3.1 Storm Water Monitoring Methods

The core monitoring program includes collection and analysis of storm water runoff at mass loading stations. Storm water was collected during three storm events at each mass loading station and analyzed for chemical constituents and toxicity to bioassay test organisms. This section describes storm water monitoring methodology.

3.1.1 Mass Loading Station (MLS) Site Selection

The 2002-2003 storm water monitoring program included eleven mass loading monitoring stations. The mass loading stations monitor large drainage areas with mixed land use characteristics. Their locations are shown in Figure 2-11. The mass loading monitoring site locations were selected by MEC, in conjunction with the San Diego Copermittees' Monitoring Workgroup, in consultation with the San Diego RWQCB. The primary site selection factors included:

- Suitability of the site drainage area to monitor area-wide contributions of storm water pollutant loading;
- Suitability of the site's hydrological characteristics to enable practical measurement of flow and collection of representative storm water samples;
- Maintenance of long-term data collection at appropriate existing monitoring stations (Agua Hedionda Creek, Tecolote Creek, and Chollas Creek);
- Safety from traffic and other hazards;
- Suitable siting for sampling equipment;
- Accessibility to phone lines (convenient, though not necessary for modem communications); and
- Crew access for retrieving samples and maintaining equipment during storm conditions.

The mass loading sites were selected to directly measure pollutant loads being discharged into San Diego's receiving waters by the major watersheds within the San Diego region. Monitoring sites were installed where flow from the catchment area passes a single hydrologically ratable point, suitable for measurements and sampling. In some instances, sites were located upstream of the drainage area discharge point for accessibility and/or to avoid tidal influences.

3.1.2 Monitoring Equipment

Flow was monitored at all stations using American Sigma flow meters. A variety of flow measurement technologies were utilized to accurately measure flow rates including ultrasonic sensors and submerged pressure transducers. The sensors provide a continuous measurement of river or stream stage (height) and relayed that information to the flow meter. The flow meter continually calculated flow rates by inserting the stage information into the preprogrammed discharge equation.

Field crews measured the flow rate of streams at stations that were not rated, using USGS stream profiling guidelines prior to the beginning of the storm season, and periodically throughout the storm season. This was accomplished by manual rating techniques using a hand held flow meter. The resulting discharge rates were used to calculate a discharge equation, which was utilized by the flow monitoring equipment at some stations. At other stations with well defined concrete trapezoidal channels (i.e. Tecolote and Chollas) velocity/stage measurements were utilized to calculate discharge rates.

3.1.3 Sampling Procedures

3.1.3.1 Grab Samples

Grab samples were collected for those constituents that are not amenable to composite sampling. The grab samples were analyzed for the following parameters:

Temperature
pH
Specific Conductance
Biochemical Oxygen Demand
Oil and grease
Total coliform
Fecal coliform
Enterococcus

Samples were collected from the horizontal and vertical center of the channel if possible and kept clear from uncharacteristic floating debris. Because oil and grease and other petroleum hydrocarbons tend to float, oil and grease grab samples were collected at the air/water interface. Bacteria samples were preserved with a small amount of sodium thiosulfate and crews were careful not to wash out the preservative by overfilling the bottle. After collecting the bacteria sample, the bottle was placed in a clean Ziploc bag and put on ice for transport to the laboratory and analysis within 6 hours.

3.1.3.2 Composite Samples

Storm water samples were flow-weighted composites of the storm event. Where practical, the entire event was sampled. At some monitoring stations this was not practical due to the runoff characteristics of the watershed. For example, San Luis Rey and San Diego Rivers are large water bodies that continue to rise following the initial flow of runoff during storm events and it is not uncommon to see a double peak in the hydrographs. The first peak (usually smaller than the second) is the immediate response from runoff. The second peak is the result of groundwater flowing from the unsaturated zone that appears as a much larger peak, usually hours or days after rainfall has stopped. Sampling this flow would dilute the constituents of concern in the composite sample and may skew results when compared with other watersheds that see only immediate runoff response. For large watersheds, the sampling strategy was determined by using best professional judgment to monitor rainfall and runoff and determine the appropriate time to terminate sampling.

In general, a larger concentration of pollutants from urban runoff enters the storm drainage system during the initial stages of flow and during peak flow and/or peak rainfall intensity for small rainfall events, which are typical in our region (Tiefenthaler et al. 2001; City of Austin 1990). Therefore a successful event was determined by capturing (at a minimum) the initial peak of runoff from the storm event.

Storm teams evaluated telemetry data from the monitoring sites during storms to ensure all of these conditions were met before terminating sampling. Storm hydrographs for each of the monitored events are presented in Appendix A.

3.1.4 Stream Rating Methods

During storms, flow rate at each of the monitoring sites was determined by water velocity and stream stage (water level) sensors that are typically secured to the bottom of the channel. However, to better quantify flow rates and produce a more complete rating curve, each of the streams was also assessed using the classical stream rating method developed by the U.S. Geological Survey.

Stream rating on Sweetwater River

The materials used for the stream rating included a Marsh-McBirney Model 2000 Portable Flow Meter connected via a cable to an electromagnetic open channel velocity sensor. The sensor is attached to a stainless steel top-setting wading rod. To make a flow measurement, a tape measure was stretched across the stream, perpendicular to flow and secured on both banks of the stream. The tape was positioned so that it was suspended approximately one foot above the surface of the water. The distance on the tape directly above the waterline (where the water met the bank) was then recorded as the initial point. Generally, depth and flow were both zero at this point unless the bank was very steep. The first measurement was then made at the first point where there was adequate depth (at least 0.2 feet) and measurable velocity. At this point three measurements were made: water depth, velocity, and distance from the bank (the initial point). Subsequent depth, velocity, and distance measurements were then made incrementally across the entire width of the channel so that a minimum of ten points were measured per site. Water depth was determined from calibrations on the wading rod in tenths of feet. Velocity measurements were made at each point along the transect by positioning the velocity sensor perpendicular to flow at 60% of the water depth (from the surface). The top setting wading rod is designed so that the sensor can be conveniently positioned at the appropriate depth. Water velocity was measured in feet per second.

Data from the field measurements were entered into a computer model that calculates the stream's cross-sectional profile from the depth and distance from bank measurements. Total flow across the channel was determined by integrating the velocity measurements over the cross-sectional surface area of the stream channel. The result is an instantaneous flow measurement in cubic feet per second. Several stream ratings were measured for each of the streams where flow was measurable after a storm and combined to produce a rating curve for each stream. Information from the rating curve was used to more accurately predict expected flow rates and appropriate sampling frequencies during storms.

3.1.5 Sample Handling and Processing

In accordance with USEPA sampling protocols and the MEC Quality Assurance Program, all samples collected were stored in the appropriate container type for the analytical method to be performed. Additionally, all samples were stored chilled in ice-chests for transfer to the laboratory and between laboratories. The sample containers used were certified as clean and sterile by the laboratory performing the analyses. Chain-of-custody forms were completed for each sample and accompanied the samples to the laboratories and between laboratories at all times.

Sample preservatives and holding time requirements for each analytical measurement (Table 3-1) were as recommended by the Standard Methods for Examination of Waters and Wastewaters and the USEPA methods. All storm water samples were transported from the field to the laboratory under MEC chain-of-custody procedures. Samples moved between laboratories were transported under the laboratories' chain-of-custody procedures. Samples were submitted by MEC to EnviroMatrix Analytical, Inc. in San Diego and Aqua-Science in Davis, California.

3.1.6 Laboratory Analysis

3.1.6.1 Chemical Constituents

General physical and chemical constituents were analyzed by EnviroMatrix Analytical, Inc. with the exception of field measured constituents (pH, conductivity, and temperature) and the organophosphate pesticides diazinon and chlorpyrifos. The field measurements were made by MEC field technicians and scientists during field sampling activities.

Both the enzyme-linked immunosorbant assay (ELISA) method and EPA 8141A were utilized to test for diazinon and chlorpyrifos. Based upon recommendations from the 2002-2003 report, the 8141A method was added to provide an ELAP-approved methodology. The ELISA technique was continued in the event the chemistry laboratory was unable to consistently meet the low reporting limit required for these analytes. Unfortunately, the chemistry laboratory was not able to consistently meet the low reporting limit requirements this year and the ELISA data was utilized for organophosphate pesticides.

The use of the ELISA method was originally adopted because in the 2000-2001 monitoring season, the chemistry laboratory was unable to consistently provide low detection limit reporting for diazinon and chlorpyrifos throughout wet season monitoring. The changes in detection limit through the wet season and the use of qualifiers in the analytical data reports made an assessment of diazinon concentrations at mass loading stations difficult. Further, the higher detection limits reported by the laboratory in 2000-2001 precluded correlation of toxicity effects to diazinon concentrations because the reporting limits provided by the laboratory were above the concentrations at which diazinon is known to cause toxicity to aquatic organisms. For these reasons, in the 2001-2002 and 2002-2003 monitoring seasons, MEC utilized the ELISA technique performed by Aqua Science in Davis, California. The ELISA method has been used successfully in other monitoring programs to determine concentrations of diazinon in surface waters and urban runoff. This technique was used in the source identification study performed in Chollas Creek (MEC 2002). The use of ELISA provides sensitive and reliable results (Sullivan 2000).

The following table (Table 3-1) lists chemical constituents measured in this monitoring program.

Table 3-1. Analytical requirements for mass loading stations.

Constituent	Volume Required	Method	Reporting Limit	Units	Holding Time
General Physical and Inorganic Non-Metals					
Total Dissolved Solids (TDS)	100 mL	SM 2540C	20	mg/L	7D
Total Suspended Solids (TSS)	100 mL	SM2540D	20	mg/L	7D
Turbidity	100 mL	SM 2130A-B	0.1	NTU	48H
Total Hardness	150 mL	SM 2340B	10	mg/L	6M
pH	In field	EPA 150.1	0.1	S.U.	I
Specific Conductance	In field	SM 2510B	1	umhos/cm	28D
Temperature	In field				I
Dissolved Phosphorus	250 mL	SM 4500PE	0.05	mg/L	48H
Total Phosphorus	250 mL	SM 4500PE	0.05	mg/L	28D
Nitrate and Nitrite	200 mL	SM4500NO2-NO3	0.1/0.05	mg/L	48H
Total Kjeldahl Nitrogen (TKN)	500 mL	SM4500C	0.1	mg/L	28D
Ammonia	250 mL	SM 4500NH3D	0.1	mg/L	28D
Biological Oxygen Demand, 5-day (BOD)	1000 mL	SM5210B	2	mg/L	48H
Chemical Oxygen Demand (COD)	25 mL	EPA 410.4	25	mg/L	28D
Organics					
Oil and Grease (O&G)	500 mL	EPA 413.1	1	mg/L	14D
Diazinon	1 liter	ELISA/8141A	0.05	µg/L	14D
Chlorpyrifos	1 liter	ELISA/8141A	0.05	µg/L	14D
Methylene Blue Active Substances (MBAS)	250 mL	SM 5540C	1	mg/L	48H
Metals, Dissolved					
Antimony (Sb)	75 mL	EPA 200.8	0.002	mg/L	6M
Arsenic (As)	75 mL	EPA 200.8	0.001	mg/L	6M
Cadmium (Cd)	75 mL	EPA 200.8	0.001	mg/L	6M
Chromium (Cr)	75 mL	EPA 200.8	0.005	mg/L	6M
Copper (Cu)	75 mL	EPA 200.8	0.005	mg/L	6M
Lead (Pb)	75 mL	EPA 200.8	0.002	mg/L	6M
Nickel (Ni)	75 mL	EPA 200.8	0.002	mg/L	6M
Selenium (Se)	75 mL	EPA 200.8	0.002	mg/L	6M
Zinc (Zn)	75 mL	EPA 200.8	0.02	mg/L	6M
Metals, Total					
Antimony (Sb)	75 mL	EPA 200.8	0.002	mg/L	6M
Arsenic (As)	75 mL	EPA 200.8	0.001	mg/L	6M
Cadmium (Cd)	75 mL	EPA 200.8	0.001	mg/L	6M
Chromium (Cr)	75 mL	EPA 200.8	0.005	mg/L	6M
Copper (Cu)	75 mL	EPA 200.8	0.005	mg/L	6M
Lead (Pb)	75 mL	EPA 200.8	0.002	mg/L	6M
Nickel (Ni)	75 mL	EPA 200.8	0.002	mg/L	6M
Selenium (Se)	75 mL	EPA 200.8	0.002	mg/L	6M
Zinc (Zn)	75 mL	EPA 200.8	0.02	mg/L	6M

See Section 1, Table 1-5 for additional constituents monitored.

3.1.6.2 Toxicity Testing

Toxicity testing is an effective tool for assessing the potential impact of complex mixtures of unknown pollutants on aquatic life in receiving water. Rather than performing chemical analysis on a sample for a host of compounds potentially toxic to aquatic life, this approach utilizes a laboratory test species to provide a direct measure of the toxicity of the sample. Interactions among the complex mixture of chemicals and physical constituents can lead to additive or antagonistic effects, potentially causing an individual compound to become either more or less toxic than it would be were it isolated. While the potential effects of these interactions cannot be derived from simple chemical measurements, they are directly accounted for in toxicity tests. If persistent toxicity is detected, specialized toxicity identification evaluations (TIE) may be used to help characterize and identify constituent(s) causing toxicity. Toxicity testing can provide information on both potential short-term or "acute" effects as well as longer-term "chronic" effects. Historically, toxicity tests, including TIEs, have been used to assess both short and long term impacts of point source discharges (e.g., POTW, power plant and industrial effluents) on aquatic life in a receiving water body. However, these tools can be applied to non-point source discharges, such as urban runoff.

Toxicity testing provides the only direct means to assess the potential toxicity of storm water runoff on receiving waters. Living organisms are able to integrate effects of multiple contaminants and account for the inherent properties of the sample matrix (e.g., hardness and alkalinity of a storm water sample) that influence bioavailability and hence toxicity. However, the same elements that make these tools so effective can contribute to variability in the response. Living organisms respond to a host of factors other than contaminants. If animals are stressed in any way prior to testing, variability of the test organism response may increase and produce equivocal results. The use of controls and reference toxicant testing are quality assurance and quality control measures that have been put in place to identify changes in test organism sensitivity due to stress or other factors. Naturally occurring characteristics of the sample matrix can also affect organism response. For example, mortality of test organisms can result from extreme variations in water hardness. Consequently, understanding the importance of such features on test organism response is critical for the accurate interpretation of test results. The test procedures employed to date represent the culmination of some 40 years of research. While this does not guarantee that they are employed properly in every circumstance, there is a wealth of information to document the utility of such procedures.

Freshwater species were used to evaluate the potential impacts of storm water at mass loading stations. These included the Santa Margarita River, San Diego River, Chollas Creek, Tecolote Creek, Escondido Creek, Peñasquitos Creek, San Luis Rey River, Sweetwater River, Tijuana River, Agua Hedionda Creek, and San Dieguito River. It is important to note that, ultimately, all of the receiving water bodies for these drainage basins are estuarine/marine (e.g., San Diego Bay, Mission Bay, various coastal lagoons and estuaries). The extrapolation of these freshwater species tests to evaluate the potential impact in the downstream marine/estuarine environments can be problematic. For example, the organic ligands present in an estuarine environment may make contaminants unavailable for uptake and reduce toxicity. In addition, marine organisms often have different sensitivities to contaminants than freshwater organisms. The core monitoring program includes ambient bay and lagoon monitoring to assess long term impacts to marine/estuarine receiving waters.

Three species were used in this monitoring program. The cladoceran *Ceriodaphnia dubia*, represents the invertebrates that live in the water column and serve as a source of food for larger invertebrates and small fish. This species is known to be sensitive to metals and pesticides in water, as well as other contaminants. The freshwater amphipod *Hyalella azteca* is an invertebrate that is associated with the sediment at the bottom of streams and lakes. It again serves as a food source for larger invertebrates as well as fish. This species is generally sensitive to metals and pesticides, as well as nitrogen compounds such as ammonia. The freshwater plant *Selenastrum capricornutum* is a unicellular alga that is present in the water column of lakes and streams. It is at the base of the food chain in freshwater systems. It is sensitive to herbicides and metals, but its growth is also greatly affected by nutrient loads (e.g., nitrates and phosphorus) in a water body. Nutrients tend to stimulate the growth of *S. capricornutum* (causing an algal bloom) and, if the nutrient loads are high enough in a water body, they can offset the toxic effect that contaminants might otherwise produce. Toxicity tests were conducted by MEC's laboratory in Carlsbad, California.

Ceriodaphnia dubia

Samples from mass loading stations were tested for toxicity according to the USEPA protocol (EPA-821-R-02-013). This protocol was developed for testing the seven-day chronic toxicity of point-source discharges where the effluent is diluted considerably in the receiving waters. Laboratory test organisms are placed in small containers of effluent sample and monitored over time to compare the response of organisms placed in non-toxic control water to the sample water. The sample is diluted (with control water) to several known concentrations before the test and test organisms are added to each concentration. The standard USEPA recommended dilution series (100%, 50%, 25%, 12.5%, 6.25%, and a control) are used for all toxicity tests. The test solutions are renewed and animals are fed daily. In the *Ceriodaphnia* chronic test, single females are placed in individual test chambers (ten test chambers per concentration) and the number of dead organisms along with the number of offspring produced per organism is recorded each day. When the controls reach an average of at least fifteen young per surviving adult, and 60% of the controls have had three broods, the test is terminated (day six to eight). Additionally, the acute, 96-hour (4-day) endpoint data (survival) is also collected from the seven-day chronic test. Only the original test organisms with which the test was begun were used for the calculation of both the acute and chronic survival endpoints.

Test Acceptability

Acceptability of the test is determined by evaluating the response of the control organisms. The test is considered acceptable if control survival is greater than 80%, control reproduction is greater than or equal to an average of fifteen young per adult, and more than 60% of the adults produce three broods by day eight of the test. If any one of these test acceptability standards is not met then the test is considered invalid and no further analysis is performed.

A reference toxicant test is also run to establish whether the test organisms used fall within the normal range of sensitivity. The reference toxicant test is conducted with known concentrations of a given toxicant (e.g., copper sulfate is used for *Ceriodaphnia*). The effect on the survival and reproduction of the animals is compared to historical laboratory data for the test species and reference toxicant. If the values are within two standard deviations of the historical average, the test organisms are considered to fall within the normal range of sensitivity.

The concentration that causes 50% mortality of the organisms (the median lethal concentration, or LC_{50}) is calculated from the data for 96 hours (96-hour acute LC_{50}) and for day seven (seven-day chronic LC_{50}) using USEPA methods. The LC_{50} values are point-estimates expressed as “percent sample;” the lower the LC_{50} percentage the more toxic the sample. For acute regulatory standards, the LC_{50} acute value is used. For chronic regulatory standards, the seven-day chronic effects are estimated using the NOEC, or No Observed Effect Concentration, for both survival and reproduction. This is the highest concentration tested in which there was no statistically significant effect on the survival or reproduction compared to the control response. The lower the NOEC, the more toxic the sample.

For regulatory purposes, the endpoints described above are transformed into toxic units (TU). Toxic units are further divided into toxic units acute (TUa) and toxic units chronic (TUc) for acute and chronic endpoints, respectively. As toxicity increases, the toxic units increase. If the TU limit in the permit is exceeded, the sample is out of compliance (similar to an exceedance of a chemistry limit). The permit limit for chronic toxicity is a TUc of 1 and the permit limit for acute toxicity is a TUa of 0 due to the differences in their derivation.

