GREEN STREETS
AND SIDEWALKS

Stormwater Design Guidelines

Alexandria, Virginia

PREFACE

This document updates the Green Sidewalks BMP Design Guidelines originally developed by the City of Alexandria in 2014 and promulgated by “Memorandum to Industry No. 04-2014*” (sic) on June 1, 2014.

Design guidance for structural stormwater best management practices (BMPs) in the right-of-way (ROW) has been updated and expanded in these Green Streets & Sidewalks Stormwater Design Guidelines (ROW BMP Design Guidelines). Typical ROW BMP plans, details, plant lists, and related standards and specifications have been moved to and linked from the City’s website. This allows City staff the maximum capability to maintain this information current with industry standards and local, state, and federal laws, policies, and regulations.

30% OF ALEXANDRIA’S IMPERVIOUS SURFACE AREA IS COMPRISED OF PUBLIC ROADS.

Acknowledgements

This updated document was made possible with the support of AECOM and the expertise and participation of work group members and others representing various departments within the City, including Transportation & Environmental Services (T&ES); Planning and Zoning (P&Z); Department of Recreation, Parks and Cultural Activities (RPCA); and the Department of Project Implementation (DPI). Acknowledgment is provided below to those whose expertise, experience, and input all helped shape these guidelines.

DC Water Rock Creek Project, Washington, DC

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SPECIAL THANKS

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1 INTRODUCTION

CHICANE, AUSTIN, TEXAS

These green stormwater design guidelines present a menu of options or “toolbox” for managing stormwater runoff from the right-of-way (ROW), including streets, pedestrian paths, and sidewalks in the City of Alexandria.

REDUCE RUNOFF VOLUME

Urban Bioretention Tree Well, Portland, Oregon

The traditional objective of managing stormwater runoff is to collect stormwater and send it as quickly as possible to storm sewers and waterways. Over time, large volumes of fast-flowing, untreated stormwater runoff have degraded the physical, chemical, and biological health of our streams and rivers, eroded stream banks, and clouded our waterways with sediment and excess nutrients that feed large algal blooms and harm fish and wildlife.

In contrast to conventional practices, green stormwater elements are designed to reduce the volume of stormwater, slow it down, and treat it near its source.

SLOW PEAK FLOWS

Strawberry Run, Alexandria, Source: John Wood Group PLC

1.1 AUDIENCE

These Guidelines are a resource for City departments, design professionals, and private developers and their consultants. Though not intended as a primary audience, the Guidelines may also serve as reference for elected officials, neighborhood groups, advocates, and interested residents.

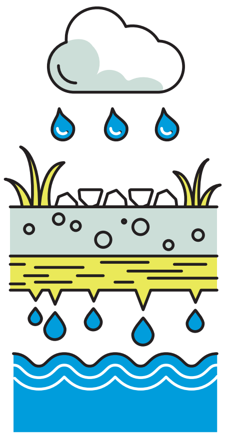
Information in the Guidelines is intended to supplement, not replace, applicable codes, regulations, ordinances, and development procedures. These guidelines support the “Green Streets” approach of the City’s Small Area Plans and the vision of the City’s *Complete Streets Design Guidelines*.

IMPROVE RUNOFF QUALITY

Source: Will Parson, Chesapeake Bay Program

1.2 GREEN STREET PRINCIPLES

The principals of green streets are found in the *Urban Street Stormwater Guide* by the National Association of City Transportation Officials (NACTO) and interpreted below as they relate to the City.



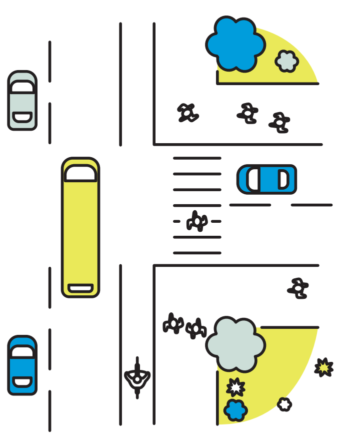
PROTECT & RESTORE NATURAL RESOURCES

Capturing, filtering, and infiltrating stormwater is critical in Alexandria where impervious surface covers a high percentage of all land area Citywide, including public streets and sidewalks. Sustainable stormwater infrastructure filters pollutants from water and, where water can infiltrate, it restores the natural hydrological cycle, protecting water resources.

