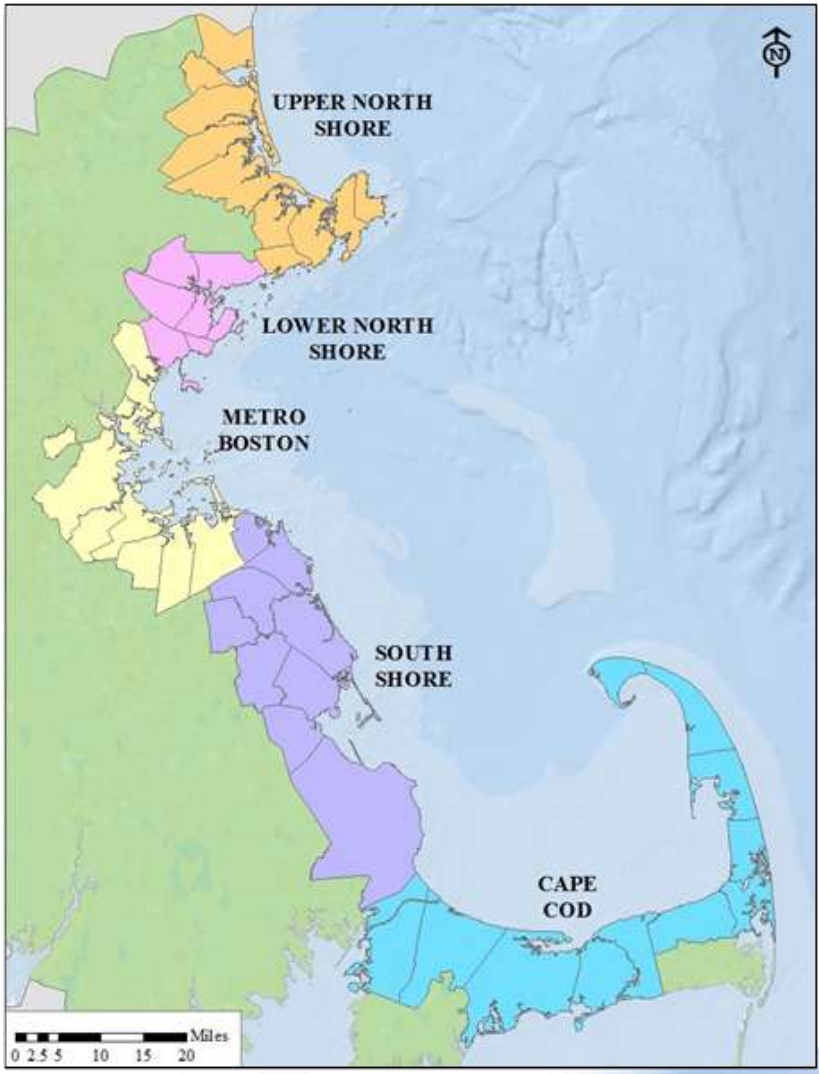
Coastal Stormwater Management Through Green Infrastructure: A Handbook for Municipalities



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Presentation Goals

- Increase Awareness of Stormwater Impacts and Need for Green Infrastructure Approach
- Present Overview of Coastal Stormwater Management Through Green Infrastructure: A Handbook for Municipalities
- Provide Understanding of How Manual Can Be Applied in Your Community
- Identify Available Resources

Stormwater and Need to Address

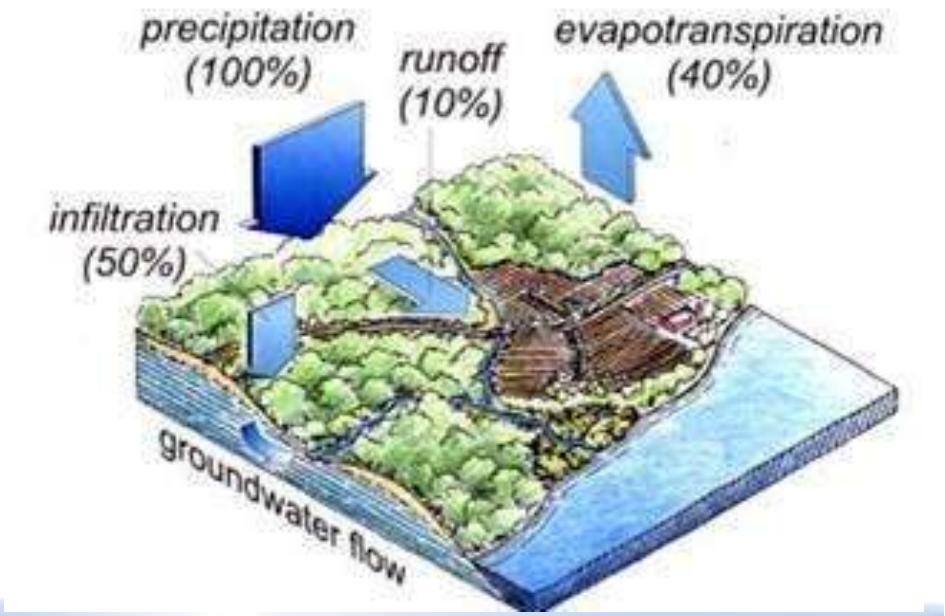
- Stormwater runoff is one of the largest sources of pollution in Massachusetts coastal waters.
- When rain hits rooftops, parking lots and roads, polluted runoff often ends up in storm drains and is sent directly to local waterways.
- Pollution that reaches our coastal waters – excess nutrients, trash, and chemicals – compromises natural habitats, including shellfish beds, wetlands, and eelgrass beds that serve as nurseries for fish.

Stormwater Runoff

Typical pre-development conditions:

Runoff = 10%

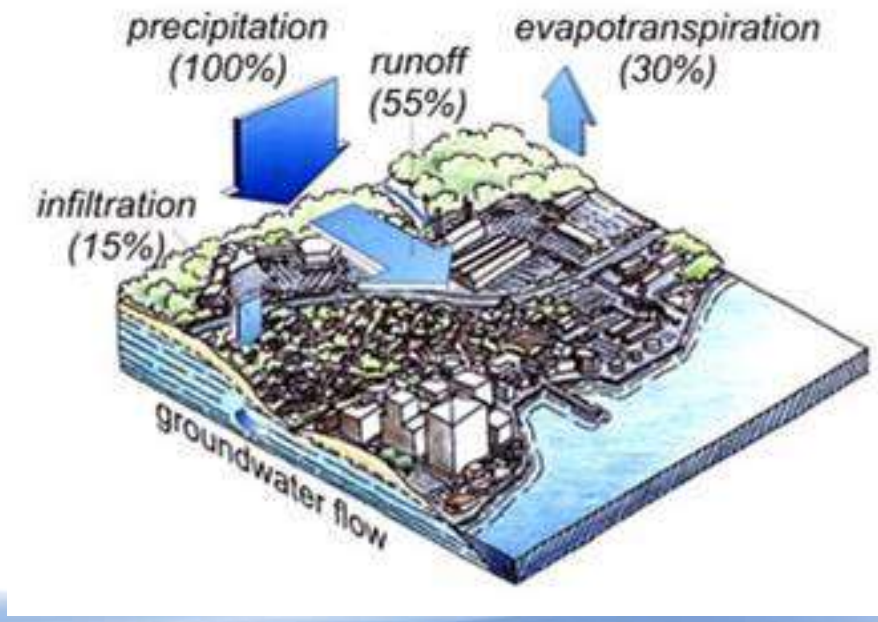
Infiltration = 50%



Typical post-development conditions:

Runoff = 55%

Infiltration = 15%



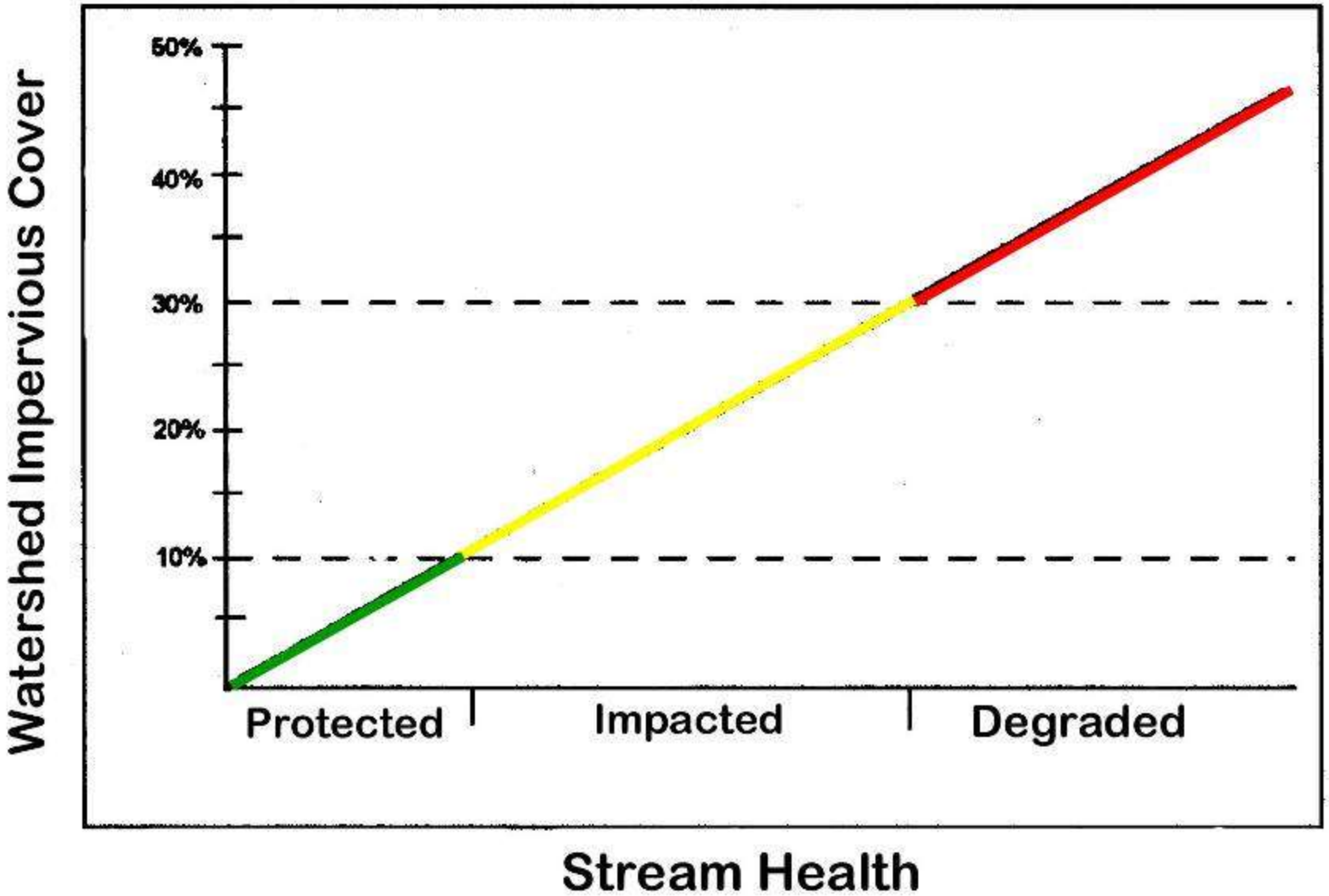
Stormwater Runoff Impacts

Nutrients
Pathogens
Sediment
Toxic Contaminants
Oil and Grease
Thermal Stress

Increased quantity

Decreased quality

Relationship of Impervious Cover to Stream Health



Center for Watershed Protection

Traditional Thinking

- Old wisdom: Treating the first inch of runoff and managing the peaks of stormwater is enough.
- Now we know it's not.

Need For A Green Infrastructure Approach

How do we make this…

function more like this?

What is Green Infrastructure?

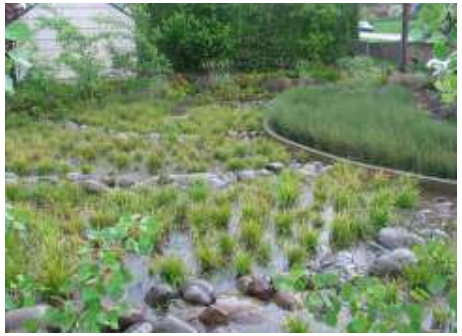
Green infrastructure uses vegetation and soil to manage rainwater where it falls.

By weaving natural processes into the built environment, green infrastructure provides not only stormwater management, but also flood mitigation, air quality management, and much more.

“Green” Stormwater Guiding Principles

1. Manage stormwater runoff both at the source and at the surface.

2. Use plants and soil to slow, filter, cleanse, and infiltrate runoff.



3. Design facilities that are simple, low-cost, and aesthetically enhance the community.

What is Green Infrastructure?

- Site Design and Green Infrastructure Principles
  - Reducing impervious surfaces
  - Disconnecting impervious areas
  - Conserving natural resources
  - Using cluster/consolidated development
  - Using xeriscaping and water conservation practices

Green Infrastructure Site Design

Reduce Impervious Surfaces

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Green Infrastructure Site Design

Conventional “Fat” Street

Source: NCSU-BAE

Green Infrastructure “Skinny” Street

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Green Infrastructure Site Design

Impervious Area Disconnection

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Green Infrastructure Best Management Practices

- Practices
  - Vegetated filter strips
  - Bioretention
  - Constructed stormwater wetlands
  - Tree box filters
  - Green roofs
  - Permeable pavement

Green Infrastructure Benefits

- Benefits of Green Infrastructure
  - Water Quality
  - Increased enjoyment of surroundings
  - Increased safety and reduced crime
  - Increased sense of well being
  - Increased property values

Benefits of Green Infrastructure

- **Increased enjoyment of surroundings**
  - Increased use of green space (Hastie 2003; Kuo 2003).
- **Increased safety and reduced crime**
  - 7 to 8 percent of the variance in crimes (Kuo 2001)
  - Reduce road rage, increase safety, decrease vehicle speeds (Wolf 1998; Kuo 2001).
- **Increased sense of well-being**
  - Enhances people's sense of well-being. (Northeastern Illinois Planning Commission 2004) and reduces mental fatigue (Wolf 1998).
- **Increased property values**
  - 0.7 to 30% increase in property values

Benefits of Green Infrastructure

- **Economic**
  - Job Creation
  - Reduced Infrastructure Cost
  - Reduced Pumping Costs
  - Increased Property Values
- **Social**
  - Improved Quality of Life and Aesthetics
  - Increased Recreational Opportunities
- **Environmental**
  - Reduced Stormwater Volume
  - Reduced Sediment Loading
  - Increased Groundwater Recharge
  - Carbon Sequestration
  - Reduced Energy Use
  - Climate Change

ENVIRONMENT – SOCIAL – ECONOMIC

Handbook Overview

- Assess Watershed
- Identify Green Infrastructure Opportunities
- Site Assessment, Planning, and Design
- Identify Green Infrastructure Practices
- Green Infrastructure Review Process

Watershed Assessment (Chapter 2)

The watershed assessment addresses the following major questions:

(1) What are the most important impacts in the watershed?

(2) What are the major stressors and sources linked to these impacts?

(3) Where in the watershed should green infrastructure efforts be focused?

Watershed Assessment (Chapter 2)

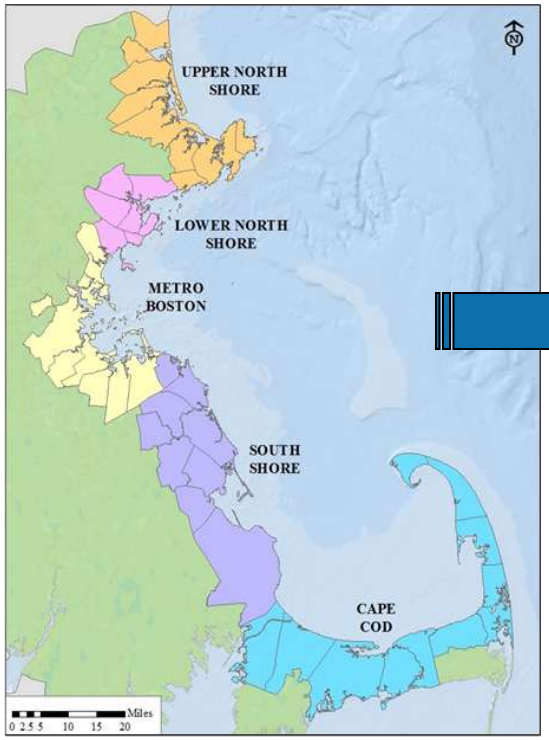
Watershed Assessment

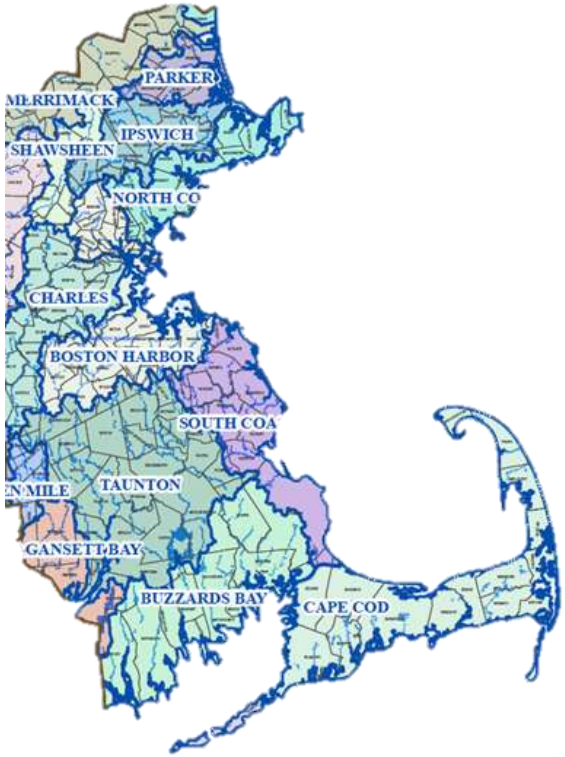
- Part 1: Identify Stakeholders and Roles
- Part 2: Identify Study Watershed
- Part 3: Identify Existing Hydrologic and Hydraulic Data
- Part 4: Characterize Known Pollutant Loadings
- Part 5: Identify Existing BMP and Green Infrastructure Practices
- Part 6: Identify Additional Data Needs

Watershed Assessment (Chapter 2)

- Part 2: Identify Study Watershed

Define the watershed or subwatershed boundary.





Watershed Assessment (Chapter 2)

- Watershed Assessment
  - Part 3: Identify Existing Hydrologic and Hydraulic Data

Search for existing data that help characterize watershed hydrology and hydraulics.

- Locations of water bodies including streams, lakes, and wetlands
- Impervious surface coverage
- Land use and land cover, including vegetation
- Topography (elevation and slope)
- Soils (types, textures, and hydrologic soil groups)
- Parcel data
- Aerial imagery

Watershed Assessment (Chapter 2)

GIS Resources

- **MORIS** (www.mass.gov/eea/agencies/czm/program-areas/mapping-and-data-management/moris)
- **MassGIS** (www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis)
- **OLIVER** (MassGIS) (http://maps.massgis.state.ma.us/map_ol/oliver.php)

Watershed Assessment (Chapter 2)

Dataset	Type	Description	Source(s)
Subwatershed boundary	GIS shapefile	Delineation of study watershed	Municipality
Hydrography	GIS shapefile	Locations of surface water features (lakes, ponds, reservoirs, wetlands, rivers, streams)	MORIS, MassGIS
Land use and land cover	GIS shapefile	Land use and land cover	MORIS, MassGIS
Impervious Area	Image file	Impervious surfaces including buildings, roads, and parking lots	MORIS, MassGIS
Roads and streets	GIS shapefile	Transportation (public and private roadways) (*if impervious surface data are insufficient*)	MORIS, MassGIS
Elevation	GIS raster file	Elevation above or below sea level	MORIS, MassGIS
Soils	GIS shapefile	Spatial extent of soil types and HSGs	MassGIS (alternately NRCS)
Parcels	GIS shapefile	Property boundaries and ownership	Municipality, MORIS, MassGIS
Aerial imagery	Image file	True-color aerial photos	MORIS, MassGIS

Watershed Assessment (Chapter 2)

- Locations and routing of existing stormwater structures and pipes
- Streamflow data and locations of streamflow gages
- Climate/rainfall data and locations of climate monitoring stations
- Water quality data and locations of existing monitoring locations
- Locations of impaired waters and corresponding impairments, both within the watershed and immediately downstream
- Environmentally sensitive areas, floodplains and floodways, water supplies, and dams

Watershed Assessment (Chapter 2)

- Watershed Assessment
  - Part 4: Characterize Known Pollutant Loadings.

Prioritize pollutant sources and develop a meaningful plan for green infrastructure implementation focused on the highest priority sources in the target watershed.

- Identify pollutants of interest and concern (e.g., 303(d) and TMDL pollutants).
- Identify and characterize pollutant sources.
- Estimate pollutant loadings using existing monitoring data and other methods.
- Develop site characterizations.

