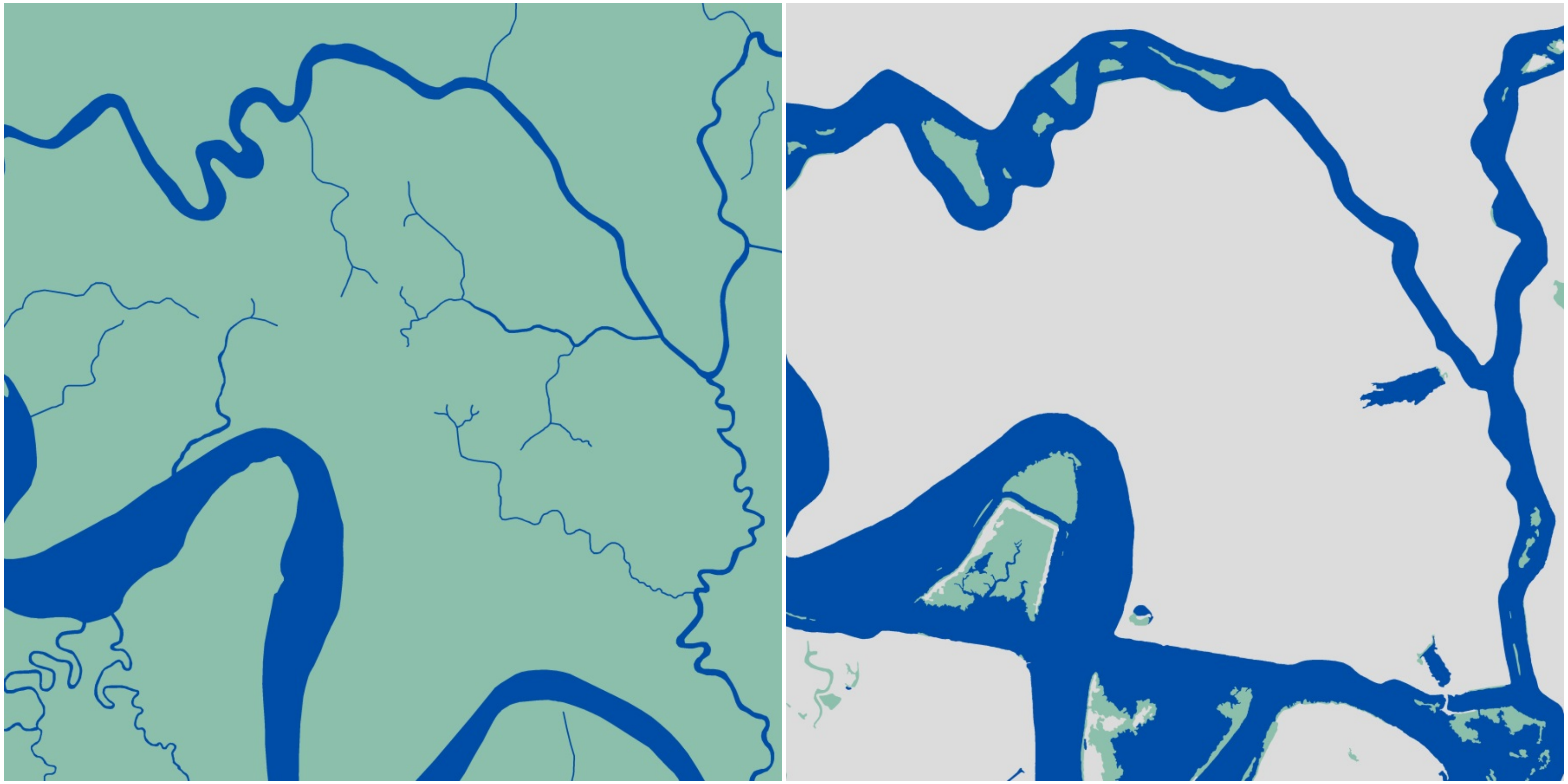
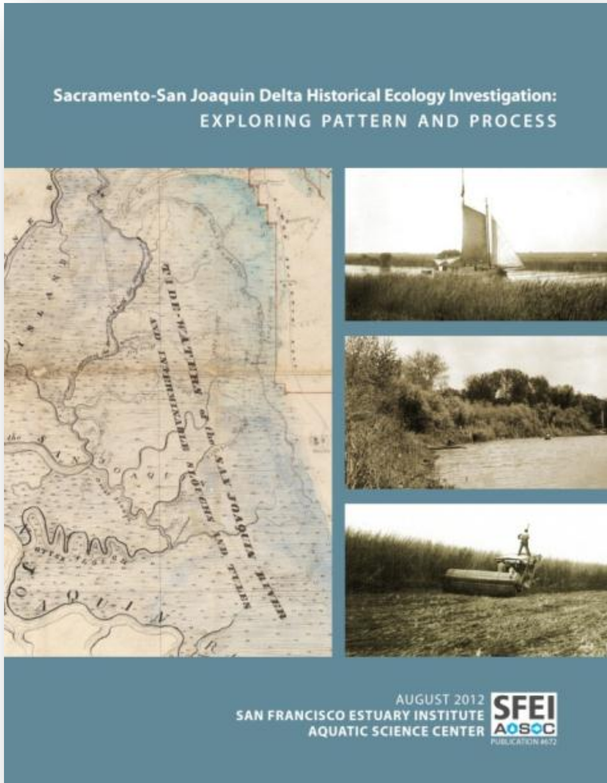
Hydrodynamic changes in the Delta and some of the possible ecological implications

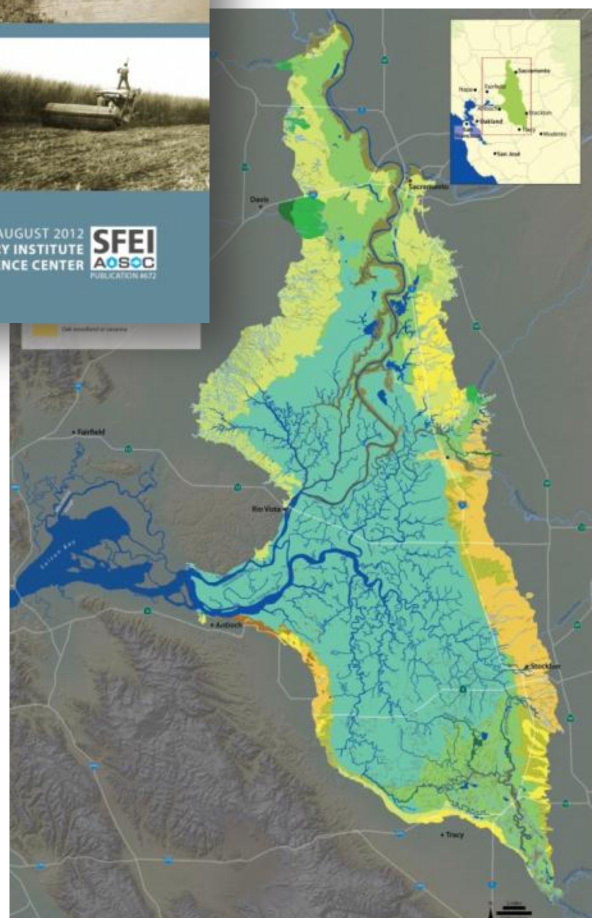
CWEMF 2015 · 3/10/15



Sam Safran
Robin Grossinger

SFEI ASC



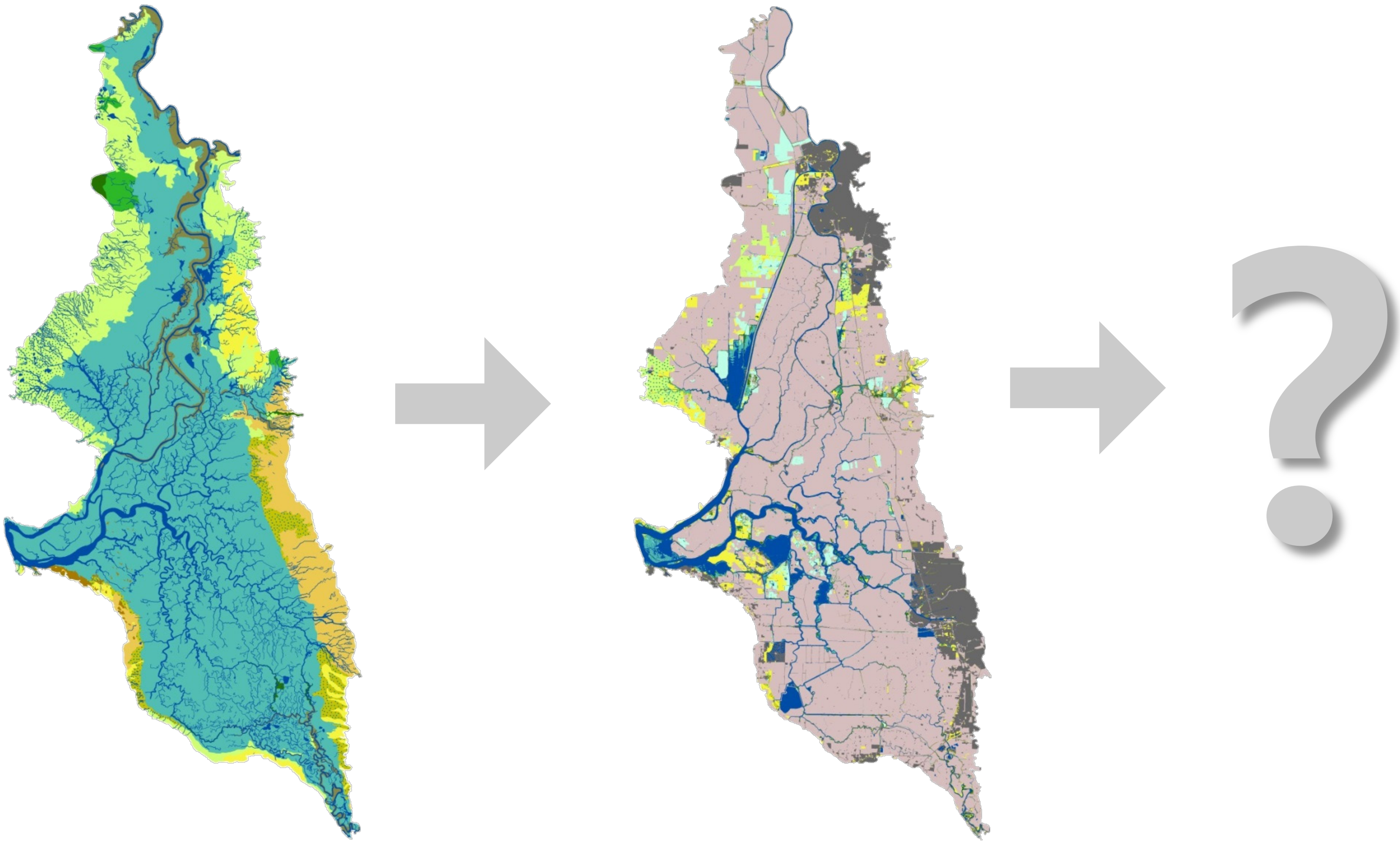


Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process

(Whipple et al. 2012)

- Funded by Ecosystem Restoration Program (CDFG, NOAA, US FWS)
- Final Report/GIS Available: www.sfei.org/DeltaHEStudy
- Collaboration with KQED QUEST and Stanford's Bill Lane Center for the American West: science.kqed.org/quest/delta-map/

Guiding questions



What were the ecological functions provided by the landscape of the Delta?

What opportunities exist to support some of these functions now and into the future?

Delta Landscapes Project

NEW! view the interactive report ebook

Photo: "View of Island Land Before Reclamation" (Yardley Collection, courtesy of The Haggin Museum)

MANAGEMENT TOOLS FOR LANDSCAPE-SCALE RESTORATION OF ECOLOGICAL FUNCTIONS

The Delta Landscapes Project seeks to develop a set of tools for facilitating landscape-scale restoration of the Sacramento-San Joaquin Delta ecosystem. The project will use the historical perspective of the Delta as a basis to identify landscape scale patterns and characteristics that provided ecological functions (based on the Sacramento-San Joaquin Delta Historical Ecology Investigation). The historical perspective will be compared to the present-day Delta to identify opportunities to restore ecological functions, not by replicating the historical Delta, but by recreating viable habitat mosaics with the vision of how they connect at the landscape scale. Conceptual models will be developed to help practitioners identify these landscape level opportunities along with assisting with the development of appropriate metrics to assess individual projects.

The project has four major components:

1. Analyzing historical and contemporary Delta landscape spatial habitat patterns
2. Comparing past and present ecological function within the Delta
3. Developing landscape-scale conceptual models, restoration principles, and target metrics
4. Visualizations and public participation

Final products will include an interactive website with landscape visualizations, technical memos, and peer-reviewed publication.

