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OPTIONS FOR MODELING WATERSHED NUTRIENT LOADING AND WATER QUALITY IN ELKHORN SLOUGH

SAG Meeting

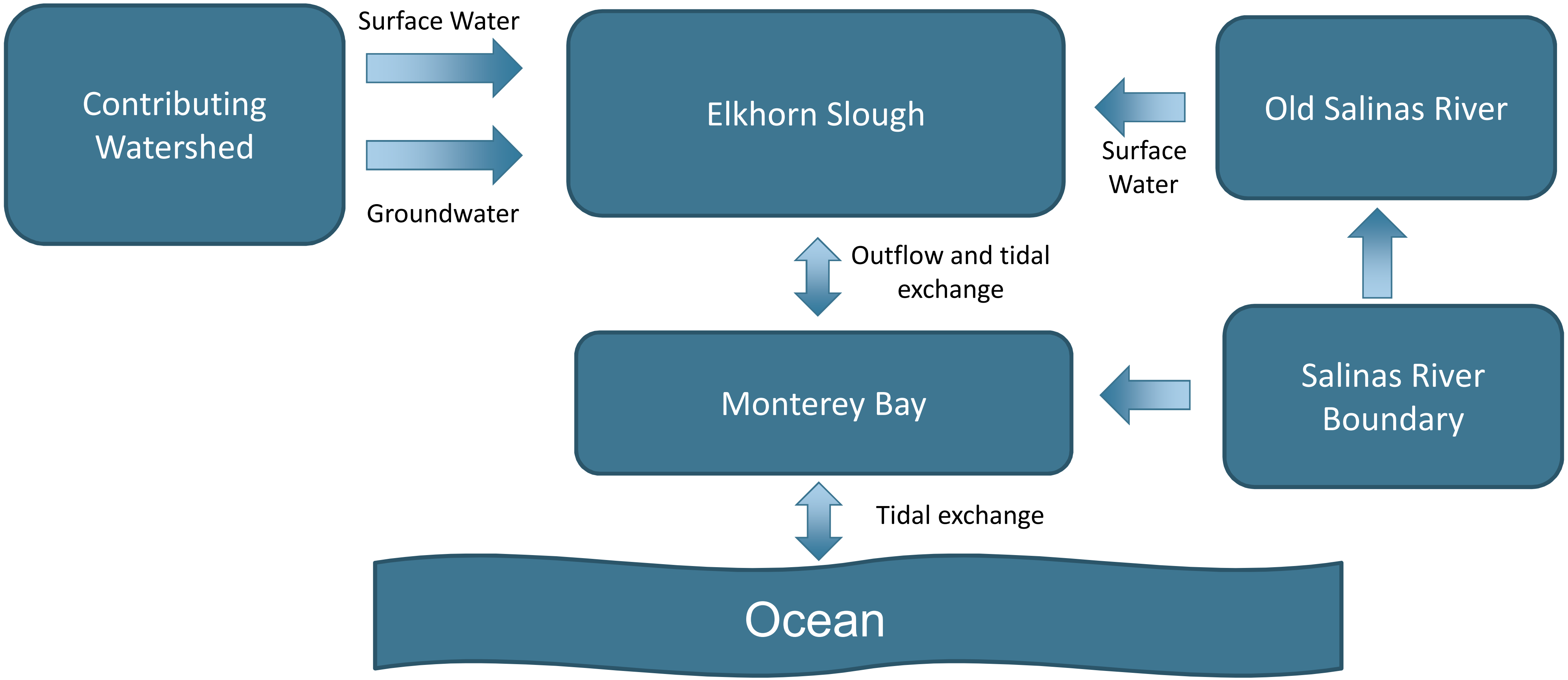
Elkhorn Slough Reserve, Watsonville, CA
July 9, 2019

Why Use Models?

