04/04/2023

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

Modeling Workgroup Quarterly Meeting – April 2023

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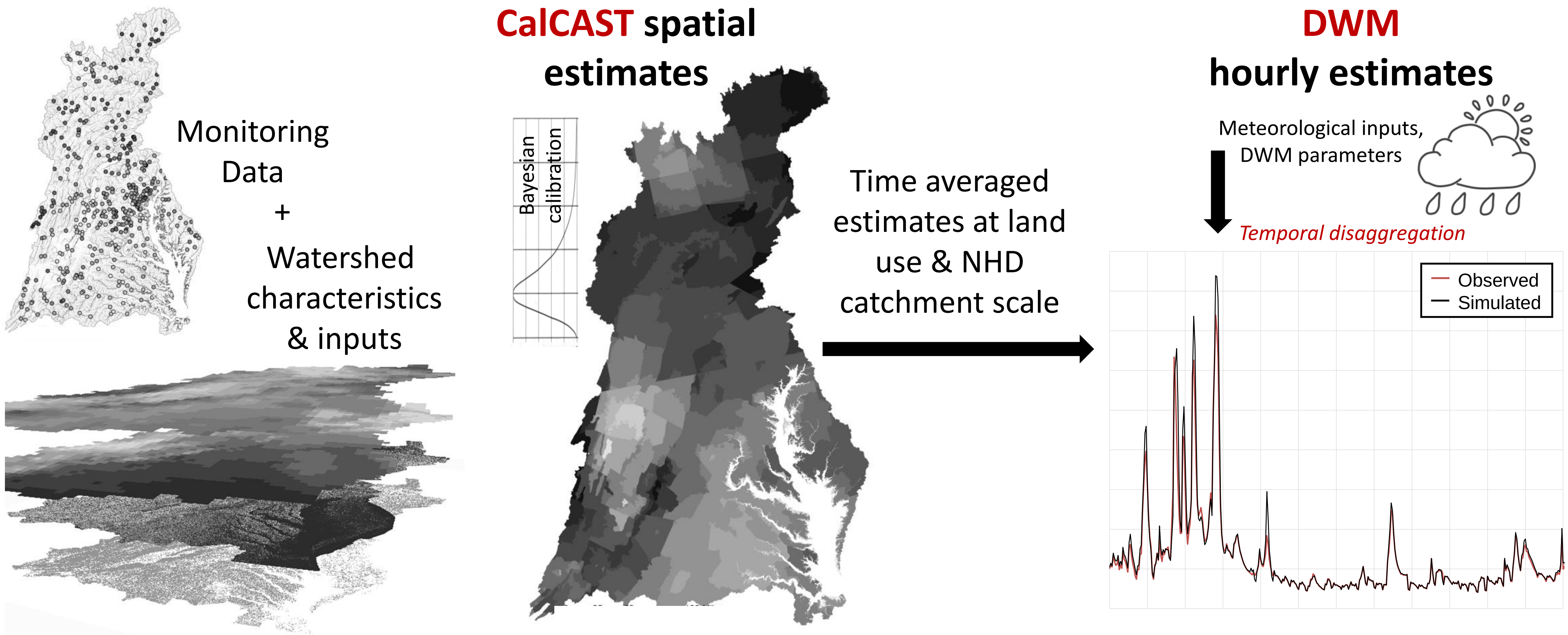
Purpose

NHD Scale Dynamic Watershed Model (DWM)

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

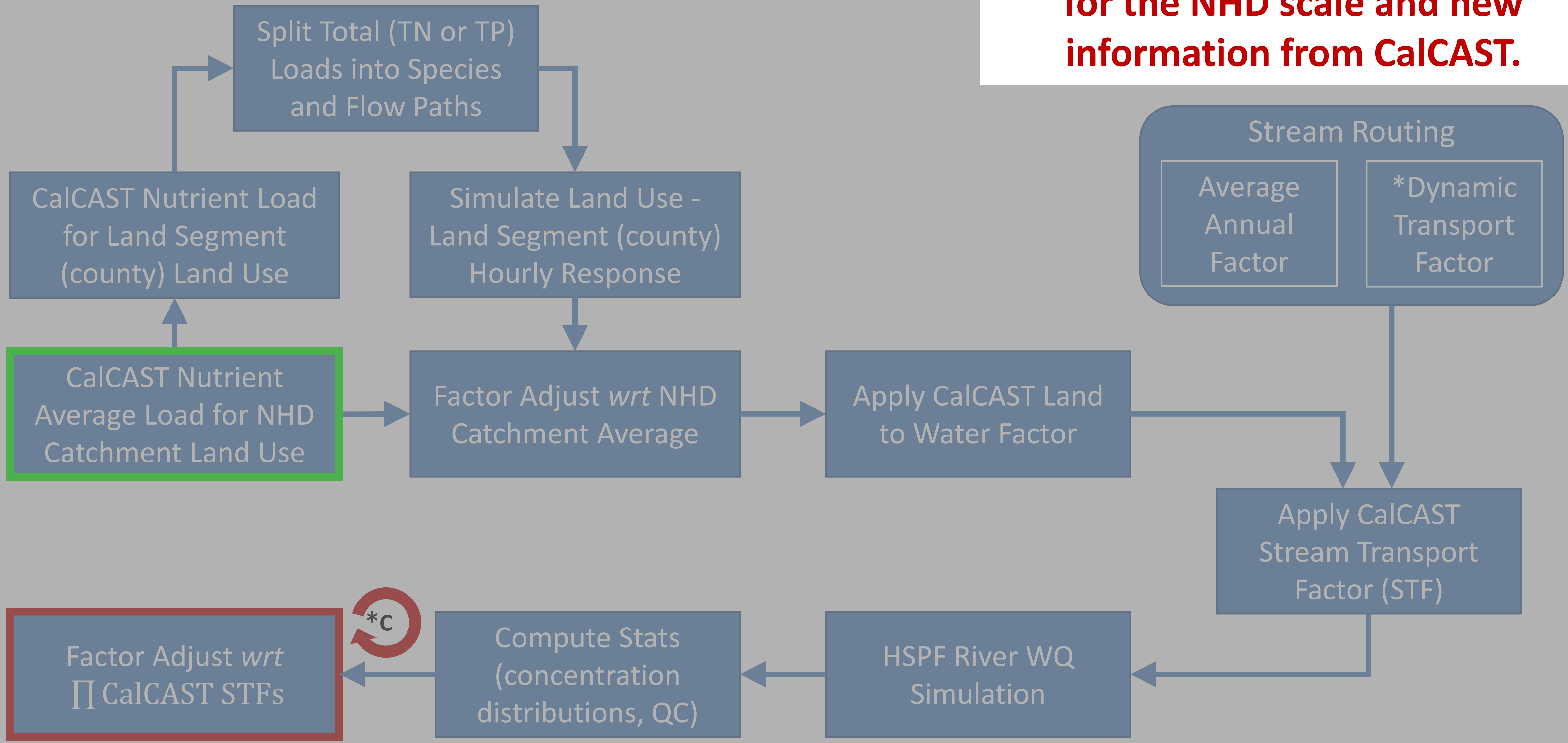
Framework: Spatial Model (CalCAST) → Dynamic Watershed Model (DWM)



- 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.

NHD Scale <u>Nutrient</u> Model Structure

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



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

Dynamic Watershed Model (DWM) Development

Calendar Year 2022

CY 2022	Progress/Major Development Elements
1Q	NHD-scale model structure; Hydrology prototype; Expanded simulation period 1985 to 2020; [1][2]
2Q	Hydrology calibration (CalCAST→DWM) method updates; Simple routing (initial testing of numerical simplifications); [3]
3Q	Sediment model; Hydrology model calibration updates with respect to stormflow; [4]
4Q	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

