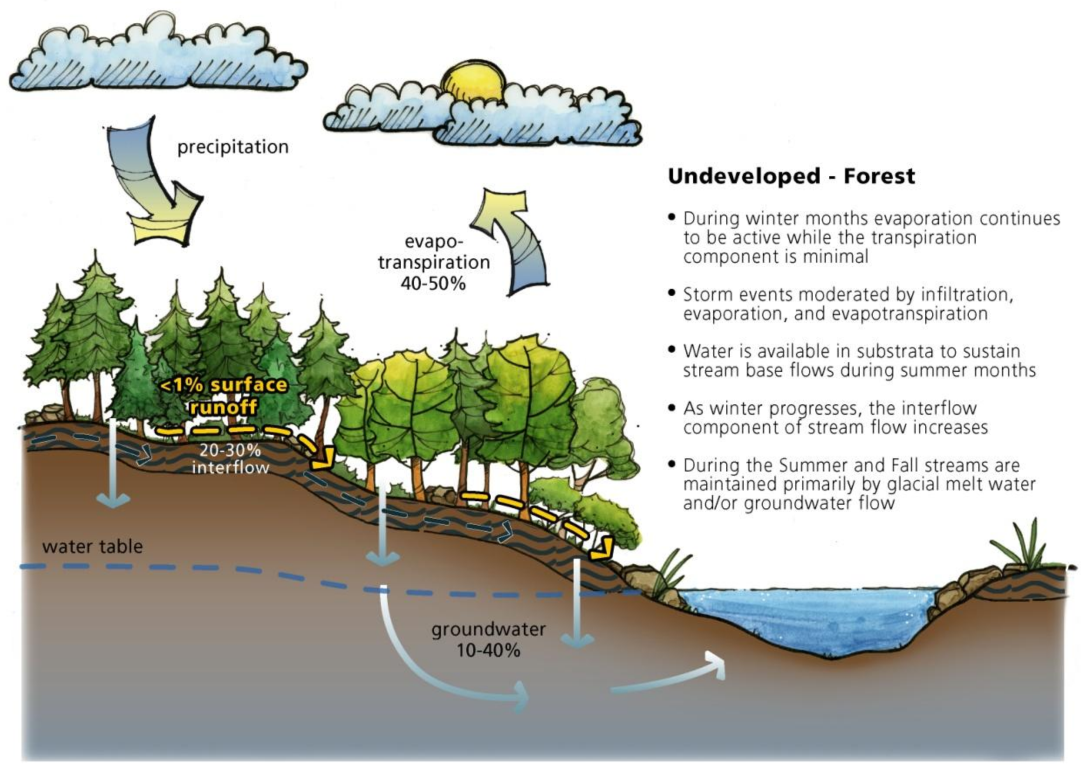
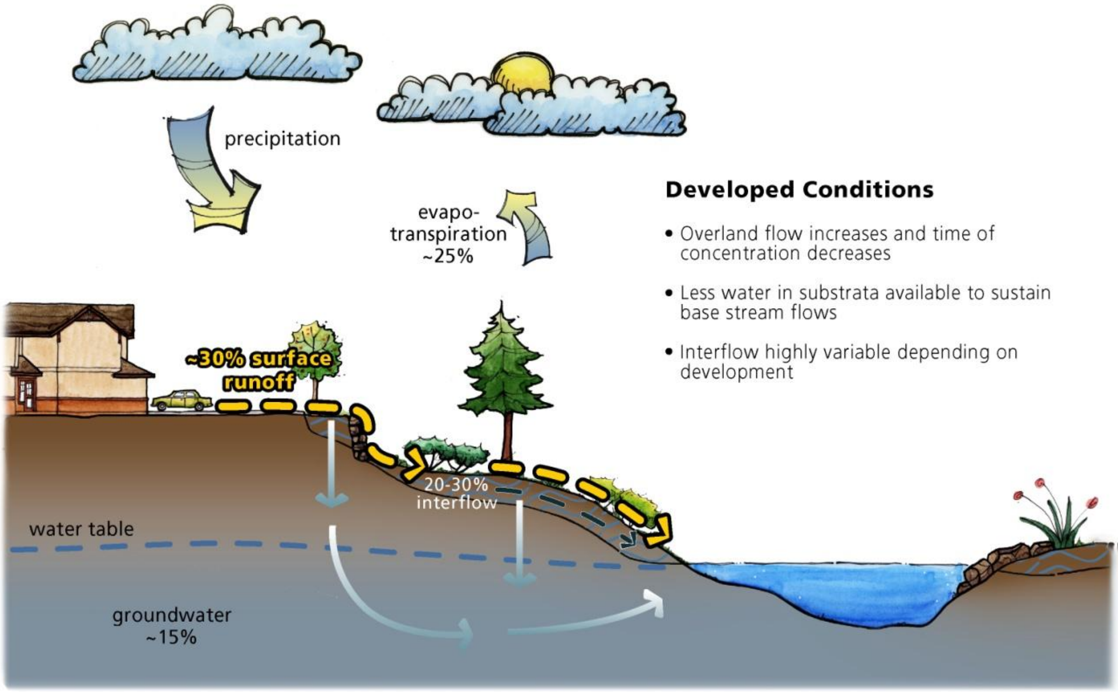
Chapter 1: Introduction

1-1: Puget Sound water budget before development.

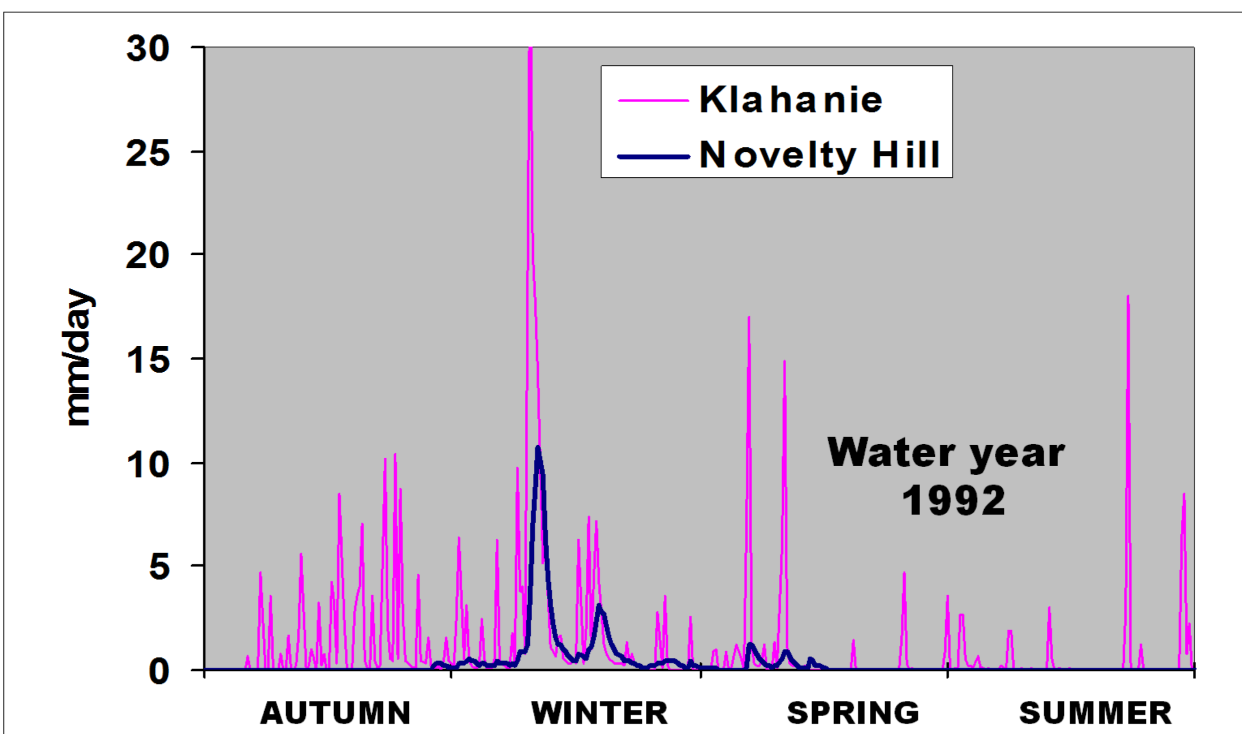


1-2: Puget Sound development.

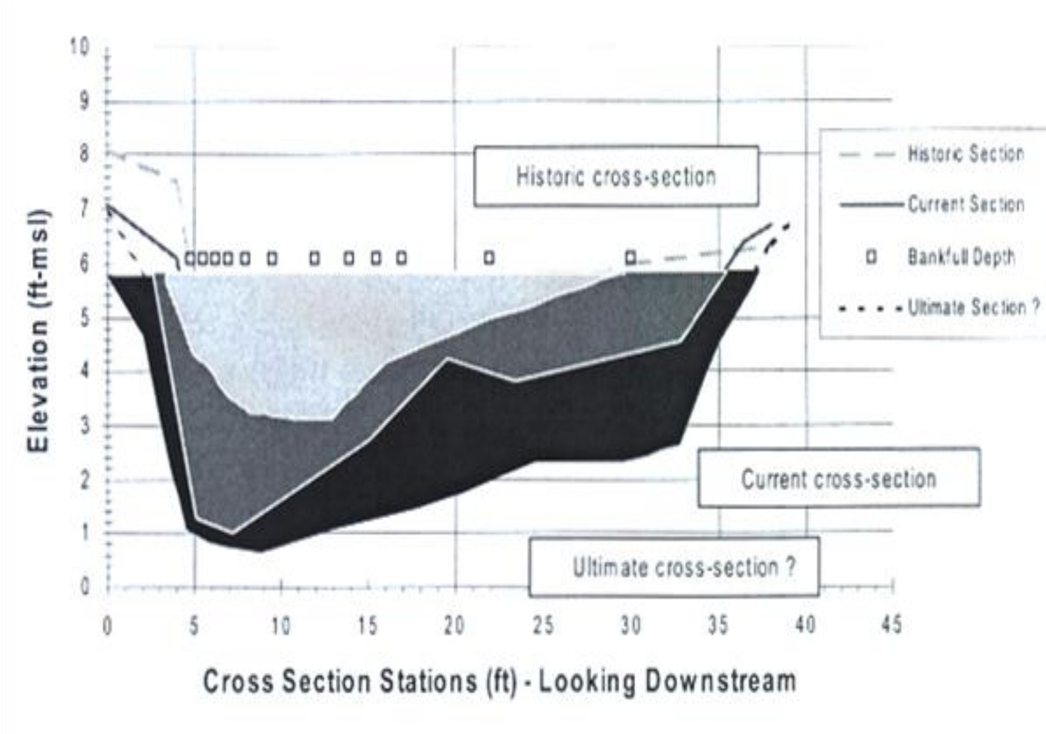
1-3: Puget Sound water budget after development.



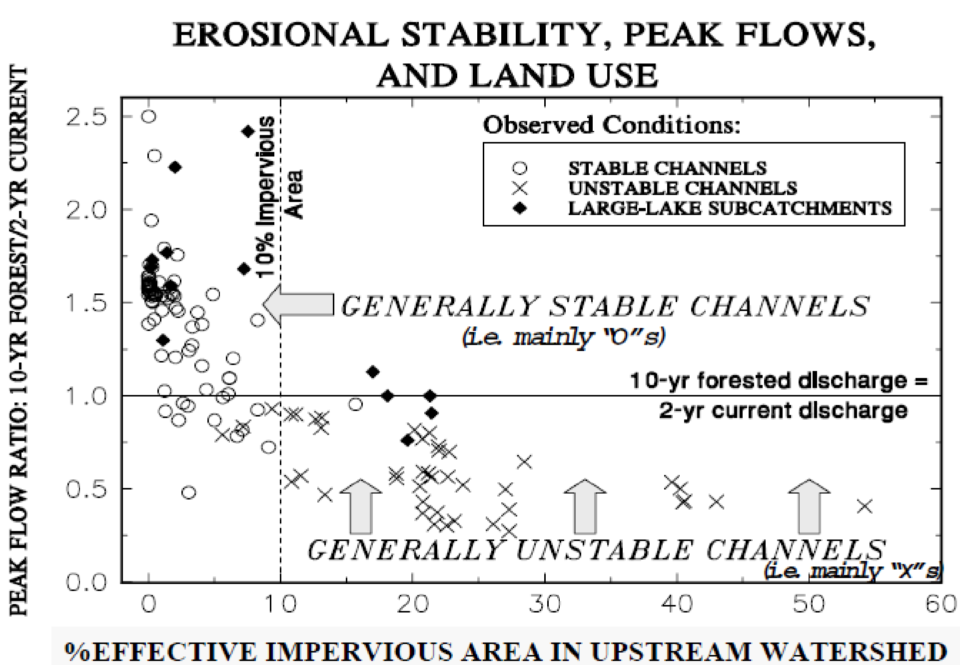
1-4: Urban vs Rural hydrograph.



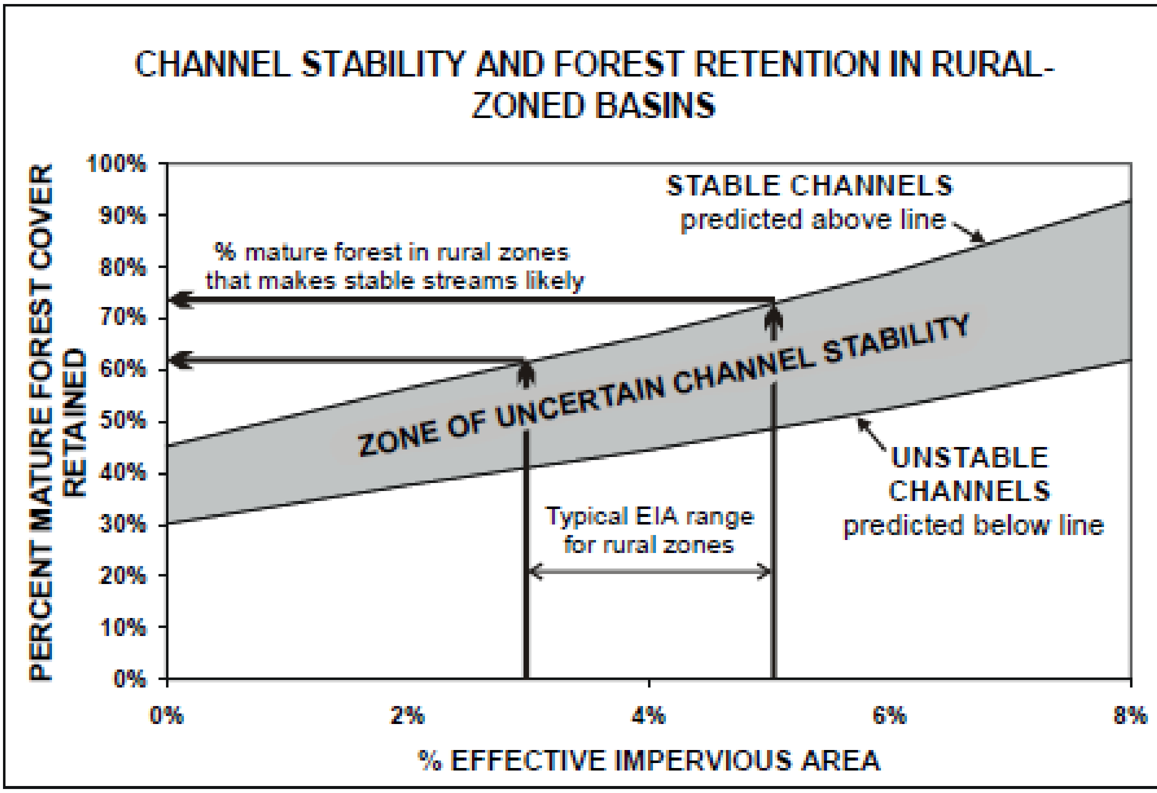
1-5: The channel cross section documents the long-term record of actual channel enlargement in response to the transition from a relatively undisturbed to increasingly urbanized watershed in the eastern U.S. From Luna Leopold.



1-6: EIA and ratio of 10yr forested to 2yr urban flow.



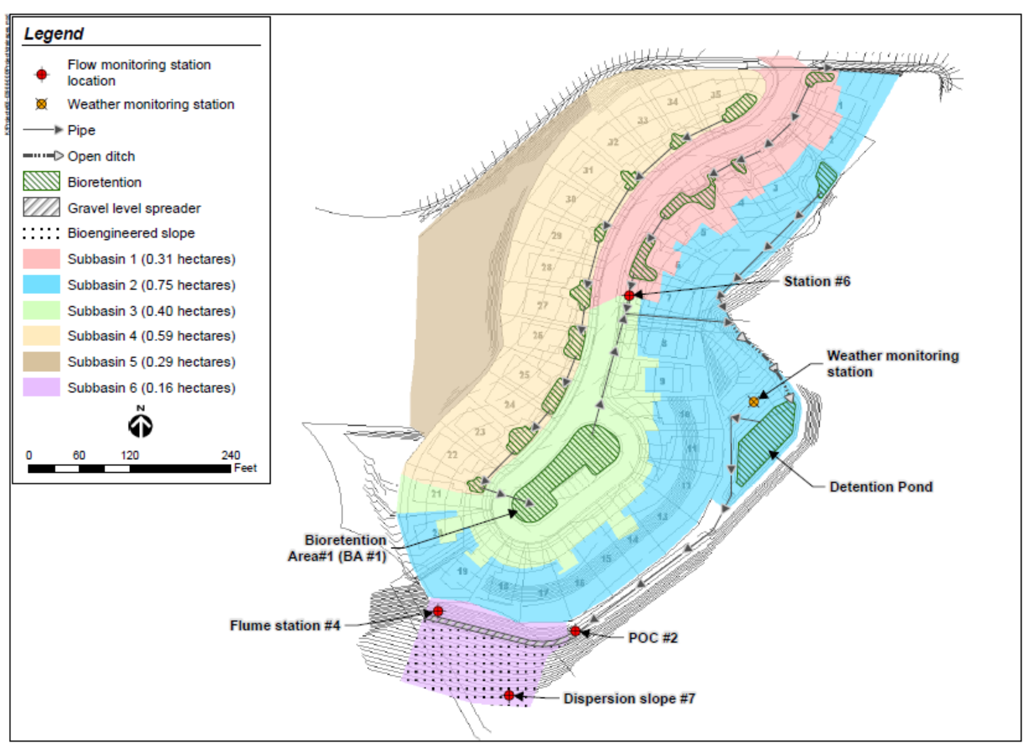
1-7: Forest cover EIA and stream channel stability.



