SWAMP
Surface Water Ambient Monitoring Program

Monitoring Plan	2012-13

Extent, Hydrology, and Ecology of Non-Perennial Streams in the San Diego Region

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1. Summary Sheet

Beneficial Uses

This proposal outlines a monitoring plan for the Surface Water Ambient Monitoring Program (SWAMP) to address aquatic life beneficial uses for wadeable, non-perennial streams in the San Diego Region. Aquatic life beneficial uses include:

- Warm Freshwater Habitat (WARM)
- Cold Freshwater Habitat (COLD)
- Wildlife Habitat (WILD)
- Rare, Threatened, or Endangered Species (RARE)
- Preservation of Biological Habitats of Special Significance (BIOL)

Assessment Questions

The proposed monitoring plan of non-perennial reference streams will be used to address the following assessment questions:

1. What hydrologic conditions can be used to characterize non-perennial reference stream sites in terms of annual duration and timing of flow and expected interannual variability in these patterns?
2. Which (non-stormflow) hydrologic conditions need to be present to support the use of current bioassessment assessment tools that were developed for perennial streams?
3. Do the two biological indicators currently available (benthic macroinvertebrates and algae) perform differently in non-perennial streams compared to perennial streams in terms of sufficiency, accuracy, precision, and responsiveness?

The three monitoring questions will be addressed by testing the following three hypotheses:

1. Non-perennial reference streams have a definable range of hydrologic conditions on an annual cycle.
2. Current bioassessment tools can be used at non-perennial stream sites that carry flow during the spring period.
3. Algae and benthic macroinvertebrates perform differently in terms of sufficiency, accuracy, precision, and responsiveness in non-perennial streams compared to perennial streams.

Link to Regional and Statewide Monitoring Framework

The proposed monitoring of biological conditions in non-perennial reference streams will support the Framework for Monitoring and Assessment in the San Diego Region (Busse and Posthumus 2012). The new approach is systematic, logical, question-driven, and is water-body oriented rather than discharge-oriented. The framework emphasizes the need for conditions monitoring on an ongoing basis to determine if/how conditions are changing in water bodies of the San Diego region.

The proposed project also follows the SWAMP strategy (SWAMP 2010) by supporting the monitoring and assessment of aquatic life uses in streams and by developing new or revised assessment tools for non-perennial streams.

Clean Water Act Section 305(b)

The data produced by this monitoring plan will be used in water body assessments required under Clean Water Act (CWA) section 305(b).

2. Background

2.1 Introduction

Non-perennial streams encompass a continuum of hydrologic variability, from ephemeral washes and headwaters that flow for only a few hours after rain events, to streams with sustained flows lasting nearly all year (and even more than a year with heavy rainfall). Although these streams function differently from perennial streams, they also provide essential ecosystem services including watershed and landscape hydrologic connections, water supply protection and water-quality filtering, wildlife habitat and movement/migration corridors, sediment transport, storage and deposition, groundwater recharge and discharge, vegetation community support, and nutrient cycling and movement (Stein et al. 2011). Urban development, especially in southern California, can affect non-perennial streams and impact their functions by adding flow through stormwater or irrigation to non-perennial streams and thereby "perennializing" these streams. On the other hand, ground water withdrawal can reduce flows in perennial streams, and can convert them into non-perennial streams.

This project will focus on testing bioassessment tools at a subset of non-perennial streams that contain flow for sufficient duration to allow the establishment and support of in-stream benthic communities (these characteristics will be more robustly defined as part of the project). Streams that are mostly dry are not included in this study because aquatic bioassessment tools cannot be applied there. Because of the focus on bioassessment, we will focus on non-storm baseflow characteristics vs. storm flow hydrology.

Non-perennial streams comprise about 75% of total stream miles in the San Diego region (Mazor et al. 2012), and are found to be relatively extensive in open space and agricultural settings, whereas many urban streams are perennial (Fig. 1). In addition, the extent of non-perennial stream length may increase due to climate change induced decreases of summer flow. Existing maps (such as those provided in the National Hydrography Dataset, NHD) do not adequately or accurately represent the location and extent of non-perennial streams making it difficult to assess their extent and distribution and complicating the selection of appropriate sample sites for current bioassessment programs.

