Can Traditionally-Sized Green Infrastructure be Used for Flood Control?

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WEFTEC 2021

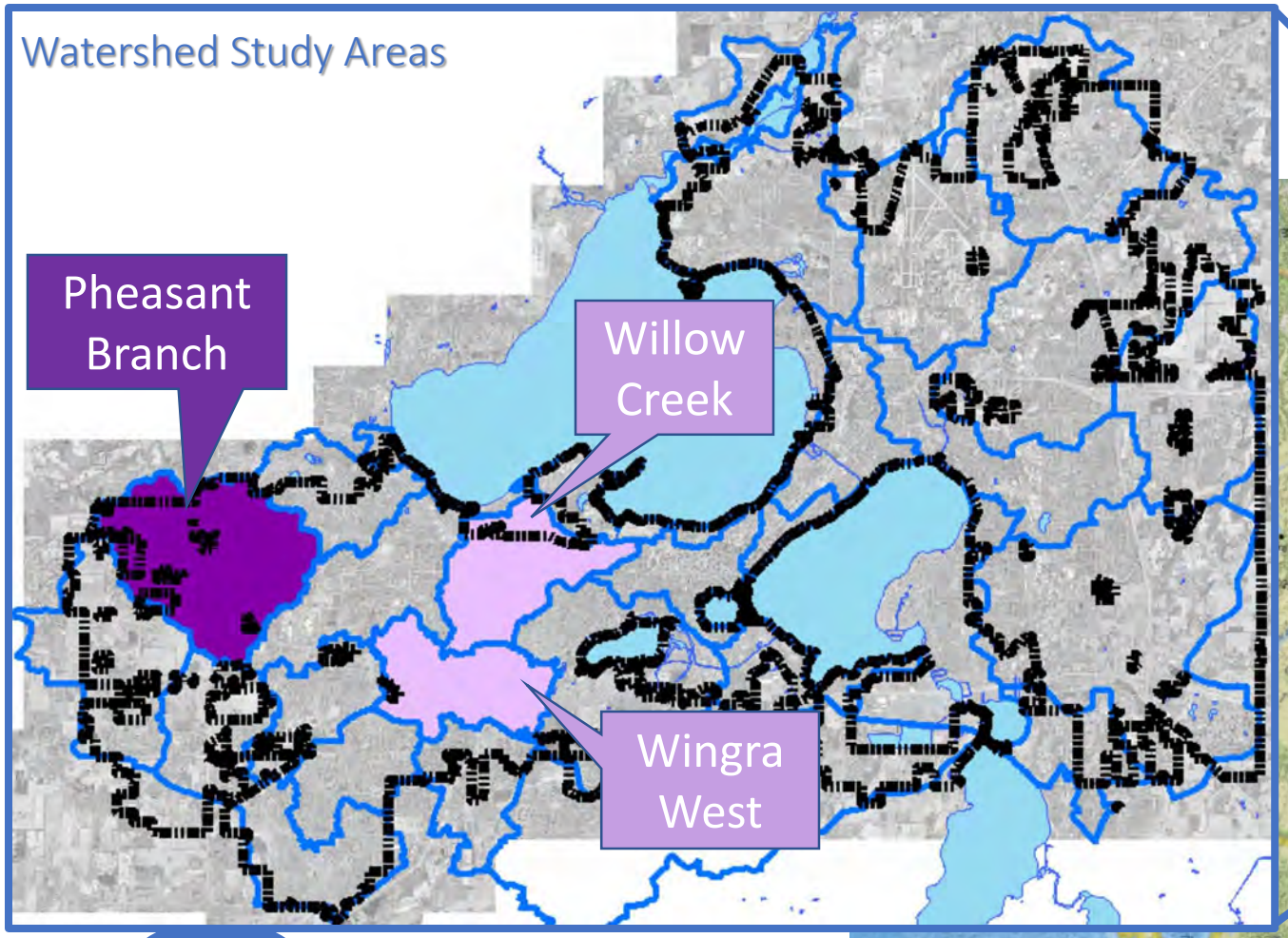
Presentation Outline

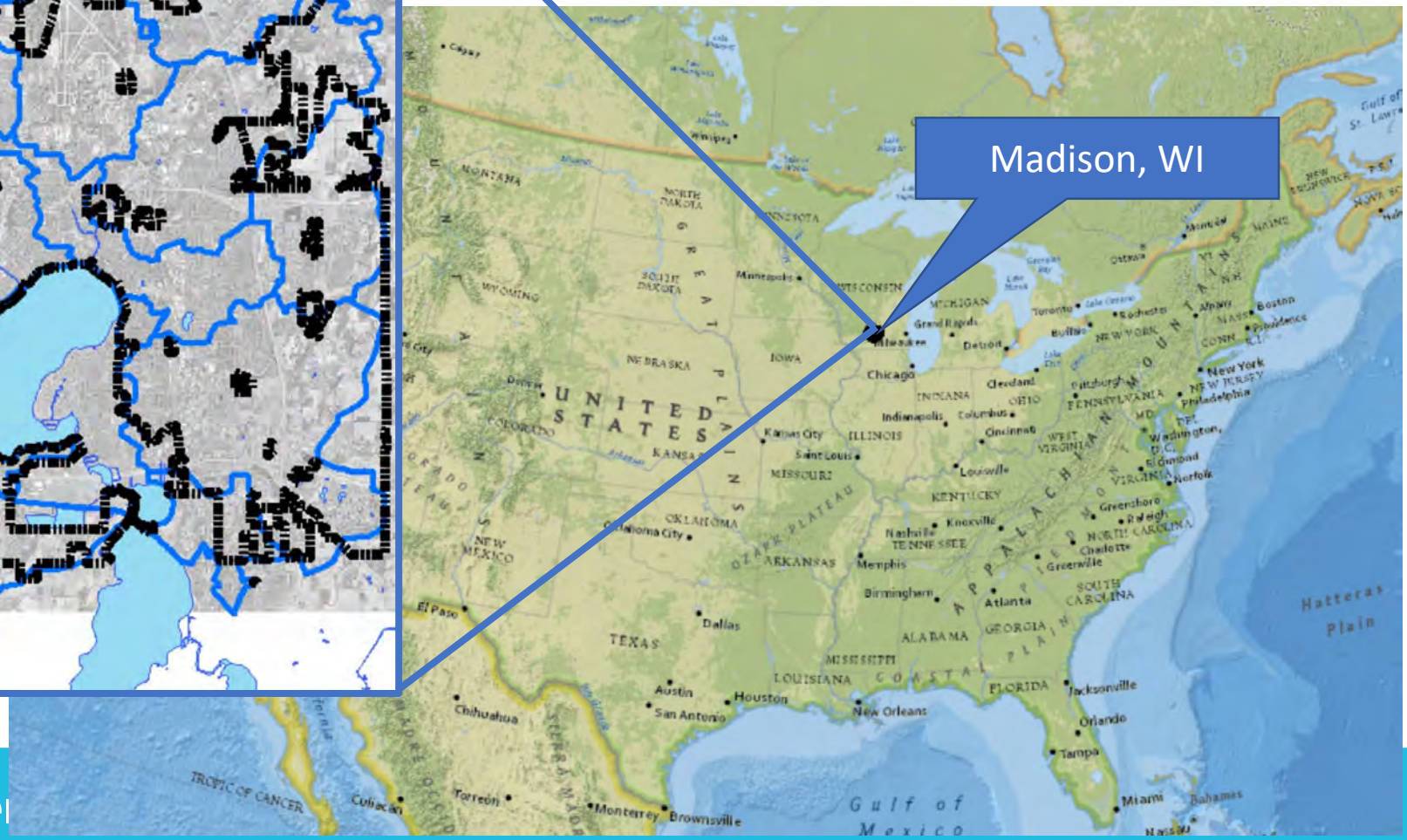
- Purpose
- Analysis Location
- Watershed Study Model Overview
- Phase I
- Phase II
- Grey Infrastructure Reduction
- Cost Estimates
- GI Pilot Study with USGS
- Conclusions and Next Steps

Purpose

- Understand if traditionally-sized green infrastructure can be used to meet flood control targets
- Targets include:
  - No surcharging onto the street during the 10% Chance (10-yr) event
  - Maximum of 0.5′ on the centerline of the road during the 4% Chance (25-yr) event
  - No structure flooding during the 1% Chance (100-yr) event

