Appendix E2:
Technical Assistance

The
Residential
Runoff Reduction
Study

Appendix E2: Technical Assistance for the Residential Runoff Reduction (R3) Report

Prepared for

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Table of Contents

List of Figures

List of Tables

1. Introduction

This report describes analyses and results of work conducted by GeoSyntec Consultants for the Irvine Ranch Water District (IRWD) to assist in the completion of the Residential Reduction Runoff (R3) Study. The R3 Study is an ambitious investigation to quantify the effectiveness of BMPs in reducing dry weather discharges and associated pollutants.

GeoSyntec Consultants completed the following tasks:

1. Review and Analysis of Water Quality Data. We reviewed the analyses described in Chapter 5 of the R3 report and conducted additional analyses of the water quality data and flux calculations to explore and potentially enhance the interpretation of the monitoring results.
2. Evaluation of Possible Implications on TMDL Compliance. We reviewed and summarized applicable TMDLs in the San Diego Creek Watershed. Results from Task 1 were compared with the TMDLs to evaluate whether the BMPs are beneficial to achieving the TMDL objectives.

2. GeoSyntec Review of Section 5 of the R3 Study Report

Section 5 in the R3 report describes the water quality monitoring data and analyses. The following are GeoSyntec review comments of Section 5.

- **Abstract and Introduction**. The abstract and introduction section provides a recap of the entire study, including a description of the study motivation and objectives. This suggests that this section of the report was originally written as a stand-alone report. In the final report we recommend that most of this information should be integrated into an earlier overall report introductory chapter. The introduction of Section 5 should be limited to a recap of the water quality and flow data, and to present the purpose/goals of the data analysis described in this section.
- **Methods**. The methods section similarly presents much of the study details (watershed descriptions, intervention description-BMPs applied-, etc). We recommend this information be presented in an earlier chapter in the report that describes the study design and procedures in a high degree of detail. This study description chapter could then be referenced as needed throughout the report.
- **Data Analysis and Results**. The 5 data analysis steps are logical and reasonable, however, the procedures, assumptions made, and results are, in some cases, unclear as discussed below. Additional details of the procedures and assumptions made, as well as the use of alternative, possibly more appropriate statistical procedures could enhance the interpretation and usefulness of the monitoring data. Some specific suggestions and comments are discussed below:

1. **Comparison of water quality data prior to intervention**. ANOVA tests were used to test for differences among the treatment sites for each constituent prior to intervention. ANOVA is a parametric test, which is identical to the t-test when comparing only two groups of data. This test assumes that all data sets are normally distributed and have equal variance. The t-test has limitedpower todetect small differences among data sets if they are not normally distributed. Currently the report states that the "data were tested for normality and homogeneous variance prior to testing...[and] only the microbiological data were determined to be non-normally distributed..." However, the results of the normality tests were not included, nor were any descriptive statistics that may indicate normality. Our analyses suggest that many of the data groups are not normally distributed. In addition the mean is not considered a good measure of central tendency for many of R3 data, because mean values can be strongly influenced by outlier values, which were frequently observed. Much of our analyses, therefore, are based on the evaluation of median concentrations. Median values are resistant to the influence of outlier values, and may therefore be a more appropriate measure of central tendency in the R3 data.

   Table WQ3 includes means and 95% confidence intervals for the water quality data before and after intervention (BMPs applied). These descriptive statistics only show part of the story. At the very least, other parametric descriptive statistics, such as the standard deviation and the coefficient of skewness should be included, as well as non-parametric (i.e., resistant to outliers) descriptive statistics, such as the median, interquartile range, and the quartile skew. These will aid in interpreting the central tendency, variation, and skewness of the data. A test on the coefficient of skewness will indicate whether the data are symmetric or not. If the null hypothesis that the data are symmetric cannot be rejected, normality tests are warranted. Otherwise, it can be safely assumed that the data do not come from a normal distribution and alternative non-parametric statistical procedures that do not require normality should to be used.

   The standard methods for calculating the 95% confidence interval about the mean (based on t-distribution) are symmetric confidence intervals that require normality, especially with small data sets. While the report does not state the method used for calculating the 95% confidence intervals, it is likely that the standard method was employed since normality was assumed for the ANOVA analysis. When data are non-normal, alternative methods for calculating the 95% confidence intervals could be used, such as the non-parametric interval estimate for the median (no specific data distribution assumed) or an asymmetric confidence interval about the mean (a specific distribution is assumed, such as the lognormal distribution). However, it should be noted that 95% confidence intervals, are appropriate, but not necessary for testing whether there are significant differences between data sets. Hypothesis tests can be used to detect differences. It is recommended that confidence intervals be reserved for showing the uncertainty in an estimate of central tendency (e.g. mean or median) to determine the likelihood for a threshold to be exceeded, such as a water quality criterion.

If one or more of the pre-intervention data sets are determined to be non-normal or unequal in variance, alternatives to the single-factor ANOVA test can be used, such as the Kruskal-Wallis (K-W) test. The K-W test will determine if all of the data sets have the same distribution and if the medians are equivalent within a specified level of confidence.

2. **Comparison of water quality concentrations over time.** Monthly mean concentrations over time were included in the report. While this is a valid approach to analyzing data, it has a tendency to mask the data's true variability, and since there were generally only two samples per month, there is no apparent advantage to averaging for this exploratory data analysis. Also, Site 1004 had large spikes in the nutrient values that when plotted on the same graph as the other sites tends to dampen and make less apparent the variability in monitoring results from the other sites. It is recommended that all data are initially plotted on separate time-series graphs to identify seasonal periodicity, step-trends, or monotonic trends for each sampling site. Time series plots are an excellent approach for presenting the data and an appropriate first step for understanding the characteristics of the data. Note that unless there are obvious trends (step or monotonic), the time-series plots should probably be placed in an appendix rather than the main body of the report, as there will be a number of them and the information provided is primarily to aid the investigator in determining the next step in the analysis.

   In addition to time series plots, other plotting procedures are available that can be useful in the visual inspection of the data. Plots that should be considered for inclusion in the report include box plots that show side-by-side comparisons of central tendency and variability, and side-by-side quantile (cumulative probability distribution) plots that give an indication of the underlying distribution and any apparent differences in those distributions. These should be included in the main body of the report.

3. **Comparison of water quality data before and after intervention.** Standard t-tests were used to compare mean concentrations before and after intervention. The report states that only 6 out of 24 constituents showed significant differences, and the differences showed a net increase from pre- to post treatment. Removing the outlier points did not affect this result. As stated above, the t-test assumes that both groups of data are normally distributed about their respective means and that they have constant variance. There is no indication that the data meet these strict requirements (water resources data rarely do). The report also states that the data were "normalized" to the grand mean of the control sites, but there is no justifiable reason for doing so, especially since the control sites varied greatly amongst themselves.

   A limitation in the comparison of mean concentrations, such as through the use of the t-test, is that the mean of the concentration data is heavily influenced by outlier values. Given that outlier values were identified and recognized to influence the results, alternative measures of central tendency that are more resistant to the influence of the outliers (e.g. median) should be investigated and presented in the report. The rank-sum test, or Mann-Whitney test, is a non-parametric test that tests whether the median of one group is significantly different from the median of another group. The rank-sum test does not assume any particular distribution or even that the two data sets come from the same distribution. Also, it has the power to detect small differences among data sets and will even work on censored data (data only known to be below the detection limit) as long as less than 50% of the data are censored. The rank-sum test is equivalent to the Kruskal-Wallis test discussed above, but applied to only two data sets. Based on the relative strengths of the rank-sum test as compared to the t-test, and for consistency in the data analysis (as it is highly unlikely the assumptions of the t-test could be met for all, if any of the data sets), it is recommended that the rank-sum (or Krsuskal-Wallis) tests be performed on all data sets.

Once it is determined that a significant difference in the medians exists, the magnitude of the difference can be calculated using the Hodges-Lehmann estimator, which is the median of all possible pair-wise differences between the two data sets. Note that this is often significantly different than the simple difference in medians. A confidence interval about the Hodges-Lehmann estimator can then be calculated to illustrate the variability of the estimate.

4. **Comparison of constituent fluxes (Mass loadings per time) before and after intervention**. Similar to the analysis of concentration data discussed above, mean fluxes for the pre- and post-intervention cases were compared using standard t-tests (for 2 sites only). In general, no difference in the mean flux was found between the pre- and post-intervention data.

   Similar to the analysis of the concentration data, the mean of the flux data is heavily influenced by outliers. Therefore, alternative measures of the central tendency should be calculated and compared. The rank-sum test could be used here as well.

5. **Correlation of toxicity measures with potential toxicants in dry weather runoff**. Correlations between toxicity data and concentration data were investigated using a Pearson product moment correlation. Based on this analysis, no correlations were found to be significant. The first and foremost step in investigating whether one variable is associated with another is to plot the two variables on opposite axes (scatterplot). This step was presented in the report and should be included. A scatterplot matrix helps to identify the nature of the correlation between several variables in one concise graph. A scatterplot will also indicate whether the use of Pearson's correlation coefficient is even appropriate, as it only tests whether there is a linear association between two variables. Due to the nature and complexity of biotic systems, the relationship between toxicity and constituent concentration are likely to be nonlinear. Therefore, an alternative measure of association should be used such as Kendall's Tau or Spearmans Rho. Both of these statistics measure the strength of the monotonic relationship between two variables.

- **Discussion and General Review Comments**. The primary conclusions drawn from the investigation were that there is no statistically significant reductions in pollutant concentration or flux (loadings) as a result of the education and/or sprinkler retrofit technology. While this may be the case, the data analysis described and presented may have had limited ability to detect differences for the particular data sets. The discussion section included two possible explanations for not being able to detect changes between pre- and post-intervention: 1) the data had too much variability and not enough samples were taken, and 2) the treatments were applied at only about one-third of the individual homes within the test watersheds, which effectively diluted the effects of the intervention. Both of these are logical explanations and should be considered in the design of future studies. A helpful assessment would be to evaluate how much data would be needed to detect levels of differences desired to be detected. This information would be valuable for planning of future studies.

Another possible explanation for having difficulty in detecting differences that was not mentioned in the report is the difference in time periods for the pre-intervention and the post-intervention. The pre-intervention period was from December 2000 to June 2001 and the post-intervention period was from July 2001 to June 2002. In other words, the post-intervention period includes summer and fall data, while the pre-intervention period does not. Moreover, there was considerably more rainfall during the pre-intervention wet season than the post intervention wet season (see Table 1).

Based on this it may be desirable to analyze differences using a truncated post-intervention data set with only winter and spring data. The downside of this approach is that it reduces the number of data points to include in the analysis. However, it is justifiable in that in the summer and fall the observed dry-weather flows are likely more associated with irrigation practices and in the winter and spring the observed dry-weather flows are likely more associated with the leaching of saturated soils. We recommend that the use of a truncated data set should be considered if additional analyses of the data using the approaches recommended above do not reveal statistically significant differences.

Table 1: Daily Rainfall Data at the Tustin-Irvine Rain Gauge (100th of inches)

		2001												2002											
	Dec 00	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 03	Mar 02	Apr 02	May 02	Jun 02	Jul 02	Aug 02	Sep 02	Oct 02	Nov 02	Dec 02
1																									
2							5						15												
3																									
4				47	7							6		5											
5																									
6				3	61												12								
7																22									
8		47																							
9				33	5																				
10													10											163	
11		184										4													
12		105	36									36													
13		8	295																						
14			14																						
15																	7								
16																									99
17															40	29									8
18			3																						
19																		7							
20			9															10							85
21					52								28												
22													8												
23			29													4									9
24		32	12									46					9								
25			85																						
26		57	90	3		8											7						5		
27		13	42											46			3								
28			32											5										3	
29												18	10												13
30													35											54	
31																									
total	0	446	647	86	125	8	5	0	0	0	0	110	106	56	40	55	38	17	0	0	0	0	5	220	214

▨ Pre-intervention period (13.2 inches from12/00-6/01)　□ Post-intervention period (3.1 inches from12/01-6/02)

3. Examples of Recommended Approaches to Data Analysis for Chapter 5

These example analyses focus on TMDL constituents: nutrients (total nitrogen and total phosphorus), metals (copper, lead, zinc, cadmium), pesticides, and pathogens (fecal coliform). The analyses also focus on dry weather flows, as reduction of these flows was the objective of the R3 study.

Recommended Data Analysis Methods

Exploratory Data Analysis

Visual inspection of data and exploration of factors that could potentially influence data (e.g. seasonal trends, rain events)

1. Divide data into pre and post- intervention groups.
2. Construct time series plots to visually inspect data and visually examine for seasonal trends. Overlay storm event markers to identify any relation to rainfall volume or antecedent dry period (ADP).
3. Investigate normality or log normality of data sets. Select appropriate statistical tests.
4. Construct probability plots for pre-intervention and post-intervention periods.
5. Prepare quantile plots.
6. Prepare side-by-side box plots.
7. Calculate descriptive statistics

Hypothesis Testing

Test data for skewness, normality, and statistically significant differences. Note that the skewness and normality tests are only needed if parametric approaches are conducted. It is our recommendation to use non-parametric approaches for consistency because normality will not be met in all cases. Nonetheless examples have been provided to show that several of the data sets do not come from a normal distribution.

1. Skewness hypothesis test for symmetry.
2. Shipiro-Wilkes normality test.
3. Mann-Whitney rank-sum test.
4. For the data sets that have greater than 50% censored data (i.e. data only known to be less than the detection limit), hypothesis tests for differences in proportions.

Example Results

The first step in the data analysis is to construct time-series plots. Time-series plots are constructed to identify seasonal periodicity, step-trends, and monotonic trends. The original report included monthly average time-series plots with all sites included per plot. The authors noted that periodicity and trends were not apparent. However, plotting all sites on one graph tends to hide much of the information. For instance, Site 1004 had much higher nutrient concentrations than the other sites, so by including this site, the minor fluctuations in data from the other stations are less apparent. Individually plotting the time-series plots reveals more information. Also, by overlaying storm events the role of rainfall volumes and the antecedent dry period (ADP) may be more apparent and may indicate whether additional analyses are warranted (e.g., correlating ADP with concentration). Figure 1 is an example time-series plot with storm event markers overlain for total phosphorus for Site 1001. Notice the pre-intervention period had much more rainfall, which likely added to the variability in runoff concentrations and fluxes. However, it is apparent that the winter and spring concentrations appear to be lower and less variable during the post-intervention period. The irrigation controllers may have had an affect on the runoff concentrations by reducing the amount of irrigation during moister weather conditions (i.e. high soil moisture). Notice a similar effect for total nitrogen in Figure 2. Additional time-series plots are provided in Appendix A.

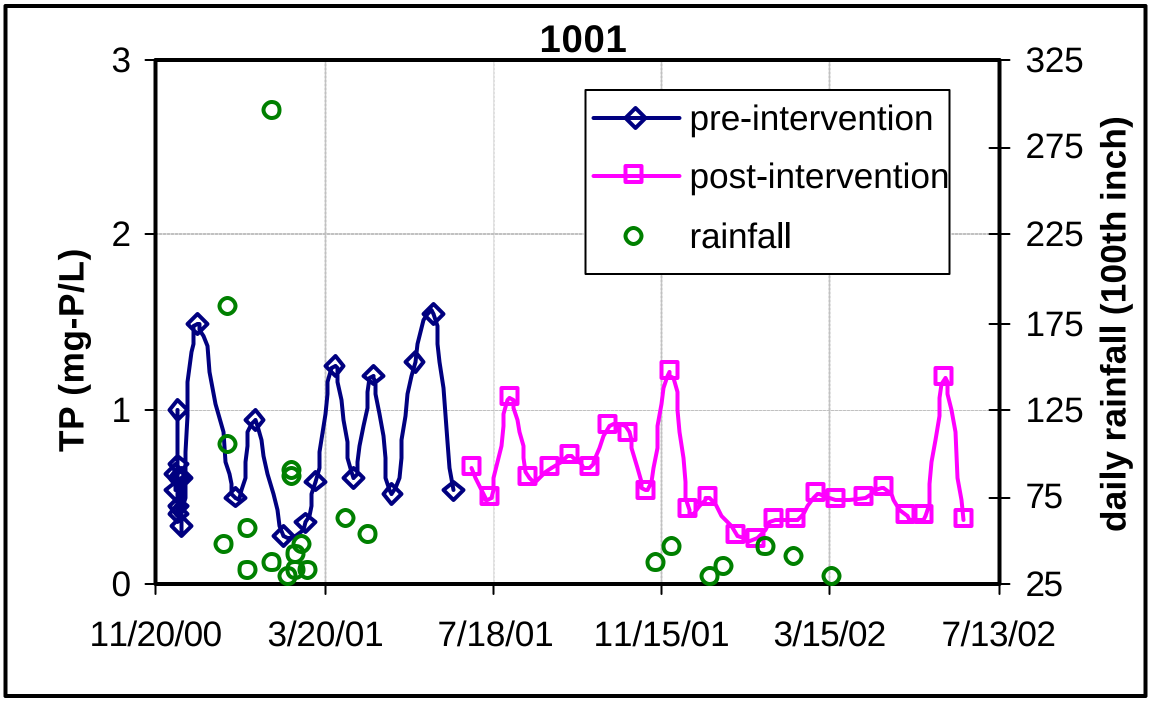


Figure 1. Example time-series plot of total phosphorus with storm event markers.

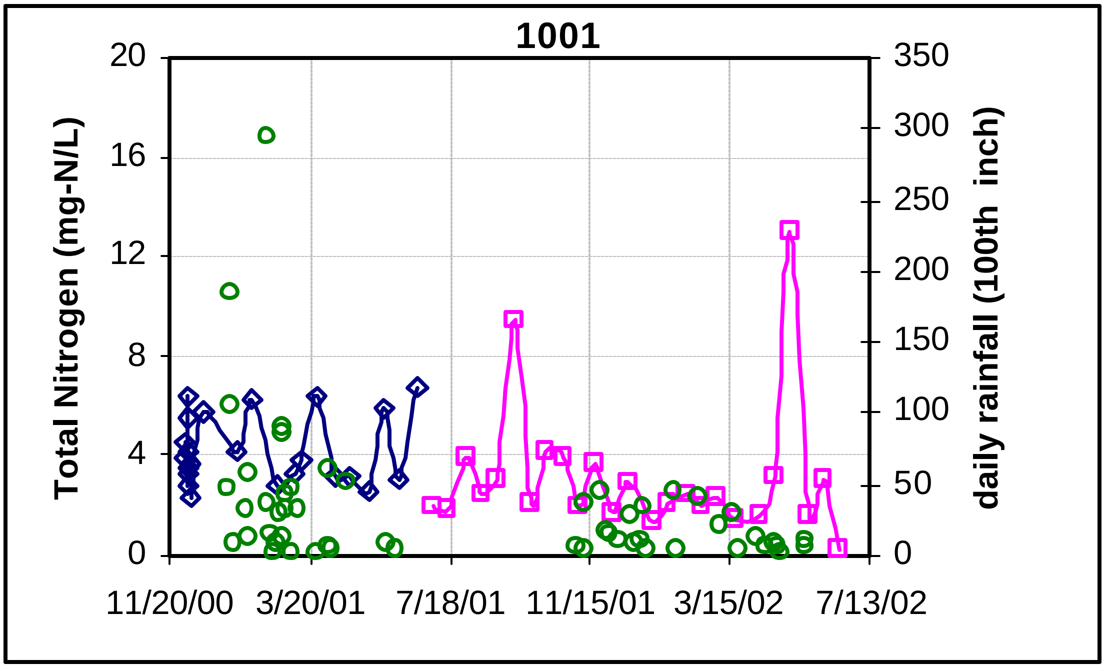


Figure 2. Example time-series plot of total nitrogen with storm event markers.

Comparison of Water Quality Data Prior to Intervention

To visually investigate whether the test sites have similar runoff characteristics, probability plots should be constructed. Figure 3 is an example of a probability plot for total phosphorus for all of the test sites. Notice that all of the sites have a similar distribution except for Site 1004. This suggests that Site 1004 should not be used for "normalizing" of the intervention sites (other information in the report indicating an unknown connection to a nursery further suggests the exclusion of site 1004). However, as mentioned above there is no advantage to normalizing the data using the control sites even if all of the sites had similar distributions.