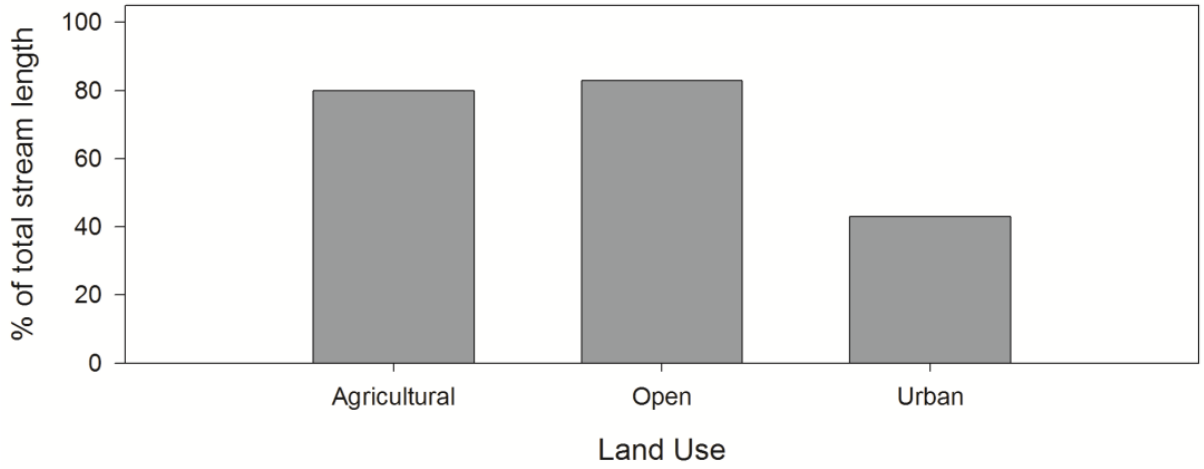

Figure 1: Extent of non-perennial stream length in southern California (Mazor et al. 2012)

Physical, chemical and biological processes and interactions of non-perennial streams remain poorly understood and documented (Stein et al. 2011). Therefore, non-perennial streams are often excluded from monitoring and assessment programs because it is not known if existing assessment methods and tools can be used to accurately evaluate their condition. This means that many stream surveys are incomplete, and regulatory programs have limited ability to evaluate stream health. Furthermore, the large extent of non-perennial streams in the San Diego Region makes their inclusion more relevant if watershed managers are to truly understand the health of their watersheds.

Preliminary research in the San Diego region has shown that some non-perennial streams are ecologically similar to perennial streams, suggesting that existing assessment tools used for perennial streams (such as the California Stream Condition Index (CSCI) based on benthic macroinvertebrates, Mazor et al. under review) may be adequate for some types of non-perennial streams (Mazor et al. 2012, Fig. 2a). However, future adjustments to the assessment tools may be required to apply to the full diversity of non-perennial stream types, such as streams with short flow durations. A pilot study conducted by Fetscher (2013) showed that IBI scores for periphyton in non-perennial streams were reasonably stable over the period when streams received flow (Fig. 2b). This study only included two non-perennial stream sites.

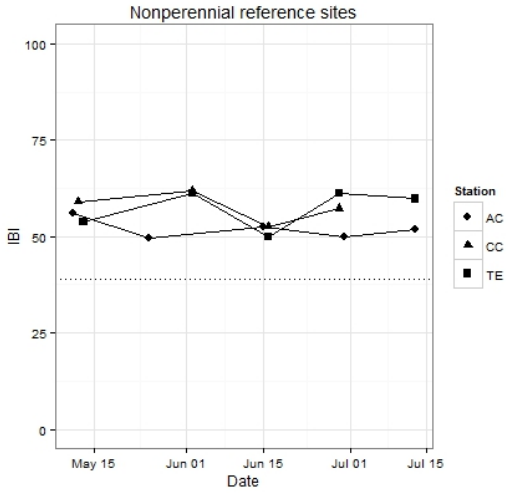

Figure 2a: Benthic macroinvertebrate index of biotic integrity scores from 3 non-perennial streams (Mazor et al. 2012)

