JASON E. UHLEY
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RIVERSIDE COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

January 17, 2020

Via Electronic Submittal to: SanDiego@waterboards.ca.gov
Subject line: Santa Margarita River Estuary and Watershed Monitoring and Assessment Program Submission—ECM PIN CW-650655 Attn: RPPU

Mr. David Gibson, Executive Officer
CRWQCB – San Diego Region
2375 Northside Drive, Suite 100
San Diego, CA 92108

Dear Mr. Gibson:

Re: Revised Final Santa Margarita River Estuary and Watershed Monitoring and Assessment Program Workplan

Please find attached a digital copy of the final Santa Margarita River Estuary and Watershed Monitoring and Assessment Program Workplan (Workplan), submitted as required by Investigative Order No. R9-2019-0007[1] (Order), issued by the San Diego Water Board on May 9, 2019 under the authority of California Water Code Section 13267. The Workplan was previously submitted for your review on November 8, 2019. We received Regional Board staff comments on the Workplan on November 26, 2019 and have incorporated the necessary revisions into this submittal. This final submittal is made on behalf of the Cities of Murrieta, Temecula and Wildomar, the Counties of San Diego and Riverside, the Riverside County Flood Control and Water Conservation District, and the United States Marine Corps Base Camp Pendleton.

We believe the submitted Workplan addresses all the comments received and satisfies the conditions of the Order.

[1] Investigative Order No. R9-2019-0007: An Order Directing the Cities of Murrieta, Temecula and Wildomar, the Counties of San Diego and Riverside, the Riverside Flood Control and Water Conservation District, and the United States Marine Corps Base Camp Pendleton to Design and Implement a Water Quality Improvement Monitoring and Assessment Program for Eutrophic Conditions in the Santa Margarita River Estuary and Watershed, California.

If you should have any questions, please call or email me at 951.955.0843, myeager@rivco.org, or Richard Boon at 951.955.1273, rboon@rivco.org.

Very truly yours,

Matt Yeager, D.Env
Senior Flood Control Planner
Water Quality Compliance-II

Attachment: Santa Margarita River Estuary and Watershed Monitoring and Assessment Program Workplan

ec: Cynthia Gorham, San Diego Water Board
Mai Son, City of Murrieta
Stuart Kuhn, City of Temecula
Dan York, City of Wildomar
Jason Farag, City of Wildomar
Jo Ann Weber, County of San Diego
Alonzo Barrera, County of Riverside Executive Office
Jan Bulinski, Riverside County Transportation Department
Richard Boon, Riverside County Flood Control and Water Conservation District
Matt Yeager, Riverside County Flood Control and Water Conservation District
Mark Bonsavage, USMC Camp Pendleton
Matt Winterbourne, USMC Camp Pendleton

MY:mc
P8/229201

CERTIFICATION

SANTA MARGARITA RIVER ESTUARY AND WATERSHED MONITORING AND ASSESSMENT PROGRAM WORKPLAN—FINAL VERSION

SAN DIEGO WATER BOARD INVESTIGATIVE ORDER NO. R9-2019-0007

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

MATT YEAGER, D. Env
Senior Flood Control Planner
Riverside County Flood Control
and Water Conservation District

1-16-20
DATE

APPROVAL SIGNATURES

PROJECT ORGANIZATION/ RESPONSIBLE PARTIES:

Agency	Name and Title	Signature	Date
County of Riverside	Alonzo Barrera, County Executive Office Management Analyst	Alonzo Barrera	1/14/2020
Riverside County Flood Control and Water Conservation District	Richard Boon, Watershed Protection Division Chief		
County of San Diego	Jo Ann Weber, Water Quality Program Coordinator		
U.S. Marine Corps Base Camp Pendleton	Mark Bonsavage, Environmental Security Environmental Engineering Branch Head		
City of Murrieta	Mai Son, NPDES Coordinator	[signature]	1/15/2020
City of Temecula	Stuart Kuhn, NPDES Coordinator	[signature]	1/15/20
City of Wildomar	Jason Farag, Acting NPDES Coordinator		
Contracted Consultant	**Name and Title**	**Signature**	**Date**
Naval Information Warfare Center Pacific (NIWC Pacific)	Kara Sorensen, Project Manager		
Naval Information Warfare Center Pacific (NIWC Pacific)	Ignacio Rivera QA Officer		

SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD (San Diego Water Board):

Agency	Name and Title	Signature	Date
San Diego Water Board	Cynthia Gorham, Project Manager		
San Diego Water Board	Cynthia Gorham, QA Officer		

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Contracted Consultant	**Name and Title**	**Signature**	**Date**
Naval Information Warfare Center Pacific (NIWC Pacific)	Kara Sorensen, Project Manager	[illegible]	13 Jan 20
Naval Information Warfare Center Pacific (NIWC Pacific)	Ignacio Rivera QA Officer	Ignacio Rivera	15 JAN 20

SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD (San Diego Water Board):

Agency	Name and Title	Signature	Date
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City of Murrieta	Mai Son, NPDES Coordinator		
City of Temecula	Stuart Kuhn, NPDES Coordinator		
City of Wildomar	Dan York, Public Works Director/ City Engineer	[signature]	Jan 16, 2020
Contracted Consultant	**Name and Title**	**Signature**	**Date**
Naval Information Warfare Center Pacific (NIWC Pacific)	Kara Sorensen, Project Manager		
Naval Information Warfare Center Pacific (NIWC Pacific)	Ignacio Rivera QA Officer		

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San Diego Water Board	Cynthia Gorham, QA Officer	Cynthia Gorham	1-15-2020

GEORGE A. JOHNSON
COUNTY EXECUTIVE OFFICER

LISA BRANDL
CHIEF OPERATING OFFICER

DON KENT
ASSISTANT COUNTY EXECUTIVE OFFICER
COUNTY FINANCE OFFICER

CERTIFICATION

SANTA MARGARITA RIVER ESTUARY AND WATERSHED MONITORING AND ASSESSMENT PROGRAM WORKPLAN—FINAL VERSION

SAN DIEGO WATER BOARD INVESTIGATIVE ORDER NO. R9-2019-0007

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Lisa Brandl (signature)
Lisa Brandl, County Chief Operating Officer

Jan 14, 2020
Date

MARINE CORPS BASE CAMP PENDLETON

CERTIFICATION

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01/07/2020

Date

Mark Bonsavage, PE
Environmental Engineering Branch
Environmental Security Department
MCIWEST-Marine Corps Base Camp Pendleton

23873 Clinton Keith Rd, Ste 201
Wildomar, CA 92595
951.677.7751 Phone
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Daniel A. York, Assistant City Manager
Public Works Director/City Engineer

January 13, 2020
Date

CITY OF MURRIETA

CERTIFICATION

SANTA MARGARITA RIVER ESTUARY AND WATERSHED MONITORING AND ASSESSMENT PROGRAM WORKPLAN—FINAL VERSION

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Robert K. Moehling
Public Works Director / City Engineer

1/16/2020
Date

County of San Diego

SARAH E. AGHASSI
DEPUTY CHIEF ADMINISTRATIVE OFFICER

LAND USE AND ENVIRONMENT GROUP
1600 PACIFIC HIGHWAY, ROOM 212, SAN DIEGO, CA 92101
(619) 531-6256 • Fax (619) 531-5476
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STATEMENT OF CERTIFICATION

SANTA MARGARITA RIVER ESTUARY AND WATERSHED MONITORING AND ASSESSMENT PROGRAM WORKPLAN—FINAL VERSION
SAN DIEGO WATER BOARD INVESTIGATIVE ORDER NO. R9-2019-0007

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Sarah Aghassi

SARAH E. AGHASSI
Deputy Chief Administrative Officer
Land Use and Environment Group
County of San Diego

Date 1/6/20

PROFESSIONAL GEOLOGIST
STEPHEN B. REICH
No. 9712
EXP. 9/21
STATE OF CALIFORNIA

Stephen B. Reich
Principal
Stetson Engineers Inc.
California Professional Geologist No. 9712

Investigative Order R9-2019-0007 requires that a state-certified geologist oversee the groundwater sampling required under the Order. In accordance with Appendix C of the Order, I participated in the development of the Field Sampling Program (Workplan - Section 2.1.1) and Data Analysis (Workplan - Section 3.2.1) for estuary resurfacing groundwater discharge rates and loading into the estuary from the Santa Margarita Valley Groundwater Basin. I also reviewed the Constituents to be Sampled (QAPP – Section 6.2, first paragraph), Sample Process Design (QAPP – Section 10.1) and Sampling Methods (QAPP – Section 11.1) for estuary resurfacing groundwater discharge rates and nutrient loading. The proposed groundwater sampling and analysis program, to be executed under my direction, will provide the data required to estimate the rates of groundwater discharge and nutrient loading into the Santa Margarita River estuary. In my capacity as a professional geologist, I will review and verify any relevant historical data that may be used to support submittals required under Investigative Order R9-2019-0007.

FINAL
MONITORING AND ASSESSMENT WORKPLAN
Santa Margarita River Estuary and Watershed Monitoring and Assessment Program

Submitted to:

California Regional Water Quality Control Board, San Diego Region
2375 Northside Drive, Suite 100
San Diego, California 92108

Prepared By:

Weston Solutions, Inc.
5817 Dryden Place, Suite 101
Carlsbad, California 92008

On Behalf of:

County of Riverside
Riverside County Flood Control and Water Conservation District
County of San Diego
United States Marine Corps Base Camp Pendleton
City of Murrieta
City of Temecula
City of Wildomar

January 2020

P8/228135

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ACRONYMS AND ABBREVIATIONS

2006 Investigative Order	San Diego Water Board Investigative Order No. R9-2006-007
2019 Investigative Order	San Diego Water Board Investigative Order No. R9-2019-0007
303(d) List	Section 303(d) List of Water Quality Limited Segments
APHA	American Public Health Association
ASTM	American Society for Testing and Materials
Basin Plan	Water Quality Control Plan for the San Diego Basin
Bight '18	Southern California Bight 2018 Regional Marine Monitoring Survey
BRI	Benthic Response Index
CDFW	California Department of Fish and Wildlife
CEDEN	California Environmental Data Exchange Network
COC	chain of custody
CWA	Clean Water Act
DO	dissolved oxygen
Draft Staff Report	*Santa Margarita River Estuary, California Nutrients Total Maximum Daily Maximum Load Project*
ELAP	Environmental Laboratory Accreditation Program
Estuary	Santa Margarita River Estuary
GPS	Global Positioning System
HA	hydrologic area
IBI	Index of Biotic Integrity
LA	load allocation
MCB CamPen	U.S. Marine Corps Base Camp Pendleton
MLLW	mean lower low water
MQO	measurement quality objective
MS4	municipal separate storm sewer system
NIWC Pacific	Naval Information Warfare Center Pacific
NNE	nutrient numeric endpoint
NPDES	National Pollutant Discharge Elimination System
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RBI	Relative Benthic Index
RIVPACS	River Invertebrate Prediction and Classification System
San Diego Water Board	San Diego Regional Water Quality Control Board
SCAMIT	Southern California Association of Marine Invertebrate Taxonomists
SCCWRP	Southern California Coastal Water Research Project
SM	Standard Methods for the Examination of Water and Wastewater
SMR	Santa Margarita River
SOP	standard operating procedure
SPAWAR	Space and Naval Warfare Systems Pacific
SQO	sediment quality objective
State Water Board	State Water Resources Control Board
SUBS Sampler	multi-SUBstrate Subtidal sampler
SWAMP	Surface Water Ambient Monitoring Program

TKN	total Kjeldahl nitrogen
TMDL	Total Maximum Daily Load
TOC	total organic carbon
U.S.	United States
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	waste load allocation
WMA	Watershed Management Area
Workplan	Monitoring and Assessment Program Workplan
WQO	water quality objective

UNITS OF MEASURE

cm	centimeter(s)
ºC	degrees Celsius
g	gram(s)
g dry weight/m^2	grams dry weight per meter squared
g wet weight/m^2	grams of wet weight per meter squared
>	greater than
≥	greater than or equal to
<	less than
<	less than or equal to
m	meter(s)
m^2	meter(s) squared
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
mm	millimeter(s)
NTU	Nephelometric turbidity units
ppt	Parts per thousand
%	percent
µg	microgram(s)

1.0 INTRODUCTION

The Santa Margarita River Estuary (Estuary) is a 192-acre coastal estuarine habitat located in northern San Diego County on the southwestern edge of the United States (U.S.) Marine Corps Base Camp Pendleton (MCB CamPen). In 1986, the Estuary was placed on the Clean Water Act (CWA) Section 303(d) List of Water Quality Limited Segments (303(d) List) for impairments related to eutrophication during dry weather conditions (State Water Resources Quality Control Board [State Water Board], 2015). Additional regulatory actions and studies conducted in the Estuary since the listing have identified total nitrogen and total phosphorus as the cause of excess algal growth and consequently eutrophication in the Estuary. On May 9, 2019, Investigative Order No. R9-2019-0007 (2019 Investigative Order) was issued by the San Diego Regional Water Quality Control Board (San Diego Water Board) to the Cities of Murrieta, Temecula, and Wildomar, the Counties of San Diego and Riverside, the Riverside Flood Control and Water Conservation District, and MCB CamPen (hereafter collectively referred to as Dischargers) to "*design and implement a water quality improvement monitoring and assessment program for eutrophic conditions in the Santa Margarita River Estuary and Watershed, California*" (San Diego Water Board, 2019). Monitoring and regulatory history leading to this action is described in further detail below. The Monitoring and Assessment Workplan presented herein has been prepared in response to the requirements of the 2019 Investigative Order. Results from the water quality monitoring and assessment program will be used to evaluate and demonstrate water quality improvements achieved within the Estuary as a result of implementation actions taken by the Dischargers and to track progress towards achieving the numeric targets and loading reductions needed to reduce eutrophication within the Estuary.

1.1 BACKGROUND AND HISTORY

1.1.1 Study Area

The Estuary is located along the southern California coast in northern San Diego County. It is in the Ysidora Hydrologic Area (HA) (902.1) within the Santa Margarita River (SMR) Watershed Management Area (WMA), on the southwestern edge of MCB CamPen (**Figure 1-1**). The Estuary is one of the few remaining and largely unmodified coastal estuaries in southern California and encompasses 192 acres of estuarine habitat including subtidal habitats, mudflats, salt marsh, and salt pannes. The Estuary provides refuge, foraging areas, and breeding grounds for multiple threatened and/or endangered species, as well as coastal marine species (Staff Report; San Diego Water Board, 2018). State and federally endangered or threatened species in the Estuary include populations of the California Least Tern (*Sterna antilarum browni*), Belding's Savannah Sparrow (*Passerculus sandwichensis beldingi*), Light-footed Ridgeway's Rail (*Rallus obsoletus levipes*), Western Snowy Plover (*Charadrius alexandrines nivosus*), Tidewater Goby (*Eucyclogobius newberryi*), and Southern California Steelhead (*Oncorhynchus mykiss*).

The SMR Watershed, which drains into the Estuary and to the Pacific Ocean, is comprised of an area of approximately 750 square miles (sq mi). Approximately 73 percent (%) lies within Riverside County and includes all or portions of the Cities of Murrieta, Temecula, Wildomar, and Menifee in addition to approximately 457 sq mi of unincorporated area that also include federal, state, and tribal lands. The remaining 26.5% of the SMR Watershed land surface lies within San Diego County which includes MCB CamPen and the unincorporated communities of Fallbrook and Rainbow. The SMR begins in

Riverside County near the City of Temecula, at the confluence of Murrieta and Temecula Creeks. The main stem of the SMR flows within San Diego County through unincorporated areas, the community of Fallbrook, and MCB CamPen and ultimately drains into the Estuary. The adjacent watershed areas of the lower SMR and Estuary are largely undeveloped and support multiple habitats for populations of federally- and/or state- listed endangered species.

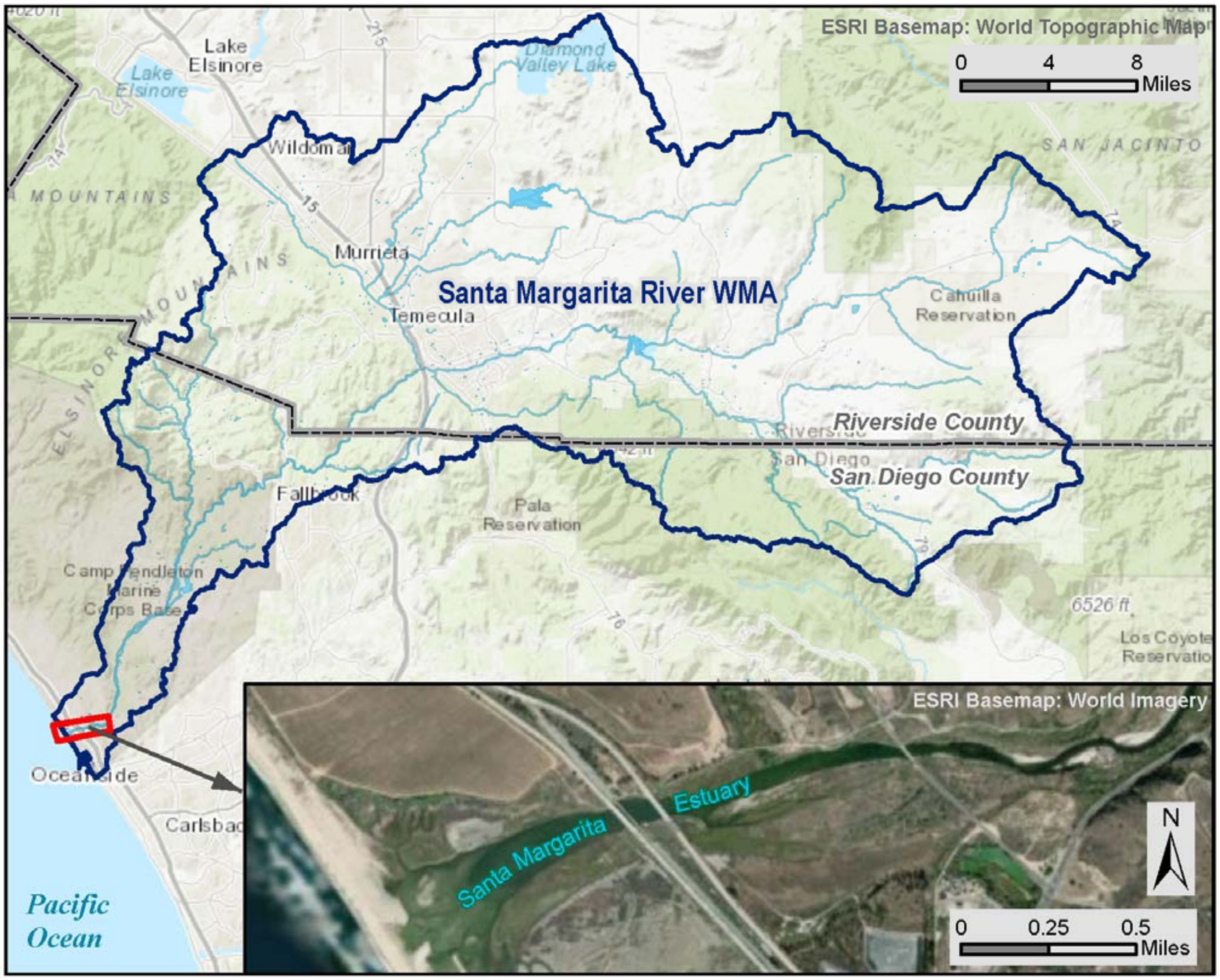

Figure 1-1. Overview of Santa Margarita River Estuary and Watershed Study Area

1.1.2 Problem Statement

The Estuary has been characterized by eutrophic conditions. Urban and agricultural land uses in the more developed portions of the watershed have resulted in hydrological modifications to the Estuary which have led to increased nutrient loading (McLaughlin et al., 2013). Throughout the year, the ocean inlet of the Estuary may be open or closed to the Pacific Ocean for extended periods depending on the amount of rainfall and flow. During periods when the inlet is open and the Estuary is connected to the Pacific Ocean, the Estuary is flushed with seawater resulting in a brackish lagoon environment. However, salinity stratification in the water column often occurs when a sand berm develops at the ocean inlet. The combination of restricted tidal flushing and watershed loading of nutrients from upstream can result in excessive algal growth in the Estuary during the summer-dry season and winter-dry season (San Diego Water Board, 2018). As the macroalgae decays, it reduces dissolved oxygen (DO) concentrations in the Estuary resulting in eutrophic conditions which can degrade the aquatic habitat. In addition, excessive algal mats and floating algal scum are aesthetically unpleasant, reducing the public's opportunities for enjoyment of non-contact water recreation through activities such as bird watching.

Total nitrogen and total phosphorus loading have been identified as contributing causes of algal growth and consequently for eutrophication in the Estuary. Significant sources of these nutrients include: resurfacing groundwater, upstream non-stormwater discharges from municipal separate storm sewer systems (MS4s) discharging into the SMR and its tributaries, and agricultural discharges (San Diego Water Board, 2019). Modeling efforts (Sutula et al 2016; Butcher, 2017) estimated at-source total nitrogen as 93% from watershed surface water, 2% watershed groundwater, and 5% Stuart Mesa Field Groundwater; and, at-source total phosphorus as 73% from watershed surface water, 27% watershed groundwater, and <0.1% Stuart Mesa Field Groundwater. Surface water sources for total nitrogen were further estimated as 88% agricultural discharges, and 12% MS4, while for total phosphorus the sources were identified as 75% agricultural discharges and 25% MS4 discharges. Approximately 0.1% was sourced to dairy farm discharges in these studies.

1.1.3 Regulatory History and Water Quality Standards

The Water Quality Control Plan for the San Diego Basin (Basin Plan) outlines water quality standards for the Estuary (San Diego Water Board, 1994). The Basin Plan designates beneficial uses for San Diego Region waterbodies and the water quality objectives (WQOs) developed to protect these beneficial uses. Beneficial uses for the Estuary include Contact Water Recreation (REC-1), Non-Contact Water Recreation (REC-2), Estuarine Habitat (EST), Wildlife Habitat (WILD) Rare, Threatened, or Endangered Species (RARE), Marine Habitat (MAR), Migration of Aquatic Organisms (MIGR), and Spawning, Reproduction, and/or Early Development (SPWN). It should be noted that access to the Estuary is controlled by MCB CamPen, and contact and non-contact recreation activities are not allowed in the Estuary. Based on the San Diego Water Board's determination that eutrophic conditions in the Estuary limit its ability to support beneficial uses, the Estuary was placed on the 303(d) List (State Water Board, 2015) for eutrophic conditions during dry weather conditions.

1.1.3.1 2006 Investigative Order and Estuary Studies

The San Diego Water Board issued Investigation Order No. R9-2006-0076 (2006 Investigative Order) (San Diego Water Board, 2006) which required the collection of data to support the development of a Total Maximum Daily Load (TMDL). In response to the 2006 Investigative Order, the Southern California Coastal Water Research Project (SCCWRP) conducted an assessment of the Estuary from 2008-2009 which confirmed the impairment of the Estuary due to eutrophication (McLaughlin et al., 2013). Findings of this assessment indicated that an average macroalgal biomass greater than 700 grams of wet weight per meter squared (g wet weight/m^2) and macroalgal cover greater than 30% would indicate eutrophic conditions. These values were less than half of what was observed in the Estuary during SCCWRP's 2008-2009 impairment assessment. Following the impairment assessment, the sampling protocol for measuring macroalgal biomass changed from measuring wet weight to measuring dry weight for a more accurate assessment of biomass.

Further studies of eutrophication in the Estuary were conducted between 2010 and 2018 by the Naval Information Warfare Center Pacific (NIWC Pacific).[1] While monitoring results show that overall conditions are improving as massive rafting algal mats have not been observed since 2010, these studies continue to show evidence of eutrophic conditions manifested as macroalgal blooms, with higher levels of macroalgae heavily tied to closed mouth conditions. On behalf of MCB CamPen, NWIC Pacific also conducted monitoring on resurfacing groundwater (Leather et al., 2015; Leather et al., 2016; Leather et al., 2017). Results from this monitoring indicated that ongoing discharge of nutrients into the Estuary through resurfacing groundwater from former agricultural fields on MCB CamPen was still occurring. However, data indicated that a reduction of nutrient loading by as much as one to two orders of magnitude[2] had occurred since the monitoring of resurfacing groundwater first began (San Diego Water Board, 2019).

1.1.3.2 2018 Draft Staff Report

A loading analysis was drafted in July 2018, which identified total nitrogen and total phosphorus as the causative pollutants for eutrophication in the Estuary. In *Santa Margarita River Estuary, California Nutrients Total Daily Maximum Load Project* (Draft Staff Report) (San Diego Water Board, 2018), the San Diego Water Board outlined a TMDL of 13,246 pounds of delivered total nitrogen per year and 1,528 pounds of delivered total phosphorus per year during dry weather, meaning that the Estuary is able to assimilate this amount of total nitrogen and phosphorus during that time period without impairments of beneficial uses. This assimilative capacity corresponds to a 76% load reduction from loading levels estimated by SCCWRP for the 2008 water year (San Diego Water Board, 2018).

In the Draft Staff Report (San Diego Water Board, 2018), numeric targets for the Estuary were developed using the nutrient numeric endpoint (NNE) framework approach for California estuaries developed by SCCWRP for the State Water Board. "*The NNE framework is founded on the premise that site-specific ecological response variables, such as dissolved oxygen concentrations, macroalgal biomass, and benthic community condition score combined with a weight of evidence approach provide a more direct and robust means of assessing beneficial use impairment than relying on nutrient concentrations alone*" (Draft Staff Report; San Diego Water Board, 2018). Following the NNE approach, macroalgal biomass and DO were selected as primary numeric targets for the Estuary and provide a scientifically defensible methodology for interpreting the narrative WQOs of the Basin Plan for biostimulatory substances, which states:

> *"Inland surface waters, bays and estuaries and coastal lagoon waters shall not contain biostimulatory substances in concentrations that promote aquatic growth to the extent that such growths cause nuisance or adversely affect beneficial uses."*

To confirm that the Estuary beneficial uses are being supported, additional secondary numeric targets were selected for macroalgal biomass, DO concentrations, and benthic community condition.

The primary numeric targets identified in the Draft Staff Report include surface water macroalgal biomass of less than (<) 57 grams dry weight per meter squared (g dry weight/m^2) and a water column

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[1] Formerly known as NAVY Space and Naval Warfare Systems Pacific (SPAWAR).
[22]Six-fold decrease (Kara Sorensen, personal communication)

dissolved oxygen concentration with a daily minima of greater than or equal to (≥) 5.0 milligrams per liter (mg/L) (**Table 1-1**). Secondary numeric targets for macroalgal biomass, DO, and benthic community condition are also provided in **Table 1-1**. The secondary numeric targets are to be used only if the primary numeric targets are not attained. **Figure 1-2** shows the pathway of how the numeric targets should be utilized to determine if the Estuary is supporting beneficial uses (Draft Staff Report; San Diego Water Board, 2018).

Table 1-1. Draft Staff Report Numeric Targets for Santa Margarita River Estuary

Metric	Primary Target	Secondary Target	Season
Surface Water Macroalgal Biomass	< 57 g dry weight/m^2	< 70 g dry weight/m^2	Winter Dry and Summer Dry
Water Column Dissolved Oxygen	Daily minima ≥ 5.0 mg/L	7-day average of daily minimum measurements ≥ 5.0 mg/L, 10 percent allowable exceedance	Winter Dry and Summer Dry
Benthic Community Condition Score	-	≤ 2.0 (Low Disturbance based on Sediment Quality Objectives [SQO] scale)	Winter Dry and Summer Dry

Source: San Diego Water Board, 2019

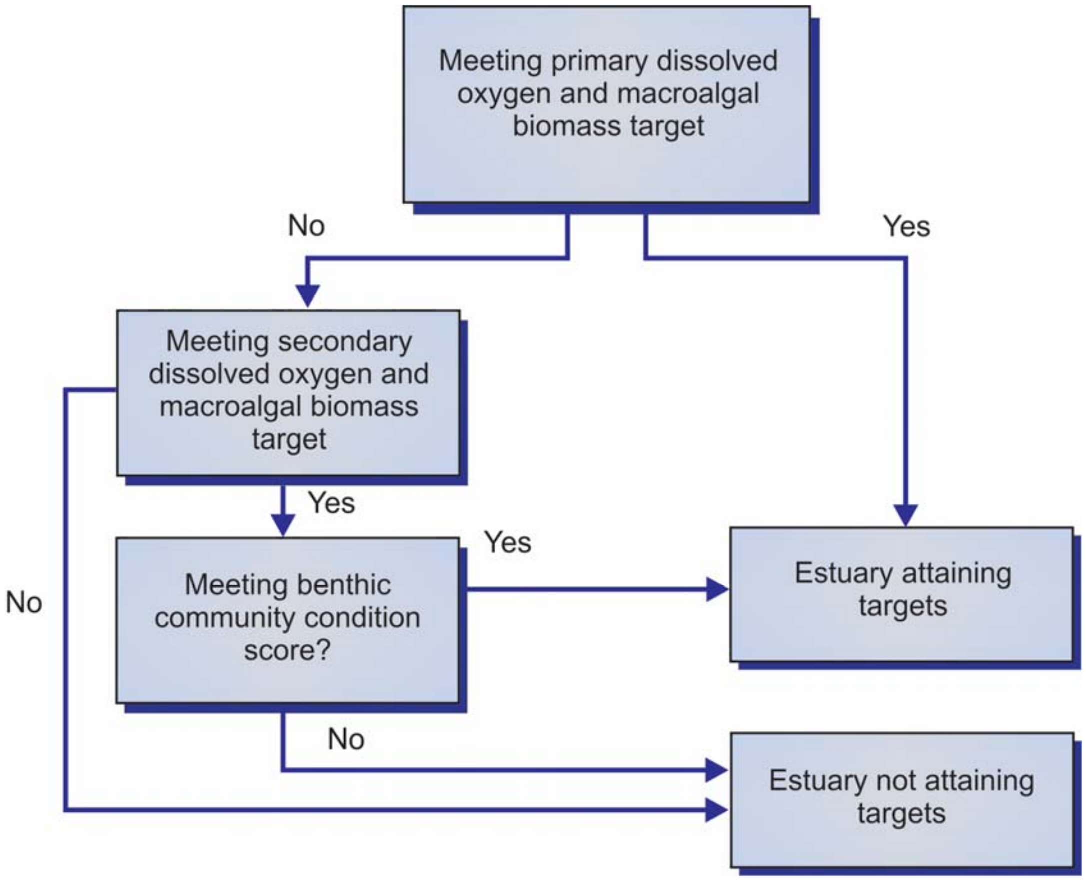

Figure 1-2. Use of Primary and Secondary Numeric Targets to Determine if the Estuary is Supporting Beneficial Uses (Modified from LWA, 2016; San Diego Water Board, 2018)

1.1.3.3 2019 Investigative Order

In May 2019, the San Diego Water Board issued the 2019 Investigative Order under the authority of California Water Code section 13267. The purpose of the 2019 Investigative Order is to "*assess the condition of the Santa Margarita River Estuary (Estuary) and to evaluate the linkage between the nutrient loading trends resulting from the implementation actions by the Cities of Murrieta, Temecula, and Wildomar, the Counties of San Diego and Riverside, the Riverside Flood Control and Water Conservation District, and the United States Marine Corps Base Camp Pendleton (collectively referred to hereafter as Dischargers) and the restoration of the water quality and beneficial uses of the Estuary*" (San Diego Water Board, 2019). The monitoring requirements were developed in collaboration with the Dischargers through the Santa Margarita River Estuary Watershed Nutrient Initiative Stakeholder Group. The 2019 Investigative Order requires the development of a Monitoring and Assessment Program Workplan (Workplan) that outlines a water quality monitoring and assessment program to track progress towards achieving the numeric targets listed in the Draft Staff Report and total nitrogen and total phosphorus loading reductions to the Estuary.

The 2019 Investigative Order outlines the primary and secondary numeric targets for the Estuary as well as the calculated capacity of the Estuary to assimilate total nitrogen and total phosphorus in pounds per year in order to still meet the numeric targets. The numeric targets are from the Draft Staff Report and are listed in **Table 1-1**. To achieve the numeric targets, the Draft Staff Report calculated "delivered" Waste Load Allocations (WLAs) and Load Allocations (LAs) for the Estuary. The sum of controlled sources of delivered WLA and LA for total nitrogen is 8,226 pounds per year, and the sum of delivered total phosphorus is 574 pounds per year (Draft Staff Report; San Diego Water Board, 2018).

1.2 SAMPLING AND TESTING OBJECTIVES

The purpose of this monitoring program is to conduct surface and ground water monitoring in the Estuary and SMR Watershed in order to assess progress toward attainment of numeric targets per the 2019 Investigative Order (San Diego Water Board, 2019).

Specifically, this monitoring program is designed to address the following questions:

1. *Is watershed mass loading of total nitrogen and total phosphorus to the River and Estuary reduced to levels that do not exceed the calculated assimilative capacity of the Estuary?*

2. *Based on available information, do monitoring results confirm the assumption that the implementation and compliance with the Discharger's existing NPDES permits is sufficient to bring about the necessary nutrient load reductions to restore the Estuary in accordance with the schedule provided in the Draft Staff Report?*

3. *Are the Estuary numeric targets for macroalgal biomass, dissolved oxygen, and Benthic Community Condition being achieved and sustained? If not, based on available information, what are the primary stressors causing unsatisfactory eutrophication conditions?*

These questions will be addressed using the data collected each year, including the monitoring program parameters shown in **Figure 1-3**.

Monitoring will be conducted for four years, beginning within 60 days of receiving the Executive Officer's approval of the Workplan to be submitted November 8, 2019. The start of the monitoring program is intended to align with the beginning of the critical growth period in April. Monitoring reports will be prepared annually to allow the Dischargers to evaluate the effectiveness of their actions to reduce nitrogen and phosphorus loading to the Estuary and achieve the numeric targets of the 2019 Investigative Order.

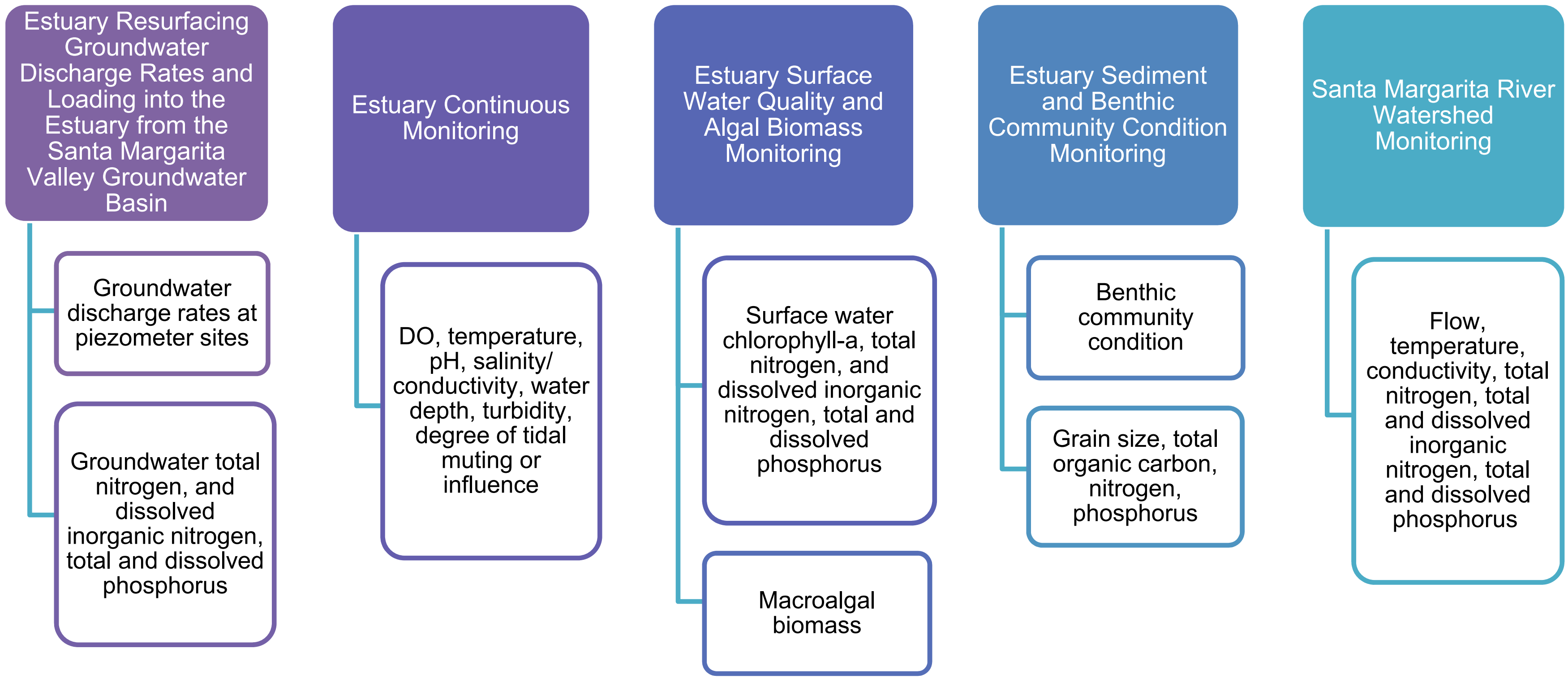

Figure 1-3. Monitoring Program Parameters

2.0 METHODS AND MATERIALS

Field and laboratory procedures are summarized in the following sections. Details can be found in the referenced Standard Operating Procedures (SOPs) and documents. Quality assurance/quality control (QA/QC) is briefly described in **Section 2.3**; more detailed QA/QC procedures are presented in the QAPP (**Appendix A**).

2.1 FIELD SAMPLING PROGRAM

Sampling events will be conducted during dry weather periods in both summer and winter. Monitoring program components include the following:

- Estuary Resurfacing Groundwater Discharge Rates and Loading into the Estuary from the Santa Margarita Valley Groundwater Basin
- Estuary Continuous Monitoring
- Estuary Surface Water Quality and Algal Biomass Monitoring
- Estuary Sediment and Benthic Community Condition Monitoring
- Santa Margarita River Watershed Monitoring

The station IDs provided in this section are consistent with historical locations monitored in the Estuary and SMR Watershed. Monitoring events will be conducted so that they are preceded by a minimum of 72 hours of dry weather (< 0.2 inch of precipitation in 24 hours). This definition of ambient conditions is consistent with the criteria used in the watershed loading model informing nutrient management in the SMR Watershed (Sutula et al., 2016). Continuous flow data and continuous DO data collected during storm events and the following 72 hours will not be included in assessment and reporting, which focus on ambient conditions. However, continuous data collected during wet weather will be available for future watershed modeling efforts and submitted to the California Environmental Data Exchange Network (CEDEN).

