Attachment 3: SCHISM 3D Hydrodynamic and Water Quality Modeling Work Plan

to the Monitoring Special Study

CY 2022–2024 Work Plan

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Abbreviations/Acronyms

TERM	DESCRIPTION
1D	one-dimensional
2D	two-dimensional
3D	three-dimensional
CMOP	Center for Coastal Margin Observation and Prediction
CNRA	California Natural Resources Agency
DCD	Delta Channel Depletion
DEMs	Digital Elevation Models
DSM2	Delta Simulation Model II
DWR	Department of Water Resources
EC	specific conductance
ELM	Eulerian–Lagrangian method
FEM	finite element method
LSC2	localized sigma coordinates with shaved cells
MSS	Monitoring Special Studies
NDVI	Normalized Difference Vegetation Index
OLD	Old River at Tracy Monitoring Station
ORM	Old River near Mountain House Creek Monitoring Station
SCHISM	Semi-implicit Cross-scale Hydroscience Integrated System Model
SDWA	South Delta Water Agency
SELFE	Semi-implicit Eulerian-Lagrangian finite-element
WT	water tracer

1 Summary

The Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM) modeling component of the Monitoring Special Studies (MSS) Plan is intended to provide a means of synthesizing observations from enhanced monitoring, examining hypotheses, and applying insights to planning and policy.

The goal of the SCHISM modeling component is for the three-dimensional (3D) Bay–Delta SCHISM model to become better tuned to the interior southern Delta, reconciled with advances in the conceptual model and available data from the study, and applied to analyze the interior southern Delta system. SCHISM, as enhanced by the MSS, is expected to have an important role as a monitoring, compliance, and real-time operational tool.

The modeling tools developed through this study will support the efforts to address the MSS goals in the following ways.

- Study the seasonal water quality tradeoffs arising from different San Joaquin River inflows, San Joaquin River salinities, exports, and interior southern Delta sources and sinks.
- Assist with study design decisions, such as monitoring instrument placement.
- Provide extensive data analysis, including the vetting of hypotheses concerning local dynamics and water use, that arise from monitoring, and prepare annual model inputs representing the state of knowledge at each stage of the project.
- Provide a virtual testbed for the concept of "reach-based compliance."
- Provide an improved analytic and predictive tool, with reduced uncertainty from interior southern Delta salinity sources.

The first of these applications is formalized as the Study Plan, as described in Chapter 4, *Exports-Inflow Study Plan*, of this attachment. The other applications are expected to arise on an as-needed basis from the other components of the MSS and the development of the Long-Term Monitoring and Reporting Plan. It is expected that the modeling tools developed under the MSS will be made available as part of ongoing monitoring capabilities at operational time scales, a task that also coincides with other California Department of Water Resources (DWR) priorities.

Chapter 2, *Methods*, details the methods, study design, and expected products associated with this effort, including a brief description of the Bay–Delta SCHISM model and an overview of why SCHISM and the one-dimensional (1D) Delta Simulation Model II (DSM2) are applied in tandem to different tasks. These general descriptions are followed by a discussion of enhancements that are expected over the course of the MSS study (Chapter 3). Following this is the Exports-Inflow Study Plan (Chapter 4), which is the core modeling activity of SCHISM for the MSS.

The major products of this modeling study will be refined and improved versions of SCHISM and its inputs, along with some matching improvements in DSM2, a documented method for incorporating mass sources based on observations and data assimilation, a report on the interactive effects of San Joaquin River inflow, and quality, exports, barriers, and local mass sources on Delta water quality. Technical memos on bulleted items above that are ad hoc, such as instrument placement and reach-based compliance, will be added in future revisions of this plan.

2 Methods

SCHISM Model

The model used in this component of the study is Bay–Delta SCHISM, which is based on SCHISM (Zhang et al. 2016), which in turn is derived from the semi-implicit Eulerian-Lagrangian finite-element (SELFE) model (Zhang and Baptista 2008). SCHISM is an open-source, community-supported modeling system whose origins were to serve as a second-generation model (following ELCIRC, a Eulerian–Lagrangian algorithm used to solve shallow water equations) for use in the Columbia River estuary by the Center for Coastal Margin Observation and Prediction (CMOP). The model has subsequently been enhanced by the Virginia Institute of Marine Sciences and used in basins throughout the world with applications as diverse as reservoir temperature, estuarine transport of salinity, morphology, and near-coast tsunami response. The model has also participated in numerous regional benchmarks. A list of peer-reviewed papers is maintained on the model website (http://ccrm.vims.edu/schismweb). The larger SCHISM suite includes modules for sediment transport, ecology/biology, wind-wave interaction, ice, oil spills, and marsh evolution, listed approximately in order from greatest to least maturity. The model has been selected by the U.S. Environmental Protection Agency as the regulatory model for the Chesapeake Bay, as well as by the National Oceanic and Atmospheric Administration for their National Water Model. It is a fully featured, open model amenable to application in estuaries with a proven record of scaling to large multiscale problems and a dedicated international user base within which the state has enjoyed a long and prominent role.

The SCHISM hydrodynamic algorithm is based on mixed triangular-quadrangular unstructured grids in the horizontal and a flexible coordinate system in the vertical (localized sigma coordinates with shaved cells [LSC^2]; Zhang et al. 2014). The modeling system utilizes a semi-implicit finite-element/finite-volume method together with a Eulerian–Lagrangian method (ELM) for momentum advection to solve the Reynolds-averaged Navier-Stokes and transport equations at ocean-to-creek scales. SCHISM has both a hydrostatic and non-hydrostatic option, but, as explained in MacWilliams et al. (2016), non-hydrostatic modeling is not feasible at field scale in the Bay–Delta.

The formulation of the core SCHISM hydrodynamic module is based on the 3D hydrostatic Reynolds-averaged shallow-water equations, including mass conservation, horizontal momentum conservation, and salinity transport. Both the formulation and algorithm in SCHISM share many points in common with other 3D models used in the estuary, including the use of an unstructured geometry, implicit treatment of certain destabilizing terms, and a splitting that features the efficient cointegration of mass conservation (Equation 1) in vertically integrated form along with vertically integrated momentum conservation (Equation 2). Technically, SCHISM departs from many of the other most-common models in its use of a finite element method (FEM) representation of some of these steps. Because of the use of FEM, SCHISM is able to use a terrain-conforming vertical mesh and is more robust to skew mesh element shape so the grid can follow internal channels without requiring very high resolution. On the other hand, the FEM formulation does not promise local (i.e., per element) mass conservation, as do finite volume representations.

As with most well-resolved applications in the estuary, horizontal momentum diffusion is neglected. The elimination of horizontal viscosity is justified on the assumption that a well-resolved horizontal grid captures mixing because the largest scales of circulation and a modest amount of numerical diffusion are sufficient to model horizontal mixing at smaller scales. Boundary conditions for the water column are given by quadratic drag formulas for wind stress at the free surface and shear at the bed.