Presentation Outline

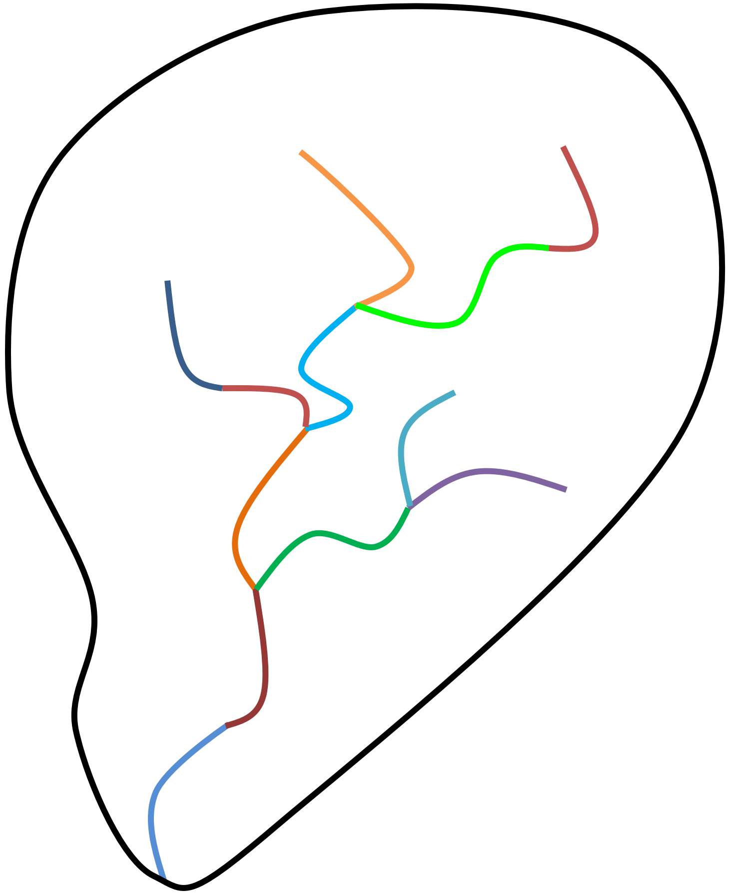
Next Steps for the Phase 7 Dynamic Watershed Model (DWM)

1. **Model Resegmentation**
   - Mainstem vs. NHD streams
   - Subwatershed boundary of river segments vs. NHD catchments
2. **Model Runtime**
3. **Monitoring Data (dynamically extend and expand)**
4. **Simple routing method for small streams**
5. **Flow and Water quality calibration**

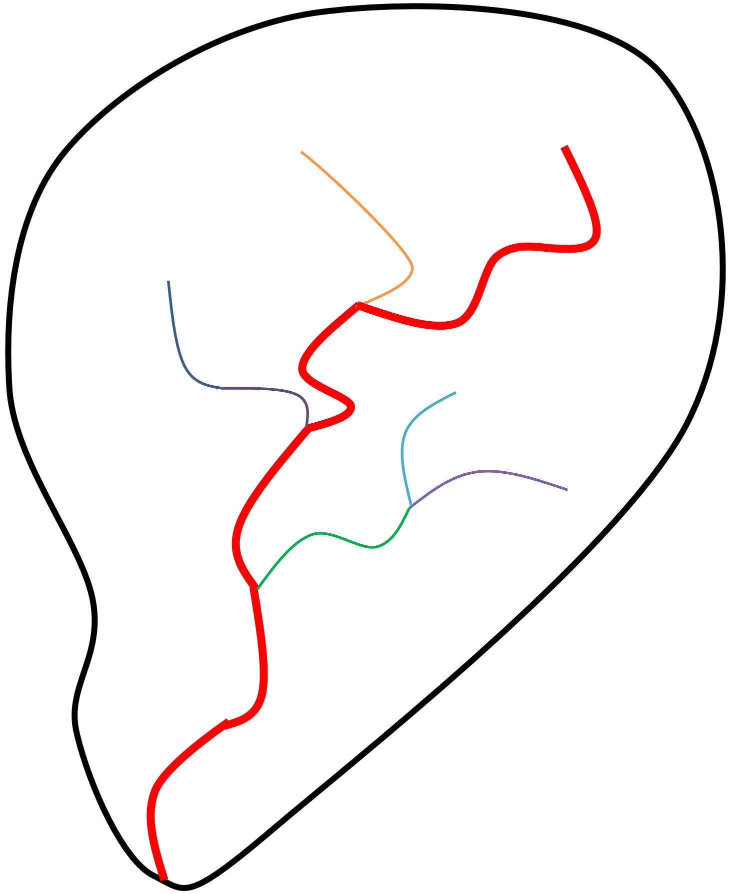
1. Resegmentation

ISSUE #1

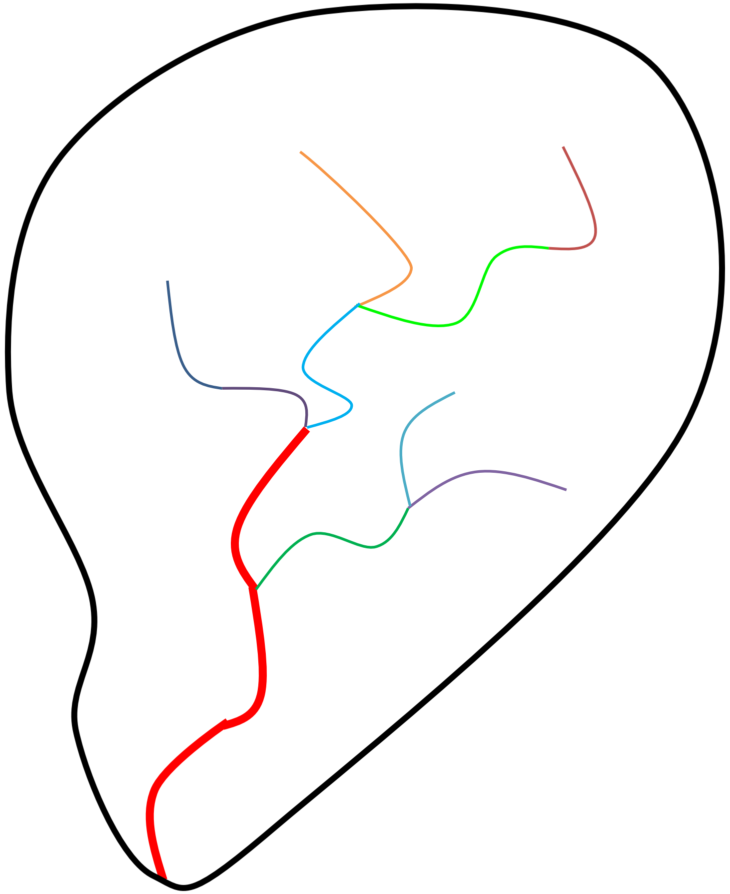
River (mainstem) delineation and 'aggregation effect'



NHD streams



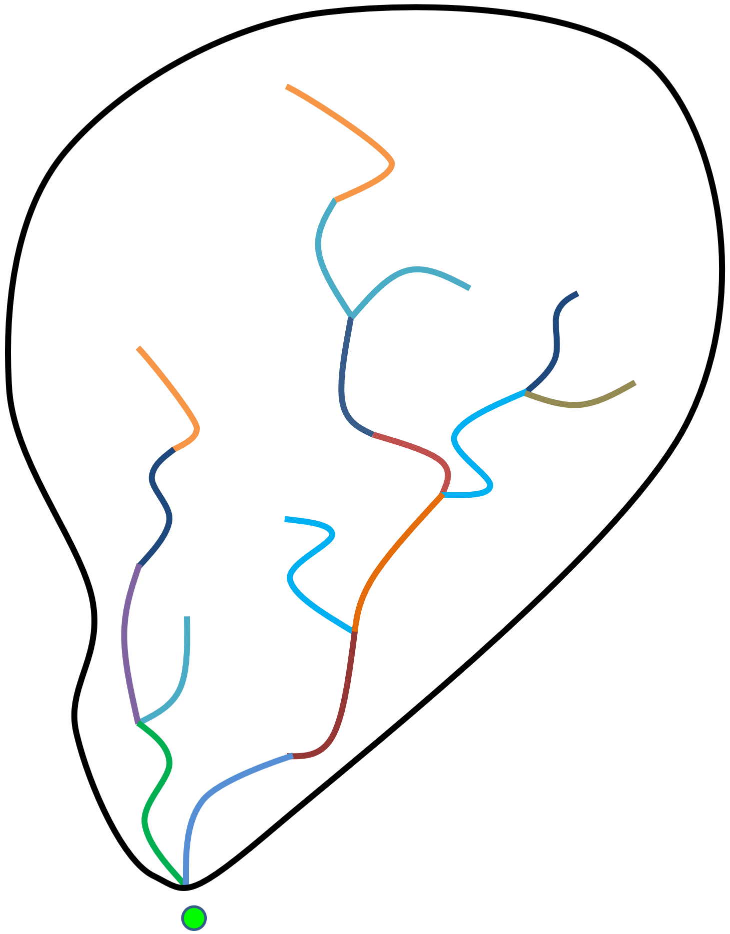
Nested streams & rivers, Hybrid WQ simulation (right now)



