SWAMP
Surface Water Ambient Monitoring Program

TOXICITY IN CALIFORNIA WATERS: SANTA ANA REGION

Marie Stillway

Dan Markiewicz

Brian Anderson

Bryn Phillips

August 2012

CALIFORNIA Water Boards

www.waterboards.ca.gov/swamp

ACKNOWLEDGEMENTS

The authors thank Heather Boyd, Linda Candelaria and Doug Shibberu of the Santa Ana Regional Board. We are grateful for the services provided by the field crews, laboratory and data management staff who participated in this project. Funding was provided by the Surface Water Ambient Monitoring Program.

TABLE OF CONTENTS TOC

TABLE OF CONTENTS TOC

List of Tables

List of Figures

TABLE OF CONTENTS TOC

EXECUTIVE SUMMARY E

Toxicity testing has been used to assess effluent and surface water quality in California since the mid-1980s. When combined with chemical analyses and other water quality measures, results of toxicity tests provide information regarding the capacity of water bodies to support aquatic life beneficial uses. This report summarizes the findings of monitoring conducted by the Surface Water Ambient Monitoring Program (SWAMP) and associated programs between 2001 and 2010.

As in Anderson et al. (2011), the majority of data presented in this report were obtained from monitoring studies designed to increase understanding of potential biological impacts from human activities. As such, site locations were generally targeted in lower watershed areas, such as tributary confluences or upstream and downstream of potential pollutant sources. Only a minority of sites was chosen probabilistically (i.e., at random). Therefore, these data only characterize the sites monitored and cannot be used to make assumptions about unmonitored areas.

Both freshwater and marine sediment toxicity was common in the Santa Ana Region. Freshwater sediment toxicity was more common than marine sediment toxicity. Sixty percent (60%) of marine sediment sites tested with *Eohaustorius estuarius* were non toxic, with 24% of sites showing *some* toxicity and 6% of sites showing *high* toxicity. Of the eight sites included in the analysis of freshwater stream sediment toxicity, 50% of stream sediments were *highly* toxic, with 12.5% of sites having *some* and *moderate* toxicity, respectively. Twenty-five percent (25%) of stream sediment sites were non toxic. Lake freshwater sediment sites were collected from Lake Elsinore, where 80% of sites showed *some* toxicity, 17% showed *moderate* toxicity, and 3% of the sites were non-toxic.

Marine amphipod survival was closely related to the site's proximity to embayments. A much lower frequency of sediment toxicity was measured in sites collected from off-shore regions compared to those collected near-shore or inland. Marine sediment sites located in embayments are influenced by the surrounding urban areas, including industrial, urban and commercial land uses. Freshwater streams are impacted by both urban and agricultural activities.

As discussed in Anderson et al. (2011), the principal approach to determine whether observations of toxicity in laboratory toxicity tests are indicative of ecological impacts in receiving waters has been to conduct field bioassessments of macroinvertebrate communities. These studies have included "triad" assessments of chemistry, toxicity and macroinvertebrate communities, the core components of SWAMP. One recommendation for future SWAMP monitoring is to conduct further investigations on the linkages between surface water toxicity and receiving system impacts on biological communities.

SECTION 1 INTRODUCTION

The California State Water Resources Control Board published a statewide summary of surface water toxicity monitoring data from the Surface Water Ambient Monitoring Program (SWAMP) in 2011 (Anderson et al., 2011; http://www.waterboards.ca.gov/water_issues/programs/swamp/reports.shtml). This report reviewed statewide trends in water and sediment toxicity collected as part of routine SWAMP monitoring activities in the nine California water quality control board regions, as well as data from associated programs reported to the California Environmental Data Exchange Network (CEDEN) database. The report also provided information on likely causes and ecological impacts associated with toxicity, and management initiatives that are addressing key contaminants of concern. The current report summarizes a subset of the statewide database that is relevant to the Santa Ana Region (Region 8). Source programs, test counts and sample date ranges are outlined in Table 1. A full list of sites included in the Santa Ana regional analysis can be found in the Appendix.

Table 1
Source programs, water and sediment toxicity test counts and test dates for Santa Ana Region regional toxicity data included in this report.

Toxicity Test Type	Program	Test Count	Sample Date Range
Water Column	SWAMP	4	5/24/05 – 05/25/05
Sediment	Anaheim Bay / Huntington Harbour	59	8/7/01 – 8/25/01
	Lake Elsinore	60	5/1/03 – 10/3/03
	Statewide Urban Pyrethroid Monitoring	6	1/7/07
	Stream Pollution Trends (SPoT)	5	5/20/08 – 6/4/08

The Santa Ana River watershed is the largest in Orange County. The Santa Ana River Basin is characterized by mountains which rise steeply from the coastal plains, which are generally undeveloped, and inland valleys, where almost all of the urban and agricultural land uses occur. The Basin is highly urbanized, with nearly five million people living within the watershed, and includes parts of Anaheim, Huntington Beach, Orange, and Santa Ana. Most of the developed watershed is residential or commercial, with large amounts of open space. There are a few pockets of agriculture which are becoming more developed. Urbanization in the Santa Ana River Basin has resulted in an alteration of stream channels and the sources of water reaching those channels. The primary source of base flow in the Santa Ana River and many of its tributaries is related to waste water effluent. Secondary sources include mountain runoff, urban runoff and ground water influx. During storm events, base flow is supplemented primarily by urban runoff, and secondarily by runoff from undeveloped and agricultural areas. Watersheds in this region are influenced by a mix of land uses.

The majority of the toxicity data collected in the Santa Ana Region was produced under SWAMP and the Southern California Coastal Water Research Project (SCCWRP), and has addressed the potential for water and sediment toxicity arising from multiple sources. In addition, recent research has expanded the consideration of the toxicity of urban runoff, particularly in regard to contamination of urban waterways by pyrethroid pesticides (Amweg et al., 2006; Holmes et al., 2008; Phillips et al., 2010b; Weston et al., 2005); Weston and Jackson, 2009)

SECTION 2
SCOPE AND METHODOLOGY

This study examined all toxicity data included in the SWAMP and CEDEN databases from toxicity tests whose controls showed acceptable performance according to the Measurement Quality Objectives of the 2008 SWAMP Quality Assurance Project Plan (QAPrP). The attached maps (Figures 4-9) show locations of sites sampled for toxicity by SWAMP and partner programs and the intensity of toxicity observed in the water and sediment samples collected at those sites. Sites are color-coded using the categorization process described in Anderson et al. (2011), which combines the results of all toxicity tests performed on samples collected at a site to quantify the magnitude and frequency of toxicity observed there. At sites where both water and sediment toxicity data were collected, two toxicity categories were calculated to separately summarize the degree of toxicity in water and in sediment. Most of the toxicity test results reported in the Santa Ana Region were from freshwater sediment tests with the amphipod *Hyalella azteca* and marine sediment tests with the amphipod *Eohaustorius estuarius*. Additional freshwater exposures with the cladoceran *Ceriodaphnia dubia* and the fathead minnow *Pimephales promelas* were conducted on two stations from the San Gabriel River-Coyote Creek Watershed. Only survival endpoints are considered in the measures of toxicity reported here; therefore sites identified as toxic showed a significant decrease in test animal survival in one or more samples.

Several steps were followed to determine the toxicity of individual samples and to categorize the toxicity of individual sites.

1. Standardize the statistical analyses: When data were submitted to the SWAMP/CEDEN databases, reporting laboratories evaluated the potential toxicity of samples using a variety of statistical protocols. In order to standardize the analysis of the entire data set, all control – sample comparisons were re-analyzed using the proposed EPA Test of Significant Toxicity (Anderson et al., 2011; Denton et al., 2010; USEPA, 2010). Individual samples were categorized as not toxic, toxic or *highly* toxic (see 2 below)

2. Calculate the High Toxicity Threshold: The High Toxicity Threshold is determined for each species' endpoint from the entire dataset summarized in the Statewide Report (Anderson et al., 2011). This threshold is the average of two numbers, both expressed as a percent of the control performance. The first number is the data point for the 99th percentile of Percent Minimum Significant Difference (PMSD), representing the lower end of test sensitivity across the distribution of PMSDs in the Statewide Report. The second value is the data point for the 75th percentile of Organism Performance Distribution of all toxic samples, representing an organism's response on the more toxic end of the distribution. This average serves as a reasonable threshold for *highly* toxic samples.

3. Determine the Toxicity Category for each site: The magnitude and frequency of toxicity at each site was categorized (Table 2) according to Anderson et al. (2011) and Bay et al. (2007), as "non-toxic", "*some* toxicity", "*moderately* toxic", or "*highly* toxic". Throughout this document the terms *some*, *moderately* and *highly* will be italicized when in reference to these categories.

Separate categories were created for sediment and for water toxicity, as well as for toxicity to individual freshwater species.

Table 2
Data conditions used to determine toxicity categories for any given sample collection site.

Category	Conditions for Categorization
Non-toxic	No sample is ever toxic to any test species
Some Toxicity	At least one sample is toxic to one or more species, and all of the species' responses fall above their species-specific High Toxicity Threshold
Moderate Toxicity	At least one sample is toxic to one or more species, and at least one of the species' responses falls below their species-specific High Toxicity Threshold
High Toxicity	At least one sample is toxic to one or more species, and the mean response of the most sensitive species falls below its respective High Toxicity Threshold

SECTION 3
REGIONAL TOXICITY

Both freshwater and marine sediment toxicity was common in the Santa Ana Region between 2001 and 2010 (Figures 1-3). Freshwater sediment toxicity was more common than marine sediment toxicity. Sixty percent (60%) of marine sediment sites tested with *E. estuarius* were non-toxic, with 24% of the sites showing *some* toxicity and 16% of sites showing *high* toxicity (Figure 1). Freshwater sediment sites were divided into two categories: stream and lake, and most were tested with *H. azteca*. Fifty percent (50%) of freshwater stream sediment sites were *highly* toxic, with 12.5% of sites showing *some* and *moderate* toxicity, respectively. Twenty-five percent (25%) of freshwater stream sites were non-toxic (Figure 2). It should be noted, however, that there were only eight sites included in the freshwater stream analysis. Lake freshwater sediment sites were collected from Lake Elsinore, where 80% of the sites showed *some* toxicity, 17% of sites showed *moderate* toxicity and 3% of sites showed no toxicity (Figure 3). Freshwater toxicity tests included exposures of fish and the invertebrate *C. dubia* and were conducted on two sites located adjacent to golf courses in the San Gabriel River-Coyote Creek Watershed (801SGB017 and 845SGB007) for this report. No toxicity was seen in either instance (Table 3).

