Central Coast Watershed Studies

CCoWS

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Agricultural Management Practices and Treatment Wetlands in the Gabilan Watershed:

Quality Assurance Project Plan

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Preface

Funding for this project has been provided in full or in part through Agreement number 03-193-553-0 with the State Water Resources Control Board (SWRCB) pursuant to the Costa-Machado Water Act of 2000 (Proposition 13) and any amendments thereto for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

An amount of $14,060 was allocated under the agreement for the preparation of this document and the associated Monitoring Plan.

This project is done in partnership with Moss Landing Marine Laboratories, the Resource Conservation District of Monterey County, Community Alliance with Family Farmers, Coastal Conservation and Research, and Return of the Natives.

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The following documents were reviewed and used to formulate the following Quality Assurance Project Plan:

- Nichol, G., Reyes, E., & Ray, W. (March 2004 version). The surface water ambient monitoring program (SWAMP) electronic template for QAPP's. Available online at: http://www.swrcb.ca.gov/swamp/docs/swampqapp_template032404.doc
- Hager, J. & Watson, F. (2003). Watsonville Sloughs Pathogen and Sediment TMDL Quality Assurance Project Plan and Field Sampling Plan (Report No. WI-2002-13). Central Coast Watershed Studies (CCoWS), Watershed Institute, California State University Monterey Bay.
- Casagrande, J. & Watson, F. (2004). The Reclamation Ditch Watershed Assessment QAPP and Monitoring Plan (Report No. WI-2004-07). Central Coast Watershed Studies (CCoWS). Watershed Institute, California State University Monterey Bay. (Approved by State, Publication pending approval by MCWRA Board of Directors)

Table of Contents

Group A: Project Management

1 Distribution List

Following approval by the Central Coast Regional Water Quality Control Board (CCRWCCB) Contract Manager and Quality Assurance Officer, this document will be made available to the following agencies and agency personnel. In addition, any interested parties will be able to view it on the CCoWS website (http://science.csumb.edu/~ccows/) under the Publications link.

Central Coast Regional Water Quality Control Board
- Amanda Bern (original copy)
- Karen Worcester

Moss Landing Marine Laboratories
- Adam Wiskind

FCSUMB Watershed Institute, Central Coast Watershed Studies
- Fred Watson
- Regina Williams
- Joy Larson

FCSUMB Watershed Institute, Return of the Natives
- Laura Lienk

Resource Conservation District of Monterey County
- Emily Hanson
- Bryan Largay
- Deborah Nares
- Karminder Brown
- Melanie Bojanowski

Community Alliance with Family Farmers
- Sam Earnshaw
- Mark Cady

2 Project Organization

2.1 Contractor and Subcontractors

Moss Landing Marine Laboratories is the primary contract holder with San Jose State University Foundation and the subcontractors are the Resource Conservation District of Monterey County (RCDMC), the Foundation of California State University at Monterey Bay (FCSUMB - CCoWS and RON) and the Community Alliance with Family Farmers (CAFF). A project organizational chart has been provided (figure 2.2) and contact information for personnel is listed in Table 2.1 of this chapter. Each group is described briefly here.

2.1.1 Moss Landing Marine Laboratories

Moss Landing Marine Laboratories (MLML) is operated by a consortium of seven California State University campuses (Fresno, Hayward, Monterey Bay, Sacramento, San Francisco, San Jose, and Stanislaus) and has an international reputation for excellence in marine science research and education. There is a small group within the Lab that through research and restoration works to improve surface water quality contributions into the Monterey Bay.

Adam Wiskind is the project's Primary Investigator and Wetland Project Manager. This group will primarily oversee tasks and deliverables associated with project administration, CEQA/NEPA documents and permits and wetland design and construction.

2.1.2 Coastal Conservation & Research

Coastal Conservation and Research (CC&R) is an environmental restoration firm that focuses on rehabilitation of threatened habitats along the central California coast. Their work is primarily directed toward the restoration of freshwater ecosystems.

Peter Nelson, Cara Clark and Kellie Rey of CC&R make up the Wetland Restoration Crew.

2.1.3 Resource Conservation District of Monterey County

The Resource Conservation District of Monterey County (RCDMC) is a non-regulatory special local district that has been serving the farming, ranching and rural communities within Monterey County since 1942. The RCDMC's mission is to conserve and improve natural resources, integrating the demand for environmental quality with the needs of agricultural and urban users.

The Co-PI from the RCDMC is Emily Hanson. Melanie Bojanowski, Projects Manager, is the lead on implementation of agricultural management practices, with technical support from Bryan

Largay, Hydrologist, and Deborah Nares, Conservation Projects Coordinator. Bryan Largay is also the liaison between the RCDMC and water quality monitoring partners for this project. Karminder Brown, Program Manager, is responsible for grant reporting.

2.1.4 FCSUMB – Central Coast Watershed Studies

The Central Coast Watershed Studies (CCoWS) team is part of the Watershed Institute, in the Division of Science and Environmental Policy at California State University Monterey Bay. The goal of CCoWS is to conduct watershed and landscape ecological research that supports land management both in California's Central Coast region, and in the world in general.

The Co-PI for the monitoring portion of the project is Dr. Fred Watson. The Monitoring Manager, Kelleen Harris, will oversee the collection and analysis of water quality data and final reporting. Wendi Newman is the CCoWS Research Manager and Joy Larson is the Laboratory Manager. Morgan Wilkinson is the project's Research Technician who will work primarily on field monitoring activities. CCoWS will work closely with MLML during the wetland construction and the RCDMC for all agricultural activities related to the project.

2.1.5 FCSUMB – Return of the Natives

The Return of the Natives Restoration Education Project (RON) is the restoration, education, and outreach branch of the Watershed Institute of the California State University Monterey Bay. RON is a community and school-based environmental education program dedicated to involving students (Kindergarten through University) in habitat restoration and service learning projects in the schoolyard and the community.

The Co-PI for RON is Laura Lee Lienk. She will oversee the growing of native plants at RON's greenhouses on the CSUMB campus. RON will be working closely with MLML during wetland construction.

2.1.6 Community Alliance with Family Farmers

The Community Alliance with Family Farmers (CAFF) is a result of efforts by both farmers and urban activists working together for more than 25 years to build a movement of rural and urban people to foster family-scale agriculture that cares for the land, sustains local economies and promotes social justice.

Sam Earnshaw (Co-PI) and Mark Cady are the representatives from CAFF. This group will work primarily on education and outreach within the community, and will be working closely with the RCD.

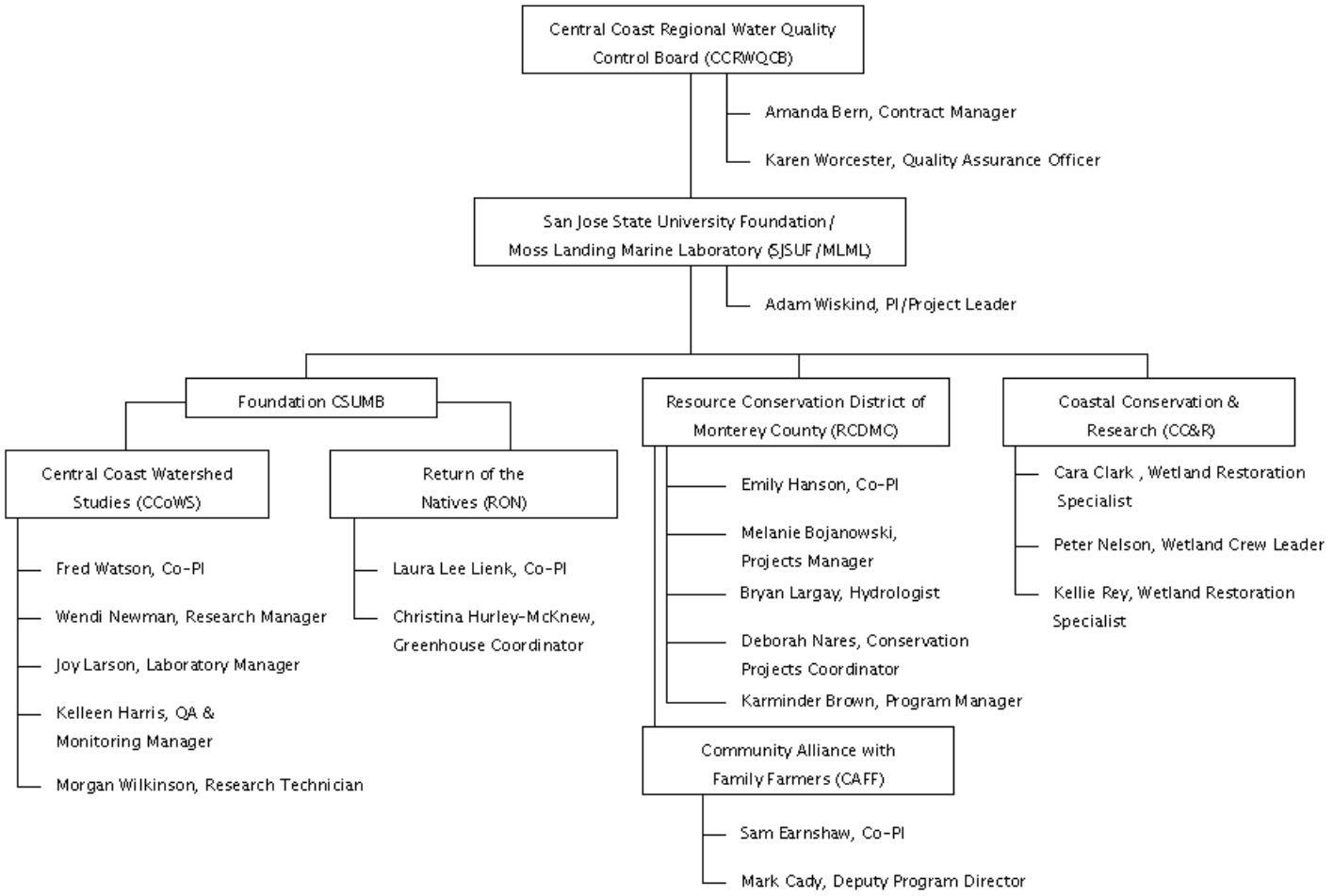

Figure 2.2. Project Organizational Chart

Table 2.1. Personnel contact information.

Name	Affiliation	Title	Contact Information
Amanda Bern	CCRWQCB	Contract Manager	805-594-6197 abern@waterboards.ca.gov
Melanie Bojanowski	RCDMC	Projects Manager	831-424-1036 melanie.bojanowski@rcdmonterey.org
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Emily Hanson	RCDMC	Co-PI (Sub-agreement)	831-424-1036 x124 emily.hanson@rcdmonterey.org
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Christina Hurley-McKnew	FCSUMB RON	Greenhouse Coordinator	831-582-3326 christina_hurley@csumb.edu
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Laura Lee Lienk	FCSUMB RON	Co-PI (Sub-agreement)	831-582-3689 laura_lienk@csumb.edu
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Peter Nelson	CC&R	Wetland Crew Leader	831-384-3861 pedropratt@hotmail.com
Fred Watson	FCSUMB CCoWS	Co-PI (Sub-agreement)	831-582-4452 fred_watson@csumb.edu
Regina Williams	FCSUMB CCoWS	Research Technician	831-582-5217 regina_williams@csumb.edu
Adam Wiskind	SJSUF/ MLML	PI/Project Leader Wetland Project Manager (Primary agreement)	831-771-4495 awiskind@mlml.calstate.edu
Karen Worcester	CCRWQCB	QA Officer	805-549-3333 kworcester@waterboards.ca.gov

2.2 Division of grant tasks

The project is organized into eight main tasks, each containing several subtasks. These tasks and subtasks have been divided as illustrated in Table 2.2. When a task is owned by more than one group, it is broken down to subtask. For a description of the subtasks, refer to SWRCB Contract Number 03-193-553-0.

Table 2.2. Division of grant tasks.

Task	Sub-task	SJSUF	MLML	CC&R	RCD	CAFF	CCoWS	RON
1. Project Administration	All	Support	Lead					
2. CEQA/NEPA Documents and Permits	All		Lead					
3. Quality Assurance Project Plan	All						Lead	
4. Project Assessment and Evaluation Plan	All		Support		Support	Support	Lead	Support
5. Implementation of Agricultural Best Management Practices	5.1.1				Lead	Support		
	5.1.2				Lead	Lead		
	5.1.3				Lead	Support		
	5.2.1				Lead	Support		
	5.2.2				Lead	Support		
	5.3.1							Lead
	5.3.2							Lead
	5.4.1				Lead	Support		
	5.4.2				Lead	Support		
	5.4.3							Lead
	5.5				Support	Lead		
6. Wetlands/Riparian Restoration	6.1.1		Lead			Support		
	6.1.2		Lead					
	6.1.3		Lead		Support			
	6.1.4		Lead					
	6.1.5		Lead					
	6.2.1		Lead		Support		Support	
	6.2.2		Lead					
	6.3.1			Lead				
	6.3.2			Lead				
	6.4.1			Lead				
	6.4.2			Lead				
	6.4.3			Lead				
	6.4.4			Lead				
	6.5		Lead					
7. Ag Practice & Wetland Monitoring	All						Lead	
8. Final Reporting	All						Lead	

2.3 Quality Assurance Officer role

The CCoWS Monitoring Manager, Kelleen Harris, will also serve as the Quality Assurance Officer. She will ensure that the QAPP and Monitoring Plan are adhered to, and review all data that is collected as described in Chapter 21 to make sure it meets all data quality objectives.

2.4 QAPP update and maintenance

Changes and updates to this QAPP may be made after a review of the evidence for change is made by Fred Watson and Kelleen Harris of CCoWS, and with the concurrence of both the CCRWQCB Contract Manager, Amanda Bern, and QA Officer, Karen Worcester. The CCoWS monitoring manager will be responsible for making the changes, submitting drafts for review, preparing a final copy, and submitting the final for signature.

3 Background

3.1 Study area and problem statement

This project addresses water quality concerns in the Gabilan Watershed – also known as the Reclamation Ditch Watershed. The Watershed is defined as the watershed of the Potrero Road Tide Gates, excluding the watershed of the Salinas River (Figure 3.1). It includes Gabilan Creek, Natividad Creek, Alisal Creek, Alisal Slough, Santa Rita Creek, Merritt Lake, Espinosa Slough, Tembladero Slough, Salinas Reclamation Channel, and the lower part of the Old Salinas River Channel. Agricultural sites on other waterways within the coastal region of the Salinas River, northern Salinas Valley, and Monterey County may also be used if they are considered valuable to the project.

