SWAMP
Surface Water Ambient Monitoring Program

| *Final Technical Report* | 2008 |
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# FINAL REPORT
# WADEABLE STREAMS BIOASSESSMENT
# REGION 8
# Sites Sampled – May - June 2006

February 2008

Water Boards

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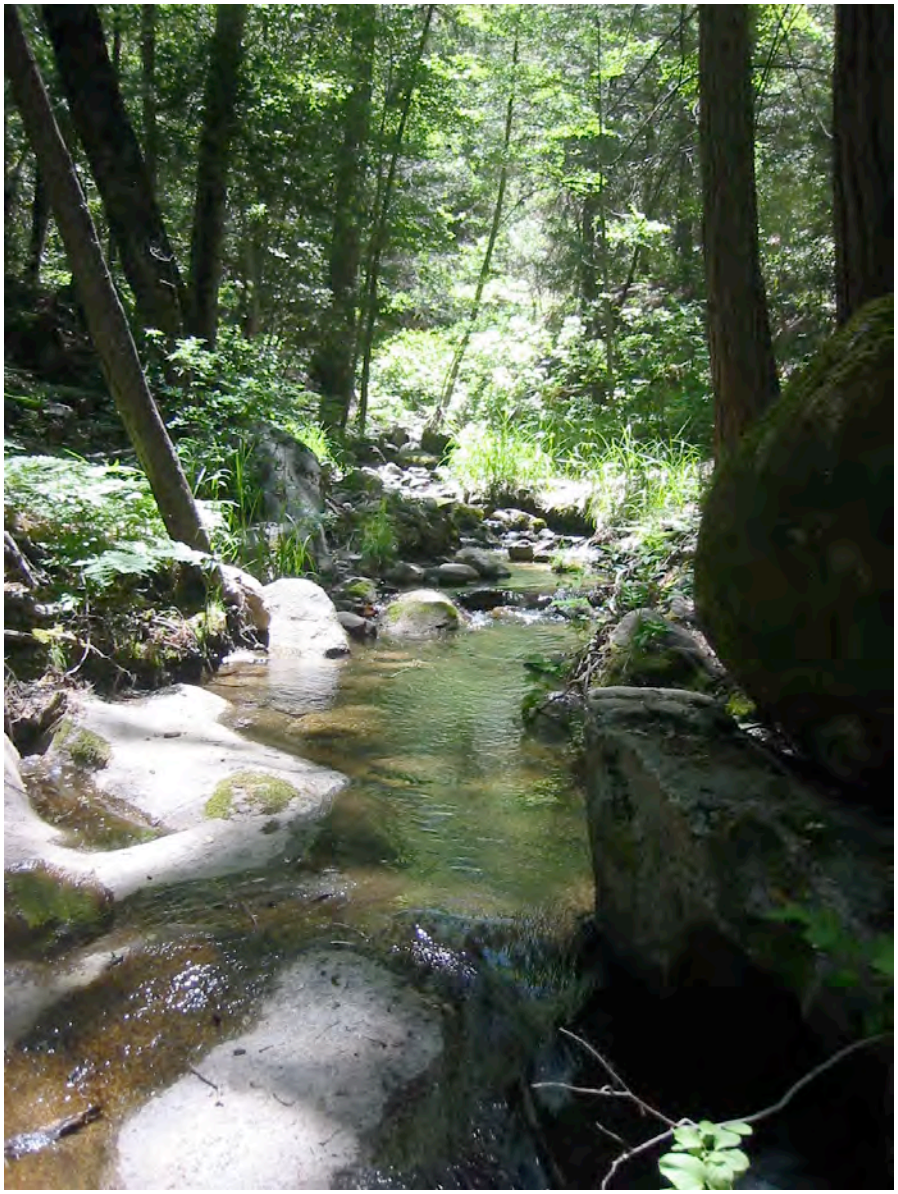

Prepared by: Craig Pernot, Dessie Underwood, Coventry Dougherty, and Danny Cuellar

California State University Long Beach
Stream Ecology and Assessment Laboratory

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## Executive Summary

The Santa Ana Regional Water Quality Control Board contracted California State University Long Beach's Stream Ecology and Assessment Laboratory, through the Institute for Integrated Research in Materials Environments and Society, to conduct a five year study of the waterways within the Santa Ana River watershed. This study is designed to address the federal EPA-mandated requirement (EPA requirement 305(b)) for an assessment of the integrity of surface waters in the Santa Ana River watershed by sampling the biological (benthic macroinvertebrates), physical (in-stream habitat, surrounding riparian habitats), and chemical (water quality measurements and water samples for further laboratory analysis) attributes at each sampling location. At the conclusion of the five year period, the data collected will be used to estimate the number of stream kilometers that are in one of five categories of health (very good, good, fair, poor, and very poor). Annual reports during these five years will provide information on the quality of the individual sites sampled.

During the spring 2006 bioassessment sampling events, a total of 144 benthic macroinvertebrate taxa were identified from the 30 sampled locations. Taxa were identified to standard taxonomic levels utilizing the California Aquatic Macroinvertebrate Laboratory Network's list of Californian Macroinvertebrate Taxa and Standard Taxonomic Effort. Sample locations were divided into three categories: low-elevation (0 meters to 350 meters), mid-elevation (350 meters to 700 meters), and high-elevation (700 meters and up). Using the Southern California Coastal Index of Biotic Integrity (Ode et al. 2005) as a measure of biotic condition, stream sites were classified (very poor, poor, fair, good, and very good). Southern California Coastal Index of Biological Integrity scores ranged from 1 to 41 (very poor to fair) for low-elevation sites, 9 to 41 (very poor to fair) for mid-elevation sites, and 19 to 63 (very poor to good) for high-elevation sites. The Southern California Coastal Index of Biological Integrity scores were positively correlated with elevation (R-square = 0.372; P-value = 0.0004) (low-elevation average score = 24 ± 18, mid-elevation average score = 25 ± 13, and high-elevation average score = 37 ± 15). The physical habitat condition of the sampled sites ranged from poor to optimal (0 to 15 "poor," 16 to 30 "marginal," 31 to 45 "suboptimal," and 46 to 60 "optimal"). Predominantly natural high-elevation channels had the highest values (averaging 44.5 and ranging from 21 to 60), followed by mid-elevation channels (averaging 27.3 and ranged from 14 to 46), and finally the low-elevation channels had the lowest values (averaging 25.7 and ranged from 15 to 41). The water quality characteristics were relatively consistent among sites with near neutral or slightly alkaline mean pH field values (6.44 to 10.5), more than adequate levels of mean dissolved oxygen (6.26 to 16), and relatively low conductivity values (0 to 2.7 mS/cm). Natural inland waters usually contain small amounts of dissolved mineral salts.

Although the data collected during the 2006 bioassessment sampling events are only a small subset of the proposed sites to be collected within the region over the next five years, the results obtained during 2006 provide baseline information to begin assessing the health of the waters within the region.

## INTRODUCTION

Freshwater is humanity's most important natural resource. Quantifying the health of our rivers, streams, and other water resources is essential for the development of management plans that protect our nation's vital water resources. Traditionally, the quality of naturally occurring freshwater was determined by chemical analyses. Currently, assessing water quality now includes direct measurements of biological communities (including plants, invertebrates, vertebrates and periphyton), in addition to other relevant measurements of watershed health (e.g. watershed characteristics, land-use practices, in-stream habitat and water chemistry), and are effective ways to monitor long-term trends of a watershed's condition (Davis and Simon 1995). Biological assessments, which integrate the effects of water quality over time and are sensitive to many aspects of both habitat and water chemistry, provide a more familiar representation of ecological health to those who are unfamiliar with interpreting the results of chemical or toxicity tests (Gibson 1996). When integrated with physical assessments and chemical test results, biological assessments can better describe the health of a waterway and provide an *in vivo* means of evaluating the effects of non-chemicals (e.g. sediments, temperature and habitat alteration) on a waterway.

The monitoring of water quality using BMIs is the most popular bioassessment method when compared with similar assessments using vertebrates or periphyton. BMIs are not only ubiquitous, but are relatively stationary and highly diverse. These traits can provide a variety of responses to a number of environmental stresses (Rosenberg and Resh 1993). Depending on the length of time an individual BMI taxon resides in an aquatic environment (a few months to several years), the sensitivity to physical and chemical alterations to their environment may vary. BMIs are an excellent indicator group in assessing the health of a waterway (Resh and Jackson 1993) and function as a significant food resource for both aquatic and terrestrial organisms. In addition, herbivorous BMIs aid in the control of periphyton populations and many BMI taxa contribute to the breakdown of detritus. Furthermore, the diversity of BMI taxa also plays an important role in the overall ecology and biogeography of a region (Erman 1996). BMIs are sensitive to environmental stressors, relatively stationary and highly diverse, making them highly effective for determining the biological integrity of a system. As defined by the 2006 Environmental Protection Agency (EPA) Wadeable Streams Assessment (WSA) document, "*biological integrity represents the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of the natural habitat of the region."*

Biological assessments are often based on multimetric techniques, which describe the condition of a particular water body. These techniques use a number of biologic measurements (metrics), each representing a particular aspect of the biological community, to assign a water quality value to the location in question. Locations can then be ranked by these values and classified into qualitative categories of "very good," "good," "fair," "poor," and "very poor." This system of ranking and categorizing biological conditions is referred to as an Index of Biotic Integrity (IBI), and is currently the recommended method for the development of biocriteria by the United States Environmental Protection Agency (US EPA 2006; Davis and Simon 1995). This method may also be used in the development of Tiered Aquatic Life Uses (TALU). The current IBI used for southern California is the Southern Coastal California Index of Biological Integrity (SCC-IBI;

Ode et al. 2005), developed by the California Department of Fish and Game's Aquatic Bioassessment Laboratory (Cal/DFG-ABL).

Water quality information for the streams in the Santa Ana River watershed (Region 8) is currently based mostly on discharger data from NPDES permits, and volunteer monitoring efforts of selected streams. This information focuses on problem areas within the region or areas where permits have been issued. Consequently, there are a large number of streams in the region that lack water quality information. Due to lack of available funding to implement a fully comprehensive "multiple biological assemblage model" to assess the biotic integrity, a decision was made by the Santa Ana Regional Water Quality Control Board (SARWQCB) to initially focus on using a macroinvertebrate bioassessment tool to assess the biotic integrity of the wadeable streams in Region 8 of California.

The SARWQCB contracted California State University Long Beach's (CSULB's) Stream Ecology and Assessment Laboratory (SEAL), through the Institute for Integrated Research in Materials Environments and Society (IIRMES), to conduct a five year study within Region 8 utilizing a probabilistic sampling design. IIRMES, a multifaceted organization was designed to promote and enhance educational and research opportunities for faculty, graduate and undergraduate students, and the greater community at large by embracing and integrating all scientists who study historical and temporally changing phenomena from the solid earth to organisms, landscapes, and societies at CSULB. By collaborating with interdisciplinary faculty, scientists within the organization are able to bring common research perspectives, techniques, and instrumentation to bear their research.

## Project Objective

The overall objective of the five year bioassessment project described within this report is to address the federal EPA-mandated requirement (EPA requirement 305(b)) for an assessment of the integrity of surface waters in Region 8 of California. Specifically, this project aims to meet this objective by collecting and subsequently analyzing macroinvertebrate data collected from random sites and generating an IBI score for each site. This method yields a single score of the biological integrity of a site based on the combination of seven of independent biological metrics. This score can then be ranked, and compared to sites that are independently designated as high-quality "reference" sites.

The data collected using this analysis will be used to identify streams that may require improvement of water quality. It will also be used to refine and compare several methods of analysis and interpretation of bioassessment data. Although not comprehensive by nature, the design of the ongoing project will also provide a basis to estimate the percentage of stream kilometers in the region that meet the aquatic life beneficial use. The region's Basin Plan related to beneficial use is as follows: *"Inland surface water communities and populations including vertebrate, invertebrate and plant species shall not be degraded as a result of the discharge of waste. Degradation is damage to an aquatic community or population with the result that a balanced community no longer exists. A balanced community is one that is diverse, has the ability to sustain itself through cyclic seasonal changes, includes necessary food chain species,*

*and is not dominated by pollution tolerant species, unless that domination is caused by physical habitat limitations. A balanced community also may include historically introduced non-native species but does not include species present because best available technology has not been implemented or because site-specific objectives have been adopted or because of thermal discharges"* (SARWQCB 1995).

IBIs are multimetric measures used to describe the biological condition of a watershed or ecoregion. These metrics vary by biogeographical area and are based on reference sites. These reference sites are locations within the biogeographical area thought to be relatively pristine and minimally impacted by anthropogenic activities. Many different metrics are measured, but only those that show responsiveness to watershed-scale and reach-scale disturbance variables and lack correlation with other responsive metrics are used (Ode et al. 2005). The IBI used to evaluate the 30 sampled sites was developed from 2000 to 2003 and is based on data from the Southern California Coastal region (Ode et al. 2005). It should be noted that the reference sites assessed during the development of the SCC-IBI did not include sites with physical alterations (i.e., concrete-lined or modified channels), and low gradient reference sites were largely underrepresented.

Table 1 provides a description of the seven biological metrics used in generating a SCC-IBI score. These include: **Richness Measures** – These metrics reflect the diversity of the aquatic assemblage where increasing diversity correlates with increasing health of the assemblage and suggests that niche space, habitat, and food sources are adequate to support survival and propagation of a variety of species. **Tolerance/Intolerance Measures** – These metrics reflect the relative sensitivity of the community to aquatic perturbations. The taxa used are usually pollution tolerant or intolerant, but are generally nonspecific to the type of stressors. The metric values usually increase as the effects of pollution in the form of organics and sedimentation increase. **Functional Feeding Groups** – These metrics provide information on the balance of feeding strategies in the aquatic assemblage. The functional feeding group composition is a surrogate for complex processes of trophic interactions, production, and food source availability. An imbalance of the functional feeding groups reflects unstable food dynamics and indicates a stressed condition.

