

Evaluating whether BMP and restoration investments improve stream condition at the watershed scale

Restoration research question addressed: Effectiveness of stormwater and stream restoration programs at the watershed/catchment scale

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Research Question and Hypotheses:

- **Restoration research question addressed:**
 - Effectiveness of stormwater and stream restoration programs at the watershed/catchment scale
- **Project question:**
 - Do watersheds with greater BMP-treated area show improved channel condition and altered baseflow nutrient chemistry?
- **Hypotheses:**
 - Watersheds with greater BMP-treated area and restoration extent will show higher stream channel integrity.
 - Streams with higher channel integrity will show lower baseflow nitrate and higher baseflow phosphate concentrations.



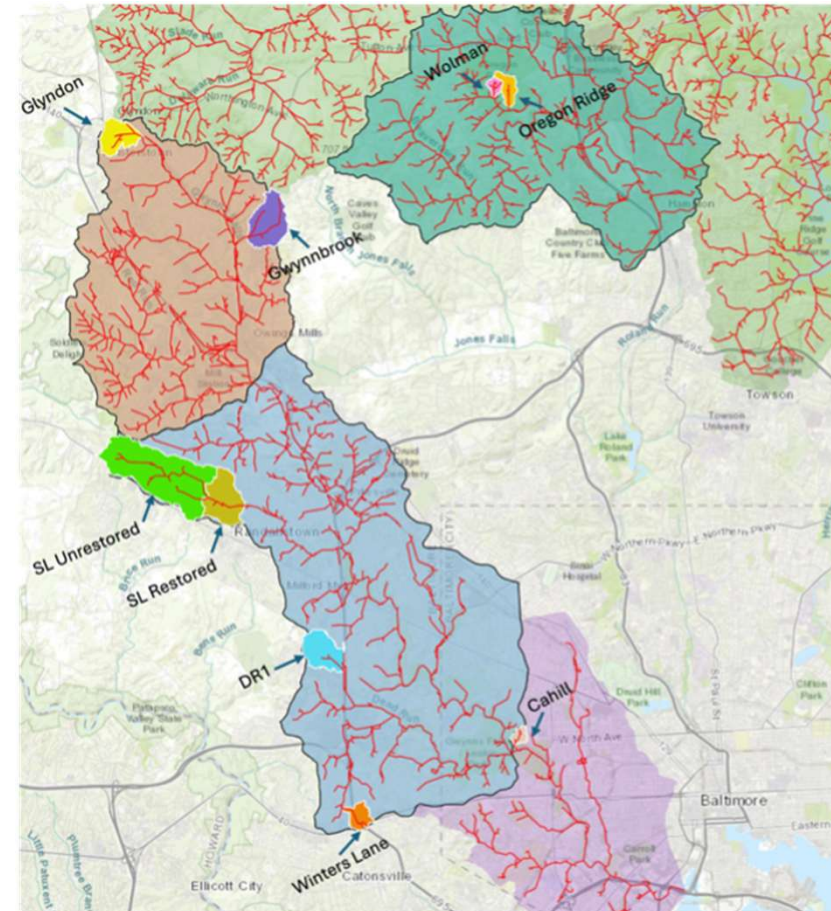
Watershed-scale BMP effectiveness is difficult to evaluate:

- At the watershed scale, responses may be shaped by:
 - Climate and rainfall patterns
 - Past and present land use
 - Existing geomorphic degradation
 - Best Management Practices (BMP) type, age, placement, and drainage area
 - Stream restoration history
- But: Stormwater BMPs and stream restoration projects are often evaluated individually.
- *Ultimately: Do restoration investments produce measurable watershed-scale improvements?*

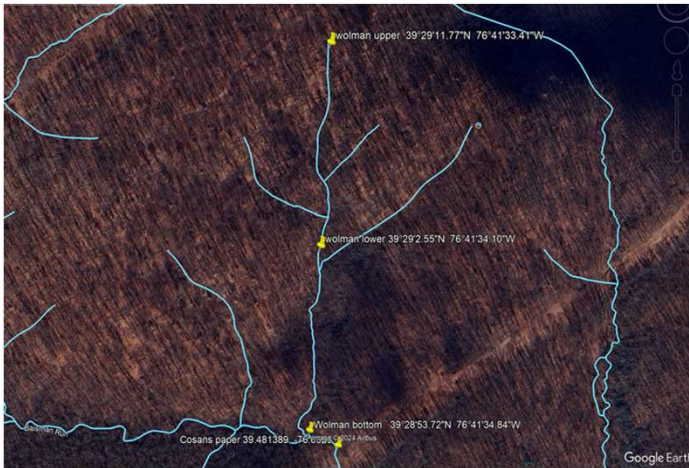


Methods: Nine watersheds in the Baltimore metropolitan area

- Forested reference, suburban, urban, restored, and unrestored watersheds:
 - Reference sites for expected natural channel condition.
 - Urban and suburban sites vary in impervious cover, BMP implementation, and stream restoration history.
- Study design:
 - 9 watersheds
 - 3 reaches per watershed
 - 3 sampling locations per reach
 - 81 sampling locations

