Prepared for

Narragansett Bay Commission

CSO Control Facilities Phase III Reevaluation Green Alternatives

22 May 2014

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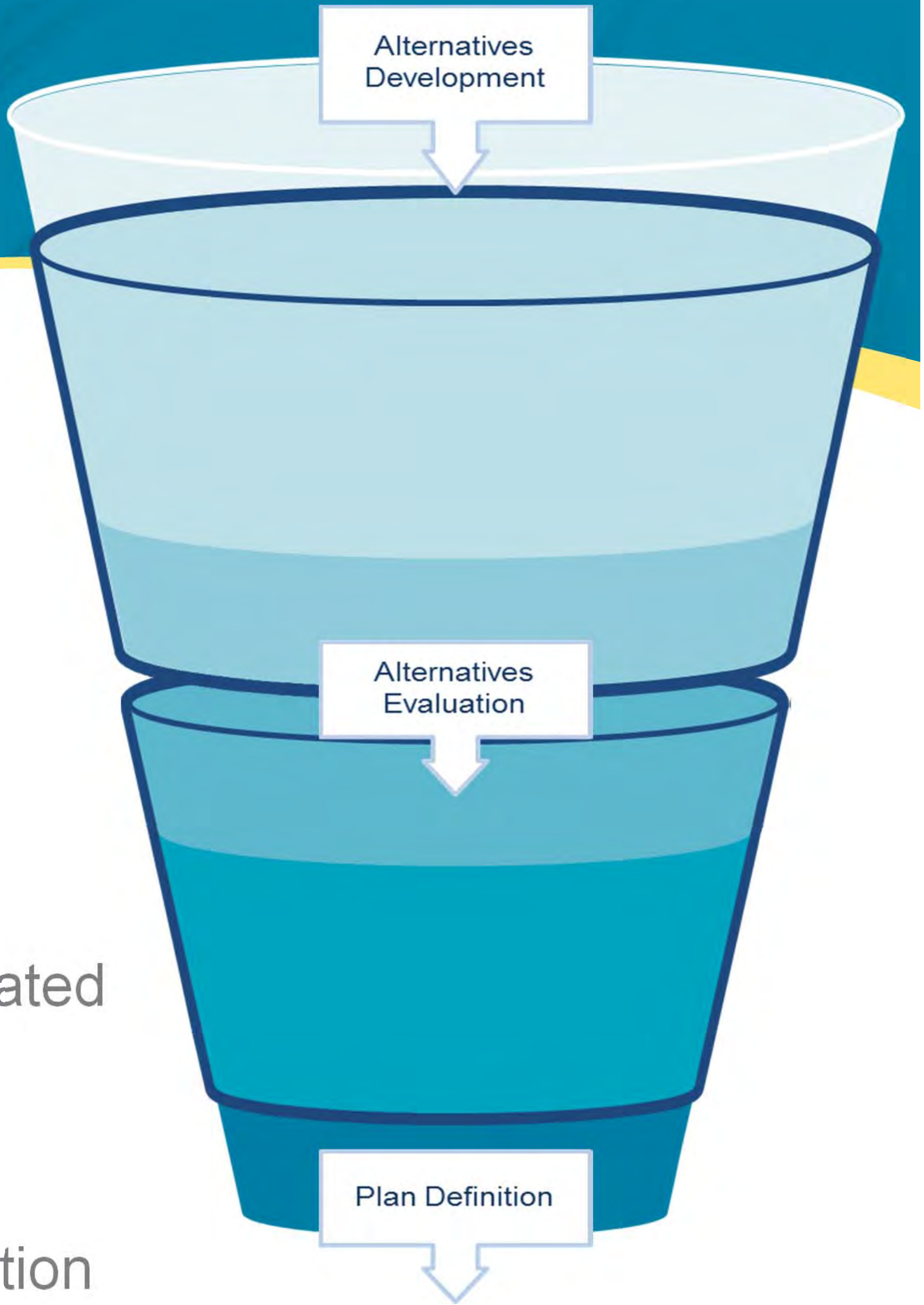
Outline

- Review of Stakeholder engagement process
- Overview of GSI for CSO control
- Specific GSI examples for Phase III
  - Infiltration
  - Detention
  - Retention
- Area-wide GSI potential
- Translating to CSO reductions
- GSI alternatives description

Development & Evaluation Process

- Alternatives Development
  - April 10, Grey Infrastructure Focus
  - May 22, Green Infrastructure Focus
- Alternatives Evaluation
  - June 19, Evaluation Criteria Focus
  - September 4, Integrated Planning Workshop
- Plan Definition
  - October 23, Plan Review and Finalization



Alternatives Development Meeting Structure

- Alternative General Overview
  - Advantages & disadvantages
  - Technical constraints
- CSO-Specific Applications
  - Detailed evaluation
- Evaluation Criteria
  - → Parking lot

Agenda

Review of engagement

Overview of GSI for CSO

Specific GSI examples

- Infiltration
- Detention
- Retention

Area-wide GSI

Translating to CSO

GSI description

CSO Regulatory Context

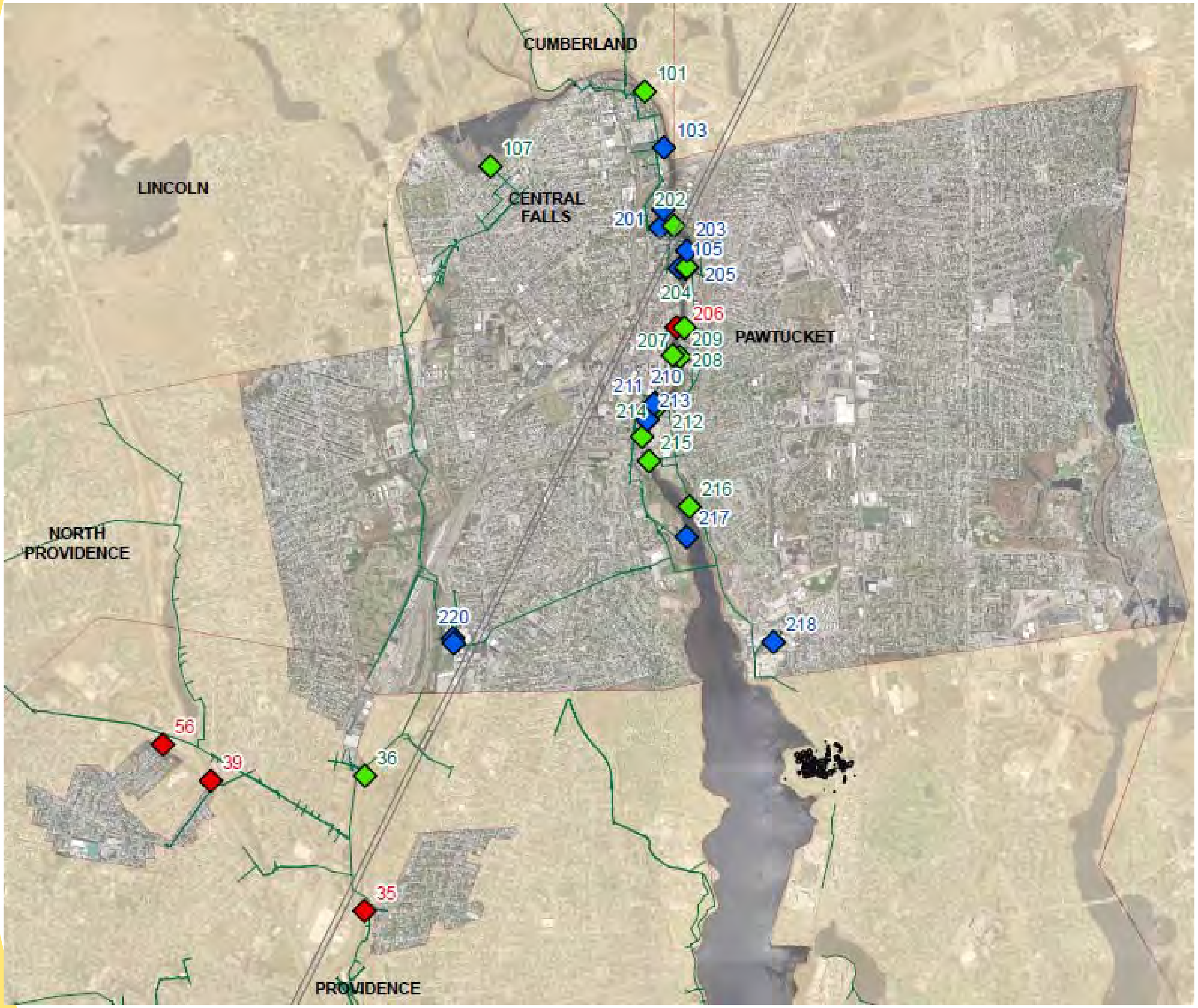
GSI within EPA CSO Enforcement Actions

- Chicago, Illinois Consent Decree 2014
  - Reduce flooding, focus on vacant parcels, improve socio-economic conditions
- Chattanooga, Tennessee Consent Decree 2013
  - Produce land use policy, public participation process, implementation schedule
- Kansas City, Kansas Consent Decree 2013
  - Pilot GSI projects that may replace or supplement grey infrastructure
- Seattle, Washington Consent Decree 2013
  - Provides opportunity for GSI to replace grey infrastructure
- Washington DC Consent Decree 2005, Partnership Agreement 2012
  - “Green Design Challenge” to private sector
- Boston, Massachusetts Consent Decree 2012
  - GSI demonstration projects, includes CSO and other pollutant controls

EPA Guidance – GSI Considerations

- Select a sample set of sewersheds that are generally representative of the service area as a whole, in terms of land uses, land ownership, soils, and topography.
- Characterize existing land use/land cover in the subwatersheds; this can often be done using aerial photographs and/or a community's geographic information system (GIS) coverages.
- Create templates for the various land uses in the sewersheds (e.g., typical single family residential lot, typical commercial/office site). Estimate the pervious and impervious areas for the templates.
- Identify green infrastructure opportunities for the different land use categories (templates) in the sewersheds, taking into account space needs, soil types, and slopes.
- Estimate the total green infrastructure that could be implemented in the sewershed by extrapolating from the templates to the sewershed as a whole. This estimate should take into account current and future zoning and institutional considerations, such as acceptance by property owners of green infrastructure features on private property. The level of buy-in to the green infrastructure program on the part of local property owners is an important variable, and needs to be explicitly considered in CSO planning. The estimate should also consider public properties and parks that may be good candidates for green infrastructure practices.
- Examine the cost-effectiveness of green infrastructure approaches. Will the green solutions reduce upfront or operational costs? Experiment with various combinations of green and grey infrastructure to determine what combination results in the lowest costs.
- Estimate the green infrastructure opportunities for the CSO service area as a whole by extrapolating from the sample set of sewersheds studied.
- Estimate the stormwater volumes that can be kept out of the system by the green infrastructure, taking into account the level of estimated implementation and the size of the practices. Also consider if there should be a margin of safety to reflect actual green implementation that may vary from projections, especially for sites not under the direct control of the sewer authority.

Sewersheds to Phase III CSOs



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GSI description

Developing GSI alternatives

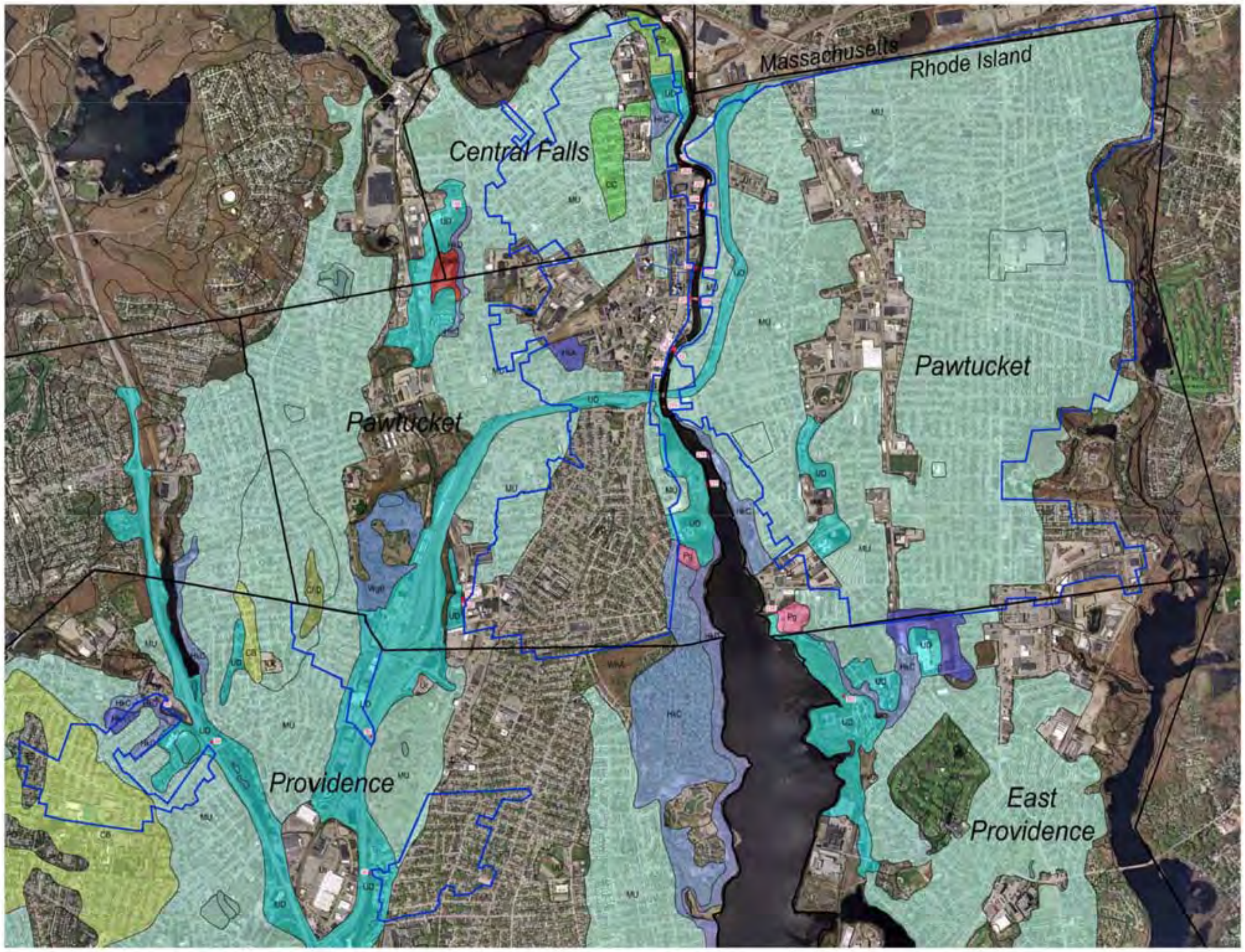
Green Stormwater Infrastructure Alternatives Fundamental Differences