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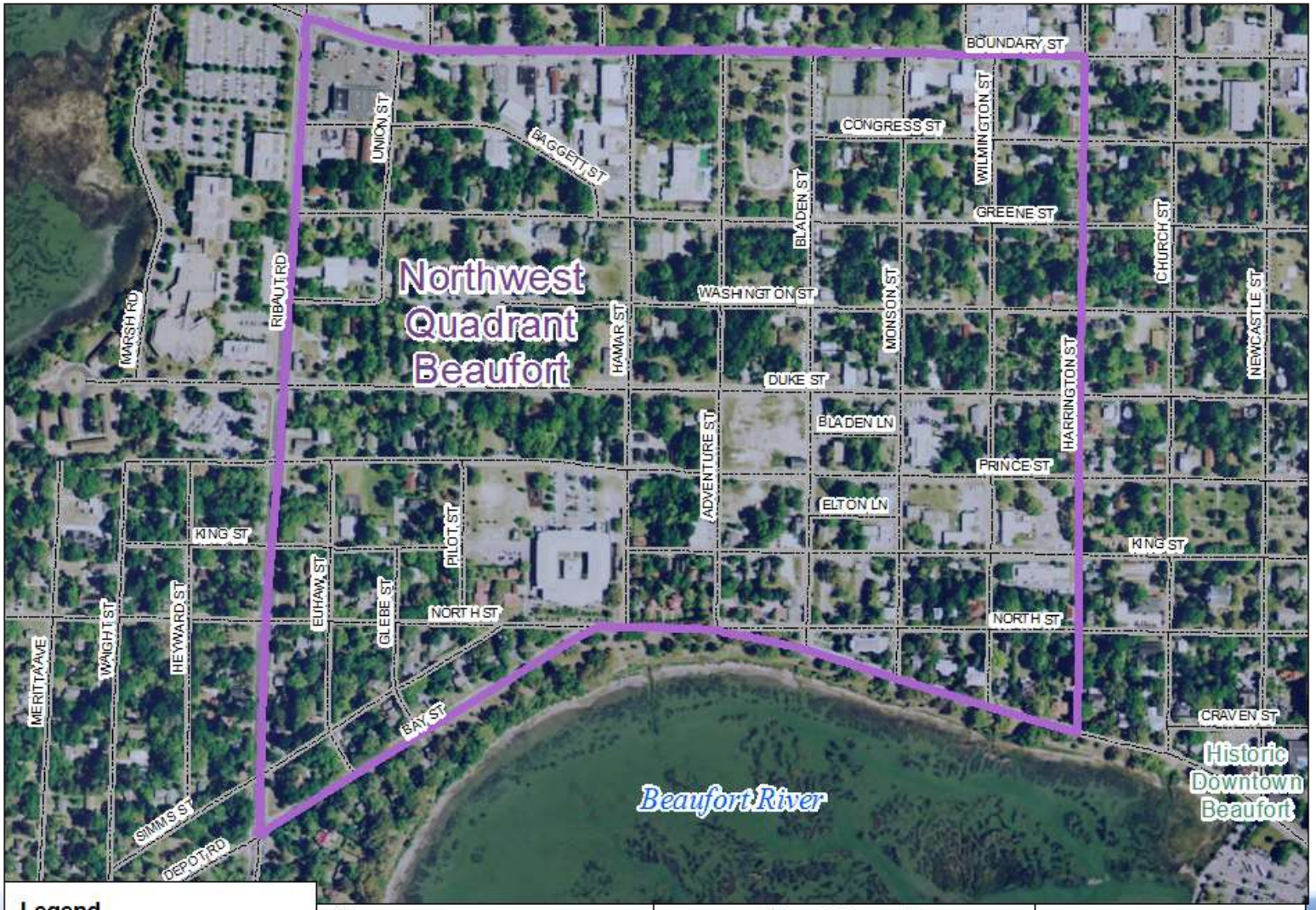
CENTEX

Charlotte-Mecklenburg
Storm Water Services

Watershed Assessment (Chapter 2)

- Watershed Assessment
  - Part 1: Identify Stakeholders and Roles
  - Part 2: Identify Study Watershed
  - Part 3: Identify Existing Hydrologic and Hydraulic Data
  - Part 4: Characterize Known Pollutant Loadings.
  - Part 5: Identify Existing BMP and Green Infrastructure Practices
  - Part 6: Identify Additional Data Needs.
    - Water quality sampling
    - Field Reconnaissance
      - Overall appearance
      - Site configuration
      - Slope

Watershed Assessment (Chapter 2)



Questions and Discussion

Identifying Green Infrastructure Opportunities – (Chapter 3)

- Identify Green Infrastructure Opportunities
  - Identification of Target Watersheds
  - Primary Screening
    - Eliminate unfeasible parcels
  - Secondary Screening
    - Prioritize implementation opportunities

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Identifying Green Infrastructure Opportunities – (Chapter 3)

- Identify Green Infrastructure Opportunities
  - Identification of Target Watersheds
    - Designated Shellfish Growing Areas (DSGAs).
      - area of potential shellfish habitat.
    - Salt Marsh Restoration Sites.
    - Areas of Critical Environmental Concern (ACECs).
      - coastal and inland areas with significant natural and cultural resources.
    - Seagrass Beds
    - Biodiversity.
      - *BioMap2*
    - Outstanding Resource Waters (ORWs).

Identifying Green Infrastructure Opportunities – (Chapter 3)

Parcel-based green infrastructure (small- and large-scale)	ROW green infrastructure
- Public ownership (except in special cases, per Table 3-1) - Proximity to targeted subwatershed - Proximity to environmentally sensitive or protected areas - Infiltration capacity - Parcel size (large-scale) - Impervious parcel area - Percent impervious - Proximity to storm drainage networks - Proximity to contaminated soils - Proximity to existing BMPs - Proximity to parks and schools - Contributing drainage area (large-scale)[1] - Drainage area percent imperviousness (large-scale) - Known stormwater/MS4 capacity issues	- Proximity to targeted subwatershed - Infiltration capacity - Available width

Identifying Green Infrastructure Opportunities – (Chapter 3)

Factor	Score (5 = Highest Priority, 1 = Lowest Priority)				
	5	4	3	2	1
Public ownership	City- or town-owned public parcels and ROWs	Other-owned public parcels (schools and universities, state and federal facilities, utilities, etc.) and certain private parcels.			
Proximity to target subwatershed[1]	Within target subwatershed				Within subwatershed draining to target watershed
Proximity to environmentally sensitive or protected areas (feet)[2]	< 100, but not within a sensitive or protected area				
Infiltration Capacity (HSG soil type)	A, B		C		D
Impervious area (acres)	> 1	> 0.5	> 0.25	> 0.1	
% Imperviousness	60%–80%	80%–90%			< 50%
Proximity to storm drainage network (feet)			< 100	< 300	> 300

Identifying Green Infrastructure Opportunities – (Chapter 3)

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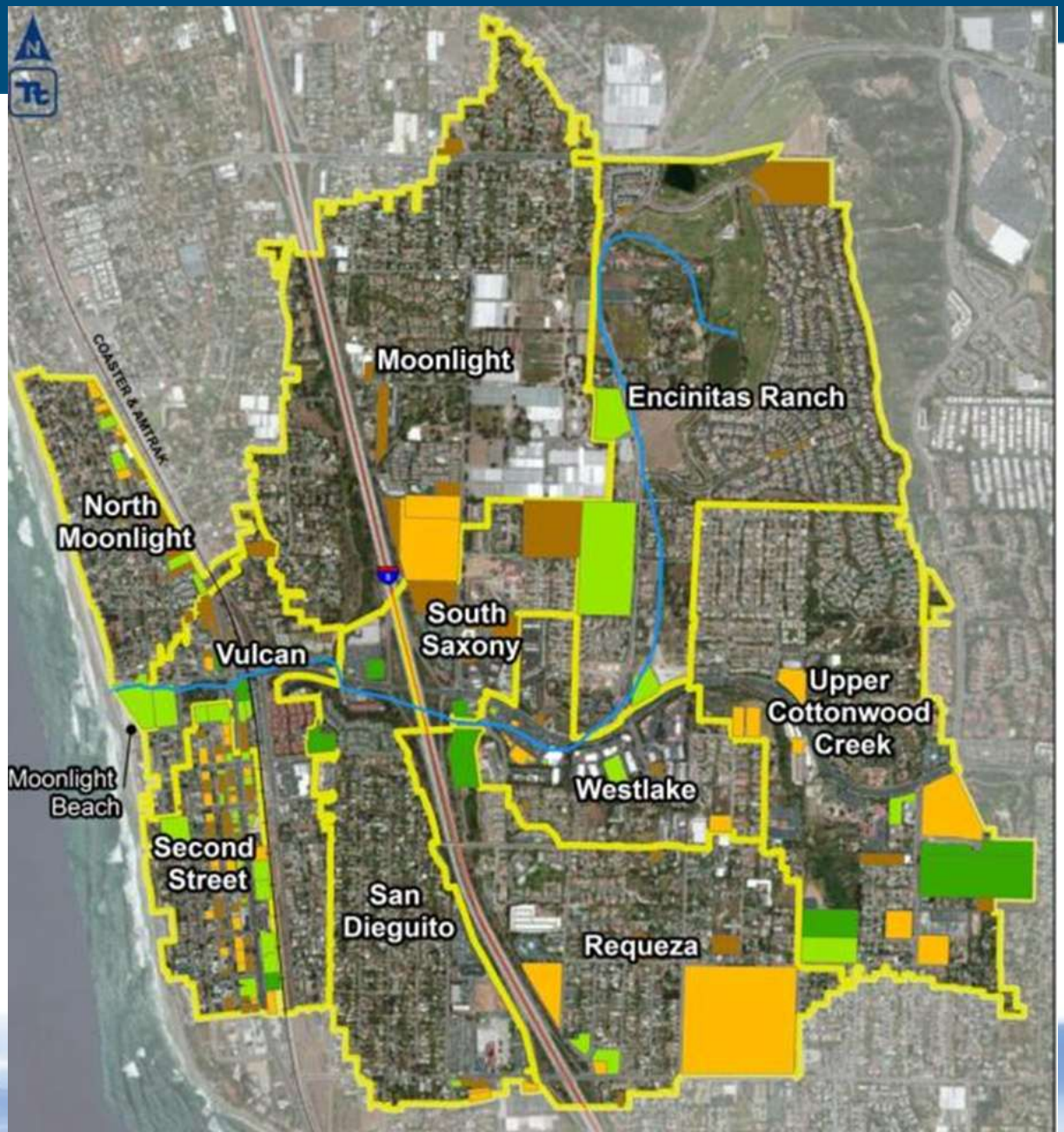

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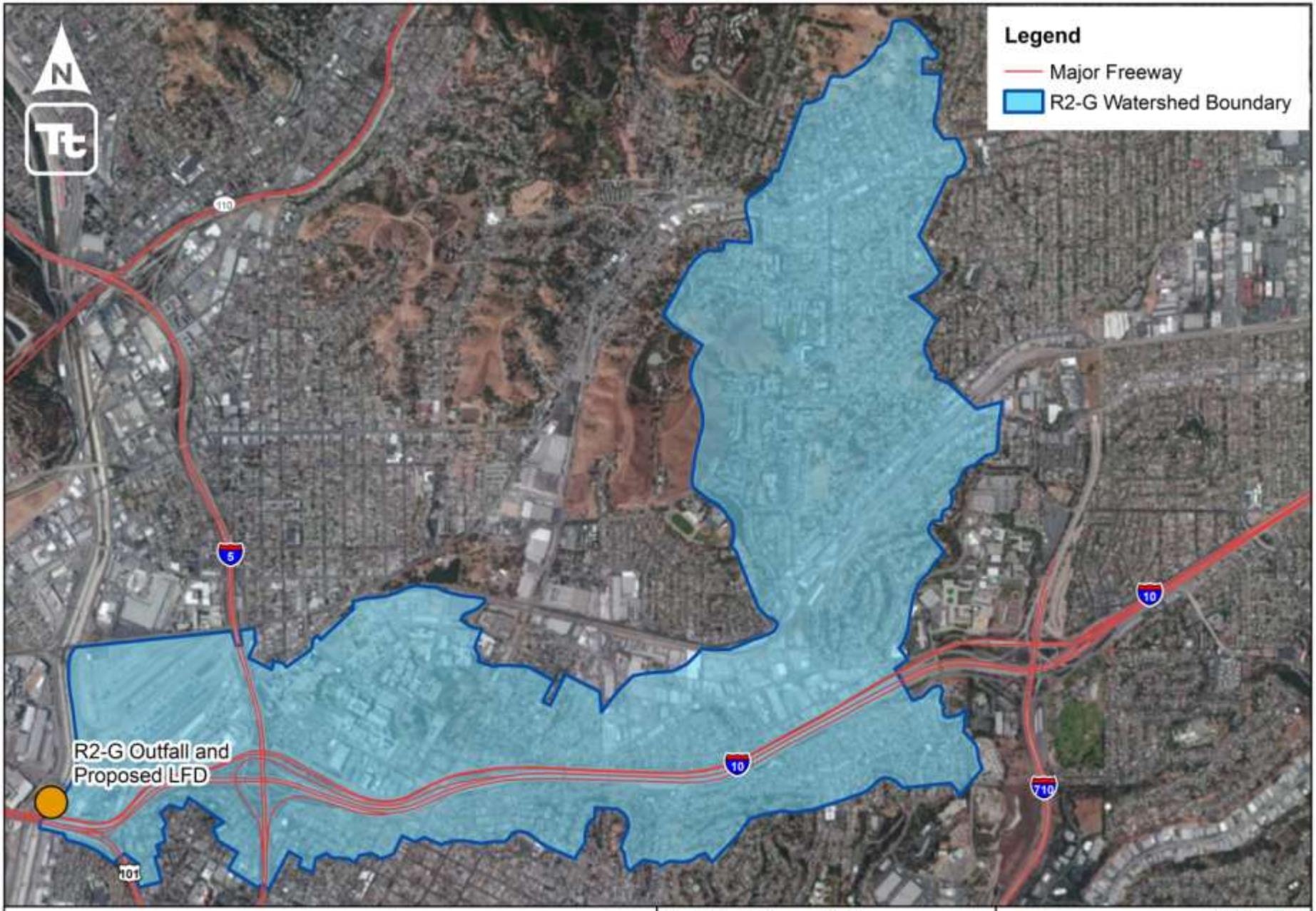

R2-G Watershed

NAD_1983_StatePlane_California_V_FIPS_0405_feet
Map produced 07-03-2013

0 250 500 1,000 Meters

0 0.25 0.5 1 Miles

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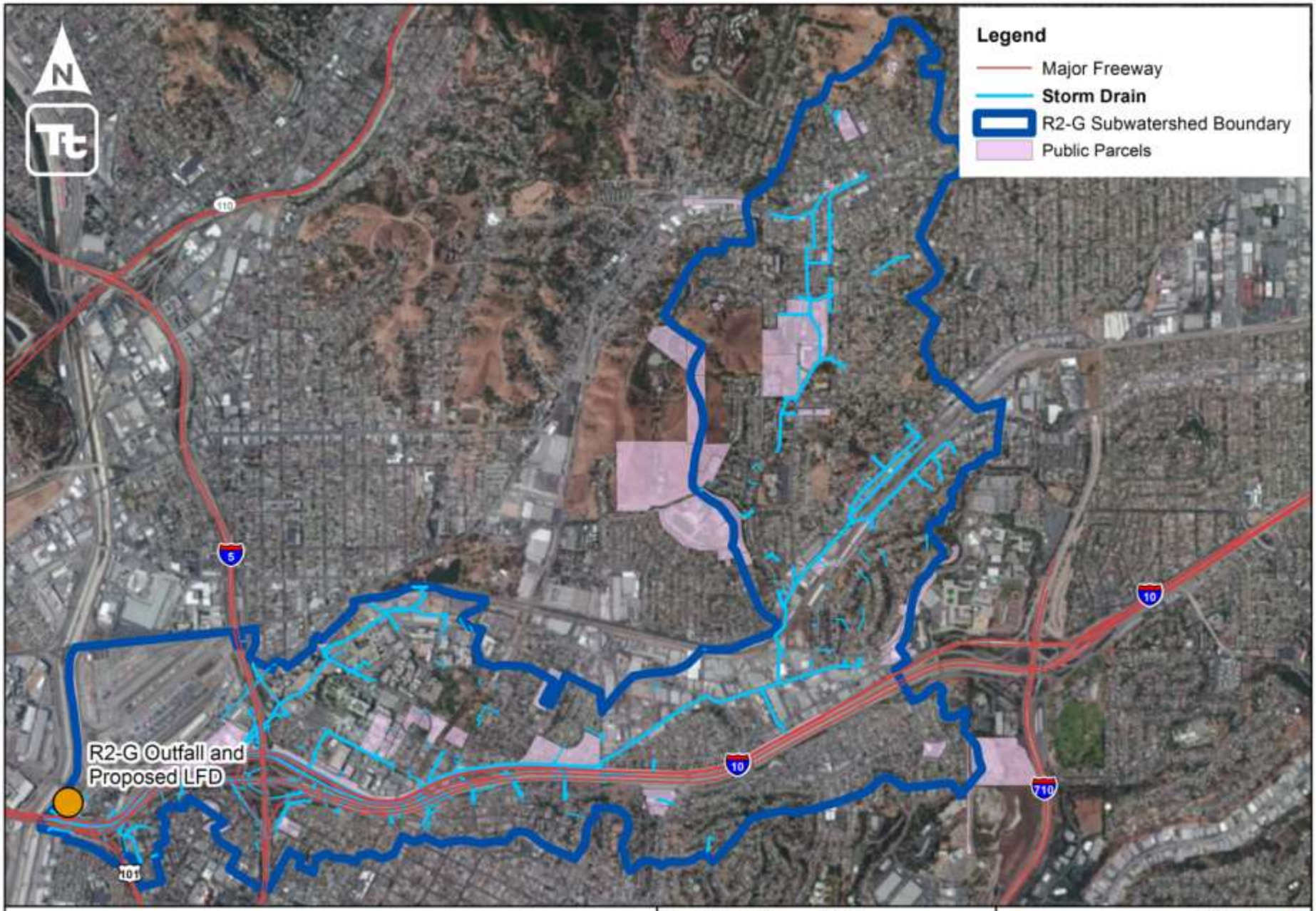

R2-G Parcel Ownership

NAD_1983_StatePlane_California_V_FIPS_0405_feet
Map produced 07-03-2013

0 250 500 1,000 Meters

0 0.25 0.5 1 Miles

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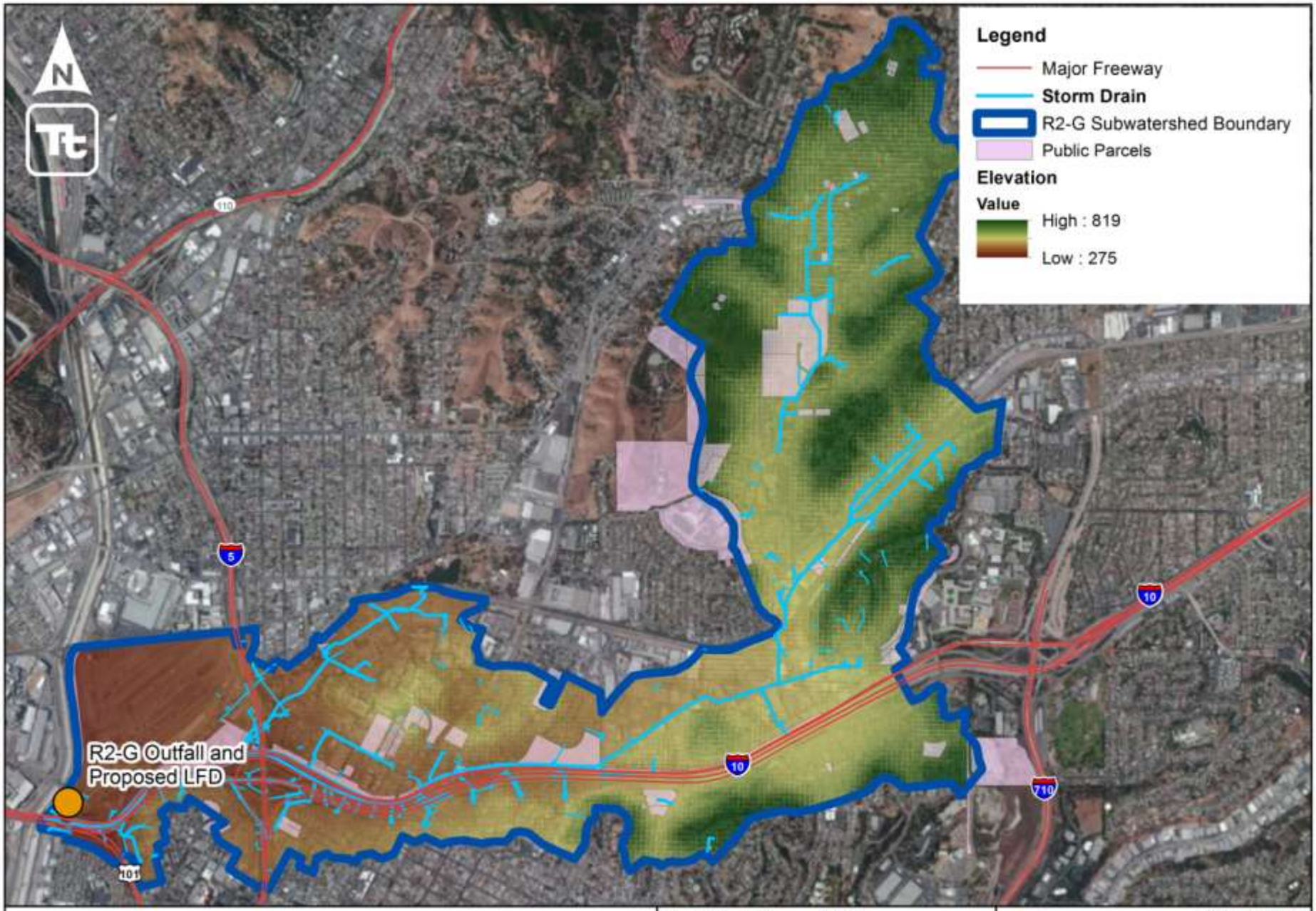