Good stewardship of our local waterways yields many public health, ecological, and recreational benefits, is one of the guiding principles of the Eco-City Alexandria Charter, and is a priority for the City under the Eco-City Alexandria Clean Waterways initiative.

PROMOTE HEALTH, EQUITY, AND HUMAN HABITAT

Green streets are part of healthy, equitable urban design that views streets as vital public spaces. Incorporating green elements into streets improves mental and physical health through better air quality, valuable shade, and beautification and contact with nature in areas where access to parks is limited. The benefits of green stormwater infrastructure should be provided equitably, especially in neighborhoods that have historically borne disproportionate air and water pollution or that lack green space. Specific opportunities for alignment may be found in Alexandria's Community Health Assessment & Improvement Plan.



DESIGN FOR SAFETY & MOBILITY

Street reconstruction projects that incorporate green infrastructure should align with the City 's *Complete Streets Design Guidelines* to ensure that Alexandria's streets meet the needs of all users, including pedestrians, bicyclists, transit users, drivers, residents, workers, visitors, and business owners. Green infrastructure can be leveraged in conjunction with other street design projects to realize complementary goals such as transit access and the City's safe mobility Vision Zero for zero traffic deaths.

DESIGN FOR LIFE CYCLE

Treatment of runoff from public streets and sidewalk is a benefit for Alexandria that reduces the City's capital costs required for stormwater permit compliance. Life-cycle costs may accrue to developers or the City or both depending on who installs the facilities and who is responsible for long-term maintenance. The Sustainable Technologies Evaluation Program released a life cycle costing tool in December 2019, recognizing that estimating the life cycle costs can be a costly and time-consuming process. Annual maintenance costs are commonly estimated at 5% to 7% of capital costs. Life cycle benefits include the potential impacts of climate change and storm events, as well as the economic benefits that have been documented with greener streetscapes.

DESIGN FOR RESILIENCE

As a tidal riverfront city, Alexandria is particularly vulnerable to the real and urgent threats of climate change. Rising sea levels and the increased frequency and intensity of storms will make localized flooding a more significant issue, impacting public safety, private property, and businesses (IPCC, 2018). Incorporating natural systems into the built environment promotes ecosystem health and urban resilience. The stormwater management elements in these design guidelines are one approach to meeting the City's *Eco-City Environmental Action Plan 2040* strategic goals.

OPTIMIZE FOR PERFORMANCE

In Alexandria, treatment of stormwater runoff quality from linear street and sidewalk projects with green infrastructure helps the City to comply with federally mandated Chesapeake Bay Total Maximum Daily Load (TMDL) targets and achieve municipal separate storm sewer system (MS4) permit compliance. In addition to being prioritized at the watershed or network scale, public and private investments in green stormwater infrastructure must be tailored to the specific conditions of the site. Use of these design guidelines on development projects and their frontages will lead to citywide investments with watershed-level benefits.

2
TOOLBOX

The green stormwater infrastructure toolbox includes a variety of stormwater management elements and potential configurations within the street and sidewalk that must be selected, sized, and configured to meet the goals and context of the project site.

2.1 GREEN STORMWATER ELEMENTS

Urban bioretention facilities and permeable pavement are called best management practices (BMPs) under state and local stormwater regulations. These Guidelines supplement the Virginia BMP Clearinghouse standards and specifications for urban bioretention practices and permeable pavement. Section 5 lists reference standards and other resources.

URBAN BIORETENTION

Stormwater runoff from streets and sidewalks is treated in an urban bioretention facility as it filters through a mixture of sand, soil, and organic material. “Urban” specifically denotes bioretention facilities that are designed to fit within the urban street and sidewalk context, such as the BMP tree well pictured at right.

The volume of stormwater runoff is reduced by plant uptake and temporarily detained in a surface ponding area to slow the rate of water entering our waterways. Under the BMP, an underdrain connects runoff to the storm sewer.