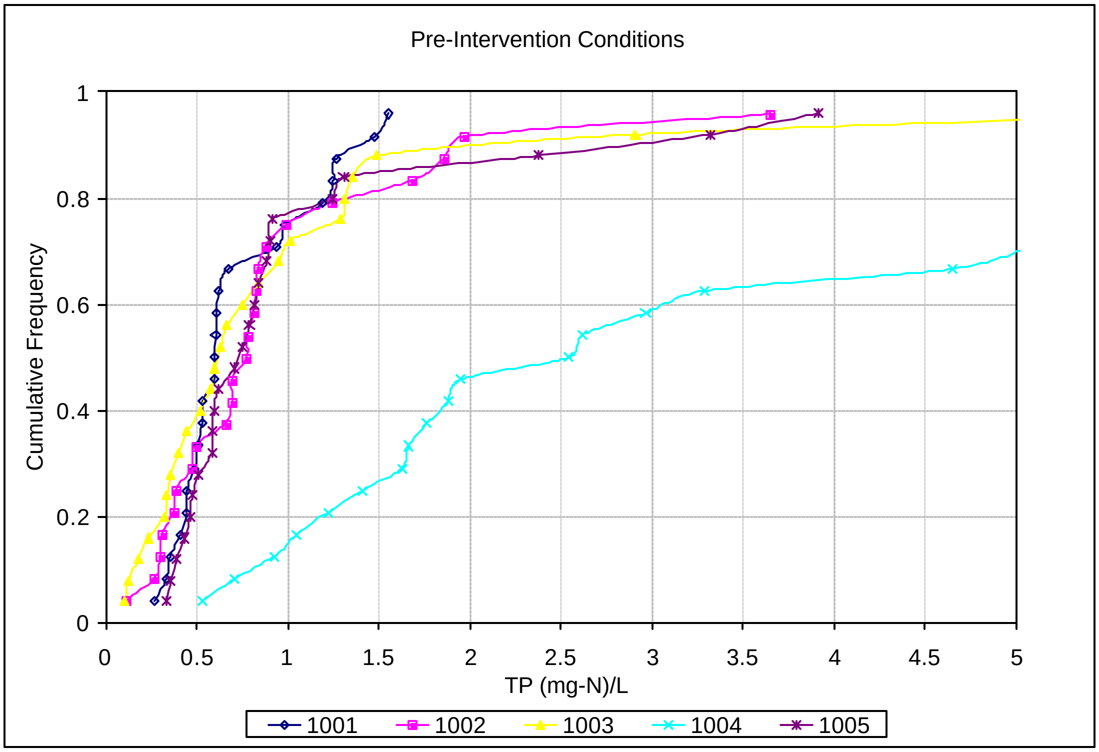


Figure 3. Example probability plot of total phosphorus for all sites prior to intervention.

The next step in the data analysis is to calculate parametric and non-parametric descriptive statistics. Table 2 is an example table of descriptive statistics for total nitrogen for all sites for both the pre- and post-intervention periods. (Additional descriptive statistics are included in Appendix B.) Table 2 includes the number of data points (n), the detection percent (%>MDL/RL), the mean, median, 25% trimmed mean, min, max, 25th percentile, 75th percentile, standard deviation, interquartile range (IQR), and the coefficient of skewness (g_s). Also included in the table are critical skewness coefficients (g_{cr}), which are readily available in statistics texts. If the coefficients of skewness are less than these critical values, then the data are symmetric. Notice that the measures of central tendency (mean and median) and variability (standard deviation) of the sites during the pre-intervention period are quite different, indicating the data arise from different distributions. The median values are consistently smaller than the mean (in some cases substantially smaller) demonstrating the influence of the outliers on the measure of central tendency. Also note that only three pre-intervention data sets are symmetric and none of the post-intervention data sets are. Failure to pass the symmetry test indicates the data are not normal. However, passing the symmetry test does not indicate the data are normal; this requires a normality test. The symmetry test, which is easier to conduct than normality tests, serves as an initial screen for normality to reduce the number of data sets needing further investigation.

Table 2. Example table of descriptive statistics for total nitrogen for each site for pre- and post-intervention.

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
TN (calculated) (mg-N/L)	**n**	23	25	23	25	23	25	23	25	23	25
	% > MDL/RL	100%	80%	98%	90%	98%	96%	98%	96%	100%	98%
	Mean	4.24	3.09	5.31	3.44	3.66	4.42	48.00	10.18	6.89	7.74
	Median	3.84	2.27	3.95	2.55	2.66	2.50	19.01	5.57	5.06	4.36
	Trimmed mean	3.94	2.40	4.53	2.76	2.93	3.01	33.11	6.47	5.08	4.42
	min	2.30	0.30	1.50	0.78	1.46	0.45	3.28	0.74	2.48	1.07
	max	6.76	12.99	13.83	11.40	12.12	19.91	141.06	40.80	20.41	67.12
	25th percentile	3.20	1.79	2.27	2.10	2.11	2.04	9.05	2.71	3.52	3.47
	75th percentile	5.68	3.13	8.02	4.36	4.81	5.17	94.79	19.18	7.07	5.62
	St Dev	1.41	2.67	3.56	2.51	2.48	4.39	49.17	10.73	5.29	12.85
	IQR	2.48	1.34	5.75	2.26	2.70	3.13	85.74	16.47	3.55	2.15
	Skewness, g_s	0.55	2.82	0.84	1.87	2.13	2.27	0.74	1.37	1.88	4.46
	g_{cr}	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	Symmetric ($g_s < g_{cr}$)?	Y	N	Y	N	N	N	Y	N	N	N

Non-parametric tests are recommended for all data analyses for consistency since all data sets do not meet the required assumptions for parametric tests (i.e. normality and constant variance). Non-parametric tests are not based on the assumption of normally distribution; therefore, normality tests were not warranted. It is important to note that if the data sets that passed the initial symmetry screening (Sites 1001, 1002, and 1004 in the table above) also passed a normality test, it does not indicate the data follow a normal distribution, especially for small data sets. The test simply indicates that normality cannot be rejected for the data.

As mentioned above, the non-parametric equivalent to the ANOVA test is the Kruskal-Wallis test, which tests for a difference between the medians of independent data groups. The K-W test will also test whether the datasets are derived from the same distribution. Several statistical packages will perform this test. Results of the K-W test shown in Table 3 was generated from a statistical add-on to Microsoft Excel® called Analyse-It™.

Comparison of the mean ranks in Table 3 provides an indication of whether the data groups are derived from the same distribution. A p values < 0.05 indicates that two or more the data groups have different distributions. Examination of the mean ranks in Table 3 shows that Sites 1001, 1002, and 1005 have somewhat similar mean ranks and Sites 1003 and 1004 have somewhat different mean ranks. This suggests that Sites 1003, 1004 have a different distribution than the other sites. Therefore, it is determined that the K-W test should be performed on just Sites 1001, 1002, and 1005. These results are shown in Table 4. Notice that the p-value is now greater than 0.05, so the distributions of the total nitrogen data are not significantly different. Based on this analysis, Site 1002 should be used as the only control site for comparison of total nitrogen data. These analyses will need to be repeated for the other water quality constituents.

Table 3. Example of Kruskal-Wallis test results for total nitrogen at the test sites prior to intervention.

Test	**Kruskal-Wallis ANOVA**		
Comparison	Total Nitrogen: 1001, 1002, 1003, 1004, 1005		
Performed by	GeoSyntec Consultants		
n	115		
Total Nitrogen	**n**	**Rank sum**	**Mean rank**
1001	23	1128.0	49.04
1002	23	1162.0	50.52
1003	23	774.0	33.65
1004	23	2150.0	93.48
1005	23	1456.0	63.30
Kruskal-Wallis statistic	41.71		
p	<0.0001	(chisqr approximation)	

Table 4: Example of Kruskal-Wallis test results for total nitrogen at the Site 1001, 1002, and 1005 prior to intervention.

Test	**Kruskal-Wallis ANOVA**		
Comparison	Total Nitrogen: 1001, 1002, 1005		
Performed by	GeoSyntec Consultants		
n	69		
Total Nitrogen	**n**	**Rank sum**	**Mean rank**
1001	23	710.0	30.87
1002	23	761.0	33.09
1005	23	944.0	41.04
Kruskal-Wallis statistic	3.27		
p	0.1948	(chisqr approximation)	

Based on these example analyses of the pre-intervention TN data, it is clear that Site 1004 should not be considered as a control site for total nitrogen, and Site 1003 should be used with caution.

Comparison of Water Quality Data Before and After Intervention

Side-by-side box plots and probability plot comparisons of pre-intervention and post-intervention were constructed to identify any apparent differences in the central tendency and concentration distributions between the two data sets. Figure 4 shows side-by-side box plots of total nitrogen at all of the test sites. Site 1004 was omitted due to its high variability. Notice that Site 1001 shows a distinct decrease in total nitrogen, while the other sites do not. However, other sites do show a decreasing trend in median concentration and inter-quartile ranges.

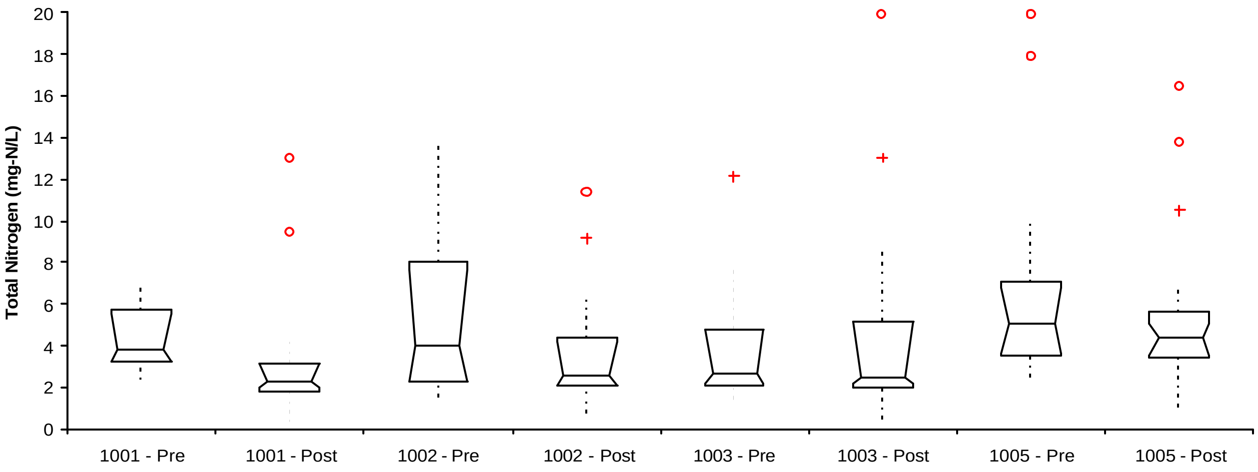


Figure 4. Side-by-side box plots of pre- versus post-intervention for total nitrogen at all sites.

Figure 5 is a probability plot of total nitrogen for Site 1001 before and after intervention. (Additional probability plot comparisons are included in Appendix C.) Notice that there is a distinct reduction in total nitrogen at the site. However, since these data are from different time-periods, this difference could be related to temporal variability.

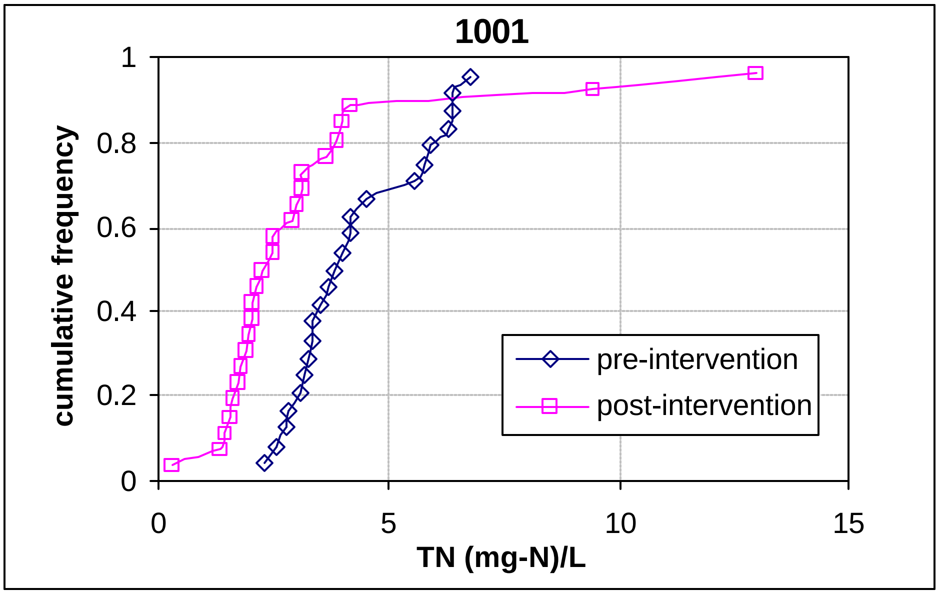


Figure 5. Example probability plot of pre- versus post-intervention at Site 1001 for total nitrogen.

To evaluate if temporal variability caused by the different monitoring periods has anything to do with the difference in total nitrogen concentrations, the probability plot of the pre- and post-intervention period for Site 1001 is plotted with those for Site 1002 and Site 1005 (as these were determined to be the only valid control sites). These comparison plots are shown in Figure 6 and Figure 7. Notice that for pre-intervention, the distribution of Site 1001 more closely follows the distribution of Site 1005 than that of Site 1002, and for post-intervention the opposite is true. This indicates that the year-to-year variability alone cannot explain the reduction in total nitrogen at Site 1001. However, this would need to be statistically verified.

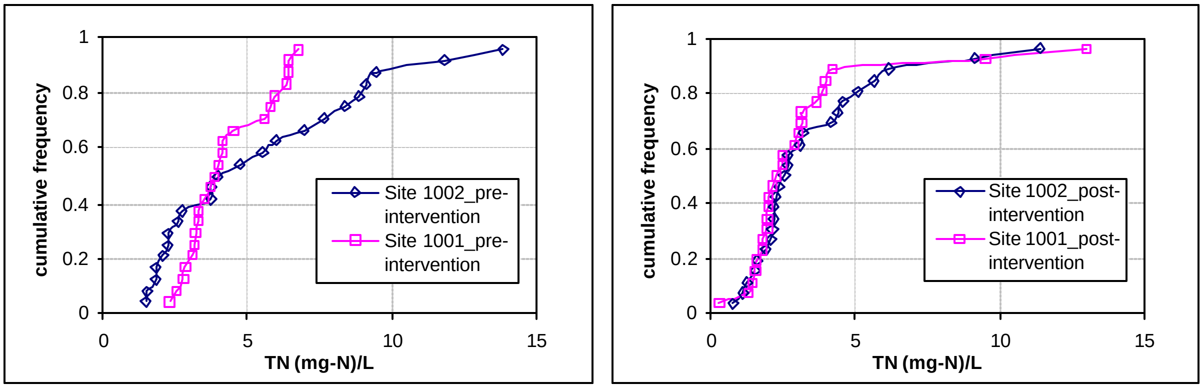


Figure 6. Example probability plot for total nitrogen of Site 1001 versus Site 1002 for the pre- and post-intervention periods.

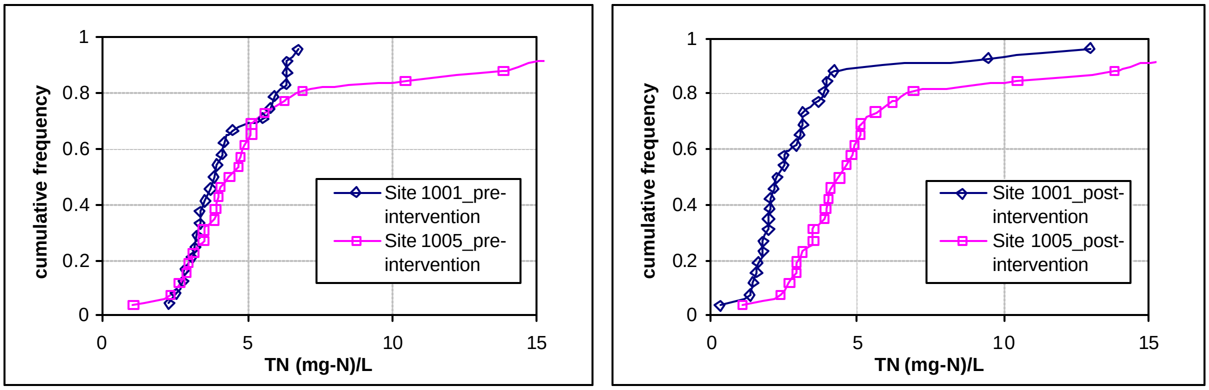


Figure 7. Example probability plot for total nitrogen of Site 1001 versus Site 1005 for the pre- and post-intervention periods.

As mentioned earlier, the Mann-Whitney test (rank-sum) can be used to determine if there is a statistical difference in the median values of two independent data sets (by rejecting the hypothesis that they are the same). Table 5, Table 6, and Table 7 show the output of the Mann-Whitney tests from the Analyse-It™ statistical package on Sites 1001, 1002, and 1005, respectively. Notice that there is a statistically significant difference ($p<0.05$) in the medians between the pre- versus post-intervention total nitrogen data at both Sites 1001 and 1002, but not at Site 1005. Furthermore, the difference in the medians at Site 1001 is at a higher level of confidence (more statistically significant) than the difference at Site 1002 (i.e., greater than 99% significant compared to about 96% significant). The magnitudes of these differences (Hodges-Lehmann estimator) are about 1.5 and 1.3 mg-N/L for Sites 1001 and 1002, respectively. These tests indicate that the difference in the total nitrogen medians at Site 1001 from pre-intervention to post-intervention cannot be explained by the year-to-year variation alone (e.g., the intervention appears to have had an effect). It also indicates that the public education applied to Site 1005 did not appear to make a significant difference.

Table 5: Example Mann-Whitney test for difference in medians for total nitrogen at Site 1001 from pre- versus post-intervention.

Test	**Mann-Whitney test**			
Alternative hypothesis	1001: Pre ≥ Post			
Performed by	GeoSyntec Consultants			
n	48			
1001	**n**	**Rank sum**	**Mean rank**	**U**
Pre	23	736.0	32.00	115.0
Post	25	440.0	17.60	460.0
Difference between medians	1.497			
95.2% CI	0.883	to +∞	(normal approximation)	
Mann-Whitney U statistic	115			
1-tailed p	0.0002	(normal approximation)		

Table 6. Example Mann-Whitney test for difference in medians for total nitrogen at Site 1002 from pre- versus post-intervention.

Test	**Mann-Whitney test**			
Alternative hypothesis	1002: Pre ≥ Post			
Performed by	GeoSyntec Consultants			
n	48			
1002	**n**	**Rank sum**	**Mean rank**	**U**
Pre	23	651.0	28.30	200.0
Post	25	525.0	21.00	375.0
Difference between medians	1.289			
95.2% CI	0.065	to +∞	(normal approximation)	
Mann-Whitney U statistic	200			
1-tailed p	0.0355	(normal approximation)		

Table 7. Example Mann-Whitney test for difference in medians for total nitrogen at Site 10052 from pre- versus post-intervention.

Test	**Mann-Whitney test**			
Alternative hypothesis	1005: Pre ≥ Post			
Performed by	GeoSyntec Consultants			
n	48			
1005	**n**	**Rank sum**	**Mean rank**	**U**
Pre	23	610.0	26.52	241.0
Post	25	566.0	22.64	334.0
Difference between medians	0.530			
95.2% CI	-0.446	to +∞	(normal approximation)	
Mann-Whitney U statistic	241			
1-tailed p	0.1686	(normal approximation, corrected for ties)		

Comparison of Constituent Fluxes Before and After Intervention

The statistical procedures applied to the concentrations examples above should also be applied to the constituent fluxes (mass loadings). For completeness, an abridged example analysis will be provided here. Figure 8 includes side-by-side box plots and probability plots of total nitrogen flux data (mg/acre/day) for Site 1001 at pre- and post-intervention. Note there appears to be a significant decrease in the median, as well as an overall reduction in the distribution of values.

