Geographic Isolation Runs & Exploring Watershed Effectiveness for Open Water Chlorophyll *a* Concentrations

Brief Overview of Methods on Connecting Watershed to Tidal Water Quality Tool Presented at the September CWGT Meeting

Modeling WG Meeting 10/28/2026

Alex Gunnerson, Koniag Government Services

Outline

- Background on Geographic Isolation Runs
- Development and Purpose of Tool
- Ideas for Future Refinements to Geographic Isolation Runs and Evolution of Tool

Context

- After the approval of the P6 suite of models and the Deep Water/Deep Chanel (DW/DC) planning targets were set, WQGIT asked for an understanding of what relative effectiveness might look like for Open Water (OW)

- Results were presented at the March 2019 WQGIT meeting

- This is how it was done before, **not** what we are suggesting to do in the future

Geographic Isolation Runs (2019) P6 Models

- CBPO modeling team ran a series of geographic isolation runs at 92 segment scale for TN & TP split up by PS and non-PS (n=368)

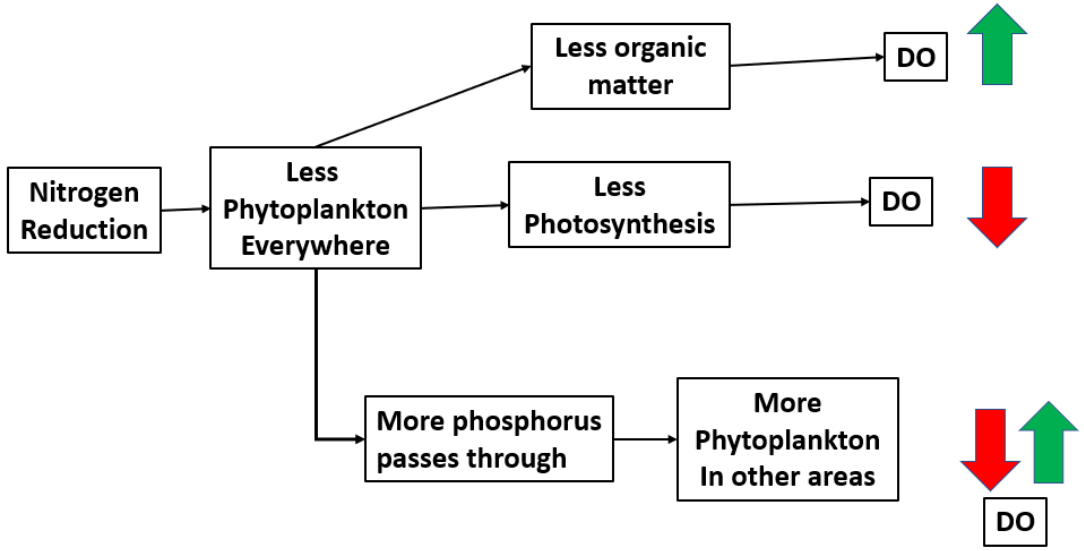
- Ran multiple scenarios, but used 2017 Progress (most recent)

- 5 million lbs of N or 0.5 Mlbs/yr P added each year by an annual coefficient to the loads in that CBSEG
  - Recorded the Change in Chlorophyll *a* concentration to the depth of the long-term surface mixed layer average June through September
    - Estuarine effectiveness is equally applied to all <u>delivered</u> loads from that watershed
  - Multiplied by watershed delivery to get the overall effectiveness measures

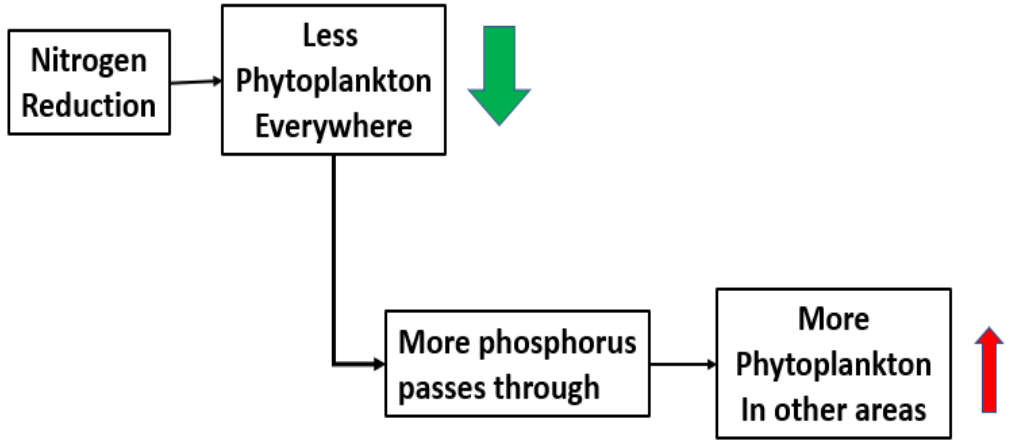
Why Use Chlorophyll-a?

- Primary productivity is more immediately responsive to nutrient loads in shallow waters and does not introduce confounding factors from the atmosphere and sediments

In Open Water, nutrient reductions lead to both more and less oxygen



Using Chl*a* in Open Water is more direct in a eutrophic coastal system, but not perfect