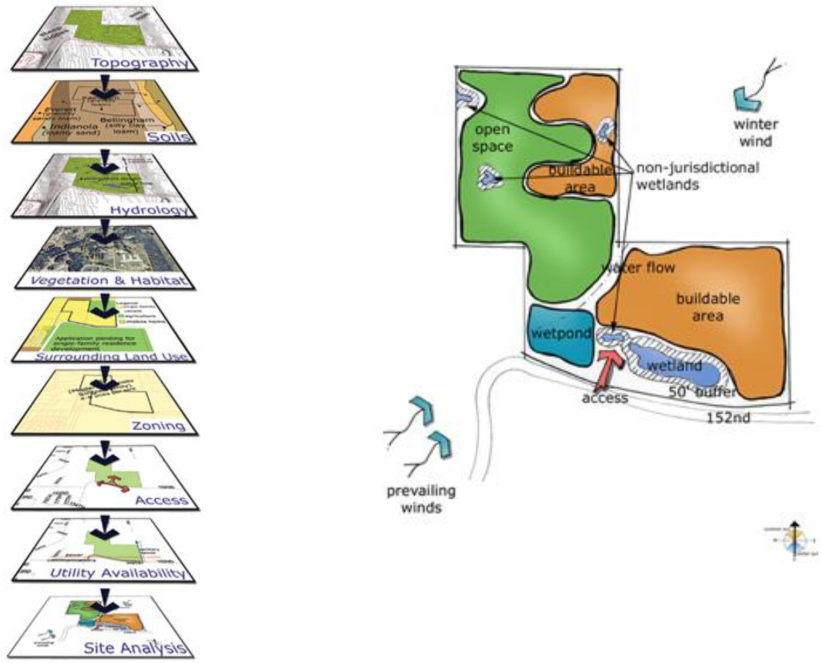
Chapter 2: Site Assessment

2-1: Pilot Infiltration Test.

2-2: This 35 home LID project is divided into sub-catchments or small contributing areas to facilitate a distributed stormwater management approach.



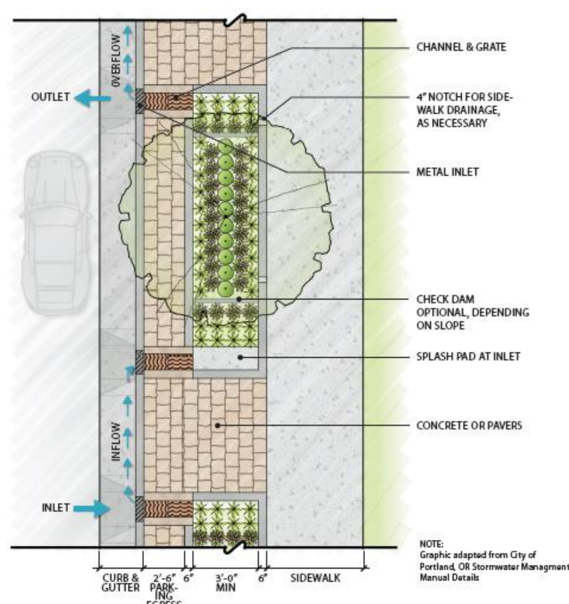
2-3 Composite site analysis for a residential subdivision



2-4 Large lot layout

3-1: Curb extensions slowing traffic and managing stormwater (Portland, OR).

3-2: Bioretention planter integrated into the streetscape (Portland, OR).

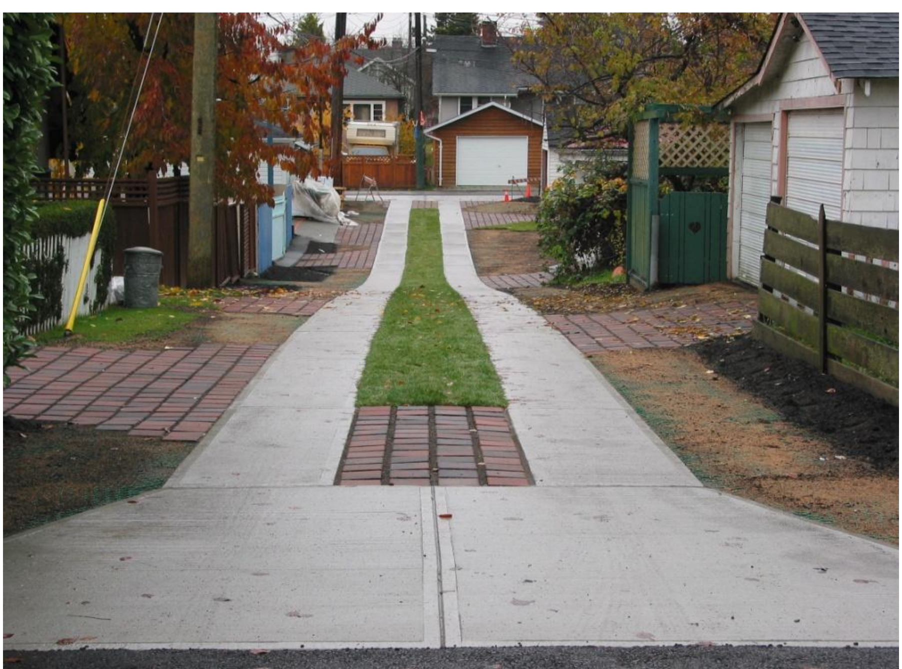


3-3: Urban trees with permeable pavement and subsurface soil galleries integrated into the streetscape (Shoreline, WA) .

3-4: Sherbourne plan view (Bellevue, WA).

3-5: Combined commons and stormwater facility at Sherbourne (Bellevue, WA) .

3-6: Vancouver, B.C. Country Lane alley uses a combination of permeable paving materials .

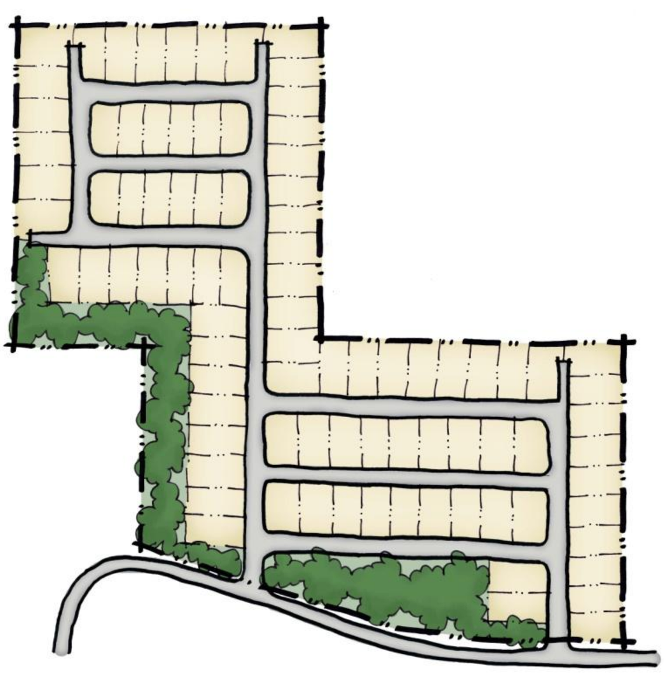


3-7: Bioretention planters (Portland State University, OR).

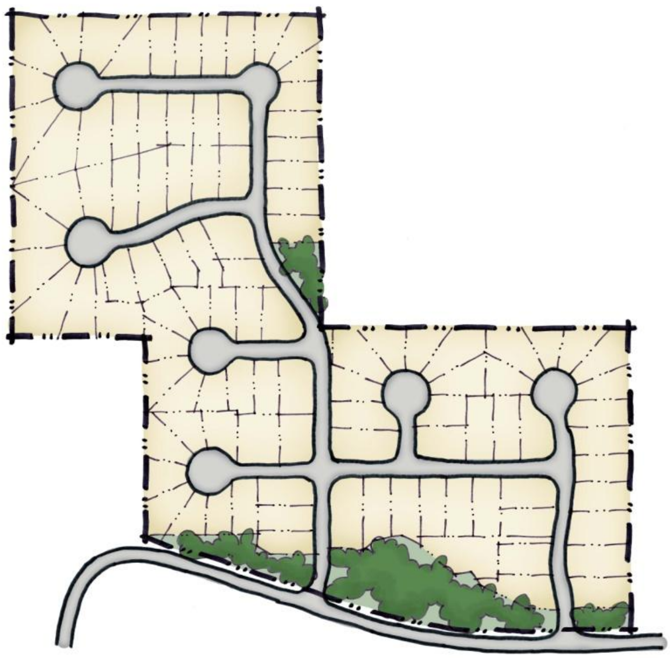
3-8: Bioretention incorporated into the center of an apartment courtyard. This apartment complex was a used car sales lot. By incorporating LID into the redevelopment , stormwater management can be enhanced over the previous land use. (Buckman Heights, Portland State, OR).

3-9: Danielson Grove case study.

3-10: Grid road layout.

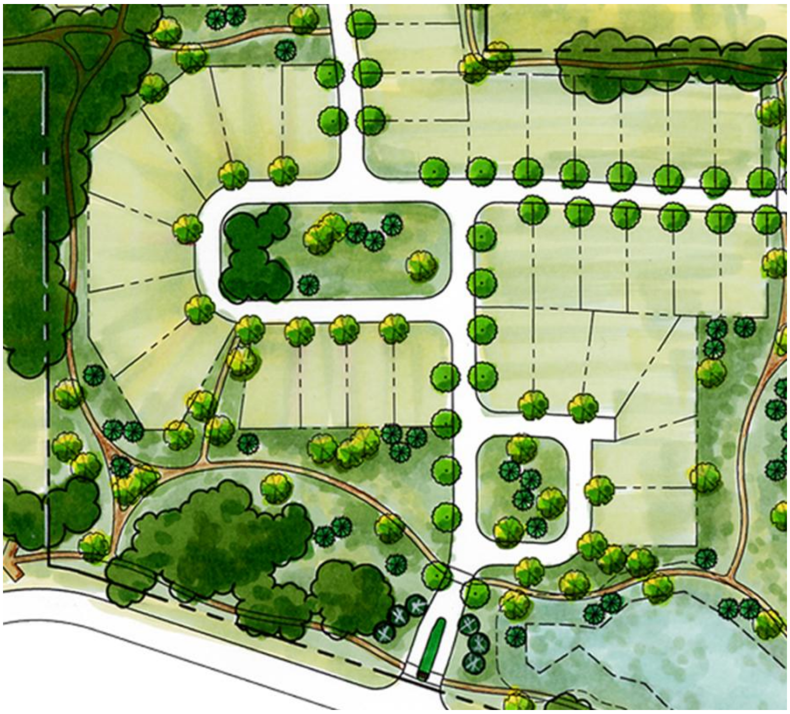


3-11: Curvlinear road layout.

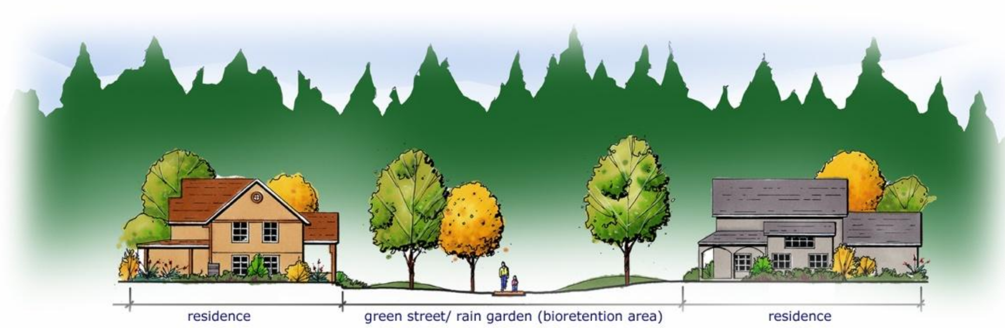


3-12: Hybrid road layout.

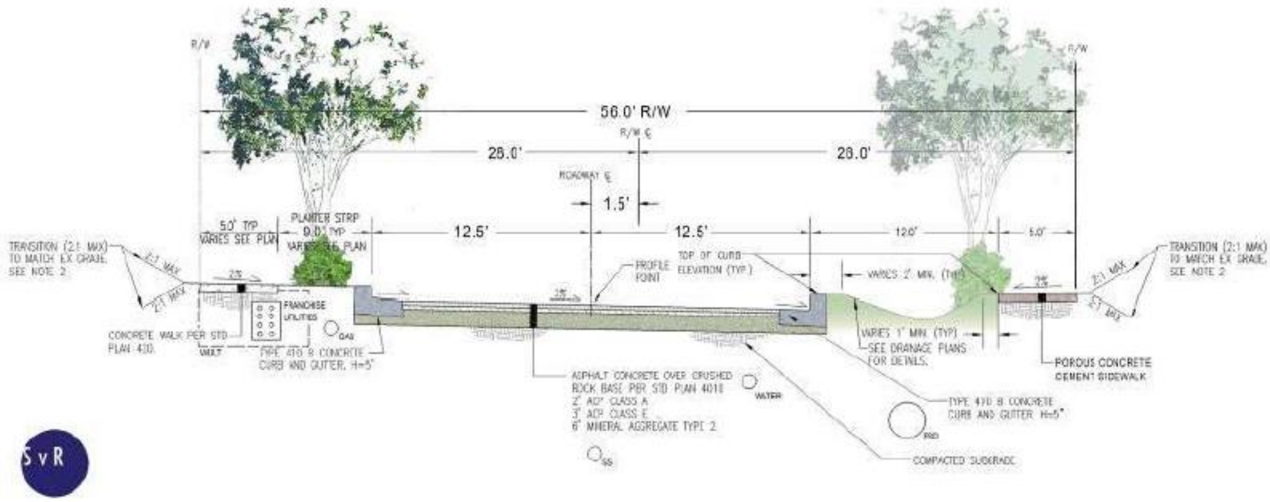
3-13: Loop road design.

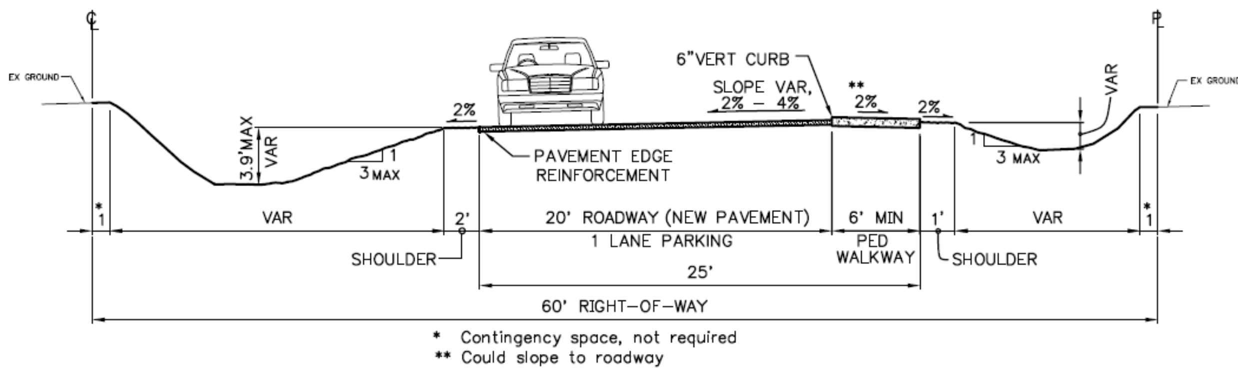


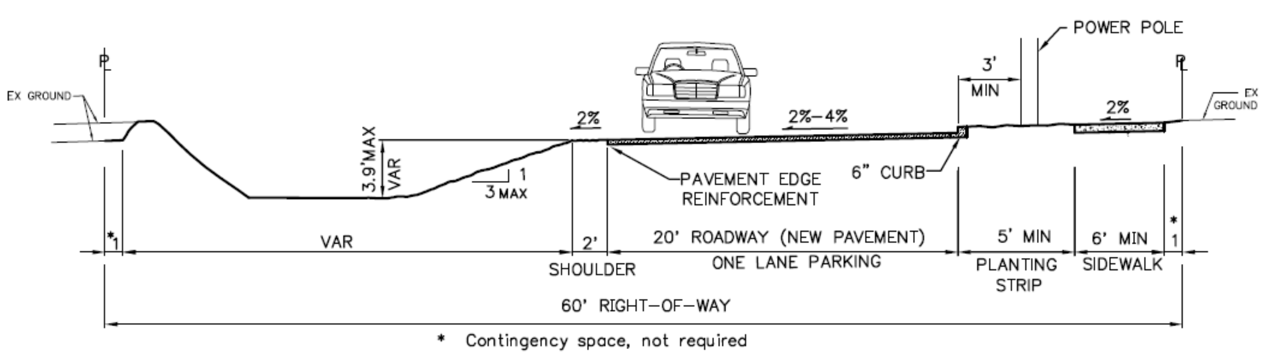
3-14: Green street section.



