EVALUATING LOW IMPACT DEVELOPMENT BEST MANAGEMENT PRACTICES AS AN ALTERNATIVE TO TRADITIONAL URBAN STORMWATER MANAGEMENT

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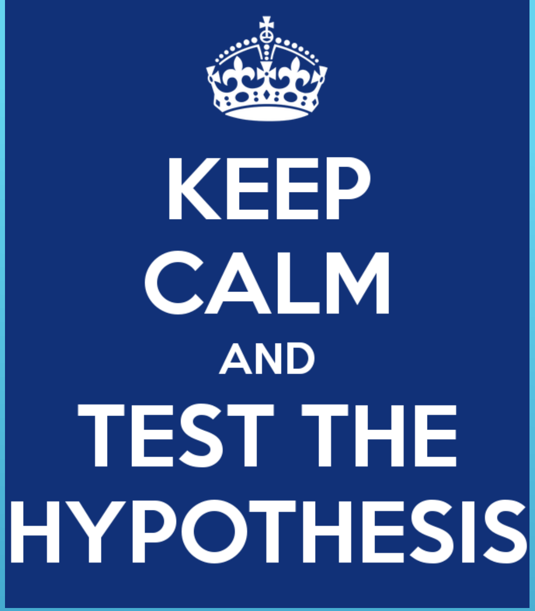
Region 6 Stormwater Conference

10/05/2016

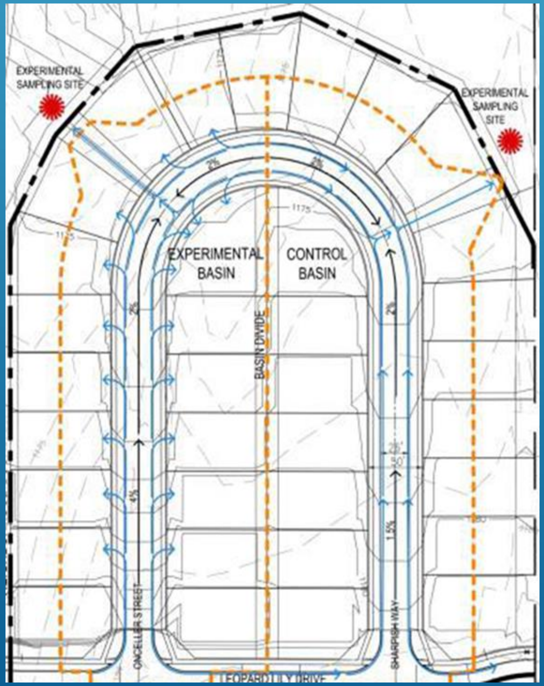
The UNIVERSITY of OKLAHOMA
GALLOGLY
College of Engineering

CREW
Center for Restoration of Ecosystems and Watersheds
University of Oklahoma

Introduction

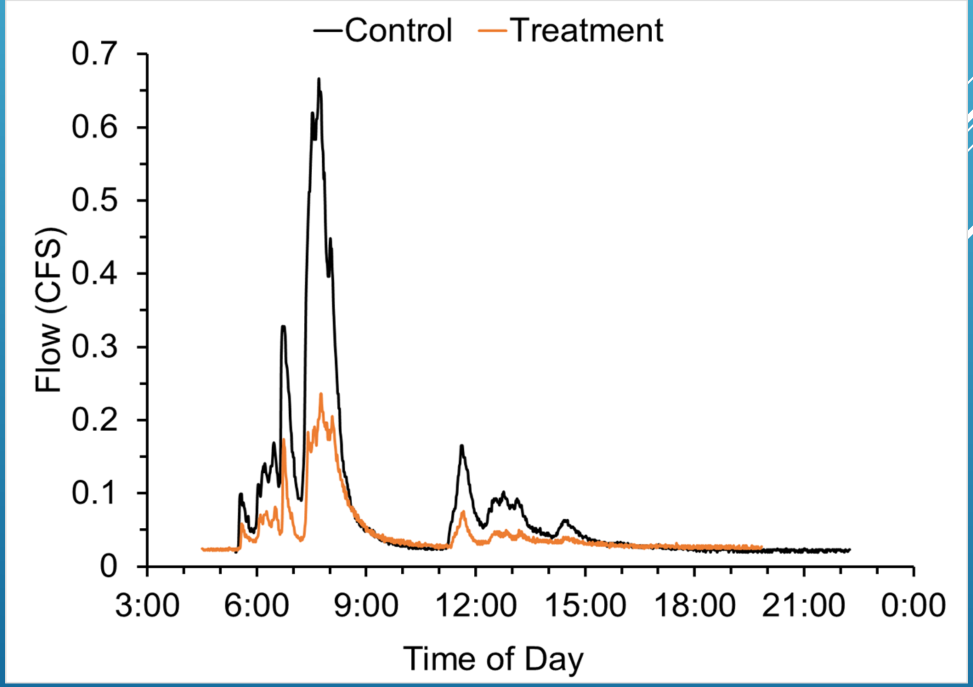


Hypothesis and Objectives



Study Site

Methodology



Results, Discussions and Conclusions

INTRODUCTION

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- **Why is this study important?**
  - **Urban land use is increasing in the Lake Thunderbird watershed**
  - **Lake Thunderbird is listed as 303 (d) impaired waterbody**

- Implementation of Low Impact Development (LID) Best Management Practices (BMPs) is an alterative stormwater management approach

- Trailwoods sampling has been completed in two phases

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URBANIZATION IMPACTS STORMWATER QUALITY

Increased imperviousness leads to:	Resulting Impacts				
	Flooding	Habitat loss	Erosion	Channel widening	Streambed alteration
Increased volume	X	X	X	X	X
Increased peak flow	X	X	X	X	X
Increased peak flow duration	X	X	X	X	X
Increased stream temperature		X			
Decreased base flow		X			
Changes in sediment loadings	X	X	X	X	X

Environmental Protection Agency., 1997. "Urbanization and Streams: Studies of Hydrologic Impacts," EPA 841-R-97-009.

Watershed Impervious Level	Effect
10%	Degraded water quality
25%	Inadequate fish and insect habitat along with shoreline and stream channel erosion
35-50%	Runoff equals 30% of rainfall volume
>75%	Runoff equals 55% of rainfall volume

Kloss, C., and Calarusse, C., 2006. "Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows," Natural Resources Defense Council, Low Impact Development Center, and University of Maryland School of Public Policy.

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EVALUATING TRADITIONAL STORMWATER MANAGEMENT

- **Typically consists of:**
  - **Curb and gutter collection systems**
  - **Drains and storm sewer conveyances**
  - **Detention and retention ponds**

- Divert stormwater runoff from urban areas as quickly as possible
- Addresses only water quantity and pays no attention to water quality

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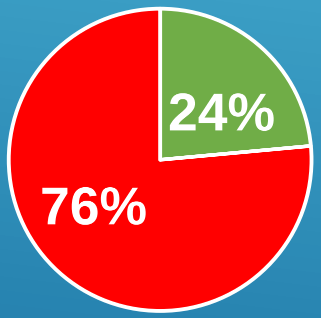
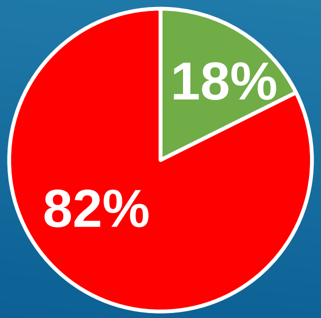
STORMWATER RUNOFF DEGRADES SURFACE WATER BODIES

- **Rivers and Streams**
  - **3271 miles “good” water**
  - **10627 miles “impaired” water**

  2014 Oklahoma Lotic Assessment



Oklahoma Lotic Waters Assessed



- **Lakes, Ponds, and Reservoirs**
  - **101717 acres “good” water**
  - **498773 acres “impaired” water**

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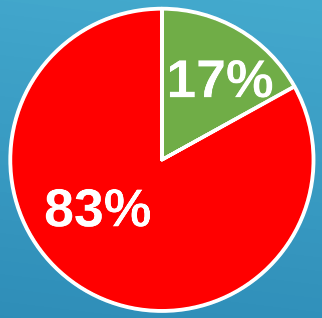

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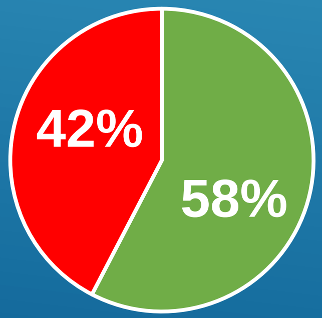

STORMWATER RUNOFF DEGRADES SURFACE WATER BODIES CONTINUED

Possible Causes of Impairment		
	Lotic (miles)	Lentic (acres)
Algal Growth		70500
Ammonia	46	
Nutrients	160	29350
Dissolved Oxygen Depletion	2110	155900
Pathogens	7800	21000
Turbidity	2700	366000

Possible Sources of Impairment		
	Lotic (miles)	Lentic (acres)
Agricultural	8150	34150
Urban Stormwater	7225	17500
Unknown	10150	500000

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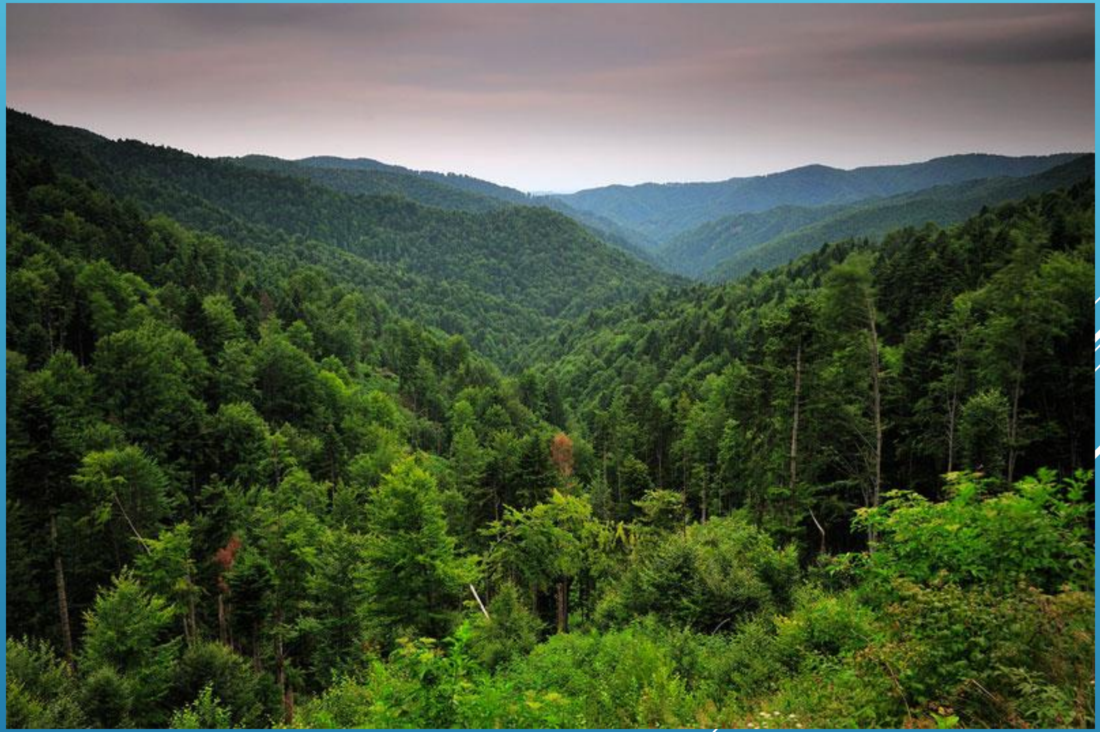
- **LID BMPs are relatively new concepts developed in the early 1990's**
- Goal:
  - Treat the water as close to where it falls as possible
- LID BMPs attempt to model natural processes and simulate pre-development hydrology