R2-G Screening and Prioritization

NAD_1983_StatePlane_California_V_FIPS_0405_feet
Map produced 07-03-2013

0 250 500 1,000 Meters

0 0.25 0.5 1 Miles

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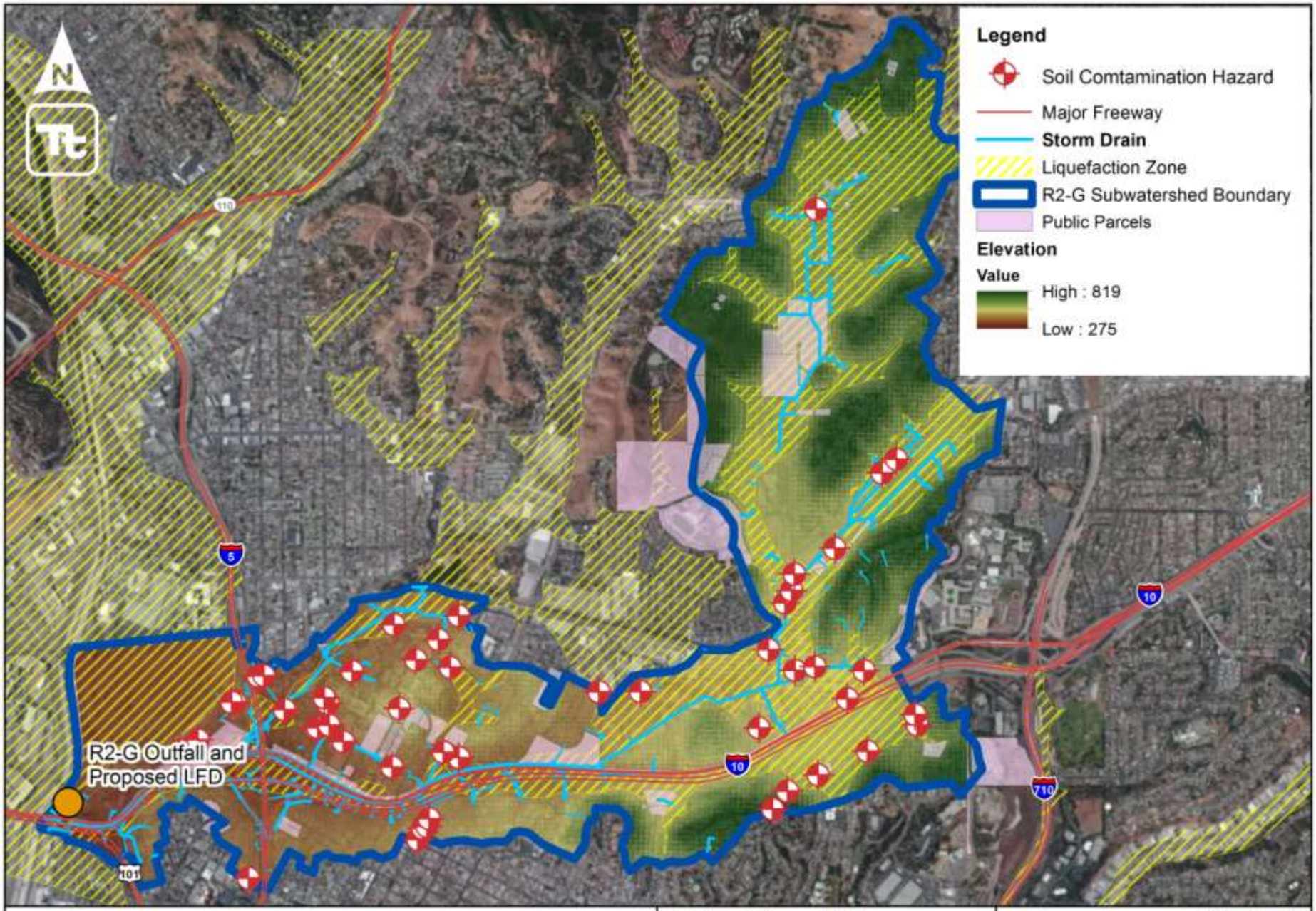

R2-G Screening and Prioritization

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Map produced 07-03-2013

0 250 500 1,000 Meters

0 0.25 0.5 1 Miles

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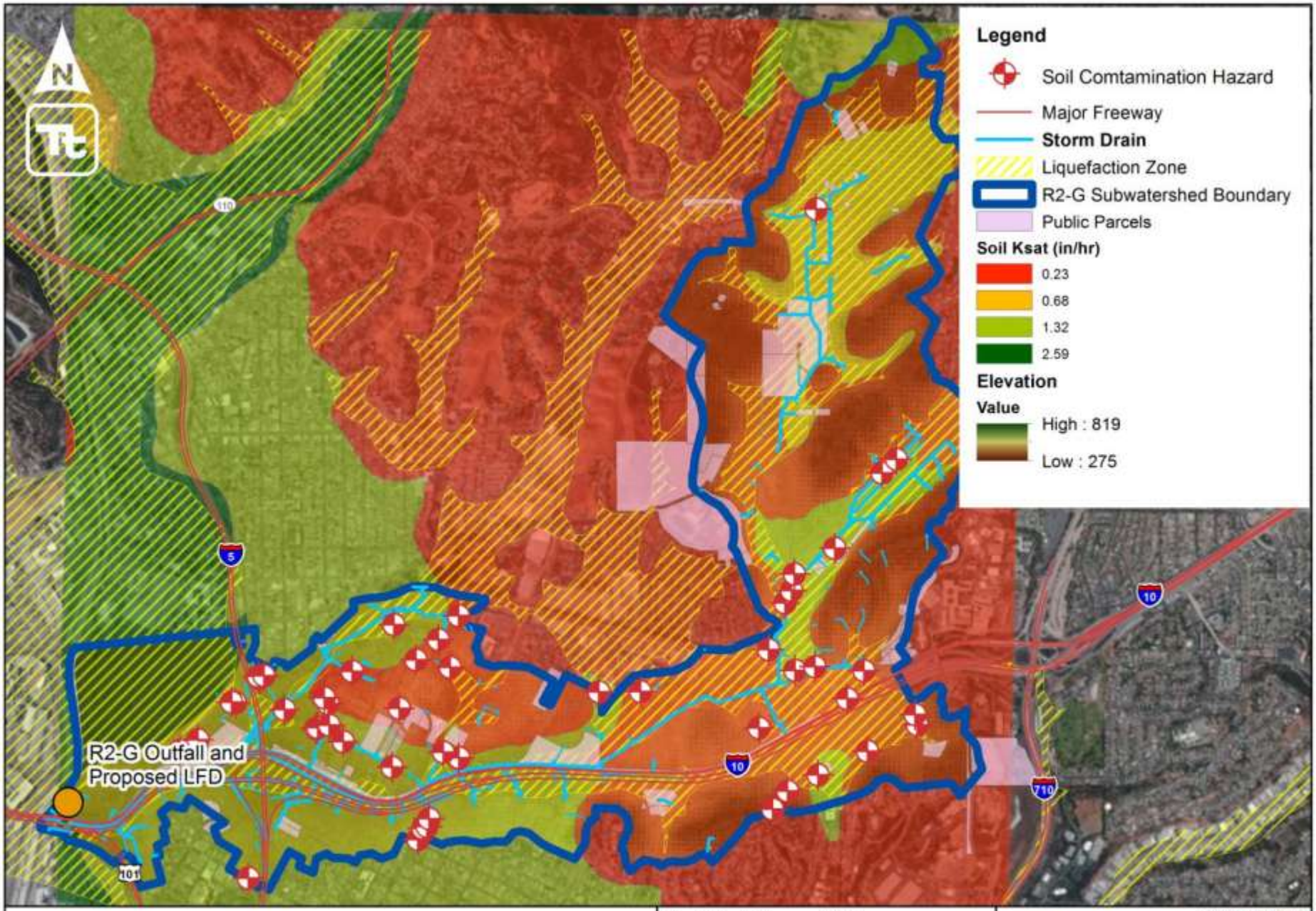

R2-G Screening and Prioritization

NAD_1983_StatePlane_California_V_FIPS_0405_feet
Map produced 07-03-2013

0 250 500 1,000 Meters

0 0.25 0.5 1 Miles

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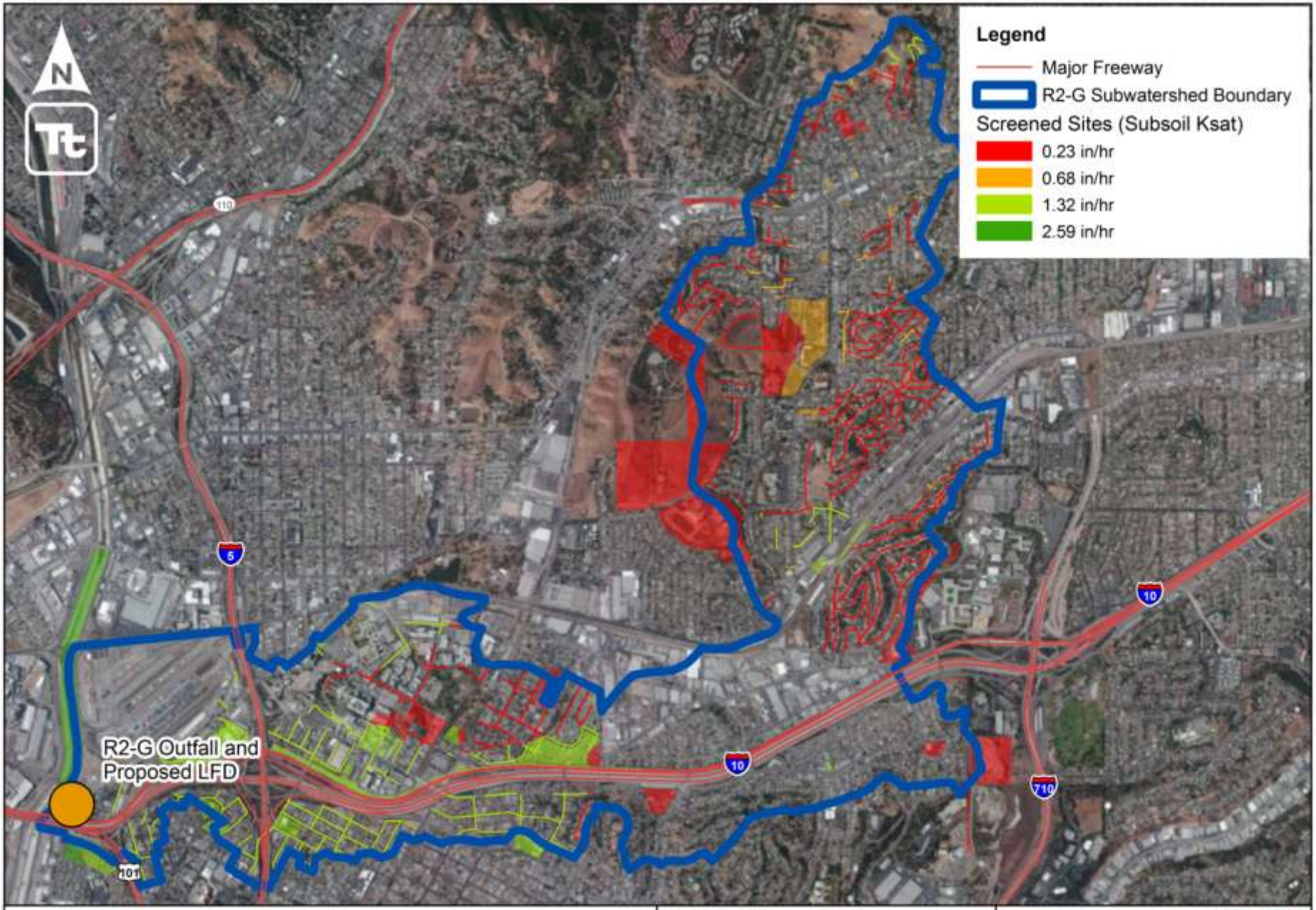

R2-G Screened and Prioritized Sites

NAD_1983_StatePlane_California_V_FIPS_0405_feet
Map produced 07-03-2013

0 250 500 1,000 Meters

0 0.25 0.5 1 Miles

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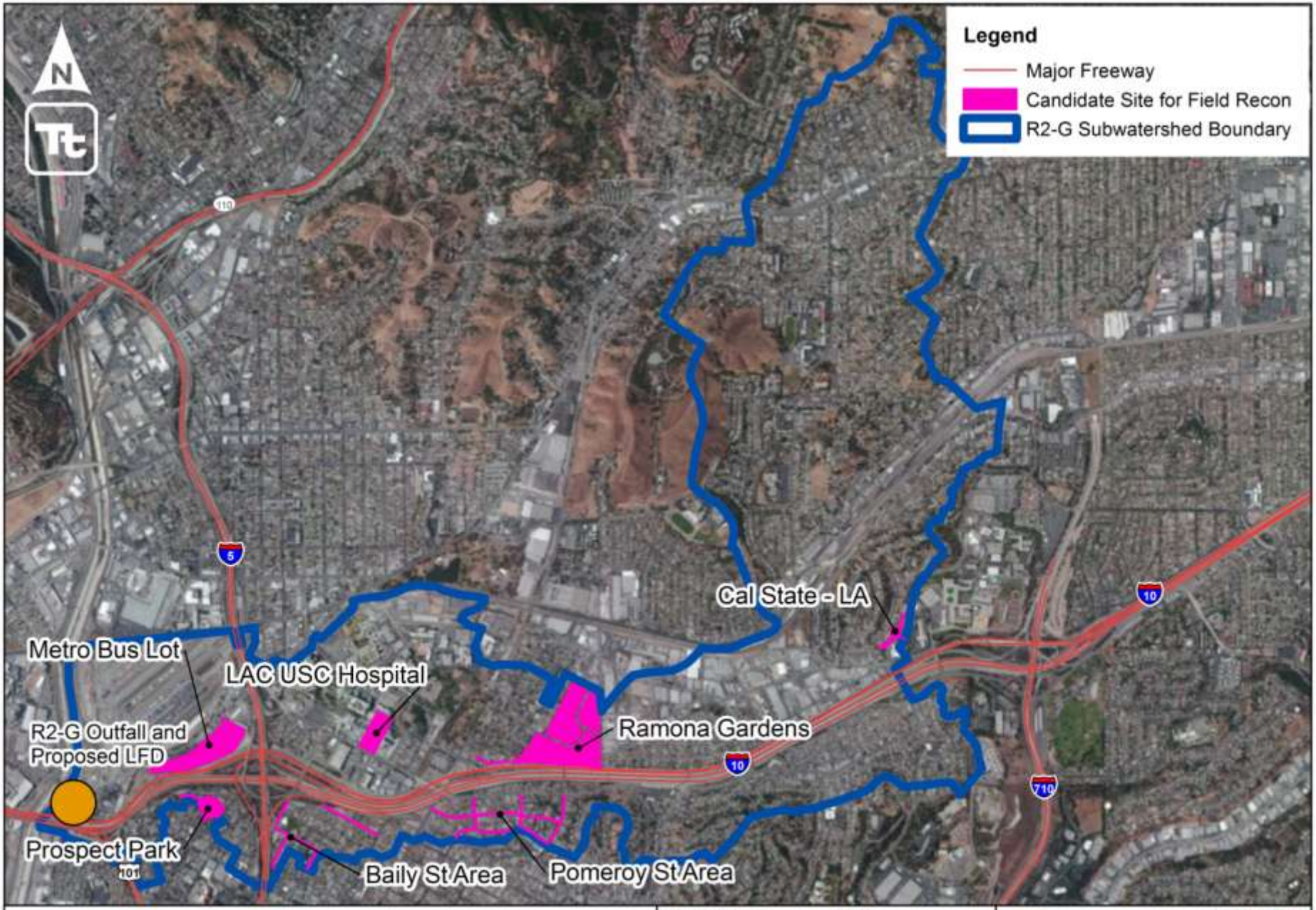

R2-G Candidate Sites for Field Reconnaisance

NAD_1983_StatePlane_California_V_FIPS_0405_feet
Map produced 07-03-2013

0 262.5 525 1,050 Meters

0 0.25 0.5 1 Miles

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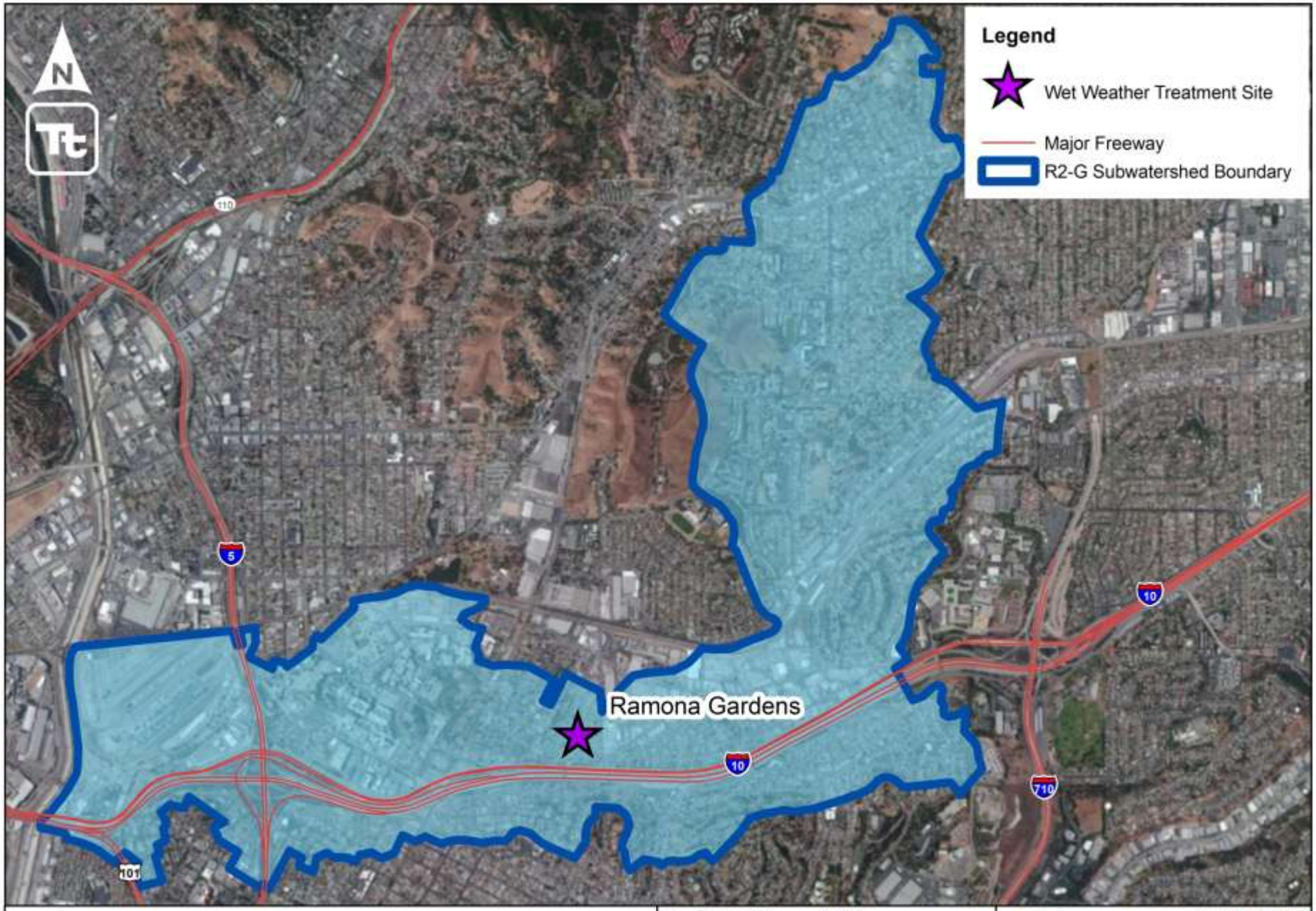