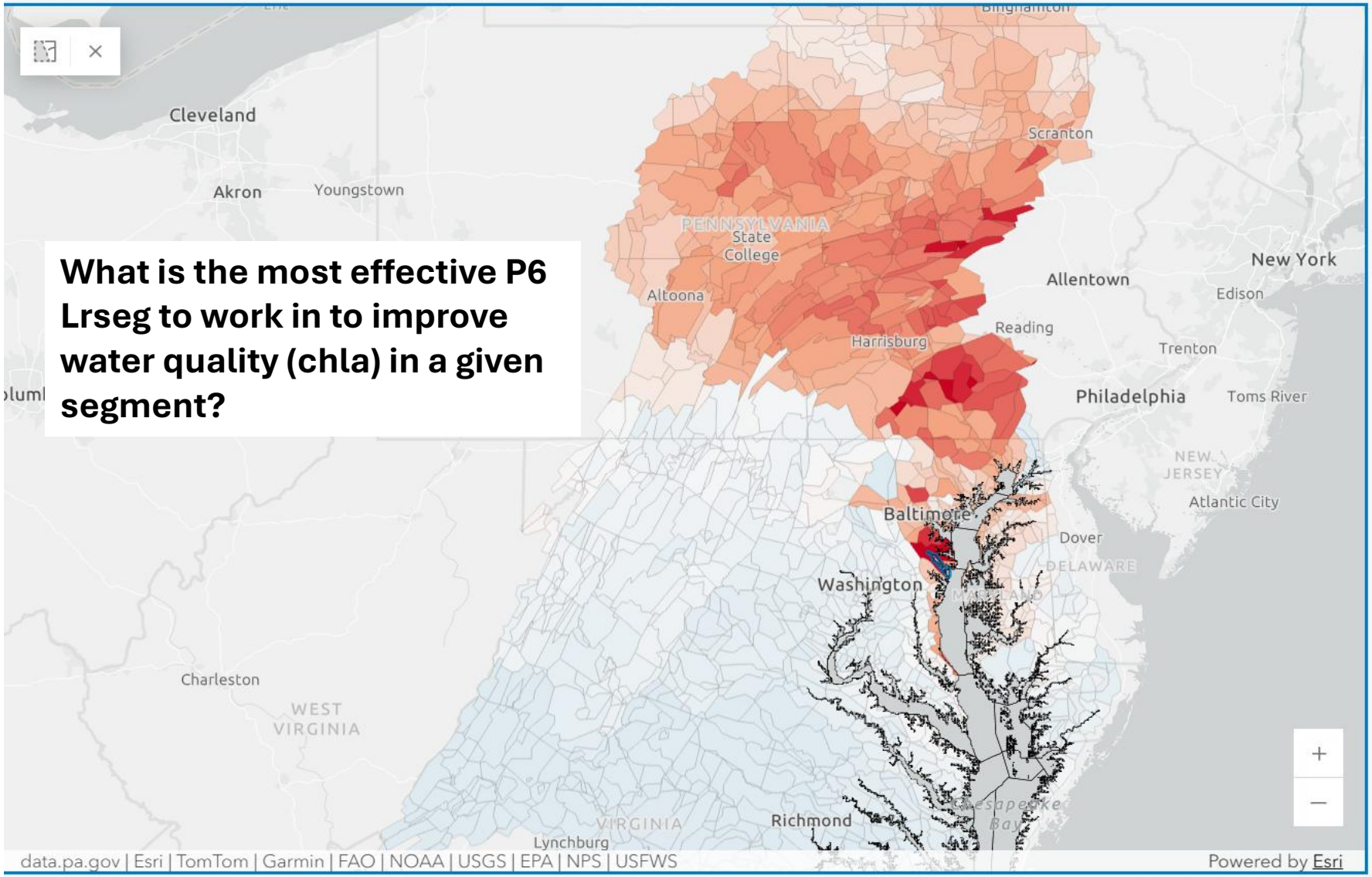


Chla Effectiveness on OW (P6 Lrseg)

GeoIsoRuns map service no segment selector

Select a Pollutant
Nitrogen

Select a Source
Non-Point Source



What is the most effective P6 Lrseg to work in to improve water quality (chla) in a given segment?

Selected Tidal Segment:

