	20	244.51	58.446	923.64	0.61406	0	1.115
December	20	317.5	99.038	961.23	0.4817	0	0.9575



Constituent-Associated Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: TP (mg/L)
Data from: 9/25/1984 to 12/19/2005 (309 Observations)

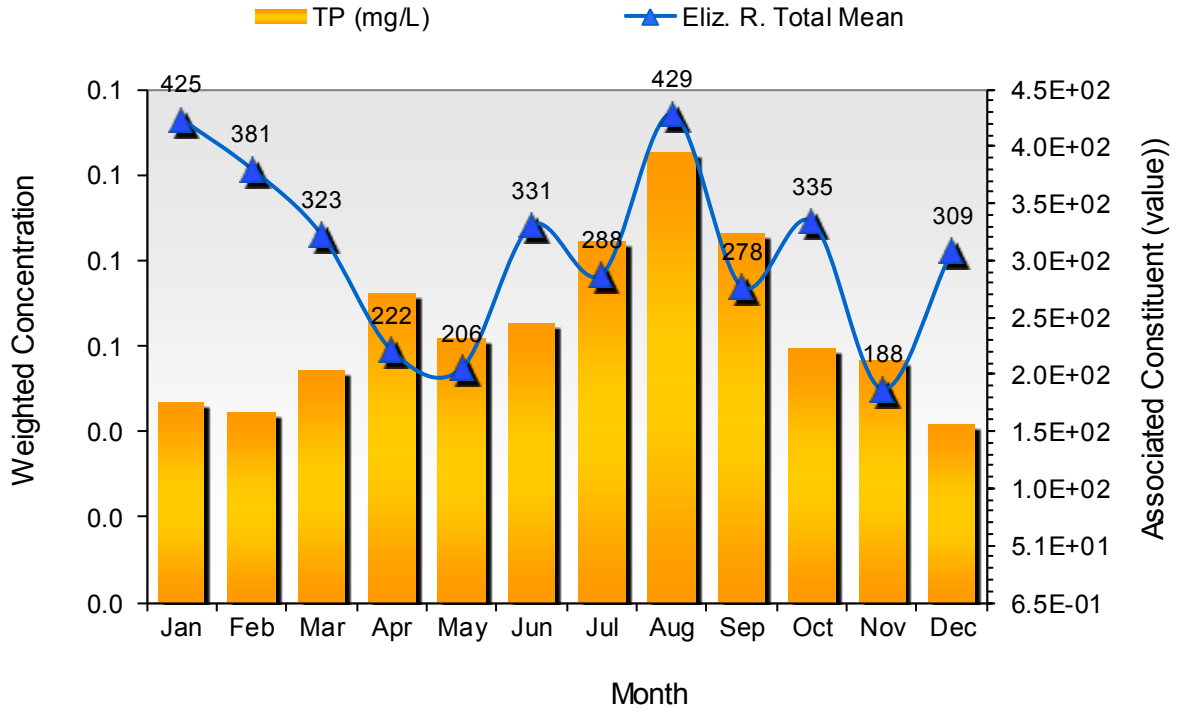
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	31	63.157	0.64721	80.072	0.082579	0	0.155
10-20	31	94.296	80.847	104.77	0.071829	0	0.135
20-30	31	116.01	105.91	128.45	0.067834	0	0.15
30-40	31	140.91	130.05	150.95	0.077706	0	0.14
40-50	30	165.89	152.04	181.59	0.074805	0	0.18
50-60	31	202.88	181.69	224.57	0.058423	0	0.15
60-70	31	261.16	225.23	300.65	0.053497	0	0.14
70-80	31	359.25	312.08	431.82	0.061787	0	0.19
80-90	31	502.34	432.63	598.14	0.063045	0	0.13
90-100	30	1064.9	611.6	2692.6	0.066624	0	0.225



Seasonal Trend Assessment

Location: LE5.6
Comparison Parameter: Eliz. R. Total
Pollutant: TP (mg/L)
Data from: 9/25/1984 to 12/19/2005 (309 Observations)

Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	16	424.56	103.31	1111.2	0.046871	0	0.095
February	19	380.98	97.007	1139.9	0.044319	0	0.13
March	28	323.27	127.56	763.69	0.054216	0	0.1
April	29	221.78	75.289	636.48	0.072232	0	0.225
May	31	205.93	59.422	509.26	0.061505	0	0.115
June	30	331.14	52.608	2692.6	0.065498	0	0.14
July	27	288.27	69.663	1023.9	0.084305	0	0.15
August	28	428.82	54.749	3221.6	0.10535	0	0.155
September	30	277.5	41.279	1849.8	0.086169	0	0.19
October	29	334.68	50.756	2605.6	0.059215	0	0.18
November	21	187.89	0.64721	899.46	0.056693	0	0.1
December	21	308.84	99.038	961.23	0.041661	0	0.09

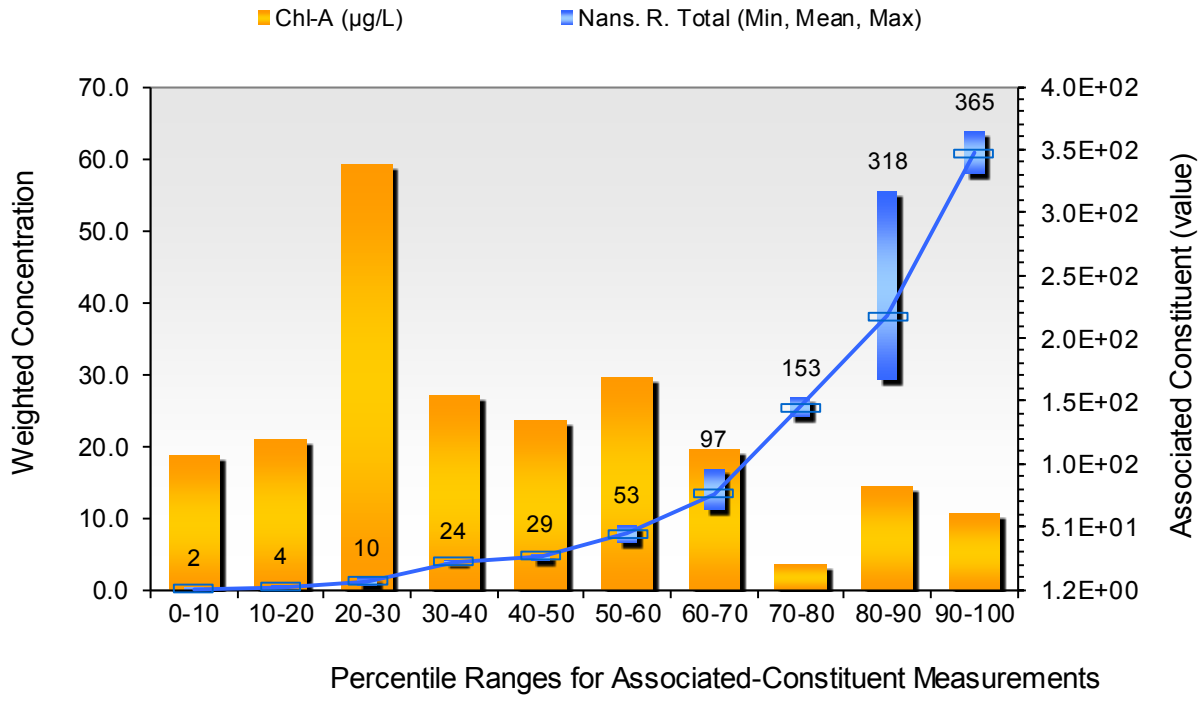


Hampton Roads-MH

Constituent-Associated Trend Assessment

Location: 2-NAN019.14
Comparison Parameter: Nans. R. Total
Pollutant: Chl-A (µg/L)
Data from: 6/12/1990 to 12/8/2005 (26 Observations)

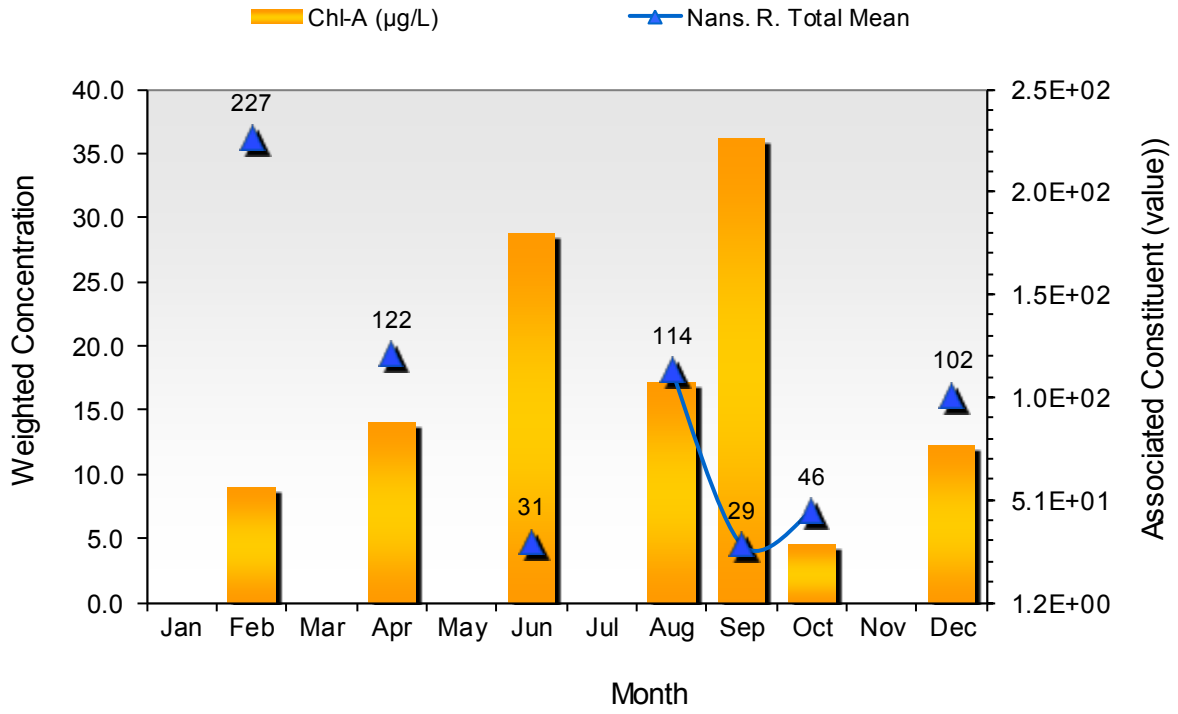
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	1.5973	1.2284	2.2918	18.656	4.98	27.02
10-20	2	3.3837	2.8159	3.9514	20.869	11.55	27.51
20-30	3	7.4498	4.1681	10.351	59.217	27.61	67.04
30-40	2	23.164	22.203	24.126	26.929	13.85	41.14
40-50	3	27.645	24.793	29.244	23.438	11.667	36.17
50-60	2	45.416	38.323	52.51	29.567	29.2	30.07
60-70	3	77.115	63.909	97.457	19.37	8.28	26.53
70-80	2	146.18	138.94	153.42	3.6377	1.58	5.91
80-90	3	218.65	168.53	318.26	14.301	12.32	15.45
90-100	2	348.34	331.42	365.25	10.451	9.45	11.36



Seasonal Trend Assessment

Location: 2-NAN019.14
Comparison Parameter: Nans. R. Total
Pollutant: Chl-A (µg/L)
Data from: 6/12/1990 to 12/8/2005 (26 Observations)

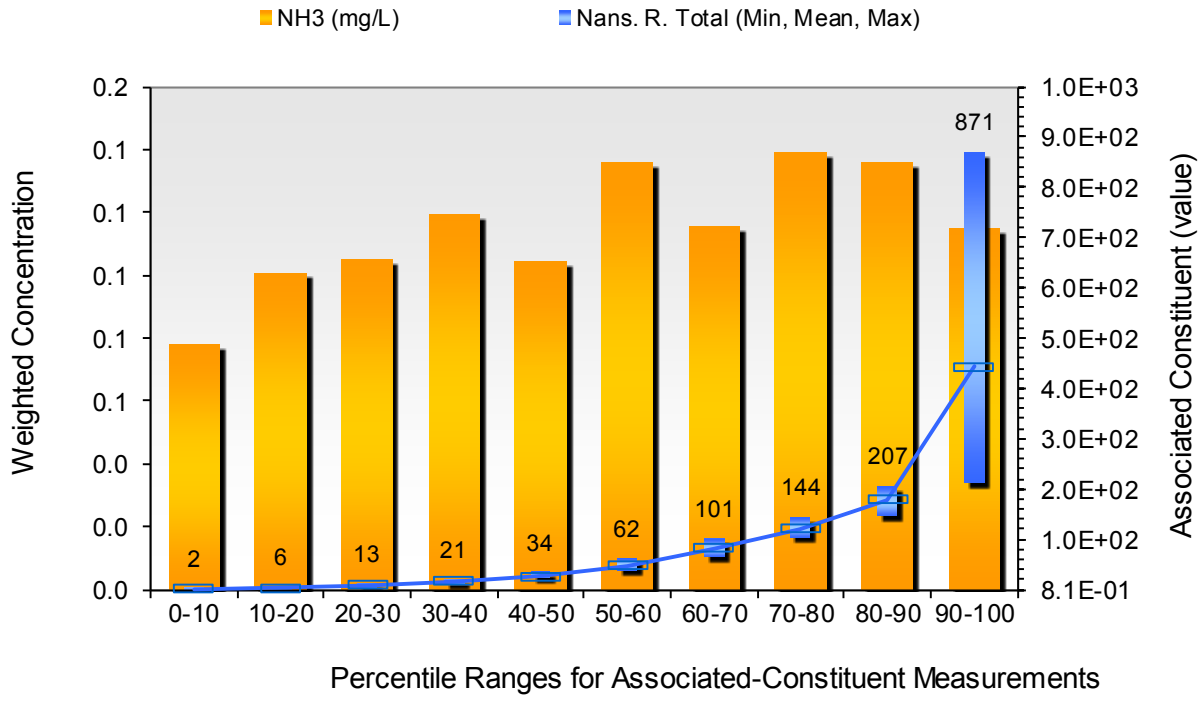
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	0	No Data	No Data	No Data	No Data	No Data	No Data
February	4	227.38	138.94	432.87	8.8949	5.91	14.12
March	0	No Data	No Data	No Data	No Data	No Data	No Data
April	4	122.23	24.793	365.25	14.096	11.36	26.53
May	0	No Data	No Data	No Data	No Data	No Data	No Data
June	5	31.046	1.2718	97.457	28.747	4.98	67.04
July	0	No Data	No Data	No Data	No Data	No Data	No Data
August	3	114.25	2.2918	318.26	17.191	15.45	41.14
September	1	29.244	29.244	29.244	36.17	36.17	36.17
October	5	45.653	2.8159	153.42	4.503	1.58	27.61
November	0	No Data	No Data	No Data	No Data	No Data	No Data
December	4	102.32	1.2284	331.42	12.266	9.45	29.2



Constituent-Associated Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: NH3 (mg/L)
Data from: 1/10/1984 to 6/5/2002 (115 Observations)

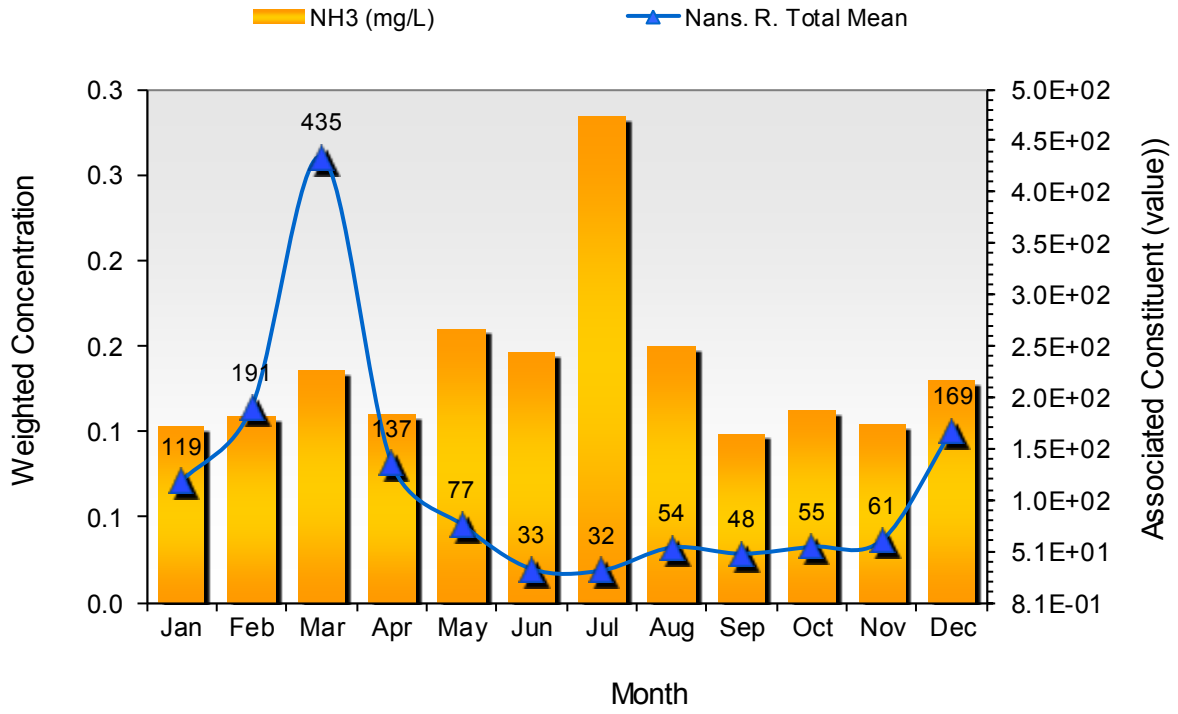
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	12	1.2004	0.81451	2.2582	0.077941	0.04	0.11
10-20	11	4.262	2.3516	6.0095	0.10049	0.04	0.24
20-30	12	8.6498	6.0212	12.76	0.10522	0.04	0.24
30-40	11	17.757	13.909	20.978	0.11944	0.04	0.27
40-50	11	27.599	22.161	34.135	0.10465	0.04	0.26
50-60	12	48.703	37.515	62.233	0.13614	0.04	0.39
60-70	11	82.077	64.823	100.69	0.11522	0.04	0.27
70-80	12	121.91	103.19	144.23	0.13875	0.04	0.24
80-90	11	180.03	147.82	206.72	0.13598	0.04	0.35
90-100	11	443.46	211.54	870.52	0.11487	0.04	0.19



Seasonal Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: NH3 (mg/L)
Data from: 1/10/1984 to 6/5/2002 (115 Observations)

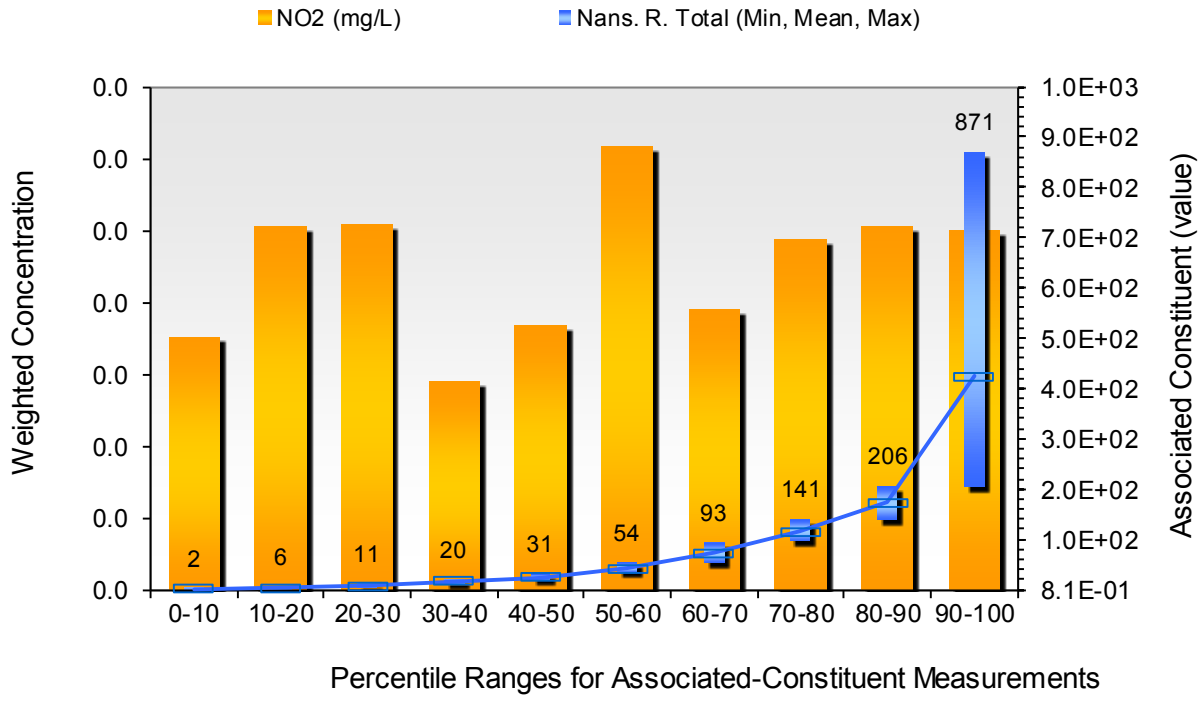
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	6	118.93	56.261	200.35	0.10365	0.04	0.25
February	16	190.54	20.978	870.52	0.10881	0.04	0.19
March	6	434.88	20.167	2418.6	0.13565	0.04	0.22
April	13	136.63	3.5072	738.52	0.10946	0.04	0.21
May	10	76.905	0.94405	265.56	0.15936	0.1	0.39
June	13	33.437	0.81451	166.49	0.14647	0.04	0.2
July	8	31.962	0.85073	175.51	0.28323	0.06	0.35
August	14	54.322	0.88545	179.78	0.14943	0.04	0.27
September	4	48.288	1.3518	177.66	0.098682	0.08	0.1
October	10	55.131	0.83203	368.44	0.11218	0.04	0.19
November	7	61.494	6.5544	140.72	0.10373	0.04	0.13
December	8	168.59	2.2582	779.16	0.12956	0.04	0.27



Constituent-Associated Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: NO2 (mg/L)
Data from: 1/10/1984 to 6/5/2002 (126 Observations)

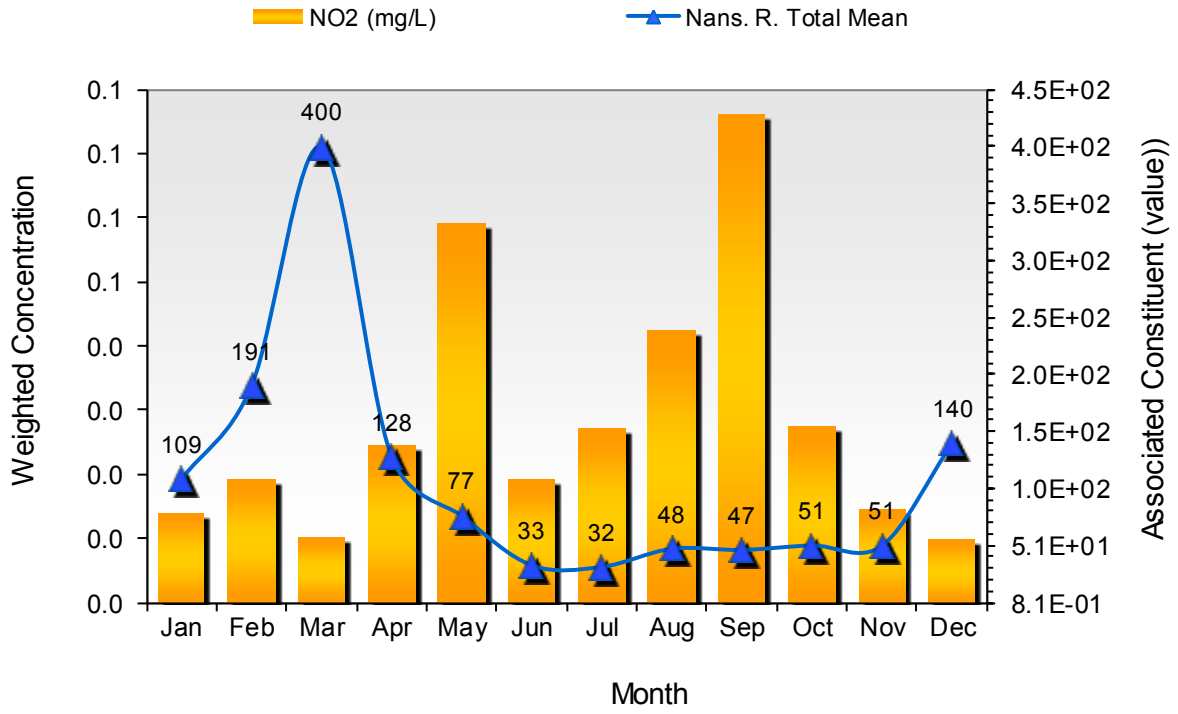
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	13	1.2312	0.81451	2.2582	0.01757	0.01	0.06
10-20	12	4.1931	2.3516	5.8444	0.025226	0.01	0.18
20-30	13	7.7455	6.0095	11.316	0.025465	0.01	0.08
30-40	12	16.358	11.375	20.41	0.014409	0.01	0.05
40-50	13	25.527	20.594	31.236	0.018376	0.01	0.06
50-60	12	43.042	34.135	53.843	0.030778	0.01	0.1
60-70	13	72.252	55.631	92.774	0.019513	0.01	0.06
70-80	12	114.74	98.244	140.63	0.024315	0.01	0.07
80-90	13	173.02	140.72	206.33	0.02523	0.01	0.08
90-100	12	423.73	206.72	870.52	0.024993	0.01	0.13



Seasonal Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: NO2 (mg/L)
Data from: 1/10/1984 to 6/5/2002 (126 Observations)

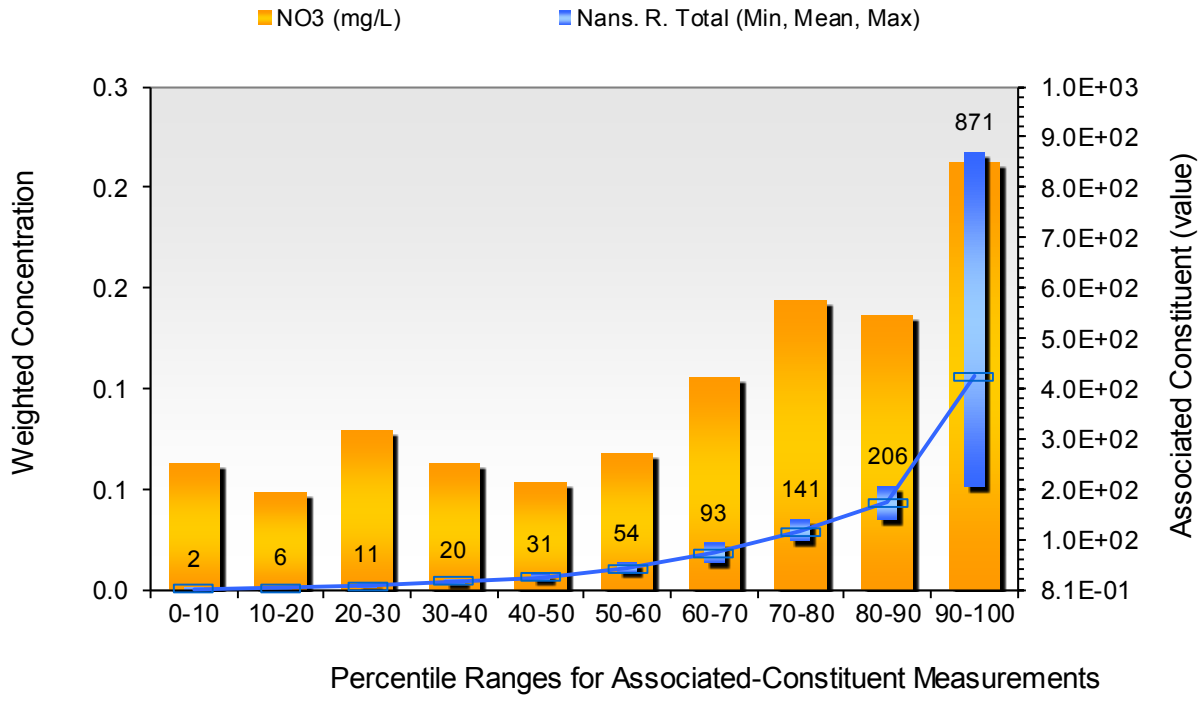
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	7	108.81	48.086	200.35	0.01393	0.01	0.03
February	16	190.54	20.978	870.52	0.019232	0.01	0.03
March	7	399.99	20.167	2418.6	0.010295	0.01	0.02
April	14	128.34	3.5072	738.52	0.024378	0.01	0.06
May	10	76.905	0.94405	265.56	0.059143	0.01	0.13
June	13	33.437	0.81451	166.49	0.019002	0.01	0.08
July	8	31.962	0.85074	175.51	0.027282	0.01	0.06
August	16	47.861	0.88545	179.78	0.042347	0.01	0.18
September	5	46.855	1.3518	177.66	0.075966	0.02	0.08
October	11	50.81	0.83204	368.44	0.027503	0.01	0.03
November	9	50.542	5.7736	140.72	0.014462	0.01	0.02
December	10	140.02	2.2582	779.16	0.01	0.01	0.01



Constituent-Associated Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: NO3 (mg/L)
Data from: 1/10/1984 to 6/5/2002 (126 Observations)

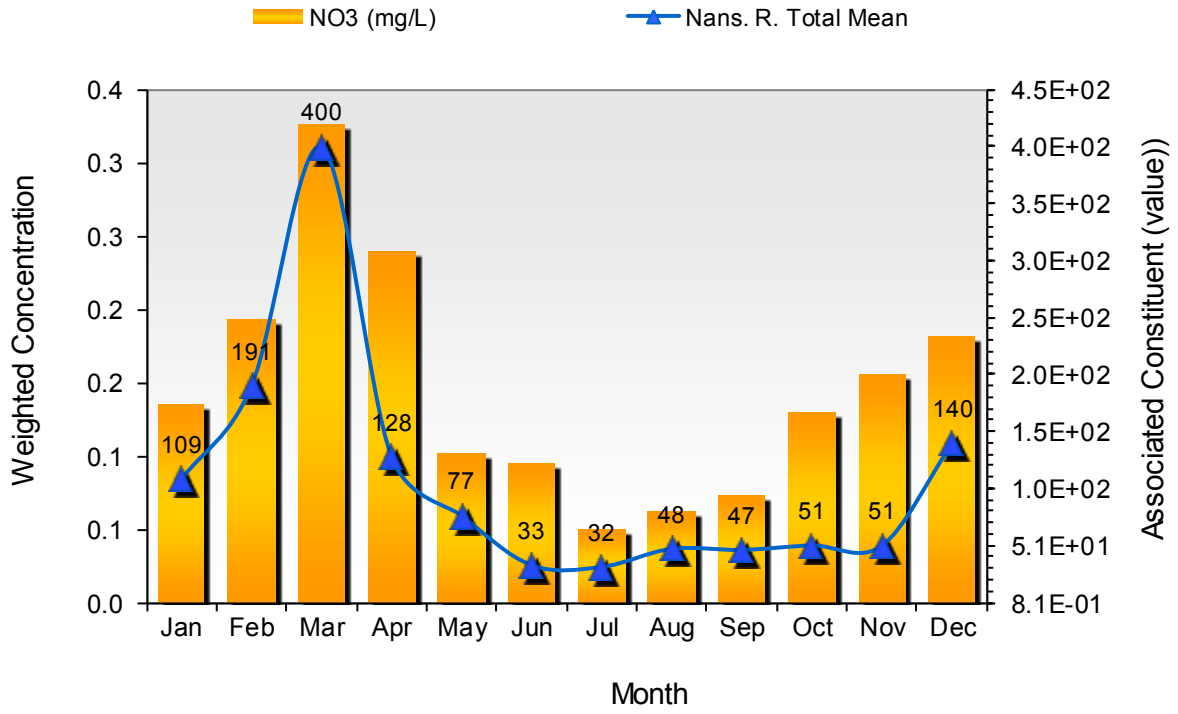
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	13	1.2312	0.81451	2.2582	0.062781	0.04	0.14
10-20	12	4.1931	2.3516	5.8444	0.048002	0.04	0.09
20-30	13	7.7455	6.0095	11.316	0.079292	0.04	0.22
30-40	12	16.358	11.375	20.41	0.062584	0.04	0.2
40-50	13	25.527	20.594	31.236	0.0533	0.04	0.11
50-60	12	43.042	34.135	53.843	0.067487	0.03	0.18
60-70	13	72.252	55.631	92.774	0.10561	0.04	0.28
70-80	12	114.74	98.244	140.63	0.14405	0.04	0.37
80-90	13	173.02	140.72	206.33	0.13633	0.04	0.26
90-100	12	423.73	206.72	870.52	0.21206	0.04	0.4