The water quality and benthic monitoring conducted by MCB CamPen is covered as a Class III activity under the existing MCB CamPen Riparian Biological Opinion (BO) from the United States Fish and Wildlife Service (1995). A brief memo of what the work entails must be submitted annually, and this information is then included in the annual Riparian BO report. MCB CamPen will conduct the National Environmental Policy Act (NEPA) review for this activity. In accordance with the Riparian BO, MCB CamPen will provide a Categorical Exclusion prior to the start of monitoring. A summary of the sampling activity is to be provided to MCB CamPen Environment & Environmental Security on a schedule to be provided by MCB CamPen for inclusion in their annual reporting. Nesting seasons of threatened and endangered bird species may prevent sampling from being conducted or may restrict access around nesting areas during certain times of year.[3]

All equipment (waders, boots, sampling equipment, and other aquatic gear) used for monitoring described in the following sections that intentionally comes into contact with surface waters on MCB

[3] Breeding season is from February 15 to August 31; sampling must not disturb the California Least Tern *Sternula antillarum browni* colony located on the sand berm at the mouth of the SMR Estuary.

CamPen must be disinfected either through chemical treatment (generally with a dilute solution of formula 409, or equivalent) or freezing. Boat hulls and trailers should be power-washed and inspected for signs of quagga mussel, zebra mussel, and New Zealand mud snail, especially if coming from surface waters associated with the lower Colorado River. No foreign ballast or other waters shall be introduced into any surface water on MCB CamPen.

2.1.1 Estuary Resurfacing Groundwater Discharge Rates and Loading into the Estuary from the Santa Margarita Valley Groundwater Basin

Each year (biannually during winter dry and summer dry periods), resurfacing groundwater and loading to the Estuary from the Santa Margarita Valley Groundwater Basin will be monitored by sampling several piezometers and monitoring wells. Groundwater samples will be collected from three historic piezometer locations (**Table 2-1**) located near the Stuart Mesa Agricultural Fields to confirm that resurfacing groundwater is no longer a significant source of nutrient loading to the Estuary. Submarine groundwater discharge rates and nutrient concentrations will be monitored at each piezometer location. Within the Estuary, nutrients will be measured by advancing a sampling probe into the top two feet of the ground surface beneath the estuary to collect samples for laboratory analysis, as well as to perform in-field measurements of temperature and conductivity. Qualitative assessment of groundwater discharge is performed by measuring temperature and conductivity contrasts in the groundwater and surface water to determine potential areas of groundwater discharge. Measured groundwater gradients determined from existing upgradient piezometers will be quantitatively used to assess groundwater flux by relying on Darcy's flow equation. Combining nutrient analysis from the laboratory samples with quantitative measurements and qualitative assessment of groundwater flux will allow for the calculation of nutrient mass loading to the estuary. Groundwater discharge rates will be estimated using the groundwater levels observed at the piezometers and in upland piezometers located upstream of the Stuart Mesa Agricultural fields.

In addition, so as to capture loading from the Santa Margarita Valley Groundwater Basin, seven historically monitored groundwater wells in the Lower Ysidora sub-basin will be monitored for nutrients biannually (wet and dry season). The Lower Ysidora sub-basin is located just upstream of the Estuary. Groundwater monitoring wells in the Lower Ysidora were selected based on proximity to the river, i.e. their ability to monitor subflow from the groundwater to the Estuary, and consistency with previous sampling locations. **Table 2-1** lists the station locations and coordinates for groundwater monitoring.

All groundwater samples will be sent to a commercial laboratory and analyzed for analytes listed in **Table 2-7** (See **Section 2.2.1**). All groundwater methods were reviewed and approved by a State Certified Geologist[4]. All field work will be performed per state-approved Standard Methods and overseen by a State Certified Geologist per the Investigative Order.

[4] See Professional Geologist certification page in front matter of Work Plan/QAPP, following the certification pages signed by the stakeholders

Table 2-1. Station Identifications and Coordinates for Estuary Resurfacing Groundwater Monitoring

Station ID	Latitude (NAD83)	Longitude (NAD83)
Santa Margarita Valley Groundwater Basin Locations		
MW 2201	33.28539	-117.37663
Well #C (SDSU)	33.26846	-117.37276
Well #B (SDSU)	33.25792	-117.37314
11/5-2D3	33.25500	-117.37865
7W-09A	33.23914	-117.38174
11/5-11D4 (7W-09B)	33.23913	-117.38175
7W-08A	33.23728	-117.38458
Stuart Mesa Agricultural Field Piezometer Locations		
DA1	33.235497	-117.407642
DA2	33.236041	-117.404666
DA3	33.236443	-117.402449

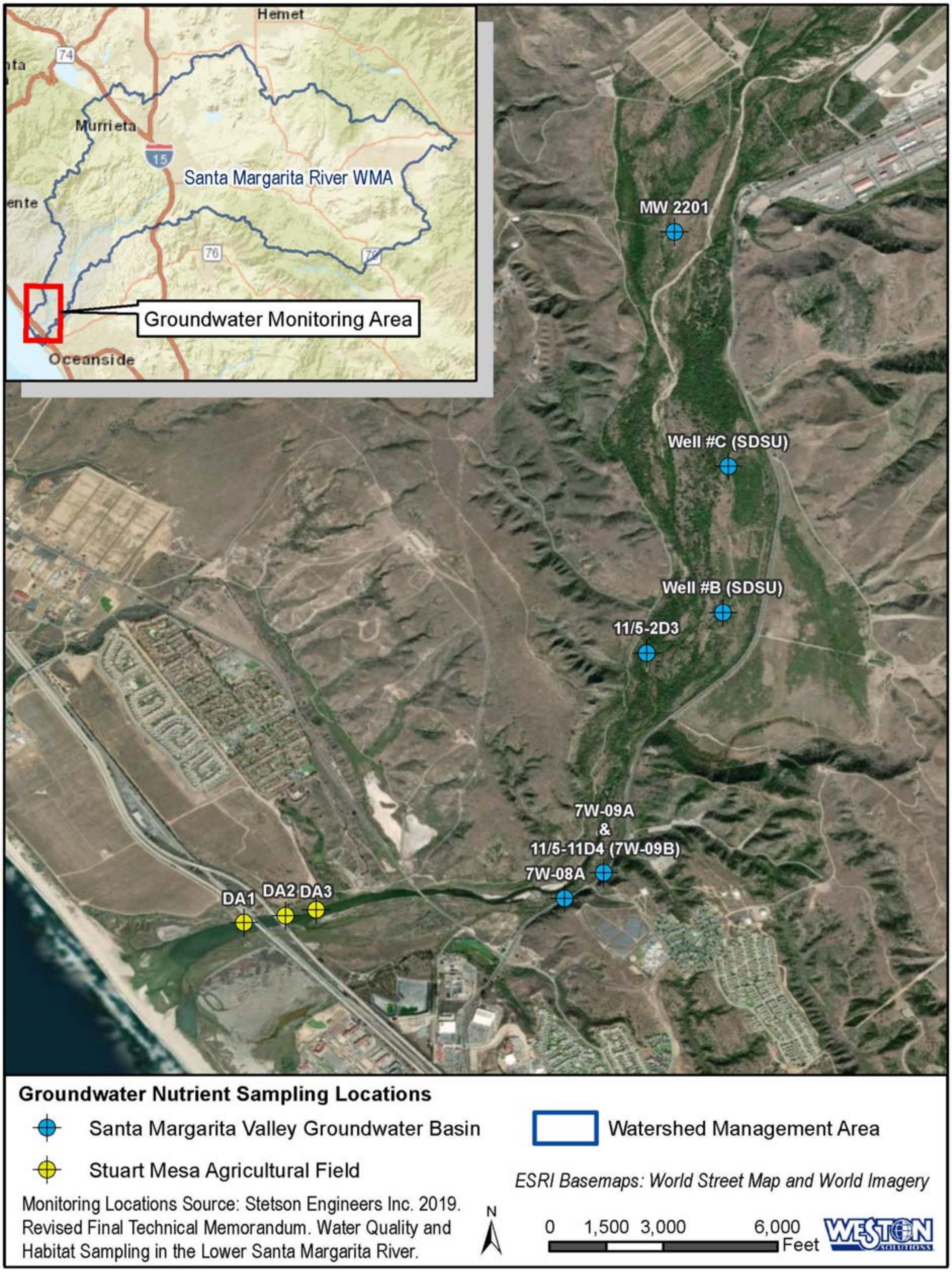

Figure 2-1. Groundwater Monitoring Station Locations

2.1.2 Estuary Continuous Monitoring

Each year, continuous water quality monitoring will be conducted by the Dischargers for seven months from April through October and during three months of the winter period (November, January, March). A multi-parameter data sonde with an optical sensor will be deployed on a stationary structure at a depth of approximately 0.5 meter (m) at two locations in the Estuary, I-5 Bridge and Stuart Mesa Bridge. Deployment will account for tidal range and depth such that the sonde probes remain submerged and do not contact the sediment surface. Because the sondes may need to be removed at times (e.g., due to severe weather in the winter months), data may not be collected for the entirety of each month; at least two weeks of continuous data will be collected during each monitored month.

Sampling locations are shown in **Table 2-2** and **Figure 2-3**; station IDs are consistent with historical monitoring. Methodology will be consistent with applicable SCCWRP Southern California Bight Regional Monitoring Program protocols (e.g., SCCWRP Technical Report 711 [McLaughlin et al., 2012]).[5] The following parameters will be continuously monitored *in situ* at 15-minute intervals:

- Dissolved oxygen (mg/L and % saturation)
- Water temperature (°C)
- pH (pH)
- Salinity/conductivity (ppt; µS/cm)
- Turbidity (NTU)
- Water depth (m)

In addition, the degree of tidal muting or influence will be documented based on the current status of connectivity between the Estuary and the Pacific Ocean.

Table 2-2. Station Identifications and Coordinates for Estuary Continuous Monitoring

Station Location	Station ID	Latitude (NAD83)	Longitude (NAD83)
I-5 Bridge	I-5 (Axial 4)	33.235317	-117.406883
Stuart Mesa Bridge	SMB	33.237620	-117.395290

Equipment will be maintained throughout the monitoring period to ensure that it is in proper working order. Data sondes will need to be removed from the water to download the data and for maintenance (e.g., removal of biofouling, verification of precision, re-calibration, replacement of batteries) at least once a month. A telemetry system may be used to check data in real-time. Summer months may require weekly maintenance. Sampling equipment can include a solar panel for battery recharge and power resiliency.

[5] Available at: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/711_B08EE_AppendixC.pdf

2.1.3 Estuary Algal Biomass Monitoring

Monthly algal biomass monitoring will be conducted in the Estuary from April through October. Sampling will be conducted in each of three Estuary regions: below the I-5 Bridge, above the Stuart Mesa Bridge to the head of the Estuary or the lower reach of the river,[6] and between the two bridges.

During each monthly monitoring event, site conditions and sample information will be recorded on field data sheets. Additionally, during each monitoring event, the status of connectivity between the Estuary and the Pacific Ocean will be documented. Effort should be made to align collection location with Estuary sediment sampling described in **Section 2.1.5.**; and, where feasible, at similar sampling depths for subtidal sampling**,** so that relationships between the benthic community condition score and other parameters may be logically inferred.[7]

Algal biomass monitoring will be conducted in accordance with the SOP for Macroalgal Collection in Estuarine Environments (SCCWRP Technical Report 872; McLaughlin et al., 2019) (**Appendix B**). The SOP includes protocols to sample two habitat types, intertidal (mud or sand) flats and shallow subtidal (<10 m). Based on knowledge gained during previous monitoring in the Estuary, data generated by the subtidal protocol is more representative of conditions in the Estuary and is recommended. The subtidal protocol is discussed herein and detailed in Section 4 of SCCWRP Technical Report 872. The intertidal protocol can be found in Section 3 of SCCWRP Technical Report 872.

Based on several years of monitoring, NIWC Pacific has recommended sampling location options for macroalgal monitoring in the three segments of the Estuary (**Figure 2-3**). Shown in **Table 2-3** are the identifications and approximate geographic coordinates for these historical stations. A minimum of three samples will be collected from each of five sampling locations within each of the three Estuary segments, for a minimum of 15 samples per Estuary segment. The sampling approach requires that all macroalgae found within a defined surface area two meters in depth or less is comprehensively sampled from surface to bottom. As feasible, selected sites should include macroalgal sampling stations that have been sampled historically during 2008-2018, which are identified with a "✓" in **Table 2-3**. Also shown are recommended sites for Estuary Sediment and Benthic Community Condition Monitoring in order to align station sampling. While the table provides six options for macroalgae biomass monitoring per sub-segment, a list of 30 sites (10 per sub-segment) with some historical data are available from NWIC Pacific if additional location options are needed. Monitoring at historical locations will facilitate analysis of trends.[8]

Sampling locations should be the same for each sampling period, and site conditions recorded on field data sheets. Due to scouring and deposition events that may occur between monitoring periods, it may not be feasible to conduct sampling at the same locations year to year. In this case, additional sites will be selected, attempting to stay as close to the original sites as possible.

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[6] The inner limit or upstream boundary of the Estuary should be defined by changes from estuarine to riparian vegetation, changes in salinity going from brackish to freshwater, and changes in river currents dominating over tidal action (San Diego Water Board, 2019).
[7] Benthic samples must be collected in subtidal conditions in order to determine SQO benthic community scores.
[8] This targeted sampling approach based on historical monitoring information was discussed and agreed upon during the July 8, 2019 Conference Call with Cynthia Gorman of the San Diego Water Board.

NWIC Pacific conducted a sampling number power analysis using 2017 and 2018 data (~630 samples) and prior model output to conservatively estimate a need for 160/200 samples total (all three segments). Collection of data as proposed at five locations in triplicate in each sub-segment (i.e., a total of 15 samples) at a frequency of seven times per year will result is 105 sample/section or 315 data points for analysis and ensure that dataset is large enough data to characterize the estuary and assess trends.

Table 2-3. Recommended Locations for Estuary Algal Biomass Monitoring

Estuary Segment	Station ID	Recommended Historical MA Site	BCA/ Sediment Site	Latitude (NAD83)	Longitude (NAD83)
Below the I-5 Bridge	W1 (MA1)	✓	✓	33.233980	-117.413111
	W8 (MA2)	✓	✓	33.235393	-117.408846
	W7 (MA3)	✓		33.234386	-117.408510
	W3	✓	✓	33.232895	-117.411361
	W4	*		33.233801	-117.409878
	W5	*		33.234402	-117.409978
Between the I-5 and Stuart Mesa Bridges	M6 (MA4)	✓	✓	33.236959	-117.399899
	M10 (MA5)	✓	*	33.237478	-117.395339
	M4	✓		33.236079	-117.402070
	M9	✓ (old MA site)		33.237657	-117.397121
	M1	*	✓	33.235302	-117.405803
	M8	*	✓	33.237211	-117.397786
Above the Stuart Mesa Bridge	E7 (MA5.5)	✓	✓	33.237630	-117.388060
	MA6	✓	*	33.238350	-117.384817
	E3	✓	✓	33.237580	-117.392260
	E5	✓		33.236980	-117.389900
	E8	✓	✓	33.238030	-117.387060
	E10	*(old ambient WQ site)		33.238600	-117.383770

*Historical sites suggested in addition to recommended historical sites to achieve 5 sites per sub-segment. All sites have some historical data and up to 10 historical sites identified per sub-segment. Full list available from NWIC.

SCCWRP Technical Report 872 provides procedures for subtidal sampling using either a multi-SUBstrate Subtidal sampler (SUBS sampler) or a combination of a bottomless mesh basket/collapsible hamper or a similar device to collect algae in the water column and a box core to collect benthic macroalgae. The SUBS sampler, which has the capacity to collect water column and benthic sediment in one sample, is advantageous due to time and cost savings associated with more efficient sampling, minimal site disturbance compared to the use of a box core, and comparability with recent data collected using this method. For these reasons, the SUBS sampler will be used for collection of macroalgal biomass samples. The SUBS Sampler may also be used to collect benthic sediment (**Section 2.1.5.1**). Local temperature and salinity will be measured with a hand-held meter and recorded on field data sheets. A kayak should be used to access water-covered areas of the Estuary, in order to limit disturbance to sampling areas and avoid walking on the shoreline and impacting birds. If water depth is too shallow to allow for deployment of the SUBS sampler (i.e., < 1 ft), the SUBS core tube will be used to collect the sample. If floating algae is present, the basket/hamper should be used to augment the SUBS sampling procedure and collect the floating algae. At each sampling point, macroalgal biomass will be collected from the surface to bottom within a defined surface area. Specific sample collection procedures for both methods are provided in Section 4.6 of SCCWRP Technical Report 872 (**Appendix B**). Examples of a mesh basket/hamper and a SUBS sampler are shown in **Figure 2-2.** Samples should be kept refrigerated at 4°C in the dark until they are processed. Laboratory processing will be completed within 48 hours. See **Section 2.2** for details on laboratory testing.

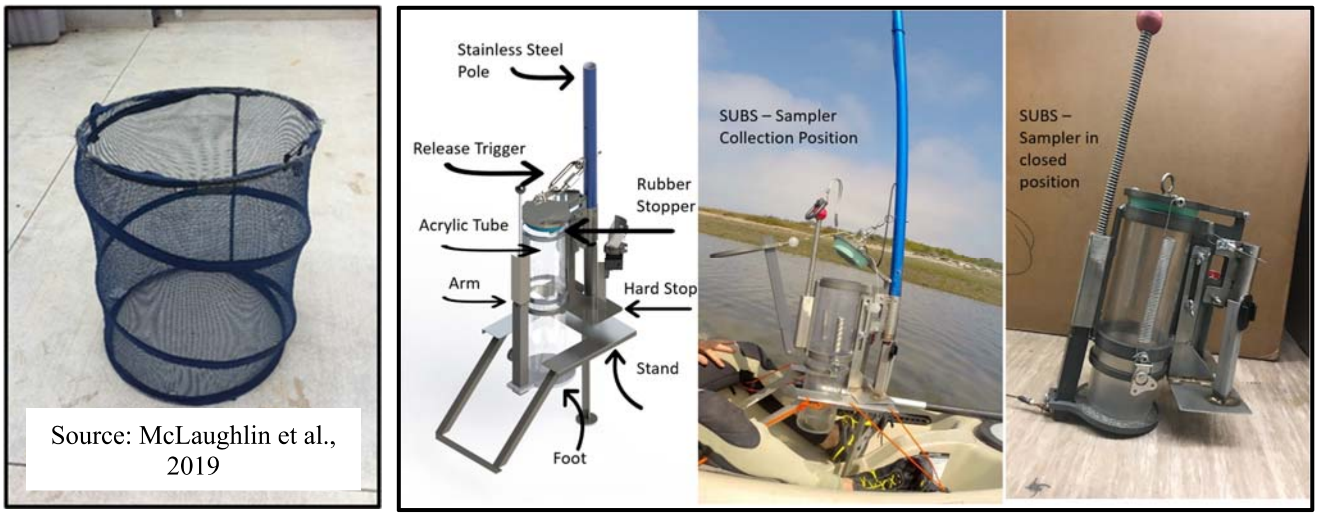

Figure 2-2. Collapsible Hamper (Left) and SUBS Sampler (Right) for Macroalgae Collection

2.1.4 Estuary Surface Water Quality Monitoring

Monthly surface water sampling will be conducted in the Estuary from April through October and during three events from November through March. During each monitoring event, sampling will be conducted at one location in each of three Estuary regions: below the I-5 Bridge, above the Stuart Mesa Bridge to the head of the Estuary or the lower reach of the river,[9] and between the two bridges. Sampling locations are shown in **Table 2-4** and **Figure 2-3**, with station IDs consistent with historical monitoring. If algal biomass (**Section 2.1.3**) and surface water quality sampling are conducted on the same date, algal biomass sampling should occur before surface water sampling (SCCWRP, 2009).

During each monthly monitoring event, site conditions and sample information will be recorded on field data sheets. Additionally, during each monitoring event, the status of connectivity between the Estuary and the Pacific Ocean will be documented.

[9] The inner limit or upstream boundary of the Estuary should be defined by changes from estuarine to riparian vegetation, changes in salinity going from brackish to freshwater, and changes in river currents dominating over tidal action (San Diego Water Board, 2019).

Estuary surface water quality monitoring will be conducted in accordance with Surface Water Ambient Monitoring Program (SWAMP) and Standard Methods (SM) for the Examination of Water and Wastewater (APHA, 2012). Ambient surface water grab samples will be collected at a depth of approximately 0.5 m, and will be analyzed for chlorophyll-a, total nitrogen, total and dissolved inorganic nitrogen, and total and dissolved phosphorus (see **Section 2.2**). Water samples will be collected using a sampling pole or peristaltic pump, and samples will be placed into appropriate bottles and preserved and transported as described in **Section 2.1.8**. Two field duplicates and one field blank will be collected for nutrient analysis per monitoring year in order to achieve the SWAMP QA requirements outlined in the QAPP.

Table 2-4. Station Identifications and Coordinates for Estuary Surface Water Monitoring

Estuary Segment	Station ID	Latitude (NAD83)	Longitude (NAD83)
Below I-5 Bridge	SMRE 1	33.2330	-117.4123
Between Bridges	SMRE 2	33.2369	-117.4001
Above Stuart Mesa Bridge*	SMRE 3	33.2373	-117.3878

*Alternative upstream location for sampling above Stuart Mesa Bridge is AX10.5 located at: 33.24116, -117.38232

2.1.5 Estuary Sediment and Benthic Community Condition Monitoring

Sediment monitoring to assess benthic community condition will be conducted in the Estuary on an annual basis, in late summer. Monitoring in marine subtidal areas of the estuary (salinity ≥ 27 ppt) will be conducted in accordance with the Sediment Quality Assessment Technical Support Manual, SCCWRP Technical Report 777 (Bay et al., 2014).[10] Sampling locations and depths (where feasible) will align with macroalgal sampling so that relationships between the benthic community condition score and other parameters may be logically inferred. However, benthic samples must be collected in subtidal conditions for use of sediment quality objective (SQO) benthic community scoring. In areas of the estuary where the criteria for assessing benthic infaunal condition using the SQO tool cannot be met (i.e., brackish areas with a salinity of < 27 ppt), an alternative sampling protocol is recommended based on protocols developed for the 2018 Southern California Bight Regional Marine Monitoring Program (Bight '18). If salinity was determined to be < 27 ppt and SQO calculated, the results should be qualified.

Monitoring will be conducted at three locations within each of the three Estuary segments, for a total of nine samples. Based on historical sampling, NWIC Pacific has provided the recommended sampling locations shown in **Table 2-5** and **Figure 2-3**. Additional suggested locations are shown in **Table 2-3**, which relates sites recommended for macroalgae biomass sampling with sediment and benthic community condition monitoring sites. One field duplicate and one field blank will be collected for

[10] Available at: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/777_CASQO_TechnicalManual.pdf. Once accepted methods are available to estimate the effect of sediment organic matter (eutrophication) upon benthic macro invertebrate communities, they may be considered for use (San Diego Water Board, 2019).

sediment chemistry analysis per monitoring year in order to achieve the SWAMP QA requirements outlined in the QAPP.

Table 2-5. Station Identifications and Coordinates for Estuary Sediment Monitoring

Estuary Segment	Station ID	Latitude (NAD83)	Longitude (NAD83)
Below I-5 Bridge	W1 (MA1)	33.233980	-117.413111
	W3	33.232895	-117.411361
	W8 (MA2)	33.235393	-117.408846
Between Bridges	M1	33.235302	-117.405803
	M6 (MA4)	33.236959	-117.399899
	M8	33.237211	-117.397786
Above Stuart Mesa Bridge	E3	33.237580	-117.392260
	E7 (MA5.5)	33.237630	-117.388060
	E8	33.238030	-117.387060

Benthic sediments will be collected as surface grabs for the analysis of total organic carbon (TOC), grain size, total nitrogen, total phosphorus, and benthic infaunal analysis (i.e., sorting and taxonomic evaluation of benthic macroinvertebrates). Prior to sampling, it is recommended that a salinity measurement be taken above the sediment-water interface to determine if the sampling site is located in marine (≥ 27 ppt) or brackish (< 27 ppt) waters. It is recommended that salinity measurements be taken as close to Mean Lower Low tide (MLLW), less than or equal to 0.5 feet on a tide chart, in order to get the most accurate measurement (SCCWRP, 2018).

A Van Veen or equivalent grab sampler with a 0.1 square meter (m^2) surface area is recommended for the collection of biology and chemistry samples in marine areas of the estuary in order to calculate the SQO benthic condition line of evidence (LOE). Equivalent grab samplers can be used with a smaller surface area as long as the sediment samples are equivalent in quality to the Van Veen grab (Bay et al., 2014). An appropriate sampler for the collection of benthic sediments will have the following characteristics:

- Constructed of a material that does not introduce contaminants.
- Causes minimal surface sediment disturbance.
- Does not leak or mix during sample retrieval.
- Has a design that enables safe/easy sample verification that samples meet all applicable sampling criteria (e.g., collects sediments to at least five cm below the sediment surface, has access doors allowing visual inspection and removal of undisturbed surface sediment).

In brackish areas of the estuary, a 4-inch diameter plastic core tube (diameter refers to inner diameter) that is a minimum of 10 cm in length is recommended for the collection of chemistry and benthic infaunal samples (e.g., the SUBS Sampler developed by NIWC Pacific can be utilized as an alternative to constructing a core tube since the SUBS Sampler is 4-inches in diameter and 16-inches in length).

At each site, two 4-inch diameter core samples will be collected for benthic infauna. These two core samples will then be composited into a single sample. Options for sample collection at intermediate depths include the following: 1) using a SUB Sampler, 2) using core tubes attached to an extension pole, 3) inserting core tubes into the sediment grab collected with a Van Veen, or 4) inserting the core tubes by hand if collection sites are in wadeable areas. The top of each core will be sealed with a rubber cap. A vacuum will be created when the core is removed from the sediment holding the contents in place; however, the bottom should be covered if the contents are not held in place (i.e., sediment is loose). For more detailed information regarding determination of salinity at a site, sample collection protocols using the cores, or construction of the cores refer to the Bight '18 Sediment Quality Assessment Field Operations Manual (SCCWRP, 2018). For more information on using the SUB Sampler as the coring device refer to the Standard Operating Procedure for Macroalgal Collection in Estuarine Environments (McLaughlin et al., 2019).

A sample will be considered acceptable if the surface of the grab is even and there is minimal surface disturbance. For marine samples, the penetration depth of the grab sampler should be a minimum of 5 cm in compact sediments (i.e., hard packed sand). Penetration depths of 7-10+ cm should be obtained in silty sediments (fine sand to clay) and whenever possible, infaunal samples should be a minimum of 7 cm, but target 10+ cm. Benthic infaunal samples collected at brackish sites must have a minimum penetration depth of 10 cm. Rejected grabs will be discarded, and the station will be re-sampled. Acceptable sediment grabs to be utilized for chemistry and grain size will have the overlying water carefully drained from the sediment surface prior to removing the sediment to be placed in the appropriate sample containers. Overlying water will not be drained from sediment samples collected for benthic infaunal analysis.

Between sampling stations, the grab sampler will be rinsed with station water. Stainless steel scoops will be rinsed with seawater and rinsed with de-ionized water between stations. During each annual monitoring event, information to be recorded on field data sheets includes station identification, date, time of arrival, coordinates and navigation system used, water depth, weather conditions, and other pertinent observations. Information about the sediment sample will also be recorded, including the sample time, depth of penetration of sediment grab, sediment composition, sediment color, sediment odor, and presence of shell hash.

2.1.5.1 Benthic Community Condition Sample Preparation and Method

The entire contents of one grab sample (equal to 0.1 m^2 surface area) will be utilized for benthic infaunal analysis in marine areas of the Estuary (salinity ≥ 27 ppt) (e.g., using a Van Veen grab sampler). If using a grab sampler with a smaller surface area (e.g., SUB Sampler), then multiple benthic infaunal samples will need to be collected to be equivalent to a surface area of 0.1 m^2. Samples collected for benthic infaunal analysis from marine areas will be rinsed through a 1.0-millimeter (mm) mesh screen.

In brackish areas of the Estuary (salinity <27 ppt), two 4-inch diameter cores with a minimum penetration depth of 10 cm will be utilized for benthic infaunal analysis (e.g., two cores collected using a SUB Sampler). Samples collected for benthic infaunal analysis from brackish areas will be rinsed through a 0.5-mm screen.

The material retained on the screen will be transferred to a labeled glass or plastic sample container. A 7% Epsom Salt ($MgSO_4$) solution will be added to the sample container to 85-90% of its volume to relax the collected specimens. The sample container will be inverted several times to distribute the relaxant solution. After 30 minutes, add enough sodium borate buffered formaldehyde to top off the sample container and gently invert the container several times to ensure the sample is mixed. This will make a 10% formalin solution. Laboratory processing procedures are described in **Section 2.2.2**.

2.1.5.2 Sediment Chemistry Sample Preparation and Method

Sediment samples for chemistry and grain size analysis from marine areas of the Estuary will be collected from the top 5 cm of the grab sample using a pre-cleaned stainless-steel scoop. Sediment within 1 cm of the sides of the grab will be avoided to prevent interaction of any contaminants and the sampling device. For chemistry and grain size analysis, equal portions of sediment will be aliquoted from a single grab.

In brackish areas of the Estuary, the 4-inch diameter core tubes utilized for benthic infaunal sampling can be used to collect sediment for chemistry analysis. Insert the core 5 cm into the sediment, then dump the sediment into a clean pan to remove overlying water. Scoop the sediment into the appropriate sampling container using a pre-cleaned stainless-steel scoop or spoon.

Sediment will be placed into the appropriate sample containers, preserved, and transported as described in **Section 2.1.8**. Physical and chemical laboratory analysis procedures are described in **Section 2.2.1**.

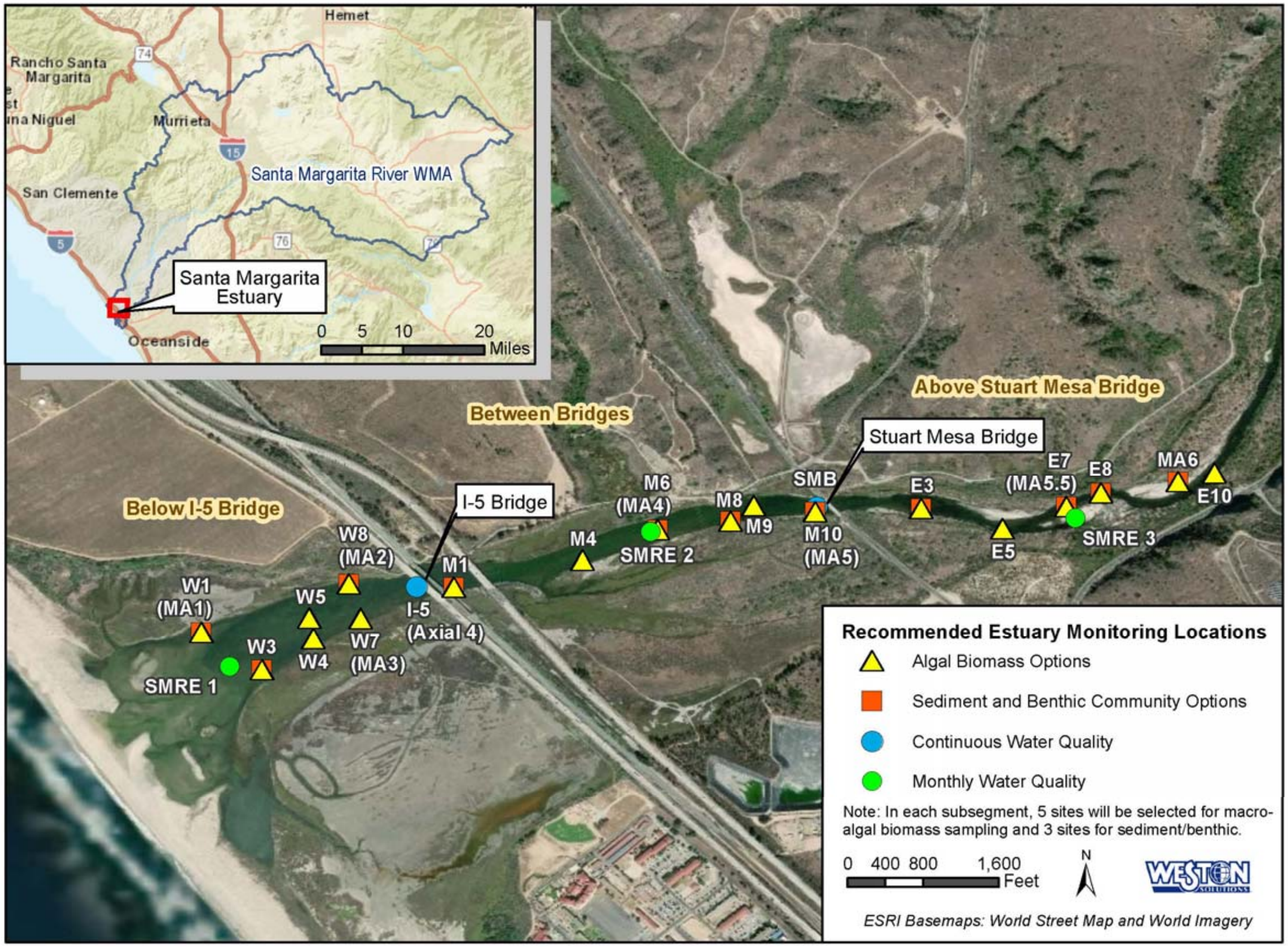

Figure 2-3. Proposed Santa Margarita Estuary Monitoring Locations

2.1.6 Santa Margarita River Monitoring

Monitoring will be conducted on the main stem of the Santa Margarita River to determine flow and ambient water quality conditions upstream of the Estuary. Methods will be consistent with relevant sections (i.e., Sections 1-3) of the *Standard Operating Procedures for the Collection of Field Data for Bioassessments of California Wadeable Streams: Benthic Macroinvertebrates, Algae, and Physical Habitat* (Bioassessment SOPs) (Ode et al., 2016).

A total of three sites will be monitored; one each within the jurisdictions of San Diego County, Riverside County, and MCB CamPen (**Table 2-6**, **Figure 2-4**). The monitoring stations should be located at the most downstream feasible location above the Estuary within each of the three jurisdictions. MCB CamPen will conduct monitoring at the USGS gage at Ysidora (11046000), which is the most reliable location for measuring streamflow along that reach of the river. The Riverside County monitoring will also incorporate an existing USGS gage (11044000) on the Santa Margarita River near Temecula. Monitoring events will be conducted monthly from May through October and bi-monthly from November through April, in November, January, and March. At each location, equipment will consist of an automated flow meter and sensor, solar panel, cellular line (where coverage is available), and rain gauge. Remote Automatic Weather Station (RAWS) or ALERT system rainfall gauges will be used where available. The Lake O'Neill rain gage will be used to monitor rainfall at the sampling location at Ysidora.

2.1.6.1 Flow Monitoring

A flowmeter for continuous flow monitoring will be installed and maintained at the County of San Diego location. MCB CamPen's surface monitoring site will use the Ysidora USGS gage (11046000) and Riverside County monitoring will use USGS gage 11044000 near Temecula. Although monitoring events occur during nine months of the year, it is recommended that flow monitoring occur throughout the year, where equipment can remain in place, for flow volume calculations used in loading estimations. At a minimum, the equipment will be comprised of Hach (or comparable) flowmeters with a bubbler or submerged pressure transducer as the primary measuring device (level sensor). The primary sensor will continuously measure stage (i.e., stream height) and relay that information to the flowmeter, which will continually calculate flow rates by inserting the stage information into the preprogrammed discharge equation. Continual flow data will be downloaded periodically to verify equipment functionality and thus reduce data gaps, ensure accuracy, and identify maintenance and calibration needs. Flow data will be entered into the data management system.

Daily and monthly flow rates will be measured or estimated in accordance with the National Pollutant Discharge Elimination System (NPDES) Storm Water Sampling Guidance Document (EPA-833-B-92-001) (United States Environmental Protection Agency [USEPA], 1992). Flow rating curves will be developed that correlate water surface levels (or stream heights) to flow rates.[11] To quantify flow rates based on stream stage, a relationship between flow and stage will be derived using standardized stream rating protocols developed by the United States Geological Survey (USGS) (Rantz, 1982; Oberg et al., 2005) and using an applicable hydraulic calculation formula(s), such as Manning's equation. If the monitoring station is found to have a steady dry weather base flow, it may be appropriate to install a

[11] At the MCB CamPen surface monitoring site at Ysidora and the Riverside County site associated with USGS gage 11044000, discharge, rating curves, and field flow measurements from the USGS will be used in lieu of a new flow measurement site. The USGS stations have real-time telemetry and report data at 15-minute intervals.

flow sensor with the ability to measure instantaneous stream velocity. However, in an ephemeral stream that tends to be wet and dry out periodically, this type of sensor may not collect high quality data. A decision to use an area-velocity flow meter and/or a weir structure will be determined based on site hydraulic and flow conditions.

Instantaneous field level and flow measurements will be periodically taken to validate the rating curves. To measure instantaneous flows during low flow and base flow conditions, two types of field flow monitoring equipment may be used. To measure small flows, a handheld velocity measurement instrument, such as a Marsh-McBirney Model 2000 Portable Flowmeter connected by a cable to an electromagnetic open channel velocity sensor, or equivalent may be used. To measure higher flows, the SonTek (YSI) FlowTracker Acoustic Doppler Velocimeter, or equivalent may be used.

2.1.6.2 Water Quality Monitoring

During each monthly monitoring event, water quality parameters (temperature and conductivity) will be measured using a multi-parameter water quality meter or sonde. Water quality measurements and site conditions will be recorded on field data sheets. A grab sample will be collected in an appropriate container using a sampling pole or similar method. The sample will be analyzed for total nitrogen, total and dissolved inorganic nitrogen and phosphorus, as described in **Section 2.2**. Two field duplicates and one field blank will be collected per monitoring year in order to achieve the SWAMP QA requirements outlined in the QAPP.