SEVMH

Legend

Effectiveness of Land River Segments on Tidal Segment Water Quality

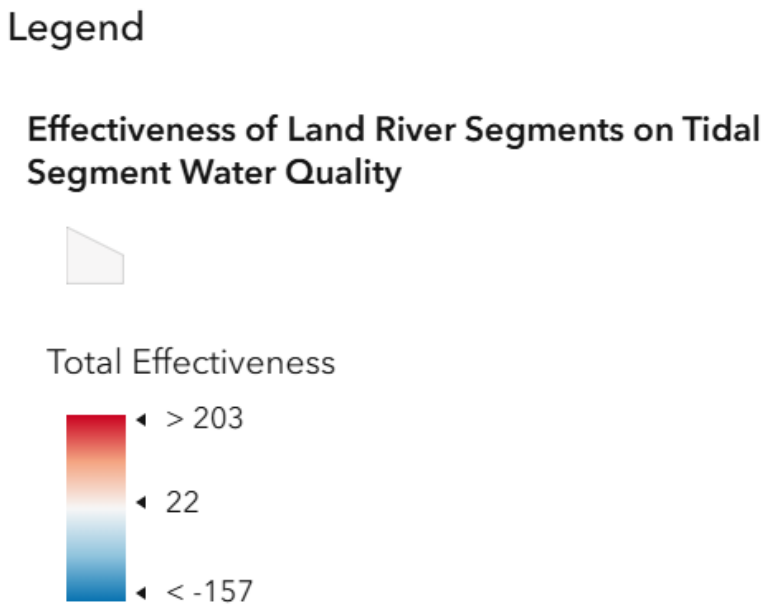
Total Effectiveness

- > 203
- 22
- < -157

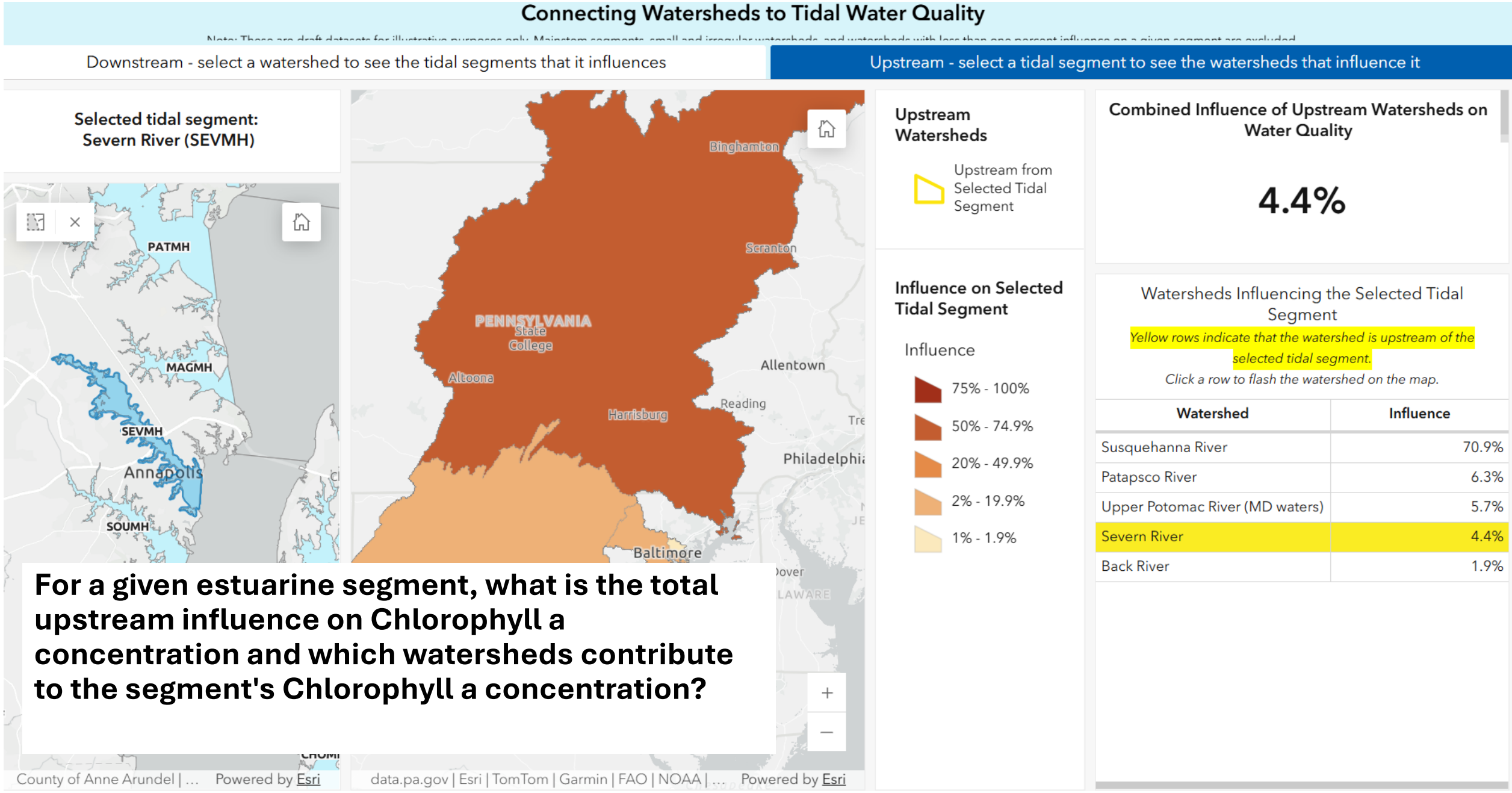
Increase in chla concentration (ng/l) per pound of non-point source Nitrogen produced

Problem: This is Difficult to Use for Management

- Issue: Negative influence concept was unintuitive
- Issue: Legend didn't facilitate effective comparison between LRsegs



So we normalized by asking a different question



For a given estuarine segment, what is the total upstream influence on Chlorophyll a concentration and which watersheds contribute to the segment's Chlorophyll a concentration?

Normalization (2026)

- **i** = Receiving tidal segment (the segment whose chl-a concentration is affected); one row of the new tool's table
- **j, u, m** = Source watersheds (where loads originate). j is the source of interest, u indexes watersheds within the upstream set, and m indexes all watersheds in the denominator
- **n** = Total number of watersheds
- **k =** Load type
- **K =** Set of load types: K = {N_{PS}, P_{PS}, N_{NPS}, P_{NPS}}
- **U(j)** = Set containing watershed j and all watersheds upstream of j
- $\mathbf{D_{k,\,j\rightarrow i}}$ = Estuarine delivery factor: increase in chl-a in segment i per lb of load type k delivered from watershed j (ng/L per lb)
- $\mathbf{L_{k,\,j}}$ = 2017 Progress EOT load of type k in watershed j (lbs)
- $\mathbf{S_k}$ = Signal size for load type k. S = 5 M lbs for N_{PS} and N_{NPS} ; S = 500,000 lbs for P_{PS} and P_{NPS}

$$R_{j\rightarrow i}^{\mathrm{cum}} = \frac{\displaystyle\sum_{u\in U(j)} \left| \sum_{k\in K} \frac{D_{k,\,u\rightarrow i}\, L_{k,\,u}}{S_k} \right|}{\displaystyle\sum_{m=1}^{n} \left| \sum_{k\in K} \frac{D_{k,\,m\rightarrow i}\, L_{k,\,m}}{S_k} \right|}$$

Normalization (2026) – Said Another Way

1. Took the estuarine delivery (chla concentration increase (ng/l) per lb delivered) and multiplied by the 2017 Progress EOT load for each of the four loads (N PS, P PS, N NPS, P NPS), then divided by the signal (5 M lbs TN or 500K lbs TP)
2. Summarize these values for each segment to get the total damage (influence on chla) it receives from every watershed
3. Take the absolute value of damage from each watershed on that watershed/sum of the absolute value of damages from all watersheds on that segment
    a. This determines the rows of the table in the new tool
4. Determined which watershed was “upstream” of a given segment (this can sometimes be artificial)
5. Sum of the absolute value of damages for each watershed and its upstream watersheds / sum of the absolute value of damages from all watersheds on that segment
    a. This determines the Combined Influence of Upstream Watersheds on Water Quality value displayed in the new tool