When trees are used in urban bioretention facilities, they must be designed to provide enough soil volume to support healthy and thriving street trees.

BMP tree wells are most commonly used where there is both a need to treat runoff from the street and sidewalk and where street trees are required along building frontages.

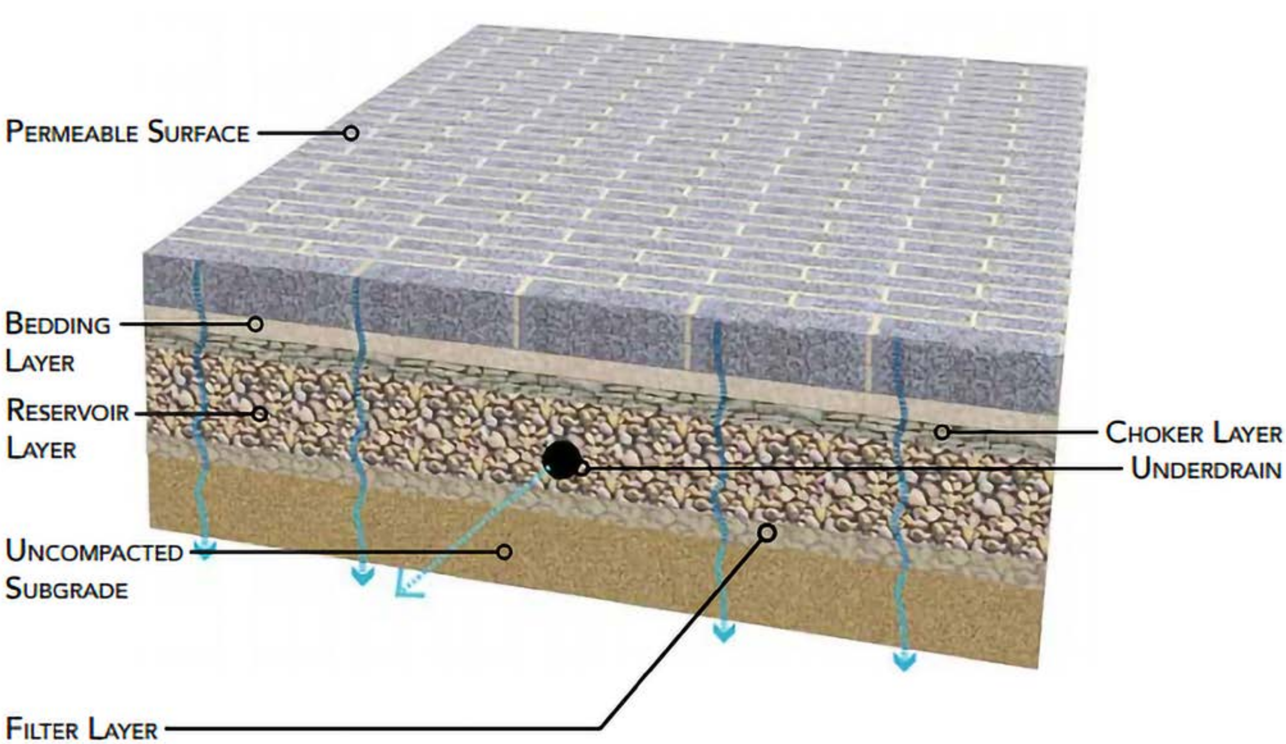
URBAN BIORETENTION TREE WELL, PORTLAND, OREGON

PERMEABLE PAVEMENT

Permeable pavement is a system that comprises a surface layer, pavement layer, and reservoir layer. The surface layer allows stormwater runoff to filter through the top pavement layer into a reservoir layer of gravel.

A variety of permeable pavement surfaces are available; however, these Guidelines will focus on pervious concrete.

Structural and hydrologic analyses must consider the pavement's location, use, and limited ability to treat more than the permeable pavement surface itself.