Table 2-6. Station Identifications and Coordinates for Santa Margarita River Monitoring

Jurisdiction	Station ID	Latitude (NAD83)	Longitude (NAD83)
San Diego County	SMR-MLS-2	33.398142	-117.26273
Riverside County	Upper Santa Margarita River 902USM828	33.47335	-117.14344
MCB CamPen	Ysidora (SMR 3)	33.31165	-117.34570

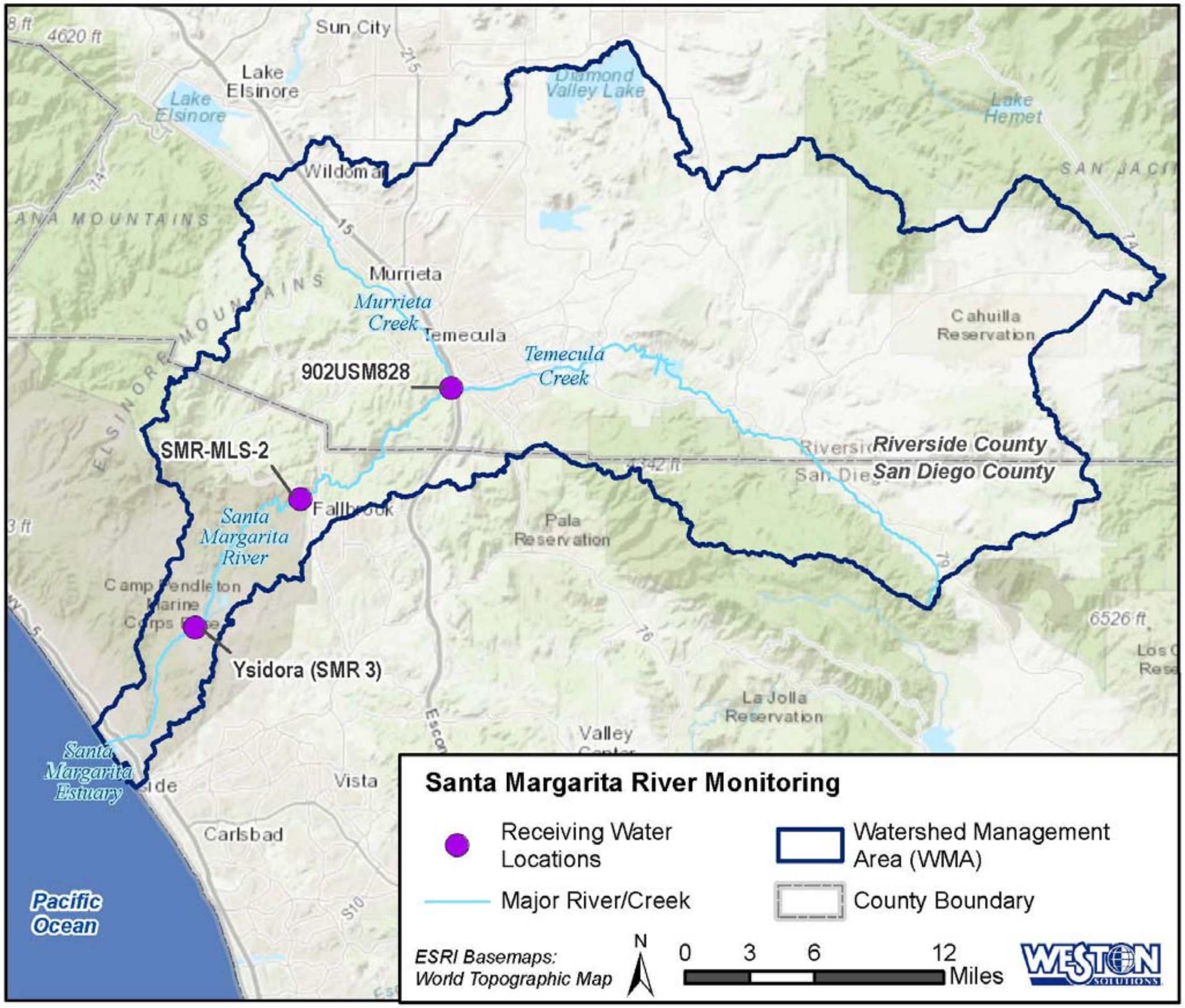

Figure 2-4. Proposed Santa Margarita River Monitoring Locations

2.1.7 Documentation of Chain-of-Custody

This section describes the program requirements for sample handling and chain-of-custody (COC) procedures. Samples are considered to be in custody if they are:

(1) in the custodian's possession or view,
(2) retained in a secured place (under lock) with restricted access, or
(3) placed in a secured container.

The principal documents used to identify samples and to document possession are COC records, field log books, and field tracking forms. COC procedures will be used for all samples throughout the collection, transport, and analytical process, and for all data and data documentation, whether in hard copy or electronic format.

COC procedures will be initiated during sample collection. A COC record will be provided with each sample or sample group. Each person who has custody of the samples will sign the form and ensure that the samples are not left unattended unless properly secured. Minimum documentation of sample handling and custody will include the following:

- Sample identification
- Sample collection date and time
- Any special notations on sample characteristics
- Initials of the person collecting the sample
- Date the sample was sent to the laboratory
- Type of sample analysis
- Shipping company and waybill information
- Sample container size, type, and preservative (if applicable)

Sample container labels will include the sample ID, date and time of collection, sampler's initials, type of analysis, and preservative used. The completed COC form will be placed in a sealable plastic envelope that will travel inside the ice chest containing the listed samples. The COC form will be signed by the person transferring custody of the samples. The condition of the samples will be recorded by the receiver. COC records will be included in the final analytical report prepared by the laboratory, and will be considered an integral part of that report. An example COC form is provided at Attachment B to the QAPP.

2.1.8 Sample Transport and Shipping Procedures

Physical and chemistry samples collected in the field will be stored on wet ice in the dark and kept at 4°C. Samples will be delivered to the appropriate analytical laboratory either by field staff or courier. All samples will be transferred to the designated analytical laboratories and analyses initiated within the method specified holding time (**Appendix A**). If samples are required to be shipped to the analytical laboratory, sample containers will be placed in sealable plastic bags and securely packed inside the coolers with ice. COC forms will be filled out (see **Section 2.1.7**), and the original signed COC forms will be inserted in a sealable plastic bag and placed inside the coolers. The cooler lids will be securely taped shut and then samples will be shipped overnight on ice to the analytical laboratories.

2.2 LABORATORY TESTING

2.2.1 Physical and Chemical Analysis

Chemical measurements for this testing program were selected to comply with the requirements of Investigative Order R9-2019-0007 (San Diego Water Board, 2019) and the Draft Staff Report (San Diego Water Board, 2018). All analytical methods utilized will follow USEPA, American Society for Testing and Materials (ASTM), or Standard Methods (SM) for the Examination of Water and Wastewater (APHA, 2012). Chemical analyses of water and sediment samples will be analyzed by an Environmental Laboratory Accreditation Program (ELAP)-certified laboratory. The specific analyses and target detection limits to be utilized for the various components of the monitoring program (**Section 2.1**) are presented in **Table 2-7**. Additional information, including holding times, preservation methods, and sampling container types and volumes, are provided in the QAPP (**Appendix A**).

In addition to the chemical analyses listed in **Table 2-7**, physical measurements of macroalgal biomass will be determined following Section 6.3 of the SOP for Macroalgal Collection in Estuarine Environments (SCCWRP Technical Report #872) (McLaughlin et al., 2019). Macroalgal biomass samples must be processed within 48 hours of collection. Biomass samples will be cleaned of all mud, bugs, and debris; weighed wet; dried in an oven at 60°C for two to three days; and weighed dry. Samples should be kept refrigerated at 4°C in the dark until they are processed. If the amount of biomass in each sub-sample (from the five sites along each transect or within each sub-segment) is small, the SOP states that they may be composited into a single sample representative of that transect/sub-segment, resulting in three biomass composites per Estuary segment. If the biomass from each sub-sample is large (i.e., enough to fill the Ziploc bag), each sub-sample will be weighed individually and added.

Table 2-7. Chemical Parameters, Analytical Methods, and Target Detection Limits for Santa Margarita Estuary and River Monitoring

Analyte	Method	Units	Target Reporting Limit[3]
Estuary Macroalgal Samples			
Macroalgal Biomass	McLaughlin et al., 2019 SOP	g dry weight/m^2	0.001
Groundwater, Estuary, and River Water Samples[1,2]			
Ammonia (as N)[4]	EPA 350.1	mg/L	0.02
Ammonia (as N)[4], Dissolved	EPA 350.1	mg/L	0.02
Chlorophyll-a, Suspended	SM 10200	mg/L	0.002
Inorganic Nitrogen, Dissolved[4]	By Calculation	mg/L	NA
Inorganic Nitrogen, Total[1,4]	By Calculation	mg/L	NA
Nitrate (NO_3) + Nitrite (NO_2)[4]	SM 4500-NO3 E/SM 4500-NO2 B	mg/L	0.01
Nitrate (NO_3) + Nitrite (NO_2), Dissolved[4]	SM 4500-NO3 E/SM 4500-NO2 B	mg/L	0.01
Nitrogen, Total[5]	By Calculation	mg/L	NA
Phosphorus, Dissolved	SM 4500 or EPA 365.1	mg/L	0.05
Phosphorus, Total	SM 4500 or EPA 365.1	mg/L	0.05
Estuary Sediment Samples[1]			
Grain Size	ASTM D4464 (M) or SM 2560 D or ASTM D422	%	NA
Nitrate (NO_3) + Nitrite (NO_2)	SM 4500 or EPA 300.0	mg/kg	0.5/1.0
Nitrogen, Total[5]	By Calculation	mg/kg	NA
Nitrogen, Total Kjeldahl	SM 4500	mg/kg	10
Phosphorus, Total	SM 4500	mg/kg	0.12
Total Organic Carbon	EPA 9060A	%	0.05

[1] Recommended analytical methods; alternative methods may be used; however, methods should follow USEPA, ASTM, or Standard Methods

[2] Groundwater Samples will include each of the analytes shown in this section except chlorophyll-a.

[3] Target reporting limits; reporting limits may vary based on the actual analytical method and method detection limits utilized by the laboratory selected to perform the analysis. Lower reporting limits may be available.

[4] Total and dissolved inorganic nitrogen in water is a calculated value comprised of NH_3 + NO_3 + NO_2. Additional water samples are identified to be collected and filtered to analyze for dissolved NH_3 + NO_3 + NO_2.

[5] Total nitrogen is a calculated value comprised of total Kjeldahl nitrogen (TKN), NO_3, and NO_2

NA = Not applicable

2.2.2 Benthic Infaunal Analysis

The benthic infaunal samples will be transported from the field to the laboratory and stored in a formalin solution for a minimum of 72 hours and no longer than 14 days. The samples will then be transferred from formalin to 70% ethanol for laboratory processing. The organisms will initially be sorted using a dissecting microscope into five major phyletic groups: polychaetes, crustaceans, mollusks, echinoderms, and miscellaneous minor phyla. While sorting, technicians will keep a count of organisms for quality control purposes, as described in **Section 2.3.3**. After initial sorting, samples will be distributed to qualified taxonomists who will identify each organism to species level or to the lowest possible taxonomic level. Data for organisms that are incidental contaminants should not be included in the data analysis and should not be counted or included in the project data. Attached parasites and other epibionts should not be recorded or submitted in annual reports but may be noted as present on bench data sheets. Nomenclature and orthography should follow the usage in the SQO species list on the *Sediment Quality Assessment Tools* page of the SCCWRP website (www.sccwrp.org) as well as Edition 5 of the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) taxonomic listing (available at www.scamit.org).

2.3 QUALITY ASSURANCE/QUALITY CONTROL

All monitoring activities and laboratory analyses will comply with the requirements set forth in the QAPP (**Appendix A**).

2.3.1 Field Monitoring

All instruments used for field and laboratory analyses will be calibrated in accordance with manufacturer's specifications. Calibration of the flow monitoring and sampling equipment will be conducted immediately prior to deployment or use and will be field verified during each data download or sample event. Calibration of the sondes utilized for Estuary continuous monitoring will be conducted prior to initial deployment in the field. Calibration will be when sondes are briefly removed for maintenance (at least once a month, although summer months may require weekly maintenance). The sondes will be cleaned and the response to a suitable standard will be recorded. If the sonde is within calibration precision, then it will not be recalibrated. If the sonde is outside the required precision, then it will be recalibrated.[12]

All field personnel will have current and relevant experience in all aspects of standard field monitoring, including use of relevant field equipment such as field instruments and monitoring equipment. Field personnel will be trained and have experience in the collection, handling/storage, and COC procedures. All personnel will be responsible for complying with the QA/QC requirements that pertain to their organizational/technical function.

Field duplicates and equipment rinse blanks will be collected and analyzed at the frequency described for each monitoring program component outlined in **Section 2.1,** in accordance with SWAMP QA sample requirements. Two field duplicates and one field blank will be collected for Estuary surface water nutrient analysis and for SMR Watershed nutrient analysis during each monitoring year. One

[12] Calibration checks on DO sensors have indicated that variations in measured DO values may be greater than the instrument accuracy specification of ± 0.2 mg/L listed in the QAPP (Kara Sorensen, personal communication).

field duplicate and one equipment rinse blank will be collected for Estuary sediment chemistry analysis during each monitoring year.

2.3.2 Physical and Chemistry Analyses

The QA objectives for physical and chemical analyses conducted by the participating analytical laboratories will be detailed in their quality assurance documents and in the associated QAPP for this program (**Appendix A**). These objectives for accuracy and precision involve all aspects of the testing process, including the following:

- Methods and SOPs
- Calibration methods and frequency
- Data analysis, validation, and reporting
- Internal QC
- Preventive maintenance
- Procedures to ensure data accuracy and completeness

Results of all laboratory QC analyses will be reported with the final data. Any QC samples that fail to meet the specified QC criteria in the methodology will be identified and the corresponding data will be appropriately qualified in the final report.

2.3.3 Benthic Infaunal Analysis

The QA/QC procedure for benthic macroinfaunal sorting and taxonomy will be evaluated based on guidance from the Sediment Quality Assessment Technical Support Manual, SCCWRP Technical Report 777 (Bay et al., 2014) and those utilized for the Southern California Bight 2018 Regional Marine Monitoring Survey (Bight '18). A QA/QC procedure will be performed on each of the sorted samples using the aliquot method to ensure a 95% sorting efficiency. QA/QC on taxonomic samples will be conducted by re-identifying 10% of the benthic infaunal samples by taxonomists other than those who originally analyzed the samples and by establishing a voucher collection. For further detail on the QA/QC process, refer to the QAPP (**Appendix A**) and the Bay et al., 2014 document.

3.0 DATA REVIEW, MANAGEMENT AND ANALYSIS

3.1 DATA REVIEW AND MANAGEMENT

All laboratory data will initially be reviewed and verified by the analytical laboratory to determine whether all measurement quality objectives (MQOs) have been met, and that appropriate corrective actions have been taken, when necessary. The laboratory will supply analytical results and related QC information in both hard copy and electronic formats. The laboratory will have the responsibility of ensuring that both forms are accurate.

The Project QA Officer will be responsible for the final review of all data generated in the field and laboratory including ensuring that all of the MQOs in the QAPP have been met. All data collected under the QAPP, including laboratory and field QC results, will be formatted and submitted to CEDEN.

3.2 DATA ANALYSIS

Data analysis will consist of tabulation of results of all monitoring program data by event and annually, where applicable. Watershed loads will be estimated for total and dissolved nitrogen and total and dissolved phosphorus, DO summarized, biomass calculated, and benthic community condition determined for comparison to Draft Staff Report numeric targets (**Section 1.1.3)**. This analysis over time will inform assessment of progress towards addressing eutrophication impairments. Long-term trends analysis for monitoring parameters, e.g., watershed nutrient loading and Estuary macroalgae biomass levels, should be conducted after at least three years of monitoring under this Monitoring and Assessment Workplan. An assessment of trends with projections for when the numeric targets would be achieved, or an explanation indicating why data is insufficient to do so, is required by the 2019 Investigative Order. Trend analysis may be conducted earlier where appropriate historical data are available to supplement monitoring data collected.

3.2.1 Estuary Resurfacing Groundwater Discharge Rates and Loading into the Estuary from the Santa Margarita Valley Groundwater Basin

Groundwater discharge rates and chemical identification will be conducted at each of the piezometer sites. Qualitative assessment of seepage near the Stuart Mesa Agricultural field will be performed by measuring temperature and conductivity in the upper two feet of the ground surface. Quantitative assessment of seepage will be performed by measuring hydraulic head difference in the groundwater surface. Grab samples at all piezometers will be collected for nutrient analysis so mass-loading calculations can be performed using quantitative and qualitative analysis of groundwater seepage.

Loading to the Estuary from groundwater through the Lower Ysidora sub-basin will be calculated as described in **Section 3.2.5**.

3.2.2 Macroalgal Biomass

Macroalgal biomass data, in g dry weight/m^2, will be averaged for each of the three Estuary segments separately. A two-month rolling average will be calculated for each Estuary segment. The results from each two-month period will be averaged across sampling periods to obtain a biomass value for each annual monitoring period.

Macroalgal data will be used to answer the third study question presented in **Section 1.2**, as to whether the numeric targets for macroalgal biomass in the Estuary are being achieved.

3.2.3 Dissolved Oxygen

DO data collected during the continuous monitoring described in **Section 2.1.2** will be used to evaluate compliance with the primary numeric target of daily minima ≥5.0 mg/L and the secondary numeric target of a 7-day average of daily minimum measurement ≥5.0 mg/L with a 10% allowable exceedance rate. Assessment of daily and seasonal patterns of minimum, maximum, and average DO values may provide additional information related to understanding conditions of eutrophication in the Estuary. Further, given that DO water quality objectives may be outdated based on recent science, additional evaluation of DO may be considered for interpreting protection of aquatic life beneficial uses per recommendations of the DO AdHoc group of the SMRNIG TAC and sources of scientific advances on this topic.

3.2.4 Benthic Community Condition

Benthic community data will be evaluated annually to determine whether the Estuary is meeting the secondary numeric target of ≤2.0 score for benthic community condition (a category of Low Disturbance based on SQO scale). Only those benthic infaunal samples collected in a salinity greater than or equal to (≥) 27 ppt at the sediment-water interface can be evaluated using the SQOs for enclosed bays and estuaries. If salinity was determined to be < 27 ppt and SQO calculated, the results should be qualified. The SQO benthic condition line of evidence (LOE) category will be calculated using the Data Integration Tool v5.5 (i.e. CalSQOCalcToolVer5.5.xls spreadsheet) and the RIVPACs Benthic Index Calculator Tool available on the SCCWRP website (http://www.sccwrp.org/about/research-areas/sediment-quality/sediment-quality-assessment-tools/). The SQO benthic condition LOE includes four benthic indices to assess benthic condition: Benthic Response Index (BRI), Index of Biotic Integrity (IBI), Relative Benthic Index (RBI), and River Invertebrate Prediction and Classification System (RIVPACS). Each benthic index result will be categorized as reference (=1.0), low disturbance (=2.0), moderate disturbance (=3.0), or high disturbance (=4.0) as described in Chapter 5 of SCCWRP Technical Report 582 (Bay et al., 2009). The median score of the four benthic indices then determines the final benthic condition category. If the median falls between categories, it will be rounded up to the next higher category.

Benthic infaunal samples collected in brackish areas of the estuary (a salinity of 0 - 27 ppt at the sediment-water interface) will need to be assessed following alternate methods such as using the modified multivariate AZTI marine biotic index (M-AMBI) (Pelletier et al., 2018; Gillett et al., 2015). This method was utilized for brackish estuarine benthic infaunal samples collected for the Bight '18 conducted by SCCWRP. At this time, SCCWRP is still developing an approach to using the M-AMBI benthic condition scores in the SQO framework; however, the M-AMBI scores can provide a best available description of the condition of the benthic infaunal community in brackish estuaries. (For information on how to run the M-AMBI calculation see Appendix A in the Gillett et al., 2019 paper available on the SCCWRP website:

(http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1070_M-AMBI.pdf) or contact David Gillett at SCCWRP).

3.2.5 Nutrient Load Calculations

Dischargers must determine dry weather nutrient loading into the Santa Margarita River and Estuary from MCB CamPen, San Diego County, and Riverside County. Nutrient loading will be calculated based on data collection described in **Section 2.1**.

The load for the nine monitored months will be calculated utilizing the concentrations from each of the nine monthly sampling events, multiplied by each corresponding monthly dry weather flow volume as follows:

$$Load(pounds) = Volume\ (cubic\ feet) \times concentration\ \left(\frac{mg\ or\ \mu g}{liter}\right) \times conversion\ factors$$

A flow weighted average concentration will be calculated from the nine monthly grab samples. The observed flow at the time of collection will be used to weight each result, the sum of which will provide a weighed concentration. If monthly flow data are available for the remaining three months, this average concentration will be applied in the equation above to estimate nutrient loads from non-monitored months. If flow data were not collected, volume for the unmonitored month will be based on an average of the preceding and succeeding months (i.e., the November and January averages will be used for the December estimate). Flow data associated with storm events (> 0.2 inch of precipitation in 24 hours) should be removed from the dry weather analysis. For estimating dry weather loading, continuous flow data associated with a storm event may be excluded for the 72-hour period following the storm.

Data produced from these calculations will be used to quantify concentrations of nutrients entering the Estuary and estimate dry weather loads during each monitoring period. Loading to the Estuary will account for surface flow from the Santa Margarita River and sub-flow from the Santa Margarita Valley Groundwater Basin. Loading from groundwater will be calculated using existing tools and data for subflow out of the Lower Ysidora sub-basin and the concentration of nutrients collected at the monitoring wells. During certain times of the year, particularly late summer and early fall, there may be no surface water flow to the Estuary, in which case the loading will be based only on loads in groundwater. Periods of intermittent or zero flow in the river will be identified using the USGS gage at Ysidora (11046000).

Hydrologic conditions that occur from 2020 through 2024 will be characterized by comparing precipitation, streamflow, and groundwater levels to historical data. A hydrologic index may be used to classify years into hydrologic year types. Subflow out of the groundwater aquifer will be estimated using data from previous modeling efforts, based on periods of similar hydrology. Historical modeling data may be analyzed statistically to yield a typical mass balance of water, including subflow out, during each hydrologic year type. The exact methodology will depend on the hydrologic conditions observed in 2020 through 2024 and the relevant historical data.

Loads will be based on concentrations in grab samples collected in 2020 through 2024 at groundwater wells and surface water monitoring locations. Empirical relationships may be developed to relate flow and concentration, i.e., a curve may be fit to describe how concentration changes with flow rate. Relationships would be developed for surface water flow and surface water concentration, as well as for subflow out and aquifer concentration. Historical data and/or modeled concentrations will be used as necessary to formulate adequate empirical relationships that represent seasonal patterns. Exact methodology will depend upon hydrologic conditions that occur, the timing of grab samples, and connectivity of the stream and aquifer.

Results will be used to answer the first two study questions presented in **Section 1.2**, i.e., *Has the watershed mass loading of total nitrogen and total phosphorus to the River and Estuary been reduced to levels that do not exceed the calculated assimilative capacity of the Estuary*[13], and *Do monitoring results confirm the assumption that the implementation and compliance with the Discharger's existing NPDES permits is sufficient to bring about the necessary nutrient load reductions to restore the Estuary in accordance with the schedule provided in the Draft Staff Report*?

[13] TMDL calculations presented in the Draft Staff Report show that the Estuary can assimilate 13,246 pounds of delivered total nitrogen and 1,528 pounds of delivered total phosphorus per year (when considering both controlled and uncontrolled sources) during the dry weather impairment period and still meet the numeric targets.

4.0 REPORTING

After all results are received and all assessments are performed, draft and final reports will be prepared. These reports will include summaries of all activities associated with collecting, transporting, and chemically analyzing the samples, data analyses and assessments for each monitoring period, and cumulative assessments as more data are collected. Monitoring reports will be submitted to the Dischargers for review. After receiving comments, reports will be revised for resubmittal as final reports.

Reports will present the results of field sample collections (including DO), chemical tests, and analysis of the macroalgae and nutrient samples. Reports will include field sampling logs, station Global Positioning System (GPS) coordinates, and descriptions of field, laboratory, data management, and data analysis methodologies. Complete laboratory results, including QA/QC results, will be provided as appendices to the main report.

Monitoring reports are required to be submitted on an annual basis. Annual monitoring reports will include the following:

- Answers to the monitoring questions outlined in the Investigative Order, including:
  - Analysis and discussion of resurfacing groundwater discharge rates and nutrient loading into the Estuary.
  - Ambient water quality conditions in the River,
  - Mass loading to the River,
  - Ambient water quality conditions in the Estuary,
  - Total nitrogen and total phosphorus mass loading to the Estuary from groundwater sources, and
  - Attainment of macroalgal biomass, dissolved oxygen, and benthic community condition numeric targets in the Estuary

- Raw field data, laboratory data reports, GIS data, and associated QA/QC reports.

While data will be assessed annually, the annual report for Year 4 will also include a comprehensive assessment of all four years of monitoring.

5.0 PROJECT SCHEDULE

Estuary and SMR Watershed monitoring events will be conducted annually from the 2019-2020 through 2022-2023 monitoring years (i.e., water years; October 1 to September 30). The first year is anticipated to begin in April 2020 and be a partial year of monitoring (i.e., April 1 – September 30, 2020). Monitoring Reports are required to be submitted on an annual basis, with the first annual report submitted January 31, 2021. The annual report for Year 4 will provide an assessment incorporating four years of monitoring data. Reports will be made available on the Regional Clearinghouse. Data collected and presented in annual reports will be submitted to CEDEN.

Submittal of Final Annual Reports to the San Diego Water Board will be on January 31st of the following calendar year after each monitoring period. The Year 4 report will be submitted by March 31, 2024.

The proposed project schedule is summarized in **Table 5-1**.

Table 5-1. Project Schedule

Activity	Date
Monitoring and Assessment	Monthly for (4) four years, ending in October 2023
Submit Final Annual Monitoring Reports	January 31 of 2021, 2022, and 2023
Submit Final Four-Year Assessment Report	March 31, 2024

6.0 REFERENCES

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APPENDIX A

Quality Assurance Project Plan

Santa Margarita River Estuary and Watershed Monitoring and Assessment Program

QUALITY ASSURANCE PROJECT PLAN

FINAL VERSION 1.0

Santa Margarita River Estuary and Watershed Monitoring and Assessment Program

Submitted to:

California Regional Water Quality Control Board, San Diego Region
2375 Northside Drive, Suite 100
San Diego, California 92108

Prepared by:

Weston Solutions, Inc.
5817 Dryden Place, Suite 101
Carlsbad, California 92008

On Behalf of:

County of Riverside
Riverside Flood Control and Water Conservation District
County of San Diego
United States Marine Corps Base Camp Pendleton
City of Murrieta
City of Temecula
City of Wildomar

January 2020

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GROUP A ELEMENTS: PROJECT MANAGEMENT

1. TITLE AND APPROVAL SHEET

Final
Quality Assurance Project Plan

Santa Margarita River Estuary and Watershed
Monitoring and Assessment Program

January 2020

APPROVAL SIGNATURES

PROJECT ORGANIZATION/ RESPONSIBLE PARTIES:

Agency	Name and Title	Signature	Date
County of Riverside	Alonzo Barrera, County Executive Office Management Analyst		
Riverside County Flood Control and Water Conservation District	Richard Boon, Watershed Protection Division Chief		
County of San Diego	Jo Ann Weber, Water Quality Program Coordinator		
U.S. Marine Corps Base Camp Pendleton	Mark Bonsavage, Environmental Security Environmental Engineering Branch Head		
City of Murrieta	Mai Son, NPDES Coordinator		
City of Temecula	Stuart Kuhn, NPDES Coordinator		
City of Wildomar	Dan York, Public Works Director/City Engineer		
Contracted Consultant	**Name and Title**	**Signature**	**Date**
Naval Information Warfare Center Pacific (NIWC Pacific)	Kara Sorensen, Project Manager		
Naval Information Warfare Center Pacific (NIWC Pacific)	Ignacio Rivera QA Officer		

SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD (San Diego Water Board):

Agency	Name and Title	Signature	Date
San Diego Water Board	Cynthia Gorham, Project Manager		
San Diego Water Board	Cynthia Gorham, QA Officer		

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LIST OF ACRONYMS AND ABBREVIATIONS

2006 Investigative Order	San Diego Water Board Investigative Order No. R9-2006-007
2019 Investigative Order	San Diego Water Board Investigative Order No. R9-2019-0007
303(d) List	Section 303(d) List of Water Quality Limited Segments
APHA	American Public Health Association
ASTM	American Society for Testing and Materials
Basin Plan	Water Quality Control Plan for the San Diego Basin
Bight '18	Southern California Bight 2018 Regional Marine Monitoring Survey
COC	chain of custody
DO	dissolved oxygen
EDD	electronic data deliverable
ELAP	Environmental Laboratory Accreditation Program
Estuary	Santa Margarita River Estuary
HA	hydrologic area
HDPE	high-density polyethylene
LA	load allocation
LCS	laboratory control sample
LSMR Model	Lower Santa Margarita River Groundwater Model
MCB CamPen	U.S. Marine Corps Base Camp Pendleton
MLLW	mean lower low water
MOU	Memorandum of Understanding
MQO	measurement quality objective
MS	matrix spike
MS/MSD	matrix spike/matrix spike duplicate
NIWC Pacific	Naval Information Warfare Center Pacific
NNE	nutrient numeric endpoint
NPDES	National Pollutant Discharge Elimination System
NWIS	National Water Information System
PM	project manager
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RPD	relative percent difference
San Diego Water Board	San Diego Regional Water Quality Control Board
SCAMIT	Southern California Association of Marine Invertebrate Taxonomists
SCCWRP	Southern California Coastal Water Research Project
SM	Standard Methods for the Examination of Water and Wastewater
SMR	Santa Margarita River
SOP	standard operating procedure
SPAWAR	Space and Naval Warfare Systems Pacific
SQO	sediment quality objective
State Water Board	State Water Resources Control Board
SUBS Sampler	multi-SUBstrate Subtidal sampler
SWAMP	Surface Water Ambient Monitoring Program
TBD	to be determined
TKN	total Kjeldahl nitrogen

TMDL	Total Maximum Daily Load
TOC	total organic carbon
U.S.	United States
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	waste load allocation
WMA	Watershed Management Area
Workplan	Monitoring and Assessment Program Workplan
WQO	water quality objective

UNITS OF MEASURE

cm	centimeter(s)
ºC	degrees Celsius
g	gram(s)
g dry weight/m^2	grams dry weight per meter squared
g wet weight/m^2	grams of wet weight per meter squared
>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to
m	meter(s)
m^2	meter squared
mg/L	milligram(s) per liter
mg/kg	milligram(s) per kilogram
mm	millimeter(s)
NTU	nephelometric turbidity units
ppt	parts per thousand
%	percent
µg	microgram(s)
µS/cm	micro Siemens per centimeter

3. DISTRIBUTION LIST

Table 3-1 identifies those individuals who will oversee the implementation of the approved Quality Assurance Project Plan (QAPP). Copies of the QAPP will be distributed in either hard copy or electronic format. Key personnel listed in **Table 3-1** will ensure that the QAPP is distributed to their respective staff within their own organization.

Table 3-1. Quality Assurance Project Plan Distribution List

Contact Agency/Organization	Name	QAPP Version No.
San Diego Water Board	Cynthia Gorham	1.0
San Diego Water Board	Cynthia Gorham – QA Officer	1.0
County of Riverside	Alonzo Barrera	1.0
Riverside County Flood Control and Water Conservation District	Richard Boon, Matt Yeager, and Rebekah Guill	1.0
Riverside County Transportation Department	Jan Bulinski	1.0
County of San Diego	Jo Ann Weber	1.0
U.S. Marine Corps Base Camp Pendleton	Mark Bonsavage and Matthew Winterbourne	1.0
City of Murrieta	Mai Son	1.0
City of Temecula	Stuart Kuhn	1.0
City of Wildomar	Jason Farag	1.0
NIWC Pacific	Kara Sorensen	1.0
NIWC Pacific	Ignacio Rivera – QA Officer	1.0
TBD -Laboratory	TBD – QA Officer	1.0

4. PROJECT/TASK ORGANIZATION

4.1 INVOLVED PARTIES AND ROLES

This element of the QAPP describes individuals and their respective roles for this project. **Table 4-1** provides a summary of individuals, their key role, and contact information. **Figure 4-1** is an organizational chart showing the roles and lines of communication between key individuals.

San Diego Regional Water Quality Control Board (San Diego Water Board) Project Manager: Cynthia Gorham will serve as the temporary Project Manager for the San Diego Water Board until the vacancy is filled. Ms. Gorham will receive annual reports and data generated from this program.

San Diego Water Board Quality Assurance (QA) Officer: The San Diego Water Board QA Officer is Cynthia Gorham. The QA Officer will be responsible for reviewing annual reports to ensure that the monitoring plan and QAPP guidelines are being met.

County of Riverside: As the Management Analyst of the County's Executive Office, Alonzo Barrera will serve as the Contact for the County of Riverside. Mr. Barrera will be responsible for representing the County in approval of final plans, annual reports, and invoices for payment in accordance with the Memorandum of Understanding (MOU).

Riverside County Flood Control and Water Conservation District (District): As Chief of the Watershed Protection Division, Richard Boon will serve as the Contact for the District. Mr. Boon will be responsible for representing the District in approval of final plans, annual reports, and invoices for payment in accordance with the MOU. As the Water Quality Compliance Section Manager Dr. Matt Yeager will serve as the Project Manager for the District, responsible for the day-to-day contract administration with Consultant, coordination with Consultant on annual field activities and schedules; technical review of plans, reports, and ensuring that the QAPP is being implemented. As the District's Watershed Monitoring Section Manager, Rebekah Guill will serve as support for the above-mentioned roles. Ms. Guill will also be responsible for oversight of County-specific river monitoring efforts in accordance with the MOU. The District will complete the Riverside County-specific river monitoring requirements on behalf of the Riverside County Copermittees under a separate cooperative agreement. The District will be responsible for timely submittal of complete river monitoring data packages to NIWC for assessment and compliance reporting.

County of San Diego: Jo Ann Weber will serve as the Contact for the County of San Diego. Ms. Weber will be responsible for representing the County in approving final plans, annual reports, and invoices for payment in accordance with the MOU. Ms. Weber will also be responsible for oversite of County-specific river monitoring efforts in accordance with the MOU. The County of San Diego will complete the San Diego County-specific river monitoring requirements and be responsible for timely submittal of complete river monitoring data packages to NIWC for assessment and compliance reporting.

United States (U.S.) Marine Corps Base Camp Pendleton (MCB CamPen) Environmental Security Engineering: As the Environmental Security Engineering Branch Head, Mark Bonsavage will serve as the Contact for MCB CamPen. Mr. Bonsavage will be responsible for representing the Base in approving final plans, annual reports, and invoices for payment in accordance with the MOU. As the Water Quality Section Head, Matt Winterbourne will serve as the Project Manager for MCB CamPen. Mr. Winterbourne will be responsible for the day-to-day contract administration with Consultant, coordination with Consultant on annual field activities and schedules; technical review of plans, reports, and additional QC of data and analyses.

City of Murrieta: Mai Son will serve as the Contact for the City of Murrieta. Ms. Son will be responsible for representing the City in approval of final plans, annual reports, and invoices for payment in accordance with the MOU.

City of Temecula: Stuart Kuhn will serve as the Contact for the City of Temecula. Mr. Kuhn will be responsible for representing the City in approval of final plans, annual reports, and invoices for payment in accordance with the MOU.

City of Wildomar: Dan York, Public Works Director/City Engineer, is the City's responsible signatory for the QAPP. The Primary contact for the City of Wildomar is water quality engineering consultant Jason Farag. Mr. Farag will be responsible for representing the City in approval of final plans, annual reports, and invoices for payment in accordance with the MOU.

Naval Information Warfare Center Pacific (NIWC Pacific).[1] **Technical Advisor**: Dr. Kara Sorensen from NIWC Pacific will serve as Technical Advisor. Dr. Sorensen will oversee groundwater and estuary monitoring in accordance with the MOU and act as a consultant to the dischargers. NIWC Pacific will be responsible for completion of the required assessment and compliance reporting in accordance with the IO on behalf of all of the "Partners" as identified in the MOU. NIWC Pacific will serve the project by fulfilling the following roles:

- **Consultant Project Manager**. The Consultant Project Manager (PM) is Dr. Kara Sorensen. The Consultant PM will be responsible for the day-to-day activities of implementing the Santa Margarita River Estuary and Watershed Monitoring and Assessment Program. These responsibilities include contract administration, coordination of annual field activities and schedules; and technical review of reports. Should NIWC Pacific use subcontractors for completion of the work outlined in the IO Workplan, the Consultant Project Manager shall ensure that all subcontractors comply with the requirements of the IO and this QAPP.

- **Consultant Field Sampling Lead**: The Consultant Field Sampling Lead is TBD. The Consultant Field Sampling Lead will be responsible for field team efforts and provide oversight for all field activities, including developing field schedules, coordinating field staff, maintaining equipment utilized for watershed and estuary monitoring, conducting the sampling, and ensuring samples are delivered to the analytical laboratory with proper documentation and sample preservation, and maintaining field records associated with each monitoring task.

[1] Formerly known as NAVY Space and Naval Warfare Systems Pacific (SPAWAR).

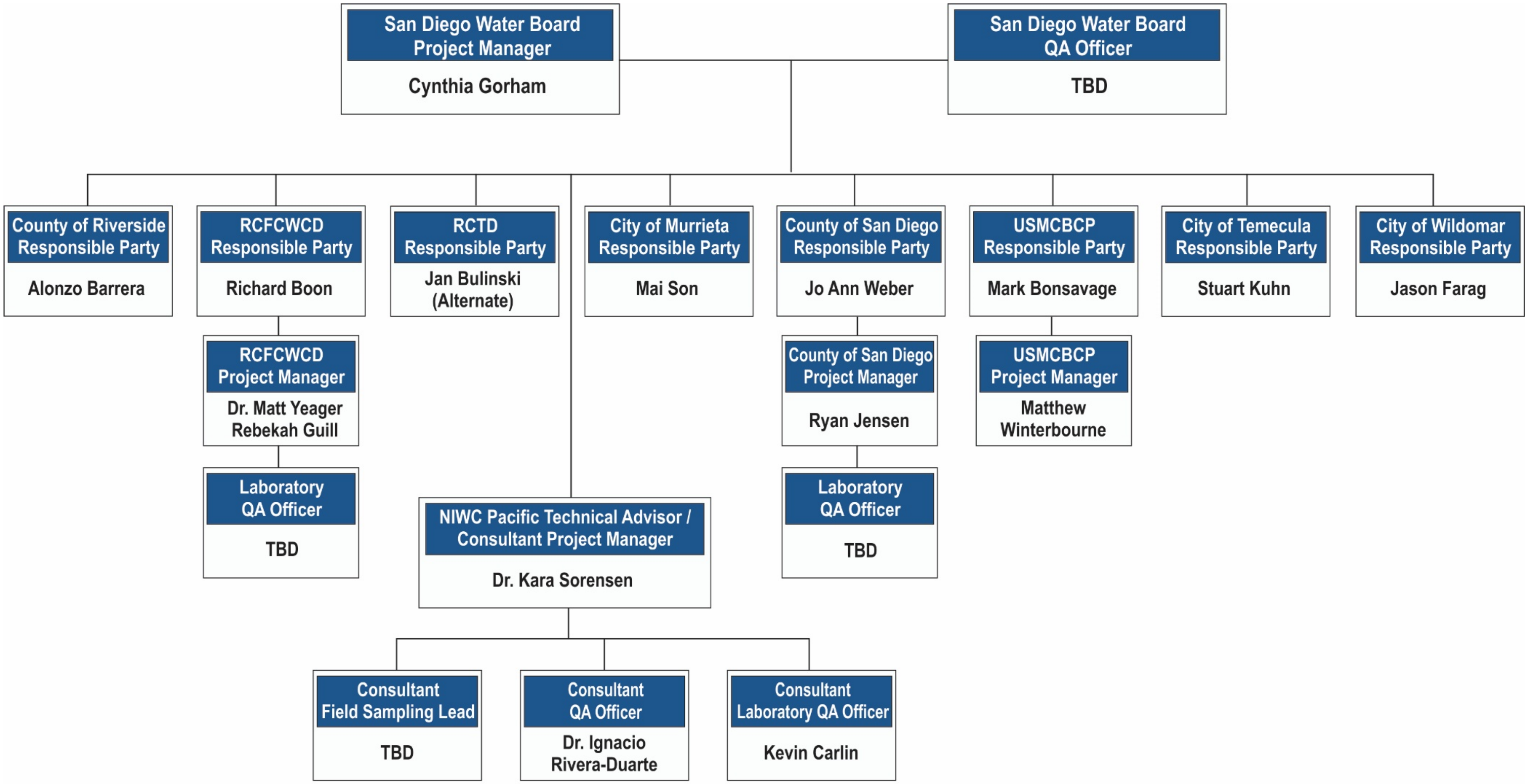
- **Consultant Quality Assurance (QA) Officer:** The Consultant QA Officer is Dr. Ignacio Rivera. The Consultant QA Officer will be responsible for guaranteeing the overall QA and QC procedures and will ensure that data reported by the Consultant have been generated in compliance with the appropriate protocols. The Consultant QA Officer will report all findings to the Consultant PM, including all requests for corrective actions. If there is evidence of significant deviations from protocols stated in this QAPP or if there is evidence of systematic failure, the Consultant QA Officer has the authority to stop all activities until corrective actions can be documented and performed.