Region 8 encompasses two Omernik (1987, 1995) Level III Ecoregions, Ecoregion 6 (chaparral and oak woodlands) and Ecoregion 8 (Southern California mountains). Table 2 provides the metric scores based on Ecoregion.

**Table 1: Bioassessment metrics used to describe characteristics of the benthic macroinvertebrate (BMI) communities at assessed sites.**

| BMI Metric | Description | Response to Impairment |
|---|---|---|
| **Richness Measures** | | |
| EPT Taxa | Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders | Decrease |
| Number of Coleoptera Taxa | Number of taxa from the insect order Coleoptera (beetles) | Decrease |
| Percent Non-insect Taxa | Percent of taxa in sample that are not in the Class Insecta | Increase |
| **Tolerance/Intolerance Measures** | | |
| Percent Tolerant Taxa | Percent of taxa in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9, or 10 | Increase |
| Percent Intolerant Individuals | Percent of individuals with a tolerance value of 0, 1, or 2 | Decrease |
| **Functional Feeding Groups (FFG)** | | |
| Number of Predator Taxa | Number of taxa from the predator functional feeding group | Decrease |
| Percent Collector Individuals | Percent of individuals that collect or gather fine particulate matter or that filter fine particulate matter | Increase |

**Table 2: SCC-IBI parameters and scoring ranges (to adjust SCC-IBI score, multiply total SCC-IBI score by 7/10; from Ode et al. 2005). Where two values are given, the top value applies to Ecoregion 6 and the bottom value, Ecoregion 8.**

| | Metric Scoring Ranges for the Southern Coastal California B-IBI | | | | | | |
|---|---|---|---|---|---|---|---|
| **Metric Score** | **# EPT Taxa** | **% Intolerant Individuals** | **# Predator Taxa** | **% Tolerant Taxa** | **% Non-Insect Taxa** | **% Collector Individuals** | **# Coleoptera Taxa** |
| **10** | > 17<br>> 18 | 25-100<br>42-100 | > 12 | 0-4 | 0-8 | 0-59<br>0-39 | > 5 |
| **9** | 16-17<br>17-18 | 23-24<br>37-41 | 12 | 5-8 | 9-12 | 60-63<br>40-46 | |
| **8** | 15<br>16 | 21-22<br>32-36 | 11 | 9-12 | 13-17 | 64-67<br>47-52 | 5 |
| **7** | 13-14<br>14-15 | 19-20<br>27-31 | 10 | 13-16 | 18-21 | 68-71<br>53-58 | 4 |
| **6** | 11-12<br>13 | 16-18<br>23-26 | 9 | 17-19 | 22-25 | 72-75<br>59-64 | |
| **5** | 9-10<br>11-12 | 13-15<br>19-22 | 8 | 20-22 | 26-29 | 76-80<br>65-70 | 3 |
| **4** | 7-8<br>10 | 10-12<br>14-18 | 7 | 23-25 | 30-34 | 81-84<br>71-76 | 2 |
| **3** | 5-6<br>8-9 | 7-9<br>10-13 | 6 | 26-29 | 35-38 | 85-88<br>77-82 | |
| **2** | 4<br>7 | 4-6<br>6-9 | 5 | 30-33 | 39-42 | 89-92<br>83-88 | 1 |
| **1** | 2-3<br>5-6 | 1-3<br>2-5 | 4 | 34-37 | 43-46 | 93-96<br>89-94 | |
| **0** | 0-1<br>0-4 | 0<br>0-1 | 0-3 | 38-100 | 47-100 | 97-100<br>95-100 | 0 |

| **Total SCC-IBI Scoring Range Adjusted Scale (0 - 100)** | 0-20<br>Very Poor | 21-40<br>Poor | 41-60<br>Fair | 61-80<br>Good | 81-100<br>Very Good |
|---|---|---|---|---|---|

# METHODS

## Sampling Site Selection

The SARWQCB worked with statistician Dr. Tony Olsen from EPA at Corvallis to design a cost effective, randomized sampling design based upon the Environmental Monitoring and Assessment Program (EMAP; USEPA 2006) criteria to representatively sample the streams in the region. Dr. Olsen generated 750 GPS coordinates as potential sampling locations. Under the original sampling design, 50 sites would be sampled annually for a period of five years to provide a total of 250 sites, which would statistically represent the 1302 linear stream kilometers of the Santa Ana regional stream network. This sampling density provided a level of statistical precision of +/- 12% with at a spatial coverage resolution of approximately 1.6 linear kilometers.

Subsequently, two approved modifications were made to the sampling design outlined above:

First, due to the constraints in the available funds for the project, the number of sites to be sampled was reduced from 50 to 30 for the 2006 sampling year. Statistical analyses show that this reduction in sampling effort increased the level of imprecision regarding the representation of the subsamples by 4% (Tony Olsen, personal communication). While not desirable, this difference was not considered to unduly compromise the objectives of the study. Furthermore it was concluded that additional sampling or an extension to the duration of the study could ultimately be undertaken to restore the original level of precision in the sampling design.

Second, the initial experimental design did not categorize potential sites using biologically relevant parameters. Conceivably a site's elevation and hydrologic unit could be important factors influencing site-specific metrics of water quality. Region 8 falls within three hydrologic units (Santa Ana, San Gabriel, and the San Jacinto units) and contains streams found from sea level to over 2000 meters in elevation. To ensure that sampling occurred throughout this heterogeneous region, the 750 GPS coordinates were categorized based on hydrologic unit and elevation. As the San Gabriel hydrologic unit in Region 8 contained only seven sites, these sites were combined with those in the Santa Ana hydrologic unit. The resultant two hydrologic units (Santa Ana and San Jacinto, with the former including the San Gabriel) were subsequently divided into three elevation strata: 0 to 350 meters, 350 to 700 meters, and greater than 700 meters. As the San Jacinto hydrologic unit did not contain sites in the 0 – 350 m elevation stratum, all GPS coordinates of potential sites fell within one of five hydrologic/elevation strata. Every effort was made to sample six sites per strata. If the region was not divided into these biologically relevant strata, an analytical bias due to intensive sampling of a small subset of the region one year and no sampling in this subset the following year might have occurred.

## Sampling Reach Determination

The sampling procedures used during the 2006 bioassessment survey followed the BASIC level of the *Standard Operating Procedures for Collecting Benthic Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessments in California* (Ode 2007), which are a modification of the California Stream Bioassessment Procedures (CSBP; DFG 2003) and Environmental Monitoring and Assessment Program (EMAP) procedures. Briefly, at each

sample location, a 150-meter reach was surveyed to locate all riffles. A riffle is defined as a shallow area with fast flowing water that supports a complex substrate and the greatest diversity of BMIs and is therefore targeted as the ideal location for BMI collection. For sample locations that were continuous riffles or lacked riffles completely, we followed the reach-wide benthos procedure (RWB) or multi-habitat approach. Each reach was broken into 11 equidistant transects, spaced every 15 meters, with each transect designated with a number representing its location along the reach (0 meters through 150 meters, downstream to upstream).

## Sample Collection

BMI samples were collected starting with the downstream transect and then proceeding upstream. This technique was used in order to avoid habitat disruption to downstream transects during sample collection. Samples were collected at either 25% instream of the right bank (R), 50% instream of the right bank (C) or 75% instream of the right bank (L) at each transect following a R, C, L pattern starting with the right bank. This alternating pattern was followed along each 150-meter sampling reach until a single sample was collected from each reach (0 meters to 150 meters).

The BMIs were collected using a one-foot wide, 0.5-millimeter mesh D-frame kick-net. A one-foot by one-foot sampling plot, directly in front of the net, was sampled as follows: heavy organisms such as clams and/or snails were removed from the substrate by hand and placed into the net; stones larger than a golf ball were carefully picked-up and rubbed in front of the net to collect all attached animals; the remaining underlying substrate was sampled by digging through the material to a depth of four inches (10-centimeters). This procedure was repeated at each of the 11 transects and sampling effort per transect was standardized (1-2 minutes total time).

The resulting 11 samples from a site were composited into one 1-liter jar and preserved in the field using 95% ethanol. Larger samples (e.g. samples that contained more than 50% sediment or 66% organic material) were split into additional jars as needed. A label containing the project, sample date, site designation, sampler's initials, and jar number was placed in each jar. A chain of custody form was completed for each sample location. As soon as the samples were returned to the lab, the ethanol, having been diluted with variable amounts of water from the samples, was replaced with fresh 75% ethanol.

## Physical Habitat Quality Assessment and Water Quality Measurements

The physical habitat was described along the entire reach of each sampling location following a DFG approved modified version of the standardized BASIC habitat scoring criteria (Ode 2007). A modified version of the standardized sampling protocols was used due to financial constraints. At every 15-meter interval along the 150-meter reach, substrate complexity, consolidation, embeddedness, sediment depth, canopy cover, and evidence of human influences were measured. In addition, at each transect, a depth profile was obtained at five equidistant points starting at banks edge and ending on the opposite banks edge. Each sampling reach was scored using the General Habitat Characterization Form that includes three variables each scored on a scale

between 1 and 20 (Channel Alteration, Sediment Deposition, and Epifaunal Substrate and Available Cover). Where possible, water velocity was directly measured using a 60% stream depth method at each transect using a Flowatch flow-meter.

Water quality parameters collected on site at each sample location using a HORIBA environmental monitoring unit included pH, dissolved oxygen (mg/l), conductivity (mS/cm), water temperature (°C), and turbidity (NTU). We measured total alkalinty using a LaMotte alkalinity kit. In addition to these on-site measurements, a 1000 ml water sample was collected at each site for laboratory analysis to measure other parameters used to describe the general chemical status of the streams. These measurements were performed by CRG Marine Laboratories, Inc. and included the quantification of ammonia nitrogen, dissolved orthophosphate, nitrate-nitrogen, nitrite-nitrogen, and total suspended solids.

## Taxonomic Identification of BMIs

BMI samples were processed by CSULB's Stream Ecology and Assessment Laboratory (CSULB-SEAL). Each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and subsampled using a Caton tray marked with twenty, 25 $cm^2$ grids. Sample material from randomly selected grids was processed using a stereomicroscope. BMIs from each grid were separated from the surrounding detritus and transferred to vials containing 75% ethanol. Grids were selected and processed until 500 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 75% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 75% ethanol and archived. BMIs were then identified to standard taxonomic levels established by CAMLnet using standard taxonomic keys, typically genus level for insects and order or class for non-insects (Brown 1972, Edmunds et al. 1976, Kathman and Brinkhurst 1998, Klemm 1985, Merritt and Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

## Data Analysis

A taxon-by-site matrix of raw abundances was created in a Microsoft Excel® spreadsheet. For each site, an IBI score was calculated using the Southern California coastal model (SCC-IBI, Ode et al. 2005). Sites were categorized as either Ecoregion 6 or 8 and the appropriate model was used accordingly. Individual metrics were calculated using only unique taxa ("phantom taxa" were excluded). Functional feeding group designations and tolerance values assigned to each taxon were based on those reported in CAMLnet.

As the So-Cal IBI was developed using a count of 500 organisms, data sets that exceeded 5% either above or below 500 organisms (fewer than 475 or greater than 525 organisms) were analyzed and reported as follows:

Sites with fewer than 475 organisms – SCC-IBI scores were calculated based on the raw abundances of organisms with no pretreatment of the data prior to calculation. These values are reported in italics.

Sites with more than 525 organisms were statistically subsampled to reduce the total number of organisms to 500 prior to calculating the metrics and the SCC-IBI scores. We assigned each individual organism a unique number and then generated 500 random numbers that were used to determine which of the individuals would be included in the final 500.

### Quality Assurance and Quality Control (QA/QC)

All QA/QC requirements were followed by sampling personnel (Appendix B) during the 2006 sampling events. Only CSULB-SEAL personnel trained in the approved sampling methods participated in the collection of BMIs during the 2006 sampling events. Data entry underwent 100% QC. All internal QA/QC procedures were followed and none of the limits described in the document were violated, with the exception of hold-times for some water quality samples collected for nutrient analyses (due to some sample locations, the 48 hour hold-time could not be met; those samples were maintained on ice at less than 4 degrees Celsius). Picking error exceeding 5% also occurred in processing some samples; these samples were entirely repicked resulting in greater than 500 BMIs for analysis. When this occurred 500 BMIs were randomly subsampled from the overall data set from that specific location and this subsample of BMIs was used in data analysis. One site (172) had fewer then 450 BMIs found in the benthic sample. Although an SCC-IBI scored was generated for site 172 scores generated from fewer then 450 BMIs have not been validated. All QA/QC documentation, including the chain of custody forms for each site, is on file with the appropriate contract laboratory and CSULB-SEAL.

## RESULTS

### Sites sampled

During the spring 2006 bioassessment sampling events, 30 sites were sampled between May 31 and June 27 (Table 3). Seven sites were in the low-elevation stratum (0-350 m), nine sites were in the mid-elevation stratum (350-700 m), and 14 sites were in the high-elevation stratum (> 700 m).