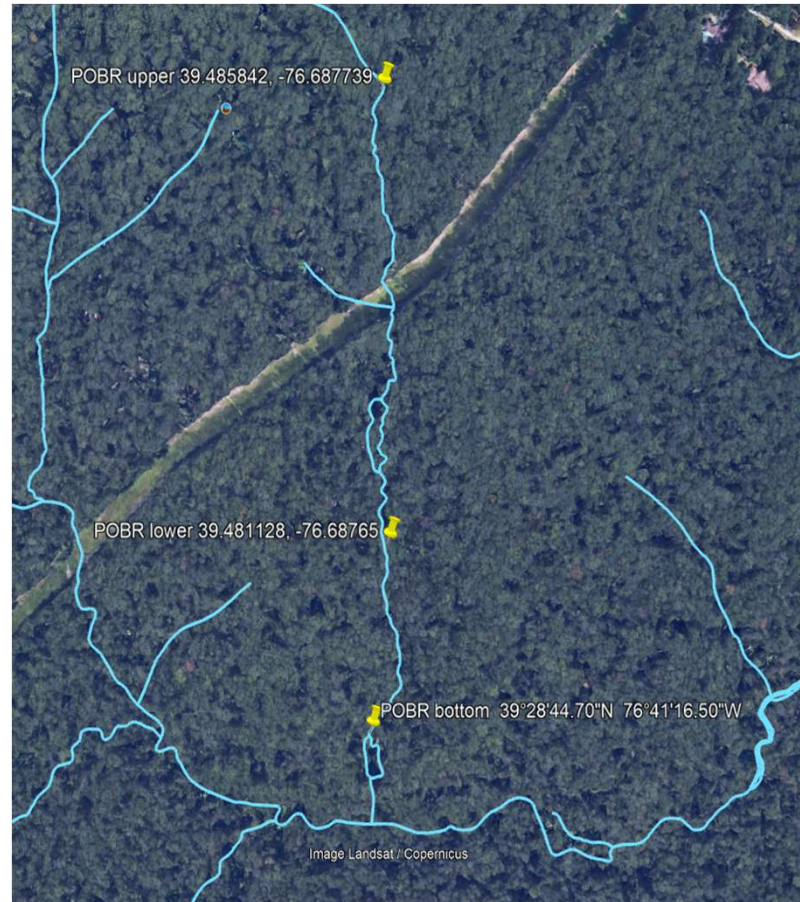
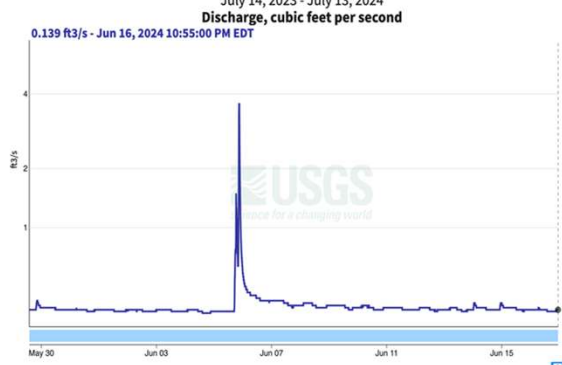


Two reference sites:

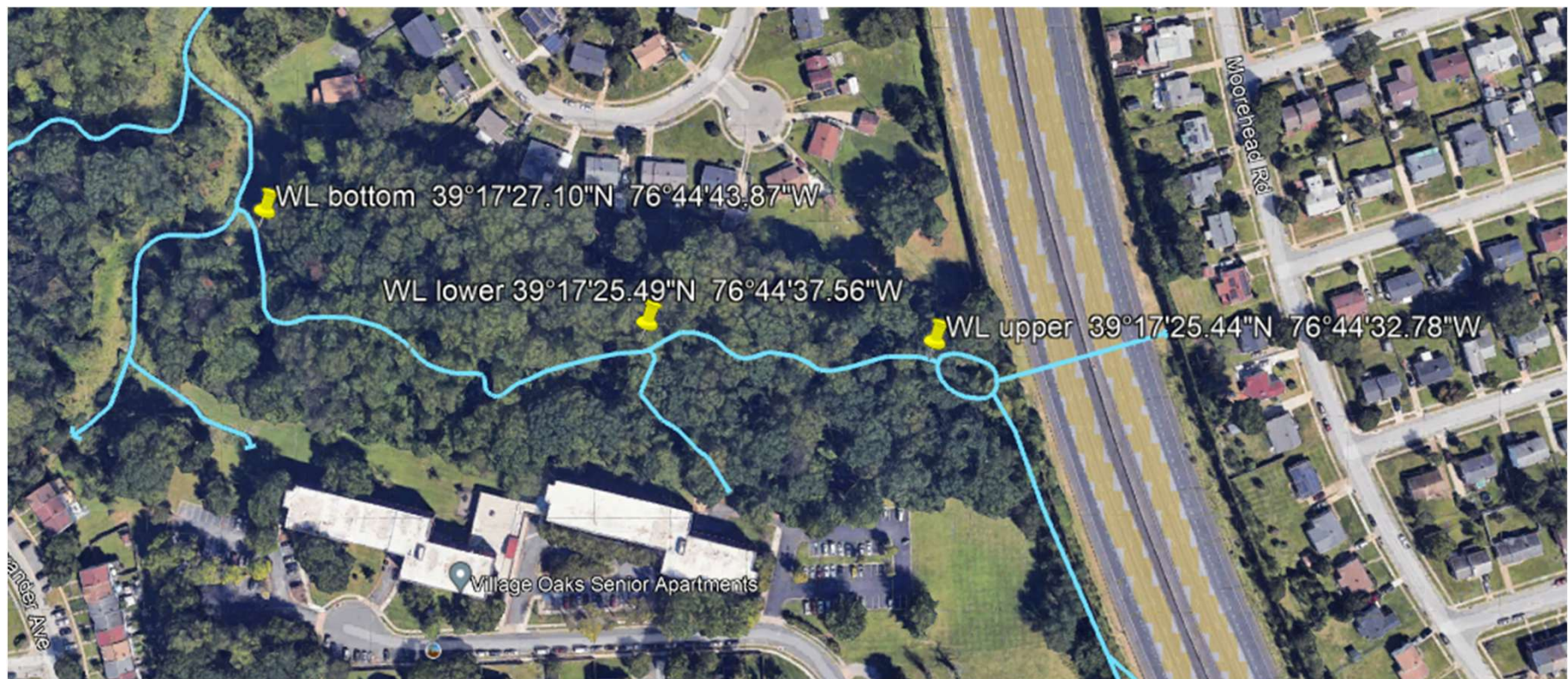


Pond Branch at Oregon Ridge, MD - 01583570

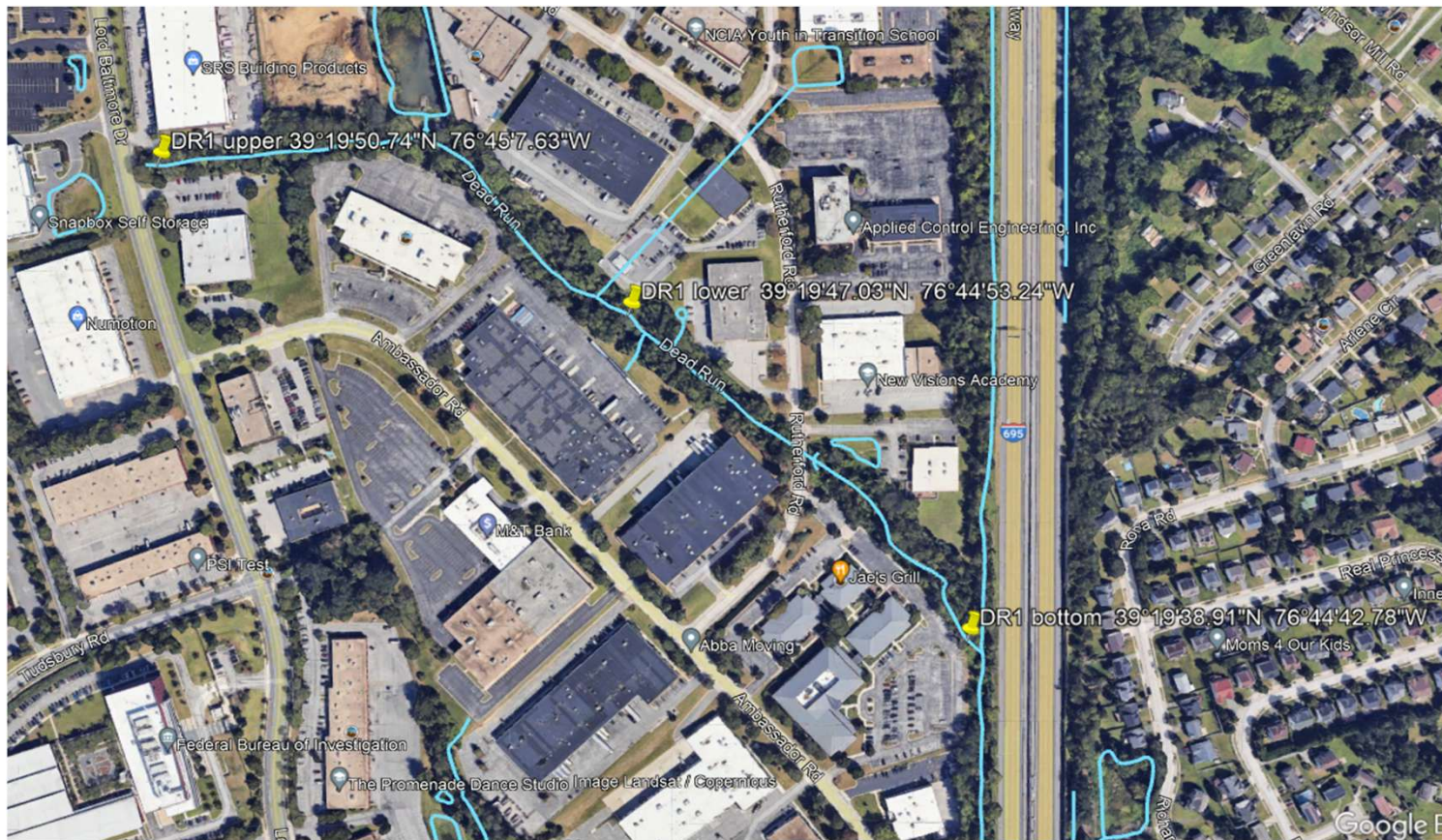
July 14, 2023 - July 13, 2024



Headwaters of Dead Run (DR5): High urban



Headwaters of Dead Run (DR1): High urban



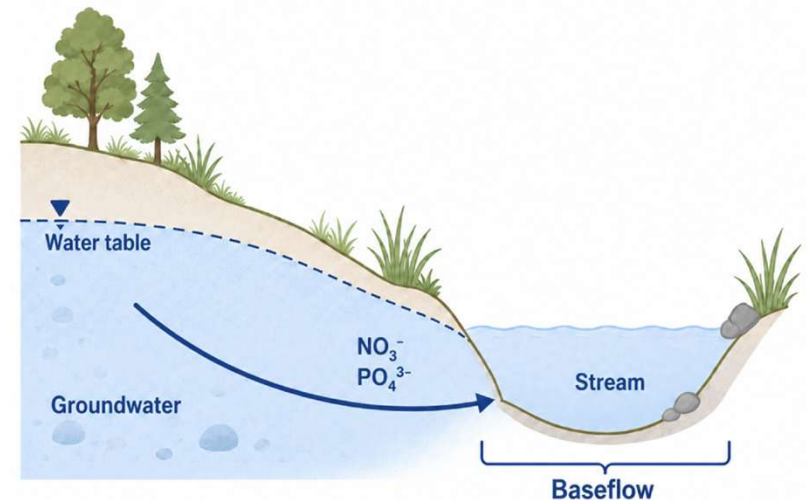
Methods: Geomorphic characterization

- Field measurements of channel depth:width as indicator of channel incision.
- Higher values indicate deeper, narrower channels.
- Compare with LiDAR-based assessments (Baker et al.)



