Green Build-Out Model:

Quantifying Stormwater Management Benefits of Trees & Green Roofs in the District of Columbia

Michael P. Sullivan, LimnoTech

Project Background

- EPA Water Quality Cooperative Grant
- Grant Partners
  - Casey Trees
  - LimnoTech
  - Advisory Team
- Used DC WASA's Mike Urban Model (H&H)

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Green Infrastructure Opportunity in DC

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Hypothesis

Washington, DC: 2005

Washington, DC: 2025

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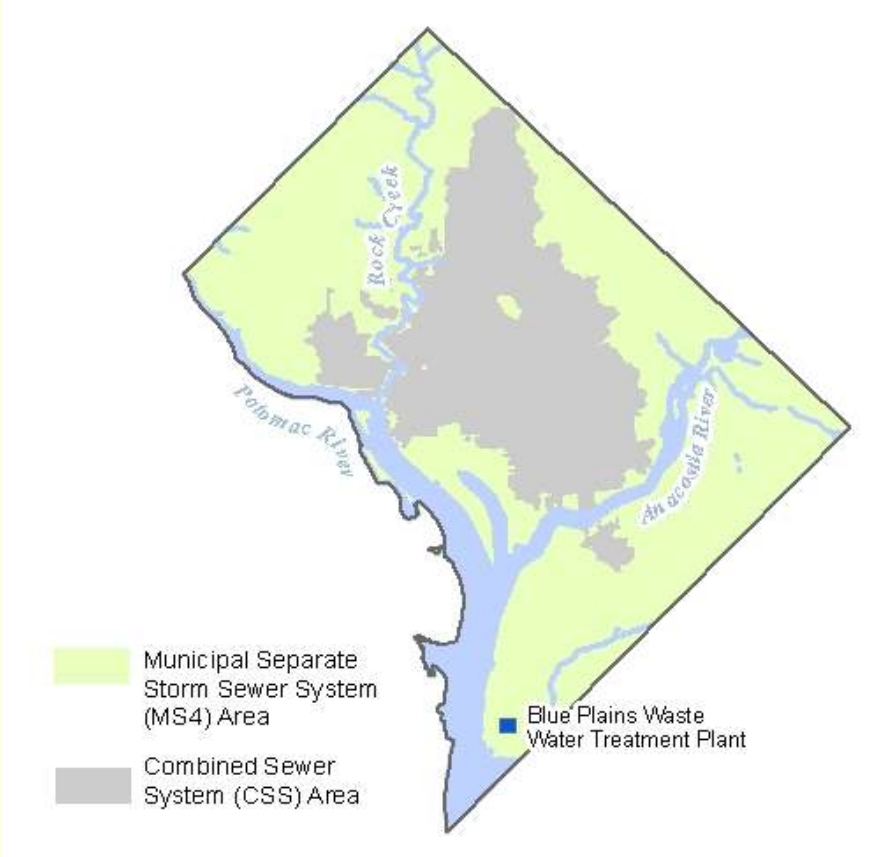
Background



- Two distinct systems
  - CSS
  - MS4
- Outfalls to Anacostia River, Potomac River, Rock Creek
- All waters impaired from stormwater runoff and CSOs, Upstream Sources
- WASA has an approved LTCP for CSOs

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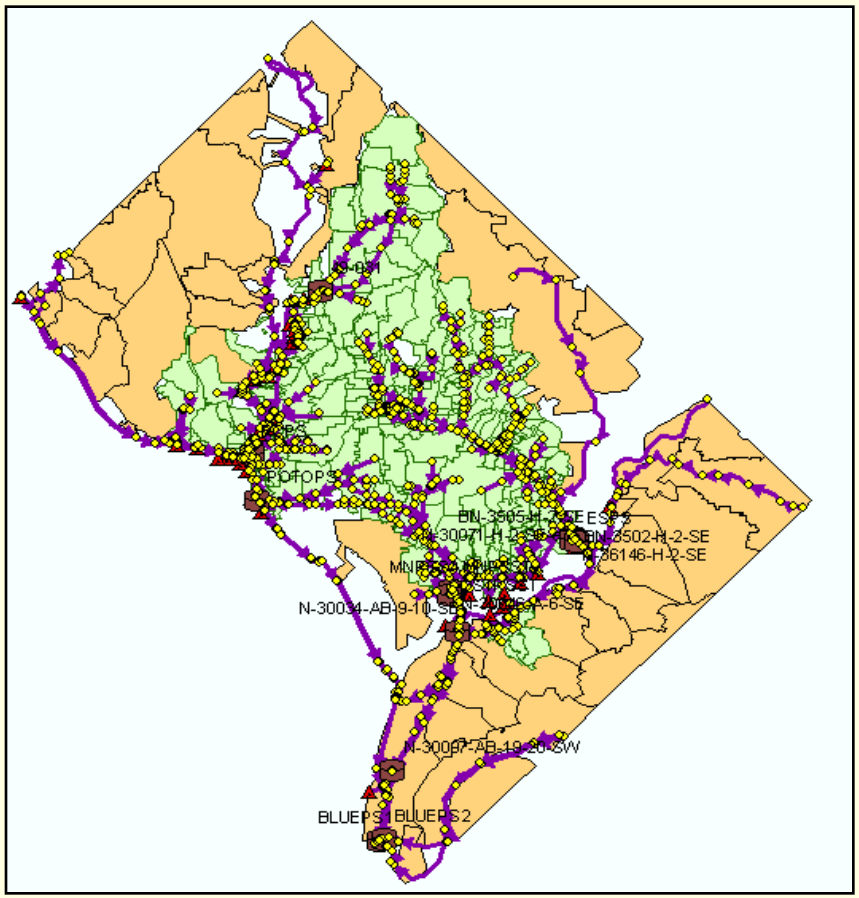
Study Objectives



- Add Green Infrastructure to Mike Urban Model (MOUSE)
  - MS4 area
  - Green component
- Quantify runoff reductions at different coverage scenarios
  - Intensive Greening Scenario
    - Physically possible
  - Moderate Greening Scenario
    - More practical

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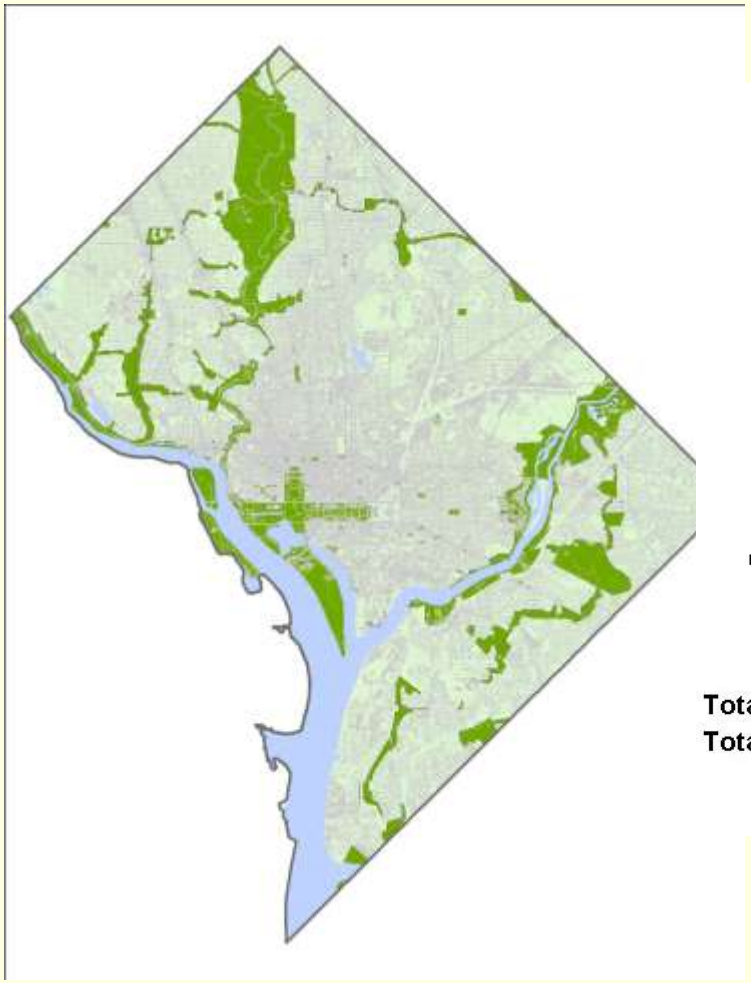
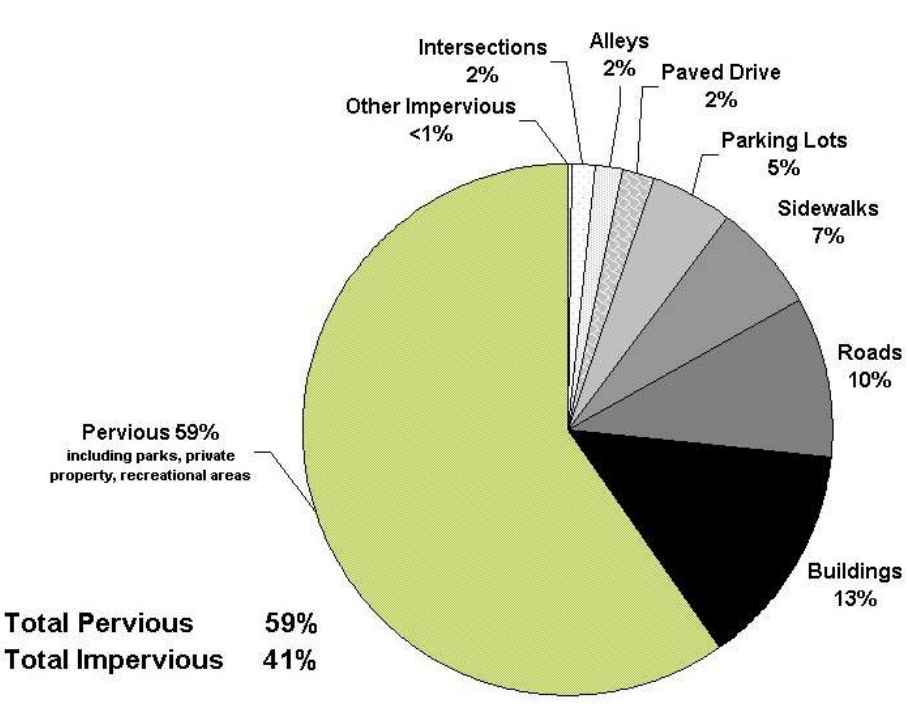
Existing Land Use In Washington, DC:





