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Adapting Urban BMPs for Climate Change

Water Resources Technical Committee Meeting

Metropolitan Washington Council of Governments

Washington DC | November 9, 2018

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Climate Change and Urban Stormwater Guide

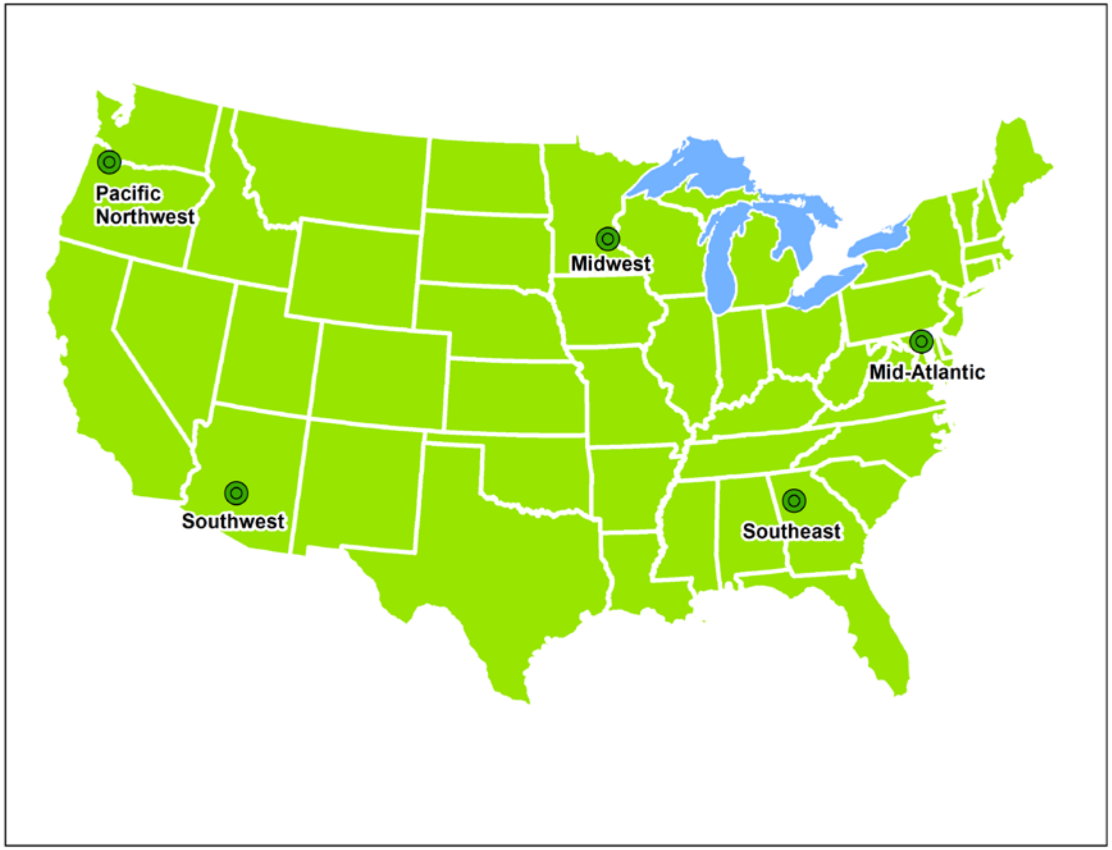
- Goal of the Guide
  - Develop information for stormwater control that advances adaptation planning in the stormwater community to potential changes in climate
- Information draws on literature review and simulation modeling
- Today's presentation
  - Describe the simulation modeling approach
  - Share results and conclusions from the modeling

Study Questions

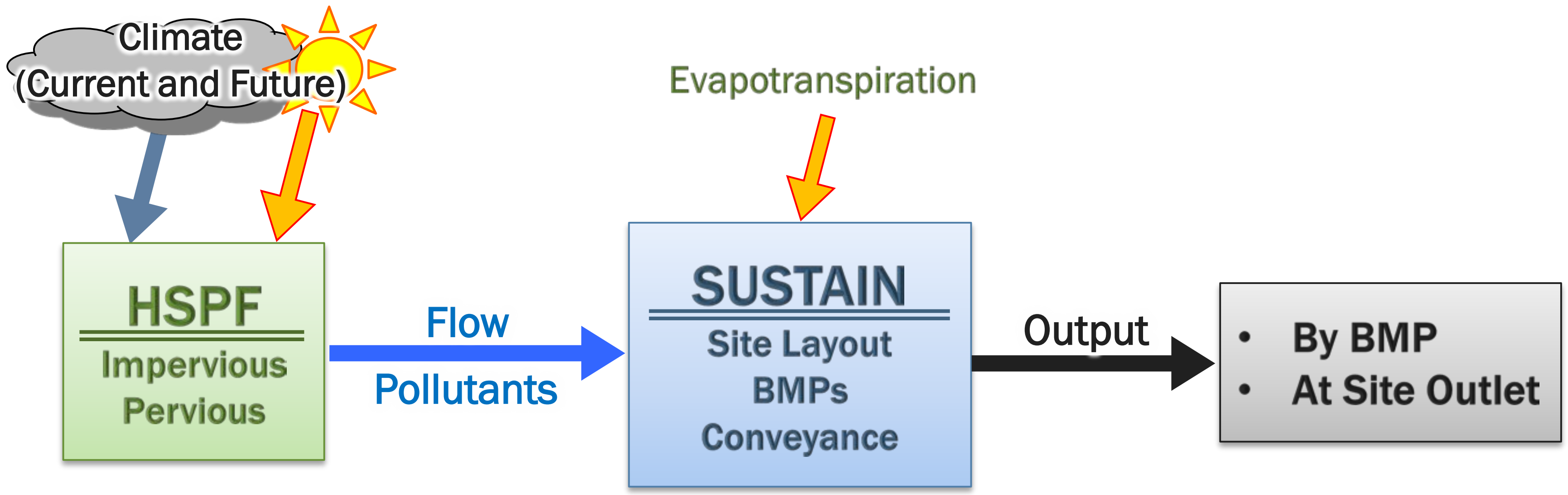
1. Climate change impacts on stormwater infrastructure performance
2. Adapt stormwater infrastructure so site performance under future climate achieves current performance
3. Compare adaptation of gray infrastructure to green infrastructure (GI)

Continuous Simulation Modeling Approach

- Site-scale focus
  - Five development types
  - Five geographic regions
- For each site
  - Different stormwater management approaches
  - Current and future climate
- Adaptation
  - modify BMPs to achieve current performance
- Performance metrics
  - Annual outflow volume
  - channel erosion risk and flooding risk
  - TSS
  - TN
  - TP