Table 3
Species-specific maximum levels of toxicity observed at sites tested with *E. estuarius* and *H. azteca* sediment toxicity tests, and *C. dubia*, and *P. promelas* water toxicity tests.

Species	Number of Sites	Maximum Toxicity Level Observed			
		Non-Toxic	Some Toxicity	Moderately Toxic	Highly Toxic
E. estuarius	87	52	21	0	14
H. azteca	38	3	25	6	4
C. dubia	2	2	0	0	0
P. promelas	2	2	0	0	0

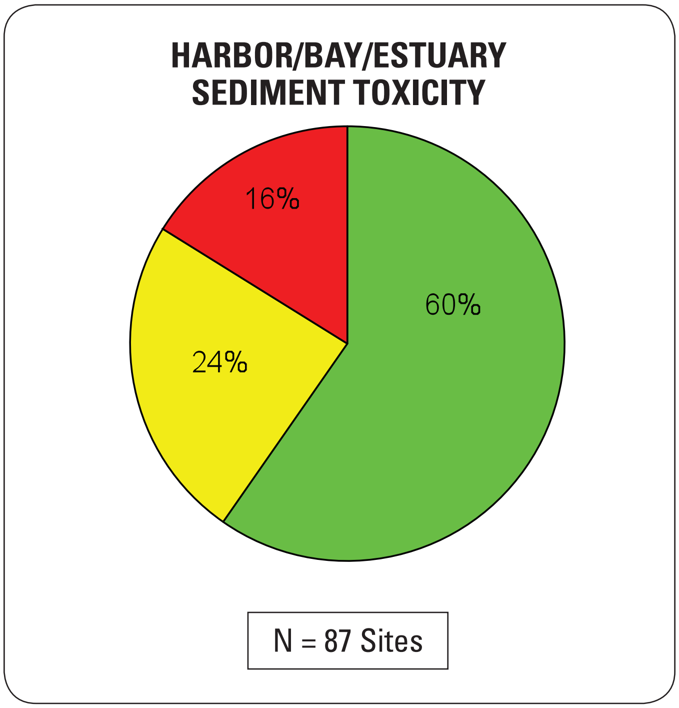


Figure 1. Magnitude of toxicity to *E. estuarius* in marine sediment samples collected from the Santa Ana Region of California.

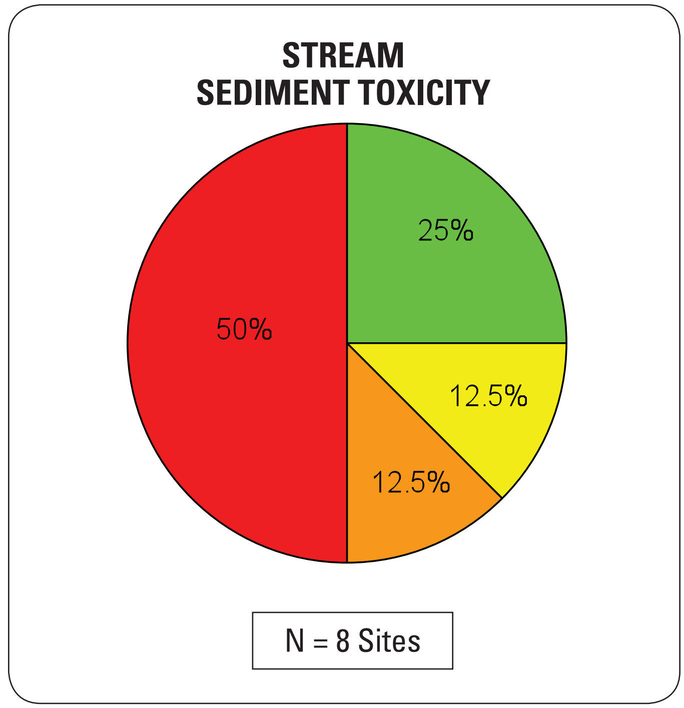


Figure 2. Magnitude of toxicity to *H. azteca* in freshwater stream sediment samples collected from the Santa Ana Region of California.

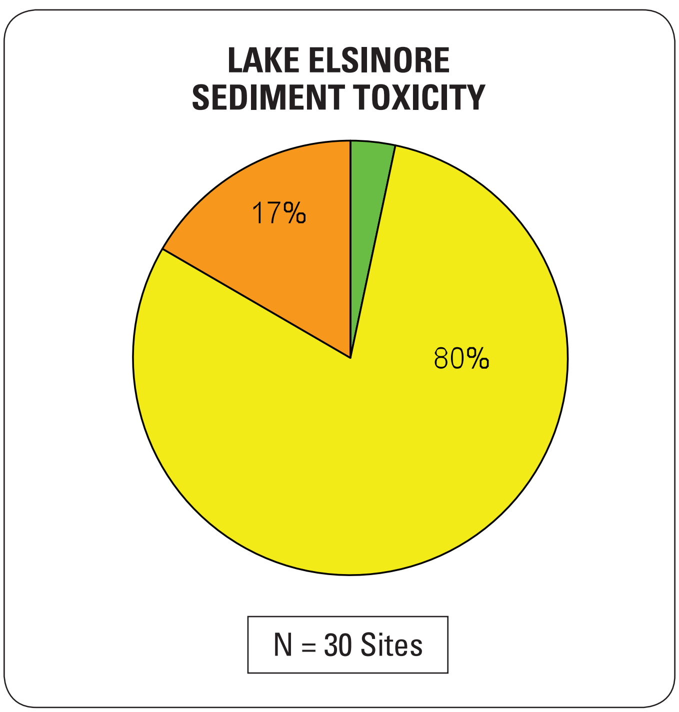
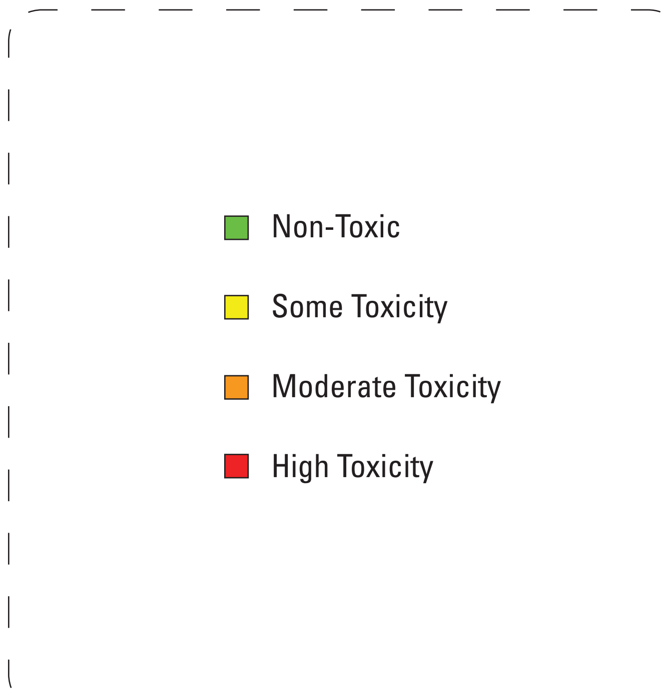


Figure 3. Magnitude of toxicity to *H. azteca* in freshwater sediment samples collected from Lake Elsinore in the Santa Ana Region of California.



SECTION 4
RELATIONSHIPS BETWEEN LAND USE AND TOXICITY

Land use was quantified as described in Anderson et al. (2011), around stream, canal and ditch sites at which samples were collected for testing in water column or sediment toxicity tests. Using ArcGIS, polygons were drawn to circumscribe the area within one kilometer of each site that was upstream of the site, in the same catchment, and within 500 meters of a waterway draining to the site. Land use was categorized according to the National Land Cover Database. All "developed" land types in the land cover database were collectively categorized as "urban". "Cultivated crops" and "hay/pasture" were categorized together as "agricultural". All other land types were categorized as "other" for the purpose of this analysis. Percentages of each land use type were quantified in the buffers surrounding the sample collection sites. Urban land category represents sites with nearby upstream land use of greater than 10% urban and less than 25% agricultural areas. Agricultural land category represents sites with nearby upstream land use of greater than 25% agricultural and less than 10% urban areas.

In the SWAMP/CEDEN databases, sediment toxicity information from the Santa Ana Region was largely limited to data from sites in urban areas, with little contribution from agricultural uses (Figure 4). Land use within the basin is approximately 35% urban, 10% agricultural and 55% undeveloped. For marine sites, those located close to shore had heavy urban influence (Figure 5).

There are two major storm channels which enter Anaheim Bay and the Huntington Harbour Complex: the Bolsa Chica Flood Control Channel, which enters lower Huntington Harbour, and the East Garden Grove Wintersburg Flood Control Channel, which enters Outer Bolsa Bay. These storm channels collect runoff from portions of urbanized areas in the cities of Anaheim, Stanton, Cypress, Orange, Santa Ana, Garden Grove, Westminster, Los Alamitos, Seal Beach and Huntington Beach. These channels, as well as their tributaries, convey runoff from highly urbanized areas into Huntington Harbour (Vitale, 2007b).

Marine amphipod survival was closely related to the site's proximity to embayments; a much lower frequency of sediment toxicity was measured in sites collected from offshore regions, compared to those collected near-shore or inland. Sites located in Huntington Harbour and within the Upper and Lower Newport Bay exhibited a *high* magnitude of toxicity. These areas in particular are heavily influenced by the surrounding urban areas, including marina, residential and industrial uses.