EXAMPLE PERMEABLE PAVEMENT CROSS SECTION. IMAGE NOT INTENDED FOR USE IN DESIGN.
Source: Washington, DC, District Department of Transportation

2.2 STREET AND SIDEWALK CONFIGURATIONS

Source: NACTO

This section presents a look book of common configurations of the stormwater elements introduced in Section 2.1, with recommendations to guide their use and configurations. Each configuration is presented as a standalone building block and is followed by recommendations as to which street typologies offer the most fitting context for its use. Street typologies are specific to Alexandria, as defined in the City 's *Complete Streets Design Guidelines*.

A combination of stormwater elements can be used to meet the stormwater management goals within a street and sidewalk setting as well as provide additional or co-benefits to users beyond stormwater management.

Green stormwater infrastructure can:

- Provide traffic calming and improved safety for pedestrians
- Reduce puddles or runoff near bus stops and transit stations that would otherwise impede wheelchair and pedestrian access
- Reduce the drying time for bike lanes, so riders are less discouraged by mud and spray
- Capture runoff and reduce flooding and ponding to promote safer driving conditions
- Improve the attractiveness and comfort of the streets, thereby improving economic performance; studies show that urban environments with green features such as planters and trees perform better than streets without green improvements
- Lower temperatures caused by the urban heat island effect

Combinations of the street and sidewalk stormwater element configurations are encouraged. For case studies and design ideas see NACTO's *Urban Street Stormwater Guide*.

CO-BENEFITS TO STREET USERS ULTIMATELY SHAPE THE WAY GREEN STORMWATER ELEMENTS ARE CONFIGURED TO MEET STORMWATER MANAGEMENT GOALS.

INDIVIDUAL TREE WELLS

Applicable Street Typologies

- Main street
- Industrial
- Commercial connector
- Mixed-use boulevard
- Shared street

Design Tips

- Individual tree wells are preferred over continuous tree wells where there is street parking.
- Individual tree wells need more underground storage space than continuous tree wells, because they do not share soil volume.
- Install where sidewalk amenity zone widths are at least 6.5 to 8 feet wide. Trees spaced closer together will need a wider box width.

Examples of individual tree wells; clockwise from top left:

ROBINSON TERMINAL SOUTH, ALEXANDRIA, VIRGINIA

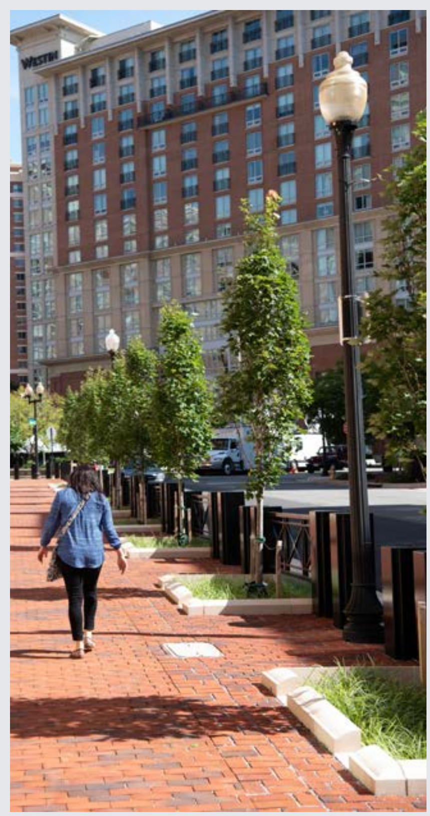
PORTLAND, OREGON

PORTLAND, OREGON

FEDERAL COURTHOUSE, ALEXANDRIA, VIRGINIA

TORONTO, ONTARIO, CANADA

YARDS PARK, WASHINGTON, DC



CONTINUOUS PLANTING STRIPS

Applicable Street Typologies

- Parkways
- Industrial
- Commercial connector
- Neighborhood connector

Design Tips

- Continuous tree wells must have a step-out zone where there is adjacent street parking. Walkway "bridges" over the BMP may also be desired and will be considered on a case-by-case basis.
- Trees in continuous planting wells require less soil volume per tree in accordance with the City's *Landscape Guidelines*.
- Install where sidewalk amenity zone widths are at least 6 feet wide.
- Preferred for optimal tree performance.