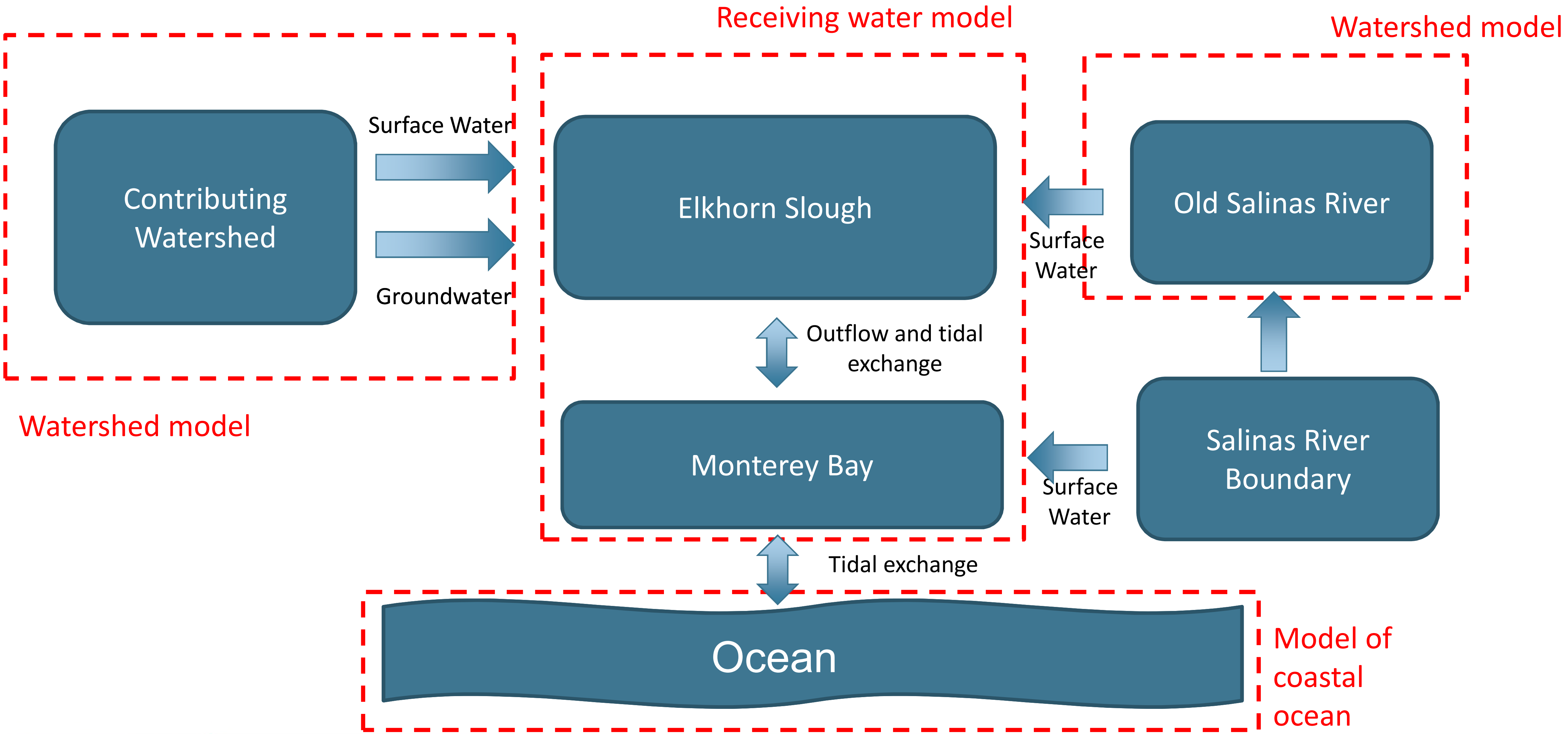
Encapsulates available data and knowledge of biogeochemical processes in a framework that allows:

- Identification of important data gaps
- Exploration of linkage between management endpoints and external drivers (linkage analysis)
- Allows testing of implementation scenarios

Conceptual Representation of Water Flows



Model Representation



Modeling Stages

- Model selection
  - Watershed loading
  - Receiving Water Model
- Model configuration
- Validation, sensitivity analyses, and other testing
- Application for new scenarios

Model Selection Considerations

- Need separate model frameworks that consider watershed and receiving water processes
- Previous receiving water models have focused on hydrodynamics and mixing, additional work needed to incorporate water quality and selected eutrophication processes
- New work on coastal modeling can provide a range of boundary conditions for the receiving water model

