DRAFT

Managing Subsidence in the Sacramento-San Joaquin Delta

Delta Independent Science Board

Draft Prospectus

April 17, 2023

If you have any public comments on this draft prospectus, please email them to disb@deltacouncil.ca.gov by May 31, 2023.

Motivation

Drainage of land in the Sacramento-San Joaquin Delta has caused extensive oxidation of peat soils, lowering approximately 386 mi^2 of land from 10 ft to as much as 29 ft below sea level. Current rates of subsidence (loss of land elevation due to oxidation of peat soils) in the Delta currently range from 0.2 to more than 0.8 in yr^{-1} (Deverel et al., 2020). Ongoing subsidence causes significant challenges, such as increases in costs to drain soils and declining arability for agricultural production (Deverel et al., 2010; Deverel et al., 2020), water quality degradation (Deverel et al., 2010; Deverel et al., 2016; Deverel et al., 2017a), vulnerability to levee failure and flooding (Bates and Lund 2013; Deverel et al., 2016; Deverel et al., 2020), and substantial emissions of greenhouse gases (Deverel et al., 2017b; Hemes et al., 2019).

The severity and impact of subsidence has prompted re-evaluation of potential incentives for subsidence management by the Delta Stewardship Council for the Delta Plan (Delta Stewardship Council, 2022). Rewetting peat soils to prevent or slow oxidation has emerged as a promising method to manage subsidence. However, efforts in the Delta to rewet peat soils to slow, arrest, or reverse subsidence are fragmented throughout the landscape. A broad cross section of stakeholders, including public agencies and private sector parties, are developing and testing approaches to mitigate subsidence, in which participation in carbon credit markets may provide an incentive to motivate practices such as (1) wetland restoration or changes in farming operations (HydroFocus Inc., 2017; Deverel et al., 2020; Windham-Myers et al., 2023), (2) reversal or arresting of land subsidence by managing water tables, and (3) practicing agriculture under wet soil conditions

(paludiculture) (Deverel et al., 2017b, Deverel et al., 2020). Actions that reduce subsidence also contribute to decreasing future hydraulic gradient effects on some levees, improving their stability, and reducing vulnerability to sea level rise (Bates and Lund 2013; Deverel et al., 2016; Deverel et al., 2020). Sea level rise may also increase the difficulty of draining severely subsided land.

Currently, farmers apply high-quality surface water to fields to leach salts (Hanson and Carlton 1979; Meyer et al., 1979), which may slow the oxidation of peat soils if water levels are above peat soils. However, effects are temporary since oxidation resumes when peat soils are exposed to oxidation. Other farmers have permanently converted fields to crops that grow with a high-water table, primarily rice. Total cessation of oxidation has been achieved by some public agency landowners who have permanently submerged their land to promote the growth and subsequent accumulation of local wetland vegetation (Valach et al., 2021). As a result, land elevations have increased, i.e., subsidence has been reversed, at rates of 1.0-1.4 in yr-1 (Miller et al., 2008; Deverel et. al. 2020), at some locations by maintaining shallow water levels on land.

In addition to agricultural efforts currently underway to rewet peat soils in the Delta, approximately 25,000 acres of wetland restoration is in progress with 60,000 to 80,000 acres of restoration funded by state programs (Delta Stewardship Council, 2022). The scale of subsidence in the Delta and the severity of its consequences for Delta agriculture, carbon cycling, and water quality indicates a need for an assessment of current subsidence management and the economic trade-offs among subsidence management actions. This review will explore ongoing and future subsidence management efforts and the effects on the balance of agricultural and ecosystem functions that support the co-equal goals in the Delta Reform Act (Delta Stewardship Council, 2022).

The goal of this review by the Delta ISB is to synthesize and evaluate the state of science related to subsidence management in order to provide recommendations to inform and guide ongoing and future subsidence management. To address this goal, the Delta ISB will summarize existing or planned programs, identify barriers and opportunities, and evaluate the state of scientific understanding in four interconnected aspects of Delta subsidence:

1. Land stabilization practices and experiments, including rewetting and subsidence reversal, through wetland restoration, changes in farm operations, and managed soil rewetting.
2. Net carbon sequestration including greenhouse gas emissions, duration of carbon pools, and comparison of alternative rewetting practices.
3. Incentives such as carbon markets and other climate and agricultural policies for shifting agricultural practices to integrate rewetting approaches and/or paludiculture into farming operations.
4. Feasibility of soil rewetting at a landscape-scale and potential regional economic benefits, climate risk mitigation, levee stability, water quality, and flooding impacts.