At the receiving end of the Gabilan Watershed is Moss Landing Harbor, a State-listed Toxic Hot Spot that is scheduled for three TMDL action plans. In addition, sixteen total maximum daily load (TMDL) action plans are in development or scheduled for these waterbodies.

Some of the highest levels of surface water pesticide contamination found statewide by the State Mussel Watch and Toxic Substances Monitoring Programs were found in the Gabilan Watershed. Elevated levels of contamination from persistent pesticides such as dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyl (PCB), dieldrin, and endosulfan have been reported from sediment and/or shellfish tissue for the Salinas Reclamation Ditch, Tembladero Slough, Old Salinas River Channel, Espinosa Slough, and Moss Landing Harbor. All of these sites are listed or are candidates for the Toxic Hot Spot List, and all of these waterways drain into the Monterey Bay National Marine Sanctuary.

There are six 303(d) listed waterbodies within the Gabilan Watershed (Casagrande & Watson, in prep.).

1. Gabilan Creek:
   303d list – fecal coliform
2. Salinas Reclamation Canal (Reclamation Ditch):
   303d list – fecal coliform*, low dissolved oxygen*, nitrate*, pesticides, priority organics
3. Alisal Creek:
   303d list – fecal coliform*, nitrate*
4. Espinosa Slough:
   303d list – nutrients, pesticides, and priority organics
5. Tembladero Slough:
   303d list – fecal coliform*, nutrients, pesticides

State-listed Toxic Hot Spot** – pesticides, PCB's, metals – Ni, Cr

6. Old Salinas River Channel:
   303d list – fecal coliform*, low dissolved oxygen*, nutrients, pesticides
   State-listed Toxic Hot Spot ** – pesticides, PCB's, metals – Ni, Cr

In addition, there are three listed waterbodies downstream of the Gabilan Watershed.

1. Moss Landing Harbor:
   303d list – pathogens, pesticides, sedimentation/siltation
   State-listed Toxic Hot Spot** – pesticides, PCB's, metals – Ni, Cr
2. Elkhorn Slough:
   303d list – pathogens, pesticides, sedimentation/siltation
3. Monterey Bay South (Coastline):
   303d list – metals, pesticides

*added since 1998. http://www.swrcb.ca.gov/tmdl/docs/2002reg3303dlist.pdf
**SWRCB Toxic Hot Spots Clean Up Plan.
http://swrcb2.swrcb.ca.gov/bptcp/docs/dftfedcp.doc

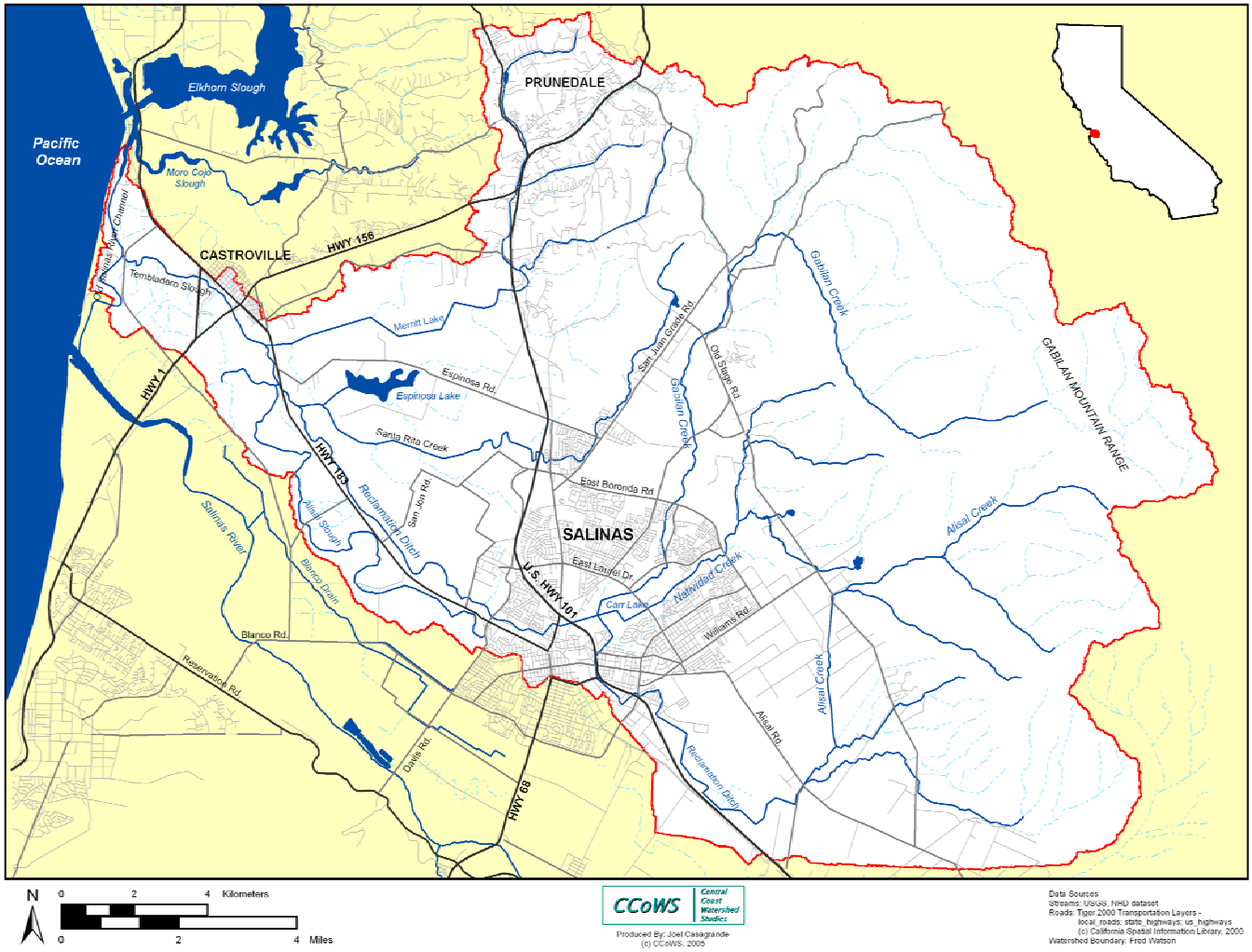

Figure 3.1. The Gabilan Watershed with watershed boundary shown in red.

3.2 Project outcomes & goals

General Project Goal: Reduce non-point source pollution in the Gabilan Watershed – particularly suspended sediment, nutrients, and pesticides – and thereby improve near-shore coastal waters of Moss Landing Harbor and the Monterey Bay.

There are two main parts to the water quality portion of this project: 1) the implementation of agricultural management practices, and 2) the creation of a treatment wetland.

The agricultural piece of the project will result in the implementation of twenty practices on at least seven properties, where the intent is to help growers control one or more types of non-point source pollution. The monitoring data collected will describe of the effectiveness of each practice at reducing pollutant loads.

The wetland piece of the project will result in a constructed treatment wetland near the bottom of the Gabilan watershed. It will be located at the Tembladero Slough and Old Salinas River channel confluence. The water intake will be located in the Tembladero Slough. Water quality monitoring will include sampling for nutrients, suspended sediment, pesticides and toxicity.

3.3 Water quality criteria

Since this project will measure the effectiveness of various practices at improving/and or reducing impacts on water quality, the determination of 'effectiveness' shall be cognizant of various applicable water quality criteria. However, the exceedance of water quality criteria will not indicate the failure of a management practice. The goal is to understand and describe the function of each practice.

Water quality criteria to be used as references for data to be collected were compiled from several sources and described in the following sections. These criteria are summarized in Tables 3.1, 3.2, and 3.3.

Table 3.1. Summary of water quality criteria for SSC, turbidity, pH and nutrients.

Analyte	Water Quality Criteria
Suspended sediment (mg/l)	10, 100, 1000
Turbidity (NTU)	2, 20, 200
pH	7.0 – 8.3
NO_3^-–N (mg/l)	1.2
NH_3–N (Un-ionized) (mg/l)	0.025
PO_4^{3-}–P (mg/l)	0.12

3.3.1 Sediment and turbidity

Water quality objectives for turbidity levels and suspended sediment concentrations are not defined numerically by the Central Coast Regional Water Quality Control Board (CCRWQCB); Hager and Watson (2005) reviewed the available literature on suspended sediment impacts to fish and aquatic invertebrates (key data reproduced here in Appendix K). Noting the absence of definitive studies for Central Coast aquatic ecosystems, CCoWS uses the following ranges as general guidelines to assess potential sediment impacts to fish and invertebrates. These ranges were based primarily on published sediment toxicity levels for rainbow trout and invertebrates.

The listed concentrations and responses are not intended for use as a reference to exact concentrations that would affect fish in a given water body, but more so to gain an understanding of the general range that can be expected to have an adverse affect on fish. It is also important to note that many factors can influence the degree of sediment impact, such as sediment composition and size, duration, species adaptation to a given area, and simultaneous presence of stressors such as elevated temperature, low DO, and pollutants.

- Up to 2 NTU or 10 mg/l: not likely to adversely affect fish and invertebrates
- Up to 20 NTU or 100 mg/l: potential change in behavior and / or slight decrease in survival
- Up to 200 NTU or 1,000 mg/l: stress, physiological changes, and potentially lethal effects

3.3.2 pH

The pH range for the Tembladero Slough was selected based on the most protective beneficial uses assigned to it by the Central Coast Region Basin Plan (CCRWQCB, 1984). Water quality objectives in the Basin Plan satisfy State and federal requirements to protect waters for the beneficial uses they have been assigned. The most stringent of the beneficial uses that list pH

values are Water Contact Recreation (REC-1) with a pH range of 6.5-8.3 and Warm Fresh Water Habitat (WARM) with a range of 7.0-8.5. In the California EPA Central Valley Regional Water Quality Control Board document *A Compilation of Water Quality Goals*, the USEPA national recommended ambient water quality criteria for freshwater aquatic life protection is cited as an instantaneous value of 6.5 – 9.0 (Marshack, 2003). The combination of these values results in a range of 7.0-8.3 that is acceptable to protect present and future beneficial uses of the Tembladero Slough.

Other present and potential beneficial uses of the Tembladero Slough are: Non-Contact Water Recreation (REC-2), Commercial and Sport Fishing (COMM), Estuarine Habitat (EST), Wildlife Habitat (WILD), Rare, Threatened, or Endangered Species (RARE), Spawning, Reproduction, and/or Early Development (SPWN) and Shellfish Harvesting (SHELL). See the Basin Plan for descriptions of these beneficial uses (CCRWQB, 1994).

3.3.3 Nutrients

Water quality values that will be used for comparison of observed nutrient concentrations in this project are taken from the following two sources:

1. The nitrate and phosphate values are from a study by San Jose State University and Merritt Smith Consulting (1994) that examined nutrient problems and sources in the Pajaro River and Llagas Creek, within the neighboring Pajaro River Watershed. The authors estimated nutrient objectives based on mean concentrations observed at relatively un-impacted sites for nitrate (NO_3^--N) to be 1.2 mg/L and for phosphate (PO_4^{3-}-P) to be 0.12 mg/L.

2. The unionized ammonia value is from the Central Coast Regional Water Quality Control Board Basin Plan (1994). This is a calculated value from total ammonia, pH, and temperature.

3.3.4 Pesticides

Of the currently used pesticides, two organophosphate pesticides, chlorpyrifos and diazinon, have been locally identified as being responsible for toxicity of crustaceans in a number of stream water samples (Siepmann & Finlayson, 2000; Hunt et al., 2003) and are present in biologically effective quantities in sediments and tissues (Kozlowski et al., 2004; Anderson et al., 2003; Hunt et al., 2003). For this reason, and because of an increased use in the study area, chlorpyrifos and diazinon are of primary interest.

Organophosphate and pyrethroid pesticides will be investigated at agricultural sites, the Tembladero Slough, and the wetland site. The LC_{50}, CMC, and CCC values for chlorpyrifos and diazinon are provided in Table 3.2. Two examples of pyrethroid pesticides used in Monterey County that are likely to show up in test results are provided in Table 3.3.

Table 3.2. LC50, Criterion Maximum Concentration and Criterion Continuous Concentration values for Chlorpyrifos and Diazinon.

	Rainbow trout 96-Hr LC_{50}	C. dubia 96-Hr LC_{50}	CMC	CCC
Chlorpyrifos	3 µg/L *	53 ppt**	0.02 µg/L ***	0.014 µg/L ***
Diazinon	16 mg/L *	320 ppt**	0.08 µg/L ***	0.05 µg/L ***

* Montgomery, 1997 ** Baily et al, 1997, ppt = parts per trillion *** Siepmann and Finlayson, 2000; 1 µg/L = 1 ppb, 1 mg/L = 1000 µg/L.

Observed organophosphate pesticide concentrations will be compared to LC50 values, Criterion Maximum Concentration (CMC), and Criterion Continuous Concentration (CCC) criteria whenever available and applicable. These criteria are explained in the following acute and chronic toxicity sections. Observed pyrethroid pesticide concentrations will be compared to available LC50 values (Table 3.3).

Table 3.3. LC50s for selected Pyrethroid Pesticides.

	Rainbow trout 48-Hr LC_{50}	Fathead Minnow 96-Hr LC_{50}	Daphnia Magna LC_{50}
Permethrin	5.4 µg/L *	--	.075 ppb**
Esfenvalerate	--	0.69 µg/L*	0.24 ppb**

*Montgomery, 1997 **DPR, 2004; 1 µg/L = 1 ppb

Acute Toxicity (Chlorpyrifos and Diazinon as examples)

Chlorpyrifos (O,O-diethyl-O-(3,4,6-trichloro-2-pyridinyl) phosphorothioate) and diazinon (O,O-diethyl-O-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate) are both organophosphate pesticides that are widely used in both agricultural and urban applications. Chlorpyrifos is a broad-spectrum organophosphate insecticide and diazinon is a nonsystemic organophosphate insecticide (EXTOXNET, 2002). They are used in the Salinas Valley on lettuce, artichokes, greenhouse transplants, strawberries, broccoli, cauliflower (chlorpyrifos), and outdoor flowers (diazinon). Common names for chlorpyrifos are Dursban and Lorsban and for diazinon are Basudin and Neocidol (Marshack, 2003).

Organophosphates work by interfering with the nervous system of insects, as well as mammals, birds, and fish. They block production of enzyme cholinesterase (ChE), which ensures that the chemical signal that causes a nerve impulse is halted at the appropriate time (Kegley, 1999).