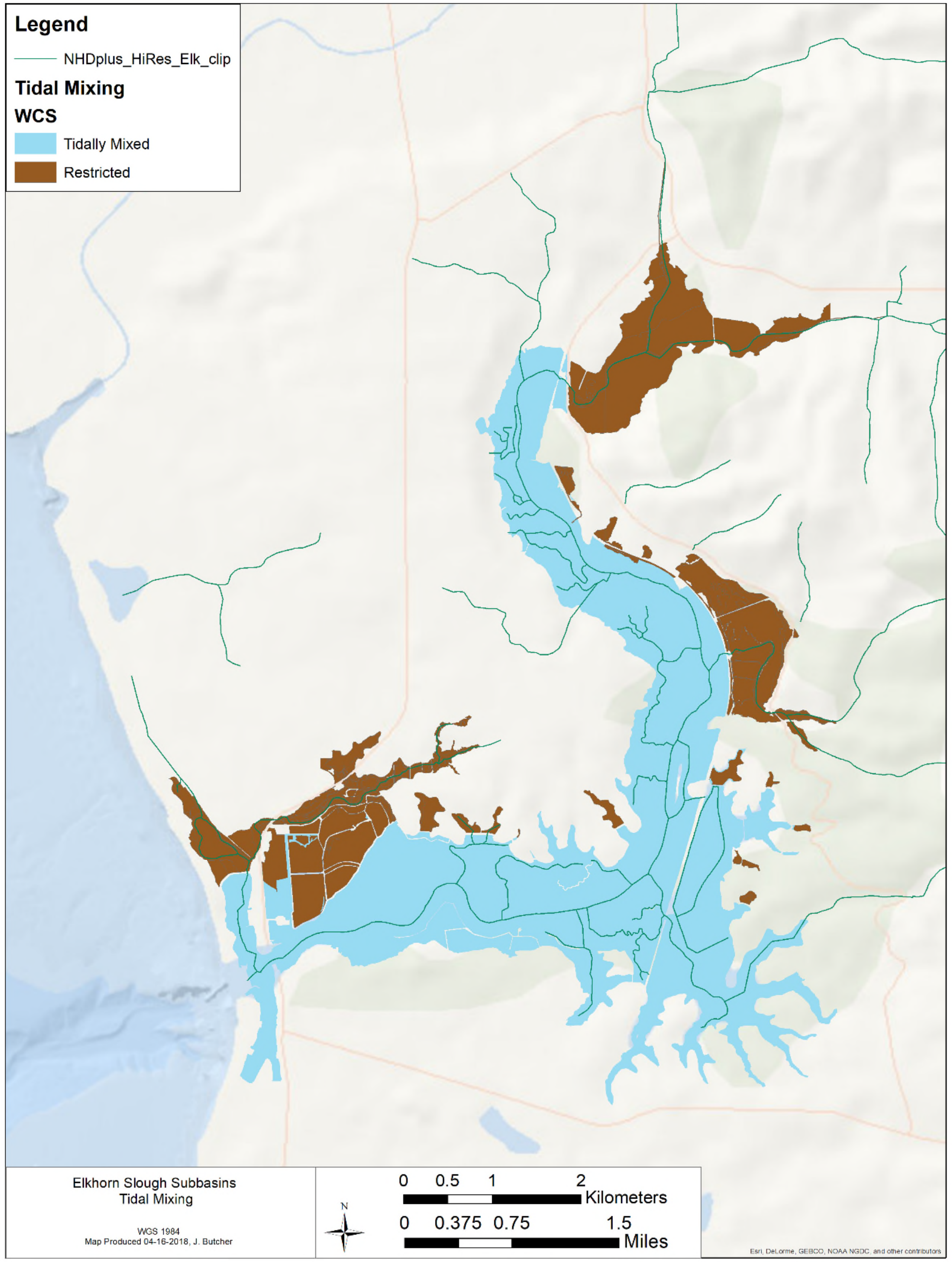
Watershed Model Recommendation from Previous Work (Tetra Tech, 2018)

Recommended the Soil and Water Assessment Tool (SWAT) to compute watershed loading, for the following reasons:

- SWAT is relatively cost-effective to apply, and has been successfully applied in the region for other TMDLs
- Represents specific crop rotations,
- Explicitly represents plant growth and agricultural management practices (e.g., fertilization, tillage, drainage) that are of key importance to nutrient loads from the Elkhorn Slough directly contributing watershed,
- Typically has broad acceptance among agricultural producers due to its ARS support.

Receiving Water Model Considerations

- How do we represent complex Slough hydrodynamics and mixing?
- What endpoints do we want to simulate?
  - nutrient concentrations, DO, pH, algal responses?
- What is the critical period?
  - Dry season only?
  - Wet and dry season?
- Do we need continuous simulation or critical condition simulations?



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Receiving Water Models

Previous work:

- TRIM3D model, documented by Monismith et al. 2005
- Delft3D model, documented in PWA, 2008
- Unpublished box model developed by Ken Johnson of Monterey Bay Aquarium Research Institute, Excel version provided to Tetra Tech

