Green Infrastructure Modeling Strategies

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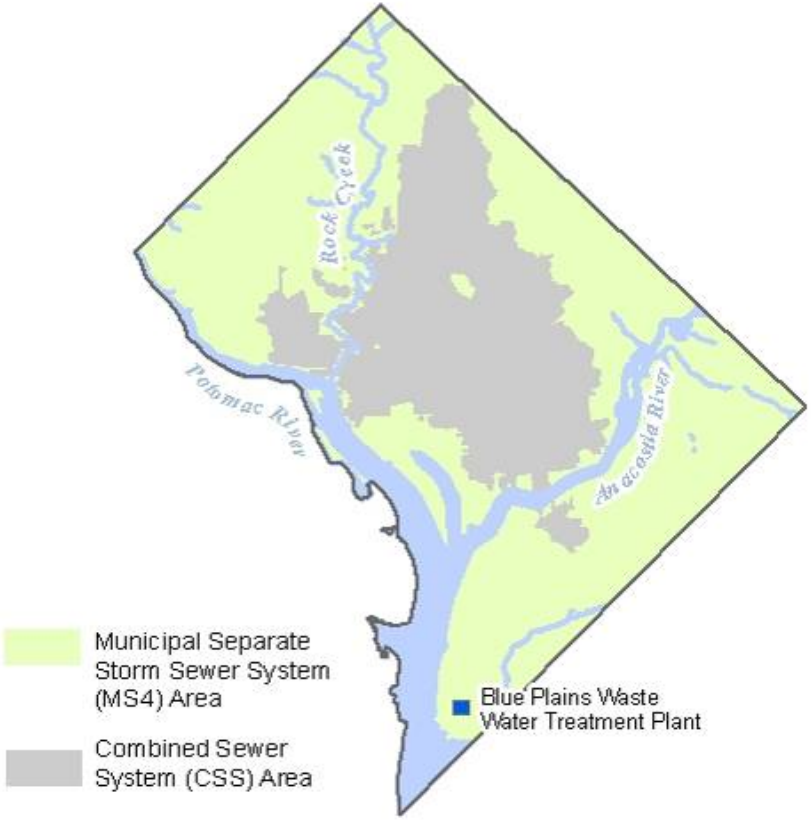
Agenda

- Green Infrastructure Modeling Overview
- DC Water Green Infrastructure
- Timeline of DC Water GI Models
- Next Steps

Green Infrastructure Model Basics

- Why do we need a computer model?
  - Models are used as tools to help us predict CSO overflows caused by different management scenarios.
- Why can we trust models?
  - The models used here are calibrated to actual sewer flow measurements specifically selected to quantify CSO overflow volume and frequency.
- How is GI modeled?

Combined vs. Separated Areas



- Different goals in combined vs separated areas
- Separate area flows directly to receiving waters
  - Reduce runoff volume
  - Reduce pollutant load
  - Capture first flush
- Combined area flows to Blue Plains AWTP
  - Reduce peak flows
  - Reduce volume during large storm events

dc clean RIVERS PROJECT

The Task

Quantify reduction in volume and frequency of CSO overflows caused by:

- Increased Green Infrastructure
- Variations in pumping
- Variations in tunnel volume
- Grey infrastructure improvements

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What is Green Infrastructure?

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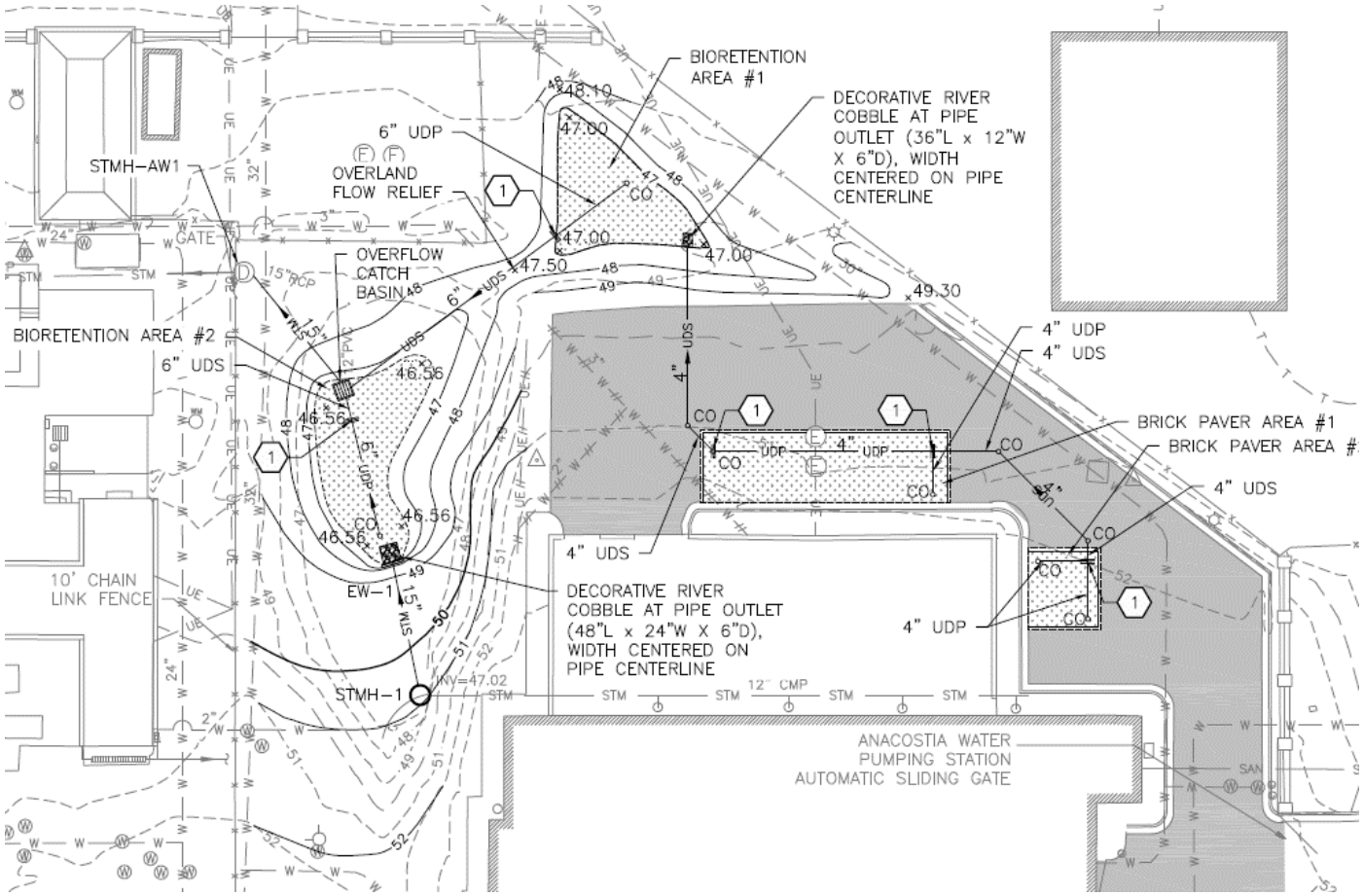
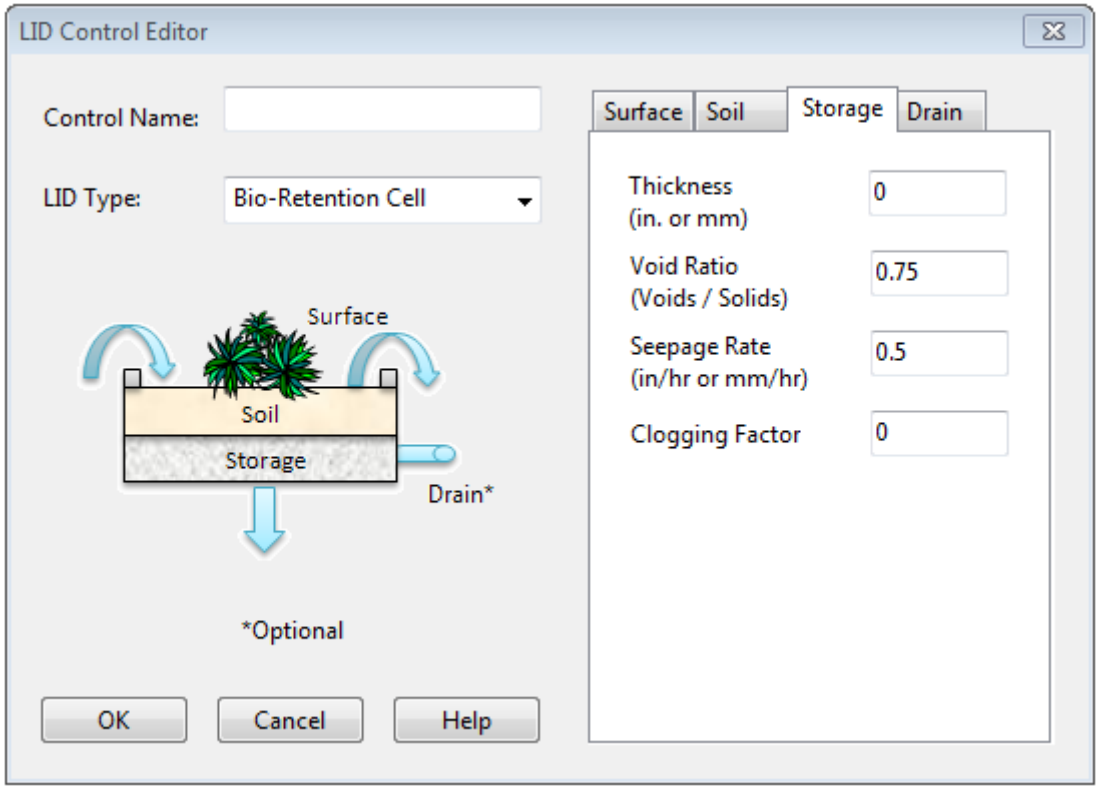
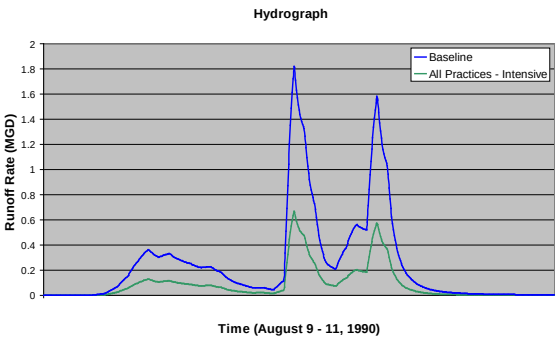


