THE CITY OF SAN BUENAVENTURA

Santa Clara River Estuary Macroinvertebrate Bioassessment Monitoring Annual Report 2008

THE CITY OF SAN BUENAVENTURA

CITY OF VENTURA

Presented by:

Aquatic Bioassay & Consulting Laboratories, Inc.

29 N. Olive St.
Ventura, CA
805 643 5621

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AQUATIC BIOASSAY & CONSULTING LABORATORIES, INC.

March 25th, 2009

Ms. Florence Jay
Ventura Sanitation District
1400 Spinnaker Drive
Ventura, CA 93001

Dear Ms Jay:

In accordance with the requirements specified in NPDES permit No. CA0053651, Monitoring and Reporting Program Order No. R4-2008-0011, for the City of Ventura's Wastewater Reclamation Facility (VWRF), Aquatic Bioassay and Consulting Laboratories, Inc. are pleased to present the 2008 Bioassessment Monitoring Report for the Santa Clara River Estuary. Please contact me if you have any questions or comments regarding the content of this report.

Yours very truly,

Scott C. Johnson
Director of Environmental Programs
Aquatic Bioassay & Consulting Laboratories
29 N. Olive St.
Ventura, CA 93001

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INTRODUCTION

This report is submitted in fulfillment of the receiving water monitoring requirements specified in the City of San Buenaventura's National Pollutant Elimination Discharge System (NPDES) permit (No. CA0053651, Order No. R4-2008-0011). A recent revision to this permit was promulgated by the Los Angeles Regional Water Quality Control Board on March 25th, 2008.

The City owns and operates the Ventura Water Reclamation Facility (VWRF) adjacent to the north edge of the Santa Clara River Estuary (SCRE). The VWRF discharges tertiary treated effluent into the Estuary at a relatively constant rate of between 7 and 10 million gallons each day. The monitoring program described herein was developed based on several past studies of the Estuary (Engineering Science 1976; Swanson 1990; USFWS 1999; ENTRIX 1999, 2002 and 2003; Aquatic Bioassay 2004 to 2007).

The objective of the monitoring program is to determine if effluent discharged from the VWRF is impacting the integrity of the biological conditions in the Estuary. To better address this question, the program was expanded under the revised NPDES permit in the summer of 2008 to include not only bioassessments, but also sediment chemistry and toxicity. These three programs represent multiple lines of evidence (MLOE) or a triad monitoring approach that analyzes the relationships between the chemical, toxicological, biological (BMIs) and physical characteristics of the Estuary. The results of this approach can provide insight into the mechanisms driving the integrity of the Estuary system. For example, if a chemical constituent is elevated in the sediment, but there is no toxicity and the biological community is healthy, it follows that the elevated concentration of the chemical constituent is not having a biological effect.

This report provides results for the surveys conducted in both the spring and fall of 2008 in the Santa Clara River Estuary. During the spring sampling was conducted based on the requirements of Order No. 000-143 and included bioassessment, water quality and sediment grain size analyses at four sites. In the fall sampling was conducted based on the revised Order (No. R4-2008-0011) and included the same set parameters, but was expanded to include sediment chemistry for priority pollutants and toxicity testing.

Site Description

The Santa Clara River is the longest free-flowing river in southern California. Its 70 mile length provides drainage to a 1,600 mi^2 watershed. Flow in the river typically reaches 100,000 cubic feet per second (cfs) during winter and spring storm flows (Swanson et al. 1990). The SCRE is located at the mouth of the river and is characterized as a typical river mouth estuary (Ferran 1989, Ferran et al. 1996). The Estuary is a highly dynamic environment due to hydrology patterns that can vary greatly during the year. The flow of water into the SCRE is influenced by dry and wet weather flow from the Santa Clara River, Pacific Ocean tides and the effluent emanating from the City of San Buenaventura's, Ventura Water Reclamation Facility

(VWRF). During the winter and spring, the river is open to the ocean due to sandbar-breaching storm flows. During the summer and fall the sandbar becomes well established due to lack of rainfall, low river flow and small summer surf. Once established, the berm creates a barrier to flow and allows the Estuary to become inundated with water from the VWRF. Depth of the estuary during peak inundation can reach nearly 10 ft above Mean Sea Level (MSL) (USFWS 1999).

In 1855, the Estuary was estimated to have encompassed 870 acres (Swanson et al. 1990, State Coastal Conservancy et al. 1997), but its size has declined to its present 160 acres, due to the diversion of upstream river flow to municipal water projects and agriculture (ENTRIX 2002). This reduction in flow has, in part, been replaced by the relatively constant flow of tertiary treated effluent (7 to 10 MGD) from the VWRF. The tertiary treatment process creates effluent essentially free of organics and is very low in nutrients. This flow provides a water source to the Estuary during periods when it would otherwise be dry. Since most southern California estuaries experience drought during the summer and fall (Zedler 1982), this has created a unique, low salinity habitat for a wide array of aquatic organisms, water birds and other vertebrates. The lack of understanding regarding the relationship between the biological resources found in the estuary and the unique habitat created by the VWRF, has prompted the use of bioassessment monitoring to elucidate the dynamics of this ecosystem.

Bioassessment Monitoring

During the past 150 years, direct measurements of biological communities including plants, invertebrates, fish, and microbial life have been used as indicators of degraded water quality. In addition, biological assessments (bioassessments) have been used as a watershed management tool for surveillance and compliance of land-use best management practices (Jones and Clark 1987; Lenat and Crawford 1994; Weaver and Garman 1994; Karr 1998 and Karr et al. 2000). Combined with measurements of watershed characteristics, land-use practices, in-stream habitat, and water chemistry, bioassessment can be a cost-effective tool for long-term trend monitoring of watershed conditions (Davis and Simons 1996).

Biological communities act to integrate the effects of water quality conditions and various anthropogenic stressors in a stream or river system by responding with changes in their population abundances and species composition over time. These populations are sensitive to multiple aspects of water and habitat quality and provide the public with more familiar expressions of ecological health than the results of chemical and toxicity tests (Gibson 1996). Furthermore, biological assessments when integrated with physical and chemical assessments, better define the effects of point-source discharges of contaminates and provide a more appropriate means for evaluating discharges of non-toxic substances (e.g. nutrients and sediment), especially when monitoring demonstrates changes over time or along concentration gradients.

Water resource monitoring using benthic macroinvertebrates (BMI) is by far the most popular method used throughout the world. BMIs are ubiquitous, relatively stationary and their large species diversity provides a spectrum of responses to environmental stresses (Rosenberg and Resh 1993). Individual species of BMIs reside in the aquatic environment for a period of months to several years and are sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution (Resh and Jackson 1993). Finally, BMIs represent a significant food source for aquatic and terrestrial animals and provide a wealth of ecological and bio-geographical information (Erman 1996).

The monitoring program specified in the VWRF's new NPDES permit requires the use of a multiple lines of evidence (MLOE) approach to assess the effect of the VWRF effluent on the biological communities in the SCRE. This approach uses three environmental end points; sediment chemistry, sediment toxicity and biological community assemblages to detect environmental impacts. This "triad" of measurements provides a way to gauge if seemingly impaired biological communities are the result of elevated sediment contaminant concentrations or due to some other source such as degraded habitat conditions related to shifts in salinity, scouring or poor habitat complexity. For example, if sediment contaminants are elevated at sites in the survey area, but there is little or no observed sediment toxicity and the naturally occurring biological community is healthy, it would follow that the sediment contaminants may be tightly bound to the sediments and not biologically available for uptake by the resident biota.

MATERIALS AND METHODS

Sampling was conducted on May 8th, 2008 and October 14th, 2008 by Aquatic Bioassay & Consulting Laboratories biologists. All procedures were conducted as outlined in the project scope of work, VWRF NPDES permit, and in accordance with modifications to the EPA's Lentic Bioassessments Procedures and the 1997-1999 USFWS study of the estuary.

Field Methods

Stations were located using a hand held DGPS. During May water quality, bioassessment and particle size samples were collected at four locations (Stations B1, B2, B3 and B7) (Figure 1). These sites were selected as a subset of the stations surveyed during previous studies (USFWS 1999, ENTRIX 2002). Station B1 is located in the main effluent channel, with Station B2 located just upstream of it in the Santa Clara River. Station B3 is located inside the sand spit berm in the lower estuary and Station B7 is located on the southwest side of the Estuary in the main river channel.

In October samples were collected for water quality, infauna, particle size, sediment chemistry and sediment toxicity at three sites (Stations R-003, R-004 and R-005) (Figure 2). The location of Station R-003 is variable and is located in the estuary where it discharges to the ocean or would potentially discharge if the berm is established. Station R-004 is located inside the sand spit berm in the lower estuary and Station R-005 is located in the upper estuary, above the Harbor Blvd. Bridge. This site was moved from the nominal coordinates specified in the permit to the north side of the estuary since there was no water flowing at that location.

Sediment Sampling

During May sampling was similar to the previous five years and was based on the requirements of the old NPDES permit. Triplicate benthic samples were collected at each station using a petite ponar grab (surface area = 0.025 m^2). Each sample was sieved through a 0.5 mm mesh screen on shore. Sediment and infauna retained on the screen were then transferred to a half gallon, wide mouth jar and preserved in 95% ethanol. Single samples for particle size were collected in Whirl Pacs from each site and placed on ice.

In October, sampling was conducted based on the requirements in the new NPDES permit. To ensure that infauna samples collected from the SCRE were comparable to samples collected in other southern California estuaries where a 0.1 m^2 van veen grab sampler is used, the following procedure was followed. Four petite ponar grabs (0.025 m^2) were collected then composited together in a plastic bucket. This resulted in a total surface area sampled that equaled 0.1 m^2, equivalent to the van veen grab. Samples were then sieved through a 0.5 mm mesh screen on shore. Sediment and infauna retained on the screen were then transferred to a half gallon, wide

mouth jar and preserved in 95% ethanol. Samples were placed in ice chests and transported back to the Aquatic Bioassay Laboratory in Ventura, CA.

Sediment chemistry samples were collected as above from a single petite ponar grab. Sediments were placed in pre-cleaned 250 mL glass containers using a stainless steel scoop. Samples were immediately placed in an ice chest on wet ice and transported to the VWRF in Ventura, CA. Particle size samples were collected from the same grab in a Whirl Pac, which was placed on wet ice and transported to the Aquatic Bioassay Laboratory.

Sediment toxicity testing samples were collected from two petite ponar grabs taken at each site. Each grab was placed in a plastic bucket and then composited together to form a single sample. Sediments were placed in (2) one liter pre-cleaned plastic jars using a plastic scoop. Samples were placed in an ice chest on wet ice and transported to the Aquatic Bioassay Laboratory.

Water quality measurements were collected using a laboratory calibrated YSI 85 handheld meter for salinity (ppt), temperature (°C), dissolved oxygen (mg/L) and pH. Site observations included latitude and longitude (decimal degrees, NAD 83), water depth (m), water color and weather conditions.

Average monthly rain data were obtained for the Oxnard Airport from the National Oceanographic and Atmospheric Administrations weather web site: http://www.srh.noaa.gov/rfcshare/precip_analysis_new.php

Stream gauge data for 2008 from the Santa Clara River below Piru, CA were taken from the USGS web site: http://waterdata.usgs.gov/nwis/dv?cb_all_00060_00065=on&cb_00060=on&cb_00065=on&format=gif_default&begin_date=2008-01-01&end_date=2008-12-31&site_no=11109000&referred_module=sw

Figure 1. Site map and sampling locations for spring 2008 survey in the Santa Clara River Estuary.

Figure 2. Site map and sampling locations for fall 2008 survey in the Santa Clara River Estuary.

Laboratory Methods

Sample Processing

During sorting/ taxonomic identification, approximately 14 ml (~1 tablespoon) of a sample was transferred to Petri dishes containing 70% alcohol (enough alcohol to prevent the sample from drying under the microscope light). The sample was then examined under the microscope at 10 times magnification. Invertebrates were identified, using the Standard Taxonomic Effort (STE) level two specified by the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT), and removed from the sample, using forceps, and sorted into separate 20 mL sample vials based upon the different taxa identified. Once all invertebrates had been removed, the remaining material was transferred from the Petri dish into a clean

container labeled "grunge." This process was repeated until all organisms were removed from the whole sample collected.

QA / QC

Sorting

The sample matrix remaining after sorting was completed, was periodically evaluated to determine elutriation efficiency. Approximately 10% of the grundge from each sample was placed into a Petri dish and observed under a microscope at 10 times magnification to verify that no BMIs had been missed during the sorting process. Sorting efficiencies were over 99.5%.

Taxonomic Effort

All organisms removed during the sorting process were identified using aforementioned STE level two, specified by the SAFIT (Richards and Rogers 2007). Standard taxonomic keys used for the identifications are listed in a separate section below. Voucher specimens were retained for all unique taxa. The identified taxa from the processed portion of each sample were placed in separate vials and preserved with 70% ethanol. Of the samples (10%) that were sent to the Department of Fish and Game's, Aquatic Bioassessment Laboratory in Rancho Cordova, CA, all met the programs data quality objectives.