- Infiltration
  - On site or nearby
  - Removes from system
  - Significant maintenance
- Detention
  - On site or in system
  - Delays discharge
  - Moderate maintenance
- Retention
  - Directly on site
  - Reuse
  - Zero discharge
  - Operations requirements

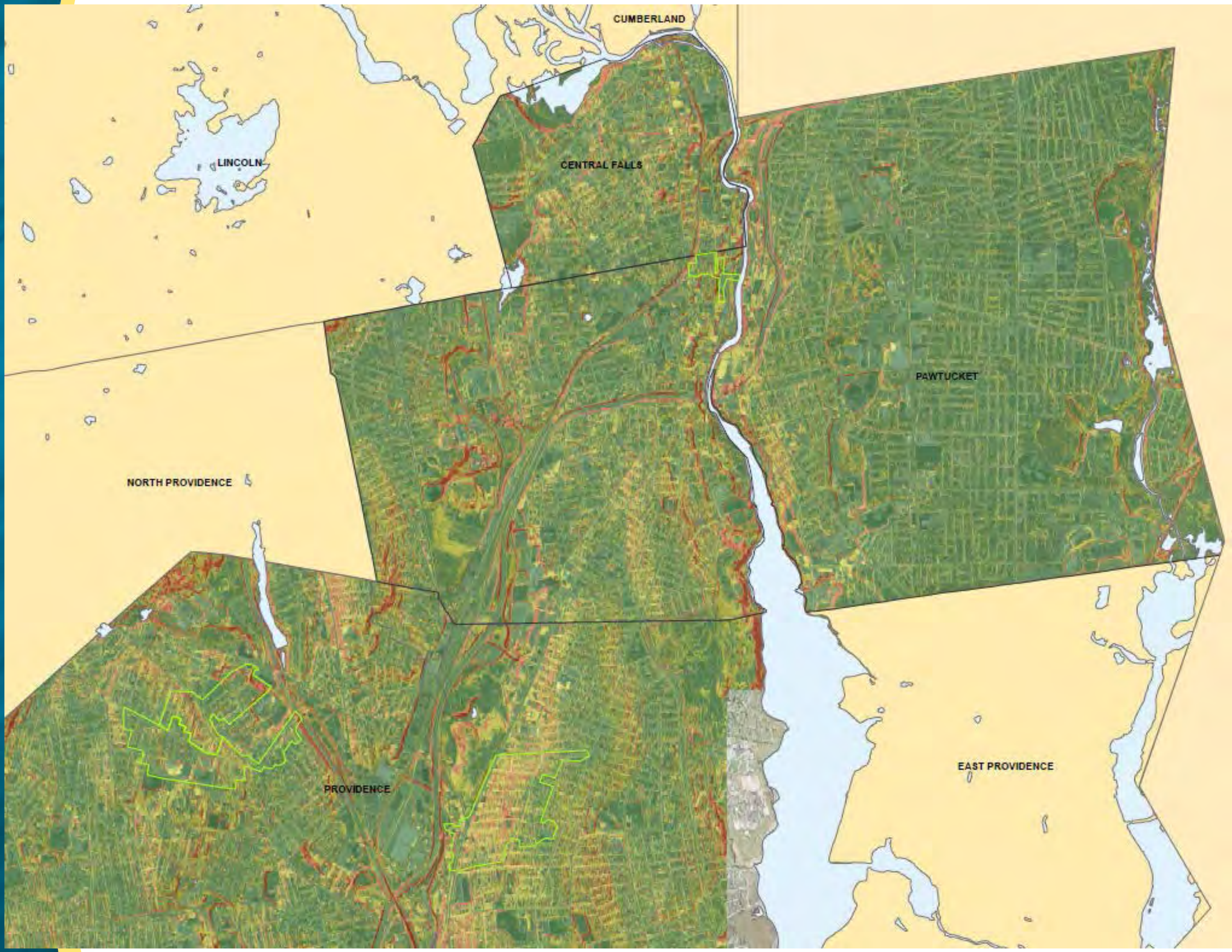
Considerations for evaluating GSI potential

- Soil types
  - Many GSI practices rely upon infiltration.
  - Tight soils restrict GSI types.
- Topography
  - Best on slopes under 5%.
  - Effectively impossible on slopes greater than 25%.

Infiltration Potential in Phase III



Topography Limitation in Phase III



Considerations for evaluating GSI potential

- Land use and ownership
  - Current imperviousness and open space.
  - Selection of GSI types dependent on:
    - public,
    - commercial or
    - residential land use.
  - Easements & maintenance plans for private land.

Matching Strategies to Land Use Types

1 Permeable paving, biofiltration (rain gardens) and geocellular storage
2 Filter strip with vegetation leading to swale
3 Biofiltration swale
4 Biofiltration area in public open space
5 Street planters
6 Water butts draining to private rain gardens with complete downspout disconnection
7 Shallow detention basin in public open space, dual use as a playing area
8 Water butts at rear of properties (with excess back to sewer), water from roofs at front drain to highway
9 Kerbside shallow channels, with street planters
10 Swale conveying surface flows to watercourse
11 Watercourse daylighting (underground culvert opened up)
12 Green roof retrofit and rain water harvesting
13 Detention basin with connecting swales and above ground channels taking flows from local area
14 Kerb drainage
15 Swale
16 Permeable pavement
17 Permeable surface driveway
18 Water butts draining to private rain garden (front and rear)
19 Verge converted to a swale
20 Kerb side shallow channel with street planters
21 Kerb side shallow channel
22 Biofiltration swale in public open space
23 Front garden with retrofit planters and water storage underneath.

24 Detention basin with connecting swales in public open space
25 Planters retrofitted in series including trees within the pedestrian area
26 Re-profiled road to divert flow downstream
27 Water tight doors and air brick covers
28 Increase kerb height to direct surface flows
29 Sunken island as a detention basin
30 Speed hump with a dual purpose to direct flow
31 Permeable surface pedestrian high street
32 Storage sink in school play areas (sunken hard surfaces)

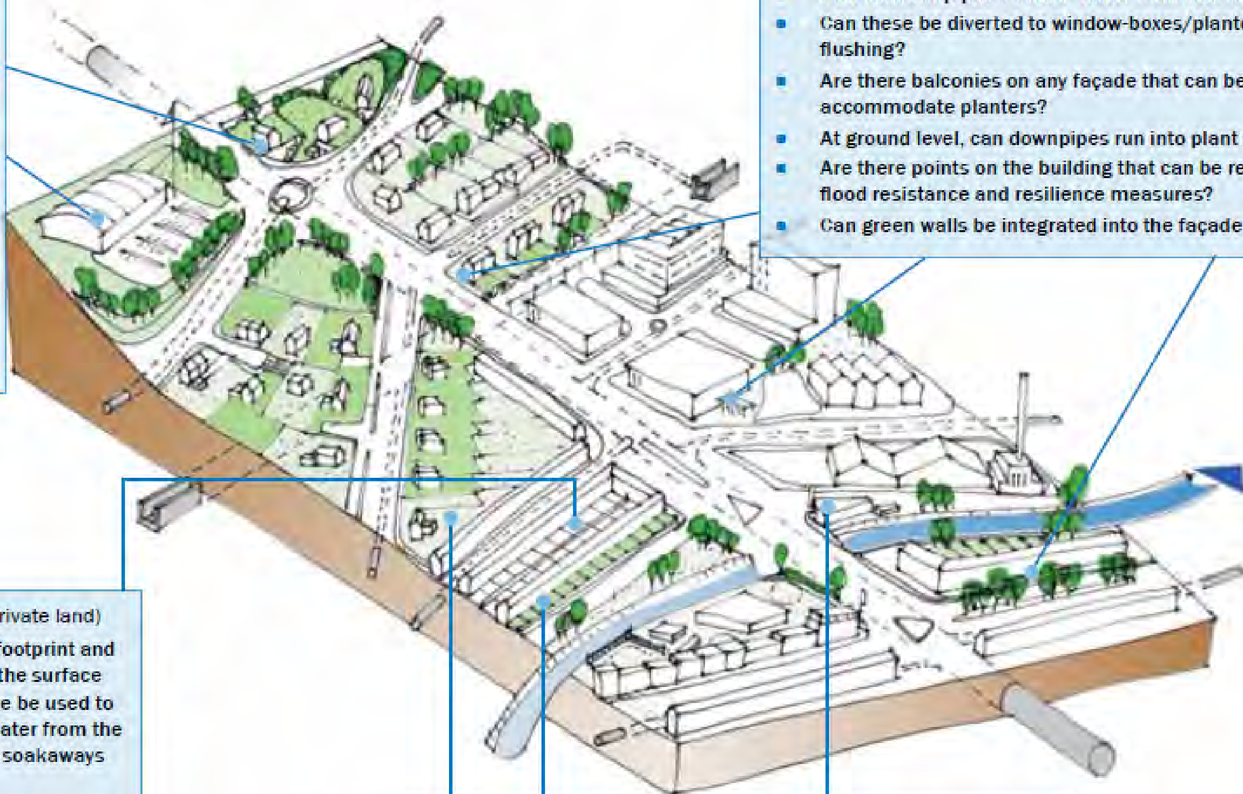
On-Site Source Control Design Considerations

Roofs of buildings

- Where does the roof transfer water to and how (via gutters and downpipes, to another roof at lower level, to ground through disconnected downpipes)?
- Is there an opportunity to retrofit with a green roof either on low pitch or flat roofs?
- Does water collect on any flat surface between roof and ground? If so can this feature be enhanced to absorb or store more rainfall? How can capturing this water benefit plants? Can this water be harvested and redirected to the home and used for WC flushing or garden irrigation? How can the flat roof be made accessible for people as a roof terrace or balcony?

Building façades

- How do downpipes transfer water from roof to ground?
- Can these be diverted to window-boxes/planters or for toilet flushing?
- Are there balconies on any façade that can be retrofitted to accommodate planters?
- At ground level, can downpipes run into plant beds?
- Are there points on the building that can be retrofitted with flood resistance and resilience measures?
- Can green walls be integrated into the façade to intercept rain?



Front and rear courtyards, terraces and gardens (private land)

- What type of surface is close to the building footprint and how does this receive and transfer water? Is the surface hard, soft or permeable? How can this surface be used to receive, infiltrate, absorb or store more rainwater from the roof, (consider the use of rain gardens where soakaways may have been limited before)?
- Can hard surfaces be replaced by permeable surfaces and still perform their function (eg parking spaces)?
- When above or reaching ground level, can downpipes connect to rainwater storage tanks or be cut off short and drain over ground surfaces diverting water flow away from footpaths, unless the surface is permeable?
- How can rills, channels or gullies be used to direct water to the next surface as desired? How do such measures integrate with pedestrian footpaths or driveways?

Boundary walls

- How can boundary walls be retrofitted to include rainwater storage?
- Can tanks be added along wall boundaries that double as benches?
- Can boundary walls be fitted with foliage to create green walls?
- Can boundary walls be retrofitted to manage flow pathways? In some cases this may mean providing new gaps in the wall to let flow through, in others making the wall waterproof (including measures at gates) to direct water away.

Figure 7.1

Strategies to retrofit in urban areas for different aspects of the built environment

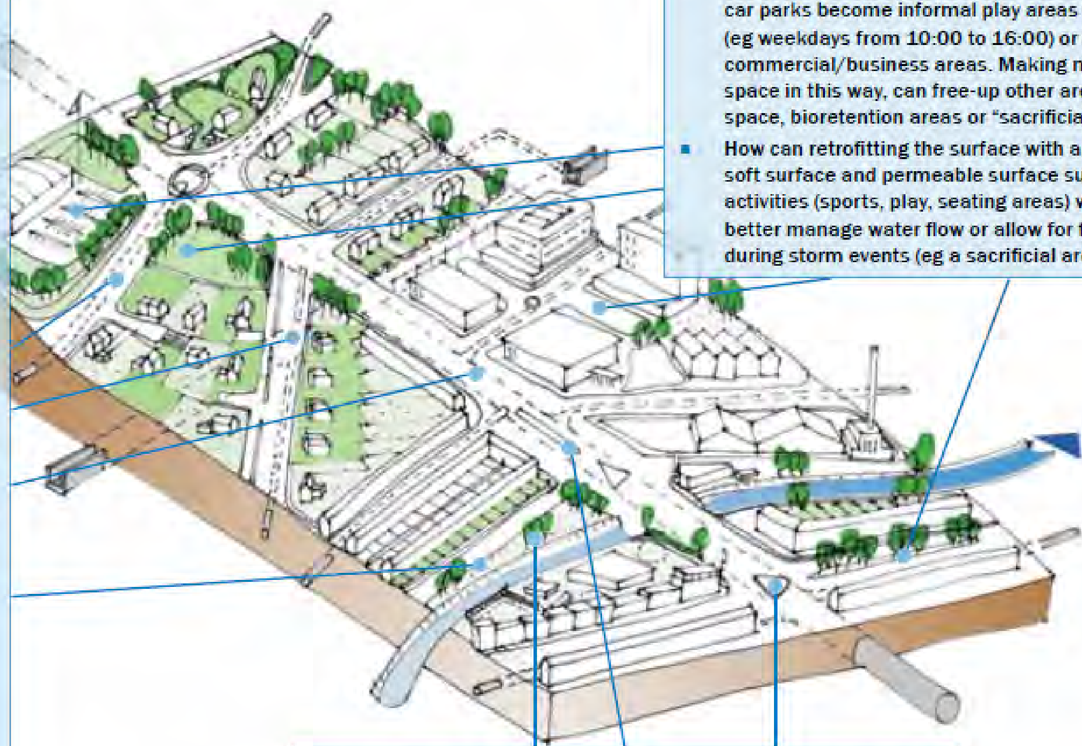
Public Way Source and Surface Pathway Design Considerations

Streets and street car parking

- Where, within the street and the footpath, are there opportunities to infiltrate, hold-back or store surface water?
- Can existing areas of trees or planting be enhanced to form more effective bioretention areas?
- How can street verges (hard or soft surfaced) be retrofitted as swales, bioretention or permeable surfaces? In general how can these “leftover” spaces be made more attractive for public use or as rich natural habitats.
- If verges are currently used as parking areas, can these be retrofitted as permeable surfaces to allow for parking and infiltration of runoff?
- How can kerbs be retrofitted to channel water effectively as pathways? It may be necessary to open the kerb line to let water through it, either on the road or vice versa.
- How can roads be retrofitted to store or transfer water during extreme events?
- How can the road be retrofitted to become a better water pathway by changing the camber, introducing rills or channels along kerbs or down centre lines?
- How can chicanes or traffic islands be retrofitted as bioretention areas? This would introduce a traffic calming measure as well as a SWMM.
- How do new lines of trees and planting (green infrastructure) support pedestrian movement? In general, how do trees and planting make pavements more attractive and enhance micro-climates by offering shade, wind shelter?
- Can roads be retrofitted with permeable surfaces while offering new spaces for public activity, play areas and community activities?

