


LID Technical Workshop – Puget Sound

Bioretention: Design and Construction

Presentation Overview

Bioretention Basics/Types
Bioretention Components
Design by Component
Layout, Elevation & Grade
Roadway Challenges
Construction Considerations

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Bioretention Basics

Bioretention vs. Rain Gardens

According to the 2012 Ecology Manual:

- Bioretention (MR 1-9)
  - Engineered facility
  - Sized for flow control/WQ goals
  - Designed soil mix
  - May include underdrains/control structures
- Rain Garden (MR 1-5)
  - Non-engineered landscape depression to manage stormwater
  - Less restrictive design criteria

Bioretention Basics

Bioretention Treatment Category

- Bioretention is a "bio-infiltration" BMP
  - Ponding system
  - Treatment via vertical flow through treatment soils while being infiltrated
  - Treatment goal = % volume infiltrated
- Bioretention is NOT a "bio-filtration" BMP
  - Flow-through system (ex. biofiltration swale)
  - Treatment via lateral flow through vegetation while being conveyed
  - Treatment goal = hydraulic residence time

Bioretention Types

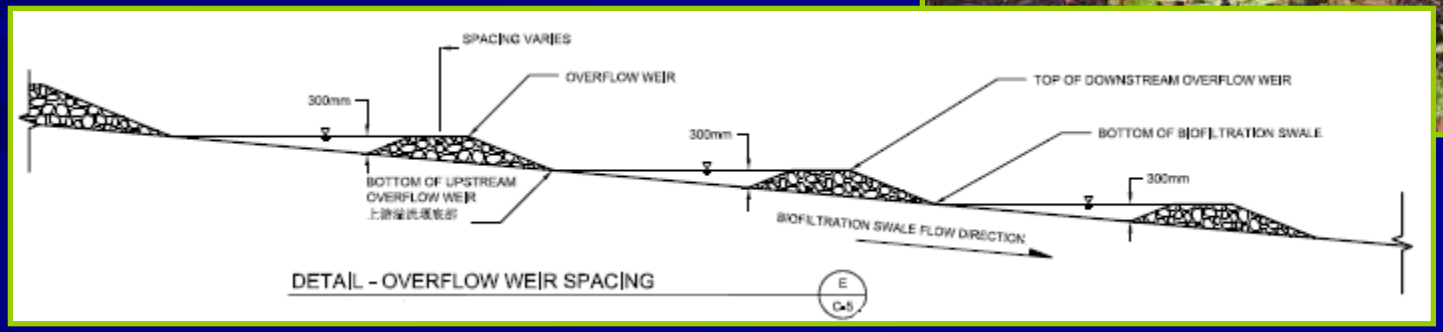
Bioretention Cells

- Shallow vegetated depressions
- Gentle side slopes typical
- Not designed as conveyance system
- Optional underdrains/control structures

Bioretention Types

Bioretention Swales

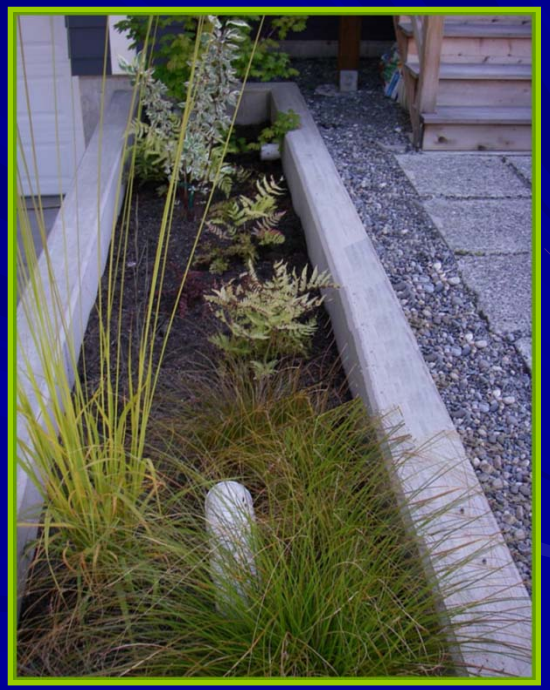
- Same design features as cells
- Interconnected series of cells
- Provide conveyance (overflow directed to downstream cell)



Bioretention Types

Bioretention Planters

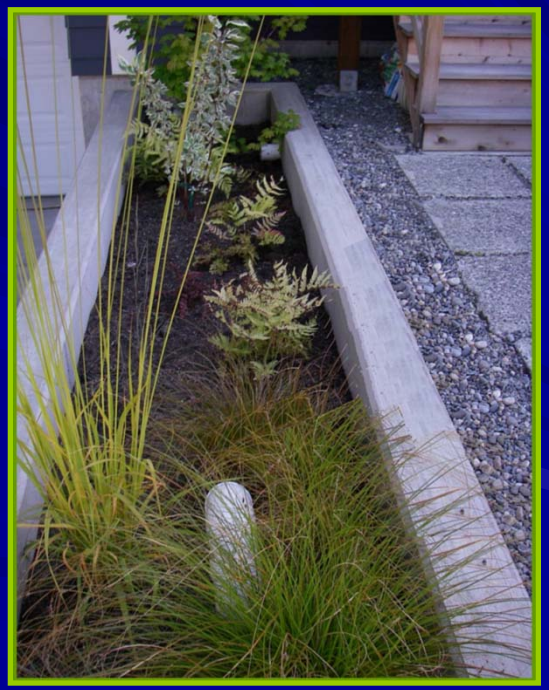
- Vertical walled reservoir (typ. concrete)
- Often used in ultra-urban settings
- Open bottom to allow infiltration to native soil
- Optional underdrains/ control structures



Bioretention Types

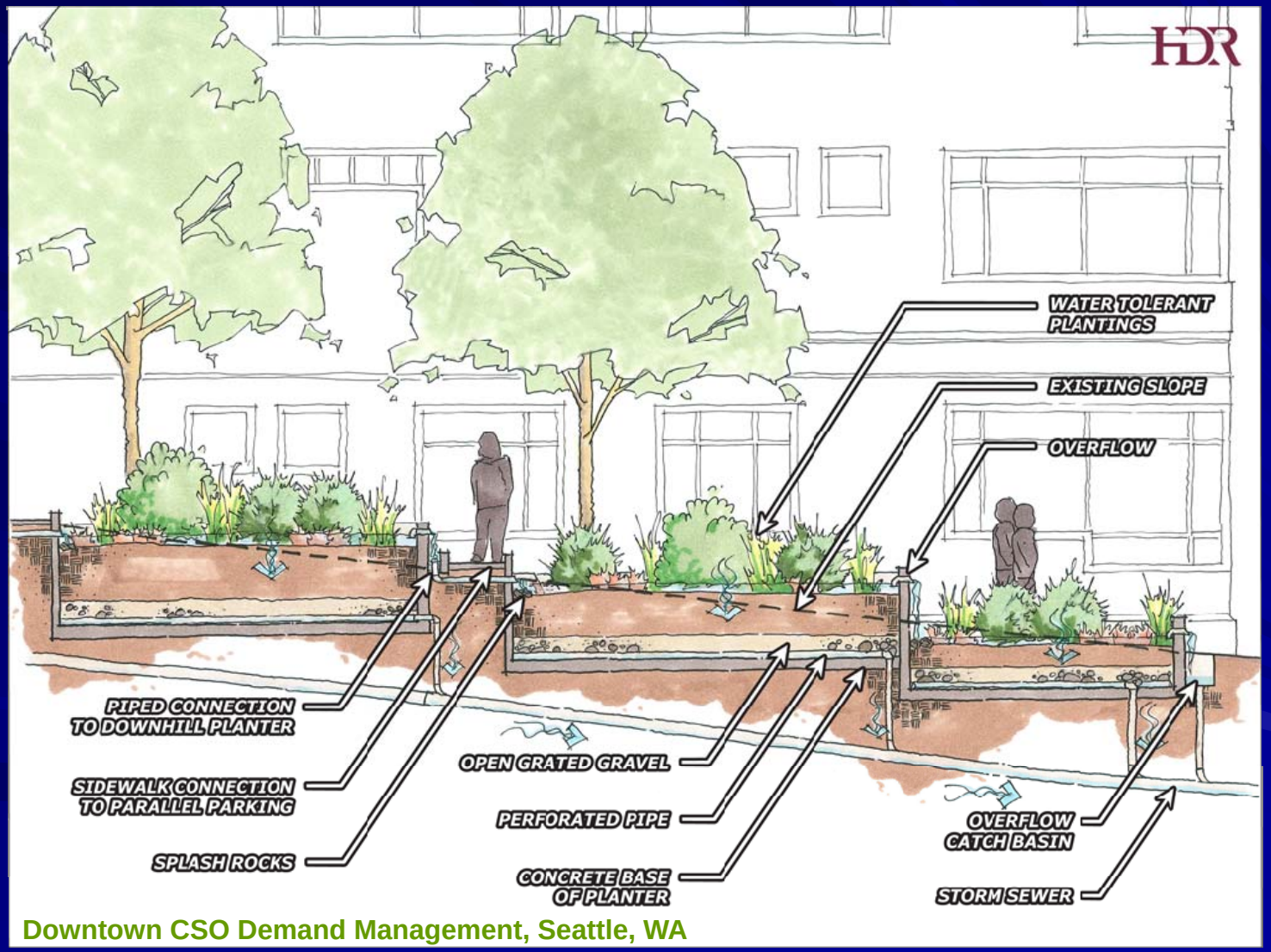
Bioretention Planter Box

- Same design features as planters
- Closed, impermeable bottom
- Must include underdrain
- Optional control structure



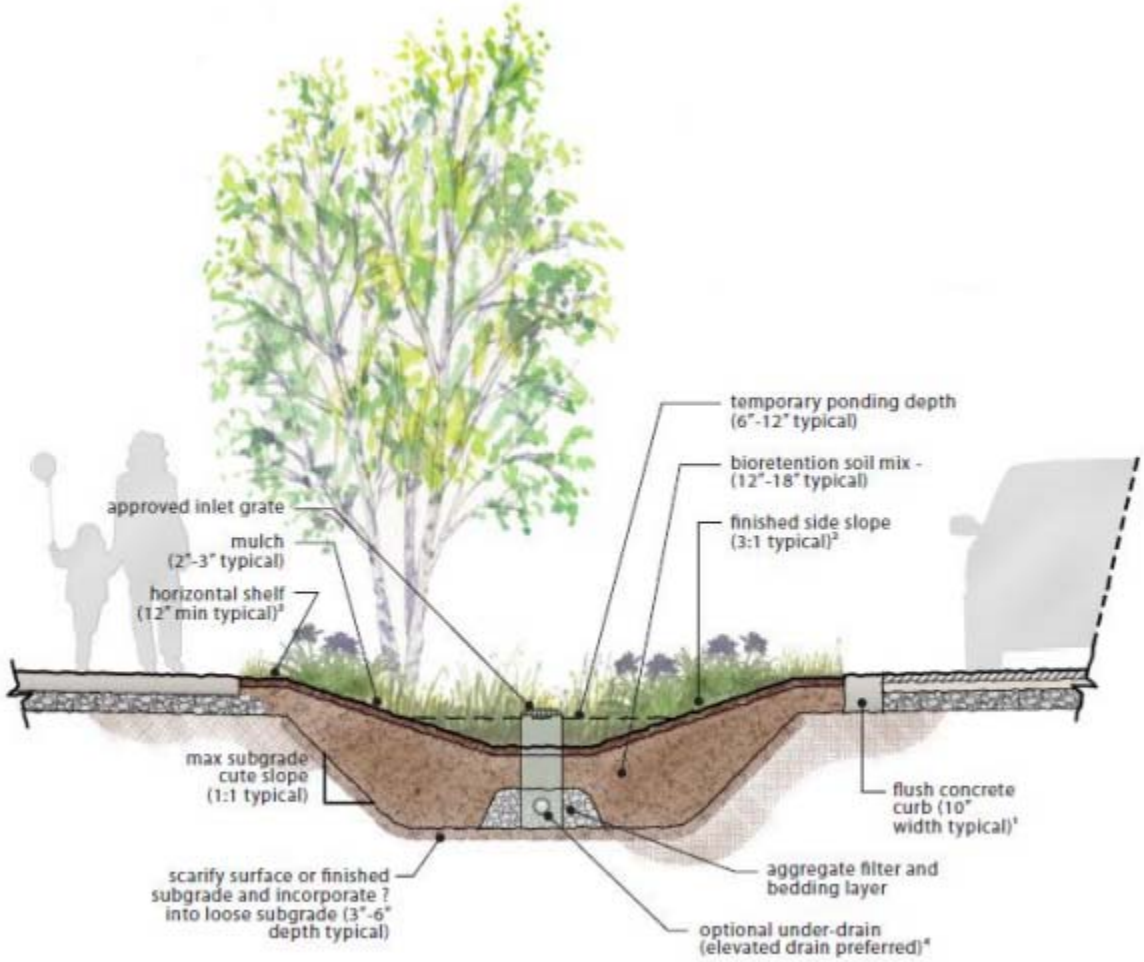
BIORETENTION TYPES

HYBRID- PLANTER SWALE



Downtown CSO Demand Management, Seattle, WA

BIORETENTION COMPONENTS



2012 LID Manual

- Flow Entrance
- Pre-Settling
- Ponding Area
- Bioretention Soil
- Mulch/Compost
- Vegetation
- Filter Fabric (?)
- Liner (optional)
- Underdrain (optional)
- Overflow

Flow Entrance

Design Criteria / Types

- Flow entering should be non-erosive
  - Velocity less than 1.0 fps
- Dispersed flow entrance → **Preferred!**
  - Vegetated buffer strip
  - Sheet flow across pavement/gravel
  - Sheet flow b/t wide wheel stops
- Concentrated flow entrance → **Requires erosion protection (e.g., rock)**
  - Piped flow
  - Curb cuts
  - Trench drains

Flow Entrance

Field Examples

High Point, Seattle, WA

Flow Entrance

Field Examples

Can use wheel stops to restrict loading

Bagley Elementary,
Seattle, WA

Coupeville High School
Coupeville, WA

FLOW ENTRANCE

FIELD EXAMPLES

Depressed gutter at inlet

Finish grade should be 2-3” lower than curb line to allow for settling

Flow Entrance

Field Examples

SW 12TH Avenue Green Street, Portland, OR

Do not use woody plants at inlet (can restrict or concentrate flows)