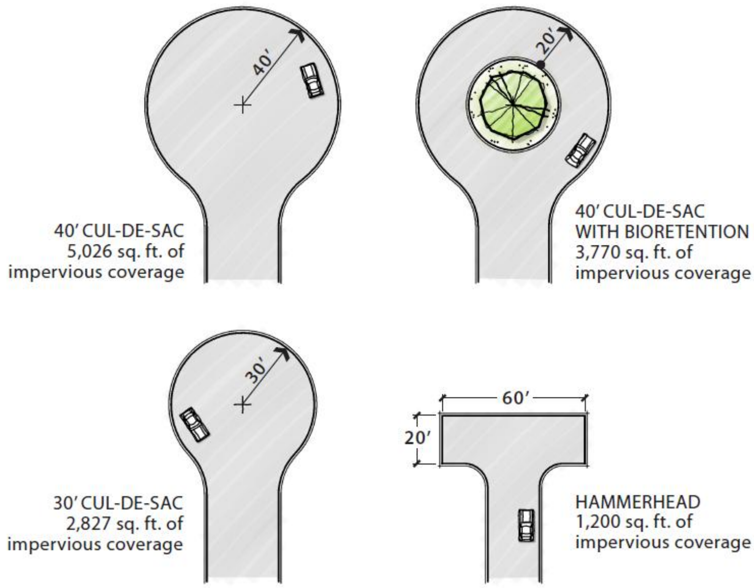
3-15: LID road sections (City of Seattle).



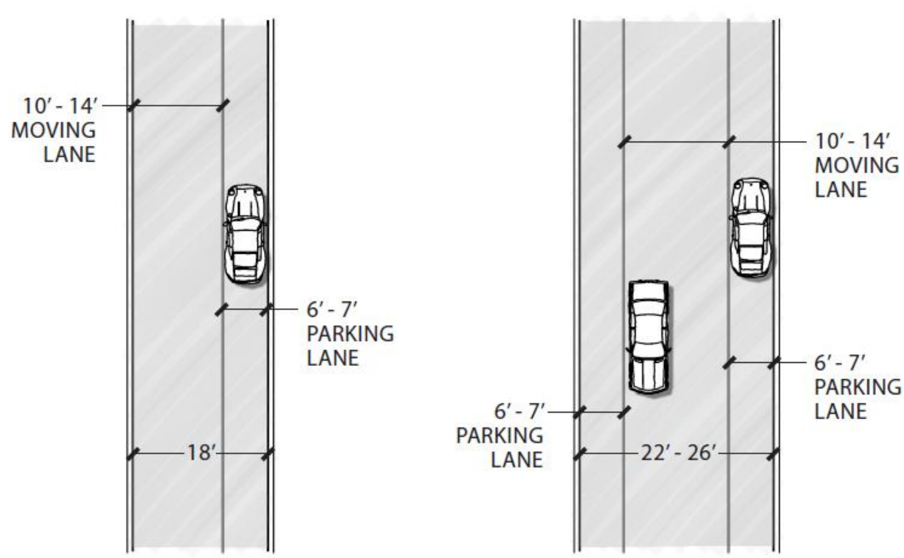




3-16: Turnaround areas and associated impervious surface coverage.

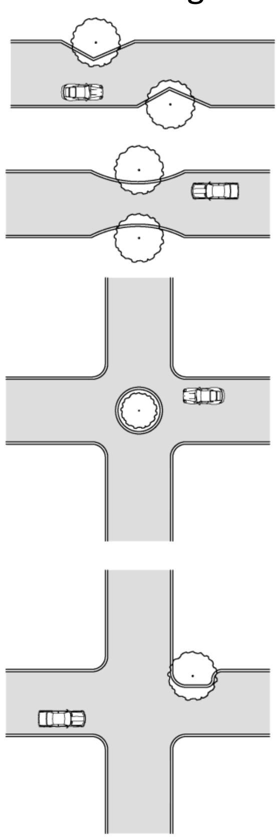


3-17: Street options to reduce impervious coverage.



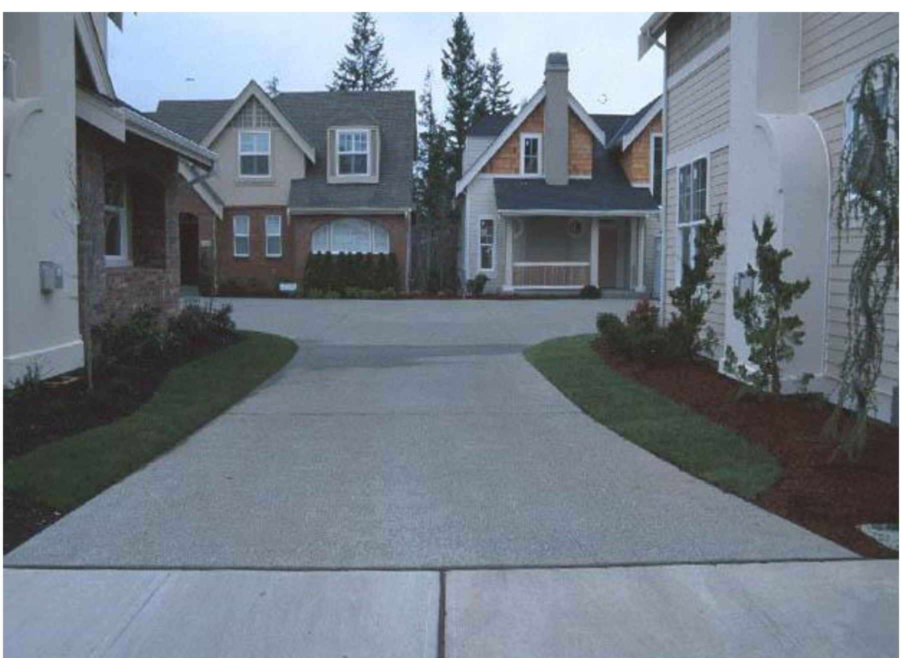
3-18: Pullout parking.

3-19: Integrated traffic calming with stormwater management.



3-20: Stormwater management integrated with traffic calming strategies (Portland, OR).

3-21: Shared driveway (Issaquah, WA).

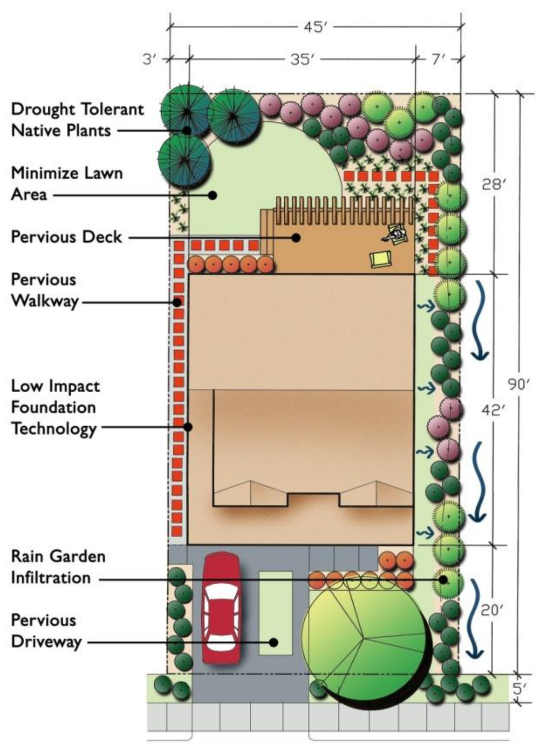


3-22: Shared driveways for large lots.

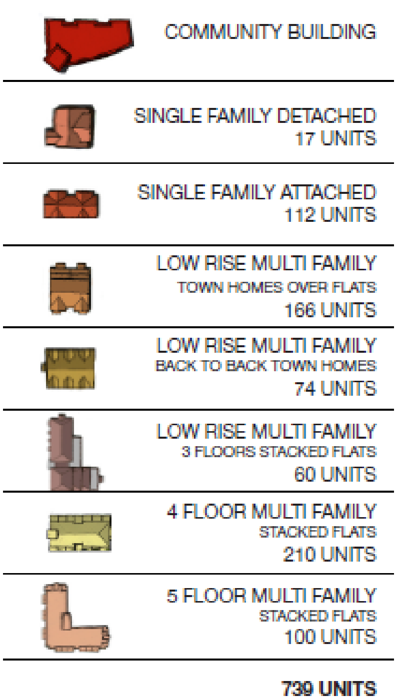
3-23: Conventional vs LID lot layout.

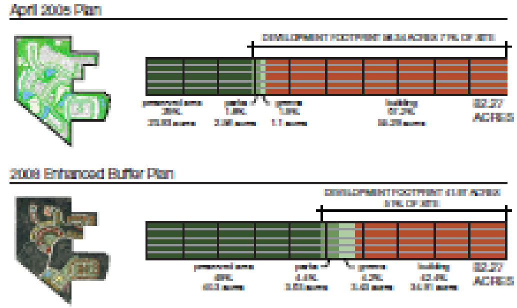
3-24: Zero lot line configuration.

3-25: Small lot layout using LID practices.

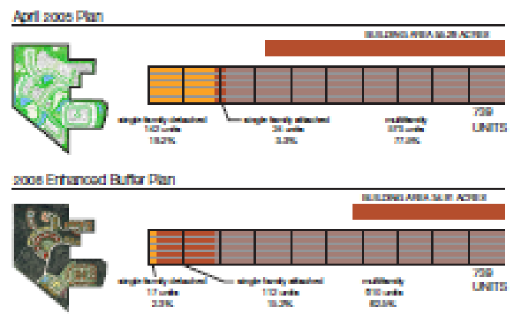


3-26: Fairhaven case study graphics

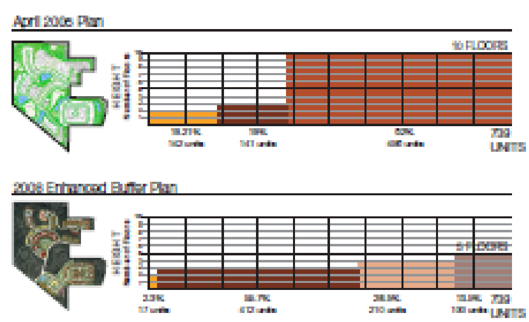




OPEN SPACE VS. BUILDING AREA

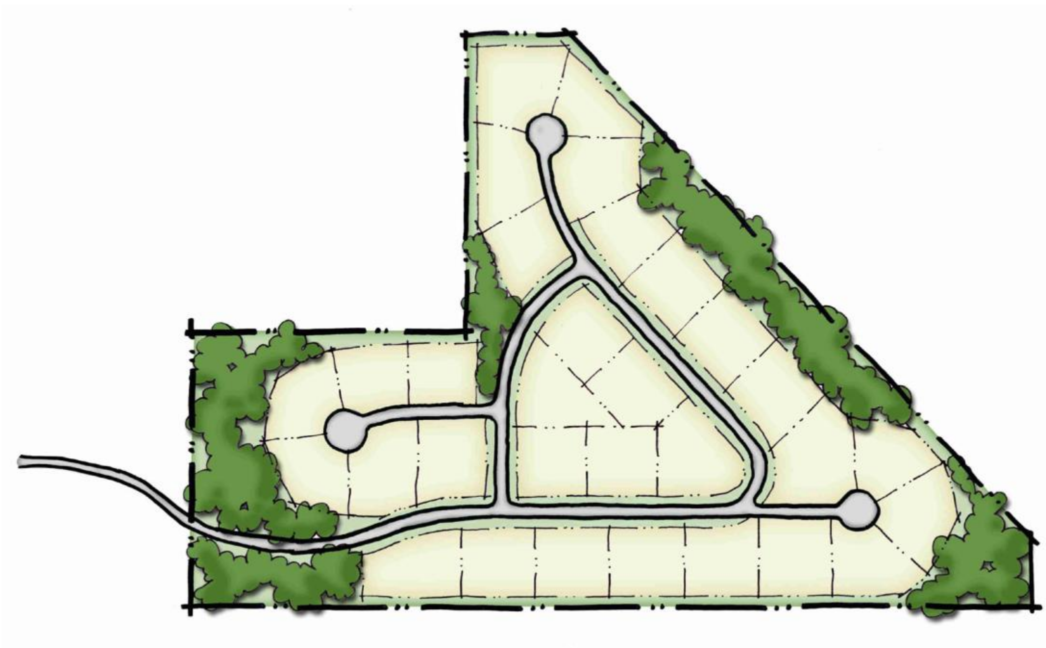


HOUSING MIX



BUILDING HEIGHT

3-27: Conventional rural large lot vs rural cluster design.

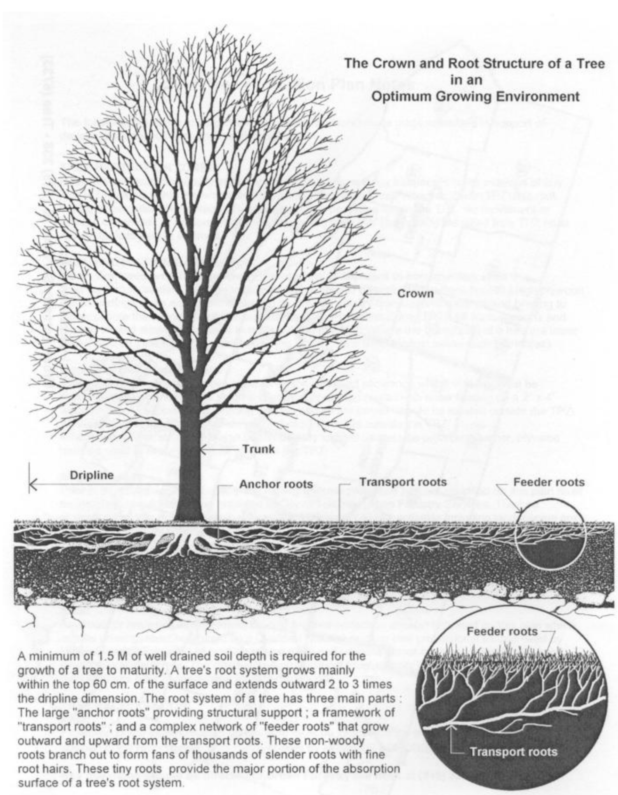


3-28: Wilson Motors graphics.

Chapter 4: Vegetation and Soil Protection, Reforestation and Maintenance

4-1 low live crown ratio tree example

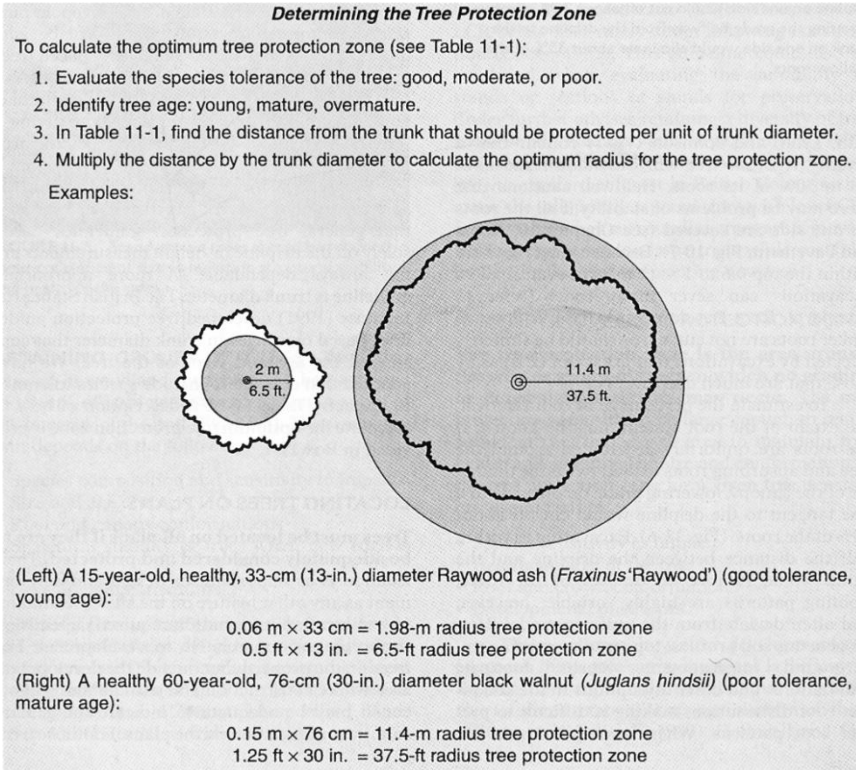
4-2 Root structure and protection area



[A] Majority root system
0 - 910 mm depth

Critical Absorbing roots in top
450 mm of soil

4-3 Root protection area



Determining the Tree Protection Zone

To calculate the optimum tree protection zone (see Table 11-1):

1. Evaluate the species tolerance of the tree: good, moderate, or poor.
2. Identify tree age: young, mature, overmature.
3. In Table 11-1, find the distance from the trunk that should be protected per unit of trunk diameter.
4. Multiply the distance by the trunk diameter to calculate the optimum radius for the tree protection zone.

