Development and Calibration of the Historical Delta Model

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Project Goals

• This study motivated by the publication of the historical ecology report by the San Francisco Estuary Institute (Whipple et al., 2012)

• Characterize hydrodynamic and salinity regime of Delta prior to geomorphic and hydrologic modifications that began in the 1850s
  • Levee construction
  • Channel modifications
  • Upstream dams
  • Bathymetric changes (hydraulic mining sed.)
  • Others…

• Comparison to Current Delta
  • Tidal prism
  • Flood vs. ebb dominance
  • Advective and dispersive flux
  • X-2 relationship to Net Delta Outflow

Changes in channel geometry

From Whipple et al. (2012)
Project Team

- **Metropolitan Water District of Southern California**
  [Funding agency]
  - Paul Hutton, Project Manager

- **San Francisco Estuary Institute**
  [Historical Delta Configuration, Bathymetry]
  - Robin Grossinger
  - Sam Safran
  - Julie Beagle

- **Hydrology Team**
  - Andy Draper (MWH)
  - J. Phyllis Fox
  - Dan Howes (CSU, San Luis Obispo)
  - Tariq Kadir (DWR)
  - Guobiao Huang (DWR)

- **Resource Management Associates**
  [Hydrodynamics]
  - Steve Andrews
  - John DeGeorge
  - Ed Gross
  - Stacie Grinbergs

- **University of California, Davis Center for Watershed Studies**
  [DEM creation, Hydrodynamics]
  - Bill Fleenor
  - Fabian Bombardelli
  - Andy Bell
  - Alison Whipple
  - Steve Micko
  - Mui Lay
  - Amber Manfree
How to Convert a Historical Delta Map and Observations into a Historical Delta Model?

Channel Planform Map → Model Grid → Hydrology and Other Inputs → Hydrodynamic Model → Results!

Historical Bathymetry → Digital Elevation Model
3D Hydrodynamic Modeling Framework
New Application of the UnTRIM Engine by RMA with UCD

**Inputs**
- Boundary Inflows
- Meteorological Data
- Grid
- Initial Conditions
  - Gate Operations
  - Flow Diversions
  - Model Parameters

**Compute**
- Interface Code
  - Read Inputs
  - Write Outputs
- Computational Submodels
  - Turbulence
  - Bed Friction
  - Wind
  - Hydraulic Structures
- UnTRIM Engine
  (Vincenzo Casulli, Univ. of Trento, Italy)

**Outputs**
- Text Files
  - Flows, velocities, water surface elevations, salinity
- netCDF Files
  - Python Post-Processing, Visualization Routines
  - Time Series
  - Maps
  - Animations

**Computational Submodels**
- Turbulence
- Bed Friction
- Wind
- Hydraulic Structures

**Python Post-Processing, Visualization Routines**
- Time Series
- Maps
- Animations
Hydrodynamic Model Information

- UnTRIM Computational Engine
  - 3D hydrodynamic and scalar transport model
  - Utilizes unstructured orthogonal grid
  - Computationally efficient and stable
  - Developed and maintained by V. Casulli (Univ. of Trento, Italy)
- $z_0$ bed friction parameterization
- Generalized length scale vertical turbulence closure scheme (Warner, 2005)
  - Implemented by Bundesanstalt für Wasserbau (BAW)
- Constant wind stress, evaporation, and precipitation by region
- Target moderate grid resolution with subgrid
  - Produces improved estimates of cell volume and channel conveyance

Model geometry with contoured subgrid bathymetry
Mesh Topology

- Flow-aligned quadrilateral elements follow levee crests in main channels
- Triangular elements fill tidal plains
- Low-order channels captured implicitly with subgrid
- Janet grid generation software (Lippert and Sellerhoff, 2006)

Full Model Grid Extent

≈175,000 elements
Historical Bathy. Data → DEM

- Channel limits mapped in detail (±10 m) as part of Delta Historical Ecology report
- Sources for historical bathymetry
  - US Coast Guard 1867 [Method 1]
  - Gibbes 1850
  - Ringgold 1850
  - Debris Commission 1908 (post hydraulic mining)
- Cubic spline thalweg depth interpolation
- General width-depth relation for smaller channels

