10.0 REGIONAL ASSESSMENT

This section presents a regional assessment of the Core Monitoring Program results. Where as the previous sections presented the results on a watershed management area basis, this regional assessment provides for an analysis of inter-relationships across watersheds, and identifies characteristics of certain watersheds that indicate difference or similarities with the other watersheds in the County. This section also presents the estimated pollutant loadings for the current year (2004-2005), and a comparison with the previous year's estimates across the watersheds.

10.1 Regional Assessment of Core Monitoring Program – 1994-2005

The regional assessment of the Core Monitoring Program for the period of 1994-2005 includes comparisons between the monitored watersheds using several different statistical tools. Watersheds were compared both by examining constituents of concern concentrations across watersheds and by grouping similar watersheds by COC relationships.

10.1.1 Cross Watershed Comparison - Statistical Analysis

Statistical analysis for regional cross watershed comparison include scatterplot analysis, regression analysis, analysis of variance (ANOVA), multivariate cluster analysis, and multiple regression. The purpose of these comparisons is to identify inter-relationships and overall trends based on the Core Monitoring Program results. Scatterplots provide a COC based comparison among watersheds and monitoring years from 1994-2005. The ANOVA was used to determine statistical differences between the watersheds for all monitoring years (1994-2005) as a whole (annual means were used for replication), and cluster analysis was used to identify mass loading stations and years with similar COC loadings. Multiple regression analysis compared total suspended solids to COC and other key constituent concentrations. Regression analysis was also performed to evaluate whether a relationship is evident between toxicity and selected COCs.

Also presented in this section is a regional comparison of water quality objective ratios. These ratios were presented in each of the watershed sections and are based on the mean concentration of all the available data from the mass emission stations divided by the applicable WQO. Only those WQO ratios that are greater than one are presented, because any ratio below one signifies that the WQO was not exceeded. Due to the high ratios for the bacterial indicators, these ratios are presented based on a log scale.

10.1.2 Scatterplot and Trend Analysis

Scatterplots provide a visual representation of the relative concentrations of COCs between watershed mass emission stations (MES) over the years monitored. The scatterplots presented in this section include comparisons of the annual mean concentrations (includes both wet and dry sampling results) of selected COC and key constituents for all the years in which data was obtained for each of the watersheds. The mean concentrations for selected constituents are plotted on the y-axis against the MES identified on the x-axis. Each annual mean concentration is identified as a different symbol. These plots are used to identify comparative differences between watersheds and sampling years. Also presented in this subsection are trend data plots for specific watersheds. These trend plots were discussed under the watershed sections and highlighted here to identify trends that relate to the scatterplots. These trends include constituents that have not been identified as COC, but are correlated to overall water quality. For scatterplots, where non-detectable results were presented, the detection limit was plotted as the value. Also, when COC concentrations during separate storm events were equivalent, the scatterplot appears to have only one point at that concentration because the points are co-located. All available data is included on these plots.

Bacterial Indicators

Annual mean concentrations of bacterial indicators (total coliform, fecal coliform and enterococcus) for each of the watersheds over the 10 years of monitoring are presented in Figures 10-1, 10-2, and 10-3, respectively. As indicated on these plots, the WQO is exceeded consistently for all the watersheds and the years monitored. The highest concentrations for the bacterial indicators appear to generally occur at the MES for Los Angeles River and Ballona Creek. The lowest mean concentrations are indicated for Dominquez Channel and Santa Clara River; however, the data from these MES is limited (2-3 years). The plots of the bacterial indicators identify that the annual mean for 2003-2004 was generally lowest across the watersheds, and generally highest in 1995-1996. However, on a watershed basis, the regression analysis did not indicate any significant trends with regard to the bacterial indicators. Regionally, these indicators remain well above the WQO throughout the watersheds and the monitoring period from 1994-2005.

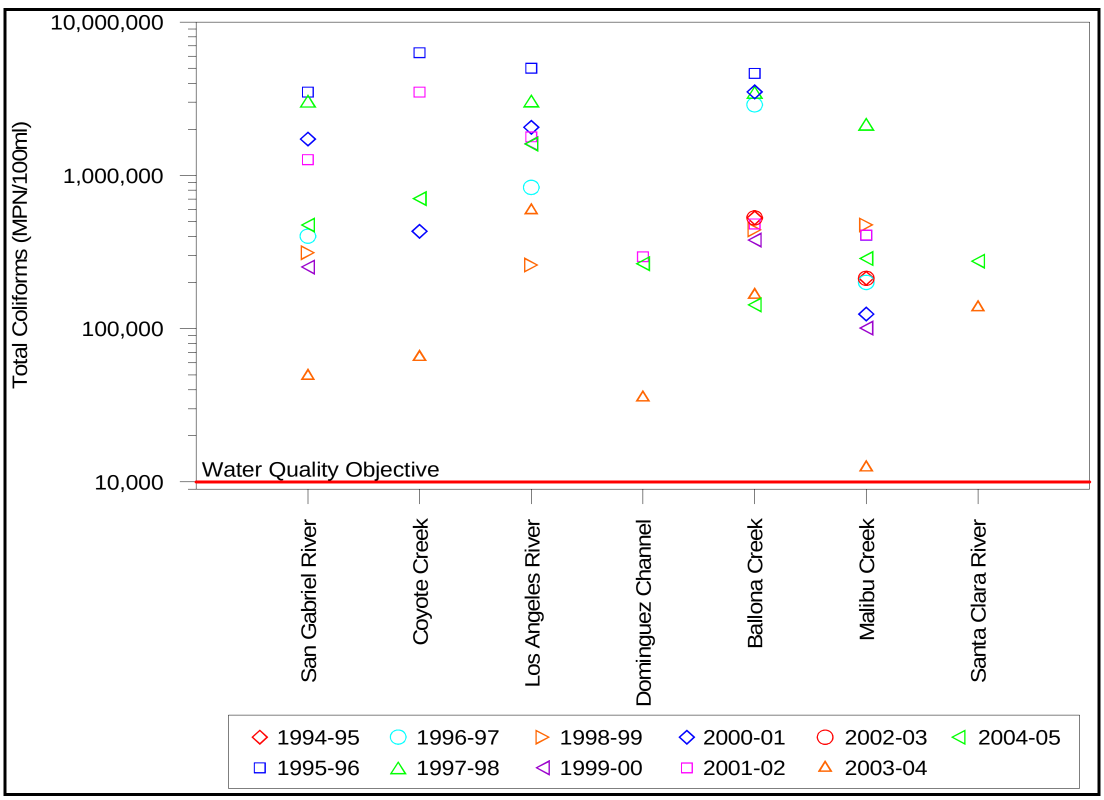

Figure 10-1. Annual Means for Regional Total Coliforms, 1994-2005 Wet and Dry Weather Monitoring.

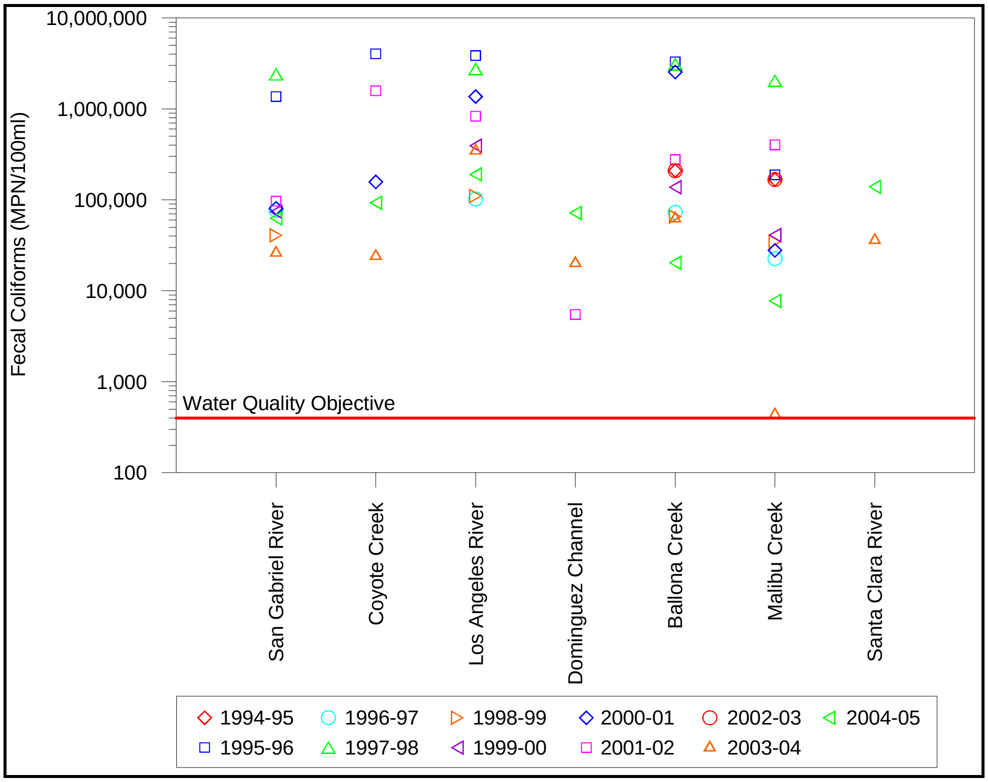

Figure 10-2. Annual Means for Regional Fecal Coliforms, 1994-2005 Wet and Dry Weather Monitoring.

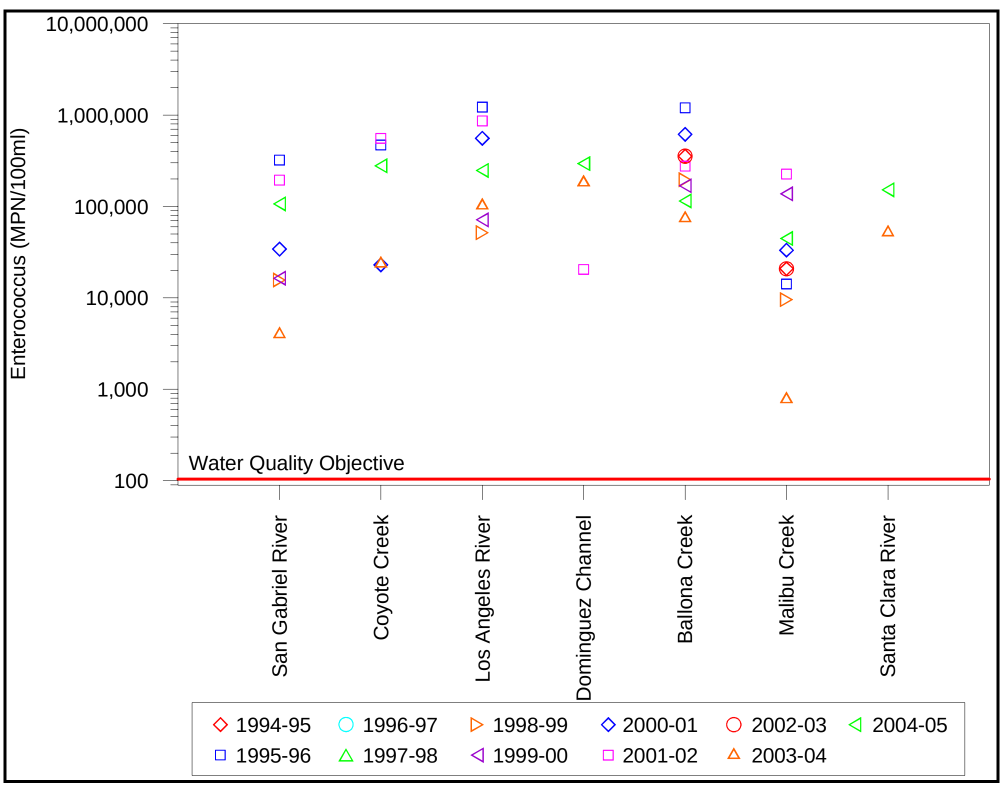

Figure 10-3. Annual Means for Regional Enterococcus, 1994-2005 Wet and Dry Weather Monitoring.

Figure 10-4 presents the ratio of the mean concentrations of the bacterial indicators to the WQO. As illustrated in Figure 10-4, the highest WQO ratios were observed for Los Angeles River, Ballona Creek and Coyote Creek. The Los Angeles River had the highest ratios for enterococcus and fecal coliform. The second highest WQO ratios following Los Angeles River, Ballona Creek and Coyote Creek, were for Dominguez Channel and San Gabriel River. The lowest ratios were observed for the Santa Clara River and Malibu Creek Watersheds. The magnitude of the WQO ratios for the bacterial indicators appears to correspond to the percentage of urbanization of the watersheds. Watersheds that have a lower percent urbanization (Santa Clara River and Malibu Creek) displayed a lower WQO ratio. This regional relationship is presented in Figure 10-5.

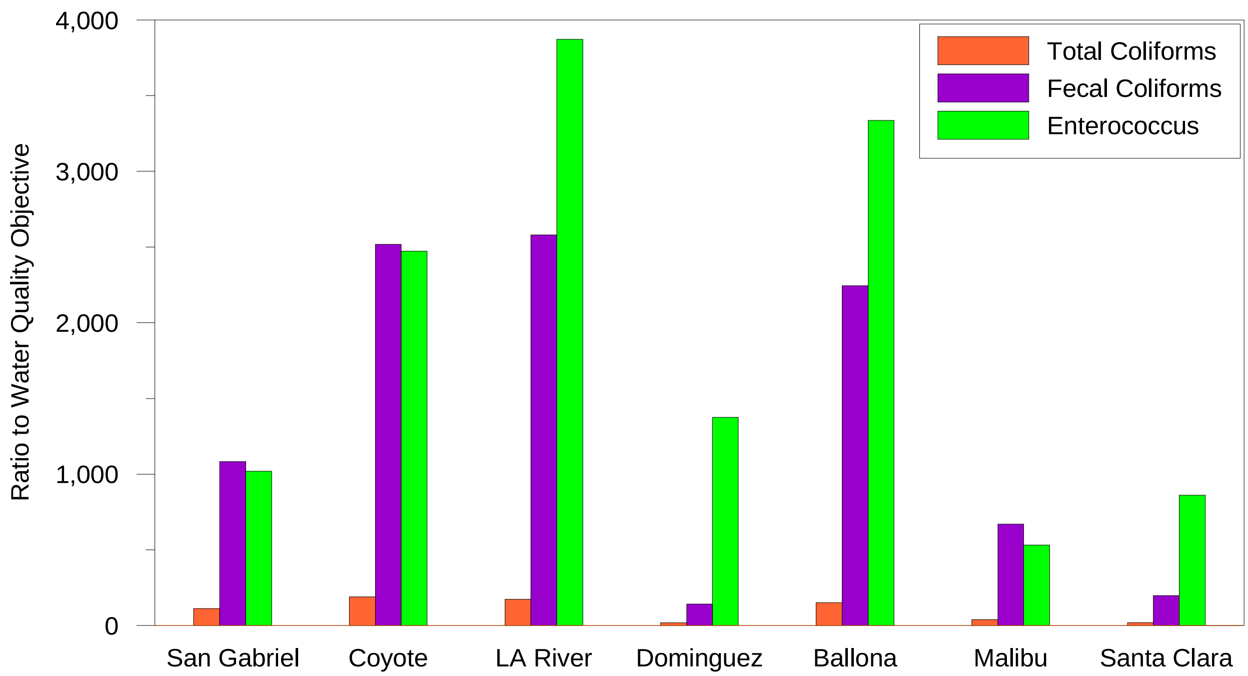

Figure 10-4. Regional Water Quality Ratios for Bacterial Indicators.

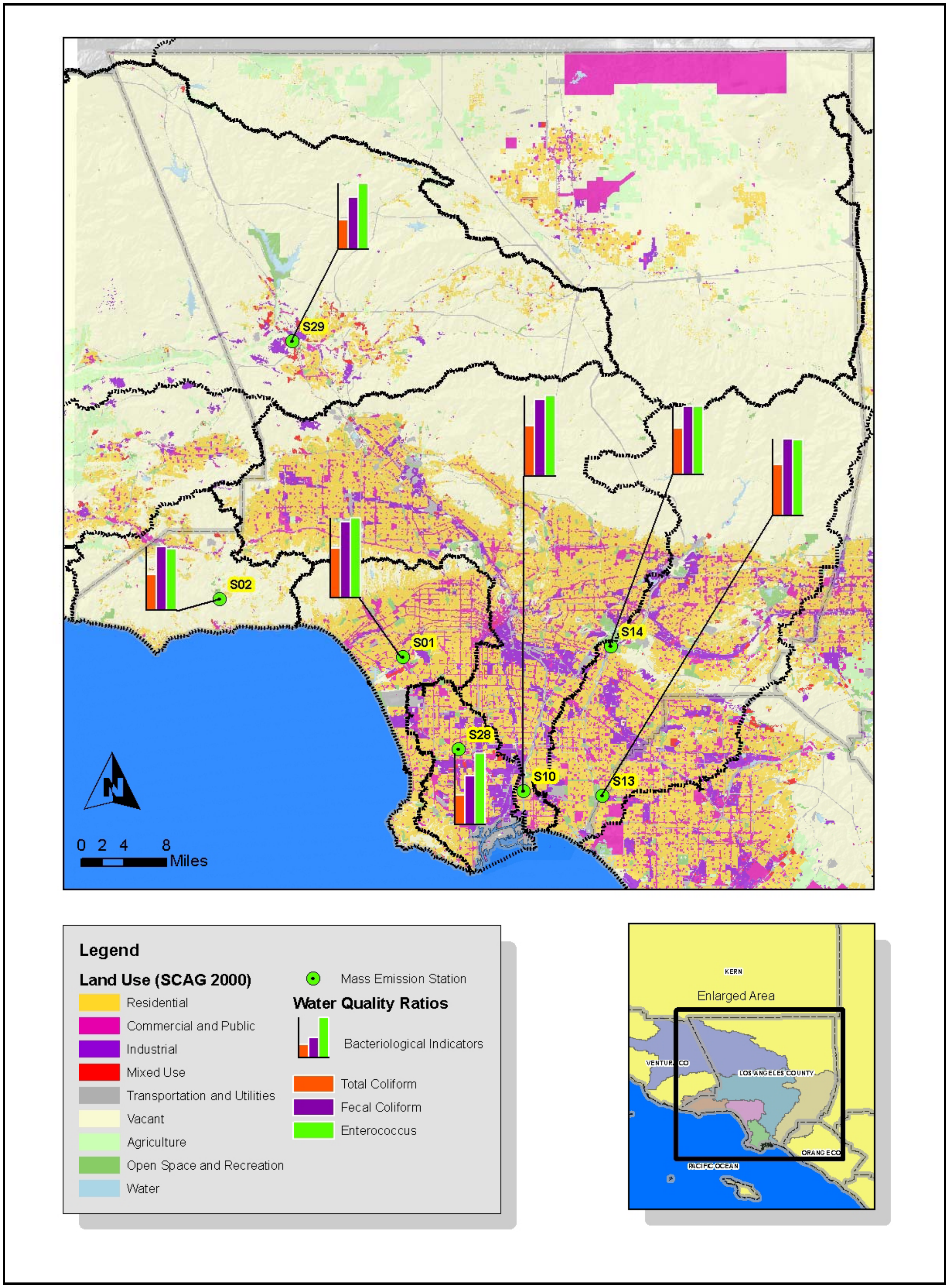

Figure 10-5. Relationship between Percent Urbanization and Water Quality Ratios for Bacterial Indicators.