Examples:

(Left) A 15-year-old, healthy, 33-cm (13-in.) diameter Raywood ash (*Fraxinus* 'Raywood') (good tolerance, young age):

0.06 m × 33 cm = 1.98-m radius tree protection zone
0.5 ft × 13 in. = 6.5-ft radius tree protection zone

(Right) A healthy 60-year-old, 76-cm (30-in.) diameter black walnut *(Juglans hindsii)* (poor tolerance, mature age):

0.15 m × 76 cm = 11.4-m radius tree protection zone
1.25 ft × 30 in. = 37.5-ft radius tree protection zone

4-2 Tree protection fencing and signage

Chapter 5: Precision Site Preparation and Construction

5-1 Site flat or sloping away from bioretention area

5-2 Sites sloping to bioretention areas require extra attention to sediment and erosion control until site is stabilized (note curb cuts are blocked to rout stormwater passed bioretention area and pervious concrete sidewalk is wrapped in filter fabric during construction).

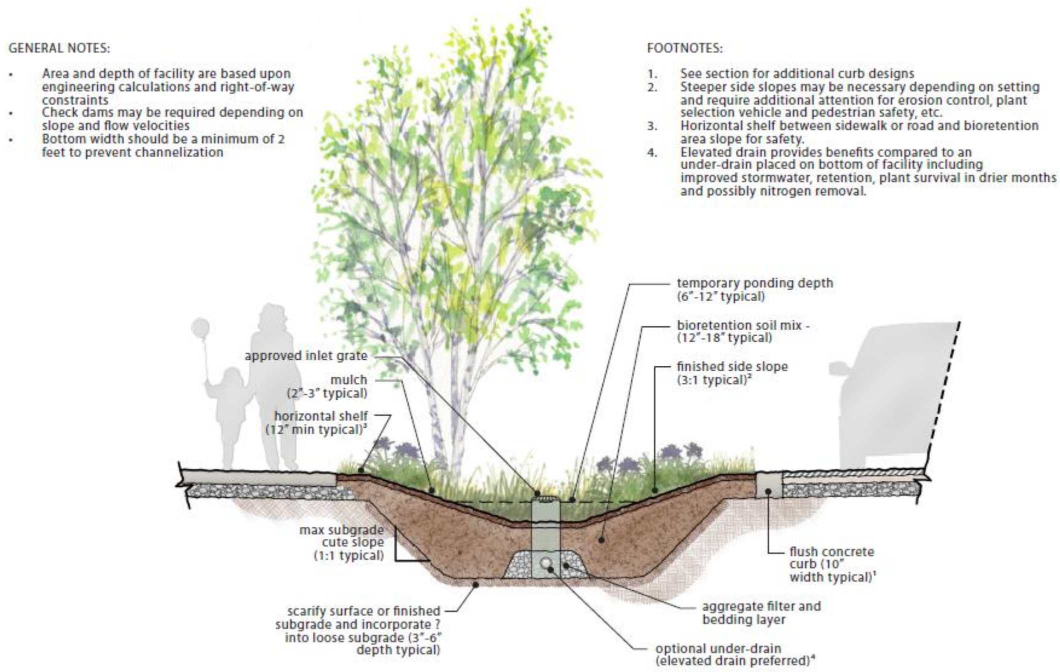
5-3 Pervious concrete sidewalk protected with filter fabric that is wrapped and secured during construction.

5-4 Filter fabric protecting aggregate base for a porous asphalt residential access road during construction.

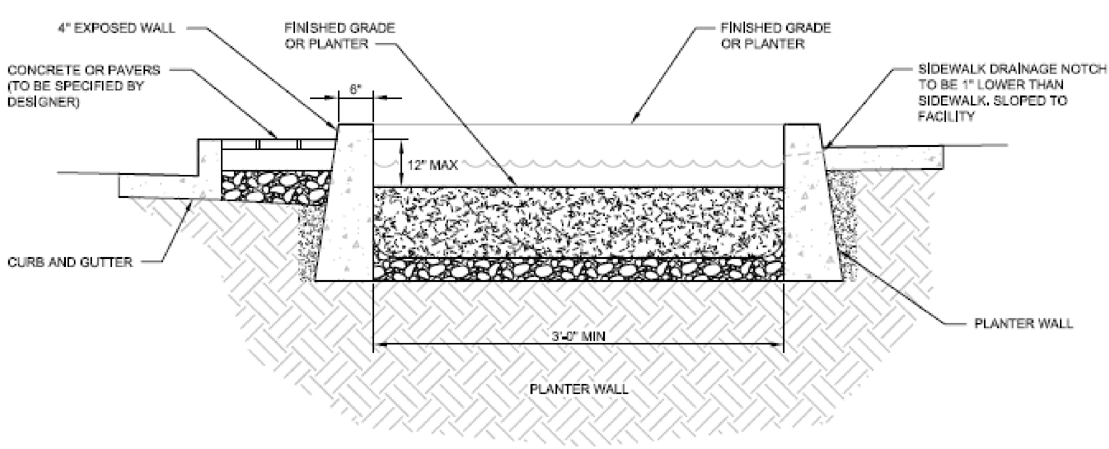
5-5 Construction example.

Chapter 6: Integrated management practices

6-1-1 Typical bioretention section with primary design elements.

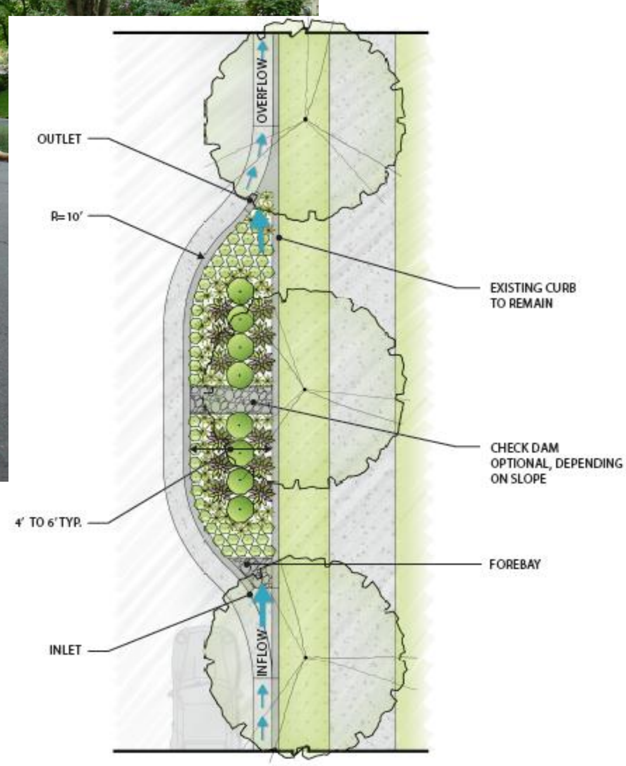


6-1-2 Typical bioretention planter section with under-drain.



6-1-3 Rain garden on individual lot.

6-1-4 Bioretention cells or swales in parking lot islands or along roadways.

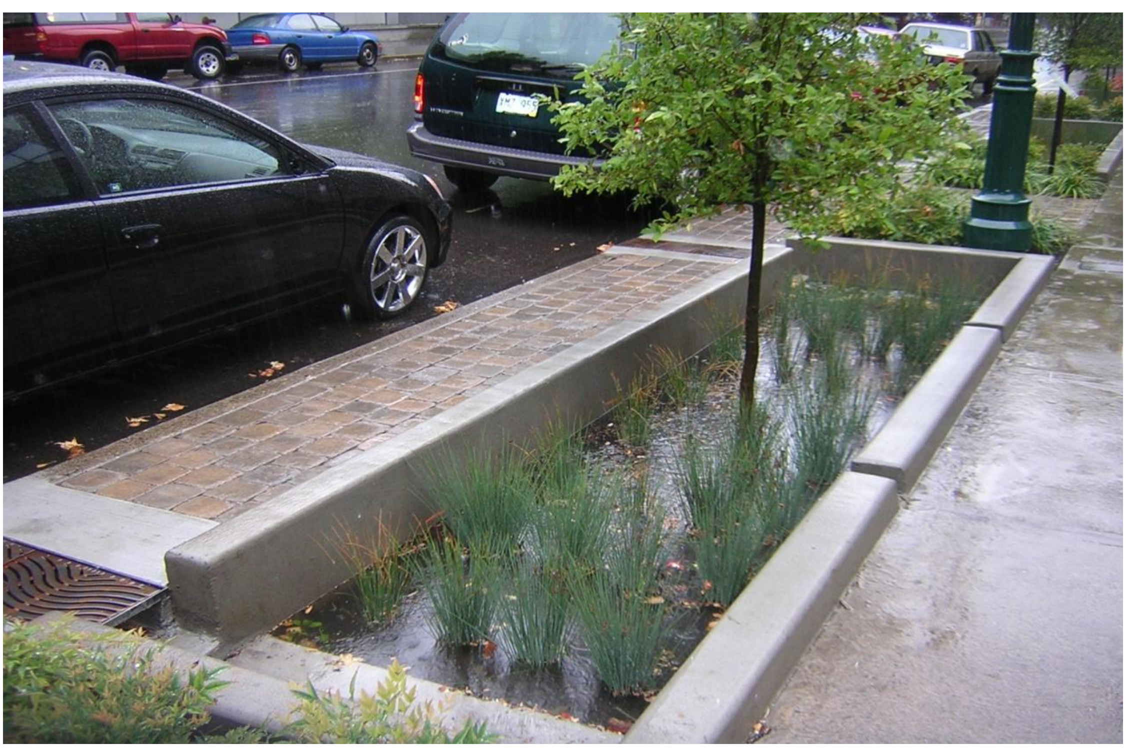


NOTE:
Graphic adapted from City of Portland, OR Stormwater Managment Manual Details

6-1-5 Bioretention swales.

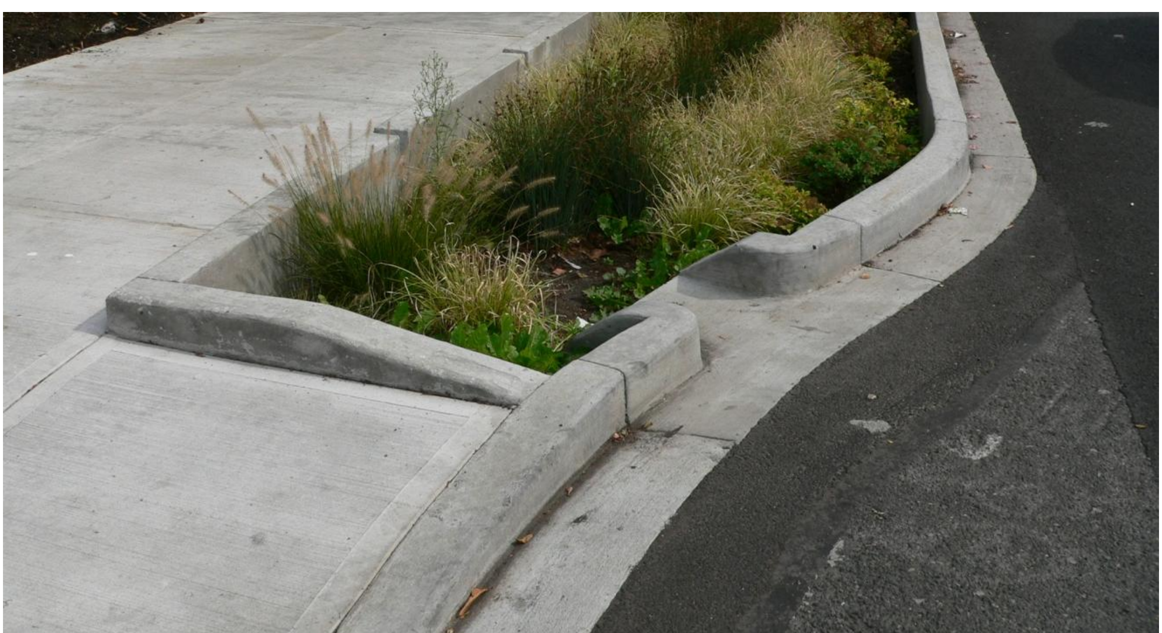
6-1-6 High gradient bioretention swale.

6-1-7 Bioretention planter.

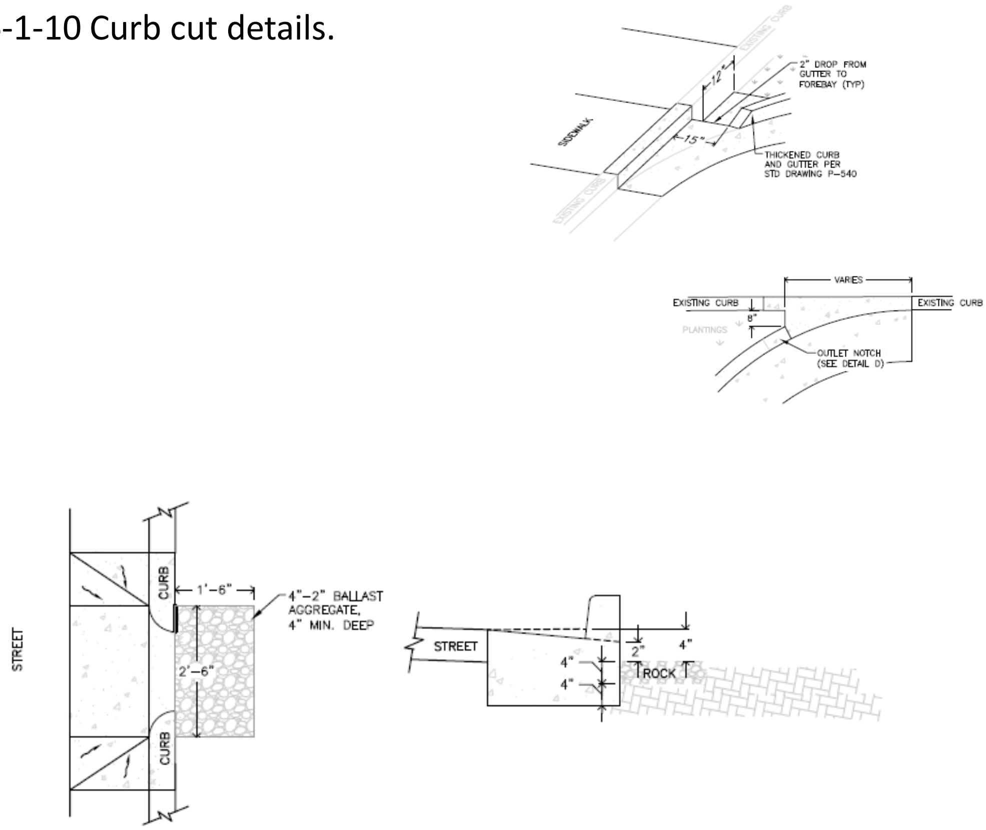


6-1-8 Utility setback section.

6-1-9 Curb cut inlet.



6-1-10 Curb cut details.

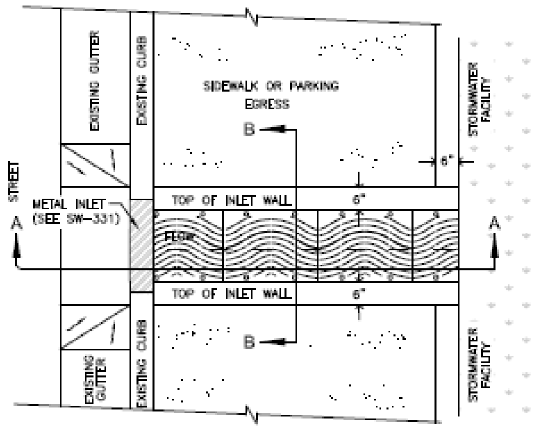


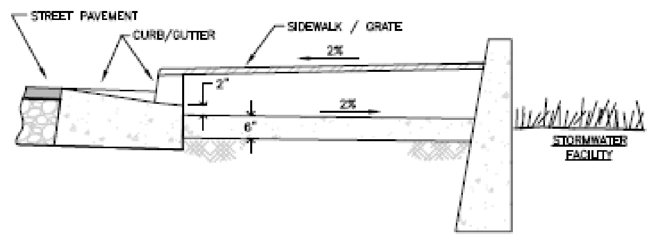
6-1-11 Catch-basin bioretention inlet to reduce flow velocity and control sediment in high gradient systems.

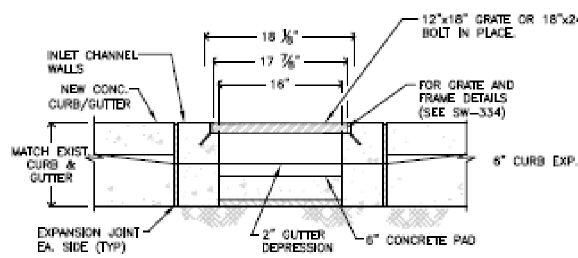
6-1-12: Trench drain bioretention inlet.

6-1-12: This trench drain bioretention inlet provides a shallow alternative to a buried pipe inlet and less elevation drop for subsequent swales.

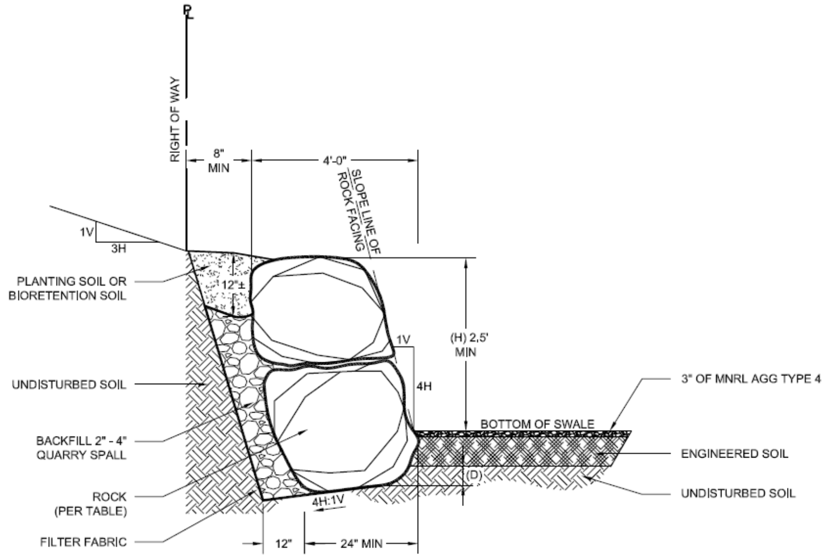
6-1-12: Trench drain bioretention inlet and details







6-1-13: Bioretention rockery wall detail.