Flow Entrance

Field Examples

2012 LID Manual

For higher/surface elevation inlets

Flow Entrance

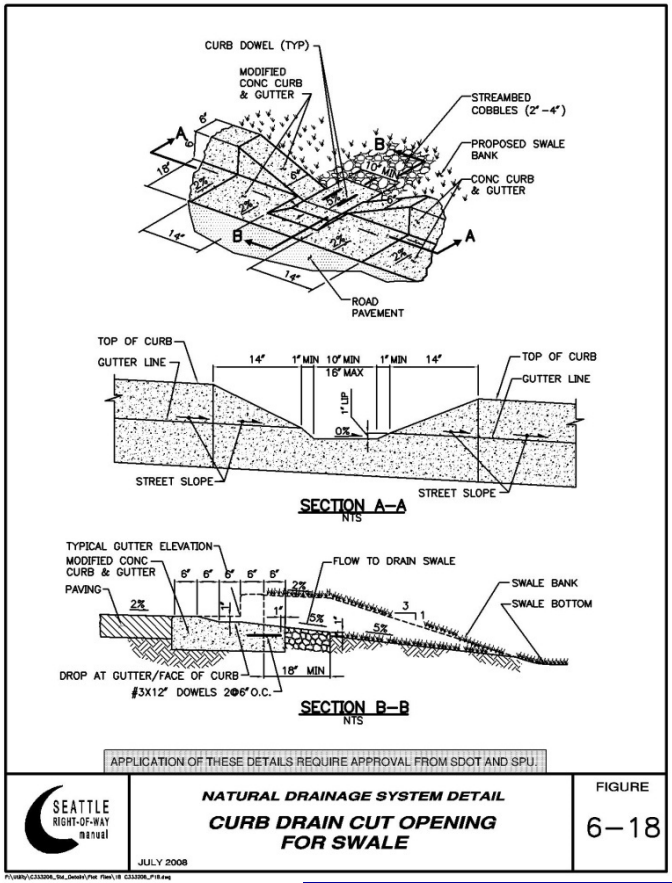
Field Examples

Rock pad for erosion protection

Pinehurst, Seattle, WA

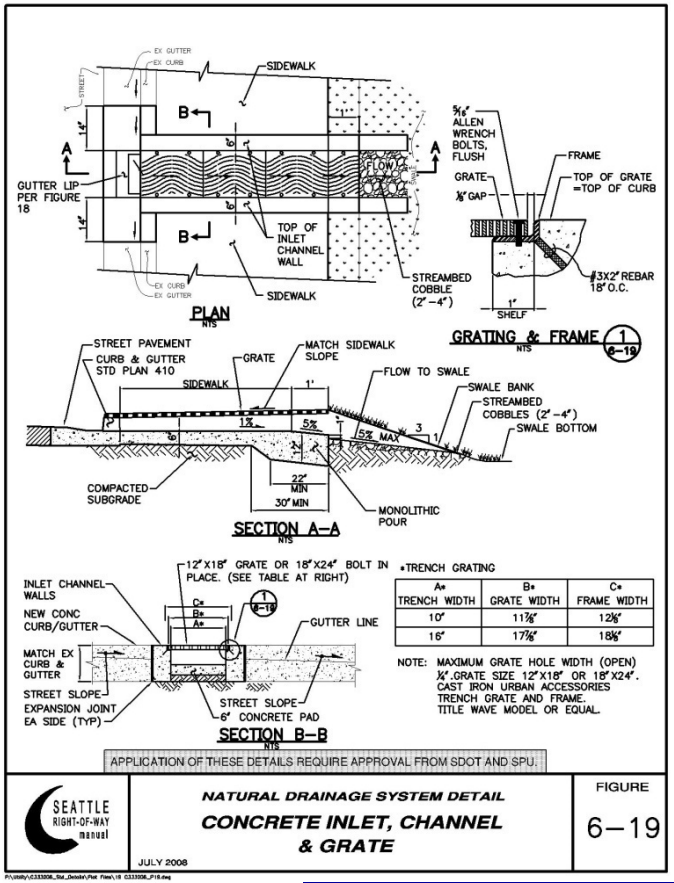
FLOW ENTRANCE

DESIGN RESOURCES



Seattle Standard Details

CURB CUT



Seattle Standard Details

CHANNEL WITH GRATE

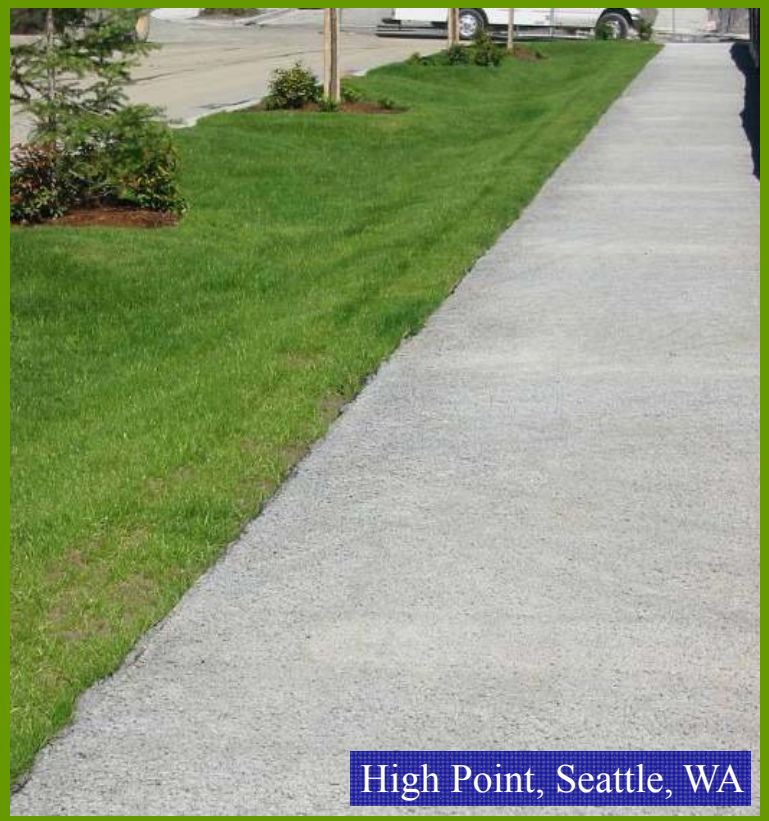
Pre-Settling

Design Criteria / Types

- To capture debris/sediment and reduce potential for clogging of BSM
- May be required for:
  - For concentrated flow entrances
  - For larger drainage areas
  - Where sediment loading is expected (e.g., high-use parking lots and roadways)
- Pre-settling methods:
  - Vegetated filter strip
  - Fore bay
  - Catch basin

Ponding Area

Ponding Reservoir Types



High Point, Seattle, WA

Earthen Depression

Pinehurst, Seattle, WA

Rockery Walls

Ponding Area

Ponding Reservoir Types

Aboveground Metal Planter

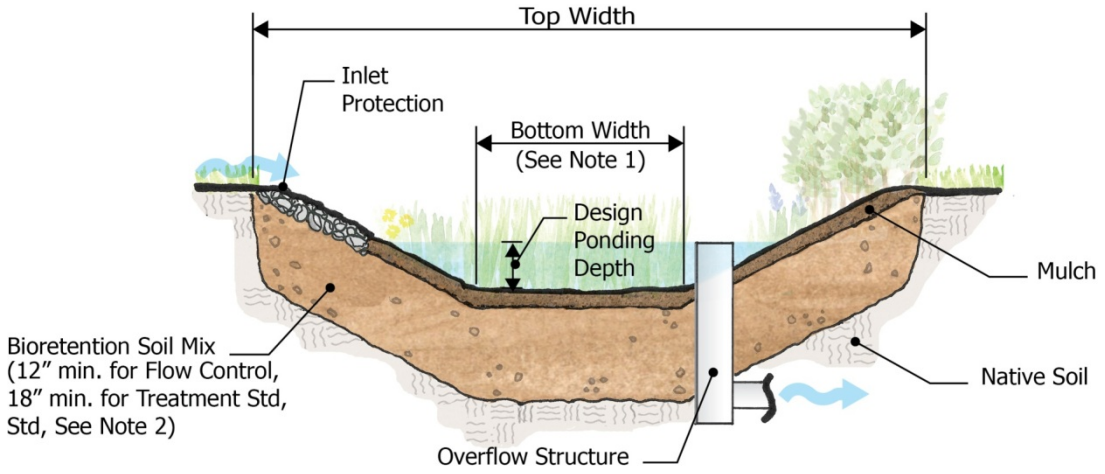
In ground Concrete Reservoir

Ponding Area

Design/Performance

Without Underdrain

- Earthen depression (w/o liner) or open-bottomed planter
- Relies on infiltration to native soil
- Can provide effective flow control and WQ treatment



Notes:
1. Bottom width shall be a minimum of 2 feet and bottom area shall be flat (0% slope).
2. Imported bioretention soil shall meet City of Seattle specifications (minimum design infiltration rate of 3 inches per hour and 40% porosity).

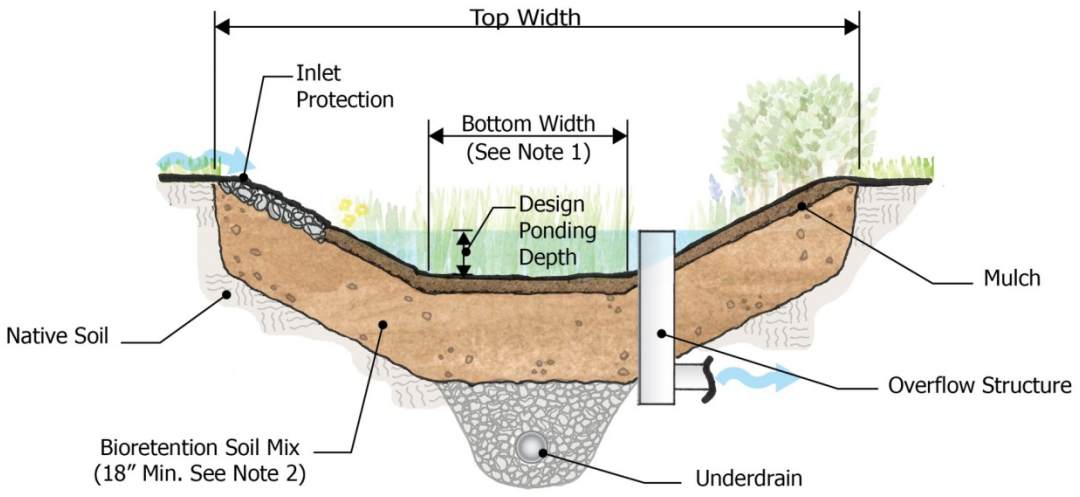
Bioretention

Ponding Area

Design/Performance

With Underdrain

- Some infiltration to native soil (w/out liner)
- Cannot meet forest duration flow control (orifice improves performance)
- Can provide effective WQ treatment



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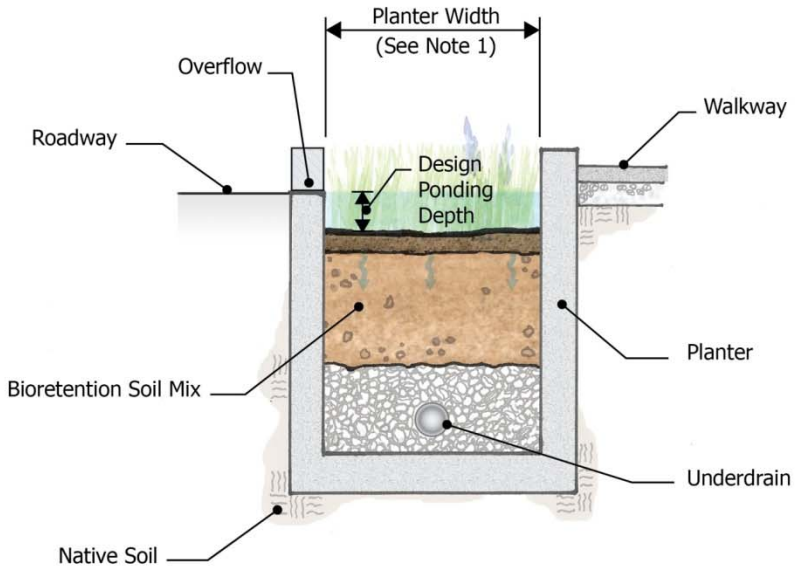
Bioretention with Underdrain

PONDING AREA

DESIGN/PERFORMANCE

With Underdrain & Liner/Impermeable Container

- No infiltration to native soil
- Typically provides minimal flow control (orifice improves performance)
- Can provide effective WQ treatment



PLANTER WITH UNDERDRAIN

Ponding Area

Sizing Criteria

- Stormwater Management Standards
  - Flow control standards (peak/duration)
  - Water quality standards (infiltrate 91% runoff volume)
- Max. surface pool drawdown time (24-48 hours)
  - Soil allowed to dry out periodically
  - Restore hydraulic capacity of system
  - Maintain adequate soil oxygen levels
  - Prevent conditions supportive of mosquito breeding

*Surface Pool Drawdown=
Ponding Depth ÷ Design Infiltration Rate

Ponding Area

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- Stormwater Management Standards
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*Surface Pool Drawdown=
Ponding Depth ÷ Design Infiltration Rate
Ex. 6 inch ÷ 0.25 inch/hour = 24 hours

Ponding Area

Ponding Area Size a Function of:

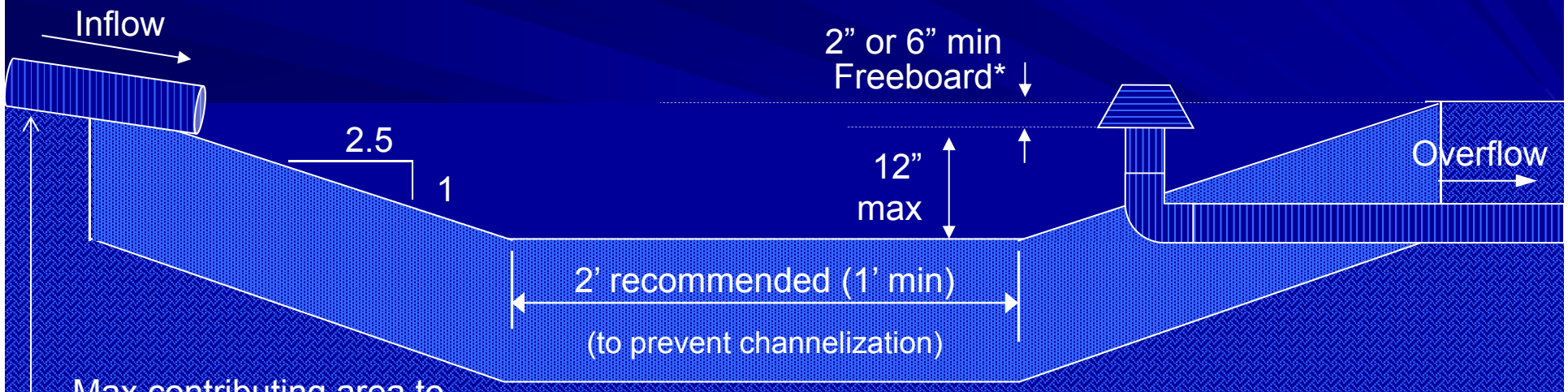
Larger Footprint Area for:

- Larger contributing area
- Higher site precipitation
- Lower native soil infiltration rate
- Shallower ponding depth
- Shallower BSM depth

Ponding Area

Cross Section Criteria

- Max ponding depth (12 inches)
- Min bottom width (1 foot)
- Max planted side slope (2.5:1) (for depth ≥ 3 ft)
- Min freeboard?
- Max contributing area or bottom area?