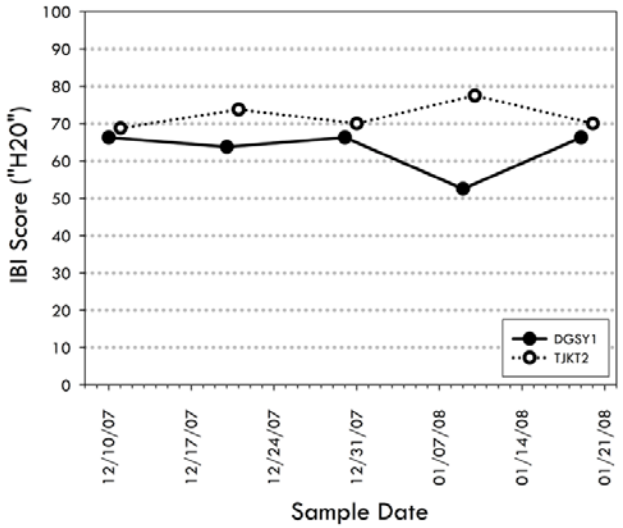

Figure 2b:Periphtyon index of biotic integrity scores from two non-perennial streams (Fetscher 2013)

The two previous projects (Mazor et al. 2012, Fetscher 2013) showed that the current assessment tools can be used at a subset of non-perennial streams; however only a small number of sites was tested, and only one biological community was tested in each study. In order to test the range of applicability of the assessment tools, there is a need to apply them at a larger number of sites and across a broader range of hydrologic gradients. In addition, benthic macroinvertebrate and algae need to be tested concurrently in order to determine how the two biological communities perform in non-perennial streams.

Project elements include updating stream maps showing probable locations of perennial and non-perennial streams in the San Diego region, characterizing the hydrology and biology across a range of non-perennial reference streams, and developing guidance for broadly applicable tools and assessment methods for non-perennial streams. This project is funded through State Board's Basin Planning Fiscal Year 12/13 funds and through the Surface Water Ambient Monitoring Program (SWAMP) San Diego region Fiscal Year 12/13 funds. Collection and taxonomic analysis of biological data (benthic macroinvertebrates and algae) will be conducted by the California Department of Fish and Wildlife funded under the SWAMP contract. San Diego Water Board staff will also conduct some sampling for this project to reduce costs. Measurements of hydrologic conditions, development of hydrologic maps, and analysis of all data (including biological data) are covered under the Basin Planning contract (Contract # 12-088-190) with the State Water Board to the Southern California Coastal Water Research Project (SCCWRP).

This monitoring plan focuses on the field elements of this project. Stream mapping and analysis of gauge data to define hydrologic characteristics of non-perennial streams are not covered by this monitoring plan.

2.2 Past Bioassessment Monitoring in the San Diego region

Bioassessment in Perennial Streams

The San Diego Water Board began conducting bioassessment in 1996 through a collaboration with California Department of Fish and Game after an oil spill in the San Diego River. Since 2001, the San Diego Water Board has included bioassessment as a major indicator in streams through the SWAMP program (Mazor and Schiff 2008) and has required bioassessment monitoring of receiving waters by municipal stormwater permittees in the region. In addition, large statewide SWAMP projects (e.g., the Perennial Stream Assessment, and the Reference Condition Management Plan) have included several bioassessment sites in the San Diego region (Ode et al. 2011). In 2009, the Stormwater Monitoring Coalition (SMC) began a probabilistic study of watershed health in southern California which uses bioassessment as a primary indicator (Mazor et al. 2011). In the past several years, bioassessment monitoring was included in several National Pollution Discharge Elimination System permits (e.g. Padre Dam Treatment Plant) as well as in 401 water quality certifications. The proposed statewide bio-objectives program will also rely on bioassessment indicators as the core tool for assessment and regulating streams. Most streams that have been included in these programs are perennial, which are defined as streams which carry water during the sampling period in spring. Nevertheless, it is likely that several streams included in previous bioassessments were non-perennial.