Large public spaces, parks, play areas and car parking

- What are the opportunities for large public areas to perform multiple functions? For example, in residential areas, can car parks become informal play areas during the daytime (eg weekdays from 10:00 to 16:00) or the opposite for commercial/business areas. Making more use of the same space in this way, can free-up other areas for use as green space, bioretention areas or “sacrificial flooding areas”.
- How can retrofitting the surface with a mix of hard surface, soft surface and permeable surface support different public activities (sports, play, seating areas) while at the same time better manage water flow or allow for flooding of some areas during storm events (eg a sacrificial area)?



Surrounding low quality landscaped areas or currently sterile land

- How can these areas be used as larger bioretention areas?
- How can these areas be used as water storage areas (including “sacrificial flooding areas”) and new opportunities for public access and use?
- Can these areas be retrofitted with vegetation and planting or can it be turned into a different use such as allotments?
- Are there traffic islands or the centre of roundabouts that could be retrofitted to do one or more of the above?

Figure 7.1

Strategies to retrofit in urban areas for different aspects of the built environment

Considerations for evaluating GSI potential

- Implementation on private property with private funds
  - Ordinance provisions / financial incentives.
  - Redevelopment rate.
- Implementation partnerships
  - Public – Public
  - Public – Private
  - Public – Non-profit

Green stormwater infrastructure alternatives development for Phase III CSOs

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__Agenda__

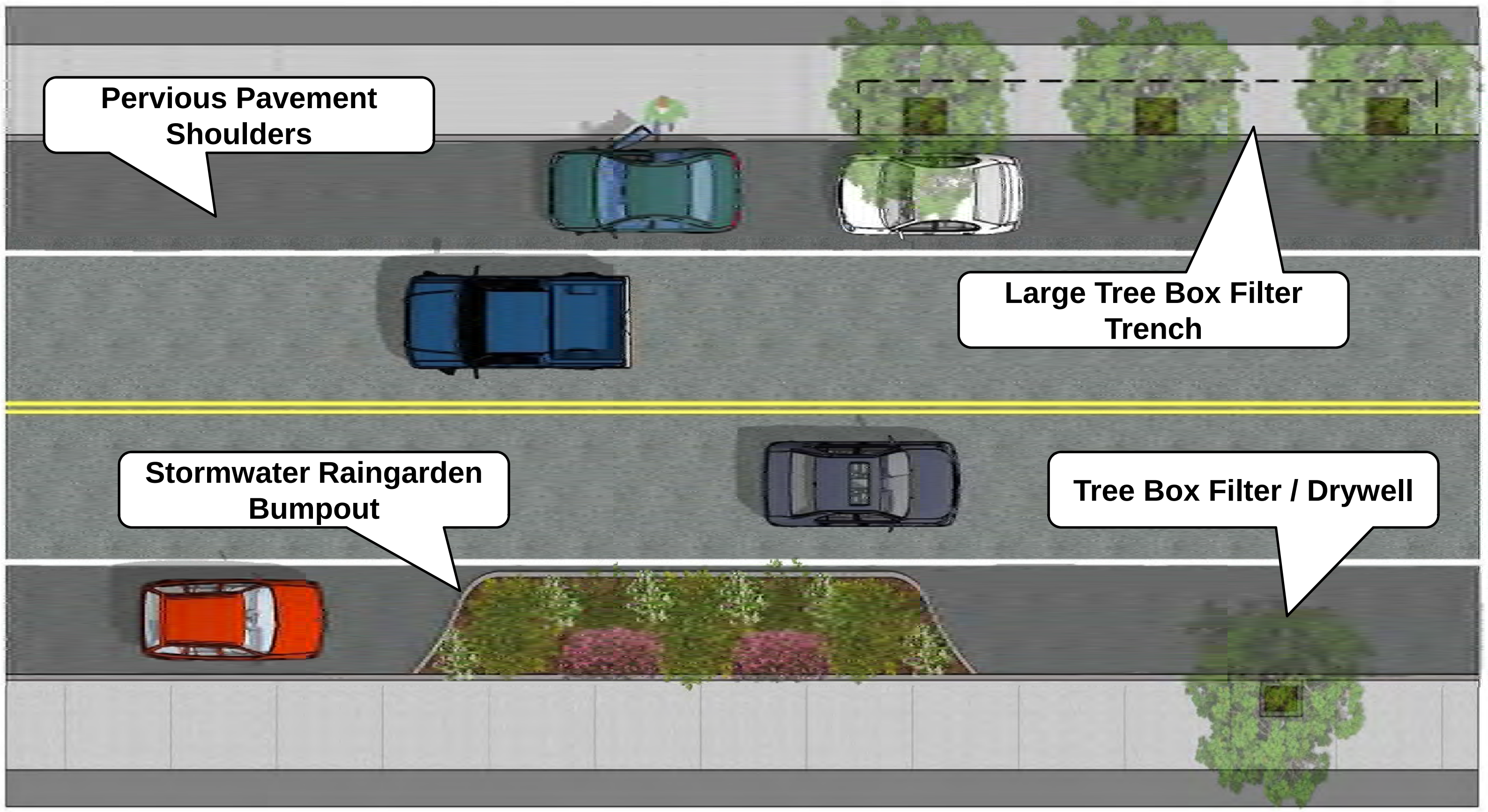
Review of engagement
Overview of GSI for CSO
Specific GSI examples
- **__Infiltration__**
- Detention
- Retention

Area-wide GSI
Translating to CSO
GSI description

039, 056 – Providence between Rte 146 and Providence College

Infiltration Solutions

Stormwater Infiltration Examples



Stormwater Infiltration Examples

- Stormwater Raingarden Bump Out
  - Curb and vegetative area installed along roadway shoulders.
  - Can be retrofitted into existing street layouts
  - Provides infiltration and water quality improvements

Image taken from: City of Philadelphia Green Streets
Design Manual - 2014

Mid-block Stormwater Bump-out

Corner Stormwater Bump-out

Stormwater Infiltration Examples

- Tree Box Filter (Single or Trench)
  - Concrete box structure with vegetative tree planting area installed along roadways
  - Can be retrofitted into existing street layouts in combination with drywell installations.
  - Provides infiltration and water quality improvements

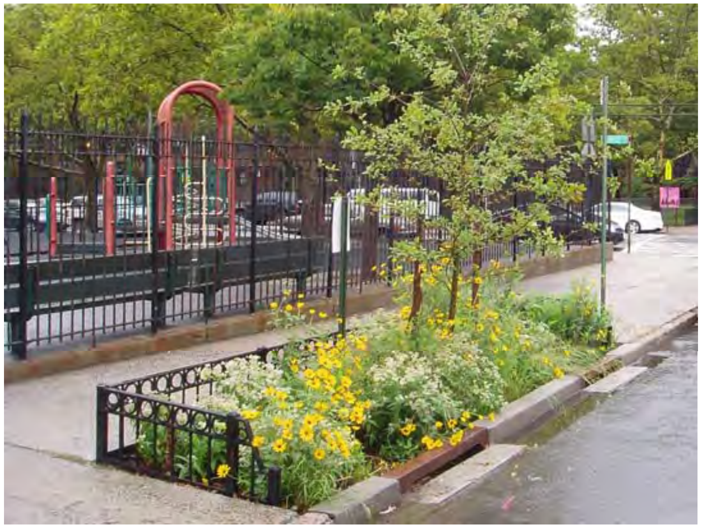


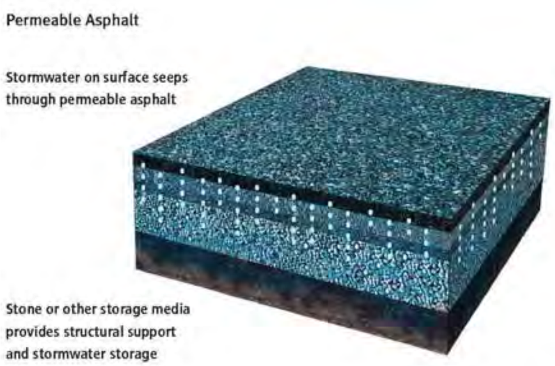
Image taken from: City of Philadelphia Green Streets Design Manual - 2014

Stormwater Infiltration Examples

- Catchbasin & Dry Well
  - Concrete structure installed along roadways upgradient of existing curb inlets
  - Can be retrofitted into existing street layouts in combination with tree box filter.
  - Provides infiltration.

- Infiltration Chambers
  - Large underground HDPE or concrete piping systems that promote infiltration
  - Utilized in new construction under parking lots and field areas.
  - Provides infiltration.

Stormwater Infiltration Examples



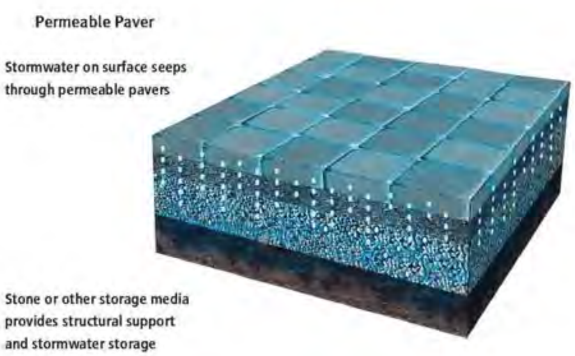


Image taken from: City of Philadelphia Green Streets Design Manual - 2014

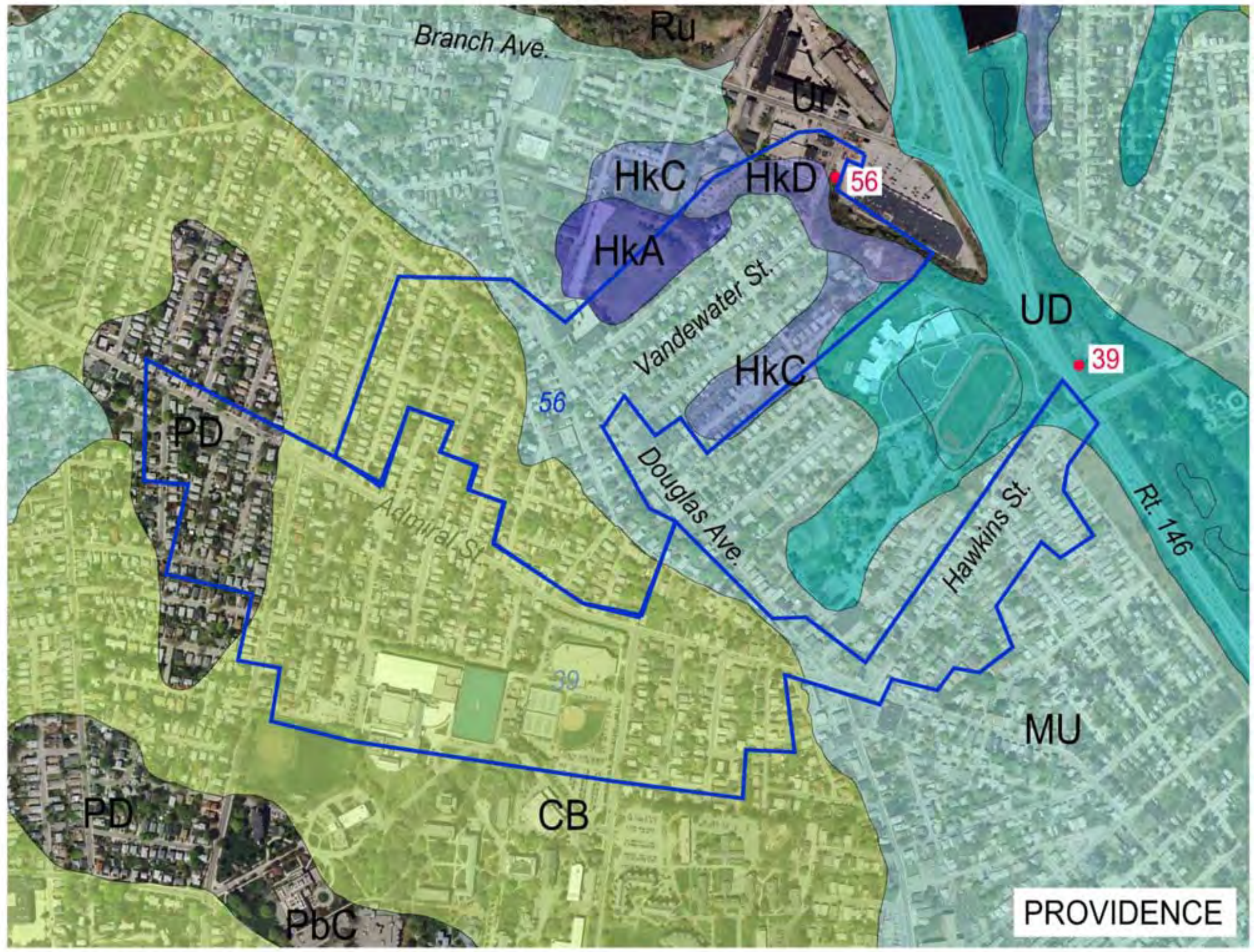
- Pervious Pavement
  - Pervious pavement, concrete or paver structure that promotes infitration.
  - Can be retrofitted into existing street layouts along shoulder in combination with stormwater raingarden bump outs.
  - Provides infiltration.