Principal Investigators

Robin Grossinger
Letitia Grenier

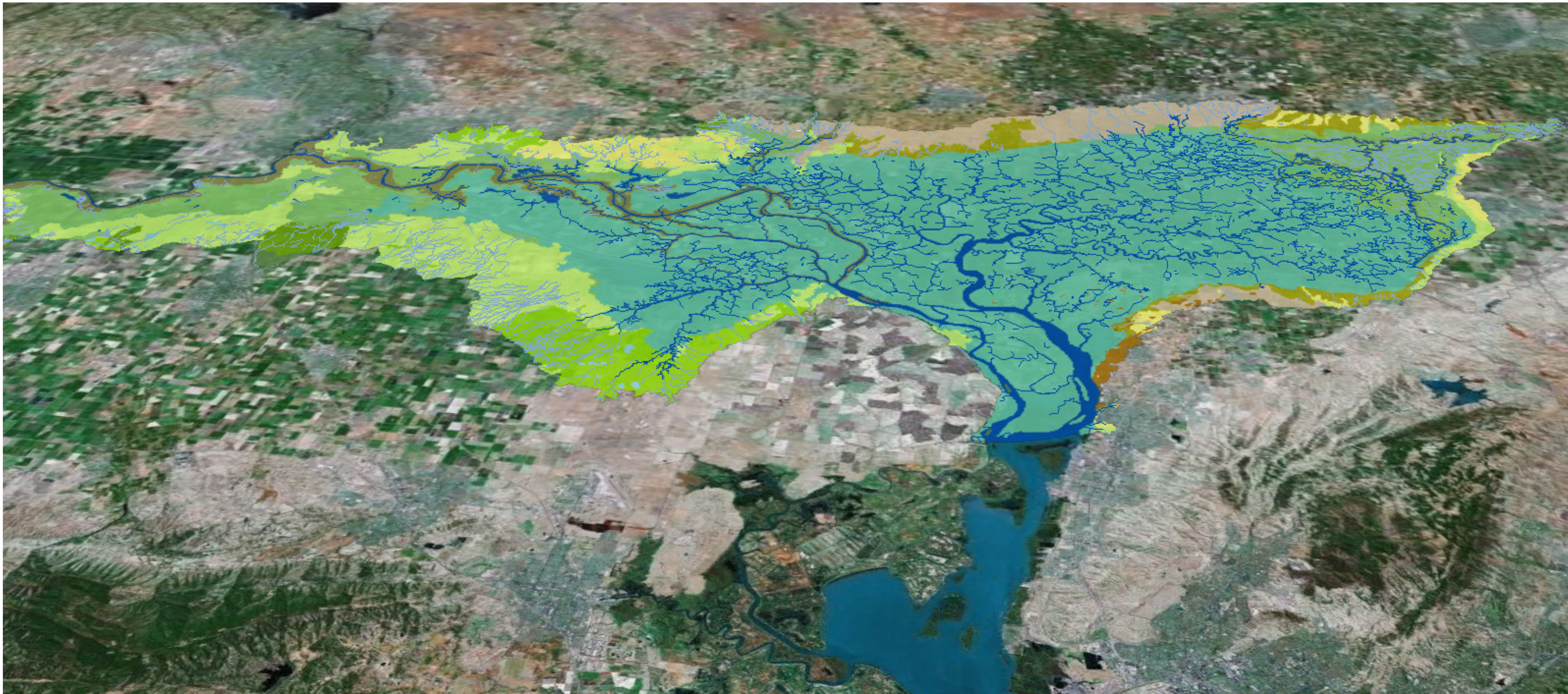
Delta Landscapes Project

Central Concept:

Use an understanding of pattern and process…

to inform landscape scale restoration…

that supports ecological function.



Delta Landscapes Project

1. **Define ecological functions provided by the historical Delta**

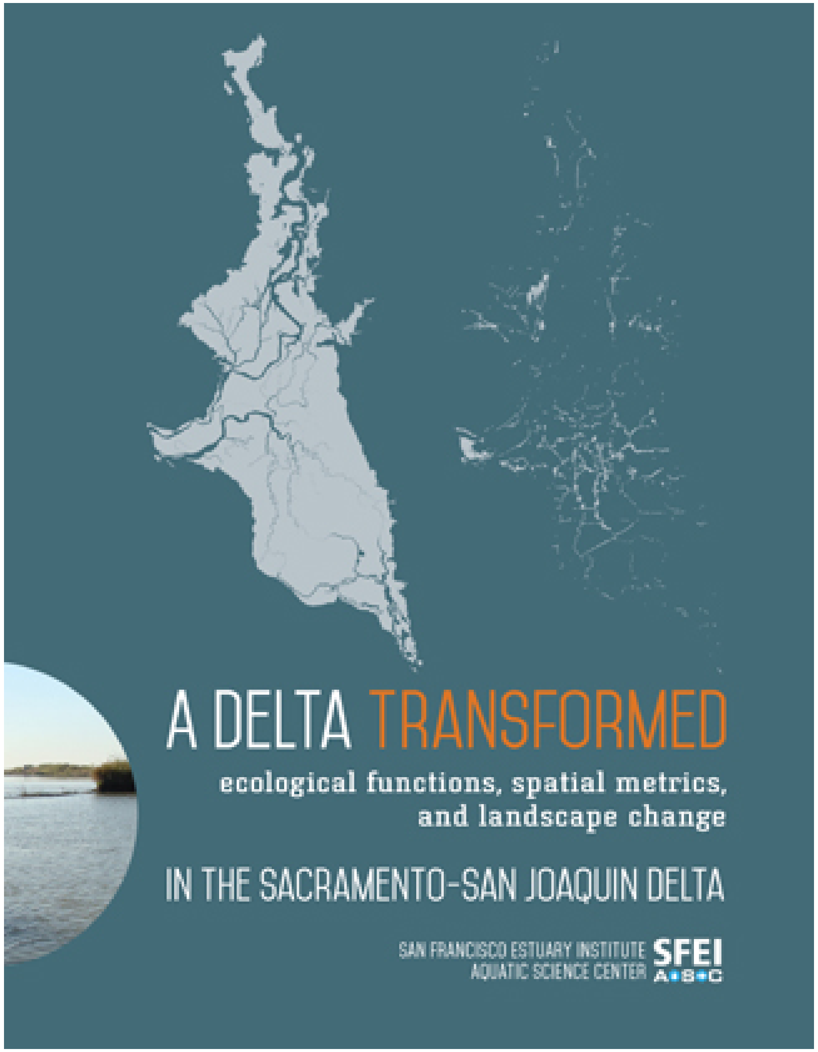
2. **Identify metrics that allow us to assess the extent and distribution of these functions**

3. **Use metrics to quantify landscape change**

4. Describe subregional potential (physical drivers, opportunities)

5. Create conceptual Operational Landscape Units (e.g. “archetypes”)

6. Produce restoration guidelines and potential performance metrics



SFEI-ASC 2014

Landscape Interpretation Team (LIT)

Stephanie Carlson (UC Berkeley)
Jim Cloern (USGS)
Brian Collins (University of Washington)
Chris Enright (Delta Science Program)
Joseph Fleskes (USGS)
Geoffrey Geupel (PRBO Conservation Science)
Todd Keeler-Wolf (CDFW)
William Lidicker (UC Berkeley)
Steve Lindley (NMFS)
Jeff Mount (UC Davis)
Peter Moyle (UC Davis)
Anke Mueller-Solger (USGS)
Eric Sanderson (Wildlife Conservation Society)
Hilde Spautz (CDFW)
Dave Zezulak (CDFW)

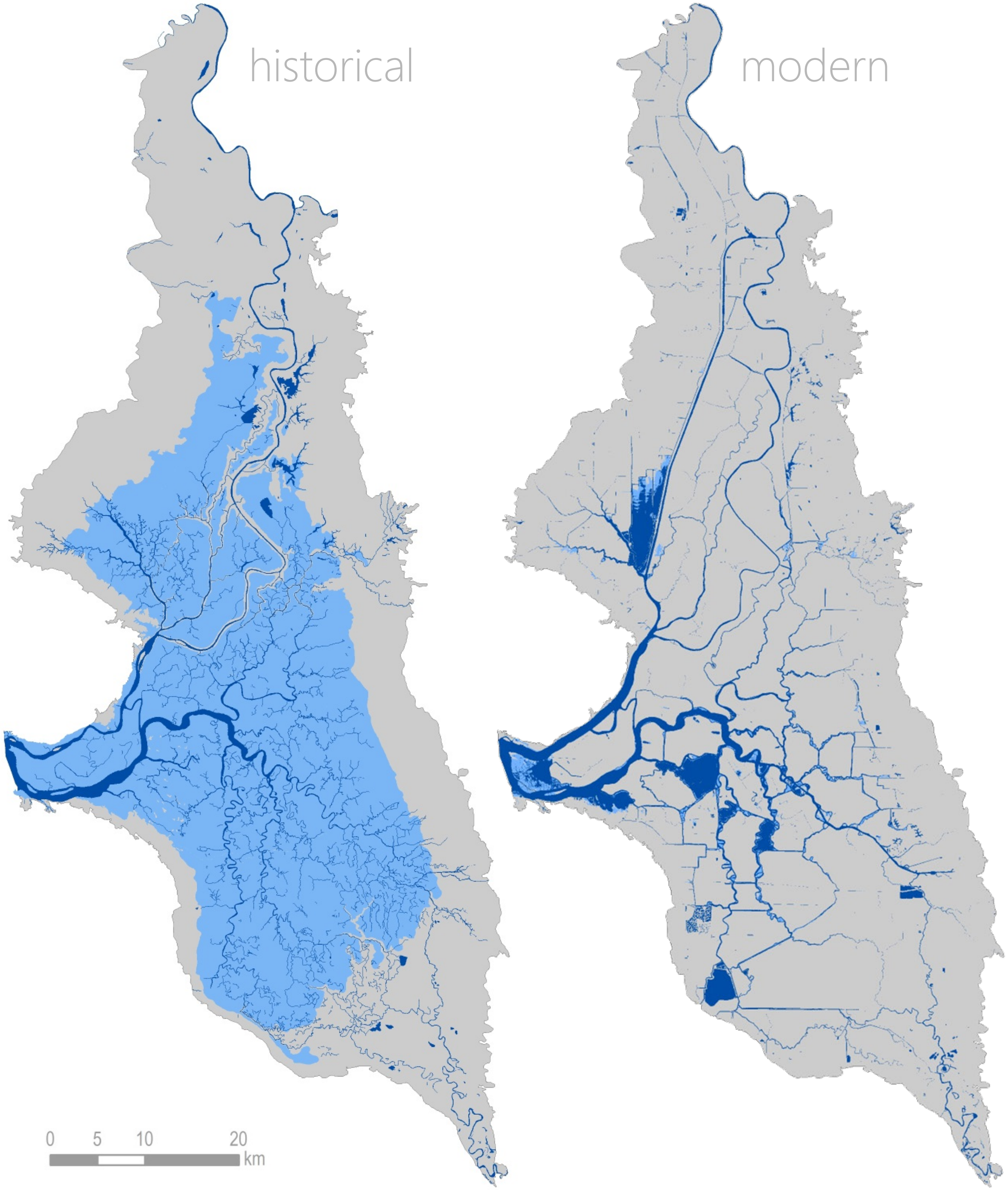
Delta Landscapes Project

LEVEL	POPULATION						COMMUNITY	
THEME	Life history support					Adaptation potential	Food webs	Biodiversity
FUNCTION	Provides habitat and connectivity for fish	Provides habitat and connectivity for marsh wildlife	Provides habitat and connectivity for waterbirds	Provides habitat and connectivity for riparian wildlife	Provides habitat and connectivity for marsh-terrestrial transition zone wildlife	Maintains adaptation potential within wildlife populations	Maintains food supplies and nutrient cycling to support robust food webs	Maintains biodiversity by supporting diverse natural communities
METRICS	Inundation extent, duration, timing, and frequency	Marsh area by patch size (patch size distribution)	Ponded area in summer by depth and duration	Riparian habitat area by patch size	Length of marsh-terrestrial transition zone by terrestrial habitat type	To be addressed with qualitative conceptual models in Task 4.	Expected to be addressed with a related project.	To be addressed with qualitative conceptual models in Task 4.
	Marsh to open water ratio	Marsh area by nearest neighbor distance	Wetted area by type in winter	Riparian habitat length by width class				
	Adjacency of marsh to open water by length and marsh patch size	Marsh core area ratio						
	Ratio of looped to dendritic channels (by length and adjacent habitat type)	Marsh fragmentation index						

Examine how the hydrodynamic models help us evaluate:

1) **inundation (inundation frequency plots)**
2) dendritic vs. looped channels (tracer drops)

