Phase 7 WSM Development – Water Quality Routing for Small 100K NHDplus Streams

Modeling Workgroup Quarterly Meeting – April 2024

Gopal Bhatt¹, Isabella Bertani², Lewis Linker³, Robert Burgholzer⁴

¹ Penn State, ² UMCES, ³ US EPA, ⁴ VA DEQ – Chesapeake Bay Program Office

Presentation Outline

Phase 7 Dynamic Watershed Model (DWM)

- 1. Dynamic Watershed Model Overview
- 2. Review of prior model development progress
- 3. Water quality (TN & TP) routing for small streams
 - Building blocks of water quality routing
 - Structure of water quality routing
 - Model testing and verification

4. Summary and next steps

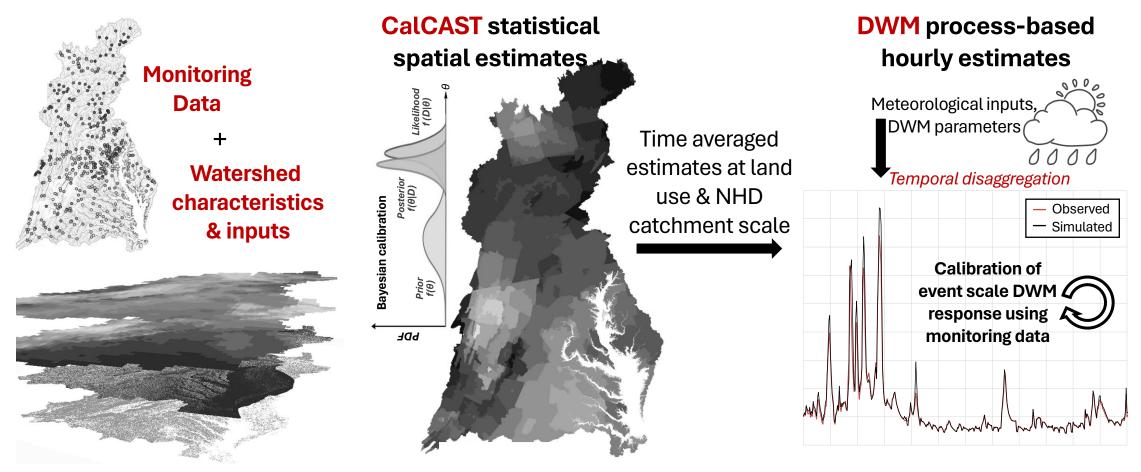
A quick note on surface water withdrawals

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.

Dynamic Watershed Model (DWM) Development

- Year 2022: NHD-scale model structure and prototypes for hydrology, sediment, and nutrients.
 - Operational prototypes with reasonable runtime and on the graph paper model results.
- Year 2023: Incremental refinements of model prototypes in terms of model segmentation, CalCAST→DWM linkage, and simulation of the small streams.

Development Milestones (2022)

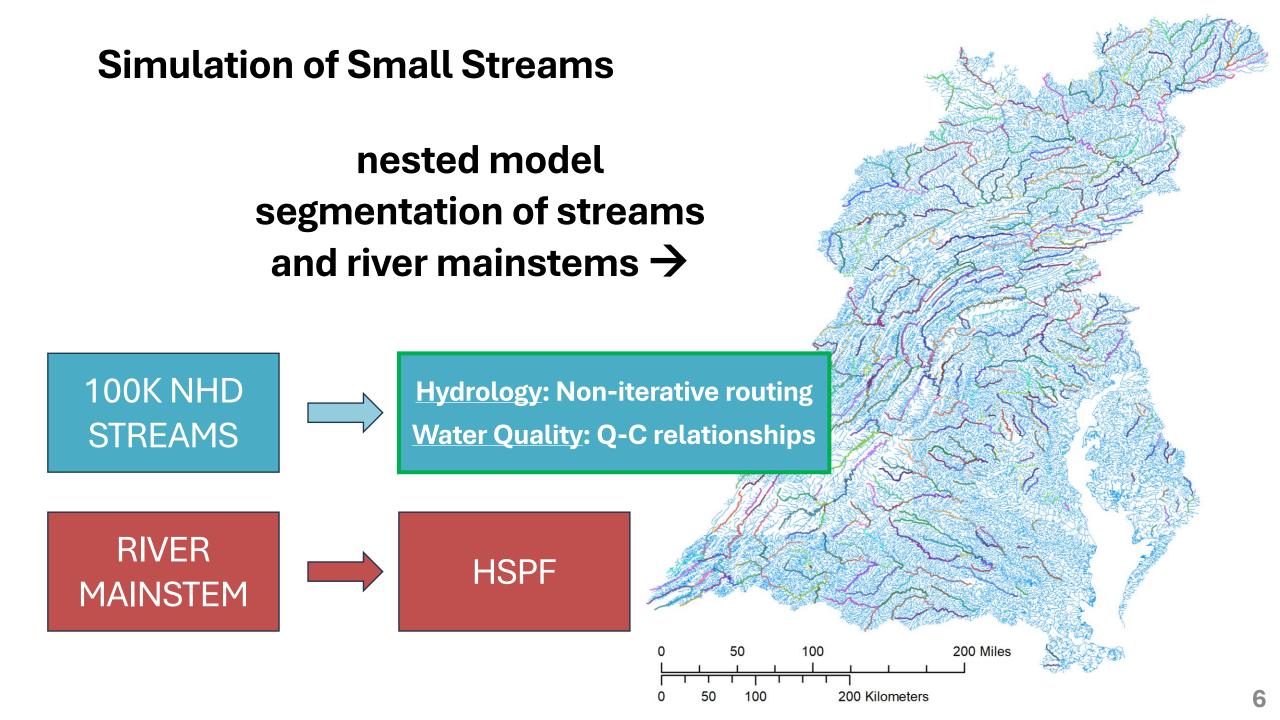
100K NHD	NHD-scale model structure; Hydrology prototype; Expanded simulation period 1985 to 2020; [1][2]			
HYDROLOGY	Hydrology calibration (CalCAST→DWM) method updates; initial testing of numerical simplifications for flow routing; [3]			
SEDIMENT	Sediment model; Hydrology model calibration updates with respect to stormflow; $^{\rm [4]}$			
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				