What is Green Infrastructure?

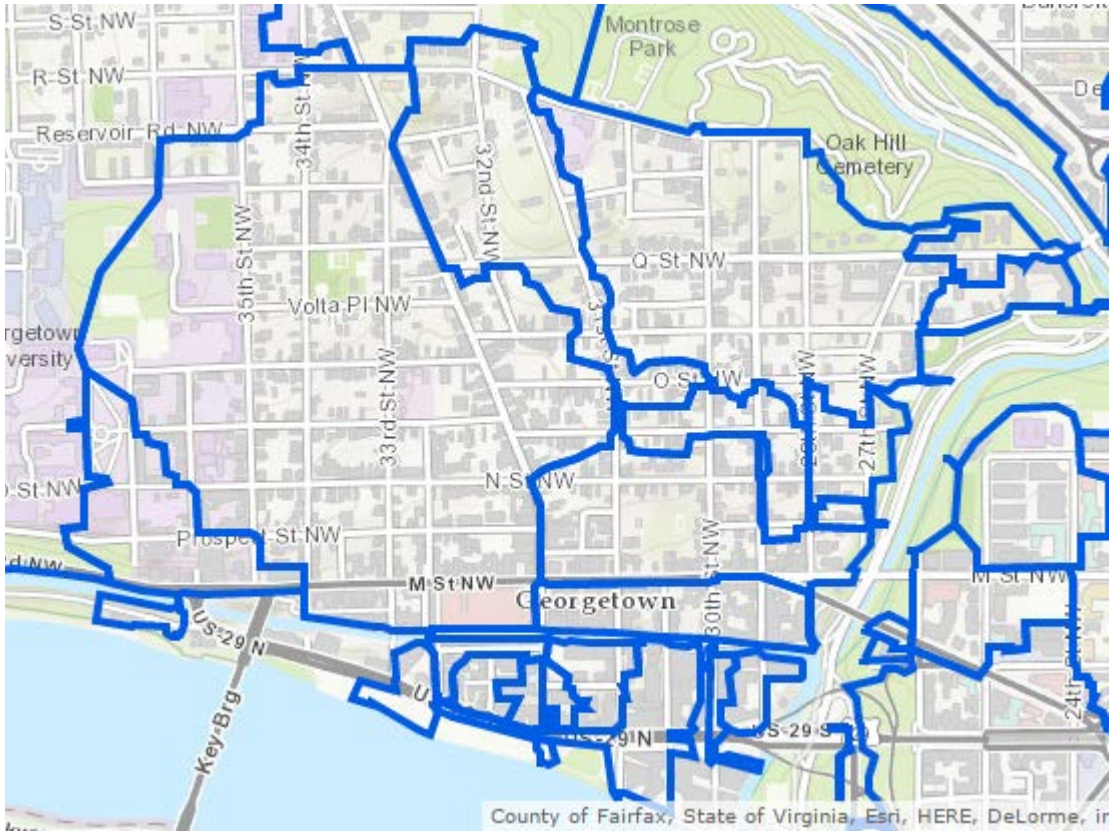


GI Modeling Methods



- Runoff/pollutant reduction
  - Volume reduction percentage
  - Treatment percentage
  - Peak flow reduction
- Drain time/volume simulation
  - Assume treatment volume and drain time
  - Link with runoff model, or use as separate model
- Complex GI representation
  - Model internal processes of GI practice: soil permeability, infiltration, underdrain, vertical conductivity
  - Must have on-the-ground data to support level of detail

