San Joaquin River Dissolved Oxygen Total Maximum Daily Load Program

Long Term Monitoring Plan

Report 7.2.1

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List of Acronyms

BQE	Biological quality elements
CDEC	California Data Exchange Center
CRAM	California Rapid Assessment Method
DO	Dissolved oxygen
DWSC	Deep Water Ship Channel
EERP	Ecological Engineering Research Program
SJR	San Joaquin River
SWAMP	Surface Water Ambient Monitoring Program
TDS	Total dissolved solids
TMDL	Total maximum daily load

Introduction

The objective of this report is to make recommendations for a long-term monitoring plan for the San Joaquin River (SJR) and estuary between Lander Avenue in the south and Disappointment Slough in the north (Figure 1). The purpose of the proposed monitoring plan is to assess compliance with any future dissolved oxygen (DO) or nutrient total maximum daily load (TMDL) allocation. Scientific and engineering studies have indicated that an integrated watershed management approach will be required to allow full compliance with DO objectives and other water quality goals in the estuary portion of the SJR, so it is recommended that ecosystem level assessments be conducted as part of future monitoring programs and that objectives for overall ecosystem health be established for the SJR.

Scientific and engineering studies conducted in the SJR and estuary between 2007 and 2013 examined factors contributing to low DO conditions in the SJR estuary and are summarized in Stringfellow and Camarillo (2014). Water quality sampling sites were selected for this plan based on previous water quality monitoring and research by the Ecological Engineering Research Program (EERP) that identified the sources of nutrients and oxygen-demanding substances in the watershed (Stringfellow and Camarillo, 2014). Continued monitoring of water quality in the basin will allow continuity with prior monitoring and will support continued modeling efforts. However, it is also recommended that measurement of biological quality elements (BQE) be initiated in addition to water quality monitoring and that reference conditions for the SJR be established to allow the development of ecological metrics and the establishment of remediation goals for this highly impaired river. Measurements of BQE are now being widely implemented in Europe and, in conjunction with the establishment of reference conditions, are being used to establish overall metrics on river health that are more complete and accurate than can be determined by water quality monitoring alone (European Commission, 2000; Pardo *et al.*, 2012; Birk *et al.*, 2013).

Water Quality Monitoring

Frequency of Monitoring Activities

For a complete and thorough program, water quality grab samples should be collected and analyzed every month, year-round. The minimum program should include water quality measurements every other month between April 1st and November 30th. This reduced time period corresponds with the agricultural irrigation season and the dry season when low DO is most likely to occur. Additionally, during September, October, and November, the DO regulatory standard in the Deep Water Ship Channel (DWSC) is raised from 5 mg/L to 6 mg/L to encourage fish migration (California Regional Water Quality Control Board Central Valley Region, 2005), so this is a critical time for water quality sampling.

Continuous monitoring should be continued for flow at key locations in the watershed. Prior studies by the EERP have found that accurate load calculations in the San Joaquin River (within 10% of the true load) can be determined with as few as 3-4 grab samples and continuous flow measurements taken during the irrigation season (Gulati et al., 2014). Continuous monitoring of DO should be continued in the DWSC and supplemented with profiling studies to determine the relationship between the sensors at Rough & Ready Island and the full extent of the low DO conditions in the channel (Spier *et al.*, 2013).

Location of Monitoring Activities

Tables 1 and 2 list the sampling sites, their locations, and their designation of primary or secondary importance to the long-term monitoring plan. Figures 2 and 3 show maps of the proposed sampling site locations.

At several key locations in the SJR Estuary and Upstream study areas, flow monitoring equipment and continuous water quality monitoring equipment such as YSI 6600 sondes (and similar multi-parameter sensor systems) have been deployed by various agencies (United States Geological Survey, California Department of Water Resources, etc.). Data from these locations should be used to provide continuous flow measurements for load calculations. Second, continuous measurement of total dissolved solids (TDS) can serve as a “true-load” check to compare with mass load calculations that are based on grab sample data. Flow and water quality data should be collected from monitoring stations (via the California Data Exchange Center (CDEC) or other data repositories), checked based on quality assurance standards, and used to determine mass loading contributions to the San Joaquin River from major tributaries.