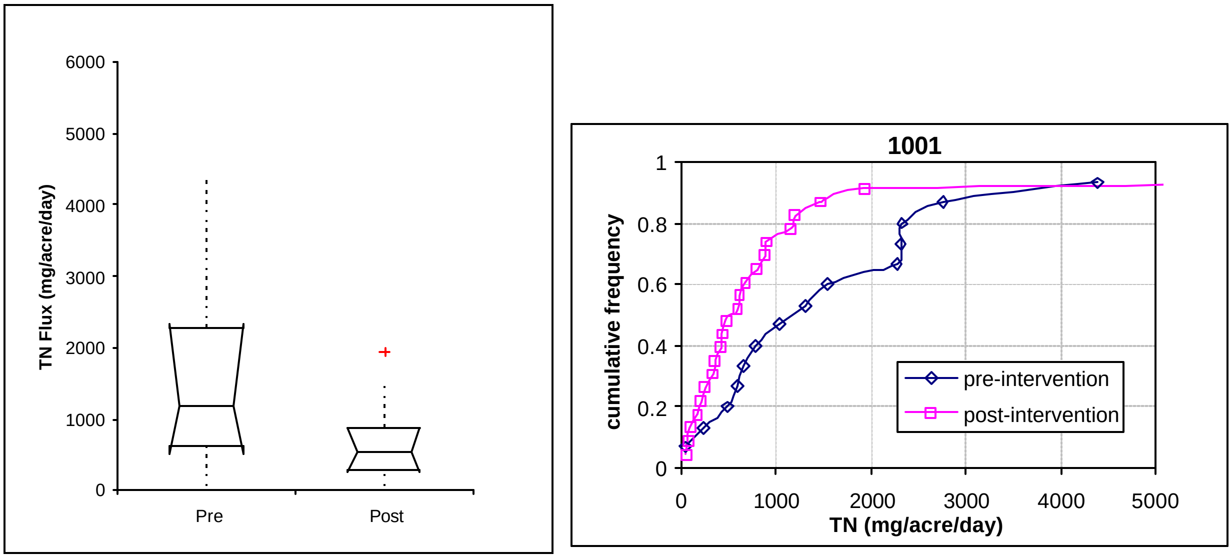


Figure 8. Side-by-side box plot and probability plots of pre- versus post-intervention for total nitrogen flues at Site 1001.

Table 8 shows the results of the Mann-Whitney test (rank-sum) for the total nitrogen flux at Site 1001. Notice the difference in the medians from pre- to post-intervention are statistically significantly different at the 95% confidence level ($p<0.05$). The magnitude of the difference (the Hodges-Lehmann estimator) is approximately 530 mg/acre/day, indicating a relatively large reduction in total nitrogen loads from the neighborhood. However, as discussed below, the extent to which the ET controllers contributed to this reduction is unclear.

The nitrogen fluxes used in this analysis were computed as the product of the measured concentration and the average daily flow. Therefore, the reduction in TN flux could be due to a reduction in flow, a reduction in concentration, or a combination of both. Analyses presented earlier showed a statistically significant reduction in median TN concentration at site 1001 between the pre- and post-intervention periods. Similarly, analyses discussed in the R3 report indicate that there was a statistically significant reduction in flow at site 1001 between the pre- to post-intervention periods; however, it was cautioned that the pre- and post-intervention periods are not comparable due to seasonal differences in the data collection period. Thus, observed reductions in flow in 1001 could be influenced by seasonal factors, and therefore the extent to which the ET controllers contributed to a reduction in flow is unknown. Consequently, reductions in TN flux could be attributed to a combination of TN reduction, flow reduction, and/or seasonal factors.

Table 8. Example Mann-Whitney test for difference in medians for total nitrogen flux at Site 1001 from pre- versus post-intervention.

Test	**Mann-Whitney test**
Alternative hypothesis	1001_flux (mg/acre/day): Pre ≥ Post
Performed by	GeoSyntec Consultants
n	36

1001_flux (mg/acre/day)	n	Rank sum	Mean rank	U
Pre	14	320.0	22.86	93.0
Post	22	346.0	15.73	215.0

Difference between medians	529.389		
95.1% CI	115.985	to +∞	(normal approximation)
Mann-Whitney U statistic	93		
1-tailed p	0.0239	(normal approximation)	

Based upon the above results, we believe that it would be valuable to complete a more robust statistical evaluation of the data, as we believe that some significant management implications could be determined.

4. Possible Implications for TMDL Compliance.

The R3 Study results were examined in the context of existing TMDLs in the San Diego Watershed. Most of the existing TMDLs are reviewed below and possible inferences and implications of the R3 Study data for TMDL compliance are discussed. The sediment and organophosphorus pesticide TMDLs were not reviewed because sediment data were not collected (the vast majority of sediments are transported by storm flows) and because Schiff and Tiefenthaler (2003) have previously conducted an extensive analysis of the organophosphorus pesticide data.

4.1. Nitrogen

Nitrogen Water Quality Objectives and TMDLs **–** The Basin Plan water quality objectives for nitrogen in San Diego Creek are 13 mg/L Total Inorganic Nitrogen (TIN) in Reach 1, and 5 mg/L TIN in Reach 2 (RWQCB, 1995). Reach 1 extends from Newport Bay to Jefferey Road, and Reach 2 extends from Jefferey Road to the headwaters. There is no numeric standard for nitrogen in Upper Newport Bay in the Basin Plan.

The nitrogen TMDL for Upper Newport Bay is based on the general goal of reducing nutrient loads to Newport Bay by 50 percent, to levels observed in the early 1970's (USEPA, 1998b). The nitrogen TMDL sets phase-in limits on total nitrogen (TN) loads to Newport Bay (see Table 9). Separate loads are established for the dry and wet seasons (dry season is from April 1 to September 30). In addition, the winter load is exclusive of storm flows with an average daily flow greater than 50 cfs in San Diego Creek at Campus Drive.

There is no TMDL for nitrogen loads in San Diego Creek, Reach 1 because it was reasoned that attainment of the 50 percent reduction in nitrogen loads to Newport Bay would result in compliance with the Basin Plan in-stream water quality standard for Reach 1 (13 mg/l TIN). However, for Reach 2 it was determined that the average in-stream nitrogen concentrations would likely remain close to or above the Basin Plan in-stream water quality standard (5 mg/L TIN), even with attainment of the Newport Bay TMDLs. Therefore a TMDL of 14 lbs/day TN was established for Reach 2 (see Table 9) and is applicable for all flows exclusive of storm flows greater than an average daily flow of 25 cfs in San Diego Creek at Culver Drive.

Table 9: Summary of Nutrient TMDLs for Upper Newport Bay and San Diego Creek

TMDL	Dec 31, 2002	Dec 31, 2007	Dec 31, 2012
Newport Bay Watershed, TN – Summer load (4/1 to 9/30)	200,097 lbs	153,861 lbs	
Newport Bay Watershed, TN – Winter load (10/1 to 3/31; non-storm)			144,364 lbs
Newport Bay Watershed, Total Phosphorus – Annual Load	86,912 lbs	62,080 lbs	
San Diego Creek, Reach 2, daily load			14 lbs/day
Urban Runoff Allocation for the Newport Bay Watershed			
Summer load	22,963	11,481	
Winter load			38,283

Study Data Comparison with Nitrogen Water Quality Objective – The Basin Plan water quality objectives are expressed in terms of total inorganic nitrogen (TIN), which is comprised of nitrate/nitrite nitrogen and ammonia. By far the majority of the TIN in San Diego Creek is comprised of nitrate/nitrite nitrogen, as measured ammonia concentrations were typically quite low with a majority below the detection limit. For this reason, only the nitrate/nitrate concentration data are compared to the Basin Plan objectives in this report.

Table 10 shows the mean and median nitrate/nitrite concentrations measured in the five study watersheds. The mean and median nitrate/nitrite concentration in all watersheds except 1004 are below the Reach 2 Basin Plan objective of 5 mg/l TIN. As discussed previously, Site 1004 may not be a representative control site because the underlying distribution of pre-intervention nitrogen data appears to be different from the other sites. Similar arguments may also be true Site 1003. With exception of Site 1004, mean nitrate/nitrite concentrations suggests that, <u>on average</u>, residential runoff from these watersheds do not contribute to the exceedance of Basin Plan standards for TIN in receiving waters in San Diego Creek, Reach 1 and 2. The Reach 2 water quality objective was occasionally exceeded in the all watersheds, except for the post intervention conditions in 1001 and 1002.

The mean and median nitrate/nitrate concentrations in watershed 1004, and 1005 exhibit exceedances of the 5 mg/l standard during pre- and/or post intervention conditions. Watershed 1004, in particular, had high levels of measured nitrate/nitrite concentrations, especially during the pre-intervention period. A number of these high readings exceed the Reach 1 water quality objective of 13 mg/l TIC. The results from watershed 1004 are not consistent with those from the other four study watersheds, and the source of the high readings is unknown. Localized conditions involving excessive fertilizer usage by a few users could possibly be a factor in these elevated readings. In particular, the R3 mentions an unknown connection to a neighboring watershed, which could explain the source of elevated nutrient levels.

Table 10: Mean and Median Nitrate/Nitrite Concentration (mg/l) by Watershed (all data)

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
n	23	25	23	25	24	25	23	25	24	25
Mean	2.56	1.47	2.57	1.07	2.13	1.71	36.50	6.61	2.61	4.13
Median	2.32	1.38	1.56	0.93	1.68	0.94	16.88	2.29	2.45	1.48
n>5 mg/l	1	0	4	0	1	2	18	8	2	1
n>13 mg/l	0	0	0	0	0	0	12	4	0	1

The Mann-Whitney (rank-sum) test was performed to compare the statistical difference between median concentrations during pre- and post-intervention periods (see example in Section 3 above). The median nitrate/nitrite in the post-intervention period was lower in all watersheds, and the difference was statistically significant at the 0.05 confidence level. As the control stations exhibited this trend, these data (i.e. entire data sets with unequal seasonal coverage) cannot be used to ascertain if the structural and educational BMPs were effective in reducing the runoff concentrations of nitrate/nitrite.

Clearly there is another factor contributing to reduced concentrations in the post intervention period. One possibility that was investigated is differences in seasons, year-to-year variability, and sampling times of the pre- and post-intervention data. Table 11 shows mean and median concentrations for comparable seasons and sampling times. Note there are still noticeable reductions in all of the median concentrations, except Site 1005. Applying the Mann-Whitney (rank-sum) test to these data it was found that statistically significant differences between median nitrate/nitrite concentrations in the pre- and post-intervention periods occurred only in watersheds 1001 and 1004, as compared to all watershed when all data are considered. These results indicate that seasonal effects are present in these data and should be considered in the study evaluation. It may be inferred from these result that there were significant reductions in the nitrate/nitrite concentration in the intervention watershed during the wet season that may, in part, be attributable to the structural BMPs. It is unknown whether similar reductions would occur in dry weather runoff during the dry season because such data were not collected during the pre-intervention period.

Table 11: Mean and Median Nitrate/Nitrite Concentration (mg/l) by Watershed for Comparable Seasons and Sampling Times[1]

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
n	18	14	18	14	19	14	18	14	19	14
Mean	2.38	1.43	1.95	0.95	2.17	1.66	26.24	6.57	2.24	6.27
Median	2.22	1.48	1.16	0.96	1.50	1.02	8.94	2.06	2.03	1.96
n>5 mg/l	0	0	2	0	1	1	13	4	1	1
n>13 mg/l	0	0	0	0	0	0	7	3	0	1

1 – evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

Study Data Comparison with Nitrogen TMDLs - The nitrogen TMDL is expressed in terms of total nitrogen (TN) loads. TN concentrations were calculated from the monitoring data as the sum of the nitrate/nitrite nitrogen and TKN nitrogen. Table 12 shows the mean and median TN concentrations measured in the five study watersheds. The mean and median TN concentration in dry weather runoff are generally in the range of 2 to 5 mg/l, with the exception of watershed 1004 where substantially higher concentrations were measured. The rank sum tests indicated that median TN concentrations are significantly lower (in a statistically sense) in the post-intervention period in watershed 1001 (structural BMPs, see Table 5), and in watershed 1002 (control, see Table 6), and based on the probability plots in Appendix C, Site 1004 is expected to as well. However, sites 1003 and 1005 did not show statistically significant reductions. These results did not change when only subsets of the data were used to consider possible affects stemming from the sampling time and sampling months.

Table 12: Mean and Median TN Concentration (mg/l) by Watershed

	1001		**1002**		**1003**		**1004**		**1005**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
All Data										
n	23	25	23	25	23	25	23	25	23	25
Mean	4.24	3.09	5.31	3.44	3.66	4.42	48.00	10.18	6.89	7.74
Median	3.84	2.27	3.95	2.55	2.66	2.50	19.01	5.57	5.06	4.36
Subsets[1]										
n	18	14	18	14	18	14	18	14	18	14
Mean	4.18	2.78	4.51	2.63	3.71	3.71	33.99	8.91	6.98	9.91
Median	3.62	2.02	3.22	2.21	2.51	2.47	12.14	3.74	4.17	3.96

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

TN flux estimates were calculated for watersheds 1001 and 1005 (Table 13). The draft R3 report indicates that the flow measurements in watershed 1002-1004 are not reliable and therefore flux estimates were not calculated for these watersheds. Flux estimates were calculated as the product of the constituent concentration and the average daily flow occurring on the day of the sample collection. The flux estimates were found to be quite variable as they depend on both flow and concentration measurements. Table 13 shows that median TN flux estimates decrease from the pre- to post-intervention periods for both watersheds. Mann-Whitney (rank sum) tests show the reductions to be statistically significant (Table 8). Because comparable data are not available for the control sites, it is not possible to infer whether these reductions are influenced by the ET controllers in the intervention watershed (1001). Also, as previously discussed, the reduction in TN flux may be attributable to a reduction in flow, a reduction in concentration, seasonal factors, or a combination of these.

Table 13: Mean and Median TN Flux (mg-N/acre/day) by Watershed

	1001		1005	
	Pre	**Post**	**Pre**	**Post**
All data				
n	14	22	10	21
Mean	1476	1667	2104	6537
Median	1164	530	1568	1177
Subset[1]				
n	12	14	10*	8
Mean	1384	587	2104	1716
Median	902	497	1568	960

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

* – Same as the all data case

Although the flux estimates in Table 13 are limited in number, duration, and location, they can be used to speculate about the magnitude of the urban area contribution of TN loads to Newport Bay and the potential reduction in loads from structural and nonstructural BMPs. Based on the limited flux data, the annual TN load to Newport Bay in dry weather runoff from urban areas in the San Diego Creek Watershed is estimated to range between 37,000 to 50,000 lbs per year under existing land-use conditions (see Table 14). This is for the most part below the 2012 urban runoff allocation of 49,764 lbs. The annual TN load is estimated to increase to 50,000-67,000 lbs per year under built-out conditions.

According to the 2001 report on the nutrient TMDL (OCPFED, 2001), the average daily TN load in San Diego Creek at Campus Drive was 540 lbs/day between July 2000 and June 2001. This converts to an annual load of about 197000 lbs, which is below the 2007 TMDL (note: San Diego Creek is the majority but not sole contributor of TN loads to Newport Bay). Estimates in Table 14 suggest that dry weather runoff from urban areas account for about 20 to 25% of the annual TN in the San Diego Creek Watershed. If it is assumed that flux reductions observed in the post intervention period are attributable to the structural and nonstructural BMPs, and if similar interventions could hypothetically be implemented on a watershed-wide basis, then the potential reduction in annual dry weather TN loads is estimated to range between 12,500-20,000. This would represent a reduction of about 6-10% of the current TN loads and about 30-40% of the estimated current dry weather urban loads. Note these estimates are based on few data collected in a limited area, and should therefore be considered preliminary in nature.

Table 14: Estimated Annual TN Loads in Dry Weather Runoff from Urban Areas in the San Diego Creek Watershed

	TN flux (mg-N/acre/d)	**Annual TN Load to Newport Bay (lbs) Existing land-use[1]**	**Annual TN Load to Newport Bay (lbs) Built-out land-use[2]**
Pre-intervention conditions	1160 – 1560	37,300 – 50,500	50,000 – 67,000
Post-intervention conditions	530 – 1180	17,000 – 38,000	23,000 – 51,000
Potential reduction		~12,500 – 20,000	~16,000 – 27,000

1 –Used 40000 acres or about 53% of the San Diego Creek Watershed area (IRWD, 2003). For comparison, urban land use in 1999 use was estimated at 35,500 acres of the watershed area at Campus Drive (Tetra-Tech, 2000).

2 – Used 53500 acres or about 71% of the San Diego Creek Watershed area (IRWD, 2003).

The following conclusion can be made based on the analyses above:

- Average and median nitrate/nitrite concentrations in dry weather runoff are below the Reach 2 water quality objective (5 mg/l), for most but not all study watersheds.
- Occasional exceedance of the Reach 2 water quality objective occurred in all study watersheds
- The majority of measured nitrate/nitrite concentrations in watershed 1004 during the pre-intervention period were greater than the Reach 2 water quality objective of 5 mg/l. These data are not consistent with those from the other watersheds. The cause is unknown, but could possibly be related to the unknown connection to neighboring nursery discussed in the R3 report.
- Sampling periods (months) and sampling time (morning versus evening) was found to affect the statistical significance of differences between pre- and post- intervention median nitrate/nitrate concentration in some of the watersheds. The sampling period and sampling time did not affect the statistical significance of differences between pre- and post-intervention median TN concentrations.
- Median TN fluxes in watershed 1001 and 1005 were statistically smaller in the post-intervention period. The extent to which the structural and nonstructural BMPs contributed to these reductions cannot be determined due to the lack of reliable flow data in the control sites.
- Preliminary estimates of annual TN loads to Newport Bay in dry weather runoff from urban sources range between 37,000 to 50,000 lbs per year, or about 20 to 25% of the current TN loads.
- The potential reductions in annual dry weather TN loads due implementation of BMPs on a watershed basis is estimated to range between 12,500-20,000 pounds per year. This would represent a reduction of about 6-10% of the current TN loads and 30-40% of the urban loads.

4.2. Phosphorus

The majority of the annual TP load in the San Diego Creek Watershed occurs in the wet season, and has been correlated with sediment loads generated by storm events (USEPA, 1998b). This correlation suggests that a majority of phosphorus occurs in particulate form attached to sediments. The main sources of the total phosphorus (TP) are in Peters Canyon Wash and San Diego Creek above Culver Drive (USEPA, 1998b).

Phosphorus TMDL – There is no numeric objective for phosphorus for San Diego Creek in the Basin Plan. Because measured TP and sediment loads are correlated, it was determined in the TMDL that a 50 percent reduction in TP loads would be achieved through compliance with the sediment TMDL (USEPA, 1998a). Accordingly, the TMDL for TP was based on a 50 percent reduction of average annual load estimated at 124,160 lbs (USEPA, 1998b). The TMDLs are applicable for all flow conditions. The target compliance date was set for December 31, 2007.

The annual TP load allocation for urban areas is 4102 lbs by 2002, reducing to 2960 lbs by 2007. According to the USEPA (1998b) the TP is allocated in the same proportion as sediments. The annual urban area (stabilized vs. construction) sediment allocation for the Newport Bay Watershed is 50 tons distributed over 95.3 square miles (see Table 5 in USEPA, 1998a). This is a very small allocation over a large area. By contrast, note that the annual construction allocation is 6500 tons distributed over the assumed 3.0 square miles under construction in any one year. Using the same proportions of sediment load allocations, the TP load rate based on the 2007 urban allocation is 2960 lbs/95.3 square miles = 0.0485 lbs/acre/yr. If the construction and urban allocations are combined, the TP load rate based on the combined 2007 urban and construction allocations is (2960+12810) lbs/(95.3+3.0) square miles = 0.251 lbs/acre/yr.

Study Data Comparison with TMDLs **–** Similar to the nitrogen TMDL, the phosphorus TMDL is expressed in terms of total annual (TP) loads. Table 15 shows the mean and median TP concentrations measured in the five study watersheds. The mean and median TP concentrations in dry weather runoff are below 1.2 mg/l in all watersheds, with the exception of watershed 1004 where substantially higher concentrations were measured. Comparison of the pre- and post-intervention median TP concentrations in all data (Table 15) reveals an increase in the median TP concentration during the post-intervention period for all watersheds except the intervention watershed 1001 and 1004. In contrast, when subsets of the data with similar seasons and sampling times are considered (Table 15), there is a decrease in the median TP concentration in all watersheds except 1005. This indicates that there are seasonal influences in the data, which presumably are related to rainfall. Unfortunately there are no data available to permit comparison of pre- and post-intervention concentrations for dry weather flows during the dry season.