Stormwater Infiltration Examples

- Ribbon Driveways
  - Pervious vegetative strip installed along center of residential driveways
  - Can be retrofitted into existing driveways
  - Promotes infiltration

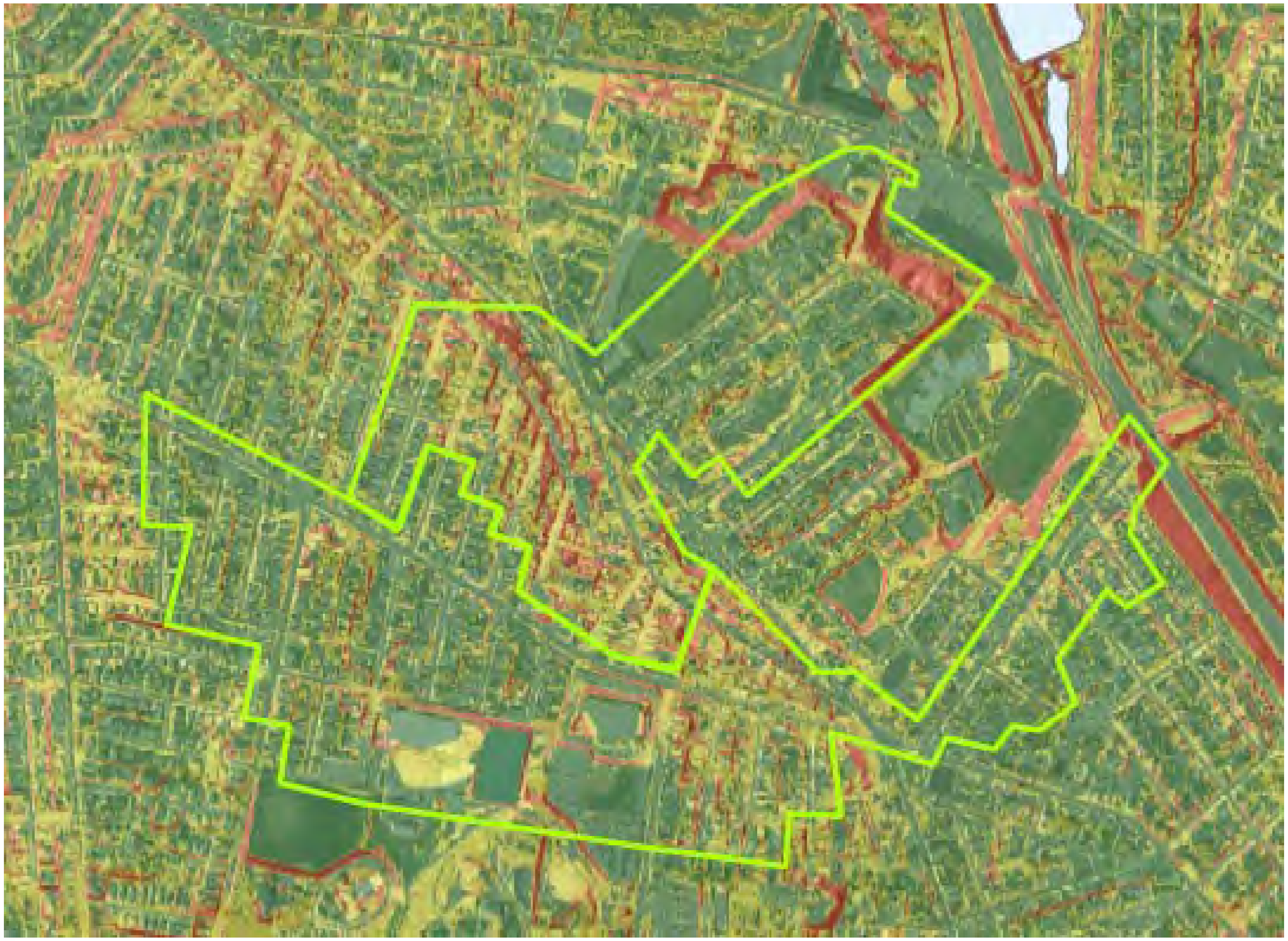
Soils & Infiltration

CSO 039, 056



Topography

CSO 039, 056



039/056 Stormwater Management

039/056 Stormwater Management

039/056 Stormwater Management

039/056 Stormwater Management

Stormwater Infiltration Summation

- Advantages
  - Provides infiltration and volume reduction
  - Provides water quality improvement
  - Can be installed at a smaller scale
- Disadvantages
  - Underlying soils need to permeable to be effective
  - Cost for larger pervious pavement & infiltration chamber installations
  - Maintenance

__Agenda__
Review of engagement
Overview of GSI for CSO
Specific GSI examples
- Infiltration
- **__Detention__**
- Retention

Area-wide GSI
Translating to CSO
GSI description

035 – Providence near North Main between Rochambeau and Pleasant

Detention Solutions

Hydraulic Controls Overview

- **Advantages**
  - Keeps stormwater out of combined sewer
  - Low Capital Costs
  - Low Operation and Maintenance Costs
- **Disadvantages**
  - Strategic surface ponding
  - Often requires specific surface conditions or improvements
  - Limited by specific health and safety consideration including FEMA regulations

Surface Stormwater Detention Example

➢Surface Stormwater Detention System

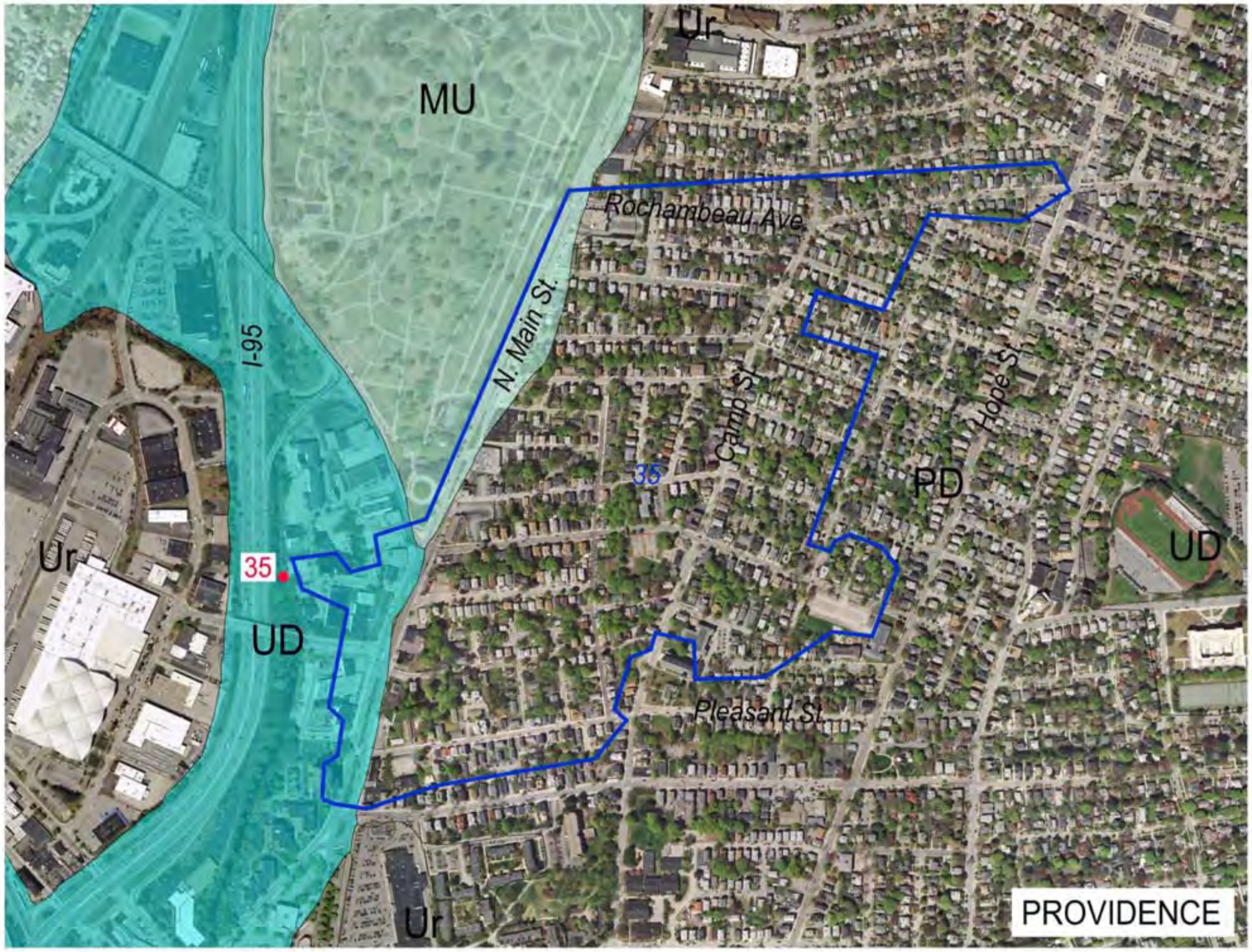
- Natural detention system alternative
- Reduces peak storm discharges
- Provides water quality improvements

Underground Stormwater Detention Example

- Underground Stormwater Detention System
  - Structural pipe network system
  - Can be installed in compact site configurations
  - Reduces peak storm discharges
  - Can be combined with infiltration for volume reduction.

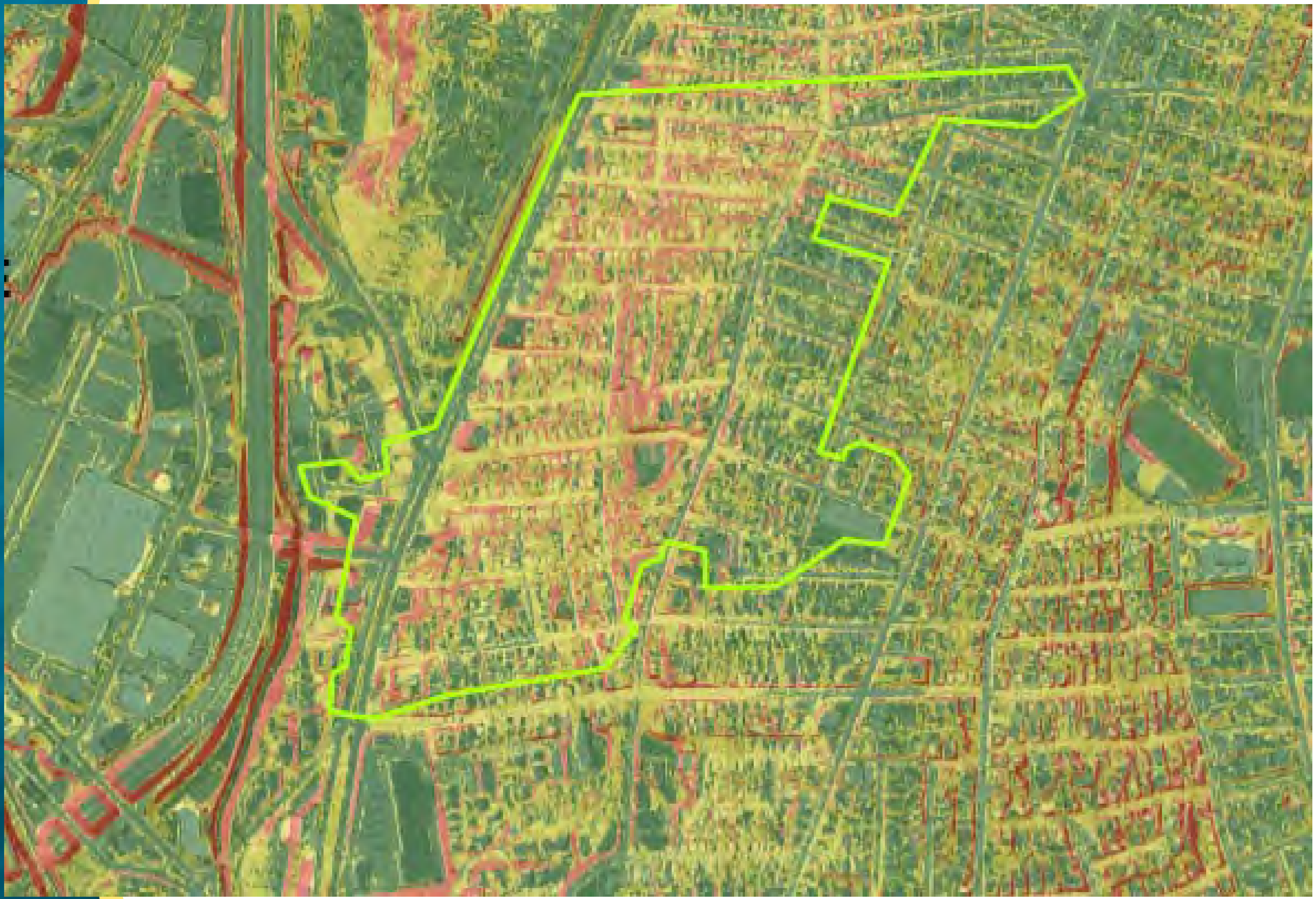
Soils & Infiltration

CSO 035

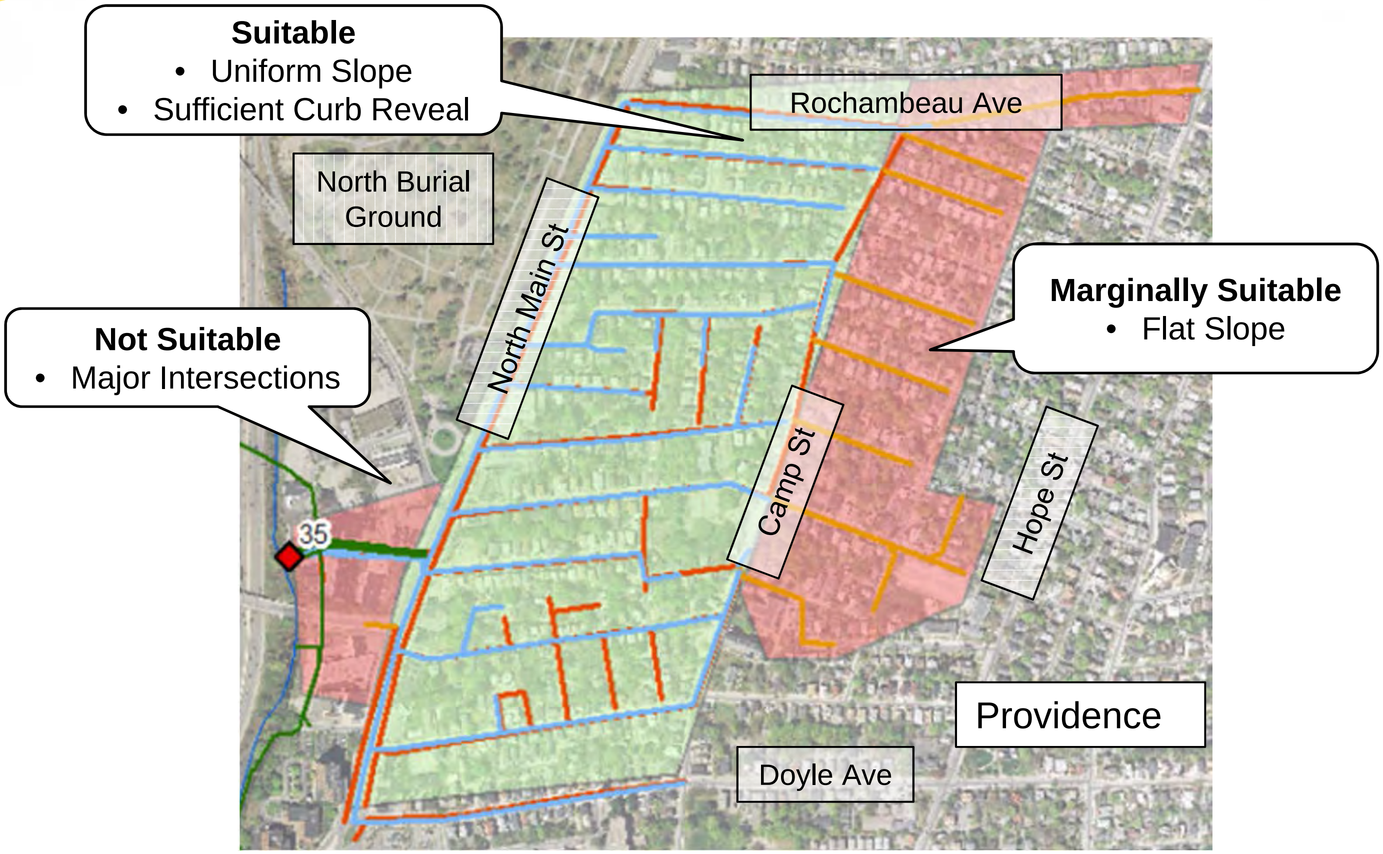


Topography

CSO 035



035 Stormwater Management



035 Stormwater Management

035 Stormwater Management

035 Stormwater Management

Stormwater Detention Summation

- Advantages
  - Reduction of peak flows
  - Water quality improvement
  - Provides opportunity for infiltration volume reduction