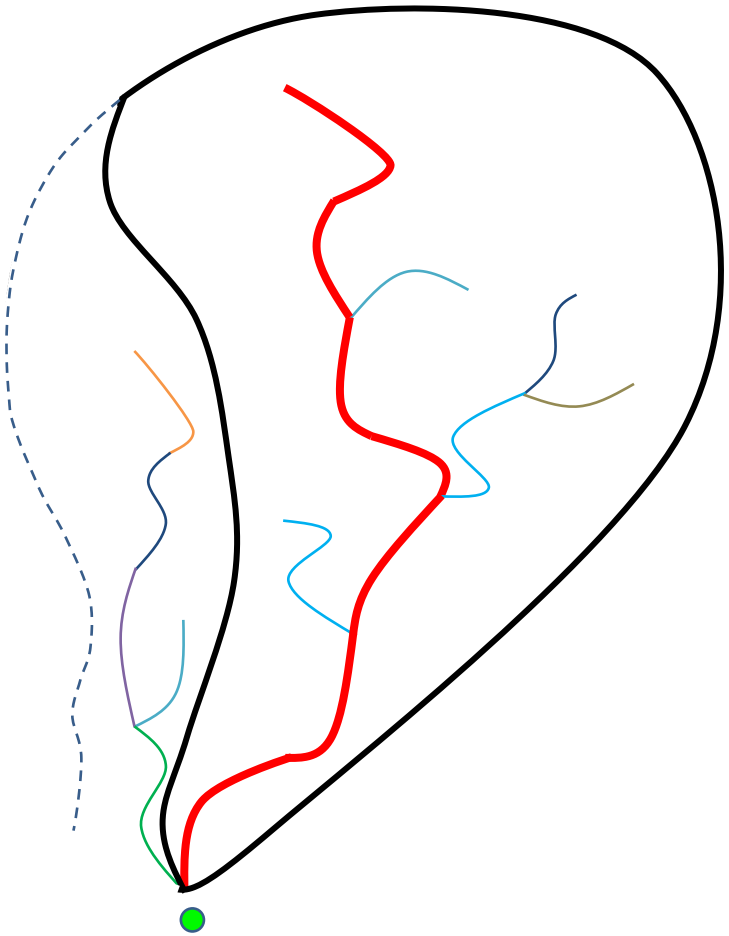
Nested streams & rivers, Hybrid WQ simulation (maybe ideal; proposed)

1. Resegmentation

ISSUE #2
Sub-watershed boundary delineation



NHD streams



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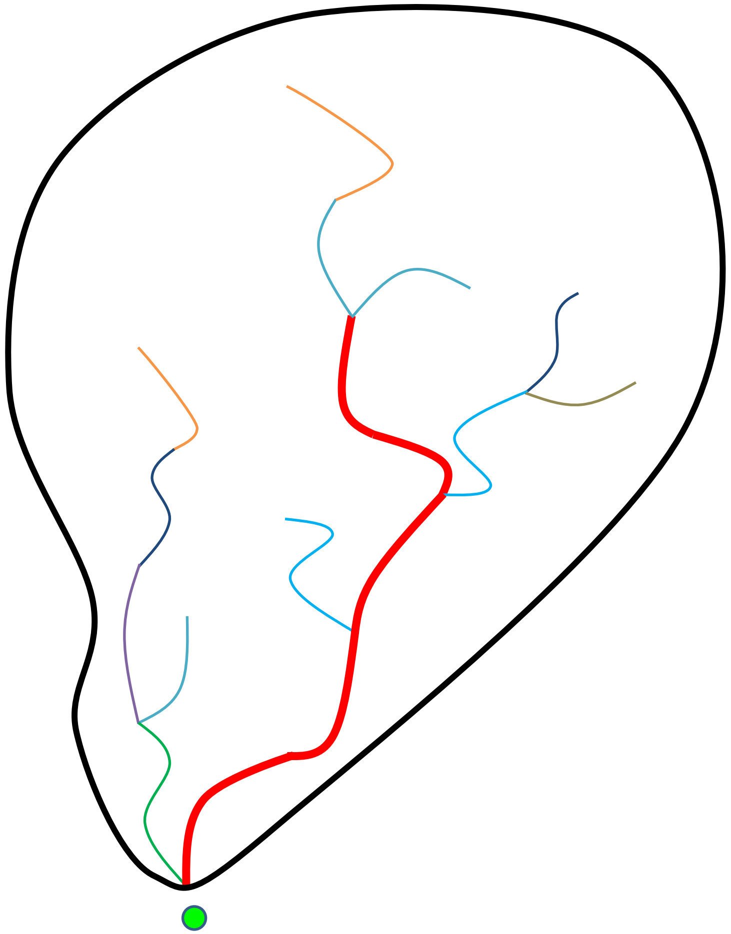


Nested streams & rivers, Hybrid WQ simulation (maybe ideal; proposed)

2. Model Runtime

Model runs were made on AWS Cloud HPC with 144 compute cores

	Model Run	Calibration
Hydrology (CalCAST Flow)	4 Hours	55 Hours
Hydrology (CalCAST Flow and Stormflow)	4.5 Hours	66 Hours
Hydrology & Sediment	11 Hours	

Aggregation of loads from land-uses took the most time, ~ 8 hours.

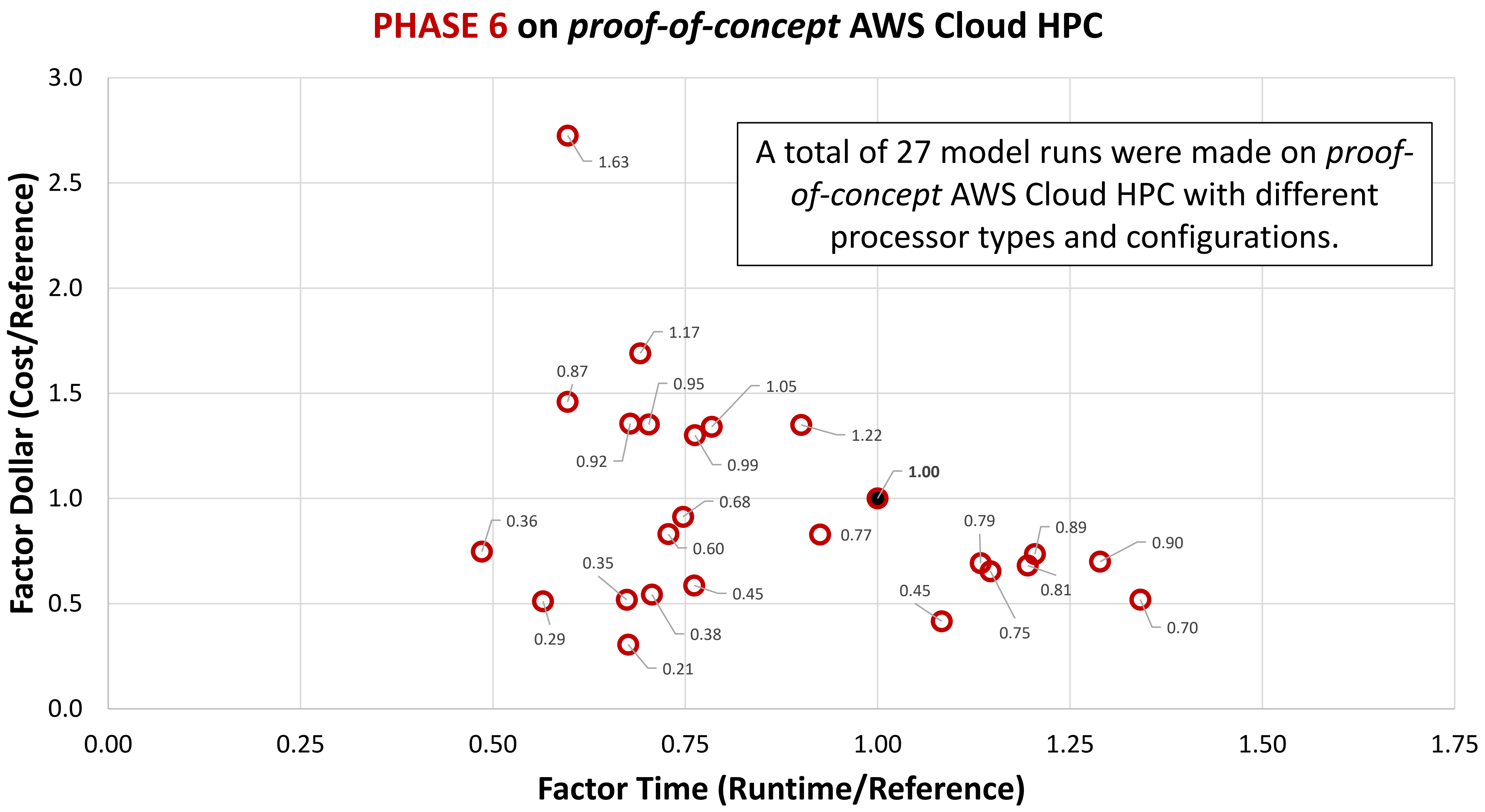
Hydrology, Sediment, Nutrients, Water Temperature, Dissolved Oxygen, Carbon	288 cores **29 Hours**	

~ 3 TB

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

Sediment added 3 model variables (i.e., sand, silt, clay). After adding water quality, we have a total of 22 variables.