Laboratory QA Officer: It is likely that the County of San Diego, the District, MCB CamPen and/or NIWC Pacific will utilize separate contracted laboratories for completion of the monitoring conducted within their respective jurisdictions; therefore, it is the responsibility of each agency to ensure that the contracted laboratory have a designated Laboratory QA Officer and to provide oversight to the contracted laboratory. The Laboratory QA Officer will be responsible for all analyses conducted by the laboratory and will ensure that the QAPP guidelines are being met.

Table 4-1. Personnel Responsibilities and Contact Information

Name	Organizational Affiliation	Title	Contact Information (Telephone Number and Email Address)
Cynthia Gorham	San Diego Water Board	Project Manager	619-521-3921 Cynthia.Gorham@waterboards.ca.gov
Cynthia Gorham	San Diego Water Board	QA Officer	619-521-3921 Cynthia.Gorham@waterboards.ca.gov
Alonzo Barrera	County of Riverside	Responsible Party Contact	951-955-1402 abarrera@rivco.org
Jan Bulinski	Riverside County Transportation Department	Responsible Party Contact (Alternate)	951-955-6589 JBulinski@rivco.org
Richard Boon	Riverside County Flood Control and Water Conservation District	Responsible Party Contact	951-955-1273 rboon@rivco.org
Matt Yeager	Riverside County Flood Control and Water Conservation District	Project Manager	951 955-0843 myeager@rivco.org
Rebekah Guill	Riverside County Flood Control and Water Conservation District	Project Manager Support	951-955-2901 rguill@rivco.org
Jo Ann Weber	County of San Diego	Responsible Party Contact	858-495-5317 joann.weber@sdcounty.ca.gov
Mark Bonsavage	U.S. Marine Corps Base Camp Pendleton	Responsible Party Contact	760-725-9753 mark.bonsavage@usmc.mil
Matthew Winterbourne	U.S. Marine Corps Base Camp Pendleton	Project Manager	760-725-0141 matthew.p.winterbour@usmc.mil
Mai Son	City of Murrieta	Responsible Party Contact	951-461-6085 mson@murrietaca.gov
Stuart Kuhn	City of Temecula	Responsible Party Contact	951-308-6387 Stuart.kuhn@temeculaca.gov
Jason Farag	City of Wildomar	Responsible Party Contact	951-677-7751 Ext 219 jfarag@cityofwildomar.org
Kara Sorensen	NIWC Pacific	Technical Advisor, Consultant Project Manager	619-553-1340 sorensek@spawar.navy.mil
Ignacio Rivera	NIWC Pacific	Consultant QA Officer	TBD

Name	Organizational Affiliation	Title	Contact Information (Telephone Number and Email Address)
TBD	NIWC Pacific	Consultant Field Sampling Lead	TBD
TBD	NIWC Pacific	Laboratory QA Officer	TBD
TBD	Consultant (Riverside) - TBD	Laboratory QA Officer	TBD
TBD	Consultant (San Diego) - TBD	Laboratory QA Officer	TBD



NIWC = Naval Information Warfare Center
RCFCWCD = Riverside County Flood Control and Water Conservation District
RCTD = Riverside County Transportation Department
USMCBCP = U.S. Marine Corps Base Camp Pendleton

Figure 4-1. Organizational Chart

4.2 QUALITY ASSURANCE OFFICER ROLE

The Project QA Officer will be responsible for maintaining the QAPP and ensuring that personnel listed in **Element 3** have the most recent version of the QAPP. The QA Officer will ensure that project staff understand and perform all QA/QC procedures related to field sample collection, laboratory analysis, and data analysis according to QAPP requirements throughout the duration of this project.

4.3 PERSONS RESPONSIBLE FOR QAPP UPDATE AND MAINTENANCE

Changes and updates to this QAPP may be made after a review of the evidence for change by the Santa Margarita River Nutrient Initiative Group Technical Advisory Committee (SMRNIG TAC) with the concurrence of the Riverside County Flood Control and Water Conservation District (District), County of San Diego, and MCB CamPen. The Consultant PM, with input from the Consultant QA Officer, will be responsible for making the changes, submitting drafts for review, preparing a final amended copy, and submitting the final for signature. Project work must be halted while revisions to the QAPP are made, unless authorized by the District, the County of San Diego, and MCB CamPen.

5. PROBLEM DEFINITION/BACKGROUND

5.1 DECISIONS OR OUTCOMES

Surface water and groundwater monitoring will be conducted in the Estuary and SMR Watershed in order to assess progress toward attainment of numeric targets in accordance with the 2019 Investigative Order (San Diego Water Board, 2019). Data collected during the four-year monitoring period will be used to address the following questions:

1. *Is watershed mass loading of total nitrogen and total phosphorus to the River and Estuary reduced to levels that do not exceed the calculated assimilative capacity of the Estuary?*

2. *Based on available information, do monitoring results confirm the assumption that the implementation and compliance with the Discharger's existing NPDES permits are sufficient to bring about the necessary nutrient load reductions to restore the Estuary in accordance with the schedule provided in the Draft Staff Report?*

3. *Are the Estuary numeric targets for macroalgal biomass, dissolved oxygen, and Benthic Community Condition being achieved and sustained? If not, based on available information, what are the primary stressors causing unsatisfactory eutrophication conditions?*

These questions will be answered utilizing the data collected each year, including the following parameters:

- Estuary resurfacing groundwater discharge rates and loading into the Estuary from the Santa Margarita Valley Groundwater Basin;
- Estuary groundwater total nitrogen, total and dissolved inorganic nitrogen, and total and dissolved phosphorus concentrations;
- Estuary ambient water quality parameters including DO (concentration and percent saturation); temperature, pH, salinity/conductivity, water depth, turbidity, and degree of tidal muting or influence;
- Estuary surface water chlorophyll-a and total nitrogen, total and dissolved inorganic nitrogen, and total and dissolved phosphorus concentrations;
- Estuary macroalgal biomass;
- Estuary benthic community condition;
- Estuary sediment grain size, total organic carbon, nitrogen, and phosphorus concentrations;
- Santa Margarita River Watershed flow, temperature, conductivity, and ambient total nitrogen, total and dissolved inorganic nitrogen, and total and dissolved phosphorus concentrations.

The monitoring will be conducted during dry weather periods in both summer and winter for four years (2020-2023). Monitoring reports will be prepared annually to allow the Dischargers to evaluate the effectiveness of their actions to reduce nitrogen and phosphorus loading to the Estuary and achieve the numeric targets of the 2019 Investigative Order.

5.2 PROBLEM STATEMENT

The Santa Margarita River Estuary (Estuary) is a 192 acre coastal estuarine habitat located in northern San Diego County on the southwestern edge of the United States (U.S.) Marine Corps Base Camp Pendleton (MCB CamPen) (**Figure 5-1**). Beneficial uses for the Estuary include Contact Water Recreation (REC-1), Non-Contact Water Recreation (REC-2), Estuarine Habitat (EST), Wildlife Habitat (WILD), Rare, Threatened, or Endangered Species (RARE), Marine Habitat (MAR), Migration of Aquatic Organisms (MIGR), and Spawning, Reproduction, and/or Early Development (SPWN). The lower Santa Margarita River (SMR) and Estuary are largely undeveloped and support multiple habitats for populations of federally- and/or state- listed endangered species. The SMR begins in Riverside County near the City of Temecula, at the confluence of Murrieta and Temecula Creeks. The main stem of the SMR flows within San Diego County through unincorporated areas, the community of Fallbrook, and MCB CamPen and ultimately drains into the Estuary. Urban and agricultural land uses in the more developed portions of the Santa Margarita River Watershed (SMR Watershed) have resulted in hydrological modifications to the Estuary which have led to increased nutrient loading (McLaughlin et al., 2013).

The ocean inlet at the mouth of the Estuary is not constricted by man-made structures, but inland from the mouth, tidal influence is constrained by rock jetties from Interstate-5 and the railroad crossings. Throughout the year, the ocean inlet of the Estuary may be open or closed to the Pacific Ocean for extended periods depending on the amount of rainfall and flow (McLaughlin et al., 2013). During periods when the Estuary is connected to the Pacific Ocean, the Estuary is flushed with seawater resulting in a brackish lagoon environment. However, salinity stratification in the water column often occurs when a sand berm develops at the ocean inlet. The combination of restricted tidal flushing and watershed loading of nutrients from upstream can result in excessive algal growth in the Estuary during the summer-dry season and winter-dry season (San Diego Water Board, 2018). As the macroalgae decayed, it reduced dissolved oxygen (DO) concentrations in the Estuary resulting in eutrophic conditions, which can degrade the aquatic habitat. In addition, excessive algal mats and floating algal scum are aesthetically unpleasant, reducing the public's opportunities for enjoyment of non-contact water recreation through activities such as bird watching.

Based on the San Diego Water Board's determination that eutrophic conditions in the Estuary limit its ability to support beneficial uses, the Estuary was placed on the 1986 Clean Water Act 303(d) List of Impaired Water Bodies (303(d) List) (State Water Resources Control Board [State Water Board], 2015) for eutrophic conditions during dry weather conditions in the summer and winter months. In 2006, the San Diego Water Board issued Investigation Order No. R9-2006-0076 (2006 Investigative Order), which established monitoring requirements for dischargers to impaired lagoons, including the Estuary, and required the dischargers to develop a monitoring program and submit monitoring program reports to aid in the development of a Total Maximum Daily Load (TMDL) (San Diego Water Board, 2006). In response to the 2006 Investigative Order, the Southern California Coastal Research Project (SCCWRP) assessed the Estuary from 2008-2009, which confirmed impairment of the Estuary due to eutrophication (McLaughlin et al., 2013). Further studies of eutrophication in the Estuary were conducted between 2010 and 2018 by the Naval Information Warfare Center Pacific (NIWC Pacific).[2] While monitoring results show that overall conditions are improving as massive rafting algal mats have not been observed since 2010, these studies continue to show evidence of eutrophic conditions

[2] Formerly known as NAVY Space and Naval Warfare Systems Pacific (SPAWAR).

manifested as macroalgal blooms, with higher levels of macroalgae heavily tied to closed mouth conditions. On behalf of MCB CamPen, NIWC Pacific also conducted monitoring on resurfacing groundwater (Leather et al., 2015; Leather et al., 2016; Leather et al., 2017). Results from this monitoring indicated that ongoing discharge of nutrients into the Estuary through resurfacing groundwater from former agricultural fields on MCB CamPen was still occurring. However, data indicated that a reduction of nutrient loading by as much as one to two orders of magnitude[3] had occurred since the monitoring of resurfacing groundwater first began (San Diego Water Board, 2019).

A loading analysis was drafted in July 2018, which identified total nitrogen and total phosphorus as the causative pollutants for eutrophication in the Estuary. In *Santa Margarita River Estuary, California Nutrients Total Daily Maximum Load Project* (Draft Staff Report) (San Diego Water Board, 2018), the San Diego Water Board outlined a TMDL of 13,246 pounds of delivered total nitrogen per year and 1,528 pounds of delivered total phosphorus per year during dry weather, meaning that the Estuary is able to assimilate this amount of total nitrogen and phosphorus during that time period without impairments of beneficial uses. This assimilative capacity corresponds to a 76% load reduction from loading levels measured in 2008 by SCCWRP.

The San Diego Water Board issued Investigative Order No. R9-2019-0007 (2019 Investigative Order) in May 2019. The basis for this order falls under California Water Code section 13267. The purpose of the 2019 Investigative Order is to "*assess the condition of the Santa Margarita River Estuary (Estuary) and to evaluate the linkage between the nutrient loading trends resulting from the implementation actions by the Cities of Murrieta, Temecula, and Wildomar, the Counties of San Diego and Riverside, the Riverside Flood Control and Water Conservation District, and the United States Marine Corps Base Camp Pendleton (collectively referred to hereafter as Dischargers) and the restoration of the water quality and beneficial uses of the Estuary*" (San Diego Water Board, 2019). The requirements were developed in collaboration with the Dischargers through the Santa Margarita River Estuary Watershed Nutrient Initiative Stakeholder Group. The 2019 Investigative Order requires the development of a Monitoring and Assessment Program Workplan (Workplan) that outlines a water quality monitoring and assessment program to track progress towards achieving the numeric targets listed in the Draft Staff Report and total nitrogen and total phosphorus loading reductions to the Estuary.

Surface water and groundwater monitoring in the Estuary and SMR Watershed will be conducted in order to evaluate whether required reductions in total nitrogen and total phosphorus loads are being attained and confirm that numeric targets are being achieved. Data will be collected for a four-year period from 2020 through 2023, with the beginning of monitoring intended to align with the beginning of the critical growth period in April 2020.

[3]Six-fold decrease (Kara Sorensen, personal communication)

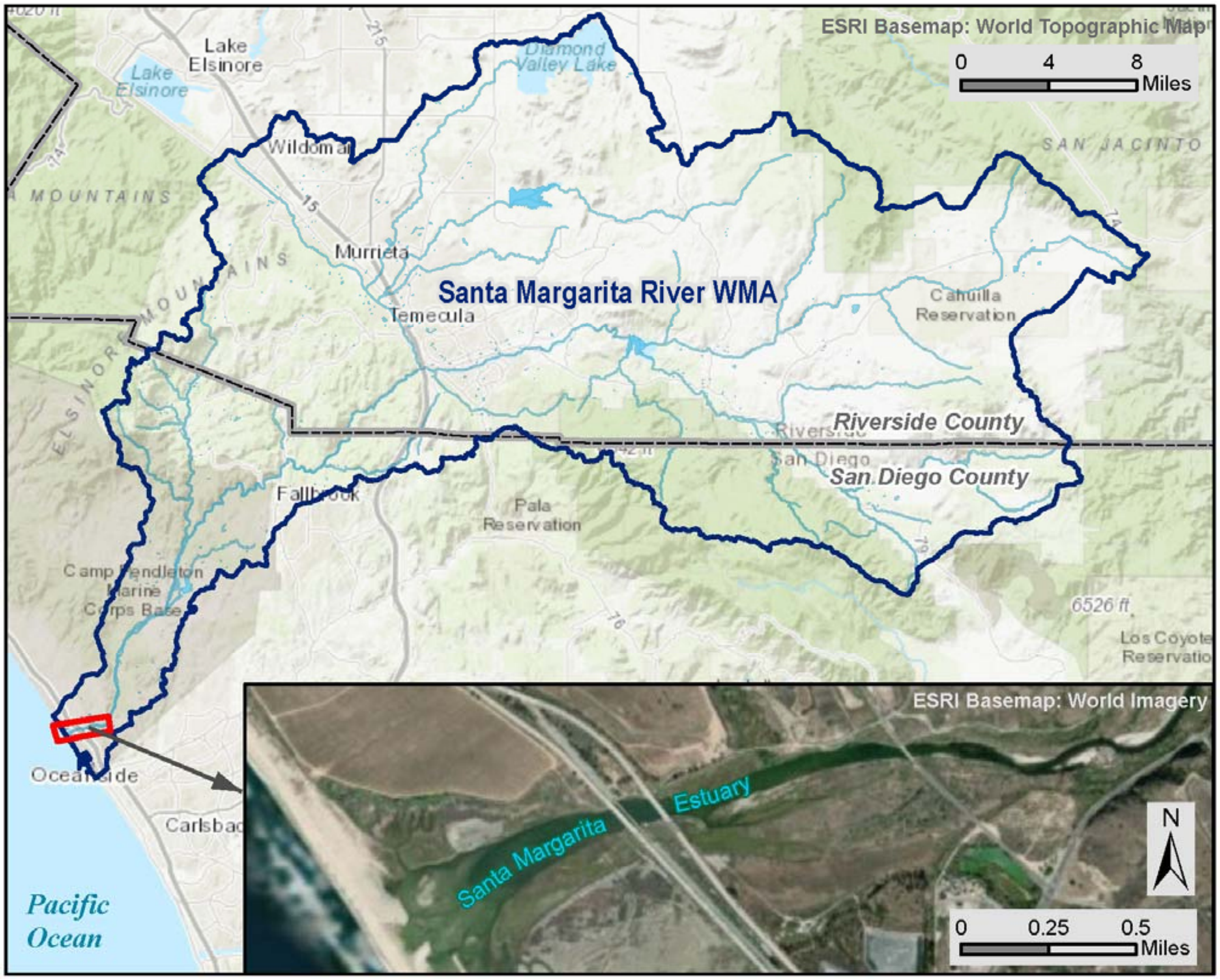


Figure 5-1. Santa Margarita River Estuary and Watershed Study Area

5.3 WATER QUALITY OR REGULATORY CRITERIA

The 2019 Investigative Order outlines the primary and secondary numeric targets for the Estuary as well as the calculated capacity of the Estuary to assimilate total nitrogen and total phosphorus in pounds per year in order to still meet the numeric targets necessary to restore the beneficial uses of the Estuary. Following the Nutrient Numeric Endpoints (NNE) approach, macroalgal biomass and DO were selected as primary numeric targets for the Estuary. The NNE approach provides a scientifically defensible methodology for interpreting the narrative WQOs for biostimulatory substances in the Water Quality Control Plan for the San Diego Basin (Basin Plan) (San Diego Water Board, 1994) and for controlling nutrient loads to levels such that the risk of impairing the designated beneficial uses is minimized (San Diego Water Board, 2019). To confirm that the Estuary beneficial uses are being supported, additional secondary numeric targets were selected for macroalgal biomass, DO, and benthic community condition. Nutrient concentrations within the water column were not selected as numeric targets for the Draft Staff Report because the macroalgal mats are most likely assimilating these nutrients from out of the water column, making measured concentrations of nutrients in the water column misleading.

Primary and secondary targets are shown in **Table 5-1**. Secondary numeric targets are to be used only if the primary numeric targets are not attained.

Table 5-1. Draft Staff Report Numeric Targets for Santa Margarita Estuary

Metric	Primary Target	Secondary Target	Season
Surface Water Macroalgal Biomass	< 57 g dry weight/m^2	< 70 g dry weight/m^2	Winter Dry and Summer Dry
Water Column Dissolved Oxygen	Daily minima ≥ 5.0 mg/L	7-day average of daily minimum measurements ≥ 5.0 mg/L	Winter Dry and Summer Dry
		10 percent allowable exceedance	
Benthic Community Condition Score	-	≤ 2.0 (Low Disturbance based on Sediment Quality Objectives (SQO) scale)	Winter Dry and Summer Dry

Source: San Diego Water Board, 2019

The Draft Staff Report calculated delivered Waste Load Allocations (WLAs) and Load Allocations (LAs) for the Estuary. The sum of delivered WLA and LA for total nitrogen is 8,226 pounds per year and the sum of delivered total phosphorus is 574 pounds per year (San Diego Water Board, 2018).

6. PROJECT/TASK DESCRIPTION

6.1 WORK STATEMENT AND PRODUCED PRODUCTS

Monitoring of the Estuary and SMR Watershed will be conducted during dry weather periods in both summer and winter for four years. Monitoring will begin within 60 days of receiving the Executive Officer's approval of the Workplan to be submitted November 8, 2019. The start of the monitoring program is intended to align with the beginning of the critical growth period in April. Monitoring locations are consistent with historical locations monitored between 2014 and 2018 in the Estuary and SMR Watershed and are provided in **Element 10**. Monitoring program components include the following:

- Estuary Resurfacing Groundwater Discharge Rates and Loading into the Estuary from the Santa Margarita Valley Groundwater Basin
- Estuary Continuous Monitoring
- Estuary Surface Water Quality and Algal Biomass Monitoring
- Estuary Sediment and Benthic Community Condition Monitoring
- Santa Margarita River Watershed Monitoring

Resurfacing groundwater and loading to the Estuary from the Santa Margarita Valley Groundwater Basin will be monitored biannually during winter and summer dry periods by sampling several piezometers and monitoring wells. Groundwater samples will be collected from three historic piezometer locations near the Stuart Mesa Agricultural Fields to confirm that resurfacing groundwater is no longer a significant source of nutrient loading to the Estuary. Piezometer locations were selected based on prior resurfacing groundwater work conducted between 2012 and 2017 (Chadwick et al., 2008; Leather et al., 2011; Leather et al., 2015; Stetson Engineers, 2011). In addition, seven historically monitored groundwater wells in the Lower Ysidora sub-basin will be monitored for nutrients biannually (wet and dry season). The Lower Ysidora sub-basin is located just upstream of the Estuary.

Continuous *in situ* water quality monitoring will be conducted at 15-minute intervals for seven months from April through October and during three months of the winter period (November, January, and March). Monitoring will be conducted at two locations in the Estuary, at the I-5 Bridge and Stuart Mesa Bridge. A multi-parameter data sonde with an optical sensor will be deployed at a depth of approximately 0.5 meter (m) at each location. Deployment will account for tidal range and depth such that the sonde probes remain submerged and do not contact the sediment surface. Because the sondes may need to be removed at times (e.g., due to severe weather in the winter months), data may not be collected for the entirety of each month; at least two weeks of continuous data will be collected during each monitored month. The sondes will continuously measure DO (mg/L and percent [%] saturation), water temperature (°C), pH (pH), salinity/conductivity (ppt; µS/cm), turbidity (NTU), and water depth (m). In addition, the degree of tidal muting or influence will be documented based on the current status of connectivity between the Estuary and the Pacific Ocean.

Algal biomass monitoring will be conducted monthly from April through October. During each monitoring event, sampling will be conducted in each of three Estuary regions: below the I-5 Bridge, above the Stuart Mesa Bridge to the head of the Estuary or the lower reach of the river,[4] and between the two bridges. Efforts will be made to align collection locations with Estuary sediment sampling and, where feasible, at similar sampling depths for subtidal sampling, so that relationships between the benthic community condition score and other parameters may be logically inferred.[5] Intertidal and subtidal protocols are available for algal biomass monitoring. Based on knowledge gained during previous monitoring in the Estuary, the subtidal protocol for macroalgal collection is more representative of conditions in the Estuary and is recommended.

Monthly surface water sampling will be conducted in the Estuary from April through October and during three events from November through March. During each monitoring event, sampling will be conducted at one location in each of the three Estuary regions. Ambient surface water grab samples will be collected at a depth of approximately 0.5 m, and will be analyzed for chlorophyll-a, total nitrogen, total and dissolved inorganic nitrogen, and total and dissolved phosphorus. Additionally, during each monitoring event, the status of connectivity between the Estuary and the Pacific Ocean will be documented.

Sediment monitoring to assess benthic community condition will be conducted in the Estuary on an annual basis, in late summer. Monitoring will be conducted at three locations within each of the three Estuary regions, for a total of nine samples. Sampling locations and depths (where feasible) will align with macroalgal sampling so that relationships between the benthic community condition score and other parameters may be logically inferred. However, benthic samples must be collected in subtidal conditions for use of sediment quality objective (SQO) benthic community scoring. Samples will be analyzed for total organic carbon (TOC; %), grain size, total nitrogen (%), total phosphorus (%), and benthic infaunal analysis (i.e., sorting and taxonomic evaluation of benthic macroinvertebrates).

Monthly monitoring on the main stem of the Santa Margarita River will be conducted at three sites, one each within the jurisdictions of San Diego County, Riverside County, and MCB CamPen. Monitoring events will be conducted monthly from May through October and bi-monthly from November through April, in November, January, and March. MCB CamPen will conduct monitoring at the United States Geological Survey (USGS) gage at Ysidora, which is the most reliable location for measuring streamflow along that reach of the river. During each monthly monitoring event, water quality data (temperature and conductivity) will be measured using a multi-parameter water quality meter or sonde, and a grab sample will be collected and analyzed for total nitrogen, total and dissolved inorganic nitrogen, and total and dissolved phosphorus.

Monitoring events will be conducted so that they are preceded by a minimum of 72 hours of dry weather (< 0.2 inch of precipitation in 24 hours). This definition of ambient conditions is consistent with the criteria used in the watershed loading model informing nutrient management in the SMR Watershed (Sutula et al., 2016). Continuous flow data and continuous DO data collected during storm events and the following 72 hours will not be included in assessment and reporting, which focus on ambient dry conditions. However, continuous data collected during wet weather will be available for future watershed modeling efforts and will be submitted to the California Environmental Data Exchange Network (CEDEN).

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[4] The inner limit or upstream boundary of the Estuary should be defined by changes from estuarine to riparian vegetation, changes in salinity going from brackish to freshwater, and changes in river currents dominating over tidal action (San Diego Water Board, 2019).

[5] Benthic samples must be collected in subtidal conditions in order to determine SQO benthic community scores.

Annual reports will be produced to present the findings of the Estuary and SMR Watershed monitoring effort each year and address the questions presented in **Element 5.1**. The annual report for Year 4 will assess all four years of monitoring data.

6.2 CONSTITUENTS TO BE MONITORED AND MEASUREMENT TECHNIQUES

Estuary Resurfacing Groundwater and Loading from the Santa Margarita Valley Groundwater Basin

Resurfacing groundwater and loading to the Estuary from the Santa Margarita Valley Groundwater Basin will be monitored by sampling several piezometers and monitoring wells. Samples will be taken at three piezometers near the Stuart Mesa Agricultural Fields and seven groundwater wells in the Lower Ysidora sub-basin of the Santa Margarita Valley Groundwater Basin. Constituents sampled will include total nitrogen, total and dissolved inorganic nitrogen, and total and dissolved phosphorus. Total and dissolved phosphorus can be analyzed using either United States Environmental Protection Agency (USEPA) Method 365.1 or Standard Method (SM) 4500. Total nitrogen, and total and dissolved inorganic nitrogen, will be determined by calculation. Groundwater methods described here were approved by a State-certified Professional Geologist[6], and future groundwater sampling will be overseen by a State certified Professional Geologist to ensure procedures meet State standards.

Estuary Continuous DO Monitoring

Continuous *in situ* DO monitoring will be performed using multi-parameter data sondes with optical sensors at 15 minutes interval and 0.5 m water depth. Additional data collected by each sonde will include pH, water temperature, conductivity/salinity, turbidity, and water depth.

Estuary Algal Biomass Monitoring

Macroalgae will be collected for determination of biomass. Physical measurements of macroalgal biomass will be determined following Section 6.3 of the standard operating procedure (SOP) for Macroalgal Collection in Estuarine Environments (SCCWRP Technical Report #872, McLaughlin et al., 2019). This SOP is provided in **Appendix B** of the Workplan.

Estuary Surface Water Quality and Macroalgae Monitoring

Monthly surface water grab samples collected during macroalgae sampling will be analyzed for the following constituents: chlorophyll-a, total nitrogen, total and dissolved inorganic nitrogen, and total and dissolved phosphorus. Total and dissolved phosphorus can be analyzed using either USEPA Method 365.1 or SM 4500. Total nitrogen, and total and dissolved inorganic nitrogen, will be determined by calculation. Suspended chlorophyll-a will be analyzed by SM 10200.

Estuary Sediment and Benthic Community Condition Monitoring

Annual sediment grab samples will be analyzed for the following constituents: grain size, total nitrogen, total phosphorus, and TOC. Grain size can be analyzed using either ASTM D4464 (M), SM 2560 D, or ASTM D422. Total nitrogen will be determined by calculation; the calculated value is comprised of total Kjeldahl nitrogen (TKN), NO_3, and NO_2. Total phosphorus will be analyzed by SM 4500. TOC will be analyzed by EPA 9060A.

[6] See Professional Geologist certification page in front matter of Work Plan/QAPP, following the certification pages signed by the stakeholders

Annual benthic macroinvertebrate samples will be collected in the late summer. Benthic organisms will be removed from the samples and sorted into five major phyletic groups (polychaetes, crustaceans, molluscs, echinoderms, and miscellaneous minor phyla) for taxonomic identification. Qualified taxonomists will identify each organism to species level or to the lowest possible taxonomic level. Data for organisms that are incidental contaminants should not be included in the data analysis and should not be counted or included in the project data. Attached parasites and other epibionts should not be recorded or submitted in annual reports but may be noted as present on bench data sheets. Nomenclature and orthography should follow the usage in the SQO species list on the *Sediment Quality Assessment Tools* page of the SCCWRP website (www.sccwrp.org) as well as Edition 5 of the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) taxonomic listing (available at www.scamit.org).

Santa Margarita River Watershed Flow Monitoring

A flowmeter will be installed and maintained at the County of San Diego monitoring location. MCB CamPen's surface monitoring site will use the Ysidora USGS gage (11046000). The Riverside County monitoring will also incorporate an existing USGS gage (11044000) at the Santa Margarita River near Temecula. Although monitoring events occur during nine months of the year, it is recommended that flow monitoring occur throughout the year, where equipment can remain in place, for flow volume calculations used in loading estimations. At a minimum, the equipment will be comprised of Hach (or comparable) flowmeters with a bubbler or submerged pressure transducer as the primary measuring device (level sensor). Sampling equipment may also include a solar panel for battery recharge and power resiliency. The primary sensor will continuously measure stage (i.e., stream height) and relay that information to the flowmeter, which will continually calculate flow rates by inserting the stage information into the preprogrammed discharge equation. Continual flow data will be downloaded periodically to verify equipment functionality and thus reduce data gaps, ensure accuracy, and identify maintenance and calibration needs. Flow data will be entered into the data management system.

Daily and monthly flow rates will be measured or estimated in accordance with the National Pollutant Discharge Elimination System (NPDES) Storm Water Sampling Guidance Document (EPA-833-B-92-001) (USEPA, 1992). Flow rating curves will be developed that correlate water surface levels (or stream heights) to flow rates.[7] To quantify flow rates based on stream stage, a relationship between flow and stage will be derived using standardized stream rating protocols developed by the USGS (Rantz, 1982; Oberg et al., 2005) and using an applicable hydraulic calculation formula(s), such as Manning's equation. If the monitoring station is found to have a steady dry weather base flow, it may be appropriate to install a flow sensor with the ability to measure instantaneous stream velocity. However, in an ephemeral stream that tends to be wet and dry out periodically, this type of sensor may not collect high quality data. A decision to use an area-velocity flow meter and/or a weir structure will be determined based on site hydraulic and flow conditions.

Instantaneous field level and flow measurements will be periodically taken to validate the rating curves. To measure instantaneous flows during low flow and base flow conditions, two types of field flow monitoring equipment may be used. To measure small flows, a handheld velocity measurement instrument, such as a Marsh-McBirney Model 2000 Portable Flowmeter connected by a cable to an

[7] At the MCB CamPen surface monitoring site at Ysidora and the Riverside County site associated with USGS gage 11044000, discharge, rating curves, and field flow measurements from the USGS will be used in lieu of a new flow measurement site. The USGS stations have real-time telemetry and report data at 15-minute intervals.

electromagnetic open channel velocity sensor, or equivalent may be used. To measure higher flows, the SonTek (YSI) FlowTracker Acoustic Doppler Velocimeter, or equivalent may be used.

Santa Margarita River Watershed Nutrient Water Quality Monitoring
Monthly and bi-monthly surface water grab samples will be analyzed for the following constituents: total and dissolved phosphorus and total nitrogen, total and dissolved inorganic nitrogen. Total and dissolved phosphorus can be analyzed using either EPA 365.1 or SM 4500. Total nitrogen, and total and dissolved inorganic nitrogen, will be determined by calculation.

In addition, water quality data, including temperature and specific conductivity, will be collected using a multi-parameter water quality meter or sonde.

6.3 PROJECT SCHEDULE

Table 6-1 details the project schedule for annual monitoring and reporting for the Estuary and SMR Watershed, including initiation and completion dates for major tasks, required deliverable(s), and the deliverable(s) due dates. Monitoring events will be conducted annually from 2020 through the 2022-2023 monitoring year (i.e., water years; October 1 to September 30). Initiation of data compilation, QA/QC, analysis and draft report preparation will begin prior to completion of monitoring to provide adequate time for these tasks given report deadlines. Submittal of Final Annual Reports to the San Diego Water Board will be on January 31st of the following calendar year[8] after each monitoring period. For Year 4, the Final Annual Report will be submitted by March 31, 2024.

[8] For Year 4, the report will be submitted by March 31, 2024.

Table 6-1. Estuary and SMR Watershed Annual Monitoring and Reporting Schedule

Task	Activity	Anticipated Date of Initiation	Anticipated Date of Completion
Task 1	Estuary and SMR Watershed Monitoring	October 1 of each year (for Year 1, within 60 days of Executive Officer Approval of Monitoring Plan)*	September 30 of each year
Task 2	Data Management and QA/QC	Ongoing throughout year	Ongoing throughout year
Task 3	Data Compilation, Analysis, Summary	September 1 of each year	November 1 of each year
Task 4	Draft Annual Report	September 1 of each year	November 1 of each year
Task 5	Review of Draft Annual Report	November 15 of each year	November 30 of each year
Task 6	Comment Response and Final Annual Report	December 1 of each year	January 15 of each year**
Task 7	Submittal of Annual Report to San Diego Water Board	January 31** of each year (for Year 4, the report will be submitted by March 31, 2024)	

* Per SMRNIG TAC, targeted start date of monitoring is April 2020 after approval of Workplan and QAPP.
** Following calendar year

6.4 GEOGRAPHICAL SETTING

The Estuary is located along the southern California coast in northern San Diego County. It is in the Ysidora Hydrologic Area (HA) (902.1) within the Santa Margarita River (SMR) Watershed Management Area (WMA), on the southwestern edge of MCB CamPen. The Estuary is one of the few remaining and largely unmodified coastal estuaries in southern California and encompasses 192 acres of valuable estuarine habitat including subtidal habitats, mudflats, salt marsh, and salt pannes. The Estuary provides important refuge, foraging areas, and breeding grounds for multiple threatened and/or endangered species, as well as coastal marine species (Staff Report; San Diego Water Board, 2018). The SMR Watershed, which drains into the Pacific Ocean, is comprised of an area of approximately 750 square miles (sq mi). Approximately 73% lies within Riverside County and includes all or portions of the Cities of Murrieta, Temecula, Wildomar, and Menifee in addition to approximately 457 sq mi of unincorporated area that also include federal, state, and tribal lands. The remaining 26.5% of the SMR Watershed land surface lies within San Diego County, which includes MCB CamPen and the unincorporated communities of Fallbrook and Rainbow.

6.5 CONSTRAINTS

Annual monitoring in the Estuary and SMR Watershed will occur during dry weather periods in both summer and winter for four years. Monitoring events will be conducted so that they are preceded by a minimum of 72 hours of dry weather (< 0.2 inch of precipitation in 24 hours). Continuous flow data and continuous DO data collected during storm events and the following 72 hours will not be included in assessment and reporting, which focus on ambient conditions. Monthly sampling will also be postponed until after a 72-hour dry period. This is consistent with the criteria used in the watershed loading model informing nutrient management in the SMR Watershed (Sutula et al., 2016).

Potential causes of equipment failure include extreme flooding, exposure to natural elements, and power failures due to the remote location.

Vandalism or theft of sampling equipment either in the Estuary itself (deployed multi-parameter data sondes) or at the receiving water stations in the watershed (flowmeters) could potentially affect the ability to collect complete data sets for the continuous monitoring portion of the program. Due to controlled access to MCB CamPen, vandalism and theft are unlikely.

7. QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

Data quality for this monitoring program will be assessed using measurement quality objectives (MQOs), also known as data quality indicators, such as accuracy, precision, completeness, or representativeness. Acceptance criteria will be based on the implementation of acceptable and recognized QA/QC procedures. Acceptable data must have been collected and analyzed using proper sample collection and handling methods, sample preparation and analytical procedures, holding times, stability issues, and QA protocols. The data quality indicators for both the field measurements and laboratory analyses are summarized in **Table 7-1**, followed by a brief discussion of the objectives of each indicator.

Table 7-1. Measurement Quality Objectives

Measurement or Analysis Type	Applicable Data Quality Indicator
Field: Dissolved Oxygen, Temperature, Conductivity, pH, Salinity, Turbidity	Accuracy, Completeness
Laboratory Analyses: Nutrients	Accuracy, Precision, Completeness, Representativeness
Laboratory Analyses: Water Column Chlorophyll-a	Accuracy, Completeness, Representativeness
Laboratory Analyses: Macroalgae Biomass	Completeness, Representativeness
Laboratory Analyses: Sediment TOC and nutrients	Accuracy, Precision, Completeness, Representativeness
Laboratory Analyses: Benthic Community	Accuracy, Completeness

QC for field collection and/or physical and chemical laboratory analyses will be conducted in accordance with Surface Water Ambient Monitoring Program (SWAMP) guidelines (State Water Board, 2017). The SWAMP QC guidelines for field measurements of DO, temperature, pH, salinity/conductivity, and turbidity are provided in **Table 7-2** (State Water Board, 2013). The SWAMP QC guidelines and associated MQOs for water column nutrients, water column chlorophyll-a, and sediment TOC, grain size, and nutrients are provided in
Table 7-3 (State Water Board, 2013). If a standard reference material is required for accuracy measurements but is not available for a specific analyte, then an LCS can be used as an alternative QC sample.

Field duplicates and equipment rinse blanks will be collected and analyzed at the frequency described for each monitoring program component in accordance with SWAMP QA sample requirements (i.e., field duplicates at a frequency of 5% of the sample count and a field or equipment rinse blank per method). Two field duplicates and one field blank will be collected for Estuary surface water nutrient analysis and for SMR Watershed nutrient analysis during each monitoring year, and one field duplicate and one equipment rinse blank will be collected for Estuary sediment chemistry analysis during each monitoring year.