[1] https://dislav/olsiaia.cloud/mont.net/chespaakebay/documents/progress-in-phase-7-varm-development-1.4.2022_oppal_bhatt_penn_state_ptf [2] https://dislav/olsiaia.cloud/mont.net/chespaakebay/documents/progress_in_phase_7-varm_development_4.2.2022_oppal_bhatt_penn_state_or_123 [3] https://dislav/olsiaia.cloud/mont.net/chespaakebay/documents/progress_in_phase_7-varm_development_-popal_bhatt_penn_state_or_1236 [4] https://dislav/olsiaia.cloud/mont.net/chespaakebay/documents/progress_in_phase_7-Varm_development_-oppal_bhatt_penn_state_or_1236 [4] https://dislav/olsiaia.cloud/mont.net/chespaakebay/documents/penn_state_or_1236 [4] https://dislav/olsiaia.cloud/mont.net/chespaakebay/documents/penn_state_or_1236 [4] https://dislav/olsiaia.cloud/mont.net/chespaakebay/documents/penn_state_or_1236 [4] https://dislav/olsiaia.cloud/mont.net

... incremental improvements during 2023

Segmentation	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 segmentations in the tidal watershed were improved		
Model	Improvements on overcoming the 'aggregation effect' in the simulation of river mainstems (CalCAST → DWM) Non-iterative hydraulic routing for small 100K NHDplus streams WQ routing (TN) for small 100K NHDplus streams		
Simulation	Testing on Amazon AWS and MS Azure cloud HPC environments with various node type and size configurations		

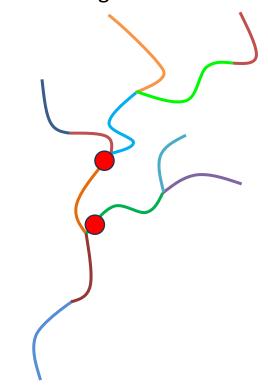
[1] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/2023040s-BHAT-Phase-7-W5M-Development-Opnamic-Model-Development-202301.pdf]
[1] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/Progress-in-Phase-7-W5M-Development-Oppal-Bhat1-Penn-State-6.20.2023 [1]
[3] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/Progress-in-Phase-7-W5M-Development-Oppal-Bhat1-Penn-State-6.20.2023 [1]
[3] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/Progress-in-Phase-7-W5M-Development-Oppal-Bhat1-Penn-State-6.20.2023 [1]
[3] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/Progress-in-Phase-7-W5M-Development-Oppal-Bhat1-Penn-State-6.20.2023 [1]
[4] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/Progress-in-Phase-7-W5M-Development-Oppal-Bhat1-Penn-State-6.20.2023 [1]
[5] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/Progress-in-Phase-7-W5M-Development-Oppal-Bhat1-Penn-State-6.20.2023 [1]
[6] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/Progress-in-Phase-7-W5M-Development-Oppal-Bhat1-Penn-State-6.20.2023 [1]
[7] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/Progress-in-Phase-7-W5M-Development-Oppal-Bhat1-Penn-State-6.20.2023 [1]
[8] https://d18lev1oK3leia.doudfront.net/chesapeakebay/documents/Progress-in-Phase-7-W5M-Development-Oppal-Bhat



Building blocks of water quality routing for small streams

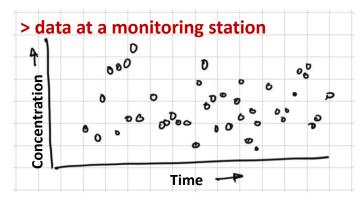
- Develop model parameters that provide information on *flow* and *seasonal* variability in concentration for small 100K NHDplus streams
 - parameters rooted in monitoring data and emergent watershed properties
 - improved loadings to the tidal estuary and to HSPF simulations of river mainstems
- Tools such as WRTDS-K and Fluxmaster-K can be useful

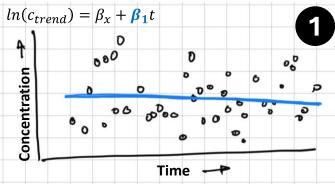
Figure: network of small streams and monitoring stations

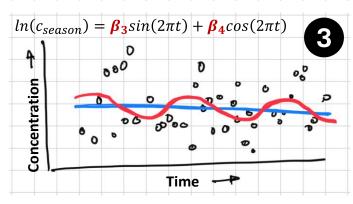


$$ln(c) = \beta_o + \beta_1 t + \beta_2 ln(Q) + \beta_3 sin(2\pi t) + \beta_4 cos(2\pi t) + \varepsilon$$

Building blocks of water quality routing for small streams







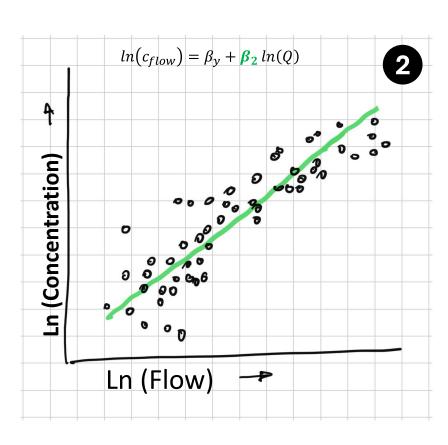
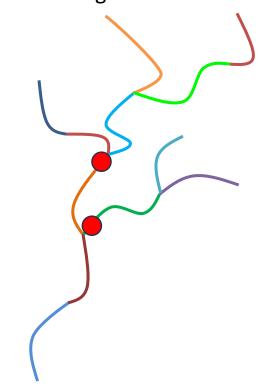