Particle Size Analysis

Sediments were analyzed for particle size distribution using a Horiba LA920 particle size analyzer following Standard Methods, 20 ed. (APHA 2005). Sub-samples from each sample were re-suspended in de-ionized water, and then injected into the analyzer. The analyzer is capable of measuring particle sizes ranging from clay (<2µ) up through course sand (2000µ). Laboratory duplicates were completed on 10% of the samples (n = 1). All QC criteria for the analyses were met.

Sediment Chemistry

Sediment chemistry was conducted by the American Scientific Laboratories, LLC located in Los Angeles, CA. The table below shows the groups of chemical constituents measured, methods and reporting units. All results for metals and organic constituents were converted to dry weight. A complete list of analytes and method detection limits can be found in Appendix C. All laboratory QC was within the ranges specified for the program data quality objectives.

Constituents	Method	Units
Title 22 metals	EPA6010B/7471A	mg/Kg dry weight
Organochlorine pesticides	EPA8081A	µg/Kg dry weight
Polychlorinated biphenyls (PCBs)	EPA 8082	µg/Kg dry weight
Volatile organic compounds	EPA 8260B	µg/Kg dry weight
Semivolatile organics	EPA 8270C	µg/Kg dry weight
Polynuclear aromatic hydrocarbons (PAHs)	EPA 8270C	µg/Kg dry weight
Total organic carbon (TOC)	EPA 9060	mg/Kg
Percent solids	SM2540-G	%
Total cyanide	SM4500-CN-E	mg/Kg dry weight
Sulfide (methylene blue method)	SM4500-S-2-D	mg/L

Sediment chemistry results were compared to the threshold limits presented in two NOAA studies (NOAA 1990 and Long, et. al. 1995). In these studies, researchers compiled published information regarding the toxicity of chemicals to benthic organisms. The data for each compound were sorted, and the lower 10th percentile and median (50th) percentile were identified. The lower 10th percentile in the data was identified as an Effects Range-Low (ER-L) or the concentration of a chemical below which biological effects are rarely seen. The upper 50th percentile was identified as an Effects Range-Median (ER-M) or the concentration of a chemical above which a biological effect are nearly always seen.

Sediment Toxicity

The 10 day freshwater sediment amphipod bioassay followed the EPA *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates Second Edition EPA/600/R-99/064,* March 2000*.* Test organisms (*Hyalella azteca*) were supplied by Aquatic Bio Systems Inc. of Fort Collins, Colorado. Sediment volume of 100 mL was placed in 300 mL high-form lipless beakers with approximately 150 mL of overlying Aquatic Bioassay control water. Additional surrogate replicates were set up to measure water quality (ammonia, conductivity, pH, temperature, ammonia, hardness, and alkalinity). Only healthy *Hyalella azteca* were added to test chambers. All replicates were covered to minimize evaporation. Daily water quality measurements were taken from each treatment, and the number of dead and surfaced animals was noted for each replicate. On the 10th and final day of the test, organisms were sieved from the sediment and the survival for each replicate was recorded. A negative control sediment test and a 96 hour reference toxicant positive control were conducted concurrently with the testing. Four replicates of each concentration 40, 80, 120, 160, 200, and 300mg/L copper chloride was used. All quality control criteria were met for these tests.

RESULTS

Annual Stream Flow & Estuary Inundation

The period between January and December, 2008, represented the third continuous year of drought conditions throughout southern California. Measurable rain fell at Oxnard Airport on only 23 days and totaled 11.65 inches (Figure 3). The heaviest rainfall of the year occurred in January (7.24 in). Rainfall during all other months ranged between 0.01 and 1.45 inches, except in March, June and July when no measurable rain was recorded. The May bioassessment survey was conducted over a month following light rain at the Oxnard airport in April. As a result the May survey was conducted when river discharge was low, the sand spit was closed and the estuary was inundated. October sampling followed a small rain event (0.02 inches) at the beginning of the month. There was essentially no rainfall during the previous four months and the estuary was inundated. Water depths during both surveys ranged from 0.8 to 1.5 meters (Table 2).

Daily river height at the USGS gauging station on the Santa Clara River below the City of Piru is presented in Figure 4. Following winter storms in early and late January, 2008 the water height in the Santa Clara River remained relatively low and stable from February through the beginning of November, 2008. As a result, there were no large spikes in river discharge that might have fully breached the mouth of the Estuary.

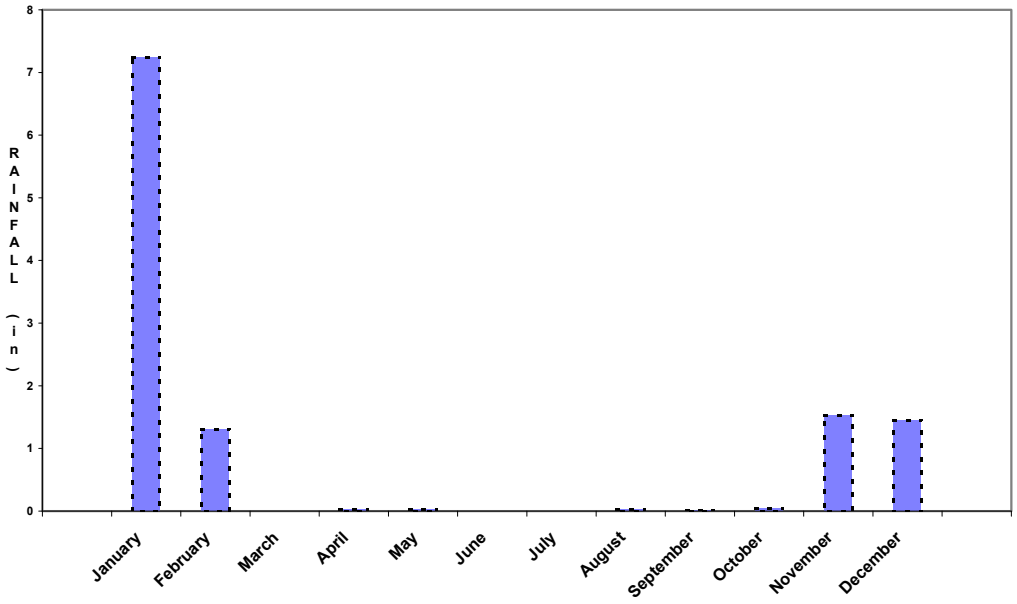

Figure 3. Monthly average rainfall recorded at Oxnard Airport, January to December, 2008. Red lines indicate days when sampling in the Estuary took place.

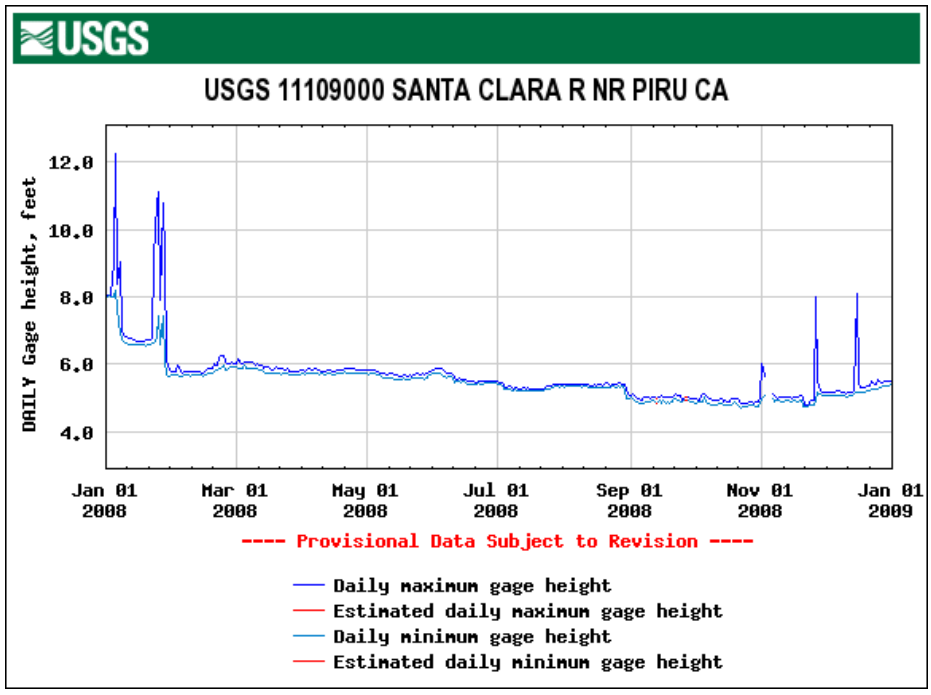

Figure 4. River discharge gage height (ft) in 2008 on the Santa Clara River at Piru, CA.

General Weather Observations

During both surveys in May and October, sampling was conducted under clear skies with 30 kilometer visibility (Table 2). In May wind was from the west to northwest from 5 to 6 knots. Water color was brown at all stations. The brown color was a result of the algal mats covering the sediments at these stations. In October winds were northwest to southwest from 4 to 12 knots. Water color was green at each station. The berm at the entrance to the Estuary as closed during both surveys.

Physical Measurements and Water Quality

May

During May pH was similar at sites dominated by the VWRF effluent (Station B1, B2 and B3) and ranged from 7.51 to 7.84) (Table 2). pH was much greater at Station B7 located in the main channel of the Santa Clara River. Dissolved oxygen concentrations varied widely from 6.79 to 5.82 at Stations B1 and B2, respectively, to 17.42 at Station B3. The lower dissolved oxygen at Stations B1 and B2 may have been due to depletion due to overnight respiration. The extremely high dissolved oxygen reading at B3 was probably the result of oxygen production by algae. Water temperatures were high and similar among sites, ranging from 17.2 to 21.5 °C. Salinity ranged from 1.5 at Stations B1 and B2 to 4.8 at Station B3 indicating that there was no connectivity between the estuary and the open ocean.

October

During October pH was similar at each station ranging from 8.8 at Station R-005 on the Santa Clara River above the Harbor Blvd Bridge to 9.65 at Station R-003 where the estuary would potentially discharge to the ocean (Table 2). Dissolved oxygen concentrations were elevated at each of the three sites and were greatest at Station R-003 (14.2 mg/L) and least at Station R-004 (9.3 mg/L) in the VWRF discharge channel. Water temperatures were similar among sites, ranging from 15.7 to 15.9 °C. Salinity ranged from 1.7 at Station R-004 to 2.2 at Station R-003 indicating that there was no connectivity between the estuary and the open ocean.

Table 1. Station locations, sampling weather, transect characteristics and water quality measurements collected from sites in the Santa Clara River Estuary during both spring and fall sampling events, 2008.

Sampling Stations	Spring				Fall		
	B1	B2	B3	B7	R-003	R-004	R-005
Date	8-May-2008	8-May-2008	8-May-2008	8-May-2008	14-Oct-2008	14-Oct-2008	14-Oct-2008
Time	10:01	10:40	9:10	8:00	11:39	10:40	9:40
Survey Program	Benthic Infauna	Benthic Infauna	Benthic Infauna	Benthic Infauna	Benthic Infauna Chem/Toxicity	Benthic Infauna Chem/Toxicity	Benthic Infauna Chem/Toxicity
Depth (m)	1.5	1.0	1.3	1.0	1.0	1.0	0.8
Latitude (°N)	34.23505	34.23486	34.23312	34.23145	34.22664	34.23456	34.23613
Longitude (°W)	119.2632	119.26294	119.26505	119.25967	119.26417	119.26515	119.25608
Weather	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Air Vis. (km)	30	30	30	30	30	30	30
Estuary Status	Closed	Closed	Closed	Closed	Closed	Closed	Closed
Wind Sp. (Kn)	5	6	5	5	12	4	4
Wind Dir.	W	W	W	NW	NW	SW	SW
Color	Brown	Brown	Brown	Brown	Green	Green	Green
Comments	None	None	None	None	None	None	None
pH	7.84	7.51	7.59	9.32	9.65	8.96	8.80
Conductance (µs)	2650	2695	6715	5648	3404	2850	2939
Salinity (ppt)	1.51	1.54	4.18	3.65	2.20	1.77	1.98
Dissolved Oxygen (mg/L	6.79	5.82	17.42	11.59	14.20	9.30	10.30
Temperature (°C)	21.09	20.49	19.60	17.20	15.94	15.87	15.70

Sediment Particle Size

The physical characteristics and distribution of particles at the Estuary stations are summarized in Table 2 and Figure 5. Results are presented in size frequency distributions in Appendix B, Table 6. Two sediment characteristics can be inferred from the graphs (Figure 5). Position of the midpoint of the curve will tend to be associated with the median particle size. If the midpoint tends to be toward the larger micron sizes, then it can be assumed that the sediments will tend to be coarser overall. If the midpoint is near the smaller micron sizes, then it can be assumed that the sediments are mostly fine. Sediment sizes that range from 2000 to 62 microns are defined as sand, sediments ranging from 62 to 3.9 microns are defined as silt, and sediments that are 3.9 microns or less are defined as clay (Wentworth Sediment Scale, see Gray 1981). A second pattern discernible from the graph is how homogeneous the distributions of sediments are. Sediments that tend to have a narrow range of sizes are considered homogeneous or well sorted. Others, which have a wide range of sizes, are considered to be heterogeneous or poorly sorted.