The drag coefficient (C_D) of roughness is calculated dynamically from a roughness parameter by using standard boundary-layer assumptions as described in Zhang and Baptista (2008). The values of roughness used here vary from approximately 0.01 millimeter in shallow areas to 8 millimeters at depth.

The turbulent eddy viscosity (ν) and eddy diffusivity (κ) is generated by using an independent set of turbulence-closure equations, specifically the k-ε 2.5 equation closure, with a background eddy viscosity of 0.00001 m^2s^{-1} to 0.008 m^2s^{-1} The closure is implemented in SCHISM by using the Generic Length Scale approach of Umlauf and Burchard (2003).

Roles of SCHISM and DSM2

Two hydrodynamic models are employed in different components of the MSS (as described in MSS Plan Chapter 3, *MSS Study Area and Technical Studies*): DSM2, a 1D model, is used for data assimilation, and SCHISM, a 3D model, is developed for general modeling. Each has associated strengths and weaknesses for interior southern Delta applications. Mutual compatibility in operational contexts is increasingly a priority for DWR because of the need for continuity, data assimilation, and high-resolution modeling.

The main roles and advantages of using the SCHISM 3D model are as follows.

- To take advantage of the SCHISM 3D model's much higher horizontal resolution and wetting/drying. The vertical direction is of secondary importance in the interior southern Delta, but the high resolution is not. Many of the mixing processes at the mouths of channels require some (statistical) fidelity to the chaotic mixing that occurs at or near junctions and the ability to model concentration and momentum differences across the channel. The spatial discretization of the MSS version of DSM2 is 330 meters (1,000 feet), whereas the length scale of the MSS enhanced-resolution SCHISM model of this region will be 4–35 meters (13–120 feet). In many areas of the interior southern Delta, bathymetric features vary more rapidly than the discretization length of DSM2, and the DSM2 cross-sections are aggregations (integrals or averages) along the computational reach. This is sufficient for regional accuracy, but not to represent local flow paths.
- Downstream, the vertical direction is important to transport, and the use of a 3D model is helpful for providing seamless transport through the stratified, baroclinic portion of the estuary. Such transport has been successfully parameterized in 1D and two-dimensional (2D) models; however, doing this requires significant tuning, and approximations are difficult to extrapolate to new scenarios, such as sea level rise.

- SCHISM simulates flow over submerged vegetation canopies and through emergent vegetation. In DSM2, drag over the entire water column by vegetation (particularly emergent vegetation) can be simulated by altering friction; however, the coarseness of the model complicates the fitting of effective drag.
- SCHISM has capabilities to model evaporation, temperature, and light/biogeochemistry. All are relevant in the interior southern Delta, but the development of biogeochemistry will follow from work performed in other parts of the Delta.
- In addition to advantages for the MSS, there is an acknowledged need to improve the interior southern Delta geometry and source/sink assumptions for better representation of the area in projects centered elsewhere.

By contrast, the need for DSM2 in the MSS arises from the following characteristics.

- **Speed**. DSM2 can simulate decades in an hour (compared to 2 days to simulate a year for SCHISM), making it ideal for use in data assimilation or other ensemble-based or iterative algorithms that require hundreds or thousands of starts and stops. Within the scaled-up real-time modeling system envisioned by this report, DSM2 is expected to take a forward role to SCHISM, resolving data discrepancies at the 1D level more economically than SCHISM can.
- **User base**. DSM2 has a large usership and is already embedded in DWR's forecasting systems for the interior southern Delta. Considerable conceptual model improvements are already accruing to the MSS project, and it is hoped that if the improvements are implemented in DSM2, then they can be more widely disseminated.
- **General appropriateness of 1D for the physics**. Aside from very local questions, the 1D representation of DSM2 is appropriate for the tight channels and avoids some issues that arise in reaches with bed variation on the same scale as the channel depth. Several caveats will be addressed within the project. The first regards resolution—the standard DSM2 computational reach of 5,000 feet is too coarse to resolve concentration slugs traversing the 5-Point Confluence. For MSS actions and data assimilation, a refined model is utilized. Second, the model's bathymetry has also not been updated recently. Cross-sections for the model will be updated after construction of suitable maps for SCHISM.

Discretization

Interior southern Delta modeling is embedded within a larger domain, encompassing the entire San Francisco Bay–Delta (Figure 1). The model domain spans from the Farallon Islands off the coast, to Vernalis on the San Joaquin River, and Knights Landing on the Sacramento River. Horizontal resolution over the full domain varies from 5 meters in a small number of narrow, small channels to 2 kilometers the near coast. The most current version (version control label: v111) of the mesh used as the base grid for this study has 327,000 triangular and quadratic elements and 305,000 nodes. As part of this study, DWR will refine the mesh in the interior southern Delta to achieve better resolution of small bathymetric and flow features.

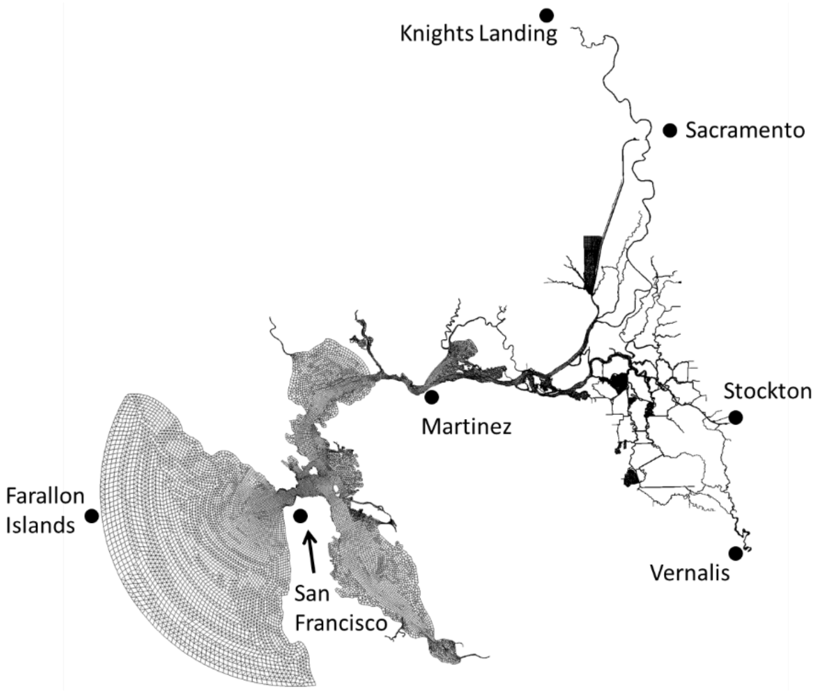

Figure 1: Bay–Delta SCHISM Full Mesh, Version 111

In the vertical direction, the model employs an adaptive, terrain-conforming LSC^2 mesh (Zhang and Baptista 2014), ranging from 23 vertical levels in deep areas near the coast to eight levels at the upstream reaches of the Sacramento and San Joaquin rivers. The use of an LSC^2 vertical grid represents a change from the original reporting of the application in Ateljevich (2014), when a 23-level terrain conforming S grid (Song and Haidvogel 1994) was used everywhere.

