APPENDIX E

COMMENT LETTERS RECEIVED

by February 28, 2018

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From: Feldheim, Cliff@DWR
To: Baginska, Barbara@Waterboards
Subject: TMDL Comment
Date: Monday, February 26, 2018 1:23:04 PM

Barbara,

How are you? Below please find my only comment on the TMDL Amendment to the Water Quality Control Plan for the San Francisco Basin.

One weakness associated with this TMDL is determining the success (or failure) of its implementation. The document states that load reductions required by the Bay Mercury TMDL are likely to be achieved by 2026, but that it may take as long as 100 years to achieve target concentrations in sport fish tissue due to the large inventory of mercury already in the Bay. If this is true, then fish tissue concentrations could be above the 0.2 mg/kg target objective for as long as one hundred years. Will project proponents need to monitor fish tissue for one hundred years in tidal wetland restoration sites? Since control sites may continue to show high fish tissue concentrations for one hundred years, how can one show that tidal restoration isn't significantly impacting the load to the system so that monitoring can cease? If fish tissue levels at tidal restoration sites are not significantly different from elevated fish tissue levels at control sites, is this enough evidence to cease monitoring? What if one does not meet target levels in Bay fish simply because of the large inventory of Hg in the Bay? Will a project proponent be held to lower and lower regulatory standards because high background levels preclude judging whether fish tissue concentrations are going down? I believe that some provision for these issues needs to be more explicitly stated.

Thank you for the opportunity to comment on this propose regulation.

Hope you are doing well,

Cliff

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GREGORY G. BAATRUP, GENERAL MANAGER

February 28, 2018

RW-100.10.10/18

Barbara Baginska
California Regional Water Quality Control Board
San Francisco Bay Region
1515 Clay Street, Suite 1400
Oakland, CA 94612

Via email to barbara.baginska@waterboards.ca.gov

RE: Suisun Marsh Total Maximum Daily Load for Dissolved Oxygen
Draft Staff Report for Proposed Basin Plan Amendment

Dear Dr. Baginska,

The Fairfield-Suisun Sewer District (District) appreciates this opportunity to provide comments on the San Francisco Bay Regional Water Quality Control Board's (Water Board) proposed Basin Plan amendment regarding Dissolved Oxygen and Mercury in Suisun Marsh. The District delivers advanced secondary effluent directly to Suisun Marsh and we are committed to the protection and preservation of these marshlands.

The District supports the staff's conclusion that new NPDES permit requirements are not necessary. We will continue to provide high quality effluent to improve dissolved oxygen conditions in the marsh.

The District has the following specific comments on the Draft Staff Report:

1. **Correct the maximum allowable BOD discharge from our facility (Page 44)**

   The origin of the "545 kg/day" value on page 44 is unclear. The District's NPDES Permit does not contain a mass-based limit for BOD. It includes an average monthly effluent limitation of 10 mg/L for BOD, and average dry weather flow is limited to 23.7 MGD. This equates to a conservatively estimated maximum allowable discharge of about 900 kg/day, not 545 kg/day. The daily BOD load cited in the report is correct—typical operations result in effluent BOD below the detection limit and well within permit limits.

   The District does not sample effluent for Dissolved Organic Carbon (DOC), so the report should include a rationale for the estimates of DOC loading; otherwise, the estimates should be removed.

   Correct page 44 to read as follows:

"Although the maximum allowable discharge of BOD load from FSSD was approximately 900 kg/day ~~was at 545 kg/day or 204 kg/day as DOC~~, actual discharges are usually much lower. For example, in 2012, the average daily BOD load was less than 107 kg/day ~~(DOC load of 40.1 kg/day)~~ (NPDES discharge data)."

2. **Be aware of limitations on the Districts ability to route "more FSSD discharges to Boynton and Peytonia Slough … at times when low DO water is being discharged from managed wetlands." (Page 77)**

   The District's ability to increase discharges depends on influent flows to the plant as well as established recycled water demands.

3. **Revise the implementation language for the District's DO receiving water limitation (Page 77)**

   Table 9-1 (Page 58) and Section 12.2.1 (Page 77) identify minor proposed changes to the DO receiving water limitations included in the District's Permit. The District requests minor changes to the text to clarify that DO limits continue to apply within one foot of the surface and that the 3-month median will be removed from the NPDES Permit.

   Revise page 77 to read as follows:

   "The wasteload allocation for the FSSD wastewater treatment plant will continue to be implemented as receiving water limitations (≥5.0 mg/L June 1-November 15, and ≥7.0 mg/L during all other times of the year and expressed as 30-day running average and within one foot of the surface). The requirement to maintain the median DO concentration for any three consecutive months at ≥ 80% of DO content at saturation will be removed from the NPDES Permit ~~not be required~~ as this objective does not apply.

4. **Edit language related to the District's discharge strategy (Page 77-78)**

   Text on pages 77 and 78 related to storage ponds and irrigation is not clearly related to the TMDL implementation plan and does not accurately reflect current District operational capabilities. Also, the District prefers the term "discharge" pipeline.

   Revise text on Pages 77-78 as follows:

   "Additionally, treated wastewater can be ~~redirected to storage ponds or irrigation conveyance and~~ used directly to flood up duck clubs located in the immediate vicinity of the discharge ~~distribution~~ pipeline. This would reduce the amount of water drawn from the sloughs, thereby reducing net upstream flows that had been associated with fish kills in the past. The FSSD currently participates in the WQIF project, which tests the best ways to utilize treated effluent from their facility to improve DO conditions in the Marsh.

The District strongly supports the Water Board's thoughtful examination of this Basin Plan Amendment, and we appreciate your consideration of our comments. Please do not hesitate to contact me at (707) 428-9109 or mherston@fssd.com if you have any questions.

Sincerely,

Meg Herston
Environmental Compliance Engineer

SAN FRANCISCO
BAYKEEPER®

February 28, 2018
Barbara Baginska and Board Members
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Transmitted via electronic mail to: barbara.baginska@waterboards.ca.gov

Re: Proposed Amendments to the Water Quality Control Plan for the San Francisco Basin: Dissolved Oxygen and Mercury TMDL for Suisun Marsh

Dear Ms. Baginska and Regional Water Board Members,

On behalf of San Francisco Baykeeper and our over five thousand members and supporters who use and enjoy the environmental, recreational, and aesthetic qualities of San Francisco Bay and its surrounding tributaries and ecosystems, we respectfully submit these comments for consideration by the San Francisco Bay Regional Water Quality Control Board, regarding Proposed Amendments to the Water Quality Control Plan for San Francisco Basin: Dissolved Oxygen TMDL Provisions and Mercury TMDL Provisions in Suisun Marsh ("DO TMDL"). We appreciate the opportunity to provide these comments.

This TMDL was largely driven by DO depletion caused by releases of water from managed ponds, yet this TMDL contains no instantaneous minimum dissolved oxygen (DO) values, consistent with other TMDLs developed based on the 'Virginia Province Approach'. Nor does the TMDL require implementation of recognized best management practices ("BMPs") identified in the DO TMDL to improve water quality at managed wetlands. We ask the Regional Board to consider our requests to address the need for more active management of Suisun Bay duck clubs and their associated ponds.

Baykeeper is primarily concerned that the DO TMDL numeric targets are under-protective of aquatic life beneficial uses, and that the proposed Implementation and Monitoring Program for the DO TMDL lacks specificity to attain these targets. The Program, as proposed, relies on a status quo approach insufficient to determine the water quality attainment or the effectiveness of BMPs. This is in conflict with minimum TMDL requirements established in U.S. Environmental Protection Agency ("EPA") guidance for TMDL development.[1]

I. Monitoring Plan and TMDL DO Targets Insufficient to Determine Protection of Aquatic Life

Although numeric targets in the DO TMDL were derived using methods outlined in the EPA's approach to deriving the lower limits of DO necessary to protect coastal and estuarine animals in the Virginia Province[2], the proposed numeric targets require less protective sampling timeframes than similar TMDLs for dissolved oxygen derived from these guidelines, including the EPA's Chesapeake Bay Dissolved Oxygen Criteria

[1] U.S. EPA, Draft Guidance for Water Quality-based Decisions: The TMDL Process (2nd Edition), EPA 841-D-99-001 (August 1999).
[2] U.S. EPA, Office of Water. 2000. Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras (EPA-822-R-00-012).

("Chesapeake DO Criteria").[3] The DO TMDL includes numeric targets of acute (3.8 mg/L) and chronic (5.0 mg/L) DO concentrations as the mean of samples taken over 1 and 30 day periods respectively (Table 1). While the numeric values in the DO TMDL are comparable to the standards implemented by the Chesapeake DO Criteria, the proposed sampling periods for DO numeric targets in Suisun Marsh are under protective of Suisun Marsh's beneficial uses and oversimplified in comparison to those found in the Chesapeake DO criteria (Table 2).

Table 4-2
TMDL DO targets for protection of aquatic life beneficial uses in Suisun Marsh

Designated Use	DO concentrations/ Duration	Protection	Time of year
All sloughs and channels	1-day mean [a] ≥3.8 mg/L (Acute - CMC)	Survival of juvenile and adult fish	Year-round
All sloughs and channels	30-day mean [b] ≥5 mg/L (Chronic – CCC)	Survival/growth of larval/juvenile and adult resident fish; protective of threatened/endangered species	Year-round
Montezuma, Nurse and Denverton Sloughs	30-day mean [b] ≥6.4 mg/L (Chronic – CCC)	Survival and growth of larval/juvenile migratory fish (salmonids); protective of threatened/endangered species	January-April

[a] estimated as daily average
[b] estimated as 30-day running average

Table 1. The proposed TMDL DO targets for Suisun Marsh, including 1-day acute values and 30-day chronic values.