support for native fish

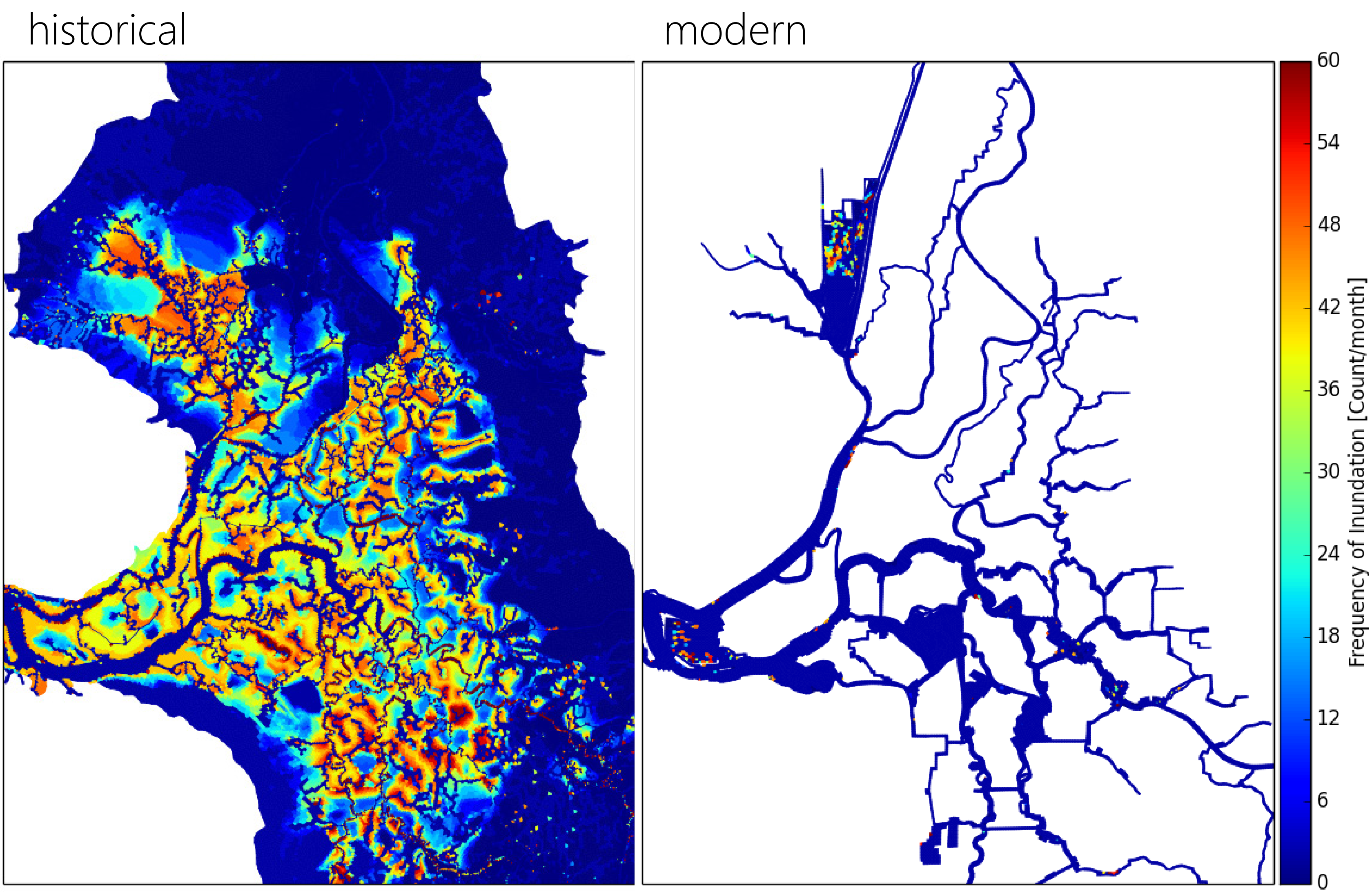


TIDAL INUNDATION

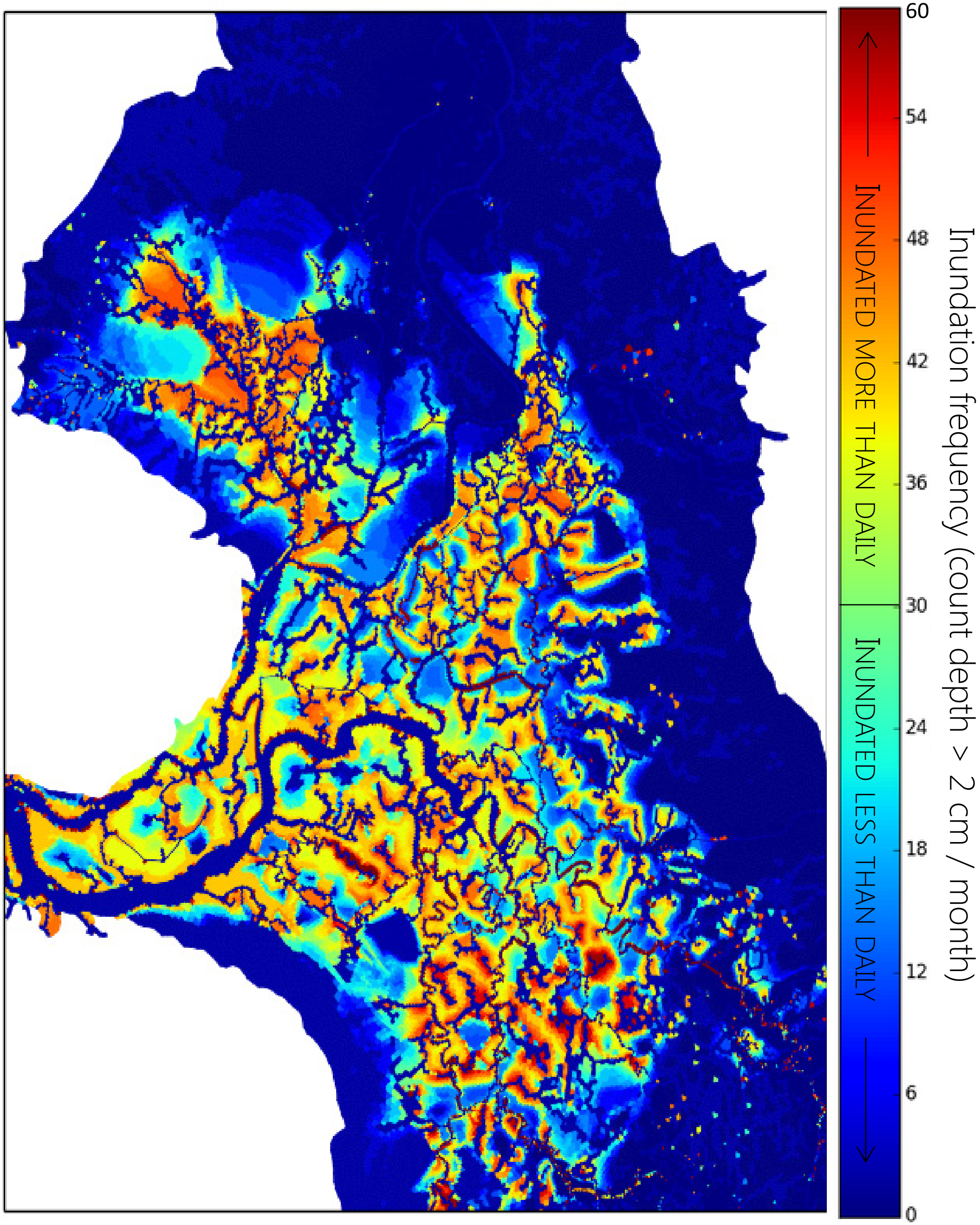
Diurnal overflow of tidal sloughs into marshes

- low duration (< 6 hrs per event)
- low depth ("wetted" up to .5 m)
- high recurrence (daily - fortnightly)

Tidal marsh inundation- model results



Tidal marsh inundation- results



In the Delta, we think tidally inundated marsh habitat was likely available **at least daily, sometimes twice-daily**.

If true, tidal marshes in the Delta were probably **inundated more frequently** than marshes in the rest of the Estuary.

E.g. less frequent inundation in Suisun: marsh inundated by ~15% of all high tides (~9x/month) (Enright et al. 2013).

Driven by marsh morphology: in freshwater conditions, **tules can grow a foot below MLLW** (Atwater and Hedel 1976). Freshwater marshes distributed across full intertidal zone (Odum 1988).

The resulting hydroperiod translates to high **temporal availability** of tidally inundated habitat.

If **diel timing** of marsh inundation matters to you, you've got year-round options (in a single day there can be marsh inundation during night *and* day).

Ecological function of tidal marsh inundation (from Ellis & Bell 2008)

Inundated marsh surface as habitat for fish

How might aquatic species that make tidal migrations into intertidal habitats benefit?

- Exploit intertidal food sources (Hampel & Cattrijsse 2004 [brackish marsh, Netherlands], Hollingsworth & Connolly 2006 [salt marsh, Australia], Rilov & Schiel 2006 [rocky intertidal, New Zealand], Brenner & Krumme 2007 [mangroves, Brazil])
- Reduced susceptibility to depth-restricted predators (Halpin 2000 [salt marsh, Rhode Island], Linehan et al. 2001 [eelgrass, Newfoundland], Ellis & Bell 2004 [mangroves, Florida])

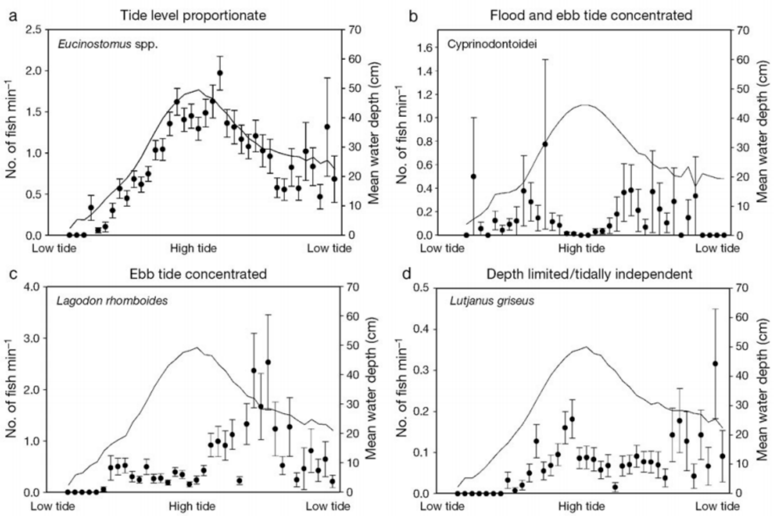
What's the mechanism?

- Passive dispersal via tidal currents for some species (Commito et al. 1995 [clams, sand flat])
- An active process for many others (e.g. Burrows 2001 [flatfish, beaches])

Many strategies and options for utilizing tidally inundated habitat…

- Ellis & Bell 2008: four migration patterns in Florida mangroves

Disclaimer: not especially well-studied along the Pacific Coast, especially in the Delta!



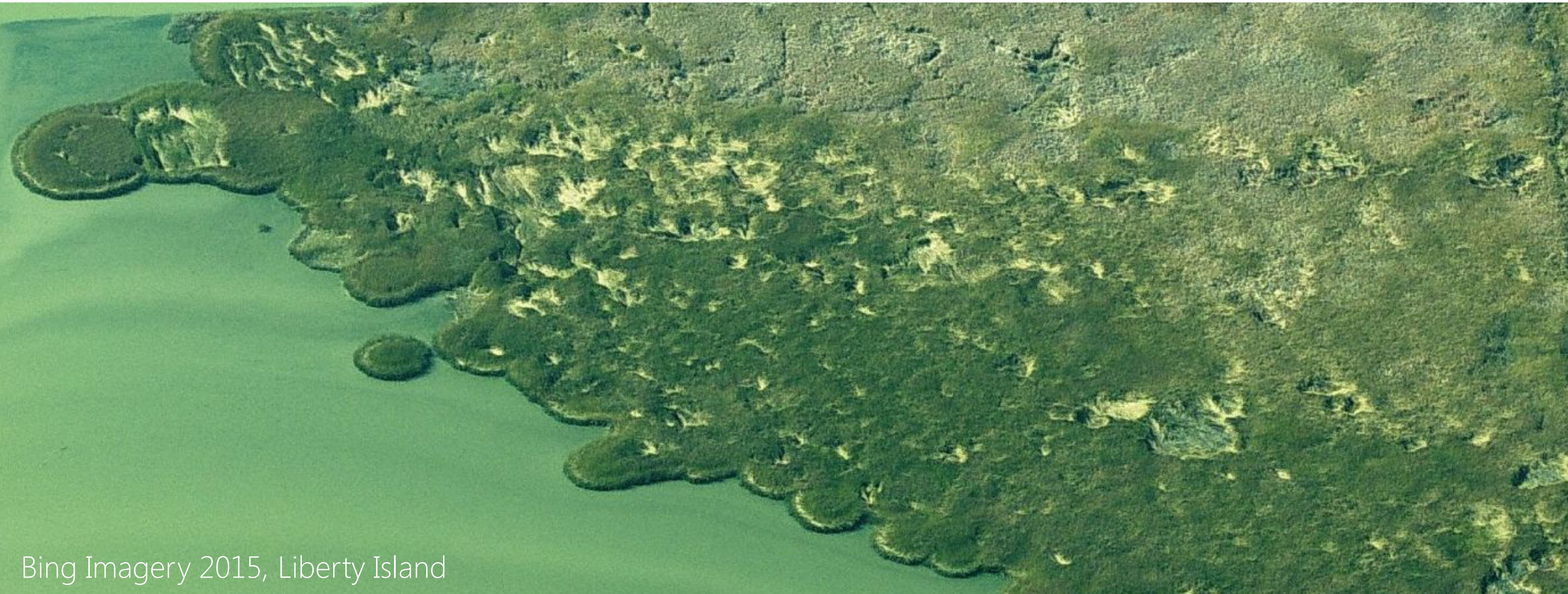
Ecological function of tidal marsh inundation

Inundated marsh surface as habitat for fish

Disclaimer disclaimer:

Fish utilize inundated marshes of Liberty Island (Whitley and Bollens 2014)

- Feeding habitat for many species, including Delta smelt, which supplemented zooplankton-based diet with larval insects in the spring and amphipods in the winter
- Authors hypothesize that marsh habitats provides smelt with high-energy resources (like chironomids), which could improve growth rates