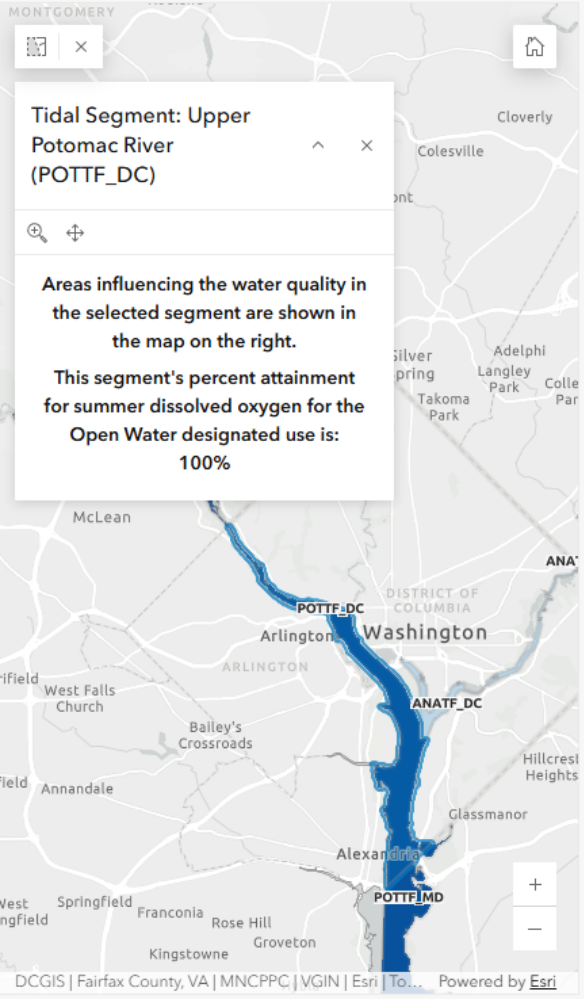
Challenges with “Upstream” Definition

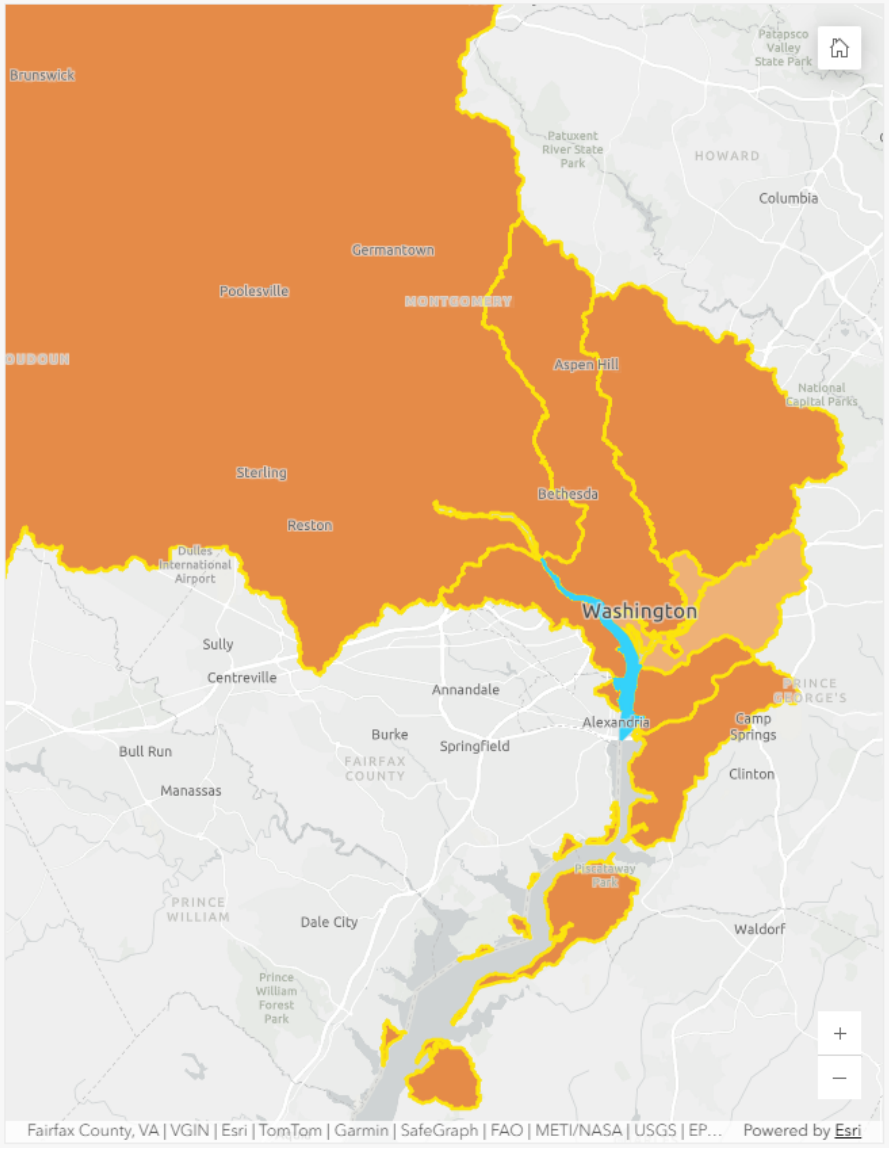
Connecting Watersheds to Tidal Water Quality

Note: These are draft datasets for illustrative purposes only. Mainstem segments, small and irregular watersheds, and watersheds with less than one percent influence on a given segment are excluded from results in the two leftmost tabs.