Table 15: Mean and Median TP Concentration (mg/l) by Watershed

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
All Data										
n	23	25	23	25	24	25	23	24	24	25
Mean	0.73	0.60	0.92	0.84	0.98	1.21	3.33	1.50	1.01	1.19
Median	0.60	0.51	0.77	0.82	0.62	0.67	2.54	1.05	0.73	0.85
Subsets[1]										
n	18	14	18	14	19	14	18	13	19	14
Mean	0.78	0.47	0.91	0.67	1.13	0.57	2.62	1.33	0.93	1.24
Median	0.61	0.41	0.73	0.56	0.75	0.58	1.82	1.07	0.75	0.83

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

TP flux estimates were calculated for watersheds 1001 and 1005 using the approach discussed in the nitrogen section above. Table 16 shows that median TP flux estimates decrease from the pre- to post-intervention periods in the intervention watershed (1001) but not in the education only watershed. Mean fluxes increase in both watersheds, but as discussed earlier, the mean values are strongly influenced by outliers and do not provide a good measure of central tendency for these data. Application of the Mann-Whitney (rank sum) test shows the reduction in median TP flux in 1001 is statistically significant. This suggests that the structural BMPs had a positive influence in reducing the TP fluxes, but because comparable data are not available for the control sites, it is not possible to ascertain the extent to which the ET controllers contributed to these reductions. Also, as discussed previously, reductions in flux could be influenced by several factors: reduction in concentration, reduction in flow, and/or seasonal variability.

Table 16: Mean and Median TP Flux (mg-P/acre/day) by Watershed (all data)

	1001		1005	
	Pre	**Post**	**Pre**	**Post**
All data				
n	14	22	10	21
Mean	265	370	473	1327
Median	164	109	219	219

Similar to the previous analyses of TN loads, the TP flux estimates in Table 16 can be used to speculate about the magnitude of the urban area contribution of TP loads to Newport Bay and the potential reduction in loads from structural BMPs. Based on the limited flux data, the annual TP load to Newport Bay in dry weather runoff from urban areas in the Newport Bay Watershed is estimated to range between about 5,000 to 11,000 lbs per year (see Table 17) based on a total urban area of 95.3 square miles obtained from Table 5 of the sediment TMDL (USEPA, 1998a). These estimated annual TP loads are greater than the urban allocation (for both dry and wet weather) and are less than the combined urban and construction allocations (Table 17). Note, however, that these estimates are based on dry weather data only, and it is expected that a major portion of the TP loads will occur in runoff from winter storms. Therefore, actual annual TP loads would be expected to be greater. If it hypothesized that flux reductions observed in the intervention watershed 1001 could be realized over the entire watershed, then the potential reduction in annual dry weather TP loads from urban areas is estimated at 2700 lbs. As stated previously, these estimates are based on few data collected in a limited area, and should therefore be considered preliminary in nature.

Table 17: Estimated Annual TP Loads in Dry Weather Runoff from Urban Areas in the San Diego Creek Watershed

	TP flux (mg-P/acre/d)	**Annual TP Load Rate to Newport Bay (lbs/acre/year)[1]**	**Annual TP Load to Newport Bay (lbs/year)**
2007 Urban Area Allocatoion for Newport Bay		0.0485	2960
2007 Combined Urban and Construction Area Allocatoion for Newport Bay		0.251	15770
Pre-intervention conditions (median fluxes)	164 – 219	0.132 – 0.176	8049 – 10748
Post-intervention conditions (median fluxes)	109 – 219	0.088 – 0.176	5350 – 10748
Potential reduction			2700

1 - urban area is 95.3 square miles and the construction area is 3.0 square miles based on Table 5 in USEPA, 1998a

4.3. Metals

Metals TMDLs **–** The USEPA (June 2002) determined that TMDLs are required for dissolved copper, lead, and zinc in San Diego Creek, Upper Newport Bay, and Lower Newport Bay, and that TMDLs are required for cadmium in San Diego Creek and the Upper Newport Bay. The TMDLs for San Diego Creek are expressed as concentration limits, based on the CTR criteria at various hardness values that are associated with different flow regimes (Table 18). The flow regimes are based on 19 years of flow measurements in San Diego Creek at Campus Drive. The concentration-based TMDLs apply to all freshwater discharges to San Diego Creek, including discharges from agricultural, urban, and residential lands, and storm flow discharges. The applicable flow regime at any location in the entire watershed is determined on the basis of discharge at Campus Drive.

Table 18: Summary of Dissolved Metal TMDLs for San Diego Creek

Dissolved Metal (mg/l)	**Base flow (0–20 cfs) hardness @ 400 mg/L**		**Small flows (21-181 cfs) hardness @ 322 mg/L**		**Medium flows (182-814 cfs) hardness @ 236 mg/L**		**Large flows (>814 cfs) hardness @ 197 mg/L**
	Acute	**Chronic**	**Acute**	**Chronic**	**Acute**	**Chronic**	**Acute**
Cadmium	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Copper	50	29.3	40	24.3	30.2	18.7	25.5
Lead	281	10.9	224	8.8	162	6.3	134
Zinc	379	382	316	318	243	244	208

Metals Sources – The USEPA (June 2002) conducted a source analysis as part of the TMDL preparation. Surface runoff is the largest contributor of metals loads in the San Diego Creek Watershed, which includes natural and man made source (USEPA , June 2002). Much of the metals loads are from natural sources. The estimated anthropogenic contributions are metal specific and range from about 33% for zinc to 63% for cadmium (USEPA, June 2002). A primary anthropogenic source of heavy metals is runoff from urban roads, which contributes to sources of cadmium (tire wear), copper (brakes, tires), lead (brakes, tires, fuels and oils), and zinc (tires, brakes, galvanized metals). Use of copper sulfate by nurseries may also be a minor source of copper loads. Other copper and zinc uses in building materials (roofing and roof drains) may be another source.

The USEPA found that metal inputs were heavily influenced by rainfall and stream flow rates. Monitoring results were reported to be highly variable due to different rainfall amounts and flows during each water year. The EPA estimated that base flows account for 25% of the total metal loadings, with the remainder from low, medium and large flows caused by storms.

The EPA's preliminary analyses suggest that: 1) a primary source of metals in dry weather runoff in the study watershed is from roads (i.e. wash off of metals in driveways, parking lots, streets, gutters, etc.); 2) the runoff concentrations will be influenced by rainfall which result in wash off of accumulated metals; and 3) the concentrations can be variable depending on the amount of rainfall.

Study Data Comparison with Base Flow TMDLs – The metals TMDLs for base flow conditions are based on meeting the CTR criteria at a total hardness of 400 mg/l. The CTR criteria express maximum allowable concentrations in receiving waters for acute (short term) and chronic (4-day) exposure periods. The acute and chronic criteria are expressed as values that cannot be exceeded more that once in three years. Although the criteria are applicable in the receiving waters and not in the urban runoff per se (i.e. the measured dry weather discharge), exceedance of the CTR in the urban discharge would suggest a potential for the discharge to contribute to an exceedance in the receiving waters.

Table 19 shows the mean and median heavy metal concentrations in the five study watersheds. (*Note to IRWD reviewer: we assumed that the analytical results are for dissolved metals based on guidance from IRWD, but this is not clearly indicated in the data base or draft report; it is likely the case as base flows are typically low in suspended sediments.*) With the exception of mean copper concentrations in some of the watersheds, all mean and median concentrations were below the chronic and acute CTR criteria. Copper, lead, and zinc concentrations occasionally exceeded the chronic CTR criteria, and copper and zinc concentrations occasionally exceeded the acute criteria. These exceedances suggest that the dry weather runoff can potentially contribute to an exceedance in the receiving waters. However, if intervention is determined to be effective in reducing runoff flows, then the BMPs would help to reduce impacts of these potential exceedances by allowing for greater dilution with the in-stream flows.

Table 19: Mean and Median Metal Concentrations (mg/l) by Watershed (all data)

	1001		**1002**		**1003**		**1004**		**1005**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Cadmium										
n	23	25	23	25	24	25	23	25	24	25
Mean	0.26	0.14	0.47	0.44	0.27	0.17	0.64	0.22	0.21	0.29
Median	0.27	0.10	0.24	0.10	0.10	0.10	0.36	0.10	0.10	0.10
n>6.2 µg/l	0	0	0	0	0	0	0	0	0	0
n>19.1 µg/l	0	0	0	0	0	0	0	0	0	0
Copper										
n	23	25	23	25	24	25	23	25	24	25
Mean	13.5	16.9	27.3	30.3	11.5	26.6	21.8	17.7	32.1	30.8
Median	11.5	11.4	10.9	14.0	11.1	14.3	12.7	11.4	12.3	20.4
n>29.3 µg/l	2	2	3	7	0	2	5	4	3	5
n>50 µg/l	0	1	3	3	0	2	2	3	3	2
Lead										
n	23	25	23	25	24	25	23	25	24	25
Mean	0.8	1.6	5.9	4.7	0.8	1.6	3.5	1.5	1.0	3.2
Median	0.6	0.6	0.9	1.2	0.6	0.8	0.7	0.7	0.7	1.3
n>10.9 µg/l	2	1	2	3	0	0	2	0	0	1
n>281 µg/l	0	0	0	0	0	0	0	0	0	0
Zinc										
n	23	25	23	25	24	25	23	25	24	25
Mean	58.7	37.2	115.2	86.3	56.3	56.8	83.6	40.9	74.0	75.0
Median	56.0	50.2	53.4	57.2	50.7	53.9	50.8	43.8	52.4	54.5
n>382 µg/l	0	0	1	2	0	0	1	0	0	0
n>379 µg/l	0	0	1	2	0	0	1	0	0	0

We were unable to locate dry weather metals monitoring information in the Central Irvine Channel, which is the immediate receiving water of the study watersheds (*IRWD please confirm*). OCPFRD dry weather monitoring data are available in San Diego Creek at Campus Drive, which is quite a ways downstream from the study watersheds. Data collected between 12/01 and 6/02 (Table 20) show that average dry weather concentrations at Campus Drive are well below mean and median concentrations measured in dry weather runoff from the study watersheds. Similar comparisons cannot be made for lead and cadmium because the method detection limits in the OCPFRD data are greater than those in the R3 data. None of the OCPFRD dry weather data exceed the chronic or acute criteria.

These comparisons suggest that metal loads in dry weather runoff from the study (urban) watersheds could be a contributing factor to dry weather copper and zinc loads measured at Campus Drive. These dry weather discharges do not result in non-compliance of the base flow metal TMDL at Campus (based on the reviewed data only). It is unknown if the elevated concentrations measured in the dry weather urban runoff result in exceedance of the CTR criteria in the immediate receiving waters. Note that if flow reductions observed in the intervention watershed are attributable to the ET controllers, then these controllers would help to reduce impacts from any potential exceedances of the TMDL because the discharges would be subject to greater dilution by the in-stream flows.

Table 20: Summary of OCPFRD Dry Weather Monitoring Data in San Diego Creek at Campus Drive (12/01 to 6/02)

	Cadmium	**Copper**	**Lead**	**Zinc**
Sample number	24	24	24	24
Range	All < 1 μg/l	<2 – 16 μg/l	<2-2.4 μg/l	<10-16
Mean		7.4 μg/l	most <2 μg/l	most <10
Median-		6.8 μg/l		

4.4. Pathogens

Pathogens are agents or organisms that can cause diseases or illnesses, such as bacteria and viruses. Fecal coliform bacteria are typically used as an indicator organism because direct monitoring of human pathogens is generally not practical. Fecal coliform are a group of bacteria that are present in large numbers in the feces and intestinal tracts of humans and animals, and can enter water bodies from human and animal waste. The presence of fecal coliform bacteria implies the water body is potentially contaminated with human and/or animal waste, suggesting the potential presence of associated pathogenic organisms.

Fecal Coliform TMDL **–** The RWQCB has adopted phased TMDL criteria for pathogens, with the initial focus on additional monitoring and assessment to address areas of uncertainty. The goal of the Newport Bay TMDL is compliance with water contact recreational standards by 2014:

> Fecal coliform concentration of not less than five samples per 30 days shall have a geometric mean less than 200 most probable number (MPN)/100ml, and not more than 10 percent of the samples shall exceed 400 MPN/100ml for any 30-day period.

A second goal is to achieve the shellfish harvesting standards by 2020:

> The monthly median fecal coliform concentration shall be less than 14 MPN/100 mL, and not more than 10 percent of the samples shall exceed 43 MPN/100 mL.

The TMDLs are applicable for all flow regimes.

***Study Data Comparison with Fecal Coliform TMDLs* –** Table 21 shows the mean and median fecal coliform concentrations measured in the five study watersheds. 70% to 100% percent of all fecal coliform measurements were greater than 400 MPN/ml in all study watersheds. This level of exceedance is substantially greater than the allowable 10%. The mean and median fecal coliform concentrations also exceed the 400 MPN/100ml criterion in all study watersheds. There was insufficient data to calculate the 30-day geometric mean (a minimum of 5 samples per 30 days needed), however, the TMDL criterion (30-day geometric < 200 MPN/100 ml) would likely be exceeded, assuming that any additional data would be of the same magnitude as those collected. Exceedance of the TMDL criteria in all study watersheds suggests that urban dry weather runoff is likely a contributing factor to any dry weather exceedance of the TMDL in the receiving waters.

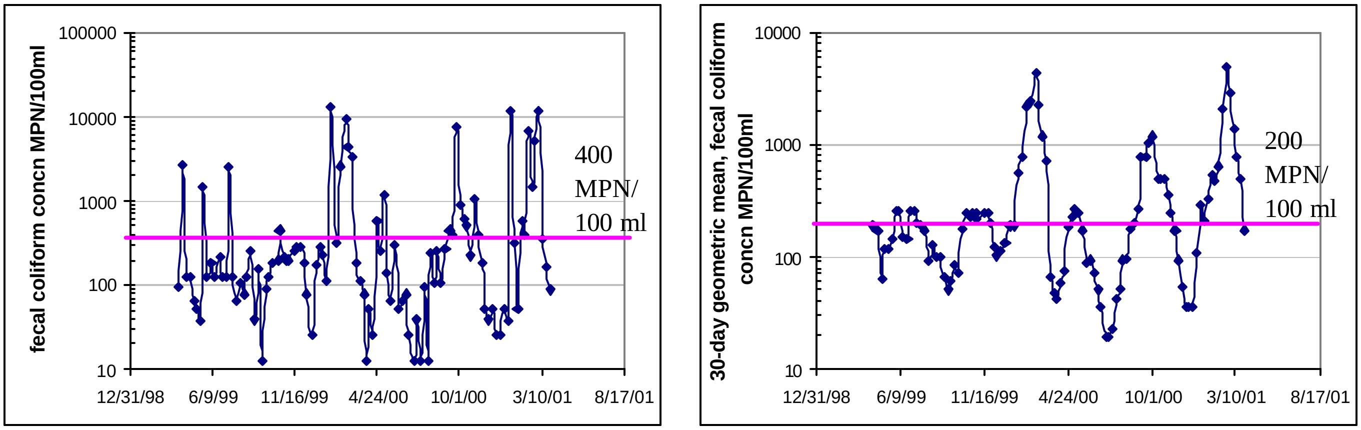
Table 21: Mean and Median Fecal Coliform Concentration (MPN/100ml) by Watershed

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
All Data										
n	22	24	21	24	23	24	21	24	23	24
Mean	4921	3003	5582	128193	34526	28980	28205	34185	17976	10326
Median	2300	1400	1700	3000	13000	4000	13000	13000	8000	8000
% > 400 MPN/100ml	82%	67%	86%	79%	100%	88%	95%	83%	92%	93%
Subsets[1]										
n	17	14	17	14	18	14	17	14	18	14
Mean	2545	3054	3090	5074	13783	37479	23312	20166	8524	6109
Median	2200	950	1400	1400	8000	2650	8000	6500	4000	2900
% > 400 MPN/100ml	100%	71%	82%	79%	100%	86%	94%	79%	100%	93%

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

We were unable to locate dry weather coliform monitoring information in the Central Irvine Channel, which is the immediate receiving water of the study watersheds (*IRWD please confirm*). Therefore it is unknown if elevated fecal coliform concentrations measured in the study watershed contribute to an exceedance of the TMDL in the immediate receiving waters. The OCPFRD has collected dry and wet weather *E. coli* monitoring information in San Diego Creek at Campus Drive (OCPFRD, September 2001), which is considerably downstream from the study watersheds. A plot of the equivalent fecal coliform concentration (assuming an 80% *E. coli* content) shows exceedance of the TMDL occurs primarily during the wet season, although dry season exceedances are also evident (see Figure 9). This suggests that dry weather urban runoff is potentially a contributing factor to exceedance of the TMDL in dry weather flows at Campus Drive. The ET controllers would reduce the impacts from these potential exceedances if they were determined to be effective reducing the dry weather runoff volumes.

Figure 9: Time Series of Fecal Coliform Levels San Diego Creek at Campus Drive (converted from measured E. coli concentrations)



Median fecal coliform concentrations presented in Table 21 may be used to evaluate the influence of the structural and non-structural BMPs. When all monitoring dataset is considered, the median fecal coliform concentrations are equivalent or increase from pre- to post-intervention conditions in all watersheds except the 1001 (intervention watershed) and 1003 (a control watershed). Based on the Mann-Whitney (rank-sum) test, the reduction in median concentrations in 1001 and 1003 is significantly significant at the 95% confidence level. Thus the watershed with the irrigation controllers corresponded to a significant reduction in median fecal coliform concentrations, in comparison to 2 of the 3 control sites, while the education only watershed exhibited no discernable reduction in median concentrations.

When subsets of the data with similar seasons and sampling times are considered (Table 21), there is a decrease in the median fecal coliform concentration in all watersheds except 1002. However, because of the smaller sample sizes, the decrease is median concentration is statistically significant only in watershed 1003. This suggests that there could be seasonal influences in the monitoring data, but the data are not sufficient to determine if there are statistically significant differences in the median concentrations.

5. References

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OCPFRD, 2001. County of Orange Public Facilities and Resources Department, NPDE Annual Progress Report.

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RWQCB, 1995. Water Quality Control Plan, Santa Ana River Basin (8).

Schiff, K.C. and L.L.Tiefenthaler, June 2003. Contributions of organophosphorus pesticides from residential land uses during dry and wet weather. Technical Report 406, Southern California Coastal Water Research Project.

USEPA (Region 9), 1998a. *Total Maximum Daily Loads for Sediment and Monitoring and Implementation Recommendations; San Diego Creek and Newport Bay, California*

USEPA (Region 9), 1998b. *Total Maximum Daily Loads for Nutrients; San Diego Creek and Newport Bay, California*

USEPA, June 2002. Total Maximum Daily Loads for Toxic Pollutants – San Diego Creek and Newport Bay, California, June 14, 2002.

Tetra Tech, Inc., July 2000c. Newport Bay Watershed Urban Nutrient TMDL Compliance Evaluation.