From SFEI-ASC (2014)
Referencing Historical Depth Data

- Historical bathymetric data is measured relative to a tidal datum (MLLW)
- Model needs bed elevations relative to an absolute datum (NAVD88)
- Need to know absolute elevations of MLLW throughout the historical Delta to convert and set channel depths
  - These vary spatially and cannot be assumed to be similar to present day values because of sea level rise and major Delta modifications
- Iterative method used for calibration

Diagram:
- Initial guess at MLLW surface
- Generate DEM
- Set model grid bathymetry
- Repeat
- Calculate MLLWs
- Run model simulation
How To Know Whether the Model is Behaving Correctly?

• Historical Observations at Specific Locations
  • Tidal Range in Channels
    • “[Q] How high do the tides rise in the M[oke]mne] five miles below Bensons? [A] About three feet and a half which will bring it about a mile or a mile and a half below the head of the Island as near as I can judge.” (J. Van Scoyk, 1859)
  • Marsh Plain Inundation Depths and Frequency
    • "[Q] To what height does the tide rise there? [A] About 6 or 8 inches above the ground, indicated by the water mark left upon the tule." (C.L. Thayer, 1859)
  • Spatial Extents of Tidal Freshwater Marsh
• General Delta Trends
  • Tidal Inundation Dynamics
  • Maximum Channel Velocities (channel stability)
  • Delta Tidal Prism
What Can We Do To Calibrate?

• Adjust marsh plain elevations
  • Influences tidal range in channels, marsh plain inundation and frequency
• Identify and fix artifacts in the DEM and grid
Tidal Range

• Try to match point observations
• Try to match general patterns

Observed “perceptible” tides up to Feather R confluence

Sacramento R at Isleton:
0.9 m observed
0.8 m modeled

Cache Slough:
1.8 m observed (really?)
0.9 m modeled

Near Sherman Is:
1.0-1.4 m observed
1.0-1.4 m modeled

Delta Mouth:
1.2-1.8 m observed
1.4 m modeled

Mok R Blw Bensons:
1.0 m observed
0.9 m modeled

SJR near Stockton:
0.3-0.6 m observed
0.3-0.6 m modeled

Tides “slight” at the head of Old River
Maximum Depth of Marsh Plain Inundation

**Neap Tide**

- Sherman Is: 0.15 m observed, 0.25 m modeled
- Bouldin Is: 0.15 m observed, 0.15 m modeled

**Spring Tide**

- Sac R at Horseshoe Bend: 0.46 m observed, 0.35 m modeled
Marsh Plain Inundation Frequency

Observed: Tyler and Staten Islands wetted twice daily at south end, only by spring tides at north end
Modeled: no strong north-south gradient in inundation frequency

Observed: Central Delta wetted twice daily, inundated on spring tides
Modeled: similar

Observed: Eastern margin only wetted by spring tides
Modeled: similar
Spatial Limits of Tidal Habitat

Ecology Study Boundary

Tidal habitat

Historical Delta Model grid boundary

Historical Delta Ecology Map

Historical Delta Model Results
Marsh Plain Inundation Patterns

High high tides spill over natural levees, drain through sloughs.

Lower high tides flood marsh from sloughs.
Continuing Work

- Refine calibration
- Higher flow simulations
- Comparison to present-day Delta:
  - X2 relationship to Net Delta Outflow
  - Flood vs. ebb tide dominance
  - Advective and dispersive flux
  - Tidal prism
    - Present-day Delta: 205M m$^3$
    - Historical Delta*: 197M m$^3$
      * at current state of calibration
- Incorporation of 1867 Suisun Bay bathymetry
- Lots more?

From Cappiella et al. (1999)
Thanks!

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• DWR and UCD are independent collaborators

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Referenced Works

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