Lumped Parameter Model



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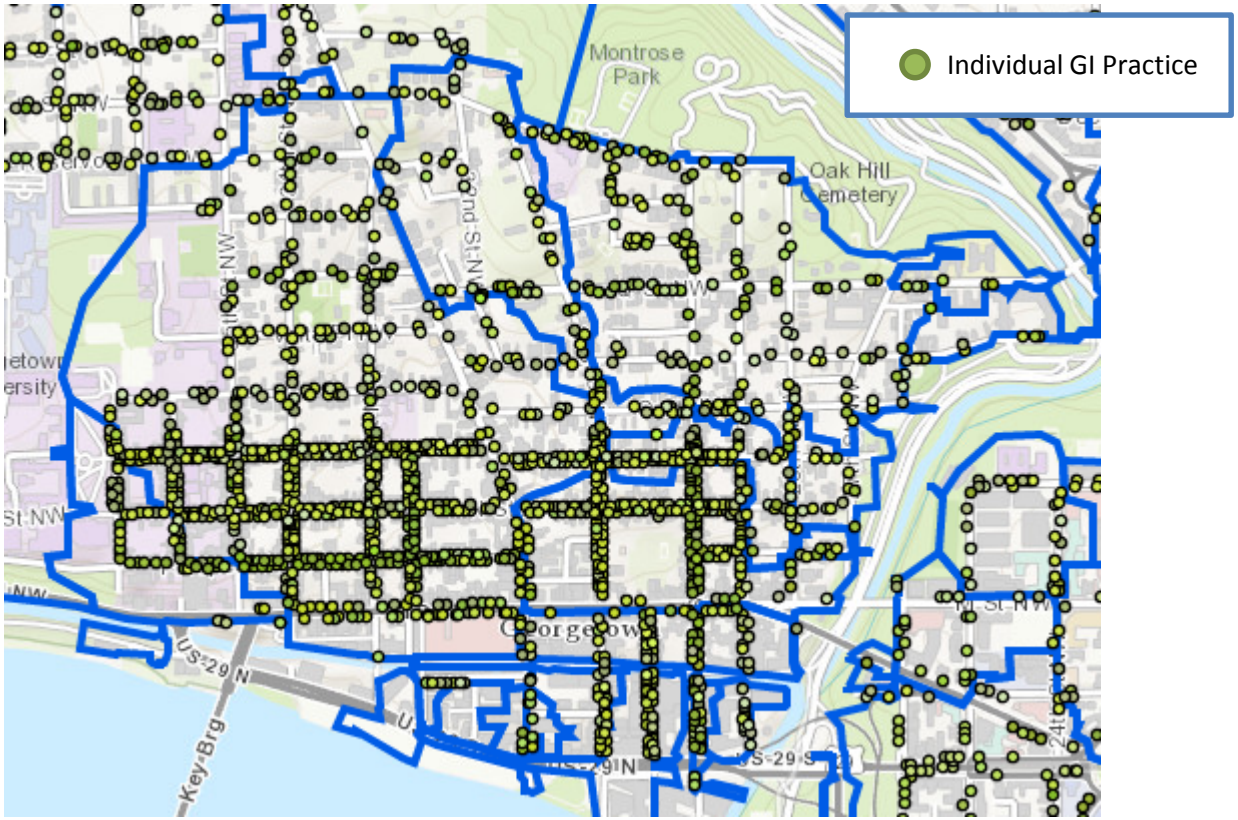
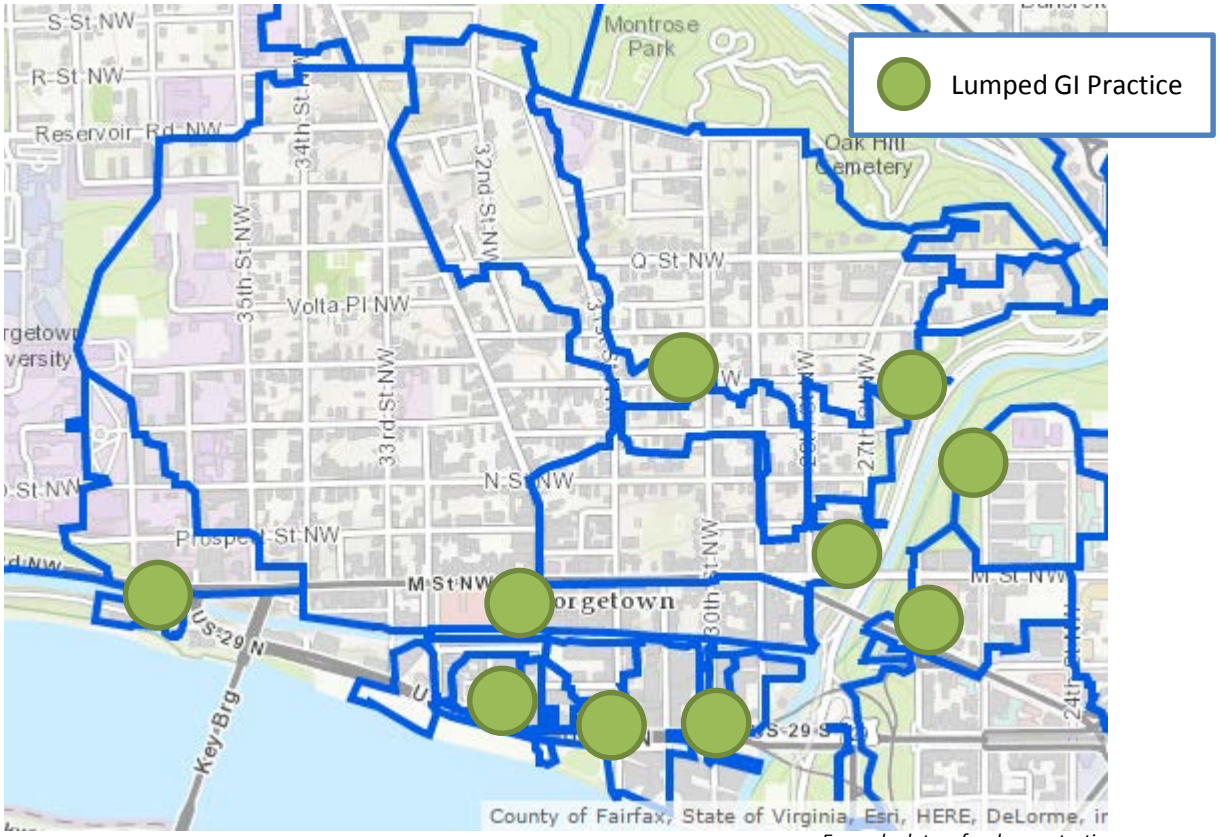


Example data – for demonstration

Lumped Parameter Model



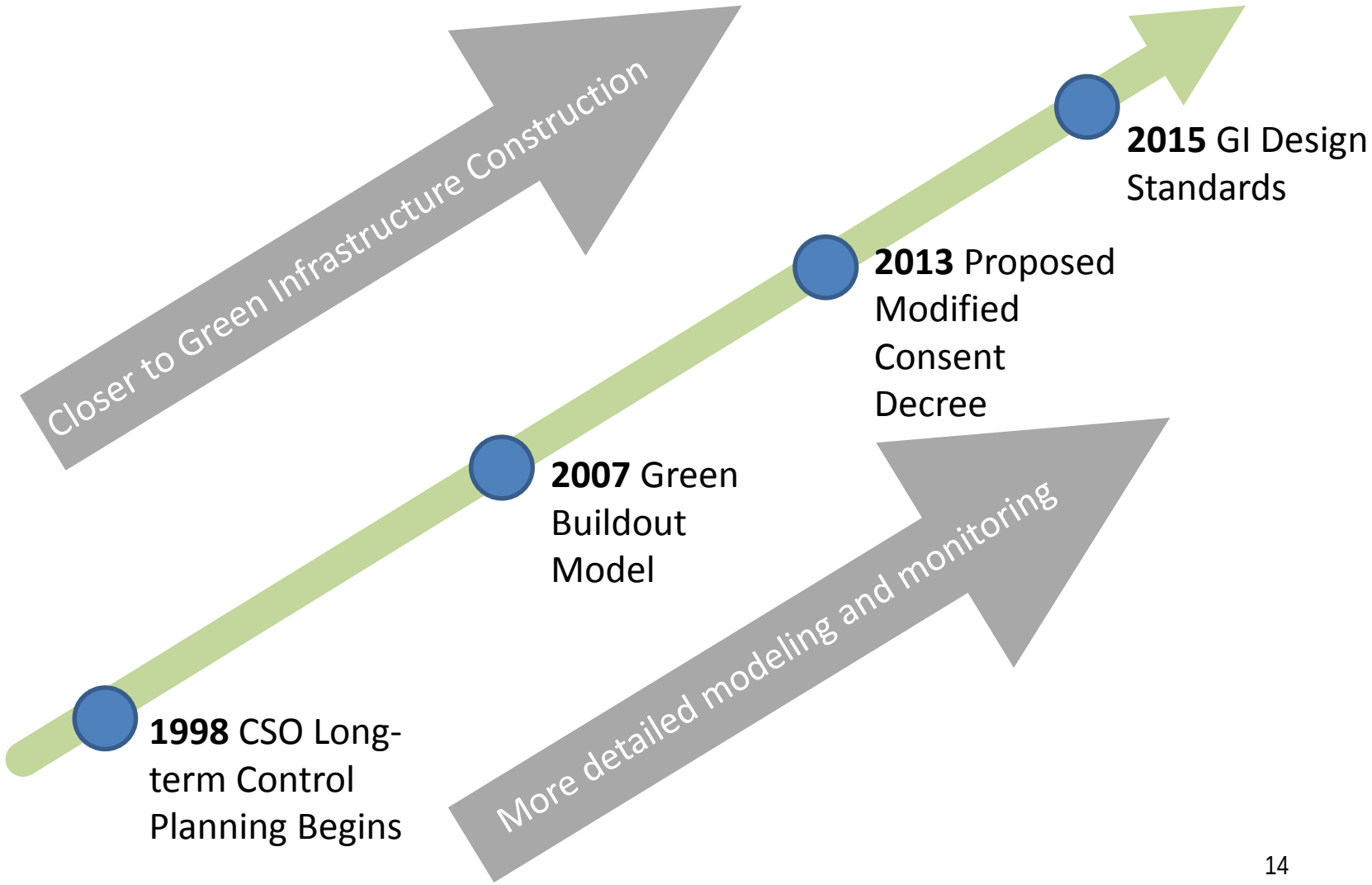
Example data – for demonstration

Represent all GI within a catchment as one GI practice per catchment

Hydrologic Modeling Tools

- MIKE URBAN by DHI Software
  - Fully dynamic hydraulic and hydrologic model
  - Developed for urban runoff and collection systems
- EPA SWMM5
  - Also fully dynamic hydraulic and hydrologic model
  - Recent built-in support for LID Controls
  - Used throughout the industry
- Other tools
  - InfoWorks, InfoSWMM, PCSWMM, xpswmm, HSPF, and other H&H modeling packages
  - EPA Stormwater Calculator, GIS, Excel, R, Python…