* Seattle requirements provided for example design criteria

Ponding Area

Roadway Facility Criteria

Roadway Cross Section

- 2-foot shoulder
- Grade at 3H:1V
- Grade at 4H:1V for intersections (Seattle)
- Compact shoulder to 90 percent standard proctor

Ponding Area

Roadway Facility Criteria (Seattle)

Fixed Object Hazards

- Rockery >1’ high, min 10’ from curb/edge of road
- Rockery <1’ high min 5’ from curb/edge of road

Ponding Area

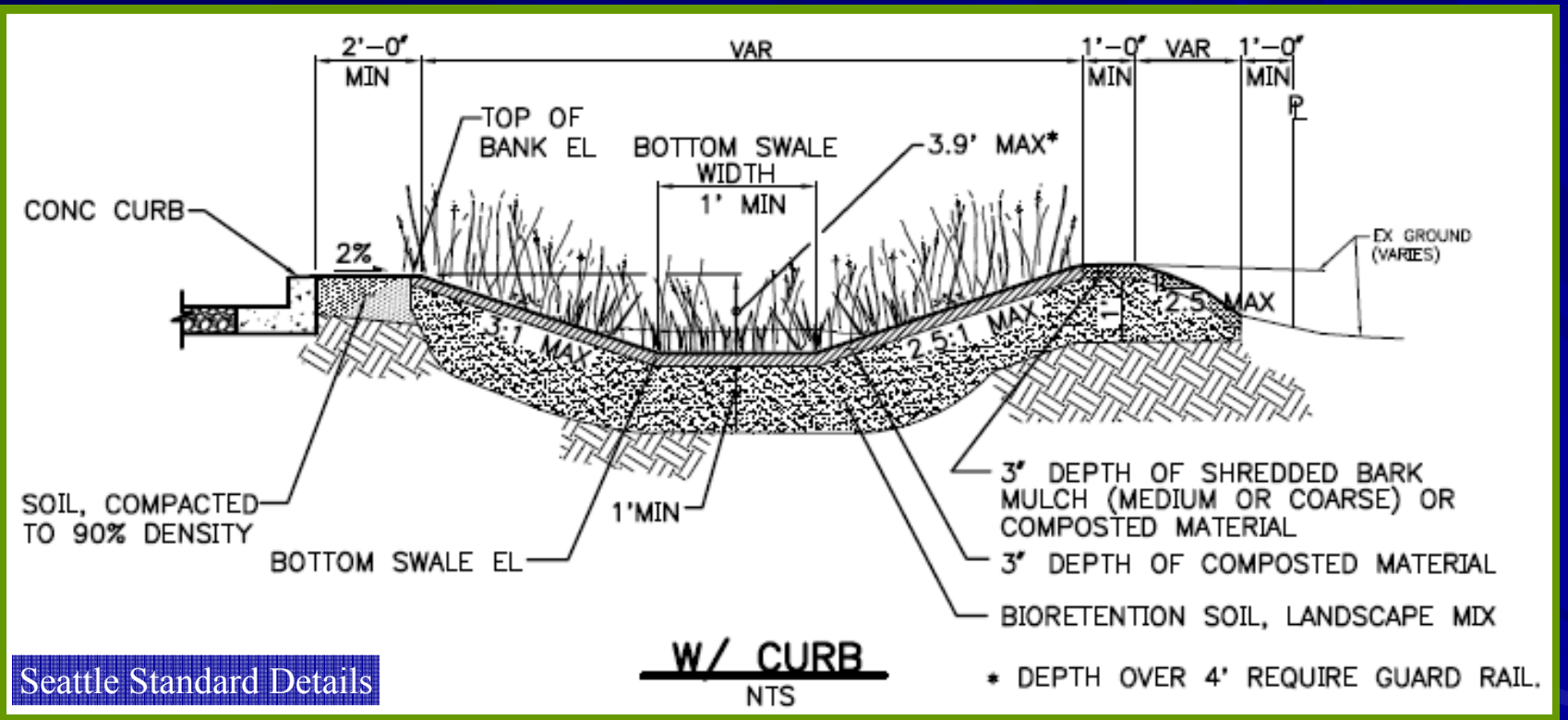
Roadway Facility Criteria (Seattle)

Maximum Facility Drop

Max 4’ drop from vehicular lane

PONDING AREA

DESIGN RESOURCES

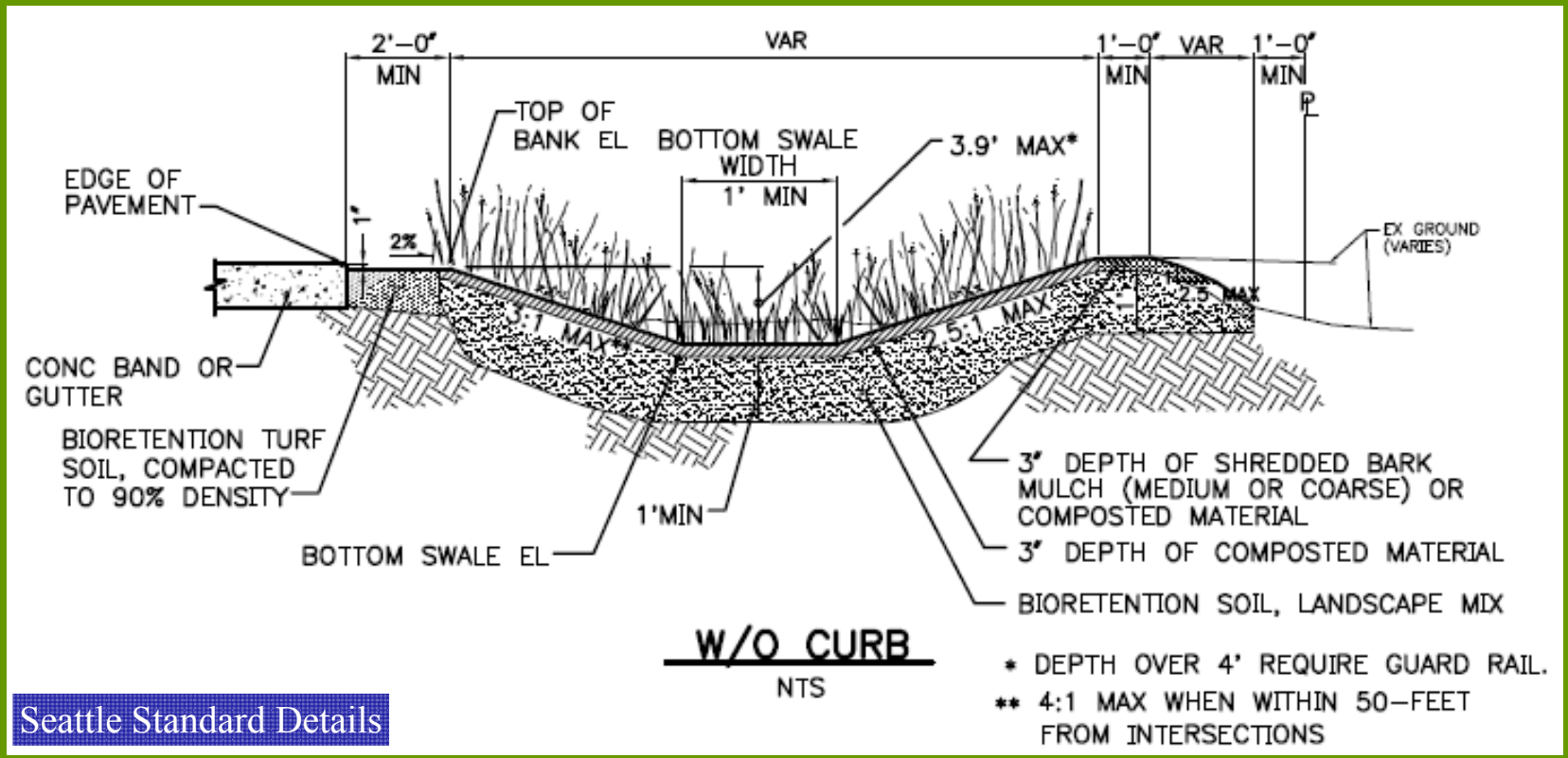


Seattle Standard Details

BIORETENTION WITH CURB

Ponding Area

Design Resources

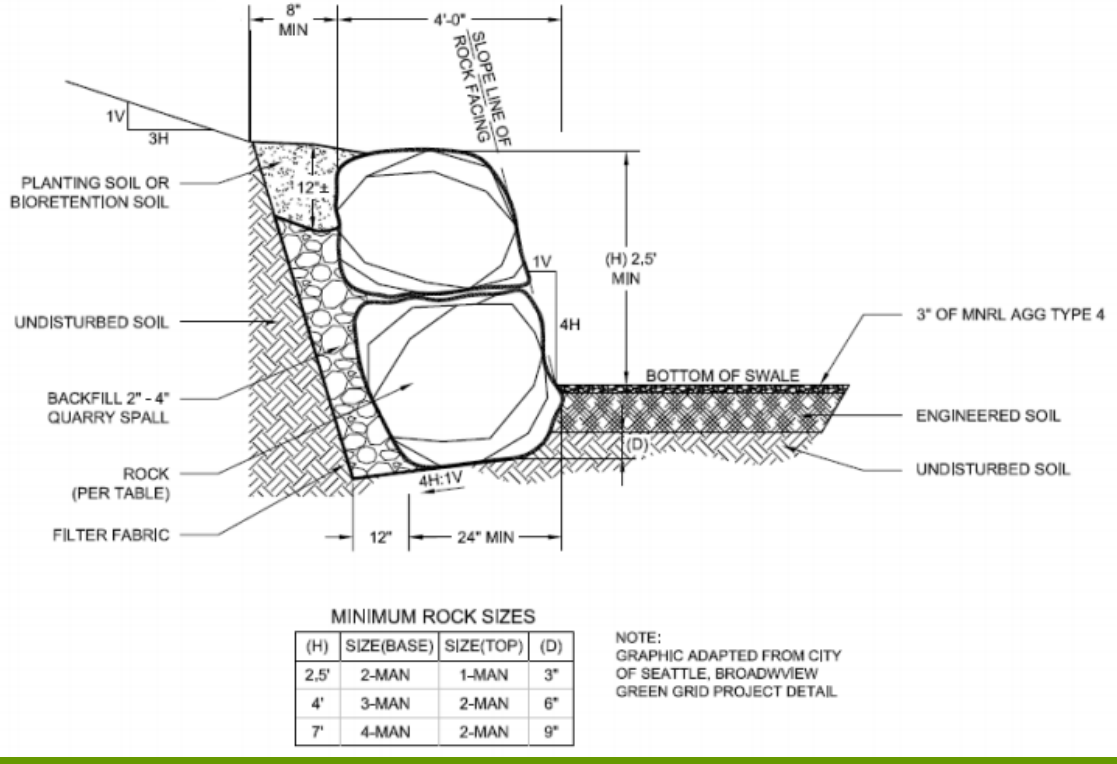


Seattle Standard Details

Bioretention without Curb

PONDING AREA

DESIGN RESOURCES



MINIMUM ROCK SIZES

(H)	SIZE(BASE)	SIZE(TOP)	(D)
2,5'	2-MAN	1-MAN	3"
4'	3-MAN	2-MAN	6"
7'	4-MAN	2-MAN	9"

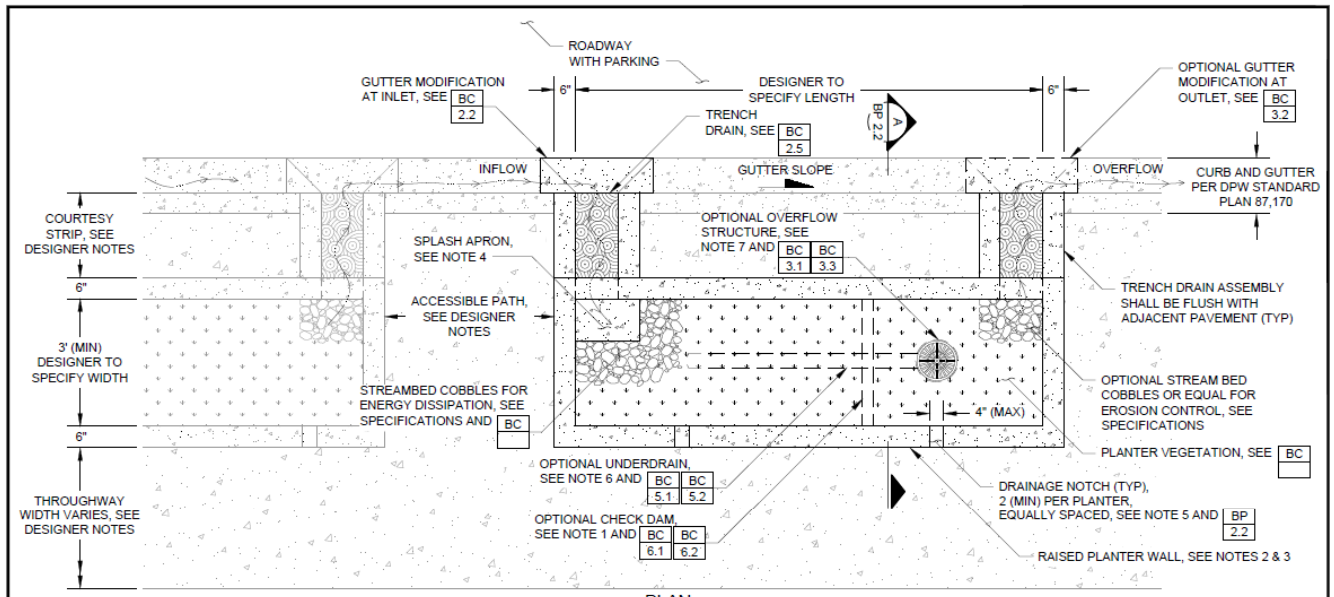
NOTE:
GRAPHIC ADAPTED FROM CITY OF SEATTLE, BROADWVIEW GREEN GRID PROJECT DETAIL

2012 LID Manual

ROCKERY WALL

PONDING AREA

DESIGN RESOURCES



PLAN

CONSTRUCTION NOTES:

1. CHECK DAMS SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN, SEE BC 6.1 AND BC 6.2.
2. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
3. FOR EDGE TREATMENT OPTIONS, REFER TO BC 1.1 THROUGH BC 1.7.
4. SPLASH APRON SHALL NOT BE INTEGRAL TO PLANTER WALL OR OTHER ADJACENT CONCRETE ELEMENTS. REFER TO [PHASE II] FOR ENERGY DISSIPATOR DETAILS.
5. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL.
6. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS, SEE GC 6.2.
7. OVERFLOW PIPE FROM OPTIONAL OVERFLOW STRUCTURE NOT SHOWN FOR CLARITY.