[3] U.S. EPA, Office of Water. 2003. Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll *a* for the Chesapeake Bay and Its Tidal Tributaries (EPA-903-R-03-002).
Available at: https://www.chesapeakebay.net/content/publications/cbp_13142.pdf

Table 1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	7-day mean ≥ 6 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species.	February 1 - May 31
	Instantaneous minimum ≥ 5 mg liter^{-1}	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean ≥ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean ≥ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean ≥ 4 mg liter^{-1}	Survi:al of open-water fish larvae.	
	Instantaneous minimum ≥ 3.2 mg liter^{-1}	Survival of threatened/endangered sturgeon species.[1]	
Deep-water seasonal fish and shellfish use	30-day mean ≥ 3 mg liter^{-1}	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean ≥ 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum ≥ 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum ≥ 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

Table 2. Chesapeake Bay DO Criteria and timeframes. Note that these criteria are separated by designated use, all of which are protected by an instantaneous minimum and a 7-day mean.

The DO TMDL numeric targets do not include a multi-day short-term DO criteria, like the 7-day sampling criteria required in the Chesapeake DO Criteria (Table 2). This short-term monitoring period is more likely than a 30-day sampling mean to show signs of short-term DO impairment following managed wetland discharges. According to the Staff Report, a 2007 study showed that managed wetland drain events could decrease DO levels to 1.5 mg/L-0 mg/L, creating hypoxic and lethal conditions lasting multiple days. Based on information provided in the DO TMDL regarding the monitoring approach, it is not clear such events would be adequately detected or that the Acute CMC (1-day mean ≤3.8 mg/L) is protective of severe DO lags that may take place over hours rather than days.

Although some aquatic life in Suisun Marsh may be naturally resilient to natural DO variation in wetland habitats, a multi-day period of extremely low DO values following a stagnant water discharge can severely impact fish growth, survival, and larval recruitment.[4] A short-term lag in DO levels caused by managed wetland discharges could easily occur unnoticed when included within a mean taken from a cumulative 30-day sampling period.

Baykeeper requests the Regional Board revise the DO TMDL to establish a numeric target with a 7-day monitoring window to protect Suisun Marsh's aquatic life from these previously observed multi-day DO lags.

[4] U.S. EPA, Office of Water. 2000. Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras (EPA-822-R-00-012).

Additionally, the DO TMDL numeric targets also fail to establish an instantaneous minimum value for any criteria, falling short of the Chesapeake DO Criteria. Instantaneous minimums, or threshold values that cannot be exceeded in a single sampling event, identify exceedances of the TMDL. These values offer greater protection against fatal DO conditions than would a mean of DO measurements taken over a 24-hour or 30-day time period. The Chesapeake DO Criteria includes instantaneous minimum values to protect aquatic life, including more stringent protections during salmonid migration and spawning season. Suisun Marsh has these same beneficial uses, and merits similar protections for its aquatic life. To account for natural variation, the Regional Board could establish a number of allowable exceedances of an instantaneous minimum value per sampling period, month, or year. However, natural variation cannot be an excuse for excluding instantaneous minimum values from the DO TMDL entirely.

Accordingly, Baykeeper requests the Regional Board revise the DO TMDL to include instantaneous minimum values.

II. There are No Response Requirements if the Sample Measurements Exceed the DO TMDL Numeric Targets

The DO TMDL fails to identify for managed wetlands any required response actions to a measured exceedance of the DO TMDL numeric targets during a sampling period. The model study discussed in Section 8.2 of the Staff Report showed that stable DO concentrations of 5 mg/L could be attained during managed wetland discharge events by reducing the volume of discharge or discharging a smaller load over a longer period of time. In response to any DO readings taken below the acute threshold (or instantaneous minimum) during a managed wetland discharge event, the managed wetland should be required to implement these or similar BMPs to immediately reduce the load until DO levels return to an appropriate threshold.

Baykeeper requests the Regional Board to revise the DO TMDL to specify immediate actions that managed wetlands exceeding their DO load allocations must take to facilitate attainment of the DO TMDL.

III. The Proposed Implementation and Monitoring Protocol Fails to Regulate Managed Wetland Discharges

The DO TMDL's Implementation and Monitoring Protocol is insufficient to reduce the impact of managed wetlands on DO levels in Suisun Marsh. Sections 12.1.1 through 12.1.6 of the DO TMDL only summarize voluntary BMPs for managed wetlands and funding sources for landowners to develop their own water quality management programs. By failing to include additional required minimum BMPs, it is likely that managed wetlands will not implement additional BMPs, and will merely carry on the current status quo under the DO TMDL.

Baykeeper requests the Regional Board revise the DO TMDL Implementation and Monitoring Protocol to require managed wetlands to implement the full suite of recommended BMPs listed in Table 12-2 of the DO TMDL, to enhance the likelihood of full attainment of the DO targets, and to reduce activities that impair DO levels and/or implement new actions that will support attaining the TMDL.

Moreover, the DO TMDL allows the Regional Board to defer the majority of its regulatory authority to other agencies, relying on the U.S. Army Corps of Engineers' RGP3 Permit requirements for mandatory BMP implementation and DO Monitoring at managed wetlands. Section 12.1.6 of the Staff Report states the primary regulatory tool to implement the DO TMDL at managed wetlands is the 401 Water Quality Certification. Waste Discharge Requirements ("WDRs") will only be issued to individual landowners if the TMDL is not achieved via voluntary compliance with the 401 Water Quality Certification. Baykeeper believes that is it highly unlikely that managed wetlands implementing their status quo BMPs will be able to voluntarily comply with the DO TMDL.

Baykeeper requests the Regional Board implement the DO TMDL through individual WDRs.

IV. Limited Fall Monitoring Requirements for Managed Wetlands are Insufficient to Determine TMDL Compliance

Section 2.1.2 of the Staff Report indicates that managed wetlands primarily discharge water into Suisun Marsh and surrounding sloughs during the "Fall Flood-Up" time period, but additional discharges also occur in winter and spring. According to Section 12.1.2 of the Staff Report, the Suisun Resource Conservation District ("SRCD") and managed wetlands only monitor for DO before and during fall water discharges, "until mid-November, when, in general, water quality starts to improve in the sloughs receiving discharge from managed wetlands." It is not enough to rely on the *assumption* that "water quality starts to improve in the sloughs [in mid-November]" in lieu of scientific monitoring to assure the DO TMDL is met. Furthermore, as discussed in Section 12.4.2 of the Staff Report, this limited monitoring of managed wetland discharges fails to meet the Water Board's 401 Water Quality Certification requirement that "the sampling frequency and spatial extent be sufficient to determine ambient DO levels before the discharge occurs and to determine whether water quality objectives for DO in the receiving waters are met after the release of water from the managed wetlands."

Baykeeper requests the Regional Board revise the DO TMDL to require managed wetland discharges in winter and spring be sampled in the same manner as fall discharges to establish DO TMDL compliance.

The Staff Report states that SRCD is responsible for submitting a monitoring report to the Regional Board, including monitoring results, any implemented BMPs, and collaboration efforts between managed wetlands to meet the DO TMDL. It is unacceptable for the Regional Board to rely on a monitoring report from an external agency that only includes a portion of discharges into Suisun Marsh from managed wetlands, as these water discharges can cause substantial DO lags in receiving waters year-round.

Baykeeper requests the Regional Board revise the DO TMDL to clarify that individual managed wetland must submit individual reports, including monitoring data and updates to BMPs.

Baykeeper is extremely concerned about the impact of unmonitored winter and spring water discharges on spawning and migratory salmonids in Suisun Marsh, including endangered species. Monitoring requirements should be stringent during this season to ensure that beneficial uses (estuarine habitat, fish migration, preservation of rare and endangered species, fish spawning, and wildlife habitat) are appropriately protected. The proposed 30-day mean DO criterion of 5.0 mg/L is raised to 6.4 mg/L in Montezuma, Nurse, and Denverton Sloughs during the winter season (Jan-April) to protect migratory and endangered fish (Table 2).

Baykeeper requests the Regional Board revise the DO TMDL to include more stringent monitoring requirements during the winter time period to ensure that this protective criterion is met.

V. The DO TMDL Does Not Include Monitoring Requirements for Methylmercury Discharge at Managed Wetlands

Section 7.6 of the Staff Report does not include any requirements or guidelines for monitoring Methylmercury ("MeHg") discharge from managed wetlands in the Implementation Plan, despite naming managed wetlands as a substantial local source of MeHg. Section 11.1 of the Staff Report only includes tidal wetland restoration projects as subject to Bay Mercury TMDL requirements (through WDRs and Section 401 Certifications), failing to include any reduction requirements for managed wetlands. Relying on the gradual process of restoring tidal wetlands instead of requiring managed wetlands to reduce activities that promote Methylation will not result in attaining the Mercury TMDL. As stated in Section 12.1.6 of the Staff Report, if tidal marsh restoration projects "must…include pre- and post- restoration monitoring [of methylmercury] to demonstrate compliance" with Section 401 Water Quality Certifications, managed wetlands should be subject to similar MeHg monitoring requirements to show they are not causing a "net increase in mercury or methylmercury loads to the Bay."

Baykeeper requests the Regional Board revise the DO TMDL to include required reductions and actionable monitoring requirements for managed wetlands to ensure that the Mercury TMDL is met.

*****

Among the highlights of the most recent State of the Estuary Report included the finding that the "Upper Estuary (Suisun Bay and the Delta) is in fair to poor condition and getting worse".[5] This is the result of multiple stressors, requiring bold integrated actions if the health of Suisun Bay and the Delta is ever to recover. Consistent with other recent management actions affecting North San Francisco Bay, notably the North San Francisco Bay Selenium TMDL, we have seen a status quo management approach – virtually assuring the gradual, relentless decline of a system that just a generation ago was considered thriving.