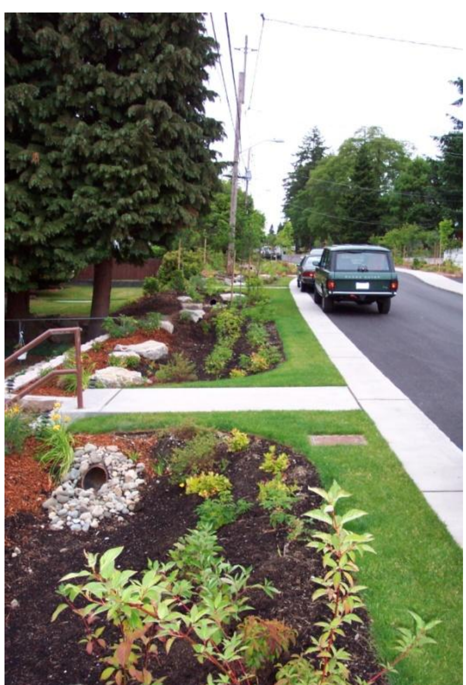


MINIMUM ROCK SIZES

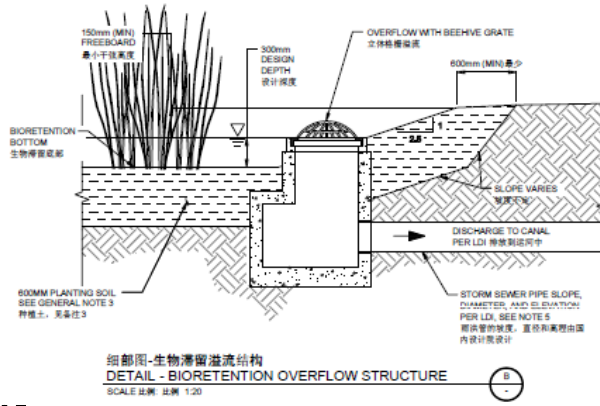
(H)	SIZE(BASE)	SIZE(TOP)	(D)
2.5'	2-MAN	1-MAN	3"
4'	3-MAN	2-MAN	6"
7'	4-MAN	2-MAN	9"

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

6-1-14: Bioretention with flush curb and shoulder.



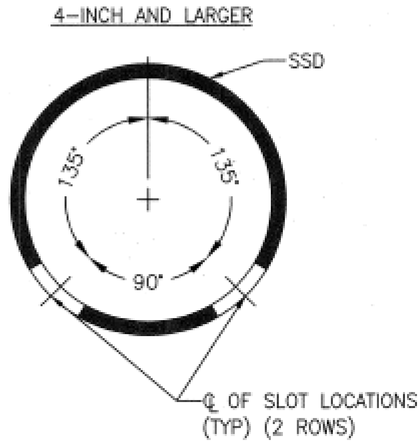
6-1-15: Bioretention with stand pipe for elevation drop to downstream swale.



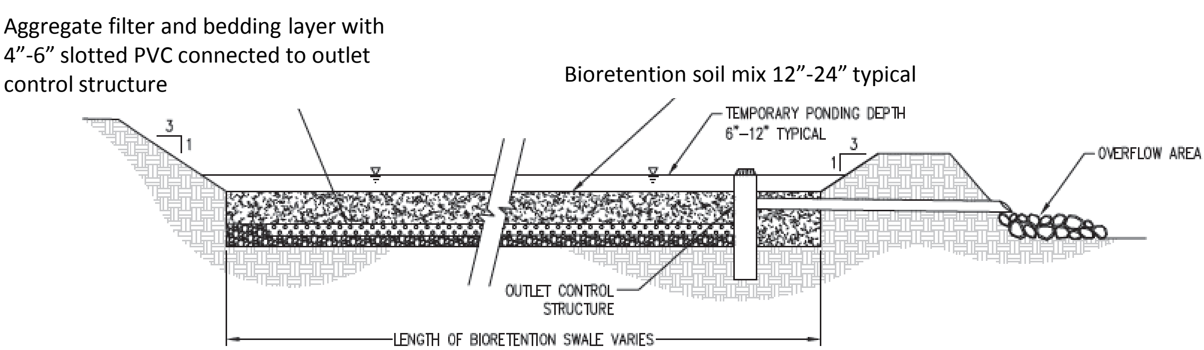
Need better section drawing

6-1-16: Rock lined overflow.

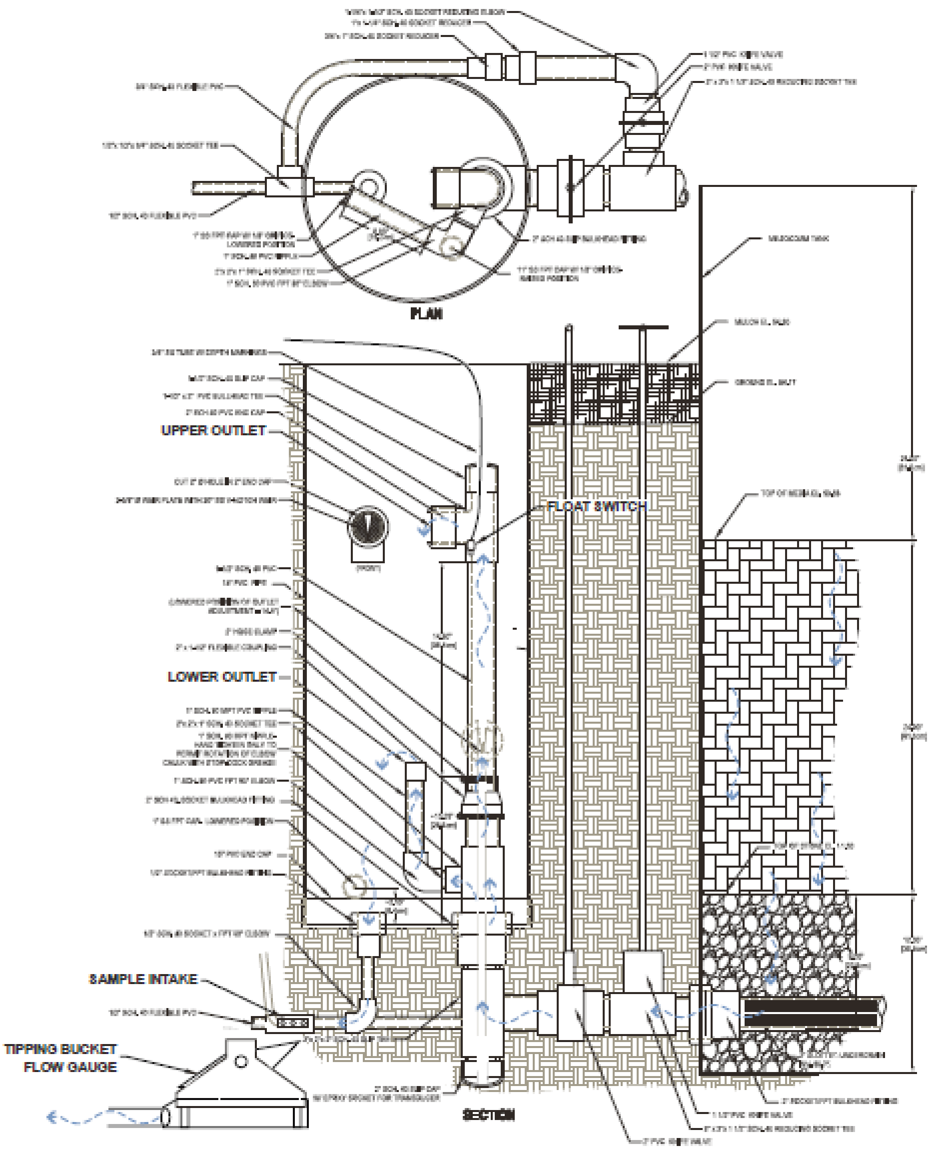
6-1-17: Slotted drain pipe detail.



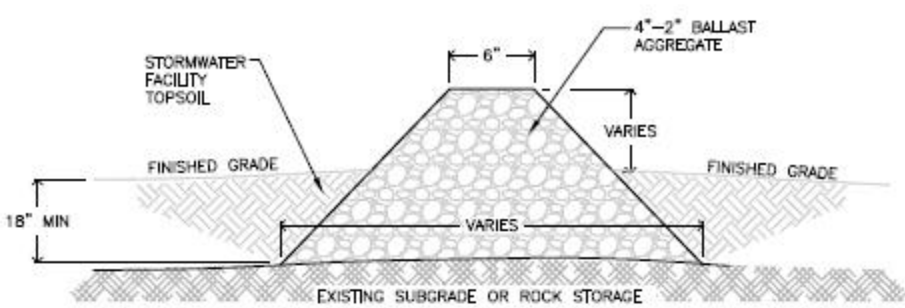
6-1-18: Upturned under-drain improves soil moisture conditions in drier season for improved plant survival, creates a fluctuating anaerobic/aerobic zone for possible nitrate removal and can be fit in shallower BSM profiles.



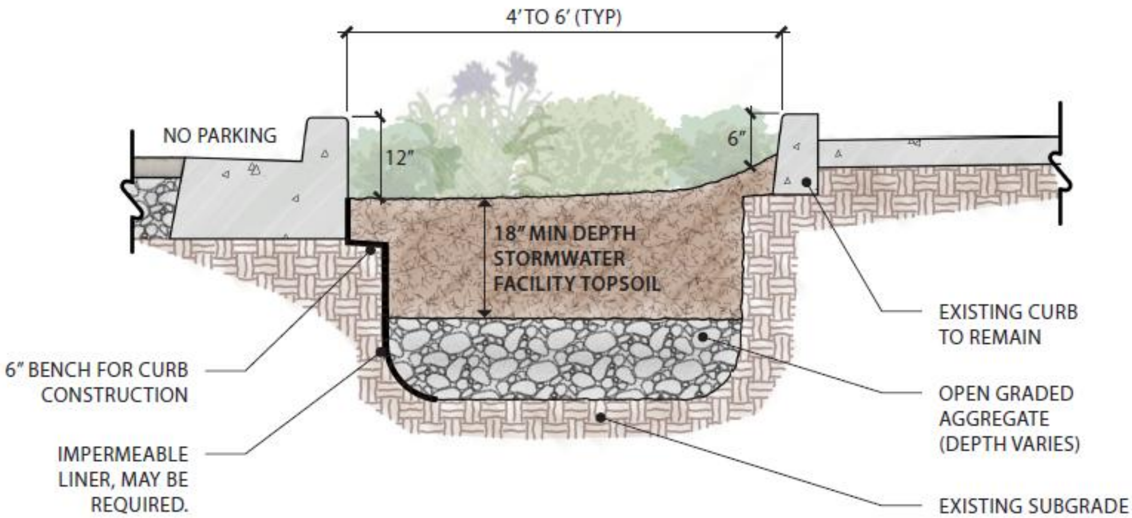
6-1-19: Dual-stage control structure controls hydraulic residence time, ponding depth and depth of saturated zone.



6-1-20: Check dams and berms with berm details.

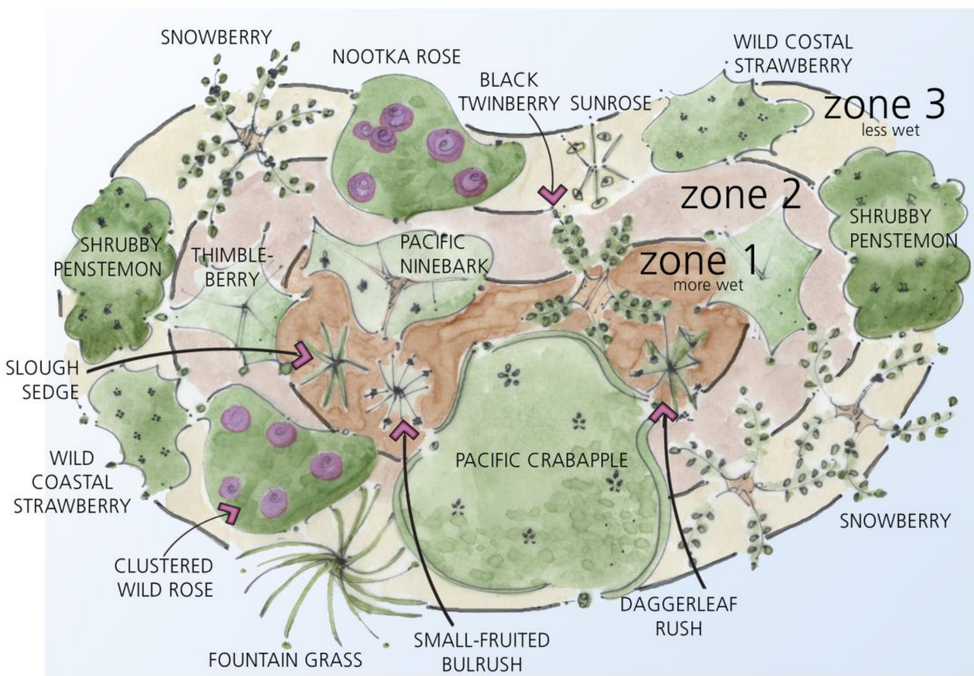


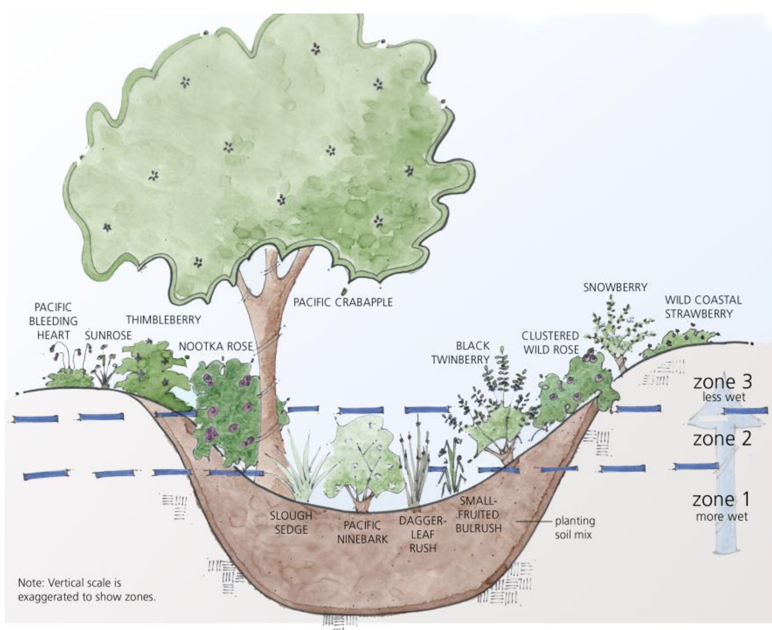
6-1-21: Bioretention with optional impermeable liner to protect adjacent infrastructure.



6-1-22: Bioretention vegetation can be selected to provide an aesthetic amenity and specific functions. The coastal strawberry on the berm dividing two bioretention swales provides a robust ground cover for pedestrian access in a high density setting.

6-1-23: Section and plan view planting plans.





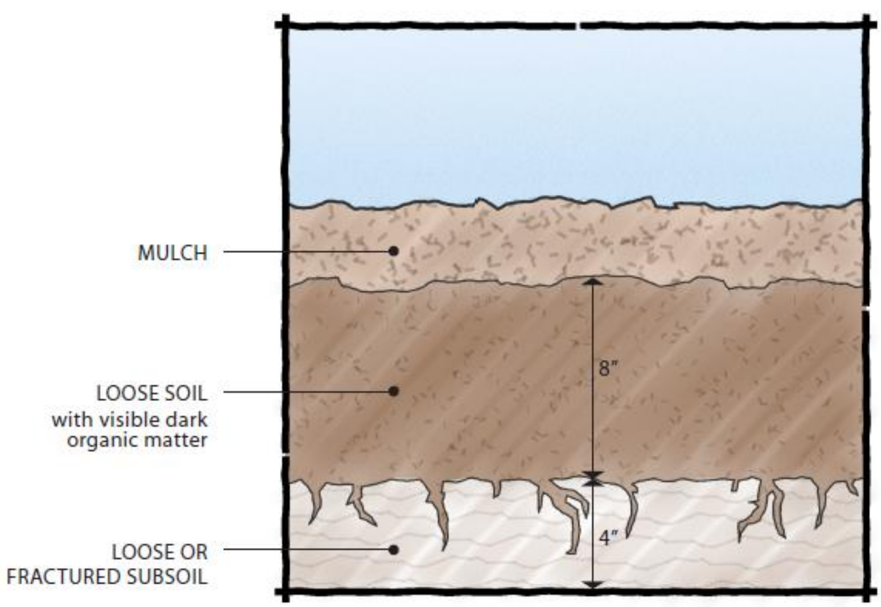
6-1-24: Two types of mulch are used on this bioretention area, coarse compost on the bottom and shredded or chipped hardwood or softwood on sides.

6-1-25: Aggregate mulch to protect the soil media from erosive flows on a high gradient bioretetention swale.