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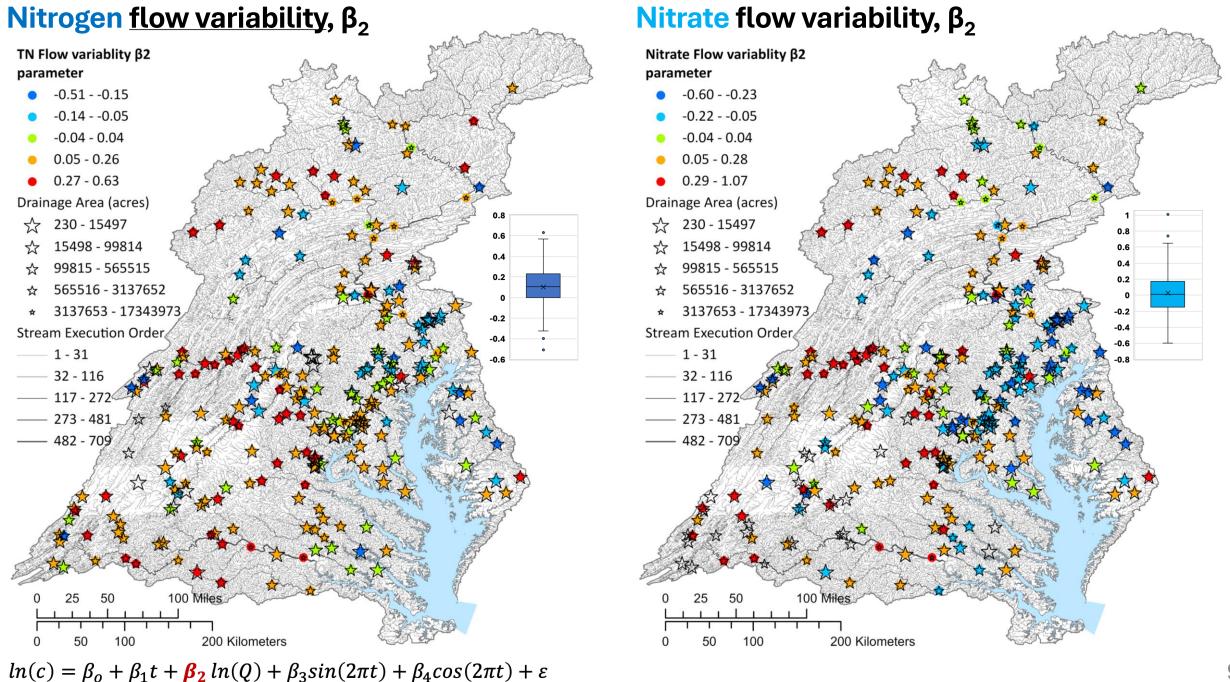


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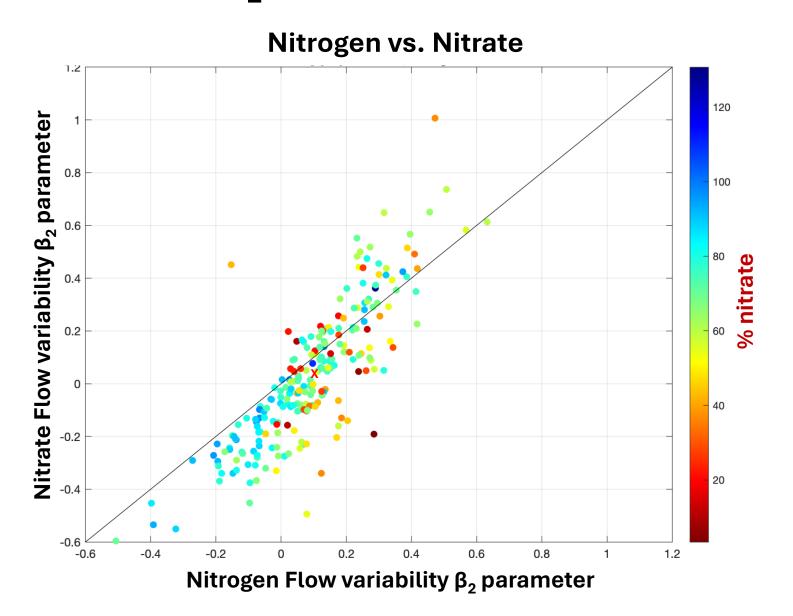