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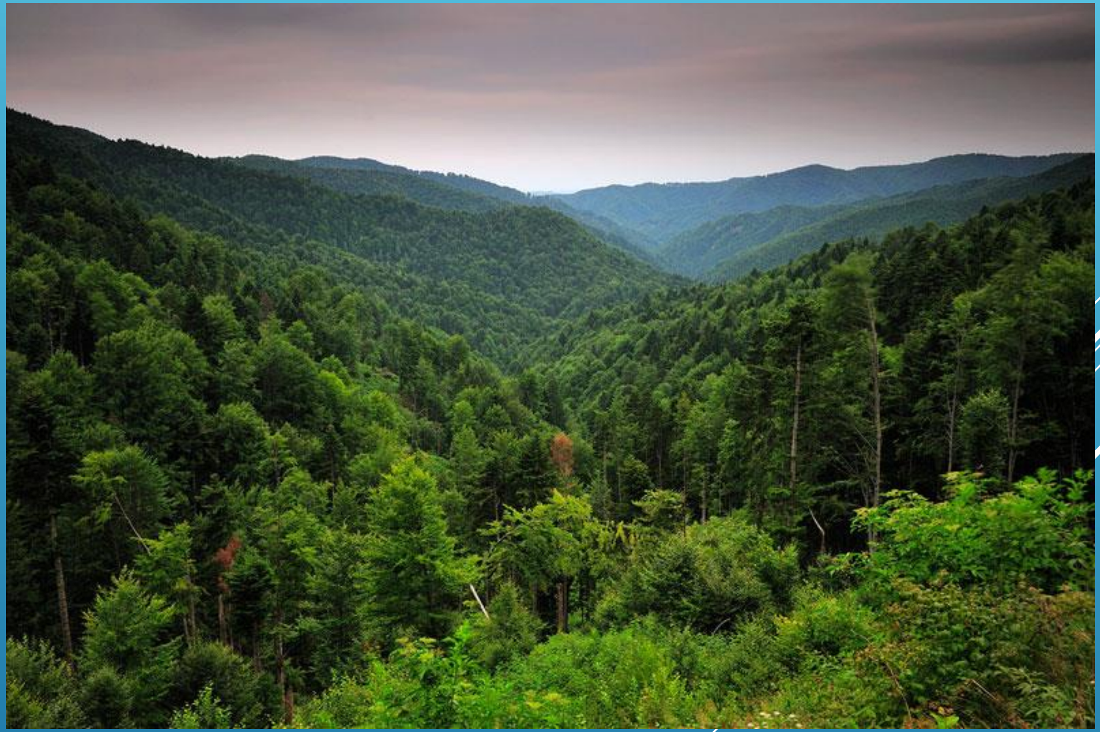

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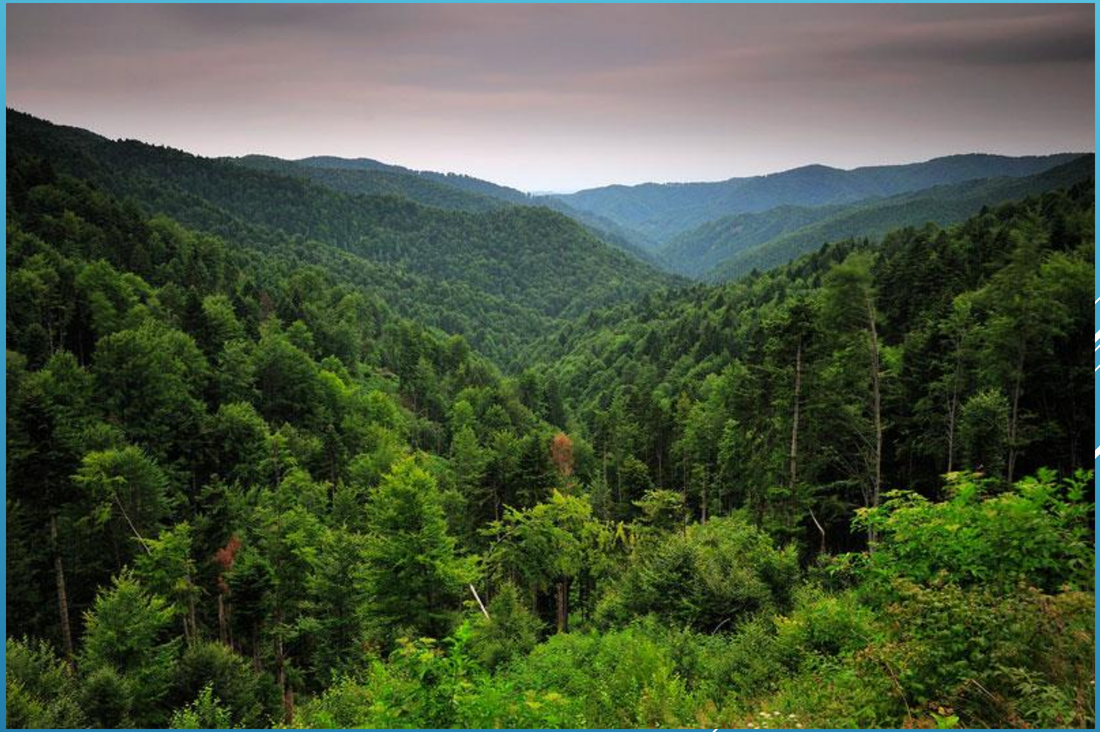


Constructed wetland


Infiltration basin

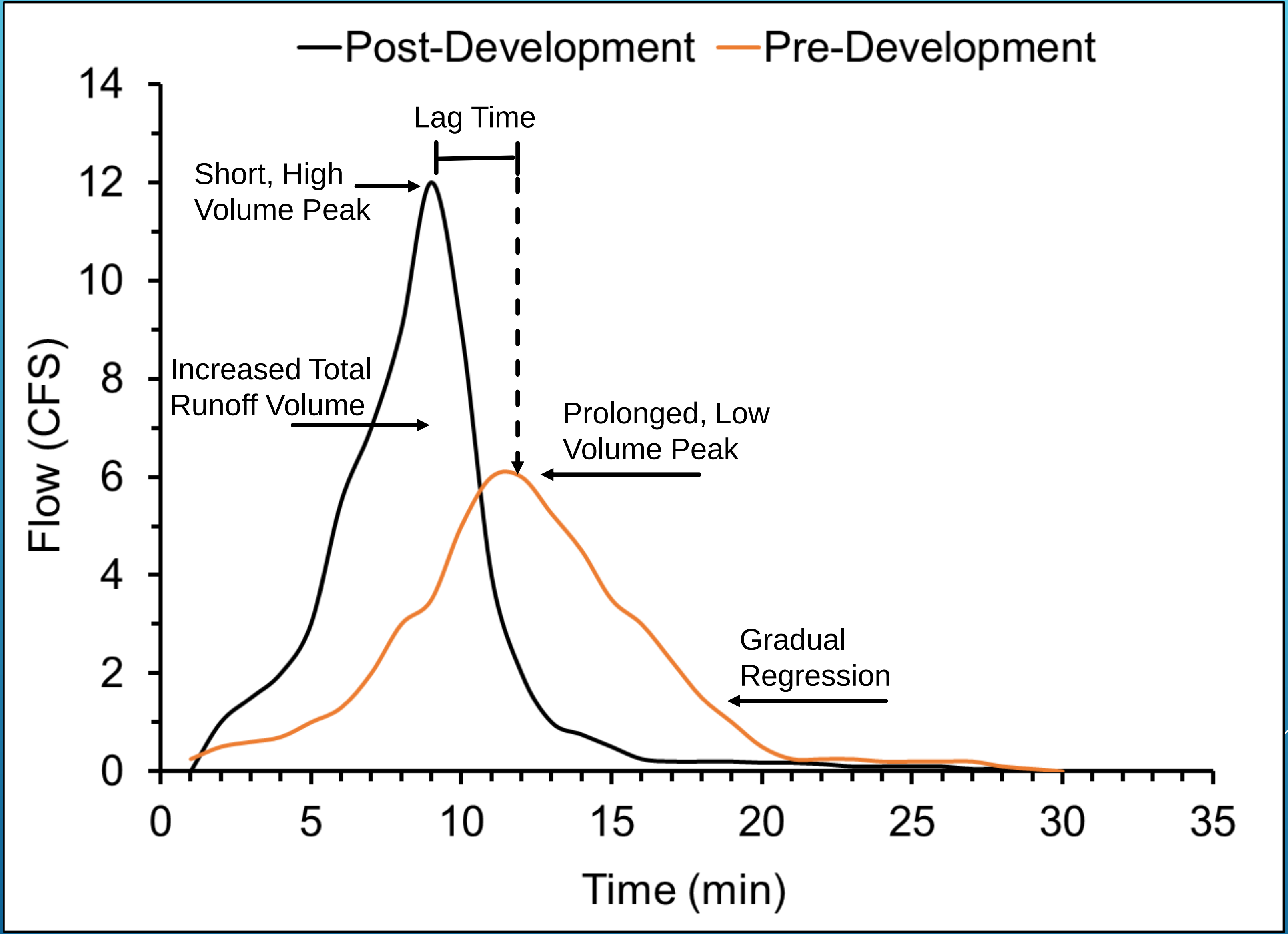

Rain garden


Rain barrel


Green roof


Permeable pavement

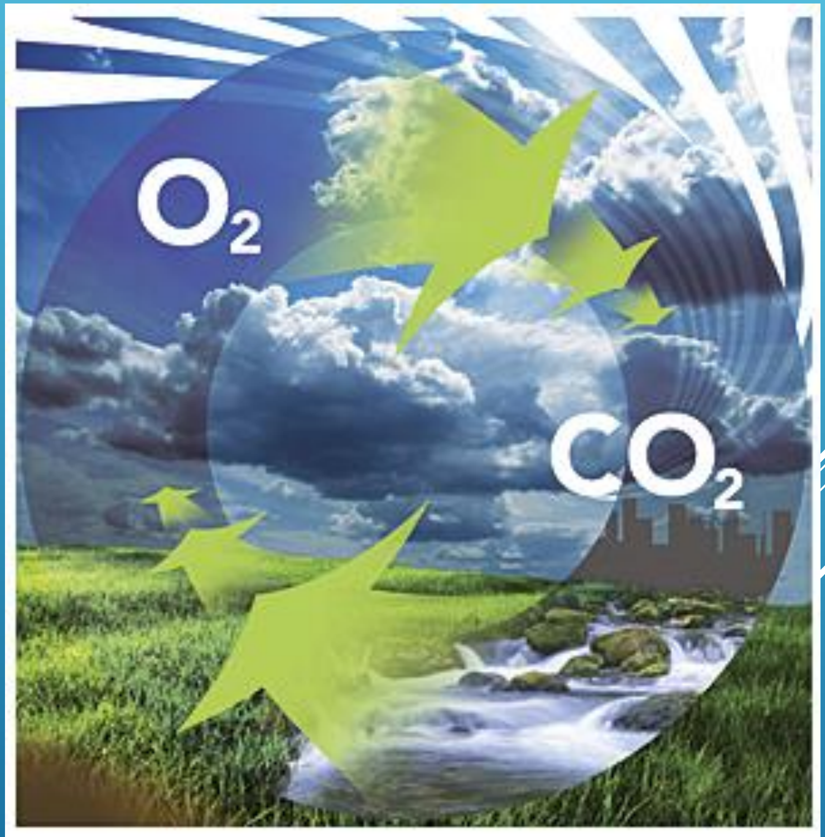
LID BMPs PURPOSE



ECOSYSTEM SERVICES

- **Ecosystems are defined by a complex set of interactions between plants, animals, microorganisms, humans, and the non-living environment**

- Evaluation is necessary to document:
  - How changes in ecosystem services impact human well-being
  - How changes to ecosystems may affect future generations
  - What modifications can be made at various scales to improve ecosystem management and drive sustainability



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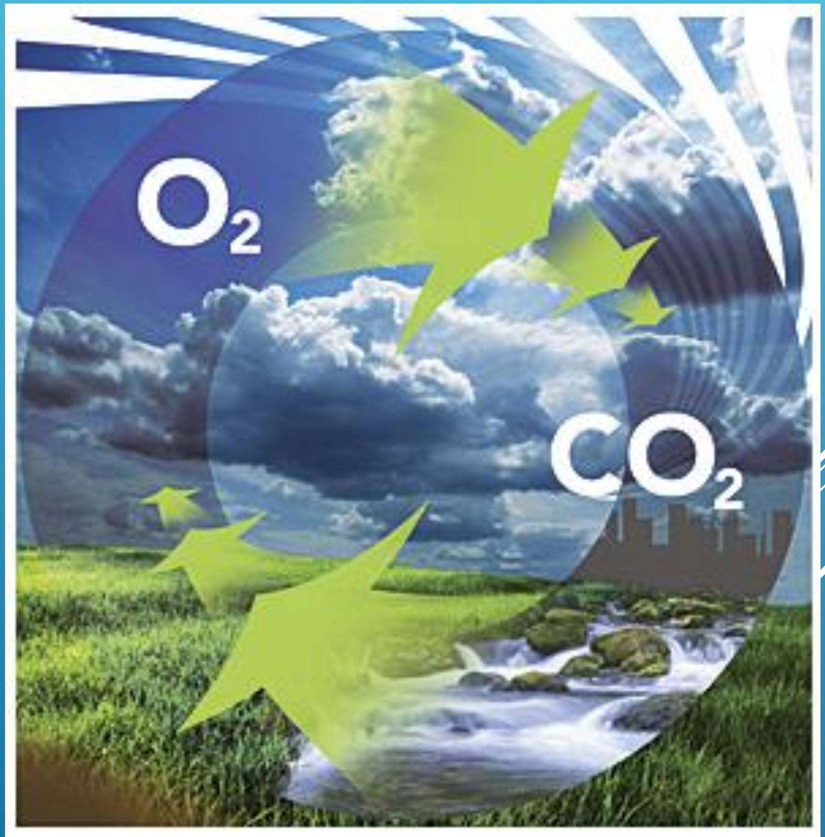