In the base discretization, the majority of the interior southern Delta is discretized vertically with eight levels. The motives of using SCHISM in 3D, as described above, include the modeling of vegetation and light penetration from the surface. The SCHISM model does allow adaptive 2D modeling and that option may be explored, as well, but, as explained in the Summary, this would have to be motivated by accuracy; given the excellent scaling and the quirks of SCHISM's load-balancing formulas, the effect on model efficiency would be minimal.

The model time step is 90 seconds for the work described in this document.

Bathymetry

The majority of the project bathymetry for SCHISM comes from the Digital Elevation Models (DEMs) prepared by Wang et al. (2019), with a number of regions updated by the preparation of new, 2-meter maps. The bathymetry has been updated several times, and the version used at the outset of this study is version 4.2, available as a mutually compatible set of GeoTiff format files from the California Natural Resources Agency's (CNRA) open data platform (https://data.cnra.ca.gov/dataset/san-francisco-bay-and-sacramento-san-joaquin-delta-dem-for-modeling-version-4-2).

The set of DEMs collates soundings from numerous collections. Recent collections and enhancements are described later in Chapter 3, *Model Enhancements under the MSS Project*.

Model Forcing

Like any physically based hydrodynamic and transport model, SCHISM requires an initial condition and tidal and flow boundaries. As implemented, the model also requires wind and pressure fields, agricultural sources of mass and tracer concentration, gate and hydraulic structure timing, and, in the case of submerged aquatic vegetation, vegetation parameters.

Hydrodynamic forcing was implemented mostly in accordance with the practices described in Ateljevich et al. (2014), including upstream inflows from USGS gauges, pumping volumes from water project operators, and tide data along the near coast. The boundary data requirements are illustrated on Figure 2.

The modeling setup for the study includes the major hydraulic structures in the Delta, including Delta Cross Channel, Montezuma Slough Salinity Control Structure, and southern Delta agricultural barriers. Timing for operable gates, Clifton Court in particular, are based on DWR historical records that are publicly disseminated with the Bay–Delta SCHISM project on GitHub (https://github.com/CADWRDeltaModeling/BayDeltaSCHISM). Details concerning the Clifton Court radial gate-rating process, as well as Harvey O. Banks Pumping Plant pumping data, can be found in Ateljevich et al. (2015) and Shu and Ateljevich (2017), which elaborate on issues described by Smith (2011) and MacWilliams and Gross (2013).

SCHISM simulates both temperature and evaporation and for that requires atmospheric forcing, including wind and air pressure as a minimum; other variables, such as air temperature, radiation, and specific humidity, are required for modeling temperature. One notable change in the modeling inputs since Ateljevich et al. (2014) is wind, which was formally based on climate reanalysis and weather products, but is now interpolated from 69 field stations operated by the National Oceanic and Atmospheric Administration, Weatherflow, National Estuarine Research Reserve, California Irrigation Management Information System, Meteorological Terminal Aviation Routine airports, DWR, and Bay Area Air Quality Management District.

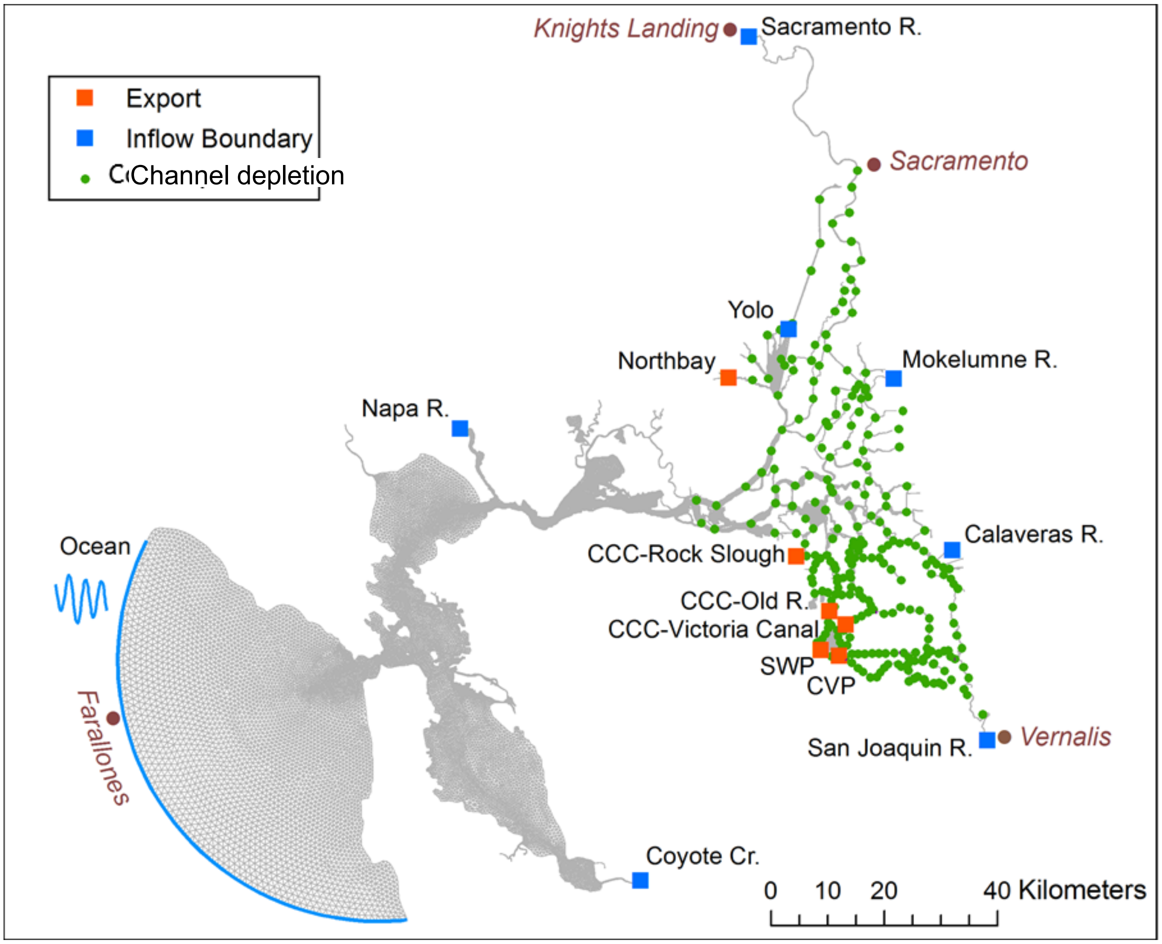

Figure 2: Location of Tidal and Flow Boundaries and DCD Channel Depletion Locations Taken from DSM2; Suisun Marsh Channel Depletion Locations Not Indicated, but Included in Model

Lastly, the model inputs will use the Delta Channel Depletion (DCD) Model as the basis for channel depletions, rather than the Delta Island Consumptive Use used in Ateljevich (2015) and other earlier work. The model is described in Liang and Suits (2017). Sandhu (2016) describes recent progress made by the Bay–Delta Office and other researchers on channel depletions and consumptive-use products for hydrodynamic modeling. DWR recently extended this work to the Suisun Marsh, the details of which are omitted here as it is outside the study area. The consumptive use models are terrestrial; assignments to nearby channels are described in DWR (1995a). These assignments are typically made to nodes in the DSM2 model grid. Only in limited cases have the assignments been modified to correspond to specific physical intakes. Salinity loadings associated with agricultural returns were determined based on observations and are documented in DWR (1995b). Outside of the interior southern Delta, these assumptions will not be altered for the MSS. Within the interior southern Delta, enhancements are planned as outlined in the following sections.