Seasonal Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: NO3 (mg/L)
Data from: 1/10/1984 to 6/5/2002 (126 Observations)

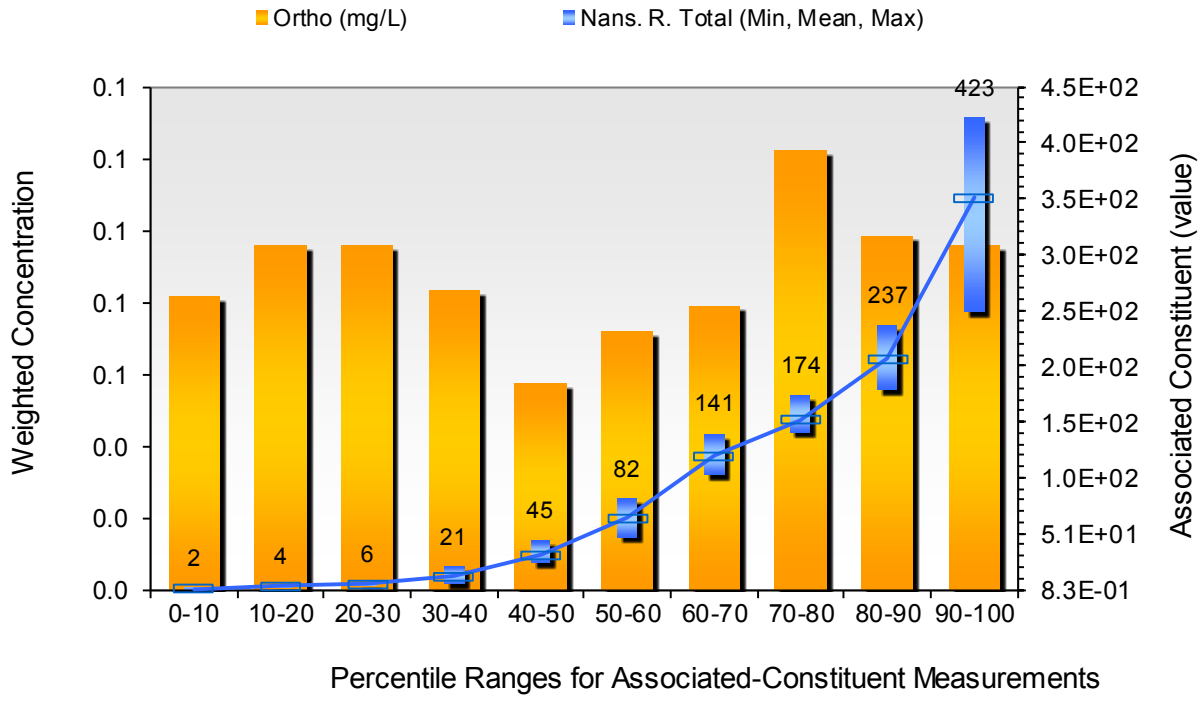
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	7	108.81	48.086	200.35	0.13461	0.04	0.37
February	16	190.54	20.978	870.52	0.19375	0.04	0.33
March	7	399.99	20.167	2418.6	0.32619	0.04	0.36
April	14	128.34	3.5072	738.52	0.23943	0.04	0.4
May	10	76.905	0.94405	265.56	0.1019	0.04	0.2
June	13	33.437	0.81451	166.49	0.095161	0.04	0.15
July	8	31.962	0.85074	175.51	0.049404	0.03	0.12
August	16	47.861	0.88545	179.78	0.061739	0.04	0.18
September	5	46.855	1.3518	177.66	0.072342	0.06	0.12
October	11	50.81	0.83204	368.44	0.12963	0.04	0.22
November	9	50.542	5.7736	140.72	0.15562	0.04	0.28
December	10	140.02	2.2582	779.16	0.18058	0.04	0.29



Constituent-Associated Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: Ortho (mg/L)
Data from: 8/4/1994 to 6/5/2002 (41 Observations)

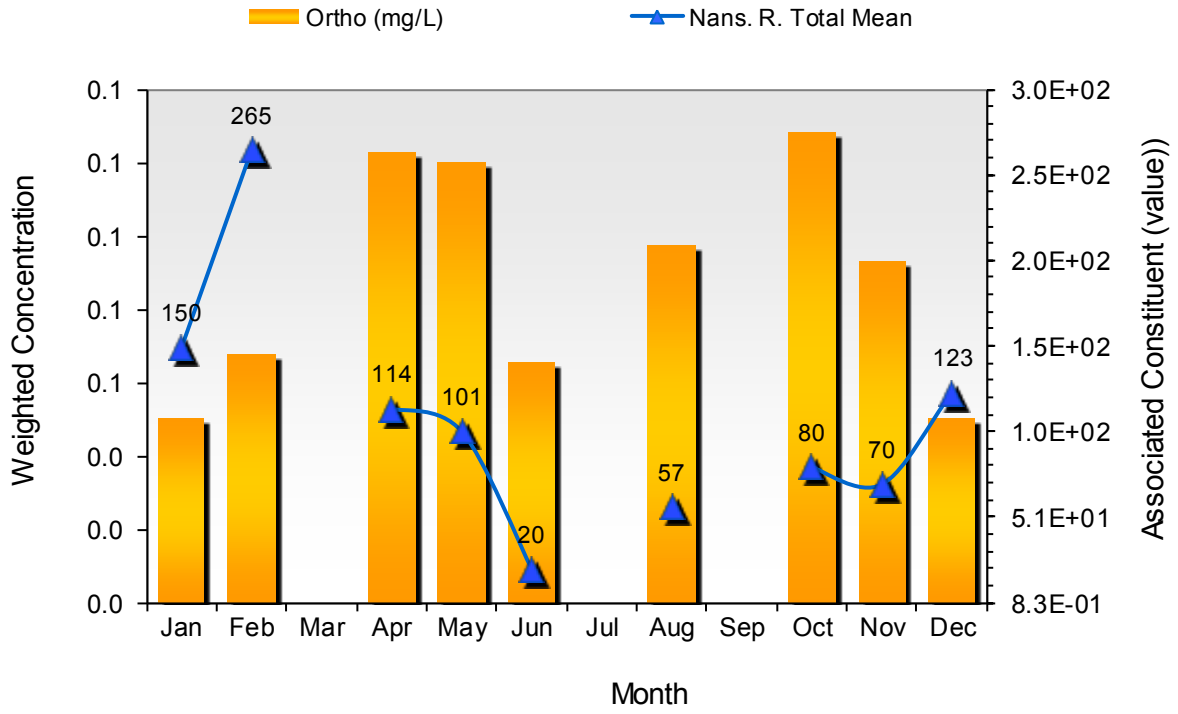
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	4	1.4018	0.83195	2.2581	0.08145	0.06	0.13
10-20	4	3.5659	2.3516	4.2343	0.095699	0.05	0.13
20-30	4	5.5696	4.9205	6.0094	0.095438	0.06	0.11
30-40	4	12.979	6.0211	20.827	0.083357	0.05	0.14
40-50	4	32.065	25.566	44.858	0.057487	0.04	0.09
50-60	4	64.782	47.175	82.323	0.071973	0.04	0.12
60-70	4	120.52	104.09	140.63	0.078754	0.04	0.14
70-80	4	152.27	140.72	174.46	0.12197	0.05	0.17
80-90	4	207.52	179.78	237.25	0.098125	0.07	0.15
90-100	4	351.01	249.31	422.64	0.095463	0.05	0.13



Seasonal Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: Ortho (mg/L)
Data from: 8/4/1994 to 6/5/2002 (41 Observations)

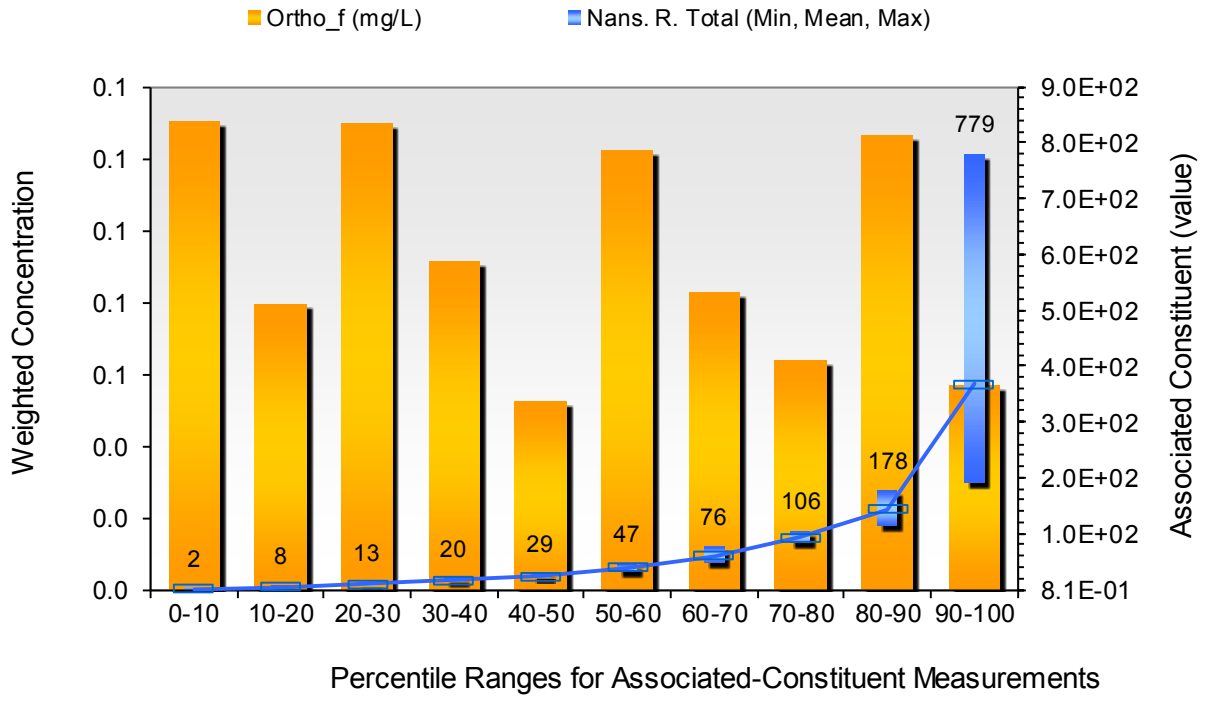
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	1	149.67	149.67	149.67	0.05	0.05	0.05
February	8	265.06	30.109	870.52	0.067614	0.04	0.16
March	0	No Data	No Data	No Data	No Data	No Data	No Data
April	5	114.07	20.827	206.72	0.12246	0.04	0.17
May	3	100.83	6.0094	249.31	0.1198	0.11	0.12
June	5	20.383	1.2744	67.396	0.065392	0.04	0.13
July	0	No Data	No Data	No Data	No Data	No Data	No Data
August	8	56.674	1.2428	179.78	0.097213	0.07	0.14
September	0	No Data	No Data	No Data	No Data	No Data	No Data
October	5	79.862	0.83195	368.44	0.12823	0.05	0.14
November	3	69.836	6.5543	140.72	0.092808	0.06	0.1
December	3	123.38	2.2581	363.66	0.050061	0.05	0.06



Constituent-Associated Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: Ortho_f (mg/L)
Data from: 1/10/1984 to 6/16/1992 (83 Observations)

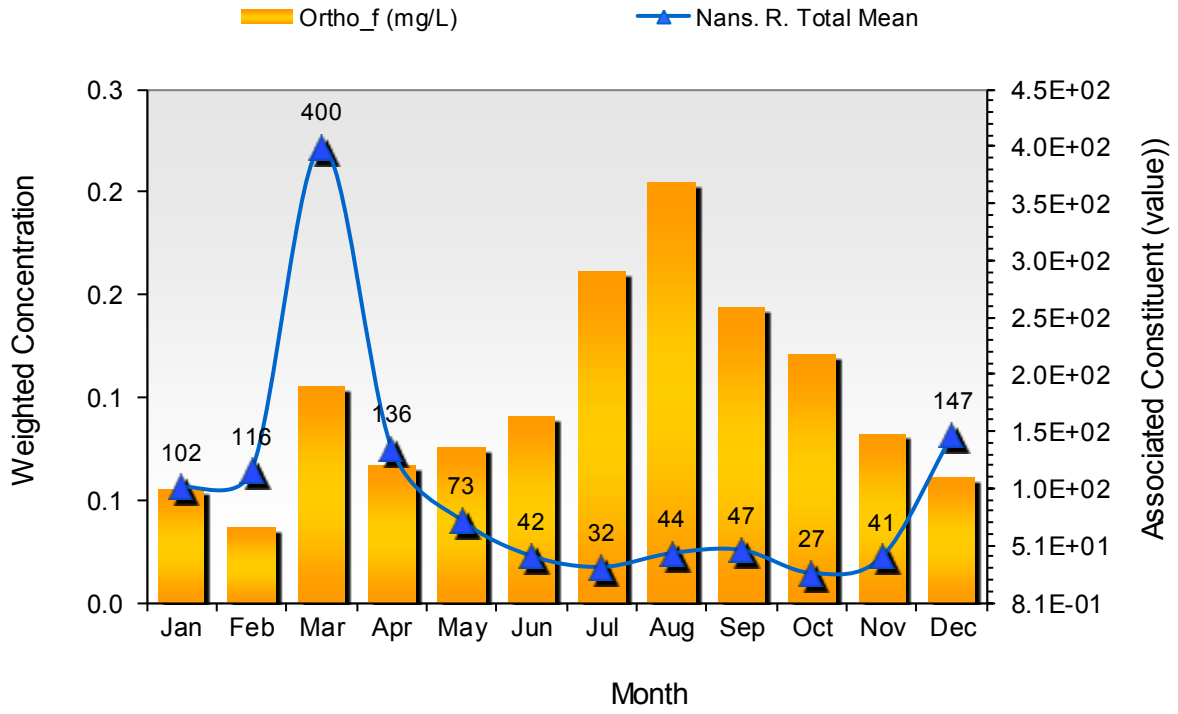
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	9	1.1553	0.81451	2.1804	0.13044	0.05	0.3
10-20	8	5.6136	2.759	7.6338	0.079606	0.04	0.14
20-30	8	9.6805	7.7297	12.76	0.1296	0.07	0.22
30-40	8	16.655	13.909	20.167	0.091216	0.03	0.23
40-50	8	23.493	20.41	28.581	0.052498	0.01	0.07
50-60	9	39.309	31.236	47.439	0.12228	0.04	0.27
60-70	8	60.254	48.086	76.353	0.082533	0.02	0.17
70-80	8	94.398	82.549	105.84	0.06366	0.03	0.09
80-90	8	144.29	114.1	177.66	0.12655	0.02	0.22
90-100	8	369.1	190.63	779.16	0.056849	0.01	0.11



Seasonal Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: Ortho_f (mg/L)
Data from: 1/10/1984 to 6/16/1992 (83 Observations)

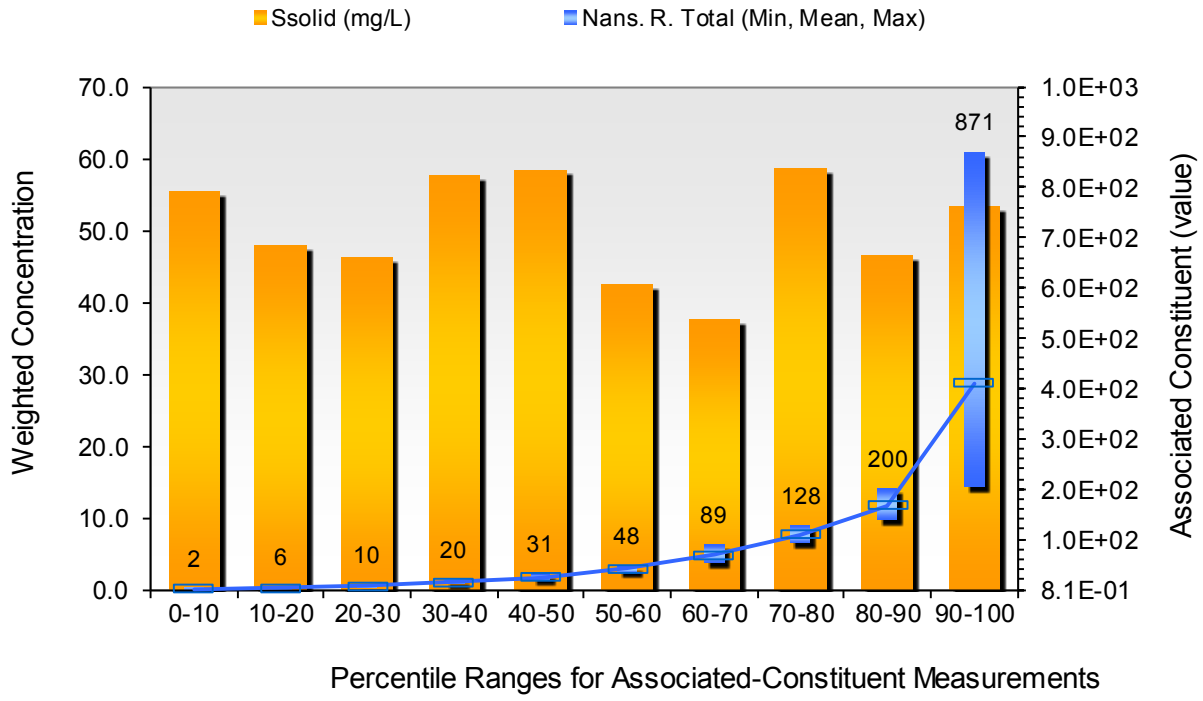
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	6	102	48.086	200.35	0.055433	0.02	0.07
February	8	116.02	20.978	371.46	0.036919	0.01	0.08
March	7	399.99	20.167	2418.6	0.10533	0.03	0.11
April	9	136.26	3.5072	738.52	0.066495	0.01	0.11
May	6	72.95	0.94405	265.56	0.075742	0.03	0.23
June	8	41.595	0.81451	166.49	0.090508	0.05	0.14
July	8	31.962	0.85073	175.51	0.16095	0.05	0.22
August	7	44.102	0.88545	127.61	0.20435	0.08	0.27
September	5	46.855	1.3518	177.66	0.1435	0.14	0.19
October	6	26.6	0.91224	76.353	0.12095	0.08	0.3
November	6	40.895	5.7736	103.19	0.081837	0.06	0.12
December	7	147.15	7.4182	779.16	0.061095	0.05	0.07



Constituent-Associated Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: Ssolid (mg/L)
Data from: 1/10/1984 to 6/5/2002 (124 Observations)

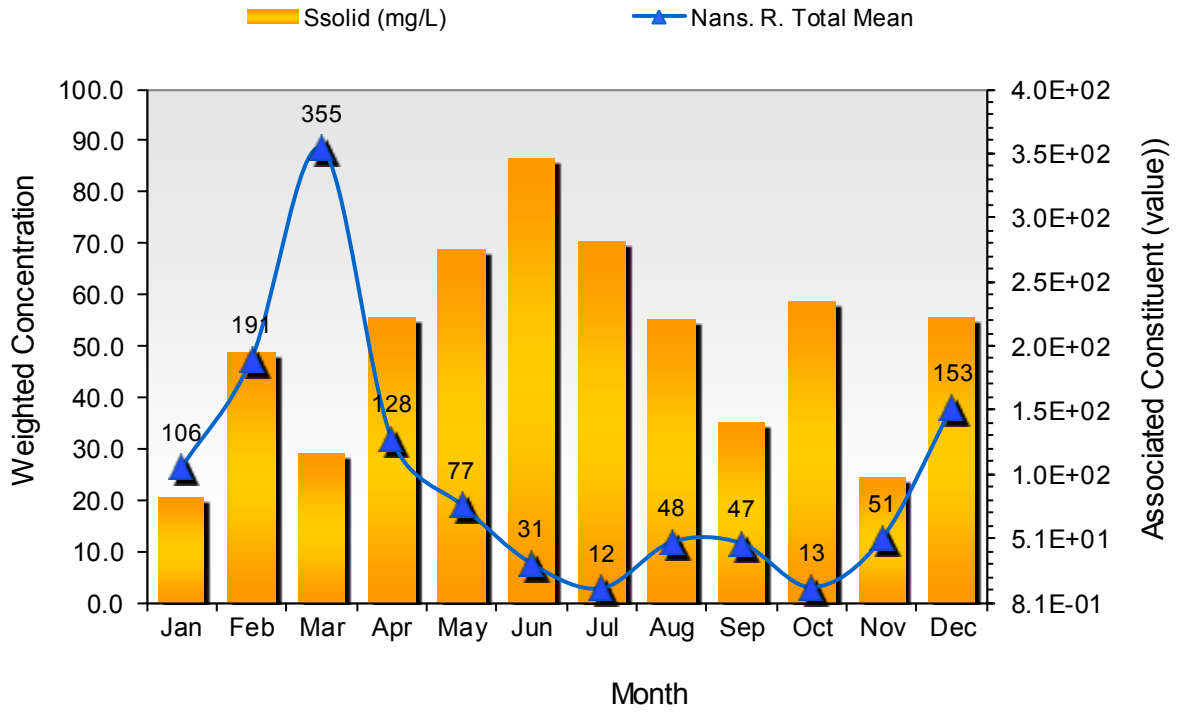
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	13	1.1219	0.81451	2.1804	55.308	22	124
10-20	12	3.8942	2.2582	5.7736	47.926	13	108
20-30	12	7.2262	5.8444	9.7275	46.098	5	80
30-40	13	15.97	11.316	20.41	57.436	17	160
40-50	12	25.808	20.594	31.236	58.388	13	182
50-60	12	41.601	34.135	48.086	42.494	10	76
60-70	13	69.993	53.843	88.823	37.459	12	77
70-80	12	110.75	92.774	127.61	58.703	10	175
80-90	12	167.33	140.63	200.35	46.362	11	152
90-100	12	410.22	206.33	870.52	53.196	20	125



Seasonal Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: Ssolid (mg/L)
Data from: 1/10/1984 to 6/5/2002 (124 Observations)

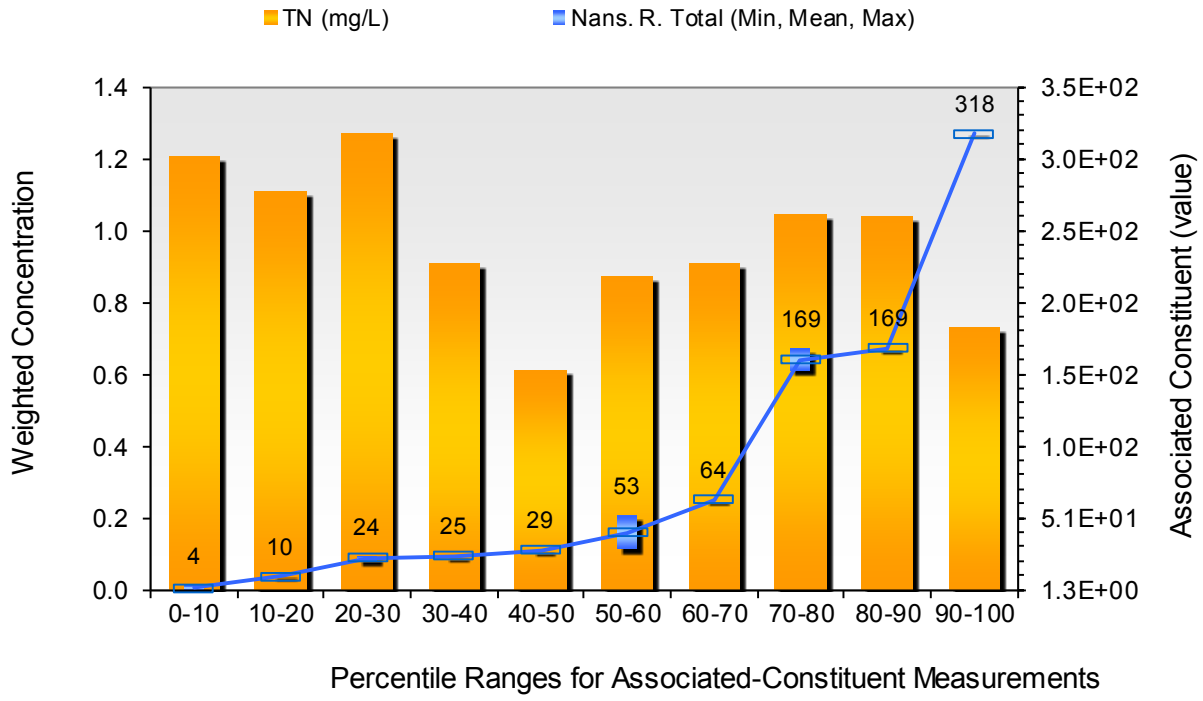
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	8	105.95	48.086	200.35	20.526	10	34
February	16	190.54	20.978	870.52	48.491	13	125
March	8	354.56	20.167	2418.6	29.091	18	182
April	14	128.34	3.5072	738.52	55.452	28	175
May	10	76.905	0.94405	265.56	68.689	48	106
June	14	31.108	0.81451	166.49	86.621	24	152
July	6	11.947	0.85073	40.154	70.415	28	76
August	16	47.861	0.88545	179.78	55.264	25	124
September	5	46.855	1.3518	177.66	35.189	32	66
October	9	12.68	0.83204	64.823	58.54	5	77
November	9	50.542	5.7736	140.72	24.484	11	46
December	9	153.12	2.2582	779.16	55.771	7	72



Constituent-Associated Trend Assessment

Location: 2-NAN019.14
Comparison Parameter: Nans. R. Total
Pollutant: TN (mg/L)
Data from: 9/4/2003 to 12/8/2005 (15 Observations)

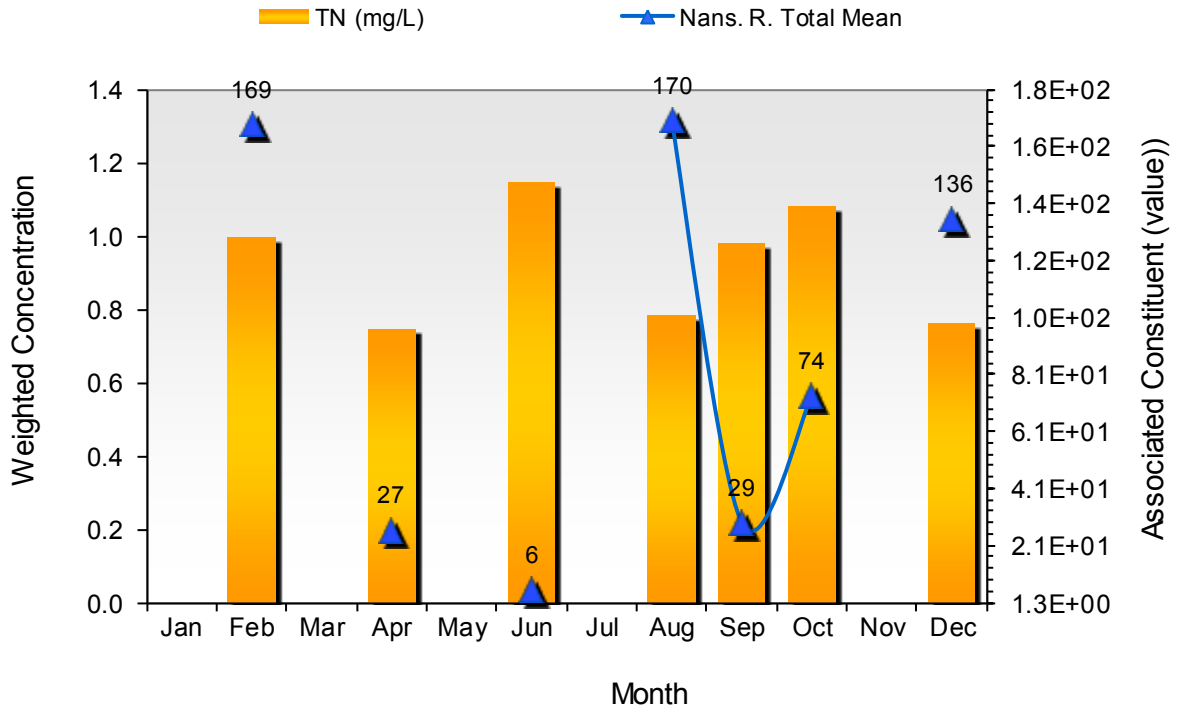
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	2	2.6116	1.2717	3.9514	1.2028	1.12	1.46
10-20	1	10.351	10.351	10.351	1.11	1.11	1.11
20-30	2	23.164	22.203	24.126	1.2723	0.98	1.59
30-40	1	24.793	24.793	24.793	0.91	0.91	0.91
40-50	1	28.898	28.898	28.898	0.61	0.61	0.61
50-60	2	40.877	29.244	52.51	0.87081	0.81	0.98
60-70	1	63.909	63.909	63.909	0.91	0.91	0.91
70-80	2	160.97	153.42	168.53	1.0453	0.95	1.15
80-90	1	169.18	169.18	169.18	1.04	1.04	1.04
90-100	1	318.26	318.26	318.26	0.73	0.73	0.73



Seasonal Trend Assessment

Location: 2-NAN019.14
Comparison Parameter: Nans. R. Total
Pollutant: TN (mg/L)
Data from: 9/4/2003 to 12/8/2005 (15 Observations)