7.1 Accuracy

Accuracy (bias) is a measure of how closely the analytical result or field measurement represents the true quantity found in the sample. To achieve accuracy in field measurements, the multi-parameter data sonde will be calibrated before starting the monitoring, and the sonde response will be verified to be within appropriate precision as shown in **Table 7-2**, after cleaning any biofouling, each time the sampling team visits the Estuary. Evaluation of the accuracy of laboratory samples in this study will be achieved through the preparation and analysis of standard reference materials or laboratory control samples (LCS), and matrix spike (MS) samples with each analytical batch. The accuracy of the laboratory samples is quantified as percent recovery.

7.2 Precision

Precision is the measure of agreement among repeated measurements of the same property under identical or substantially similar conditions calculated as either the range or as the standard deviation. The precision of field measurements will be controlled by measuring field duplicates or replicates. The precision of laboratory measurements will be controlled by comparison of the sample to either a laboratory duplicate or a laboratory matrix spike/matrix spike duplicate (MS/MSD). Results of the duplicate analysis are evaluated by calculating the relative percent difference (RPD) as shown in the following equation.

$$RPD = (X_1-X_2)/[(X_1+X_2)/2]*100$$

Where:
X_1= larger of two concentrations, and X_2 = smaller of two concentrations

The MQO for field and laboratory duplicate RPDs for each of the physical and chemical analytes is <25% (
Table **7-3**).

7.3 Representativeness

Representativeness is a qualitative term that describes how characteristic a sample is of the actual environmental condition from which it was collected. Determining appropriate sampling locations, sampling frequency, and use of approved/documented SOPs and analytical methods will control to the greatest extent possible that the measurement data represent the conditions at the monitoring site.

7.4 Completeness

Completeness is a measure of the percentage of sample results that are collected and analyzed and determined to be valid. Field personnel and the analytical laboratory will strive for 90% data completeness, which accounts for unexpected field conditions, equipment problems, and laboratory error.

7.5 MQOs for Benthic Macroinfaunal Samples

The MQOs for benthic macroinfaunal sorting and taxonomy will be evaluated based on guidance from the Sediment Quality Assessment Technical Support Manual, SCCWRP Technical Report 777 (Bay et al., 2014) and those utilized for the Southern California Bight 2018 Regional Marine Monitoring Survey (Bight '18). An accuracy MQO for benthic infaunal sample sorting will be evaluated by ensuring a 95% removal efficiency during the sorting process. Using the aliquot method, a minimum of 10% of all material in each benthic infaunal sample will be re-sorted to monitor sorter performance and to determine achievement of the MQO of 95%. Percent sorting efficiency using the aliquot method is calculated as follows:

$$\%_{Efficiency} = 100 * [\# \text{ Organisms}_{sorted} \div (\# \text{ Organisms}_{sorted} + \# \text{ Organisms}_{from\ Re\text{-}sort} * \%_{aliquot})]$$

When the sorting efficiency of the sample is below 95%, the remainder of the sample (90%) will be re-sorted.

An accuracy MQO for taxonomic analysis of the benthic macroinfaunal community will be evaluated via two QC procedures. The first QC procedure will be to re-identify 10% of the samples by taxonomists other than those who originally analyzed the samples. Taxonomic discrepancies between the original and secondary QC taxonomists will be resolved by comparing results of the two sets of identifications through the completion of a Discrepancy Resolution Report (Bay et al., 2014). Further detail on how to complete this re-analysis process is provided in the Bay et al., 2014 document. The second QC procedure will be for the primary taxonomists to establish a voucher collection of all macroinfaunal organisms identified during the first year of monitoring. Following the first year of monitoring, only new specimens not included in the original voucher collection will be added. The purpose of the voucher collection is to provide the means of resolving questions regarding nomenclature between the primary and secondary taxonomists.

Table 7-2. Quality Control for Field Measurements in Fresh and Marine Water

Water Quality Parameter	Recommended Device	Units	Resolution	Instrument Accuracy Specs	Points per Calibration	Pre-Sampling Calibration Check Frequency	Post-Sampling Calibration Check Frequency	Allowable Drift
Dissolved Oxygen	Polarographic or luminescence quenching probe	mg/L	0.01	±0.2*	1	Before every monitoring day or prior to long-term deployment	After every monitoring day or retrieval from long-term deployment (within 24 hours)	±0.5 or 10%
pH	Electrode	pH	0.01	±0.2	2	Per manufacturer	Per manufacturer	±0.2 units
Salinity	Refractometer of conductivity cell	ppt	0.01	±2%	Per manufacturer	Per manufacturer	Per manufacturer	Per manufacturer
Specific Conductance	Conductivity cell	µS/cm	1	±0.5%	Per manufacturer	Per manufacturer	Per manufacturer	±10%
Temperature	Thermistor or bulb	°C	0.1	±0.15%	Per manufacturer	Per manufacturer	Per manufacturer	±0.5
Turbidity	Portable turbidimeter or optical probe	NTU	0.1	±1% up to 100 NTU; ±3% from 100-400 NTU; and ±5% from 400-3000 NTU	2	Per manufacturer	Per manufacturer	Per manufacturer

Reference: State Water Board, 2017

* Calibration checks on DO sensors have indicated that variations in measured DO values may be greater than this instrument accuracy specification (Kara Sorensen, personal communication).

Table 7-3. Measurement Quality Objectives for Laboratory Measurements

Group	Parameter	Frequency	Accuracy	Precision	Recovery	Completeness
Water Samples						
Laboratory Analyses	Total and Dissolved Phosphorus, and Inorganic Nitrogen	Per 20 samples or per analytical batch, whichever is more frequent	Standard Reference Materials (SRM, CRM) within 95% confidence interval stated by provider of material. If not available, then an LCS with 90–110% of true value	Laboratory duplicate, blind field duplicate, or MS/MSD ±25% RPD	Matrix Spike 80% to 120%	90%
Laboratory Analyses	Chlorophyll-a	Per 20 samples or per analytical batch, whichever is more frequent	LCS with 80–120% of true value	Blind field duplicate ±25% RPD	–	90%
Sediment Samples						
Laboratory Analyses	Total Phosphorus, Total Nitrogen, Grain Size, and TOC	Per 20 samples or per analytical batch, whichever is more frequent	Total organic carbon only: Standard Reference Materials (SRM, CRM) within 95% confidence interval stated by provider of material. If not available, then an LCS with 80–120% of true value	Laboratory duplicate or blind field duplicate ±25% RPD	–	90%

8. SPECIAL TRAINING NEEDS/CERTIFICATION

8.1 SPECIALIZED TRAINING OR CERTIFICATIONS

Field personnel will have current and relevant experience in the aspects of standard field monitoring, including use of relevant field instruments and monitoring equipment, experience in the collection and handling/storage of samples, and chain-of-custody (COC) procedures. Training in techniques for proper field sampling and sample-handling will be reviewed prior to each sampling event, and only those staff with proficiency will be permitted to conduct field work.

All laboratory analysts will be proficient in the use of analytical equipment, conducting analytical protocols, and other general laboratory processes. The QA Officer is responsible for distributing the most up-to-date QAPP for this monitoring project to the respective laboratory staff and ensuring that the staff understand and follow all SOPs and the QAPP for the duration of this study.

All samples must be analyzed by laboratories accredited by the Environmental Laboratory Accreditation Program (ELAP) using methods approved by the USEPA for the type of analysis to be performed.

8.2 TRAINING AND CERTIFICATION DOCUMENTATION

Personnel are responsible for complying with QA/QC requirements that pertain to their organizational/technical function. Technical staff members must have a combination of experience and education to adequately demonstrate a specific knowledge of their particular function and a general knowledge of laboratory operations, test methods, QA/QC procedures, and records management. The analytical laboratory QA officer will ensure that all laboratory staff is proficient at analyses applicable to this project. Training and certification documents for laboratory staff will be maintained by the laboratory QA officer, or their designee.

8.3 TRAINING PERSONNEL

The Consultant PM and/or Field Task Lead will provide training for field personnel in proper field sampling techniques prior to work initiation to ensure consistent and appropriate sampling, sample handling/storage, and chain of custody (COC) procedures. The analytical laboratory QA officer will ensure that training is provided to the laboratories' personnel for implementing standard laboratory procedures and maintaining proper documentation.

9. DOCUMENTS AND RECORDS

The Consultant will document and track the aspects of the sample collection process, including generating field logs at each site and COC forms for the samples collected. An example COC form is provided in **Attachment A**. COC forms will accompany samples to the analytical laboratory. The consultant and analytical laboratory will document and track the aspects of receipt and storage, analyses, and reporting related to their respective samples. Minimum documentation of sample handling and custody will include the following:

- Sample identification
- Sample collection date and time
- Any special notations on sample characteristics
- Initials of the person collecting the sample
- Date the sample was sent to the laboratory
- Type of sample analysis
- Shipping company and waybill information
- Sample container size, type, and preservative (if applicable)

Sample container labels will include the sample ID, date and time of collection, sampler's initials, and type of analysis. The Consultant will maintain a database of information collected during this project. The database will include field observations, data sheets, COC records, and analytical results. The original data sheets, statistical worksheets, and reports produced will be accumulated into project-specific files maintained by the Consultant after the report has been submitted. Data from outside contractors are kept exactly as received. Records will be maintained for at least five years or transferred according to agreement between the Consultant and the client.

The Consultant's PM will be responsible for maintaining records for this project, overseeing the operations of the project, maintaining the sample collection, sample transport, COC, field analysis forms, and laboratory data. The Consultant's PM will also arbitrate any issues relative to records retention and any decisions to discard records.

Copies of this QAPP will be distributed to the parties identified previously in **Element 3**. Updates to this QAPP will be distributed in like manner, and previous versions will be discarded from the project file. The Consultant PM under the direction, supervision, and review of the Consultant's QA Officer, will be responsible for distributing an updated version of the QAPP.

Electronic copies of the final report, including laboratory results and field records, will be maintained for a minimum of five years after project completion. A summary of document and record retention, archival information, and disposition of documents is provided in
Table 9-1.

Table 9-1. Summary of Document and Record Retention, Archival, and Disposition

	Type of Document	Retention	Archival	Disposition
Field Sampling Documentation	Field Notebook containing logs, data sheets, etc.	Paper or electronic	Notebook/Electronic	5 years
Sample Collection Records	Chain of Custody	Paper or electronic	Notebook/Electronic	5 years
Analytical Records	Lab notebooks, bench sheets, and sorting forms	Paper	Notebook	5 years
	Lab Results QA/QC	Paper and electronic	Notebook/Database	5 years
	Electronic data deliverables	Electronic	Database	5 years
Data Records	Data Entry	Electronic	Database	5 years
Assessment Records	QA/QC Assessment	Electronic	Database	5 years
	Final Report	Electronic	Database	5 years

GROUP B: DATA GENERATION AND ACQUISITION

10. SAMPLE PROCESS DESIGN

Sampling events will be conducted during dry weather in both summer and winter. Monitoring will be conducted for four years, beginning within 60 days of receiving the Executive Officer's approval of the Workplan to be submitted November 8, 2019. The start of the monitoring program is intended to align with the beginning of the critical growth period in April. The sampling program includes Estuary resurfacing groundwater discharge rate and nutrient loading, Estuary continuous water quality monitoring, Estuary algal biomass monitoring, Estuary surface water quality, and SMR Watershed flow and water quality monitoring, as described in the following subsections. The sampling design designates the following:

- Three piezometer sites near the Stuart Mesa Agricultural Fields and seven groundwater wells in the Santa Margarita Valley Groundwater Basin for discharge and nutrient monitoring;
- Two Estuary continuous water quality monitoring stations (I5 and Stuart Mesa Bridges);
- Three sub-segments in each Estuary segment for macroalgal biomass monitoring;
- One location in each Estuary segment for surface water quality monitoring;
- Three locations in each Estuary segment for sediment and benthic community condition monitoring;
- One location on the main stem of the SMR for each of three jurisdictions (Riverside and San Diego Counties and MCB CamPen).

10.1 ESTUARY RESURFACING GROUNDWATER DISCHARGE RATES AND LOADING INTO THE ESTUARY FROM THE SANTA MARGARITA VALLEY GROUNDWATER BASIN

Bi-annual groundwater sampling will be conducted (once in wet weather and once in dry weather conditions). During each monitoring event, sampling will be conducted at ten locations: three piezometers near Stuart Mesa Agricultural Fields and seven wells in the Lower Ysidora sub-basin. Proposed station locations are shown in **Table 10-1** and **Figure 10-1**. During each monitoring event, site conditions and sample information will be recorded on field data sheets. All groundwater work will be performed per Standard Methods and be overseen by a State Certified Geologist per the Investigative Order.

Groundwater discharge estimates and chemical identification will be conducted at each of the piezometer sites. Qualitative assessment of seepage near the Stuart Mesa Agricultural field will be performed by measuring temperature and conductivity in the upper two feet of the ground surface. Quantitative assessment of seepage will be performed by measuring hydraulic head difference in the groundwater surface. Grab samples at all piezometers will be collected for nutrient analysis so mass-loading calculations can be performed using quantitative and qualitative analysis of groundwater seepage.

At the seven monitoring wells, nutrient grab samples will be collected. The groundwater level and sampling depth in each well will be recorded on field sheets. Sampling depths at groundwater wells will be selected to best characterize subflow, corresponding to recognized coarse-grained lithologic layers within the screened intervals of the wells. Groundwater flow at monitoring wells in the Lower Ysidora sub-basin will not be directly measured, but will be estimated using existing data and tools, including prior groundwater modeling data.

Table 10-1. Station Identifications and Coordinates for Estuary Resurfacing Groundwater Monitoring

Station ID	Latitude (NAD83)	Longitude (NAD83)
Santa Margarita Valley Groundwater Basin Locations		
MW 2201	33.28539	-117.37663
Well #C (SDSU)	33.26846	-117.37276
Well #B (SDSU)	33.25792	-117.37314
11/5-2D3	33.25500	-117.37865
7W-09A	33.23914	-117.38174
11/5-11D4 (7W-09B)	33.23913	-117.38175
7W-08A	33.23728	-117.38458
Stuart Mesa Agricultural Field Piezometer Locations		
DA1	33.235497	-117.407642
DA2	33.236041	-117.404666
DA3	33.236443	-117.402449

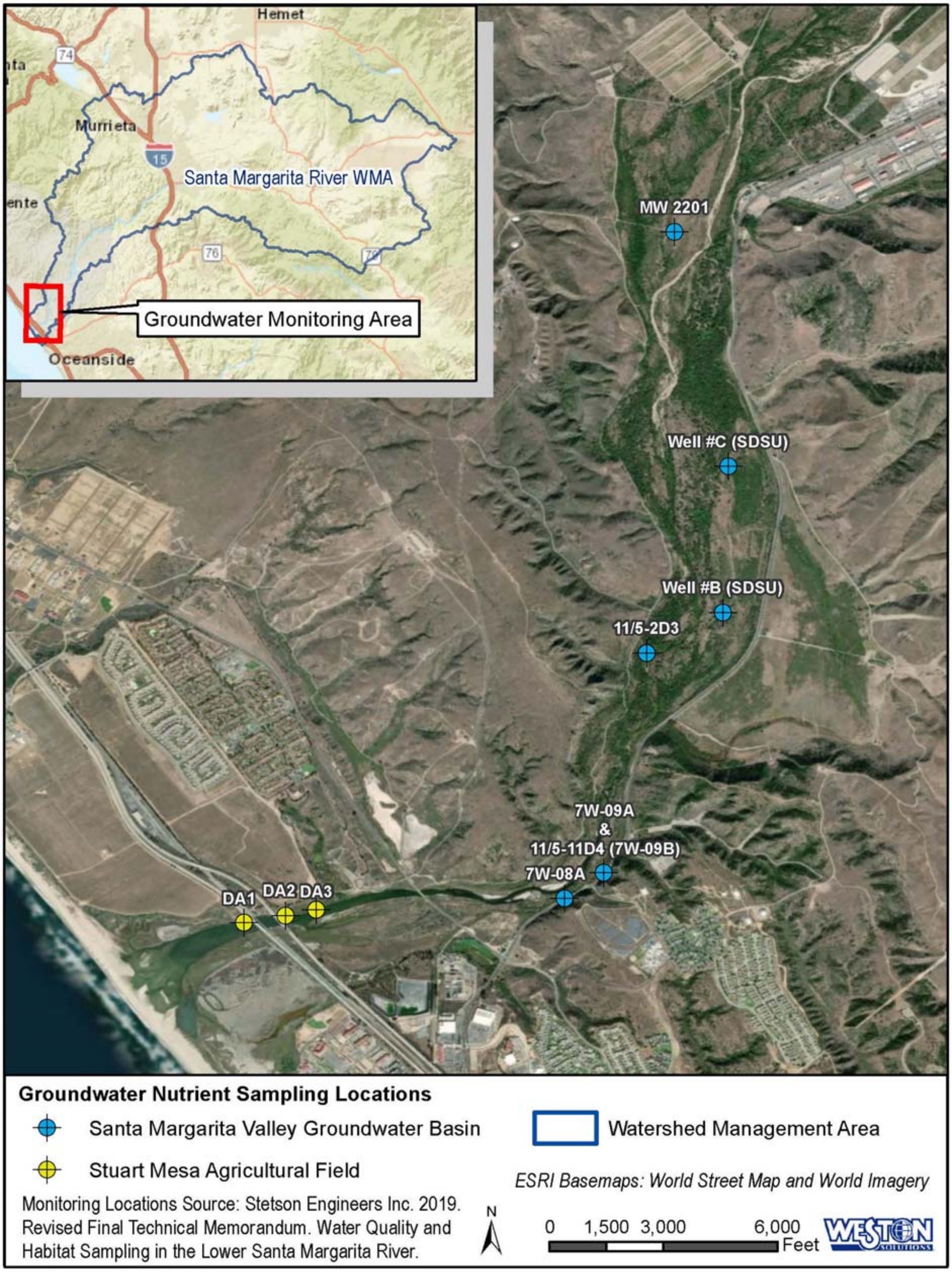

Figure 10-1. Groundwater Monitoring Station Locations

10.2 ESTUARY CONTINUOUS MONITORING

Each year, continuous water quality monitoring will be conducted by MCB CamPen for seven months from April through October and during three months of the winter period (November, January, and March). Because the sondes may need to be removed at times (e.g., due to severe weather in the winter months), data may not be collected for the entirety of each month; at least two weeks of continuous data will be collected during each monitored month.

Data sondes will be deployed at two locations in the Estuary, I-5 Bridge and Stuart Mesa Bridge. Sampling locations are shown in **Table 10-2** and **Figure 10-2**; station IDs are consistent with historical monitoring. DO (mg/L and % saturation), water temperature (°C), salinity/conductivity (ppt; µS/cm), turbidity (NTU), and water depth (m) will be continuously monitored *in situ* at 15-minute intervals. In addition, the degree of tidal muting or influence will be documented based on the current status of connectivity between the Estuary and the Pacific Ocean.

Table 10-2. Station Identifications and Coordinates for Estuary Continuous Monitoring

Station Location	Station ID	Latitude (NAD83)	Longitude (NAD83)
I-5 Bridge	I-5 (Axial 4)	33.235317	-117.406883
Stuart Mesa Bridge	SMB	33.237620	-117.395290

10.3 ESTUARY ALGAL BIOMASS MONITORING

Monthly algal biomass monitoring will be conducted in the Estuary from April through October. During each monitoring event, sampling will be conducted in each of three Estuary regions: below the I-5 Bridge, above the Stuart Mesa Bridge to the head of the Estuary or the lower reach of the river,[9] and between the two bridges (**Figure 10-2**). Algal biomass monitoring will be conducted in accordance with the SOP for Macroalgal Collection in Estuarine Environments (SCCWRP Technical Report 872; McLaughlin et al., 2019) (**Appendix B** of the Workplan).

Effort should be made to align collection location with Estuary sediment sampling described in **Element 10.5**; and, where feasible, at similar sampling depths for subtidal sampling**,** so that relationships between the benthic community condition score and other parameters may be logically inferred.[10]

The SOP includes protocols to sample two habitat types, intertidal (mud or sand) flats and shallow subtidal (<10 m). Based on knowledge gained during previous monitoring in the Estuary, data generated by the subtidal protocol is more representative of conditions in the Estuary and is recommended. The subtidal protocol is discussed herein and detailed in Section 4 of SCCWRP

[9] The inner limit or upstream boundary of the Estuary should be defined by changes from estuarine to riparian vegetation, changes in salinity going from brackish to freshwater, and changes in river currents dominating over tidal action (San Diego Water Board, 2019).
[10] Benthic samples must be collected in subtidal conditions in order to determine SQO benthic community scores.

Technical Report 872. The intertidal protocol can be found in Section 3 of SCCWRP Technical Report 872.

Based on several years of monitoring, NIWC Pacific has recommended sampling location options for macroalgal monitoring in the three segments of the Estuary (**Figure 10-2**). Shown in **Table 10-3** are the identifications and approximate geographic coordinates for these historical stations. A minimum of three samples will be collected from each of five sampling locations within each of the three Estuary segments, for a minimum of 15 samples per Estuary segment. The sampling approach requires that all macroalgae found within a defined surface area two meters in depth or less is comprehensively sampled from surface to bottom. As feasible, selected sites should include macroalgal sampling stations that have been sampled historically during 2008 to 2018, which are identified with a "✓" in **Table 10-3**. Also shown are recommended sites for Estuary Sediment and Benthic Community Condition Monitoring in order to align station sampling. While the table provides six options for macroalgal biomass monitoring per sub-segment, a list of 30 sites (10 per sub-segment) with some historical data are available from NWIC if additional location options are needed. Monitoring at historical locations will facilitate analysis of trends.[11]

Sampling locations should be the same for each sampling period, and site conditions recorded on field data sheets. Due to scouring and deposition events that may occur between monitoring periods, it may not be feasible to conduct sampling at the same locations year to year. In this case, additional sites will be selected, attempting to stay as close to the original sites as possible.

NWIC conducted a sampling number power analysis using 2017 and 2018 data (~630 samples) and prior model output to conservatively estimate a need for 160/200 samples total (all three segments). Collection of data as proposed at five locations in triplicate in each sub-segment (i.e., a total of 15 samples) at a frequency of seven times per year will result is 105 sample/section or 315 data points for analysis and ensure that dataset is large enough data to characterize the estuary and assess trends.

[11] This targeted sampling approach based on historical monitoring information was discussed and agreed upon during the July 8, 2019 Conference Call with Cynthia Gorman of the San Diego Water Board.

Table 10-3. Recommended Locations for Estuary Algal Biomass Monitoring

Estuary Segment	Station ID	Recommended Historical MA Site	BCA/ Sediment Site	Latitude (NAD83)	Longitude (NAD83)
Below the I-5 Bridge	W1 (MA1)	✓	✓	33.233980	-117.413111
	W8 (MA2)	✓	✓	33.235393	-117.408846
	W7 (MA3)	✓		33.234386	-117.408510
	W3	✓	✓	33.232895	-117.411361
	W4	*		33.233801	-117.409878
	W5	*		33.234402	-117.409978
Between the I-5 and Stuart Mesa Bridges	M6 (MA4)	✓	✓	33.236959	-117.399899
	M10 (MA5)	✓	*	33.237478	-117.395339
	M4	✓		33.236079	-117.402070
	M9	✓ (old MA site)		33.237657	-117.397121
	M1	*	✓	33.235302	-117.405803
	M8	*	✓	33.237211	-117.397786
Above the Stuart Mesa Bridge	E7 (MA5.5)	✓	✓	33.237630	-117.388060
	MA6	✓	*	33.238350	-117.384817
	E3	✓	✓	33.237580	-117.392260
	E5	✓		33.236980	-117.389900
	E8	✓	✓	33.238030	-117.387060
	E10	*(old ambient WQ site)		33.238600	-117.383770

10.4 ESTUARY SURFACE WATER QUALITY MONITORING

Monthly surface water sampling will be conducted in the Estuary from April through October and during three events from November through March. During each monitoring event, sampling will be conducted at one location in each of three Estuary regions: below the I-5 Bridge, above the Stuart Mesa Bridge to the head of the Estuary or the lower reach of the river,[12] and between the two bridges. Sampling locations are shown in **Table 10-4** and **Figure 10-2**, with station IDs consistent with historical monitoring. Ambient surface water grab samples will be collected at a depth of approximately 0.5 m, and will be analyzed for chlorophyll-a, total nitrogen, and total and dissolved inorganic nitrogen and phosphorus, as described in **Element 6.2**.

[12] The inner limit or upstream boundary of the Estuary should be defined by changes from estuarine to riparian vegetation, changes in salinity going from brackish to freshwater, and changes in river currents dominating over tidal action (San Diego Water Board, 2019).

Table 10-4. Station Identifications and Coordinates for Estuary Surface Water Monitoring

Estuary Segment	Station ID	Latitude (NAD83)	Longitude (NAD83)
Below I-5 Bridge	SMRE 1	33.2330	-117.4123
Between Bridges	SMRE 2	33.2369	-117.4001
Above Stuart Mesa Bridge*	SMRE 3	33.2373	-117.3878

*Alternative upstream location for sampling above Stuart Mesa Bridge is AX10.5 located at: 33.24116, -117.38232

10.5 ESTUARY SEDIMENT AND BENTHIC COMMUNITY CONDITION MONITORING

Sediment monitoring to assess benthic community condition will be conducted in the Estuary on an annual basis, in late summer. Monitoring in marine subtidal areas of the estuary (salinity ≥ 27 ppt) will be conducted in accordance with the Sediment Quality Assessment Technical Support Manual, SCCWRP Technical Report 777 (Bay et al., 2014).[13] Sampling locations and depths (where feasible) will align with macroalgal sampling so that relationships between the benthic community condition score and other parameters may be logically inferred. However, benthic samples must be collected in subtidal conditions for use of SQO benthic community scoring. In areas of the estuary where the criteria for assessing benthic infaunal condition using the SQO tool cannot be met (i.e., brackish areas with a salinity of < 27 ppt), an alternative sampling protocol is recommended based on protocols developed for Bight '18. The types of equipment used for sampling in either the marine or brackish subtidal areas of the Estuary are described in detail in **Element 11.5**. If salinity was determined to be < 27 ppt and SQO calculated, the results should be qualified.

Monitoring will be conducted at three locations within each of the three Estuary segments, for a total of nine samples. Based on historical sampling, NWIC Pacific has provided the recommended sampling locations shown in **Table 10-5** and **Figure 10-2**. Surficial benthic sediment samples will be collected and analyzed for TOC, grain size, total nitrogen ($NO_3 + NO_2$), TKN, total phosphorus, and benthic infaunal analysis.

[13]Available at: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/777_CASQO_TechnicalManual.pdf. Once accepted methods are available to estimate the effect of sediment organic matter (eutrophication) upon benthic macro invertebrate communities, they may be considered for use (San Diego Water Board, 2019).

Table 10-5. Station Identifications and Coordinates for Estuary Sediment Monitoring

Estuary Segment	Station ID	Latitude (NAD83)	Longitude (NAD83)
Below I-5 Bridge	W1 (MA1)	33.233980	-117.413111
	W3	33.232895	-117.411361
	W8 (MA2)	33.235393	-117.408846
Between Bridges	M1	33.235302	-117.405803
	M6 (MA4)	33.236959	-117.399899
	M8	33.237211	-117.397786
Above Stuart Mesa Bridge	E3	33.237580	-117.392260
	E7 (MA5.5)	33.237630	-117.388060
	E8	33.238030	-117.387060

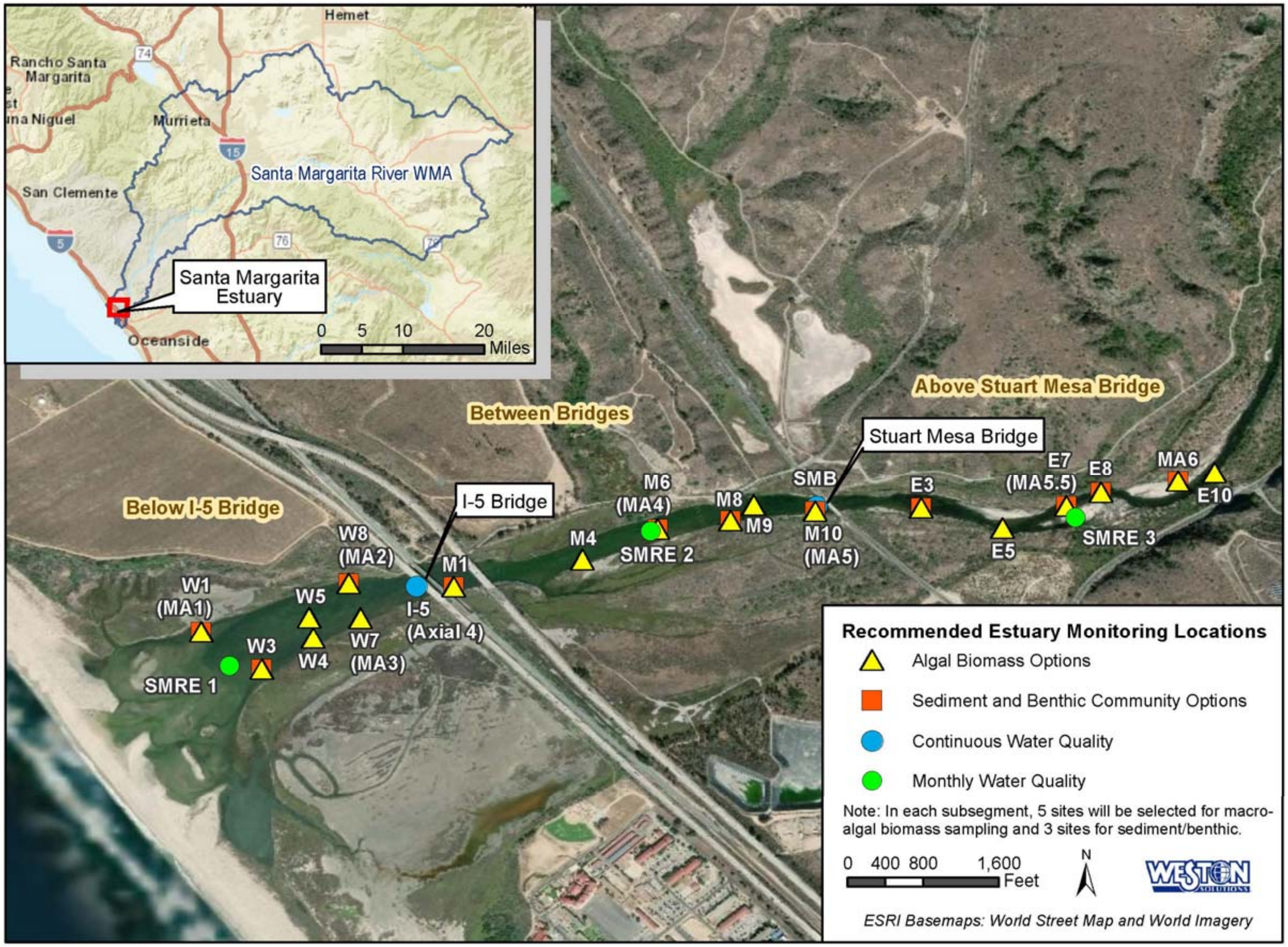

Figure 10-2. Proposed Santa Margarita Estuary Monitoring Locations

10.6 SANTA MARGARITA RIVER MONITORING

Monitoring will be conducted on the main stem of the Santa Margarita River to determine flow and ambient water quality conditions upstream of the Estuary. Methods will be consistent with relevant sections (i.e., Sections 1-3) of the *Standard Operating Procedures for the Collection of Field Data for Bioassessments of California Wadeable Streams: Benthic Macroinvertebrates, Algae, and Physical Habitat* (Bioassessment SOPs) (Ode et al., 2016).

A total of three sites will be monitored; one each within the jurisdictions of San Diego County, Riverside County, and MCB CamPen (**Table 10-6**, **Figure 10-3**). The monitoring stations should be located at the most downstream feasible location above the Estuary within each of the three jurisdictions. MCB CamPen will conduct monitoring at the USGS gage at Ysidora, which is the most reliable location for measuring streamflow along that reach of the river. The Riverside County monitoring will also incorporate an existing USGS gage (11044000) on the Santa Margarita River near Temecula. Monitoring events will be conducted monthly from May through October and bi-monthly from November through April, in November, January, and March. At each location, equipment will consist of an automated flow meter and sensor, solar panel, cellular line (where coverage is available), and rain gauge. Remote Automatic Weather Station (RAWS) or ALERT system rainfall gauges will be used where available. The Lake O'Neill rain gage will be used to monitor rainfall at the sampling location at Ysidora.

Flowmeters will be installed and maintained at the County of San Diego monitoring location. MCB CamPen's surface monitoring site will use the Ysidora USGS gage (11046000) and Riverside County river monitoring will use USGS gage 11044000 near Temecula. During each monthly monitoring event, water quality parameters (temperature and conductivity) will be measured using a multi-parameter water quality meter or sonde, and a grab sample will be collected and analyzed for total nitrogen, total and dissolved inorganic nitrogen and total and dissolved phosphorus, as described in **Element 6.2** .

Table 10-6. Station Identifications and Coordinates for Santa Margarita River Monitoring

Jurisdiction	Station ID	Latitude (NAD83)	Longitude (NAD83)
San Diego County	SMR-MLS-2	33.398142	-117.26273
Riverside County	Upper Santa Margarita River 902USM828	33.47335	-117.14344
MCB CamPen	Ysidora (SMR 3)	33.31165	-117.34570

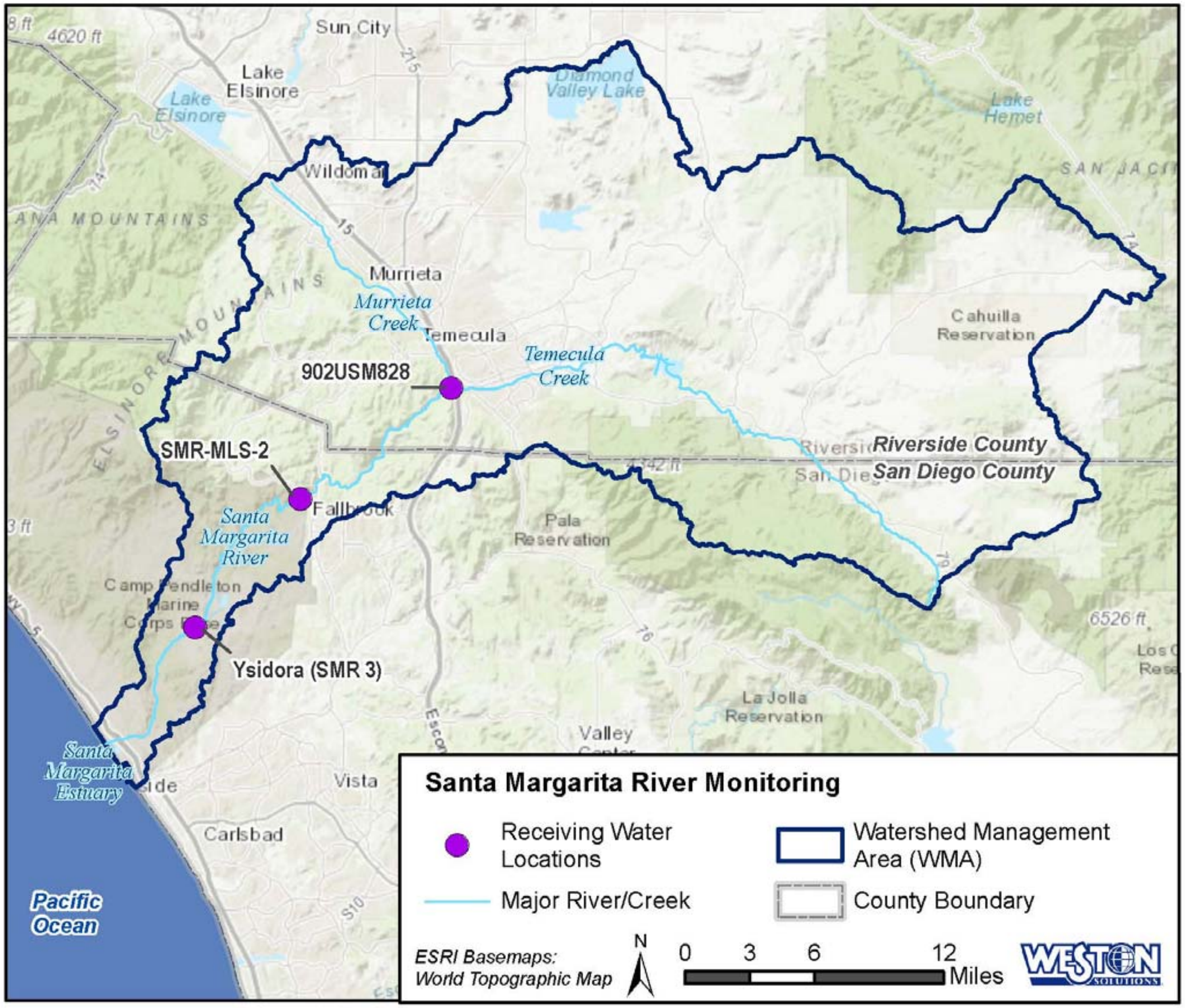

Figure 10-3. Proposed Santa Margarita River Monitoring Locations

11. SAMPLING METHODS

All equipment (waders, boots, sampling equipment, and other aquatic gear) used for monitoring described in the following sections that intentionally comes into contact with surface waters on MCB CamPen must be disinfected either through chemical treatment (generally with a dilute solution of formula 409, or equivalent) or freezing. Boat hulls and trailers should be power-washed and inspected for signs of quagga mussel, zebra mussel, and New Zealand mud snail, especially if coming from surface waters associated with the lower Colorado River. No foreign ballast or other waters shall be introduced into any surface water on MCB CamPen.

11.1 ESTUARY RESURFACING GROUNDWATER DISCHARGE RATES AND NUTRIENT LOADING

Bi-annual groundwater sampling will be conducted once during the dry season (April through October) and once during the wet season (November through March). During each monitoring event, sampling will be conducted at ten locations: three piezometers near the Stuart Mesa Agricultural Fields and seven wells in the Lower Ysidora sub-basin, as listed in **Element 10.1**. All groundwater sampling will be overseen by a State Certified Geologist.

Groundwater discharge to the estuary will be estimated based on hydraulic gradients, measured at the piezometers, and the Darcy equation. In the vicinity of the Stuart Mesa Agricultural fields, previously developed relationship between hydraulic head and groundwater seepage may be relied upon (Leather, 2016). All historic data and relationships previously developed by others will be checked and verified by a State-certified professional geologist. Nutrient grab samples will be taken at the piezometers using a peristaltic pump and sampling depth will be noted on the field sheets.

At the seven groundwater wells, nutrient samples will be taken using a peristaltic pump. The groundwater level in the well and the sampling depth will be noted on field sheets.

For nutrient grab samples at all ten sites; analytical methods, sample container requirements, and analytical holding times will be in accordance with the SCCWRP QAPP for Monitoring in Support of Nutrient Management in the Lower Santa Margarita River (SCCWRP, 2014).