Total Pervious	59%
Total Impervious	41%

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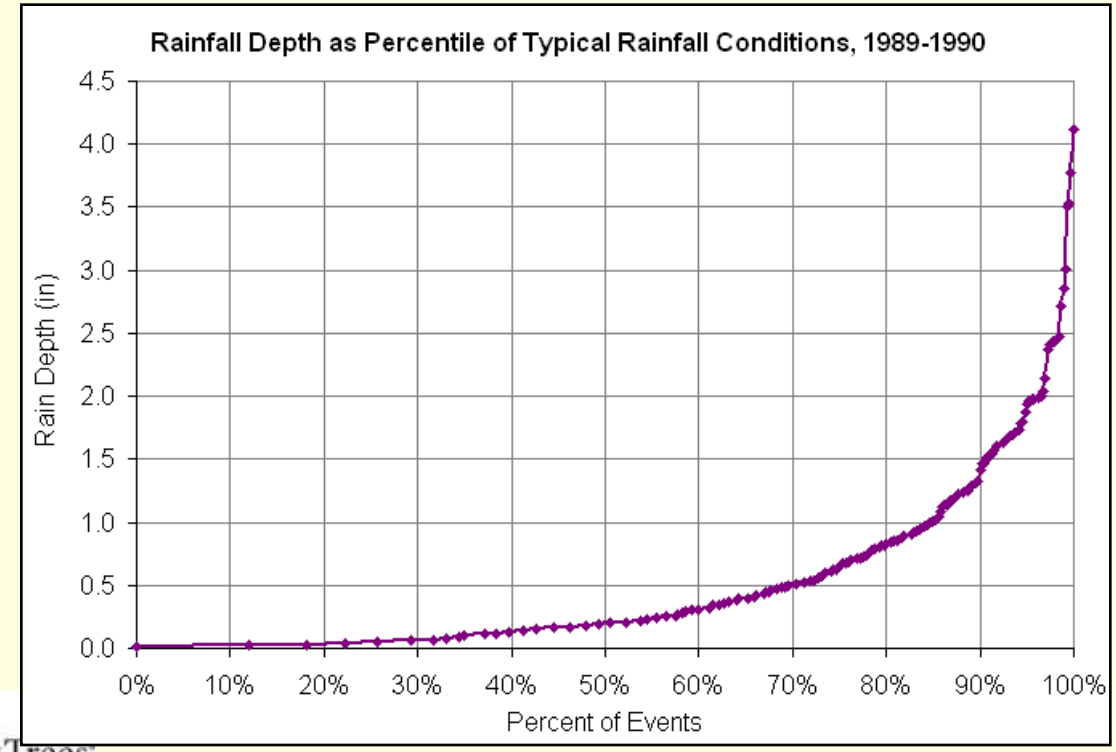
Model Input: Precipitation

- 70% of rain events are less than 0.5 inches
- 85% of rain events are less than 1 inch
- 97% of rain events are less than 2 inches



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Green Infrastructure Opportunities: Streets

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Green Infrastructure Opportunities: Streets

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Green Infrastructure Opportunities: Parking Lots

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Green Infrastructure Opportunities: Parking Lots

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Green Infrastructure Opportunities: Roof Tops

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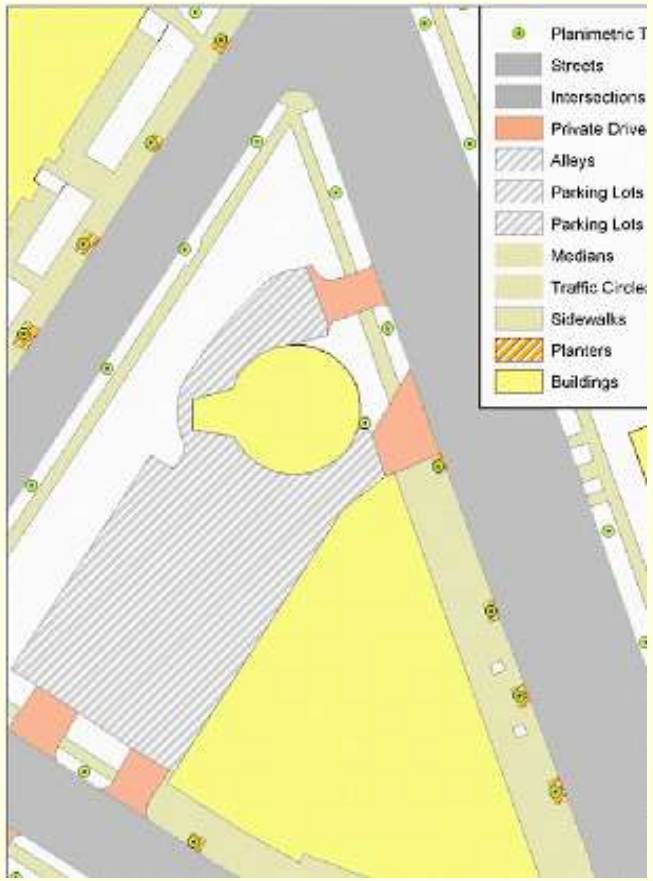
Land Use Example: Impervious Surfaces



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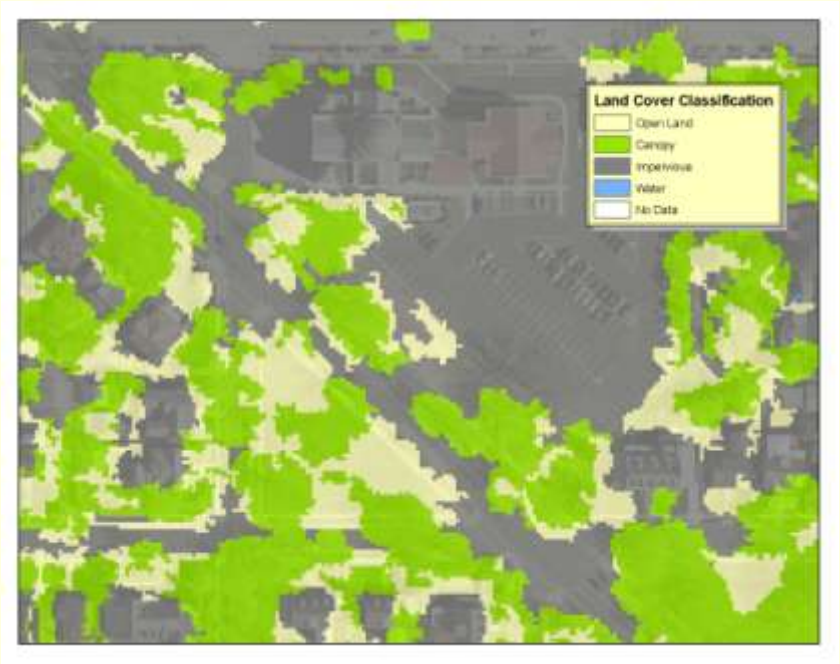
Land Cover Example: Trees



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Tree Cover Assumptions

Land Cover Type	Existing Tree Cover	Moderate Greening Scenario	Intensive Greening Scenario
Impervious			
Streetscapes (roads, sidewalks, intersections)	22%	25%	35%
Parking lots	7%	30%	50%
Paved drives	23%	50%	80%
Alleys	26%	35%	50%
Median islands, traffic islands, hidden medians, other	23%	30%	40%
Pervious			
Includes parks, open space, recreational areas, golf courses, soccer fields, cemeteries, front & back yards, school yards, etc	53%	57%	80%
TOTAL Tree Cover	**35%**	**40%**	**57%**