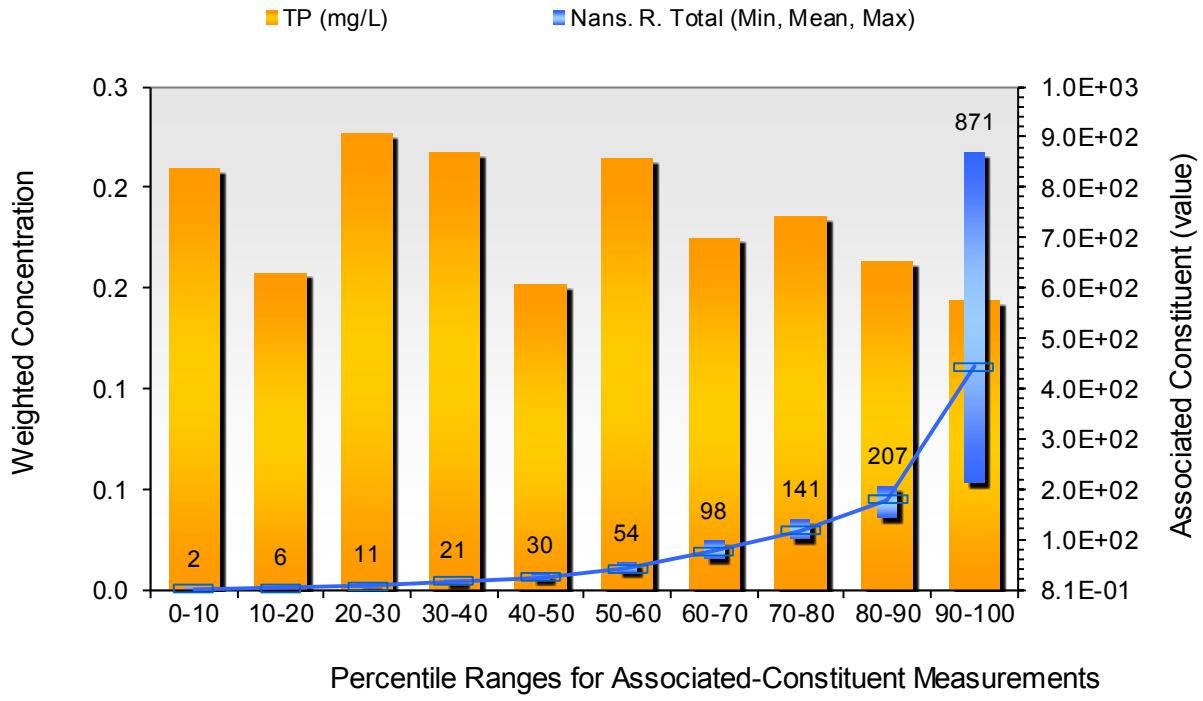
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	0	No Data	No Data	No Data	No Data	No Data	No Data
February	2	168.85	168.53	169.18	0.99509	0.95	1.04
March	0	No Data	No Data	No Data	No Data	No Data	No Data
April	2	26.846	24.793	28.898	0.74853	0.61	0.91
May	0	No Data	No Data	No Data	No Data	No Data	No Data
June	2	5.8113	1.2717	10.351	1.1483	1.11	1.46
July	0	No Data	No Data	No Data	No Data	No Data	No Data
August	2	170.23	22.203	318.26	0.78608	0.73	1.59
September	1	29.244	29.244	29.244	0.98	0.98	0.98
October	3	73.76	3.9514	153.42	1.0801	0.91	1.15
November	0	No Data	No Data	No Data	No Data	No Data	No Data
December	3	136.02	24.126	331.42	0.7632	0.74	0.98



Constituent-Associated Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: TP (mg/L)
Data from: 1/10/1984 to 6/5/2002 (119 Observations)

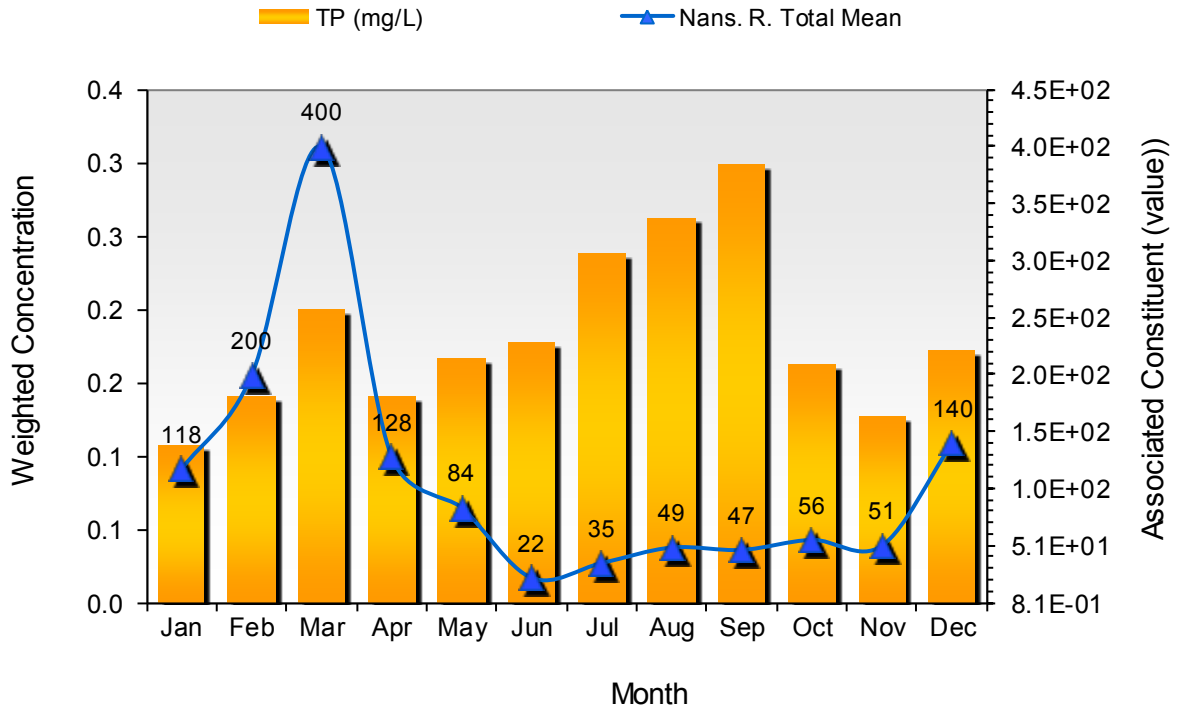
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	12	1.152	0.8145	2.2582	0.2091	0.1	0.4
10-20	12	4.1931	2.3516	5.8444	0.15726	0.09	0.3
20-30	12	7.7075	6.0095	11.316	0.2273	0.1	0.7
30-40	12	16.915	11.375	20.594	0.21697	0.1	0.3
40-50	11	25.457	20.827	30.11	0.15163	0.07	0.3
50-60	12	43.042	34.135	53.843	0.21387	0.1	0.4
60-70	12	77.136	61.232	98.244	0.17439	0.08	0.3
70-80	12	118.28	100.69	140.72	0.18531	0.1	0.4
80-90	12	179.06	144.23	206.72	0.1628	0.1	0.3
90-100	11	443.46	211.54	870.52	0.14428	0.1	0.2



Seasonal Trend Assessment

Location: DEQ-2-NAN010.69
Comparison Parameter: Nans. R. Total
Pollutant: TP (mg/L)
Data from: 1/10/1984 to 6/5/2002 (119 Observations)

Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	6	117.57	48.086	200.35	0.10637	0.1	0.13
February	15	199.53	20.978	870.52	0.14087	0.08	0.2
March	7	399.99	20.167	2418.6	0.19971	0.1	0.3
April	14	128.34	3.5072	738.52	0.14019	0.07	0.3
May	9	83.905	0.94404	265.56	0.16644	0.1	0.2
June	12	22.349	0.8145	100.69	0.17705	0.1	0.3
July	7	35.356	0.85073	175.51	0.23718	0.2	0.7
August	15	48.97	0.88544	179.78	0.26267	0.1	0.4
September	5	46.855	1.3518	177.66	0.29825	0.2	0.3
October	10	55.673	0.83203	368.44	0.16241	0.1	0.3
November	9	50.542	5.7736	140.72	0.12756	0.1	0.2
December	10	140.02	2.2582	779.16	0.1712	0.09	0.2

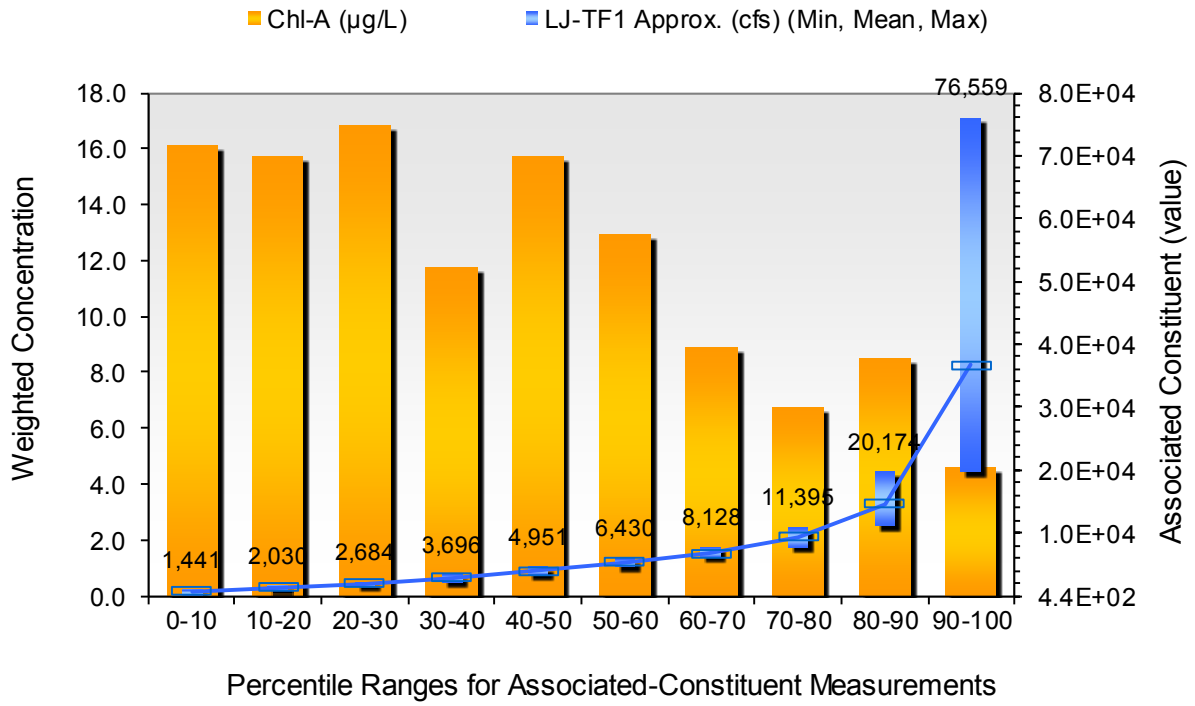


Lower James-TF1

Constituent-Associated Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 9/20/2012 (380 Observations)

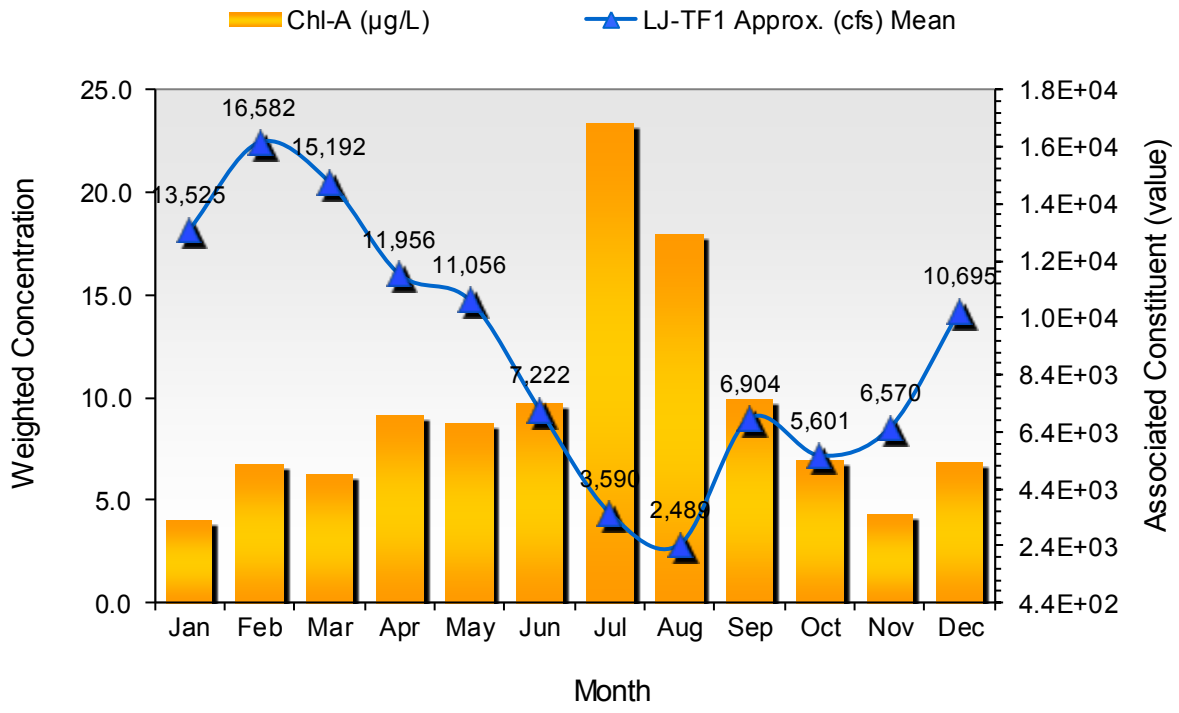
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	1105.52	435.086	1440.64	16.1177	2.06	58.09
10-20	38	1719.9	1459.31	2030.31	15.7191	1.66	42.04
20-30	38	2310.05	2041.47	2683.86	16.7872	1.23	54.5
30-40	38	3238.48	2709.4	3696.42	11.7375	1	35.5
40-50	38	4384.07	3734.35	4950.77	15.7116	1.48	47
50-60	38	5727.45	4956.84	6430.3	12.9241	0.5805	46.89
60-70	38	7164.99	6470.69	8127.91	8.87288	0.5	38.31
70-80	38	9773.02	8284.81	11395.4	6.73822	0.5	37.93
80-90	38	15037.9	11438.4	20174	8.46458	1	26.08
90-100	37	37097.8	20345.7	76559.3	4.6012	0.5	32



Seasonal Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 9/20/2012 (380 Observations)

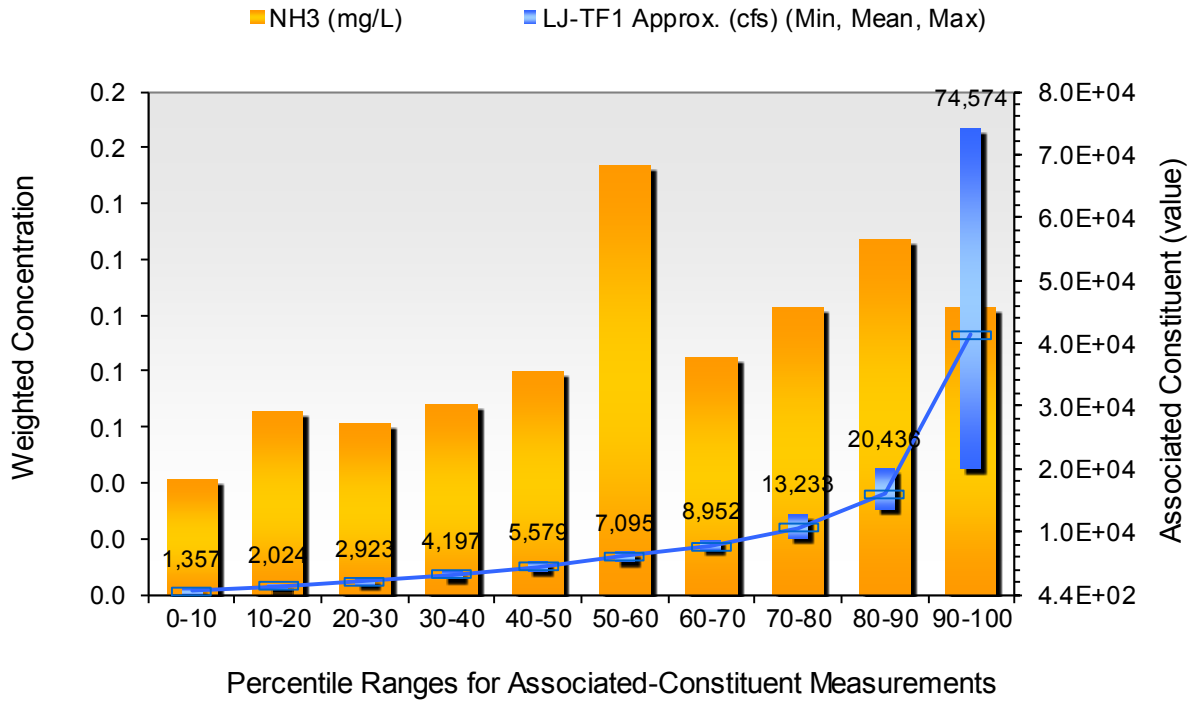
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	25	13525.1	2505.29	59581	3.97651	0.82	33.9
February	25	16582	1832.02	116527	6.67942	0.5	23.1
March	34	15191.8	3627.84	53744.3	6.20433	1	34.02
April	34	11956	3767.21	49356.5	9.12188	1	44.74
May	35	11056.1	2359.58	56593.9	8.73393	0.5	33.79
June	37	7222.22	742.965	74574.1	9.71302	0.5	46.89
July	34	3590.34	830.414	15716.9	23.3257	4.1	54.5
August	35	2488.51	435.086	10232	17.8851	3.9	58.09
September	35	6903.87	665.625	76559.3	9.93806	1.83	31.24
October	35	5600.94	729.247	52069.3	6.92589	1.23	35.17
November	28	6570.24	1167.74	25616.2	4.30122	1	24.07
December	23	10694.9	1516.42	37113.3	6.84997	0.5	32



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: NH3 (mg/L)
Data from: 1/25/1995 to 12/10/2007 (153 Observations)

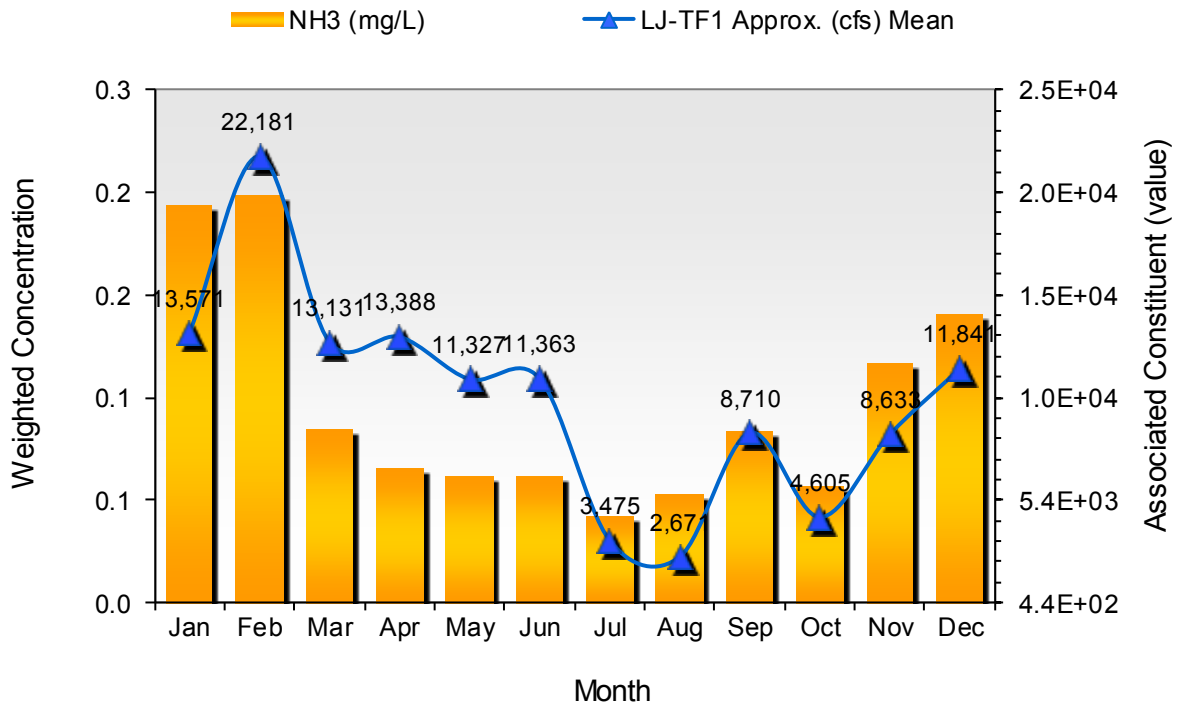
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	16	990.443	435.086	1356.55	0.0407369	0.04	0.05
10-20	15	1719.73	1489.07	2024.11	0.0650743	0.04	0.27
20-30	15	2450.98	2044.04	2923.47	0.0611444	0.04	0.21
30-40	15	3595.64	3051.91	4197.2	0.0680383	0.04	0.13
40-50	15	4873.18	4290.83	5578.85	0.0796718	0.04	0.42
50-60	16	6499.03	5725.31	7094.91	0.153553	0.04	0.5
60-70	15	8113.54	7406.8	8951.64	0.0850407	0.04	0.23
70-80	15	11022	9255.43	13232.7	0.102741	0.04	0.24
80-90	15	16439.5	14104.6	20435.9	0.127015	0.04	0.27
90-100	15	41788.6	20506.3	74574.1	0.102533	0.04	0.22



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: NH3 (mg/L)
Data from: 1/25/1995 to 12/10/2007 (153 Observations)

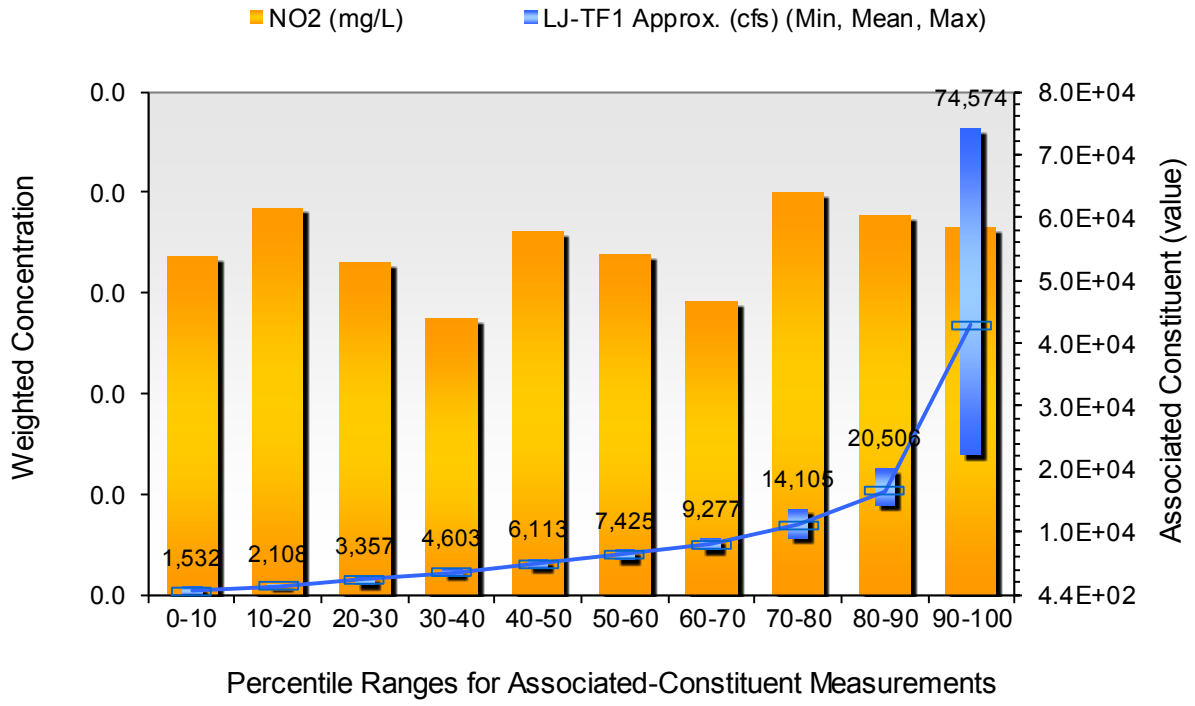
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	12	13570.7	2505.29	55288.9	0.194111	0.04	0.27
February	13	22180.9	1832.02	116527	0.198521	0.1	0.5
March	13	13130.8	3627.84	41514.6	0.0847774	0.04	0.3
April	13	13388.1	3767.21	49356.5	0.0656057	0.04	0.14
May	13	11327.4	2359.58	56593.9	0.061801	0.04	0.09
June	13	11363.2	742.965	74574.1	0.0613297	0.04	0.08
July	13	3474.64	830.413	10968.9	0.0419256	0.04	0.07
August	13	2670.85	435.086	10232	0.052596	0.04	0.1
September	13	8710.48	665.625	62161.4	0.0839885	0.04	0.15
October	13	4605.23	729.247	18521.7	0.0569467	0.04	0.13
November	13	8633.19	1167.74	25616.2	0.116793	0.04	0.2
December	11	11841.4	1516.42	37113.3	0.140297	0.04	0.42



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: NO2 (mg/L)
Data from: 1/25/1995 to 5/30/2007 (146 Observations)

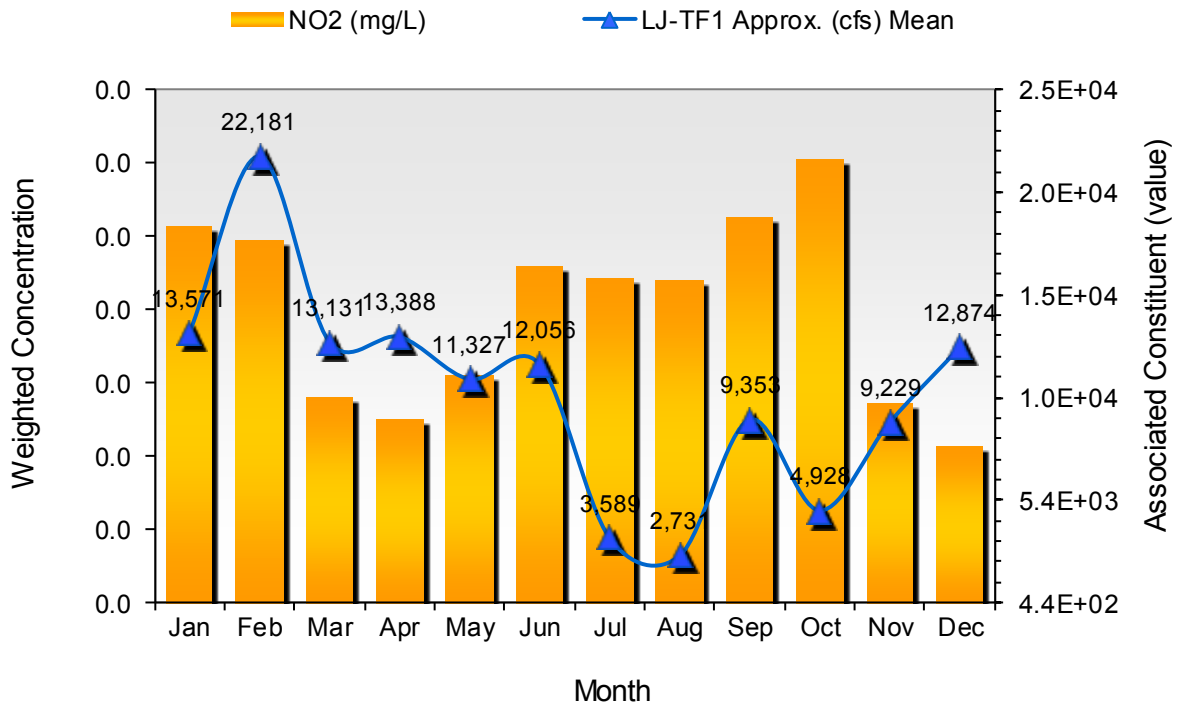
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	15	1043.62	435.086	1531.96	0.016776	0.01	0.09
10-20	14	1822.68	1553.04	2108.28	0.0192328	0.01	0.11
20-30	15	2767.49	2124.55	3357.28	0.0164649	0.01	0.03
30-40	14	3976.05	3412.17	4602.62	0.0136813	0.01	0.04
40-50	15	5277.95	4673.86	6112.67	0.0180126	0.01	0.04
50-60	14	6778.27	6131.79	7425	0.0169398	0.01	0.04
60-70	15	8360.25	7427.29	9277.01	0.0146131	0.01	0.04
70-80	14	11493	9365.46	14104.6	0.0200083	0.01	0.05
80-90	15	16866.3	14555.1	20506.3	0.0188245	0.01	0.04
90-100	14	43308.7	22666.9	74574.1	0.0182349	0.01	0.08



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: NO2 (mg/L)
Data from: 1/25/1995 to 5/30/2007 (146 Observations)

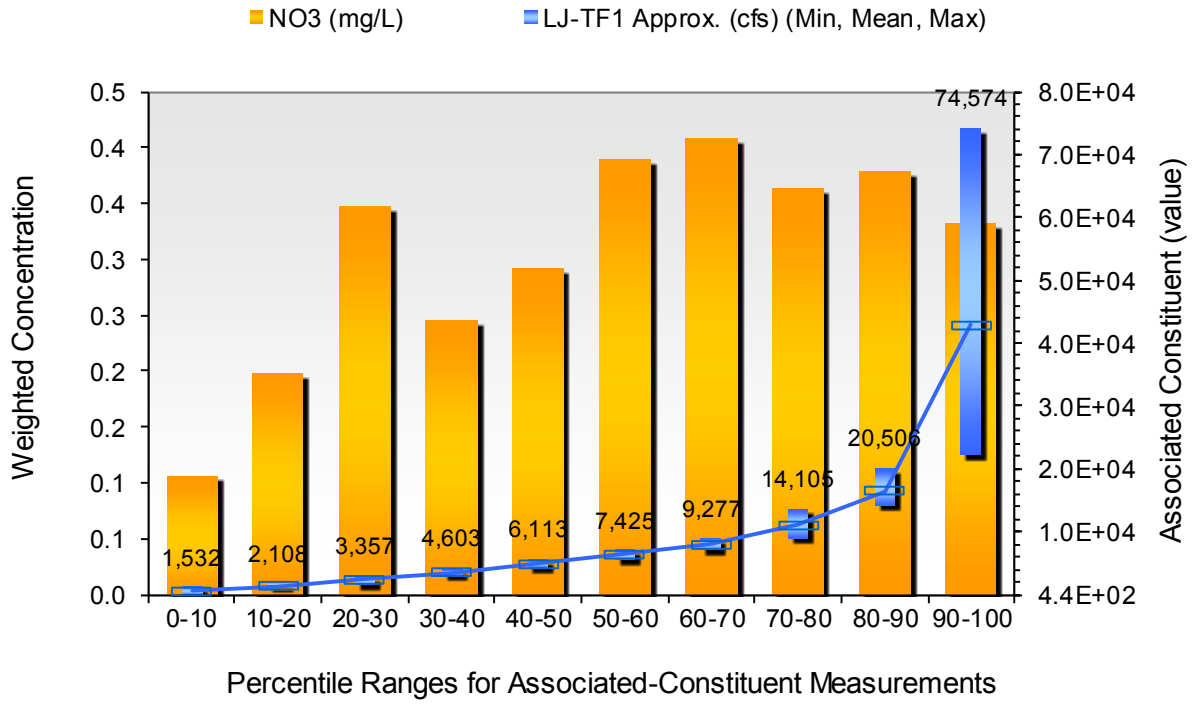
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	12	13570.7	2505.29	55288.9	0.0256868	0.01	0.05
February	13	22180.9	1832.02	116527	0.0246559	0.01	0.04
March	13	13130.8	3627.84	41514.6	0.0140603	0.01	0.03
April	13	13388.1	3767.21	49356.5	0.0124871	0.01	0.04
May	13	11327.4	2359.58	56593.9	0.0154798	0.01	0.04
June	12	12055.8	742.965	74574.1	0.0229315	0.01	0.03
July	12	3588.7	830.413	10968.9	0.0221105	0.01	0.04
August	12	2730.58	435.086	10232	0.0219946	0.01	0.05
September	12	9353.39	665.625	62161.4	0.026351	0.01	0.09
October	12	4928.23	904.652	18521.7	0.0301877	0.01	0.11
November	12	9228.53	1167.74	25616.2	0.0136181	0.01	0.02
December	10	12873.9	1676.05	37113.3	0.0106941	0.01	0.02