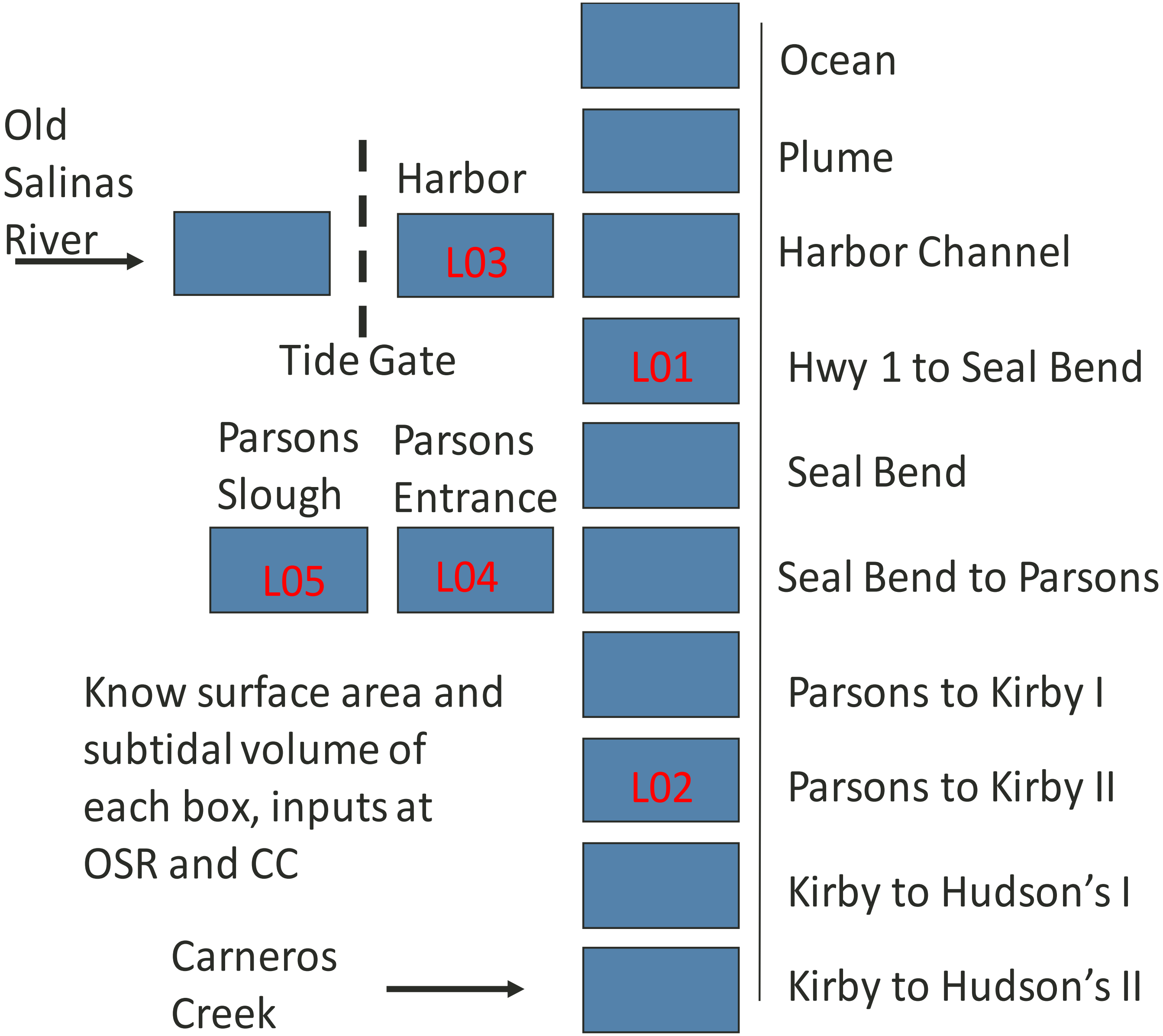
Monismith, S., N. Jones, M. Bela, N. Nidzieko, A. Paytan, G. Misra, and J. Street. 2005. Hydrodynamics and Sediment Dynamics in Elkhorn Slough. Report to Monterey Bay Sanctuary Foundation. Dept. of Civil and Environmental Engineering, Stanford University.

PWA. 2008. Elkhorn Slough Tidal Wetlands Project, Hydrodynamic Modeling and Morphologic Projections of Large-Scale Restoration Actions, 100% Draft Report. Prepared for The Elkhorn Slough Tidal Wetlands Project by Philip Williams & Associates, Ltd., San Francisco, with H.T. Harvey & Associates, 2nd Nature, Edward Thornton, and Stephen Monismith.