6-1-26: Good TESC: upslope areas are stabilized, pervious concrete sidewalk covered and curb inlets blocked while these bioretention swales are completed.

6-2-1 Example of a Soil Management Plan.

6-2-2 Properly amended soil section.



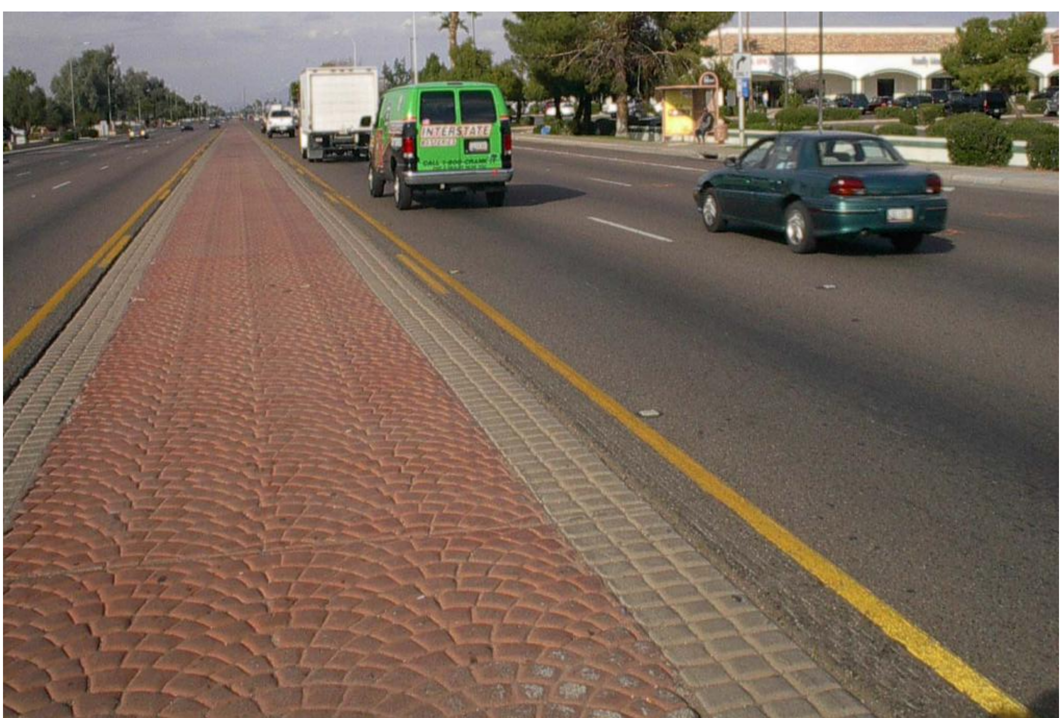
6-2-3 Verifying soil quality and depth with a shovel and penetrometer.

6-3-1 .

6-3-2 Pervious concrete is used throughout this Puget Sound residential subdivision .

6-3-3 Permeable interlocking concrete pavement.

6-3-4 Full-depth porous asphalt on Highway 87 near Phoenix Arizona .



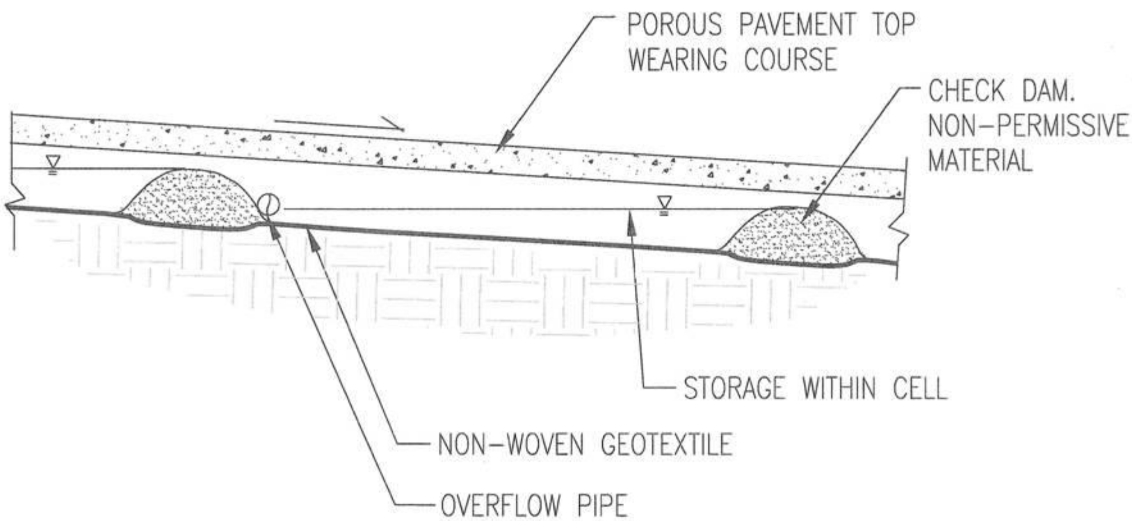
6-3-5 Pervious concrete is used for many of the paved surfaces at this Olympia Washington recreation center.

6-3-6 Permeable interlocking concrete pavement used for the main entrance to the Mukulteo Lighthouse State Park.

6-3-7 Gravel-filled plastic grid system used for the entrance to the material handling complex at Point Defiance Zoo, Tacoma Washington.

6-3-8

6-3-9 Impermeable check dams to retain subsurface flow on permeable pavement installations with sloped subgrade.



6-3-10 Geotextile placed under this pervious concrete sidewalk is left long, wrapped over the pavement and secured during construction.

6-3-11 Elevated drain designs (optional overflow) for permeable pavement aggregate base/reservoir (Ferguson pg 40).

6-3-12 Backup infiltration using an infiltration area in the parking landscape median that is hydraulically connected the aggregate base (adopted from Cahill).

6-3-13 Conceptual diagram of the load distribution for rigid (pervious concrete) and flexible permeable pavement systems (Ferguson pg 83).

6-3-14 Minimum total flexible vehicular pavement thickness required for two different loads at various CBRs (Ferguson pg 85).

6-3-15 Large ring infiltrometer test.

6-3-16 Flow chart for determining infiltration rates .

6-3-17 Porous asphalt section.

6-3-17 Porous asphalt parking lot with conventional impervious asphalt sections to test the water quality treatment capability of the porous sections.

6-3-19 Pervious concrete parking for a high density residential project in Bellingham Washington.

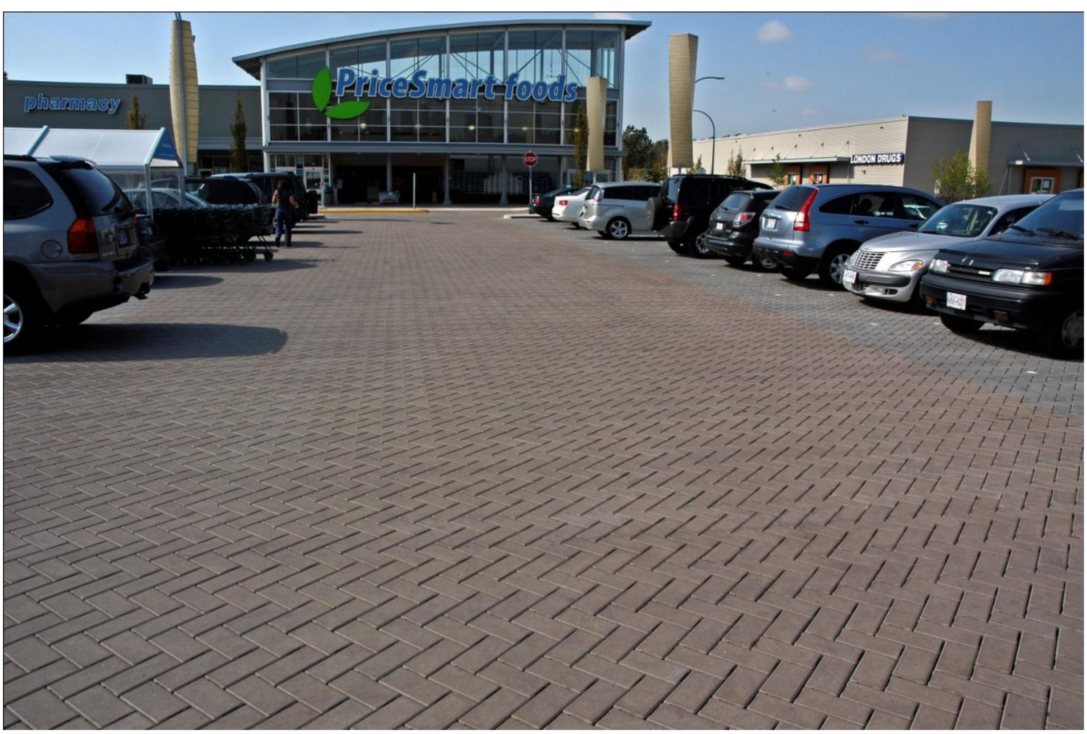
6-3-20 Pervious concrete section.

6-3-21 Pervious concrete consistency.

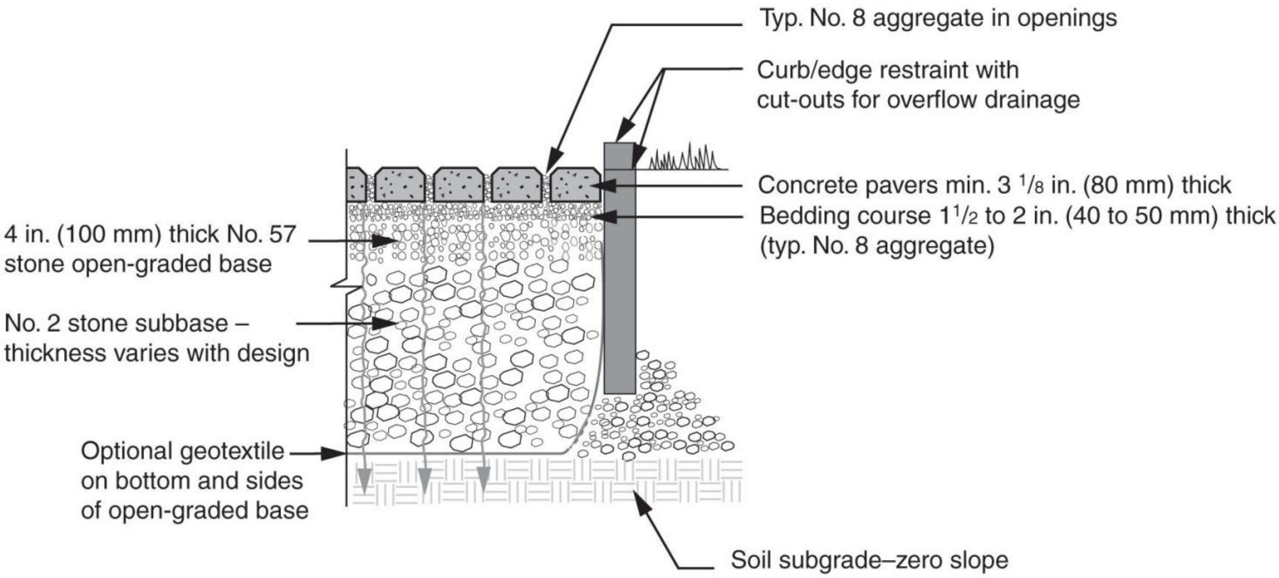
6-3-22 Bunyan Screed compacts and provides the finished elevation in one operation.

6-3-23 Two types of permeable interlocking concrete pavement.

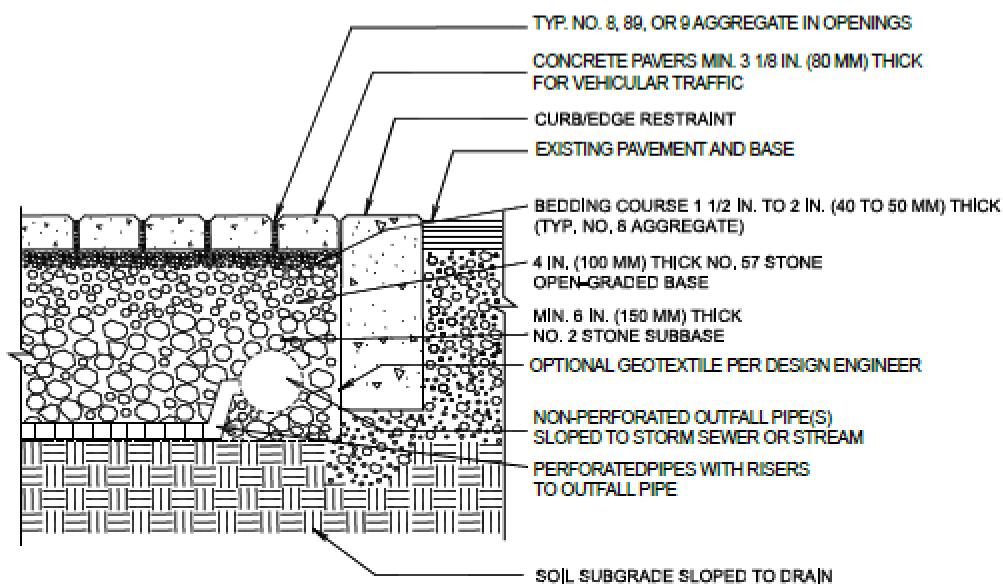
6-3-24 Permeable interlocking concrete pavement Burnaby, British Columbia.



6-3-25 Permeable interlocking concrete pavement section.



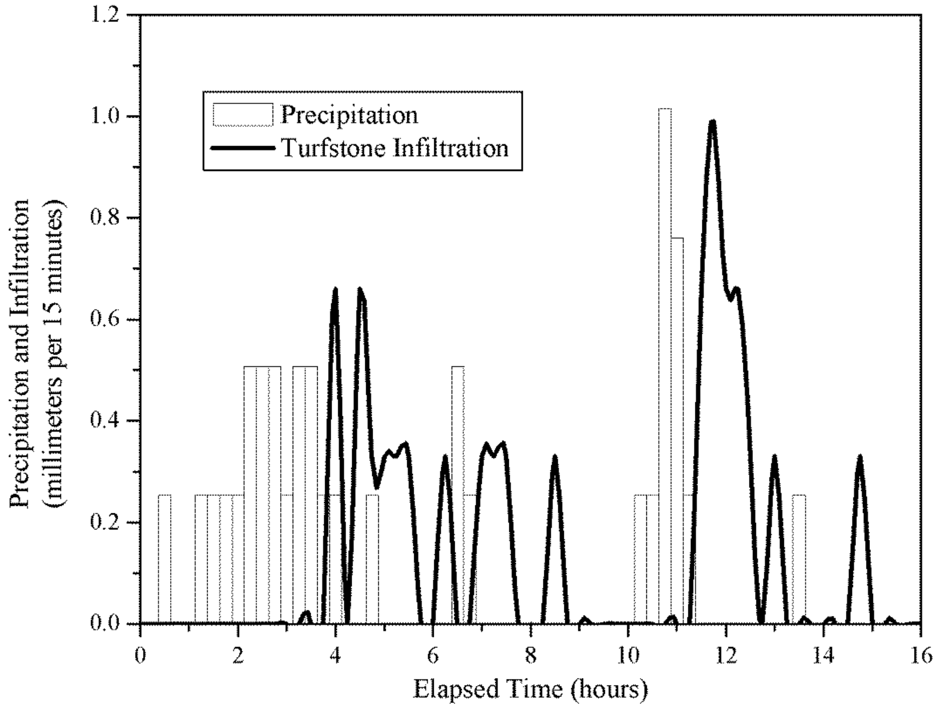
6-3-26 Permeable interlocking concrete pavement section with elevated drain.



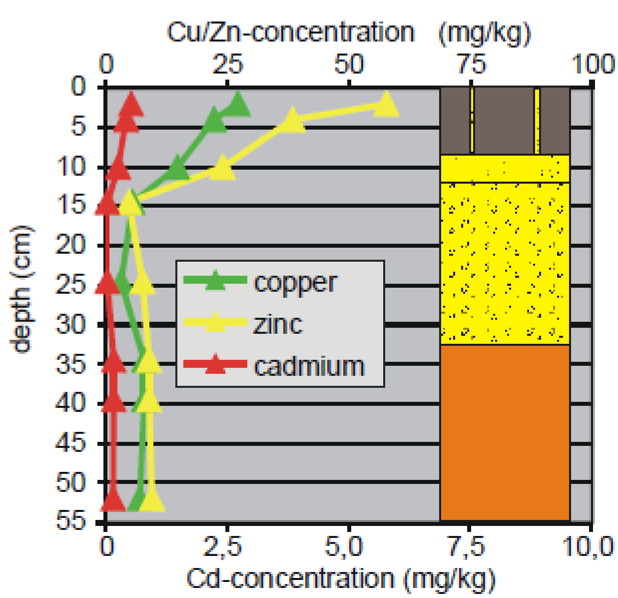
6-3-27 Mechanical installation of pavers.

6-3-28 Permeable plastic or concrete grid systems.