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: NO3 (mg/L)
Data from: 1/25/1995 to 5/30/2007 (146 Observations)

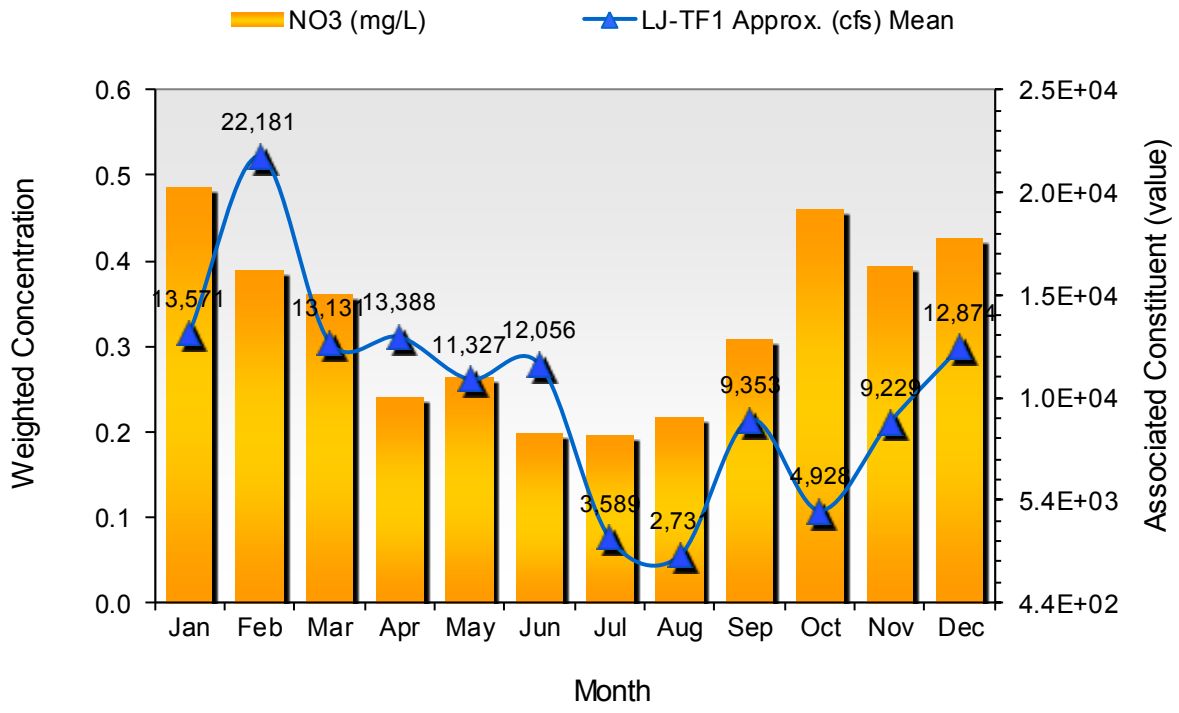
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	15	1043.62	435.086	1531.96	0.105737	0.04	0.27
10-20	14	1822.68	1553.04	2108.28	0.198105	0.04	0.58
20-30	15	2767.49	2124.55	3357.28	0.348205	0.04	0.65
30-40	14	3976.05	3412.17	4602.62	0.24503	0.04	0.49
40-50	15	5277.95	4673.86	6112.67	0.292669	0.04	0.56
50-60	14	6778.27	6131.79	7425	0.390006	0.1	0.66
60-70	15	8360.25	7427.29	9277.01	0.40843	0.04	0.64
70-80	14	11493	9365.46	14104.6	0.362421	0.19	0.57
80-90	15	16866.3	14555.1	20506.3	0.377951	0.17	0.57
90-100	14	43308.7	22666.9	74574.1	0.332297	0.15	0.49



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: NO3 (mg/L)
Data from: 1/25/1995 to 5/30/2007 (146 Observations)

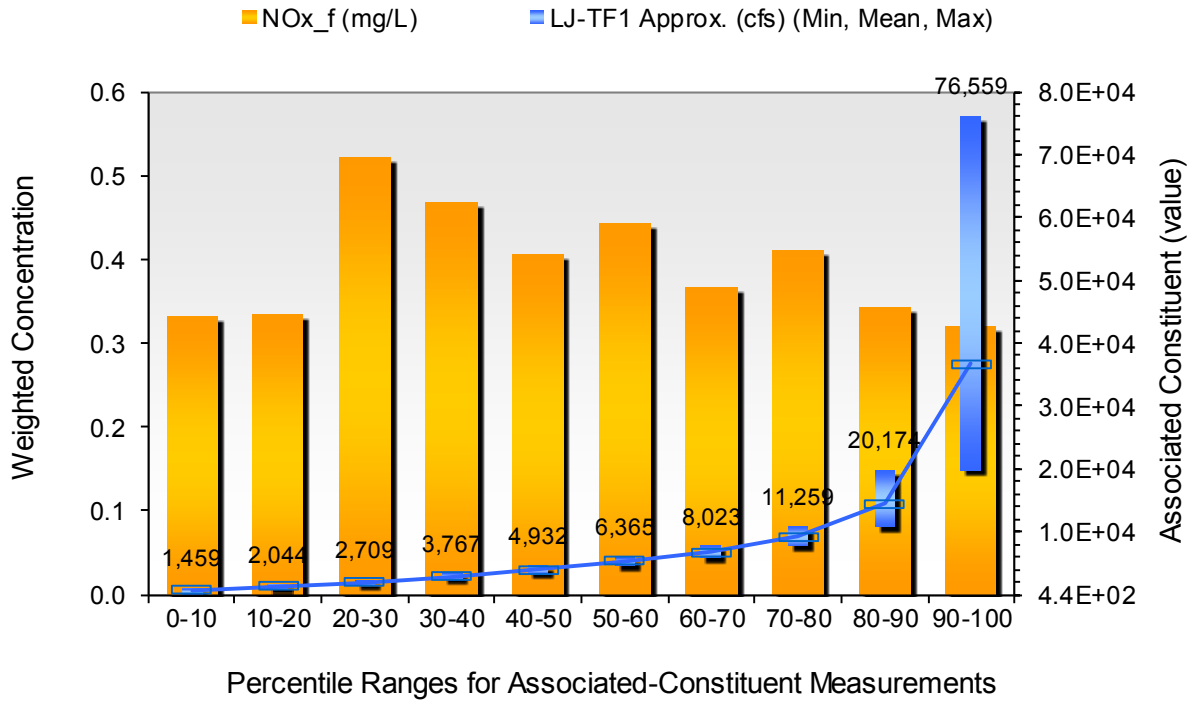
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	12	13570.7	2505.29	55288.9	0.485242	0.29	0.61
February	13	22180.9	1832.02	116527	0.389362	0.19	0.64
March	13	13130.8	3627.84	41514.6	0.361703	0.17	0.66
April	13	13388.1	3767.21	49356.5	0.240307	0.1	0.42
May	13	11327.4	2359.58	56593.9	0.263377	0.04	0.5
June	12	12055.8	742.965	74574.1	0.197394	0.04	0.43
July	12	3588.7	830.413	10968.9	0.196729	0.04	0.36
August	12	2730.58	435.086	10232	0.217572	0.04	0.42
September	12	9353.39	665.625	62161.4	0.307177	0.04	0.51
October	12	4928.23	904.652	18521.7	0.459649	0.045	0.65
November	12	9228.53	1167.74	25616.2	0.392672	0.15	0.63
December	10	12873.9	1676.05	37113.3	0.425593	0.22	0.62



Constituent-Associated Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/4/1985 to 9/20/2012 (389 Observations)

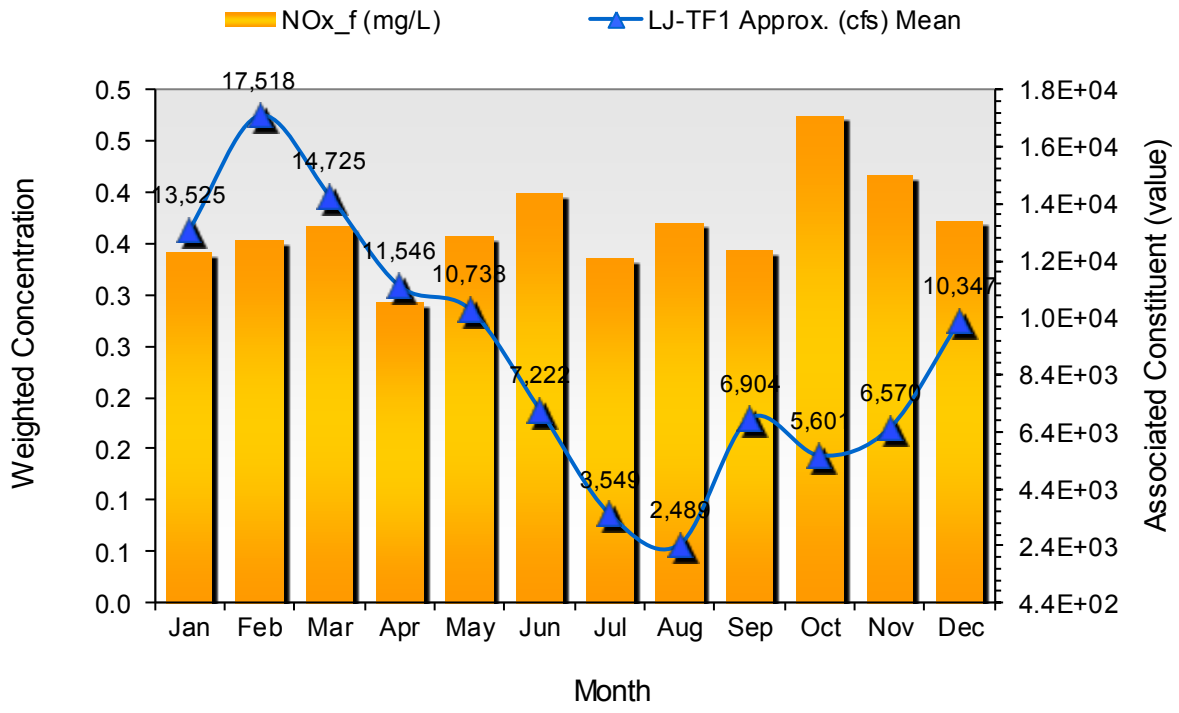
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	39	1114.59	435.086	1459.31	0.331215	0	1.15
10-20	39	1743.14	1489.07	2044.04	0.334131	0	1.11
20-30	39	2330.16	2055.47	2709.4	0.520322	0	1.37
30-40	39	3278.32	2780.68	3767.21	0.468133	0	1.02
40-50	38	4406.61	3777.78	4932.08	0.405332	0	1.075
50-60	39	5693.5	4950.77	6364.6	0.442287	0	1
60-70	39	7139.81	6430.3	8022.89	0.365775	0	0.735
70-80	39	9656.24	8127.91	11258.6	0.409257	0	0.7225
80-90	39	14944.5	11395.4	20174	0.341883	0	0.63375
90-100	38	37132.6	20345.7	76559.3	0.31979	0	0.608



Seasonal Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/4/1985 to 9/20/2012 (389 Observations)

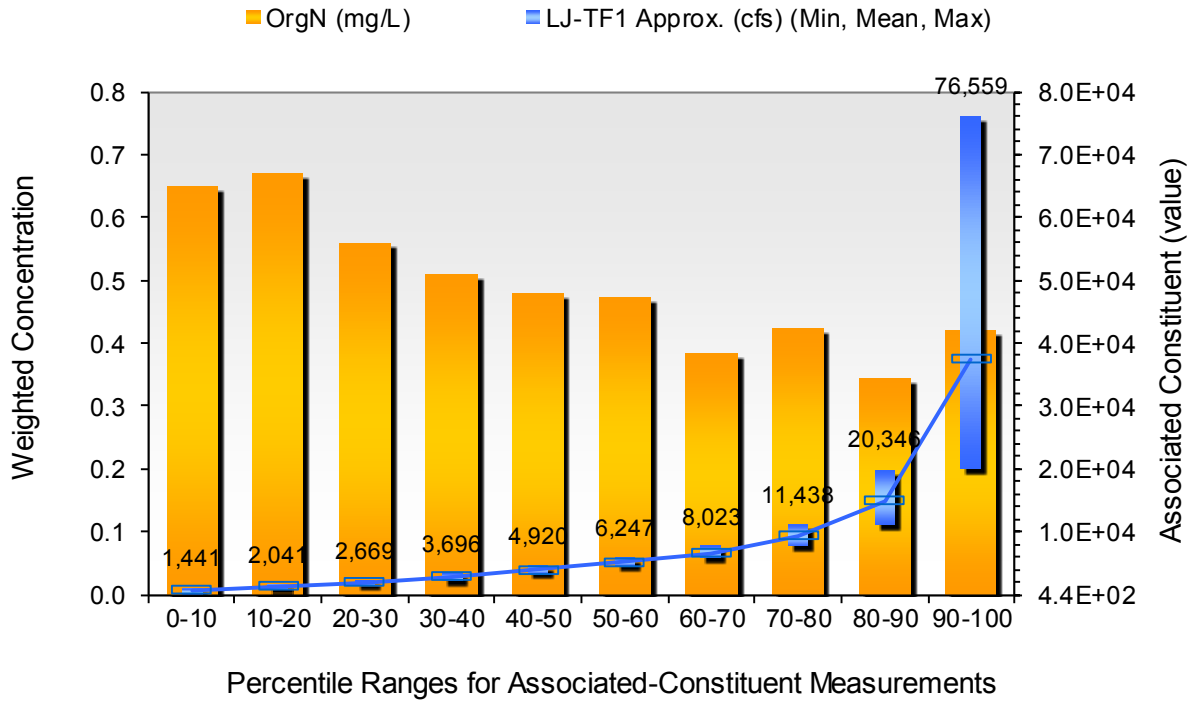
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	25	13525.1	2505.29	59581	0.341789	0	0.9325
February	26	17518.2	1832.02	116527	0.351744	0	0.7975
March	36	14724.6	3627.84	53744.3	0.365637	0	0.6645
April	36	11545.6	3767.21	49356.5	0.293319	0	0.7
May	37	10738.3	2359.58	56593.9	0.356142	0	1.075
June	37	7222.22	742.965	74574.1	0.398894	0	1.02
July	35	3548.69	830.414	15716.9	0.334656	0	0.8
August	35	2488.51	435.086	10232	0.3708	0	0.865
September	35	6903.87	665.625	76559.3	0.342824	0	1.15
October	35	5600.94	729.247	52069.3	0.473907	0	1.2
November	28	6570.24	1167.74	25616.2	0.417117	0	1.37
December	24	10346.7	1516.42	37113.3	0.371398	0	1.165



Constituent-Associated Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (370 Observations)

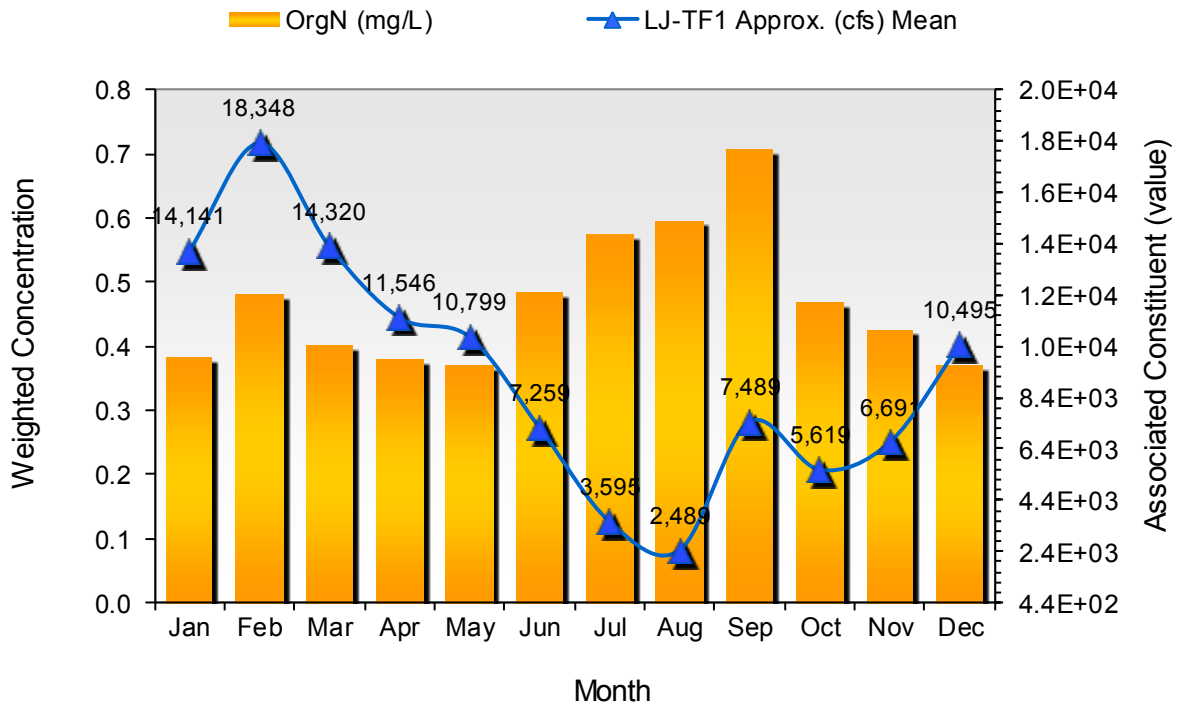
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	37	1100.81	435.086	1440.64	0.649803	0	1.3
10-20	37	1727.15	1459.31	2041.47	0.668807	0	1.35
20-30	37	2309.89	2044.04	2669.03	0.558577	0	1.025
30-40	37	3228.47	2683.86	3696.42	0.510501	0	1.05
40-50	37	4344.11	3734.35	4920.39	0.480001	0	1
50-60	37	5622.29	4932.08	6247.33	0.473589	0	0.915
60-70	37	7031.24	6293.41	8022.89	0.383964	0	0.9
70-80	37	9807.86	8127.91	11438.4	0.423144	0	0.805
80-90	37	15303.8	11581.8	20345.7	0.342013	0	0.685
90-100	36	37828.2	20435.9	76559.3	0.41988	0	1.0625



Seasonal Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (370 Observations)

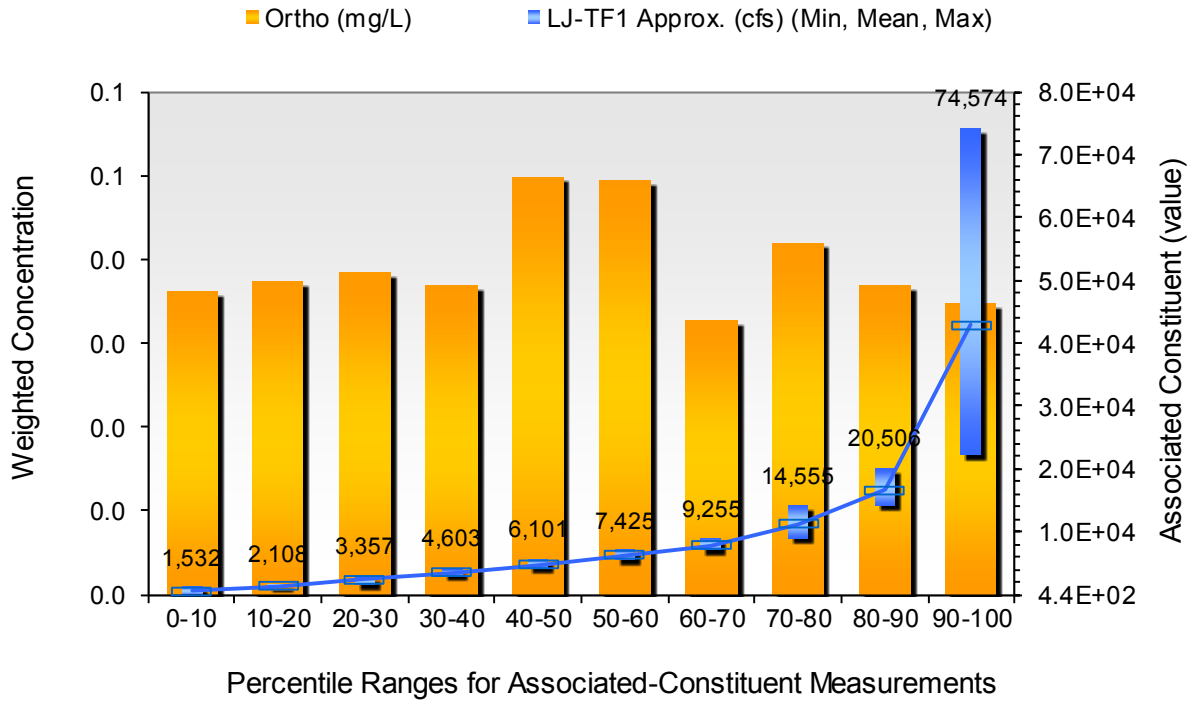
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	21	14141.1	2505.29	59581	0.38264	0	0.6775
February	24	18347.5	1832.02	116527	0.480467	0	0.987
March	35	14320.2	3627.84	53744.3	0.399333	0	0.915
April	36	11545.6	3767.21	49356.5	0.377748	0	0.895
May	36	10798.6	2359.58	56593.9	0.369751	0	1
June	35	7259.05	742.965	74574.1	0.483797	0	0.9135
July	34	3595.39	830.414	15716.9	0.573266	0	1.09667
August	35	2488.51	435.086	10232	0.596599	0	1.09
September	31	7489.04	665.625	76559.3	0.707092	0	1.35
October	33	5619.48	729.247	52069.3	0.467913	0	1.32
November	27	6690.67	1167.74	25616.2	0.424289	0	1.025
December	23	10495	1516.42	37113.3	0.368237	0	0.765



Constituent-Associated Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: Ortho (mg/L)
Data from: 2/27/1995 to 5/30/2007 (145 Observations)

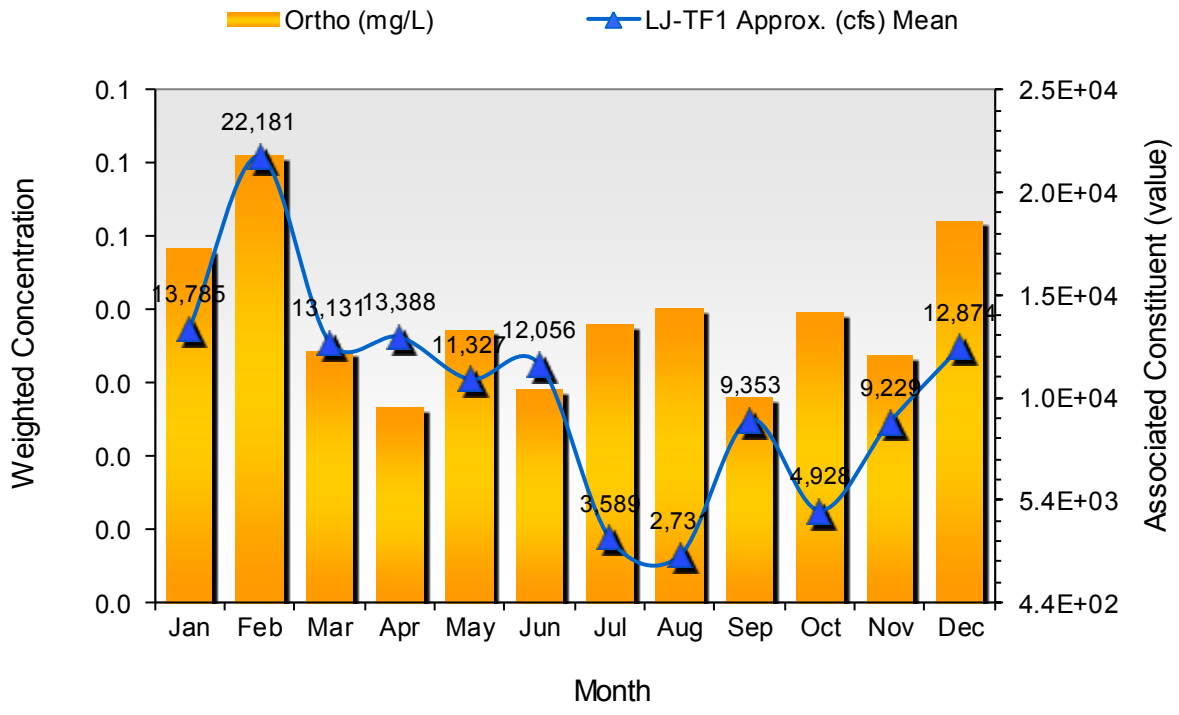
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	15	1043.62	435.086	1531.96	0.0362076	0.02	0.07
10-20	14	1822.68	1553.04	2108.28	0.0373081	0.02	0.08
20-30	15	2767.49	2124.55	3357.28	0.0385128	0.02	0.07
30-40	14	3976.05	3412.17	4602.62	0.0369228	0.02	0.09
40-50	14	5218.33	4673.86	6101.46	0.0497682	0.02	0.1
50-60	15	6733.9	6112.67	7425	0.0492972	0.02	0.09
60-70	14	8294.76	7427.29	9255.43	0.0326845	0.02	0.07
70-80	15	11568.1	9277.01	14555.1	0.0419102	0.02	0.1
80-90	14	17031.4	14562.5	20506.3	0.0368274	0.02	0.09
90-100	14	43308.7	22666.9	74574.1	0.0346523	0.01	0.07



Seasonal Trend Assessment

Location: 2-JMS110.30
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: Ortho (mg/L)
Data from: 2/27/1995 to 5/30/2007 (145 Observations)

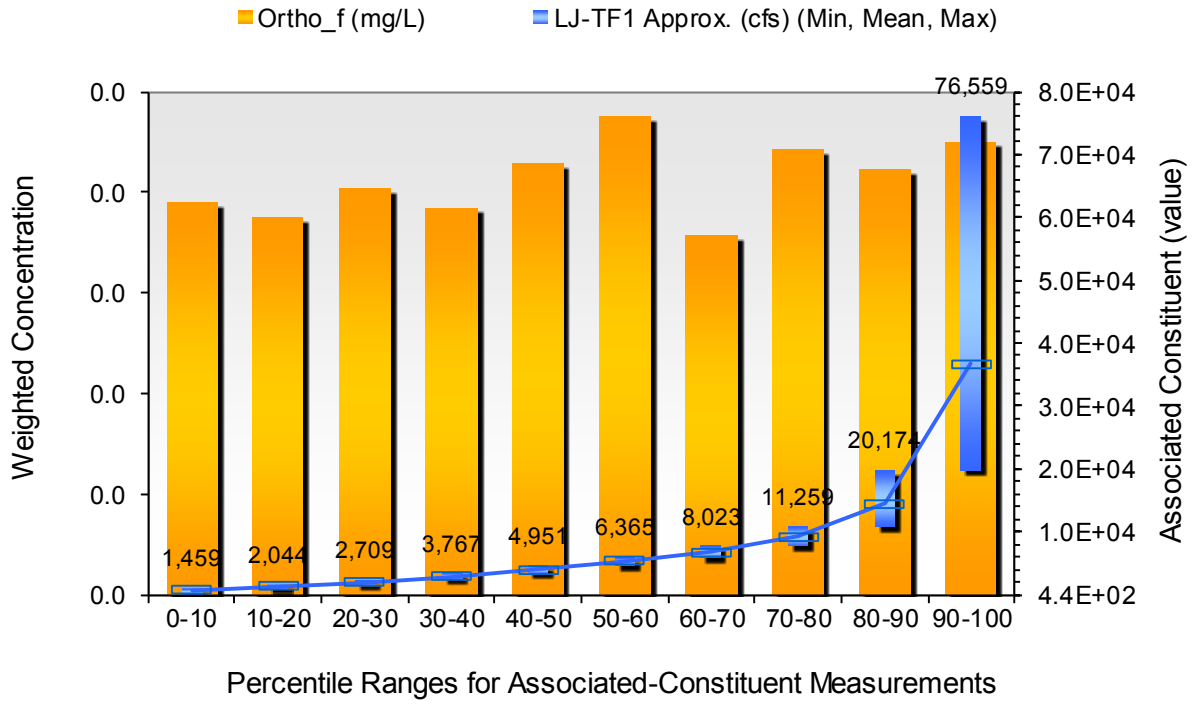
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	11	13785	2505.29	55288.9	0.0482016	0.02	0.1
February	13	22180.9	1832.02	116527	0.0610595	0.02	0.09
March	13	13130.8	3627.84	41514.6	0.0342571	0.02	0.07
April	13	13388.1	3767.21	49356.5	0.0267579	0.01	0.06
May	13	11327.4	2359.58	56593.9	0.0373403	0.02	0.09
June	12	12055.8	742.965	74574.1	0.0290009	0.02	0.06
July	12	3588.7	830.413	10968.9	0.0379376	0.02	0.08
August	12	2730.58	435.086	10232	0.0402483	0.02	0.07
September	12	9353.39	665.625	62161.4	0.028012	0.02	0.08
October	12	4928.23	904.652	18521.7	0.0396496	0.02	0.07
November	12	9228.53	1167.74	25616.2	0.0336198	0.02	0.06
December	10	12873.9	1676.05	37113.3	0.0519697	0.02	0.1



Constituent-Associated Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 2/4/1985 to 9/20/2012 (390 Observations)

