UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

Michael Montgomery, Executive Officer
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, California 94612

Subject: Amendments to the Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan) to Establish Site-Specific Water Quality Objectives for Dissolved Oxygen in Suisun Marsh

Dear Mr. Montgomery:

I am pleased to approve the revised water quality standards in the subject amendment consistent with the requirements of section 303(c) of the Clean Water Act (CWA) and 40 C.F.R. Part 131. Supported by robust science and stakeholder engagement, the standards include the establishment of site-specific water quality objectives for dissolved oxygen (DO) in Suisun Marsh.

Summarized below are the approved revised standards, which take effect immediately for CWA purposes. Incorporated as part of this letter are Enclosure A (Table of Approved Standards) and Enclosure B (EPA's detailed analysis of the standards and rationale for approval).

Approved Revised Standards

EPA approves the revised site-specific water quality objectives for DO in Suisun Marsh, which include:

- Acute DO objective of 3.8 mg/L minimum, as a daily average, year-round in all sloughs and channels;
- Chronic DO objective of 5.0 mg/L minimum, as a 30-day running average, year-round in all sloughs and channels; and
- Chronic DO objective of 6.4 mg/L minimum, as a 30-day running average, from January 1 through April 30 in Montezuma, Nurse, and Denverton Sloughs only.

I look forward to our continued partnership to protect water quality and advance human health and wildlife protection. Please call me if you would like to discuss further, or your staff may contact Daniel Oros at (415) 972-3583 with specific questions concerning this approval.

Sincerely,

July 2, 2019

Tomás Torres
Director, Water Division

Enclosures

cc: Rebecca Fitzgerald, SWRCB
Kevin Lunde, San Francisco Bay RWQCB

Enclosure A

Table of Approved Standards

DO Objectives	DO Concentrations	Applicability
Acute Objective	3.8 mg/L minimum (daily average)	Year-round in all sloughs and channels
Chronic Objectives	5.0 mg/L minimum (30-day running average)	Year-round in all sloughs and channels
	6.4 mg/L minimum (30-day running average)	January 1 through April 30 in Montezuma, Nurse, and Denverton sloughs only

Enclosure B

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

MEMORANDUM

DATE: July 1, 2019

SUBJECT: Recommendation for EPA Approval Under Clean Water Act Section 303(c) of Amendments to the Water Quality Control Plan for the San Francisco Bay Basin to Revise Dissolved Oxygen Water Quality Objectives for Suisun Marsh.

FROM: Daniel R. Oros, PhD

THROUGH: Terry Fleming, Manager, Water Quality Assessment Section

TO: Administrative Record

I. Background

This memorandum provides the rationale for the recommendation that EPA approve the water quality standards provisions included in the "Amendment to the Water Quality Control Plan for the San Francisco Bay Region (Basin Plan) to Establish Site-Specific Objectives and TMDL for Dissolved Oxygen in Suisun Marsh and to Amend the San Francisco Bay Mercury TMDL to Include Suisun Marsh." The subject amendment was adopted by the San Francisco Bay Regional Water Quality Control Board (Regional Board) on April 11, 2018 under Resolution No. R2-2018-0015, approved by the State Water Resources Control Board (State Board) on August 21, 2018 under Resolution No. 2018-0040, and was approved by the California Office of Administrative Law on November 29, 2018 (OAL Matter No. 2018-1016-04). The request for approval and the State's administrative record were received by EPA Region 9 on September 28, 2018 and the State's Office of Administrative Law (OAL) approval was received on December 7, 2018. EPA considers the State's submittal complete as of the date of receipt of the full submittal, December 7, 2018.

This memorandum pertains only to the portions of the amendment that are subject to EPA approval under Clean Water Act (CWA) section 303(c) and 40 CFR Part 131.21. Pertinent changes that are under the authority of CWA section 303(c) include: the establishment of site-specific water quality objectives for dissolved oxygen in Suisun Marsh and clarifying revisions to the Basin Plan in Chapter 2 (Beneficial Uses) and Chapter 3 (Water Quality Objectives).

Around 2010, the Regional Board started working on a package to determine protective water quality objectives for dissolved oxygen in response to successive fish die-offs during certain

seasons in western portions of Suisun Marsh. Duck clubs and other managed wetlands periodically discharge nutrient-enriched water that cause low dissolved oxygen levels in back-end marshes. To protect aquatic life beneficial uses, the Regional Board, while working directly with stakeholders, established revised acute and chronic site-specific water quality objectives for dissolved oxygen in Suisun Marsh. The acute objective is 3.8 mg/L minimum (daily average) year-around in all sloughs and channels. The chronic objectives are 5.0 mg/L minimum (30-day running average) year-around in all sloughs and channels and 6.4 mg/L minimum (30-day running average) from January 1 through April 30 in Montezuma, Nurse and Denverton sloughs only.

In addition, the Regional Board made minor clarifications or corrections to Chapters 2 and 3 of the Basin Plan. These editorial changes are intended to clarify or correct narrative passages or specific tables of the Basin Plan. These proposed non-regulatory edits do not affect or change any State or regional policy, program, or implementation plan. The revisions are described in detail in Table 13-1 (see Staff Report, p.85). The specific changes, shown in underline-strikeout, are included in the Basin Plan amendment (see Regional Board Resolution R2-2018-0015, Appendix A, Exhibit A, Proposed Basin Plan Amendment).

This recommendation for approval is based on information provided in the Regional Board's amendment, "Amending the Water Quality Control Plan for the San Francisco Bay to Establish Water Quality Objectives and a Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Suisun Marsh, to Include Suisun Marsh in the San Francisco Bay Mercury TMDL, and to Make Minor Editorial Revisions". The recommendation for approval is also based on information in the Regional Board's staff report, "Establish Water Quality Objectives and A Total Maximum Daily Load For Dissolved Oxygen in Suisun Marsh and Add Suisun Marsh to SF Bay Mercury TMDL; Staff Report for Proposed Basin Plan Amendment" (Staff Report), dated April 11, 2018.

II. Water Quality Standards Provisions Subject to EPA Review

A. Amendments Pertaining to Designated/Beneficial Uses (Basin Plan, Chapter 2)

1. Amend the Language of Section 2.2.1, 2.2.2, and Tables 2-2, 2-3

The Regional Board made minor clarifications or corrections to the Basin Plan, Chapter 2. The revisions to the sections and tables, with rationale, are described in Table 13-1 (see Staff Report, p.85) and are shown in detail below.

The revisions to the sections and tables include:

- Section 2.2.1, 2.2.2: Corrected the abbreviation for Industrial Process Supply (PROC) to match the definition in the text of Chapter 2. The abbreviation was incorrectly given as PRO in these two locations.
- Section 2.2.1, 2.2.2, and Tables 2-2 and 2-3: Corrected the abbreviation for Freshwater Replenishment (FRSH) to match the definition in the text of Chapter 2. In these two Chapter 2 sections and the headers for these two tables (and footnotes for Table 2-2), the

abbreviation was incorrectly given as FRESH. All instances of this abbreviation were changed to "FRSH".

- Section 2.2.2 and Table 2-2: Corrected typos in this section and table in which "Industrial Water Supply, Industrial process water supply, or Industrial service water supply" were given as the beneficial use names. "Industrial Process Supply" and "Industrial Service Supply" are the correct names.

The revised Sections 2.2.1 and 2.2.2, and Tables 2-2 and 2-3 are shown below (see Regional Board Resolution R2-2018-0015, Exhibit A Proposed Basin Plan Amendment). Additions are shown as underlined text (added text) and deletions are indicated as strike-through text (deleted text).