ECOSYSTEM SERVICES

Functions	Processes and Components	Goods and Services
Regulating	Maintenance of essential ecological processes	
Water regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation
Nutrient regulation	Role of biota in storage and recycling nutrients	Maintenance of productive ecosystems
Supporting	Providing habitat for plant and animal species	
Nursery	Suitable reproductive habitat	Hunting; Gathering; Aquaculture
Provisioning	Provisioning of natural resources	
Food and Water	Conversion of solar energy into edible plants and animals; purification and storage of water	Fuel and Energy
Cultural	Providing opportunities for cognitive development	
Science and education	Variety in nature with scientific and educational values	Use of nature of education and research

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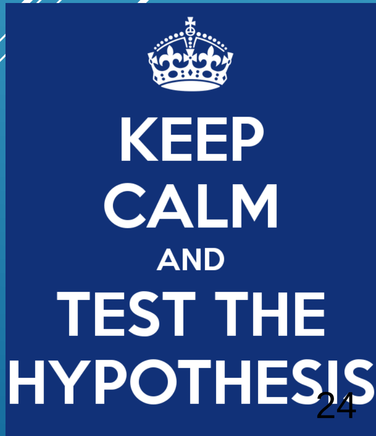
HYPOTHESES AND OBJECTIVES

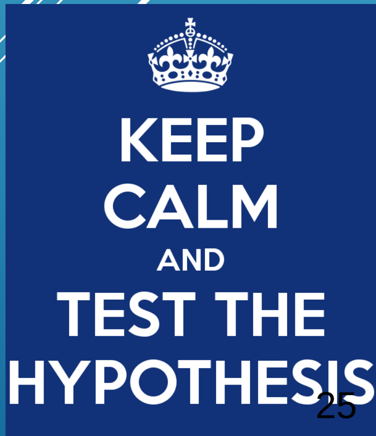


HYPOTHESES

- **Utilization of LID BMPs will demonstrate a difference in the total volume of stormwater runoff generated and the peak volumetric discharge rate for any given storm event**

- Implementation of LID BMPs will demonstrate a difference in urban stormwater runoff pollutant concentrations and loads for ammonia-nitrogen, nitrate-nitrogen, total nitrogen, total dissolved phosphorus, total phosphorus, trace metals, and total suspended sediment

- Employment of LID BMPs for urban stormwater management will provide ecosystem services (compared to traditional stormwater management) that can result in long term economic benefits



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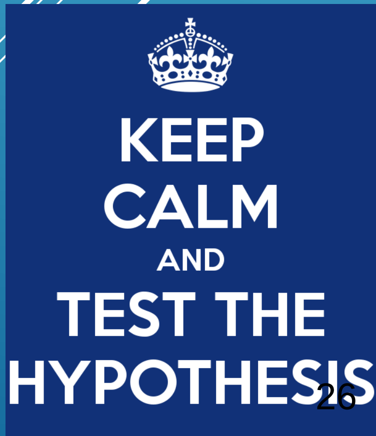

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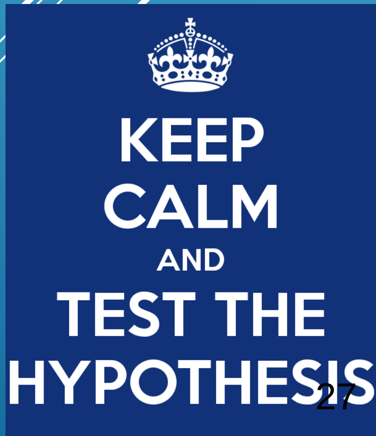

OBJECTIVES

- **Collect storm-event derived stormwater runoff <u>quantity data</u> from treatment (incorporating LID BMP stormwater management practices) and control (incorporating traditional stormwater management practices) watersheds of similar size and residential land use**

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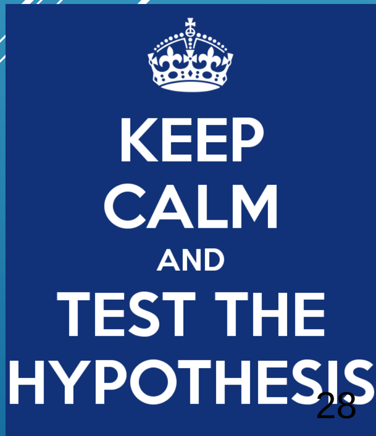
- Investigate the differences in economic benefits derived from ecosystem services between treatment (incorporating LID BMP stormwater management practices) and control (incorporating traditional stormwater management practices) watersheds of similar size and residential land use



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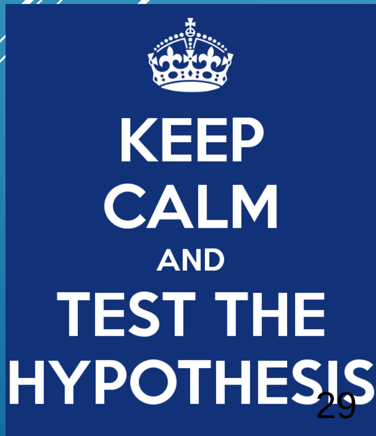

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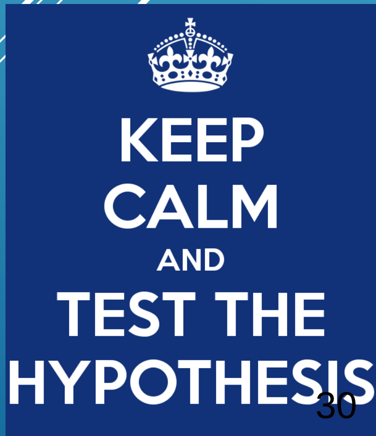
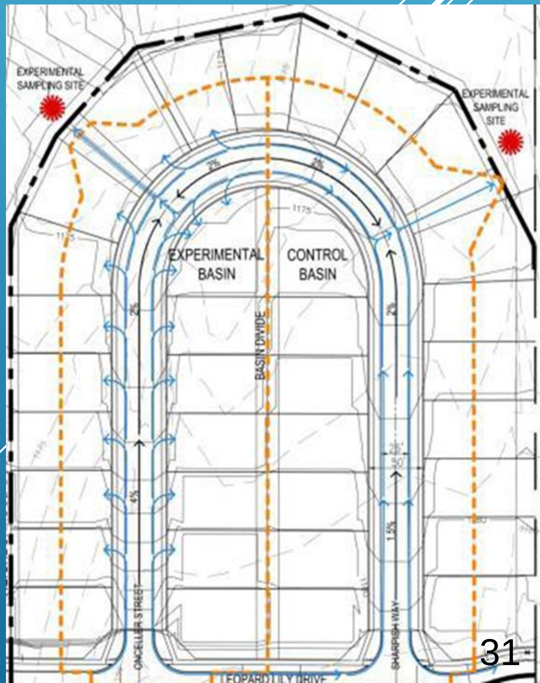


STUDY SITE



EXPERIMENTAL SAMPLING SITE
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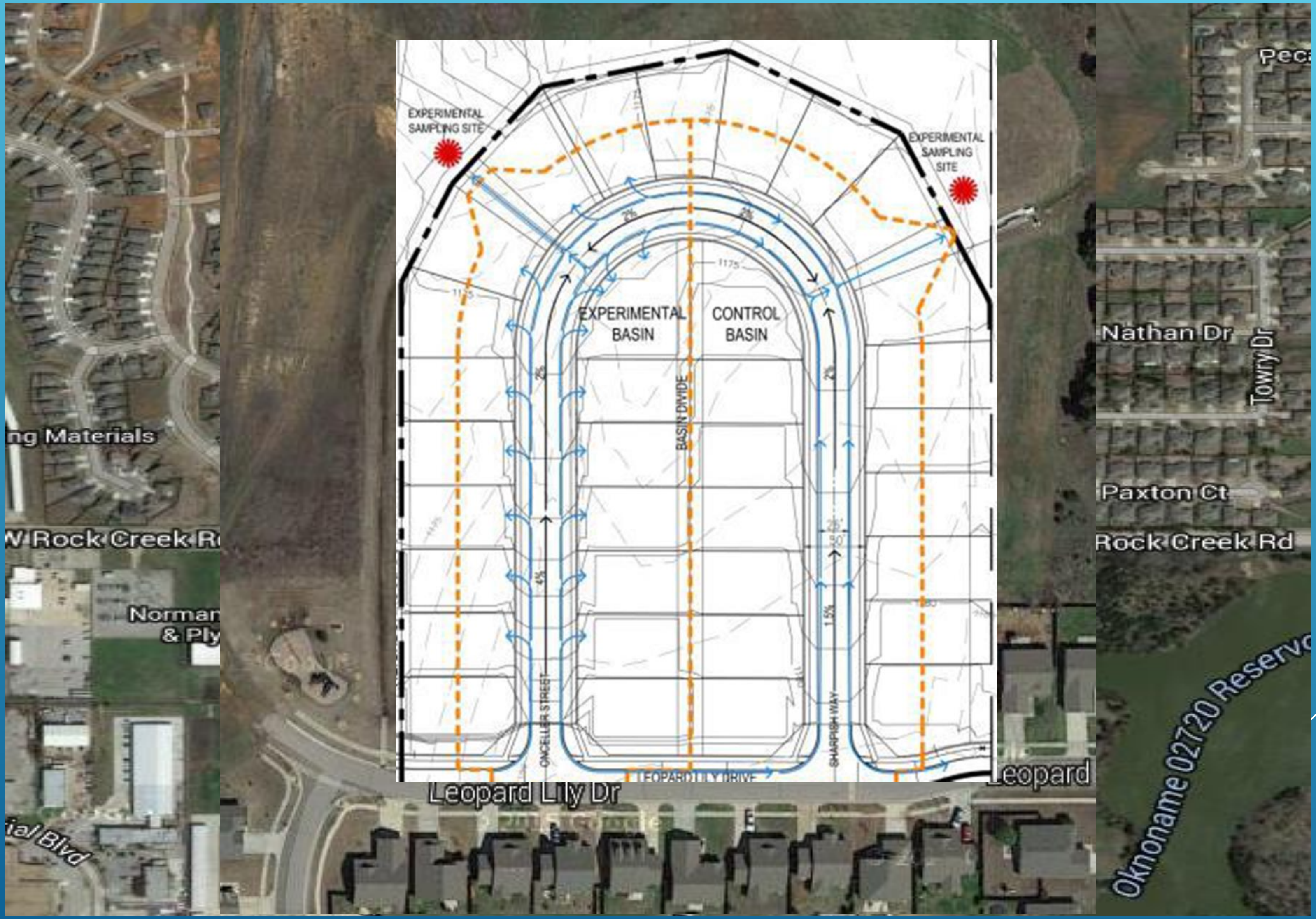
EXPERIMENTAL BASIN
CONTROL BASIN
BASIN DIVIDE