Project Location



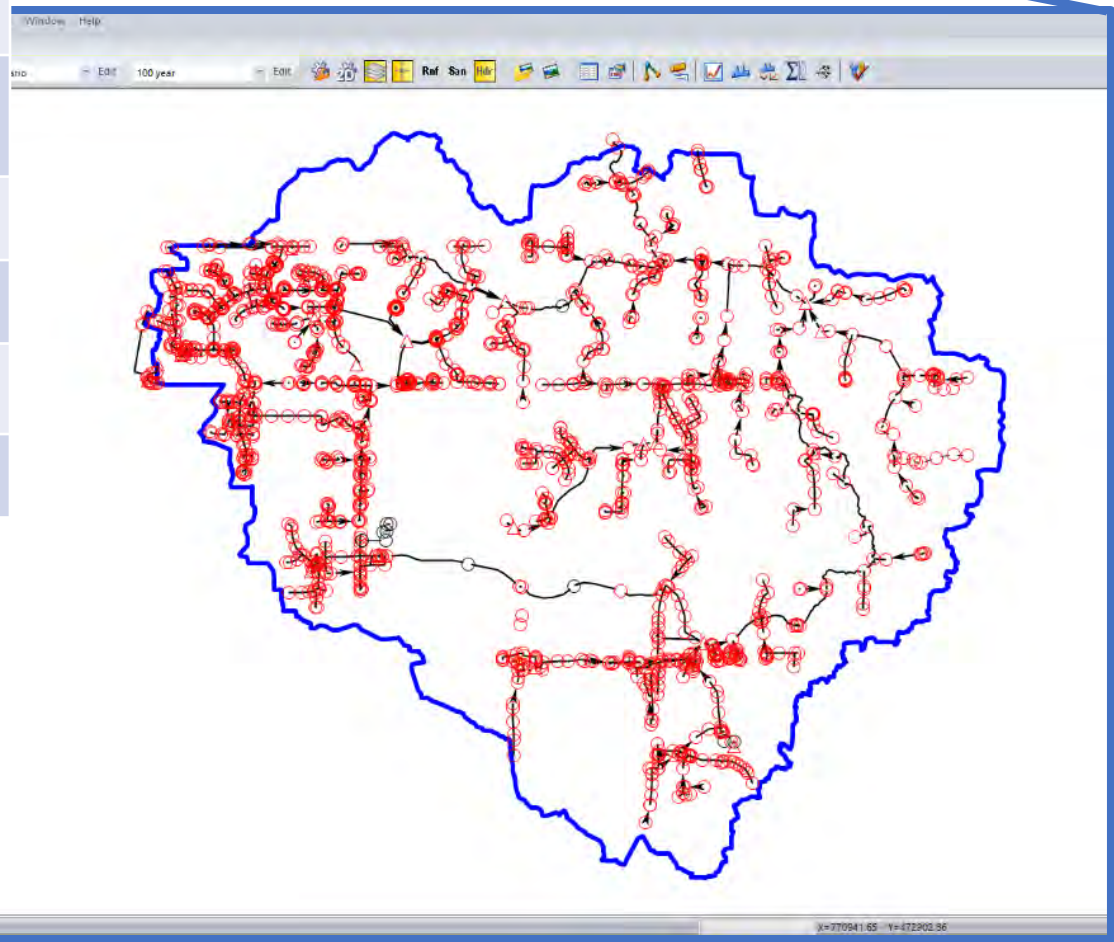


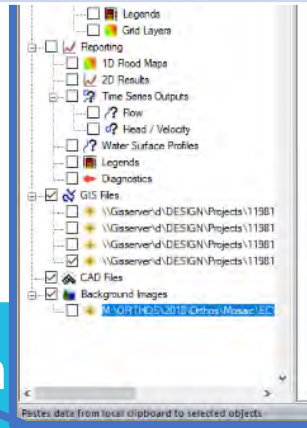
Watershed Study Model Overview

- 1D/2D Computer Modeling Software
  - XP-SWMM or PC-SWMM
  - Pipes and some channels/ponds modeled in 1D
  - Surface overflow, channels/ponds modeled in 2D
- Watersheds ranging from 500 acres to 15,000 acres
- SWMM Hydrology
- Subcatchments Separated Into:
  - Directly Connected Impervious Area (DCIA)
  - Non-Directly Connected Impervious Area (NDCIA)
  - Pervious Area
- Models constructed for purposes of flood analysis – aka – large storms

Pheasant Branch Watershed Study Model

Item	Quantity
Watershed Area (acres)	3,300
Number of Subcatchments (#)	451
Public Stormwater Inlets and Access Structures in Watershed (#)	2,500
Total storm sewer pipes in Watershed (#)	2,200 segments; 31.4 miles
Storm sewer pipes in Model (#; length)	1,452 segments; 27.4 miles
Open channels in Model (#; length)	90 segments; 6.7 miles
Detention Ponds in Model (#)	44