Johnson Box model

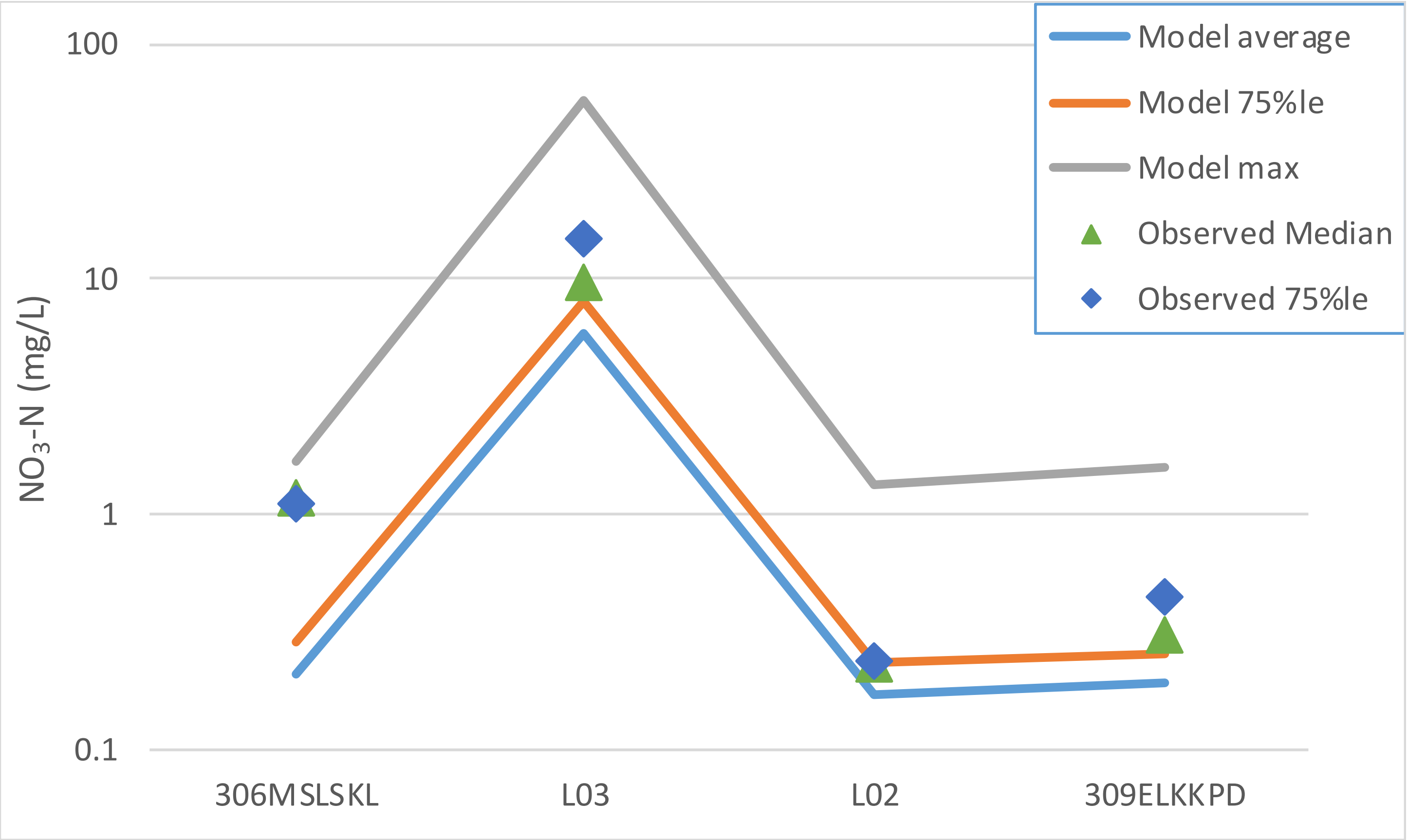
- Available as a code implemented in Excel with rapid run times (provided by Ken Johnson)
- The model uses tidal prism theory of mixing over the tide cycle and is driven by tides at Moss Landing, freshwater inflows, and a description of tidal prism volume as a function of tide height.
- After optimization of rate processes, the box model provides a reasonable fit to salinity and nitrate at the LOBO L01 and L02 moorings

