DRAFT

Science Supporting Decision-Making Under Deep Uncertainty

Delta Independent Science Board

Draft Prospectus

May 15, 2023

If you have any public comments on this draft prospectus, please email them to disb@deltacouncil.ca.gov by June 26, 2023.

Motivation

Rapidly changing conditions and increasing uncertainty of future projections (e.g., atmospheric rivers) highlight how extreme and hard-to-predict conditions challenge effective management of the Bay-Delta system. Similarly, changing social, policy, and economic conditions can alter resource use and desirable management approaches, sometimes substantially. When conditions change rapidly and unexpectedly, managers are forced to prioritize some goals at the expense of others and may not have time to consider all management options or elicit stakeholder preferences.

The Delta Independent Science Board (Delta ISB) will conduct a review to build understanding of scientific tools and concepts that can increase the capacity to anticipate and adapt to growing uncertainty of future conditions in the Sacramento-San Joaquin Delta. These approaches use decision science tools to compare performance of management options under extreme or unpredictable events (e.g., global pandemics). The benefits of applying these tools include agencies having opportunities to anticipate concerns and prepare by engaging stakeholders in problem-solving, and building plans and relationships to coordinate actions when unlikely events occur. Furthermore, anticipatory modeling and pre-planning for unlikely, but still plausible, conditions provide the opportunity to create new insights about effective preparation for change. Anticipating extreme conditions can also speed up response time to emergencies by providing an opportunity for managers to consider potential outcomes of various actions and plan procedures to increase the likelihood of more positive outcomes.

Scientific analysis can reduce some types of uncertainty to improve the accuracy and the time and space scales of those predictions. However, other types of change have unknown or unknowable likelihoods of occurrence and research cannot substantially improve predictability. For example, new research may not increase our ability to predict global pandemics, collapses in fish populations, or novel species invasions far in advance. These conditions exhibit *Deep Uncertainty,* which are defined here as unpredictable events or system variability that cannot be well characterized with existing data, models, and understanding. Often, there is little or no agreement among stakeholders on how systems are likely to behave or the probabilities of occurrence of such events, including the duration, sequence, and co-occurrence of events (Haasnoot et al. 2013; Hallegatte et al. 2012). For the purpose of the Delta ISB's review, these types of uncertainties include low probability-high consequence events that are important for the Bay-Delta system.

Decision-making under deep uncertainty (DMDU) includes a set of tools for stakeholder engagement and anticipatory planning. Multiple approaches may be used to identify and evaluate a wide range of possible futures and pathways, assess the robustness of potential decisions under each scenario, and select the decision that minimizes risk over the planning horizon. Instead of planning for a single "best guess" future, DMDU approaches aim to evaluate all the conditions under which a policy or plan might fail, in order to understand if an alternative approach may be more robust to uncertainty. Some DMDU approaches emphasize adaptive planning (e.g., decision triggers or tipping points) so that risk mitigation efforts might be sequenced in time to promote cost-effective and responsive management (e.g., Haasnoot et al. 2013). More generally, the time horizon for planning and the frequency with which management can change from one plan to another can have a large effect on the applicability of DMDU.

These tools are also usefully applied to manage risk associated with low probability-high consequence events that impact water supplies, ecosystems, and human well-being. Those events include extreme droughts, extreme floods, or wildfires that have some predictability but are often ignored in management due to their perceived low probability of occurrence. Further, they could also occur in combination with less predictable events, such as tsunamis or sudden mass human migration, that make their management even more challenging. These events are being included here to direct more attention to advance planning and to recognize that probabilities based on historic conditions may no longer be accurate.

One DMDU tool commonly used to support forward-looking, future-oriented thinking is scenario analysis. Scenario analysis is uniquely valuable among decision support tools in that it can be used to examine different risks and probe deep uncertainties that reach beyond those that have been estimated using existing data and models. For example, California agencies who participated in the ARkStorm (Atmospheric River 1000 Storm) tabletop exercise to model and plan for a hypothetical scenario of an extreme weather event, or "megastorm", reported using results of that storm to improve preparations (Kaplan 2023), and to evaluate opportunities to consider using greener approaches to stormwater management (Smith 2022). ARkStorm was originally developed by the US Geological Survey based on historical data (Porter et al. 2011), but climate change is expected to intensify this effect (e.g., Espinoza et al. 2018). According to one study, runoff in the future extreme storm scenario is 200 to 400% greater than historical values in the Sierra Nevada due to the influence of climate change (Huang and Swain 2022).

Formal techniques have been developed in the interdisciplinary social sciences (especially decision science) to generate scenarios that systematically account for deep uncertainties that can include many stressors, such as climate change, human behavior, and compounding events. The science of scenario development uses data-informed approaches to understand evidence of change and incorporates horizon-scanning activities that identify how the system may be changing in the future. These approaches are particularly valuable for stress-testing policies to understand the conditions under which a proposed approach will fail, rather than only representing the optimal approach for a single, best-guess future scenario (e.g., Lempert et al. 2004). These techniques are also valuable for mitigating some of the common cognitive biases in decision-making that can limit our capacity to anticipate and effectively plan for potential future scenarios.