In addition to summarizing current efforts in the Delta to rewet peat soils and the state of the science, this review will build on previous reviews by integrating and identifying gaps and scientific needs in the existing studies that evaluate economic and community trade-offs associated with different management actions and economic incentives. For example, rewetting is potentially compatible with some types of farm operations but may require conversion from current crops (Deverel et al., 2017b). In addition, incentives provided by some carbon credit markets may not support optimal management of farm operations (Windham-Myers et al., 2023). Through this effort, the Delta ISB will develop an interdisciplinary synthesis of the state of science related to subsidence and the extent to which subsidence management reflects that science. Furthermore, the review will identify science gaps that could improve a more coordinated approach for subsidence management.

Audience

Subsidence and efforts to slow or reverse subsidence directly impacts agricultural production, water quality, carbon fluxes, and the future economic and cultural values of the Delta landscape. This review will inform ongoing and future subsidence management actions by describing what is understood about subsidence, determining where science can improve current efforts, identifying knowledge gaps, and summarizing the current and potential incentives for different subsidence management actions, including wetland restoration and agricultural land management. The broad nature of the review is intended to serve a diverse

audience that includes Delta stakeholders, managers, researchers, legislators, and decision-makers from local, state, and federal agencies.

Input

The primary input to this review will be a two-day public workshop consisting of panel presentations by invited experts and public discussions. Panelists will be asked to provide perspectives on existing programs, barriers and opportunities, state of scientific understanding, scientific gaps and deficiencies, and the economic considerations of managing subsidence within the four topical areas:

1. State of knowledge on subsidence reversal and land stabilization practices through peat soil rewetting.
2. Greenhouse gas emissions, carbon sequestration effectiveness, and existing incentives to sequester carbon through wetland restoration, changes in farm operations, and managed soil rewetting.
3. Economic incentives to motivate shifts in agricultural practices and adoption of paludiculture crops.
4. Known and future economic benefits and costs of soil rewetting for farm productivity, climate risk mitigation, levee stability under different geologic conditions, water quality, and flooding impacts.

The first panel of the workshop will discuss the state of the science on various rewetting approaches, water-table controls, and floating peats to reverse subsidence and stabilize land. The second panel will discuss the geochemistry of greenhouse gases and peat soils to reveal gaps in understanding the science related to carbon sequestration such as quantifying carbon mitigation, characterizing the impacts of annual changes in land management on sequestration, and the differences between wetland restoration or changes in farm operations for carbon crediting. The third panel will discuss the opportunities and barriers for paludiculture in the Delta and compare trade-offs in agricultural practices to examine their implications for subsidence management. The fourth panel will discuss economic considerations of managing subsidence to better understand if demonstrated benefits have meaningful economic benefits and whether there are adequate economic incentives to meet desired objectives.

The Delta ISB review will consist of findings and recommendations to address current and future subsidence management in the Delta based on a synthesis of

the workshop presentations and panel discussions supplemented by relevant literature.

Timeframe

Target Date	Benchmark
May 2023	Prospectus finalized
June 2023	Finalize workshop agenda and invite speakers
August 2023	Open registration for workshop
October 2023	Host workshop
January 2024	Release draft workshop summary report for public comments
Spring 2024	Finalize summary report and findings

Related Reviews

Although the Delta ISB has reviewed documents that include consideration of subsidence, it has not engaged in reviews that focused on subsidence *per se* or rewetting of Delta soils to mitigate subsidence. Relevant reviews include the following:

- 2016 Delta ISB Workshop Report on Earthquakes and High Water as Levee Hazards in the Sacramento-San Joaquin Delta
- Delta Plan Ecosystem Amendment Performance Measures

In addition, the 2023 State of Bay-Delta Science had an article on carbon sequestration and subsidence reversal.

- Carbon Sequestration and Subsidence Reversal in the Sacramento-San Joaquin Delta and Suisun Bay: Management Opportunities for Climate Mitigation and Adaptation

Expected Products and Outcomes

This review will consist of findings and recommendations based on a synthesis of workshop presentations, panel discussions, and relevant literature. The review builds on previous work by examining the existing heterogeneity of economic incentives and broadening understanding of the range of subsidence management actions within the context of ensuring robustness to climate change.

By summarizing the state of science of subsidence management, assessing whether current subsidence efforts are consistent with best available science, and identifying any science gaps, this review aims to provide management recommendations that could guide a more coordinated approach for adaptive management of subsidence in the Delta.