- Disadvantages
  - Land area needed for installation
  - Costs for larger installations

Agenda

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- **Retention**

Area-wide GSI

Translating to CSO

GSI description

206 – Pawtucket between Exchange St and Central Falls

Retention Solutions

Stormwater Retention Example

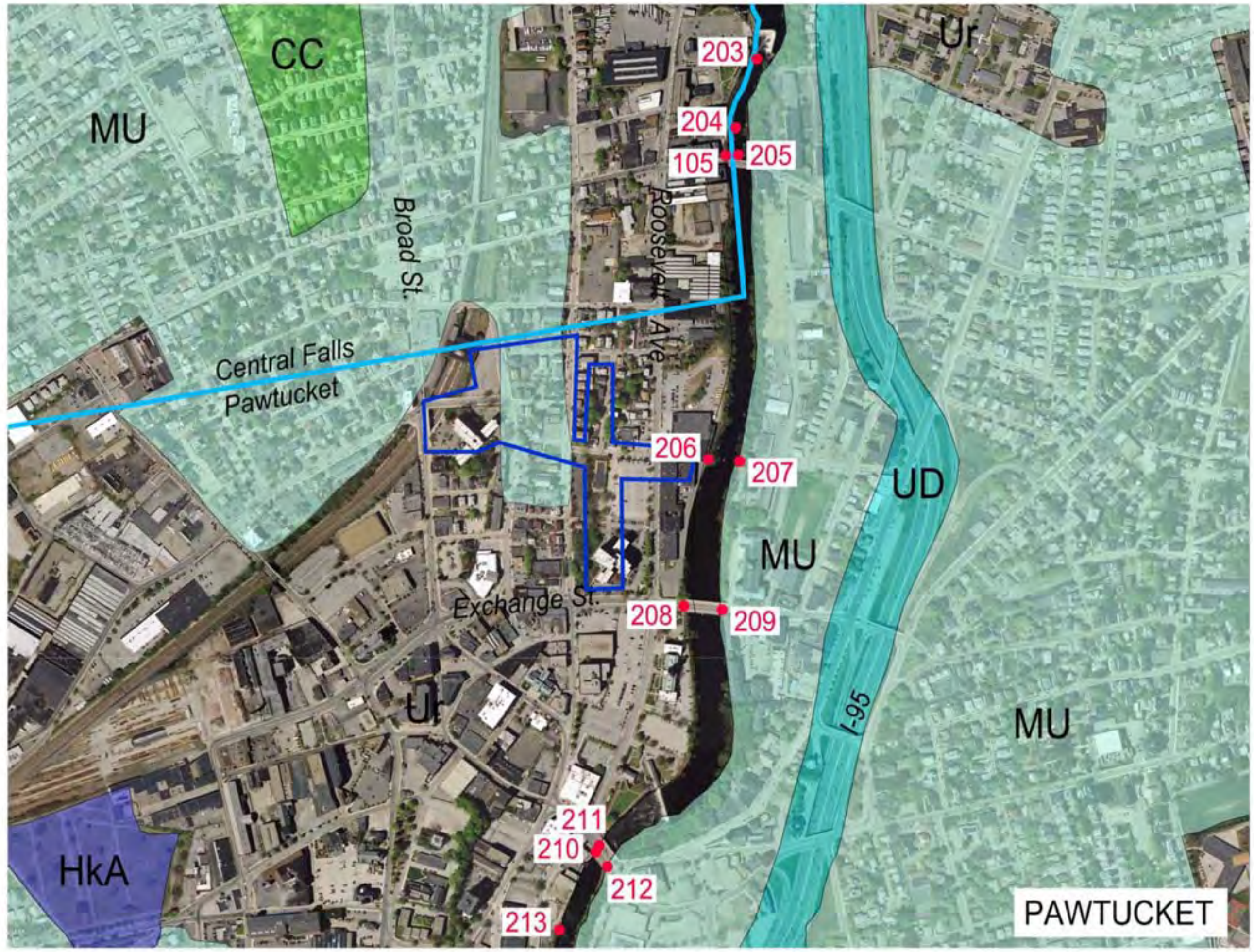
- Concrete Stormwater Retention Structures
  - Underground structural solution
  - Large land area required

Stormwater Retention Example

- Stormwater Wetlands
  - Natural surface retention solution
  - Water quality improvement
  - Large land disturbance required