EPA finds the revisions to the Basin Plan, Chapter 2, Sections 2.2.1 and 2.2.2, and Tables 2-2 and 2-3 are necessary. The editorial changes add clarifying language or make corrections of narrative passages or specific tables of the Basin Plan. These minor, non-regulatory edits do not affect or change any State or regional policy, program, or implementation plan.

EPA considers non-substantive edits to existing WQS to constitute new or revised WQS that EPA has the authority and duty to approve or disapprove under CWA section 303(c)(3).[1] EPA believes that it is reasonable to treat such non-substantive changes in this manner to ensure public transparency as to which provisions are effective for purposes of the CWA. EPA notes that the scope of its action in reviewing and approving or disapproving such non-substantive changes would extend only as far as the actual non-substantive changes themselves. In other words, EPA's action on non-substantive changes to previously approved WQS would not constitute an action on the underlying previously approved WQS. Any challenge to EPA's prior approval of the underlying WQS would be subject to any applicable statute of limitations and prior judicial decisions.[2] Therefore, the EPA is approving these revisions under CWA 303(c) authorities.

[1] What Is a New or Revised Water Quality Standard Under CWA 303(C)(3)? Frequently Asked Questions October 2012 https://www.epa.gov/sites/production/files/2014-11/documents/cwa303faq.pdf

[2] U.S. Environmental Protection Agency (EPA). 2014. *Water Quality Standards Handbook Chapter 1: General Provisions.* EPA 820-B-14-008. EPA Office of Water, Office of Science and Technology, Washington, DC. Accessed https://www.epa.gov/sites/production/files/2014-10/documents/handbook-chapter1.pdf

2.2 EXISTING AND POTENTIAL BENEFICIAL USES

2.2.1 SURFACE WATERS

Inland surface waters support or could support most of the beneficial uses described above. The specific beneficial uses for inland streams include municipal and domestic supply (MUN), agricultural supply (AGR), commercial and sport fishing (COMM), freshwater replenishment (~~FRESH~~FRSH), industrial process supply (PROC), groundwater recharge (GWR), preservation of rare and endangered species (RARE), water contact recreation (REC1), noncontact water recreation (REC2), wildlife habitat (WILD), cold freshwater habitat (COLD), warm freshwater habitat (WARM), fish migration (MIGR), and fish spawning (SPWN).

2.2.2 GROUNDWATER

Existing and potential beneficial uses applicable to groundwater in the Region include municipal and domestic water supply (MUN), industrial ~~water~~service supply (IND), industrial process supply (PROC), agricultural water supply (AGR), groundwater recharge (GWR), and freshwater replenishment to surface waters (~~FRESH~~FRSH). Table 2-2 lists the 28 identified groundwater basins and seven sub-basins located in the Region and their existing and potential beneficial uses.

Table 2-2: Existing and Potential Beneficial Uses in Groundwater in Identified Basins

County	Groundwater Basin Name1	Groundwater Sub-Basin1	Basin Number1	MUN[2]	PROC[3]	IND[4]	AGR[5]	FRESH[6]

Notes:

1. Department of Water Resources (DWR) Bulletin 118 "California Groundwater", 2003.
2. MUN = Municipal and domestic water supply.
3. PROC = Industrial process ~~water~~ supply.
4. IND = Industrial service ~~water~~ supply.
5. AGR = Agricultural water supply.
6. FR~~E~~SH = Freshwater replenishment to surface water; designation will be determined at a later date; for the interim, a site-by-site determination will be made.
7. The existing and potential beneficial uses for groundwater basins listed in the 1995 Basin Plan (Table 2-3) were assigned to the new groundwater basins based on the geographic location of the old basins compared to the new basins. The basin names, such as Westside A, and Westside B, etc., are informal names assigned by the Water Board to preserve the beneficial use designations in the 1995 Basin Plan and do not represent sub-basins identified by the Department of Water Resources.
8. The Santa Clara Valley groundwater basin/Santa Clara groundwater sub-basin is also known as Coyote Valley.
9. This groundwater basin is also located in the North Coast Region (RB1); beneficial uses of groundwater are specified in the Basin Plan for RB1.
10. This groundwater basin is also located in the Central Coast Region (RB3); beneficial uses of groundwater are specified in the Basin Plan for RB3.

E = Existing beneficial uses; based on best available information.

P = Potential beneficial uses; based on best available information.

X = This groundwater basin was not listed in the 1995 Basin Plan; designation will be determined at a later date; for the interim, a site-by-site determination will be made.

See DWR Bulletin 118 (2003) for groundwater basin characteristics.

Table 2-3: Examples of Existing and Potential Beneficial Uses of Selected Wetlands

	TYPE OF WETLAND				
BENEFICIAL USE	MARINE	ESTUARINE	RIVERINE	LACUSTRINE	PALUSTRINE
AGR		o	o	o	o
COLD			o	o	o
COMM	o	o			
EST		o			
FRESH			o	o	o
GWR	o	o	o	o	o
IND		o	-	-	
MAR	o				
MIGR	o	o	o	o	
NAV	o	o	o	o	o
PROC					
REC-1	o	o	o	o	o
REC-2	o	o	o	o	o
SHELL	o	o	o		
SPWN	o	o	o	o	o
WARM			o	o	o
WILD	o	o	o	o	o
RARE	o	o	o	o	o

NOTE:
o Existing beneficial use
- Potential beneficial use

B. Amendments Pertaining to Water Quality Criteria/Objectives (Basin Plan, Chapter 3)

1. Amend the Language of Tables 3-3 and 3-3A

The Regional Board made minor clarifications or corrections to the Basin Plan, Chapter 3. The editorial revisions to the sections and tables, with rationale, are described in Table 13-1 (see Staff Report, p.85) and are shown in detail below.

The revisions include:

- Table 3-3: Footnotes b and f of Table 3-3 were updated to note that Table 3-3A contains site-specific nickel water quality objectives for South San Francisco Bay and site-specific copper water quality objectives for all segments of San Francisco Bay.
- Table 3-3: Footnote k on Table 3-3 does not currently have sufficient information about the derivation of the PAH objective. The required information was available in the 1986 version of the Basin Plan but was accidentally dropped in subsequent versions. The original footnote was restored and appended to the current footnote k of this table to provide explanatory context for the PAH objective.
- Tables 3-3 and 3-4: Updated footnotes to Tables 3-3 and 3-4 to remove the citation of the draft criteria and cite U.S. EPA's final tributyltin criteria adopted in 2003.

- Table 3-3A: Included a footnote 3 to Table 3-3A explaining that water effect ratios are already included in copper and nickel site-specific objectives as originally adopted and provided information about converting dissolved metal objectives to total metal concentrations. This is to eliminate confusion and clarify the meaning of the site-specific objectives.

The revised Tables 3-3 and 3-3A are shown below (see Regional Board Resolution R2-2018-0015, Exhibit A Proposed Basin Plan Amendment). Additions are shown as underlined text (added text) and deletions are indicated as strike-through text (deleted text).

EPA finds the revisions to the Basin Plan, Chapter 3, Tables 3-3, 3-3A and 3-4 are necessary. The editorial changes add clarifying language or make corrections of narrative passages or specific footnotes in these tables. These minor, non-regulatory edits do not affect or change any State or regional policy, program, or implementation plan.

As discussed previously, EPA considers non-substantive edits to existing WQS to constitute new or revised WQS that EPA has the authority and duty to approve or disapprove under CWA section 303(c)(3). Therefore, the EPA is approving these revisions under CWA 303(c) authorities.