May

Sediment particle sizes during the spring varied widely by site (Table 2, Figure 5). Stations B1 and B3 were characterized as course and fine silt, with median particle sizes of 19 and 15 µm, respectively. In contrast, Stations B2 and B7 were characterized as very fine sand and fine sand, with median particle sizes of 69 and 137 µm, respectively. Sediments at all stations were poorly sorted.

October

Sediment particle sizes during the fall also varied widely by site (Table 2, Figure 6). Particle sizes graded from nearly 100% medium sand at Station R-003 (median = 430 µm) at the estuary discharge point to the ocean, to nearly 100% fine silt at Station R-004 (median = 9 µm) in the VWRF effluent channel. Particle sizes at Station R-005 (median = 33 µm), located above the Harbor Blvd Bridge, were more homogeneous containing mixtures of fine particles and sand. Sediments at each site ranged from moderately well sorted (R-003) to poorly sorted at Stations R-004 and R005.

Table 2. Sediment particle size fractions (%), percentiles (16th, 50th & 84th) and sorting index values for stations located in the Santa Clara River Estuary during the spring and fall, 2008.

Station / Season	Particle Fraction Summary (%)					Percentile (microns)			Category [2.]	Percentile (phi)			Sorting Index [3.]	Sorting [3.]
	Gravel[1.]	Sand	Silt	Clay	Fines	16%	50% [2.]	84%		16%	50%	84%		
May														
B1	0.0	16.2	71.7	12.1	83.8	4	19	45	course silt	8.0	5.7	4.5	1.8	poorly sorted
B2	0.0	62.3	34.7	3.0	37.7	15	69	209	very fine sand	6.1	3.9	2.2	1.9	poorly sorted
B3	0.0	11.0	75.8	13.2	89.0	3	15	38	fine silt	8.2	6.0	4.7	1.7	poorly sorted
B7	0.0	80.2	19.2	0.6	19.8	33	137	268	fine sand	4.9	2.9	1.9	1.5	poorly sorted
October														
R-003	0.0	99.4	0.6	0.0	0.6	273	430	685	medium sand	1.9	1.2	0.5	0.7	moderately well sorted
R-004	0.0	0.2	81.0	18.8	99.8	2	9	19	fine silt	8.7	6.9	5.7	1.5	poorly sorted
R-005	0.0	38.7	59.1	2.1	61.3	13	33	133	course silt	6.3	4.9	2.9	1.7	poorly sorted

1. Percentage of sample retained on a 2 mm sieve.
2. 0-4 = clay, 4-8 = very fine silt, 8-16 = fine silt, 16-31 = medium silt, 31-63 = coarse silt, 63-125 = very fine sand, 125-250 = fine sand, 250-500 = medium sand, 500-1000 = coarse sand.
3. <0.35 = very well sorted, 0.35-0.50 = well sorted, 0.50-0.71 = moderately well sorted, 0.71-1.00 = moderately sorted, 1.0-2.0 = poorly sorted, 2.0-4.0 = very poorly sorted, >4.0 = extremely poorly sorted.

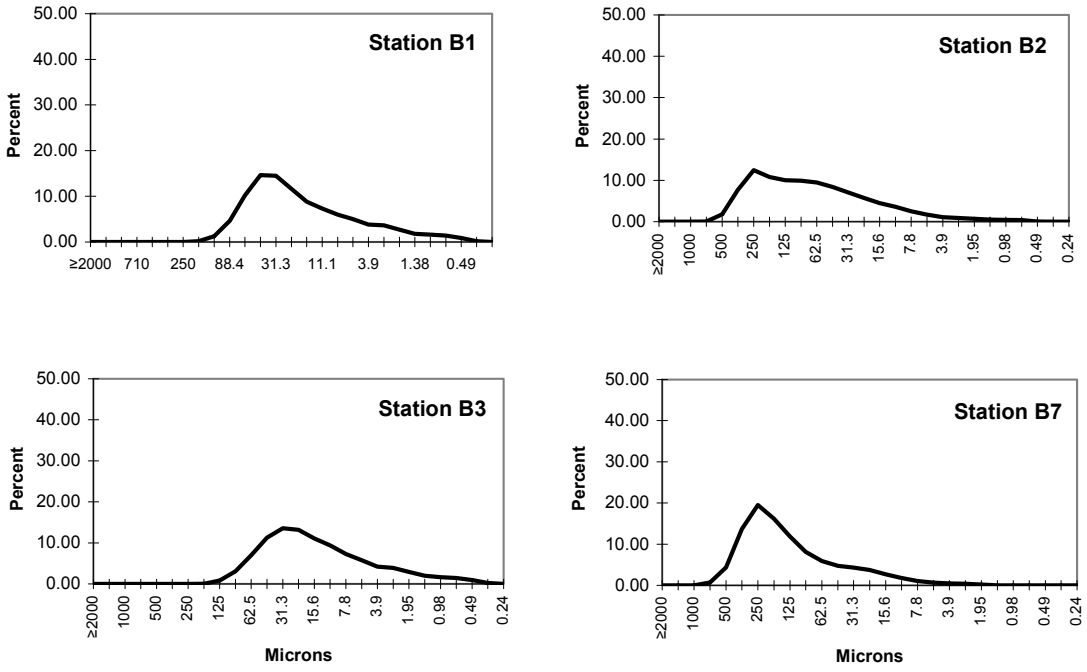

Figure 5. Sediment particle size in microns by percent distribution (%) for the spring 2008 survey.

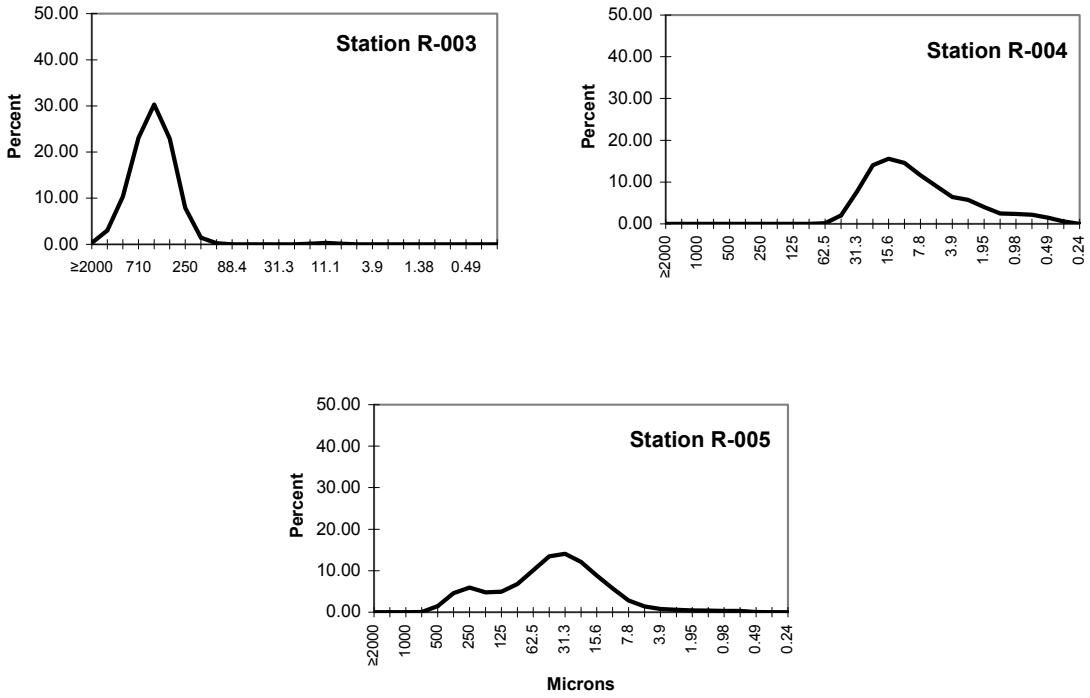

Figure 6. Sediment particle size in microns by percent distribution (%) for the fall 2008 survey.

Sediment Chemistry

Sediment chemistry results are presented in Table 3 and divided into three main categories: undifferentiated organics, heavy metals and complex organics. When available the chemical concentrations measured in SCRE sediments are compared to NOAA ER-L and ER-M threshold levels. The full list of analytes measured along with detection limits, units and methods are presented in Appendix C, Table 7.

Undifferentiated Organics

The undifferentiated organics discussed in this report includes groups of compounds whose concentrations can help to determine the extent of anthropogenic contaminant loading in an area. These groups are discussed below:

- **Cyanide** enters air, water, and soil from both natural processes and industrial activities. Most cyanide in surface water will form hydrogen cyanide and evaporate. Cyanide in water does not build up in the bodies of fish. Cyanides are fairly mobile in soil.
- **Sulfide (H_2S)** is an indicator of organic decomposition occurring particularly in anoxic sediments and characterized by a rotten egg smell. No sediment reference values are available for sulfides.
- **Total organic carbon (TOC)** is a measure of the amount of carbon derived from plant and animal sources. It is a better measure of the portion of a sample derived from these sources than is percent volatile solids (Soule et al. 1996).

Both dissolved sulfides and cyanide were below detection at the three sampling locations in the SCRE during the fall survey (Table 3). TOC concentrations were least at Station R-003 near the estuary discharge point to the ocean. TOC concentrations at Stations R-004 and R-005 were much greater and similar to each other. The low TOC concentrations at Station R-003 are typical of sites where sand is prevalent and routine scouring occurs. Stations R-004 in the effluent channel and R-005 above the Harbor Blvd Bridge are more protected and were composed of finer particles where organic carbon tends to accumulate.

Heavy Metals

The heavy metals discussed in this report include groups of compounds whose concentrations can help to determine the extent of anthropogenic contaminant loading in an area. These groups are discussed below:

- **Arsenic** is carcinogenic and teratogenic (causing abnormal development) in mammals and is mainly used as a pesticide and wood preservative. Inorganic arsenic can affect marine plants at concentrations as low as 13 to 56 ppm and marine animals at about 2000 ppm (Long and Morgan 1990). The USEPA (1983) gives a terrestrial range of 1-50 ppm, with an average of 5 ppm.
- **Cadmium** is widely used in manufacturing for electroplating, paint pigment, batteries and plastics. Toxicity in water to freshwater animals ranges from 10 ppb to 1 ppm, as low as 2 ppm for freshwater plants, and 320 ppb to 15.5 ppm for marine animals (Long and Morgan 1990). The USEPA (1983) places the terrestrial range for cadmium at 0.01 to 0.7 ppm, with an average of 0.06 ppm.

- **Chromium** is widely used in electroplating, metal pickling, and many other industrial processes. Chromium typically occurs as either chromium (III) or chromium (VI), the latter being considerably more toxic. Acute effects to marine organisms range from 2,000 to 105,000 ppm for chromium (VI) and 10,300 to 35,500 ppm for chromium (III). Chronic effects range from 445 to 2,000 ppb for chromium (VI) and 2,000 to 3,200 ppb for chromium (III) (Long and Morgan 1990). The terrestrial range is 1 to 1,000 ppm with an average of 100 ppm (USEPA, 1983).
- **Copper** is widely used in anti-fouling paints. Saltwater animals are acutely sensitive to copper in water at concentrations ranging from 5.8 to 600 ppm. Mysid shrimp indicate chronic sensitivity at 77 ppm (Long and Morgan 1990).
- **Lead** is found in older paint products and leaded gasoline. It can be washed into the environment or become waterborne from aerial particulates. Adverse effects to freshwater organisms range from 1.3 to 7.7 ppm, although marine animals may be more tolerant (Long and Morgan 1990).
- **Mercury** is a common trace metal once used in industry and as a biocide. Acute toxicity to marine organisms in water ranges from 3.5 to 1678 ppm. Organic mercury may be toxic in the range of 0.1 to 2.0 ppm (Long and Morgan 1990).
- **Nickel** is used extensively in steel alloys and plating. Nickel is chronically toxic to marine organisms in seawater at 141 ppm (Long and Morgan 1990).
- **Silver** has many uses in commerce and industry including photographic film, electronics, jewelry, coins, and flatware and in medical applications. Silver is toxic to mollusks and is sequestered by them and other organisms. Silver increases in the Southern California Bight with increased depth; high organic content and percent silt (Mearns et. al., 1991). The range in the rural coastal shelf is from 0.10 to 18 ppm, in bays and harbors from 0.27 to 4.0 ppm, and near outfalls 0.08 to 18 ppm (Soule et al. 1996). The normal terrestrial level ranges from 0.01 to 5.0 ppm, with a mean of 0.05 ppm.
- **Zinc** is widespread in the environment and is also an essential trace element in human nutrition. It is widely used for marine corrosion protection, enters the waters as airborne particulates, and occurs in runoff and sewage effluent. Acute toxicity of zinc in water to marine fish begins at 192 ppm, and chronic toxicity to marine mysid shrimp can occur as low as 120 ppm (Long and Morgan 1990). The normal terrestrial range is from 10 to 300 ppm, with a mean of 50 ppm (Soule et al. 1996).