Bing Imagery 2015, Liberty Island

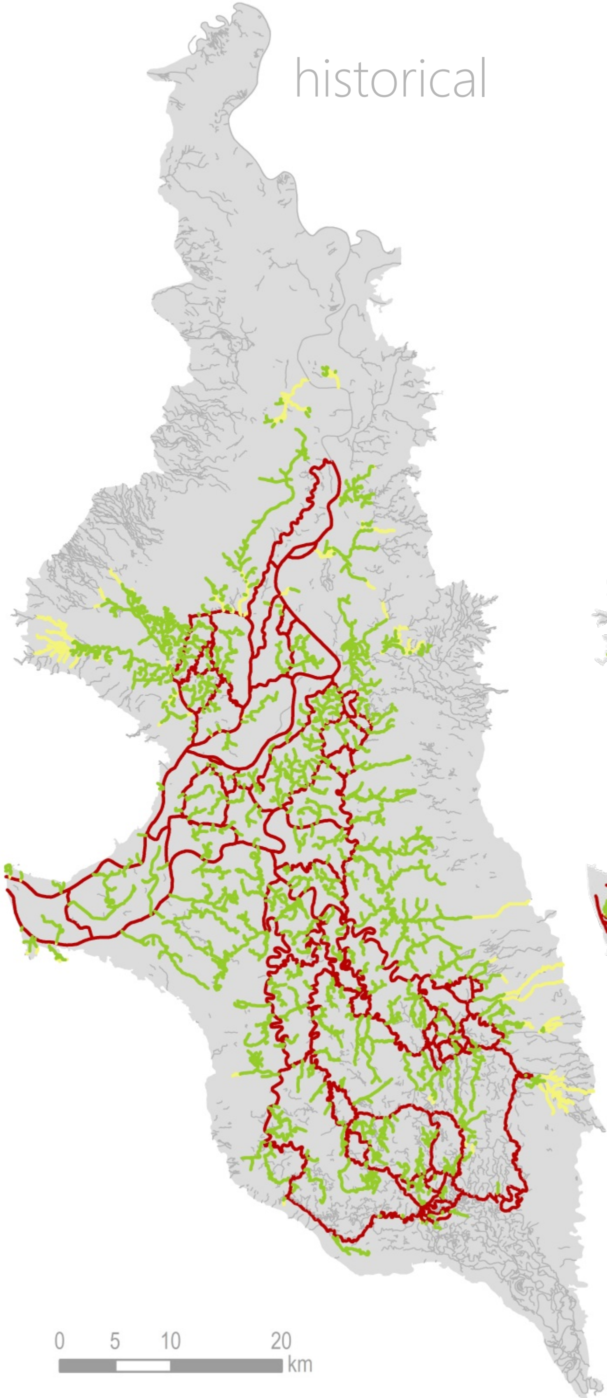
Delta Landscapes Project

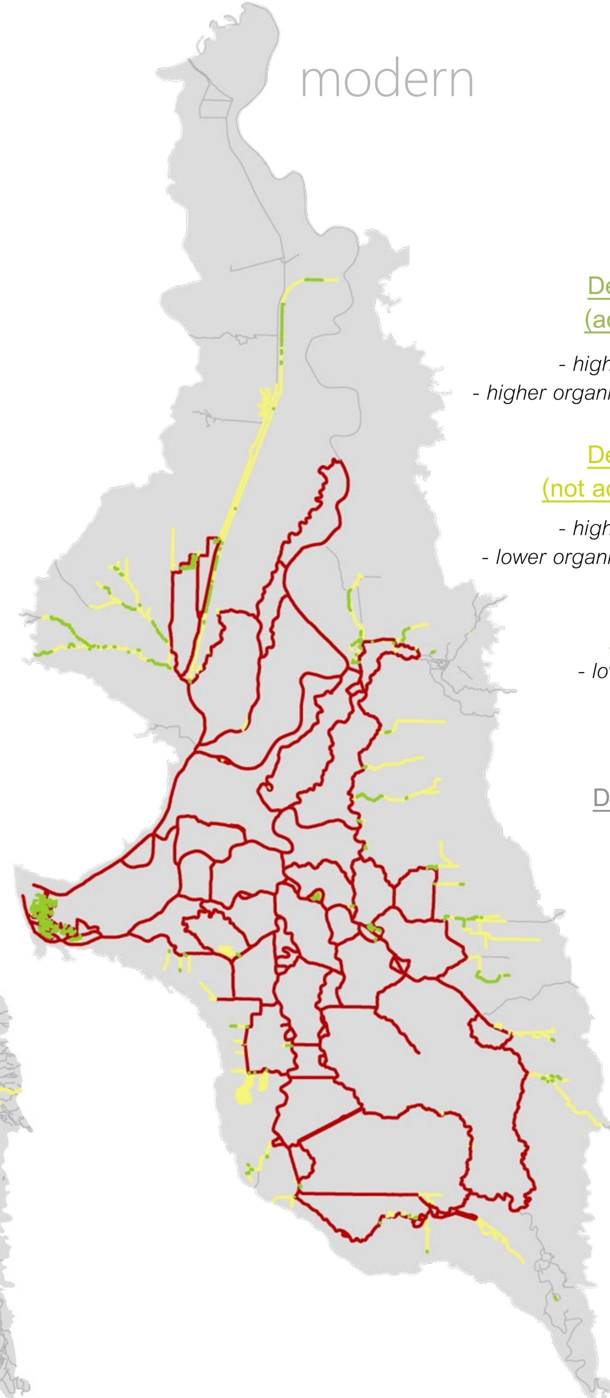
LEVEL	POPULATION						COMMUNITY	
THEME	Life history support					Adaptation potential	Food webs	Biodiversity
FUNCTION	**Provides habitat and connectivity for fish**	**Provides habitat and connectivity for marsh wildlife**	**Provides habitat and connectivity for waterbirds**	**Provides habitat and connectivity for riparian wildlife**	**Provides habitat and connectivity for marsh-terrestrial transition zone wildlife**	**Maintains adaptation potential within wildlife populations**	**Maintains food supplies and nutrient cycling to support robust food webs**	**Maintains biodiversity by supporting diverse natural communities**
METRICS	Inundation extent, duration, timing, and frequency	Marsh area by patch size (patch size distribution)	Ponded area in summer by depth and duration	Riparian habitat area by patch size	Length of marsh-terrestrial transition zone by terrestrial habitat type	To be addressed with qualitative conceptual models in Task 4.	Expected to be addressed with a related project.	To be addressed with qualitative conceptual models in Task 4.
	Marsh to open water ratio	Marsh area by nearest neighbor distance	Wetted area by type in winter	Riparian habitat length by width class				
	Adjacency of marsh to open water by length and marsh patch size	Marsh core area ratio						
	$\boxed{\text{Ratio of looped to dendritic channels (by length and adjacent habitat type)}}$	Marsh fragmentation index						

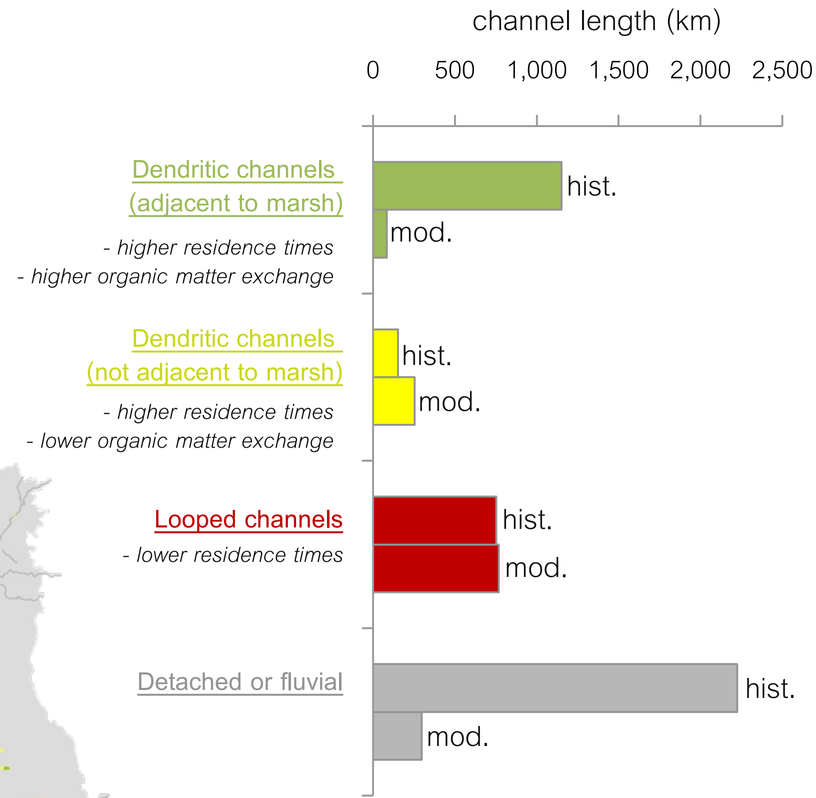
Examine how the hydrodynamic models help us evaluate:

1) inundation (inundation frequency plots)
2) **dendritic vs. looped channels (tracer drops)**

support for native fish



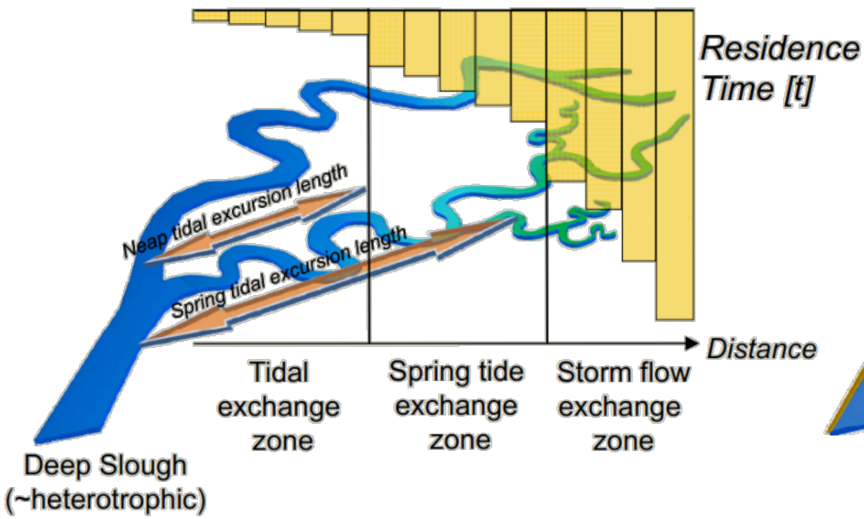


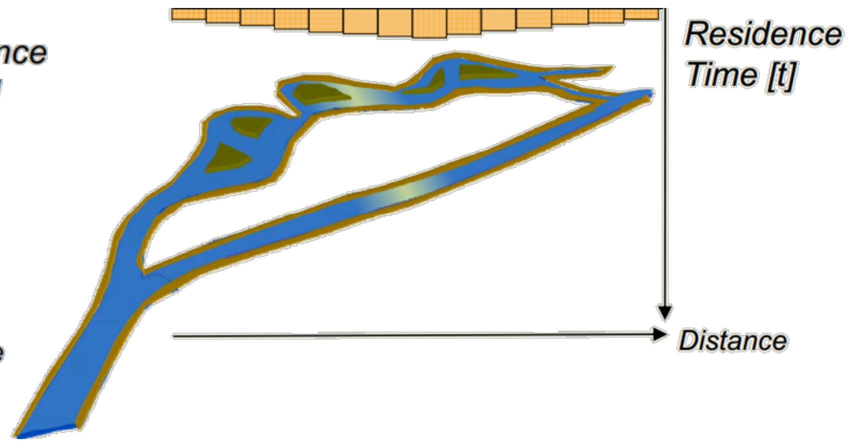


Reversal in the ratio of looped channels to dendritic channels

Tracer runs

A conceptual model of changes in the slough physical gradients **(Chris Enright, 2010)**





"Historical Delta morphology"

low "distance to different"

"Modern Delta characteristic engineered-morphology"

high "distance to different"

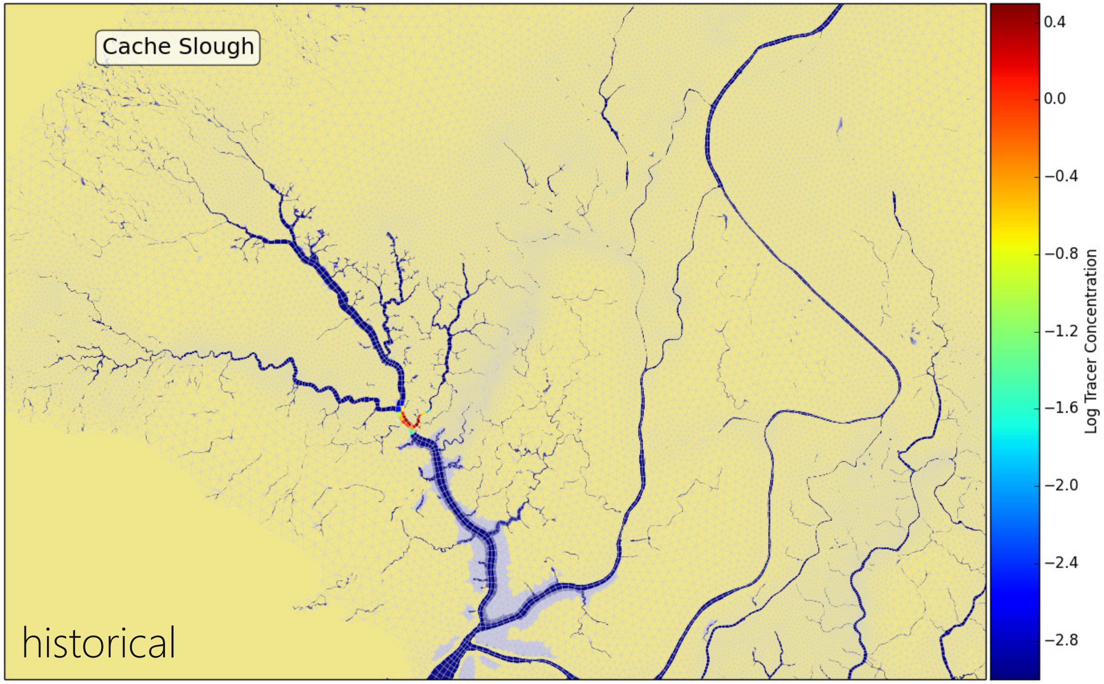
Low flow **tracer runs**, which let us view the movement and dispersal of water, are a first step towards illustrating this concept.