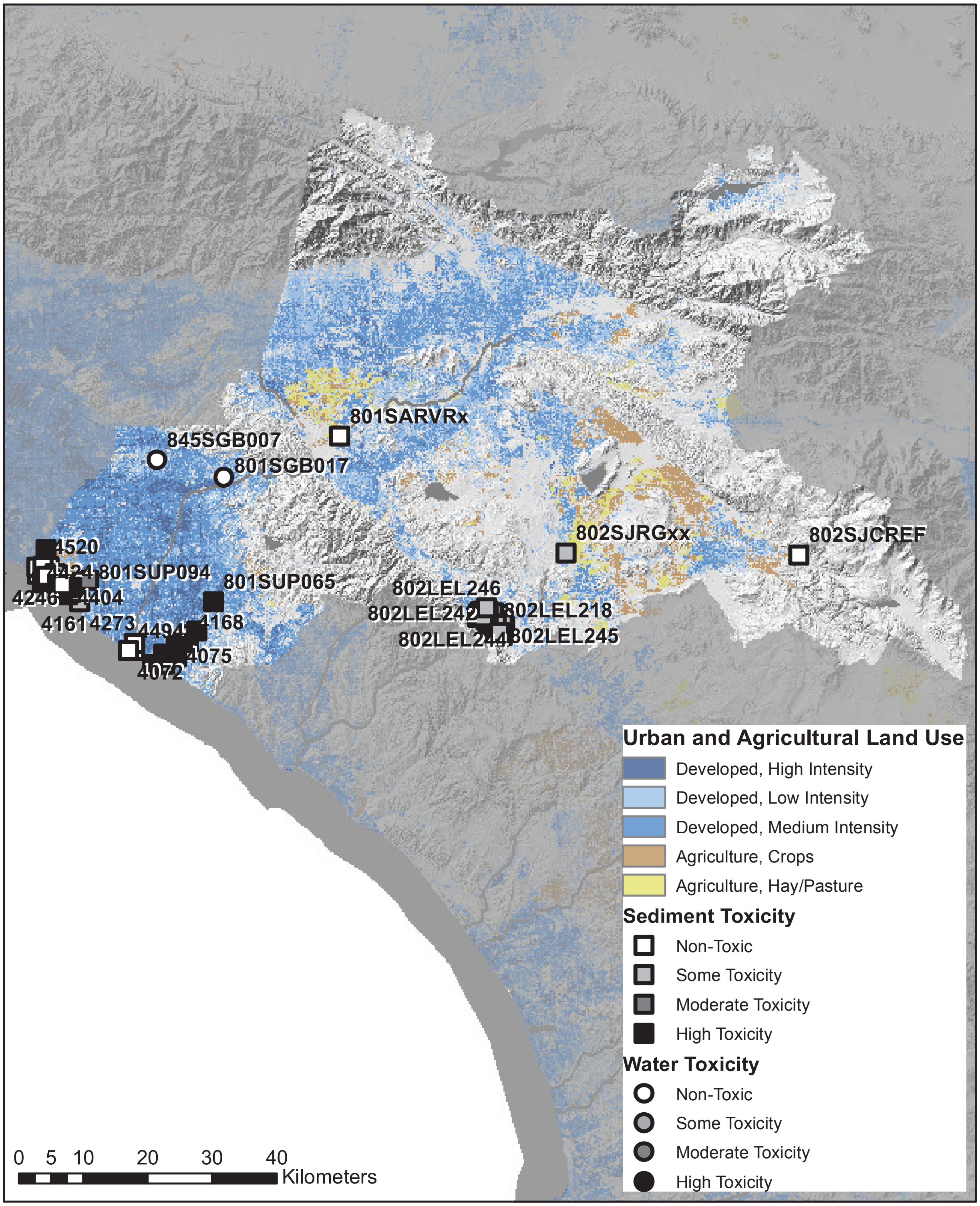


Figure 4. Magnitude of sediment and water toxicity at sites in the Santa Ana River Basin of California. Sediment toxicity was based on 10-d amphipod survival (*E. estuarius* - marine; *H. azteca* - freshwater) in sediment samples, while water toxicity was based on the most sensitive species (*C. dubia, P. promelas*) in water samples. Only two (2) water samples (SGB) were tested for toxicity in this study.

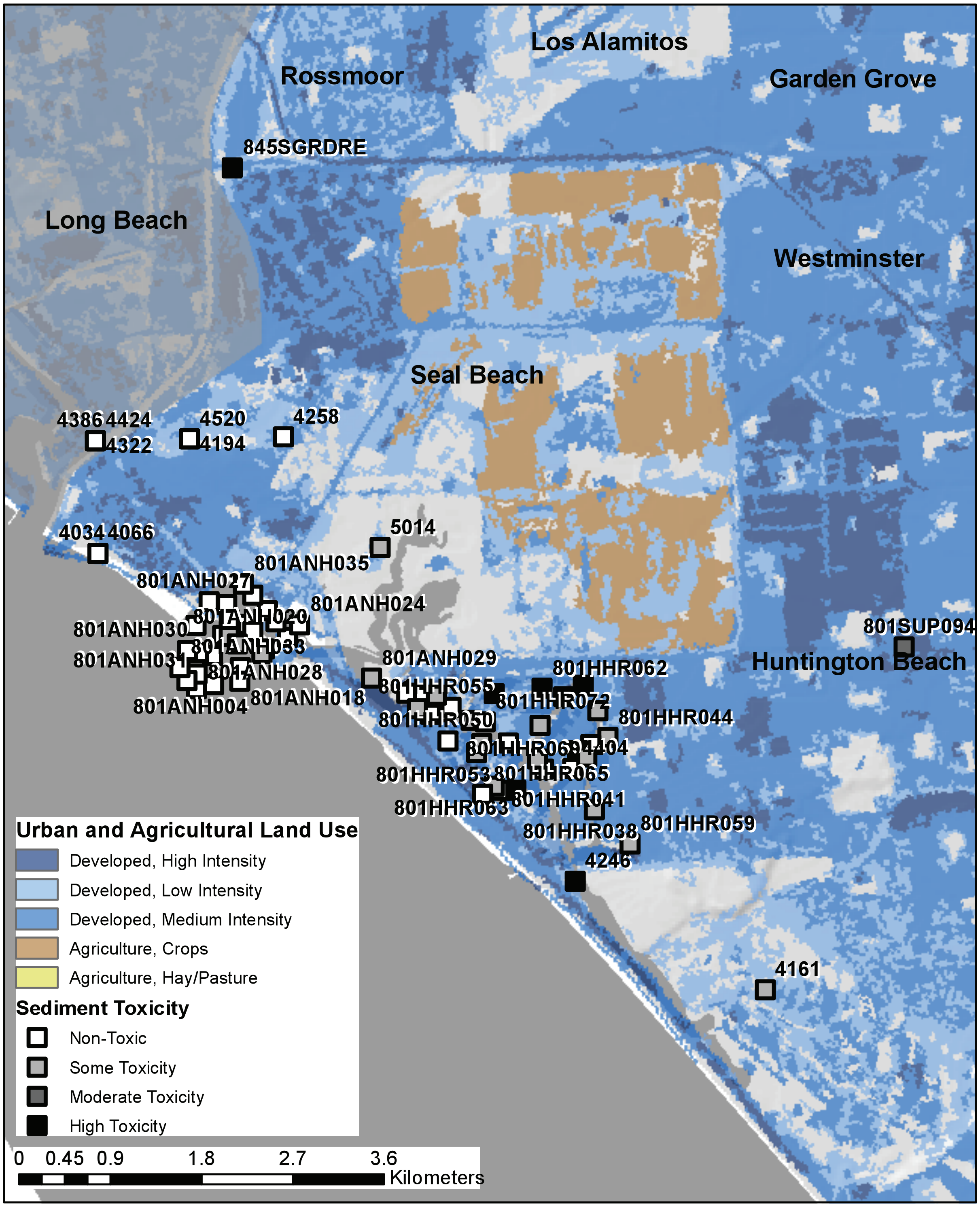


Figure 5. Magnitude of sediment toxicity in harbor, bay and estuary sites in the Santa Ana Region of California based on 10-day amphipod survival in sediment samples collected at each site.

SECTION 5
GEOGRAPHICAL PATTERNS IN TOXICITY

Freshwater streams receive wet and dry weather runoff from highly developed watersheds within the Region, and include urban and agricultural activities. Half of the freshwater stream sediment sites exhibited *high* toxicity. Sediments showed widespread *high* toxicity in the vicinity of urban areas such as Irvine, Westminster, and Seal Beach, and sediment toxicity in the Santa Ana Region was clearly elevated in urban areas compared to the outlying marine reaches. Greater *H. azteca* sediment toxicity in urban areas has been reported previously by Brown et al. (2010) and Holmes et al. (2008) some of whose data was incorporated into the data set analyzed in the current report.

ANAHEIM BAY

Some to no sediment toxicity was observed throughout Anaheim Bay and its oceanic mainland slope (Figure 6). *Some* toxicity was seen in sediments collected from the mouth of Anaheim Bay (801ANH025, 801ANH029, 801ANH032 and 801ANH034) and one site within the Anaheim Bay Estuary (5014).

HUNTINGTON HARBOUR

The majority of sites in Huntington Harbour showed *some* or no toxicity, although a small subset of sites were *highly* toxic (804HHR039, 801HHR043, 801HHR054, 801HHR057, 801HHR058, 801HHR062 and 4246). With the exception of site 4246, these sites were clustered in the inner-most inland reaches of the harbor. Site 4246 is located further south of the residential areas of Huntington Harbour, in the northernmost portion of Outer Bolsa Bay (Figure 7).

NEWPORT BAY

High toxicity was prevalent throughout both the Lower and Upper Newport Bay regions (BRI-08, BRI-09, BRI-10, 4221, 4305, 4337, and BRI-11) as well as further upstream in San Diego Creek (801SDC065) and Peter's Canyon Wash (801SUP065). *Some* to no toxicity was found in parts of the watershed, with non-toxic sites located north of Newport Bay along the coast (Figure 8).

LAKE ELSINORE

Of the sites sampled within Lake Elsinore, all but one showed *some* to *moderate* toxicity (Figure 9). The majority of these sites showed *some* toxicity, but *moderate* toxicity was seen in the southwest to southeast region of the lake, spanning the profundal zone.