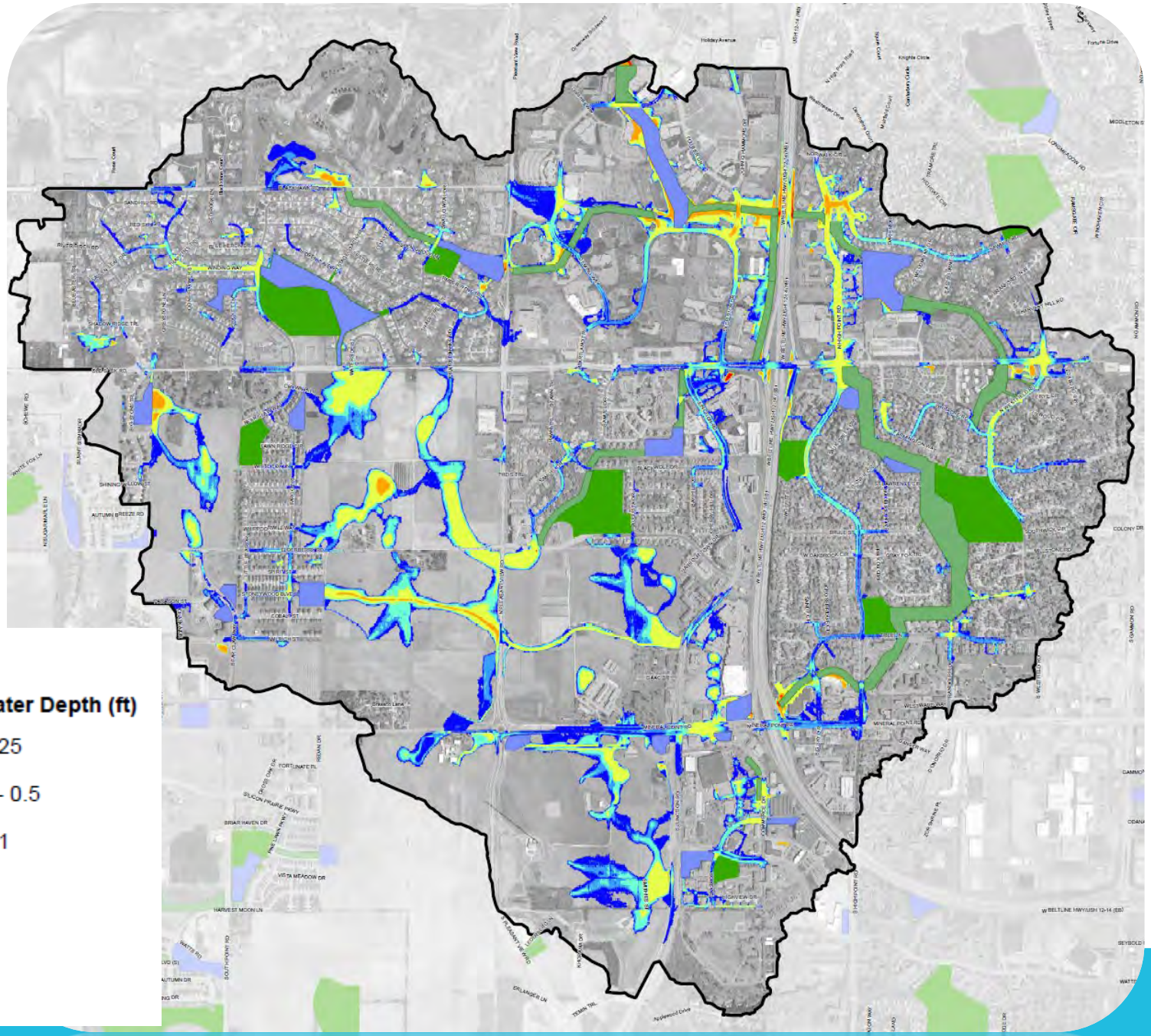




Watershed Study Inundation Mapping

1% Chance (100-yr) Inundation Mapping

Existing Conditions

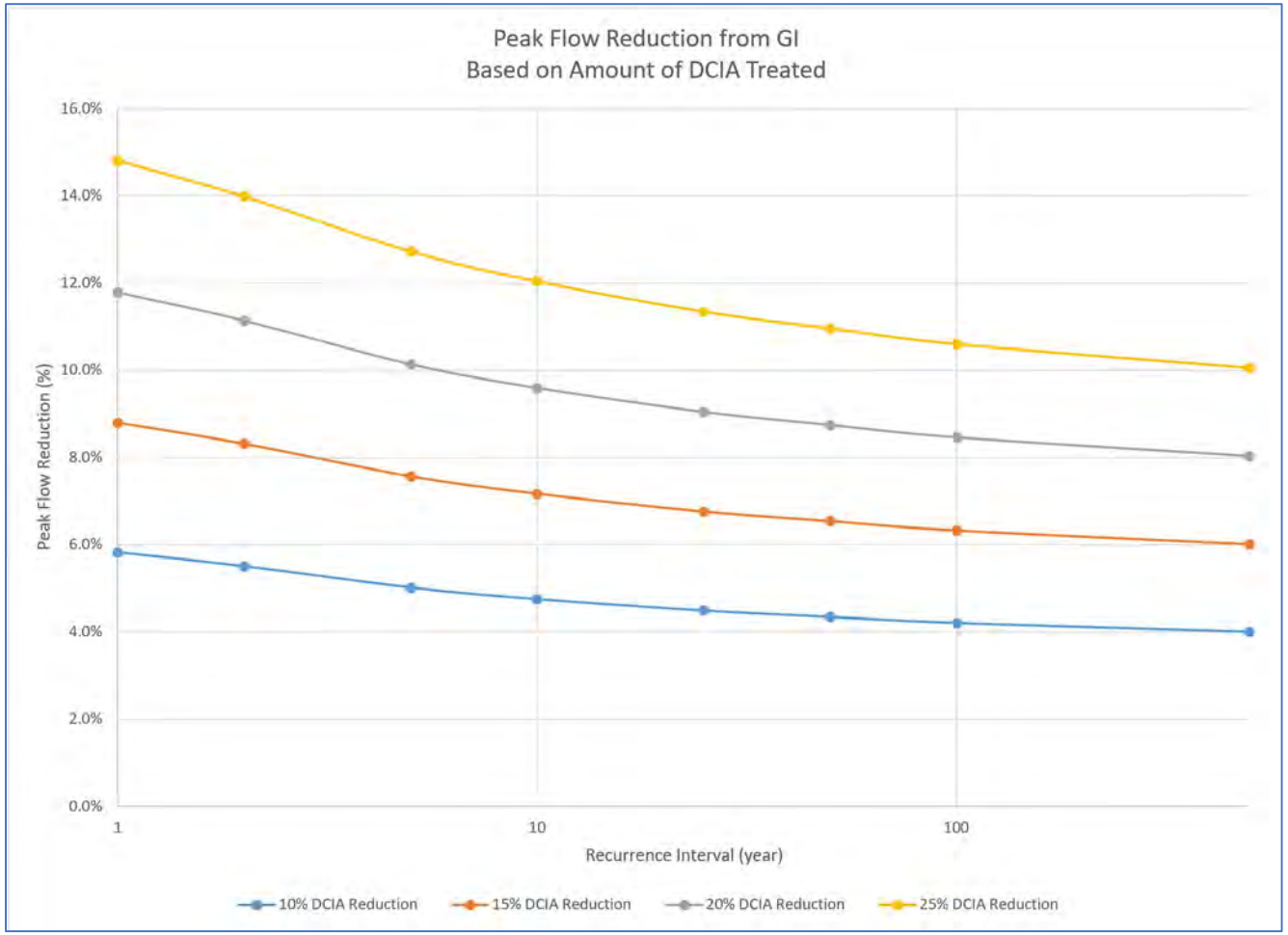


Phase I Analysis

- Purpose: How much flood reduction does traditionally-sized GI provide?
- Traditionally-sized means:
  - Sized for small storm events (100% Chance/1-yr Event)
  - Treating Directly Connected Impervious Area (DCIA)
- GI assumed to be:
  - 2 feet deep
  - 1 foot filled with engineered soil with porosity of 0.3
  - 3-foot buffer to grade into existing grades
  - No underdrain
  - Native soil seepage rate of 0.3 in/hr (Madison generally has silty soils)
  - Area based on needs for treatment