TUa and TUc values are calculated very differently and are not interchangeable or related. The TUa equals $100/LC_{50}$. If the LC_{50} is greater than 100%, then the TUa is calculated by the following formula: TUa = log(100-S)/1.7 where S = percentage of survival in 100% sample. If S > 99%, the TUa is reported as zero, which is the lowest TUa value possible. The percent survival in the 100% concentration used in this formula is expressed as a percentage of the control survival. The TUc equals 100/NOEC. The lowest TUc possible, which indicates no toxicity, is 1. TUc values were calculated separately for survival and reproduction endpoints.

Hyalella azteca

Storm water samples from each of the mass loading stations were also evaluated for acute toxicity using the freshwater amphipod *Hyalella azteca* according to a modified version of the USEPA protocol for testing sediment-associated contaminants with freshwater invertebrates (EPA-821-R-02-012). This protocol provides test methods for measuring acute and chronic toxicity in *Hyalella* exposed to freshwater sediments, as well as a test method for conducting a water-only acute reference toxicant test. The reference toxicant test protocol was modified to conduct the toxicity testing on samples collected from the mass loading stations. The test solution is prepared using the dilution series described above, and placed in 250-mL aliquots into 4 replicate test chambers. Clean sand is placed as a thin "monolayer" in the bottom of the test chamber and 10 organisms per replicate are added. The animals are exposed for four days and fed on day 2. At the end of the test, the survivors are removed from the sand and counted. A 96-hour LC_{50} is calculated from this data.

Prior to analysis of the data, test acceptability is determined by evaluating the response of the control organisms. The test is considered invalid if survival of control animals is less than 90%. As with *Ceriodaphnia*, a reference toxicant test using copper sulfate is also conducted with *Hyalella* to establish whether the test organisms used fall within the normal range of sensitivity.

If the test data meet acceptability criteria, the LC_{50} is calculated from the 96-hour test data. From this data, a toxic unit acute (TUa) is calculated as described above.

Selenastrum capricornutum

In previous years, toxicity testing for the storm water monitoring program was conducted using a freshwater vertebrate species: the fathead minnow (*Pimephales promelas*). Results of tests conducted with this species failed to show any toxicity relative to the other species tested. Consequently, the San Diego Regional Water Quality Control Board (RWQCB) approved the replacement of this test with a chronic *Hyalella* toxicity test measuring a sublethal endpoint (e.g., growth). Attempts to develop a short-term sublethal toxicity test with *Hyalella* during the 99/00 and 00/01 storm seasons proved unsuccessful due to the variability of the growth endpoint. Consequently, it was recommended and the RWQCB subsequently approved replacing the proposed *Hyalella* chronic test with the *Selenastrum capricornutum* chronic test. This algal species has the potential to be sensitive to metals (in waters low in nutrients) and herbicides. This is the second season that this test has been used to assess toxicity in this storm water monitoring program.

Samples from the mass loading stations were tested for toxicity according to the USEPA protocol (EPA-821-R-02-013) using the unicellular algae *Selenastrum*. This protocol was developed for testing the 96-hour chronic toxicity of point-source discharges. The sample and the control water are spiked with equal amounts of nutrients and subsequently filtered to remove any unicellular algae that might be present prior to test initiation. The concentration series is prepared and 50-mL aliquots are placed into four replicate test chambers. Approximately 10,000 cells per mL are added to the test chamber and placed in random order under high-intensity 24-hour light for four days. The test chambers are shaken twice and randomized daily. At the end of the test period, chambers are analyzed for turbidity (absorbance). Cell density is determined by counting a subset of the sample under a microscope and then plotted against turbidity to calculate cell densities for all concentrations.

Test acceptability is determined by evaluating the response of the control organisms. The test is considered invalid if the criterion of a cell density of 200,000 cells per mL in the control is not met. Variability between the control replicates should not exceed 20%. A reference toxicant test using copper sulfate is also run parallel with the test to establish the sensitivity of the organisms.

If the test data meet acceptability criteria, inhibition concentrations, an IC_{25} and an IC_{50}, are calculated from the data: the concentrations that cause a 25% or 50% inhibition in the growth, or cell density, of the algae. A NOEC is also calculated from this data and the endpoint is recorded as a TUc, similar to the *Ceriodaphnia* test.

*(note: the name of this species has recently been changed to *Pseudokirchneriella subcapitata*)

3.1.6.3 Microbiology Testing

Measures of bacteria from grab samples were made by MEC Analytical Systems, Inc. microbiology laboratory located in Carlsbad, California. Samples were collected during the storm event using grab poles and aseptic techniques by MEC field technicians and scientists and delivered to the microbiology laboratory within the 6 hour holding time requirement. Sample analyses was initiated immediately upon receipt for all three indicators by multiple tube fermentation, total coliform using SM 9221B, fecal coliform using SM 9221E, and *Enterococcus* using SM9230. All results were reported to a most probable number value with no "greater than" values reported.

3.2 Storm Event Summary

3.2.1 Representative Storm Event

Estimation of a representative storm event in the San Diego region was based on the statistical evaluation of the long-term data records from the National Weather Service rain gauge located at Lindbergh Field. Based on the results of this statistical analysis, the "typical" storm event at Lindbergh Field yields 0.19 to 0.57 inches of rain and lasts 6 to 12 hours. Since the depth and duration of a typical storm event varies in different parts of the county where monitoring stations are located, storm events forecast to be greater than 0.10 inches were considered viable events for mobilization. Table 3-2 provides all rainfall measured during the 2002-2003 storm season at Lindberg Field.

Table 3-2. Total rainfall at Lindbergh Field, San Diego, CA for October 2002 – April 2003.

Date	Measured Rain (inches)	Date	Measured Rain (inches)
1 Oct 02	0.01	12 Feb 03	1.20
26 Oct 02	0.03	13 Feb 03	0.93
8 Nov 02	0.13	14 Feb 03	0.35
9 Nov 02	0.07	25 Feb 03	1.48
28 Nov 02	0.02	26 Feb 03	0.11
29 Nov 02	0.10	27 Feb 03	0.26
16 Dec 02	0.40	04 Mar 03	0.15
17 Dec 02	0.05	15 Mar 03	0.80
18 Dec 02	0.05	16 Mar 03	0.41
20 Dec 02	0.43	13 Apr 03	0.03
21 Dec 02	0.82	14 Apr 03	1.06
29 Dec 02	0.23	15 Apr 03	0.03
20 Jan 03	0.02	17 Apr 03	0.27
8 Feb 03	0.03	22 Apr 03	0.02
11 Feb 03	0.52	**02-03 Total**	**10.01**

*Excludes trace amounts of rainfall
Source: www.wrh.noaa.gov/sandiego/climate/lcdsan-archive.htm

3.2.2 Precipitation During Monitored Events

Rainfall during the 2002-2003 wet season was slightly below the average of 10.44 inches (NWS 2002). Rainfall totals for each mass loading station are presented in Table 3-3 for each of the three monitored storm events. Rainfall distributions were calculated by interpolating between rainfall amounts from available National Weather Service and San Diego County ALERT rain gages for the San Diego County area and data available form rain gauges installed at the mass loading stations. Using ArcView, an inverse distance weighting interpolation method was used to create a color-coded grid of rainfall values across the San Diego County watersheds. Figures 3-1 through 3-5 present the countywide rainfall totals from the model results.

Table 3-3. Rainfall summary for monitored storm events.

MLS	8-9 Nov 02	16-17 Dec 02	11-12 Feb 03	25 Feb 03	15 March 03
Santa Margarita River	-	0.60	1.93	2.37	-
San Luis Rey River	1.00	-	2.01	2.73	-
Agua Hedionda Creek	0.72	-	1.93	1.93	-
Escondido Creek	0.78	-	1.92	1.74	-
San Dieguito Creek	-	-	1.85	1.63	1.43
Peñasquitos Creek	0.64	0.80	1.77	-	-
Tecolote Creek	0.38	0.61	1.86	-	-
San Diego River	0.38	0.61	1.69	-	-
Chollas Creek	0.37	-	1.51	1.24	-
Sweetwater River	-	0.72	1.45	1.07	-
Tijuana River	0.36	-	1.25	1.25	-

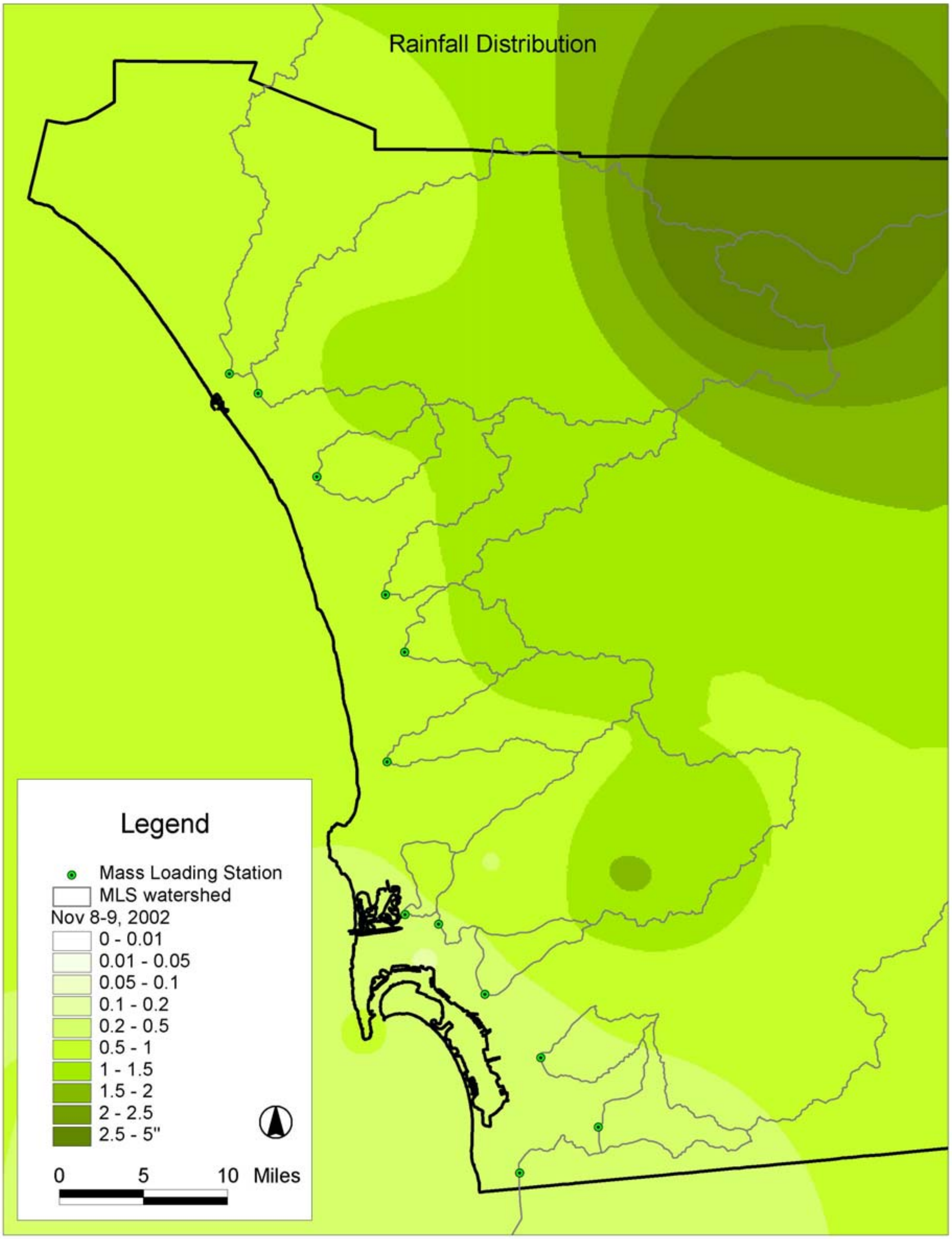

Figure 3-1. November 8-9, 2002 rainfall distribution for San Diego County.

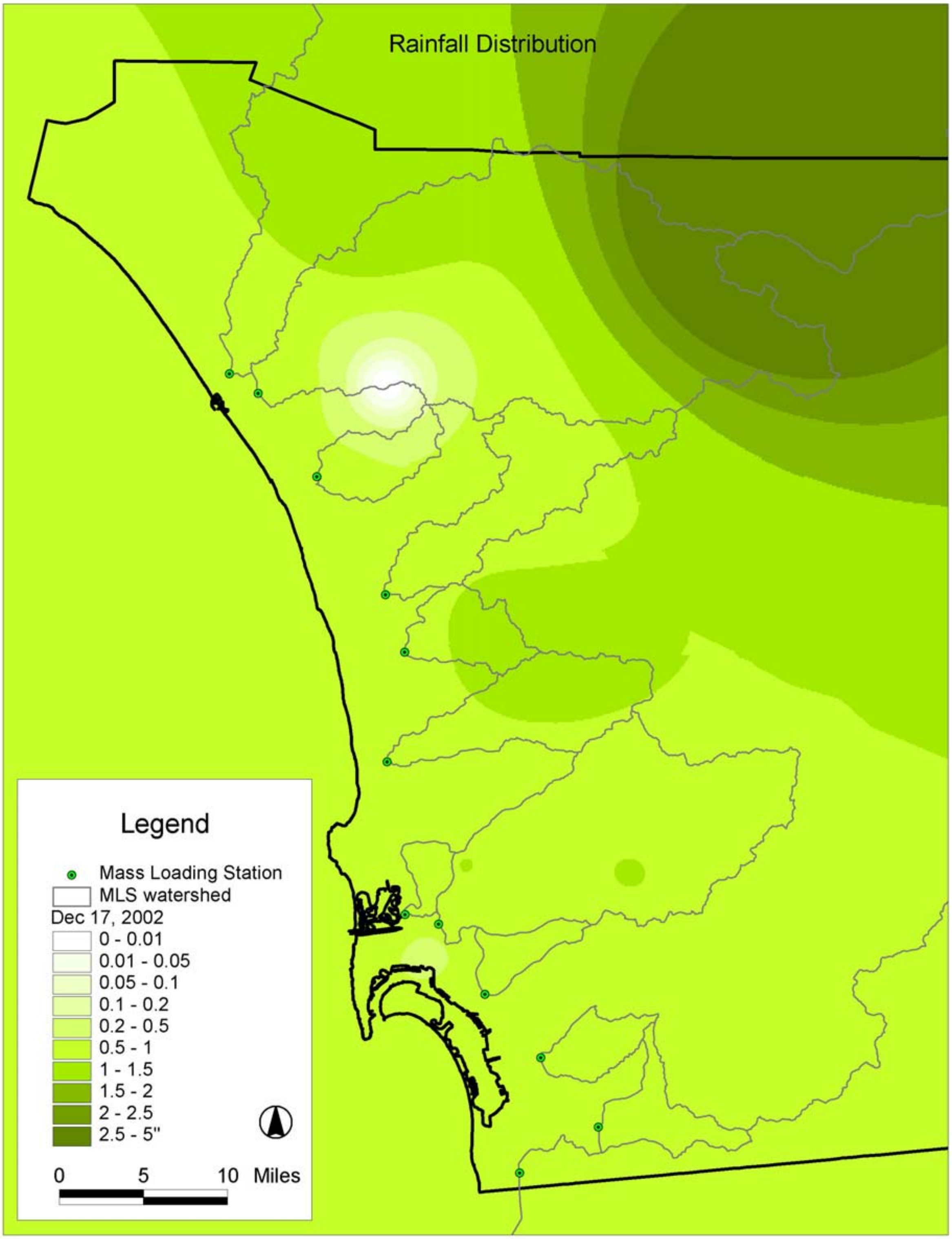

Figure 3-2. December 17, 2002 rainfall distribution for San Diego County.

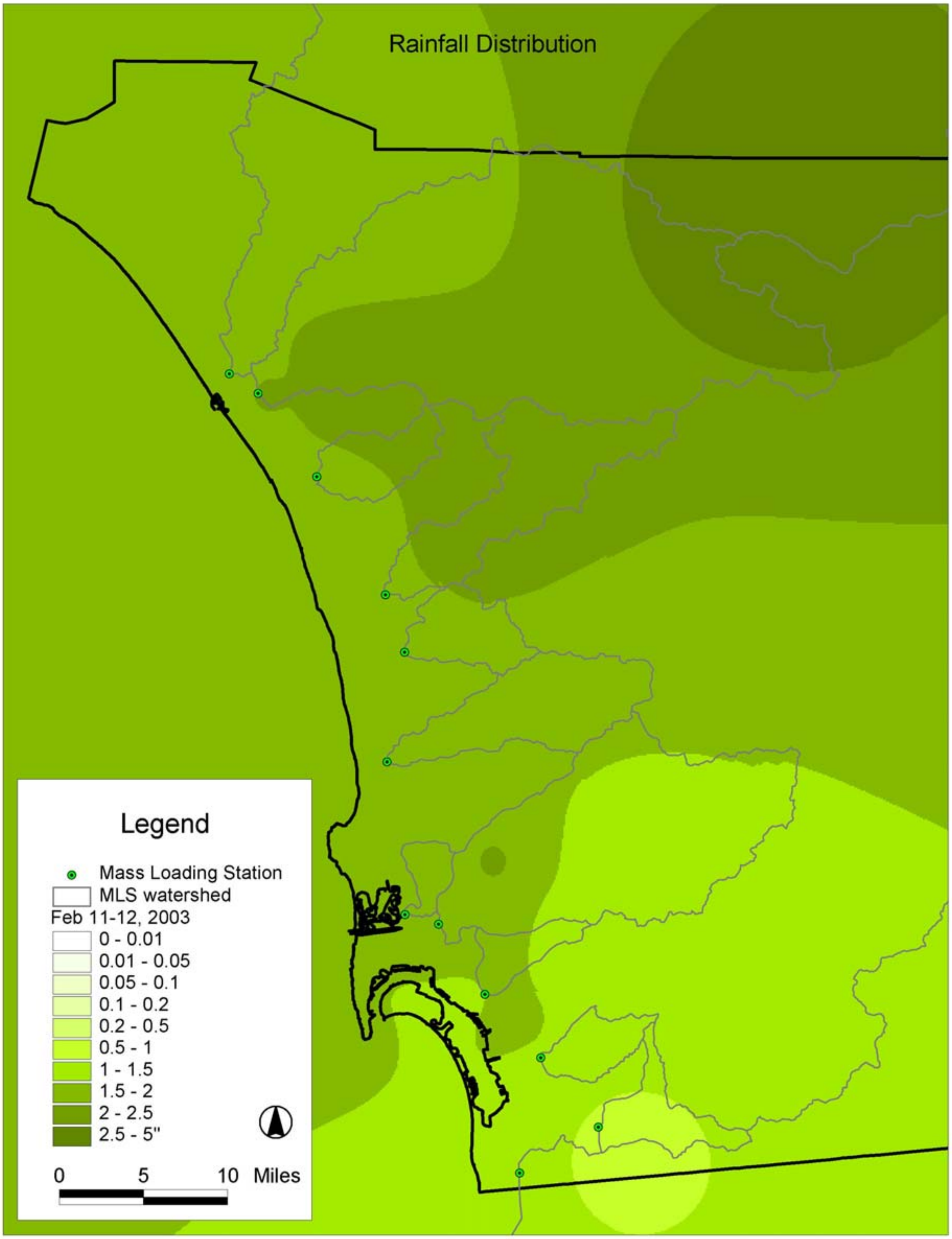

Figure 3-3. February 11-12, 2003 rainfall distribution for San Diego County.