**Table 3: Sampled sites for 2006 SARWQCB Region 8 bioassessment survey (sorted by elevation strata).**

| Site ID Number | Stream name/ Sample Location | County | Latitude (North) | Longitude (West) | Elevation (Meters) | Elevation Strata | Collection Date |
|---|---|---|---|---|---|---|---|
| 180 | San Diego Creek | Orange | 33.67263 | 117.78944 | 23 | 0 - 350 | 20-Jun-06 |
| 532 | Santiago Creek | Orange | 33.77896 | 117.83864 | 64 | 0 - 350 | 20-Jun-06 |
| 011 | Santa Ana River | Orange | 33.85815 | 117.78667 | 85 | 0 - 350 | 15-Jun-06 |
| 012 | Carbon Canyon | Orange | 33.91909 | 117.82201 | 138 | 0 - 350 | 31-May-06 |
| 019 | Prado Flood Control Basin | Riverside | 33.92417 | 117.59778 | 156 | 0 - 350 | 15-Jun-06 |
| 042 | Mill Creek | San Bernardino | 33.94623 | 117.61423 | 166 | 0 - 350 | 31-May-06 |
| 110 | Santa Ana River | Riverside | 33.96468 | 117.46518 | 207 | 0 - 350 | 15-Jun-06 |
| 085 | San Timoteo Canyon | San Bernardino | 34.0499 | 117.23238 | 352 | 350 -700 | 4-Jun-06 |
| 055 | San Timoteo Canyon | San Bernardino | 34.0396 | 117.21973 | 384 | 350 -700 | 3-Jun-06 |
| 116 | San Jacinto River | Riverside | 33.66396 | 117.2787 | 410 | 350 -700 | 21-Jun-06 |
| 243 | Perris Valley Storm Drain | Riverside | 33.82798 | 117.20878 | 440 | 350 -700 | 7-Jun-06 |
| 258 | San Timoteo Canyon | San Bernardino | 34.01399 | 117.17834 | 443 | 350 -700 | 26-Jun-06 |
| 051 | San Timoteo Canyon | Riverside | 33.99512 | 117.15212 | 484 | 350 -700 | 3-Jun-06 |
| 226 | East Twin Creek | San Bernardino | 34.19146 | 117.27421 | 597 | 350 -700 | 26-Jun-06 |
| 079 | East Kimbark Canyon | San Bernardino | 34.22123 | 117.40798 | 622 | 350 -700 | 4-Jun-06 |
| 160 | North Fork San Jacinto | Riverside | 33.73134 | 116.8102 | 647 | 350 -700 | 7-Jun-06 |
| 028 | Lytle Creek | San Bernardino | 34.2026 | 117.44583 | 726 | 700 + | 4-Jun-06 |
| 032 | Mill Creek | San Bernardino | 34.07629 | 117.06626 | 729 | 700 + | 3-Jun-06 |
| 062 | Lytle Creek | San Bernardino | 34.21257 | 117.45844 | 730 | 700 + | 23-Jun-06 |
| 172 | Indian Creek | Riverside | 33.78651 | 116.8323 | 814 | 700 + | 16-Jun-06 |
| 041 | Cajon Canyon | San Bernardino | 34.29543 | 117.45882 | 849 | 700 + | 23-Jun-06 |
| 027 | Cajon Canyon | San Bernardino | 34.3061 | 117.4697 | 917 | 700 + | 23-Jun-06 |
| 007 | Mill Creek Canyon | San Bernardino | 34.0952 | 116.96447 | 1293 | 700 + | 22-Jun-06 |
| 267 | Herkey Creek | Riverside | 33.67606 | 116.67606 | 1321 | 700 + | 27-Jun-06 |
| 070 | Stone Creek | Riverside | 33.77122 | 116.7675 | 1385 | 700 + | 17-Jun-06 |
| 713 | Icehouse Canyon | San Bernardino | 34.24908 | 117.63127 | 1557 | 700 + | 23-Jun-06 |
| 034 | Mill Creek Canyon | San Bernardino | 34.08909 | 116.92669 | 1600 | 700 + | 22-Jun-06 |
| 035 | Mill Creek Canyon | San Bernardino | 34.08193 | 116.89027 | 1819 | 700 + | 22-Jun-06 |
| 206 | Strawberry Creek | Riverside | 33.73283 | 116.74047 | N/A | 700 + | 15-Jun-06 |
| 020 | Strawberry Creek | Riverside | 33.76698 | 116.6902 | 1890 | 700 + | 16-Jun-06 |

## BMI Community Structure

A total of 144 BMI taxa were identified from the 30 sampled locations (Appendix C). Of the 144 BMI taxa, only a few of these taxa dominated each site. Low elevation sites (0 meters to 350 meters) were dominated by aquatic fly larvae from the family Chironomidae, fly larvae *Simulium* sp., aquatic crustaceans from the order Ostracoda, as well as crustaceans from the genus *Hyalella* sp. Mid elevation sites (350 meters to 700 meters) were not only dominated by the aforementioned organisms, but also were dominated by baetid mayfly larvae *Baetis* sp. and *Paracloedes* sp. High elevation sites (700 meters and up) were as dominated by aquatic fly larvae from the family Chironomidae, fly larvae *Simulium* sp., aquatic crustaceans from the order Ostracoda, baetid mayfly larvae *Baetis* sp., heptageniid mayfly larvae *Epeorus* sp, hydroptilid caddisfly larvae *Hyalella* sp., and aquatic worms from the order Oligochaeta.

**Index of Biological Integrity –** Figure 1 geographically depicts Region 8 with the adjusted SCC-IBI scores for sites sampled during 2006. SCC-IBI scores are adjusted from a scale of 0 to 70 (seven summed metrics ranging from 0 to 10), to a scale of 0 to 100 for ease of interpretation. Adjusted SCC-IBI scores were obtained by multiplying the summed SCC-IBI scores by 10 and dividing that score by seven. SCC-IBI scores were positively correlated with elevation (Figure 2). Adjusted SCC-IBI scores for the low-elevation sites ranged between 1 (very poor) to 41 (fair) (Table 4), with an average score of 24 ± 18. The mid-elevation sites total adjusted SCC-IBI scores ranged between 4 (very poor) to 41 (fair), with an average score of 25 ± 13. The high-elevation sites total adjusted SCC-IBI scores ranged between 19 (very poor) to 63 (good), with an average score of 37 ± 15.

Figure 1. Map of Region 8 showing the SCC-IBI scores for the 30 sites sampled in 2006. All scores are based on a 0-100 scale.

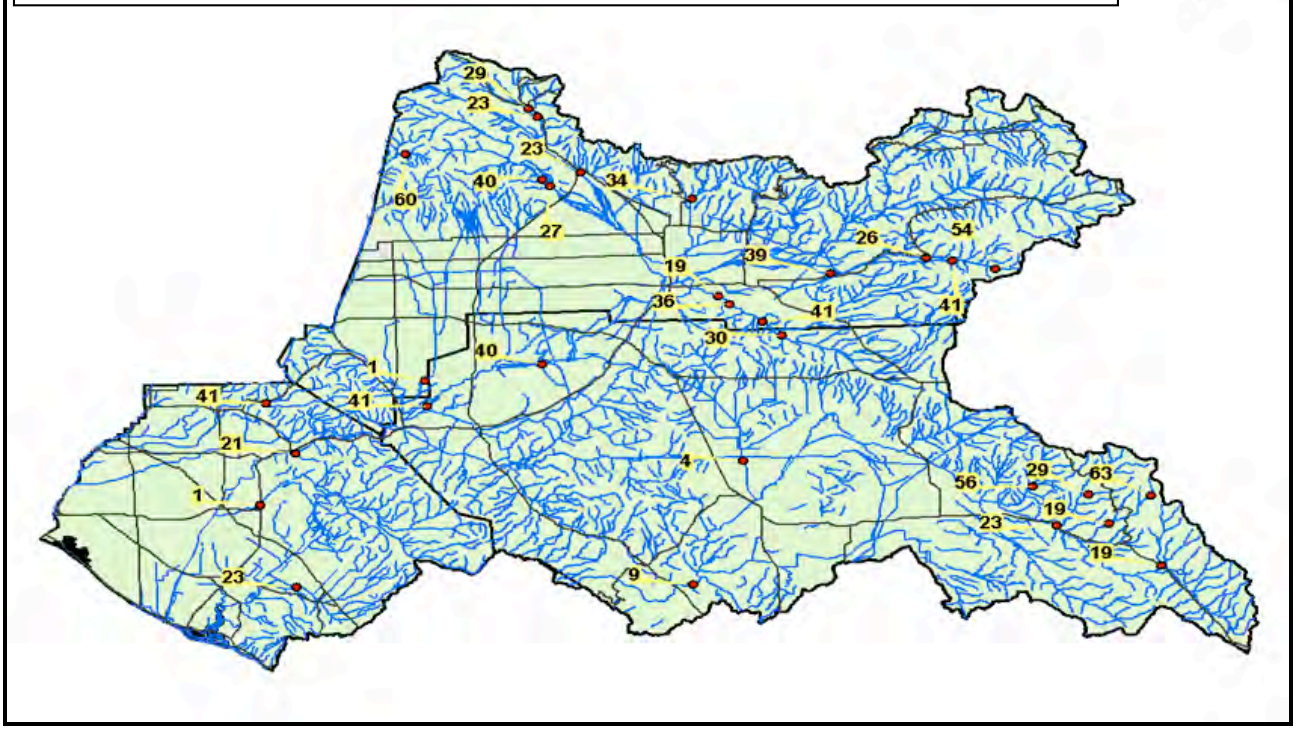
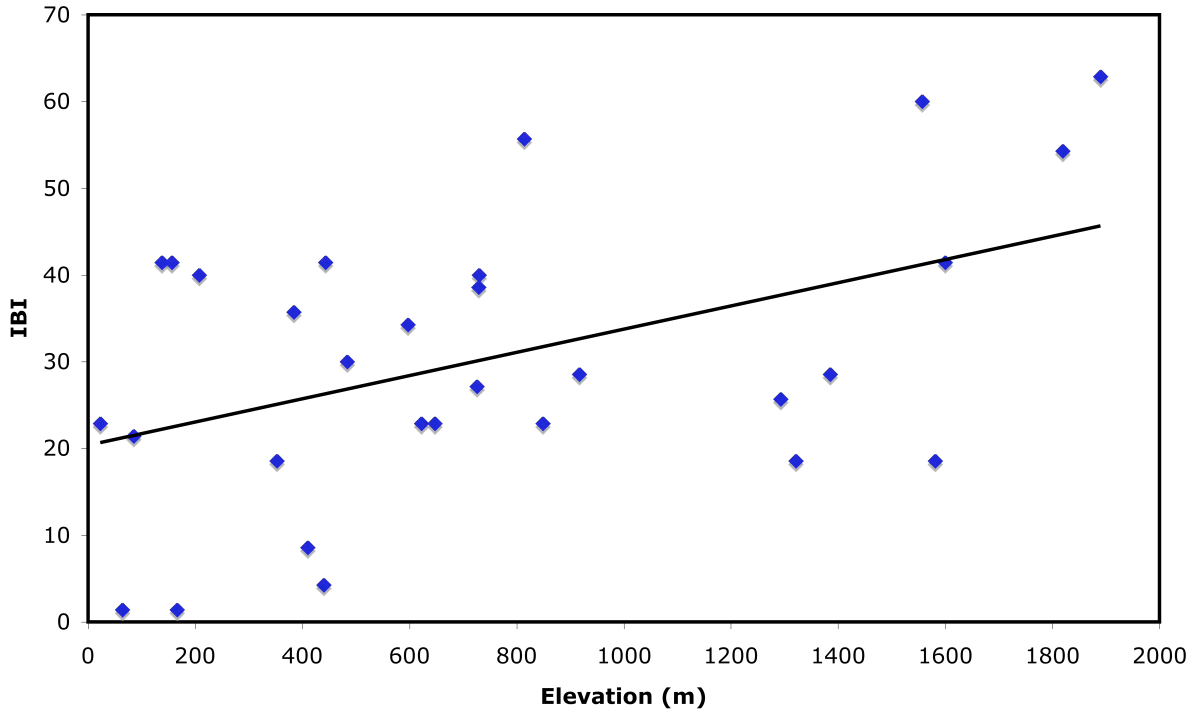


Figure 2. Correlation and trend line between SCC-IBI scores for the 30 sites sampled in 2006 and the elevation (m) of each site ($R^2$ = 0.372; P-value = 0.0004).




**Physical Habitat** – For each of the 30 sampling events, a total physical habitat (p-HAB) score was calculated by summing the three individual scores, Channel Alteration, Sediment Deposition, and Epifaunal Substrate and Available Cover (Table 5). As the scale of each of the individual scores was between 1 (poor) and 20 (optimal), the total p-HAB score fell between 3 and 60. The low-elevation sites total p-HAB scores ranged between 15 (poor) to 41 (suboptimal), with an average score of 26. The mid-elevation sites total p-HAB scores ranged between 14 (poor) to 46 (optimal), with an average score of 27. The high-elevation sites total p-HAB scores ranged between 21 (marginal) to 60 (optimal), averaging 45.