GENERAL UTILITY NOTES:

1. UTILITY CONFLICTS SHALL BE MITIGATED PER SAN FRANCISCO PUC SURFACE IMPROVEMENT STANDARDS [PENDING COMPLETION]. INCLUDE MEASURES TO ENSURE WATER TIGHT UTILITY PENETRATIONS THROUGH PLANTER WALL (REFER TO GC 2.2 AND GC 2.3) AND TO PREVENT PREFERENTIAL FLOW INTO UTILITY TRENCHES (E.G., WATER STOP, TRENCH BLOCK, OR TRENCH COLLAR). PROPOSED UTILITY LINES TO BE LOCATED OUTSIDE OF FACILITY.
2. ABANDONED UTILITIES WITHIN FOOTPRINT OF FACILITY AND OBSERVED DURING CONSTRUCTION MUST BE REMOVED. COORDINATE WITH MUNICIPAL OR PRIVATE OWNER AND ENGINEER.

NOTES		W/PARKING		W/O PARKING		BULBOUT		PARCEL APPLICATIONS					
		PLAN	SECTIONS	PLAN	SECTIONS	PLAN 1	PLAN 2	NOTES		PLAN	SECTIONS		
BP 1.1	BP 1.2	BP 2.1	BP 2.2	BP 3.1	BP 3.2	BP 4.1	BP 4.2	BP 5.1	BP 5.2	BP 5.3	BP 5.4	BP 5.5	BP 5.6

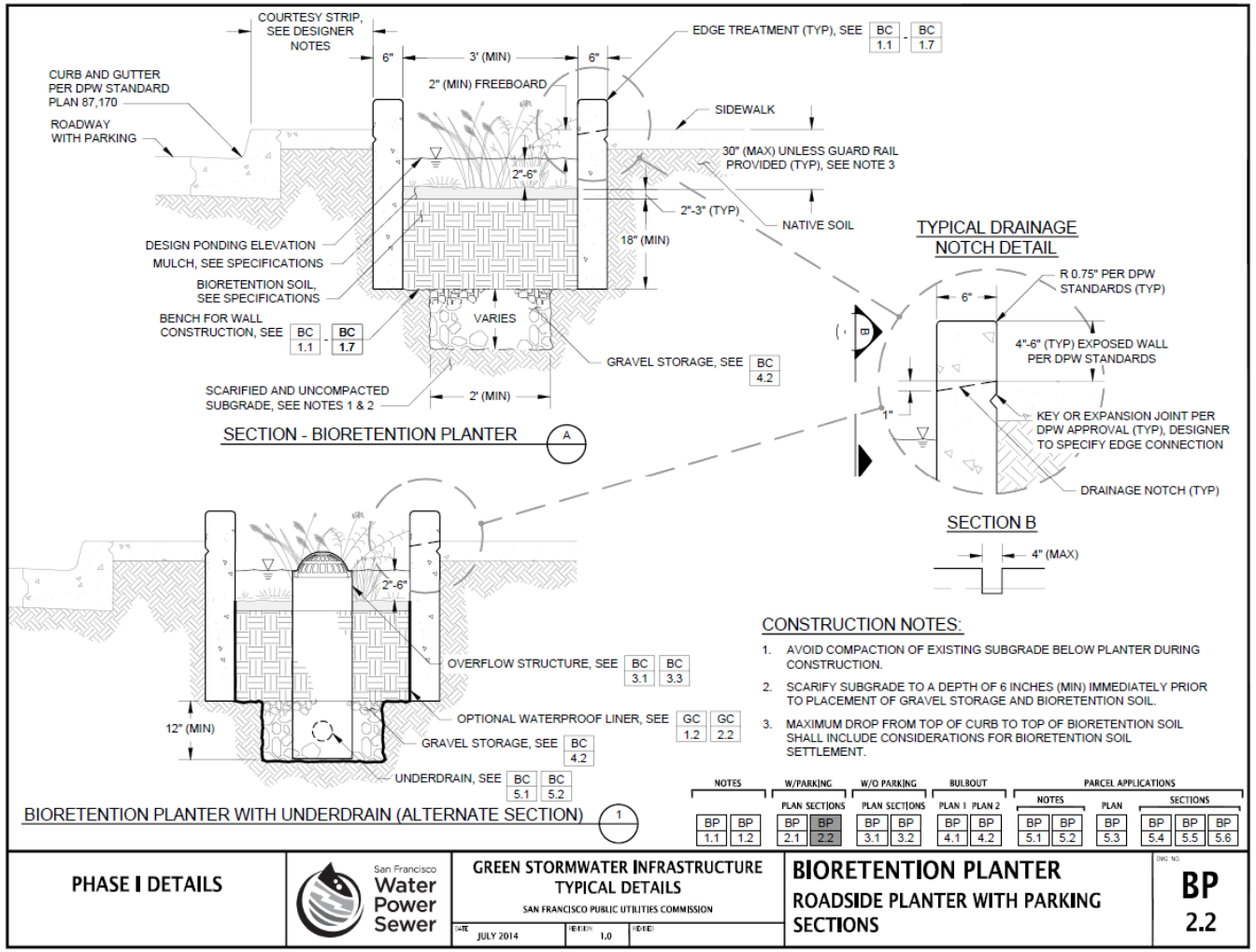
PHASE I DETAILS	San Francisco Water Power Sewer	GREEN STORMWATER INFRASTRUCTURE TYPICAL DETAILS SAN FRANCISCO PUBLIC UTILITIES COMMISSION DATE JULY 2014 REVISION 1.0 REVISED	BIORETENTION PLANTER ROADSIDE PLANTER WITH PARKING PLAN	DWG NO. BP 2.1

2014 San Francisco Typical Details

BIORETENTION PLANTERS

PONDING AREA

DESIGN RESOURCES

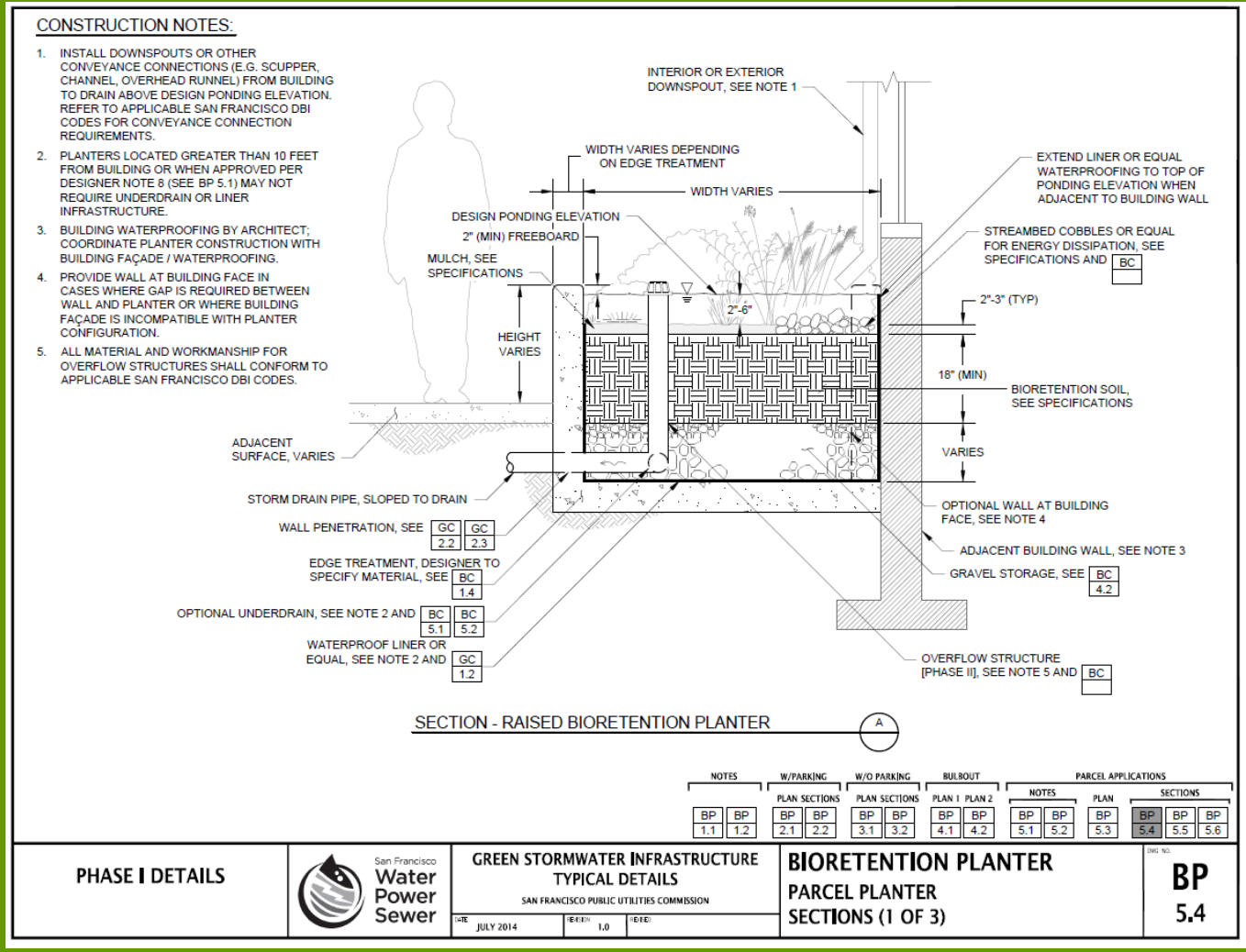


2014 San Francisco Typical Details

BIORETENTION PLANTERS

PONDING AREA

DESIGN RESOURCES



2014 San Francisco Typical Details

BIORETENTION PLANTERS

BIORETENTION SOIL

OVERVIEW

- Purpose
  - Supports plants & microbes
  - Removes pollutants
- Options
  - Amend Native soils in place
  - Over excavate and place imported soil
- Minimum soil depth
  - 12 inches for flow control
  - 18/24 inches for water quality treatment

BIORETENTION SOIL

OVERVIEW

- For treatment → meet Ecology trtmnt soil rqmnts
  - Minimum depth = 18 inches
  - Minimum CEC = 1meq/100g dry soil
  - Organic matter content = 4 – 8%
  - Maximum initial infiltration rate = 12 in/hr
  - Minimum long-term (corrected) rate = 1 in/hr
- Approved BSM Specification in 2012 LID Manual
  - 40% porosity
  - Short-term infiltration rate of 6 inches / hour
  - Design rate of 3 in/hr (for cont. areas up to 5,000 sf)
  - Design rate of 1.5 in/hr (for cont. areas exceeding 5,000 sf)

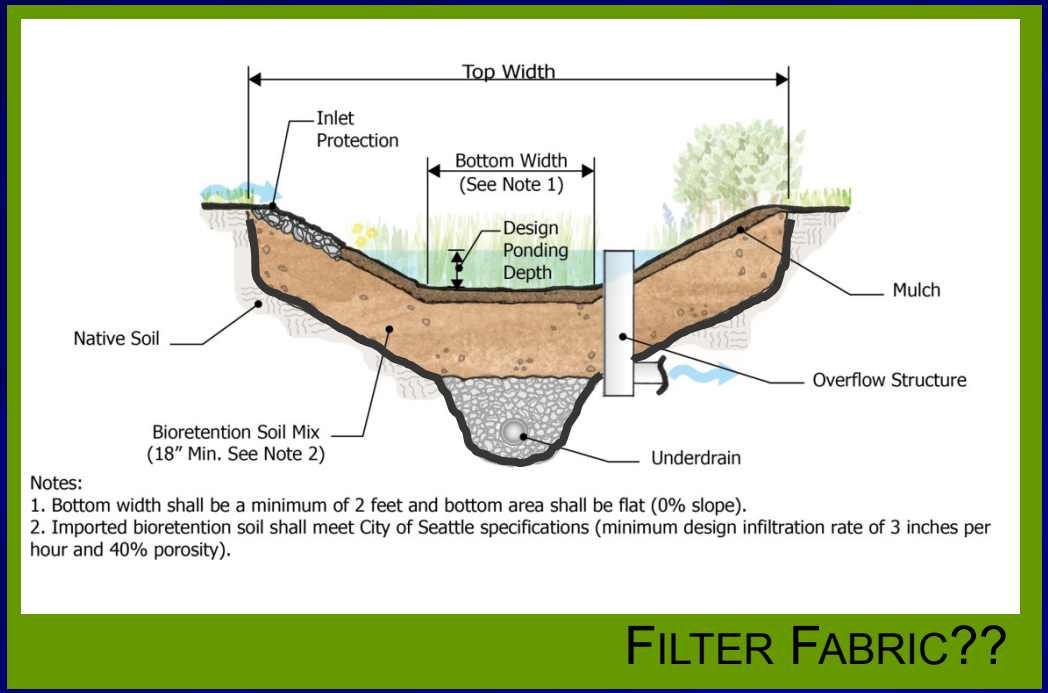
MULCH/COMPOST

OVERVIEW

- Purpose
  - Reduces weed establishment
  - Regulates soil temp & moisture
  - Adds organic matter to soil
  - Attenuates heavy metals

- Composition
  - Course compost in the bottom of the cell
  - Arborist wood chip mulch composed of shredded or chipped hardwood / softwood on cell slopes
- Depth: 2 to 3 inches
- Alternatives: Dense ground cover or aggregate

FILTER FABRIC??