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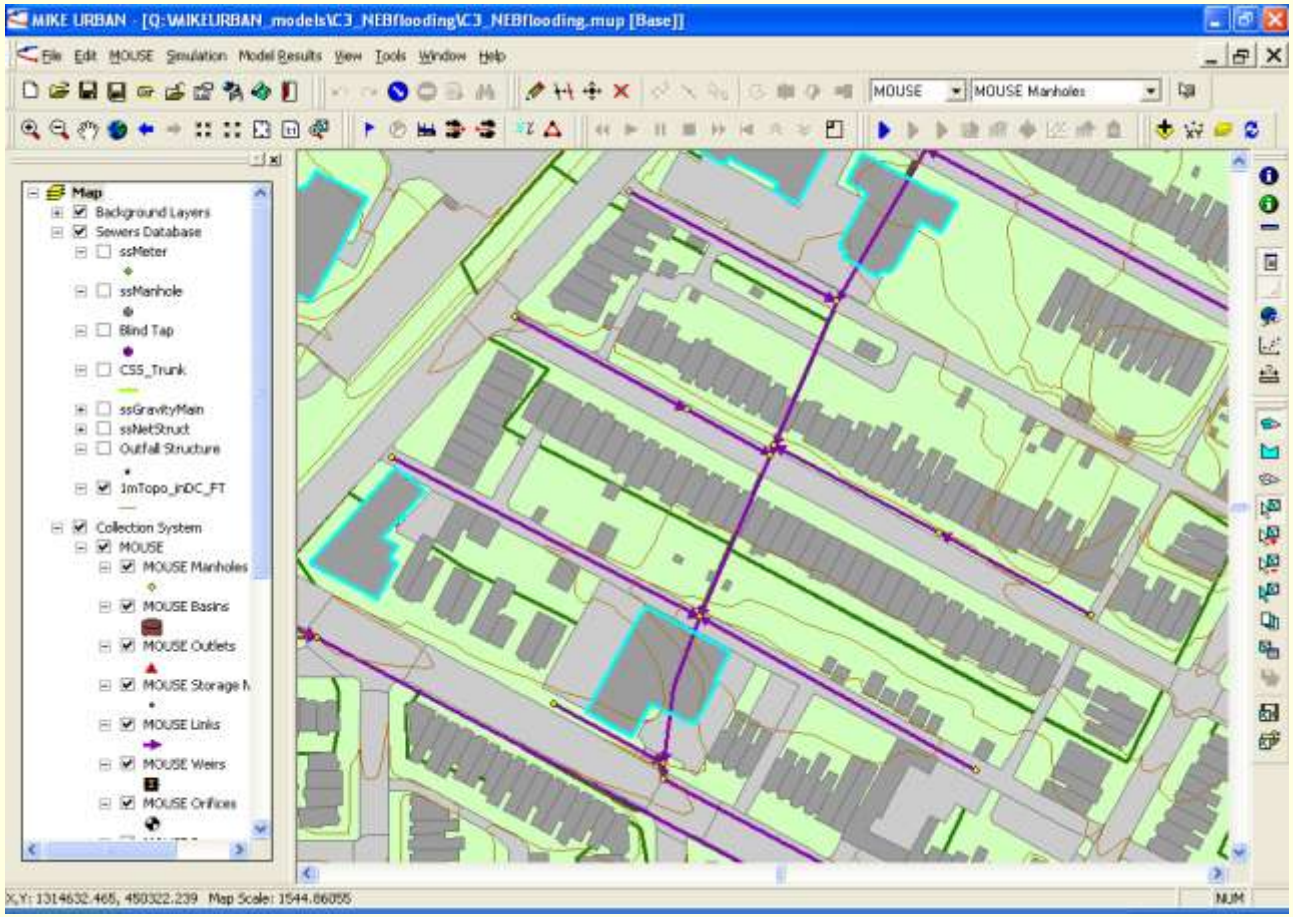
Mike Urban: GIS integration

- Includes:
  - Roads
  - Buildings
  - Soils
  - Topography
  - Trees
  - Sewers
  - Other



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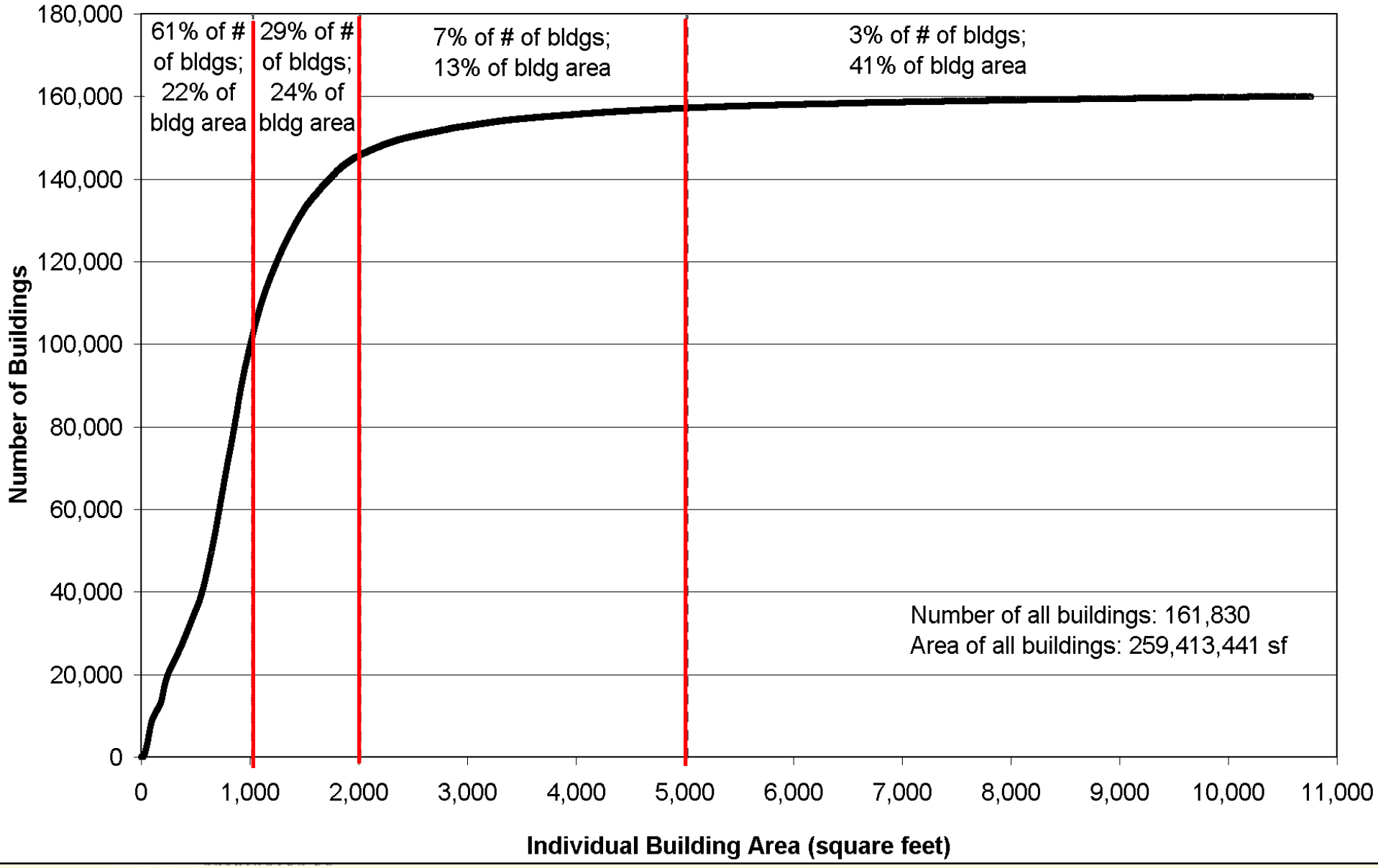
Distribution of Buildings in DC



Green Roof Coverage Assumptions[1]

Roof Type (size)	Existing Coverage	Moderate Greening Scenario[2]	Intensive Greening Scenario[2]
< 1,000sf	0%	2%	10%
1,000sf – 2,000sf	0%	6%	30%
2,000sf – 5,000sf	0%	10%	50%
> 5,000sf	0%	18%	90%
TOTAL	**0%**	**10.5% 20 million sf**	**53% 103 million sf**

Notes
1. These percentages are based on the building area (not the number of buildings)
2. The scenarios represent the building area that is “green roof ready”.

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Benefits and Key Findings

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Summary of Stormwater Runoff and Sewer System Discharge Reductions

	Moderate Greening Scenario		Intensive Greening Scenario	
	MG	%	MG	%
Stormwater Runoff Reductions				
CSS	170	2.2	634	8.3
MS4	141	1.6	581	6.6
Entire Sewer System	311	1.9	1,216	7.4
Sewer System Discharge Reductions				
CSS	141	6.1	514	22.0
MS4	141	1.6	581	6.6
Entire Sewer System	282	2.6	1,095	10.0

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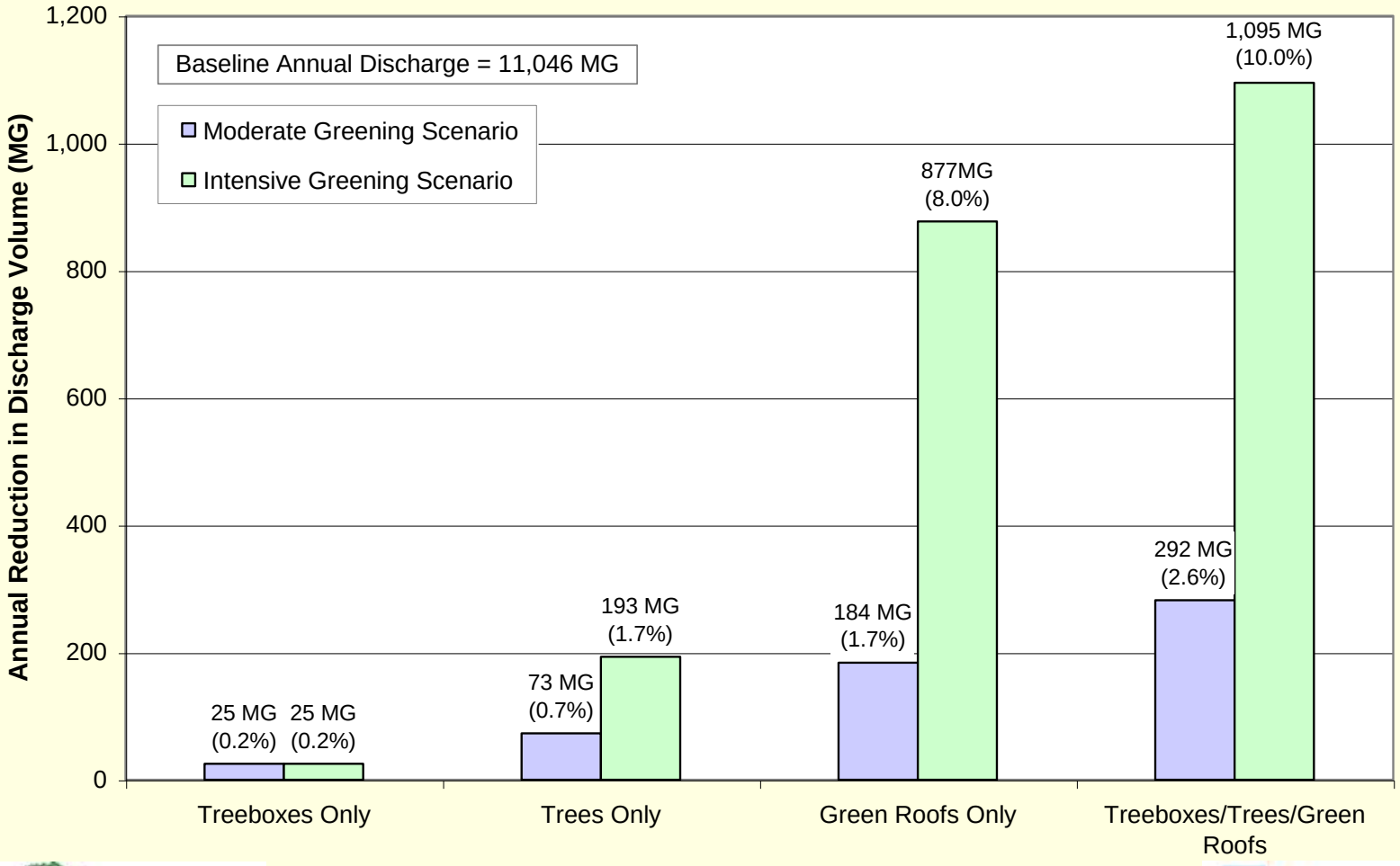
Reduction in CSO and Stormwater Discharge to All Waterbodies