Bioassessment in Non-Perennial Streams

The first study dedicated to non-perennial streams was conducted under a Proposition 50 grant awarded to SCCWRP in 2007 (Mazor et al. 2012). That study included sampling of 12 non-perennial sites in the San Diego region, 3 of which were non-perennial reference sites. Each site was sampled at least three (and up to eight) times in one season, and three sites were sampled over multiple years. At a subset of sites, continuous data loggers were deployed to measure water level and temperature throughout the course of the study. In addition, a Proposition 50 funded study on algal indicators in southern California included the sampling of two non-perennial reference sites (Fetscher 2013).

2.3 Objective and Monitoring Questions

Objectives and Monitoring Questions

The objective of this study is to evaluate how far along the gradient of non-perenniality benthic macroinvertebrates and algae can be used to assess stream conditions with current indices of biotic integrity or other indices. It is expected that this study will provide recommendations to the San Diego Water Board as to the range of non-perennial streams (if any), which comprise the majority of streams in the San Diego region, can be effectively monitored and assessed with existing scoring tools and where there is a need to develop new tools specific to non-perennial systems (or a subset of non-perennial systems).

The following monitoring questions are asked through this study:

1. What hydrologic conditions can be used to characterize non-perennial reference stream sites in terms of annual duration and timing of flow and expected interannual variability in these patterns?
2. Which (non-stormflow) hydrologic conditions need to be present to support the use of current bioassessment assessment tools that were developed for perennial streams?
3. Do the two biological indicators currently available (benthic macroinvertebrates and algae) perform differently in non-perennial streams compared to perennial streams in terms of sufficiency, accuracy, precision, and responsiveness?

3 Study Methods and Materials

A targeted monitoring design will be used to sample non-perennial reference sites representing a range of natural physical and hydrological gradients. Broad representation is necessary to test the applicability of existing assessment tools in non-perennial settings. A list of about 40 non-perennial reference sites will be compiled that consists of reference sites that were sampled before and new reference sites. The status of reference will be determined through the definition of reference conditions that was developed for the biological objectives project (Ode et al., in preparation). From the pool of non-perennial reference sites, 23 will be chosen for this study. Sites will be selected to represent several different watersheds in the San Diego region with a gradient of non-perennial stream flows (as defined by a hydrologic analysis of existing gauge data).

Hydrologic analysis will focus on characterizing the duration, seasonality and variability of non-storm (baseflow) conditions, which are relevant for bioassessment. Analysis will consist of both field and office evaluations. Field measurements will be taken by HOBO

Water Level Data Loggers. HOBOs will be deployed at every site that will be sampled for this study. The HOBO data loggers will measure the water level throughout the period of this project (approximately 2 years). Because of limited funding, raingages cannot be installed at the sites that will be studied for this project. However, raingage information will be used from existing raingages if available. In addition, water depth will be measured for 5 locations at 21 transects at every site according to the PHAB protocol and flow habitats will be measured at 10 inter-transects.

Starting June 2013, SCCWRP will conduct data analysis of historic gage data that are available throughout southern California. This data analysis will assess ranges of duration, seasonality and variability of flow to help define different classes (or types) of non-perennial streams. This analysis will be used to help identify the characteristics of the class of non-perennial streams that will be the focus of this study.

3.2 Selected Parameters

The field data collected for this study falls into the following parameter groupings:

(1) Conventional water chemistry;

(2) Benthic macroinvertebrates and algae; and

(3) Physical habitat.

The proposed study also includes collection of hydrologic information measured using data loggers. Hydrologic measurements are funded from a separate source and therefore not included in this monitoring plan.

Sample Collection and Field Measurements

Field crews from the California Department of Fish and Wildlife and the San Diego Water Board will collect the water chemistry and bioassessment samples in addition to performing physical habitat assessments. Collection of samples and field information for conventional water chemistry will be collected simultaneously with the bioassessment samples and physical habitat assessment. Field sampling for bioassessment and physical habitat can only be conducted when flow is present at the sites. If the entire stream site is ponded or water is absent at the sites, bioassessment samples cannot be taken.