Phase I Analysis

- Evaluated peak flow reduction from treating 10%, 15%, 20%, 25% DCIA
- As expected, peak flow reduction goes down as the storm event size increases
- 1% chance peak flow reduction ranges from 4% to 10.5%



Phase I Analysis

- Chose 25% DCIA Scenario to do further analysis
  - Opportunities analysis revealed pervious land available to treat 25% DCIA
  - Equates to 0.5 inch of runoff
    - Goal Milwaukee Metropolitan Sewerage District is using for its green infrastructure plan
    - Generally represents "first flush" of stormwater runoff
- Would result in approximately 380 lbs of Total Phosphorus (TP) reduction annually

  (City's MS4 Permit Goal is 18,000 lbs TP reduction annually)
- Need total of 45 acres of area to install GI
- Using the unit cost from the City of Madison Pilot Study:
  - Estimated constructed cost: $78,400,000
  - Estimated annual maintenance cost: $5,900,000

Phase I Analysis

- Similar analysis conducted in two watersheds by consultants
  - Willow Creek
  - Wingra West
- Analyses found similar levels of peak flow reductions

Phase II Analysis

- Purpose: How much traditionally-sized GI does it take to achieve the flood control targets?
- Targets not Met in Pheasant Branch Watershed
  - 10% chance event
    - 9.9 out of 52.1lane-miles of streets (19%)
  - 4% chance event
    - 13.1 out of 52.1lane-miles of streets (25%)
  - 1% chance event
    - 118 out of 2,920 structures (4%)
    - 14 out of 14 greenway crossings (100%)

Phase II Analysis

- Increased % DCIA Treatment to 75% and 100%
- Progress towards meeting targets:

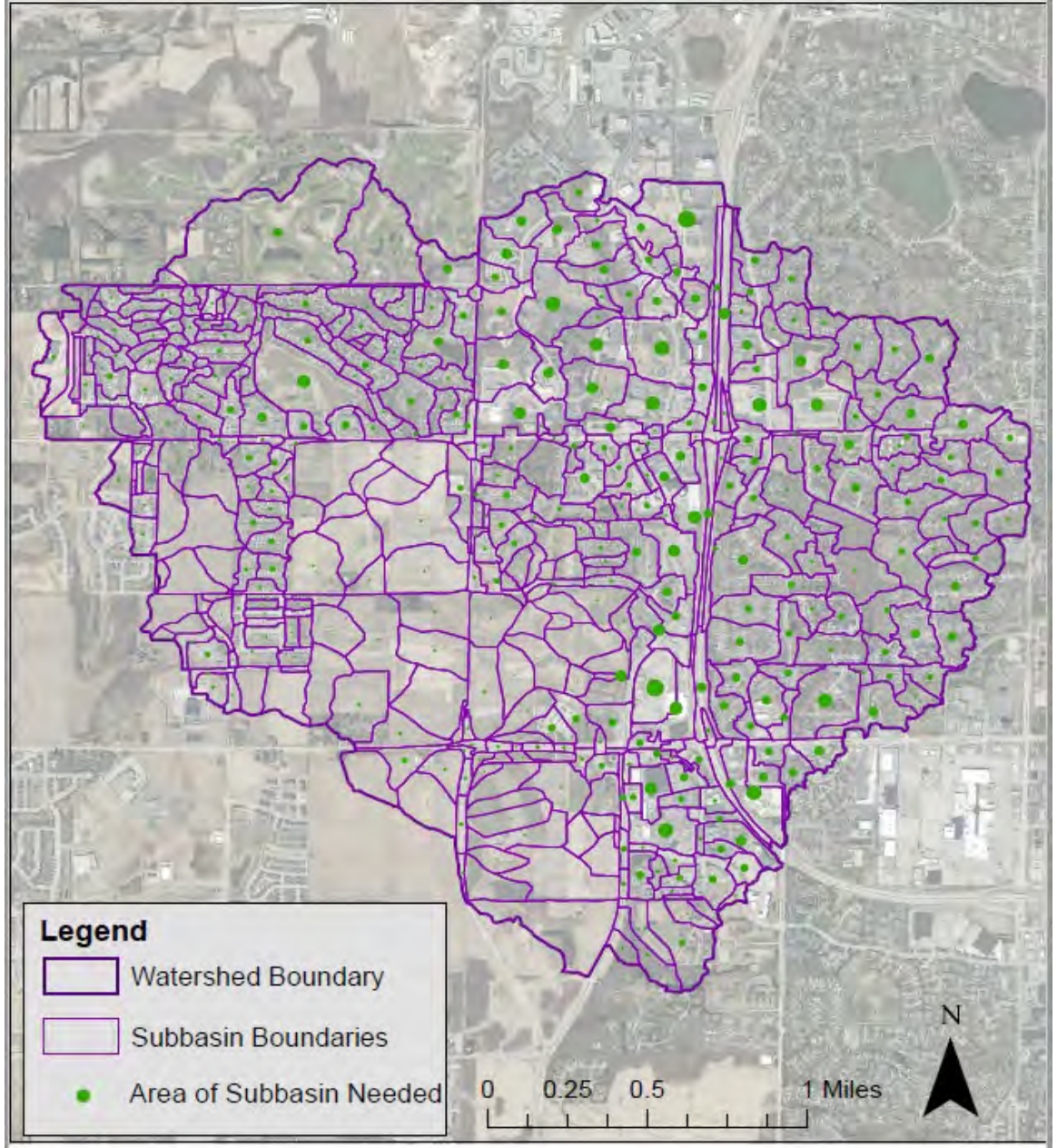
	Street Segments (miles) 10-year Storm Event			Structures (#) 100-year Storm Event		
Total	52.1			2,920		
Scenario	**Flooded**	**Percent**	**Removed**	**Flooded**	**Percent**	**Removed**
Existing Conditions	9.9	19%	N/A	118	4%	N/A
Grey Infrastructure						
Proposed Conditions	1.0	2%	8.9	57	2%	61
Green Infrastructure						
25% DCIA	8.7	17%	1.1	109	4%	9
75% DCIA	5.8	11%	4.1	79	3%	39
100% DCIA	2.3	4%	7.5	51	2%	67
Both Green and Grey	0.5	1%	9.3	15	1%	103