Of the nine heavy metals measured for this survey, six were above method detection limits at each of the three sites, while cadmium and silver were below detection at each site (Table 3). Mercury was just above detection only at Station R-004. In all cases, metals that were above detection at each site were greatest at Station R-004, located in the VWRF effluent channel. Metal concentrations were lower and similar at Stations R-003 and R-005. When compared to the NOAA ER-L and ER-M threshold limits, copper slightly exceeded the ER-L, as did nickel. None of the metals exceeded the ER-M.

Metal concentrations were normalized to the percentage of fine sediments measured at each site to assess the effect of particle size on metal concentrations (Table 3). When normalized to percent fines, metal concentrations were greatest at Station R-003 and least at Stations R-004 and R-005.

Complex Organics

Pesticides, PCBs and PAHs are contaminants that are widespread in the environment, are toxic to marine organisms when concentrations are increased and can cause reproductive failure in organisms at higher levels in the food chain. The sources and relative toxicity of each of these organic chemical groups are discussed below.

- **DDT** is a pesticide that has been banned since the early 1970's, but the presence of non-degraded DDT suggests that either subsurface DDT is being released during erosion and runoff in storms, or that fresh DDT is still in use and finding its way into coastal waters (Soule et al. 1996). DDT has been found to be chronically toxic to bivalves as low as 0.6 ppb in sediment. Toxicity of two of DDT's breakdown products, DDE and DDD, were both chronically toxic to bivalve larvae as low as about 1 ppb (Long and Morgan 1990).
- Of the **non-DDT pesticides**, concentrations of **chlordane** between 2.4 and 260 ppm in water are acutely toxic to marine organisms. Heptachlor is acutely toxic in water from 0.03 to 3.8 ppm. **Heptachlor** epoxide, a degradation product of heptachlor, is acutely toxic to marine shrimp at 0.04 ppm in water. **Dieldrin** is acutely toxic to estuarine organisms from 0.7 to 10 ppb. **Endrin** shows acute toxicity within a range of 0.037 to 1.2 ppb. **Aldrin** is acutely toxic to marine crustaceans and fish between 0.32 and 23 ppb. The EPA freshwater and saltwater criteria for aldrin are 3.0 and 1.3 ppb, respectively (Long and Morgan 1990). No toxicity data were found for any of the other chlorinated compounds measured during this survey.
- Although **PCBs** are not pesticides, their similarity to other chlorinated hydrocarbons makes their inclusion in this section appropriate. Before being banned in 1970, the principal uses of PCBs were for dielectric fluids in capacitors, as plasticizers in waxes, in transformer fluids, and hydraulic fluids, in lubricants, and in heat transfer fluids (Laws 1981). **Arochlor** 1242, a PCB congener, was acutely toxic in water to marine shrimp in ranges of 15 to 57 ppm (Long and Morgan 1990).
- The major sources of **polynuclear aromatic hydrocarbons (PAH's)** are believed to be the combustion of fossil fuels and petroleum or oil shales. PAH impact is characterized by altered community structure, abundance, and diversity near the pollutant source (Daily, et.al. 1993).

Of the 187 individual organic constituents measured during the fall SCRE survey none were measured in concentrations above the detection limit (Table 3).

Table 3. Sediment chemical concentrations at three sites in the SCRE during October, 2008. Concentrations are compared to NOAA ER-L (bolded) and ER-M (grayed) threshold concentrations where possible.

Constituents [1., 2.]	Sediment Stations			NOAA (1990), Long,et.al. (1995)		Normalized to % Fine Sediments		
	R-003	R-004	R-005	ER-L[3.]	ER-M[4.]	R-003	R-004	R-005
Undifferentiated Organics								
Dissolved Sulfides (detection = 0.01 mg/L)	0.00	0.00	0.00	---	---	---	---	---
Cyanide (detection = 1.00 mg/Kg)	0.00	0.00	0.00	---	---	---	---	---
TOC (detection = 1 mg/Kg)	860	21500	23000	---	---	---	---	---
Heavy Metals (mg/Kg dry weight)								
Arsenic (detection = 0.15 mg/Kg)	1.43	7.63	1.21	8.20	70.00	2.38	0.08	0.02
Cadmium (detection = 0.04 mg/Kg)	0.00	0.00	0.00	1.20	9.60	0.00	0.00	0.00
Chromium (detection = 0.05 mg/Kg)	3.93	33.65	5.04	81.00	370.00	6.55	0.34	0.08
Copper (detection = 0.05 mg/Kg)	4.76	**35.00**	2.01	34.00	270.00	7.94	0.35	0.03
Lead (detection = 0.1 mg/Kg)	1.29	12.92	1.73	46.70	218.00	2.16	0.13	0.03
Mercury (detection = 0.01 mg/Kg)	0.00	0.09	0.00	0.15	0.71	0.00	0.00	0.00
Nickel (detection = 0.1 mg/Kg)	5.02	**38.27**	4.28	20.90	51.60	8.37	0.38	0.07
Silver (detection = 0.05 mg/Kg)	0.00	0.00	0.00	1.00	3.70	0.00	0.00	0.00
Zinc (detection = 0.35 mg/Kg)	14.40	122.69	12.58	150.00	410.00	24.00	1.23	0.21
Complex Organics (ng/g dry weight)[2]								
Chlorinated Pesticides								
Aldrin (detection = 0.23 µg/Kg)	0.00	0.00	0.00	---	---	---	---	---
Dieldrin (detection = 0.2 µg/Kg)	0.00	0.00	0.00	---	---	---	---	---
Endrin (detection = 0.25 µg/Kg)	0.00	0.00	0.00	---	---	---	---	---
Alpha-BCH (detection = 0.27 µg/Kg)	0.00	0.00	0.00	---	---	---	---	---
Beta-BCH (detection = 0.37 µg/Kg)	0.00	0.00	0.00	---	---	---	---	---
Delta-BCH (detection = 0.15 µg/Kg)	0.00	0.00	0.00	---	---	---	---	---
Toxaphene (detection = 17 µg/Kg)	0.00	0.00	0.00	---	---	---	---	---
Total DDTs	0.00	0.00	0.00	1.58	46.10	---	---	---
Total Chlordane	0.00	0.00	0.00	---	---	---	---	---
Non-Chlorinated Pesticides								
Phenols (detection = 16.9 µg/Kg)	0.00	0.00	0.00	---	---	---	---	---
Total PCBs	0.00	0.00	0.00	22.70	180.00	---	---	---
Total PAHs	0.00	0.00	0.00	4022.00	44792.00	---	---	---

1. All derivatives not listed are below detection.
2. Minimum detection limits, reporting limits and methods are listed in Appendix C.
3. Bold = Exceeds ERL
4. Bold & Gray = Exceeds ER-L and ER-M

Toxicity Testing

There was no toxicity to the amphipod (*Hyalella azteca*) exposed to sediments from each of the three sites in the SCRE (Table 4). Control adjusted survival ranged from 97% at Station R-003 to 111% at Station R-005 (test sediment survival exceeded control survival).

Table 4. 10-day sediment survival test using the amphipod, *Hyalella azteca*, exposed to SCRE and control sediments (EPA 600/R-99/064).

Station	Mean Percent Survival	Percent of Control
Control	90.0	NA
R-003	87.5	97.2
R-004	92.5	102.8
R-005	100.0	111.1

NA=Not Applicable

Macrobenthic Invertebrates

Results for the spring and fall bioassessment portion of the survey are presented in Table 5 and Figures 7, 8 and 9. Replicate species abundances for the spring and ranked abundances for each season are presented in Appendix D. Note that collection locations and methods were different between the May and October surveys. As a result, comparisons between seasons are not made in this year's report. Seasonal comparisons will be made in the 2009 report when the collection methodologies for both spring and fall surveys are the same. In brief, spring samples were collected in triplicate from each of four sampling locations. In the fall four grabs were collected and composited together at each of three sites for a total of one sample per site. See the Methods section for further details regarding the sampling protocols.

Summary

There were a combined total of 3,011 organisms collected from all stations during the spring and fall 2008 bioassessment surveys. The combined total number of organisms collected in the spring (2,054) was greater than in the fall (957) (for spring see Appendix D, Table 8; for fall see Table 5).

A total of 23 unique species were collected during both surveys combined, with a total of 22 collected in the spring and 16 in the fall. In the spring the greatest numbers of species were collected at Station B2 (20) and the least were at Station B7 (9). In the fall, the greatest numbers of species were collected at Station R-005 (14) and the least were collected at Stations R-003 and R-004 (7 each).

Bioassessment Metrics

Biological metrics were calculated according to the California Lentic and Stream Bioassessment protocols and are presented in Table 5. The EPT (Ephemeroptera, Plecoptera, and Tricoptera) metrics could not be applied because there were no members of these indicator groups present in the estuary.

Total abundance is a measure of the total number of individuals found at a site. The simplest measure of resident animal health is the abundance of invertebrates collected per sampling effort. However, abundance is not a particularly good indicator of benthic infauna health. For example, some of the most populous benthic areas are those within the immediate vicinity of organic enrichment. The reason for this apparent contradiction is that environmental stress can exclude many sensitive species from an area. Those few organisms that can tolerate the stressful condition (e.g. pollutant) flourish because they have few competitors. If the area becomes too stressful, however, even the tolerant species cannot survive, and the abundance declines, as well.

Spring abundances were greatest at Station B1 in the VWRF effluent channel (260) and least at Station B3 in the outer estuary (91) (Table 5). In the fall abundances were greatest at Station R-003 in the outer estuary and least at Station R-004 in the VWRF effluent channel (30).

Taxonomic richness is a simple measure of population health and is the number of separate macroinvertebrate species collected per sampling effort (i.e. one grab). Because of its simplicity, numbers of species is often underrated as an index. If the sampling effort and area sampled are the same for each station, however, this index can be one of the most informative. In general, stations with higher numbers of species per grab tend to be in areas of healthier communities.

Average taxonomic richness was greatest in the spring at Station B2 located above the VWRF discharge channel (20) and least at Station B7 in the River channel (9) (Table 5). In the fall the numbers of species was greatest at Station R-005 and least at Stations R-003 and R-004 (7 each).

Percent dominance: reflects the number of species required to account for 75% of the abundance at a site. The greater the number of species accounting for 75% of the total abundance, the healthier a site is considered to be. In contrast, when fewer species account for 75% of the abundance the site is not considered to be healthy.

Dominance was low at all sites during both the spring and fall (Table 5). In the spring the greatest dominance was at Station B3 and the least was at Stations B1 and B7 (2 each). In the fall dominance was greatest at Station R-005 (4) and least at Station R-003 (1).

Shannon diversity: is similar to numbers of species; but contains an evenness component as well. For example, two samples may have the same numbers of species and the same numbers of individuals. However, one station may have most of its numbers concentrated into only a few species while a second station may have its numbers evenly distributed among its species. The diversity index would be higher for the latter station. Diversity values range from 0 to 4, with values approaching four indicating greater diversity and presumably a more healthy population.

Diversity was low at all sites during both seasons (Table 5). In the spring diversity was greatest at Staitons B2 and B3 (1.83 and 1.97, respectively) and least at Station B7 (1.16). In the fall diversity was greatest at Station R-005 (1.74) and least at Station R-003 (0.55).

Species Composition

The most abundant species collected during the spring and fall by grab at each station are presented in Figure 7 and Appendix D, Tables 9 and 10.

In keeping with past surveys, few species accounted for most of the abundance at each site during both seasons (Figure 7). During the spring oligochaete worms were the most abundant species collected at each station (39 to 66%). Dipteran flies accounted for next most abundant species including *Tanytarsus sp*. (7 to 36%), *Chironomus sp*. (8 to 31%), and *Cladotanytarsus sp*. (1 to 13%). Ostracods were also relatively abundant. Combinations of these species

combined to account for at least 75% of the abundances found at each station. In the fall, *Tanytarsus sp*. accounted for the majority of the abundances found at Stations R-003 and R-004 (85 and 50%, respectively), while *Chironomus sp*. accounted for 38% of the abundance at Station R-005. The water flea, *Daphnia sp.* (10%) and *Chironomus sp.* (30%) were next most abundant at Stations R-003 and R-004, respectively, while *Cladotanytarsus sp*. (25%) and *Daphnia sp*. (16%) were next most abundant at Station R-005.