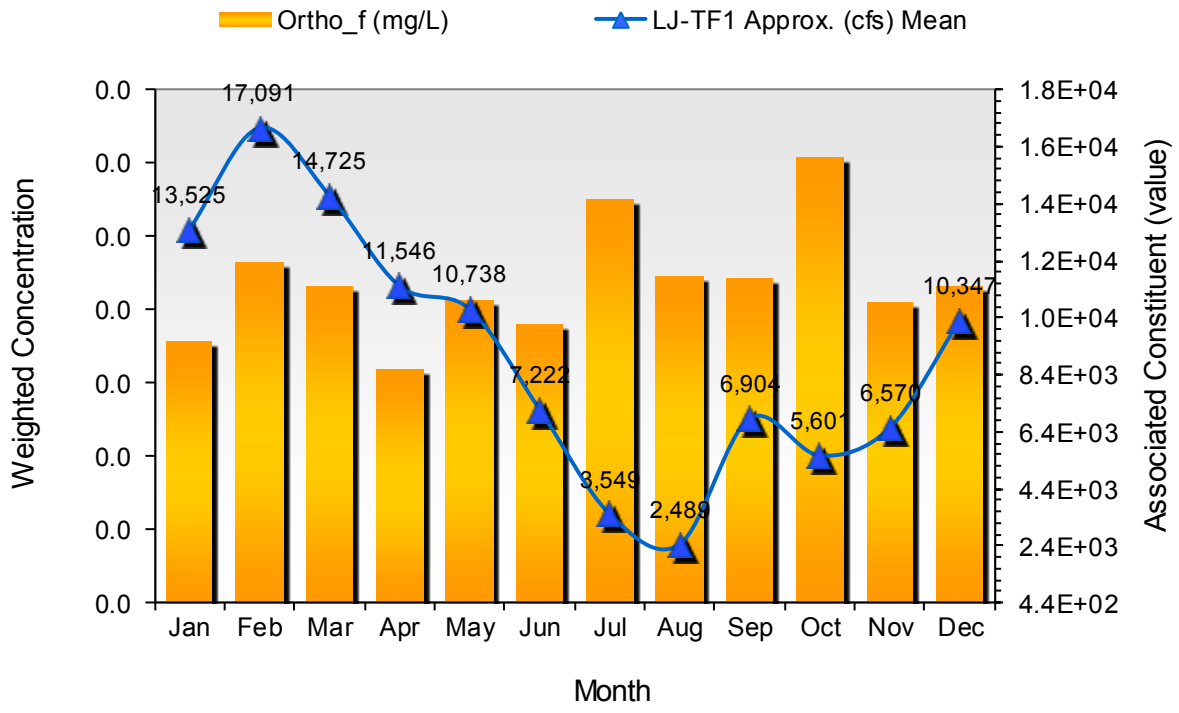
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	39	1114.59	435.086	1459.31	0.0194531	0	0.035
10-20	39	1743.14	1489.07	2044.04	0.0187089	0	0.0315
20-30	39	2330.16	2055.47	2709.4	0.0202193	0	0.04
30-40	39	3278.32	2780.68	3767.21	0.0191977	0	0.032
40-50	39	4420.56	3777.78	4950.77	0.021392	0	0.075
50-60	39	5719.91	4956.84	6364.6	0.0237185	0	0.11
60-70	39	7139.81	6430.3	8022.89	0.0179022	0	0.05
70-80	39	9656.24	8127.91	11258.6	0.0221191	0	0.05
80-90	39	14944.5	11395.4	20174	0.0211359	0	0.095
90-100	38	37132.6	20345.7	76559.3	0.022448	0	0.095



Seasonal Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 2/4/1985 to 9/20/2012 (390 Observations)

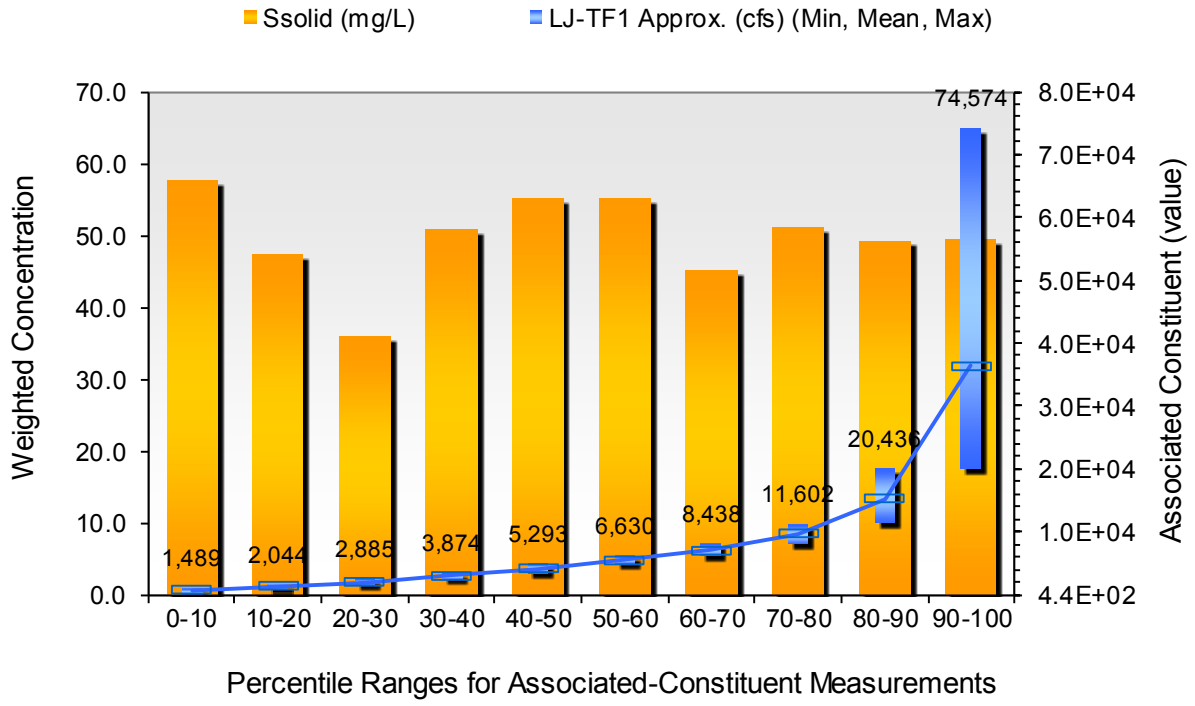
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	25	13525.1	2505.29	59581	0.0177924	0	0.07
February	27	17090.9	1832.02	116527	0.0232018	0	0.095
March	36	14724.6	3627.84	53744.3	0.0215598	0	0.11
April	36	11545.6	3767.21	49356.5	0.0159022	0	0.04
May	37	10738.3	2359.58	56593.9	0.0206313	0	0.045
June	37	7222.22	742.965	74574.1	0.0189878	0	0.04
July	35	3548.69	830.414	15716.9	0.0275618	0	0.05
August	35	2488.51	435.086	10232	0.0222375	0	0.035
September	35	6903.87	665.625	76559.3	0.022079	0	0.05
October	35	5600.94	729.247	52069.3	0.0303286	0	0.05
November	28	6570.24	1167.74	25616.2	0.0204785	0	0.035
December	24	10346.7	1516.42	37113.3	0.0216015	0	0.075



Constituent-Associated Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: Ssolid (mg/L)
Data from: 11/12/1985 to 9/20/2012 (329 Observations)

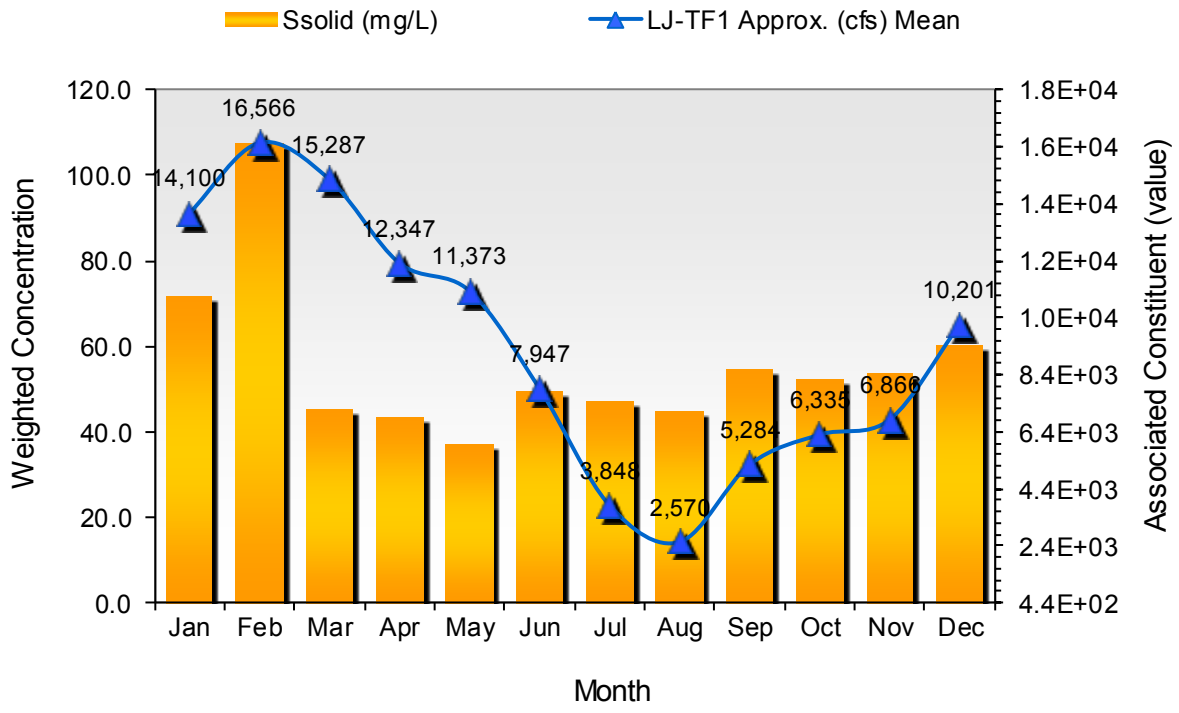
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	33	1112.61	435.086	1489.07	57.6826	13.5	323
10-20	33	1728.3	1489.88	2044.04	47.3707	19.5	131
20-30	33	2370.6	2059.84	2884.99	36.0261	10.5	126
30-40	33	3381.94	2899.37	3873.73	50.7263	13.5	102
40-50	32	4584.98	3902.93	5292.54	55.1299	16.5	415.5
50-60	33	5978.87	5339.23	6630.46	55.1374	13.5	130.5
60-70	33	7430.67	6710.3	8437.85	45.0538	19.5	126.5
70-80	33	10051.2	8465.51	11601.9	51.1318	17	123.5
80-90	33	15722.6	11773.2	20435.9	49.1296	12.5	172
90-100	32	36812.4	20506.3	74574.1	49.3318	15	174.5



Seasonal Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: Ssolid (mg/L)
Data from: 11/12/1985 to 9/20/2012 (329 Observations)

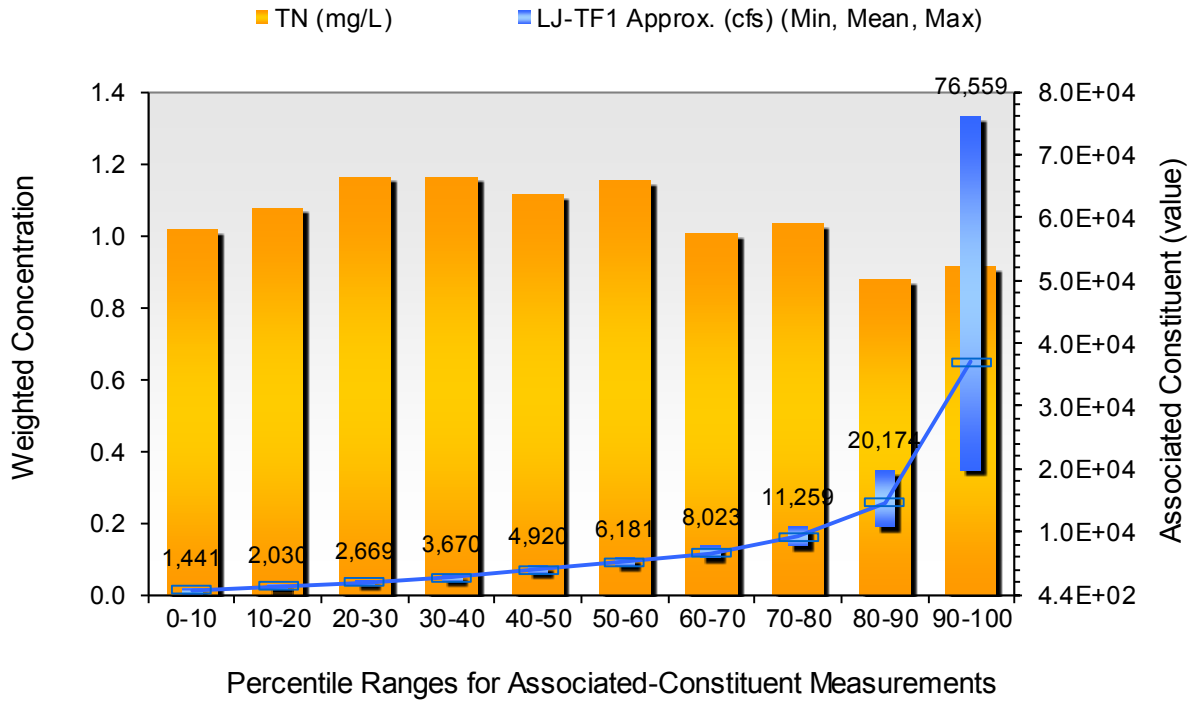
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	14100.4	2505.29	59581	71.7947	21	174.5
February	24	16565.6	1832.02	116527	107.508	12.5	266
March	28	15286.6	3627.84	47323.3	45.2897	17	123.5
April	30	12346.7	3767.21	49356.5	43.2533	18.5	415.5
May	30	11372.6	2359.58	56593.9	36.9994	14	104.5
June	31	7946.51	742.965	74574.1	49.5262	15.5	85.5
July	30	3847.74	830.414	15716.9	47.3146	19.5	130.5
August	30	2569.58	435.086	10232	44.9548	11	131
September	28	5283.66	665.625	62161.4	54.655	13.5	323
October	29	6334.9	729.247	52069.3	52.1508	10.5	106
November	25	6866.07	1167.74	25616.2	53.5262	15	172
December	21	10200.9	1516.42	37113.3	59.9195	13.5	102.5



Constituent-Associated Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (376 Observations)

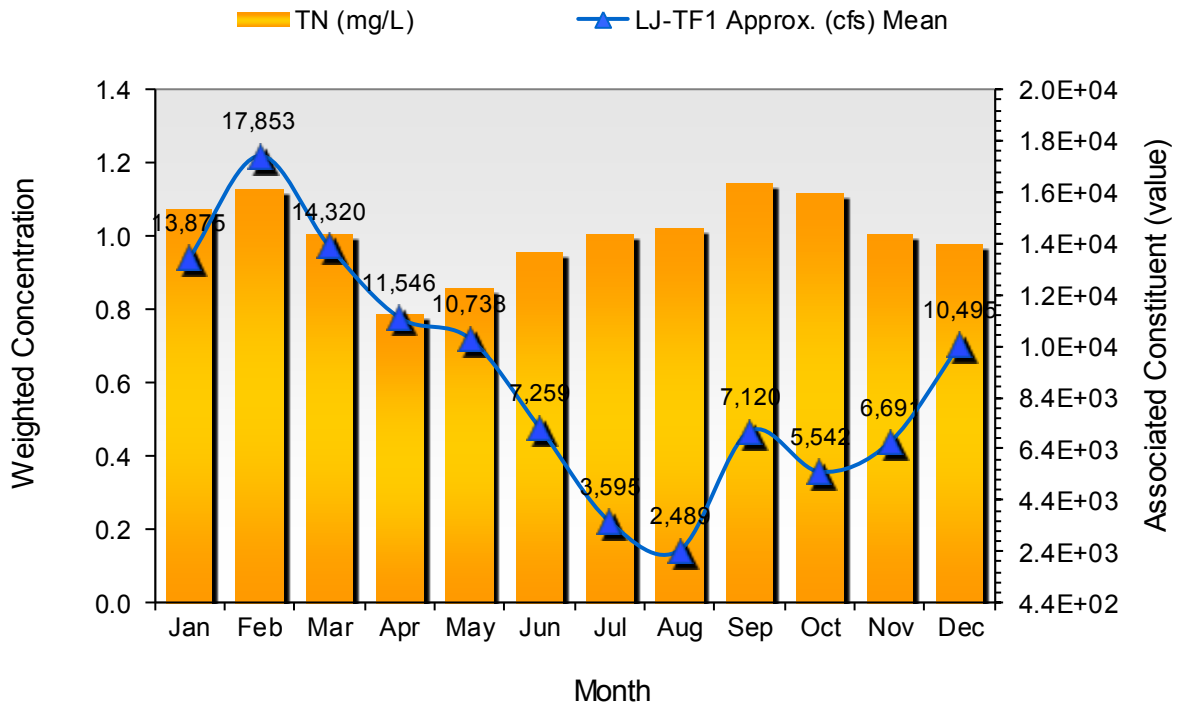
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	1105.52	435.086	1440.64	1.01733	0	2.21
10-20	37	1713.38	1459.31	2030.31	1.07408	0	2.26
20-30	38	2302.83	2041.47	2669.03	1.16018	0	2.315
30-40	37	3208.95	2683.86	3670.22	1.15954	0	2.058
40-50	38	4327.07	3696.42	4920.39	1.11119	0	2.6825
50-60	37	5615.09	4932.08	6181.38	1.15356	0	2.345
60-70	38	7010.61	6247.33	8022.89	1.0029	0	2.031
70-80	37	9646.23	8127.91	11258.6	1.03376	0	1.75
80-90	38	14966.6	11395.4	20174	0.874983	0	1.5325
90-100	37	37355.7	20345.7	76559.3	0.913914	0	2.15



Seasonal Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 9/20/2012 (376 Observations)

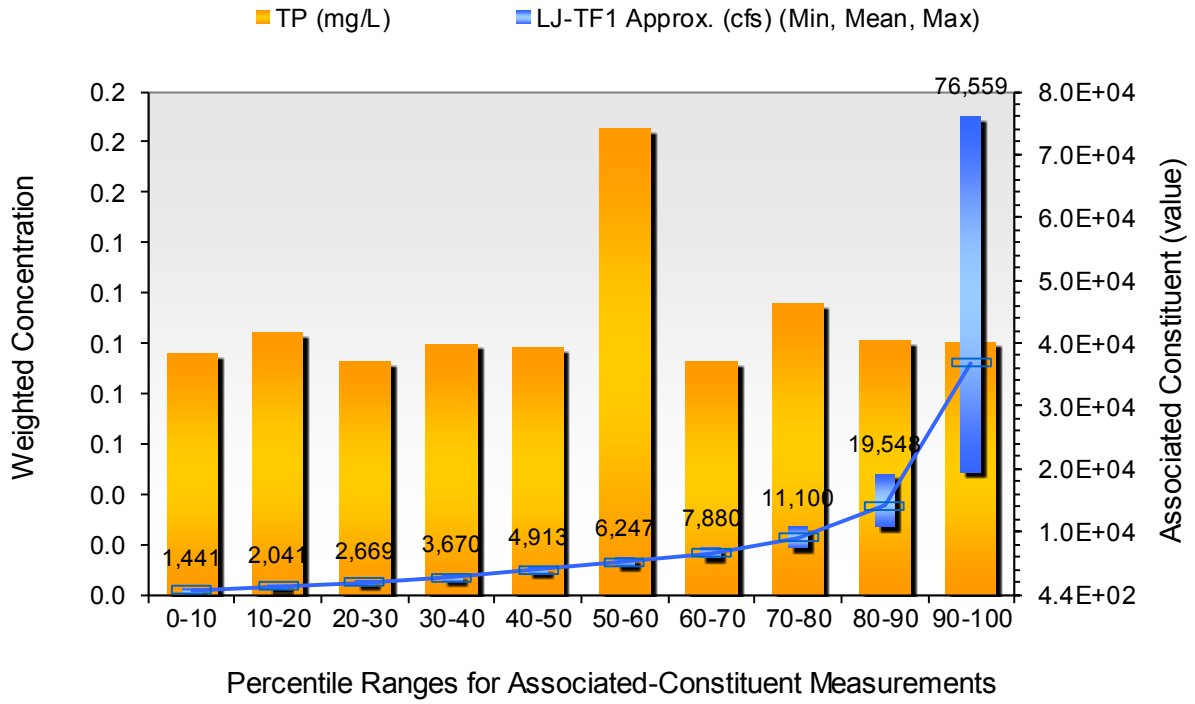
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	22	13874.9	2505.29	59581	1.07461	0.7875	2.6825
February	25	17852.8	1832.02	116527	1.12633	0	2.345
March	35	14320.2	3627.84	53744.3	1.002	0	2.26
April	36	11545.6	3767.21	49356.5	0.786141	0	1.71
May	37	10738.3	2359.58	56593.9	0.857338	0	1.825
June	35	7259.05	742.965	74574.1	0.955281	0	1.74
July	34	3595.39	830.414	15716.9	1.00507	0	1.645
August	35	2488.51	435.086	10232	1.02006	0	1.865
September	33	7120.36	665.625	76559.3	1.14501	0.5	2.21
October	34	5541.67	729.247	52069.3	1.11683	0	2.26
November	27	6690.67	1167.74	25616.2	1.00336	0	2.255
December	23	10495	1516.42	37113.3	0.976262	0	2.315



Constituent-Associated Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 9/20/2012 (380 Observations)

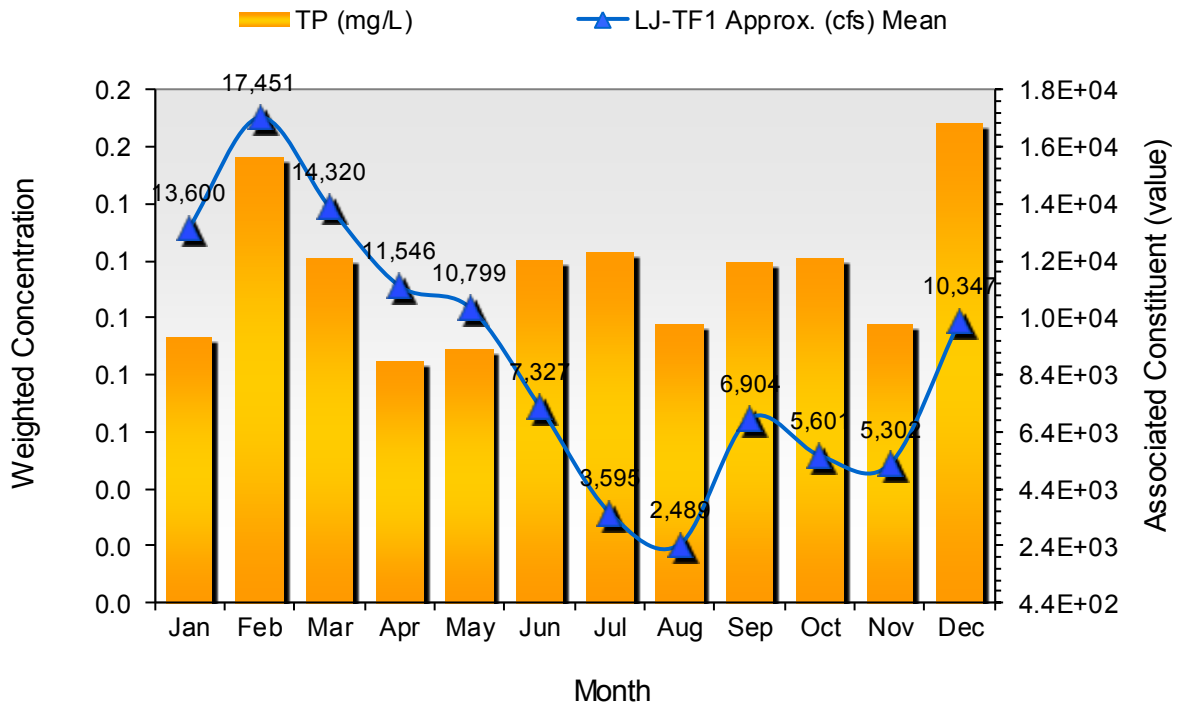
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	1105.52	435.086	1440.64	0.0957509	0	0.17205
10-20	38	1722.02	1459.31	2041.47	0.104215	0	0.204
20-30	38	2303.34	2044.04	2669.03	0.09277	0	0.2018
30-40	38	3211.83	2683.86	3670.22	0.0998269	0	0.24
40-50	38	4318.71	3696.42	4912.72	0.0981944	0	0.18
50-60	38	5600.65	4920.39	6247.33	0.185353	0	2.61885
60-70	38	6995.04	6293.41	7879.54	0.0923171	0	0.265
70-80	38	9428.74	7880.48	11099.8	0.11566	0	0.34915
80-90	38	14498.9	11127.2	19548.1	0.101174	0	0.255
90-100	37	37194.5	19982.5	76559.3	0.10069	0	0.23



Seasonal Trend Assessment

Location: TF5.6
Comparison Parameter: LJ-TF1 Approx. (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 9/20/2012 (380 Observations)

Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	13600.4	2505.29	59581	0.0929879	0	0.23
February	26	17451	1832.02	116527	0.155979	0	0.38395
March	35	14320.2	3627.84	53744.3	0.12072	0	0.27
April	36	11545.6	3767.21	49356.5	0.084489	0	0.21
May	36	10798.6	2359.58	56593.9	0.0884364	0	0.18
June	35	7326.71	742.965	74574.1	0.119953	0	0.1799
July	34	3595.39	830.414	15716.9	0.122637	0	0.24
August	35	2488.51	435.086	10232	0.0975931	0	0.204
September	35	6903.87	665.625	76559.3	0.119049	0	0.255
October	35	5600.94	729.247	52069.3	0.120661	0	0.185
November	26	5301.7	1167.74	20345.7	0.0975466	0	0.265
December	24	10346.7	1516.42	37113.3	0.168162	0	2.61885

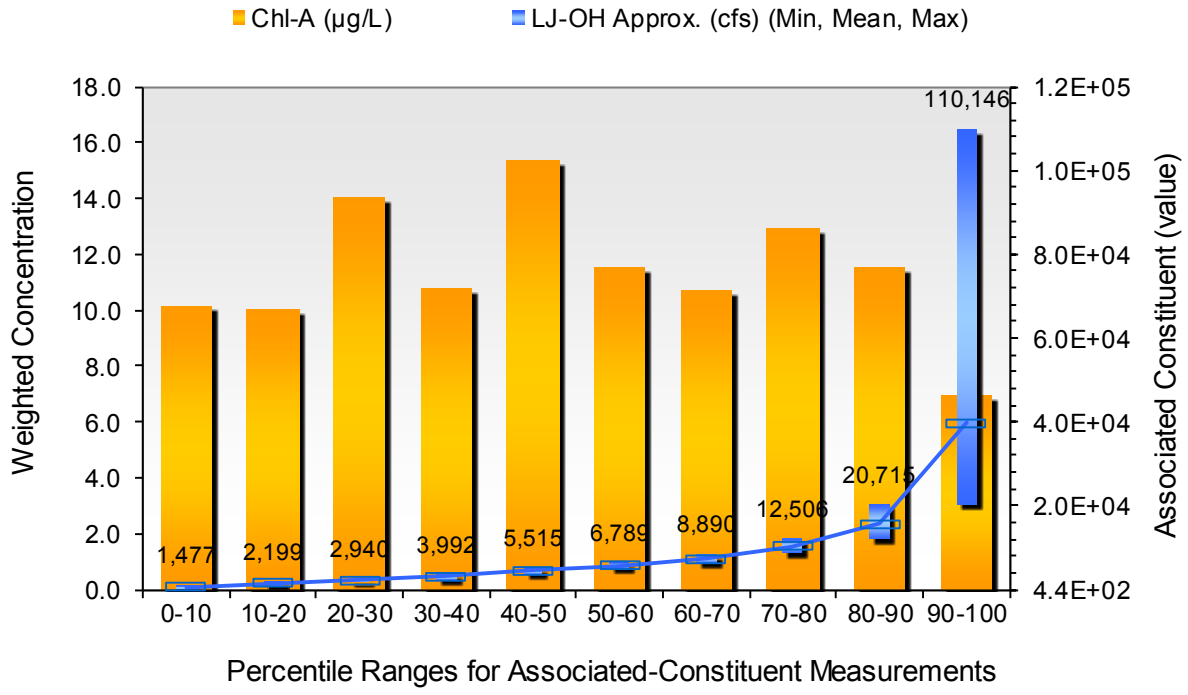


Lower James-OH

Constituent-Associated Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 9/6/2012 (373 Observations)

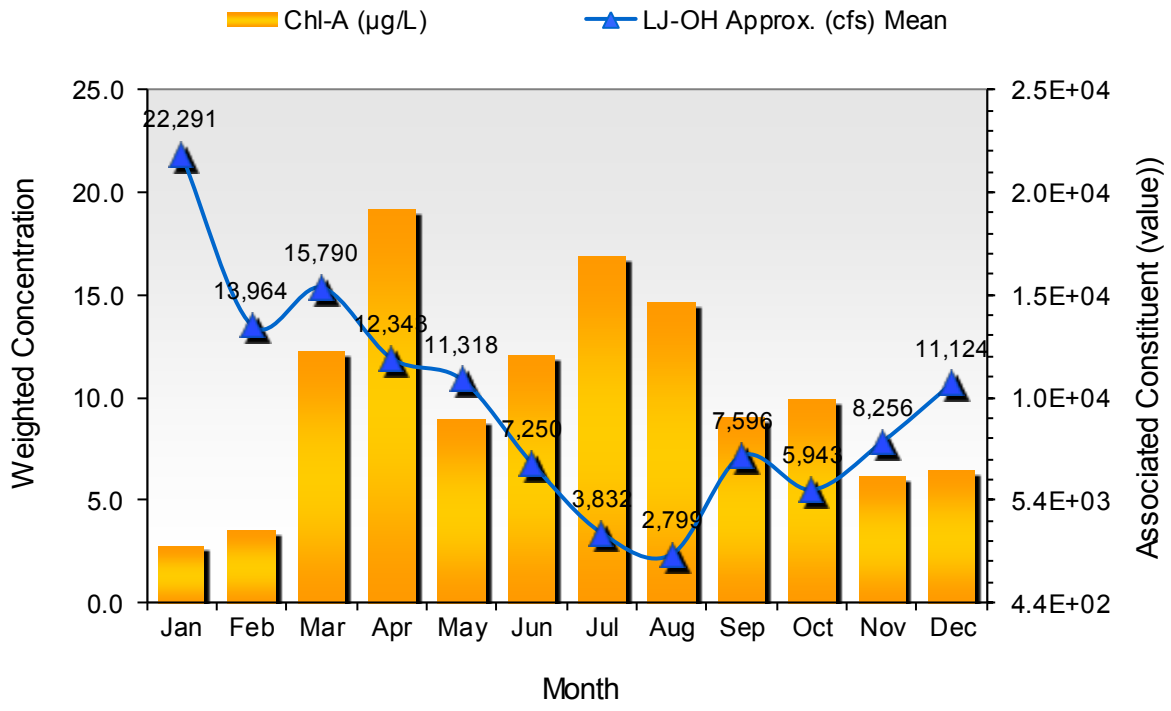
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	1113.39	436.322	1476.72	10.1175	4.5	22.65
10-20	37	1871.89	1532.24	2199.12	10.0061	1	21.08
20-30	37	2533.94	2205.27	2939.61	14.0106	2.63	122.3
30-40	37	3471.73	2957.53	3992.17	10.7671	1	20.56
40-50	37	4862.63	4000.2	5515.24	15.3313	1.67	82
50-60	38	6174.38	5541.44	6788.89	11.5183	0.7009	41.97
60-70	37	7802.18	6821.23	8889.63	10.701	1	28.86
70-80	37	10692.4	9020.31	12506.3	12.927	1	66.04
80-90	37	15964.7	12636.4	20714.7	11.5175	1	57.65
90-100	37	40131.2	20776.3	110146	6.92232	1	26.7