Table 3-3: Marine[a] Water Quality Objectives for Toxic Pollutants for Surface Waters (all values in µg/l)

Compound	4-day Average	1-hr Average	24-hr Average
Arsenic[b, c, d]	36	69	
Cadmium[b, c, d]	9.3	42	
Chromium VI[b, c, d, e]	50	1100	
Copper[c, d, f, l]			
Cyanide[g]			
Lead[b, c, d]	8.1	210	
Mercury[h]	0.025	2.1	
Nickel[b, c, d, l]	8.2	74	
Selenium[i]			
Silver[b, c, d]		1.9	
Tributyltin[j]			
Zinc[b, c, d]	81	90	
PAHs[k]			15

Notes:

a. Marine waters are those in which the salinity is equal to or greater than 10 parts per thousand 95% of the time, as set forth in Chapter 4 of the Basin Plan. Unless a site-specific objective has been adopted, these objectives shall apply to all marine waters except for the South Bay south of Dumbarton Bridge (where the California Toxics Rule (CTR) applies) or as specified in note h (below). For waters in which the salinity is between 1 and 10 parts per thousand, the applicable objectives are the more stringent of the freshwater (Table 3-4) or marine objectives.

b. Source: 40 CFR Part 131.38 (California Toxics Rule or CTR), May 18, 2000.

c. These objectives for metals are expressed in terms of the dissolved fraction of the metal in the water column.

d. According to the CTR, these objectives are expressed as a function of the water-effect ratio (WER), which is a measure of the toxicity of a pollutant in site water divided by the same measure of the toxicity of the same pollutant in laboratory dilution water. The 1-hr. and 4-day objectives = table value X WER. The table values assume a WER equal to one.

e. This objective may be met as total chromium.

f. Water quality objectives for copper were promulgated by the CTR and may be updated by U.S. EPA without amending the Basin Plan. Note: at the time of writing, the values are 3.1 µg/l (4-day average) and 4.8 µg/l (1-hr. average). The most recent version of the CTR should be consulted before applying these values.

g. Cyanide criteria were promulgated in the National Toxics Rule (NTR) (Note: at the time of writing, the values are 1.0 µg/l (4-day average) and 1.0 µg/l (1-hr. average)) and apply, except that site-specific marine water quality objectives for cyanide have been adopted for San Francisco Bay as set forth in Table 3-3C.

h. Source: U.S. EPA Ambient Water Quality Criteria for Mercury (1984). The 4-day average value for mercury does not apply to San Francisco Bay; instead, the water quality objectives specified in Table 3-3B apply. The 1-hour average value continues to apply to San Francisco Bay.

i. Selenium criteria were promulgated for all San Francisco Bay/Delta waters in the National Toxics Rule (NTR). The NTR criteria specifically apply to San Francisco Bay upstream to and including Suisun Bay and Sacramento-San Joaquin Delta. Note: at the time of writing, the values are 5.0 µg/l (4-day average) and 20 µg/l (1-hr. average).

j. Tributyltin is a compound used as an antifouling ingredient in marine paints and toxic to aquatic life in low concentrations. ~~U.S. EPA has published draft criteria for protection of aquatic life (Federal Register: December 27, 2002, Vol. 67, No. 249, Page 79090-79091). These criteria are cited for advisory purposes. The draft criteria may be revised.~~ Ambient Aquatic Life Water Quality Criteria for Tributytin (TBT) – Final (EPA 822-R-03-031, December 2003).

k. The 24-hour average aquatic life protection objective for total PAHs is retained from the 1995 Basin Plan. Source: U.S. EPA 1980. The U.S. EPA (1980) Water Quality Criteria document indicates acute toxicity concentrations for salt water at or below 300 µg/l. An acute-to-chronic ratio of 20 yields an objective of 15 µg/l. Total PAHs are those compounds identified by EPA method 610.

l. Table 3-3A contains site-specific water quality objectives for copper and nickel applicable to San Francisco Bay segments.

Table 3-3A: Water Quality Objectives for Copper and Nickel in San Francisco Bay Segments (µg/L)[1]

Compound	4-day Average (CCC)[42]	1-hr Average (CMC)[23]	Extent of Applicability
Copper	6.9	10.8	The portion of Lower San Francisco Bay south of the line representing the Hayward Shoals shown on Figure 7.2.1-1. and South San Francisco Bay
Copper	6.0	9.4	The portion of the delta located in the San Francisco Bay Region, Suisun Bay, Carquinez Strait, San Pablo Bay, Central San Francisco Bay, and the portion of Lower San Francisco Bay north of the line representing the Hayward Shoals on Figure 7.2.1-1.
Nickel	11.9	62.4*	South San Francisco Bay

[1]The Site-Specific Water Quality Objectives in this table already include the Water Effects Ratio appropriate for each San Francisco Bay segment. See Basin Plan Section 7.2.1.2 for information on translating the dissolved metal concentrations shown in this table to total metal concentrations, if required for NPDES permits.

[42]Criteria Continuous Concentration

[23]Criteria Maximum Concentration

*Handbook of Water Quality Standards, 2nd ed. 1994 in Section 3.7.6 states that the CMC = Final AcuteValue/2; 62.4 is the Final Acute Value (resident species database)/2; so the site-specific CMC is lower than the California Toxics Rule value because we are using the resident species database instead of the National Species Database.

Table 13-1
Miscellaneous editorial revisions to Basin Plan Chapters 2 and 3

Location	Description of Edit
Section 2.2.1, 2.2.2	We corrected the abbreviation for Industrial Process Supply (PROC) to match the definition in the text of Chapter 2. The abbreviation was incorrectly given as PRO in these two locations.
Section 2.2.1, 2.2.2, and Tables 2-2 and 2-3	We corrected the abbreviation for Freshwater Replenishment (FRSH) to match the definition in the text of Chapter 2. In these two Chapter 2 sections and the headers for these two tables (and footnotes for Table 2-2), the abbreviation was incorrectly given as FRESH. All instances of this abbreviation were changed to "FRSH".
Section 2.2.2 and Table 2-2	We corrected typos in this section and table in which "Industrial Water Supply, Industrial process water supply, or Industrial service water supply" were given as the beneficial use names. "Industrial Process Supply" and "Industrial Service Supply" are the correct names.
Table 3-3	Footnotes b and f of Table 3-3 have been updated to note that Table 3-3A contains site-specific nickel water quality objectives for South San Francisco Bay and site-specific copper water quality objectives for all segments of San Francisco Bay.
Table 3-3	Footnote k on Table 3-3 does not currently have sufficient information about the derivation of the PAH objective. The required information was available in the 1986 version of the Basin Plan, but was accidentally dropped in subsequent versions. The original footnote has been restored and appended to the current footnote k of this table to provide explanatory context for the PAH objective.
Tables 3-3 and 3-4	We updated footnotes to Tables 3.3 and 3-4 to remove the citation of the draft criteria and cite U.S. EPA's final tributyltin criteria adopted in 2003.
Table 3-3A	We included a footnote 3 to Table 3-3A explaining that water effect ratios are already included in copper and nickel site-specific objectives as originally adopted and provided information about converting dissolved metal objectives to total metal concentrations. This is to eliminate confusion and clarify the meaning of the site-specific objectives.

2. Insert Revised Water Quality Criteria/Objective Table into Section 3.3.5 Dissolved Oxygen

A. Review of Supporting Data

The amendment establishes revised water quality objectives for dissolved oxygen (DO) in Suisun Marsh (see Regional Board Resolution R2-2018-0015, Exhibit A, Proposed Basin Plan Amendment, p.A-1), which are to be inserted into Section 3.3.5 Dissolved Oxygen in the Basin Plan. The scientific basis for the revised DO objectives is presented in the Staff Report and the supporting data are reviewed below in detail.