Conventional Water Chemistry

The following parameters will be measured *in-situ*: (1) temperature, (2) dissolved oxygen, (3) pH, (4) conductivity and (5) turbidity. Temperature, dissolved oxygen, pH, and conductivity will be measured in the field with a Quanta Hydrolab multisensor. Turbidity will be measured in the field with a LaMotte 2020e.

The following water chemistry will be collected and analyzed in the laboratory: (1) total nitrogen, (2) nitrate and nitrite, (3) ammonia, (4) total phosphorus, (5) ortho-phosphorus, (6) silica, (7) chloride, (8) dissolved organic carbon, and (9) alkalinity. Water chemistry results will be generated by the Water Pollution Control Lab of the California Department of Fish and Wildlife.

Benthic Macroinvertebrates and Algae

Benthic macroinvertebrates and algae will be collected concurrently. In addition, algal samples for chlorophyll *a* and ash free dry mass will be collected. The benthic macroinvertebrates will be analyzed to SAFIT STE level II (Richards and Rogers 2011) by the California Department of Fish and Wildlife. Taxonomic analysis of diatoms will be conducted by EcoAnalysts. Taxonomic analysis of soft-bodied algae will be conducted by the California State University San Marcos. Chlorophyll a and ash free dry mass will be analyzed by the Water Pollution Control Lab of the California Department of Fish and Wildlife.

Physical habitat assessment

Physical habitat (PHAB) will be assessed simultaneously with the bioassessment collection. The full PHAB protocol will be used (Ode 2007) with additional parameters required by the algae field SOP (Fetscher et al. 2009). At sites that will be re-sampled (see section 3.4), only a subset of PHAB parameters will be assessed during the second sampling. PHAB parameters that do not change dramatically over several weeks will not be collected (e.g. bank stability, human influence, gradient and sinuosity).

3.3 Data Analysis and Assessment

Benthic invertebrate and algae data will be analyzed using both existing scoring tools and raw data on community compositions. Benthic macroinvertebrate data will be analyzed with the new California Stream Condition Index (CSCI, Mazor et al., under review). For algae, the preliminary periphyton index for biotic integrity will be applied (Fetscher2013). For both biological communities, new indices and metrics might be tested. For physical habitat data, the new scoring tool for PHAB metrics (PHAB Multi-Metric Index (PHAB MMI)) will be applied (Ode 2013, personal communication). Conventional water chemistry data will be used to describe ambient conditions at the non-perennial stream sites.

The performance of bioindicators at the nonperennial stream sites may be assessed in several ways: sufficiency, accuracy, precision, and responsiveness. Sufficiency may be assessed as the proportion of samples of sufficient size to calculate assessment indices (specifically, 500 BMI, 600 diatom valves, or 300 soft algae entities). Accuracy may be assessed as the proportion of samples from reference sites that have index scores

indicating reference condition. Precision may be assessed as the standard deviation of scores from repeat visits at the same site. Responsiveness may be assessed as the difference in scores at reference sites from scores at stressed sites. Information from stressed sites is available from previous projects. Factors such as geology, climate, and watershed area will be used to interpret the data and to understand variables that may influence performance of the tools.

3.4 Data Collection and Frequency

Each of the 23 sampling sites will be sampled once in spring of either 2013 or 2014.A subset of 8 sites will be re-sampled not earlier than 1 month after the first sampling. Before sampling, site reconnaissance will be used to determine site selection, including alternate sites. SCCWRP and the San Diego Water Board will conduct site reconnaissance in order to: (1) Identify land ownership and access issues; (2) Determine if the site meets reference site criteria; (3) Provide photo-documentation of the site; and (4) Record on the ground GPS coordinates (NAD83, decimal degrees) for the site.

3.5 Spatial and Temporal Scale

The proposed study will only sample non-perennial reference streams in the San Diego region. If not enough non-perennial reference site streams can be identified in the San Diego region, then non-perennial reference sites will be chosen outside the San Diego region but within southern California. This study is a 2-year study; however, it is planned that a subset of the non-perennial reference sites will be sampled over several years in order to study the inter-annual variability of non-perennial reference sites.