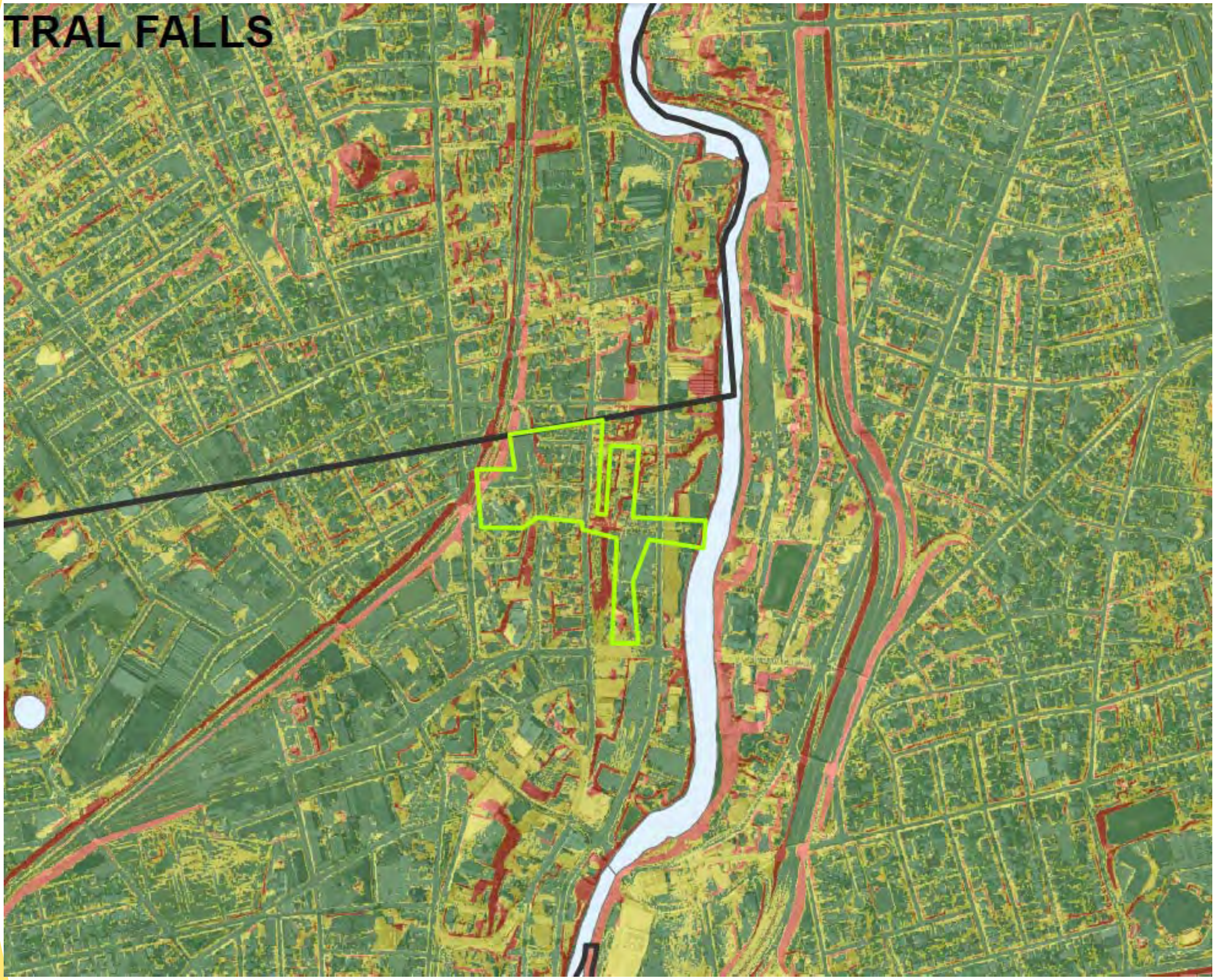
Infiltration

CSO 206



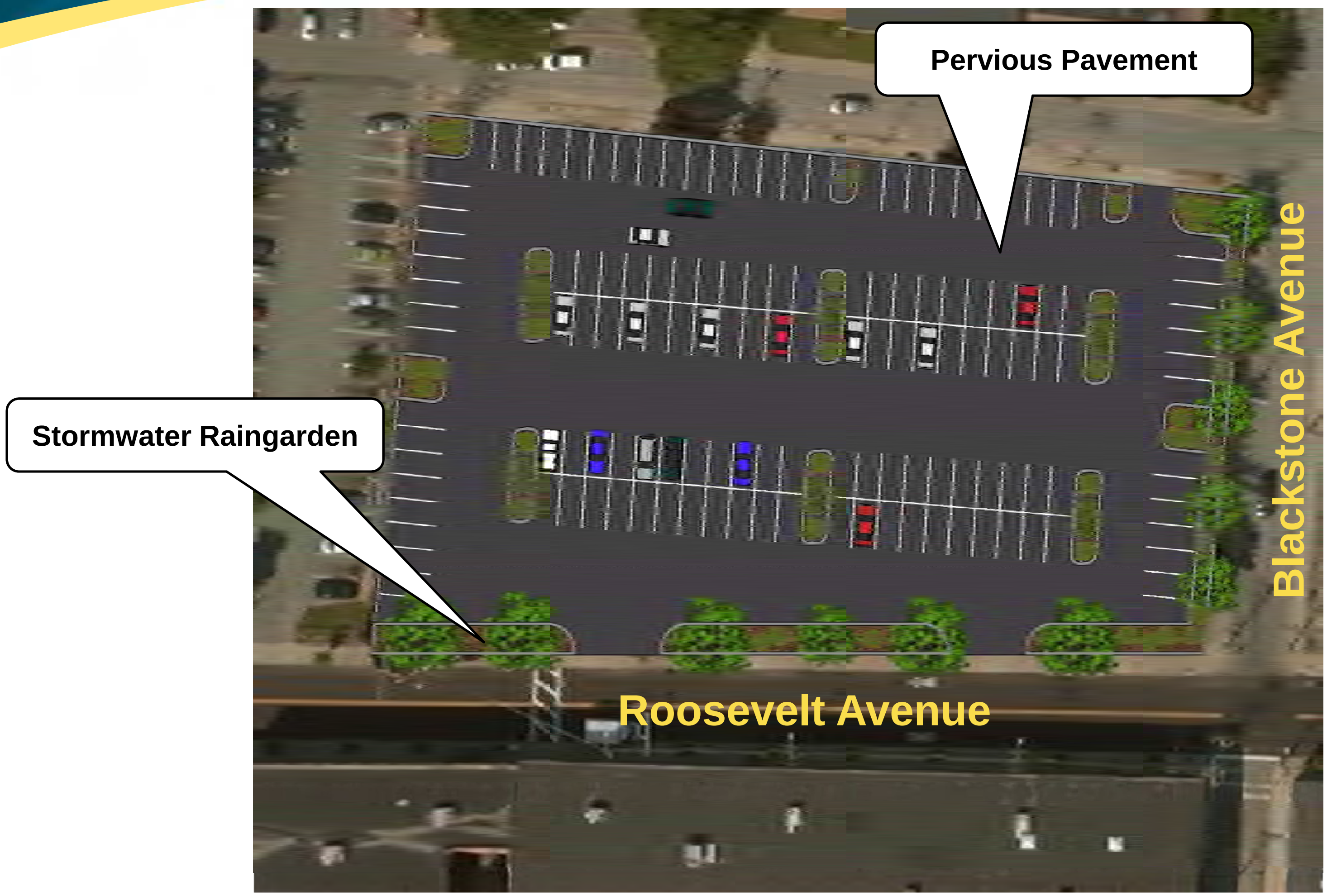
Topography

CSO 206

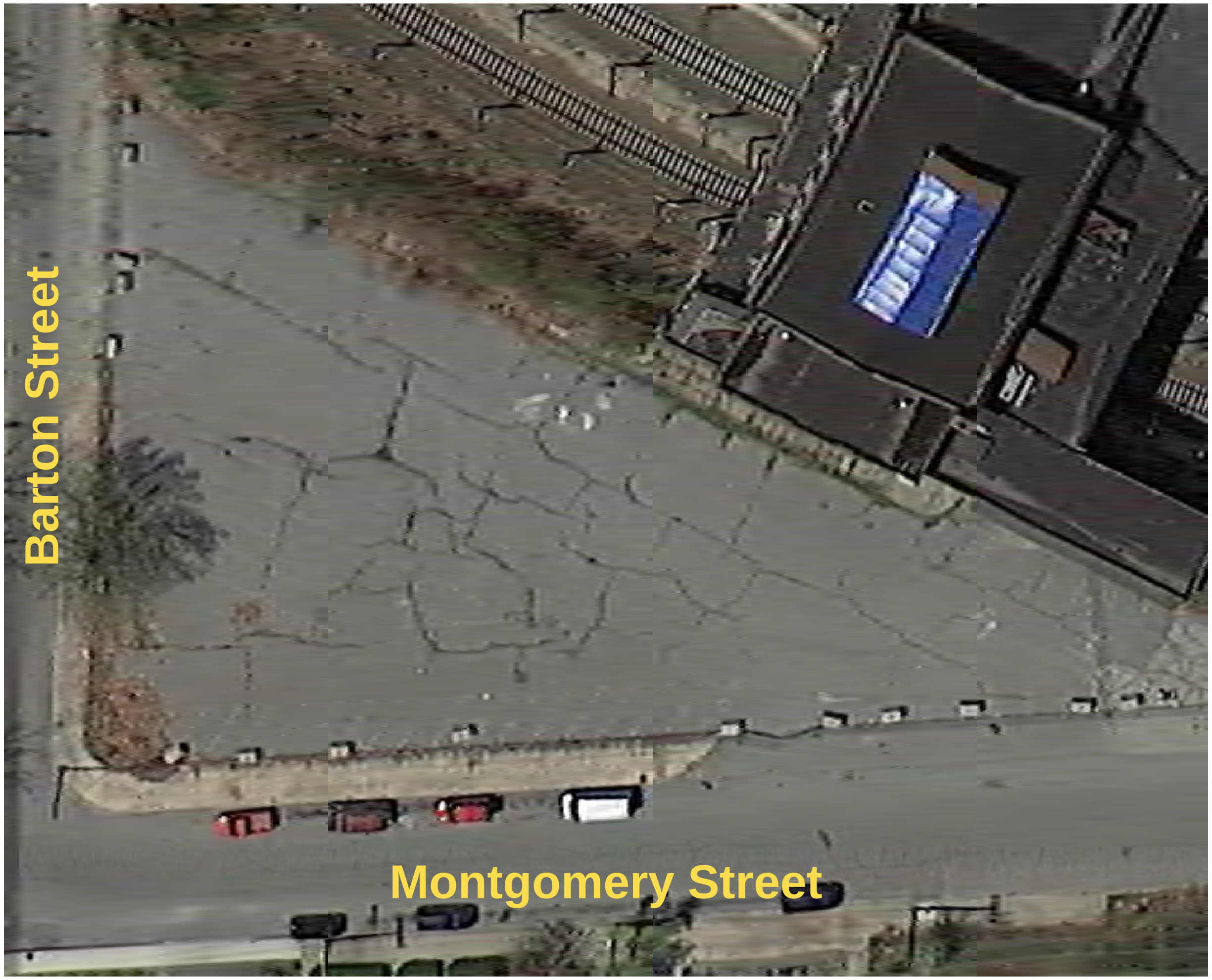


206 Stormwater Management

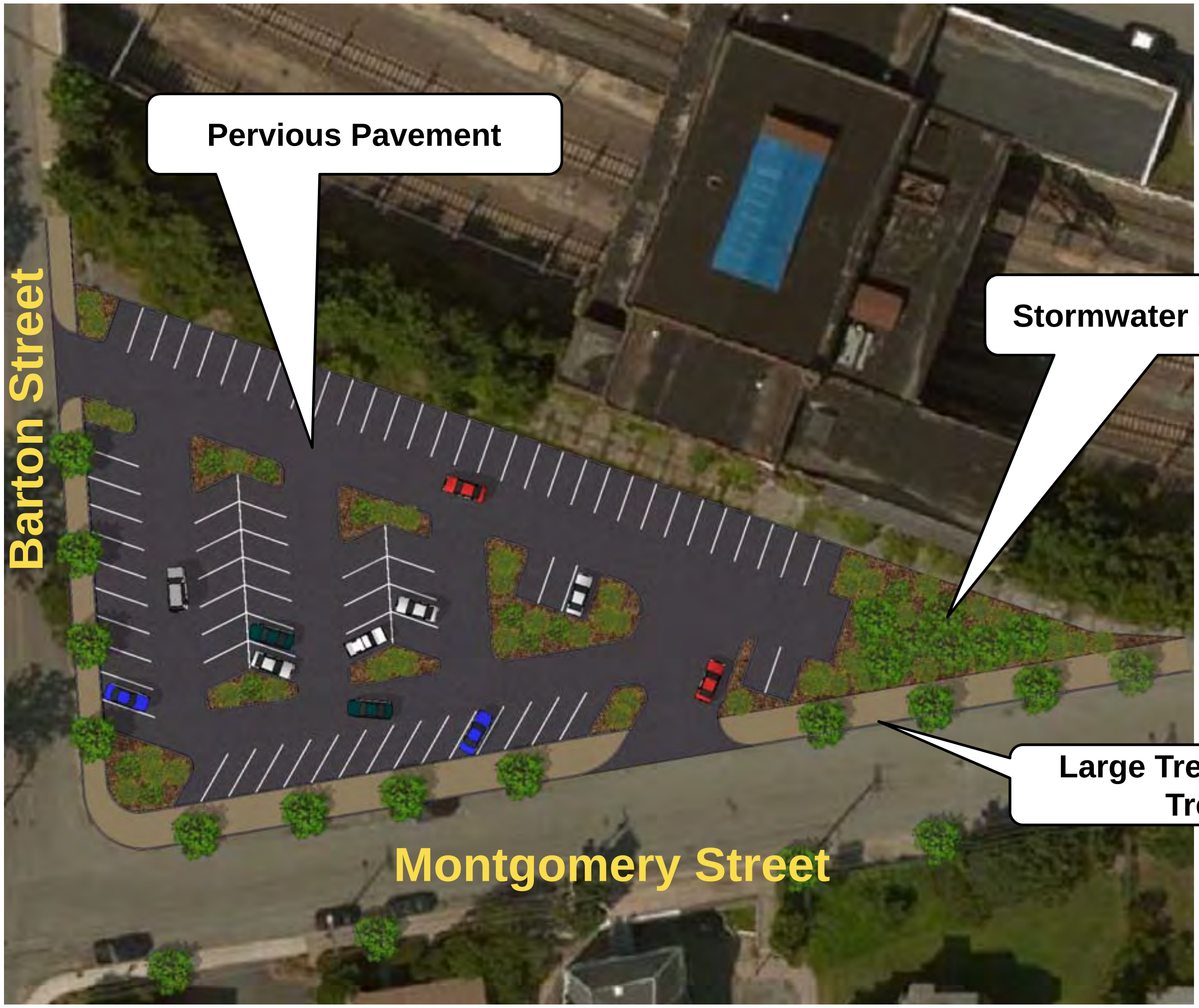
206 Stormwater Management



206 Stormwater Management



206 Stormwater Management



Stormwater Retention Summation

- Advantages
  - Large volume of stormwater storage
  - Stormwater wetland water quality improvement

- Disadvantages
  - Construction cost
  - Land disturbance

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Area-Wide GSI Potential

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NBC Stormwater Mitigation Program Description

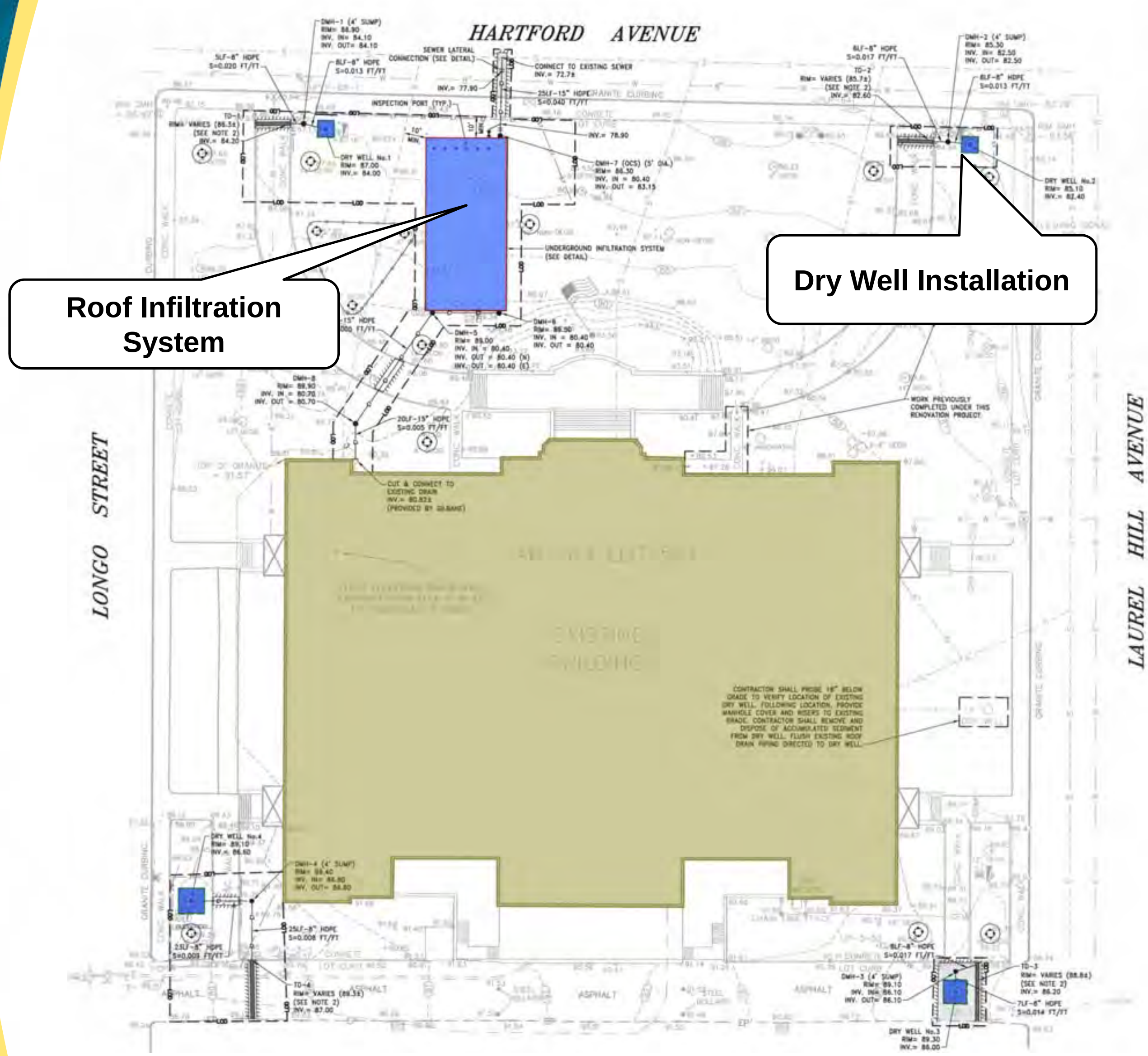
- Since 2003, the Narragansett Bay Commission (NBC) has implemented a Stormwater Mitigation Program to deal with the large amounts of stormwater runoff that enters the NBC's sanitary sewer system during large rain events.
- The NBC's Rules and Regulations require all builders of new projects to develop a Stormwater Management Plan to mitigate and reduce stormwater runoff by the installation of Green Stormwater Infrastructure and LID techniques.
- From 2003 to 2013 the NBC Stormwater Mitigation Program has permitted over 113 projects that have incorporated stormwater GSI and LID technologies and have mitigated over 6.8 Million Gallons of stormwater from the NBC sewer system. (based upon a 3-month - 1.65 inch storm event)

NBC Stormwater Mitigation Locus Map

Achievement First – Oliver Hazard Perry School

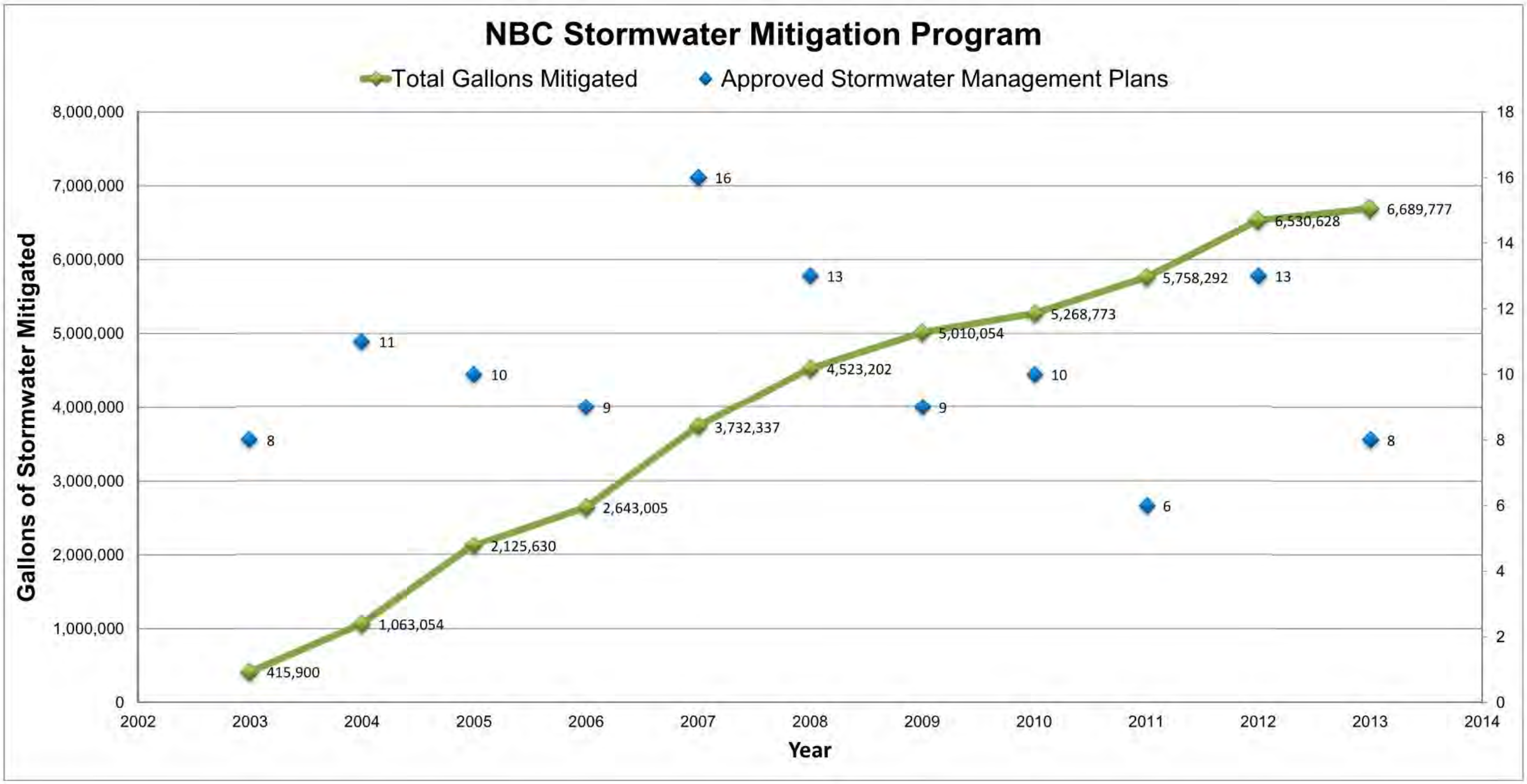
370 Hartford Avenue

Providence Rhode Island



59,450 Gallons Infiltrated and removed from NBC system. (3-month 1.65 inch storm event)