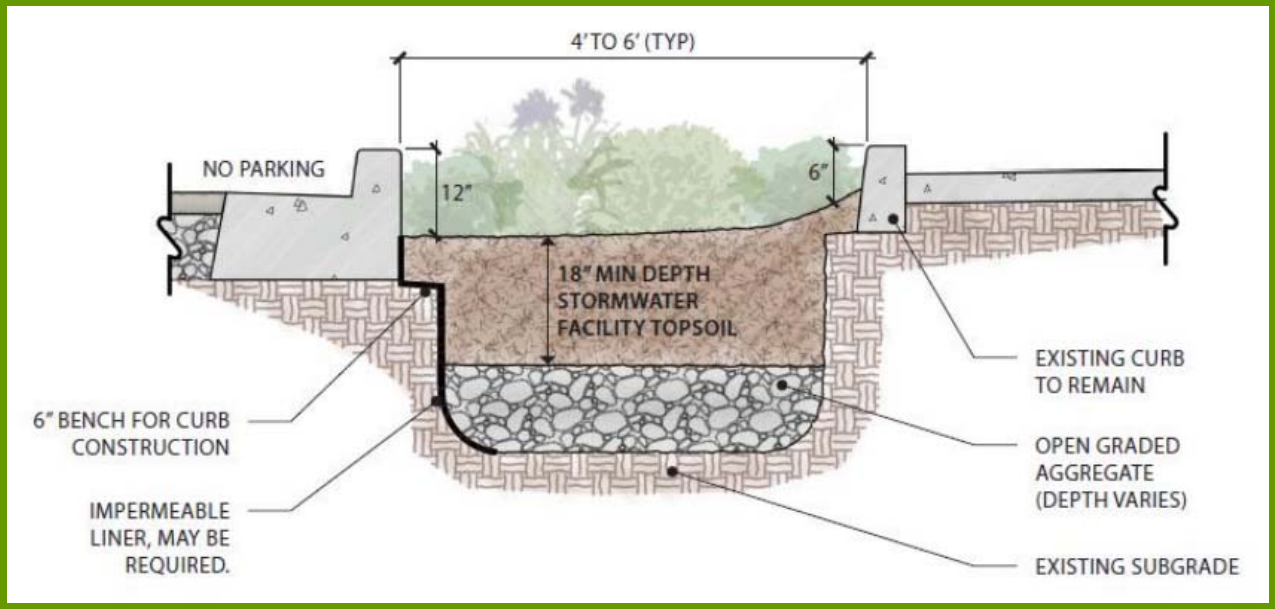
FILTER FABRIC??

- Typically NOT recommended between existing soil and BSM because of clogging potential
- Gradation difference between existing soil and BSM is typically small so no migration of fines

HYDRAULIC RESTRICTION LAYERS

RESTRICT LATERAL FLOWS

- Geomembranes on vertical walls
- For facilities adjacent to roads, foundations, etc.



2012 LID MANUAL

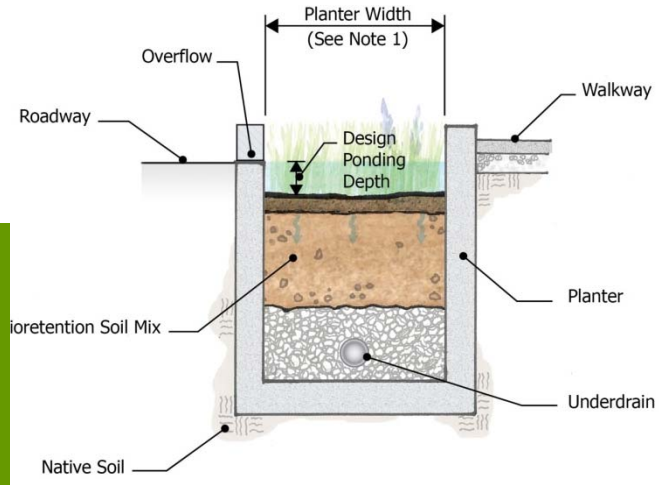
RESTRICT LATERAL FLOWS

Hydraulic Restriction Layers

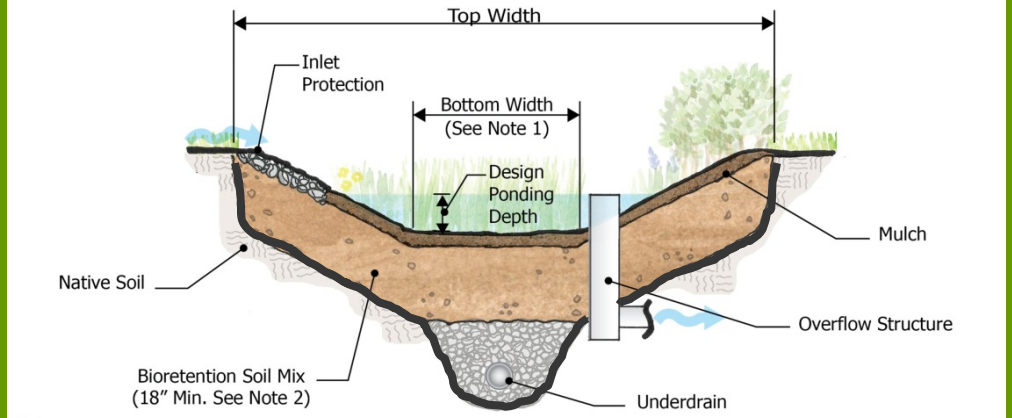
Prevent All Infiltration

- Where infiltration is prohibited or not prudent
- Must use underdrain

Impermeable reservoir (concrete, metal)



Impermeable Planter



Notes:
1. Bottom width shall be a minimum of 2 feet and bottom area shall be flat (0% slope).
2. Imported bioretention soil shall meet City of Seattle specifications (minimum design infiltration rate of 3 inches per hour and 40% porosity).

Bioretention with Liner

← Clay (bentonite) or geomembrane

UNDERDRAINS

DO YOU NEED THEM? WHY? WHEN?

BROADVIEW GREEN GRID, SEATTLE, WA

- Where liner is used
- Where infiltration is prohibited or not prudent
- Near sensitive infrastructure with high flood potential
- Soil infiltration rates not adequate to meet surface pool drawdown time

UNDERDRAINS

RECOMMENDED DESIGN

Slotted PVC Pipe with Aggregate Filter Blanket

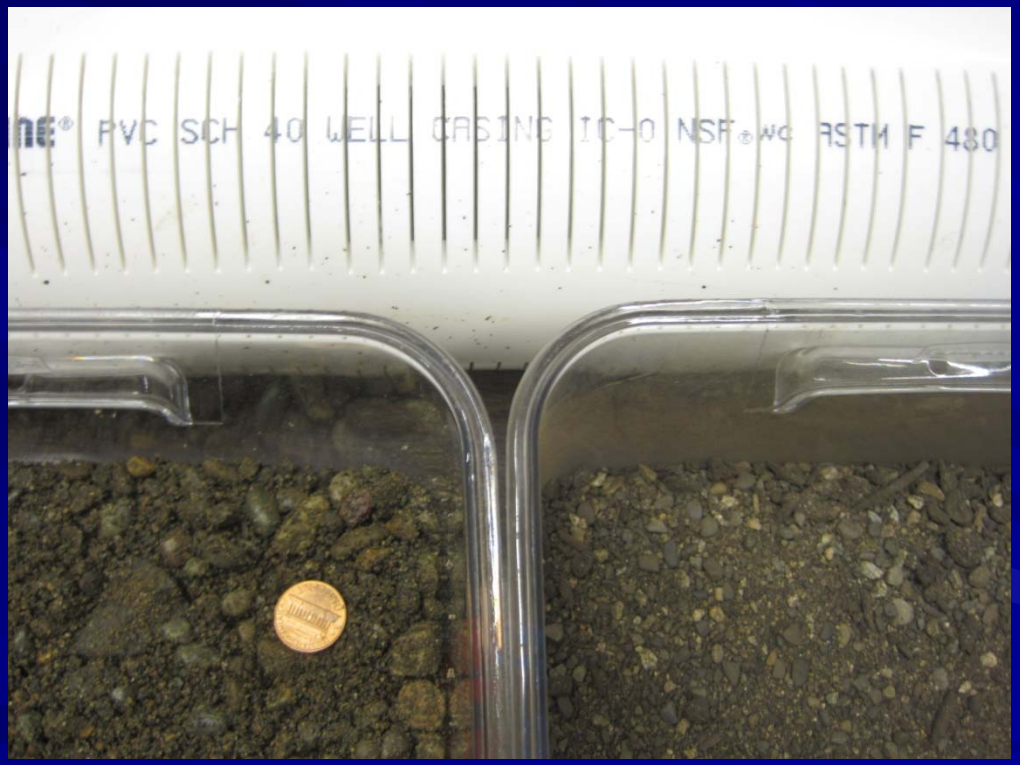
- Slotted, thick-walled plastic pipe
  - Minimum 4” diameter Schedule 40 PVC
- Slot openings
  - Smaller than smallest aggregate gradation of filter material
  - Slots perpendicular to long axis of pipe
- Gravel filter/bedding material
  - Prevent migration of fine material into drain
  - City of Seattle Mineral Aggregate Type 26 (sandy gravel)
- NOT wrapped in filter fabric

Note: If using City of Seattle Mnrl Agg 26, slots shall be 0.069 inches by 1-inch long, spaced 0.25 inches apart. Slots arranged in four rows spaced on 45-degree centers.

UNDERDRAINS

RECOMMENDED DESIGN

PVC Slotted Pipe



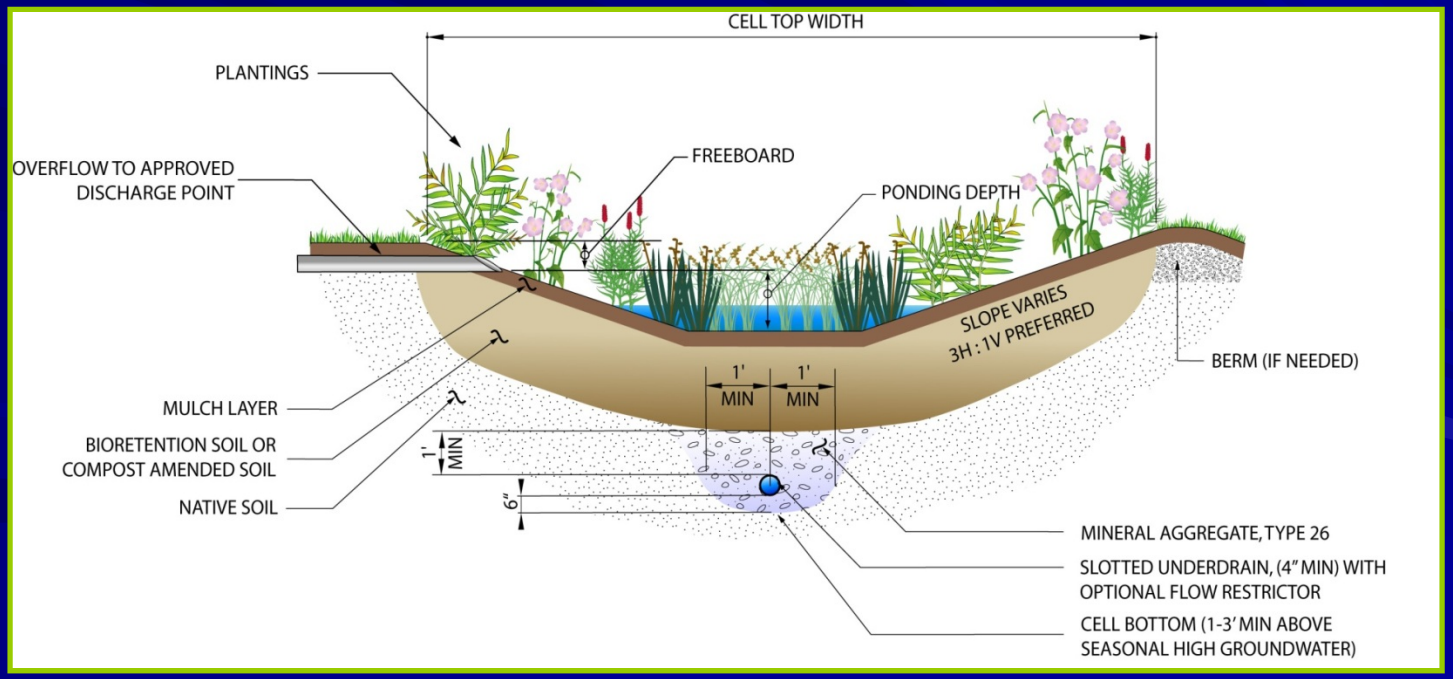
Filter Material (Ag 26)

BR Soil

UNDERDRAINS

RECOMMENDED DESIGN

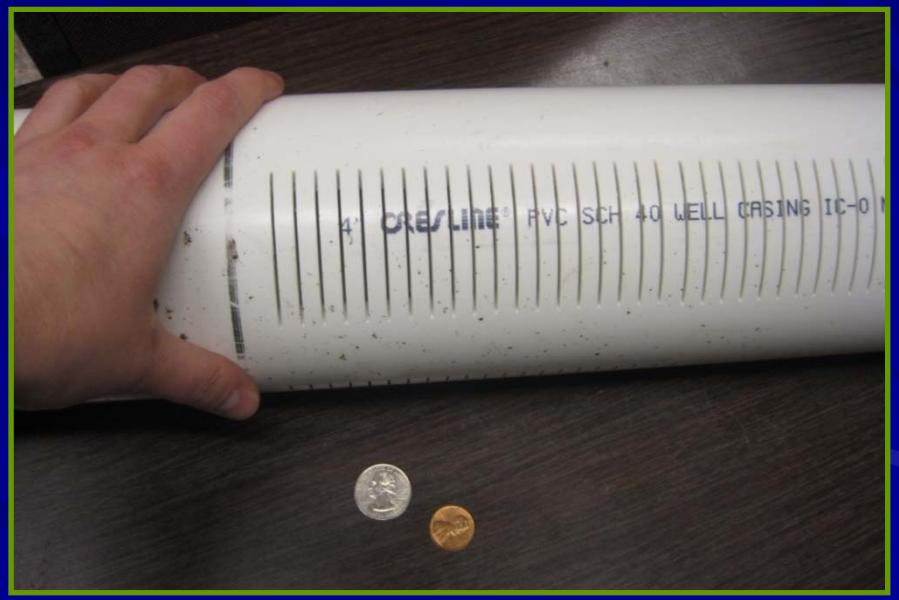
- Slotted pipe placement (Seattle)
  - 6” blanket under
  - 12” blanket on top
  - 12” blanket each side



UNDERDRAINS

RECOMMENDED DESIGN BENEFITS

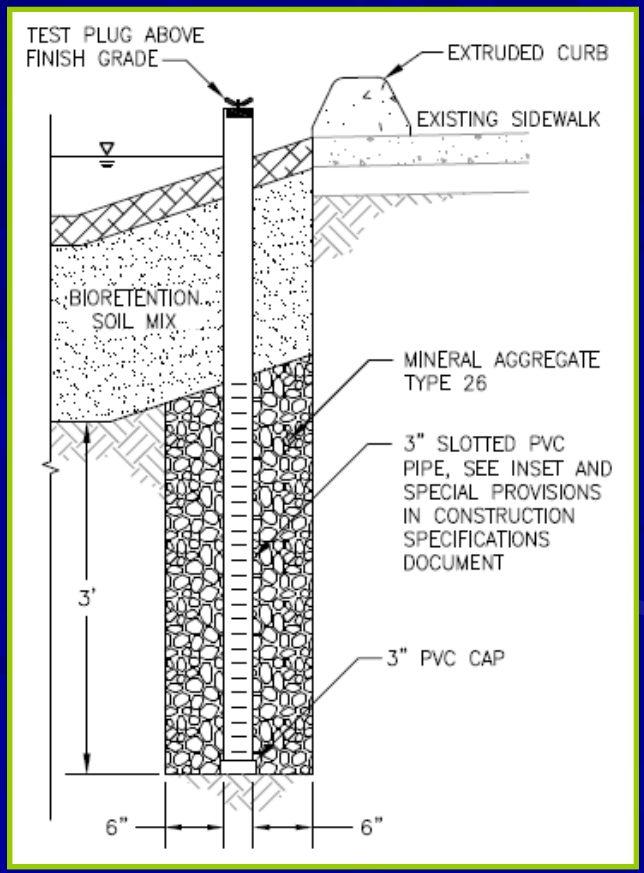
- Increased media area provides better filtering
- Reduced potential for clogging
  (versus perforated pipe wrapped in filter fabric)
- More durable and easier to clean (rotary root cutter or water jet)
  (versus perforated PVC or flexible slotted HDPE)