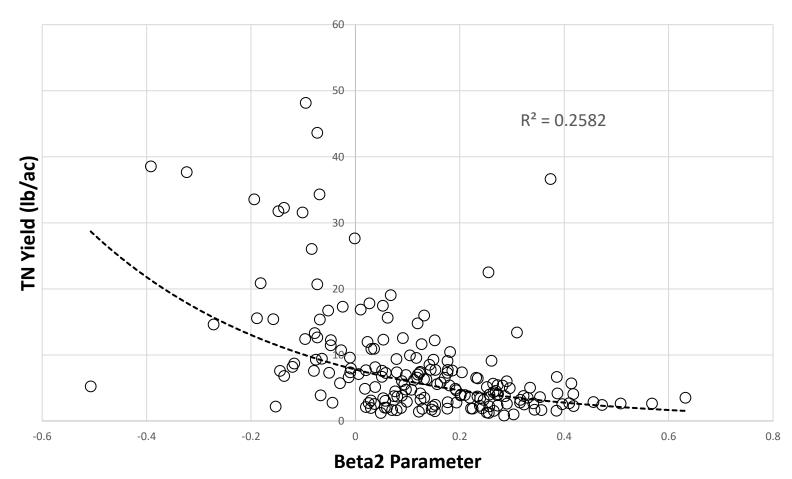




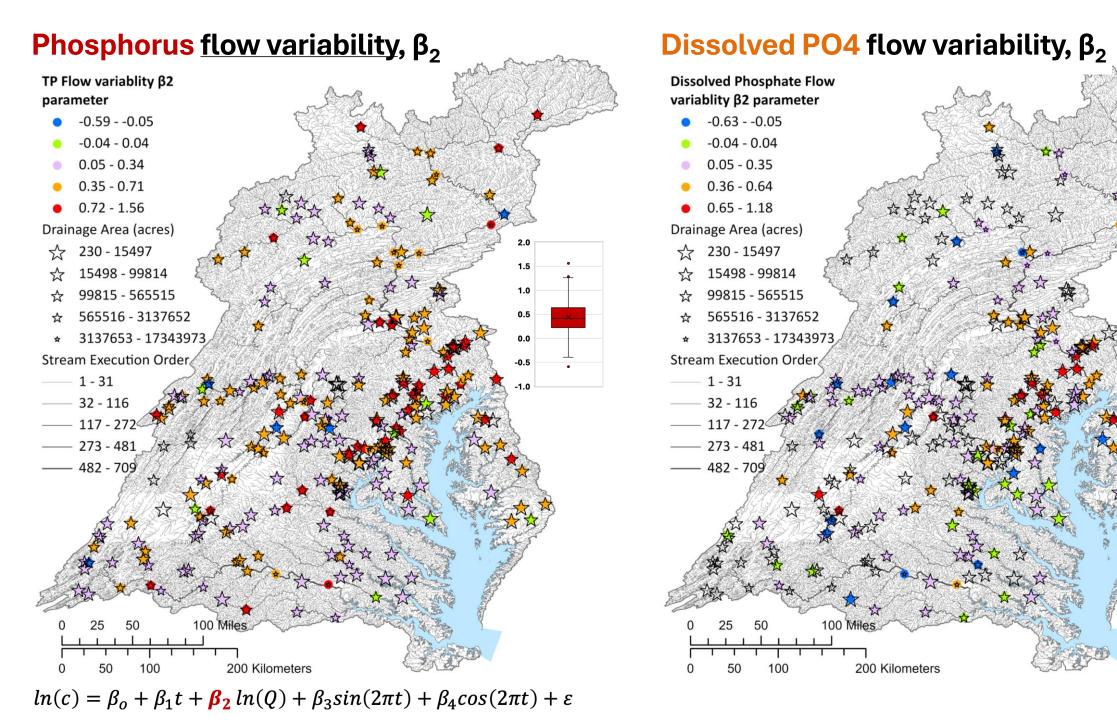
Flow variability, β_2 parameter



Explaining variability in β_2 parameter



- We have not fully investigated explaining the variability in β_2 parameters.
- But spatial patterns are intriguing and so we think use of watershed properties and better analysis tools should be successful.



Structure of water quality routing for small streams



HSPF: <u>hourly</u> surface and groundwater hydrology of land uses

UNEC: <u>annual</u> surface and groundwater concentrations as a function of input history and estimates of lag-times





Input to the stream

(ucutation of the stream)

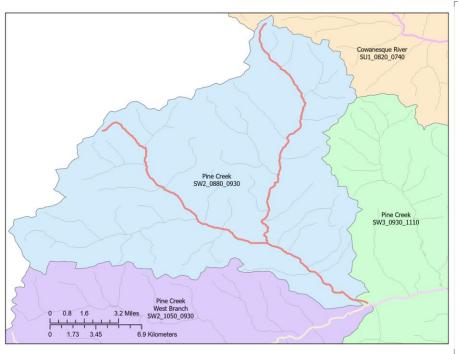
Ln (Flow)

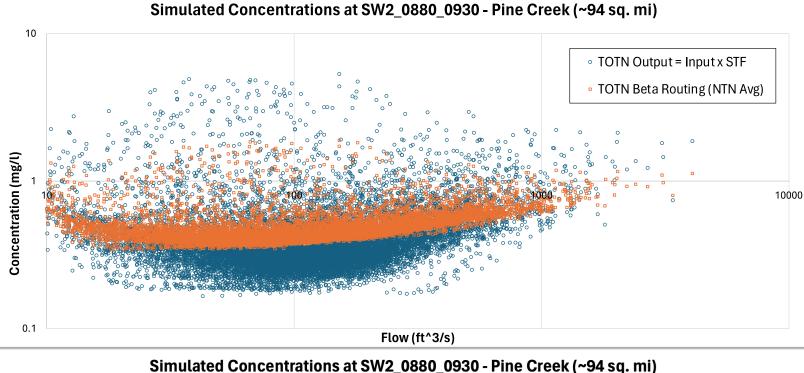
Biogeochemical processing,
Storage/deposition, Scour