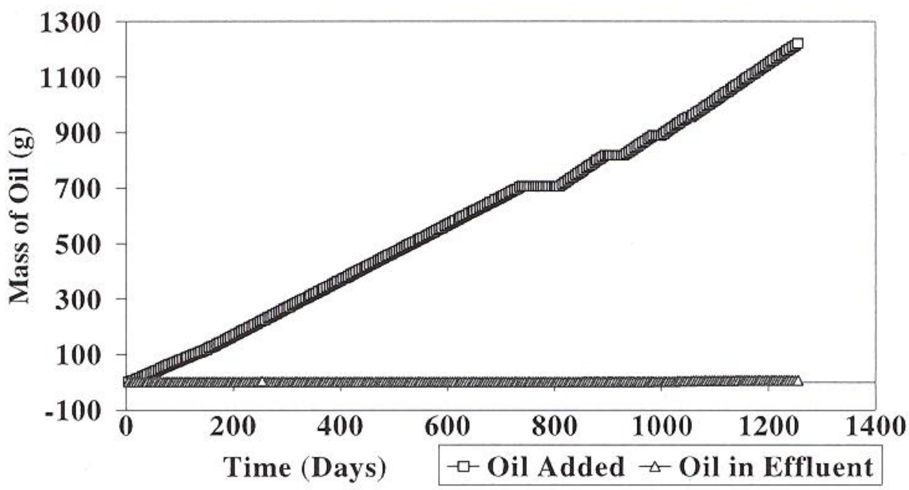
6-3-29 Amount of precipitation infiltrated for permeable concrete grid system at a permeable pavement research project in Renton, Washington.



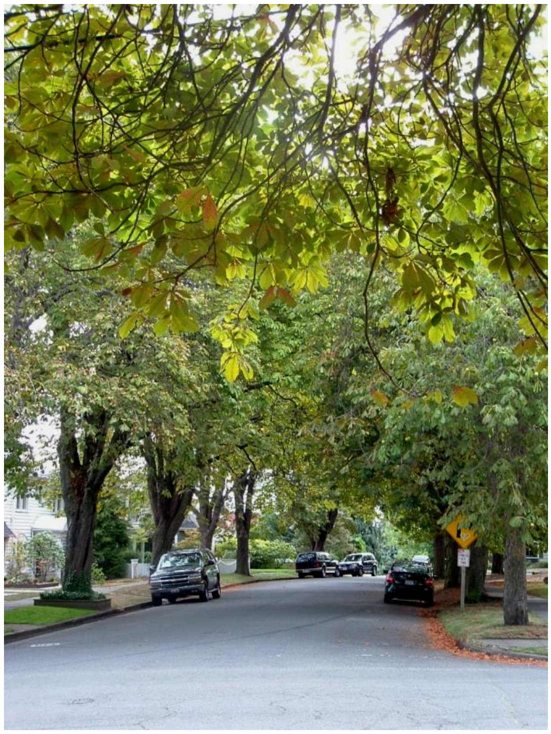
6-3-30 Metal concentrations in the aggregate and soils under a 15 year old permeable paver retail center in Germany (Dierkes et al., 2002).



6-3-31 Mass of motor oil added (ascending line) and oil in effluent (flat line) for permeable pavement experiments in England. Removal efficiency was approximately 99% (Pratt, Newman and Bond, 1999).



6-4-1: Tree canopy Seattle, Washington .



6-4-2:.

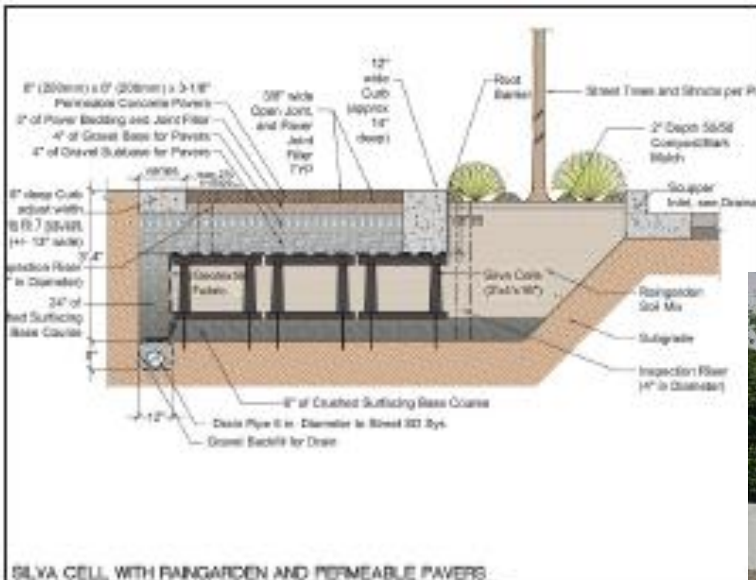
6-4-3: .

6-4-4: Trunk flare.

6-4-5: The same species of trees planted at the same time, but the trees on the left have more soil volume for root growth.

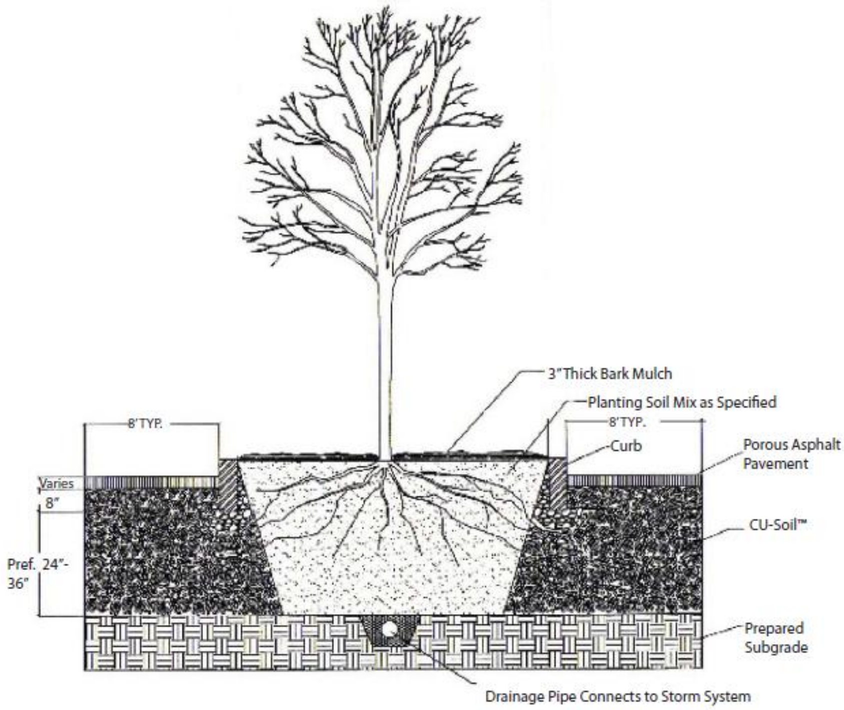
6-4-6: .

6-4-7: A rigid cell system placed under the sidewalk to increase soil volume and quality for street trees. This Shoreline, WA installation is built in conjunction with bioretention between the sidewalk and the street.

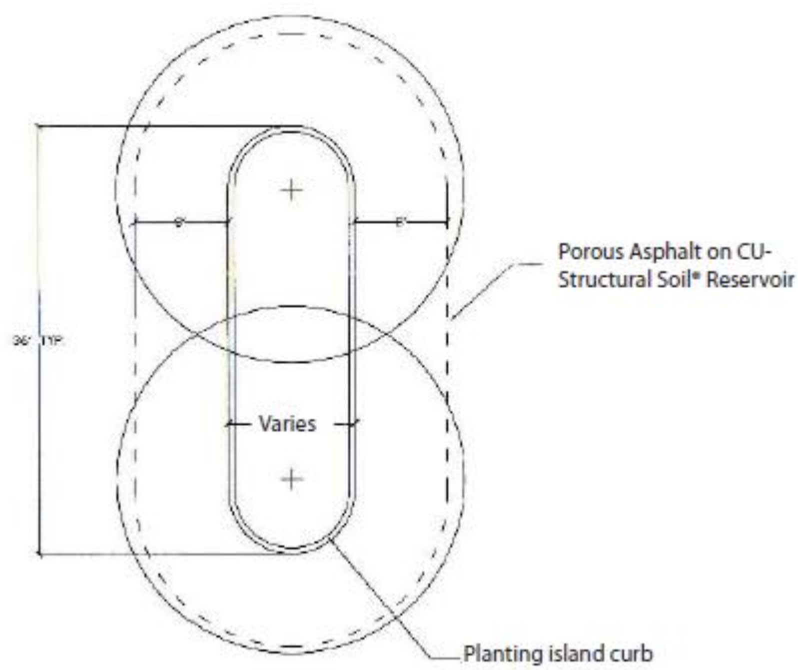


6-4-8: Newly planted trees in Structural Soil under porous asphalt parking.

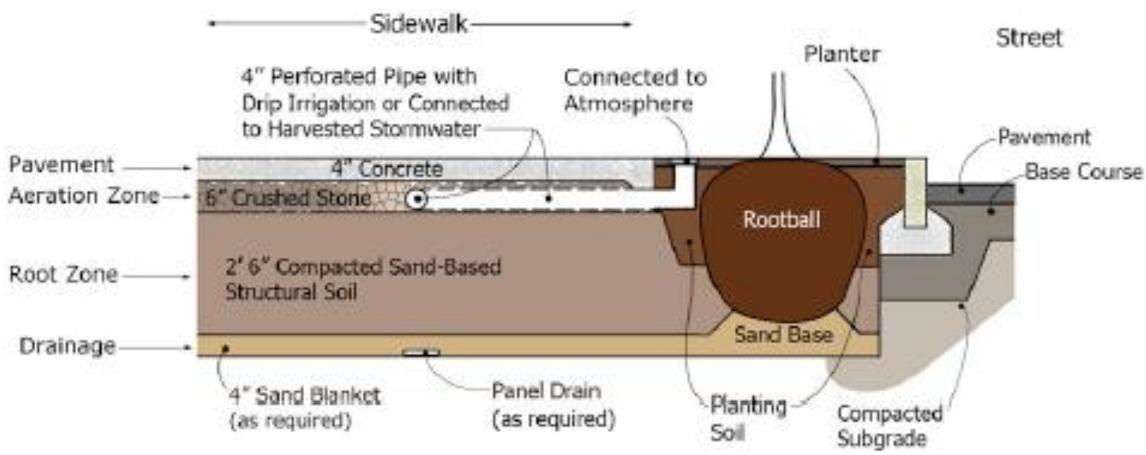
6-4-9: Typical planting section using Structural Soil.



6-4-10: Typical Structural Soil parking lot island with porous asphalt.



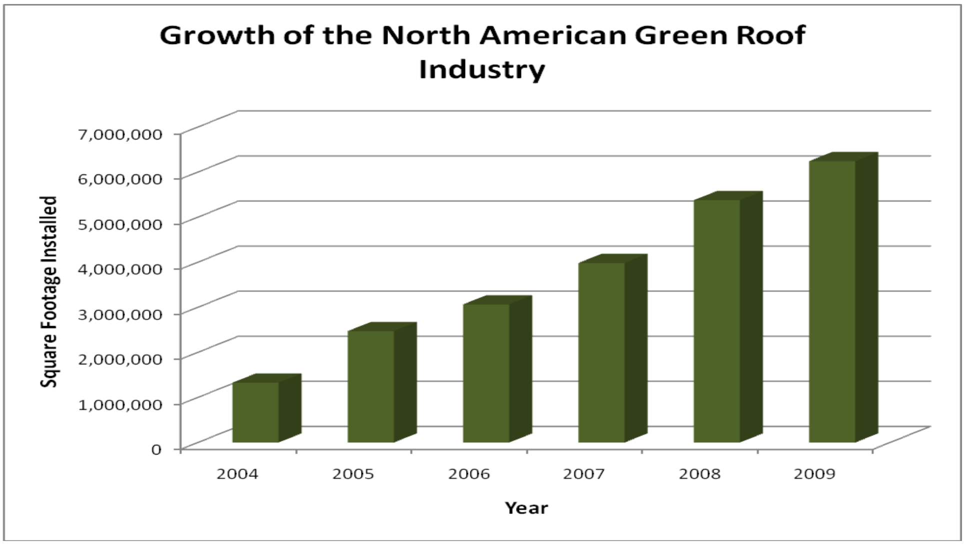
6-4-11: Typical Sand Based Structural Soil section .



6-4-12: .

6-4-13: .

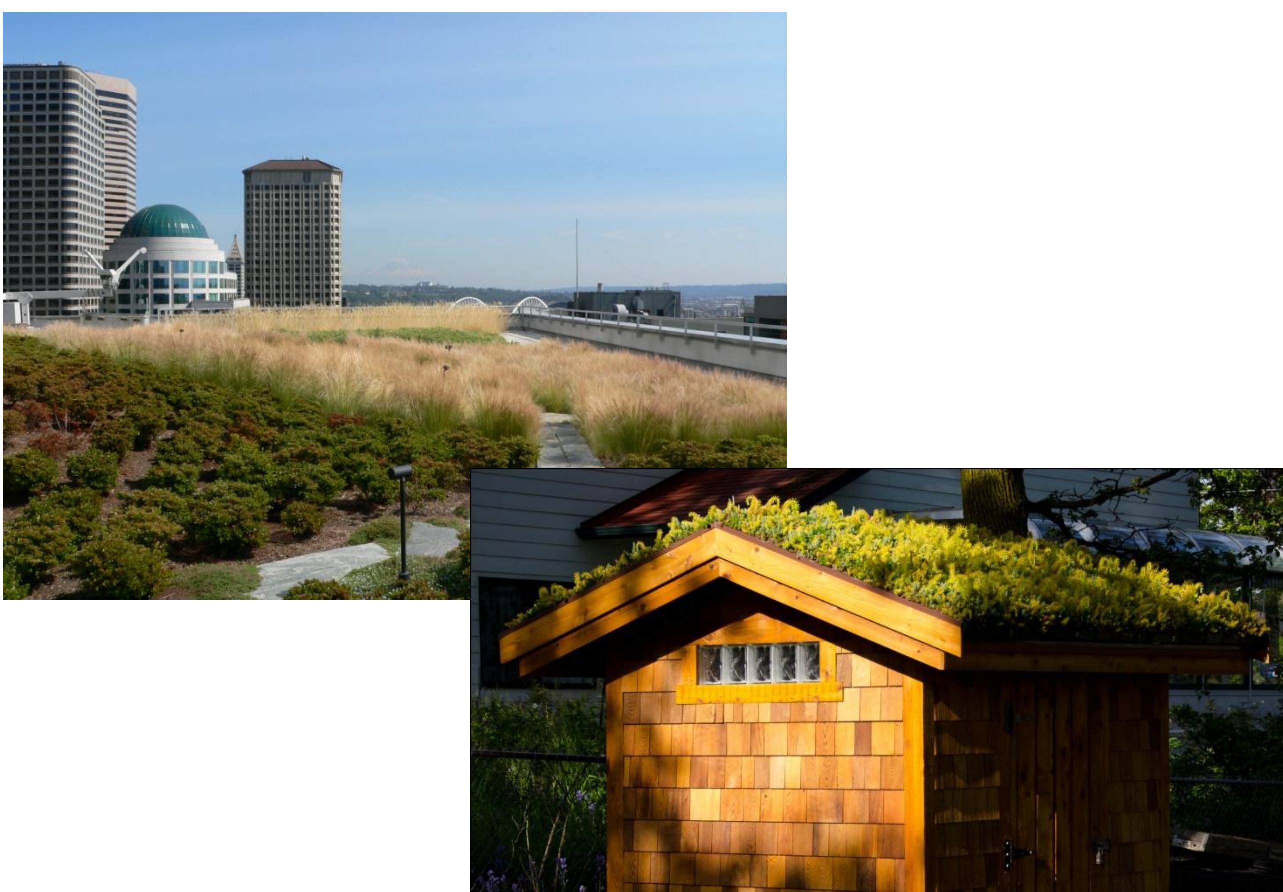
6-5-1: Growth of the North American Green Roof industry.



6-5-2: Ceremonial chamber covered with a green roof in Ireland.

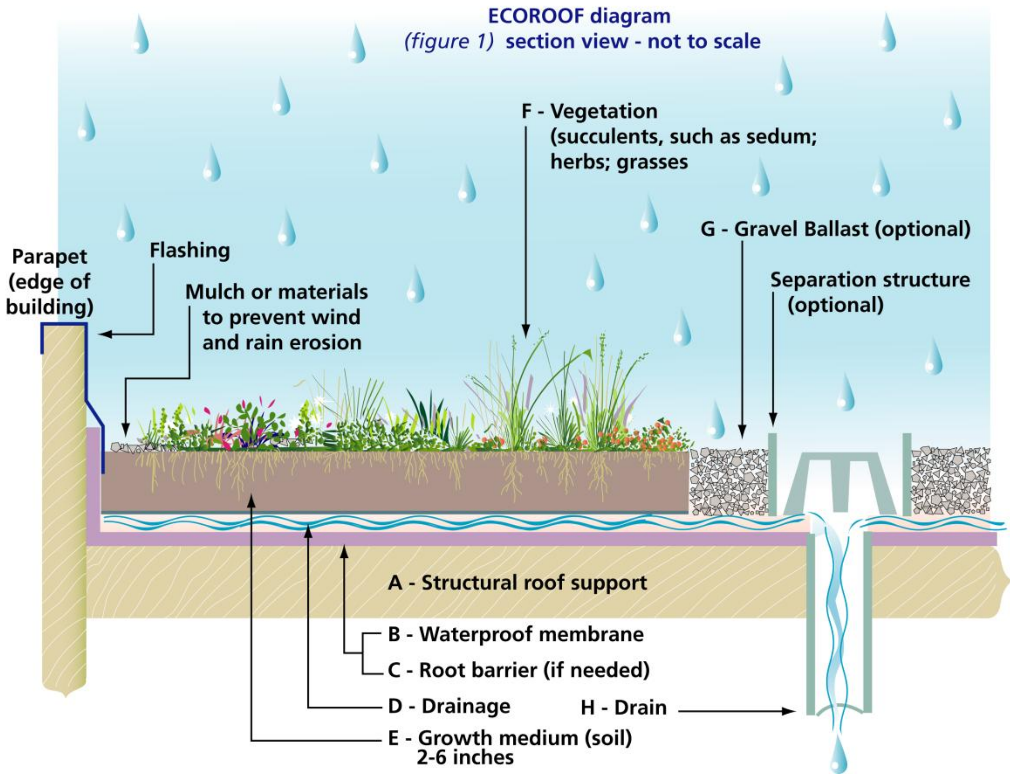
6-5-3: Urban green roofs.