UNDERDRAINS

ADDITIONAL GUIDANCE:

- Minimum underdrain slope = 0.5%
- Observation pipe/clean out
  - 6” rigid non-perforated
  - Every 250 to 300 feet
  - Clean out port
  - Observation well for dewatering rates
- Raised underdrain
  - Maximize infiltration
  - Fluctuating aerobic/ anaerobic conditions → Denitrification



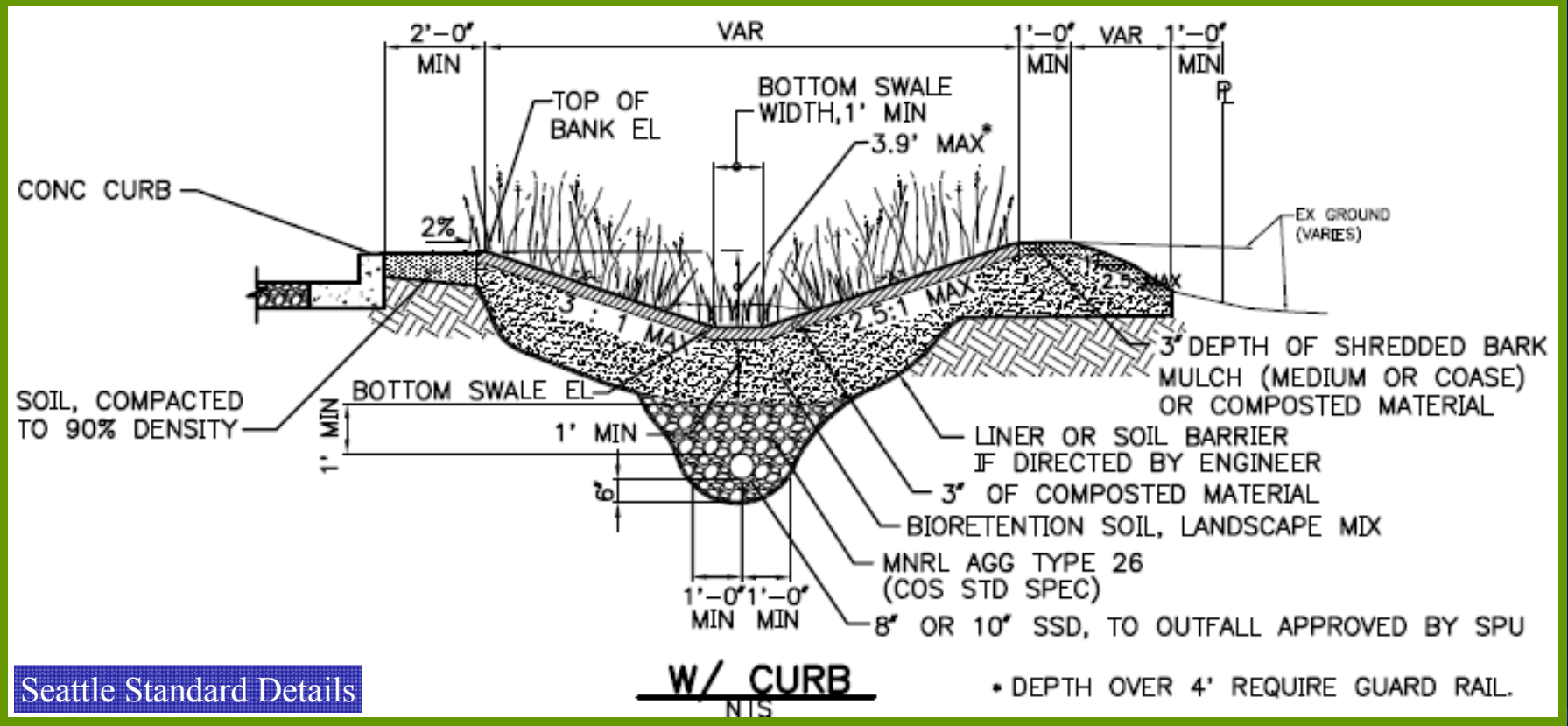
UNDERDRAINS

ADDITIONAL GUIDANCE:

- Orifice/control structures
  - Improve flow control performance
  - Minimum 0.5” orifice diameter
- Design with access for future modification
  - “Adaptive management”
  - Cap drain pipe
  - Throttle flows with orifice

UNDERDRAINS

DESIGN RESOURCES



Seattle Standard Details

BIORETENTION WITH CURB

Overflow

Design Criteria/Types

- Necessary to safely convey flows that exceed capacity
  - Typically required unless designed for full infiltration
  - Protect downstream property and resources
- Overflow elevation set at max. ponding depth
- Directed to downstream BMP or approved discharge pt
- Sizing
  - Conveyance sized for local jurisdiction level of service
  - Consider larger overflows (e.g., grade so overflows to ROW)

Overflow

Surface Overflow

- Sheet flow
- Gravel level spreader
- Exit curb cut / trench drain

Sheet Flow Overflow

Exit Curb Cut Trench Drain

Overflow

Subsurface Overflow

- Catch basin
- Vertical stand pipe
- Horizontal pipe
- Can be connected to underdrain system

Vertical Stand Pipe with Beehive Grate

Layout Options

Single Cell →

Series of Connected Cells ↓

Broadview Green Grid, Seattle, WA

Series

Single

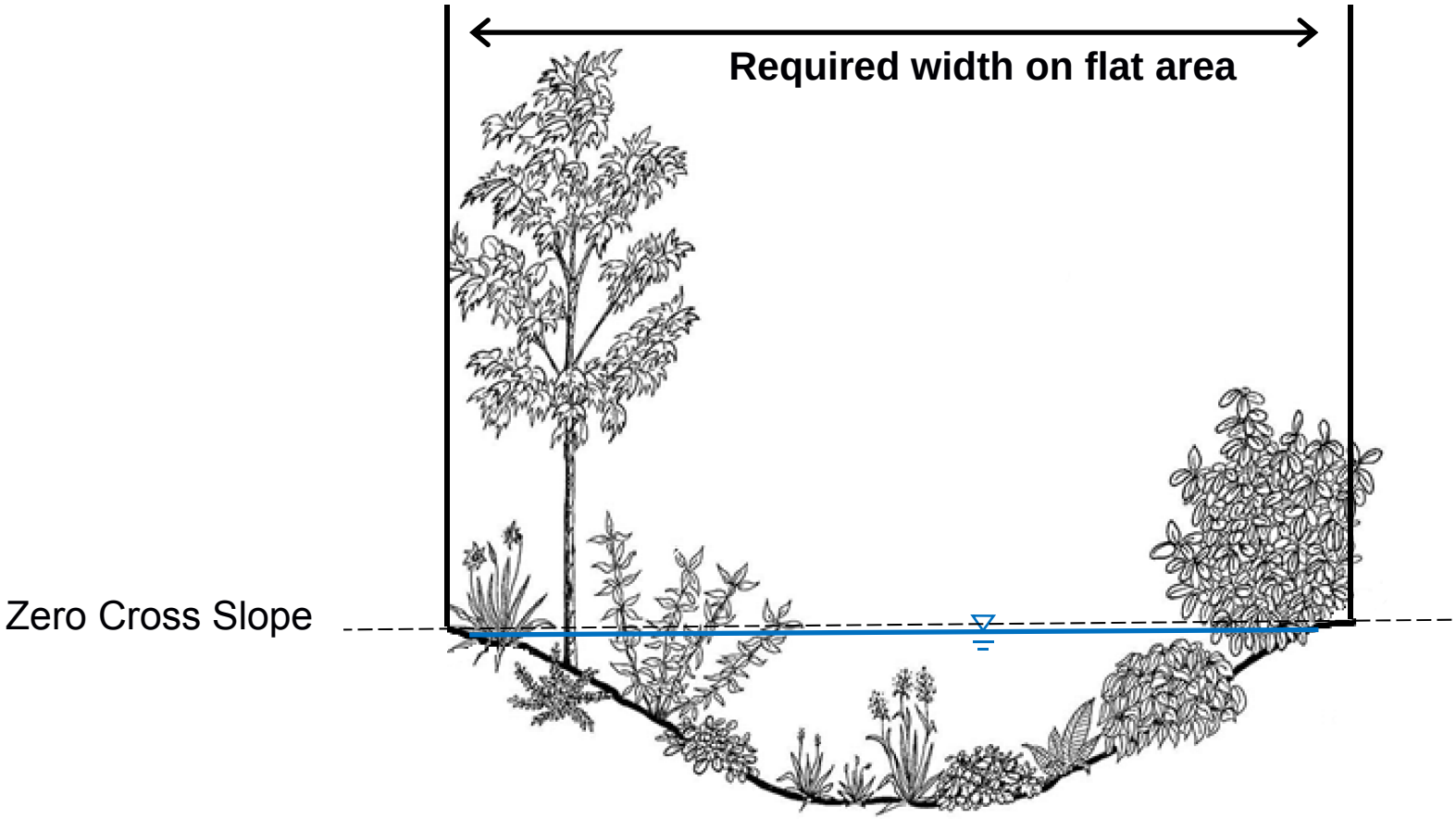
Elevations and Grade

Design Considerations

- Cross Slope
  - Larger footprint area and berming or wall(s) to achieve ponding area
- Longitudinal Slope (series of flat-bottomed cells)
  - Optimum slope is 2% / Maximum slope = 8%
  - Steep slopes: control gradient with intermittent weirs or berms or standpipe overflow to provide ponding and dissipate energy
  - Flat slopes: may need weir to create ponding
- Need positive grade for gravity flow
  - Inflow from contributing area to bioretention cell
  - Overflow from bioretention cell

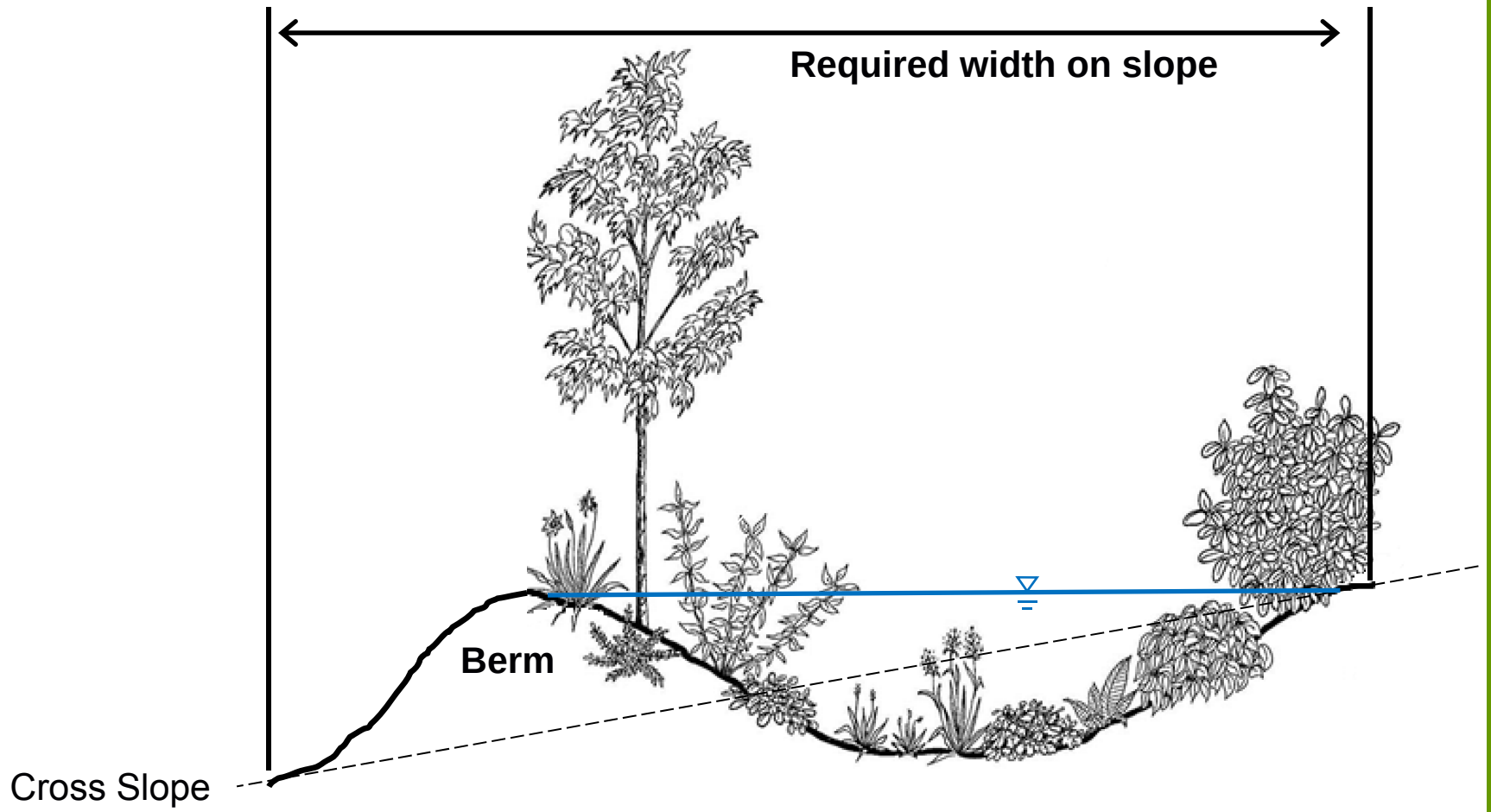
Elevations and Grade

Cross Slope



Elevations and Grade

Cross Slope



Elevations and Grade

Cross Slope

Broadview Green Grid, Seattle, WA

Elevations and Grade

Longitudinal Slope- Create Series of Flat-Bottomed Cells

- Check dams / weirs or vertical stand pipe overflow
  - Reduce flow velocities & erosion potential/dissipates energy
  - Create ponding to promote infiltration
- Types of check dams / weirs
  - Compacted earthen berms covered with vegetation
  - Vegetated hedgerows
  - Rock
  - Wood
  - Concrete
- Optimum spacing determined by longitudinal slope, performance goals and cost

