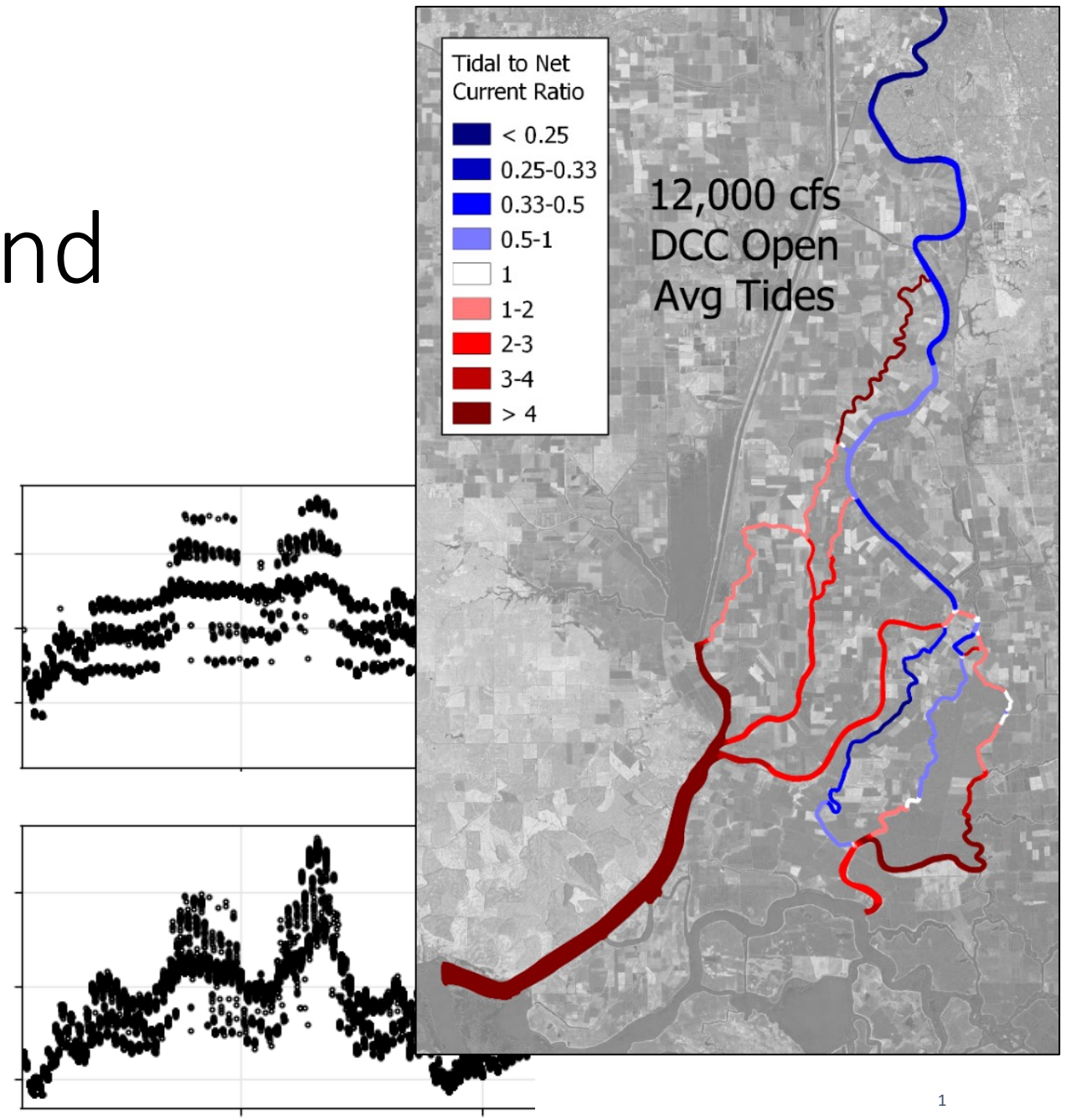
RMA RESOURCE MANAGEMENT ASSOCIATES
WATER RESOURCES ENGINEERING

Transport Pathways and Processes in the North Delta

Stephen Andrews, RMA
Jon Burau, USGS
Paul Stumpner, USGS

CWEMF Presentation, 6 Apr 2022



Project Study Area and Motivation

- Primary study motivation: understand hydrodynamic controls on outmigrating juvenile salmon survival
- "Transitional reaches" – change character between riverine and tidal depending upon Sacramento River flow at Freeport
  - Higher flow -> more riverine
  - Lower flow -> more tidal

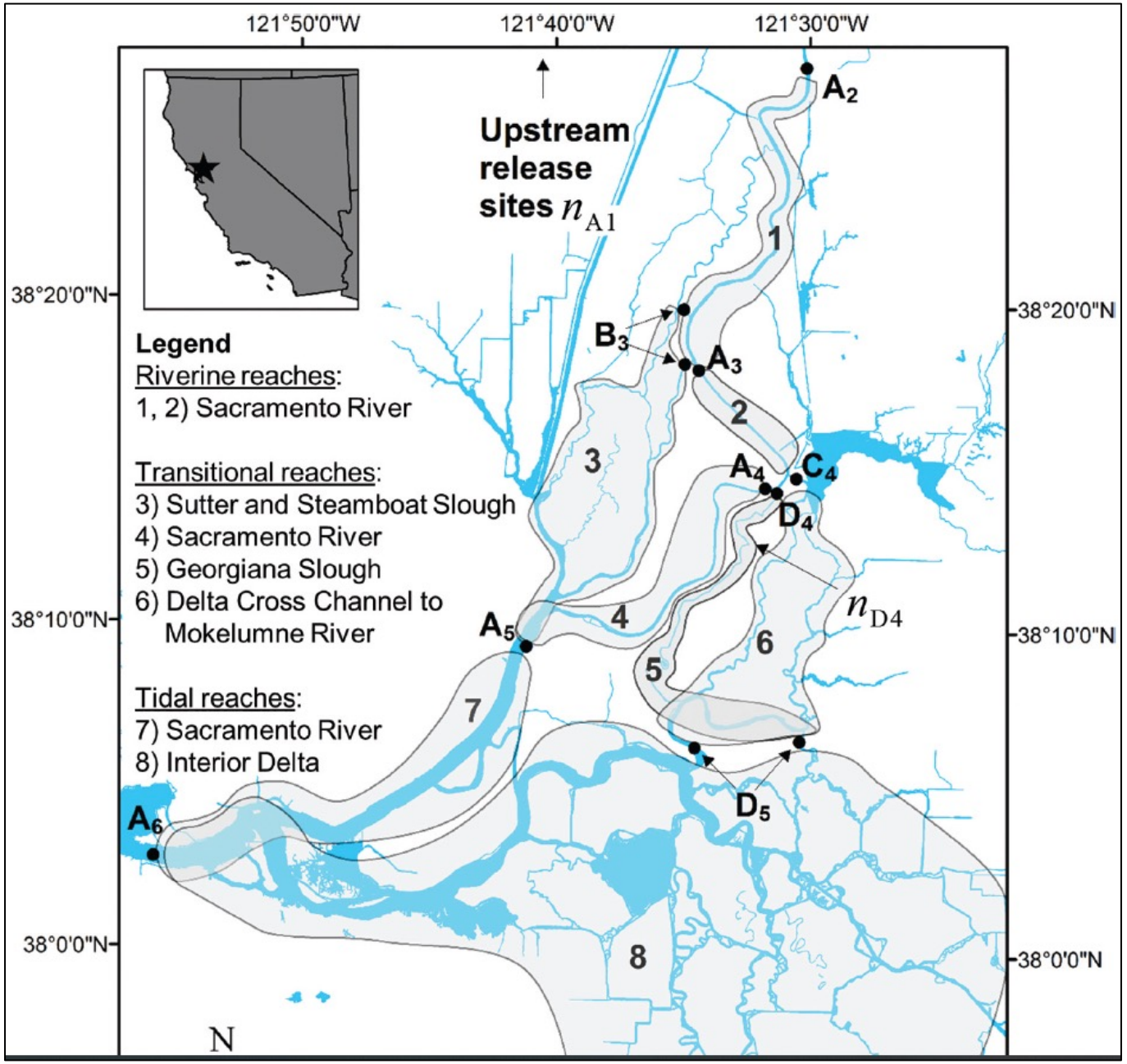


Figure from Perry et al. 2017

Observed Juvenile Salmon Survival

- No dependence of survival on Freeport flow in reaches that are always riverine (Upper Sacramento) or always tidal (Rio Vista to Chipps)
- For transitional reaches, lower survival when reach is more tidal
- Tidal reaches -> greater time spent in reach and greater distance traveled than riverine reaches
  - Possibly the reason why lower survival (predator exposure)

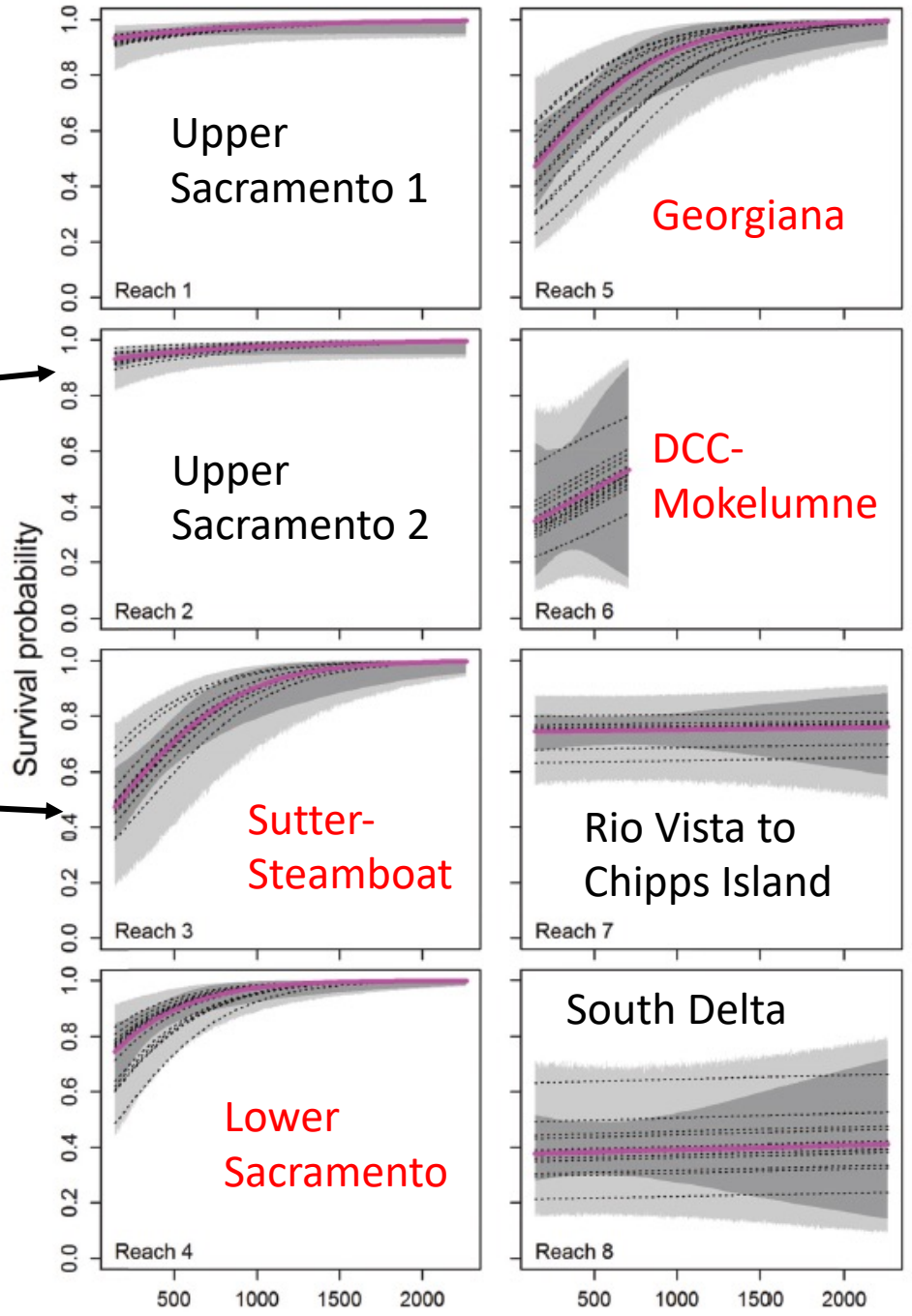


Figure from Perry et al. 2017

Project Objectives

- Use hydrodynamic and particle tracking model simulations to calculate the travel time and distance traveled for particles through different reaches of the North Delta
  - Simulate WY 2007-2011 and provide covariate time series to USGS salmon survival Bayesian model
  - See if travel time or distance traveled provides statistically significant improvement in predicting survival over just using Freeport flow
    - E.g., high flow correlated with colder water -> predators eat less
- But more generally -> Describe the pathways and processes of transport through the North Delta
  - Majority of water, sediment, and large portion of nutrients supplied to Delta come from Sacramento River
  - Steady Sacramento River flow simulations
- How do metrics change with large-scale restoration and changes to operations?