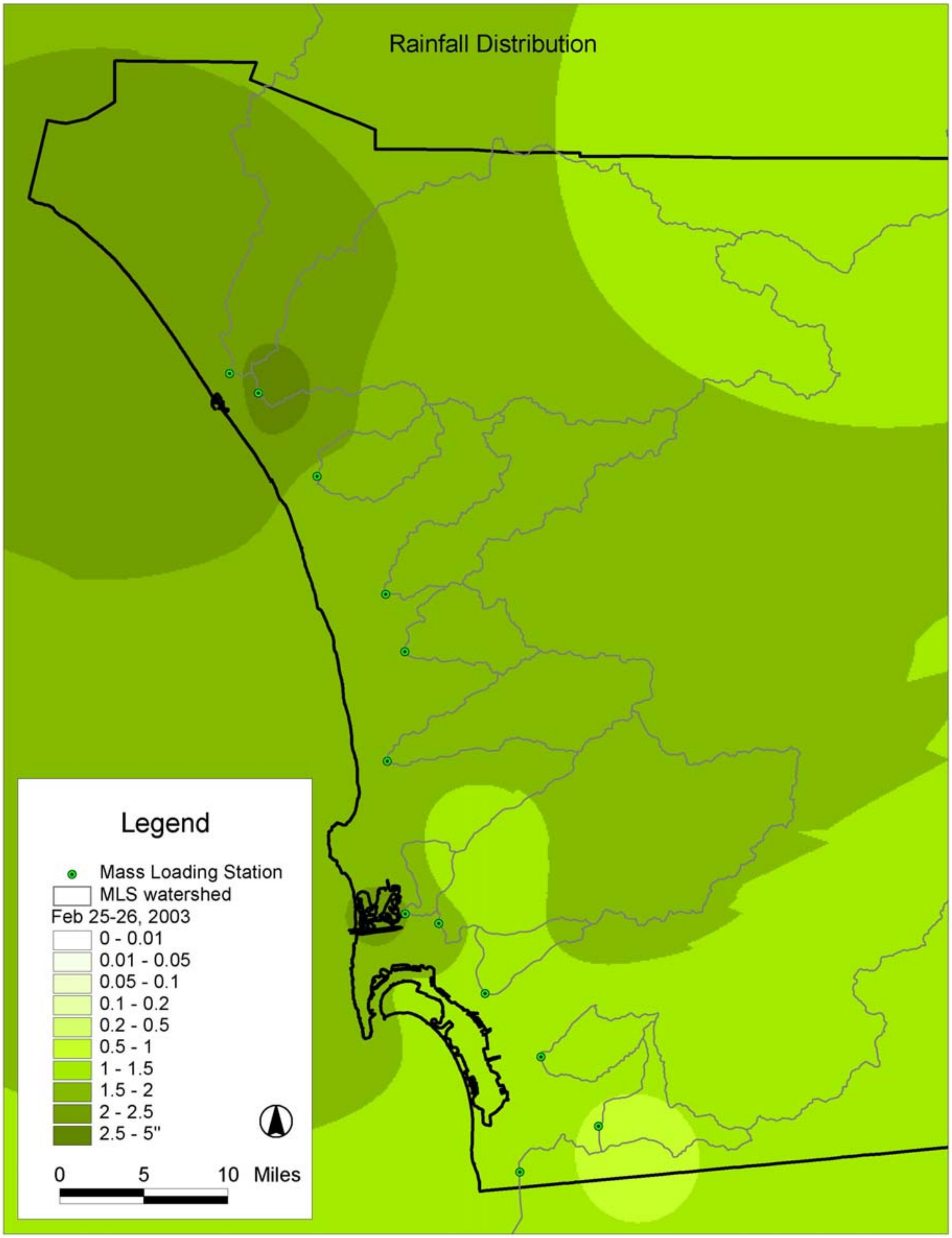

Figure 3-4. February 25-26, 2003 rainfall distribution for San Diego County.

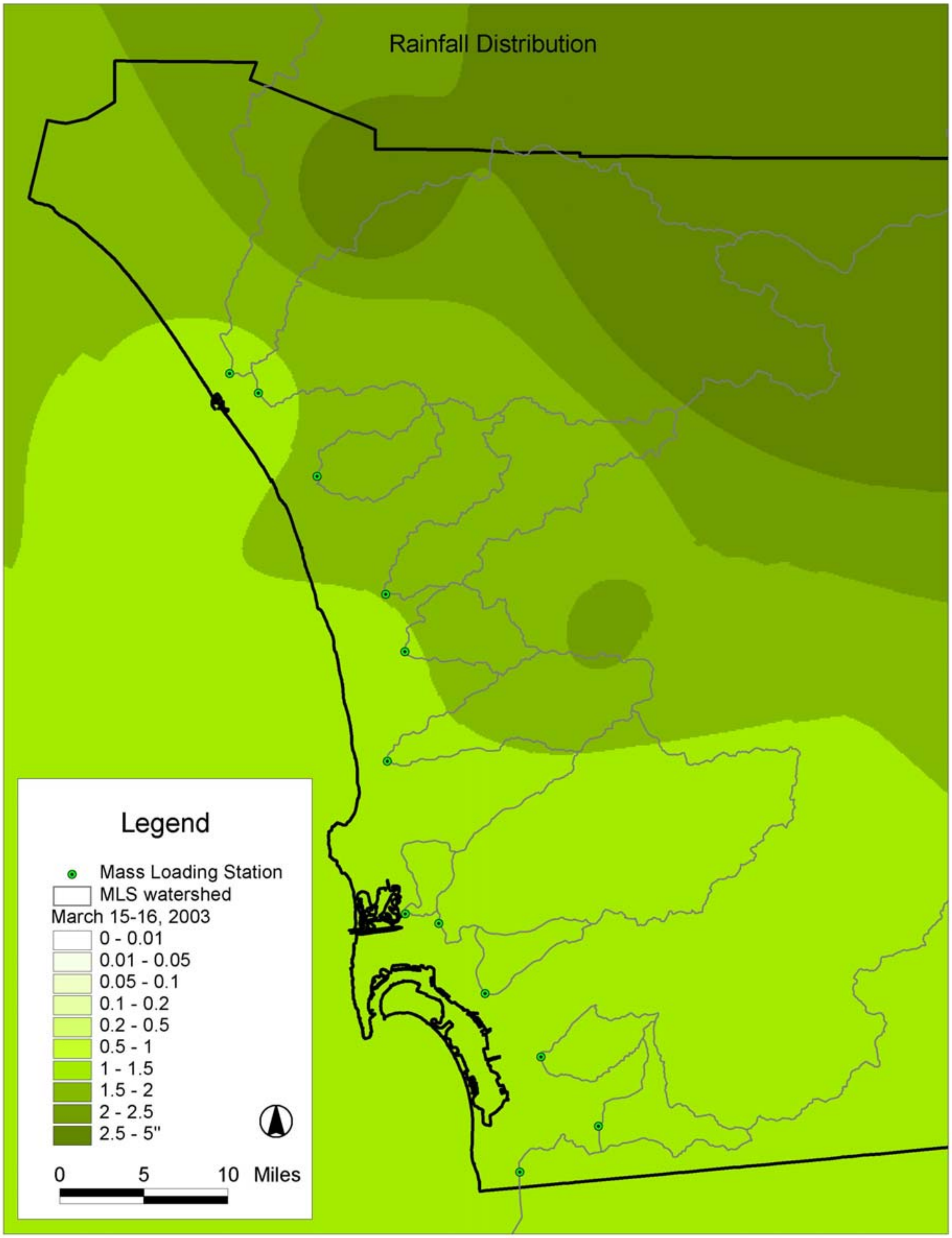

Figure 3-5. March 15-16, 2003 rainfall distribution for San Diego County.

3.2.3 Storm Water Runoff During Monitored Events

The design of the storm water monitoring program is based upon the isolation of individual storm events. Storm water runoff sampling protocol requires that a flow-weighted composite sample be obtained over the duration of runoff in order to sample total flow resulting from the precipitation event. Water quality sampling was terminated based upon the end of the precipitation and cessation of storm water flow. In larger watersheds with extended periods of runoff response, it was often necessary to manually terminate sampling of runoff in order to prevent sampling commingled groundwater. Hydrographs for each monitored event at the eleven mass loading stations that recorded flow are presented in Appendix A. The Navy did not submit flow data for the Santa Margarita River mass loading station.

3.3 Storm Water Monitoring Results

Each mass loading station was monitored during three separate storm events during the 2002-2003 wet weather monitoring season. Samples were collected at mass loading stations in the Santa Margarita River, San Luis Rey River, Agua Hedionda Creek, Escondido Creek, San Dieguito Creek, Peñasquitos Creek, Tecolote Creek, San Diego River, Chollas Creek, Sweetwater River, and Tijuana River. Results of wet weather monitoring are presented in Table 3-4.

This section includes the results from the two storm events collected at Santa Margarita River by the US Marine Corps Base. The data reported from the Santa Margarita mass loading station was analyzed by different analytical testing laboratories than all other stations. In some cases, the detection limits reported for Santa Margarita are different than those reported for the other stations.

3.3.1 Bacteria

During the 2002-2003 storm season, grab samples were collected at mass loading stations during storm events for bacteria analysis. Samples were analyzed within required holding times for total coliform, fecal coliform, and *Enterococcus*.

As a reference, the Basin Plan standards for REC-1 and REC-2 are used for comparison in those watersheds where they apply. Most storm water runoff in urbanized areas is anticipated to exceed bacterial water quality criteria for water contact. However, this is not always the case.

The Basin Plan REC-1 criteria of 400 MPN/100 mL for fecal coliform applies to most inland surface waters including Santa Margarita River, San Luis Rey River, Agua Hedionda Creek, Escondido Creek, San Dieguito River, Peñasquitos River, San Diego River, and Sweetwater River. This standard was not exceeded during two storm events at San Luis Rey River and one event at San Dieguito River during the 2002-2003 storm season. The one storm event that did exceed REC-1 standards at San Luis Rey River was the same order of magnitude as the REC-1 standard with counts of 500 MPN/100 mL. The fecal coliform standard was exceeded at San Dieguito River with counts of 700 MPN/100 mL, the same order of magnitude as the REC-1 standard. However, another event resulted in counts of 5,000 MPN/100 mL at this location. Both San Luis Rey and San Dieguito Rivers did not exceed REC-1 criteria during the 2001-2002 storm season.

Table 3-4. Results of wet weather monitoring.

ANALYTE	UNITS	WQO	Watershed	Santa Margarita		San Luis Rey River			Carlsbad						San Dieguito River			Peñasquitos Lagoon		
			Source	Santa Margarita 2/12/03	Santa Margarita 2/25/03	San Luis Rey 11/8/02	San Luis Rey 2/11/03	San Luis Rey 2/25/03	Agua Hedionda 11/08/02	Agua Hedionda 2/11/03	Agua Hedionda 2/25/03	Escondido Creek 11/08/02	Escondido Creek 2/11/03	Escondido Creek 2/25/03	San Dieguito Creek 2/11/03	San Dieguito Creek 2/25/03	San Dieguito Creek 3/15/03	Peñasquitos Creek 11/08/02	Peñasquitos Creek 12/16/02	Peñasquitos Creek 2/11/03
General/Physical/Organic																				
Electrical Conductivity	umhos/cm			1050	492	4190	1965	2680	955	588	548	1826	1192	1675	277	2700	257	1827	1939	2600
Oil & Grease	mg/L	15	USEPA Multi-Sector General Permit	<5	<5	<1	<1	<1	<1	1.54	<1.00	<1.00	1.16	<1.00	<1.00	<1.00	1.38	3.24	<1.00	1.39
pH	pH scale	6.5-8.5	Basin Plan	7.5	7.4	**6.40**	7.32	7.67	7.76	7.50	7.67	7.55	7.46	7.41	7.83	7.56	7.64	7.46	7.63	7.78
Bacteriological																				
Enterococci	MPN/100mL			130	300	500	800	16,000	50,000	13,000	110,000	50,000	80,000	80,000	17,000	5,000	1,700	230,000	500	22,000
Fecal Coliform	MPN/100mL	400/4000	Basin Plan REC1/REC2	**>1600**	**>1600**	230	130	**500**	**23,000**	**7,000**	**5,000**	**13,000**	**23,000**	**22,000**	**5,000**	300	**700**	**30,000**	**500**	**1,700**
Total Coliform	MPN/100mL			>1600	>1600	300	300	1,700	80,000	50,000	50,000	30,000	50,000	80,000	50,000	3,000	13,000	500,000	1,400	50,000
Wet Chemistry																				
Ammonia as N	mg/L			<4	0.1	<0.1	<0.1	<0.1	0.25	0.25	0.62	0.29	0.32	0.41	0.52	0.20	0.13	<0.1	<0.1	<0.1
Un-ionized Ammonia as N	µg/L	25 (a)	Basin Plan	<28.9	0.57	<0.1	<0.43	<1.09	4.51	1.93	6.94	2.78	2.37	3.19	9.21	1.82	1.36	<0.84	<1.13	<1.35
Biochemical Oxygen Demand	mg/L	30	USEPA Multi-Sector General Permit	16	22	<2.0	3.34	2.02	4.32	20.4	5.6	4.07	9.93	5.0	15.9	2.51	3.89	5.55	<2.0	8.31
Chemical Oxygen Demand	mg/L	120	USEPA Multi-Sector General Permit	**185**	**447**	38	49	25	88	46	60	73	51	69	51	41	82	73	53	115
Dissolved Organic Carbon	mg/L			NA	NA	1.49	6.86	9.36	11.0	9.75	11.9	4.1	11.1	9.86	7.98	10.4	7.67	16.8	11.0	11.2
Dissolved Phosphorus	mg/L	2	USEPA Multi-Sector General Permit	0.26	0.34	0.22	0.19	0.10	0.13	0.20	0.14	0.32	0.32	0.13	0.11	0.08	<0.05	0.52	0.40	0.28
Nitrate as N	mg/L	10	Basin Plan	1.2	1.5	0.72	1.10	0.65	1.27	1.15	0.55	2.32	0.95	2.25	0.06	0.40	0.27	1.32	0.98	0.60
Nitrite as N	mg/L	1	Basin Plan	<0.1	<0.1	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	<0.05	0.11	<0.05	<0.05
Methylene Blue Active Substances	mg/L	0.5	Basin Plan	0.18	<0.04	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.2	<0.1	<0.1
Total Dissolved Solids	mg/L	500-2100	Basin Plan by watershed	616	374	**1730**	**1500**	**818**	**851**	**641**	310	**1360**	**681**	**717**	**1900**	**1440**	**1490**	**955**	**1280**	**997**
Total Kjeldahl Nitrogen	mg/L			0.6	0.7	<0.5	0.8	0.7	1.8	0.9	2.4	1.6	2.0	1.7	0.8	1.4	0.9	1.9	0.8	1.2
Total Organic Carbon	mg/L			NA	NA	5.61	11.10	4.93	20.3	13.8	5.21	14.5	14.0	8.04	9.68	8.59	11.0	22.7	57.4	13.6
Total Phosphorus	mg/L	2	USEPA Multi-Sector General Permit	0.3	0.85	0.29	0.23	0.22	0.87	0.83	1.14	0.49	0.62	0.72	0.14	0.08	0.12	0.73	0.60	0.39
Total Suspended Solids	mg/L	100	USEPA Multi-Sector General Permit	**405**	**3090**	14	8	**152**	**508**	**380**	**674**	54	**150**	**221**	10	23	34	35	58	38
Turbidity	NTU	20	Basin Plan	**193**	**1160**	6.96	3.3	**185**	**264**	**184**	**290**	**38.3**	**111**	**192**	4.72	17.5	17.7	17.1	**45.4**	**29.9**
Pesticides																				
Chlorpyrifos	µg/L	0.02	CA Dept. of Fish & Game	<3.0*	<3.0*	<0.03*	<0.03*	<0.03*	**0.047**	<0.03*	<0.03*	<0.03*	<0.03*	**0.030**	<0.03*	<0.03*	<0.03*	**0.055**	**0.067**	<0.03*
Diazinon	µg/L	0.08	CA Dept. of Fish & Game	<6.0*	<6.0*	<0.03	<0.03	0.053	**0.464**	**0.194**	**0.320**	**0.122**	**0.163**	0.063	<0.03	<0.03	<0.03	**0.231**	0.040	0.077
Malathion	µg/L	0.43	CA Dept. of Fish & Game	NA	NA	<0.10	<0.10	<0.10	0.10	0.36	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Hardness																				
Hardness	mg CaCO3/L			341	242	779	832	463	418	370	205	530	365	388	1030	726	767	428	602	602
Total Metals																				
Antimony	mg/L	0.006	Basin Plan	<0.002	<0.002	<0.002	0.002	0.003	<0.002	0.003	0.003	<0.002	0.003	0.004	0.002	0.003	<0.002	<0.002	0.005	**0.009**
Arsenic	mg/L	0.34/0.05	40 CFR 131/ Basin Plan	0.005	0.006	0.001	0.001	0.003	0.008	0.005	0.010	0.003	0.003	0.004	0.002	0.003	0.003	0.012	0.005	0.003
Cadmium	mg/L	0.0046	40 CFR 131	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	0.016	CTR (Cr VI)	**0.018**	**0.053**	<0.005	<0.005	0.007	0.006	0.009	**0.017**	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	0.008	0.006	<0.005
Copper	mg/L	0.0135	40 CFR 131	**0.017**	**0.064**	<0.005	**0.014**	0.009	**0.021**	**0.020**	**0.042**	0.009	**0.015**	**0.019**	**0.014**	0.004	<0.005	**0.021**	0.004	0.010
Lead	mg/L	0.082	40 CFR 131	0.008	0.039	0.004	0.002	<0.002	0.008	0.006	0.008	0.005	0.005	0.005	0.002	<0.002	<0.002	0.011	0.004	0.003
Nickel	mg/L	0.47/0.1	40 CFR 131/ Basin Plan	0.013	0.024	<0.002	0.002	0.006	0.009	0.007	0.014	0.004	0.004	0.006	0.002	<0.002	0.003	0.026	<0.002	0.002
Selenium	mg/L	0.02	40 CFR 131	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Zinc	mg/L	0.122	40 CFR 131	0.050	**0.200**	<0.02	<0.02	0.022	0.047	0.053	0.089	0.022	0.046	0.066	<0.020	0.008	0.005	0.058	0.006	<0.020
Dissolved Metals																				
Antimony	mg/L	(e)	40 CFR 131	<0.002	<0.002	<0.002	0.002	0.004	<0.002	0.002	0.002	<0.002	0.002	0.002	<0.002	0.002	0.003	<0.002	0.002	<0.002
Arsenic	mg/L	0.34 (c)	40 CFR 131	0.005	<0.002	0.001	0.002	0.001	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.004	0.003	0.003
Cadmium	mg/L	(b)	40 CFR 131	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.0002	<0.001	<0.001
Chromium	mg/L	(b)	40 CFR 131	0.002	0.004	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/L	(b)	40 CFR 131	0.009	0.012	<0.005	0.018	0.005	<0.005	0.041	0.010	<0.005	0.049	0.008	0.016	0.005	0.005	0.007	<0.005	0.027
Lead	mg/L	(b)	40 CFR 131	0.005	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.0007	<0.002	0.002	<0.002
Nickel	mg/L	(b)	40 CFR 131	0.007	<0.005	0.002	0.003	<0.002	0.005	0.003	0.002	0.003	0.002	<0.002	0.002	<0.002	0.009	0.003	<0.002	0.002
Selenium	mg/L	0.2 (d)	40 CFR 131	0.007	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Zinc	mg/L	(b)	40 CFR 131	0.05	0.01	<0.020	0.070	0.024	<0.020	0.291	0.030	<0.020	0.230	0.022	0.086	0.033	<0.020	<0.020	0.020	0.106
Toxicity																				
Ceriodaphnia 96-hr	LC50 (%)	100		>100	>100	>100	>100	>100	**81.25**	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
Ceriodaphnia 7-day survival	NOEC (%)	100		100	100	100	100	100	**50**	**50**	**50**	100	100	100	100	100	100	100	100	100
Ceriodaphnia 7-day reproduction	NOEC (%)	100		**50**	**<25**	100	100	100	**50**	100	**50**	100	100	100	**12.5**	100	**50**	100	100	100
Hyalella 96-hr	NOEC (%)	100		**50**	100	100	100	100	100	**50**	**50**	100	100	100	100	100	100	100	100	100
Selenastrum 96-hr	NOEC (%)	100		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

(a) Un-ionized Ammonia is a calculated value, non-detectable values calculated at the detection limit. Basin Plan WQO is 0.025 mg/L; values shown here have been converted to µg/L.
(b) Water Quality Objective for dissolved metal fractions are based on total hardness and are calculated as described by the USEPA Federal Register Doc. 40 CFR Part 131, May 18, 2000.
(c) Water Quality Objectives for dissolved metal fractions are based on water effects ratios (WER) and are calculated as described by the USEPA Federal Register Doc. 40 CFR Part 131, May 18, 2000.
(d) Water Quality Objective is based on the total recoverable form as described by the USEPA Federal Register Doc. 40 CFR Part 131, May 18, 2000.
(e) USEPA has not published an aquatic life criterion value.