Elevations and Grade

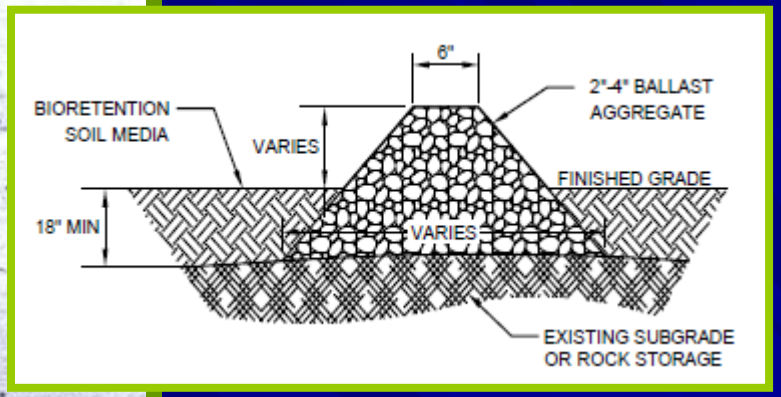
Mild Longitudinal Slope

High Point, Seattle, WA

Mild Longitudinal Slopes

Elevations and Grade

Mild Longitudinal Slope



Mild Longitudinal Slopes

Elevations and Grade

Moderate Longitudinal Slope

Moderate Longitudinal Slopes

Elevations and Grade

Steeper Longitudinal Slope

Walls for cross slopes

110th Street Cascade, Seattle, WA

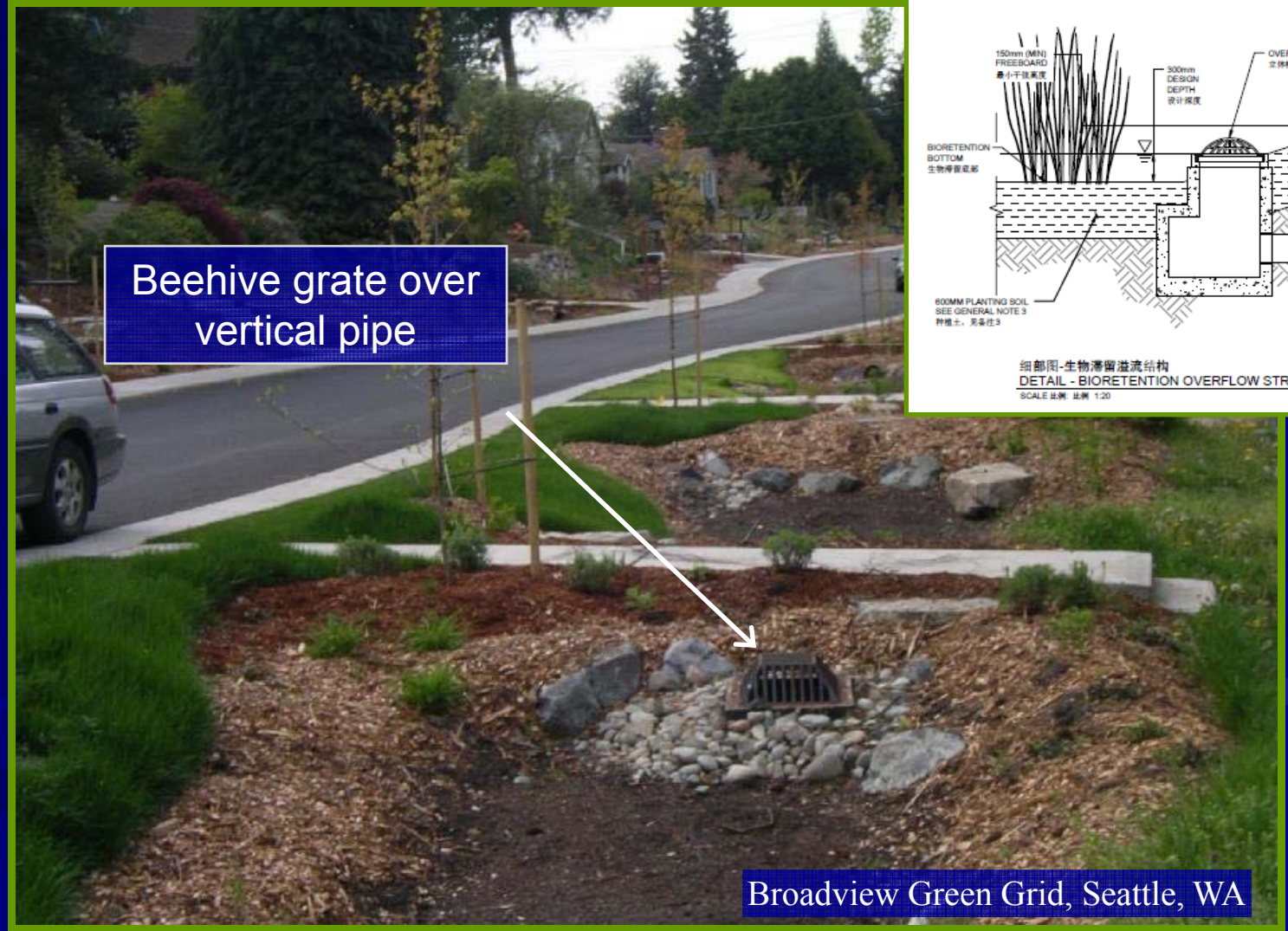
Concrete weirs for longitudinal slopes

107th Street Cascade, Seattle, WA

Steep Longitudinal Slopes

Elevations and Grade

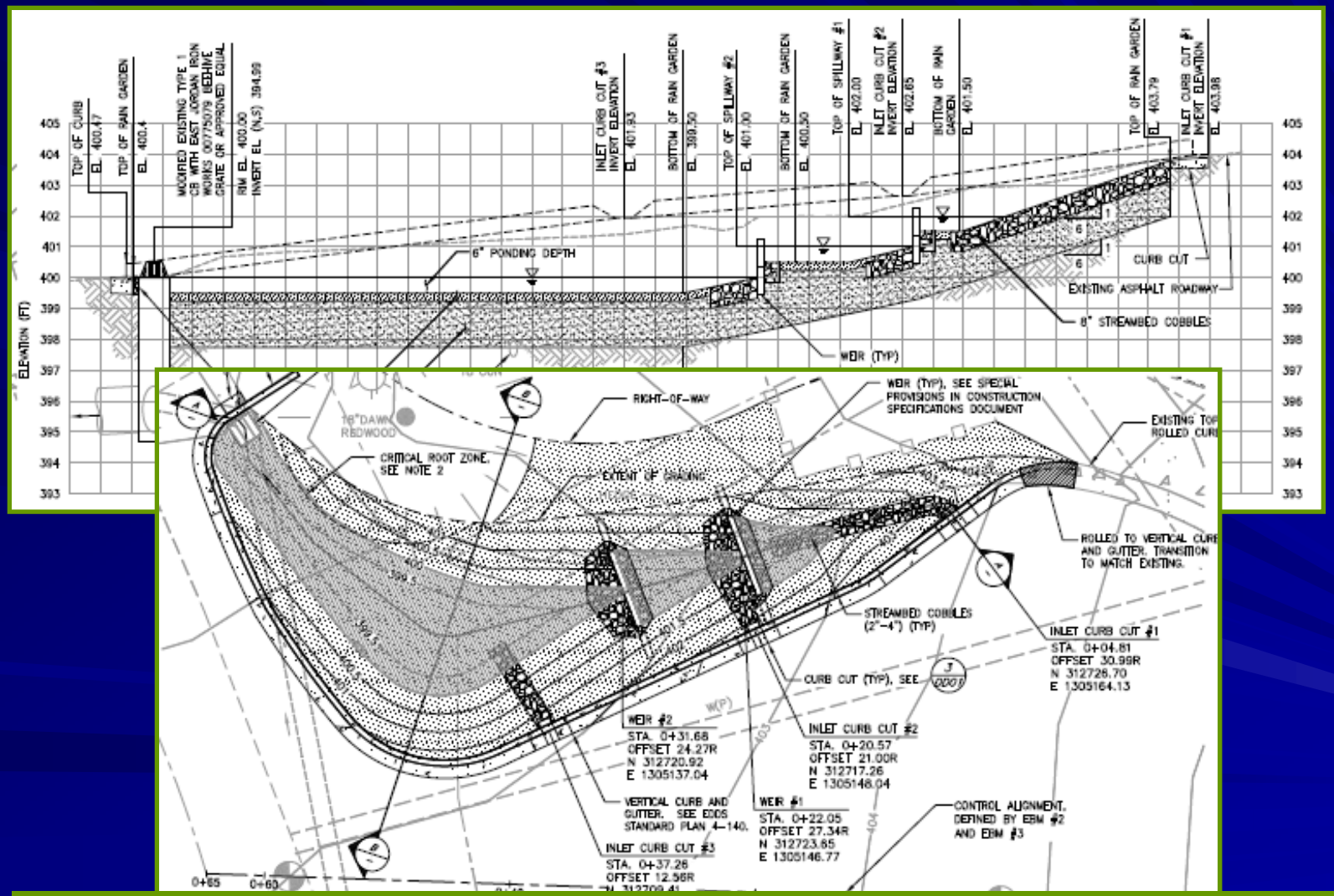
Steeper Longitudinal Slope



Steep Longitudinal Slopes

ELEVATIONS AND GRADE

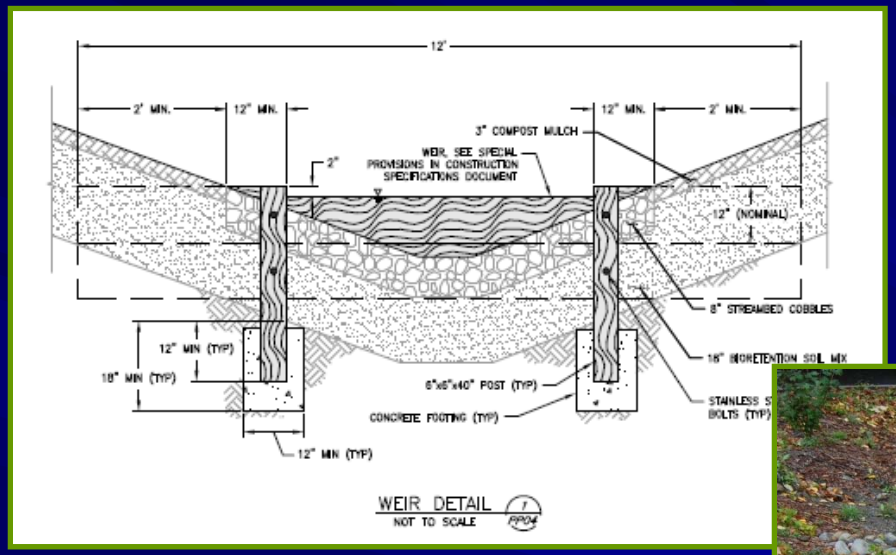
DESIGN EXAMPLE- LONGITUDINAL SLOPE (WEIRS)



SNOHOMISH COUNTY- UPPER SILVER & NICKEL CREEK LID RETROFIT

Elevations and Grade

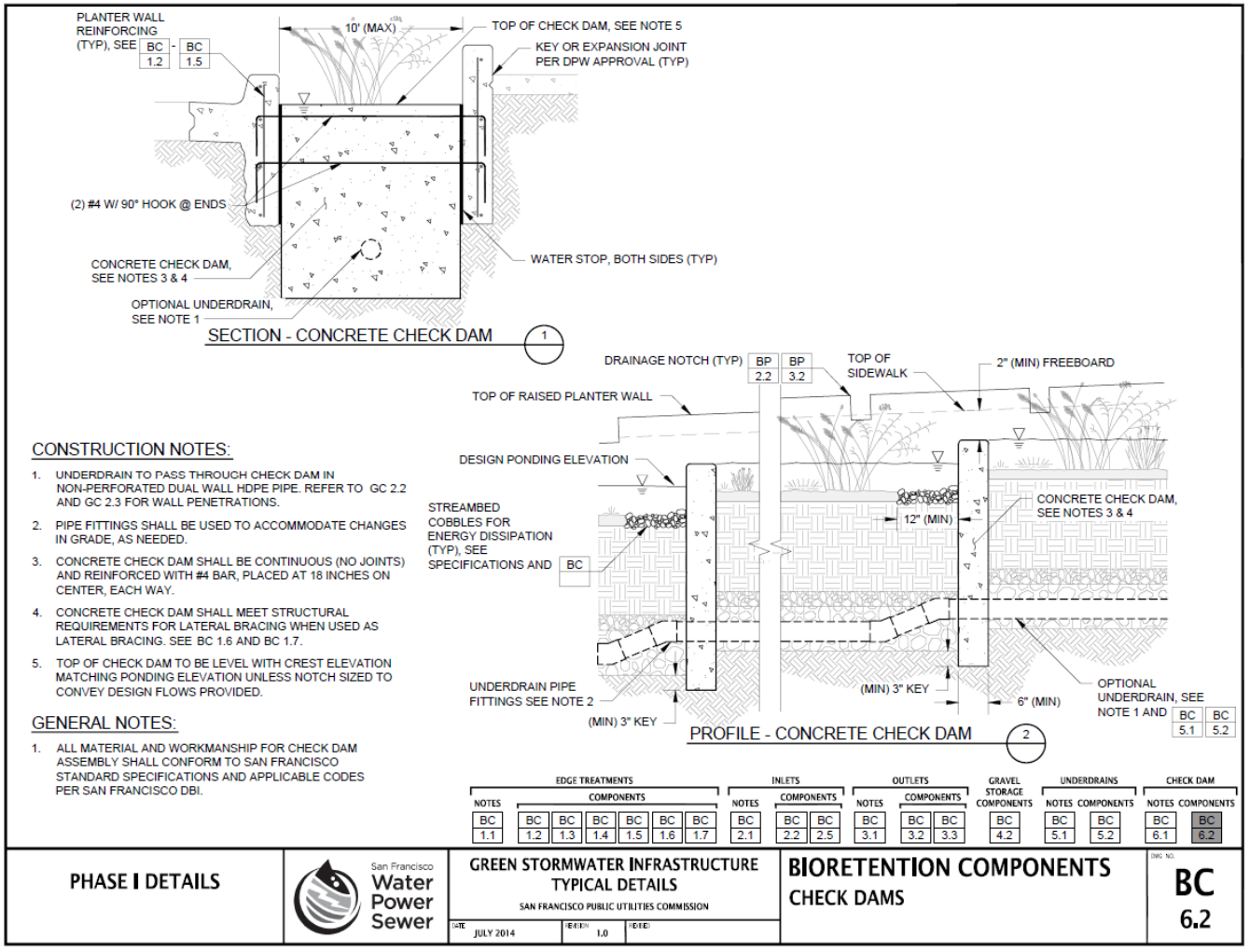
Design Example- Longitudinal Slope (Weirs)