→ Fate and Transport

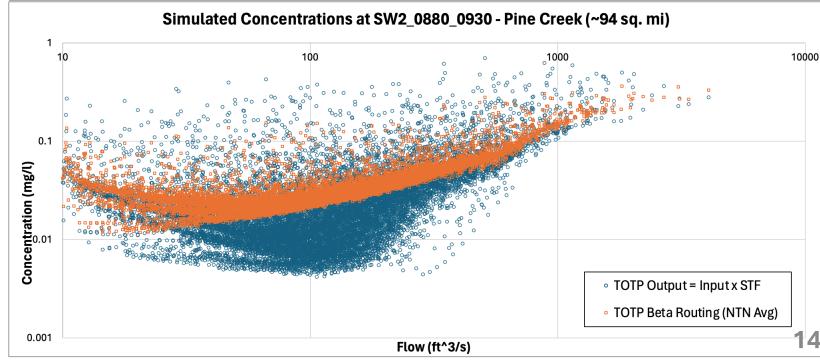




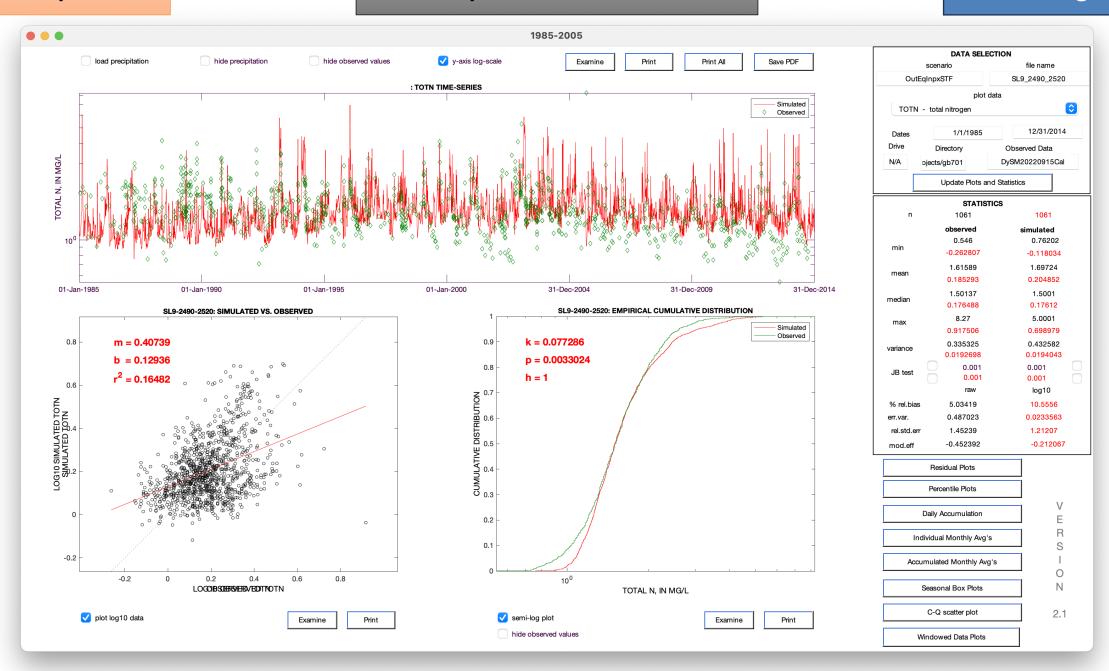


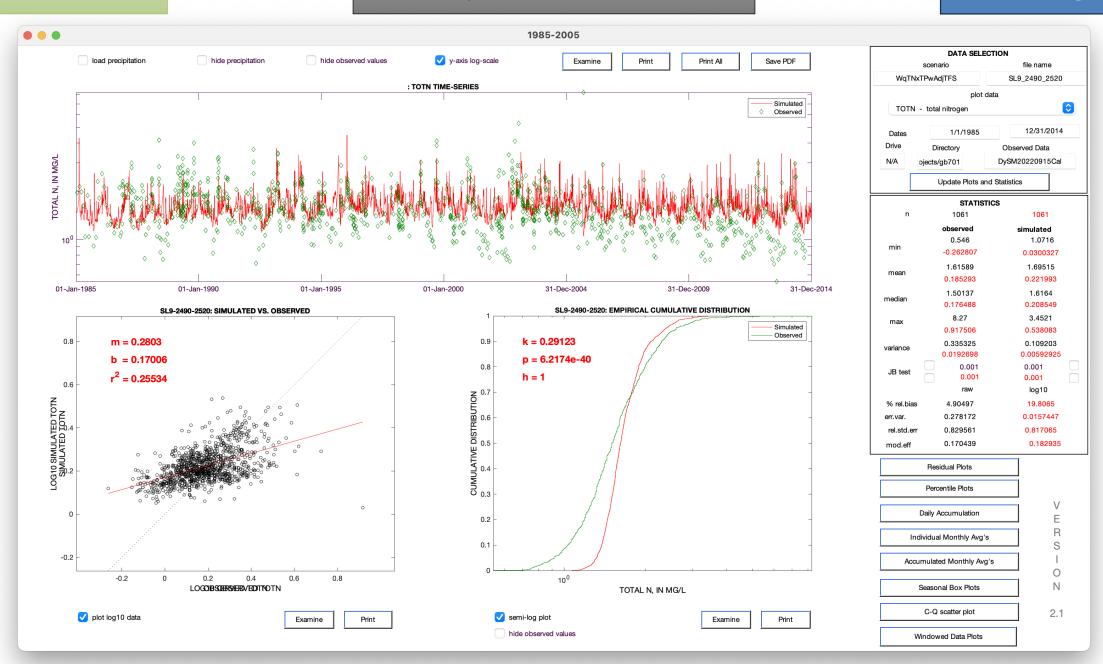


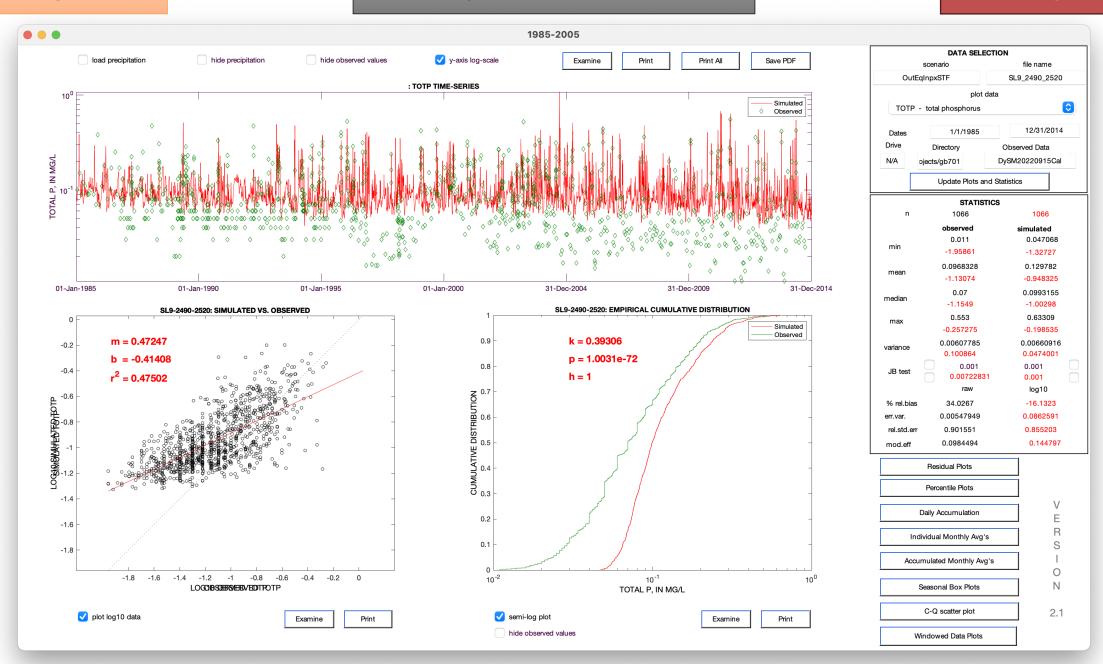
Flows and loads are routed as per topology of NHD streams and then into a mainstem.