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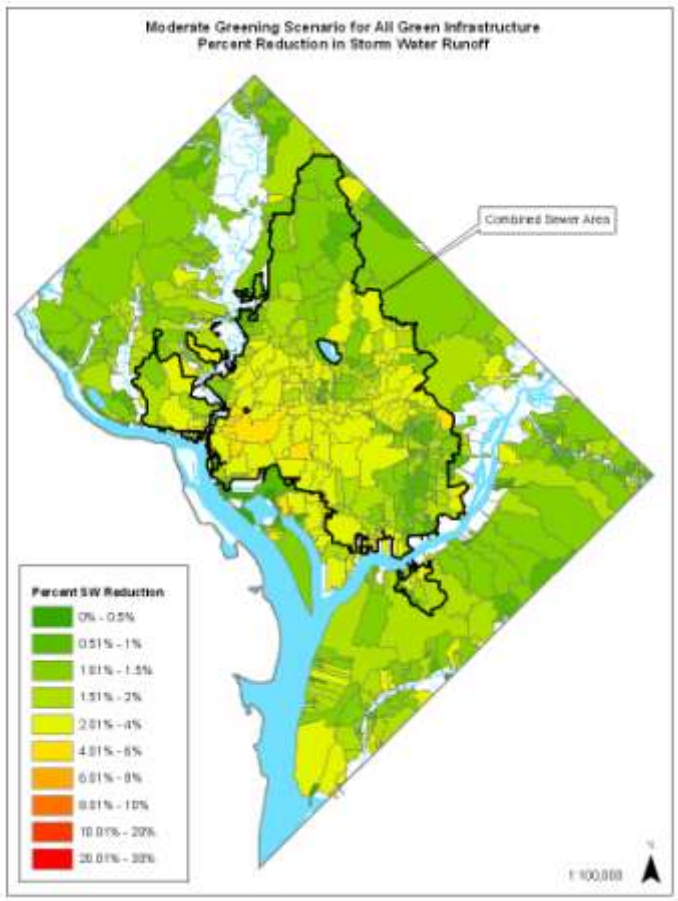
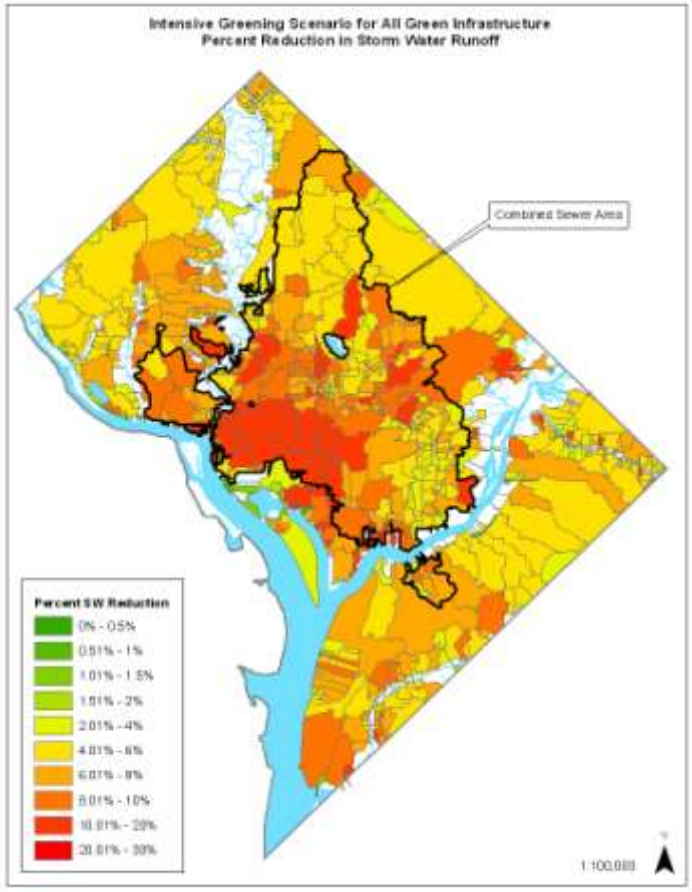
Runoff Reduction By Sewershed: Moderate vs. Intense Greening





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Hydrologic Relationships: Unit Area Reduction Factors

Type of Greening	Stormwater runoff volume reduction per unit area (MG/acre/year)	Acres required to achieve a one MG reduction in stormwater over an average year (acres/MG)
Green roofs	0.38960	2.5667
Trees over impervious areas	0.11117	8.9952
Trees over pervious areas (NRCS Soil Type D)	0.02210	45.249
Trees over pervious areas (NRCS Soil Type C)	0.00276	362.32
Trees over pervious areas (NRCS Soil Type A/B)	0.00008	12,500

- Can be used for quick planning calculations in the Washington, DC area or for other urban areas with similar climate conditions and rainfall distribution patterns

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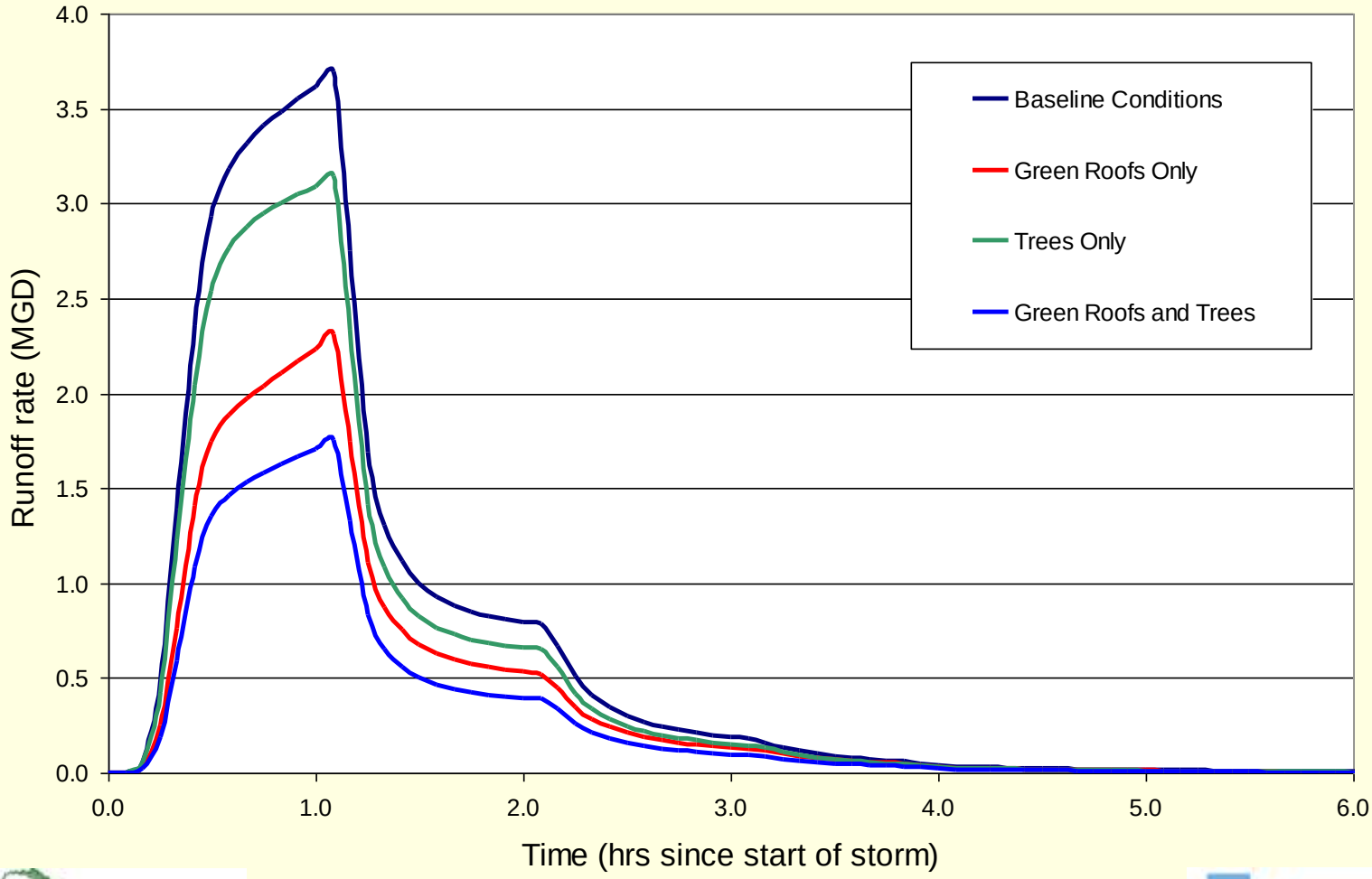
Peak Shaving



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Potential Operational Savings for WASA

- Operational costs assumed to decrease proportionally for every gallon avoided
  - Utility costs for pumping (electricity)
  - Treatment costs
- Exploratory review of literature = $0.01/gallon
- Savings approximately $1.4 - $5.1 million/year

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Pollutant Loading Benefits (reductions)