Shaded text – exceeds water quality objective.

* Indicates detection limit exceeds water quality objective.

Sources
USEPA National Pollutant Discharge Elimination System (NPDES) Storm Water Multi-Sector General Permit for Industrial Activities, 65 Federal Register (FR) 64746, Final Reissuance, October 30, 2000. Table 3 - Parameter benchmark values.
Siepmann and Finlayson 2000.
Basin Plan, September 8, 1994.
Assembly Bill 411 - Title 17 of the California Code of Regulations, Section 7958.
USEPA Federal Register Document 40 CFR Part 131, May 18, 2000.

Table 3-4. Results of wet weather monitoring.

ANALYTE	UNITS	WQO	Watershed	Mission Bay			San Diego River			San Diego Bay						Tijuana River		
			Source	Tecolote 11/08/02	Tecolote 12/16/02	Tecolote 2/11/03	San Diego River 11/08/02	San Diego River 12/16/02	San Diego River 2/11/03	Chollas 11/08/02	Chollas 2/11/03	Chollas 2/25/03	Sweetwater 12/16/02	Sweetwater 2/11/03	Sweetwater 2/25/03	Tijuana River 11/08/02	Tijuana River 2/11/03	Tijuana River 2/25/03
General/Physical/Organic																		
Electrical Conductivity	umhos/cm			1694	311	322	1568	811	1550	315	211	91.2	2990	2760	1955	1664	1830	2890
Oil & Grease	mg/L	15	USEPA Multi-Sector General Permit	2.00	1.69	3.16	10.70	<1.00	2.39	4.24	3.54	2.47	4.47	2	1	3.93	1.23	8.56
pH	pH scale	6.5-8.5	Basin Plan	6.67	7.61	7.55	7.68	7.64	7.61	6.96	7.58	7.41	7.56	6.87	6.94	7.30	**8.51**	7.32
Bacteriological																		
Enterococci	MPN/100mL			35,000	23,000	14,000	17,000	13,000	7,000	30,000	50,000	80,000	8,000	14,000	30,000	2,400,000	50,000	30,000
Fecal Coliform	MPN/100mL	400/4000	Basin Plan REC1/REC2	**110,000**	**13,000**	2,200	**110,000**	**17,000**	**5,000**	**50,000**	**30,000**	**13,000**	**23,000**	**7,000**	**1,700**	**5,000,000**	**500,000**	**16,000,000**
Total Coliform	MPN/100mL			300,000	50,000	30,000	220,000	50,000	23,000	2,400,000	230,000	300,000	30,000	30,000	170,000	>16,000,000	1,300,000	16,000,000
Wet Chemistry																		
Ammonia as N	mg/L			0.44	0.34	0.26	0.34	0.13	0.19	0.54	0.79	0.52	0.25	0.28	0.19	5.22	8.00	10.40
Un-ionized Ammonia as N	μg/L	25 (a)	Basin Plan	0.64	3.79	2.40	5.11	1.5	2.04	1.52	8.93	3.12	2.28	0.64	0.42	**39.2**	**636**	**63.0**
Biochemical Oxygen Demand	mg/L	30	USEPA Multi-Sector General Permit	6.75	22.4	25.4	4.73	<2.0	20.7	8.01	**31.8**	21.0	<2.0	20.4	5.89	3.56	**86.4**	23.2
Chemical Oxygen Demand	mg/L	120	USEPA Multi-Sector General Permit	79	67	**125**	71	48	63	119	**184**	43	59	85	39	**152**	**257**	113
Dissolved Organic Carbon	mg/L			8.3	13.2	15.9	6.80	8.68	10.70	11.3	19.2	10.8	9.68	25.2	8.94	30.6	35.7	23.4
Dissolved Phosphorus	mg/L	2	USEPA Multi-Sector General Permit	0.16	0.32	0.82	0.19	0.24	0.19	0.41	0.40	0.14	0.34	0.20	0.10	1.75	1.90	0.93
Nitrate as N	mg/L	10	Basin Plan	0.81	0.84	0.90	0.67	0.56	0.57	0.71	1.04	0.45	0.54	0.81	0.39	3.12	0.72	0.44
Nitrite as N	mg/L	1	Basin Plan	<0.05	0.06	0.06	<0.05	<0.05	<0.05	0.09	0.12	0.07	0.06	<0.05	<0.05	0.98	0.37	0.13
Methylene Blue Active Substances	mg/L	0.5	Basin Plan	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.3	0.2	<0.1	<0.1	<0.1	<0.1	0.3	**2.0**	<0.1
Total Dissolved Solids	mg/L	500-2100	Basin Plan by watershed	757	220	373	**1260**	676	896	195	121	87	793	**1660**	1150	885	883	794
Total Kjeldahl Nitrogen	mg/L			2.1	1.4	3.7	1.6	1.2	1.5	2.5	2.4	1.6	1.0	1.0	0.8	9.5	13.6	22.0
Total Organic Carbon	mg/L			21.9	27.0	15.4	18.3	39.8	12.4	22.8	27.0	5.45	40.7	12.9	6.72	47.5	51.0	18.6
Total Phosphorus	mg/L	2	USEPA Multi-Sector General Permit	0.6	1.84	1.03	0.57	1.01	0.33	0.68	0.67	0.76	0.54	0.22	0.14	**2.37**	**2.04**	**2.38**
Total Suspended Solids	mg/L	100	USEPA Multi-Sector General Permit	**158**	**346**	**301**	43	**212**	66	63	**193**	**295**	74	14	51	**160**	97	**1070**
Turbidity	NTU	20	Basin Plan	**102**	**200**	**200**	**40.7**	**104**	**34.5**	**57.1**	**121**	**178**	**62.9**	13	**46.5**	**141**	**72.8**	**1000**
Pesticides																		
Chlorpyrifos	μg/L	0.02	CA Dept. of Fish & Game	<0.03*	**0.087**	<0.03*	**0.043**	**0.051**	**0.048**	**0.111**	<0.03*	**0.038**	**0.053**	**0.059**	<0.03*	**0.168**	<0.03	<0.03
Diazinon	μg/L	0.08	CA Dept. of Fish & Game	**0.185**	**0.095**	**0.155**	0.051	0.051	0.038	**0.424**	**0.260**	**0.090**	**0.301**	**0.146**	**0.171**	**0.372**	**0.506**	**0.339**
Malathion	μg/L	0.43	CA Dept. of Fish & Game	<0.10	<0.10	**0.87**	<0.10	<0.10	<0.10	0.25	0.28	<0.10	0.24	<0.10	<0.10	**1.00**	**0.88**	0.27
Hardness																		
Hardness	mg CaCO3/L			344	245	298	545	331	483	69.1	78	44	344	758	549	279	334	395
Total Metals																		
Antimony	mg/L	0.006	Basin Plan	<0.002	0.006	**0.009**	<0.002	0.006	**0.007**	<0.002	0.005	0.004	0.004	0.004	0.003	<0.002	0.002	0.003
Arsenic	mg/L	0.34/0.05	40 CFR 131/ Basin Plan	0.008	0.015	0.013	0.005	0.008	0.004	0.003	0.004	0.003	0.004	0.002	0.003	0.005	0.008	0.018
Cadmium	mg/L	0.0046	40 CFR 131	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	0.016	CTR (Cr VI)	<0.005	**0.020**	**0.018**	<0.005	**0.020**	0.005	<0.005	0.010	<0.005	0.009	0.005	<0.005	<0.005	0.006	**0.049**
Copper	mg/L	0.0135	40 CFR 131	**0.030**	**0.050**	**0.038**	0.009	**0.021**	**0.017**	**0.028**	**0.033**	**0.016**	0.010	**0.018**	0.007	0.008	**0.021**	**0.053**
Lead	mg/L	0.082	40 CFR 131	0.018	0.052	0.040	0.007	0.035	0.011	0.017	0.029	0.023	0.010	0.003	<0.002	0.004	0.011	0.045
Nickel	mg/L	0.47/0.1	40 CFR 131/ Basin Plan	0.008	0.011	0.012	0.007	0.005	0.005	0.007	0.008	0.004	<0.002	0.002	<0.002	0.003	0.021	0.040
Selenium	mg/L	0.02	40 CFR 131	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Zinc	mg/L	0.122	40 CFR 131	0.096	**0.208**	**0.235**	0.031	0.118	0.077	0.118	**0.230**	**0.154**	0.042	0.029	0.025	<0.02	0.077	**0.269**
Dissolved Metals																		
Antimony	mg/L	(e)	40 CFR 131	0.002	0.002	0.002	0.002	0.007	0.002	0.002	0.002	0.002	0.006	<0.002	0.004	0.004	0.003	0.004
Arsenic	mg/L	0.34 (c)	40 CFR 131	0.003	0.004	0.003	0.004	0.003	0.003	0.003	0.002	0.002	0.003	0.003	0.003	0.010	0.008	0.005
Cadmium	mg/L	(b)	40 CFR 131	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	(b)	40 CFR 131	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	mg/L	(b)	40 CFR 131	0.008	0.006	**0.042**	0.005	0.006	0.015	**0.022**	**0.052**	**0.008**	0.007	0.025	0.008	0.011	**0.060**	0.013
Lead	mg/L	(b)	40 CFR 131	<0.002	0.005	<0.002	0.006	0.002	<0.002	0.006	<0.002	<0.002	0.002	<0.002	<0.002	0.003	<0.002	<0.002
Nickel	mg/L	(b)	40 CFR 131	0.004	<0.002	0.003	0.006	<0.002	0.003	0.006	0.004	<0.002	<0.002	0.002	<0.002	0.018	0.017	0.013
Selenium	mg/L	0.2 (d)	40 CFR 131	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Zinc	mg/L	(b)	40 CFR 131	0.021	0.039	0.144	0.026	0.037	0.070	**0.152**	**0.139**	0.018	0.043	0.097	0.021	0.062	0.130	0.046
Toxicity																		
Ceriodaphnia 96-hr	LC50 (%)	100		>100	>100	**70.71**	>100	>100	>100	**77.78**	>100	>100	**72.22**	>100	>100	**19.5**	**10.15**	**32.98**
Ceriodaphnia 7-day survival	NOEC (%)	100		100	100	**50**	100	100	100	**25**	**50**	100	**50**	100	100	**12.5**	**6.25**	**12.5**
Ceriodaphnia 7-day reproduction	NOEC (%)	100		100	100	**50**	100	100	100	**50**	100	100	**50**	100	100	**12.5**	**6.25**	**12.5**
Hyalella 96-hr	NOEC (%)	100		100	100	100	100	100	100	**50**	100	100	100	100	100	100	100	**50**
Selenastrum 96-hr	NOEC (%)	100		100	100	100	100	100	100	100	100	100	**12.5**	100	100	100	100	100

(a) Un-ionized Ammonia is a calculated value, non-detectable values calculated at the detection limit. Basin Plan WQO is 0.025 mg/L; values shown here have been converted to μg/L.
(b) Water Quality Objective for dissolved metal fractions are based on total hardness and are calculated as described by the USEPA Federal Register Doc. 40 CFR Part 131, May 18, 2000.
(c) Water Quality Objectives for dissolved metal fractions are based on water effects ratios (WER) and are calculated as described by the USEPA Federal Register Doc. 40 CFR Part 131, May 18, 2000.
(d) Water Quality Objective is based on the total recoverable form as described by the USEPA Federal Register Doc. 40 CFR Part 131, May 18, 2000.
(e) USEPA has not published an aquatic life criterion value.

Shaded text – exceeds water quality objective.

* Indicates detection limit exceeds water quality objective.

<u>Sources</u>

USEPA National Pollutant Discharge Elimination System (NPDES) Storm Water Multi-Sector General Permit for Industrial Activities, 65 Federal Register (FR) 64746, Final Reissuance, October 30, 2000. Table 3 - Parameter benchmark values.
Siepmann and Finlayson 2000.
Basin Plan, September 8, 1994.
Assembly Bill 411 - Title 17 of the California Code of Regulations, Section 7958.
USEPA Federal Register Document 40 CFR Part 131, May 18, 2000.

All REC-2 waters (Tecolote Creek, Chollas Creek, and Tijuana River) exceeded the REC-2 standard of 4,000 MPN/100 mL for fecal coliform with the exception of the February 11, 2003 event at Tecolote Creek. Fecal coliform counts were 2,200 MPN/100 mL. It is important to note that Tecolote Creek falls under REC-2 criteria, although the creek empties directly into a REC-1 beach area at Mission Bay (Basin Plan 1994). Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) concentrations at all three sites were also elevated, particularly during the February 11, 2003 event, which can indicate a potential sewage spill, sewage overflow, or other source.

The highest counts of all three bacterial indicators during the three storm events were at Tijuana River. Results showed total coliform counts greater than 16,000,000 MPN/100 mL and *Enterococcus* results of 2,400,000 MPN/100 mL during the November 8, 2002 event and fecal coliform counts as high as 16,000,000 MPN/100 mL during the February 25, 2003 storm. Concentrations of unionized ammonia, COD, and BOD were also high. Bacteria counts and concentrations of other Constituents of Concern (COC) are indicative of sewage sources (untreated wastewater) in the river.

In general, the first storm event of the season resulted in higher counts of total coliform, fecal coliform, and *Enterococcus* at San Dieguito River, Peñasquitos River, Tecolote Creek, and San Diego River. This "first-flush" effect was also observed at Agua Hedionda Creek and Chollas Creek for fecal and total coliform only. Tijuana River measured higher on the first storm for total coliform and *Enterococcus*. Sweetwater River only measured higher on the first event for fecal coliform. San Luis Rey River and Escondido Creek did not show a "first-flush" effect for any of the bacterial parameters.

3.3.2 Conventional Constituents

General chemical, physical, and inorganic non-metal constituents were measured from storm samples. Grab samples were used to measure pH, temperature, and conductivity in the field during storm events. Grab sampling was used for the collection of biochemical oxygen demand and oil and grease samples, which were later analyzed in the laboratory. All other COC were measured from flow-weighted composite samples.

Field pH measurements collected at mass loading stations during storm events varied between 6.4 and 8.5 and were within or very near Basin Plan objectives. The measurement of pH provides a reading of acidity or alkalinity and may indicate the presence of other constituents of concern. The level of conductivity is a measure of how well water conducts an electrical current. Conductivity (also referred to as specific conductance) can be an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, iron, magnesium, and calcium. Naturally occurring soils and sediment particles can increase conductivity readings in storm water. Conductivity measurements are often a good indicator of the amount of dissolved solids in water. Conductivity measured during storm events ranged from 91 to 4,190 umhos/cm.

Total dissolved solids (TDS) measurements were conducted on composite samples and ranged from 87 to 1,900 mg/L. TDS is a measure of the amount of dissolved solids in water and can include carbonate, bicarbonate, sulfate, chloride, nitrate, calcium, phosphate, sodium, magnesium, organic ions and other ions. Several watersheds have water quality objectives for total dissolved solids based upon the municipal drinking water beneficial use (Basin Plan 1994). While Table 3-4 lists the water quality objective for TDS, the standard is a municipal drinking water objective and is not based on potential ecological impact concerns.

Whereas TDS measures solid materials that pass through a 0.45 micron filter in a given water sample, total suspended solids (TSS) measures the solid material trapped on a filter. TSS can include decaying plant matter, silts, clays, etc. TSS concentrations ranged from 8 to 3,090 mg/L. Concentrations were compared to the USEPA Multi-Sector General Permit for Industrial Activities for reference purposes. The USEPA benchmark for TSS is 100 mg/L. San Dieguito River, Peñasquitos River, and Sweetwater River were the only sites that did not exceed the TSS benchmark for all three storm events. San Luis Rey and San Diego Rivers exceeded the benchmark during one storm with levels of 152 and 212 mg/L respectively. Escondido Creek (150 and 221 mg/L), Chollas Creek (193 and 295 mg/L), and Tijuana River (160 and 1,070 mg/L) exceeded the benchmark level during two storm events. Agua Hedionda Creek (508, 380, and 674 mg/L) and Tecolote Creek (158, 346, and 301 mg/L) were the only sites to exceed the TSS benchmark for all three storms. Santa Margarita exceeded the benchmark for the two events that were monitored at that site with levels of 405 and 3,090 mg/L.

For this project/report, turbidity is reported in Nephelometric Turbidity Units (NTUs). Turbidity is a measure of the amount of light that can pass through water and is caused by suspended particulate matter such as clay, silt, and organic matter and by plankton and other organisms. A higher presence of these particles in a water sample represents lower transparency and, thus, higher turbidity units. Turbidity was compared to the Basin Plan objective of 20 NTUs. Concentrations measured at mass loading stations for the storm events ranged from 3.3 to 1,160 NTUs. Samples from San Dieguito River did not exceed this objective. The highest turbidity monitored was at Santa Margarita River, where both storms exceeded water quality objectives with concentrations measured at 193 and 1160 NTUs. The turbidity objective was exceeded during all three storms at Agua Hedionda Creek (264, 184, and 290 NTUs), Escondido Creek (38.3, 111, and 192 NTUs), Tecolote Creek (102, 200, and 200 NTUs), San Diego River (40.7, 104, and 34.5 NTUs), Chollas Creek (57.1, 121, and 178 NTUs), and Tijuana River (141, 72.8, and 1000 NTUs). Two of three storms exceeded the objective at Peñasquitos Creek (45.4 and 29.9 NTUs) and Sweetwater River (62.9 and 46.5 NTUs). The objective was exceeded during one of three storms at San Luis Rey River with a level of 185 NTUs.