Recommended grab sampling sites were categorized as having primary or secondary importance based on their flow, historic mass loads, and continuity with past and on-going monitoring data sets. Primary recommended grab sample sites include four Estuary sites and nine Upstream sites. Secondary recommended sites include 13 Estuary sites and 10 Upstream sites. Although the secondary upstream sites listed are not the largest contributors of nutrients and oxygen-demanding substances to the DWSC, these sites often have high concentrations of pollutants and low flows, making them optimal targets for remediation actions. Measurements made along the SJR sites, other than at Vernalis and Mossdale, were listed as secondary sites because these sites provide useful information about which river sections are receiving the highest mass loadings of pollutants and which transformations are occurring along the main stem of the river. In the Estuary, the tributaries are not currently measured for flow so they were included as secondary sites to analyze, as flow stations would need to be installed to accurately calculate their mass load contributions to the DWSC.

Constituents to be Monitored

Tables 3 and 4 summarize the recommended laboratory and field water quality parameters to be measured as part of the long term monitoring plan. During sampling trips, measurements should be made on time-sensitive parameters *in-situ* using an YSI 6600V2 sonde (Yellow Springs Instruments, Ohio) or other similar device. Measurements that should be made *in-situ* include chlorophyll and phycocyanin fluorescence, turbidity, temperature, specific conductance, dissolved oxygen and pH. Grab samples should be taken for measurements that cannot be completed in the field including chlorophyll and pheophytin concentrations, total suspended solids, and nitrogen and phosphorus nutrients. Algal loads in the DWSC contribute to low DO concentrations when the algae decompose in the light-limited environment. Nutrients and basic water quality parameters such as pH, temperature, and turbidity are of primary importance because they effect algal growth. Additionally, ammonia is important because it directly contributes to oxygen demand. Measurements such as total organic carbon, volatile suspended solids, and biochemical oxygen demand can be used as secondary measurements of oxygen-consuming materials. Microcystin is a toxin produced by cyanobacteria, which, unlike other algae, are not well-characterized by fluorescence measurements and have been observed to represent an increasing portion of the algae found in the Estuary in recent years. While microcystin does not contribute directly to low DO, it is a good proximal measurement for cyanobacteria biomass. All samples should be collected and analyzed according to procedures outlined in a quality assurance plan (i.e. Spier et al., 2011) and should be compatible with the

Surface Water Ambient Monitoring Program (SWAMP) (Surface Water Ambient Monitoring Program Quality Assurance Team, 2008).

Monitoring of Biological Quality Elements

Overall stream health and ecosystem functionality should be monitored. In addition to water quality measurements, measurements of BQEs such as benthic flora and fauna and fish populations should be used as metrics of ecosystem health (European Commission, 2000; Pardo *et al.*, 2012; Birk *et al.*, 2013). In addition to other BQEs, the California Rapid Assessment Method (CRAM) (California Wetlands Monitoring Workgroup, 2009) should be applied for the assessment of riparian habitat in the SJR valley. This method was developed specifically for California and has been successfully applied for ranking and grading ecosystem function in the SJR basin (Stringfellow *et al*. 2010). The BQEs and CRAM measurements can be made annually until baseline conditions are determined, then the frequency of measurements can be reduced to every two years or less frequently. BQEs and CRAM results are used in conjunction with water quality measurements in indices of ecosystem health and are quantitative measures of ecosystem status (California Wetlands Monitoring Workgroup, 2009; Stringfellow *et al*. 2010; Pardo *et al.*, 2012; Birk *et al.*, 2013). Remediation and restoration activities in the basin directed toward improving water quality, BQEs indices, and CRAM results will provide better outcomes than activities directed at improving water quality outcomes alone.

Conclusions

The San Joaquin River is an impaired waterbody which is out of compliance with DO and other water quality criteria. Monitoring is needed to provide guidance for remedial activities and to gauge progress in the restoration of the river ecosystem. A long term water quality monitoring program is necessary for management of the river, but water quality monitoring needs to be supplemented with biological monitoring if management activities are to be fully evaluated. Combined water quality and biological monitoring is needed to inform management decisions and restoration activities in the basin.