Both chlorpyrifos and diazinon are considered moderately toxic (EXTOXNET, 2002). The LD50 and LC50 for a chemical is the lethal dose (LD) or lethal concentration (LC) that has been found in controlled experiments to kill 50% of a large number of test animals (LC50 is for aquatic organisms). The lower the LD50 or LC50, the more toxic the chemical. It is an acute toxicity test that refers to the immediate (hours to a few days) effects of a pesticide when the subject is exposed to a particular dose. Chlorpyrifos exhibits greater toxicity than diazinon. The data from a study designed to evaluate the joint acute toxicity of chlorpyrifos and diazinon suggest that chlorpyrifos (53 µg/L) may be 3 to 10 times more toxic than diazinon (320 µg/L) to the water flea *Ceriodaphnia dubia*, a frequently used test organism for LC50 determination (Bailey et al, 1997). The data from this joint acute toxicity study suggested that diazinon and chlorpyrifos also exhibit additive toxicity when present together. (Bailey et al, 1997).

The most commonly used guideline for toxicity in California for short-term exposure is the Criterion Maximum Concentration (CMC) (Siepmann & Finlayson, 2000). The CMC is the EPA national water quality criteria recommendation for the highest in-stream concentration of a toxicant or an effluent to which organisms can be exposed for a brief period of time without causing an acute effect (USEPA, 1991). It is calculated as a 1-hour average (Marshack, 2003) and is a concentration that should not be exceeded more than once every 3 years (Table 3.2). Since there are no criteria available for instantaneous maximum values of chlorpyrifos or diazinon (Marshack, 2003), the CMC will serve as the closest available criteria for comparison.

Chronic Toxicity (Chlorpyrifos and Diazinon as examples)

Chronic toxicity refers to the toxicity due to long-term or repeated exposure to a compound and results in the same effects as acute exposure including delayed symptoms. The guideline for longer-term exposure is the Criterion Continuous Concentration (CCC) (USEPA, 1991). The CCC is the 4-day average concentration of a pollutant in ambient water that should not be exceeded more than once every 3 years (Table 3.2).

Although concentrations will not be measured and averaged over any period of time for this project, it is still worthwhile to note whether measured values reach the CCC levels. If so, at least there is a chance they are being exceeded.

4 Project Description

The monitoring portion of this project, completed by CCoWS, will include data collection, analyses, and reporting as discussed in the following sections. Project constraints are also addressed and the schedule of deliverables is included.

4.1 Field measurements

4.1.1 Agricultural sites

At agricultural sites, monitoring will include both irrigation (dry-season) and storm-based field sampling (as appropriate to each site) for a minimum of 7 properties and 20 practices. Monitoring strategy will be site specific and will be dependent on the constituent/s and the practice design and function. Samples will be collected, as applicable, for nutrients, suspended solids concentration (SSC), pyrethroid and OP pesticides.

In addition, practices addressing problems with gullies may best be addressed with pre and post rainy-season land surveys rather than water sampling. Due to the sporadic nature of the formation of gullies, it is unlikely that the monitoring team would be present during the major events of formation. The potential load of sediment to nearby waterbodies that the practice prevents will be estimated via comparison to a previous gully event (taking into account variations in rainfall between different years).

4.1.2 Wetland site

Monitoring will include field measurements for pH and temperature. Samples will be collected for nutrients (total ammonia-nitrogen, orthophosphate, and nitrate-nitrogen), suspended sediment concentration (SSC), benthic macroinvertebrates (BMIs), pyrethroids and orthophosphate (OP) pesticides, and toxicity. Changes in water quality will be measured via a series of detailed sampling regimes with alteration of flow rate and water depth. Photo monitoring will track changes throughout the project and avian usage data will be collected.

4.2 Analysis methods and instruments

Nutrient, suspended sediment (SSC), turbidity, transparency, total dissolved solids, and BMI analyses will occur in the CCoWS laboratory. These methods are described in detail in the next Chapter, Quality Objectives & Criteria for Measurement Data. Pesticide samples will be sent to the CDFG SWAMP laboratory in Rancho Cordova for analysis using GC/MS. Toxicity samples will be hand-delivered to the U.C. Davis Department of Environmental Toxicology at the Granite

Canyon Marine Laboratory, south of Monterey, California. All project analysis methods and instruments are listed in Table 4.1.

Table 4.1. Analysis methods and instruments.

Constituent	Analysis method / instrument
Nitrate (NO_3^--N)	HACH DR 2500 Spectrophotometer; chromotropic acid method 10020 HR, AmVer Test 'N Tube (0.2 to 30 mg/L NO_3^--N)
Total Ammonia (NH_3-N)	HACH DR 2500 Spectrophotometer; salicylate method 10023 LR, AmVer Test 'N Tube (0.02 to 2.50 mg/L NH_3-N)
Orthophosphate (PO_4^{3-}-P)*	HACH DR 2500 Spectrophotometer; ascorbic acid method 8048, PhosVer 3; AmVer Test 'N Tube (0.06 to 5.0 mg/L PO_4^{3-})
pH	Oakton pH Testr 1
Temperature	Thermometer (Celsius)
Suspended sediment conc.	Vacuum filtration comparable to ASTM D 3977 - Based on Woodward and Foster (1997)
Turbidity	Hach Turbidimeter 2100P, SM2130B
Transparency	60cm Transparency Tube
Total Dissolved Solids	TDS Testr 4
BMIs	Adapted from Harrington & Born (2000)
Pesticides	CDFG using GC/MS; Organochlorines: EPA 8081; Pyrethroids: EPA 8081A; Organophosphates: EPA 8141A
Toxicity	UC Davis Granite Canyon Marine Laboratory. Water toxicity: *C. dubia* 7-day survival and reproduction; Sediment toxicity: *H. azteca* 10-day survival and growth

* HACH test method yields PO_4^{3-} values that will be converted to PO_4^{3-}-P for analysis and data display.

4.3 Analyses

At agricultural sites, both "above/below" and "before/after installation" methodologies will be considered (ie. above and below a sediment retention basin, for example). Physical measurements of gully sizes before practices are installed may be compared to gully sizes the next year.

At the wetland, analyses will include changes in constituent loads pre and post, both seasonally and based on hydraulic loading rate. BMI samples will be collected and analyzed from the Tembladero Slough and within the treatment wetland using Harrington and Born (2000) as guidance.

4.4 Reporting

The reporting of monitoring activities will include (from Agreement No. 03-193-553-0):

1) Final report that includes the results of all tasks and analyses, including the following narrative sections:
   a. A brief introduction section including a statement of purpose, the scope of the project, and a description of the approach and techniques used during the project.
   b. A list of the task deliverables previously submitted as outlined in the Schedule of Deliverable Due Dates.
   c. Any additional information that is deemed appropriate by the Contractor's Project Representative.
   d. Indicate whether the objectives of the project have been met. Include information collected in accordance with the project monitoring and reporting ("assessment and evaluation") plan, including a determination of the effectiveness of the agricultural management practices or management measures implemented as part of the project in preventing or reducing non-point source pollution.
2) Electronic water quality database containing all water quality data collected.
3) Collection of photos from photo monitoring of agricultural practices and wetland development.
4) Poster map of the Gabilan Watershed showing the location of the constructed wetland and the approximate locations of agricultural practices (subject to any applicable grower confidentiality and anonymity requirements).

4.5 Constraints

A constraint on the wetland portion of this project is time. It may take many years for wetland plant community establishment, nutrient retention and wildlife enhancement to reach optimal functioning, or "maturation" (Mitsch & Gosselink, 1993).

In general, monitoring runs are also constrained by factors such as the timing of rainfall events, personnel availability and accessibility to sample sites. These will be evaluated on a case-by-case basis.

4.6 Project Schedule of Deliverables

Table 4.2 lists the project deliverable due dates as they appear in SWRCB Agreement No. 03-193-553-1 with San Jose State University Foundation. These dates reflect the project extension which has been granted through March 13, 2007.

Table 4.2. Schedule of Deliverables.

TASK	SUB-TASK	DELIVERABLE	GROUP	DUE DATE
1.0		PROJECT ADMINISTRATION	MLML – lead SJSUF – support	
	1.2	Progress Reports		6/10/04 and quarterly thereafter
	1.5	Contract Summary Form		03/10/05
	1.6	Subcontractor Documentation		06/10/05 and quarterly thereafter
	1.7	Expenditure/invoice projections		09/10/05 and every 6 months thereafter
	1.8	Project Survey Form		03/01/07
2.0		CEQA/NEPA DOCUMENTATION AND PERMITS	MLML	
	2.1	CEQA/NEPA Documentation		12/10/05
	2.2	Permits		12/10/05
3.0		QUALITY ASSURANCE PROJECT PLAN	CCoWS	
	3.1	Approved and signed QAPP		06/10/05
4.0		PROJECT ASSESSMENT AND EVALUATION PLAN	CCoWS	
	4.1	Project Assessment and Evaluation Plan		09/10/05
5.0		IMPLEMENTATION OF AGRICULTURAL Practices		
	5.1.3	Signed landowner agreements	RCD – Lead CAFF – Support	09/10/05 and quarterly thereafter
	5.2.2	Engineering and/or Conservation Design Plans	RCD – Lead CAFF – Support	09/10/05 and as developed thereafter
	5.3.2	List of native plants propagated	RON	09/10/05 and quarterly thereafter
6.0		WETLANDS/RIPARIAN RESTORATION		
	6.1.2	Signed landowner agreements.	MLML	03/10/05 and quarterly thereafter
	6.2.2	Restoration project design plans	MLML	06/10/05 and as developed thereafter
	6.3.2	List of native plants propagated	CC&R	06/10/05 and quarterly thereafter
	6.5.1	Notification letter	MLML	12/10/05
7.0		MONITORING	CCoWS	
	7.1.1	Monitoring plan		06/10/05
	7.2.2	Database of all Water Quality Measurements		03/10/06
	7.2.3	Poster Map		03/10/06
	7.3.1	Photos of restoration sites		06/10/05 and quarterly thereafter
	7.4.2	Bird survey data		06/10/05 and quarterly thereafter
	7.5	Benthic Macro Invertebrate data		06/10/05 and quarterly thereafter
8.0		DRAFT AND FINAL REPORT	CCoWS	
	8.2	Draft Project Report		01/10/07
	8.3	Final Project Report		03/01/07

5 Quality Objectives & Criteria for Measurement Data

The following sections describe the data quality objectives (DQOs) for field measurements, sample collection and analysis. All DQOs will comply with SWAMP requirements and/or suggestions.

5.1 Field measurement DQOs for temperature and pH

Water quality measurements made in the field will be for temperature and pH. Temperature will be measured with a thermometer (in °C) and pH will be measured with an Oakton pH Testr 1 (table 5.1). To ensure precision, the first pH and temperature measurements of each sample run will be duplicated three times.

Table 5.1. Temperature and pH DQOs. There is no SWAMP requirement for precision for these parameters; however, the suggested values will be used.

Parameter	Method	Resolution	Accuracy	SWAMP Suggested Precision
Temperature	Thermometer	±0.5°C	±0.5°C	±0.5°C
pH	Oakton pH Testr 1 (Range: 1.0–15.0)	0.1 units	±0.2 units	±0.5 units

5.2 Nutrient DQOs

During sample collection, field duplicates will be taken to define the precision of the samples at representing the water body. Duplicates will be collected at 5% of samples with at least one per sample run.

In the laboratory, standard solutions, reagent or method blanks, bottle blanks, replicates, and spikes will be run with the samples to assess the accuracy and precision of the laboratory method and techniques. Dissolved nutrients will be analyzed using a HACH Odyssey DR/2500 Spectrophotometer. All analysis is done according the manufacturer's instructions and

specifications for each individual analysis. Each sample run is documented on a *Nutrient QC Evaluation Form* (Appendix F).

The accuracy of the spectrophotometer will be checked against standard solutions of known concentrations. These standards are obtained from HACH and include a low range, middle range, and high range concentration. Accuracy will be assessed by the percent error between the known concentration of the standard, and the reading or measured value from the spectrophotometer. The acceptable % error for each method is presented in Table 5.2.

$$\% \text{ Error} = |(\text{measured value} - \text{standard value}) / \text{standard value}|$$

The manual for the spectrophotometer suggests running reagent blanks (or method blanks) to compensate for the contribution of the reagents to the final reading. The procedure is performed with RO (water purified by reverse osmosis) water in place of the sample. The reading of this RO water is then recorded on the *Nutrient QC Evaluation Form* and zeroed out of the instrument.

The bottle blank consists of RO water in a re-used, cleaned, and acid washed sample bottle. To ensure no contamination from the sample bottle, method blanks must not detect any nutrients.

One sample is chosen as the QC sample, and will be used for the replicate and spikes. This is random, simply by choosing a sample that has enough water to complete all of the necessary tests, without knowing where it came from. At least one replicate will be run, or 5% of samples, which ever is greater, to ensure precision. Calculating the % difference between the replicates will assess precision:

$$\% \text{ Difference} = |(\text{replicate 1} - \text{replicate 2}) / \text{average of replicates}|$$

Sample spikes will ensure the accuracy of laboratory results. At least one sample spike will be conducted per sample run. Sample spikes are made with a 1:1 ratio of the QC sample and standard solution. The percent recovery from this spike will be used to assess the accuracy of the method and technique:

$$\% \text{ Recovery} = (\text{measured spike value} / \text{expected spike value}) * 100$$

where the expected spike value is the average of the sample value and standard concentration.

Table 5.2 illustrates the HACH nutrient analysis methods employed by CCoWS, the SWAMP DQO requirements for precision and spike recovery and the completeness goals that will be utilized in this project.

Table 5.2. DQOs for nutrient analyses. There are no SWAMP requirements for completeness; however, the suggested values will be used.

Analysis	Method	Resolution	Accuracy of the Method (95% Conf. Limits of Distribution)	SWAMP Precision Requirement	SWAMP Recovery Requirement	Acceptable % Error for Standards
Total Ammonia-Nitrogen (NH_3-N)	HACH Method 10023 LR	0.02 - 2.50 mg/L	0.96-1.04 mg/L for a 1.00 mg/L standard	Laboratory replicate within ±25%	Matrix Spike 80% - 120%	4%
Ortho-phosphate (PO_4^{3-})	HACH Method 8048	0.06 - 5.00 mg/L	2.89-3.11 mg/L for a 3.00 mg/L standard	Laboratory replicate within ±25%	Matrix Spike 80% - 120%	4%
Nitrate-Nitrogen (NO_3^--N)	HACH Method 10020 HR	0.2 - 30.0 mg/L	9.5-10.5 mg/L for a 10.0 mg/L standard	Laboratory replicate within ±25%	Matrix Spike 80% - 120%	10% 20% for lowest standard

5.3 SSC DQOs

Table 5.3 lists the method and resolution for suspended sediment concentrations. A field duplicate sample will be taken to define the precision of the samples at representing the water body. Laboratory accuracy and precision cannot be determined for each sample run due to the destruction of the sample during analysis (no possible replicate or spike). However, in order to assess the accuracy and precision of CCoWS lab analysis of suspended sediment concentration (SSC) a recovery experiment was conducted in January 2003. The objective of the experiment was to measure the ability to recover both sand and silt/clay from SSC samples using CCoWS established laboratory procedures. The experiment also shows how the concentration of SS affects accuracy.