Pollutant	Intensive Greening Scenario	
	lbs reduced/year	% reduction
Total Suspended Solids	77,000	0.8%
Biochemical oxygen demand (BOD)	34,000	1.5%
Total phosphorous	340	0.6%
Total Kjeldahl nitrogen (TKN)	11,000	4.6%
Ammonia	3,400	4.1%
Copper	120	2.3%
Lead	180	1.8%
Zinc	3,100	16.1%

- Green roofs
  - Replaces pollutant contributions from conventional roofs
  - Highly effective at storing and filtering pollutants
- Conservative estimate of expected pollutant load reduction
  - Does not include pollutant scouring reductions from peak shaving

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Overall Key Findings

- Substantial reduction in runoff & discharge volumes (Green Roofs are much more effective than Trees)
- Limited reduction in CSO frequencies
- Reduction in stormwater peak flow & velocity
- Operational savings in CSS
  - Less volume to be stored, pumped and treated
- Multiple other benefits for same investment
  - Air quality, urban heat island effect, energy, climate change, public health, social capital, economic development, aesthetics, urban ecology, etc

Grant Products

- Data Results Display Tool
- Mini-Model
- Final report documentation
  - www.caseytrees.org

Project won award from the
American Society of Landscape Architects

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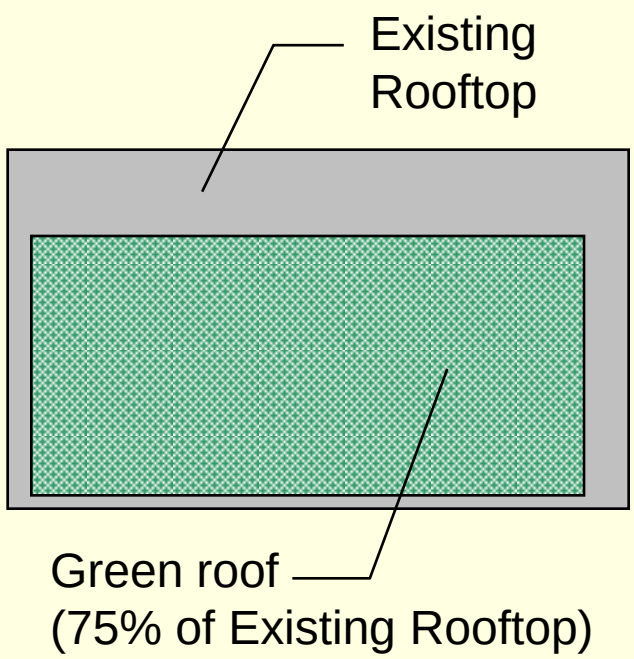
Ongoing/Future Work

- Addition of other Green Infrastructure practices to Mike Urban Model for WASA (rain barrels, infiltration, porous pavement, bioretention, etc.)
- Development of guidance on incorporation of Green Infrastructure practices to existing SWMM applications
- Incorporation of other benefits assessments
  - Air quality
  - Urban heat island
  - Carbon
  - Aesthetics
  - Etc.

Building Coverage



- Green Roof Ready area
  - Space needed for HVAC, access, and maintenance
- Total bldg footprint area = 260 million sf
- Green Roof Ready area = 194 million sf

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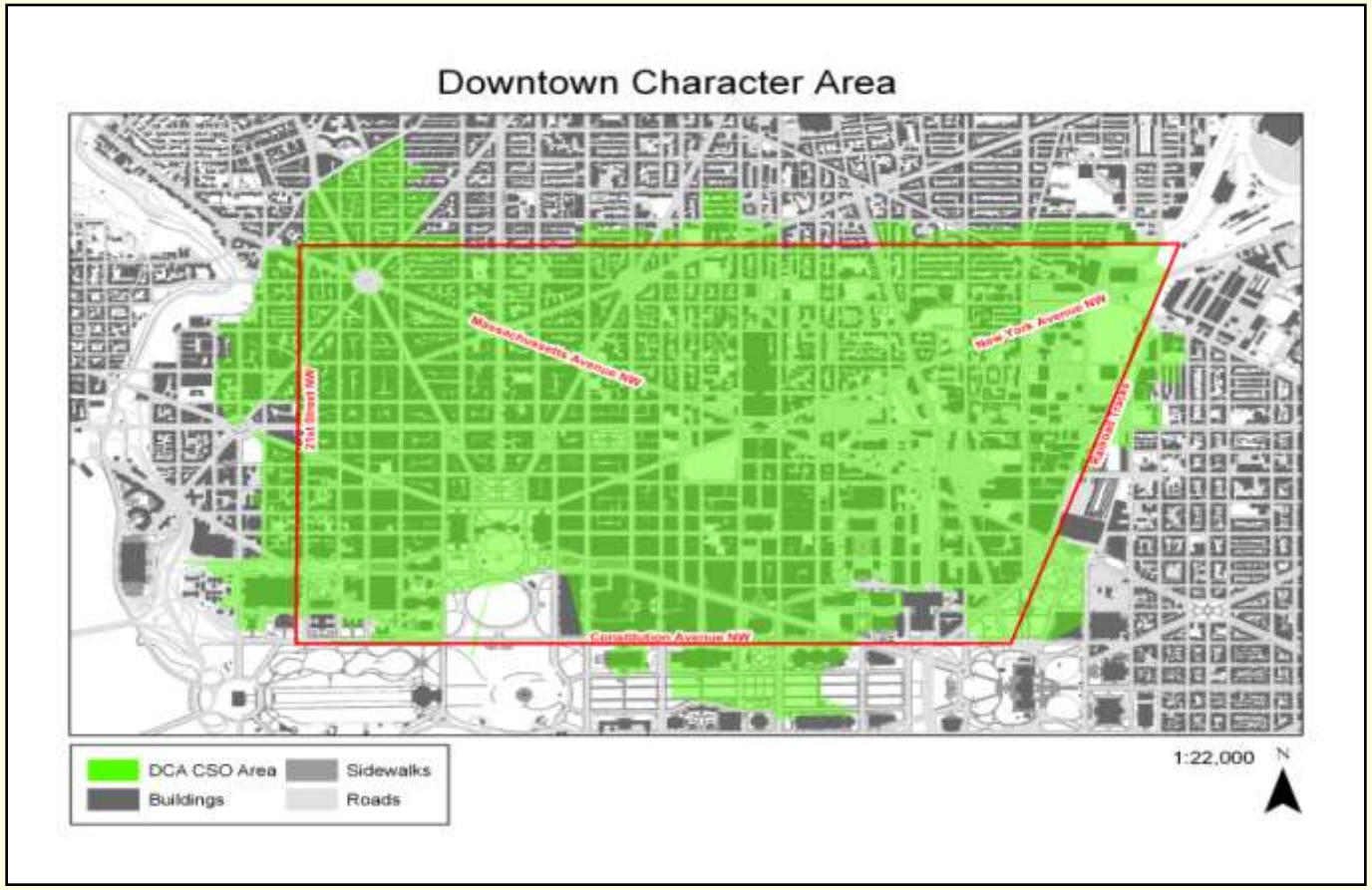
Tree Boxes (from average 4x6 ft to 6x20 ft)



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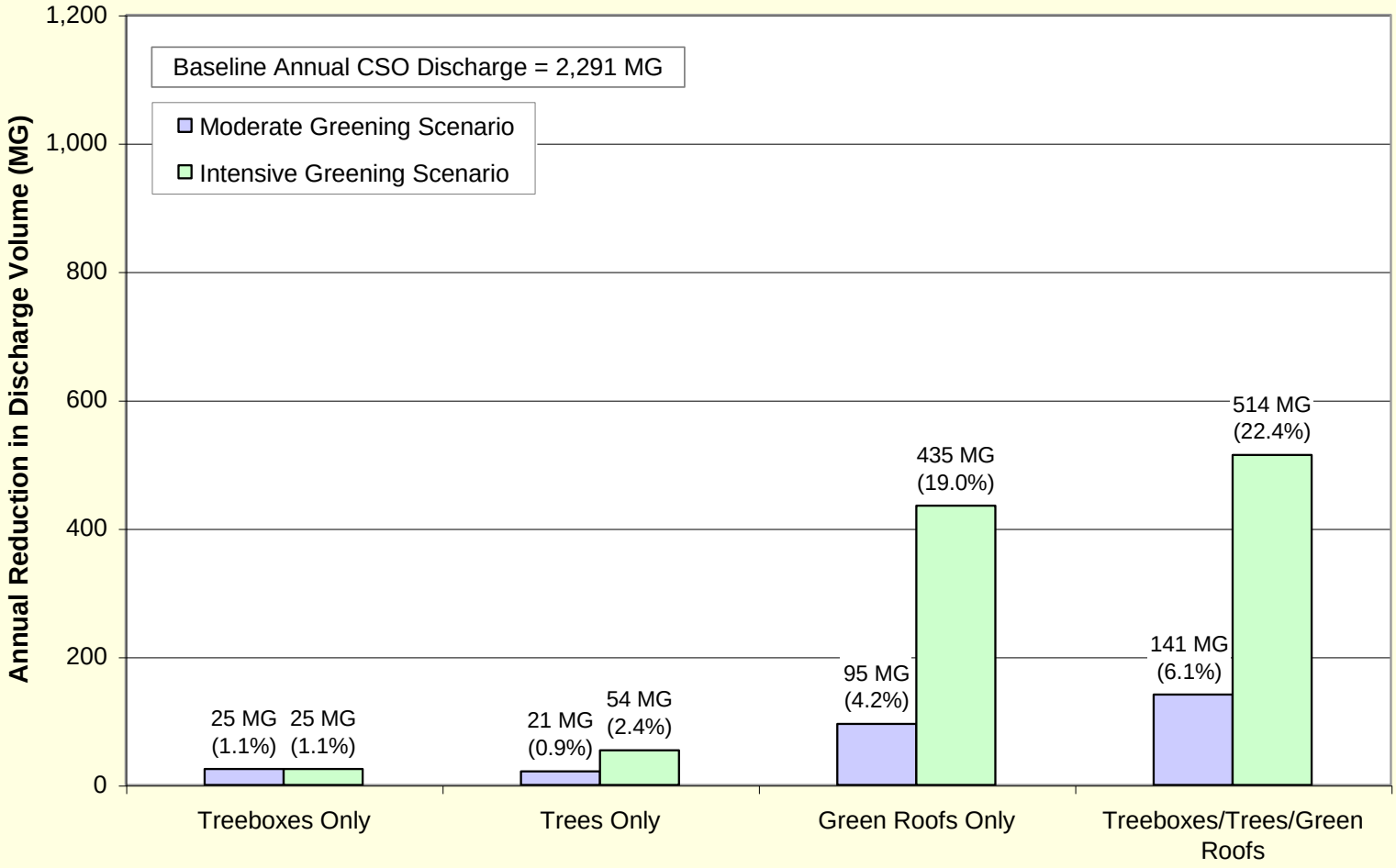
Reduction in CSO Discharge