Modeling Approach – Framework



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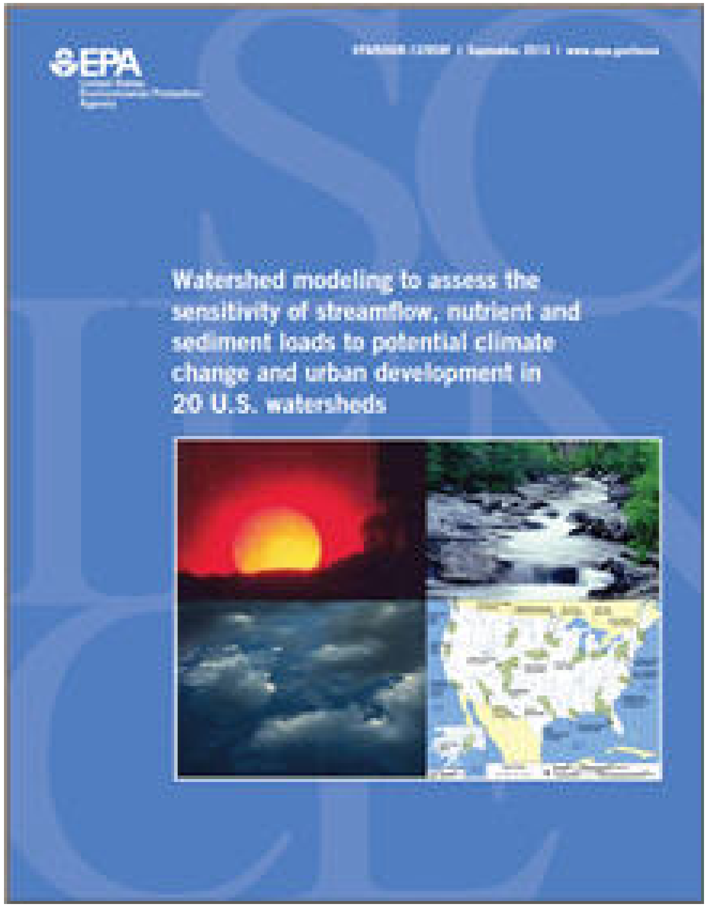
Modeling Approach – Scenario Matrix

Region	Location	Development Scenario	Management Approach		
			Gray	Mixed	GI only
Midwest	Scott County, MN	Residential	X	X	X
Southeast	Atlanta, GA	Ultra-urban	X	X	
Mid-Atlantic	Harford County, MD	Mixed Use	X	X	
Arid Southwest	Maricopa County, AZ	Commercial	X		X
Pacific Northwest	Portland, OR	Green Street			X

Modeling Approach – Climate Scenarios

- Global Climate Models (GCMs)
  - From EPA "20 Watersheds" project
  - All locations: greatest increase in precipitation intensity
  - Midwest: additional low and medium intensity change
- Percent Change Scenarios
  - Midwest and Mid-Atlantic
  - Percent change applied to entire precipitation record
  - Evapotranspiration also adjusted



Climate Scenarios for each Geographic Location

- Climate scenario representing the largest increase in precipitation intensity

Geographic region	River basin	NCDC station[a]	Climate scenario
Mid-Atlantic	Susquehanna River	PA 366289 (New Park)	BCSD HADCM3
Midwest	Minnesota River	MN 215435 (Minneapolis/St. Paul Airport)	Low: NARCCAP GFDL High Res GFDL Medium: NARCCAP RCM3 GFDL High: BCSD CCSM
Arid southwest	Salt River	AZ 026840 (Punkin Center)	BCSD GFDL
Southeast	ACF Rivers	GA 096407 (Atlanta Hartsfield Intl. Airport)	NARCCAP RCM3 GFDL
Pacific northwest	Willamette River	OR 356749 (Portland KGW TV)	BCSD GFDL

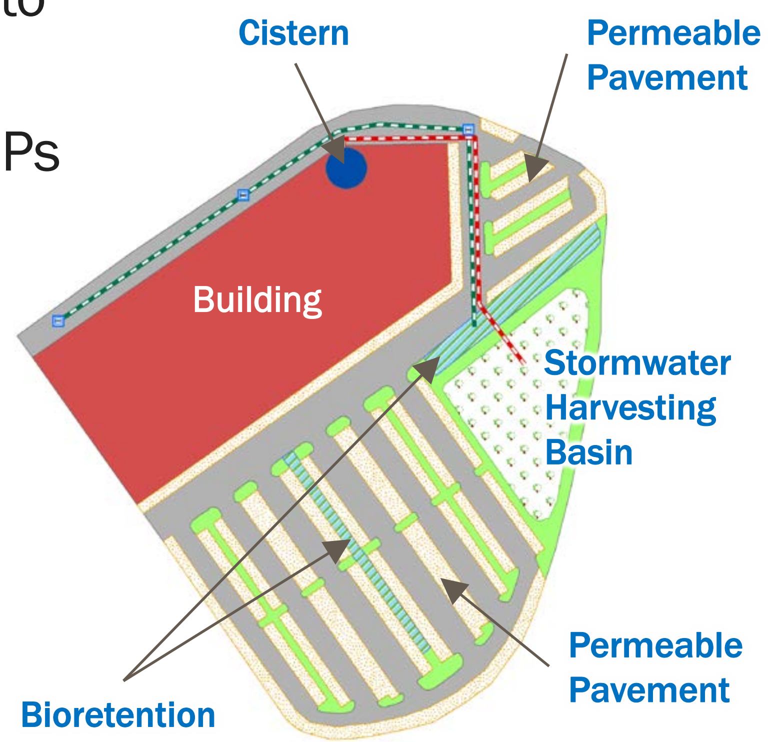
CCSM = Community Climate System Model, GFDL = Geophysical Fluid Dynamics Laboratory, HADCM3 = Hadley Centre Coupled Model, Version 3.

[a]State and cooperative summary of the day identification number.