Metals

Figures 10-6, 10-7 and 10-8 present the concentrations of total and dissolved copper, lead and zinc, respectively, based on annual means from 1994 to 2005 (where available) for each watershed. As indicated on these scatterplots, the highest mean concentrations for both total and dissolved copper, lead and zinc on a regional basis were observed in the Los Angeles River. Excluding the maximum mean concentration, the Dominguez Channel possessed the highest dissolved zinc mean concentrations compared to the other watersheds. The range of concentrations of total copper was generally similar for the Coyote Creek, Dominguez Channel, Ballona Creek and Malibu Creek Watersheds. Similar mean concentrations of total zinc were observed in the Coyote Creek and Ballona Creek Watersheds. The lowest concentrations of all constituents were generally observed for the San Gabriel River and Santa Clara River Watersheds. The Santa Clara River Watershed is the least urbanized of the watersheds under the Core Monitoring program.

It is also indicated on Figures 10-6 through 10-8, that the highest annual mean concentrations for dissolved and total copper, lead and zinc for several watersheds occurred in 1997-1998. As shown on Figure 10-9, the highest monthly rainfall, as recorded at the Los Angeles Civic Center, was observed in February 1998. The higher intensity storms recorded for that period may have resulted in the mobilization and transport of greater sediment/particle loads into the watersheds that likely resulted in higher copper and other metal concentrations at the MES. For that high rainfall year, total and dissolved copper, lead and zinc concentrations were highest in the Los Angeles River Watershed, followed by the Ballona Creek and Coyote Creek Watersheds.

Exceedances of the WQO for total and dissolved lead, copper and zinc were observed regionally in all the watersheds monitored with the exception of the Santa Clara River and Malibu Creek Watersheds. Figure 10-10 presents the ratio of the mean concentrations to the WQO adjusted for hardness. As presented graphically in Figure 10-10, the highest WQO ratios for all constituents were observed for the Los Angeles River. The Los Angeles River had much higher ratios for total and dissolved lead than the other watersheds, suggesting that there is a possible source of lead upstream of the mass emission station. The Dominguez Channel, Ballona Creek and Coyote Creek Watersheds had the next highest WQO ratios. Dominguez Channel had higher ratios for total and dissolved copper and zinc, while Ballona Creek and Coyote Creek had higher WQO ratios for total and dissolved lead. The San Gabriel River followed with the next highest WQO ratios and the Santa Clara River and Malibu Creek Watersheds had the lowest WQO ratios for all constituents. The ranking of the magnitude of these WQO ratios for lead, copper and zinc appeared to correspond to the percentage of urbanization of the watersheds. Watersheds with a greater percentage of urbanization resulted in higher WQO ratios. This relationship is presented on Figure 10-11.

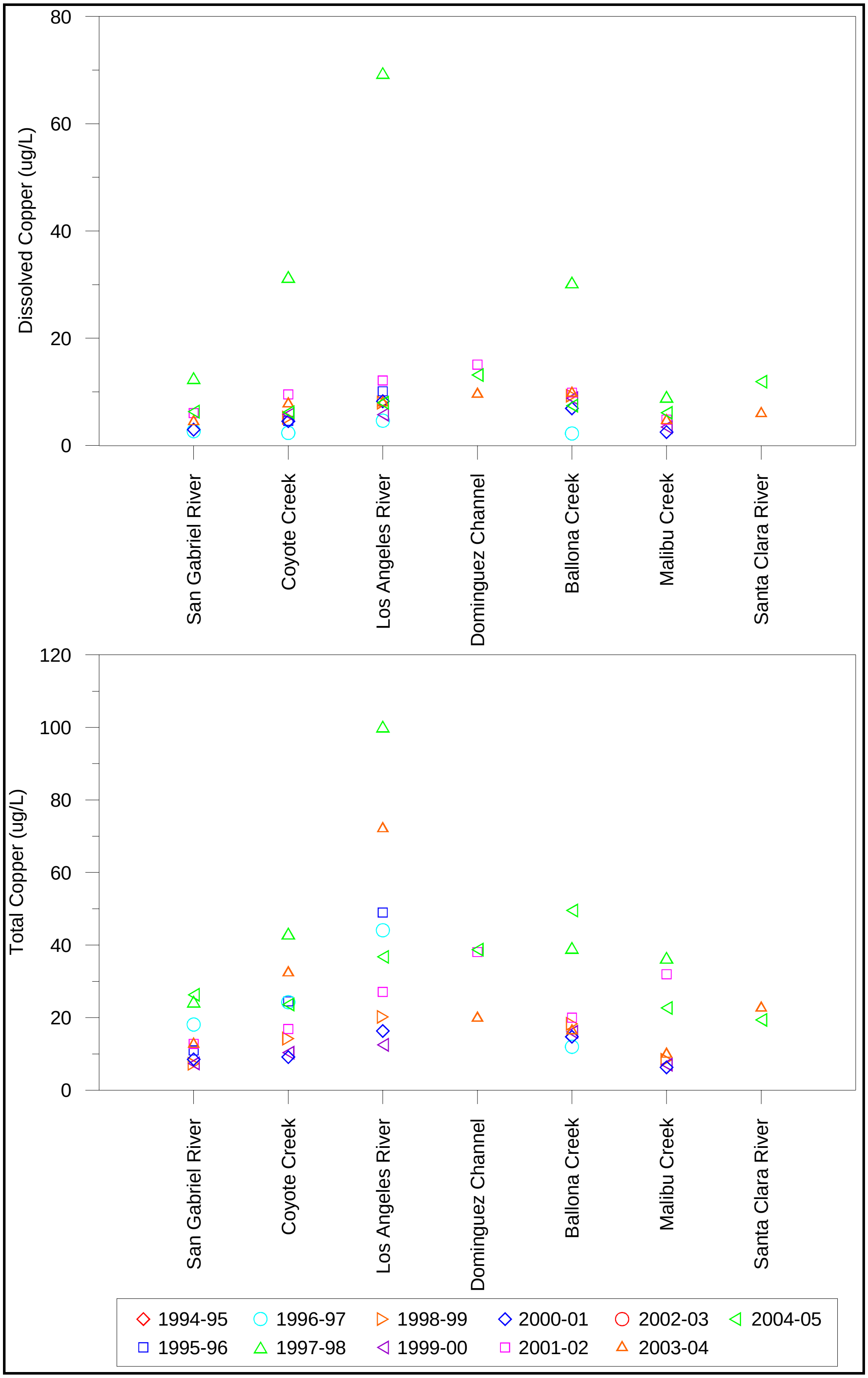

Figure 10-6. Annual Mean Dissolved and Total Copper Concentrations, 1994-2005 Wet and Dry Weather Monitoring.

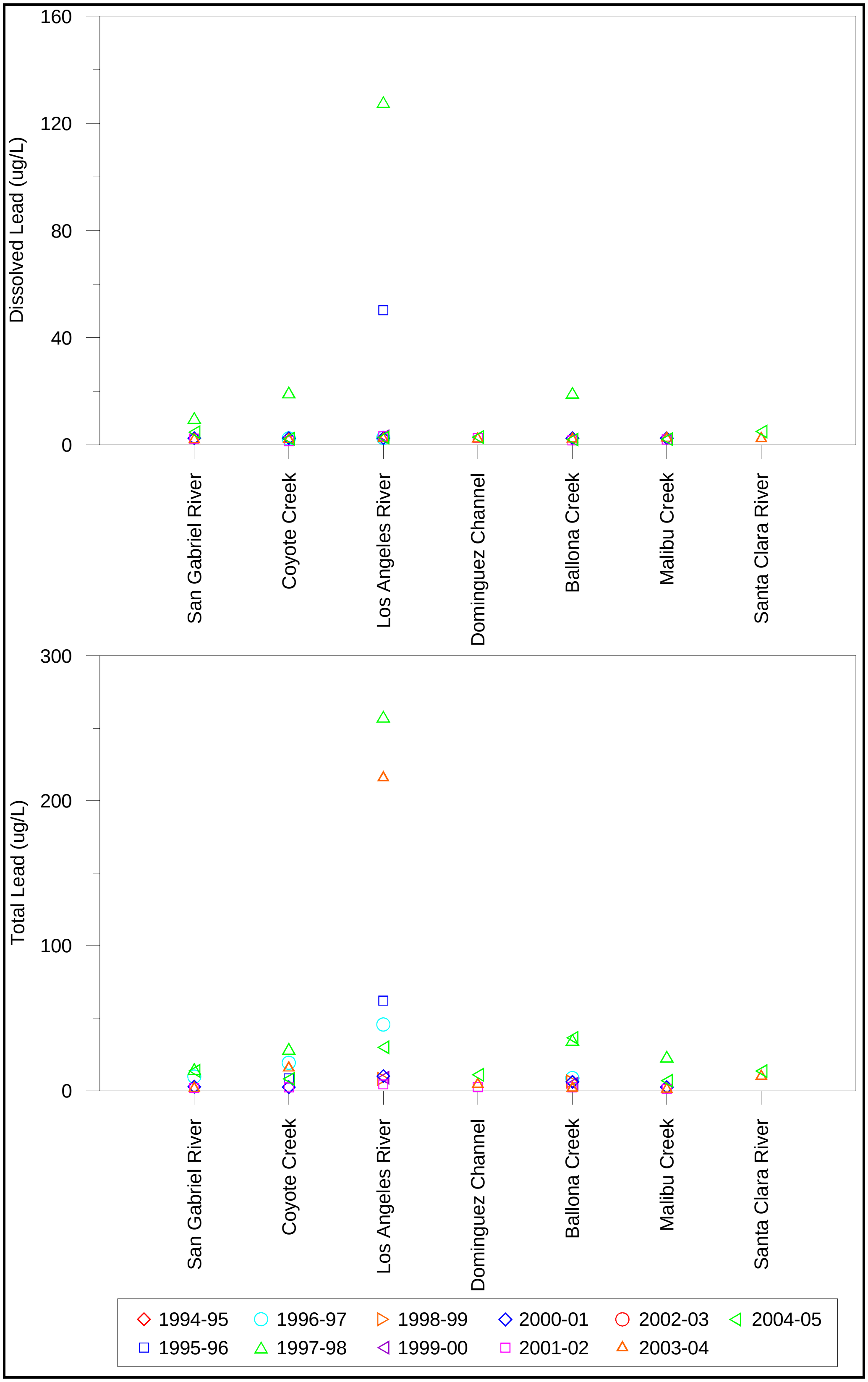

Figure 10-7. Annual Mean Dissolved and Total Lead Concentrations, 1994-2005 Wet and Dry Weather Monitoring.

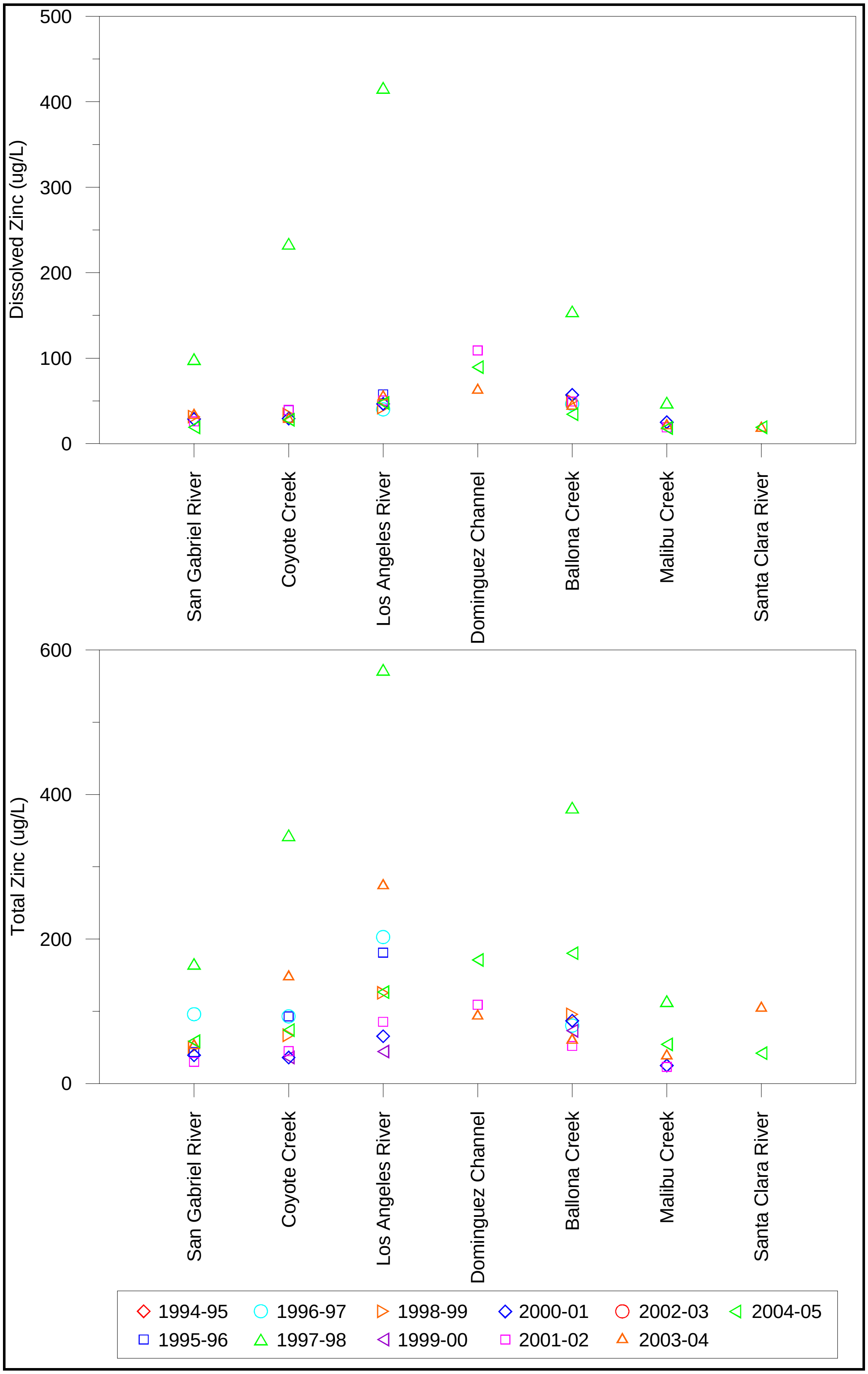

Figure 10-8. Annual Mean Dissolved and Total Zinc Concentrations, 1994-2005 Wet and Dry Weather Monitoring.

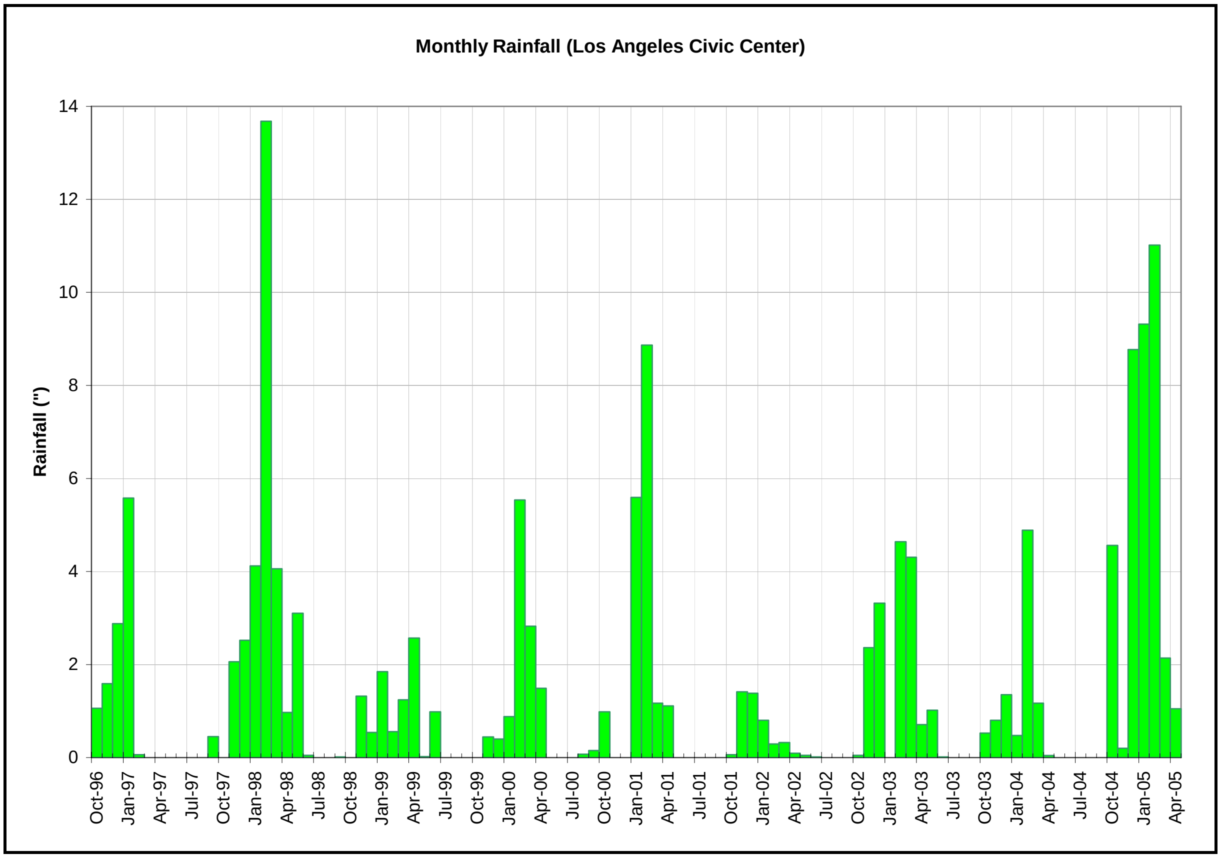

Figure 10-9. Monthly Rainfall Recorded at the Los Angeles Civic Center.