Known amounts of sediment were added to water and then measured via vacuum filtration. The estimated error of the results was dependent upon the mass and volume of the sample. The error associated with a large sample (approximately one liter) with highly concentrated sediment was approximately 2%. Accuracy decreased with small sample sizes (approximately 1/4 liter) or smaller suspended sediment concentrations. Small samples with small sediment concentrations can have errors near 100%. This large error in "clean" samples is not viewed as

a problem, because a 100% error in small sediment concentrations has little affect on estimated loads. Furthermore, most samples taken are large enough (0.5 L) and "dirty" enough to keep errors low.

Table 5.3. SSC, turbidity, tds and BMI DQOs. There are no SWAMP requirements for accuracy and precision for these analyses; however, the suggested values will be used.

Analysis	Method	Resolution	SWAMP Suggested Accuracy	SWAMP Suggested Precision
Suspended Sediment Concentration	Vacuum filtration comparable to ASTM D 3977 – Based on Woodward and Foster (1997)	±2% in concentrated samples	None given	None given
Turbidity	HACH 2100P portable turbidimeter, SM2130B	0.01–1000 NTU	±10% or 0.1, whichever is greater	±10% or 0.1, whichever is greater
TDS	TDS Testr 4	0 – 19.90 mS	±10%	±10%
BMIs	Adapted from Harrington and Born (2000)	N/A	±5%	±5%

5.4 Turbidity DQOs

Turbidity samples are analyzed using a HACH 2100P portable turbidimeter, SM2130B. Turbidity is measured on every SSC sample, therefore, the field duplicate for SSC will also serve as the field duplicate for turbidity. One sample will also be randomly chosen to be replicated three times in the laboratory. Please see Table 5.3 for DQOs.

5.5 BMI DQOs

BMI samples will be analyzed in the CCoWS laboratory via methods adapted from Harrington and Born (2000) (see section 11.4). Internal bioassessment validation (for accuracy and precision) will be conducted by another staff person completing re-identification on 100% of samples until accuracy and precision are within ±5% difference, and then on 20% of samples. Bioassessment validation will also be conducted externally on one out of every six samples (one

per run) by an independent laboratory, Aquatic Biology Associates (ABA, Inc.), located in Corvallis, Oregon.

5.6 Pesticide DQOs

Samples collected by CCoWS will be sent to the CDFG Water Pollution Control Laboratory in Rancho Cordova for Gas Chromatography with a Mass Spectrometer (GC/MS). This is the lead SWAMP laboratory. Tables 5.4, 5.5, and 5.56 list the Minimum Detection Limits (MDL), Target Reporting Limits (TRL), and recovery percentages for the analyses that will be utilized.

Table 5.4. DQOs for Organochlorines. Source: CDFG WPCL Rancho Cordova.

Analysis/EPA Method #	MDL	TRL	Recovery
Organochlorines 8081A	Weight corrected	Weight corrected	%
Sediment Sample - 50% moisture	ng/g (ppb)	ng/g (ppb)	
Aldrin	0.52	2.0	50-150
Chlordane, cis	1.43	2.0	50-150
Chlordane, trans	0.81	2.0	50-150
Chlordene, alpha	0.55	1.0	50-150
Chlordene, gamma	0.51	1.0	50-150
Chlorpyrifos	1.67	2.0	50-150
Dacthal	1.26	2.0	50-150
DCBP, p,p'	1.6	2.0	50-150
DDD, o,p'	1.54	2.0	50-150
DDD, p,p'	1.8	2.0	50-150
DDE, o,p'	1.34	4.0	50-150
DDE, p,p'	1.15	4.0	50-150
DDMU, p,p'	2.41	6.0	50-150
DDT, o,p'	2.03	6.0	50-150
DDT, p,p'	4.94	10.0	50-150
Diazinon	13.52	40.0	50-150
Dieldrin	0.84	1.0	50-150
Endosulfin I	2.16	4.0	50-150
Endosulfin II	5.44	10.0	50-150
Endosulfan sulfate	5.44	10.0	50-150
Endrin	1.88	4.0	50-150
HCH, alpha	0.95	1.0	50-150
HCH, beta	1.23	2.0	50-150
HCH, delta	0.72	4.0	50-150
HCH, gamma	0.68	1.0	50-150
Heptachlor	1.03	2.0	50-150
Heptachlor epoxide	1.01	2.0	50-150
Hexachlorobenzene	0.22	0.6	50-150
Methoxychlor	2.96	6.0	50-150
Mirex	1.89	3.0	50-150
Nonachlor, cis	1.96	2.0	50-150
Nonachlor, trans	0.78	2.0	50-150
Oxadiazon	1.87	2.0	50-150
Oxychlordane	0.74	2.0	50-150
Parathion, ethyl	1.68	4.0	50-150
Parathion, methyl	3.04	8.0	50-150
Tedion	1.47	4.0	50-150

Table 5.5. DQOs for Organophosphate Pesticides. Source: CDFG WPCL Rancho Cordova.

Analysis/EPA Method #	MDL	TRL	Recovery
Organophosphates 8141A	(µg/L)	(µg/L)	%
Aspon	0.03	0.05	85-105
Azinphos ethyl	0.03	0.05	95-110
Azinphos methyl	0.03	0.05	50-90
Bolstar (Sulprofos)	0.03	0.05	80-95
Carbophenothion	0.03	0.05	90-100
Chlorfenvinphos	0.03	0.05	80-100
Chlorpyrifos	0.02	0.05	80-100
Chlorpyrifos methyl	0.02	0.05	95-110
Ciodrin (Crotoxyphos)	0.03	0.05	90-110
Coumaphos	0.04	0.05	50-90
Demeton (Total)	0.04	0.05	30-80
Diazinon	0.01	0.02	95-110
Dichlofenthion	0.03	0.05	95-105
Dichlorvos	0.03	0.05	85-105
Dicrotophos	0.03	0.05	20-70
Dimethoate	0.03	0.05	90-100
Dioxathion	0.03	0.05	50-90
Disulfoton	0.10	0.05	80-95
Ethion	0.02	0.05	80-105
Ethoprop	0.03	0.05	80-100
Famphur	0.03	0.05	90-105
Fenchlorphos (Ronnel)	0.03	0.05	90-105
Fenitrothion	0.03	0.05	90-110
Fensulfothion	0.03	0.05	40-80
Fenthion	0.03	0.05	80-100
Fonofos (Dyfonate)	0.02	0.05	85-110
Leptophos	0.03	0.05	80-110
Malathion	0.03	0.05	95-105
Merphos	0.03	0.05	85-110
Methidathion	0.03	0.05	95-105
Mevinphos (Phosdrin)	0.03	0.05	80-90
Molinate	0.10	0.20	65-100
Naled (Dibrom)	0.03	0.05	40-80
Parathion, ethyl	0.03	0.05	85-110
Parathion, methyl	0.01	0.05	90-105
Phorate	0.03	0.05	80-95
Phosmet	0.03	0.05	80-100
Phosphamidon	0.03	0.05	85-100
Sulfotep	0.03	0.05	95-110
Terbufos	0.03	0.05	85-100
Tetrachlorvinphos	0.03	0.05	85-105
Thiobencarb	0.10	0.20	90-110
Thionazin	0.04	0.05	95-110
Tokuthion	0.03	0.05	85-105
Trichlorfon	0.03	0.05	90-115
Trichloronate	0.03	0.05	80-105
Triphenyl phosphate (surrogate)	0.03	0.05	90-105

Table 5.6. DQOs for Pyrethroids. Source: CDFG WPCL Rancho Cordova.

Analysis/EPA Method #	MDL	TRL	Recovery
Pyrethroids 8081	(ng/L)	(ng/L)	%
Bifenthrin	1.16	5	75-125
Cyfluthrin	3.99	5	75-125
Cypermethrin	5.46	10	75-125
Esfenvalerate/fenvalerate	1.19	5	75-125
Lambda-cyhalothrin	1.99	5	75-125
Permethrin	2.32	20	75-125

5.7 Toxicity DQOs

Toxicity analyses will be completed by the Marine Pollution Studies Laboratory of University California Davis at Granite Canyon. Samples will be immediately dropped off after collection. We retrieved Granite Canyon's data acceptability criteria for toxicity testing from the SWRCB website (SWRCB. Data acceptability criteria for toxicity testing samples.). See Table 5.7.

Table 5.7. Toxicity DQOs.

Analysis	Method	Acceptability Criteria
Water Toxicity	*C. dubia* 7-day survival and reproduction	Control water survival ≥80% with surviving females averaging 15 neonates and 60% having 3 or more broods Reference Toxicant Test LC50 and EC50 within 2 SD of the mean
Sediment Toxicity	*Hyalella azteca* 10-day survival and growth	Control water survival ≥80% with measurable growth. Reference Toxicant Test LC50 and EC50 within 2 SD of the mean

5.8 Completeness, representativeness and comparability

Completeness will be defined at the ratio of usable data or samples to the total amount collected.

$$C = 1 - (\#\text{ failing acceptability criteria} / \text{total } \#\text{ collected}) * 100$$

Failures = Holding time violations, laboratory errors, samples spilled or broken, equipment not calibrated properly, or quality control violations.

The objective for completeness in this project for all parameters is the SWAMP suggested level of 90%.

Representativeness is the extent to which measurements actually represent the true environmental condition of a waterbody (EPA, 1996). When CCoWS does storm sampling, multiple efforts are expended to capture the pre and post storm water conditions. In addition, sampling happens multiple times during the event to identify the peak discharge. A detailed hydrograph is then constructed to calculate the total load of measured constituents that moved through the sampling location during the storm event. Field duplicates show if any variability exists between samples taken in the same location at the same time.

"Comparability is the degree to which data can be compared directly to similar studies" (USEPA, 1996). Since the data in this study will be assessed against SWAMP QA/QC requirements in order to be used in analyses, it will be comparable to other studies also adhering to SWAMP guidelines. Field sampling and laboratory methods used in this study are also based on common practice in environmental science, such as is documented in the *Standard Methods for the Examination of Water and Wastewater* (APHA, 1998). Data and results, therefore, should be comparable to similar studies that have been performed.

6 Training Needs

All personnel and students participating in fieldwork and/or laboratory analyses will need to be trained in the tasks they will assist with, if they were not trained prior to this project. The following sections discuss potential laboratory and field training needs.

6.1 Laboratory training

Staff training on laboratory safety procedures is provided by the Department of Science and Environmental Policy (DSEP) laboratory staff at CSU Monterey Bay and is a requirement prior to laboratory use. It is CCoWS responsibility to assure that all technicians performing laboratory work have attended a safety training session.

The laboratory manager or a senior technician will oversee laboratory analyses and technicians will be knowledgeable of all equipment and tests before analyzing samples independently. This will include both training with the laboratory manager and/or an experienced technician as well as the study of instrument and procedure manuals.

Training in nutrient, BMI, SSC and turbidity analyses may be required.

6.2 Field training

The monitoring manager will oversee field activities and staff training for field procedures. The monitoring manager or a senior technician is responsible for safety in the field and staff and students will not undertake any field activity without prior training. Some field tasks that may require training include:

- Field notes and observations
- Measuring discharge (Q)
- Using the crane bridge sampler
- Survey techniques (ie. total station or tape & brunton)
- Nutrient, SSC, pesticide, toxicity and BMI sampling
- Labeling and sample preservation
- Quality assurance procedures

For toxicity sample collection, Granite Canyon Laboratory staff will provide CCoWS staff with field training immediately prior to the first collection.

6.3 Training documentation

Documentation of lab safety training is kept on file by the Department of Science and Environmental Policy (DSEP) laboratory staff. All training by CCoWS (field and laboratory) will be documented on a *Technician Training Tracking Sheet* (Appendix B), and kept on file at the Watershed Institute. Accidents and incidents will be reported to the lab manager and the DSEP lab director and documented on the *Accident/Incident Report Form* (Appendix C).

7 Documents & Records

The monitoring manager is responsible for maintaining all reports and records. All data collected as part of this project shall be added to the CCoWS master water quality Access database and backed up to CD. A new master version of the MS Access database file shall be copied and renamed each time modifications are made. The data file names shall contain the last date on which they were significantly modified (in the format Name_YYMMDD_initials of user.*).

Copies of the QAPP will be distributed as described in Chapter 1. Any future versions will also be distributed to this group. All versions of the QAPP that are distributed will be maintained on the CCoWS main server and backed up on CD.

All grant required monitoring deliverables will be passed on to the State Board Contract Manager, Amanda Bern, at project completion. Copies of all documents, records and all original field books and laboratory data will be maintained permanently at CCoWS. Requests for access to information archives should be made to Fred Watson or Kelleen Harris.

Group B: Data Generation & Acquisition

8 Sampling Process Design

Sample collection points and explanations for selection are described further in the project Monitoring Plan, along with site photos where available.

In brief, sample points will be selected at agricultural sites before and after management practices. For example, sampling will occur at the inlet and outlet of a retention basin or top and bottom of a grassed waterway. At the Wetland site, sample points will be located at the inlet and outlet of each of the two sections.

Three bridges upstream of the Wetland site were considered for sampling to characterize loads in the Tembladero Slough delivered from the Gabilan watershed: Molera road, Preston road and Haro road. Haro road (CCoWS site code TEM-HAR), which runs parallel to Highway 156, was selected due to several desirable characteristics. This location is far enough upstream that tidal effects, evident at the Molera road bridge, are dampened. Haro road is also removed from potential influences of the Old Salinas River Channel at its confluence with the Tembladero Slough. There is ample roadside space to use a crucial piece of equipment for collecting flow data, a USGS Type AA Crane (see section 9.4.2). Finally, it is the safest location for the sampling team to conduct storm monitoring, which often occurs during the night, due to lack of traffic and proximity to the city of Castroville.

9 Sampling & Data Collection Methods

The following sections outline general sampling methods and protocols that will be used by CCoWS to ensure consistency in collection of field data and samples. The following areas are addressed:

- Site preparation
- Field notes
- Field measurements: pH and temperature
- Flow measurements (Q)
- Sample collection

9.1 Site preparation

Once agricultural sites are determined several generalized tasks are performed. The Monitoring manager and the Research Technician will make a site visit to learn about the practices that are being implemented and determine which type of sampling regime will best evaluate their effectiveness. The practices will be photo documented and the general land use described. If irrigation events will be evaluated, the baseline levels of nutrients in the source water will be determined. It may also be necessary to install staff plates in sediment retention basins or survey sections of the property.