Modeling Approach – Site Configurations

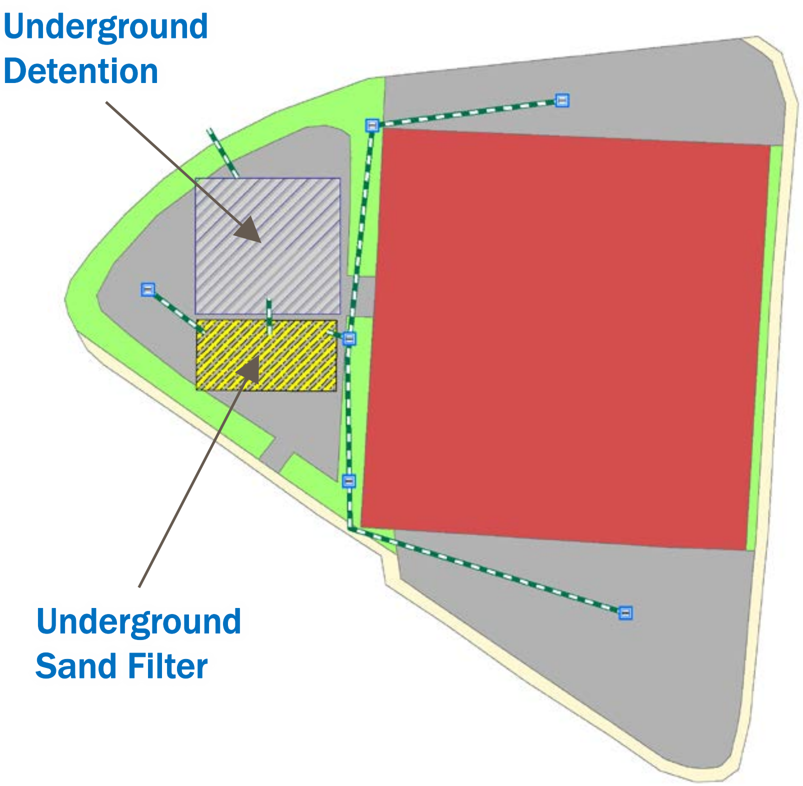
- Reviewed stormwater manuals/requirements for specific city/county
- Selected appropriate BMPs and routing to meet criteria/requirements
- Scoping-level engineering design for BMPs
  - Volume
  - Depth
  - Outlet structure
  - Media properties
  - Treatment
  - Etc.
- Developed cost estimates

Commercial Site

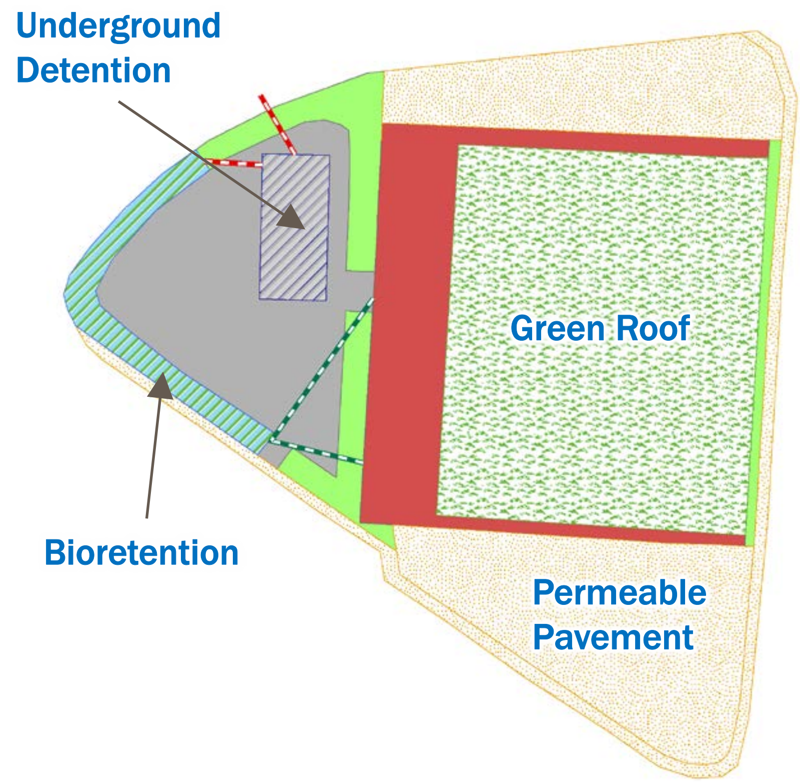


Atlanta, GA – BMP Configurations

Conventional (Gray)



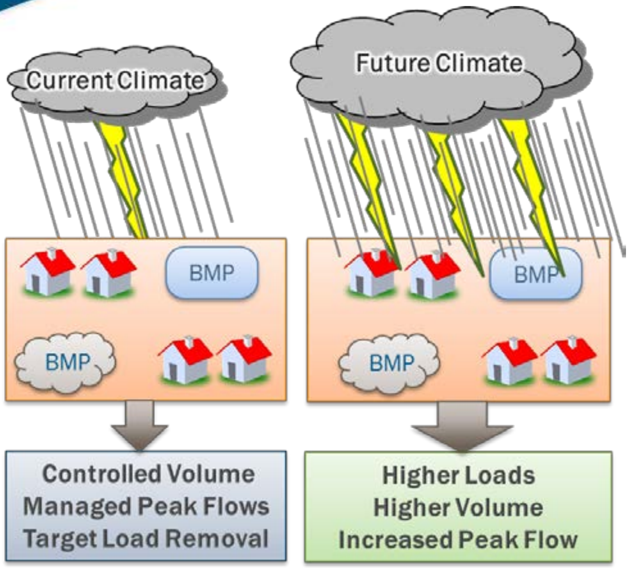
GI with Gray



Matrix of Regions, Locations, Land Uses, Future Climate Scenarios, Stormwater Management Approaches, and Stormwater Practices

Region	Location	Land Uses and Characteristics	Climate Scenarios	Stormwater Management Approach	Stormwater Practices
Southeast	Atlanta, GA	Ultra-Urban 2 acres 90% impervious	• GCM High Intensity	Conventional (gray) infrastructure	Underground sand filter, underground dry detention basin
				GI with gray infrastructure	Green roof, permeable pavement, bioretention, and underground dry detention basin
Arid Southwest	Maricopa County, AZ	Commercial 10 acres 80% impervious	• GCM High Intensity	Conventional (gray) infrastructure	Detention/infiltration basin
				GI only	Permeable pavement, cistern, bioretention, and stormwater harvesting basin
Pacific Northwest	Portland, OR	Transportation Corridor 0.35 acres 89% impervious	• GCM High Intensity	GI only	Bioretention swales, permeable pavement
Mid-Atlantic	Harford County, MD	Mixed Use 20 acres 65% impervious	• GCM High Intensity • Minus 10 Percent • Plus 10 Percent • Plus 20 Percent	Conventional (gray) infrastructure	Surface sand filters, extended dry detention basin
				GI with gray infrastructure	Infiltration trenches, infiltration basins, permeable pavement, and dry detention basin
				Conventional (gray) infrastructure with distributed GI	Surface sand filters, extended dry detention basin, distributed infiltration trenches
Midwest	Scott County, MN	Residential 30 acres 48% impervious	• GCM Low Intensity • GCM Medium Intensity • GCM High Intensity • Minus 10 Percent • Plus 10 Percent • Plus 20 Percent	Conventional (gray) infrastructure	Wet pond
				GI with gray infrastructure	Distributed bioretention and dry detention basin
				GI only	Distributed bioretention, permeable pavement, and impervious surface disconnection
				Conventional (gray) infrastructure with distributed GI	Wet pond, distributed bioretention