This Delta ISB review will draw on the interdisciplinary sciences that support DMDU by synthesizing current uses of scenario planning in the Delta and examining whether data-informed methods of scenario development may be usefully applied toward Delta management challenges. The scenario methods of DMDU are usually intended to evaluate what could plausibly occur, rather than normative scenarios of what should occur. The social aspects of scenario development and communication will be explored in the associated seminar series. The ultimate goal of this Delta ISB review is to support planning and management of events that are largely

unpredictable or of greater magnitude in outcomes than are typically prepared for in current management practices (e.g., long-term average conditions).

Audience

The intended audiences for this work are those who manage resources or design projects using intermediate to long planning horizons, along with scientific and technical staff at government agencies, research institutions, and environmentally focused public or private organizations. We expect the results will be of interest to a wide range of management applications, such as salinity management, water supply, fisheries management, and ecosystem restoration goals.

Inputs to the review

Inputs will include information gathered through 1) public seminars, 2) an inventory and synthesis of current scenario development processes in the Delta, and 3) interviews with Delta decision-makers.

Seminars

A public seminar series introducing concepts from the decision sciences, futurism, and other relevant scientific fields will engage stakeholders, rights holders, and other interested and affected parties. The seminar series will feature experts speaking on the science of DMDU, scenario development methods, major sources of deep uncertainty in the Delta, and current efforts to address those deep uncertainties. The seminars will also be an opportunity to explore social science research that evaluates community responses and reactions to future scenarios, and potential approaches to mitigate concerns. The seminar series will be hosted by the Delta ISB with support from the Delta Science Program (DSP).

Inventory and analysis of scenarios

The Delta ISB DMDU review will include a synthesis of scenario design and development methods being applied in the region. Scenarios relevant to the Delta region will be compiled and examined to understand how they are being designed to explore future socio-ecological changes and how they are being applied to decision-making and addressing uncertainty. Scenario elements to be captured in the assessment will include the scope of drivers and outcomes considered, methods of incorporating historical data, types of stakeholders engaged, and how uncertainty was identified and incorporated. Examples of existing scenario analysis efforts relevant to the Delta include, “Sacramento-San Joaquin River Basin Robust

Decision Making Case Study" (Kalra and Groves) and, "Future of Agriculture in the San Joaquin Valley" (Escriva-Bou et al. 2023; see Appendix A for draft list of scenarios). The information gathered will be relevant to understanding opportunities to apply deep uncertainty concepts or otherwise expand the usefulness of scenarios for different management goals in the Delta.

Interviews

Semi-structured interviews are planned with Delta decision-makers to deepen understanding of how scenarios are being developed and applied to address uncertainty in Delta analysis and decision-making. These interviews will contribute to providing recommendations for the potential application of DMDU tools and concepts to management challenges in the Delta.

Timeframe

Target Date	Benchmark
July 2023	Prospectus finalized
Ongoing (Throughout 2023)	Hold public seminar series to: a) Introduce concepts of DMDU b) Explore/identify deep uncertainties in the Delta as perceived from diverse individual and/or organizational perspectives c) Identify some signals of future change d) Provide other useful background information
Summer 2023	Scenario inventory and qualitative analysis to systematically characterize and critically evaluate existing Delta scenario design and development processes through an interdisciplinary decision science and futurism lens.
Summer-Fall 2023	Interviews with Delta decision-makers to understand use of scenarios to address uncertainty in their decision-making processes.

Target Date	Benchmark
Winter 2024	Release draft report summarizing information gained through seminar series, scenario inventory and analysis, and interviews, with recommendations to improve the science of scenario analysis to inform decision-making under deep uncertainty in the Delta.
Spring 2024	Finalize summary report and findings

Related Reviews

We are not aware of any similar in-depth investigation of DMDU in previous or current review efforts. However, the Water Supply Reliability Review emphasized the importance of long-term preparations and improving estimates of water reliability by increasing the range of water management portfolios represented in water supply reliability analyses. Furthermore, the Review highlighted the critical need to apply risk-based decision support and forecast-informed reservoir operations to manage the impact of extreme events on water management systems (Delta ISB 2022).

The Delta ISB review of DMDU is responsive to calls for DMDU made in the memo for the Delta Plan Interagency Implementation Committee (DPIIC) entitled, "Science Needs Assessment - Integrating Science for a Rapidly-Changing Delta, Principal Recommendation: Interagency Forecasting" (Delta ISB 2021), the article, "Preparing Scientists, Policy-Makers, and Managers for a Fast-Forward Future" by Delta ISB members that discussed the importance of scenario analyses, horizon scanning, expert elicitation, and dynamic planning for anticipating and responding to rapid future changes (Norgaard et al. 2021), and other recommendations produced by the Delta ISB and the DSP that have noted the need for anticipatory management (Delta Independent Science Board 2022; Delta Stewardship Council, Delta Science Program 2019).