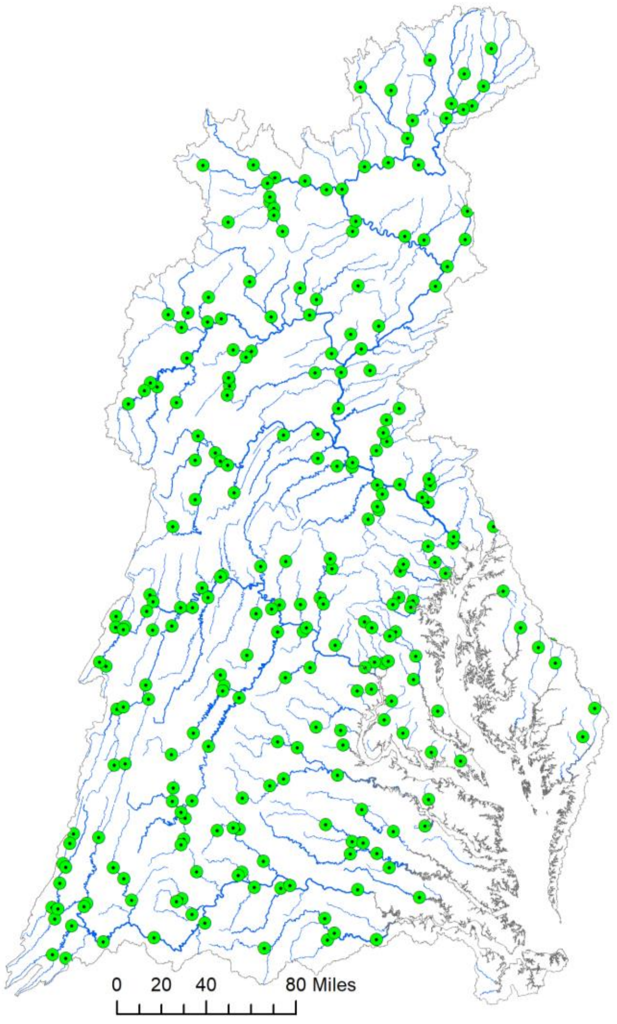
2. Model Runtime

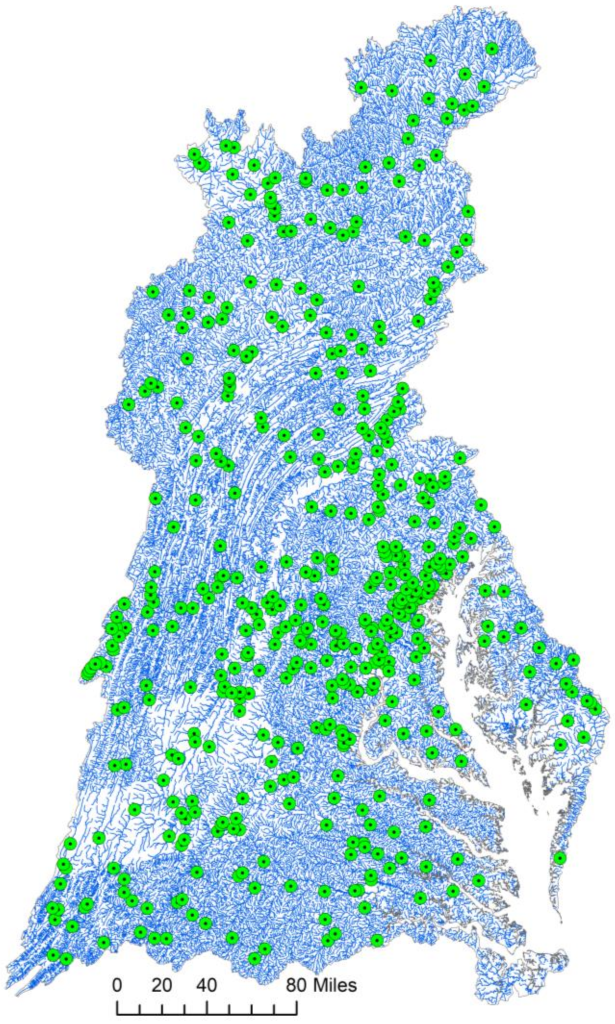


Data labels show product of "Factor Time" and "Factor Dollar".

3. Monitoring Data

Monitoring data informs watershed model calibration, and we need tools for effectively and efficiently extending and expanding it.





The dataset includes flow, and concentration and loads for the water quality variables.

We calibrated Phase 6 DWM using –

WQ Variable	Number of Stations
Daily flow	253
Water temperature	215
Dissolved oxygen	212
Nitrate	221
Ammonia	216
Nitrogen	188
Dissolved orthophosphate	176
Phosphorus	215
Chlorophyll	39

We have tools in place for processing daily flow data and we have processed 1985-2020 data for 629 stations.

3. Monitoring Data

For water quality we want to ensure that we use all available monitoring data in the model calibrations.

Table 10-4: The aggregation rules used for creating the calibration dataset from water quality observations

Phase 6 observed data	USGS parameter name and code
Total Nitrogen	1. Total nitrogen [P600] 2. Total ammonia [P610] + total nitrate [P620] + total nitrite [P615] + total organic nitrogen [P605] 3. Total nitrite + nitrate [P630] + total kjeldahl [P625] 4. Total nitrate [P620] + total kjeldahl [P625] 5. Dissolved nitrogen [P602] + particulate nitrogen [P601] 6. Total nitrite + nitrate [P630]
Nitrate	1. Dissolved nitrite [P613] + total nitrate [P620] 2. Total nitrite + nitrate [P630] 3. Dissolved nitrite + nitrate [P631] 4. Total nitrate [P620] 5. Dissolved nitrate [P618]
Ammonia	1. Dissolved ammonia [P608] 2. Total ammonia [P610]
Total Phosphorus	Total phosphorus [P665]
Dissolved Phosphate	Dissolved phosphate [P671]
Total Suspended Sediment	1. Total suspended sediment [P80154] 2. Total suspended solids [P530]
Dissolved Oxygen	Dissolved Oxygen [P300]
Water Temperature	Temperature [P10]
Chlorophyll a	Chlorophyll a [P32211]

We are getting assistance from different jurisdictions – in terms of availability of additional data for WQ concentrations and estimates of loads.

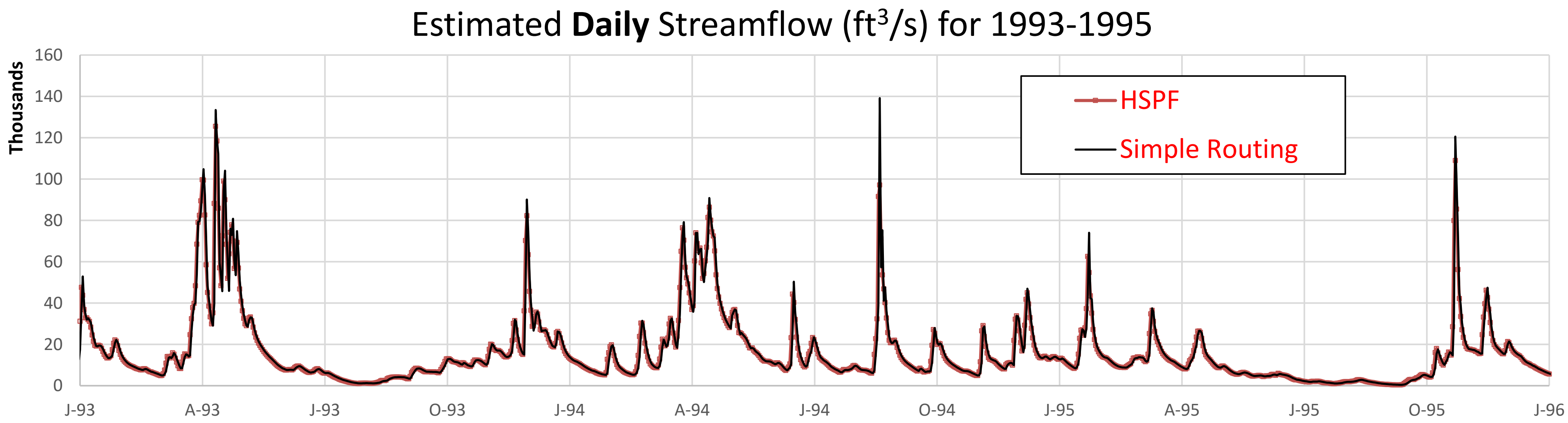
We are assessing how we can use monitoring data at a finer field scale (STAC Workshop).