Normalized Site-Export under Current and Future Climate Conditions



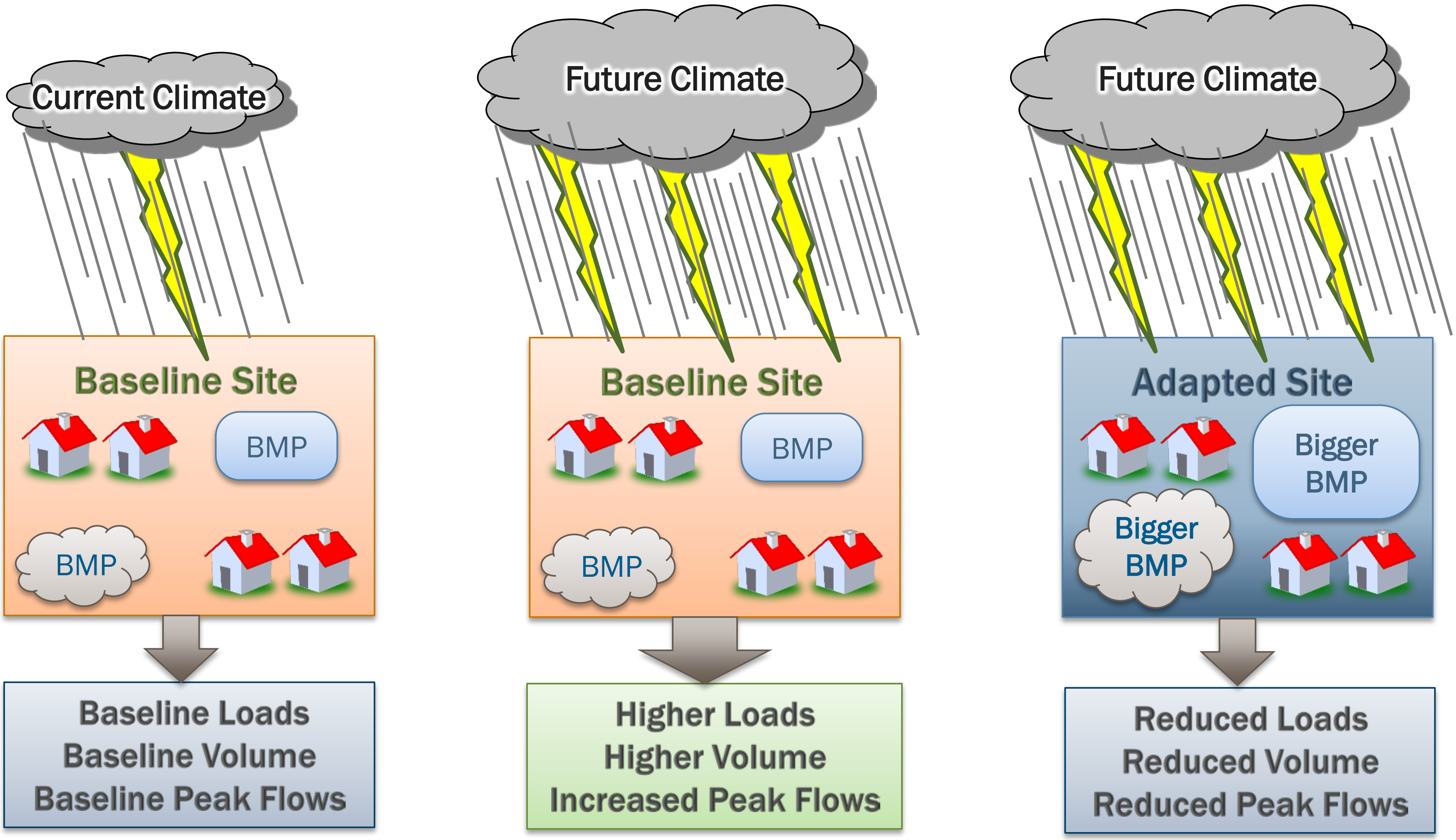
Results indicate a likely risk that climate change will negatively affect BMP performance for both gray and green stormwater management approaches

Example Current and Future performance of Harford County, MD site by stormwater management approach

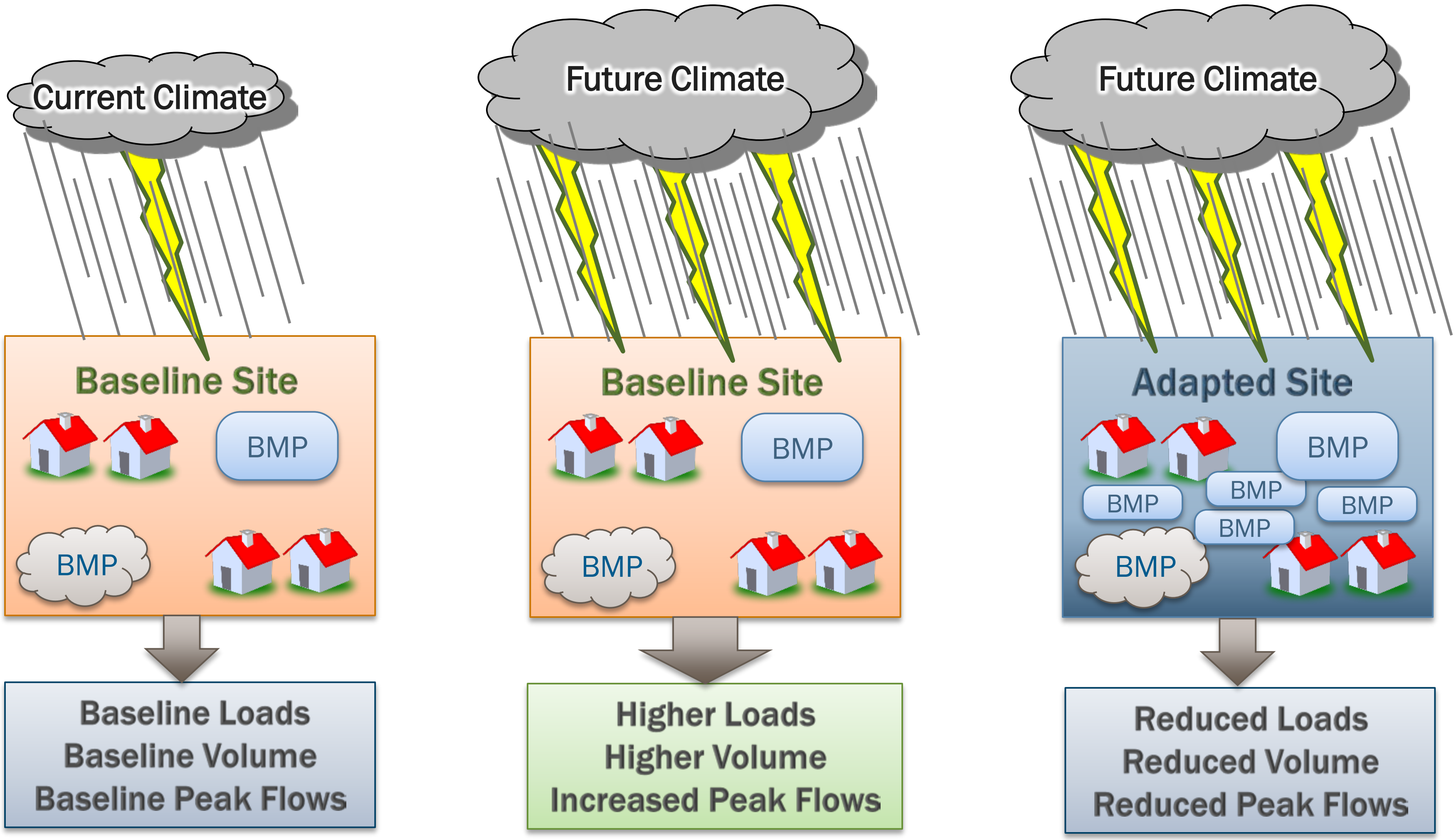
Stormwater management approach	Current	Future	Change
Runoff (inch/yr)			
Conventional	7.04	10.96	+3.92
GI + Gray	1.52	3.40	+1.88
Maximum hourly peak flow (cfs/ac)			
Conventional	1.12	1.80	+0.67
GI + Gray	0.85	1.52	+0.67
Sediment (ton/ac/yr)			
Conventional	0.12	0.20	+0.09
GI + Gray	0.04	0.11	+0.08
TN (lb/ac/yr)			
Conventional	2.74	4.34	+1.60
GI + Gray	0.64	1.58	+0.94
TP (lb/ac/yr)			
Conventional	0.32	0.51	+0.18
GI + Gray	0.07	0.18	+0.11