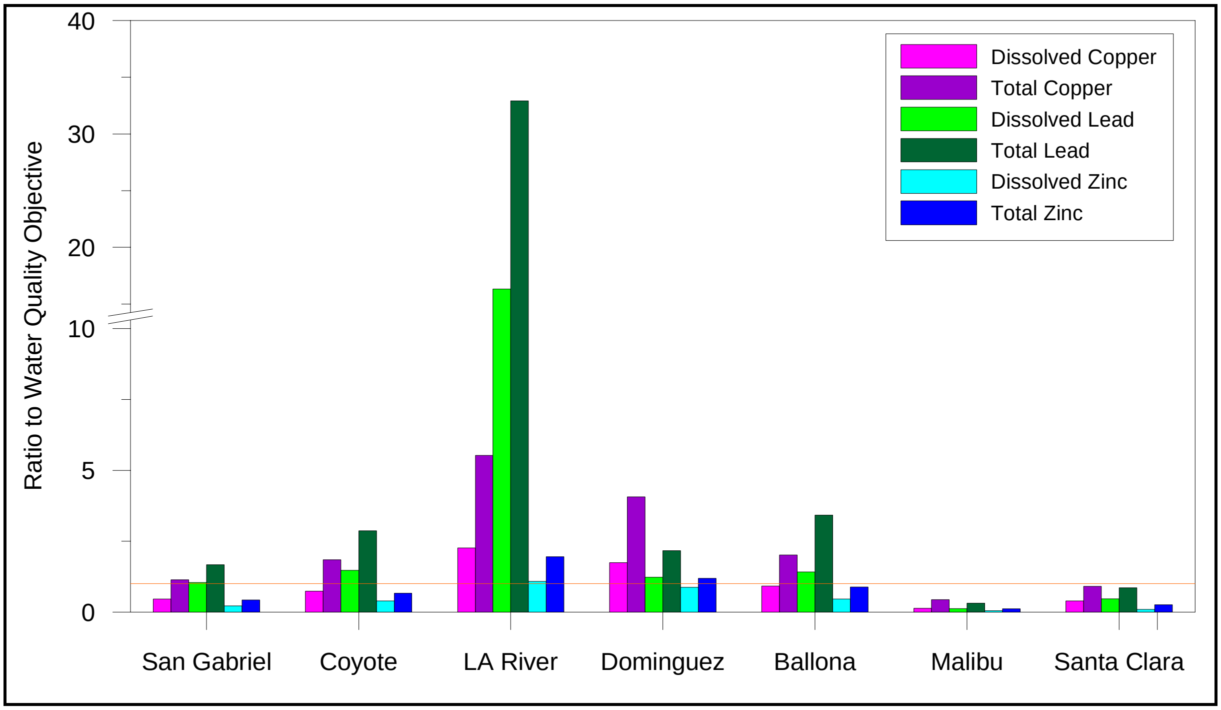

Figure 10-10. Regional Water Quality Ratios for Copper, Lead, and Zinc.

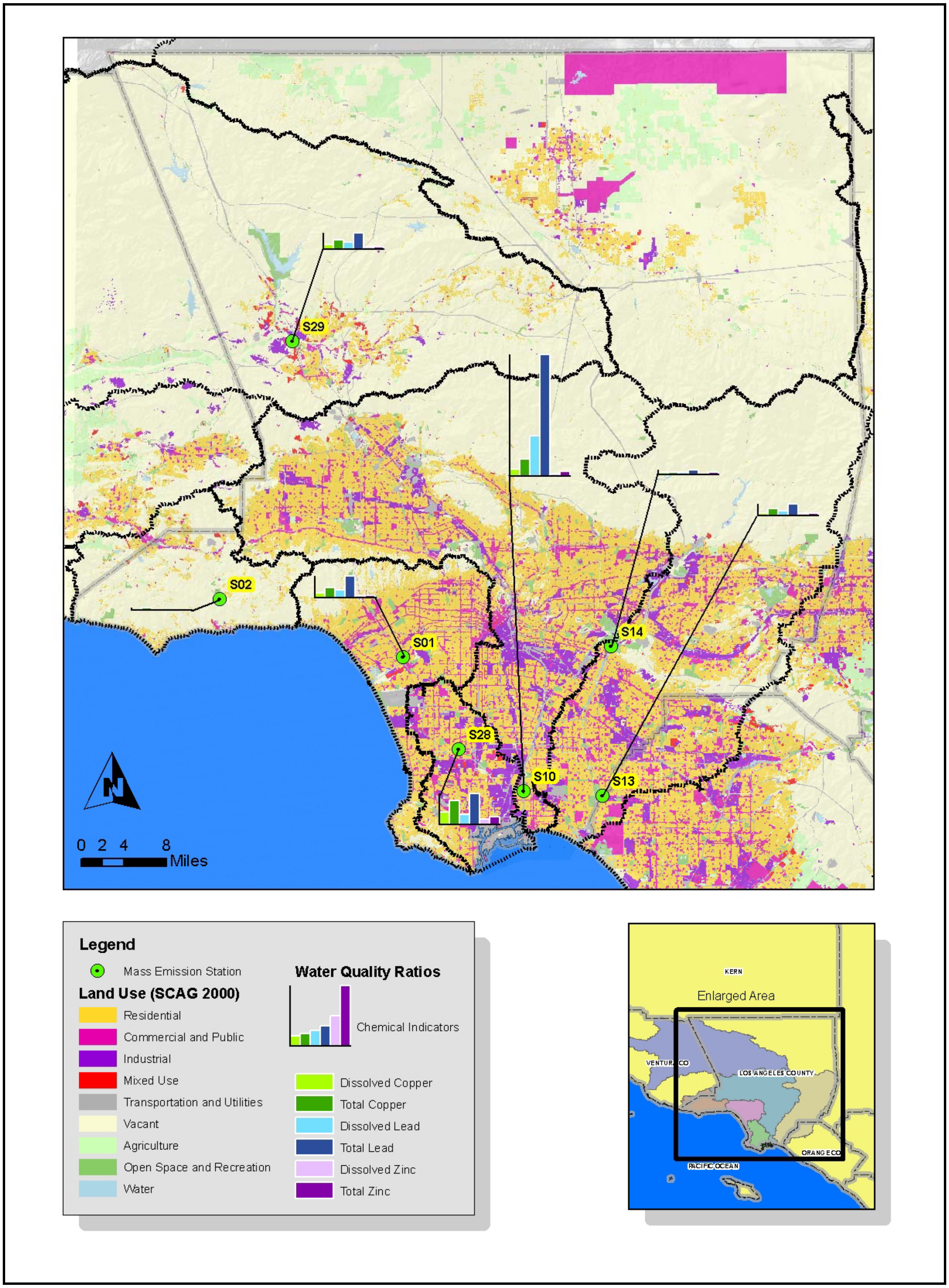

Figure 10-11. Relationship between Percent Urbanization and Water Quality Ratios for Copper, Lead and Zinc (Total and Dissolved).

No trends (increasing or decreasing over time) in the annual mean concentrations as measured at the MES were observed for copper, lead and zinc on a watershed basis with the exception of Dominguez Channel. Figure 10-12 provides trend analysis scatterplots for those metals where a trend in mean concentrations at the MES was observed by watershed. These trends were discussed in the individual watershed sections of this report, but are presented here to provide a regional summary of observed trends. An increasing trend in total lead concentrations was observed in the Dominguez Channel based on the annual mean concentrations measured at the MES. The annual data at this MES is however limited to four annual sampling periods.

An increasing trend in total selenium concentrations and a deceasing trend in dissolved chromium concentrations were observed in Malibu Creek as shown on Figure 10-12. Neither of these metals annual mean concentration exceeded the WQO. An additional trend indicated in the annual mean results for Malibu Creek is a decrease trend in turbidity. An increasing trend in annual mean boron concentrations is observed for the San Gabriel River Watershed. No current WQO exists for boron. Finally, there is an observed increase trend in alkalinity in the Los Angeles River. Increases in alkalinity decrease the bio-availability of metals. The WQO for metals are adjusted for hardness. As discussed above, the highest WQO ratios for metals are observed for the Los Angeles River.

<u>Pesticides</u>
The only pesticide that was detected above its WQO as part of the wet and dry weather Core Program monitoring was diazinon. Figure 10-13 presents the annual mean concentrations of diazinon for each of the watersheds. As shown on Figure 10-13, the WQO was exceeded in 2001-2002 in the Dominguez Channel and Coyote Creek Watersheds based on the annual mean of the samples collected at the MES. The overall highest annual concentrations of diazinon were observed during this period followed by the 2004-2005 period. Diazinon exceeded the WQO in only one other annual mean at the Santa Clara River MES during 2004-2005.

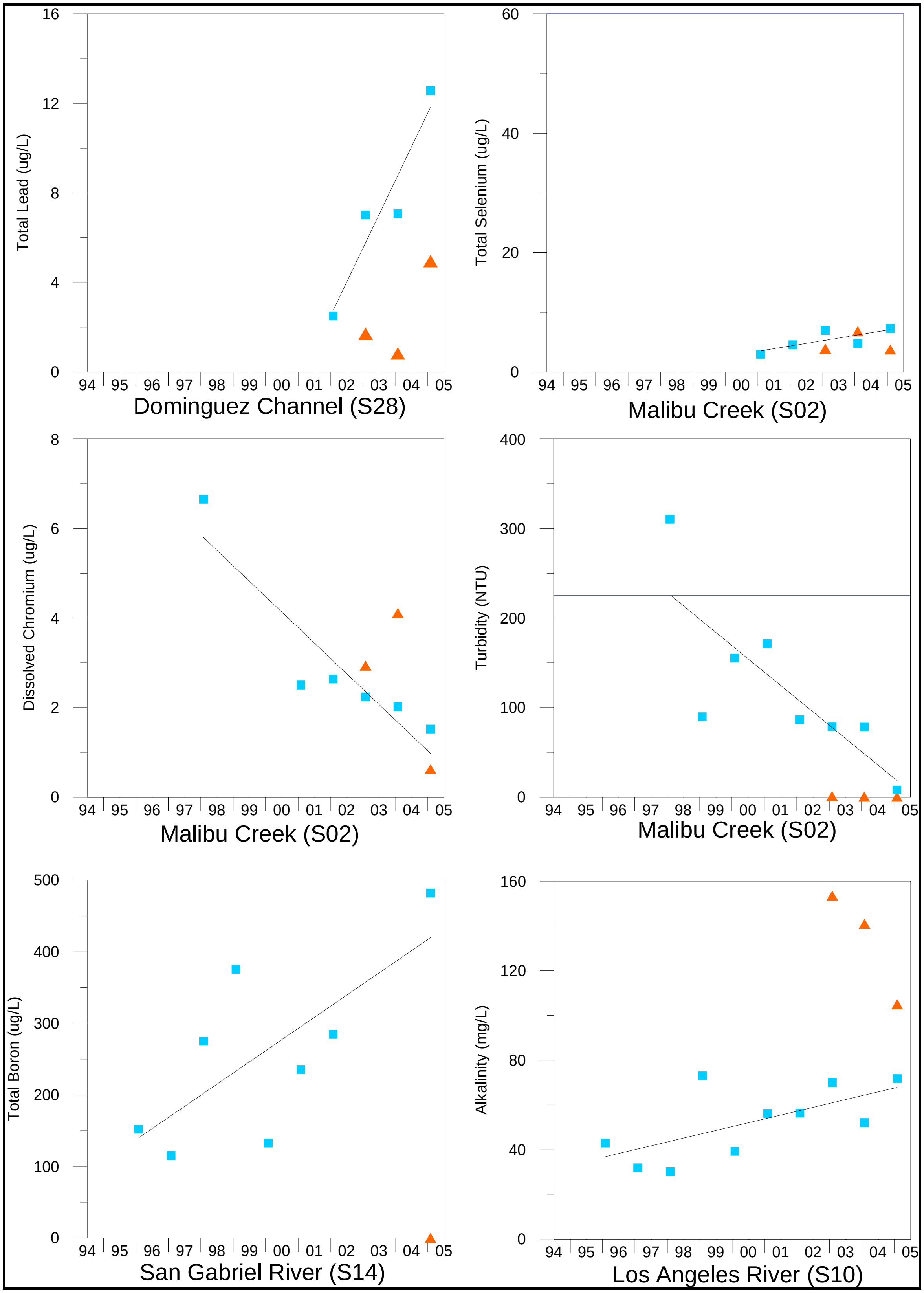

Figure 10-12. Summary of Observed Trends in Annual Mean Concentrations, 1994-2005 (where available) – Blue is Wet Weather – Red is Dry Weather Results.

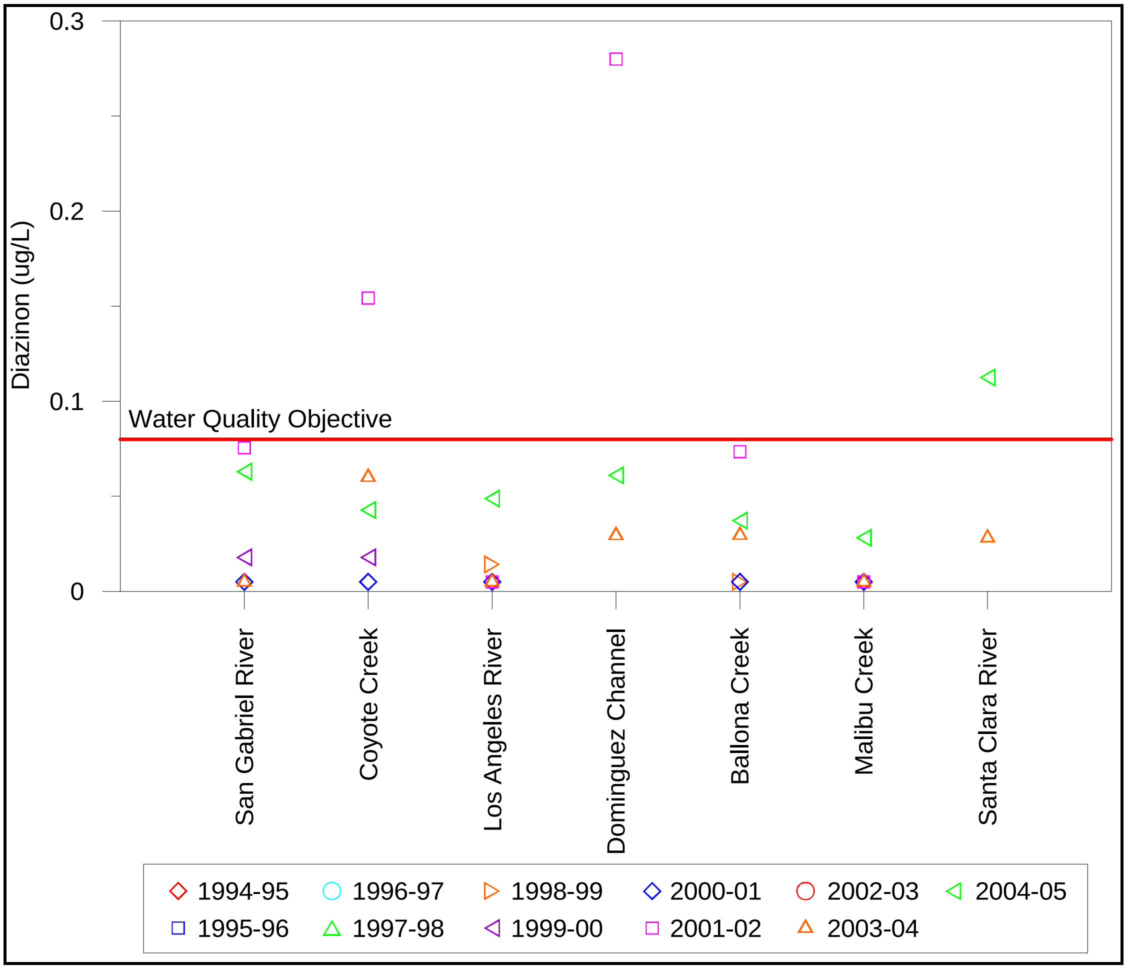

Figure 10-13. Annual Mean Diazinon Concentrations, 1994-2005 Wet and Dry Weather Monitoring.

<u>Other Trends</u>

Other notable trends that were observed in mean annual concentrations include decreasing concentration in total petroleum hydrocarbons (TPH) for the MES for Ballona Creek, Coyote Creek and Santa Clara River Watersheds. These trend plots are shown on Figure 10-14.