R2-G Selected Wet Weather Treatment Site

NAD_1983_StatePlane_California_V_FIPS_0405_feet
Map produced 07-03-2013

0 250 500 1,000 Meters

0 0.25 0.5 1 Miles

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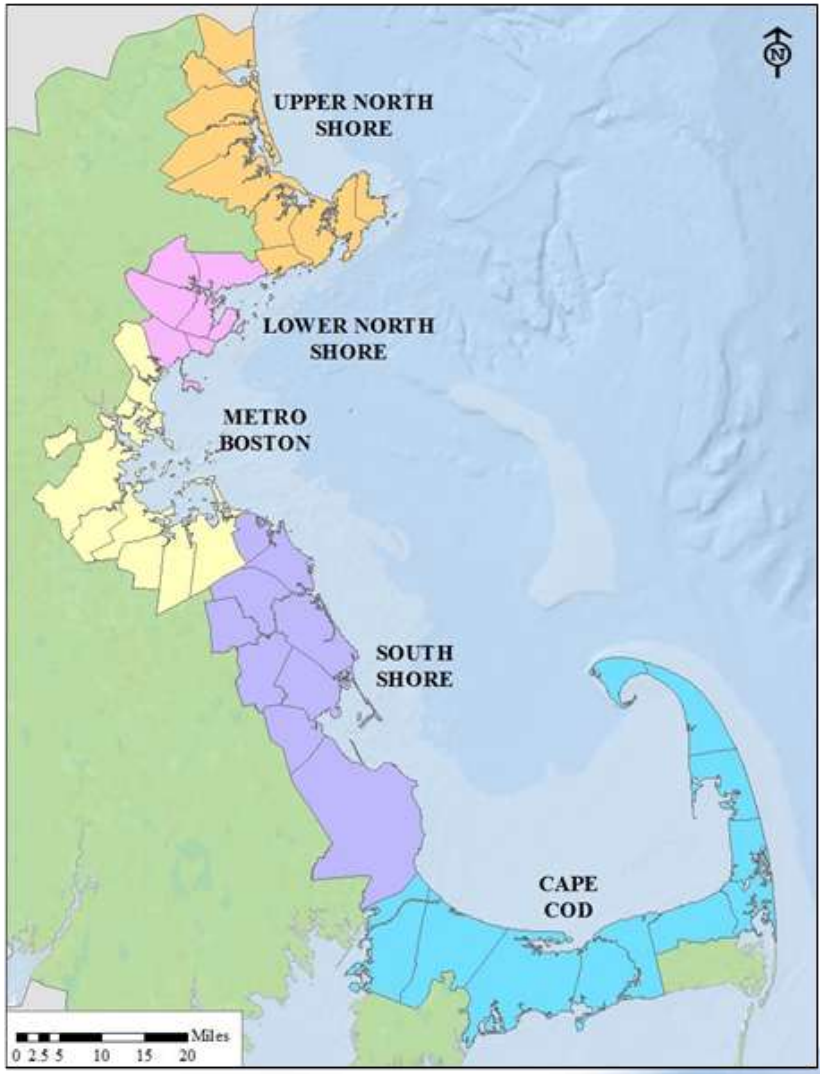
Questions and Discussion

Coastal Stormwater Management Through Green Infrastructure: A Handbook for Municipalities Part II



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Site Assessment, Planning, and Design (Chapter 4)

- Site Assessment, Planning, and Design
  - 1. Using hydrology as the integrating framework
  - 2. Use distributed practices
  - 3. Controlling stormwater at the source
  - 4. Using simple, non-engineered methods
  - 5. Creating a multifunctional landscape

Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase I: Site Assessment
    - Step I: Identify Regulatory Needs
    - Step 2: Conduct Hydrologic and Geo
    - Step 3: Protect Key Hydrologic Feat
  - Phase II: Preliminary LID Design
    - Step 4: Use Drainage and Hydrology
    - Step 5: Establish Clearing and Grad
    - Step 6: Reduce/Minimize Total and E
    - Step 7: Determine LID Practices
  - Phase III: Final Design
    - Step 8: Determine Appropriate Size
    - Step 9: Final Site Design

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Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase I: Site Assessment
    - Step I: Identify Regulatory Needs
    - Step 2: Conduct Hydrologic and Geotechnical Survey
    - Step 3: Protect Key Hydrologic Features
  - Phase II: Preliminary LID Design
  - Phase III: Final Design

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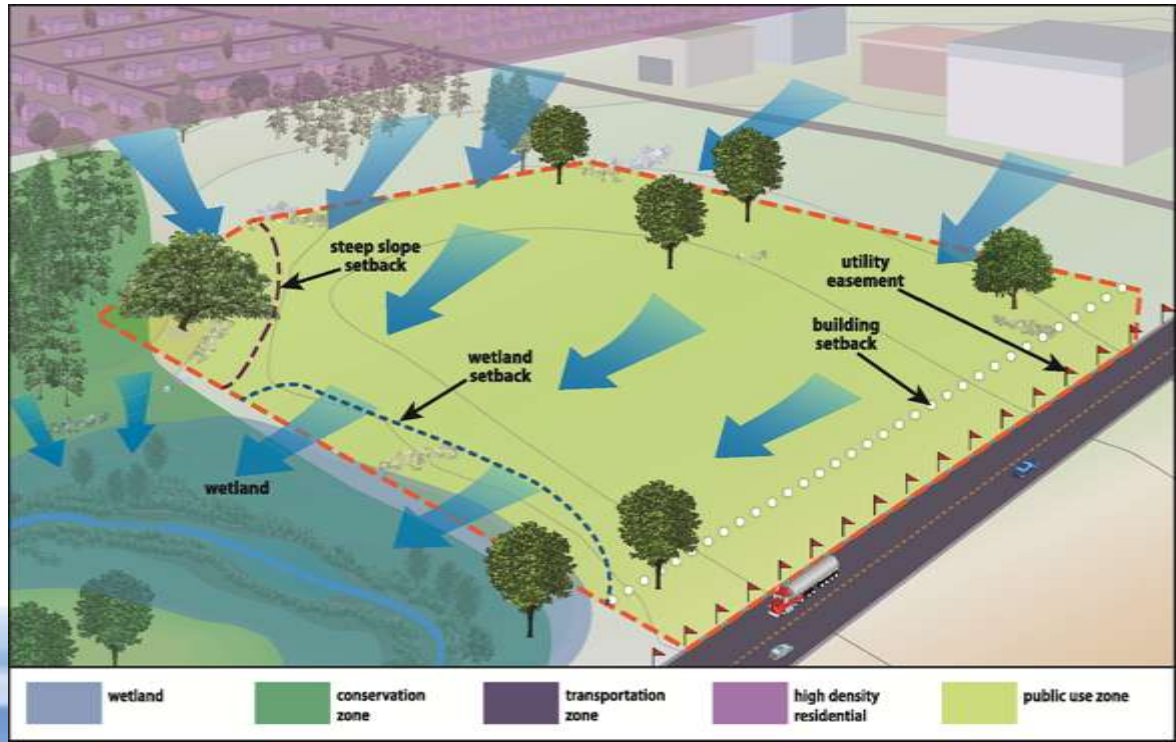
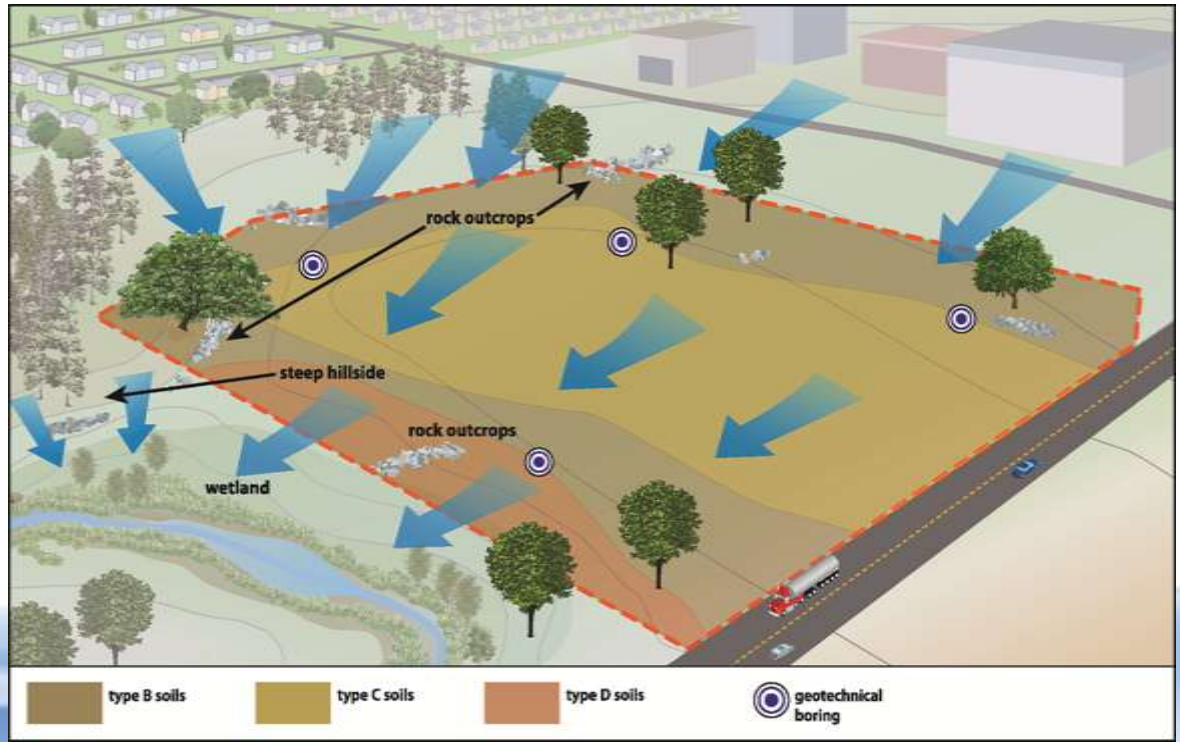
Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase I: Site Assessment
    - Step I: Identify Regulatory Needs
      - Identify applicable zoning, land use, subdivision, and other regulations
      - Identify setbacks, easements, and utilities (Call 811 for utility location)
      - Identify targeted pollutants and pollutants of concern



Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase I: Site Assessment
    - Step 2: Conduct Hydrologic and Geotechnical Survey
      - Identify natural site features to be conserved or restored
      - Conduct a geotechnical survey including drainage characteristics, hydrologic flow paths, and soil infiltration tests



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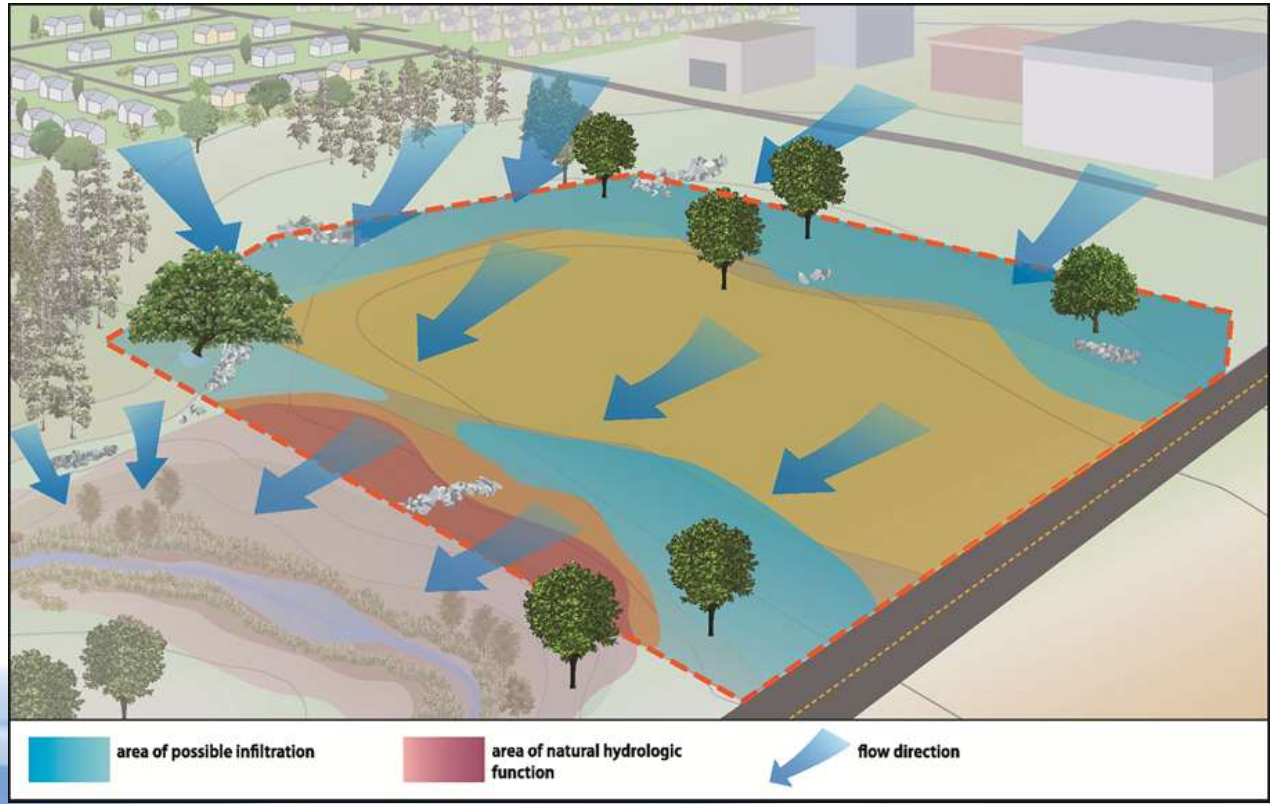
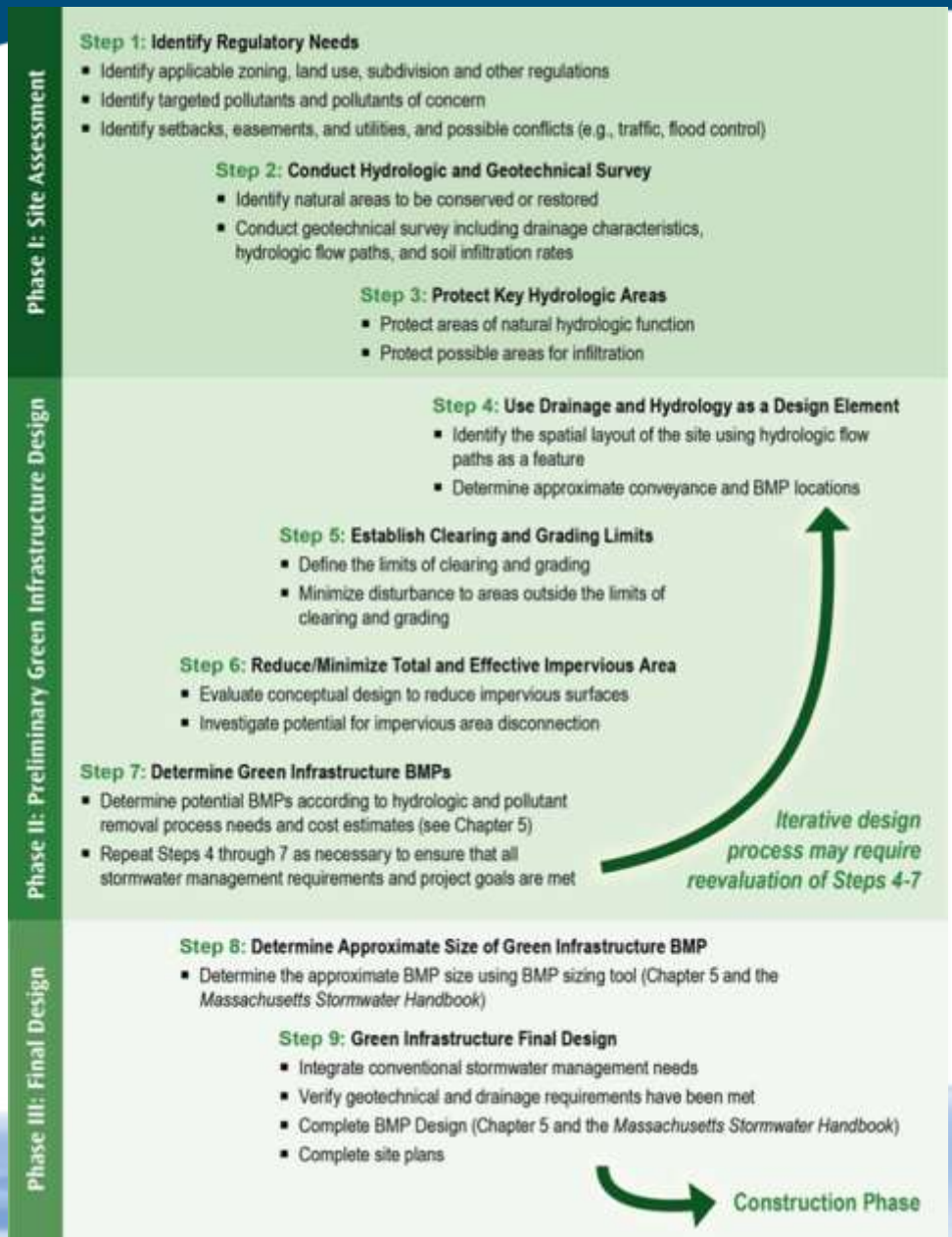
Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase I: Site Assessment
    - Step 3: Protect Key Hydrologic Features
      - Protect areas of natural hydrologic function
      - Protect possible areas for infiltration



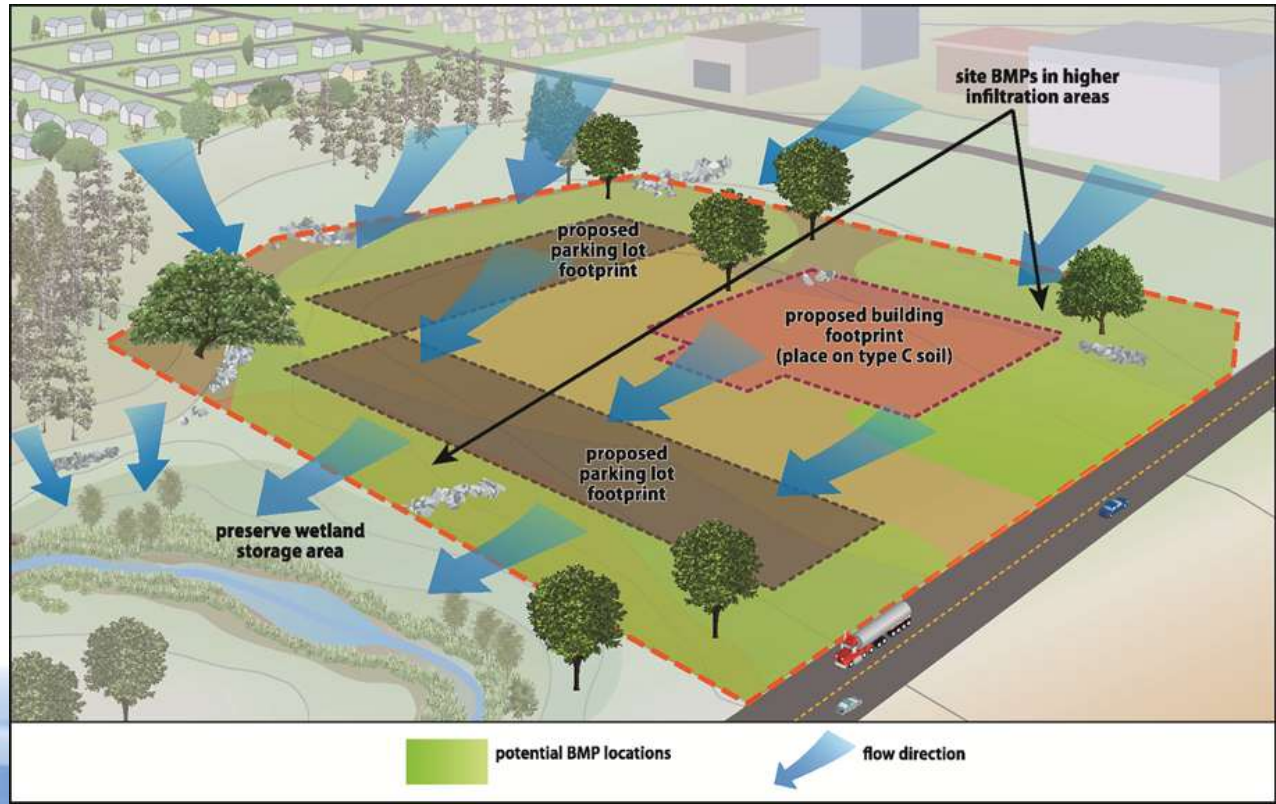
Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase I: Site Assessment
  - Phase II: Preliminary LID Design
    - Step 4: Use Drainage and Hydrology as Design Elements
    - Step 5: Establish Clearing and Grading Limits
    - Step 6: Reduce/Minimize Total and Effective Impervious Area
    - Step 7: Determine LID Practices
  - Phase III: Final Design



Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase II: Preliminary LID Design
    - Step 4: Use Drainage and Hydrology as Design Elements
      - Identify the spatial layout of the site using hydrologic flow paths and natural drainage as a feature
      - Determine approximate locations for infiltration and conveyance BMPs