To address the need for additional protections, Baykeeper respectfully requests that the Regional Board implement more protective DO Criteria and a stronger Implementation and Monitoring Plan to ensure that the DO and Mercury TMDL is met in Suisun Marsh. Baykeeper firmly believes that protections extended to managed wetland landowners should not exceed the protections extended to Suisun Marsh.

Sincerely,

Sienna Courter

Field Investigator, San Francisco Baykeeper

5 The State of the Estuary 2015, San Francisco Estuary Partnership. Available at http://www.sfestuary.org

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28 February 2018

Barbara Baginska
San Francisco Bay Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Dear Barbara,

The Suisun Resource Conservation District (SRCD) is submitting a comment letter to the proposed amendment of the Water Quality Control Plan for the San Francisco Bay Basin. The amendment includes establishing water quality objectives and a total maximum daily load (TMDL) for dissolved oxygen in Suisun Marsh and addressing mercury impairment in Suisun Marsh under the San Francisco Bay Mercury TMDL. The SRCD represents private landowners in Suisun Marsh on conservation issues to achieve water supplies of adequate quality to promote managed wetland preferred habitats and support wetland resource values through best management practices.

The Basin Plan amendment report and plan provide a comprehensive examination of water quality impairment issues. We appreciate the effort of the Water Board to work with the SRCD and landowners on development and implementation of Best Management Practices (BMPs) for managed wetlands to improve water quality in Suisun Marsh. In general, close coordination of wetland management with real-time monitoring will be most beneficial in meeting water quality objectives. We have provided specific comments to the draft of the plan below, mostly focused on dissolved oxygen (DO), and we look forward to providing feedback on its implementation.

Introduction (p. 1, para 3): *"Salinity conditions in Suisun Marsh are to a great degree dependent on Delta water management regulations and decisions, and affected by the overall hydrology of the Central Valley watershed (ranging from wet to critically dry)."* It should be noted that many wetland management practices in Suisun Marsh were initiated under conditions of lower salinity preceding changes in the Delta water management regulation.

Introduction (p. 1, para 4): "From 2009 to 2018, ~~*Over the past two decades,*~~ *low DO concentrations* ~~*and fish kills*~~ in the fall *have been* ~~*frequently*~~ *observed in 4 out of 20 years in Peytonia, Boynton, Suisun, and Goodyear Sloughs in Suisun Marsh (O'Rear and Moyle, 2010, Schroeter and Moyle, 2004). Fish kills were documented in the fall seasons of 1999, 2001,* ~~*and*~~ *2003,* and 2004*. In October 2004, a widespread fish kill was observed in Peytonia, Boynton, Goodyear, and Suisun Sloughs (Schroeter and Moyle, 2004). In October 2009, 100% mortality of fishes was observed in Goodyear Slough (O'Rear and Moyle, 2010). The fish kills were linked to the releases of low DO waters from managed wetlands. DO concentrations below 1-2 mg/L were measured in the Marsh sloughs when discharges from the managed wetlands occurred, which can result in mortality to some species of fish."* Fish kills may occur under historical conditions or those without managed wetlands, but that rate is not known; hence, it is better to be specific here rather than suggest what is occurring "frequently."

Introduction (p. 2, para 2): *Two-thirds, or about 52,000 acres, of the Suisun Marsh wetlands are managed wetlands, meaning they are diked and managed to provide* seasonal wetland *habitat for* resident and migratory wildlife focused on better *waterfowl* food resources*. Accordingly, water control actions and vegetation management at managed wetlands play an important role in maintaining adequate DO levels* of discharge water.

Introduction (p. 2, para. 3): *"…restoration of tidal action to at least* ~~7,000~~ 5,000 *acres of managed wetlands in Suisun Marsh* (USFWS Tidal Marsh Recovery Plan, 2013)." The recovery plan and EIS report at least 5,000 acres.

2.1 Suisun Marsh Area (p.5, para 2): "*The majority of the Marsh is used by over 150 private duck clubs today, which maintain diked seasonal wetlands for wintering waterfowl and hunting (Figure 2-2)* as well as other resident and migratory wildlife species*. In addition, some publicly owned portions of the marsh, including Grizzly Island Wildlife Area, are managed as wetlands supporting public waterfowl hunting."*

2.1.1 Hydrology: "*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."*

2.1.2 Role of Managed Wetlands: while management is directed at wintering habitat for waterfowl, seasonal wetland management contributes a wide array of other beneficial ecosystem services that should be mentioned include enhancing biodiversity of species such as wintering shorebirds and other aquatic organisms, contributing invertebrate food resources for higher trophic level predators including fish, supporting breeding wildlife, sequestering carbon, and enriching cultural values.

Figure 3-2, Causes of low DO in small tidal sloughs in Suisun Marsh: the key element requiring vegetation management is elevated salinity levels in waters linked to Delta water management regulations. The conceptual model should include a box that indicates Salinity is a primary External Source or Driver of wetland Vegetation Management. Without elevated salinities, leaching and discharge cycles would not be necessary.

3.6 Mercury Effects and Impairment Assessment, p. 21, para 1: it would be good to note here that Mississippi silversides is a non-native species that forages in shoreline and shallow water habitats and exhibits greater potential for Hg methylation (p. 8, Sec 5.2.2).

5.2.2 p. 39, para 1: correct "(California least tern)"

6.2.1 Surrounding Watersheds, p. 43, para 2: it may be relevant to note that runoff concentrations also have and will be affected by changes in watershed conditions following events such as wildfires.

Section 7.6 Managed Wetlands, p. 51, para 5: specify here that export will vary greatly with seasonal flooding and draining periods of pond management.

8.2 Impact of Discharge Timing and Volume on DO, p. 55: *"The HEC-RAS simulations demonstrated that changes to water management at the duck club properties, and specifically reductions in discharge by 40 to 60%, could result in a significant improvement in DO conditions in the receiving slough*, but could have detrimental impacts to the managed wetland habitats. *Similar improvements could be accomplished by allowing for* *discharge to occur over longer periods of time. This confirms implementation actions that improve water management, such as staggering discharges in individual sloughs, redirecting discharges to larger sloughs when possible, and coordinated release of FSSD high DO treated effluent, provide the best opportunity to improve DO and is the most efficient use of the available resources."* Text was added to specify trade-offs. Also, it would be good to indicate when possible a rough idea of what "longer periods" of discharge will make a difference.

9.3. Seasonal Variations and Critical Conditions: was there any consideration of impending effects of climate change? Extended drought conditions with earlier runoff may result in warmer water temperatures and more likelihood of low DO events despite management best efforts.

12. Suisun Marsh DO TMDL Implementation Plan, p. 69, para 2: *"In developing the proposed implementation actions priority was given to those that were lower-cost and could be completed on-site now at managed wetlands."* It would be good to have Water Board support for allocation of potential funding sources listed in the report directed to implementation of BMPs and continuous monitoring.

12.1.1. Changes in Vegetation and Water Management at Managed Wetlands, p. 70, para 2-3:
1. Hydrology Management BMPs: these voluntary measures require coordination and cooperation of diverse landowners, and any efforts to support participation would be beneficial.
2. Carbon (Vegetation and Soil) Management BMPs: the results of these measures will vary widely depending on annual conditions and timing of plant growth and soil types.

12.1.1. Changes in Vegetation and Water Management at Managed Wetlands, p. 70-71, para 2-3:
"During TMDL development, Water Board staff coordinated with the Suisun Resource Conservation District (SRCD) to initiate early implementation actions in the Marsh, targeting the most affected sloughs (Table 12-2)." We look forward to providing landowners with technical assistance to enact the BMPs that are part of the Clean Water Act Section 401 certification.

12.1.1. *"Early implementation continued throughout the 5-year permit term (2013-2017), which resulted in the improved water quality conditions and significantly reduced frequency of low DO. There have not been any documented fish kills since RGP3 was renewed."* We are pleased with the landowner participation in the BMPs to date, but participation will likely vary widely with differing annual conditions, cost of BMPS, and water years.

12.1.1. *"BMP implementation and regional coordination of managed wetland operations in the western region of Suisun Marsh appear to be successful at helping to reduce impacts of managed wetland discharges on slough water quality."* High daytime temperatures in late October of 2017 resulted in decreased DO at most stations in the western marsh. Increased fall temperatures related to climatic change may result in reduced DO levels in some periods despite following BMPs.

12.1.1. For early implementation, western duck clubs implemented BMPs that included:
• *DO measurements to coordinate flood-up and drain events across multiple managed wetlands;*
--We are working with DWR to add sondes to areas where real-time DO information would be helpful.

• *Staggered flood-up and discharges across multiple duck clubs to avoid simultaneous*

discharges of low DO water to a particular slough or sloughs;
--Success on this BMP varies depending on voluntary landowner participation and logistics.
• *Modified intake and discharge points to enhance water mixing in receiving sloughs;*
--While beneficial, only a few opportunities are available on a limited number of managed wetlands.
• *Cleaned and removed sediment from swales and ditches to improve internal water circulation;*
--circulation improvement is part of the goal for effective managed wetland operations.
• *Circulated water through the managed wetlands more quickly to reduce organic enrichment;*
--This is being examined by SRCD and California Waterfowl Association under an ongoing Managed Wetland Assessment Project supported by DWR.
• *Maximized use of discharge from the Fairfield Suisun Sewer District outfall for initial flood-up of managed wetlands close to the outfall to provide higher DO inflows;*
• *Completed vegetation management earlier to facilitate longer decomposition prior to fall flooding, reducing organic enrichment in discharged water;*
--This will vary with the water year, as work occurs earlier in dry years.
• *Mechanically removed broadleaf vegetation and promoted annual grasses; and*
• *Coordinated water management activities at duck clubs with vector control requirements and the constraints imposed by DFW and the US Fish and Wildlife Service. Specifically, coordinated diversion and intake restrictions to avoid entrainment of listed species.*
--indicate vector control is led by the Solano County Mosquito Abatement District; their regulations for public health and safety and support for control efforts will affect the ability meet DO levels.