**Table 4: SCC-IBI scores and overall rating for each location sampled during the 2006 bioassessment survey.**

| Elevation Strata (meters) | Site | EPT Taxa | % Intolerant Individuals | # Predator Taxa | % Tolerant Taxa | % Non-Insect Taxa | % CF + CG | # Coleoptera Taxa | Total IBI Score (Adjusted on a scale of 0 to 100) | IBI Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 350 | 180 | 2 | 0 | 0 | 6 | 6 | 0 | 2 | 23 | Poor |
| 0 - 350 | 532 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | Very Poor |
| 0 - 350 | 011 | 4 | 0 | 0 | 9 | 1 | 1 | 0 | 21 | Poor |
| 0 - 350 | 012 | 2 | 2 | 0 | 7 | 8 | 2 | 8 | 41 | Fair |
| 0 - 350 | 019 | 3 | 0 | 0 | 9 | 8 | 9 | 0 | 41 | Fair |
| 0 - 350 | 110 | 4 | 0 | 2 | 8 | 7 | 3 | 4 | 40 | Poor |
| 0 - 350 | 042 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | Very Poor |
| 350 -700 | 116 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 9 | Very Poor |
| 350 -700 | 243 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 4 | Very Poor |
| 350 -700 | 051 | 1 | 0 | 1 | 8 | 6 | 1 | 4 | 30 | Poor |
| 350 -700 | 160 | 1 | 1 | 0 | 7 | 5 | 0 | 2 | 23 | Poor |
| 350 -700 | 085 | 1 | 0 | 0 | 4 | 6 | 0 | 2 | 19 | Very Poor |
| 350 -700 | 055 | 2 | 0 | 2 | 7 | 10 | 0 | 4 | 36 | Poor |
| 350 -700 | 258 | 1 | 0 | 1 | 8 | 10 | 2 | 7 | 41 | Fair |
| 350 -700 | 226 | 0 | 3 | 0 | 8 | 9 | 2 | 2 | 34 | Poor |
| 350 -700 | 079 | 1 | 0 | 1 | 5 | 7 | 0 | 2 | 23 | Poor |
| 700 + | 172 | 3 | 2 | 3 | 7 | 10 | 6 | 8 | 56 | Fair |
| 700 + | 267 | 0 | 1 | 0 | 7 | 0 | 3 | 2 | 19 | Very Poor |
| 700 + | 070 | 2 | 2 | 1 | 6 | 5 | 0 | 4 | 29 | Poor |
| 700 + | 020 | 5 | 4 | 6 | 10 | 9 | 5 | 5 | 63 | Good |
| 700 + | 206 | 1 | 0 | 0 | 9 | 3 | 0 | 0 | 19 | Very Poor |
| 700 + | 028 | 0 | 0 | 0 | 10 | 9 | 0 | 0 | 27 | Poor |
| 700 + | 032 | 3 | 2 | 0 | 10 | 10 | 0 | 2 | 39 | Poor |
| 700 + | 062 | 4 | 2 | 4 | 7 | 8 | 1 | 2 | 40 | Poor |
| 700 + | 041 | 0 | 0 | 0 | 6 | 7 | 1 | 2 | 23 | Poor |
| 700 + | 027 | 0 | 0 | 0 | 7 | 10 | 1 | 2 | 29 | Poor |
| 700 + | 007 | 1 | 1 | 0 | 8 | 7 | 1 | 0 | 26 | Poor |
| 700 + | 713 | 6 | 10 | 0 | 9 | 7 | 10 | 0 | 60 | Fair |
| 700 + | 034 | 2 | 4 | 2 | 9 | 8 | 2 | 2 | 41 | Fair |
| 700 + | 035 | 7 | 5 | 2 | 10 | 10 | 4 | 0 | 54 | Fair |

**Table 5: Individual p-HAB scores (1-20) and total p-HAB score (3-60) for each location sampled during the 2006 bioassessment survey.**

| Elevation Strata (meters) | Site | Epifaunal Substrate | Sediment Deposition | Channel Alteration | Total p-HAB Score 0 - 60 | Rating |
|---|---|---|---|---|---|---|
| 0 - 350 | 180 | 5 | 2 | 13 | 20 | Marginal |
| 0 - 350 | 532 | 10 | 18 | 8 | 36 | Suboptimal |
| 0 - 350 | 011 | 5 | 5 | 5 | 15 | Poor |
| 0 - 350 | 012 | 17 | 4 | 20 | 41 | Suboptimal |
| 0 - 350 | 019 | 1 | 0 | 17 | 18 | Marginal |
| 0 - 350 | 110 | 5 | 0 | 18 | 23 | Marginal |
| 0 - 350 | 042 | 6 | 2 | 19 | 27 | Marginal |
| 350 -700 | 116 | 12 | 3 | 20 | 35 | Suboptimal |
| 350 -700 | 243 | 2 | 20 | 6 | 28 | Marginal |
| 350 -700 | 051 | 11 | 17 | 18 | 46 | Optimal |
| 350 -700 | 160 | 14 | 10 | 20 | 44 | Suboptimal |
| 350 -700 | 085 | 0 | 19 | 0 | 19 | Marginal |
| 350 -700 | 055 | 3 | 2 | 9 | 14 | Poor |
| 350 -700 | 258 | 4 | 0 | 10 | 14 | Poor |
| 350 -700 | 226 | 15 | 11 | 20 | 46 | Optimal |
| 350 -700 | 079 | N/A | N/A | N/A | N/A | N/A |
| 700 + | 172 | 17 | 13 | 20 | 50 | Optimal |
| 700 + | 267 | 13 | 8 | 19 | 40 | Suboptimal |
| 700 + | 070 | 15 | 12 | 19 | 46 | Optimal |
| 700 + | 020 | 19 | 15 | 20 | 54 | Optimal |
| 700 + | 206 | 14 | 5 | 20 | 39 | Suboptimal |
| 700 + | 028 | 5 | 16 | 17 | 38 | Suboptimal |
| 700 + | 032 | 5 | 20 | 19 | 44 | Suboptimal |
| 700 + | 062 | 18 | 19 | 15 | 52 | Optimal |
| 700 + | 041 | 5 | 3 | 20 | 28 | Marginal |
| 700 + | 027 | 0 | 2 | 20 | 22 | Marginal |
| 700 + | 007 | 17 | 20 | 20 | 57 | Optimal |
| 700 + | 713 | 20 | 20 | 20 | 60 | Optimal |
| 700 + | 034 | 17 | 20 | 18 | 55 | Optimal |
| 700 + | 035 | 17 | 20 | 20 | 57 | Optimal |

**Water Chemistry** – Refer to Appendix C for water chemistry results.

## Discussion

This report gives the results from the first year of an ongoing five-year monitoring project to assess the quality of the waterways within Region 8. Although the protocol for assessing the surrounding physical habitat used during the 2006 sampling events was a modified California Stream Bioassessment Protocol, the data collected during 2006 will still be comparable with the full SWAMP procedures.

**BMI Community Structure -** A majority of the low and mid elevation sites were dominated by the facultative and tolerant insects and non-insects. These include midge larvae Chironomidae, crustaceans *Hyalella* sp. and Ostracoda, as well as mayflies *Baetis* sp. High-elevations sites were not only dominated by the aforementioned organisms of the low and mid elevations, but were also dominated by intolerant mayflies *Epeorus* sp.

Chironomidae larvae are highly tolerant of impaired conditions and a documented signature of urbanization (Wang and Lyons 2002). Although Chironomidae larvae were present at all but one site, their presence was not entire determined by urbanization. Sites that were isolated from the influence of urbanization still exhibited similar levels of Chironomidae larvae when compared to sites surrounded by urbanization. Most Baetidae mayfly genera are moderately tolerant members of the EPT group of BMIs and have a preference for sediment-dominated streambeds, having no need for complex habitat with high volume of interstitial areas. They are, however, sensitive to contamination and low dissolved oxygen levels. The presence of *Epeorus* sp. within high-elevation sites indicates relatively pristine habitat conditions for these sensitive organisms.

**Physical/Habitat Quality and Chemical Characteristics –** The physical habitat condition of the sampled sites ranged from poor to optimal (0 to 15 "poor," 16 to 30 "marginal," 31 to 45 "suboptimal," and 46 to 60 "optimal;" Table 5). Predominantly natural high-elevation channels had the highest values (averaging 44.5 and ranged from 21 to 60), followed by mid-elevation channels (averaging 27.3 and ranged from 14 to 46), and finally the low-elevation channels had the lowest values (averaging 25.7 and ranged from 15 to 41).

The water quality characteristics were relatively consistent among sites with near neutral or slightly alkaline mean pH field values (6.44 to 10.5; Appendix C), more than adequate levels of mean dissolved oxygen (6.26 to 16; Appendix C), and relatively low conductivity values (0 to 2.7 mS/cm; Appendix C). Natural inland waters usually contain small amounts of dissolved mineral salts; low levels of dissolved salts can be harmful to living organisms not able to osmoregulate causing the uptake of water into the organism's cells which can be lethal. Surveys of inland fresh waters indicate that a good mix of fish fauna is found where conductivity values range between 150 and 500 mS/cm and that the upper tolerance limit for freshwater organisms is 2000 mS/cm (McKee and Wolf 1971).

**SCC-IBI and Region 8 –** While an IBI is an informative tool for assessing waterway condition, this multimetric technique is not without its limitations. All IBI models are built on site-specific

data gathered from a particular region; the characteristics of these sites define the 'model experience.' The SCC-IBI is based on high-gradient streams whose BMIs were sampled using the targeted riffle protocols. While Region 8 falls within the geographic boundaries of the SCC-IBI, many of the sites sampled in 2006 occurred in low-gradient streams, which lacked targeted riffles and therefore, were sampled using the multi-habitat sampling protocols. Furthermore, many low elevation sites were channelized systems and these types of waterways are underrepresented in the sites used to build the SCC-IBI. Therefore, some sites within Region 8 may not be within the model's experience, and the resultant SCC-IBI scores may not adequately reflect waterway condition or health. The SCC-IBI scores reported here for the low elevation sites sampled in 2006 should be evaluated with the above limitations in mind.

Another important aspect to consider when evaluating the IBI scores presented here is the margin of error inherent in the SCC-IBI. A specific IBI score cannot precisely reflect the biotic condition of a site as the SCC-IBI model has a 12-point margin of error (P. Ode, personal communication). This error is the result of the natural variability across the sites that were used in building the SCC-IBI model. Practically speaking, this margin of error means that a given site's IBI score could actually be 12 points lower or higher than that calculated. As the categories of stream health fall in 20-point increments, this margin of error could place a particular site in two categories.

Furthermore, the SWAMP mandated sampling protocols used in 2006 only included the targeted riffle and multi-habitat approaches. The targeted riffle approach is used for high gradient streams, while the multi-habitat approach is used for low gradient streams. Recently (2007), SWAMP funded a study comparing the multi-habitat sampling protocol with a third approach, the 'margin-center-margin (MCM)' protocol for low gradient streams. This study found that the MCM captured a greater diversity of BMIs than the multi-habitat protocol; the resultant SCC-IBI scores generated from the samples collected using the MCM sampling protocols were higher than those calculated from multi-habitat samples. As a consequence of this study, beginning in 2009, SWAMP now advocates sampling all low gradient streams using the MCH.

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## Appendix A:

## Location Photos

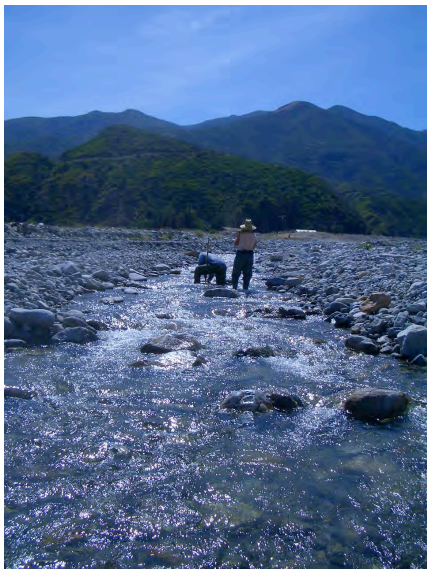
Site 055 Transect 0

Site 051 Transect 0

Site 032 Transect 0

Site 085 Transect 0

Site 079 Transect 0



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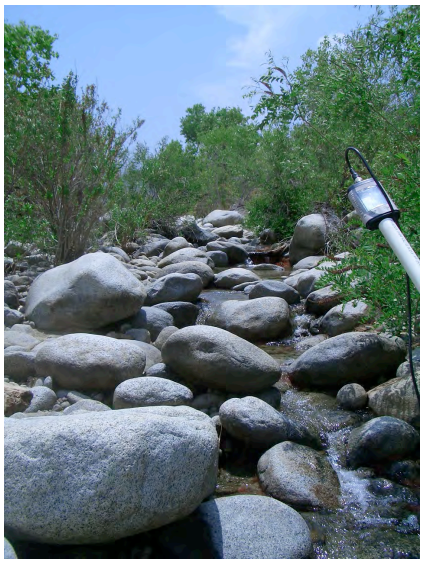

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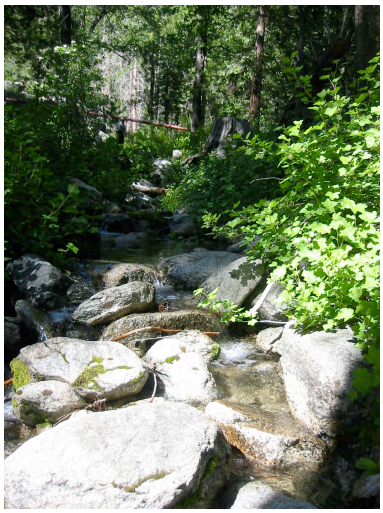
Site 019 Transect 30

Site 011 Transect 0

Site 110 Transect 0

Site 172 Transect 0



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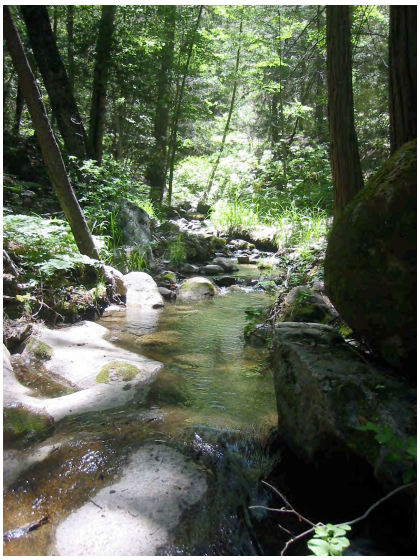