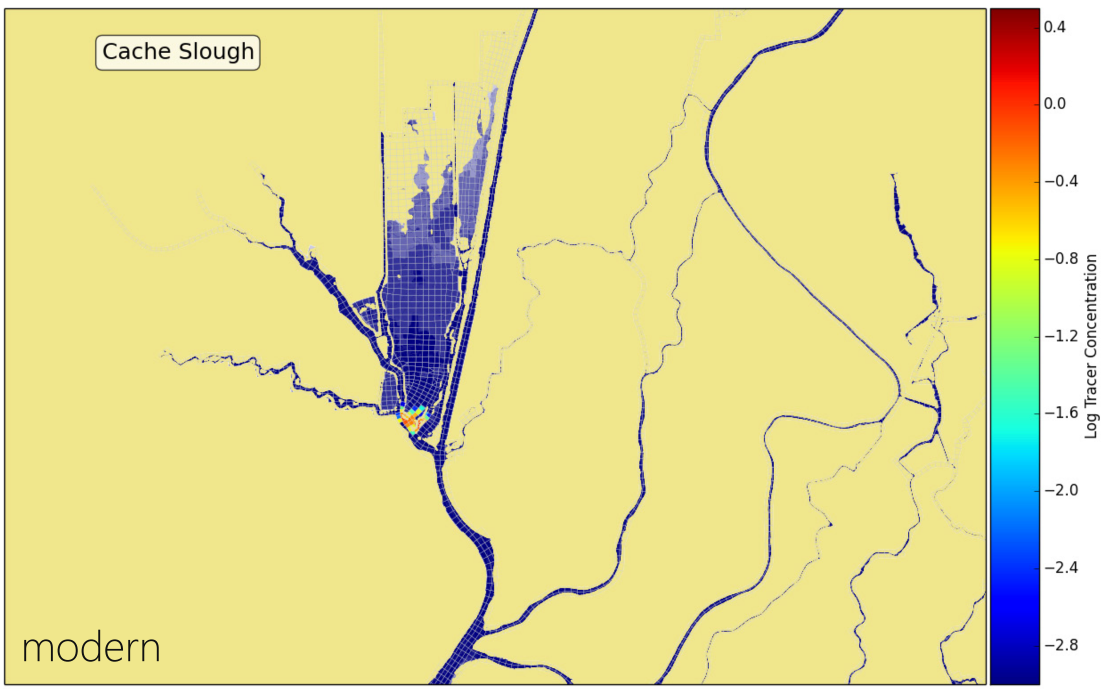
Tracer runs
Cache Slough

Tracer runs- Cache Slough

1000 kg tracer

tidal days: 0





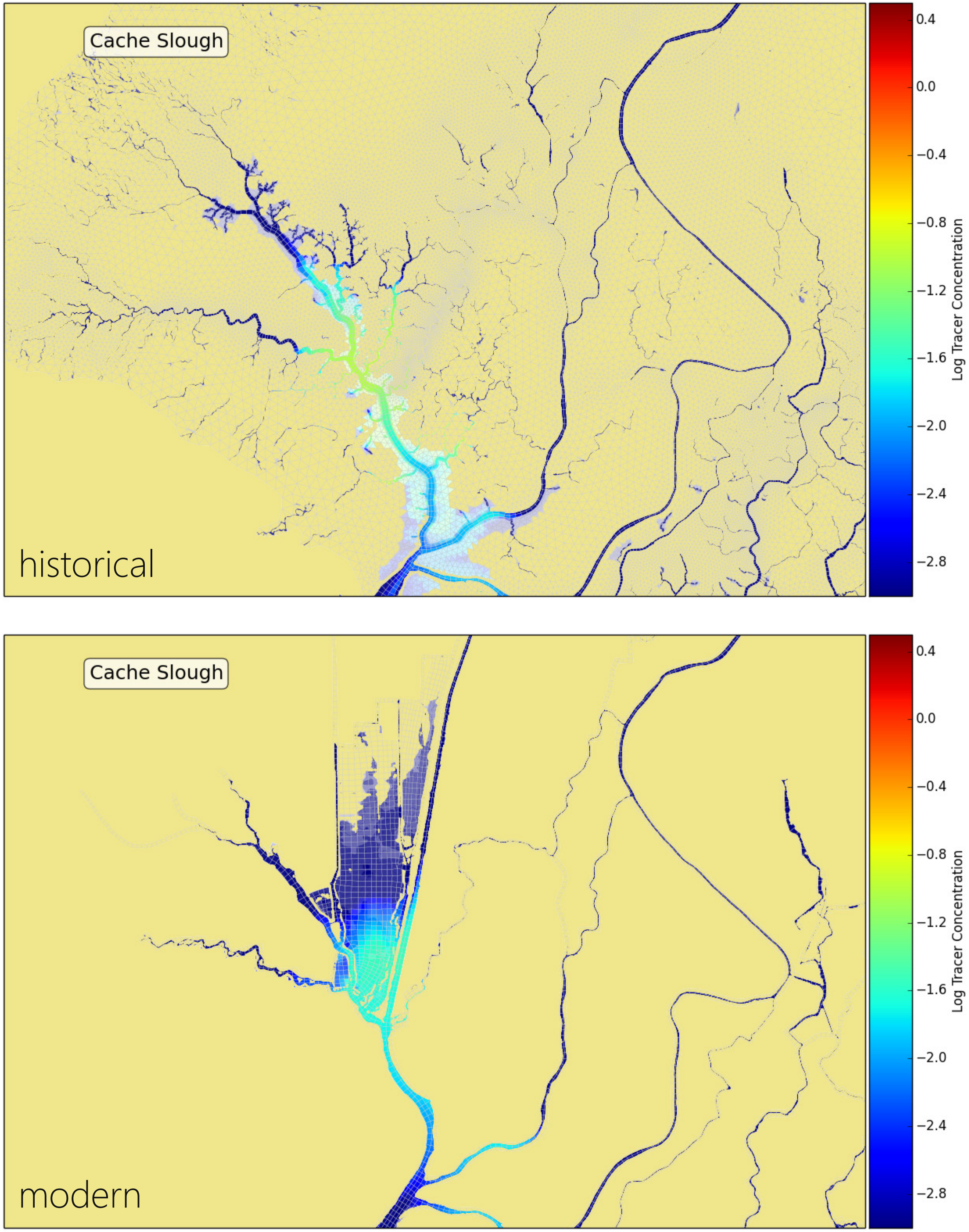
Simulation conditions:

- **Low flow** (Sac flow = 8K cfs, SJR flow = 1K, Mok flow = 150 cfs)
- Released during **filling period** of spring-neap filling-draining cycle (which means **negative net Delta outflow**)