Project and Model Progression



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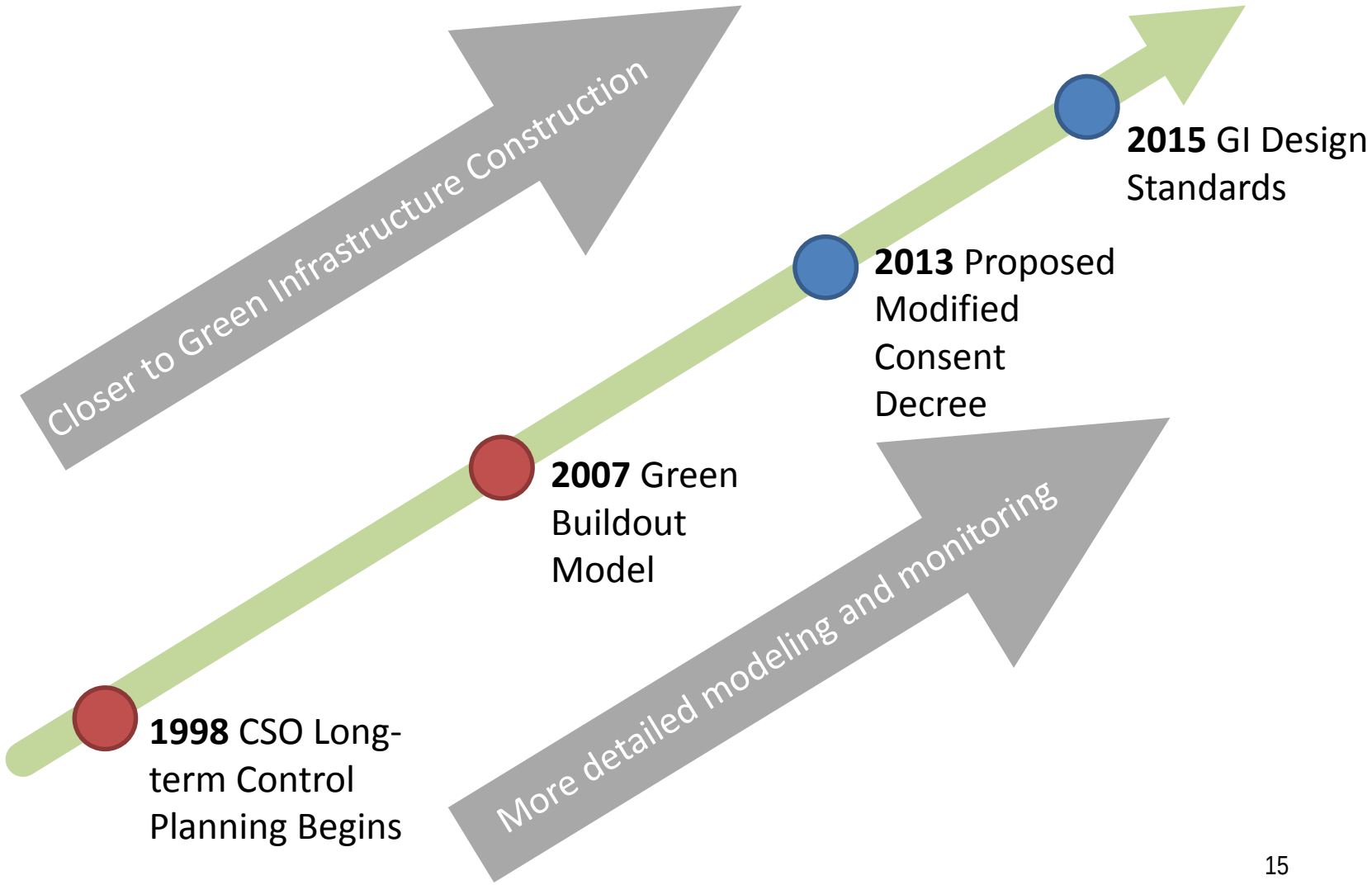
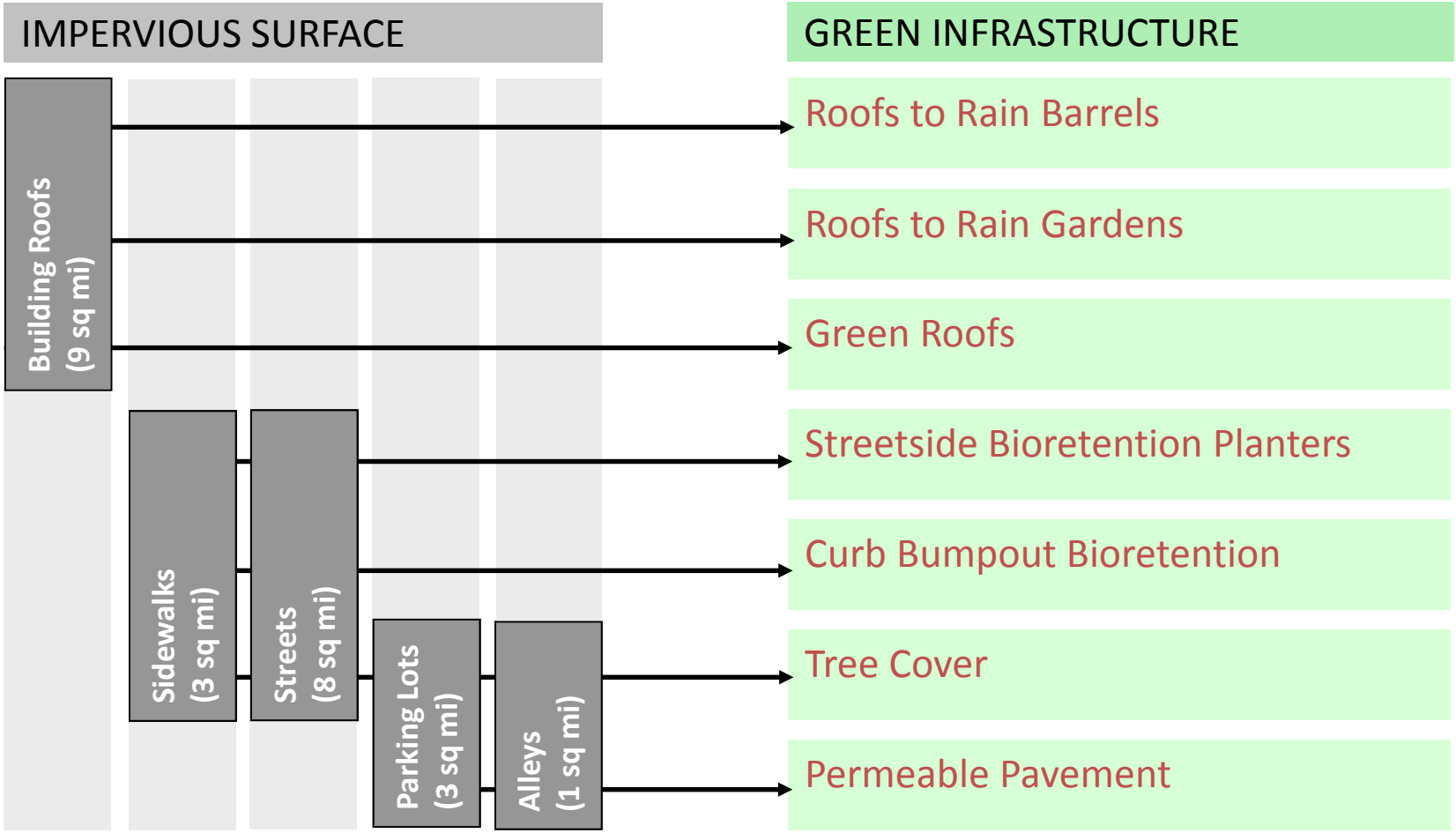