9.2 Field notes

A record of each field visit shall be made in a numbered Rite-in-the-Rain field book. The following information will be included:

- Names of field party
- Date and time of visit, using AM/PM notation or military time (to reduce possible ambiguity)
- CCoWS site code (specific ag sites will not be identified)
- Site observations and notes, including descriptions of relevant water conditions and weather at the time of sample collection
- Present and recent weather conditions
- Type of sample/s collected
- Sample collection or measurement time
- Instrument type and ID
- Method of collection (e.g. “direct” or “grab” samples)
- Description of any unusual occurrences associated with the sampling event, particularly those that may affect sample or data quality

For wetland/Tembladero Slough visits, the following additional information shall also be recorded:

- Stage at arrival, before and after Q measurements
- Presence of wildlife within or near the wetland area

A sample field book entry is presented in Appendix E.

9.3 Field measurements: temperature and pH

During sample collection, pH and temperature will be taken directly in water flows. The one exception to this is the Tembladero Slough, where a bucket will be lowered from bridge locations to collect water. This allows moving water from the center of the flow to be measured, which is more well-mixed and representative of the entire body of water than if measurements were taken from the bank.

9.4 Flow measurements (Q)

A number of techniques for flow (discharge) measurement may be used, depending on the nature of the flow. Protocols for each technique are described below, organized by whether they will be used at agricultural sites or at the wetland site. In all cases, the method of measurement used will be recorded.

9.4.1 Agricultural sites

Calibrated bucket

A 5-gallon bucket may be used to measure discharge from flows falling over a vertical drop under which the bucket can be placed. The bucket should be marked on the inside surface at 1 liter intervals (by pouring twenty 1-liter water samples into it before the sample run). A stopwatch will be used to determine the time to fill the container. Care should be taken to record the exact duration and volume of each sample. The longer the duration, the more accurate the measurement will be. Smaller flows with small vertical drops may be measured using a calibrated jug.

Rapid filling bucket

Where flows are so great as to overtop a bucket or jug in less than 2 seconds, at least 5 repeated measurements of the time taken to fill the bucket completely should be made. Estimates made in this way are relatively inaccurate, but repetition minimizes this error.

Rapid filling bin

Flows overtopping a bucket or jug in less than half a second may be measured using a 20-gallon bin. If the bin is overtopped in less than half a second, the bin may be placed successively under separate parts of the flow. At least 5 repeated measurements will be made when using this method. Estimates made in this way are relatively inaccurate and therefore only used lacking other options.

9.4.2 Wetland & Tembladero Slough

Pump adjustment & Calibrated bucket

Flows entering and exiting the Wetland will be controlled by adjusting the pump and/or inlet/outlet valves. The accuracy of these settings can be easily verified using the calibrated bucket method previously discussed for usage with agricultural flows.

Cross section with Crane

A Crane with Four-Wheel Truck (Model 4350, purchased from Rickly Hydrological Company) will be the primary method used to measure flow in the Tembladero Slough. It is too deep and the sediment too soft to wade into with a handheld current meter, even during low flows. The crane suspends a fish with a USGS AA-MH Model 6215 current meter or a DH-76 suspended sediment sampler (Figure 9.1).

Figure 9.1. Cross section with crane. Photo: Joy Larson, February 26, 2004.

The current meter that will be used is a larger version of the standard pygmy meter used for small streams in the US. Other than the size and number of cones, the device is the same. Six stainless steel cones are mounted on arms extending from a vertical axle with pointed ends mounted within a precision smooth conical bearing. This meter is sensitive to very slow flow that often occurs in the lower Tembladero Slough but also works well in fast flow.

The following steps will be taken when measuring discharge in the Tembladero Slough:

- Determine that no dangerous debris is likely to enter the site. One team member should serve as a spotter for any debris moving downstream.
- Stretch a tape measure across the downstream side of the bridge, meter side facing up.
- Draw up in a table in the field book with columns for 'offset', 'depth', and 'velocity' (Appendix E).
- Record the times of commencement and completion of measurements, and the stage at those times.
- One person will record while the other operates the crane.
- Where time permits, even cross-sectional measurement intervals will be used, and at least 20 velocity measurements will be taken across the width of the slough. When time is scarce, an uneven measurement interval may be used, with most measurements taken at points of rapid change in velocity, and at points of high velocity and/or high depth.
- For high flows, set the computer to take a 'count' every 5 seconds; for slow flows every 1 second, and record this in the field book.
- Record the offset from zero on the tape where the free water surface begins on the right bank when looking downstream (normally protocol calls for starting on the left bank, however, right bank works better at this site).
- Take velocity measurements across the width of the Slough until the opposite bank is reached, and record the point where the free water surface ends.

Each velocity measurement will be taken as follows:

- Set the point where the bottom of the fish barely touches the water's surface as zero depth on the depth reader.
- Gently lower the fish with the current meter to the bed to record the depth.
- Position the fish at the depth indicated on the depth chart (60% of depth) for the velocity measurement to be taken.
- The time for each measurement is 60 seconds if time allows, and 30 seconds if time is limited. The measurement time used must be recorded.
- Record the amount of 'counts' reported by the computer in the field book.

The discharge will be estimated using a Microsoft Excel spreadsheet as follows:

- Enter the discharge table from the field book into the spreadsheet.
- Equations in the spreadsheet assign each velocity measurement a representative width, calculated as the difference in offset between the halfway points to adjacent measurement points on either side of the point at which the velocity was measured.
- The flow rate for each measurement point will be the product of the velocity and the representative width.
- The total stream flow rate will be the sum of the flows for all measurement points.

Rating curve

Using the flow measurements collected at TEM-HAR, a rating curve will be constructed. This will be useful to establish so that discharge can be determined during outings limited by personnel availability, time or safety issues. The rating curve will not be used to determine flows not represented in its data set.

The stage-discharge 'rating' curve will be hand-fitted to the discharge data where applicable (i.e. where enough points have been collected for a reliable curve). This curve is of the form:

$$Discharge = Scale \times (Stage + Offset)^{Power}$$

Where *Scale*, *Offset* and *Power* are parameters that will be fitted for each site (Larson & Watson, 2004).

Because individual measurement errors are likely to be smoothed by the curve we make the assumption that discharge estimates based on the curve are more accurate than actual measurements. This practice is also effectively followed by the USGS (although the USGS uses a more complex rating curve). In the case that a discharge-curve is not applicable to a particular monitoring run, then interpolation over time will be used to estimate total discharge based on individual discharge measurements. Discharge estimates (m^3/s) will be multiplied by the concentration of the constituent of interest (mg/L) to calculate the instantaneous constituent load (g/s). These data may then be extrapolated to infer a longer time series (ie. seasonal or annual loads).

Estimation based on surface velocity and depth

If measuring flow with the flow meter is impossible due to lack of sufficient personnel or safety issues, and the stage is one that is not represented by the rating curve (i.e. a previously unmeasured stage), an estimation of flow may be made based on measuring

the surface velocity. In many natural channels, the mean velocity of a stream at a given point across its width is 85% of the surface velocity at that point (Gordon, McMahon, & Finlayson, 1992). Bright, biodegradable floating objects such as a fluorescent wooden dowels or orange peels may be used to estimate the surface velocity by measuring the time taken for the object to traverse under the bridge and the measured width of the bridge. The velocity at three points across the width of the stream should be measured. In this case, the flow rate (m^3/s) shall be estimated as the sum of the products of the width represented by each surface velocity measurement, the depth of the water at each measurement, and 85% of the surface velocity. Depth can be estimated by lowering down a tape measure with a lead ball attached to its end.

9.5 Sample collection

The following sections cover sample collection for nutrients, suspended sediment, pesticides, toxicity and BMIs.

9.5.1 Nutrient samples

Nutrient samples will be collected in 125 mL plastic bottles. These are cleaned with Liquinox and acid washed between uses. Nutrient samples will be taken as grab samples directly from just below the surface of the water body. These will be taken in the Tembladero Slough and wetland with a sampling pole into the approximate center of the flow, and by hand at agricultural sites.

When sampling for nutrients, the following methods apply:

- Use sample bottles that have been cleaned in Liquinox phosphate free detergent and acid rinsed.
- Rinse sample bottle & cap in sample water 3 times prior to taking sample.
- Technicians wear latex gloves to prevent contamination of the sampling container and for health safety.
- Insert the sample bottle just below the water surface with the mouth of the bottle facing upstream & fill bottle. Take caution not to disturb bottom sediment.
- Temperature and pH will be measured at the time of sample collection with a thermometer and an Oakton pH Testr 1.
- Samples will be stored in a cooler with ice packs for return to the laboratory.

9.5.2 SSC samples

This section describes field-monitoring protocol for collecting a suspended sediment sample in the Tembladero Slough, at the wetland and at agricultural sites.

Tembladero Slough

Depending on the magnitude of flow, the concentration of suspended sediment can range from well mixed to a vertically and horizontally stratified solution. To ensure that an accurate representation of the Slough water column is collected, a depth-integrated sample using a DH-76 sampler suspended from the Haro Road bridge with a crane will be taken. A DH-76 is similar to a DH-48, but is much larger and heavier. It is attached to end of the sounding line in the same manner as the current meter/fish and hanger bar (Figure 9.2).

Figure 9.2. DH-76 sampler suspended from bridge crane. Photo: Joy Larson, February 26, 2004.

This sample should be taken from several evenly spaced stations along a transect utilizing the same motion each time. Depending on time constraints, a single sample may be taken in the thalweg, or the deepest portion of the stream channel. The DH-76 should be lowered into and raised out of the water at equal rates. This requires rapid cranking of the sounding reel as the water is usually very deep and the sample bottle fills quickly. Special care should be taken not to fill the bottle entirely, which would result in incomplete depth integration, and not to disturb sediment on the channel bottom.

Agricultural sites

At agricultural sites where a taking depth-integrated sample is often impossible due to shallow flows or flow exiting from a pipe, a surface water sample or 'grab' is collected. Grab samples are taken by simply inserting the sample bottle into the water column in a

quick downward motion with the mouth of the bottle facing 'upstream'. A quick downward motion will facilitate the collection of a relatively integrated sample, rather than only water from the surface. Once again, special caution should be taken not to disturb bottom sediment (if present).

9.5.3 BMI samples

Dissolved oxygen, temperature, salinity and pH will be collected with BMI samples. The BMI sample collection methods that will be employed are heavily altered from Harrington and Born (2000), although the text was carefully reviewed and will be followed where applicable and possible.

Modifications to Harrington and Born

Typically, an individual riffle, or riffles within a defined reach of stream, would be the sampling unit for collecting BMIs. These riffles are used because they are the richest habitat. However, riffle areas are not present in the Tembladero slough. The water depth at the sampling location (Molera Rd) is also not safe for wading. Although water is always present, flow is often not evident. The bottom material is very soft sediment (silts and clays), not the cobbles the Harrington and Born collection method was based on.

Since the Tembladero Slough is a different physical habitat than where Harrington and Born was designed, and essentially unwadable, the following adaptations will be made to the California Stream Bioassessment Procedure:

- Monitoring will cover 100 meters of the Tembladero Slough from the Molera Road Bridge to the Old Salinas River confluence, and the wetland, not the entire watershed. This is based on surrounding lands being private property, and the need for continued future access to the sites.
- Since no riffles are present, transects will be selected by laying down a measuring tape and selecting three numbers from a random number table.
- Samples will be retrieved using a bottom sled with net (figure 9.3). Harrington and Born's protocol of disturbing a $2ft^2$ area into a net cannot be used for two reasons:
    1) the water is almost always too deep to safely wade into at Molera Rd bridge.
    2) there is a high liklihood of getting stuck in the deep mud.
- The Habitat Assessment Worksheet will be completed during each collection.

Tembladero Slough sampling methods

Three random transects will be selected each time using a random number table. Samples will still be collected via one complete transect, utilizing a sled with 500 µm net (figure 9.3), instead of separate collections using a D-net. Transects will go from the right bank to left bank, starting with the most downstream location. Samples will be rinsed into collection jars and immediately brought back to the lab to remove fine silts and preserve in 100% ethyl alcohol until sorting.

Figure 9.3. BMI sampling sled. Photo: Kelleen Harris, May 17, 2005.

Wetland sampling methods

In the wetland, three random transects will be selected each time using a random number table. Harrington and Born's protocol of working upstream will be followed. The most downstream transect will be sampled first, working "upstream" to avoid any disturbance to other sites prior to sample collection. Samples will be rinsed into collection jars and immediately brought back to the lab to remove fine silts and preserve in 100% ethyl alcohol until sorting.

Since the wetland is not finished, the collection method may need to be altered based on the vegetation patterns that develop. If the vegetation is too thick for a transect with the sled, a D-net or benthic claw may be used.

9.5.4 Pesticide samples

Water samples will be collected via a grab sample from the middle of the flow, a few centimeters below the surface, into an amber glass bottle. Duplicate water samples will be obtained in the same manner.

Bottom sediment samples will be collected to 2 cm depth using a sediment sampling dredge, a benthic claw, or a Teflon sampling scoop, and then placed into a stainless

steel bowl and mixed with a stainless steel spoon. An aliquot of this mixture will be placed into the collection jar. Duplicates will be obtained from the same mixture. All equipment is cleaned thoroughly with Liquinox and rinsed with de-ionized water between samples to avoid cross contamination.

Samples will be placed in a cooler with ice packs and transported to the CCoWS laboratory, where they will be immediately shipped to the CDFG Laboratory for analysis.

9.5.5 Toxicity Samples

Water samples for toxicity will be collected as grab samples from just below the surface into 2.25 L amber glass bottles. Sediment samples will be collected with Poly carbonate cores. Granite Canyon laboratory will supply the bottles and the ice chest for transport. Samples will be packed with ice packs for immediate transport to Granite Canyon Laboratory.

Water quality measurements at the time of sampling will include dissolved oxygen, pH, and conductivity. A water sample will be collected for ammonia analysis at Granite Canyon. TIEs will not be conducted in association with the toxicity samples.

10 Sample Handling & Custody

10.1 Protocol for sample preparation and management

The following sections describe how each type of sample will be handled.

Information about the collection containers used, initial field preservation, and holding times are listed in Table 10.1.