Tidal vs. Riverine Character of Reaches

- Metric: u'/<u>
  - Decompose channel velocity (u) into tidal-average (<u>) and residual (u') components
  - u = <u> + u'
  - Tidal: u'/<u> > 1.0
  - Riverine: u'/<u> < 1.0
- When u'/<u> = 1.0, flow becomes unidirectional and it's no longer possible for fish to "ride the tides" upstream

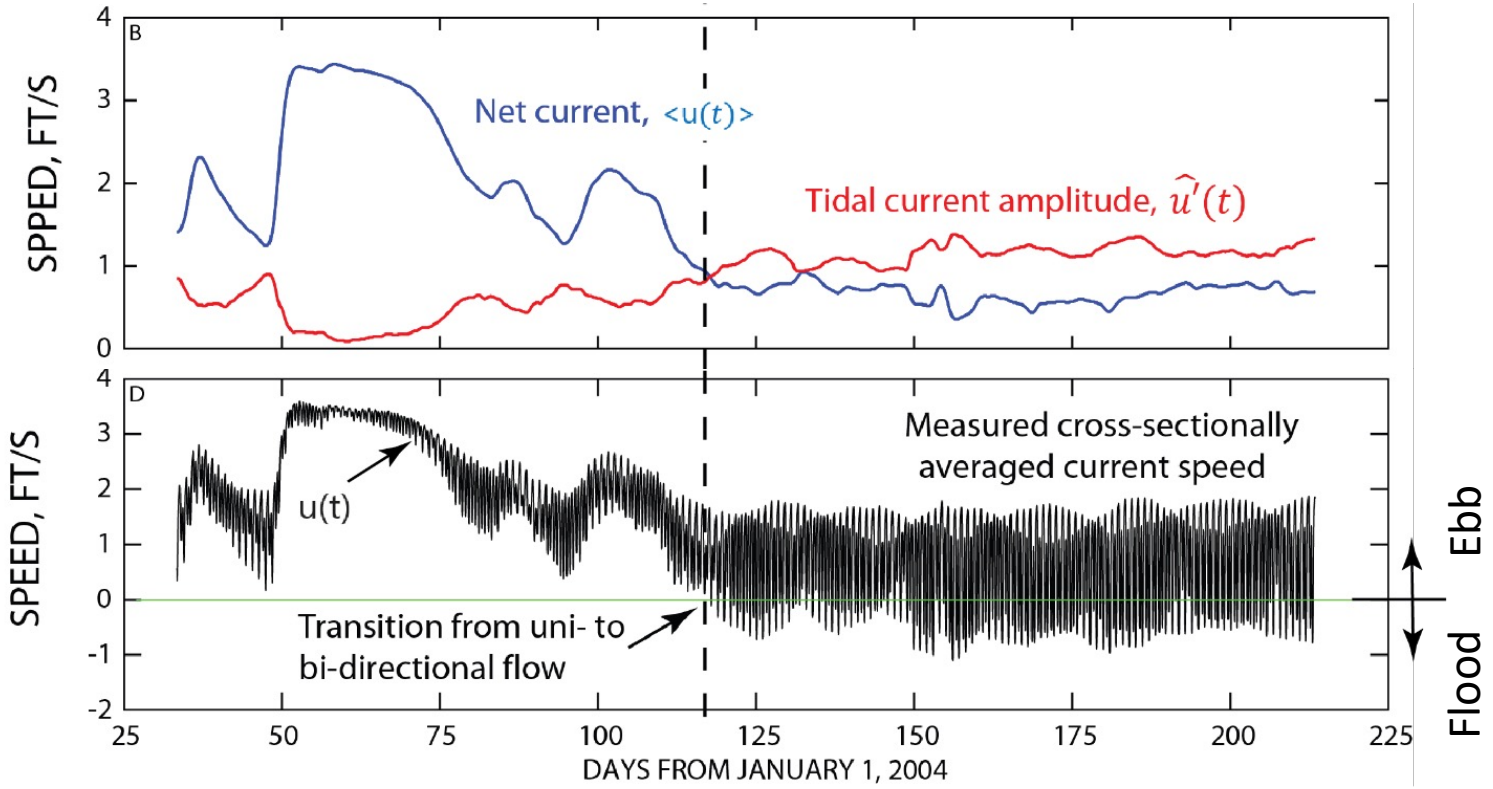
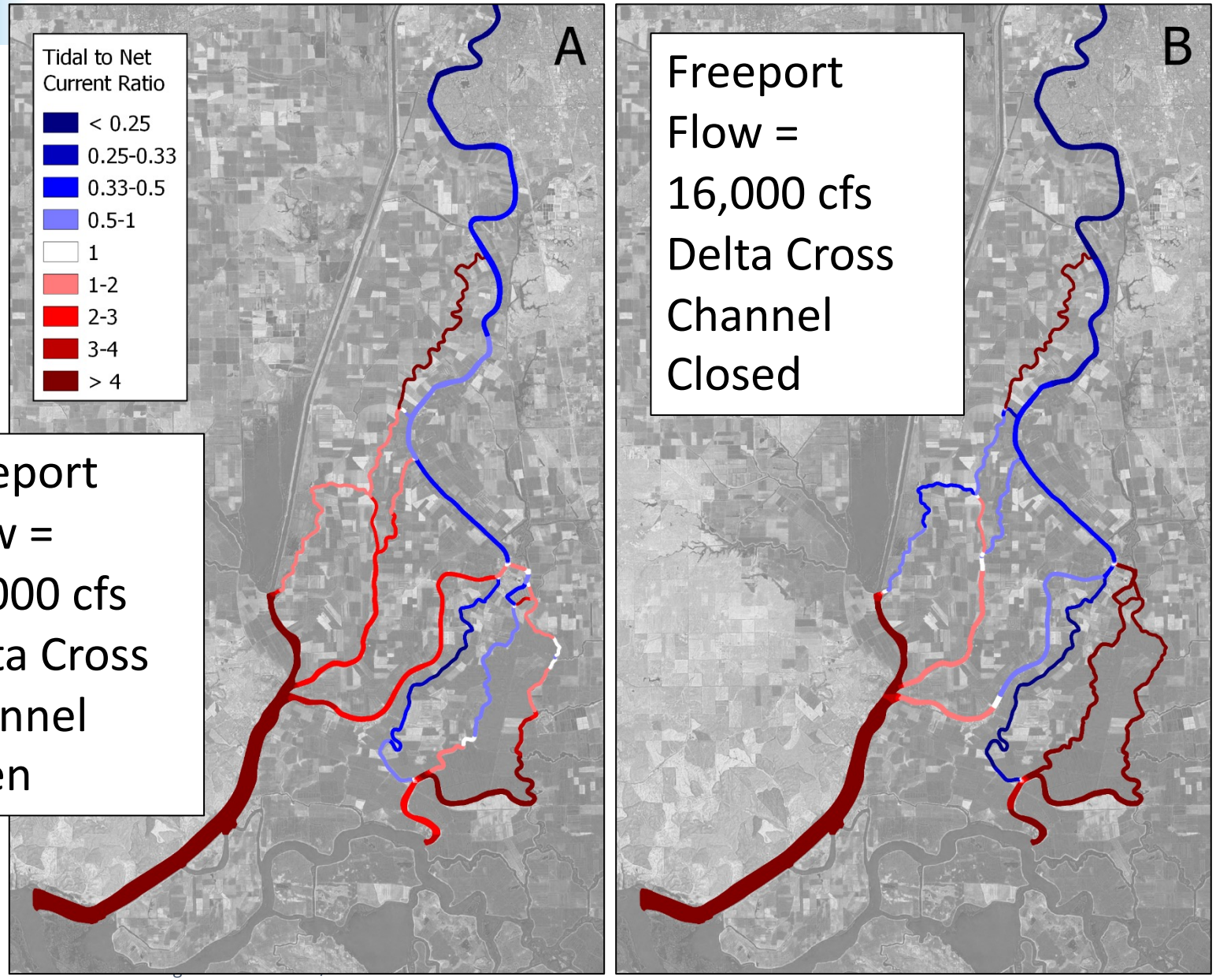
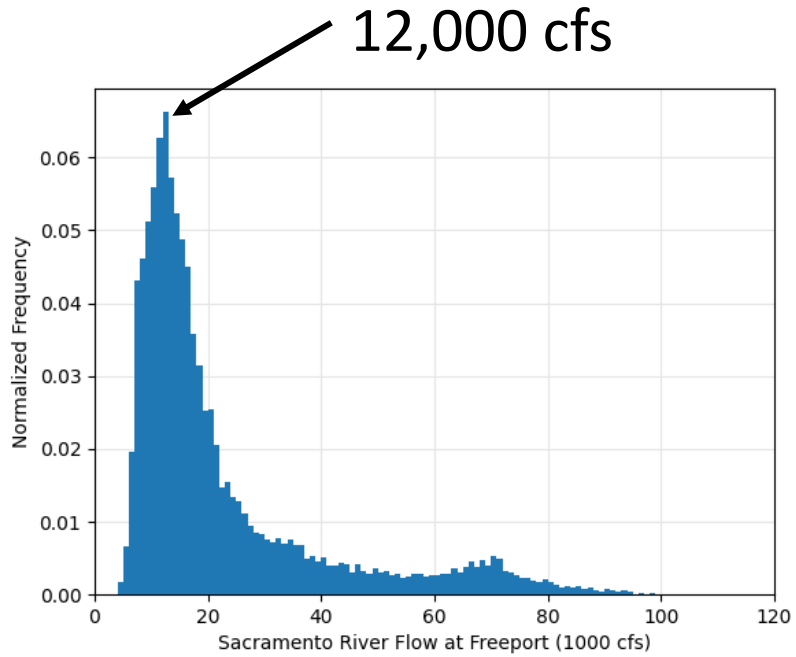


