Co-managing CECs and Nutrients for a Much Healthier Potomac Watershed

2012 – 2025: Where we've been, where we are, and where to go?

Collaborators:

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University of Maryland
Adil Godrej,
Virginia Tech
Sudhir Murthy,
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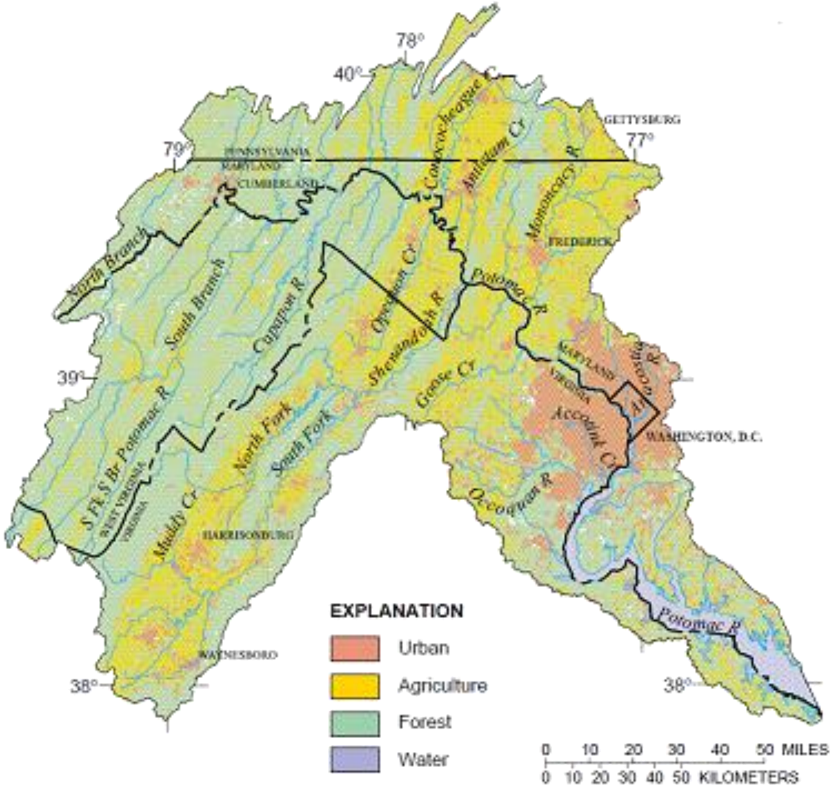

Presentation Overview

- Brief History of the Research Program
  - A Unique Collaboration
  - Program Drivers
- Overview of the Approach
- Project 1: Assessing Relative Source Contributions and Impacts of BMPs on Nutrients and EDCs.
- Project 2: EPA STAR- Improving Reuse for a Healthier Potomac
- Other Things Going on in the Potomac Watershed…

A Unique Collaboration

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Project Driver: Intersex fish in Potomac Watersheds

The Washington Post

Health & Science

Bay's smallmouth bass under siege, report says

Chesapeake Bay News Aug 09 2012
Intersex fish widespread in Potomac River basin

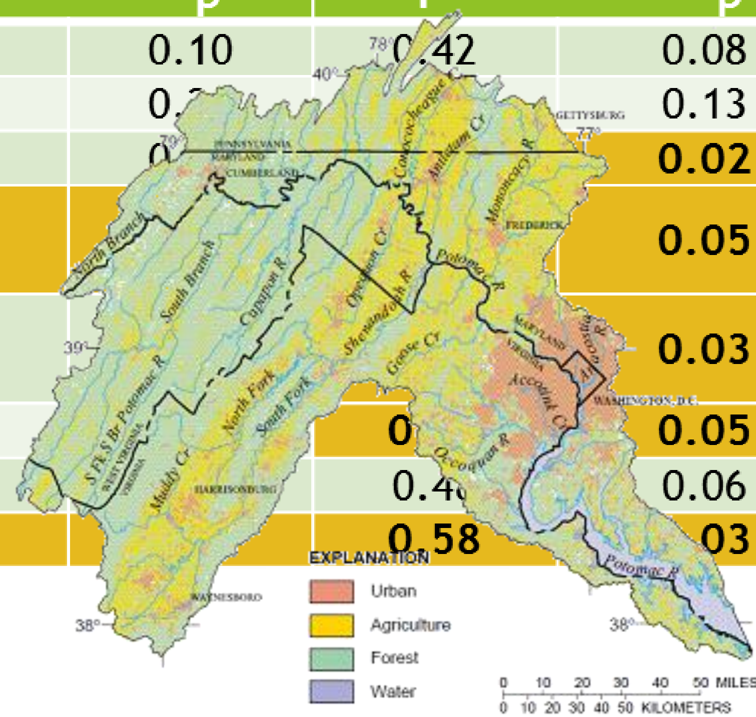
Intersex Fish Now in Three Pennsylvania River Basins
Released: 6/30/2014 7:00:00 AM
http://www.usgs.gov/newsroom

Impacts of Point and Non-point Sources

Comparing Land Use and Observed Intersex Activity

Land-use	Intersex prevalence r^2	Intersex prevalence p	Intersex severity r^2	Intersex severity p
Human population density	0.39	0.10	0.42	0.08
Number of WWTPs	0.22	0. [illegible]	[illegible]	0.13
WWTP flow	0.32	0 [illegible]	[illegible]	**0.02**
Percent agricultural land use	**0.63**	[illegible]	[illegible]	**0.05**
Number of animal feeding operations	0.28	[illegible]	[illegible]	**0.03**
Number of poultry houses	0.27	[illegible]	0 [illegible]	**0.05**
Total number of animals	0.27	[illegible]	0.4 [illegible]	0.06
Animal density	**0.49**	[illegible]	**0.58**	**[illegible]03**

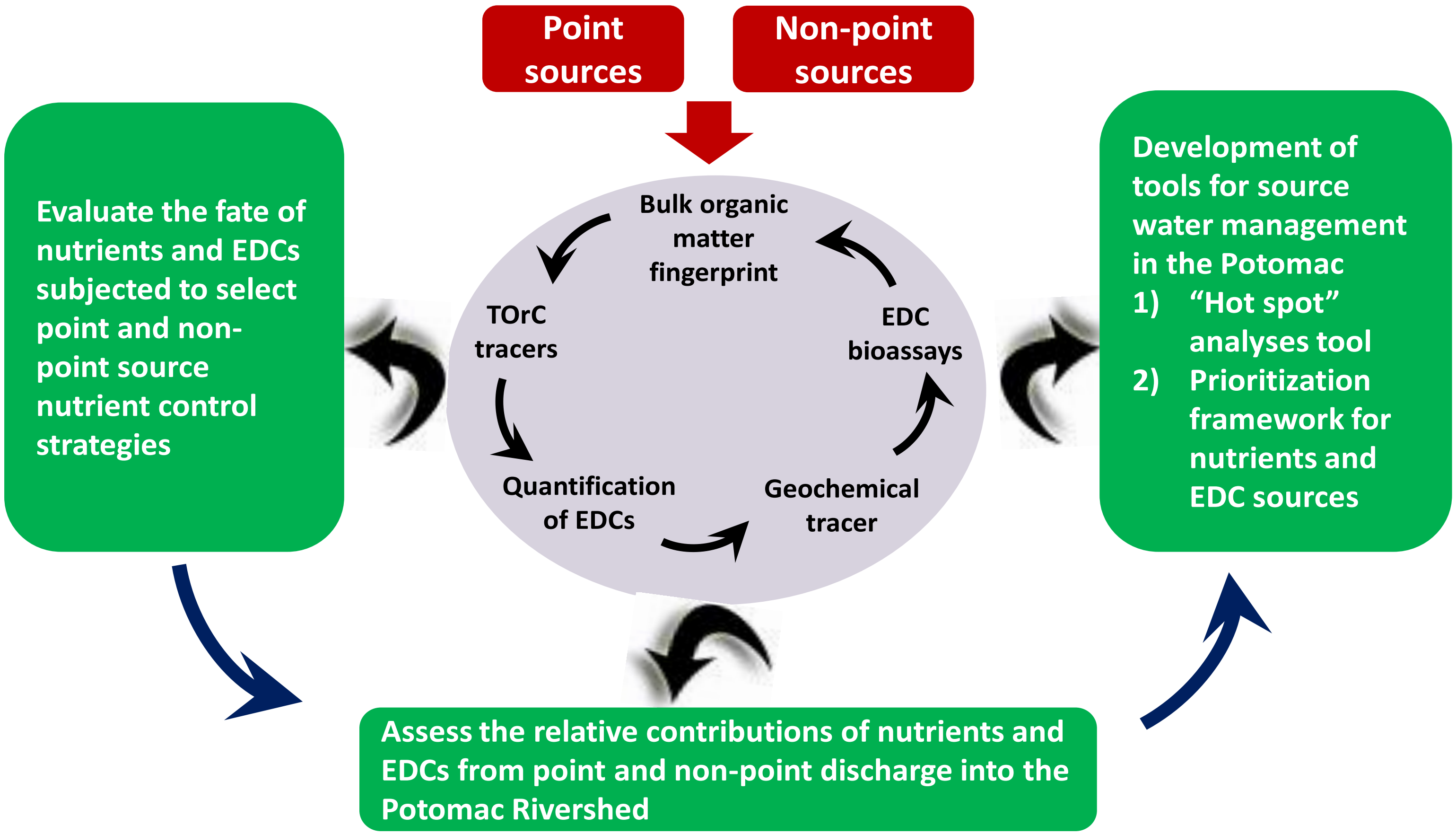
Modified from Blazer et al., 2011



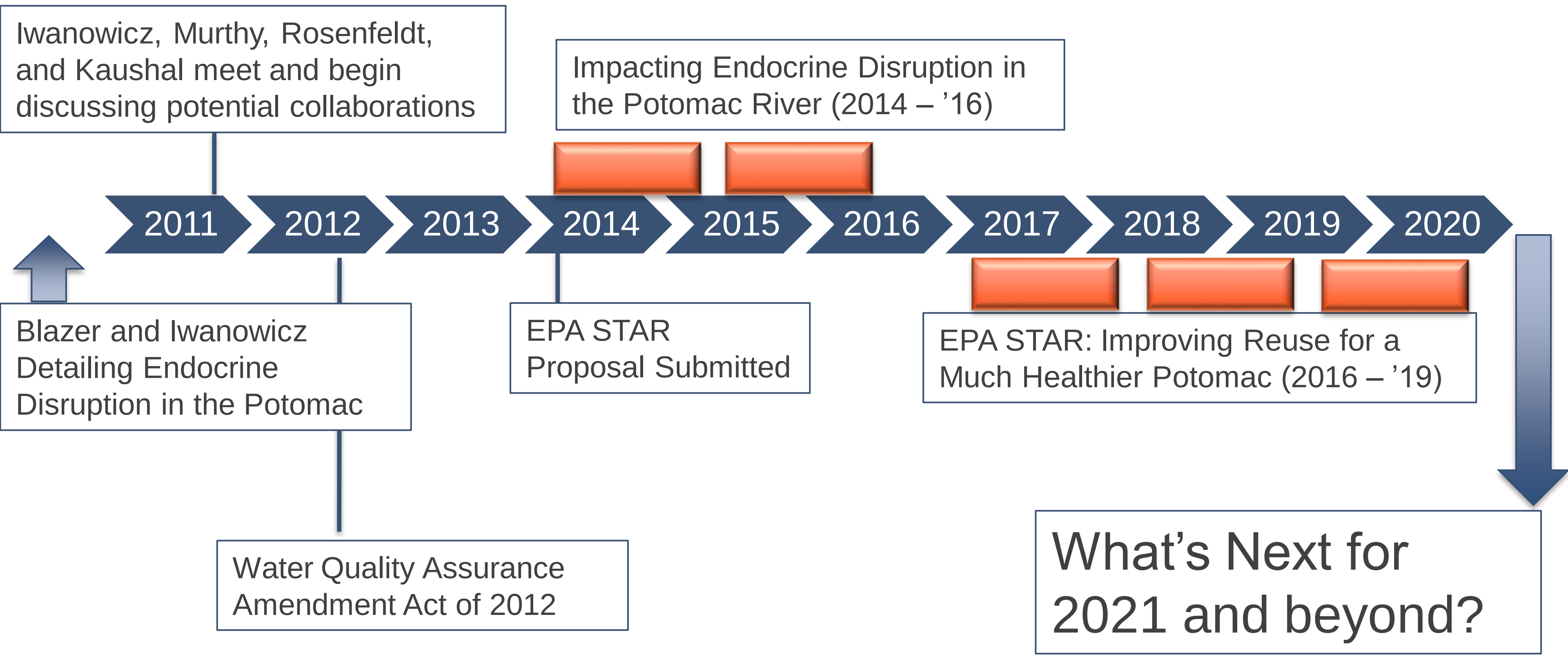
Land Use in the Potomac Watershed

Our Approach

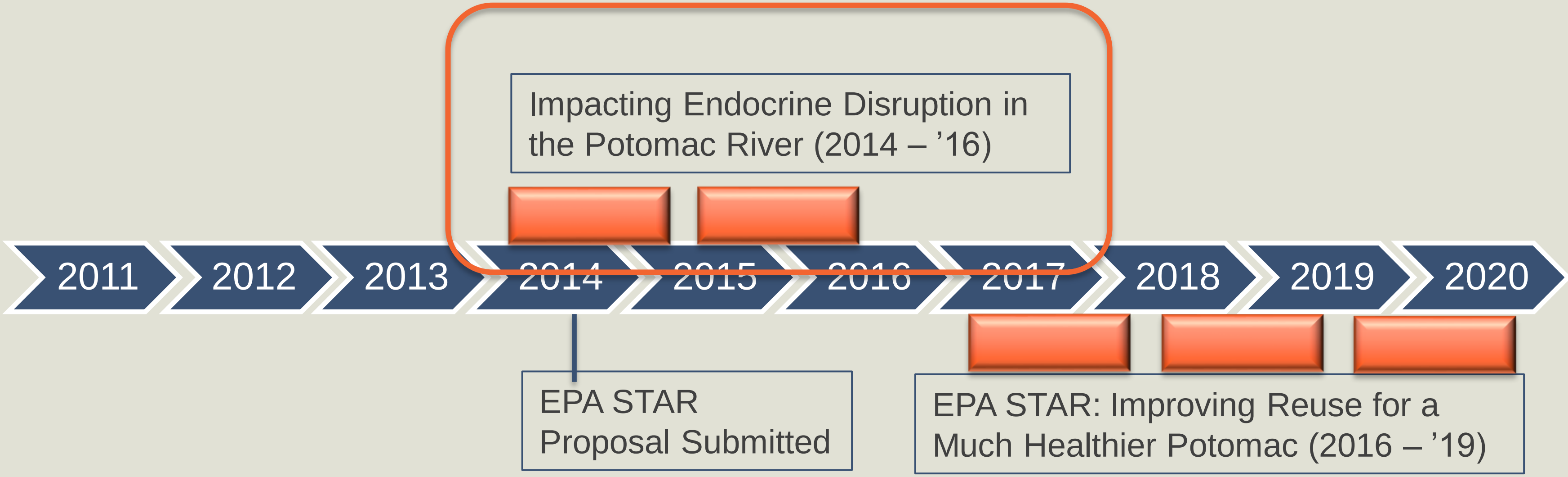
Towards Managing Co-pollutants



Timeline of Research Projects



Project 1: Assessing Relative Source Contributions and Impacts of BMPs on Nutrients and EDCs.



Project 1 Funding: Water Quality Assurance Amendment Act of 2012

Washington DC Council

Act Required:

- Establishment of a Water Quality Assurance Panel to monitor and identify emerging and unregulated contaminants in the District's drinking water* and wastewater discharge
- Mandated quarterly testing for unregulated contaminants in the District's drinking water* and wastewater effluent
- Provide recommendations to the Mayor an appropriate course of action for improving the reduction of unregulated contaminants and endocrine disruptor compounds at their source.

*Note: A quarterly sampling event required by the Environmental Protection Agency's Safe Drinking Water Act Unregulated Contaminant Monitoring Rule 3 (UCMR3) was performed throughout 2014 as a separate monitoring program from this study. Results can be found at https://www.dcwater.com/emerging-compounds-testing

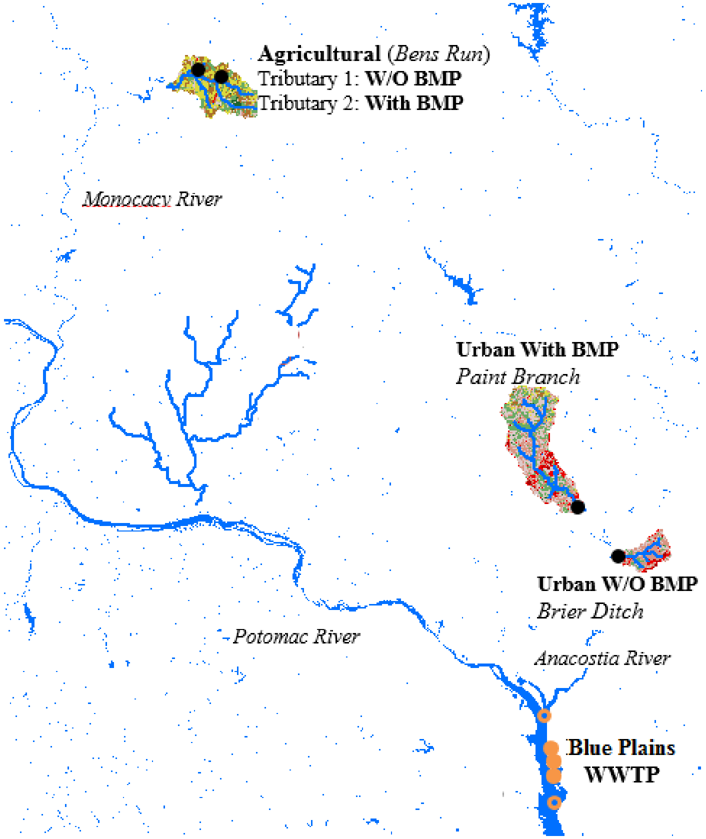
Resulting Project: DC DOE funded / DC Water Managed

Objectives:

Evaluate upstream and downstream impacts from nutrient control, agriculture management, stormwater management and wastewater treatment strategies

Evaluate impacts of EEDC in receiving waters attributed to point versus non-point sources

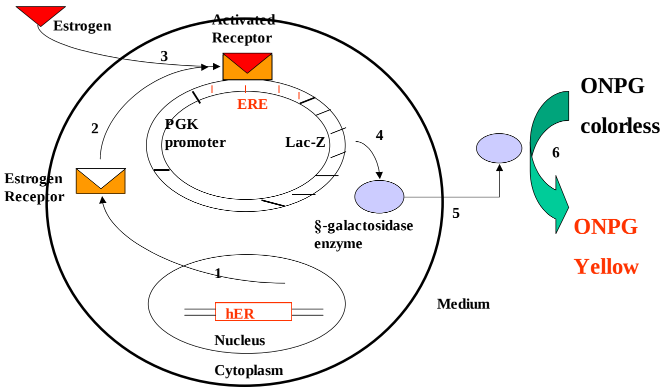
Question: What can you do with $267k?

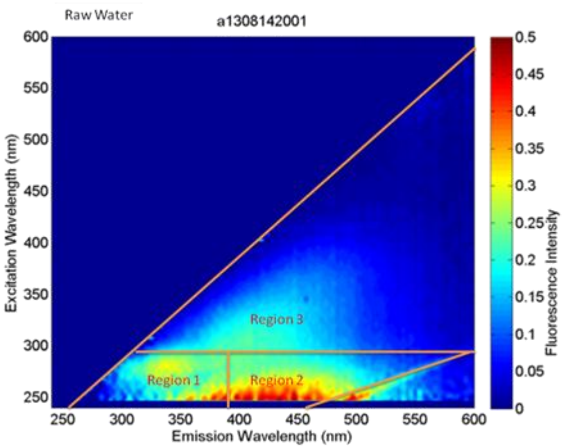


Methods – Chemical and WQ Endpoints

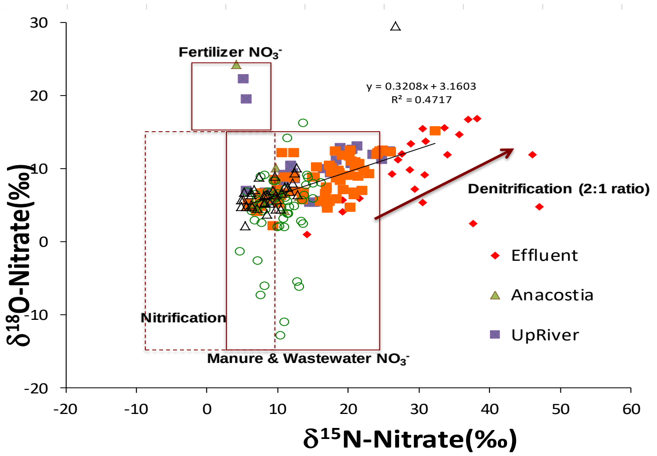
Analytical Detection
- Hormones *and* metabolites

Bioactivity: Yeast Estrogen Assay





Advanced NOM Characterization
- Fluorometry

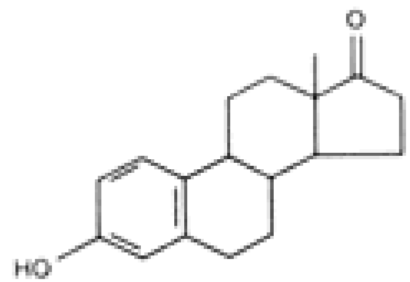


Nitrate Isotopes
- Source Tracking

Focus on Estrogen-based Endocrine-disrupting chemicals (EEDCs):

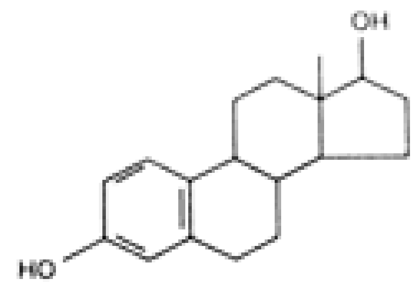
Substances in our environment, food, and consumer products that interfere with hormone biosynthesis, metabolism, or action resulting in a deviation from normal homeostatic control or reproduction.

Xenoestrogen: a type of xenohormone that imitates estrogen; steroidal estrogens



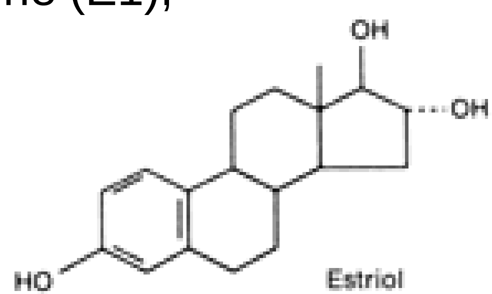
Estrone

estrone (E1),



Estradiol

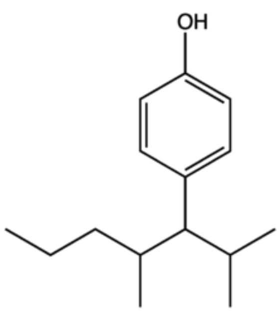
estradiol (E2),



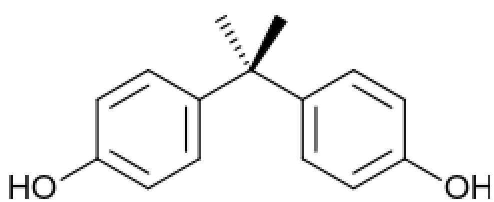
Estriol

estriol (E3)

Alkylphenol:



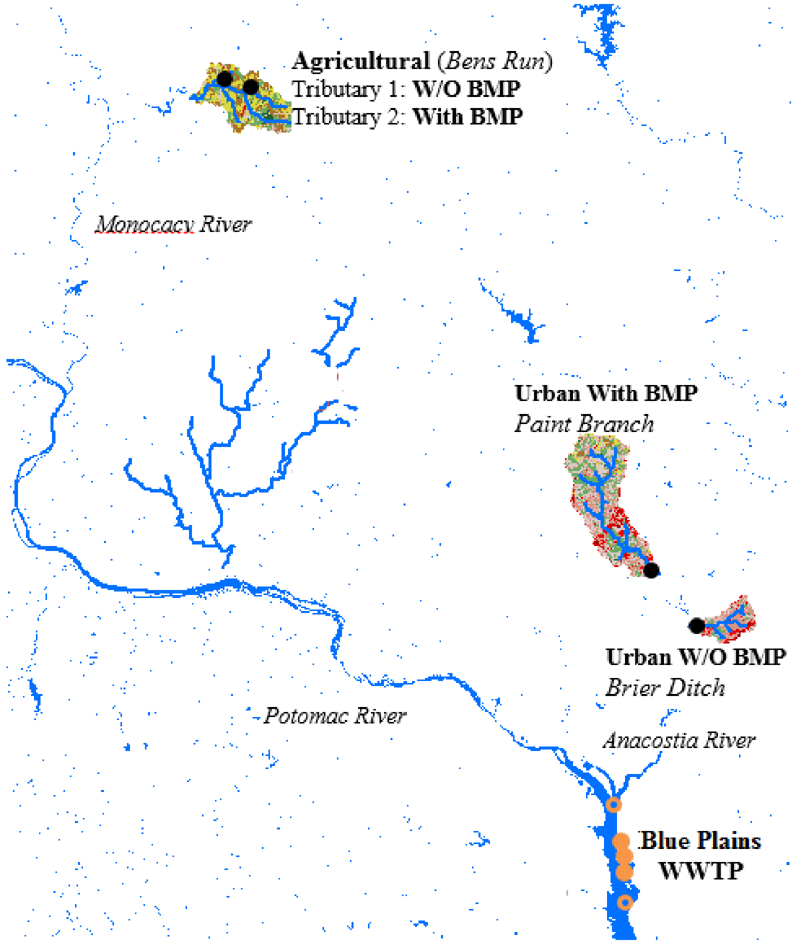
Bisphenol A



Sampling Locations

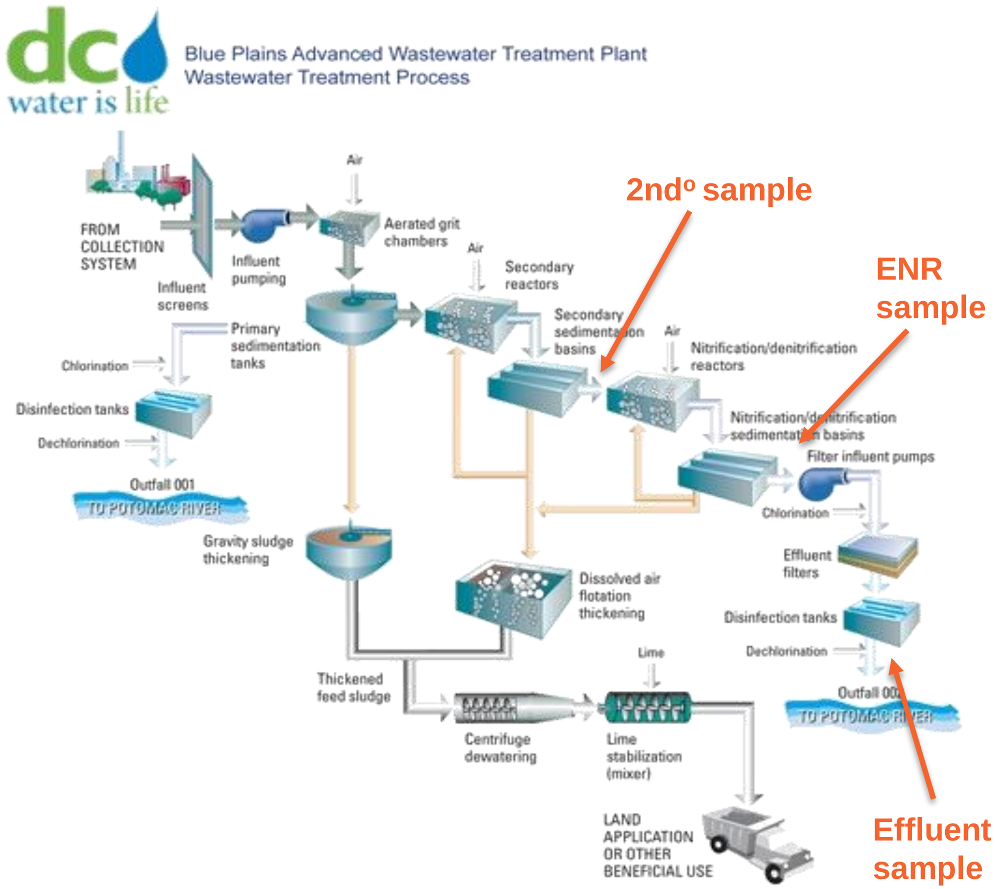
- Locations include:
  - "Paired" Watershed Samples
    - With and Without BMPs
  - Agriculture
  - Urban
  - WWTP (Blue Plains)

- Bimonthly Sampling Frequency for 1 year + 1 rain event

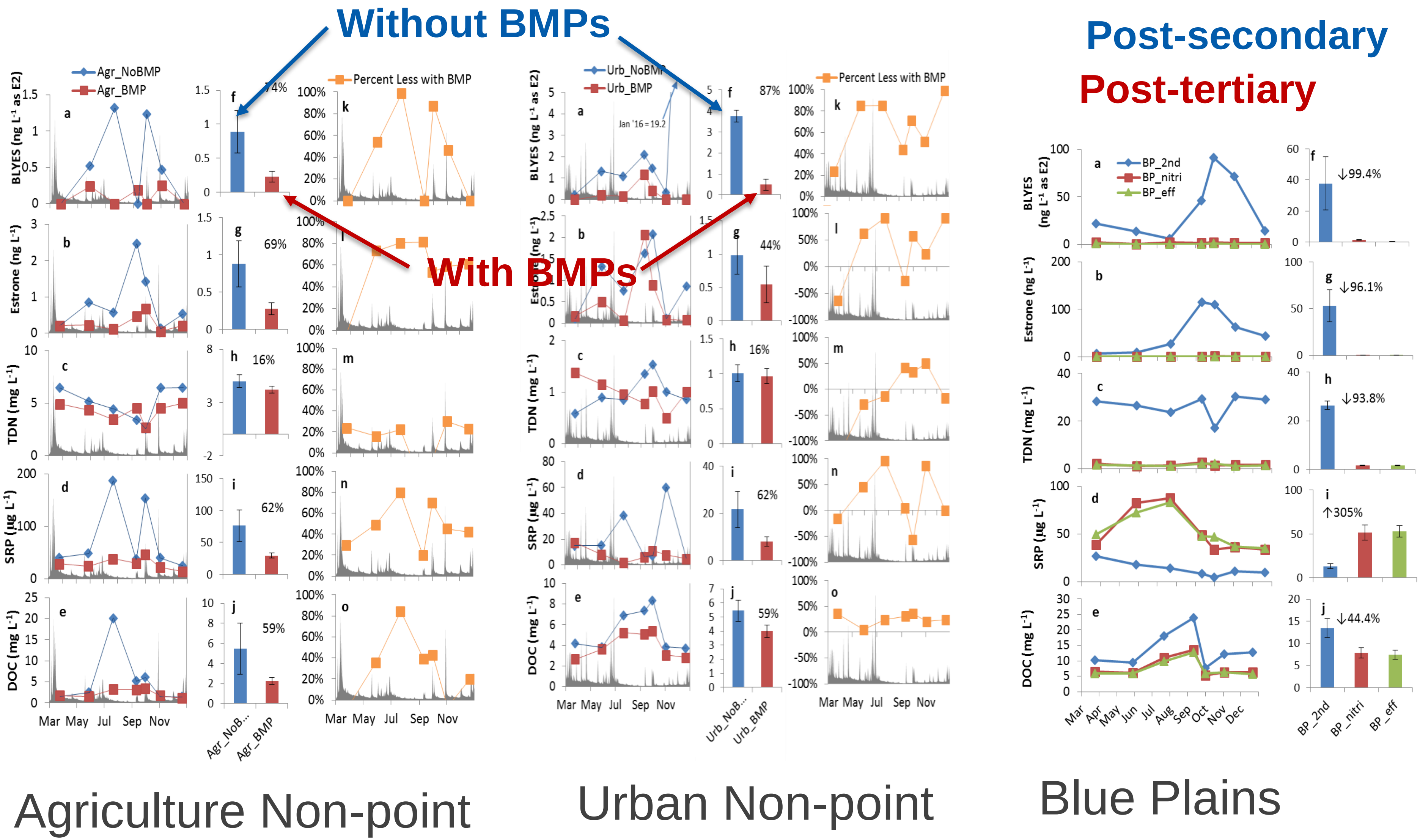


Objective 1: Assess the Performance of BMPs for EEDCs and nutrients

- Compare agriculture and urban stormwater nutrient control strategies via paired watershed analysis
- Assess EDC impacts on receiving water from point-source discharges (Blue Plains)
- Evaluate Blue Plains WWTP advanced nutrient control strategies for removal of EDCs.

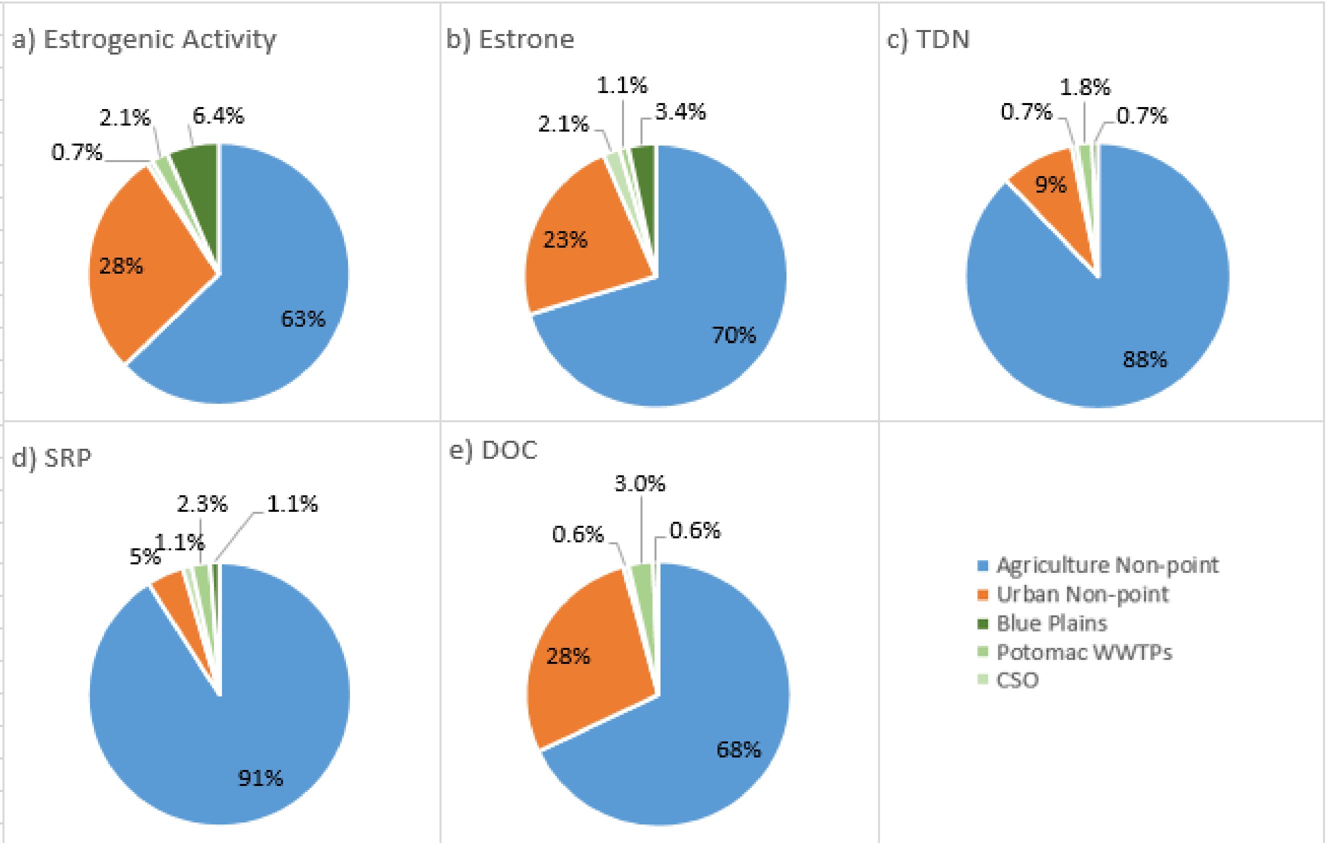


Impact of BMPs on Nutrients and EDCs



Objective 2: Assess the relative contribution of EDCs from WWTPs performing biological nutrient removal

- Load contributions (mass/year) to the Potomac



Comparing Discharges with Background Levels and Other Sources

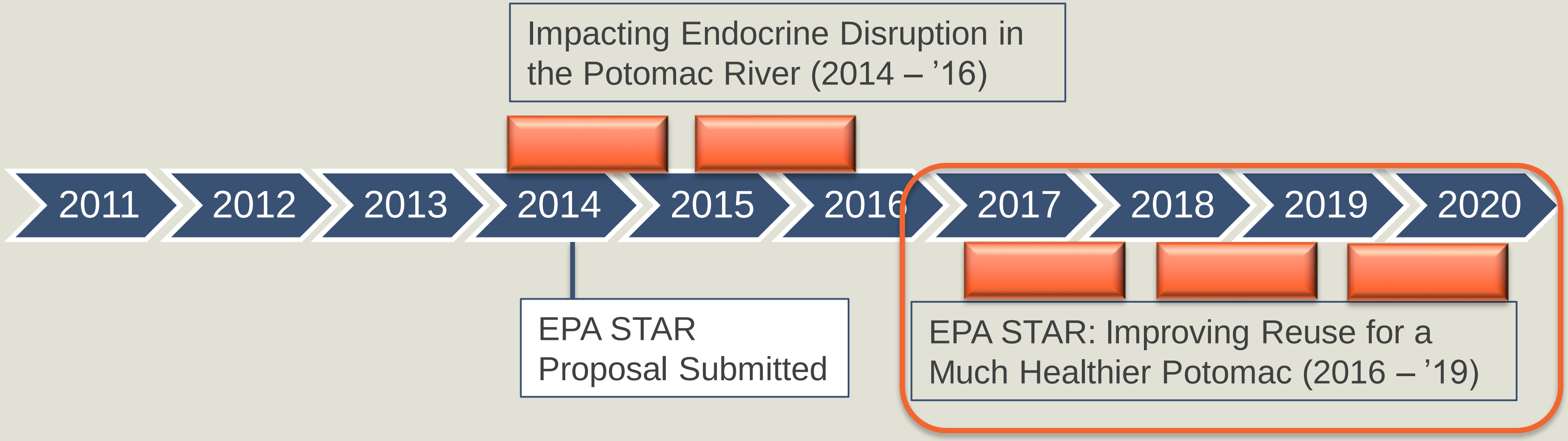
		E1 (ng/L)							
		Background Potomac	Blue Plains	WWTP 2	CSO	Agr. (No BMPs)	Agr. (BMPs)	Urb. (No BMPs)	Urb. (BMPs)
Estrogenic Activity (ng/L as E2)	Background Potomac		0.304	0.387	0.033	0.004	0.177	0.0005	0.181
	Blue Plains	0.246		0.411	0.211	0.055	0.314	0.022	0.231
	WWTP 2	0.430	0.024		0.219	0.067	0.264	0.029	0.266
	CSO	0.121	0.187	0.241		0.401	0.197	0.438	0.219
	Agr. (No BMPs)	0.494	0.087	0.348	0.267		0.042	0.408	0.219
	Agr. (BMPs)	0.191	0.158	0.001	0.169	0.038		0.017	0.183
	Urb. (No BMPs)	0.004	0.107	0.121	0.207	0.128	0.102		0.147
	Urb. (BMPs)	0.495	0.309	0.205	0.208	0.193	0.144	0.112	

Conclusions: Project 1

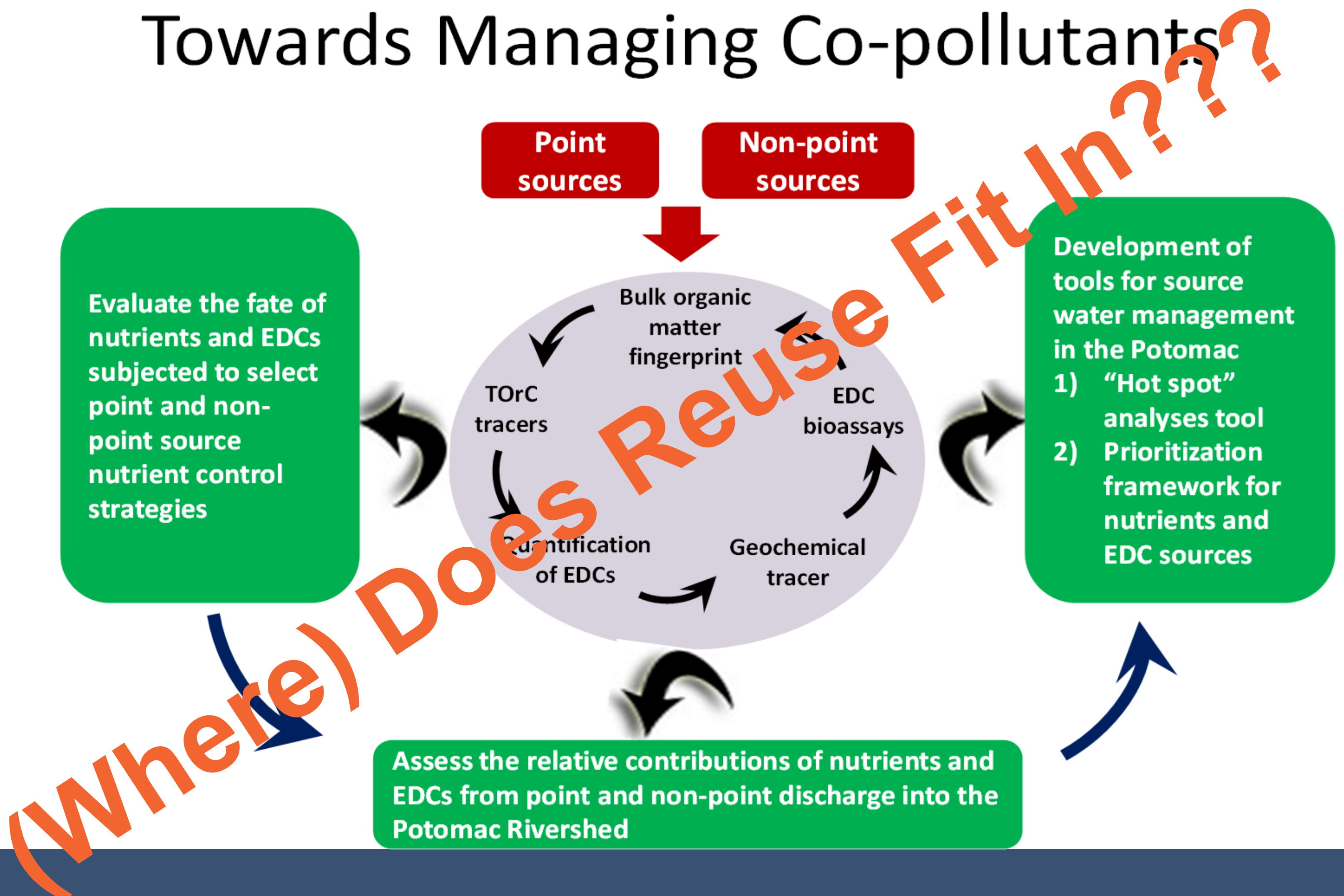
Upstream and Downstream Impacts on EEDCs from “best-in-class” nutrient management strategies

- Annual load analysis indicated non-point sources accounted for over 80% of EDC load to the Potomac
  - Blue Plains contributing less than 3%.
- BMPs showed significant reductions in EEDC inputs to the Potomac Aquifer from agriculture and urban runoff.
  - Agriculture: restricting livestock access to streams, planting grasses for stream shading and improving streambank stability.
  - Urban: maintaining shaded habitat, reducing impervious area, restoring stream habitat and riparian, and creating wetlands.
  - Blue Plains profile sampling revealed large reductions in EEDCs with advanced nitrogen control.

Project 2: EPA STAR-Improving Reuse for a Healthier Potomac



Extending the Approach



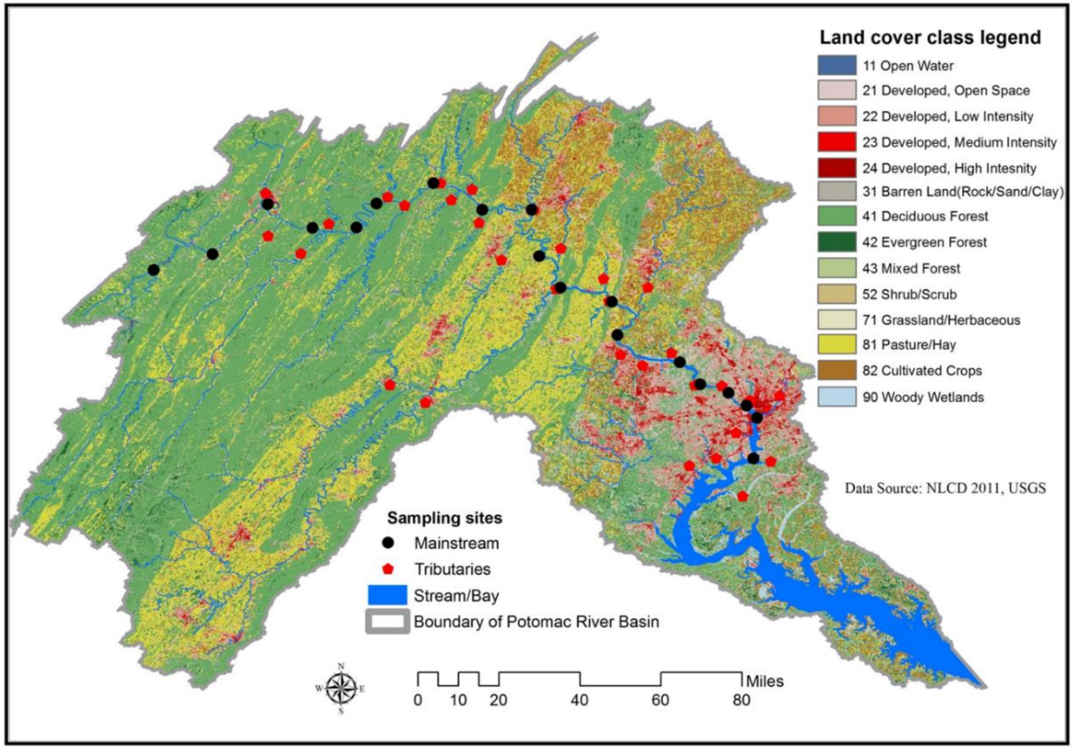
EPA STAR Project Study Objectives

4 year, $1.2M study of EDCs in the Potomac

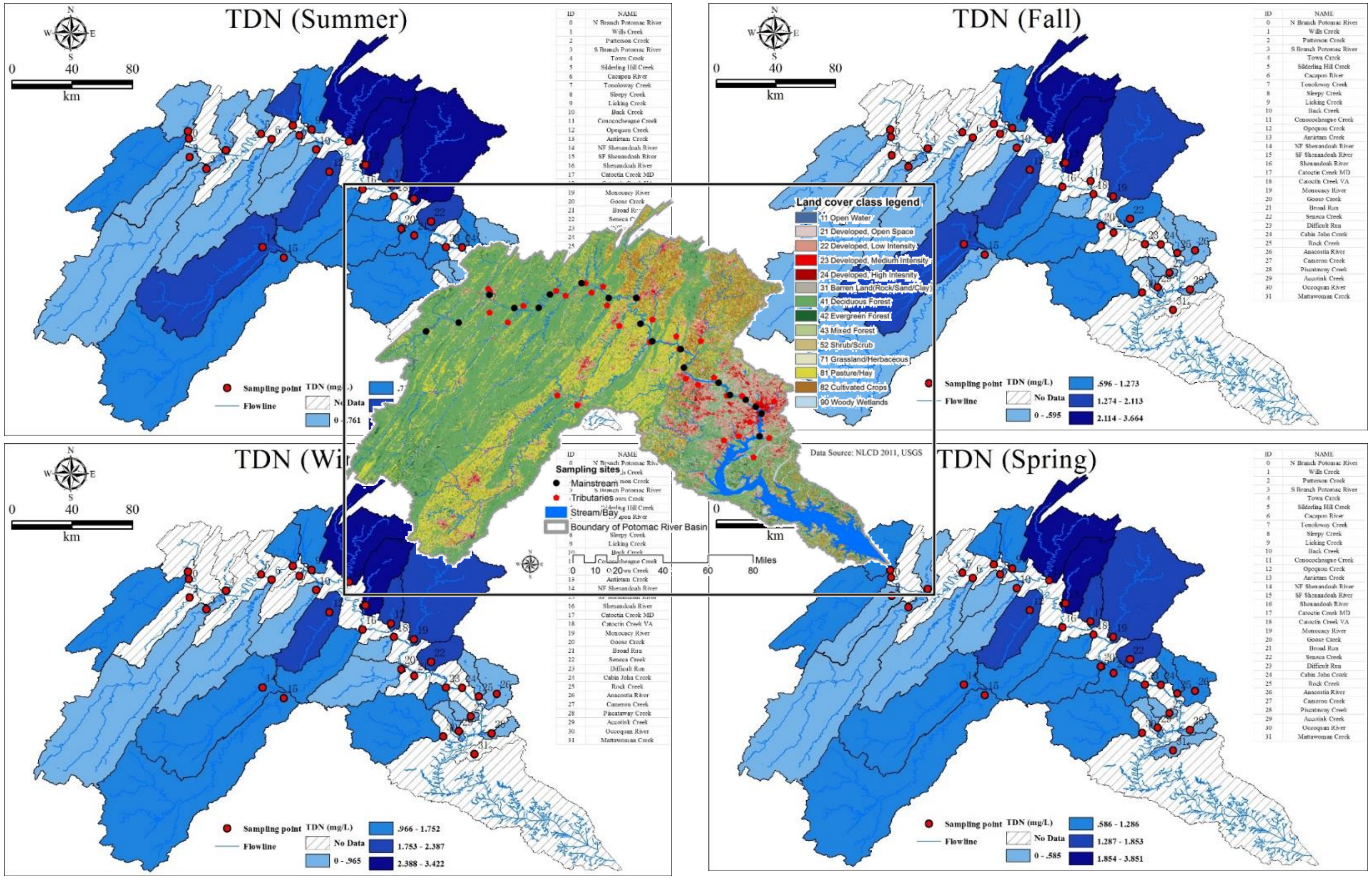
1) *Use multiple analytical, biological activity, isotopic, and fluorescence tracers to identify and track spatial and temporal variability **hot spots of EDC and nutrient sources** at a large watershed scale,*
2) *Use case studies to examine **impacts of** advanced wastewater reclamation, stormwater reuse, and agricultural **best management practices** on source controls of **nutrient and EDCs***
3) *Utilize a sustainable approach to quantitatively analyze the costs, impact, and **benefits of the reuse and management strategies** for achieving human and ecological health improvement.*

Year 1 – "Hot Spot" and Source Contribution Analysis

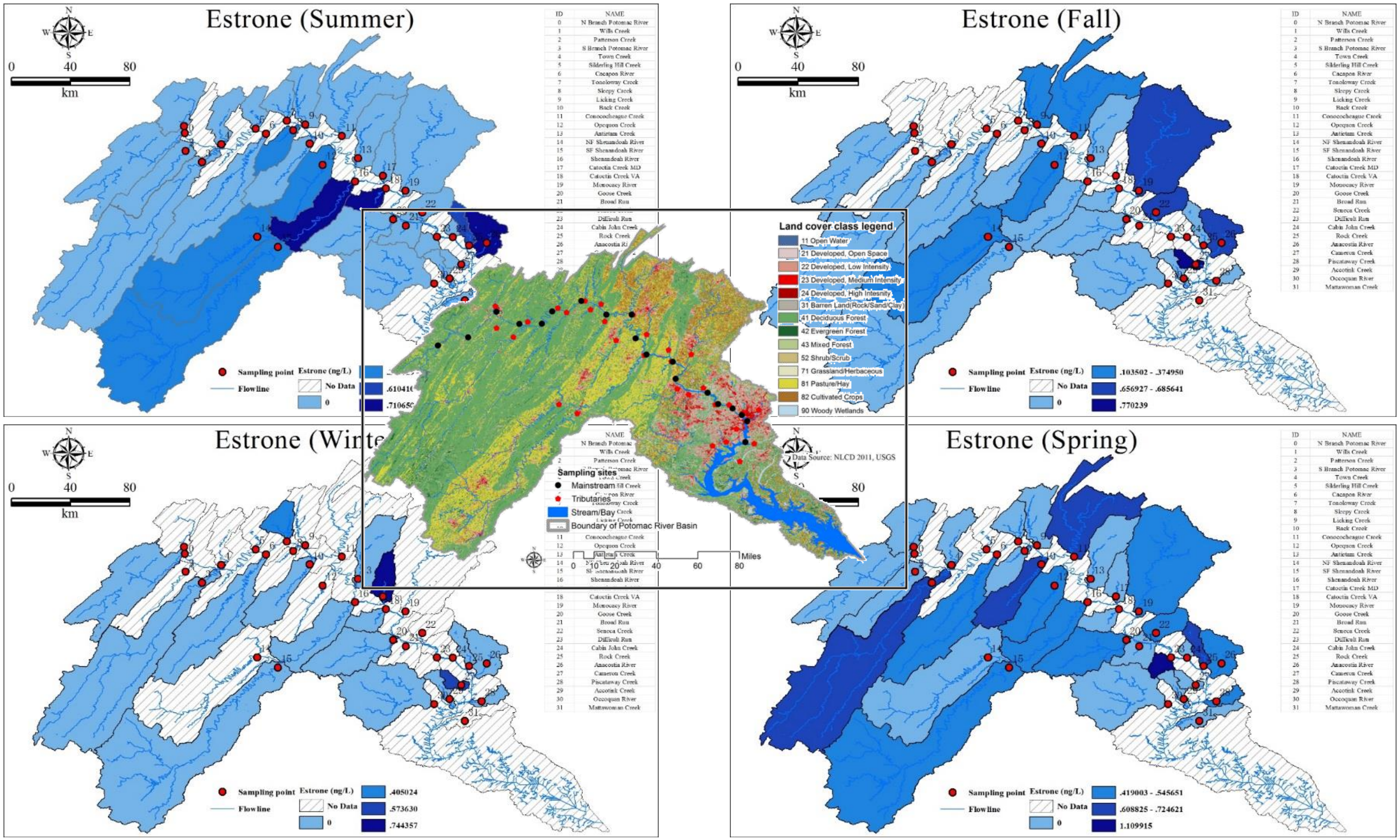
- Identify and track spatial variations in "hot spots" of **EDCs**, biological activity, and **nutrients**
- USGS and Chesapeake Bay Program sites
- Includes sites impacted by treated wastewaters, mineral fertilizers, animal manure, and atmospheric deposition



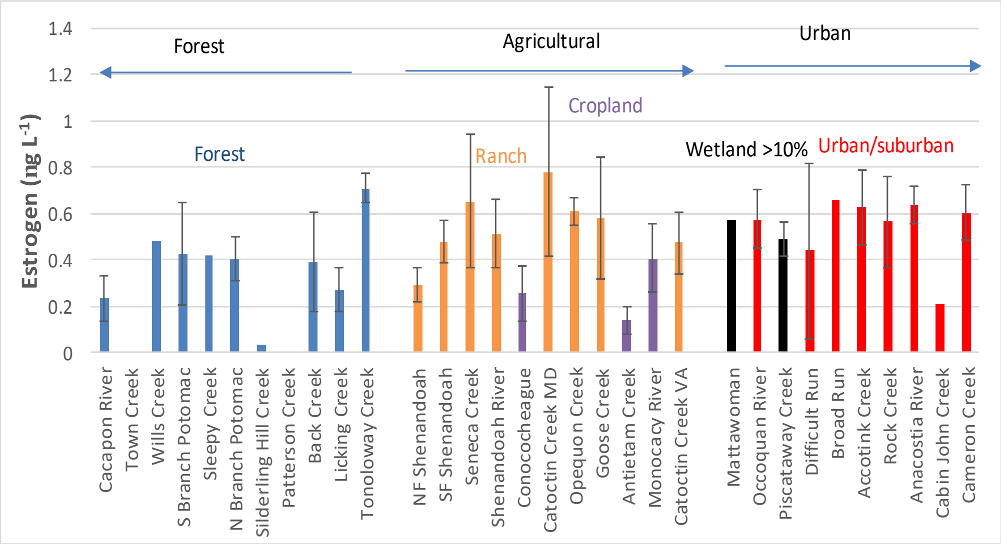
Year 1: Dissolved Nitrogen Hotspots (TDN)

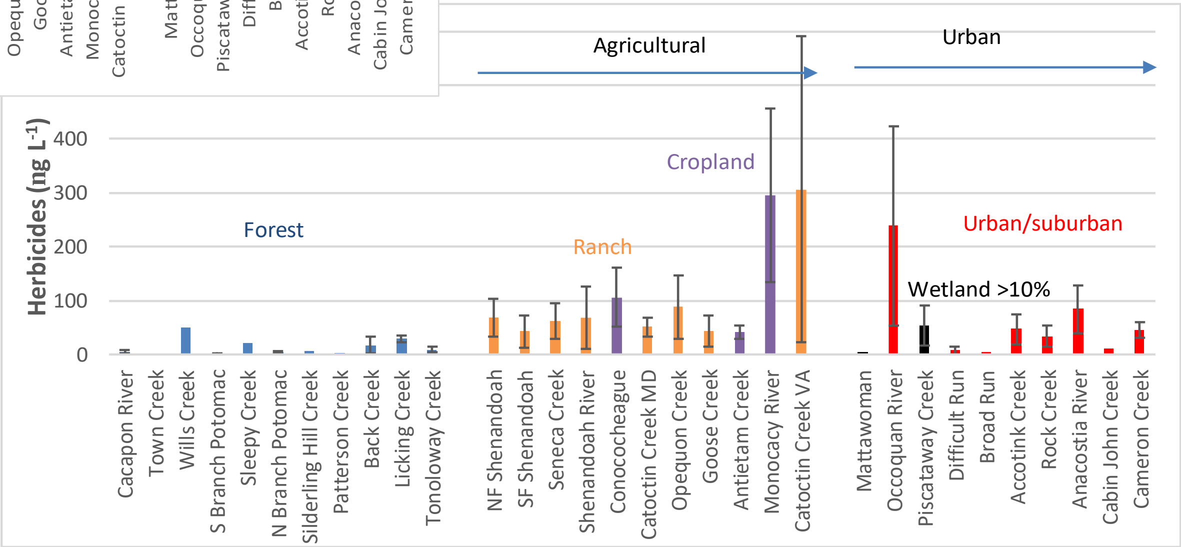


Year 1 – Estrogen Hotspots (mainly Estrone)



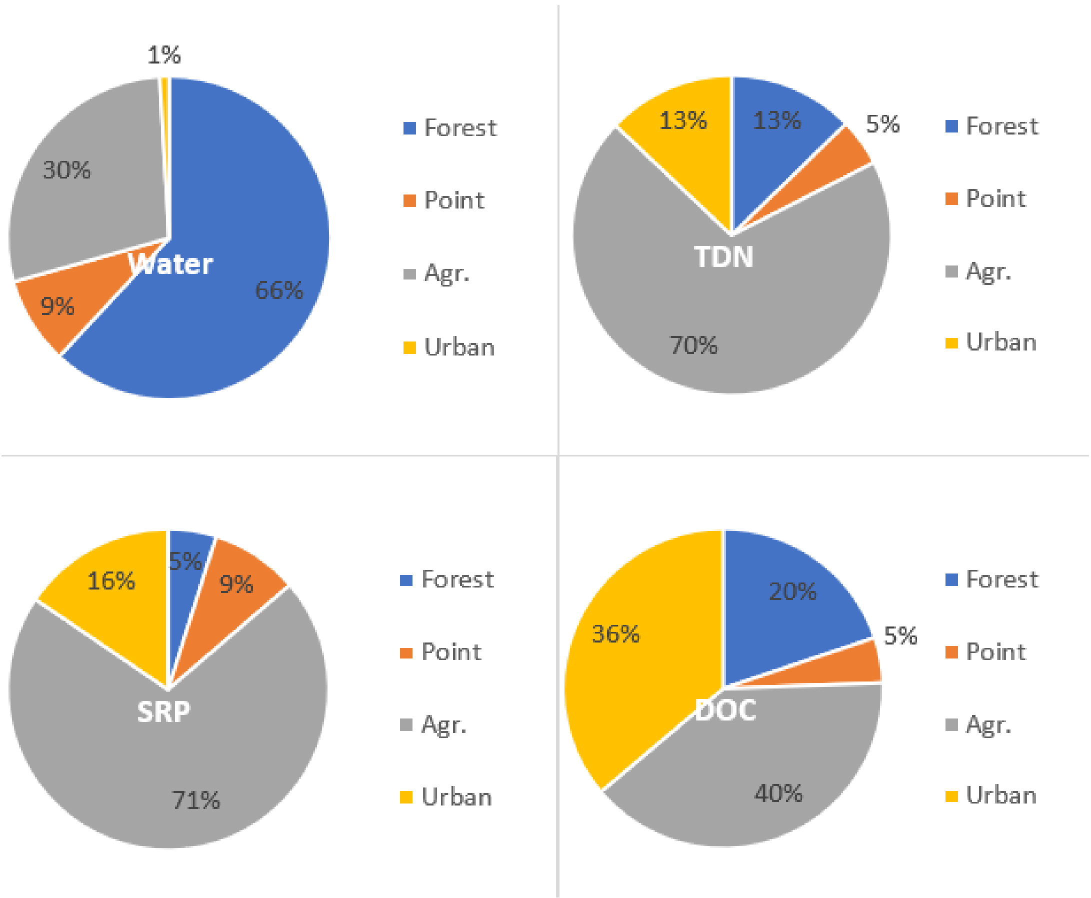
Defining Inputs of CECs According to Land Use





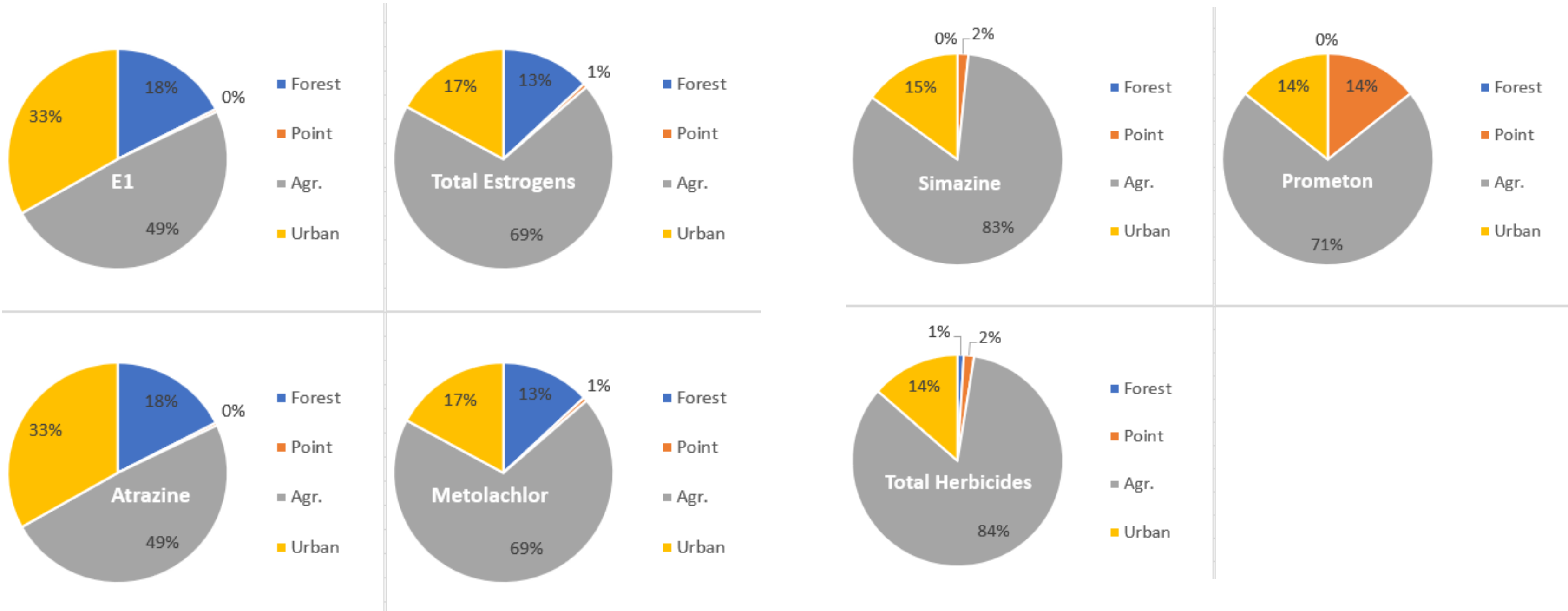
Major Findings from Year 1 Sampling

Conventional Pollutant Loads



Major Findings from Year 1

CEC Loads



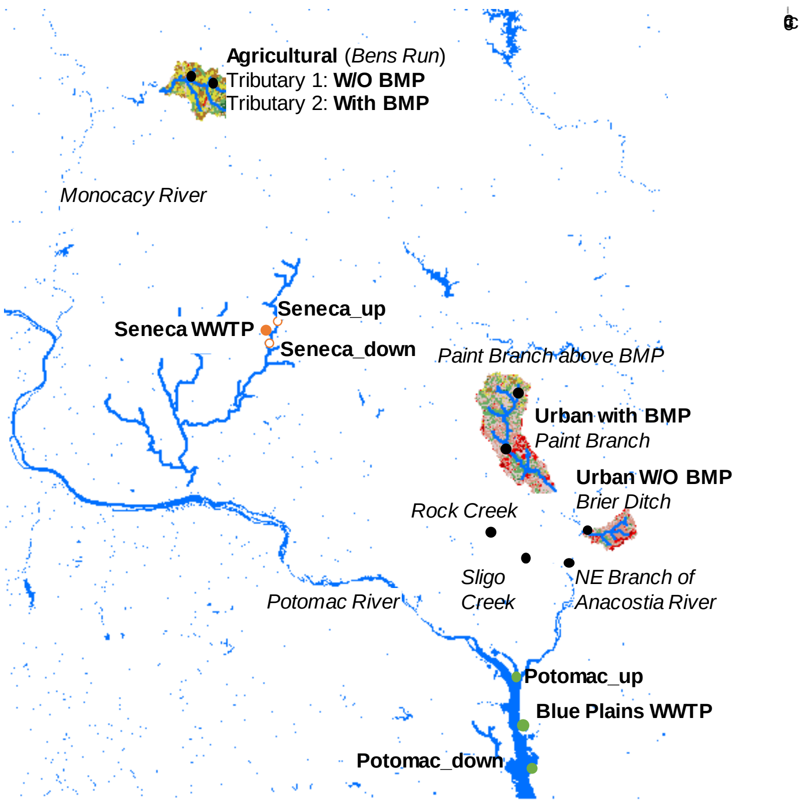
Agriculture Inputs are Big Contributors

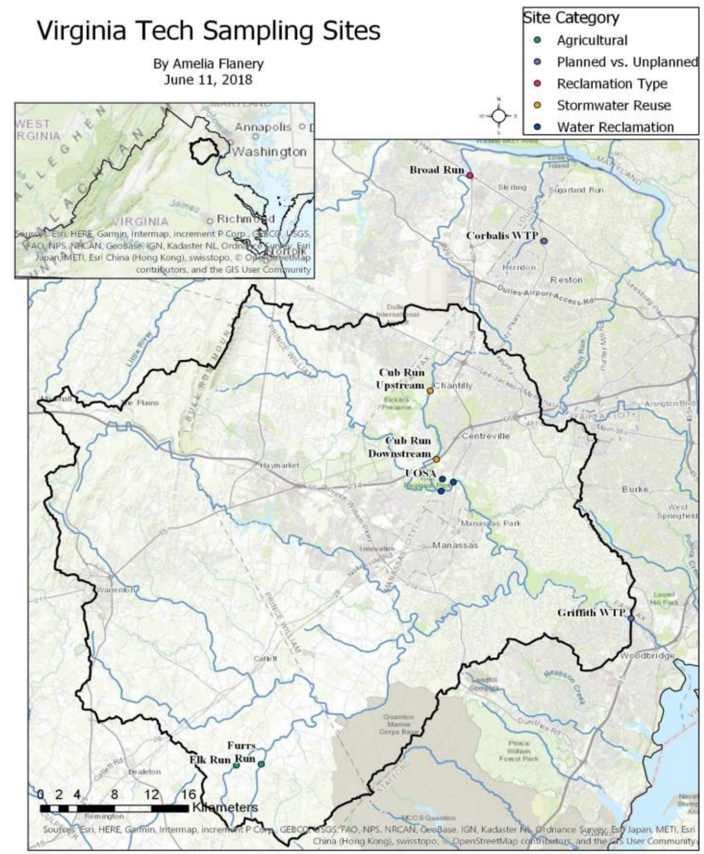
Point Sources are very small Contributors

Work plans for Year 2

- Year 1 – Hot Spot Analysis
  - Identify and track spatial and temporal variations in "hot spots"
- **Year 2a – Impact of current management strategies (University of Maryland)**
  - Use paired watershed studies to evaluate impacts and outcomes of current reclamation, reuse, harvesting, and management strategies on source controls of pollutants.
- **Year 2b – Impact of planned potable reuse (Virginia Tech)**
  - Focused study on the comparative impact of planned potable reuse.
- Year 3 – Cost-benefit analysis of EDC/Nutrient Co-management strategies
  - Will the control framework change with inclusion of EDCs?

Year 2 Sampling Plan: Paired Watershed





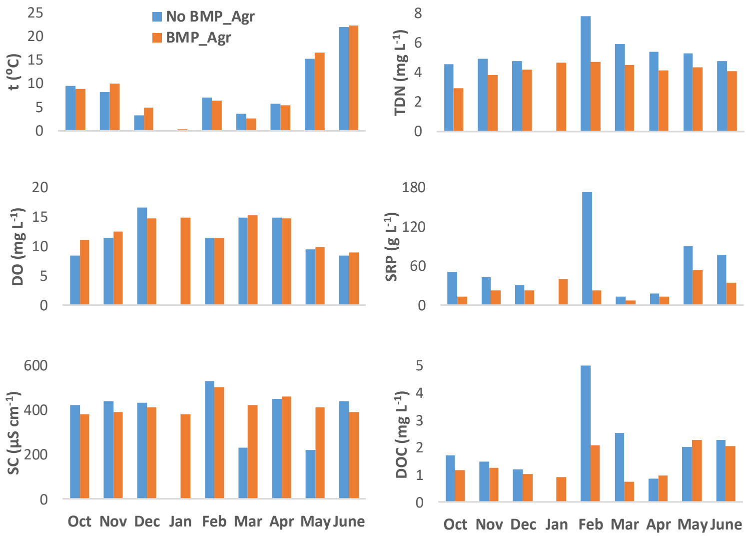
Agricultural runoff **Urban runoff** **Point Sources:**

Enhanced Nutrient Control

Advanced Water Treatmetn

Agriculture BMPs

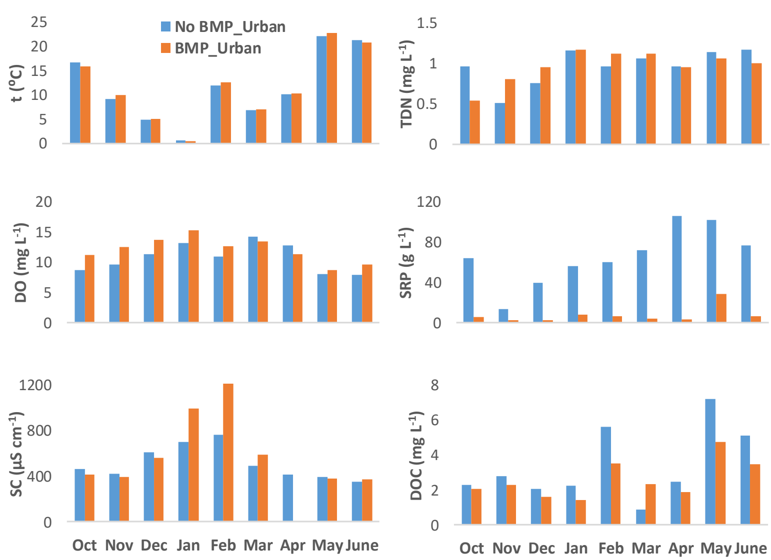
Fencing, Stream Restoration, Cover Crops



CEC Load	No BMP	BMP	Reduction (%)
E1 (g/km²/yr)	0.144	0.001	99
E1-S (g/km²/yr)	1.68	0.004	100
4-Nonylphenol (g/km²/yr)	22.30	2.85	87
Atrazine (g/km²/yr)	6.26	1.93	69
Metolachlor(g/km²/yr)	1.01	0.86	15
Prometon (g/km²/yr)	0.007	0.021	-213
Simazine (g/km²/yr)	0.078	0.076	2
Imidacloprid (g/km²/yr)	0.011	0.0002	98
Fipronil (g/km²/yr)	0.008	0.005	30
Dinotefuran (g/km²/yr)	BDL	BDL	
Acetamiprid (g/km²/yr)	0.023	0.021	9
Clothianidin (g/km²/yr)	0.374	0.656	-75

Urban Stormwater BMPs

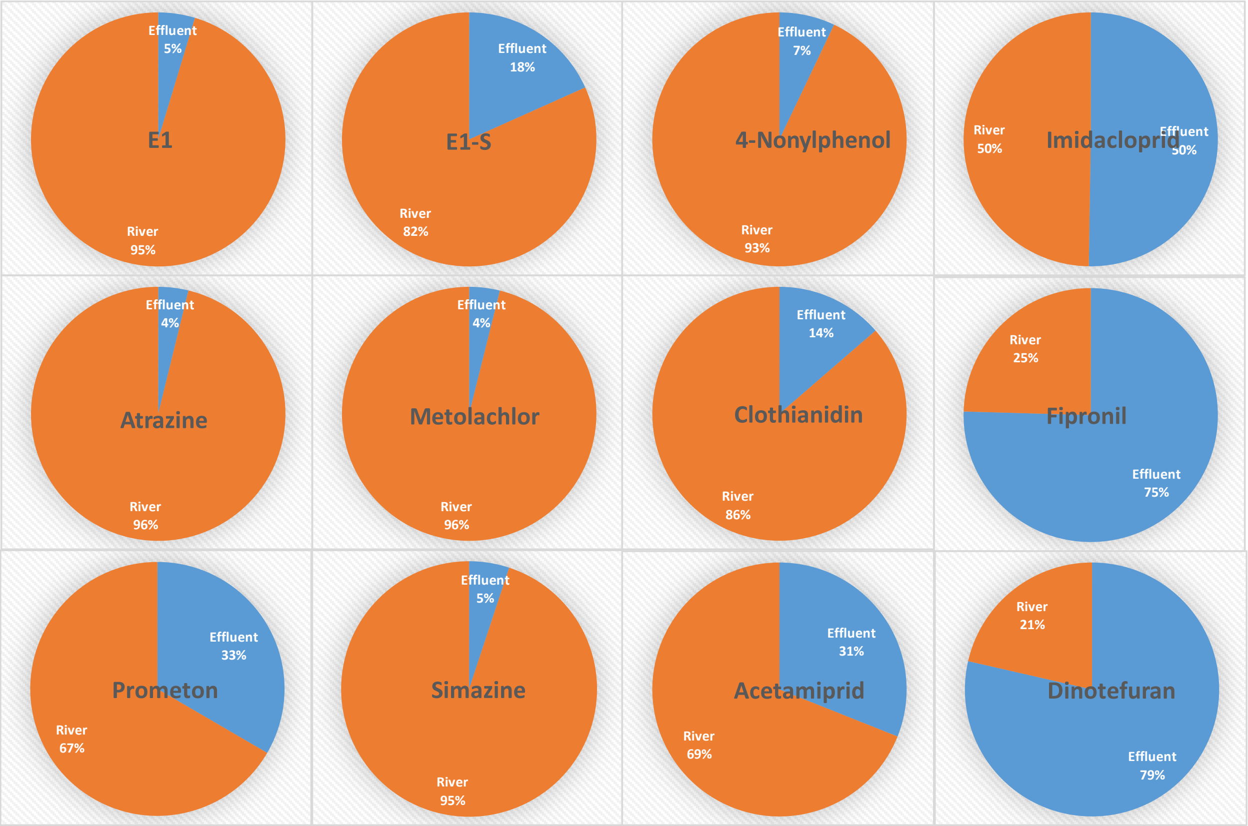
Permeable hardscape, Urban stream restoration



CEC Load	No BMP	BMP	Reduction (%)
E1 (g/km²/yr)	0.0011	0.0007	34
E1-S (g/km²/yr)	0.0020	0.0017	17
4-Nonylphenol (g/km²/yr)	4.996	1.114	78
Atrazine (g/km²/yr)	0.76	0.04	94
Metolachlor(g/km²/yr)	0.82	0.22	73
Prometon (g/km²/yr)	0.051	0.214	-318
Simazine (g/km²/yr)	0.133	0.015	88
Imidacloprid (g/km²/yr)	0.217	0.129	41
Fipronil (g/km²/yr)	0.043	0.026	39
Dinotefuran (g/km²/yr)	0.014	0.019	-35
Acetamiprid (g/km²/yr)	0.019	0.013	33
Clothianidin (g/km²/yr)	0.023	0.018	24

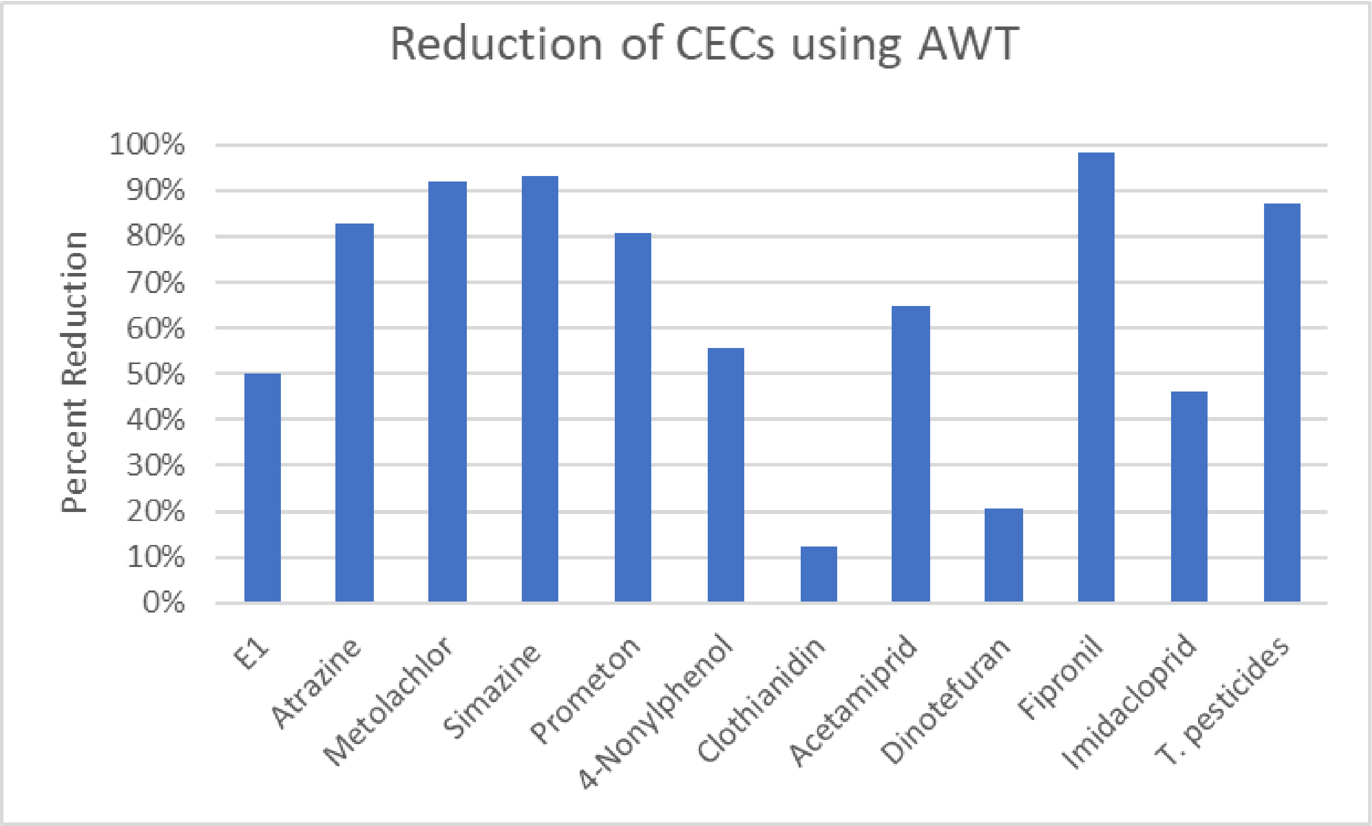
Point Source Impacts – Impact of WRFs

Enhanced Nutrient Control Technology

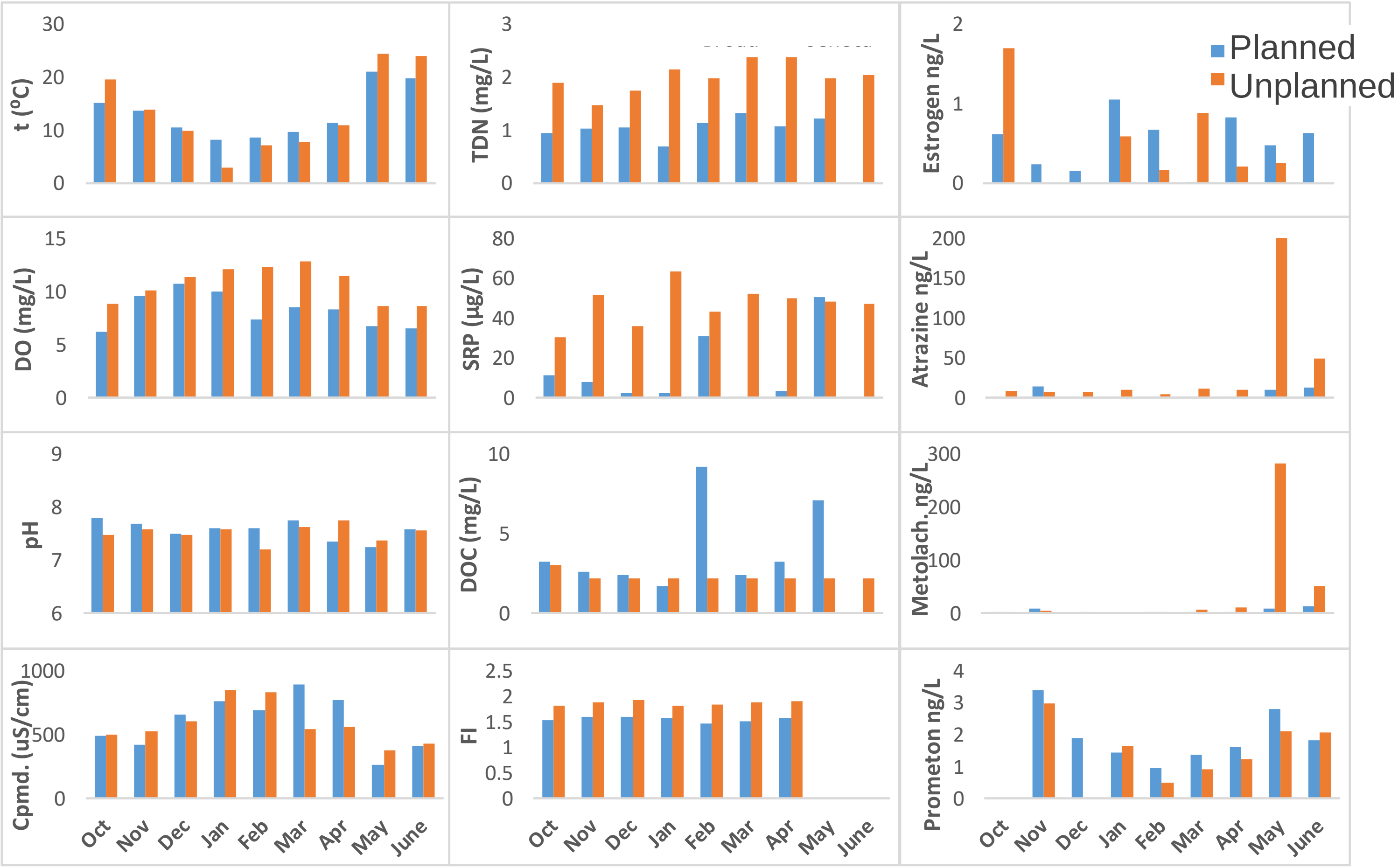


Point Source Impacts – Improvement with AWT

Planned Potable Reuse

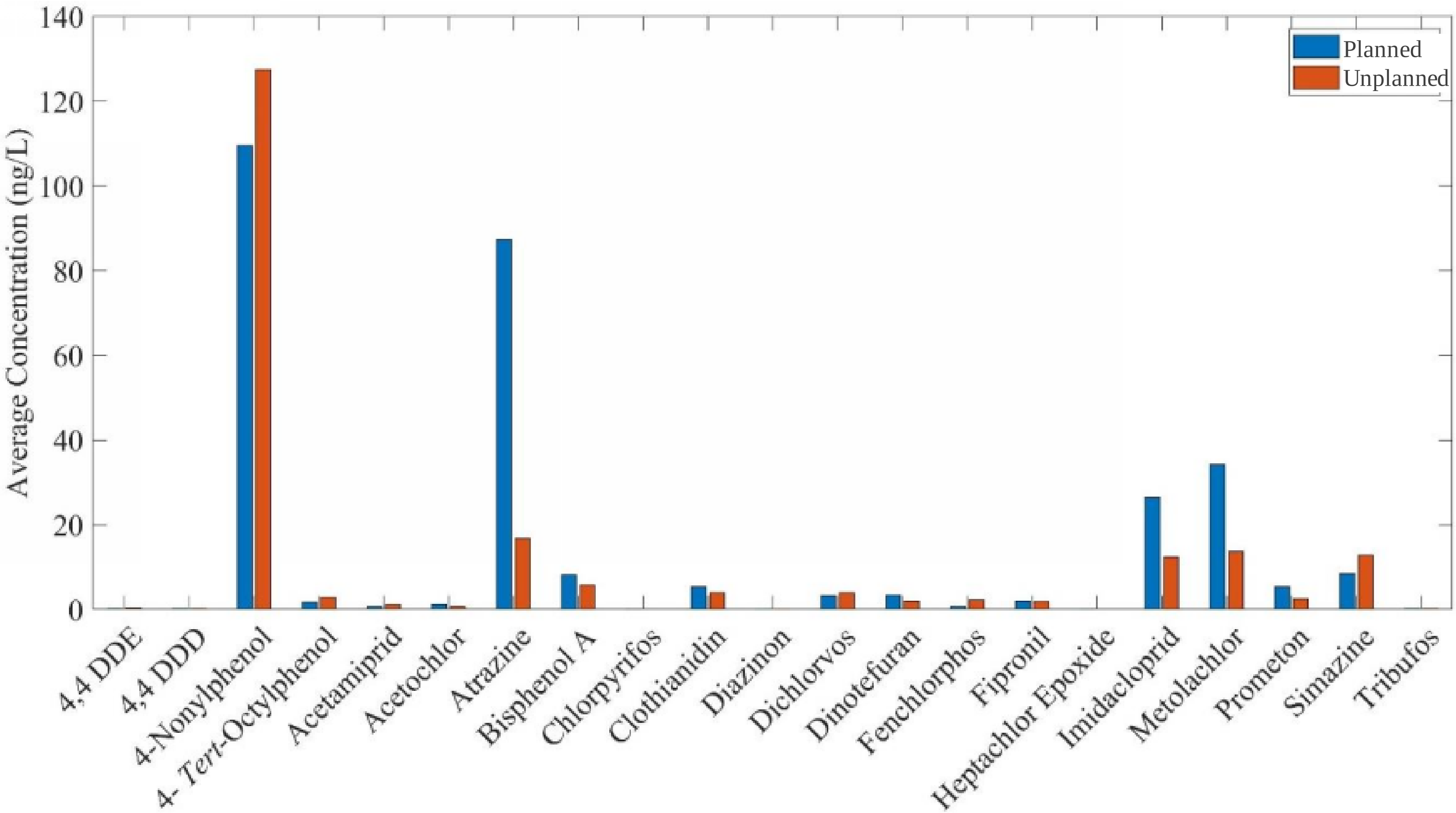


Impact of planned IPR

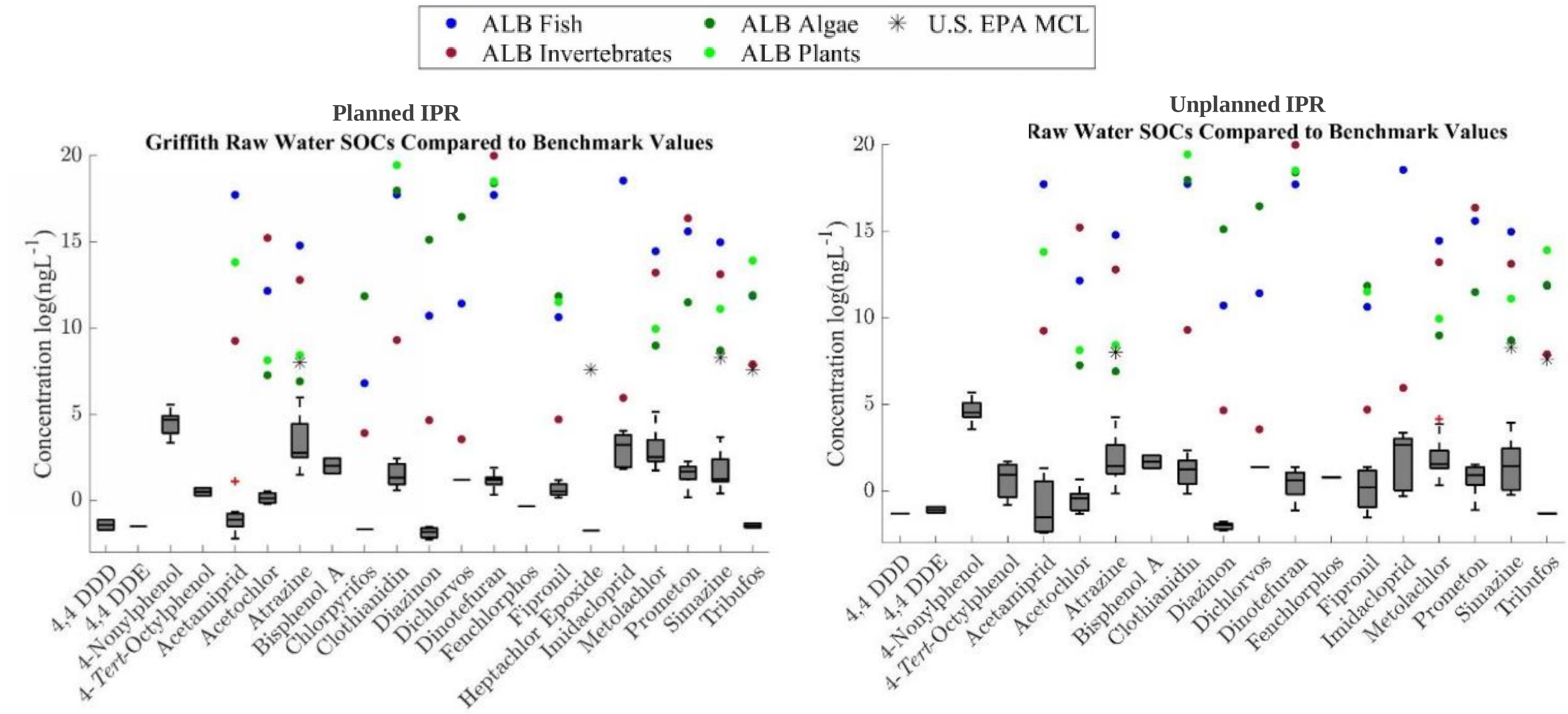


The stream representing with "planned" potable use had lower concentrations of SRP, DOC, atrazine and metolachlor than the stream representing "unplanned" potable use.

Planned vs. Unplanned IPR – CECs at the Water Plant Intake



Some More context on CECs…

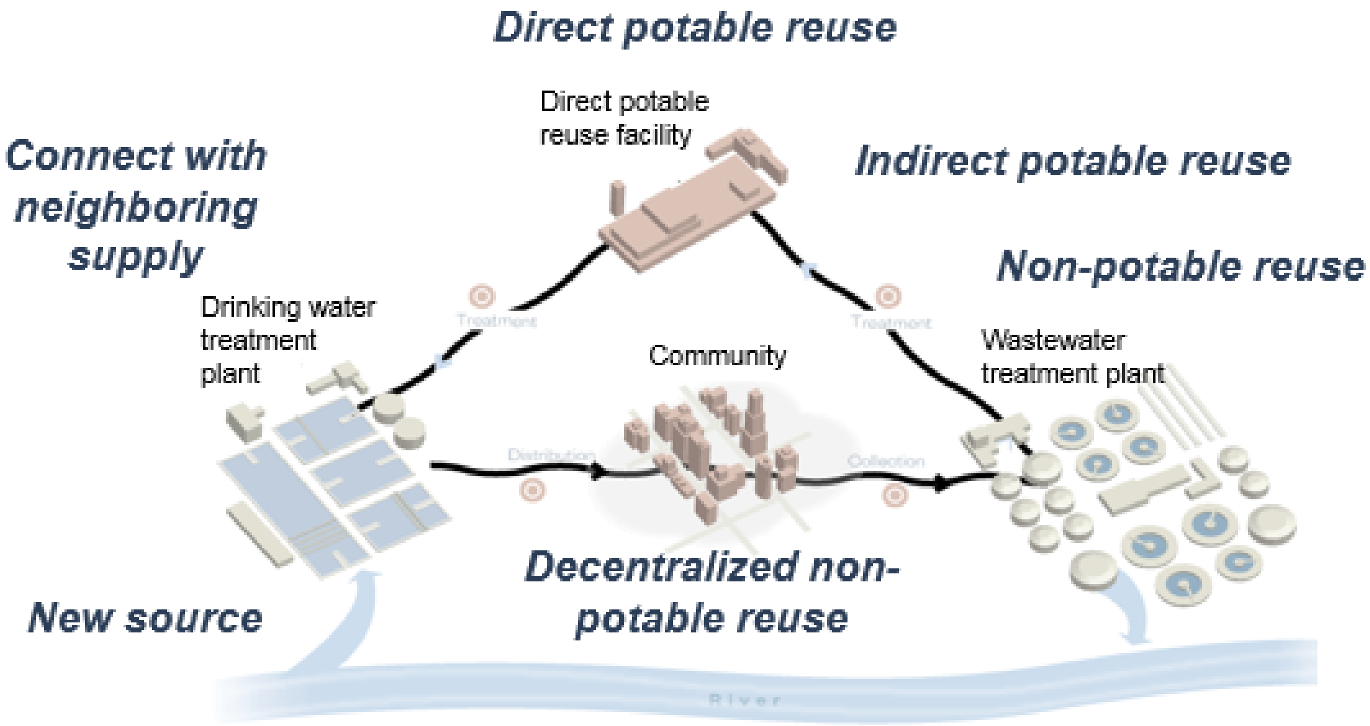


Every Detected CEC below Ecological or Human Health Levels of Concern

Year 3: CBA for co-managing EDCs and Nutrients

Multi-Criteria Decision Analysis Framework, based on TBL

- Leveraging: "A Framework and Tool for Triple Bottom Line Water Supply Planning" (WRF Reuse 14-03)



Comparing Alternatives with the "Right" Criteria

HazenConverge Facilitates Multi-Criteria Decision Analysis (MCDA)

Define Objectives for Evaluation

Co-management of Nutrients and CECs

Define Considered Alternatives

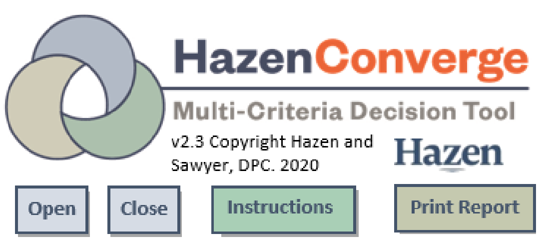
- Agriculture BMPs
- Urban BMPs
- Point Source – Enhanced Nutrient Control
- Point Source – Advanced Water Treatment

Develop Criteria

- Stakeholder Workshop 1
- Regional and National Experts
- Identify Criteria for evaluation
- Pairwise Analysis to weight criteria

Develop Scores and compare Alternatives

- Quantitative scoring
- Qualitative scoring



Workshop Attendees

water is life
Fairfax Water
LOUDOUN WATER
Hazen
GHD
UNIVERSITY OF MARYLAND 18 56

Criteria Development Approach

Several approaches to Criteria Development

"Biased" Representation

Criterion	Group 1 - Institutional and policy	Group 2 - Academic research and consulting	Group 3 - Utility and Watershed Management
1	Degree of effectiveness	Performance	Cost
2	Consequences of implementation	Cost	Ease of implementation
3	Co-benefits	Cost/reduction metric	Does a regulatory framework exist
4	Impacts on waste balance	Distribution of improvements	Cost equity
5	Air emissions	Aesthetics	Social justice
6	Consumption of energy	Recreation	Economic impact
7	Incidental waste streams	Local economic stimulus	'Bang for your buck'
8	Political palatability	Ease of implementation	Net benefits
9	Ease of implementation	Ease of maintenance	Implementable
10	Regulatory/voluntary palatability	Resilience to climate change	Spatial footprint
11	Number of impacted stakeholders		Carbon footprint
12	Degree of uncertainty in info		Energy needs, demand
13			Bio-habitat
14			Environmental benefits
15			Effectiveness certainty
16			Operability
17			Incentives
18			Mandates

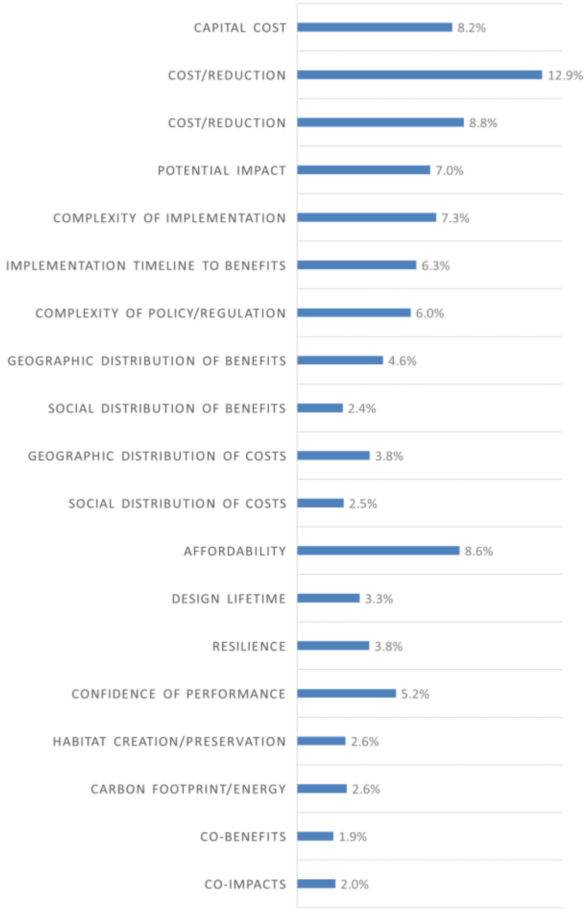
"Balanced" Representation

Criterion	Group 1	Group 2	Group 3
1	Cost effectiveness (life cycle)	Cost/reduction (lifecycle unit)	Cost $
2	Policy/regulatory drivers	Effectiveness	Cost effectiveness ($/unit of removal or performance)
3	Ease of implementation	Cost distribution (regionally/socially)	Performance (#, acres, mg/L)
4	Resilience (climate change)	Benefit distribution (regionally/socially)	Implementable (H-M-L)
5	Equity	Certainty	Geographic distribution (H-M-L)
6	Economic impact	External impacts (resilience?)	Social impact distribution (justice) (H-M-L)
7		Carbon footprint	Co-benefits (composite effectiveness?)
8		Energy	Lifecycle – of solution (time), maintenance ($), replacement (time/$)
9		Future sustainability	Uncertainty of solution/performance (probability/error bar, box whisker, end members)
10		Habitat	Equity-fairness
11		Water quality	
12		Green alternative	
13		Ease of implementation	
14		Implementation timeline	
15		Would require enforcement	

Criteria Development Approach

Grouped and Filtered and ran "pairwise analysis" to determine final criteria

List of Ranked Criteria



Final Evaluation Criteria

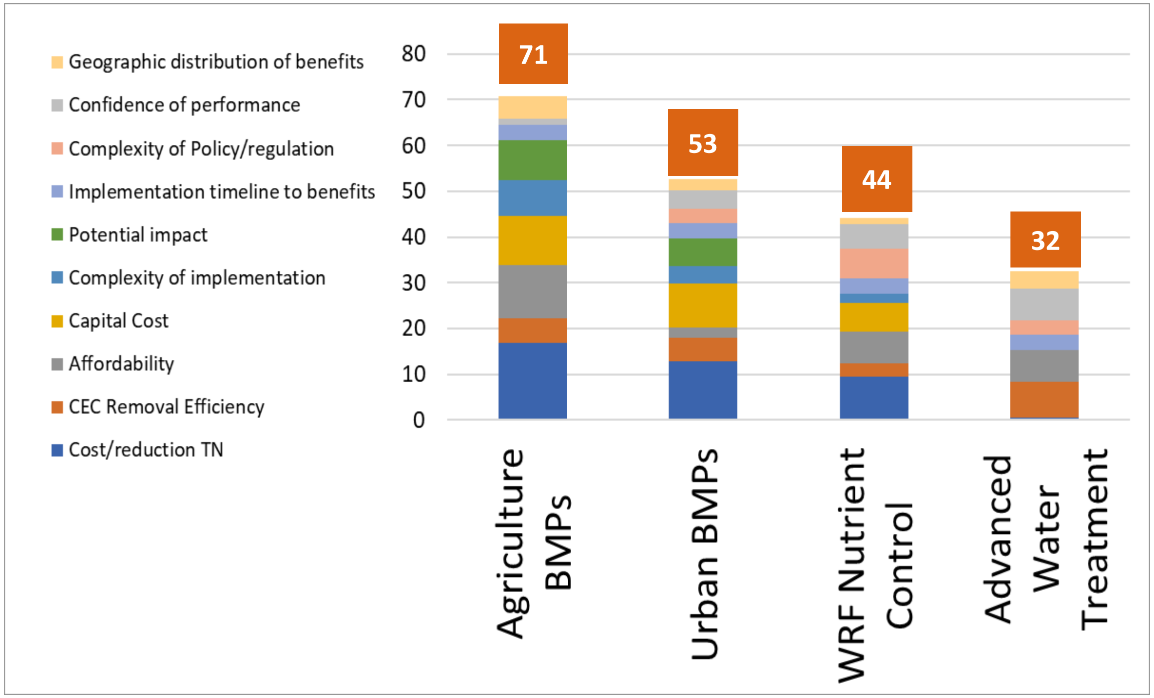
	Criteria	Category	% Weighting
1	Cost/reduction TN	Cost	12.9%
2	CEC Reduction Efficiency	Performance	8.8%
3	Affordability	Equity	8.6%
4	Capital Cost	Cost	8.2%
5	Complexity of Implementation	Implementability	7.3%
6	Potential Impact	Performance	7.0%
7	Implementation Timeline to Benefits	Implementability	6.3%
8	Complexity of Policy/Regulation	Implementability	6.0%
9	Confidence of Performance	Risk	5.2%
10	Geographic Distribution of Benefits	Equity	4.6%

These 10 criteria account for 75% of the total weighting

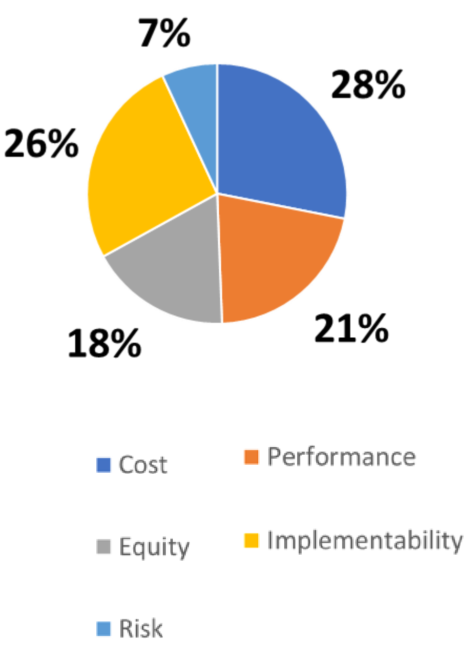
And the winner is…

Scores were developed for each criteria, and weighted accordingly

Weighted Scores



A balanced evaluation



Implementing Agriculture BMPs are clearly the preferred option

Project 2 Summary

A truly comprehensive evaluation of sources and co-management opportunities for nutrients and CECs in the Potomac River Watershed

Agriculture Inputs of Nutrients and CECs dominated the watershed inputs

“Paired” Watershed analysis of BMP effectiveness indicated the following:

- Agriculture BMPs variable but effective for nutrient control and moderately effective for CEC control
- Urban BMPs variable and less effective for nutrient control and moderately effective for CEC control
- Point sources both very effective for nutrient control; ENR less effective for CEC control, AWT very effective for CEC control

MCDA indicated that Implementing Agricultural BMPs was the preferred option for cost-effective, equitable, high performing co-management of nutrients and CECs in the Potomac Watershed

Some More Interesting Results Stemming from the Research

Expanding the Analytical Techniques

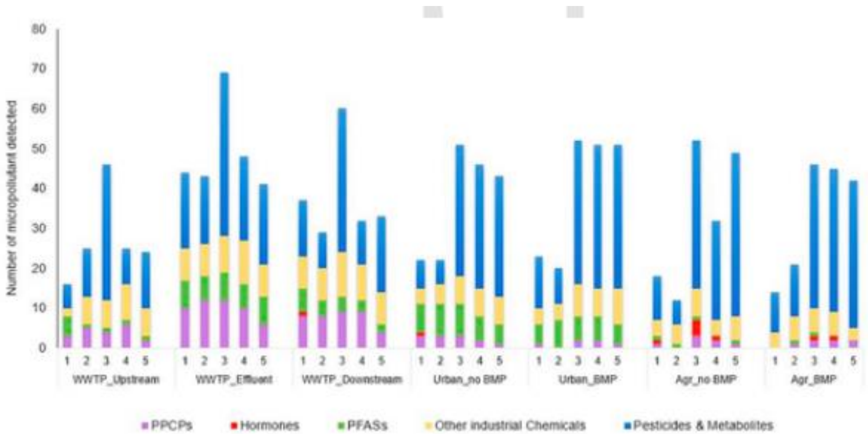


Fig. 4. Summary of the number and class of micropollutants detected at each sampling site from Oct 2017–June 2018 (1 —Oct 2017; 2 —Dec 2017; 3 —Feb 2018; 4 —Apr 2018; 5 —Jun 2018).

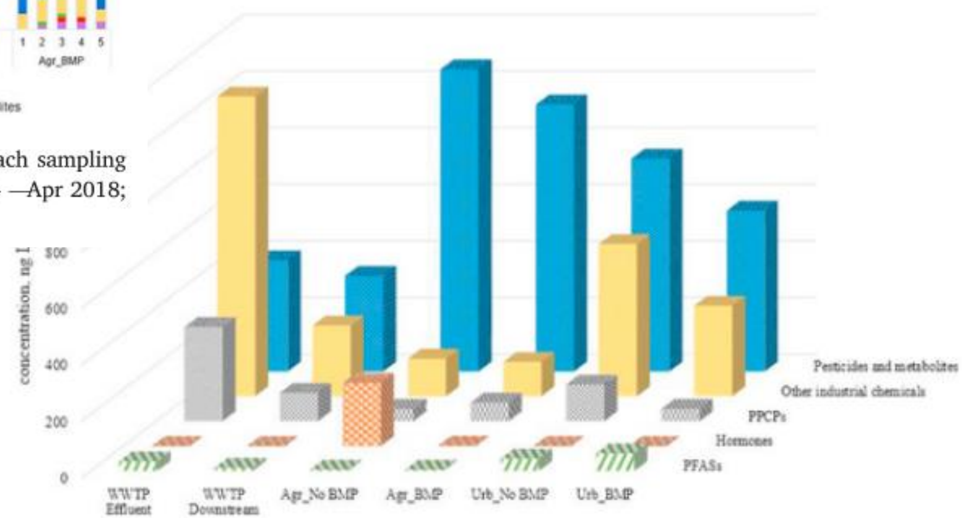


Fig. 5. Summary of the total concentration for each micropollutant class in the paired streams/sampling site studied (WWTP effluent vs. downstream; Agr without BMP vs. with BMPs installed; Urban without BMP vs. with BMPs installed). The total concentration for

Questions?

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Hazen