2008 Cluster Analysis

Results of species and station cluster analyses for the spring and fall surveys separately are presented in Figures 8 thru 11. Cluster analysis is useful because it groups stations by the relative abundances of species found at each site in the survey area. Sites with species compositions that are very different from one another will be more dissimilar and will group a greater "distance" apart from one another. If the VWRF effluent is creating a habitat in the effluent channel that is different from other locations in the survey area, we would expect the species composition to be different when compared to other locations in the estuary. It must be noted that many different physical characteristics, including sediment grain size and salinity, can have a profound affect on the composition of benthic communities.

In the spring cluster analysis delineated stations along a gradient, with sites in or closest to the effluent channel (B1 and B2) being more similar to one another than to sites located in the outer estuary (Stations B3 and B7) (Figure 8). However, the cluster distances between station nodes were not great. Species grouped into two main nodes that were most different from one another (Figure 9). Species in the first group (*Chironomus sp., oligochaete, Tanytarsus sp.*) were relatively most abundant at Stations B1 and B2.

In the fall the relative abundance and composition of species were clearly different at Station R-003 (near the sand spit at the discharge point to the ocean) compared to Stations R-004 (located in the effluent channel) and R-005 (located upstream of the Harbor Blvd Bridge), which were most similar to one another. Station R-003 was dominated by *Tanytarsus sp*. (Figure 11).

Table 5. Summary of abundances by species and location during both spring and fall, 2007 bioassessment surveys of the Santa Clara River Estuary. Stations B1 thru B7 abundances are averages (n = 3; except Station B2 in the spring where n = 1); littoral sweep samples are total counts.

Identified Taxa	Spring (n =3)				Fall (n =1)		
	B1	B2	B3	B7	R-003	R-004	R-005
Apedilum sp		1		1			
Chironomidae		3			11		
Chironomus sp	29	55	7	14		9	46
Chydoridae		1	3	2			
Cladotanytarsus sp	12	2	12		5	2	31
Corisella sp							2
Corixidae	2	3	1			1	1
Cricotopus sp		1	3	10	13	1	1
Cryptochironomus							4
Cyclopoida		2	4	3			
Daphnia sp					86		19
Dasyhelea sp		5					
Dicrotendipes sp	5		1		1		
Dolichopodidae		1	1	1			
Ephydra sp	1	6	3				1
Isopoda		1					
Isotomidae	1	1	4	2		1	2
Nematoda	1	1					
Oligochaeta	103	66	36	106	2	1	1
Ostracoda	5	6	5				1
Parachironomus sp		1					
Paratanytarsus sp		2					
Physa sp	5						1
Tanytarsus sp	96	13	13	21	687	15	11
Tipula sp		1					1
Abundance	**260**	**172**	**91**	**160**	**805**	**30**	**122**
Taxa	**11**	**20**	**13**	**9**	**7**	**7**	**14**
Shannon Diversity	**1.45**	**1.83**	**1.97**	**1.16**	**0.55**	**1.34**	**1.74**
Dominance	**2**	**3**	**5**	**2**	**1**	**2**	**4**

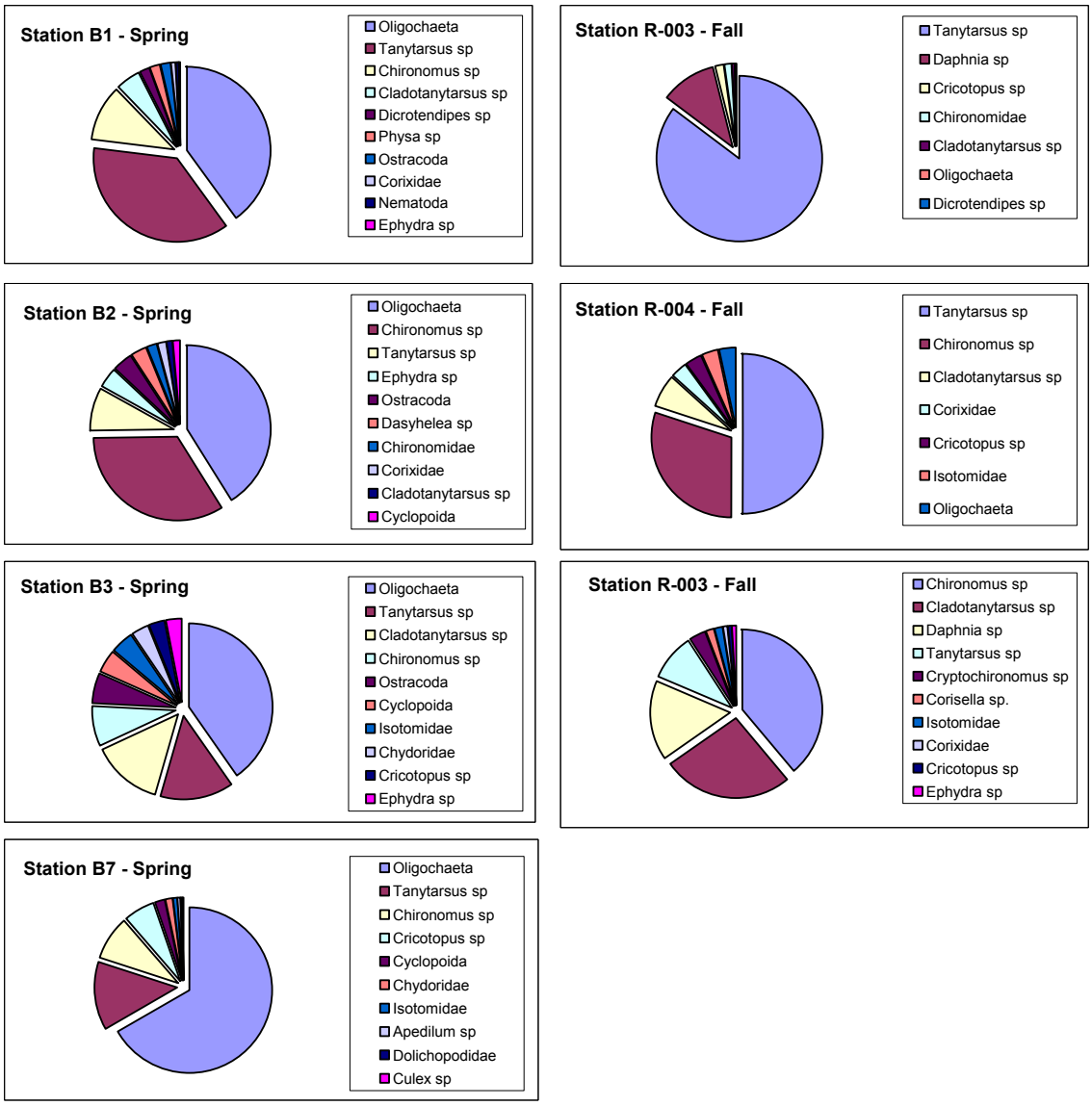

Figure 7. Cumulative percent abundance of the ten most common species collected in the Santa Clara River Estuary during the spring (n = 4) and fall (n = 3), 2008. In the fall, fewer than ten species were collected at Stations R-003 and R-004.

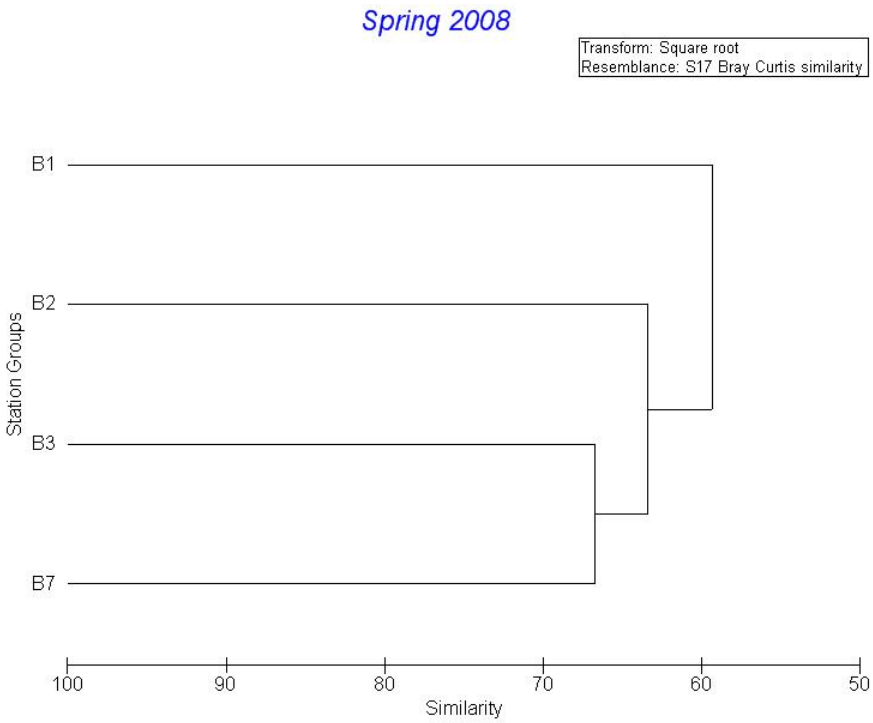

Figure 8. Station cluster dendrogram for BMI population collected in spring 2008. Distances calculated using Bray-Curtis dissimilarity index.

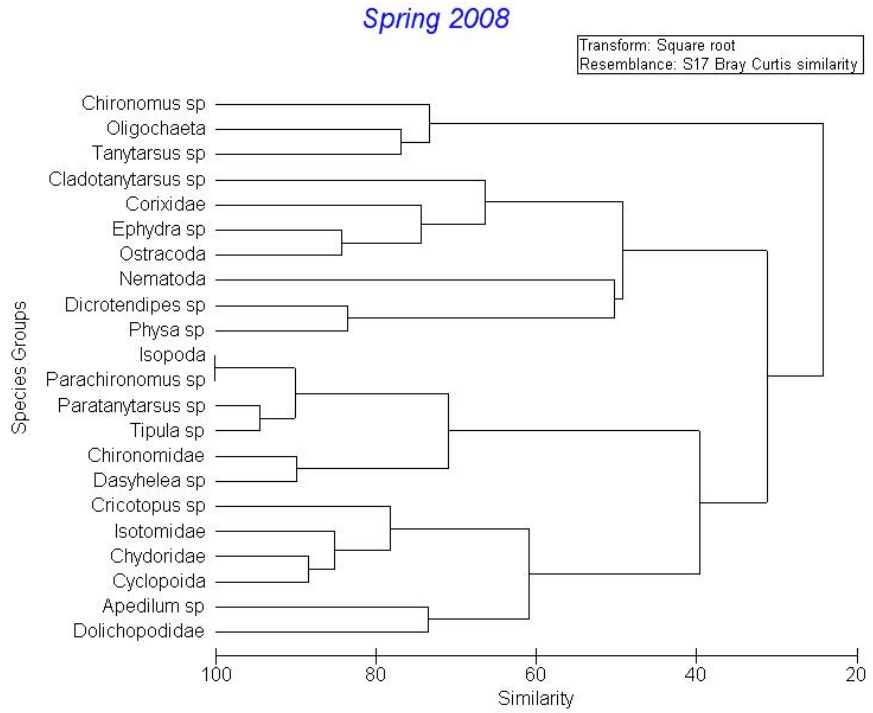

Figure 9. Species cluster dendrogram for BMI population collected in spring 2008. Distances calculated using Bray-Curtis dissimilarity index.

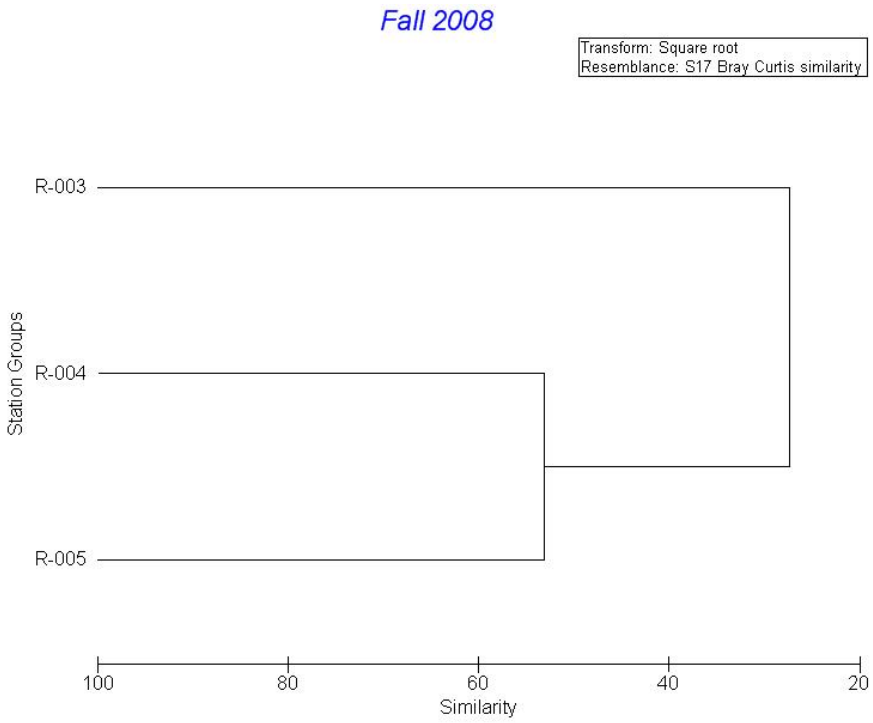

Figure 10. Station cluster dendrogram for BMI population collected in fall 2008. Distances calculated using Bray-Curtis dissimilarity index.