Current w/ BMP
Future GCM High Intensity Climate Scenario w/BMP

Modeling Approach:
Adaption to Projected Future Climate Conditions
Resize Existing BMPs (all geographic locations)



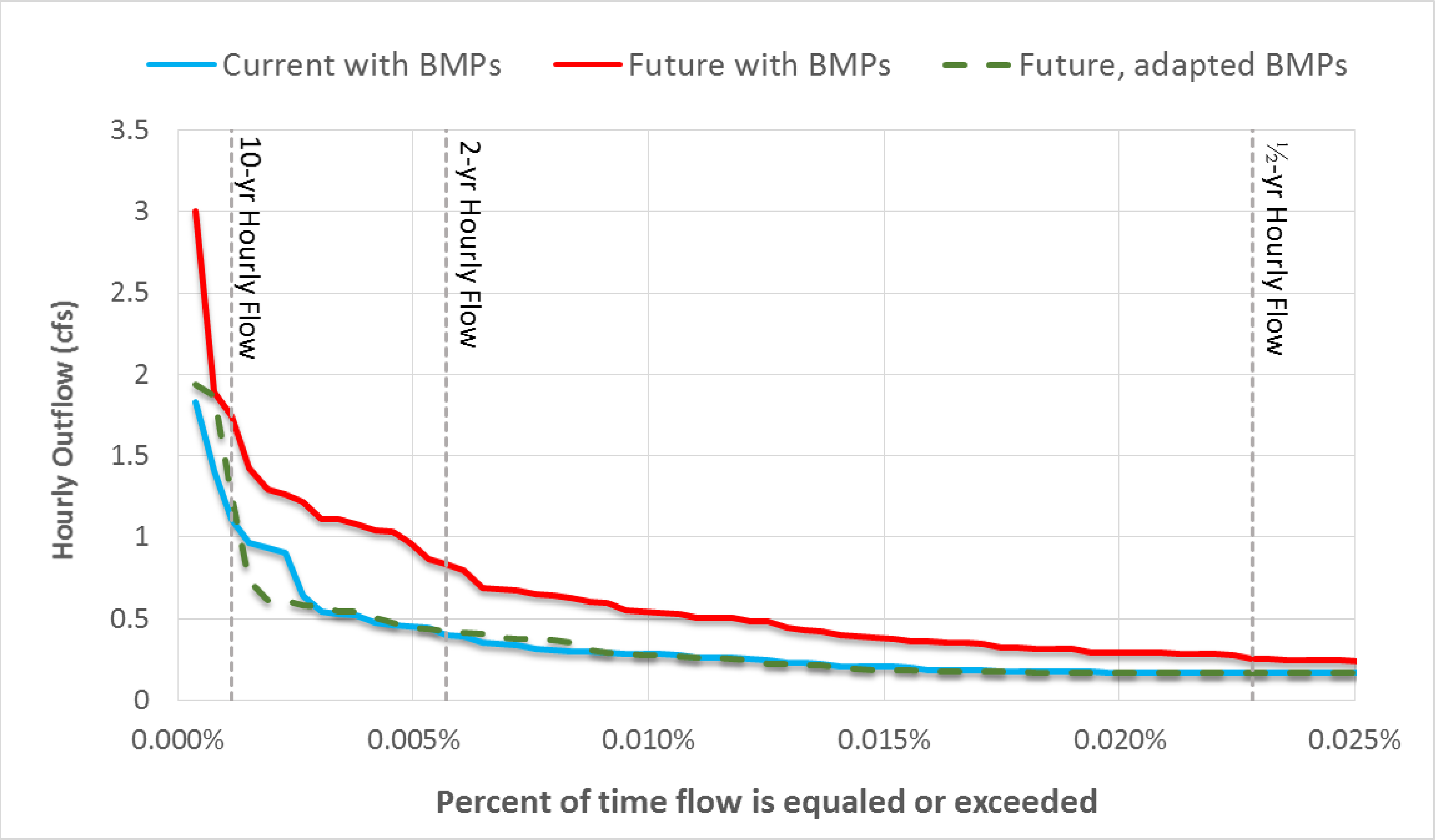
Modeling Approach:
Adaption to Projected Future Climate Conditions
Add Distributed GI BMPs (Midwest and Mid-Atlantic)



Site Example – Southeast (Atlanta, GA)

- Ultra-urban, 2 acres, 90% impervious area
- Stormwater requirements
  - Retain runoff from 1st inch of rainfall ~or~ 80% TSS removal
  - Detain runoff from 1-yr 24-hr storm, release over 24 hours
  - Match pre-development peaks for 2-yr through 100-yr 24-hr events
- Future climate scenario
  - 20% increase in large storm event depth
  - 90th percentile event increases from 1.03 in to 1.15 in
  - 7% increase in annual rainfall