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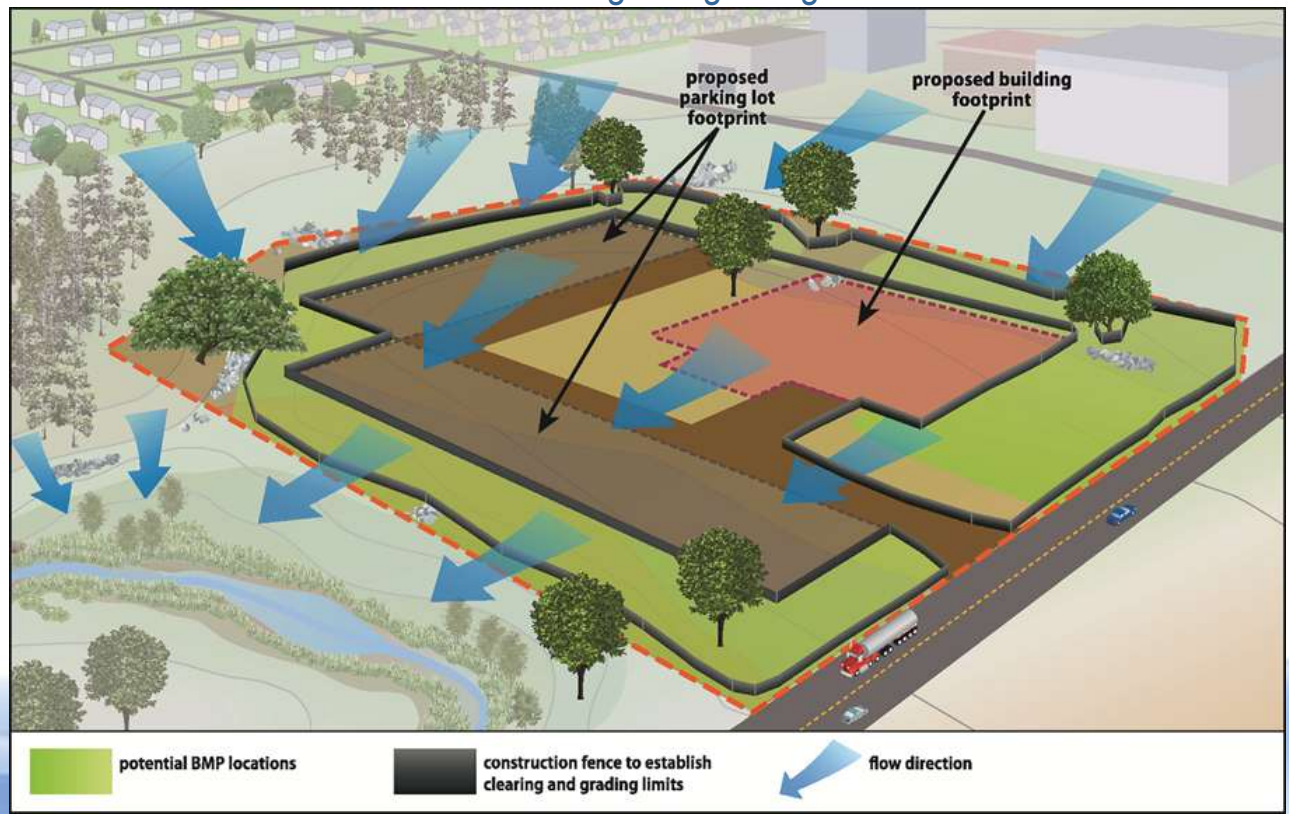
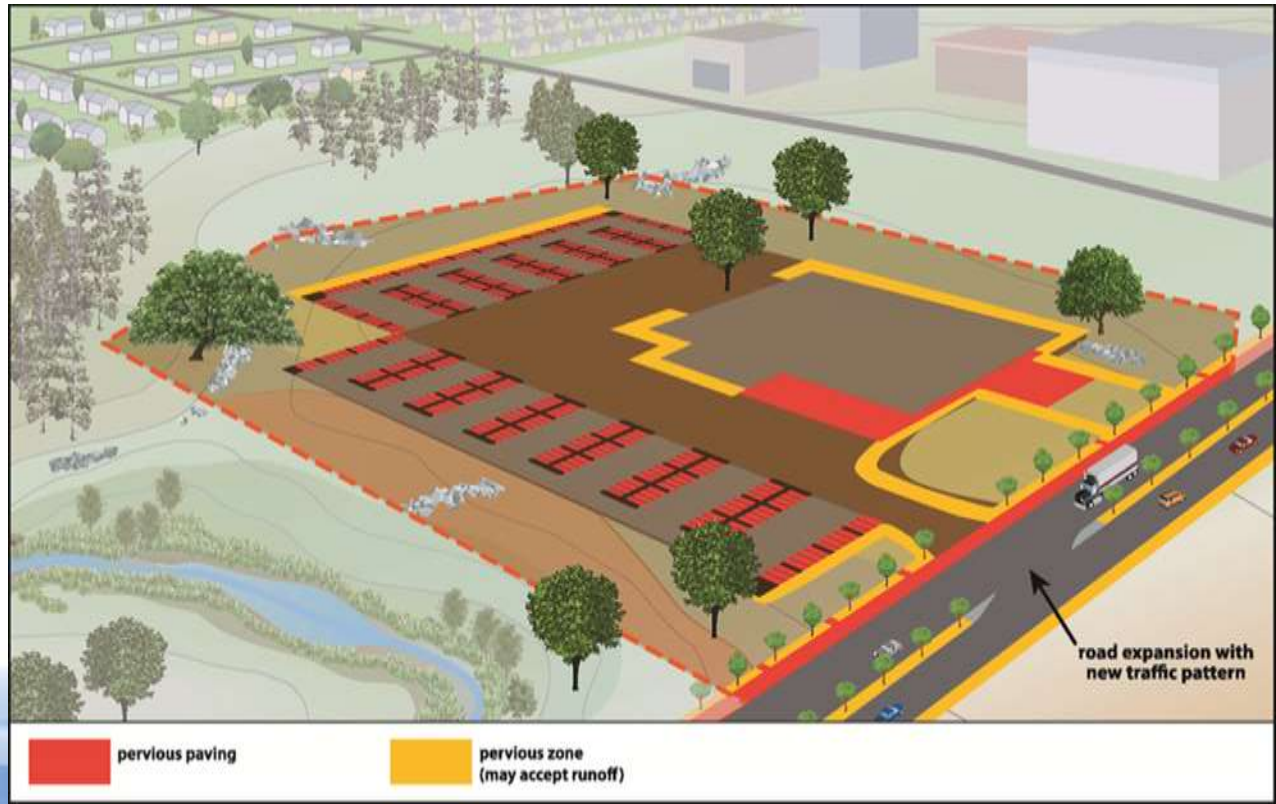
Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase II: Preliminary LID Design
    - Step 5: Establish Clearing and Grading Limits
      - Define the limits of clearing and grading
      - Minimize disturbance to areas outside the limits of clearing and grading



Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase II: Preliminary LID Design
    - Step 6: Reduce/Minimize Total and Effective Impervious Area
      - Investigate the potential for impervious area disconnection
      - Evaluate the conceptual design to reduce impervious surfaces



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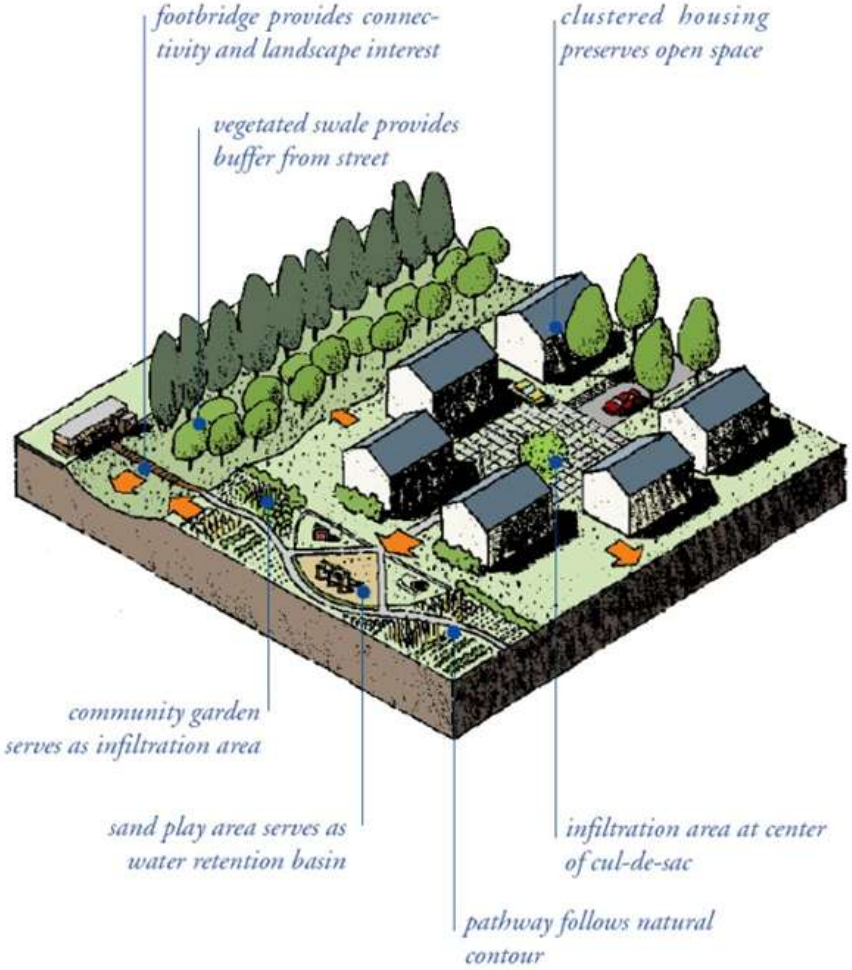
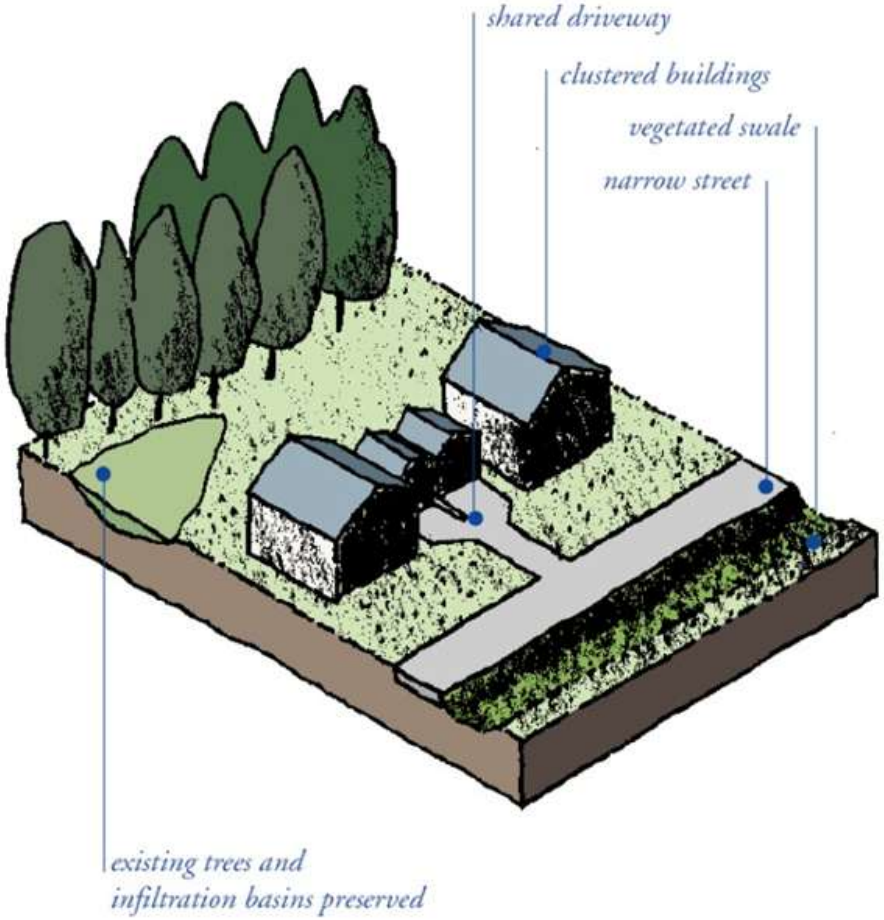
Site Assessment, Planning, and Design (Chapter 4)

Impervious Area Disconnection



Reduce Impervious Surfaces



Source: County of San Diego LID Handbook

Site Assessment, Planning, and Design (Chapter 4)

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Site Assessment, Planning, and Design (Chapter 4)

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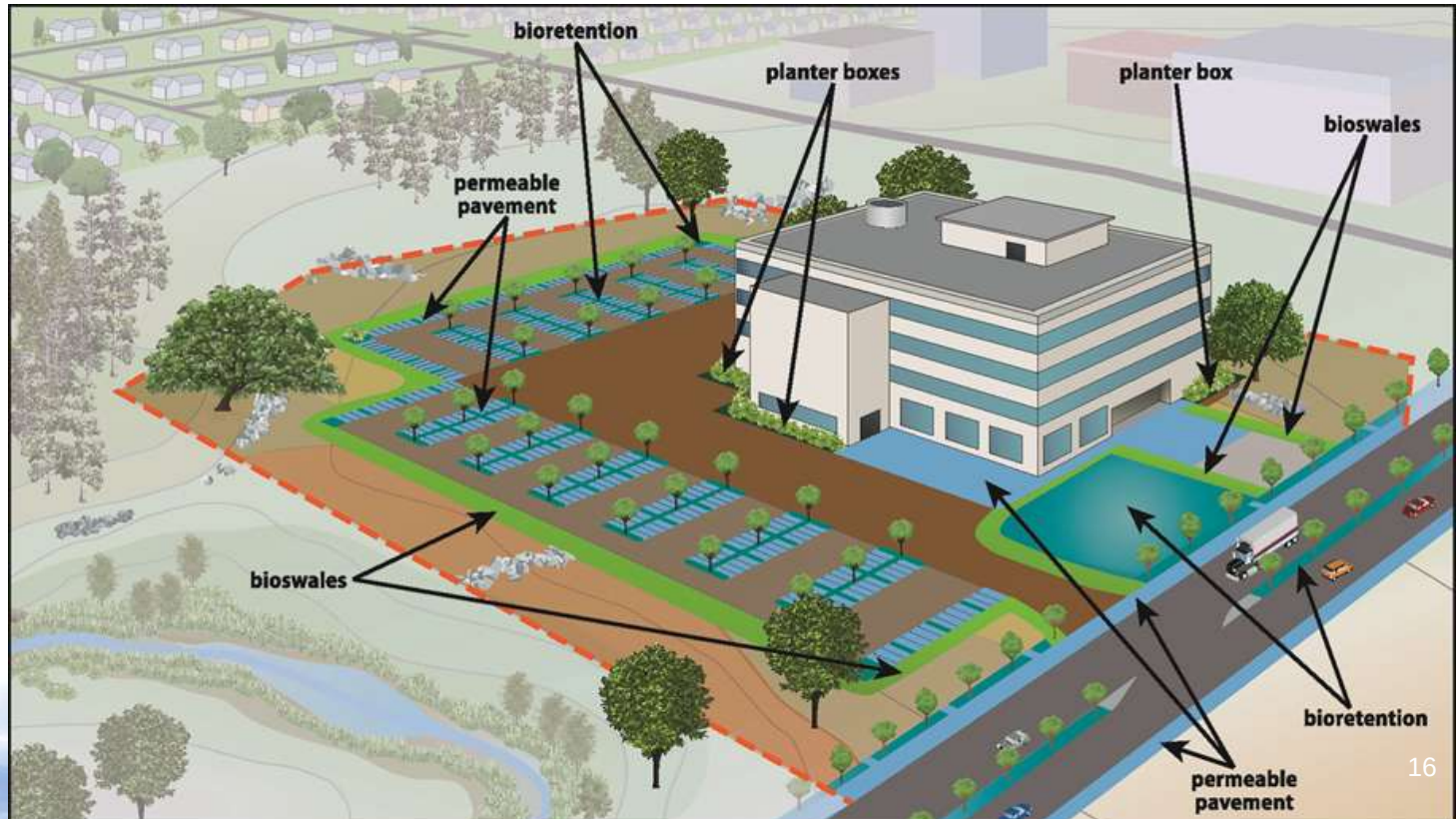
Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase II: Preliminary LID Design
    - Step 7: Determine LID Practices
      - Determine potential BMPs according to hydrologic and pollutant removal process needs and cost estimates



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Site Assessment, Planning, and Design (Chapter 4)

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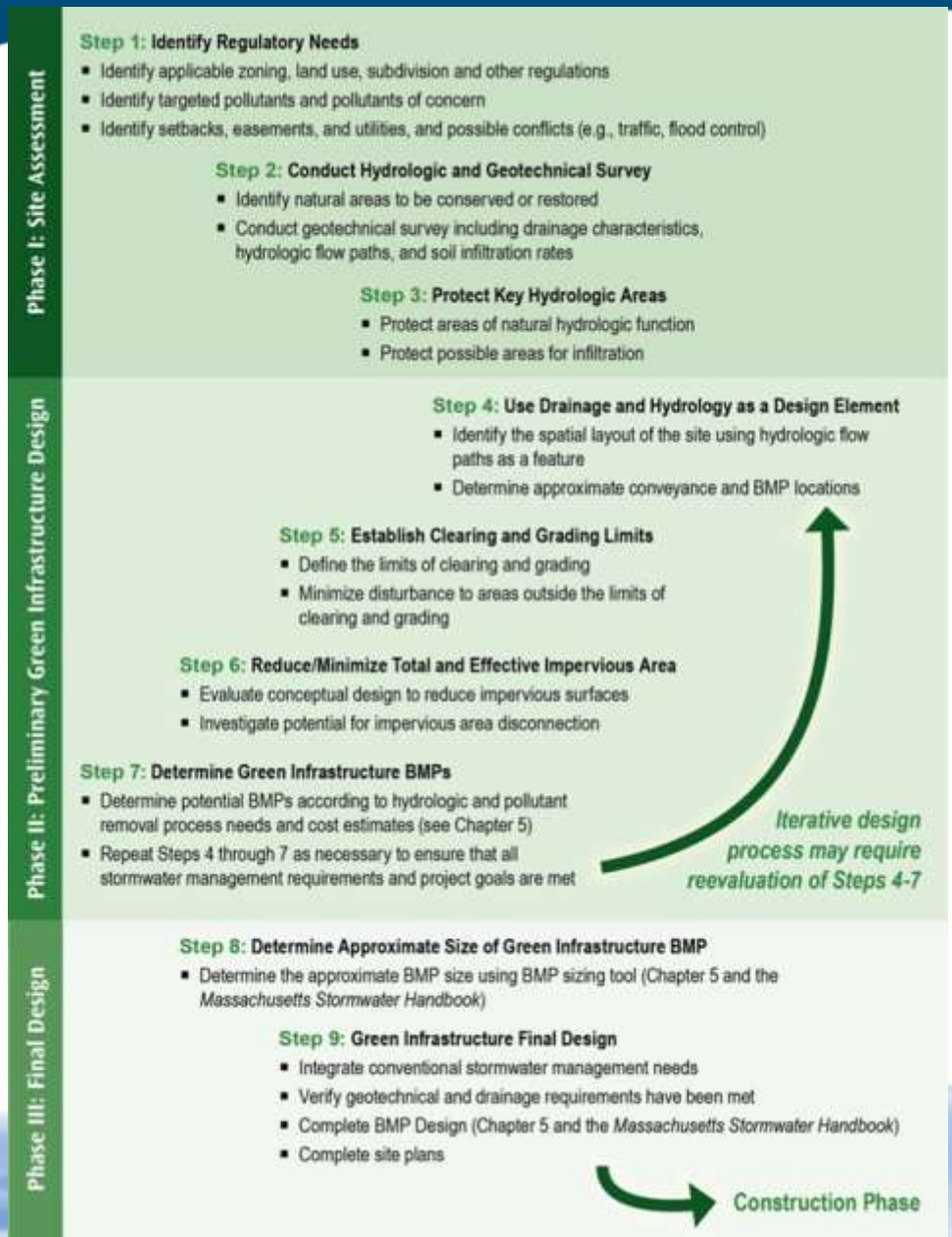
Site Assessment, Planning, and Design (Chapter 4)

Site Assessment, Planning, and Design (Chapter 4)

- Results of Phase II
  - The analyses in Phase II should produce a preliminary site plan that includes:
    - Hydrologic flow paths and natural drainage features (Step 4)
    - Locations where infiltration and conveyance features could be located (Step 4)
    - Limits of clearing and grading (Step 5)
    - Results of an impervious area reduction analysis (e.g., parking area reduction, permeable pavement options) (Step 6)
    - Candidate BMPs and their approximate locations (Step 7)

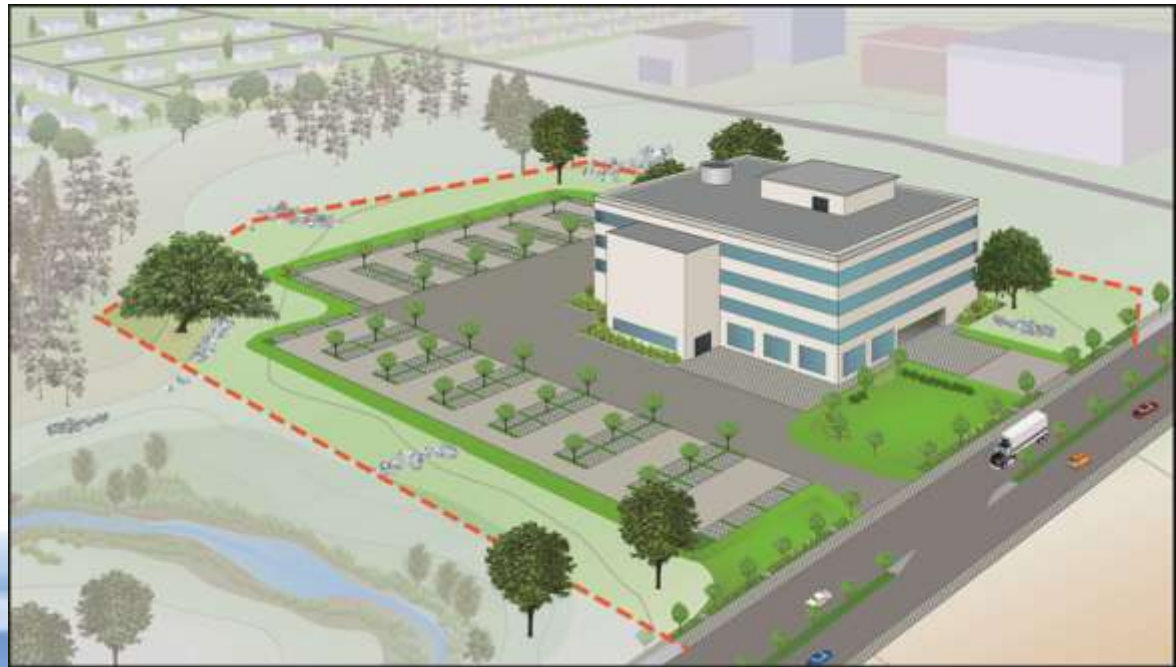
Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase I: Site Assessment
  - Phase II: Preliminary LID Design
  - Phase III: Final Design
    - Step 8: Determine Appropriate Size of LID Practices
    - Step 9: Final Site Design



Site Assessment, Planning, and Design (Chapter 4)

- Site Design Principles of LID
  - Phase III: Final Design
    - Step 8: Determine Appropriate Size of LID Practices
      - Determine the approximate BMP size using the BMP sizing tool
    - Step 9: Final Site Design
      - Verify that geotechnical and drainage requirements have been met
      - Complete BMP designs such as finish details and notes
      - Complete the site plans



Site Assessment, Planning, and Design (Chapter 4)

Photo courtesy Watershed Management Group

Photos courtesy Watershed Management Group

Site Assessment, Planning, and Design (Chapter 4)

Photos courtesy City of Phoenix

Site Assessment, Planning, and Design (Chapter 4)

School micromanaging stormwater.