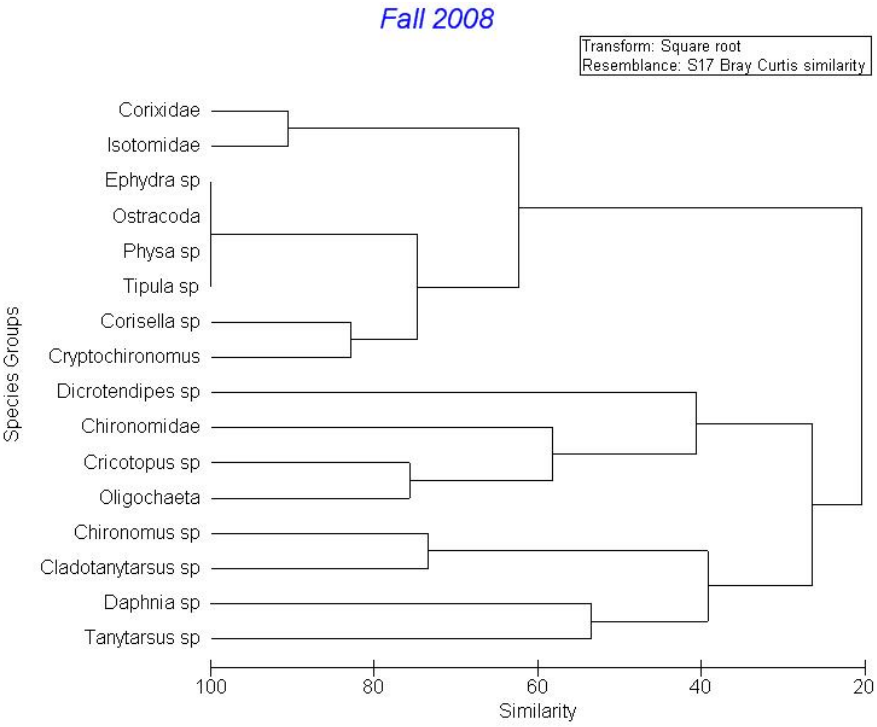

Figure 11. Species cluster dendrogram for BMI population collected in fall 2008. Distances calculated using Bray-Curtis dissimilarity index.

SUMMARY AND CONCLUSIONS

The 2008 bioassessment survey of the Santa Clara River Estuary included two sampling events in May and October. The station locations, parameters and sampling methodologies were different for each survey due to new requirements specified in the City's revised NPDES permit that was promulgated during the summer of 2008. In May sampling was conducted based on the methodologies used since 2004 (Aquatic Bioassay 2004 to 2008). During the October survey the new permit required the use of a "multiple lines of evidence (MLOE)" approach that uses a triad of the combined results of sediment chemistry, sediment toxicity and bioassessment to determine the health of the benthic habitats in the SCRE. As a result sediment samples were collected and analyzed for undifferentiated organics (TOC, sulfide and cyanide), heavy metals, organics (chlorinated and non-chlorinated pesticides, PCBs, PAHs), toxicity (*Hyalella sp*. 10-day survival test), and bioassessment.

The SCRE is a highly dynamic system that undergoes periodic filling and draining throughout the year as a result of the opening and closing of the sand spit on its western edge that connects it to the Pacific Ocean. The Estuary is usually closed to the ocean during low river flow in the summer and fall. Open Estuary conditions prevail after rainfall events in the winter and spring as increased river flow breaches the estuary opening. The fluctuation in inundated conditions between seasons has created a highly dynamic and harsh freshwater habitat. The period between January and December, 2008, represented the third continuous year of drought conditions throughout southern California. Measurable rain fell at Oxnard Airport on only 23 days and totaled 12 inches. The water height in the Santa Clara River remained relatively low and stable from February through the beginning of November, 2008. As a result, there were no large spikes in river discharge that might have fully breached the mouth of the Estuary. During both the May and October surveys the berm at the mouth of the Estuary was closed and water depths in the estury ranged from 0.8 to 1.5 meters.

Water quality in the Estuary during 2008 was typical of past surveys and depicted the dynamic and quickly changing environment of this system. Water temperature in the Estuary was relatively warm during both surveys and ranged from 15 to 20 °C. These findings were within the range of past studies (13.94 to 29.04, USFWS 1999). Dissolved oxygen concentrations varied widely from 7 to 6 mg/L at Stations B1 and B2 located in the effluent channel, respectively, to 17 at Station B3. The lower dissolved oxygen at Stations B1 and B2 may have been due to depletion due to overnight respiration. The supersaturated dissolved oxygen reading at B3 was probably the result of oxygen production by algae. Temperature, pH and dissolved oxygen all fell well within the ranges reported by Greenwald et al (USFWS 1999) during a comprehensive survey in the Estuary conducted from July 1997 to July

1998. This year's water quality results were also similar to measurements collected during 2002 (ENTRIX 2003), and 2003 thru 2007 (Aquatic Bioassay 2004 to 2008).

Salinity has been shown in past studies to be the most controlling factor influencing the composition and distribution of invertebrates under estuarine conditions (Kennish 1986, Chapman and Wang 2001). Salinities during the 2008 surveys were within or slightly exceed the EPA's freshwater criterion (<2.0 ppt, 95% of the time) at each station. Salinity during the spring survey ranged between 1.5 and 4.2 ppt in the effluent channel and outer estuary, respectively, and 1.8 and 2.2 ppt in fall. These salinities were lower compared to a recent Metals Translator Study in the Estuary, when salinity was examined over a year's time (ENTRIX 2002). In that study, low salinities (1 to 4 ppt) were observed near the discharge channel and upper Estuary where the Santa Clara River flows into the Estuary. Brackish conditions (5 to 10 ppt) were observed in the middle of the Estuary. More marine-like (>10 ppt) conditions were isolated to the area near the mouth and far southwestern portion of the Estuary, the highest salinity measurement being 30 ppt. Past studies of the Estuary by Merrit-Smith from August 1998 to January 1999 and USFWS from 1997 to 1999 indicate salinity ranges from 0.6 to 32.8 ppt, with high levels of variance both temporally and spatially (ENTRIX 1999; USFWS 1999).

The Santa Clara River estuary is a highly dynamic environment with seasonal river flow and inundation patterns continuously modifying the composition of the surface sediments. To begin to understand the distributions of aquatic organisms and chemical contaminants within the estuary, it is critical to first understand the distribution of sediments and any seasonal changes that may occur between surveys (Gray 1981). The particle size results for the May and October surveys varied widely by site, ranging from course and fine silt to medium sand. In October, particle sizes graded from nearly 100% medium sand at Station R-003 at the estuary discharge point to the ocean, to nearly 100% fine silt at Station R-004 in the VWRF effluent channel. Particle sizes at Station R-005, located above the Harbor Blvd Bridge, were more homogeneous containing mixtures of fine particles and sand. This shift in particle size distributions between stations and seasons creates a highly dynamic habitat that makes it difficult for benthic organisms to maintain stable populations. After salinity, sediment particle size appears to have the greatest influence on the distribution of invertebrates in an estuary system (Kennish 1986).

Sediment contaminants (representing the first leg of the sediment triad) were measured at each of the three sites in the October survey as part of the MLOE approach. Of the 187 individual organic constituents measured during the fall SCRE survey none were measured in concentrations above the detection limit. Of the nine heavy metals measured, six were above detection for at least one site. Of these six, each was greatest at Station R-004 in the VWRF effluent channel compared to sites located in the outer estuary near the berm (Station R-003) and above the Harbor Blvd Bridge (Station R-005). Each metal concentration in the estuary was below the NOAA ER-L and ER-M threshold limits, except copper and nickel. The copper concentration (34 ppm) slightly exceeded the ER-L threshold (34 ppm). The nickel concentration at Station R-004 (38 ppm) was in the middle of range between the ER-L (21 ppm) and ER-M (52 ppm).

The NOAA ER-L and ER-M are based on a series of studies in which researchers compiled published information regarding the toxicity of chemicals to benthic organisms (NOAA 1990 and Long, et. al. 1995). The data for each compound were sorted, and the lower 10th percentile and median (50th) percentile were identified.

The lower 10th percentile in the data was identified as an Effects Range-Low (ER-L) or the concentration of a chemical below which biological effects are rarely seen. The upper 50th percentile was identified as an Effects Range-Median (ER-M) or the concentration of a chemical above which a biological effect are nearly always seen.

Sediment toxicity (the second leg of the sediment triad) was measured using the amphipod, *Hyalella azteca* in a ten day exposure survival test. None of the sediments measured were acutely toxic to the amphipod with control adjusted survival ranging from 97% at Station R-003 to 111% at Station R-005 (test sediment survival exceeded control survival). These results suggest that any contaminants that may be present in the SCRE sediments are tightly bound to the sediments and are not biologically available. Metal binding studies on estuary sediments have shown that copper concentrations in the SCRE sediments and water column are not available for uptake by organisms (ENTRIX 2003).

The macrobenthic invertebrate community (the third leg of the sediment triad) found in the Santa Clara River Estuary represents a community that has adapted to the highly dynamic conditions discussed above. As with past surveys, all of the organisms represented during the 2008 survey were those found in either freshwater or estuarine environments (USFWS 1999, ENTRIX 2003, Aquatic Bioassay 2004 to 2008). The fall 2008 data set should be compared to past survey results from 2003 thru 2008 (spring) with caution since the sampling locations and methodology changed as a result of the VWRF's revised NPDES permit. Instead of three replicate petite ponar grabs being collected, processed and analyzed separately, in 2008 four petite ponar grabs (0.025 m^2 x 4 = 0.1 m^2) were collected and composited together to form a single sample that was processed and analyzed. This change was made so that future SCRE samples could be compared to other estuaries where a van veen grab (0.1 m^2) is used. Previous to 2003, a core sampler was used to collect samples in the SCRE.

The total combined numbers of organisms collected by grab in 2008 (3,001) was far less than the numbers collected in 2004 (12,207) and 2007 (13,259), but was similar to 2005 (4,637). Also, the numbers were far greater than the numbers collected by Greenwald (et al. 1999) using a coring device (total = 1,359) across 5 stations during 12 separate surveys between 1997 and 1998. These differences are the result of both changes in sampling methodology and the highly dynamic nature of the SCRE benthic habitat.

A total of 25 unique species were collected during both surveys combined, with a total of 22 collected in the spring and 16 in the fall. The numbers of species collected in 2008 were similar to 2007, 2003 and 2004, but greater than in 2005 (Aquatic Bioassay 2004, 2005 and 2006). In addition, numbers of species were similar to past surveys (ENTRIX 2003, Greenwald et al. 1999).

The species collected during this and past surveys were dominated by those with high tolerance values, typical of organisms capable of living under stressful conditions that include either habitat disruption or pollution (CDFG 1999). The composition of species in the Estuary during the 2008 surveys was dominated by only a few species that were similar to those collected in past surveys. During the spring oligochaete worms were the most abundant species collected at each station followed by dipteran flies including *Tanytarsus sp*., *Chironomus sp*., and *Cladotanytarsus sp*.. Ostracods were also relatively abundant. Combinations of these species combined to account for at least 75% of the abundances found at each station. In the fall, *Tanytarsus sp*. accounted for the majority of the abundances

found at Stations R-003 and R-004 (85 and 50%, respectively), while *Chironomus sp*. accounted for 38% of the abundance at Station R-005. The water flea, *Daphnia sp.* and *Chironomus sp.* were the next most abundant at Stations R-003 and R-004, respectively, while *Cladotanytarsus sp*. and *Daphnia sp*. were next most abundant at Station R-005.

Cluster analysis was used to identify how the composition of biological communities in the estuary differed between sites. For the spring and fall surveys the VWRF effluent was not clearly altering the composition and abundances of species in the estuary. In past surveys, seasonal differences in the biological assemblages of the estuary were much greater than differences between stations (Aquatic Bioassay 2004 to 2008). Cluster analysis is useful because it groups stations by the relative abundances of species found at each site in the survey area. Sites with species compositions that are very different from one another will be more dissimilar and will group a greater "distance" apart from one another.