12.1.2 DO Monitoring to Aid BMPs Implementation: *"Each year, SRCD submits to the Water Board a monitoring report describing the results of DO monitoring, the BMPs implemented during the fall discharge period, and co-ordination details among adjacent duck clubs. The monitoring proved to be valuable in assessing the effectiveness of various BMPs and in focusing implementation in low-DO areas. ...Accordingly, the TMDL anticipates that implementation actions and monitoring should be continued, with some consideration for adaptive implementation based on the results of the monitoring."* Effective monitoring will need to be representative and aligned with adaptive BMPs for the best effect.

Please let me know if you have any questions.

Sincerely yours,

Steve Chappell
Executive Director

SCIENTIFIC PEER REVIEW COMMENTS

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REVIEW OF: ESTABLISH WATER QUALITY OBJECTIVES AND TOTAL MAXIMUM DAILY LOAD FOR LOW DISSOLVED OXYGEN/ORGANIC ENRICHMENT IN SUISUN MARSH AND ADD SUISUN MARSH TO SF BAY MERCURY TMDL

REVIEWER: TIM ESSINGTON

AFFILIATION: UNIVERSITY OF WASHINGTON

DATE: SEPTEMBER 15, 2017

In accordance with the section 303(d) of the federal Clean Water Act, the San Francisco Bay Regional Water Quality Control Boar seeks to set water quality criteria for Suisun Marsh. The Water Board already have criteria for downstream portions of San Francisco Bay but these are not appropriate for upstream reaches that contain tidal wetlands that are naturally lower in dissolved oxygen (DO). Moreover, fish kills have been observed in Peytonia, Boynton, Suisun and Goodyear Sloughs, primarily in Autumn. These appear to be related to timing of inundation and drainage of managed wetlands, principally those part of duck clubs.

The document "Establish water quality objectives and total maximum daily load for low dissolved oxygen/organic enrichment in Suisun Marsh and add Suisun Marsh to SF Bay mercury TMDL" describes the context, the system, and the methods used to set water quality criteria, identify acceptable nutrient loads, and set mercury criteria.

The report is well prepared and provides a thorough and rigorous review of the state of the system, the data that are available, and the alternative causes for low dissolved oxygen. These include carbon inputs, wastewater treatment, runoff from urban creeks, and flooding and drainage of managed wetlands. The report makes a convincing case that managed wetlands are the primary cause of extreme low dissolved oxygen events in autumn.

Before getting into specific comments related to my charge, I note the following minor issues with the report:

Table 3-1 and 3.2 are inconsistent. Table 3-1 states that in 2004 "DO levels were recorded as low as 2.8 mg/L for three sites, and a low of 2.3 mg/L was recorded for Goodyear Slough", while Table 3-2 shows DO levels that are much lower than this. Please clarify

Figure 3-1. Legend needs to explain what the inset plots are showing. I think they are bar plots of measured DO through time, where each bar is a year. The bars are further color coded to indicate DO. It is confusing because the time axis is not specifically identified, and both bar height and bar color convey the same information. Also, are these annual averages? Minima?

Figure 3-2 is confusing, because the outcomes appear linked. For instance, the outcome of "growth of algae, macrophyte" is linked by an arrow into the outcome "Duck Club low DO and high BOD exports". It is not clear that this refers to growth of algae and macrophyte within the managed wetland or something else. Some of the dotted areas have text labels, others do not. A more detailed figure legend is needed.

Figure 8.1 Denverton is misspelled on map, Union Creek is labeled as Laurel Creek.

My review of this report is focused on three goals:

*1.The proposed SSOs for DO are fully protective of the resident sensitive aquatic organisms in Suisun Marsh sloughs (**Section 4**).*
*2.The derivation of the objectives is supported by sound scientific information and methods(**Section 4**).*
*3. The SSOs are appropriate targets for the Suisun Marsh TMDL for low DO/organic enrichment (**Section 9**).*
*4.The concentration-based TMDL is protective and supportive of aquatic life beneficial uses in Suisun Marsh sloughs (**Section 9**).*

To this end, I reviewed multiple documents, including but not limited to:
Stephan et al. 1985 Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. NTIS Publication No: PB85-227049

EPA 2000. Ambient aquatic life water quality criteria for dissolved oxygen (saltwater): Cape Cod to Cape Hatteras EPA 822-R-00-12.

Bailey et al. 2014 Science supporting dissolved oxygen objectives for Suisun Marsh. Southern California Coastal Research Project Technical Report 830.

Tetra Tech 2017. Technical Report: DO Criteria Recommendations for Suisun Marsh.

This document, including review comments on the Tetra Tech 2017 report from the Science Advisory Panel.

To address the goals I posed the following questions
- Does the document and cited material provide sufficient information to address goal?
- Are conclusions clearly linked to analyses, and readily follow from analyses?
- Have the authors appropriately considered uncertainties and other factors that might influence the SSO calculations?
- Was the choice of method and information used well supported?

1.The proposed SSOs for DO are fully protective of the resident sensitive aquatic organisms in Suisun Marsh sloughs (Section 4).

Does the document and cited material provide sufficient information to address goal?

The report assesses species that provide *beneficial uses*. These were defined as those that serve key ecological functions, are of commercial or recreational importance, or are threatened / endangered species. Non-native species are used when deemed an appropriate surrogate for native species. There is a good, rationale and transparent basis for selecting species. The Bailey et al. 2014 report provided the first compilation of species to be used in analysis, which was then revised following feedback from the Science Advisory Panel.

The process resulted in a collection of 17 fishes, and 5 invertebrates. The species list includes Chinook salmon and steelhead trout, and white sturgeon, which is relevant because they are ESA listed. The species clearly meets the defined guidelines and represents a wide taxonomic diversity.

For each species, LD50 values were obtained from review of laboratory experiments or, when available, field observations. When information was not available for a species, surrogate species of same genera, or same family were used. The report failed to provide citations to the information sources used to create Table 8 in Tetra Tech (2017), and also failed to provide the method by which information was gathered. For instance, though Tetra Tech (2017) states that they identified new lab studies and field studies, a list of search terms and search databases were not provided. The report also failed to provide information on quality control on LD50 values e.g. minimum sample size, appropriate temperature, precision of estimate. For this reason it is not possible to assess the appropriateness, accuracy, or precision of the information used to generate the SSOs. In comparison, the EPA2000 report provides some information on quality control (there, they removed studies that were conducted on temperatures out of range of the area being considered). I understand that many of the LD50 values used in the present report were based on those reported in the EPA 2000 report, yet it is not clear to me how information on additional species, or updated information collected over the past 15+ years were identified.

The calculations of CMC and CCC are clearly laid out, in Tetra Tech 2017 and in Bailey et al. 2014. They apply the method to define minimum DO level needed to provide protection of 95% of all species. This method assumes a log-triangle distribution of LD50 levels, and assumes that LD05 is 1.38 times higher than LD50. The latter assumption comes from EPA (2000). However, in Tetra Tech 2017 tables, a ratio of 1.43 is indicated (although the text refers to a 1.38 ratio). The ratio used needs to be clarified.

The application of the EPA (2000) framework is clearly laid out. This framework considers effects on juvenile and adult survival, effects on juvenile and adult growth, and effects on egg / larval survivorship. The latter is based on a simple model that calculates degree of exposures and consequence as a function of spatio-temporal overlap of egg and larval periods with periods of low DO. Here, however, the Tetra Tech (2017) report provides little information regarding inputs to the model, or the sources for each.

In addition to the EPA (2000) method, the draft report sent to the Science Advisory Panel (Tetra Tech, 2017) also applies a second analysis to confirm that the resulting criteria are realistic given the natural biophysical conditions of affected water bodies. Here they used two reference areas, First and Second Mallard sloughs, where there has been minimal anthropogenic alteration of hydrology or nutrient loadings, and asked how commonly DO dropped below calculated CMC and CCC. This is a good approach, but a comparison table showing similarities and differences in temperature, salinity, tidal current velocities, etc. would be useful to judge the appropriateness of the reference areas. Apart from this omission, the data presented are clear and the analysis steps are transparent.

Are conclusion clearly linked to analyses, and readily follow from analyses?
The resulting application of the Stephan et al. (1985) numerical method and the EPA (2000) framework yielded a criterion minimum concentration (daily average) of 3.8 mg / l, and a criteria chronic concentration that varies depending on location. This latter point was important because of spatial heterogeneity in the Suisun Marsh, particularly with respect to where and when salmonids are present. Salmonids are less tolerant of low DO and therefore areas that serve as juvenile rearing habitat need higher dissolved oxygen levels to protect them. Thus, all sloughs and channels, at all times, must maintain monthly averages greater than or equal to 5.0 mg / l, while Montezuma, Nurse, and Denverton sloughs must maintain monthly averages greater than or equal to 6.4 mg / l during January - April.

The species list is entirely appropriate, based on an extensive long term monitoring effort by UC Davis scientists (and with considerable input from one of California's pre-eminent fish biologists). The conclusion that the species considered fully capture beneficial species is fully warranted.

It is clear how the CRC follow from the application of Stephan et al. (1985) and related calculations. The Final Acute Value, calculated from the 4 most sensitive genera from 12 LD50 measurements was 2.67 mg / l, and this is multiplied by 1.42 (see Table 3.1.3 in Tetra Tech 20017) to translate into CMC. Note that this value is more precautious than the 1.38 multiplier used in EPA 2000, though the text of the report claims that a 1.38 multiplier was used. The CCC follows from applying the Stephan et al. (1985) method with and without salmonids, to 7 measurements of chronic effects (again, using the 4 most sensitive genera). The report claims that CCC is based upon larval fish endpoints (Tetra Tech 2017, page34), but this seems inconsistent with the EPA 2000 framework. Some clarity on this point is needed.