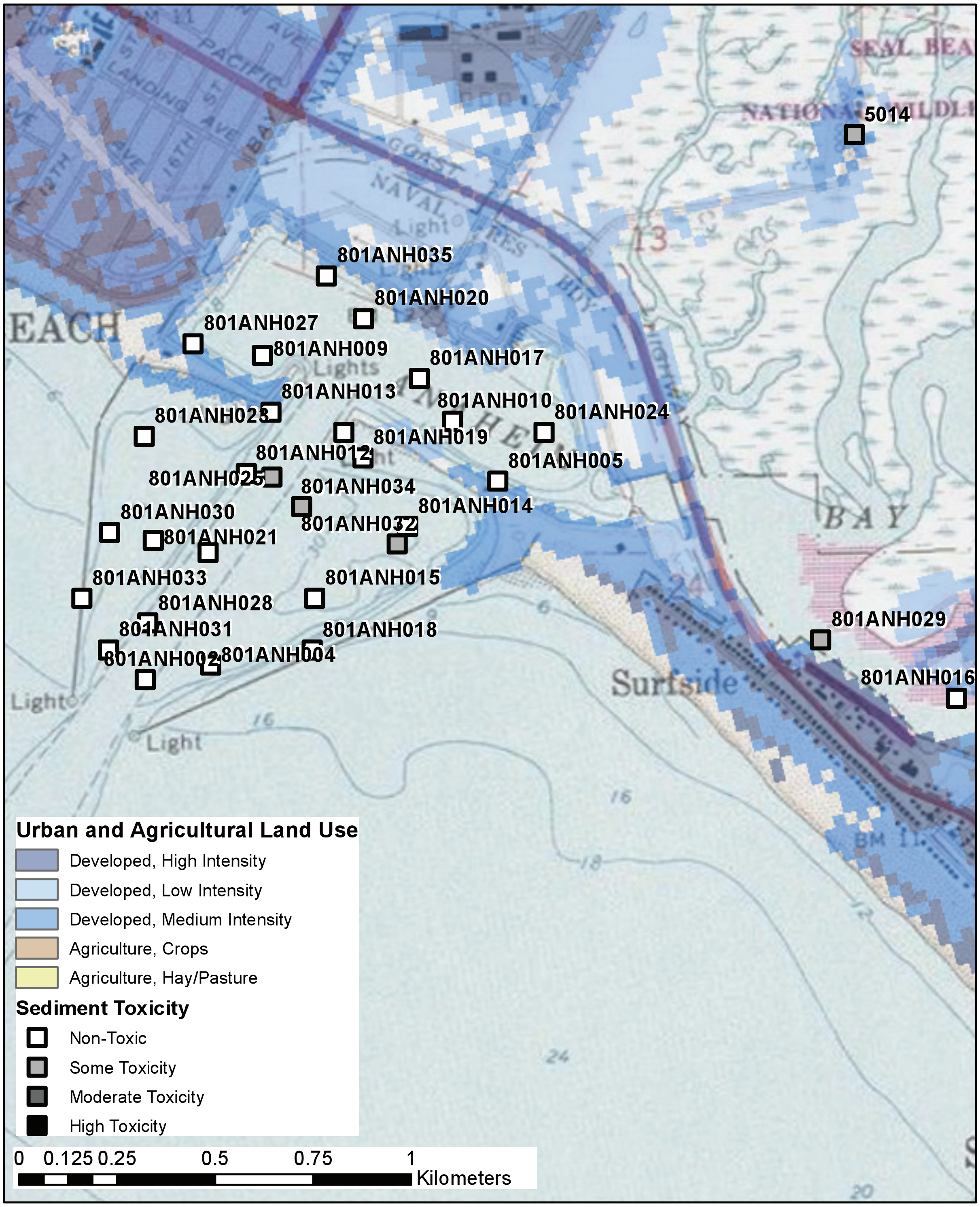


Figure 6. Magnitude of sediment toxicity at sites in Anaheim Bay in the Santa Ana Region of California based on 10-day amphipod survival in sediment samples collected at each site.

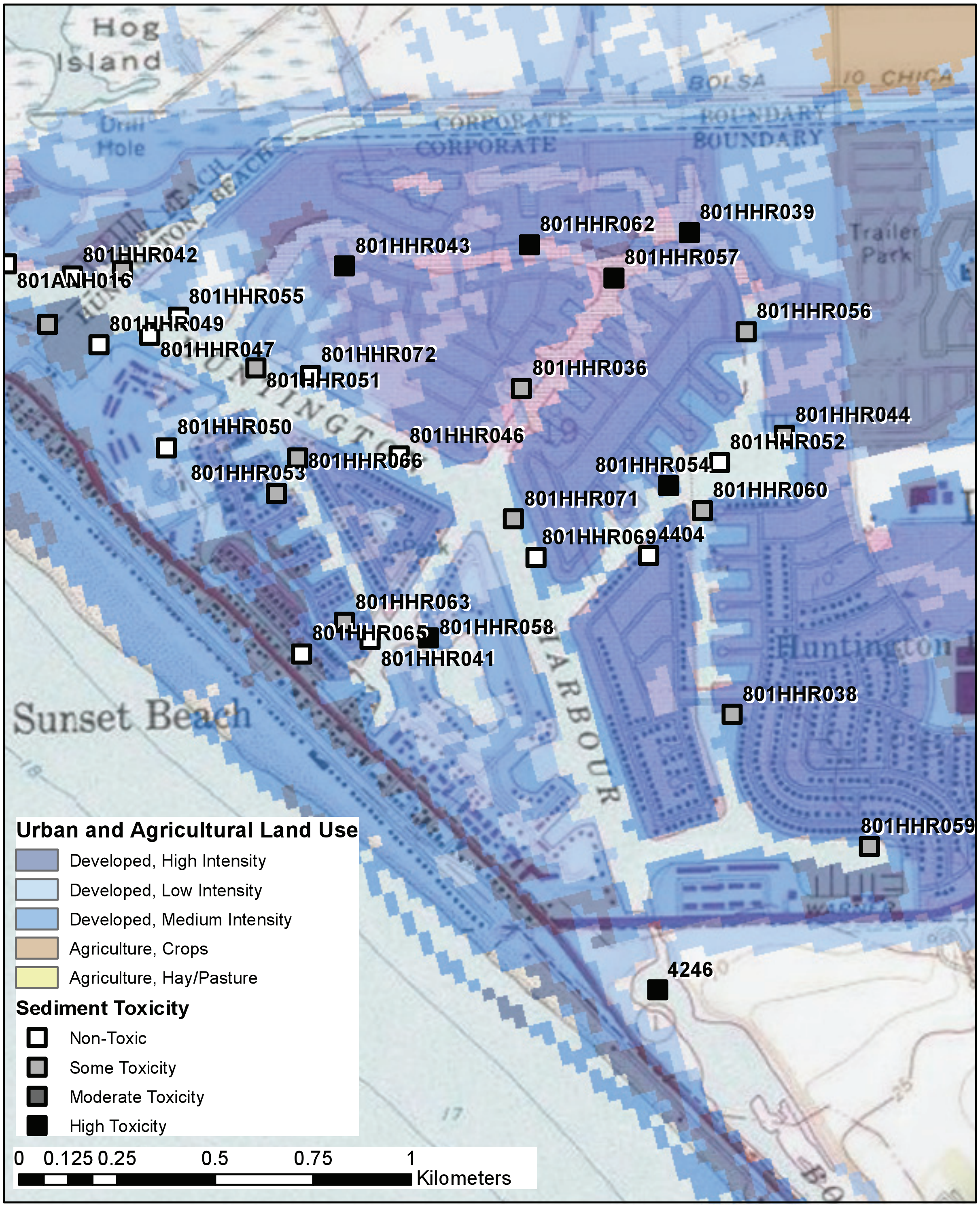


Figure 7. Magnitude of sediment toxicity at sites in Huntington Harbour in the Santa Ana Region of California based on 10-day amphipod survival in sediment samples collected at each site.

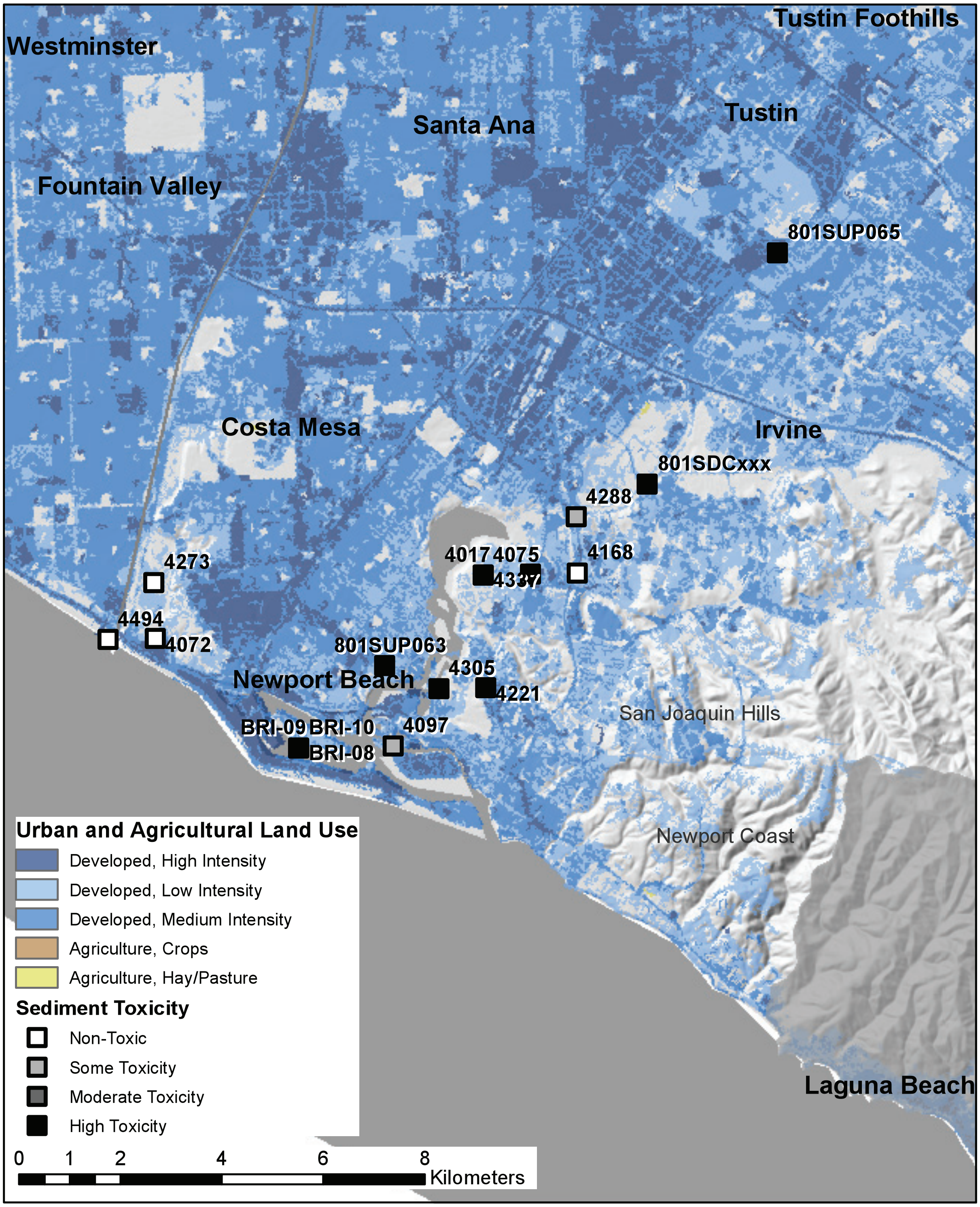


Figure 8. Magnitude of sediment toxicity at sites in Newport Bay and the San Diego Creek watershed in the Santa Ana Region of California based on 10-day amphipod survival in sediment samples collected at each site.