Samples will be placed into appropriate bottles and preserved and transported as described in **Element 12**. Two field duplicates and one field blank will be collected for nutrient analysis per monitoring year in order to achieve the SWAMP QA sample requirements (i.e., field duplicates at a frequency of 5% of the sample count and a field blank per method).

11.2 ESTUARY CONTINUOUS MONITORING

Each year, continuous water quality monitoring will be conducted for seven months from April through October and for up to one month during each of three winter periods (November, January, and March). A multi-parameter data sonde with an optical sensor will be deployed on a stationary structure at a depth of approximately 0.5 m at two locations in the Estuary, I-5 Bridge and Stuart Mesa Bridge. Deployment will account for tidal range and depth such that the sonde probes remain submerged and do not contact the sediment surface. Methodology will be consistent with applicable SCCWRP Southern California Bight Regional Monitoring Program protocols (e.g., SCCWRP Technical Report 711 [McLaughlin et al., 2012]).[14] DO (mg/L and % saturation), water temperature (°C), salinity/conductivity (ppt; µS/cm), turbidity (NTU), and water depth (m) will be continuously monitored *in situ* at 15-minute intervals. In addition, the degree of tidal muting or influence will be documented based on the current status of connectivity between the Estuary and the Pacific Ocean.

11.3 ESTUARY ALGAL BIOMASS MONITORING

Monthly algal biomass monitoring will be conducted in the Estuary from April through October. During each monitoring event, sampling will be conducted in each of three Estuary regions: below the I-5 Bridge, above the Stuart Mesa Bridge to the head of the Estuary or the lower reach of the river,[15] and between the two bridges (**Figure 10-2**).

During each monthly monitoring event, site conditions and sample information will be recorded on field data sheets. Additionally, during each monitoring event, the status of connectivity between the Estuary and the Pacific Ocean will be documented. Effort should be made to align collection location with Estuary sediment sampling described in **Element 11.5**; and, where feasible, at similar sampling depths for subtidal sampling**,** so that relationships between the benthic community condition score and other parameters may be logically inferred.[16]

Algal biomass monitoring will be conducted in accordance with the SOP for Macroalgal Collection in Estuarine Environments (SCCWRP Technical Report 872; McLaughlin et al., 2019) (**Appendix B** of the Workplan). The SOP includes protocols to sample two habitat types, intertidal (mud or sand) flats and shallow subtidal (<10 m). Based on knowledge gained during previous monitoring in the Estuary, data generated by the subtidal protocol is more representative of conditions in the Estuary and is recommended. The subtidal protocol is discussed herein and detailed in Section 4 of SCCWRP Technical Report 872. The intertidal protocol can be found in Section 3 of SCCWRP Technical Report 872.

SCCWRP Technical Report 872 provides procedures for subtidal sampling using either a multi-SUBstrate Subtidal sampler (SUBS sampler) or a combination of a bottomless mesh basket/collapsible hamper or a similar device to collect algae in the water column and a box core to collect benthic macroalgae. The SUBS sampler, which has the capacity to collect water column and benthic sediment in one sample, is advantageous due to time and cost savings associated with more efficient sampling, minimal site disturbance compared to the use of a box core, and comparability with recent data collected using this method. For these reasons, the SUBS sampler will be used for collection of macroalgal biomass samples. The SUBS Sampler may also be used to collect benthic sediment (**Element 11.5**). Local temperature and salinity will be measured with a hand-held meter and recorded on field data sheets. A kayak should be used to access water covered areas in the Estuary, in order to limit disturbance to sampling areas and avoid walking on the shoreline and impacting birds. If water depth is too shallow to allow for deployment of the SUBS sampler (i.e., < 1 ft), the SUBS core tube

[14] Available at: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/711_B08EE_AppendixC.pdf
[15] The inner limit or upstream boundary of the Estuary should be defined by changes from estuarine to riparian vegetation, changes in salinity going from brackish to freshwater, and changes in river currents dominating over tidal action (San Diego Water Board, 2019).
[16] Benthic samples must be collected in subtidal conditions in order to determine SQO benthic community scores.

will be used to collect the sample. If floating algae is present, the basket/hamper should be used to augment the SUBS sampling procedure and collect the floating algae. At each sampling point, macroalgal biomass will be collected from the surface to bottom within a defined surface area. Specific sample collection procedures for both methods are provided in Section 4.6 of SCCWRP Technical Report 872 (**Appendix B** of the Workplan). Examples of a mesh basket/hamper and a SUBS sampler are shown in **Figure 11-1.** Samples should be kept refrigerated at 4°C in the dark until they are processed. Laboratory processing will be completed within 48 hours.

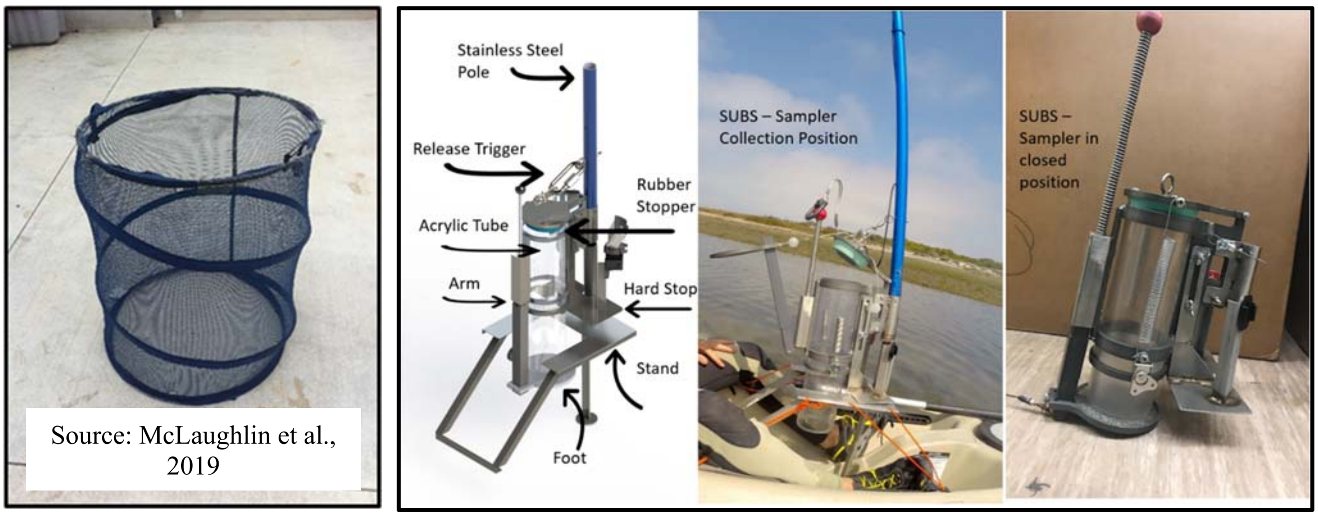

Figure 11-1. Collapsible Hamper (Left) and SUBS Sampler (Right) for Macroalgae Collection

11.4 ESTUARY SURFACE WATER QUALITY MONITORING

Monthly surface water sampling will be conducted in the Estuary from April through October and during three events from November through March. During each monitoring event, sampling will be conducted at one location in each of three Estuary regions: below the I-5 Bridge, above the Stuart Mesa Bridge to the head of the Estuary or the lower reach of the river,[17] and between the two bridges (**Figure 10-2**).

During each monthly monitoring event, site conditions and sample information will be recorded on field data sheets. Additionally, during each monitoring event, the status of connectivity between the Estuary and the Pacific Ocean will be documented.

Estuary surface water quality monitoring will be conducted in accordance with SWAMP and Standard Methods (SM) for the Examination of Water and Wastewater (American Public Health Association [APHA], 2012). Ambient surface water grab samples will be collected at a depth of approximately 0.5 m, and will be analyzed for chlorophyll-a, total nitrogen, total and dissolved inorganic nitrogen and phosphorus. Water samples will be collected using a sampling pole or peristaltic pump, and samples will be placed into appropriate bottles and preserved and transported as described in **Element 12**. Two

[17] The inner limit or upstream boundary of the Estuary should be defined by changes from estuarine to riparian vegetation, changes in salinity going from brackish to freshwater, and changes in river currents dominating over tidal action (San Diego Water Board, 2019).

field duplicates and one field blank will be collected for nutrient analysis per monitoring year in order to achieve the SWAMP QA sample requirements (i.e., field duplicates at a frequency of 5% of the sample count and a field blank per method).

11.5 ESTUARY SEDIMENT AND BENTHIC COMMUNITY CONDITION MONITORING

Sediment monitoring to assess benthic community condition will be conducted in the Estuary on an annual basis, in late summer. Monitoring marine subtidal areas of the estuary (salinity ≥ 27 ppt) will be conducted in accordance with the Sediment Quality Assessment Technical Support Manual, SCCWRP Technical Report 777 (Bay et al., 2014).[18] Sampling locations and depths (where feasible) will align with macroalgal sampling so that relationships between the benthic community condition score and other parameters may be logically inferred. However, samples must be collected in subtidal conditions for use of SQO benthic community scoring. In areas of the estuary where the criteria for assessing benthic infaunal condition using the SQO tool cannot be met (i.e., brackish areas with a salinity of < 27 ppt), an alternative sampling protocol is recommended based on protocols developed for Bight '18. If salinity was determined to be < 27 ppt and SQO calculated, the results should be qualified. Monitoring will be conducted at three locations within each of the three Estuary segments, for a total of nine samples (**Figure 10-2**).

Benthic sediments will be collected as surface grabs for the analysis of TOC, grain size, total nitrogen, total phosphorus, and benthic infaunal analysis (i.e., sorting and taxonomic evaluation of benthic macroinvertebrates). Prior to sampling, it is recommended that a salinity measurement be taken above the sediment-water interface to determine if the sampling site is located in marine (≥ 27 ppt) or brackish (< 27 ppt) waters. It is recommended that salinity measurements be taken as close to Mean Lower Low tide (MLLW), less than or equal to 0.5 feet on a tide chart, in order to get the most accurate measurement (SCCWRP, 2018).

A Van Veen or equivalent grab sampler with a 0.1 square meter (m^2) surface area is recommended for the collection of biology and chemistry samples in marine areas of the estuary in order to calculate the SQO benthic condition line of evidence (LOE). Equivalent grab samplers can be used with a smaller surface area as long as the sediment samples are equivalent in quality to the Van Veen grab (Bay et al., 2014). An appropriate sampler for the collection of benthic sediments will have the following characteristics:

- Constructed of a material that does not introduce contaminants.
- Causes minimal surface sediment disturbance.
- Does not leak or mix during sample retrieval.

[18] Available at: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/777_CASQO_TechnicalManual.pdf. Once accepted methods are available to estimate the effect of sediment organic matter (eutrophication) upon benthic macro invertebrate communities, they may be considered for use (San Diego Water Board, 2019).

- Has a design that enables safe/easy sample verification that samples meet all applicable sampling criteria (e.g., collects sediments to at least five cm below the sediment surface, has access doors allowing visual inspection and removal of undisturbed surface sediment).

In brackish areas of the estuary, a 4-inch diameter plastic core tube (diameter refers to inner diameter) that is a minimum of 10 cm in length is recommended for the collection of chemistry and benthic infaunal samples (e.g., the SUBS Sampler developed by NIWC Pacific can be utilized as an alternative to constructing a core tube since the SUBS Sampler is 4-inches in diameter and 16-inches in length). At each site, two 4-inch diameter core samples will be collected for benthic infauna. These two core samples will then be composited into a single sample. Options for sample collection at intermediate depths include the following: 1) using a SUB Sampler, 2) using core tubes attached to an extension pole, 3) inserting core tubes into the sediment grab collected with a Van Veen, or 4) inserting the core tubes by hand if collection sites are in wadeable areas. The top of each core will be sealed with a rubber cap. A vacuum will be created when the core is removed from the sediment holding the contents in place; however, the bottom should be covered if the contents are not held in place (i.e., sediment is loose). For more detailed information regarding determination of salinity at a site, sample collection protocols using the cores, or construction of the cores refer to the Bight '18 Sediment Quality Assessment Field Operations Manual (SCCWRP, 2018). For more information on using the SUB Sampler as the coring device refer to the Standard Operating Procedure for Macroalgal Collection in Estuarine Environments (McLaughlin et al., 2019).

A sample will be considered acceptable if the surface of the grab is even and there is minimal surface disturbance. For marine samples, the penetration depth of the grab sampler should be a minimum of 5 cm in compact sediments (i.e. hard packed sand). Penetration depths of 7-10+ cm should be obtained in silty sediments (fine sand to clay) and whenever possible, infaunal samples should be a minimum of 7 cm, but target 10+ cm. Benthic infaunal samples collected at brackish sites must have a minimum penetration depth of 10 cm. Rejected grabs will be discarded, and the station will be re-sampled. Acceptable sediment grabs to be utilized for chemistry and grain size will have the overlying water carefully drained from the sediment surface prior to removing the sediment to be placed in the appropriate sample containers. Overlying water will not be drained from sediment samples collected for benthic infaunal analysis.

Between sampling stations, the grab sampler will be rinsed with station water. Stainless steel scoops will be rinsed with seawater and rinsed with de-ionized water between stations. During each annual monitoring event, information to be recorded on field data sheets includes station identification, date, time of arrival, coordinates and navigation system used, water depth, weather conditions, and other pertinent observations. Information about the sediment sample will also be recorded, including the sample time, depth of penetration of sediment grab, sediment composition, sediment color, sediment odor, and presence of shell hash.

11.5.1 Benthic Community Condition Sampling

The entire contents of one grab sample (equal to 0.1 m^2 surface area) will be utilized for benthic infaunal analysis in marine areas of the Estuary (salinity $\geq$ 27 ppt) (e.g., using a Van Veen grab sampler). If using a grab sampler with a smaller surface area (e.g., SUB Sampler), then multiple benthic infaunal samples will need to be collected to be equivalent to a surface area of 0.1 m^2. Samples collected for benthic infaunal analysis from marine areas will be rinsed through a 1.0-millimeter (mm) mesh screen.

In brackish areas of the Estuary (salinity <27 ppt), two 4-inch diameter cores with a minimum penetration depth of 10 cm will be utilized for benthic infaunal analysis (e.g., two cores collected using a SUB Sampler). Samples collected for benthic infaunal analysis from brackish areas will be rinsed through a 0.5-mm screen.

The material retained on the screen will be transferred to a labeled glass or plastic sample container. A 7% Epsom salt ($MgSO_4$) solution will be added to the sample container to 85-90% of its volume to relax the collected specimens. The sample container will be inverted several times to distribute the relaxant solution. After 30 minutes, add enough sodium borate buffered formaldehyde to top off the sample container and gently invert the container several times to ensure the sample is mixed. This will make a 10% formalin solution. Laboratory processing procedures are described in **Element 13.3**.

11.5.2 Sediment Chemistry Sampling

Sediment samples for chemistry and grain size analysis from marine areas of the Estuary will be collected from the top 5 cm of the grab sample using a pre-cleaned stainless-steel scoop. Sediment within 1 cm of the sides of the grab will be avoided to prevent interaction of any contaminants and the sampling device. For chemistry and grain size analysis, equal portions of sediment will be aliquoted from a single grab.

In brackish areas of the Estuary, the 4-inch diameter core tubes utilized for benthic infaunal sampling can be used to collect sediment for chemistry analysis. Insert the core 5 cm into the sediment, then dump the sediment into a clean pan to remove overlying water. Scoop the sediment into the appropriate sampling container using a pre-cleaned stainless-steel scoop or spoon.

Sediment will be placed into the appropriate samples' containers, preserved, and transported as described in **Element 12**. Physical and chemical laboratory analysis procedures are described in **Element 13.2**. One field duplicate and one equipment rinse blank will be collected for chemical analysis per monitoring year in order to achieve the SWAMP QA sample requirements (i.e., field duplicates at a frequency of 5% of the sample count and an equipment rinse blank per method).

11.6 SANTA MARGARITA RIVER MONITORING

Monitoring will be conducted on the main stem of the Santa Margarita River to determine flow and ambient water quality conditions upstream of the Estuary. A total of three sites will be monitored; one each within the jurisdictions of San Diego County, Riverside County, and MCB CamPen (**Figure 10-3**). Monitoring events will be conducted monthly from May through October and bi-monthly from November through April, in November, January, and March. At each location, equipment will consist of an automated flow meter and sensor, solar panel, cellular line (where coverage is available), and rain gauge. Remote Automatic Weather Station (RAWS) or ALERT system rainfall gauges will be used where available. The Lake O'Neill rain gage will be used to monitor rainfall at the sampling location at Ysidora.

11.6.1 Flow Monitoring

Flowmeters for continuous flow monitoring will be installed and maintained at each location. Flowmeters will be installed and maintained at the County of San Diego and Riverside County monitoring locations. MCB CamPen's surface monitoring site will use the Ysidora USGS gage (11046000). Although monitoring events occur during nine months of the year, it is recommended that flow monitoring occur throughout the year, where equipment can remain in place, for flow volume calculations used in loading estimations. At a minimum, the equipment will be comprised of Hach (or comparable) flowmeters with a bubbler or submerged pressure transducer as the primary measuring device (level sensor). The primary sensor will continuously measure stage (i.e., stream height) and relay that information to the flowmeter, which will continually calculate flow rates by inserting the stage information into the preprogrammed discharge equation. Continual flow data will be downloaded from each location periodically to verify equipment functionality and thus reduce data gaps, ensure accuracy, and identify maintenance and calibration needs. Flow data will be entered into the data management system.

Daily and monthly flow rates will be measured or estimated in accordance with the National Pollutant Discharge Elimination System (NPDES) Storm Water Sampling Guidance Document (EPA-833-B-92-001) (United States Environmental Protection Agency [USEPA], 1992). Flow rating curves will be developed that correlate water surface levels (or stream heights) to flow rates.[19] To quantify flow rates based on stream stage, a relationship between flow and stage will be derived using standardized stream rating protocols developed by the USGS (Rantz, 1982; Oberg et al., 2005) and using an applicable hydraulic calculation formula(s), such as Manning's equation. If the monitoring station is found to have a steady dry weather base flow, it may be appropriate to install a flow sensor with the ability to measure instantaneous stream velocity. However, in an ephemeral stream that tends to be wet and dry out periodically, this type of sensor may not collect high quality data. A decision to use an area-velocity flow meter and/or a weir structure will be determined based on site hydraulic and flow conditions.

Instantaneous field level and flow measurements will be periodically taken to validate the rating curves. To measure instantaneous flows during low flow and base flow conditions, two types of field flow monitoring equipment may be used. To measure small flows, a handheld velocity measurement instrument, such as a Marsh-McBirney Model 2000 Portable Flowmeter connected by a cable to an electromagnetic open channel velocity sensor, or equivalent may be used. To measure higher flows, the SonTek (YSI) FlowTracker Acoustic Doppler Velocimeter, or equivalent may be used.

11.6.2 Water Quality Monitoring

During each monthly monitoring event, water quality parameters (temperature and conductivity) will be measured using a multi-parameter water quality meter or sonde. Water quality measurements and site conditions will be recorded on field data sheets. A grab sample will be collected in an appropriate container using a sampling pole or similar method. The sample will be analyzed for total nitrogen, total and dissolved inorganic nitrogen, and total and dissolved phosphorus, as described in **Element 13.2**.

[19] At the MCB CamPen surface monitoring site at Ysidora, discharge, rating curves, and field flow measurements from the USGS will be used in lieu of a new flow measurement site. The USGS station at Ysidora has real-time telemetry and reports data at 15-minute intervals.

12. SAMPLE HANDLING CUSTODY

12.1 SAMPLE COLLECTION

Samples for water, sediment, and macroalgal analysis will be uniquely identified with sample labels in indelible ink. All sample containers will be identified with the project title, appropriate ID number, date and time of sample collection, and preservation method. All samples collected in glass or high-density polyethylene (HDPE) bottles will be kept on ice from the time of sample collection until delivery or transport to the analytical laboratory. All samples will be transferred to the designated analytical laboratories and analyses initiated within the method specified holding time (**Table 12-1**).

Table 12-1. List of Analytes with Sample Volume, Container Type, Holding Time, and Preservation Method

Analyte	Recommended Container	Holding Time	Recommended Preservation
Estuary Field Measurements			
Dissolved Oxygen	*In situ*		
pH			
Salinity/Conductivity			
Temperature			
Turbidity			
River Field Measurements			
Conductivity	*In situ*		
Temperature			
Estuary Macroalgal Measurements			
Macroalgal Biomass	Plastic Bag	NA	Refrigerate at 4°C in dark; do not freeze
Groundwater, Estuary, and River Water Measurements[1]			
Ammonia	Plastic	48 hours; 28 days if acidified[4]	H_2SO_4, cool to ≤6°C
Ammonia, Dissolved	Plastic	48 hours; 28 days if acidified[4]	Filter before adding H_2SO_4, cool to ≤6°C
Chlorophyll-a, Suspended	per method	Samples must be frozen or analyzed within 4 hours of collection; filters can be stored frozen for 28 days	Filter as soon as possible after collection; if sample processing must be delayed, keep samples on ice or at ≤6°C; store in the dark
Inorganic Nitrogen, Dissolved[2] (calculation)	N/A	N/A	N/A
Inorganic Nitrogen, Total[2] (calculation)	N/A	N/A	N/A
Nitrate (NO3) + Nitrite (NO2), Dissolved	Plastic	48 hours; 28 days if acidified[4]	Filter before adding H_2SO_4, cool to ≤6°C

Table 12-1. List of Analytes with Sample Volume, Container Type, Holding Time, and Preservation Method

Analyte	Recommended Container	Holding Time	Recommended Preservation
Nitrate (NO3) + Nitrite (NO2), Total	Plastic	48 hours; 28 days if acidified[4]	H_2SO_4, cool to ≤6°C
Nitrogen, Total[3] (Calculation)	NA	NA	NA
Phosphorus, Dissolved	Plastic	28 Days	Filter before adding H_2SO_4, cool to ≤6°C
Phosphorus, Total	Plastic	28 Days	H_2SO_4, cool to ≤6°C
Estuary Sediment Measurements			
Grain Size	Glass or Plastic	1 year	Wet ice to ≤6°C in the field, then refrigerate at ≤6°C
Nitrate (NO3) + Nitrite (NO2)	Glass	14 days[4]	Cool to ≤6°C
Nitrogen, Total[4] (Calculation)	NA	NA	NA
Nitrogen, Total Kjeldahl	Glass	14 days[4]	Cool to ≤6°C
Phosphorus, Total	Glass	14 days[4]	Cool to ≤6°C
Total Organic Carbon	Glass	28 Days at ≤6°C; 1 year at ≤-20°C	Cool to ≤6°C or freeze to ≤-20°C
Estuary Benthic Community Condition Measurements			
Benthic Macroinfaunal Community	Glass or Plastic	NA	Minimum of 72 hours to maximum of 2 weeks in formalin fixative, then transfer to 70% ethanol[5]

[1]Groundwater samples will include each of the analytes shown in this section except chlorophyll-a.

[2]Total and dissolved inorganic nitrogen is a calculated value comprised of NH3 and NO3 + NO2

[3]Total nitrogen in sediment is a calculated value comprised of total Kjeldahl nitrogen (TKN), NO3, and NO2

[4]Holding time may vary depending on the analytical method

[5]Start with 95% ethanol solution, not denatured ethanol. If ethanol is produced by industrial distillation rather than fermentation, buffer with marble chips (Bay et al., 2014); for preparation of 70% ethanol solution refer to Bay et al., 2014.

12.2 CHAIN-OF-CUSTODY PROCEDURES

Samples will be considered to be in custody if they are retained as follows (1) in the custodian's possession or view, (2) retained in a secured place (under lock) with restricted access, or (3) placed in a container and secured with an official seal such that the sample could not be reached without breaking the seal. The principal documents used to identify samples and to document possession will be COC records, field logbooks, and field tracking forms. COC procedures will be used for samples throughout the collection, transport, and analytical process.

COC procedures will be initiated during sample collection. A COC record will be provided with each sample or group of samples. Each person who will have custody of the samples will sign the form and ensure the samples will not be left unattended unless properly secured. Documentation of sample handling and custody on the COC includes the following:

- Sample identifier.
- Sample collection date and time.
- Any special notations on sample characteristics or analysis.
- Initials of the person collecting the sample.
- Date the sample was sent to the analytical laboratory.
- Shipping company and waybill information.

Field staff will verify sample container labels include the sample ID, date and time of collection, sampler's initials, and type of analysis during the completion of the COC. Completed COC forms will be placed in a plastic envelope and kept inside the cooler containing the samples. Once delivered to the analytical laboratory, the COC form will be signed by the person receiving the samples. The condition of the samples will be noted and recorded by the receiver. COC records will be included in the final reports prepared by the analytical laboratories and are considered an integral part of the report.

12.3 SAMPLING TRANSPORT, SHIPPING, AND STORAGE PROCEDURES

Prior to shipping or transport, field staff will verify samples were preserved properly and stored at the required temperature and light conditions. COC forms will be filled out and the original signed COC forms will be inserted in a sealable plastic bag and placed inside the coolers. The cooler lids will be securely taped shut before shipment. All samples collected in the field will be delivered or shipped overnight via coolers to the analytical laboratory for analysis. Transport of the samples will be coordinated by the appropriate Field Task Lead to ensure that all samples are sent at the appropriate temperature and light conditions, and within designated holding times. The analytical laboratory will properly and safely dispose of the samples after the analyses are complete and analytical QA/QC procedures have been reviewed and accepted.

13. ANALYTICAL METHODS

13.1 FIELD ANALYTICAL METHODS

In situ water quality measurements of DO (mg/L and % saturation), pH (pH), temperature (°C), conductivity/ salinity (µS/cm; ppt), and turbidity (NTU) will be determined using multi-parameter data sondes at two sites within the Estuary (I-5 Bridge and Stuart Mesa Bridge). Sondes will be set up to continuously collect data at 15-minute intervals for the duration of the monitoring period (April – October) and up to one month during each of three winter periods (November, January, March). Data sondes will need to be removed from the water to download the data and for maintenance (e.g., removal of biofouling, verification of precision, re-calibration, replacement of batteries) at least once a month. Summer months may require weekly maintenance. A telemetry system may be used to check data in real-time.

Continual flow data will be downloaded from the three sites located on the main stem of SMR periodically to verify equipment functionality and thus reduce data gaps, ensure accuracy, and identify maintenance and calibration needs. The MCB CamPen surface monitoring site at Ysidora will use the USGS station at Ysidora for flow data, which has real-time telemetry and reports data at 15-minute intervals. In situ water quality measurements of temperature and specific conductivity will be determined at these three sites using a multi-parameter water quality meter (or sonde).

Analytical methods for water quality parameters are provided in **Table 13-1**. Operation of all field equipment will be conducted as per manufacturer instructions. Calibrations will be performed and recorded to ensure accurate functionality. Maintenance will include removing biofouling to ensure the sondes are operating correctly.

Table 13-1. Analytical Methods for Water Quality Parameters

Parameter	Method	Units	Accuracy	Resolution
Dissolved oxygen	Polargraphic or luminescence quenching probe	mg/L	±0.2*	0.01
pH	Electrode	pH units	±0.2	0.01
Salinity	Refractometer of conductivity cell	ppt	±2	0.01
Specific Conductance	Conductivity cell	µS/cm	±0.5%	1
Temperature	Thermistor or bulb	°C	±0.15%	0.1
Turbidity	Portable turbidimeter or optical probe	NTU	±1% up to 100 NTU; ±3% from 100-400; and ±5% from 400-3000 NTU	0.1

Reference: State Water Board, 2017

*Calibration checks on DO sensors have indicated that variations in DO values may be greater than this instrument accuracy specification (Kara Sorenson, personal communication).

13.2 LABORATORY ANALYTICAL METHODS

The specific analyses and target reporting limits are outlined in **Table 13-2** for water, sediment, and macroalgal samples. All analytical methods utilized should follow the USEPA, American Society for Testing and Materials (ASTM), or Standard Methods (SM) for the Examination of Water and Wastewater. Analytical laboratories should provide results within standard turn-around time. Before the analytical laboratory disposes of any samples, authorization is required from the Consultant PM.

In addition to the chemical analyses listed in **Table 13-2**, physical measurements of macroalgal biomass will be determined following Section 6.3 of the SOP for Macroalgal Collection in Estuarine Environments (SCCWRP Technical Report #872) (McLaughlin et al., 2019). Macroalgal biomass samples must be processed within 48 hours of collection. Biomass samples will be cleaned of all mud, bugs, and debris; weighed wet; dried in an oven at 60°C for two to three days; and weighed dry. Samples should be kept refrigerated at 4°C in the dark until they are processed. If the amount of biomass in each sub-sample (from the five sites along each transect or within each sub-segment) is small, the SOP states that they may be composited into a single sample representative of that transect/sub-segment, resulting in three biomass composites per Estuary segment. If the biomass from each sub-sample is large (i.e., enough to fill the Ziploc bag), each sub-sample will be weighed individually and added.

Table 13-2. Analytes, Analytical Methods, and Target Reporting Limits

Analyte	Method	Units	Target Reporting Limit[3]
Estuary Macroalgal Samples			
Macroalgal Biomass	McLaughlin et al., 2019 SOP	g dry weight/m^2	0.001
Ground Water, Estuary, and River Water Samples[1,2]			
Ammonia (as N)[4]	EPA 350.1	mg/L	0.02
Ammonia (as N)[4], Dissolved	EPA 350.1	mg/L	0.02
Chlorophyll-a, Suspended	SM 10200	mg/L	0.002
Inorganic Nitrogen, Dissolved[4]	By Calculation	mg/L	NA
Inorganic Nitrogen, Total[1,4]	By Calculation	mg/L	NA
Nitrate (NO_3) + Nitrite (NO_2)[4]	SM 4500-NO3 E/SM 4500-NO2 B	mg/L	0.01
Nitrate (NO_3) + Nitrite (NO_2), Dissolved[4]	SM 4500-NO3 E/SM 4500-NO2 B	mg/L	0.01
Nitrogen, Total[5]	By Calculation	mg/L	NA
Phosphorus, Dissolved	SM 4500 or EPA 365.1	mg/L	0.05
Phosphorus, Total	SM 4500 or EPA 365.1	mg/L	0.05
Estuary Sediment Samples[1]			
Grain Size	ASTM D4464 (M) or SM 2560 D or ASTM D422	%	NA
Nitrate (NO_3) + Nitrite (NO_2)	SM 4500 or EPA 300.0	mg/kg	0.5/1.0
Nitrogen, Total[5]	By Calculation	mg/kg	NA
Nitrogen, Total Kjeldahl	SM 4500	mg/kg	10
Phosphorus, Total	SM 4500	mg/kg	0.12
Total Organic Carbon	EPA 9060A	%	0.05

[1] Recommended analytical methods; alternative methods may be used; however, methods should follow USEPA, ASTM, or Standard Methods

[2] Groundwater Samples will include each of the analytes shown in this section except chlorophyll-a.

[3] Target reporting limits; reporting limits may vary based on the actual analytical method and method detection limits utilized by the laboratory selected to perform the analysis. Lower reporting limits may be available.

[4]Total and dissolved inorganic nitrogen in water is a calculated value comprised of NH_3 + NO_3 + NO_2. Additional water samples are identified to be collected and filtered to analyze for dissolved NH_3 + NO_3 + NO_2.

[5]Total nitrogen is a calculated value comprised of total Kjeldahl nitrogen (TKN), NO_3, and NO_2

NA = Not applicable

13.3 BENTHIC INFAUNAL ANALYSIS

The benthic infaunal samples will be transported from the field to the laboratory and stored in a formalin solution for a minimum of 72 hours and no longer than 14 days. The samples will then be transferred from formalin to 70% ethanol for laboratory processing. The organisms will initially be sorted using a dissecting microscope into five major phyletic groups: polychaetes, crustaceans, molluscs, echinoderms, and miscellaneous minor phyla. While sorting, technicians will keep a count of organisms for quality control purposes, as described in **Element 14.4**. After initial sorting, samples will be distributed to qualified taxonomists who will identify each organism to species level or to the lowest possible taxonomic level. Data for organisms that are incidental contaminants should not be included in the data analysis and should not be counted or included in the project data. Attached parasites and other epibionts should not be recorded or submitted in annual reports but may be noted as present on bench data sheets. Nomenclature and orthography should follow the usage in the SQO species list on the *Sediment Quality Assessment Tools* page of the SCCWRP website (www.sccwrp.org) as well as Edition 5 of the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) taxonomic listing (available at www.scamit.org).

13.4 SAMPLE DISPOSAL

After completion of analysis and QA/QC protocols, samples will be disposed according to procedures outlined in each laboratory's SOPs. The minimum required storage time for sample components of benthic infaunal samples before disposing are as follows:

- Vials of taxonomically identified organisms: 5 years
- Unsorted remainder of sample: 2 years
- Residue from sorted sample: 1 year

14. QUALITY CONTROL

14.1 FIELD MEASUREMENTS

QA/QC for sampling processes begins with proper collection of the samples to minimize the possibility of contamination. Water samples will be collected in laboratory-certified, contaminant-free bottles. Calibration of the flow monitoring and sampling equipment will be conducted immediately prior to deployment or use and will be field verified during each data download or sample event. Field instruments will be recalibrated if data quality is suspect or instruments are compromised in between downloads or sampling events, after cleaning the sensor surfaces from biofouling. All field instruments will be calibrated and deployed in accordance with manufacturer specifications.

Field measurements for DO, pH, conductivity/salinity, turbidity, and temperature will be made using a multi-parameter water quality meter or sonde according to the manufacturer's specifications. The meter or sonde will be calibrated with calibration solutions, and it will be verified that the expiration date has not been exceeded. Proper storage and maintenance procedures of field equipment will be followed.

14.2 WATER, SEDIMENT, AND MACROALGAE SAMPLING

Water, sediment, and macroalgae samples will be collected in appropriate containers, kept on wet ice at 4°C during the sampling event, and placed into coolers along with completed COC for transfer to the analytical laboratory. Sample containers for applicable constituents will be laboratory-certified. Samples requiring preservation will either be collected in pre-preserved laboratory containers or preservative will be added as soon as possible after collection. Field crews will ensure that sampling containers are being filled properly and the requirement to avoid contamination of samples at all times is met. A field log will be completed at each site for each event. The field data log sheets will include empirical observations of the site and water quality characteristics.

Field duplicates and equipment rinse blanks will be collected and analyzed at the frequency described for each monitoring program component in accordance with SWAMP QA sample requirements. Two field duplicates and one field blank will be collected for Estuary surface water nutrient analysis and for SMR Watershed nutrient analysis during each monitoring year, and one field duplicate and one equipment rinse blank will be collected for Estuary sediment chemistry analysis during each monitoring year.

14.3 LABORATORY ANALYSES

All samples must be analyzed by laboratories accredited by ELAP using methods approved by the USEPA for the type of analysis to be performed. Efforts will be made to ensure analytical techniques are consistent with those utilized in historic monitoring efforts. The laboratory quality control of all samples will be performed under the guidelines of this QAPP and the designated analytical laboratory SOPs. Quality control samples, frequency, and control limits specific to this project are discussed in **Element 7** and listed in **Table 7-2** through Error! Reference source not found.. Laboratory quality control checks will include the use of method blanks, laboratory control samples, matrix spikes, and matrix spike duplicates. These checks are performed to identify possible contamination problem(s), to facilitate the ability to duplicate results, and to assess the magnitude of matrix interference and bias that may be present in the samples. If control limits are exceeded, the Laboratory QA Officer will perform corrective actions to determine the cause of the exceedance. Analytical procedures based on laboratory SOPs will be reviewed with appropriate laboratory staff; and errors will be identified, documented, corrected, and reported. Samples will be re-analyzed, if available and within their respective holding times, and deemed necessary. All laboratories must maintain and provide QA/QC records for the San Diego Water Board's review.

14.4 BENTHIC INFAUNAL ANALYSIS

The QA/QC procedure for benthic macroinfaunal sorting and taxonomy will be evaluated based on guidance from the Sediment Quality Assessment Technical Support Manual, SCCWRP Technical Report 777 (Bay et al., 2014) and those utilized for Bight '18. A QA/QC procedure will be performed on each of the sorted samples using the aliquot method to ensure a 95% sorting efficiency (see **Element 7**). QA/QC on taxonomic samples will be conducted by re-identifying 10% of the benthic infaunal samples by taxonomists other than those who originally analyzed the samples and by establishing a voucher collection.

15. INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

15.1 FIELD EQUIPMENT

Prior to conducting field sampling, field technicians will be responsible for preparing sampling kits that include field logs, COC forms, sample labels, sampling containers, and tools. Field measurement equipment will be checked for operation in accordance with the manufacturer's specifications. Equipment will be inspected prior to use and when returned from use for damage. The Consultant Field Task Lead will be responsible for implementing the field maintenance program.

Instrumentation malfunctions are immediately noted in the instrument logbook, and the Consultant PM is notified. Senior technical staff with specific in-depth knowledge of the particular instrument will then review the problem and attempt to fix the instrument. Major problems may require trained field service personnel and/or spare parts from the manufacturer to be brought in to fix the problem. If a critical measurement is found to be out of compliance during analysis, the results of that analysis will not be reported, corrective action will be taken and documented, and the analysis will be repeated. Effectiveness of the corrective action will be assessed by repeating the measurement, recording the corrected result, and documenting the chain of events and actions taken in field logs.

15.2 ANALYTICAL LABORATORY

The contract analytical laboratory is responsible for maintaining their equipment in accordance with their SOPs, which include those specified by the manufacturer and those specified by the method. Laboratory analysts are responsible for equipment testing, inspection, and maintenance. Corrective actions will be taken to repair equipment, document the issue, and reanalyze the sample if necessary.

16. INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

The field equipment and instruments used should be operated and calibrated according to manufacturer recommendations as well as by criteria defined in the Consultant's individual SOPs. Operation and calibration are performed by properly trained personnel. The multi-parameter water quality meters or sondes used for instantaneous readings will be calibrated prior to and following use. The multi-parameter water quality sondes used for long-term deployment in the field will be calibrated prior to deployment and following final retrieval. Precision of the sonde will be verified after biofouling cleaning of the sensors. When sondes are pulled for calibration during deployment periods, data will be downloaded, and the sensors cleaned from biofouling prior to calibration. A response to an appropriate standard will be verified to be within QA/QC. If the QA/QC passes, then the sensor will not be recalibrated and will be redeployed. If the QA/QC fails, then the sensor will be re-calibrated before re-deployment. Documentation of calibration information will be recorded in appropriate logbooks. If calibration is unsuccessful, then the instrument will be cleaned and parts replaced until a successful calibration can occur.[20] If the instrument fails to calibrate after several attempts, then that instrument will be replaced. If a critical measurement is found to be out of compliance during the deployment of the sondes, then the Consultant PM will be notified. Results of that measurement will either not be reported, or data will be flagged. Corrective action will be taken to recalibrate the equipment and document the issue.