Phase II Analysis

- Opportunities Analysis
  - Do we have the land available to install the GI?
- GIS Exercise
  - Areas removed:
    - Airports
    - Primary building footprints with a 10 foot buffer
    - Accessory building footprints
    - Buffer of 3 feet along parcel boundaries
    - Cemeteries
    - Depth to bedrock < 5’
    - Depth to groundwater < 5’
    - Hydrologic soil group D
    - Open water
    - Landfills
    - Railroads
    - Springs
    - Wellhead protection zone
    - Wetlands
    - Salt routes
    - Arterial and collector streets (0 < function class < 5)
    - Slope > 12 %

Phase II Analysis

- Opportunities Analysis
  - Do we have the land available to install the GI?
- GIS Exercise
  - Yes, there is enough land area



Pheasant Branch Watershed
Area Needed to Treat 75% DCIA

Phase II Analysis

- Area Treated, Cost, Estimated TP Reduction

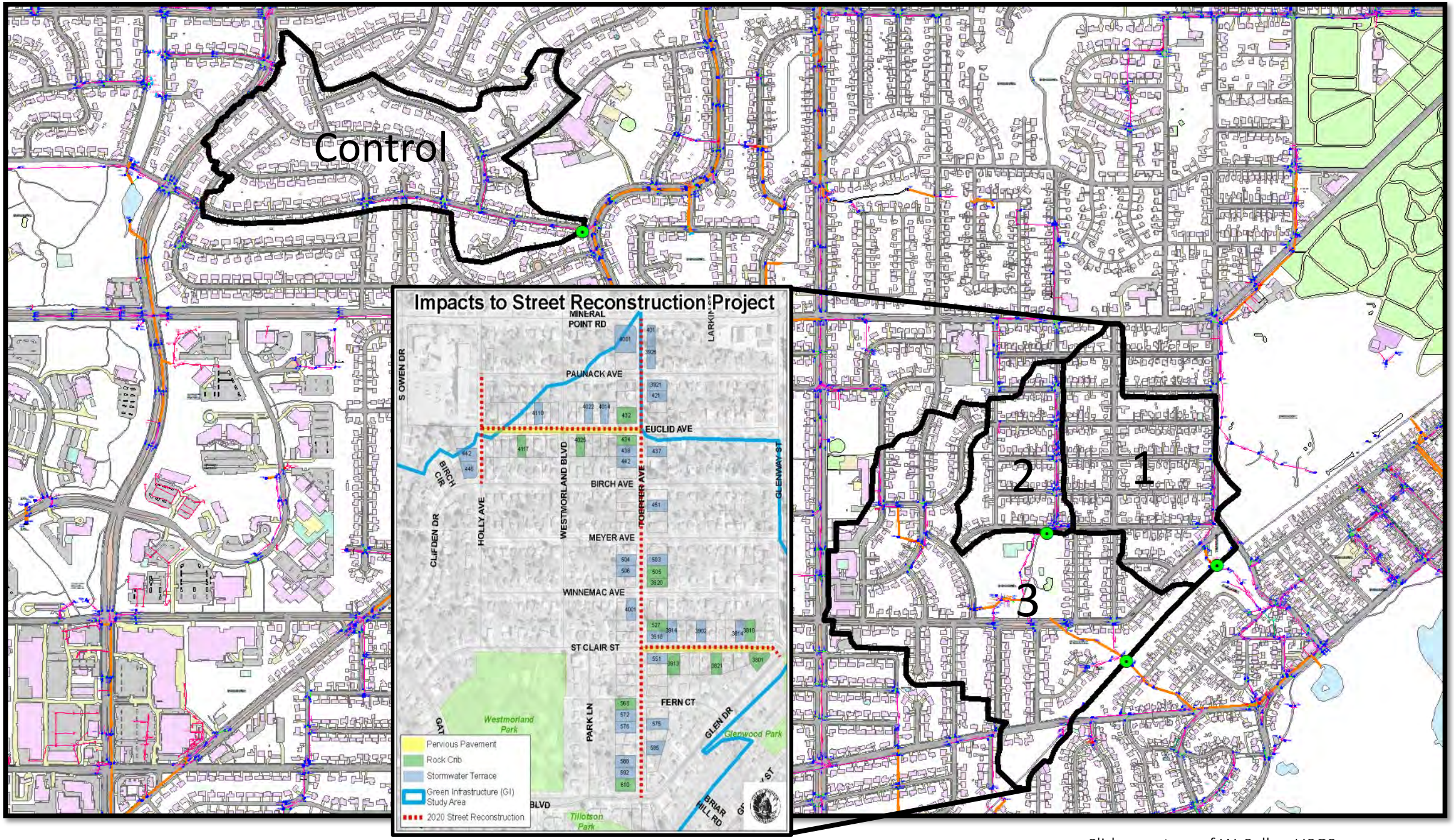
Scenario	Total Impervious Area Treated (acres)	Total Treatment Area (ac)	Estimated VCI Construction Cost ($)	Estimated VCI Maintenance Cost ($/yr)	Estimated TP Reduction (lbs)
25% DCIA Treated	221.4	28	$49,000,000	$3,700,000	382
75% DCIA Treated	664.2	84	$147,100,000	$11,000,000	1,141
100% DCIA Treated	885.6	113	$196,100,000	$14,700,000	1,528