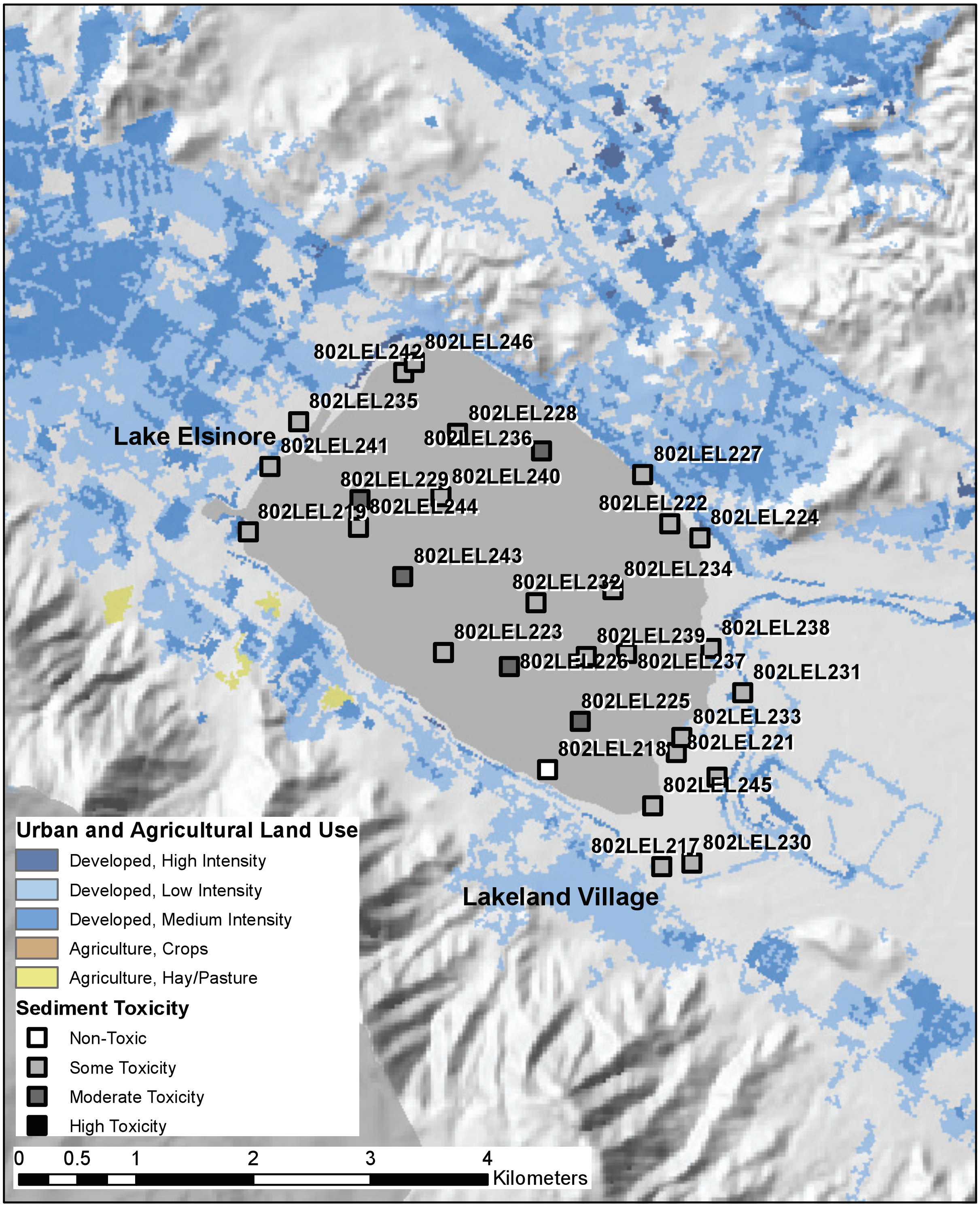


Figure 9. Magnitude of sediment toxicity at sites in Lake Elsinore in the Santa Ana Region of California based on the 10-day survival of *H. azteca* in sediment samples collected at each site.

SECTION 6
CAUSES OF TOXICITY

Correlation analyses and Toxicity Identification Evaluations (TIEs) were used to determine causes of water and sediment toxicity statewide. The results of these analyses showed that the majority of toxicity was caused by pesticides (Anderson et al., 2011a).

MARINE SEDIMENT

The marine amphipod *E. estuarius* is frequently utilized in marine sediment toxicity tests and toxicity identification evaluations (TIEs). Several studies of Southern California harbors have identified significant sediment toxicity and chemical contamination using this amphipod. Greenstein et al. (2003) utilized whole-sediment and pore water TIEs to investigate toxicity in Upper and Lower Newport Bay sediments. Non-polar organic constituents were thought to be the dominant type of toxicant present in Upper Newport Bay in both whole-sediment and pore-water tests, whereas multiple contaminants, including metals, were likely the cause of toxicity in Lower Newport Bay sediments. The lack of contaminant-specific TIE results, however, made it difficult for the authors to determine which specific chemical was responsible for the observed toxicity. The authors note the possibility that an unmeasured contaminant, such as an organophosphate or pyrethroid pesticide, with a source related to runoff discharge, may have been responsible for the toxicity seen in Upper Newport Bay, as these pesticides have been detected in San Diego Creek which receives runoff from residential and agricultural areas. Further sediment TIE experiments conducted for the Water Environment Research Foundation determined that the primary cause of toxicity in Upper Newport Bay sediment and pore-water was pyrethroid pesticides (Anderson et al., 2007).

Although not included in the analysis for the current report, data from the 2010-2011 Unified Annual Progress Report (SARWQCB, 2011) indicate a trend in the reduction of sediment toxicity over the past years in the Harbor Island Reach (LNBHIR) and Upper Newport Bay at mouth of San Diego Creek (UNBJAM), compared to 2003 Bight Survey data. In this study, the authors conclude that the absence of toxicity in the majority of samples collected from Upper Newport Bay since April 2008 may have been related to dredging that was took place between May and June, 2008. The dredged area included station UNBJAM and it is thought that toxicants responsible for observed toxicity in prior analyses may have been removed with the dredged sediments. Additionally, the Rhine Channel in Lower Newport Bay has continued to show an absence of toxicity despite levels of copper, zinc, mercury and DDE above their respective NOAA ERM values. Interestingly, both 1998 and 2003 Bight Surveys have demonstrated that Lower Newport Bay has the highest sediment toxicity of any embayment along the southern California coast, yet data indicate that the observed toxicity was not due to the usual sources of metals, DDT/DDE or PCBs, but to some unknown toxicant (SARWQCB, 2011).

Vitale (2007b), under SWAMP funding, evaluated the sediment quality of Anaheim Bay and Huntington Harbour in a large-scale monitoring study. There was a higher frequency of toxicity in Huntington Harbour than in Anaheim Bay, although concentrations of metals and organic compounds were generally not high enough to exceed established Effect Range Median (ERM) sediment guidelines for those individual constituents. These data suggest that an unmeasured contaminant (e.g., chlorpyrifos), synergistic effect of multiple contaminants, physical condition (e.g., limited tidal flushing), or a combination of these factors, exists in Huntington Harbour that was adversely affecting toxicity. These results were similar to those of Barnett et al. (2008) and Bay et al. (2004), who found Southern California embayments, such as Newport Bay and Huntington Harbour, to be negatively impacted with a *high* frequency of sediment toxicity to amphipods and contaminant concentrations present in sediments. The California Department of Pesticide Regulation has detected a number of pesticides such as bifenthrin, malathion, dimethoate, and fonos in San Diego Creek and its tributaries (Bay et al., 2003). Ports and marinas have a number of potential sources that can contribute to sediment toxicity, including shipyard and boating activities, which can release petroleum hydrocarbons, and antifouling paints, mostly copper, used on vessel hulls. In addition, given the close proximity of high-density urbanization within the Region, it is likely that current-use pesticides used in nurseries and residential areas are contributing to the observed toxicity in this area.

FRESHWATER SEDIMENT

Sediment TIEs using *H. azteca* have been conducted in most regions of California where toxicity has been observed. The majority of sediment TIEs and chemical analyses of toxic sediments have identified pyrethroid pesticides as agents of toxicity (Anderson et al., 2011a). Other studies have shown that sediment toxicity is due to mixtures of organophosphate pesticides and pyrethroids. Brown et al. (2010) identified pyrethroids as the probable cause for most of the *H. azteca* toxicity documented in their study of Southern California freshwater wetlands receiving urban runoff. Sediment from freshwater wetland sites in parts of Orange and San Diego Counties receiving urban runoff contained concentrations of several pyrethroids, such as bifenthrin, permethrin, lambda-cyhalothrin and cyfluthrin, exceeding *H. azteca* sediment LC50 values. Bifenthrin was the most frequently detected pyrethroid within the study area. Holmes et al. (2008) had similar results in their examination of urban creeks in the Santa Ana Region. Bifenthrin was detected in every sediment sample, and other detected pyrethroids included cypermethrin, esfenvalerate, and lambda-cyhalothrin. These pyrethroids are prevalent in agricultural-use areas as well as areas of urban influence. Budd et al. (2007) examined a range of mixed land-use sediment sites within the San Diego Creek-Newport Bay watersheds. These sites included nursery/agriculture, residential, and mixed-commercial/residential uses. Bifenthrin and fenpropathrin were detected most frequently, and there were several detections of cyhalothrin, permethrin, cyfluthrin, and deltamethrin. The highest concentrations of pyrethroids were detected in sediments which were in close proximity to agricultural land uses, especially those located near outlets of commercial nurseries, as these sites contained the highest concentrations of bifenthrin and fenpropathrin. TIEs conducted on sediment and pore water samples from San Diego Creek and Peter's Canyon Wash concluded that pyrethroids, particularly bifenthrin, were contributing to the observed sediment toxicity in this watershed (Anderson et al., 2007; Phillips et al., 2010b). Additional data from SWAMP's Stream Pollution Trends Monitoring Program also indicate that pyrethroids play a large role in the cause of the observed toxicity in the San Diego Creek watershed (Hunt et al., 2011). In light of the mandatory use of bifenthrin in Southern California nurseries as part of quarantine requirements for red and imported fire ant control, and the overall increase in pyrethroid use throughout the State (Oros and Werner, 2005) these detections are not surprising.

WATER COLUMN TOXICITY

Although few water samples were collected as part of this data set, a thorough review of water column toxicity in the Newport Bay watershed was published in 1999 (Lee et al., 1999). This study also reviewed bioaccumulation, sediment toxicity data, and data from several other studies. At the time, enzyme linked immuno sorbent assay (ELISA) determined the primary causes of the observed water column toxicity were the organophosphate pesticides chlorpyrifos and diazinon. The suspected sources of these pesticides were local residential use for structural and lawn and garden pest control. Chlorpyrifos and diazinon have recently been banned for urban use and have been replaced by pyrethroids in residential products. Although pyrethroids are generally hydrophobic chemicals that associate with particles, concentrations of these pesticides can often be detected in solution at levels high enough to cause toxicity to aquatic organisms and can impact resident biota.