The report concludes "The chronic 30-day mean DO ≥5.0 mg/L will ensure survival, recruitment and growth of aquatic organisms as well as it will protect threatened and endangered species across Suisun Marsh habitats. 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. "

I believe this is overstated and is not substantiated by evidence presented here. More accurately, the application of the EPA (2000) method produced a value of 5.0 mg /l as the value likely to ensure survival, recruitment, and growth of aquatic organisms. Whether or not this is correct depends on the degree to which this method accounts for all relevant effects of dissolved oxygen and whether assumptions of underlying calculations are supported. The Science Advisory Panel wording was more careful and I believe more appropriate. In their review, they stated that ""The SAP finds that the use of the VP approach is considered as a viable and protective technical framework for setting DO criteria." and that it is a "scientifically defensible" approach.

Have the authors appropriately considered uncertainties and other factors that might influence the SSO calculations

The report carefully considers spatio-temporal patterns and salmonid habitat use (and considers uncertainty in chronic effects of low DO on salmonids). It is not clear how uncertainty in LD50 is incorporated e.g. when a range of LD50 values are provided, what value is used?

More significantly, unlike the EPA (2000) report, the information used here to inform the CRC and CCC was limited. That is, EPA (2000) devoted considerable effort to explore non-lethal effects of low DO exposure that is not related to growth (e.g. increased predation risk through distributional shifts, physiological stress reflected in endpoints other than growth). Though EPA (2000) found that such field related work was not suited to numerical calculation, it was useful to consider these effects to evaluate whether the numerical solutions would provide protections for other kinds of effects.

Also, the temperature range of Suisun Marsh sloughs varies considerably during the period when low DO conditions are most likely to occur (by as much as 5 C), and these will alter the sensitivity to low DO (Pörtner and Knust 2007, Duetsch et al. 2015). It is not clear to me whether temperature-dependency of DO sensitivity was considered.

Finally, the CRC and CCC are based largely on lab studies, which may not account for local adaptation or acclimation (particularly for chronic sub lethal exposure) (Decker et al. 2003, Lefevre et al. 2017).

The report would have been strengthened had it explicitly noted these uncertainties and considerations that were not explicitly addressed. My suspicion is that the SSOs would be robust to these considerations, however. I base this on the reference site work that appeared in Tetra Tech (2017) that showed that areas that have been less directly altered have DO conditions that would satisfy the criteria.

2.The derivation of the objectives is supported by sound scientific information and methods(Section 4).

Is the information appropriate?
Yes. This is largely attributable to the due diligence in maintaining species lists to be used in calculations. Use of surrogate species, and in particular including the non-native but well established Striped Bass is appropriate.

Is the information up to date?
There is a large body of research of work on hypoxia effects on marine and brackish ecosystems that has been published since the EPA (2000) report, yet I see little evidence that this was used to inform or guide the process. Indeed, Tetra Tech (2017) contained only 3 citations to sources published in peer reviewed literature since 2000, and the present document contains only a single

citation since 2000 related to dissolved oxygen tolerance or effects of exposure. I am surprised that the recent work by Vaquer - Sunyer and Duarte (2008) is not used as an alternative source for thresholds inducing lethal and non-lethal effects.

In summary, I find that this report, and supporting documents fail to demonstrate that the dissolved oxygen criteria were based on best available science. I provide a semi annotated bibliography to highlight the scope of ecological effects of hypoxia, to identify papers that provide alternative methods to calculating DO thresholds, and to suggest papers that could be used to place findings in context because they are based on the same or related species as used in the report. These should serve to provide more context about ecological effects, sensitivity of species to low DO, and ultimately provide more strength to the claim that the fairly rigid application of the Virginia Criterion method (along with the Stephan et al. 1985 calculations) is capturing all relevant aspects of this ecosystem

Are the methods used sufficient? Are there other methods and approaches that could have improved the calculations?

The report uses the EPA (2000) "Virgina Province" framework together with the Stephan et al. (1985) numerical method to calculate acute and chronic DO thresholds for Suisun Marsh. This framework has been applied in the U.S. East coast and elsewhere, and is advantageous because it is well known and transparent. It considers multiple types of population responses to low dissolved oxygen by looking at both mortality and growth responses and looking at juvenile / adults separate from early life history. The cited report (Tetra Tech, 2017) also used a reference system approach to described dissolved oxygen conditions in areas with similar biophysical characteristics but have protected lands in wetlands and surrounding uplands. That served as a useful "check" to evaluate whether the criteria values produced from the EPA (2000) framework are similar to water quality conditions that would naturally be expected in Suisun Marsh.

There are important limitations to the methods used to generate dissolved oxygen criteria. The first is that the EPA (2000) was applied in a somewhat perfunctory manner, such that this report lacks the depth and rigor of the effects of dissolved oxygen that characterizes the EPA (2000) report. Indeed, a full six pages of the main text of the EPA (2000) report explores other information on behavioral effects and other effects that were not used explicitly in the calculation, and appendix materials provided further information and context.

In addition, the EPA (2000) framework has its limitations and requires many assumptions, many of which are not explicitly identified in the present report. A quick list of these include:

- The recruitment model, though scoring high for transparency, is not rooted in direct empirical evidence or shown to have predictive power
- The calculation of FAV requires assumptions regarding probability density function of LD50s (a log - triangular distribution) that is not well supported by data.
- There is no explicit consideration of uncertainty. In fact, it is difficult to know what level of risk protection this method provides. Does it have a 90 percent chance of protecting 95% of species? 50% chance? There is no way to tell. This is particularly relevant given the very small sample sizes used to generate FAV values; 7 and 12 data points were used to generate CCC and CMC, respectively. A fixed ratio of LD50 to LD05 was used (with three significant figures!)

although there is certainly a range of plausible values for this ratio. Consequently the precision of these estimates is not known and the report does not specifically consider this in making recommendations.

- The EPA (2000) framework does not consider physiological affects that impair physiological processes necessary for reproduction (e.g (Wu 2009)), does not consider effects that increase mortality through predation (Mistri 2004, Eggleston et al. 2005, Long and Seitz 2008, Howard et al. 2017), and does not implicitly consider joint effects of temperature and dissolved oxygen on aquatic life (Pörtner and Knust 2007, Pörtner and Lannig 2009, Duetsch et al. 2015).

Finally, there appears to be an outstanding opportunity to use existing data to find site-specific thresholds. The report provides information on presence / absence and abundance of fish species within each site as a function of DO, which was very useful to evaluate the proposed SSOs. These data could be used in a much more rigorous way however, to statistically model the data to reveal acute and chronic DO levels associated with species presence / absence or abundance. Standard mixed effects generalized linear models could reveal water quality conditions that fish species avoid, while accounting for confounding effects of other environmental variables. This is standard practice and has been used elsewhere (e.g. (Schmitt and Osenberg 1996, McDonald et al. 2015)).

3. The SSOs are appropriate targets for the Suisun Marsh TMDL for low DO/organic enrichment (Section 9).
and
4.The concentration-based TMDL is protective and supportive of aquatic life beneficial uses in Suisun Marsh sloughs (Section 9).

The recommended SSO's consider both acute (daily) and chronic (monthly) exposure to dissolved oxygen.:

Average daily dissolved oxygen ≥ 3.8 mg / l
Average monthly dissolved oxygen ≥ 5 mg / l

In addition, Winter / Spring average monthly dissolved oxygen criteria is ≥ 6.4 mg / l in Montezuma, Nurse, and Denverton Sloughs to ensure adequate water quality conditions for salmonids present in those areas and times.

Based on the information that was presented in this report (estimates of acute lethal and chronic growth effects on species), these thresholds are well supported. Moreover, they are realistic, in that they account for natural fluctuations in dissolved oxygen in regions of Suisun Marsh that have lower tidal exchange and high biological productivity.

By applying the dissolved oxygen criteria to water that is discharged into the Suisun Marsh, the proposed SSO's have a high likelihood of achieving water quality conditions that meet the criteria. The TMLD allocations in table 9-1 are appropriate and precautionary because they are equal to the Marsh SSOs.

I therefore conclude that these are appropriate targets given the information that was provided. However, as noted above, attention to other information on low dissolved oxygen effects on aquatic life will strengthen the confidence in these SSOs.

References

Bailey, H. C. Curran, S. Poucher, and M. Sutula 2014 Science supporting dissolved oxygen objectives for Suisun Marsh. Southern California Coastal Research Project Technical Report 830.

Decker, M. B., D. L. Breitburg, and N. H. Marcus. 2003. Geographical differences in behavioral responses to hypoxia: Local adaptation to an anthropogenic stressor? Ecological Applications **13**:1104-1109.

Duetsch, C., A. Ferrel, B. Seibel, H. O. Portner, and R. B. Huey. 2015. Climate change tightens a metabolic constraint on marine habitats. Science **348**:1132-1135.

Eggleston, D. B., G. W. Bell, and A. D. Amavisca. 2005. Interactive effects of episodic hypoxia and cannibalism on juvenile blue crab mortality. Journal of Experimental Marine Biology and Ecology **325**:18-26.

Environmental Protection Agency. 2000. Ambient aquatic life water quality criteria for dissolved oxygen (saltwater): Cape Cod to Cape Hatteras EPA 822-R-00-12.

Howard, A. C., M. A. Poirrier, and C. E. Caputo. 2017. Exposure of rangia clams to hypoxia enhances blue crab predation. Journal of Experimental Marine Biology and Ecology **489**:32-35.

Lefevre, S., D. J. McKenzie, and G. E. Nilsson. 2017. Models projecting the fate of fish populations under climate change need to be based on valid physiological mechanisms. Glob Chang Biol **23**:3449-3459.

Long, W. C. and R. D. Seitz. 2008. Trophic interactions under stress: hypoxia enhances foraging in an estuarine food web. Marine Ecology Progress Series **362**:59-68.