Tracer runs- Cache Slough

1000 kg tracer

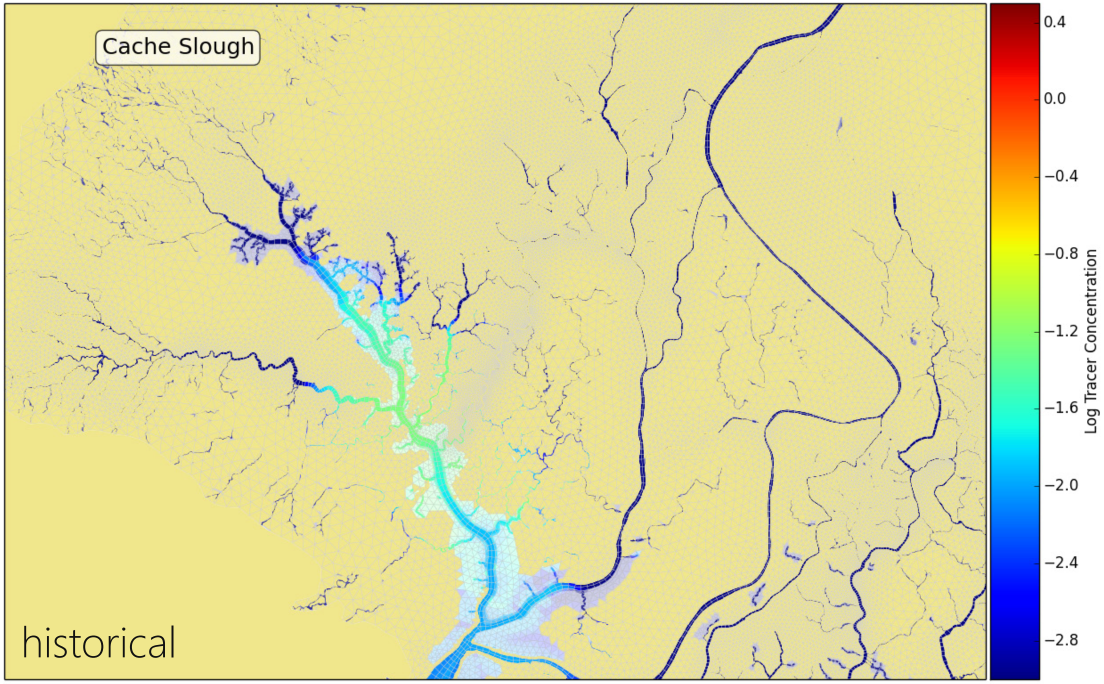
tidal days: 1

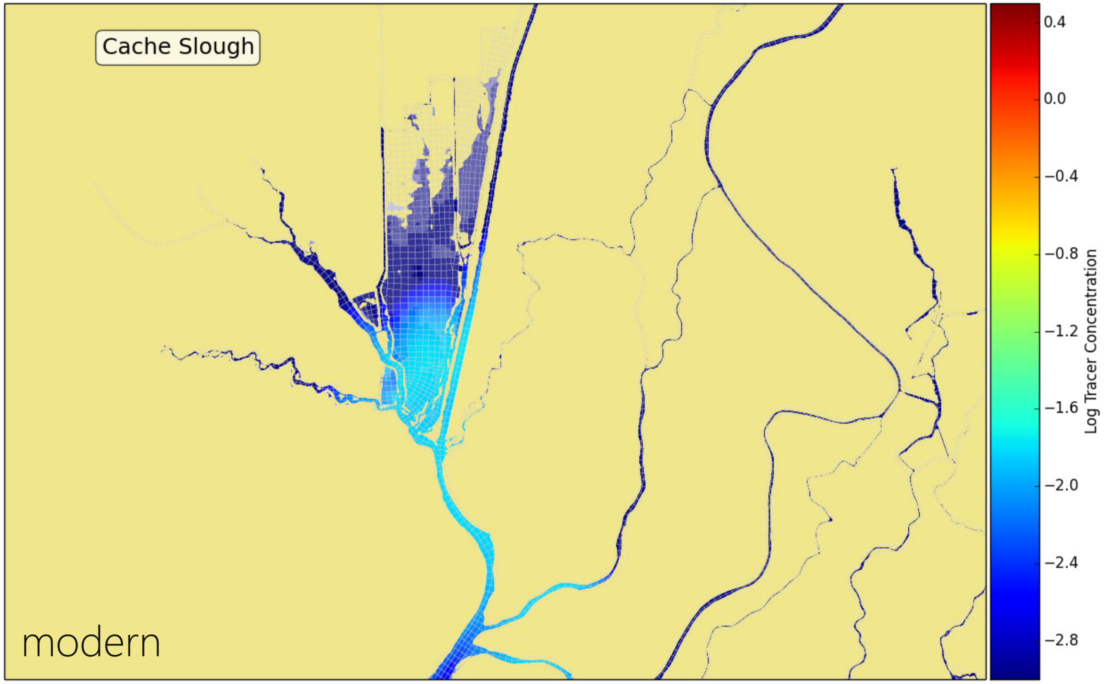


Tracer runs- Cache Slough

1000 kg tracer

tidal days: 2

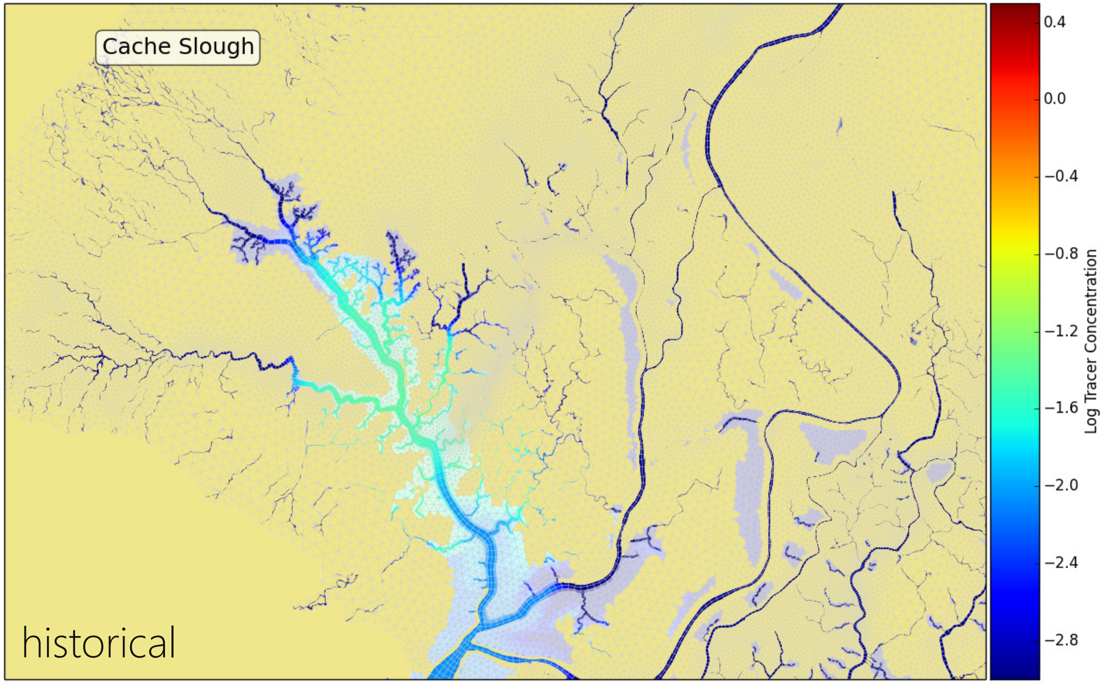


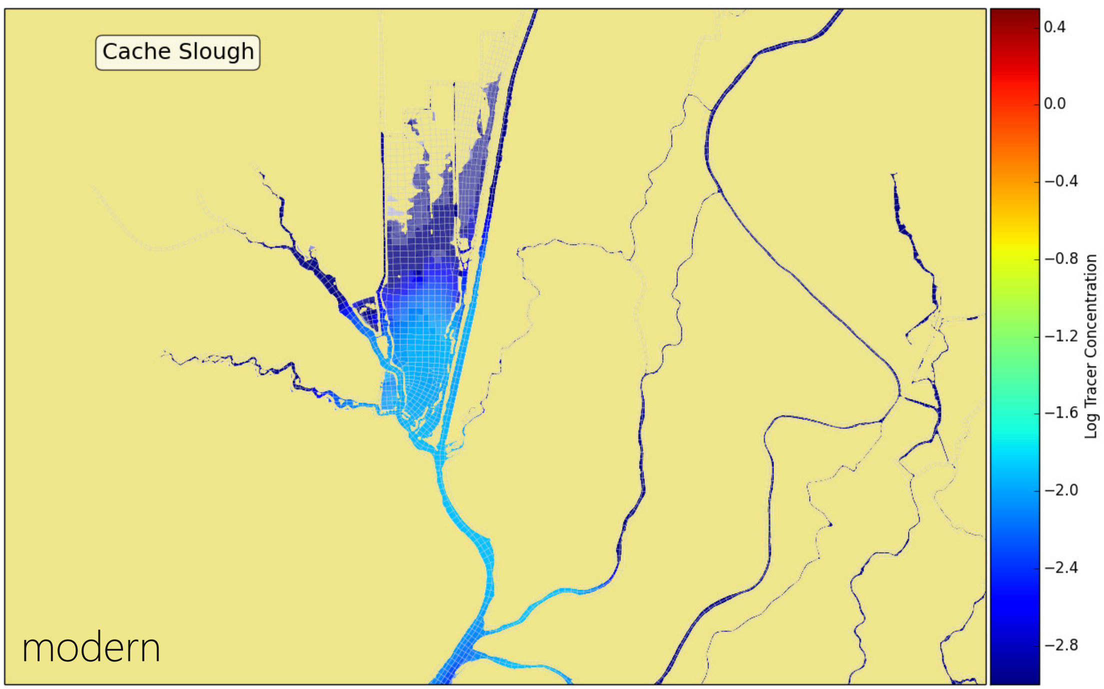


Tracer runs- Cache Slough

1000 kg tracer

tidal days: 3

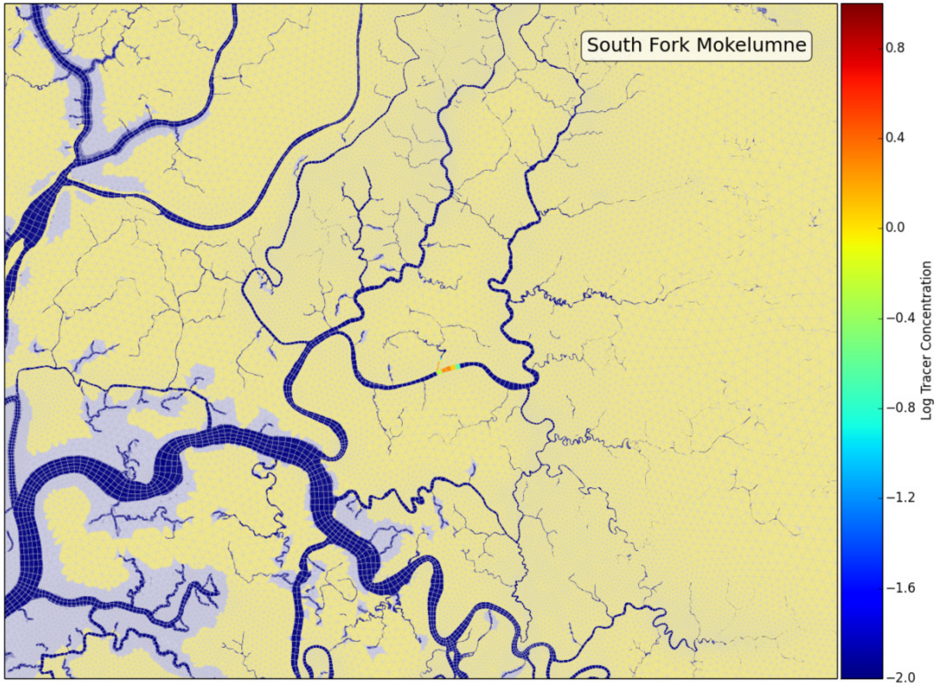




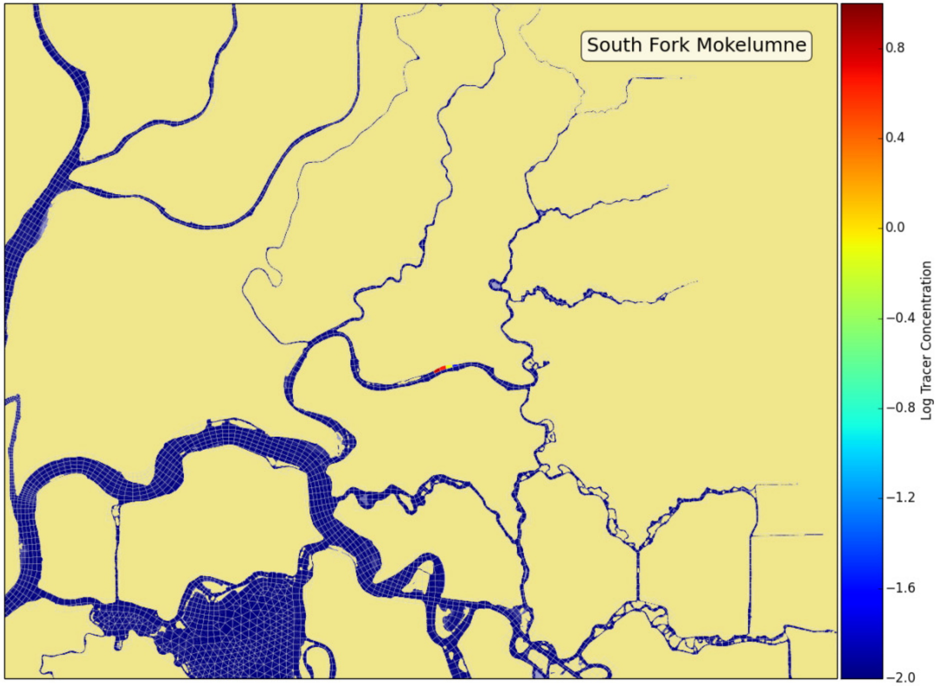
Tracer runs

Mokelumne North Fork

Tracer runs- Mokelumne River



historical

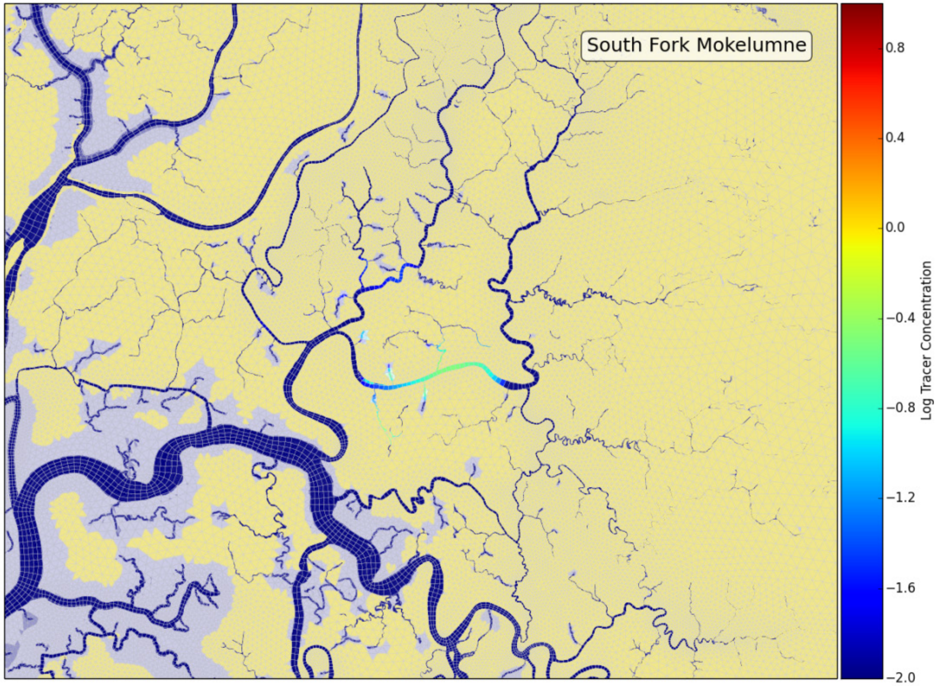


modern

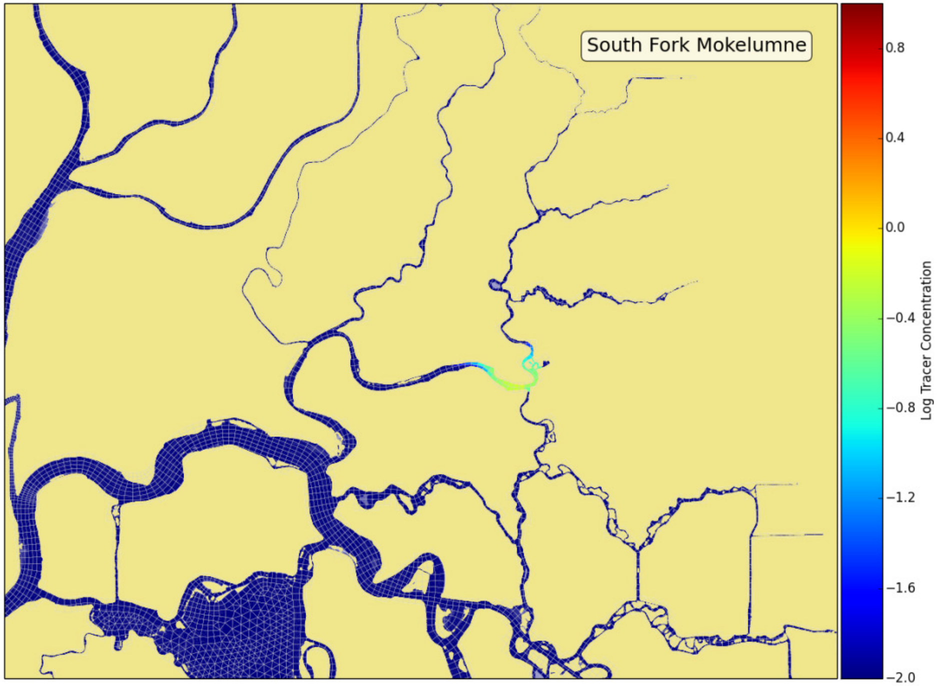
1000 kg tracer

tidal days: 0

Tracer runs- Mokelumne River



historical

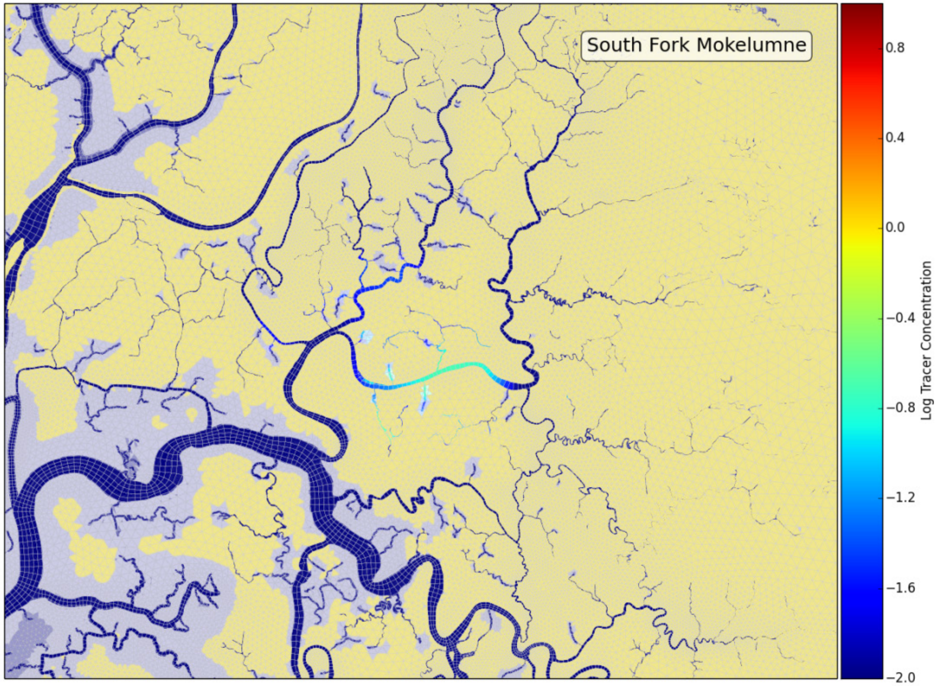


modern

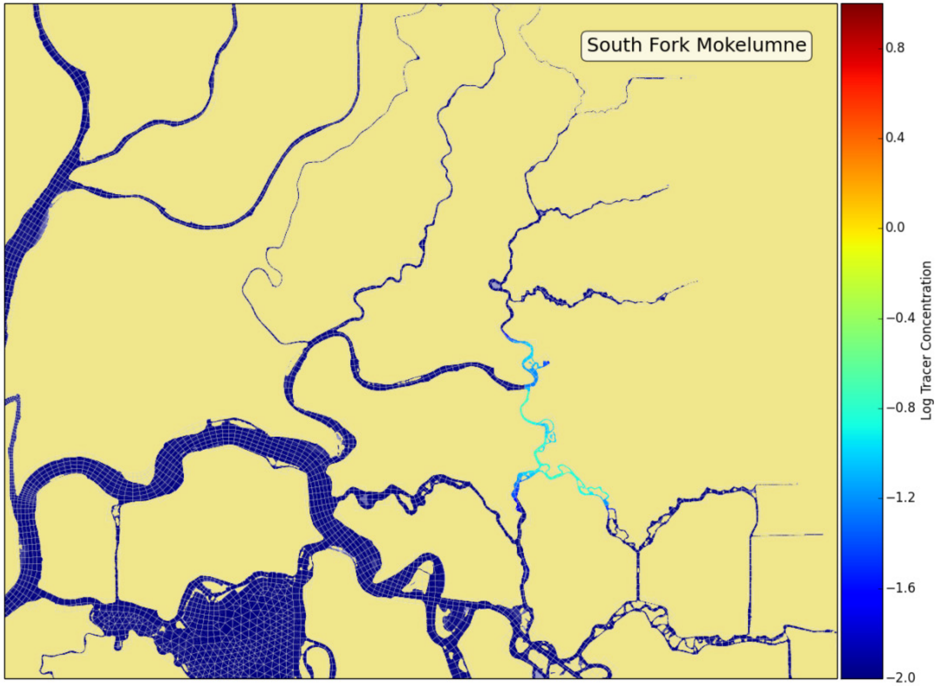
1000 kg tracer

tidal days: 1