Appendix A - Time-Series Plots

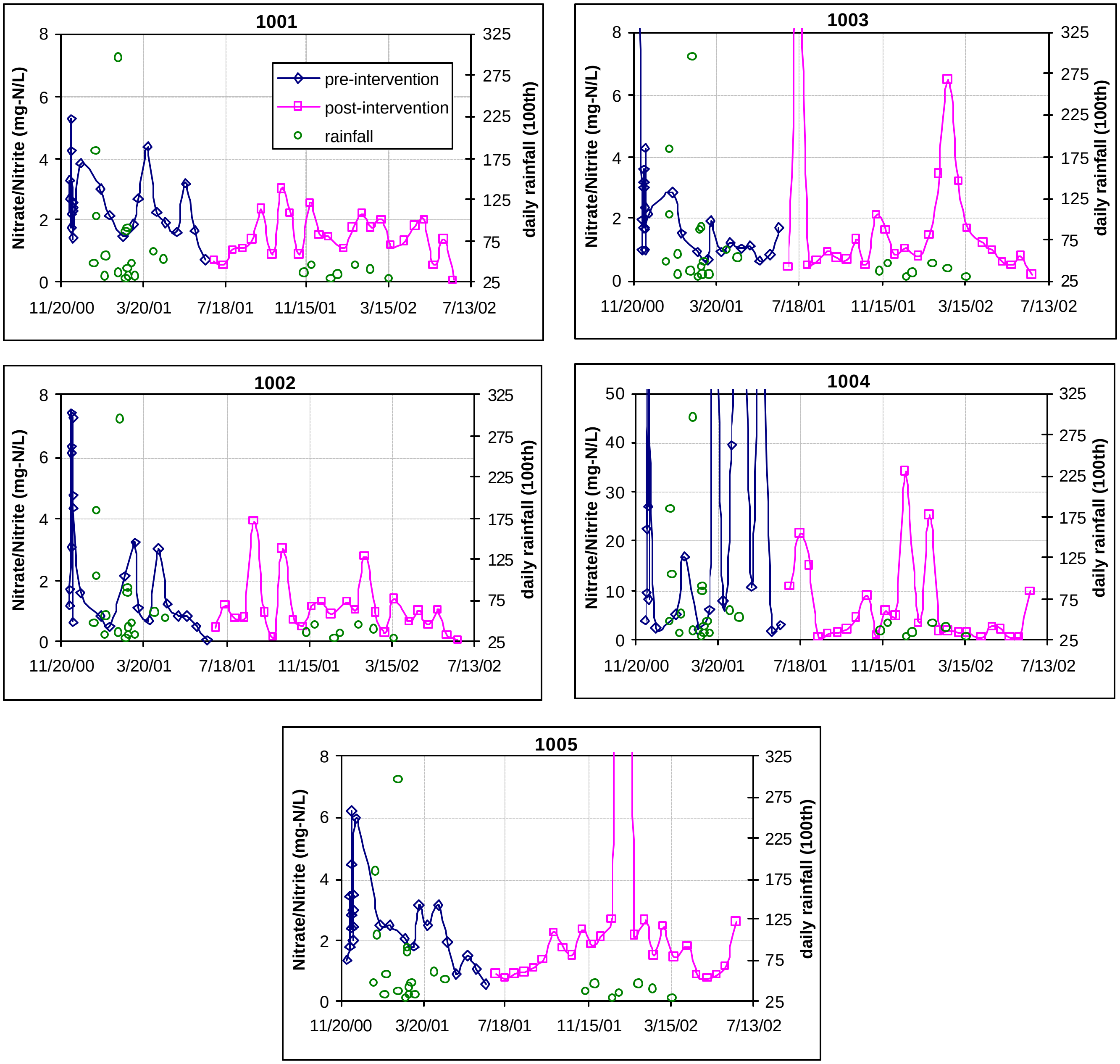

Figure A-1: Time Series of Nitrate/Nitrite in Dry Weather Samples (all data)

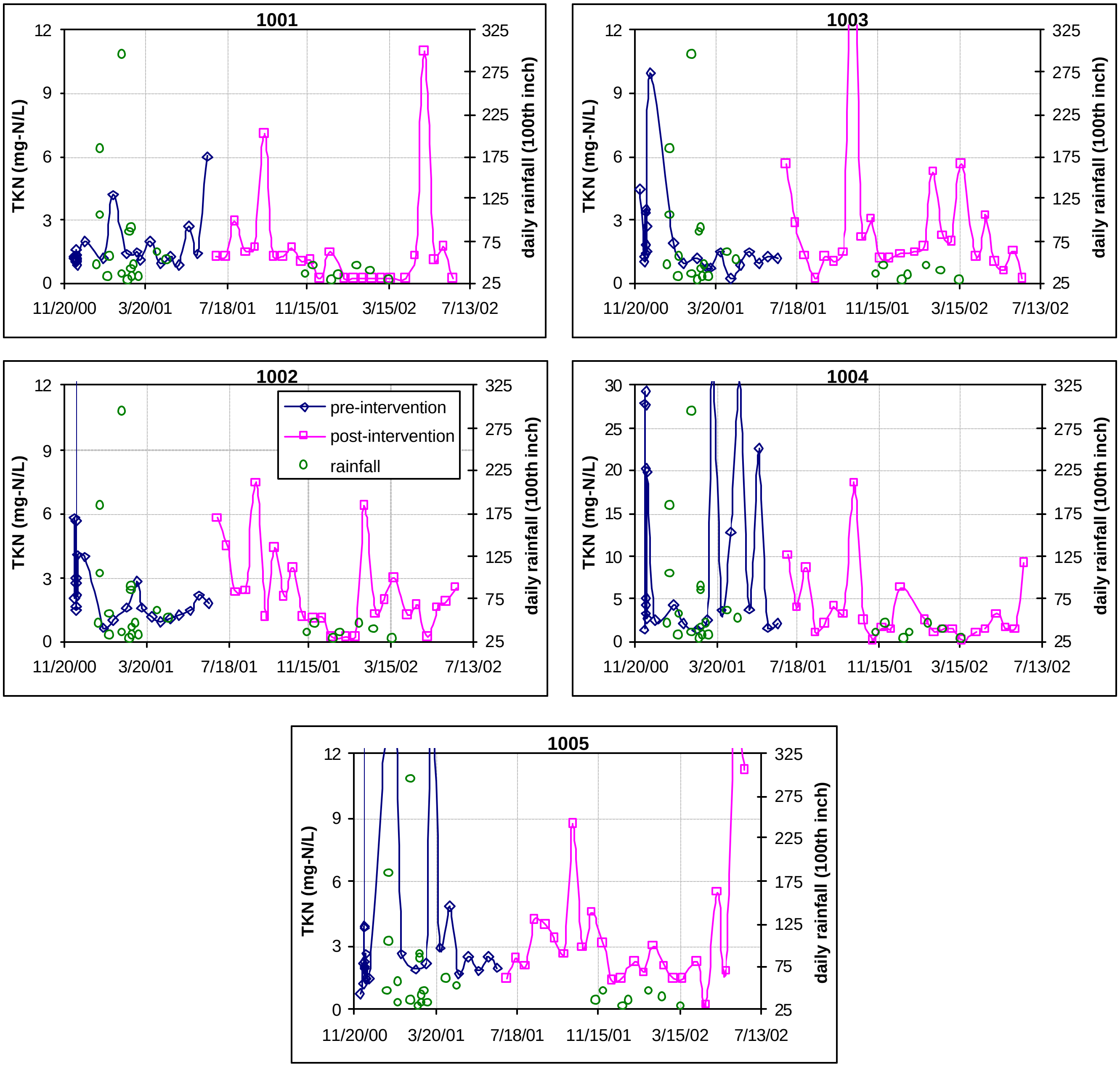

Figure A-2: Time Series of TKN in Dry Weather Samples (all data)

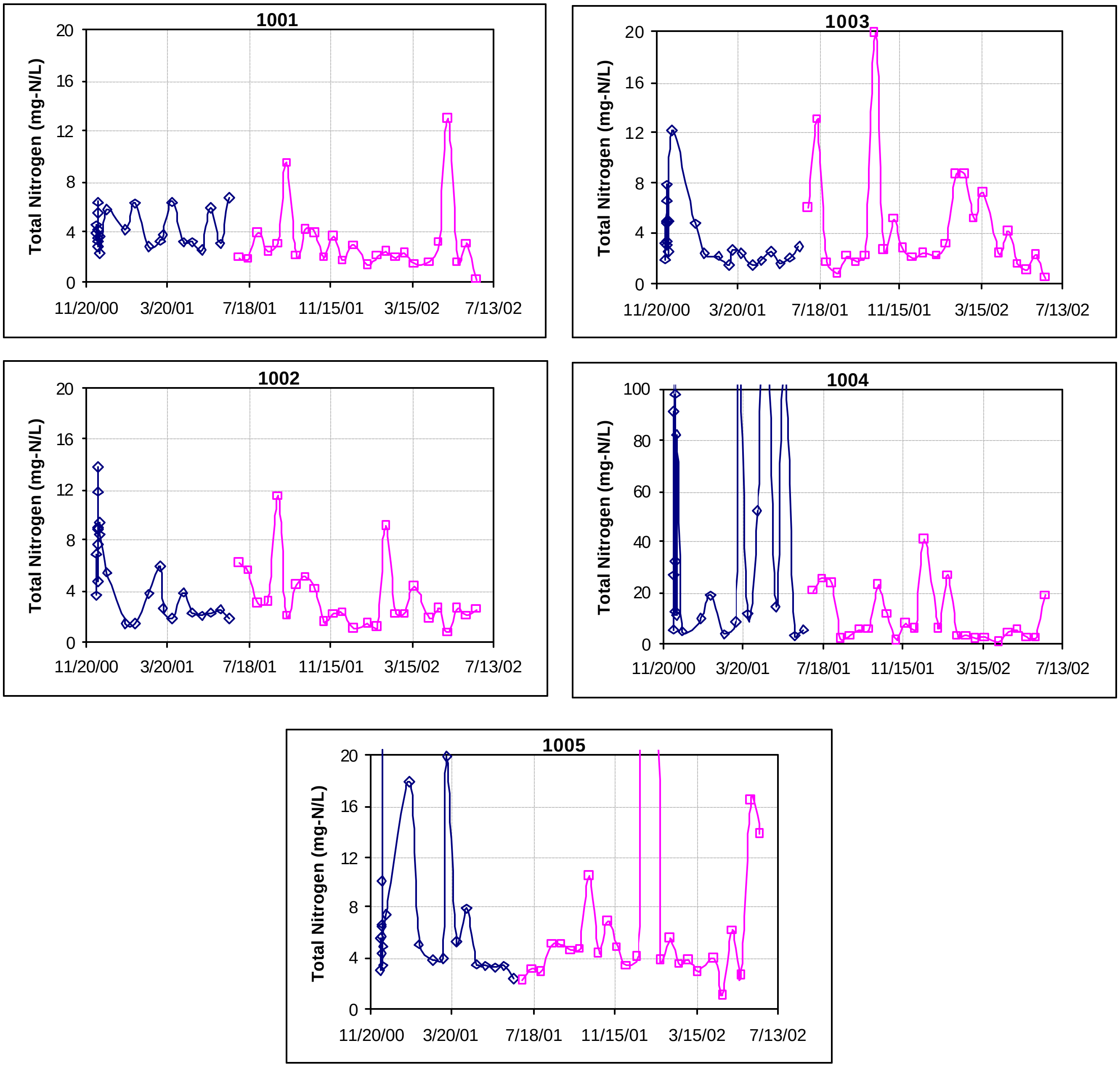

Figure A-3: Time Series of TN (Calculated) in Dry Weather Samples (all data)

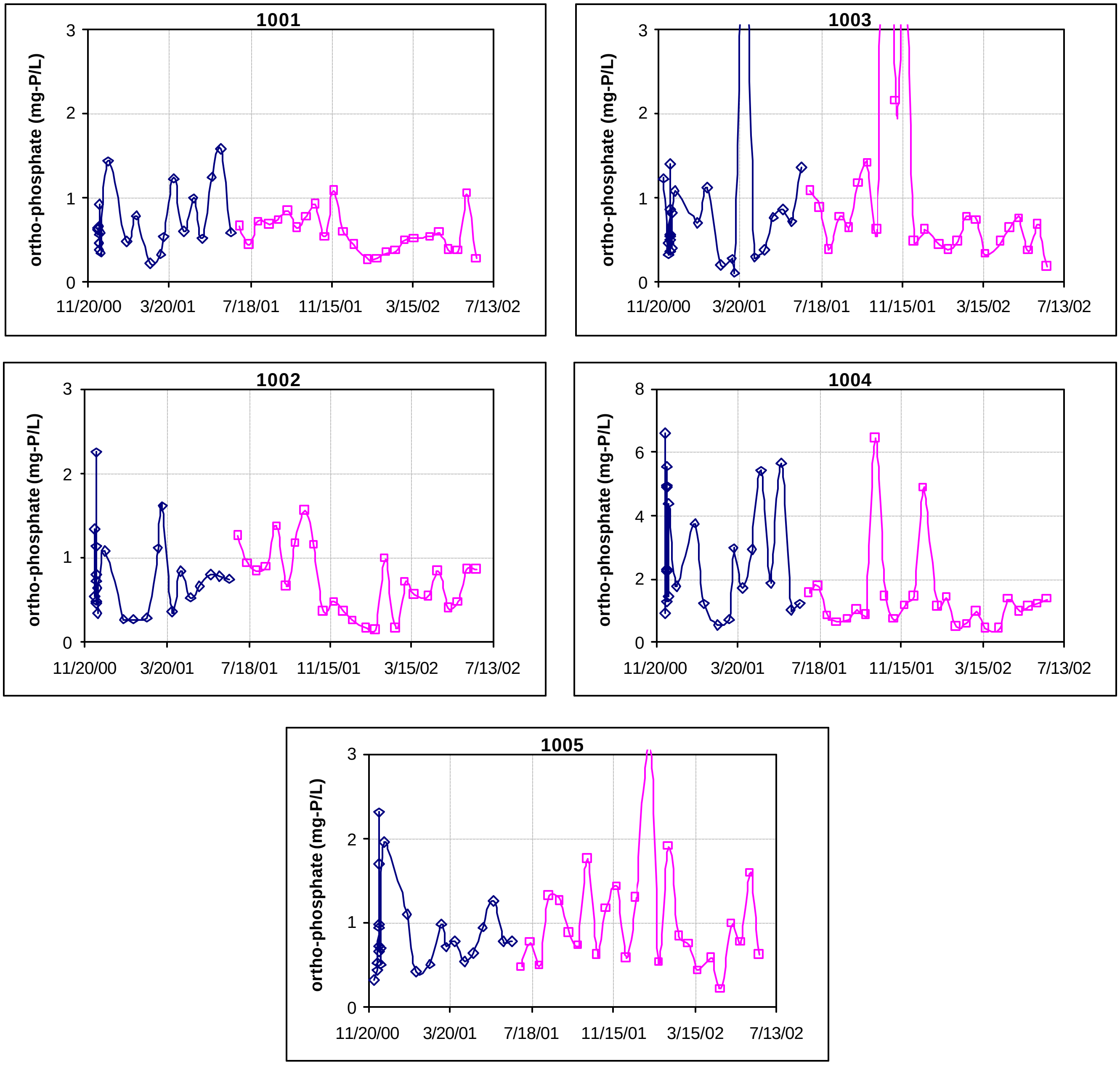

Figure A-4: Time Series of Ortho-Phosphate in Dry Weather Samples (all data)

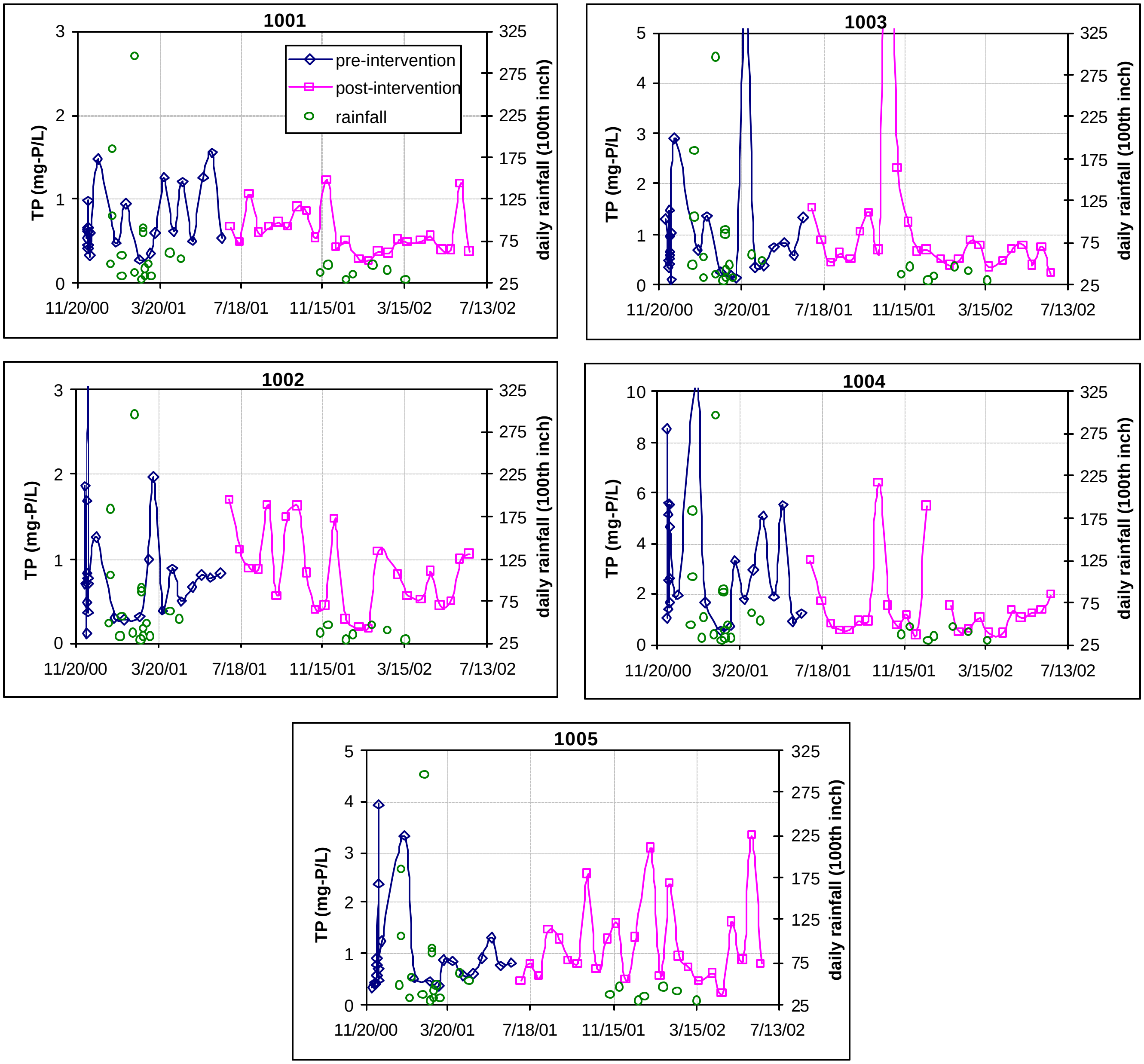

Figure A-5: Time Series of Total-Phosphorus in Dry Weather Samples (all data)

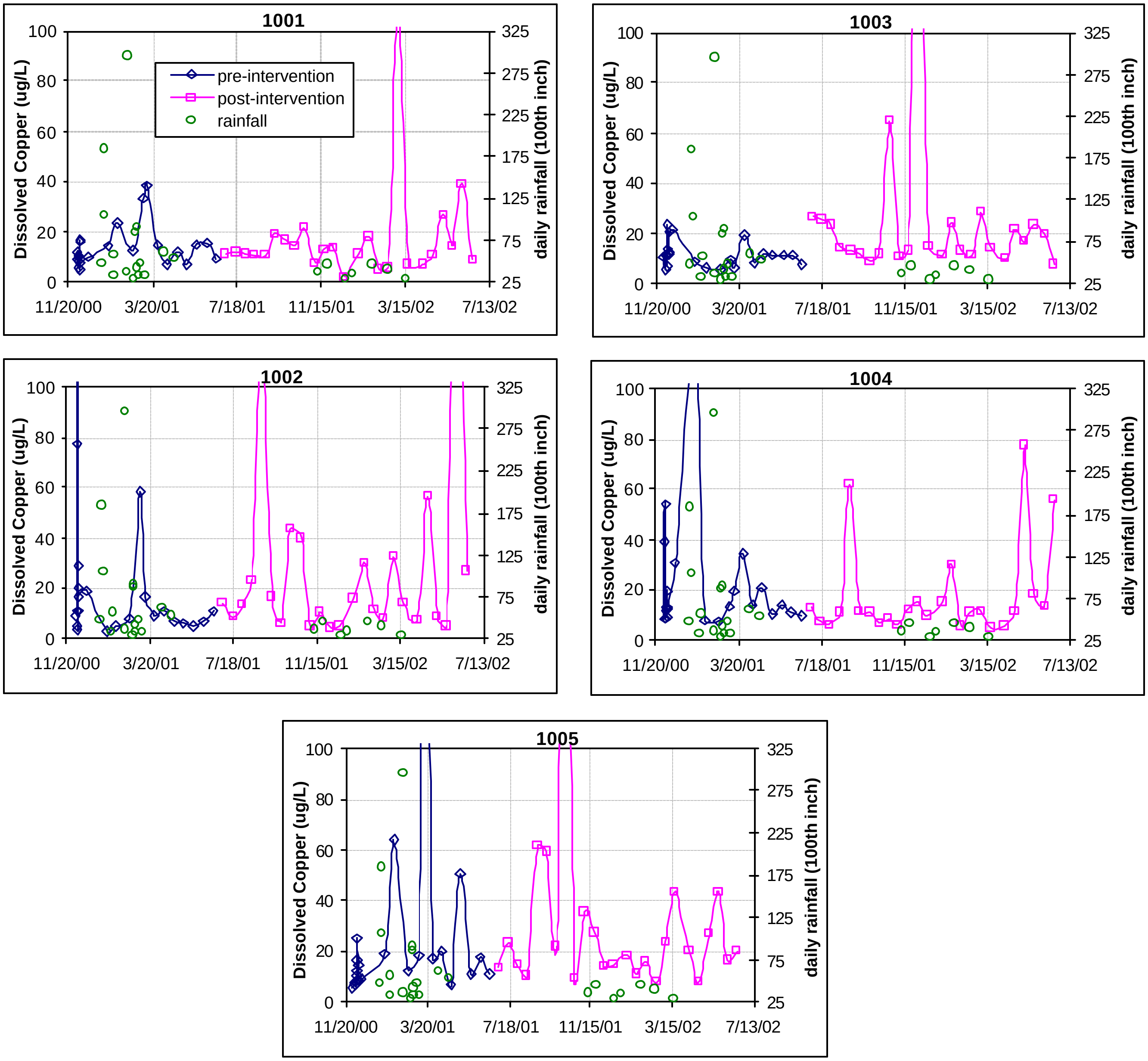

Figure A-6: Time Series of Dissolved Copper in Dry Weather Samples (all data)