Schematic of Box Model



Know surface area and subtidal volume of each box, inputs at OSR and CC

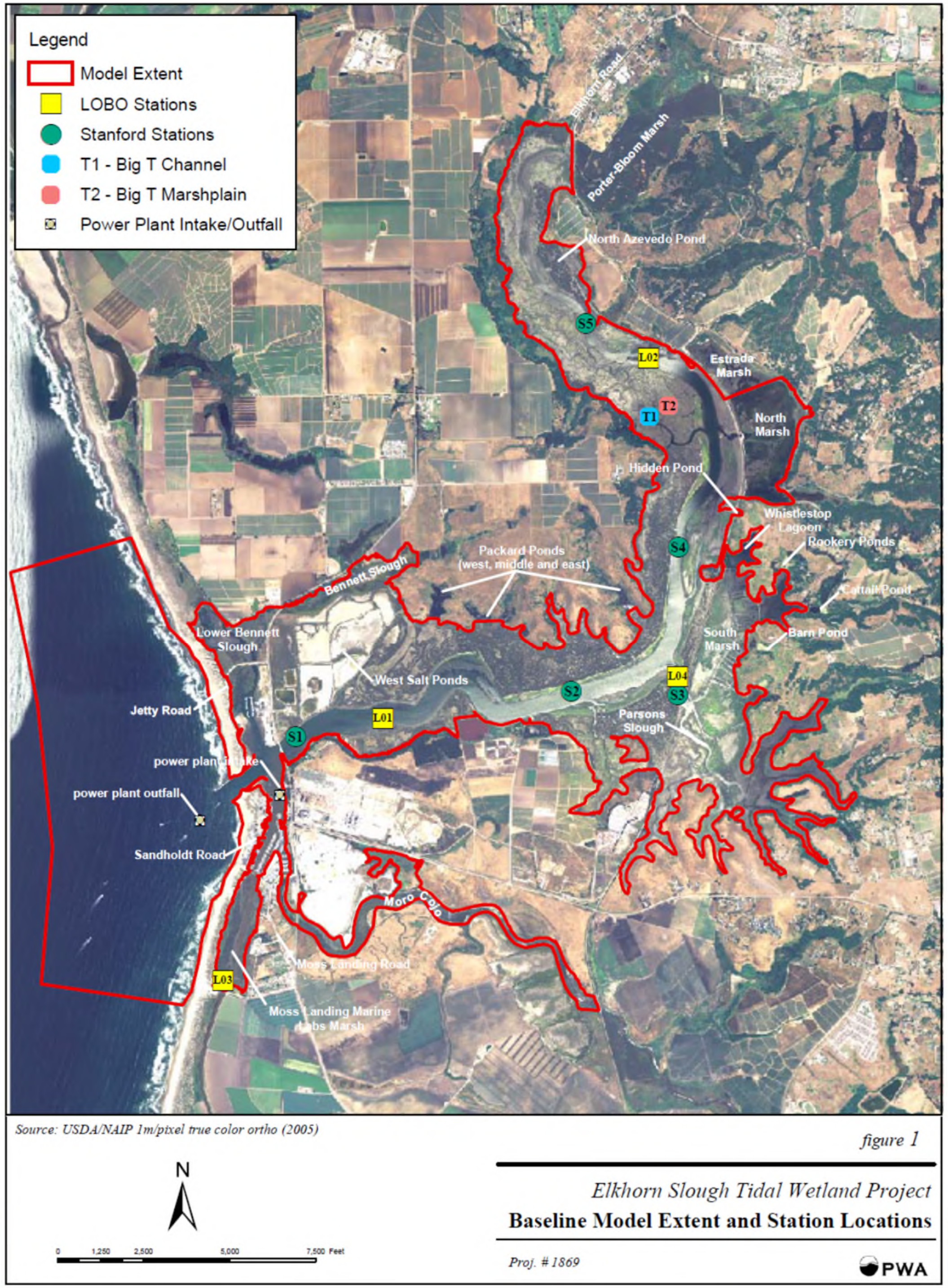
Box Model Results Compared to Observed NO_3-N Concentrations