The laboratory equipment used at the contract analytical laboratory will be operated and calibrated according to manufacturer recommendations as well as by criteria defined in individual SOPs. Operation and calibration will be performed by properly trained personnel. Documentation of calibration information will be recorded in appropriate logbooks. If calibration is unsuccessful, then the equipment will be cleaned, and parts replaced until a successful calibration can occur. If the equipment fails to calibrate after several attempts, then the Consultant PM will be notified that analyses have stopped until functional equipment is available. Affected data will be flagged with appropriate qualifiers. Once equipment is functioning again, the samples will be reanalyzed. Issues with an instrument will be documented and corrective actions will be recorded by the laboratory. The Consultant PM will be notified if data are affected by the documented issue.

[20] Calibration checks on DO sensors have indicated that variations in measured DO values may be greater than the instrument accuracy specification of ± 0.2 mg/L listed in the QAPP (Kara Sorensen, personal communication).

17. INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

It is the duty of each staff member responsible for equipment ordering to inspect equipment and materials for quality and report any equipment or materials that do not meet acceptance criteria to the appropriate Laboratory Manager and/or QA Officer. Upon receipt of materials or equipment, a designated employee will receive and sign for the materials. The items will be reviewed to ensure the shipment is complete, then they will be delivered to the proper storage location. Chemicals will be dated upon receipt. Supplies will be stored appropriately and discarded on the expiration date. The equipment and supplies purchased for use in field sampling activities will be inspected for damage as they are received.

Sample containers will be provided by the contract analytical laboratory. They will be shipped to and stored at the Consultant's facility prior to use in the field. Confirmation that sample bottles are laboratory-certified clean will be made when received from the laboratory. The Field Task Lead will oversee this element.

18. NON-DIRECT MEASUREMENTS

Historical data in the watershed may be used to support loading calculations to the Estuary. Surface water and groundwater data collected and published by the USGS as part of their National Water Information System (NWIS; https://waterdata.usgs.gov/nwis) may be used to supplement the loading calculations. Historical or current USGS data may be used. Any data that are designated as 'provisional' by the USGS will be noted.

Modeling work previously performed by Camp Pendleton may be used to support the loading calculations. This includes the Lower Santa Margarita River Groundwater Model (LSMR Model), which has been previously used to study groundwater flow and nutrient loading (e.g., Stetson, 2007; Stetson, 2012; Sutula et al., 2016).

Historical and current groundwater level and groundwater quality data collected by MCB CamPen and others may be used to supplement loading calculations (e.g., Stetson, 2019). The well locations, collection methods, and data quality will be described for any measurements used to support the loading calculations. Historical data collected by NIWC, the USGS, MCB CamPen, and others will be technically reviewed by the State-certified Professional Geologist and appropriately referenced if used for assessing and describing loading calculations. Raw and processed historical data, and relevant descriptive QA/QC data will be collected and stored in appropriate file formats on a computer. Such historical data may be used to develop empirical relationships between flow and concentration.

19. DATA MANAGEMENT

The Consultant PM will document and track the aspects of the sample collection process, including generating field logs at each site and COC forms for the samples collected. COC forms will accompany samples to the laboratory for analysis. The analytical laboratory will document and track the aspects of sample receipt and storage, analyses (including lab QA/QC data), and reporting pertaining to all laboratory analyses. The analytical laboratory's results will be stored in a database system at their office and will be provided to the Consultant PM both electronically and in hard copy. Further details of the analytical laboratory's data management protocols can be found in their respective quality manuals.

The Consultant's PM and QA officer will maintain and control the database of information and documents collected during this project. Data will be maintained as described in **Element 9**. Field and laboratory data will be entered into the Consultant's database based on nomenclature developed specifically for this project. Data entry oversight will be the responsibility of the Consultant's QA Officer. All data records, including field-generated data and laboratory data, will be accumulated into project-specific files that are maintained at the Consultant's office. All continuous monitoring raw data will be kept in the original files and stored in an electronic database. Data endpoints (e.g. hourly or daily averages) can be calculated and maintained in separate files or spreadsheets. Records will be maintained for at least five years or transferred according to agreement between the Consultant and the client.

All surface water data, including laboratory and field QC results, collected under the QAPP must be submitted to CEDEN. CEDEN data templates and documentation are available at: http://ceden.org.

GROUP C: ASSESSMENT AND OVERSIGHT

20. ASSESSMENTS AND RESPONSE ACTIONS

Data collected and analyzed for this monitoring program need to be consistently assessed and documented throughout the project to determine whether the project objectives are being met. Field staff will review sampling procedures prior to conducting sampling to ensure that all methods of collection are understood and that equipment/instruments used for sample collection and analysis are functioning and ready for use. Field data sheets will be reviewed prior to leaving the sample location to ensure that all samples were collected, and field observations were documented. If the field staff encounters any issues related to sample collection or equipment failure that cannot be immediately corrected at the sample site, they will notify the Consultant PM. Either re-sampling will occur on another day or errors will be noted on field data sheets and reported in the annual report.

The laboratory technicians are responsible for following the procedures and operating analytical equipment, including conducting instrument maintenance, calibration of equipment/instruments, and performing laboratory QC sample analyses at the required frequency stated in this QAPP. The laboratory QA Officer is responsible for reviewing the associated QC results that are reported with all of the sample results to evaluate the analytical process performance, verifying that the performance criteria of this QAPP were met, recommending or approving proposed corrective actions, and verifying that corrective actions have been completed.

The need for corrective action comes from several sources, including equipment malfunction, failure of internal QA/QC checks, failure of follow-up on performance or system audit findings, and noncompliance with QA requirements. When measurement equipment or analytical methods fail QA/QC requirements, the problem(s) will be brought immediately to the attention of the laboratory supervisor and QA Officer. Corrective measures will depend entirely on the type of analysis, the extent of the error, and whether or not the error is determinant. Final approval of what the corrective measure will be is the responsibility of the QA Officer and/or Consultant Project Manager. If failure is due to equipment malfunction, the equipment will not be used until repaired. Precision and accuracy will be reassessed, and the analysis will be rerun. Attempts will be made to reanalyze the affected parts of the analysis so that in the end, the product is not affected by failure of QC requirements. When a result in a performance audit is unacceptable, the laboratory will identify the problem(s) and implement corrective actions immediately. A step-by-step analysis and investigation to determine the cause of the problem will take place as part of the corrective action program. If the problem cannot be controlled, the laboratory will analyze the impact on data. The client will be notified if their data are affected.

21. REPORTS TO MANAGEMENT

The Consultant PM is responsible for preparation and submittal of all project deliverables. The analytical laboratory's QA Officer is responsible for the preparation of all data packages and laboratory reports originating from their laboratory. Draft and final reports will be provided for review. **Table 21-1** presents the proposed schedule for management reporting.

Table 21-1. Management Report Schedule

Type of Report	Frequency	Projected Delivery Dates(s)	Person(s) Responsible for Report Preparation	Report Recipients
Draft Monitoring Plan	Once	August 27, 2019	Responsible Parties Contact[3]	County of Riverside, Riverside Flood Control and Water Conservation District, County of San Diego, United States Marine Corps Base Camp Pendleton, City of Murrieta, City of Temecula, City of Wildomar, San Diego Water Board[2]
Draft QAPP	Once	August 27, 2019		
Final Monitoring Plan/QAPP to Dischargers	Once	November 6, 2019		
Final Monitoring Plan/QAPP to San Diego Water Board	Once	November 12[4], 2019		
In-Stream River Monitoring Data Submittals to NWIC Pacific	Quarterly[5]	July 31 October 31 January 31 April 30		
Draft Annual Report to Dischargers	Annually (Years 2020-2022)	November 15[6]		
Final Annual Report to Dischargers	Annually (Years 2021-2023)	January 15[1]		
Final Annual Report to San Diego Water Board	Annually (Years 2021-2023)	January 31[1]		
Draft Four-year Report to Dischargers	Once	January 15, 2024		
Final Four-year Report to Dischargers	Once	March 15, 2024		
Final Four-year Report to San Diego Water Board	Once	March 31, 2024		

1 – Following calendar year

2 –The San Diego Water Board will receive the final versions of the Monitoring Plan, QAPP, Annual Reports, and Four-year Report.

3 – The agency(s) designated to lead contract management and development of reports will be identified in the MOU.

4 – The Workplan and QAPP are due six months from May 9, 2019 when Investigative Order was issued, which is Saturday, November 9. Due to Veteran's Day holiday on November 11, the first business day is Tuesday, November 12, 2019. This date was agreed upon with the San Diego Water Board at the SMRNIG TAC meeting on October 2, 2019.

5 – Target interim data submittals to NWIC Pacific for annual assessment. Schedule may be modified as agreed upon by dischargers.

6 – Target draft report date may be modified as agreed upon by dischargers.

GROUP D: VALIDATION AND USABILITY

22. DATA REVIEW, VERIFICATION, AND VALIDATION REQUIREMENTS

All data generated by this project's activities will be reviewed against the MQOs presented in **Element 7** of this QAPP. The field and laboratory personnel, including QA Officers, will be responsible for verifying that the sample collection, handling, and analytical procedures were in accordance with the approved QAPP. The Field Task Lead will review all COC forms to ensure adherence to collection, transport to analytical laboratory, and receipt requirements are completed within appropriate holding times.

Laboratory technicians generating the data have the prime responsibility for the accuracy and completeness of data. The laboratory supervisor and QA Officer are responsible for reviewing laboratory data forms and sample logs to ensure that all requirements for sample preservation, sample integrity, data quality assessments, and equipment calibration have been met. Data that do not meet these requirements will be reanalyzed, not reported, or will be reported with qualifiers which provide adequate explanations for the data discrepancies. If data cannot be reported, then the Consultant's PM will be notified.

23. VERIFICATION AND VALIDATION METHODS

After each survey, the field data sheets will be removed from the field logbooks, and sheets will be checked for completeness and accuracy (including sample location, sample date and time, and sample type) by the Consultant's Field Task Lead or PM. Any field changes or discrepancies will be noted on the field sheets. Any changes to the COCs in the field should be indicated by a single line through the error, a revised value/change next to the original, and an initial of the field technician responsible. Copies of the COC forms with signatures from laboratory personnel showing that the laboratory has received the samples will be kept with field data sheets in a designated folder. If there are any questions, clarification from the Field Task Leader will be obtained as soon as possible. Data collected from field instruments, such as DO, will be validated and verified by the Consultant's PM or QA Officer.

Verification and validation of the laboratory data are the responsibility of the laboratory. All sample preparation and analytical activities will be documented in bound laboratory notebooks or on bench sheets. The laboratory technician generating the data has the prime responsibility for the accuracy and completeness of the data. Laboratory technicians and the laboratory QA Officer will review the analytical data to ensure that the following information is correct and complete: sample description information, analysis information, instrument calibration, analytical results, QC samples meet performance criteria, and documentation. The laboratory supervisor will maintain analytical reports and QA/QC documentation for this project in a database format. All corrective actions required during the analytical process that may affect sample results will be recorded by the laboratory's QA Officer and reported to the Consultant's PM and QA Officer.

In addition to the laboratory performing verification and validation of laboratory data, the Consultant's QA Officer will review all laboratory analytical reports and electronic data deliverables when they are received from the laboratory to ensure that the data provided are complete and MQOs in this QAPP have been met. Laboratory reports/electronic data deliverables (EDDs) that do not meet the Consultant's QC check will be returned to the laboratory with requests for correction.

The Consultant's PM will be responsible for final review of data analysis and rough drafts of annual reports prior to submission to the client for their review.

24. RECONCILIATION WITH USER REQUIREMENTS

The goal of this monitoring program is to conduct surface water and groundwater monitoring in the Estuary and SMR Watershed in order to assess progress toward attainment of numeric targets in accordance with the 2019 Investigative Order (San Diego Water Board, 2019). Data collected in each year of the monitoring program will aid in addressing the questions outlined in **Element 5.1**.

In order to answer Question 1, watershed and resurfacing groundwater nutrient loading data will be evaluated to quantify concentrations of total nitrogen and phosphorus entering the SMR Watershed and Estuary, and to estimate dry weather loads on an annual basis. Determining the annual loading of nutrients will also help answer Question 2 as to whether the Discharger's existing NPDES permits are enough to bring about the necessary nutrient load reductions to restore the Estuary and to confirm that resurfacing groundwater is no longer a significant source of nutrient loading to the Estuary.

In order to answer Question 3, macroalgal biomass, DO, and benthic community condition data will be assessed to determine whether numeric targets are being met (see **Element 5.3**). Results of the continuous DO monitoring and Estuary nutrient samples will be used as an indicator of the eutrophication status of the Estuary.

Data analysis for the Estuary and SMR Watershed will consist of tabulation of results, load estimates, DO summary, macroalgal biomass calculations, and assessment of the benthic community condition of the Estuary. Results will be compared to the Draft Staff Report numeric targets (see **Element 5.3**) to determine progress toward addressing the eutrophication impairments. In addition, statistical analyses and data interpretation will be conducted as related to observed trends in watershed nutrient loading and Estuary macroalgae levels across monitoring years after at least three years of monitoring have been conducted. The usability of the verified data will be assessed by comparing the data to verification criteria and MQOs in **Element 7**. Data that have been rejected will not be used in the data analyses. Data that have been flagged will be carefully evaluated for inclusion in the final analyses. If flagged data are used, then they will be documented in the final report.

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Attachment A

Example Chain of Custody Form

CHAIN OF CUSTODY

SDG Number:

Company Name: Task Order Number:

Address: Project Name:

City / State / Zip: Project Location:

Project Manager: Activity:

Phone/Fax Number: Lab Destination:

Client Contact: Lab Contact:

Phone/Fax Number: Lab Phone #:

Special Instructions:

Preservation Code / Bottle Type: H3

Requesting Testing Program/ Contract Elin

Collection Information

LAB_SAMPLE_ID	SAMPLE_NAME	Date	Time	Matrix	Method/ SOP#:	No. of Bottles

1

Sampler(s) Name(s):

Turnaround Time:

Hours Sampling:

Condition upon Receipt
Cooler Temp ______ °C Received on Ice Y N Correct Container Y N
Preserved Y N

Associated Forms
BAC-T Form Y N Field Notes Y N

Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Relinquished By:	Date:	Time:	Received By:	Date:	Time:

Matrices / Regulatory Programs

HAZ/GW (RCRA) WW (NPDES/CWA)
DW (SDWA) Solid (HUD) LIQ / Other

Bottle Type/Preservative Codes

1 = HCl	7 = $C_6H_8O_6$	C=50 ml
2 = $Na_2S_2O_3$	8 = $NaHSO_4 * H_2O$	D=100 ml
3 = H_2SO_4	9 = HNO_3	E=250 ml
4 = NaOH	10 = Ice	F=500 ml
5 = NH_4Cl	A=Glass	G=1 Liter
6 = NaOH + ZoAC	B=HDPE	H=1L Amber

APPENDIX B

SOP for Macroalgal Collection in Estuarine Environments

Standard Operating Procedure (SOP) for Macroalgal Collection in Estuarine Environments

January 2019

Karen McLaughlin, Martha Sutula, and Mayra Molina

Southern California Coastal Water Research Project
3535 Harbor Blvd., Suite 110
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SCCWRP Technical Report #872

P8/228140

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Acknowledgments:

The standard operating procedures were developed and tested by the Southern California Bight 2008 Regional Monitoring Program's Estuarine Eutrophication Workgroup; in particular: Lillian Busse, Sean Anderson, Jeff Crooks, Rosi Dagit, Doug Gibson, Karina Johnston, and Lisa Stratton and their teams from California State University Channel Islands, the Tijuana River Estuarine Research Reserve, City of Los Angeles Resource Conservation District of the Santa Monica Mountains, San Elijo Lagoon Conservancy, Santa Monica Bay Restoration Commission, and the Cheadle Center for Biodiversity and Eutrophic Restoration at UC Santa Barbara.

Citation:

McLaughlin, Karen, Martha Sutula, Mayra Molina. 2018. Standard Operating Procedure (SOP) for Macroalgal Collection in Estuarine Environments. Technical Report #872. Southern California Coastal Water Research Project. Costa Mesa, CA.

1. Introduction and Purpose

Eutrophication of aquatic habitats is a global environmental issue, with demonstrated links with anthropogenic changes in watersheds. *Eutrophication*, defined as the accelerated delivery, *in situ* production, and/or accumulation of organic matter within an aquatic ecosystem (Howarth 1988, Nixon 1995, Cloern 2001), can have far-reaching ecological impacts, from headwater streams, lakes, estuaries to the coastal ocean (Valiela et al. 1992). These impacts include hypoxia, fish-kills, and lowered fishery production (Glasgow and Burkholder 2000), loss or degradation aquatic beds (Twilley 1985, Burkholder et al. 1992, McGlathery 2001), smothering of benthic macroinvertebrates, bivalves, and other organisms (Rabalais and Harper 1992), nuisance odors, impacts on aquatic life from increased frequency and extent of toxic harmful algal blooms, and poor water quality (Bates et al. 1989, Bates et al. 1991, Trainer et al. 2002). There are also a range of impacts to human health (algal toxins), drinking water (algal toxins, odors and disinfection biproducts) and recreation (nuisance blooms, loss of clarity, aesthetic impairments; Nixon 1995, Paerl et al. 2011). These impacts have significant economic and social costs (Turner et al. 1998). According to the U.S. Environmental Protection Agency (US EPA), eutrophication is one of the top three leading causes of impairments of the nation's waters (US EPA 2001). California has significant nutrient pollution and eutrophication issues. Almost 6,000 acres of estuaries and over 9,000 acres of bays and harbors have 303(d) listings for nutrient related impairments (California Integrated Report 2014/2016)[1]. In Southern California estuaries, macroalgal blooms and hypoxia have been observed at the majority of monitored segments (McLaughlin et al. 2014).

Nutrient pollution is the leading cause of eutrophication. Though in a risk prevention framework, scientific literature has demonstrated the shortcomings of using ambient nutrient concentrations alone to protect against eutrophication, e.g., in streams (Welch et al. 1989, Fevold 1998, Chetelat et al. 1999, Heiskary and Markus 2001, Dodds et al. 2002) and estuaries (Cloern 2001, Dettman et al. 2001, Kennison et al. 2003). In some cases, surface water nutrient concentrations alone are generally not effective for assessing eutrophication and the subsequent impact on beneficial use because nutrients are rapidly taken up by plants and micro-organisms and cycled through the environment. As a result, ambient concentrations are not temporally and spatially representative and do not reflect the biological processing that has already occurred. In addition, other factors can cause or significantly contribute to eutrophication. These factors include changes associated with conversion of natural landscapes to developed land uses, such as hydromodification, altered riparian and channel physical habitat, water temperature, and light availability, and grazing pressure, among others (Paerl et al. 2011). Biological response to nutrients (e.g., algal productivity) depends on a variety of mitigating factors such as basin morphology and substrate characteristics, stratification, temperature, light availability, biological community structure, and seed populations. Thus, high concentrations are not entirely predictive of eutrophication and low concentrations do not necessarily indicate absence of eutrophication.

[1] www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2014_2016.shtml

The California State Water Resources Control Board (State Water Board) has developed an approach to regulating eutrophication impacts of nutrient pollution through an existing "biostimulatory" water quality narrative objective (WQO). As used here, "biostimulatory" refers to substances such as nutrients (i.e., nitrogen and phosphorus) or conditions, such as altered temperature, hydrology, etc., that can cause eutrophication (Figure 1). All California Regional Water Quality Control Boards (Regional Water Boards) have a narrative biostimulatory objective, e.g. "waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses" (Central Coast Waterboard Basin Plan, 1989); similar narrative language is used throughout California Water Board Basin Plans. While narrative biostimulatory objectives theoretically cover a wide range of environmental drivers, no consistent guidance exists to interpret this narrative objective to prevent eutrophication in specific waterbodies or to guide nutrient management actions across the state. To address this issue, the State Water Board is adopting a statewide WQO for Biostimulatory Substances and a program to implement it, as an amendment to the Water Quality Control Plan for Inland Surface Water, Enclosed Bays and Estuaries of California. Recently, the scientific principles and assumptions underpinning the development of an over-arching biostimulatory policy have been published (Sutula, 2018), including conceptual models, indicators, and guiding principles that provide the initial basis for Water Board guidance to support consistent application of narrative biostimulatory objectives across waterbody types, in advance of numeric guidance for each waterbody class.

The purpose of this document is to build on the Sutula (2018) framework by providing standardized protocols for monitoring a key indicator of eutrophication in California estuaries, macroalgal abundance, along with recommended additional parameters that support its interpretation. This protocol is recommended for applications to regional ambient monitoring, permit and TMDL monitoring.

Figure 1. Examples of macroalgae in different habitat types: mats on the intertidal (upper left), rafting mats on seagrass (upper right), floating mats in closed river mouth estuary (lower left), rafting mats intercalated with Ruppia in a closed lagoon (lower right).

2. Sampling Overview and Approach

2.1. Why Assess Macroalgal Abundance?

Macroalgae are a natural and important component of estuarine habitats. In intertidal and shallow subtidal estuaries macroalgae provide food and refuge for invertebrates, juveniles fish, crabs and other species. However, when the estuary is subject to nutrient pollution or other stresses such as hydromodification, some species of macroalgae can outcompete other primary producers (e.g., benthic microalgae, seagrass) and may result in extensive blooms that can cover large expanses of intertidal and shallow subtidal habitat. These blooms in estuarine ecosystems, can result in hypoxia, reduced biodiversity, fish and invertebrate mortality, loss or degradation of seagrass and kelp beds (Twilley 1985, Burkholder et al. 1992, McGlathery 2001), altered food webs and energy flow, disruption of biogeochemical cycling (Sfriso et al. 1987; Valiela et al. 1992, 1997; Coon 1998; Young et al. 1998; Raffaelli et al. 1989; Bolam et al. 2000), nuisance odors, and impacts on human and marine mammal health (Bates et al. 1991, Bates et al. 1998, Trainer et al. 2002).

Although, macroalgae of all divisions and functional forms have been known to form nuisance blooms, the overwhelming majority are red (Rhodophyta) or green (Chlorophyta) algae with very simple body forms (thalli) and relatively rapid turnover times (life spans) of weeks to months. All species of the green alga *Ulva* (common name: sea lettuce) that dominate in estuaries undergo an ontogenetic shift in habitat usage (Kennison 2008) that makes them particularly successful in estuarine environments. Early stages of the life cycle are tied to benthic habitat, restricting their distribution to intertidal or shallow subtidal regions where sufficient light penetrates (Figure 1). However, once the thallus reaches a critical size, which depends on local current velocities (Kennison 2008), it detaches from the benthos and forms floating mats (Astill and Lavery 2001, Cummins et al. 2004, Kopecky and Dunton 2006). These mats are no longer restricted to intertidal or shallow subtidal regions; rather, they accumulate into floating rafts and can grow in virtually any portion of the estuary where the current transports them (Thomsen et al. 2006). However, because of logistical considerations, macroalgal biomass is typically assessed in the shallow subtidal (< 10 m) and on unvegetated intertidal flats.

2.2. Applicable Estuary Classes and Habitat Types

For the purposes of understanding whether macroalgal blooms proliferate, California estuaries can be placed into two broad categories: 1) well flushed, large lagoons and enclosed bay with a wide, perennially open tidal inlet and a strong tidal prism such as San Francisco Bay and San Diego Bay and 2) "bar-built" river mouth estuaries and coastal lagoons, so named because of the presence of a sand berm that can restrict tidal exchange. The tidal inlets of bar-built estuaries can become seasonally restricted or entirely closed to surface water exchange with the ocean. When tidal inlets are open, estuaries can have ample intertidal habitat during little or no tidal variation in water level.

Generally, macroalgal blooms are a very common symptom of eutrophication in bar-built estuaries, with peak biomass occurring during time periods of inlet restriction or closure. Blooms are less common in large, well flushed estuaries, but still common in "backwater" tidal sloughs and flats where tidal circulation is restricted.

This document provides protocols to sample two major habitat types: 1) intertidal (mud or sand) flats and 2) shallow subtidal habitat (< 10 m). Intertidal flats are the unvegetated band of habitat found in the lower intertidal zone. Shallow subtidal habitat can be either vegetated (i.e., seagrass or other submerged aquatic vegetation) or unconsolidated sediments.

For perennially tidal or for intermittently tidal estuaries that are open to tidal exchange for most of the year, the intertidal protocol is recommended because of logistical issues and costs associated with subtidal sampling. However, if an estuary regularly features a seasonally restricted or closed inlet condition, particularly during the growing season (April-November), sampling the estuary utilizing the subtidal protocol is strongly recommended.

For regional (ambient) monitoring, it is not recommended to characterize both intertidal and subtidal habitats at the same time because of costs of sampling. However, for some site-intensive or research studies, a thorough characterization of both habitats may be desirable.

2.3. Seasonal Sampling Period, Frequency, and Recommended Time of Day to Sample

California's coastal climate is Mediterranean, with peak rainfall and freshwater flow to estuaries occurring during the winter months. Due to the freshwater input, the tidal inlets of bar-built estuaries are typically open and macroalgae that bloom during this period are often flushed from the estuary. As freshwater input slows and the tidal inlets begin to restrict, conditions for macroalgal blooms are enhanced. Therefore, typical optimum periods for blooms are during the "growing season," (i.e., April- November). However, winter blooms have been occasionally recorded, occurring during periods of peak nutrient inputs to the estuary or due to tidal inlet closure. Therefore, during the first phase of characterization of an estuary, it should be monitored throughout the year to capture seasonal variability in bloom events. Monitoring should occur on a monthly to bimonthly basis to maximize the likelihood of capturing the peak bloom event, which is not consistent from year to year. Both intertidal flats and shallow subtidal sampling should be scheduled during low tide to maximize available habitat that can be monitored and to facilitate logistics of sampling.

2.4. Additional Indicators

In addition to collecting macroalgae, other supporting indicators should be included in the assessment. Macroalgal abundance and sediment organic matter accumulation are tightly linked (Sutula et al. 2014) and, for this reason, indicators of sediment organic matter (sediment grain size, sediment % organic carbon (%OC) and % total nitrogen (%TN)) are useful supporting indicators. Additional rationale for monitoring sediment grain size, %OC, and %TN, and suggestions for their interpretation are given in the macroalgal assessment framework (Sutula et al. 2016).

Water column dissolved oxygen should also be considered for estuaries with significant sub-tidal habitat, supporting critical fish and invertebrate habitat. Changes in dissolved oxygen reflect the consumption of oxygen during organic matter respiration. Excessive photosynthesis from algal blooms and respiration from decomposition of organic matter result in changes in oxygen concentrations within the water column. These can manifest as large variability in dissolved oxygen (DO) in both in time and space. Continuous measurements of water column DO can track diel changes in oxygen (produced during photosynthesis during the day and consumed by respiration at night). Continuous monitoring can also help assess if low DO occurs for short- or long-time periods, is associated with hydrophysical events such as stratification, or is correlated with algal biomass and water column chlorophyll a. Vertical profiles of DO can be used to understand oxygen dynamics in the water column. Oxygen is typically produced near the surface in the euphotic zone (zone where light is sufficient to support algal growth) depleted at depth, though the depth to low-oxygen waters is likely to vary seasonally. Vertical profiles can be used to extrapolate the hypoxic (oxygen deficient) volume of the estuary. If oxygen levels are depleted over a large area or for extended periods of time, it may result in habitat loss and fish kills.

2.5. Site Access and Other Considerations

Access permission must be acquired for all sites prior to sampling. When considering site access, consider parking for vehicles, any required keys or lock combinations to open gates, and whether arrangements must be made in advance for an on-site escort to accompany the field crew. For any sampling on private and public land, be sure to acquire permission from the landowner and contact the on-site manager before sampling, as applicable. During sampling, the field lead should carry the name and contact information for private land owners and managers. A scientific collecting permit[2] is required for all sites, including private and public lands. An encroachment or additional biological sampling permit is also often needed. Both types of permits can take weeks or months to be issued, so plan accordingly. It is also necessary to be aware of sensitive species issues, and potential restrictions due to breeding season, etc. Presence of state or federally listed threatened or endangered species may limit or preclude sampling at a site and/or may require state or federal "take" permits[3]. Regardless of whether the site is on private or public lands, the appropriate property manager should be notified a few days in advance of when the intended sampling is to occur.

2.6. Field Crew Size and Time Estimates

These field methods are designed to be completed in one day for most estuaries. Depending on the time needed for sampling and traveling for that day, an additional day may be needed for pre-departure and post-sampling activities (e.g., cleaning equipment, repairing gear, shipping samples, etc.

A field crew typically will consist of at least two people to execute sampling activities and to ensure safety, though additional crew members can provide logistical support and aid in data collection. Each field crew should define roles and responsibilities for each crew member to split the work load efficiently.

[2] Collecting permits should be obtained from the California Department of Fish and Wildlife.

[3] U.S. Fish and Wildlife Service and the California Department of Fish and Wildlife should be contacted regarding restrictions or permit requirements associated with threatened or endangered species.

2.7. Measures to Avoid Transfer of Invasive Species

The transfer of invasive species and pathogens should be considered for each member of the team when moving from site to site. Protocols to prevent such transfer should be in place before sampling. See Appendix A for resources to avoid transmission of invasive species.

3. Protocol for Monitoring Macroalgae on Intertidal Flats

3.1. Sampling Approach

Although macroalgal mats can be found throughout the vegetated (tidal marsh) and unvegetated (tidal flat) habitat, unvegetated intertidal flats (sand or mud flats) are chosen as an index area for sampling because of logistics (fewer restrictions due to seasonal nesting of endangered birds), repeatability of method, and scientific evidence pointing to impacts of blooms on benthic habitat quality (Green et al. 2013, Sutula et al. 2014). Biomass is estimated as grams dry weight of algal tissue per square meter of area sampled.

Larger estuaries may be divided into segments. A segment is defined as a spatially homogenous unit with respect to habitat, morphology and/or hydrology, relative to the rest of the estuary. Many Regional Boards have already established segmentation for certain estuaries that can be used. For regional (ambient) monitoring purposes, a thorough characterization of the estuary may not be possible. Previous surveys (McLaughlin et al. 2014) have used an index area approach to select one segment to represent that estuary. For intensive investigations such as TMDL studies, permit monitoring, etc., monitoring of two or more representative segments is typically warranted, depending on the size of the estuary and complexity of habitat.

3.2. Number of Transects and Stations Per Estuarine Segment

For estuaries with intertidal flats, transects are the unit of assessment. Within a segment, a minimum of three transect stations are assessed during each sampling period for the purposes of regional monitoring. For intensive site monitoring, additional stations should be added to represent approximately 15-30% of the channel length. Each transect should be 60 meters long unless the total channel length of the estuary segment is less than 300 meters in which case transects are 30 meters long. Within a channel, sampling of the intertidal flat should always occur on the depositional bank of the channel.

Characterization of both banks of a channel is not required. Sampling of back channel tidal sloughs 2nd order or lower is not advised, unless is it part of a targeted research study, since these areas will have naturally higher biomass due to restricted circulation. Many estuaries have been hydrologically modified and their tidal channels have been straightened, in which case this rule may not apply.

3.3. Transect Layout

In general, transects for each station will be located on the mid- to upper-mudflats and below the mean lower low water level (MLLW). See Figures 2 and 3 for layout of transects and sampling locations. A piece of grey PVC pipe will be inserted into the emergent vegetation and the distance from the pipe to the start of the transects will be recorded and used to find the location of transects each sampling period. In bar built estuaries, seasonal restriction of tidal inlets can cause mean water levels to rise within the estuary, such that macroalgae transects partially or fully become subtidal. If this occurs only during 1-2 sampling periods throughout the year, the transect method can be used to quantify biomass. However, if this is a persistent condition, it may be more appropriate to utilize the subtidal monitoring approach (Section 4).

Five points are randomly sampled along the transect. Random points must be selected in the office prior to departing for the field to avoid bias. Any randomized approach to sample collection is acceptable; one approach is to use a random number generator to randomly select five numbers between 1 and 60 and collect samples along the transect at distances represented by the numbers chosen. Macroalgal biomass and sediment samples are collected from these five points per transect. Biomass samples should be collected separately, not composited.

Since macroalgal blooms are spatially patchy, consideration should be given to the precision required for the assessment. For TMDL or intensive monitoring, double the number of stations to increase the precision of the estimate within each segment.

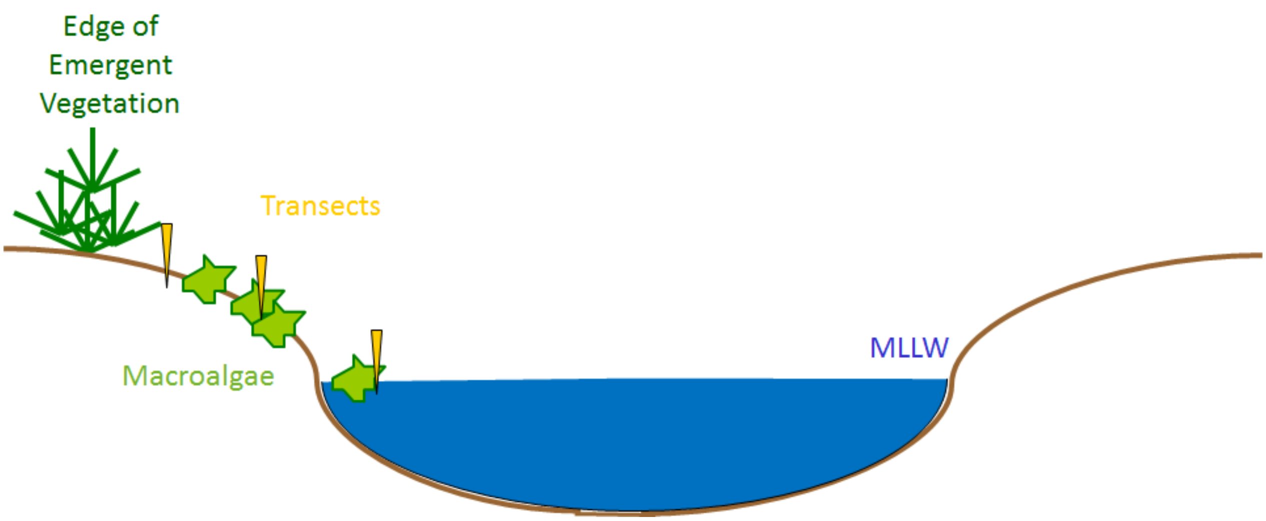

Figure 2. Cross sectional view of one station with three transects. One transect is laid out near the emergent vegetation, another between the vegetation and MLLW, and a third within the shallow subtidal.

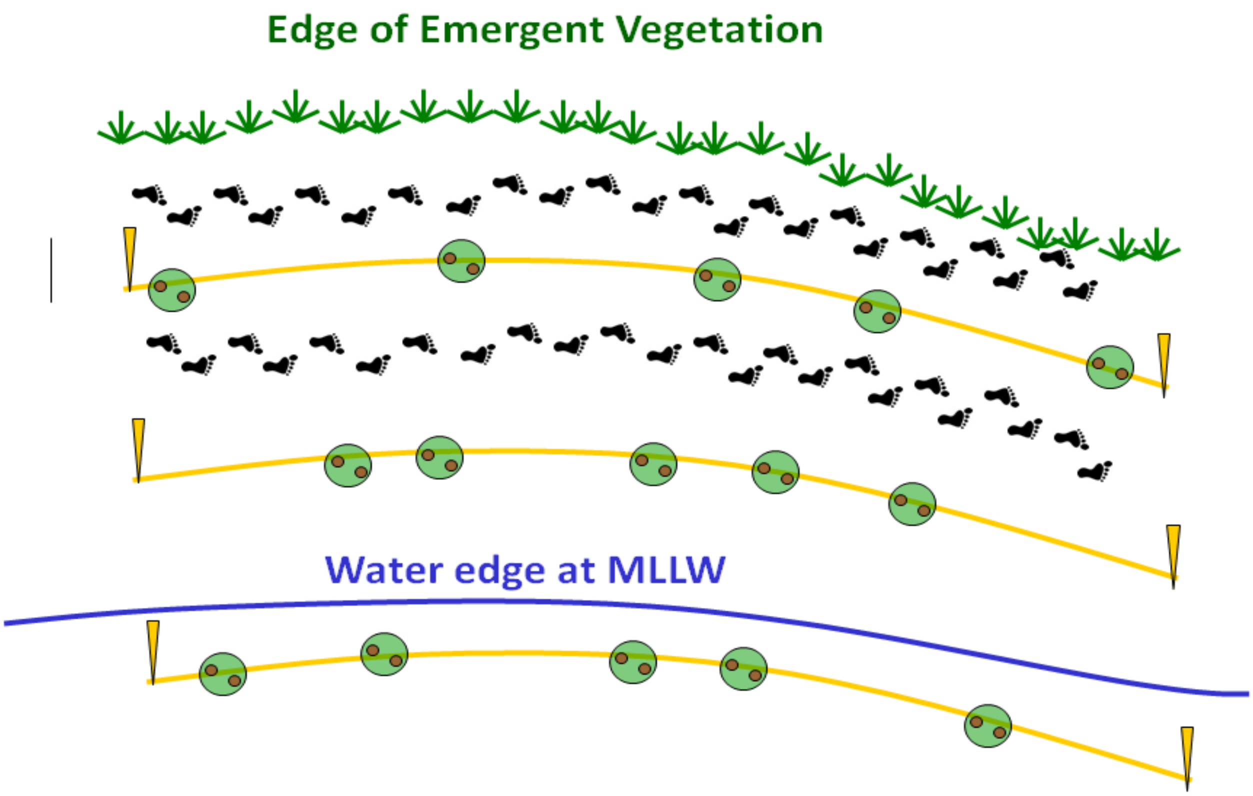

Figure 3. Top-down view of transect layout at one station in the intertidal flats and shallow subtidal. Three transects per station are set along the shore with one transect near the emergent vegetation, another transect between the vegetation and MLLW, and below the MLLW. Green circles represent macroalgal biomass samples and within these are two sediment samples collected after biomass. Sampling points are randomly chosen along the transect. Note that it is not recommended to step on the transect path, but to walk in between transects.

3.4. Equipment and Gear

Below is a list of equipment needed for sampling the intertidal flats. Please note that this protocol should occur before water chemistry collection.