Seasonal Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 9/6/2012 (373 Observations)

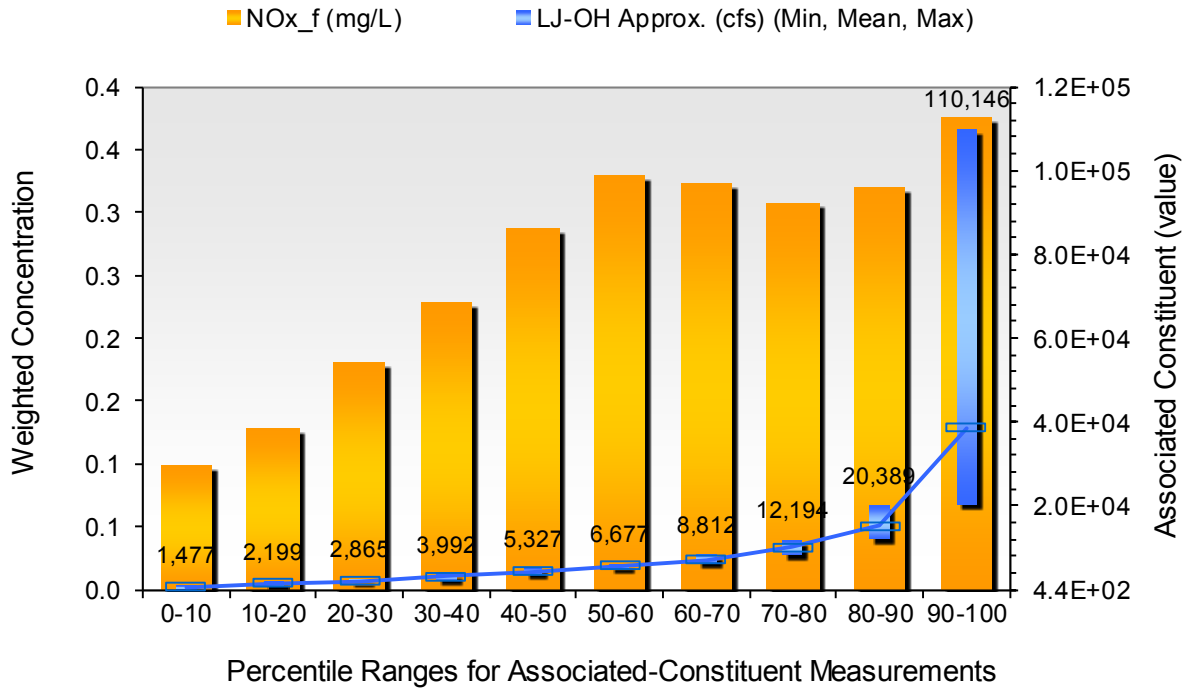
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	22290.7	2840.47	126749	2.79595	1	17.91
February	24	13964.2	1951.86	68428.2	3.49264	1	17.62
March	32	15789.7	3760.79	54948.3	12.2477	1	66.04
April	34	12342.8	3870.2	51049.3	19.1988	1	82
May	36	11317.8	2088.5	60694.7	8.97627	1	26.37
June	37	7250.39	748.769	75100.3	12.0347	2	33.52
July	33	3831.71	830.545	16514.6	16.8117	3.6	41.62
August	34	2798.76	436.322	12291.8	14.6817	4.41	32.7947
September	33	7596.11	674.426	76578	9.02869	3.1	122.3
October	34	5942.55	743.478	52792.1	9.87463	2.6	34
November	27	8255.66	1028.5	35320.4	6.14514	1	51.73
December	26	11124.3	1777.17	40521.2	6.45833	0.7009	26.7



Constituent-Associated Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/4/1985 to 9/6/2012 (385 Observations)

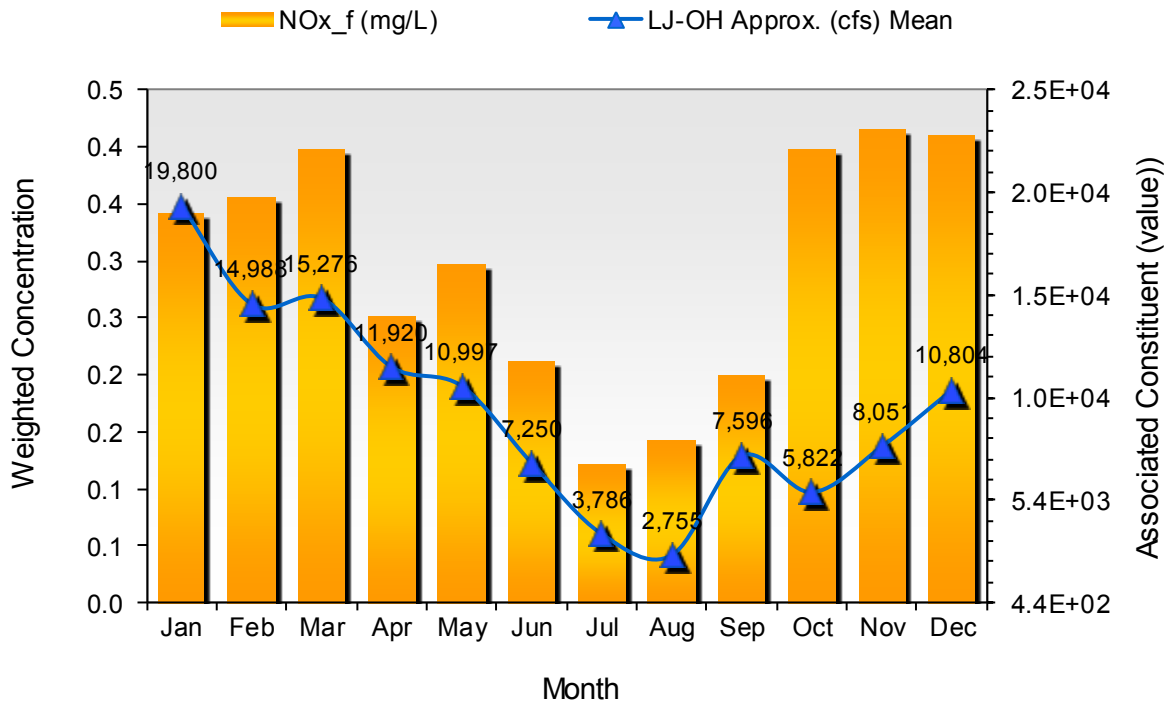
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	39	1117.28	436.322	1476.72	0.0983092	0	0.3625
10-20	38	1867.77	1532.24	2199.12	0.128512	0	0.5625
20-30	39	2515.55	2205.27	2864.57	0.180913	0	0.69
30-40	38	3457.73	2939.61	3992.17	0.229013	0	0.56
40-50	38	4787.18	4000.2	5327.26	0.288009	0	1.25
50-60	39	6050.46	5338.67	6677.27	0.329334	0	0.7825
60-70	38	7590.89	6741.22	8812.35	0.322827	0	0.7
70-80	39	10418	8822.61	12193.6	0.307628	0	0.73
80-90	38	15652	12291.8	20389.3	0.320312	0	0.6485
90-100	38	39032.6	20714.7	110146	0.375611	0	0.815



Seasonal Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/4/1985 to 9/6/2012 (385 Observations)

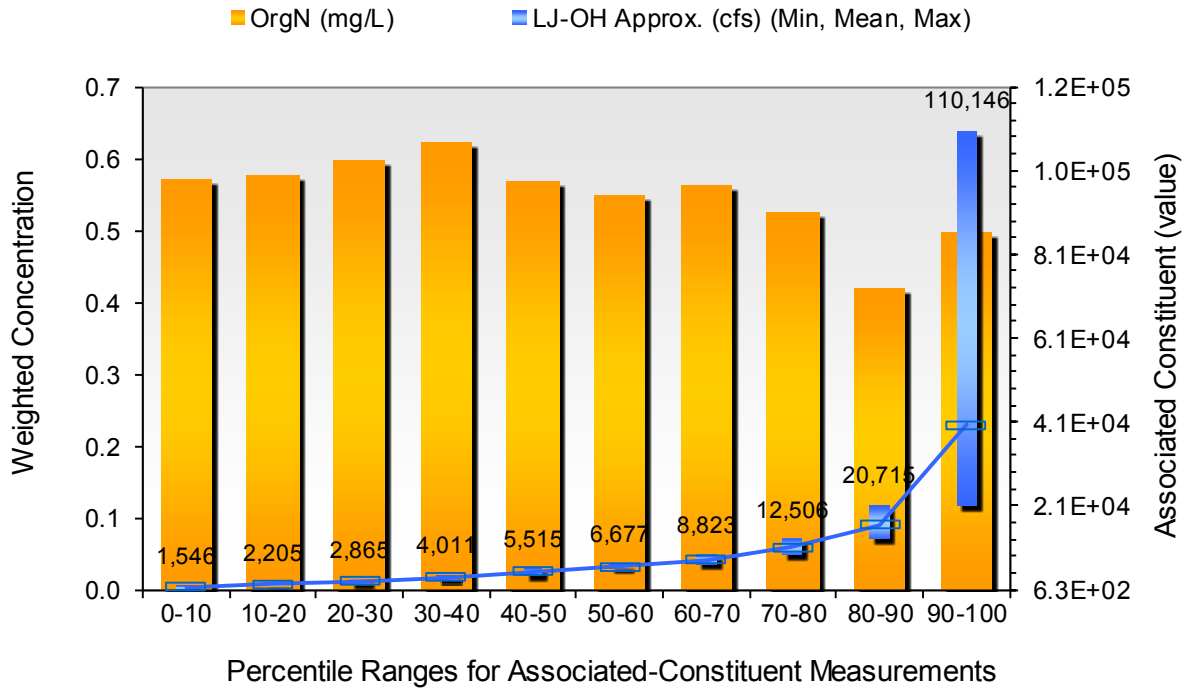
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	19799.6	2840.47	126749	0.341122	0	0.825
February	25	14987.8	1951.86	68428.2	0.355581	0	0.6325
March	34	15276	3760.79	54948.3	0.39733	0	0.7
April	36	11919.6	3870.2	51049.3	0.251767	0	0.5075
May	38	10996.8	2088.5	60694.7	0.296641	0	0.585
June	37	7250.39	748.769	75100.3	0.212185	0	0.6325
July	34	3786.21	830.545	16514.6	0.121861	0	0.53
August	35	2754.94	436.322	12291.8	0.141231	0	0.3045
September	33	7596.11	674.426	76578	0.199456	0	0.545
October	35	5821.78	743.478	52792.1	0.397038	0	0.608333
November	28	8051.3	1028.5	35320.4	0.414977	0	0.7595
December	27	10803.9	1777.17	40521.2	0.409581	0	1.25



Constituent-Associated Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 8/8/2012 (364 Observations)

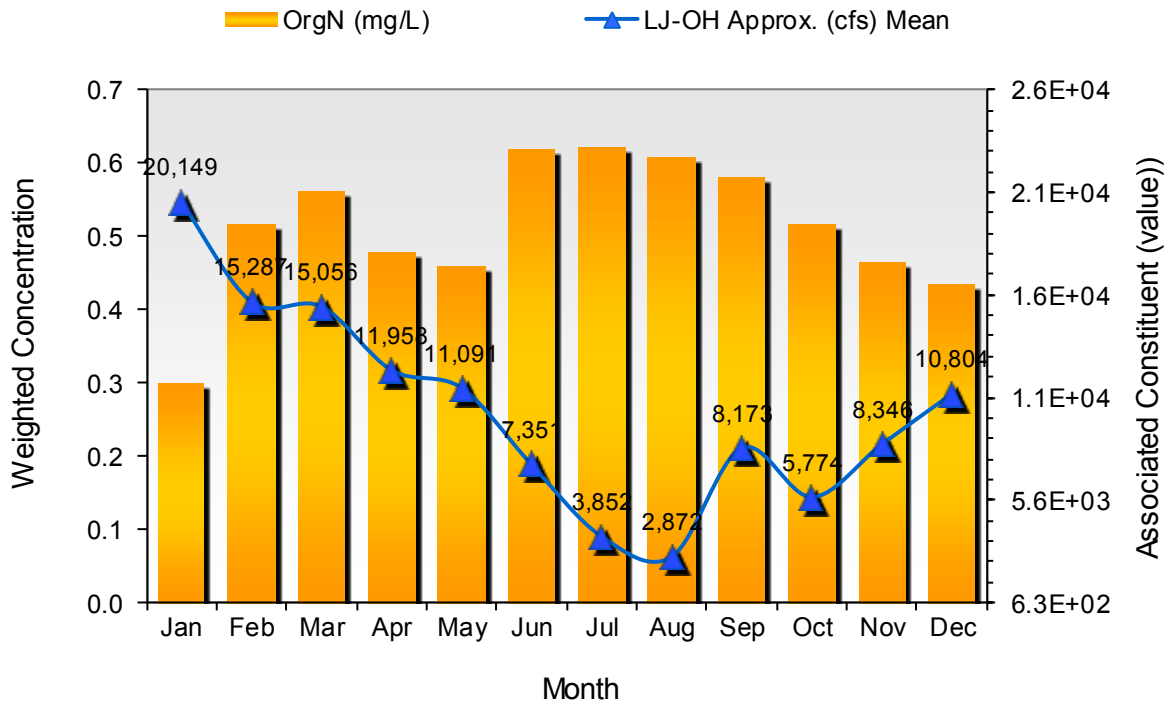
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	37	1138.66	625.102	1545.94	0.570106	0	1.17
10-20	36	1891.55	1551.08	2205.27	0.576207	0	1.12
20-30	36	2511.52	2209.06	2864.57	0.598635	0	1.47
30-40	37	3465.1	2939.61	4010.58	0.62134	0	1.15
40-50	36	4893.1	4088.95	5515.24	0.56812	0	1.175
50-60	36	6103.81	5541.44	6677.27	0.549685	0	1.37
60-70	37	7620.49	6741.22	8822.61	0.563155	0	1.142
70-80	36	10592	8883.02	12506.3	0.5239	0	1.5
80-90	36	16055.3	12636.4	20714.7	0.418587	0	0.87
90-100	36	39933.8	20776.3	110146	0.497546	0	1.035



Seasonal Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 8/8/2012 (364 Observations)

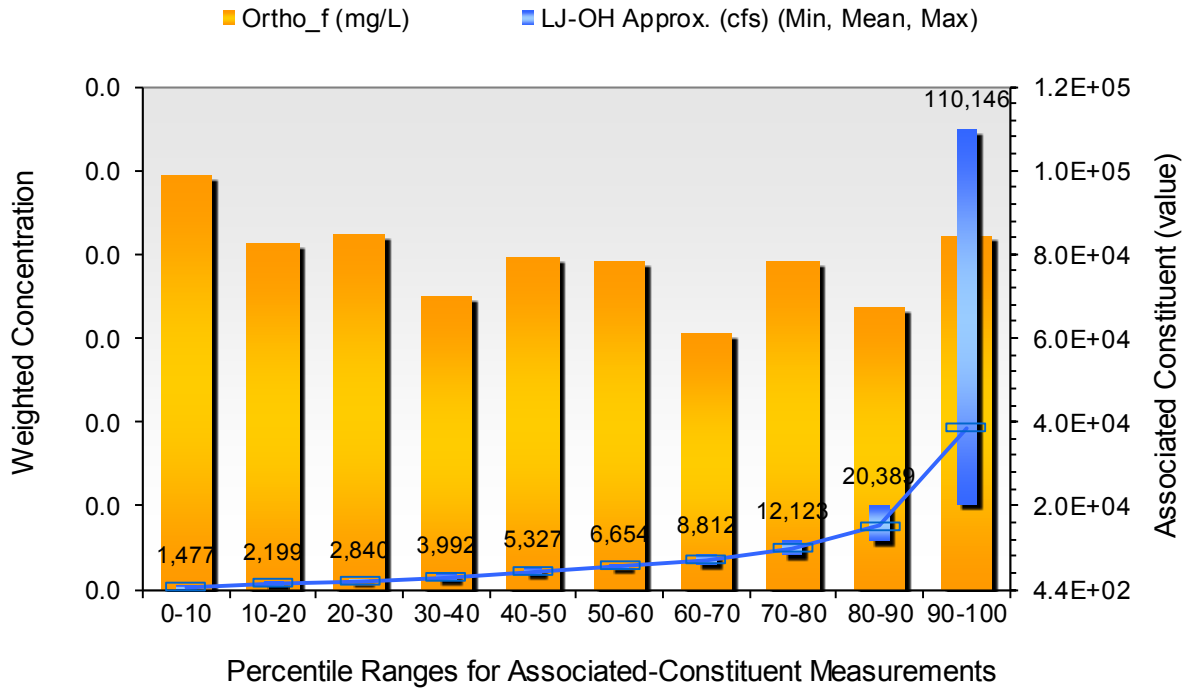
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	22	20148.6	2840.47	126749	0.298857	0	0.806
February	24	15287.3	1951.86	68428.2	0.515085	0	1.142
March	32	15055.5	3760.79	54948.3	0.561711	0	1.12
April	35	11958.3	3870.2	51049.3	0.476449	0	1.175
May	37	11090.9	2088.5	60694.7	0.457318	0	1.37
June	34	7350.76	748.769	75100.3	0.618464	0	1.215
July	32	3851.69	830.545	16514.6	0.620854	0	1.47
August	32	2872.1	625.102	12291.8	0.606784	0	1.12
September	30	8172.63	674.426	76578	0.580882	0	1.5
October	33	5774.31	743.478	52792.1	0.515204	0	1.17
November	26	8346.3	1028.5	35320.4	0.462626	0	1.22
December	27	10803.9	1777.17	40521.2	0.434282	0	0.98



Constituent-Associated Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 2/4/1985 to 9/6/2012 (384 Observations)

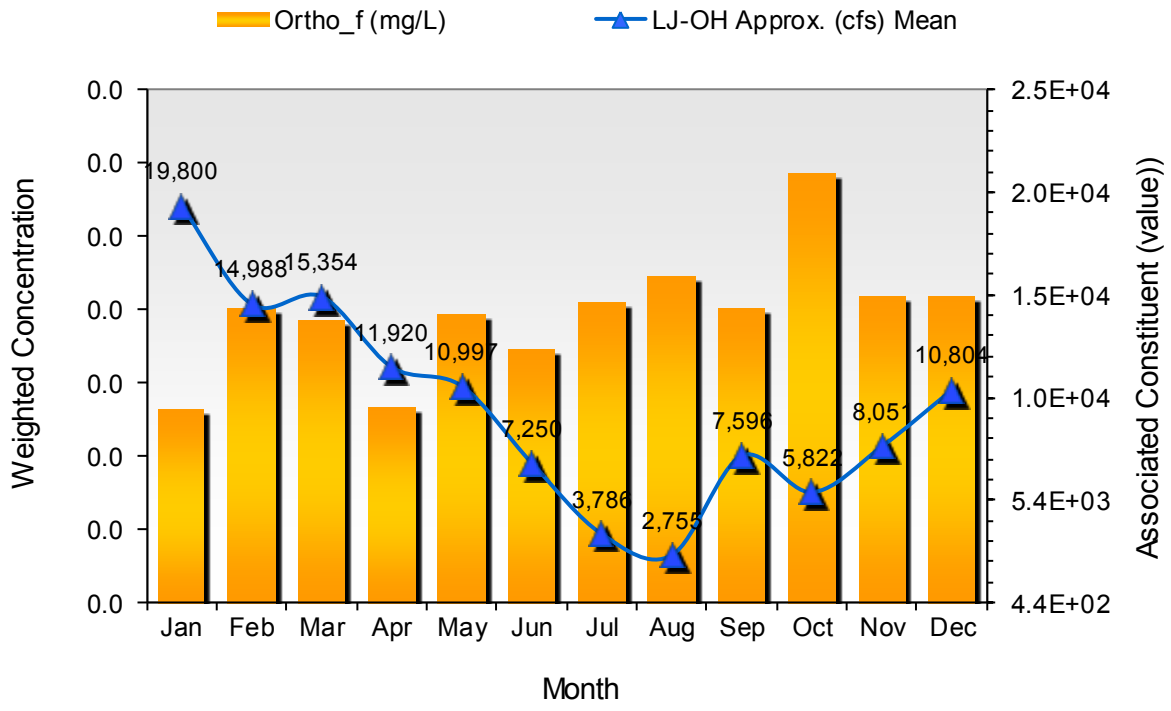
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	39	1117.28	436.322	1476.72	0.0247286	0	0.0545
10-20	38	1867.77	1532.24	2199.12	0.0206228	0	0.045
20-30	38	2506.37	2205.27	2840.47	0.0211869	0	0.054
30-40	39	3442.52	2864.57	3992.17	0.0174408	0	0.0345
40-50	38	4787.18	4000.2	5327.26	0.0198433	0	0.14
50-60	38	6033.96	5338.67	6653.85	0.0196073	0	0.0465
60-70	39	7567.46	6677.27	8812.35	0.0152775	0	0.045
70-80	38	10371.2	8822.61	12123.3	0.0195754	0	0.05
80-90	38	15638.6	12193.6	20389.3	0.0168465	0	0.06
90-100	38	39032.6	20714.7	110146	0.0210796	0	0.05



Seasonal Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 2/4/1985 to 9/6/2012 (384 Observations)

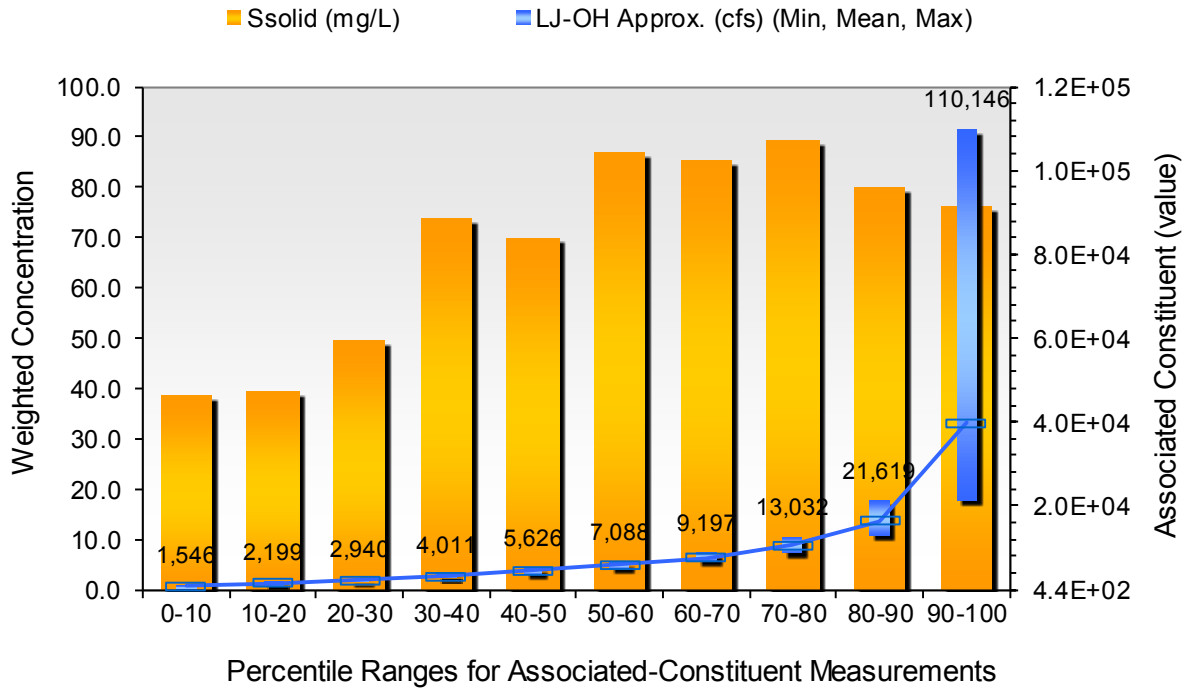
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	19799.6	2840.47	126749	0.0131775	0	0.04
February	25	14987.8	1951.86	68428.2	0.0200457	0	0.06
March	33	15354	3760.79	54948.3	0.0192795	0	0.14
April	36	11919.6	3870.2	51049.3	0.0133583	0	0.04
May	38	10996.8	2088.5	60694.7	0.0197224	0	0.035
June	37	7250.39	748.769	75100.3	0.0172658	0	0.031
July	34	3786.21	830.545	16514.6	0.0205545	0	0.03
August	35	2754.94	436.322	12291.8	0.0222647	0	0.043
September	33	7596.11	674.426	76578	0.0201133	0	0.0545
October	35	5821.78	743.478	52792.1	0.0292553	0	0.054
November	28	8051.3	1028.5	35320.4	0.0208934	0	0.037
December	27	10803.9	1777.17	40521.2	0.020964	0	0.041



Constituent-Associated Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: Ssolid (mg/L)
Data from: 11/12/1985 to 9/6/2012 (322 Observations)

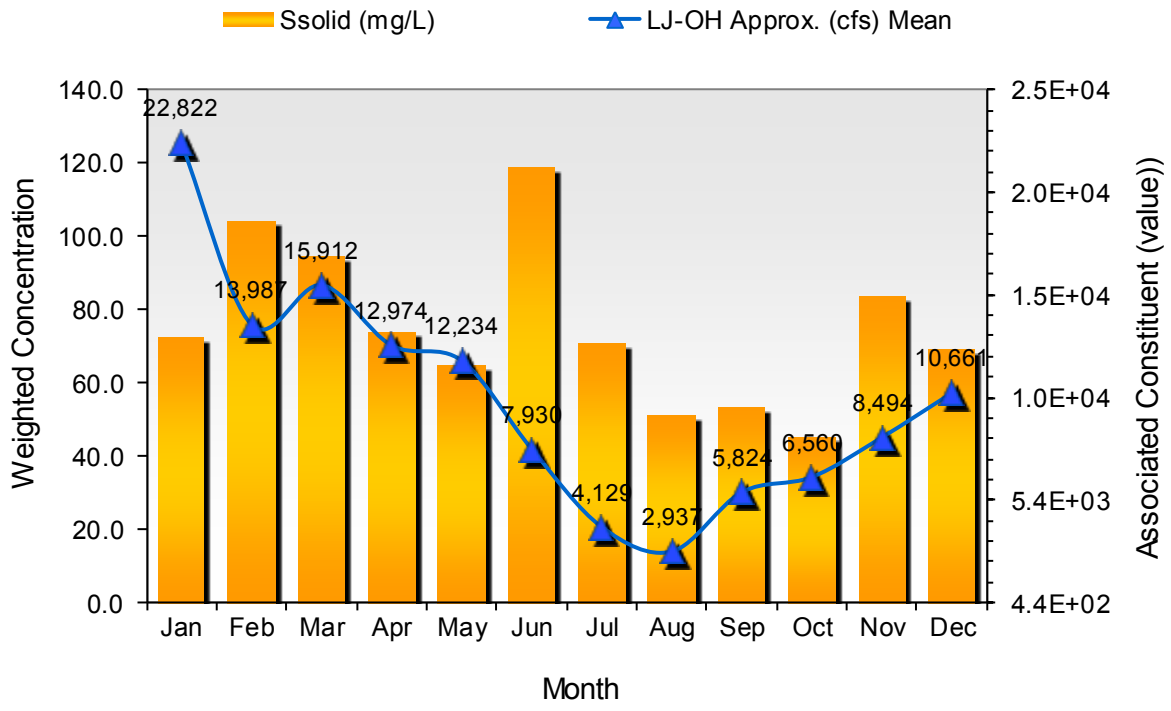
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	33	1142.6	436.322	1545.94	38.5193	16.5	91.5
10-20	32	1877.26	1551.08	2199.12	39.4094	15	81.5
20-30	32	2533.79	2209.06	2939.61	49.4126	9.5	116.5
30-40	32	3544.43	3023.55	4010.58	73.8838	7.5	323
40-50	32	4983.71	4088.95	5626.15	69.9025	25.5	175
50-60	32	6381.54	5630.62	7087.62	86.7945	24.5	216.5
60-70	32	8079.14	7179.18	9197.35	85.474	28.5	240.5
70-80	32	11061.4	9209.57	13032.4	89.2949	15.5	248
80-90	32	16660	13395.1	21618.6	80.0215	17	414
90-100	32	40196.2	21836.5	110146	76.1105	8	221



Seasonal Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: Ssolid (mg/L)
Data from: 11/12/1985 to 9/6/2012 (322 Observations)

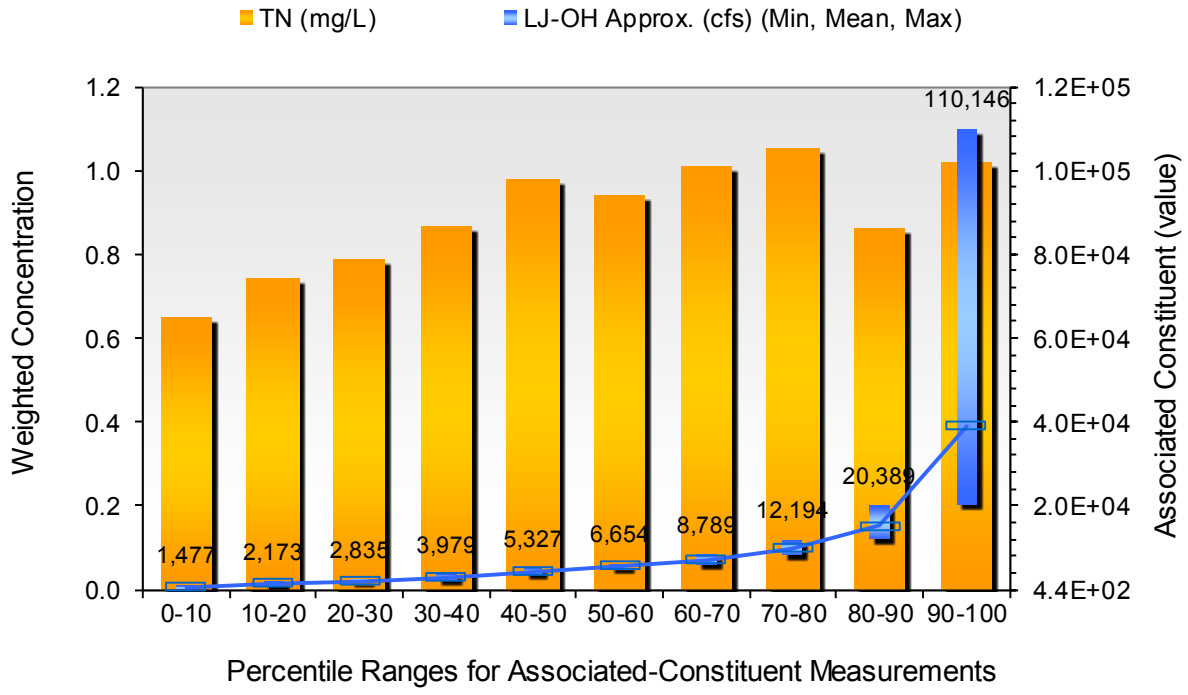
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	22	22821.7	2840.47	126749	72.2099	8	248
February	22	13987.4	1951.86	68428.2	103.984	22	190.5
March	26	15912.3	3760.79	47916.9	94.4191	15.5	221
April	29	12974.4	3870.2	51049.3	73.9912	17	204
May	28	12234.2	2088.5	60694.7	64.6047	22.5	240.5
June	31	7930.05	748.769	75100.3	118.47	16.5	216.5
July	29	4129.05	830.545	16514.6	70.6158	20.5	156.5
August	29	2936.95	436.322	12291.8	51.1673	17	113.5
September	28	5824.38	674.426	66243.5	53.1404	16.5	323
October	29	6560.37	743.478	52792.1	44.9862	7.5	102.5
November	25	8493.85	1028.5	35320.4	83.779	9.5	414
December	24	10660.5	1777.17	40521.2	68.9962	13	150