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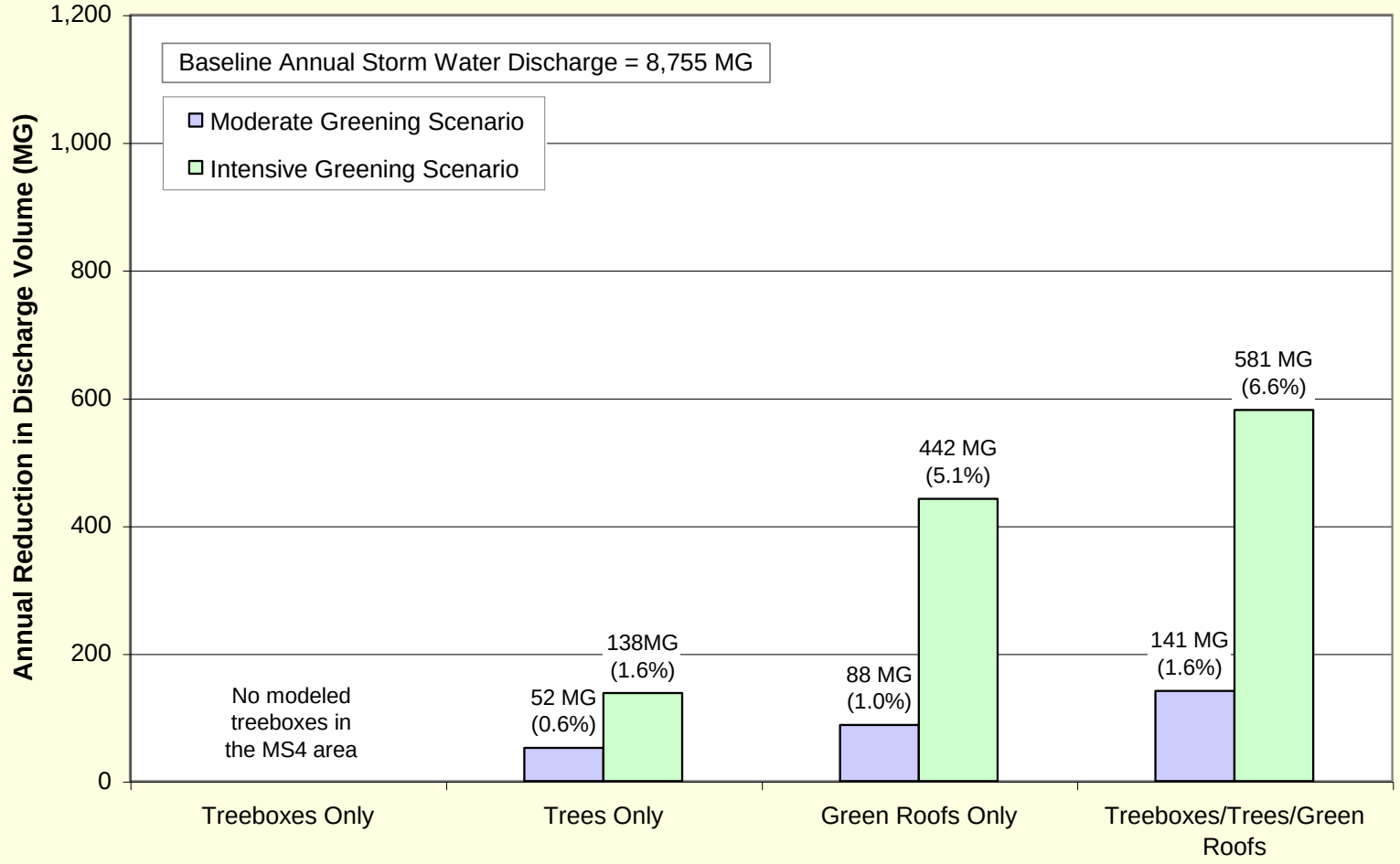
Reduction in Storm Water Discharge from the MS4 Area



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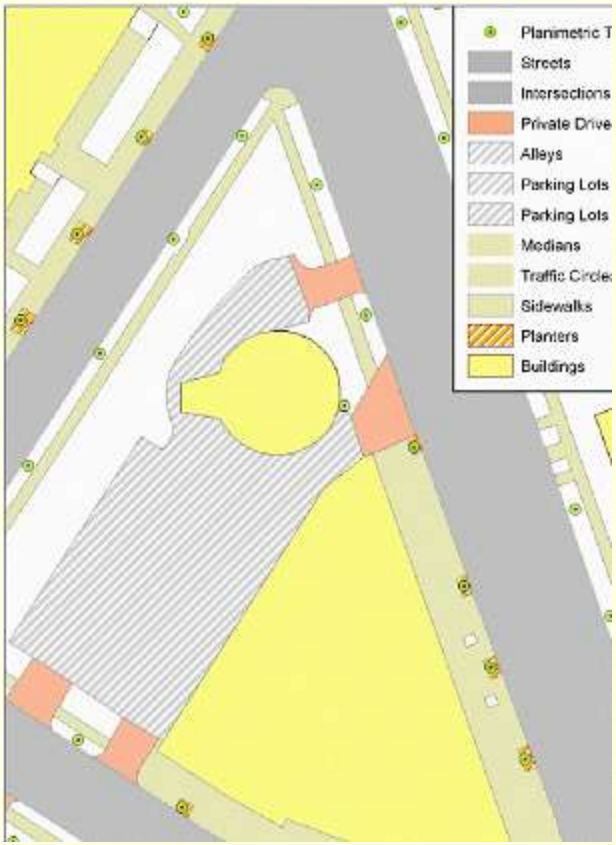
Organization of Key Findings to Date

- Trees, Green Roofs, & Tree Boxes Combined
- Findings by Sewer System (CSS and MS4)
- Targeted Results by Sewershed
- General Hydrologic Relationships
  - Unit area reduction factors
  - Peak shaving
- Potential Operational Savings
- Pollutant Load Reductions from Green Roofs

Presentation Forecast

- Green Infrastructure Opportunities
- Land Use, Cover Data and GIS
- Precipitation
- Modeling Assumptions
- Key Findings
- Grant Products
- Ongoing/Future Work

Tree Box Analysis



- Increase tree box size in downtown area from 3x5 to 6x20
- Changes 105 sf of impervious to pervious per tree space

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Grant Objectives

- Quantify the city-wide contribution that trees and green roofs could make towards reducing stormwater runoff and the frequency of discharges to the rivers in DC
- Identify policy recommendations to facilitate implementation of trees and green roofs as stormwater controls

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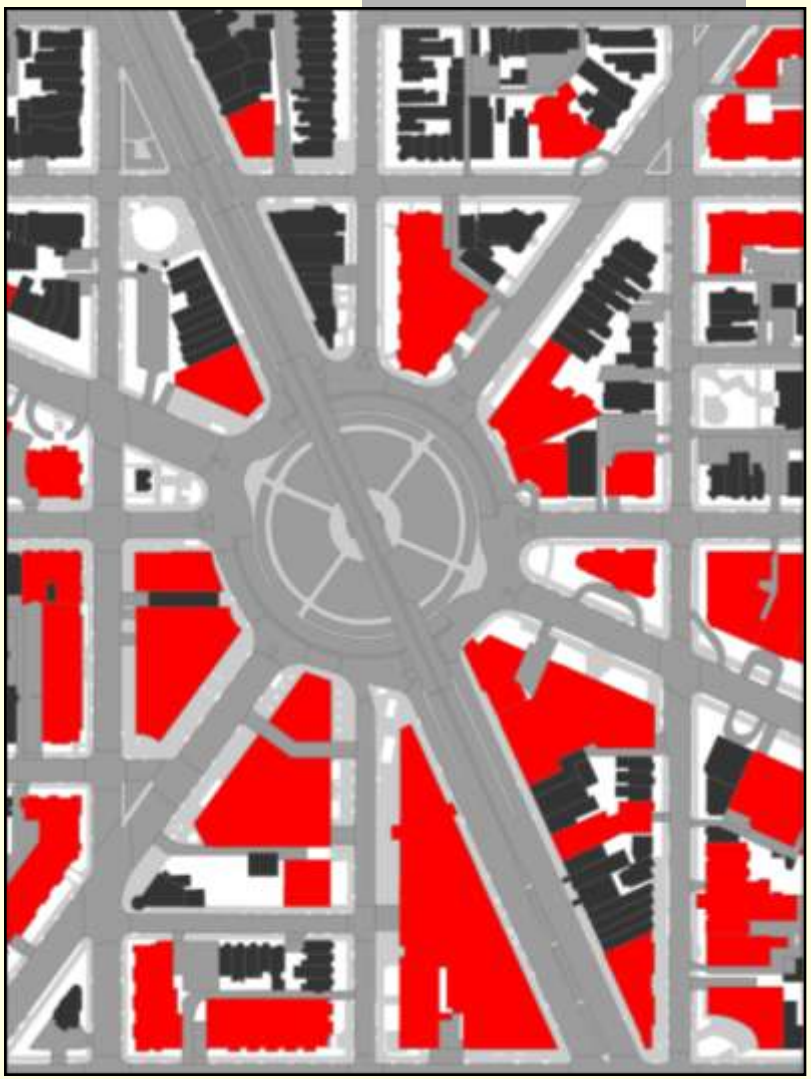
Scenario Description