HARVARD STREET, ALEXANDRIA, VA

MID-SIDEWALK BIORETENTION

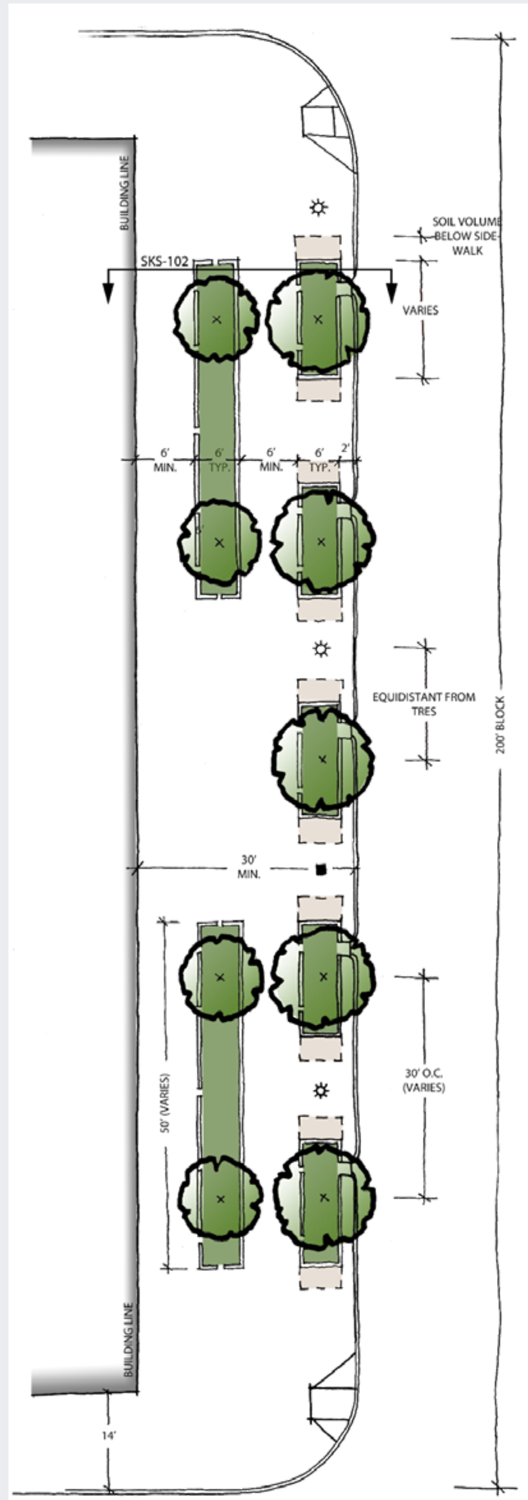
Applicable Street Typologies

› Commercial connector
› Mixed-use boulevard
› Shared street

Design Tips

› Mid-sidewalk planters can be hydraulically connected to tree wells in the amenity zone to maximize treatment.

Top: CONSTITUTION SQUARE, 1ST ST NE, WASHINGTON, DC
Above: CONSTITUTION SQUARE, 1ST ST NE, WASHINGTON, DC Source: Dan Reed