Snohomish County- Upper Silver & Nickel Creek LID Retrofit

ELEVATIONS AND GRADE

DESIGN RESOURCES



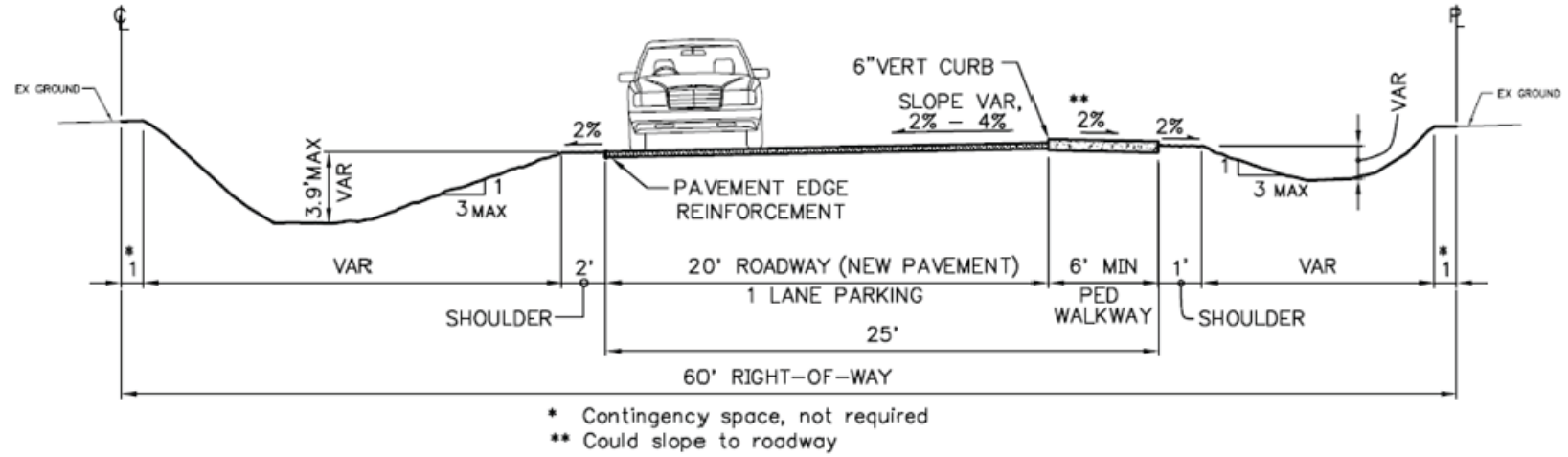
2014 San Francisco Typical Details

CHECK DAMS

Roadway Considerations

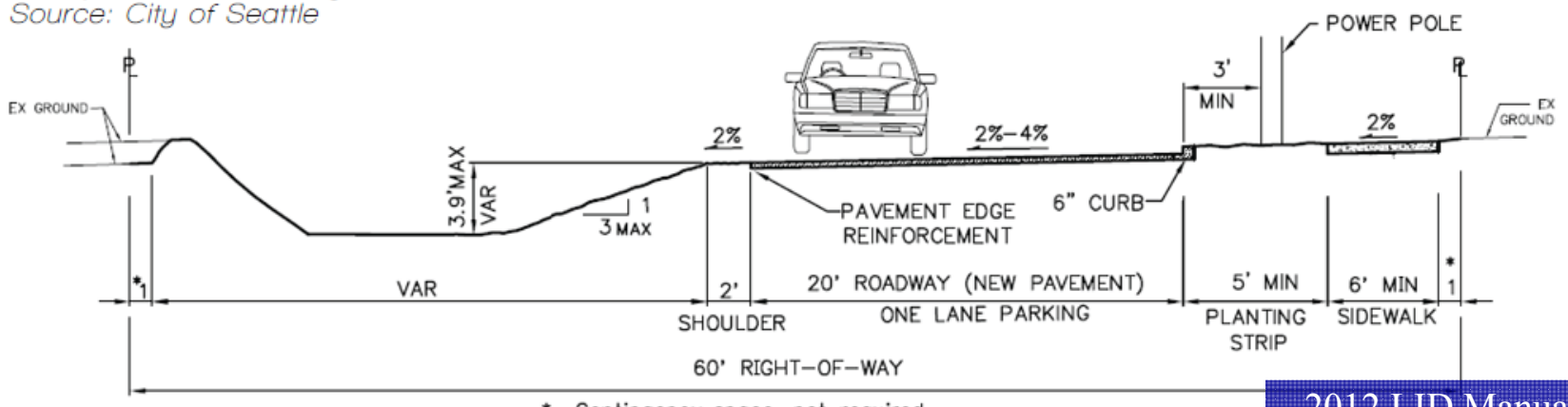
Cross Sections

Example of 20' roadway bioretention on both sides.
Source: City of Seattle



* Contingency space, not required
** Could slope to roadway

Example of 20' roadway bioretention on one side.
Source: City of Seattle

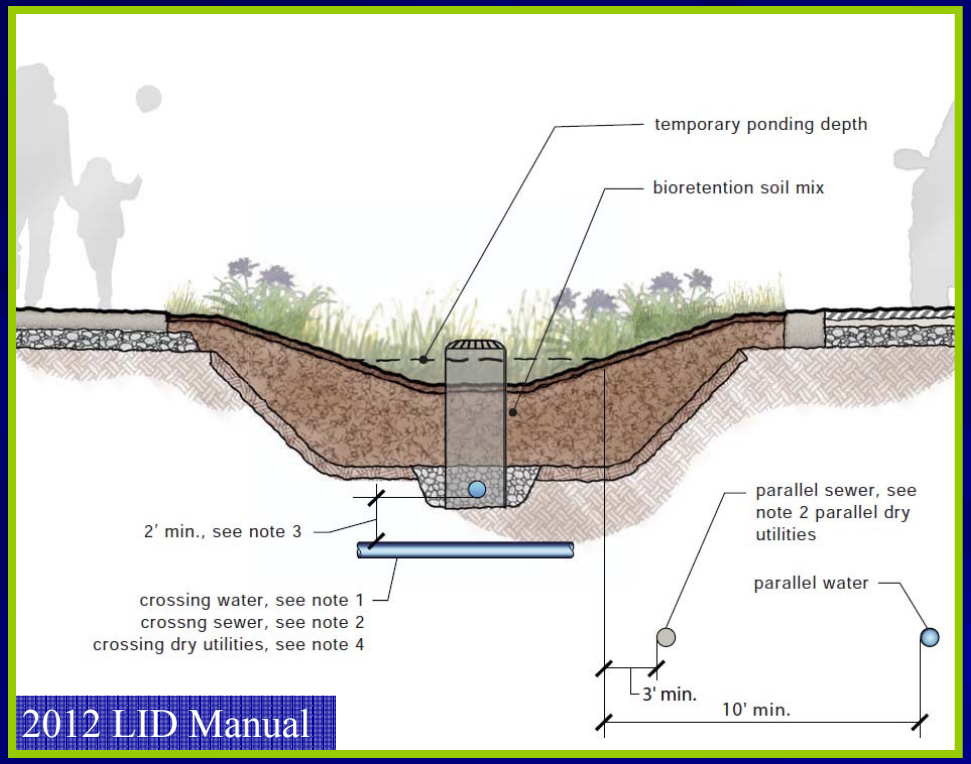


* Contingency space, not required

2012 LID Manual

ROADWAY CONSIDERATIONS

UTILITY SETBACKS



- Publicly owned: water, sewer, SW
- Franchise: communications, gas, power
- Horizontal and vertical setbacks
- Mitigation measures if setbacks not met:
  - Liners over utility
  - Sleeve utility
  - Water stops/trench dams

CONSTRUCTION CONSIDERATIONS

- Minimize site disturbance
- Tree protection
- Preventing over compaction
- Erosion and sediment control
- Construction sequencing (covered tomorrow)

CONSTRUCTION CONSIDERATIONS

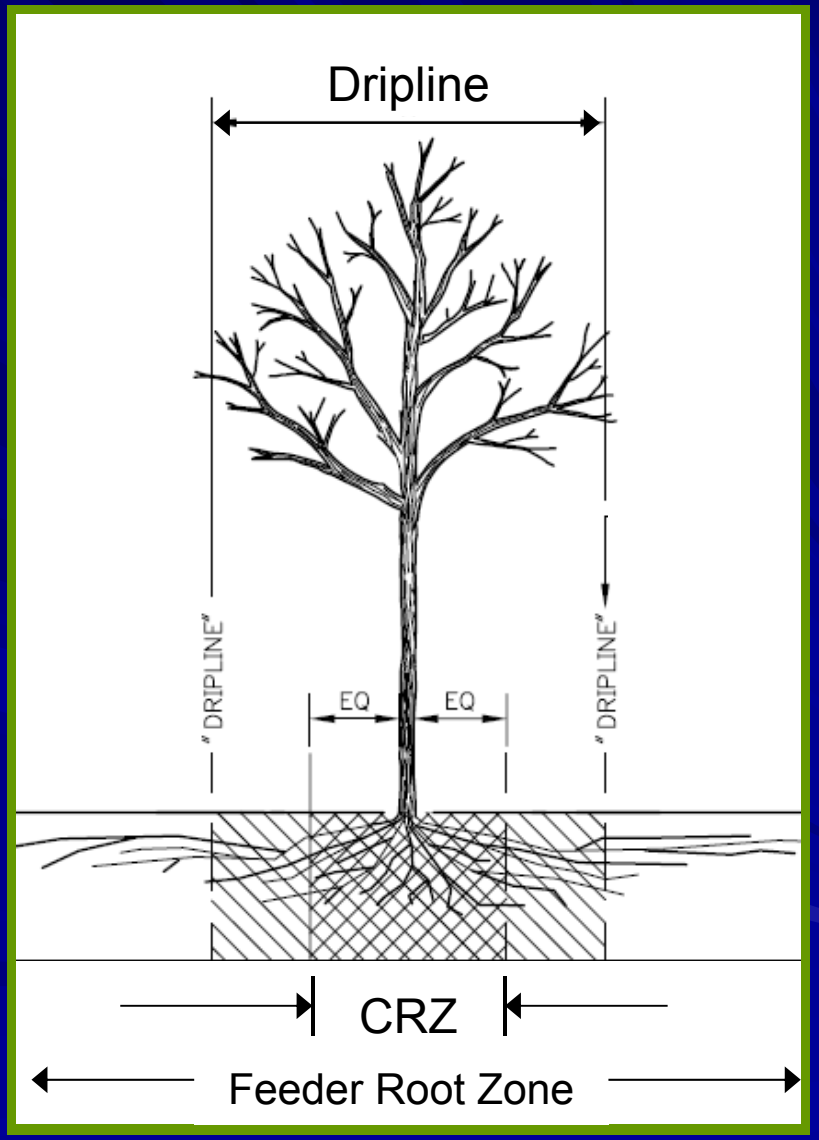
TREE PROTECTION

- Trees are valuable!
- Arborist evaluation
- Valuation posted on each tree
- Vegetation protection in TESC

CONSTRUCTION CONSIDERATIONS

TREE PROTECTION

- Critical Root Zone (CRZ) →
  - No disturbance
  - Arborist present for construction in CRZ
- Dripline →
  - Fence during construction
- Feeder Root Zone →
  - Limit heavy equipment/ stockpiling
  - Limit Trenching
- Utility Boring
  - Tunnel/bore under trees to avoid open cut trench through CRZ and dripline



Construction Considerations

Back-Up Plan for Native Soil Variability

- Do they look like test pit?
- If lower permeability:
  - Increase size
  - Over-ex and add more BR soil
  - Increase ponding depth (if drawdown can be maintained)
  - Add underdrain

Broadview Green Grid, Seattle, WA

Construction Considerations

Preventing Over-Compaction

- Prevent over compaction CRITICAL FOR PERFORMANCE
- No excavation, soil placement, or soil amendment during wet or saturated conditions
- Operate equipment adjacent to (not in) the facility
- If machinery must operate in the facility, use light weight, low ground-contact pressure equipment

Construction Considerations

Vehicular Loading Prism- Some Compaction is Necessary

For road or parking lot stability, need heavily compacted from road prism-2H:1V from edge

High Point, Seattle, WA

Construction Considerations

Scarify Native Soil

Smeared and sealed by bucket

Scarify subgrade to refracture soil and till in BSM at interface

Construction Considerations

Erosion and Sedimentation Control

- Protect adjacent properties
- Protect public waterways and storm systems
- Protect installed work
- Protect infiltration systems including swales, soils and porous pavement

High Point, Seattle, WA

RESOURCES

- LID Technical Guidance Manual for Puget Sound
  www.psp.wa.gov/LID_manual.php
- Rain Garden Handbook for WWA Homeowners
  www.pierce.wsu.edu/water_quality/LID/raingarden_handbook.pdf
- Seattle Public Utilities GSI
  www.seattle.gov/util/greeninfrastructure
- Seattle Stormwater Manual
  www.seattle.gov/dclu/codes/dr/DR2009-17.pdf
- Seattle Right-of-Way Improvements Manual
  http://www.seattle.gov/transportation/rowmanual/manual/
- Portland Sustainable Stormwater
  www.portlandonline.com/bes/index.cfm?c=34598

SEATTLE DESIGN REVIEW

Technology Description
A bioretention cell is a shallow depression with a designed soil mix and plants, with or without an underdrain. See Figures 4.7 and 4.8 of the Manual Bioretention cells may be connected in series, with the overflows of upstream cells directed to downstream cells.

Infiltration Feasibility Requirements (Manual Volume 3, Section 4.3.4)

	Review Item
FC	1. Facility is not within landslide-prone areas as defined by the Regulations for Environmental Critical Areas (SMC 25.09) and shown on the Critical Areas theme of GIS.
FC	2. Facility is not located in areas likely to have excessive sediment contamination (such as areas to be sanded) or high potential for concentrated pollutant spills.
FC	3. For projects located on arterial streets and/or in areas of dense underground infrastructure, the facility is limited to the sidewalk and planting strip area only and only receives sidewalk runoff, unless otherwise approved by SPU.
FC	4. Infiltration is typically not permitted within any of these specified setbacks:
	▪ Within the top of steep sloped areas, as defined by the Regulations for Environmental Critical Areas (SMC 25.09) and shown on the Critical Areas theme of GIS, calculated as 10 times the slope rise (to a 500 foot maximum) unless demonstrated as feasible by geotechnical analysis
	▪ Within 5 feet from property lines (excluding the property line abutting ROW)
	▪ Within 5 feet from structure without basement, 10 feet from structure with basement when runoff from< 5,000 square feet of new/replaced impervious area is infiltrated on site
	▪ Within a 1H:1V slope between the bottom edge of an infiltration facility and a building structure when runoff from = 5,000 square feet of new/replaced impervious area is infiltrated on site. The resulting setback is no less than 5 feet from structure without basement, 10 feet from structure with basement.
	▪ Within 100 feet of a contaminated site or abandoned landfill

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