- Green Roof Build-Out
  - All buildings > 5,000sf
  - 75% vegetation coverage
  - 1 inch of storage



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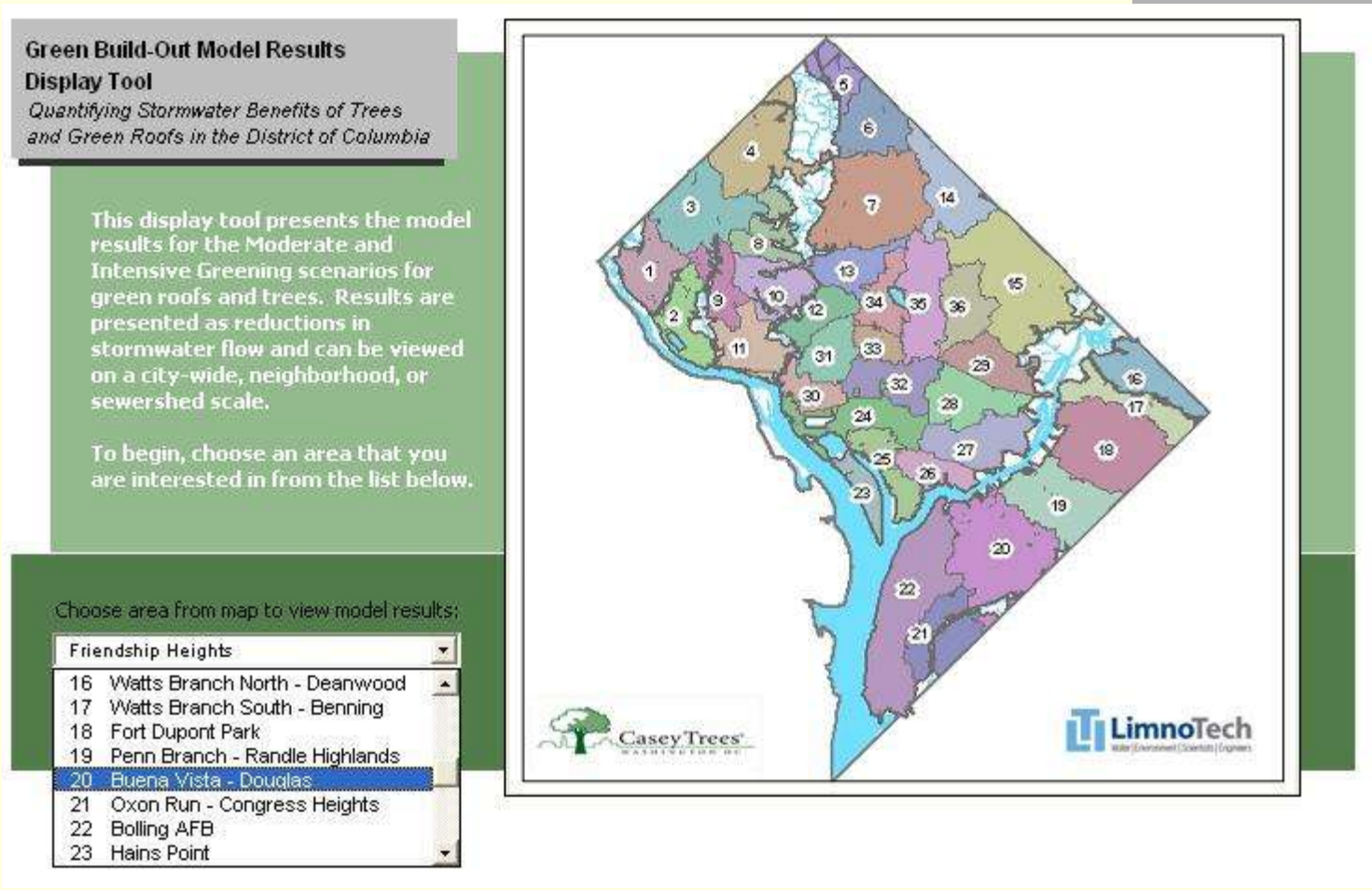
Data Display Tool



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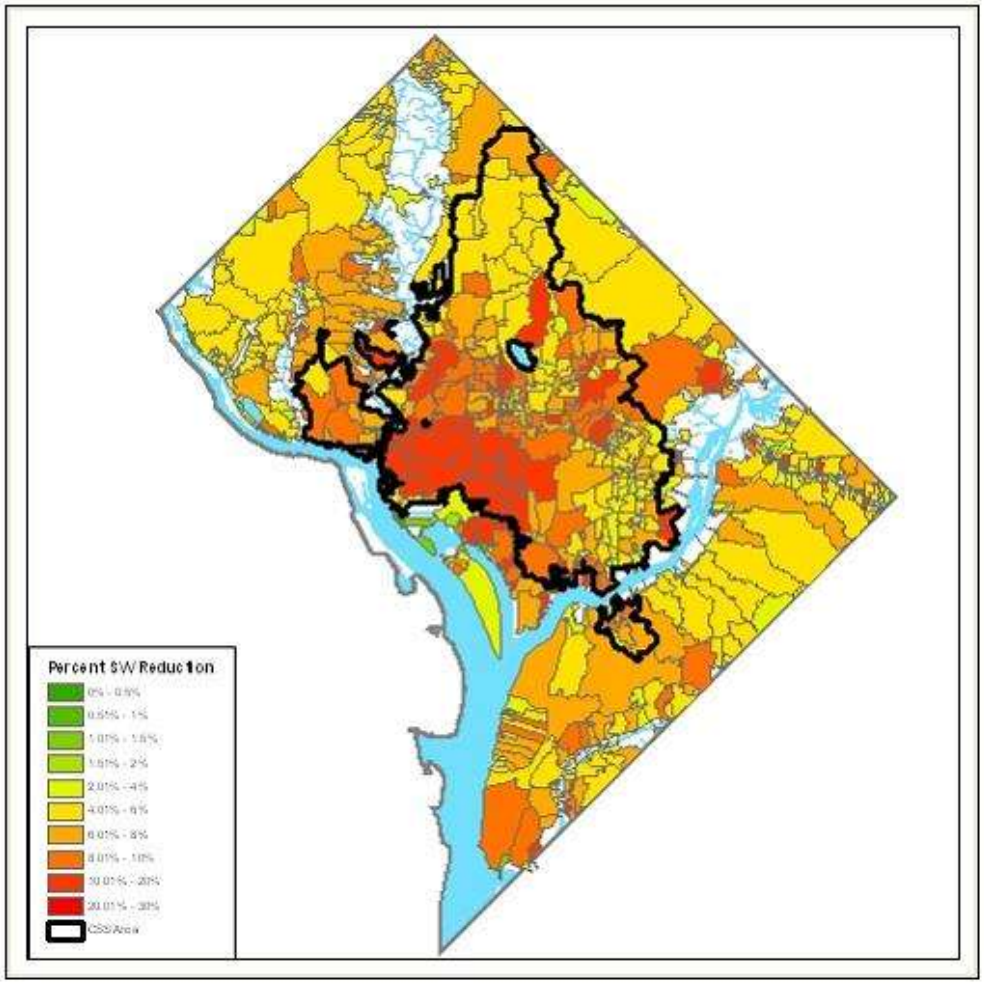
DC Summary

Print Results | Return to Main Map

Choose a green coverage type to view associated data: ○ Green Roofs ○ Trees ○ Tree Boxes ◉ Total



Watershed/Sewer System	Baseline Flow (MGY)	Moderate Greening Scenario Flow (MGY)	Moderate Greening Scenario Flow Reduction	Intensive Greening Scenario Flow (MGY)	Intensive Greening Scenario Flow Reduction
Anacostia CSS	4,219	4,129	2.13%	3,888	7.83%
Potomac CSS	1,013	983	2.96%	902	10.96%
Rock Creek CSS	2,437	2,386	2.09%	2,244	7.92%
Total CSS	7,668	7,498	2.2%	7,034	8.3%
Anacostia MS4	3,719	3,659	1.61%	3,478	6.48%
Potomac MS4	3,177	3,122	1.72%	2,952	7.07%
Rock Creek MS4	1,860	1,833	1.44%	1,744	6.22%
Total MS4	8,755	8,614	1.61%	8,174	6.64%
Anacostia	7,938	7,788	1.88%	7,366	7.20%
Potomac	4,189	4,105	2.02%	3,854	8.01%
Rock Creek	4,296	4,219	1.81%	3,988	7.19%
Total	16,423	16,112	1.90%	15,208	7.40%

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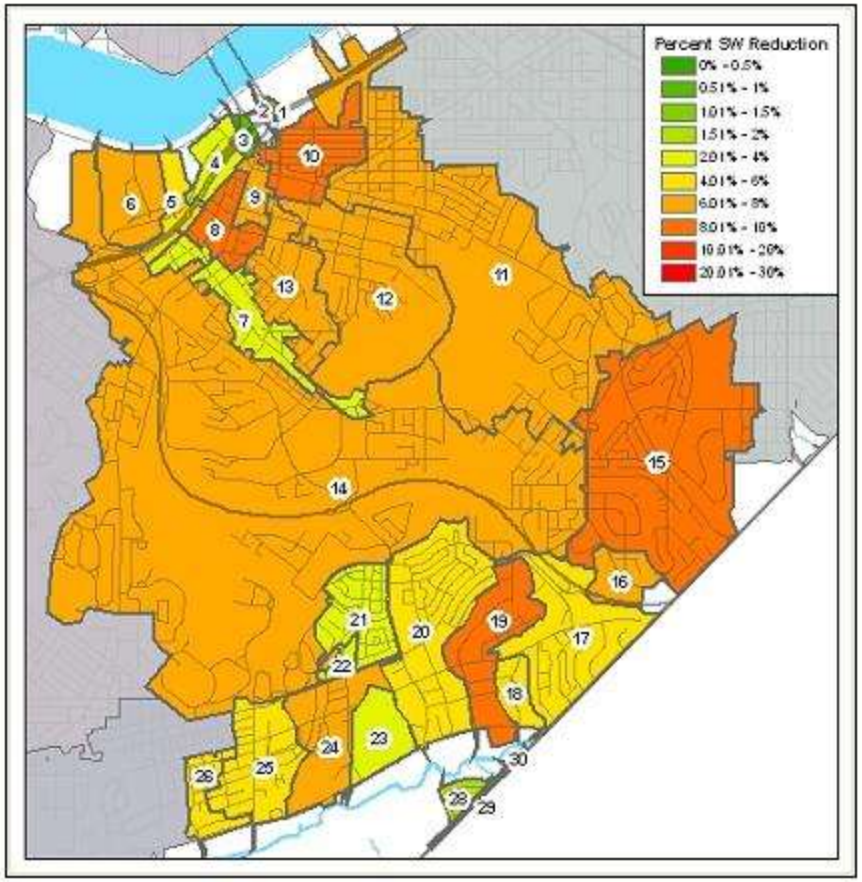
Buena Vista - Douglas Print Results Return to Main Map

Choose a green infrastructure type to view associated data:* ○ Green Roofs ○ Trees ◉ Total



*Map depicts percent flow reduction associated with Intensive Greening scenario and all green infrastructure types.