Model Development

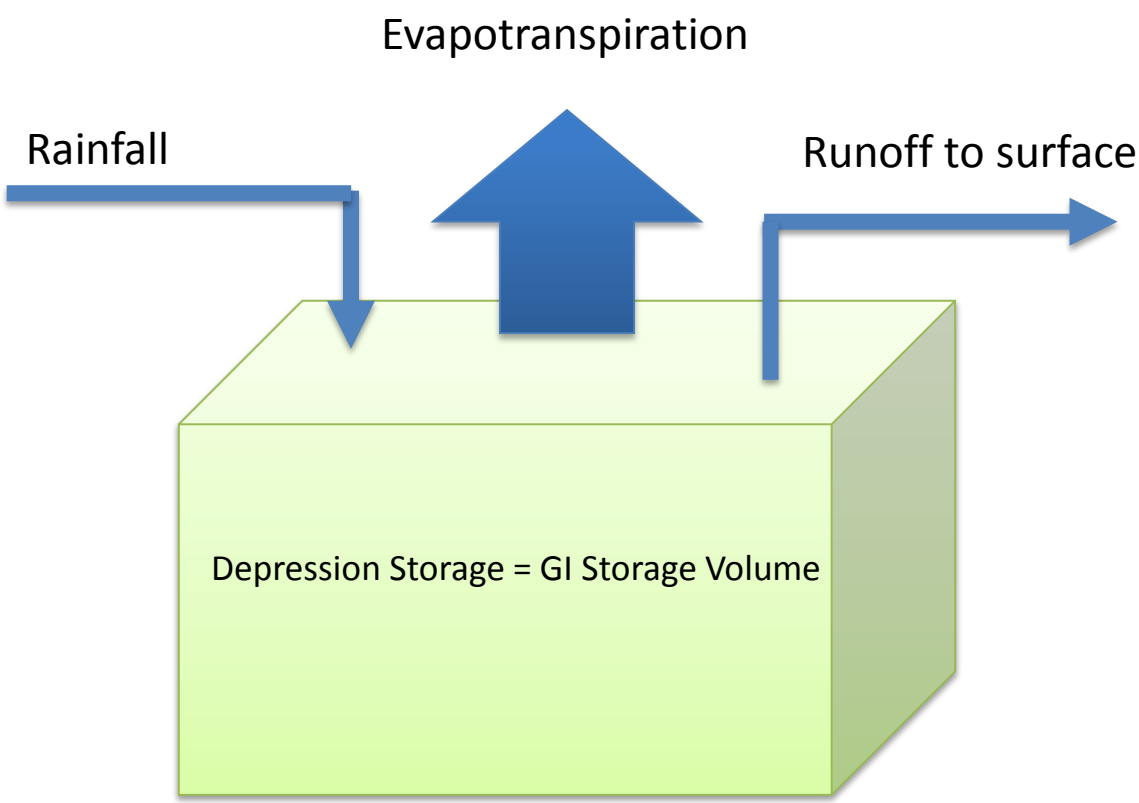
- 1998-2006 MIKE MOUSE/MIKE URBAN collection system model
  - Calibrated model of combined sewer area
  - Pumps and inflatable dams operated with real-time controls
  - Quantify volume and frequency of CSO overflows
  - Tunnels (and other grey improvements) to reach LTCP goals

- 2007-2009 Green Build-out Model (GBOM) – MIKE URBAN
  - What runoff volume can we capture with GI in DC?
  - Green Infrastructure as **depression storage** with **evaporation**

Green Buildout Model

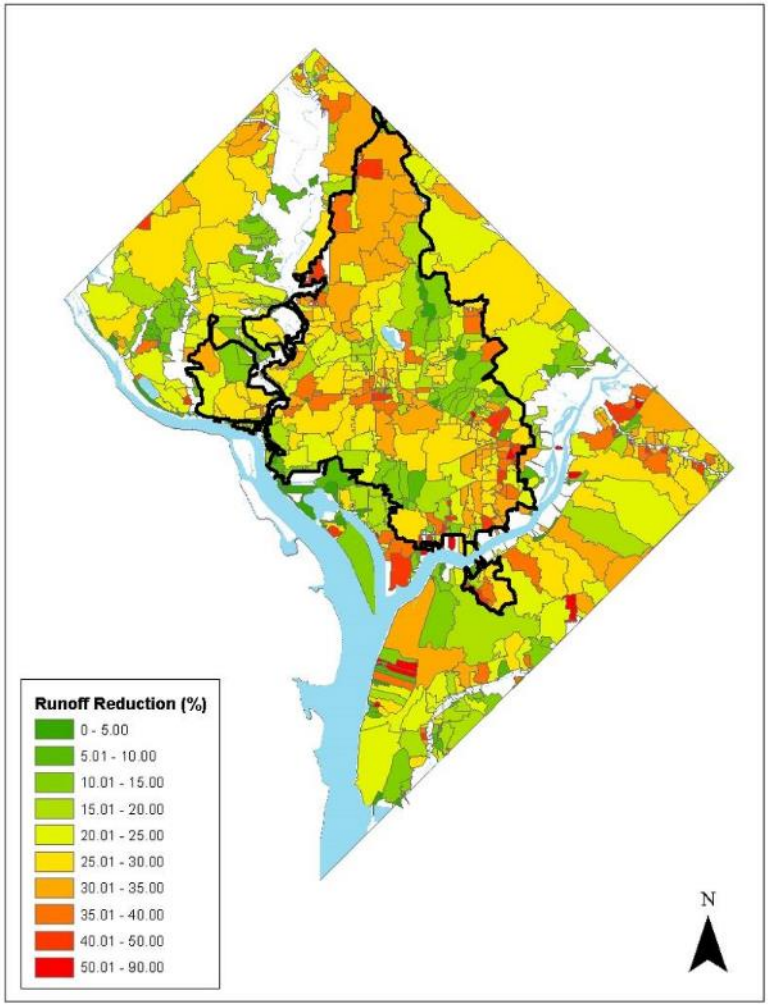


GBOM Green Infrastructure Representation



Green Buildout Model

- Identified the potential benefits of GI implementation
- Quantified District-wide runoff reductions
- Formed basis for moving forward with Green Infrastructure