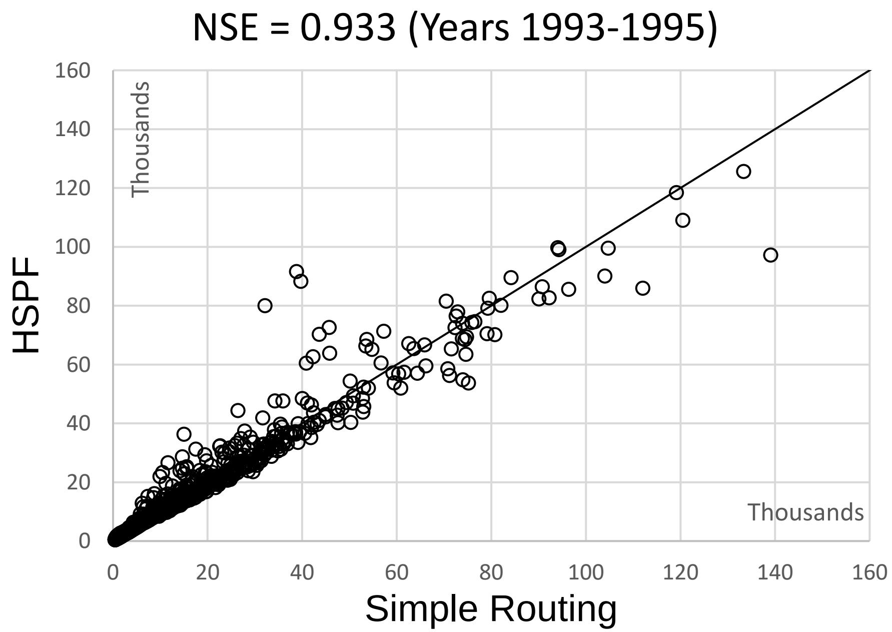
For efficiency and transparency, we think it would be good for us to use data made available on Water Quality Portal[1] that integrates data from USGS NWIS and BioData, EPA STORET, and USDA-ARS STEWARDS.

[1] https://www.waterqualitydata.us

Estimate of loads using WRTDS.

4. Simple routing method for small streams





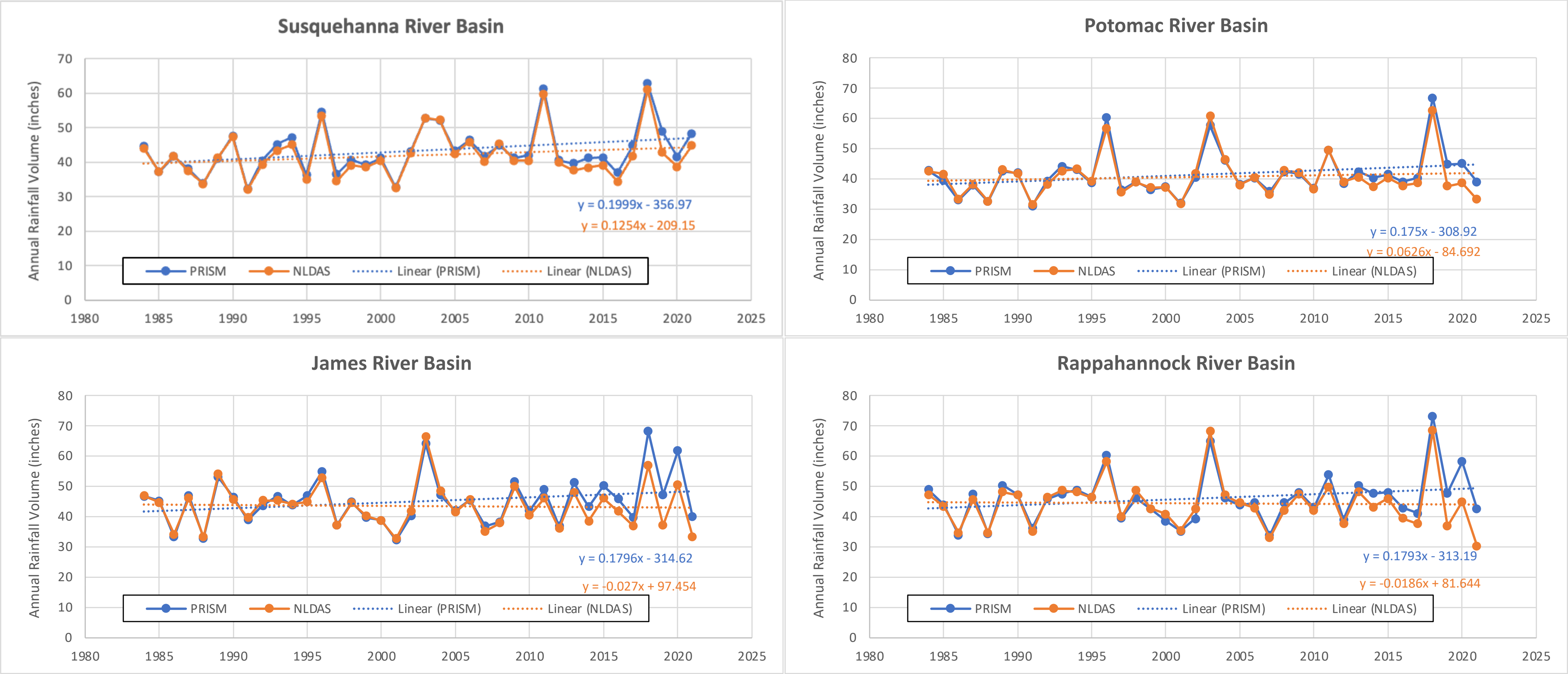
Proof-of-concept tests of “simple routing” have shown promising results. Implementations of numerical simplifications were done in MS Excel.

It is yet to be integrated in the model source code as subroutines along with the estimates of channel parameters.

5. Flow and Water Quality Calibration

Objective: Revise model calibration to improve model performance in estimating trends in loads and its application in climate and land use change scenarios.

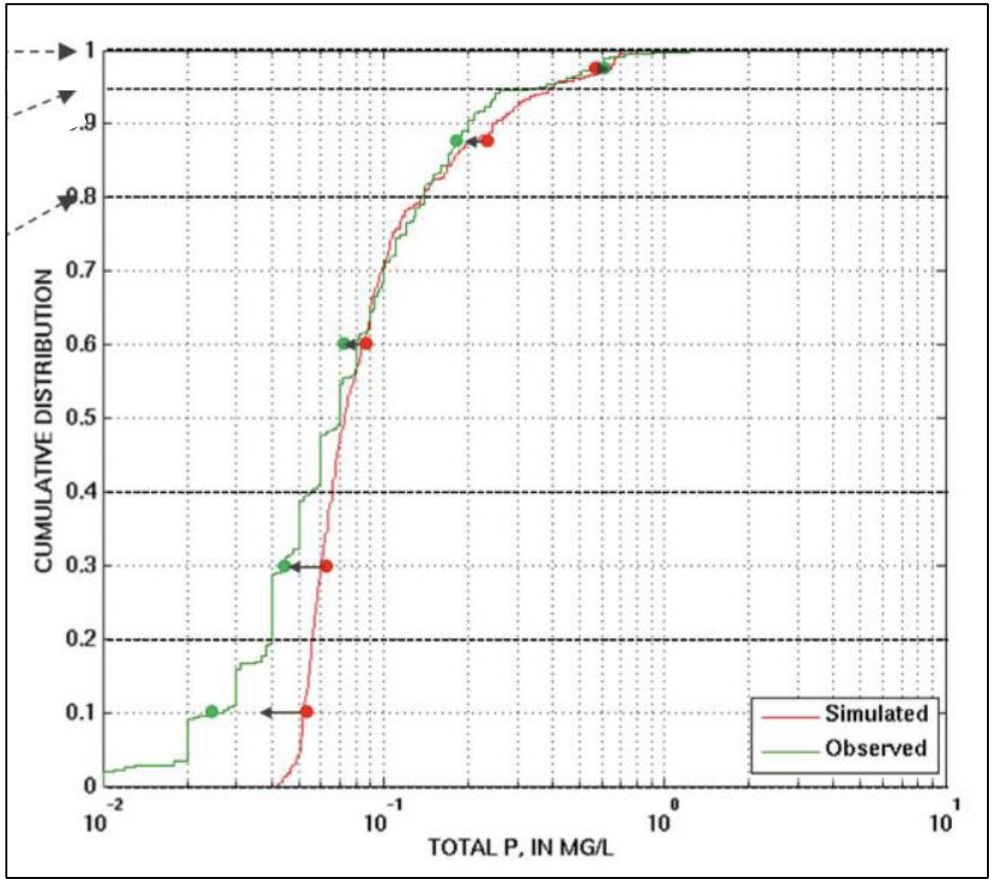
> Method changes for the flow calibration are working as expected.