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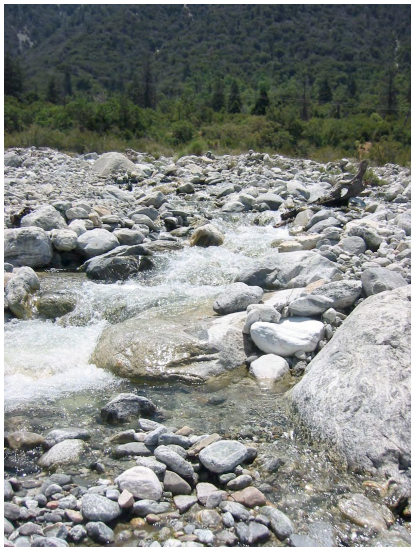
Site 180 Transect 0

Site 532 Transect 30

Site 116 Transect 60



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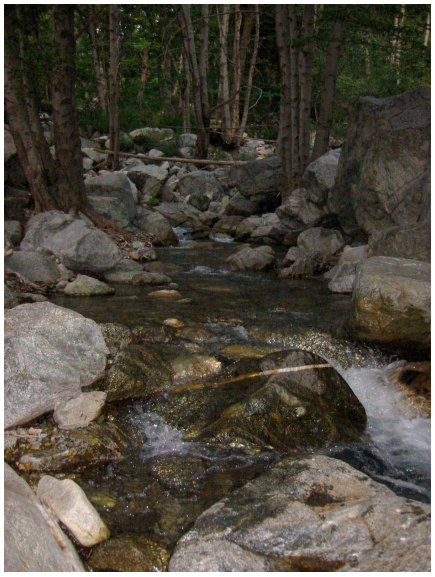
Site 027 Transect 0

Site 062 Transect 0



Site 713 Transect 0

Site 226 Transect 0

Site 258 Transect 0

Site 267 Transect 0

## Appendix B:

## QA/QC Procedures

**California State University, Long Beach**
**Stream Ecology and Assessment Laboratory (CSULB-SEAL)**

# QUALITY ASSURANCE PROJECT PLAN

**for**

**Aquatic invertebrate bioassessment monitoring for the Santa Ana Regional Water Quality Control Board (Region 8)**

Version 3.4

## A01. TITLE AND APPROVAL SHEET

Prepared by:
Drs. Dessie Underwood and Bruno Pernet
Department of Biological Sciences
California State University, Long Beach
1250 Bellflower Blvd
Long Beach, CA 90840
email: dlunderw@csulb.edu, bpernet@csulb.edu

APPROVALS

CSULB-SEAL Project Manager (Zed Mason) Date

CSULB-SEAL Quality Assurance Officer (Bruno Pernet) Date

Water Board Contract Manager (Pavlova Vitale) Date

Water Board Quality Assurance Officer Date

# A02. TABLE OF CONTENTS

**PROJECT MANAGEMENT**



**LIST OF TABLES**



# A03. DISTRIBUTION LIST

Pavlova Vitale, Santa Ana Regional Water Quality Control Board
Dr. Zed Mason, California State University, Long Beach
Rich Gossett, CRG Marine Laboratories
Dr. Dessie Underwood, California State University, Long Beach
Dr. Bruno Pernet, California State University, Long Beach

## A04. PROJECT/TASK ORGANIZATION

Project Manager: Dr. Zed Mason, CSULB. Oversight of the project, generation of reports
Quality Assurance Officer: Dr. Bruno Pernet, CSULB.; Quality control – will NOT be involved with generating data
Maintenance of the QAPP: Dr. Dessie Underwood, CSULB
Field/Lab Supervisor: Dr. Dessie Underwood, CSULB; Training and oversight of technicians and students involved in data collection
Field Biologists/Taxonomists: Mark Canfield, Coventry Dougherty, Kacy Jones, Craig Pernot
Chemical Analyst: Rich Gossett, CRG Marine Laboratories

**Table 1. Personnel responsibilities**

| Name | Organizational Affiliation | Title | Contact Information |
|---|---|---|---|
| Dr. Zed Mason | CSULB | Project Manager | Tel: (562)-985-5266<br>Fax: (562)-985-8878<br>zedmason@csulb.edu |
| Dr. Bruno Pernet | CSULB | Quality Assurance Officer | Tel: (562)-985-5378<br>Fax: (562)-985-8878<br>bpernet@csulb.edu |
| Dr. Dessie Underwood | CSULB | Field/Lab Supervisor | Tel: (562)-985-7475<br>Fax: (562)-985-8878<br>dlunderw@csulb.edu |
| Mark Canfield | CSULB | Field Biologist/Taxonomist | Tel: (562)-985-7475<br>Fax: (562)-985-8878<br>mcanfiel@csulb.edu |
| Coventry Dougherty | CSULB | Field Biologist/Taxonomist | Tel: (562)-985-7475<br>Fax: (562)-985-8878<br>Crayolanut31@aol.com |
| Kacy Jones | CSULB | Field Biologist/Taxonomist | Tel: (562)-985-7475<br>Fax: (562)-985-8878<br>kacyj@sbcglobal.net |
| Craig Pernot | CSULB | Field Biologist/Taxonomist | Tel: (562)-985-7475<br>Fax: (562)-985-8878<br>cpernot@csulb.edu |
| Rich Gossett | CRG Marine Laboratories | Chemical Analyst | Tel: (310) 533-5190<br>Fax: (310) 533-5003<br>crglabs@sbcglobal.net |

## A05. PROBLEM DEFINITION/BACKGROUND

Bioassessment is a tool for measuring stream water quality and habitat quality based on the types and numbers of organisms living there. It is a direct method for assessing the biological health or integrity of stream ecosystems. The objectives of the bioassessment program described here are to meet the federal EPA-mandated requirement (EPA requirement 305(b)) for an assessment of the integrity of surface waters in Region 8 (Santa Ana Region) of California. In addition, the data collected in this program will be used to identify streams that may require improvement of water quality. It will also be used to refine and compare several methods of analysis and interpretation of bioassessment data.

The Santa Ana region encompasses over 8000 stream-km distributed among three hydrologic units (Santa Ana, San Jacinto, and San Gabriel). These streams range from sea-level, low-gradient streams to high-gradient streams found well above 700 meters in elevation in the San Bernadino and San Jacinto Mountains. A great variety of land uses may affect water quality in this region, including urbanization, agriculture, manufacturing, livestock grazing, erosion, and channelization. This program will represent the first comprehensive bioassessment of streams in this region.

## A06. PROJECT/TASK DESCRIPTION

Work to be performed under this QAPP focuses on selecting sites for bioassessment sampling in 2006; field surveys of the physical habitat and water chemistry parameters, and benthic macroinvertebrates in 30 stream sites distributed throughout the area of interest; laboratory analyses of water chemistry and taxonomy and enumeration of benthic invertebrates; and analysis and summary of the data for presentation as technical reports. A specific timetable is shown below:

**Table 2. Project schedule timeline**

| Activity | **Start and expected completion dates** |
|---|---|
| Site selection, reconnaissance, and obtaining permission from landowners for sampling | Aug 05- Mar 06 |
| Field surveys | May 06-Jul 06 |
| Laboratory analysis: water chemistry and benthic macroinvertebrate taxonomy and enumeration | May 06-Jan 07 |
| Reporting | Mar 07-Mar 07 |

We will summarize our findings by calculating IBI scores using the Southern California – IBI developed by Ode et al. 2005. For each site sampled, we will provide the quantitative IBI score as well as the category of impairment that this score generates. Additionally, we will also analyze the benthic macroinvertebrate assemblages using Hawkins' RIVPACS model for Southern California (Utah State University, BugLab). This model will provide a comparison of which benthic macroinvertebrates should be present (expected) to what is actually captured (observed). As we are not a regulatory agency, we will not recommend specific water quality improvement activities; this will be left up to the appropriate personnel within the Region 8 administration.

## A07. QUALITY OBJECTIVES AND CRITERIA

A. Data quality objectives for this project will consist of the following:

Field Measurements – Accuracy, Precision, Completeness
Laboratory Measurements - Accuracy, Precision, Completeness

Accuracy will be determined by measuring each parameter from performance test samples or standard solutions from sources other than those used for calibration.

Precision measurements will be determined on both field and laboratory replicates. The number of replicates for field measurements will be three.

Completeness is the number of analyses generating useable data for each analysis divided by the number of samples collected for that analysis.

Project specific action limits are not applicable for this study.

Previously collected information must meet the minimum criteria for newly collected information as outlined in this document to be considered acceptable in this study.

Objectives for the precision, accuracy, and measurement ranges of selected physical and chemical parameters:

**Table 3. Data quality objectives for field measurements**

| Parameter | Accuracy | Precision | Target Reporting Limits | Completeness |
|---|---|---|---|---|
| Conductivity | ± 1% | ± 1% | 2.5 | 90% |
| Dissolved $O_2$ | ± 0.2 mg/L | ± 0.4 mg/L | 0.2 mg/L | 90% |
| Turbidity | ± 2% | ± 1% | 0.5 ntu | 90% |
| pH | ± 0.01 | ± 0.10 | | 90% |

**Table 4. Data quality objectives for laboratory measurements**

| Parameter | Accuracy | Precision | Target Reporting Limits | Completeness |
|---|---|---|---|---|
| Ammonia - N | 75-125% | 0-25% | 0.05 mg/L | 90% |
| Dissolved Orthophosphate | 75-125% | 0-25% | 0.01 mg/L | 90% |
| Nitrate-N | 75-125% | 0-25% | 0.05 mg/L | 90% |
| Nitrite-N | 75-125% | 0-25% | 0.05 mg/L | 90% |
| Total Suspended Solids | 75-125% | 0-25% | 0.5 mg/L | 90% |

B. Data representativeness: Previous studies suggest that physical and chemical parameters are typically within 10% of actual values. Measures of diversity (total and component) are likely to be underestimates but by no more than 30% of true richness and this due entirely to rare taxa or those not present in riffle habitat zones. Density is also underestimated, likely by about 10-20% due to incomplete capture of some organisms.

C. Data comparability: The field sampling and laboratory methods described here are based on evolving standard methods in the state of California, and as such should be fully comparable with other data collected by similar means. These data will be able to be used with preexisting IBI measures and RIVPACS models.

D. Data completeness (for each study reach unit): The completeness of data is a relationship of what percentage of the data are available for use compared to the total potential data before any conclusion is reached. Ideally, 100% of the data should be available. However, the possibility of data becoming unavailable due to laboratory error, insufficient sample volume, or samples broken in shipping must be expected. Also, unexpected situations may arise where field conditions do not allow for 100% data completeness. Therefore, 90% data completeness is required by SWAMP for data usage in most cases.

A high level of completeness is essential in all phases of this study due to the limited number of samples and sampling effort. The overall goal is to obtain completeness of 100 percent; however, the data quality objective is established at 90% to ensure an adequate level of data return.

E. Precision and Accuracy: The precision and accuracy of data are determined by particular actions of the analytical laboratory and field staff. The precision of data is a measure of the reproducibility of the measurement when an analysis is repeated. It is reported in Relative Percent Difference (RPD) or Relative Standard Deviation (RSD). The accuracy of an analysis is a measure of how much of the constituent actually present is determined. It is measured, where applicable, by adding a known amount of the constituent to a portion of the sample and determining how much of this spike is then measured. It is reported as Percent Recovery. The acceptable percent deviations and the acceptable percent recoveries are dependent on many factors including: analytical method used, laboratory used, media of sample, and constituent being measured. It is the responsibility of the program manager to verify that the data are representative while the analytical data's precision, accuracy, and comparability are mainly the responsibility of the laboratory supervisor. The program manager also has prime responsibility for determining that the 90% data completeness criteria (85% for tissue analyses as outlined previously) are met or for justifying acceptance of a lesser percentage. Laboratories performing the analysis of samples for this project have developed precision and accuracy limits for acceptability of data. For parameters and matrices, which have USEPA established criteria, the limits are either equal to, or more stringent than, the established limit. For matrices without USEPA established criteria, the laboratories have developed control limits following the procedures published in the USEPA Handbook for Analytical Quality Control in Water and Wastewater Laboratories. These DQO's are used to evaluate the acceptability of each set of results. If the objectives are not passed for a particular analysis, the lab will immediately determine the cause of the discrepancy and resolve the problem.

## A08. SPECIAL TRAINING/CERTIFICATIONS

Field and laboratory technicians will be provided with this QAPP and with detailed standard operating procedures (SOPs) for all protocols used in the field and in the laboratory. Prior to each field season the project QA officer will involve all personnel in a training session on each protocol used in physical habitat, chemical, and biological sampling, including practice in each of the above protocols. Field quality control (QC) involves regular review of sample collection, preservation, and labeling. Laboratory training involves QC checking of all samples sorted during an initial training period. When a technician has met initial QC standards for removal of specimens from sample debris (<5% organisms missed), then 20% (1 of 5) samples are

subsequently checked for completeness of removal. Log sheets and sample processing sheets are used to track who processed samples, time spent on each sample, number of organisms recovered, who did QC checks, and the number of organisms missed (in QC-checked samples). These data are used for feedback and improvement of sorting rate and effectiveness. Each technician will maintain a notebook with copies of taxonomic keys, notes, and illustrations. All identified sample replicates are reviewed with a supervisor during QC checks (each taxon verified, changed, or deleted). During initial training 100% of identified sample replicates are QC checked, but later only 20% of samples are so checked. Regular work performance evaluations are performed to certify compliance with the QC goals of quality in completing field and laboratory tasks (see section 20). The QA officer is responsible for assuring that the training and QC requirements are satisfied.

Training documentation will be stored in Peterson Hall 2, Room 03.