10.1.1 BMI samples

Samples will be transported to the laboratory in a carrying case or cooler to prevent breakage. The BMI tracking worksheet (Appendix G) will be filled out upon arrival to the laboratory. Each sample will have a label placed inside the jar that indicates the site of collection, date, and initials of the collector. Samples are initially preserved in 70% ethyl alcohol. Once sorted, a solution of 70% ethyl alcohol/30% glycerin solution is used for the specimen vials. All samples are stored in labeled drawers in the chemistry laboratory.

10.1.2 Nutrient samples

Samples will be transported in a cooler with ice packs. Upon arrival to the laboratory, samples will be immediately frozen for later analysis.

All samples should be placed in plastic *Ziploc* bags with the sample collection date/time and campaign title written on the bag. A log of current samples within the refrigerator/freezer will be kept taped to the door of the cooler and updated as the status of samples changes. This form *Sample Storage Management Log* (Appendix A) will be saved to file when full. Sample preservation status will be recorded on the *Nutrient QC Evaluation Form* (Appendix F).

Samples shall be brought to room temperature before analysis by thawing overnight in the refrigerator. If a water bath is used to complete the thawing process, care will be taken to not raise the sample temperature above room temperature at any time.

10.1.3 SSC samples

Samples for suspended sediment will be transported from the field in a cooler with ice packs and stored in the refrigerator at 4°C for a maximum of 7 days. Typically turbidity and transparency should be measured immediately or within one day. However, our samples are filled with suspended sediment and dark brown in color. Any slight

discoloration that could result from bacterial growth over a few days in the refrigerator is not going to alter the results.

10.1.4 Pesticide samples

Pesticide samples will be transported to the CCoWS laboratory in a cooler with ice packs, placed in the refrigerator, and then packed and shipped the same day for 10am next day delivery to CDFG.

10.1.5 Toxicity samples

Toxicity samples will be transported immediately in a cooler with ice packs to Granite Canyon Laboratory.

Table 10.1. Sample handling. Nutrient samples will all be taken in the same bottle, but filtering will occur in the field only if Orthophosphate will be tested for. Otherwise, filtering occurs in the laboratory.

Parameter	Container	Volume	Field Preservation	Holding Time
Ammonia-Nitrogen Nitrate – Nitrogen Orthophosphate	Plastic bottle – acid washed	125 mL	Cooler w/ice packs	Frozen immediately at return to lab
Organophosphates Pyrethroids Organochlorines	Amber glass bottle – trace clean	1 L	Cooler w/ice packs	7 days at 4°C will be immediately shipped
Suspended Sediment Conc.	Plastic bottle	500 mL	Cooler w/ice packs	7 days at 4°C
Turbidity	Plastic bottle	500 mL	Cooler w/ice packs	7 days at 4°C
Benthic Macro Invertebrates	Glass jar	500 mL	70% ethyl alcohol	Processed as soon as time allows
Toxicity – water	Amber glass bottle – trace clean	2.25 L	Cooler w/ice packs	48 hours at 4°C will be immediately delivered
Toxicity – sediment	I-Chem wide-mouth polyethylene jar	1 L (2 jars per sample)	Cooler w/ice packs	48 hours at 4°C will be immediately delivered

10.2 Protocol for sample disposal

Remaining nutrient sample may be disposed of when analysis is completed and all analytical quality assurance/quality control procedures are reviewed and accepted. Used sample that has been processed with reagent is a regulated hazardous waste and disposed of according to CSUMB's Environmental Protection, Health & Safety Program

(EPHS, 2005). Each nutrient test has a separate waste bottle that is clearly labeled and stored within secondary containment. When full, these are turned over to CSUMB's science department for disposal.

BMI samples will not be disposed of, and are to be stored at least through the duration of the project.

10.3 Protocol for the Chain of Custody (COC) form

The Chain of Custody (COC) form is a QA/QC legal form that is used to track samples on their way to outside laboratories not affiliated with CCoWS. COC forms shall be used for pesticide, toxicity, and BMI samples transferred to outside laboratories. The outside laboratory shall provide COC forms prior to the sample exchange.

COC forms are not used for in-house nutrient, BMI, or sediment samples because there is no transfer of samples between personnel. All internal samples will be overseen from collection through analysis by the monitoring manager and research technician.

11 Analytical Methods

This section describes and refers to the laboratory procedures used by CCoWS to analyze dissolved nutrients in water samples including oxidized nitrate-nitrogen, ammonia-nitrogen and orthophosphate. Protocols for determining suspended solids concentrations, BMI analysis, and toxicity are also discussed. For a detailed explanation of test methods and specifications, see Watson et al., 2005.

11.1 Dissolved Nutrients

CCoWS uses the *HACH Odyssey* DR/2500 Spectrophotometer for nutrient analysis. All the manufacturer's specifications and instructions are followed step by step with the addition of some QAQC measures described in section 5.2 (standard solutions, reagent or method blanks, bottle blanks, replicates, and spikes).

The SWAMP Target Reporting limit (TRL) for nitrate and phosphate are both 0.01 mg/L, which is lower than these methods can detect. However, the high levels of nutrients found in agricultural drains and the Tembladero Slough will be adequately detected with these methods. In addition, detecting extremely low levels of these nutrients is not a concern because they will not have a significant effect on load calculations.

Table 11.1 summarizes the test ranges and concentrations of standard solutions used for the accuracy assessment of the spectrophotometer. If any standards should fall outside the limits presented, the procedures are rechecked and the standard is run again. Procedures for the all tests are detailed in the *HACH Odyssey* DR/2500 Spectrophotometer Procedure Manual (te/dk 04/01 2ed) under the above-mentioned methods.

Table 11.1 Summary of nutrient test ranges, method descriptions, and standard solutions.

Analysis	HACH Method	Method Description	Acceptable % Error for Standards	Test Range (mg/L)	STANDARDS		
					Low	Mid	High
NO_3^--N	10020 HR	chromotropic acid method Test 'N Tube	10% Mid, High 20% Low	0.2 – 30.0	0.5	10	25
NH_3-N	10023 LR	salicylate method; AmVer Test 'N Tube	4%	0.02 – 2.50	0.05	1	2.5
PO_4^{3-}	8048	ascorbic acid method; PhosVer 3 Test 'N Tube	4%	0.06 – 5.00	0.05	1	5

Between collection and analysis, nutrient samples are filtered through a 0.45 µm syringe driven filter. A clean syringe and filter is used for each sample, and the used filters are disposed of.

A sample run is a group of samples that are analyzed as one batch, usually 10 to 20 samples per batch. Everything from a nutrient sample run (date and time of sample collection, date of preservation, lab date, analysts, blank values, measured standard values, spike values, replicate values, sample data values, etc.) is recorded on a laboratory template *Nutrient QC Evaluation Form* (Appendix F).

Should the concentration of a sample fall under the range of the test, the data value will be reported as "non-detect". If the test indicates an over-range value, then a 3:1 dilution of the sample will be performed and the sample will be retested.

11.2 SSC

A vacuum filtration process is used to determine the concentration of suspended sediment in a water sample. This process is based on Woodward and Foster (1997). The procedure is summarized briefly here.

Total dissolved solids (TDS) and transparency are measured and recorded. TDS (in µS/cm) is measured with an Oakton TDS Testr4 (calibrated regularly according to the manufacturer's instructions) and transparency is measured with a 60 cm transparency tube.

In the filtration procedure, samples are weighed and sodium hexametaphosphate is added to the sample and the sample is shaken thoroughly. This helps suspend particles and keep them from flocculating. Samples are first filtered through a 63 µm sieve to remove the sand component, and then glass microfibre filters (1.5 and 0.7 µm) are used to vacuum filter the water sample and the fine sediment component. The disposable glass filters are weighed before and after filtration (before weight – after weight determines the amount of sediment in the sample to the mg). The volume of the sample is determined from the weight of the sample and the density of water. Concentrations of samples are recorded in mg/L. All information is recorded on the *Lab Processing of SSC Samples* data sheet (Appendix D).

11.3 Turbidity

Turbidity is analyzed from SSC samples using a HACH 2100P portable turbidimeter, SM2130B. Samples are analyzed according to directions outlined in the factory manual. The sample is poured into a small glass vial, dried off, and inserted into the machine.

The automatic range setting measures turbidity from 0.01 to 1000 NTU. All information is recorded on the *Lab Processing of SSC Samples* data sheet (Appendix D).

11.4 BMIs

The following procedure to analyze BMI samples in the laboratory is adapted from Harrington and Born (2000). The three level-system has been adapted and modified to suit the needs of this study and is as follows.

A macroinvertebrate datasheet (a form with all laboratory notes and tallies of the BMI's identified for each sample) (Appendix H), is used to document every step of the sorting and identification processes.

11.4.1 Sorting

All samples are emptied into the #35 sieve, and debris larger than ½ inch, green leaves, twigs, and rocks are removed. The material is then placed to one side in shallow a plastic tray. A small portion of the sample is moved to the middle of the tray where it is thoroughly scanned for any invertebrates present. After this small portion has been completely sorted and all specimens have been removed and placed in a plastic Petri dish, the sorted portion of the sample is then moved to the other side of the tray, and another small portion of the original sample is moved to the middle where it is sorted. This process is continued until the entire sample has been sorted. The remaining contents of the tray are put into a pint jar with the sample label (this label includes site code, date, and name of collectors) and enough 70% ethanol/30% glycerin solution to completely cover the contents.

11.4.2 Identification

The petri dish with all the sorted BMI's from the sample is placed under a dissecting microscope. Each specimen is examined for distinguishing characteristics and tallied into taxonomic categories, classified according to varies keys (Merritt & Cummins, 1996; Harrington & Born, 2000; McCafferty, 1998; Smith, 2001; Fitzpatrick, 1983; NAMC, 2001; APHA, 1998).

All specimens are identified to a level 2 taxonomic effort (Harrington and Born, 2000). Specimens are put in a clean vile with ethanol/glycerin solution and the vial is put in a vial tray. A specimen label is made with the taxa name, location, collector, collection date, and identifier. This specimen label is then slipped under the plastic strip on the vial tray in front of that vial. The petri dish is then searched for other BMI's that have similar characteristics and put into the same-labeled vial.

All rows of the *BMI Data Sheet* (Appendix H) are tallied and it is signed. The total number of specimens in each vial is written on its sorting label and the lid is secured to the vial. Specimens will be photographed through the dissecting scope. Photos may include documentation of each collection site and close-ups of the substrate when possible.

Bioassessment validation will be conducted by Aquatic Biology Associates, Inc. (ABA) at a rate of 1 sample per run.

11.4.3 Internal CCoWS re-identification check procedure

Each vial that contains specimens of each identified organism, ethanol/glycerin mixture, & its Order & Family ID is assigned another ID (single capitol letter) by placing a small piece of 3x5 card with the letter written on it into the vial. These vials are then placed in a clear plastic strip and this strip is labeled with the site code.

One specimen from each black-topped vial is placed in its own vial with ethanol/glycerin mixture. This specimen is labeled with the corresponding single letter ID (but not the order & family ID). These vials are then placed together separate from the original specimen vials. These will be the specimens that are re-identified.

The re-identifier then keys out each specimen and records Order & Family on the *BMI Identification Evaluation* sheet (Appendix I) next to the corresponding single letter ID. This re-identification list is then compared to the Family & Order identification located in each vial containing the specimens using the single letter ID. The 'agreement' field on the identification evaluation sheet is checked if both identifiers agree on the Family & Order ID. It is left blank if the two identifiers disagree. Both identifiers meet to discuss disagreements, confer with identification keys, and try to come to agreement.

11.4.4 Data analysis

Species richness and composition will be described. Tolerance values are not applicable in this case since the Tembladero Slough receives some saltwater inputs from the tide gates. It will be difficult to determine if a species is absent due to pollution or unsuitable habitat due to salinity.

The BMIs present in the samples will also be related to the tolerance values published for each family (Harrington and Born, 2000; Hilsenhoff, 1988).

11.5 Pesticides

The California Department of Fish and Game laboratory will analyze samples for multiple current and legacy pesticides using broad spectrum GC/MS scans.

11.6 Toxicity

Water toxicity will be evaluated with *Ceriodaphnia dubia* 7-day survival and reproduction tests, and sediment toxicity with *Hyalella azteca* 10-day survival and growth tests. The following summaries provide an overview of the toxicity testing that will be done by the U.C. Davis Granite Canyon Laboratory. They were copied directly from the SWAMP Quality Assurance Management Plan, Appendix F, that is available online (SWRCB. Summary of Methods Used for Toxicity Testing).

11.6.1 Water toxicity

Ceriodaphnia dubia 7-day toxicity tests are conducted on water samples using US EPA standard test protocols (US EPA 1994). Each undiluted sample is tested using 10 replicates. Each replicate contains one *Ceriodaphnia* neonate (<24-h-old). Survival and reproduction are monitored daily in each replicate of each sample. Water quality parameters including conductivity, hardness, alkalinity, pH, dissolved oxygen, and ammonia are measured at the beginning of each test. Test solutions are renewed daily and dissolved oxygen and pH are measured on the old solution. Dissolved oxygen is measured on the new solution. Temperature is monitored continuously by placing a temperature probe in an additional test solution in the controlled temperature room.

11.6.2 Sediment toxicity

The toxicity of freshwater sediment is assessed using the *Hyalella azteca* 10-day growth and survival test following EPA standard protocols (US EPA 2000). Each sediment sample is tested with 8 replicates of 10 *Hyalella* individuals each, with growth and survival recorded on day 10. MPSL well water is used as overlying water for each sediment sample. Water quality parameters, including conductivity, hardness, alkalinity, pH, dissolved oxygen, and ammonia are measured in one replicate of each sample at the beginning and end of each sediment test. Dissolved oxygen in measured daily in one replicate of each sediment sample. Temperature is monitored continuously by placing a probe in an additional test solution in the controlled temperature room.

12 Quality Control

The following sections summarize the quality control measures that will be taken to ensure data quality. Most of this information has already been presented in previous sections.

12.1 Field measurements

- Temperature and pH: 3 replicate measurements at the beginning of each sampling run
- Flow using a bucket: 5 replicate measurements
- Flow using floats: 3 replicate measurements

12.2 Nutrient samples

Sample collection:

- Field duplicate: 1 per sample run or 5% of samples

Laboratory analysis:

- Method/Reagent blanks: 1 per sample run
- Standards/Controls: 3 per sample run, per analysis
- Bottle blank: 1 per sample run
- Sample replicates: at least 1 per sample run or 5% of samples
- Sample spikes: at least 1 set per sample run or 5% of samples

12.3 SSC and turbidity

- Field duplicate: 1 per sample run or 5% of samples (this is taken from the duplicate suspended sediment sample)
- Turbidity: 3 replicate measurements of one sample

12.4 BMI samples

- To ensure uniformity of sampling, only the monitoring manager and primary research technician will collect samples.
- Field data forms are cross-checked for completeness at the end of each site visit.
- Internal specimen re-identification checks: 100% and reduced to a 20% sort check when < 5 % error is achieved.
- Bioassessment validation: 1 sample per run sent to Aquatic Biology Associates, Inc., in Corvallis, Oregon.