For Suisun Marsh, the following objectives shall apply:

DO Objectives	DO concentrations	Applicability
Acute objective	3.8 mg/l minimum (daily average)	Year-round in all sloughs and channels
Chronic objectives	5.0 mg/l minimum (30-day running average)	Year-round in all sloughs and channels
	6.4 mg/l minimum (30-day running average)	January 1 through April 30 in Montezuma, Nurse, and Denverton sloughs only

Physical Characteristics of Suisun Marsh

There are two major tidal sloughs that connect Suisun Marsh with Grizzly Bay: Montezuma and Suisun Sloughs (see Figure 2-1, Staff Report, p.6). The major tributary sloughs to Montezuma are Denverton and Nurse Sloughs. Cutoff Slough and Hunters Cut connect Suisun and Montezuma Sloughs. The major tributaries to Suisun Slough are Peytonia, Boynton, Cutoff, Wells, and Goodyear (see Figure 8-1, Staff Report, p.53). The hydrology of Suisun Marsh is affected by several factors, including Delta outflows, rainfall, tides, local creek inflow, and the Fairfield Suisun Sewer District (FSSD) Wastewater Treatment Plant discharge. The flooding and draining operations of the managed wetlands also have a strong effect on the hydrology in the sloughs.

Managed Wetlands and Causes of Low DO Events

The general wetland management cycle includes a summer period, when wetlands are left to be relatively dry, although some level of ponding may be present year-round. During the summer, vegetation is mowed or disked and the vegetation debris left in situ. Water management usually begins in early October with the "fall flood-up," when managed wetlands (or ponds) are flooded with water from the adjacent sloughs and channels (DWR 2001). When managed wetlands are flooded, vegetation in them starts to decompose, which may result in the depletion of oxygen and the production of sulfides. During the fall flood-up, water that has remained ponded in the wetland over the summer is discharged, along with the vegetation debris. Because of the decomposition of organic matter in the ponded wetland, the ponded water and the water that has initially entered during the fall flood-up, may have very low DO concentrations, or be anoxic. When this potentially anoxic water is discharged to adjoining sloughs, it may lead to a dramatic decrease in DO concentrations especially in smaller sloughs. These low DO events prevail when temperatures are high, circulation rates are low, and there is a large amount of dead broad-leafed

vegetation and other organic material (DFG 2010). Although this combination of factors often occurs in fall, it can also occur throughout the winter. The water management contains several flood and drain cycles, including the major cycle in the fall and several minor cycles during late winter/spring. Complete and partial drainage of the ponds begins after the waterfowl season ends in January.

Low DO Events and Fish Kills in Sloughs

Suisun Marsh sloughs have experienced frequent low DO events and fish kills since at least 1993, when black water and dead fish were first observed (Schroeter and Moyle 2004). The University of California at Davis (UC Davis) has monitored fish abundance in the marsh monthly since 1979 but after a reported fish kill in the fall of 1999, also initiated DO monitoring. Since then, several fish kills and low DO events were observed in Suisun Marsh during the fall of 2001, 2003, 2004, and 2009 (see Staff Report, Table 3-1, p.11).

Causes of Low DO in Sloughs and Channels

Low DO concentrations in the sloughs are likely to result from decomposition of organic material originating from terrestrial inputs and *in situ* production. The sloughs are naturally highly productive and accumulate large amounts of aquatic plant material and detritus, which is essential for a healthy estuarine ecosystem. Although the sloughs receive inputs from creeks that drain agricultural and urbanized areas, the operation of managed wetlands was shown to have a strong effect on the DO concentrations when hypoxic water from managed ponds was discharged into sloughs during fall and spring draining events. DO concentrations were notably higher in April, possibly due to higher wind speeds that promote mixing and re-aeration that time of the year (Siegel et al. 2011).

1975 Basin Plan DO Objectives for SF Bay – Current Suisun Marsh Objectives That Are Revised Through This Amendment

The San Francisco Bay Basin Plan identifies DO objectives for waters that are upstream of the Carquinez Bridge as being a minimum of 7.0 mg/l. It also includes a requirement that the median DO concentration for any three consecutive months shall not be less than 80 percent of the dissolved oxygen content at saturation. These water quality objectives were adopted in the 1975 Basin Plan and are generally being attained in most of the Bay's subtidal waters. The Basin Plan does not clearly address the applicability of these objectives to Marsh tidal sloughs and managed ponds as in Suisun Marsh, where there is some evidence they may not be attainable, and which is the primary reason for the Regional Board's development of these revised DO site-specific objectives for Suisun Marsh.

Development of Refined DO Site-Specific Objectives for Suisun Marsh

The Regional Board convened an Expert Panel of scientific and policy experts to provide advice on the development of refined objectives. The Panel included Peter Moyle (UC Davis, CA), Paul Stacey (Great Bay National Estuarine Research Reserve, NH) and Peter Tango (USGS Chesapeake Bay, MD). The proposed objectives reflect the best available science and the Expert Panel recommendations regarding fish and invertebrate responses to stress from the low DO, the level of protection needed for sensitive and endangered species, and the application of a U.S. EPA approved approach to provide scientifically-defensible DO objectives for Suisun Marsh.

Approach for Deriving Refined DO Objectives for Suisun Marsh

In the refinement of the DO objectives for Suisun Marsh the Regional Board followed the approach recommended by U.S. EPA for the Virginian Province (USEPA 2000). This approach supports the derivation of region-specific DO criteria tailored to the species, habitats and DO exposure regimes of varying estuarine, coastal and marine waters. The ability to select aquatic organisms and their life stage allows the criteria to be adapted to protect species relevant to Suisun Marsh. This method provides a framework for the establishment of DO thresholds under persistent long-term exposure and episodic short-term exposure and considers three aspects of biological health: 1) survival of juveniles and adults, 2) growth of juveniles, and 3) larval recruitment. This approach combines current understanding of biological responses to hypoxic stressors in an estuarine ecosystem and establishes a basis for the development of site-specific DO requirements. A detailed description of this methodology and how it was applied to derive the objectives for Suisun Marsh is provided in Tetra Tech (2017) and is shown in next section below.

The Virginian Province Approach Methodology for Developing DO Criteria

A recent report, *Science Supporting Dissolved Oxygen Objectives for Suisun Marsh,* by Bailey et al. (2014), used the Virginian Province Approach to develop DO water quality targets for Suisun Bay and Marsh. The Virginian Province Approach (USEPA 2000) was developed to recommend DO criteria protective of coastal and estuarine organisms living in the Virginian Province (Cape Cod, MA to Cape Hatteras, NC). The resulting criteria are based on laboratory data for organisms that may occur in the geographical region of interest and follows the general approach used to develop criteria for toxic compounds. This approach has subsequently been used to develop DO criteria in estuarine waters, such as in Florida (Florida Department of Environmental Protection, 2013) and Chesapeake Bay (USEPA, 2003).

This method uses endpoints analogous to those used to set criteria for toxics. Acute endpoints describing lethality to 50% of test organisms (LD50) and chronic endpoints describing the most sensitive endpoint (growth in the case of DO) are gathered from available sources of appropriate laboratory data. Toxicity data are ranked according to genus mean acute (or chronic) values (GMAV or GMCV) from most to least sensitive to DO. The four most sensitive GMAVs for acute criteria or GMCVs for chronic criteria and the number of genera for which acceptable data are available are used in a series of equations to determine the Final Acute Value (FAV) or Final Chronic Value (FCV). The FAV/FCV is designed to be protective of at least 95% of the species likely to be present (Stephan et al., 1985). The FAV can be modified by correction factors to result in the acute *Criterion Minimum Concentration* (CMC, analogous to the Criterion Maximum Concentration for traditional toxics). In the case of DO, the FAV was adjusted to the CMC by multiplying by 1.38, the average LC5 to LC50 ratio for juvenile and adult species (USEPA 2000). The FCV can be modified to result in the chronic *Criterion Continuous Concentration* (CCC), but no further modifications were used in the Virginian Province approach. The CMC, CCC and FRC values are defined as follows:

- Criterion Minimum Concentration (CMC). An estimate of the lowest concentration of DO in ambient water to which an aquatic community can be exposed briefly without resulting in an unacceptable adverse effect. This is the acute criterion.