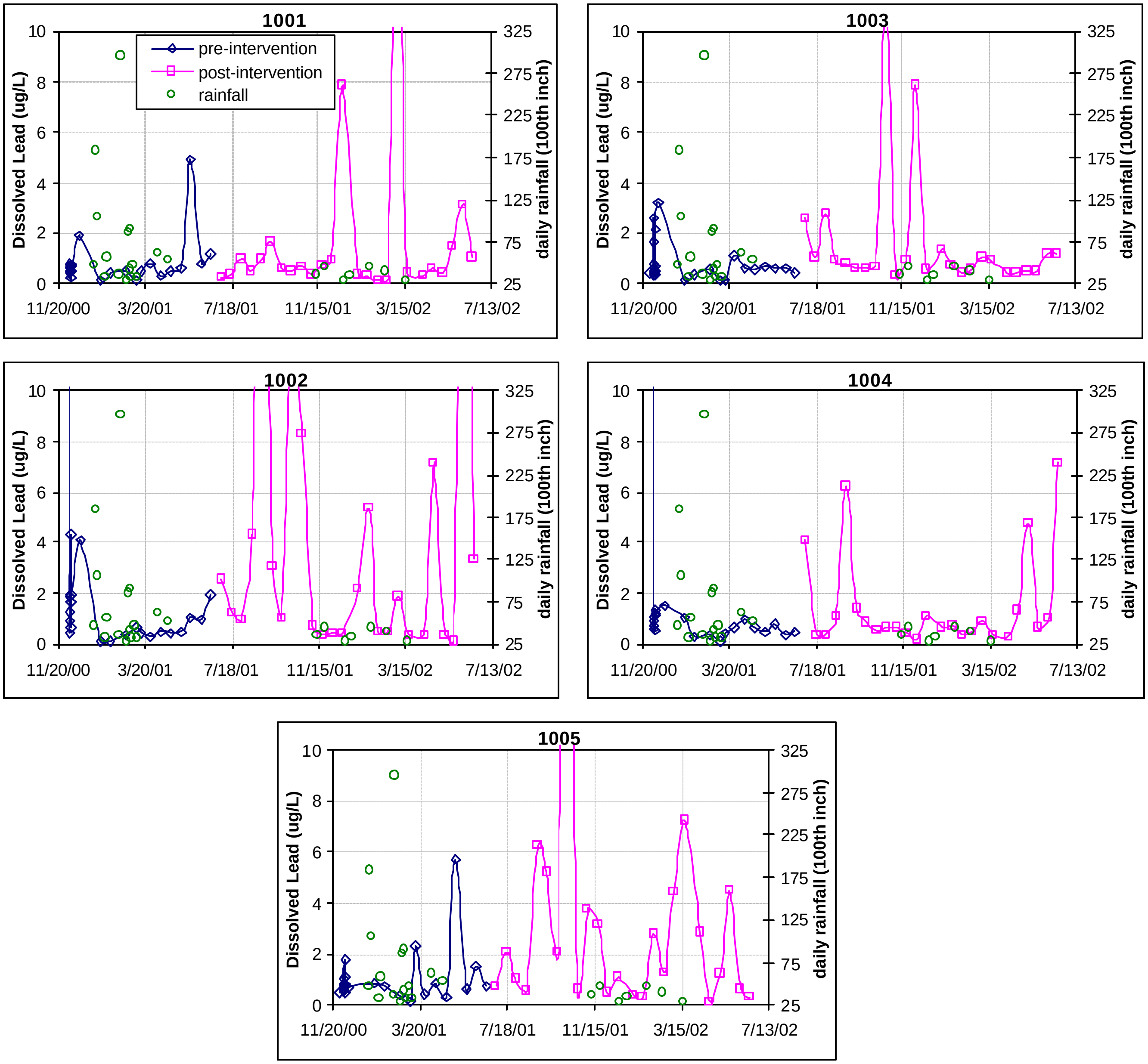

Figure A-7: Time Series of Dissolved Lead in Dry Weather Samples (all data)

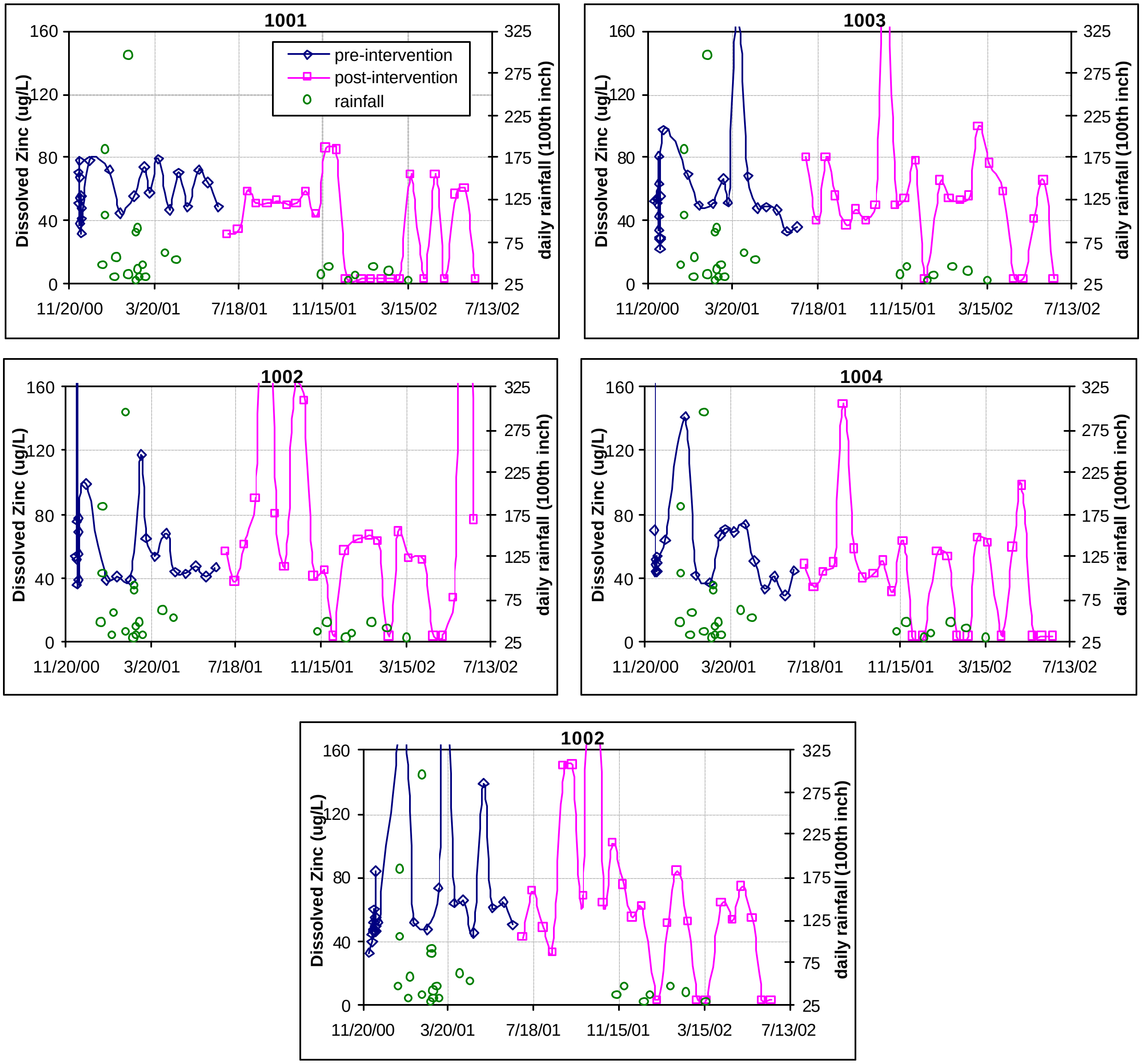

Figure A-8: Time Series of Dissolved Zinc in Dry Weather Samples (all data)

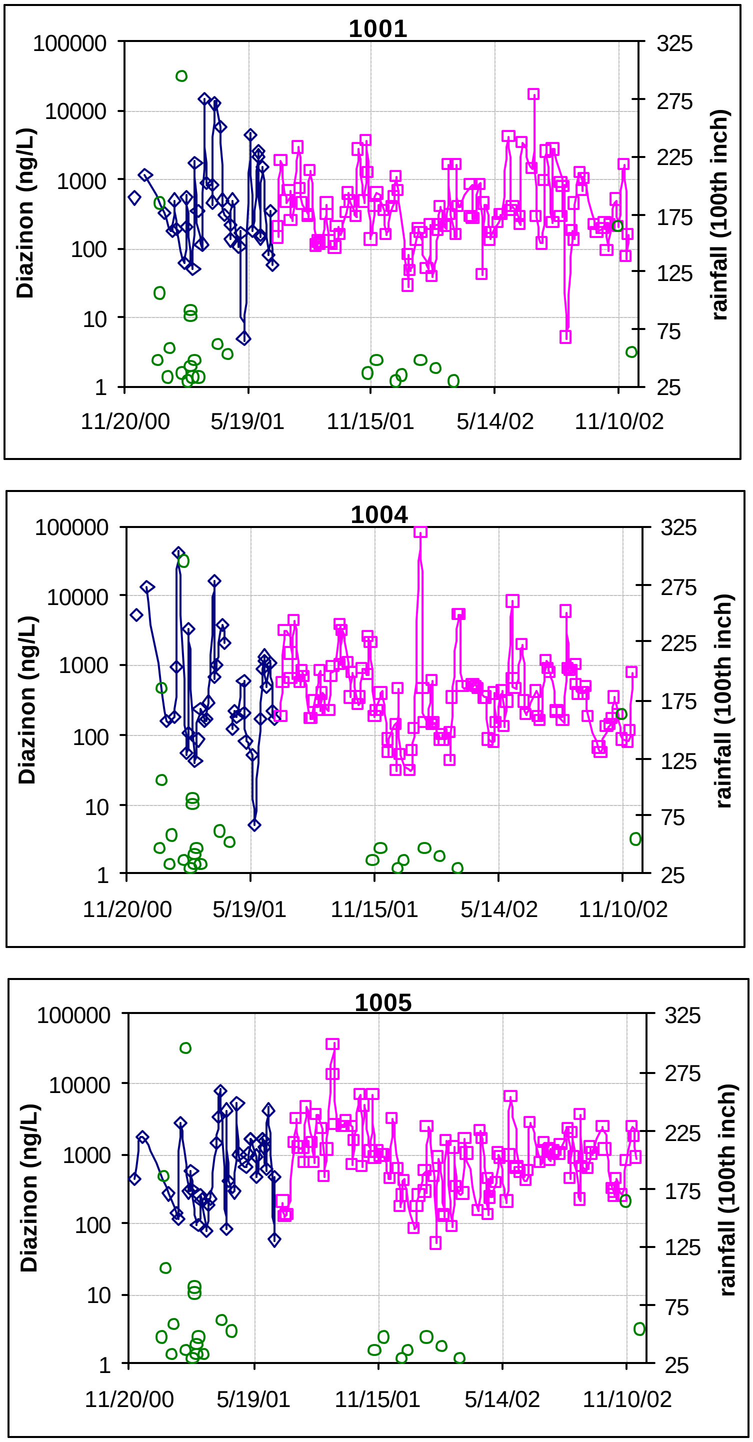

Figure A-9: Time Series of Diazinon in Dry Weather Samples (all data)

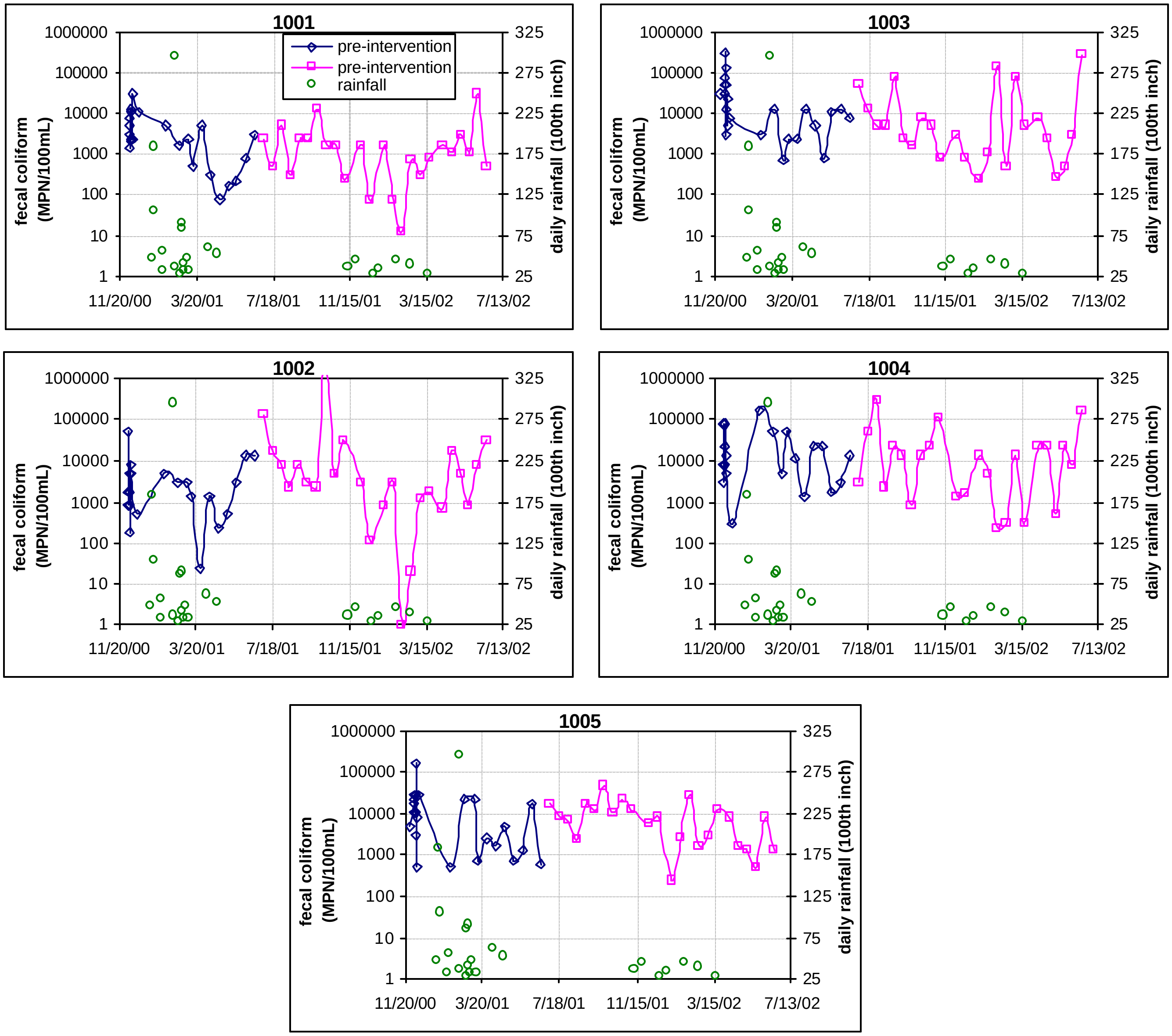

Figure A-10: Time Series of Fecal Coliform in Dry Weather Samples (all data)

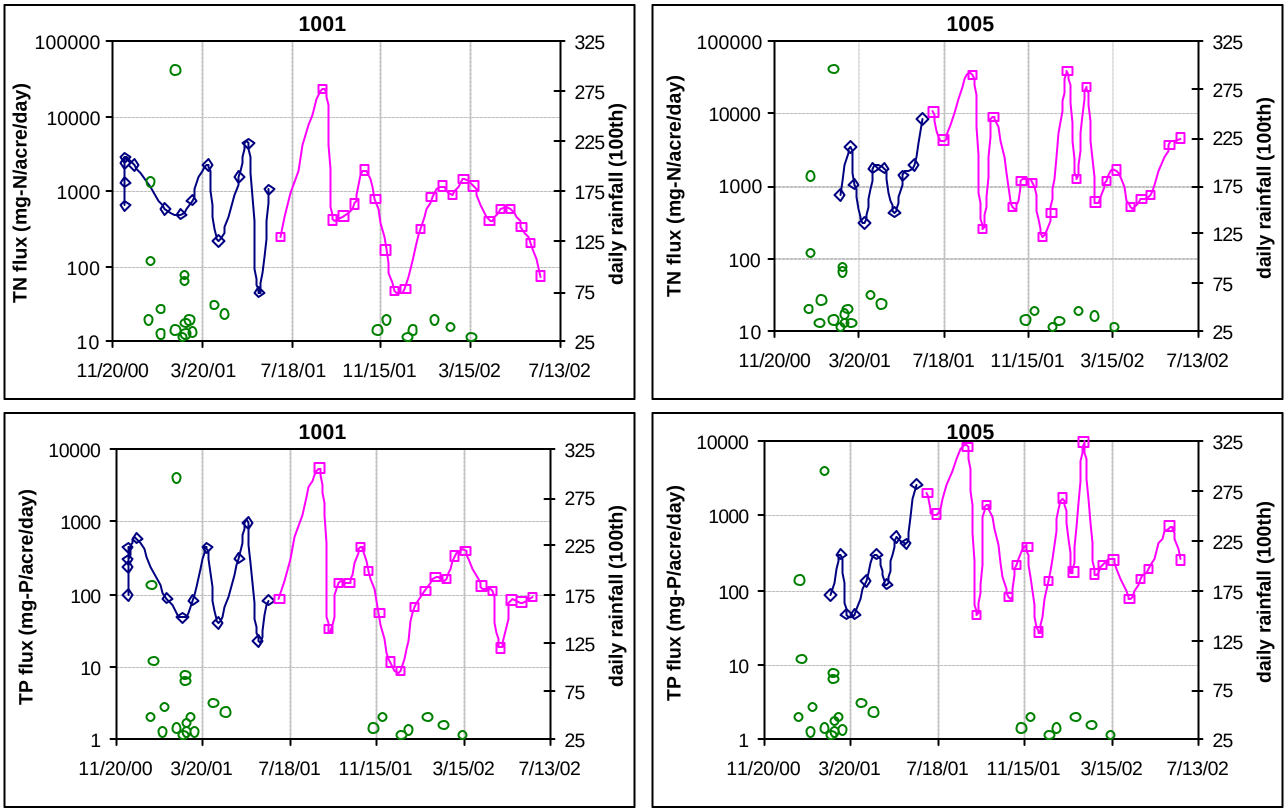

Figure A-11: Time Series of Nutrient Fluxes in Dry Weather Samples (all data)