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Tables

Table 1. Proposed Estuary Sample Sites

Site	Sample Station Name	Latitude	Longitude	Primary or Secondary Importance
402	Light 18 (Node 96) DWSC	38.0259	-121.4682	Primary
406	Light 38 DWSC	37.9836	-121.3887	Primary
426	Turning Basin at Morelli Park Launch	37.953	-121.3064	Primary
4	SJR at Mossdale Park	37.7871	-121.3076	Primary
433	Paradise Marina (Node 70)	38.0442	-121.4195	Secondary
410	Bear Creek at Trinity Bridge	38.0432	-121.3708	Secondary
420	Mosher Slough at Mariners Dr.	38.0325	-121.3651	Secondary
421	5 Mile Slough at Hazelwood Ave	38.0138	-121.3491	Secondary
424	14mi slough	38.006	-121.3979	Secondary
428	RM 33.2 Upstream of Acker Isl.	37.9937	-121.4326	Secondary
425	Turner Cut	37.9852	-121.4677	Secondary
405	Calaveras River	37.9813	-121.314	Secondary
413	Smith Canal at Yosemite lake	37.9674	-121.3067	Secondary
427	RM 39 near Louise park	37.954	-121.3454	Secondary
11	French Camp Slough	37.9192	-121.3119	Secondary
127	SJR at Brant Bridge	37.8649	-121.3227	Secondary
2	SJR at DosReis Park	37.8306	-121.3116	Secondary

Table 2. Proposed Upstream Sample Sites

Site	Sample Station Name	Latitude	Longitude	Primary or Secondary Importance
12	Stanislaus River at Caswell Park	37.7016	-121.1772	Primary
5	SJR at Vernalis-McCune Station (River Club)	37.6794	-121.265	Primary
14	Tuolumne River at Shiloh Bridge	37.6035	-121.1313	Primary
34	Ingram Creek	37.6003	-121.2251	Primary
29	Turlock ID Harding Drain	37.4643	-121.0309	Primary
21	Orestimba Creek at River Road	37.414	-121.0149	Primary
16	Merced River at River Road	37.3504	-120.962	Primary
18	Mud Slough near Gustine	37.2625	-120.9056	Primary
19	Salt Slough at Lander Avenue	37.248	-120.8519	Primary
25	Modesto ID Main Drain to Stan. R. via Miller Lake	37.6703	-121.219	Secondary
6	SJR at Maze	37.6414	-121.229	Secondary
28	Turlock ID Westport Drain Flow Station	37.542	-121.0941	Secondary
36	Del Puerto Creek Flow Station	37.5395	-121.1221	Secondary
7	SJR at Patterson	37.4937	-121.0808	Secondary
57	Ramona Drain at Levee	37.4788	-121.0685	Secondary
8	SJR at Crows Landing	37.432	-121.0117	Secondary
30	Turlock ID Lateral 6 & 7 at Levee	37.3978	-120.9723	Secondary
10	SJR at Lander Avenue	37.2942	-120.8513	Secondary
44	San Luis Drain End	37.2609	-120.9052	Secondary

Table 3. Recommended Laboratory-Based Water Quality Parameters

Parameter	Importance
Chlorophyll-a	Primary
Phaeophytin-a	Primary
Total Suspended solids	Primary
Total Nitrogen	Primary
Nitrate and Nitrite Nitrogen	Primary
Ammonia Nitrogen	Primary
Orthophosphate, Soluble	Primary
Total Phosphate	Primary
10-Day Biochemical Oxygen Demand	Secondary
10-Day Carbonaceous and Nitrogenous Biochemical Oxygen Demand	Secondary
Total Organic Carbon	Secondary
Dissolved Organic Carbon	Secondary
Volatile Suspended Solids	Secondary
Silica	Secondary
Alkalinity	Secondary
Microcystin	Secondary

Table 4. Recommended Field-Based Water Quality Parameters

Parameter	Importance
Chlorophyll-a Fluorescence	Primary
Phycocyanin (Blue Green Algae) Fluorescence	Primary
Turbidity	Primary
Temperature	Primary
Specific Conductance	Primary
Total Dissolved Solids	Primary
Dissolved Oxygen (DO)	Primary
pH	Primary

Figures

Figure 1. The San Joaquin River and Estuary. The Vernalis Monitoring Station marks the legal limit of the Sacramento-San Joaquin Delta, where the San Joaquin River transitions from a riverine ecosystem to a fresh-water estuary.