STUDY SITE



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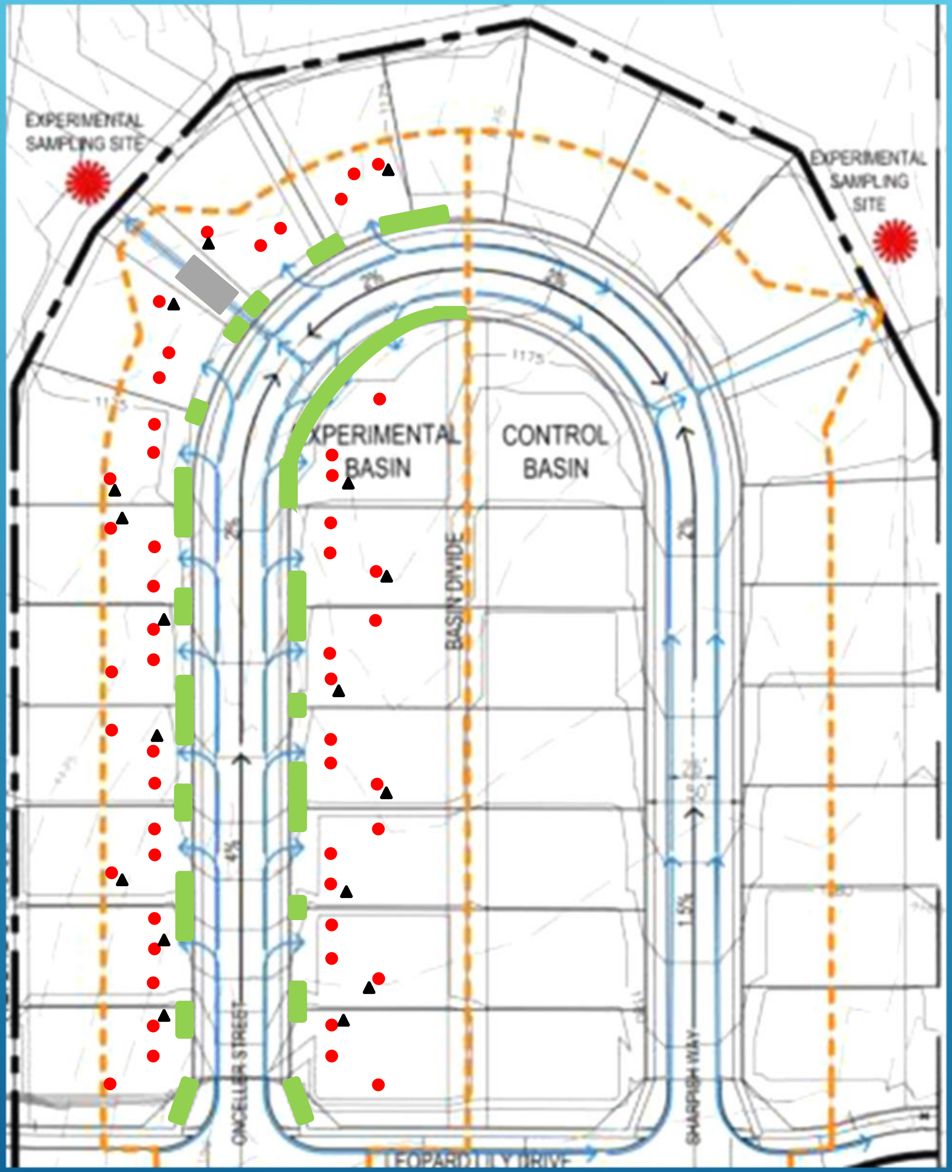
LEOPARD LILY DRIVE
Leopard Lily Dr
Leopard
Nathan Dr
Towry Dr
Paxton Ct
Rock Creek Rd
W Rock Creek Rd
Oknoname 02720 Reserv

STUDY SITE DESIGN

- 51 Diversion downspouts
- 17 Rain barrels
- 18 Rain gardens
- 1 Strip of permeable pavement



METHODOLOGY

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- **Paired watershed study**

- Each watershed was implemented with a trapezoidal flume

$$Q\ (cfs) = 2.853[(level + 0.13558)^{2.497}]$$

- Flow weighted composite samples were collected with an ISCO 6712 Portable Sampler paired with an ISCO 730 Bubbler Module to measure flow

- Analyzed for laboratory parameters

Parameter	Units	Methods
Total suspended solids	mg/L	EPA 160.2 (1999)
Total nitrogen	mg/L	HACH TNT 10071
Ammonia-nitrogen	mg/L	HACH TNT 10031
Nitrate-nitrogen	mg/L	EPA 352.1 (1971)
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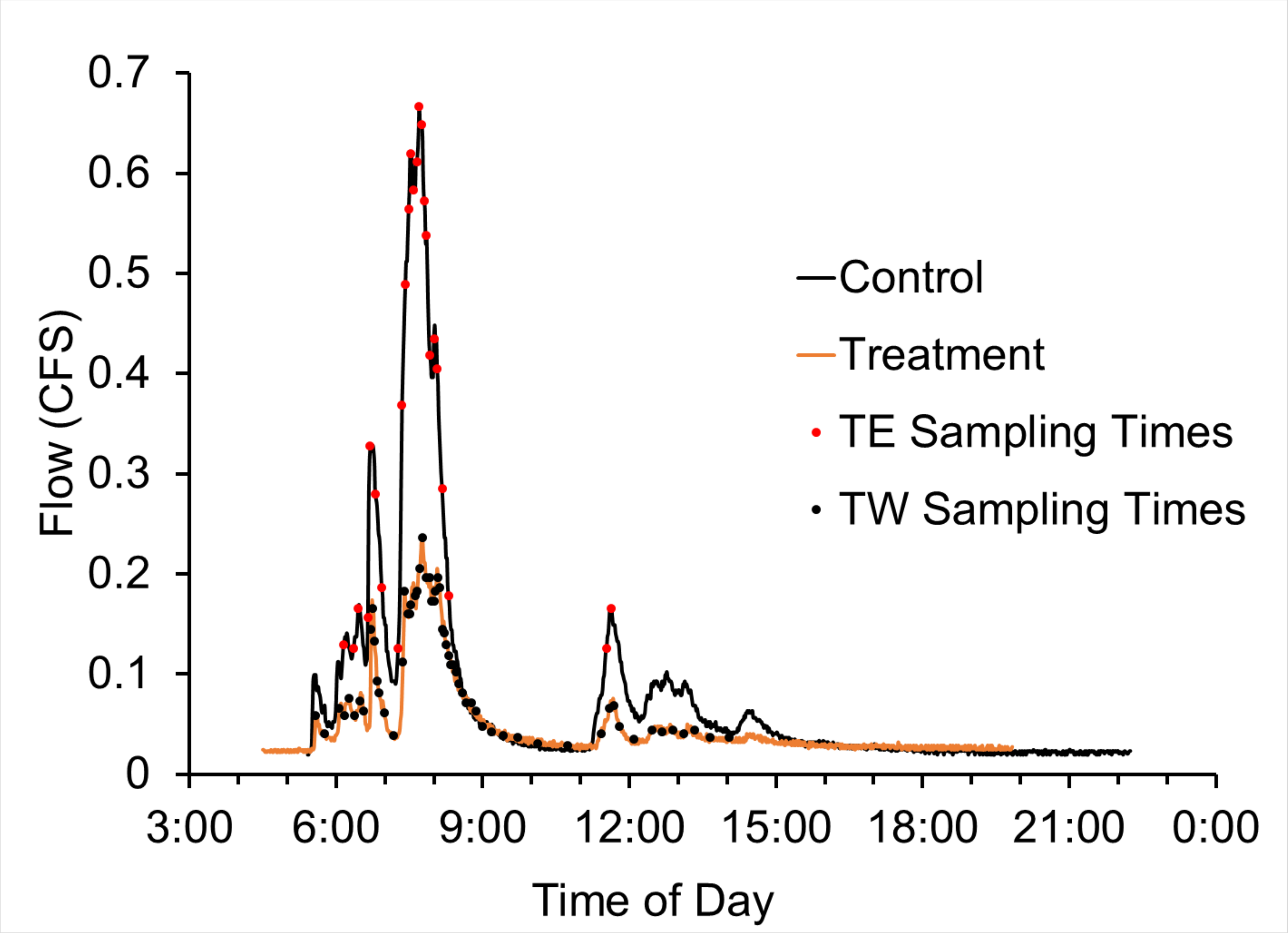
COMPOSITE SAMPLING REGIME



ECOSYSTEM SERVICES: PROVISIONING

- **Assumptions**
  - **Runoff percentage**
  - **Roof percent drainage**
  - **Precipitation events > 0.24 inches completely filled the rain barrels**
  - **Precipitation events < 0.24 inches partially filled the rain barrels**
  - **Residents used the captured water**
- Steps
  - Determine quantity and size present
  - Determine percent of roof draining into rain barrels
  - Calculate event magnitude and frequency
  - Determine value/gallon of potable water
  - Calculate values of rain barrels (USD Household^{-1} Year^{-1})

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ECOSYSTEM SERVICES: FLOOD ATTENUATION

- **Assumptions**
  - **Stormwater pond optimally sized and designed**
  - **All stormwater was converted into runoff**
  - **Operation and maintenance cost was 4 percent of the capital cost**
  - **Design parameters: HRT and Depth**

Step	Task
1	Total discharge rate difference
2	Design storm and subsequent design for event
3	HRT assumption
4	Depth assumption
5	Calculate pond volume
6	Input into cost equations
7	Calculate surface area required
8	Determine land costs
9	Calculate construction costs
10	Calculate operation and maintenance costs

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ECOSYSTEM SERVICES: NUTRIENT RETENTION

- **Assumptions**
  - **No costs incurred besides LID BMP costs**
  - **Cost data provided by Coffman (2014)**
  - **Two laborers and one supervisor**
  - **37 days for installation**
  - **Revenue generated was constant for study duration**
  - **Only two sources of revenue exist**
- Steps
  - Determine discount rates
  - Calculate the net present value
  - Calculate the annuity rate
  - Calculate the equivalent annual cost
  - Calculate cost effectiveness (USD $Year^{-1}$ one percent $change^{-1}$ and X percent change $Year^{-1}$ USD^{-1})

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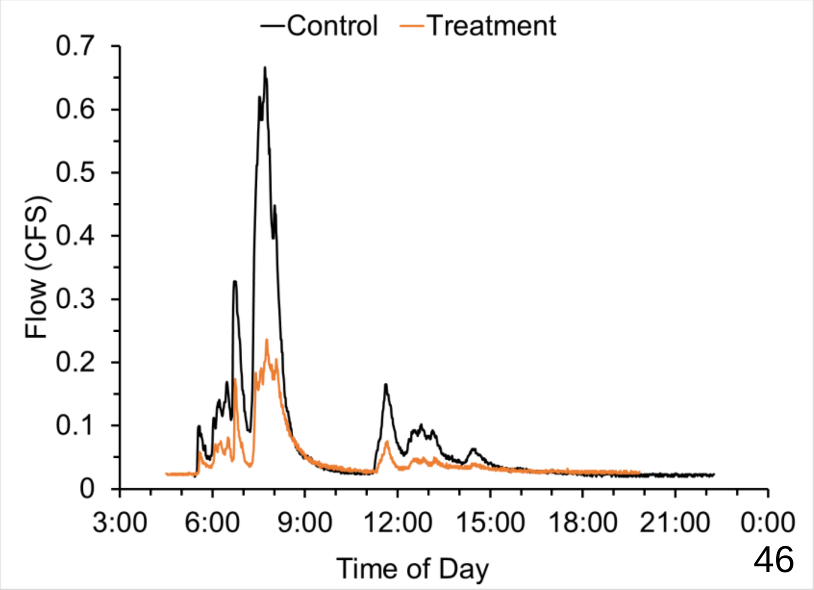
- **Steps**
  - **Determine discount rates**
  - **Calculate the net present value**
  - **Calculate the annuity rate**
  - **Calculate the equivalent annual cost**
  - **Calculate cost effectiveness (USD Year^{-1} one percent change^{-1} and X percent change Year^{-1} USD^{-1})**