Park stormwater detention basin also serving as playing field.

Municipal facility onsite capture.

Site Assessment, Planning, and Design (Chapter 4)

Site Assessment, Planning, and Design (Chapter 4)

- Modeling and Optimization of BMP Placement for Green Infrastructure Sites
- Conceptual Design Report
  - Project Description
  - Drainage Area Limits
  - Screening of Soils and Infiltration Rates
  - Performance Specifications
  - Concept Plan/Drawings
  - Architectural Schematic Designs
  - Cost Estimate
  - Operation and Maintenance Requirements
  - Calculations
  - Management Questions
  - Plant Selection

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Questions and Discussion

Green Infrastructure Practices (Chapter 5)

- Practices
  - Vegetated filter strips
  - Bioretention
  - Constructed stormwater wetlands
  - Tree box filters
  - Sand Filters
  - Vegetated Swales
  - Cisterns and rain barrels
  - Vegetated (Green) roofs
  - Permeable pavement

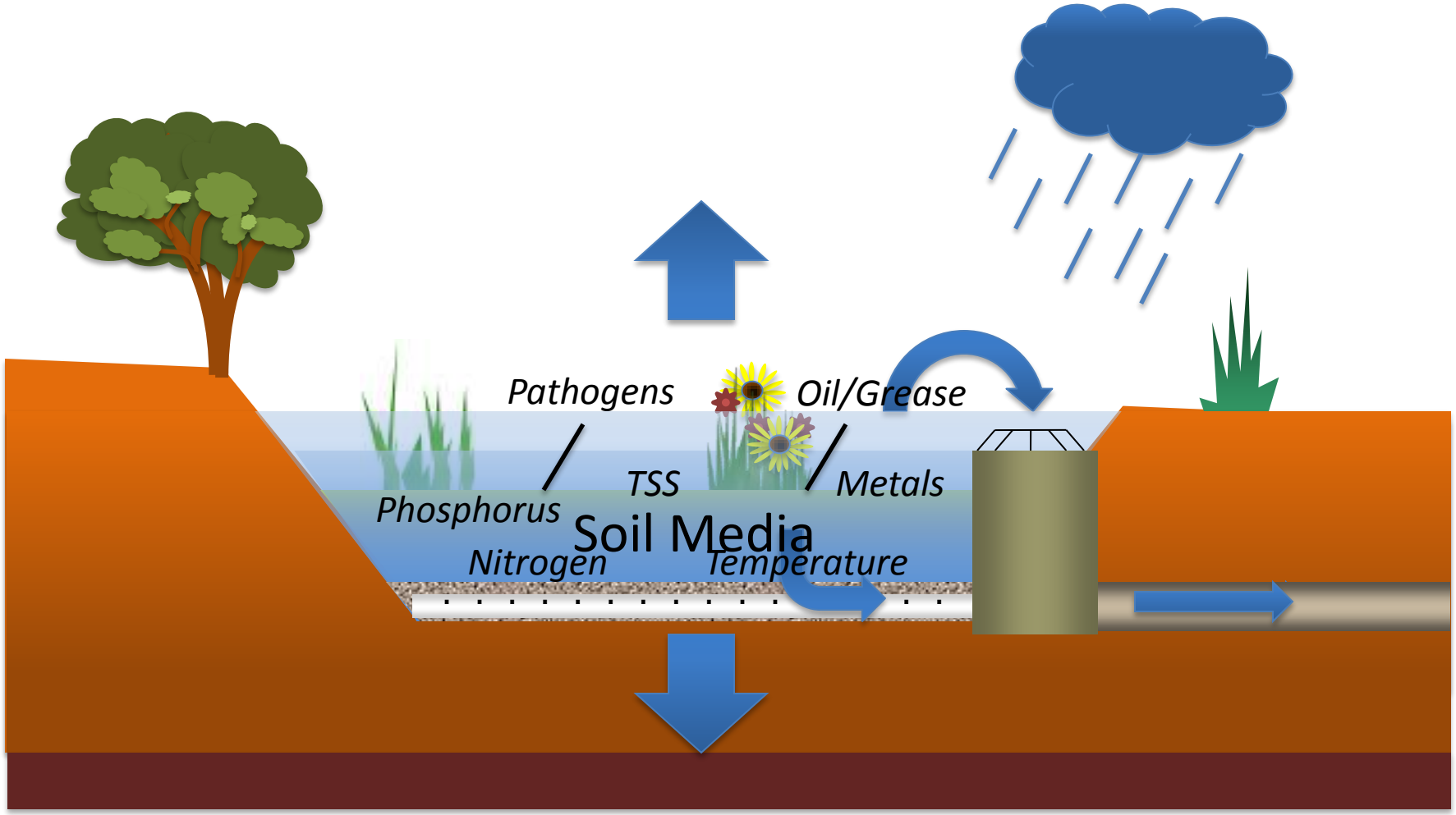
Green Infrastructure Practices (Chapter 5)
Vegetated Filter Strips

Green Infrastructure Practices (Chapter 5)
Vegetated Filter Strips

Pollutant	Typical literature removal efficiency	Median effluent concentration (mg/L unless otherwise noted)[1]
Sediment	High (-195% to 91%)	19.1
Metals	Medium	TAs: 0.94 µg/L, TCd: 0.18 µg/L, TCr: 2.73 µg/L, TCu: 7.30 µg/L, TPb: 1.96 µg/L, TNi: 2.92 µg/L, TZi: 24.3 µg/L
Total phosphorus	Low (-126% to 40%)	*0.18*
Total nitrogen	Low (TN: -17% to 40%, TKN: -18% to 39%, $NO_{2,3}$-N:-18% to 43%)	TN: 1.13, TKN: 1.09, $NO_{2,3}$-N: 0.27
Bacteria	Low (likely exports pathogens)	N/A

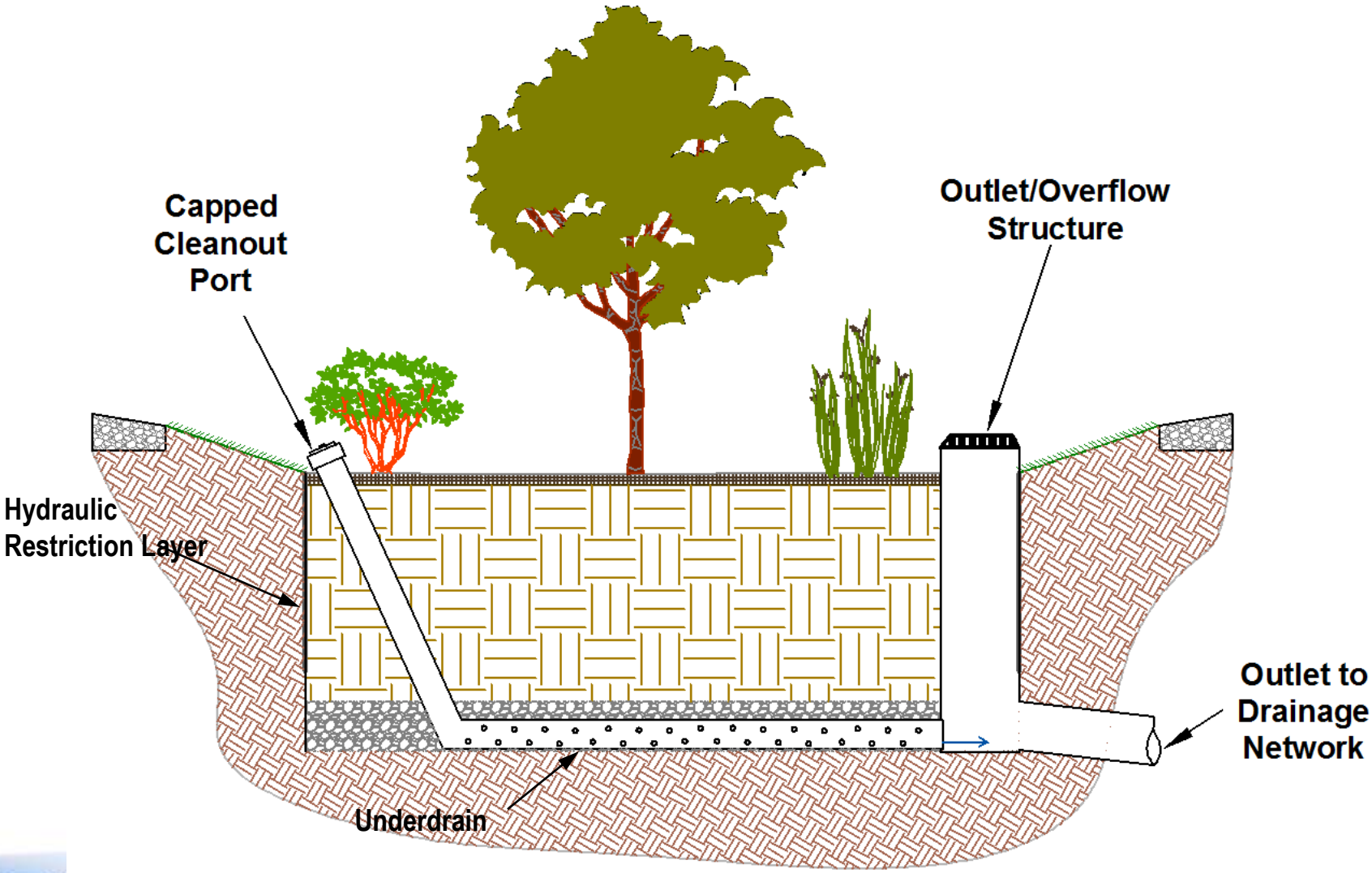
Green Infrastructure Practices (Chapter 5)
Bioretention

Green Infrastructure Practices (Chapter 5)
Bioretention

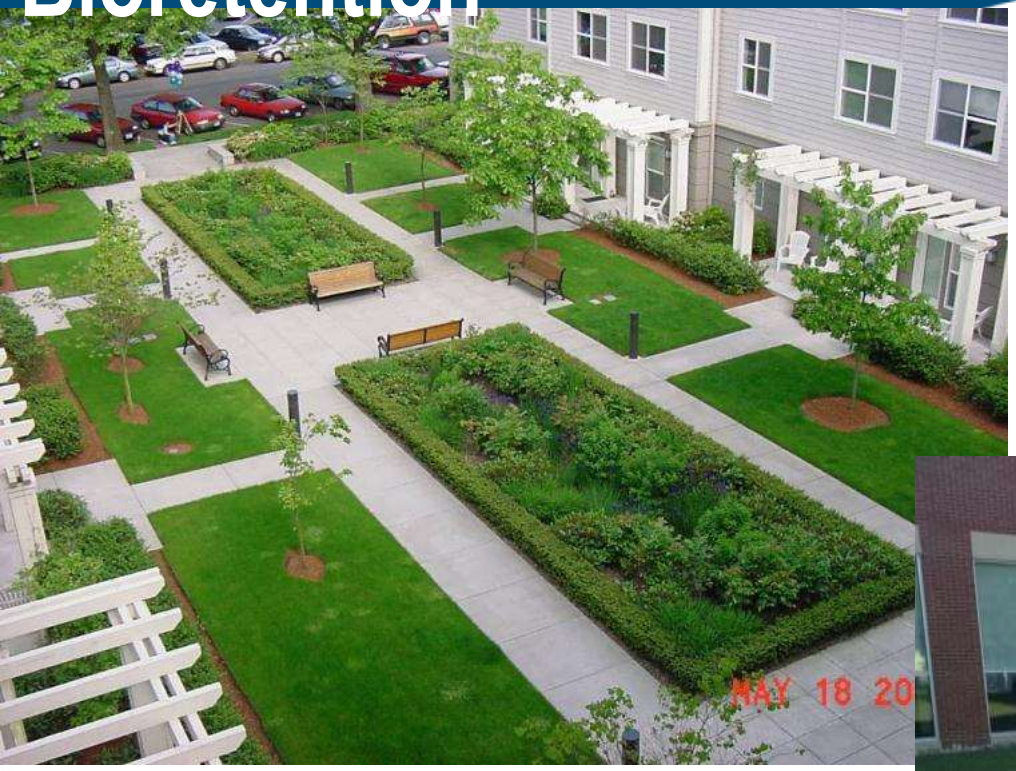


Source: NCSU BAE

Green Infrastructure Practices (Chapter 5)
Bioretention



Green Infrastructure Practices (Chapter 5)
Bioretention



Buckman Heights Apartments, Portland, Oregon Source: NCSU E

Landscaped Areas

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Green Infrastructure Practices (Chapter 5)
Bioretention

Parking Lots

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Green Infrastructure Practices (Chapter 5)
Bioretention

Rights-of-Way

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Green Infrastructure Practices (Chapter 5) Bioretention

- Bioswales / Bioretention Swales

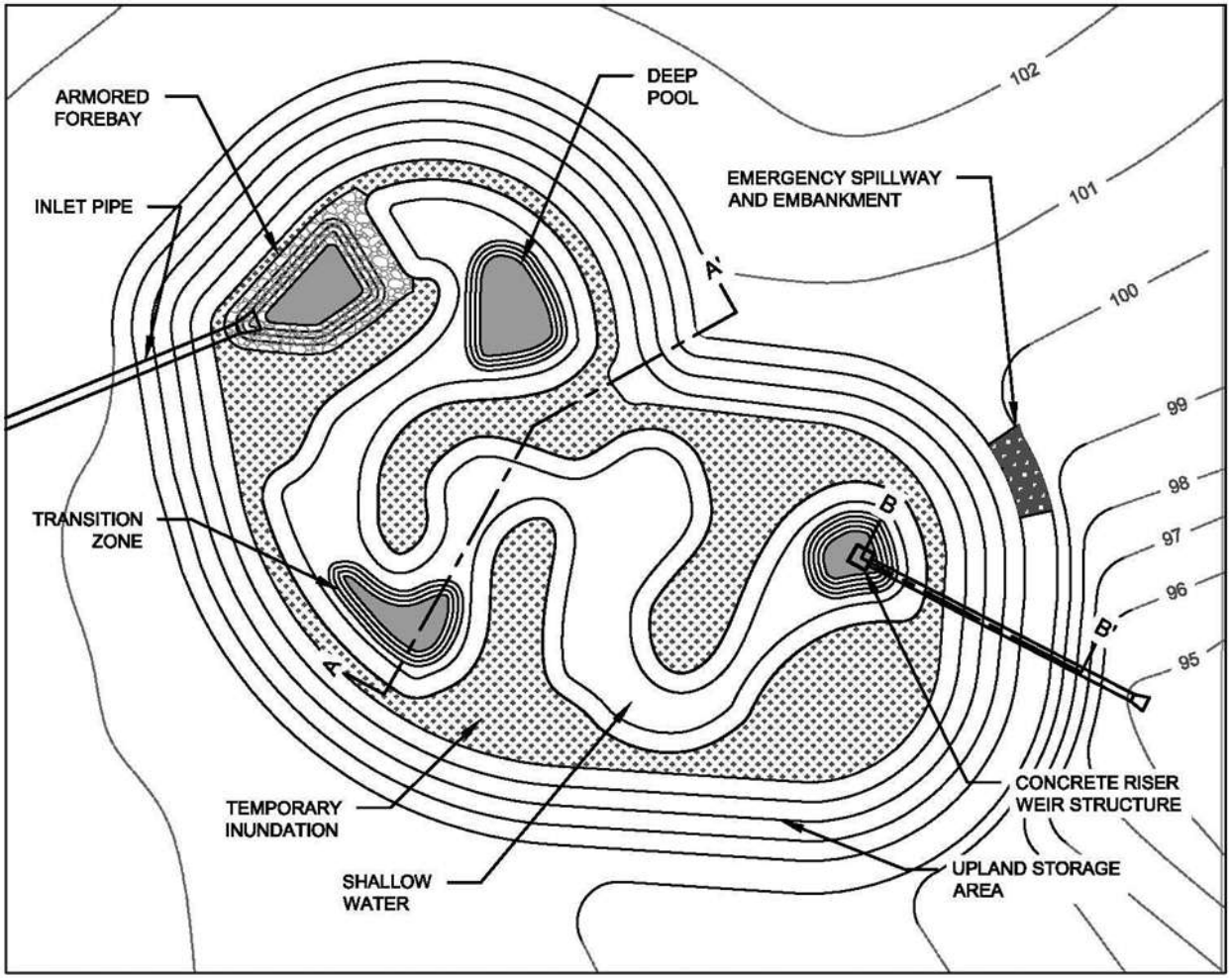
Section 2.1

Green Infrastructure Practices (Chapter 5) Bioretention

Pollutant	Typical literature removal efficiency	Median effluent concentration (mg/L unless otherwise noted)1	Minimum recommended media depth for treatment
Sediment	High	8.3	1.5 feet
Metals	High	TCd: 0.94 µg/L, TCu: 7.67 µg/L, TPb: 2.53 µg/L, TZn: 18.3 µg/L	2 feet
Hydro-carbons	High	N/A	N/A
Total phosphorus	Medium (-240% to 99%)	0.09	2 feet
Total nitrogen	Medium (TKN: -5% to 64%, Nitrate: 1% to 80%)	TN: 0.90, TKN: 0.60, NO2,3-N: 0.22	3 feet
Bacteria	High	Enterococcus: 234 MPN/ 100 mL, *E.coli*: 44 MPN/100 mL	2 feet
Thermal load	High	68–75 °F	4 feet

Green Infrastructure Practices (Chapter 5)
Constructed Wetlands

Green Infrastructure Practices (Chapter 5)
Constructed Wetlands



Green Infrastructure Practices (Chapter 5) Constructed Wetlands

- Should have enough water supplied from groundwater, runoff, or basefllow permanent pools will not draw down by more than 2 feet after a 30-day drought
- Seasonally low groundwater elevations may be sufficient to supply enough water to ensure plant survival