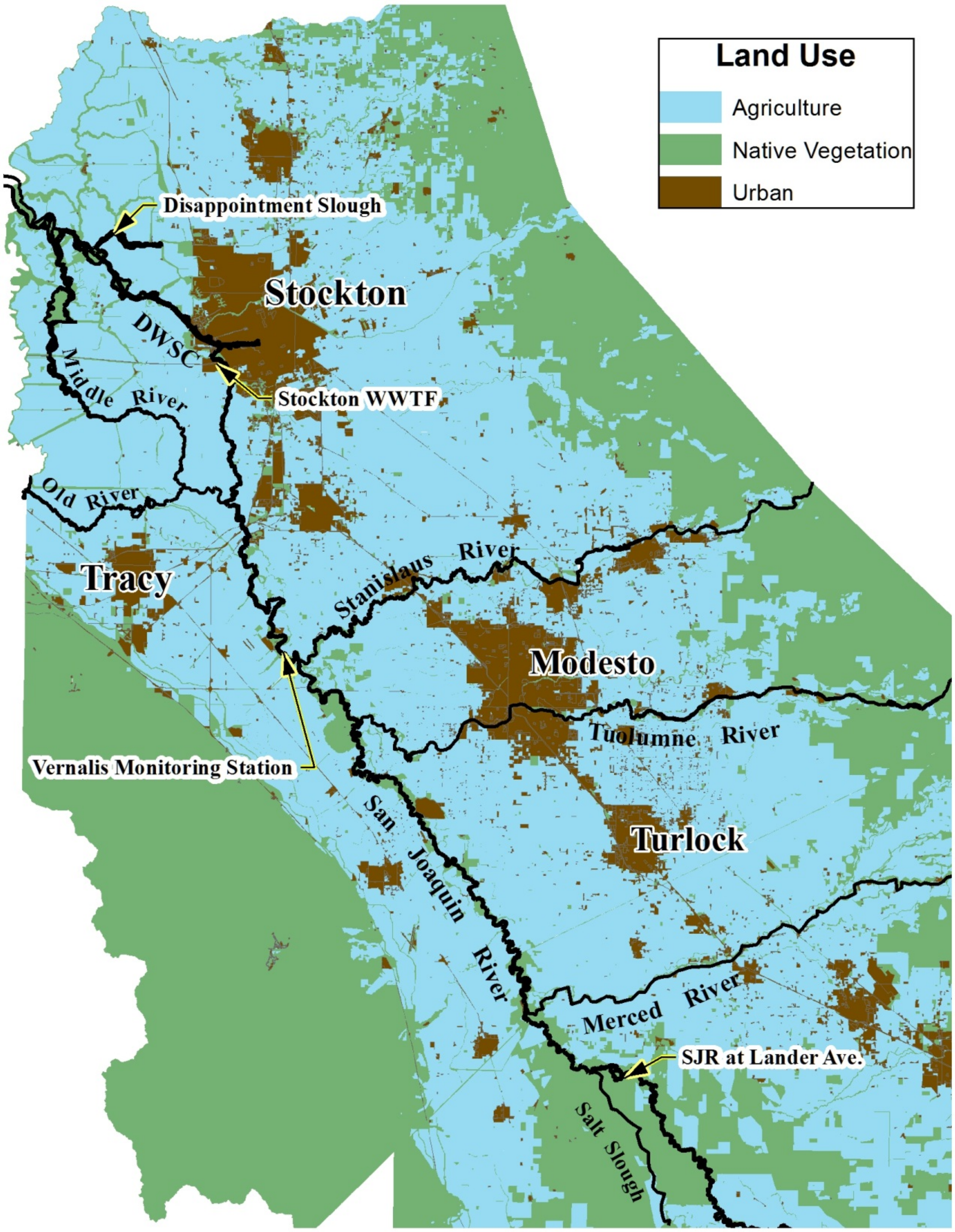

Figure 2. Suggested Core Estuary Grab Sample Site Locations.