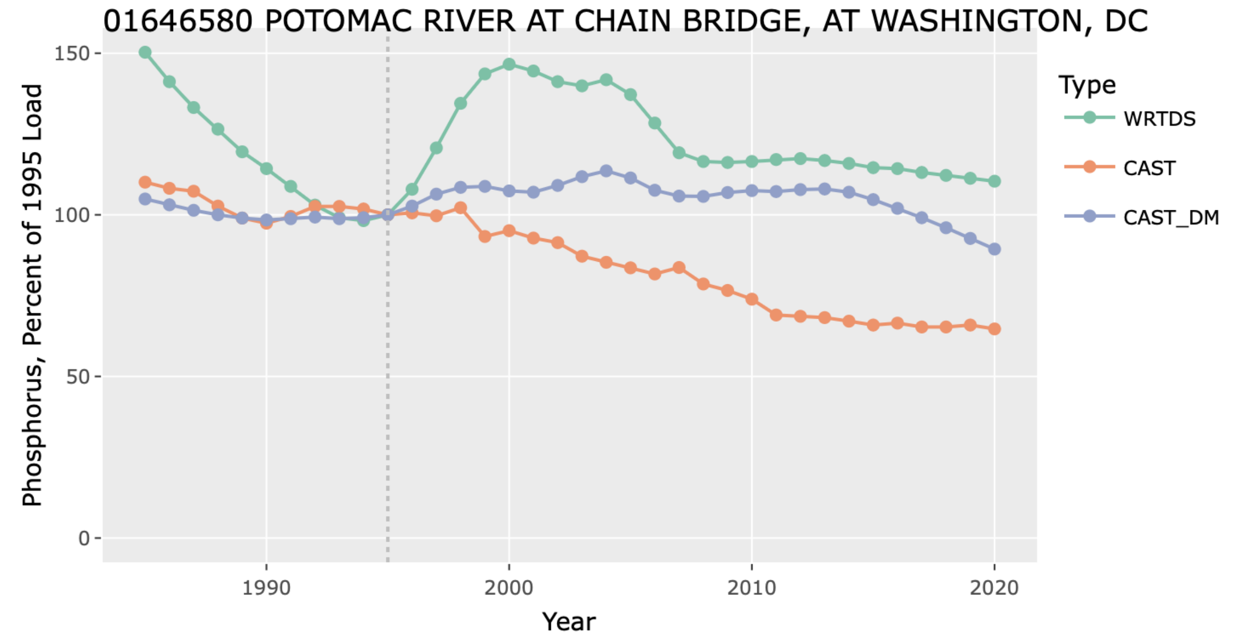


>> We are tracking differences in rainfall volume between NLDAS and PRISM in recent years.

5. Flow and Water Quality Calibration

For water quality we think we need to investigate model calibration in terms of improving simulation of Q-C dynamics and estimation of load trends.





Data Type

WRTDS: Monitored load - computed using the USGS WRTDS flow-normalization method (source).

CAST: Expected load in the long term - computed using the Chesapeake Bay Program Watershed Model (source).

CAST_DM: Expected load with lags - computed using the Chesapeake Bay Program Watershed Model (source).

https://zhangqian0324.shinyapps.io/CBNTN_TMDL_Indicator/

Prior model calibrations focused on the accuracy of spatial variability in loads and distribution of water quality concentration.

Summary

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

1. Model resegmentation

- Mainstem vs. NHD streams
- Subwatershed boundary of river segments vs. NHD catchments

2. Model runtime

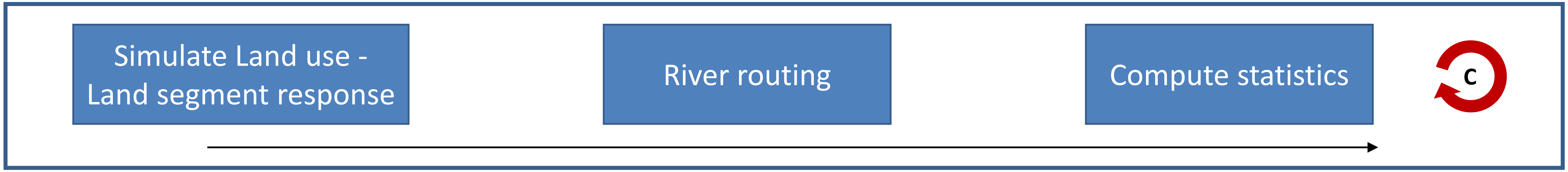
3. Monitoring data (dynamically extend and expand)