Current NBC Stormwater Mitigation Program



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Translating GSI Benefits to CSO Reductions

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Combined Sewer Overflows (CSOs)

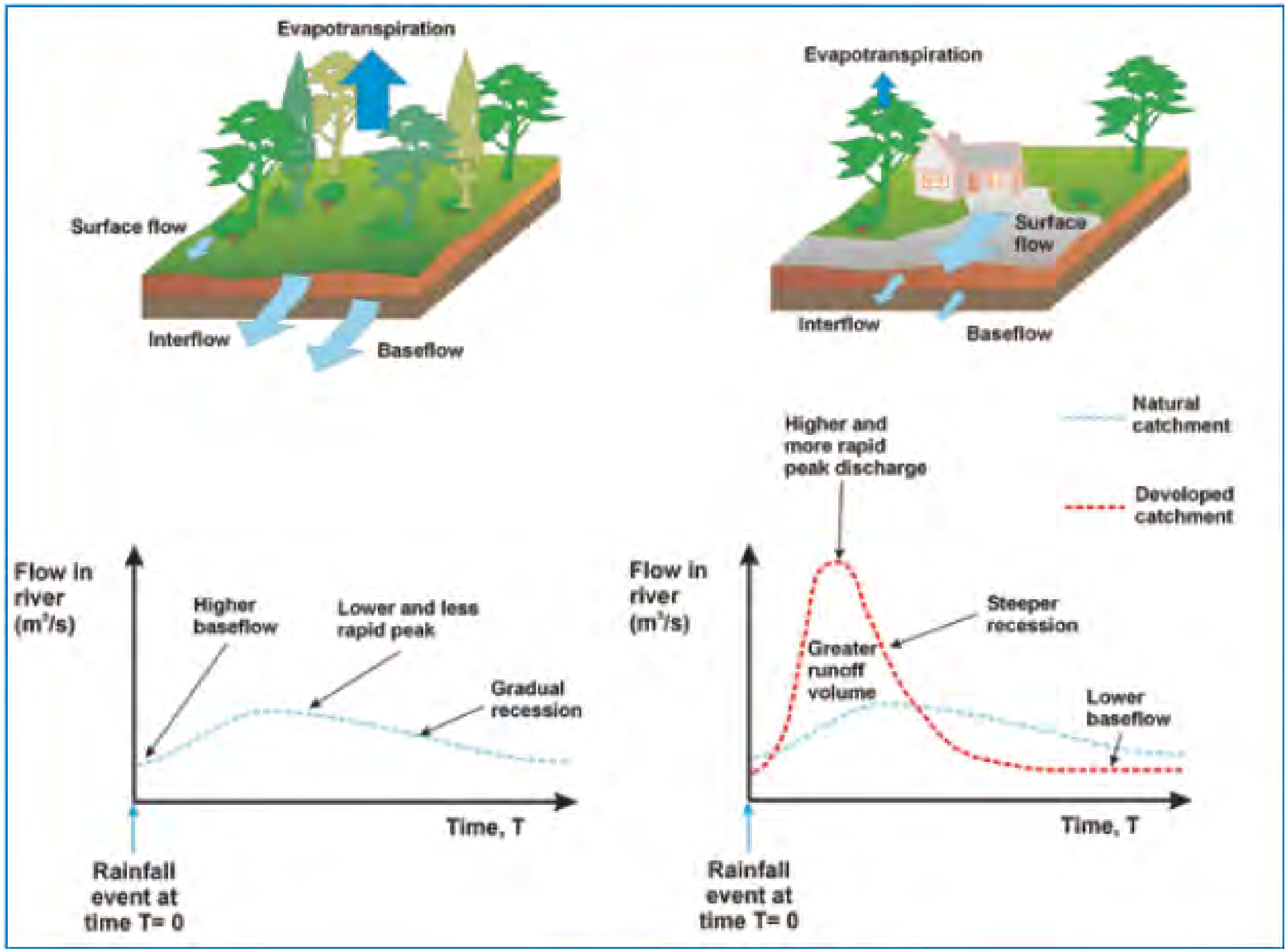
What they do……..

- to provide local relief from flooding
- to protect the downstream sewerage system/treatment plant from overloading
- to safeguard the receiving water from pollution

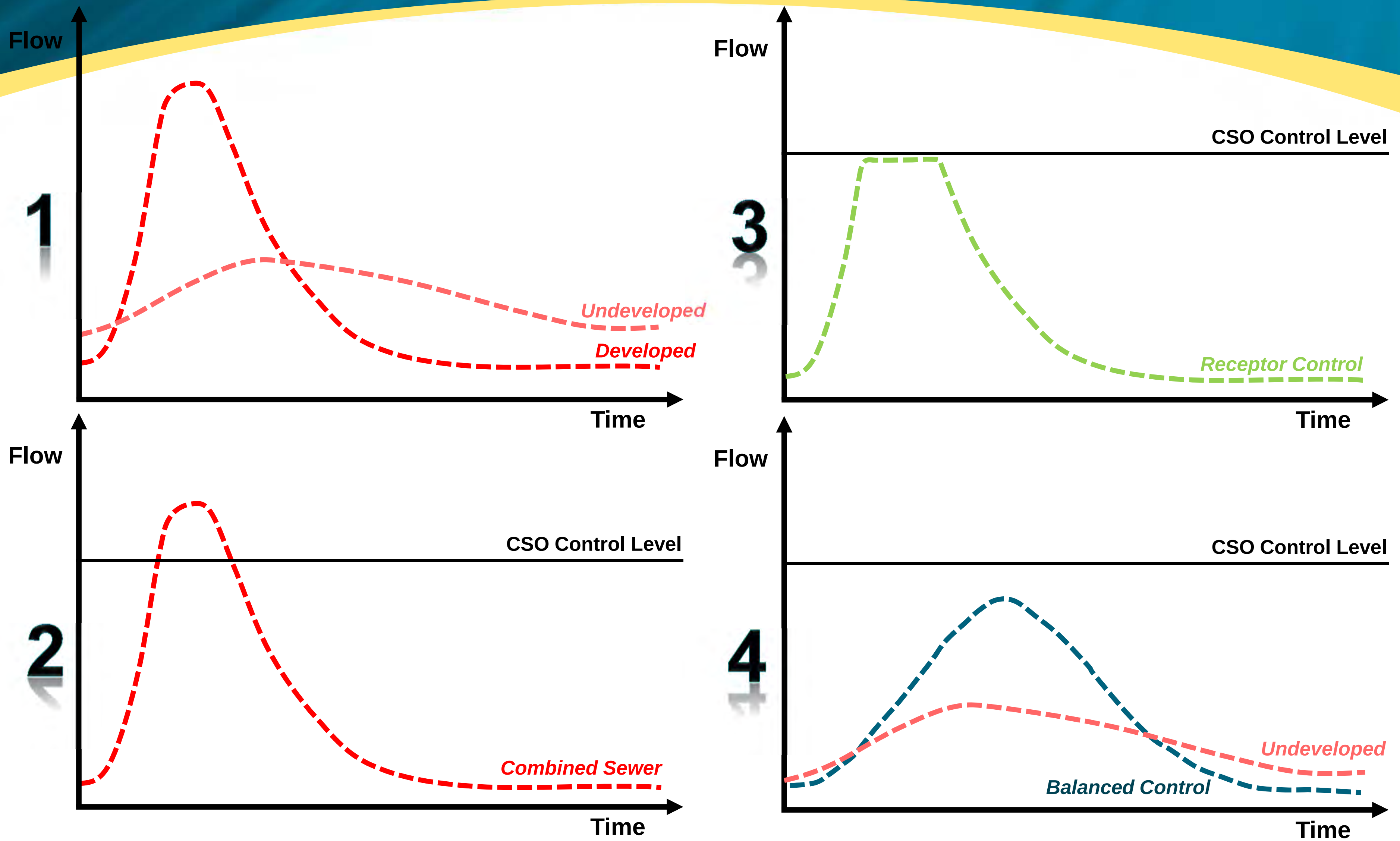
What are the issues……..

- Storm flows conveyed in the same pipe as waste water
- Uneconomic to convey storm flows
- Uneconomic to treat storm flows
- Solution is to overflow excess flows
- But….excess flow contains untreated wastewater
- Primary cause of non-point source pollution