Green Infrastructure Practices (Chapter 5)
Constructed Wetlands

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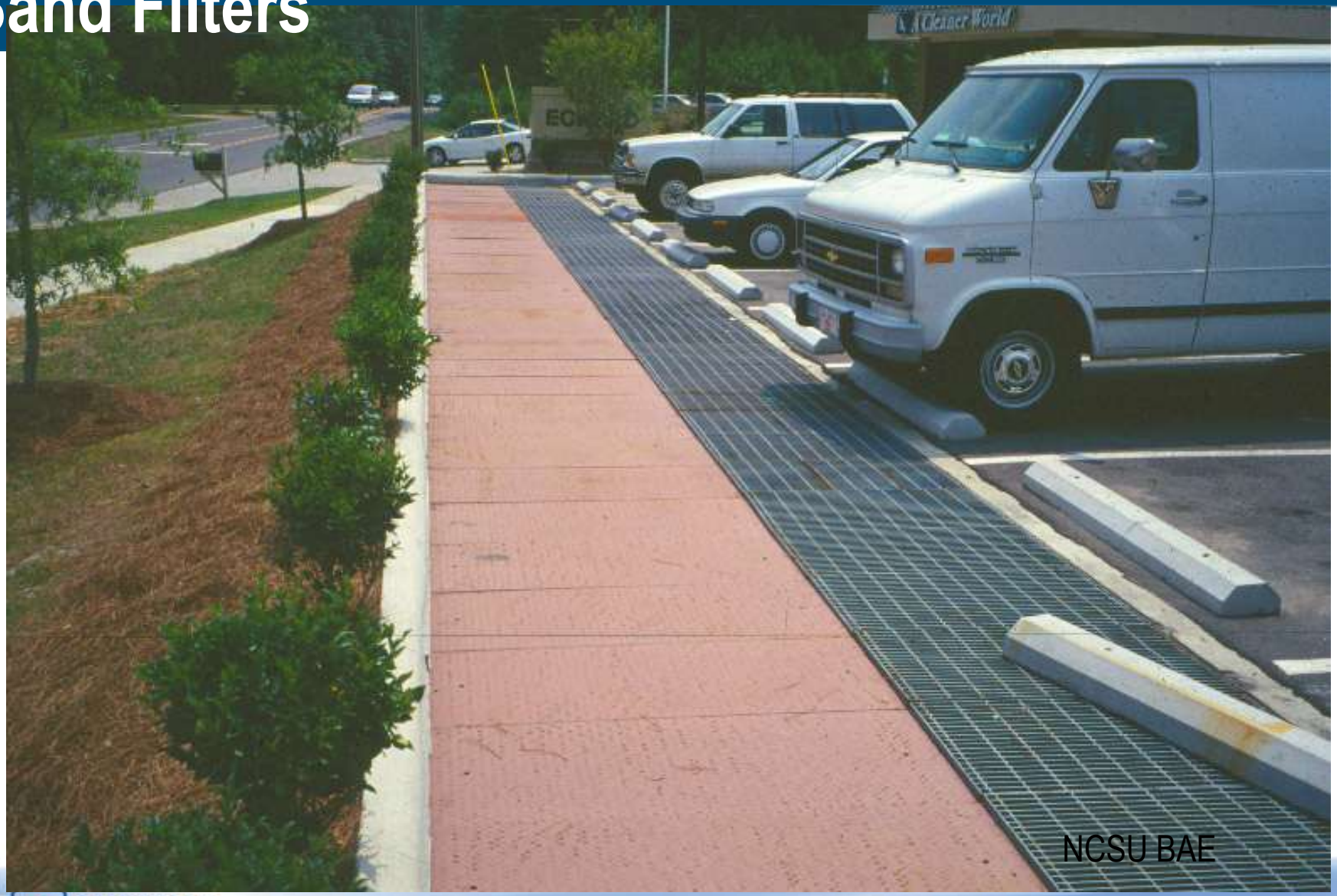
Green Infrastructure Practices (Chapter 5)
Constructed Wetlands

Green Infrastructure Practices (Chapter 5) Constructed Wetlands

Pollutant	Typical literature removal efficiency	Median effluent concentration (mg/L unless otherwise noted)[1]
Sediment	High (50% to 80%)	9
Metals	High	
Total phosphorus	High	
Total nitrogen	High	
Bacteria	High	

Green Infrastructure Practices (Chapter 5)
Sand Filters



NCSU BAE

Green Infrastructure Practices (Chapter 5)
Sand Filters

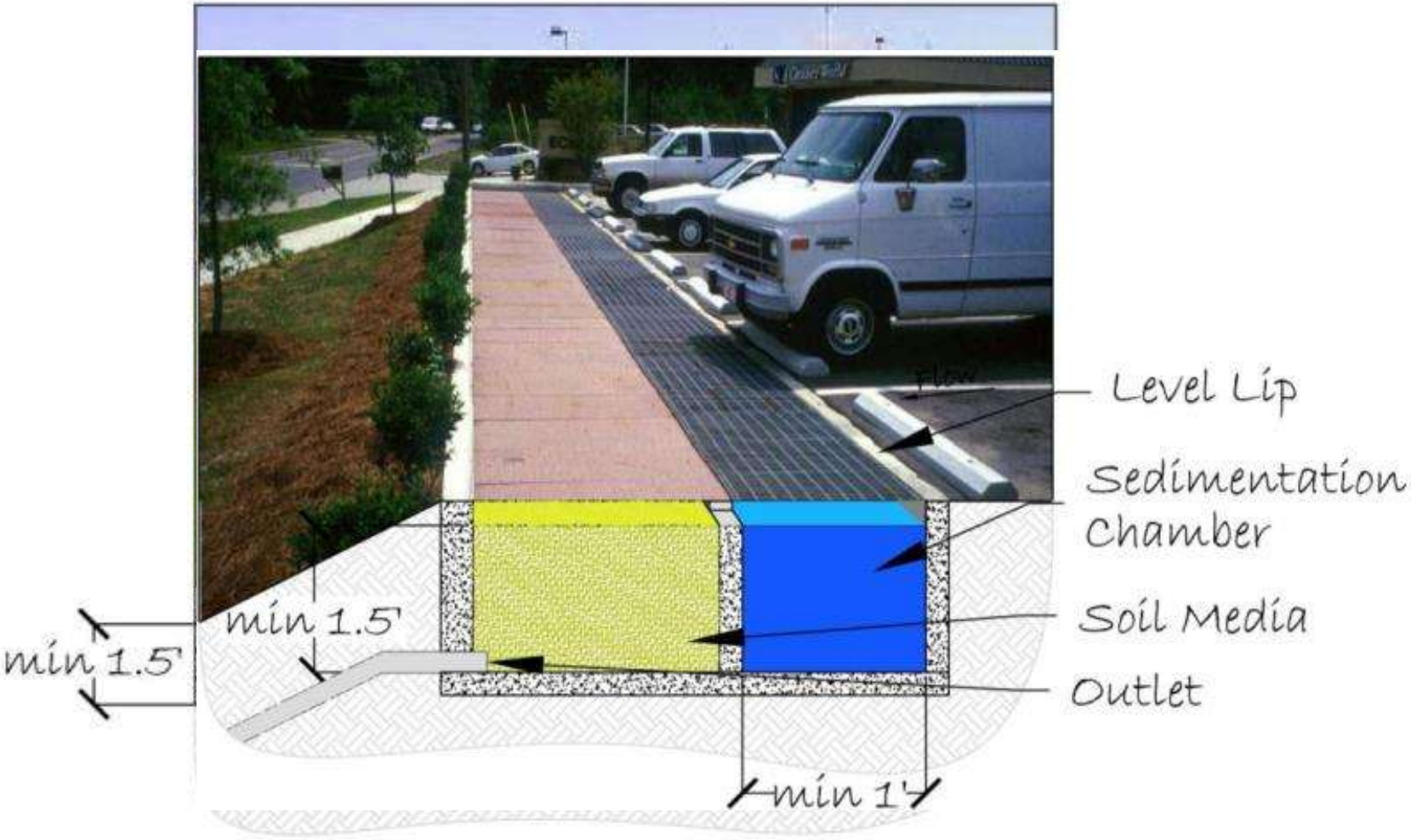
- Two types of sand filters
  - Above Ground
    - Portland Style

Portland BES

  - Below ground
    - Delaware Style

NCSU BAE

Green Infrastructure Practices (Chapter 5)
Sand Filters



Green Infrastructure Practices (Chapter 5)
Sand Filters

- Higher Infiltration Rates
  - 5 in/hr
- Highly permeable; free of fines, stones, and other debris
  - Clean washed concrete or masonry sand
  - Media should be analyzed for background levels of nutrients
    - Total phosphorus should not exceed 15 ppm

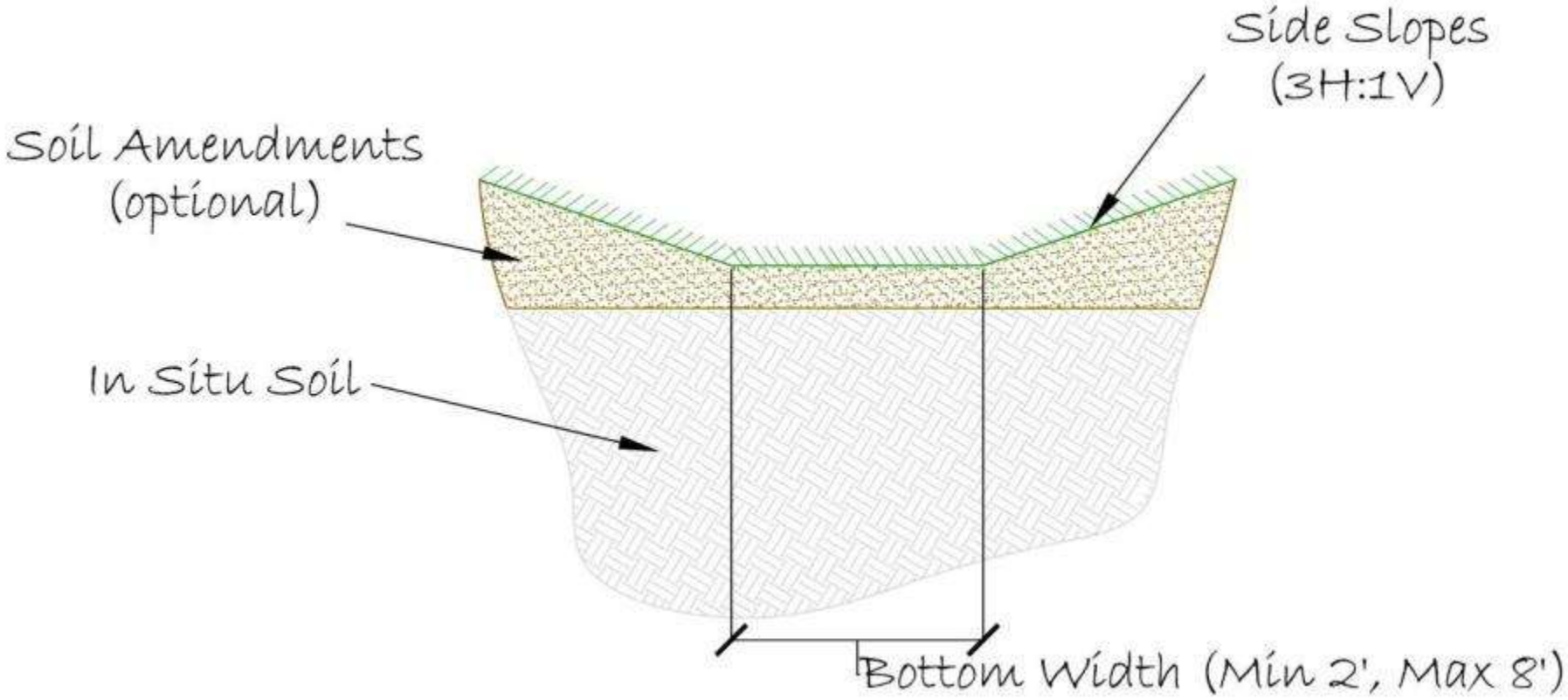
Green Infrastructure Practices (Chapter 5)
Sand Filters

Pollutant	Typical literature removal efficiency	Median effluent concentration (mg/L unless otherwise noted)[1]
Sediment	High (74% to 95%)	8.7
Metals	High (14% to 87%	TAs: 0.87µg/L, TCd: 0.16µg/L, TCr: 1.02µg/L, TCu: 6.01µg/L, TPb: 1.69µg/L, TNi: 2.20µg/L, TZi: 19.9µg/L
Total phosphorus	Low (-14% to 69%)	0.09
Total nitrogen	Low (20%)	TN: 0.82, TKN: 0.57, *$NO_{2,3}$-N: 0.51*
BOD	High (-27% to 55%)	N/A
Bacteria	High (fecal coliform: -70% to 54%, fecal streptococcus: 11% to 68%)	Fecal coliform: 542 MPN/100mL

Green Infrastructure Practices (Chapter 5) Vegetated Swales

- More soil/water contact compared to pipes, more opportunity for infiltration
- Filtration of sediment and debris by the grass, especially when kept long
- Larger bottom widths result in lower velocities, shallower flow depths, more infiltration and filtration

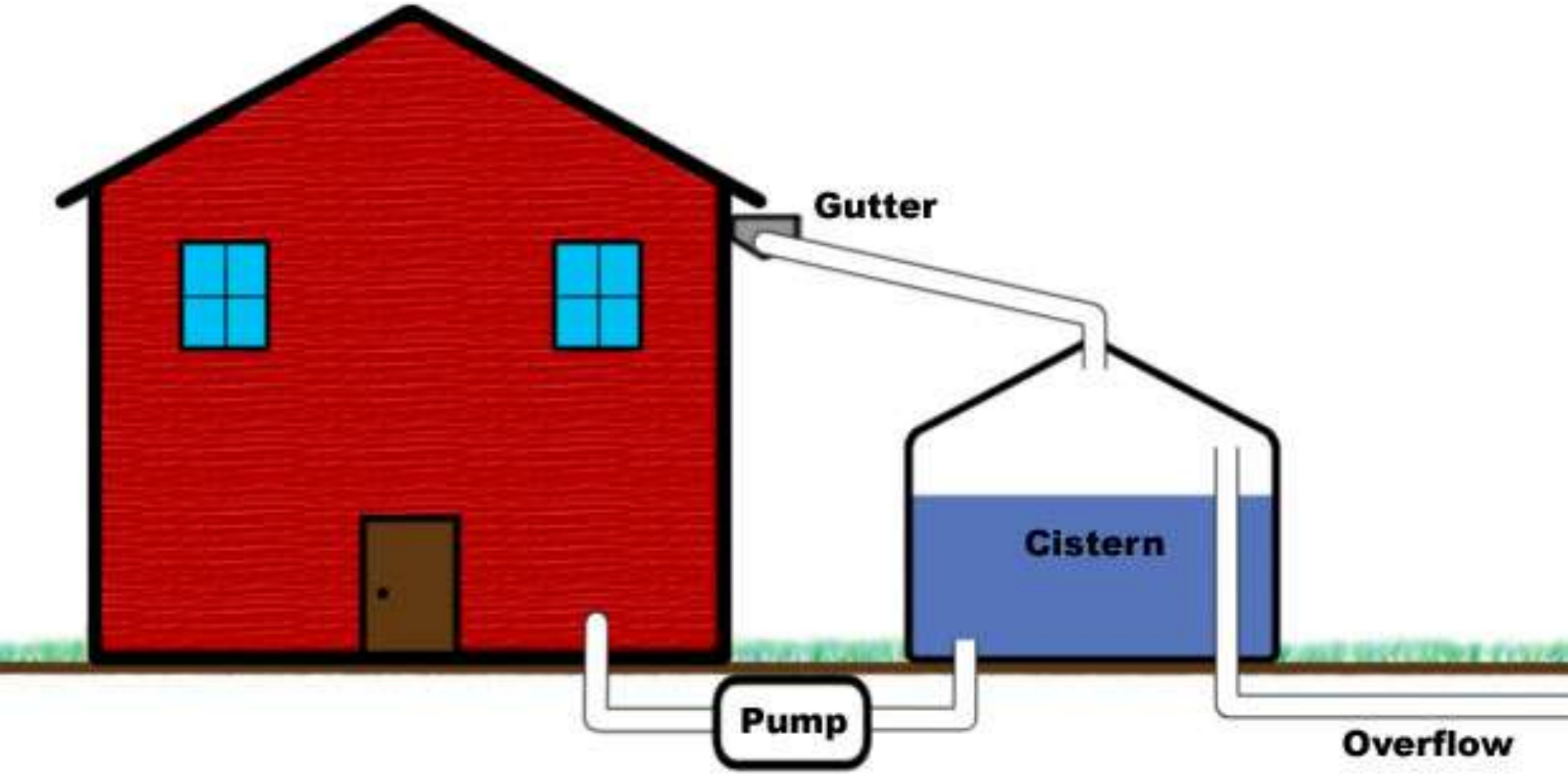
Green Infrastructure Practices (Chapter 5)
Vegetated Swales



Green Infrastructure Practices (Chapter 5)
Vegetated Swales

Pollutant	Typical literature removal efficiency	Median effluent concentration (mg/L unless otherwise noted)[1]
Sediment	High (20% to 98%)	13.6
Metals	Medium	TAs: 1.17µg/L, TCd: 0.31µg/L, TCr: 2.32µg/L, TCu: 6.54µg/L, Pb: 2.02µg/L, TNi: 3.16µg/L, TZi: 22.9µg/L
Total phosphorus	Low	*0.19*
Total nitrogen	Low	TN: 0.71, TKN: 0.62, $NO_{2,3}$-N: 0.25
Bacteria	Low (typically exports pathogens)	E. coli: 4190 MPN/100 mL, Fecal coliform: 5000 MPN/100 mL

Green Infrastructure Practices (Chapter 5)
Cisterns/Rain Barrels



Green Infrastructure Practices (Chapter 5)
Cisterns/Rain Barrels

Green Infrastructure Practices (Chapter 5)
Cisterns/Rain Barrels

Source: Kathy DeBusk

Green Infrastructure Practices (Chapter 5)
Cisterns/Rain Barrels

Green Infrastructure Practices (Chapter 5)
Vegetated (Green) Roof

Intensive green roof

Extensive green roof

Green Infrastructure Practices (Chapter 5)

Vegetated (Green) Roof

Green Infrastructure Practices (Chapter 5)
Vegetated (Green) Roof

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Green Infrastructure Practices (Chapter 5)
Vegetated (Green) Roof

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Green Infrastructure Practices (Chapter 5)
Vegetated (Green) Roof

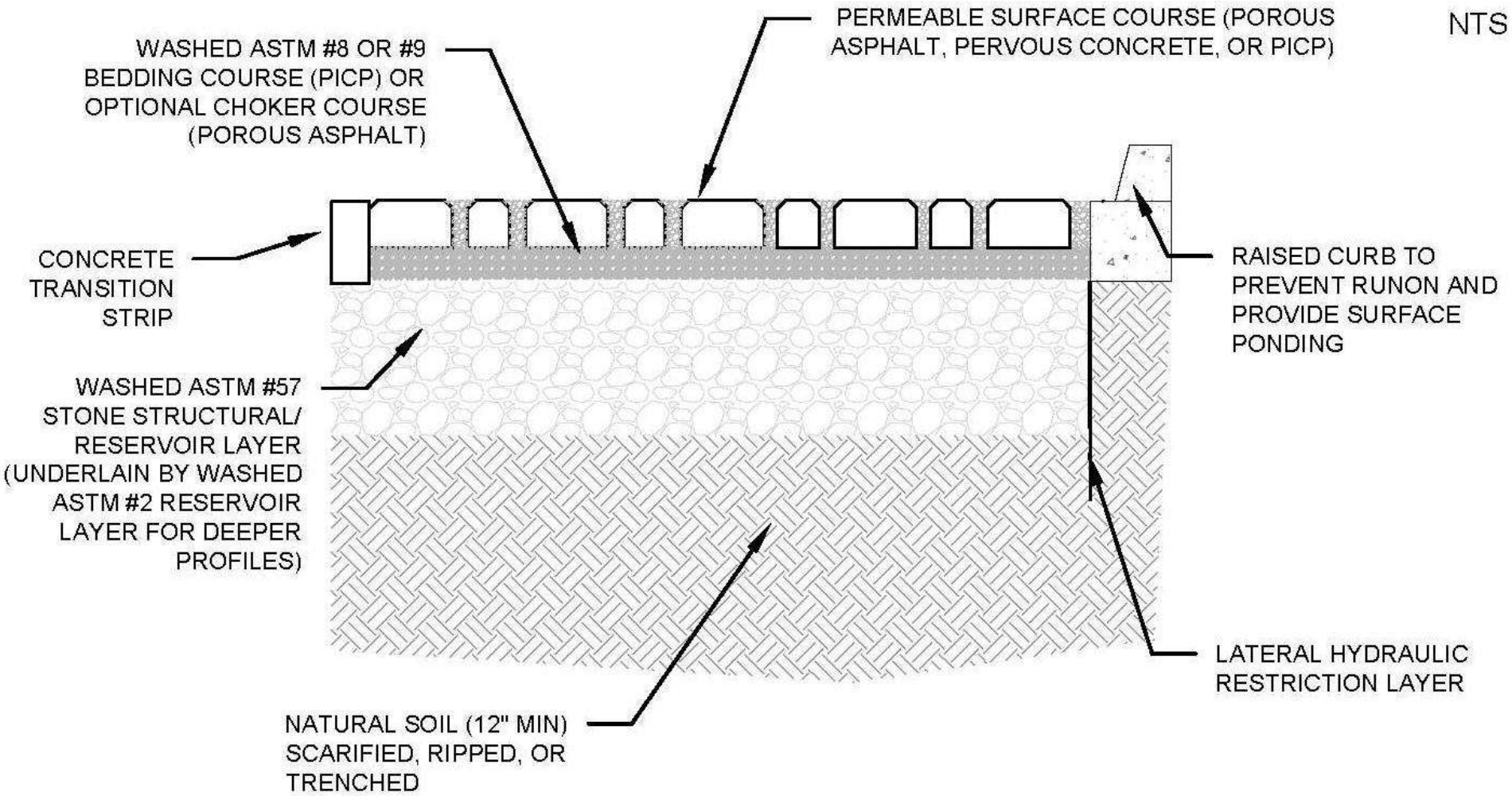
- Volume reduction
- Extended roof life span (due to additional sealing, liners, and insulation)
- Improved building insulation and energy use
- Reduction of urban heat island effects
- Opportunities for recreation and rooftop gardening
- Noise attenuation
- Air quality improvement
- Bird and insect habitat
- Aesthetics