Downstream — Select a watershed to see the tidal segments that it influences | **Upstream — Select a tidal segment to see the watersheds that influence it** | Upstream — Select a tidal segment to see the Phase 6 Land-River segments that influence it

Selected tidal segment:
Upper Potomac River (POTTF_DC)





Legend - Right Map

Upstream Watersheds

Upstream from Selected Tidal Segment

Influence on Selected Tidal Segment

Influence on Chlorophyll-a

- 75% - 100%
- 50% - 74.9%
- 20% - 49.9%
- 2% - 19.9%
- 1% - 1.9%

Legend - Left Map

Tidal Segments - Tributaries

Percent Attainment - Open Water Summer Dissolved Oxygen

- > 97%
- 87 - 97%
- 75 - 87%
- 40 - 75%
- <= 40%

Combined Influence of Upstream Watersheds on Water Quality

99.9%

Watersheds Influencing the Selected Tidal Segment

Yellow rows indicate that the watershed is upstream of the selected tidal segment.

Click a row to flash the watershed on the map.

Watershed	Influence
Upper Potomac River (DC waters)	41.2%
Upper Potomac River (MD waters)	30.4%
Anacostia River (MD waters)	23.1%
Anacostia River (DC waters)	5.2%

Tool Notes

- Summarized chla damage to segmentsheds to look at the overall influence
  - Reminder: this is a different question from most effective LRsegs!

- Any segment that had <1% influence was omitted from the tool

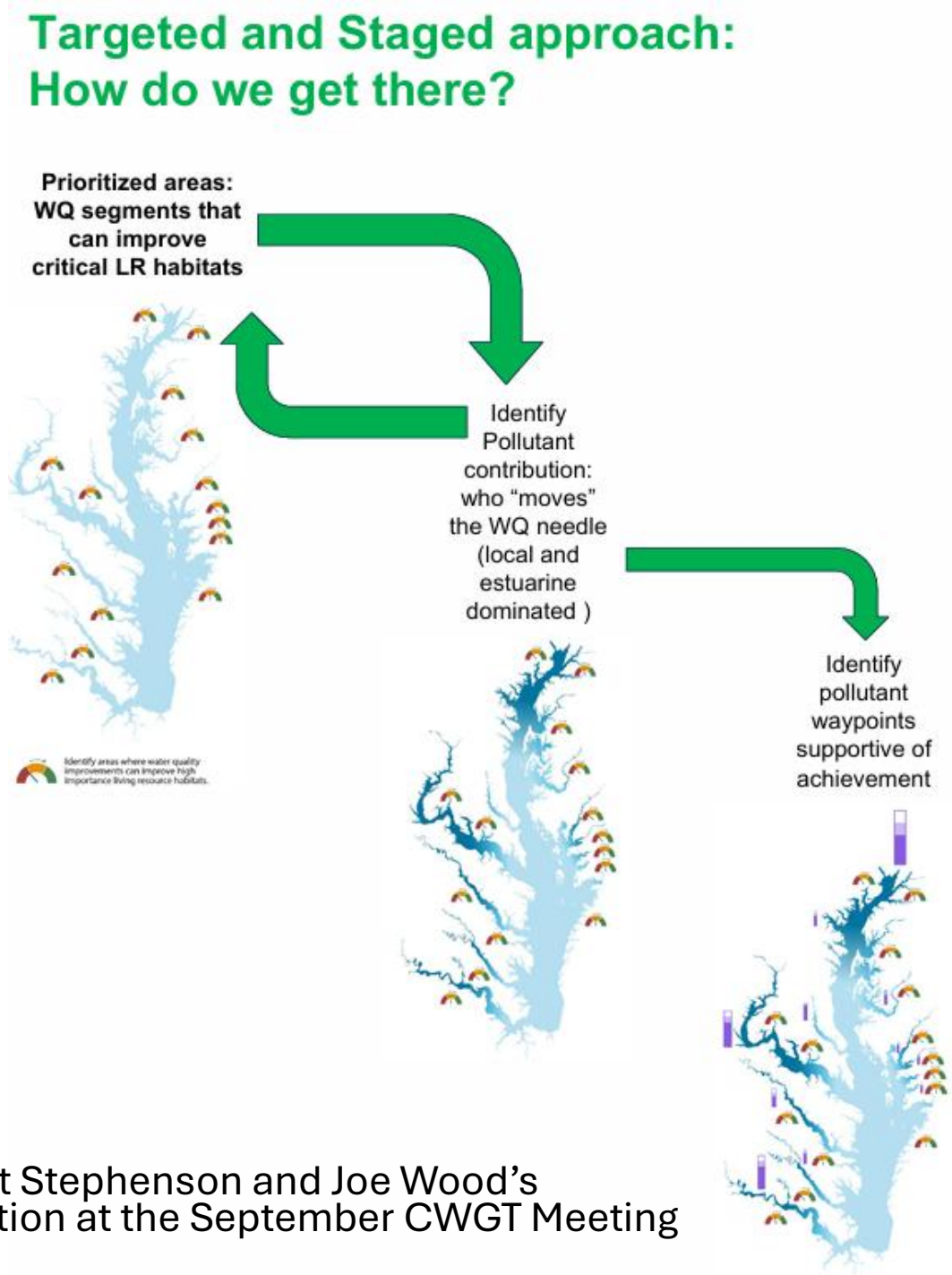
- Left off Main Bay segments because of artificial construction of “upstream” watersheds and nutrient fluxes from sediment

- Because this tool is operating at the 92 segment scale, it obscures intra segment variation, meaning that it will not directly reflect local water quality data in the shallows

Intended Usage for a Future Version of the Tool

- Serve as a linkage in the tiered implementation approach for identifying waypoints