## A09. DOCUMENTATION AND RECORDS

Records of field surveys will be maintained on standard forms (Appendix 1) for each site studied, using water-resistant paper. All field data are entered on these forms at the time data are gathered. All laboratory records are also maintained on standard forms (Appendix 1). These data will be transferred to a database system for summary and analysis. The database system that we will use is a Microsoft ACCESS database in a format compatible with the evolving SWAMP database. Backups of electronic record will be made as described below (section 19). All biological samples, including remnant samples, will be archived for five years. Voucher specimens for each invertebrate taxon encountered will be maintained in a separate laboratory collection.

Data will be submitted to the SWAMP database and a final report will be generated that outlines the site-specific IBI scores and RIVPACS O/E values. Both submission of data to the SWAMP database and the generation of a final report constitute the final work product.

Data will be stored indefinitely on computers in Peterson Hall 2, Room 3, with electronic back ups kept on the CSULB server.

Dr. Underwood will be responsible for distributing the most recent copy of the QAPP.

## B01. SAMPLING PROCESS DESIGN

Sites will be selected according to specific research questions and to address the primary objective (quantifying the integrity of streams in the entire region). Briefly, we will classify stream sites by hydrologic unit (HU) and elevation. Because the portion of the San Gabriel HU included in Region 8 is so small, we will pool those sites with those in the Santa Ana HU. The two hydrologic units (Santa Ana and San Jacinto, with the former including the San Gabriel) will be divided into three elevation strata – 0-350 meters, 350-700 m, and 700+ m. Because there are no sites in the San Jacinto HU in the 0-350 m stratum, the combination of HU and elevation yields five sampling units. The target 30 sites sampled per year will be evenly distributed among these five sampling units. Sampling will take place between May and July 2006, and samples will be transported to the laboratory within three days of collection for water chemistry analyses, storage and subsequent processing.

Potential sources of variability and bias are as follows:

Variability: During the index period variation in weather may increase inter-site variability due to periodic rainfall, changes in air and water temperature, etc. There should be little variation due to sampling as the field crew membership will be stable and training was extensive during the fall months of 2005. Additional training will occur prior to sampling.

Bias: Sampling may be constrained by access and will be limited to sites that do not pose a safety hazard to the field crew. Some bias may be introduced as higher elevation sites may also be characterized by increased slope and inaccessibility. Higher elevation sites may also be correlated with decreased human impacts and, as such, might be expected to exhibit IBI scores above regional averages. We will avoid these biases whenever possible by selecting alternative sites that are as similar as possible to the inaccessible sites with respect to elevation and potential human influences both upstream and immediately surrounding each site.

## B02. SAMPLING METHODS

For details of methods of field sample collection, please see the Field Sampling SOP (Appendix 2 – SOP 2.1 [2/20/06]). How water samples will be collected, preservation methods, sampling containers, equipment, etc. are discussed in SOP 2.1 (2/20/06).

All work will be carried out according to these detailed instructions. Briefly, field work will include measurement of physical habitat parameters, measurement of some water chemistry parameters and collection of water samples for later laboratory assessment of others, and collection of benthic macroinvertebrates for bioassessment. For all three categories of field work we will follow California's evolving standard protocols for sampling. For example, current recommendations from the State Water Resources Control Board are to use the EMAP multihabitat sampling methods for low-gradient, sandy bottom streams; for high-gradient streams, the targeted riffle approach used by the US Forest Service is recommended. We will use these methods.

Water samples will be transported on ice from the field to the lab. They will not be preserved beyond the time required for lab analysis.

Sampling equipment and samplers will be cleaned after each use. As we are only sampling water and macroinvertebrates, thorough rinsing in fresh water will suffice for decontamination and no by-products will be produced (and hence, no need to state how these by-products will be disposed of).

All equipment needed is clearly stated in the SOPs. Support facilities including laboratory and office space are provided by CSULB.

## B03. SAMPLE HANDLING AND CUSTODY

Samples collected in the field and returned to the laboratory from each site include one composited benthic invertebrate sample (labeled with stream, site name, and date) preserved in ethanol, and water samples for chemical analyses. Upon return to the laboratory, which will occur immediately after the completion of each field survey trip (so within one week of collection), all biological samples will be logged into a Sample Tracking Log, and will subsequently be stored in cabinets; water samples will be analyzed immediately on return to the laboratory. Biological samples will be sorted and identified within nine months of collection. All samples will be in the custody of the CSULB research team or contractors at all times, from

the time of collection to completion of processing, identification, and analysis. Log sheets (Appendix 1) are used to track benthic macroinvertebrate samples in the laboratory through sorting, subsampling, identification, and quality control. Chain-of-custody forms (Appendix 1) are used for transferring samples to external laboratories for identification verification checks. Because the research laboratory is a new one, all biological samples taken during the first year of the study will be archived for five years.

The maximum holding time for all water samples is 48 hours.

## B04. ANALYTICAL METHODS AND FIELD REQUIREMENTS

Please refer to SOPs (Appendix 2 – SOP 01 [2/20/06], SOP 02 [2/20/06], SOP 03 [2/20/06]) for methods used in field surveys and laboratory analysis. Some water chemistry parameters will be measured by CRG Marine Laboratories, Inc, Torrance, CA.

No *in situ* or continuous monitoring will be done.

Specific method performance criteria are not applicable for this project.

If problems are encountered in the field (e.g. access problems, safety issues, inadequate supplies), the field team leader will be responsible for corrective actions. If problems are encountered in the lab, the lab supervisor will be responsible for corrective actions.

Samples will be disposed of following the policy and regulations of the California State University Long Beach.

Lab turn around times can only be estimated as this is a new research laboratory, but it is anticipated to be in the range of six to nine months.

PBMS method validation and documentation are not applicable to this study.

Equipment needed for laboratory analyses is listed in SOPs 02 and 03.

When failures occur, the laboratory supervisor is responsible for initiating corrective action. All corrective action is documented by entry into the Corrective Action File (CAF).

## B05. QUALITY CONTROL

Field and laboratory quality control measures include extensive training sessions in habitat surveys and sampling prior to each field season, cross-checks between observers in paired teams to ensure uniformity in how measures are taken and recorded, supervisor oversight of all technicians, use of standardized data forms for all records, and the availability of detailed SOPs for all procedures. Cross-checks of field-data forms are made at the end of each survey. During initial training of laboratory technicians, 100% checks are made during sorting (reduced to 20% when <5% error is achieved), and 100% re-identification checks with laboratory supervisors are routine. QC results are entered on the Sample Processing Lab Sheet and the Sample Tracking Log. If control limits are exceeded, 100% checks will be made during sorting and again reduced to 20% when <5% error is achieved.

Twenty percent of identified specimens will be randomly selected and sent to an external laboratory for verification. If there are errors in identification, all samples that included those taxa will be reevaluated and corrections made.

The calculation of relative percent difference or error is as follows. Each measured value is compared against the known value of the standard, and accuracy is expressed as the relative percent difference.

$$RPD = \frac{[V_m - V_k]}{V_k} \times 100\%$$

Where: RPD = the relative percent difference
Vm = the measured value,
Vk = the known value.

Duplicate field samples will be collected for all parameters at an annual rate of 5% of total samples to be collected within a given year's Work Plan. The duplicate sample will be collected in the same manner and as close in time as possible to the original sample. This effort is to attempt to examine field homogeneity as well as sample handling, within the limits and constraints of the situation.

All biological samples, including remnant samples, will be archived for five years sampling.

## B06. INSTRUMENT/EQUIPMENT TESTING, INSPECTION AND MAINTENANCE

The primary types of equipment for use in the field are GPS units, a rangefinder, a flowmeter, and a dissolved oxygen/pH meter. This equipment will be examined for proper function, part replacement, battery life, and re-filling of solutions before each field survey. Spare batteries, parts and supplies are carried in the field so as to be able to deal with simple malfunctions on site. Equipment will be stored in conditions recommended by the manufacturers. Biological sampling equipment will be visually inspected before each field survey so as to detect and repair any damage.

This equipment does not have "spare parts" beyond the routine maintenance, e.g. batteries, probes, etc. In the event of malfunction, a new piece of equipment will be purchased.

Testing, inspection, and maintenance of equipment are the responsibility of the lab supervisor. The lab supervisor will also be responsible for employing any corrective actions and documenting these actions in the equipment log. The effectiveness of the corrective action will be determined by re-calibration and testing of the equipment.

## B07. INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Regular calibration of field and laboratory instruments described above (section 15) will be conducted prior to each field survey, or prior to each use in the laboratory. Calibration will be carried out according to the manufacturer's instructions, and will be recorded in calibration logbooks. Deficiencies will be resolved by repair or replacement of equipment. All equipment will be recalibrated and tested following repair or replacement. Corrective action will be logged in the Corrective Action File.

## B08. INSPECTION/ACCEPTANCE FOR SUPPLIES AND CONSUMABLES

All shipments received are checked to verify that the packing slip is complete and matches the materials ordered. Standard supplies are stored in designated areas. Most supplies and equipment are ordered from: Fisher Scientific, Forestry Suppliers, and BioQuip.

The lab supervisor is responsible for supplies and consumables.

## B09. NON-DIRECT MEASUREMENTS

This project will not require non-direct measurements to generate the final report.

## B10. DATA MANAGEMENT

Data will be recorded on standardized forms for all procedures (Appendix 1). After QC checks, habitat, chemistry, and taxonomy data will be recorded in an ACCESS database described above (section 9) for summary and analysis. After data entry, entries on field or laboratory data sheets will be checked against those in the database. Where there is disagreement, corrections will be made as necessary. Original field and laboratory datasheets will be stored in a secure location. Database records will be stored on a computer hard drive, and copies on storage media (CD or DVD) will be stored in separate locations.

The lab supervisor is responsible for data management.

## C01. ASSESSMENTS AND RESPONSE ACTIONS

Field and laboratory personnel will be evaluated at 6-month intervals. These evaluations will focus on performance in terms of accuracy in carrying out procedures and in taxonomic identifications. Audits of equipment and analysis will occur during QC checks, data management, and comparisons of data quality objectives with actual data products. Corrective actions for assessment not meeting objectives are described above (sections 14 & 19).

The QA officer is responsible for conducting assessments. The assessment information is reported to the lab supervisor in the form of a report that includes all the pertinent information: date, type of assessment, control limits, and results.

## C02. REPORTS TO MANAGEMENT

Reports will be produced as required and specified by contracts for this project. Each report will first be produced as a draft for review by the funding source and any individuals or organizations specified by the source. After review, revisions will be made and the final report will be generated for distribution to the funding source and other specified recipients. Progress reports are made quarterly to the project manager and the Regional Water Resources Control Board Project Official. Reports will generally follow the structure of a scientific paper, and will include extensive presentation of data in graphical or tabular format so that these may be inspected relatively directly.

The QA officer is responsible for writing project QA status reports. These reports will be distributed to project manager and the lab supervisor.

## D01. DATA REVIEW, VERIFICATION, AND VALIDATION

Responsibility for data review and verification is in the hands of the program leader and program manager. This process involves use of the QAPP for defining acceptance or rejection of the data results and conclusions produced.

## D02. VERIFICATION AND VALIDATION METHODS

Please refer to sections 7, 8, 12, 14, 19, and 20 above, as well as the SOPs (Appendix 2).

The QA officer is responsible for data verification and validation. Laboratory technicians will confirm accurate data entry. The lab supervisor will re-check all data entered. We require 100% accuracy in data entry. QA officer will perform a check of 10% of the reports.

Issues will be resolved as soon as possible after they become apparent. The resolution process will involve investigating all potential sources resulting in the issue, discussion among project leaders as to necessary corrective actions, then implementation of these corrective actions.

The project manager is responsible for reporting to data users the nature of any issues, corrective actions taken, and if there are any implications for data use.

## D03. RECONCILIATION WITH USER REQUIREMENTS

Correspondence of the data produced with the measurement quality objectives specified in this QAPP (section 7) will be reviewed during analysis. Corrective actions as specified in the QAPP will be taken to address any problems detected. If revisions of this QAPP are necessary (due to changing standards for data collection or analysis, or problems detected), this document will be revised and submitted to the appropriate agency QC officers for approval.

