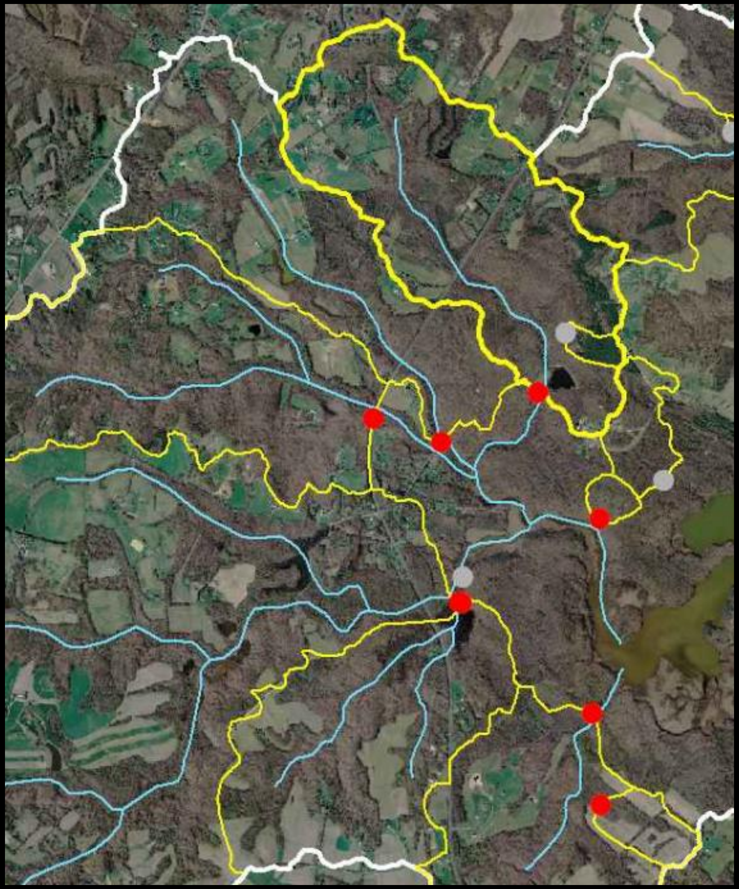
City Stream, Country Stream: Getting a Clearer Picture of Stream Restoration



Tom Jordan

Smithsonian Environmental Research Center

Urban Stream Syndrome

“Restoration?”

- What:
  - Restoring function, not pre-impact condition
- Why:
  - Stop erosion caused by urban runoff
  - Reconnect the stream with its floodplain
  - Control flooding downstream
  - Improve stream habitats
  - And…

Main Motivation=

Reduce discharges of:

nitrogen, phosphorus,
and suspended solids

Nitrogen and Phosphorus

- Essential nutrients for all living things
- Often limit growth of plants and algae
- Cycles greatly altered by human activities
- Overloading coastal waters worldwide

In Chesapeake Bay

Excess nutrients and sediments have caused:

- Algal blooms
- Low dissolved oxygen
- Loss of submerged aquatic vegetation
- Food web disruption

Reductions in nitrogen, phosphorus, and sediment loads to the Chesapeake are now mandated by an EPA "Total Maximum Daily Load pollution diet."

Can Stream Restorations Help?

- Studies show variable but potentially significant improvements in nutrient reduction.*

- Restoration approaches differ

- Streams differ

- Long-term effectiveness is not known

*e.g. Filoso et al. 2015, Filoso and Palmer 2011, Williams et al. 2017, Cizek et al. 2017

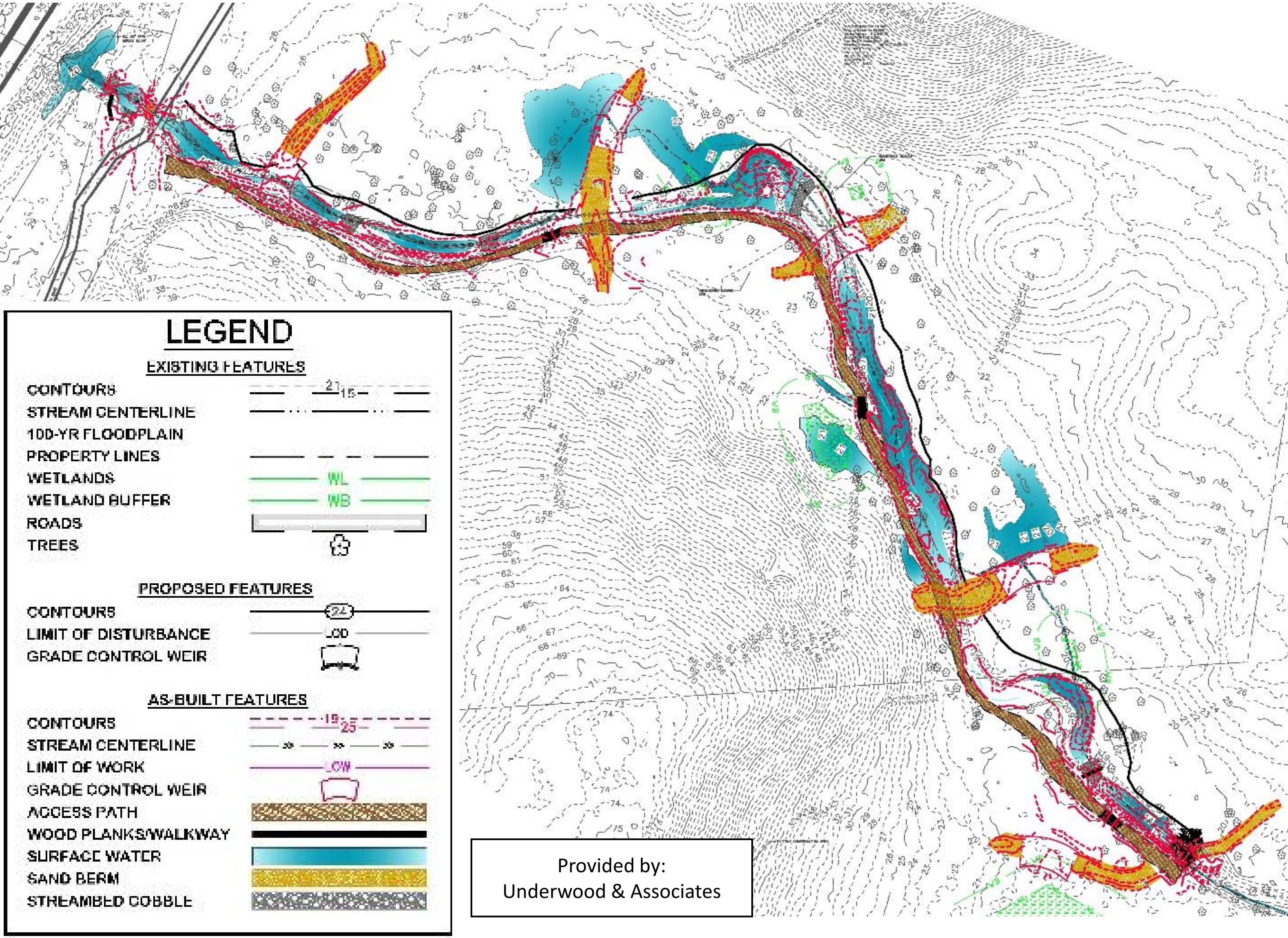
Muddy Creek Restoration

Muddy Creek Restoration

RSC:

Regenerative Stormwater Conveyance

Installing weir at outlet of Muddy Creek RSC

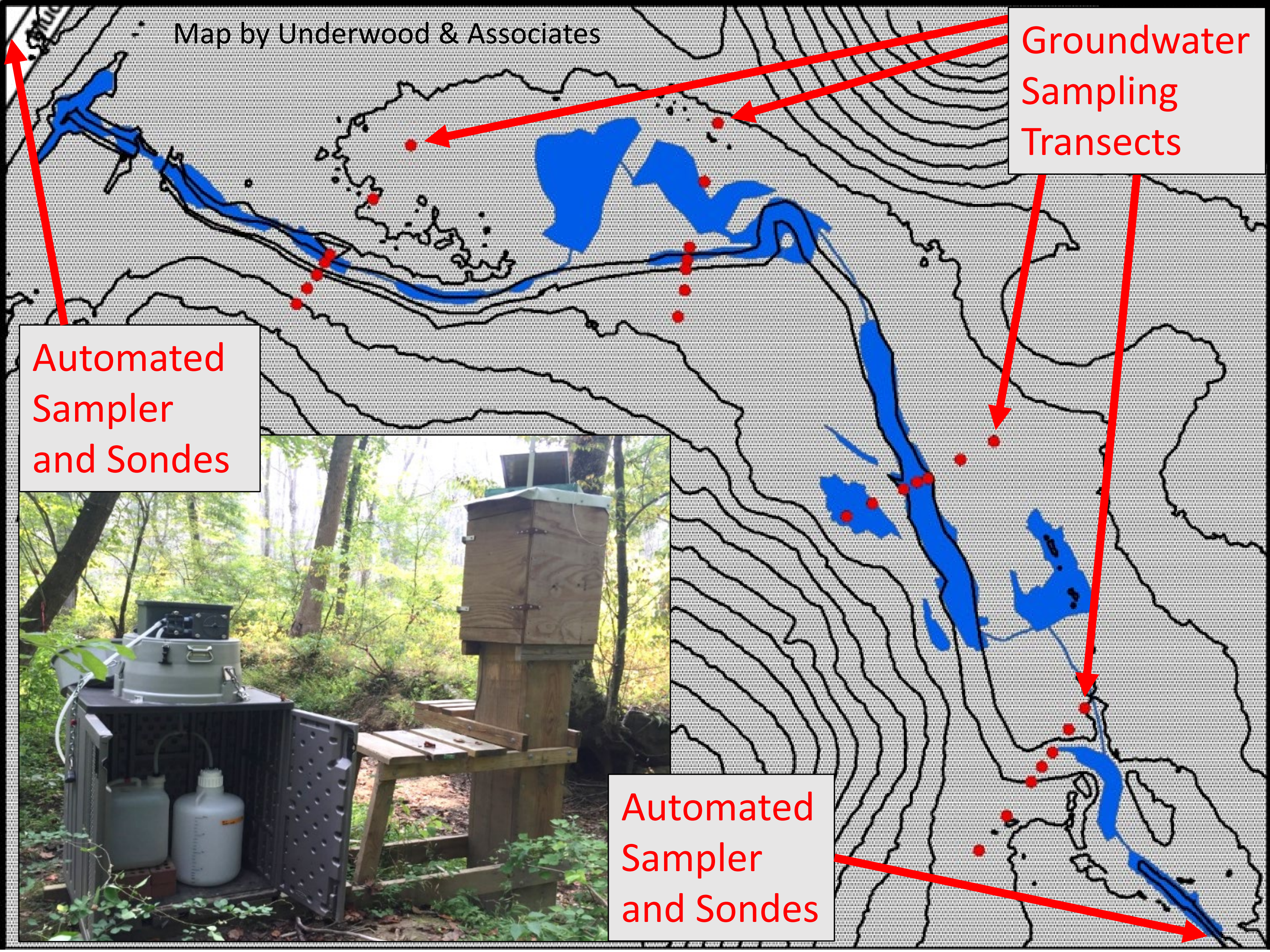


Provided by:
Underwood & Associates

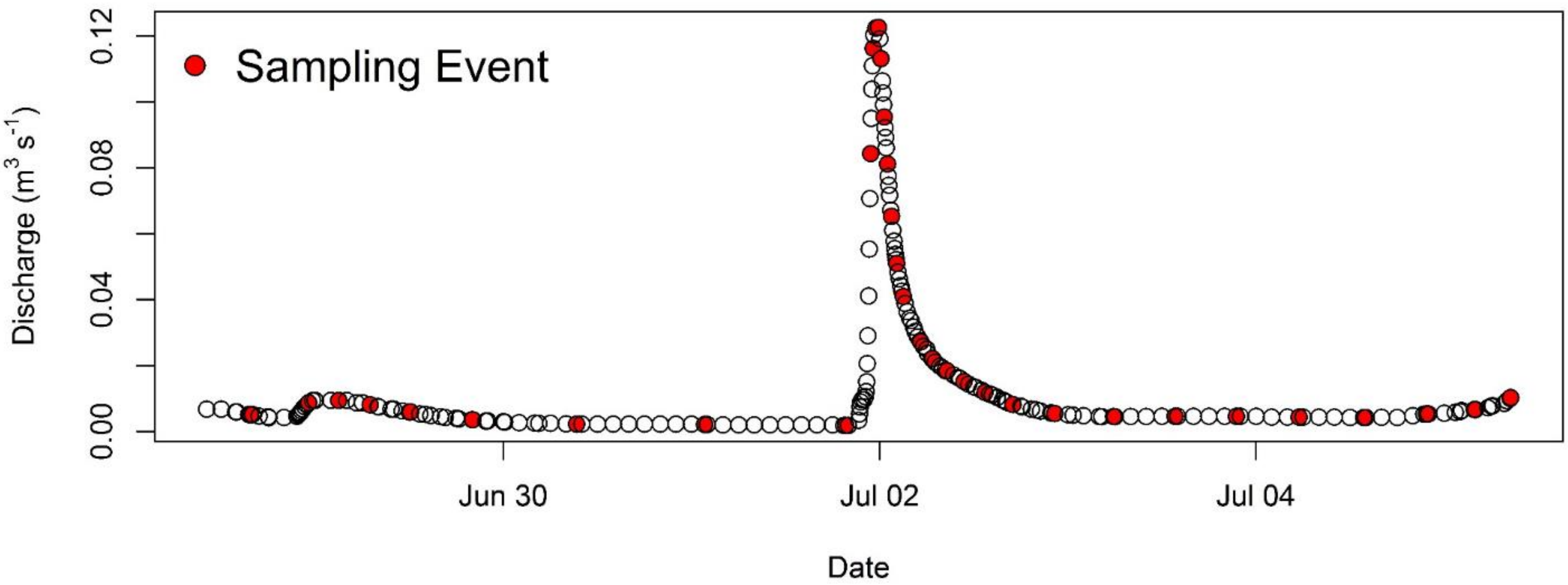
The weir and automated sampler at the outlet of the restored reach

A Pool in Muddy Creek After Restoration

A Riffle and a Berm in Muddy Creek After Restoration

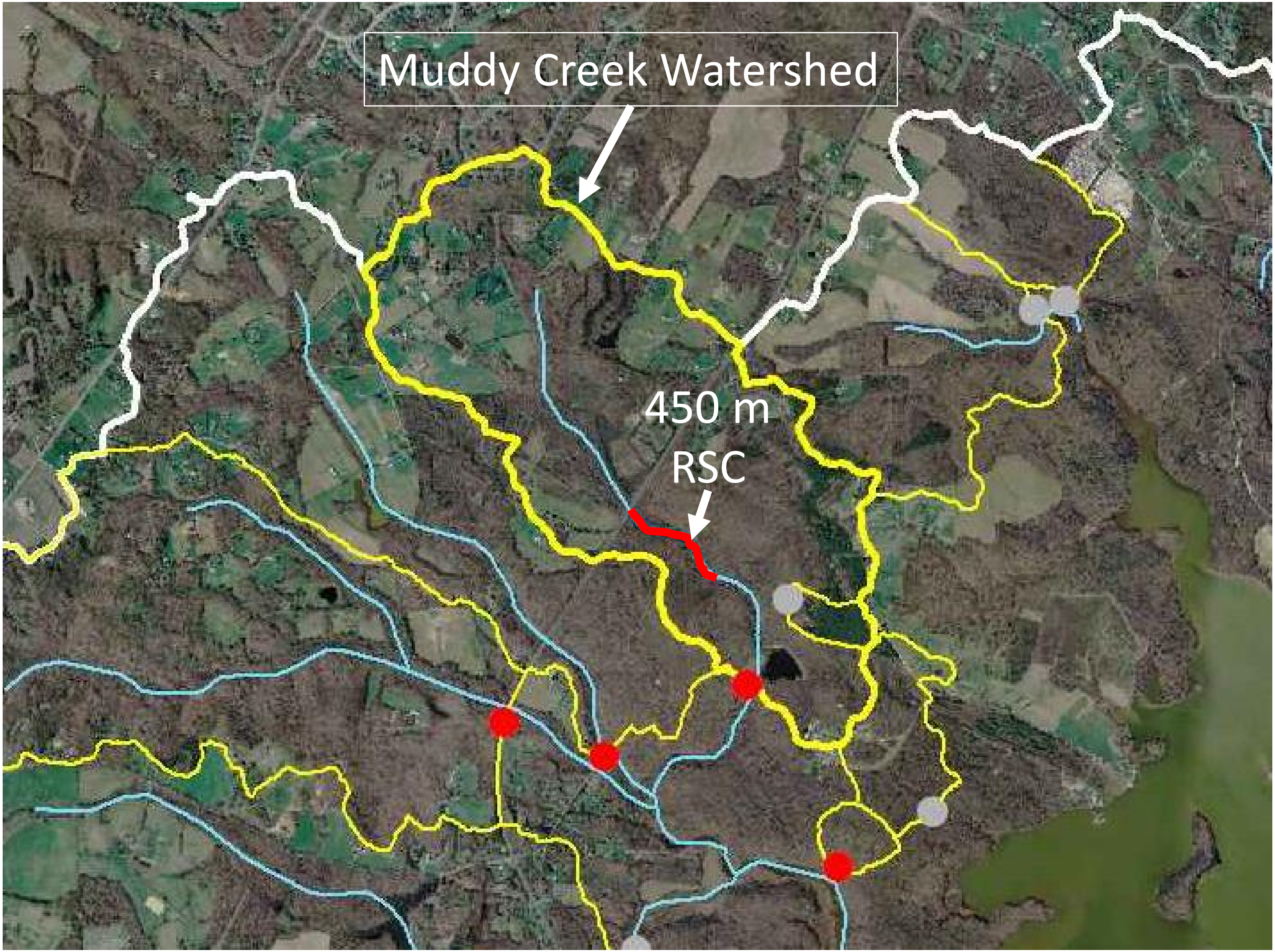


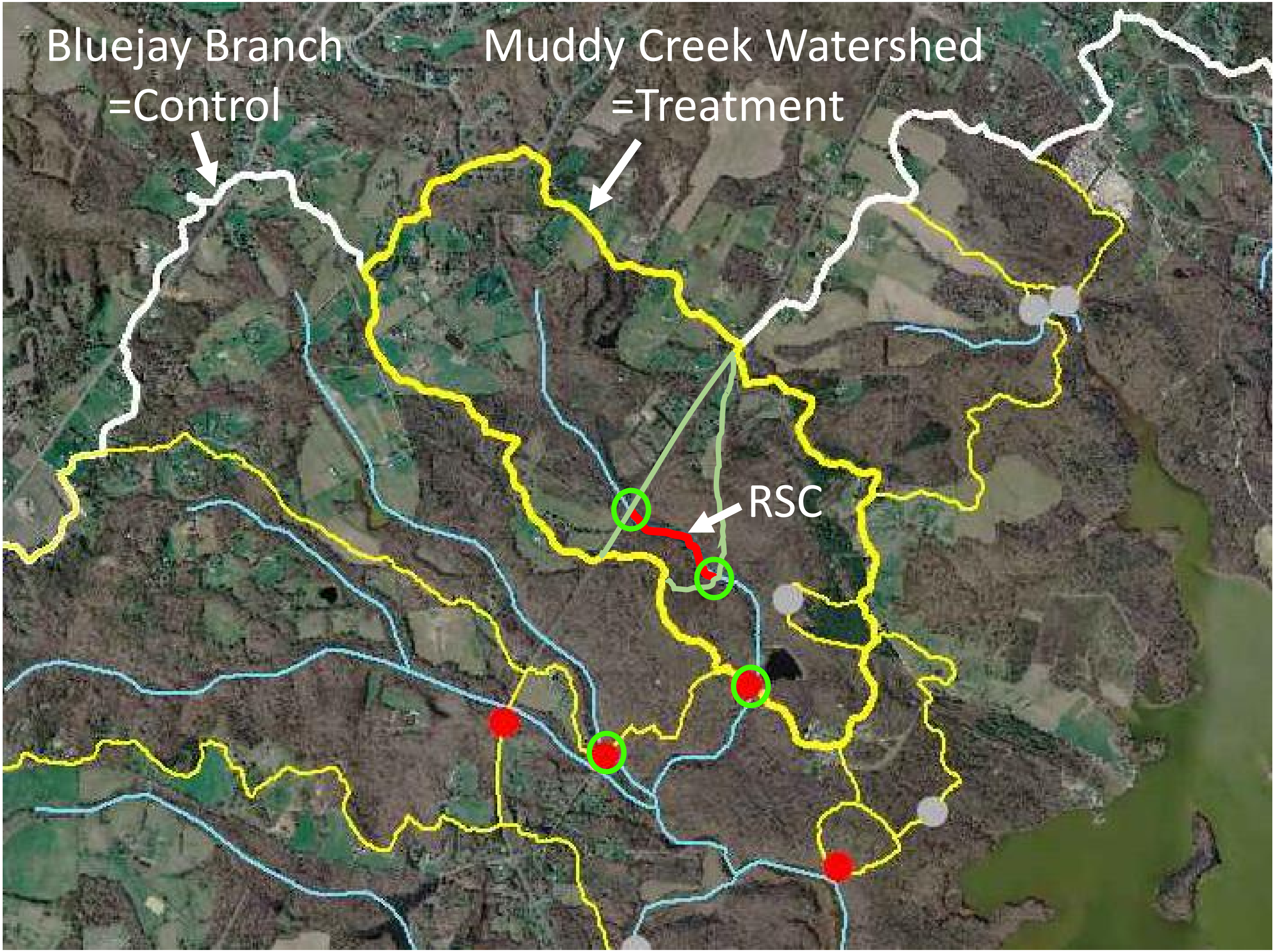
Map by Underwood & Associates
Groundwater Sampling Transects
Automated Sampler and Sondes
Automated Sampler and Sondes



- Flow-paced sampling (e.g. 30-60 water samples per week).
- Water samples composited for a weekly mean concentration.
- Concentration X weekly water flow = Weekly load.

Thompson et al. 2018. The multiscale effects of stream restoration on water quality. Supplementary Data. Ecological Engineering 124:7-18.


Muddy Creek Watershed
450 m
RSC


Bluejay Branch
=Control
Muddy Creek Watershed
=Treatment
RSC

Calculating Nutrient Removal

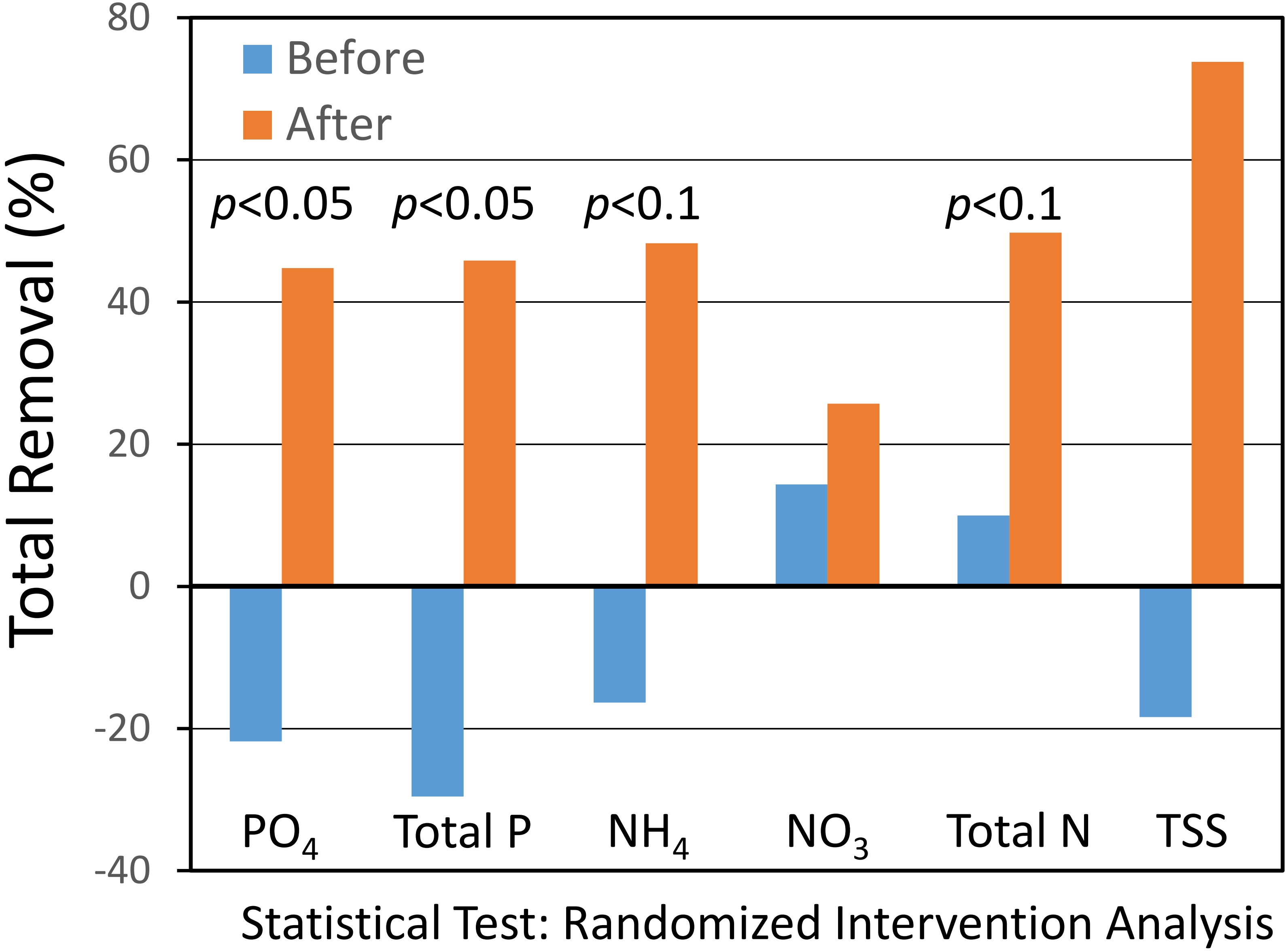
Concentration X Water Flow = Load

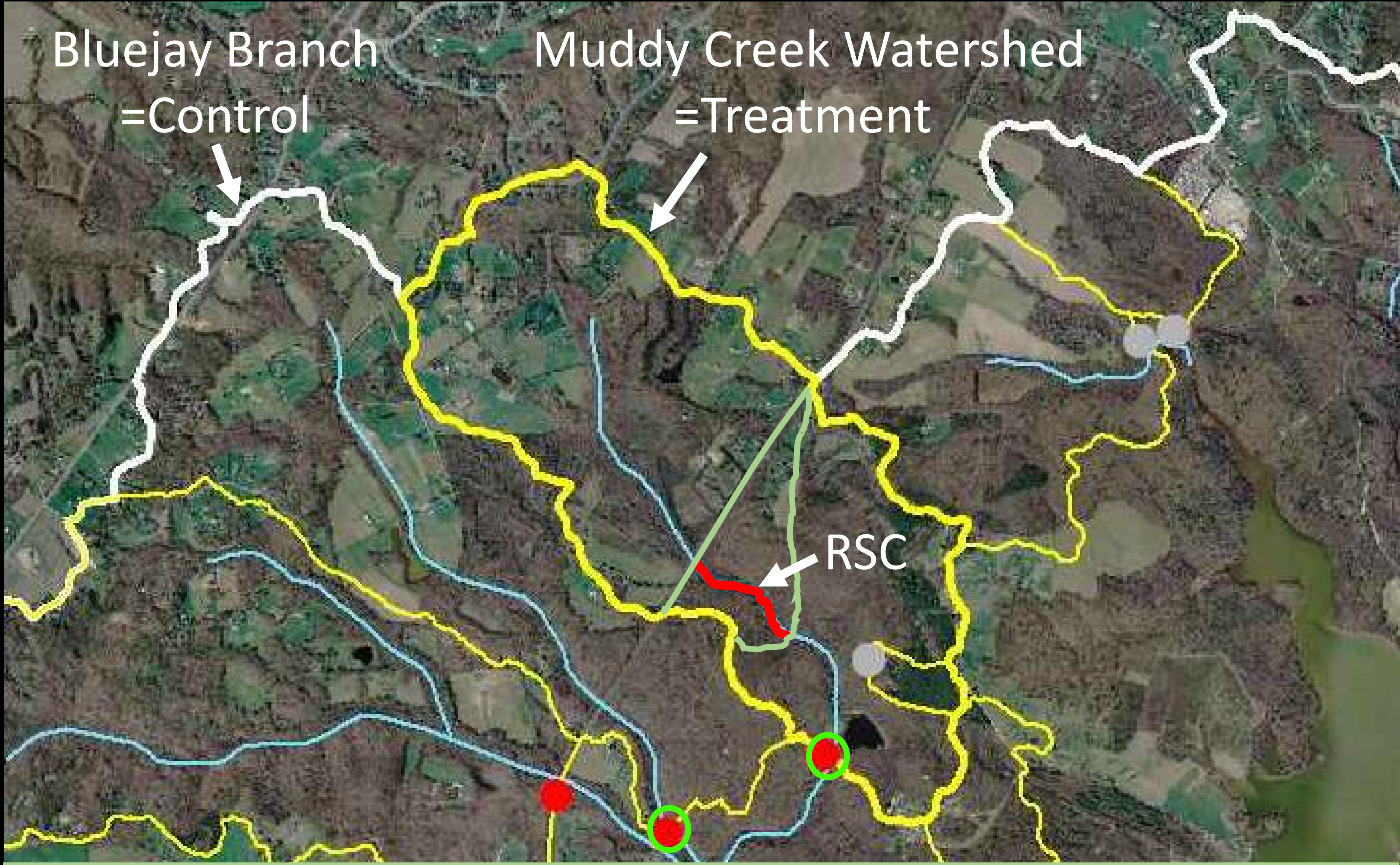
Load in – Load Out = Amount Removed

% Removed = (Amount Removed / Load In) X 100

Comparing the inlet and outlet of the restored reach: Percentage of inflow removed increased after restoration

Thompson et al. 2018. The multiscale effects of stream restoration on water quality. Ecological Engineering 124:7-18.

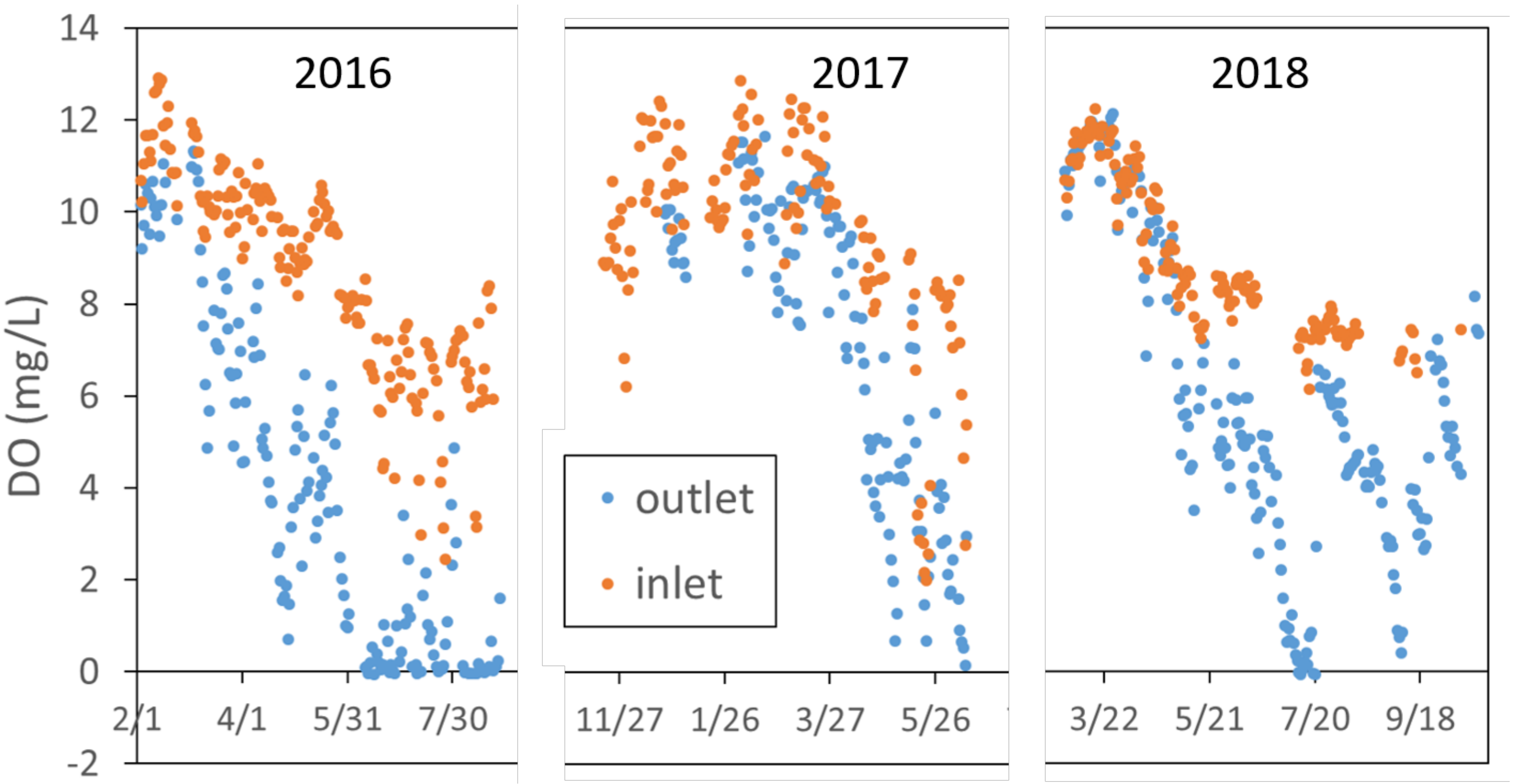




Comparing the treatment and control watersheds:

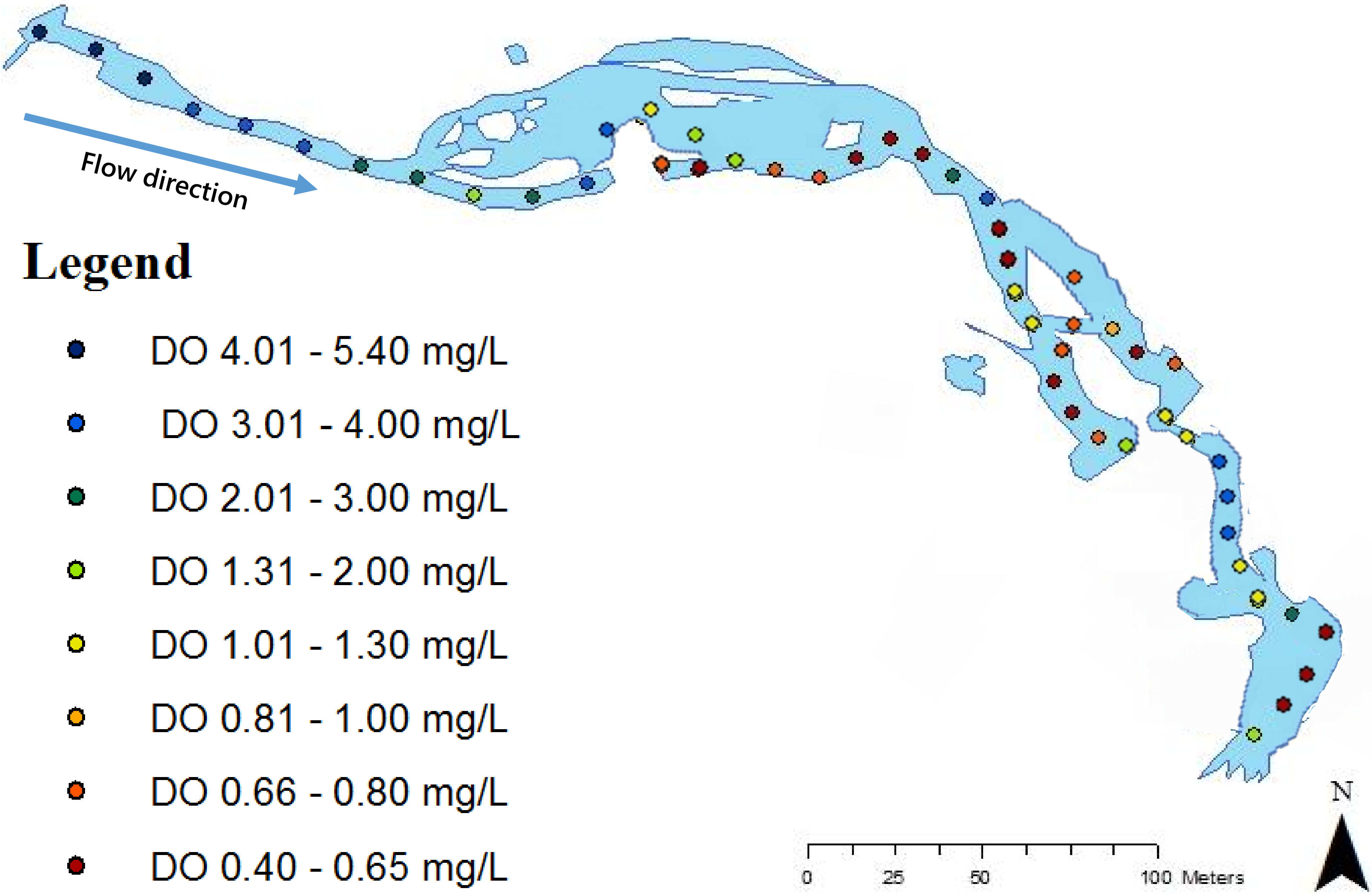
No statistically significant changes in loads could be attributed to the restoration.
The effects may have been masked by the effects of beaver ponds downstream of the restoration (Thompson et al. 2018. Ecological Engineering 124:7-18).

Dissolved Oxygen Concentration at Inlet and Outlet

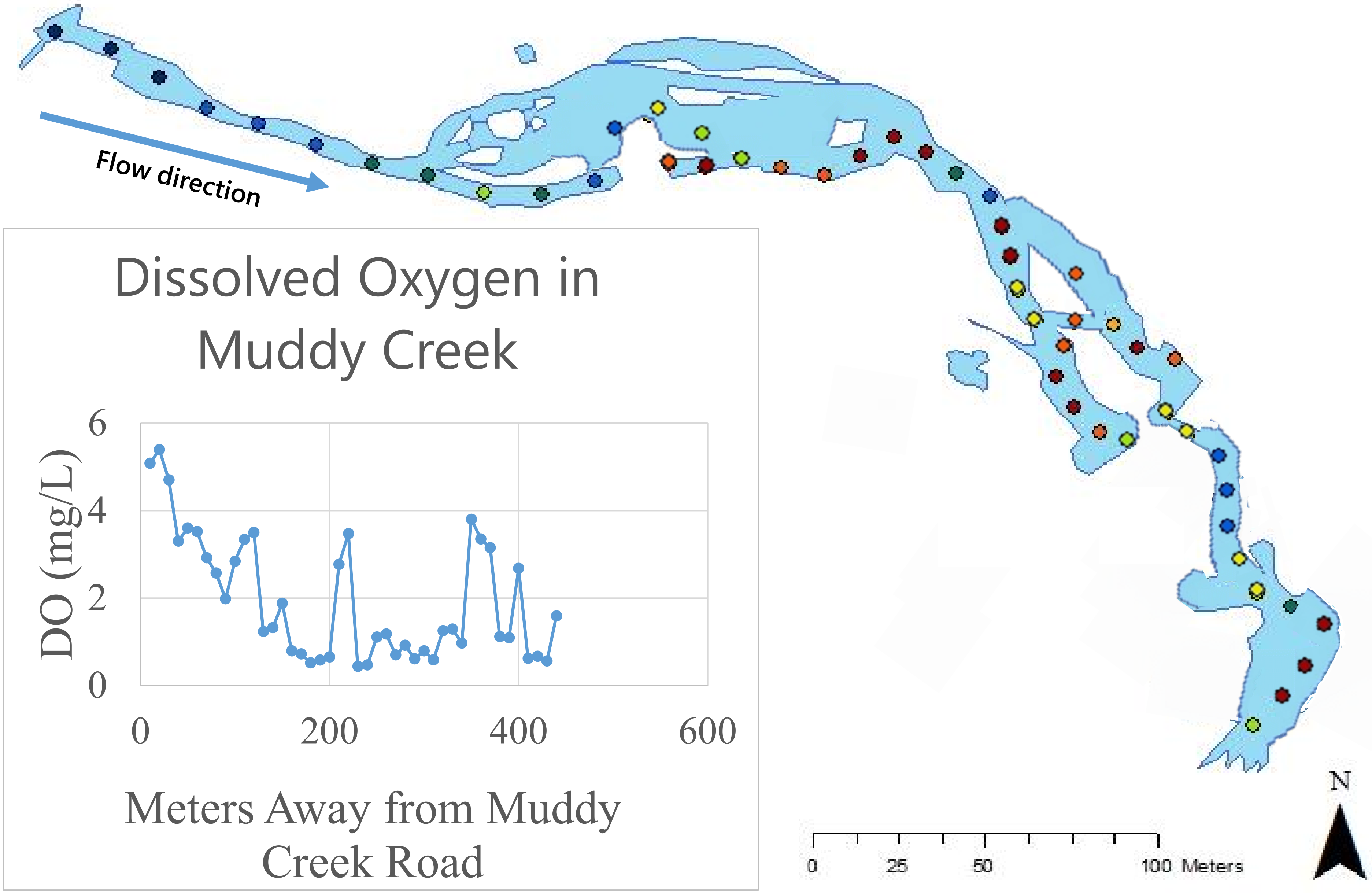


Note: Data here and elsewhere in this presentation are unpublished and should be considered preliminary unless a specific publication is cited.

Dissolved Oxygen profile of Muddy Creek on July 19th 2016

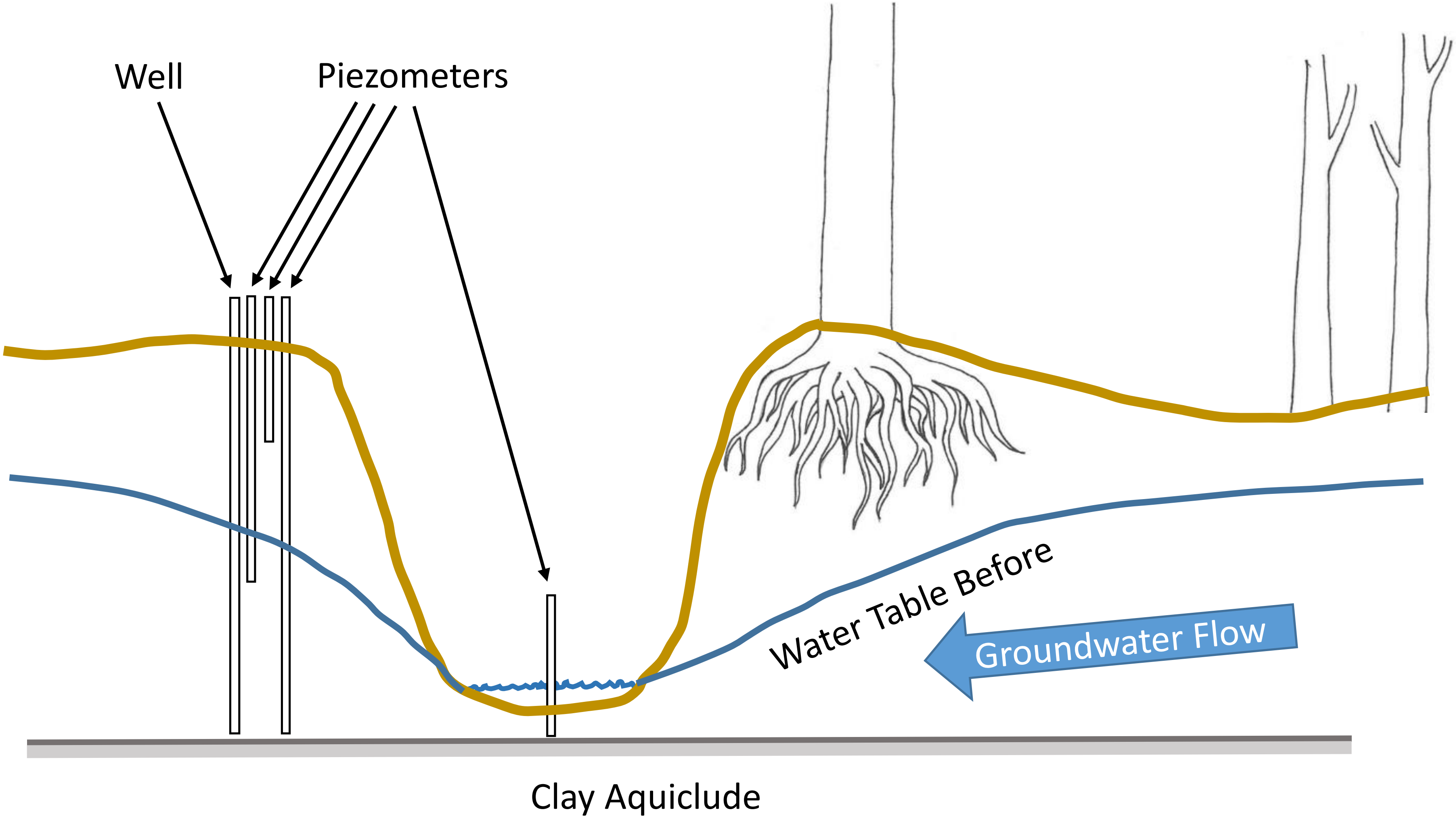


Dissolved Oxygen profile of Muddy Creek on July 19th 2016

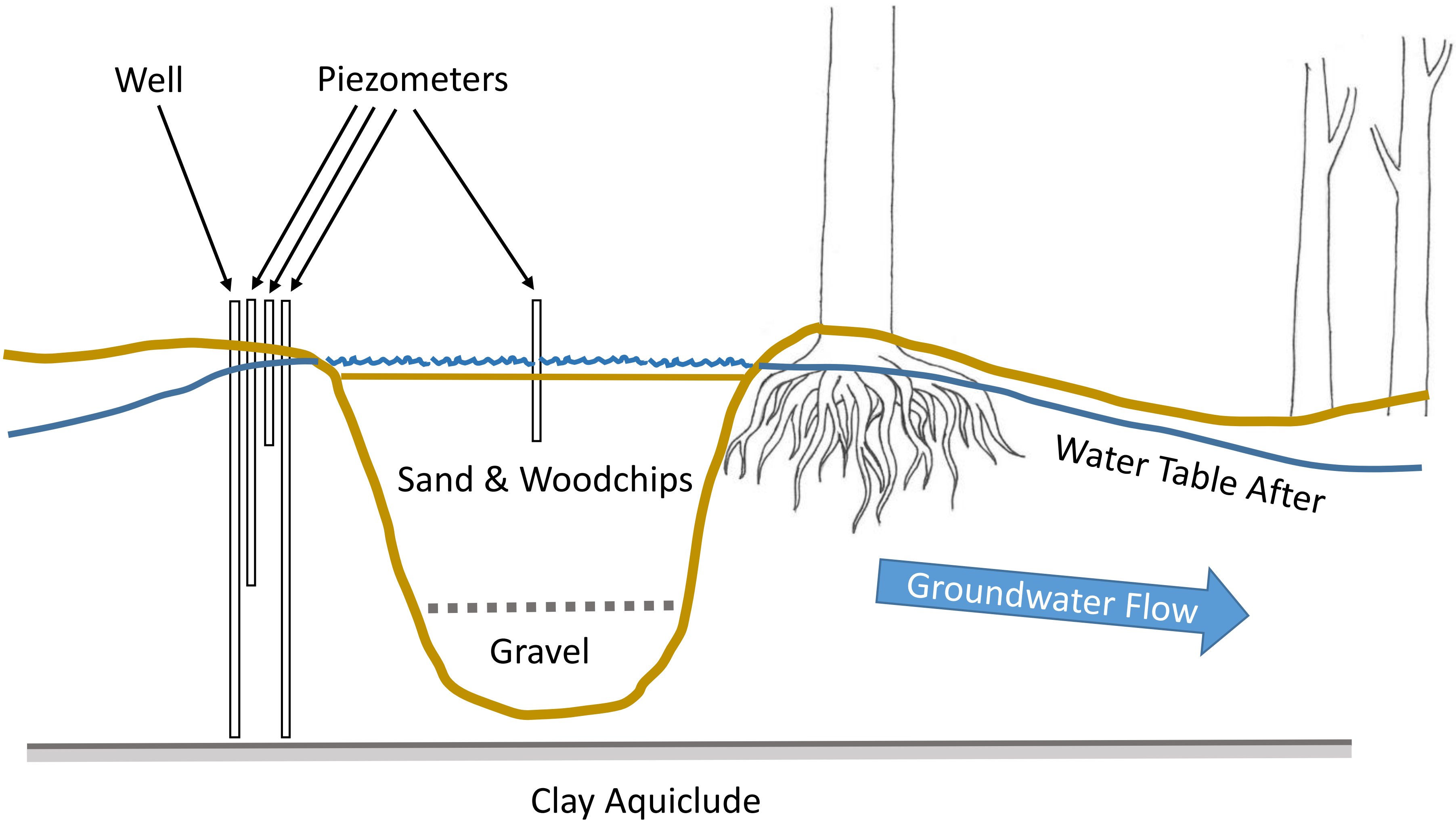


Transect of Wells and Piezometers

Before restoration, the eroded channel drained the banks.



After restoration, the water table elevation increased.

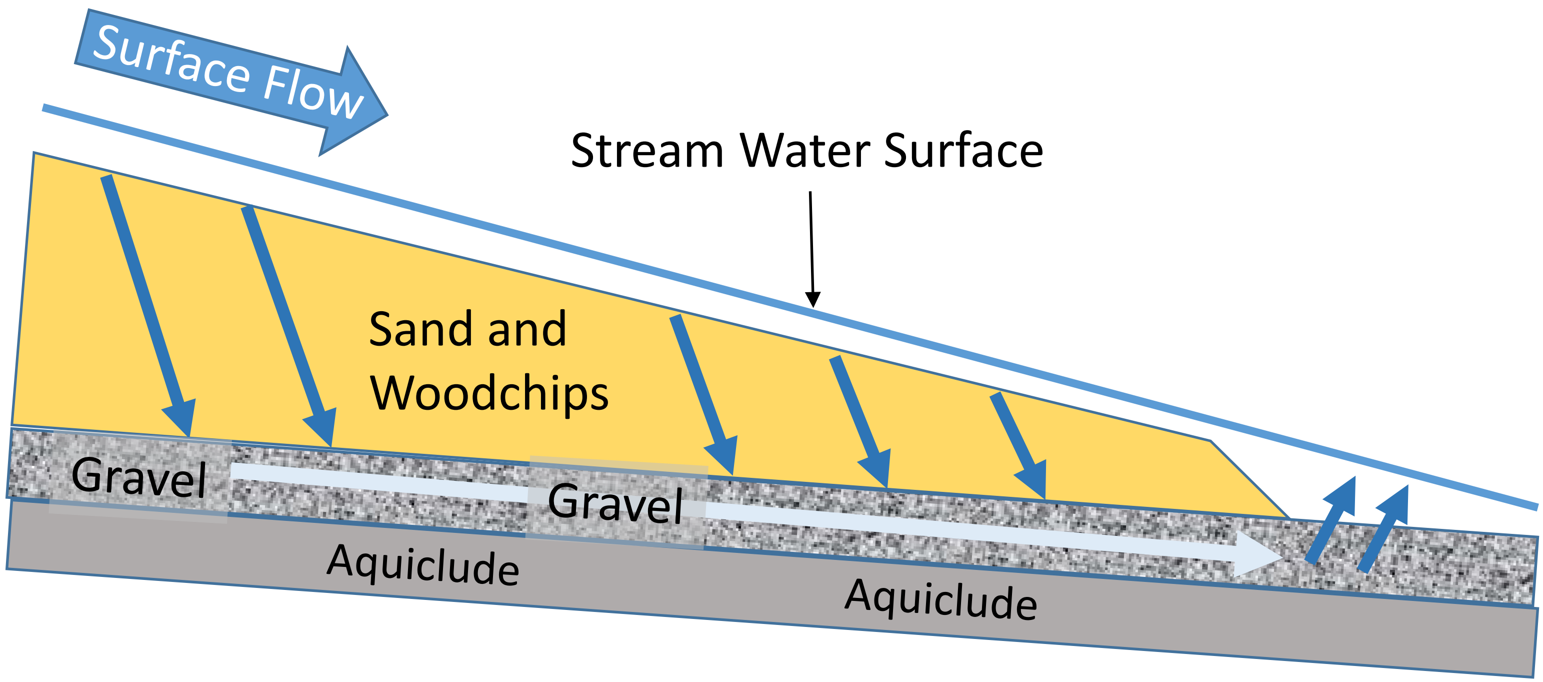


Sand Filter Concept:

-The gravel layer allows faster groundwater flow than the overlying sand.

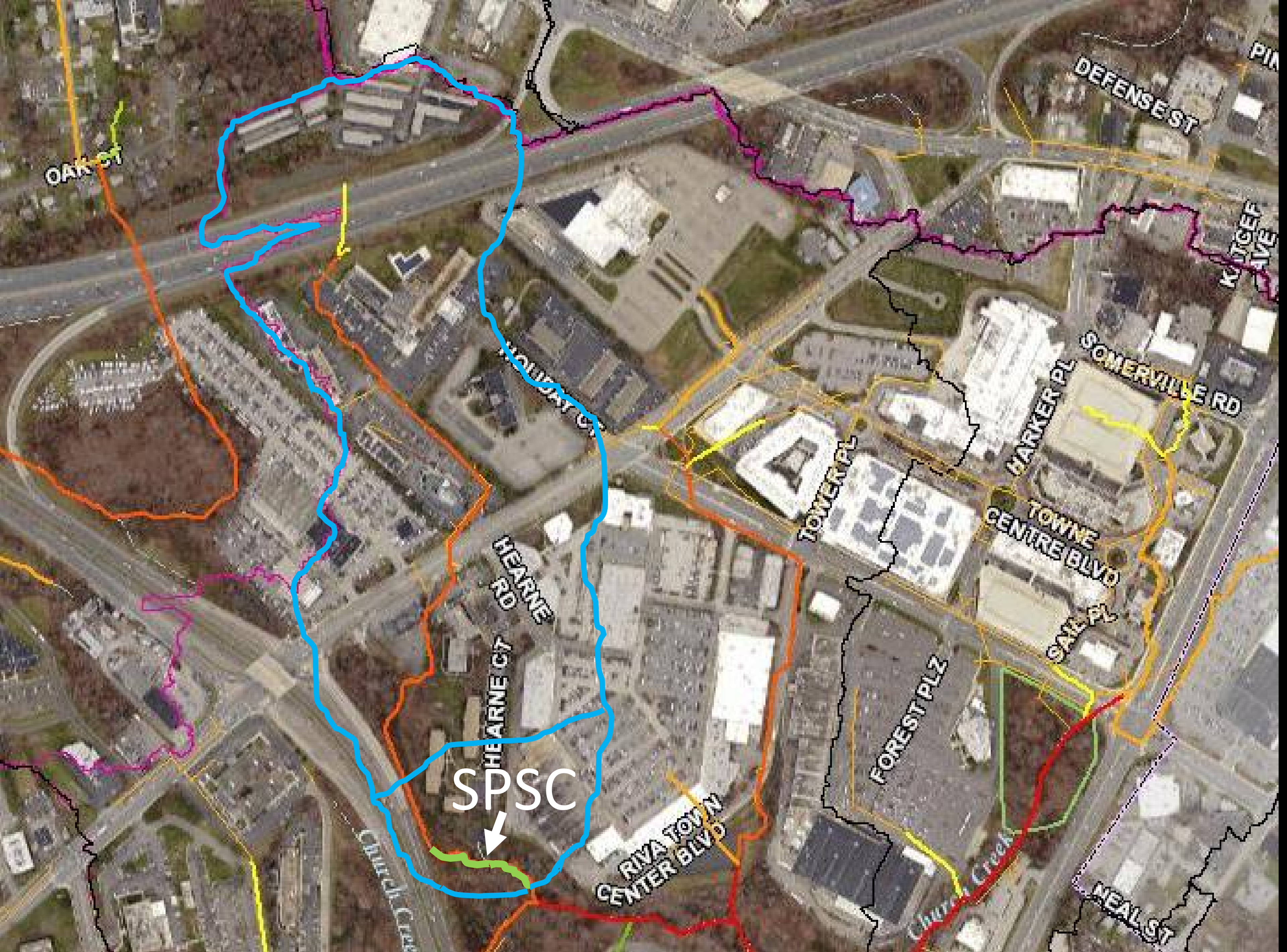
-This pulls water downward through the sand.

-At the end of the restored reach groundwater carried through the gravel is released back into the surface flow.



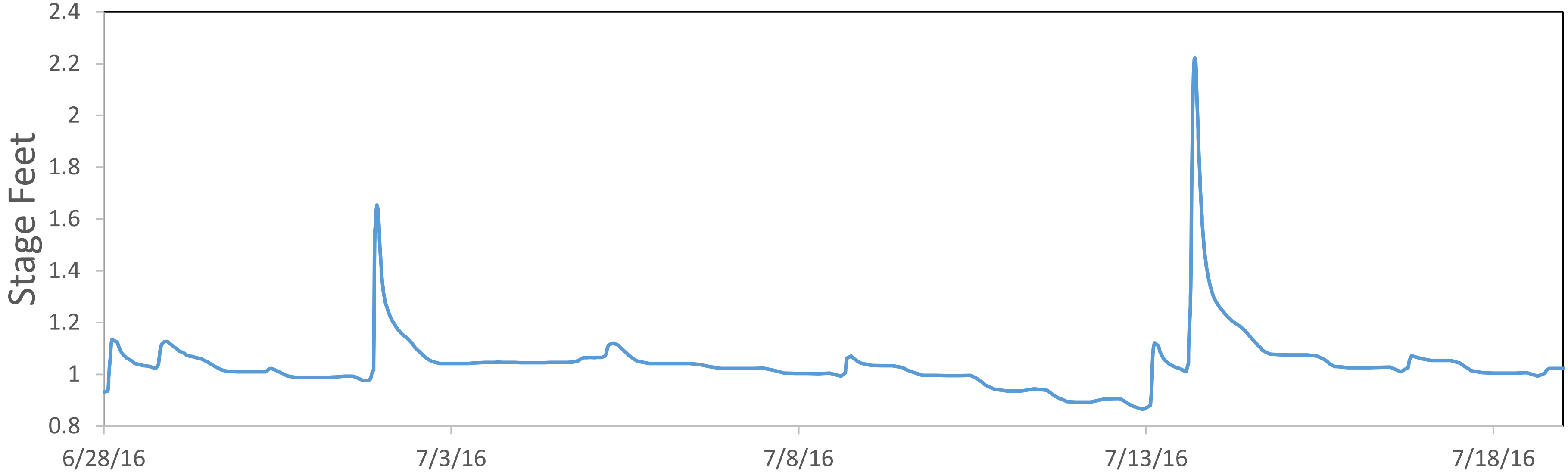
Changes in Groundwater after Restoration

Decreased:	Increased:	No change:
Phosphate	Organic C	Nitrate
Ammonium	Iron	
Sulfate	Oxygen	
pH	Conductivity	

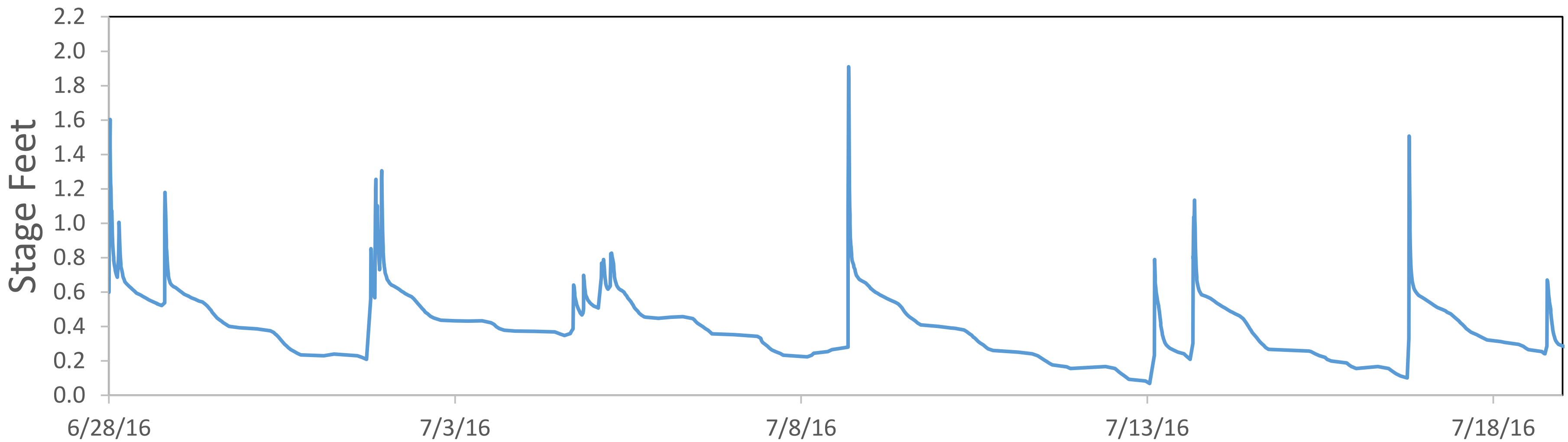


SPSC
OAK CT
DEFENSE ST
SOMERVILLE RD
MARKER PL
TOWER PL
TOWNE CENTRE BLVD
HEARNE RD
HEARNE CT
SAIL PL
FOREST PLZ
RIVA TOWN CENTER BLVD
NEAL ST

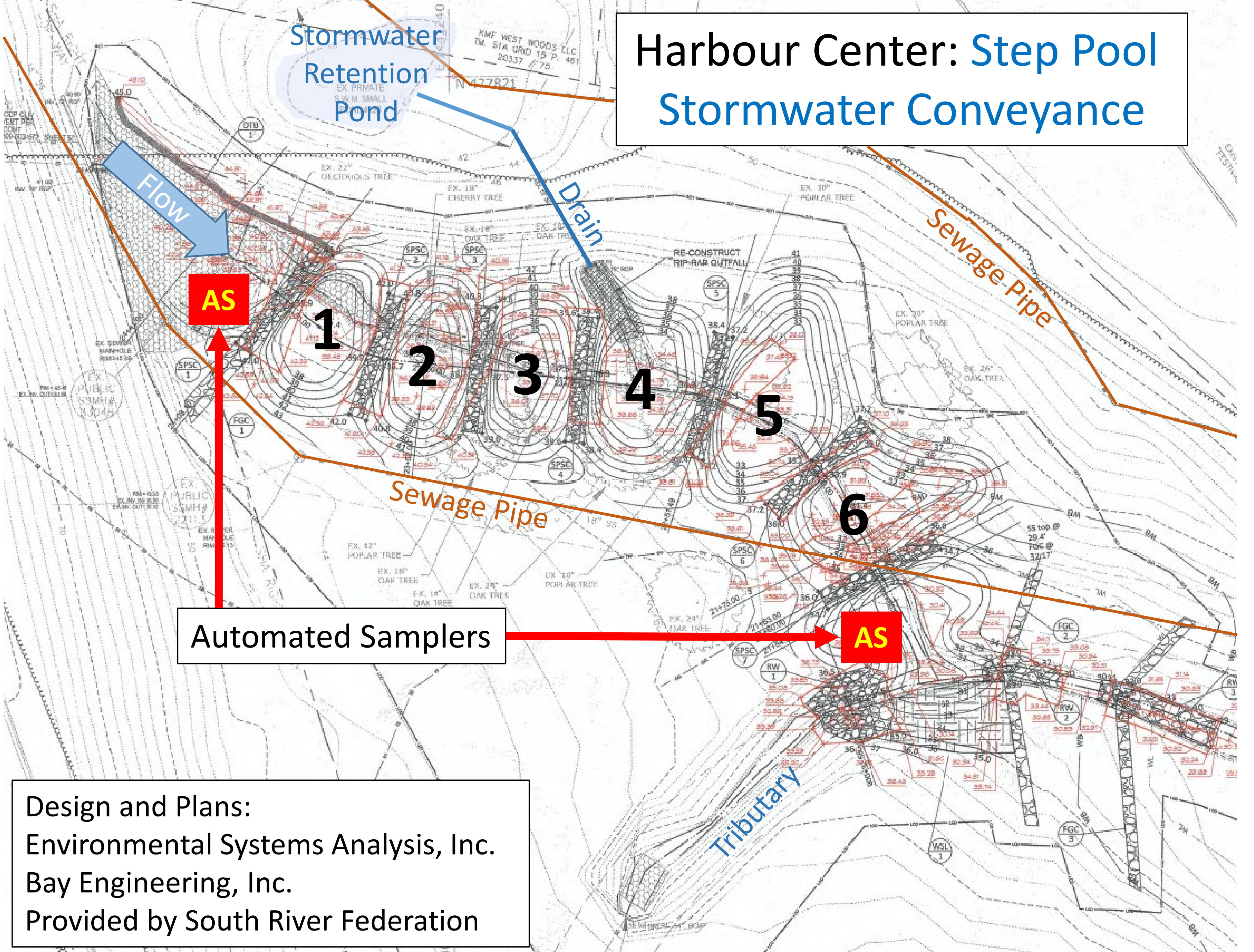
Stage at Muddy Creek RSC Inlet



Stage at Harbour Center RSC Inlet



Harbour Center: Step Pool Stormwater Conveyance



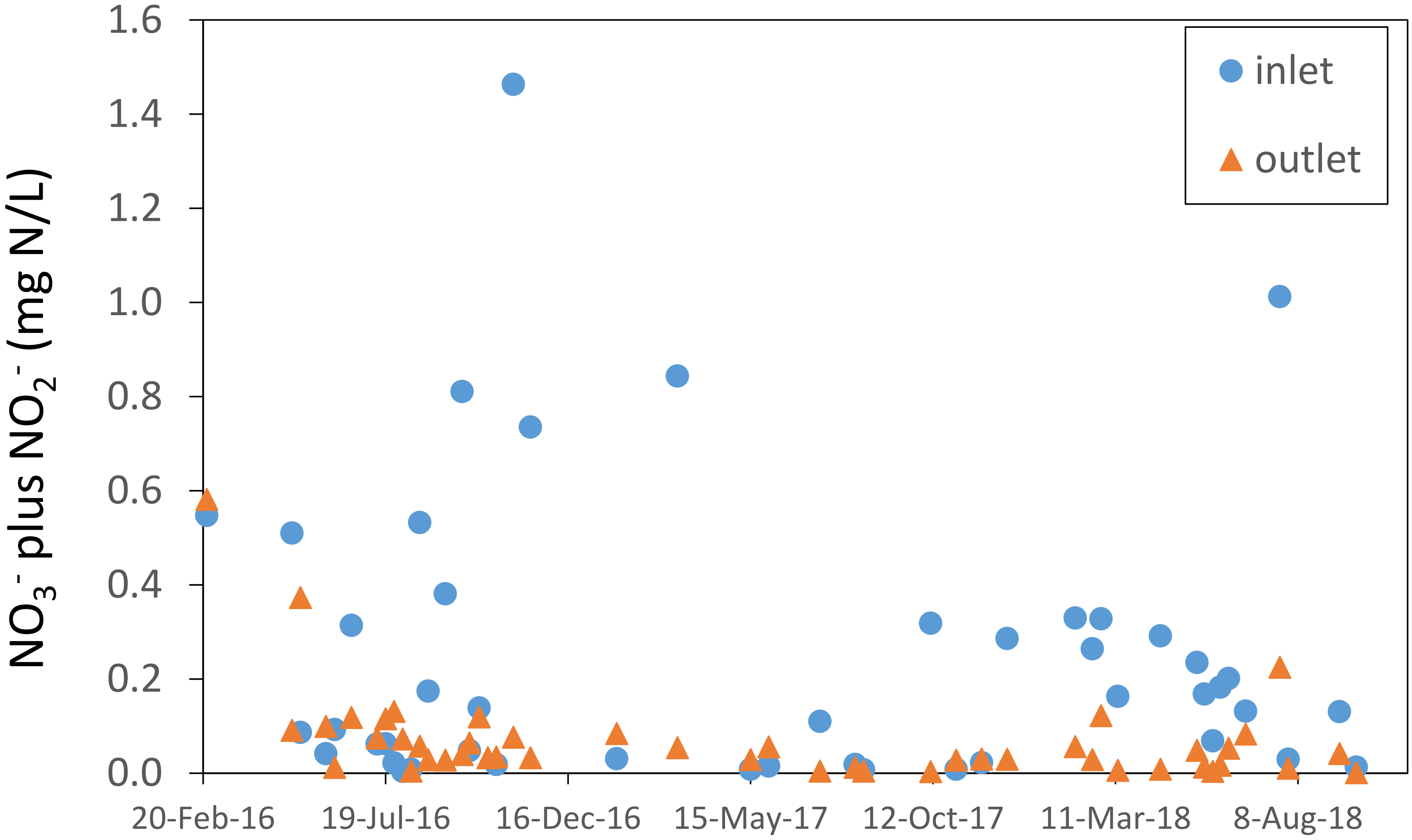
Design and Plans:
Environmental Systems Analysis, Inc.
Bay Engineering, Inc.
Provided by South River Federation

Upstream End of Harbour Center SPSC

Rock Weirs Along Harbour Center SPSC

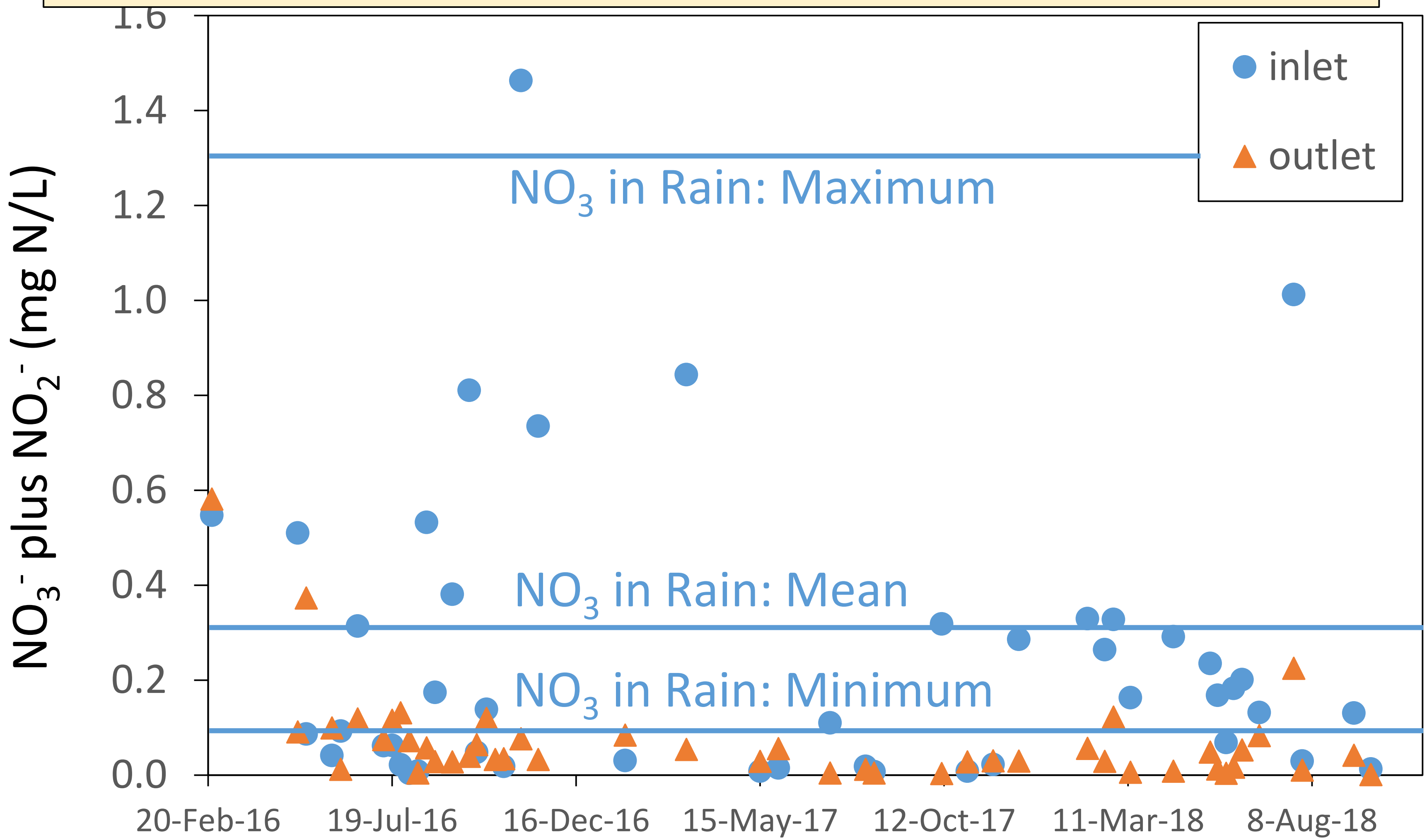
Automated Sampler at the downstream end of the Harbour Center SPSC

Nitrate plus Nitrite (mg N/L) at inlet and outlet of SPSC



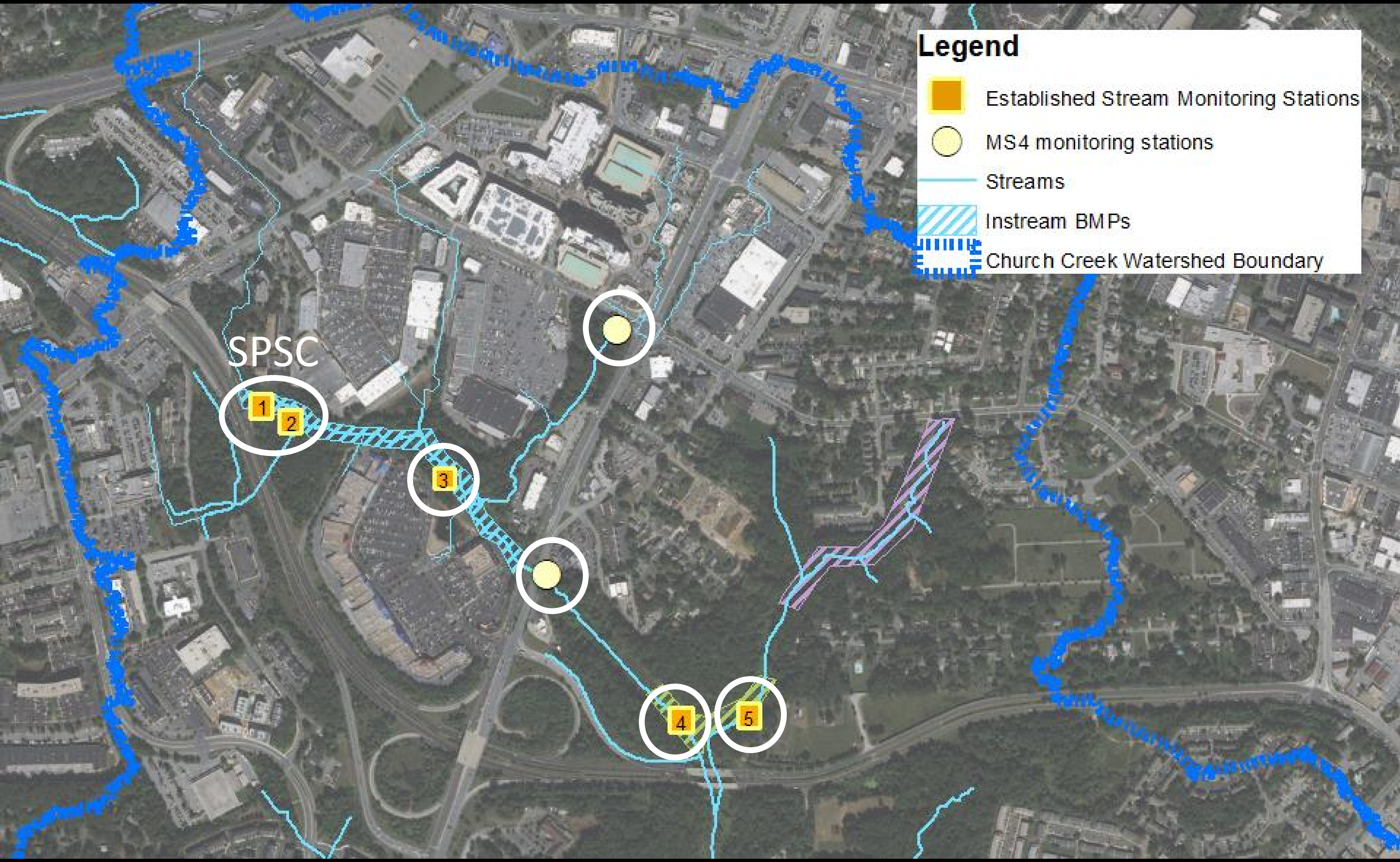
Nitrate plus Nitrite (mg N/L) at inlet and outlet of SPSC

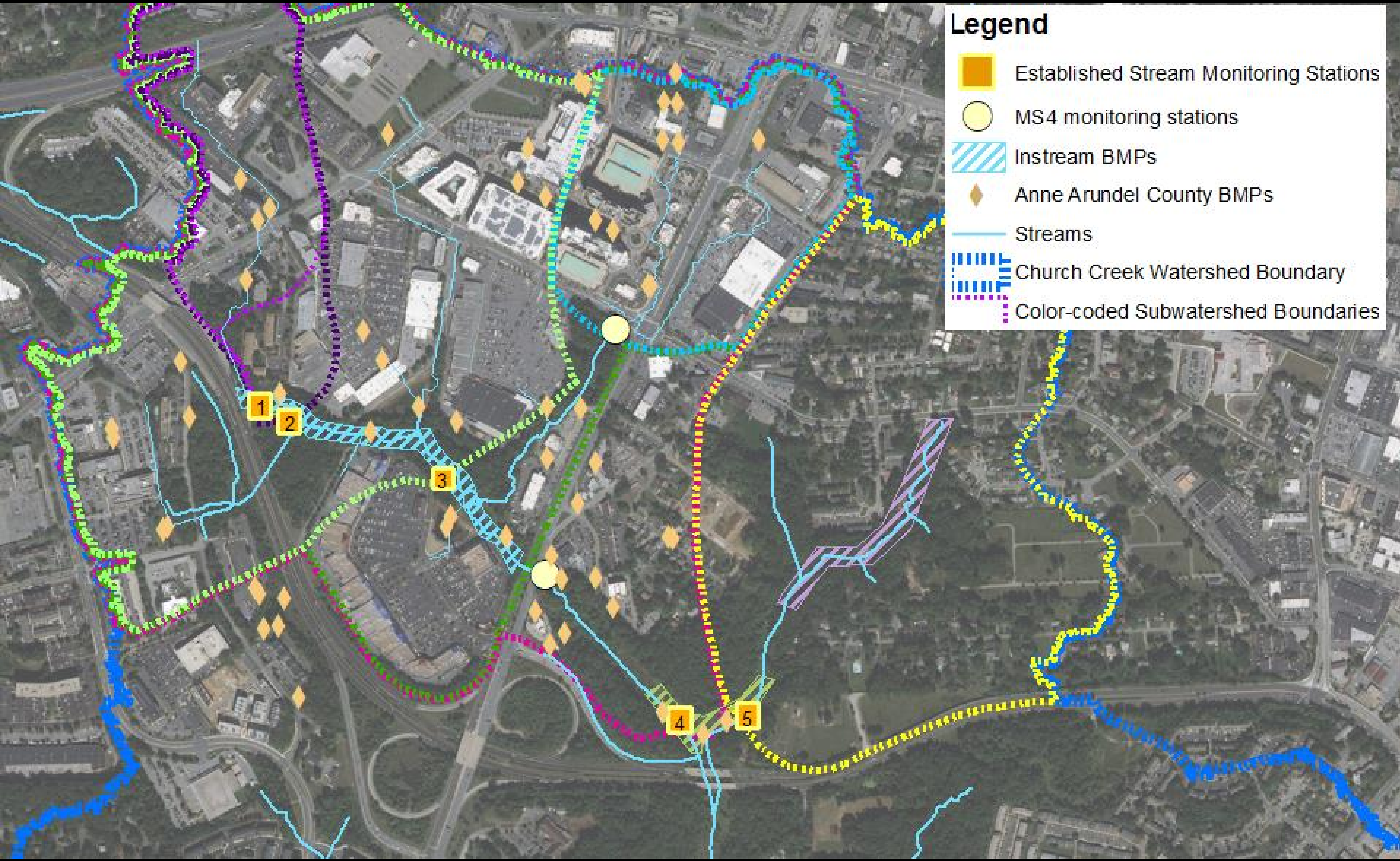
70% of the Nitrate plus Nitrite was removed



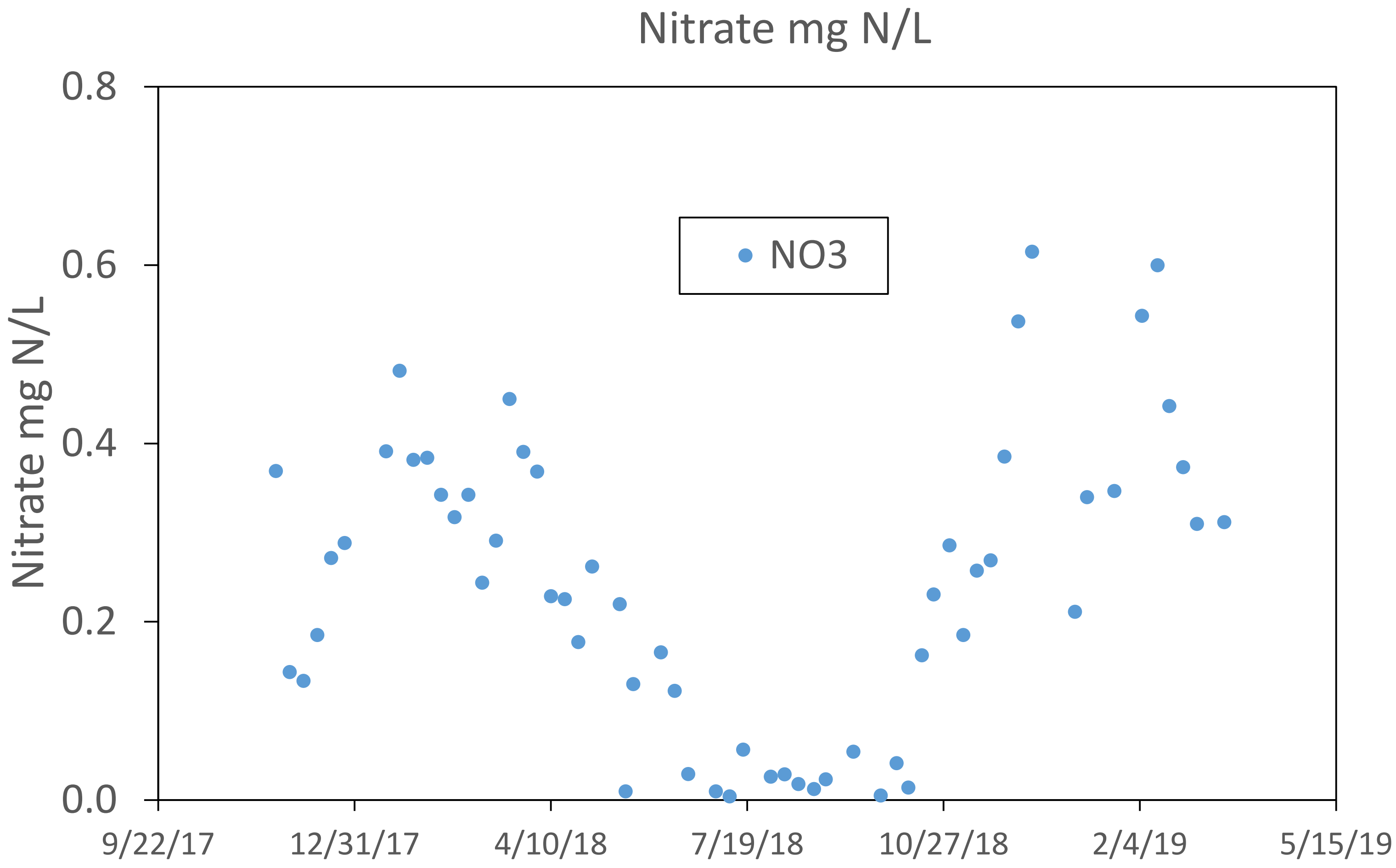
Other Nutrient Forms and Suspended Solids Were Not Removed

- Ammonium Nitrogen
- Organic Nitrogen
- Total Nitrogen (including 12% Nitrate plus Nitrite)
- Phosphate
- Total Phosphorus
- Total Suspended Solids

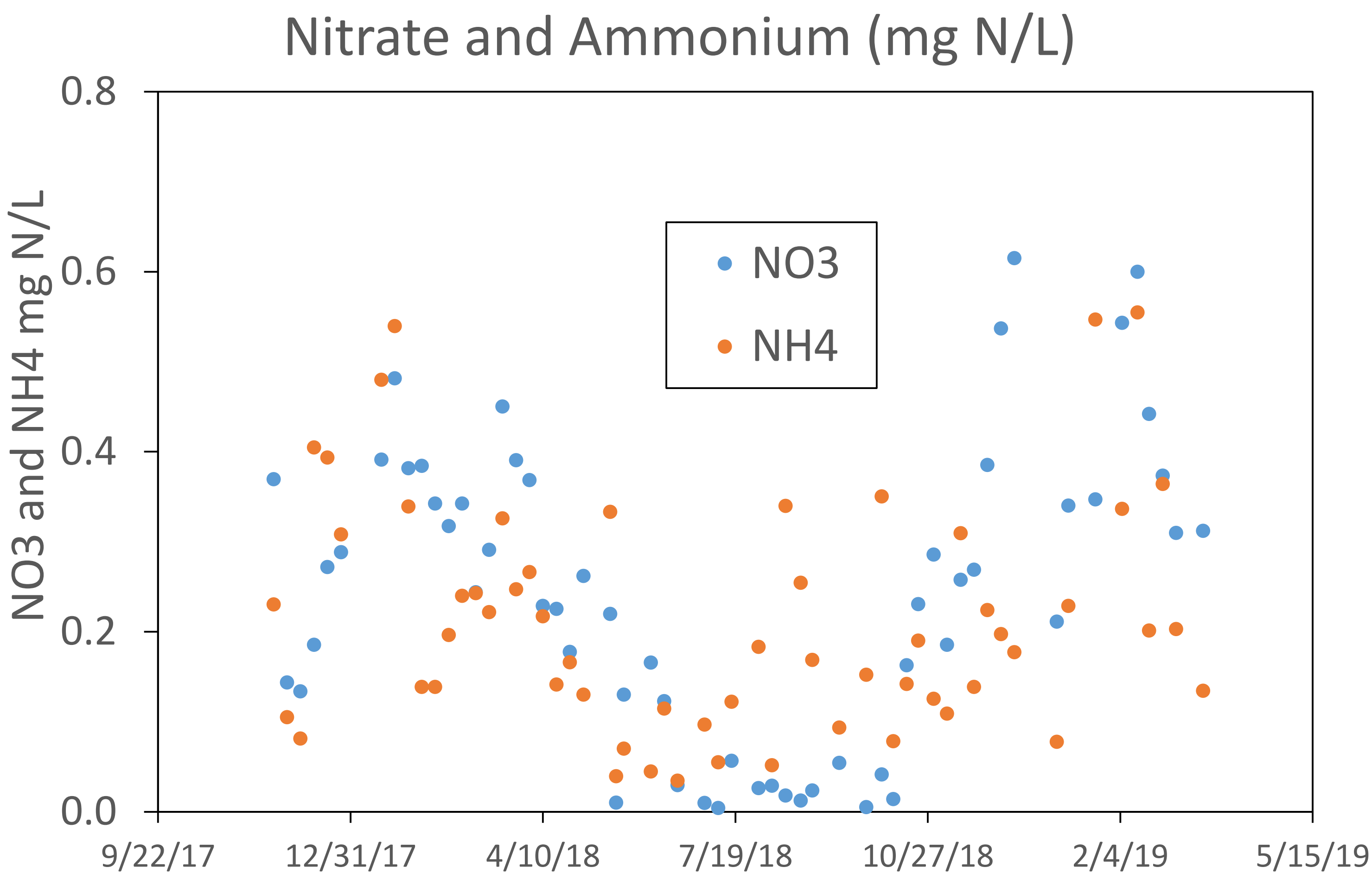

Legend
Established Stream Monitoring Stations
MS4 monitoring stations
Streams
Instream BMPs
Church Creek Watershed Boundary
SPSC
1
2
3
4
5


Legend
Established Stream Monitoring Stations
MS4 monitoring stations
Instream BMPs
Anne Arundel County BMPs
Streams
Church Creek Watershed Boundary
Color-coded Subwatershed Boundaries
1
2
3
4
5

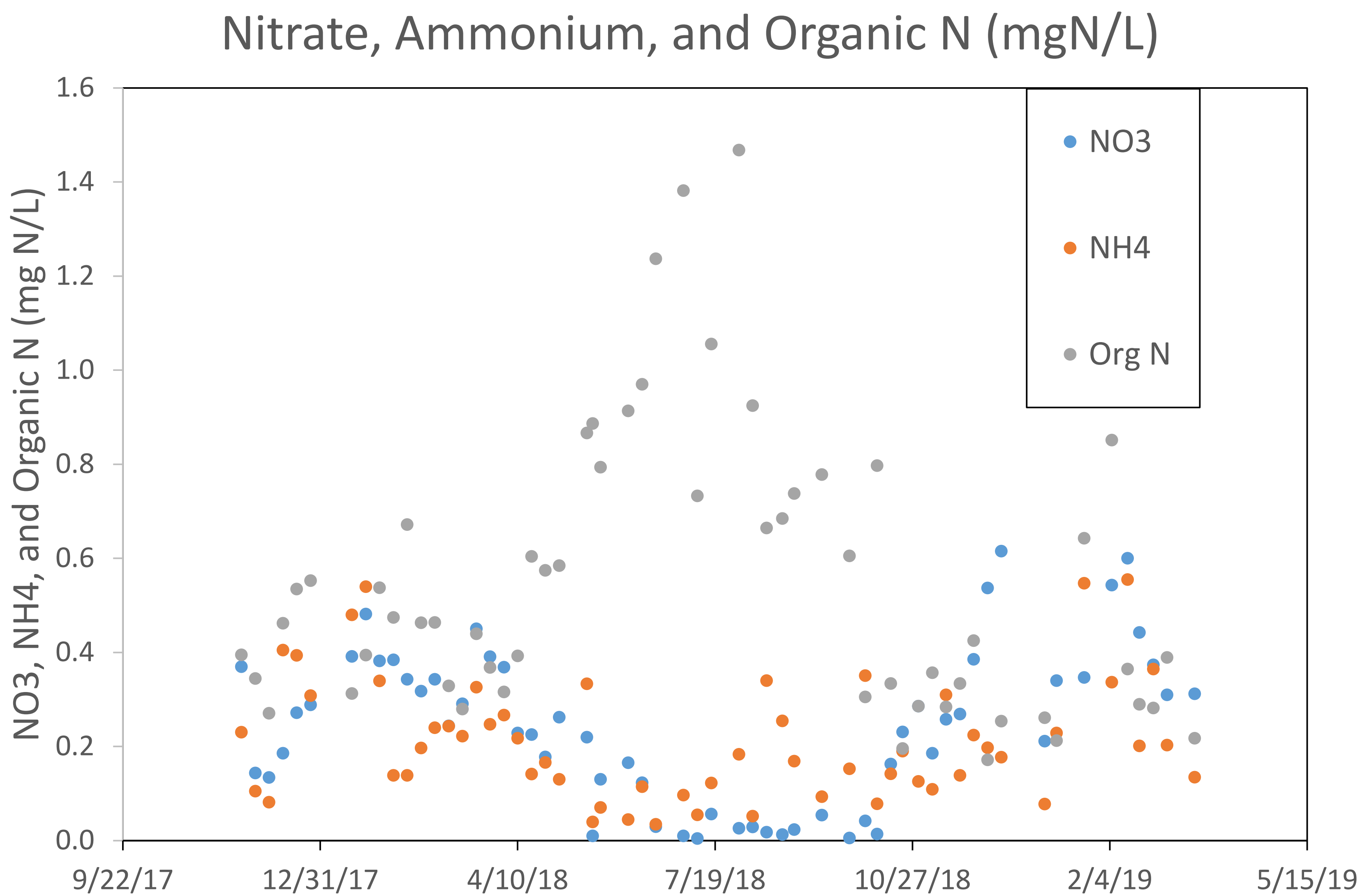
Concentrations in Church Creek downstream of Route 2 (station 4)



Concentrations in Church Creek downstream of Route 2 (station 4)



Concentrations in Church Creek downstream of Route 2 (station 4)

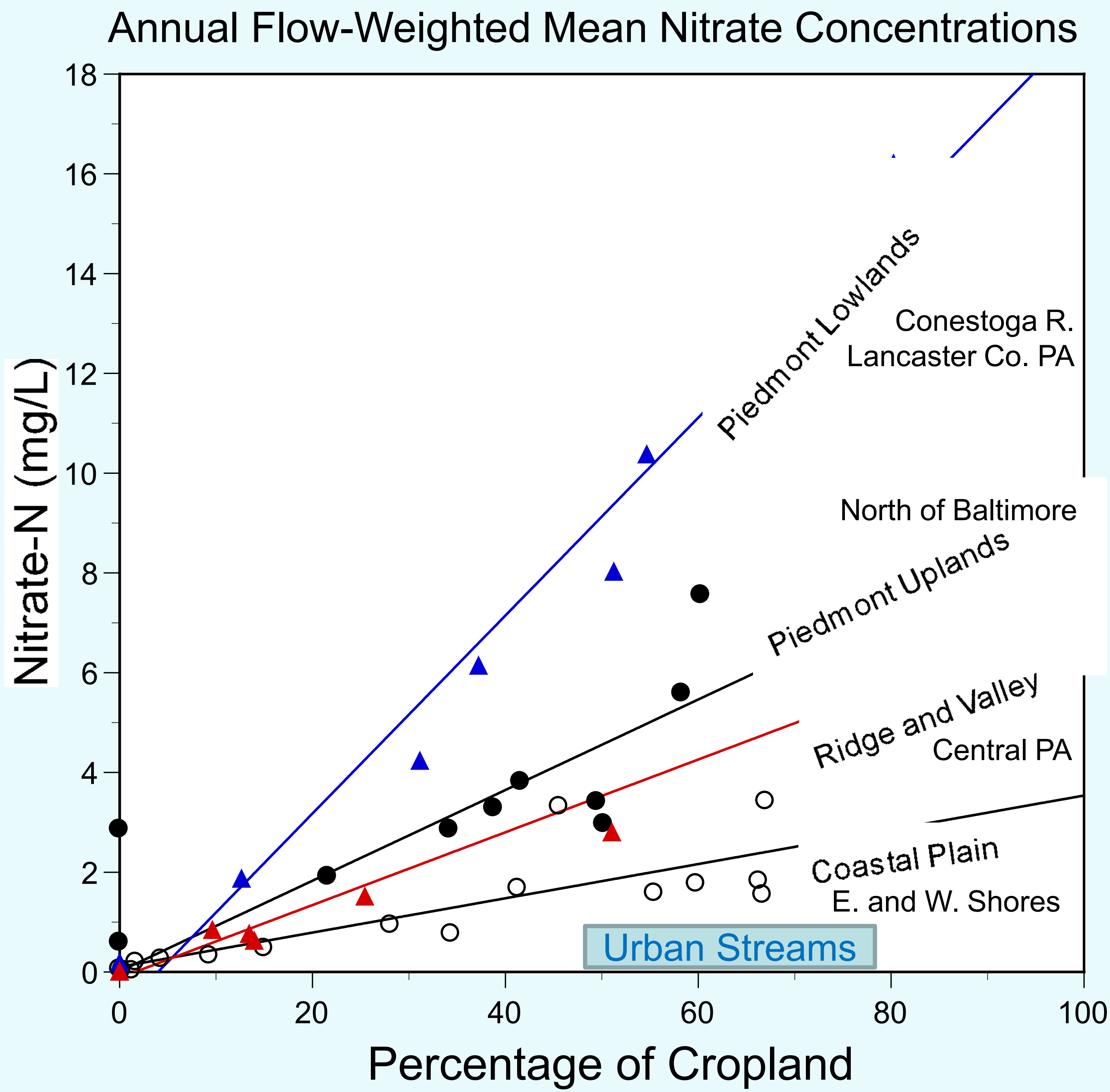


Where does the nitrate go?

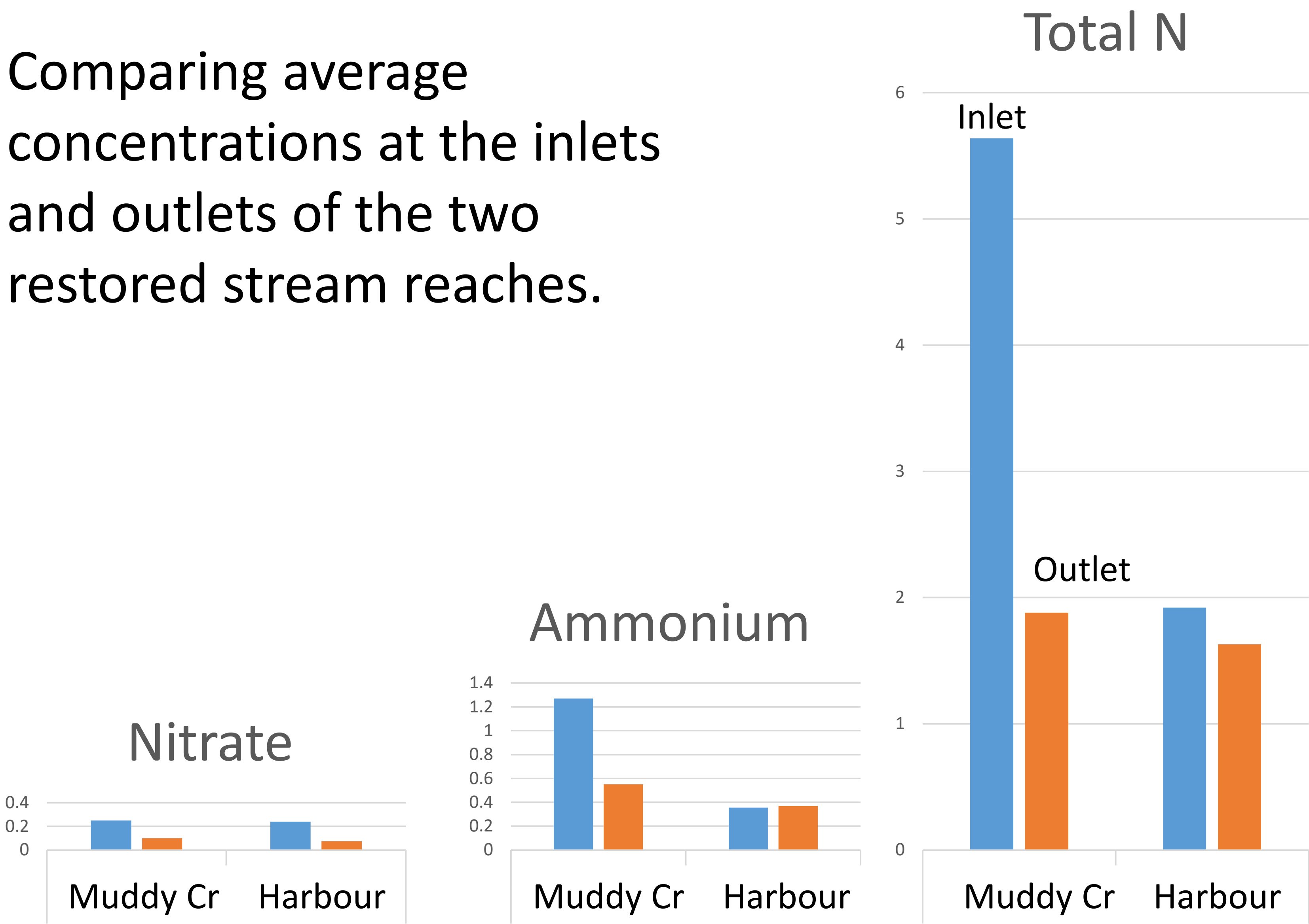
- Converted to nitrogen gas by denitrification and released to the atmosphere.

- Converted to organic nitrogen and held in the stream.

- Converted to organic nitrogen and carried downstream.


Annual Flow-Weighted Mean Nitrate Concentrations
Nitrate-N (mg/L)
Percentage of Cropland
0
2
4
6
8
10
12
14
16
18
0
20
40
60
80
100
Piedmont Lowlands
Conestoga R.
Lancaster Co. PA
North of Baltimore
Piedmont Uplands
Ridge and Valley
Central PA
Coastal Plain
E. and W. Shores
Urban Streams

Comparing average concentrations at the inlets and outlets of the two restored stream reaches.



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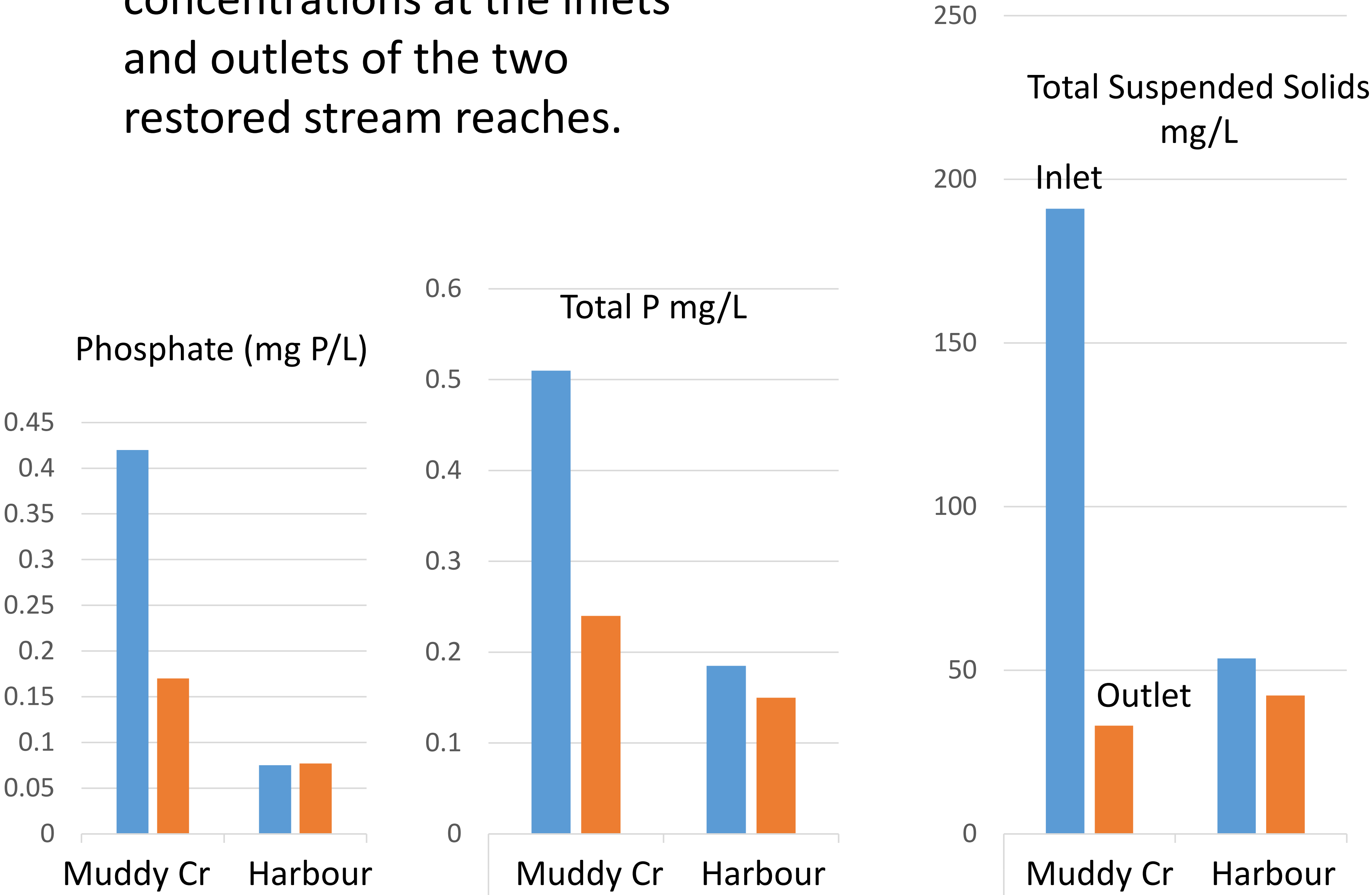
Data for the Harbour Center SPSC are unpublished.

Comparing average concentrations at the inlets and outlets of the two restored stream reaches.



Data for Muddy Creek are from Thompson et al. 2018. Ecological Engineering 124:7-18
Data for the Harbour Center SPSC are unpublished.

The City Stream

- Urban SPSC retained about 70% of the nitrate input.
- SPSC effects uncertain without preconstruction data.
- Low concentrations in the summer suggest biological uptake in the streams and SPSCs.
- Nitrate concentrations in urban streams were low compared to rainfall and agricultural watersheds.

The Country Stream

- The Muddy Creek RSC removed high percentages of phosphate, total phosphorus, ammonium, total N, and total suspended solids (TSS)

- But the changes in removal rates of TN and TSS after restoration were not statistically significant.

Parting Thoughts…

Before restoring streams to remove nutrients maybe one should:

- -Measure the nutrient concentrations
- -Consider ways to reduce the sources

Runoff from impervious surfaces is very destructive to stream ecosystems.

Deicing salts and other substances pollute urban runoff and should be managed.

The SERC Researchers:

- Co-Investigator: Cynthia Gilmour
- Postdocs: William Brogan III and Joshua Thompson
- Technicians: Carey Pelc, Max Ruehrmund, Sean Hartnett, Emily O'Gwin, Tyler Bell, Shannon Insley, Ana Morales, Denise Butera, Will McBurney, and Patricia Dubyoski
- Interns: Julianne Rolf, Jan Kreibich, Brendan Player, Lauren Mosesso, Emily O'Gwin, Christina Klein, and Calvin Parker
- Citizen Science Volunteers: Joe Miklas, Ed Ambrogio, Sue Zeisler, and Keidra Douglas

Partners:

South River Federation
(Now the Arundel Rivers Federation)

Sarah Giordano
Jesse Iliff
Wayne Martin
Dianna Muller
Kate Fritz

We thank these organizations for support:

CBTRUST
Chesapeake Bay Trust

SEVERN RIVERKEEPER®
PROGRAM

UNDERWOOD & ASSOCIATES
LANDSCAPE ARCHITECTURE ♦ ECOLOGICAL RESTORATION
A DESIGN/BUILD Co.

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Rathmann Family Foundation

EPA United States
Environmental Protection
Agency

NSF