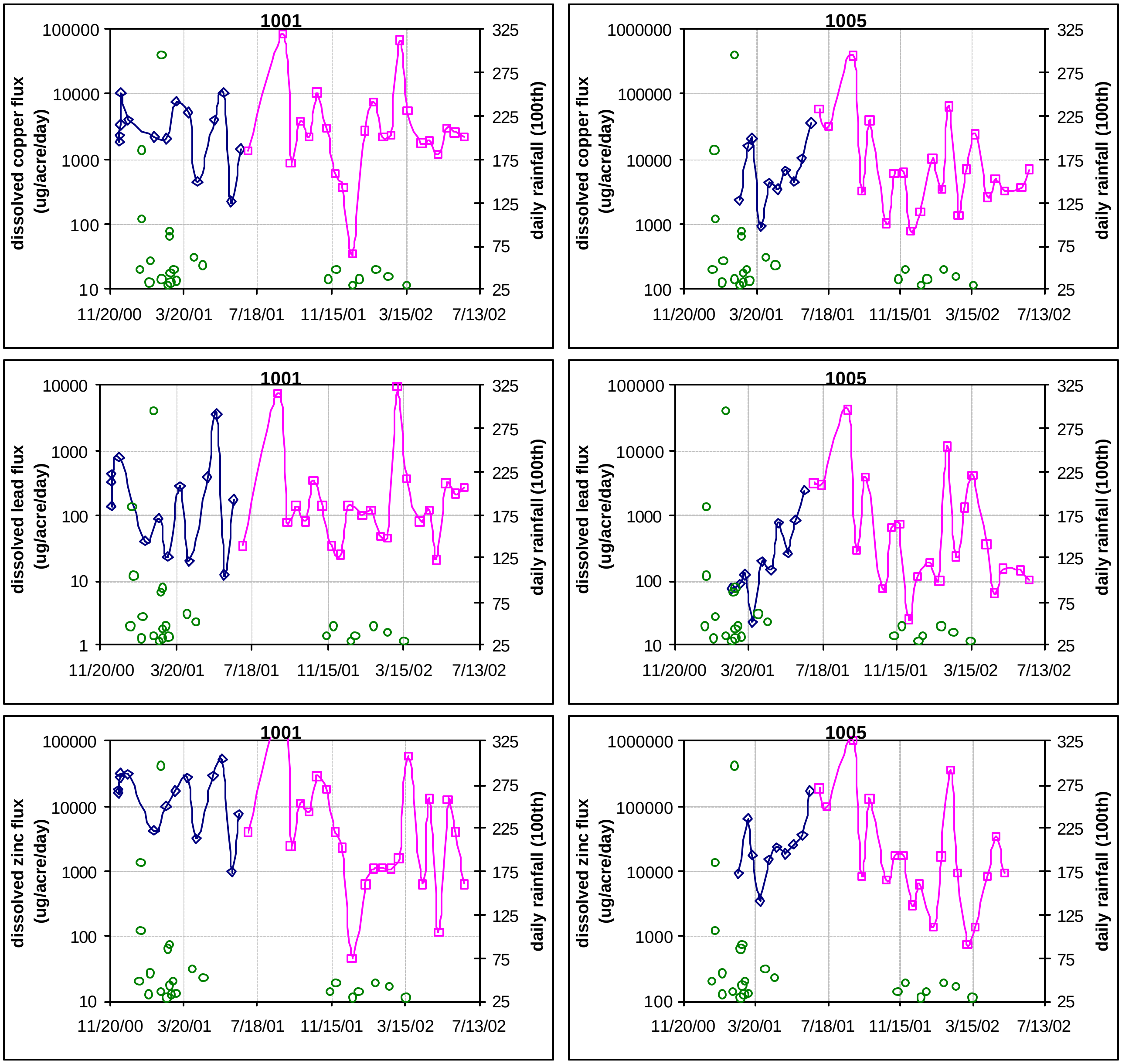

Figure A-12: Time Series of Dissolved Metal Fluxes in Dry Weather Samples (all data)

Appendix B – Summary Statistics

Table B-1: Descriptive Statistics

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Nitrate/Nitrite as N	**n**	23	25	23	25	24	25	23	25	24	25
(mg-N/L)	**% > MDL/RL**	100%	96%	96%	96%	100%	100%	100%	100%	100%	100%
	Mean	2.56	1.47	2.57	1.07	2.13	1.71	36.50	6.61	2.61	4.13
	Median	2.32	1.38	1.56	0.93	1.68	0.94	16.88	2.29	2.45	1.48
	Trimmed mean	2.37	1.44	1.80	0.89	1.61	1.01	25.04	3.33	2.41	1.60
	min	0.74	0.05	0.05	0.05	0.65	0.20	1.70	0.60	0.54	0.73
	max	5.26	2.97	7.42	3.92	9.96	10.16	109.90	34.40	6.21	64.90
	25th percentile	1.81	1.05	0.82	0.53	0.98	0.64	5.62	1.43	1.79	0.96
	75th percentile	3.10	1.99	3.77	1.18	2.49	1.60	70.76	8.95	3.11	2.22
	St Dev	1.08	0.70	2.34	0.91	1.94	2.21	37.82	8.78	1.40	12.68
	IQR	1.29	0.94	2.95	0.65	1.51	0.96	65.14	7.52	1.32	1.26
	Skewness, gs	0.84	0.14	1.00	1.89	3.11	2.96	0.76	2.01	1.19	4.98
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	Y	Y	N	N	N	N	Y	N	N	N
TKN	**n**	23	25	23	25	24	25	23	24	24	25
(mg-N/L)	**% > MDL/RL**	100%	64%	100%	84%	96%	92%	96%	92%	100%	96%
	Mean	1.68	1.63	2.74	2.37	1.97	2.71	11.50	3.72	4.08	3.61
	Median	1.27	1.21	1.78	1.90	1.38	1.46	4.26	1.91	2.23	2.39
	Trimmed mean	1.29	0.77	1.95	1.87	1.40	1.69	7.51	2.23	2.29	2.57
	min	0.88	0.25	0.68	0.25	0.25	0.25	1.44	0.25	0.76	0.25
	max	6.02	11.00	13.20	7.48	9.97	18.60	31.81	18.60	17.43	15.30
	25th percentile	1.13	0.25	1.33	1.13	1.01	1.20	2.55	1.41	1.88	1.71
	75th percentile	1.57	1.46	2.86	2.98	1.85	2.87	21.46	4.03	3.15	4.01
	St Dev	1.19	2.40	2.68	1.96	1.97	3.64	11.61	4.21	4.90	3.41
	IQR	0.44	1.21	1.53	1.85	0.84	1.67	18.90	2.62	1.26	2.30
	Skewness	2.84	3.16	3.00	1.23	3.24	3.77	0.75	2.31	2.29	2.34
	Gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	N	N	N	Y	N	N	N
Ammonia as N	**n**	23	25	23	25	24	25	23	24	24	25

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
(mg-N/L)	**% > MDL/RL**	30%	20%	74%	64%	75%	52%	87%	71%	92%	96%
	Mean	0.13	0.08	0.25	0.42	0.26	0.29	7.05	0.25	0.85	0.42
	Median	0.05	0.05	0.18	0.20	0.17	0.10	0.71	0.14	0.43	0.22
	Trimmed mean	0.05	0.05	0.19	0.13	0.19	0.11	3.43	0.12	0.50	0.24
	min	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	max	1.12	0.36	0.90	5.45	1.06	2.29	26.34	2.03	6.92	2.41
	25th percentile	0.05	0.05	0.08	0.05	0.09	0.05	0.24	0.05	0.24	0.15
	75th percentile	0.12	0.05	0.30	0.28	0.29	0.36	13.69	0.28	0.94	0.42
	St Dev	0.23	0.07	0.22	1.06	0.26	0.48	9.14	0.40	1.39	0.50
	IQR	0.07	0.00	0.22	0.23	0.20	0.31	13.45	0.23	0.70	0.27
	Skewness	4.04	3.08	1.66	4.78	1.98	3.40	0.93	4.09	3.95	3.01
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	N	N	N	Y	N	N	N
TN (calculated)	**n**	23	25	23	25	23	25	23	25	23	25
(mg-N/L)	**% > MDL/RL**	100%	80%	98%	90%	98%	96%	98%	96%	100%	98%
	Mean	4.24	3.09	5.31	3.44	3.66	4.42	48.00	10.18	6.89	7.74
	Median	3.84	2.27	3.95	2.55	2.66	2.50	19.01	5.57	5.06	4.36
	Trimmed mean	3.94	2.40	4.53	2.76	2.93	3.01	33.11	6.47	5.08	4.42
	min	2.30	0.30	1.50	0.78	1.46	0.45	3.28	0.74	2.48	1.07
	max	6.76	12.99	13.83	11.40	12.12	19.91	141.06	40.80	20.41	67.12
	25th percentile	3.20	1.79	2.27	2.10	2.11	2.04	9.05	2.71	3.52	3.47
	75th percentile	5.68	3.13	8.02	4.36	4.81	5.17	94.79	19.18	7.07	5.62
	St Dev	1.41	2.67	3.56	2.51	2.48	4.39	49.17	10.73	5.29	12.85
	IQR	2.48	1.34	5.75	2.26	2.70	3.13	85.74	16.47	3.55	2.15
	Skewness	0.55	2.82	0.84	1.87	2.13	2.27	0.74	1.37	1.88	4.46
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	Y	N	Y	N	N	N	Y	N	N	N
ortho-phosphate	**n**	23	25	23	25	24	25	23	25	24	25
(mg-P/L)	**% > MDL/RL**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Mean	0.71	0.58	0.79	0.72	0.81	1.26	2.84	1.40	0.89	1.00
	Median	0.58	0.53	0.73	0.72	0.64	0.64	2.23	1.10	0.76	0.77
	Trimmed mean	0.60	0.56	0.69	0.70	0.63	0.66	2.42	1.10	0.77	0.87
	min	0.23	0.26	0.28	0.15	0.11	0.19	0.52	0.43	0.33	0.22
	max	1.58	1.08	2.25	1.56	4.01	10.60	6.57	6.45	2.31	3.11
	25th percentile	0.47	0.38	0.48	0.41	0.38	0.47	1.25	0.75	0.55	0.59
	75th	0.86	0.72	0.96	0.93	0.92	0.89	4.63	1.42	0.98	1.29

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
	percentile										
	St Dev	0.37	0.23	0.47	0.39	0.77	2.11	1.89	1.35	0.49	0.62
	IQR	0.39	0.34	0.48	0.52	0.54	0.42	3.38	0.67	0.44	0.70
	Skewness	1.13	0.60	1.55	0.32	3.27	4.03	0.60	3.03	1.66	1.79
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	Y	N	Y	N	N	Y	N	N	N
TP	**n**	23	25	23	25	24	25	23	24	24	25
(mg-P/L)	**% > MDL/RL**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Mean	0.73	0.60	0.92	0.84	0.98	1.21	3.33	1.50	1.01	1.19
	Median	0.60	0.51	0.77	0.82	0.62	0.67	2.54	1.05	0.73	0.85
	Trimmed mean	0.61	0.53	0.72	0.77	0.65	0.68	2.73	1.06	0.72	0.95
	min	0.27	0.26	0.11	0.16	0.11	0.23	0.53	0.34	0.33	0.22
	max	1.55	1.22	3.65	1.69	6.18	11.70	10.37	6.38	3.92	3.32
	25th percentile	0.47	0.39	0.43	0.49	0.35	0.49	1.52	0.60	0.50	0.60
	75th percentile	0.97	0.67	0.94	1.08	1.08	0.87	5.11	1.55	0.91	1.46
	St Dev	0.38	0.27	0.77	0.47	1.26	2.23	2.58	1.51	0.92	0.83
	IQR	0.50	0.28	0.51	0.59	0.73	0.38	3.59	0.96	0.40	0.86
	Skewness	1.00	1.07	2.27	0.49	3.39	4.68	1.26	2.41	2.35	1.38
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	Y	N	N	N	N	N	N
Cadmium	**n**	23	25	23	25	24	25	23	25	24	25
(ug/L)	**% > MDL/RL**	61%	12%	61%	36%	38%	16%	74%	36%	38%	44%
	Mean	0.26	0.14	0.47	0.44	0.27	0.17	0.64	0.22	0.21	0.29
	Median	0.27	0.10	0.24	0.10	0.10	0.10	0.36	0.10	0.10	0.10
	Trimmed mean	0.20	0.10	0.20	0.12	0.12	0.10	0.33	0.12	0.12	0.15
	min	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	max	0.56	0.79	3.40	3.50	1.77	0.92	4.54	1.22	0.92	1.89
	25th percentile	0.10	0.10	0.10	0.10	0.10	0.10	0.16	0.10	0.10	0.10
	75th percentile	0.39	0.10	0.40	0.26	0.26	0.10	0.42	0.23	0.25	0.45
	St Dev	0.15	0.15	0.78	0.79	0.37	0.20	1.15	0.25	0.20	0.37
	IQR	0.29	0.00	0.30	0.16	0.16	0.00	0.27	0.13	0.15	0.35
	Skewness	0.29	4.04	3.21	3.06	3.37	3.08	3.09	3.05	2.56	3.47
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	Y	N	N	N	N	N	N	N	N	N
Copper	**n**	23	25	23	25	24	25	23	25	24	25
(ug/L)	**% > MDL/RL**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Mean	13.5	16.9	27.3	30.3	11.5	26.6	21.8	17.7	32.1	30.8
	Median	11.5	11.4	10.9	14.0	11.1	14.3	12.7	11.4	12.3	20.4

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
	Trimmed mean	11.6	12.1	10.7	15.4	10.7	16.2	13.9	11.3	13.2	19.8
	min	5.2	1.9	3.2	4.6	5.6	7.2	7.3	5.1	5.4	7.9
	max	38.4	108.0	278.4	226.6	23.4	227.0	119.3	77.4	389.6	210.0
	25th percentile	8.4	8.8	6.2	8.0	8.0	11.6	10.0	7.5	8.7	14.2
	75th percentile	15.0	16.9	17.9	29.8	12.3	23.4	20.5	15.2	18.6	27.5
	St Dev	8.3	20.5	57.5	48.2	5.1	43.3	24.2	18.9	77.4	40.2
	IQR	6.7	8.1	11.8	21.8	4.2	11.8	10.5	7.7	9.9	13.3
	Skewness	1.9	4.0	4.1	3.3	1.1	4.5	3.3	2.3	4.7	4.0
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	N	N	N	N	N	N	N
Lead	**n**	23	25	23	25	24	25	23	25	24	25
(ug/L)	**% > MDL/RL**	91%	92%	91%	96%	88%	100%	96%	100%	96%	96%
	Mean	0.79	1.59	5.93	4.72	0.82	1.59	3.47	1.47	1.01	3.24
	Median	0.60	0.60	0.89	1.20	0.59	0.81	0.72	0.69	0.74	1.30
	Trimmed mean	0.57	0.62	0.94	1.65	0.56	0.81	0.77	0.76	0.72	1.79
	min	0.10	0.10	0.10	0.10	0.10	0.28	0.10	0.21	0.10	0.10
	max	4.91	14.90	81.70	30.87	3.19	10.90	37.74	7.16	5.70	28.10
	25th percentile	0.46	0.38	0.41	0.40	0.42	0.53	0.48	0.44	0.52	0.62
	75th percentile	0.74	0.97	1.91	4.30	0.71	1.14	1.13	1.09	0.92	3.77
	St Dev	0.97	3.18	17.63	8.10	0.79	2.46	9.19	1.91	1.11	5.56
	IQR	0.28	0.59	1.50	3.90	0.29	0.61	0.65	0.65	0.40	3.15
	Skewness	3.81	3.63	4.06	2.58	1.95	3.16	3.32	2.14	3.62	4.02
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	N	N	N	N	N	N	N
Zinc	**n**	23	25	23	25	24	25	23	25	24	25
(ug/L)	**% > MDL/RL**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Mean	58.7	37.2	115.2	86.3	56.3	56.8	83.6	40.9	74.0	75.0
	Median	56.0	50.2	53.4	57.2	50.7	53.9	50.8	43.8	52.4	54.5
	Trimmed mean	58.6	26.4	54.2	57.6	51.2	53.1	53.2	27.7	54.5	58.3
	min	32.5	2.5	35.4	2.5	22.1	2.5	29.5	2.5	32.3	2.5
	max	79.2	86.2	1069.7	429.6	171.0	231.0	429.0	149.0	330.0	512.0
	25th percentile	48.1	2.5	41.7	40.4	40.9	40.2	43.3	2.5	46.9	42.8
	75th percentile	71.4	58.2	72.1	76.9	63.9	65.5	69.0	58.6	64.6	74.5
	St Dev	14.1	29.1	219.7	109.1	29.9	44.4	97.0	35.1	63.0	99.1
	IQR	23.2	55.7	30.4	36.5	23.0	25.3	25.7	56.1	17.7	31.7
	Skewness	-0.1	-0.1	4.1	2.6	2.6	2.4	3.0	1.1	3.4	3.8
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
	symmetric?	Y	Y	N	N	N	N	N	N	N	N
Diazinon	**n**	37	104					36	104	39	104
(ng/L)	**% > MDL/RL**	97%	99%					97%	100%	100%	100%
	Mean	1457	748					2694	1556	1295	1711
	Median	345	291					231	346	614	884
	Trimmed mean	420	352					442	369	783	902
	min	5	5					5	29	60	53
	max	14465	16590					41402	80969	7910	34838
	25th percentile	156.8	166.6					157.6	150.2	262.8	415.8
	75th percentile	890.4	641.6					1119.2	791.3	1601.5	1609.8
	St Dev	3140.5	1753.2					7505.6	7977.2	1655.4	3741.7
	IQR	733.6	475.0					961.6	641.1	1338.7	1194.0
	Skewness	3.4	7.5					4.4	9.8	2.3	7.2
	gcr	0.77	0.47					0.78	0.47	0.75	0.47
	symmetric?	N	N					N	N	N	N
Chlorpyrifos	**n**	37	104								
(ng/L)	**% > MDL/RL**	57%	40%								
	Mean	38.3	456.4								
	Median	25.0	10.0								
	Trimmed mean	18.9	10.0								
	min	5.0	5.0								
	max	213.7	45094.0								
	25th percentile	10.0	5.0								
	75th percentile	42.2	28.7								
	St Dev	51.1	4419.7								
	IQR	32.2	23.7								
	Skewness	2.5	10.2								
	gcr	0.77	0.47								
	symmetric?	N	N								

Appendix C – Probability Plot Comparisons

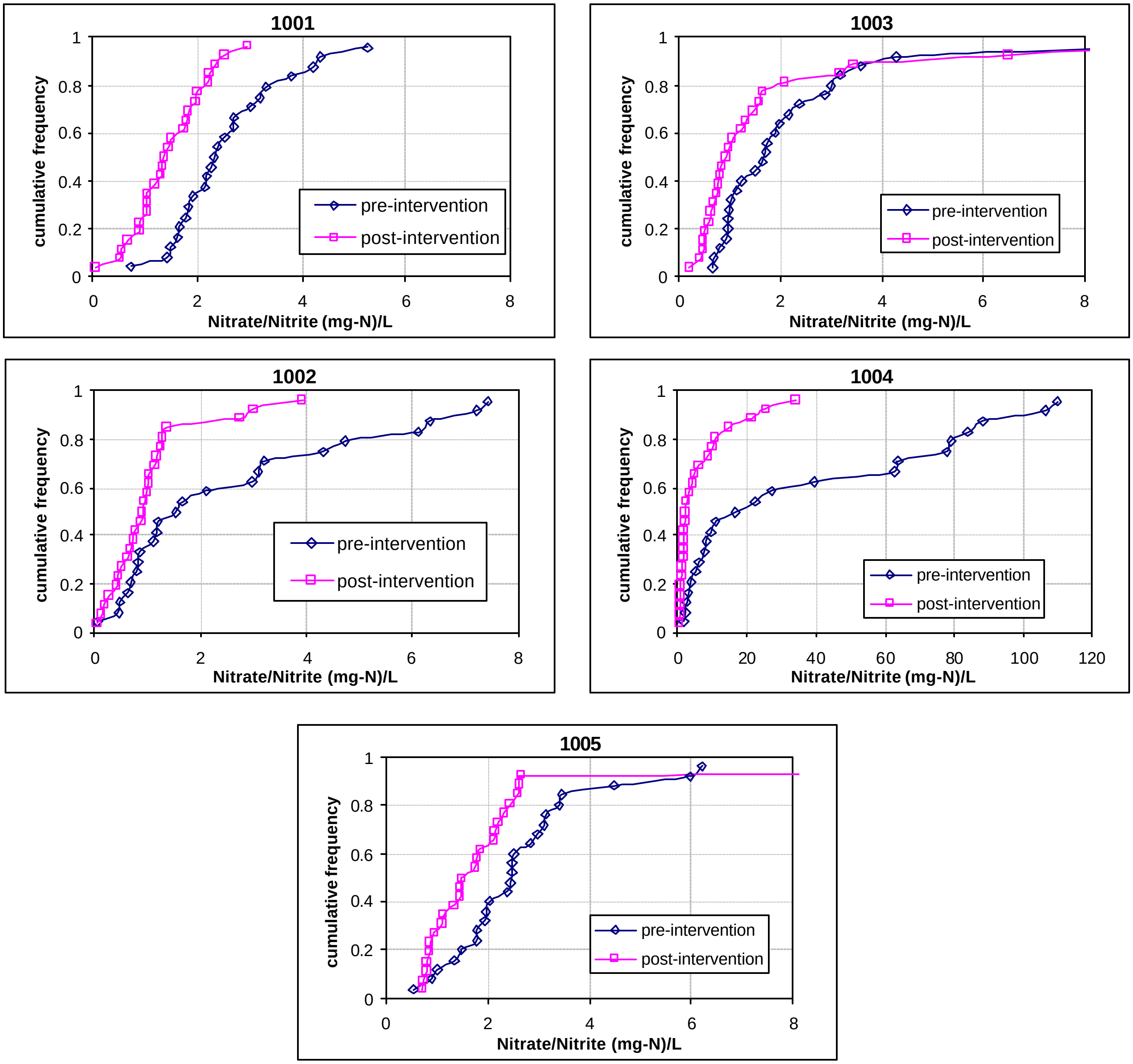

Figure C-1: Cumulative Frequency of Nitrate/Nitrite in Dry Weather Samples (all data)