Tracer runs- Mokelumne River



historical

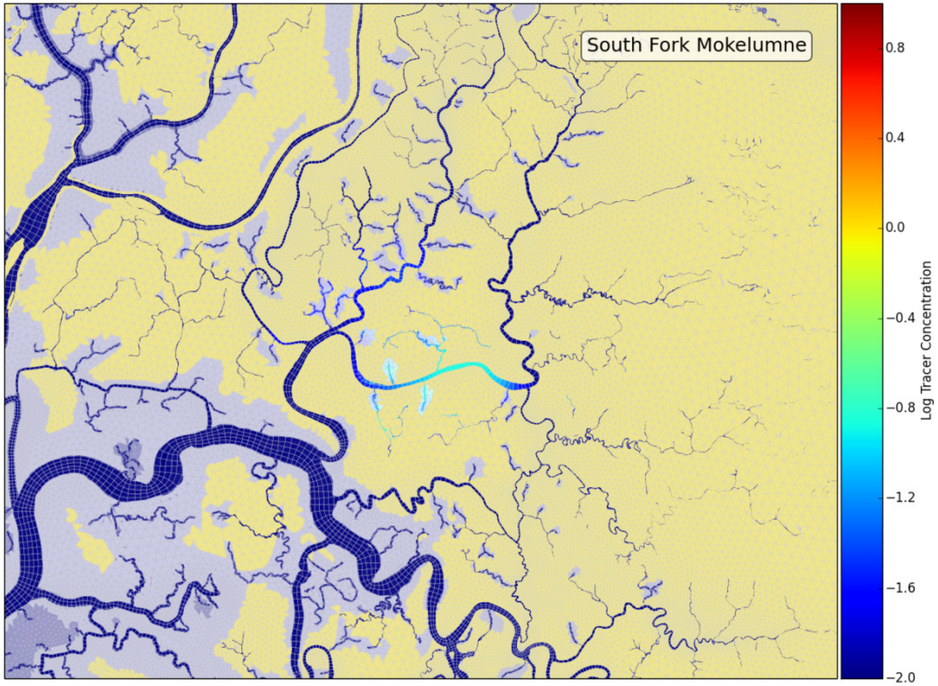


modern

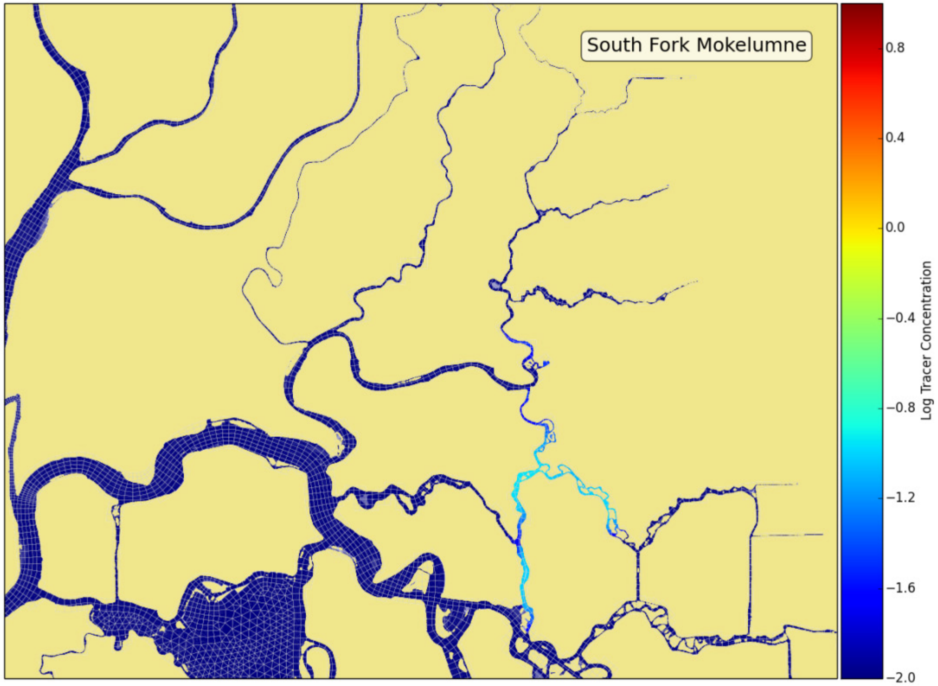
1000 kg tracer

tidal days: 2

Tracer runs- Mokelumne River



historical

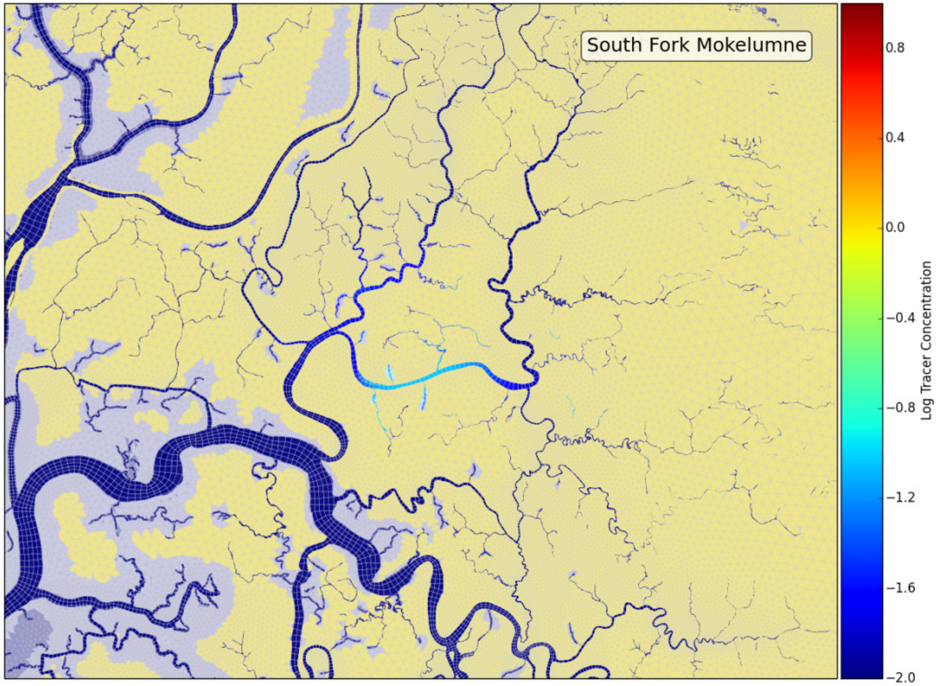


modern

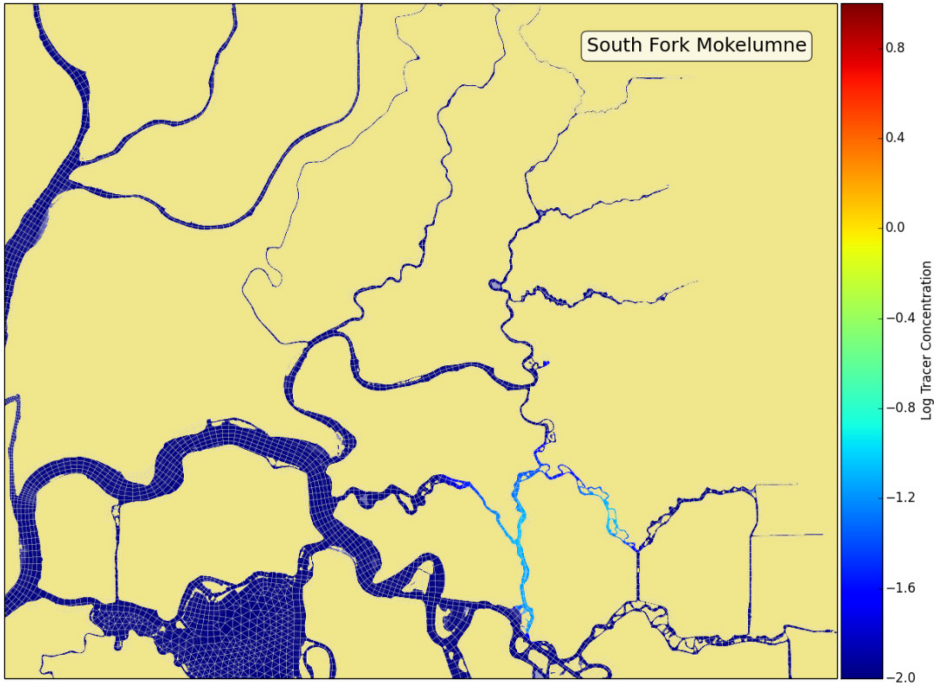
1000 kg tracer

tidal days: 3

Tracer runs- Mokelumne River



historical

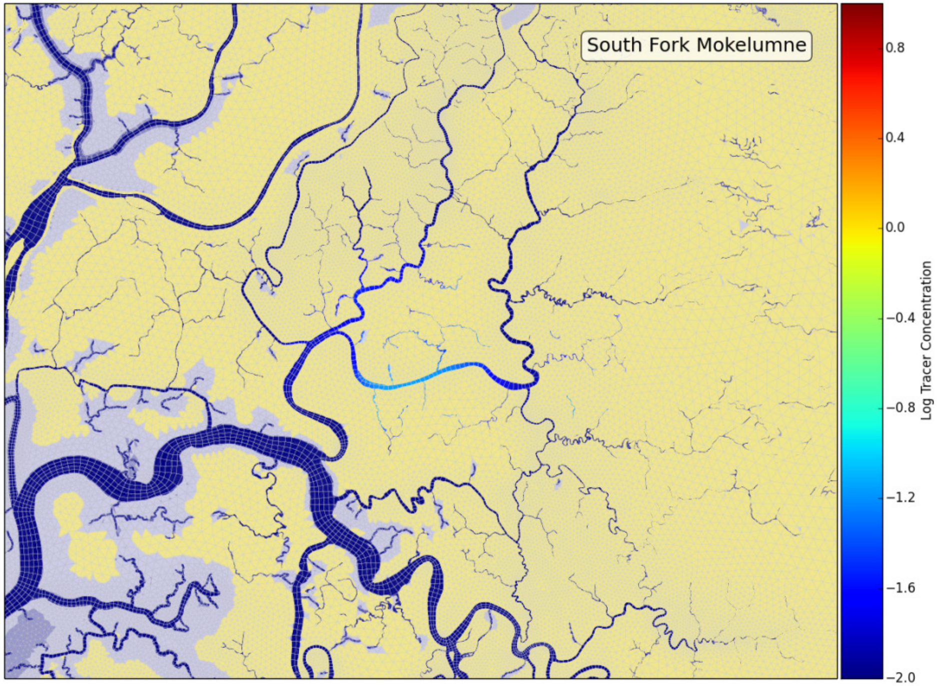


modern

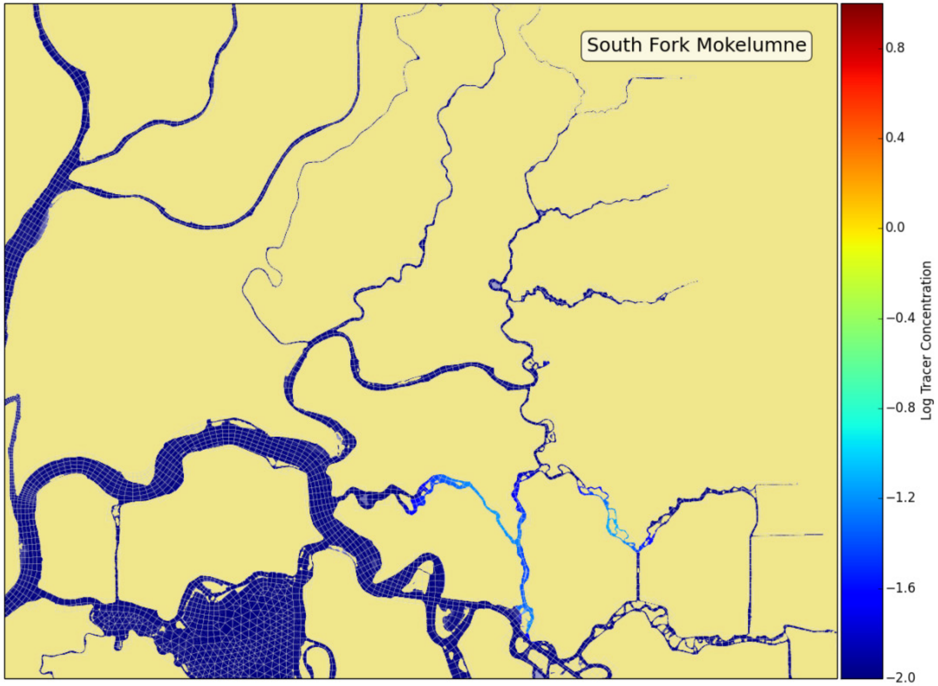
1000 kg tracer

tidal days: 4

Tracer runs- Mokelumne River



historical

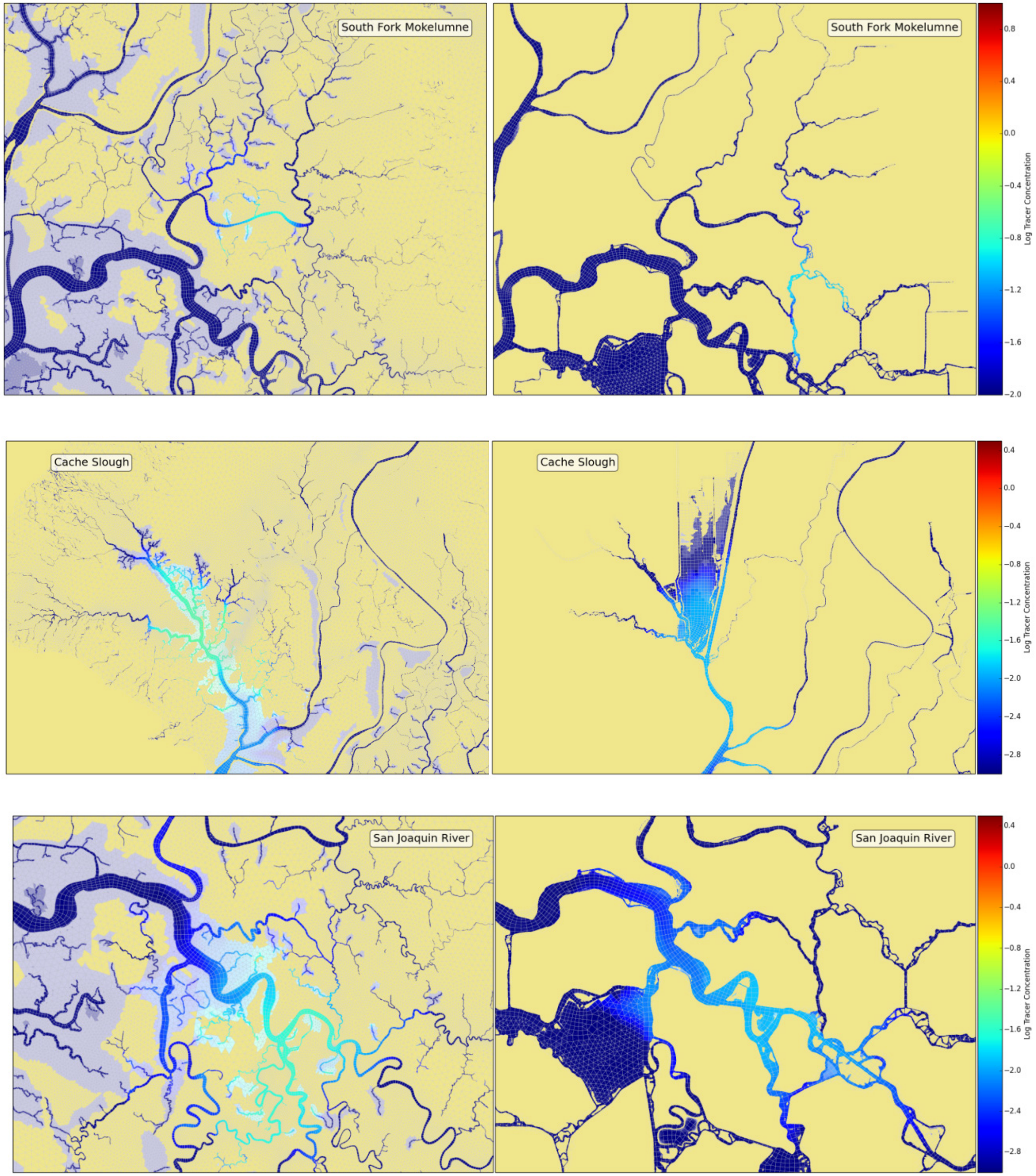


modern

1000 kg tracer

tidal days: 5

Tracer runs- conclusions



<u>Qualitative observations from visual inspection:</u>

Total **areal dispersion after three days is similar** in historical and modern systems…