- Criterion Continuous Concentration (CCC). An estimate of the lowest concentration of DO in ambient water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable adverse effect. This is the chronic criterion.
- Final Recruitment Curve (FRC). A function that defines the maximum allowable exposure duration at DO concentrations between the CMC and CCC necessary to prevent unacceptable reductions in seasonal larval recruitment for sensitive species. Duration of exposure must be reduced when DO concentrations decrease.

Selection of Fish, Invertebrate and T&E Species Relevant to Suisun Marsh

The site-specific acute and chronic DO values for Suisun Marsh were first calculated by Bailey et al. (2014) using the biological approach recommended for the Virginian Province, but with fish and invertebrate species characteristic of Suisun Bay and Suisun Marsh waters. The species list was further refined with the recommendations of the Expert Panel to focus on the species ecologically important to Suisun Marsh, both introduced and native, while species rarely encountered in the marsh were removed from considerations (Tetra Tech 2017; see below Table 4-1, Staff Report, p.27). Fish and invertebrate species representative of Suisun Marsh were then evaluated using currently available data on sensitivity to low levels of DO. *Threatened and endangered (T&E) species were also considered in the analysis, including steelhead, chinook and coho salmon, green sturgeon, and Delta smelt.* It was determined that sufficient data were available for either locally-occurring species as well as for genus and family-level surrogates of local species to calculate the acute (CMC) and chronic (CCC) values for DO using the U.S. EPA procedures for deriving water quality criteria.

Table 4-1
Refined list of species to calculate DO objectives for Suisun Marsh

Species	Baily et al. 2014 List	Refined Species List (Tetra Tech 2017)
Threespine stickleback (*Gasterosteus aculeatus)*	X	X
Striped bass (*Morone saxatilis)*	X	X
American shad (*Alosa sapidissima)*	X	X
Starry flounder (*Platichthys stellatus)*	X	X
Mississippi silversides (*Menidia audens)*	X	X
White sturgeon (*Acipenser transmontanus)*	X	X
Sacramento splittail (*Pogonichthys macroelepidotus)*	X	X
Longfin smelt (*Spirinchus thaleichtys)*	X	X
Tule perch (*Hysterocarpus traski)*	X	X
Prickly sculpin (*Cottus asper)*	X	X
Staghorn sculpin (*Leptocottus armatus)*	X	X
Threadfin shad (*Dorsoma petenense)*		X
Common carp (*Cyprinus carpio)*		X
White catfish (*Ameierus catus)*		X
Yellowfin goby (*Acanthogobius flavimanus)*		X
Siberian prawn (*Exopalaemon modestus)*		X
Oriental shrimp (*Palaemon macrodactylus)*		X
Scud (*Gammarus daiberi)*		X
Opossum shrimp (*Hyperacanthomysis longirostris)*		X
Opossum shrimp (*Neomysis kadiakensis)*		X
Chinook salmon (*Oncorhynchus tshawytscha)*	X	X[1]
Rainbow trout/steelhead (*Oncorhynchus mykiss)*	X	X[1]
Pacific lamprey (*Entosphenus tridentatus)*	X	
Green sturgeon (*Acipenser medirostris)*	X	
Delta smelt (*Hypomesus transpacificus)*	X	
Longjaw mudsucker (*Gillichthys mirabilis)*	X	
Bay pipefish (*Syngnathus leptorhyncus)*	X	
California halibut (*Paralichthys californicus)*	X	
Northern anchovy (*Engraulis mordax)*	X	
Pacific herring (*Clupea pallasi)*	X	
Shiner perch (*Cymatogaster aggregate)*	X	

[1] spatially and temporally restricted

Acute LD50 (DO, mg/L) Toxicity Endpoints of Relevant Fish Species Used for Virginian Province Approach (see Tetra Tech 2017, Table 8, p.24-26)

Table 8. Acute data for species of interest and surrogate species toxicity data used to perform the Virginian Province Approach. Two species lists were developed for Suisun Marsh—Bailey et al (2014) and a revised list proposed by the Panel. In both cases, surrogates were selected when Suisun species and surrogate species shared at least common family classifications.

Bailey et al (2014) Species		Panel Refined List*		Surrogate Species with Available DO Data		LD 50 (DO, mg/L)
Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	
White sturgeon	*Acipenser transmontanus*			Shortnose sturgeon	*Acipenser brevirostrum*	2.33
Green sturgeon	*Acipenser medirostis*			Shortnose sturgeon	*Acipenser brevirostrum*	2.33
		White sturgeon	*Acipenser transmontanus*	Shortnose sturgeon	*Acipenser brevirostrum*	2.33
American shad	*Alosa sapidissima*			Scaled sardine	*Harengula jaguana*	2.17
		Threadfin shad	*Dorsoma petenense*	Scaled sardine	*Harengula jaguana*	2.17
		American shad	*Alosa sapidissima*	Scaled sardine	*Harengula jaguana*	2.17
White croaker	*Genyonemus lineatus*			Spotted sea-trout	*Cynoscion nebulosus*	1.88
Bay pipefish	*Syngnathus leptorhyncus*			Pipefish	*Sygnathus fuscus*	1.63
Silversides	*Menidia audens*			Silversides	*Menidia beryllina*	1.59
		Mississippi Silversides	*Menidia beryllina*	Silversides	*Menidia beryllina*	1.59
Striped bass	*Morone saxatilis*			Striped bass	*Morone saxatilis*	1.58
		Striped bass	*Morone saxatilis*	Striped bass	*Morone saxatilis*	1.58
White Croaker	*Genyonemus lineatus*			Redfish	*Sciaenops ocellatus*	1.45
mysid shrimp	*Neomysis mercedis*			Mysid shrimp	*Americamysis bahia*	1.40
		Opossum shrimp	*Hyperacanthomysis longirostris*	Mysid shrimp	*Americamysis bahia*	1.40
		Opossum shrimp	*Neomysis kadiakensis*	Mysid shrimp	*Americamysis bahia*	1.40
Starry flounder	*Platichthys stellatus*			Winter flounder	*Pleuronectes americanus*	1.38
		Starry flounder	*Platichthys stellatus*	Winter flounder	*Pleuronectes americanus*	1.38
California halibut	*Paralichthys californicus*			Summer flounder	*Paralichthys dentatus*	1.35

Bailey et al (2014) Species		Panel Refined List*		Surrogate Species with Available DO Data		LD 50 (DO, mg/L)
Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	
copepod	*Acartia tonsa*			Copepod	*Acartia tonsa*	1.26
		copepod	*Acartia tonsa*	Copepod	*Acartia tonsa*	1.26
oyster	*Ostrea lurida*			Oyster	*Crassostrea virginica*	1.19
oyster	*Crassostrea gigas*			Oyster	*Crassostrea virginica*	1.19
Pacific herring	*Clupea pallasi*			Menhaden	*Brevoortia tyrannus*	1.13
American shad	*Alosa sapidissima*			Menhaden	*Brevoortia tyrannus*	1.13
		Threadfin shad	*Dorsoma petenense*	Menhaden	*Brevoortia tyrannus*	1.13
grass shrimp	*Crangon franciscorum*			Sand shrimp	*Crangon septemspinosa*	0.97
Threespine stickleback	*Gasterosteus aculeatus*			Four-spine stickleback	*Apeltes quadracus*	0.91
		Threespine stickleback	*Gasterosteus aculeatus*	Four-spine stickleback	*Apeltes quadracus*	0.91
amphipod	*Ampelisca abdita*			Amphipod	*Ampelisca abdita*	0.9
				Amphipod	*Ampelisca abdita*	0.9
grass shrimp	*Palaemon macrodactylus*			Grass shrimp	*Paleomonetes pugio, P. vulgaris*	0.87
		Siberian prawn	*Exopalaemon modestus*	Grass shrimp	*Paleomonetes pugio, P. vulgaris*	0.87
		Oriental shrimp	*Palaemon macrodactylus*	Grass shrimp	*Paleomonetes pugio, P. vulgaris*	0.87
Dungeness crab	*Cancer magister*			Dungeness crab	*Cancer magister*	0.78
littleneck clam	*Protothaca staminea*			Littleneck clam	*Protothaca staminea*	0.78
White croaker	*Genyonemus lineatus*			Spot	*Leiostomus xanthurus*	0.7
Copepod	*Eurytemora affinis*			Copepod	*Eurytemora affinis*	0.6
		Copepod	*Eurytemora affinis*	Copepod	*Eurytemora affinis*	0.6
Harris mud crab	*Rhithropanopeus harrisii*			Harris mud crab	*Rhithropanopeus harrisii*	0.51