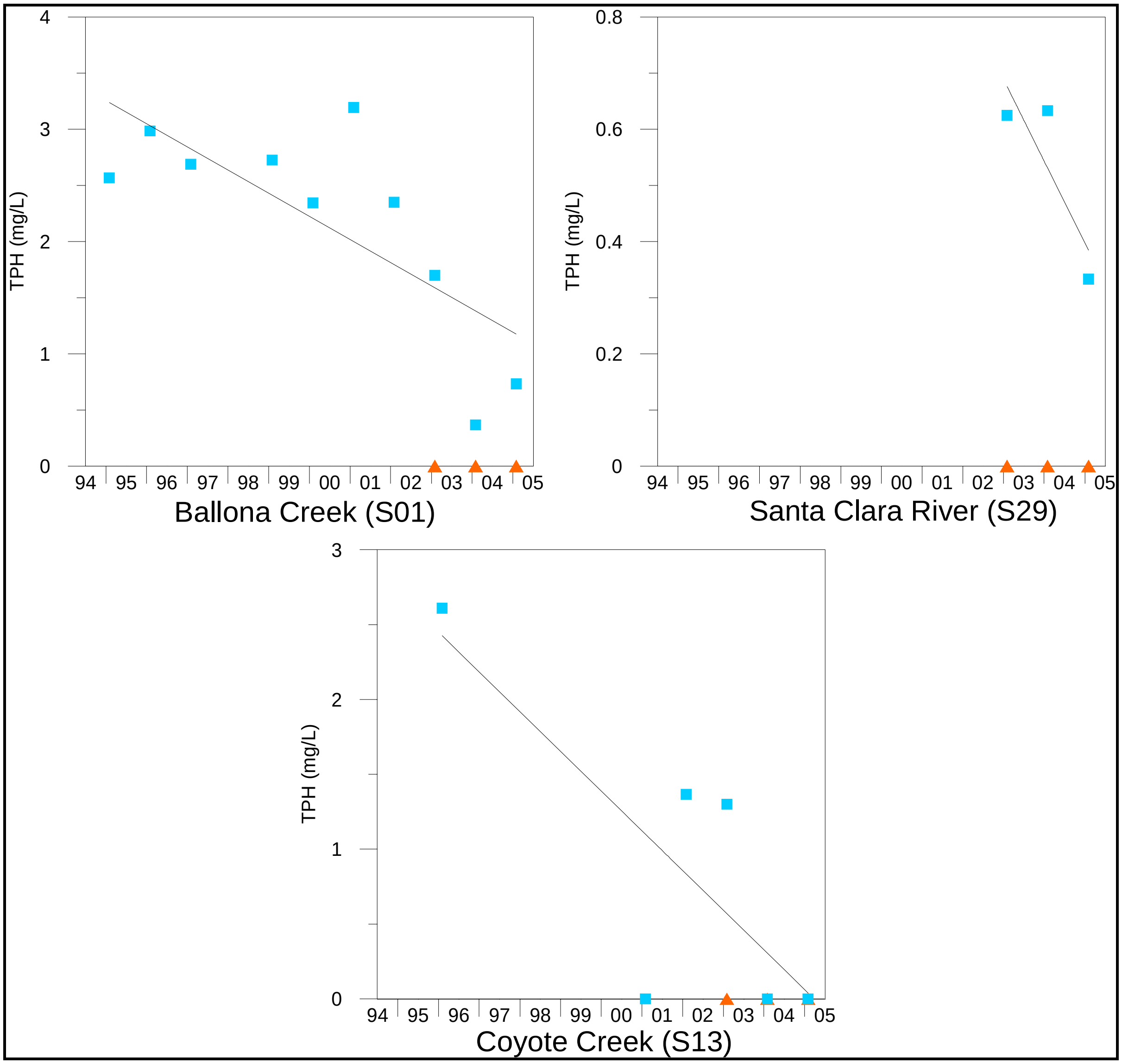

Figure 10-14. Observed Trends in TPH Annual Mean Concentrations, 1994-2005 (Blue is Wet Weather Results – Red is Dry Weather Results).

Isolated trends that were also highlighted in the individual watershed sections include an increasing trend in oil and grease concentrations in the San Gabriel River Watershed. Also observed in this watershed, based on the mean annual concentrations, is a decrease in BOD. These trends are presented on Figure 10-15. Finally, an increased trend in MBAS is observed for the Ballona Creek Watershed as indicated on Figure 10-15. These trends appear to be isolated for these noted watersheds and do not indicate a regional trend.

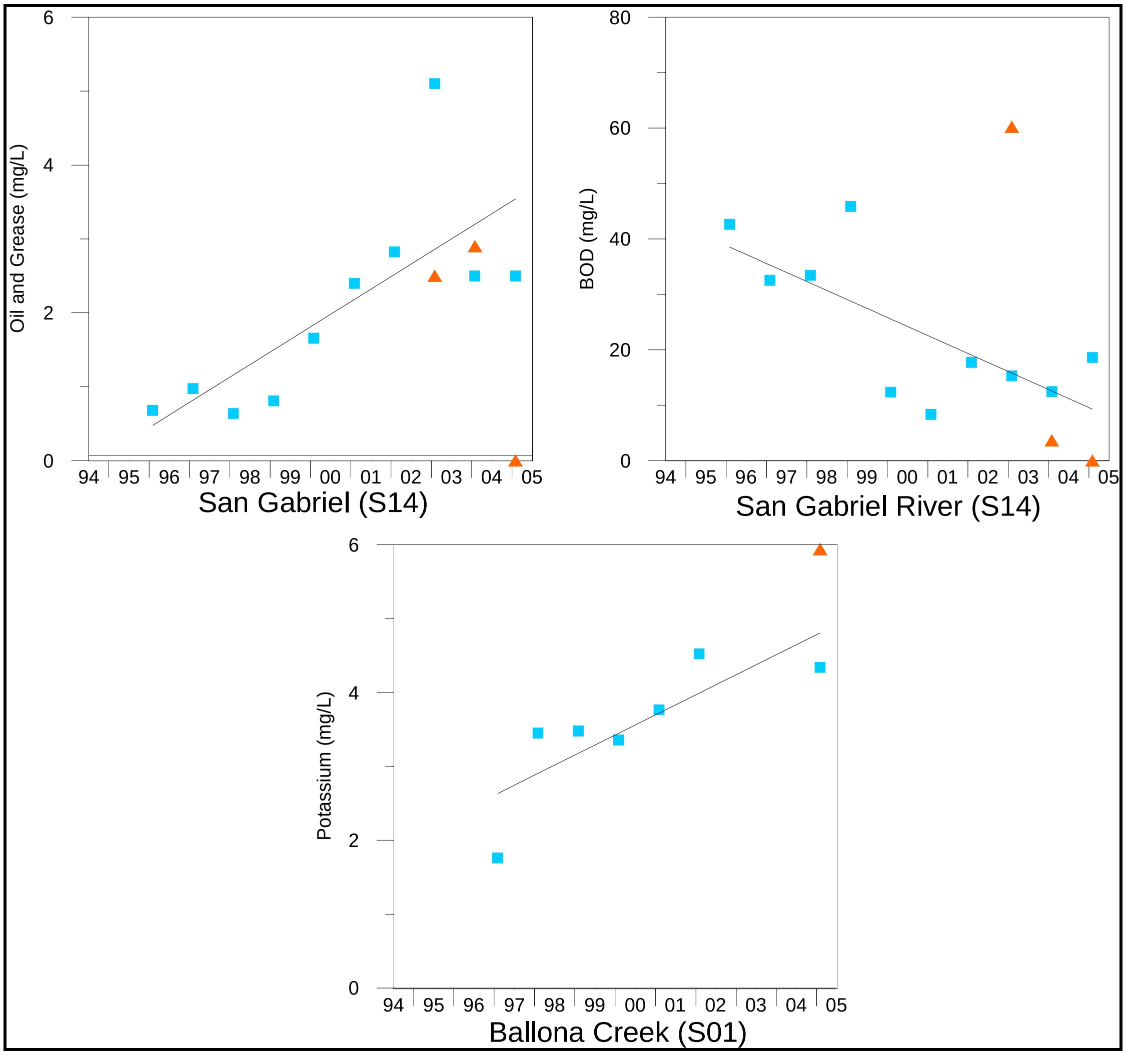

Figure 10-15. Summary of Other Observed Trends in Annual Mean Concentrations, 1994-2005 (Blue is Wet Weather Results – Red is Dry Weather Results).

10.1.2 ANOVA Results

ANOVA was used to determine differences between MES for the COCs and other key constituents. The term *analysis of variance* is sometimes a source of confusion. In spite of its name, ANOVA is concerned with differences between *means* of groups, not differences between *variances.* The analysis uses variances to detect whether the means are different. The ANOVA determines the variation (variance) *within* the groups that are being compared (e.g., monitoring stations), then compares that variation to the differences *between* the groups, taking into account how many subjects there are in the groups. If the observed differences between the means of groups are larger than those expected by chance relative to the underlying variance, statistical significance is achieved. For this report, each of the COC and key constituents that were observed in any sample above the MDL was tested by ANOVA. The bacteriological measures were $\log_{10}$ transformed for this analysis.

The results of the ANOVA analyses, performed on the 1994-2005 wet and dry weather monitoring results from the MES, indicate that there were statistically significant differences ($p < 0.05$) between mean station concentrations for 31 of the 61 constituents analyzed. ANOVA results with comparisons of the mean values for significant test results are shown in Figure 10-16. The probability value of the ANOVA for each of the COC and key constituents are shown next to the corresponding test. Probabilities (Prob > F) less than 0.05 indicate statistically significant differences between stations. Watersheds with the same color line under the mean values designate those MES that were not significantly different from each other. Conversely, stations without the same color line were significantly different from each other. These groupings may also overlap with one another resulting in some watersheds being in multiple groups. For example, the mean value for alkalinity (first constituent listed) for Malibu Creek is significantly different than the other watersheds as shown by the red bar only under Malibu Creek (MC). The next grouping shown by the green bar indicates the means for San Gabriel River (SGR), Santa Clara River (SCR), Ballona Creek (BC), Coyote Creek (CC) and Los Angeles River (LAR) are not significantly different from one another, and are therefore grouped together. Malibu Creek and the Dominguez Channel (DC) are outside this group. Dominguez Channel is however grouped with three other watersheds as indicated by the yellow bar. From this analysis, one can distinguish characteristics common or significantly different on a cross-watershed basis.

Constituent	Prob > F	Mass Emission Station Means						
Alkalinity	<0.001	MC	SGR	SCR	BC	CC	LAR	DC
		175.8	91.5	91.2	81.3	77.2	52.4	37.0
Ammonia	0.001	SGR	LAR	CC	DC	BC	MC	SCR
		1.1	0.8	0.8	0.7	0.6	0.2	0.2
Bicarbonate	<0.001	MC	SCR	SGR	CC	BC	LAR	DC
		201.4	147.6	97.8	85.0	72.8	58.4	42.4
BOD	0.041	LAR	CC	SGR	BC	SCR	DC	MC
		27.7	24.0	23.9	20.9	17.7	14.7	9.9

Constituent	Prob > F	Mass Emission Station Means						
Calcium	<0.001	MC 107.0	SCR 54.7	SGR 43.9	CC 31.1	BC 25.5	LAR 22.6	DC 13.5
Chloride	<0.001	MC 106.6	SGR 59.8	SCR 40.5	CC 33.8	BC 30.1	DC 20.3	LAR 19.6
Hardness	<0.001	MC 570.0	SGR 175.4	SCR 157.1	BC 129.3	CC 117.9	LAR 80.4	DC 55.5
Magnesium	<0.001	MC 69.0	SCR 17.7	SGR 13.5	CC 9.4	BC 9.0	LAR 6.2	DC 3.9
NH3-N	0.004	CC 0.78	SGR 0.75	LAR 0.69	DC 0.64	BC 0.50	SCR 0.21	MC 0.18
Nitrate	<0.001	MC 13.1	SGR 11.9	CC 5.8	LAR 4.9	SCR 4.0	BC 3.3	DC 3.2
Nitrate-N	<0.001	MC 3.0	SGR 2.7	CC 1.3	LAR 1.1	SCR 0.9	BC 0.8	DC 0.7
pH	<0.001	MC 8.00	SGR 7.56	CC 7.34	SCR 7.33	BC 7.26	LAR 7.05	DC 6.86
Potassium	<0.001	MC 6.7	SCR 6.1	SGR 5.9	LAR 4.3	CC 4.2	BC 3.5	DC 3.2
Sodium	<0.001	MC 101.8	SGR 43.2	SCR 43.1	CC 37.9	BC 19.6	LAR 19.0	DC 17.3
Specific Conductance	<0.001	MC 1662.2	SGR 579.4	SCR 452.5	CC 411.9	BC 365.6	LAR 253.0	DC 194.8
Sulfate	<0.001	MC 428.2	SCR 87.7	SGR 86.1	CC 58.8	BC 47.4	LAR 29.0	DC 15.7
Total Dissolved Solids	<0.001	MC 1081.2	SGR 360.2	SCR 298.3	CC 264.7	BC 232.6	LAR 161.4	DC 127.6
Total Organic Carbon	0.020	CC 15.9	LAR 13.8	SCR 13.3	DC 12.9	SGR 9.9	MC 9.9	BC 9.7
Total Suspended Solids	<0.001	SCR 1727.0	LAR 393.4	CC 379.8	MC 355.9	SGR 262.9	BC 227.0	DC 175.7

Constituent	Prob > F	Mass Emission Station Means						
TPH	<0.001	LAR	BC	CC	DC	SCR	SGR	MC
		2.2	2.2	1.1	0.6	0.5	0.5	0.2
Turbidity	0.029	SCR	MC	SGR	LAR	CC	BC	DC
		214.0	122.2	113.4	97.4	74.4	50.9	29.6
Volatile Suspended Solids	0.005	SCR	CC	LAR	BC	MC	SGR	DC
		153.7	74.9	66.3	58.8	42.3	42.0	40.6
Fecal Coliform	0.015	LAR	CC	BC	SGR	SCR	MC	DC
		576,580	316,384	260,020	137,337	101,035	43,563	41,867
Fecal Enterococcus	0.003	BC	LAR	CC	DC	SCR	SGR	MC
		270,973	254,937	169,158	126,660	119,311	55,272	24,928
Fecal Streptococcus	0.024	LAR	BC	CC	SCR	DC	SGR	MC
		515,534	382,121	230,784	184,046	159,198	147,440	75,419
Total Coliform	0.006	LAR	CC	BC	SGR	SCR	MC	DC
		1,445,967	842,269	808,526	616,742	277,267	197,653	197,355
Dissolved Boron	<0.001	MC	SCR	SGR	LAR	BC	CC	DC
		389.1	273.0	176.8	171.9	162.2	146.8	142.4
Dissolved Selenium	<0.001	MC	BC	LAR	CC	DC	SCR	SGR
		4.9	2.9	2.5	2.4	2.3	2.3	2.3
Total Copper	0.035	LAR	DC	CC	BC	SCR	MC	SGR
		43.7	33.0	23.6	22.9	22.8	17.5	15.8
Total Nickel	0.020	LAR	MC	SCR	CC	SGR	DC	BC
		15.9	14.8	13.7	9.4	8.1	7.5	6.7
Total Selenium	<0.001	MC	BC	CC	LAR	SGR	DC	SCR
		5.3	2.8	2.8	2.6	2.5	2.4	2.2

Constituents with non-significant results:

COD	MBAS	Dissolved Aluminum	Total Aluminum
Cyanide	Nitrite-N	Dissolved Antimony	Total Antimony
Dissolved Oxygen	Oil and Grease	Dissolved Arsenic	Total Arsenic
Dissolved Phosphorus	Total Phosphorus	Dissolved Barium	Total Barium
Fluoride	Diazinon	Dissolved Chromium	Total Boron
Kjedahl-N		Dissolved Copper	Total Chromium
		Dissolved Iron	Total Iron
		Dissolved Lead	Total Lead
		Dissolved Nickel	Total Zinc
		Dissolved Zinc	

Figure 10-16. Results of Mass Emission Stations Combined Annual Means (1994-2005) Comparisons by Analysis of Variance (ANOVA).

The means of several constituents measured at the Malibu Creek MES were significantly different compared to the other MES. These constituents included alkalinity, calcium, chloride, hardness, magnesium, sodium, specific conductance, sulfate, and total suspended solids. This comparison indicates a greater mean concentration in mineral salts and ions in wet and dry weather runoff at the Malibu Creek MES. This may indicate a contribution from natural minerals from groundwater seepage that contains higher dissolved mineral concentrations potentially due to natural geologic sources within this watershed compared to the other watersheds in the County. Further evaluation of any potential differences in geology and soil types within the Malibu Creek Watershed is needed to draw any definitive conclusions.

Also indicated by the ANOVA comparisons include a grouping of the watersheds that include Malibu Creek, San Gabriel River and Coyote Creek with regard to higher mean values for nitrate and nitrate-N. The mean for these watersheds was significantly different than the other watersheds. The mean for Malibu Creek MES was the highest of the watersheds. Higher nitrate concentrations could be the result of greater use of fertilizers in agricultural, golf courses or nursery activities, and seepage from in-ground septic systems near and up-stream of the MES. Further evaluation of land use near and upstream of the MES at these watersheds compared to the others is needed to determine if the higher means at these MES can be correlated to land activities upstream of the MES.

The highest mean for the related parameters of total suspended solids, turbidity and volatile suspended solids is identified for the Santa Clara River Watershed. The mean for total suspended solids and volatile suspended solids was significantly different than the means for all the other watersheds. Santa Clara River Watershed was grouped with Malibu Creek, San Gabriel River and Los Angeles River Watersheds for turbidity. The higher suspended solids and turbidity mean concentrations for the Santa Clara River may be associated with the mobilization and suspension of small clay and silt size particles during larger storm events through stream bank erosion and from disturbed lands in this largely undeveloped watershed. Studies being conducted in the Santa Clara River Watershed include the impact of new development and peak discharge impacts. The results of these studies may indicate a correlation with the higher suspended solids found at the MES compared to the more urbanized watersheds of the County.

The bacterial indicators for the watersheds monitored all possess mean values well above the WQO as discussed previously and the combined means are not significantly different between the watersheds for fecal streptococcus and total coliform. The combined mean for fecal enterococcus indicated a grouping of two sets of watersheds; one group with the highest means from Ballona Creek and Los Angeles River Watersheds, and the second grouping with the lowest mean for Malibu Creek. These comparisons confirm previously discussed results in that the highest mean concentrations correspond to the more urbanized watersheds, and these are statistically different from the less developed watersheds with regard to bacterial indicators. However, these indicators are high throughout all the watersheds.

There were no significant differences as indicated in the ANOVA comparisons between the annual means for the watersheds monitored for the metal COCs previously discussed (lead, copper and zinc).

10.1.3 Cluster Results

Multivariate cluster analysis was applied to the annual mean concentrations of the COCs and key constituents for the years from 1994 to 2005, for which data is available, measured at the MES in each of the watersheds monitored. This approach groups the watershed MES for the specific annual mean by the commonality of the COC concentrations found at each one. Likewise, it groups the COCs according to similar concentrations at the MES. Prior to the analysis the bacteriological measures were $\log_{10}$ transformed and the data for each COC was standardized by the overall mean value for each COC and key constituent. Constituents that were not consistently measured were excluded from the analysis.

Cluster analyses are performed to determine the degree of similarity among watersheds and/or monitored year relative to the COC concentrations for those years monitored. They can be useful in assessing the characteristics of a watershed in relation to a year's stormwater characteristics as well as providing information on the inter-relationships of the COCs. Figure 10-17 presents the cluster analysis for the annual means from 1995 to 2005 (for the years that data is available) for wet and dry weather sampling at the MES for each watershed monitored. The results of the wet and dry weather sampling are presented separately to determine if similarities exist that are specific to the wet or dry weather monitoring. The size of the square in each cell of the table was determined by the value of the COC at each MES and monitored year compared to the mean value for that COC for all stations and all years monitored. Thus, large squares represent values that were greater than the mean COC value and small squares represent values that were less than the mean. The colored boxes indicate the COC groups that best-define each MES and/or monitored year cluster group.

As highlighted by color in the lower right corner of Figure 10-17, there is a cluster for both wet and dry weather sampling at the Malibu Creek MES corresponding to higher concentrations compared to the overall mean for the constituents of ammonia, nitrate, nitrate-N, sulfate, total dissolved solids, specific conductance, hardness and chloride. This finding correlates to the conclusions for the Malibu Creek Watershed based on the ANOVA analysis discussed in the previous subsection. This cluster appears to also include numerous dry weather annual means for most of the other watersheds. Nutrients and constituents related to dissolved minerals are clustered with the Malibu Creek Watershed possibly due to potentially higher nitrate and dissolved minerals in groundwater seepage. The cluster around dry weather sampling at the various MES likely corresponds to a larger load of nutrients and dissolved mineral salts during dry weather flows.

Clusters for numerous COCs and key constituents are observed across watersheds, with the exception of Malibu Creek Watershed, for the 2004-2005 and 1997-1998 annual wet weather sampling. As previously presented in Figure 10-9, the greatest monthly precipitation occurred in these same years. High peak and intensity storm events result in greater mobilization and transport of sediment and particles that can increase turbidity, suspended solids, BOD and total metals when compared to the overall mean. Clusters are observed across multiple watersheds for the wet weather sampling for BOD, COD, turbidity, total and total volatile suspended solids, total iron, bacterial indicators, total and dissolved phosphorus, total copper, and total zinc. This analysis indicates that the high intensity and long-duration storm events, as experienced in the monitoring years 1997-1998 and 2004-2005, result in some of the greatest overall impacts to water quality as measured at the MES.

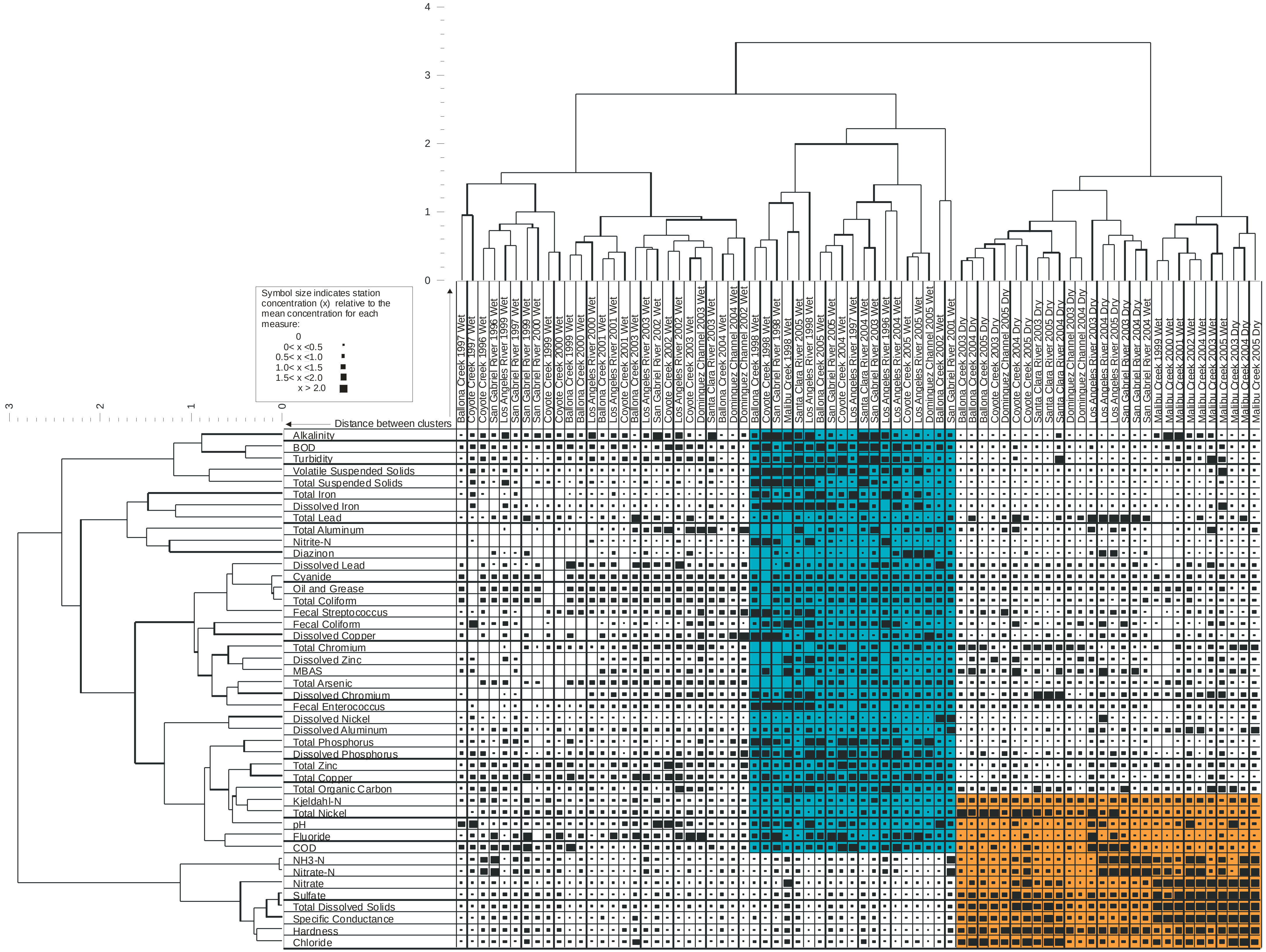

Figure 10-17. Cluster Analysis for Annual Means from 1995 to 2005.

10.1.4 Relationships/Trend Analysis Between TSS and COC

Trends between TSS and selected COCs and key constituents, primarily metals, is presented in this subsection. The current permit requires an evaluation of TSS with the Core Monitoring data results to identify relationships between TSS and COC. Because metals often bind to sediment that is carried by urban runoff, increased sediment load that can be indicated by greater TSS, may correspond to an increase in total metal concentrations. This would be expected for metals with a greater affinity to adsorb with sediment particles in stormwater. The following discussion focuses on the evidence of trends in TSS with total and dissolved concentrations of twelve metal constituents.

Figures 10-18 to 10-21 present a regional comparison between TSS concentrations and total and dissolved metal concentrations. The results are plotted using the wet and dry weather core sampling data at the MES, and represent annual mean concentrations. Where a trend is indicated based on statistical comparison of the TSS results with the metal concentrations, the points are identified in red. Figures 10-18 to 10-21 provide a legend for the symbols used in these graphs that correspond to the specific watersheds.

As shown on Figures 10-18 to 10-21, an increasing or decreasing trend is statically indicated for the Santa Clara River Watershed for total chromium, iron, lead and arsenic. A trend is also indicated for this watershed for dissolved copper and boron. The greatest number of trends was identified for the Santa Clara River Watershed compared to the other watersheds. The Santa Clara River Watershed is the least urbanized of the watersheds in the County. These results may indicate that correlations between TSS and metal concentrations are evident in the Santa Clara River Watershed possibly due to less diverse sources of metals within the watershed and a better correlation between sediment load and total metal concentrations in stormwater.

Trends were also observed for the Coyote Creek Watershed for total and dissolved nickel, and the Dominguez Channel Watershed for dissolved nickel and total and dissolved antimony. A trend was also indicated for the San Gabriel River Watershed for total barium and arsenic. These trends are noted by the red highlighted symbols on Figures 10-18 to 10-21.

A regression analysis was also conducted to determine if a relationship exists between TSS and diazinon based on the annual means for all the watersheds. No trends were identified.

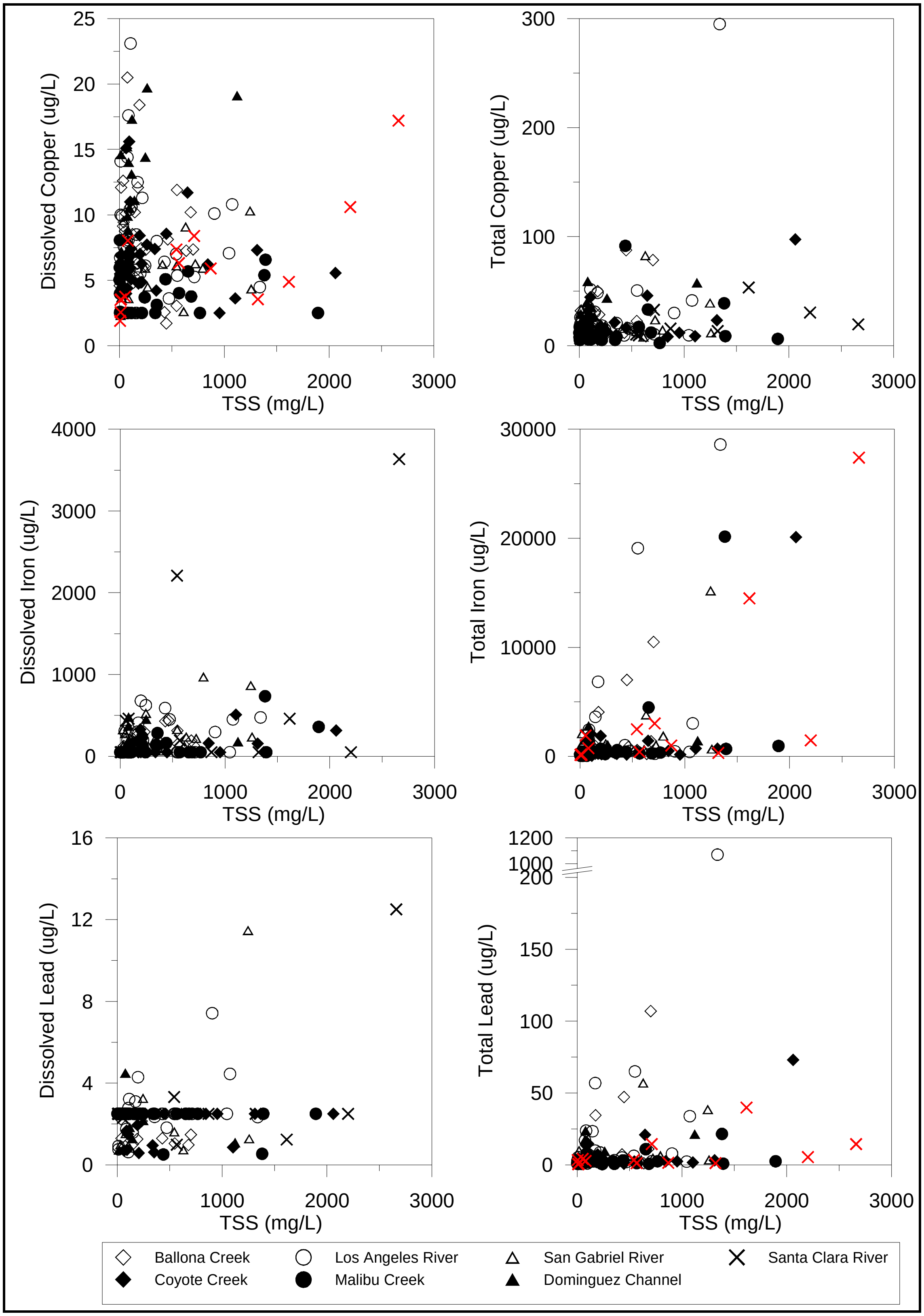

Figure 10-18. Regional Trend Analysis of TSS and Copper, Iron, and Lead Concentrations (Red Symbols Indicate Significant Trend).

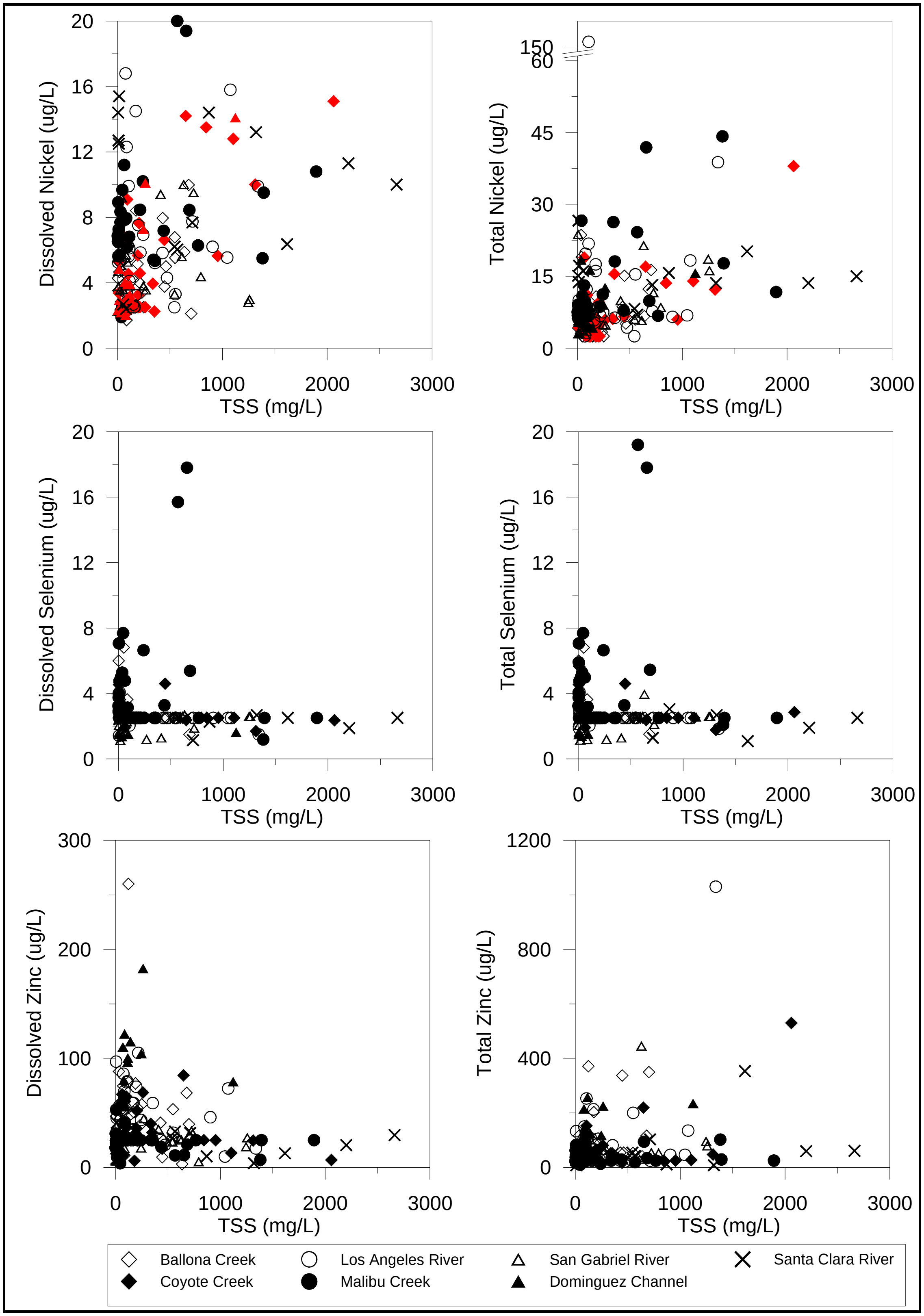

Figure 10-19. Regional Trend Analysis of TSS and Nickel, Selenium, and Zinc Concentrations (Red Symbols indicate Significant Trend).