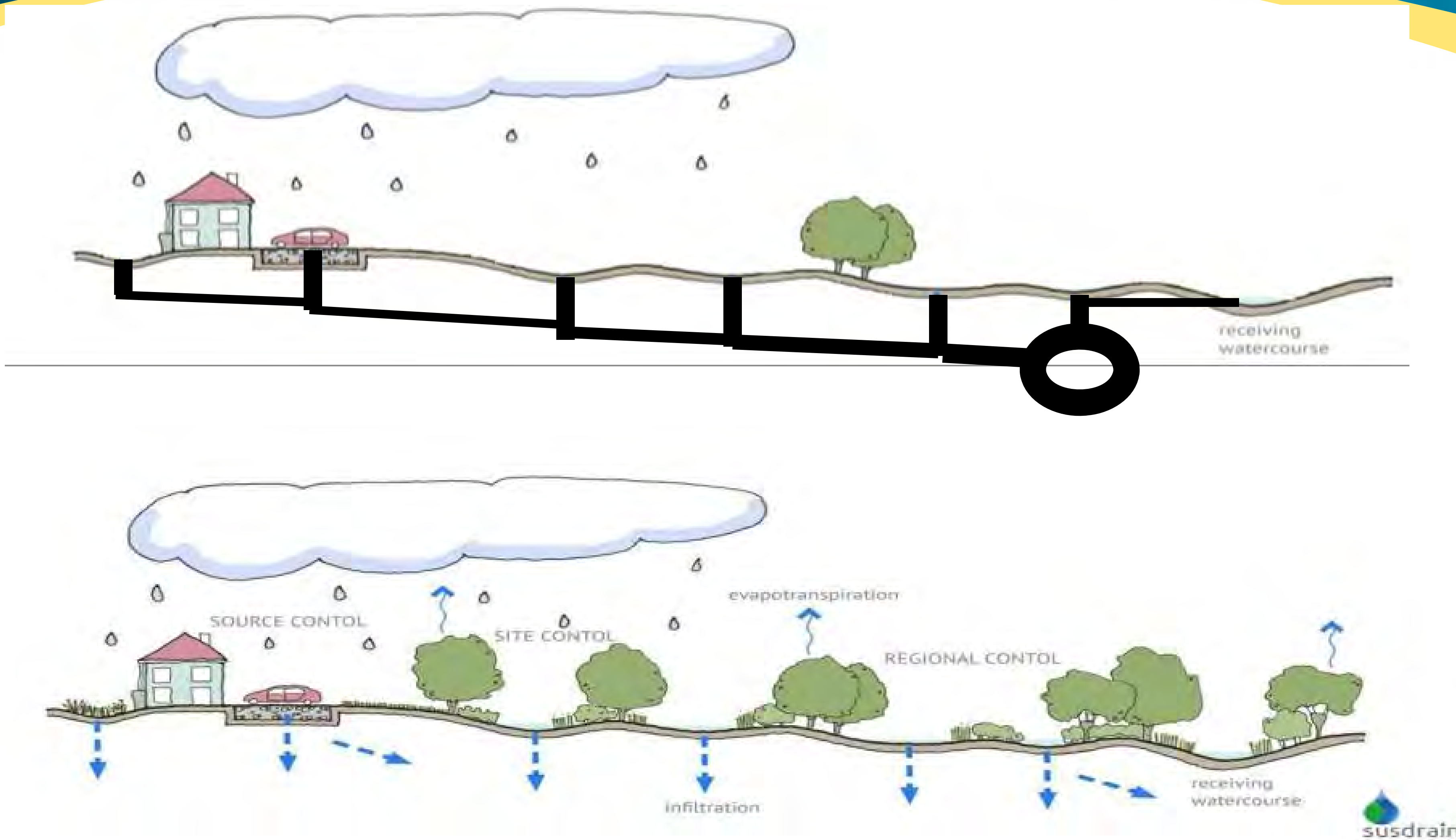
Urbanization's Affect on Runoff



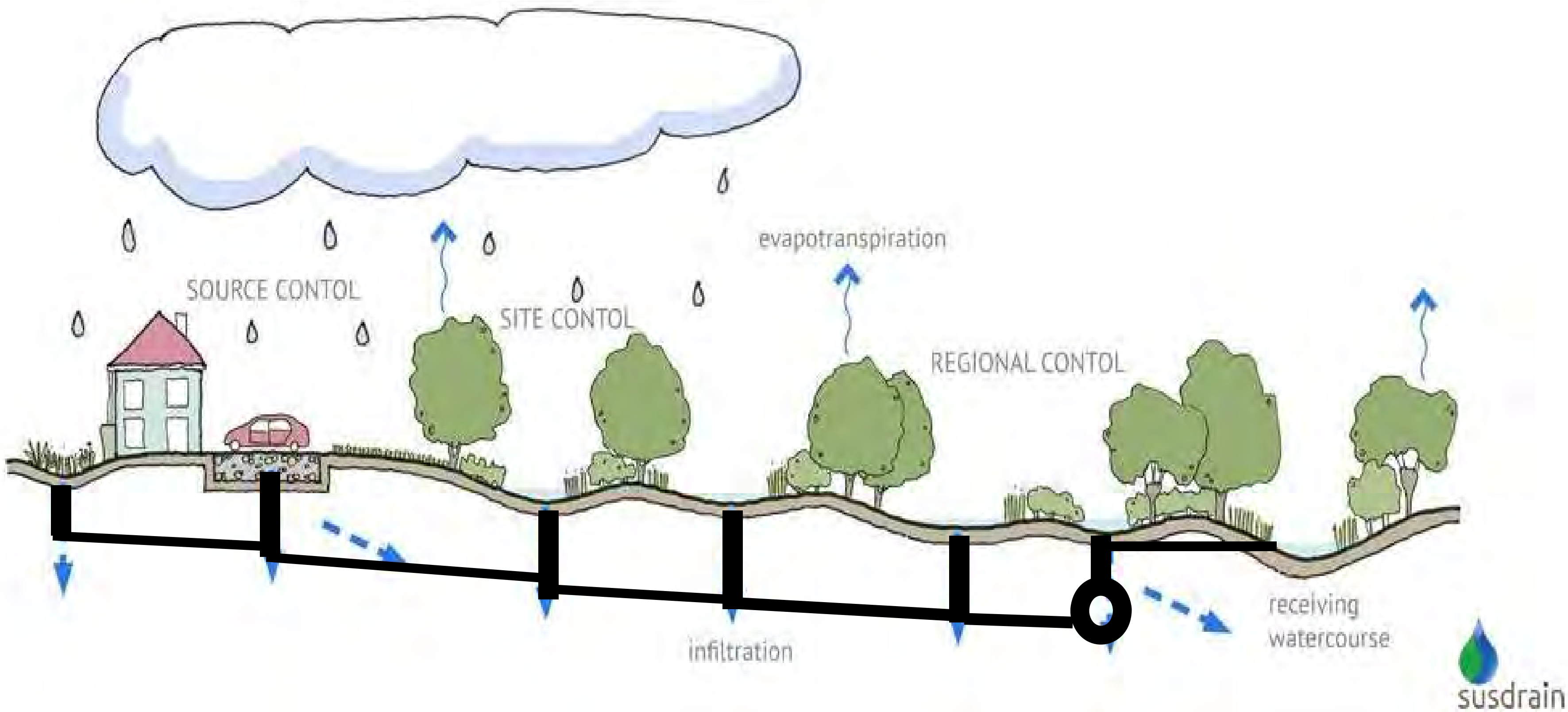
Understanding the hydraulics



The “grey” vs. “green” question

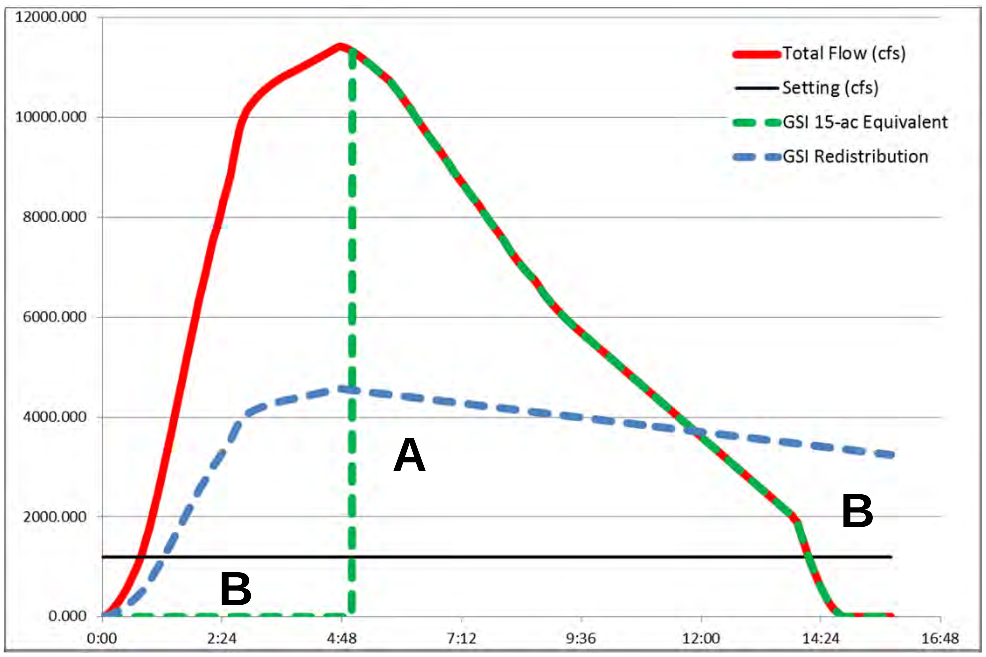


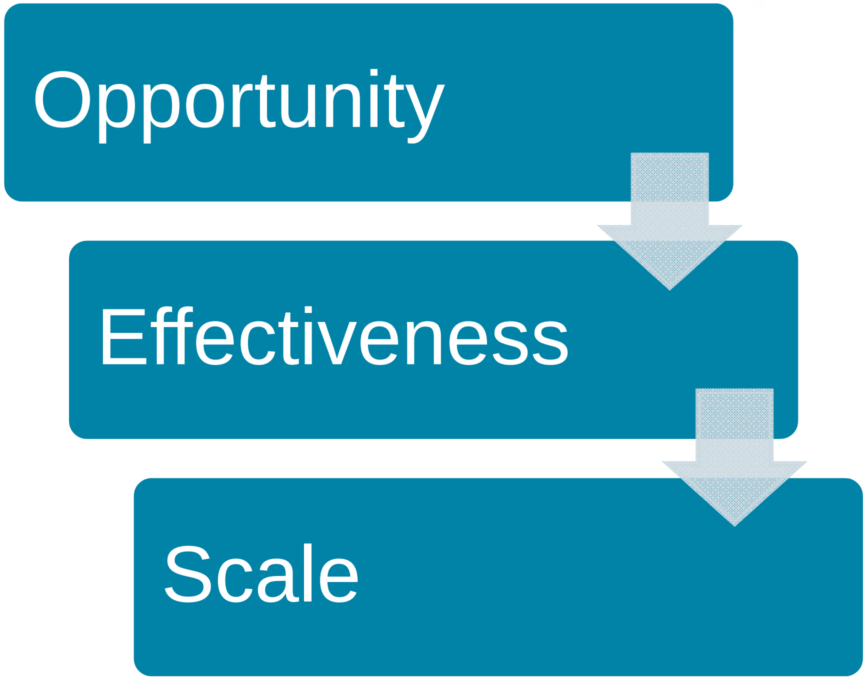
The reality of applying GSI……………………



Challenges and appropriate solutions 1 of 2

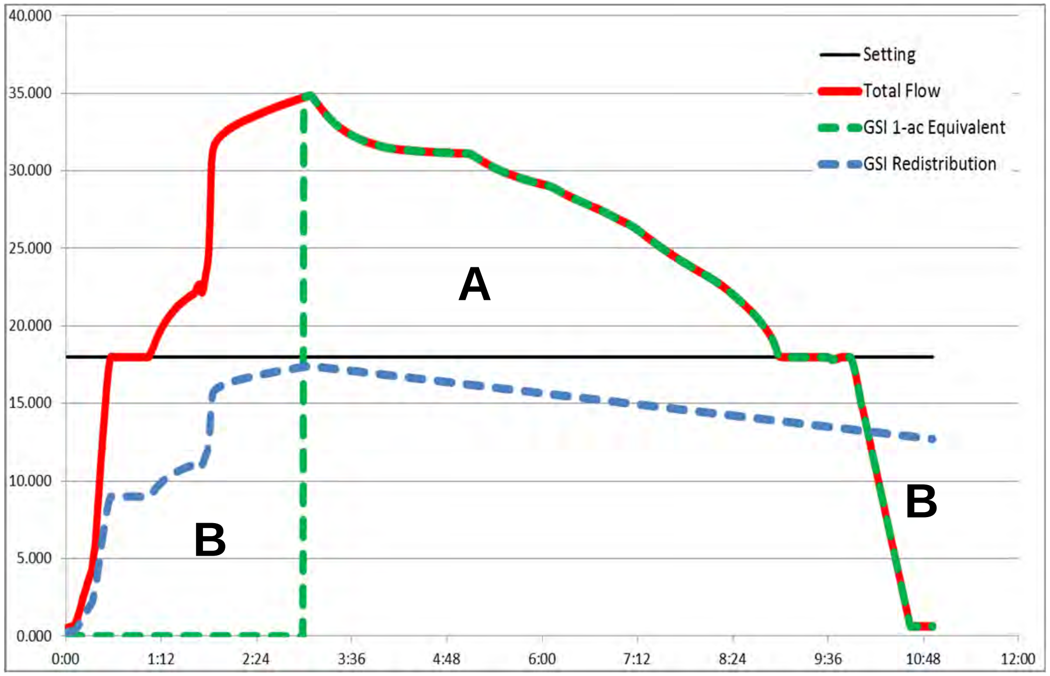
Catchment Area = 1,500 acres
GSI 15-ac coverage across 75-ac area

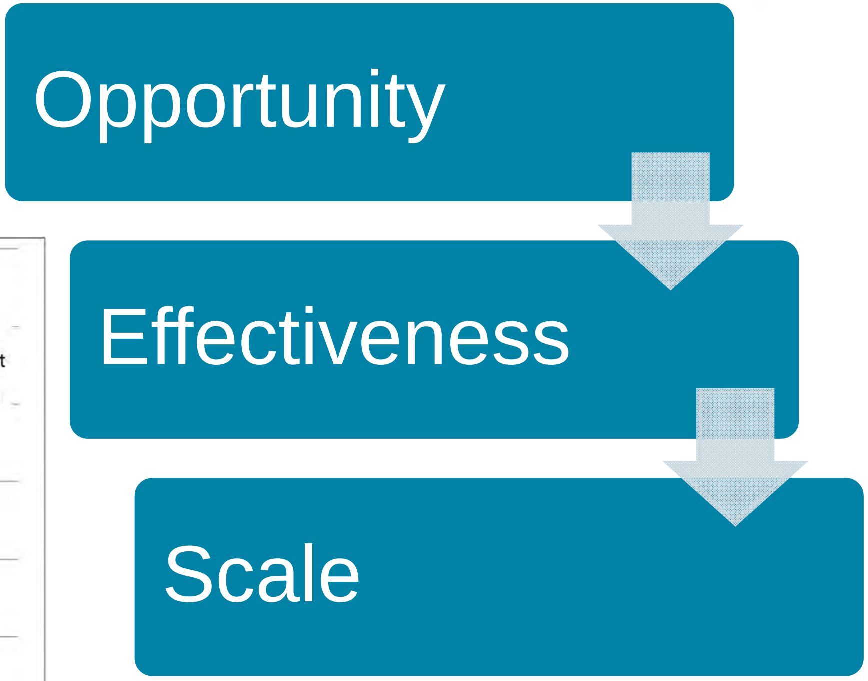




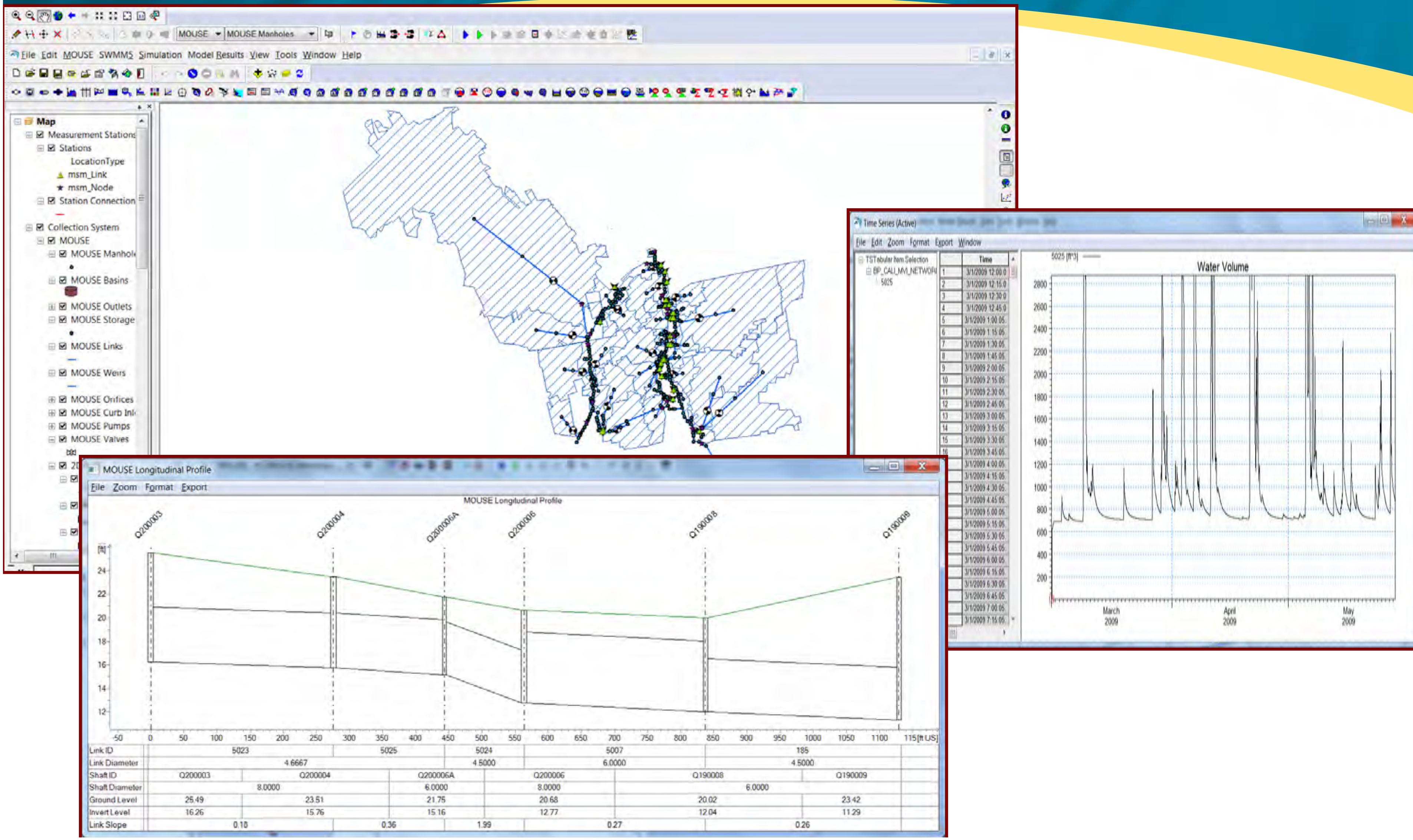
Challenges and appropriate solutions 2 of 2

Catchment Area = 4 acres
GSI 1-ac coverage across 4-ac area





Hydraulic and Hydrologic Model – MIKE Urban



Agenda
Review of engagement
Overview of GSI for CSO
Specific GSI examples
    Infiltration
    Detention
    Retention
Area-wide GSI
Translating to CSO
GSI description

GSI alternatives description

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Green Stormwater Infrastructure Overview

- Advantages
  - Reduces flooding & CSO volumes
  - Improves community livability
  - Improves air quality
  - Reduces urban head island effects
  - Improves water quality
  - Reduces energy use
  - Improves wildlife habitat (for large-scale)
  - Increases recreational opportunities (for large-scale)
- Disadvantages
  - Requires provisions to preserve and maintain functionality in perpetuity
  - Requires strong community and political support

GSI in Public Ways

- Advantages
  - Centralized control of O&M
  - Public amenity
- Disadvantages
  - Public entity bears cost

GSI on Private Property

- Advantages
  - Cost shifted to developers
- Disadvantages
  - Less control of operations
  - Economic development impacts

Expansion of Stormwater Mitigation Program

- Increase NBC sewer connection permits
  - More stringent requirements
  - More broad applicability
  - Technical & construction assistance
- Adopt requirements into building, zoning or planning
  - Administrative issues
  - Technical review requirements
  - Economic development impacts

Next Meeting

19 June 2014, 9:00AM
Evaluation Criteria Focus