RESULTS AND DISCUSSION: WATER QUANTITY AND QUALITY

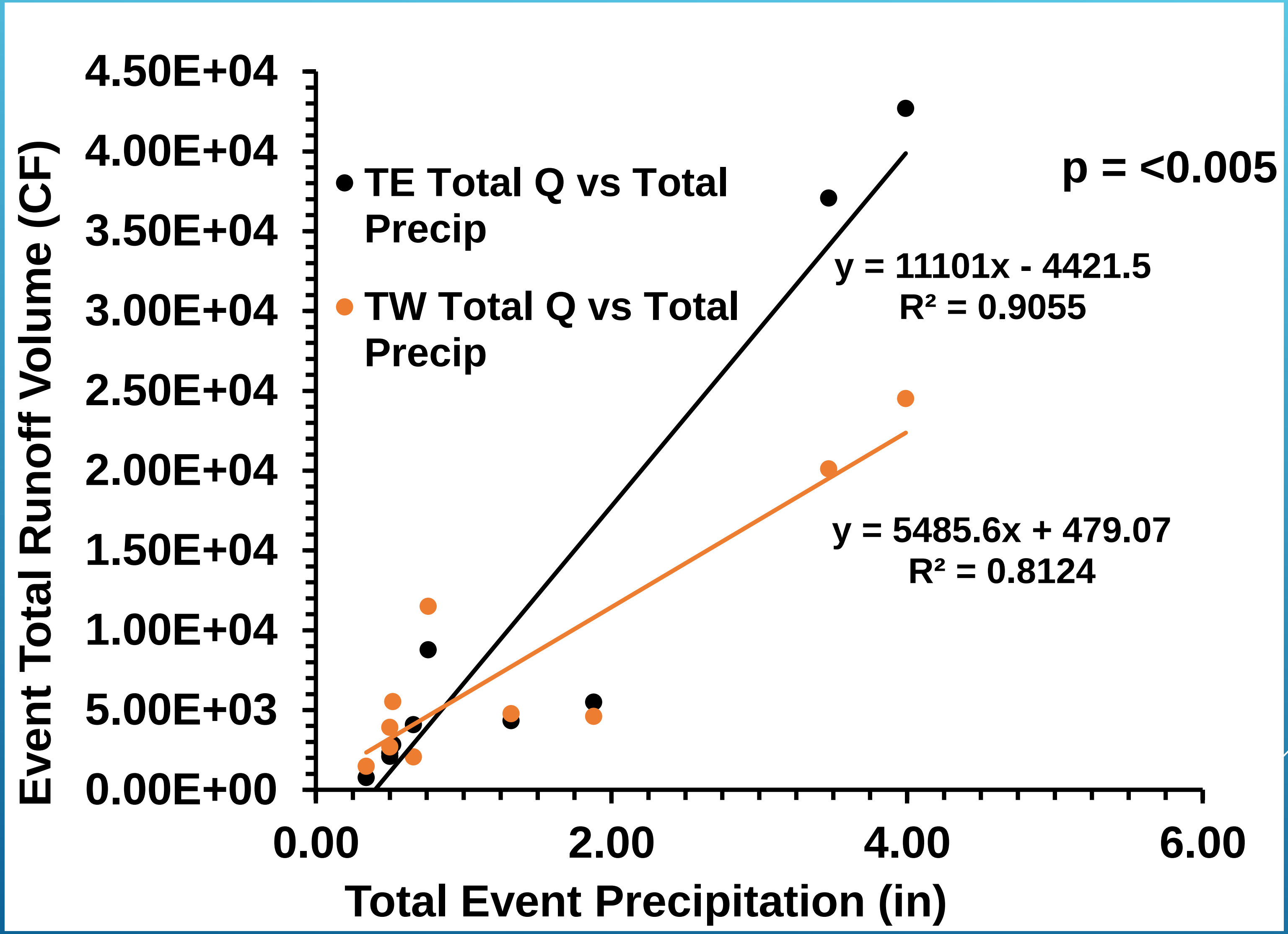


SUMMARIZED RESULTS

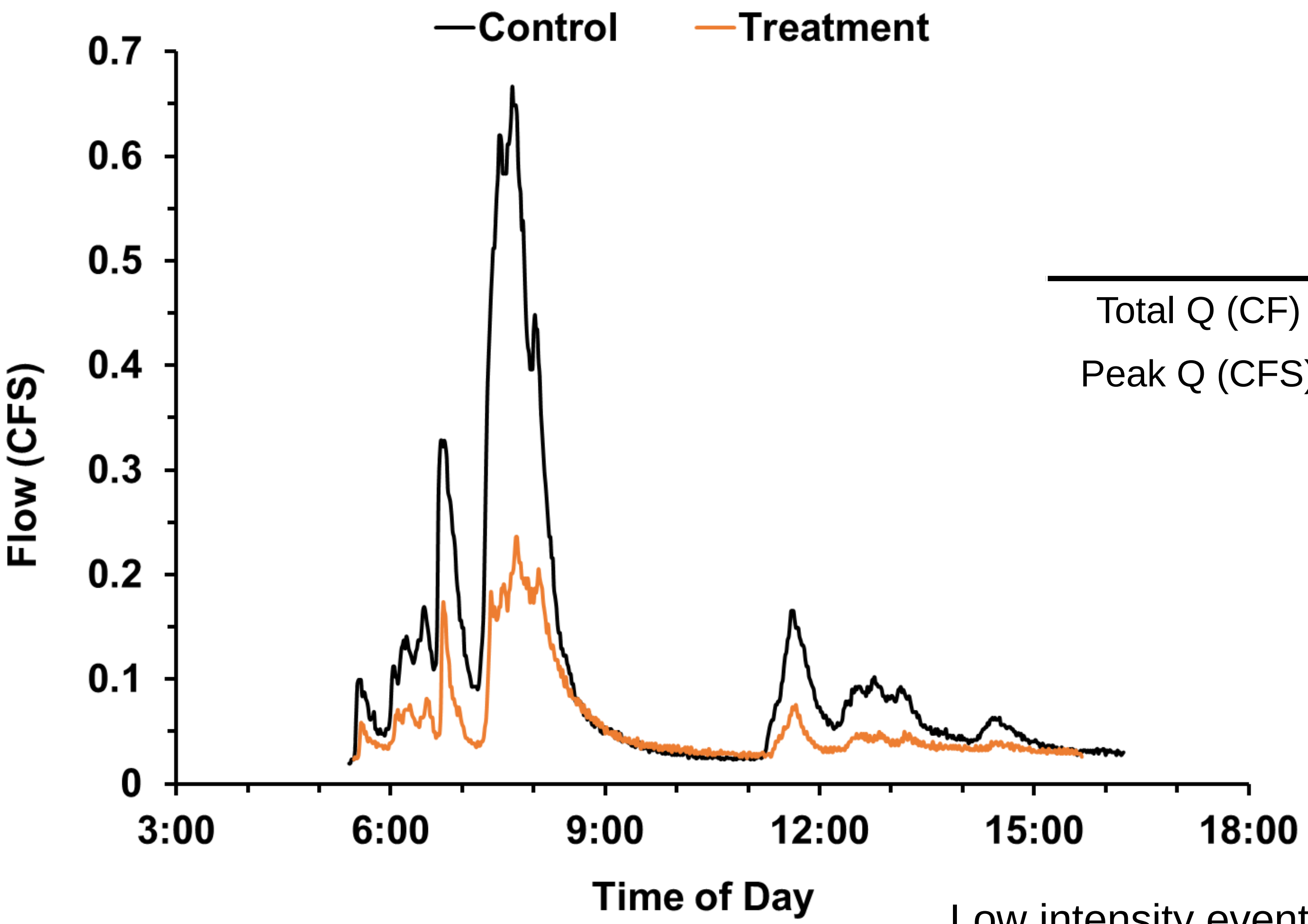
Precipitation Data	
# of events	10
Study period	05/22-09/20 2015
Precipitation magnitude Ranges	0.34-3.99 inches (mean = 1.39)
Precipitation intensity ranges	0.48-2.64 inches hour^{-1} (mean = 1.31)
2014 total precipitation	21.63 inches
05/2015 total precipitation	23.39 inches
2015 total precipitation	63.22 inches
Norman Mesonet station average	34.67 inches

	Total Runoff Volume (CF)		**Peak Discharge Rate (CFS)**	
	TE (Control)	TW(Treatment)	TE (Control)	TW (Treatment)
Mean	11053	8126	2.62	1.38
Median	4217	4700	0.80	0.67
Maximum	42700	24500	9.93	5.13
Minimum	775	1500	0.36	0.23

RELATIONSHIP BETWEEN PRECIPITATION AND DISCHARGE



TOTAL RUNOFF VOLUMES AND PEAK DISCHARGE RATES WERE DIFFERENT

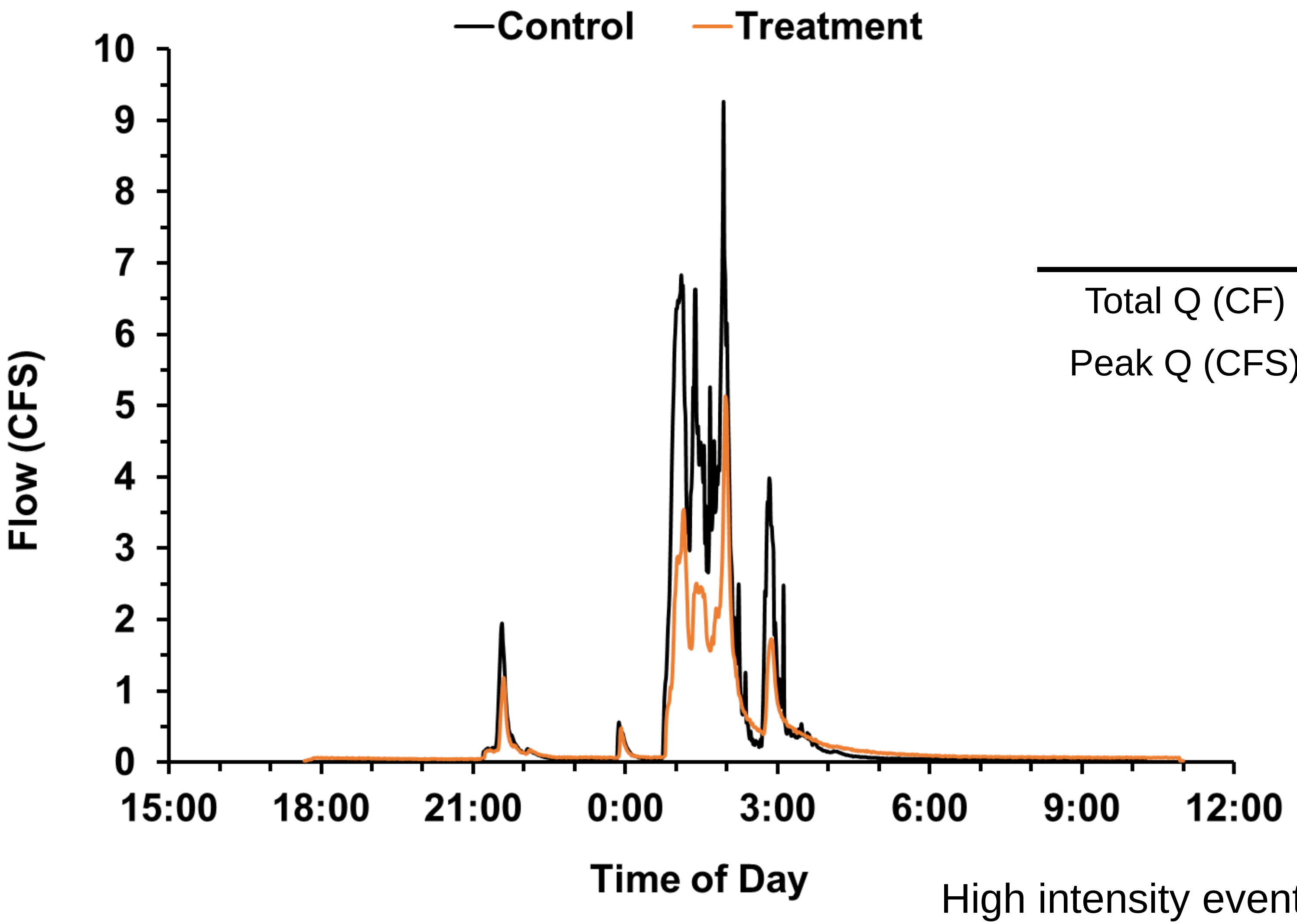


Total precip. = 0.66 inches
Max intensity = 0.48 inches hr^{-1}

	Control	Treatment	% Difference
Total Q (CF)	4093	2078	49
Peak Q (CFS)	0.67	0.24	65