Expected Products and Outcomes

Results and insights gained through the inputs described above will be synthesized in a report and shared through public presentations and other methods. The Delta ISB review will provide an exploration of tools, techniques, and recommendations that could be applied to help the Delta science and management community better characterize, prepare for, and adapt to uncertainty for a range of management

needs such as salinity management, water supply, and ecosystem goals. Recommendations could inform new analyses, simulations, and approaches for coordinating multi-agency responses to events, strategic scientific planning and collaboration by agencies, and other activities to anticipate and prepare for the future.

Appendix A: Draft List of Scenarios

This preliminary list represents scenarios identified to date that evaluate expected or plausible future conditions or develop visions of desirable futures using environmental, social, and/or policy elements. We expect to expand this list as we examine various ways that scenarios are used in the Delta or relevant areas, and we invite anyone to share additional scenarios that do not appear on this list.

If you use scenario analysis or conduct any type of anticipatory planning to account for future uncertainty to support decision-making and stakeholder engagement purposes in the Delta, please provide the information, as part of your public comment, to disb@deltacouncil.ca.gov by June 26, 2023.

Below is a current list:

- Brown et al., 2013: Implications for Future Survival of Delta Smelt from Four Climate Change Scenarios for the Sacramento–San Joaquin Delta, California
    - See also Cloern et al., 2011: Projected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change
    - Used IPCC Fourth Assessment Report 2007 scenarios
- California Department of Fish and Wildlife: Franks Tract Futures
- Center for Western Weather and Water Extremes: Forecast-Informed Reservoir Operations
    - Center for Western Weather and Water Extremes: Watershed Precipitation Forecasts
    - Department of Water Resources article: California's Forecast-Informed Reservoir Operations Are Key to Managing Floods and Water Supplies
- Metropolitan Water District of Southern California: Delta Island Adaptations
- Delta Stewardship Council: Delta Adapts
- Department of Water Resources: State Water Project Delivery Capability Report 2021- Appendix B Future Condition with Climate Change and 55 cm Sea Level Rise Scenario
- Public Policy Institute of California

    - Escriva-Bou et al., 2023: Policy Brief: The Future of Agriculture in the San Joaquin Valley
        - Technical Appendix
    - Hanak and Bedsworth 2008: Preparing California for a Changing Climate
        - Luers and Mastrandrea 2008: Climate Change in California: Scenarios for Adaptation
    - Hanak et al., 2007: Envisioning Futures for the Sacramento-San Joaquin Delta
    - Hanak et al., 2008: Comparing Futures for the Sacramento-San Joaquin Delta
        - Fleenor et al., 2008: Delta Hydrodynamics and Water Salinity with Future Conditions Technical Appendix C
        - Lund et al., 2008: Decision Analysis of Delta Strategies Technical Appendix J
        - Medellín-Azuara et al., 2008: The Economic Effects on Agriculture of Water Export Salinity South of the Delta Technical Appendix I
    - Medellín-Azuara et al., 2012: Transitions for the Delta Economy
- United States Geological Survey: Porter et al., 2011 Overview of the ARkStorm Scenario
- RAND Corporation and Delta Stewardship Council: Delta Levees Investment Strategy Support Tool
    - Chapter 2: Risk Evaluation Methodology
- RAND Corporation: Sacramento-San Joaquin River Basin Robust Decision-Making Case Study
- RMA Featured Modeling Projects
    - Prospect Island Tidal Restoration Modeling
    - Turbidity and Delta Smelt Forecasting Modeling
- San Francisco Estuary Institute: Landscapes Scenario Planning Tool
- Underwood et al., 2017: Quantifying Trade-Offs Among Ecosystem Services, Biodiversity, and Agricultural Returns in an Agriculturally Dominated Landscape Under Future Land-Management Scenarios
- United States Bureau of Reclamation: Sacramento and San Joaquin Rivers Basin Study
- United States Geological Survey CASCaDE: Computational Assessments of Scenarios of Change for the Delta Ecosystem

    - Achete et al., 2017: How can climate change and engineered water conveyance affect sediment dynamics in the San Francisco Bay-Delta system
    - Cloern et al., 2011: Projected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change
    - Ganju et al., 2010: Decadal-Timescales Estuarine Geomorphic Change Under Future Scenarios of Climate and Sediment Supply
    - Knowles et al., 2018: Modeling managed flows in the Sacramento/San Joaquin watershed, California, under scenarios of future change for CASCaDE2
    - Stern et al., 2020: The future of sediment transport and streamflow under a changing climate and the Implications for long-term resilience of the San Francisco Bay-Delta
    - Swanson et al., 2015: Modeling Tidal Freshwater Marsh Sustainability in the Sacramento-San Joaquin Delta Under a Broad Suite of Potential Future Scenarios
    - Wagner et al., 2011: Statistical Models of Temperature in the Sacramento-San Joaquin Delta Under Climate-Change Scenarios and Ecological Implications
- Vicuña, Hanemann, and Dale 2006: Economic Impacts of Delta Levee Failure Due to Climate Change: A Scenario Analysis

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2021. "Science Needs Assessment - Integrating Science for a Rapidly-Changing Delta Principal Recommendation: Interagency Forecasting," Draft Proposal to DPIIC. February. https://deltacouncil.ca.gov/pdf/isb/meeting-materials/2021-02-09-isb-sna-proposal-to-dpiic.pdf.

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