Constituent-Associated Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 9/6/2012 (376 Observations)

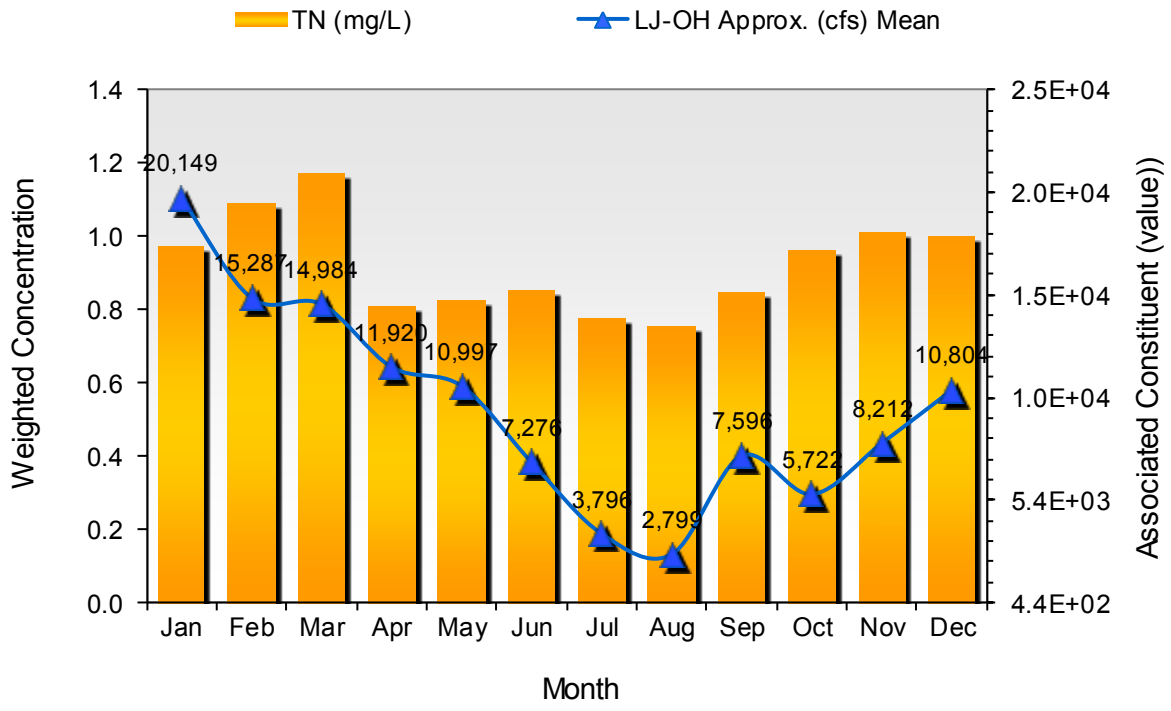
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	1113.39	436.322	1476.72	0.648133	0	1.2825
10-20	37	1858.81	1532.24	2173.23	0.740081	0	1.66
20-30	38	2489.49	2199.12	2835.33	0.786837	0	1.5375
30-40	37	3403	2840.47	3978.88	0.868359	0	1.6375
40-50	38	4773.11	3992.17	5327.26	0.976288	0	2.35
50-60	38	6033.96	5338.67	6653.85	0.942601	0	1.9
60-70	37	7527.53	6677.27	8789.1	1.01139	0.5	1.891
70-80	37	10397.7	8812.35	12193.6	1.04978	0	2.03
80-90	38	15652	12291.8	20389.3	0.861839	0	1.77167
90-100	37	39414.4	20714.7	110146	1.01766	0	1.965



Seasonal Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 9/6/2012 (376 Observations)

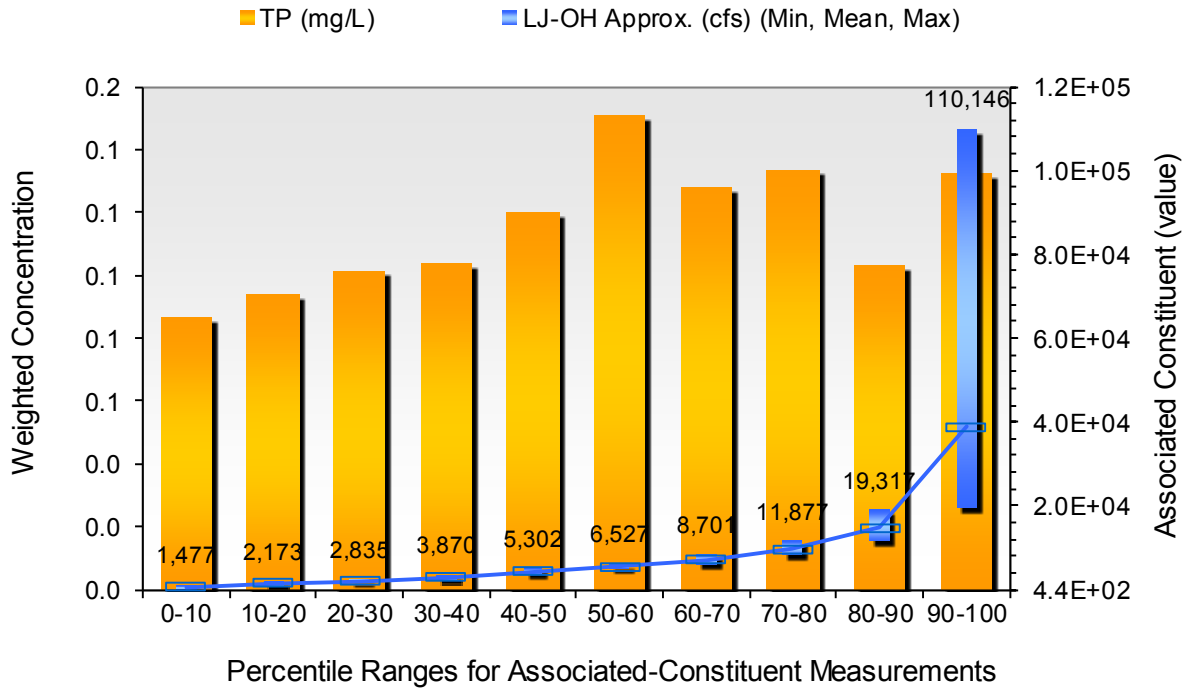
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	22	20148.6	2840.47	126749	0.971977	0.5	2.03
February	24	15287.3	1951.86	68428.2	1.08874	0	1.891
March	33	14984.1	3760.79	54948.3	1.16854	0	1.74
April	36	11919.6	3870.2	51049.3	0.809717	0	1.7025
May	38	10996.8	2088.5	60694.7	0.823133	0	1.6675
June	35	7276.36	748.769	75100.3	0.851261	0	1.4225
July	33	3795.77	830.545	16514.6	0.77867	0	1.5375
August	34	2798.76	436.322	12291.8	0.752824	0	1.29
September	33	7596.11	674.426	76578	0.848721	0	2
October	34	5722.13	743.478	52792.1	0.960945	0	1.2375
November	27	8211.54	1028.5	35320.4	1.00949	0	1.75
December	27	10803.9	1777.17	40521.2	1.00063	0	2.35



Constituent-Associated Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 9/6/2012 (376 Observations)

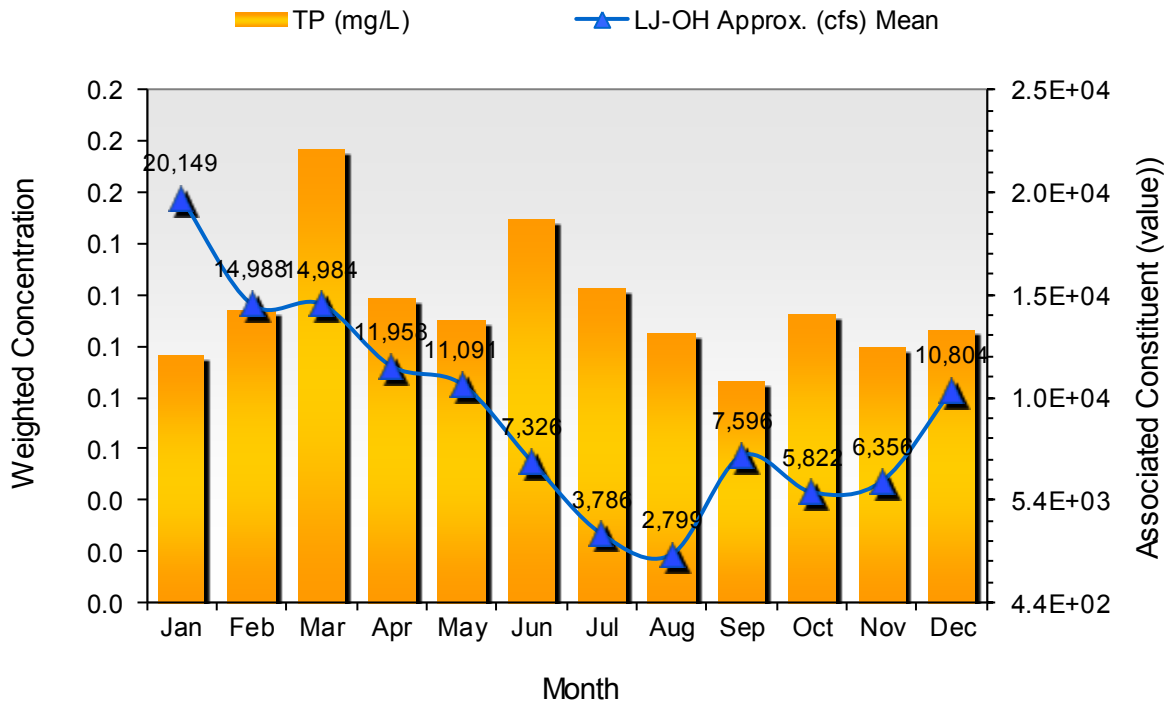
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	1113.39	436.322	1476.72	0.086464	0	0.15
10-20	37	1858.81	1532.24	2173.23	0.0940576	0	0.245
20-30	38	2489.49	2199.12	2835.33	0.101538	0	0.26
30-40	37	3383.32	2840.47	3870.2	0.103535	0	0.27
40-50	38	4701.49	3944.89	5301.66	0.119708	0	0.365
50-60	37	5950.19	5318.04	6527.48	0.150463	0	0.62
60-70	38	7395.63	6543.19	8701.38	0.12774	0	0.29
70-80	37	10105.2	8756.32	11876.7	0.133417	0	0.33
80-90	38	15085.8	11937.6	19317.1	0.103433	0	0.29
90-100	37	39172.7	19711.8	110146	0.132435	0	0.51



Seasonal Trend Assessment

Location: RET5.2
Comparison Parameter: LJ-OH Approx. (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 9/6/2012 (376 Observations)

Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	22	20148.6	2840.47	126749	0.0965557	0	0.38
February	25	14987.8	1951.86	68428.2	0.114263	0	0.34
March	33	14984.1	3760.79	54948.3	0.176439	0	0.51
April	35	11958.3	3870.2	51049.3	0.118869	0	0.37
May	37	11090.9	2088.5	60694.7	0.109938	0	0.62
June	36	7326.05	748.769	75100.3	0.149258	0	0.29
July	34	3786.21	830.545	16514.6	0.122301	0	0.26
August	34	2798.76	436.322	12291.8	0.104508	0	0.226
September	33	7596.11	674.426	76578	0.0864483	0	0.245
October	35	5821.78	743.478	52792.1	0.112778	0	0.16
November	25	6355.86	1028.5	35320.4	0.0994587	0	0.285
December	27	10803.9	1777.17	40521.2	0.106274	0	0.28

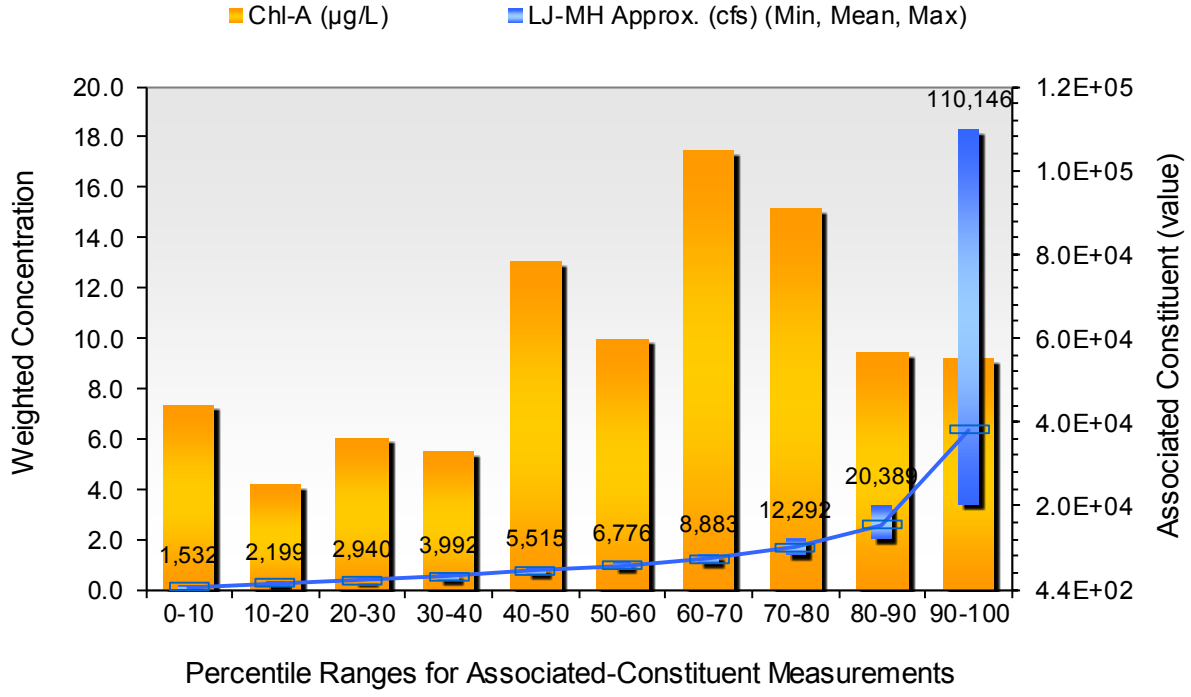


Lower James-MH

Constituent-Associated Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 9/6/2012 (372 Observations)

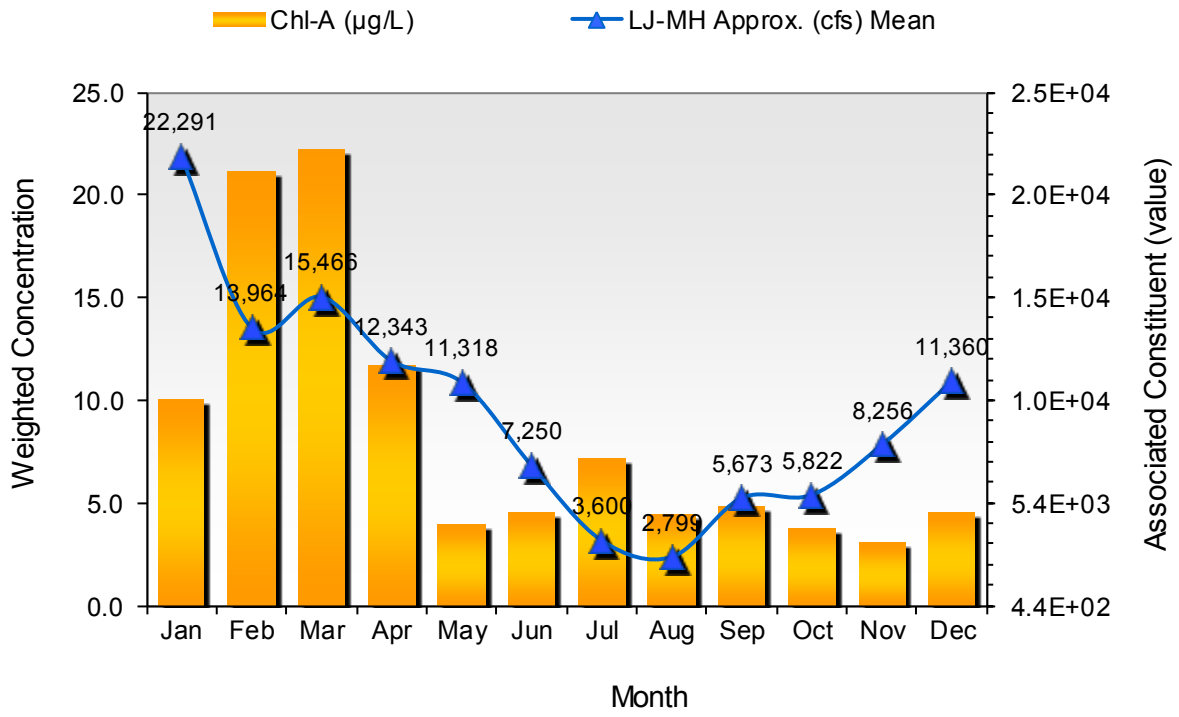
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	1117.76	436.322	1532.24	7.34376	1.48	131.5
10-20	37	1876.83	1545.94	2199.12	4.19975	0.5	12
20-30	37	2533.94	2205.27	2939.61	6.03854	1.05	43.2
30-40	37	3471.73	2957.53	3992.17	5.49877	1	21.16
40-50	37	4858.9	4000.2	5515.24	13.0728	1	87.49
50-60	37	6157.77	5541.44	6775.84	9.94923	0.80105	63.4
60-70	37	7743.31	6788.89	8883.02	17.4532	1	189
70-80	37	10531.1	8884.95	12291.8	15.1639	1	88.22
80-90	37	15742.8	12506.3	20389.3	9.40002	1	65.13
90-100	37	38621.4	20714.7	110146	9.2189	1	78.65



Seasonal Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: Chl-A (µg/L)
Data from: 6/19/1985 to 9/6/2012 (372 Observations)

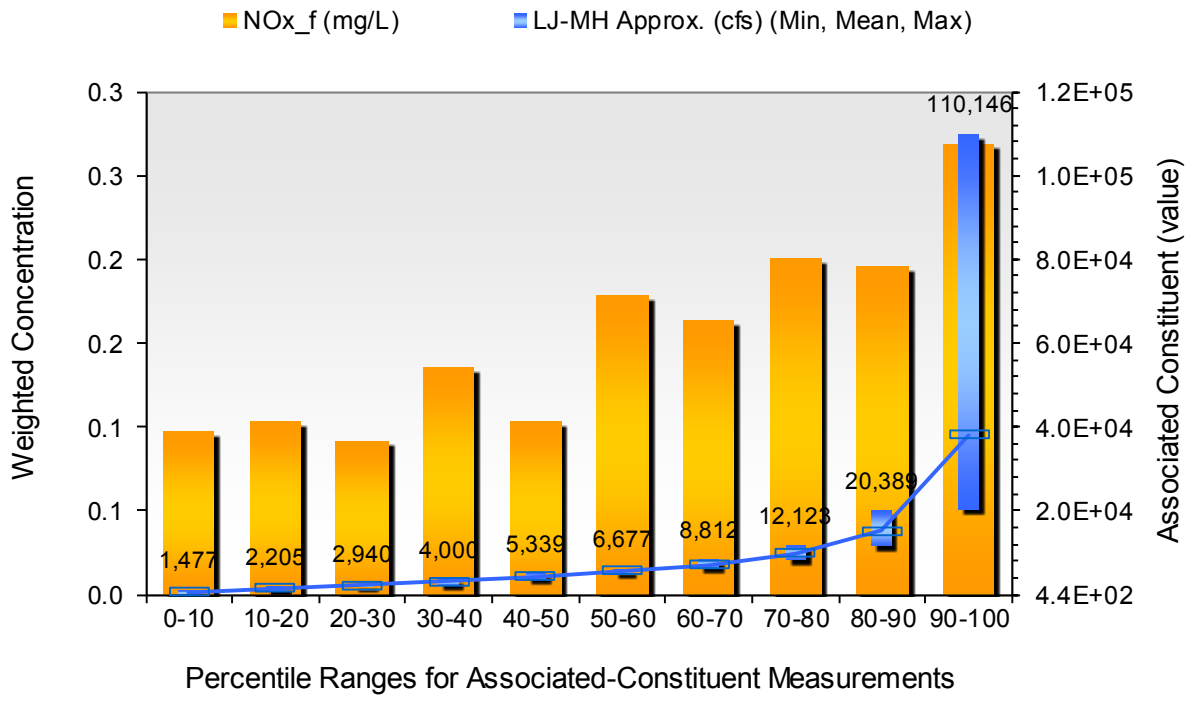
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	22290.7	2840.47	126749	10.0627	1	87.49
February	24	13964.2	1951.86	68428.2	21.1575	1	189
March	33	15466.1	3760.79	54948.3	22.166	1	88.22
April	34	12342.8	3870.2	51049.3	11.6675	1	63.4
May	36	11317.8	2088.5	60694.7	3.99496	1	9.5
June	37	7250.39	748.769	75100.3	4.53066	1	13.07
July	32	3600.36	830.545	16514.6	7.13619	3	43.2
August	34	2798.76	436.322	12291.8	4.40593	1.3	10.6
September	32	5672.98	674.426	66243.5	4.81573	1.87	131.5
October	35	5821.78	743.478	52792.1	3.78307	1.05	9
November	27	8255.66	1028.5	35320.4	3.1001	0.5	11.5
December	25	11359.5	1777.17	40521.2	4.57125	0.80105	26.65



Constituent-Associated Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/4/1985 to 9/6/2012 (386 Observations)

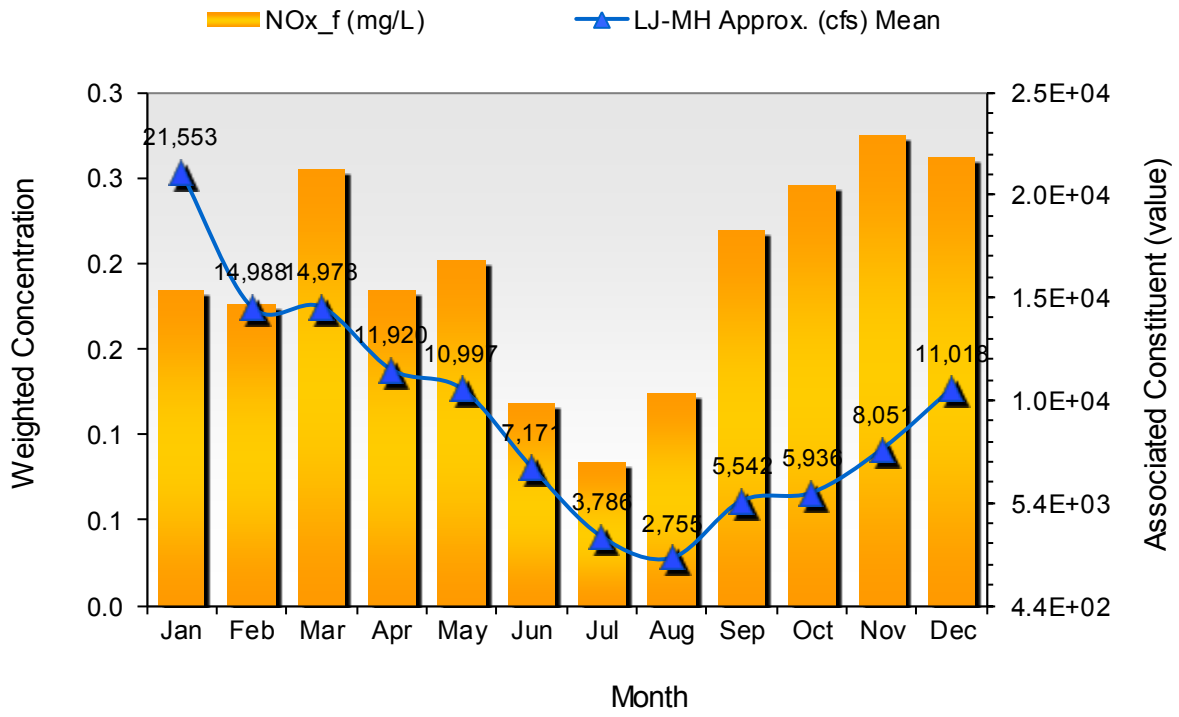
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	39	1117.28	436.322	1476.72	0.0971666	0	0.26275
10-20	38	1875.03	1532.24	2205.27	0.103222	0	0.278
20-30	39	2534.38	2209.06	2939.61	0.0920109	0	0.328
30-40	38	3485.64	2957.53	4000.2	0.135471	0	0.3645
40-50	39	4804.12	4010.58	5338.67	0.103005	0	0.36
50-60	38	6069.19	5376.8	6677.27	0.178589	0	0.4425
60-70	39	7615.44	6741.22	8812.35	0.16292	0	0.3975
70-80	38	10371.2	8822.61	12123.3	0.20039	0	1.20833
80-90	39	15563.4	12193.6	20389.3	0.196182	0	0.525
90-100	38	38645.9	20714.7	110146	0.269035	0	0.575



Seasonal Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: NOx_f (mg/L)
Data from: 2/4/1985 to 9/6/2012 (386 Observations)

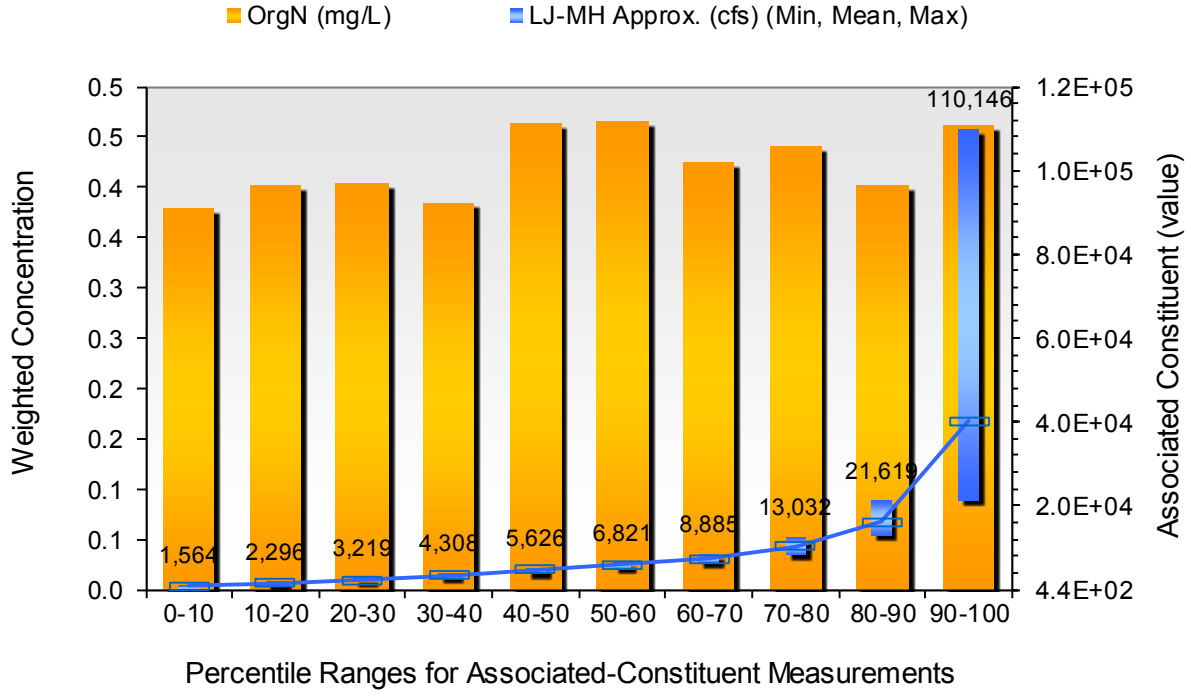
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	24	21553.2	2840.47	126749	0.184685	0	1.20833
February	25	14987.8	1951.86	68428.2	0.176192	0	0.545
March	35	14978.1	3760.79	54948.3	0.255336	0	0.51
April	36	11919.6	3870.2	51049.3	0.184693	0	0.525
May	38	10996.8	2088.5	60694.7	0.201288	0	0.335
June	38	7171.36	748.769	75100.3	0.118618	0	0.395
July	34	3786.21	830.545	16514.6	0.0838676	0	0.215
August	35	2754.94	436.322	12291.8	0.124509	0	0.395
September	33	5542.46	674.426	66243.5	0.219012	0	0.414
October	34	5936.27	743.478	52792.1	0.245614	0	0.43
November	28	8051.3	1028.5	35320.4	0.274904	0	0.416
December	26	11017.6	1777.17	40521.2	0.262307	0	0.575



Constituent-Associated Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 5/7/2012 (350 Observations)

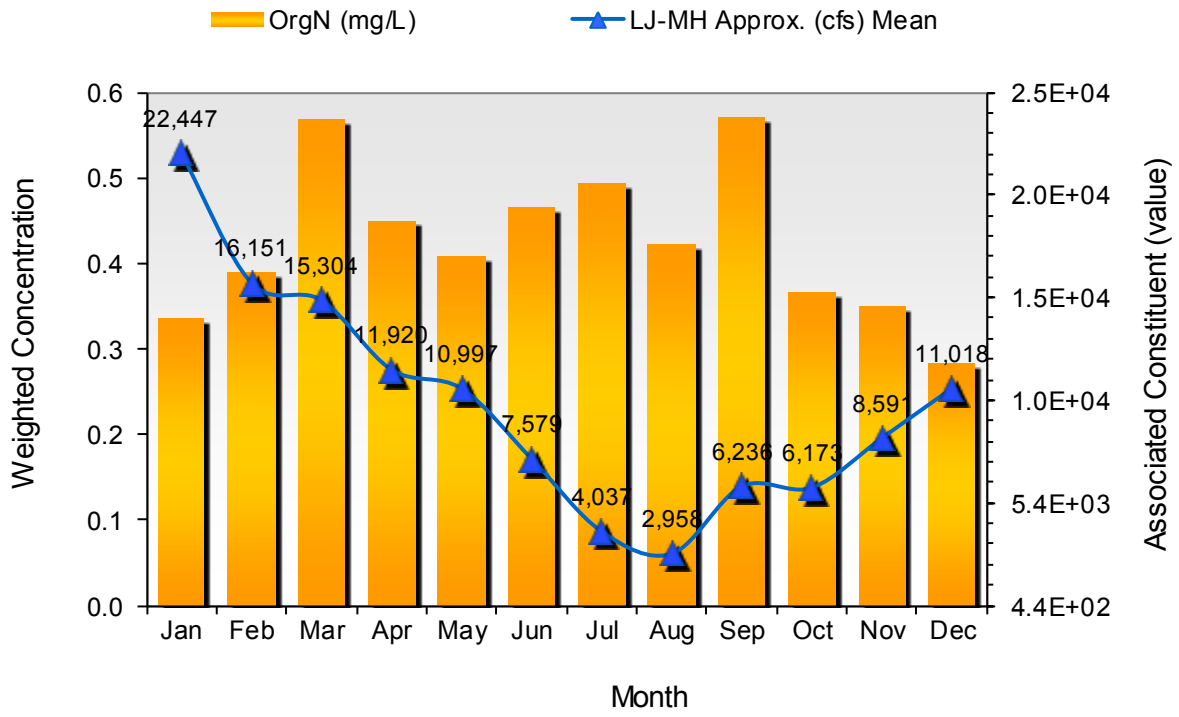
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	35	1152.17	436.322	1563.97	0.377835	0	0.72
10-20	35	1991.97	1587.18	2296.37	0.401401	0	0.717
20-30	35	2693.22	2323.72	3218.63	0.403616	0	1.02
30-40	35	3708.16	3244.77	4307.52	0.383292	0	0.58
40-50	35	5088.6	4315.37	5626.15	0.464103	0	1.605
50-60	35	6257.06	5630.62	6821.23	0.465098	0	1.62
60-70	35	7819.73	6951.85	8884.95	0.423964	0	1.54633
70-80	35	10840.1	8889.63	13032.4	0.440997	0	1.12
80-90	35	16627.8	13395.1	21618.6	0.401184	0	0.9675
90-100	34	40633.3	21836.5	110146	0.461808	0	1.17