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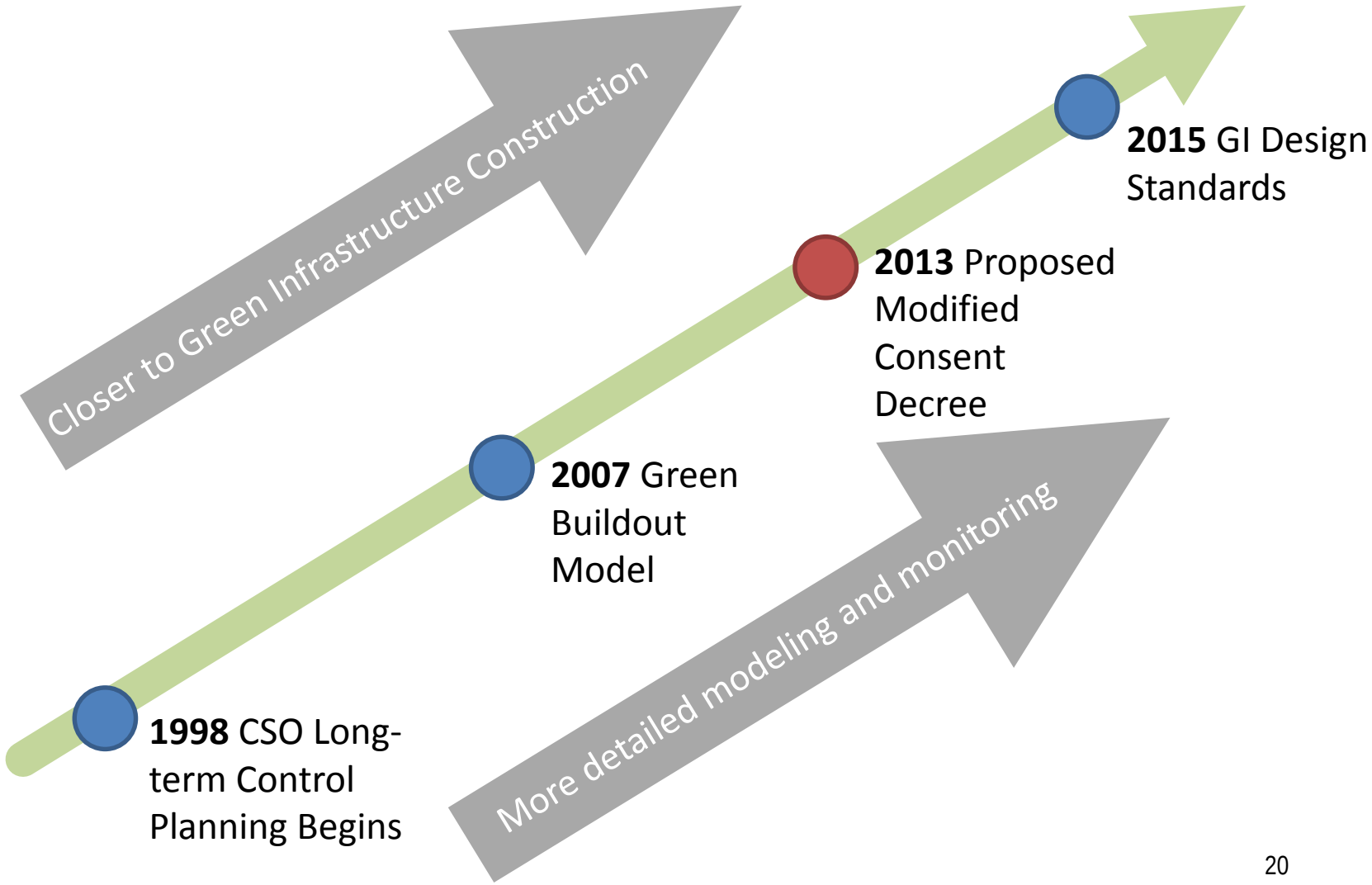
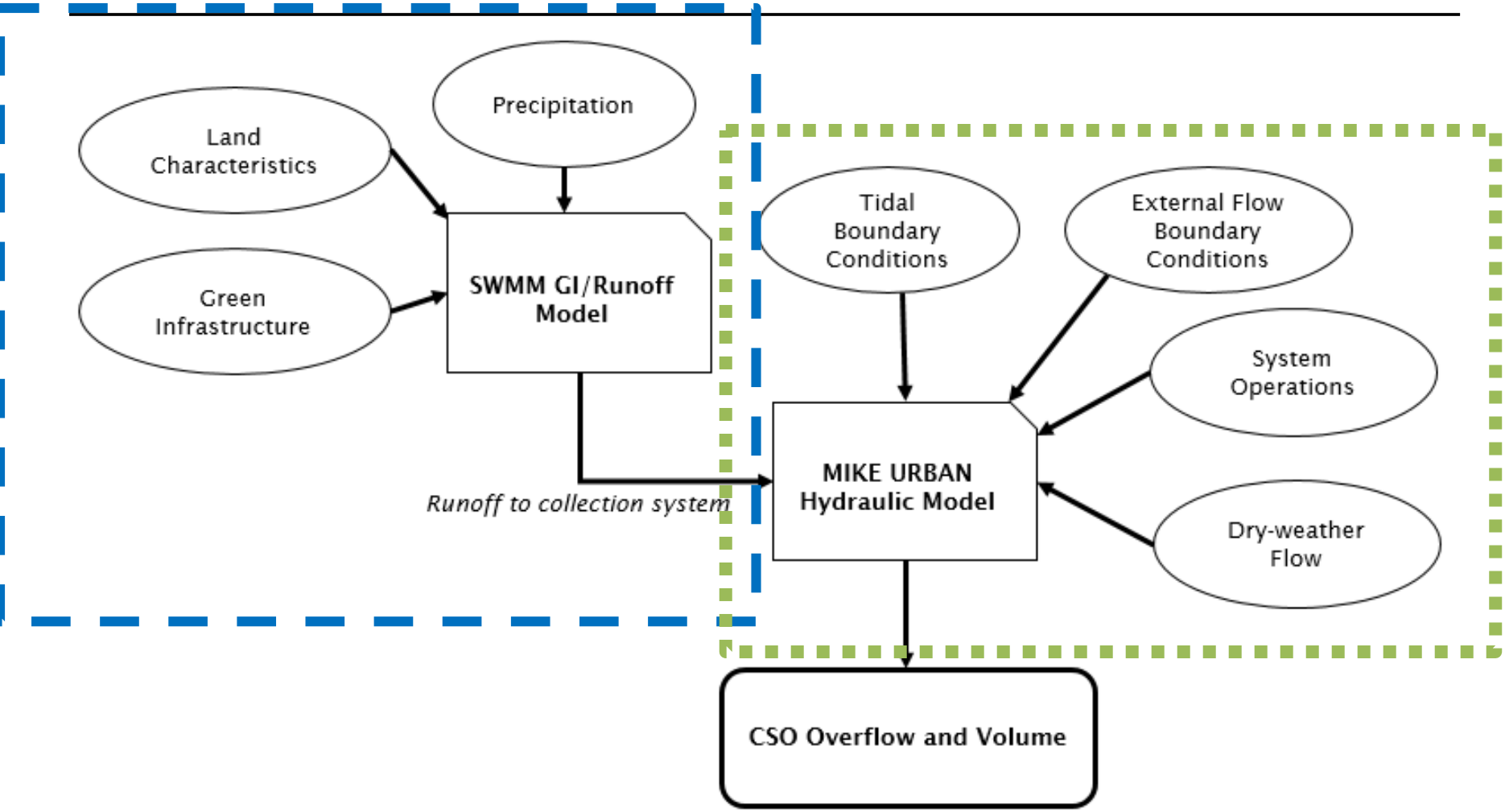


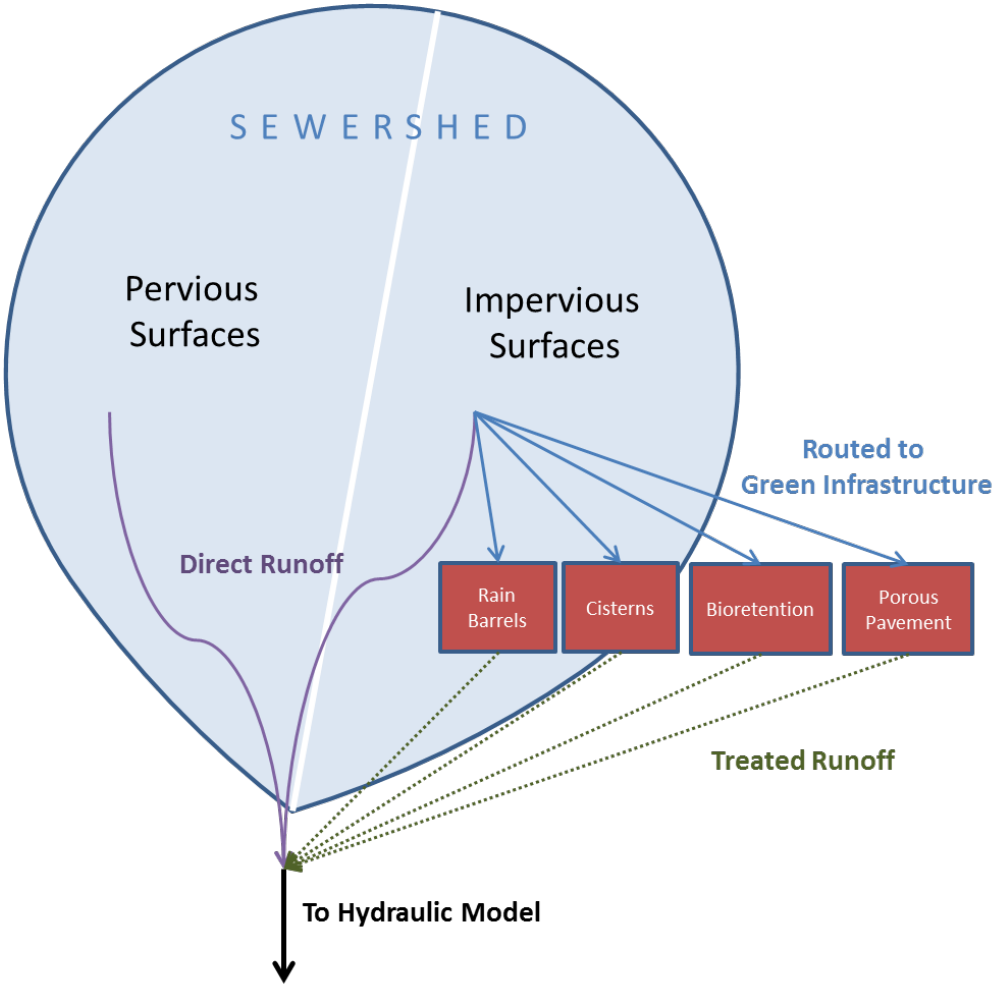
Model Development

- 2010-2013 SWMM5/MIKE URBAN coupled model
  - We know that GI is feasible in certain areas. How much do we need?
  - Shift to SWMM5 to leverage LID Controls
  - GI represented as mix of bioretention, pervious pavement, cisterns, and rain barrels
  - Higher resolution drainage areas
  - Link runoff reduction to combined sewer overflow reduction
  - Can we use GI to offset tunnels?