The objective of this project is to provide the first bioassessment completed within Region 8. As such, it is not hypothesis driven, but strictly descriptive in nature. We will use the recently published Southern California B-IBI (Ode et al. 2005) and the RIVPACS model developed for California by Dr. Hawkins at Utah State University to assess degree of impairment for all sites sampled. These two models combined will provide two independent estimates to the ecological integrity of the streams in Region 8

## Appendix C:

**Water Quality Data**

Table C1: Water chemstry results for measurements recorded both within the field prior to BMI collection, as well as samples sent for analysis. The table also includes the three overall reach assessment categories for assessing overall stream viability. "R2" represents random 10% QA of the lab samples processed.

| | pH (Field) | pH (Lab) | Water Temp.(°C) | Conductivity (mS/cm) | Turbidity (NTU) | Dissolved $O_2$ (mg/l) | Alkalinity (P) | Alkalinity (T) |
|---|---|---|---|---|---|---|---|---|
| 012 | 8.08 | 7.9 | 17.3 | 2.7 | 1.2 | 10.5 | 0 | 430 |
| R2 | | | | 2.7 | 1.2 | | | |
| 042 | 10.49 | 10 | 33.9 | 0.7 | 1.9 | 14.7 | 88 | 112 |
| 055 | 8.94 | 8.7 | 20.8 | N/A | 27 | 16 | 20 | 180 |
| R2 | | | | | | | | |
| 051 | 8.5 | 7.7 | 27.4 | N/A | 34.8 | 8.2 | 0 | 140 |
| R2 | | 7.7 | | | | | | |
| 032 | 8.59 | 8.1 | 23.2 | N/A | 1.5 | 8.1 | 0 | 116 |
| 085 | 9.47 | 9.3 | 29 | N/A | 23.2 | 14.2 | 64 | 156 |
| 079 | 8.74 | 8.1 | 30.8 | N/A | 2.6 | 7.6 | 16 | 196 |
| R2 | | | | | | | | |
| 028 | 8.44 | 8.1 | 24.5 | N/A | 1.1 | 9 | 4 | 132 |
| R2 | | | | | 1.3 | | | |
| 160 | 9.8 | 8.2 | 25.1 | 0.2 | 0.6 | 1.8 | 4 | 112 |
| R2 | | | | | | | | |
| 243 | 10.03 | 9.1 | 31.4 | 0.7 | 16.5 | 1.45 | 56 | 132 |
| R2 | | | | 0.7 | 16.1 | | | |
| 011 | 8.48 | 8.3 | 21.8 | 1.1 | 19.5 | 0.24 | 12 | 220 |
| R2 | | 8.3 | | 1.1 | 20.2 | | | |
| 019 | 8.23 | 8.2 | 27.7 | 1 | 32.7 | 6.76 | 12 | 212 |
| 110 | 8.41 | 8.3 | 31 | 1 | 27.5 | N/A | 12 | 252 |
| 172 | 7.72 | 7.8 | 19.3 | 0.2 | 2.4 | 0.01 | 0 | 52 |
| 020 | 7.37 | 7.6 | 11.2 | 0.1 | 0.3 | N/A | 0 | 36 |
| 206 | 7.63 | 7.5 | 17.9 | 0 | 2 | 2.45 | 0 | 56 |
| 070 | 7.87 | 7.6 | 13.6 | 0 | 0.5 | 0.09 | 0 | 44 |
| 180 | 8.1 | 8 | 22.5 | 0 | 1.2 | 11.3 | 0 | 240 |
| R2 | | 8 | | | 1.2 | | | |
| 532 | 9.26 | 9.2 | 29.2 | 0.1 | 1.8 | 14.47 | 50 | 200 |
| 116 | 8.19 | 8 | 21.5 | 1.8 | 11.6 | 6.72 | 0 | 256 |
| 007 | 8.39 | 8.3 | 18.5 | 0.2 | 1 | 7.62 | 8 | 104 |
| 035 | 6.44 | 7.9 | 14.5 | 1.8 | 2.5 | 8.45 | 0 | 80 |
| 034 | 6.9 | 8.1 | 16.1 | 1.7 | 0 | 8.5 | 0 | 78 |
| 041 | 8.38 | 8.3 | 21.7 | 0.7 | 1.2 | 8.4 | 12 | 288 |
| 027 | 8.13 | 8.1 | 23.1 | 0.7 | 1.7 | 9.35 | 0 | 260 |
| 062 | 8.44 | 8.4 | 22.4 | 0.3 | 0 | 7.91 | 0 | 140 |
| 713 | 7.48 | 8.3 | 11.9 | 0.2 | 0 | 8.85 | 0 | 88 |
| 226 | 8.65 | 8.4 | 22.8 | 0.3 | 0 | 7.72 | 8 | 120 |
| R2 | | 8.4 | | 0.3 | 0 | | | |
| 258 | 8.39 | 8.3 | 28.6 | 0.8 | 53.3 | 6.26 | 8 | 152 |
| 267 | 8.22 | 8 | 19.2 | 0.2 | 6.4 | 9.07 | 0 | 96 |

Table C1: Continued.

| | Ammonia (mg/L) | Dissolved Ortho-phosphate (mg/L) | Nitrate (mg/L) | Nitrite (mg/L) | Total Suspended Solids (mg/L) | Epifaunal Substrate | Sediment Deposition | Channel Alteration |
|---|---|---|---|---|---|---|---|---|
| 012 | 0.01 | 0.045 | 4.95 | 0.173 | 3.7 | 17 | 4 | 20 |
| R2 | | 0.046 | 4.92 | 0.18 | | | | |
| 042 | 0.14 | 0.044 | 4.98 | 0.175 | 0 | 6 | 2 | 19 |
| 055 | 0.06 | 1.17 | 3.96 | 0.18 | 26 | 3 | 2 | 9 |
| R2 | | 1.18 | 3.91 | 0.18 | 116 | | | |
| 051 | 0.08 | 3.23 | 6.89 | 0.1 | | 11 | 17 | 18 |
| R2 | | | | | | | | |
| 032 | 0.02 | N/A | 0.15 | 0.05 | 7 | 5 | 20 | 19 |
| 085 | 0.06 | 0.68 | 1.9 | 0.17 | 14 | 0 | 19 | 0 |
| 079 | 0.04 | 0.02 | 0.83 | 0.07 | 8.7 | N/A | N/A | N/A |
| R2 | | | | | 8.7 | | | |
| 028 | 0.02 | 0.01 | 0.66 | 0.05 | 1.3 | 5 | 16 | 17 |
| R2 | | | | | | | | |
| 160 | 0.02 | 0.038 | 0 | 0 | 0 | 14 | 10 | 20 |
| R2 | | 0.035 | 0 | 0 | | | | |
| 243 | 0.1 | 0.133 | 0.04 | 0 | 2.3 | 2 | 20 | 6 |
| R2 | | | | | | | | |
| 011 | 0.02 | 0.637 | 3.74 | 0.15 | 27 | 5 | 5 | 5 |
| R2 | 0.02 | 0.663 | 0.16 | 0.16 | 29 | | | |
| 019 | 0.01 | 1.3 | 7.32 | 0.1 | 49 | 1 | 0 | 17 |
| 110 | 0.02 | 0.769 | 6.1 | 0.09 | 49.3 | 5 | 0 | 18 |
| 172 | 0.01 | 0.029 | 0 | 0 | 6 | 17 | 13 | 20 |
| 020 | 0.01 | 0.014 | 0 | 0 | 0 | 19 | 15 | 20 |
| 206 | 0.02 | 0.169 | 0.04 | 0 | 4.75 | 14 | 5 | 20 |
| 070 | 0.01 | 0.014 | 0 | 0 | 1 | 15 | 12 | 19 |
| 180 | 0.02 | 0.135 | 3.78 | 0.15 | 2 | 5 | 2 | 13 |
| R2 | 0.03 | 0.113 | 3.81 | 0.14 | 2 | | | |
| 532 | 0.05 | 0.297 | 0.92 | 0.08 | 1.5 | 10 | 18 | 8 |
| 116 | 0.03 | 0.315 | 0.52 | 0 | 18.5 | 12 | 3 | 20 |
| 007 | 0 | 0 | 0.16 | 0 | 1 | 17 | 20 | 20 |
| 035 | 0 | 0 | 0.05 | 0 | 4 | 17 | 20 | 20 |
| 034 | 0 | 0 | 0.06 | 0 | 0 | 17 | 20 | 18 |
| 041 | 0 | 0.01 | 3.37 | 0.03 | 0.7 | 5 | 3 | 20 |
| 027 | 0 | 0.01 | 3.52 | 0.04 | 0 | 0 | 2 | 20 |
| 062 | 0.01 | 0 | 0.75 | 0.04 | 0 | 18 | 19 | 15 |
| 713 | 0.01 | 0 | 0.04 | 0.04 | 0 | 20 | 20 | 20 |
| 226 | 0.01 | 0.035 | 1.51 | 0.06 | 1.67 | 15 | 11 | 20 |
| R2 | 0.01 | 0.034 | 1.44 | 0.05 | 1.67 | | | |
| 258 | 0.03 | 2.04 | 7.71 | 0.1 | 105 | 4 | 0 | 10 |
| 267 | 0.02 | 0.009 | 0 | 0 | 20.3 | 13 | 8 | 19 |

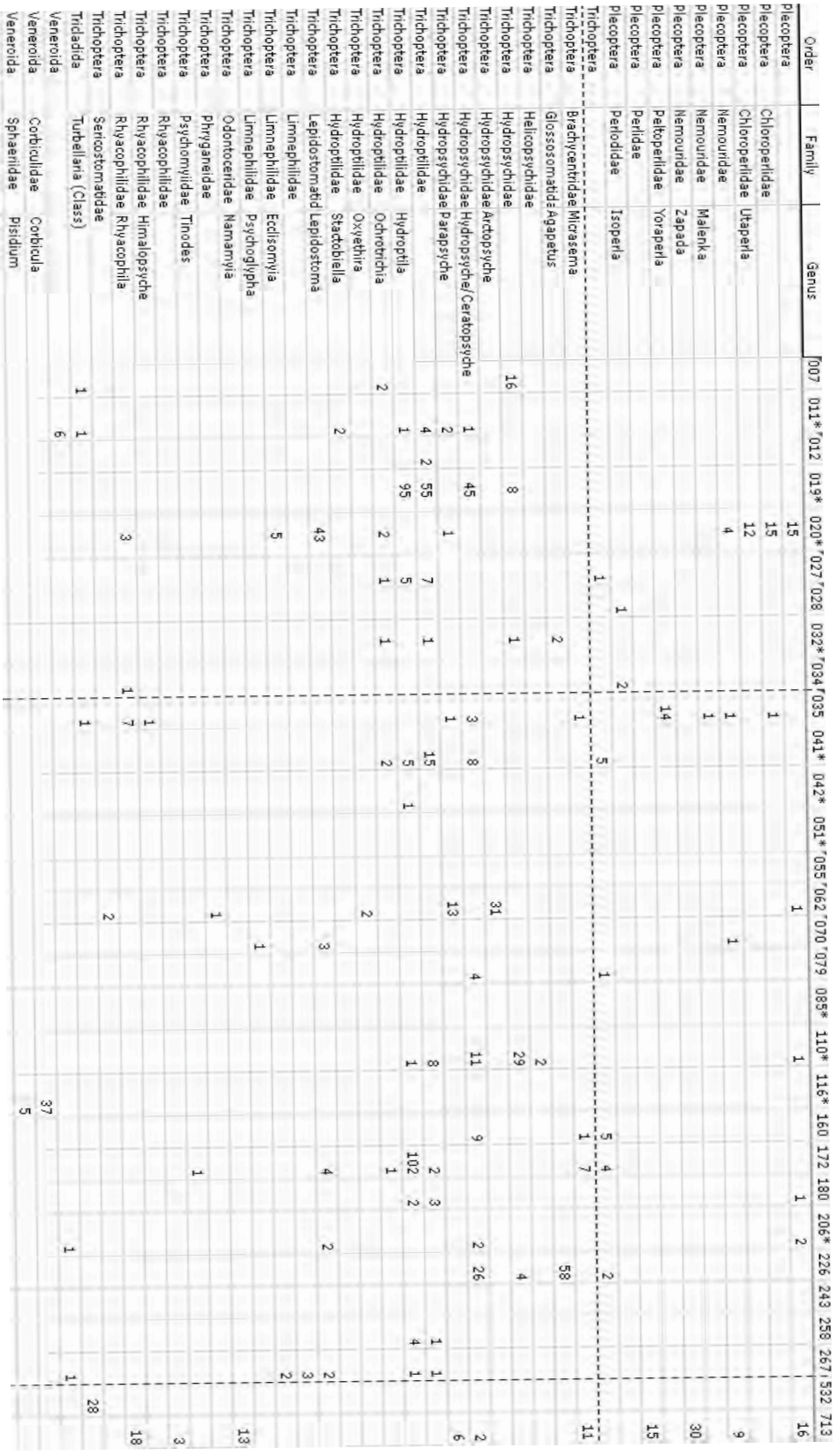
**Table C2. Abundances of BMIs per site.**

| Order | Family | Genus | D07 | D11* | D12 | D19* | D20* | D27 | D28 | D32* | D34 | D35 | D41* | D42* | D51* | D55 | D62 | D70 | D79 | D85* | 110* | 116* | 160 | 172 | 180 | 206* | 226 | 243 | 258 | 267 | 532 | 713 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acari | Hydrryphantidae | Wandesia | | 1 | | 1 | 28 | | | | 1 | | | | 3 | | | | | | 3 | | 2 | | | 2 | | | | | | 2 |
| Acari | Hygrobatidae | Atractides | | | | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | 1 | | |
| Acari | Lebertiidae | Lebertia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acari | Limnesiidae | Limnesia | | | | | | | | | | | | | | | | 1 | | | | | 1 | | | | | | | | | |
| Acari | Hydryphantidae | Hydryphantes | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acari | Sperchonidae | Sperchon | 1 | | | | | | | | | | 4 | | | | 1 | 1 | 5 | | 2 | 5 | | | | 2 | | | | | | |
| Amphipoda | Hyalellidae | Hyalella | | 7 | | | | | | | | | | 7 | | | | | | | 4 | | | 1 | | 304 | | | | 422 | |
| Basommatophora | | | | 2 | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | |
| Basommatophora | Physidae | Physa | | | 22 | | | | | | | | | | 1 | | | | | | | | 5 | | | 1 | | | 15 | | | |
| Basommatophora | Planorbidae | Gyraulus | | | | | | | | | | | | 20 | | | | | | | | | | | | | | | 1 | 8 | | |
| Cladocera | | | | 7 | | | | | | | | | 2 | | | | | | | | | | | | | 6 | | | 67 | | | |
| Coleoptera | Carabidae | | | | | | | | | | 1 | | | | 1 | | | | | | | | | | | | | | | | | |
| Coleoptera | Curculionidae | | | | | | | | 1 | | | | | | | 1 | 1 | | 1 | | | | | 1 | | | | | | | | |
| Coleoptera | Dytiscidae | Agabus(a) | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Coleoptera | Dytiscidae | Celina(a) | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Coleoptera | Dytiscidae | Dytiscus | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Coleoptera | Dytiscidae | Laccophilus (a) | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | 1 | | | |
| Coleoptera | Dytiscidae | Laccophilus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Coleoptera | Dytiscidae | Oreodytes | | | | | | 3 | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| Coleoptera | Dytiscidae | Scuticaria(a) | | | | | | | | | | | | | | | | | | | | | 4 | | | | | | | | | |
| Coleoptera | Dytiscidae | Scuticaria | | | | | | | | | | | | | | | | | | | | | 24 | | | | | | | | | |
| Coleoptera | Elmidae | Ampumixis | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| Coleoptera | Elmidae | Cleptelmis | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| Coleoptera | Elmidae | Microcylloepus | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| Coleoptera | Elmidae | Narpus | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | |
| Coleoptera | Gyrinidae | Gyrinus | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| Coleoptera | Haliplidae | Peltodytes | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Coleoptera | Hydrophilidae | | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | | | | 1 | 1 | | |
| Coleoptera | Hydrophilidae | Berosus | | | 2 | | | | | | | | | | | | | | | | | | 3 | | | | | | 1 | | | |
| Coleoptera | Hydrophilidae | Enochrus | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| Coleoptera | Hydrophilidae | Hydrobius | | | 7 | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | |
| Coleoptera | Hydrophilidae | Laccobius | | | 2 | | | | | | | | | | | | | | | | | | | 3 | | | | | | | | |
| Coleoptera | Hydrophilidae | Tropisternus | | | | | | 2 | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| Copepod | | | | 7 | | | | | | | | | | | | | | | | | | 8 | | | | 1 | | | | | | |
| Diptera | Ceratopogonidae | | | | | | | | | | | | | | 5 | | | | | | | 1 | 1 | 1 | | 1 | 1 | | 1 | 5 | | |
| Diptera | Ceratopogonidae | Alluaudomyia | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| Diptera | Ceratopogonidae | Bezzia/Palpomyia | | | | 3 | | | | | | | | | | | | | | | | 1 | | | | | | | | | | |
| Diptera | Ceratopogonidae | Ceratopogon | | | | | 1 | | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| Diptera | Ceratopogonidae | Culicoides | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | | | | |
| Diptera | Ceratopogonidae | Dasyhelea | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| Diptera | Ceratopogonidae | Probezzia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Chironomidae | | 54 | 305 | 47 | 71 | 274 | 103 | 92 | 259 | 112 | 16 | 210 | 378 | 148 | 132 | 13 | 265 | 106 | 308 | 153 | 165 | 210 | 258 | 114 | 123 | 184 | 37 | 248 | 12 | 5 | 58 |