Oil and grease is a measure of petroleum oils, animal fats, and natural oils. Oil and grease was compared to the USEPA Multi-Sector General Permit for Industrial Discharges benchmark of 15 mg/L. Concentrations measured during storm events ranged from less than 1 to 10.7 mg/L with no mass loading stations exceeding the benchmark. San Diego River had the highest level of 10.7 mg/L during the November 8, 2002 event.

Biological Oxygen Demand (BOD) is measured over 5 days and represents the oxygen consumed through the biodegradation of organic matter in the sample. Chemical Oxygen Demand (COD) is measured over 24 hours and represents the oxygen consumed in the oxidation of organic matter by a strong chemical oxidizer during that time period. Both BOD and COD are useful in assessing the organic matter load or content of the sample.

For reference purposes, the storm water results for BOD and COD are compared to the benchmarks in the USEPA Multi-Sector General Permit for Industrial Activities. These benchmarks are 30 mg/L for BOD and 120 mg/L for COD. The highest concentrations of BOD and COD were at Tijuana River, which exceeded the BOD benchmark with a level of 86.4 mg/L during the February 11, 2003 storm and exceeded the COD benchmark with levels of 152 and 257 mg/L during the November 11, 2002 and February 11, 2003 events respectively. Chollas Creek exceeded benchmarks during the February 11, 2003 storm with BOD and COD levels of 31.8 and 184 mg/L respectively. Both Santa Margarita River and Tecolote Creek exceeded the benchmark for COD during the February 11, 2003 storm with levels of 185 and 125 mg/L respectively. All other sites had BOD and COD levels below benchmark levels.

Organic carbon in water is composed of a variety of organic compounds in various oxidation states. Biological or chemical processes can oxidize some of these carbon compounds further and BOD or COD tests may be used to characterize these fractions. Total Organic Carbon (TOC) is a more direct measure of total organic content than either BOD or COD. TOC is the amount of carbon covalently bound in organic compounds in a water sample. TOC is measured by the amount of carbon dioxide produced when a water sample is atomized in a combustion chamber. Dissolved Organic Carbon (DOC) is the fraction of total organic carbon in water that passes through a 0.45 micron pore-diameter filter. No water quality objective or benchmark was identified for TOC or DOC. TOC levels ranged from 4.93 mg/L at San Luis Rey River during the February 25, 2003 event to 57.4 mg/L at Peñasquitos Creek during the December 16, 2002 storm event. DOC levels ranged from 1.49 mg/L at San Luis Rey River during the November 8, 2002 storm to 35.7 mg/L at Tijuana River during the February 11, 2003 storm event. Tijuana River generally had higher levels of TOC and DOC during storm events than most other sites.

Surfactants are also known as Methylene Blue Active Substances (MBAS). For reference purposes, the Basin Plan objective of 0.5 mg/L was compared to samples collected during storm events. Most mass loading stations had results for MBAS of non-detect (below 0.1 mg/L). Tijuana River was the only site to exceed the Basin Plan objective with a level of 2 mg/L during the February 11, 2003 storm event.

Total Kjeldahl Nitrogen (TKN) is a measure of organic nitrogen. No water quality objective or benchmark was identified for TKN. One sample resulted in a non-detect level for TKN, while all others ranged from 0.6 to 22 mg/L. TKN concentrations were higher in samples collected from the Tijuana River mass loading station (9.5 13.6 and 22 mg/L) than in all other mass loading stations.

Nitrogen is a basic building block of life and the various forms of nitrogen are part of the nitrogen cycle. Nitrogen is essential to plant growth and excessive nitrogen compounds can cause algal blooms or be indicative of pollution sources from agricultural/household fertilizer runoff, sewage, and other sources. Inorganic forms of nitrogen include nitrate, nitrite, ammonia, and nitrogen gas. Nitrate is highly soluble, dissolving easily in water, and is stable over a wide range of conditions in the environment. Nitrite is less stable in water and is converted to nitrate. Ammonia is another inorganic form of nitrogen and is not stable in water. Ammonia is easily transformed to nitrate in water with moderate oxygen levels. In low oxygen conditions, ammonia is transformed to nitrogen gas. Nitrate and nitrite concentrations were compared to Basin Plan objectives of 45 mg/L for nitrate and 1 mg/L for nitrite. The Basin Plan lists the water quality objective only for unionized ammonia at 25 μg/L. No stations exceeded either nitrite or nitrate water quality objectives. The highest levels of ammonia were detected at Tijuana River with levels of 5.22, 8, and 10.4 mg/L. Tijuana River also exceeded objectives for unionized ammonia during all three events with levels of 39.2, 63.6, and 63 μg/L. The calculation of un-ionized ammonia levels were performed for 2002-2003 from the laboratory measured ammonia as N (using pH and Temperature of the grab sample to convert to unionized ammonia) and compared to the Basin plan WQO of 0.025 mg/L.

Phosphorus, together with inorganic nitrogen, is an important nutrient for plant and phytoplankton growth. Both total and dissolved phosphorus concentrations were compared to USEPA Multi-Sector General Permit for Industrial Activities benchmarks for reference. The benchmark for both total and dissolved phosphorus is 2 mg/L. Samples from Tijuana River exceeded the benchmark for total phosphorus during all three storm events with levels of 2.37, 2.04, and 2.38 mg/L. All other storms and stations were below the benchmark with dissolved phosphorus levels ranging from 0.1 to 1.90 mg/L and total phosphorus levels ranging from 0.12 to 1.84 mg/L.

3.3.3 Trace Metals and Hardness

Trace metals are naturally occurring crustal metals that are ubiquitous in the environment. Trace metals are also present in urban discharges from anthropogenic sources. Trace metals exist in various chemical forms, both dissolved and bound to particulates. In certain chemical forms, trace metals are biologically available to organisms and, at high enough concentrations, cause or contribute to toxic effects. The measure of dissolved metals is a proxy for measuring concentrations of metals that are more biologically available.

Flow weighted composites collected at each mass loading station during each storm event were analyzed for the total and dissolved metals antimony, arsenic, cadmium, chromium, copper, lead, nickel, selenium, and zinc. Total hardness concentrations were also measured because 40 CFR Part 131 - California Toxic Rule benchmark for dissolved metals are based on total hardness in the water. Hardness levels ranged from 44 to 1,030 mg $CaCO_3$/L.

Benchmarks for dissolved metals were not exceeded for any of the storms monitored at Santa Margarita River, San Luis Rey River, Agua Hedionda Creek, Escondido Creek, San Dieguito River, Peñasquitos Creek, San Diego River, and Sweetwater River. Tecolote Creek and Tijuana River both exceeded the benchmark for dissolved copper during the February 11, 2003 event. Chollas Creek exceeded the dissolved copper benchmark during all three events and also exceeded benchmarks for dissolved zinc during two storms.

Benchmarks for total metals were exceeded during at least one storm at every station. Tecolote Creek had the majority of exceedences with the benchmark for copper being exceeded during each storm, chromium and zinc benchmarks exceeded during two storms, and the antimony benchmark exceeded during one storm. San Diego River exceeded the copper benchmark during two events and antimony and chromium benchmarks during one event. Chollas Creek exceeded the copper benchmark during all three storms and also exceeded the zinc benchmark during two storms. Tijuana River exceeded the copper benchmark during two storms and chromium and zinc benchmarks during one storm. Agua Hedionda Creek exceeded the copper benchmark during all three events and exceeded the chromium benchmark during one storm. Santa Margarita River exceeded the benchmark for copper during both storms and exceeded the benchmark for zinc during one storm. Escondido Creek exceeded the copper benchmark during two storms. Peñasquitos Creek exceeded the copper benchmark during one storm and the antimony benchmark during one storm. San Luis Rey River, San Dieguito River, and Sweetwater River each had one benchmark exceedance for copper.

3.3.4 Diazinon and Chlorpyrifos

The organophosphate pesticides diazinon and chlorpyrifos were added to the core monitoring program in the 1998-1999 storm season after diazinon was linked to toxicity at Chollas Creek. Organophosphate pesticides are a specific chemical class of common insecticides.

Samples from all stations were analyzed for organophosphate pesticides including diazinon, chlorpyrifos, and malathion. The storm sample collected at Santa Margarita River mass loading station was analyzed using EPA 8141A with a higher detection limit. All other stations were analyzed for diazinon, chlorpyrifos, and malathion using ELISA to provide an ultra-low detection limit. Chlorpyrifos was detected in 13 of 32 samples at concentrations ranging from 0.030 to 0.168 μg/L. Diazinon was detected in 26 of 32 samples at concentrations ranging from 0.038 to 0.506 μg/L. Malathion was detected in 10 of 32 samples at concentrations ranging from 0.10 to 1 μg/L.

Diazinon, chlorpyrifos, and malathion results are compared to the California Department of Fish and Game water quality objectives for freshwater aquatic life. These objectives are 0.02 μg/L for chlorpyrifos, 0.08 μg/L for diazinon, and 0.43 μg/L for malathion. It is important to note the lowest attainable detection limit for chlorpyrifos, 0.03 μg/L, exceeds the water quality objective. However, the detection limits for diazinon of 0.03 μg/L and for malathion of 0.10 μg/L were both less than their respective water quality objectives.

Diazinon and chlorpyrifos were not detected in the two storms monitored at Santa Margarita River. Malathion is not reported at this site. Diazinon, chlorpyrifos, and malathion did not exceed objectives during any of the storms at San Luis Rey and San Dieguito River. Malathion objectives were only exceeded at Tecolote Creek during one event and Tijuana River during two events. With the exception of Santa Margarita River, San Luis Rey River, San Dieguito River, and San Diego River, diazinon was detected above the water quality objective at every mass loading station in one or more storm events, with the highest concentrations of diazinon found at Agua Hedionda Creek, Chollas Creek, and Tijuana River.

3.3.5 Toxicity Testing

Samples collected were evaluated in chronic tests with a freshwater cladoceran (*Ceriodaphnia*), acute tests with a freshwater amphipod (*Hyalella*), and chronic tests with a freshwater algae (*Selenastrum*). Results are presented below by species. A summary of all bioassay test results are presented in Table 3-5.

Reporting Toxicity for Storm Water

The 2001-2002 Urban Runoff Monitoring Report included a recommendation that the TUa no longer be considered when assessing toxicity in this program for the reasons discussed below.

The California Ocean Plan states that it is only possible to have a TUa of 0 when the survival in the 100% concentration is 99% or better. As it is not clear from this document whether the percent survival is absolute or relative to control, the endpoint was calculated relative to the control for this monitoring program. Even given this more liberal interpretation of the calculation of a TUa, in a test with forty animals per treatment, if one animal more dies in the 100% treatment than in the control, the sample exceeds its acute toxicity limit. The death of one animal in a toxicity test is more likely due to variability in response than to actual toxicity of a sample. Setting the limit at a TUa of 0 does not account for any of the variability inherent in toxicity tests. This is evidenced, for example, when the results for 2002-2003 *H. azteca* are reviewed (Table 3-5). Out of 122 samples only 25 exceeded the acute toxicity limit with a range in TUa from 1.12 to 0.23, yet only 5 of those samples had mortality that was significant when compared to the control and all had a NOEC of 50%. The TUa for the remaining samples ranged between 0.85 and 0.23. Therefore, it is more appropriate to set the limit based on an endpoint that statistically takes into account variability in its calculation. The summary of results presented below focuses on the acute toxicity limit as the No Observed Effect Concentration (NOEC) of 100% test sample. This limit will take into account any inherent variability in the test, yet still be protective of the watershed.

3.3.5.1 Ceriodaphnia dubia

All *Ceriodaphnia* tests met test acceptability standards and results of reference toxicant tests indicated that all animals tested fell within the normal range of sensitivity, with the exceptions outlined below.

The Tijuana River test initiated on November 10th, 2002 was accidentally ended on November 11th. The test was begun again on November 11th, which was outside of the 36-hour holding time but within 48 hours of sample collection.

The Chollas Creek test initiated on February 11th, 2003 did not meet acceptability criteria for control survival. The test was begun again on February 22nd, outside of the 36-hour holding time.

Samples with No Toxicity to *Ceriodaphnia dubia*

Samples from San Luis Rey, Escondido Creek, Peñasquitos Creek, and San Diego River did not cause toxicity for any of the storm events sampled.

A sample from the San Luis Rey River for the November 8, 2002 storm had a TUa of 0.59. The NOEC values for 96-hour survival, 7-day survival, and reproduction were all 100% of the test sample, indicating that any toxicity observed was not statistically significant. No toxicity was expressed in samples collected during either of two following storm events.

Samples with Toxicity to *Ceriodaphnia dubia* During One of Three Storm Events

Samples from Tecolote Creek and Sweetwater River all caused toxicity for one of the three storm events sampled, as described below.

A sample from Tecolote Creek showed toxicity for the February 11, 2003 storm. The LC_{50} at 96-hours was 70.71%, resulting in a TUa of 1.4. The NOEC for both seven-day survival and reproduction was 50% of the test sample which results in a TUc of 2 for both endpoints. The seven-day or chronic LC_{50} (60.73% of the test sample) was lower than that of the acute endpoint, indicating that mortality occurred during the entire test period. No toxicity was expressed in samples collected during either of two previous storm events.

A sample from Sweetwater Creek showed toxicity for the December 16, 2002 storm. The LC_{50} at 96-hours was 72.22%, resulting in a TUa of 1.4. The NOEC for both seven-day survival and reproduction was 50% of the test sample, which results in a TUc of 2 for both endpoints. The seven-day or chronic LC_{50} (64.29% of the test sample) was lower than that of the acute endpoint, indicating that mortality occurred during the entire test period. No toxicity was expressed in samples collected during either of two following storm events.

Table 3-5. Toxicity of storm water samples, 2002-2003.

Station	Event	*Ceriodaphnia dubia* Acute Endpoints: NOEC (% Sample)	*Ceriodaphnia dubia* Acute Endpoints: 96-Hour LC_{50} (% Sample)	*Ceriodaphnia dubia* Acute Endpoints: TUa	*Ceriodaphnia dubia* Chronic Endpoints: 7-Day LC_{50} (% Sample)	*Ceriodaphnia dubia* Chronic Endpoints: 7-Day NOEC Survival / Reproduction	*Ceriodaphnia dubia* Chronic Endpoints: TUc Survival / Reproduction	*Hyalella azteca*: NOEC (% Sample)	*Hyalella azteca*: 96 hour LC_{50} (% Sample)	*Hyalella azteca*: TUa	*Selenastrum capricornutum*: NOEC (% Sample)	*Selenastrum capricornutum*: 96-hour IC_{25}/IC_{50} (% Sample)	*Selenastrum capricornutum*: TUc
Santa Margarita River	2/12/2003	100	>100	<0.59	>100	>100/50	1/2	50	89.2	1.12	100	>100	<1
	2/25/2003	100	>100	0.77	>100	100/<25	1/>4	100	>100	<0.41	100	>100	<1
San Luis Rey River	11/8/2002	100	>100	0.59	>100	100/100	1/1	100	>100	0.51	100	>100/>100	1
	2/11/2003	100	>100	0	>100	100/100	1/1	100	>100	0	100	>100/>100	1
	2/25/2003	100	>100	0	>100	100/100	1/1	100	>100	0.23	100	>100/>100	1
Agua Hedionda Creek	11/8/2002	50	81.25	1.2	74.36	50/50	2/2	100	>100	0.85	100	>100/>100	1
	2/11/2003	100	>100	0	80.79	50/100	2/1	50	>100	0.77	100	>100/>100	1
	2/25/2003	100	>100	0.59	>100	50/50	2/2	50	>100	1.01	100	>100/>100	1
Escondido Creek	11/8/2002	100	>100	0	>100	100/100	1/1	100	>100	0.73	100	>100/>100	1
	2/11/2003	100	>100	0	>100	100/100	1/1	100	>100	0.41	100	>100/>100	1
	2/25/2003	100	>100	0	>100	100/100	1/1	100	>100	0.41	100	>100/>100	1
San Dieguito River	2/11/2003	100	>100	0	>100	100/12.5	1/8	100	>100	0.23	100	>100/>100	1
	2/25/2003	100	>100	0	>100	100/100	1/1	100	>100	0.51	100	>100/>100	1
	3/15/2003	100	>100	0	>100	100/50	1/2	100	>100	0	100	>100/>100	1
Penasquitos Creek	11/8/2002	100	>100	0	>100	100/100	1/1	100	>100	0	100	>100/>100	1
	12/16/2002	100	>100	0	>100	100/100	1/1	100	>100	0	100	>100/>100	1
	2/11/2003	100	>100	0	>100	100/100	1/1	100	>100	0	100	>100/>100	1
Tecolote Creek	11/8/2002	100	>100	0	>100	100/100	1/1	100	>100	0.51	100	>100/>100	1
	12/16/2002	100	>100	0	>100	100/100	1/1	100	>100	0.24	100	>100/>100	1
	2/11/2003	50	70.71	1.4	60.73	50/50	2/2	100	>100	0.59	100	>100/>100	1
San Diego River	11/8/2002	100	>100	0	>100	100/100	1/1	100	>100	0.41	100	>100/>100	1
	12/16/2002	100	>100	0	>100	100/100	1/1	100	>100	0.41	100	>100/>100	1
	2/11/2003	100	>100	0	>100	100/100	1/1	100	>100	0	100	>100/>100	1
Chollas Creek	11/8/2002	50	77.78	1.3	39.31	25/50	4/2	50	>100	0.69	100	>100/>100	1
	2/11/2003	100	>100	0	>100	50/100	2/1	100	>100	0.51	100	>100/>100	1
	2/25/2003	100	>100	0	>100	100/100	1/1	100	>100	0.85	100	>100/>100	1
Sweetwater River	12/16/2002	50	72.22	1.4	64.29	50/50	2/2	100	>100	0.41	12.5	18.37/24.91	8
	2/11/2003	100	>100	0	>100	100/100	1/1	100	>100	0	100	>100/>100	1
	2/25/2003	100	>100	0	>100	100/100	1/1	100	>100	0.41	100	>100/>100	1
Tijuana River	11/8/2002	12.5	19.5	5.1	18.75	12.5/12.5	8/8	100	>100	0.23	100	>100/>100	1
	2/11/2003	6.25	10.15	9.9	8.5	6.25/6.25	16/16	100	>100	0.23	100	85.01/>100	1
	2/25/2003	25	32.98	3.0	17.68	12.5/12.5	8/8	50	>100	0.91	100	>100/>100	1

Shaded text = bioassay endpoint exceeds toxicity criterion.

Samples with Toxicity to *Ceriodaphnia dubia* During Two of Three Storm Events

Samples from Santa Margarita River, San Dieguito River and Chollas Creek showed toxicity for two of the three storm events sampled, as described below.

The testing for Santa Margarita River was not performed at the MEC laboratory but the interpretation of the results presented here is based on MEC's approach and a comparison with results from the other watersheds. The toxicity for the sample collected during the February 12, 2003 storm event produced a TUc value of 1 for survival (NOEC of >100%) and 2 for reproduction (NOEC of 50%) and a TUa of <0.59 (100% survival in 100% concentration at 96 hours). The February 25, 2003 storm event produced TUc values of 1 for survival (NOEC of 100%) and >4 for reproduction (NOEC of <25%) and a TUa of 0.77. The LC_{50} for both 96 hours and seven days was greater than 100%.

In San Dieguito River, toxicity was highest in the sample collected during the February 11, 2003 storm, no toxicity was observed during the February 25, 2003 storm, and toxicity reappeared at a lower level during the March 15, 2003 storm. The February 11 storm event produced TUc values of 1 for survival (NOEC of 100%) and 8 for reproduction (NOEC of 12.5%) and a TUa of 0 (100% survival in 100% concentration at 96 hours), indicating that toxicity was only expressed in the reproduction endpoint. The March storm event produced TUc values of 1 for survival and 2 for reproduction (NOEC of 50%) and a TUa of 0, indicating much lower toxicity. The LC_{50} for both 96 hours and seven days was greater than 100%.

Samples from Chollas Creek caused toxicity during the November 8, 2002 storm. Toxicity decreased during the February 11, 2003 storm and no toxicity was expressed during the February 25, 2003 storm. For the November 8 storm the LC_{50} at 96-hours was 77.78%, resulting in a TUa of 1.3. The NOEC for seven-day survival was 25% and the NOEC for reproduction was 50% of the test sample, which results in a TUc of 4 and 2 for each endpoint, respectively. The seven-day or chronic LC_{50} (39.31% of the test sample) was lower than that of the acute endpoint, indicating that mortality occurred during the entire test period. For the February 11 storm, however, the toxicity did not occur until the latter half of the test period. At 96 hours, the LC_{50} and the NOEC were greater than 100% and the TUa was zero, indicating no toxicity. The NOEC for seven-day survival was 50% (TUc of 2) and the NOEC for reproduction was 100% (TUc of 1), indicating a slight expression of toxicity in the chronic survival endpoint but not the reproduction endpoint.

Samples with Toxicity to *Ceriodaphnia dubia* During All Three Storm Events

Samples from Agua Hedionda Creek and Tijuana River caused toxicity for all three storm events sampled, as described below.

Agua Hedionda Creek samples caused the greatest toxicity in test organisms during the first storm event (November 8, 2002), decreased in toxicity during the second storm event (February 11, 2003), and results were similar to the second storm results during the third storm event (February 25, 2003). For the November 8 storm, the LC_{50} at 96-hours was 81.25%, resulting in a TUa of 1.2. The NOEC for seven-day survival and reproduction were both 50%, which results in a TUc of 2 for both endpoints. The seven-day or chronic LC_{50} (74.36% of the test sample) was lower than that of the acute endpoint, indicating that mortality occurred during the entire test period. For the February 11 storm, however, the toxicity did not occur until the latter half of the test period. At 96 hours, the LC_{50} and the NOEC were greater than 100% and the TUa was zero, indicating no toxicity. The NOEC for seven-day survival was

50% (TUc of 2) and the NOEC for reproduction was 100% (TUc of 1), indicating a slight expression of toxicity in the chronic survival endpoint but not the reproduction endpoint. The 7-day or chronic LC_{50} was 80.79%. For the February 25 storm, there was slight but not statistically significant toxicity during the first, or acute, part of the test period. The TUa was 0.59 (90% survival in the 100% concentration) but the NOEC was 100%. The chronic NOEC for survival and reproduction was 50% for both endpoints, resulting in a TUc of 2 for both endpoints, indicating that the toxicity for the most part was chronic and not acute. The 96-hour and 7-day LC_{50} values were both greater than 100%.

The toxicity of Tijuana River samples was the highest of all of the samples tested. The first storm event (November 8, 2002) produced a TUa of 5.1 and 96-hour LC_{50} and NOEC of 19.5 and 12.5%, respectively. The TUc values were 8 for both survival and reproduction (NOEC of 12.5% for both). The 7-day or chronic LC_{50} was 18.75%, which was about the same as the acute LC_{50}, indicating that most of the mortality occurred during the first part of the test. The storm event of February 11, 2003 produced a higher acute toxicity (TUa of 9.9, or LC_{50} of 10.15%), and chronic for survival and reproduction (TUc of16, or NOEC of 6.25%, for both). The 7-day or chronic LC_{50} was 8.5%, which was only slightly lower than the acute LC_{50}, indicating that most of the mortality occurred during the first part of the test. The February 25, 2003 storm was the least toxic of the events, producing a TUa of 3.0 (96-hour LC_{50} of 32.98%) and TUc values of 8 for both survival and reproduction (NOEC values of 12.5). The chronic LC_{50} (17.68%) was lower than the acute LC_{50}, indicating that mortality occurred throughout the test period.

A Toxicity Identification Evaluation (TIE) was conducted on Tijuana River storm water in an effort to identify the source of toxicity to *Ceriodaphnia dubia*. The discussion on the TIE can be found in Section 3.5.

3.3.5.2 *Hyalella azteca*

A summary of the results from the *H. azteca* 96-hour acute bioassays performed is provided in Table 3-5. Control and reference toxicant test criteria were met for all tests with the following exceptions. Control survival (77.5%) for the sample from San Luis Rey collected on November 8, 2002 was below the recommended limit of ≥ 90%. All other controls run at the same time were within limits and the survival was greater than 90% in the 100% concentration. Therefore, it was not believed that the poor control survival significantly impacted the results. Control survival was again slightly lower than protocol limits for samples from Tecolote Creek (82.5%) and San Diego River (87.5%) for the December 16, 2002 sampling. The survival in all other concentrations of these samples was above 90% and the controls for the other two samples tested during this event had survival above 90%. Therefore, it is unlikely that this poor survival impacted the results.

All samples had 96-hour LC_{50} values of greater than 100% of the test sample.

Samples with No Toxicity to *Hyalella azteca*

Samples from several mass loading stations caused toxicity but the NOEC was 100%, as described below.

San Luis Rey River showed acute toxicity in the November 8, 2002 storm event sample with a TUa of 0.51 and the February 25, 2003 storm with a TUa of 0.23. However, while the TUa values were higher than zero, there was no statistically significant decrease in survival as the NOEC was the 100% concentration for both storm events.

Escondido Creek had TUa values of 0.73, 0.41, and 0.41 for the November 8, 2002, February 11, 2003, and February 25, 2003 storm events samples respectively. Survival was not significantly reduced when compared to the control in any of the samples evaluated as the NOEC values were all equal to 100% of the sample.

San Dieguito River caused acute toxicity for the February 11, 2003 storm with a TUa of 0.23 and for the February 25, 2003 storm with a TUa of 0.51. However, while the TUa values were higher than zero, there was no statistically significant decrease in survival as the NOEC was the 100% concentration for both storm events.

Tecolote Creek had TUa values of 0.51, 0.24, and 0.59 for the November 8, 2002, December 16, 2002 and February 11, 2003 storm events samples respectively. Survival was not significantly reduced when compared to the control in any of the samples evaluated as the NOEC values were all equal to 100% of the sample.

San Diego River caused acute toxicity for the November 8, 2002 storm with a TUa of 0.41 and for the December 16, 2002 storm, again with a TUa of 0.41. However, while the TUa values were higher than zero, there was no statistically significant decrease in survival as the NOEC was the 100% concentration for both storm events.

Sweetwater River caused acute toxicity for the December 16, 2002 storm with a TUa of 0.41 and for the February 25, 2003 storm, again with a TUa of 0.41. However, while the TUa values were higher than zero, there was no statistically significant decrease in survival as the NOEC was the 100% concentration for both storm events.

Samples with Toxicity to *Hyalella azteca* During One of Three Storm Events

Samples from Santa Margarita River, Chollas Creek, and Tijuana River caused toxicity for one out of three storm events sampled, as described below.

Santa Margarita River TUa values were 1.12, and <0.41 for the February 12, 2003 and February 25, 2003 storm events respectively. Only the first storm event sample caused a statistically significant decrease in survival with a NOEC of 50% of the test sample.

Chollas Creek TUa values were 0.69, 0.51, and 0.85 for the November 8, 2002, February 11, 2003, and February 25, 2003 storm events respectively. Only the first storm event sample caused a statistically significant decrease in survival with a NOEC of 50% of the test sample.

A TIE was conducted on Chollas Creek storm water in an effort to identify the source of toxicity to *Hyalella azteca*. Section 3.5 below describes the results of the TIE.

Tijuana River had TUa values of 0.23, 0.23, and 0.91 for the November 8, 2002, February 11, 2003, and February 25, 2003 storm events samples respectively. Only the third storm event sample caused a statistically significant decrease in survival with a NOEC of 50% of the test sample.

Samples with Toxicity to *Hyalella azteca* During Two of Three Storm Events

Samples from Agua Hedionda Creek caused toxicity for two storm events sampled, as described below.

Agua Hedionda Creek TUa values were 0.85, 0.77, and 1.01 for the November 8, 2002, February 11, 2003, and February 25, 2003 storm events respectively. Only the last two storm event samples caused a statistically significant decrease in survival, with a NOEC of 50% of the test sample for each.

3.3.5.3 *Selenastrum capricornutum*

A summary of the results from the *Selenastrum* 96-hour chronic bioassays performed is provided in Table 3-5. Test acceptability standards and reference toxicant test criteria were met for all tests.

Samples with No Toxicity to *Selenastrum capricornutum*

Samples from stations in San Luis Rey River, Agua Hedionda Creek, Escondido Creek, San Dieguito River, Peñasquitos Creek, Tecolote Creek, San Diego River, and Chollas Creek did not cause toxicity in *S. capricornutum* during any storm event.

The Tijuana River sample showed much lower toxicity for the February 11, 2003 storm. The NOEC was 100% of the test sample, giving a TUc of 1 which complies with the permit limits. The IC_{25} was 85.01% of the test sample and the IC_{50} greater than 100% of the test sample indicating a slight inhibition in cell replication. All other storm events indicated no toxicity.

Samples with Toxicity to *Selenastrum capricornutum* During One of Three Storm Events

Samples from stations in Sweetwater River caused toxicity for one of the three storm events sampled, as described below.

The Sweetwater River sample from the December 16, 2002 storm had an NOEC of 12.5% of the test sample, which equals a TUc of 8. The IC_{25} was 18.37% of the test sample, and the IC_{50} was 24.91% of the test sample. All other storm events indicated no toxicity.

A TIE was conducted on Sweetwater River storm water in an effort to identify the source of toxicity to *Selenastrum capricornutum*.

3.4 Relationship Between Storm Water Toxicity Measurements Constituents of Concern

The relationship between toxicity and constituents of concern (COC) has been evaluated by two methods. The first method presented below uses a multiple regression model to correlate changes in toxicity to changes in COC levels in the water. This method groups data from all watersheds, is useful in providing general trends across the county, and evaluating the effects of several COC at once. Sometimes thresholds of chemical concentrations are involved with toxicity whereby the organisms do not respond negatively until a certain chemical level is reached. Concentrations of COC above a specific threshold may no longer illicit a linear response in organism toxicity. Consequently, thresholds detract from the regression model. Therefore, a second method, threshold analysis, was used to clarify relationships following the regression analyses using the COC that were significant components of the final multiple regressions. The threshold analysis uses COC levels reported to be toxic in the literature where available and compares them to COC levels in the storm water samples.

3.4.1 Statistical Methods

3.4.1.1 Multiple Regression Analysis of Toxicity Data

Multiple regression was the statistical tool used to look for relationships between toxicity results and the physical, chemical, and biological COC across all watersheds. This type of statistical analysis looks for the best relationship between the response variable (i.e., toxicity units for each endpoint) and the regressor variables (COC). To best fit a multiple regression model, the number of observations must be larger than the number of regressor variables. Because the number of COC was greater than the number of samples, it was first necessary to reduce the number of COC used in the analysis. To do this reduction, a principal component analyses (PCA) was performed on the COC. Two PCA analyses were run, the first for metal constituents and the second for the physical and organic results (excluding bacteria and pesticides). The PCA creates factor loadings along multiple axes that define (or explain) the variance in the data and identifies the contribution of each constituent to each axis. The resultant axes that accounted for a significant portion of the variance were run as regressors in addition to bacteria and pesticide measurements for each toxicity endpoint.

The best-fit regression was selected for each endpoint by running a backward regression. This type of multiple regression starts with all regressors and eliminates them step-by-step according to their contribution to the model (least significant are dropped first) until all regressors remaining are significant. The adjusted R^2 values (adjusted for the number of observations and number of regressors) tend to stabilize when an adequate number of regressors remain in the model and are therefore used to determine the best model for the regression. When one of the PCA axes was retained as a significant regressor in the model, a second regression was run with the individual COC that were weighted at least 0.75 on the axis to further refine the analysis. Due to differences in detection limits for pesticides and dilutions for bacteria analyses for the data collected at Santa Margarita, this site was excluded from these analyses.

Additionally, another multiple regression was run combining the results from 2001-02 and 2002-03. With the additional observations, it was not necessary to screen the regressor variables and all COC that were measured in both years were included in the analyses.

3.4.1.2 Threshold Analyses

Threshold values from literature, the total maximum daily load (TMDL) Study in Chollas Creek (MEC 2002), and other studies not yet published (personal communication with Jack Word) were assigned to COC retained in the final regressions of each toxic response test (e.g., *Ceriodaphnia* chronic test for survival). Where threshold values were not available, "best-fit" values (those that gave the best match to the observed toxicity results) were selected. Values were available for diazinon, nickel, lead, zinc, nitrate, and conductivity.

Resources

The EPAs "Ecotox" database (www.epa.gov/ecotox) provides toxicity data by species and chemical, which is collected from a large number of independent studies. This resource also provides information on test duration, endpoints observed, as well as other parameters. Toxicity values for nitrate, metals, and all three test species were collected from this resource.

The Handbook of Environmental Data on Organic Chemicals (Vershueren 1983) provides data on air and water pollution factors, bioconcentration and toxicity for a variety of organic chemicals, including pesticides. Toxicity data are provided by species and endpoint. Toxicity values for diazinon, chlorpyrifos, and malathion for species related to *Ceriodaphnia dubia* and *Hyalella azteca* were collected from this resource.

Other resources included the Chollas Creek TMDL Study conducted over several storm seasons in Chollas Creek (MEC 2002) and private client studies not yet published conducted by MEC (personal communication, Jack Word).

Despite the usefulness of these resources, they have limitations. Toxicity values are not always provided for the test durations used in this storm water toxicity study. When using a value from a longer test period (say a 21-day test), the value will likely be a conservative estimate of what level would actually cause toxicity in a 7-day test. Data are also not provided for all COC or it is possible that the data provided is for a related species to the test species used in this study, which will most likely have a different sensitivity to the toxicants than the test species selected for this study. Criteria used in the selection of the literature value reported in this study include the test period (close to that used for the current study), the endpoint measured (one that was measured in this study [e.g.: no behavioral endpoints]), the test species (either the test species used in this study or the one most closely related to it for which there is a value available), and the value itself (the lowest value reported).

These resources do not provide toxicity data of physical parameters (e.g., total dissolved solids, hardness, turbidity) to the test species. For the relationship between physical parameters and toxicity it is best to rely upon the regression analysis. These resources also do not provide information on possible interactions between chemicals or the interactions between chemicals and physical parameters.

Threshold Statistical Analyses

The statistical testing procedure is used to establish a two-by-two matrix with one column of "less than the threshold" and the second column of "greater or equal to the threshold" and with one row of "no observed effect" and a second row of "effect observed". Fisher's Exact Test (2-tail) was used to establish the exact probability of the table outcome by chance. A small probability (<0.05) was used to determine if the assigned threshold values were significant in explaining the outcomes of the toxicity tests.

3.4.2 Results

3.4.2.1 Principal Components Analyses (PCA) Results

The PCA on the metal (dissolved and total) COC had 36% of the variance explained by the first component. The next three components were fairly close in explaining another 45% of the variance (17, 15, and 13%) and therefore all four components were used for the multiple regressions. Total arsenic, chromium, copper, lead, nickel, and zinc defined metal component 1. The second metal component represented dissolved arsenic and nickel. Dissolved copper and zinc were the main contributors to metal component 3 while dissolved and total selenium defined metal component 4. The PCA on the physical and organic measures had 85% of the variance explained by the first four components. All four components were retained in the regression analyses. Component 1 was composed of biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved organic carbon, and dissolved phosphate. The second component represented the measures of MBAS surfactants, total Kjeldahl nitrogen (TKN), TSS, and turbidity. TDS and hardness were the main contributors to component 3 while nitrite and nitrate dominated component 4.

The retained PCA components, the pesticides chlorpyrifos, diazinon, and malathion; and the bacterial measures of total coliforms and Enterococci (fecal coliforms were not included as they were 87% correlated with total coliforms) were used as regressors with each of the toxicity endpoints. A second set of multiple regressions was run using only the retained individual regressors and the main COC of each significant PCA component to determine which individual COC explained the toxicity results.

3.4.2.2 Regression and Threshold Analyses Results 2002-03

This is the second year of monitoring at all 11 mass loading stations and therefore the second year of multiple regression analysis for these stations. Regression analyses indicated some different results from last year with regard to significant regressors. For example, diazinon and nitrogen compounds were significant regressors with both *Ceriodaphnia dubia* acute and chronic survival. Although diazinon and nitrogen compounds are still significant regressors, additional analytes also appear to be contributing including some metals and total suspended solids. Even with two years of data, this is still a limited data set and the relationships will continue to be evaluated as the long-term data set is developed.

Ceriodaphnia dubia Survival

Strong relationships were found with diazinon, malathion, TSS, and other compounds for *Ceriodaphnia dubia* survival, both acute and chronic (Table 3-6). The relationships (slopes) were negative for all significant COC, indicating that as COC concentrations increase, toxicity also increases (the NOEC decreases). These regressions correlated well with the data (Figures 3-6 and 3-7), especially with respect to diazinon and malathion.

Table 3-6. Multiple regression results.

Toxicity Endpoint (NOEC)	Prob > F	R^2	Significant Regressors*
Ceriodaphnia dubia acute survival	0.0001	0.93	diazinon (-), malathion (-), TSS (-) turbidity (-), nitrate (-), dissolved copper (-)
Ceriodaphnia dubia chronic survival	0.0001	0.93	diazinon (-), malathion (-), TSS (-),enterococci (-)
Ceriodaphnia dubia chronic reproduction	0.0001	0.72	diazinon (-), malathion, (-), TSS (-), hardness (-)
Hyalella azteca acute survival	0.0001	0.75	diazinon(-),dissolved copper (-), dissolved zinc (-), dissolved phosphate (+), TKN (-), TSS (-), turbidity (-)
* + indicates positive slope, - indicates negative slope Unshaded results indicate a strong correlation.			