The results of the 2008 bioassessment surveys showed that conditions in the SCRE are heavily influenced by the shifting habitat conditions that occur as a result of fluctuating salinity, the continuous rise and fall of the water level and the scouring and deposition that occur as a result of seasonal storms. In addition, the estuary receives flow year round from upstream runoff that includes both heavy agricultural inputs and non-point sources. These factors combine to make this a very difficult habitat for benthic organisms to survive in. The highly tolerant biological population found at the estuary stations reflects these conditions.

For the first time in 2008, the City used the MLOE approach to assess the biological conditions in the estuary. Although sediment concentrations of copper and nickel exceeded the NOAA ER-L threshold limits, amphipod toxicity tests indicated that the estuary sediments were not toxic. In addition, there was no clear indication that the sites located in the effluent channel had biological communities that were altered compared to other locations in the estuary. These results indicate that the VWRF effluent is not adversely effecting the benthic macroinvertebrate populations residing in the SCRE.

APPENDIX A - REFERENCES

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APPENDIX B – SEDIMENT PARTICLE SIZE

Table 6. Cumulative particle sizes in microns and phi for the four sampling locations in the Santa Clara River Estuary for spring and fall, 2008.

Station / Season	phi Size																										
	-1	-0.5	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	5	11	11.5	12
	Microns																										
	≥2000	1410	1000	710	500	354	250	177	125	88.4	62.5	44.2	31.3	22.1	15.6	11.1	7.8	5.5	3.9	2.8	1.95	1.38	0.98	0.69	0.49	0.35	0.24
	crs sand	crs sand	med sand	med sand	fine sand	med sand	fine sand	very fine sand	very fine sand	very fine sand	very fine sand	very fine sand	crs silt	crs silt	crs silt	silt	fine silt	very fine silt	very fine silt	clay	clay	clay	clay	clay	clay	clay	clay
May																											
B1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.24	4.61	10.18	14.64	14.53	11.65	8.79	7.32	5.97	4.98	3.80	3.61	2.68	1.77	1.61	1.41	0.84	0.20	0.00
B2	0.00	0.00	0.00	0.08	1.79	7.68	12.47	10.84	10.04	9.92	9.51	8.41	7.08	5.74	4.50	3.60	2.52	1.71	1.09	0.92	0.67	0.50	0.45	0.37	0.08	0.00	0.00
B3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.84	3.08	7.00	11.26	13.56	13.21	11.11	9.39	7.31	5.75	4.20	3.93	2.95	1.97	1.69	1.50	0.95	0.23	0.00
B7	0.00	0.00	0.00	0.69	4.36	13.69	19.49	16.16	11.85	8.10	5.86	4.73	4.29	3.69	2.66	1.77	1.04	0.65	0.42	0.36	0.21	0.00	0.00	0.00	0.00	0.00	0.00
October																											
R-003	0.29	2.97	10.34	23.12	30.27	22.92	7.89	1.42	0.22	0.00	0.00	0.00	0.00	0.00	0.14	0.30	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R-004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	2.02	7.73	14.06	15.61	14.59	11.61	9.03	6.40	5.73	4.00	2.49	2.36	2.19	1.47	0.56	0.00
R-005	0.00	0.00	0.00	0.07	1.49	4.59	5.93	4.79	4.94	6.80	10.12	13.41	14.08	12.07	8.85	5.74	2.81	1.40	0.76	0.60	0.45	0.36	0.34	0.31	0.07	0.00	0.00

APPENDIX C - CHEMISTRY

Table 7. Sediment chemistry analyte list, method and reporting limits, units and methods.

Parameter	MDL	RL	Units	Method
Arsenic	0.15	0.25	mg/Kg	6010B/7471A
Cadmium	0.04	0.5	mg/Kg	6010B/7471A
Chromium	0.05	0.5	mg/Kg	6010B/7471A
Copper	0.05	0.5	mg/Kg	6010B/7471A
Lead	0.1	0.25	mg/Kg	6010B/7471A
Mercury	0.01	0.05	mg/Kg	6010B/7471A
Nickel	0.1	0.5	mg/Kg	6010B/7471A
Silver	0.05	0.5	mg/Kg	6010B/7471A
Zinc	0.35	0.5	mg/Kg	6010B/7471A
4,4'-DDD (DDD)	0.27	4	µg/kg	8081A
4,4'-DDE (DDE)	0.22	4	µg/kg	8081A
4,4'-DDT (DDT)	0.22	4	µg/kg	8081A
Aldrin	0.23	2	µg/kg	8081A
alpha-Chlordane	0.2	2	µg/kg	8081A
alpha-Hexachlorocyclohexane	0.27	2	µg/kg	8081A
Beta-Hexachlorocyclohexane	0.37	2	µg/kg	8081A
delta-Hexachlorocyclohexane	0.15	2	µg/kg	8081A
Dieldrin	0.2	4	µg/kg	8081A
Endosulfan 1	0.2	2	µg/kg	8081A
Endosulfan 11	0.24	4	µg/kg	8081A
Endosulfan sulfate	0.27	4	µg/kg	8081A
Endrin	0.25	4	µg/kg	8081A
Endrin aldehyde	0.44	4	µg/kg	8081A
Endrin ketone	0.3	4	µg/kg	8081A
Gamma-Chlordane	0.19	2	µg/kg	8081A
gamma-Hexachlorocyclohexane	0.21	2	µg/kg	8081A
Heptachlor	0.23	2	µg/kg	8081A
Heptachlor epoxide	0.23	2	µg/kg	8081A
Methoxychlor	0.39	17	µg/kg	8081A
Toxaphene	17	170	µg/kg	8081A
% Solids	1	1	%	SM2540-G
Aroclor-1016 (PCB-1016)	3.6	33	µg/kg	8082
Aroclor-1221 (PCB-1221)	4.2	67	µg/kg	8082
Aroclor-1232 (PCB-1232)	2.1	33	µg/kg	8082
Aroclor-1242 (PCB-1242)	2.1	33	µg/kg	8082
Aroclor-1248 (PCB-1248)	2.1	33	µg/kg	8082
Aroclor-1254 (PCB-1254)	2.1	33	µg/kg	8082
Aroclor-1260 (PCB-1260)	2.1	33	µg/kg	8082
Acenaphthene	8.22	20	µg/kg	8270C
Acenaphthylene	7.14	20	µg/kg	8270C
Anthracene	1.38	5	µg/kg	8270C
Benz(a)anthracene	5.9	15	µg/kg	8270C
Benzo(a)pyrene	2.56	10	µg/kg	8270C
Benzo(b)fluoranthene	2.54	10	µg/kg	8270C
Benzo(ghi)perylene	6.24	15	µg/kg	8270C
Benzo(k)fluoranthene	2.68	10	µg/kg	8270C
Chrysene	4.33	10	µg/kg	8270C
Dibenz(a,h)anthracene	7.95	20	µg/kg	8270C
Fluoranthene	3.18	10	µg/kg	8270C
Fluorene	3.87	10	µg/kg	8270C
Indeno(1,2,3-cd)pyrene	3.74	10	µg/kg	8270C
Naphthalene	8.53	20	µg/kg	8270C
Phenanthrene	5.18	15	µg/kg	8270C
Pyrene	4.82	10	µg/kg	8270C
Sulfide,dissolved	0.01	0.02	mg/L	SM4500-S-2-D
Carbon, Total Organic	1	1	mg/Kg	9060
1,1,1,2-Tetrachloroethane	1.28	10	µg/kg	8260B
1,1,1-Trichloroethane	2.03	10	µg/kg	8260B
1,1,2,2-Tetrachloroethane	3.25	10	µg/kg	8260B
1,1,2-Trichloroethane	1.74	10	µg/kg	8260B
1,1-Dichloroethane	1.3	10	µg/kg	8260B
1,1-Dichloroethene	2.6	10	µg/kg	8260B
1,1-Dichloropropene	1.12	10	µg/kg	8260B
1,2,3-Trichlorobenzene	1.23	10	µg/kg	8260B
1,2,3-Trichloropropane	1.74	10	µg/kg	8260B
1,2,4-Trichlorobenzene	2.82	10	µg/kg	8260B
1,2,4-Trimethylbenzene	3.19	10	µg/kg	8260B
1,2-Dibromo-3-chloropropane	2.69	50	µg/kg	8260B
1,2-Dibromoethane	2.75	10	µg/kg	8260B
1,2-Dichlorobenzene	1.03	10	µg/kg	8260B
1,2-Dichloroethane	1.57	10	µg/kg	8260B
1,2-Dichloropropane	0.66	10	µg/kg	8260B
1,3,5-Trimethylbenzene	1.23	10	µg/kg	8260B
1,3-Dichlorobenzene	1.65	10	µg/kg	8260B
1,3-Dichloropropane	0.92	10	µg/kg	8260B
1,4-Dichlorobenzene	2.23	10	µg/kg	8260B
2,2-Dichloropropane	1.36	10	µg/kg	8260B
2-Butanone	5.83	50	µg/kg	8260B
2-Chloroethyl vinyl ether	5.53	50	µg/kg	8260B
2-Chlorotoluene	2.35	10	µg/kg	8260B
2-Hexanone	3.18	50	µg/kg	8260B
4-Chlorotoluene	1.34	10	µg/kg	8260B
4-Methyl-2-pentanone	3.14	50	µg/kg	8260B
Acetone	12.7	50	µg/kg	8260B
Benzene	0.93	2	µg/kg	8260B
Bromobenzene	3.39	10	µg/kg	8260B
Bromochloromethane	0.38	10	µg/kg	8260B
Bromodichloromethane	0.63	10	µg/kg	8260B
Bromoform	3.39	50	µg/kg	8260B
Bromomethane	2.75	30	µg/kg	8260B
Carbon disulfide	5.53	10	µg/kg	8260B
Carbon tetrachloride	2.48	10	µg/kg	8260B
Chlorobenzene	0.89	10	µg/kg	8260B
Chloroethane	2.15	30	µg/kg	8260B
Chloroform (Trichloromethane)	1.24	10	µg/kg	8260B
Chloromethane (Methyl chloride)	1.74	30	µg/kg	8260B
cis-1,2-Dichloroethene	1.6	10	µg/kg	8260B
cis-1,3-Dichloropropene	0.98	10	µg/kg	8260B