3 Model Enhancements under the MSS

The baseline model described in the previous section will be enhanced as data becomes available from the different components of the MSS. The proposed improvements include higher-resolution modeling, incorporation of better bathymetry and, most of all, refinement of interior southern Delta mass sources and sinks in accordance with measurements and inferences gathered from the other MSS studies.

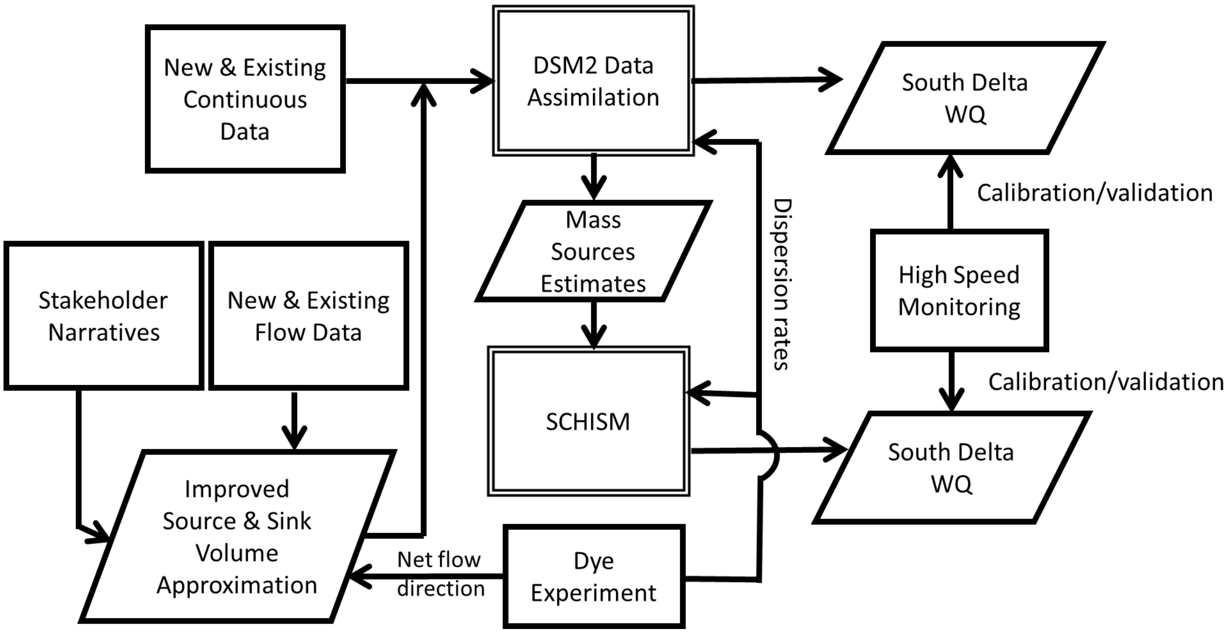

Figure 3: Flow Chart Showing Relationship Between MSS Monitoring and Modeling Components for Improving Characterization of Delta Sources and Sinks

Synthesis of Observations and Revision of Modeling Assumptions

One limiter to accuracy of southern Delta models has traditionally concerned trends in the local flow field that are missing due to the somewhat generic distribution of source and sink flows and drainage salinity to channels. Over the lifetime of the project, more detailed information concerning the local flow field and characteristics of barriers will continue to be derived from field trips, collation of water use reporting data and pump capacity experiments, and participant-hosted field trips.

One of the goals of both modeling projects (i.e., data assimilation and SCHISM) is to fold in these new data and reconcile them with existing land use and channel depletion models—for example, to make the adjustments with minimal perturbation to evapotranspiration and crop efficiency. In many cases, it appears possible to simply redistribute diversions and drainage that better fit anecdotal and observed terrestrial and aquatic data. Revisions of model inputs will be vetted annually, according to a template that will include the proposed revision to assumptions, justification and corroboration, and level of certainty. Participating organizations[1] will be invited to comment or propose sensitivity experiments. This sort of data analysis activity straddles the observation, data assimilation, and SCHISM components of the MSS project and will be coordinated across the efforts.

Mass Sources and Volumetric Sinks

In modeling work, Vernalis inflow and export pumping volumes can usually be specified without significant uncertainty, either because they are accurately measured or because they are

[1] This document uses the term *participating organization* instead of *stakeholder*.

hypothetical. Based on consistency with adjoining gauges, the accuracy of these flows appears, on average, to be within 5 percent.

The main difficulty faced by modelers in this region is the paucity of specific information and data about local mass loadings of salt and volumetric sinks of water (e.g., diversions, seepage). Information from numerous components of the project will be synthesized to improve upon this uncertainty, as shown on Figure 3.

Improvements are to be pursued both for volume of flow and for salinity and other water quality constituents. A key source of information for these improvements comes from local narratives by participating organizations that have improved the conceptual model of the 5-Points region and brought about revisions in the spatial assignments of sources and sinks. Other changes come from improved monitoring. Local flow stations are currently being rerated, and short-term deployments are proposed as part of the MSS goal to confirm and better understand null zones identified on page 1 of the MSS Plan. A pilot rhodamine water tracer (WT) dye experiment is also planned in some of the upper reaches of Paradise Cut, with the goal of confirming the somewhat-delicate mean flow direction. Depending on the results of this pilot experiment, additional dye experiments may be performed at other dead-end sloughs, including Sugar Cut and Mountain House Creek. Modeling will proceed on a best-available-science basis: estimates will be incorporated early, based on existing data that tally with current qualitative and quantitative information, and revisions will be made as improvements from the project come online.

There are a few inconsistencies between observed field conditions and model inputs that will be the focus of model improvement work, including the following.