4. Simple routing method for small streams

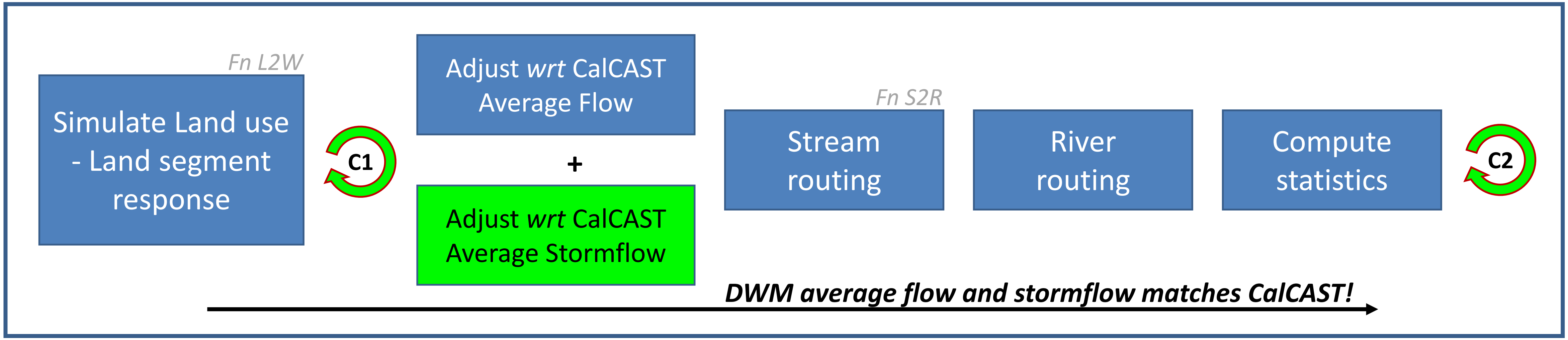
5. Flow and water quality calibration

Hydrology Calibration Method

PHASE 6: HYDROLOGY CALIBRATION

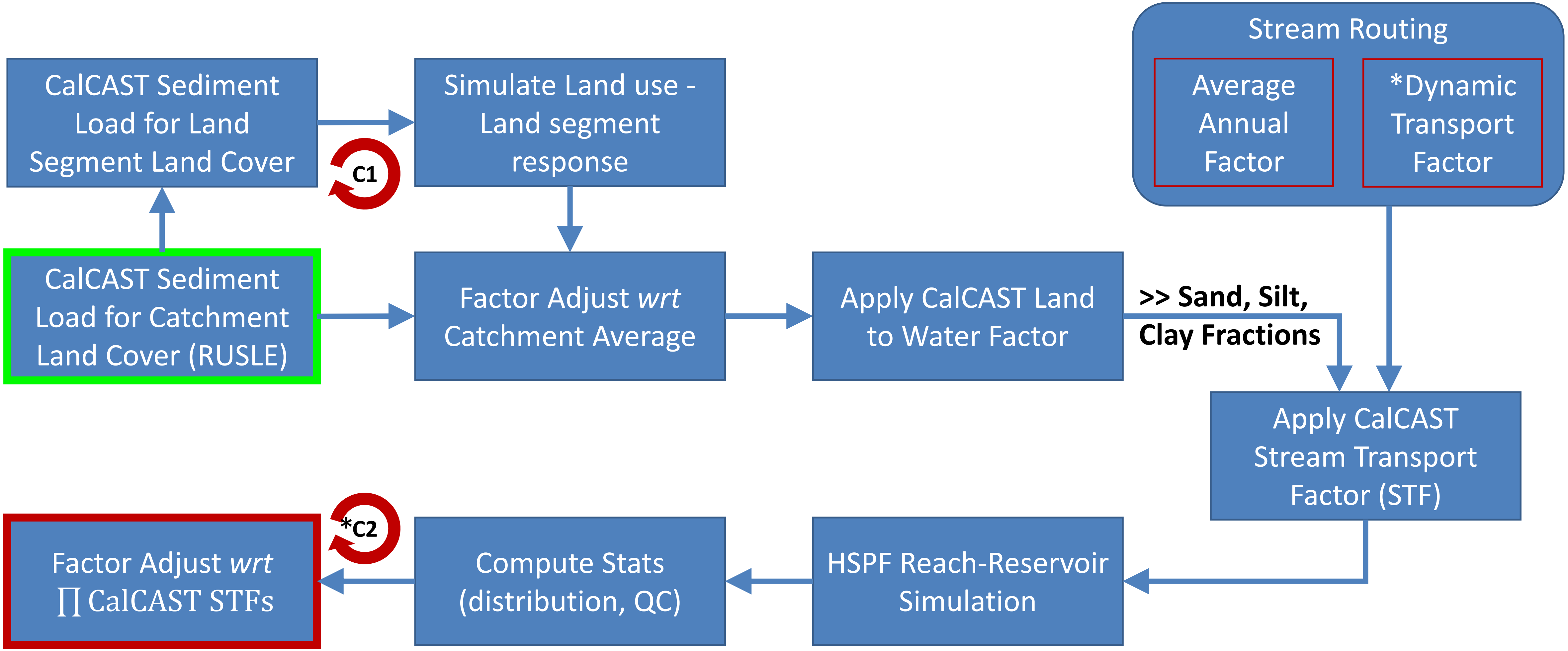


PHASE 7: PROPOSED DWM HYDROLOGY CALIBRATION



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

NHD Scale Sediment Model Structure



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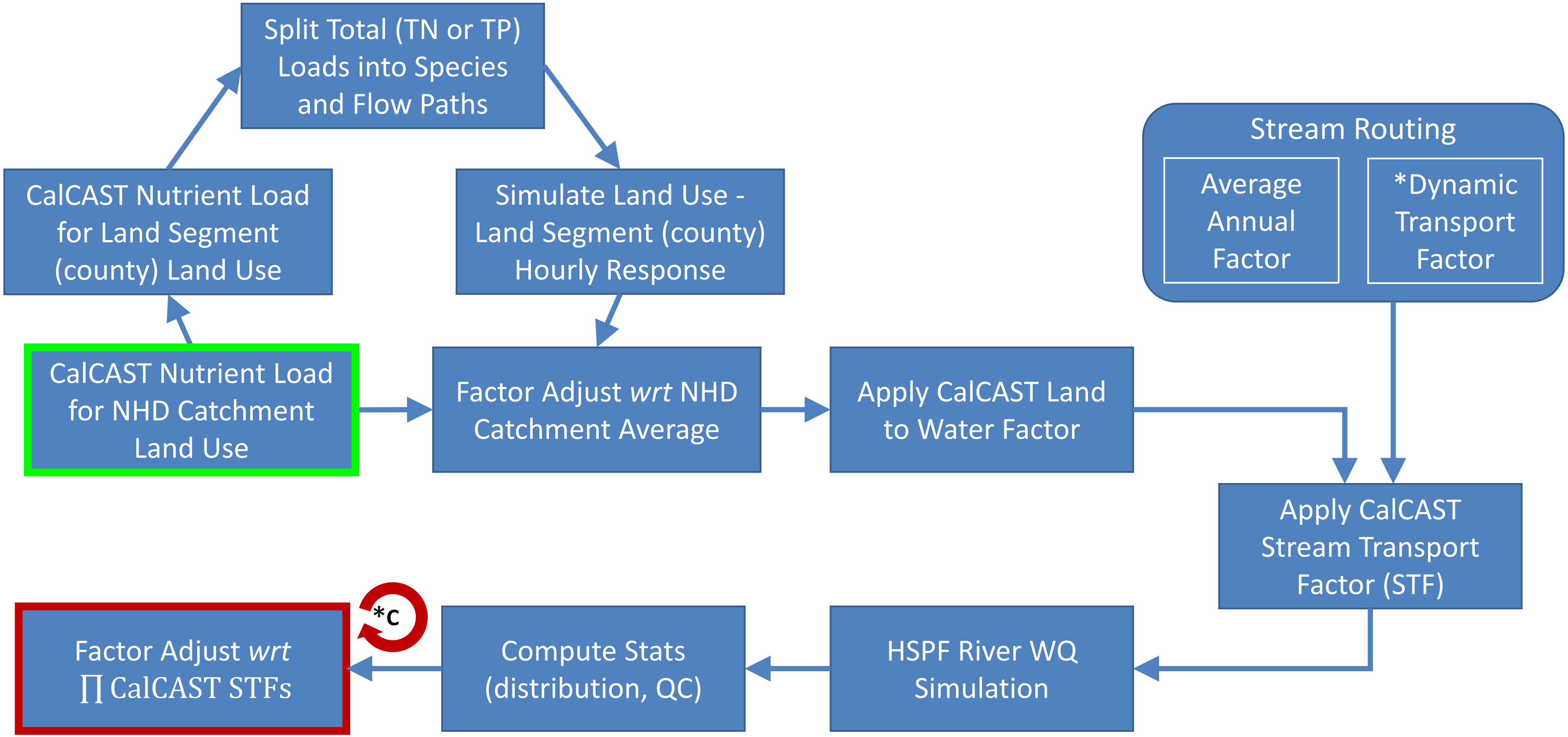
NHD Scale Nutrient Model Structure



