ARCADIS Design & Consultancy for natural and built assets

STORMWATER NUTRIENT REDUCTION

Using Riparian Buffers and Upland Urban Forest Systems

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Introductions

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Overview

- **Forest System Function**
- **Urban Forest Systems**
  - Nutrient Load Reduction Research
  - Benefits/Costs
- **Riparian Buffers**
  - Architecture
  - Nutrient Load Reduction Research
- **Case Studies**

Stream Nutrient Research: Forest vs Urban

For every 10% increase in forest cover water treatment costs decreased by approximately 20%

- Ernst et al. 2004

Increased forest cover = decreased N and P concentration

- Schoonover et al., 2005, 2006 (NO_3^-)
- Deemer et al., 2012 (DIN)

Source: Google Earth, 2015

Increased urban area = increased nutrient concentrations

Urban Forest Systems Help Control Volume

Source: foresternetwork.com, 2016

- Rainfall retention
- Temporary detention
- Intensity reduction
- Increased infiltration
- Research review articles
- Teague and Kuehler 2016
  - Stormwater
- Kuehler et al. 2017
  - Ecohydrology
- Berland et al. 2017
  - Landscape and Urban Planning

Nutrient Reduction by Trees in GSI Practices

Three Australian studies:

- Read et al., 2008
  - 3 tree species
- Bratieres et al., 2008
  - 1 tree species (Melaleuca)
- Denman et al. (2015)
  - 4 common street tree species

Sandy loam mesocosm study

- Typical biofiltration media
  - 4 -10% compost
- Sat. hydraulic conductivity
  - 90 - 180 mm/hr

	Soil only (mg L^{-1})	Soil+Tree (mg L^{-1})	% Reduced	Reference
TN	2.2 6.68	1.8 - 2.3 1.19	-5% – 18%* 82%	Read et al., 2008 Bratieres et al., 2008
NO_x	0.38 5.23 7.43	0.01 - 0.16 0.38 1.96	58 - 97%* 93% 74%*	Read et al., 2008 Bratieres et al., 2008 Denman et al., 2015
TP	0.11 0.083	0.06 - 0.10 0.070	9 - 45%* 16%	Read et al., 2008 Bratieres et al., 2008
PO_4^{3-}	0.075 0.064 0.85	.020 - .025 0.034 0.18	67 - 73%* 47% 79%*	Read et al., 2008 Bratieres et al., 2008 Denman et al., 2015

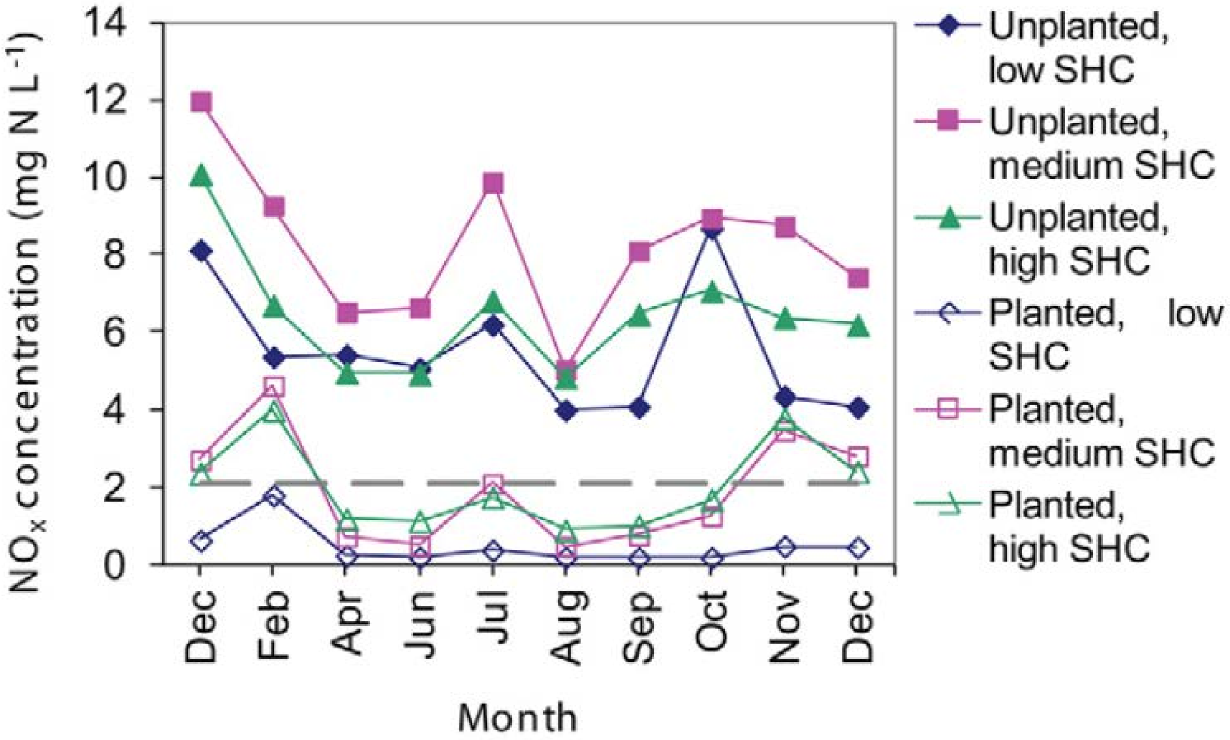
Reduction compared to unplanted systems

*Averaged over entire study period

Nutrient Reduction by Trees Compared to Stormwater Dosing

	Dose (mg/L)	Soil+Tree (mg/L)	Reduced %	Reference
TN	2.21	1.19	46	Bratieres et al., 2008
NO_x	0.79 2.0	0.38 1.96	52 2 *	Bratieres et al., 2008 Denman et al., 2015
TP	0.427	0.070	84	Bratieres et al., 2008
PO_4^{3-}	0.127 0.6	0.034 0.18	74 70 *	Bratieres et al., 2008 Denman et al., 2015

* Averaged over entire study period (13 months)