- **Null zones**. Convergent flow has been observed to occur in Old River, Middle River, and Grant Line Canal in DSM2 upstream of the temporary barriers during the season when they are installed. For example, Old River flow at Old River at Tracy (OLD) can be observed to be positive during the barrier season and at Old River near Mountain House Creek (ORM) can be observed to be negative (Figure 4). Mass conservation suggests that for the models to reproduce the characteristics of the reach, a roughly similar volume of water must be accounted, and the net depletions due to diversions, seepage, and returns in DCD are not sufficient.
- Based on weights developed in DWR (1995a), the DCD model assigns diversions and returns in Tom Paine Slough, Paradise Cut, and Sugar Cut in an equivalent manner, without considering the net circulation that occurs because of the terrestrial drainage direction on Pescadero Tract (Figure 5). The revised conceptual model based on observations and following field trips hosted by South Delta Water Agency (SDWA) is that Tom Paine is used more for diversions and Paradise Cut more for returns.
- Salinity from agricultural sources in Paradise Cut, Tom Paine Slough or Sugar Cut discharges are represented in model inputs by a single climatology of monthly specific conductance (EC) values, repeated year-to-year and taken from sparse samples described in DWR (1995b). These input concentrations are in places lower than field measurements in the adjoining channels. Patches of elevated salinity are observed in the high-speed and continuous EC monitoring efforts in areas of substantial volume (i.e., where evaporation

does not provide a physical explanation for their presence). Correction of the volume sinks and mass loadings in the Pescadero Tract region will be performed through a combination of improved field monitoring and data assimilation with DSM2. SCHISM will be a client of these improvements and confirm that inferences from observations and data assimilation are model independent.

Figure 4: Flow Convergence at Old River

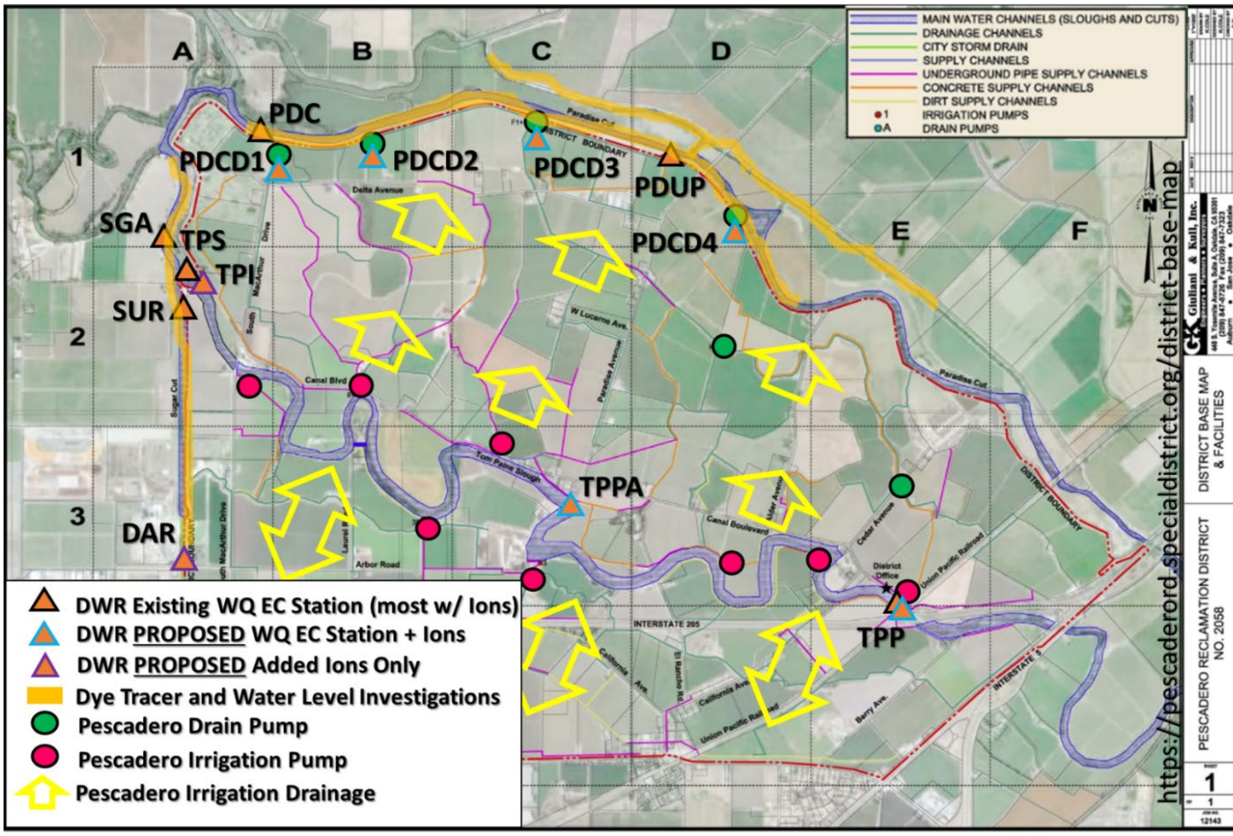

Figure 5: Pescadero Tract Water Circulation Diagram

Enhanced Model Resolution

Although Bay–Delta SCHISM contains most channels of the interior southern Delta, the resolution in the Five Points area and in some areas of adjoining channels (Old River, Middle River, and Grant Line Canal) is not detailed enough to resolve lateral differences of concentration and velocity that develop during tidal exchanges between Old River and adjoining dead-end sloughs, such as Sugar Cut and Paradise Cut. Similarly, it is not known yet whether coarse resolution oversimplifies mixing processes that happen as the tides traverse back and forth across the maze-like structure of the 5-Points Confluence. In this area of enhanced mixing, resolution will be doubled, resulting in a grid that is approximately doubled (Figure 6a). Typical mesh scales in Figure 6b are approximately 15–35 meters in the along-channel direction and 8–10 meters horizontally. Some very small channels, including the upstream section of Middle River, will be double this resolution, model performance, and bathymetry, quality permitting.

Regridding must also be coordinated with bathymetry, but is faster than bathymetry to deploy; the regridding will thus be undertaken twice, once over a reduced region with enhanced resolution, and once later to adjust to new findings over a larger area once better bathymetry has been collected and processed, roughly by the end of calendar year 2022.

Dispersion rates in Paradise Cut and other reaches will be calculated in the SCHISM model, compared to parameterized rates in DSM2 and dye plume evolution from the dye experiments. Results of that comparison will comprise one portion of the model evaluation report.