ID	Subshed	Sewer Area	Baseline Flow (MGY)	Moderate Greening Scenario Flow (MGY)	Moderate Greening Scenario Flow Reduction	Intensive Greening Scenario Flow (MGY)	Intensive Greening Scenario Flow Reduction
1	SW-ANA61	MS4	0.51	0.51	0.04%	0.51	1.12%
2	CSO 007-a	CSS	0.60	0.59	0.25%	0.59	1.07%
3	CSO 006-a	CSS	1.87	1.86	0.30%	1.85	0.94%
4	SW-ANA54	MS4	5.77	5.70	1.24%	5.59	3.20%
5	CSO 005-a	CSS	5.26	5.19	1.34%	5.05	4.02%
6	SW-ANA52	MS4	12.32	12.08	1.95%	11.57	6.16%
7	CSO 005-b	CSS	17.34	17.17	1.00%	16.71	3.63%
8	CSO 005-c	CSS	15.73	15.30	2.72%	14.27	9.27%
9	CSO 006-b	CSS	7.42	7.27	2.10%	6.88	7.26%
10	CSO 007-d	CSS	24.65	24.15	2.07%	22.62	8.26%
11	SW-ANA30	MS4	116.07	114.06	1.73%	107.99	6.96%
12	CSO 007-c	CSS	35.66	35.12	1.53%	33.41	6.33%
13	CSO 007-b	CSS	20.21	19.89	1.59%	18.97	6.15%
14	SW-ANA50	MS4	241.86	237.12	1.96%	224.26	7.28%
15	SW-OXR46	MS4	79.87	78.36	1.89%	73.37	8.14%
16	SW-OXR47	MS4	6.93	6.82	1.66%	6.48	6.49%
17	SW-OXR1	MS4	30.61	30.19	1.36%	28.96	5.38%
18	SW-OXR3	MS4	4.58	4.51	1.57%	4.36	4.86%
19	SW-OXR4	MS4	19.52	19.09	2.18%	17.67	9.46%
20	SW-OXR5	MS4	35.34	34.89	1.26%	33.46	5.31%
21	SW-OXR32	MS4	4.32	4.27	1.11%	4.17	3.55%
22	SW-OXR33	MS4	2.26	2.24	0.92%	2.17	4.00%
23	SW-OXR6	MS4	3.36	3.34	0.56%	3.26	2.88%
24	SW-OXR7	MS4	17.24	16.98	1.51%	16.05	6.87%
25	SW-OXR8	MS4	21.84	21.54	1.39%	20.60	5.70%
26	SW-OXR9	MS4	7.32	7.21	1.48%	6.91	5.66%
27	SW-OXR20	MS4	27.60	27.01	2.13%	25.71	6.83%
28	SW-OXR2	MS4	3.65	3.63	0.44%	3.58	1.80%
29	SW-OXR38	MS4	2.31	2.31	0.13%	2.30	0.28%
30	SW-OXR34	MS4	0.32	0.32	0.00%	0.32	0.00%

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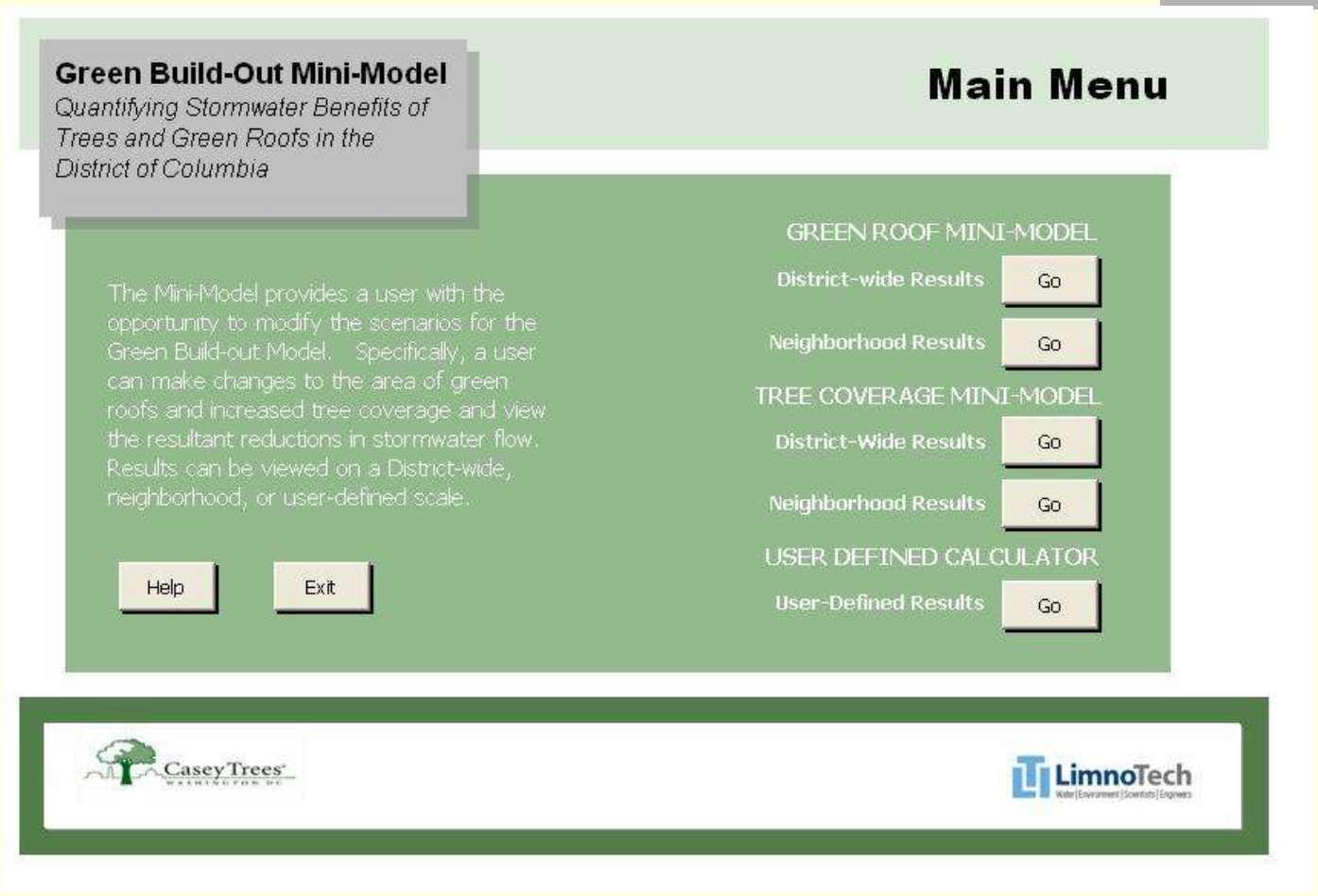
Mini-Model



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Green Roof Mini-Model Editor

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Existing Conditions

Roof Type	Available Roof Area (sf)
< 1,000 sf	42,934,330
1,000 - 2,000 sf	46,417,327
2,000 - 5,000 sf	24,765,320
> 5,000 sf	80,738,983
TOTAL	194,855,959

Model Scenario Builder

Choose Green Roof Area for Model Run	Model Greenroof Area (sf)	Model Greenroof %
0% 2% 10% 100%	13,738,985	32%
0% 6% 30% 100%	14,853,545	32%
0% 10% 50% 100%	7,924,902	32%
0% 18% 90% 100%	25,836,475	32%
0% 10.5% 53% 100%	62,353,907	32%

Intensive Greening Scenario

Moderate Greening Scenario

District-Wide Model Results

System/ Watershed	Runoff Volume Without Green Roofs (MG)	Runoff Volume With Green Roofs (MG)	Reduction In Runoff Volume (MG)	Percent Reduction In Runoff Volume
CSS Total	7,668	7,379	289	3.8%
MS4 Total	8,755	8,480	275	3.1%
Anacostia Total	7,938	7,673	265	3.3%
Potomac Total	4,189	4,050	140	3.3%
Rock Creek Total	4,296	4,137	160	3.7%
TOTAL	**16,423**	**15,859**	**564**	**3.4%**

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Advisory Team Policy Recommendations

- Stormwater & sewer fee, incentive program
- Impervious surface limits
- Greenroof Cover Objectives, Strategy, & Leadership
- District-wide Urban Tree Canopy goals & Management Plan
- Tree cover objectives by land cover area e.g. Parking Lots = 40%
- Increase tree box size from minimum 3x5 ft to 6x20 ft
- Fill and maintain all street tree spaces
- GIS database for tracking & monitoring

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