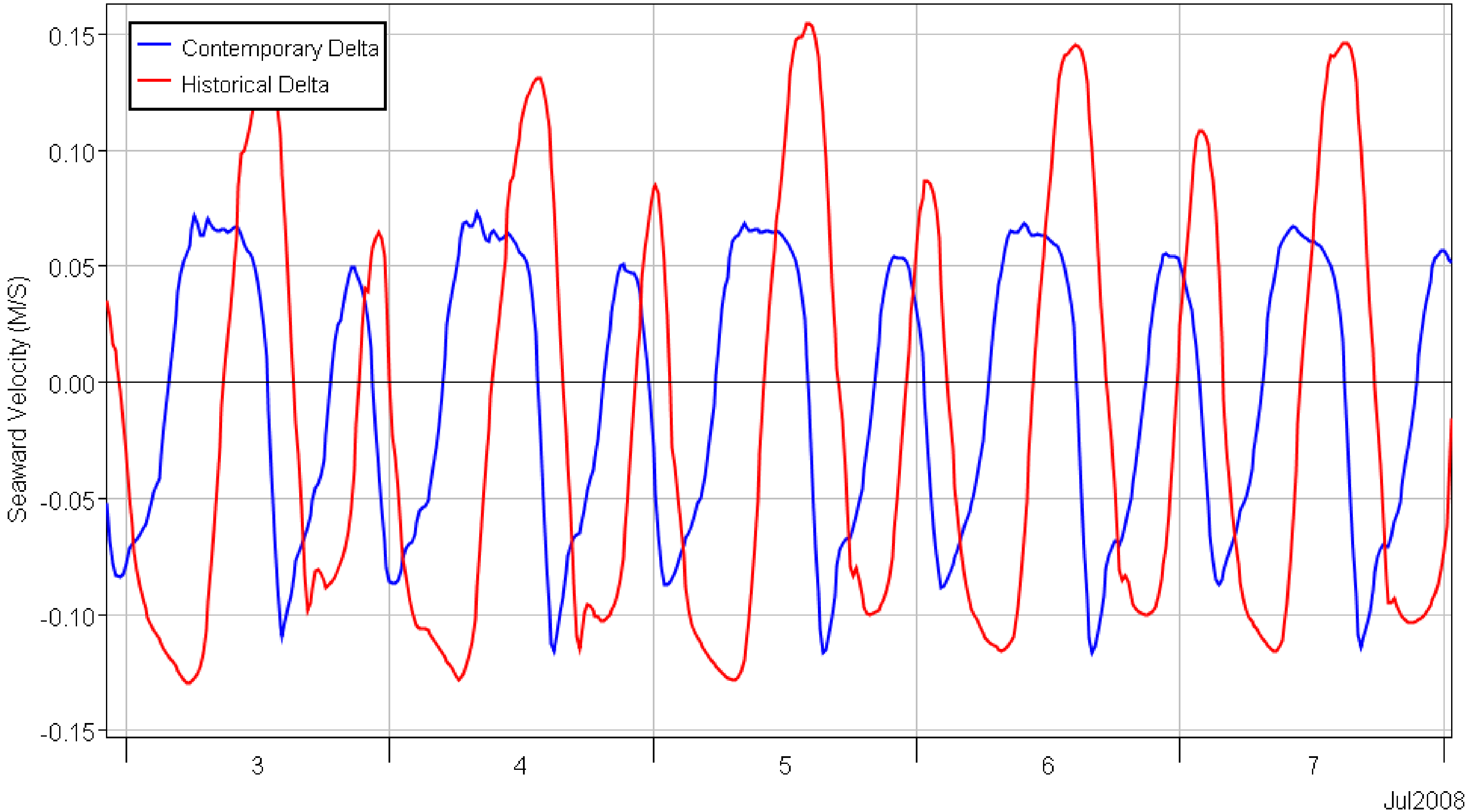
…but **historical systems are less mixed** from a gross areal perspective:

- Gradients are more pronounced in historical system
- Greater range of constituent concentrations within a given distance.
- Lower “distance to different”
- Greater potential opportunity for fish to fine-tune position vis-a-vie tracer concentration.

Tidal asymmetry

Marsh Causes Shifts To Flood Dominance?

- Hypothesis: marsh draining elongates ebb period, shifts velocities towards flood dominance (however, we saw the opposite)



Tidal asymmetry

Enright et al. 2013: **flood dominance** in First Mallard Slough associated with peak velocities

Morgan-King and Schoellhammer 2012: **flood dominance** in Cache Slough helps create maintain turbidity maxima at the upper ends of the dead-end slough.

Fagherazzi et al. 2004: **ebb-dominance** in tidal channels of China Camp Marsh

Leopold et al. 1993: **ebb-dominance** in Tule Slough in Petaluma marsh

SFEI 2004: "A **channel system may consist of both flood-dominated reaches and ebb-dominated reaches**. For larger channel networks, there may be a shift from flood-dominance to ebb dominance with distance upstream from the tidal source (Fagherazzi et al. 2004)."

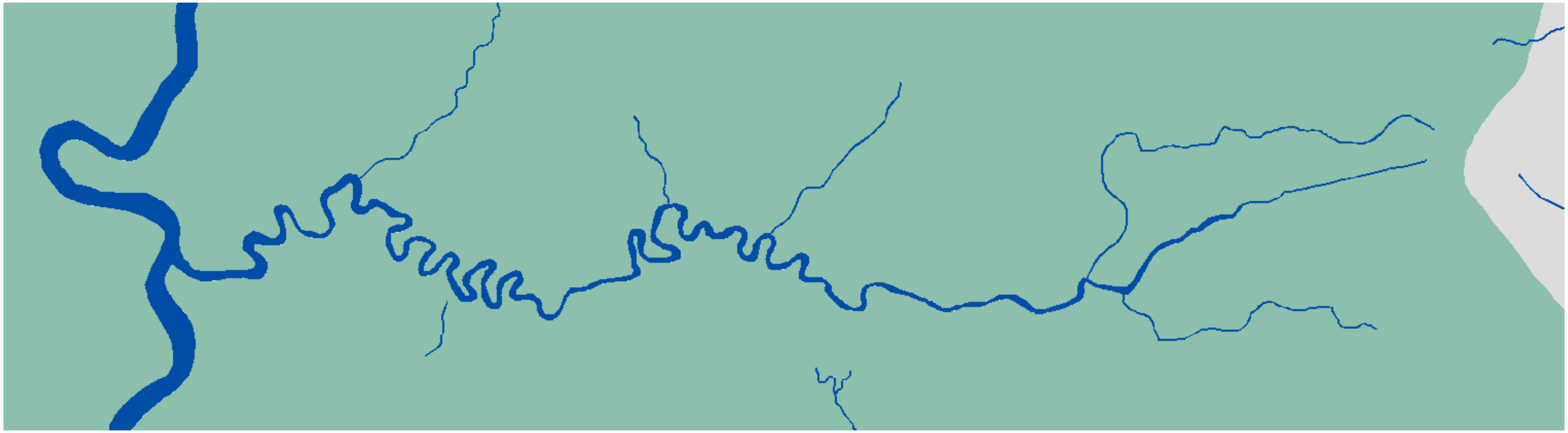
Hard to know what to expect…

Tidal asymmetry

The direction of the dominant flow can be determined using channel plan-form geometry by assessing meander asymmetry (Fagherazzi et al. 2004)

Ebb-dominated meanders: the point of maximum curvature is closer to the upstream inflection point

Flood-dominated meanders: the point of maximum curvature is closer to the downstream inflection point



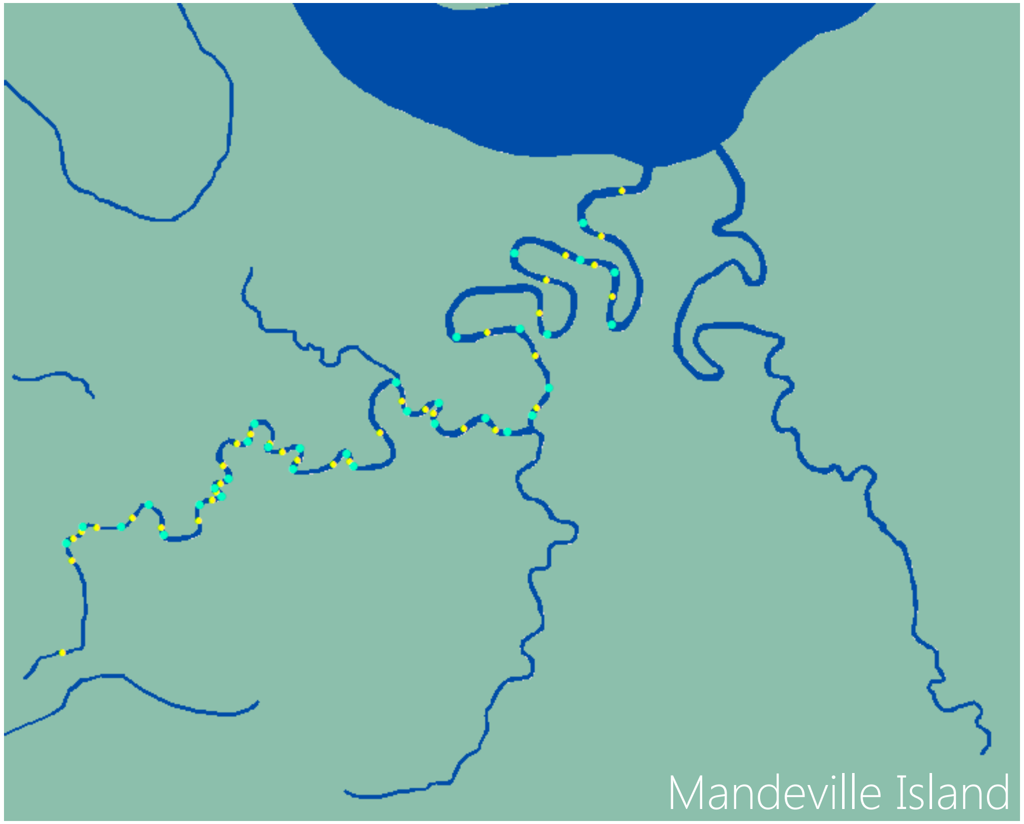
Sycamore Slough

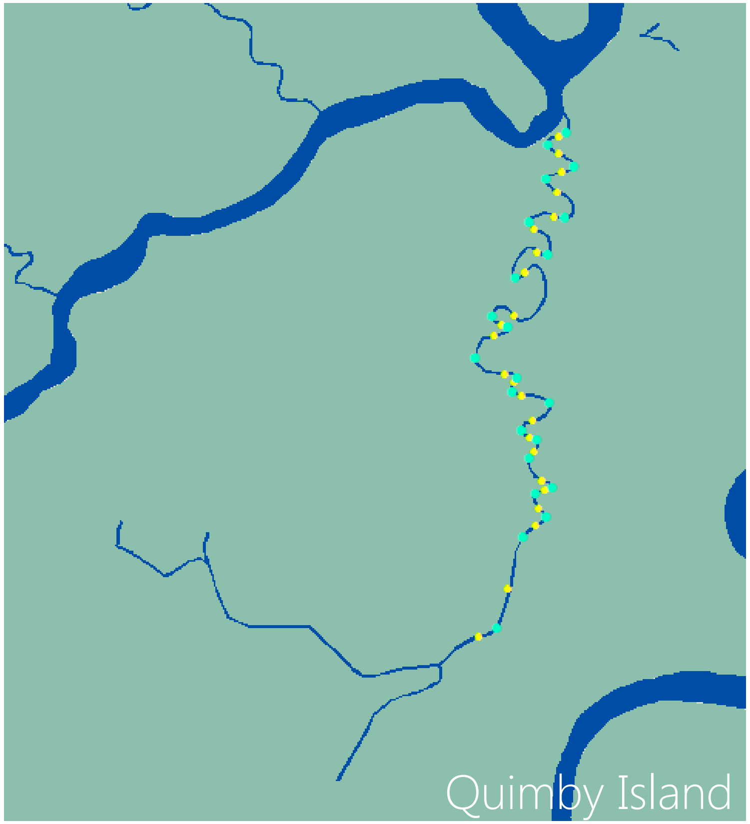
Tidal asymmetry

The direction of the dominant flow can be determined using channel plan-form geometry by assessing meander asymmetry (Fagherazzi et al. 2004)

Ebb-dominated meanders: the point of maximum curvature is closer to the upstream inflection point

Flood-dominated meanders: the point of maximum curvature is closer to the downstream inflection point





Conclusions and future directions

- Modeled inundation frequency of Delta marshes quite high.
  - Implications for fish that access inundated marsh surface for feeding and predator-avoidance
- Tracer drops illustrate conceptual model of historical Delta that had pronounced physical gradients and low "distance to different"
  - More options for fish
- Work out tidal asymmetry results
  - Conduct analysis of velocities along a tidal slough that's since been converted to a flow-through channel
  - Use plan-form geometry of historical Delta channels to assess flood/ebb dominance of individual meander bends
- Expand suite of comparative hydrodynamic metrics
  - Tidal excursions vs. channel length
  - Residence time
  - Habitat connectivity
  - Others?

Thank you…

- Paul Hutton
- Bill Fleenor
- Andy Bell
- Alison Whipple
- Mui Lay
- Amber Manfree
- John DeGeorge
- **Steve Andrews**
- Ed Gross
- **Chris Enright**
- Julie Beagle
- **Josh Collins**
- David Senn

Historical Delta hydrodynamics project funded by the **Metropolitan Water District**

Contemporary Delta hydrodynamic model developed by **Resource Management Associates (RMA)**

Independent collaboration with the **UC Davis Center for Watershed Science** and the **California Department of Water Resources**.

Delta Landscapes Project funded by the funded by the **California Department of Fish and Wildlife** and the **Ecosystem Restoration Program**