BACK OF SIDEWALK BIORETENTION

Applicable Street Typologies

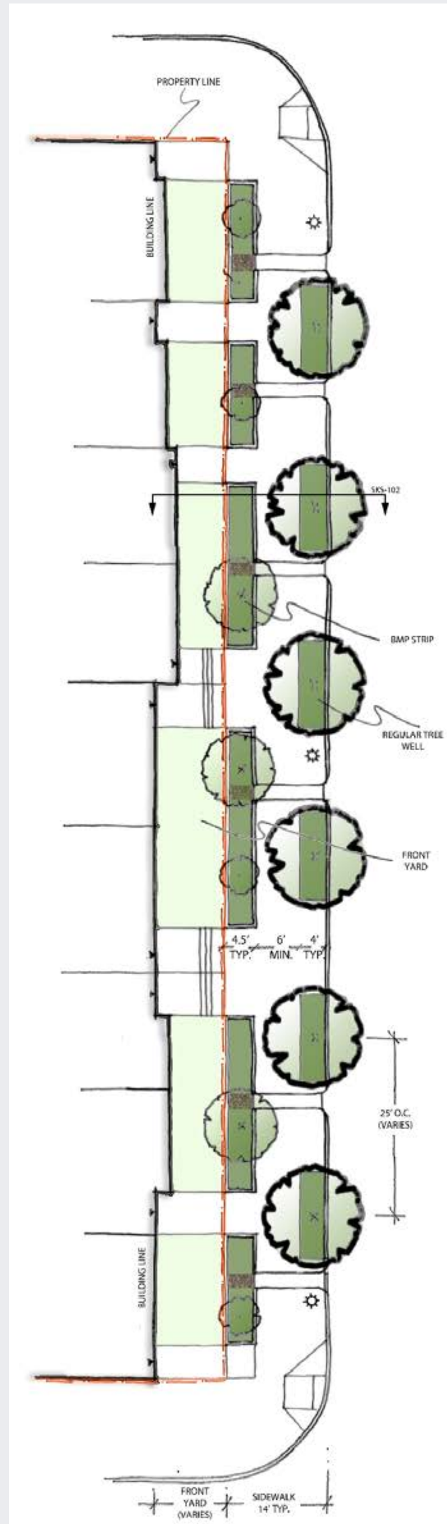
› Main street
› Mixed-use boulevard
› Neighborhood connector
› Neighborhood residential
› Shared street

Design Tips

› Back of sidewalk planters may need a minimum setback (typically 10 feet) from buildings.

› Keep the extent of the bioretention facility within the limits of the ROW.

GWU Campus, Washington, DC



CURB EXTENTIONS

Applicable Street Typologies

› Main street
› Mixed-use boulevard
› Neighborhood connector
› Neighborhood residential
› Parkways
› Shared street

Design Tips

› Angle curb returns 30 to 60 degrees to accommodate street sweeping.

› Locate to intercept stormwater ahead of existing catch basins.

Source: Integrity Land Works

Top left: **QUEEN LANE, PHILADELPHIA, PENNSYLVANIA**
Source: Philadelphia Water Department

Above: PORTLAND, OREGON

Right column: FREMONT GREEN STREET PROJECT, PORTLAND, OREGON

STORMWATER MEDIANS

Applicable Street Typologies

› Commercial connector
› Mixed-use boulevard
› Neighborhood connector
› Parkways
› Industrial
› Shared street

Design Tips

› Site and trim trees planted in the median to promote visibility for vehicles and pedestrians.

› Provide sufficient soil volume for trees planted in the median in accordance with the City's *Landscape Guidelines*.

Left: 28TH AVENUE CONNECTOR, NASHVILLE, TENNESSEE Source: Hawkins Partners, Inc.
Right: EMERYVILLE, CALIFORNIA Source: Peter Schultze-Allen, EOA Inc.

BUS BULB BIORETENTION

Top: BUS BULB BOARDING ISLAND, PORTLAND, OREGON Source: Ben Baldwin

Above: EMERYVILLE, CALIFORNIA
Source: Peter Schultze-Allen, EOA Inc.

Applicable Street Typologies

- Commercial connector
- Main street
- Mixed-use boulevard
- Transit vision

Design Tips

- At a minimum, maintain a 4-foot clear path from the pedestrian zone to any transit door, as well as into transit shelters and access to any transit amenities.
- Review sizing and location requirements for boarding pads to accommodate riders who use wheelchairs.