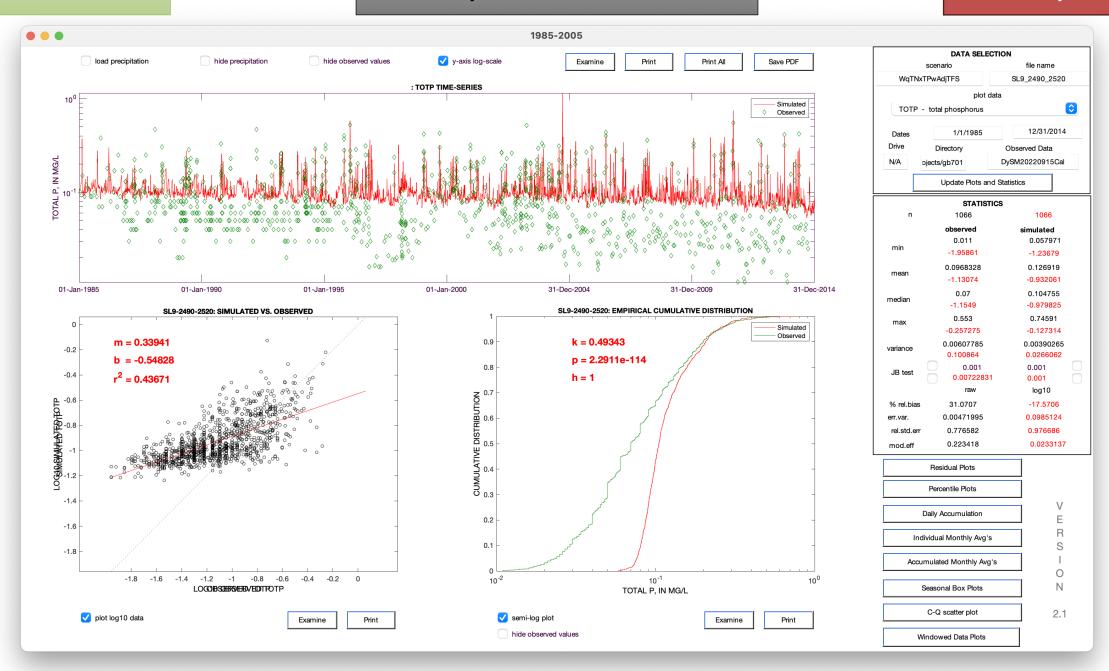


Nitrogen

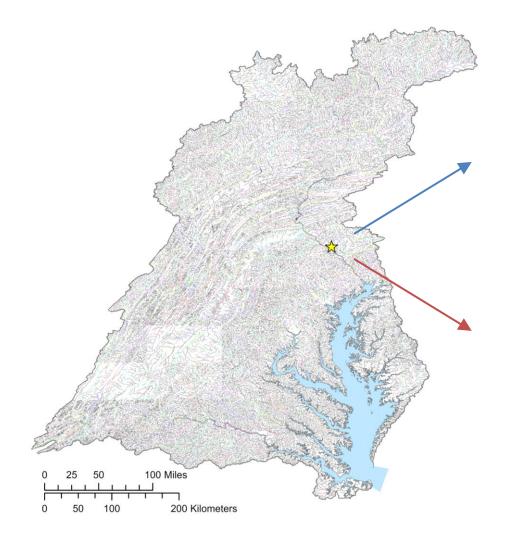


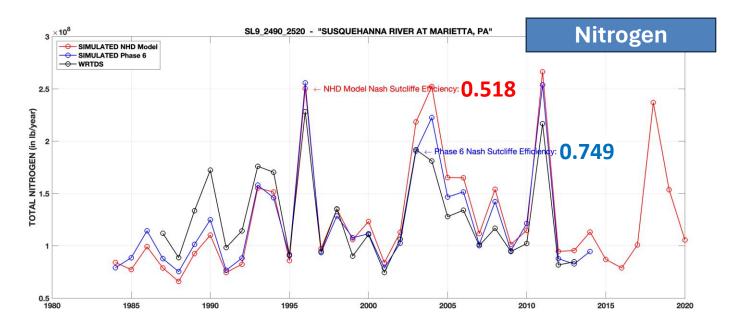


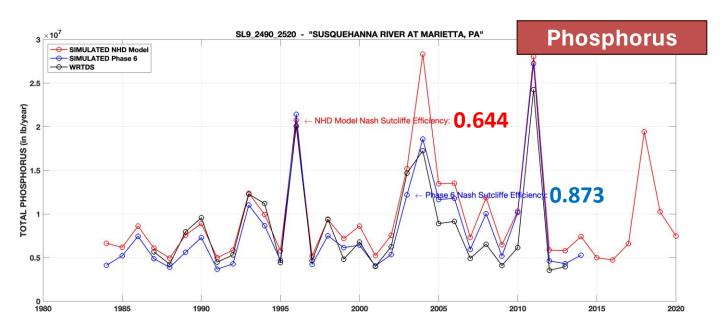




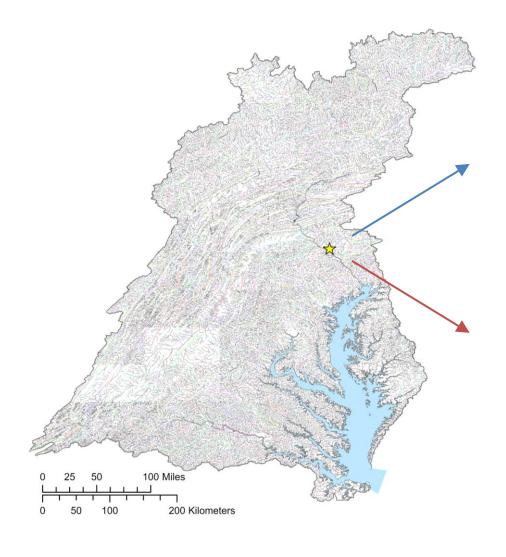
Output = Input x STF

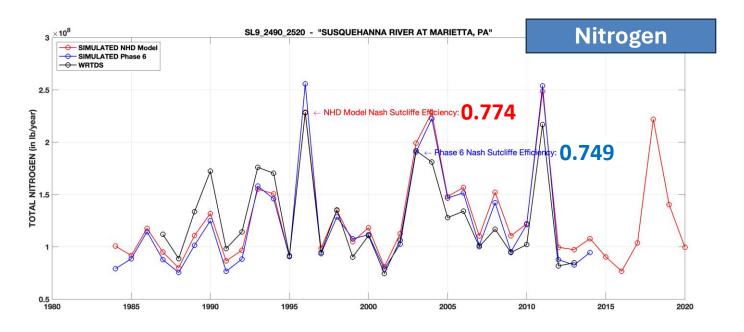


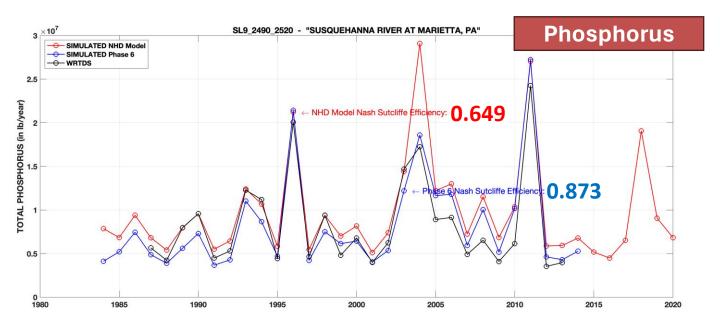




Beta Parameters







Summary

1. We implemented water quality routing for small streams for total nitrogen, total phosphorus, and its species

- routing modules are functioning as expected in simulating flow and seasonal variability in concentrations
- our analysis showed that riverine simulation of water quality processes were not degraded significantly