6-5-4: Vegetated roof examples.



6-5-5: Various methods for placing growing media.

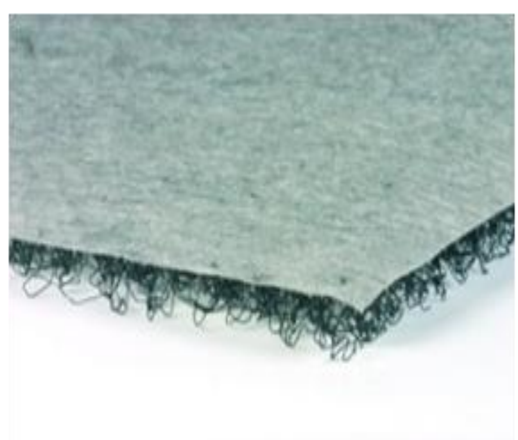
6-5-6: Typical vegetated roof section.



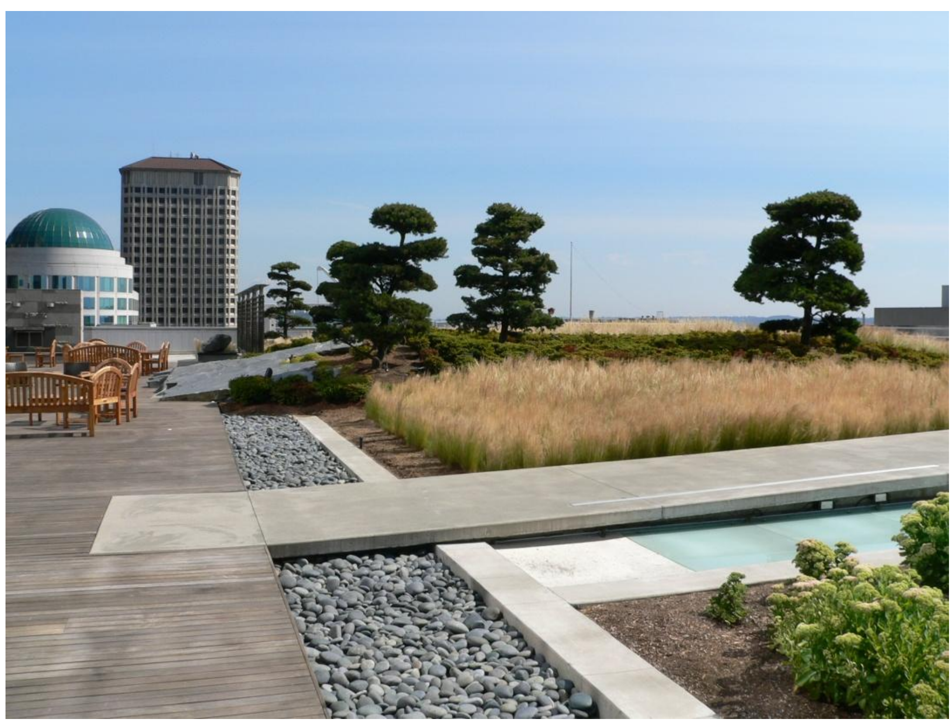
6-5-7: Pre-vegetated trays are assembled independently to cover the roof.

6-5-8: Assembling a waterproof membrane.

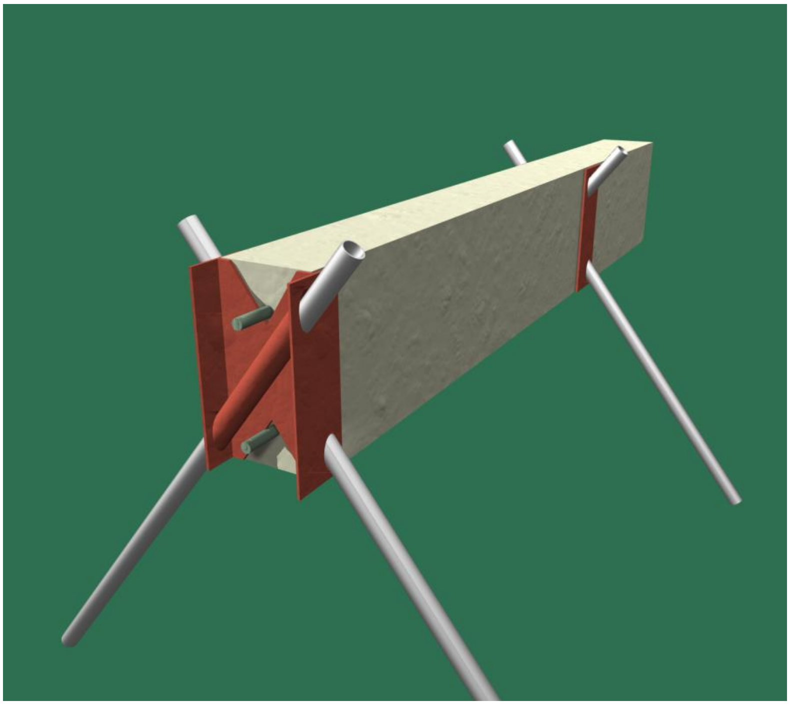
6-5-9: Drain mats.



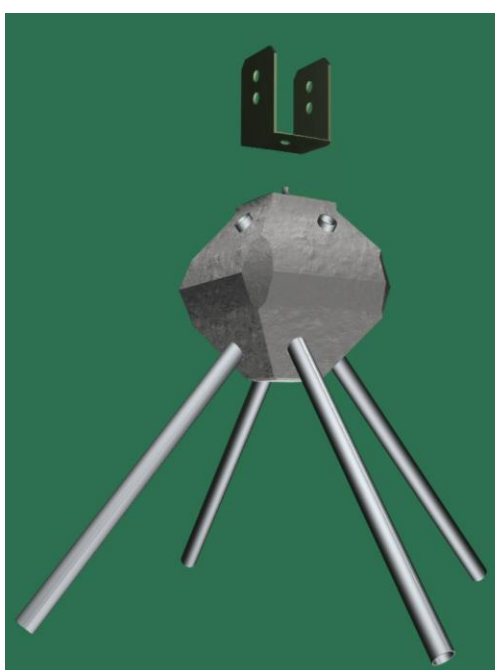
6-5-10: The Portland roof (top) is planted with a mix of grasses and sedums and the Seattle roof (below) has varying soil depths to accommodate grasses, herbs and trees.



6-6-1: Pin foundation application for grade beam construction.



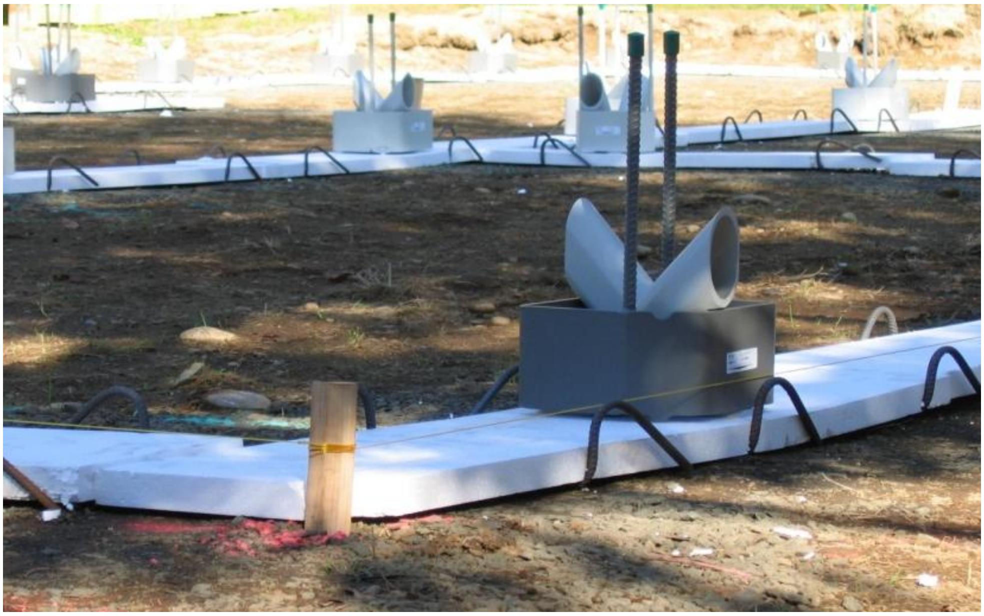
6-6-2: Pin foundation application for pier construction.



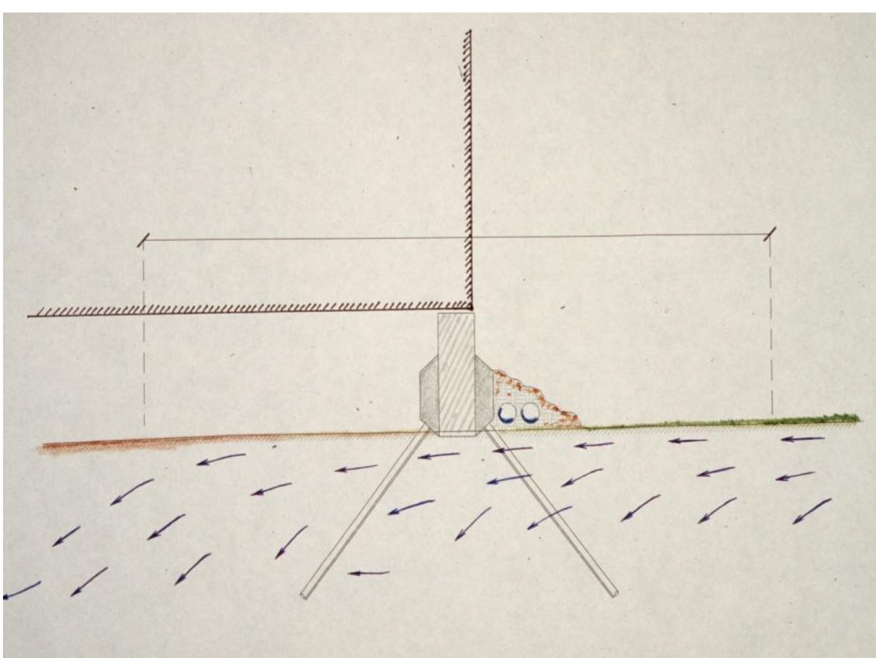
6-6-3: This small commercial building in Olympia, WA is constructed on a minimal excavation pin foundation. The project also includes pervious concrete and bioretention.

6-6-4: Pin pier foundation house on Bainbridge Island, WA .

6-6-5: Buffer material and pin pile guides placed before concrete wall is poured.



6-6-6: For maximum benefit, roof water should be dispersed up-gradient of the structure.

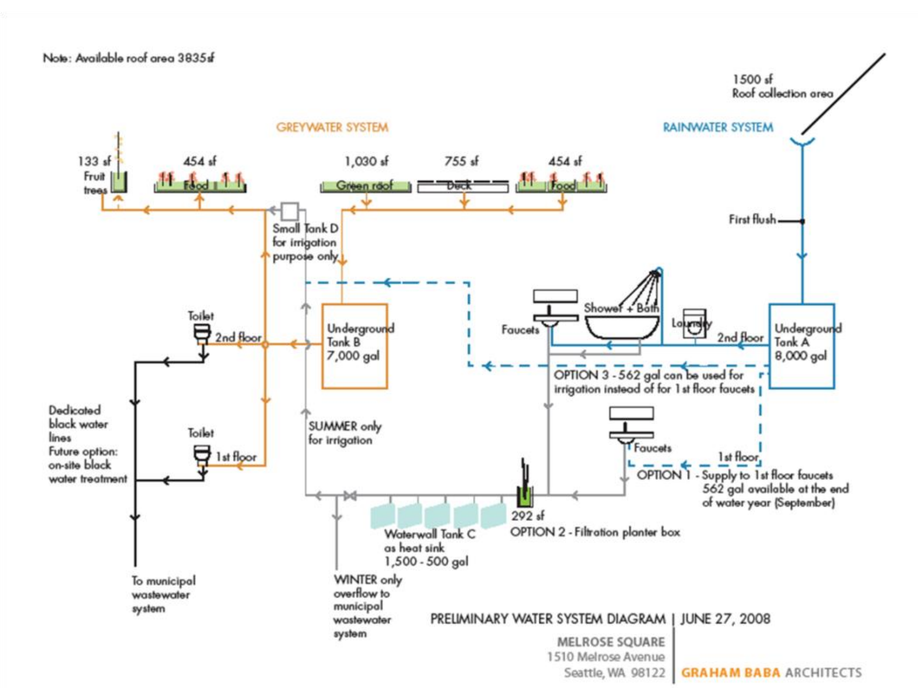


6-6-7: The grade beam and pin pile guides are placed first and pins then driven in this post pile application.

6-6-8: Driving pins with machine-mounted and hand-held hammers.

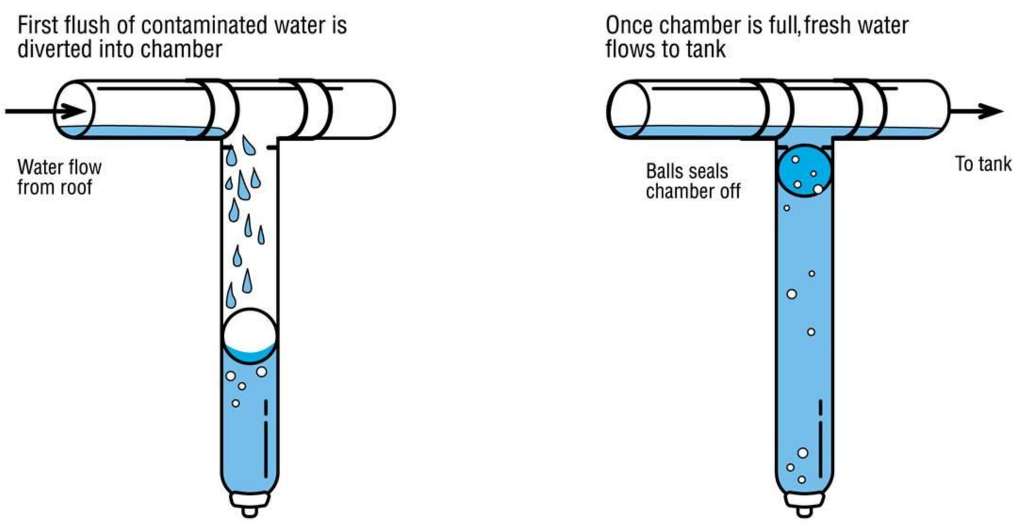
6-7.1: Buried cisterns for storing collected rain water for indoor use on Capital Hill, Seattle.

6-7-2: Main components of a rain water collection system.



6-7-3: Gutter screen.

6-7-4: First flush diverter.



6-7-5: Roof washer.

6-7-6 Various types of cisterns for storing rainwater.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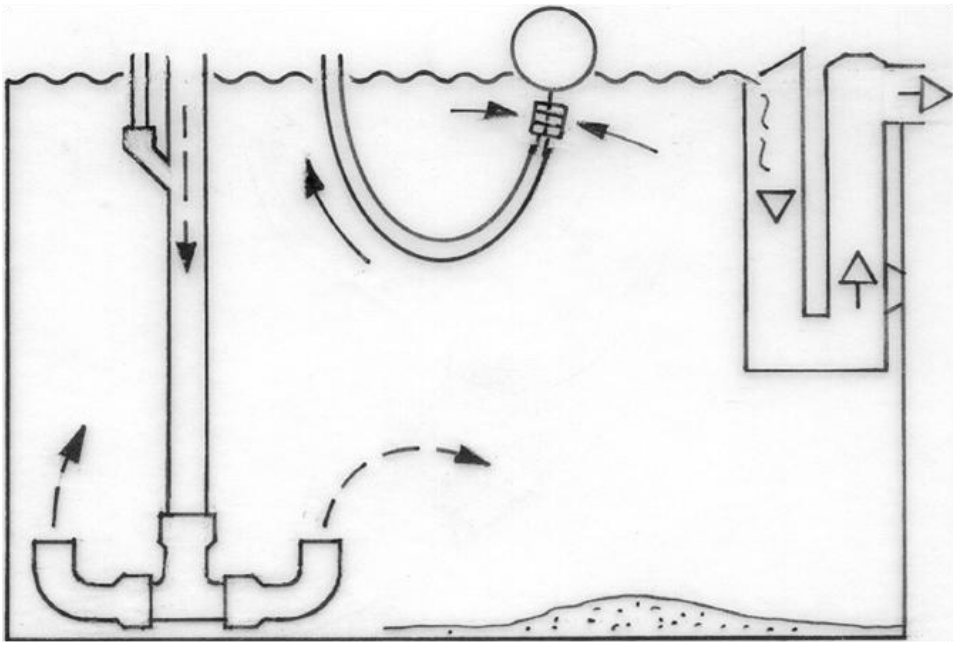
6-7-7: Float filter for a rain water cistern.



6-7-8 Filter array for a residential rain water harvesting system.

6-7-9: Typical rain water storage requirements (western Washington) for different levels of household water use by month.