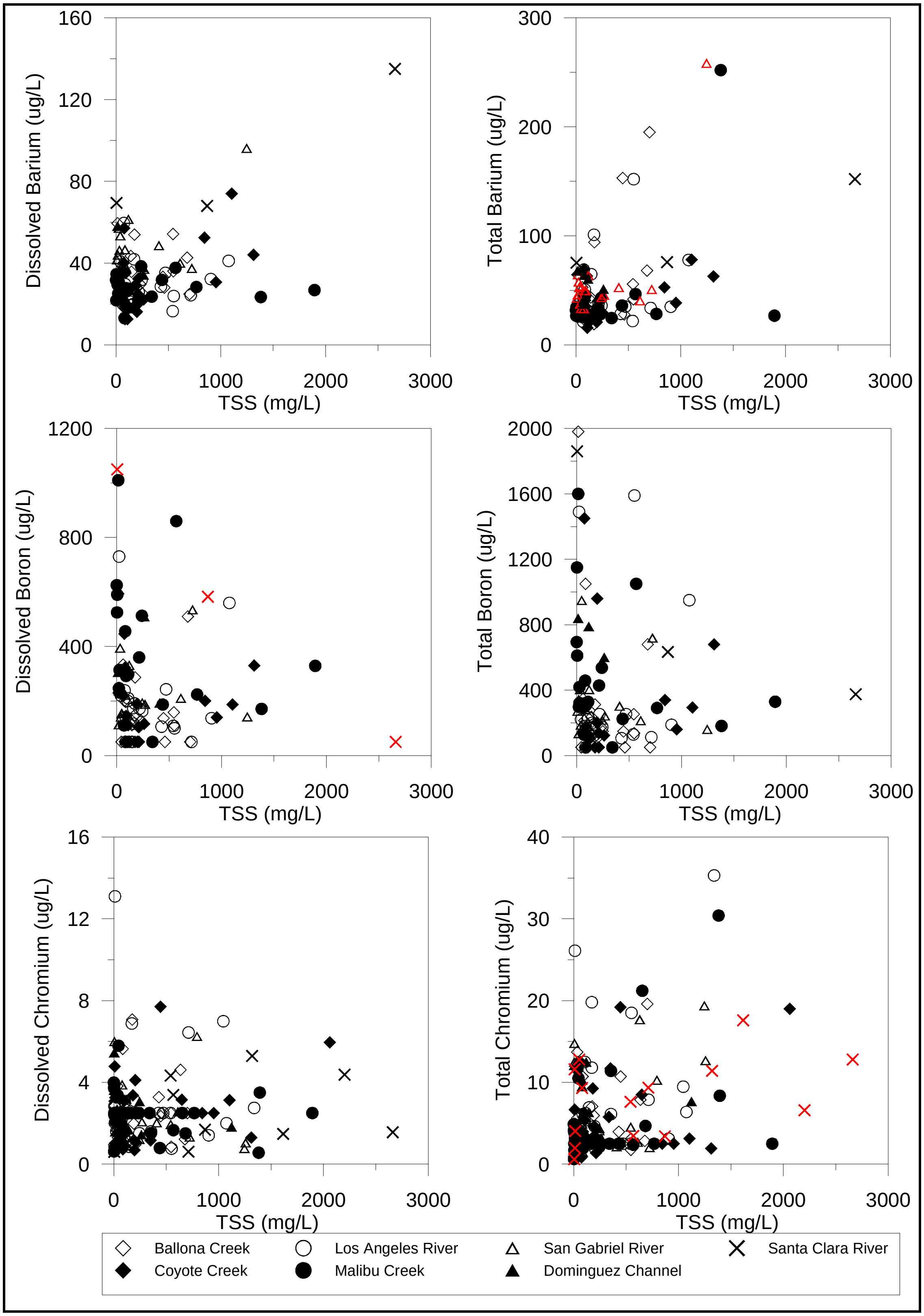

Figure 10-20. Regional Trend Analysis of TSS and Barium, Boron, and Chromium Concentrations (Red Symbol indicates Significant Trend).

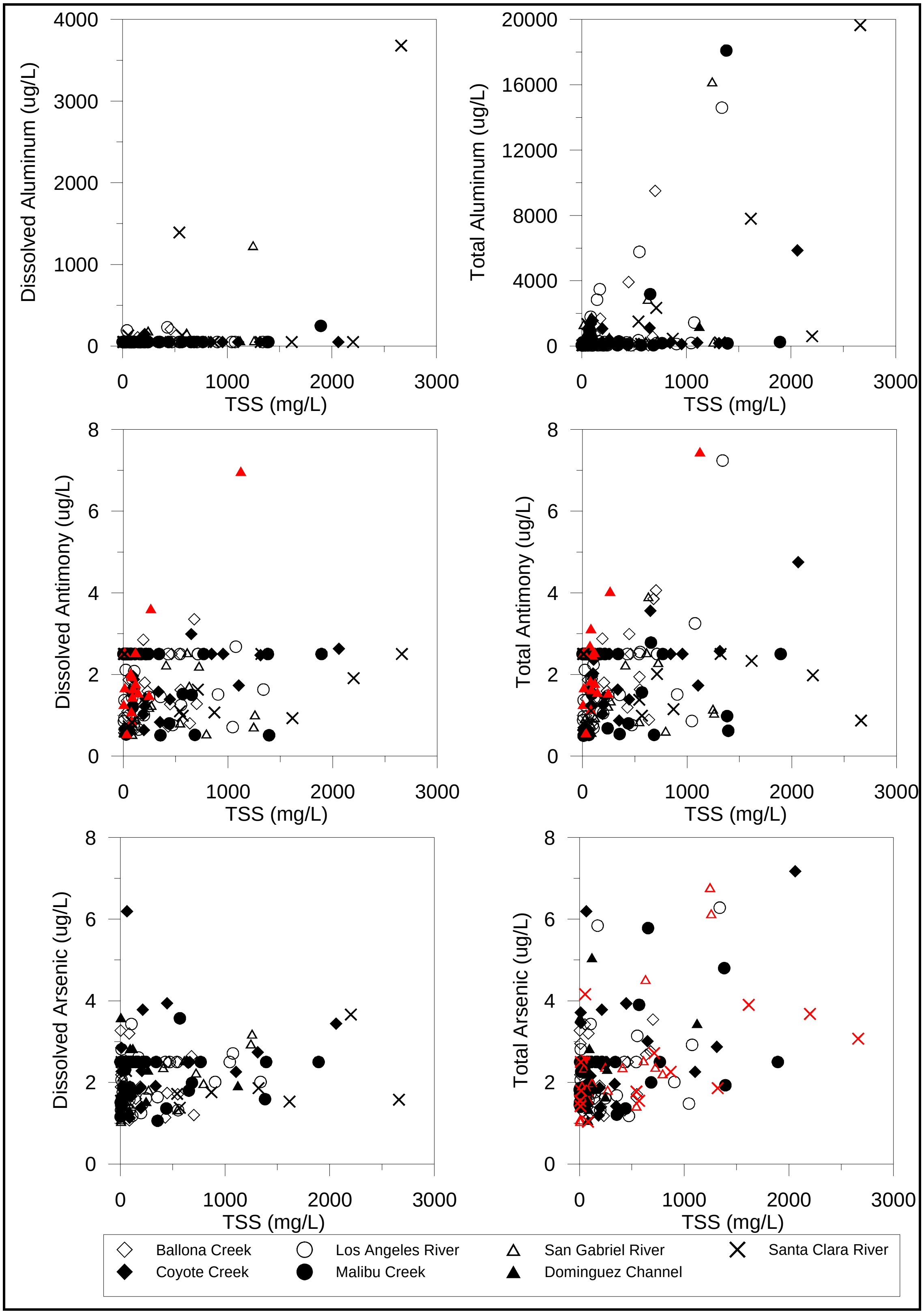

Figure 10-21. Regional Trend Analysis of TSS and Aluminum, Antimony, and Arsenic Concentrations (Red Symbol indicates Significant Trend).

10.1.5 Relationships Between Toxicity and COC

Toxicity has been measured during the 2002-2003, 2003-2004, and 2004-2005 monitoring years for *Ceriodaphnia dubia* survival and reproduction and for sea urchin fertilization. Table 10-1 summarizes the results of this sampling.

Table 10-1. Summary of Toxicity Test Results for 2002-2005.

Wet/ Dry Event	Date	Mass Emission Station						
		San Gabriel River	Coyote Creek	Los Angeles River	Dominguez Channel	Ballona Creek	Malibu Creek	Santa Clara River
Ceriodaphnia dubia survival (NOEC %)								
Dry	10/10/2002	100	100	100	100	100	100	100
	4/23/2003	100	100	100	100	100	100	100
	10/28/2003	100	100	100	100	100	100	100
	1/13/2004	NA	100	100	100	100	100	100
	6/22/2005	100	100	100	100	100	100	100
	7/6/2005	100	100	100	100	100	100	100
Wet	11/8/2002	100	13	100	50	100	100	100
	12/16/2002	100	100	100	100	100	100	100
	10/31/2003	100	100	100	100	100	100	50
	2/2/2004[1]	100	100	100	100	100	100	100
	10/17/2004	100	100	50	50	100	100	100
	10/26/2004	100	25	100	50	100	100	100
Ceriodaphnia dubia reproduction (NOEC %)								
Dry	10/10/2002	100	100	100	100	100	100	100
	4/23/2003	100	100	100	100	100	100	100
	10/28/2003	100	100	100	100	100	100	100
	1/13/2004	NA	100	100	100	100	100	100
	6/22/2005	<6.25	100	100	6.25	6.25	100	12.5
	7/6/2005	100	100	100	100	100	50	6.25
Wet	11/8/2002	100	12.5	100	50	100	100	100
	12/16/2002	100	100	100	100	100	100	100
	10/31/2003	100	100	100	100	100	100	100
	2/2/2004[1]	100	100	100	100	100	100	100
	10/17/2004	100	100	100	100	100	12.5	100
	10/26/2004	100	25	100	100	6.25	100	100
Sea urchin fertilization (LC_{50} %)								
Dry	4/23/2003	>100	>100	>100	>100	>100	>100	>100
	10/28/2003	>100	>100	45	>100	>100	>100	>100
	1/13/2004	NA	29	45	86	>100	>100	>100
	6/22/2005	>50	>50	46	>50	>50	>50	>50
	7/6/2005	>60	>60	56	>60	>60	>60	>60
Wet	11/8/2002	>100	86	>100	>100	69	>100	>100
	12/16/2002	>100	>100	>100	>100	>100	>100	>100
	10/31/2003	>100	>100	>100	>100	>100	>100	>100
	2/2/2004[1]	>100	74	78	68	83	>100	>100
	10/17/2004	>61	>61	>61	>61	>61	>61	>61
	10/26/2004	>57	>57	>57	>57	>57	>57	>57

NA = Not Available
[1] Chemistry data not available for comparison with these results

As evident in Table 10-1, few samples produced a toxic response and there were no strong patterns for the toxic responses observed for *Ceriodaphnia* (NOEC concentrations below 100). Dry weather samples did not show reduced survival or reproduction in any of the events. Wet weather samples showed a toxic response for survival in three samples from Dominguez

Channel, two samples from Coyote Creek, and one sample each from Los Angeles River and Santa Clara River. Fewer toxic responses were observed for reproduction; those were found in Ballona Creek, Coyote Creek, Dominguez Channel, and Malibu Creek.

Sea urchin fertilization tests had toxic responses (shown by LC_{50} concentrations less than 100) in both dry and wet weather in Los Angeles River, Dominguez Channel, Ballona Creek, and Coyote Creek. The results for Los Angeles River indicate a persistent toxic response for the dry weather samples. In accordance with the permit, a Toxicity Identification Evaluation (TIE) was performed.

The first dry weather sample of S-10 (Los Angeles River Wardlow) collected on June 28, 2005 resulted in a Toxic Unit Chronic (TUc) of 2.19 for sea urchin fertilization. This value exceeded the Permit requirement of 1 TUc and indicated the presence of significant toxicity within the sample. Based on these results, a Toxicity Identification Evaluation (TIE) was conducted on sample S-10 to investigate the sources of toxicity within the sample. The second dry weather sampling event was collected shortly after the first (7 days) on July 6, 2005. This sample was utilized for the TIE testing summarized below. In addition, the standard test performed on the second dry weather sample of S-10 resulted in a TUc of 1.80, indicating that there was not a significant change in the toxicity of the sample between the two events.

A Phase I TIE was initiated on sample S-10 on July 7, 2005. In summary, the Phase I TIE included the following manipulations; baseline (unmanipulated), centrifugation, C-18 solid phase extraction, sodium thiosulfate addition, EDTA addition, and methanol elution (C-18 add-back). The results of the TIE performed on sample S-10 are summarized in Table 10-2.

Table 10-2. Results of the Toxicity Identification Evaluation Performed on Sample S-10 (Los Angeles River Wardlow) July 7, 2005

Sample Manipulation	Mean Percent Fertilization Relative to Treatment Blank
Baseline (Unmanipulated)	66.8
Centrifugation	55.2
C-18 Filtration	76.6
Sodium Thiosulfate 10 mg/L	66.1
Sodium Thiosulfate 25 mg/L	73.7
EDTA 3 mg/L	107.1
EDTA 8 mg/L	108.4
MeOH (C-18 add-back)	100.3

The EDTA (Ethylenediaminetetraacetic Acid) manipulation appears to have removed a majority of the toxicity observed in sample S-10 to urchin fertilization. The results of this treatment indicate that metal toxicity is likely to be responsible for the reduction in urchin fertilization.

A preliminary review of the water quality results for constituents measured in the Los Angeles River mass emission station indicate that copper has been present in the sample at levels known to impact urchin fertilization. Table 10-3 summarizes the measured levels of copper with effect-based responses. Differences, however, lie in the amounts of dissolved and total amounts of this metal within the sample. The TIE manipulation with sodium thiosulfate (STS) also has the ability to remove metal toxicity, especially that of copper (Hockett and Mount 1996). It should be noted that this data comes from experiments conducted in freshwater and that saltwater manipulations (as in this case) offer differences in complexation due to the high ionic content of salt water. The STS manipulation in thie evaluation only slightly improved sea urchin fertilization at the 25 mg/L concentration. This information may indicate that copper is not the sole contributor to toxicity. EDTA has the greatest affinity for removing the toxicity of copper, lead, cadmium, nickel and zinc. Copper, zinc and lead have historically been detected at levels exceeding the water quality criterion under the Permit. These and other metals routinely measured in the Los Angeles River mass emission sample do not appear to be present in toxic amounts by themselves. This does not account for synergistic effects that may be occurring between the multiple compounds found in the sample. Cationic surfactants are also removed by the EDTA addition; however, the low levels of surfactants observed in this sample indicate that surfactant toxicity is unlikely.

Table 10-3. Copper Results Measured at the Los Angeles River Mass Emission Site Compared to Laboratory Responses.

Constituent	Measured Values (October 2004 – March 2005)[1] (µg/L)	Laboratory Mean EC_{50} (µg/L)	Literature Mean LC_{50} (µg/L)[2]
Dissolved Copper	5.36-10.80	37.5	18
Total Copper	14.50-41.50		

[1]Range of 6 sample events
[2]Obtained from the EPA Ecotox database

Regressions were performed to look for relationships between toxicity results and constituents measured in the water. Analyses of the constituents in the water was not done for one event, therefore the samples collected on February 2, 2004 were not included in the analysis. No significant regressions were found in the analysis. In some instances, thresholds of chemical concentrations are involved with toxicity whereby the organisms do not respond negatively until a certain chemical level is reached. Concentrations of constituents above a specific threshold may no longer illicit a linear response in organism toxicity. Consequently, these constituents detract from the regression model. Therefore, a second method, threshold analysis, was used to test relationships for constituents with established thresholds. The threshold analysis uses constituent levels reported to be toxic in the literature where available and compares them to constituent levels in the stormwater samples.

Survival of test organisms can be influenced by pesticides in urban runoff. The lowest literature value for diazinon found to be toxic to a species related to *Ceriodaphnia* is 0.26 µg/L (21-day NOEC for *D. magna*) (Vershueren 1983). Diazinon at this concentration does not appear to be a factor in reduced survivorship in this program. Diazinon was observed above 0.26 µg/L on four occasions; only one of these had a NOEC value below 100% for *Ceriodaphnia* survival. The other six toxic responses for survival were in samples with concentrations well below this threshold value.

Indications of thresholds that may affect *Ceriodaphnia* survival were found only for dissolved copper and zinc (Figure 10-22). No confirmatory results could be found in the literature; but based on the observed results, concentrations of dissolved copper above 10.5 µg/L and dissolved zinc above 70 µg/L may be contributing to toxicity in the wet weather stormwater samples.

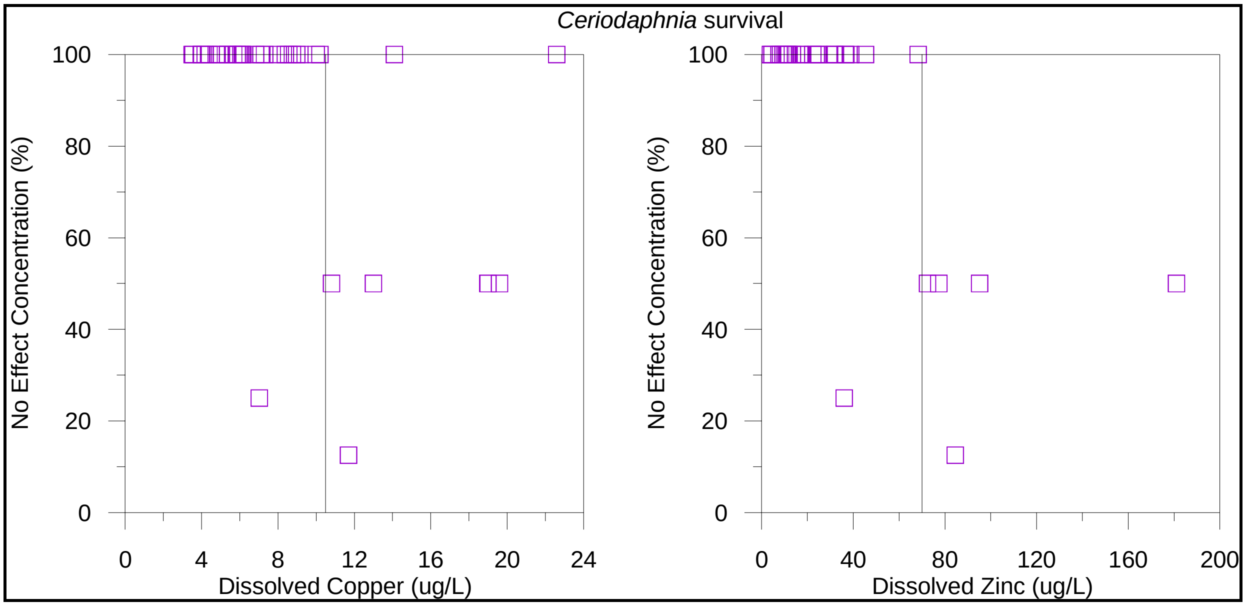

Figure 10-22. Relationships between *Ceriodaphnia* survival and dissolved copper and zinc.

10.2 Stormwater Modeling – Pollutant Loading Estimates

This subsection presents the estimated pollutant loadings for both wet and dry weather for the current monitored year (2004-2005) and also presents loading estimates for several COC for the monitoring years from 2002 to 2005. The pollutant loadings are based on the Event Mean Concentrations determined from the MES data and the flow data as measured at the MES. Hydrographs for the 2004-2005 monitoring program are provided in Appendix G.