McDonald, P. S., T. E. Essington, J. P. Davis, A. W. E. Galloway, B. C. Stevick, G. C. Jensen, G. R. Vanblaricom, and D. A. Armstrong. 2015. Distribution, Abundance, and Habitat Associations of a Large Bivalve (Panopea generosa) in a Eutrophic Fjord Estuary. Journal of Shellfish Research **34**:137-145.

Mistri, M. 2004. Effects of hypoxia on predator-prey interactions between juvenile Carcinus aestuarii and Musculista senhousia. Marine Ecology-Progress Series **275**:211-217.

Pörtner, H. O. and R. Knust. 2007. Climage change afects marine fishes through the oxygen limitation of thermal tolerance. Science **315**:95-96.

Pörtner, H. O. and G. Lannig. 2009. Oxygen and Capacity Limited Thermal Tolerance. Fish Physiology **27**:143-191.

Schmitt, R. J. and C. W. Osenberg, editors. 1996. Detecting ecological impacts: Concepts and applications in coastal habitats. Academic Press, San Diego, CA.

Stephan, C.E., D.I. Mount, D.J. Hansen, G.H. Gentile, G.A. Chapman, and W.A. Brungs 1985 Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. NTIS Publication No: PB85-227049

Tetra Tech 2017. Technical Report: DO Criteria Recommendations for Suisun Marsh.

Vaquer-Sunyer, R. and C. M. Duarte. 2008. Thresholds of hypoxia for marine biodiversity. Proceedings of the National Academy of Sciences **105**:15452-15457.

Wu, R. S. S. 2009. Effects of Hypoxia on Fish Reproduction and Development. Fish Physiology **27**:79-141.

Semi Annotated Bibliography

Relevant publications since 2002 illustrating effects of hypoxia on aquatic communities and species. Papers particularly relevant or useful for Suisun Marsh SSOs are indicated in **bold**.

1. Aumann CA, Eby LA, Fagan WF. 2006. How transient patches affect population dynamics: The case of hypoxia and blue crabs. Ecological Monographs 76: 415-438.
2. Baird D, Christian RR, Peterson CH, Johnson GA. 2004. Consequences of hypoxia on estuarine ecosystem function: Energy diversion from consumers to microbes. Ecological Applications 14: 805-822.
3. Baustian MM, Craig JK, Rabalais NN. 2009. Effects of summer 2003 hypoxia on macrobenthos and Atlantic croaker foraging selectivity in the northern Gulf of Mexico. Journal of Experimental Marine Biology and Ecology 381: S31-S37.
4. Baustian MM, Rabalais NN. 2009. Seasonal composition of benthic macroinfauna exposed to hypoxia in the Northern Gulf of Mexico. Estuaries and Coasts 32: 975-983.
5. Bell GW, Eggleston DB, Wolcott TG. 2003. Behavioral responses of free-ranging blue crabs to episodic hypoxia. II. Feeding. Marine Ecology-Progress Series 259: 227-235.
6. Bell GW, Eggleston DB. 2004. Species-specific avoidance responses by blue crabs and fish to chronic and episodic hypoxia. Marine Biology 146: 761-770.
7. Bishop M, Powers S, Porter H, Peterson C. 2006. Benthic biological effects of seasonal hypoxia in a eutrophic estuary predate rapid coastal development. Estuarine, Coastal and Shelf Science 70: 415-422.
8. **Brandt SB, Gerken M, Hartman KJ, Demers E. 2009. Effects of hypoxia on food consumption and growth of juvenile striped bass (*Morone saxatilis*). Journal of Experimental Marine Biology and Ecology 381: S143-S149.**
   Highly relevant because provides newer information on Striped bass
9. Breitburg DL, Adamack A, Rose KA, Kolesar SE, Decker MB, Purcell JE, Keister JE, Cowan JH. 2003. The pattern and influence of low dissolved oxygen in the Patuxent River, a seasonally hypoxic estuary. Estuaries 26: 280-297.
10. Breitburg DL, Hondorp DW, Davias LA, Diaz RJ. 2009. Hypoxia, Nitrogen, and Fisheries: Integrating Effects Across Local and Global Landscapes. Annual Review of Marine Science 1: 329-349.
11. **Conley DJ, Carstensen J, Aertebjerg G, Christensen PB, Dalsgaard T, Hansen JLS, Josefson AB. 2007. Long-term changes and impacts of hypoxia in Danish coastal waters. Ecological Applications 17: 165-S184.**
   Important because it illustrates consequences of chronic exposure
12. **Costantini M, Ludsin SA, Mason DM, Zhang X, Boicourt WC, Brandt SB. 2008. Effect of hypoxia on habitat quality of striped bass (*Morone saxatilis*) in Chesapeake Bay. Canadian Journal of Fisheries and Aquatic Sciences 65: 989-1002.**
   Important because provides updated information on striped bass
13. **Craig JK, Crowder LB. 2005. Hypoxia-induced habitat shifts and energetic consequences in Atlantic croaker and brown shrimp on the Gulf of Mexico shelf. Marine Ecology-Progress Series 294: 79-94.**
   Important because it provides more information on surrogate species behavioral and energetic responses

14. Craig JK. 2012. Aggregation on the edge: effects of hypoxia avoidance on the spatial distribution of brown shrimp and demersal fishes in the Northern Gulf of Mexico. Marine Ecology Progress Series 445: 75-95.
15. **Decker MB, Breitburg DL, Marcus NH. 2003. Geographical differences in behavioral responses to hypoxia: Local adaptation to an anthropogenic stressor? Ecological Applications 13: 1104-1109.**
Important because illustrates and examines potential for local adaptation
16. **Decker MB, Breitburg DL, Purcell JE. 2004. Effects of low dissolved oxygen on zooplankton predation by the ctenophore *Mnemiopsis leidyi*. Marine Ecology-Progress Series 280: 163-172.**
Important because illustrates non-lethal effects not considered in the EPA 2000 framework
17. **Eby LA, Crowder LB, McClellan CM, Peterson CH, Powers MJ. 2005. Habitat degradation from intermittent hypoxia: impacts on demersal fishes. Marine Ecology-Progress Series 291: 249-261.**
Important because it is a very similar ecosystem
18. **Eby LA, Crowder LB. 2002. Hypoxia-based habitat compression in the Neuse River Estuary: context-dependent shifts in behavioral avoidance thresholds. Canadian Journal of Fisheries and Aquatic Sciences 59: 952-965.**
Important because illustrates context dependency
19. **Eggleston DB, Bell GW, Amavisca AD. 2005. Interactive effects of episodic hypoxia and cannibalism on juvenile blue crab mortality. Journal of Experimental Marine Biology and Ecology 325: 18-26.**
Important because illustrates non-lethal effects not considered in the EPA 2000 framework
20. Ekau W, Auel H, Portner HO, Gilbert D. 2010. Impacts of hypoxia on the structure and processes in pelagic communities (zooplankton, macro-invertebrates and fish). Biogeosciences 7: 1669-1699.
21. Essington TE, Paulsen CE. 2010. Quantifying hypoxia impacts on an estuarine demersal community using a hierarchical ensemble approach. Ecosystems 13: 1035-1048.
Potentially useful source of behavioral response thresholds for fish taxonomic groups
22. Farrell AP, Richards JG. 2009. Defining Hypoxia. Fish Physiology 27: 487-503.
Potentially useful physiological perspective on DO thresholds
23. Froehlich HE, Essington TE, Beaudreau AH, Levin PS. 2013. Movement Patterns and Distributional Shifts of Dungeness Crab (*Metacarcinus magister*) and English Sole (*Parophrys vetulus*) During Seasonal Hypoxia. Estuaries and Coasts.
Potentially useful source for of information for surrogate species (e.g. for Starry flounder)
24. **Howard AC, Poirrier MA, Caputo CE. 2017. Exposure of *rangia* clams to hypoxia enhances blue crab predation. Journal of Experimental Marine Biology and Ecology 489: 32-35.**
Important because illustrates non-lethal effects not considered in the EPA 2000 framework
25. **Jeppesen R, Rodriguez M, Rinde J, Haskins J, Hughes B, Mehner L, Wasson K. 2016. Effects of Hypoxia on Fish Survival and Oyster Growth in a Highly Eutrophic Estuary. Estuaries and Coasts.**
Important because illustrates effects at high DO, and illustrates interactive effect on DO. Provides information on staghorn sculpin which may be a surrogate species for Suisun Marsh