Additionally, chemical analyses of organophosphate and pyrethroids on stormwater samples from 2010-2011 Mass Emissions monitoring (SARWQCB, 2011), have demonstrated that malathion was the most frequently detected organophosphate pesticide, found in approximately 70% of all Mass Emissions samples, whereas pyrethroid pesticides such as bifenthrin, cypermethrin and cypermethrin were detected 20-35% of the time. Most of these detections were found in the channels of the Coyote Creek watershed (SARWQCB, 2011).

SECTION 7
ECOLOGICAL IMPACTS ASSOCIATED WITH TOXIC WATERS

Field bioassessments provide information on the ecological health of streams and rivers, and bioassessments of macroinvertebrate communities have been used extensively throughout California. When combined with chemistry, toxicity, and TIE information, these studies indicate linkages between laboratory toxicity, chemistry and ecosystem impacts.

Several studies in Southern California have coordinated sediment toxicity, chemistry and bioassessments in order to evaluate ecosystem health. In Barnett et al. (2010) marine benthic community condition was classified as moderate disturbance in Huntington Harbour, and low to moderate disturbance in benthic communities in both Upper and Lower Newport Bay. Conversely, the majority of benthos was not disturbed, or had low disturbance, in Anaheim Bay. These varying degrees of benthic community degradation are reflected in amphipod sediment toxicity tests conducted in these regions, with *some* to *high* toxicity prevalent in Huntington Harbour and Newport Bay, and *some* toxicity measured in Anaheim Bay. Sediment classifications used in this study were consistent with previous studies conducted by the Bay Protection and Toxic Cleanup Program (BPTCP), which also found a high frequency of sediment toxicity to amphipods, benthic community degradation, and contaminant concentrations in Newport Bay and Huntington Harbour (Phillips et al., 1998). These findings are corroborated by Vitale (2007b) in her evaluation of benthic community structure in Anaheim Bay and Huntington Harbour. The data suggest that the infaunal community of Anaheim Bay was in general, not impaired. Huntington Harbour, however, did exhibit some degree of impairment. Thirty percent (30%) of samples collected in Huntington Harbour exhibited chemical contamination high enough to indicate a potential negative biological response, and Benthic Response Indices (BRI) scores indicated moderate to severe impacts to the benthic community. In both studies, the exact cause of the observed biological response was not discernible, and both authors recommended further studies. Given the prevalence of urban development within this region, adverse effects to benthic community condition due to urban runoff contaminants (i.e., current-use pesticides, metals) is likely.

Multiple studies have documented urban runoff as a source of benthic community impairment in freshwater streams. Brown et al. (2010) found that the macroinvertebrate (MI) community in over 85% of the urban wetlands examined was at risk due to sediment contamination. Most of those sites were toxic to *H. azteca*, exceeded sediment quality guidelines (SQOs) for individual contaminants, or both. Contaminant(s) concentration present in sediment was found to significantly correlate with decreased MI diversity. Moreover, amphipod sediment TIEs conducted on these sites implicated pyrethroid pesticides as the dominant toxicant responsible for the observed toxicity. The Mean Probable Effects Concentration Quotient (an index of degree of sediment contamination) was found to negatively correlate with MI diversity in the wetlands, suggesting that toxicity was affecting organisms at the base of the food chain.

Generally, given the widespread urban sediment toxicity in the Santa Ana Region, it is likely that pesticide toxicity plays a role in the impairment of urban benthic communities throughout the Region, impacting both marine and freshwater areas. Concurrent toxicity testing of samples from these sites and other waterways with impaired benthic communities could help to determine if water or sediment contamination is a significant stressor at a given site, and can also be used measure the success of implemented best management practices (BMPs) and mediation activities.

For example, The Newport Bay/San Diego Creek Watershed Diazinon and Chlorpyrifos TMDL and Implementation Plan was adopted by the Santa Ana Regional Board in April, 2003, which required Orange County stormwater NPDES permittees to implement a monitoring program for diazinon and chlorpyrifos, as well as for water column toxicity. Subsequent to the TMDL, Orange County introduced toxicity testing with *C. dubia* to their NPDES programs. Two locations on San Diego Creek and two locations on tributary creeks to San Diego Creek were monitored during both baseflow and stormflow conditions. Toxicity testing demonstrated a significant improvement in water quality, with an average of 90% of acute *C. dubia* toxicity tests showing no toxicity in baseflow conditions, and an average of 84% of toxicity tests showing no toxicity in stormflow conditions. This is compared to 20% of baseflow tests showing no toxicity and 55% of stormflow tests exhibiting toxicity of greater than one toxic unit during pre-TMDL years. Chronic toxicity tests with *C. dubi*a have shown similar results (Shibberu, 2012). In addition, the TMDL has also demonstrated an absence of deteriorating sediment quality. Major replacements for organophosphates have been pyrethroids, which, as mentioned above (see Water Column Toxicity), are strongly hydrophobic and are typically detected in sediment rather than the water column. In *H. azteca* sediment toxicity tests conducted from 2005 to 2010, toxicity was absent in 78% of tests (Shibberu, 2012).

The implementation of toxicity testing has demonstrated the success of the TMDL, showing reductions of pesticide concentrations such that water column toxicity has been reduced to levels that are not detrimental to beneficial uses. Additionally, increases of pyrethroid pesticide use have not correlated with a significant increasing trend in sediment toxicity within this watershed area. These data suggest that efforts to change pesticide use practices and to reduce pesticide runoff by the measures implemented in the TMDL were successful, and the Santa Ana Regional Board is recommending the delisting of these reaches within San Diego Creek for chlorpyrifos and diazinon from the Clean Water Act 303(d) list.

Given the frequency of toxicity seen in both water and sediment throughout the Region, and the success of the Newport Bay/San Diego Creek Watershed TMDL, implementing pesticide use practices and the reduction of stormwater runoff can have a significant impact on the improvement of water quality.

SECTION 8
MONITORING RECOMMENDATIONS

An examination of toxicity monitoring sites with data recorded in the SWAMP/CEDEN databases shows that toxicity in the Santa Ana Region is likely due to pyrethroid pesticides in most areas, and metals in some areas. While 60% of marine sediment samples were non-toxic, the amount of toxicity varied among marine water bodies: Newport Bay had the highest percent of samples with *high* toxicity, the majority of samples in Huntington Harbor showed *some* or no toxicity, and Anaheim Bay had the highest percentage of samples with no toxicity. Freshwater sediment toxicity was seen frequently. Water toxicity for this reporting period was non-toxic; however previous studies have attributed water toxicity within the Region to pesticides (Lee et al., 1999). Based on these results, we offer the following recommendations:

WATER COLUMN TOXICITY

Sediment toxicity testing and analytical chemistry have been used as the dominant tool in the evaluation of ecosystem health within the coastal region, including harbors, ports, marinas and bays in the Santa Ana Region, as well as upstream areas of the San Diego Creek and San Gabriel River-Coyote Creek Watersheds. In contrast, water column toxicity in urban and marine waterways in the Santa Ana Region has been largely unexamined over the past decade. The need for more comprehensive water sampling of urban areas is clear, given that the urban sites examined so far have shown widespread sediment toxicity. The adoption of a Multiple Lines of Evidence (MLOE) approach, utilizing water column toxicity testing in sites which exhibit frequent sediment toxicity, could provide a more thorough assessment of the waterbody. If funding allows, the addition of water column toxicity along with analytical chemistry should be conducted. Water column toxicity testing with Mytilus edulis can be utilized in marine waters, while *H. azteca* can be utilized in saline-influenced freshwater sites, especially in light of the amphipod's sensitivity to pyrethroids (Werner et al., 2010). TIE testing can help to identify contaminants when acute toxicity is observed.

SEDIMENT TIES

Sediment toxicity testing and analytical chemistry should continue, along with analyses of benthic community degradation. Application of sediment and pore-water TIEs would be beneficial in determing the cause(s) of toxicity. A more rigourous examination of sediment toxicity with the application of recently developed TIE treatments would be beneficial in determining the causes of toxicity. Pyrethroid-specific treatments have been used to successfully identify the contribution of this class of pesticides to observed toxicity in both water column and sediment samples (Amweg and Weston, 2007; Anderson et al., 2010; Phillips et al., 2010a; Phillips et al., 2010b; Weston and Amweg, 2007; Weston and Jackson, 2009; Weston et al., 2009) . Application of these treatments, coupled with accurate toxicity threshold values, increases the ability to determine the presence of specific chemicals rather than chemical class alone.

REFERENCES R

Amweg, E.L., D. Weston,, 2007. Whole-sediment toxicity identification evaluation tools for pyrethroid insecticides: I. Piperonyl butoxide addition. Environmental Toxicology and Chemistry 26, 2389-2396.

Amweg, E.L., D. Weston, J. You, M. Lydy, 2006. Pyrethroid Insecticides and Sediment Toxicity in Urban Creeks from California and Tennessee. Environ. Sci. Technol. 40, 1700-1706.

Anderson, B.S., J.W. Hunt, D. Markewicz, K. Larsen, 2011. Toxicity in California Waters, Surface Water Ambient Monitoring Program. California Water Resources Control Board. Sacramento, CA.

Anderson, B.S., J.W. Hunt, B.M. Phillips, R.S. Tjeerdema, 2007. Navigating the TMDL Process: Sediment Toxicity. 02-WSM-2. Water Environment Research Foundation, p. 194 pp.

Anderson, B.S., B.M. Phillips, J.W. Hunt, S.L. Clark, J.P. Voorhees, R.S. Tjeerdema, J. Casteline, M. Stewart, D. Crane, A. Mekebri, 2010. Evaluation of methods to determine causes of sediment toxicity in San Diego Bay, California, USA. Ecotoxicol Environ Safety. 73, 534-540.

Anderson, B.S., J.W. Hunt, B.M. Phillips, R. Fairey, C.A. Roberts, J.M. Oakden, H.M. Puckett, M. Stephenson, R.S. Tjeerdema, E.R. Long, C.J. Wilson and J.M. Lyons. 2001. Sediment quality in Los Angeles Harbor, USA: A triad assessment. Environmental Toxicology and Chemistry 20: 359-370.

Barnett, A.M., S. Bay, K. Ritter, S. Moore, and S. Weisberg. 2008. Sediment Quality in California Bays and Estuaries. Technical Report 522. Southern California Coastal Water Research Project. Costa Mesa, CA.

Bay, S.M., D. Greenstein, D. Young, 2007. Evaluation of methods for measuring sediment toxicity in California bays and estuaries. Technical Report 503. Southern California Coastal Water Research Project. Costa Mesa, CA.