12.5 Pesticide samples

- Field duplicate: 1 per sampling event or 5% of the annual samples, whichever is more frequent.
- Samples will be sent to CDFG in Rancho Cordova for laboratory analysis. They will process a blank, and complete a series of spikes for each sample. The recovery ranges were provided in section 5.6.

12.6 Toxicity samples

- Field duplicate: 1 per sampling event or 5% of the annual samples, whichever is more frequent.
- Water quality measurements at time of sampling to include dissolved oxygen, pH and conductivity, and a sample collected for ammonia.
- Positive and negative controls will be completed, including:
    - Reference toxicant tests are performed once per month in the laboratory (positive control)
    - Field blank will be completed with laboratory control water (negative control). This will be analyzed before the start of data collection.
    - Sediment control will be completed for the *H. azteca* test.
    - Conductivity controls will be completed for the water samples.

13 Instrument/Equipment Testing, Inspection & Maintenance

All equipment used in this project is inspected by management upon arrival from the supplier and given a unique ID. Factory manuals, specifications, and instructions are kept on file by CCoWS at the Watershed Institute.

Prior to each sampling run, all equipment is visually inspected for proper function, replacement of parts, and batteries. In the field, extra parts and supplies are carried to attend to any malfunctions.

Following each sampling run, field equipment is cleaned and stored until future use.

They current meter is cleaned and oiled after each use. To test that it is has been properly put back together, it is held level in the air and the cones are gently spinned. Spinning should continue freely for 3 to 4 minutes without stopping.

14 Instrument/Equipment Calibration & Frequency

Various pieces of CCoWS sampling equipment require periodic calibration and maintenance to assure accuracy and reliability. This equipment includes:

- Current meter
- HACH 2100P portable turbidimeter
- Oakton pH Testr 1
- Oakton TDS Testr 4

The scheduling of the calibration and maintenance varies according to the amount of use and manufacturer's requirements. CCoWS maintains an *Equipment Calibration & Maintenance Records* document that outlines specific calibration and maintenance schedules/procedures along with logs for the recording of calibrations and all maintenance performed. These records may be reviewed upon request.

The current meter is newly purchased and does not require calibration, only routine cleaning and oiling, and the spin test described in the previous section.

The scheduled calibration for the turbidimeter is once every three months according to manufacturer protocols. As a secondary accuracy check, *Gelex* factory standards are used before each series of measurements are taken. If the reported measurement is within the *Gelex* standard range, samples are then measured according to protocol. If out of range, the turbidimeter shall be calibrated prior to analysis of samples.

The Oakton pH Testr 1 and TDS Testr 4 will be calibrated before each use. Pre and post calibration results will be checked to make sure that there isn't excessive instrument drift. Calibration records are kept CCoWS and will be included in the final report.

15 Inspection/Acceptance of Supplies & Consumables

All shipments are received by the campus shipping and receiving department. Upon arrival to CCoWS, shipments are checked to be certain the packing slip is complete and matches the materials ordered (supplies or equipment). Standard supplies are stored in designated areas.

16 Non-Direct Measurements (Existing Data)

Existing data will be used for planning purposes only (for example, which test to try first, high range or low range, etc.), and will not be incorporated into the analysis portion of this project.

17 Data Management

The following protocols will be followed for data management:

- The primary data storage shall be on a central university server.
- Periodically, all electronic data shall be backed up on CD (at least every 6 months). Backup CDs or tapes shall be stored at the Watershed Institute building in a fireproof safe for 3 years.
- A new master version of the *MS Access and or Excel* database file shall be copied and renamed each time modifications are made.
- The data file names shall contain the last date on which they were significantly modified (in the format Name_YYMMDD_initials of user.*).
- Previous versions (with earlier dates) shall be maintained on the server as intermediate backups until they are backed up to CD (see above).
- All initial data from field books shall be entered into the appropriate database on the day following field sample collection, or as soon as is reasonably possible.
- After laboratory analysis is complete, all results should be entered into the database record for that particular field monitoring campaign as soon as is reasonably possible.
- All laboratory data sheets are then kept on file for 3 years in the wet lab at the Watershed Institute.
- CCoWS shall keep all original field books permanently on file at the Watershed Institute.
- Primary water quality data shall be maintained in the CCoWS *MS Access* Water Quality database. The following exception applies:
    - Individual flow and depth measurements within stream flow cross-sections shall be maintained in *MS Excel* spreadsheets (as opposed to the total calculated discharge that results from these measurements which is maintained in the CCoWS *MS Access* database).
- The CCoWS *MS Access* database shall be a relational database, with tables for:
    - Site codes (agricultural site locations are confidential)
    - Site visit information (e.g. date/time, container ID, sample type)
- All data collected from receiving waters will be submitted to the RWQCB in SWAMP compatible format as well.

Group C: Assessment & Oversight

18 Assessment & Response Actions

Project activities such as field techniques, laboratory procedures, and data management will be assessed as follows:

- The monitoring manager and primary research technician will oversee all fieldwork, field training, and ensure that field equipment is inspected and calibrated as scheduled. Each sampling run will be assigned a team leader responsible for assuring that procedures are followed and that data is accurately recorded.
- The laboratory manager will oversee laboratory analysis, training and is also responsible for ensuring that calibrations of laboratory equipment are performed as scheduled when and where applicable.
- Quality control exercises will be conducted as previously described in Chapter 12. Following each monitoring run, a quality control checklist will be followed to keep track of when tasks are completed (Appendix J). If problems are detected, such as failure to meet accuracy and precision objectives, immediate action will be taken (see below).

Any problem encountered during assessment may lead to the following responses:

- Equipment calibration prior to scheduled date
- Equipment repair
- Supplemental training for team members
- Discussion at CCoWS team meeting
- Consultation with CCoWS PI
- Re-evaluation of methods

19 Reports to Management

Progress reports will be submitted to the CCRWQCB Contract Manager, Amanda Bern, quarterly beginning Dec 15th, 2004 by the project PI, Rob Burton. Each sub-contractor submits information to the Wetland Project Manager, Adam Wiskind, for these reports. They are organized by sub-contractor and task numbers (from SWRCB Agreement No. 03-193-553-0), and may include descriptions of activities undertaken, accomplishments of milestones, any problems encountered in the performance of the work, and delivery of any intermediate products.

The draft and final project reports will be written by the CCoWS Monitoring Manager and reviewed by all project PIs. Two copies of the draft report will be submitted to the Contract Manager for review and comment. The final report will be submitted to the Contract Manager via one reproducible master and two hardcopies of the final report. An electronic (PDF and CD) copy will also be provided. Once the final report is approved, it will be published on the CCoWS web site (http://science.csumb.edu/~ccows/).

Group D: Data Validation and Usability

20 Data Review, Verification, & Validation

Data generated by project activities will be reviewed against the DQOs discussed in Chapter 5. Based on this review, data will be separated into three categories:

1. Meets all DQOs
2. Fails precision or recovery criteria
3. Fails to meet accuracy criteria

Data meeting all applied data quality objectives, but with incomplete QA/QC practices will be set aside until it can be determined if the data quality has been compromised.

When data does not meet all DQOs it will be flagged in the database. The use of any data with limitations that is deemed usable will be clearly identified and addressed in the final report.

21 Verification & Validation Methods

All data will be reviewed and verified in the following manner:

21.1 Field work & data entry

- Field books will be reviewed following each sampling run to make sure all samples were collected and information was accurately recorded.
- All excel entries will be compared to original field books.
- All discharge calculations will be double checked.

21.2 Review of the database

- The monitoring manager will review the water quality master database by comparing entries to the original field books. This check is scheduled to follow each monitoring campaign.
- The monitoring manager will query each sampling run of data by analyte to look for any gaps and outliers. Data will also be reviewed in graphic format.
- Following data analysis data will be reviewed by the CCoWS PI.
- Any detected data errors will be flagged in the database, and categorized within the three categories discussed previously in Section 20.

21.3 Checking calibration records and DQOs

- Calibration records will be reviewed before each sampling run to ensure equipment is currently calibrated before data collection.
- Percent completeness, accuracy, and precision will be calculated and compared to original objectives listed in Chapter 5.

22 Reconciliation with User Requirements

This element asks for a description of whether the project's objectives have been satisfied. This will be discussed in the Project Assessment and Evaluation Plan.

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APPENDICES

Appendix A. Sample Storage Management Log

Sample Storage Management Log

Campaign	# of Samples	Date Collected	Date/time Stored	Initial	Frozen? (y/n)	Date Frozen	Initial	Date Thawed	Initial

Appendix B. Technician Training Tracking Sheet

Technician Training Tracking Sheet

Technique	Trainee (print)	Trainee (signature)	Trainer (print)	Trainer (signature)	Date
Lab Safety Training					
Nutrient Analyses					
SSC + Turb Analysis					
Q (flow probe)					
Q (bucket & misc)					
Q (Crane)					
Sample collection & preservation:					
Nutrients					
SSC					
Pesticides					
Toxicity					
BMIs					
Other:					

Appendix C. Accident/Incident Report Form

Earth Systems Science & Policy

California State University, Monterey Bay

Accident/Incident Report Form

Date of Incident:_____ **Time** of Incident:_____

Location Where Incident Occurred: _____

_____

Identity of any involved persons:

Name _____ _____

Address _____ _____

_____ _____

_____ _____

Contact Info _____ _____

Identity of any witnesses:

Name _____ _____

Contact Info _____

Description of Incident:

_____

_____

_____

Actions Taken:

_____

_____

_____

Name of Person Completing Report _____Date_____

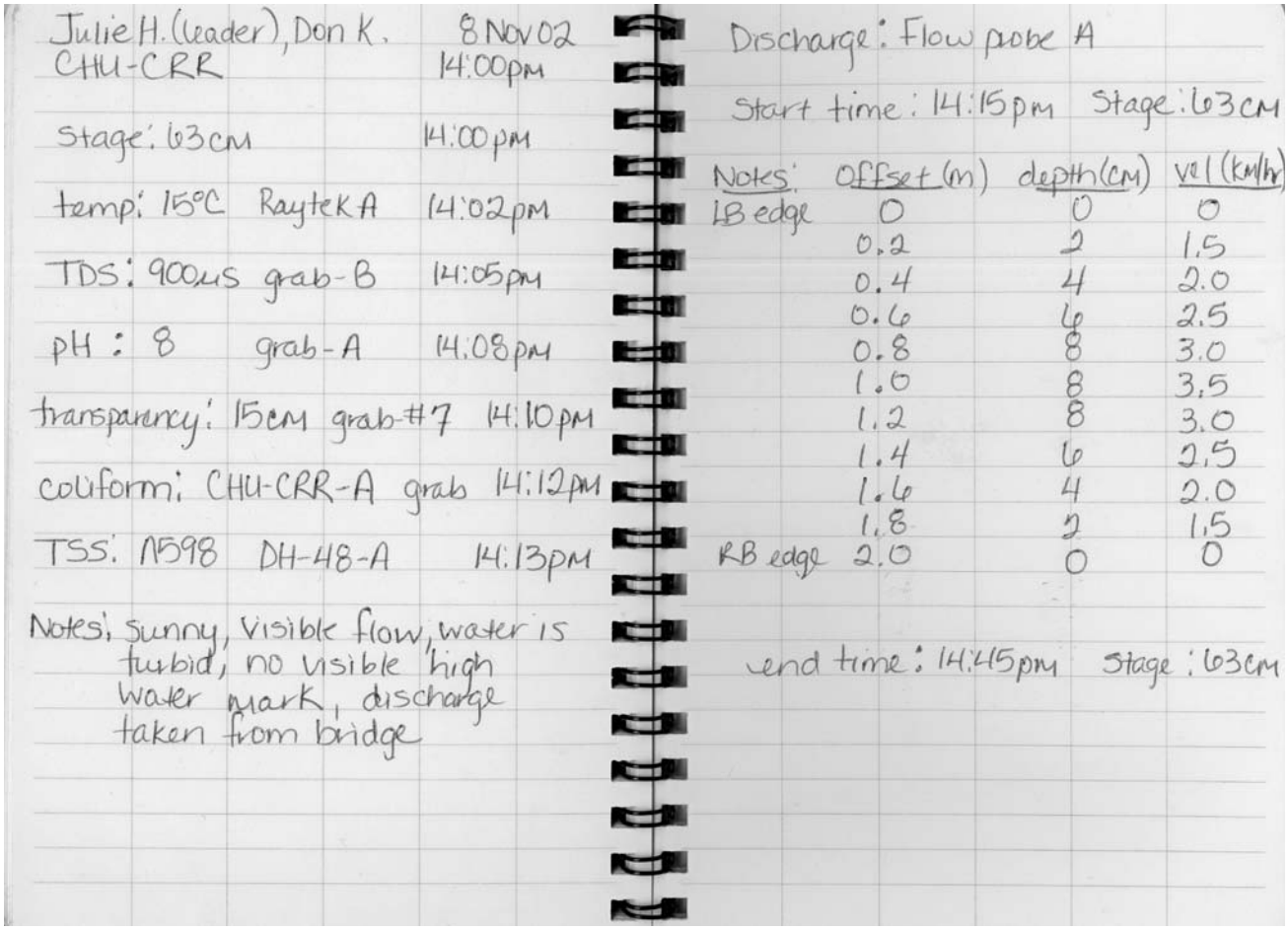
Staff/Faculty Signature _____Date_____

Supervisor Signature _____Date_____

Appendix D. Recording Template for Lab Processing of SSC Samples

Lab Processing of Water Samples- Suspended Sediment Concentrations (SSC)											**DATE:**						
Pre vacuum		Date:	Date:			Sand		Coarse Filter		Fine Filters		Post Vacuum and Oven					
Sample ID	**Bottle #**	**TDS (uS)**	**Transp(cm)**	**Turb (NTU)**	**Total Bottle's (w/sample) wt (g)**	**Sand Filter ID**	Filter wt	**934-AH Filter ID**	AP40 Filter Dry wt w/tin (g)	**GF/F Filter ID**	934-AH Filter Dry wt w/ tin (g)	**Sand Filter ID**	**Sand Filter wt**	**934-AH Filter ID**	AP40 Filter sample wt w/tin (g)	**GF/F Filter ID**	934-AH Filter sample wt w/ tin (g)

Appendix E. Sample Field Book Entry



Julie H. (leader), Don K. 8 Nov 02
CHU-CRR 14:00pm

Stage: 63cm 14:00pm

temp: 15°C RaytekA 14:02pm

TDS: 900µS grab-B 14:05pm

pH: 8 grab-A 14:08pm

transparency: 15cm grab-#7 14:10pm

coliform: CHU-CRR-A grab 14:12pm

TSS: N598 DH-48-A 14:13pm

Notes: sunny, visible flow, water is turbid, no visible high water mark, discharge taken from bridge

Discharge: Flow probe A

Start time: 14:15pm Stage: 63cm

Notes:	Offset (m)	depth (cm)	vel (km/hr)
LB edge	0	0	0
	0.2	2	1.5
	0.4	4	2.0
	0.6	6	2.5
	0.8	8	3.0
	1.0	8	3.5
	1.2	8	3.0
	1.4	6	2.5
	1.6	4	2.0
	1.8	2	1.5
RB edge	2.0	0	0

end time: 14:45pm Stage: 63cm

Appendix F. QC Evaluation Form – Nutrients

Nutrient Sample Run Data

Nutrient Test Type:				
Campaign:				
Date/Time of Collection:				
Field Book #:				
Date of Preservation:				
Test Date:				
Analysts:				
Analysis Method:				
Detection Limit:				

Blank Value:	

Calibrators *

	#1	#2	#3
Standard Value:			
Measured Value:			
** % difference:			

Spike		% Recovery ***		**Replicates**	
sample # spiked:				sample ID	Value (mg/L)
sample original value:					
standard & amount added:					
expected spike value:					
actual spike value:					

***** Standards that should be used for calibrators (mg/L):

	#1	#2	#3	** Acceptable % difference
NO3-N (method10020 HR):	0.5	10	25	10%
NH3-N (method 10023 LR):	0.5	1	2.5	4%
PO4 (method 8048):	0.5	1	5	4%

****** % difference = absolute value [(measured value - standard value) / standard value]

******* 1:1 ratio of QAQC sample and a standard

expected spike value = average of sample value & spike concentration

% recovery = measured spike value / expected spike value * 100

Acceptible values: 80 - 120% (SWAMP Requirements)

see 'nutrient_QAQC_calculation_template.xls' (on the CCoWS server at :\admin\lab+field\Templates_Forms\nutrient_templates) for QAQC calculations.

Appendix G. BMI Lab Chain of Custody

CCoWS Lab Chain of Custody Form for BMIs											
sample information					preservation		lab identification			photographs	
sample ID	sample location	sample type	date collected	sampled by (initials)	date preserved (ethanol & glycerin)	preserved by (initials)	beginning lab date (sorting)	ending lab date (identification complete)	lab tech initials	photos taken?	photo file name

Appendix H. BMI Data Sheet

MACROINVERTEBRATE DATA SHEET

Type of Sampler_____ Sample No._____
Collection Depth_____ Date_____
Substrate Type_____ Location_____
Remarks_____
Station #_____
Identification by_____ Collector_____
Enter Family and/or Genus and Species Name on Blank Line.

Organisms	No.	A.	I.
Diptera			
Chironomidae			
Other			
Trichoptera			
Plecoptera			
Ephemeroptera			
Odonata			
Hemiptera			

	No.	A.	I.
Coleoptera			
Neuroptera and Megaloptera			
Crustacea			
Oligochaeta			
Hirudinea			
Bivalvia			
Gastropoda			
Bryozoa			
Coelenterata			
Other			

A = Adult. I = Immature
Total No. Organisms_____ Total No. Taxa_____

248

Appendix I. BMI Indentification Evaluation

INTERNAL CCoWS INVERTIBRATE IDENTIFICATION EVALUATION				
		Site name:		
		Sample date:		
		Preservation date:		
		Origonal identification completed by:		
		Origonal identification completion date:		
		Re-Identification completed by:		
		Re-identification completion date:		
AGREEMENT *	**ID**	**ORDER**	**FAMILY**	**NOTES/DISTINGUISHING CHARACTERISTICS**
	A			
	B			
	C			
	D			
	E			
	F			
	G			
	H			
	I			
	J			
	K			
	L			
	M			
	N			
	O			
	P			
	Q			
	R			
	S			
	T			
	U			
	V			
	W			
	X			
	Y			
	Z			
* AGREEMENT: check if both identifications agree, leave blank if disagree.				

Appendix J. QA/QC Checklist

Prop 13 Project QA/QC Checklist (to be completed for each sample run)						
Run Date:						
Location:						
Sample types:						
		Task	**Y/N**	**Init**	**Date**	**Notes**
Field	**All**	Temp and pH replicate measurements (3 times at start, 3 at QA/QC site)				
Tasks	**All**	Field duplicate collected: Nutrients SSC Pesticides (5% rate)				
	Nutrients	Nutrient bottles rinsed 3 times prior to collection				
	Nut & Pest	Field blank conducted: Nutrients Pesticides (circle applicable)				
	Nut & Pest	Preservation: filter orthophosphate, nutrients and pesticides on ice				
	Flow	Flow using bucket method or floats: 5 duplicate measurements				
	BMIs	BMIs: DO, pH, temp measured w/YSI				
	Toxicity	Tox sample: DO, conductivity, pH, & ammonia sample collected				
		Field book checked for completeness				
Lab	**All**	Samples properly preserved (Ch 10 in QAPP)				
Tasks		Holding times observed (Ch 10 in QAPP)				
	Turbidity	3 replicate measurements				
	Nutrients	Passed standards, spike, field duplicate, lab replicate requirements				
	BMIs	Specimen sort checks completed (100% unless <5% error, then 20%)				
		Sent reconstituted sample to ABA Lab (1 per sample run)				
		Compare CCoWS results to ABA results (less than 5% difference)				
Data		Data entry of field work				
Processing		Data entry of lab work				
		Data entry checked by another person				
		Excel discharge calculations double checked				
		Excel SSC calculations double checked				
		All data entred into Access master water quality database				
		Query master database by analyte, look for outliers and data gaps				
		Flag and categorize data errors (Ch 20 of QAPP)				
		Data reviewed by PI				

Appendix K. Suspended sediment toxicity to fish

Source (as cited in Hager & Watson, 2005)	Species	Life Stage	Exposure Concentration (mg/L)	Exposure Duration (h)	Fish Response	Reference (as cited in Hager & Watson, 2005)
Newcombe and Jensen 1996	Smelt (rainbow)	Adult	3.5	168	Increased vulnerability to predation	Swenson (1978)
	Steelhead	Adult	500	3	Signs of sublethal stress	Redding and Schreck (1982)
	Steelhead	Adult	500	9	Blood cell count and blood chemistry change	Redding and Schreck (1982)
	Trout	Adult	16.5	24	Feeding behavior apparently reduced	Townsend (1983); Ott (1984)
	Trout	Adult	75	168	Reduced quality of rearing habitat	Slaney et al. (1977b)
	Trout	Adult	270	312	Gill tissue damaged	Herbert and Merkens (1961)
	Trout	Adult	525	588	No mortality (other end points not investigated)	Griffin (1938)
	Trout	Adult	300	720	Decrease in population size	Peters (1967)
	Trout (rainbow)	Adult	66	1	Avoidance behavior manifested part of the time	Lawrence and Scherer (1974)
	Trout (rainbow)	Adult	665	1	Overhead cover abandoned	Lawrence and Scherer (1974)
	Trout (rainbow)	Adult	100	0.10	Fish avoided turbid water	Suchanek et al. (1984a,1984b)

Source (as cited in Hager & Watson, 2005)	Species	Life Stage	Exposure Concentration (mg/L)	Exposure Duration (h)	Fish Response	Reference (as cited in Hager & Watson, 2005)
Newcombe and Jensen 1996	Trout (rainbow)	Adult	100	0.25	Rate of coughing increased	Hughes (1975)
	Trout (rainbow)	Adult	250	0.25	Rate of coughing increased	Hughes (1975)
	Trout (rainbow)	Adult	810	504	Gills of fish that survived had thickened epithelium	Herbert and Merkens (1961)
	Trout (rainbow)	Adult	17,500	168	Fish survived; gill epithelium proliferated and thickened	Slanina (1962)
	Trout (rainbow)	Adult	50	960	Rate of weight gain reduced	Herbert and Richards (1963)
	Trout (rainbow)	Adult	810	504	Some fish died	Herbert and Merkens (1961)
	Trout (rainbow)	Adult	270	3240	Survival rate reduced	Herbert and Merkens (1961)
	Trout (rainbow)	Adult	200	24	Test fish began to die on first day	Herbert and Richards (1963)
	Trout (rainbow)	Adult	18	720	Abundance reduced	Peters (1967)
	Trout (rainbow)	Adult	4,250	588	Mortality rate 50%	Herbert and Wakeford (1962)
	Trout (rainbow)	Adult	49,838	96	Mortality rate 50%	Lawrence and Scherer (1974)
	Trout (rainbow)	Adult	80,000	24	No mortality	D. Herbert, personal comm. to Alabaster and Lloyd (1980)
	Trout (rainbow)	Adult	3,500	1,488	Catastrophic reduction in population size	Herbert and Merkens (1961)

Source (as cited in Hager & Watson 2005)	**Species**	**Life Stage**	**Exposure Concentration (mg/L)**	**Exposure Duration (h)**	**Fish Response**	**Reference (as cited in Hager & Watson, 2005)**
Newcombe and Jensen 1996	Trout (rainbow)	Adult	160,000	24	Mortality rate 100%	D. Herbert, personal comm. to Alabaster and Lloyd (1980)
	Trout (rainbow)	Yearling	90	456	Mortality rates 0–20%	Herbert and Merkens (1961)
	Trout (rainbow)	Yearling	90	456	Mortality rates 0–15%	Herbert and Merkens (1961)
	Trout (rainbow)	Yearling	270	456	Mortality rates 10–35%	Herbert and Merkens (1961)
	Trout (rainbow)	Yearling	810	456	Mortality rates 35–85%	Herbert and Merkens (1961)
	Trout (rainbow)	Yearling	810	456	Mortality rates 5–80%	Herbert and Merkens (1961)
	Trout (rainbow)	Yearling	270	456	Mortality rates 25–80%	Herbert and Merkens (1961)
	Trout (rainbow)	Yearling	7,433	672	Mortality rate 40%	Herbert and Wakeford (1962)
	Trout (rainbow)	Yearling	4,250	672	Mortality rate 50%	Herbert and Wakeford (1962)
	Trout (rainbow)	Yearling	2,120	672	Mortality rate 100%	Herbert and Wakeford (1962)
	Trout (rainbow)	Juvenile	4,887	384	Hyperplasin of gill tissue	Gouldes (1983)
	Trout (rainbow)	Juvenile	4,887	384	Parasitic infection of gill tissue	Gouldes (1983)
	Trout (rainbow)	Juvenile	171	96	Particles penetrated cells of branchial epithelium	Gouldes (1983)

Source (as cited in Hager & Watson, 2005)	Species	Life Stage	Exposure Concentration (mg/L)	Exposure Duration (h)	Fish Response	Reference (as cited in Hager & Watson, 2005)
Newcombe and Jensen 1996	Trout (rainbow)	Juvenile	4,315	57	Mortality rate ~100%	Newcombe et al. (1995)
	Carp (common)	Adult	25,000	336	Some mortality	Wallen (1951)
	Sunfish (green)	Adult	9,600	1	Rate of ventilation increased	Horkel and Pearson (1976)
	Stickleback (threespine)	Adult	28,000	96	No mortality in test designed to identify lethal threshold	LeGore and DesVoigne (1973)
Lloyd 1987	Rainbow Trout (Great Britain)	Juvenile	270 (ppm)		Reduced survival (marked)	Herbert and Merkens (1961)
	Rainbow Trout (Great Britain)	Juvenile	200 (ppm)		Reduced survival (marked)	Herbert and Richards (1963)
	Rainbow Trout (Oregon)	Juvenile	1,000–2,500 (ppm)		Reduced survival (marked)	Campbell (1954)
	Rainbow Trout (Great Britain)	Juvenile	90 (ppm)		Reduced survival (slight)	Herbert and Merkens (1961)
	Rainbow Trout (Great Britain)	Juvenile	50 (ppm)		Reduced growth (slight)	Herbert and Richards (1963)
	Rainbow Trout (Arizona)	Juvenile	<70 (JTU)		Reduced food conversion	Olson et al. (1973)

Source (as cited in Hager & Watson, 2005)	Species	Life Stage	Exposure Concentration (mg/L)	Exposure Duration (h)	Fish Response	Reference (as cited in Hager & Watson, 2005)
Lloyd 1987	Rainbow Trout (Arizona)	Juvenile	70 (JTU)		Reduced feeding	Olson et al. (1973)
	Rainbow Trout (Great Britain)	Juvenile	110		Reduced condition factor	Scullion and Edwards (1980)
	Rainbow Trout (Great Britain)	Juvenile	110		Altered diet (terrestrial instead of aquatic)	Scullion and Edwards (1980)
	Steelhead (Oregon)	Juvenile	2,000		Stress (increased plasma cortisol, hematocrit, and susceptibility to pathogens)	Redding and Schreck (1980)
	Rainbow Trout (Great Britain)	Juvenile	270 (ppm)		Disease (fin rot)	Herbert and Merkens (1961)
	Rainbow Trout (Great Britain)	Juvenile	100 (ppm); 200 (ppm)		Disease (fin rot)	Herbert and Merkens (1961)
	Steelhead (Idaho)	Juvenile	22-265 (NTU)		Avoidance	Sigler (1980), Sigler et al. (1984)
	Steelhead (Idaho)	Juvenile	40-50 (NTU)		Displacement	Sigler (1980)
	Rainbow Trout (Great Britain)	Juvenile	110		Displacement	Scullion and Edwards (1980)
	Trout		25 JTU		Altered behavior (feeding)	Langer (1980)

Source (as cited in Hager & Watson, 2005)	Species	Life Stage	Exposure Concentration (mg/L)	Exposure Duration (h)	Fish Response	Reference (as cited in Hager & Watson, 2005)
Newcombe and MacDonald (1991)	Rainbow trout		68	720	25% reduction in population size	Peters (1967)
	Rainbow trout		1,000–6,000	1,440	85% reduction in population size	Herbert and Merkens (1961)
	Steelhead		84	336	Reduction in growth rate	Sigler et al. (1984)
	Rainbow trout		50	1,848	Reduction in growth rate	Sykora et al. (1972)
Bell (1986)	Mosquitofish			181,500 (average)	fatal	Bell (1986)
	Largemouth bass			101,000 (average)	fatal	Bell (1986)
	Black crappie			145,000 (average)	fatal	Bell (1986)