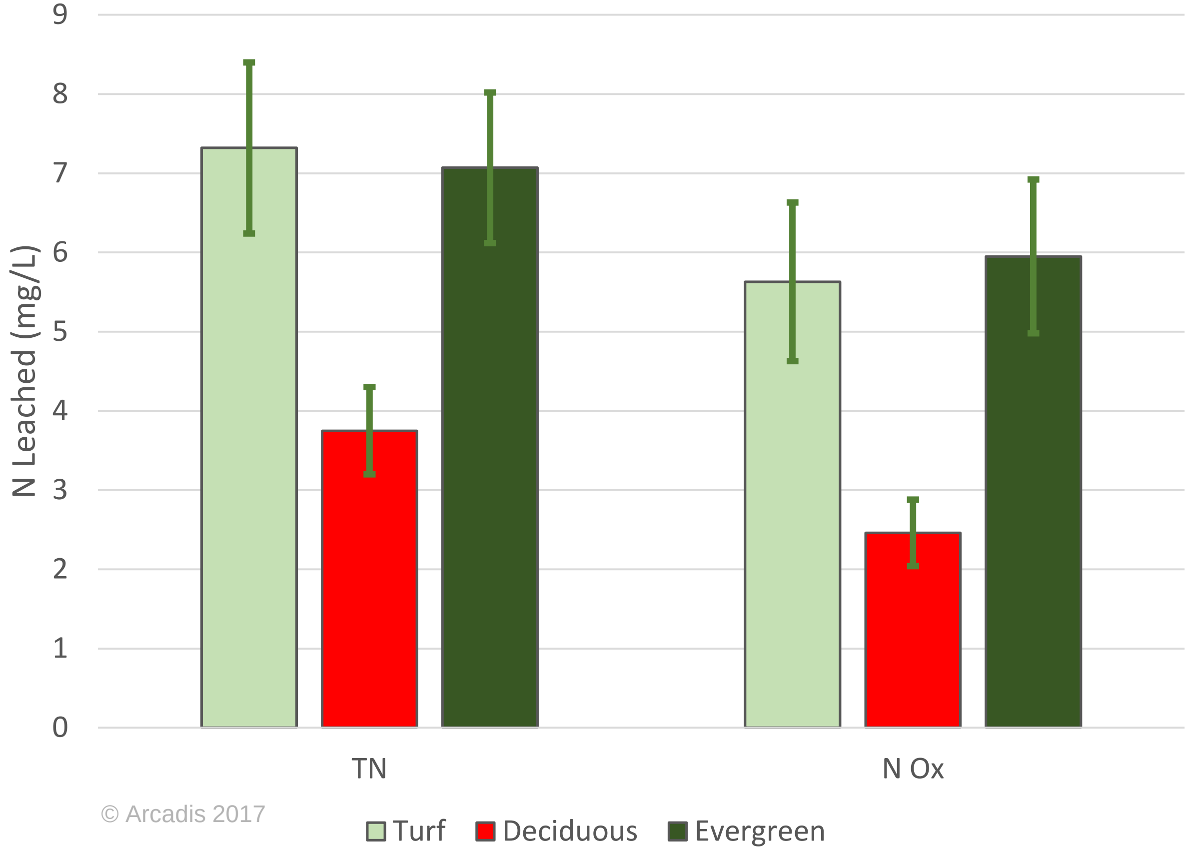


Low SHC = 4 mm/hr
Medium SHC = 95 mm/hr
High SHC = 175 mm/hr

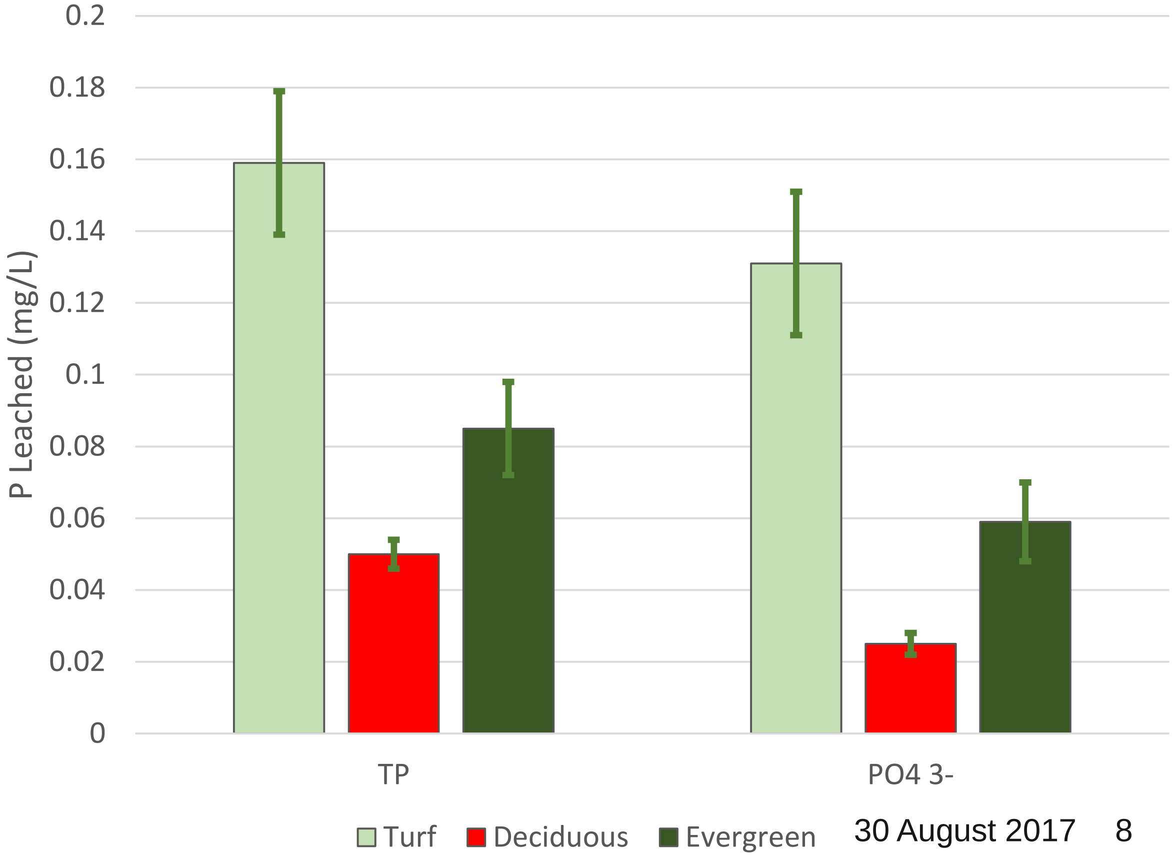
Source: Denman et al., 2015

Urban Trees Reduce Nutrient Leaching to Groundwater (Nidzgorski and Hobbie, 2016)

Effect of Park Trees on **N** Leaching into Groundwater Under Tree Canopy



Effect of Park Trees on **P** Leaching into Groundwater Under Tree Canopy



Managing Upland Urban Forest Systems to Maximize Nutrient Reduction

- Mimic forested systems
  – Increase leaf area
    - Layered canopy structure
- Provide adequate rooting volume
- Slow runoff velocity
  – Trees can take up nutrients