Figure from J. Burau

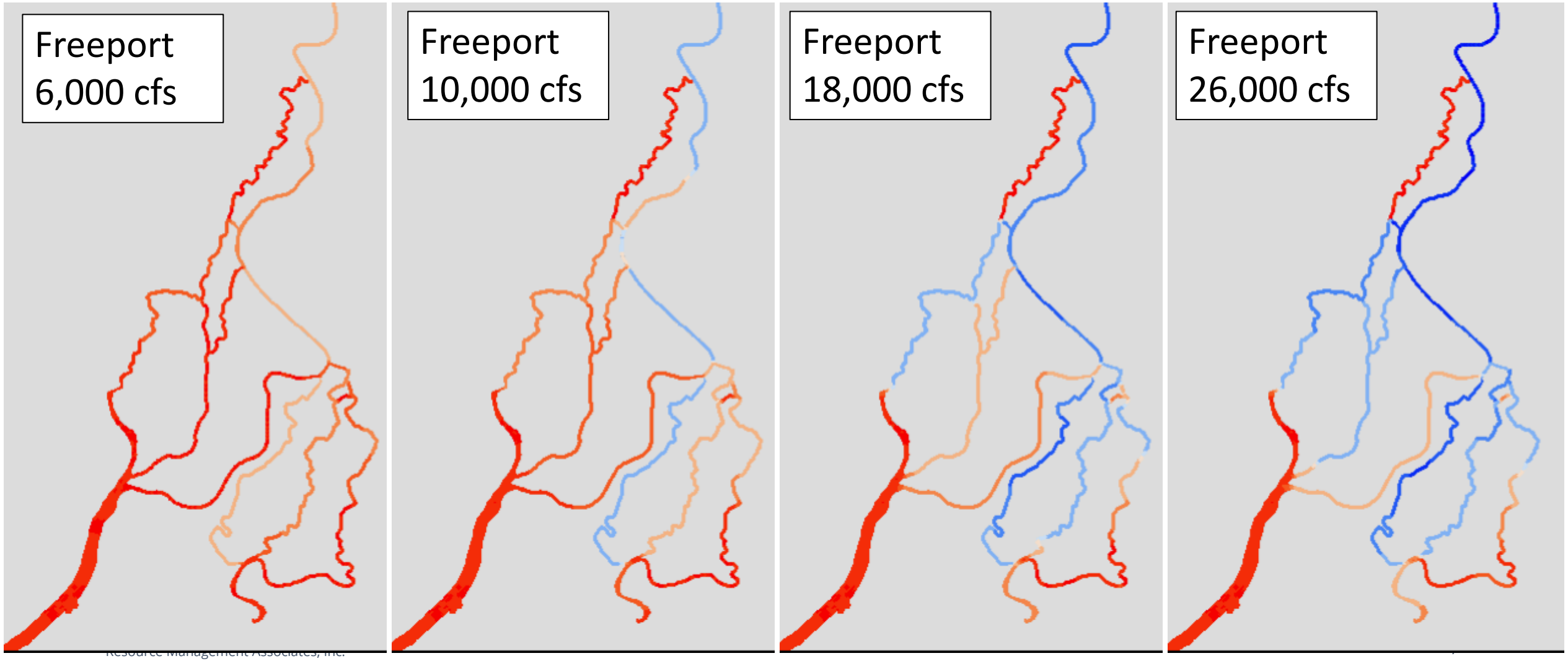
Tidal to Net Current Ratio Heatmaps





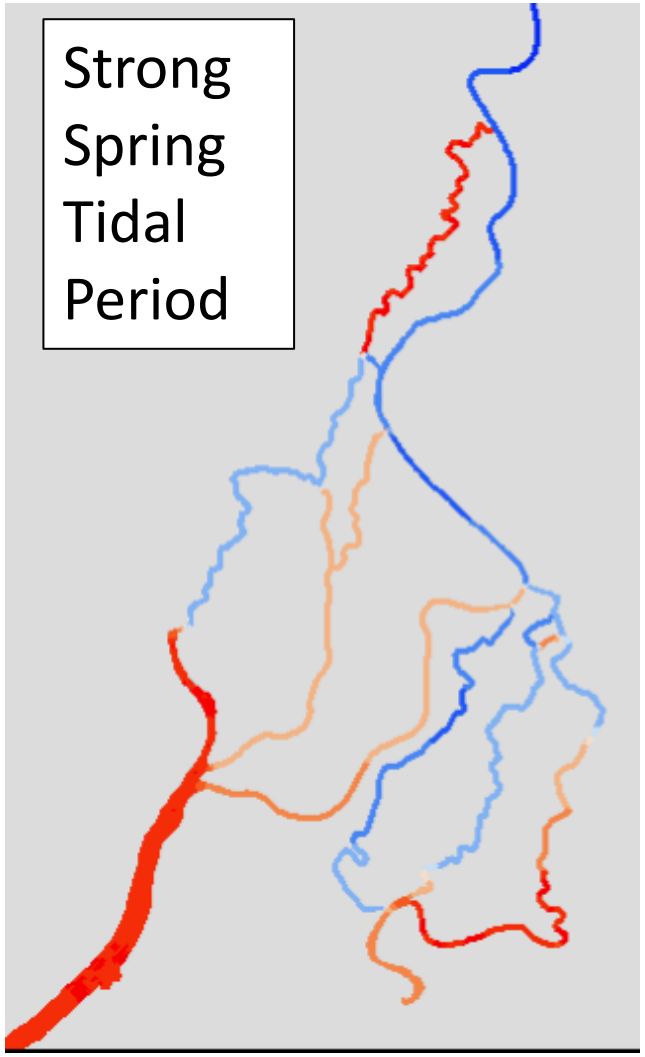
Daily Freeport Flow histogram, USGS station period of record

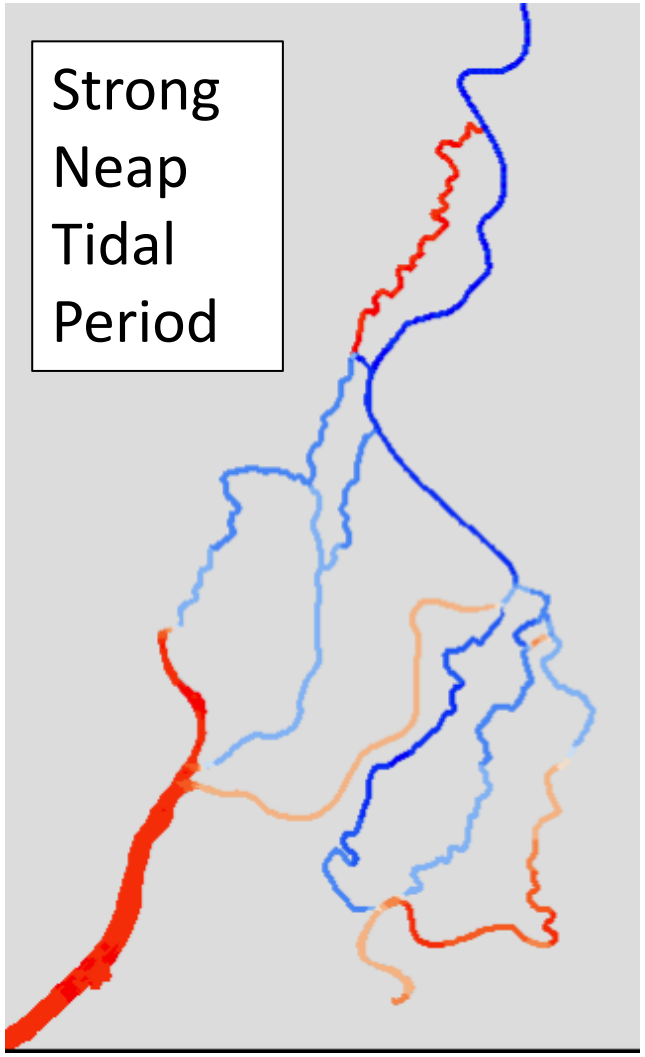
Transitions between Riverine and Tidal Can Happen within a Narrow Range of Flows



Spring-Neap Tidal Cycling

- Freeport Flow = 22,000 cfs
- Full length of Steamboat Slough goes from tidal during spring tides to riverine (unidirectional) during neap tides



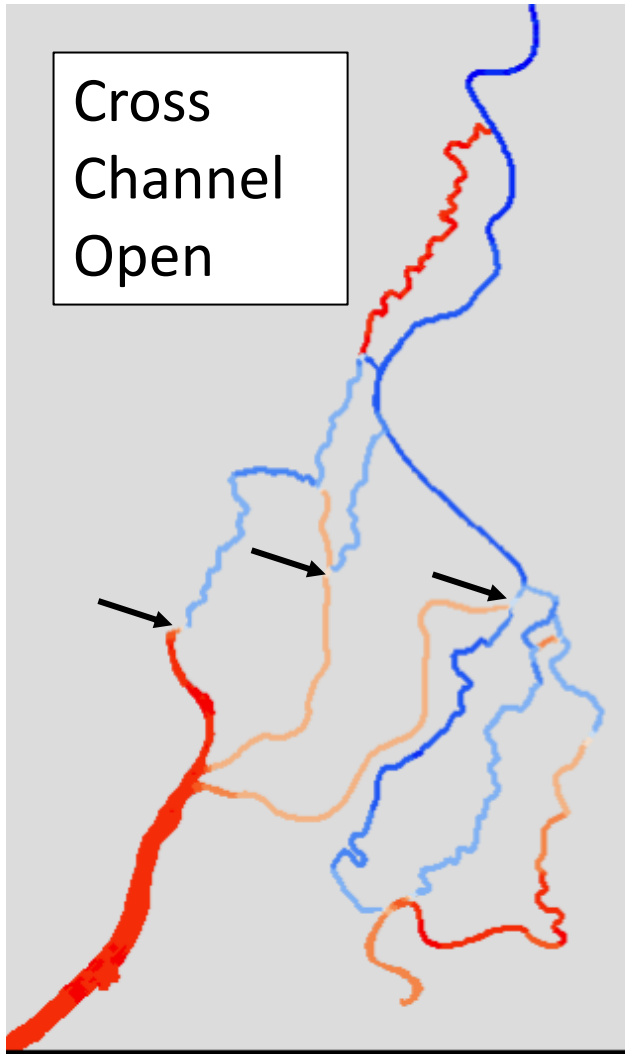


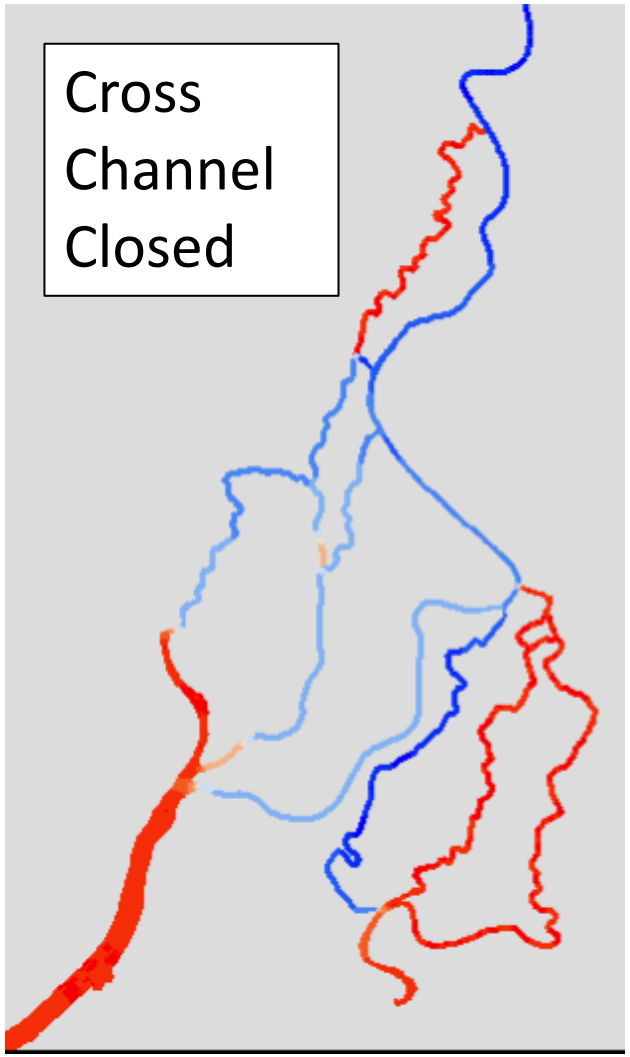
Impact of Delta Cross Channel Closure

- Freeport Flow = 22,000 cfs

Transition from
blue (riverine, unidirectional flow)
to
red (tidal, bidirectional flow)

Call this the “Reversing Current Limit”

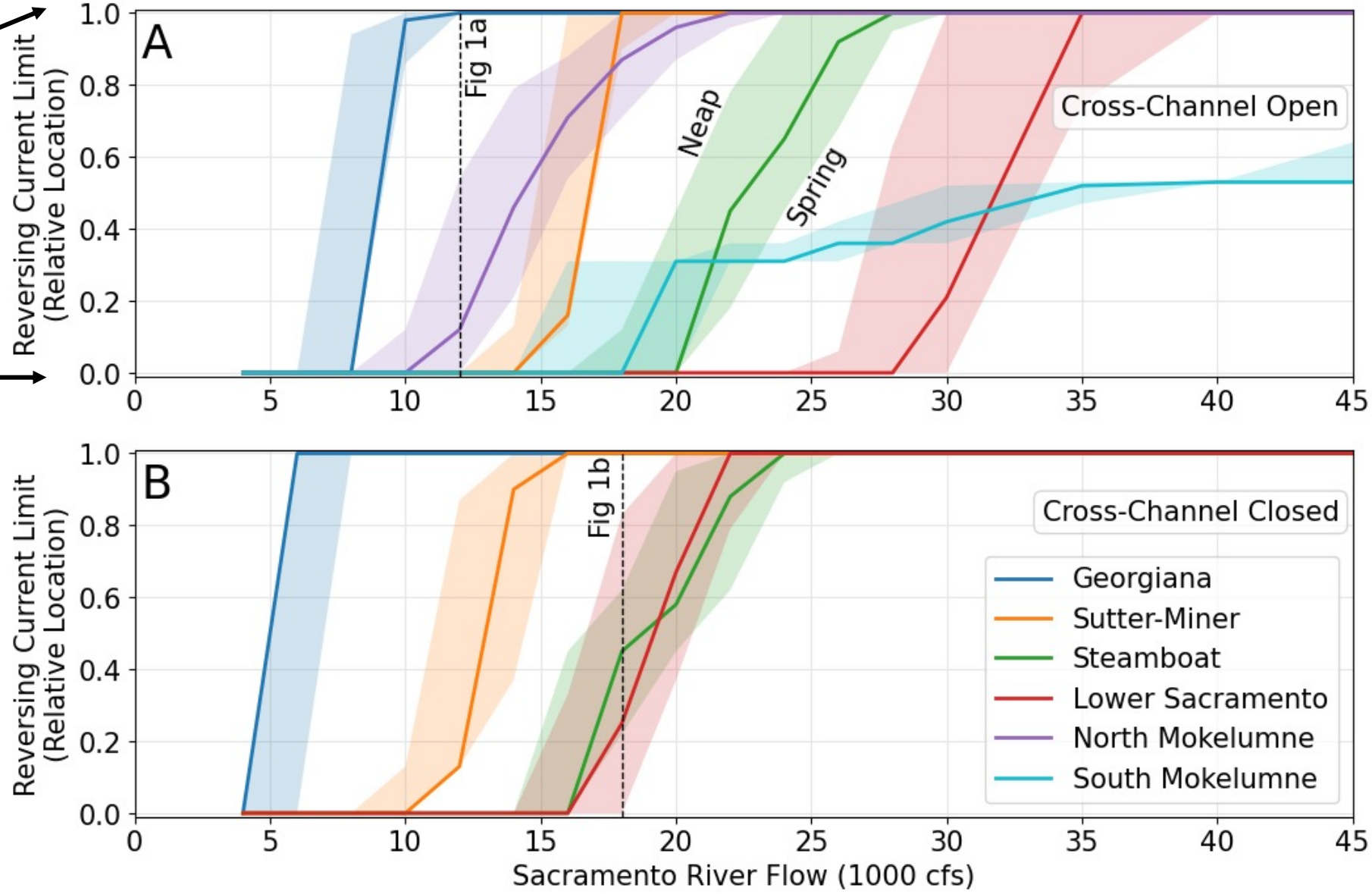




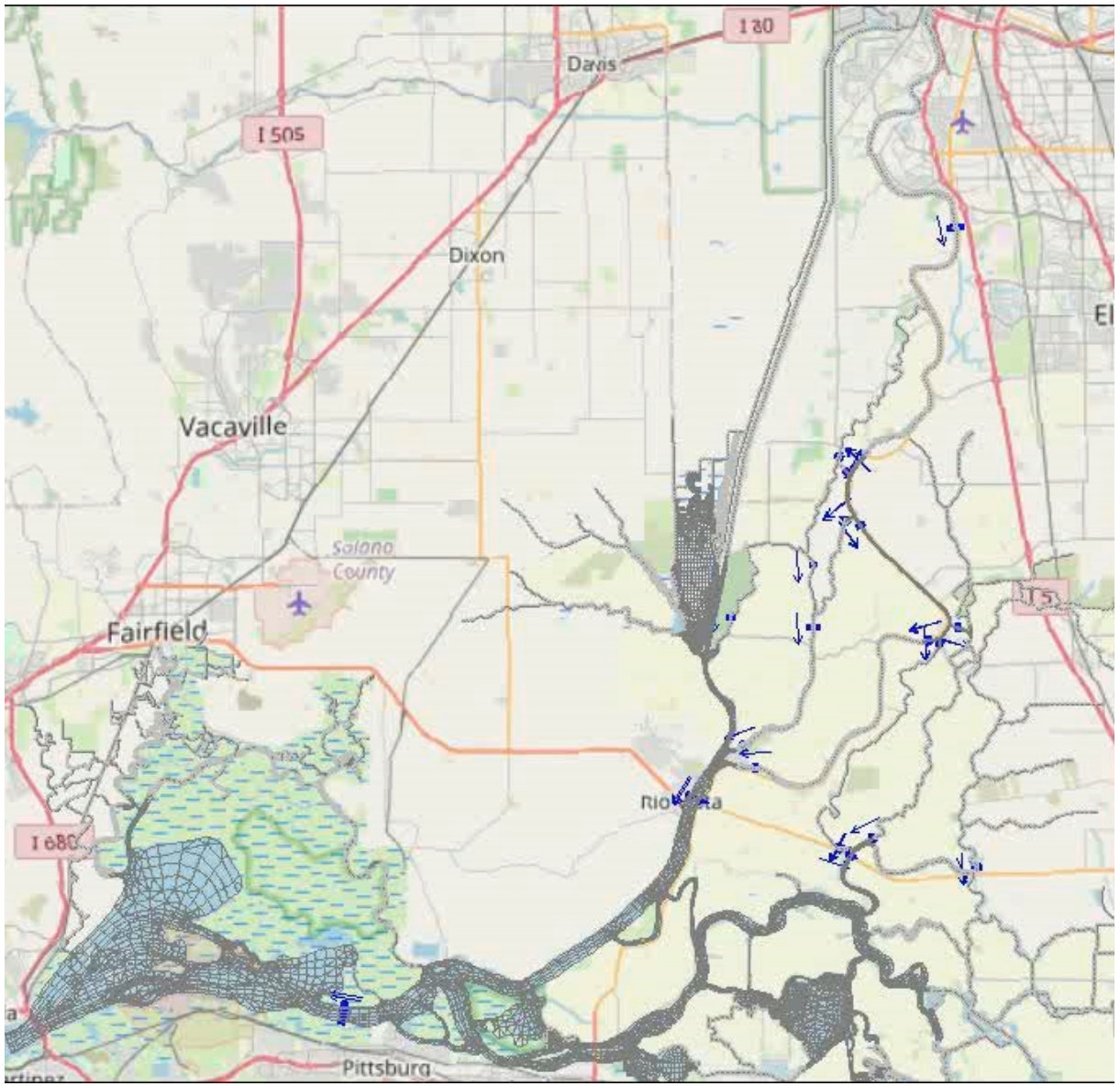
When and How Fast Do They Transition?

Reversing Current Limit at Downstream End (Reach is fully riverine)

Reversing Current Limit at Upstream End (Reach is fully tidal)



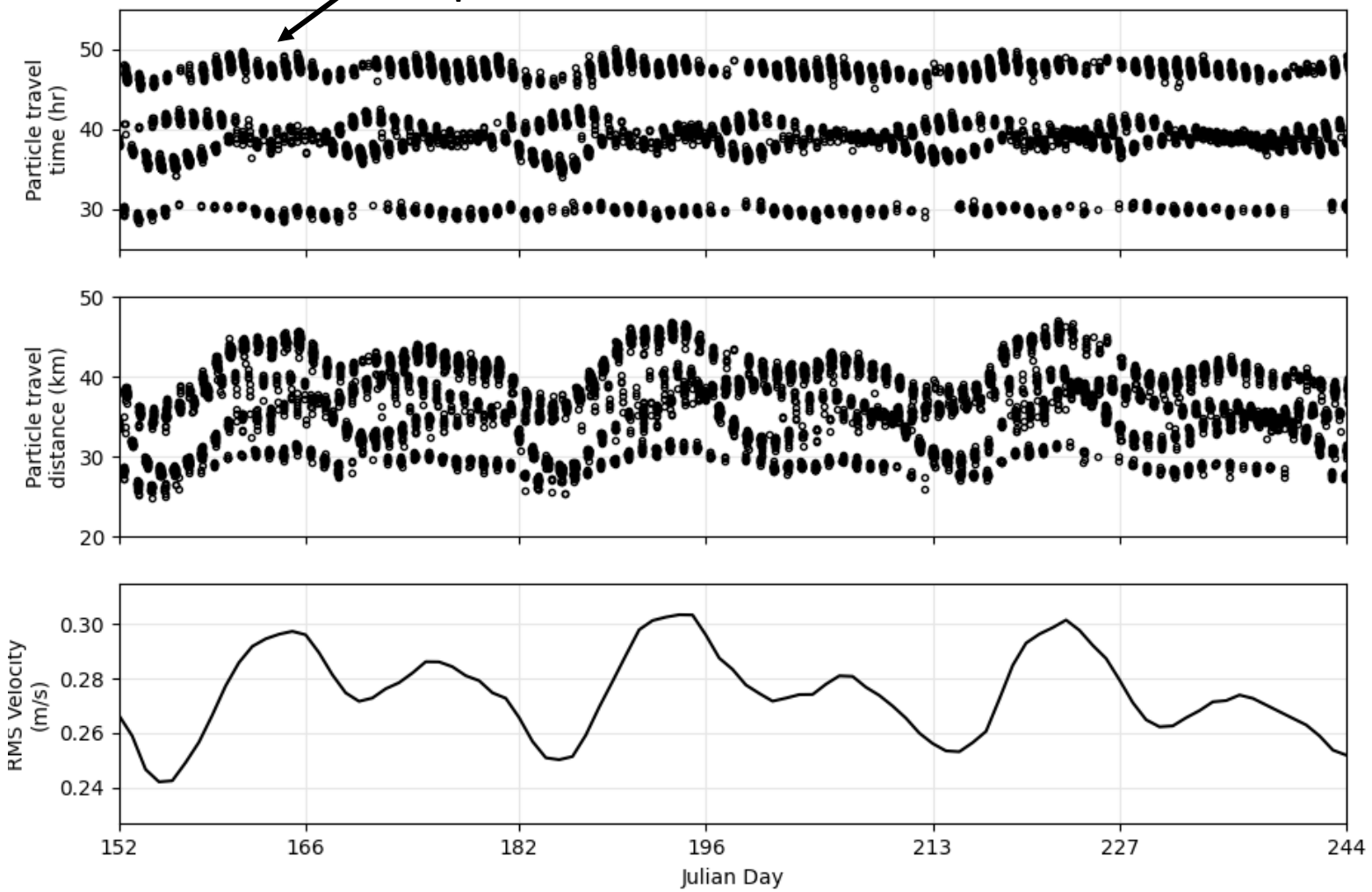
Travel Time and Distance Results - Particle Tracking



Travel Time and Distance Results - Particle Tracking

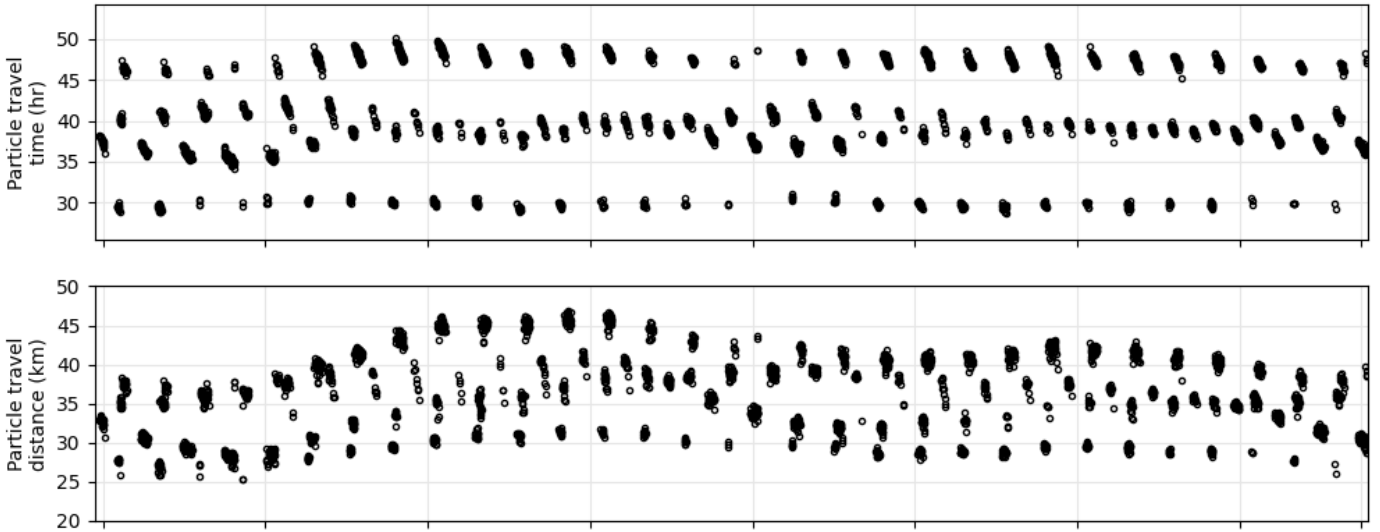
- Steady flow runs to understand system without having to deal with unsteady flows
- Results shown for Steamboat Slough, Sacramento flow = 10,000 cfs

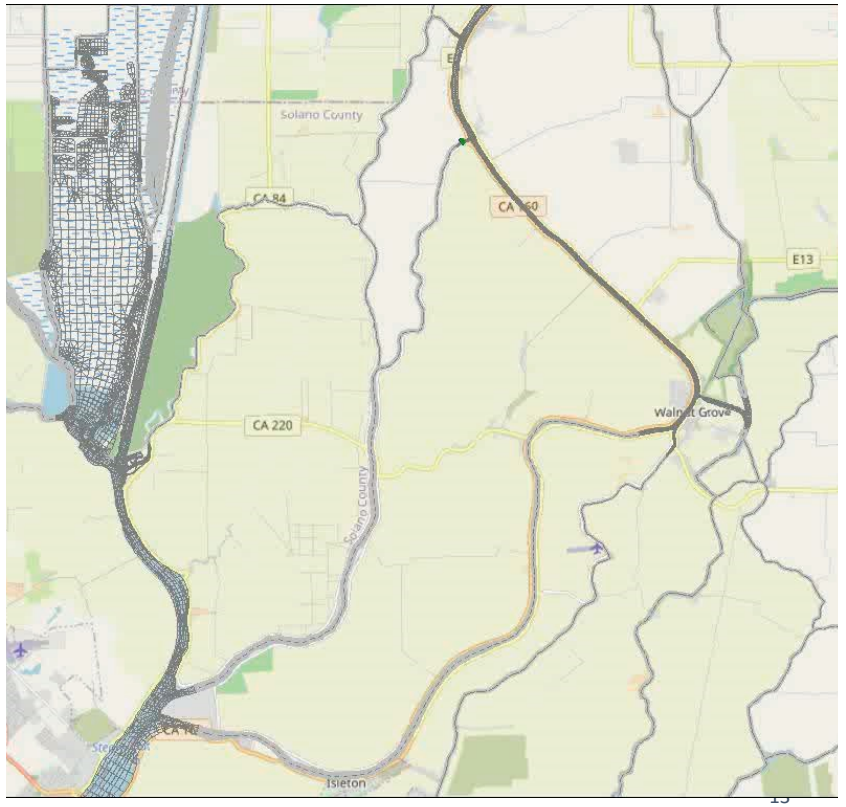
Each dot is data from a single simulated particle



Proxy for spring-neap character of flows (Spring = stronger velocities and higher RMS)

Why are there several “rows” of results for particle travel time and distance?



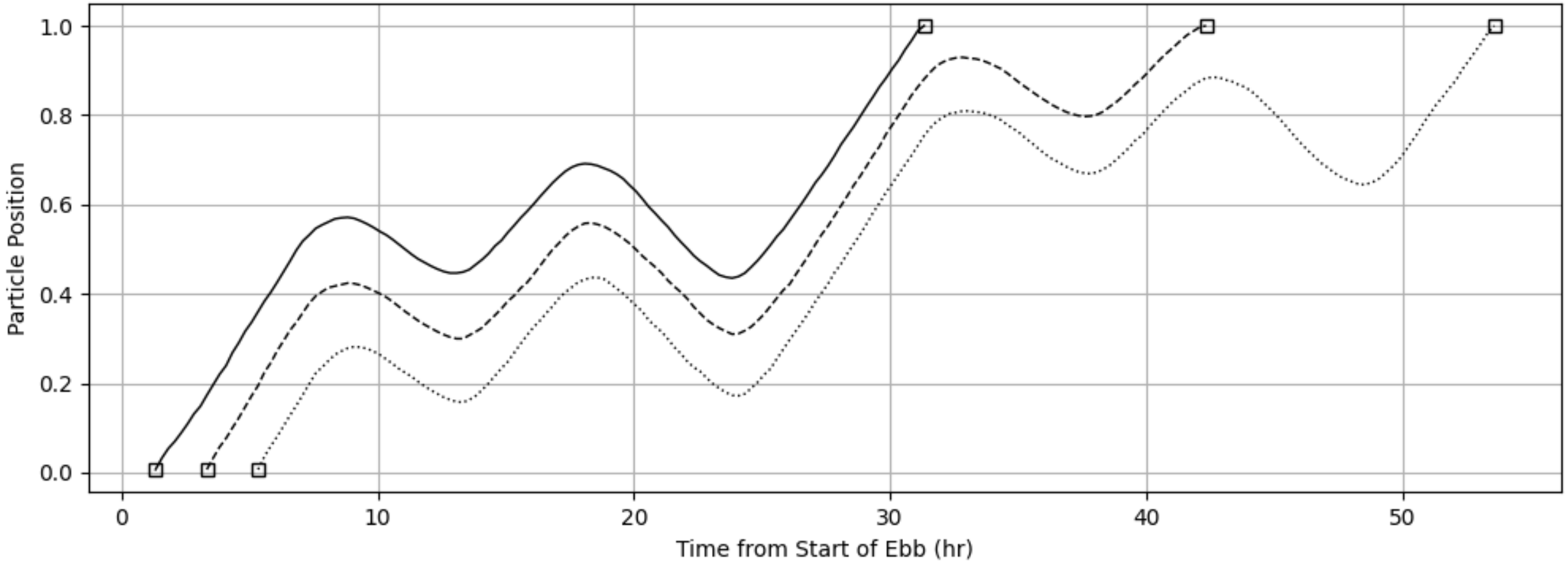


Length of reach is short compared to tidal excursion

Particles take whole number of back-and-forth excursions during their travel down the channel

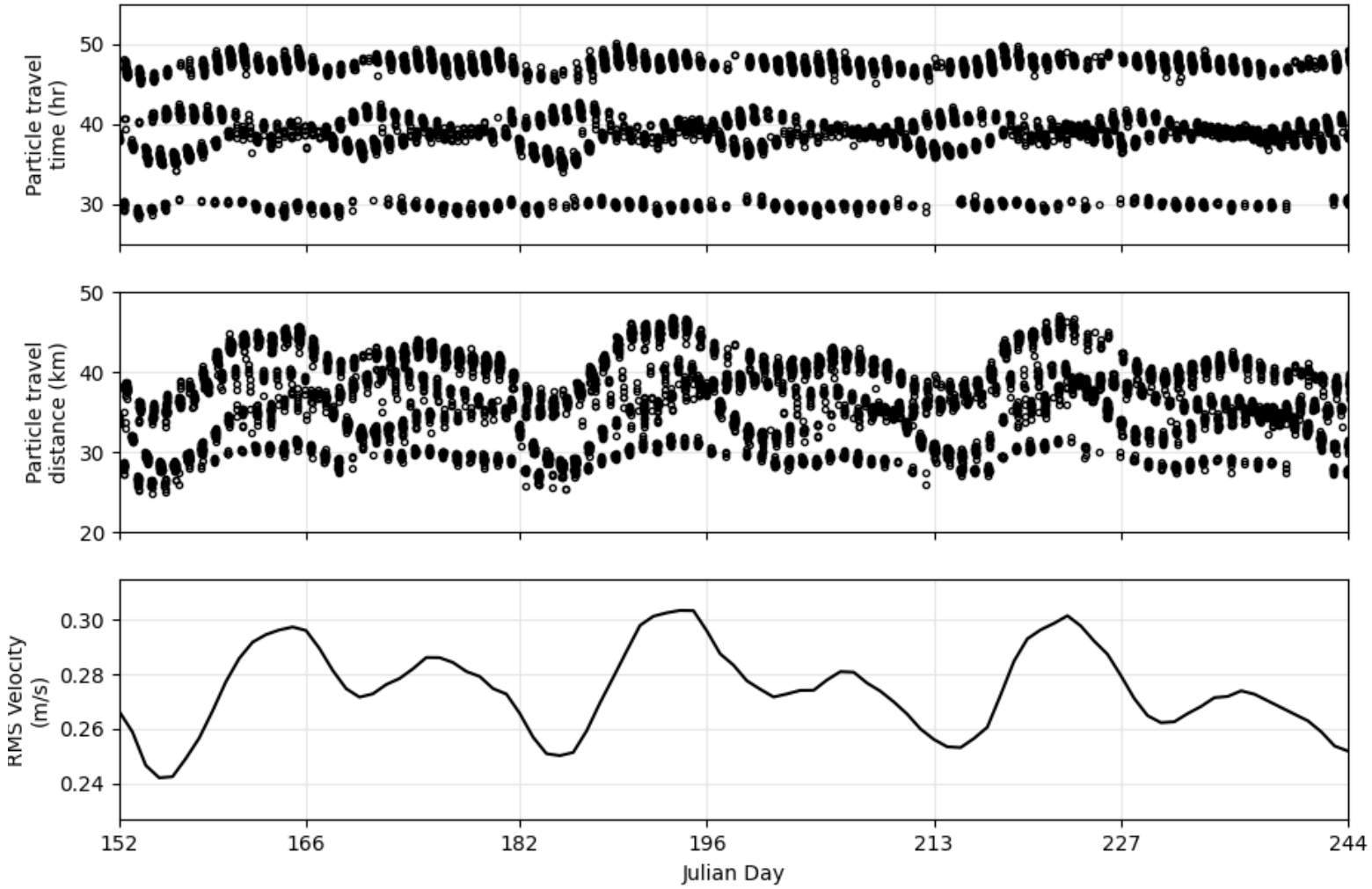
Large differences in particles entering on start of ebb vs end of ebb

Large differences in particles entering on start of ebb vs end of ebb



Spring-Neap Effects

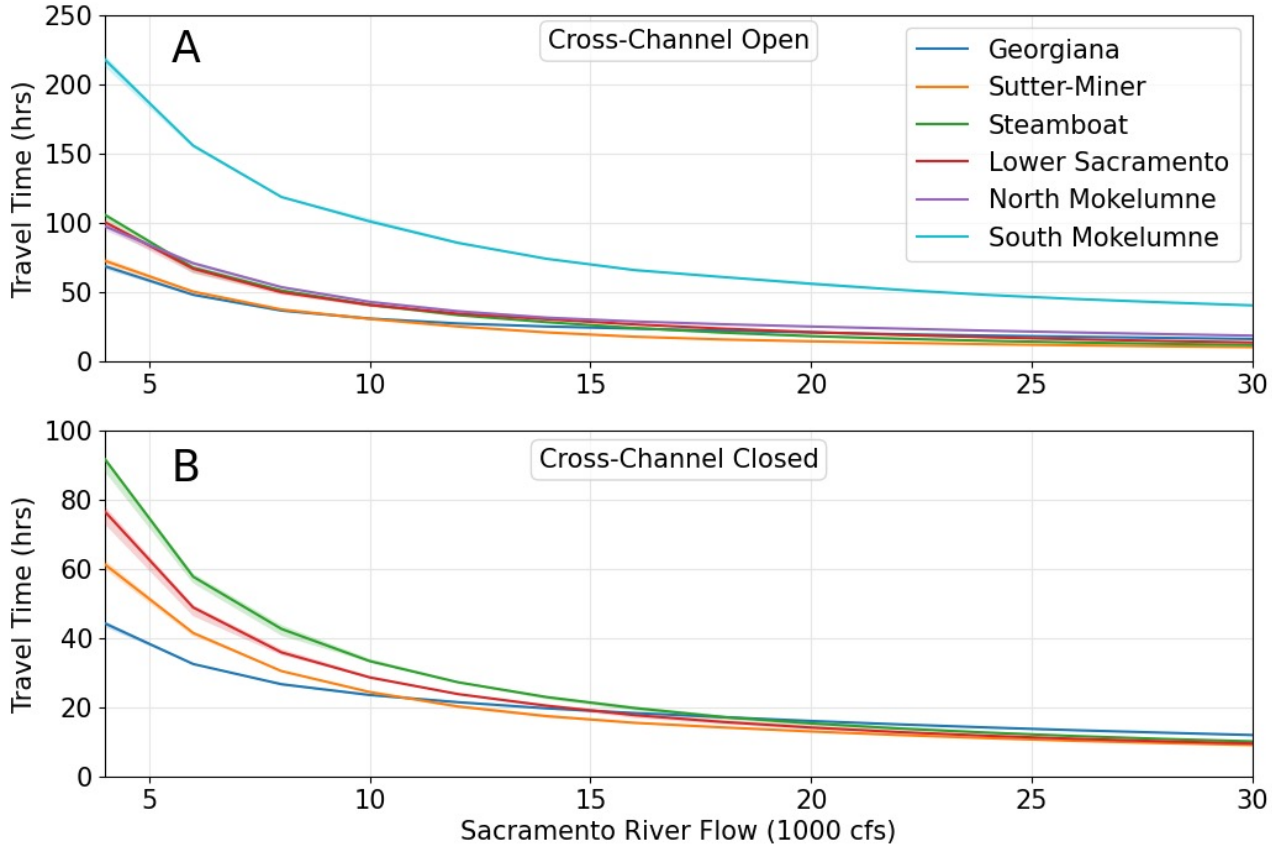
- More important at lower flows
- Spring tides make particles travel farther back and forth
- But don’t have a large impact on the time spent in the reach

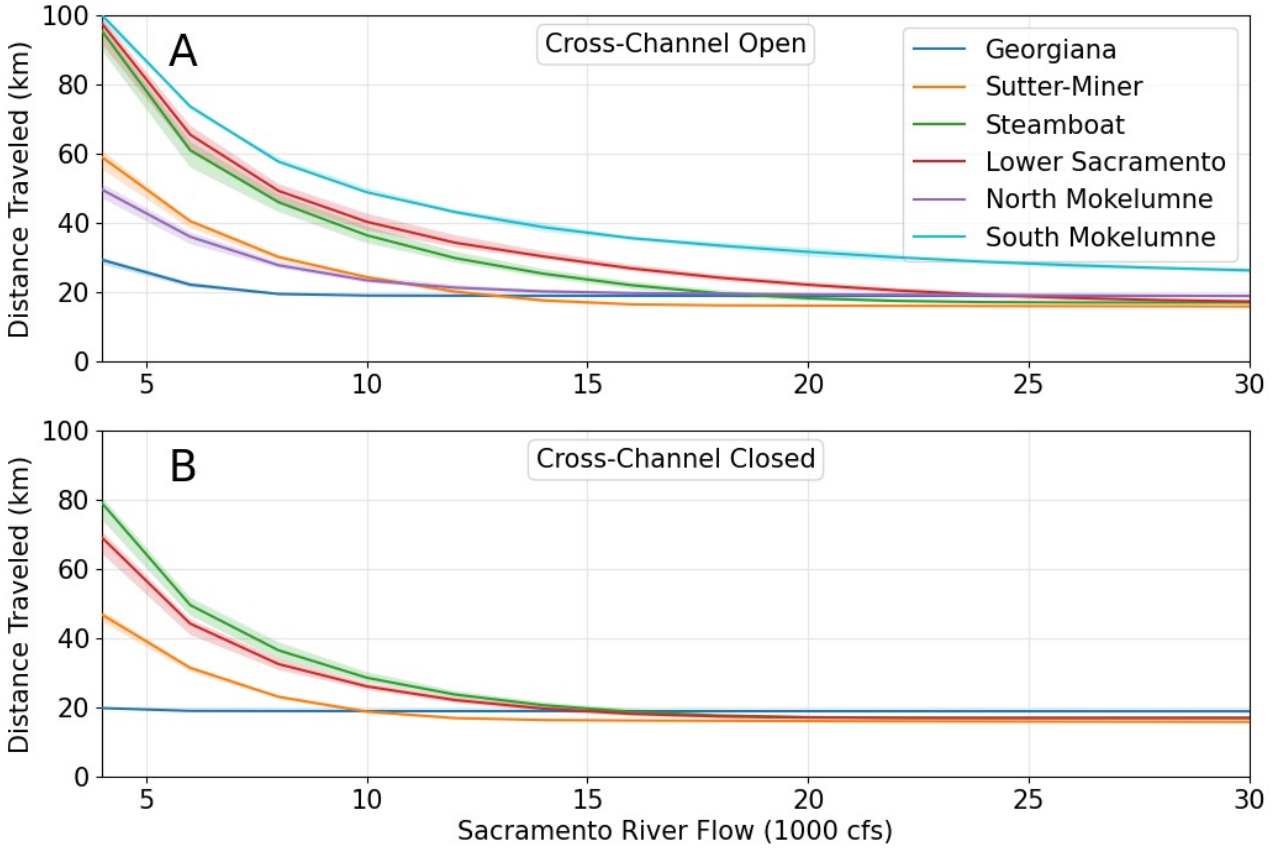


Trends with Sacramento River Flow

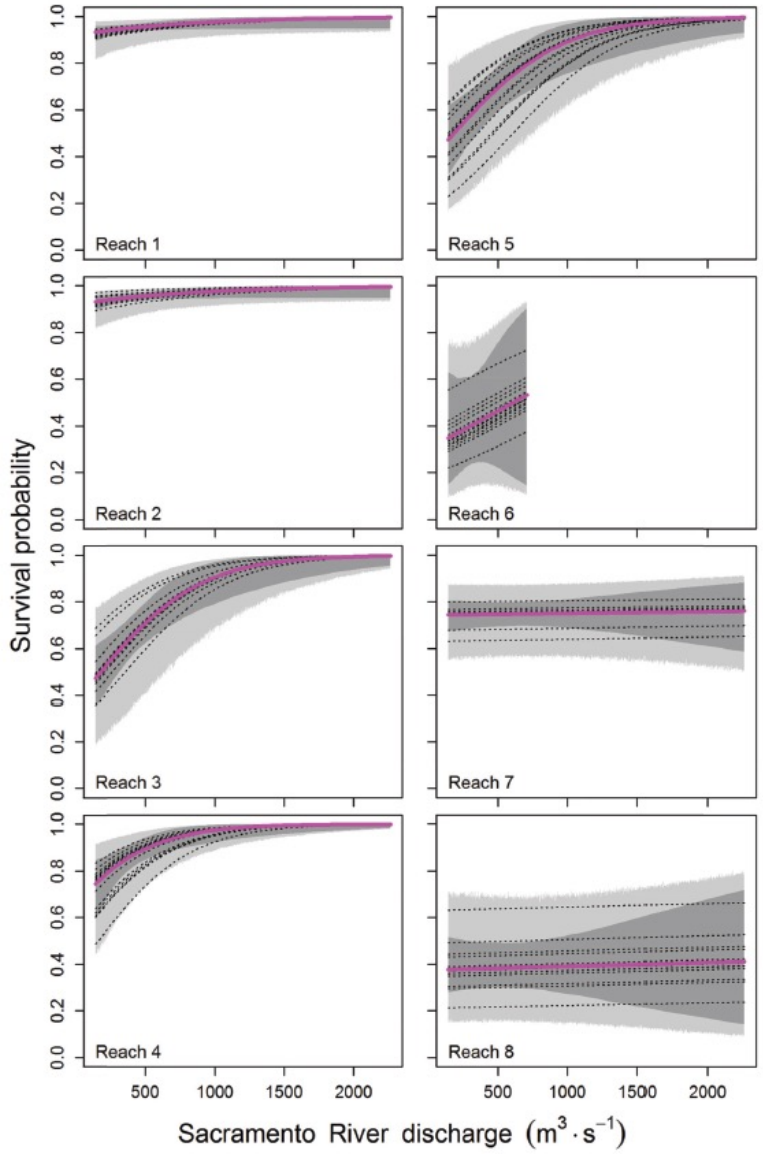
Travel time continues to decrease as velocities get incrementally faster

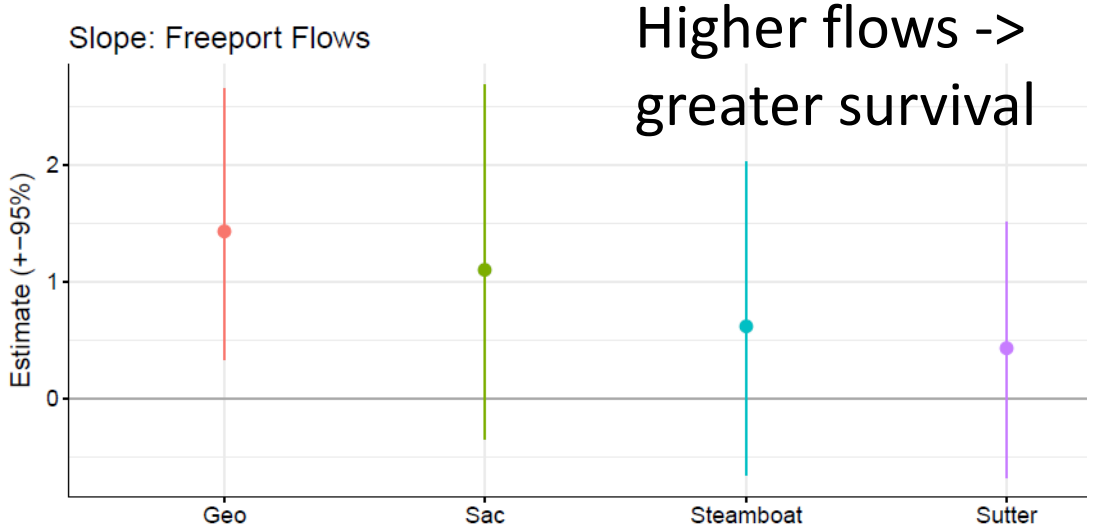
Distance traveled asymptotes to length of each reach



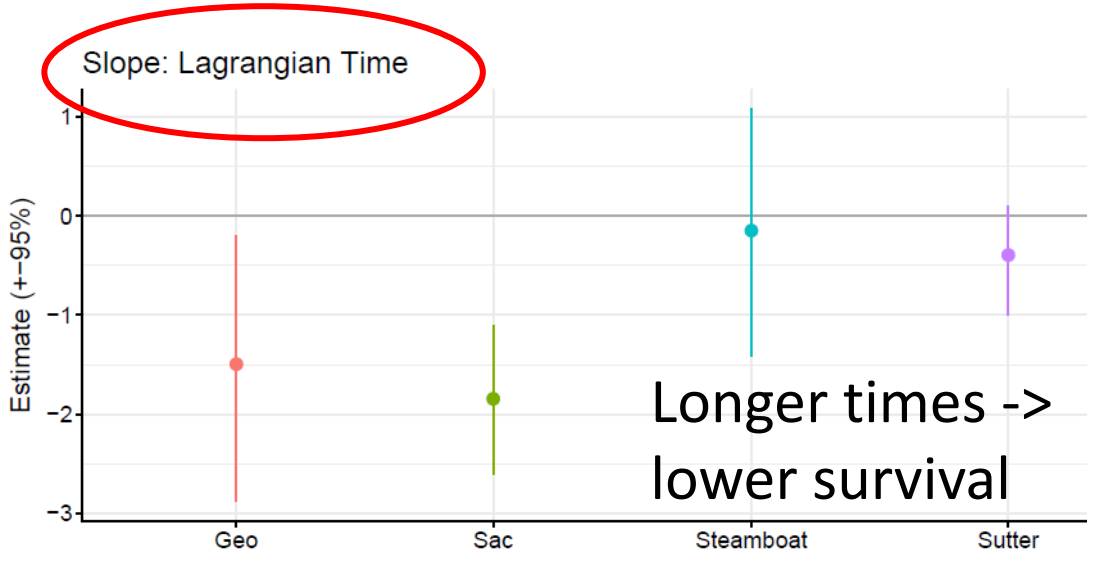


Historical Modeling Results: Is Travel Time or Distance Traveled a Useful Covariate in Predicting Juvenile Salmon Survival?





Higher flows -> greater survival



Longer times -> lower survival

Travel times showed greater predictive ability than travel distances

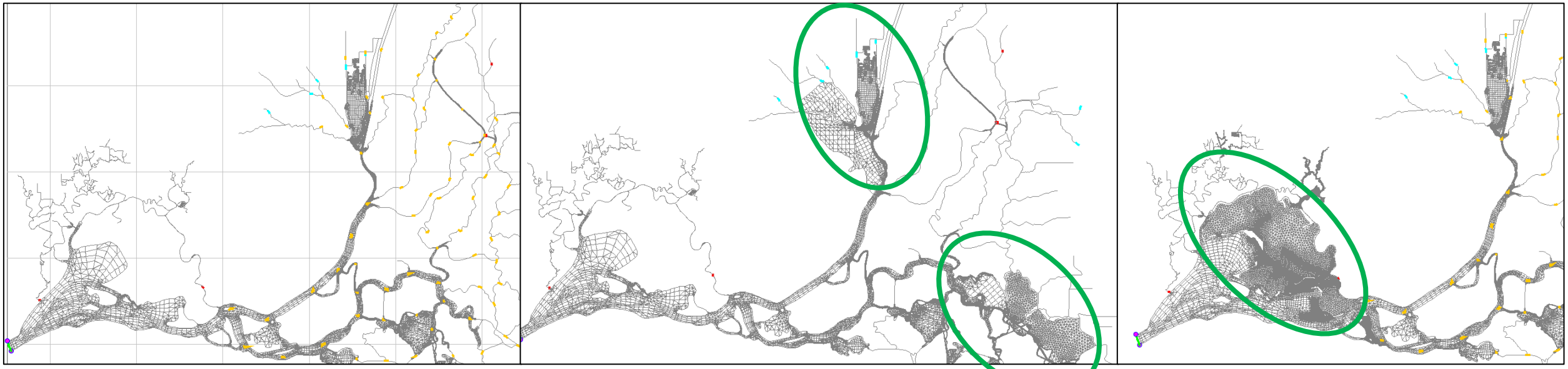
Preliminary Results from R. Perry, A. Pope, M. Dodrill (USGS)

Historical Modeling Results – What % of Particles Ultimate Reach Chipps Island?

Water Year	Reach				
	Sutter-Miner Slough	Steamboat Slough	Lower Sacramento	Georgiana Slough	DCC-Mokelumne
2007	73.6	75.1	72.8	12.5	2.2
2008	73.0	76.5	76.4	31.5	13.0
2009	79.3	81.8	81.8	35.5	26.1
2010	84.1	86.7	87.1	52.5	15.8
2011	88.6	92.3	92.7	79.9	14.2
Average	79.7	82.5	82.2	42.4	14.3

Many of these particles languish in low-residence time areas of the Central Delta or are entrained into the South Delta

Impacts of Large-Scale Tidal Marsh Restoration

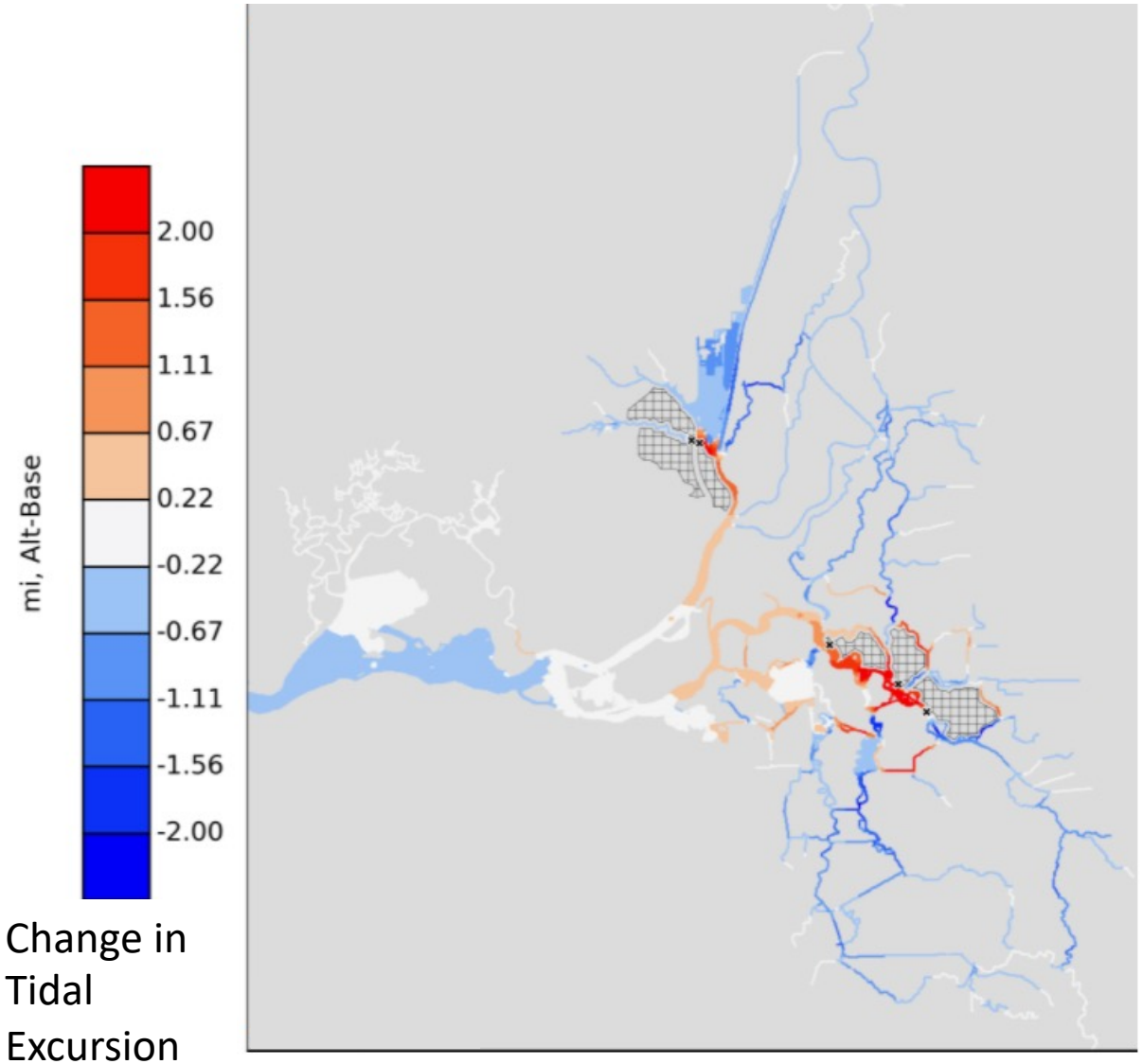


Base

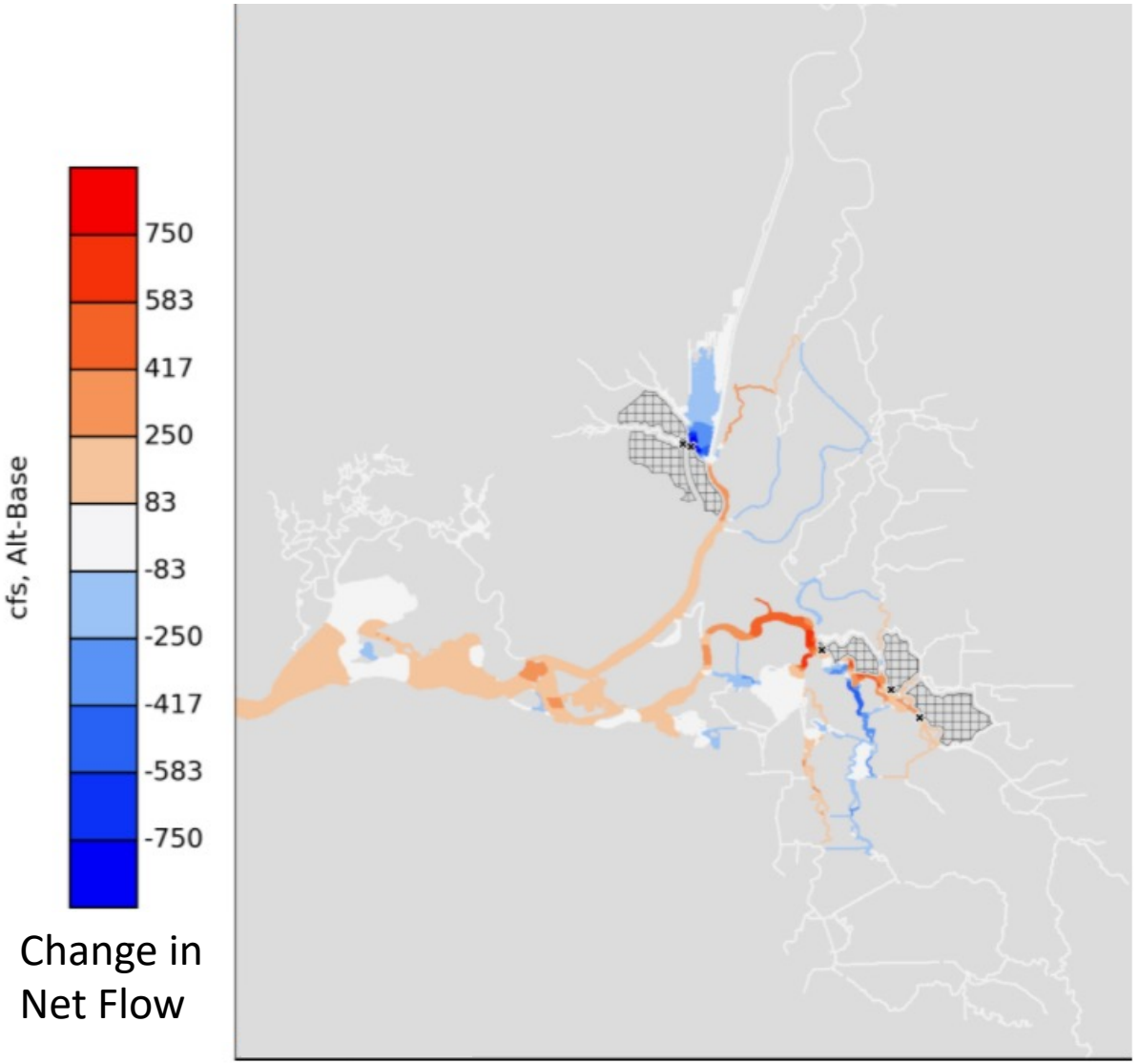
Cache Slough and Central Delta Restorations