Low intensity event

TOTAL RUNOFF VOLUMES AND PEAK DISCHARGE RATES WERE DIFFERENT

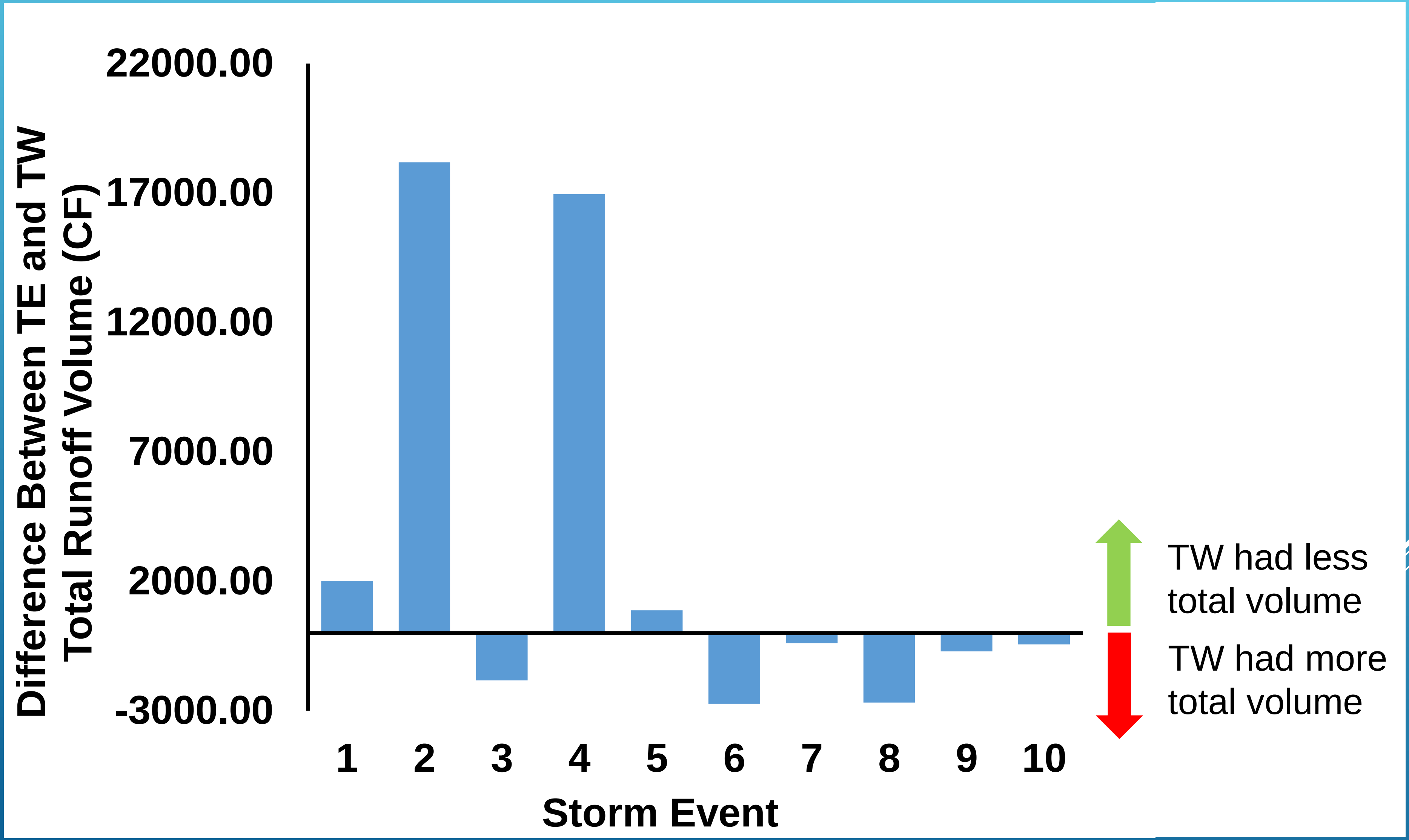


Total precip. = 3.47 inches
Max intensity = 2.64 inches hr^{-1}

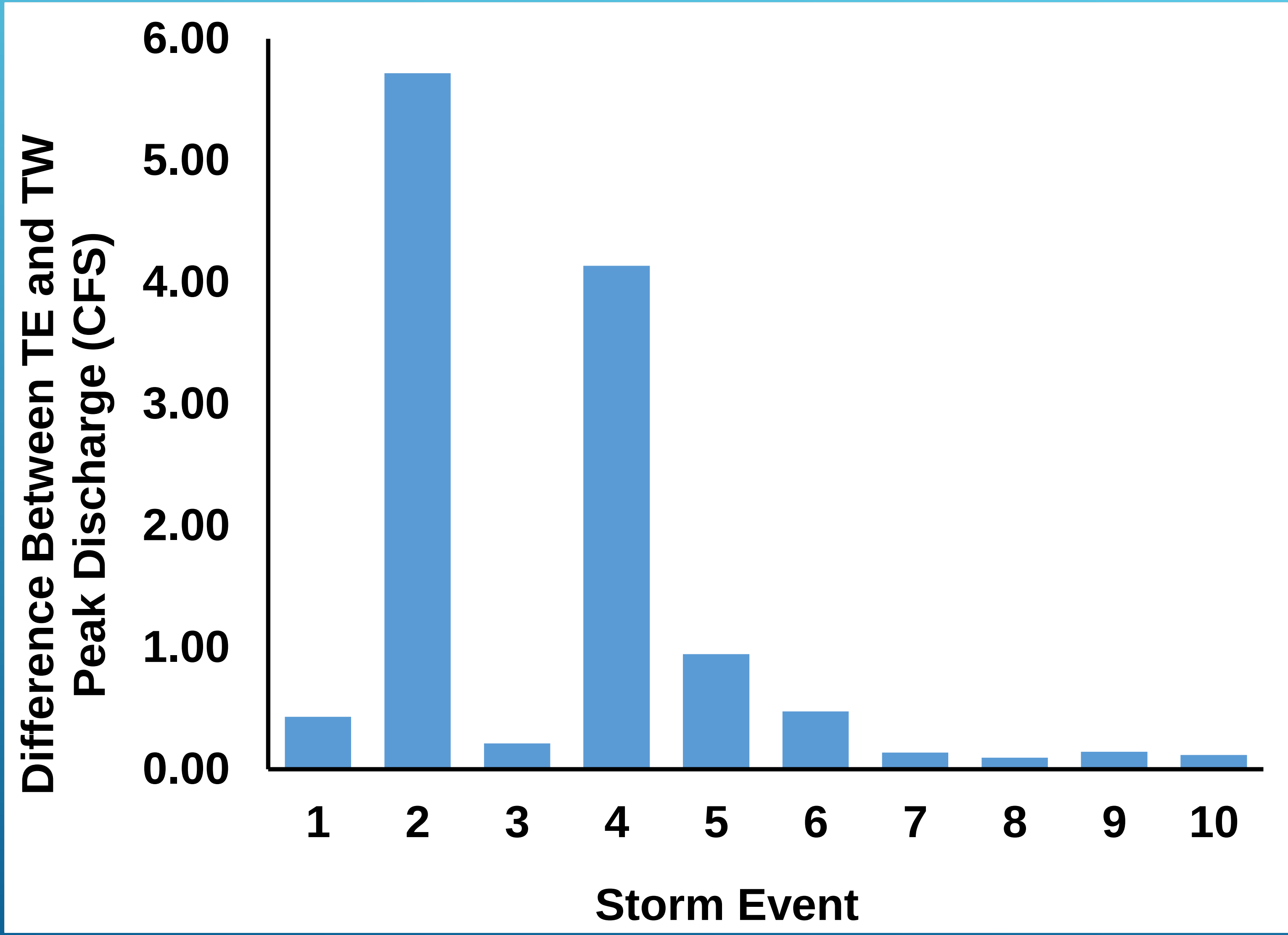
	Control	Treatment	% Difference
Total Q (CF)	37079	20119	46
Peak Q (CFS)	9.26	5.13	45