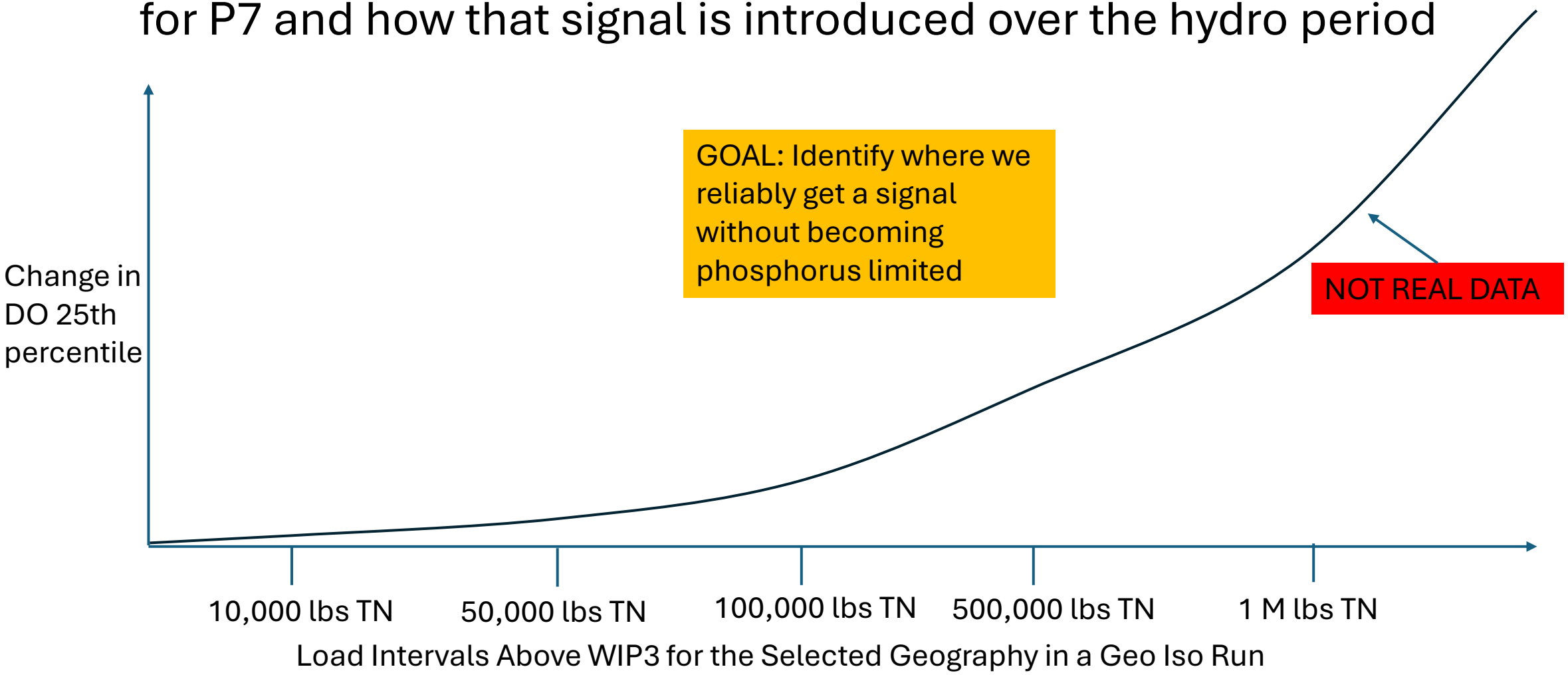
- Example: For habitat suitability constrained by water quality, use a refined version of this tool to guide WIP development and implementation to improve water quality in that segment