**Table C2 continued**

| Order | Family | Genus | 007 | 011* | 012 | 019* | 020* | 027 | 028 | 032* | 034 | 035 | 041* | 042* | 051* | 055 | 062 | 070 | 079 | 085* | 110* | 116* | 160 | 172 | 180 | 206* | 226 | 243 | 258 | 267 | 532 | 713 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diptera | Culicidae | Culex | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Dixidae | | | | | | | | | | | 1 | | | | | | | | | | | | | | 2 | | | | | | |
| Diptera | Dixidae | Dixa | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Dixidae | Dixella | | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | |
| Diptera | Dolichopodidae | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| Diptera | Empididae | Chelifera/Metachela | | | | | | | | | | | | | 1 | | 2 | | 1 | | | | | | | | | | | | | |
| Diptera | Empididae | Clinocera | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Empididae | Hemerodromia | 4 | | 20 | 1 | 1 | | | | | | 2 | | | | | | | | 2 | | | | | | | | | | | |
| Diptera | Empididae | | | 1 | | 5 | | | 1 | | | | | | 3 | 1 | 1 | | | | | 17 | | | | | 3 | | | | 29 | |
| Diptera | Ephydridae | allcombined | | | | 1 | | 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Muscidae | | | | | | | 9 | 2 | 1 | 10 | 1 | | 8 | | | | | | | | 1 | 3 | 2 | 2 | | | | | | |
| Diptera | Sciomyzidae | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Simuliidae | Prosimulium | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Simuliidae | Simulium | 198 | 23 | 21 | 117 | | 231 | 240 | 113 | 195 | 1 | 52 | | 131 | 7 | 175 | 37 | 98 | 1 | 102 | 2 | 9 | 2 | 62 | 59 | | 43 | | | | |
| Diptera | Simuliidae | | 6 | | | | | 1 | | 6 | | | | | 2 | | 4 | | | 21 | | | | | | | | 4 | | | | |
| Diptera | Stratiomyidae | Caloparyphus/Euparyphus | | | 4 | | | 7 | 1 | | | | 11 | | 3 | | 39 | | 71 | | | | | 4 | | 3 | | 7 | | | | |
| Diptera | Stratiomyidae | Myxosargus | | | | | | | | | | | | | | | | | | | | | | | | | | 8 | | | | |
| Diptera | Stratiomyidae | Nemotelus | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| Diptera | Stratiomyidae | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Tabanidae | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| Diptera | Tabanidae | Atylotus/Tabanus | | | | | | | | | | | | 1 | | | | | | | 1 | | | | | | | | | | | |
| Diptera | Tipulidae | Antocha | | | | | 2 | | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | |
| Diptera | Tipulidae | Dicranota | | | | | | | | | | | | | | | | | | | | | | | | | | | 14 | | | |
| Diptera | Tipulidae | Hexatoma | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Tipulidae | Limnia | | | | | | | | | 1 | | | | 1 | | | | | | | | | | | | | | | | | |
| Diptera | Tipulidae | Tipula | | | | | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ephemeroptera | Ameletidae | Ameletus | | | | 7 | | | | | 1 | | | | | | | | 3 | | 1 | | | | | | | | | | | |
| Ephemeroptera | Baetidae | | 4 | 1 | 25 | 5 | 10 | 4 | 10 | 1 | 69 | 324 | 178 | | 3 | 3 | 6 | 12 | | | 17 | | 13 | 1 | 14 | 3 | | 10 | | | 6 | |
| Ephemeroptera | Baetidae | Baetis | 199 | 2 | 20 | 3 | 5 | 107 | 179 | 82 | | | | | 179 | 113 | 204 | 9 | 194 | 157 | 2 | | 227 | 16 | 49 | 229 | | 31 | 1 | | 54 | |
| Ephemeroptera | Baetidae | Callibaetis | | | | | | | | | | | | | | 1 | | | | | | | | 4 | | | | | | | | |
| Ephemeroptera | Baetidae | Camelobaetidius | | 3 | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ephemeroptera | Baetidae | Centroptilum | | | | | | | | | | | | | 7 | 4 | 3 | 31 | | | | | | | | | | | | | | |
| Ephemeroptera | Baetidae | Fallceon | | 14 | 9 | 35 | 9 | 7 | 1 | | | | 7 | | | | | | 10 | 3 | 63 | | 2 | 85 | | | | 15 | | | 6 | |
| Ephemeroptera | Baetidae | Procloeon | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| Ephemeroptera | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ephemeroptera | Ephemerellidae | Caudatella | 1 | | | 1 | | | | 2 | 1 | | | | | | | | | | | | 4 | | | | | | | | | |
| Ephemeroptera | Ephemerellidae | Drunella | 14 | | | 3 | | | 23 | 21 | 21 | | | | | | 2 | 3 | | | | | | | | | | | | | 10 | |
| Ephemeroptera | Ephemerellidae | Serratella | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | | | |
| Ephemeroptera | Heptageniidae | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | 40 | |
| Ephemeroptera | Heptageniidae | Cinygmula | | | | | | | | 1 | 23 | | | | | | | 4 | | | | | 1 | | | | | | | | | |
| Ephemeroptera | Heptageniidae | Epeorus | 4 | | | | | | | 46 | 53 | | | | | | 1 | | | | | | | | | 1 | | | | 9 | |
| Ephemeroptera | Heptageniidae | Ironodes | | | | 12 | | | | | 17 | | | | | | | | | | | | | | | | | | | | 134 | |
| Ephemeroptera | Leptohyphidae | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 19 | |
| Ephemeroptera | Leptohyphidae | Tricorythodes | | 1 | | | | | | | | | | | | 2 | | | | | 2 | | | | | | | | | | | |
| Ephemeroptera | Leptophlebiidae | | | 70 | 7 | 13 | | | | | | | | | | | | | | | 66 | | 3 | | | | | | | | |
| Hemiptera | | | | | | | | | | | | | | | | | | | | | | | 9 | | | | | | | | | |
| Hemiptera | Belostomatidae | | | | | | | | | | | | 6 | | | | | | | | | | | | | | | | 1 | | | |
| Hemiptera | Corixidae | | | | | | | | | | | | | | | | | | | | | 25 | | | | | | | | | | |
| Hemiptera | Corixidae | Corixella | | | | | | | | | | | | | | 1 | | | | | | 2 | | | | | 2 | | | | | |
| Leptoptera | Pyralidae | Petrophila | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| Odonata | Coenagrionidae | Argia | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| Odonata | Gomphidae | Erpetogomphus | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| Odonata | Lestidae | Archilestes | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Odonata | Libellulidae | | | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | | | | | | |
| Oligochaeta | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | | |
| Ostracoda | | | 15 | | | 19 | | | | | | | | | | | | | | | | | | 2 | 140 | | 11 | 67 | 20 | 3 | 1 | |
| | | | 24 | 316 | 1 | 24 | 2 | | 2 | | 1 | | 4 | 18 | 1 | 1 | 4 | 4 | 3 | 3 | 4 | 8 | 3 | 5 | 91 | 141 | | | 400 | 33 | 12 | |

**Table C2 continued**



| Order | Family | Genus | 007 | 011* | 012 | 019* | 020* | 027 | 028 | 032* | 034 | 035 | 041* | 042* | 051* | 055 | 062 | 070 | 079 | 085* | 110* | 116* | 160 | 172 | 180 | 206* | 226 | 243 | 258 | 267 | 532 | 713 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plecoptera | | | | | | 15 | | | | | | 1 | | | | | 1 | | | | 1 | | | | 1 | 2 | | | | | 16 |
| Plecoptera | Chloroperlidae | | | | | 15 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Plecoptera | Chloroperlidae | Utaperla | | | | 12 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Plecoptera | Nemouridae | | | | | 4 | | | | | | 1 | | | | | 1 | | | | | | | | | | | | | | 9 |
| Plecoptera | Nemouridae | Malenka | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| Plecoptera | Nemouridae | Zapada | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 30 | |
| Plecoptera | Peltoperlidae | Yoraperla | | | | | | | | | | 14 | | | | | | | | | | | | | | | | | | | | |
| Plecoptera | Perlidae | | | | | | | | 1 | | 2 | | | | | | | | | | | | | | | | | | | | 15 | |
| Plecoptera | Perlodidae | Isoperla | | | | | | 1 | | | | | 5 | | | | | | 1 | | | | 5 | 4 | | 2 | | | | | | |
| Trichoptera | | | | | | | | | | | | 1 | | | | | | | | | | | 1 | 7 | | | | | | | 11 | |
| Trichoptera | Brachycentridae | Micrasema | | | | | | | | 2 | | | | | | | | | | | | | | | | 58 | | | | | | |
| Trichoptera | Glossosomatidae | Agapetus | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | |
| Trichoptera | Helicopsychidae | | | | 16 | | 8 | | | 1 | | | | | | | 31 | | | | 29 | | | | | 4 | | | | | | |
| Trichoptera | Hydropsychidae | | | | | | | | | | | 3 | 8 | | | | | 4 | | | 11 | | 9 | | | 2 | 26 | | | | 2 |
| Trichoptera | Hydropsychidae | Arctopsyche | | | | 1 | 45 | | | | | 1 | | | | | 13 | | | | | | | | | | | | | | 6 |
| Trichoptera | Hydropsychidae | Hydropsyche/Ceratopsyche | | | 2 | | 1 | | | | | | 15 | | | | | | | | 8 | | 2 | 3 | | | 1 | | 1 | | |
| Trichoptera | Hydroptilidae | | | 4 | 2 | 55 | 7 | | 1 | | | | 5 | 1 | | | | | | | 1 | | 102 | 2 | | | 4 | 1 | | | |
| Trichoptera | Hydroptilidae | Hydroptila | | 1 | | 95 | 5 | | | | | | 2 | | | | | | | | | | 1 | | | | | | | | |
| Trichoptera | Hydroptilidae | Ochrotrichia | 2 | | | | 2 | 1 | 1 | | | | | | | | 2 | | | | | | | | | | | | | | |
| Trichoptera | Hydroptilidae | Oxyethira | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Trichoptera | Hydroptilidae | Stactobiella | | 2 | | | 43 | | | | | | | | | | 3 | | | | | | 4 | | | 2 | | | 2 | | |
| Trichoptera | Lepidostomatid | Lepidostoma | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | |
| Trichoptera | Limnephilidae | | | | | | 5 | | | | | | | | | | | 1 | | | | | | | | | | | 2 | | |
| Trichoptera | Limnephilidae | Ecclisomyia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Trichoptera | Limnephilidae | Psychoglypha | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| Trichoptera | Odontoceridae | Namamyia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 13 |
| Trichoptera | Phryganeidae | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Trichoptera | Psychomyiidae | Tinodes | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| Trichoptera | Rhyacophilidae | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | 3 |
| Trichoptera | Rhyacophilidae | Himalopsyche | | | | | | | | | | 7 | | | | | | | | | | | | | | | | | | | |
| Trichoptera | Rhyacophilidae | Rhyacophila | | | | | 3 | | | | 1 | | | | | | 2 | | | | | | | | | | | | | | 18 |
| Trichoptera | Sericostomatidae | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 28 | |
| Tricladida | Turbellaria (Class) | | 1 | | | | | | | | | 1 | | | | | | | | | | | | | | 1 | | | | | |
| Veneroida | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| Veneroida | Corbiculidae | Corbicula | | 6 | | | | | | | | | | | | | | | | | | | 37 | | | | | | | | |
| Veneroida | Sphaeriidae | Pisidium | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | |