Phase 7 WSM Development – Progress & Next Steps for the Dynamic Watershed Model

Modeling Workgroup Quarterly Meeting – June 2023

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Another addition to the JAWRA Featured Collection: “Influence of Climate Change on Chesapeake Bay Water Quality”.

TITLE: WATER QUALITY IMPACTS OF CLIMATE CHANGE, LAND USE, AND POPULATION GROWTH IN THE CHESAPEAKE BAY WATERSHED

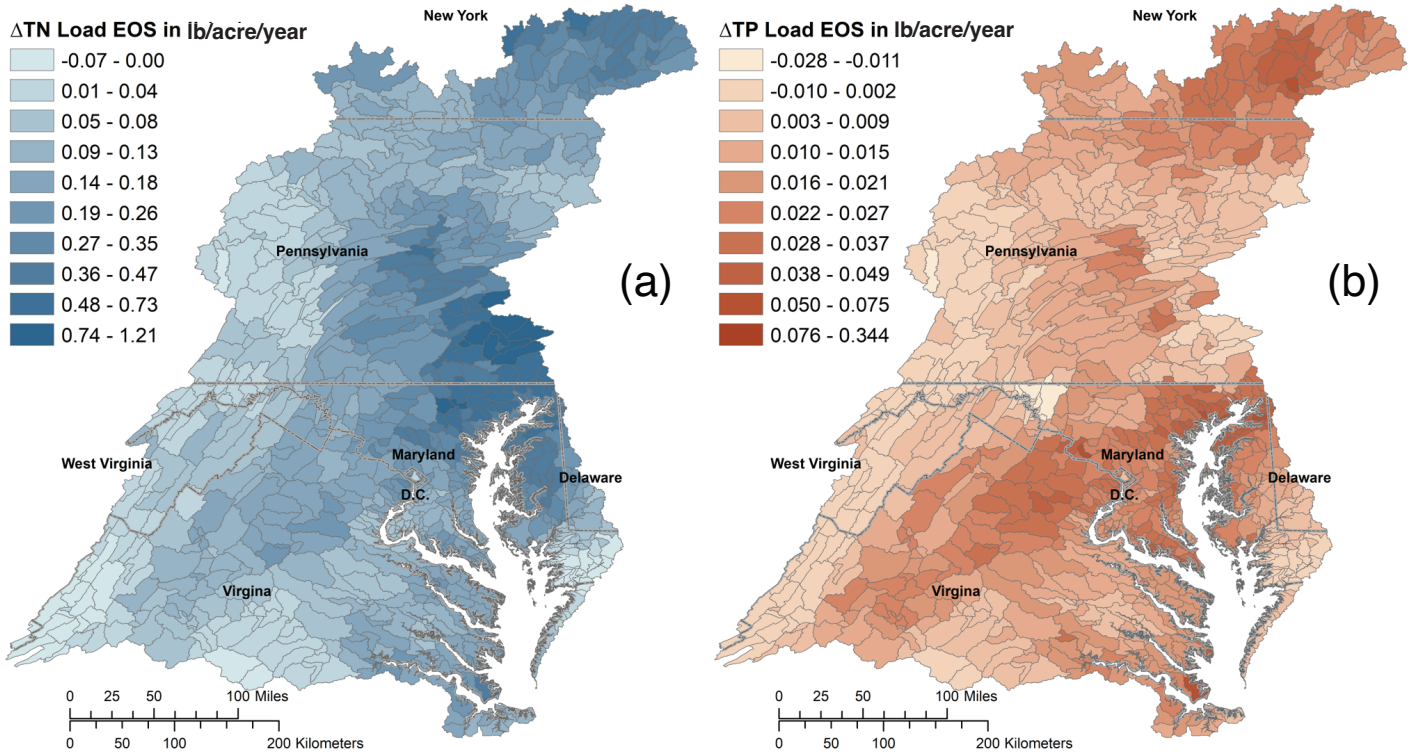


Figure: Changes in nutrient delivery to the tidal Bay due to 30-years of climate change assessed in the 2025 scenario. Average change in edge of stream (EOS) delivery of (a) total nitrogen (ΔTN), and (b) total phosphorus (ΔTP) loads.

Accepted
Article DOI: 10.1111/1752-1688.13144

*“The entire effort was guided by the participation and inputs from state, federal, and academic stakeholders as well as by recommendations of the **CBP’s Modeling Workgroup** and Scientific and Technical Advisory Committee (STAC), an independent expert committee that provides scientific and technical guidance to the CBP (Pyke et al. 2008, 2012; Johnson et al. 2016; Shenk et al. 2021a).”*

*“By suggestion of the **CBP Modeling Workgroup**, we then calculated …”*

Presentation Outline

Phase 7 Dynamic Watershed Model (DWM)

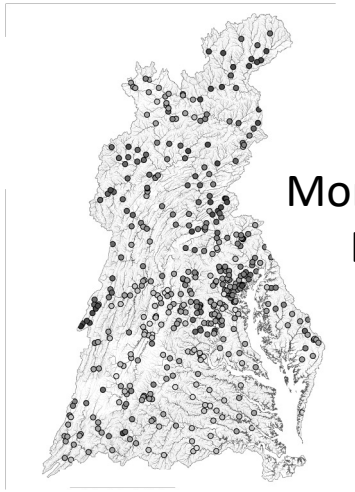
1. **Dynamic Watershed Model Overview**
2. **Summary of prior model development progress**
3. **Issues and refinements that we said we want to make**
4. **Updated model segmentation**
   - Reclassification of streams (non-tidal, terminal, tidal)
   - Mainstem vs. streams
   - Subwatershed boundary
5. **Model Runtime**
6. **Summary and next steps**

Purpose

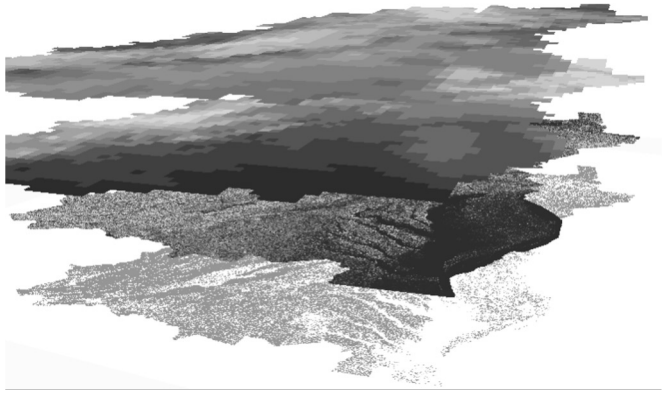
NHD Scale Dynamic Watershed Model (DWM)

- Inputs for the estuarine models (MBM/MTMs)
- Watershed model calibration and scenario applications
- Support research and collaboration activities

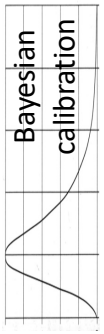
Framework: Spatial Model (CalCAST) → Dynamic Watershed Model (DWM)



Monitoring Data + Watershed characteristics & inputs



CalCAST spatial estimates

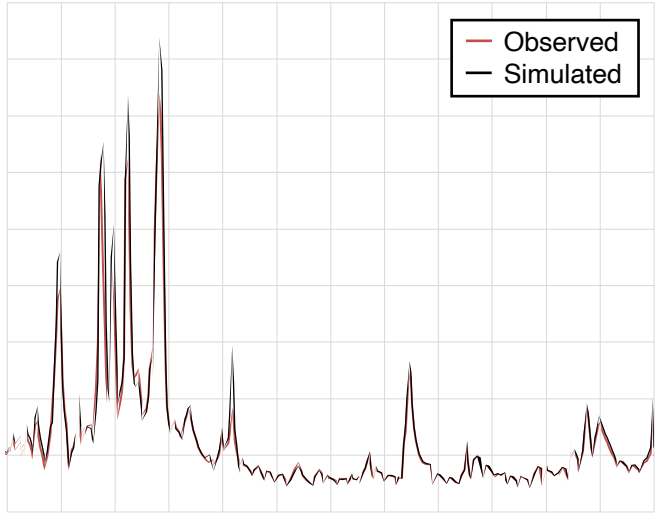


Time averaged estimates at land use & NHD catchment scale

DWM hourly estimates

Meteorological inputs, DWM parameters

Temporal disaggregation



- Data-driven CalCAST informs DWM parameters and responses.
- NHD-scale DWM prototype is now using CalCAST *average annual* (a) total flow, (b) stormflow, (c) sediment erosion and delivery factors, and (d) total nitrogen and total phosphorus loads and delivery factors.

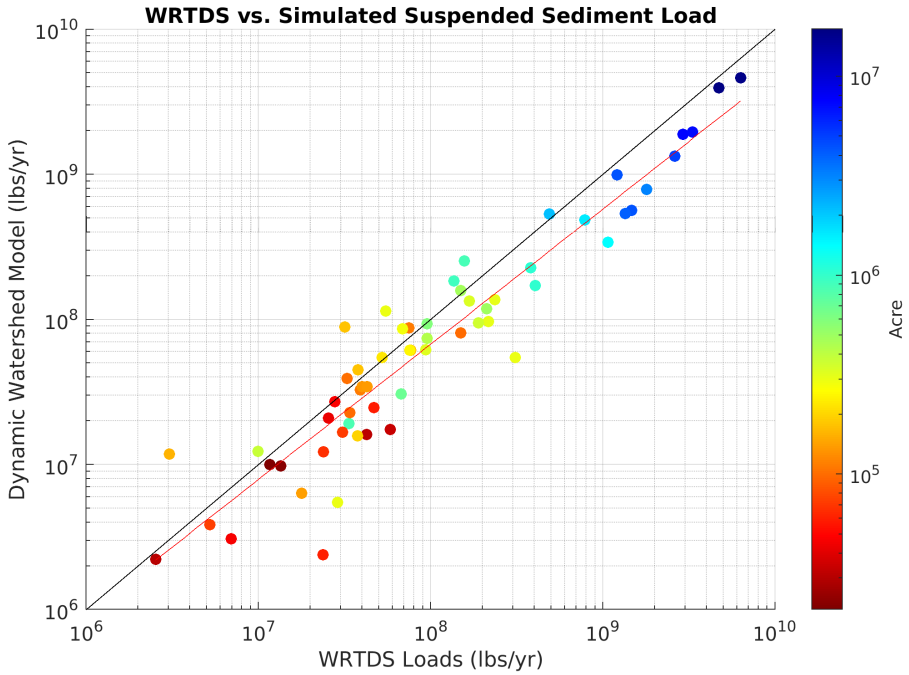
Dynamic Watershed Model (DWM) Development

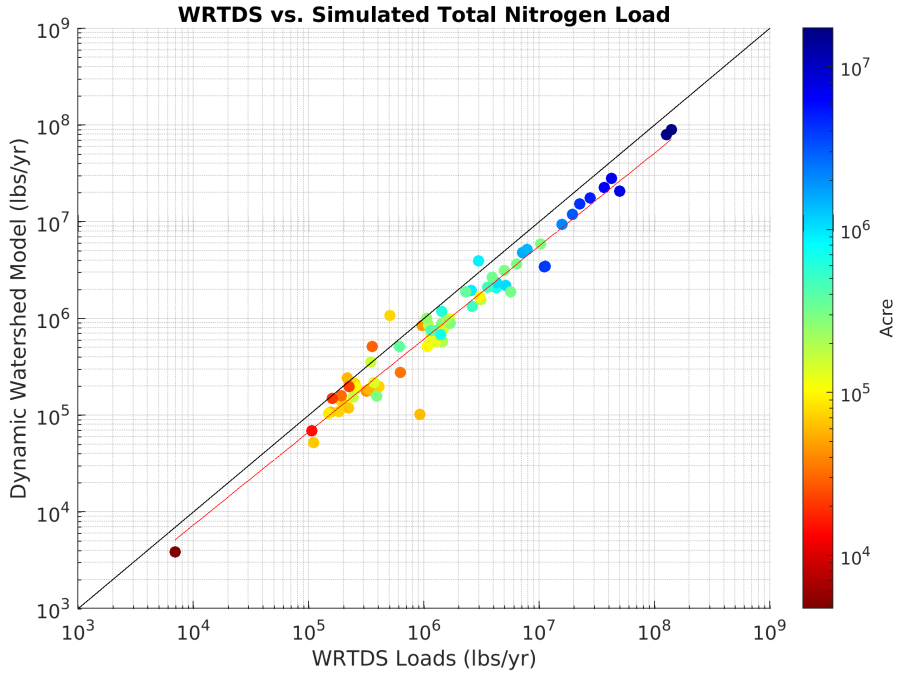
Development Milestones

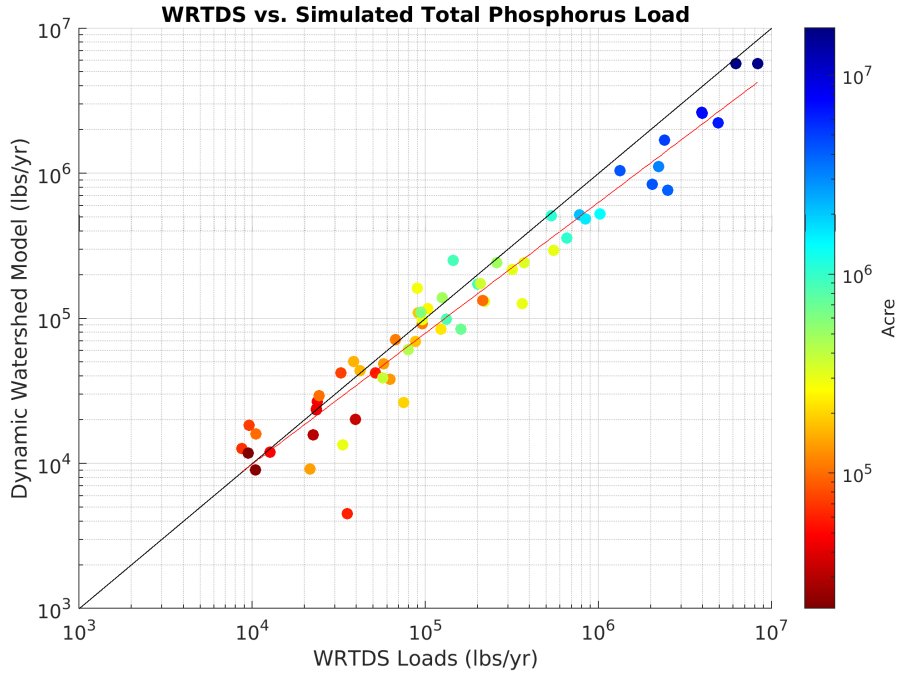
100K NHD	NHD-scale model structure; Hydrology prototype; Expanded simulation period 1985 to 2020; [1][2]
HYDROLOGY	Hydrology calibration (CalCAST→DWM) method updates; Simple routing (initial testing of numerical simplifications); [3]
SEDIMENT	Sediment model; Hydrology model calibration updates with respect to stormflow; [4]
NUTRIENTS	Nutrient (Nitrogen and Phosphorus) model; Updated sediment model; [5]

[1] https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/progress-in-phase-7-wsm-development-1.4.2022-gopal_bhatt_penn_state.pdf
[2] https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/progress_in_phase_7_wsm_development_4.5.2022_-_gopal_bhatt_penn_state.pdf
[3] https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/progress_in_phase_7_wsm_development_-_gopal_bhatt_penn_state_7.12.22.pdf
[4] https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/Progress-in-Phase-7-WSM-Development-Gopal-Bhatt-Penn-State-10.4.22-v2.pdf
[5] https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/Progress-in-Phase-7-WSM-Development-Gopal-Bhatt-Penn-State-1.10.2023.pdf

- **Operational prototypes**
- **Reasonable runtime (~29 hours)**
- **Reasonable model prototype results**
- **Need for improving/growing the model on multiple fronts**

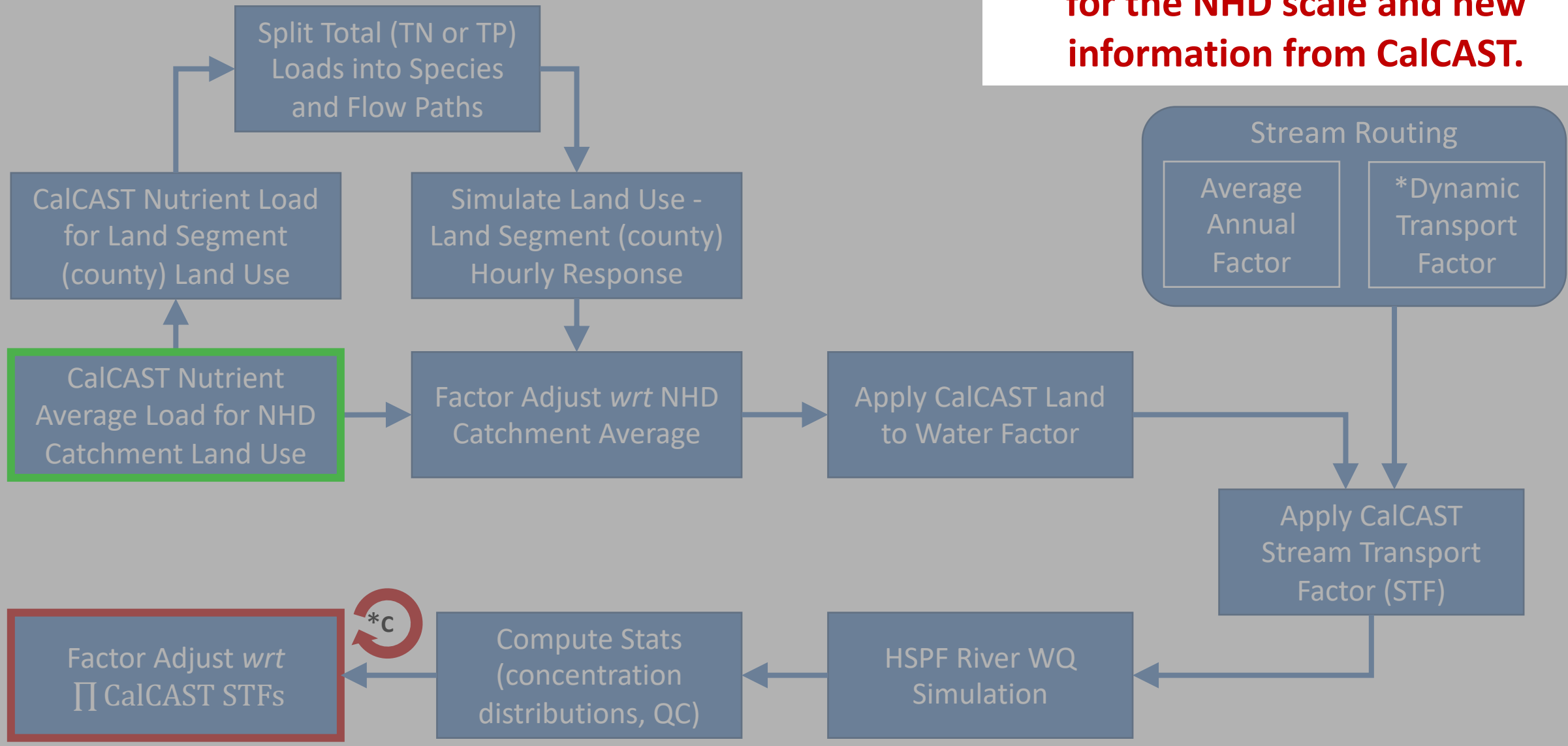






NHD Scale Nutrient Model Structure

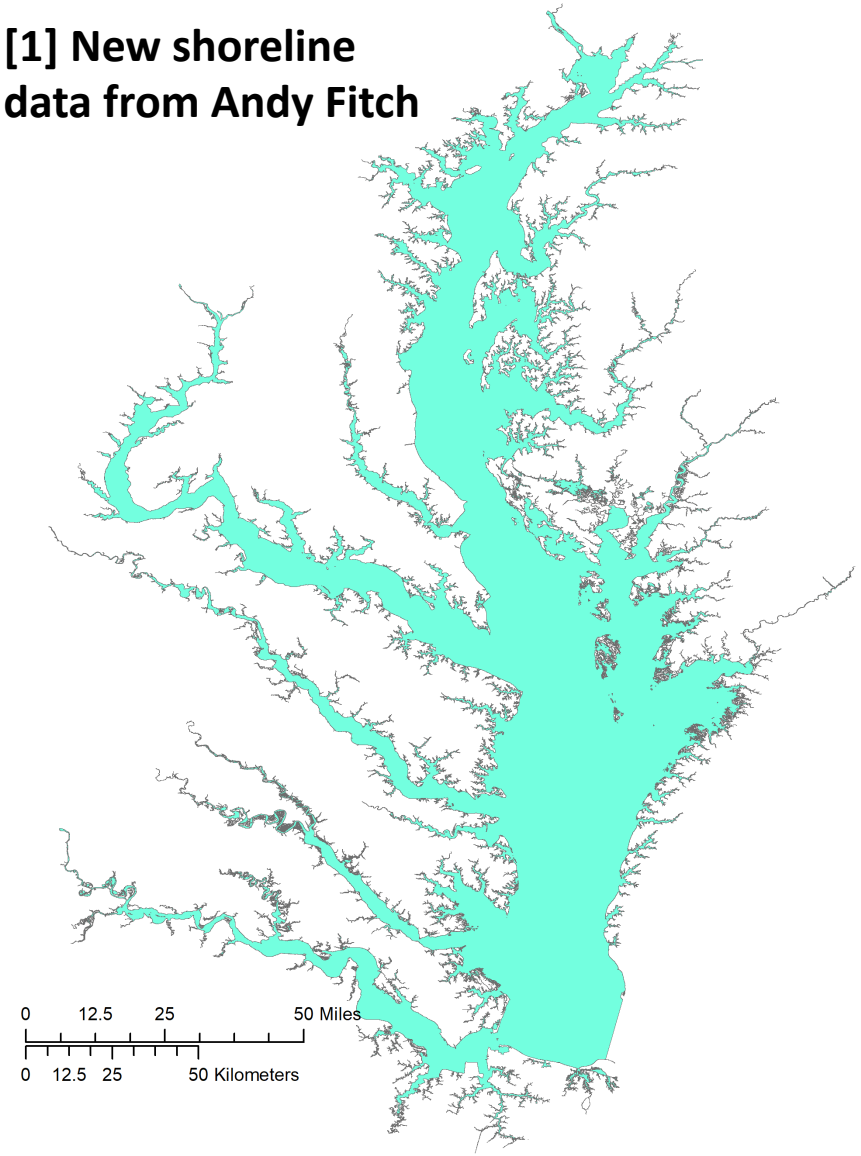
We are revising DWM structure for the NHD scale and new information from CalCAST.

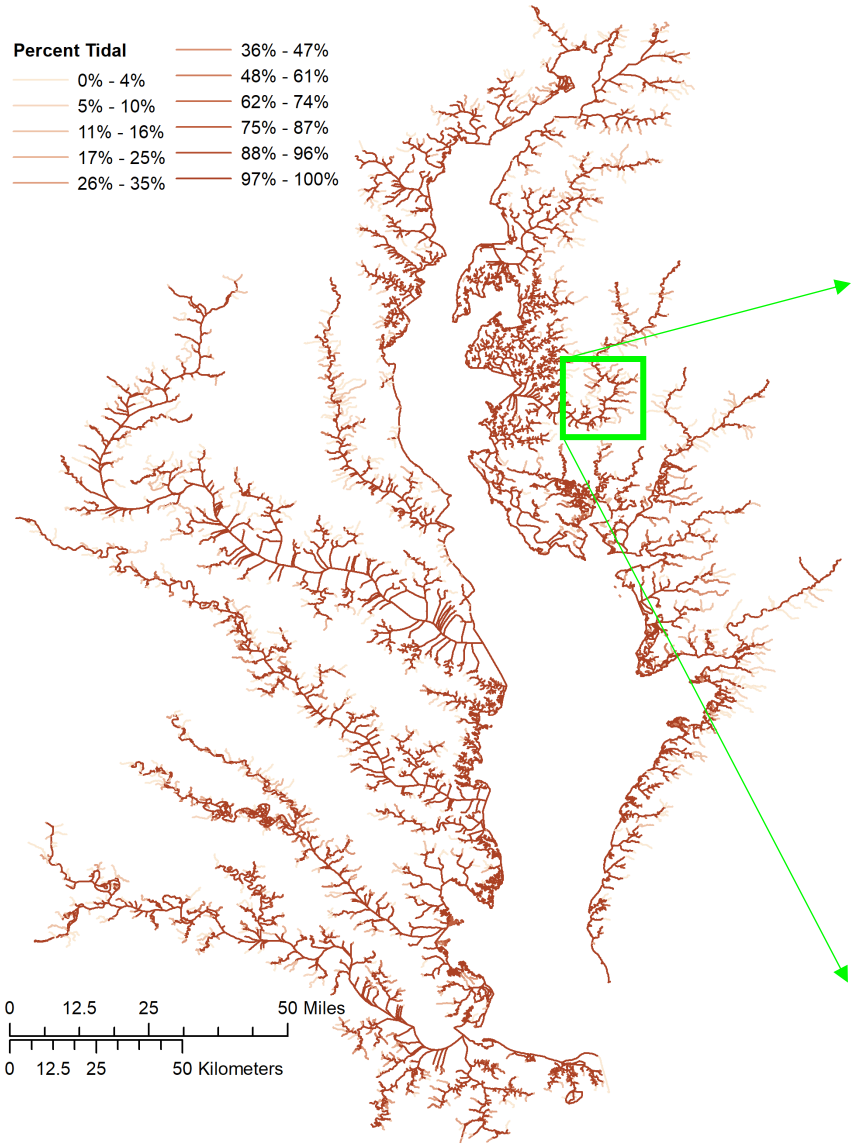


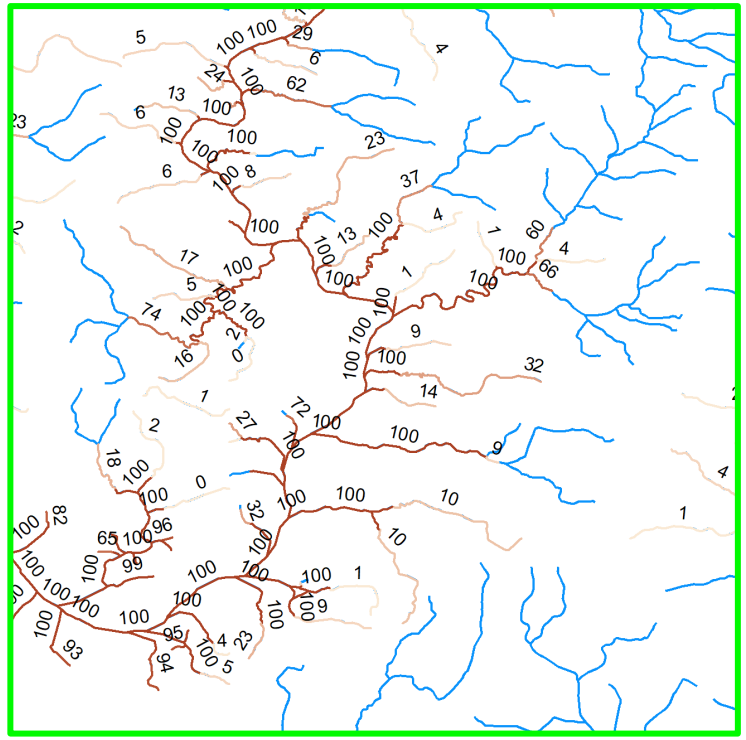
Modules marked with * are not yet implemented or applied in the prototype we are discussing today.

Towards linking DWM with the estuarine models …

[1] New shoreline data from Andy Fitch







<u>Percent Tidal Attribute</u>

Processing Steps:

- **GIS data processing; and**
- **Apply 3 quality constraints**

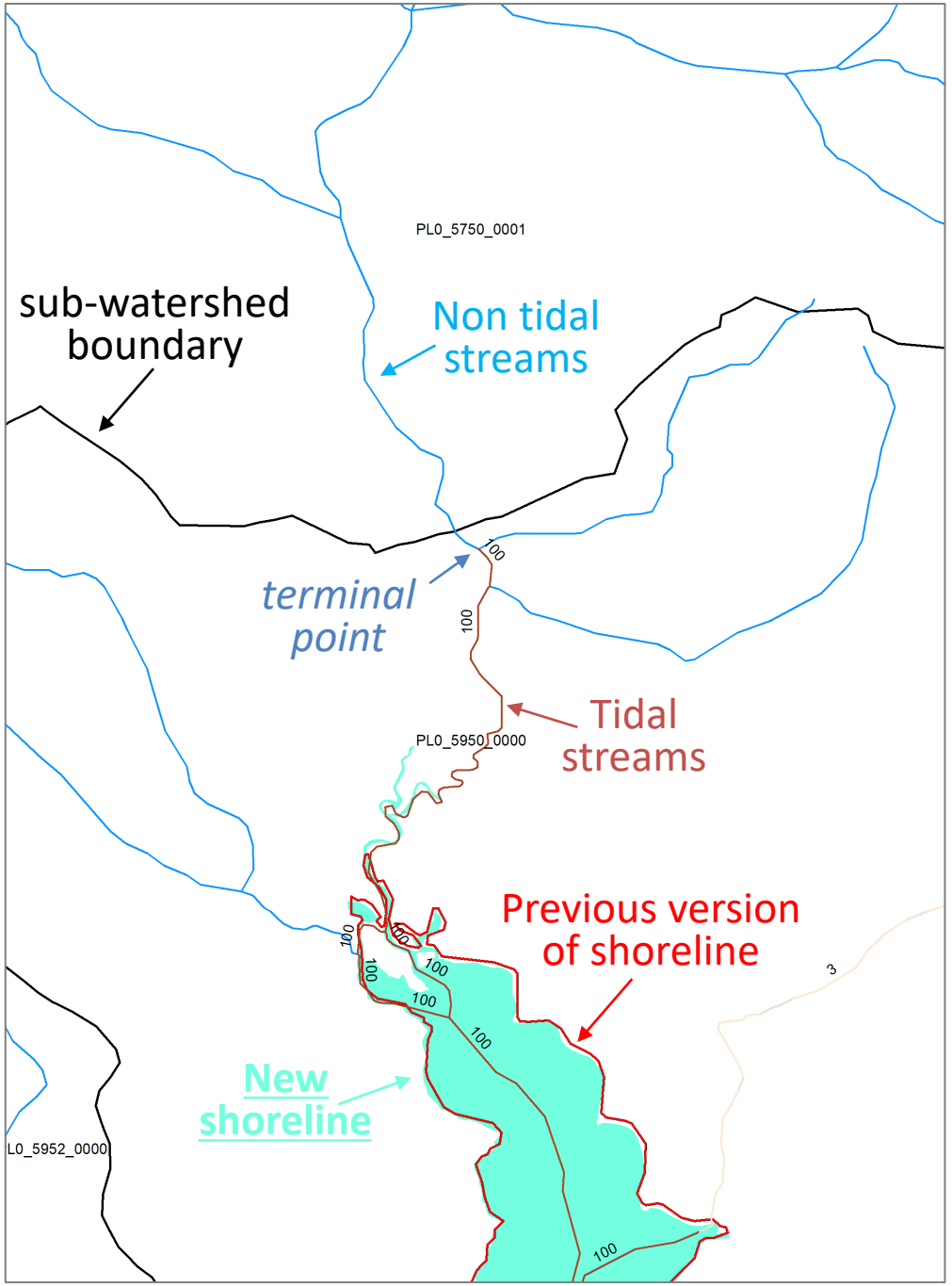
[1] https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/Progress-on-Phase-7-Watershed-and-Tidal-Water-Model-Boundaries-Andy-Fitch-CBPO-USGS.pdf

Quality constraints

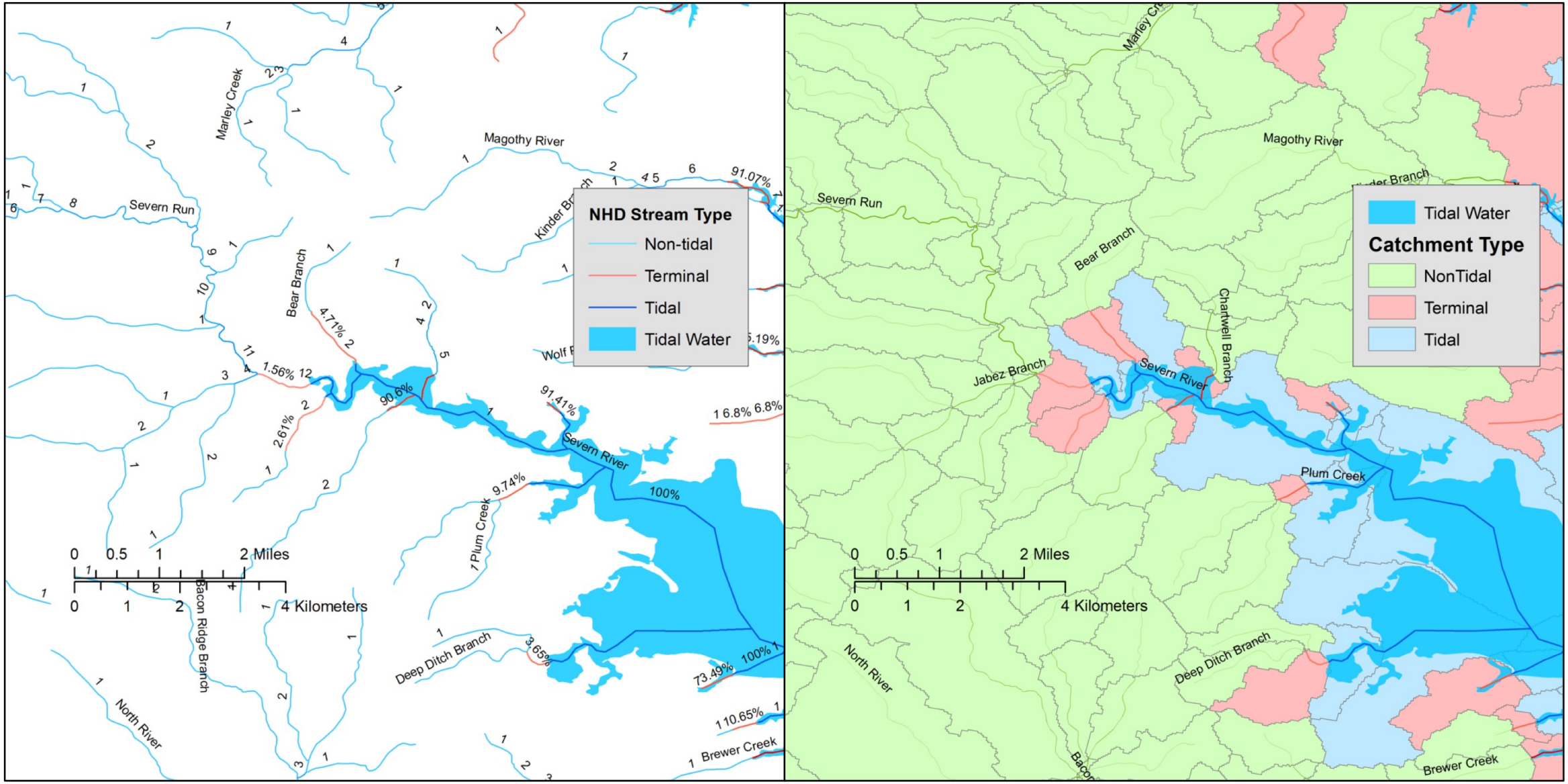
Constrain #1: Use Phase 6 segmentation boundary for guiding tidal delineation.

Constrain #2: If the upstream reach is tidal (i.e., % > 0) then downstream reach is 100% tidal.

Constrain #3: If the stream is a coastline, then it is 100% tidal.



Towards linking DWM with the estuarine model …

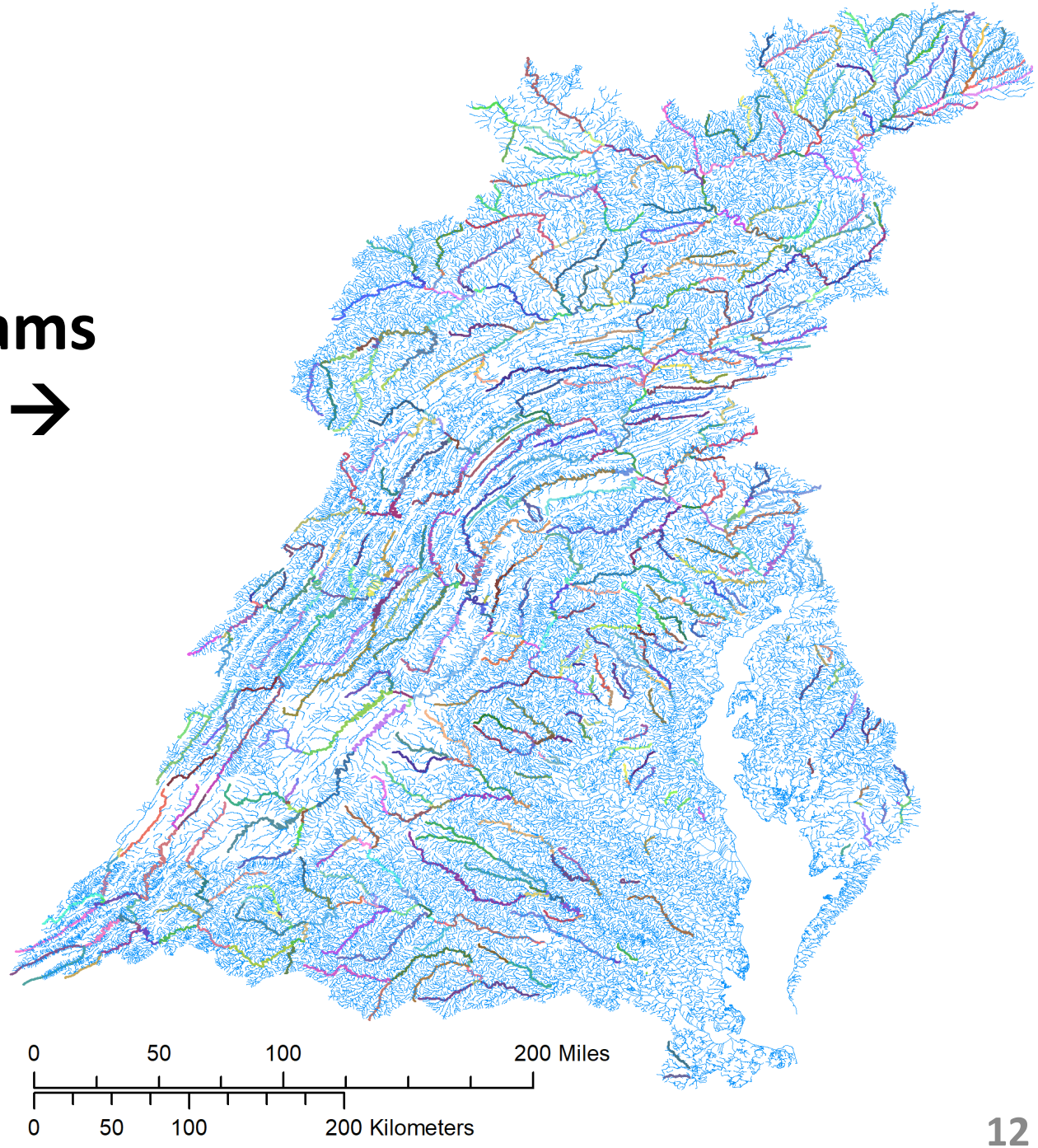


Updated segmentation …

nested model segmentation of streams and river mainstems →

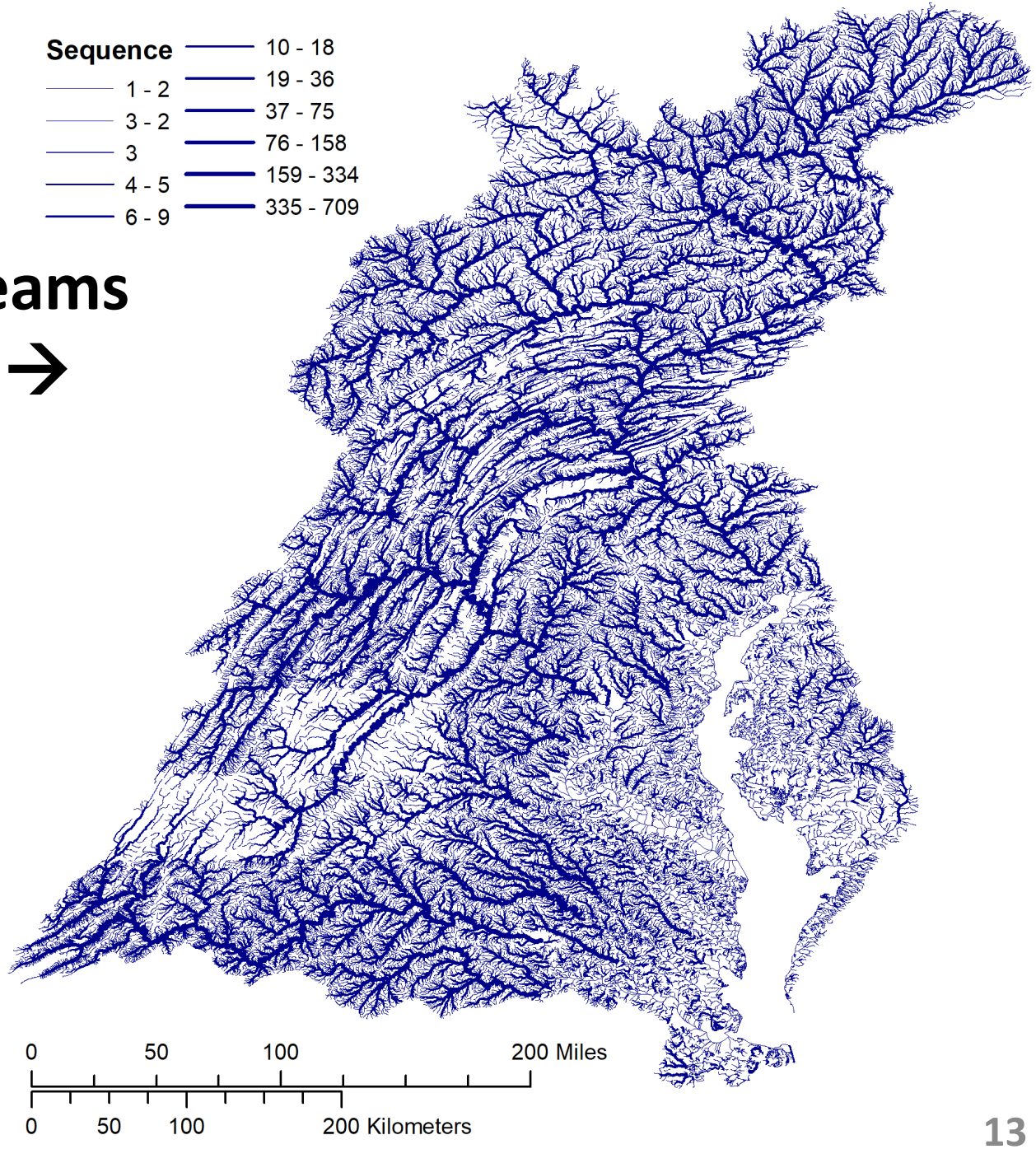
100K NHD STREAMS → Simple Routing

RIVER MAINSTEM → HSPF



Updated segmentation …

topology of nested streams and river mainstems →

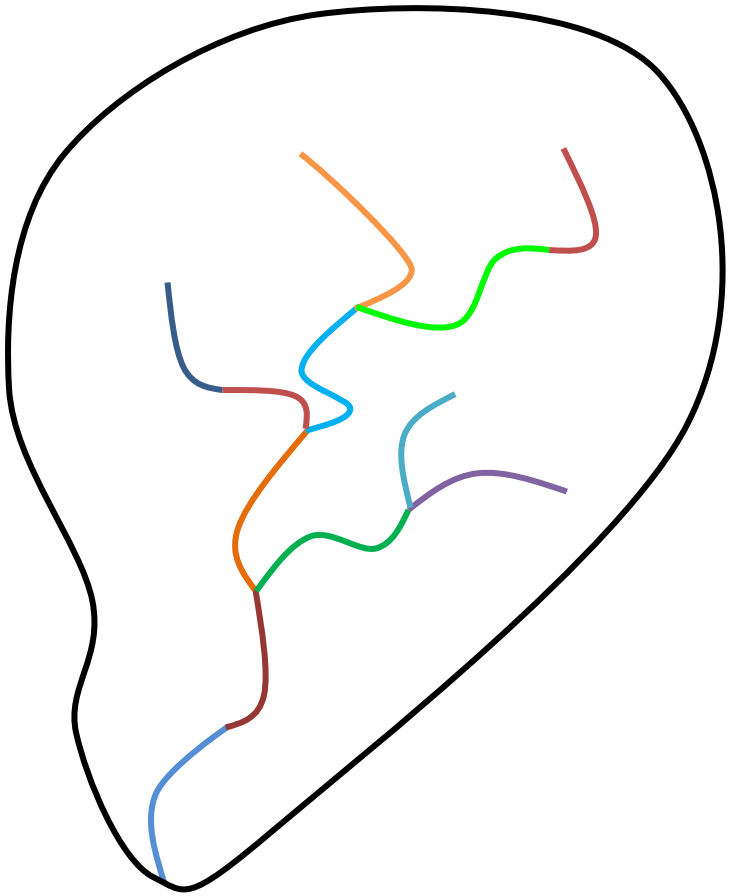


100K NHD STREAMS → Simple Routing

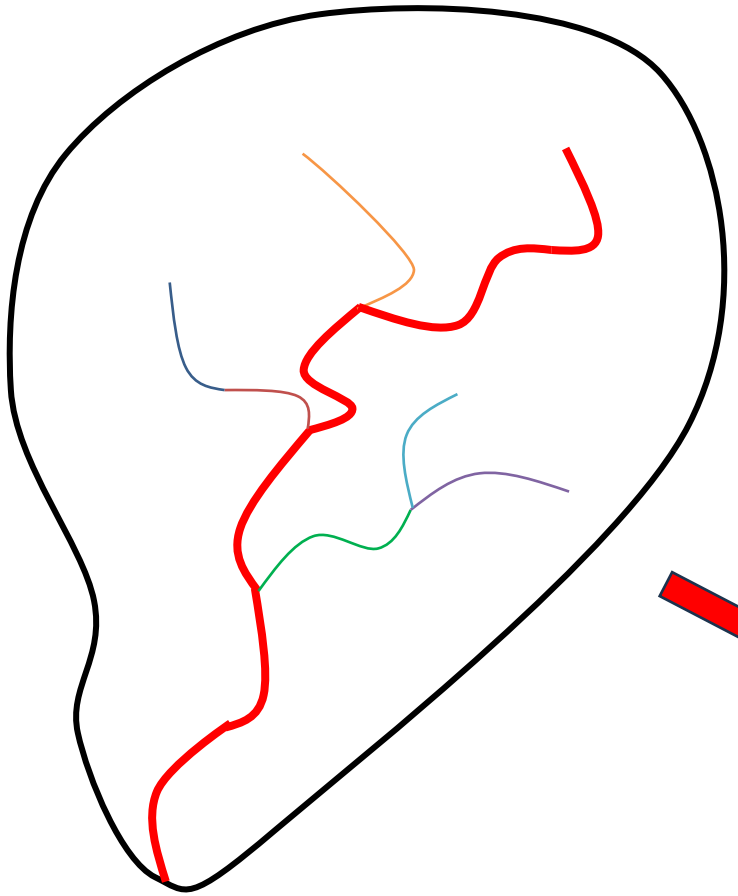
RIVER MAINSTEM → HSPF

Issues …

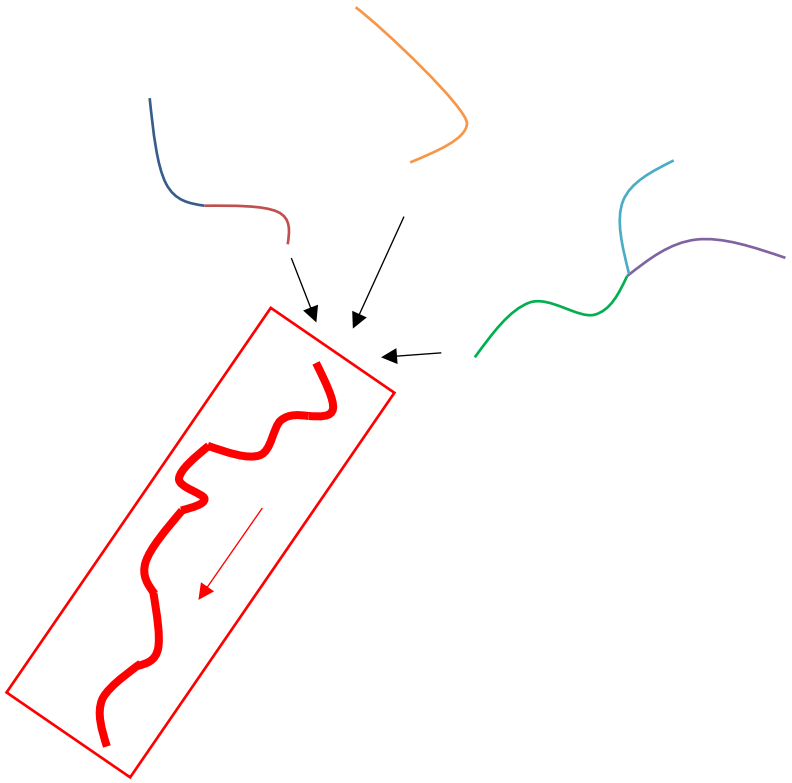
River (mainstem) delineation and ‘aggregation effect’



NHD streams



Nested streams & rivers,
Hybrid WQ simulation
(right now)



“aggregation effect”

An example …

We discussed a few ideas –

? stream order

? mean annual flow

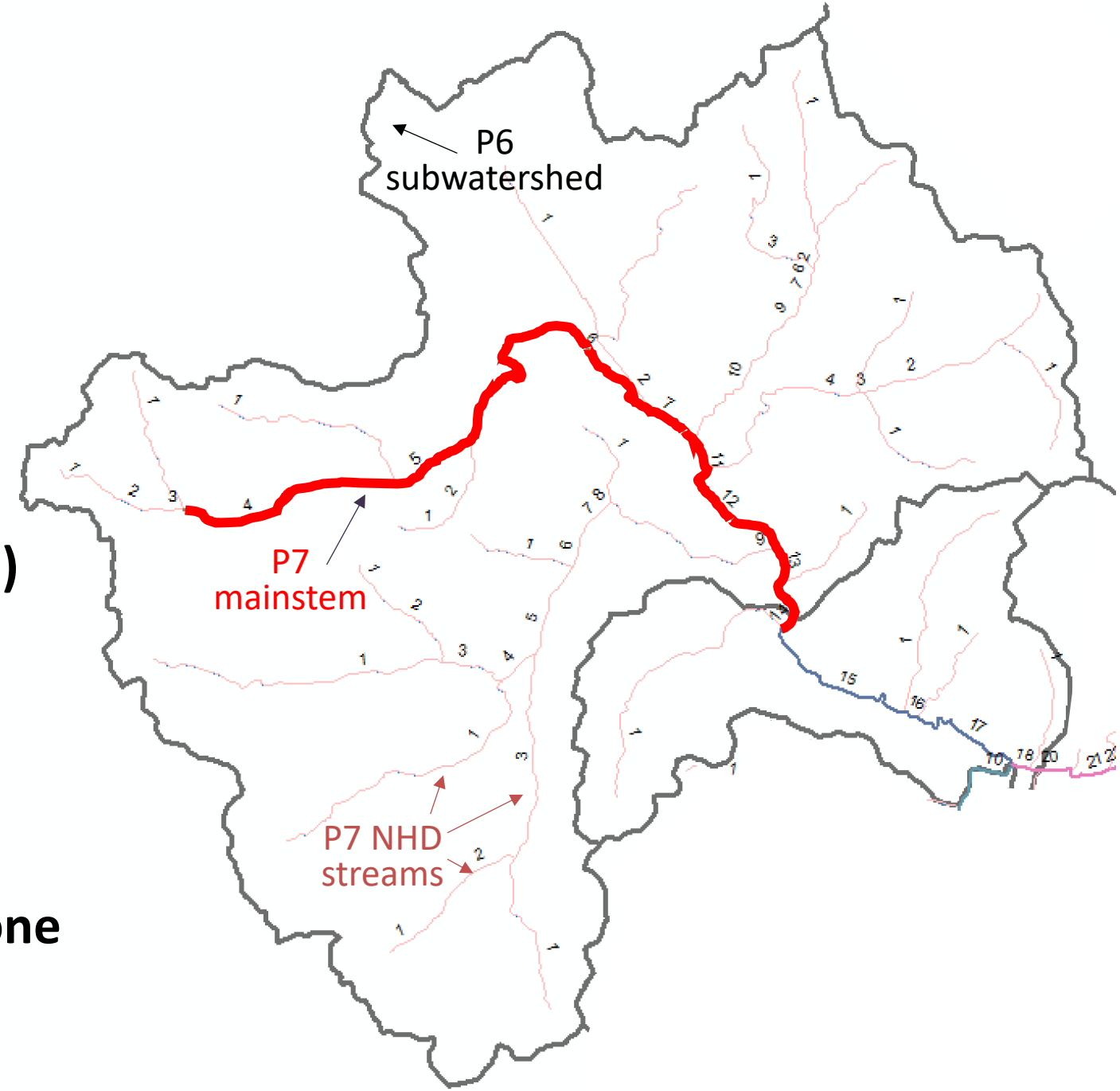
? reach with small impoundments

? channel properties (in the works)

? which branch is the mainstem

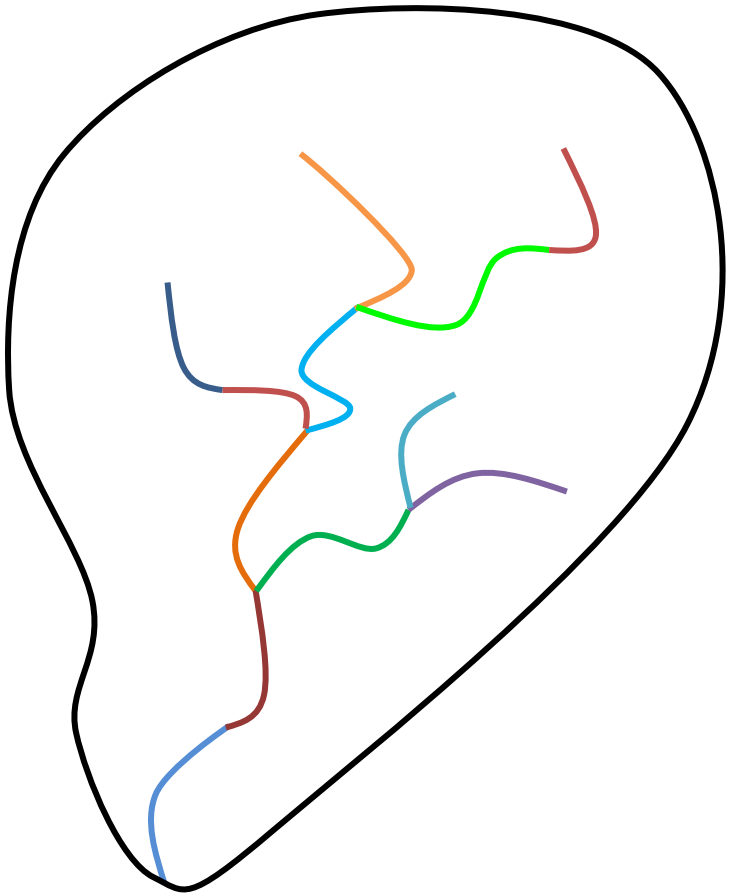
? a few other clever ideas

… but in the end, we punted this one for now, to try again later.

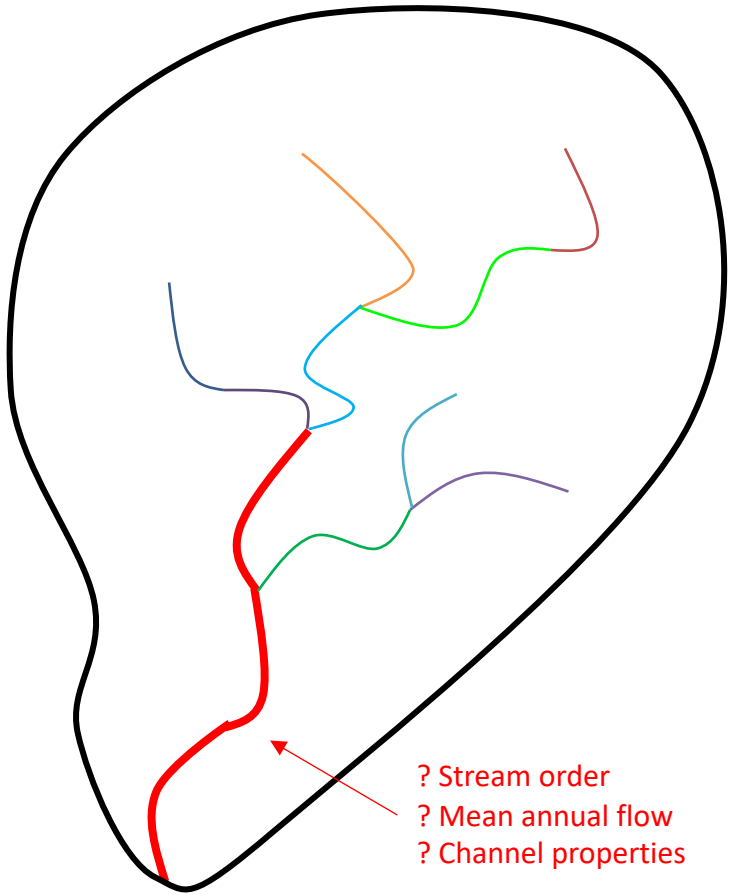


Issues …

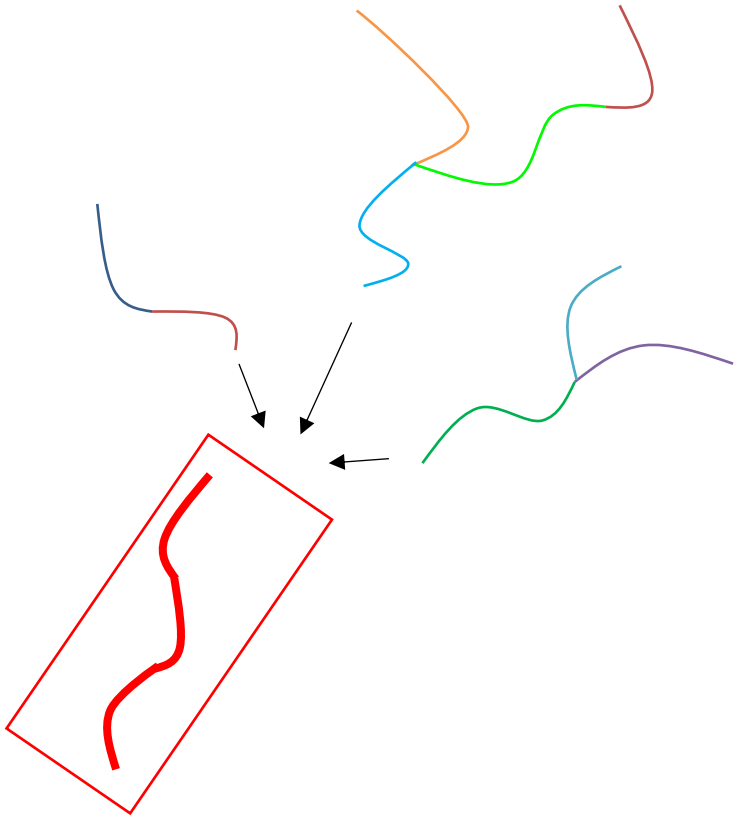
River (mainstem) delineation and 'aggregation effect'



NHD streams



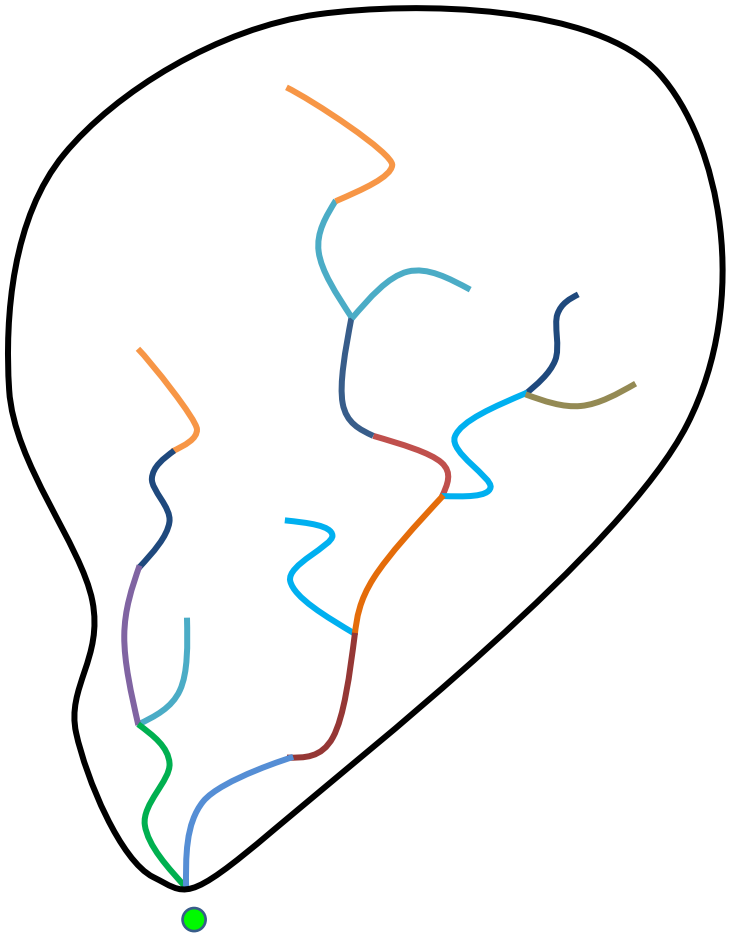
Nested streams & rivers,
Hybrid WQ simulation
(maybe ideal; ~~proposed~~)



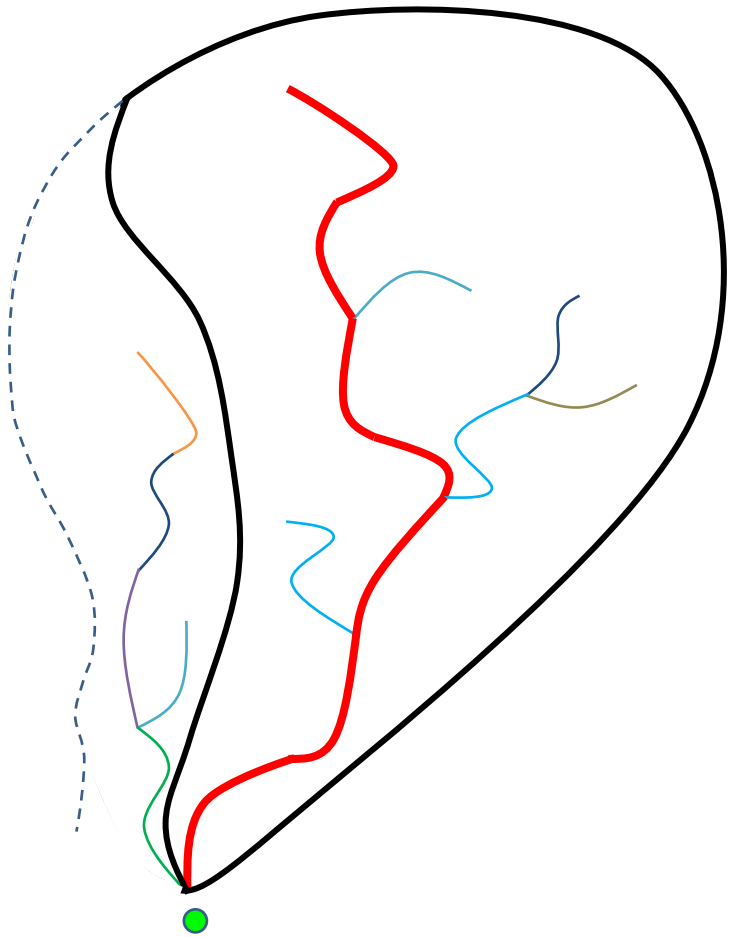
It minimizes 'aggregation effect' but doesn't fix it!

Issues …

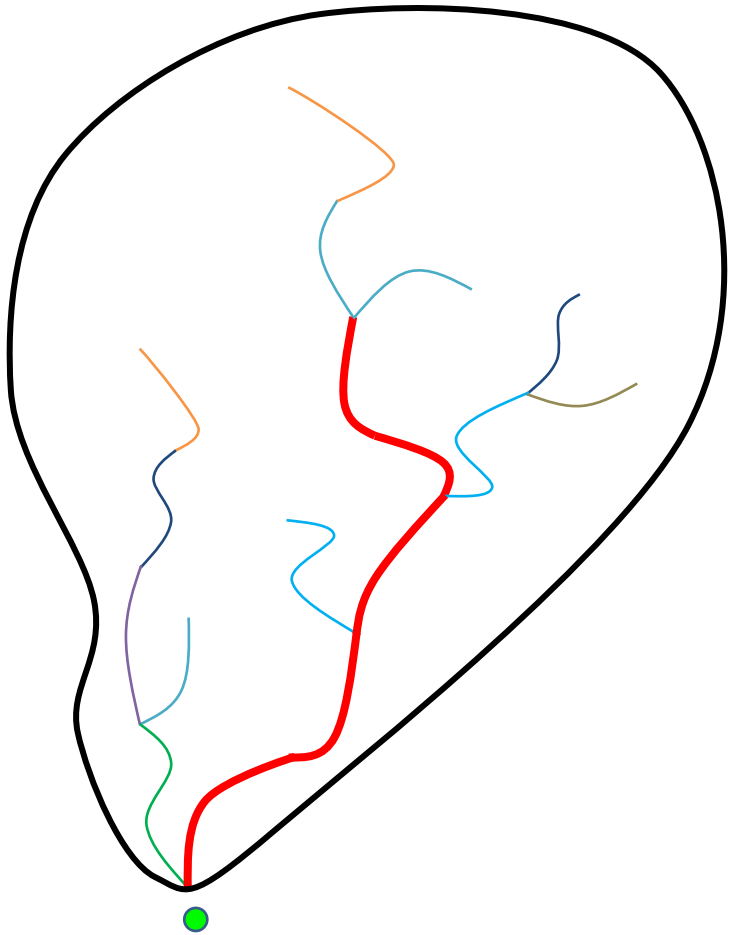
Sub-watershed boundary delineation



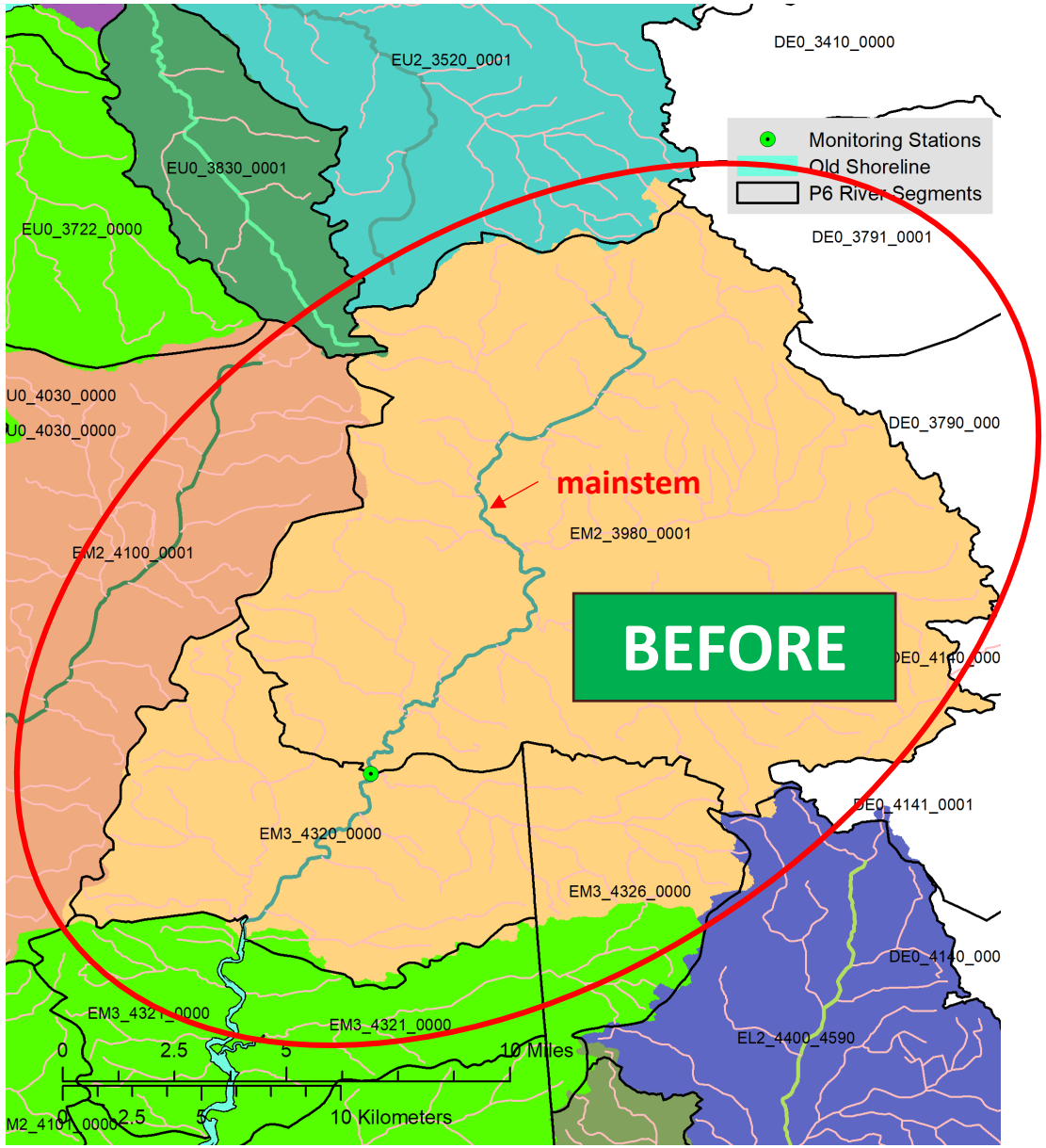
NHD streams

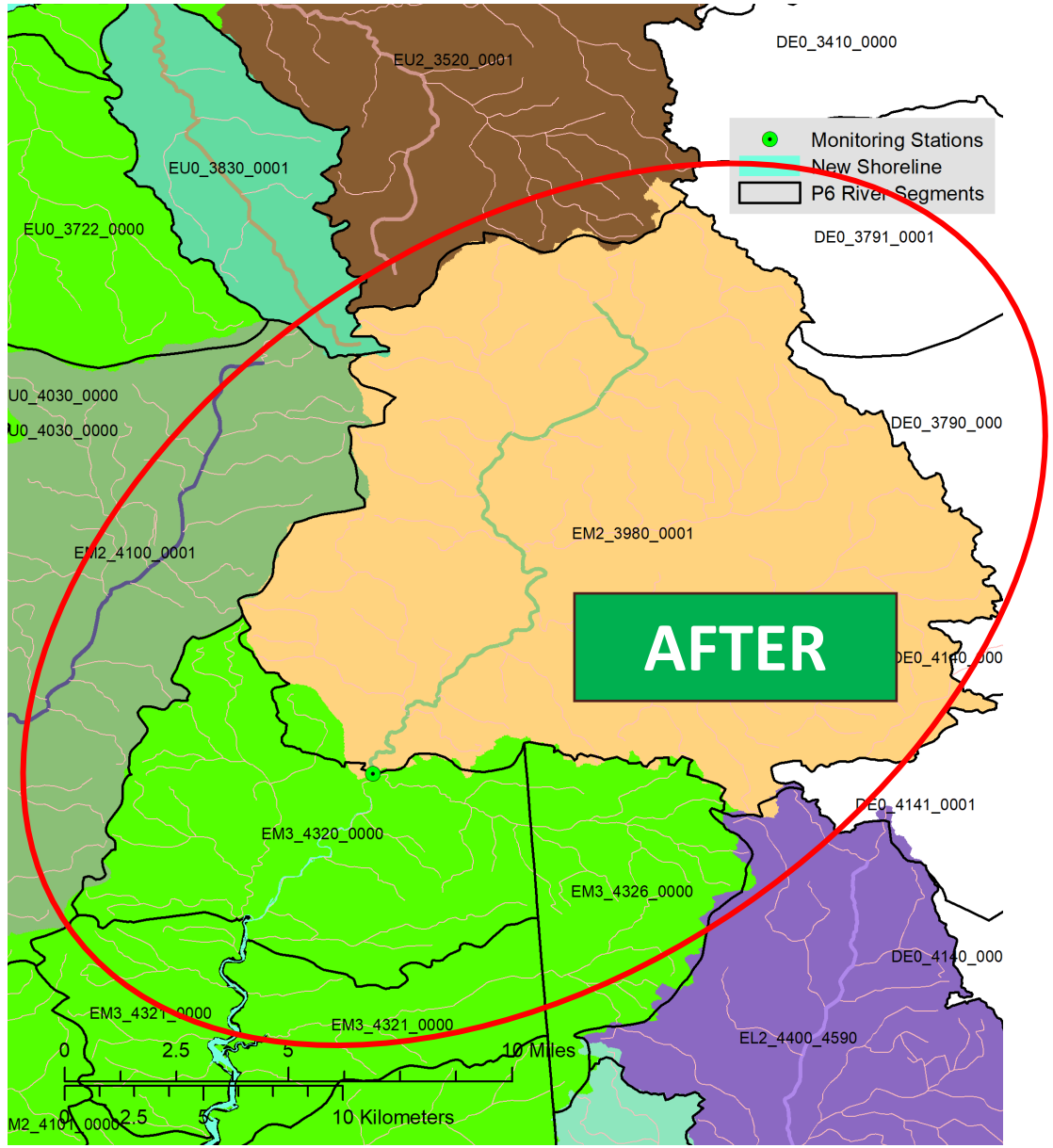


Nested streams & rivers, Hybrid WQ simulation (right now)

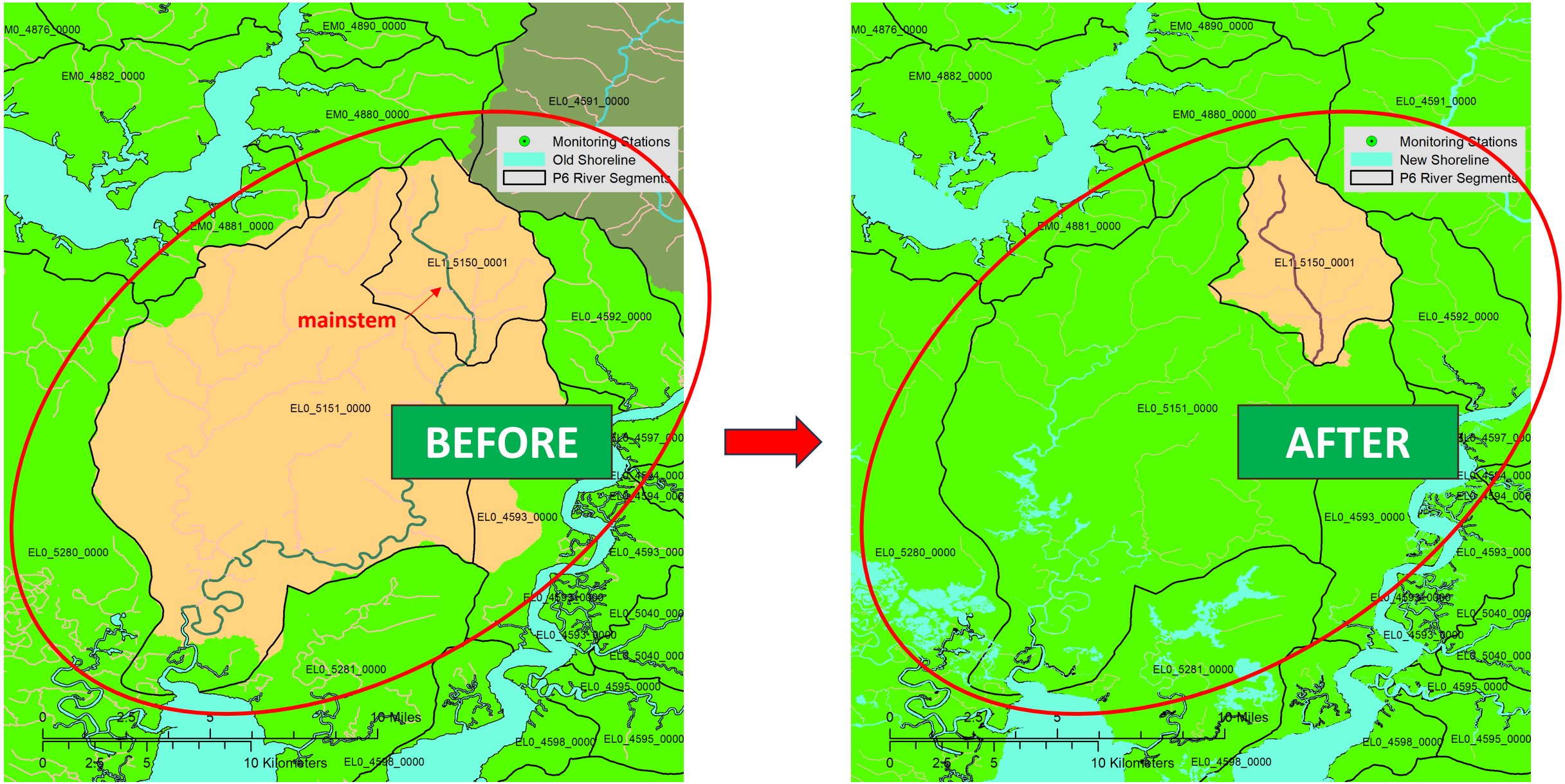


Nested streams & rivers, Hybrid WQ simulation (maybe ideal; ~~proposed~~ we did)



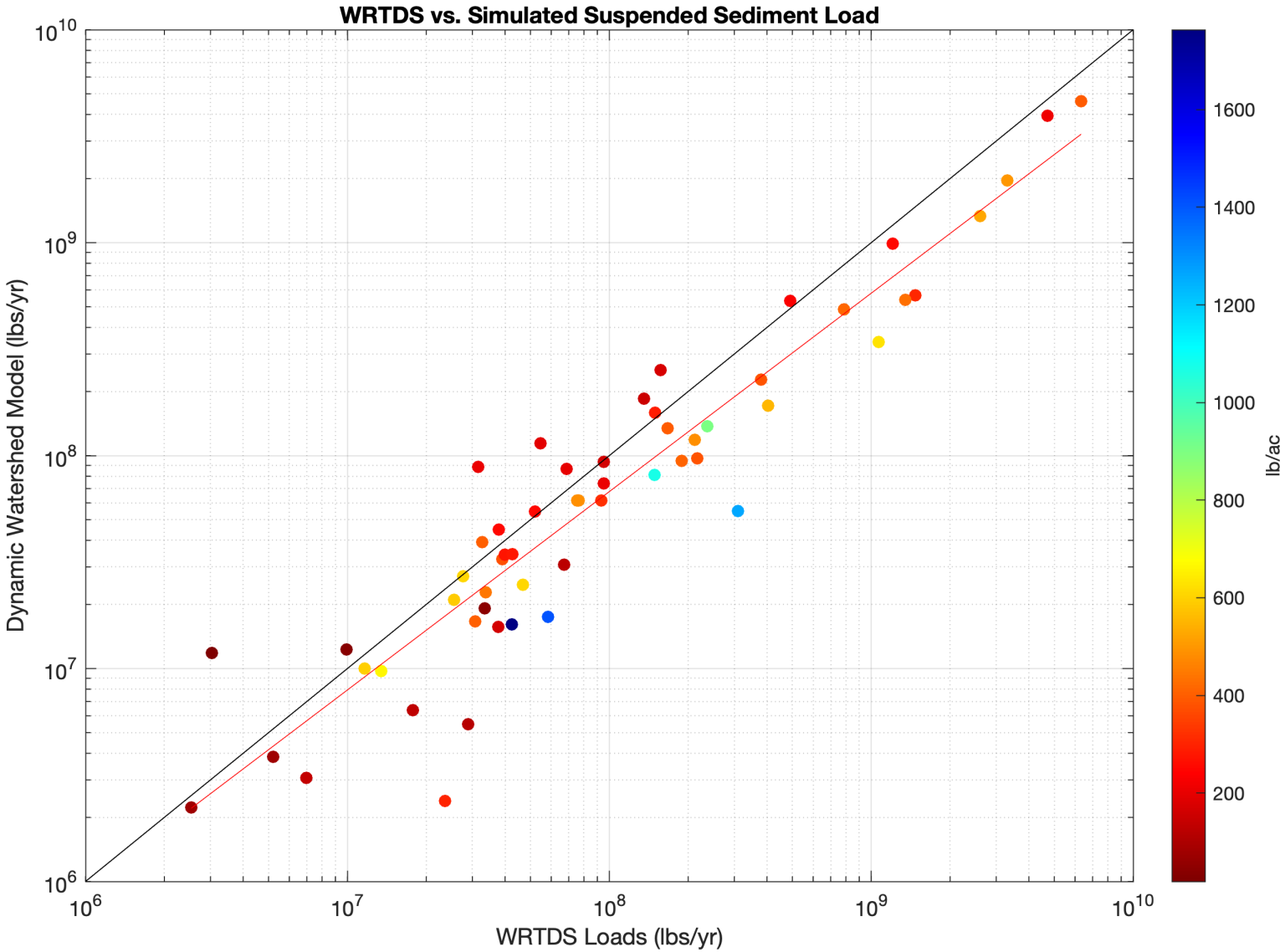


Figures show differences in the delineation of mainstem and its drainage area of Choptank River.

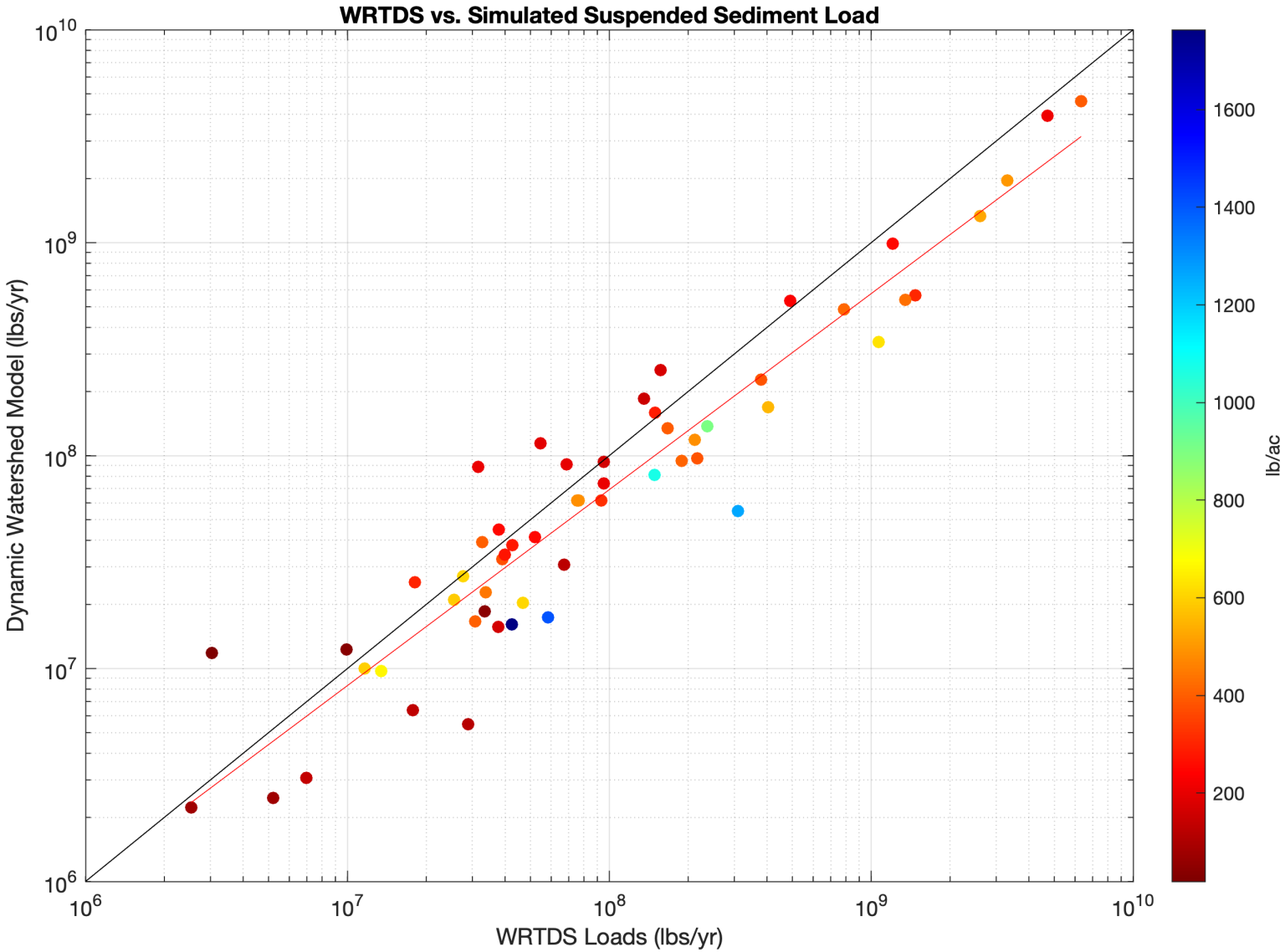


Figures show differences in the delineation of mainstem and its drainage area of Chicamacomico River.

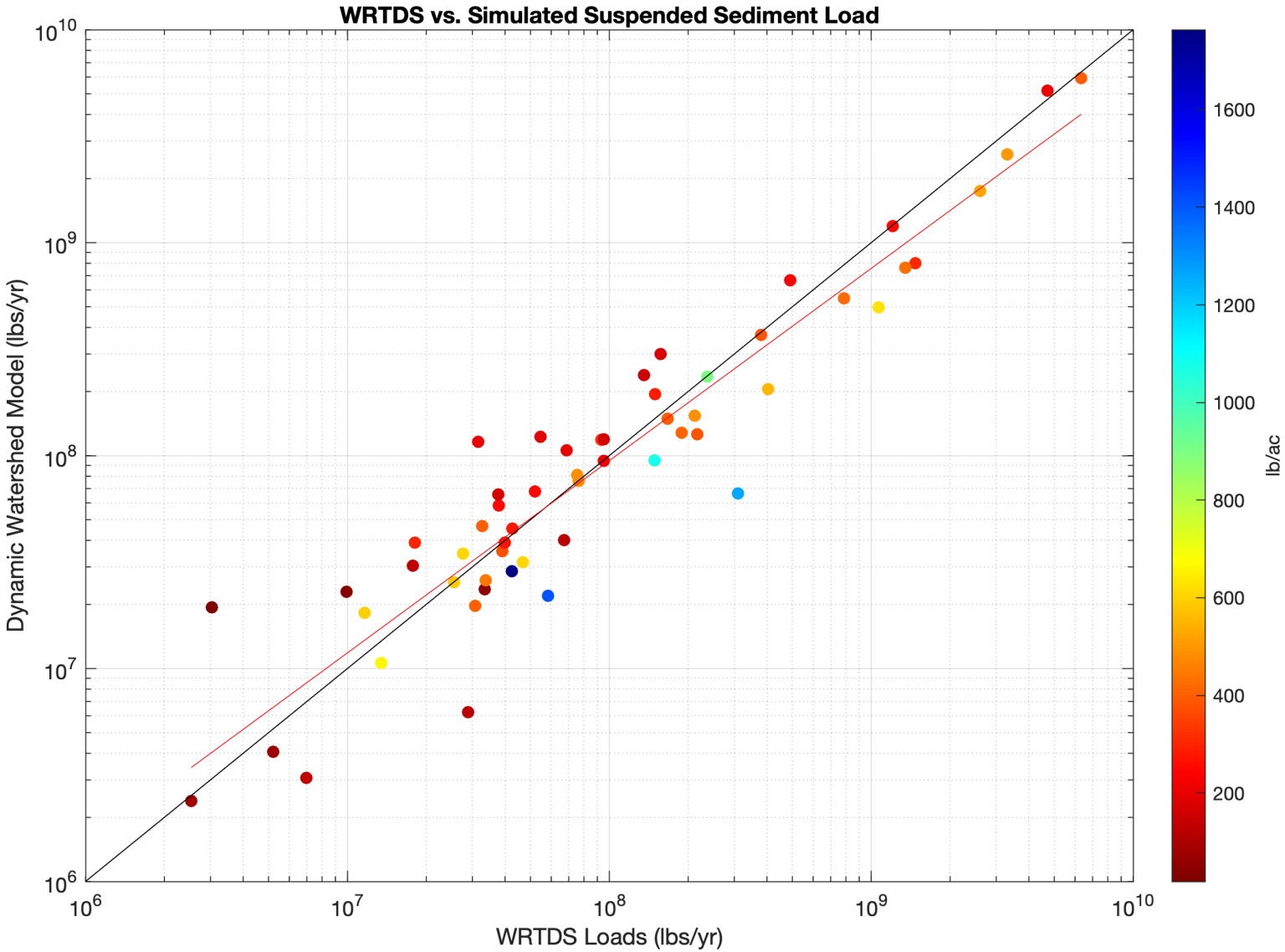
Before segmentation update …



After segmentation update …



+ changes for fixing the aggregation effect



Model runtime *(in collaboration with David Kintgen, CBPO)*

Model runs were made on AWS Cloud HPC and on a research *proof-of-concept* HPC

	Model Run	Calibration	Cores
Hydrology (CalCAST Flow)	4 Hours	55 Hours	144
Hydrology (CalCAST Flow and Stormflow)	4.5 Hours	66 Hours	144
Hydrology & Sediment	11 Hours		144
Hydrology, Sediment, Nutrients, Water Temperature, Dissolved Oxygen, Carbon	29 Hours		288
– do –	**21 Hours**		384
– do –	**16 Hours**		768
– do –	**–**		1536

~ 3 TB of storage

We are exploring the possibility of using 1536 cores.

We expect land use will change from 12 to something else.

We have plans to test the model on MS Azure cloud HPC as well.

Summary

1. We performed re-segmentation and tested the revised model.

- tidal percent attribute was updated using new shoreline layer
- all databases (river mainstem, topology, etc.) were updated
- we focused on improving segmentations in the tidal watershed
- overall, we have a better prototype than we had previously

2. We tested model with more compute capacity and results were encouraging.

>> Next Steps for the Phase 7 Dynamic Watershed Model (DWM)

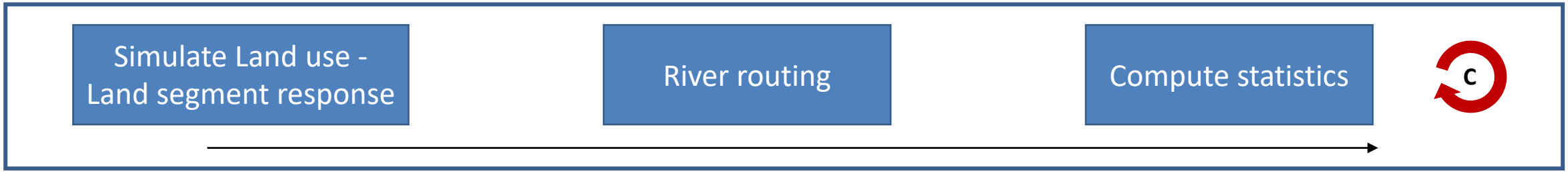
3. Additional QA QC of the segmentation

4. Simple routing method for small streams (flow, water quality)

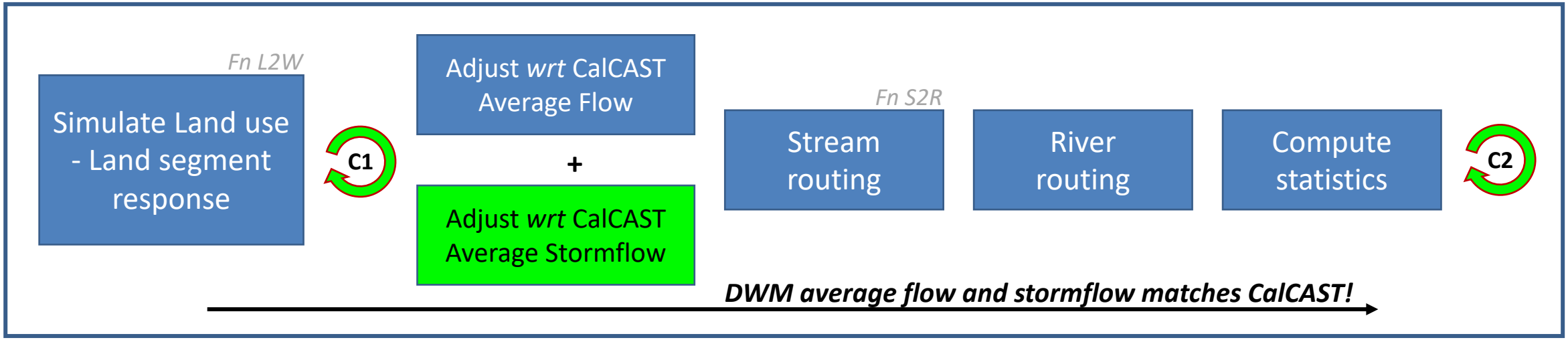
5. Water quality calibration

Hydrology Calibration Method

PHASE 6: HYDROLOGY CALIBRATION

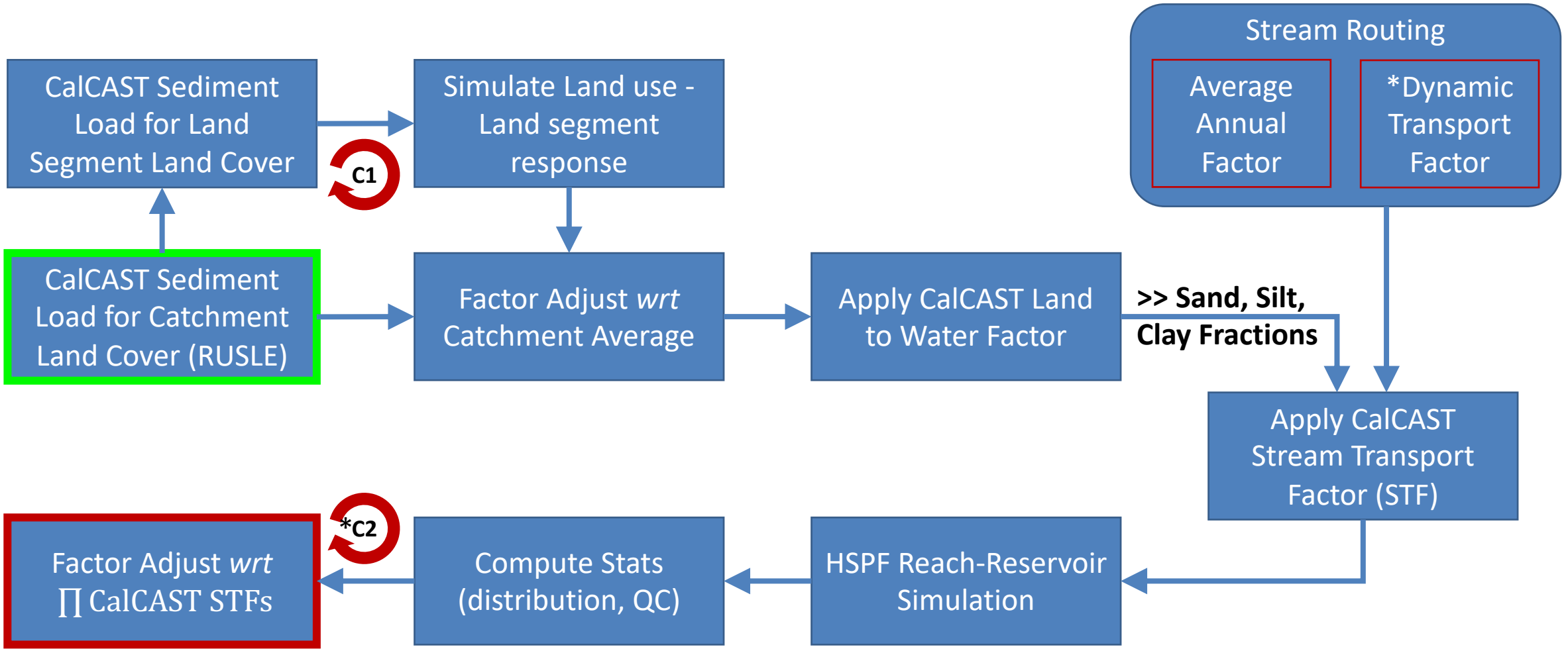


PHASE 7: PROPOSED DWM HYDROLOGY CALIBRATION



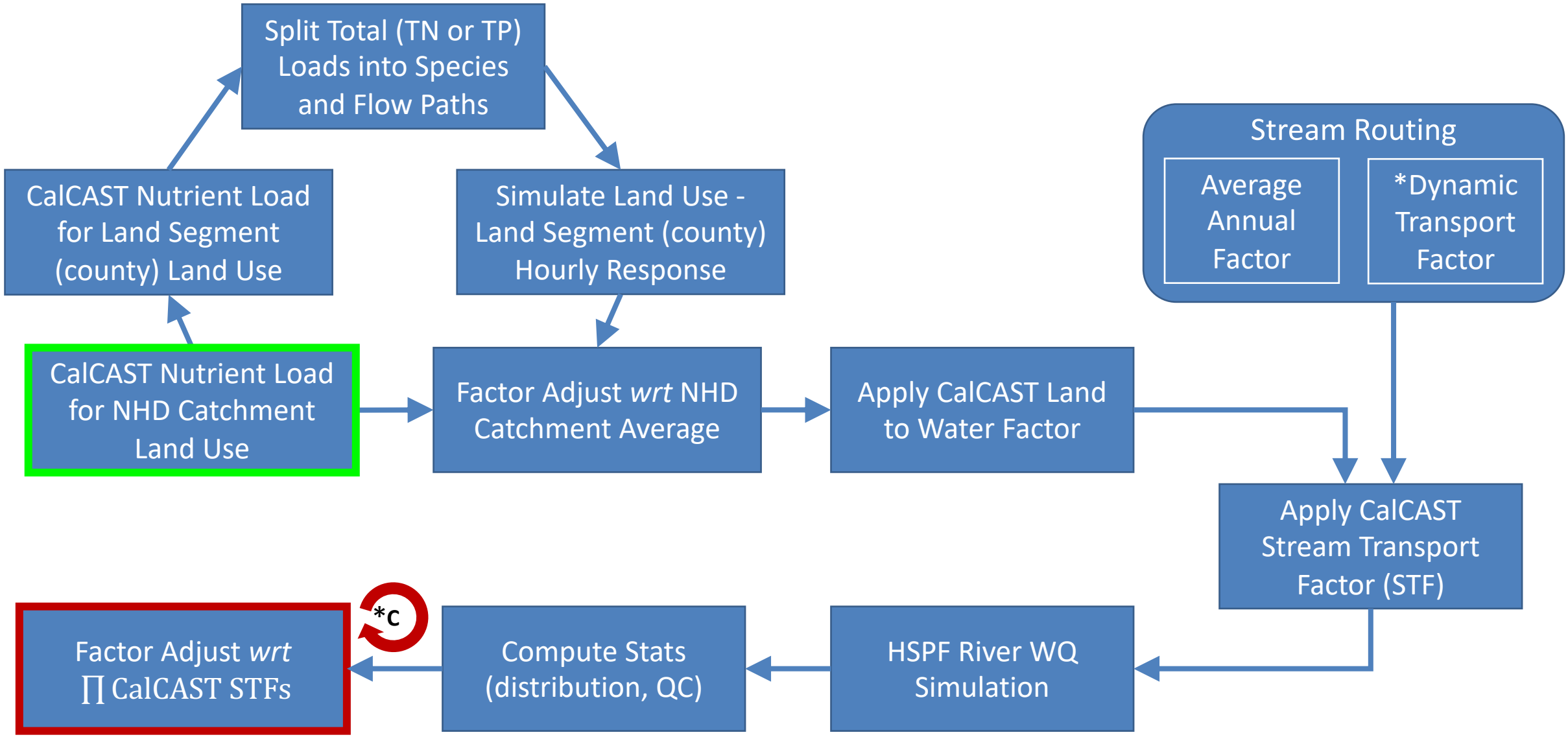
Can we improve DWM hydrology in addition to new data from CalCAST?

NHD Scale Sediment Model Structure



Modules marked with * are not yet implemented or applied in the prototype we are discussing today.

NHD Scale Nutrient Model Structure



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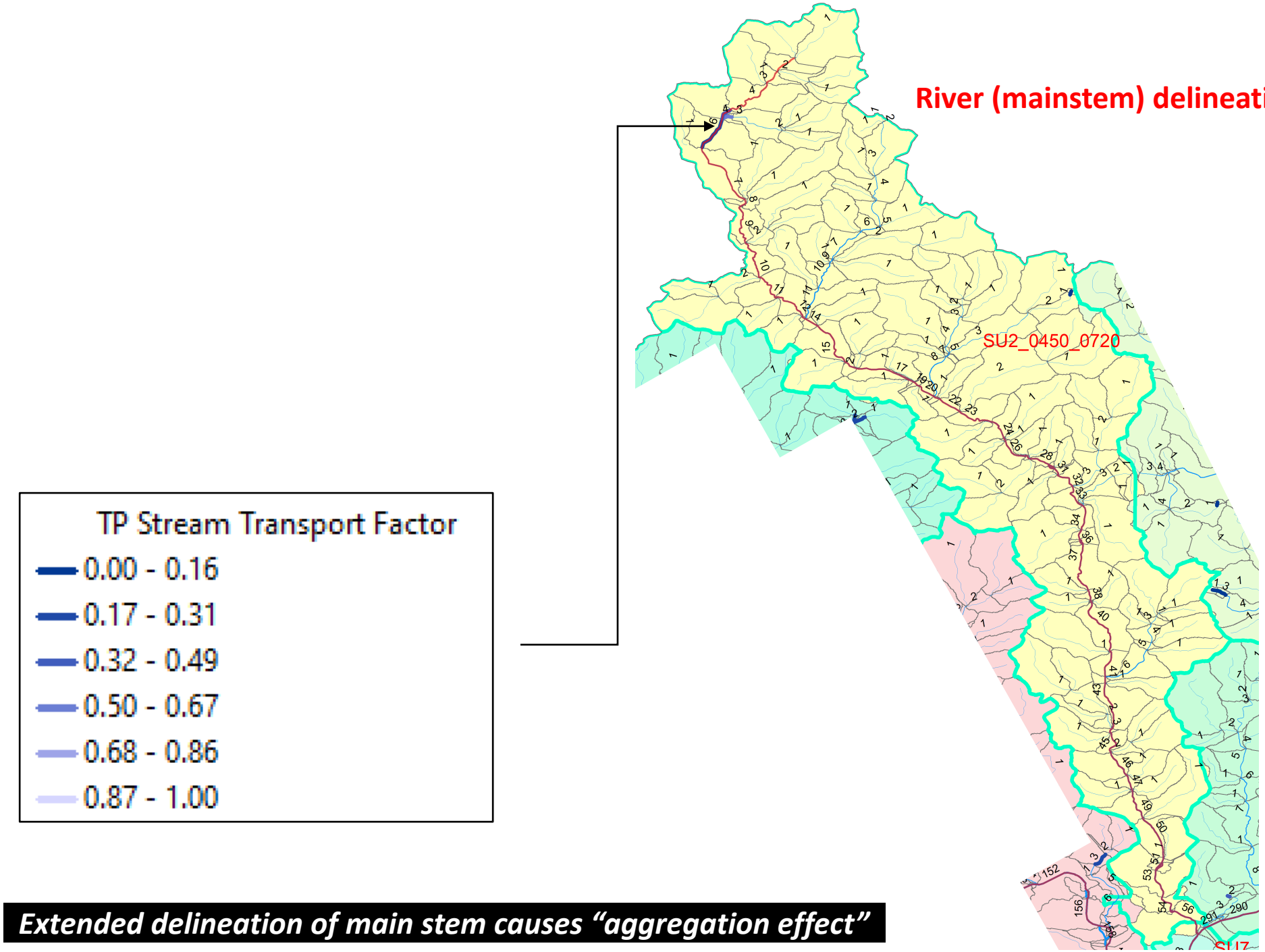
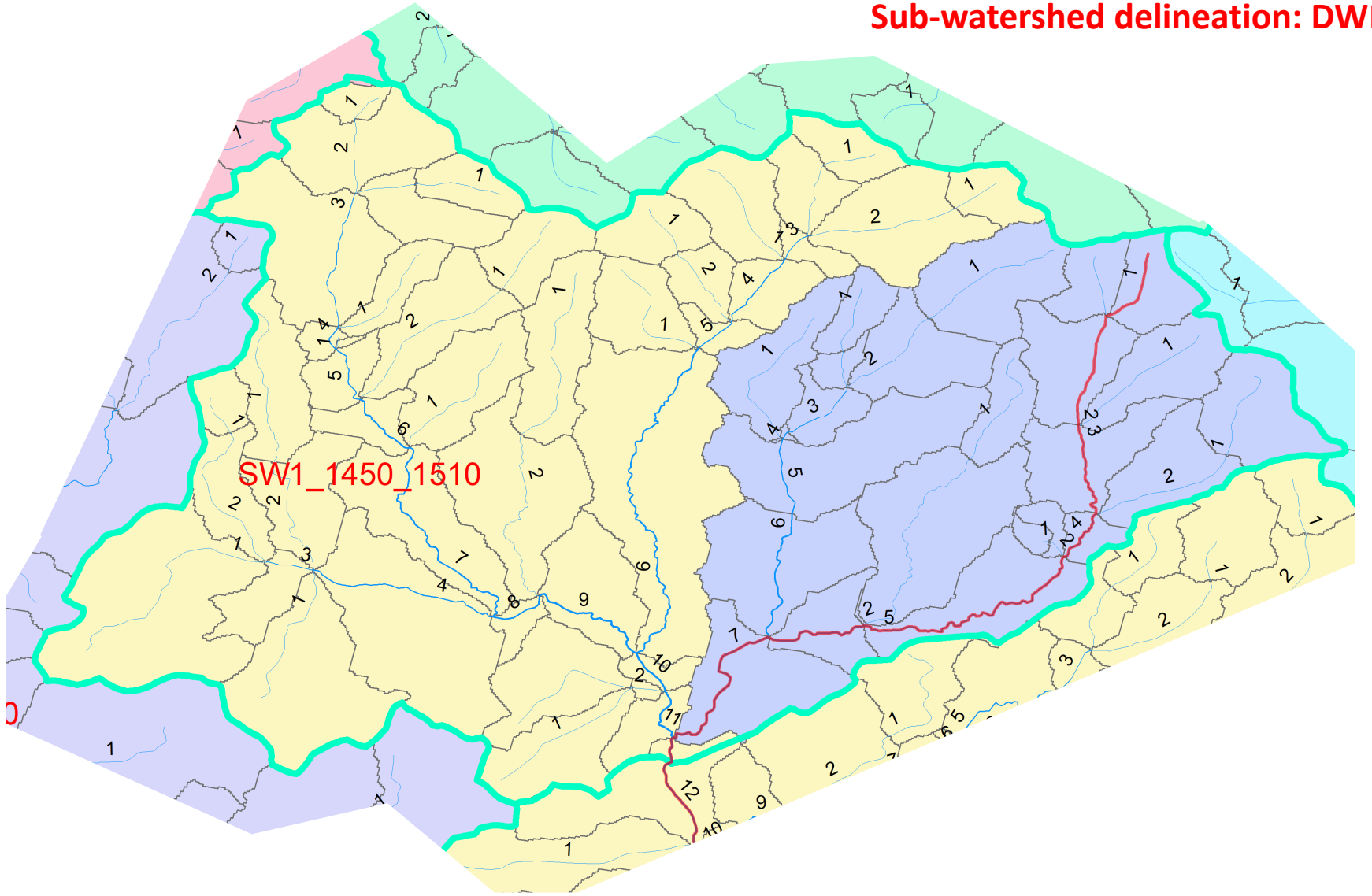
ISSUE #1
River (mainstem) delineation and ‘aggregation effect’



Extended delineation of main stem causes “aggregation effect”

ISSUE #2

Sub-watershed delineation: DWM vs. CalCAST stats



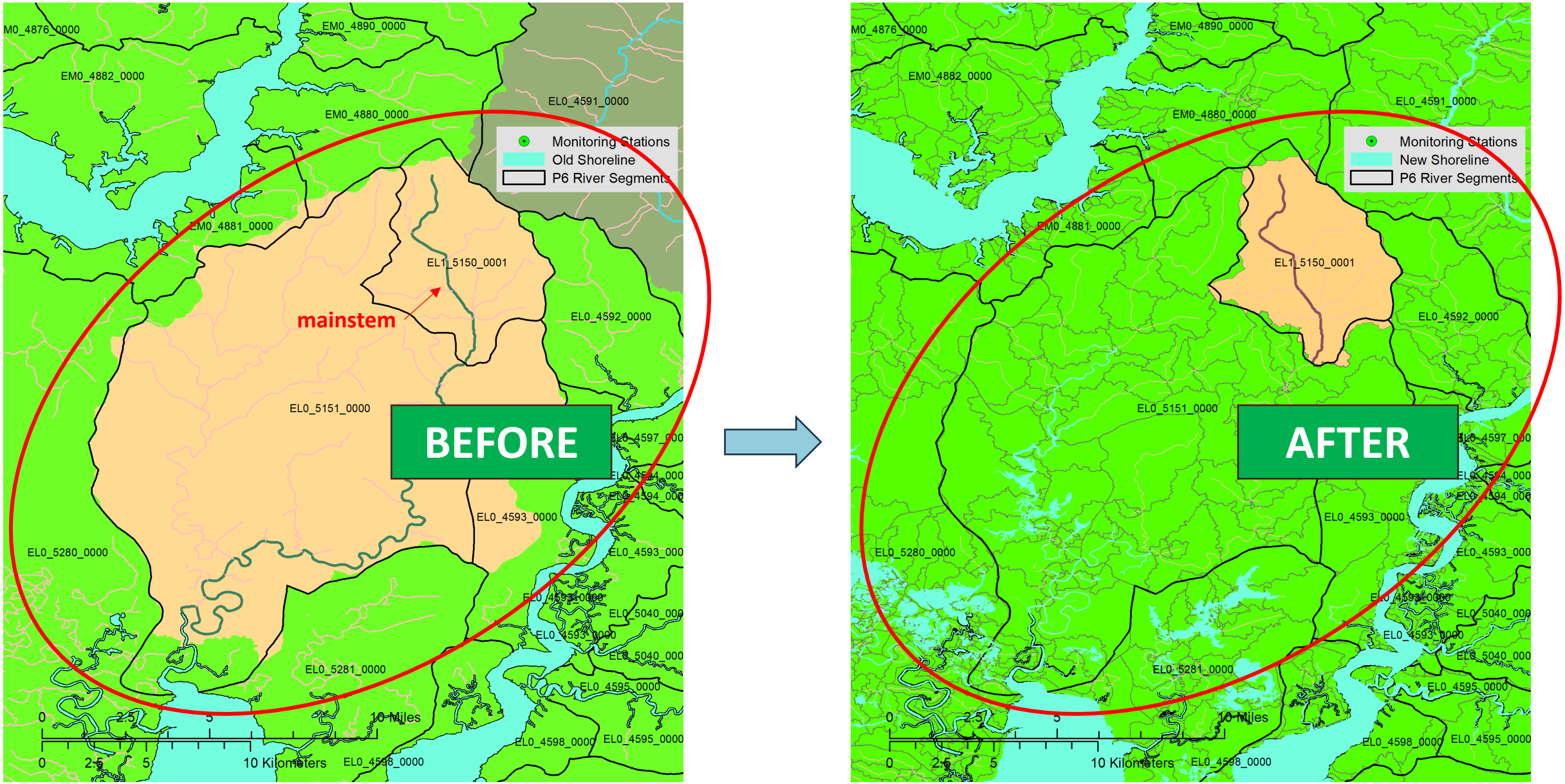
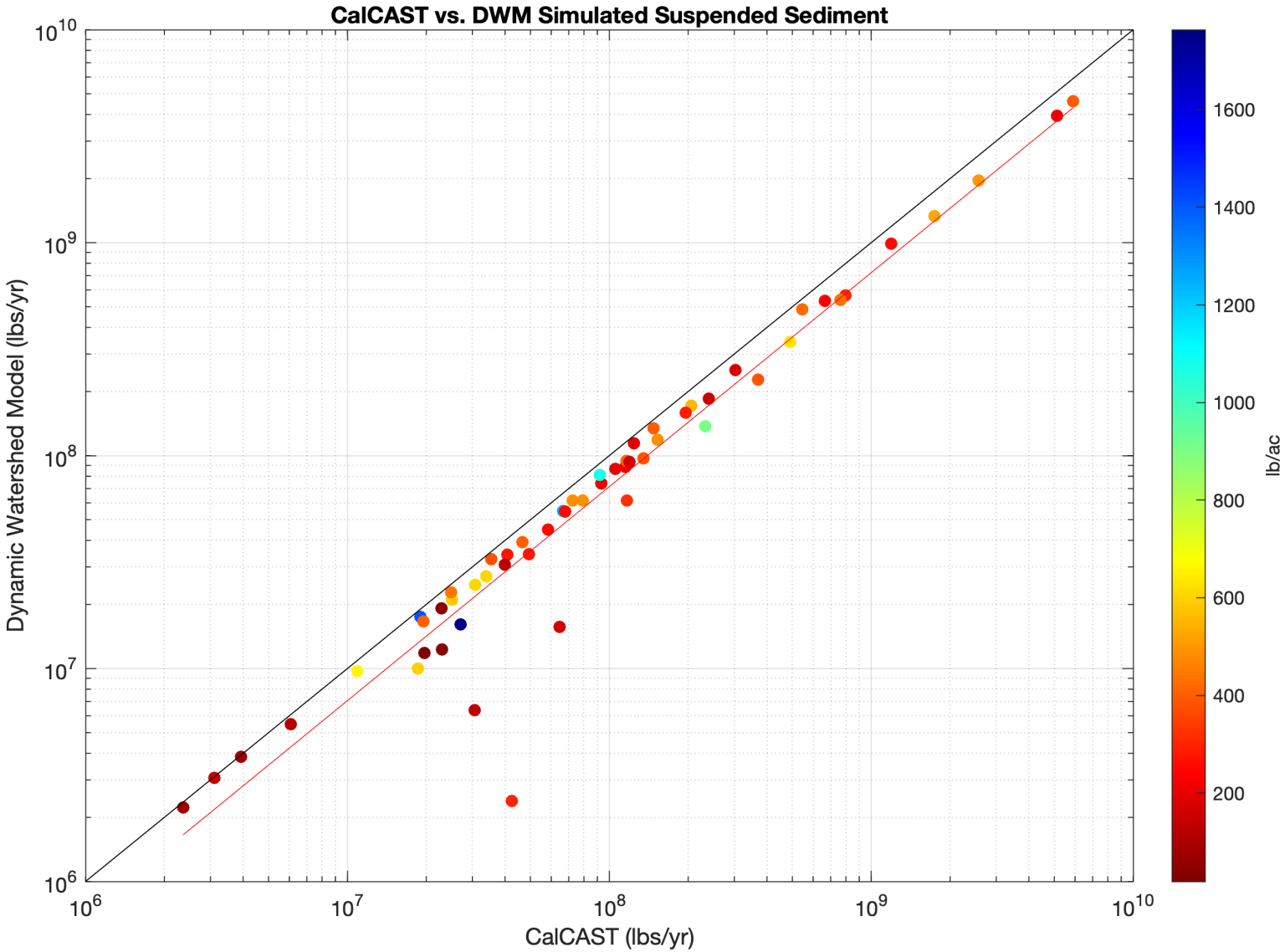
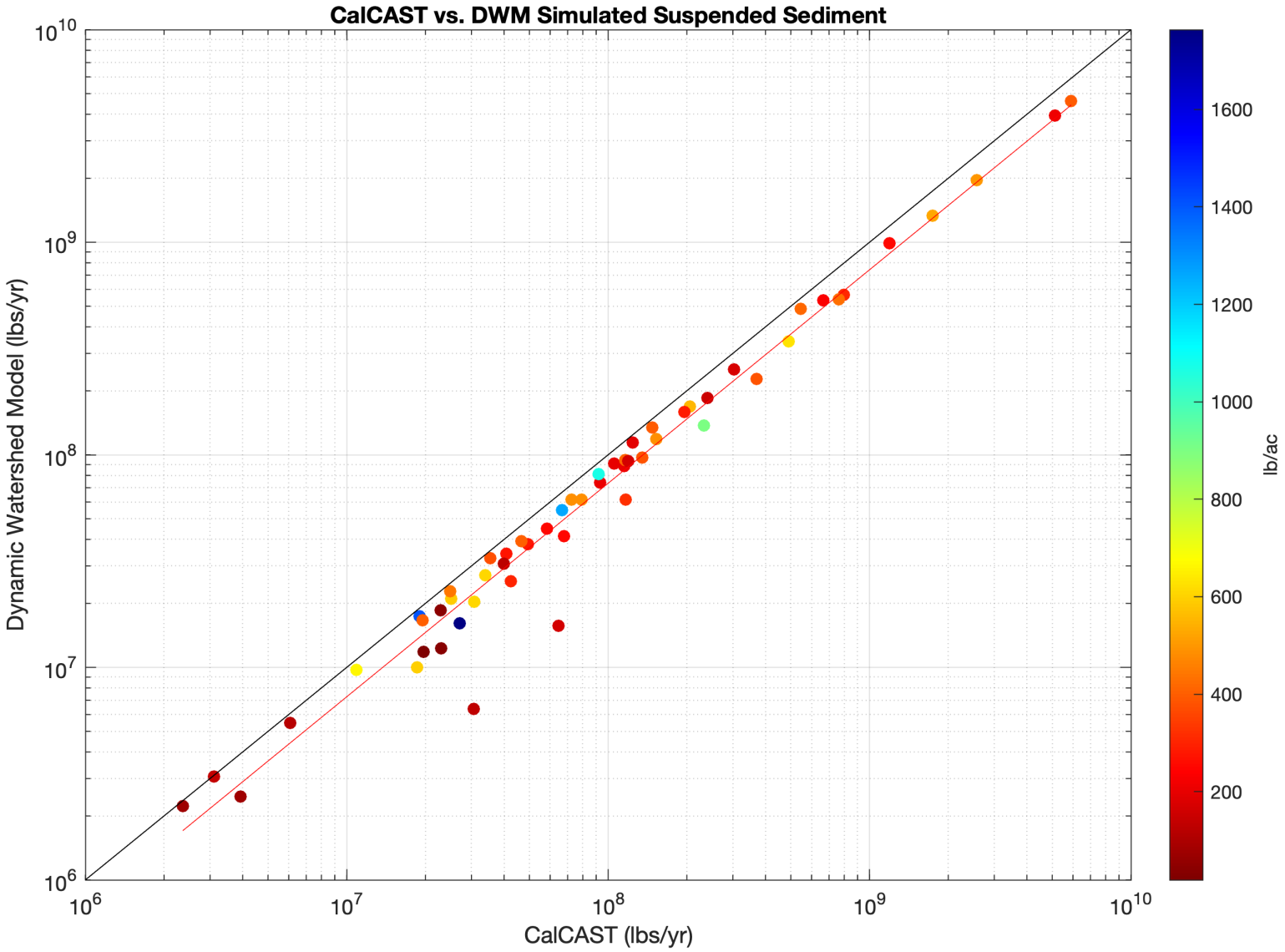


Figure shows differences in the delineation of mainstem and its drainage area.

Before segmentation update …



After segmentation update …



+ updated model for aggregation effect …