3.6 Data Management

Data generated from the proposed monitoring plan will be stored in the SWAMP database. Field crews will be responsible for entering all field generated data into the SWAMP database. Results from the laboratory analyses will be uploaded into the SWAMP database. The data will also be uploaded to the California Environmental Data Exchange Network (CEDEN).

4. Coordination and Collaboration

The proposed project is a collaboration between the San Diego Water Board, the California Department of Fish and Wildlife, and the Southern California Coastal Water

Research Project. In addition, this project will be coordinated with any other projects that address non-perennial streams in southern California. The proposed study will be coordinated with the regional monitoring program conducted by the Stormwater Monitoring Coalition (SMC) and the study on background concentrations of contaminants in San Diego reference streams (SCCWRP). In addition, the project partners will collaborate with the San Francisco Regional Board because non-perennial streams are included in their regional monitoring program. In addition, the San Diego Water Board will internally collaborate with the 401 water quality certification program, the Municipal Stormwater Program, the Monitoring, Assessment and Research Unit, and the Basin Planning Unit.

5. Quality Assurance

Quality assurance procedures and quality control requirements for the proposed project are specified in the SWAMP Quality Assurance Project Plan (QAPrP). No separate Quality Assurance Project Plan (QAPP) will be developed for the proposed study; rather the study will reference the SWAMP QAPrP (SWAMP 2008b and updates) for the majority of the project QA requirements. The following sections document instances where the project will deviate from a specified SWAMP QA requirement in addition to QA information for project parameters not currently regulated by the SWAMP QA program. Data quality evaluation and data reporting will follow the specifications in the SWAMP Quality Assurance Project Plan (SWAMP 2008b). We do not anticipate needing additional special data quality evaluation or data reporting procedures.

Field Sampling Quality Assurance

SWAMP field SOPs for sampling benthic macroinvertebrates, algae, and physical habitat will be followed (Ode 2007, Fetscher et al. 2009). Before the field sampling, the field crews will attend trainings that are held for the Storm Water Monitoring Coalition. During the training, audits will be conducted by Jim Harrington, Department of Fish and Wildlife. The SWAMP field protocols will not be modified for this project.

Field duplicates for water chemistry will be collected at 5% of the sites (total of 31 sites – 2 field duplicates). Field duplicates for bioassessment samples will be collected at 10% of the sites.

Conventional Water Chemistry Quality Assurance

For water chemistry analysis, sampling procedures, preservation requirements, measurement quality objectives, reporting limits, and holding times of the SWAMP Quality Assurance Project Plan will be followed (SWAMP 2008b and updates) for all parameters except ortho-phosphate.

Samples collected and analyzed for ortho-phosphate will not be analyzed within the required 48-hour holding time between collection and analysis. Following collection, samples for ortho-phosphate will be stored refrigerated at 4°C and analyzed within 7 days from collection. Preliminary data show that ortho-phosphate remains almost unchanged if refrigerated over 7 days (Ode, personal communication). The ortho-phosphate results for this study will be flagged for missing the required holding time and classified in the SWAMP database as "qualified". The ortho-phoshate data flagged for the holding time violation is suitable for use in the proposed project.

Benthic Macroinvertebrates and Algae Quality Assurance

The analysis of benthic macroinvertebrate samples will follow the benthic macroinvertebrate lab SOP (Woodard et al. 2012). For analysis of diatoms and soft-bodied algae, no SWAMP SOPs exist yet; therefore EcoAnalysts and California State University San Marcos will use their current internal laboratory procedures.

6. Reporting

A technical report will be produced to present the findings and recommendations of the study outlined in this monitoring report. The technical report will be finalized by March 31, 2015 and made available to the public on the San Diego Water Board website by June 30, 2015. In addition, a fact sheet will be prepared based on the results of the study and a presentation will be made to the SWAMP Roundtable. Results and recommendations from the proposed study will be presented through a SWAMP webinar.