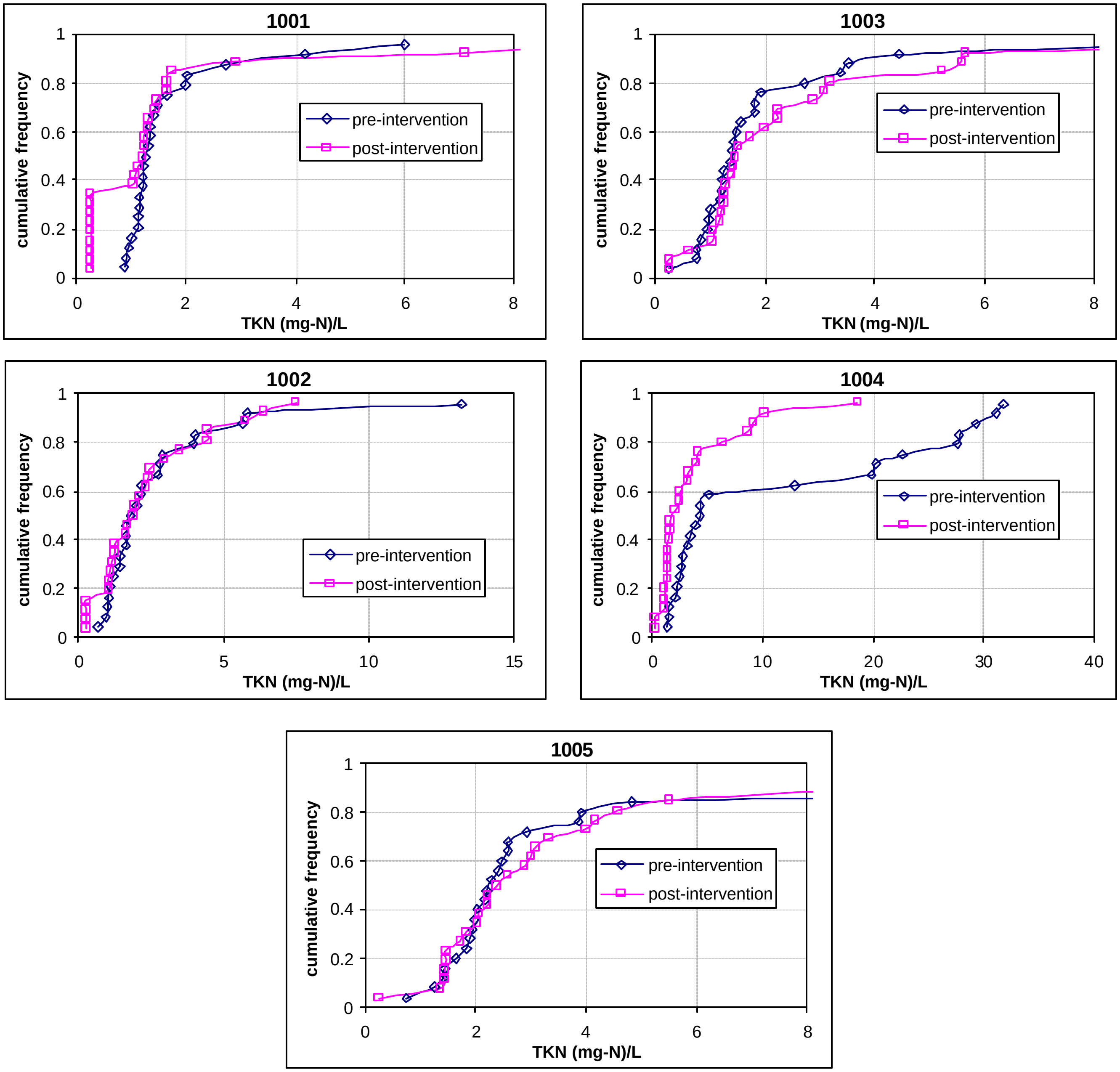

Figure C-2: Cumulative Distribution of TKN in Dry Weather Samples (all data)

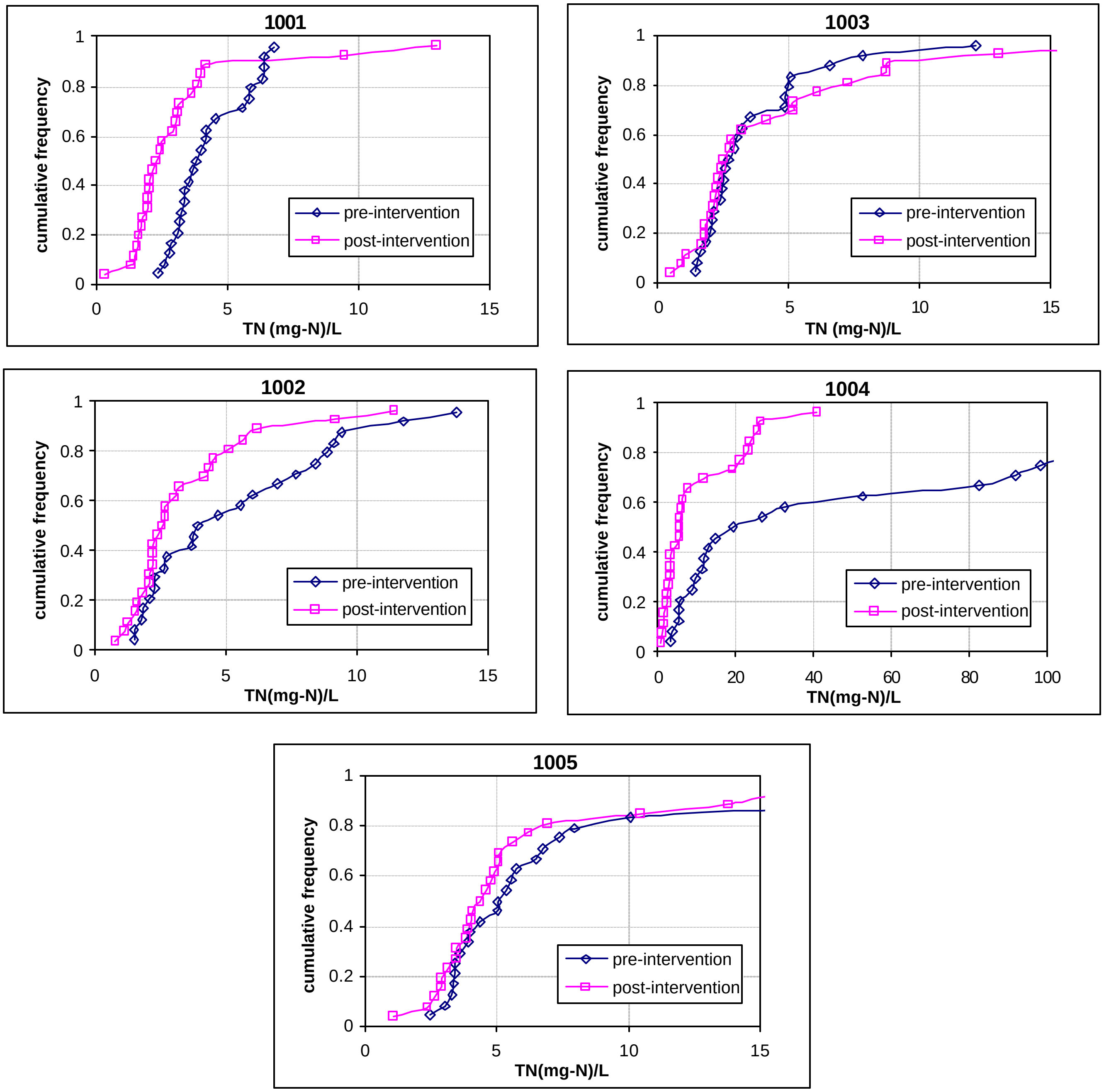

Figure C-3: Cumulative Distribution of TN (Calculated) in Dry Weather Samples (all data)

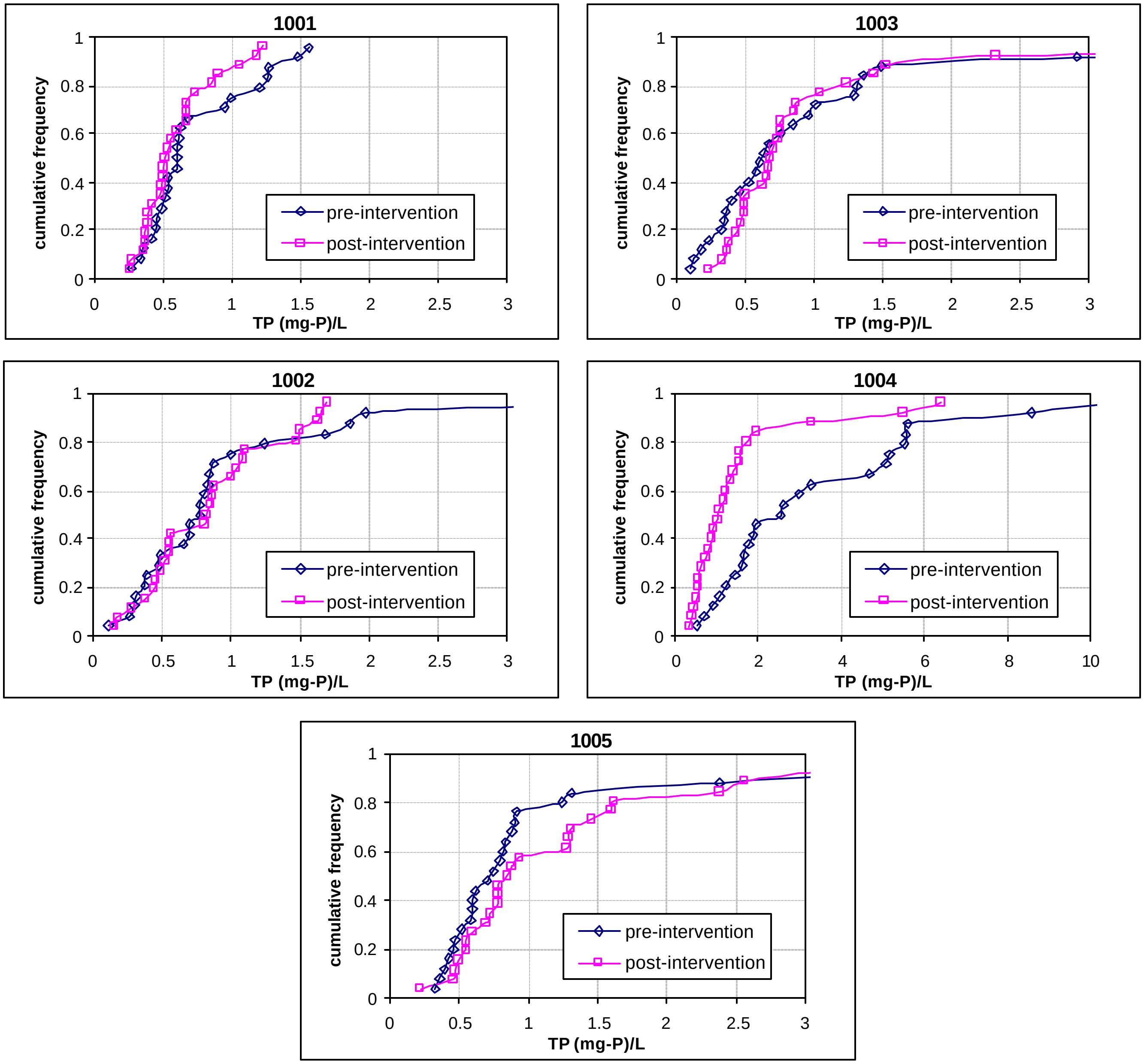

Figure C-4: Cumulative Distribution of TP in Dry Weather Samples (all data)

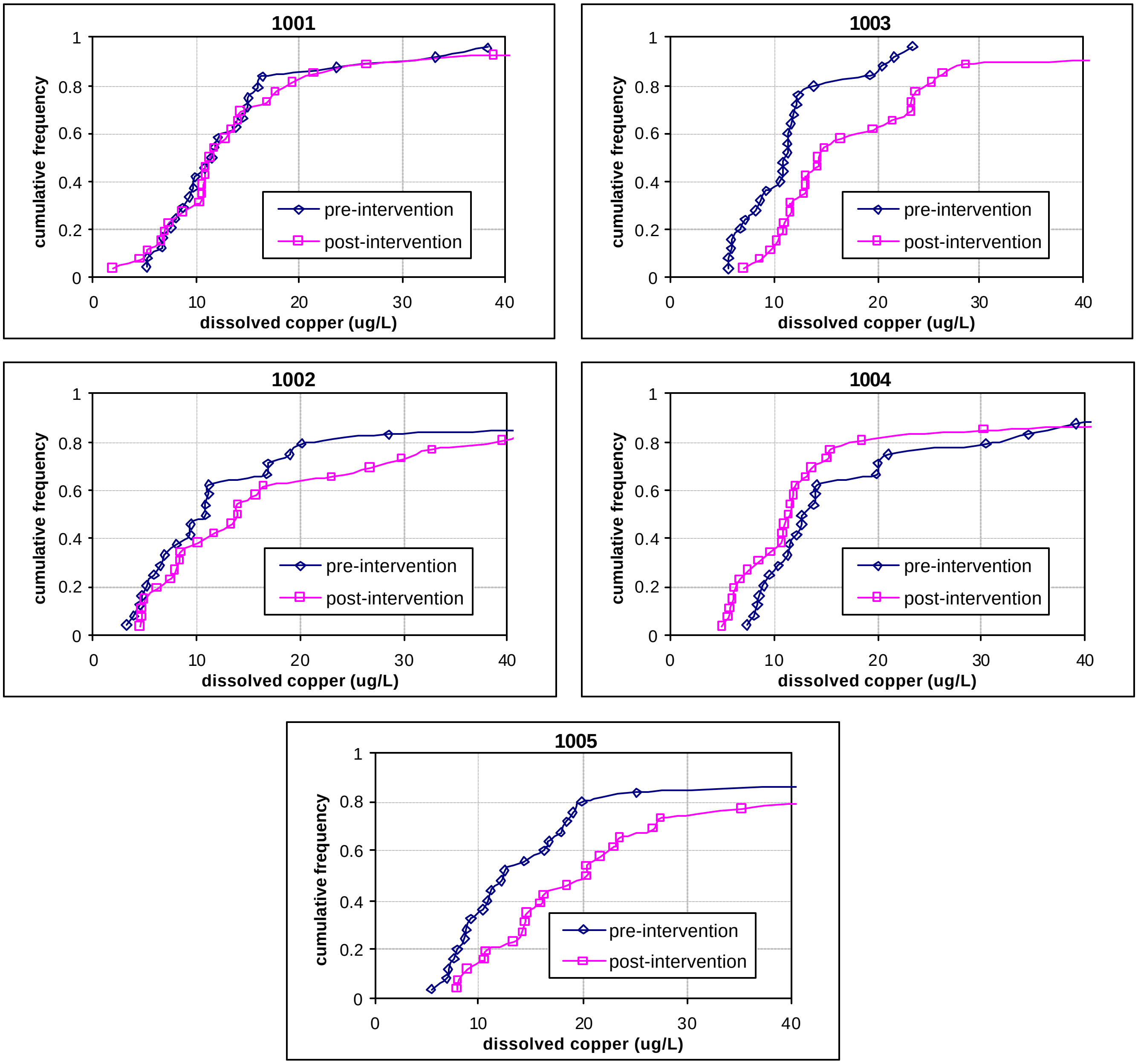

Figure C-5: Cumulative Distribution of Dissolved Copper in Dry Weather Samples (all data)

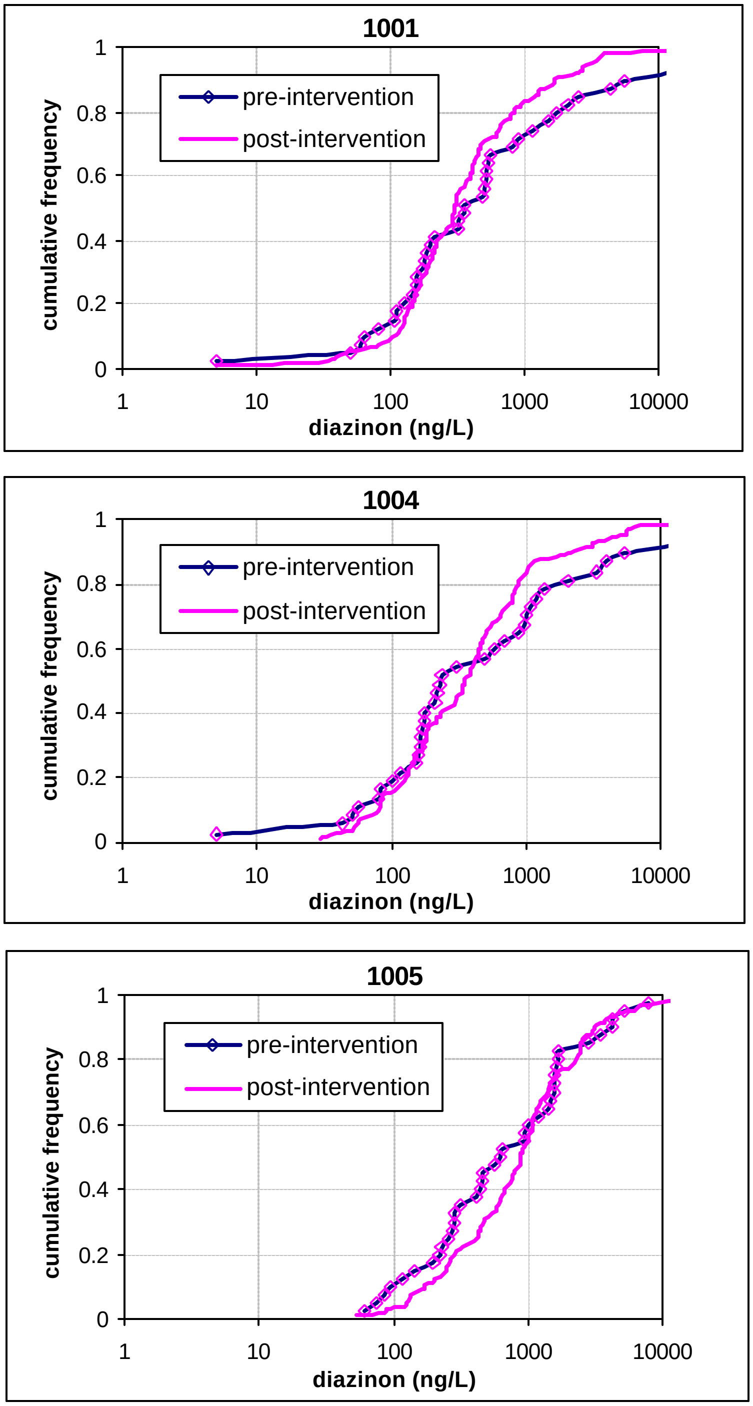

Figure C-6: Cumulative Distribution of Diazinon in Dry Weather Samples (all data)