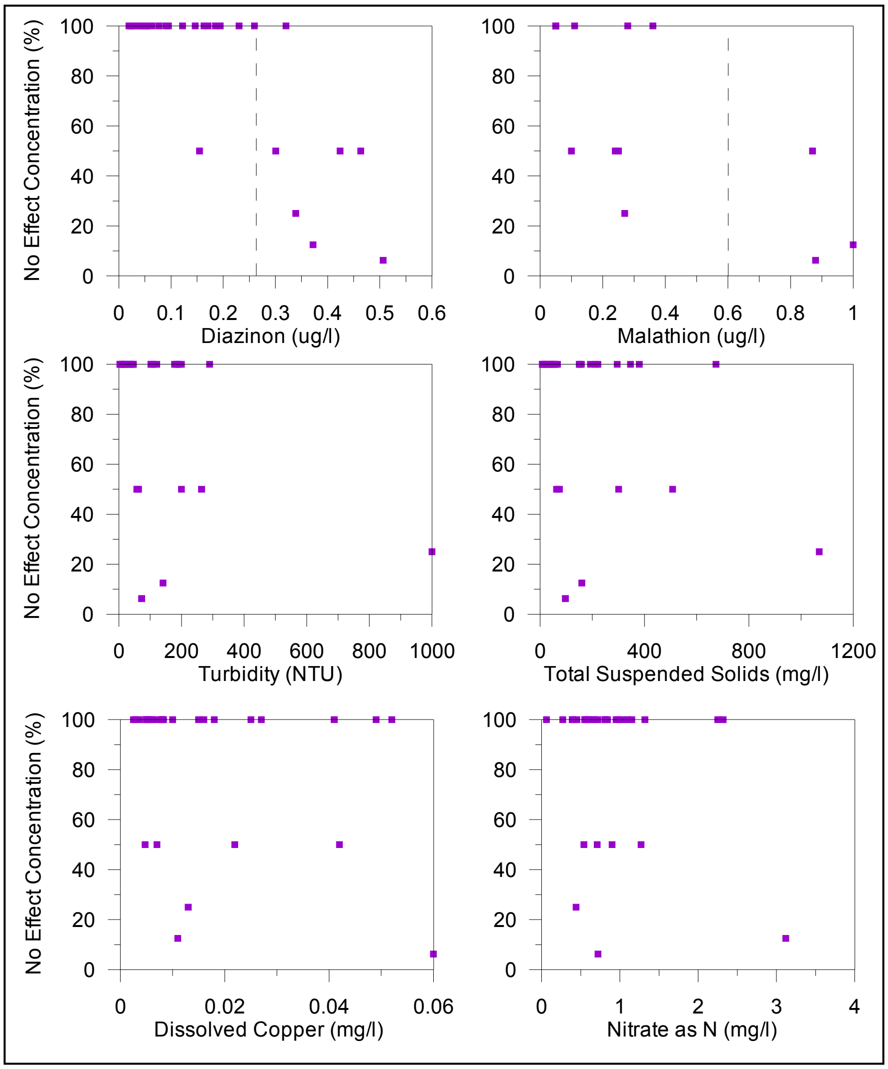

Figure 3-6. Relationships of *Ceriodaphnia dubia* acute survival with significant regressors from multiple regression analysis. Threshold concentrations are shown with a dashed line when available.

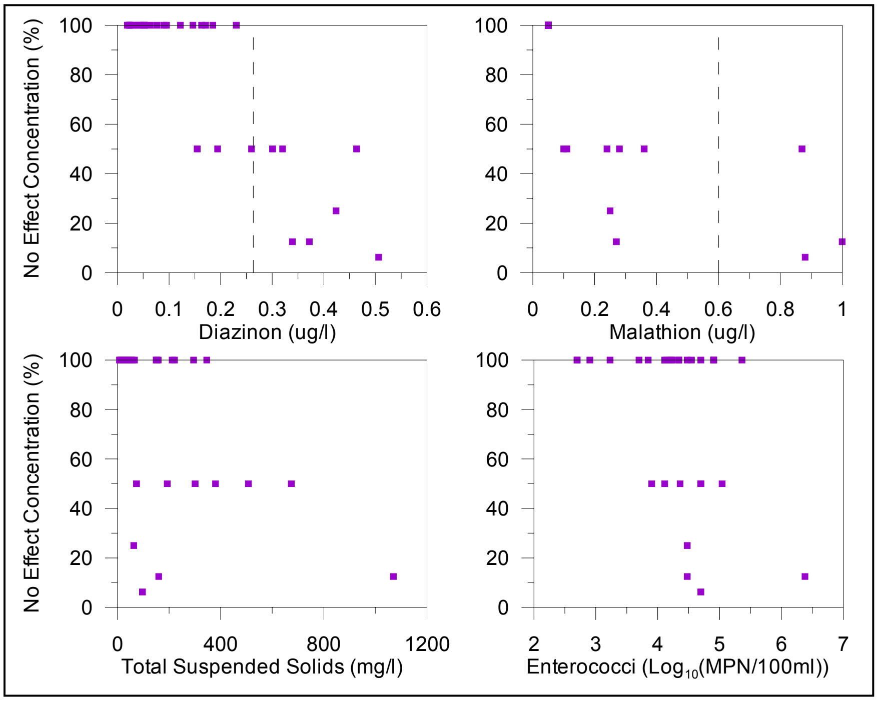

Figure 3-7. Relationships of *Ceriodaphnia dubia* chronic survival with significant regressors from multiple regression analysis. Threshold concentrations are shown with a dashed line when available.

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). When this threshold was applied, for *Ceriodaphnia* acute survival, the observed test outcomes from all mass loading stations (MLS)/storms matched the expected outcomes 27 out of 30 times. The diazinon threshold was exceeded at 8 MLS/storms and LC_{50} was less than 100% storm water concentration for 6 of those 8 tests. Diazinon was below the threshold level for 22 MLS/storms and LC_{50} was 100% storm water concentration for all but one of those tests. The probability of this occurring by chance was <0.0001. The literature value for malathion toxicity to *D. magna* is 0.6 μg/L (21-day NOEC) (Vershueren 1983). Application of this threshold to *Ceriodaphnia* acute survival resulted in 27 of 30 matches to the expected results. The LC_{50} was less than 100% on 4 of the 7 MLS/storms when malathion was above 0.6 μg/L. Reviewing the data for *Ceriodaphnia* acute survival and malathion (Figure 3-6), it appears that in the storm water data, a lower threshold may be triggering a response (note that the data point at NOEC=100% and malathion at 0.05 μg/L actually represents 20 MLS/storm observations where malathion was below detection limits). Running the threshold analysis at 0.1 μg/L, results in all 7 of the MLS/storms with a toxic response occurring with malathion above this threshold. Three MLS/storms had no toxic response when malathion exceeded 0.1 μg/L. There were no other significant variables in the regression equation with available threshold values.

The literature value for diazinon of 0.26 μg/L was again used as the threshold for *Ceriodaphnia* chronic survival. The observed toxicity test outcomes from all MLS/storms matched the expected outcomes 28 out of 30 times. The diazinon threshold was exceeded at 8 MLS/storms and LC_{50} was less than 100% storm water concentration on all of the tests. Diazinon was below the threshold level for 22 MLS/storms and LC_{50} was 100% storm water concentration for 20 of those tests. The probability of this occurring by chance was <0.0001. Malathion was above the detection limit (0.1 µg/L) for 10 MLS/storms. All of these showed a toxic response for *Ceriodaphnia* chronic survival.

Ceriodaphnia dubia Reproduction

The regression for *Ceriodaphnia* reproduction was weaker with an R^2 of 0.72 using diazinon, malathion, and TSS again as significant regressors (Table 3-6 and Figure 3-8). The other significant regressor was hardness. Threshold analyses with diazinon at 0.26 µg/L and malathion at 0.1 µg/L were also significant with 26 of 30 matches for the expected results. Comparing the results to malathion at the literature threshold (0.6 µg/L) was also significant with 24 of 30 correct matches.

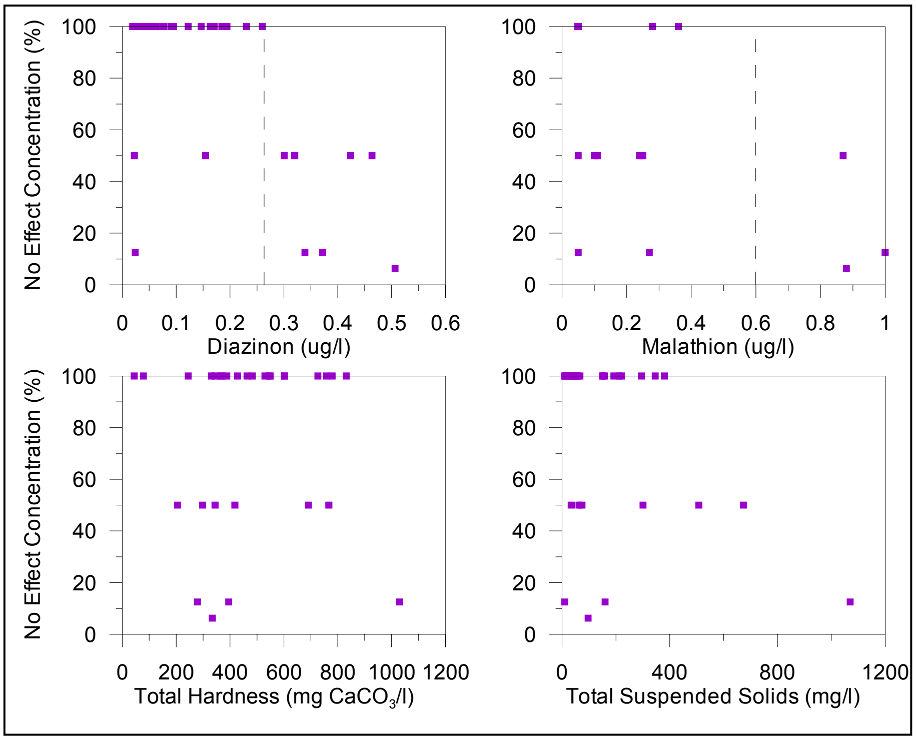

Figure 3-8. Relationships of *Ceriodaphnia dubia* reproduction with significant regressors from multiple regression analysis. Threshold concentrations are shown with a dashed line when available.

Hyalella azteca Survival

The *Hyalella* regression was not as strong as those for *Ceriodaphnia* survival (R^2 = 0.75; see Table 3-6 and Figure 3-9). Only four samples were significantly toxic to *Hyalella*, which is most likely too small of a sample size to create a meaningful regression. As seen in Figure 3-9, the ranges of the various regressors with toxic and non-toxic responses are typically similar. Several of the regressors had one extreme value that is most likely influencing the relationships and each of these was at a different time or location.

Selenastrum capricornutum Growth

Selenastrum had only one toxic response during the 2002-03 storm season and, therefore, no statistical tests were performed for this species.

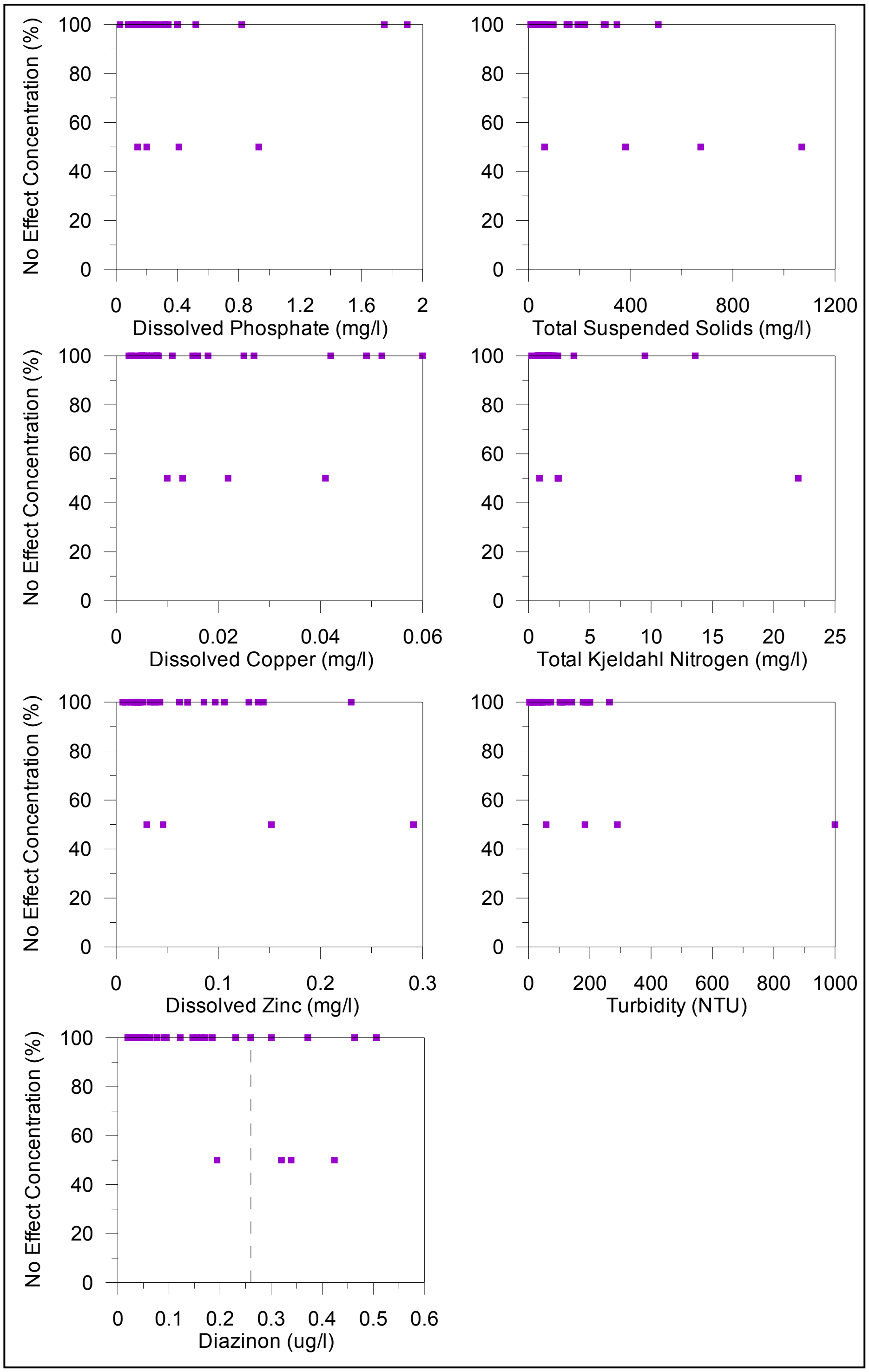

Figure 3-9. Relationships of *Hyalella azteca* survival with significant regressors from multiple regression analysis. Threshold concentrations are shown with a dashed line when available.

3.4.2.3 Regression and Threshold Analyses Results 2001-02 and 2002-03 Combined

Ceriodaphnia dubia Survival

Ceriodaphnia survival, when analyzed with both years combined, shows a strong relationship with diazinon, TSS, and TKN for both acute and chronic tests (Table 3-7). The threshold analysis for diazinon continues to be significant at a threshold of 0.26 µg/L. From this data set, there appears to be a threshold for TKN at about 5 mg/L as seen in Figures 3-10 and 3-11, particularly for the more toxic samples. Total and dissolved nickel show a similar relationship to acute survival at values above the threshold of 0.008 mg/L.

Table 3-7. Multiple regression results for 2001-02 and 2002-03 combined.

Toxicity Endpoint (NOEC)	Prob > F	R^2	Significant Regressors*
Ceriodaphnia dubia acute survival	0.0001	0.90	diazinon (-), dissolved nickel (-), total nickel (-), total arsenic (-), TKN (-), TSS (-), turbidity (-), enterococci (-), nitrate (+)
Ceriodaphnia dubia chronic survival	0.0001	0.84	diazinon (-), nitrite (-), dissolved copper (-), TKN (-), dissolved chromium (-), TSS (-)
Ceriodaphnia dubia chronic reproduction	0.0001	0.73	diazinon (-), TDS, (-), TKN (-), conductivity (+), enterococci (-), nitrate (+), dissolved chromium (-)
Hyalella azteca acute survival	0.0001	0.65	TSS (-), dissolved zinc (-), chlorpyrifos (-), total zinc (-), turbidity (-), nitrite (+), surfactants (-), total lead (+), total antimony (+), BOD (+)
Selenastrum capricornutum	0.0001	0.50	ammonia (+), conductivity (-), total coliform (-), dissolved chromium (-), BOD (-)

* + indicates positive slope, - indicates negative slope
Unshaded results indicate a strong correlation.

Ceriodaphnia dubia Reproduction

Regression results for *Ceriodaphnia* reproduction were less significant and did not show as strong a pattern as those for survival (Table 3-7 and Figure 3-12). Diazinon and TKN showed similar patterns with the NOEC as were found for survival. The patterns for the other regressors, although significant, contribute less visible information to the relationship with decreased reproduction.

Hyalella azteca Survival

Toxicity in *Hyalella* only occurred in 7 of 63 MLS/storms. While the multiple regression resulted in significant relationships (Table 3-7), the large number of significant regressors indicates that each only contributes a small portion in explaining the toxicity. This can be seen in Figure 3-13, where the plots for the six most significant regressors show weak relationships that may be influenced by single points. Chlorpyrifos was identified as a possible factor in *Hyalella* toxicity in 2001-02 at the literature threshold of 0.11 µg/L (96-hour LC_{50} in *G. lacustris*) (Vershueren 1983) but with more results for 2002-03, this pattern is definitely weaker.

Selenastrum capricornutum Growth

Tests on growth for *Selenastrum* showed toxic reactions in 9 of 63 MLS/storms and only one of these results was in the 2002-03 season. The multiple regression on the combined years resulted in a weak correlation (Table 3-7) with five COC. No strong patterns can be seen in the regressors (Figure 3-14).

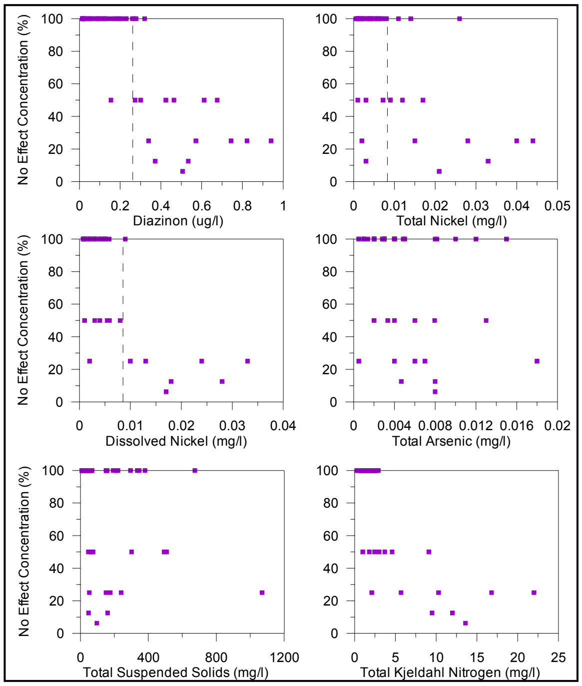

Figure 3-10. Relationships of *Ceriodaphnia dubia* acute survival with the six most significant regressors from multiple regression analysis for 2001-03. Threshold concentrations are shown with a dashed line when available.

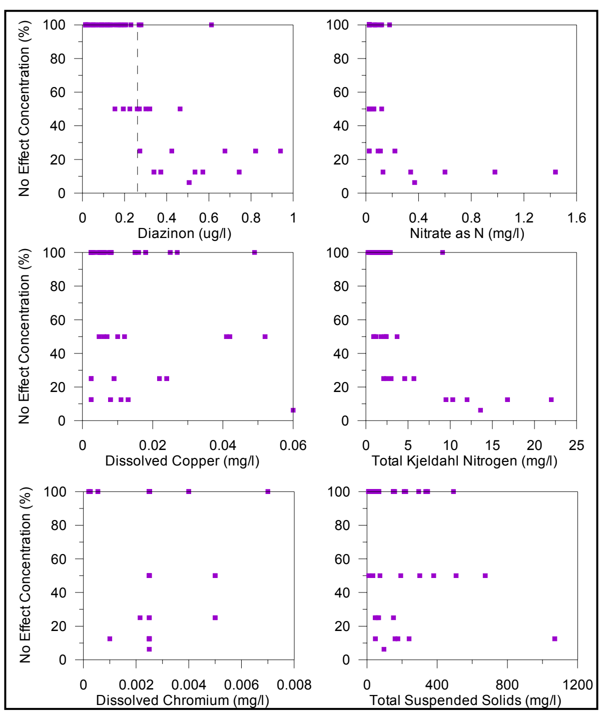

Figure 3-11. Relationships of *Ceriodaphnia dubia* chronic survival with the six most significant regressors from multiple regression analysis for 2001-03. Threshold concentrations are shown with a dashed line when available.