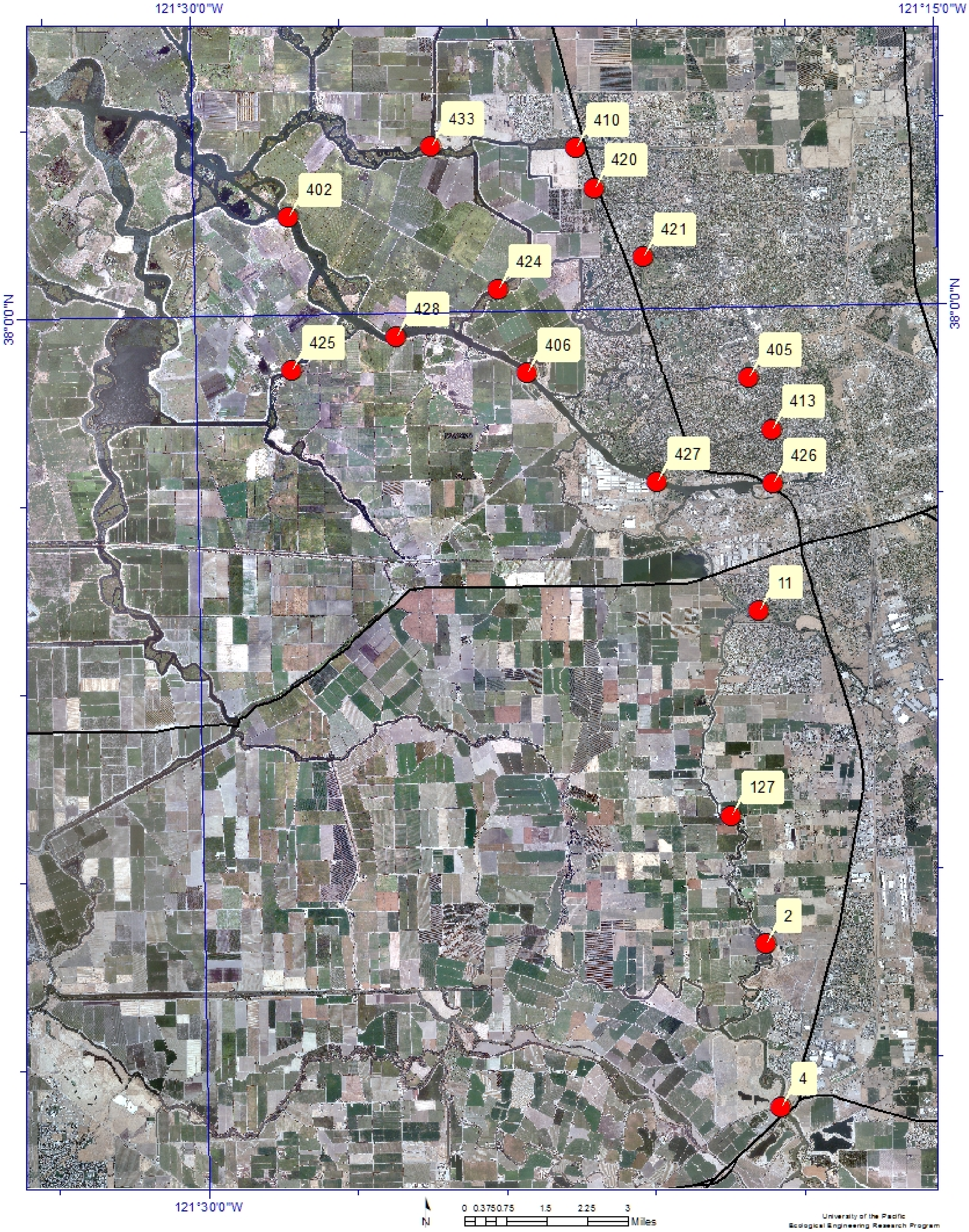

Figure 3. Suggested Core Upstream Grab Sample Site Locations.