26. Kimura M, Takahashi T, Takatsu T, Nakatani T, Maeda T. 2004. Effects of hypoxia on principal prey and growth of flathead flounder Hippoglossoides dubius in Funka Bay, Japan. Fisheries Science 70: 537-545.
27. Kolesar SE, Breitburg DL, Purcell JE, Decker MB. 2010. Effects of hypoxia on *Mnemiopsis leidyi*, ichthyoplankton and copepods: clearance rates and vertical habitat overlap. Marine Ecology-Progress Series 411: 173-188.
28. **Long WC, Seitz RD. 2008. Trophic interactions under stress: hypoxia enhances foraging in an estuarine food web. Marine Ecology Progress Series 362: 59-68.**
    Important because illustrates non-lethal effects of hypoxia
29. **Ludsin SA, Zhang XS, Brandt SB, Roman MR, Boicourt WC, Mason DM, Costantini M. 2009. Hypoxia-avoidance by planktivorous fish in Chesapeake Bay: Implications for food web interactions and fish recruitment. Journal of Experimental Marine Biology and Ecology 381: S121-S131.**
30. **McNatt RA, Rice JA. 2004. Hypoxia-induced growth rate reduction in two juvenile estuary-dependent fishes. Journal of Experimental Marine Biology and Ecology 311: 147-156.**
    Important because it may provide information on surrogate species
31. **Mistri M. 2004. Effects of hypoxia on predator-prey interactions between juvenile *Carcinus aestuarii* and *Musculista senhousia*. Marine Ecology-Progress Series 275: 211-217.**
    Important because illustrates effects on predation
32. **Montagna PA, Froeschke J. 2009. Long-term biological effects of coastal hypoxia in Corpus Christi Bay, Texas, USA. Journal of Experimental Marine Biology and Ecology 381: S21-S30.**
    Important because illustrates effects of chronic exposure
33. Nilsson GE, Ostlund-Nilsson S. 2004. Hypoxia in paradise: widespread hypoxia tolerance in coral reef fishes. Proc Biol Sci 271 Suppl 3: S30-33.
34. Nilsson GE, Ostlund-Nilsson S. 2008. Does size matter for hypoxia tolerance in fish? Biol Rev Camb Philos Soc 83: 173-189.
35. Pollock MS, Clarke LMJ, Dube MG. 2007. The effects of hypoxia on fishes: from ecological relevance to physiological effects. Environmental Reviews 15: 1-14.
36. Richards JG. 2009. Metabolic and Molecular Responses of Fish to Hypoxia. Fish Physiology 27: 443-485.
37. Roberts JJ, Hook TO, Ludsin SA, Pothoven SA, Vanderploeg HA, Brandt SB. 2009. Effects of hypolimnetic hypoxia on foraging and distributions of Lake Erie yellow perch. Journal of Experimental Marine Biology and Ecology 381: S132-S142.
38. Rose KA, Adamack AT, Murphy CA, Sable SE, Kolesar SE, Craig JK, Breitburg DL, Thomas P, Brouwer MH, Cerco CF, Diamond S. 2009. Does hypoxia have population-level effects on coastal fish? Musings from the virtual world. Journal of Experimental Marine Biology and Ecology 381: S188-S203.
39. Sato M, Horne JK, Parker-Stetter SL, Essington TE, Keister JE, Moriarty PE, Li L, Newton J. 2016. Impacts of moderate hypoxia on fish and zooplankton prey distributions in a coastal fjord. Marine Ecology Progress Series 560: 57-72.
40. **Seitz RD, Dauer DM, Llansó RJ, Long WC. 2009. Broad-scale effects of hypoxia on benthic community structure in Chesapeake Bay, USA. Journal of Experimental**

Marine Biology and Ecology 381: S4-S12.
Relevant because looks at system – level effects

41. **Seitz RD, Marshall LS, Hines AH, Clark KL. 2003. Effects of hypoxia on predator-prey dynamics of the blue crab *Callinectes sapidus* and the Baltic clam *Macoma balthica* in Chesapeake Bay. Marine Ecology-Progress Series 257: 179-188.**
Relevant because it illustrates non lethal effects non treated in report
42. **Stow CA, Scavia D. 2009. Modeling hypoxia in the Chesapeake Bay: Ensemble estimation using a Bayesian hierarchical model. Journal of Marine Systems 76: 244-250.**
Important because shows use of Bayesian application
43. Switzer TS, Chesney EJ, Baltz DM. 2009. Habitat selection by flatfishes in the northern Gulf of Mexico: Implications for susceptibility to hypoxia. Journal of Experimental Marine Biology and Ecology 381: S51-S64.
44. **Vanderploeg HA, Ludsin SA, Ruberg SA, Hook TO, Pothoven SA, Brandt SB, Lang GA, Liebig JR, Cavaletto JF. 2009. Hypoxia affects spatial distributions and overlap of pelagic fish, zooplankton, and phytoplankton in Lake Erie. Journal of Experimental Marine Biology and Ecology 381: S92-S107.**
Excellent paper showing how predator – prey / food web interactions are affected by low DO
45. **Vaquer-Sunyer R, Duarte CM. 2008. Thresholds of hypoxia for marine biodiversity. Proceedings of the National Academy of Sciences 105: 15452-15457.**
Very important paper that shows how taxonomic groups vary in hypoxia thresholds, should be used to inform Suisun Marsh thresholds
46. Wang T, Lefevre S, Thanh Huong DT, Cong Nv, Bayley M. 2009. The Effects of Hypoxia On Growth and Digestion. Fish Physiology 27: 361-396.
47. **Wu RSS. 2009. Effects of Hypoxia on Fish Reproduction and Development. Fish Physiology 27: 79-141.**
Important paper showing how and when low DO exposure might impair physiological processes for reproduction
48. Zhang H, Ludsin SA, Mason DM, Adamack AT, Brandt SB, Zhang X, Kimmel DG, Roman MR, Boicourt WC. 2009. Hypoxia-driven changes in the behavior and spatial distribution of pelagic fish and mesozooplankton in the northern Gulf of Mexico. Journal of Experimental Marine Biology and Ecology 381: S80-S91.

ESTABLISH WATER QUALITY OBJECTIVES AND TOTAL MAXIMUM DAILY LOAD
FOR Low Dissolved Oxygen/Organic Enrichment in Suisun Marsh
AND
Add Suisun Marsh to SF Bay Mercury TMDL

External Peer Review of Conclusions 4, 5, 6, 7, 9

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Overview

I have read the Draft Staff Report "ESTABLISH WATER QUALITY OBJECTIVES AND TOTAL MAXIMUM DAILY LOAD FOR Low Dissolved Oxygen/Organic Enrichment in Suisun Marsh AND Add Suisun Marsh to SF Bay Mercury TMDL" from the California Regional Water Quality Control Board San Francisco Bay Region. Below I provide a review of the scientific portions of the draft report relevant to my expertise in coastal estuarine biogeochemistry and dissolved oxygen dynamics. My review of this document is focused on the controls on dissolved oxygen sags within the marsh sloughs, including the simulations of dissolved oxygen in the Suisan Marsh sloughs and the relationships between oxygen and organic carbon, chlorophyll-a, and nutrient concentrations. I considered the physical, biological, and anthropogenic aspects of dissolved oxygen dynamics in the marsh sloughs and I comment on the relative role of anthropogenic eutrophication versus wetland pond management in controlling oxygen sags in the sloughs. In my review, I did not address the impacts of low dissolved oxygen on living resources or the TMDL for mercury because these topics are outside of my particular expertise. Although I read the entire documentation, I only provide review of Sections 1-3, 6, 8, 12 and 13, which are related to Conclusions 4, 5, 6, 7, and 9. My review addresses the primary findings and conclusions of the document, as well as specific aspects of the analysis and minor edits/corrections edits to the text. I also read Siegel et al. (2011) and Tetra Tech (2013, 2017) to support my review.

Conclusion 4 – DO sags are triggered by discharges from managed wetlands. Hydrologic conditions and distance from the open bay contribute to low DO in back-end sloughs (Section 3)

A considerable amount of information was synthesized to arrive at the conclusion that this unique system suffers dissolved oxygen sags due to the periodic discharge of low oxygen and high organic matter water from managed wetland ponds. The data and model simulations presented in this report, including extensive continuous oxygen records, clearly illustrate that the timing of discharges from managed wetlands correspond to oxygen sags in several of the Suisan Bay sloughs. Existing literature includes several examples of shallow, physically isolated creeks and canals displaying similar depleted oxygen conditions. The HEC-RAS modeling effort displayed that simulated wetland discharges can lead to oxygen depletion events associated with inputs of low oxygen, high DOC water to adjacent sloughs. These simulations are presently the most quantitative evidence to associate pond management with oxygen depletion. The association of the discharged water with high oxygen-demand potential is clearly made through the identification of high DOC concentrations in the wetland ponds, which should be expected to exist given high rates of organic production in the marsh. Therefore, targeting alternative wetland pond management approaches involving altered timing and asynchrony in the draining of managed wetland ponds seems achievable and appropriate to relieve oxygen depletion events in the sloughs. The report conclusions are drawn from an extensive review and analysis of a substantial and diverse amount of data, providing a solid basis for making recommendations for management of this system.

In view of the provided oxygen time-series, the timing and nature of low dissolved oxygen seems to be tightly linked to the wetland pond management, justifying these activities as a target for dissolved oxygen remediation. The continuous dissolved oxygen data measured by the sensors in Denverton and Goodyear Sloughs in 2012 and Boynton and Peytonia Sloughs in 2007 clearly display that the sags (or minima) in oxygen occur in October when marsh flushing occurs. The report suggests that if anthropogenic eutrophication was the cause of the depleted oxygen, the oxygen minima would occur in summer when peak seasonal temperatures drive respiration of organic material that is being regularly produced via nutrient-fueled phytoplankton growth. Given the data provided, this appears to be a reasonable conclusion. The fact that severe oxygen sags below 2 mg/l do not appear to routinely occur each year suggests that there is some interannual variability in these dynamics that is not fully addressed by the model and analysis. For example, oxygen sags clearly occur in Denverton and Goodyear Sloughs in 2012 and Boynton and Peytonia Sloughs in 2007 (Figures B15-B19), but there are other years where similar sags do not appear to occur. The dissolved oxygen time-series provided in the report and Appendix B do not allow for a clear interpretation of exactly when during the year that the low oxygen events occurred (the x-axis is too constrained), so I acknowledge that I lack a clear picture of a full annual cycle of dissolved oxygen for many of the creeks when I make this general conclusion. Finally, this conclusion states that "Hydrologic conditions and distance from the open bay contribute to low DO in back-end sloughs" and while this could in fact be true, less quantitative analysis was performed to address these dynamics and the association of wetland management to oxygen sags is not necessarily dependent on the fact that these environments may be naturally susceptible to oxygen depletion.