Phase II Analysis

- Install 75% DCIA and downsize proposed grey infrastructure and still meet Proposed Conditions reductions?
- Yes – Can be downsized by 1 size:
  - Circular Pipe – 6-inch diameter reduction
  - Box Culvert – 1-foot by 1-foot reduction
  - Horizontal Elliptical Pipe – 1 size – i.e. 53”x34” went to 49”x32”
- Also evaluated 2-size reduction
  - Did not meet Proposed Conditions reductions
- Results in $7,000,000 reduction in grey infrastructure costs
- Total grey infrastructure costs = $70,000,000; therefore green and grey = $210,100,000

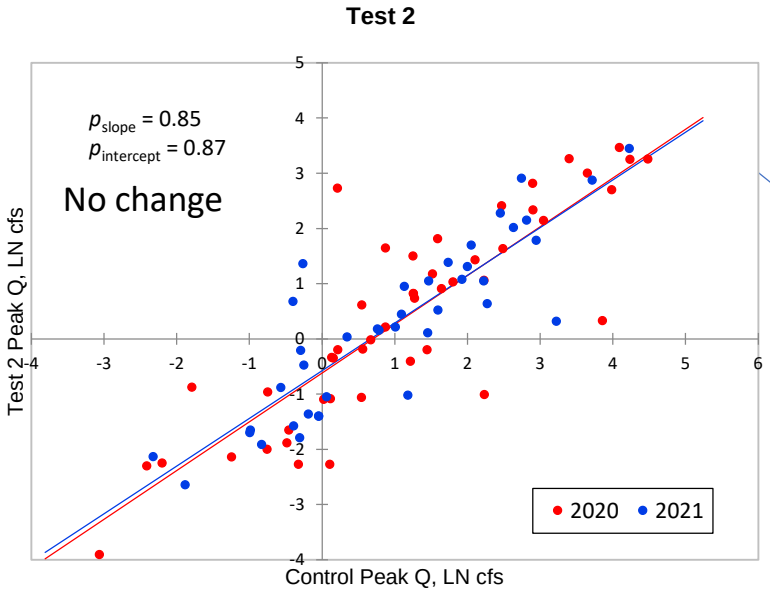
GI Pilot Study with USGS

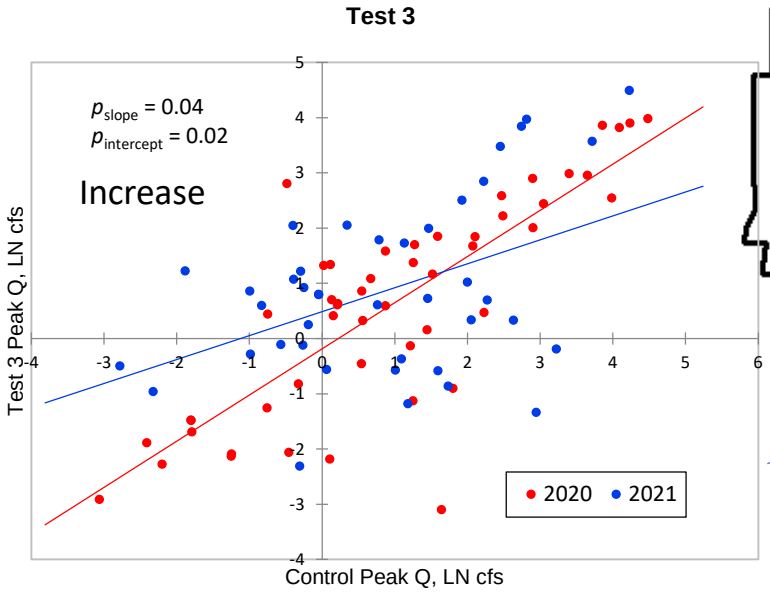
- City of Madison conducting GI Pilot Study with USGS
- Purpose is to understand how much GI is needed to see a measureable reduction in peak flow and runoff volume
- Installed Green Infrastructure in a concentrated area (Wingra Proper Watershed)
  - Pervious pavers
  - Pervious sidewalk panels
  - Infiltration trenches
  - Rain gardens
- USGS will monitor area for 5 years