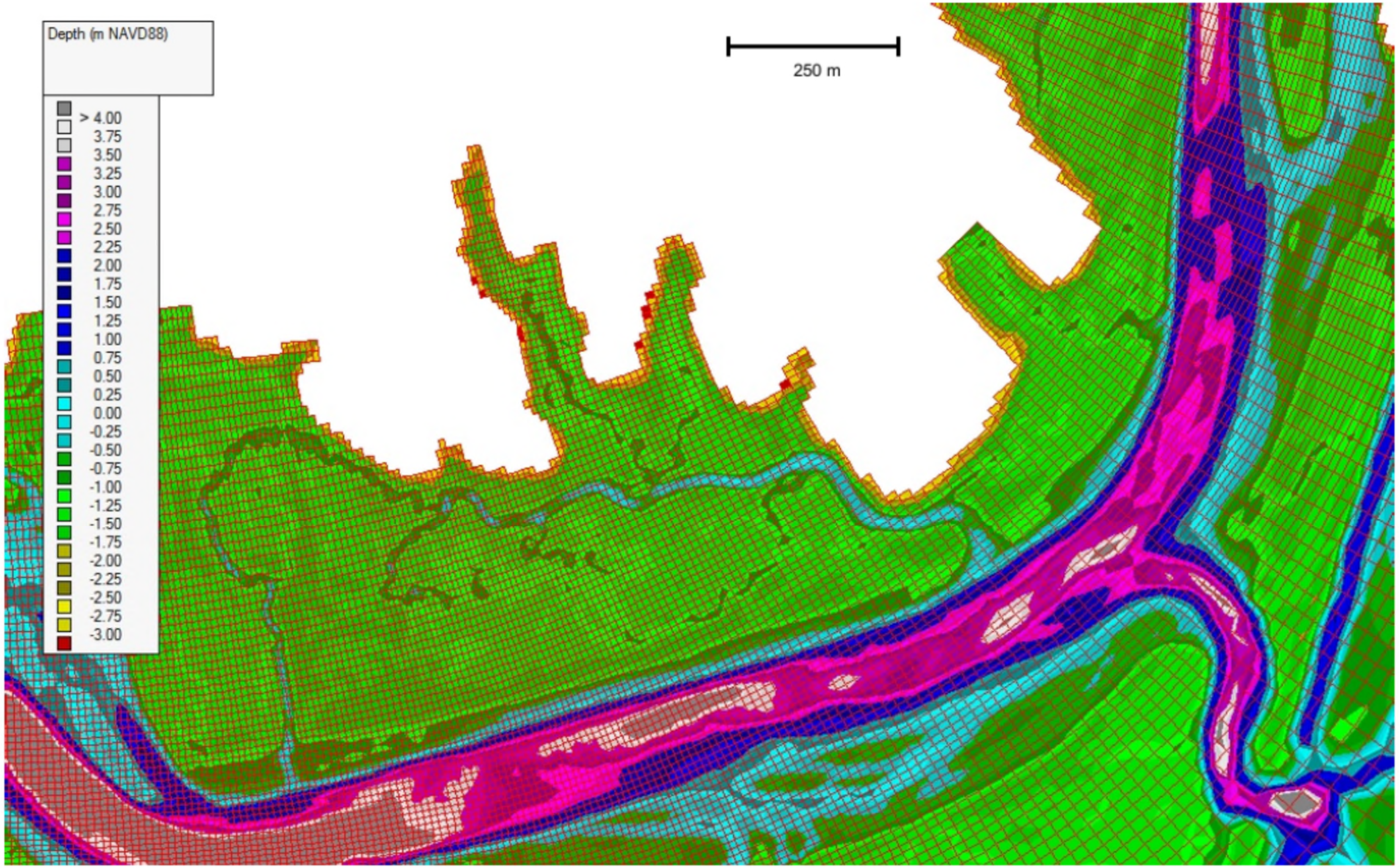
ESA Delft3D Model

- Currently in use for studies related to restoration in Elkhorn Slough
- The Delft3D model includes 58,000 grid cells and simulation of one tidal cycle at a 30-second time step required 1.5 days of computer time (~2007)
- Based on 30-m bathymetry for Monterey bay
- Calibrated to water levels at four stations and current speeds at five stations
- Typically run for periods of about 1 month

Delft-3D Model Extent



Grid Cells



Note: Depths are positive downwards.

figure 4

Elkhorn Slough Tidal Wetlands Restoration

Zoomed View of Rubis Marsh Grid and Bathymetry

PWA Ref# 1869.5

PWA

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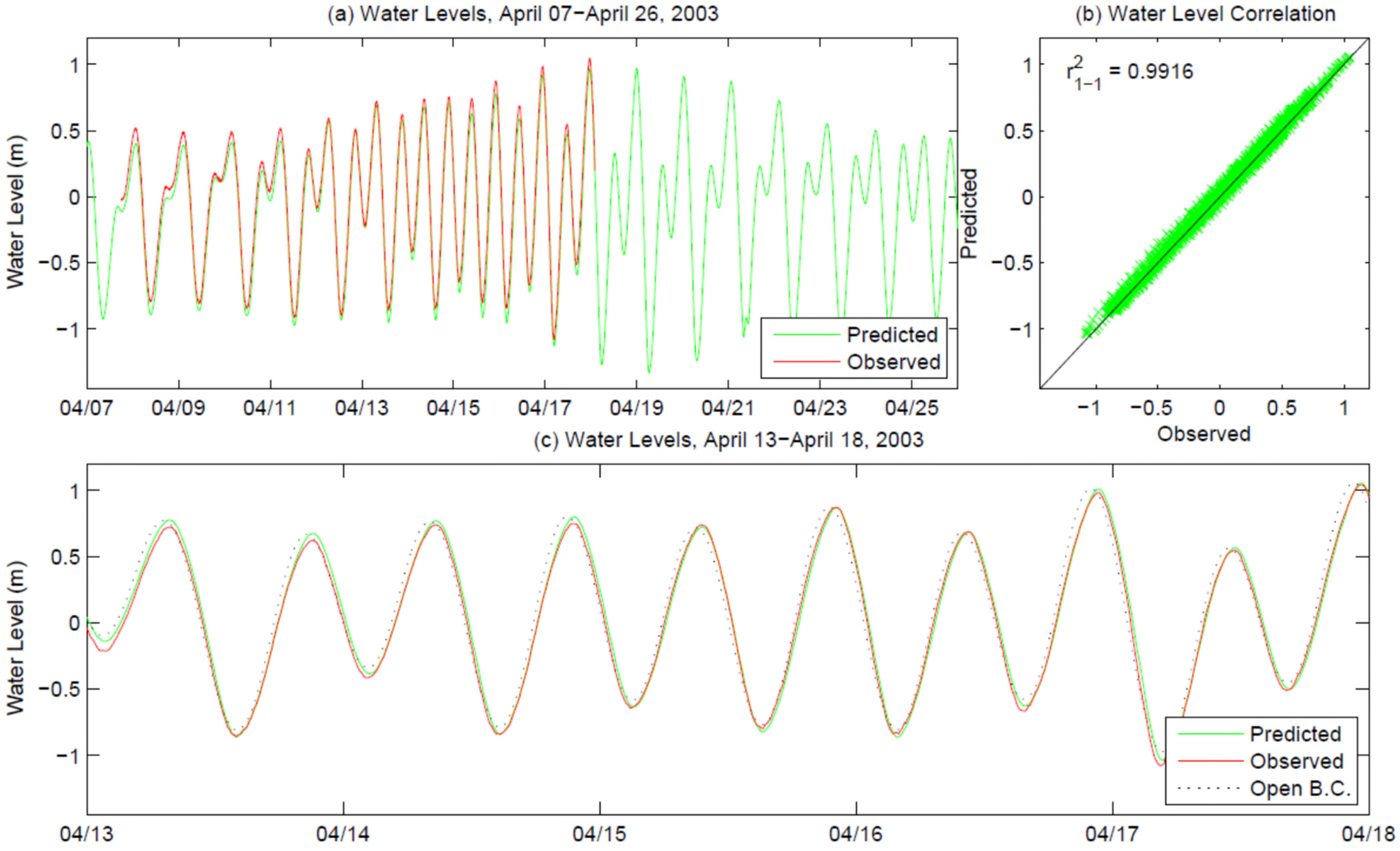
Water Level Calibration