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

- 2. perform testing and verification of new modules for the TN & TP species
- 3. examine surface and groundwater transport in the land simulation
- 4. Water quality calibration and linkage with the estuarine models

Surface water withdrawals

- Surface water withdrawals for (a) public water supply, and (b) irrigation & agricultural use are inputs to the watershed model.
- The data are used in estimating the removal of water, nutrients, and sediment loads in the riverine streamflow and water quality simulation.

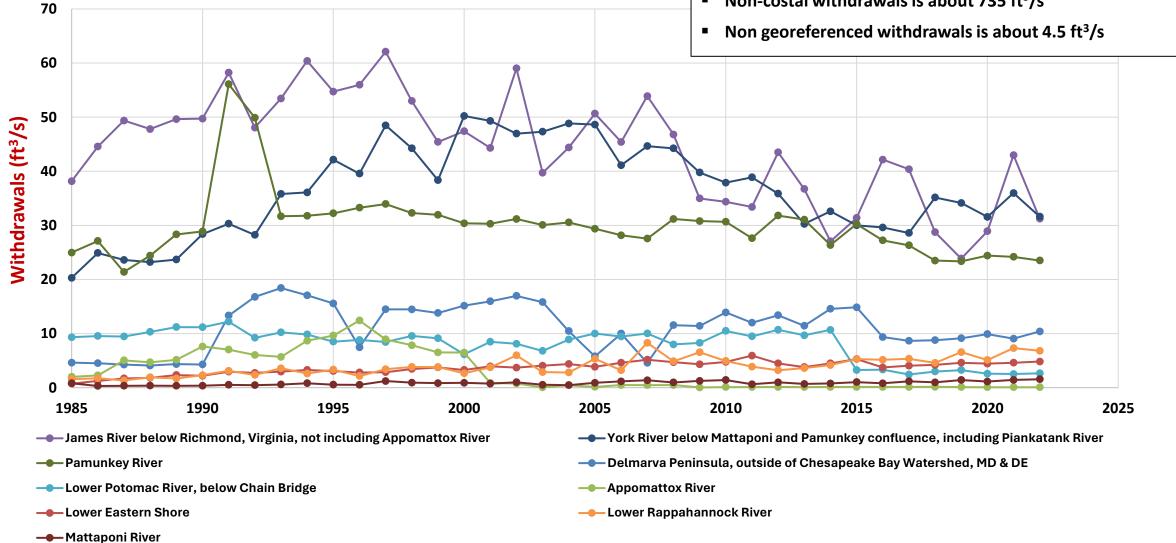
- In Phase 6, the effect of withdrawals from <u>coastal</u> sub-watersheds without riverine simulation was not assessed.
- We received 1982-2022 QAQC withdrawals data from VADEQ.

Thanks to Brendan Brogan

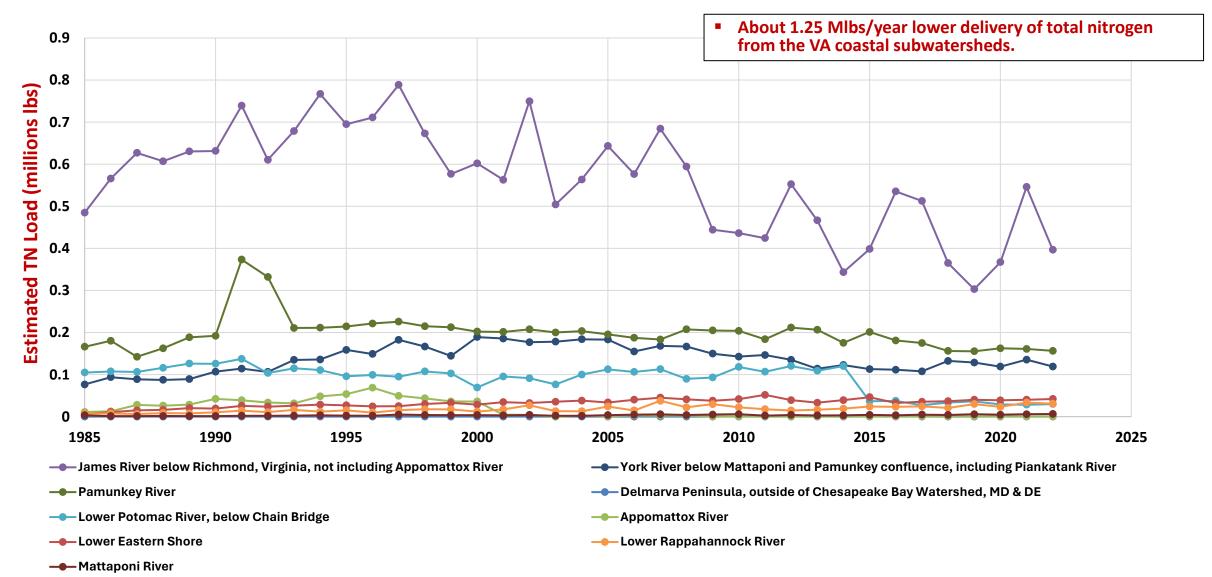
Analysis of VADEQ data

Use Type: Hydropower, nuclear power, fossil power, municipal, manufacturing, mining, irrigation, agriculture, commercial

- Average withdrawals of about 165 ft³/s (VA data only!)
- Non-costal withdrawals is about 735 ft³/s