From Kurt Stephenson and Joe Wood's presentation at the September CWGT Meeting

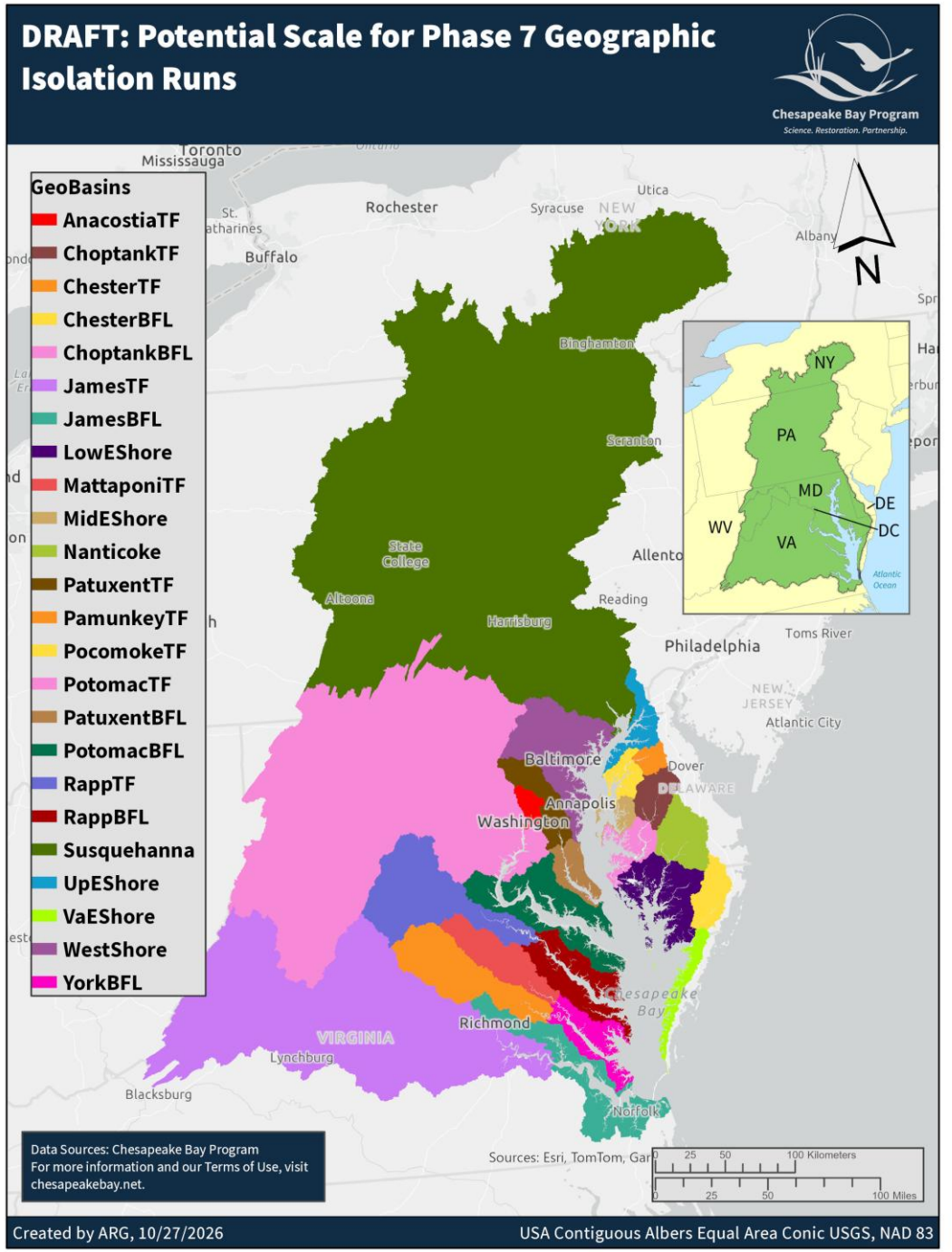
Suggested Work on Geo Iso Runs for P7

- Informal sensitivity analysis to determine appropriate load signal for P7 and how that signal is introduced over the hydro period



Suggested Work on Geo Iso Runs for P7

- Investigate geographic scale for runs
  - Hypothetical hybrid between 16 geobasins from P6 DW/DC DO and 92 segments from P6 OW Chla
  - N=24, subject to change
- Investigate whether PS/NPS distinction is needed
  - NPS only used in P6 DW/DC DO estuarine effectiveness
  - Suggestion: combine NPS and PS in P7 because
    - Better for overall planning targets relative effectiveness values



Suggested Work on Geo Iso Runs for P7

- Corroborate results with other lines of evidence (monitoring data, inert tracers, and other scientific studies) by collaborating with STAC, USGS, MWG, academia, Data, Analysis, & Reporting WG, etc.