DO Criteria Recommendations for Suisun Marsh

Bailey et al (2014) Species		Panel Refined List*		Surrogate Species with Available DO Data		LD 50 (DO, mg/L)
Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	
		Harris mud crab	*Rhithropanopeus harrisii*	Harris mud crab	*Rhithropanopeus harrisii*	0.51
Green crab	*Carcinus maenus*			Green crab	*Carcinus maenus*	0.38

* Additional species recommended by the Panel, but with no appropriate DO surrogate data, include Sacramento splittail (*Pogonichthys macroelepidotus*), Longfin smelt (*Spirinchus thaleichtys*), Tule perch (*Hysterocarpus traski),* Prickly sculpin (*Cottus asper*), Staghorn sculpin (*Leptocottus armatus*), Common carp (*Cyprinus carpio*), White catfish (*Ameierus catus*), Yellowfin goby (*Acanthogobius flavimanus*), and Delta smelt (*Hypomesus transpacificus*)

Chronic GMCV (DO, mg/L) Toxicity Endpoints of Relevant Fish Species Used for Virginian Province Approach (see Tetra Tech 2017, Table 9, p.27-28)

Table 9. Chronic data for species of interest and surrogate species toxicity data used to perform the Virginian Province Approach. Two species lists were developed for Suisun Marsh—Bailey et al (2014) and a revised list proposed by the Panel. In both cases, surrogates were selected when Suisun species and surrogate species shared at least common family classifications.

Bailey et al (2014) Species		Panel Refined List*		Surrogate Species with Available DO Data		GMCV (DO mg/L)
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**	**Common Name**	**Scientific Name**	
		Salmonids				
		Salmonids (see 1986 DO guidelines)				5-6
White sturgeon	*Acipenser transmontanus*			Shortnose sturgeon	*Acipenser oxyrinchus*	4.77
Green sturgeon	*Acipenser medirostis*			Shortnose sturgeon	*Acipenser oxyrinchus*	4.77
		White sturgeon	*Acipenser transmontanus*	Shortnose sturgeon	*Acipenser oxyrinchus*	4.77
grass shrimp	*Palaemon macrodactylus*			Grass shrimp	*Paleomonetes vulgaris*	4.67
		Siberian prawn	*Exopalaemon modestus*	Grass shrimp	*Paleomonetes vulgaris*	4.67
		Oriental shrimp	*Palaemon macrodactylus*	Grass shrimp	*Paleomonetes vulgaris*	4.67
Harris mud crab	*Rhithropanopeus harrisii*			Say's mud crab	*Dyspanopeus sayi*	4.63
		Harris mud crab	*Rhithropanopeus harrisii*	Say's mud crab	*Dyspanopeus sayi*	4.63
California halibut	*Paralichthys californicus*			Summer flounder	*Paralichthys dentatus*	4.52
Silversides	*Menidia audens*			Atlantic silversides	*Menidia menidia*	4.33
		Mississippi Silversides	*Menidia beryllina*	Atlantic silversides	*Menidia menidia*	4.33
Amphipod	*Corophium sp.*			Amphipod	*Corophium volutator*	4.0
		Amphipod	*Corophium sp.*	Amphipod	*Corophium volutator*	4.0
mysid shrimp	*Neomysis mercedis*			Mysid shrimp	*Americamysis bahia*	3.64

Bailey et al (2014) Species		Panel Refined List*		Surrogate Species with Available DO Data		GMCV (DO mg/L)
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**	**Common Name**	**Scientific Name**	
		Opossum shrimp	*Hyperacanthomysis longirostris*	Mysid shrimp	*Americamysis bahia*	3.64
		Opossum shrimp	*Neomysis kadiakensis*	Mysid shrimp	*Americamysis bahia*	3.64
Littleneck clam	*Protothaca staminea*			Quahog	*Mercenaria mercenaria)*	3.17
Dungeness crab	*Cancer magister*			Atlantic rock crab	*Cancer irroratus*	2.87
Striped bass	*Morone saxatilis*			Striped bass	*Morone saxatilis*	2.80
		Striped bass	*Morone saxatilis*	Striped bass	*Morone saxatilis*	2.80

* Additional species recommended by Panel, but with no appropriate DO surrogate data, include Sacramento splittail (*Pogonichthys macroelepidotus*), Longfin smelt (*Spirinchus thaleichtys*), Tule perch (*Hysterocarpus traski),* Prickly sculpin (*Cottus asper*), Staghorn sculpin (*Leptocottus armatus*), Common carp (*Cyprinus carpio*), White catfish (*Ameierus catus*), Yellowfin goby (*Acanthogobius flavimanus*), and Delta smelt (*Hypomesus transpacificus*)

Calculation of CMC and CCC Using Revised Species List

Based on the fish and invertebrate species identified by the Expert Panel a total of N=12 data points that relate the survival of juvenile and adult organisms to low DO were used to re-calculate the acute DO threshold for Suisun Marsh. The data were ranked by species based on sensitivity (see above Table 8 for acute LD50s and Table 9 for chronic GMCVs). The four most sensitive species were used to calculate the final acute value (FAV) and included (from most tolerant to least tolerant): striped bass, Mississippi silversides, American shad, and sturgeon. Based on the four most sensitive genus mean acute values (GMAV), the FAV calculated was 2.67 mg/L. This translated into a CMC value of 3.8 mg/L. Below is Table 3.1.3 (from Tetra Tech 2017, p.29-33) which shows the model and formula for how the CMC and CCC values were derived.

3.1.3 Calculation of CMC and CCC Using the Revised Species List (Recommended by Panel)

The CMC and CCC are calculated based on the four most sensitive genus mean acute or chronic values for DO (USEPA, 2000; Section 3.1 above), as summarized below.