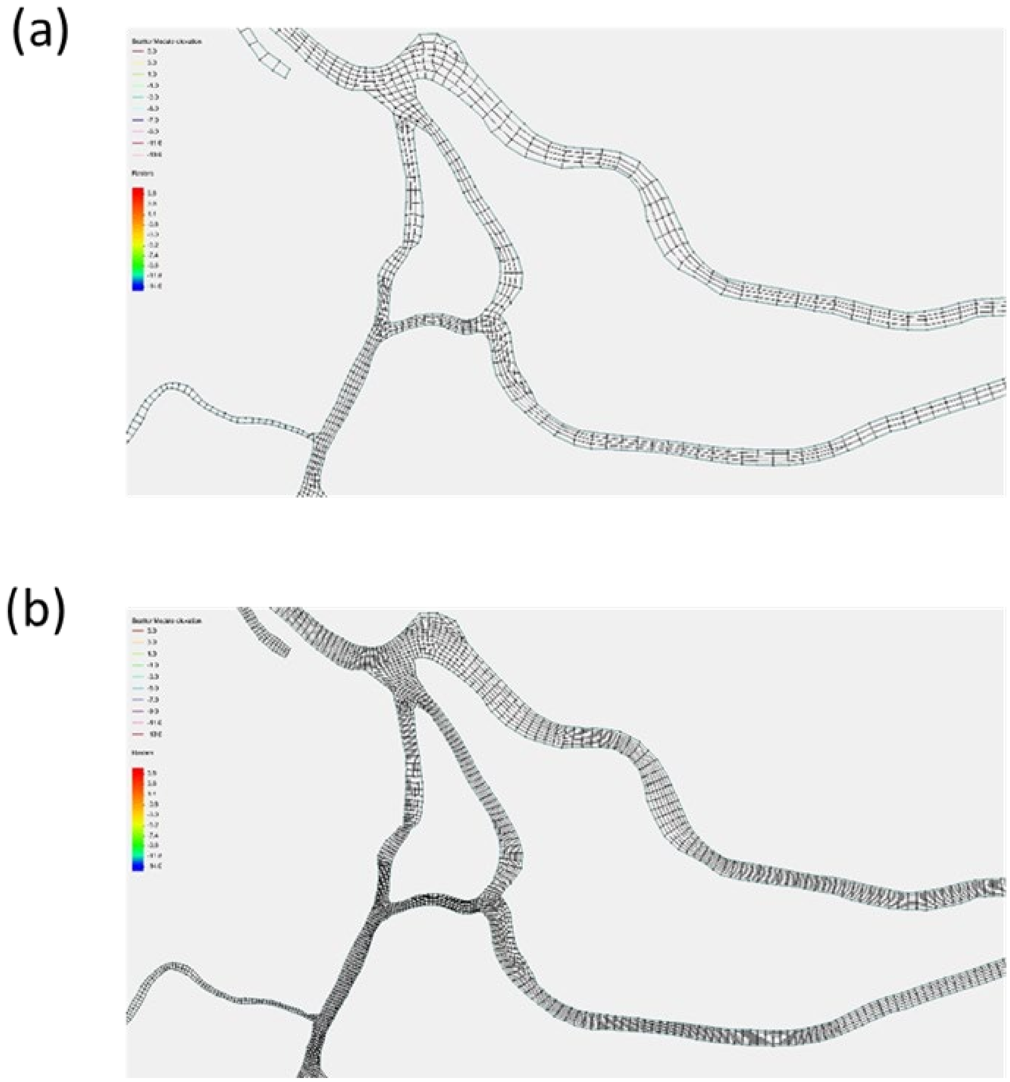

Figure 6: (a) Coarser Base Resolution (b) MSS Refinements

Bathymetry

Bathymetry in the interior southern Delta is regarded as rapidly varying compared to other areas in the Delta. Because elevations are an important driver of circulation in tidal channels, modernization of the bathymetric database is included as part of the SCHISM (and DSM2) modeling improvements. Figure 7 shows the years of last major collection for a number of sub-reaches of the interior southern Delta as logged by DWR's Bathymetry and Technical Support Section. Generally, participating organization concern in the region has been concentrated in areas of accretion within the Old River, such as the 5-Points Confluence indicated on Figure 7 by Box 3. Cinquini and Passarino, Inc., acting under contract for SDWA, based on a cost-sharing arrangement with DWR and DWR's Bathymetry and Technical Support Section, are both actively surveying this area in early 2022. The two data-collection groups are coordinating efforts to minimize redundancy and ensure continuous coverage in difficult regions, such as vegetation and gaps between lidar and multibeam sonar. The Cinquini and Passarino collection plan is indicated on Figure 8; complementary surveys in Italian Slough and Victoria Canal will be undertaken by DWR partners to supplement this effort. The raw soundings will be disseminated on the Bathymetry and Technical Support Section public bathymetry catalog, as well as incorporated into the Delta Modeling Section integrated bathymetry maps for modeling, as the data become available and can be processed into continuous surfaces distributed on the CNRA Open Data Portal.

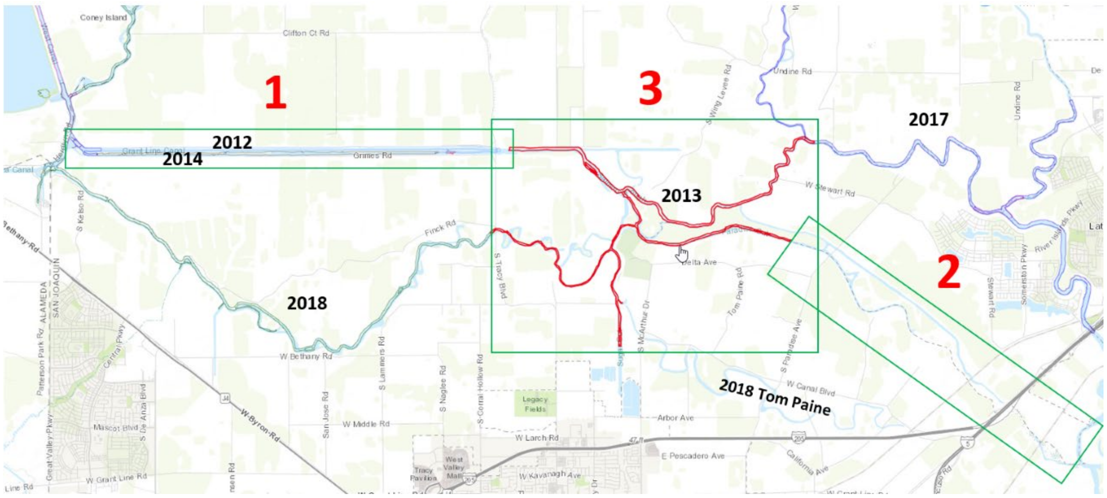

Figure 7: Dates of Large-Scale Historical Surveys by DWR's Bathymetry and Technical Studies Section