SWMM5 and MIKE URBAN Linkage

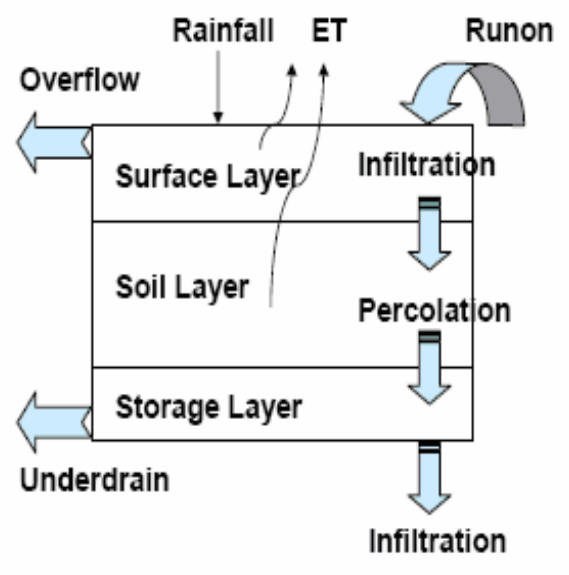


SWMM5 Runoff Framework



SWMM5 LID Controls

- Environmental Variables
  - Infiltration
  - Evapotranspiration (ET)
- Design Variables
  - Volume capture
  - Time to empty



Results

- Indicated performance comparable to Long Term Control Plan using mix of green infrastructure and grey infrastructure

EXAMPLE RESULTS FROM GROUP OF SCENARIOS

GI Optimization Group 2: Optimization of Piney Branch					
SCENARIO	% GI	TUNNEL VOL (ML)	STRUCTURE 70 WEIR HEIGHTS	CSO PREDICTIONS (AVE YR)	
				# CSOs	VOL (ML)
TM7-1	30%	0	+101 cm / +101 cm / +31 cm	0	0
TM7-2	0%	0	+40 cm / +40 cm / +0	5	15
TM7-2B	0%	0	No change	24	140
TM7-3B	30%	0	+40 cm / +40 cm / +0	3	5.3
TM7-3C	30%	0	+55 cm / +55 cm / +0	1	2.3

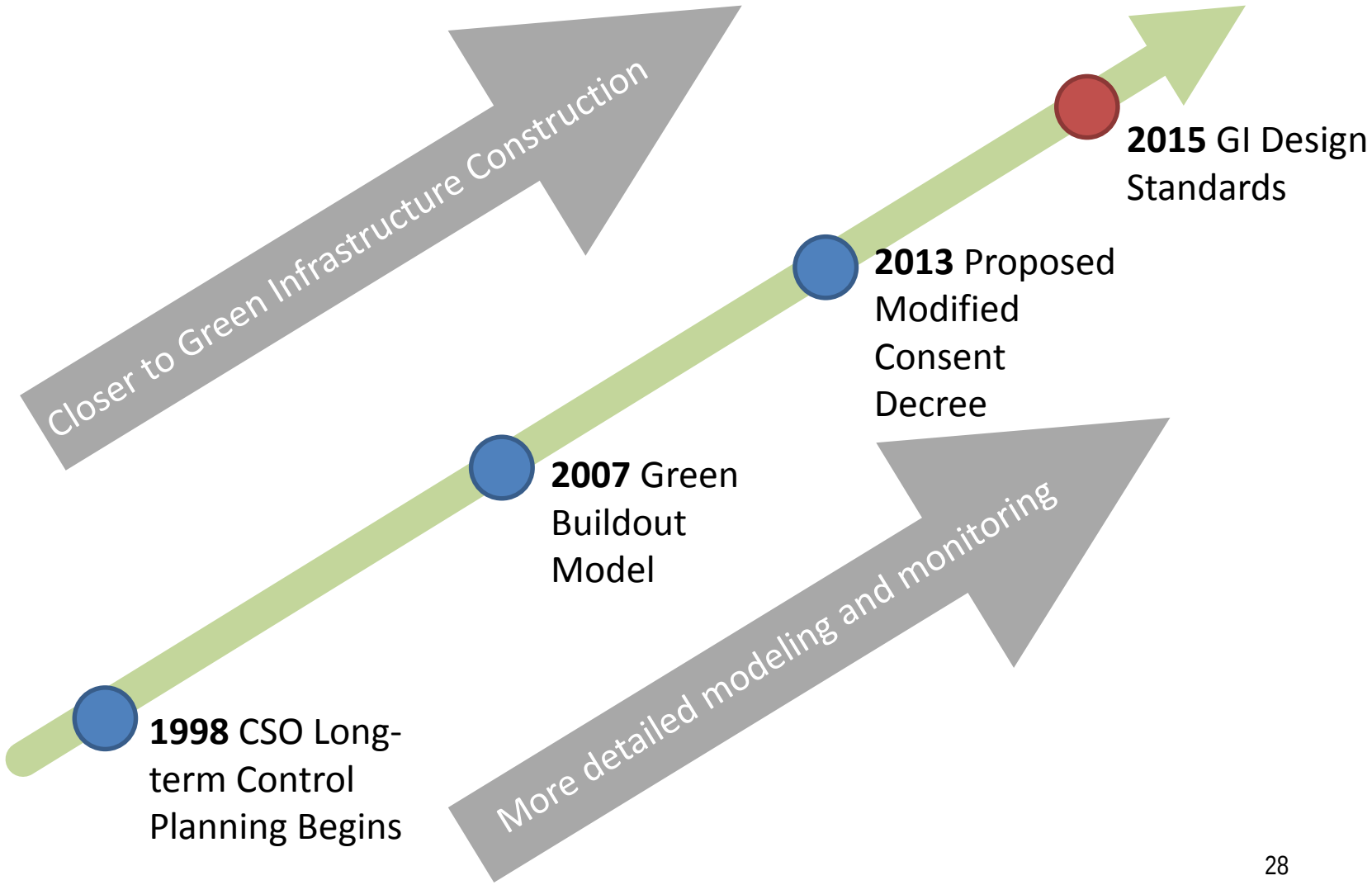
Model Scenario Progression

- General approach:
  - Increase GI within reasonable limits
  - Is increase in GI enough to offset tunnel?
  - Make small but detailed changes in grey infrastructure controls necessary to meet reduction goal
- Over 60 scenarios evaluated and modeled for CSO overflow frequency and volume

Results

- Optimized Green/Gray approach
  - Remove and/or “right-size” tunnels
    - Potomac River Tunnel reduced from 58 MG to 30 MG
    - Piney Branch Tunnel eliminated
  - Determined % GI implementation
    - Range 30% to 60% across select sewersheds
  - Refined control structure modifications

Project and Model Progression



Develop GI Design Standards

- What if we let low flows bypass GI?
- What if GI is not uniformly distributed?
- What if we make our GI larger/smaller?

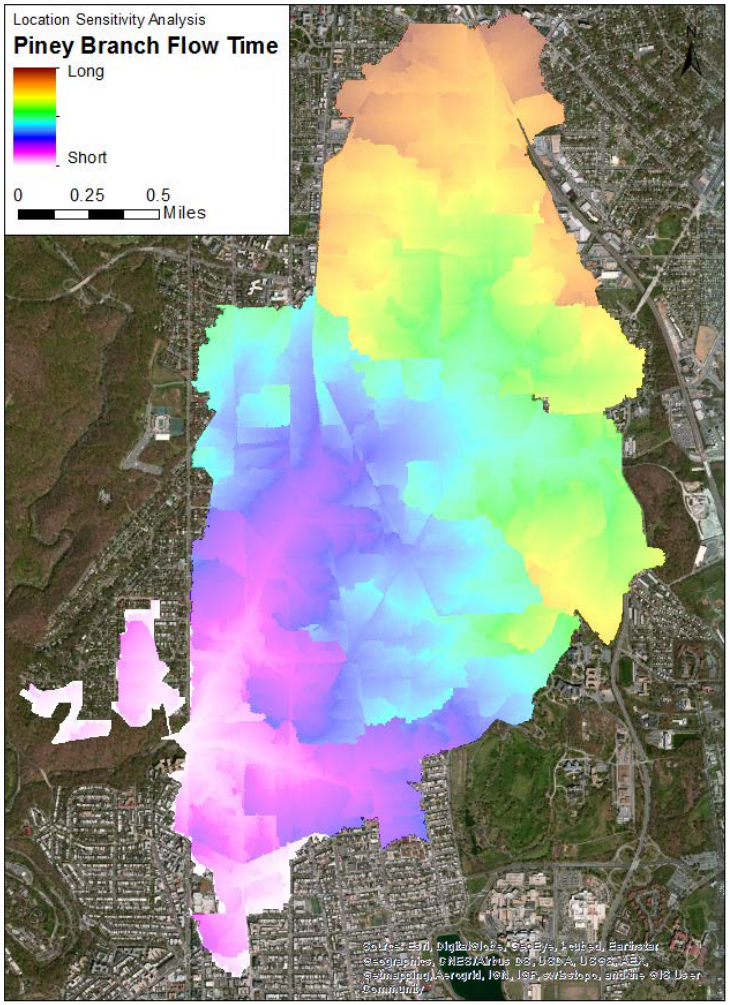
First Flush Bypass Modeling

- Bypass small amount of flow to save storage volume for the “peak” of the storm
- Used 3-year “average” period to test concept
- Results were mixed. In general, bypass only beneficial if full treatment depth cannot be obtained.