Conclusion 5 – Anthropogenic sources of nutrients are not associated with declines in DO in the sloughs (Sections 3 and 6)

It is reasonable and justified to conclude that anthropogenic nutrient sources are not a primary driver of the majority of low dissolved oxygen in the sloughs, given the timing of oxygen depletion (fall, spring) and the moderate (but not low) chlorophyll-a levels reported. These types of wetland creeks are typically turbid, imposing light limitation of phytoplankton and benthic algae, which generally means that oxygen is less controlled by the production-respiration cycle that anthropogenic nutrients accelerate. However, nutrient concentrations can be extremely high in many of the sloughs (NO_3^- up to 12 mg/l and PO_4^{3-} up to 3 mg/l), the highest nutrient levels are closest to the FSSD outfall (Figure B-25 and B-26), and some of the most impacted sloughs (with respect to low oxygen) are located in the region of the marsh near anthropogenic nutrient sources (Boynton Slough), suggesting some degree of eutrophication. Modeled photosynthesis rates also appear to be a large part of the oxygen budget (Figure 8-2), which would suggest that phytoplankton production rates are indeed high and likely supported by anthropogenic nutrient inputs. Phytoplankton blooms and fish kills have been reported in similar shallow creeks with low flushing and high nutrient concentrations. While the timing of the largest oxygen sags is most tightly linked to wetland pond discharges and the mechanistic link between discharges and the oxygen sags is scientifically sound, the sloughs are clearly not free from the influence of anthropogenic nutrient influence. Thus, although the discharges appear to be the primary contributor to oxygen sags in the sloughs, further investigation into the role of traditional eutrophication in these creeks might identify it as a secondary contributor to oxygen sags through diel oxygen consumption associated with autotrophic respiration.

I will specifically address the potential role of anthropogenic nutrient inputs in the text that follows. It is reported that nutrient concentrations are well above limiting levels (Table 6-4), so the observations of moderate chlorophyll-a are likely explained by either light limitation of phytoplankton growth or the physical flushing of phytoplankton biomass. One could suspect that CDOM concentrations are high in this type of environment, which attenuate light and limit photosynthesis, but no CDOM or light profile data are provided to evaluate light availability or its controls. Residence times are suggested to be high (but are not quantified so far as I can tell), so this high nutrient, high residence time environment should be expected to generate phytoplankton blooms, which the sensor data indicate to occur within the perimeter stations of some wetland ponds (Figure B-32). The HEC-RAS model simulations (Figure 8-2) reveal that photosynthesis is a large contributor to the slough oxygen dynamics, although these modeled rates were not directly validated with measured rates of phytoplankton metabolism or biomass. Figure 8.2 also indicates that photosynthesis is comparable in magnitude to CBOD, but the units of mg/l are difficult to interpret because they are not the traditional units used to express these rates (e.g., g O_2 m^{-2} d^{-1}). Figure 8-2 illustrates that the simulations are generating rates of photosynthesis that greatly exceed aerobic respiration which would explain why the model consistently overestimates dissolved oxygen concentrations in many of the sloughs (see response to **Conclusion 6** below for further detail).

Conclusion 6 – The analysis accurately identifies organic material and low dissolved oxygen waters as the main reason for declines in DO in slough water

Overall, I find the conclusion that discharges of high DOC, low oxygen water from managed marshes is the primary cause of oxygen depletion events in the sloughs to be supported by the available data. There is a direct mechanistic link between DOC availability and oxygen consumption rates and the largest observed oxygen sags in the sloughs clearly coincide with wetland pond draining activities during the fall. The numerical model that simulates wetland pond discharge of low oxygen, high-DOC successfully captures the seasonal and fortnightly depletion of oxygen in several of the sloughs. While all models are imperfect, the model included here appears to consider the dominant processes and is an appropriate tool to address the questions posed in a quantitative and data-constrained way.

I do, however, wish to address the shortcomings of the numerical models used to set management targets. The HEC-RAS model appears to capture the impact of wetland discharge events in time and (to some extent) in magnitude, but the baseline model simulations fail to capture the lower range of oxygen concentrations observed during wetland pond drainages. This inability to capture the lowest of the oxygen concentrations appears to be directly related to the model's overall tendency to over-predict dissolved oxygen concentrations (e.g., Figure C-19, C-21, C-23). While the modeled oxygen minima clearly occur in October-December for Boynton and Peytonia Slough in 2007 and Goodyear and Denverton Slough in 2012, consistent with the observations, the oxygen concentrations predicted during the times beyond of the simulated discharge period are often too high. The numeric targets for the TMDL may be affected by these discrepancies between modeled and measured oxygen concentrations.

The model also appears to underestimate the sub-daily variations in dissolved oxygen in the marsh sloughs (e.g., Figure C-19, C-21). Although the data as presented are difficult to read from the graphs, it appears that the measurements indicate large diurnal or semi-diurnal variations in dissolved oxygen. The model generally fails to capture these large, short-term swings in oxygen, which could result from an underestimation of either (a) the diel cycling of oxygen associated with photosynthesis and respiration of the primary producers (e.g., phytoplankton) or (b) the tidal transport dynamics that flush the sloughs with water or conversely isolate them from adjacent waters. Figure 8-2 indicates that photosynthesis tends to be much greater than respiration in Boynton Slough, which would suggest that modeled diurnal variations in oxygen associated with daytime photosynthesis and nighttime respiration would favor oxygen production over consumption, leading to over-predicted oxygen concentrations. If the model-simulated photosynthesis and respiration rates were more comparable in magnitude (which is common in other shallow marsh creeks where observations are available), the diel cycle of oxygen would presumably span a larger range of concentration. In Figure 3-3 and 3-5, there are clear sub-daily variations in oxygen during the sag periods that are quite large, indicating that there could be a strong diel cycling of oxygen associated with phytoplankton that overlies the longer-term sag associated with high DOC and low oxygen water exported from the managed ponds. Figure C-19, C-21 clearly show stronger sub-daily variation in the observations than is captured by the model. I cannot further investigate these dynamics without more information from model simulations, but it appears that there are secondary sources of variability in the oxygen data.

Despite the extensive and useful modeling efforts, a more complete evaluation of the model simulations would have been possible if more extensive validation of the model variables was performed. The report adequately describes validation efforts with respect to dissolved oxygen dynamics in the sloughs, which benefits from high-quality oxygen concentration time-series to allow for an assessment that the model prediction of oxygen is reasonable overall. However, a more complete evaluation of the numerical model would include validations of the model predictions of chlorophyll-a, dissolved organic carbon, nutrient availability, and primary production and respiration rates. Without an opportunity to review such validations (this material was not available for my review), it is difficult to fully evaluate the potential secondary roles of nutrient-induced phytoplankton production and respiration, as well as tidal flushing (or lack thereof) in contributing to oxygen concentration changes.

Conclusion 7 – The Staff Report describes linkages and provides a valid description of the relationship between the desired DO conditions and sources of low DO (Section 8)

The report is comprehensive in the sense that it reviews, synthesizes, or estimates all relevant nutrient and BOD sources, addresses dissolved oxygen time-series in a large number of sloughs, adequately summarizes the management of the wetlands, and includes numerical model simulations of the marsh dynamics. Clear and justifiable links are made to describe the accumulation of high DOC and low oxygen water in marsh ponds that is seasonally discharged into the slough to drive oxygen sags, and continuous oxygen data are available to confirm these dynamics. Numerical model simulations clearly document that altering the discharge of high-DOC, low oxygen water from the managed marsh ponds into the adjacent sloughs will lead to depressed oxygen concentrations in the sloughs by liming the input of not only low oxygen water, but also sources of oxygen demand.

I think the assessment of phytoplankton contributions to oxygen dynamics would benefit from better data on continuous chlorophyll-a time-series in the marsh, measures of current velocity and stage within the sloughs, and direct measurements of BOD and other metabolic rates in the sloughs at different times of year. All of these data are relatively easy to collect, but do require additional effort and funding. The assessment of the influence of nutrient loading from the discharging streams (Page 43) is limited by small sample size (concentrations were measured during 2 storms + ~4 “dry weather” days) and combined with monthly discharge rates that were not clearly described. This small subset of samples would only allow for nutrient concentration estimates over roughly half of the months of a year, and it was not clear how exactly the data were converted into loads. While this particular source of nutrients was not high relative to others (Table 6-3), these inputs are not dismissible.

Conclusion 9 – Actions proposed in the implementation plan will reasonably ensure progress towards attaining water quality objectives and supporting aquatic life beneficial uses (Section 12).

The actions proposed in Section 12 provide a comprehensive summary of the options for meeting water quality objectives and focus on current actions that seem pragmatic and achievable for managing dissolved oxygen sags in the marsh sloughs. Given the relative ease at which high quality, continuous dissolved oxygen measurements can be made – and given both the high and low frequency variation in oxygen already displayed – it is appropriate to make extended (e.g., year-round) deployments of oxygen sensors in the western sloughs (at least). These data will not only help document improvements associated with marsh management, but will also continue to provide information concerning other possible features of oxygen depletion in the marsh sloughs, deriving from both natural and anthropogenic forces. The addition of sensors to measure or estimate turbidity and chlorophyll-a would greatly enhance the value of the oxygen time-series. The adaptive implementation as described in 12.5 is a reasonable plan given that many of the BMPs proposed can be adaptively altered in a relatively short amount of time.

Summary Comments

Overall, I was impressed by the comprehensive nature of the Draft Staff Report and the quality and clarity of the presentation. The report, assessments, and conclusions are based on a large volume of data and extensive analysis and modeling. Organic enrichment associated with marsh pond management appears to be the primary driver of the most severe oxygen depletion events observed in several of the marsh sloughs. My comments, where critical, are primarily aimed at improving the understanding and simulation of the natural variability in the marsh sloughs and the balance between physical replenishment and internal sources and sinks of oxygen beyond the discharges from managed ponds. Such an improved understanding will enhance the adaptive management proposed for this system, yield useful lessons for similar systems outside of the Delta, and help to further refine and maximize the efficacy of BMPs for the Suisan Bay sloughs.

Minor edits to the text

(1) Page 8, last paragraph: I think “sulfites” should be “sulfides”

(2) Page 23, middle paragraph: “Dissolve” should be “Dissolved”

(3) Page 64, last paragraph: “decrease” should be “decreased” or “decreases”