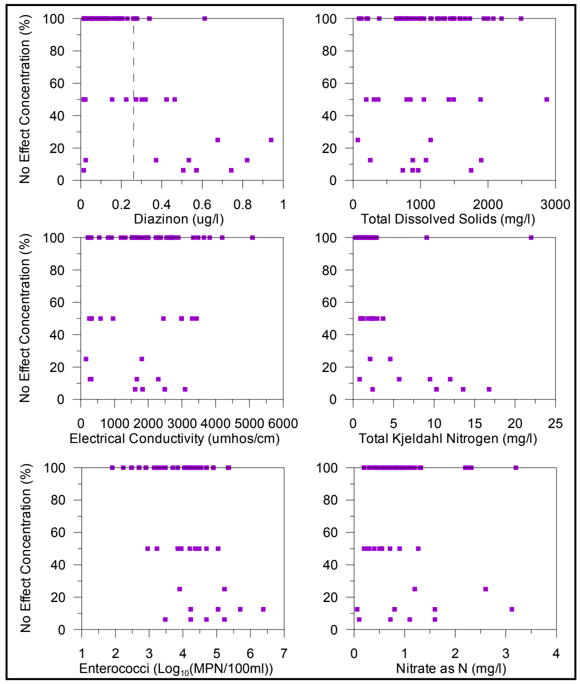

Figure 3-12. Relationships of *Ceriodaphnia dubia* reproduction with the six most significant regressors from multiple regression analysis for 2001-03. Threshold concentrations are shown with a dashed line when available.

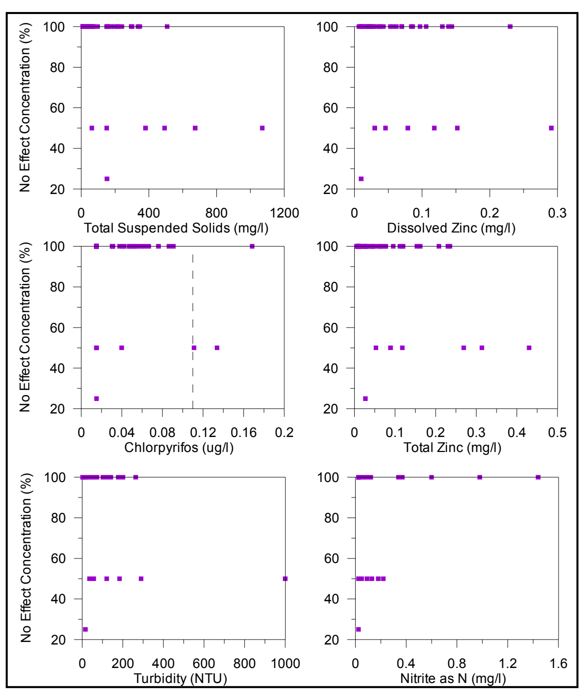

Figure 3-13. Relationships of *Hyalella azteca* survival with the six most significant regressors from multiple regression analysis for 2001-03. Threshold concentrations are shown with a dashed line when available.

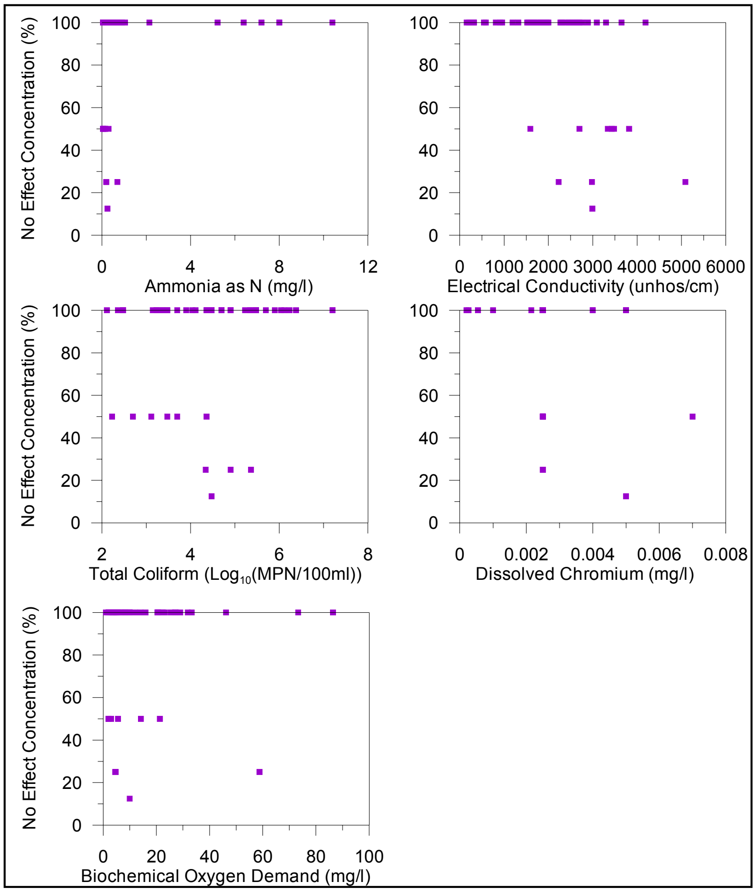

Figure 3-14. Relationships of *Selenastrum capricornutum* growth with the significant regressors from multiple regression analysis for 2001-03.

3.4.2.4 Summary of Statistical Analyses

The statistical evaluation of storm water COC relationships to toxic responses in bioassay test organisms found a strong correlation between toxicity to the organism *Ceriodaphnia dubia* and increasing concentrations of the organophosphate pesticides diazinon and malathion and increasing TSS in 2002-03. Threshold analyses for *Ceriodaphnia* indicated that the literature value of 0.26 μg/L diazinon was an applicable threshold concentration for toxicity. The observed outcome from storm events matched the expected outcomes 28 out of 30 times when diazinon concentrations exceeded this threshold value. Based on this study's observations, the threshold for malathion may be lower than the literature value of 0.6 μg/L. All samples with malathion above this threshold showed a toxic response for the three *Ceriodaphnia* endpoints and most samples with malathion values above the detection limit of 0.1 μg/L. The higher concentrations of diazinon and malathion tend to co-occur; therefore, it can not be determined at this point which one of these pesticides is the major contributor to the response. As additional data is collected, the relationships will continue to be evaluated.

When the past two years of data were combined, the statistics were performed without malathion which was not measured in 2001-02. Diazinon was strongly correlated with toxicity to *Ceriodaphnia* with contributions from increasing TSS and TKN.

These and other relationships will be re-evaluated with the additional data from each storm water monitoring year. Continuing to assess these relationships as additional data are available will provide an increased understanding of toxicity and COC relationships in the region and within each watershed.

3.5 Toxicity Identification Evaluations (TIE)

When findings from toxicity tests performed at mass loading stations indicate the presence of persistent toxicity, a TIE is to be conducted to determine the potential cause or causes of toxicity. Due to the transient nature of storm water, consistent sources of significant toxicity are difficult to identify. It is important to determine when toxicity at a given location is persistent and significant enough to provide clear and useful information in a TIE. To determine when increased toxicity testing and/or a TIE would be called for, a decision making process was developed based on a weight of evidence approach. The decision making process was developed using an approach modified from the Sediment Quality Triad Approach (Chapman 1996). Areas requiring a TIE are identified by integrating the triad of data collected in the program including toxicity and water chemistry from the mass loading stations and benthic community structure analysis from rapid stream bioassessment.

Utilizing this weight of evidence approach, three stations were selected for TIE testing in the 2002-03 storm water season, Chollas Creek using the test species *H. azteca*, Sweetwater River using the test species *S. capricornutum*, and Tijuana River using the test species *C. dubia*. These three locations had TIEs performed during every storm event sampled for the storm water season in which toxicity was induced in their given test species (Table 3-8).

Table 3-8. Recommended actions 2002-2003 from the triad assessment.

Watershed/MLS	Recommended Actions	TIEs
Chollas Creek	Diazinon, chlorpyrifos, turbidity, total and dissolved copper, and total zinc persistently exceed water quality objectives and benchmarks. A TIE has been conducted (SCCWRP 1999) to link diazinon to *Ceriodaphnia dubia* toxicity. Toxicity to *Hyalella azteca* is also persistent in the watershed, however, it is unclear what COC may be responsible for toxicity to this organism. The following actions are recommended: 1) add a bioassessment station (if possible) in Chollas Creek to provide benthic information and 2) perform a TIE using *H. azteca* to establish the COC responsible for toxicity.	Yes
Sweetwater River	There is no persistent exceedance of COC at this station; however, toxicity to *S. capricornutum* was persistent in all three storms monitored. There is evidence of benthic community impacts. The recommended action in this watershed is to conduct a TIE using *S. capricornutum* to determine the COC(s) responsible for toxicity. Once those COC are identified, they should be added to long-term monitoring at this site.	Yes
Tijuana River	Diazinon, chlorpyrifos, and total and dissolved phosphorus persistently exceeded water quality objectives and benchmarks for all storms. Metals and ammonia concentrations also exceeded water quality objectives and/or benchmarks. There is evidence of persistent toxicity to *Ceriodaphnia dubia*, however, no clear linkage has been identified to determine the COC responsible for toxicity. Bioassessment is only conducted in the upper reaches of the watershed. The recommended actions in this watershed are: 1) continue monitoring and add bioassessment information and 2) perform a TIE using *C. dubia* to identify or link COC to toxicity effects.	Yes

The U.S. EPA has issued TIE testing guidelines for characterizing toxic effluents (USEPA 1991, 1992, 1993a, 1993b). These guidelines are often effective for effluents where the toxic constituents are similar to those identified in the model effluents used to develop them. The TIE is a prerequisite to a Toxicity Reduction Evaluation (TRE) for which TIE results can be applied to the TRE treatability approach. The TIE typically consists of three test phases.

Phase I of a TIE involves procedures designed to provide information for identifying the class of the effluents toxic constituents (e.g., volatile, chelatable, filterable, non-polar, reducible or pH sensitive). These classification characteristics are indicated by comparing the results of tests conducted using unaltered effluent samples to those using manipulated effluent samples. Phase I testing involves altering the sample using the following manipulations:

1. EDTA Addition: Detects certain cationic metals
2. Sodium Thiosulfate Addition: Detects oxidative compounds (e.g. chlorine)
3. Aeration: Detects oxidizable or spargeable compounds
4. Filtration: Detects filterable compounds (e.g. TSS related)
5. C_{18} Column Extraction: Detects non-polar organics and some surfactants
6. Graduated pH Adjustment: Detects pH dependent toxicants (e.g. ammonia)
7. Piperonyl Butoxide Treatment: Detects organophosphate pesticides

Phase II TIE methods focus on the identity of the toxicants, while Phase III methods are used to confirm that the suspected toxicants are the true cause of toxicity in the effluent samples (USEPA 1993a, 1993b). It should be noted that the boundaries between Phases I, II and III are not distinct and there may be cases where it is appropriate for their respective procedures to overlap because confirmation information can be obtained during Phases I and II.

TIEs are triggered by toxicity detected during application of standard test methods. These methods sometimes rely on sublethal endpoints, such as *C. dubia* reproduction, as indicators of chronic toxicity and require substantially more time and resources to evaluate than methods that rely exclusively on a mortality endpoint. Therefore, conducting the tests strictly as detailed in those manuals is not always necessary and sometimes not possible. Modifications for conducting TIEs in a more proficient fashion have been developed and include the following:

1. Reduced test volumes
2. Shorter test duration
3. Smaller number of replicates
4. Reduced number of test concentrations
5. Reduction in frequency of test solution renewal

Any loss of precision due to these modifications is not as critical in Phase I testing as it is in Phases II and III. Phase I test procedures are designed to identify obvious alterations in effluent toxicity which may be achieved using modified chronic test methods.

Chollas Creek

Chollas Creek storm water caused slight but significant toxicity during the November 9, 2002 storm event with 85% survival in the undiluted sample and a NOEC of 50%. MEC initiated Phase I TIE testing on November 16, 2002 with this sample. The baseline, or untreated toxicity test, run with the TIE did not indicate significant toxicity and had 97.5% survival in the undiluted storm water which rendered TIE uninterpretable since no manipulation could reduce the toxicity. The storm water sample collected on February 11, 2003 did not produce significant toxicity and had 92.5% survival in the undiluted sample, therefore no TIE was initiated as it was unlikely to produce useful results. The storm water sample collected on February 25, 2003 again did not produce significant toxicity but had a lower survival (72.5%) in the undiluted sample than the previous storm event. A TIE was initiated on March 4, 2003 in the hopes that the baseline would produce enough toxicity to allow interpretation of the effects of the various treatments. The baseline, however, did not produce any toxicity (100% survival in the undiluted sample); therefore, no conclusions could be drawn. The bioassay method used for both rounds of TIE testing was a modified version of the test method used for compliance monitoring (Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates,EPA-821-R-02-012).

Sweetwater River

Sweetwater River storm water caused significant toxicity during the December 16, 2002 storm event with a TUc of 8 and a NOEC of 12.5%. MEC initiated Phase I TIE testing on December 19, 2002. Results indicated the source of toxicity to be a non-polar organic. The storm water samples collected on February 11, 2003 and February 25, 2003 did not produce significant toxicity; therefore, no TIE was initiated as it was unlikely to produce useful results. Due to this lack of toxicity in subsequent storms no further identification of the source of toxicity was possible. The bioassay method used for the Phase I Tier I TIE testing was a modified version of the 4-day *Selenastrum capricornutum* chronic test (USEPA 1994).

Tijuana River

The storm water samples from Tijuana River were the most consistently toxic out of the three chosen for TIE testing. Therefore, it was possible to narrow down the source of toxicity much further than for the other two sites.

Tijuana River storm water caused significant acute toxicity during the November 8, 2002 storm event with an acute NOEC of 12.5% and chronic NOEC values of 12.5% for both survival and reproduction. MEC initiated Phase I TIE testing on November 13, 2002 with this sample. Results indicated the source of toxicity to be a non-polar organic.

Tijuana River storm water again caused significant toxicity during the February 11, 2003 storm event with an acute NOEC of 6.25% and chronic NOEC values of 6.25% for both survival and reproduction. MEC initiated Phase I TIE testing on February 15, 2003 with this sample. Results again indicated the source of toxicity to be a non-polar organic. As the results of the first Phase I test were confirmed, a Phase II test was initiated on February 19, 2003 which included fractionation of the sample on the C_{18} SPE column, followed by fractionation on a High Performance Liquid Chromatography (HPLC) column, and identification of the remaining constituents through Gas Chromatography/Mass Spectrometry (GC/MS).

Tijuana River storm water again caused significant toxicity during the February 25, 2003 storm event with an acute NOEC of 25% and chronic NOEC values of 12.5% for both survival and reproduction. Phase I testing was initiated with this sample on March 27, 2003 and again indicated non-polar organics as the source of toxicity but there was also slight removal of toxicity with the aeration manipulation. Phase II testing was initiated on April 8, 2003 and included the manipulations above for non-polar organics as well as manipulations of the aeration test. Aeration results were inconclusive. Non-polar organic results were compared to those from the first Phase II test and three compounds were singled out as consistently associated with the toxic fraction of the effluent: diazinon, methyl dihydrojasmonate, and quinoline and its products.

Another sample of Tijuana River storm water was collected on May 5, 2003 and, after a screening test to ensure that the sample was toxic (100% mortality in the undiluted sample at 24 hours), a Phase III test was initiated. Testing included determining the concentration of the above mentioned compounds then spiking these concentrations into the sample to recreate the toxicity. Results of the GC/MS analyses for these compounds are listed in Table 3-9.

Table 3-9. Concentrations of compounds of interest from the May 5, 2003 Tijuana River storm water sample.

Compound	Concentration
Chlorpyrifos	None Detected
Diazinon	0.5 µg/L
Dihydrojasmonate	3 µg/L
Substituted Quinoline	0.1 µg/L*

* Heavy matrix interferences prevented positive identification. Quantitation estimated from previous fractionated samples of Tijuana River stormwater samples.

Spiking tests were conducted to confirm the contribution of each compound to the toxicity of the Tijuana River storm water. *C. dubia* were exposed to concentrations of diazinon, methyl dihydrojasmonate, and quinaldine (a commercially available derivative of quinoline) at concentrations bracketing the detected levels of each compound. These tests were conducted by spiking these compounds into standard laboratory water and C_{18} filtered Tijuana River storm water. Testing was inconclusive and unable to recreate the toxicity of the original sample.

The chemicals identified in Tijuana River TIE testing were best matches using GC/MS. Confirmation of these compounds persistence as sources of toxicity (versus single event inputs) requires verification in future storm events. Quinoline is a constituent of creosote, coal tar, and certain other products derived from fossil fuels. It is also produced by combustion of a number of substances including tobacco. It is used as a solvent, a decarboxylation reagent, and as a raw material for manufacture of dyes, antiseptics, fungicides, niacin, pharmaceuticals, and 8-hydroxyquinoline sulfate. (http://www.oehha.ca.gov/prop65/hazard_ident/pdf_zip/quinolin.pdf) Quinoline is used in a variety of industrial processes including petroleum, coal processing, wood preservation, production and use facilities, and shale oil. It is used as an intermediate in the production of various compounds including 8-hydroxyquinoline, hydroxyquinoline sulfate, and copper-8-hydroxyquinolate. Quinoline is also a solvent for resins and terpenes and is used in the production of paints. (http://www.epa.gov/IRIS/toxreviews/1004-tr.pdf) Quinaldine is a derivative of quinoline and is a quinoline plus aldehyde and aniline. It is used in the preparation of oil soluble dyes. These dyes are used in colors for petroleum products, plastic synthetic fibres, and smoke colors. Quinaldine is also used in the production of Quinoline Yellow WS, a food color. Quinaldine Sulphate is used as anaesthetic in the transportation of fish. Quinaldic Acid is an intermediate in the production of antiviral drugs and narrow range pH indicators.

Methyl dihydrojasmonate is a natural essential oil and major scent chemical. It is found naturally in jasmin, tea, and *Heliotropium peruvianum*. It is manufactured to produce a jasmine-based scent for a wide range of uses, mainly in fragrances. It can also be used in flavor compounds with a nuance of citrus flavor. (http://www.zeon.co.jp/business_e/enterprise/spechemi/spechemi2-1.html)

The confirmation of the presence of the above compounds in future storm events, as well as, possible synergistic, or additive effects will be explored through future storm events. Further investigation of literature sources and peer-review publications may provide additional support to the laboratory data and TIE results. Due to the persistent evidence of non-polar organic compounds as the source of toxicity to the Tijuana River storm water, future TIE testing will be streamlined to focus more attention to this area and to expand on the information gathered in the 2002-2003 storm season. Pyrethroid pesticide contamination may also be useful in exploring, as results from the piperonyl butoxide (PBO) manipulation of the second storm event indicate this as a possible source of toxicity. Unpublished procedures under development by U.C. Davis' Marine Pollution Studies Laboratories offer innovative strategies to examine this in the following year. Ultimately, the goal will be to identify the contaminant or contaminants contributing to the toxicity of the Tijuana River storm water.