- General equipment:
    - Hand-held GPS unit (accurate to sub-meter)
    - PVC pipe (small diameter) or stakes (to mark transects)
    - Hand-held temperature/salinity meter
    - Transect tape
    - Short ruler
    - Digital camera (Q-p Card, Length Scale)
    - Data sheets, clipboard, and pencils/pens/sharpies
        - Macroalgae Transect Data Sheet
        - Sediment Data Sheet
    - Boots, waders or wet suit

    - Breakfast table and bench paper for sample management
    - Gloves (latex, nitrile, or similar)
    - Cooler and ice
    - Chain of Custody Form
    - QA checklist
- Macroalgae biomass:
    - Buckets or dish bins (3)
    - Biomass surface area delineator (8-inch diameter plastic cylinder) and end cap
    - Spatula
    - Squirt Bottle filled with Estuary Water
    - Scissors or shears
    - Labels and Ziploc sample bags
- Sediment grain size and nutrient content:
    - Sediment syringe sampler (cut off tip of a disposable 60 ml syringe, mark 1 cm from end with black sharpie)
    - Spatula
    - Labels and Ziploc sample bags
    - Pre-weighed 50 mL centrifuge tubes with labels
    - Aluminum foil

3.5. Approaching a Station and Laying Out Transects

- When approaching a station minimize footprints within the designated sampling areas.
- At the edge of the emergent vegetation stake in a small piece of grey PVC pipe or stake to mark the start of the transect and record the GPS coordinates on the data sheet.
- Carefully lay the transect tape out to 60 m or 30 m (depending on the total length of the channel greater than 300 m or less than 300 m respectively) near the edge of the emergent vegetation parallel to the shore.
- Record the GPS coordinates of the endpoints of the transect. Record the distance in meters from the PVC pipe.
- Carefully lay out the second transect tape out to the same distance as the first (either 60 m or 30 m) between the MLLW and the emergent vegetation parallel to the shore. Stake in the landward end of the transect.
- Record the GPS coordinates of the endpoints of the transect. Record the distance in meters from the PVC pipe to the transect.
- Carefully lay the third transect tape out to 60 m or 30 m below the MLLW line and parallel to the shore. This transect should be in a very shallow area where you are able to reach your hands in to grab the samples.
- Record the GPS coordinates of the endpoints of the transect. Record the distance in meters from the PVC pipe to the transect.
- The oceanward location of each transect is designated as distance 0 m along the transect.
- Once the tapes are laid out, take a digital photograph of the station from the oceanward end.

3.6. Macroalgal Biomass and Sediment Sampling

- Before collecting samples, you should already have 5 random sample points selected per transect. Record the location of the sample points on the Data Sheet.
- Make sure to wear gloves
- Beginning with the first sampling point at the first transect, place the biomass delineator (8-inch plastic cylinder) into the sediment about 4 cm deep
- Use a spatula to slide under the delineator to hold sediment in while you remove the delineator slowly place it into a bucket or dish bin.
- If any algae are hanging outside of the delineator, use scissors to cut off algae.
- Quantitatively remove all biomass from within the delineator but set aside the sediment. Use the squirt bottle filled with estuary water to clear mud from the algae as needed. Do not use the squirt bottle on the sediment you have set aside.
- Place algal biomass into a pre-labeled Ziploc bag. Fill in a water-proof label and place it into the sample bag with the biomass sample. Ziploc bags should be labeled on the outside as well.
- Store biomass sample in a cooler with ice.
- Retrieve sediment from earlier, carefully remove any sticks or other non-sediment debris.
- Insert the sediment syringe sampler into the mud past 1 cm depth (marked as a hash on the side of the sampler) while pulling up on the syringe plunger.
- Remove the sampler from the sediment.
- Gently push in the plunger, expelling sediment until only the top 1 cm remains in the syringe.
- Open a pre-labeled 50 mL centrifuge tube and push the plunger to expel the 1 cm of sediment.
- Close tube and repeat the syringe process again to collect one more sediment plug. There should be a total of 2 sediment plugs collected at each sampling point.
- Take the sediment bag up to the edge of the vegetation.
- Repeat this procedure until five samples are collected for the first transect and then repeat the process for the other two transects.
- Sediment samples should be stored on ice in the dark and delivered to the processing lab along with the biomass samples after sampling the estuary segment.
- Repeat process for the other segments of the estuary.

At the End of Field Sampling

- From the 60 m or 30 m end of the second transect tape (upstream/watershed end), walk down to the edge of the water.
- Record the local temperature and salinity using a hand-held meter.
- Field leader should check that the data sheets have been filled out and should sign the bottom of the sheets.
- Field leader should check the cooler to ensure that all samples have been collected and placed on ice.
- Check the number of samples against the Chain of Custody form.
- Samples should be prepared for laboratory processing, with processing completed within 48 hours.
- Prepare the Chain of Custody form, sign and date, for delivery to processing lab at the end of sampling.

4. Protocol for Monitoring Macroalgae in Estuarine Shallow Subtidal Habitat

4.1. Sampling Approach

Because macroalgae in subtidal habitat can be either benthic (attached) or as free floating rafting mats in water column, the subtidal sampling approach requires that all macroalgae found within a defined surface area 2 meter in depth or less be comprehensively sampled from surface to bottom. As with intertidal flat sampling, the final estimate of biomass is given in units of grams dry weight per square meter.

4.2. Number of Points Per Segment and Number of Segments Per Estuarine

For subtidal sampling, a grid-based approach or probabilistic sampling design is recommended unless the width of the estuary's channel is very small (< 5 m), in which case the point-intercept approach using transects can be used, as is done for intertidal flats.

As with intertidal flats, larger or complex estuaries should be divided into segments representing areas that are spatially homogenous with respect to habitat, morphology and/or hydrology relative to the rest of the estuary. Within each segment, assessments should generally be made in the 2nd order tidal channels or larger. Small tidal channels, pannes and pools located in the back of the marsh away from the main channel should not be assessed, as reduced tidal exchange may create natural conditions conducive to macroalgal growth. The tidal channel or open water subtidal habitat within the segment should be divided into three sub-segments and five randomly selected points should be sampled in each sub-segment for a total of 15 random sample points per segment (analogous to the transect sampling for intertidal flats). For regional (ambient) monitoring, three sub-segments are recommended and for a more intensive study such as a TMDL or permit monitoring, more sub-segments should be included and will depend on the size of the estuary segment.

4.3. Establishing the Sample Frame and Sample Location within the Grid

Any randomized approach to sampling locations on a sample grid within the estuary segment can be used to delineate sampling sites; however, random points should be selected prior to departure to avoid sampling bias. Mapping software like ArcGIS can be used to establish a sample frame, R packages like spsurvey[4] can be used for probabilistic sample draws. The grid-based approach can be used to select points to sample macroalgal biomass by laying a grid over an aerial map of the estuary (e.g. Figure 4). From the grid, delineate the estuary into 3 roughly even sub-segments and randomly select 5 points on the grid within each sub-segment (a total of 15 stations per segment), this can be done with a software package like R (as mentioned above) or using a random number generator to select numbers representing the intercepts on the grid. Make sure to record the latitude and longitude coordinates for each point. For each sampling event, samples should be collected at these same points.

[4] https://cran.r-project.org/web/packages/spsurvey/index.html

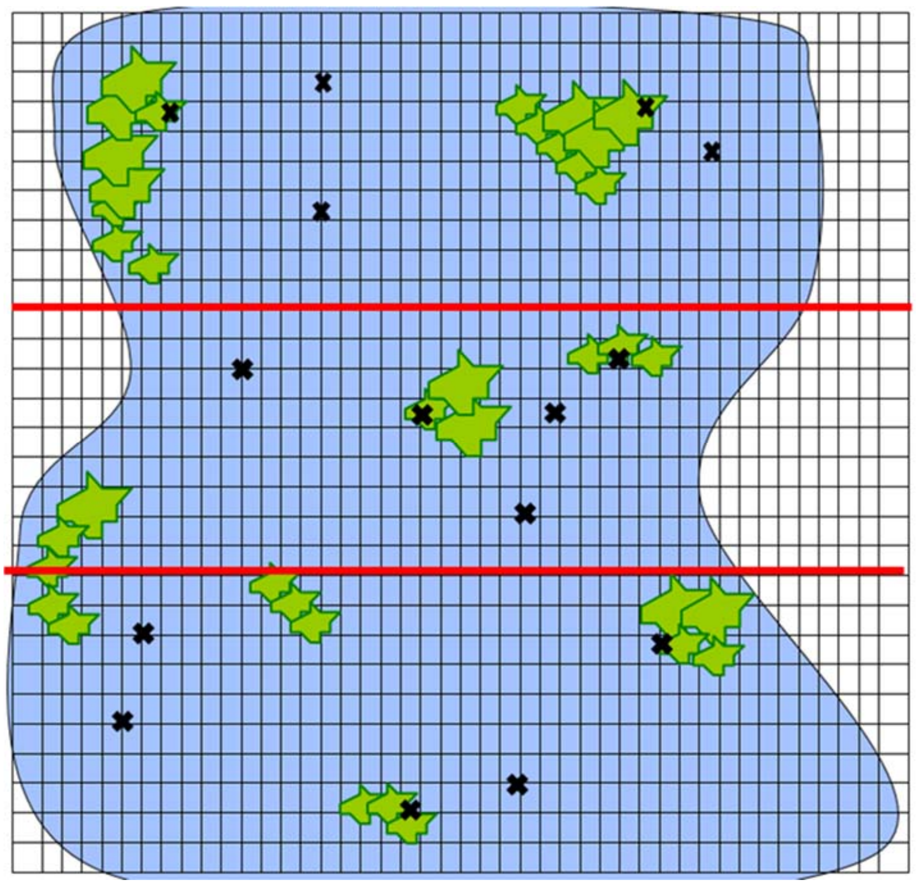

Figure 4. Grid layout over estuary segment. Red lines designate three sub-segments. Black x's are the random sampling points where macroalgal biomass and sediment samples will be collected.

4.4. Collection of Macroalgae Biomass and Sediment Samples

At each sample point, macroalgal biomass is comprehensively collected from the surface to the bottom in a defined surface area. There are two available methods for collecting macroalgae biomass samples. The first method is the multi-SUBstrate Subtidal sampler (SUBS Sampler) developed by the Navy (Sorensen et al., in prep). The second is the hamper, based on Sutula et al. (2014). Sutula et al. (2019) compared the two methods in an estuary that was, at the time, dominated by benthic (attached) forms of macroalgae. Overall, they found that the SUBS method seemed to provide higher estimates of total biomass across the entire gradient of biomass, suggesting that it may more comprehensively sample biomass relative to the hamper method. It also scored substantially better (80%) than the hamper method in user rate evaluation of logistics and ease of field and post-sample processing, relative to the hamper method (46%). The SUB sampler is ideal sampling of benthic primary producers. However, when most of the biomass is floating or rafting or canopy forming SAV, the small inner diameter of the core tube may provide an underestimate of biomass due to incomplete entrainment of material in the water column. In contrast, the hamper method is not designed to benthic forms at all thus it's no surprise that it appears to grossly underestimate SAV and macroalgal biomass, especially at higher values. For this reason, we suggest that in environments with substantial floating macroalgae or canopy forms of SAV, the method be combined with the hamper method to capture both types of available biomass.

For the basket method of macroalgae sample collection, water column macroalgal mats will be collected using a dip net, bottomless mesh basket/collapsible hamper (Figure 5), or a similar device; benthic macroalgae and sediment samples will be collected using a box core. The surface area of the basket for water column sampling of macroalgal biomass should be of equal surface area as that of the box corer, such that the integrated composite from both habitats has a standardized surface area. If the surface area of the dip net or basket is different from that of the box corer, then the benthic biomass should be maintained in a separate composite bucket from the water column biomass; the combined biomass can be estimated after laboratory processing.

Figure 5. Collapsible hamper, used to quantitatively collect all water column macroalgae within a designated surface area and volume of water column

The SUBS sampler was developed by the Energy and Environmental Sciences Group at NIWC Pacific for quantitatively collecting macroalgal biomass in the subtidal zone (Sorensen et al., in prep) but has the capacity to collect sediment for bulk chemistry (e.g., total nutrients and organic carbon) and benthic chlorophyll-a, macroalgae in one sample. The device consists of a 4-inch ID cylindrical acrylic beveled core tube, encased in a stainless-steel collection frame that has an aluminum telescope "trigger" pole attachment and adjustable sediment hard stop (Figure 6). The entire device can be "loaded" and deployed from a small craft, such as a kayak, via the small craft sampler deployment stand (SDS). With the pole attached, the SUBS sampler can reach depths up to 3.66 meters. The adjustable sediment hard stop allows the user to increase or decrease the volume of sediment collected by the SUBS (range from 2.5 in (recommended minimum limit) to 8.5 inch (when using the long SUBS). The SUBS sampler comes in two core tube lengths, a ~12 inch (short sampler) and a 16 inch (long sampler), respectively. Total weight for each SUBS sampler (empty w/out sediment hard stop) is 7.5 to 8 lbs. respectively. To create a sufficient enough vacuum seal, we would recommend use of long SUBS when sampling in finer sediments at deeper depths (>1.5 meters), however, the long SUBS is not recommended for use in depths <0.5 m. The SUBS sampler collects samples by creating a tight vacuum seal when release cord is pulled triggering closer of foot and cap portion of collection frame. The SUBS sampler can also be used to collect sediment samples, however if a box corer is used to collect sediment samples, and the surface area of the SUBS sampler is thus different then the box corer then would recommend following similar procedure as discussed for dip net method above regarding combined biomass assessment.

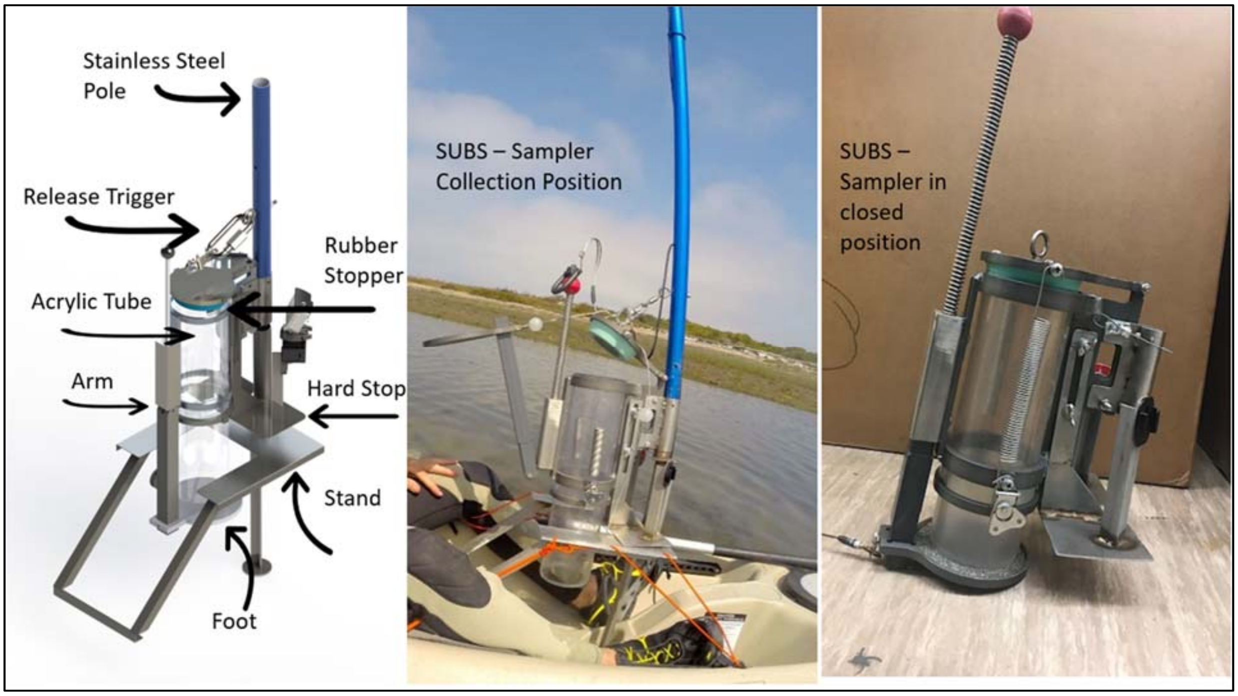

Figure 6. SSC Pacific Multi-substrate Subtidal Sampler (SUBS-Sampler). Note, while in the closed position the foot plate is released by pushing down on the red or black bulb atop the spring portion of the frame arm. Red bulb as well as foot plate line is visible in collection and closed position pictures above. SUBS frame coil springs attached to the cap screws can be seen in closed position picture above.

4.5. Equipment and Gear

Below is a list of equipment needed for subtidal sampling. Please note protocol should occur with water chemistry collection.

- General equipment:
  - Hand-held GPS unit (accurate to sub-meter)
  - Digital camera
  - Gloves
  - Data sheets, clipboard, and pencil/pen/sharpie
  - Boots, waders or wet suit
  - Cooler and ice/dry ice
  - Chain of Custody Form
  - QA checklist
  - List of Sites with Directions/Permits
  - Kayak/paddles
  - Stakes to anchor kayak (optional)

- Tie downs

- Water Column Macroalgal Biomass (Basket Method):
  - Dip net
  - Collapsible mesh hamper or basket
  - Scissors or shears
  - Small oyster tongs/net
  - Labels, sample bags
  - Buckets or dish bins
  - Estuary water in squirt bottle

- Benthic Macroalgal Biomass and Sediment Sampling (Box Core Method):
  - Box core
  - Buckets
  - Sample bags with labels
  - Pre-weighed 50 mL centrifuge tubes with labels
  - Aluminum foil
  - plastic dish bin

- Benthic Macroalgal Biomass and Sediment Sampling (NIWC PAC Method):
  - Sample Device
  - Labels, sample bags
  - Buckets or dish bins
  - Estuary water in squirt bottle
  - kitchen strainers / or .750 mm sieve
  - Suction tubing

4.6. Collection

Subtidal Sampling:

- Wear gloves
- Use a kayak to access deep areas of the estuary; make sure to disturb sampling areas as little as possible
- Use GPS to find a sampling point
- Record coordinates (should be the same for each sampling period)
- Collect water column macroalgal biomass
  - If sampling by dip net, lower the dip net at an angle near the sampling point, close to the bottom but not close enough to touch the sediment. Pull up the dip net above the sampling point to grab any macroalgal biomass. Cut any mat of macroalgae that exceeds the rim of the dip net with scissors.
  - If sampling with bottomless mesh basket, lower basket into water column. Use dip net to pull out any macroalgal biomass within basket throughout the water column.
  - Using the oyster tongs or net, scoop all biomass from the net/basket, rinse any mud as necessary with squirt bottle, and carefully place biomass into pre-labeled bag.
  - Store the bag in a cooler with ice
  - If sampling by NIWC PAC method

- Put SUBS into "collection position" by first attaching SUBS sampler to SDS and then attaching the trigger pole using attachment pin. Next, put SUBS into "collection" position by pushing down on the spring loaded arm and pulling back the foot plate and then attaching the foot plate line and SUBS cap to the trigger pole release line (Figure 6- collection position). Last, secure the two coil springs attached to the body of the frame to the cap screws (Figure 6-closed position). If using a sampler with a release valve, make sure release valve is tightened down in cap.
- Lower "loaded" SUBS into water column. Once SUBS reaches sediment surface, gently twist into sediment by pivoting pole left to right until it hits sediment hard stop. Once SUBS is inserted into sediment to desired depth, pull trigger line to release SUBS cap and foot. Once trigger line has been released, pull SUBS out of sediment and lift out of water column. Reattach SUBS to SDS frame. If this is your last sample at this site remove trigger pole release pin from frame and detach pole from frame. (Recommend collection of 3 samples/site).
- Biomass can be collected from SUBS sampler either by first suctioning out water into strainer over collection bin or by dropping entire sample (sediment, macroalgae, and water) into strainer.
    - To collect biomass by first removing water from core tube, first place collection bin under sampler (this will ensure no sample is loss should pressure release and water pore out when cap is opened). Next release springs from frame cap and open cap. Place sieve over collection bin. Syphon off water using small gauge flexible suction tubing. So as to avoid loss of smaller pieces of biomass that might be pulled up during the syphoning process make sure to syphon water into sieve. Once water has been removed, release foot from frame by pushing down on spring portion of frame arm and drop sediment + macroalgae into sieve. As necessary use squirt bottle to flush any biomass which might be stuck to core tube into sieve/collection bin.
    - Rinse any mud as necessary and remove biomass from sieve, and carefully place biomass into pre-labeled bag. Make sure to remove any biomass that might have falling into collection bin and add to same collection bag.
    - To collect biomass without first removing water, place collection bin under sampler and place sieve over collection bin. Next release springs from frame and open cap enough to break seal. Once seal has been broken, push down on arm spring to open foot plate. Sample should then drop into sieve atop collection bin.
    - Repeat core tube rinse and biomass rinse and placement into collection bag as described above.
    - Repeat sample collection process a total of 3 times, sequentially from each collection site and place rinsed biomass from each collection into one combined bag.
- Store the bag in a cooler with ice

● To collect benthic macroalgal biomass and sediment samples
- If sampling by box core, slowly lower box core at the sampling site until it hits the benthos at the designated sample point, release lever that closes the box core and

slowly bring it up, place it in the plastic dish bin and open it so that it releases the sediment and any algae.

    - If box core surface area = surface area of dip net or basket, then pick out any algae and place it into composited pre-labeled bag with biomass from surface water.
    - If box core surface area ≠ surface area of dip net or basket, then pick out any algae and place it into a separate pre-labeled bag.
  - If sampling using SUBS sampler method load sampler and slowly lower device until it hits the benthos. Make sure a layer of sediment will be retrieved as part of the sample, to ensure a good seal. Release cap and foot plate as described above. Once cap and foot plate have been closed creating tight seal. Pull device back up to surface and place on SDS. Place collection bin under SUBS sampler. Release springs from cap screws and release pressure by slightly opening cap. Push down on frame arm spring as described above and open so that it releases sediment and algae into plastic collection bin. Repeat two additional times.
  - If using SUBS sampler to collect macroalgae then pick out any algae and place into pre-labeled collection bag.
  - Store the bag in a cooler with ice
- To collect sediment samples:
  - Insert the sediment syringe sampler into the sediment collected in the box core or SUBS sampler past 1 cm depth (marked as a hash on the side of the sampler) while pulling up on the syringe plunger.
  - Remove the sampler from the sediment.
  - Gently push in the plunger, expelling sediment until only the top 1 cm remains in the syringe.
  - Open a pre-labeled 50 mL centrifuge tube and push the plunger to expel the 1 cm of sediment.
  - Repeat the syringe process again to collect one more sediment plug. There should be a total of 2 sediment plugs collected at each sampling point.
  - Store in cooler with ice
- Repeat this process at each point

5. In-Situ Water Chemistry

Measurements of water chemistry can provide additional information on diel variability in system productivity and respiration and can serve as additional information on eutrophication in the estuary. Both vertical profiles and continuous measurements can provide contextual information for interpretation of macroalgal cover.

5.1. Vertical Water Column Chemistry Profiles

Vertical water column chemistry profiles can provide information on the spatial variability in water column chemistry in the system and can be used to estimate valuable indicators like hypoxic volume. Profiles are recommended as a supplemental measurement, particularly for estuaries with significant sub-tidal habitat for fish and invertebrates. A vertical, water column chemistry profile may be taken at the deepest point of the channel at each transect site or at the deepest point in the estuarine sub-segment for subtidal systems for a total of 3 profiles for each estuary segment. Use a multi-parameter water quality meter (or sonde) to measure temperature, DO, pH, turbidity and chlorophyll fluorescence at predefined depth intervals. Measurement intervals for profiles are based on the site depth (See Table 2). The multi-probe or sonde must be heavy enough to minimize wobbling as it is lowered and raised in the water column. Experiment with the meter/sonde prior to sampling and add weight to the cable, if needed. The meters and probes are delicate; take care to avoid putting the probe into contact with the bottom sediments. An accurate measure of the site depth will help prevent this from occurring. Record weather and water conditions when taking any in situ measurements.

Vertical Profile Procedure:

1. Define roles. One crew member should be lowering the instrument while the other records site information, start and end time for profile, and depth interval readings for water chemistry parameters.
2. Take an accurate depth reading. Delineate depth intervals, if the depth is less than 0.5 meters take a measurement at the surface and bottom, if the depth is >0.5 but < 1.0 m, take measurements at 3 evenly spaced depth intervals, if the depth is greater than 1 meter, take a measurement at 5 evenly spaced depth intervals.
3. Lower the sonde into the water. At each depth interval, ensure the measurements have stabilized prior to recording the readings. Record measurements of temperature, DO, turbidity, specific conductivity, and pH, and chlorophyll fluorescence, at the predetermined depth intervals on the data sheet. Water chemistry parameters may also be logged on the meter/sonde, although paper back-up measurements should always be recorded as a fail-safe against logging failure.
4. Return sonde to the surface. Record a duplicate measurement of DO must be made at the surface and recorded. This measurement should be within ± 0.5 mg/L of the initial surface reading. This measurement is used to assess measurement precision and possible calibration drift during the profile.

5.2. Continuous, In-situ Water Column Chemistry

Moored sensors can provide a time series of this diel variability and is recommended as a supplemental measurement. For each estuary, estuary segment an index site should be selected as the continuous monitoring station. The site should be selected in the deepest area of the estuary where potential to capture hypoxia is maximized, while accounting for the need for the site to be accessible and minimize potential vandalization. Data sondes will be deployed on a moored buoy or stationary structure (piling, post, etc.). The sonde should be deployed at the bottom of the water column approximately 0.5 m above the sediment. The location of the continuous monitoring station should be recorded with a GPS unit.

The following parameters will be continuously monitored at each site: temperature, conductivity, dissolved oxygen, pH, turbidity, and chlorophyll fluorescence (to assess phytoplankton biomass). These parameters will be measured using *in situ* sensors equipped with data loggers (data sondes) or another moored sensor platform. These data sondes should be programmed to measure parameters every 30 minutes and, with routine maintenance, should be deployed at minimum throughout the growing season to capture development and decay of algal blooms. Data sondes will need to be removed from the water to download the data and for maintenance (removal of biofouling, re-calibration, replace batteries, etc.) approximately once every two or three weeks.

Pre-Deployment Protocol.

1. In the laboratory, within 2 days of deployment, data sondes should be calibrated according to manufacturer's specifications using commercially available standards. Evaluate condition of the sonde:
    a. Replace/recharge batteries
    b. Ensure battery case is sealed
    c. Ensure probes are clean
    d. Clean casing and check for damage
    e. Check wiper functioning
    f. Check that the data sonde is set up with the correct date and time
    g. Ensure the sonde has enough available memory for the expected deployment duration
2. Copper tape and wire can be applied to the probes and sonde casing to minimize biofouling (refer to manufacturer's recommendations to minimize fouling).
3. Run a test of the sonde's functionality by programming the sonde to record the required parameters and leaving it in a bucket of water overnight. The following morning, check that the sonde logged all the required constituents and that they fall within the expected range.
4. Program the sonde for unattended sampling at 30-minute intervals. You may start logging in the laboratory or start logging in the field if you have a field computer or the hand-held interface for the sonde.

Deployment Protocol.

1. Install an anchored mooring with surface float or stationary structure (if the lake is shallow) for the sondes. Sondes may be deployed within an additional structure to prevent theft/vandalism, but the structure must allow flow through to the sonde.
2. If you have not done so in the laboratory, begin the logging program for each sonde.
3. Mount a data sonde 0.5 meters above the sediment.

4. Record the date and time of the deployment and GPS coordinates of the monitoring station.

Recovery Protocol.

1. Sonde recovery should be done approximately every two to four weeks, depending on the amount of fouling estimated at the site.
2. Pull the sondes from the water, rinse with Tap or DI water and dry as much as possible
3. Evaluate the condition of the sonde:
    a. Note if there is any damage to the sonde casing
    b. Note if there is any damage to any of the probes
    c. Photo document the sonde paying attention to the sensors and the sensor guard
    d. Note anything unusual in the metadata; animals or algae growth in the sensor guard will result in data spikes that may require additional counter measures to prevent in future deployments (e.g., wire caging).
4. Connect sonde to computer or hand-held interface to establish communications. Note whether the sonde logged for the full time or if stopped logging during deployment. Transfer data files to the computer or interface.
5. Quality control standards should be measured during each maintenance event to estimate sensor drift during the deployment. Record all measurements in the standards once the sensors stabilize.
6. If the sonde is to be re-deployed, clear the sonde memory to prepare for the next deployment and follow the pre-deployment protocols.

6. Laboratory Processing

6.1. Macroalgae Processing

All macroalgal biomass samples must be processed within 48 hours of collection, ideally upon returning to the lab or during the workday immediately following field collection (i.e., all samples collected on a Monday should be processed the following Tuesday). One biomass sample will take approximately 30 minutes to 1 hour to process so plan accordingly. It is recommended to have a field and lab processing team.

All biomass samples will need to be cleaned of all mud, bugs, and debris, weighed wet, dried in an oven at 60° C, and then weighed dry. All samples should be kept refrigerated at 4°C in the dark until they are processed (do not freeze). Once samples have a wet and dry weight they can be discarded.

If the amount of biomass in each sub-sample (from the 5 sites along each transect or within each sub-segment), they can be composited into a single sample representative of that segment transect/sub-segment. In this scenario, you will have 3 biomass composites per estuary segment. If the biomass from each sub-sample is large (enough to fill the Ziploc bag), weigh each subsample individually and add 5 subsamples at the end. This will improve accuracy of the weight measurements.

6.2. Equipment

- Data sheet
- Biomass Samples
- Labels
- Weighing Dishes
- Sharpie
- Small wash tub
- Forceps
- Estuarine water or seawater
- Deionized (DI) water
- Gloves
- Salad Spinner

6.3. Macroalgal Biomass Lab Protocol

- Wear gloves
- Take one biomass sample from the refrigerator
- Carefully remove biomass sample from bag and place into small wash tub
- Fill wash tub with seawater
- Let macroalgae float in seawater to gently clean off all mud, insects, and debris. This may take several rinses to remove all non-algae material
- Once clean, dip the algae in DI water to remove the salts

- Lay out algae carefully on aluminum foil
- Sort algae into red or green (or genus level if identifying)
- Using your gloved hand, squeeze or shake excess water out of algae; if there is a lot of biomass and/or biomass is in large sheets, use a salad spinner to remove excess water
- Tare the balance
- Write the sample ID on the bottom of the dish with a sharpie
- Record weight of dish on the data sheet
- Carefully place algae on dish and reweigh
- Record wet weight on data sheet
- Dry algae in oven at 60°C for two or three days
- Weigh dish with algae and record the dry weight on data sheet
- Return to oven after an hour from initial measurement, then reweigh and record the weight on the data sheet. If the weight is the same as the first dry weight, then use that measurement. If dry weight is different, then return dish with algae back into the oven and repeat the next day or until measurement is the same
- Record final dry weight of dish with algae on data sheet
- Discard algae sample and dish and repeat this process with other algae samples.

6.4. Sediment Processing

- Wear gloves
- Tare the balance with nothing on it (make sure it reads 0.00 g)
- Place a large weigh dish on the scale and record the dish weight on data sheet (DO NOT RE-TARE THE BALANCE).
- Combine the sediment plugs from each of the five subsamples from each transect/sub-segment by carefully removing the sediment from each centrifuge tube into the pre-weighed, large weigh dish. Use a spatula to scrape out all the sediment, you may also use a squirt bottle filled with DI water to remove sediment but be careful not to over load the dish.
- Carefully stir the sediment in the weigh dish to homogenize the sediment from the five sub-samples
- Place the dish in an oven at 60°C for two or three days to dry the sediment
- Once sediment is dry, re-weigh the dish, subtract the weight of the dish and record the dry weight of the sediment.

Sediment Grinding Protocol

To be completed after sediment is dry and dry weights have been recorded.

- Break off a chunk of dried sediment (~8 grams), you may need to use a hammer to break the sediment up.
- Grind the 8 g sediment chunk into fine powder with a mortar and pestle.
- Place glass scintillation vial labeled for CHN onto the balance and press "tare"
- Weigh out at least 1 gram (preferably 2 g) into the scintillation vial labeled for total organic carbon and total nitrogen (CHN) analysis.
- Place a glass scintillation vial labeled for TP onto the balance and press "tare"

- Weigh out at least 2 grams into the total phosphorus (TP) vial.
- Record that the splits were collected onto the data sheet.
- If samples are to be sent to a contract lab, wrap the vials bubble wrap and prepare for shipment.

Sediment Grain Size Protocol:

- Tare the balance with nothing on it (make sure it reads 0.00 g)
- Place a weigh dish on the scale and record the dish weight on data sheet (DO NOT RE-TARE THE BALANCE).
- Weigh a series of weigh dishes and record the weights on the data sheets.
- Write the sample ID on the bottom of a weigh dish with the sharpie
- Weigh the remainder of the dried sediment (sediment not used for grinding) into the weigh dishes and record the weight as "total dry weight" on the sediment grain size portion of the table on the data sheets.
- Place the dried sediment into a small 150 mL bottle and fill half to ¾ full with 5% sodium metaphosphate solution (5 grams of sodium phosphate in 1000mL of water).
- Place in sonicator for at least 30min. Be sure that sonicator is filled to the recommended level with tap water.
- After the sample has been sonicated, pour the sediment into a 65mm sieve
- Rinse all sediment from the bottle into the sieve using a squirt bottle filled with DDI water, rinsing out all fine particles from the sieve. Rinse the sediment until the water comes out clear.
- Using a spatula and squirt bottle, remove all sediment from the sieve into the original weigh-dish.
- Place dish in the oven at 60 °C for two to three days until dry.
- Rinse the metal table down so that all the sediment has been cleaned from the table.
- Re-weigh the dish and record the new dry weight on the data sheets as "Sand weight".
- Re-weigh in an hour to make sure the weight has stabilized and record final unchanging weight on the data sheets.
- Discard sediment once final weights are recorded
- The difference between the total dry weight and the sand weight is the weight of the fine-grained sediment. Divide the fine-grained sediment weight by the total weight and multiply by 100 to get Percent Fines.

7. Quality Assurance and Quality Control

7.1. Field Team Training

All field teams should conduct practice runs of the sampling, prior to the start of the sampling period, so they can confidently collect samples without contamination. Following initial training, each team should explore the estuary with wildlife specialists appointed by the landowners (Fish and Game, etc.) to identify areas of sensitive habitat that should be avoided during sampling. These meetings should create a sampling plan designating specific routes to sampling areas that can be adhered to during each sampling event. The Lead Scientist from each organization will be responsible for ensuring that their field personnel have been trained properly on all field methods and procedures that will be used during the survey. It will be their responsibility to review the Field Operations Manual with their field crews, and to make sure that each person understands that these procedures must be followed during the survey. Personnel that cannot perform a required operation will not participate in conducting that operation.

7.2. Data QA/QC

Field Data Sheets are used to record QA information and flags for questionable data. Site observations/information collected on the Data Sheet include:

- Current weather conditions
- Status of the estuary mouth (open, closed, restricted)
- Presence/absence of large debris
- Construction in or near the estuary
- Any other site-specific considerations that may affect data quality

These data will help provide context for spurious data or missing data.

All data collected on the data sheet should be entered clearly. Team Leaders should double check that all samples have been collected, have been marked on the chain of custody forms, and have been stored on ice for transport back to the laboratory, and that the Data Sheets have been completely filled out before leaving the site.

Information collected on the Data Sheets should be transferred to an electronic format back in the lab. This transfer should be conducted by the individual who recorded the data in the field. User QA/QC checks that should be conducted are as follows:

- Ensure all columns are properly labeled,
- Ensure all fields are populated with correct data in the proper format
- Ensure the template has not been altered.

8. Data Interpretation

A framework to assess estuarine condition with respect to eutrophication based on macroalgal biomass has been proposed for California estuaries (Sutula et al. 2017). This assessment framework is a quantitative scheme intended to classify estuarine segments in tiers of ecological condition, from very high to very low, based on risk of potential adverse effects of eutrophication, similar to the construct of a biological condition gradient model. The intent is to provide a decision framework for quantifying the extent to an estuary is supporting beneficial uses with respect to nutrients. The assessment framework is comprised of two elements: 1) conceptual models that define symptoms (indicators) of eutrophication, the adverse effects on estuarine beneficial uses, 2) classification tables that specify magnitude, frequency and duration of macroalgal biomass associated with adverse effects.

Each estuary segment should be classified separately. Figure 7 provides the proposed assessment framework to diagnose eutrophication in seagrass dominated and unvegetated intertidal and subtidal habitats. Bins of biomass are used to categorize an estuarine segment into five categories from very high to very low ecological condition. The moderate category merits management attention, including additional monitoring of fauna to further investigate potential impairment.

Condition Category	Unvegetated	Seagrass
Very Low	≥140	≥170
Low	70 to < 140	100 to < 170
Moderate	30 to < 70	75 to < 100
High	15 to < 30	15 to ≤ 75
Very High	≤ 15	≤ 15

Figure 7. Proposed assessment framework to diagnose eutrophication using macroalgae in seagrass dominated and unvegetated intertidal flat and subtidal habitat for California estuaries. Assessment is based on average biomass (grams of dry weight per meter squared) of the two highest consecutive sampling periods if sampled monthly; if sampled bi-monthly, the assessment is based on the maximum segment-averaged biomass from any single sampling event. In habitats in which seagrass beds are distributed into the intertidal zone, the seagrass density is sparse or intermixed with unvegetated habitat, the framework for unvegetated intertidal and shallow subtidal habitat should be employed.

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Appendix A. Resources for Avoiding Introduction of Invasive Species

The following is an adaptation of an excerpt taken from an EMAP-based Quality Assurance Project Plan developed by the California Department of Fish and Game Aquatic Bioassessment Laboratory (2008).

Organisms of concern in the U.S. include, but may not be limited to, Eurasian watermilfoil (Myriophyllum spicatum), New Zealand mud snail (Potamopyrgus antipodarum), zebra mussel (Dreissena polymorpha), Myxobolus cerebralis (the sporozoan parasite that causes salmonid whirling disease), and Batrachochytrium dendrobatidis (a chytrid fungus that threatens amphibian populations).

Load the boat on the trailer and inspect the boat, motor, and trailer for evidence of weeds and other macrophytes. Clean the boat, motor, and trailer as completely as possible before leaving the launch site. Inspect all equipment for pieces of macrophyte or other organisms and remove as much as possible before packing the nets for transport. Pack all equipment and supplies in the vehicle and trailer for transport; keep them organized as presented in the equipment checklists (Appendix A). Lastly, be sure to clean up all waste material at the launch site and dispose of or transport it out of the site if a trash can is not available.

Field crews must be aware of regional species of concern and take appropriate precautions to avoid transfer of these species. Crews should make every attempt to be apprised of the most up-to-date information regarding the emergence of new species of concern, as well as new advances in approaches to hygiene and decontamination to prevent the spread of such organisms (e.g., Hosea and Finlayson, 2005; Schisler et al., 2008).

There are several online resources regarding invasive species, including information on cleaning and disinfecting gear:

Whirling Disease Foundation
www.whirling-disease.org

USDA Forest Service - Preventing Accidental Introductions of Freshwater Invasive Species
www.fs.fed.us/invasivespecies/documents/Aquatic_is_prevention.pdf

California Department of Fish and Game
www.dfg.ca.gov

U.S. Geological Survey Nonindigenous Aquatic Species: general information about freshwater invasive species
http://nas.er.usgs.gov

Protect your Waters - Co-sponsored by the U.S. Fish and Wildlife Service
www.protectyourwaters.net/hitchhikers

The California State Water Resources Control Board Aquatic Invasive Species website
www.swrcb.ca.gov/water_issues/programs/swamp/ais