Source: Stanford University observations and DELFT3D model predictions. Observation data ends on April 18 because the instrument package fell over.

Figure 8
Elkhorn Slough Tidal Wetlands Restoration

April 2003 Water Levels, Station S2

PWA Ref# 1869.5

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Comparison of Receiving Water Modeling Options

Box Model

Pros:

- Available, can be modified and adjusted as needed
- Fast run times

Cons:

- Highly simplified representation of hydrodynamics

Delft3D + WASP Models

Pros:

- Available, and in current use
- Detailed representation of slough
- WASP model allows for adequate representation of water quality as needed for TMDL

Cons:

- Longer run times
- New development

Proposed Approach Using ESA Delft-3D Model

- Delft-3D Model cannot be used directly because the water quality components of interest have not been developed
- Development of the needed water quality processes is possible with Delft-3D, but is a major new effort; the level of spatial detail is not needed for the water quality components of the TMDL
- A proposed alternative is to export results from the Delft3D model, aggregate over larger units, and implement in a less spatially detailed form
- The WASP model (for Water Quality Analysis Simulation Program), used widely in TMDL studies, is recommended for this part of the analysis

Recommended Proposed Approach

- Use SWAT to provide boundary conditions for flows and loads from the watershed
- ESA Delft3D derivative (hydrodynamics) + WASP (water quality)
- Use existing ocean model simulations (SCCWRP) to provide boundary conditions for tidal boundaries and loads from the ocean

Modeling Stages

- Model selection
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Model Configuration, Calibration and Validation: Watershed model

- Compile flow and water quality data in tributaries
- Recent data on land use and cropping practices
- Define periods for calibration and set aside data for additional testing
- Calibrate to stream concentrations
- Evaluate model performance and sensitivity to key inputs

Model Configuration: Receiving Water Model

- Use the existing Delft3D two-dimensional hydrodynamic model developed for Elkhorn Slough (58,000 grid cells) to simulate approximately six months of dry-season hydrodynamic conditions
- Will consider coastal boundary conditions from SCCWRP’s ongoing ocean modeling efforts, reflecting factors such as ocean tides and upwelling
- Multiple scenarios may be developed
- Model hydrodynamic output exported for each scenario in a form that will allow aggregation of hydrodynamics at a coarser spatial scale (~100 cells)
- Hydrodynamics embedded in WASP model

Model Calibration and Validation: Receiving Water Model

- Use model setup to calibrate against measured dry season values of the following quantities:
  - Salinity (as a conservative constituent)
  - Total nitrogen and nitrate-N
  - Total phosphorus
  - Planktonic and benthic chlorophyll a
- Separate data for testing and validation, evaluate model performance during periods of interest, with elevated nutrient levels and expression of eutrophication

Model Application for Scenario Runs

- Use the modeling framework to evaluate scenarios of interest to the TMDL and to stakeholders. Examples include:
  - Identify effects of changes in land use such as reduced tile drainage, nutrient management, alternative crops
  - Required changes in watershed loads to achieve proposed targets in the TMDL
  - Identify the main drivers of impact for eutrophication across space and time
  - Effects of changes in mixing in tidally restricted areas
  - Explore effects of drivers outside Elkhorn Slough, such as the coastal boundary and also the loads from the Old Salinas River Channel
  - Explore effects related to the ocean boundary (such as tides, upwelling, etc.)

Questions? Comments?