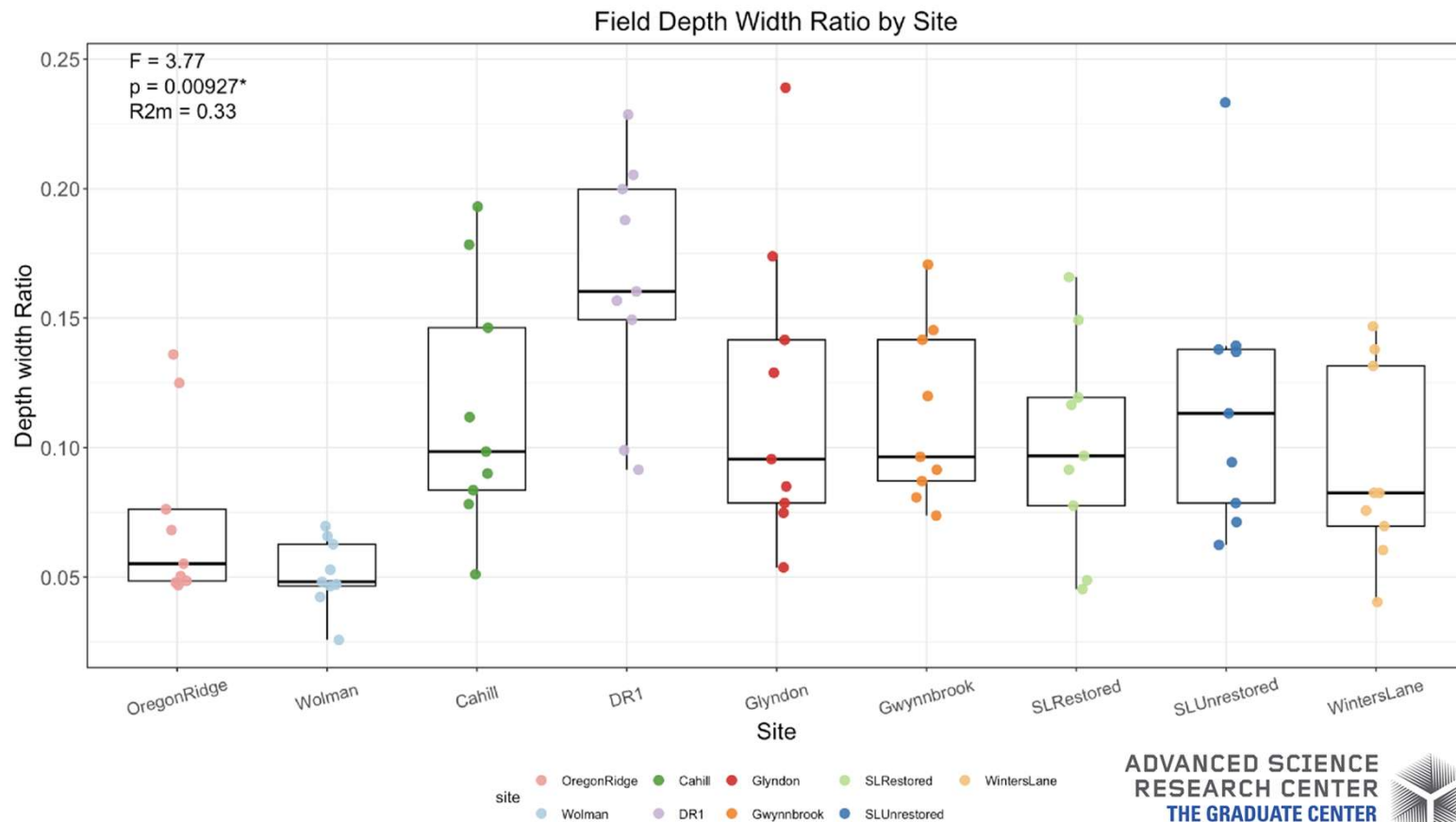
Methods: Baseflow stream sampling

- After 10 days of no rain, streamwater is dominated by groundwater (Welty et al. 2023).
- Baseflow sampling provides insight into spatial patterns of groundwater chemistry and watershed connectivity.
- Five sampling campaigns: July 2024, March 2025, April 2025, two in August 2025.
- Measurements of nitrate, phosphate, dissolved organic carbon in lab. In field measurements of temperature, conductivity, pH, turbidity.



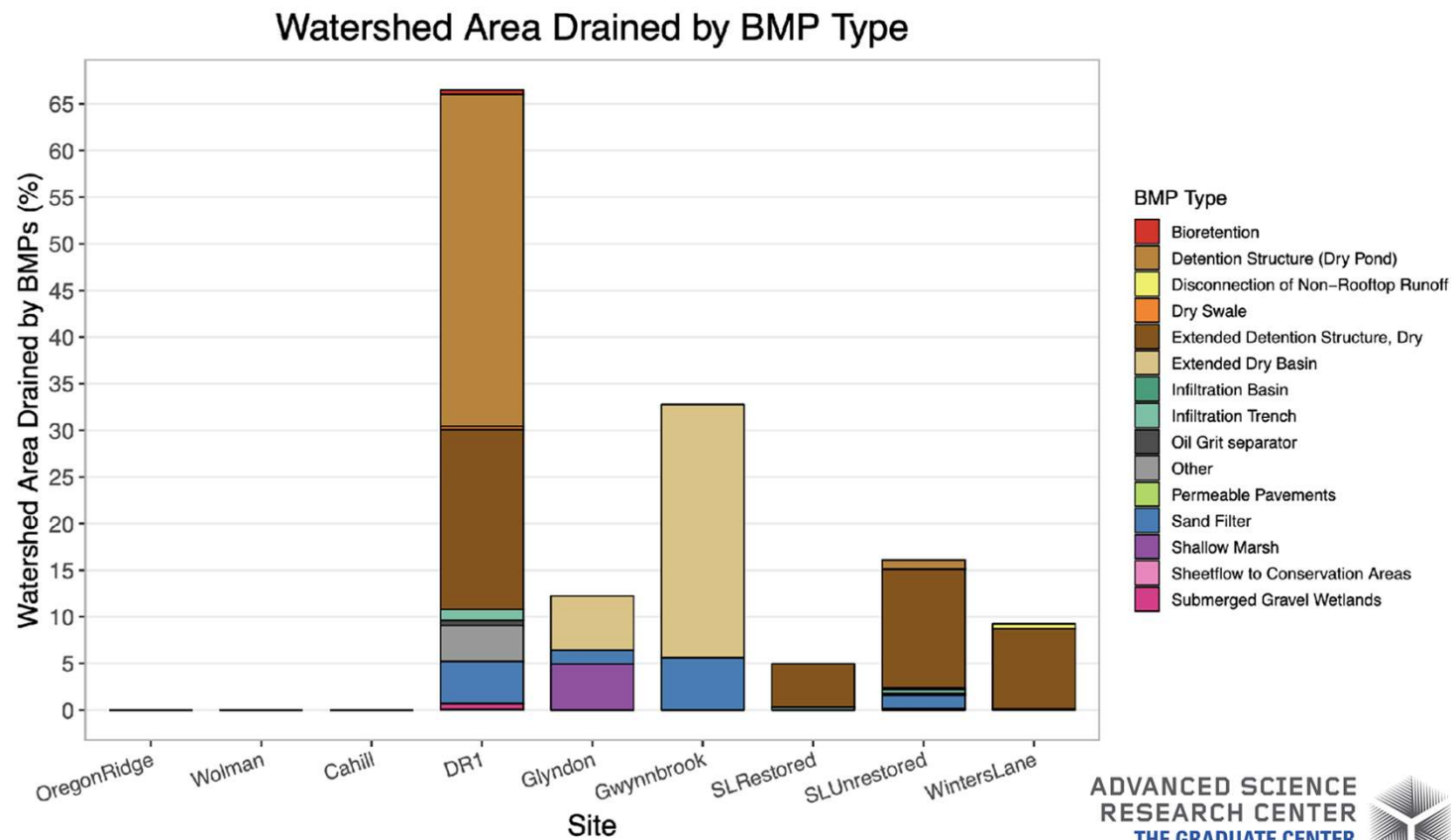
Results: Geomorphic characterization shows urban streams more incised than forest reference streams

- Big difference between reference and urban sites.
- No differences among urban sites.
- Focus on DR1 (lots of BMPs) versus Winters Lane (few BMPs).
- Also compare Glyndon and Gwynnbrook, both in headwaters of Gwynns Falls.



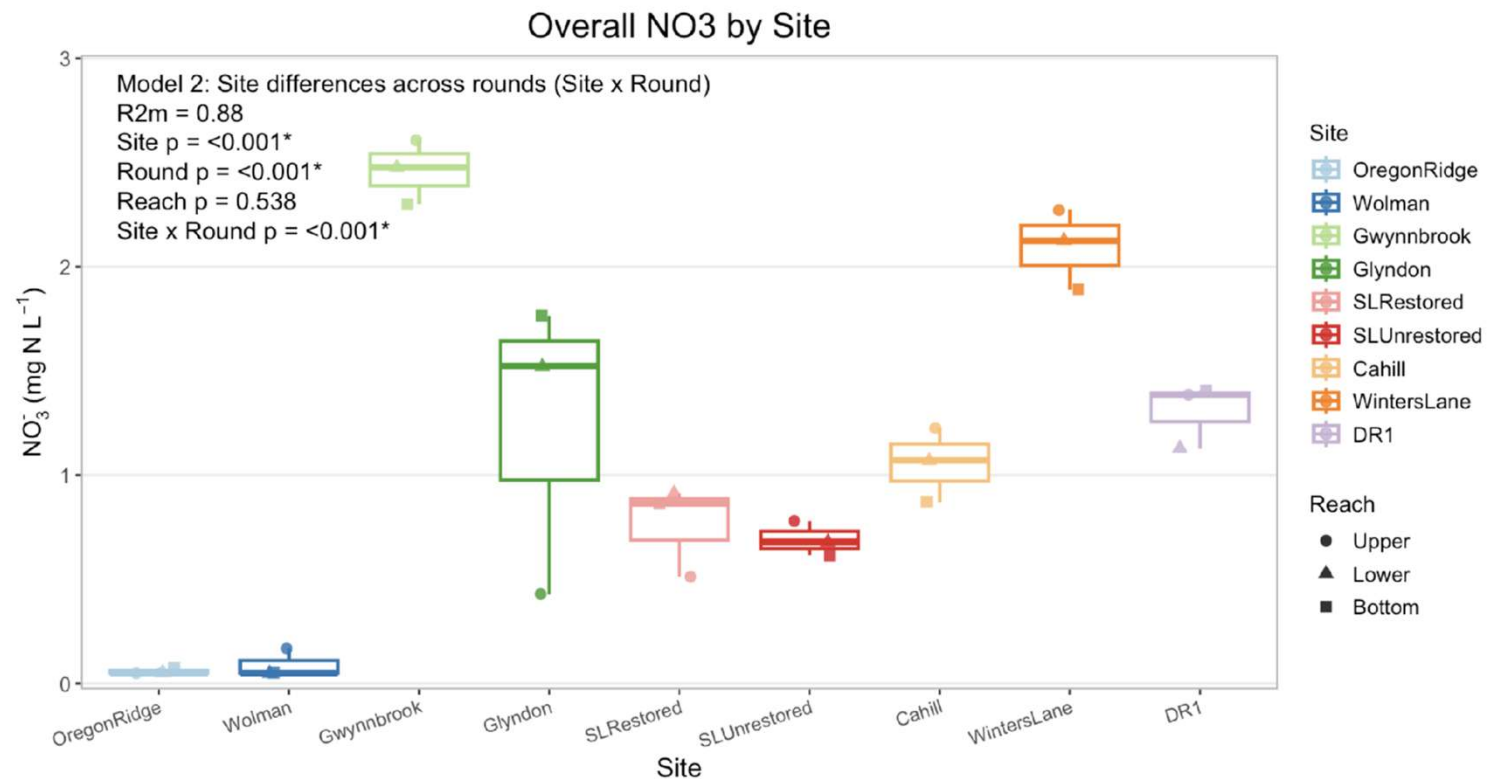
Results: Wide variation in the nature and extent of BMPs among our study watersheds

- Particular focus on DR1 (lots of BMPs) versus Winters Lane (few BMPs). Both are in the headwaters of Dead Run watershed.
- Also compare Glyndon and Gwynnbrook, both in headwaters of Gwynns Falls.



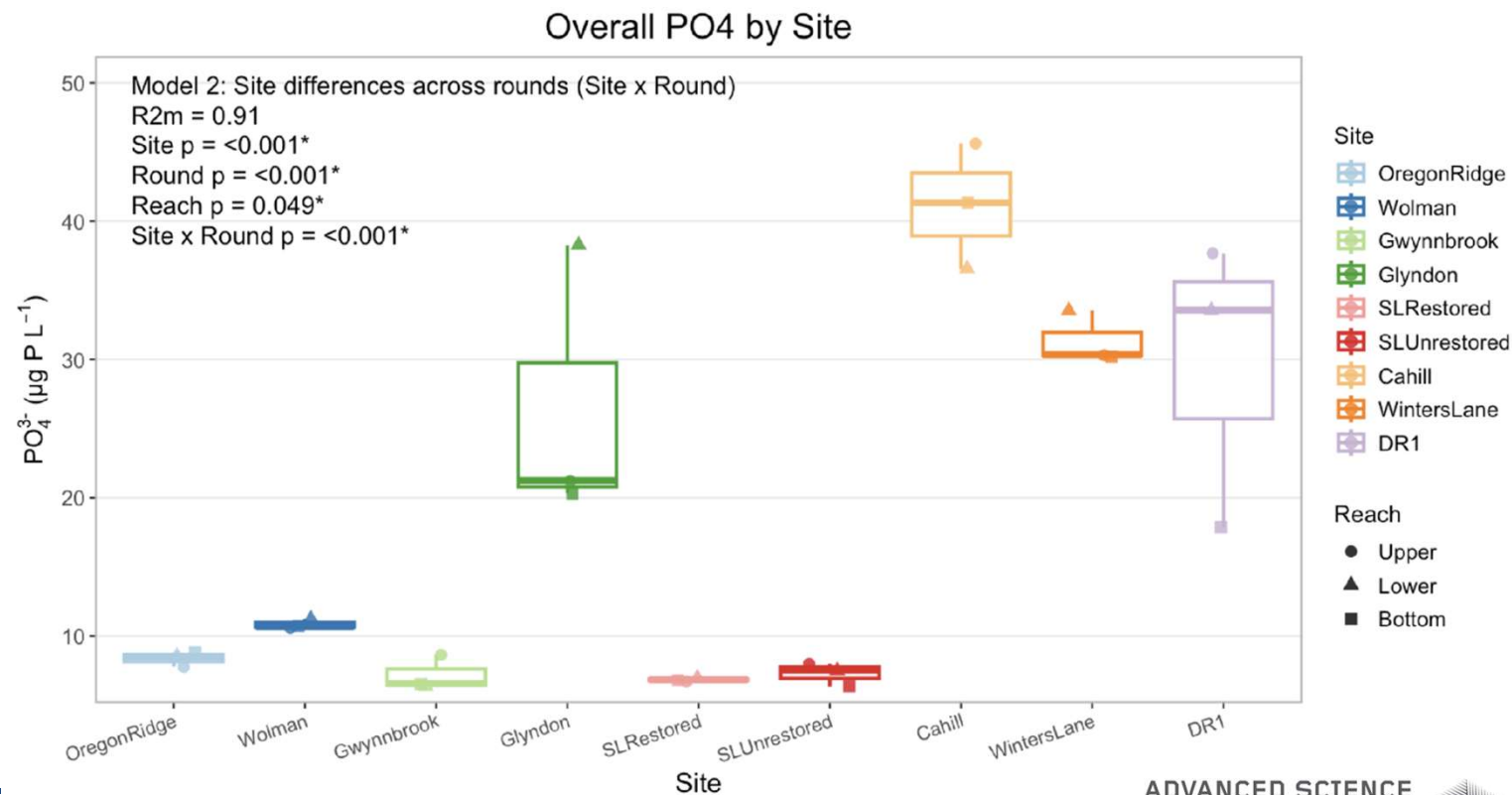
Results: Stream chemistry shows marked differences between urban and forest reference streams

- Nitrate concentrations very low in forest reference sites.
- Some differences among the urban sites, e.g., low concentrations at Scotts Level.
- Big differences between Glyndon and Gwynnbrook.
- No relationships between nitrate and BMPs or geomorphic condition.



Results: Stream chemistry shows marked differences between urban and forest reference streams

- Phosphate concentrations more variable than nitrate.
- Some urban sites have very low phosphate (e.g., Scotts Level, Gwynnbrook).
- No relationships between phosphate and BMPs or geomorphic condition.



Conclusions: BMPs do not appear to improve geomorphic condition or water quality at the watershed scale

- We do not see strong relationships between BMP coverage and channel condition or baseflow nutrient chemistry.
- Weak relationships do not necessarily mean BMPs have no value:
 - Do we need to pay more attention to location and other factors? Watershed response depends on placement, design, age, drainage area, restoration history, existing channel degradation, and legacy land use effects.
 - The BMPs in many of our watersheds are older and not “state-of-the-art.”
 - Would these urban streams be in much worse condition if the BMPs had not been implemented?
 - BMPs have been shown to be highly effective in carefully planned new developments.
 - For already degraded streams, retrofit BMPs may need to be paired with more targeted channel or watershed interventions.
 - For water quality, highly localized sources may dominate over BMP effects, e.g., Glyndon versus Gwynnbrook.

Future work: BMP location may help explain weak watershed-scale relationships

- Percent watershed treated may be an inadequate indicator of BMP effectiveness. Location matters! We will more analysis of relationships between BMP location and geomorphic condition.
- Focus on variation among reaches within each stream. BMP influence on stream condition may be easier to “see” at this scale.
- More focused comparison of restored and unrestored streams and reaches.
- More detailed comparisons of LiDAR-based estimates of stream geomorphic condition and stream chemistry.
- Look for possible “hotspot” sources of nutrients in our streams.



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The Pooled Monitoring Initiative funds applied science to advance restoration research for cumulative impacts, comparative effectiveness of stormwater practices, pollutants of emerging concern, and trade-offs with new research questions added annually.

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TRANSLATION SLIDES

What are the take home points?
What does this mean for me?

Translation Slides by Ari Engelberg,
Maryland Department of Natural
Resources.



WHAT DOES THIS MEAN FOR ME?

1. Stream baseflow chemistry not significantly correlated to BMP implementation at the watershed scale
 - Is there actually no impact of BMPs on baseflow nutrient concentrations in these watersheds or...
 - Is this an artifact of the experimental design? For example, maybe we need greater spatiotemporal resolution of baseflow samples to capture impacts of BMPs on nutrient levels?
2. Channel geomorphic condition negatively correlated to % BMP in watershed
 - Is that result because of the BMPs or something else? E.g., could it be due to autocorrelation between the amount of BMPs and % urbanization in the study watersheds
1. Either way, it seems like you can't expect significant improvements in baseflow chemistry and stream geomorphology to occur in highly urbanized watershed as a result of BMP retrofits.



WHAT DOES THIS MEAN FOR ME?

What do I take from this if I am a practitioner:

Targeted siting and design of BMPs will be critical to achieving water quality uplift at the watershed scale. These improvements won't be realized without holistic planning.

What do I take from this if I am a regulator:

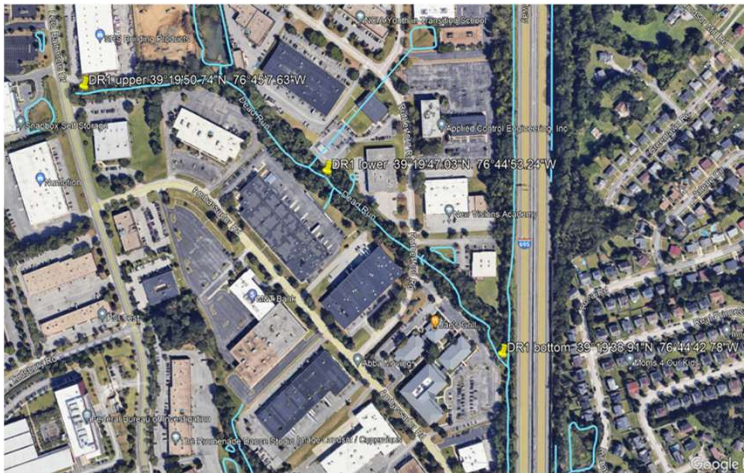
See above comment, also, this type of monitoring approach should be considered for wider adoption. For example, pre-post restoration baseflow chemistry sampling of stream restorations. There is likely more to learn here through this type of cost-effective sampling approach.



Q&A: DR1 versus Winters Lane

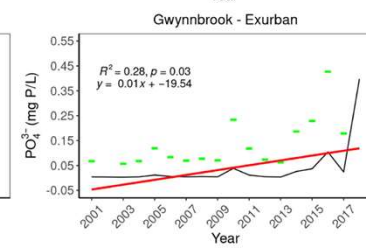
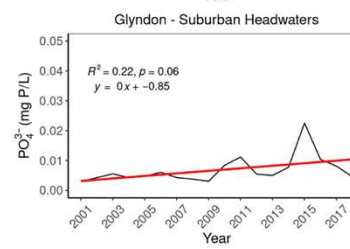
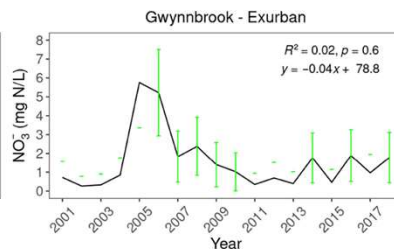
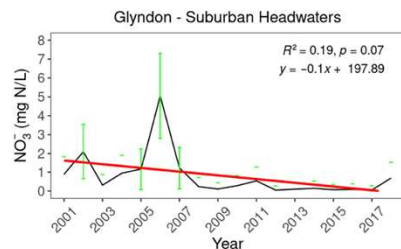
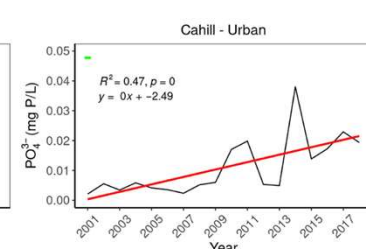
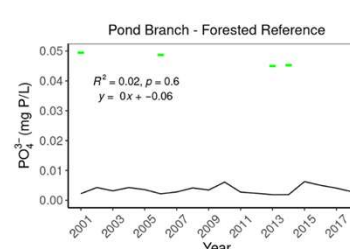
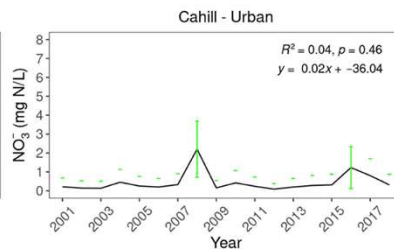
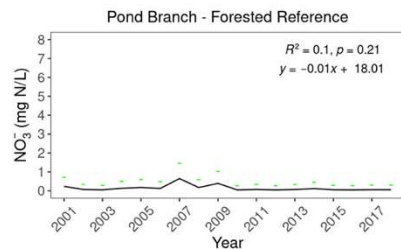
Stability despite similar incision measurements

- DR1 has extensive development and substantially greater BMP coverage than Winters Lane.
- The incision measurements do not clearly distinguish the two streams.
- Winters Lane shows visible signs of active erosion, including bare and collapsing banks and unstable trees.
- DR1 is not pristine, but it appears comparatively stable and does not show the same visible evidence of active erosion.
- This suggests that stability may be an important measure of BMP success, even when the channel has not returned to reference condition.



Q&A: Long-Term Changes in Stream Chemistry

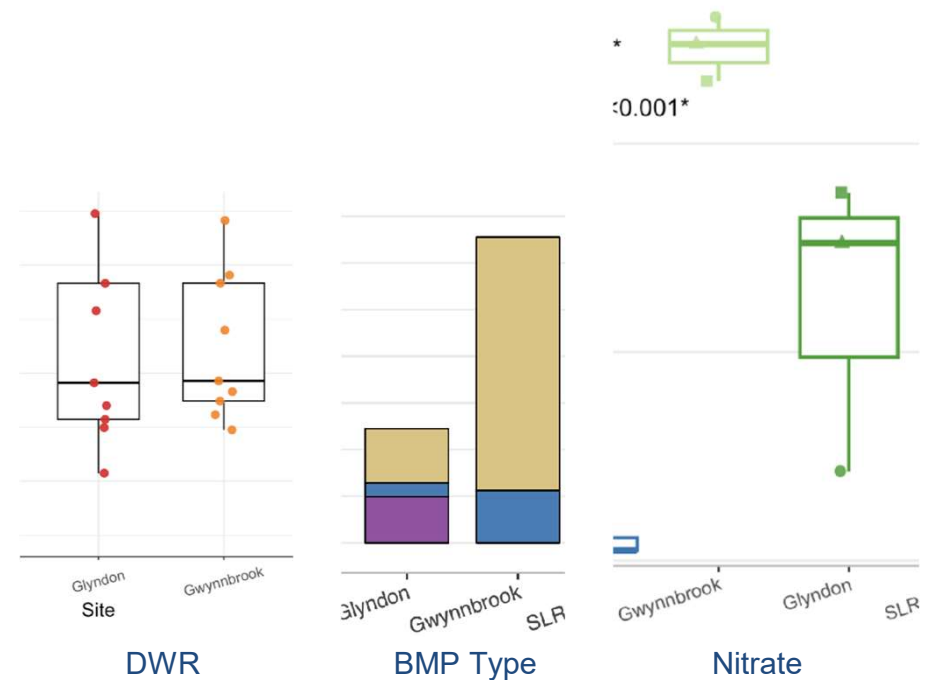
- Long-term monitoring shows that nutrient trajectories differ among watersheds.
- Nitrate declined at some sites
- Phosphate increased at some sites
- Some changes were linked to water-table depth and hydrologic connectivity.
- The synoptic study compares watersheds across sampling rounds.
- Long-term monitoring captures gradual change within each watershed.
- BMP effects may become clearer over time.



Q&A: Local nutrient sources and watershed chemistry

Glyndon and Gwynnbrook: why chemistry varies so strongly among apparently comparable watersheds?

- The two watersheds have similar geomorphic condition.
- Their BMP coverage and BMP types differ.
- Glyndon has much higher nitrate concentrations.
- A localized nutrient source may be influencing Glyndon.
- Local sources may mask broader BMP effects.



Q&A: Temporal Processes

BMP and restoration effectiveness should be evaluated over time, not only through a single geomorphic or chemistry assessment.

Possible components:

- Repeat site photographs
- Periodic rapid visual assessments
- Repeated synoptic chemistry sampling
- Updated LiDAR comparisons
- Selection of monitoring locations based on LiDAR change detection

Q&A: Could the BMP database be incomplete or outdated?

BMP data source and limitations

- BMP records came from the Baltimore County NPDES database.
- The database was reviewed recently.
- Some BMPs may still be missing from the available records.
- Many recorded BMPs are older designs.
- We used the best available county data and welcome updated records.

BMP Source: <https://www.baltimorecountymd.gov/departments/information-technology/gis/data-download>