		50% Impervious															
		FFB Flow Rate per 10 acres (cfs)															
		0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.3	1.7	2.2	2.6	3	3.5
Treatment Depth (in)	1	0.76	0.61	0.51	0.44	0.38	0.34	0.30	0.28	0.25	0.23	0.17	0.13	0.11	0.10	0.09	0.09
	0.8	1.62	1.28	1.06	0.90	0.78	0.69	0.62	0.56	0.51	0.47	0.33	0.26	0.22	0.20	0.19	0.18
	0.6	0.99	0.99	1.08	1.50	1.38	1.21	1.08	0.97	0.88	0.81	0.57	0.45	0.38	0.34	0.32	0.30
	0.4	1.11	1.35	1.35	1.54	1.66	1.59	1.56	1.47	1.60	1.83	1.28	1.00	0.84	0.76	0.71	0.67
	0.2	1.01	1.03	1.05	1.11	1.15	1.16	1.23	1.25	1.27	1.31	1.26	1.47	1.26	1.13	1.05	1.00

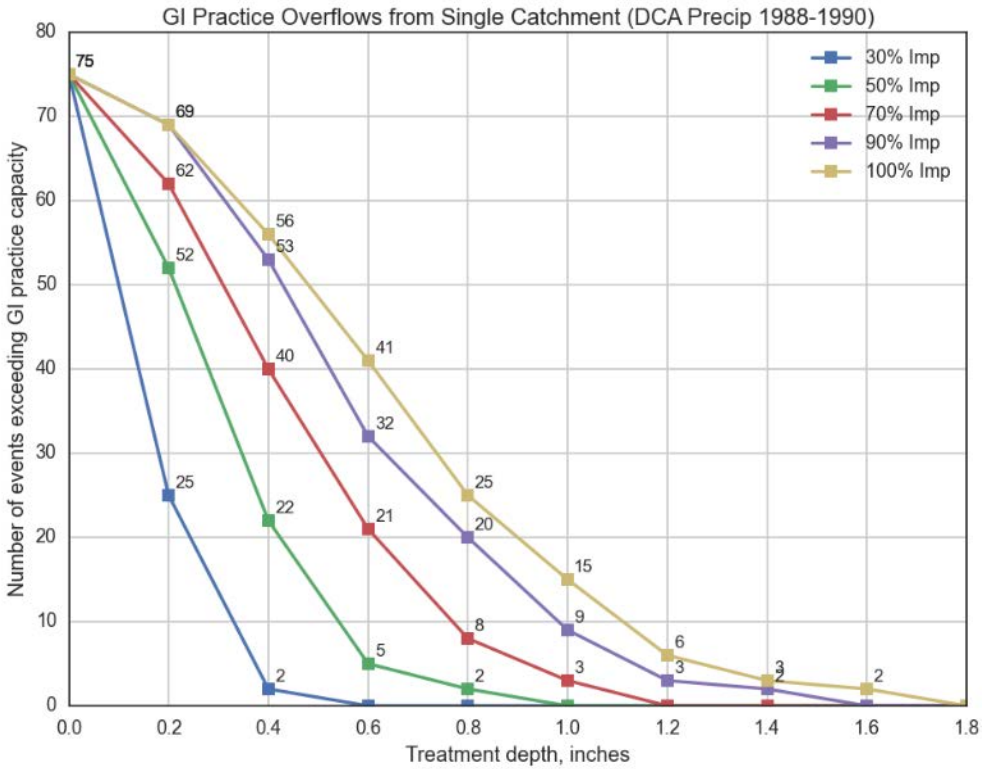
Location Sensitivity

- Determine if effect exists from applying GI in upstream vs. downstream locations (sewershed wide)
- Catchments grouped into near, mid and far travel times
- 1.2 inches runoff routed into idealized GI practices, which drain in 48 hours



Maximum Facility Size

- Volume of GI practices used in model were varied to capture full range of runoff depths over contributing area
- As treatment depth increases, the number of events exceeding GI capacity decreases
- At treatment depth greater than 1.2” diminishing to no returns on investment



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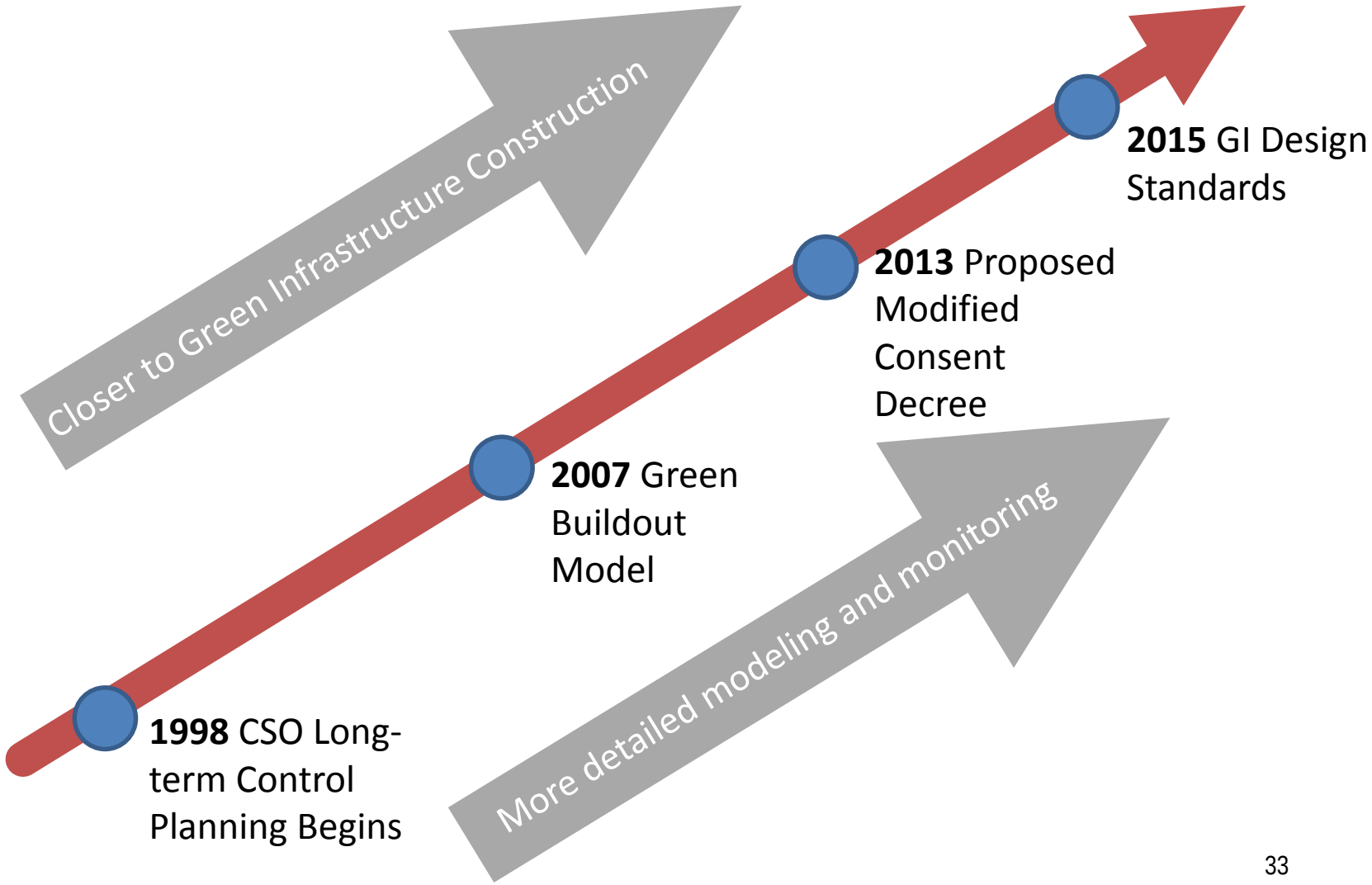

Next Steps

- Monitor green infrastructure sites before and after GI implementation
- Incorporate detailed GI practices into models based on site-specific monitoring
- Incorporate GI model results in receiving water quality modeling of rivers – link runoff reduction and water quality improvement
- Use modeling to inform the GI implementation process as the DC Clean Rivers Project moves forward

Contact

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