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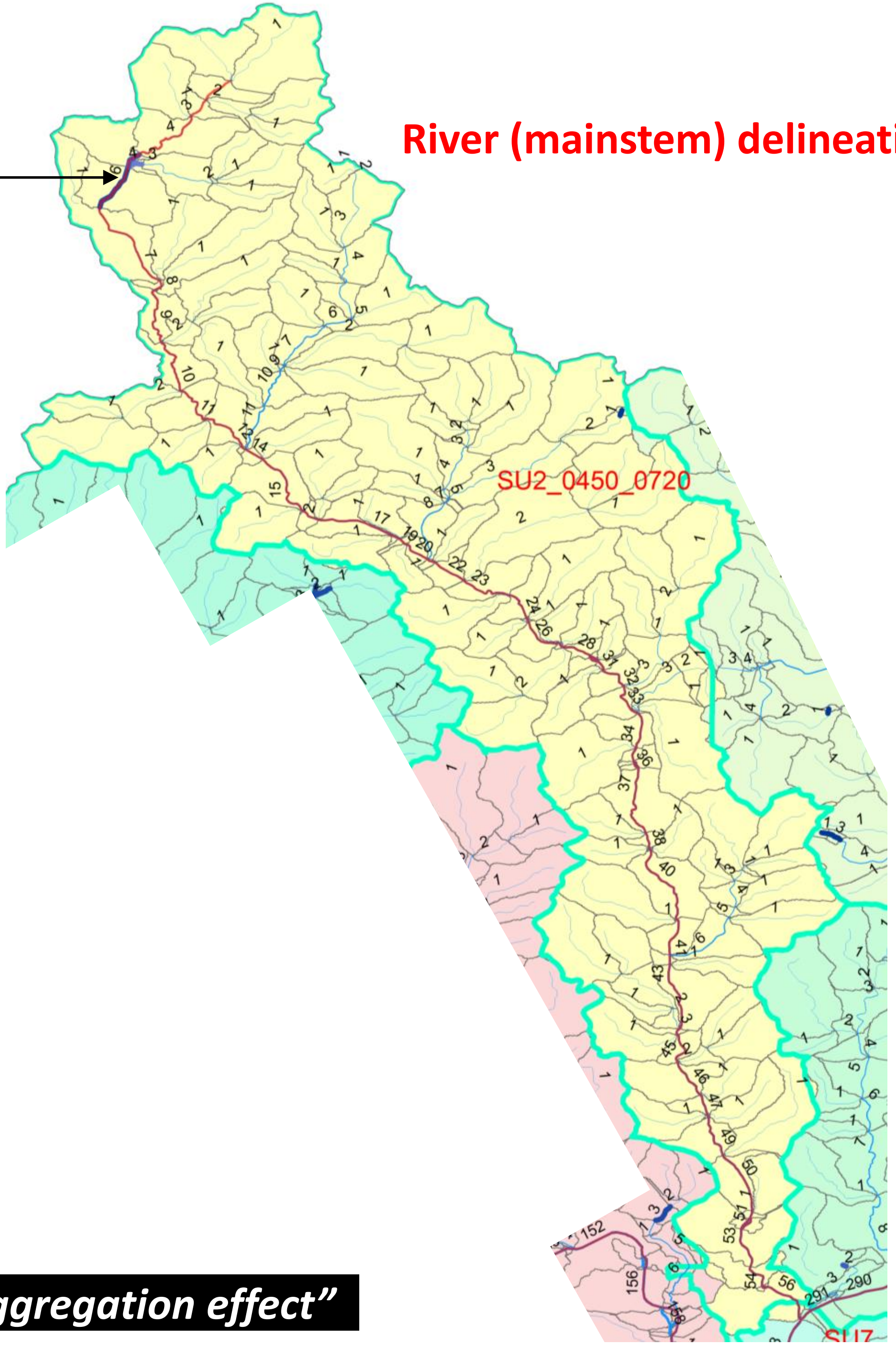
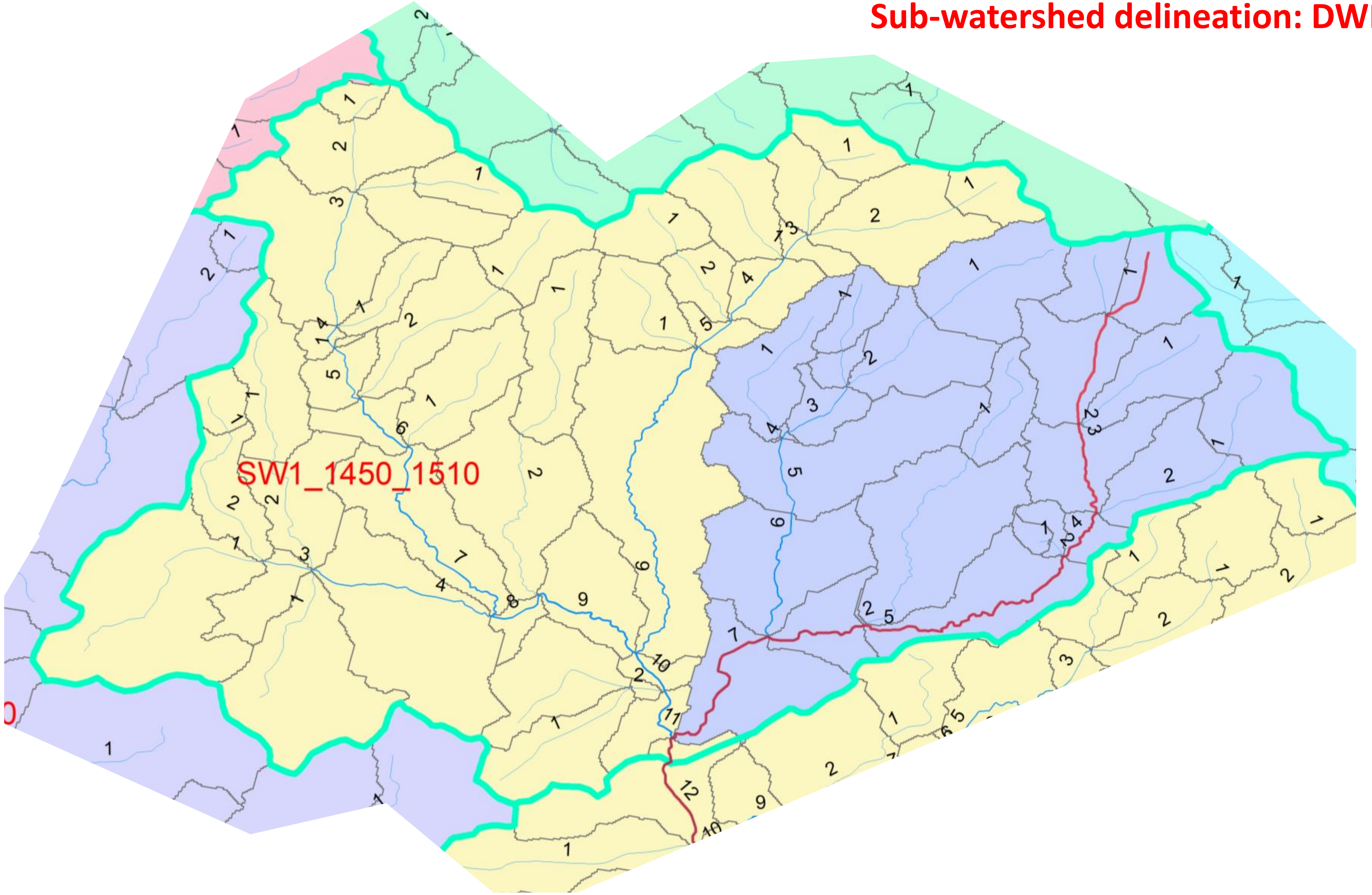


TP Stream Transport Factor

- 0.00 - 0.16
- 0.17 - 0.31
- 0.32 - 0.49
- 0.50 - 0.67
- 0.68 - 0.86
- 0.87 - 1.00

Extended delineation of main stem causes "aggregation effect"

ISSUE #2
Sub-watershed delineation: DWM vs. CalCAST stats



2. Model Runtime

We ported Phase 7 Model on the *proof-of-concept* AWS Cloud HPC, and operationalized the scripts needed for the model runs.

> Testing is in progress…

Processor	Nodes	Cores	Tasks	Runtime
Intel Xeon (Production)	8	36	288	29 H : 00 M
AMD EPYC 7R13	2	96	192	23 H : 55 M
AMD EPYC 7R13	4	96	384	18 H : 45 M
AMD EPYC 7R13	4	96	384	16 H : 15 M
AMD EPYC 7R13	8	16	128	?? H : ?? M

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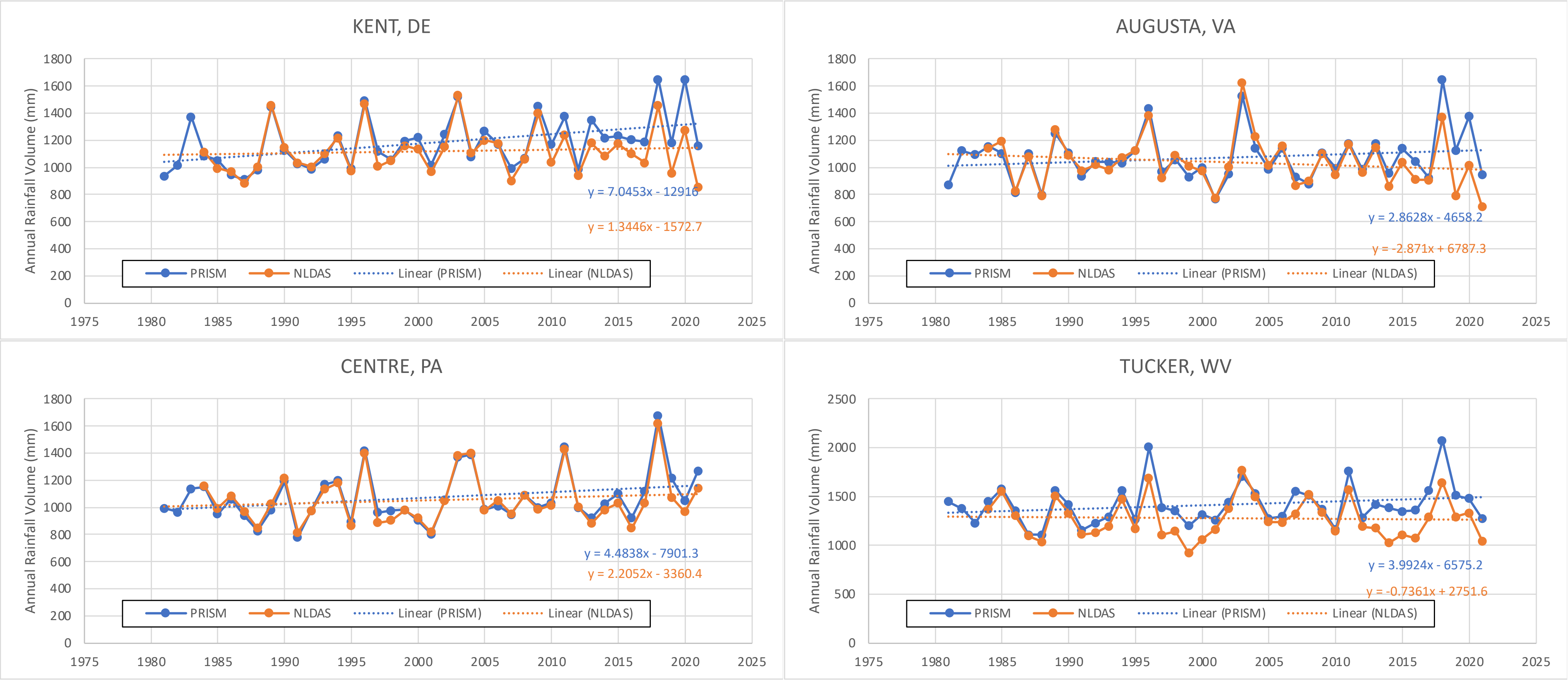

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