Trade Offs

- Dry pollutant deposition
  – Halverson et al., 1984
- Annual foliage fall
  – Hobbie et al., 2012
- Maintenance costs
  - Natural disasters
  - Utilities

Structure of a Healthy Riparian Buffer System

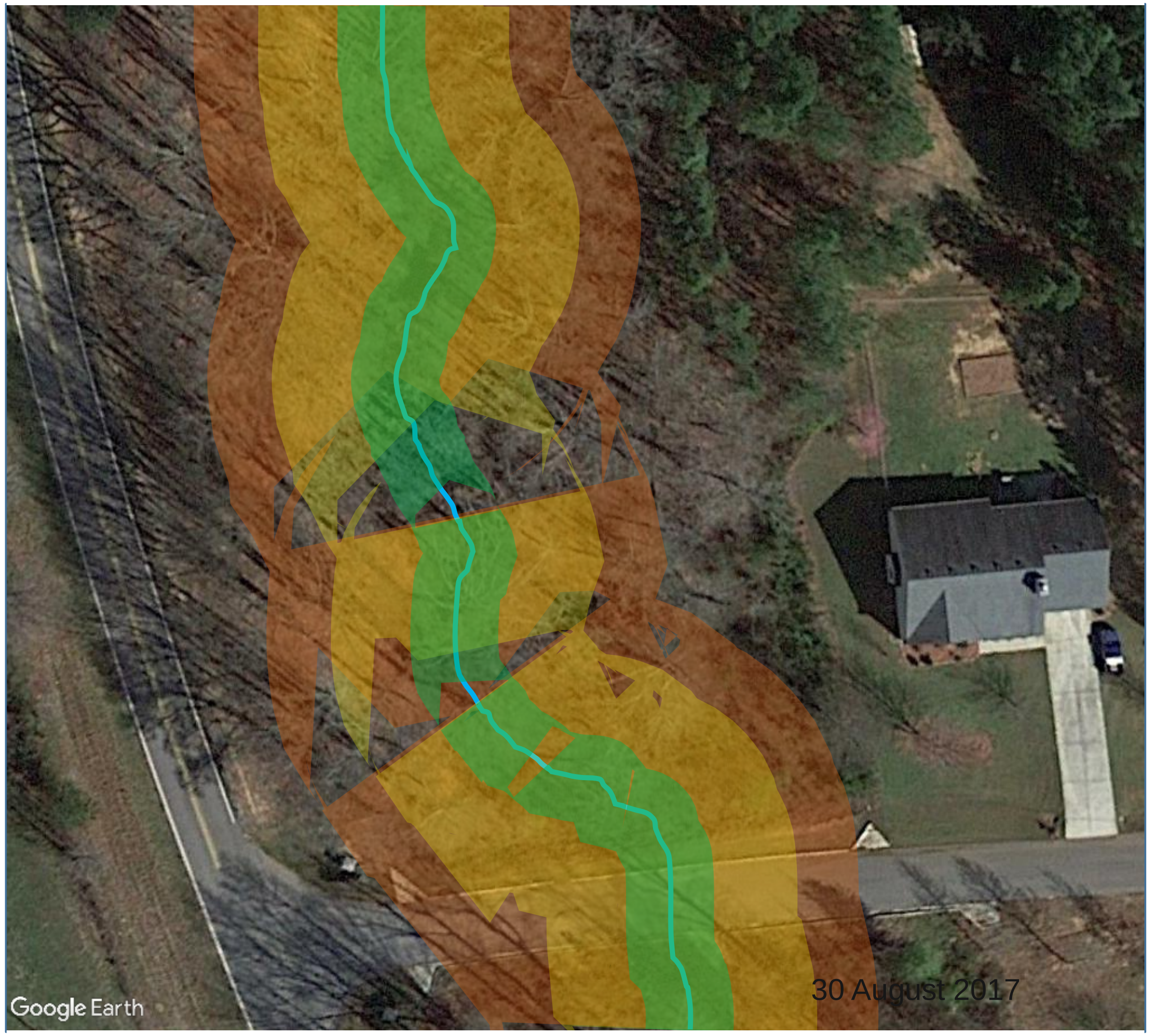
Schueler (2000)

- Architecture of Urban Stream Buffers
- Watershed Protection Techniques
  - http://owl.cwp.org/mdocs-posts/elc_pwp39/

Minimum base width = 100’

Three-zone buffer system

- Streamside zone – 25’
  - Protects integrity of stream
- Middle zone – variable width
  - Protects key components of stream
- Outer zone – 25’
  - Buffer’s buffer



Scientific Literature on Riparian Buffers

Wenger, 1999

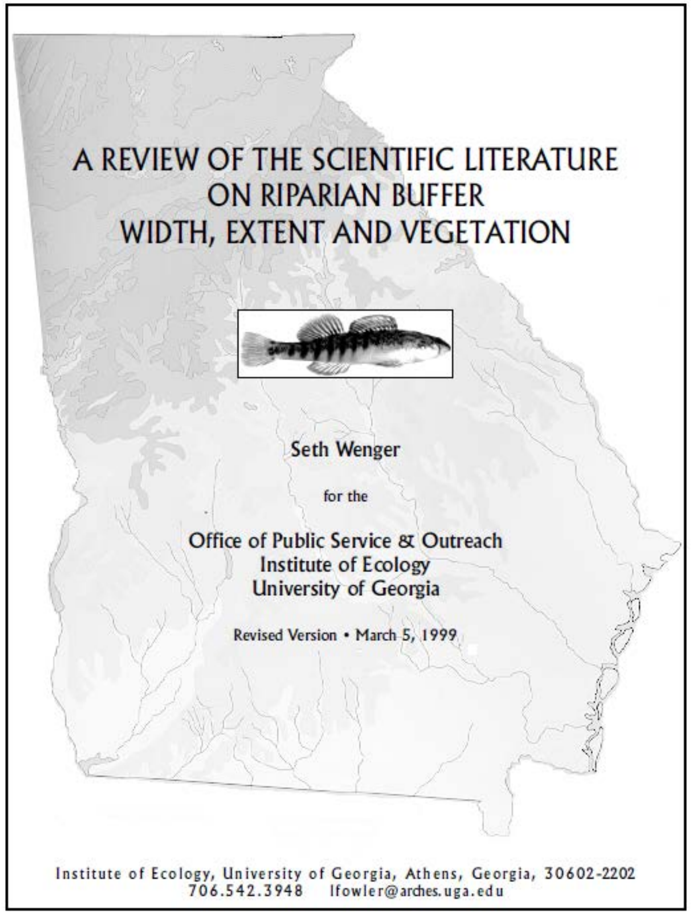
Phosphorus effectiveness

- Short-term storage
  - Linked to sediment removal
- P retention increases with buffer width
  - Less effective at filtering soluble P

Nitrogen effectiveness

- Very high rate of N removal
  - For surface and sub-surface runoff
  - Includes nitrates and ammonium
- Denitrification increases with wider buffers

Pretreatment increases effectiveness


A REVIEW OF THE SCIENTIFIC LITERATURE
ON RIPARIAN BUFFER
WIDTH, EXTENT AND VEGETATION

Seth Wenger

for the

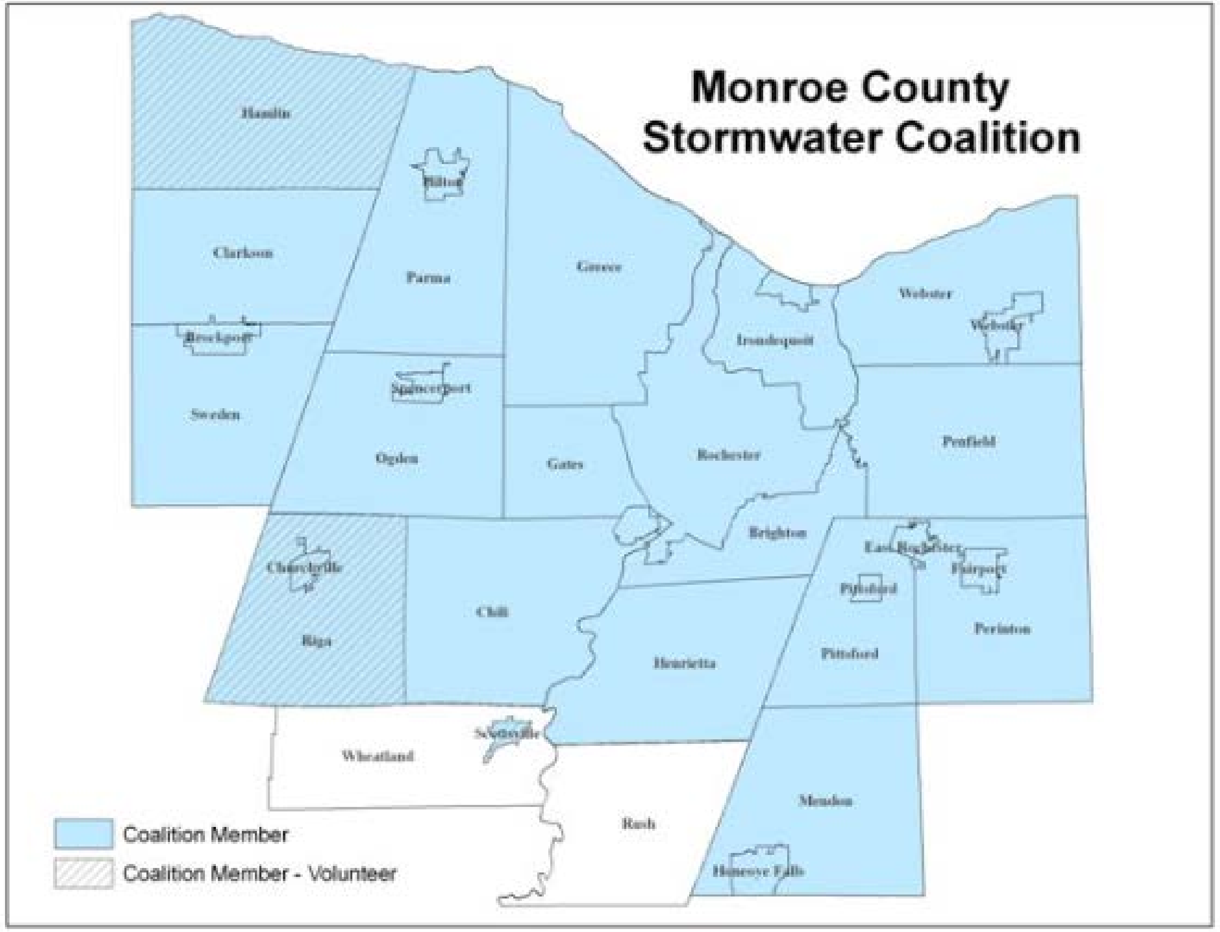
Office of Public Service & Outreach
Institute of Ecology
University of Georgia

Revised Version • March 5, 1999

Institute of Ecology, University of Georgia, Athens, Georgia, 30602-2202
706.542.3948 lfowler@arches.uga.edu

Source: Wenger, 1999

Case Study: Monroe County, New York



Source: Monroe County, NY, 2017

Goals

- Improve water quality in Allen Creek,
- Irondequoit Bay, Lake Ontario
- Support Great Lakes Water Quality Agreement

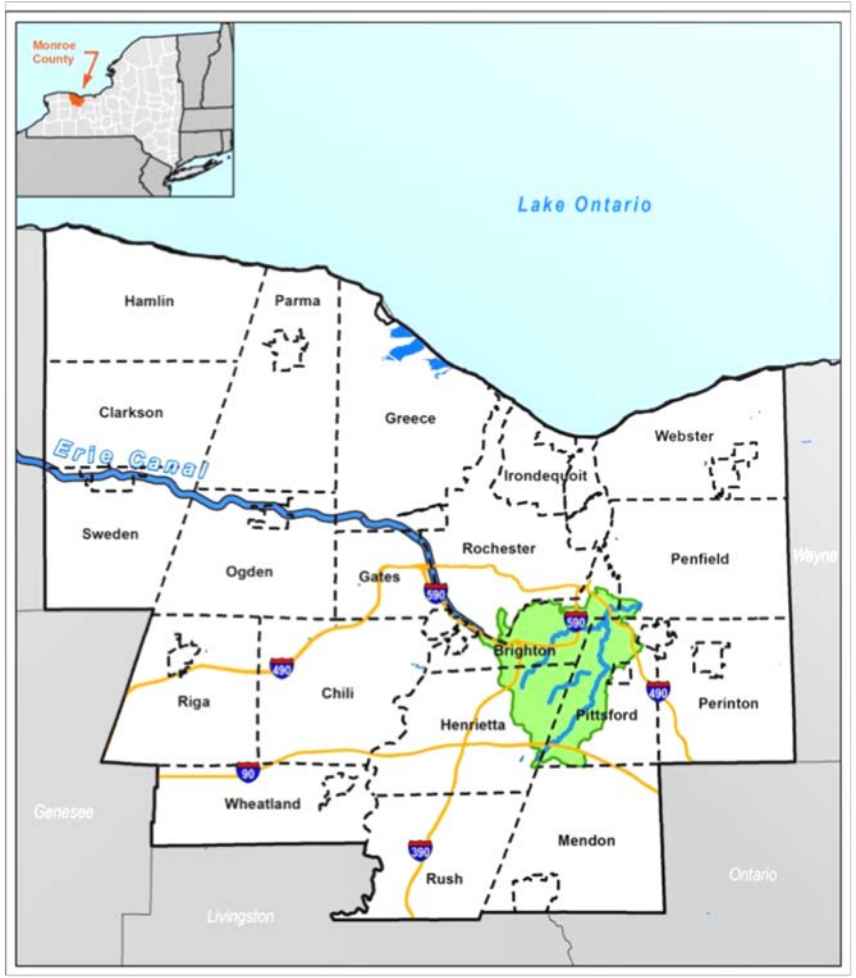
Objectives

- Develop a watershed-based plan that identifies retrofit projects
- Quantify average annual pollutant load and runoff reductions from retrofits

Why Allen Creek Watershed?

Challenges:

- Urbanization – Allen Main Branch
- Agricultural – Allen East Branch
- Water quality degradation
  - Nutrients,
  - Sediment/silt, salt
  - Fecal coliform
- 60 miles of stream on NY PWL



Project Drivers

Client "wants"

- Quick
- Cheap
- Planning-level
- Use existing data
  - GIS based analysis
- Consistency with other completed SW assessments
  - Ranking Criteria
  - Support Stormwater Master Plan

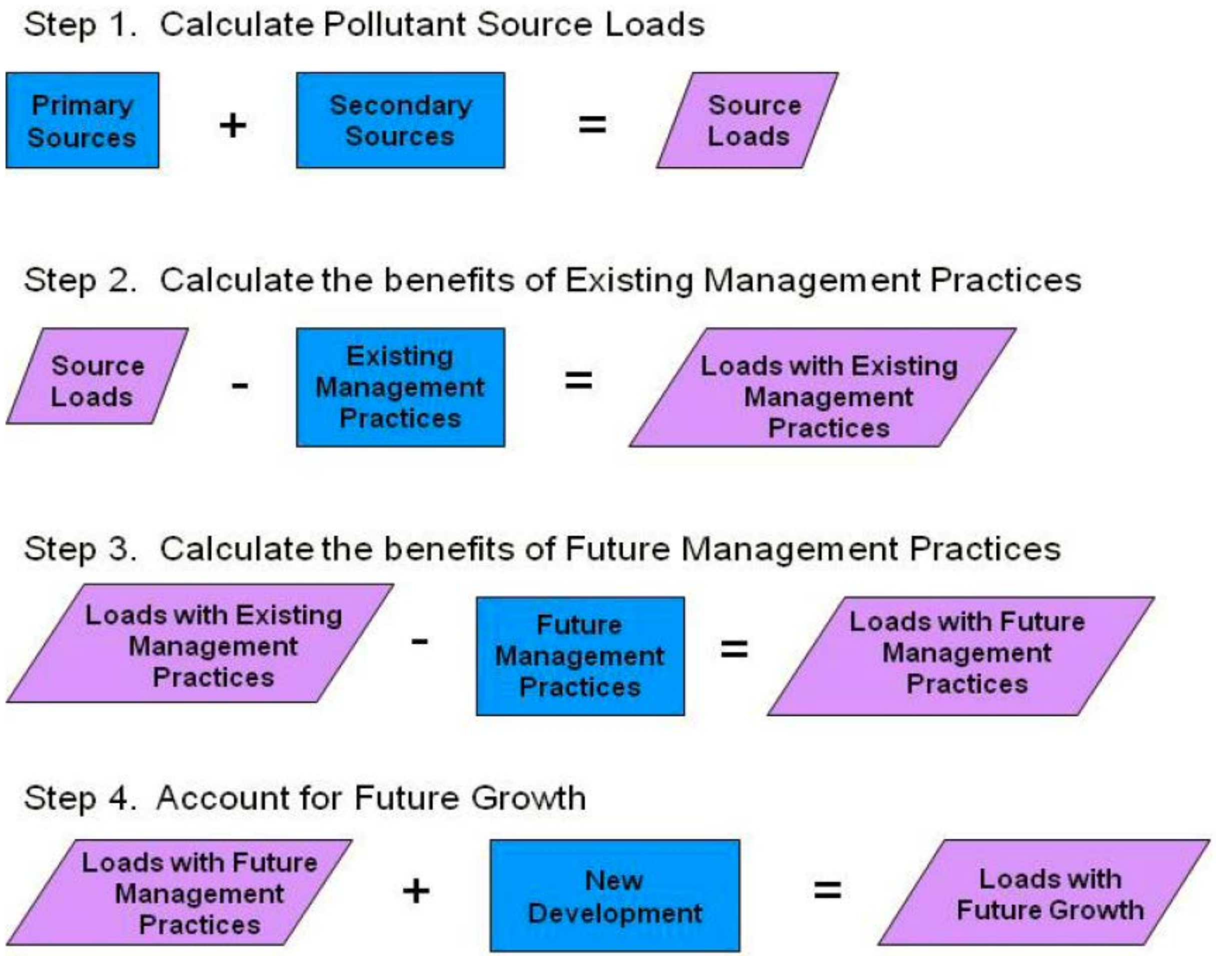
Regulatory

- Federal Clean Water Act
- NY State WQ
- Local stormwater ordinances

Approach

1. Collect data	GIS: land use, land cover, aerial imagery, hydrology, water quality, infrastructure, parks, greenspace
2. Develop watershed model	Baseline conditions model
3. Perform Desktop Analysis	Site potential retrofit projects. Proposed conditions model
4. Evaluate results	Average annual pollutant loads and runoff for baseline and proposed conditions
5. Rank retrofit projects	Watershed benefits, feasibility, cost-effectiveness
6. Final recommended projects	Final list of top 25 projects

Watershed Treatment Model



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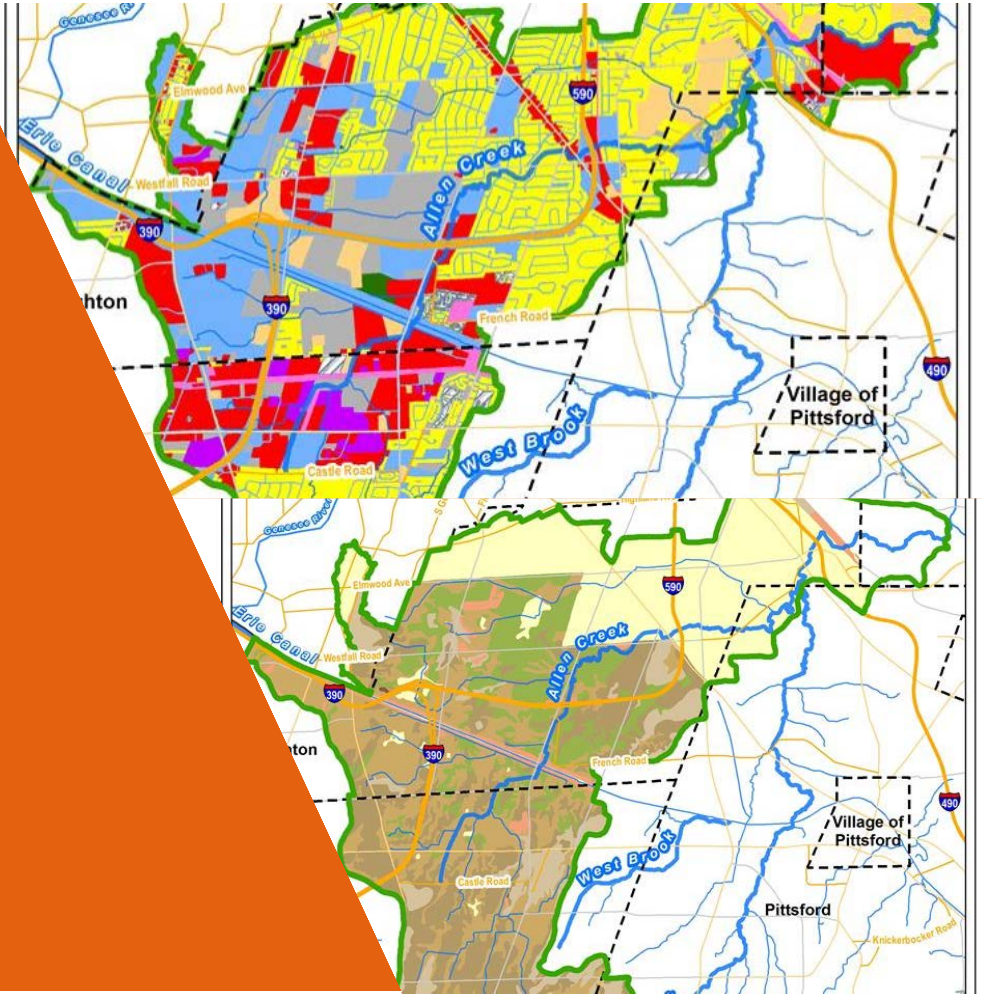
Primary Sources

- Land use/Land Cover
- Drainage Area
- Stream Length
- Rainfall
- Soil Hydrologic Group



Desktop Analysis

- Siting of potential retrofit projects using GIS
- Project Types:
  - Bioretention (GI)
  - Buffers
  - Dry ponds
  - Wetlands
  - Wet ponds

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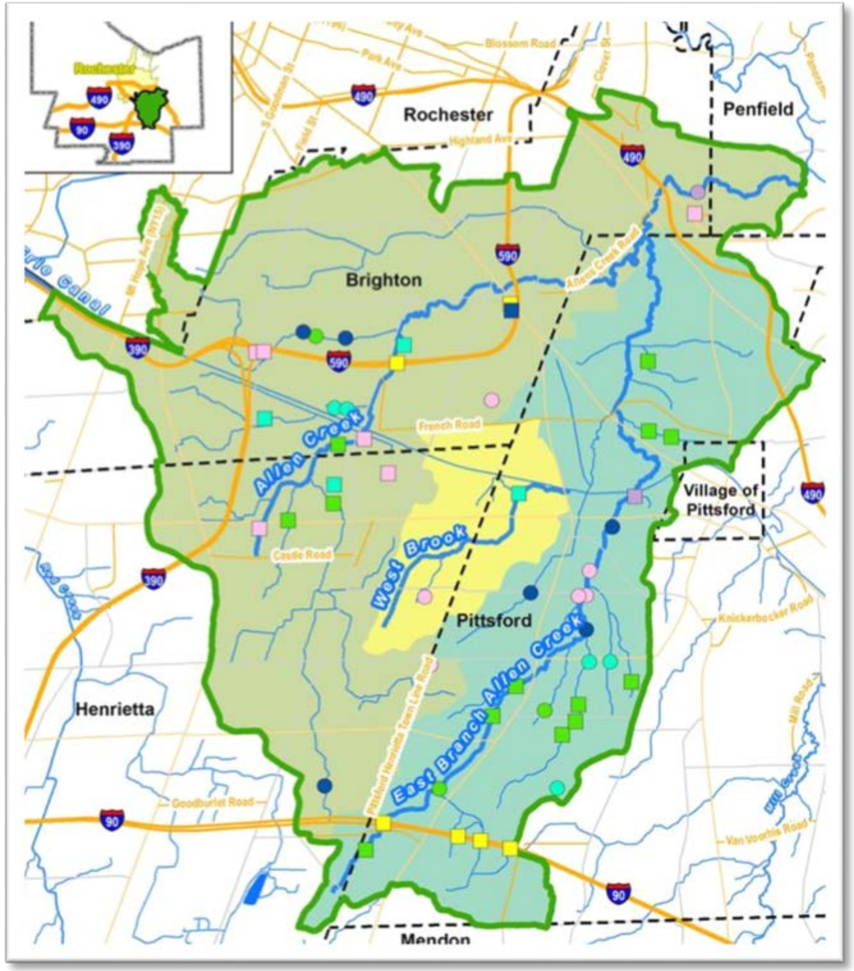
Potential Retrofit Projects in Allen Creek



Project Ranking

Criteria:

- Watershed benefits
- Cost-effectiveness
- Feasibility

Project Ranking

	Load Reductions (largest to smallest)								Runoff Volume Reduction (largest to smallest)		Total Score from Rapid Assessment	
	Total Nitrogen (TN)		Total Phosphorus (TP)		Total Suspended Solids (TSS)		Fecal Coliform (FC)		Runoff Reduction			
FINAL RANK	**Project ID**	**TN (lbs/year)**	**Project ID**	**TP (lbs/year)**	**Project ID**	**TSS (lbs/year)**	**Project ID**	**FC (billion colonies/year)**	**Project ID**	**RV acre-feet/year)**	**Project ID**	**Total Score**
1	P1-E	819	P1-E	278	P1-E	56,650	P1-E	64,758	P2-E	6	Rip-16-M	14
2	P13-E	602	P13-E	207	P13-E	41,271	P13-E	47,177	Rip-7-E	5	D1-E	13
3	P3-M	481	P3-M	193	P5-M	32,644	P5-M	36,651	Rip-12-E	4	D2-M	13
4	P5-M	469	P5-M	165	P3-M	30,715	P3-M	34,485	O1-M	4	D3-M	13
5	P1-M	393	P1-M	145	P1-M	26,550	P1-M	29,809	P3-E	4	D6-E	13
6	P2-M	292	P2-M	101	P2-M	20,603	P2-M	23,132	P4-E	3	D8-E	13
7	Wtlnd-1-M	257	P12-E	87	P12-E	17,466	P12-E	19,965	Rip-14-M	3	P12-E	13
8	P12-E	254	Wtlnd-1-M	75	W20-M	11,837	W20-M	13,290	Rip-15-M	3	P13-E	13
9	W20-M	168	W20-M	58	Wtlnd-1-M	10,252	Wtlnd-1-M	12,381	Rip-6-E	1	P1-E	13
10	W4-E	127	W4-E	44	W4-E	8,719	W4-E	9,967	P5-E	1	P2-M	13

Allen Creek Summary

Forested riparian buffers ranked high among other BMPs in terms of:

- Watershed benefits
- Feasibility
- Cost Effectiveness

Conclusions: Allen Creek Case Study

Forested riparian buffers:

1. Ranked high amongst other retrofit projects in terms of:
   - ✓ Watershed benefits
   - ✓ Feasibility
   - ✓ Cost effectiveness
2. Offer many additional co-benefits besides WQ and quantity, including:
   - ✓ habitat
   - ✓ recreational areas (e.g. parks, greenways, trails),
   - ✓ aesthetics
   - ✓ Low O&M costs

Overall Summary

- Forested riparian buffers = viable option for watershed restoration
- Most effective when used in conjunction with other BMPs, structural and programmatic
- Treatment train approach (upland forest systems + riparian buffers)

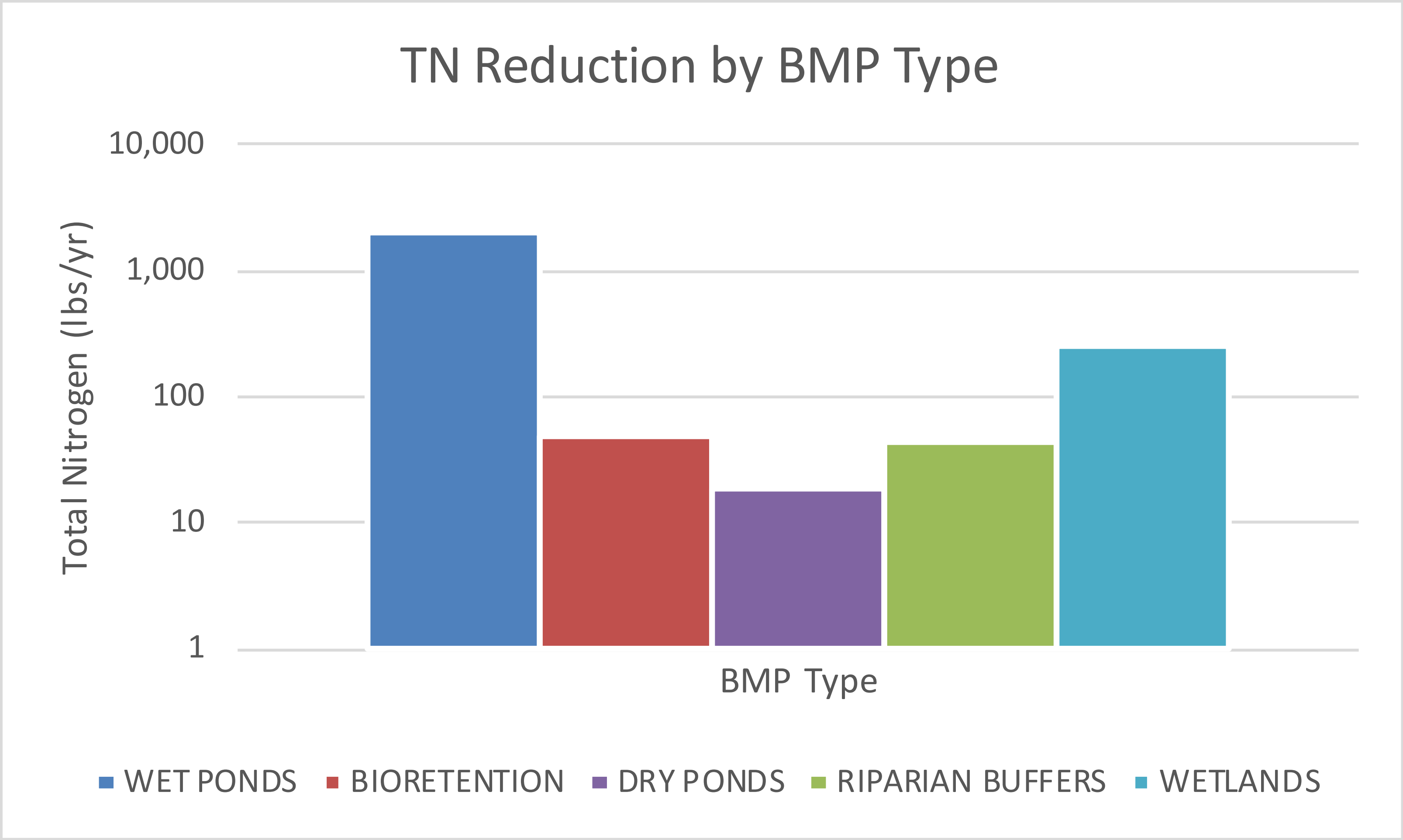
Many co-benefits to communities:

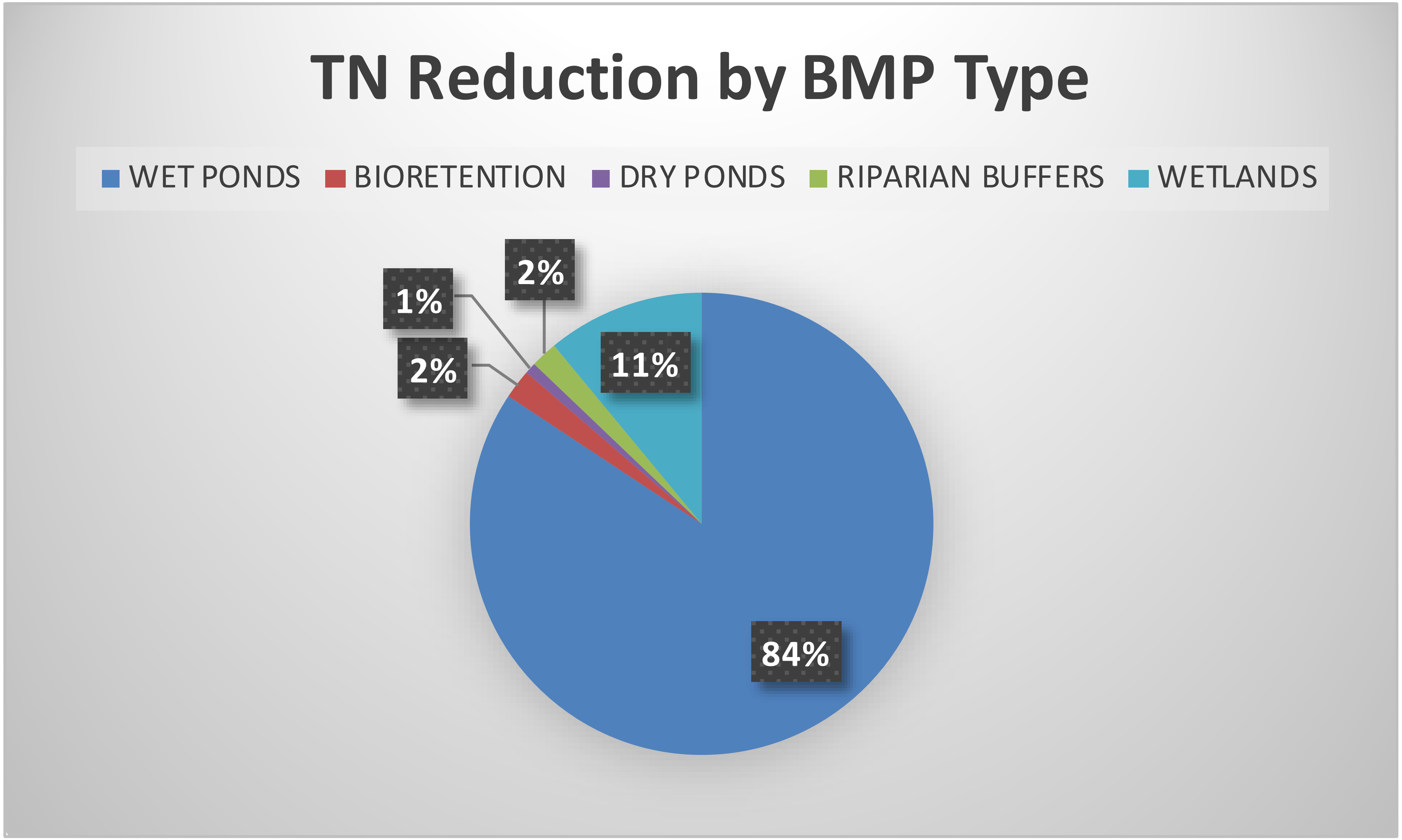
- Water quality, water quantity, habitat, recreational areas (e.g. parks, greenways, trails), aesthetics, cost, public education + outreach

Forested riparian buffers benefit communities

EXTRA SLIDES

Model Results: Allen Creek Main Branch




TN Reduction by BMP Type
WET PONDS
BIORETENTION
DRY PONDS
RIPARIAN BUFFERS
WETLANDS
1%
2%
2%
11%
84%

Project Type	Feasibility	Watershed Benefits	Cost Effectiveness	Maximum Possible Score
New or Retrofit Stormwater Management Ponds	**New projects:** Vacant public lands = 4 points Other public lands = 3 points Projects on commercial property or HOA = 2 points Ease of access = 1 additional point ***5 possible points*** *(Or)* **Upgrades to existing stormwater facilities** On public land = 4 points On private land with easement = 2 points Ease of access = 1 additional point ***5 possible points***	Infiltration = 2 points Flood storage = 1 point Water quality = 1 point Channel protection = 1 point Education = 1 point ***6 possible points***	3 points = $1 to $11 2 points = $12 to $25 1 point = >$26 Note: new ponds = new storage ***3 possible points***	14
Green Infrastructure on Public Highways	1. Planned road reconstruction = 5 points 2. Area within ROW is: • Vacant/unused paved = 3 points • Lawn = 2 points • In use by adjacent business = 1 point 3. Average number of property owners: • One property owner per 125 or more linear feet = 2 points • Greater than one property owner per 125 feet = 1 point ***5 possible points***	Infiltration = 2 points A or B soil types = 1 point Water quality = 1 point Channel protection = 1 point Education = 1 point Source control = 1 point ***8 possible points***	3 points = $1 to $11 2 points = $12 to $25 1 point = >$26 based on table ***3 possible points***	16
Neighborhood Green	Neighborhoods considered meet these criteria and	Community revitalization =	Neighborhood green infrastructure	8

Project Type	Feasibility	Watershed Benefits	Cost Effectiveness	Maximum Possible Score
Infrastructure	receive 1 point each: • Neighborhood was built in 1975 or before whose stormwater is not being treated with any management practice. • Average property size is 10,000 square feet or larger, but less than 1 acre. • A, B, or C soil type ***2 points***	1 point Water quality = 1 point Education = 1 point Source control = 1 point ***4 points***	practices vary in cost effectiveness from a score of 3 to 1; therefore, average with 2 points each ***2 points***	
Other Green Infrastructure Retrofits	Vacant public lands = 4 points Other public lands = 3 points Projects on commercial property or HOA = 2 points Ease of access = 1 additional point ***5 possible points***	Same as green infrastructure on public highways ***8 possible points***	Same as above ***3 possible points***	16

Cost Effectiveness Scoring

- *Cost Effectiveness scores based on:*
  - planning-level cost estimates
  - Retrofit project type
  - Retrofit project drainage area

- Method limitations
  - Cost of land acquisition
  - Long-term forecasting of O&M costs

Source: Urban Subwatershed Restoration Manual No. 3 (Center for Watershed Protection 2007)
Guillozet et al. 2014