Atlanta, GA – Bankfull/Flooding Event Performance



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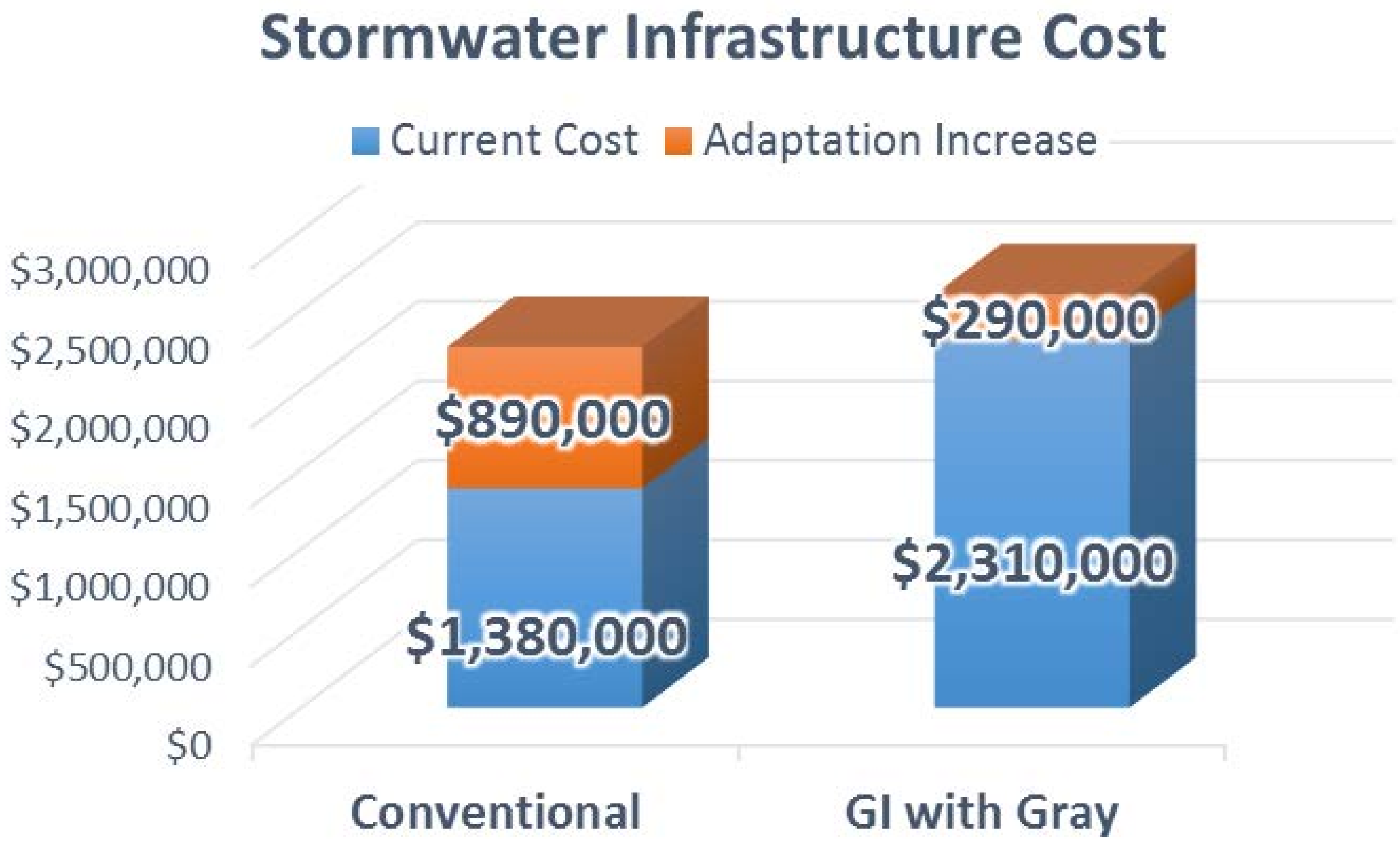
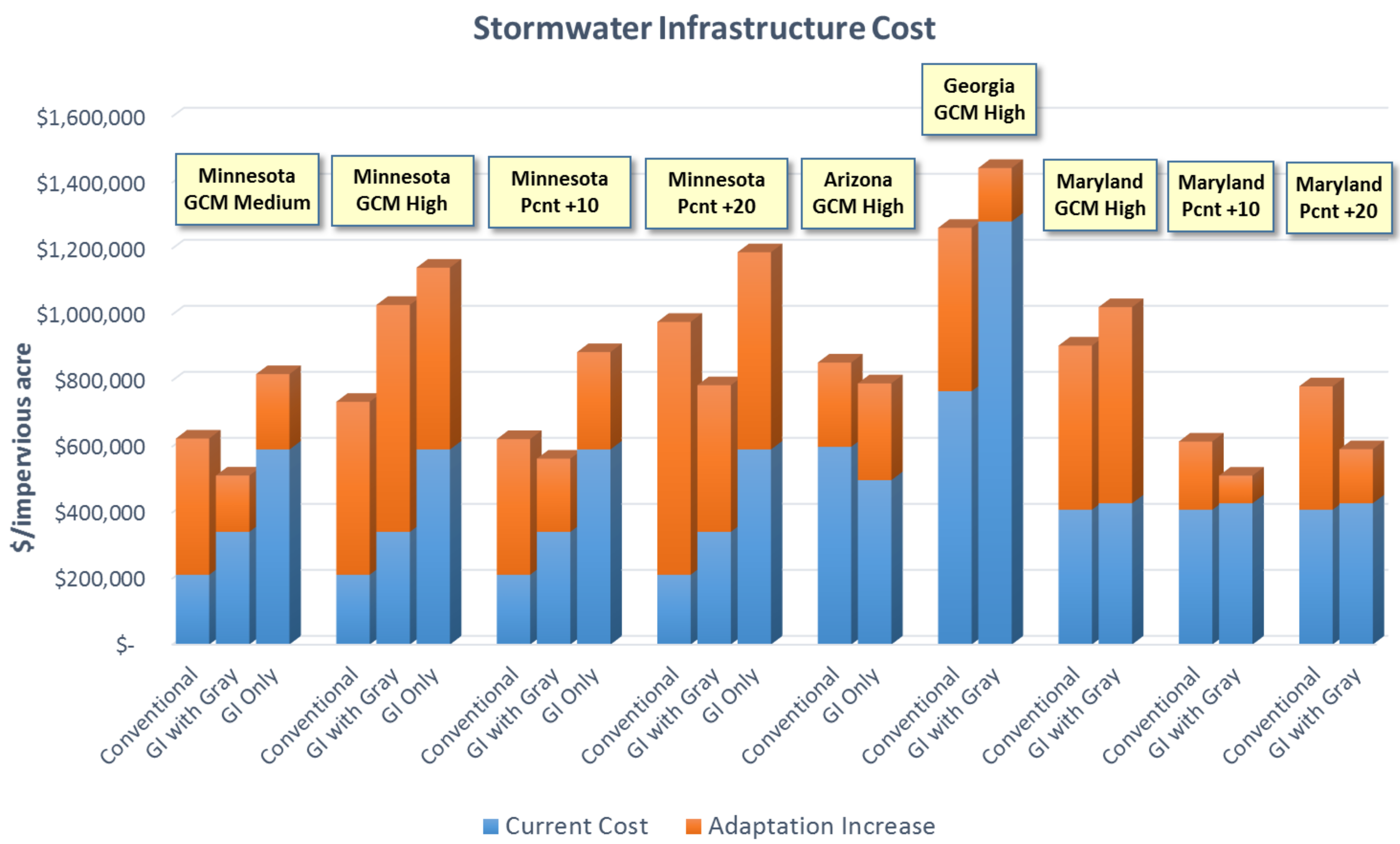
Atlanta, GA – Adaptation to Achieve Current Performance