High intensity event

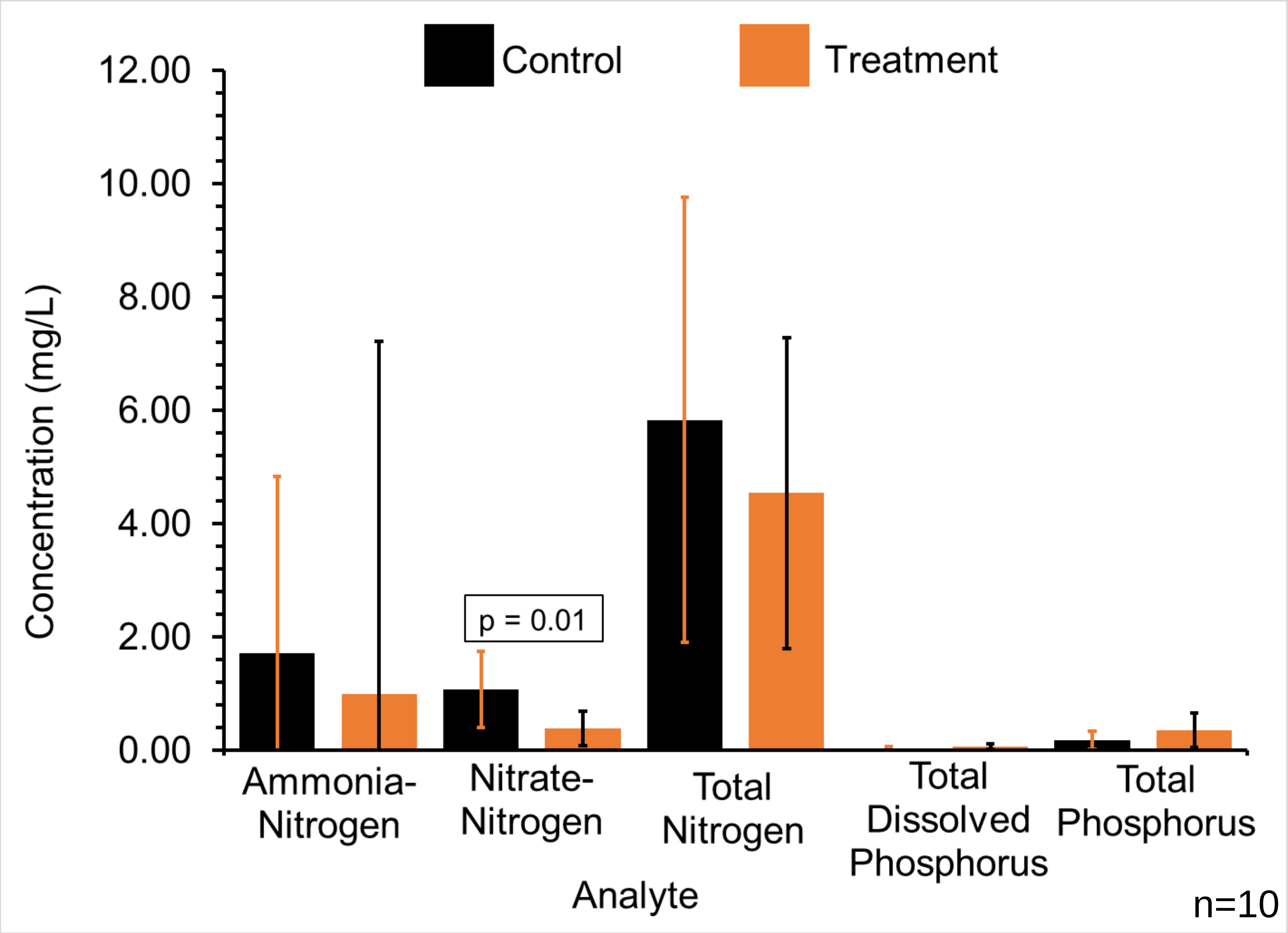
TOTAL RUNOFF VOLUME DIFFERENCES



PEAK DISCHARGE DIFFERENCES



NUTRIENT CONCENTRATIONS WERE DIFFERENT



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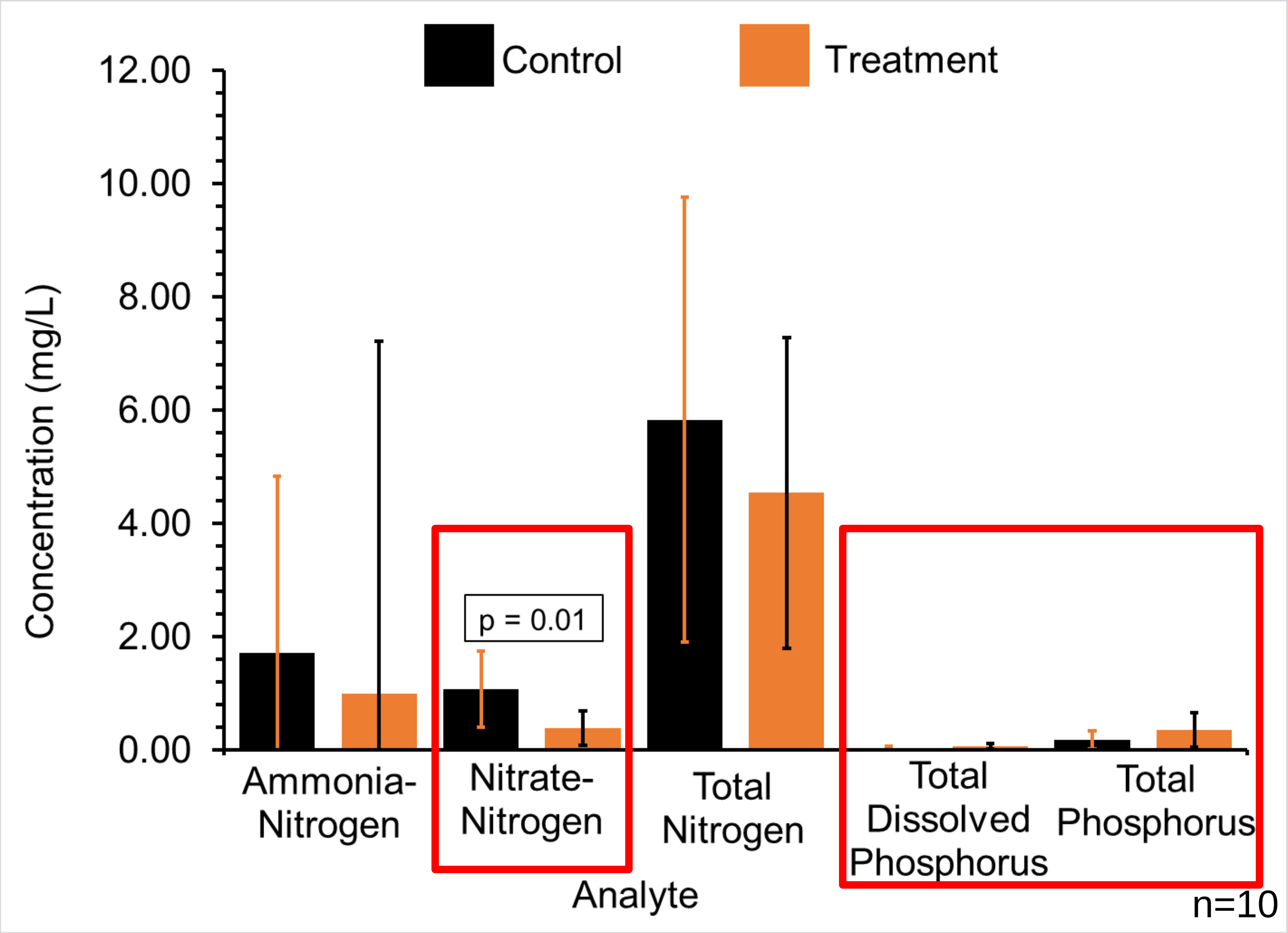
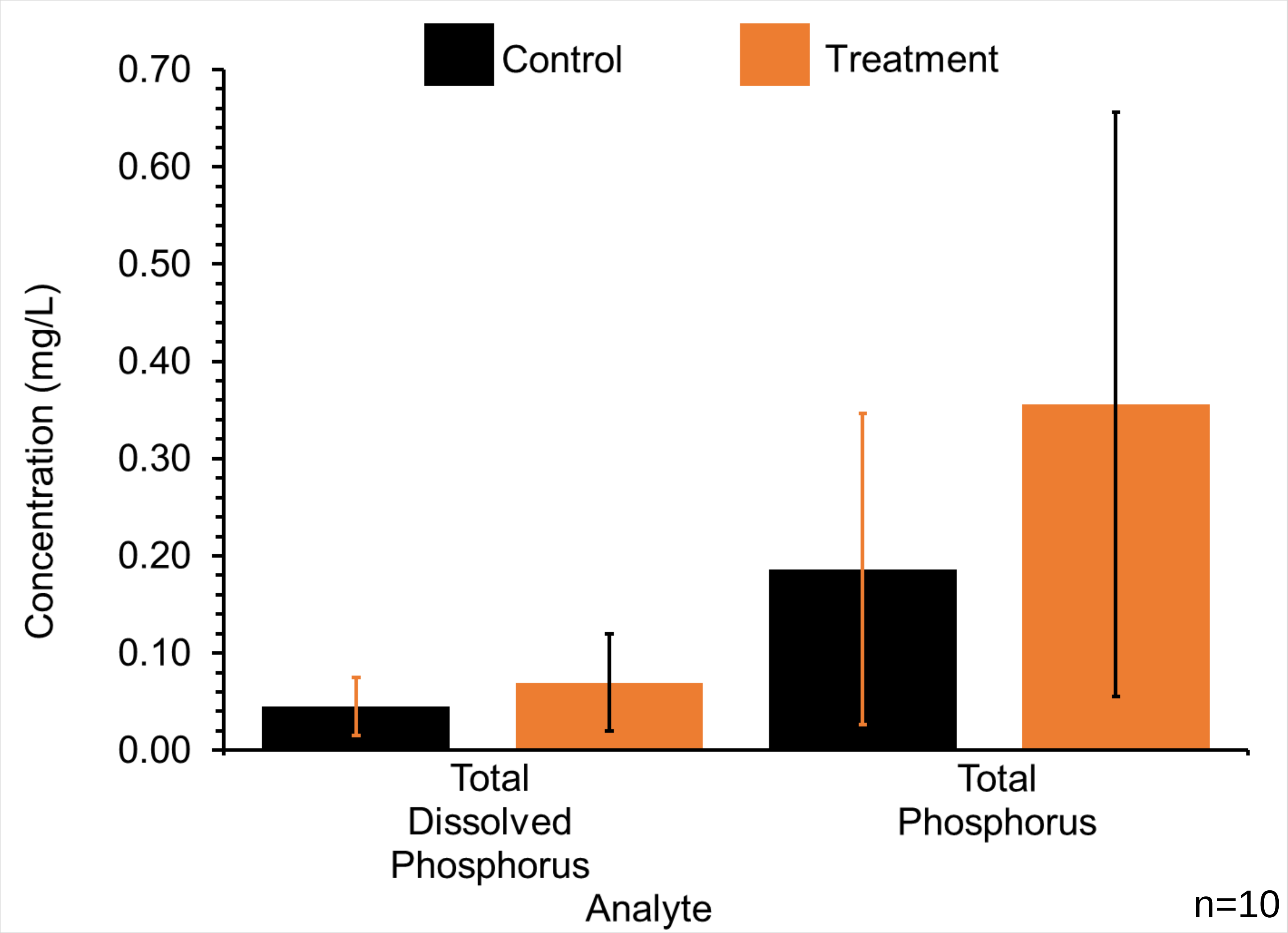
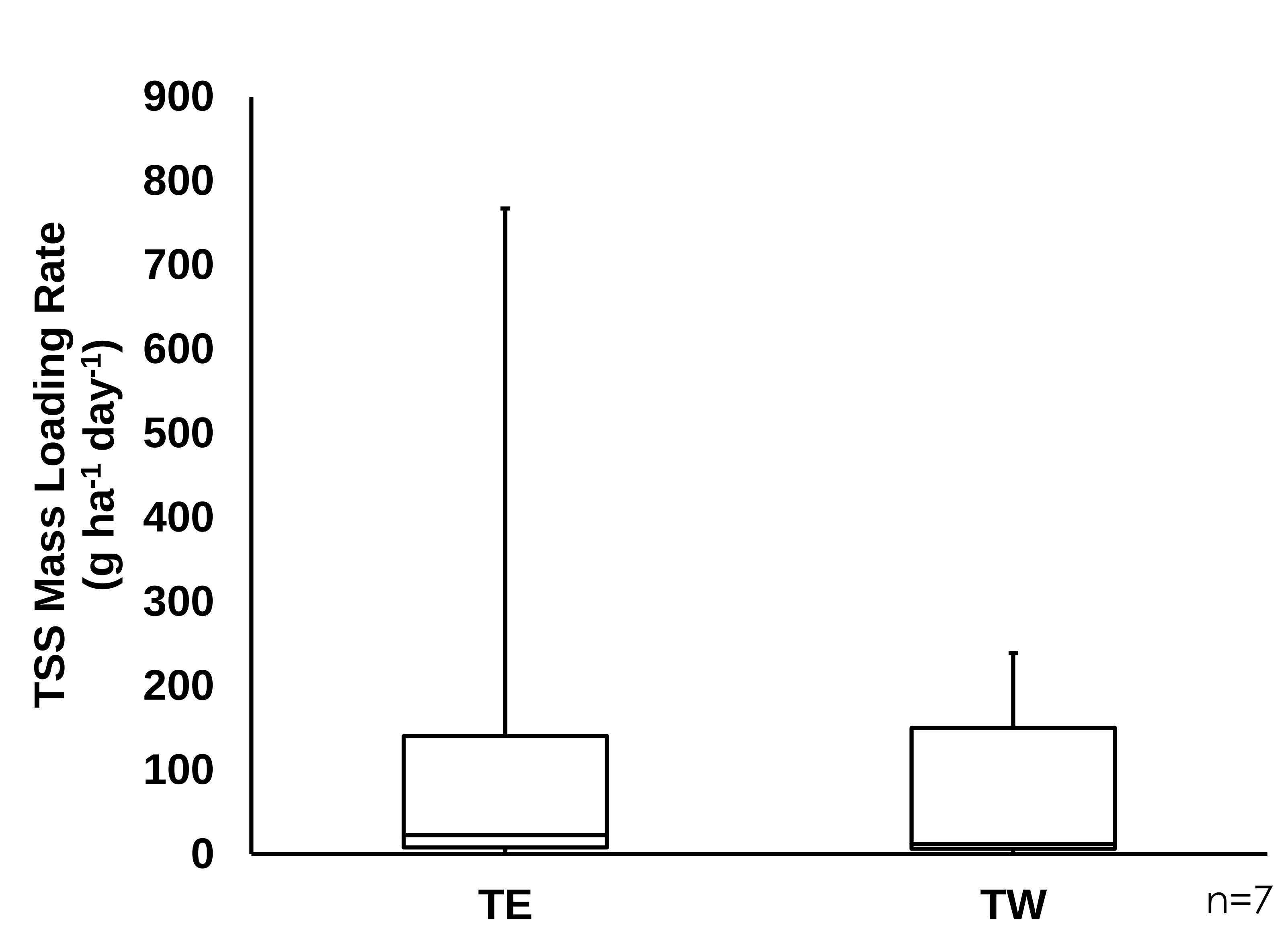