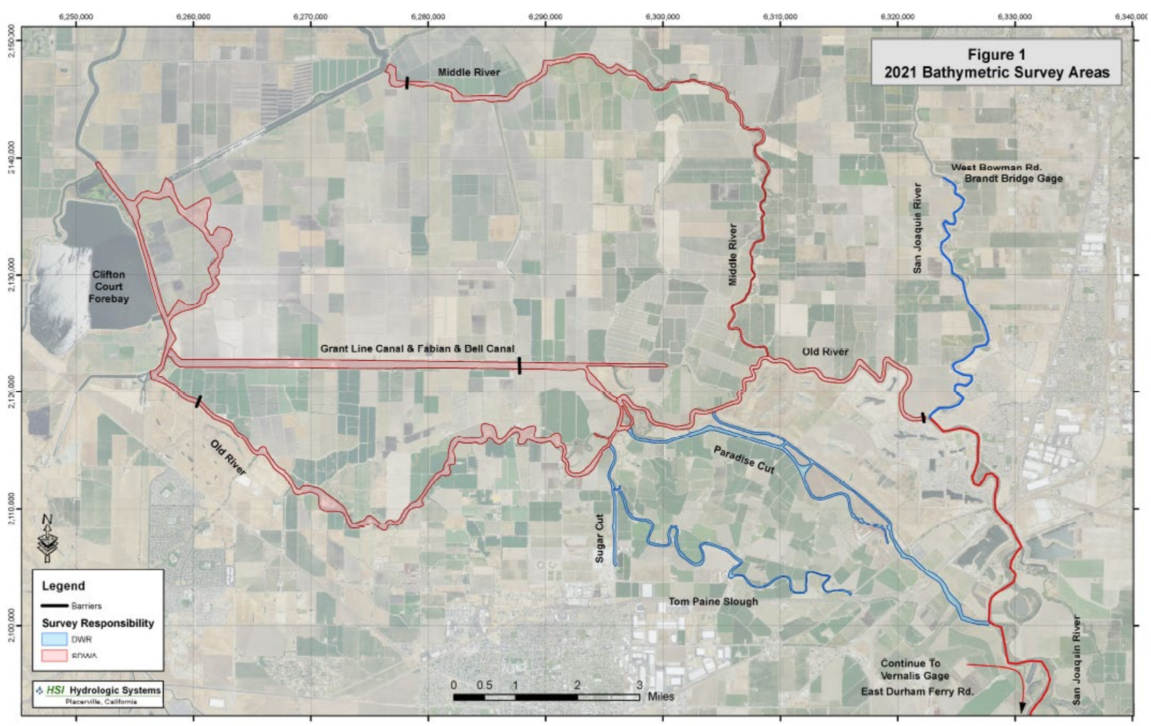

Figure 8: Cinquini and Passarino Survey Plan for Winter 2021–2022

Vegetation

Submerged vegetation has a major effect on local flow dynamics and, for this reason, a module for vegetation has been developed within SCHISM (Zhang et al. 2019) and tested in other portions of the Delta. Typically, the limiter for incorporating vegetation into models is the difficulty defining the effective drag elements through (mostly unknown) density, diameter, and height of the canopy and coefficient of drag. Offsetting this difficulty is the striking and thorough way that substantial vegetation canopies disrupt velocity (Work 2021), which typically means that correctly inferring the presence of vegetation is sufficient to improve qualitative flow fields and model results. This approximation can be done based on a parameterized basis using Normalized Difference Vegetation Index (NDVI) (Ustin 2016) or on heuristics such as depth (Durand 2016). In either case, the characterization improves on any model that omits vegetation entirely. In the interior southern Delta, the characterization is most often based on depth, given that NDVI image resolution is coarse compared to the tight channels of the region.

The prioritization of localized work on vegetation will be coordinated with participating organizations. The emphasis in the first year will be on developing and disseminating a first-cut set of assumptions for sources and fluxes.

Barrier Representations

Tide conditions permitting, DWR will be measuring flow in culverts and across weirs in many of the southern Delta temporary barriers. The existing gate parameterizations will be checked against these flows.

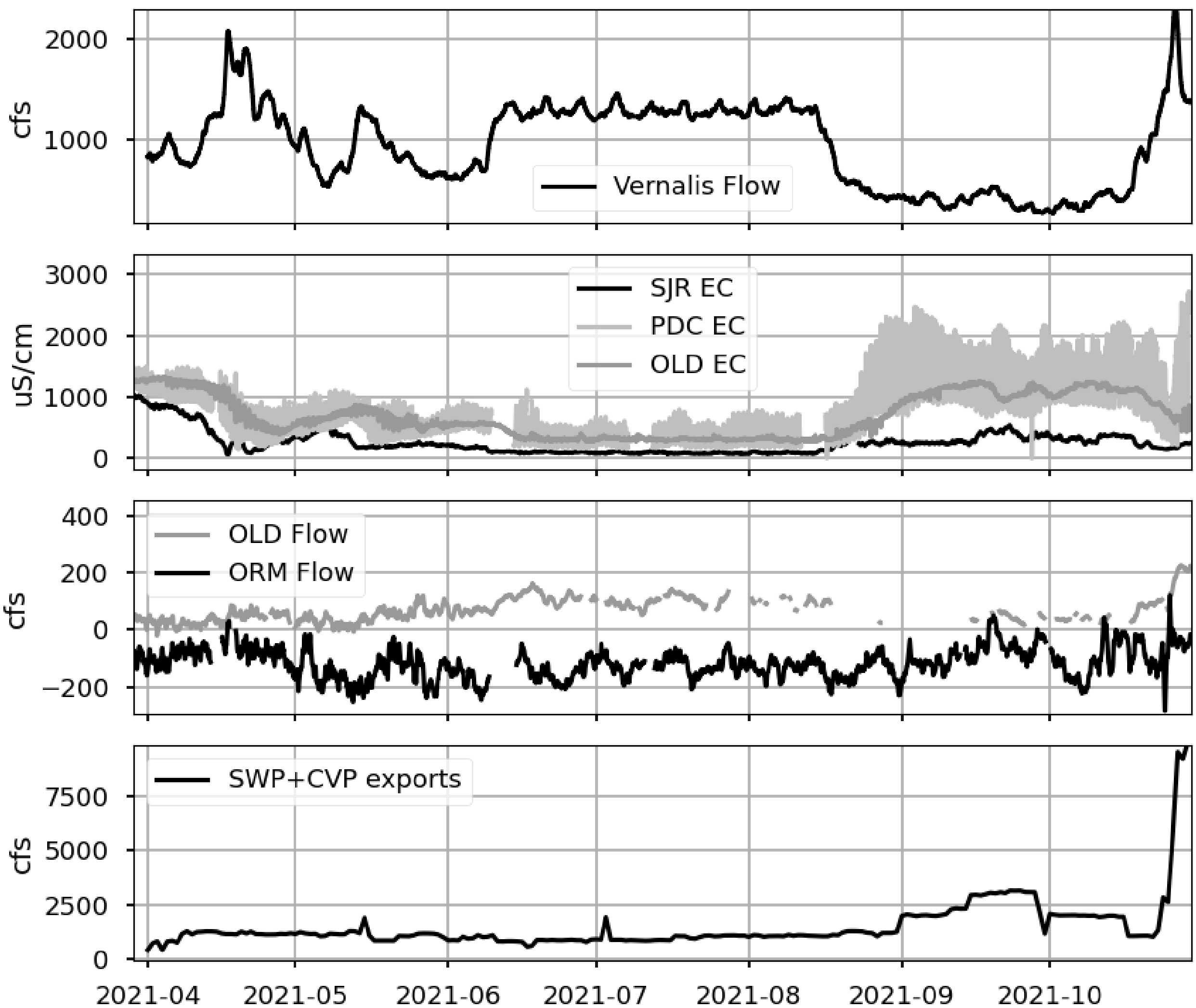

Figure 9: Interior Southern Delta Inflows, Exports, Channel Flows and Selected EC Values in 2021. OLD = Old River near Tracy. ORM = Old River at Mountain House PDC = Paradise Cut (downstream) SJR = San Joaquin at Vernalis

4 Exports-Inflow Study Plan

2021 Simulation and Extensions

There is considerable interest within the participating organization community in modeling the calendar year 2021. This year featured flow and water-quality transitions that are rare and provide a good entry point to the more structured study described below. Pertinent flow and salinity time series are depicted on Figure 9. The following conditions are of note.