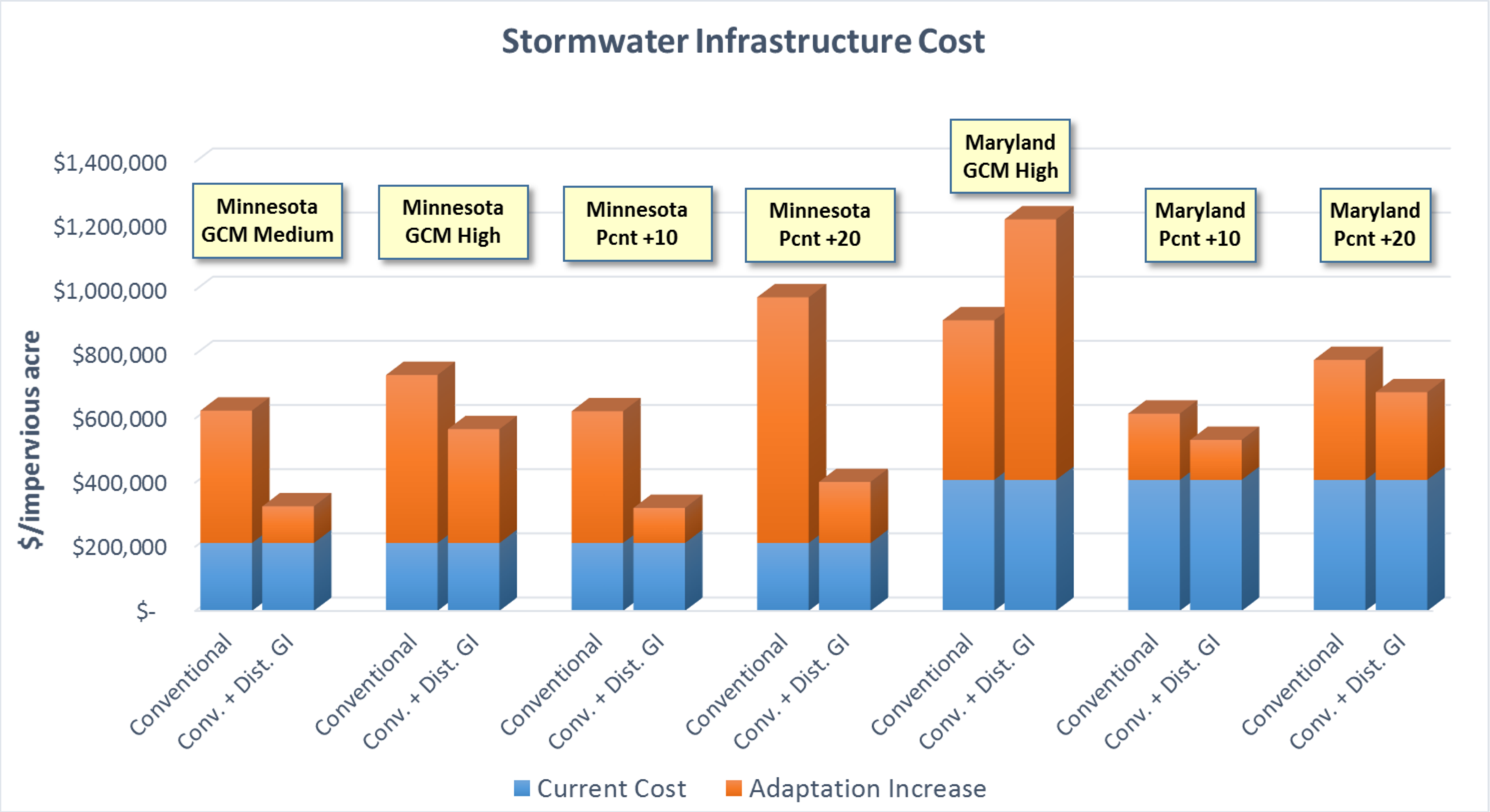


Total Cost:	$2,270,000	$2,600,000

Adaptation Cost – Resize Practices



Adaptation Cost – Add Distributed GI



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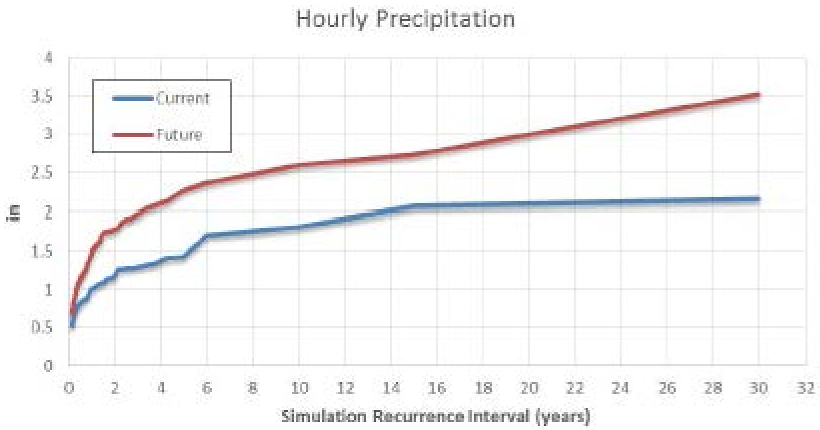
Conclusions

- Volume/load increase generally 2% to 27%, while highest peak flows increase from 42% to 91%
- Meeting the FDC metric was the limiting or colimiting factor in over 80% of the optimization runs
  - Flood event runoff volume control is generally the most difficult
  - Matching the annual runoff volume was the limiting or co-limiting factor 40% of the time
  - Of the three pollutants, TSS load was the most common limiting factor (20% of the scenarios)
- Gray infrastructure with detention storage more effective for mitigating extreme event volume increase
- GI has greater flexibility for addressing multiple objectives