Seasonal Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: OrgN (mg/L)
Data from: 2/4/1985 to 5/7/2012 (350 Observations)

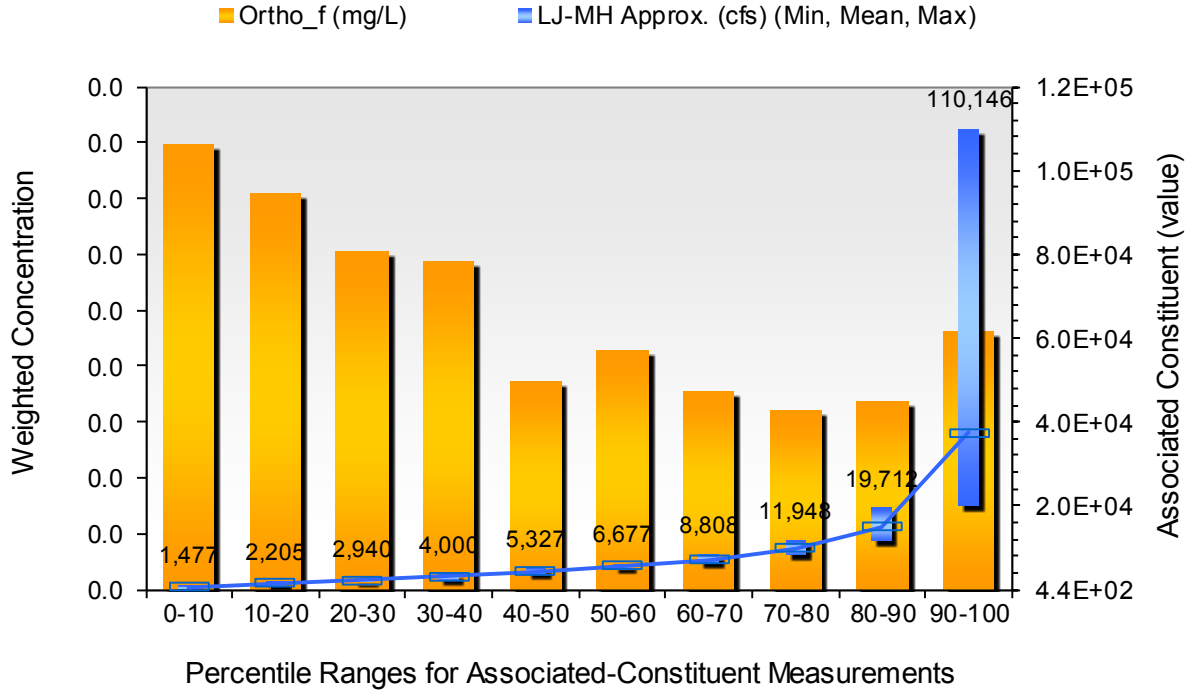
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	22	22446.9	2840.47	126749	0.3353	0	1.32767
February	20	16151.3	1951.86	68428.2	0.389678	0	1.54633
March	32	15304.1	3760.79	54948.3	0.568059	0	1.605
April	36	11919.6	3870.2	51049.3	0.449926	0	1.62
May	38	10996.8	2088.5	60694.7	0.408734	0	0.66
June	33	7579	1091.96	75100.3	0.46593	0	1.1405
July	30	4036.62	830.545	16514.6	0.493207	0	1.02
August	30	2957.95	436.322	12291.8	0.421867	0	0.9585
September	28	6235.52	674.426	66243.5	0.571014	0	0.90575
October	30	6172.95	743.478	52792.1	0.365048	0	0.72
November	25	8591.19	1028.5	35320.4	0.350163	0	0.67
December	26	11017.6	1777.17	40521.2	0.281489	0	0.526667



Constituent-Associated Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 2/4/1985 to 9/6/2012 (383 Observations)

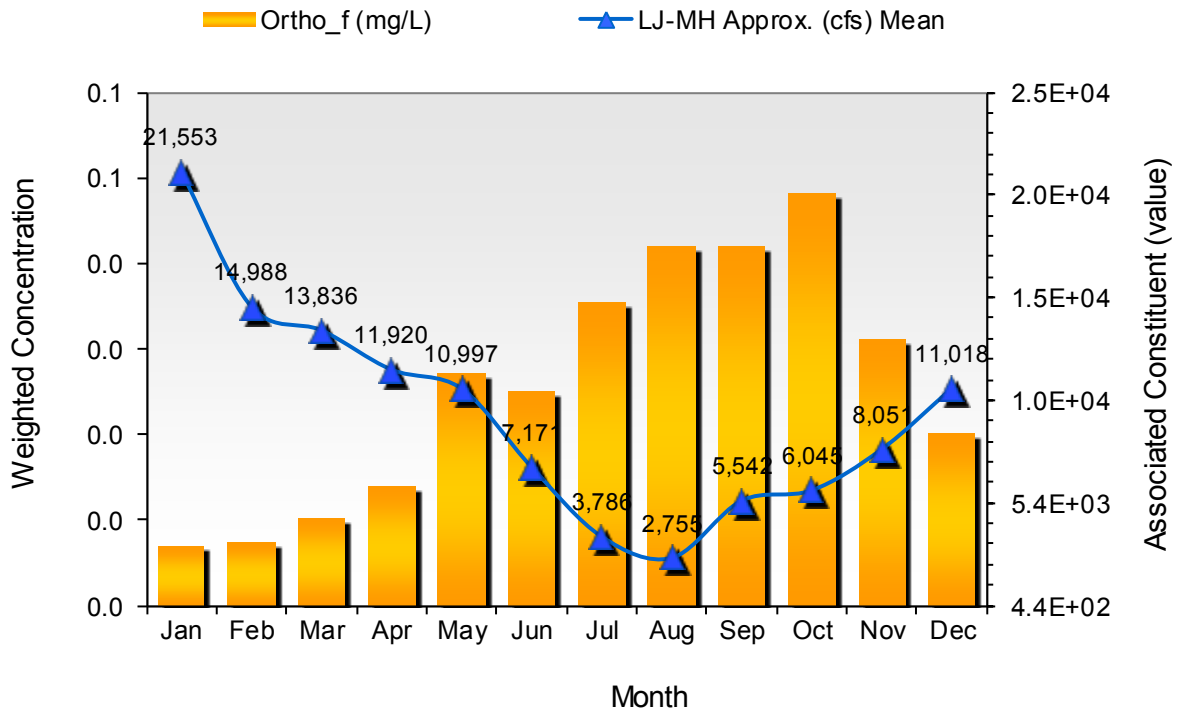
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	39	1117.28	436.322	1476.72	0.0398006	0	0.071
10-20	38	1875.03	1532.24	2205.27	0.0354169	0	0.075
20-30	38	2538.91	2209.06	2939.61	0.030204	0	0.0775
30-40	38	3485.64	2957.53	4000.2	0.0292987	0	0.07
40-50	38	4790.05	4010.58	5327.26	0.0186282	0	0.075
50-60	39	6050.46	5338.67	6677.27	0.0213764	0	0.06
60-70	38	7583.94	6741.22	8807.83	0.0177911	0	0.06
70-80	38	10284.1	8812.35	11948.1	0.0160213	0	0.07
80-90	38	15421.1	12123.3	19711.8	0.0169379	0	0.065
90-100	38	37736.5	20389.3	110146	0.0230623	0	0.065



Seasonal Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: Ortho_f (mg/L)
Data from: 2/4/1985 to 9/6/2012 (383 Observations)

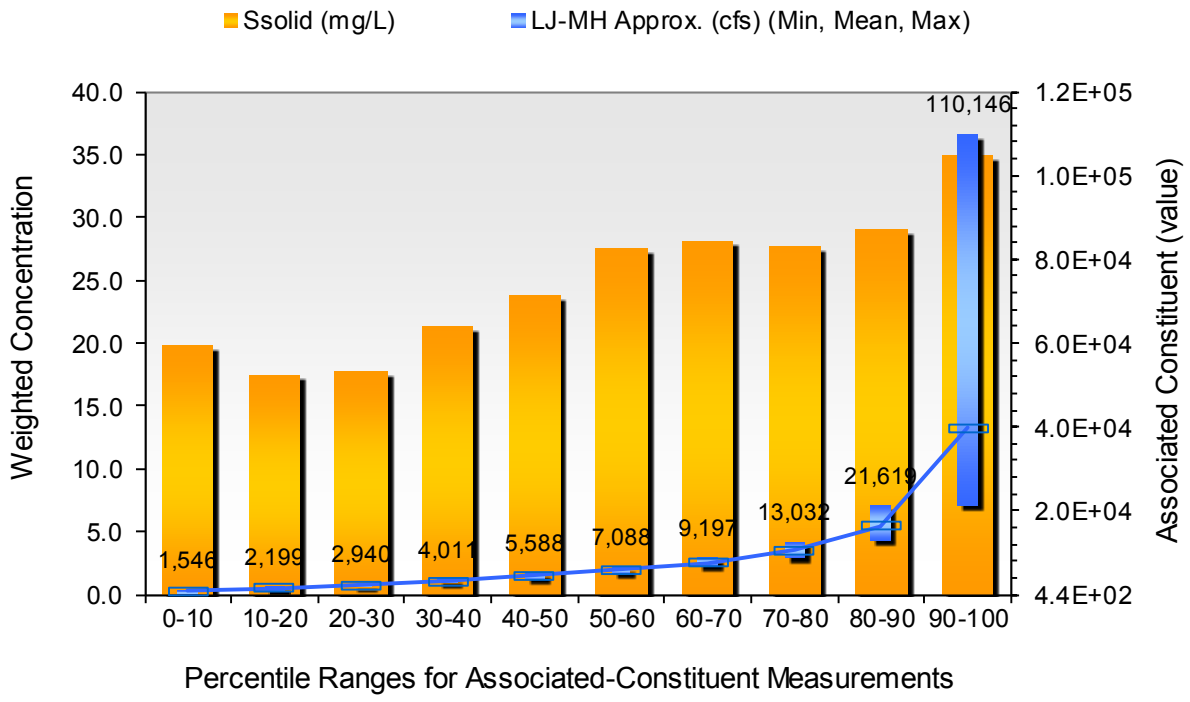
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	24	21553.2	2840.47	126749	0.00697487	0	0.03
February	25	14987.8	1951.86	68428.2	0.00736285	0	0.025
March	33	13835.8	3760.79	47916.9	0.0102405	0	0.035
April	36	11919.6	3870.2	51049.3	0.0138924	0	0.035
May	38	10996.8	2088.5	60694.7	0.0272098	0	0.05
June	38	7171.36	748.769	75100.3	0.0251007	0	0.04
July	34	3786.21	830.545	16514.6	0.0353536	0	0.07
August	35	2754.94	436.322	12291.8	0.0418404	0	0.075
September	33	5542.46	674.426	66243.5	0.0419639	0	0.075
October	33	6044.56	743.478	52792.1	0.0481079	0	0.0775
November	28	8051.3	1028.5	35320.4	0.0310818	0	0.05
December	26	11017.6	1777.17	40521.2	0.0202269	0	0.04



Constituent-Associated Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: Ssolid (mg/L)
Data from: 11/12/1985 to 9/6/2012 (323 Observations)

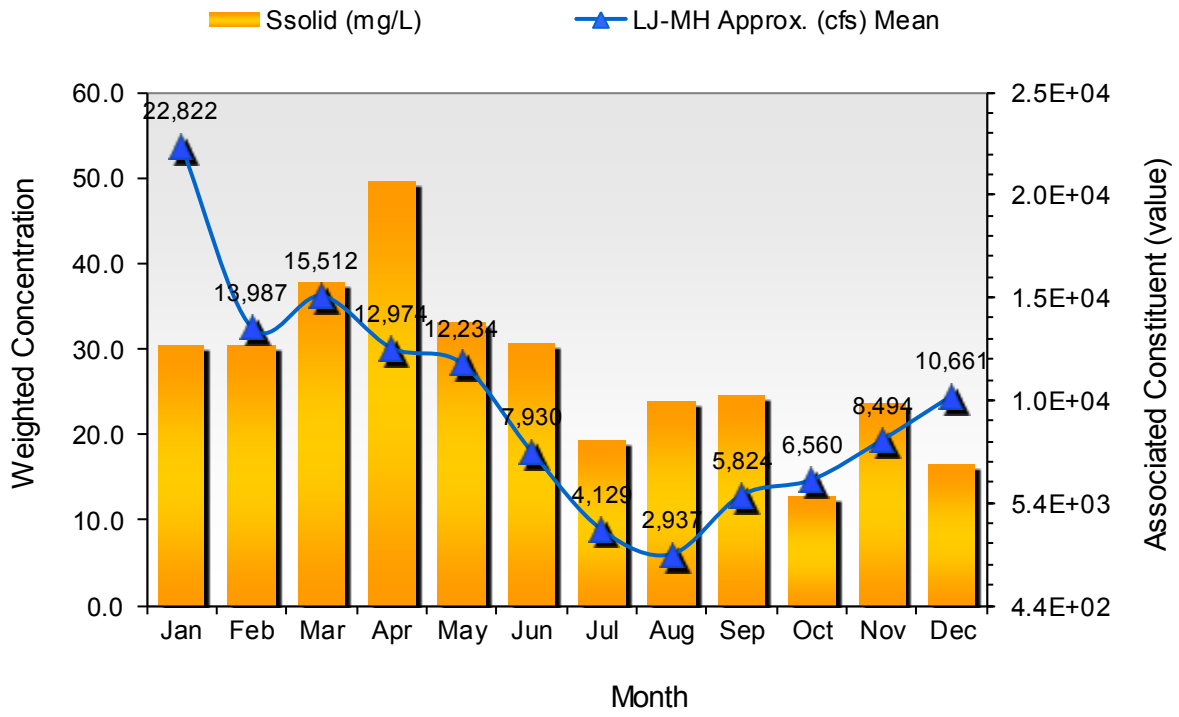
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	33	1142.6	436.322	1545.94	19.707	3	58
10-20	32	1877.26	1551.08	2199.12	17.4302	4	61
20-30	32	2533.79	2209.06	2939.61	17.755	3.5	53
30-40	32	3544.43	3023.55	4010.58	21.3722	1.5	77
40-50	32	4967.53	4088.95	5587.68	23.8094	5	86.5
50-60	33	6358.65	5626.15	7087.62	27.4574	5	103.5
60-70	32	8079.14	7179.18	9197.35	28.0514	5.5	69.5
70-80	32	11061.4	9209.57	13032.4	27.659	9.5	85
80-90	32	16660	13395.1	21618.6	29.0866	5.5	126
90-100	32	40196.2	21836.5	110146	34.9031	7	102



Seasonal Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: Ssolid (mg/L)
Data from: 11/12/1985 to 9/6/2012 (323 Observations)

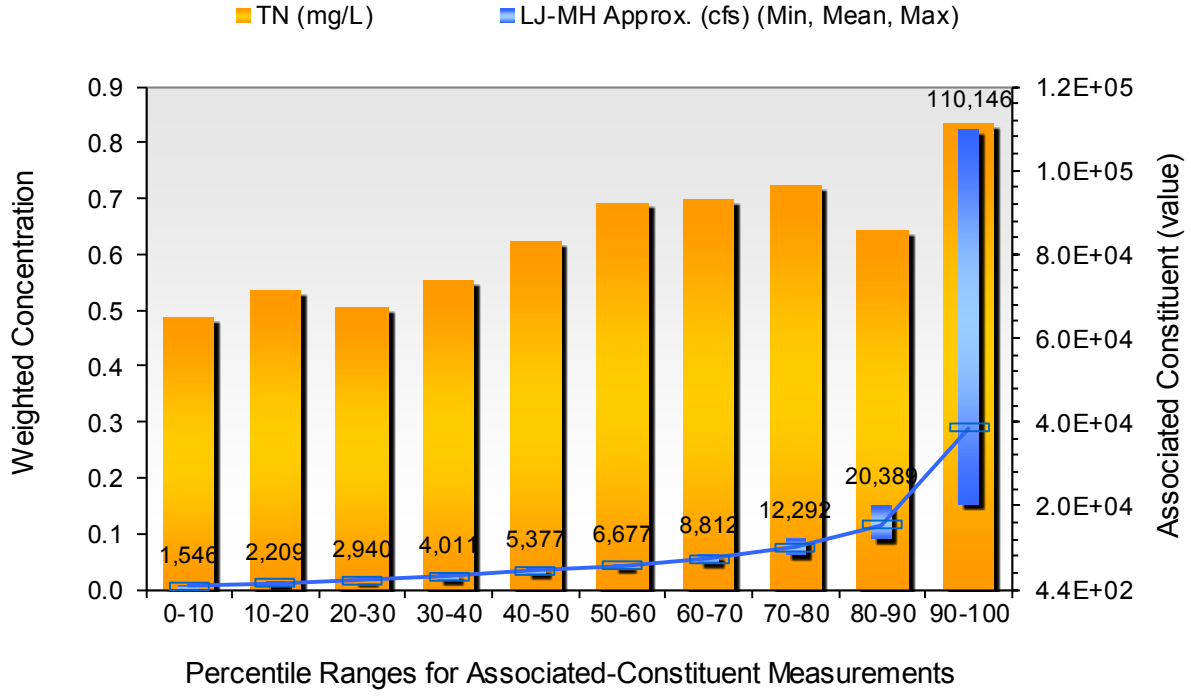
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	22	22821.7	2840.47	126749	30.3645	7	48.5
February	22	13987.4	1951.86	68428.2	30.3808	7	67.75
March	27	15512.2	3760.79	47916.9	37.8011	8	102
April	29	12974.4	3870.2	51049.3	49.6516	10.5	96.5
May	28	12234.2	2088.5	60694.7	33.1638	18	71.5
June	31	7930.05	748.769	75100.3	30.6174	7.5	103.5
July	29	4129.05	830.545	16514.6	19.2825	11	36
August	29	2936.95	436.322	12291.8	23.9006	1.5	85
September	28	5824.38	674.426	66243.5	24.6608	8	58
October	29	6560.37	743.478	52792.1	12.715	4	42.5
November	25	8493.85	1028.5	35320.4	23.6887	3	126
December	24	10660.5	1777.17	40521.2	16.4945	4	37.5



Constituent-Associated Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 8/8/2012 (372 Observations)

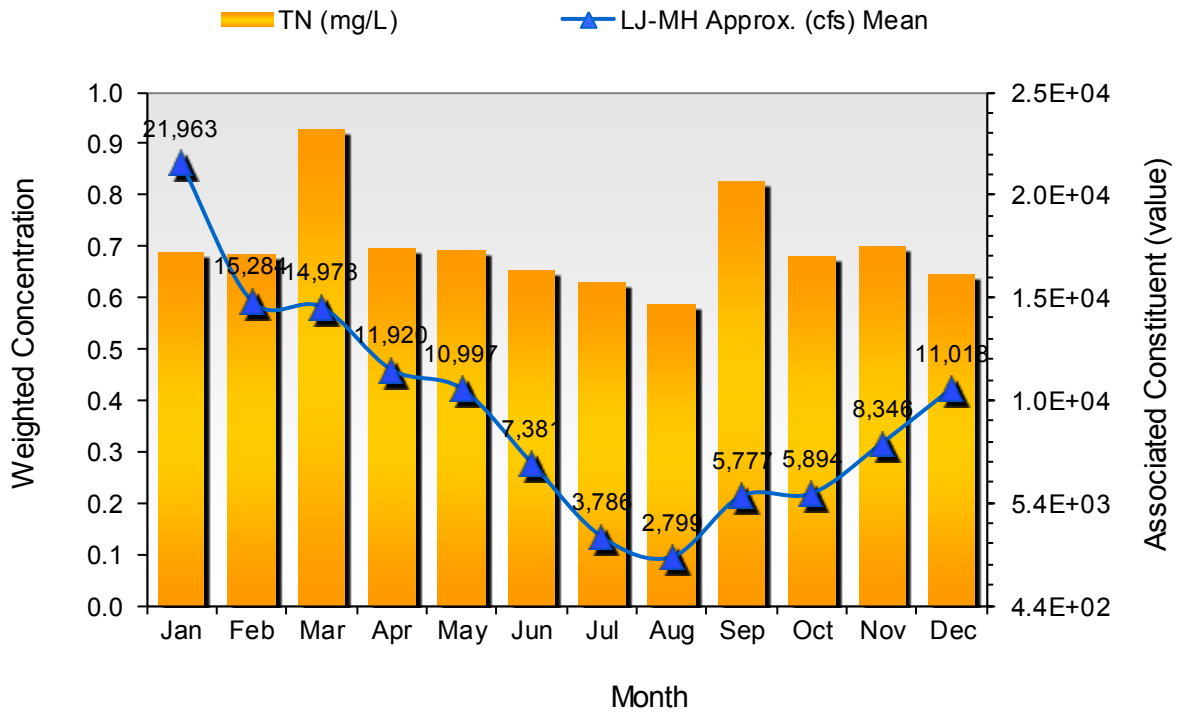
Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	1144.95	436.322	1545.94	0.488222	0	0.845
10-20	37	1902.22	1551.08	2209.06	0.533783	0	0.875
20-30	37	2539.45	2214.67	2939.61	0.505069	0	1.08875
30-40	37	3479.45	2957.53	4010.58	0.552066	0	0.88
40-50	37	4855.33	4088.95	5376.8	0.621474	0	1.8975
50-60	37	6087.9	5515.24	6677.27	0.692495	0	1.7425
60-70	37	7634.08	6771.09	8812.35	0.699215	0	1.7455
70-80	37	10491.8	8822.61	12291.8	0.72428	0	1.94167
80-90	37	15742.8	12506.3	20389.3	0.642713	0	1.125
90-100	37	39044.4	20714.7	110146	0.833878	0	1.745



Seasonal Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: TN (mg/L)
Data from: 2/4/1985 to 8/8/2012 (372 Observations)

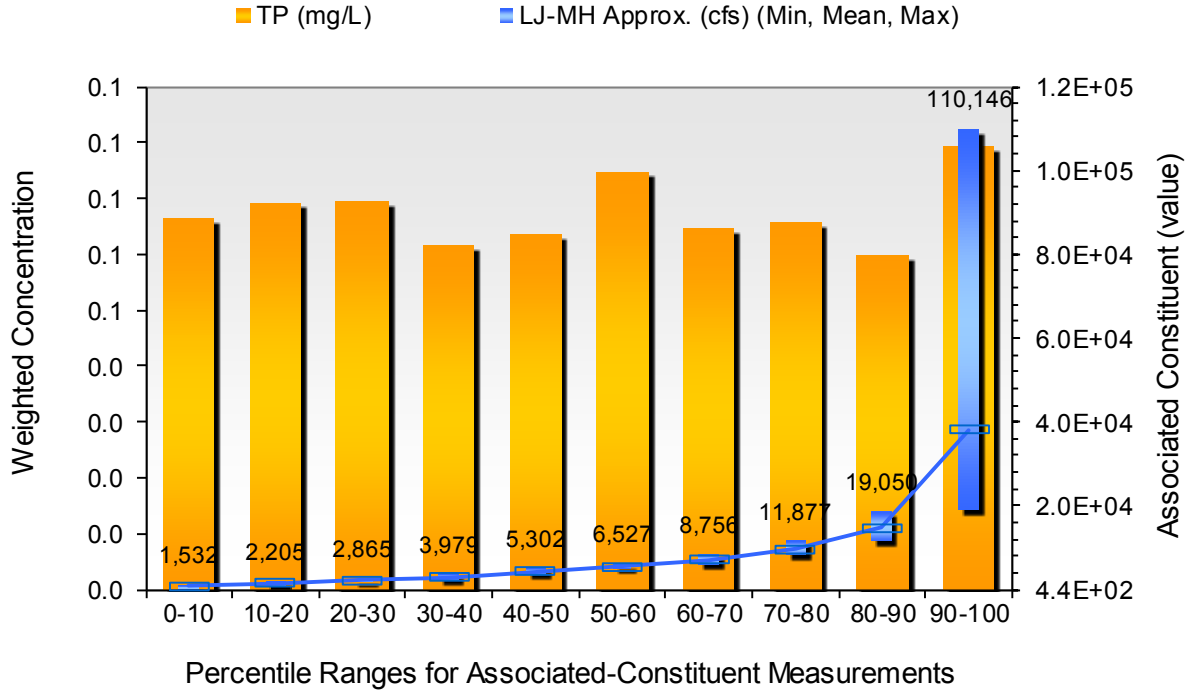
Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	23	21963.2	2840.47	126749	0.686886	0	1.94167
February	22	15284.1	1951.86	68428.2	0.682606	0	1.7455
March	35	14978.1	3760.79	54948.3	0.925075	0	1.8975
April	36	11919.6	3870.2	51049.3	0.696573	0	1.7425
May	38	10996.8	2088.5	60694.7	0.689699	0	0.975
June	35	7380.74	1091.96	75100.3	0.652024	0	1.46
July	34	3786.21	830.545	16514.6	0.628378	0	1.08875
August	34	2798.76	436.322	12291.8	0.587092	0	1.0425
September	31	5777.39	674.426	66243.5	0.827752	0	1.22375
October	32	5894.48	743.478	52792.1	0.677966	0	0.9745
November	26	8346.3	1028.5	35320.4	0.698358	0	1.05
December	26	11017.6	1777.17	40521.2	0.644379	0	1.1925



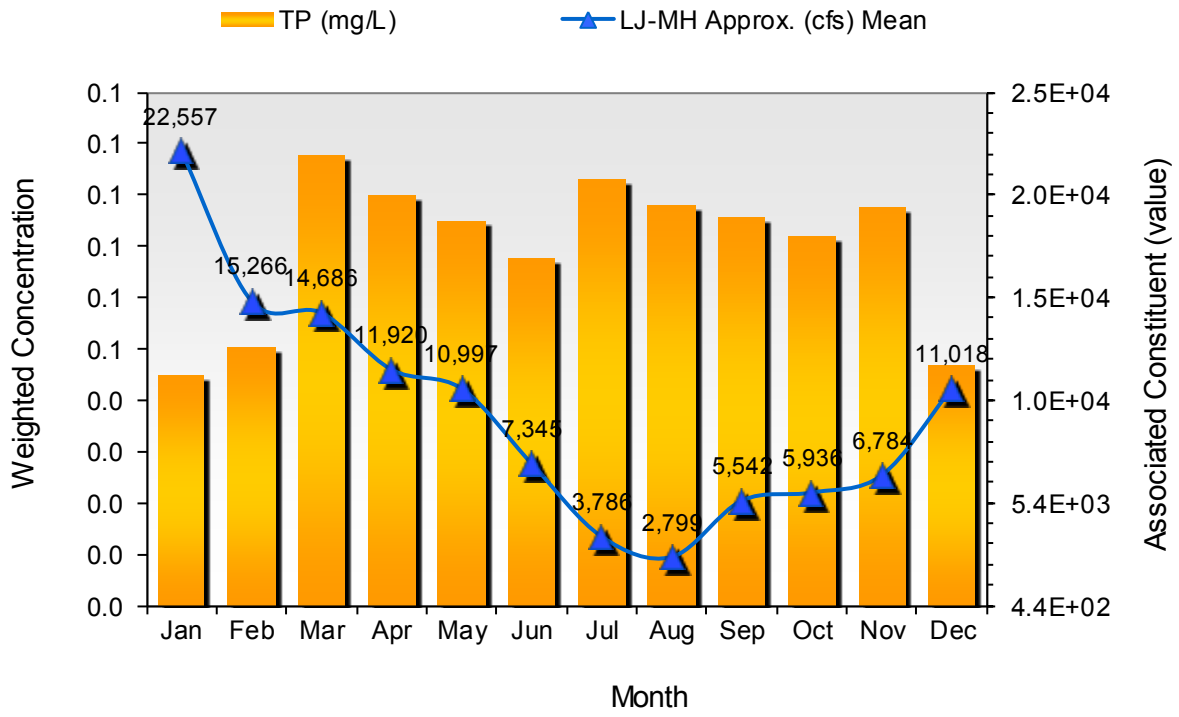
Constituent-Associated Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 9/6/2012 (376 Observations)

Flow Range	# Obs	Associated Constituent			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	38	1134	436.322	1532.24	0.0664254	0	0.17
10-20	37	1884.3	1545.94	2205.27	0.0692887	0	0.125
20-30	38	2523.72	2209.06	2864.57	0.0696277	0	0.2619
30-40	37	3443.28	2939.61	3978.88	0.0614006	0	0.1109
40-50	38	4720.24	3992.17	5301.66	0.0636456	0	0.125
50-60	37	5950.19	5318.04	6527.48	0.0745397	0	0.145
60-70	38	7423.79	6543.19	8756.32	0.0645389	0	0.14
70-80	37	10151.8	8789.1	11876.7	0.0656444	0	0.17
80-90	38	15037.8	11937.6	19049.7	0.0596078	0	0.25
90-100	37	38651.6	19317.1	110146	0.0791891	0	0.265



Seasonal Trend Assessment

Location: LE5.2
Comparison Parameter: LJ-MH Approx. (cfs)
Pollutant: TP (mg/L)
Data from: 2/4/1985 to 9/6/2012 (376 Observations)

Time Period	# Obs	Associated Constituent			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	22	22557.4	2840.47	126749	0.0447148	0	0.10765
February	22	15265.7	1951.86	68428.2	0.050059	0	0.12205
March	34	14686	3760.79	54948.3	0.087547	0	0.265
April	36	11919.6	3870.2	51049.3	0.0798419	0	0.16
May	38	10996.8	2088.5	60694.7	0.0748491	0	0.145
June	37	7344.95	1091.96	75100.3	0.0675304	0	0.1174
July	34	3786.21	830.545	16514.6	0.0831063	0	0.2619
August	34	2798.76	436.322	12291.8	0.0780515	0	0.125
September	33	5542.46	674.426	66243.5	0.07585	0	0.17
October	34	5936.27	743.478	52792.1	0.0717032	0	0.125
November	26	6784.33	1028.5	35320.4	0.0776201	0	0.25
December	26	11017.6	1777.17	40521.2	0.0468641	0	0.085