References

Bates, M. E., and Lund, J. R. (2013). Delta subsidence reversal, levee failure, and aquatic habitat - A cautionary tale. *San Fr. Estuary Watershed Sci.* 11. doi:10.15447/sfews.2013v11iss1art1. https://escholarship.org/uc/item/9pp3n639

Delta Stewardship Council. 2022. "Chapter 4 - Protect, Restore, and Enhance the Delta Ecosystem (Amended June 2022)." In *The Delta Plan*. https://deltacouncil.ca.gov/pdf/delta-plan/2022-06-29-chapter-4-protect-restore-and-enhance-the-delta-ecosystem.pdf

Deverel, Steven J., and David A. Leighton. 2010. "San Francisco Estuary and Watershed Science Historic, Recent, and Future Subsidence, Sacramento-San Joaquin Delta, California, USA." *San Francisco Estuary and Watershed Science* 8 (2): 1–24. https://escholarship.org/uc/item/7xd4x0xw

Deverel, S. J., Bachand, S., Brandenberg, S. J., Jones, C. E., Stewart, J. P., and Zimmaro, P. (2016). Factors and processes affecting delta levee system vulnerability. *San Fr. Estuary Watershed Sci.* 14. doi:10.15447/sfews.2016v14iss4art3. https://escholarship.org/uc/item/36t9s0mp

Deverel, S. J., Leighton, D. A., Lucero, C., and Ingrum, T. (2017a). Simulation of subsidence mitigation effects on island drain flow, seepage, and organic carbon loads on subsided islands, Sacramento-San Joaquin Delta. *San Fr. Estuary Watershed Sci.* 15. doi:10.15447/sfews.2017v15iss4art2. https://escholarship.org/uc/item/4q340190

Deverel, S., Jacobs, P., Lucero, C., Dore, S., and Kelsey, T. R. (2017b). Implications for Greenhouse Gas Emission reductions and economics of a changing agricultural mosaic in the Sacramento - San Joaquin Delta. *San Fr. Estuary Watershed Sci.* 15. doi:10.15447/sfews.2017v15iss3art2. https://escholarship.org/uc/item/99z2z7hb

Deverel, S.J., S. Dore, C. Schmutte (2020) "Solutions for subsidence in the California Delta, USA, an extreme example of organic-soil drainage gone astray." Proc. IAHS

382, 837-942. https://piahs.copernicus.org/articles/382/837/2020/piahs-382-837-2020.html

Hanson, Blain R. and Carlton, Alan B., 1979. "Subsurface movement of water and salt in Delta organic soils". *California Agriculture*. November-December 1979.

Hemes, Kyle S., Samuel D. Chamberlain, Elke Eichelmann, Tyler Anthony, Amy Valach, Kuno Kasak, Daphne Szutu, Joe Verfaillie, Whendee L. Silver, and Dennis D. Baldocchi. 2019. "Assessing the Carbon and Climate Benefit of Restoring Degraded Agricultural Peat Soils to Managed Wetlands." *Agricultural and Forest Meteorology* 268 (April): 202–14. https://doi.org/10.1016/j.agrformet.2019.01.017.

HydroFocus, Inc. 2017. "Restoration of California Deltaic and Coastal Wetlands (Version 1.1)." Arlington, VA: American Carbon Registry. https://americancarbonregistry.org/carbon-accounting/standards-methodologies/restoration-of-california-deltaic-and-coastal-wetlands

Meyer J, Prichard T, Kegel F, Mullen R. 1979. Salinity in Delta peat soils. Hilgardia 33(11):10-11. DOI:10.3733/ca.v033n11p10. https://hilgardia.ucanr.edu/fileaccess.cfm?article=172545&p=YMJFJB

Miller, Robin L., Miranda S. Fram, Roger Fujii, and Gail Wheeler. 2008. "San Francisco Estuary and Watershed Science Subsidence Reversal in a Re-Established Wetland in the Sacramento-San Joaquin Delta, California, USA." *San Francisco Estuary & Watershed Science* 6 (3). https://escholarship.org/uc/item/5j76502x

Valach AC, Kasak K, Hemes KS, Anthony TL, Dronova I, Taddeo S, et al. (2021) Productive wetlands restored for carbon sequestration quickly become net CO2 sinks with site-level factors driving uptake variability. PLoS ONE 16(3): e0248398. https://doi.org/10.1371/journal.pone.0248398

Windham–Myers, Lisamarie, Patty Oikawa, Steve Deverel, Dylan Chapple, Judith Drexler, and Dylan Stern. 2023. "Carbon Sequestration and Subsidence Reversal in the Sacramento-San Joaquin Delta and Suisun Bay: Management Opportunities for Climate Mitigation and Adaptation." *San Francisco Estuary and Watershed Science* 20 (4). https://doi.org/10.15447/sfews.2023v20iss4art7.