Conclusions

- Study suggests a need for greater temporary volume storage and/or reconfiguration of outlet structures to mitigate flooding and channel erosion risk due to climate change
- Stormwater requirements will likely need to be adapted in the future to address higher precipitation depths



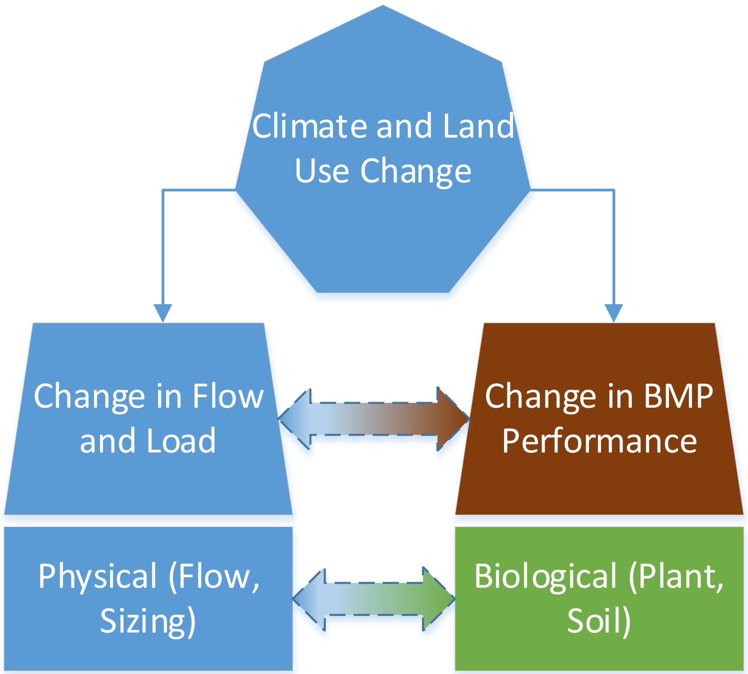
Percentile	Current conditions 24-h depth (in)	Future climate 24-h depth (in)	Change (+/−in)
85th	0.81	0.90	+0.09
90th	1.03	1.15	+0.12
95th	1.39	1.58	+0.19
99th	2.33	2.76	+0.43

e.g. data from Harford County, MD

Conclusions

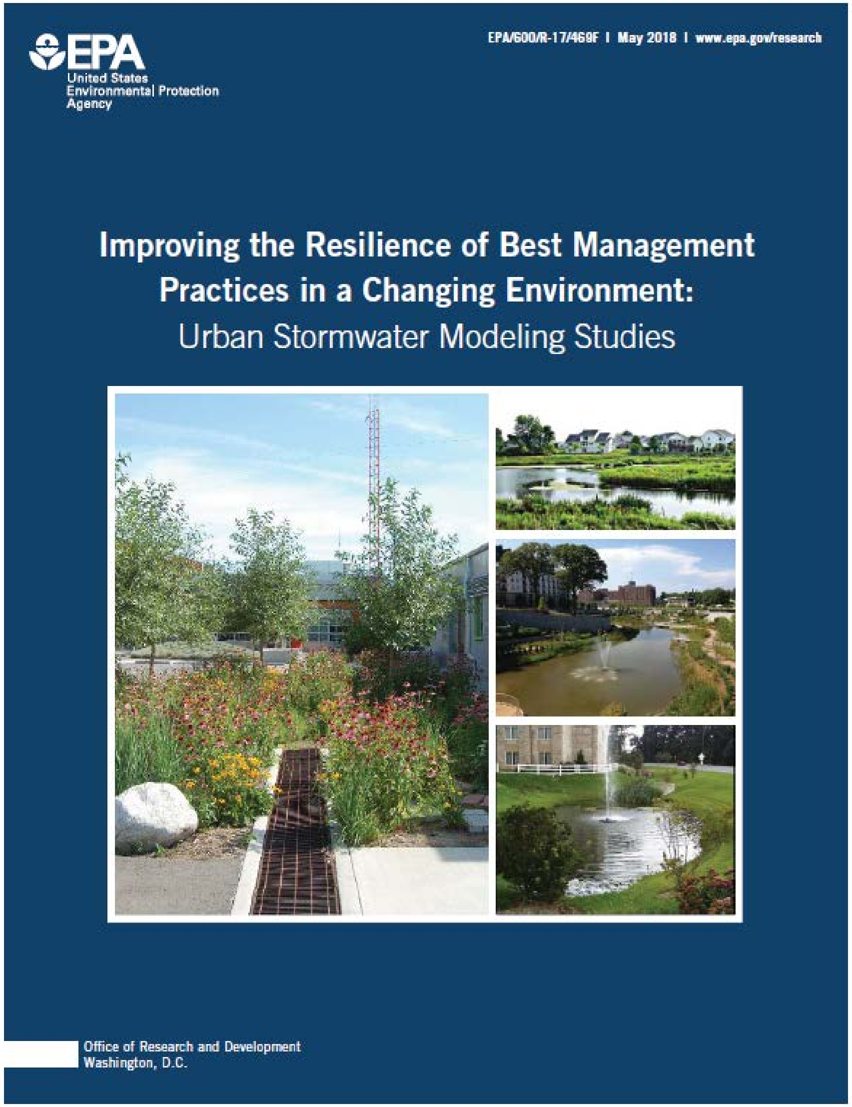
- Conventional stormwater management approaches tended to be more cost-effective than their GI counterparts
  - However, the additional cost of adapting sites using GI approaches tended to be less than adapting conventional only approaches
- Stormwater management that combines gray and green approaches tends to have better cost resiliency

Additional Considerations (GI and Climate Change)



- Need to consider both changes in flow and load to BMPs and changes in BMP performance associated with climate
- GI components such as bioretention depend on the biology of plants and soil organisms to achieve performance
- Rising temperatures and altered soil moisture will affect these components
  - Potential for water balance to alter vegetation density and vigor
  - Changes in rates of nutrient mineralization and recycling
- Pollutant removal efficiency under current climate may not accurately predict future performance
  - This is an area of ongoing research

Acknowledgments



U.S. EPA (Environmental Protection Agency). 2018. Improving the resilience of BMPs in a changing environment: urban stormwater modeling studies. Office of Research and Development, Washington, DC; EPA/600/R-17/469F. Available online at http://www.epa.gov/research.

Funding for this work was provided by U.S. EPA, Office of Research and Development's Air, Climate and Energy Research Program (ACE).

The views expressed in this presentation represent those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.