- Water quality at Vernalis was consistently fresh, allowing a separation of factors upstream of Vernalis from influences in the Delta. Mass sources in the interior southern Delta appear to have been overwhelmingly local.
- The volume of Vernalis flow switched from consistently high before August 15 (1,400 cubic square feet) to consistently low (250 cubic square feet).

- Water quality changed from fresh to over 1,000 microSiemens when the inflow transition occurred.
- Net flow at Old River at Mountain House was directed upstream and relatively unaffected by the Vernalis transition. Net flow at Old River near Tracy was only slightly affected by the higher Vernalis flow rate in early summer.
- Step function transitions at the State Water Project and Central Valley Project pumps from low (**) to medium (***) values had no apparent effect on either net flow or EC in the area.

Because of the focused interest, the initial modeling will be focused on the 2021 water year and will based on a best-available-science methodology. Inferred loadings from data assimilation will be used so that loadings are consistent with the spatial structure and concentrations observed by continuous stations and high-speed EC monitoring. As the project progresses, these inferences will be improved or replaced by improved data collection.

Analysis of Export and Inflow Effects on Salinity

The Inflow and Export South Delta Modeling Experiment described herein will use simulation to explore a matrix of San Joaquin inflows, San Joaquin EC, and federal and state diversions (Figure 10). The main question under investigation will be how inflows and exports interact with southern Delta features, such as temporary agricultural barriers, diversions, and mass sources to affect local water quality, and the main question that will be tested is whether inflows and/or exports can be used to ameliorate interior southern Delta salinity and bring it to levels at or below salinity objectives. The answer to this question is expected to be seasonal, depending on both the agricultural calendar and the status of the temporary agricultural barriers.

The experiment will be conducted by varying model inputs for San Joaquin flow and water quality and State Water Project/Central Valley Project exports in a quasi-historical setting, using 2021, 2022, and one or two other modern historical years (e.g., 2019 are 2020 are slated), as needed to represent a wide variety of scenarios matrix within plausible historical and seasonal settings and for validation against historical water quality. The approach is branded here as quasi-historical because scenarios will be derived by holding some elements at historical levels, while perturbing others. Boundary inputs remote from the interior southern Delta (i.e., tides, Sacramento and other remote inflows, channel depletions in other regions, and atmospheric forcing) will be historical or adjusted to meet outflow requirements.

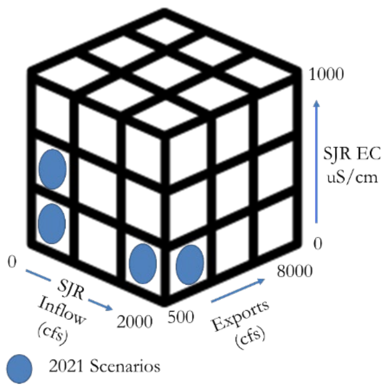

Figure 10: Parameters to Be Varied in the Inflow and Export South Delta Modeling Experiment

5 Timeline and Deliverables

The anticipated timeline of activities (Table 1) for the SCHISM modeling component includes participation in ongoing monthly MSS coordination meetings, as well as quarterly MSS technical workgroup and participating-organization meetings, initiated in 2021. Model evaluation and study reports will be revised in January of 2023 and 2024. Deliverables include model inputs, elevation models, outputs, validation plots, study analysis, and reporting.

Anticipated milestones are reproduced below in Table 1. The model evaluation report and inflow-exports experiments are anticipated to have 2023 and 2024 versions. The 2023 versions will include model-validation statistics, conclusions, and methodologies. The 2023 report will be the basis of substantial participating organization feedback and serve as the final opportunity to identify information gaps in the monitoring. The 2024 version will be similar in form and will consider input from participating organizations, as well as data collected in the 2023–2024 period.

The following timetable has been revised to accommodate recent work on revised modeling assumptions and delays in the arrival of survey data.

Table 1: SCHISM Anticipated Timeline and Milestones

Date	Milestone
Aug 2022	Bathymetric Survey Data Assumed Available
Sep 2022	2022 Revision of South Delta Assumptions Memo and Presentation
Oct 2022	Initial Findings of 2021 Modeling
Feb 2023	DEM Release, Including collections (based on August delivery of survey data)
Mar 2023	Revised Interior Southern Delta Mesh
Apr 2023	South Delta Model Evaluation Report 2023
May 2023	SCHISM Modeling Participating Organization Presentation and Feedback Solicitation
Jul 2023	SCHISM Modeling Study Plan and Modeling Assumptions Revision
Sep 2023	Inflow-Exports Experiment Report 2023
Dec 2023	Real-time Modeling Prototype Inputs and Scripts to Repository

Date	Milestone
Jan 2024	South Delta Model Evaluation Report 2024 (Final)
Mar 2024	Inflow-Exports Report 2024 (Final)
Jun 2024	Biogeochemistry Modeling Progress Report

Data Management and Accessibility

The SCHISM model code and associated utilities are distributed by Virginia Institute of Marine Sciences using the open-source GitHub repository. Bay–Delta inputs and templates are distributed by DWR in the open-source GitHub repository maintained by the Delta Modeling Section. Large binary inputs and elevation data needed to run the model that are too large to serve on GitHub are distributed separately on the CNRA Open Data Portal. Revised bathymetric maps will be offered on the same portal. Model inputs developed in this project will initially be stored on DWR high-performance cluster-storage servers and on Microsoft Azure clusters. Postprocessed output will be reduced to the region of the interior southern Delta and stored in storage area network devices at the DWR data-service center and eventually served on the CNRA Open Data Portal. Inferred mass loadings and novel inputs will be disseminated as the standard or alternate Bay–Delta SCHISM inputs and disseminated on GitHub or distributed as text (.csv) files. Station output for the inflow-exports experiment and for validating the model will be distributed as SCHISM output text files, a simple format that can be parsed as a modified csv format by tools such as Excel.

Participating-Organization Coordination

Modeling progress and study results will be presented on an ongoing basis at participating-organization and technical coordination groups. The presentations will include status, changes in modeling assumptions in response to fundamental data research, data assimilation, and new observations, as well as results from the structured study on import and export effects.

The SCHISM modeling described here is important to long term salinity monitoring and reporting in two ways. First, the model will serve as a virtual testbed for the concept of "reach-based compliance," part of a toolchain that can assess feasibility, representativeness, and equitability of compliance proposals. It is also anticipated that it will be transitioned into an operational planning tool, able to assess probable salinity and water level outcomes of federal, state, and local operations.

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