Loading estimates for all the mass emissions stations based on the concentrations detected and flow measurements obtained for the 2004-2005 monitoring period are presented graphically in Appendix H. Figures 10-23 through 10-26 present the estimated mean loadings on a per acre basis based on the 2004-2005 results for the constituent groups of bacteriological indicators, metals, nutrients and solids. The loadings per acre are presented using a log scale. Figures 10-23 through 10-26 provide further data for comparing loadings to predominant land use in the different watersheds. As was indicated by the previously discussed comparison of water quality exceedance ratios for constituents associated with urban runoff to the predominant land use, loadings per unit area estimates for these constituents of concern should be higher for more urbanized watersheds. In contrast, the loading estimates per acres for these constituents should be lower for watersheds that have a greater percentage of the total drainage area designated as vacant land. Watersheds that are characterized by a higher percentage of total area with a vacant land use include Malibu Creek, Santa Clara River and the upper reaches of the San Gabriel River WMA. These WMAs would therefore be expected to have lower loadings per acre for constituents that have been found to exceed WQO in the more urbanized watersheds. These constituents include bacteriological indicators and total copper, lead and zinc. Figures 10-23 through 10-26 provides the percentage of total drainage area that has been designated as un-developed (vacant) and the urbanized percentage to allow for comparison with the plotted loadings per acre. A comparison of the loadings by constituent group for this current monitoring period is summarized as follows:

- ***Bacteriological Indicators (total and fecal coliforms and enterococcus)*** – The mean total loading estimates for all three indicators were highest for the Los Angeles River followed by Coyote Creek. The total loads for all the other MES were lower and similar in totals, with the exception of Malibu Creek, which was the lowest. As presented on Figure 10-23, the mean total loadings for the bacteriological indicators on a per acre basis indicate that the Los Angeles River, Coyote Creek, Dominguez Channel and Ballona Creek had the highest loadings per acre, and correspond to more urbanized watersheds. The lowest loadings per acre were determined for Malibu Creek, Santa Clara River and San Gabriel River Watersheds that are characterized by a greater percentage of vacant land of the total drainage area. The results of the loading estimates on a per acre basis indicate a correlation between higher loadings per acre for more urbanized watersheds compared to watersheds with higher percentages of total drainage area that remains undeveloped (vacant).

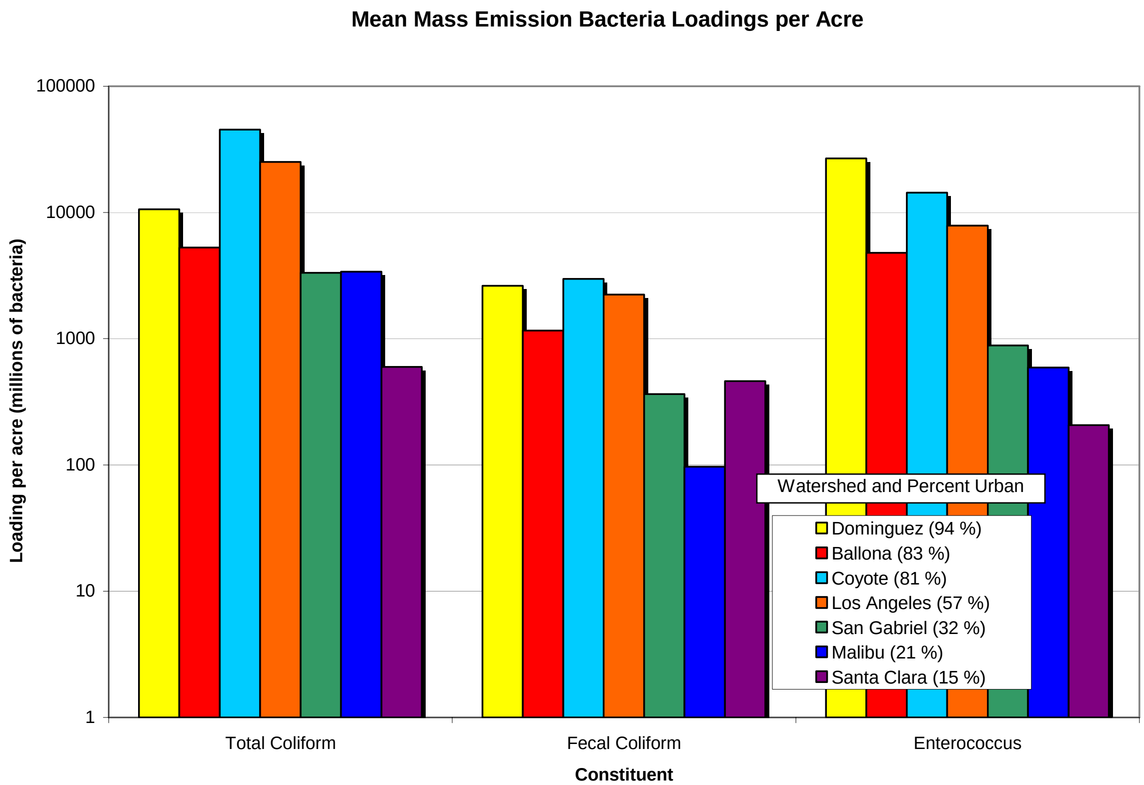

Figure 10-23. Loading Estimates Per Acre – Bacteriological Indicators – 2004-2005 Mean Loadings.

- ***Metals (total copper, lead and zinc)*** - The mean total loading estimates for all three metals were highest for the Los Angeles River followed by Coyote Creek and Ballona Creek MES. The total loads for all the other MES were lower and similar in totals, with the exception of Malibu Creek, which was the lowest. These results are similar to those of the bacteriological indicators which represent constituents often associated with urban runoff. As discussed previously, the source of these metals is often identified with non-point urban sources that include vehicle emissions and wear of automobile tires and brake pads. As presented on Figure 10-24, the mean total loadings for total copper, lead and zinc on a per acre basis indicate that Dominguez Channel and Ballona Creek have the highest loadings per acre, followed by the Los Angeles River and Coyote Creek, which corresponds to more urbanized watersheds. The lowest loadings per acre were determined for Malibu Creek, Santa Clara River and San Gabriel River Watersheds that are characterized by a greater percentage of vacant land of the total drainage area. The results of the loading estimates on a per acre basis for total copper, lead and zinc indicate a correlation between higher loadings per acre for more urbanized watersheds compared to watersheds with higher percentages of total drainage area that remains undeveloped (vacant). These results correlate with the loadings per acre for the bacterial indicators, and are also consistent with the findings of the comparison of the water quality exceedance ratio for these constituents to the percent urbanization within the WMA monitored.

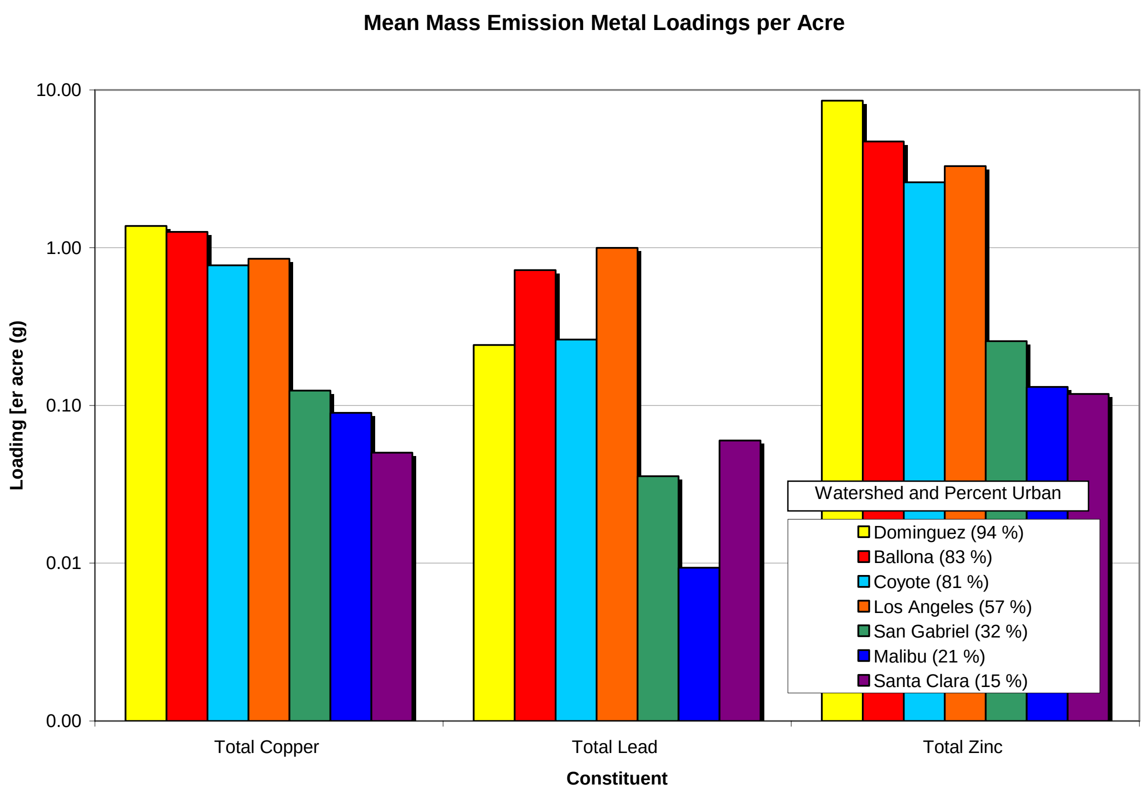

Figure 10-24. Loading Estimates Per Acre – Metals – 2004-2005 Mean Loadings.

- ***Nutrients (total phosphorus, Nitrate-N, Kjeldahl-N)*** – The highest mean loadings for nutrients based on the 2004-2005 results from the MES were determined for the Los Angeles River, which is the largest monitored watershed in the County. The total nutrient loadings were lower and similar for Coyote Creek, Ballona Creek and San Gabriel River. The lowest total loadings were calculated for Malibu Creek, Dominguez Channel and Santa Clara River. Figure 10-25 presents the loading per acre for nutrients based on the mean loads for 2004-2005. As shown on Figure 10-25, the highest total phosphorus per acre was determined for Ballona Creek. The next set of watersheds that are characterized by slightly lower loads per acre included Coyote Creek, Dominguez Channel and Los Angeles River. The lowest was calculated for Santa Clara River. The results for nitrogen (Kjeldahl-N) were similar as presented in Figure 10-25. The highest nitrate (as nitrogen) loads per acre were determined for Coyote Creek and Dominguez Channel, followed by Malibu Creek. These results indicate a relatively high load per acre estimate for Malibu Creek, compared to more urbanized watersheds such as the Los Angeles River. These results are collaborated by the ANOVA analysis which indicated a significant difference in the nutrient results for Malibu Creek. The potential sources of nitrates in the Malibu Creek watershed may include greater use of fertilizer per acre and seepage from in-ground septic systems which are prevalent in this watershed.

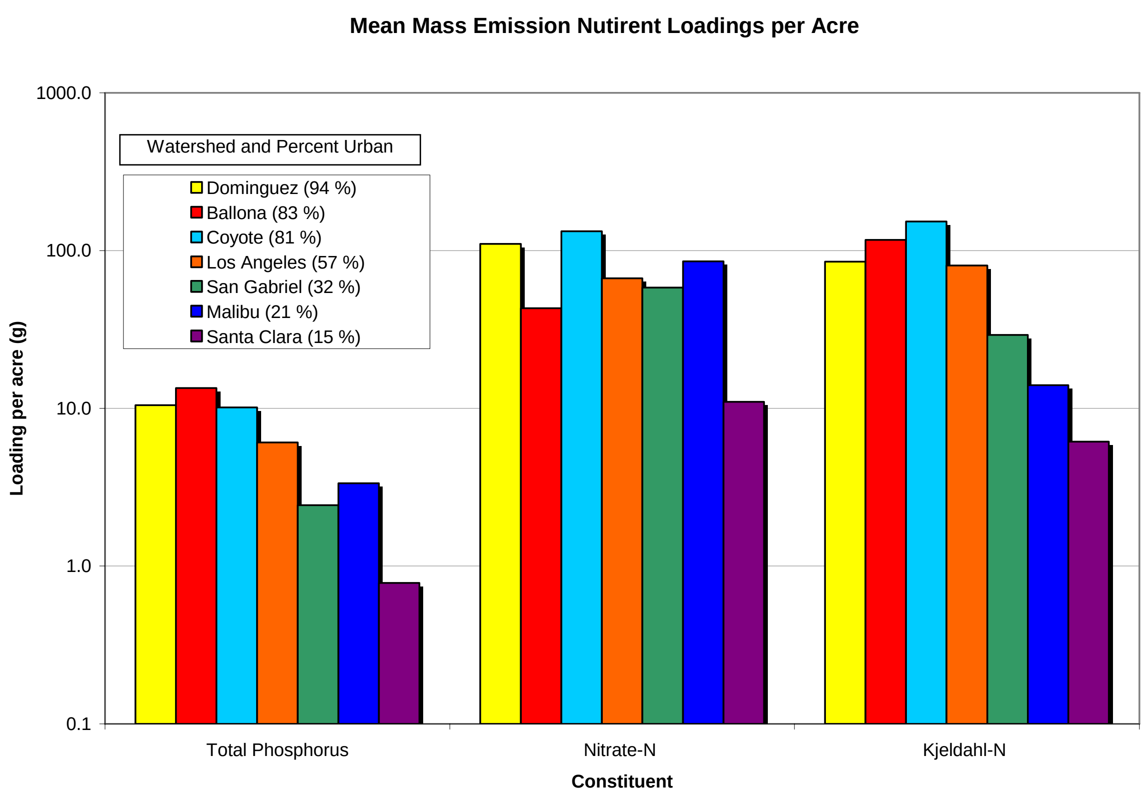

Figure 10-25. Loading Estimates Per Acre – Nutrients – 2004-2005 Mean Loadings.

- ***Solids (TDS, TSS, TOC)*** **–** The highest mean total loadings for TDS were determined for the Los Angeles River, however, the total loads were only slightly lower for Ballona Creek, Coyote Creek, Malibu Creek and San Gabriel River. The Los Angeles River is the largest monitored watershed in the County. As presented in Figure 10-26, the highest TDS loadings per acre were calculated for Ballona Creek, Malibu Creek, and Coyote Creek. The lowest TDS per acre was indicated for Santa Clara River. Both Malibu Creek and the Santa Clara River Watersheds are the least urbanized. The much higher TDS loadings from Malibu Creek suggest possible greater contributions from natural sources such as groundwater seepage into the creek that contains higher dissolved salts and metals than in Santa Clara River. These findings are collaborated by the ANOVA and Cluster Analysis results which indicated significant differences in the Malibu Creek water quality compared to the other watersheds with regard to TDS and other parameters that would suggest these same inputs and sources.

  TSS total mean loads were highest for the Santa Clara River and lowest for Malibu Creek. The higher TSS for Santa Clara River may indicate greater suspended sediment loads due to erosion of stream banks and disturbed areas. Special Studies being conducted in the Santa Clara WMA are investigating both the impact from development and increases in peak discharge. As presented in Figure 10-26, the mean loading of TSS per acre is highest for Ballona Creek, Los Angeles River, Coyote Creek and Santa Clara River. The lowest was for Malibu Creek. The higher TSS loadings per acre for most of these watersheds represent contributions from various urban sources within the more urbanized watersheds. As discussed above, the higher TSS loadings per acre for Santa Clara River may be related to erosion. This is also indicated by a low TDS loading per acre compared to the high TSS loading per acre for Santa Clara River, which correspond to a larger particle source such as soils (measured by the TDS) compared to dissolved constituents (measured by TSS).

  The TOC mean loadings for 2004-2005 were highest in the Los Angeles River, followed by Coyote Creek and Ballona Creek. The lowest was for Malibu Creek. Figure 10-26 presents the mean loadings per acre for TOC. As shown on Figure 10-26, the highest mean loadings per acre was determined for Coyote Creek, followed by Ballona Creek and Dominguez Channel, and then the Los Angeles River. The lowest was for Santa Clara River. The lower relative loading per acre compared to the total mean loading for the Los Angeles River is likely due to large drainage area of this watershed. The higher TOC loadings both as totals and on a per acre basis correspond to greater urbanized areas of the total drainage area. TOC loadings appear to be an indicator of greater urbanization within the watershed.

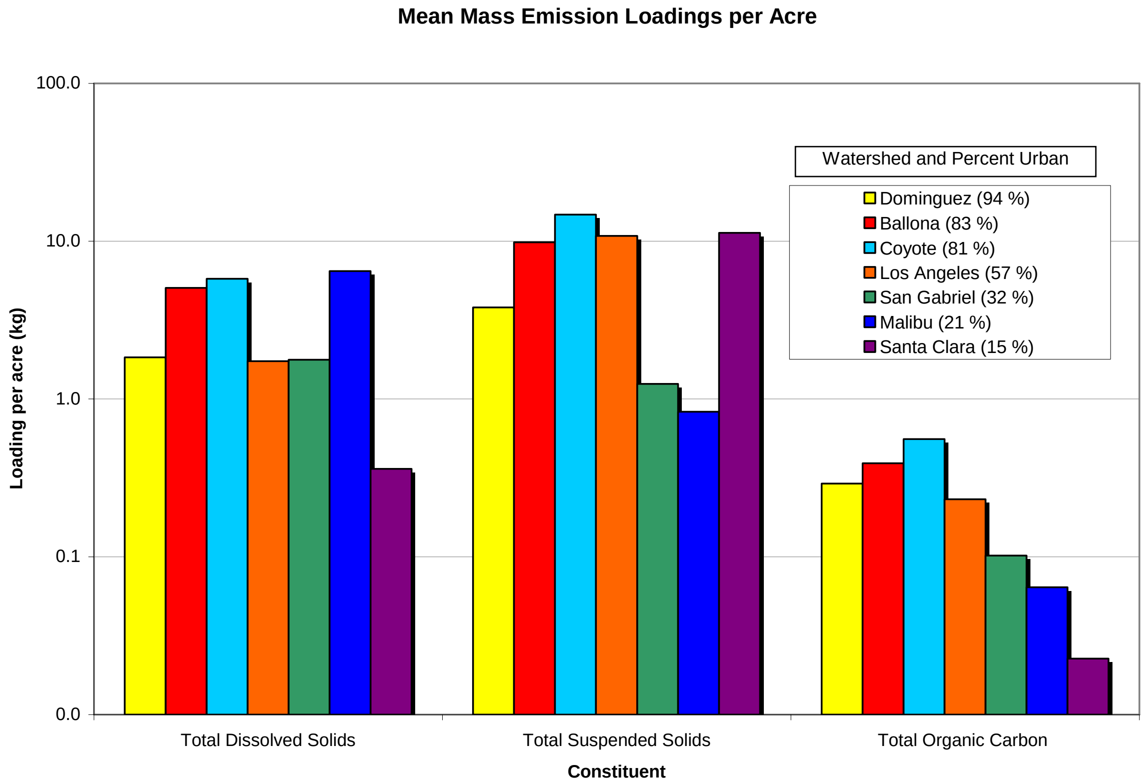

Figure 10-26. Loading Estimates Per Acre – Solids – 2004-2005 Mean Loadings.