PHOSPHORUS CONCENTRATIONS WERE HIGHER

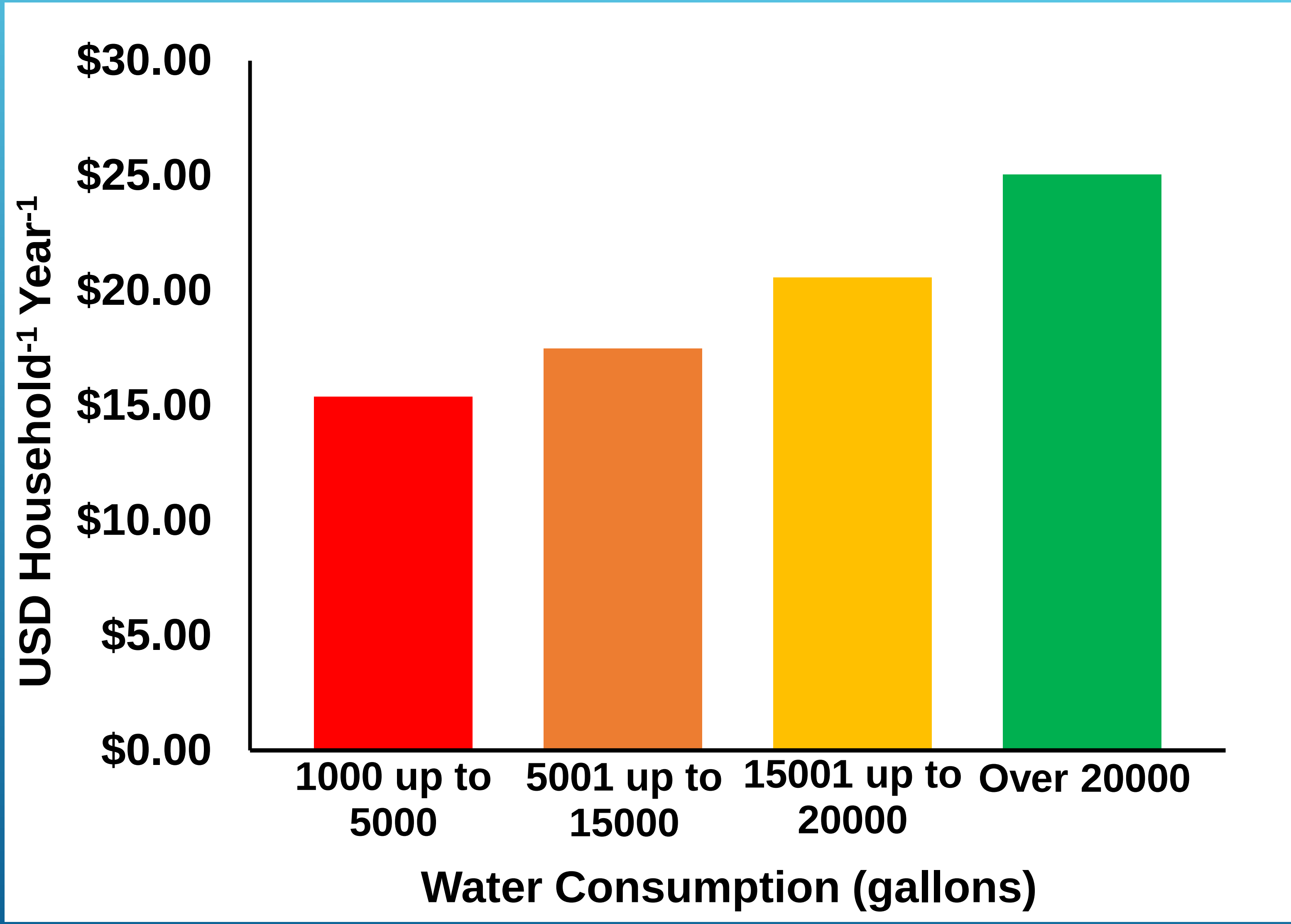


MASS LOADING RATES TRACKED CONCENTRATIONS

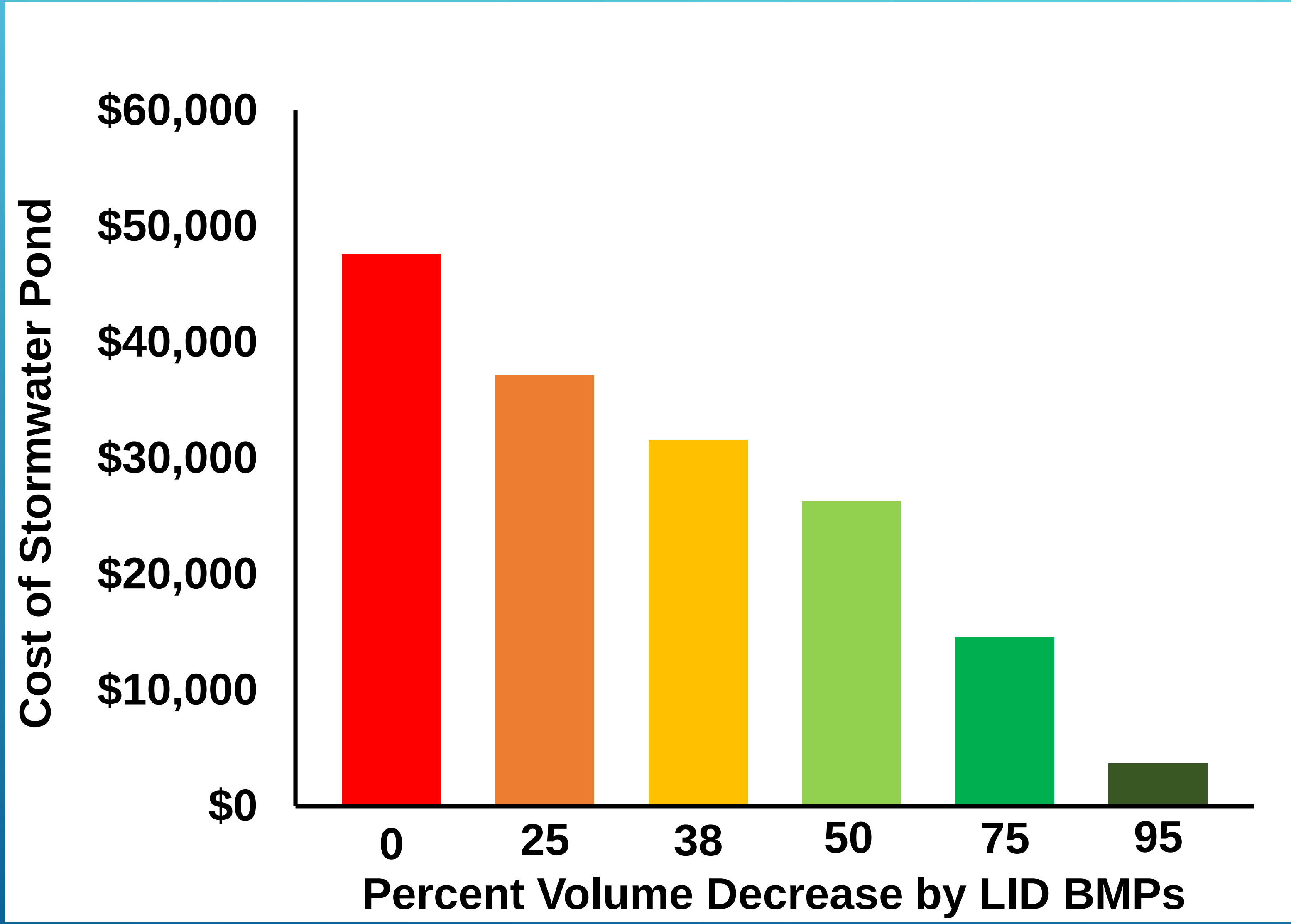


RESULTS AND DISCUSSION: ECOSYSTEM SERVICES

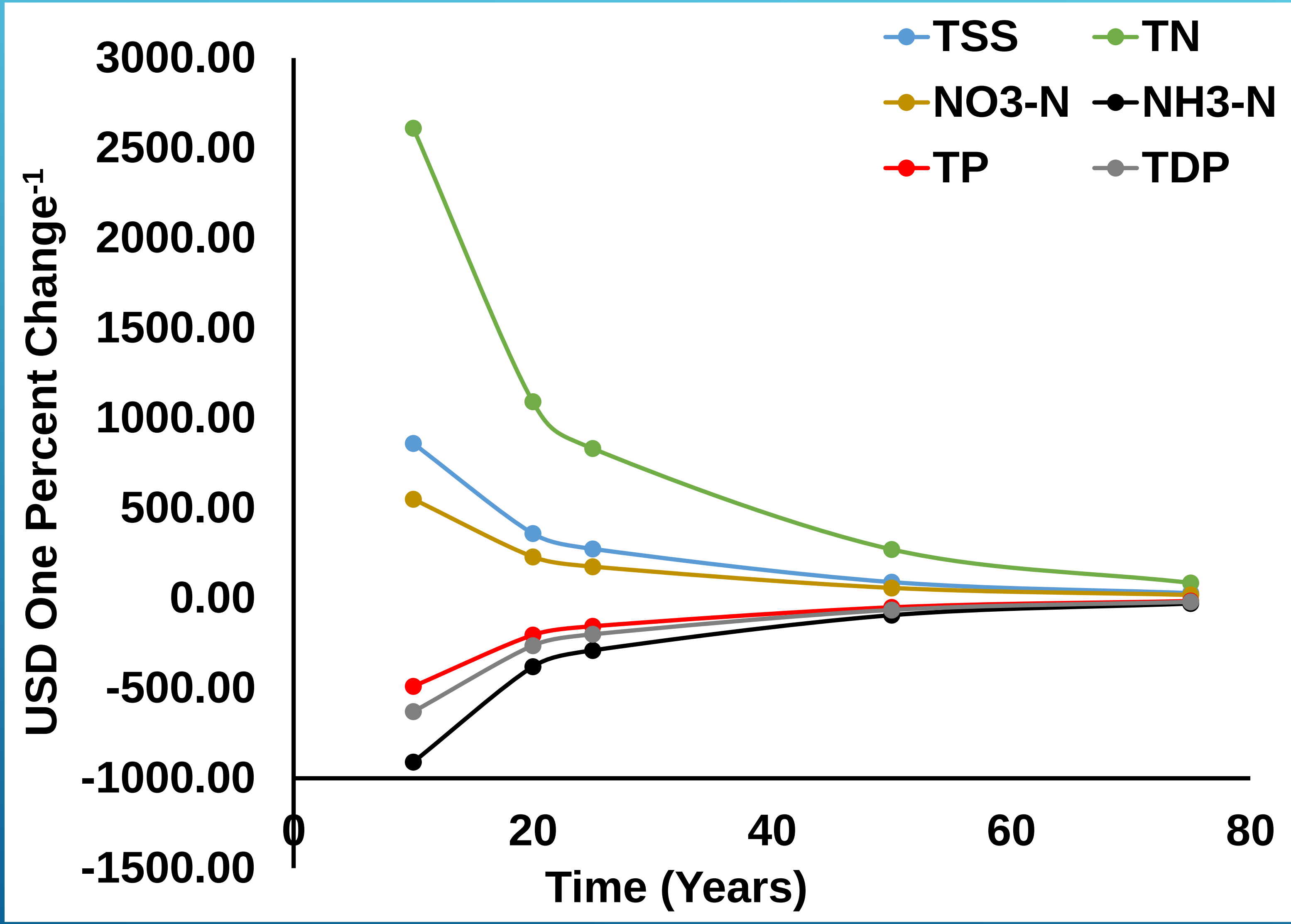
VALUE WAS PROVIDED BY RAIN BARRELS



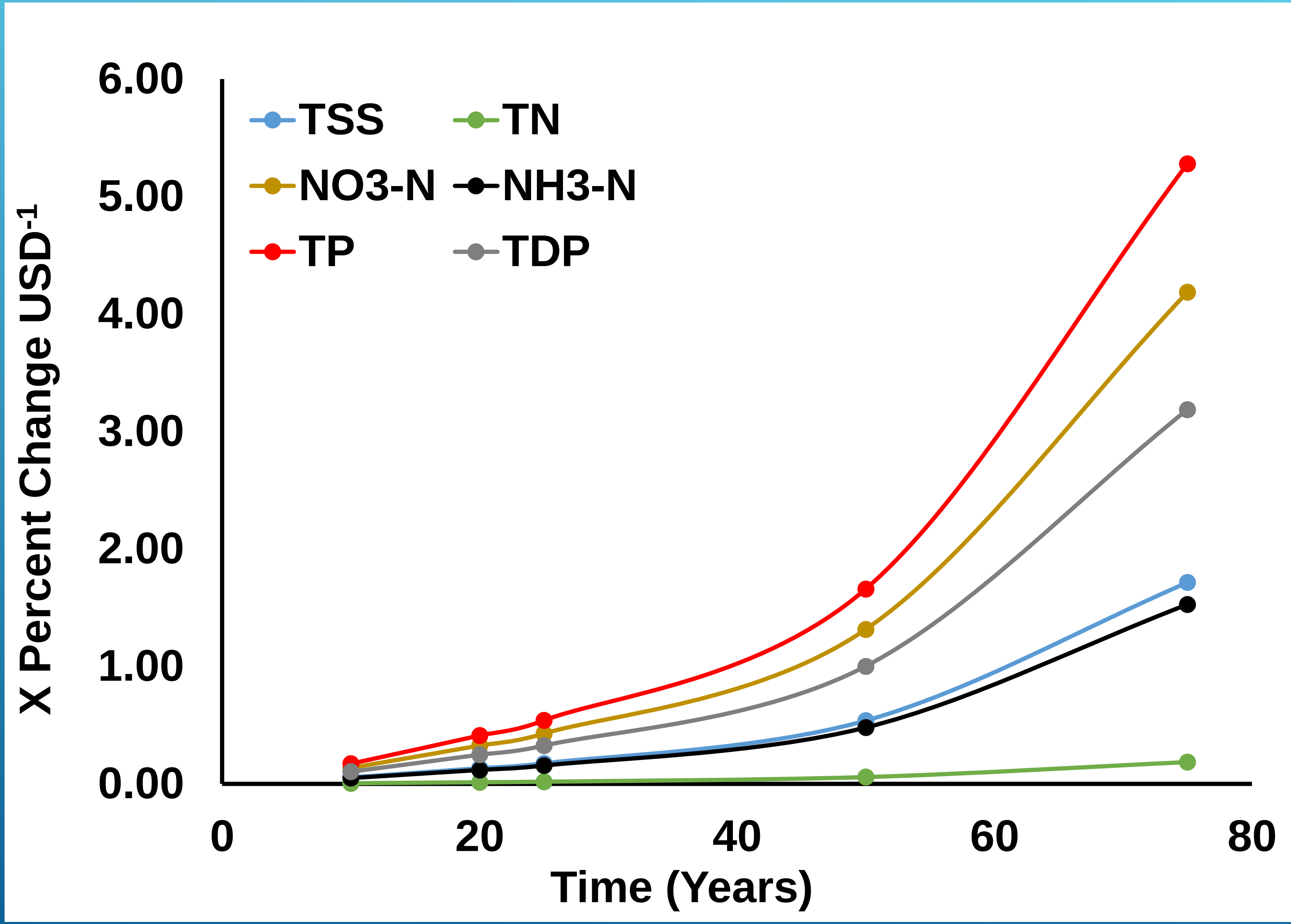
LID BMPS PROVIDED VALUE THROUGH FLOOD ATTENUATION



NUTRIENT RETENTION AS A MONETARY METRIC (USD YEAR^{-1} ONE PERCENT CHANGE^{-1})



NUTRIENT RETENTION AS A MONETARY METRIC (X PERCENT CHANGE YEAR^{-1} USD^{-1})



CONCLUSIONS

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- **LID BMPs significantly decreased peak discharge rates ($p = 0.040$), when comparing TE (Control) to TW (Treatment)**
- Total runoff volumes showed no significant differences between the two sub-basins even though 25 percent less water passed through TW (Treatment) compared to TE (Control)
- Nitrate-nitrogen concentrations were significantly different ($p = 0.01$) between sub-basins
- Ecosystem services provided by LID BMPs did provide the TW (Treatment) sub-basin with long term economic benefits which over time could outweigh the capital costs of construction
- In conclusion, the data collected represent a highly variable manmade system in which LID BMPs do provide beneficial water quantity and quality functions, as well as economic alternatives to traditional stormwater management

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ACKNOWLEDGEMENTS

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- **I would like to thank Heather Kohl, Kathy Schweitzer, and Shana Wild for their moral support as I progressed through this project**

QUESTIONS/COMMENTS