Parameter	MDL	RL	Units	Method
Dibromochloromethane	0.65	10	µg/kg	8260B
Dibromomethane	2.3	10	µg/kg	8260B
Dichlorodifluoromethane	2.07	30	µg/kg	8260B
Ethylbenzene	1	2	µg/kg	8260B
Hexachlorobutadiene	2.77	30	µg/kg	8260B
Isopropylbenzene	1.42	10	µg/kg	8260B
m- & p-Xylenes	1.8	4	µg/kg	8260B
Methylene chloride	3.31	50	µg/kg	8260B
MTBE	2.9	5	µg/kg	8260B
Naphthalene	1.14	10	µg/kg	8260B
n-Butylbenzene	2.05	10	µg/kg	8260B
n-Propylbenzene	1.14	10	µg/kg	8260B
o-Xylene	1	2	µg/kg	8260B
p-Isopropyltoluene	3.86	10	µg/kg	8260B
sec-Butylbenzene	3.04	10	µg/kg	8260B
Styrene	0.8	10	µg/kg	8260B
tert-Butylbenzene	1.34	10	µg/kg	8260B
Tetrachloroethene	0.93	10	µg/kg	8260B
Toluene (Methyl benzene)	1	2	µg/kg	8260B
trans-1,2-Dichloroethene	2.16	10	µg/kg	8260B
trans-1,3-Dichloropropene	0.96	10	µg/kg	8260B
Trichloroethene (TCE)	1.15	10	µg/kg	8260B
Trichlorofluoromethane	3.15	10	µg/kg	8260B
Vinyl acetate	10.8	50	µg/kg	8260B
Vinyl chloride	2.79	30	µg/kg	8260B
1,2,4-Trichlorobenzene	16.6	330	µg/kg	8270C
1,2-Dichlorobenzene	17.8	330	µg/kg	8270C
1,3-Dichlorobenzene	20.2	330	µg/kg	8270C
Acenaphthene	13.8	330	µg/kg	8270C
Acenaphthylene	16.1	330	µg/kg	8270C
Anthracene	9.9	330	µg/kg	8270C
Benz(a)anthracene	12.8	330	µg/kg	8270C
Benzo(a)pyrene	18.9	330	µg/kg	8270C
Benzo(b)fluoranthene	21.8	330	µg/kg	8270C
Benzo(ghi)perylene	18.4	330	µg/kg	8270C
Benzo(k)fluoranthene	19	330	µg/kg	8270C
Chrysene	14.4	330	µg/kg	8270C
Dibenz(a,h)anthracene	16.1	330	µg/kg	8270C
Fluoranthene	8	330	µg/kg	8270C
Fluorene	14.2	330	µg/kg	8270C
Hexachlorobutadiene	15.9	330	µg/kg	8270C
Indeno(1,2,3-cd)pyrene	16.8	330	µg/kg	8270C
Naphthalene	18.9	330	µg/kg	8270C
Phenanthrene	10.9	330	µg/kg	8270C
Pyrene	8.2	330	µg/kg	8270C
Benzoic acid	36.7	1700	µg/kg	8270C
Benzyl alcohol	22.6	660	µg/kg	8270C
Bis(2-chloroethoxy)methane	19.6	330	µg/kg	8270C
Bis(2-chloroethyl)ether	20.3	330	µg/kg	8270C
Bis(2-chloroisopropyl) ether	17.3	330	µg/kg	8270C
Bis(2-ethylhexyl) phthalate	11.1	330	µg/kg	8270C
4-Bromophenyl phenyl ether	14.6	330	µg/kg	8270C
Butyl benzyl phthalate	13.3	330	µg/kg	8270C
4-Chloro-3-methylphenol	23.2	660	µg/kg	8270C
4-Chloroaniline	20	660	µg/kg	8270C
2-Chloronaphthalene	19.5	330	µg/kg	8270C
2-Chlorophenol	18.8	330	µg/kg	8270C
4-Chlorophenyl phenyl ether	17.2	330	µg/kg	8270C
Di-n-butyl phthalate	10.1	330	µg/kg	8270C
Di-n-octyl phthalate	14.7	330	µg/kg	8270C
Dibenzofuran	15.7	330	µg/kg	8270C
1,4-Dichlorobenzene	18.4	330	µg/kg	8270C
3,3'-Dichlorobenzidine	14.6	660	µg/kg	8270C
2,4-Dichlorophenol	24.1	1700	µg/kg	8270C
Diethyl phthalate	13.9	330	µg/kg	8270C
2,4-Dimethylphenol	22.4	330	µg/kg	8270C
Dimethyl phthalate	15.5	330	µg/kg	8270C
2,4-Dinitrophenol	128	1700	µg/kg	8270C
2,4-Dinitrotoluene	17.3	330	µg/kg	8270C
2,6-Dinitrotoluene	16	330	µg/kg	8270C
Hexachlorobenzene	9.7	330	µg/kg	8270C
Hexachlorocyclopentadiene	16.5	660	µg/kg	8270C
Hexachloroethane	22.6	330	µg/kg	8270C
Isophorone	20.1	330	µg/kg	8270C
2-methyl-4,6-Dinitrophenol	31.2	1700	µg/kg	8270C
2-Methylnaphthalene	19.1	330	µg/kg	8270C
2-Methylphenol	21.2	330	µg/kg	8270C
4-Methylphenol	22.5	330	µg/kg	8270C
N-Nitroso-Di-n-propylamine	22.7	330	µg/kg	8270C
N-Nitrosodiphenylamine	11.4	330	µg/kg	8270C
2-Nitroaniline	16.7	1700	µg/kg	8270C
3-Nitroaniline	17.5	1700	µg/kg	8270C
4-Nitroaniline	12.9	1700	µg/kg	8270C
Nitrobenzene	18.7	330	µg/kg	8270C
2-Nitrophenol	26	330	µg/kg	8270C
4-Nitrophenol	26	1700	µg/kg	8270C
Pentachlorophenol	22.7	1700	µg/kg	8270C
Phenol	16.9	330	µg/kg	8270C
2,4,5-Trichlorophenol	23.6	330	µg/kg	8270C
2,4,6-Trichlorophenol	19.4	330	µg/kg	8270C
1-Methylnaphthalene	330	330	µg/kg	8270C
1-Methylphenanthrene	330	330	µg/kg	8270C
2,3,5-Trimethylnapthalene	330	330	µg/kg	8270C
2,6-Dimethylnapthalene	330	330	µg/kg	8270C
Benzo[e]pyrene	330	330	µg/kg	8270C
Biphenyl	330	330	µg/kg	8270C
Dibenzothiophene	330	330	µg/kg	8270C
Perylene	330	330	µg/kg	8270C

APPENDIX D - MACROINVERTEBRATES

Table 8. Taxa list and abundances by replicate for spring 2008. (No replicates were collected in during the fall survey, per the new permit)

Identified Taxa	Tol Val (TV)	Func Feed Grp	B1			B2			B3			B7		
			1	2	3	1	2	3	1	2	3	1	2	3
Insecta Taxa														
Collembola														
Isotomidae	5	cg	2					4	2		10	1	4	
Hemiptera														
Corixidae	8	p	4		3		8		2					
Diptera														
Apedilum sp	6	cg						3	1					2
Chironomidae	6	cg					3	7						
Chironomus sp	10	cg	29	32	25	17	35	112	8	4	9		39	2
Cladotanytarsus sp	7	cg	4	8	23	4	2		1	5	30			
Cricotopus sp	7	cg					3		5	1	2	7	3	19
Culex sp	8	cg												1
Dasyhelea sp	6	cg						15						
Dicrotendipes sp	8	cg		9	7				1		1			
Dolichopodidae	4	p						2	2					2
Ephydra sp	6	sh	3				7	12	7	1				
Parachironomus sp	6	cg				3			1					
Paratanytarsus sp	6	cf						5						
Tanytarsus sp	6	cf	88	96	103	21	12	7	15	8	15		62	2
Tipula sp	4	om						4						
Non-Insecta Taxa														
Nematoda	5	p			4		2							
Oligochaeta	5	cg	26	232	52	56	67	76	12	16	80	11	294	14
Ostracoda	8	cg	5	9		2	5	11	12	1	3			1
Basommatophora														
Physa sp	8	sc		8	7	1								1
Cycopoida														
Cyclopoida	8	cf					4	2	3		9	7	3	
Diplostraca														
Chydoridae		cf					3		2		7	3	3	
Isopoda														
Isopoda	8	cg					3							
TOTAL			**161**	**394**	**224**	**104**	**154**	**260**	**74**	**36**	**166**	**29**	**408**	**44**

Table 9. Ten most abundant species collected from each sampling site (reps = 3) in Santa Clara River Estuary during the spring 2008.

SCRE B1		SCRE B2		SCRE B3		SCRE B7	
Taxa	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**
Oligochaeta	39.8	Oligochaeta	38.4	Oligochaeta	39.1	Oligochaeta	66.3
Tanytarsus sp	36.8	*Chironomus* sp	31.7	*Tanytarsus* sp	13.8	*Tanytarsus* sp	13.3
Chironomus sp	11.0	*Tanytarsus* sp	7.7	*Cladotanytarsus* sp	13.0	*Chironomus* sp	8.5
Cladotanytarsus sp	4.5	*Ephydra* sp	3.7	*Chironomus* sp	7.6	*Cricotopus* sp	6.0
Dicrotendipes sp	2.1	Ostracoda	3.5	Ostracoda	5.8	Cyclopoida	2.1
Physa sp	1.9	*Dasyhelea* sp	2.9	Cyclopoida	4.3	Chydoridae	1.2
Ostracoda	1.8	Chironomidae	1.9	Isotomidae	4.3	Isotomidae	1.0
Corixidae	0.9	Corixidae	1.5	Chydoridae	3.3	*Apedilum* sp	0.4
Nematoda	0.5	*Cladotanytarsus* sp	1.2	*Cricotopus* sp	2.9	Dolichopodidae	0.4
Ephydra sp	0.4	Cyclopoida	1.2	*Ephydra* sp	2.9	*Culex* sp	0.2
Isotomidae	0.3	*Paratanytarsus* sp	1.0	Corixidae	0.7	Ostracoda	0.2
		Isotomidae	0.8	*Dicrotendipes* sp	0.7	*Physa* sp	0.2
		Tipula sp	0.8	Dolichopodidae	0.7		
		Apedilum sp	0.6	*Apedilum* sp	0.4		
		Chydoridae	0.6	*Parachironomus* sp	0.4		
		Cricotopus sp	0.6				
		Isopoda	0.6				
		Parachironomus sp	0.6				
		Dolichopodidae	0.4				
		Nematoda	0.4				
		Physa sp	0.2				

Table 10. Ten most abundant species collected from each sampling site (reps = 1) in Santa Clara River Estuary during the fall 2008.

SCRE R-003		SCRE R-004		SCRE R-005	
Taxa	**%**	**Taxa**	**%**	**Taxa**	**%**
Tanytarsus sp	85.3	*Tanytarsus* sp	50.0	*Chironomus* sp	37.7
Daphnia sp	10.7	*Chironomus* sp	30.0	*Cladotanytarsus* sp	25.4
Cricotopus sp	1.6	*Cladotanytarsus* sp	6.7	*Daphnia* sp	15.6
Chironomidae	1.4	Corixidae	3.3	*Tanytarsus* sp	9.0
Cladotanytarsus sp	0.6	*Cricotopus* sp	3.3	*Cryptochironomus* sp	3.3
Oligochaeta	0.2	Isotomidae	3.3	*Corisella* sp.	1.6
Dicrotendipes sp	0.1	Oligochaeta	3.3	Isotomidae	1.6
				Corixidae	0.8
				Cricotopus sp	0.8
				Ephydra sp	0.80
				Oligochaeta	0.80
				Ostracoda	0.80
				Physa sp	0.80
				Tropisternus sp	0.80

APPENDIX D - STATISTICS

Statistical Analyses

Six biological metrics were used to compare the benthic infauna assemblages that were collected from both on and near the NEIBP CAD site (Table 2-1). Abundance, numbers of species, Shannon Diversity and the Benthic Response Index (BRI) were calculated for the benthic infauna data.

Total Abundance – is the abundance of infauna collected per sampling effort. Abundance included all of the non-colonial animals collected from one replicate Van Veen grab (0.1 square meter surface area) and retained on a 1.0.

Numbers of Species – is the number of separate infauna species collected per sampling effort (i.e. one Van Veen grab). In general, stations with higher numbers of species per grab tend to be in areas of healthier communities.

Shannon Diversity (H') – is a diversity index whose calculation includes both numbers of species and the relative abundance of each species. For example, two samples may have the same numbers of species and the same numbers of individuals. However, one station may have most of its numbers concentrated into only a few species while a second station may have its numbers evenly distributed among its species. The diversity index would be higher for the latter station.

The Shannon Diversity Index (H') (Shannon and Weaver 1963) is defined as:

$$H' = -\sum_{s} \{(n_j/N) \, Ln(n_j/N)\}$$

where: n_j = number of individuals of the jth species

N = total indiv. of all species in the sample

s = number of species in the sample.

Schwartz' Dominance. Schwartz's Dominance Index (D) is defined as the minimum number of species required accounting for 75% of the individuals in a sample (Schwartz 1978).

Table 2-1. Community population metrics and their expected response to an impact.

Indicator	Reference	Expected Pattern with Increasing Disturbance
Total abundance	Pearson and Rosenberg (1978)	Increases, then decreases with increasing outfall effects
Number of species	Pearson and Rosenberg (1978)	Initial increase, then decrease with increasing impact
H' - Shannon information diversity	Pielou (1969)	Initial increase, then decrease with increasing impact

Cluster Analysis

Cluster analysis defines groups of stations with similar community composition. The results are displayed in a hierarchical tree-like structure called a dendrogram. On the dendrogram, two groups are first defined, and within these groups subgroups are defined. Subsequently, subgroups within the subgroups are defined. This process is continued until all stations are a separate subgroup. The hierarchical nature of the dendrogram allows the analyst to choose groups of stations that represent a scale of community differences relevant to the present project.

Cluster analysis is also used to define groups of species that tend to have similar distributional patterns among stations.

Dissimilarity Index

Both the ordination and cluster analyses require the input of a dissimilarity matrix, which quantifies the (biological community) dissimilarity between all pairs of stations. The Bray-Curtis dissimilarity index (Bray and Curtis 1957) with the stepacross procedure was used (Williamson 1978, Bradfield and Kenkel 1987). Before computation of the dissimilarity index, the species abundance data were transformed by square root and were standardized by a species mean of abundance values greater than zero. The square root transformation tends to dampen some of the noise often found in positively skewed species abundance data. The Bray-Curtis index has been shown to perform well when used with a species standardization (Faith et al. 1987, Smith 1976). Smith (1976) demonstrates how the species mean standardization in particular should best emphasize species abundance counts that change commensurate to changes along community gradients.

All dissimilarity indices are incapable of properly measuring community change for highly dissimilar stations (Swan 1970, Beals 1973). This is because that once two stations have no species in common, the dissimilarity index values cannot continue to increase in value as stations become more dissimilar in community composition. The non-monotonic pattern of species abundance values along community gradients also contributes to this lack of index sensitivity for relatively large amounts of community change. The stepacross procedure applied to the computed dissimilarity matrix corrects for this deficiency of the dissimilarity index. Here the larger dissimilarity values (>0.8 on a scale of 0 to 1) are reestimated from the shorter dissimilarity values, resulting in larger dissimilarity values that are more commensurate with the degree of actual community change.