Bay, S.M., D. Greenstein, J. Brown. 2004. Newport Bay Sediment Toxicity Studies. Technical Report 433. Southern California Coastal Water Research Project. Westminster, CA.

Bay, S.M., D. Greenstein, D. Vidal, D. Schlenk. 2003. Investigation of Metals Toxicity in San Diego Creek. Technical Report 407. Southern California Coastal Water Research Project. Westminster, CA.

Brown, J.S., M. Sutula, C. Stransky, J. Rudolph, E. Byron, 2010. Sediment contaminant chemistry and toxicity of freshwater urban wetland in southern California. Journal of the American Water Resources Association. 46, 367-384.

Budd, R., S. Bondarenko, D. Haver, J. Kabashima, and J. Gan. 2007. Occurrence and Bioavailability of Pyrethroids in a Mixed Land Use Watershed. J. Environ. Qual. 36:1006-1012.

Greenstein, D., S. Bay, and J. Brown. 2003. Characterization of sediment toxicity in Newport Bay.

Holmes, R.W., B.S. Anderson, B.M. Phillips, J.W. Hunt, D. Crane, A. Mekebri, G. Blondina, L. Nguyen, V. Connor, 2008. Statewide Investigation of the Role of Pyrethroid Pesticides in Sediment Toxicity in California's Urban Waterways. Environ Sci Technol 42, 7003-7009.

Hunt, J.W., B.M. Phillips, B.S. Anderson, C. Siegler, S. Lamerdin, M. Sigala, R. Fairey, S. Swenson, G. Ichikawa, A. Bonnema, D. Crane, 2011. Statewide perspective on chemicals of concern and connections between water quality and land use. Surface Water Ambient Monitoring Program – Stream Pollution Trends (SPoT) Program. California State Water Resources Control Board. Sacramento, CA.

Lee, G.F., S. Taylor, D. Neiter, R. Bein, 1999. Review of existing water quality characteristics of upper Newport Bay, Orange County CA and its watershed and results of aquatic life toxicity studies conducted during 1997-98 in the upper Newport Bay watershed. Interim Summary Report to the State Water Resources Control Board, Santa Ana Regional Water Quality Control Board, and Orange County Public Facilities and Resources Department.

Ode, P.R., T.M. Kincaid, T. Fleming, A.C. Rehn, 2011. Ecological Condition Assessments of California's Perennial Wadeable Streams: Highlights from the Surface Water Ambient Monitoring Program's Perennial Streams Assessment (PSA) (2000-2007).

Oros, D.R., I. Werner. Pyrethroid Insecticides: An Analysis of Use Patterns, Distributions, Potential Toxicity and Fate in the Sacramento-San Joaquin Delta and Central Valley. Rep. Oakland, CA: San Francisco Estuary Institute, 2005. Print. White Paper for the Interagency Ecological Program SFEI Contribution. 415.

Pernot, C. and D. Underwood. 2010. Wadeable Streams Bioassessment Region 8. Final Technical Report. Surface Water Ambient Monitoring Program.

Phillips, B.M., B.A. Anderson, J.W. Hunt, K. Siegler, J.P. Voorhees, K. McNeill, 2010a. Santa Maria River Watershed and Oso Flaco Creek Watershed TMDL Monitoring Study – Final Report. Central Coast Regional Water Quality Control Board, San Luis Obispo, CA.

Phillips, B.M., B.S. Anderson, J.P. Voorhees, J.W Hunt , R.W. Holmes, A. Mekebri, V. Connor, R.S. Tjeerdema, 2010b. The contribution of pyrethroid pesticides to sediment toxicity in four urban creeks in California, USA. Journal of Pesticide Science. 35, 302-309.

Phillips, B.M., B.S. Anderson, J.W. Hunt, P.A. Nicely, R.A. Kosaka, R.S. Tjeerdema, V. de Vlaming, N. Richard, 2004. In situ water and sediment toxicity in an agricultural watershed. Environmental Toxicology and Chemistry. 23, 435-442.

Phillips, B.M., J.W. Hunt, B.S. Anderson, J. Newman, R.S. Tjeerdema, C.J. Wilson, E.R. Long, M. Stephenson, H.M. Puckett, R. Fairey, J. Oakden, S. Dawson, H. Smythe, 1998. Sediment chemistry, toxicity, and benthic community conditions in selected water bodies of the Santa Ana region. Final Report for the Bay Protection and Toxic Cleanup Program. California State Water Resources Control Board.

SARWQCB. 2011. Unified Annual Progress Report: Program Effectiveness Assessment. Technical Report. Santa Ana Regional Water Quality Control Board.

Shibberu, Doug. 2012. Reducing toxicity due to organophosphate pesticides (diazinon and chlorpyrifos) in the Newport Bay Watersheds, Orange County, California. Revised Draft. May 14, 2012. Santa Ana Regional Water Quality Control Board.

USEPA, 2010. National Pollutant Discharge Elimination System Test of Significant Toxicity Technical Document. EPA 833-R-10-004. Office of Wastewater Management. Washington, D.C.

Vitale, Pavlova. 2007a. Surface Water Ambient Monitoring Program Report: Lake Elsinore- Sediment and Water Column Toxicity Study. Final Technical Report. Santa Ana Regional Water Quality Control Board.

Vitale, Pavlova. 2007b. Surface Water Ambient Monitoring Program Report: Anaheim Bay and Huntington Harbour Sediment and Water Column Toxicity Study. Final Technical Report. Santa Ana Regional Water Quality Control Board.

Werner, I., L.A. Deanovic, D. Markewicz, M. Khamphanh, C.K. Reece, M. Stillway, C. Reece, 2010. Monitoring acute and chronic water column toxicity in the northern Sacramento-San Joaquin Estuary, California, USA, using the euryhaline amphipod, Hyalella azteca: 2006 to 2007. Environmental Toxicology and Chemistry. 29, 2190-2199.

Weston, D., C. Jackson, 2009. Use of engineered enzymes to identify organophosphate and pyrethroid-related toxicity in toxicity identification evaluations. Environ Sci Tech. 43, 5514-5520.

Weston, D., J. You, A. Harwood, M.J. Lydy, 2009. Whole sediment toxicity identification evaluation tools for pyrethroid insecticides: III. Temperature manipulation. Environ Toxicol Chem. 28, 173-180.

Weston, D.P., E.L. Amweg, 2007. Whole-sediment toxicity identification evaluation tools for pyrethroid insecticides: II. Esterase addition. Environmental Toxicology and Chemistry. 26, 2397-2404.

Weston, D.P., R.W. Holmes, J. You, M.J. Lydy, 2005. Aquatic toxicity due to residential use of pyrethroid insecticides. Environmental Science & Technology. 39, 9778-9784.

APPENDIX A

Table A1
List of sites, GPS coordinates, matrix type and magnitude of toxicity included in the Santa Ana regional analysis

Matrix	Site Code	Site Name	Latitude	Longitude	Waterbody category	Magnitude of Toxicity
Water	845SGB007	San Gabriel Random Site 7	33.896179	-117.905403	Freshwater	Non-toxic
Water	801SGB017	San Gabriel Random Site 17	33.870201	-117.793266	Freshwater	Non-toxic
Sediment	801SARVRx	Santa Ana River at River Road	33.923599	-117.598	Freshwater	Non-toxic
Sediment	801SDCxxx	San Diego Creek at Campus	33.65556	-117.844719	Freshwater	Highly Toxic
Sediment	801SUP063	Costa Mesa Channel	33.62429	-117.90136	Freshwater	Highly Toxic
Sediment	801SUP065	Peter's Canyon Wash @ Warner	33.696159	-117.815964	Freshwater	Highly Toxic
Sediment	801SUP094	Westminster Channel @ Springdale	33.730228	-118.024498	Freshwater	Moderately Toxic
Sediment	802SJCREF	San Jacinto River - Reference Site	33.738079	-116.833908	Freshwater	Non-toxic
Sediment	802SJRGxx	San Jacinto River at Goetz/ TMDL site	33.751099	-117.223999	Freshwater	Some Toxicity
Sediment	845SGRDRE	Drain East of San Gabriel River at Hwy22	33.77401	-118.094887	Freshwater	Highly Toxic
Sediment	802LEL217	Lake Elsinore 217	33.637997	-117.337944	Freshwater	Some Toxicity
Sediment	802LEL218	Lake Elsinore 218	33.645721	-117.348198	Freshwater	Non-toxic
Sediment	802LEL219	Lake Elsinore 219	33.664642	-117.375114	Freshwater	Some Toxicity
Sediment	802LEL220	Lake Elsinore 220	33.644756	-117.332634	Freshwater	Some Toxicity
Sediment	802LEL221	Lake Elsinore 221	33.646748	-117.336304	Freshwater	Some Toxicity
Sediment	802LEL222	Lake Elsinore 222	33.664379	-117.336304	Freshwater	Some Toxicity
Sediment	802LEL223	Lake Elsinore 223	33.654957	-117.357468	Freshwater	Some Toxicity
Sediment	802LEL224	Lake Elsinore 224	33.663235	-117.333588	Freshwater	Some Toxicity
Sediment	802LEL225	Lake Elsinore 225	33.649338	-117.345032	Freshwater	Moderately Toxic
Sediment	802LEL226	Lake Elsinore 226	33.653725	-117.35144	Freshwater	Moderately Toxic
Sediment	802LEL227	Lake Elsinore 227	33.668243	-117.338669	Freshwater	Some Toxicity
Sediment	802LEL228	Lake Elsinore 228	33.671787	-117.355598	Freshwater	Some Toxicity
Sediment	802LEL229	Lake Elsinore 229	33.666882	-117.364761	Freshwater	Moderately Toxic