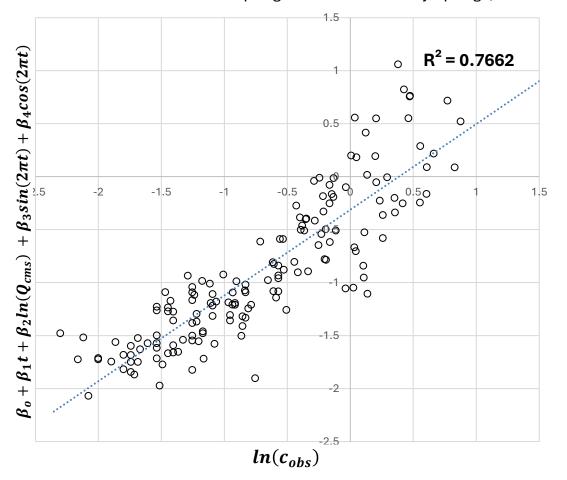
A very rough assessment of TN loads



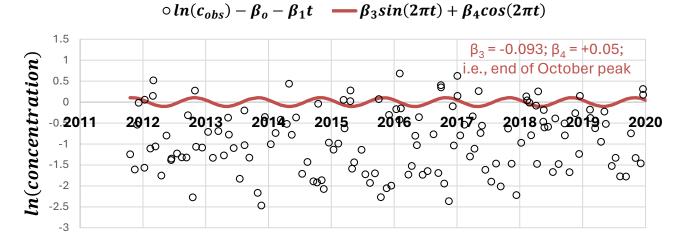
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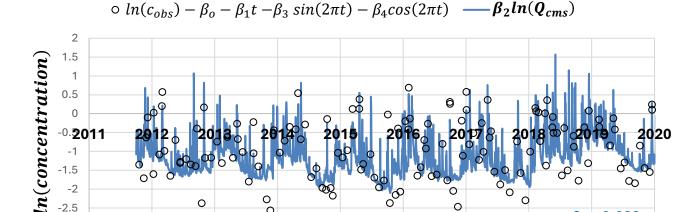
USGS 01613030 - Warm Springs Run Near Berkeley Springs, WV

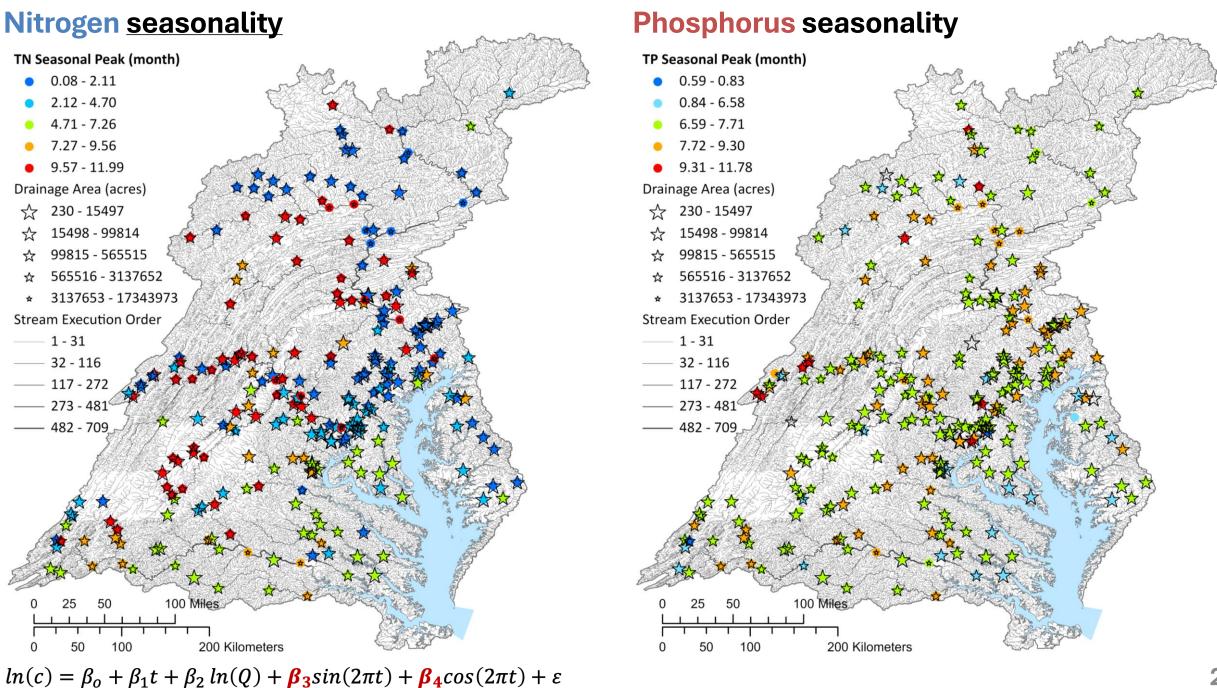


TN Seasonal Variablity

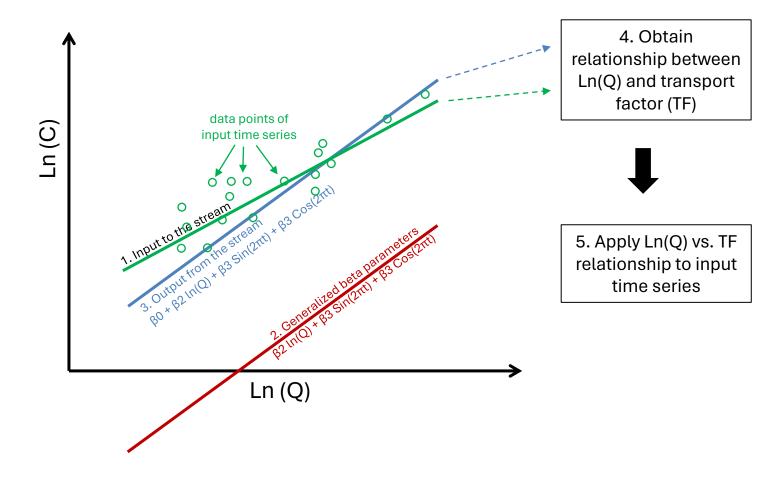


TN Flow Variability





Structure – two good options



Option 1: Concentration time series generated at the end of Step #3

Option 2: Concentration time series generated at the end of Step #5

Flow variability, β_2 parameter