CMC Calculation

Rank	Genus	GMAV	1/GMAV	LN GMAV	(LN GMAV)^2	P=R/(N+1)	sqrt P
4	*Morone*	1.58	0.632911	-0.457	0.209	0.3077	0.5547
3	*Menidia*	1.59	0.628931	-0.464	0.215	0.2308	0.4804
2	*Harengula*	2.17	0.460829	-0.775	0.600	0.1538	0.3922
1	*Acipenser*	2.33	0.429185	-0.846	0.715	0.0769	0.2774
			Sum	-2.54	1.74	0.77	1.70

N = 12

Variables:

P = cumulative probability
N = sample size
R = rank

S^2= 2.919975

S= 1.708793

L= -1.36367

A= -0.98157

FAV= 2.668647

Ratio= 1.43 (Bailey et al)

CMC= 3.8 mg/l

==========

Remaining 8 species: *Americamysis bahia, Pleuronectes americanus, Acartia tonsa, Brevoortia tyrannus, Apeltes quadracus, Paleomonetes pugio/ P. vulgaris, Eurytemora affinis, Rhithropanopeus harrisii*

CCC Calculation (Without Salmonids)

Rank	Genus	GMCV	1/GMCV (mg/l)	LN GMCV	(LN GMCV)^2	P=R/(N+1)	sqrt P
4	*Menidia*	**4.33**	**0.23**	-1.47	2.15	0.5000	0.7071
3	*Dysapanopeus*	**4.63**	**0.22**	-1.53	2.35	0.3750	0.6124
2	*Paleomonetes*	**4.67**	**0.21**	-1.54	2.38	0.2500	0.5000
1	*Acipenser*	**4.77**	**0.21**	-1.56	2.44	0.1250	0.3536
			Sum	-6.10	9.31	1.25	2.17

N = 7

Variables:

P = cumulative probability
N = sample size
R = rank

S^2= 0.07548

S= 0.274736

L= -1.67466

A= -1.61323

FCV= 5.018982

CCC= 5.0 mg/l

==========

Remaining 3 species: *Corophium volutator, Americamysis bahia, Morone saxatilis*

CCC Calculation (With Salmonids)

Alternative 1 (DO for Salmonids 30 Day Effects)

Rank	Genus	GMCV	1/GMCV (mg/l)	LN GMCV	(LN GMCV)^2	P=R/(N+1)	sqrt P
4	*Dysapanopeus*	**4.63**	**0.22**	-1.53	2.35	0.4444	0.6667
3	*Paleomonetes*	**4.67**	**0.21**	-1.54	2.38	0.3333	0.5774
2	*Acipenser*	**4.77**	**0.21**	-1.56	2.44	0.2222	0.4714
1	Salmonid	6.00	0.17	-1.79	3.21	0.1111	0.3333
			Sum	-6.43	10.38	1.11	2.05

N = 8

Variables:

P = cumulative probability
N = sample size
R = rank

S^2= 0.744904

S= 0.863078

L= -2.04901

A= -1.85602

FCV= 6.398248

CCC= 6.4 mg/l

==========

Remaining 4 species: *Menidia menidia, Corophium volutator, Americamysis bahia, Morone saxatilis*

For salmonids, USEPA's 1986 DO criteria (USEPA, 1986) report a small impact on growth over a 30 day period when DO is 6 mg/L. This calculation is the first of two alternatives.

Alternative 2 (DO for Salmonids 7 Day Effects):

Rank	Genus	GMCV	1/GMCV (mg/l)	LN GMCV	(LN GMCV)^2	P=R/(N+1)	sqrt P
4	*Dysapanopeus*	**4.63**	**0.22**	-1.53	2.35	0.4444	0.6667
3	*Paleomonetes*	**4.67**	**0.21**	-1.54	2.38	0.3333	0.5774
2	*Acipenser*	**4.77**	**0.21**	-1.56	2.44	0.2222	0.4714
1	Salmonid	5.00	0.20	-1.61	2.59	0.1111	0.3333
			Sum	-6.25	9.76	1.11	2.05

N = 8

Variables:

P = cumulative probability
N = sample size
R = rank

S^2= 0.057481

S= 0.239752

L= -1.68417

A= -1.63056

FCV= 5.10675

CCC= 5.1 mg/l

==========

Remaining 4 species: *Menidia menidia, Corophium volutator, Americamysis bahia, Morone saxatilis*

For salmonids, EPA's 1986 DO criteria (USEPA, 1986) report a moderate growth impact over a 7-day period when DO is 5mg/L. This is the second alternative calculation.

Recalculated CMC and CCC Criteria Using Updated Species List (Staff Report, Table 4-1, p.27)

The recalculated values (see below Tetra Tech 2017, Table 10, p.33) were similar to those calculated by Bailey et al. (2014). The methodology derives values largely based on the most sensitive species. However, the number of genera (N = sample size) also influences the calculations. As the number of genera decreases, the final acute value (FAV) becomes more conservative (i.e., increases in the case of DO) even though the four most sensitive species do not change. As a result, by excluding toxicity data for some surrogate species or species that do not occur in the marsh region, the current CMC and the CCC are somewhat higher than the values calculated in Bailey et al. (2014).

Table 10. Calculated CMC and CCC criteria using the updated species list (Table 7).

Species Represented	CMC (DO mg/l)	CCC (DO mg/L)
All available	3.8	N/A
Salmonids, Using 6.0 as chronic value*	N/A	6.4
Salmonids, Using 5.0 as chronic value*	N/A	5.1
No Salmonids	N/A	5.0

*EPA's 1986 DO criteria (USEPA, 1986) report a moderate salmonid growth effect over a 7-day period when DO is 5mg/L, and a small effect on growth over a 30 day period when DO is 6 mg/L. It may be appropriate to use 5 mg/L for shorter durations and less conservative values or 6 mg/L for longer durations and more protective values. Salmon are relatively uncommon in Suisun Marsh and generally occur in months when low dissolved oxygen is not prevalent.

Duration of Toxicity Tests Used in Virginian Province Approach

Acute CMC - The duration of acute toxicity tests used to develop the CMC are between 1-4 days (24-96 hours). This suggests that the results are most applicable to understanding the adverse effects of DO experienced over a similar observed duration. The CMC is expected to protect against lethal concentrations of DO to juvenile and adult aquatic organisms because it is calculated using juvenile and adult LC50 values.

Chronic CCC - The duration of chronic toxicity tests used to develop the CCC are between 7-30 days. This suggests that the results are most applicable to understanding the adverse effects of DO experienced over a similar observed duration. The CCC is expected to protect against growth effects for larval organisms because it is calculated using larval growth endpoints.

Regional Board Recommended Acute and Chronic DO Site-Specific Objectives for Suisun Marsh

The Basin Plan amendment establishes revised water quality objectives for DO in Suisun Marsh, which are shown in table below (Regional Board Resolution R2-2018-0015, Exhibit A Proposed Basin Plan Amendment, p.A-1). The scientific basis for the revised DO objectives is presented in the Staff Report. The Staff Report contains a thorough review of DO in Suisun Marsh. It describes the importance of DO, factors influencing DO concentrations, and DO requirements of the various life stages of fish species including threatened and endangered species. The Regional Board established the following revised acute and chronic site-specific water quality objectives for DO:

- An acute DO objective of 3.8 mg/L minimum (as a daily average) applies year-around in all sloughs and channels of Suisun Marsh to protect the survival of juvenile and adult fish.

- A chronic DO objective of 5.0 mg/L minimum (as a 30-day running average) applies year-around in all sloughs and channels of Suisun Marsh to protect the survival/recruitment/growth of larval/juvenile and adult resident fish, and to protect threatened and endangered species.

- A chronic DO objective of 6.4 mg/L minimum (as a 30-day running average) applies from January 1 through April 30 in Montezuma, Nurse and Denverton Sloughs to protect the survival and growth of larval/juvenile migratory fish (listed salmonids including steelhead and Chinook), and to protect threatened and endangered species.

The first two DO water quality objectives apply to all sloughs within the Suisun Marsh regardless of size or connectivity to open waters. They do not apply to waters not in the sloughs (i.e., to the tidal or managed wetlands).