Grizzly Bay Restoration

Why Choose These Restoration Scenarios?



Change in Tidal Excursion



Change in Net Flow

Reductions in Travel Time and Distance With Large-Scale Restorations

Grizzly Island Restoration Scenario

Reach	Sacramento River Flow					
	10,000		16,000		24,000	
	Travel Time Change (%)	Distance Change (%)	Travel Time Change (%)	Distance Change (%)	Travel Time Change (%)	Distance Change (%)
Sutter-Miner	0.1	-1.4	0.4	-0.2	0.7	0.1
Steamboat	-0.4	-2.2	-0.7	-2.2	-0.4	-0.3
Georgiana	0.5	0.0	0.8	0.0	0.6	0.0
Lower Sac	-0.2	-1.8	0.0	-1.7	-0.6	-1.5
N Mokelumne	-1.0	-0.8	0.7	-0.1	1.1	0.3
S Mokelumne	-1.7	-1.3	1.2	-0.1	1.7	0.3

No significant impacts

Cache + East Delta Restoration Scenario

Reach	Sacramento River Flow					
	10,000		16,000		24,000	
	Travel Time Change (%)	Distance Change (%)	Travel Time Change (%)	Distance Change (%)	Travel Time Change (%)	Distance Change (%)
Sutter-Miner	-10.5	-24.0	-4.7	-1.6	-0.1	-0.1
Steamboat	7.4	-3.2	0.0	-7.4	-0.3	-0.7
Georgiana	5.2	-0.2	3.3	0.0	2.5	0.0
Lower Sac	9.4	-0.5	3.6	-5.6	-0.8	-5.1
N Mokelumne	-5.6	-12.5	-0.1	-2.4	0.2	-1.2
S Mokelumne	-15.0	-29.3	-7.2	-20.0	-3.9	-14.0

Changes caused by changes in net flow

Changes caused by changes in net flow and tidal dampening

What if There Was a Gate at the Head of Georgiana Slough?

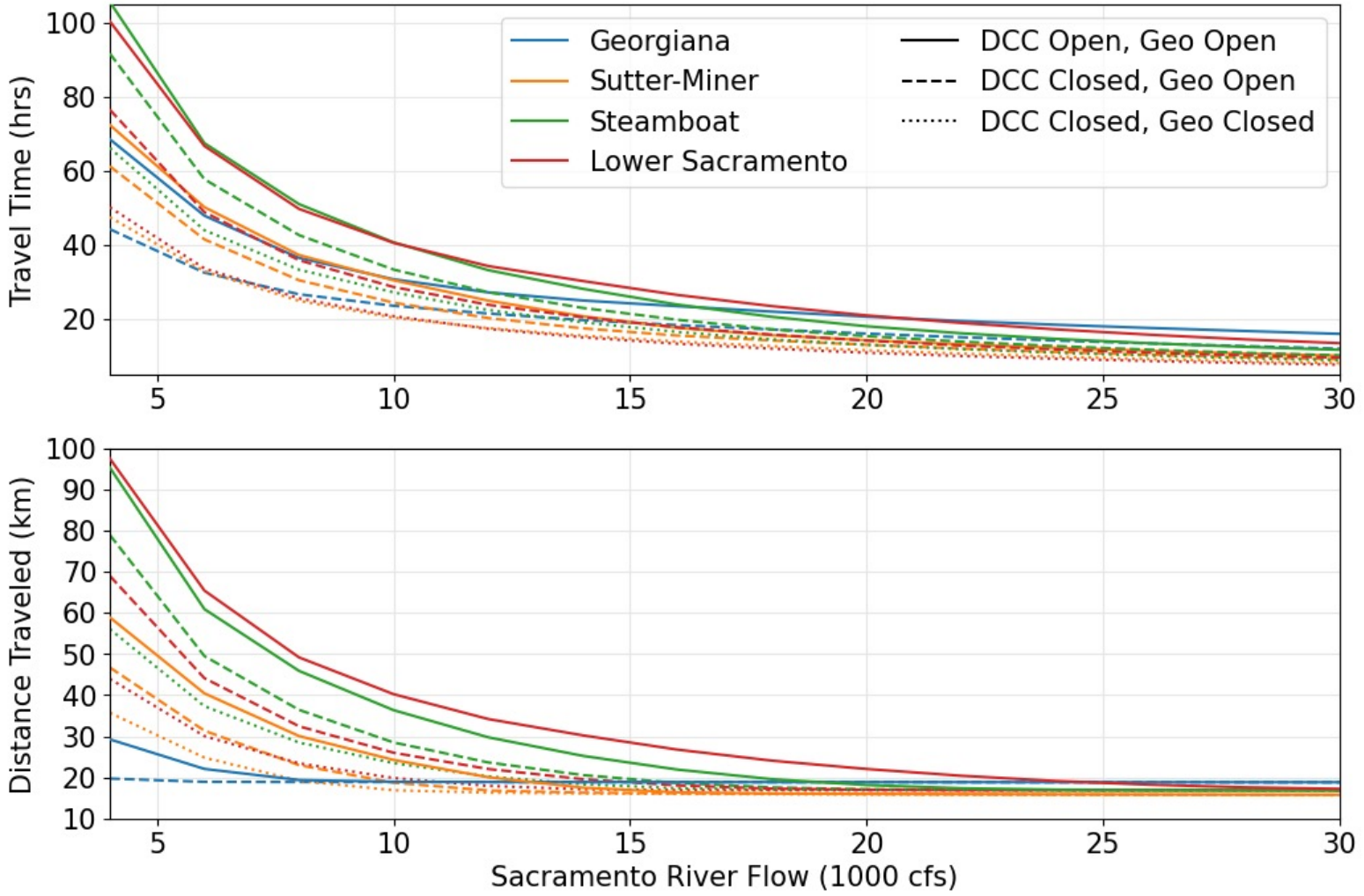
- Increase net flows through Sutter, Steamboat, Sacramento
- Increase proportion of particles that ultimately reach Chipps Island

**Please address any comments/criticisms of this alternative to:

Jon Burau, USGS
jrburau@usgs.gov

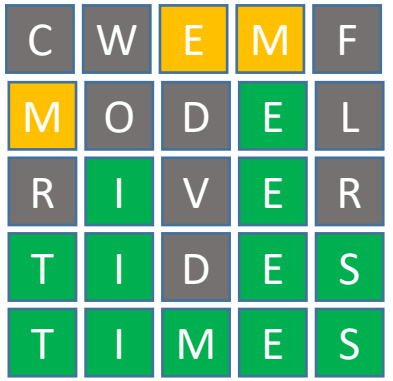
What if There Was a Gate at the Head of Georgiana Slough?

- At lower flows, travel times decrease 20-30% with DCC closed
- Decreases of 40-50% with DCC and Georgiana closed



Conclusions

- Hydrodynamic character of reaches in the North Delta can change between riverine and tidal in character over a relatively narrow range of flows
  - Can also change with spring-neap tidal conditions
- Travel times and distances dependent on when particle enters reach, relative to start of ebb tide
- Changing tide strength impacts distance traveled, but not travel time
- Restoration and operation changes have largest impacts on travel metrics when they change the net flow rather than just dampen the tides



Questions?

Contact Information

- Stephen Andrews, Ph.D.
  Senior Water Resources Engineer
  Resource Management Associates
  1756 Picasso Ave, Suite G
  Davis, CA 95618
  (530) 564-7043
  steve@rmanet.com
  www.rmanet.com

Acknowledgements

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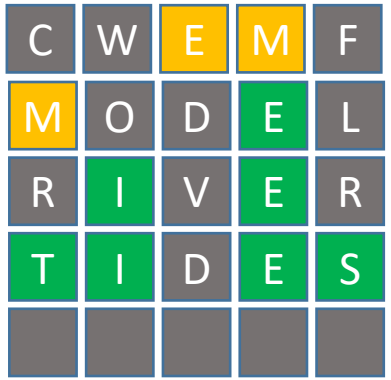
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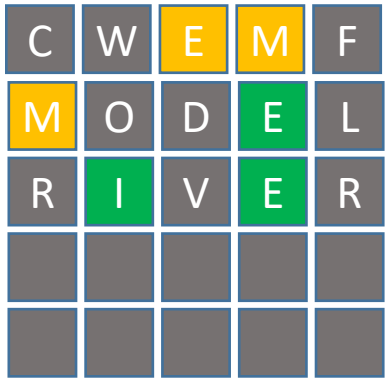
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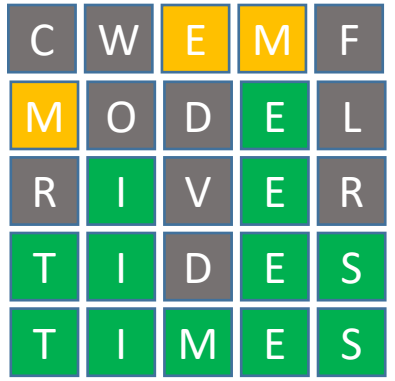
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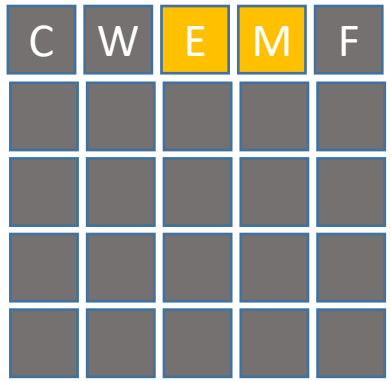
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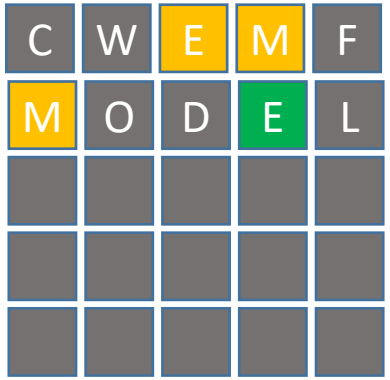
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