Matrix	Site Code	Site Name	Latitude	Longitude	Waterbody category	Magnitude of Toxicity
Sediment	802LEL230	Lake Elsinore 230	33.63821	-117.335144	Freshwater	Some Toxicity
Sediment	802LEL231	Lake Elsinore 231	33.651218	-117.330055	Freshwater	Some Toxicity
Sediment	802LEL232	Lake Elsinore 232	33.658577	-117.348839	Freshwater	Some Toxicity
Sediment	802LEL233	Lake Elsinore 233	33.647907	-117.335747	Freshwater	Some Toxicity
Sediment	802LEL234	Lake Elsinore 234	33.659435	-117.34169	Freshwater	Some Toxicity
Sediment	802LEL235	Lake Elsinore 235	33.673038	-117.370209	Freshwater	Some Toxicity
Sediment	802LEL236	Lake Elsinore 236	33.67025	-117.347939	Freshwater	Moderately Toxic
Sediment	802LEL237	Lake Elsinore 237	33.654484	-117.340607	Freshwater	Some Toxicity
Sediment	802LEL238	Lake Elsinore 238	33.654701	-117.332848	Freshwater	Some Toxicity
Sediment	802LEL239	Lake Elsinore 239	33.65435	-117.344345	Freshwater	Some Toxicity
Sediment	802LEL240	Lake Elsinore 240	33.666939	-117.357285	Freshwater	Some Toxicity
Sediment	802LEL241	Lake Elsinore 241	33.669651	-117.372963	Freshwater	Some Toxicity
Sediment	802LEL242	Lake Elsinore 242	33.676594	-117.36039	Freshwater	Some Toxicity
Sediment	802LEL243	Lake Elsinore 243	33.6609	-117.361008	Freshwater	Moderately Toxic
Sediment	802LEL244	Lake Elsinore 244	33.664768	-117.364944	Freshwater	Some Toxicity
Sediment	802LEL245	Lake Elsinore 245	33.6427	-117.338631	Freshwater	Some Toxicity
Sediment	802LEL246	Lake Elsinore 246	33.677353	-117.359406	Freshwater	Some Toxicity
Sediment	4002	San Gabriel River Estuary	33.75	-118.1	Marine	Non-toxic
Sediment	4017	Upper Newport Bay	33.64	-117.88	Marine	Non-toxic
Sediment	4034	San Gabriel River Estuary	33.74	-118.11	Marine	Non-toxic
Sediment	4066	San Gabriel River Estuary	33.74	-118.11	Marine	Non-toxic
Sediment	4072	Santa Ana River Estuary	33.63	-117.95	Marine	Non-toxic
Sediment	4075	Upper Newport Bay	33.64	-117.88	Marine	Non-toxic
Sediment	4097	Newport Bay	33.61	-117.9	Marine	Some Toxicity
Sediment	4161	Bolsa Chica Estuary	33.7	-118.04	Marine	Some Toxicity
Sediment	4168	Upper Newport Bay	33.64	-117.86	Marine	Non-toxic
Sediment	4194	San Gabriel River Estuary	33.75	-118.1	Marine	Non-toxic
Sediment	4221	Upper Newport Bay	33.62	-117.88	Marine	Highly Toxic
Sediment	4246	Huntington Harbor	33.71	-118.06	Marine	Highly Toxic
Sediment	4258	San Gabriel River Estuary	33.75	-118.09	Marine	Non-toxic
Sediment	4273	Santa Ana River Estuary	33.64	-117.95	Marine	Non-toxic
Sediment	4288	Upper Newport Bay	33.65	-117.86	Marine	Some Toxicity
Sediment	4305	Upper Newport Bay	33.62	-117.89	Marine	Highly Toxic
Sediment	4322	San Gabriel River Estuary	33.75	-118.11	Marine	Non-toxic
Sediment	4337	Upper Newport Bay	33.64	-117.88	Marine	Highly Toxic
Sediment	4386	Alamitos Bay	33.75	-118.11	Marine	Non-toxic

Matrix	Site Code	Site Name	Latitude	Longitude	Waterbody category	Magnitude of Toxicity
Sediment	4404	Huntington Harbor	33.72	-118.06	Marine	Non-toxic
Sediment	4424	Alamitos Bay	33.75	-118.11	Marine	Non-toxic
Sediment	4494	Talbert Marsh	33.63	-117.96	Marine	Non-toxic
Sediment	4520	San Gabriel River Estuary	33.75	-118.1	Marine	Non-toxic
Sediment	5014	Anaheim Bay Estuary	33.74	-118.08	Marine	Some Toxicity
Sediment	BRI-08	Newport Bay	33.61	-117.92	Marine	Highly Toxic
Sediment	BRI-09	Newport Bay	33.61	-117.92	Marine	Highly Toxic
Sediment	BRI-10	Newport Bay	33.61	-117.92	Marine	Highly Toxic
Sediment	BRI-11	Upper Newport Bay	33.64	-117.87	Marine	Highly Toxic
Sediment	801ANH001	Anaheim Bay 1	33.733398	-118.0942	Marine	Non-toxic
Sediment	801ANH002	Anaheim Bay 2	33.727798	-118.0998	Marine	Non-toxic
Sediment	801ANH004	Anaheim Bay 4	33.7281	-118.098	Marine	Non-toxic
Sediment	801ANH005	Anaheim Bay 5	33.732201	-118.089996	Marine	Non-toxic
Sediment	801ANH008	Anaheim Bay 8	33.730701	-118.098	Marine	Non-toxic
Sediment	801ANH009	Anaheim Bay 9	33.735199	-118.096397	Marine	Non-toxic
Sediment	801ANH010	Anaheim Bay 10	33.733601	-118.091202	Marine	Non-toxic
Sediment	801ANH012	Anaheim Bay 12	33.732498	-118.096901	Marine	Non-toxic
Sediment	801ANH013	Anaheim Bay 13	33.733898	-118.096199	Marine	Non-toxic
Sediment	801ANH014	Anaheim Bay 14	33.731201	-118.092499	Marine	Non-toxic
Sediment	801ANH015	Anaheim Bay 15	33.729599	-118.0951	Marine	Non-toxic
Sediment	801ANH016	Anaheim Bay 16	33.727001	-118.077499	Marine	Non-toxic
Sediment	801ANH017	Anaheim Bay 17	33.7346	-118.092102	Marine	Non-toxic
Sediment	801ANH018	Anaheim Bay 18	33.728401	-118.0952	Marine	Non-toxic
Sediment	801ANH019	Anaheim Bay 19	33.7328	-118.093697	Marine	Non-toxic
Sediment	801ANH020	Anaheim Bay 20	33.736	-118.093597	Marine	Non-toxic
Sediment	801ANH021	Anaheim Bay 21	33.730999	-118.099503	Marine	Non-toxic
Sediment	801ANH023	Anaheim Bay 23	33.733398	-118.099701	Marine	Non-toxic
Sediment	801ANH024	Anaheim Bay 24	33.733299	-118.088699	Marine	Non-toxic
Sediment	801ANH025	Anaheim Bay 25	33.732399	-118.096199	Marine	Some Toxicity
Sediment	801ANH027	Anaheim Bay 27	33.7355	-118.098297	Marine	Non-toxic
Sediment	801ANH028	Anaheim Bay 28	33.729099	-118.099701	Marine	Non-toxic
Sediment	801ANH029	Anaheim Bay 29	33.728401	-118.0812	Marine	Some Toxicity
Sediment	801ANH030	Anaheim Bay 30	33.731201	-118.1007	Marine	Non-toxic
Sediment	801ANH031	Anaheim Bay 31	33.7285	-118.1008	Marine	Non-toxic
Sediment	801ANH032	Anaheim Bay 32	33.730801	-118.092796	Marine	Some Toxicity
Sediment	801ANH033	Anaheim Bay 33	33.729698	-118.101501	Marine	Non-toxic
Sediment	801ANH034	Anaheim Bay 34	33.731701	-118.095398	Marine	Some Toxicity

Matrix	Site Code	Site Name	Latitude	Longitude	Waterbody category	Magnitude of Toxicity
Sediment	801ANH035	Anaheim Bay 35	33.737	-118.094597	Marine	Non-toxic
Sediment	801HHR036	Huntington Harbour 36	33.7239	-118.0634	Marine	Some Toxicity
Sediment	801HHR038	Huntington Harbour 38	33.716301	-118.0578	Marine	Some Toxicity
Sediment	801HHR039	Huntington Harbour 39	33.727402	-118.058701	Marine	Highly Toxic
Sediment	801HHR041	Huntington Harbour 41	33.718201	-118.067703	Marine	Some Toxicity
Sediment	801HHR042	Huntington Harbour 42	33.7267	-118.075699	Marine	Non-toxic
Sediment	801HHR043	Huntington Harbour 43	33.726799	-118.068199	Marine	Highly Toxic
Sediment	801HHR044	Huntington Harbour 44	33.722698	-118.056198	Marine	Some Toxicity
Sediment	801HHR046	Huntington Harbour 46	33.722401	-118.066803	Marine	Non-toxic
Sediment	801HHR047	Huntington Harbour 47	33.7253	-118.073601	Marine	Non-toxic
Sediment	801HHR049	Huntington Harbour 49	33.725101	-118.074997	Marine	Non-toxic
Sediment	801HHR050	Huntington Harbour 50	33.722698	-118.073196	Marine	Non-toxic
Sediment	801HHR051	Huntington Harbour 51	33.724499	-118.070702	Marine	Some Toxicity
Sediment	801HHR052	Huntington Harbour 52	33.722099	-118.057999	Marine	Non-toxic
Sediment	801HHR053	Huntington Harbour 53	33.7216	-118.070198	Marine	Some Toxicity
Sediment	801HHR054	Huntington Harbour 54	33.7216	-118.059402	Marine	Highly Toxic
Sediment	801HHR055	Huntington Harbour 55	33.7257	-118.0728	Marine	Non-toxic
Sediment	801HHR056	Huntington Harbour 56	33.725101	-118.057198	Marine	Some Toxicity
Sediment	801HHR057	Huntington Harbour 57	33.726398	-118.060799	Marine	Highly Toxic
Sediment	801HHR058	Huntington Harbour 58	33.718201	-118.066101	Marine	Highly Toxic
Sediment	801HHR059	Huntington Harbour 59	33.7132	-118.0541	Marine	Some Toxicity
Sediment	801HHR060	Huntington Harbour 60	33.721001	-118.058502	Marine	Some Toxicity
Sediment	801HHR062	Huntington Harbour 62	33.7272	-118.063103	Marine	Highly Toxic
Sediment	801HHR063	Huntington Harbour 63	33.718601	-118.068398	Marine	Some Toxicity
Sediment	801HHR065	Huntington Harbour 65	33.717899	-118.069603	Marine	Non-Toxic
Sediment	801HHR066	Huntington Harbour 66	33.722401	-118.069603	Marine	Some Toxicity
Sediment	801HHR068	Huntington Harbour 68	33.725601	-118.076401	Marine	Some Toxicity
Sediment	801HHR069	Huntington Harbour 69	33.720001	-118.063103	Marine	Non-toxic
Sediment	801HHR070	Huntington Harbour 70	33.726799	-118.074303	Marine	Some Toxicity
Sediment	801HHR071	Huntington Harbour 71	33.720901	-118.063698	Marine	Some Toxicity
Sediment	801HHR072	Huntington Harbour 72	33.7243	-118.069199	Marine	Non-toxic

SWAMP
Surface Water Ambient Monitoring Program

For more information, please contact:

Marie Stillway
Aquatic Health Program
University of California, Davis
Department of Anatomy, Physiology and Cell Biology
One Shields Ave
Davis, California

CALIFORNIA Water Boards

www.waterboards.ca.gov/swamp