A comparison of the mean storm loadings of several selected constituents from the 2001/2002, 2002/03, 2003/2004 and 2004/2005 monitoring seasons is presented in Figure 10-27. Figure 10-27 presents the mean total loadings for total copper, total lead, TSS, TDS, total Kjeldahl Nitrogen, total phosphorus, fecal coliform and enterococcus coliform for the last four years of monitoring. The total loadings are presented on a log scale. No overall trends are indicated, however, the following observations can be made from the focused data set:

- The greatest total loadings for all the constituents presented were determined for the Los Angeles River MES. The drainage area for this MES is the largest of the watersheds monitored.

- No trends in loading were clearly identified and therefore represent the variation in the monitored flows over the years presented. The total flows that were used for the loading determinations represent the flows during the sampling period and may not represent the actual total flows or magnitude of total flow for that year. For example, the loadings for the most recent year (2004-2005) should be one of the larger loadings due to the high total precipitation for this year. Figure 10-27 does not indicate this conclusion suggesting some of the larger storm events were not monitored.

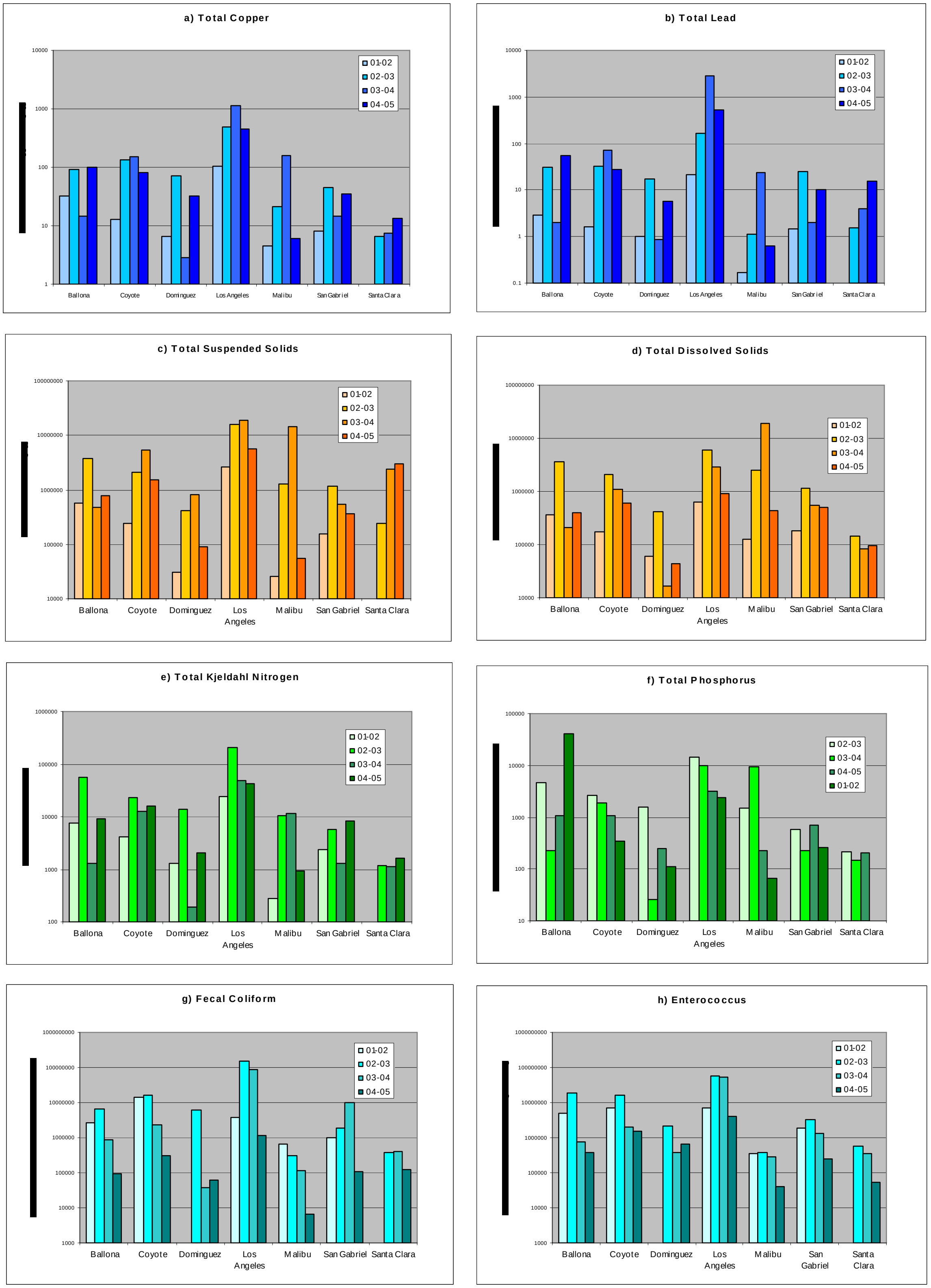

Figure 10-27. Mean Total Loading Estimates– Bacteriological Indicators – Monitoring Period of 2002-2005.

- The metal constituent loadings for Malibu Creek for the year 2003/2004 do not correlate with the other years presented. The loadings were significantly higher than the other years monitored. Further investigation on the cause of this observation is recommended based on the body of evidence that indicate that theses loading should be lower in comparison to the other watersheds.

10.3 Conclusions

The overall conclusions that can be made from this regional assessment include:

Bacterial Indicators - The highest concentrations for the bacterial indicators generally occurred at the Los Angeles River and Ballona Creek mass emission stations. The lowest mean concentrations were indicated for Dominquez Channel and Santa Clara River; however, the data from these MES was limited (2-3 years). The regression analysis did not indicate any significant trends with regard to the bacterial indicators. Regionally, these indicators remained well above the WQO throughout the watersheds and the monitoring period from 1994-2005. The regional evaluation of the ratios of the mean concentrations to the WQO, indicated that the highest WQO ratios were observed for the Los Angeles River, Ballona Creek and Coyote Creek Watersheds. The lowest ratios were observed for the Santa Clara River and Malibu Creek Watersheds. The magnitude of the WQO ratios for the bacterial indicators corresponded to the percentage of land use that relates to urbanization (use other than vacant lands or recreational uses) of the watersheds. A lower percentage of urbanization resulted in a lower WQO ratio.

The mean total loading estimates for all three bacteriological indicators were highest for the Los Angeles River followed by Coyote Creek. The total loads for all the other MES were lower and similar in totals, with the exception of Malibu Creek. Malibu Creek was the lowest. The mean total loadings for the bacteriological indicators on a per acre basis indicate that the Los Angeles River, Coyote Creek, Dominguez Channel and Ballona Creek had the highest loadings per acre, and correspond to more urbanized watersheds. The lowest loadings per acre were determined for Malibu Creek, Santa Clara River and San Gabriel River watersheds that are characterized by a greater percentage of vacant land of the total drainage area. The results of the loading estimates on a per acre basis indicate a correlation between higher loadings per acre for more urbanized watersheds compared to watersheds with higher percentages of total drainage area that remains undeveloped (vacant). The conclusions for the loading estimates are consistent with those summarized above regarding a relationship with the magnitude of exceedances with percent urbanization.

Metals - The highest mean concentrations for total and dissolved copper, lead and zinc on a regional basis were observed in the Los Angeles River. The lowest concentrations were generally observed for the Santa Clara River and Malibu Creek Watersheds. These two watersheds are the least urbanized of the watersheds under the Core Monitoring program. Exceedances of the WQO for total and dissolved lead, copper and zinc were observed regionally in all the watersheds monitored with the exception of the Santa Clara River and Malibu Creek Watersheds. The highest WQO ratios were observed for the Los Angeles River, followed by the Dominguez Channel, Ballona Creek and Coyote Creek Watersheds. The Santa Clara River and Malibu Creek Watersheds had the lowest WQO ratios. The ranking of the magnitude of these

WQO ratios for lead, copper and zinc generally corresponded to a greater percentage of urbanization of the watersheds. It was also indicated that the highest annual mean concentrations for dissolved and total copper, lead and zinc for several watersheds occurred in 1997-1998. This year corresponded with the highest monthly rainfall, as recorded at the Los Angeles Civic Center. The higher intensity storms recorded for that period could have resulted in the mobilization and transport of greater sediment/particle loads into the watersheds that likely resulted in higher copper and other metal concentrations at the MES.

No trends (increasing or decreasing over time) in the annual mean concentrations as measured at the MES were observed for copper, lead and zinc on a watershed basis with the exception of Dominguez Channel. An increasing trend in total lead concentrations was observed in Dominguez Channel. The annual data at this MES was however limited to four annual sampling periods.

The mean total loading estimates for total copper, lead and zinc were highest for the Los Angeles River followed by Coyote Creek and Ballona Creek MES. The total loads for all the other MES were lower and similar in totals, with the exception of Malibu Creek. Malibu Creek was the lowest. These results are similar to those of the bacteriological indicators which represent constituents often associated with urban runoff. As discussed previously, the source of these metals is often identified with non-point urban sources that include vehicle emissions and wear of automobile tires and brake pads. The mean total loadings for total copper, lead and zinc on a per acre basis indicate that Dominguez Channel and Ballona Creek have the highest loadings per acre, followed by the Los Angeles River and Coyote Creek, which corresponds to more urbanized watersheds. The lowest loadings per acre were determined for Malibu Creek, Santa Clara River and San Gabriel River watersheds that are characterized by a greater percentage of vacant land of the total drainage area. The results of the loading estimates on a per acre basis for total copper, lead and zinc indicate a correlation between higher loadings per acre for more urbanized watersheds compared to watersheds with higher percentages of total drainage area that remains undeveloped (vacant). These results correlate with the loadings per acre for the bacterial indicators, and are also consistent with the findings of the comparison of the water quality exceedance ratio for these constituents to the percent urbanization within the WMA monitored.

Based on the evaluation of inter-relationships between TSS and metals, the greatest number of trends was identified for the Santa Clara River Watershed compared to the other watersheds. The Santa Clara River Watershed is the least urbanized (over 80% vacant lands) of the watersheds in the County. These results may indicate that correlations between TSS and metal concentrations were evident in the Santa Clara Watershed, possibly due to a less diverse source of metals within the watershed and a better correlation between sediment load and total metal concentrations in stormwater.

Nutrients - The results of the ANOVA comparisons indicated a grouping of watersheds that include Malibu Creek, San Gabriel River and Coyote Creek with regard to higher mean values for nitrate and nitrate-N. The means for these watersheds were significantly different than the other watersheds. The mean for Malibu Creek MES was the highest of the watersheds. Higher nitrate concentrations could be the result of greater use of fertilizers in agricultural, golf courses or nursery activities, and seepage from in-ground septic systems near and up-stream of the MES. Further evaluation of land use near and upstream of the MES at these watersheds compared to the others is needed to determine if the higher means at these MES can be correlated to land activities upstream of the MES.

Based on the cluster analysis, there was a cluster for both wet and dry weather sampling at the Malibu Creek MES corresponding to higher concentrations compared to the overall mean for the constituents of ammonia, nitrate, nitrate-N, sulfate, total dissolved solids, specific conductance, hardness and chloride. This finding correlates to the conclusions for the Malibu Creek Watershed based on the ANOVA analysis and WQO ratio comparisons. This cluster appeared to also include numerous dry weather annual means for most of the other watersheds. Nutrients and constituents related to dissolved minerals were clustered with the Malibu Creek Watershed possibly due to potentially higher nitrate and dissolved minerals in groundwater seepage. The cluster around dry weather sampling at the various MES likely corresponds to a larger load of nutrients and dissolved mineral salts during dry weather flows.

The highest mean loadings for nutrients based on the 2004-2005 results from the MES were determined for the Los Angeles River, which is the largest monitored watershed in the County. The total nutrient loadings were lower and similar for Coyote Creek, Ballona Creek and San Gabriel River. The lowest total loadings were calculated for Malibu Creek, Dominguez Channel and Santa Clara. The highest total phosphorus per acre was determined for Ballona Creek. The next set of watersheds that are characterized by slightly lower loads per acre included Coyote Creek, Dominguez Channel and Los Angeles River. The lowest was calculated for Santa Clara River. The results for nitrogen (Kjeldahl-N) were similar. The highest nitrate (as nitrogen) loads per acre were determined for Coyote Creek and Dominguez Channel, followed by Malibu Creek. These results indicate a relatively high load per acre estimate for Malibu Creek, compared to more urbanized watersheds such as the Los Angeles River. These results are collaborated by the ANOVA analysis which indicated a significant difference in the nutrient results for Malibu Creek. As mentioned previously, the potential sources of nitrates in the Malibu Creek watershed may include greater use of fertilizer per acre and seepage from in-ground septic systems which are prevalent in this watershed.

<u>Other Water Quality Parameters</u> - The means of several constituents measured at the Malibu Creek MES were significantly different compared to the other MES. These constituents included alkalinity, calcium, chloride, hardness, magnesium, sodium, specific conductance, sulfate, and total suspended solids. This comparison indicated a greater mean concentration in mineral salts and ions in wet and dry weather runoff at the Malibu Creek MES. This may indicate a contribution from natural minerals from groundwater seepage that contains higher dissolved mineral concentrations potentially due to natural geologic sources within this watershed compared to the other watersheds in the County. Further evaluation of any potential differences in geology and soil types within the Malibu Creek Watershed is needed to draw any definitive conclusions.

<u>Solids (TDS, TSS, TOC</u>) – The highest mean total loadings for TDS were determined for the Los Angeles River, however, the total loads were only slightly lower for Ballona Creek, Coyote Creek, Malibu Creek and San Gabriel River. The Los Angeles River is the largest monitored watershed in the County. The highest TDS loadings per acre were calculated for Ballona Creek, Malibu Creek, and Coyote Creek. The lowest TDS per acre was indicated for Santa Clara River. Both Malibu Creek and the Santa Clara River watersheds are the least urbanized. The much higher TDS loadings from Malibu Creek suggest possible greater contributions from natural sources such as groundwater seepage into the creek that contains higher dissolved salts and metals than in Santa Clara River. These findings are collaborated by the ANOVA and Cluster Analysis results which indicated significant differences in the Malibu Creek water quality compared to the other watersheds with regard to TDS and other parameters that would suggest these same inputs and sources.

TSS total mean loads were highest for the Santa Clara River and lowest for Malibu Creek. The higher TSS for Santa Clara may indicate greater suspended sediment loads due to erosion of stream banks and disturbed areas. Special Studies being conducted in the Santa Clara WMA are investigating both the impact from development and increases in peak discharge. The mean loading of TSS per acre is highest for Ballona Creek, Los Angeles River, Coyote Creek and Santa Clara River. The lowest was for Malibu Creek. The higher TSS loadings per acre for most of these watersheds represent contributions from various urban sources within the more urbanized watersheds. As discussed above, the higher TSS loadings per acre for Santa Clara River, maybe related to erosion. This is also indicated by a low TDS loading per acre compared to the high TSS loading per acre for Santa Clara River, which correspond to a larger particle source such as soils (measured by the TDS) compared to dissolved constituents (measured by TSS).

The TOC mean loadings for 2004-2005 were highest in the Los Angeles River, followed by Coyote Creek and Ballona Creek. The lowest was for Malibu Creek. The highest mean loadings per acre was determined for Coyote Creek, followed by Ballona Creek and Dominguez Channel, and then the Los Angeles River. The lowest was for Santa Clara River. The lower relative loading per acre compared to the total mean loading for the Los Angeles River is likely due to large drainage area of this watershed. The higher TOC loadings both as totals and on a per acre basis correspond to greater urbanized areas of the total drainage area. TOC loadings appear to be an indicator of greater urbanization within the watershed.

Pesticides - The only pesticide that was detected above its WQO as part of the wet and dry weather Core Program monitoring was diazinon. The WQO was exceeded in 2001-2002 in the Dominguez Channel and Coyote Creek Watersheds, and in the Santa Clara Watershed during the 2004-2005 period, based on the annual mean of the samples collected at the MES.

TPH - Other notable trends that were observed in mean annual concentrations included a decreasing concentration in total petroleum hydrocarbons (TPH) for Ballona Creek, Coyote Creek and Santa Clara River Watersheds.

Toxicity – No strong patterns in toxicity were observed. The fewest toxic responses for all three tests performed were at San Gabriel River, Malibu Creek, and Santa Clara River. *Ceriodaphnia* survival may have decreased due to high concentrations of dissolved copper and zinc in the wet weather runoff.

Peak and High Intensity Storm Events – The potentially greater impact of high intensity storm events on water quality was indicated in the cluster analysis. Clusters for numerous COCs and key constituents were observed across watersheds, with the exception of Malibu Creek Watershed, for the 2004-2005 and 1997-1998 annual wet weather sampling. The greatest monthly precipitation occurred during these same years. High peak and intensity storm events resulted in greater mobilization and transport of sediment and particles that can increase turbidity, suspended solids, BOD and total metals when compared to the overall mean. Clusters were observed across multiple watersheds for the wet weather sampling for BOD, COD, turbidity, total volatile suspended solids, total iron, bacterial indicators, total and dissolved phosphorus, total copper, and total zinc. This analysis indicated that the high intensity and long-duration storm events, as experienced in the monitoring years 1997-1998 and 2004-2005, resulted in some of the greater overall impacts to water quality as measured at the MES.