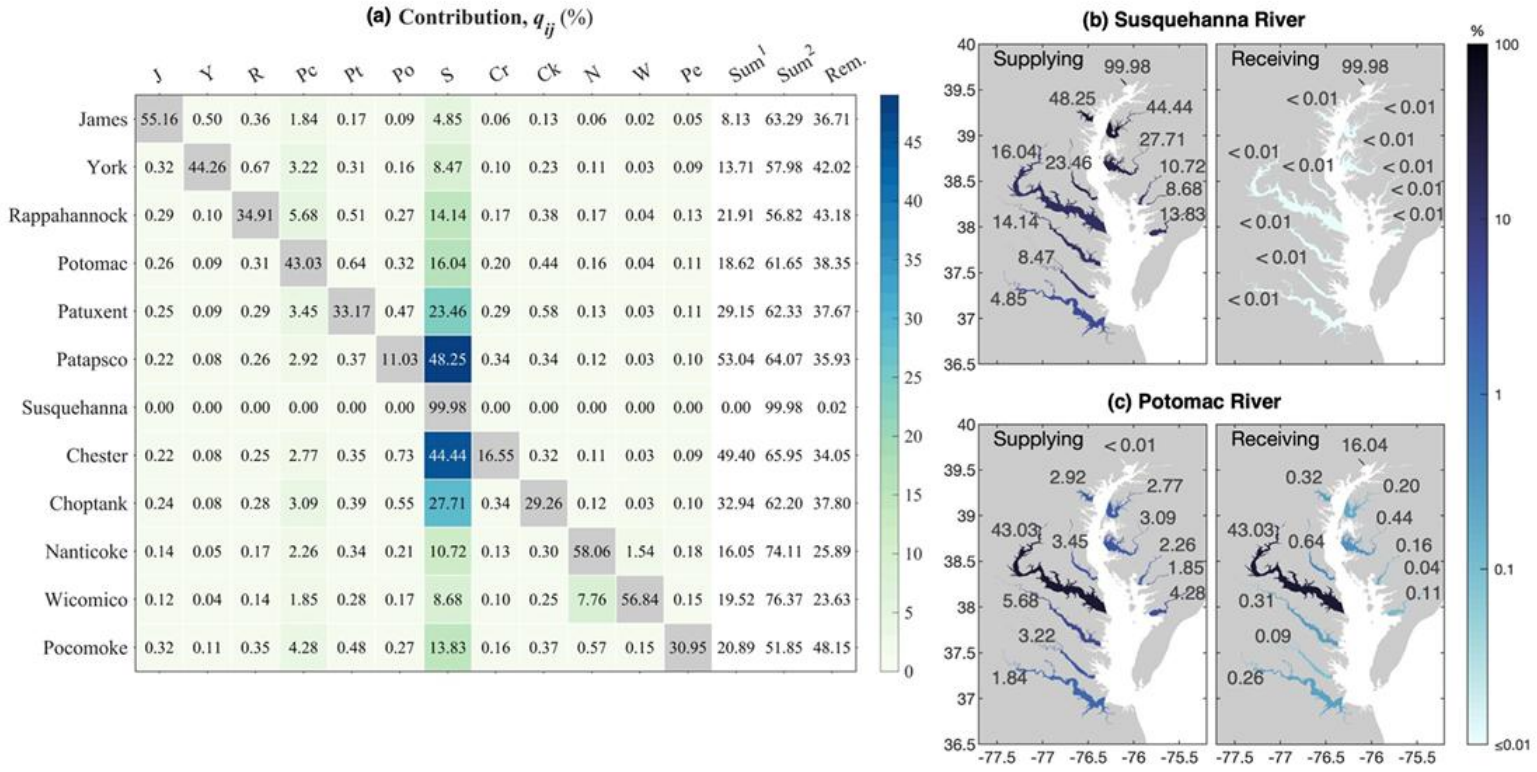
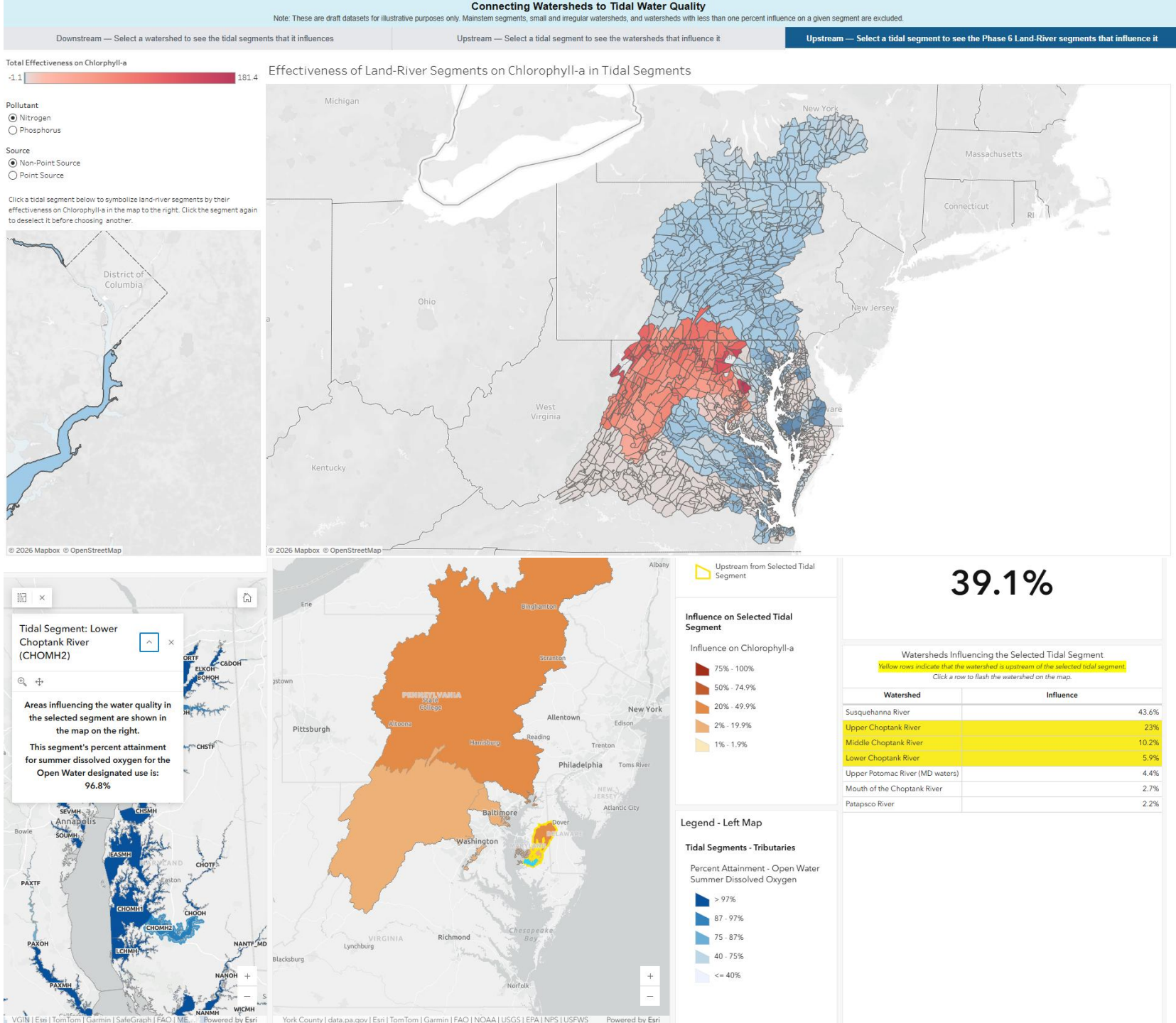


Figure 6. Mean values of the contribution metric of riverine freshwater connectivity, averaged over 2011–2014. (a) Heatmap showing the mean contribution of freshwater constituents from each supplying tributary (*x*-axis) to each receiving tributary (*y*-axis). Sum^1 represents the contribution from the 11 external tributaries excluding the local tributary, while Sum^2 represents the total contribution from all 12 tributaries. *Rem.* indicates the percentage of water in each receiving tributary not accounted for by these freshwater sources (i.e., 100% – Sum^2), which is primarily attributed to oceanic saltwater. (b–c) Contribution metrics for the Susquehanna and Potomac Rivers. Left panels: mean contribution of the supplying tributary's freshwater constituent in each receiving tributary (columns of heatmap). Right panels: mean contribution of external freshwater constituents within the tributary (rows of heatmap).

From Qin, Q., Cai, X., Shen, J., & Linker, L. (2026). Riverine freshwater connectivity among major tributaries in a large estuary. Water Resources Research, 62, e2025WR041719. https://doi.org/10.1029/ 2025WR041719

Suggested Work on Geo Iso Runs for P7

- Refine tools to include both views (Lrseg scale and total influence at segmentshed scale)
  - Integrate with layers like water quality standards attainment and VIMS/NOAA work



Takeaway Points

- Geographic isolation runs for OW Chla in P6 give us a placeholder to use in tiered implementation discussions at the 92 segment scale

- We can and should conduct more testing of geographic isolation run parameters and scales with the P7 suite of models

- Integrate multiple lines of evidence to support tiered implementation planning efforts in 2028 and 2029

Questions?

Alex Gunnerson: agunnerson@chesapeakebay.net