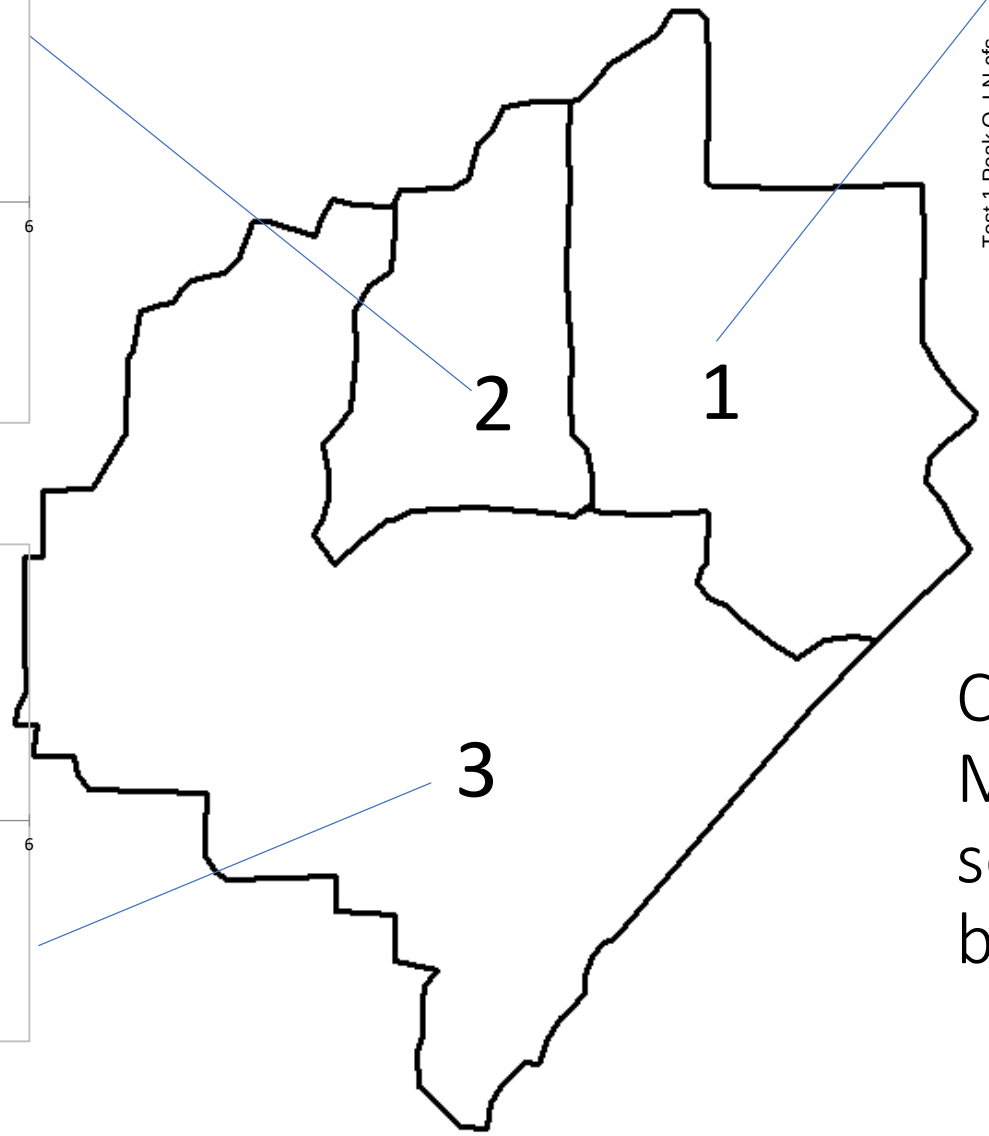


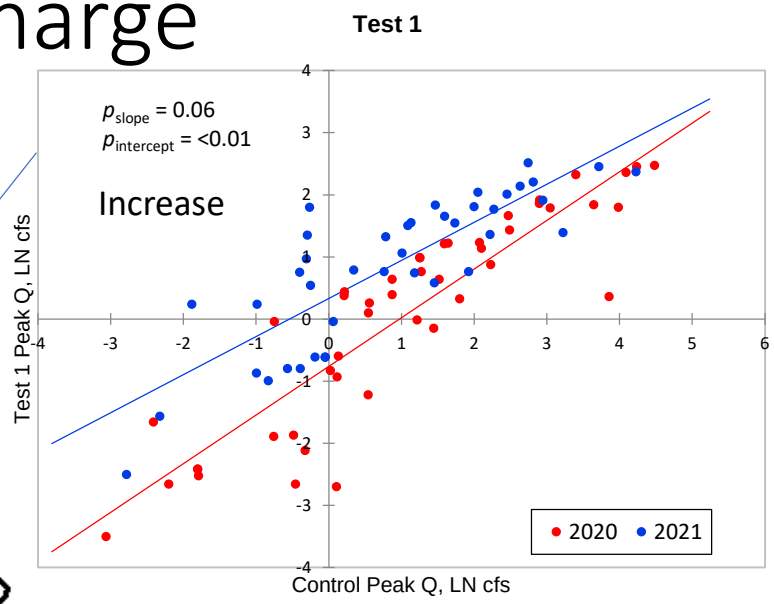
Slide courtesy of W. Selbg, USGS

Changes to Peak Discharge









Conclusion:
More GI needed to see measureable benefit

Tested for significance at alpha level =0.05
Slide courtesy of W. Selbg, USGS

Conclusions and Next Steps

- Green Infrastructure is effective at reducing flooding, however, it requires a significant amount

- Next Steps:
  - Do similar analysis for other watershed study areas
  - Get direction on the magnitude of green infrastructure investment to include for flood control

Questions?