For Suisun Marsh, the following objectives shall apply:

DO Objectives	DO concentrations	Applicability
Acute objective	3.8 mg/l minimum (daily average)	Year-round in all sloughs and channels
Chronic objectives	5.0 mg/l minimum (30-day running average)	Year-round in all sloughs and channels
	6.4 mg/l minimum (30-day running average)	January 1 through April 30 in Montezuma, Nurse, and Denverton sloughs only

The acute DO objective of 3.8 mg/L minimum calculated as a daily (1 day) average will ensure protection of juvenile and adult fish against unacceptable lethal conditions. A Daily Average is a daily average where the minimum value must be maintained as a daily average; the DO is sampled several times during the day and the average DO for the day should not go below the daily average. This value also protects the survival of sturgeon as laboratory data for the sensitive shortnose sturgeon suggest that it can withstand short-term exposures to low DO from 2.3 to 3.1 mg/L (Campbell and Goodman 2004). The daily objective is also more stringent than the U.S. EPA daily value of 2.3 mg/L.

The chronic DO objective of 5.0 mg/L minimum calculated as a 30-day running average will ensure survival, recruitment and growth of aquatic organisms as well as *it will protect threatened and endangered species across Suisun Marsh habitats*. A 30-Day Average is a long term moving average taken during a 30-day period. According to the U.S. EPA methodology, exposures to DO concentrations above this level will not result in any adverse effects on growth as that value was derived by observing growth effects in the most sensitive larval and juvenile life stages. The 30-day averaging period is consistent with, and fully protects against the effects on larval recruitment greater than five percent. For larval recruitment, the striped bass recruitment curve calculated for the conditions in Suisun Marsh indicates that DO above 4.3 mg/L for 30 days will protect against losses in larval recruitment and it is also protective of other larval species in Suisun Marsh.

The chronic DO objective of 6.4 mg/L minimum calculated as a 30-day running average will apply from January 1 through April 30 in Montezuma, Nurse and Denverton Sloughs to protect listed juvenile salmonids (steelhead, Chinook). Data from the UC Davis long-term fish study tracking fish abundance and DO concentrations (O'Rear and Moyle, 2015) were evaluated to assess the spatial and temporal changes in fish presence and their use of the marsh. This study helps identify types of fish present in different habitats and sloughs throughout the year, and especially when low DO conditions are likely to occur.

Reference to the National Marine Fisheries Service – Biological Opinion (NMFS 2013)
In addition, the National Marine Fisheries Service (NMFS) in its biological opinion issued for the 30-year Suisun Marsh Habitat Management, Preservation, and Restoration Plan (SMP) examined the effects of the SMP on the listed and endangered species (Chinook salmon, steelhead and green sturgeon) as the only species potentially sensitive to low DO (NMFS 2013). The NMFS concluded:

- Adults and juvenile salmonids and green sturgeon use Montezuma Slough as a secondary migratory pathway as they move downstream through the Delta and Suisun Bay to the Pacific Ocean.

- Listed juvenile salmonids use the tidal sloughs seasonally as a rearing habitat, which they enter at smolt stage, and are expected to be actively emigrating. In particular, Chinook salmon smolts may utilize major tributaries of their migratory route (Montezuma Slough), such as Nurse or Denverton Slough.

- Adult or smolt life stages of Chinook salmon and steelhead are unlikely to be found in the back-end sloughs in the west part of the marsh because these areas are beyond the migratory routes of these species.

- Additionally, the peak emigration of steelhead smolts usually occurs between March and early May, and the upstream migration of adult steelhead occurs from January through April, which coincides with high flow events. Therefore, the timing of migration combined with the low probability of fish entering the small back-end sloughs make it unlikely that steelhead will experience low DO conditions.

- Similarly, the migratory routes for green sturgeon make it unlikely for this fish to frequent the sloughs in the west part of the marsh. Green sturgeon are considered as generally tolerant of DO levels ranging from 2 to 5 mg/L.

Considering the NMFS's assessment of the effects of operation and maintenance of managed wetlands on listed and endangered species, Regional Board concluded that the proposed DO objectives are protective of all sensitive species and beneficial uses in Suisun Marsh.

2. EPA Assessment of the Revised DO Site-Specific Objectives for Suisun Marsh

EPA finds the addition of an acute DO objective of 3.8 mg/L minimum (calculated as daily average from continuous data and that applies year-around in all sloughs and channels of Suisun Marsh) will protect juvenile and adult fish against unacceptable lethal conditions.

EPA finds the addition of a chronic DO objective of 5.0 mg/L minimum (calculated as a 30-day running average and that applies year-around in all sloughs and channels of Suisun Marsh) will protect survival/recruitment/growth of larval/juvenile and adult resident fish and protect threatened and endangered species across Suisun Marsh habitats.

EPA finds the addition of a chronic DO objective of 6.4 mg/L minimum (calculated as a 30-day running average and that applies from January 1 through April 30 in Montezuma, Nurse and

Denverton sloughs) will protect survival/growth of larval/juvenile migratory fish (listed salmonids including steelhead and Chinook) and protect threatened and endangered species in Suisun Marsh.

The first two DO objectives (Regional Board Resolution R2-2018-0015, Exhibit A Proposed Basin Plan Amendment, p.A-1) will apply to all sloughs within the Suisun Marsh regardless of size or connectivity to open waters. They do not apply to waters not in the sloughs (i.e., to the tidal or managed wetlands).

III. Compliance with the Endangered Species Act (ESA) Section 7

EPA initiated consultation with the U.S. Fish and Wildlife Service and National Marine Fisheries Service (the Services) regarding the proposed CWA approval of revised DO water quality objectives for Suisun Marsh on September 30, 2018.

The EPA completed and submitted to the Services on December 7, 2018, a Biological Evaluation (BE) conveying the EPA's evaluation that the approval of revised DO water quality objectives for Suisun Marsh, **may affect but is not likely to adversely affect listed species.**

On February 13, 2019, the U.S. Fish and Wildlife Service (FWS) sent EPA a letter of non-concurrence after reviewing EPA's BE. The EPA promptly addressed FWS's concerns and sent a revised BE to the FWS on April 8, 2019, reiterating its determination that the proposed action **may affect but is not likely to adversely affect listed species**.

IV. EPA's Assessment of the Basin Plan Amendments

The EPA first approves the removal of the current DO objectives for Suisun Marsh, and the adoption of revised DO site-specific objectives for all Suisun Marsh sloughs and channels, and for Montezuma Slough, Nurse Slough, and Denverton Slough. EPA approves the removal of the current objectives for Suisun Marsh only where revised DO site-specific objectives are established and these are shown in the Basin Plan amendment (Regional Board Resolution R2-2018-0015, Exhibit A Proposed Basin Plan Amendment, p.A-1).

Based on the above analyses, staff recommends the EPA approve the revised DO water quality objectives for Suisun Marsh to include:

- An acute DO objective of 3.8 mg/L minimum (as a daily average) applies year-around in all sloughs and channels of Suisun Marsh to protect the survival of juvenile and adult fish.

- A chronic DO objective of 5.0 mg/L minimum (as a 30-day running average) applies year-around in all sloughs and channels of Suisun Marsh to protect the survival/recruitment/growth of larval/juvenile and adult resident fish, and to protect threatened and endangered species.

- A chronic DO objective of 6.4 mg/L minimum (as a 30-day running average) applies from January 1 through April 30 in Montezuma, Nurse and Denverton Sloughs to protect the survival and growth of larval/juvenile migratory fish (listed salmonids including steelhead and Chinook), and to protect threatened and endangered species.

The first two revised DO objectives will apply to all sloughs within the Suisun Marsh regardless of size or connectivity to open waters. They do not apply to waters not in the sloughs (i.e., to the tidal or managed wetlands).

The EPA concludes that the Regional Board has provided reasonable explanations to support the recommended amendments to the Basin Plan. The Regional Board's modifications to the beneficial uses and water quality criteria/objectives specified in the Basin Plan are based on new data and analysis. Following review of the Regional Board's submittal, the EPA staff supports and recommends approval of the Regional Board's amendments to the Basin Plan.