7. Project Schedule

Sampling for the project will occur in spring of 2013 and in spring of 2014. The taxonomic analysis of the benthic macroinvertebrates samples and the algae samples are expected to be finalized by 09/30/2013 for the 2013 samples, and by 09/30/2013 for the 2014 samples. The final report will be submitted by 3/31/2015.

Per SWAMP work order, the following deliverables have to be met:

1. List of sites for non-perennial stream study with GPS locations, deliverable date: 09/30/2013
2. Sampling of sites for non-perennial stream study, and submitting field data to SWAMP database, one month after sampling
3. Analysis of samples and submission of data for bioassessment samples and nutrient samples to SWAMP database: 03/31/2015

8. References

Busse, L. and Posthumus, B. 2012. A Framework for Monitoring and Assessment in the San Diego Region. California Regional Water Quality Control Board, San Diego Region. Staff Report.

Fetscher, A.E., Busse, L., and Ode, P.R. 2009. Standard Operating Procedures for Collecting Stream Algae Samples and Associated Physical Habitat and Chemical Data for Ambient Bioassessments in California.California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP).Bioassessment SOP 002. (updated May 2010)

Fetscher, A.E. 2013: Development of Multimetric Tools for Setting Numeric Nutrients Targets including a Periphyton Index of Biotic Integrity. Final Project Report for Agreement No. 06-375-559-2.

Mazor, R. and Schiff, K. 2008: Surface Water Ambient Monitoring Program (SWAMP) Synthesis Report on Stream Assessments in the San Diego Region. SWAMP Final Technical Report.

Mazor, R., Gillett, D.J., Schiff, K., Ritter, K., and Stein, E.D. 2011: Ecological Conditions of watershed in coastal southern California. Summary of the Stormwater Monitoring Coalition's Stream Monitoring Program First Year (2009).SCCWRP Technical Report 639.

Mazor, R., Schiff, K., Ode, P., and Stein, E.D. 2012: Final Report on Nonperennial Streams. SCCWRP Technical Report 695.

Mazor, R., Rehn, A., Ode, P., Engeln, M., and Schiff, K. under review: Maximizing the applicability of bioassessment scoring tools in environmentally complex regions.

Ode, P. R. 2007.Standard Operating Procedures for Collecting Benthic Macroinvertebrate Samples and Associated physical and Chemical Data for Ambient Bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP). Bioassessment SOP 001.

Ode, P.R., Kincaid, T.M., Fleming, T.and Rehn, A.C. 2011. Ecological Condition Assessments of California's Perennial Wadeable Streams: Highlights from the Surface Water Ambient Monitoring Program's Perennial Streams Assessment (PSA) (2000-2007). A collaboration between the State Water Resources Control Board's Non-Point Source Pollution Control Program (NPS Program), Surface Water Ambient Monitoring Program (SWAMP), California Department of Fish and

Game Aquatic Bioassessment Laboratory, and the U.S. Environmental Protection Agency.

Richards, A.B., and Rogers, D.C. 2011: List of Freshwater Macroinvertebrate Taxa from California and Adjacent States including Standard Taxonomic Effort Levels. Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT).

Stein.E.D.,Vyverberg, K. Kondolf, M., Kelley, J. 2011: Episodic Stream Channels: Imperatives for Assessment and Environmental Planning in California. Proceedings of a Special Technical Workshop, November 8-10, 2010. SCCWRP Technical Report 645.

SWAMP 2008a: Incorporating Bioassessment Using Freshwater Algae into California's Surface Water Ambient Monitoring Program (SWAMP). SCCWRP Technical Report 563.

SWAMP.2008b. Quality Assurance Program Plan, Version 1.0.SWAMP Final Technical Report.

SWAMP 2010: 2010 SWAMP Strategy. 2010 Update of the Comprehensive Monitoring and Assessment Strategy to Protect and Restore California's Water Quality. Prepared by the Surface Water Ambient Monitoring Program, December 2010.

Woodard, M.E., Slusark, J. and Ode, P.R. 2012.Standard Operating Procedures for Laboratory Processing and Identification of Benthic Macroinvertebrates in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 003.