Tolderlund 2010; Berndtsson 2010; Getter and Rowe 2006)

Green Infrastructure Practices (Chapter 5)
Permeable Pavement

- Allows for rainfall infiltration
- Ideal for low traffic surfaces (driveways, parking lots, walk ways)
- Provides peak flow mitigation, volume storage, and some water quality improvement

Green Infrastructure Practices (Chapter 5)
Permeable Pavement



Green Infrastructure Practices (Chapter 5)
Permeable Pavement

Parking Lots

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Green Infrastructure Practices (Chapter 5)
Permeable Pavement

Rights-of-Way

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Green Infrastructure Practices (Chapter 5)
Permeable Pavement

Artistic Uses

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Green Infrastructure Practices (Chapter 5)
Permeable Pavement

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Green Infrastructure Practices (Chapter 5)
Permeable Pavement

Driveways and Alleys

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Green Infrastructure Practices (Chapter 5)
Permeable Pavement

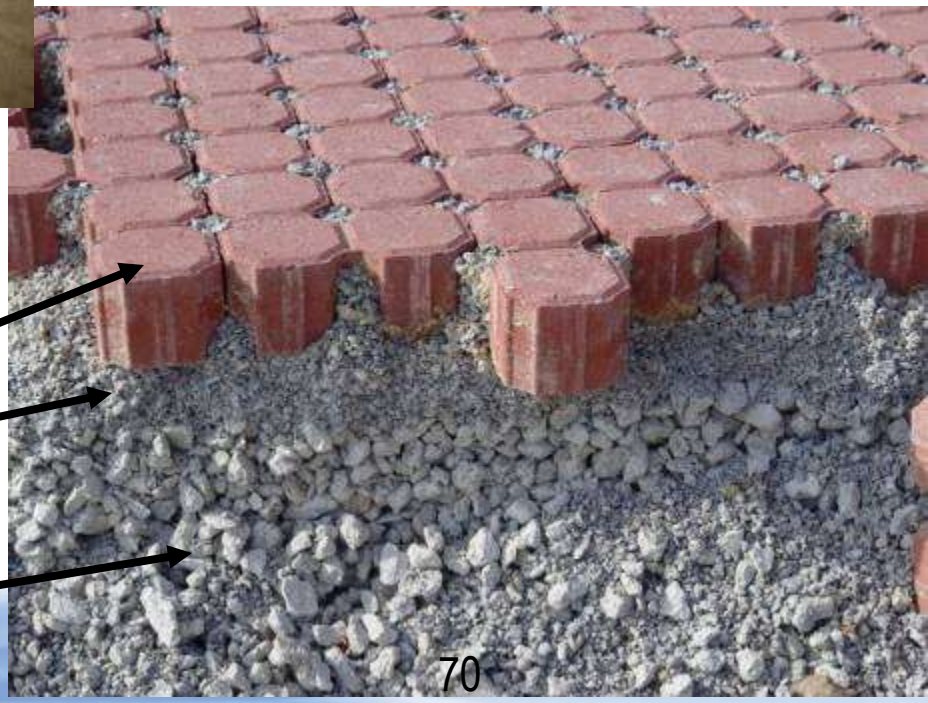
- Permeable Interlocking Concrete Pavers (PICP)
- Concrete Grid Pavers (CGP)
- Pervious Concrete
- Porous Asphalt
- Plastic Reinforcing Grids (PG)

Green Infrastructure Practices (Chapter 5)

Permeable Pavement

PICP with sand fill

PICP with gravel fill



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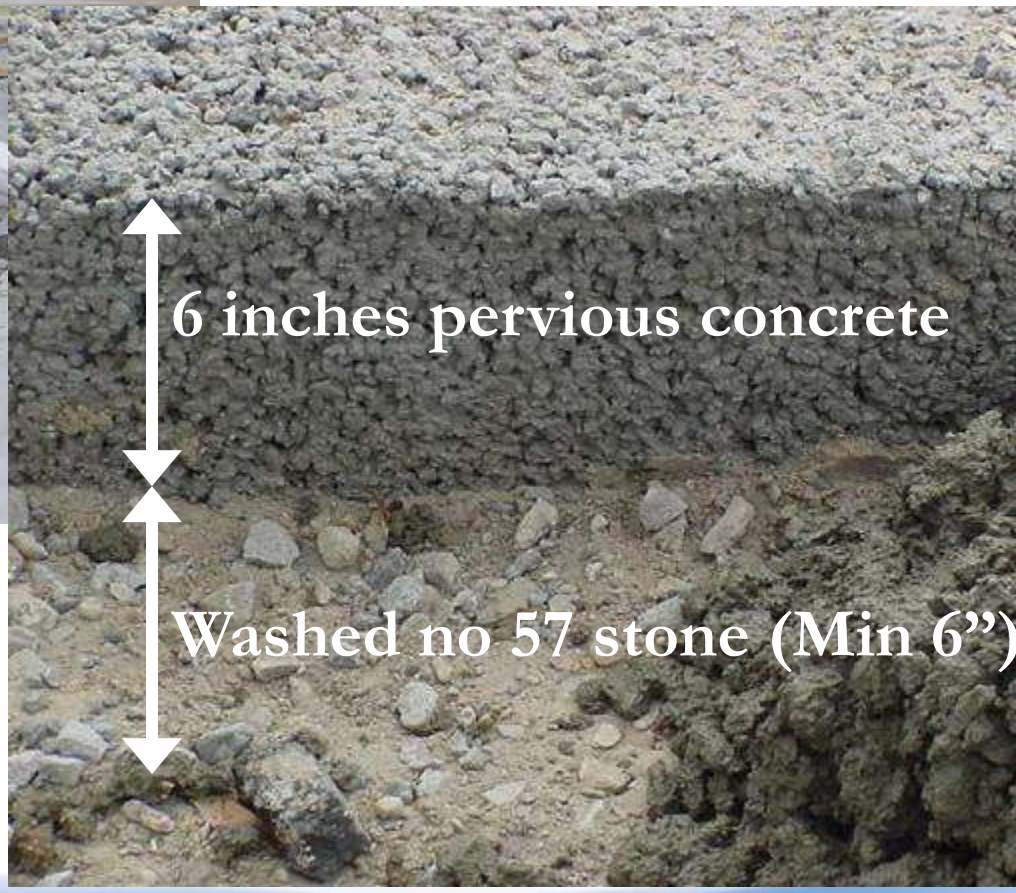
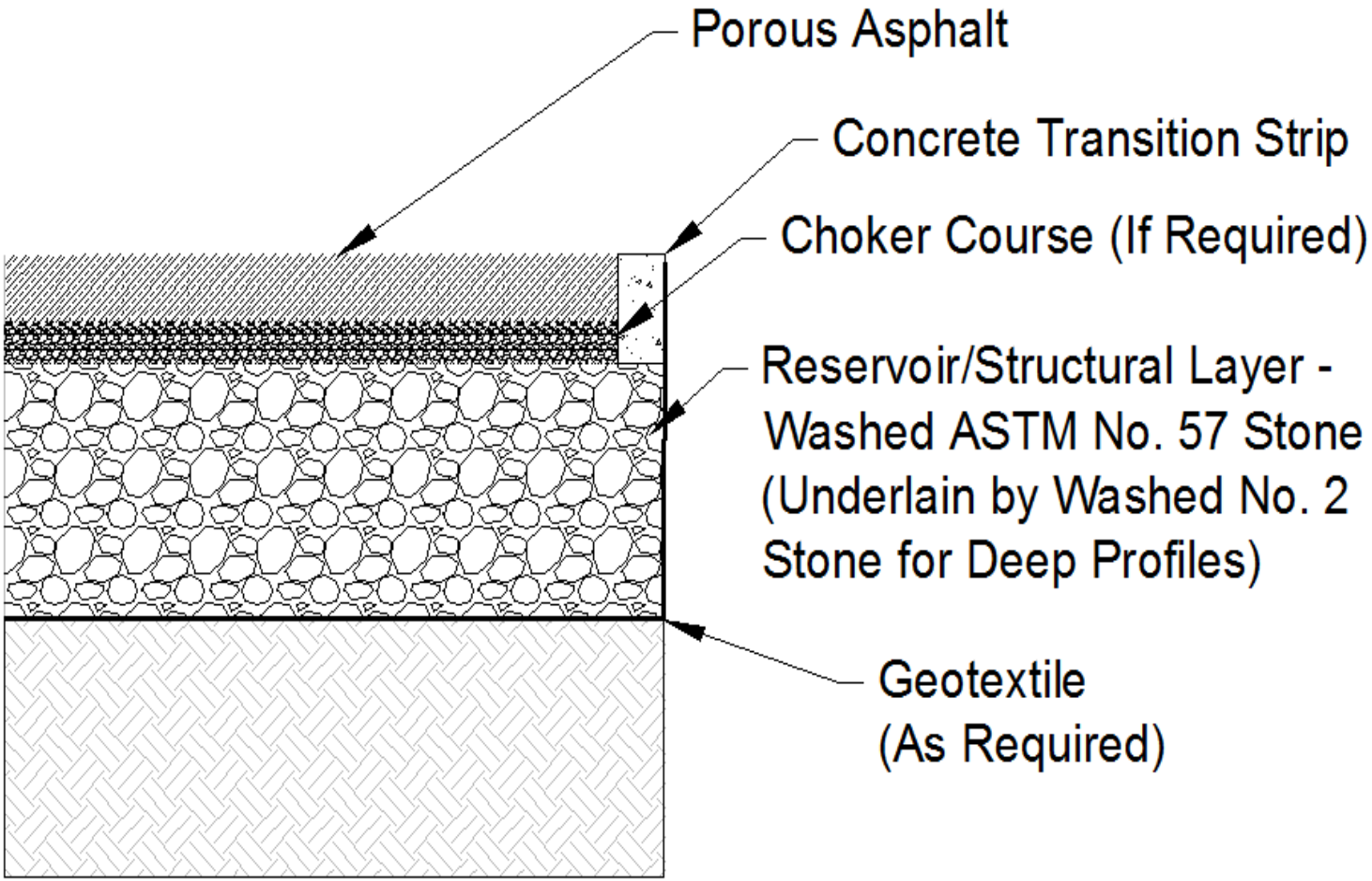
Green Infrastructure Practices (Chapter 5)

Permeable Pavement



Green Infrastructure Practices (Chapter 5)
Permeable Pavement



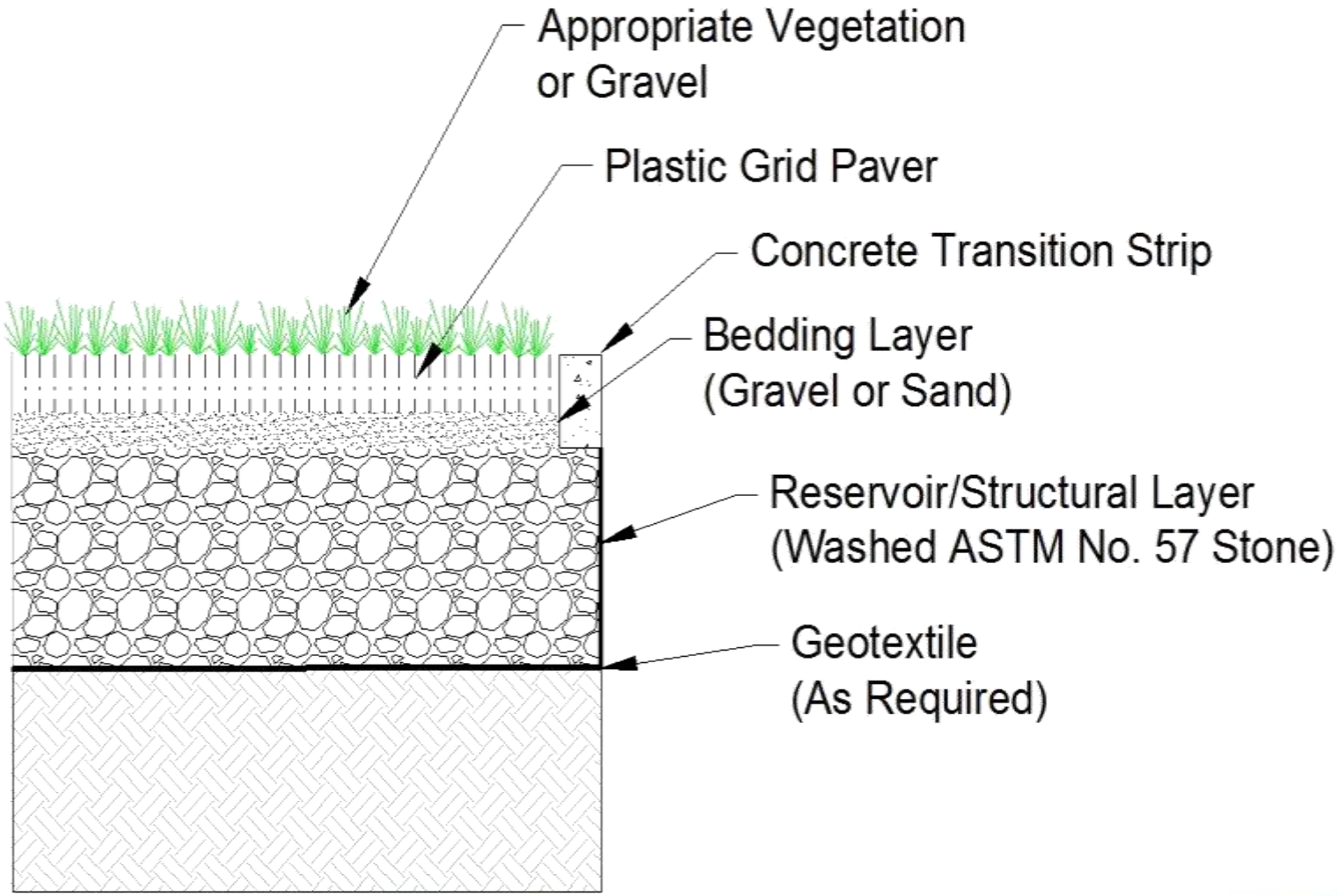
Green Infrastructure Practices (Chapter 5)
Permeable Pavement

Green Infrastructure Practices (Chapter 5)
Permeable Pavement

Porous Asphalt – Pervious Friction Course

Source: Texas DOT Construction Division

Green Infrastructure Practices (Chapter 5)
Permeable Pavement



Green Infrastructure Practices (Chapter 5)
Permeable Pavement

Green Infrastructure Practices (Chapter 5)
Permeable Pavement

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Green Infrastructure Practices (Chapter 5)
Permeable Pavement

Pollutant	Typical literature removal efficiency	Median effluent concentration (mg/L unless otherwise noted)[1]
Sediment	High[1] (32% to 96%)	13.2
Metals	High (65% to 84%)	TAs: 2.50µg/L, TCd: 0.25µg/L, TCr: 3.73 µg/L, TCu: 7.83µg/L, TPb: 1.86µg/L, TNi: 1.71 µg/L, TZn: 15.0 µg/L
Hydro-carbons	Medium (92% to 99%)	N/A
Total phosphorus	Low (20% to 78%)	0.09
Total nitrogen	Low (-40% to 88%)	TKN: 0.80, *$NO_{2,3}$-N: 0.71*
Bacteria	Medium	N/A
Thermal load	Medium	58–73 °F

Green Infrastructure Practices (Chapter 5)

Green Infrastructure Practices (Chapter 5)

Resources

Massachusetts Department of Environmental Protection Publications

Massachusetts Stormwater Handbook. Revised February 2008. http://www.mass.gov/eea/agencies/massdep/water/regulations/massachusetts-stormwater-handbook.html

Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers, and Municipal Officials. 2003

Manual Organization – Chapter 6

Encourage Public Open Space	**Provided?**		**Comments**
Provide high-value undisturbed open space in addition to low-value land (e.g., steep slopes, wetlands).	☐ Yes	☐ No ☐ N/A	
Design compact residential lots with shared common open space.	☐ Yes	☐ No ☐ N/A	
Increase residential unit densities through vertical building or zero lot lines.	☐ Yes	☐ No ☐ N/A	
Maximize Infiltration	**Provided?**		**Comments**
Locate green infrastructure practices on the relatively lower runoff/higher infiltrating soil types.	☐ Yes	☐ No ☐ N/A	
Incorporate bioretention or infiltration features into landscaping plan.	☐ Yes	☐ No ☐ N/A	
Extend drainage flow paths of swales as long as possible.	☐ Yes	☐ No ☐ N/A	
Provide practices and guidelines to minimize soil compaction.	☐ Yes	☐ No ☐ N/A	
Hydrologic Evaluation	**Provided?**		**Comments:**
Provide a detailed description of site design on-site and how the proposed project maximizes the use of green infrastructure site design.	☐ Yes	☐ No ☐ N/A	
Provide tabulation of all impacted areas including contributing drainage area, pervious area, slope, soil, surface cover, and runoff coefficient.	☐ Yes	☐ No ☐ N/A	
Provide channel assessment for receiving streams between the project discharge and the domain of analysis.	☐ Yes	☐ No ☐ N/A	

Manual Organization – Chapter 6

Treatment Control (TC) BMPs	Provided?		Comments:
Provide details regarding the proposed project site drainage network, including storm drains, concrete channels, swales, detention facilities, stormwater treatment facilities, natural and constructed channels, and the method for conveying off-site flows through or around the proposed project.	☐ Yes	☐ No ☐ N/A	
Provide narrative description of TC BMP selection procedure based on soil infiltration potential, hydromodification management criteria applicability, and required pollutant removal efficiency.	☐ Yes	☐ No ☐ N/A	
Provide sizing calculation for each proposed BMP including water quality design flow, design volume, outlet design, overflow design, drawdown, ponding depth, etc.	☐ Yes	☐ No ☐ N/A	
Provide standard details for bioretention BMP facilities, including underdrain design, soil mix specifications, and overflow design.	☐ Yes	☐ No ☐ N/A	
Identify green roofs, if applicable, along with BMP-specific design details.	☐ Yes	☐ No ☐ N/A	
Identify areas of proposed permeable pavement along with applicable design details including underdrains, if applicable.	☐ Yes	☐ No ☐ N/A	
Identify areas of active landscaping that will require irrigation.	☐ Yes	☐ No ☐ N/A	
Identify rainwater harvesting facilities and standard detail, if applicable.	☐ Yes	☐ No ☐ N/A	
Provide required documentation regarding BMP operation and maintenance, access easements, and certification to accept maintenance responsibility.	☐ Yes	☐ No ☐ N/A	

Manual Organization – Chapter 6

Maintenance	Provided?		Comments:
Provide details regarding method for maintenance extending into perpetuity (Homeowners Association, Community Facilities District, etc.).	☐ Yes	☐ No ☐ N/A	
Provide details regarding the required BMP maintenance activities and frequency required for each BMP.	☐ Yes	☐ No ☐ N/A	
Provide signed documentation providing for BMP maintenance access into perpetuity if access is needed.	☐ Yes	☐ No ☐ N/A	
Sediment and Erosion Controls	**Provided?**		**Comments:**
Protect sensitive environmental features (e.g., streams, ponds, buffers, wetlands, Natural Heritage Inventory sites) from construction impacts.	☐ Yes	☐ No ☐ N/A	
Protect post-construction BMPs and from construction runoff, such as from sediment clogging bioretention areas.	☐ Yes	☐ No ☐ N/A	
Delineate locations and extents all features off-limits to construction traffic, such as drip lines for protected specimen trees and critical habitats.	☐ Yes	☐ No ☐ N/A	

Local Incentives for Green Infrastructure

Fee discounts or credits require a stormwater fee that is based on impervious surface area. If property owners can reduce need for service by reducing impervious area, the municipality reduces the fee.

Development incentives are offered to developers during the process of applying for development permits. They include zoning upgrades, expedited permitting, reduced stormwater requirements, and other incentives.

Rebates and installation financing give funding, tax credits or reimbursements to property owners who install specific practices. These incentives are often focused on practices needed in certain areas or neighborhoods.

Awards and recognition programs provide marketing opportunities and public outreach for exemplary projects. These programs can include monetary awards.

Source: USEPA 2010

Questions and Discussion