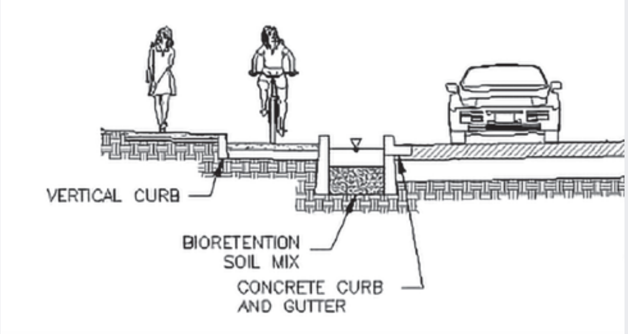
PERMEABLE AND PROTECTED BIKE LANES

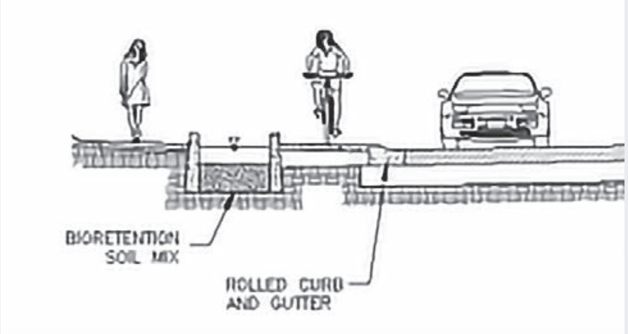
Applicable Street Typologies

- Commercial connector
- Mixed-use boulevard
- Neighborhood connector
- Neighborhood residential
- Parkways
- Bike overlay

Design Tips

- Bike lanes can be raised to sidewalk level or lowered to same grade as the roadway and may be pervious concrete.
- Bioretention can be used to protect bike lanes, which can also extend into a protected bike intersection with islands designed as bioretention facilities.





Source: Mackay & Sposito, Inc.

Left and center left: CHILCO STREET, MENLO PARK, CALIFORNIA

Below: PERVIOUS CONCRETE BIKE LANE, OLYMPIA, WASHINGTON

Bottom left: ROSEMEAD BLVD, TEMPLE CITY, CALIFORNIA
Source: Joe Linton/Streetsblog LA

Bottom right: FELL & OAK STREETS, SAN FRANCISCO, CALIFORNIA
Source: Sergio Ruiz

PERMEABLE SIDEWALKS

Applicable Street Typologies

- Neighborhood connector
- Neighborhood residential
- Parkways
- Shared street

Design Tips

- Historic districts and some small area plans have specific restrictions on sidewalk materials, refer to the City's *Sidewalk Materials – Staff Guidance Map*. Consider pervious concrete where City-standard concrete is allowed.

Commonwealth Avenue, Alexandria, Virginia

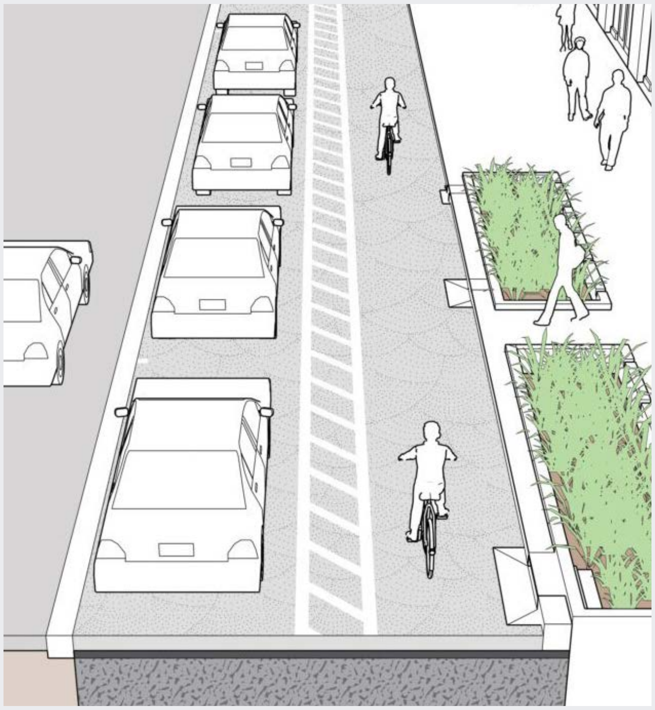
PERMEABLE PARKING LANES

Applicable Street Typologies

- Main street
- Mixed-use boulevard
- Neighborhood connector
- Neighborhood residential
- Parkways
- Shared street

Design Tips

- Avoid the use of permeable parking lanes on snow emergency routes.
- For more detailed technical guidance, refer to American Society of Civil Engineer's (ASCE's) *Permeable Pavements Recommended Design Guidelines*.



Source: NACTO

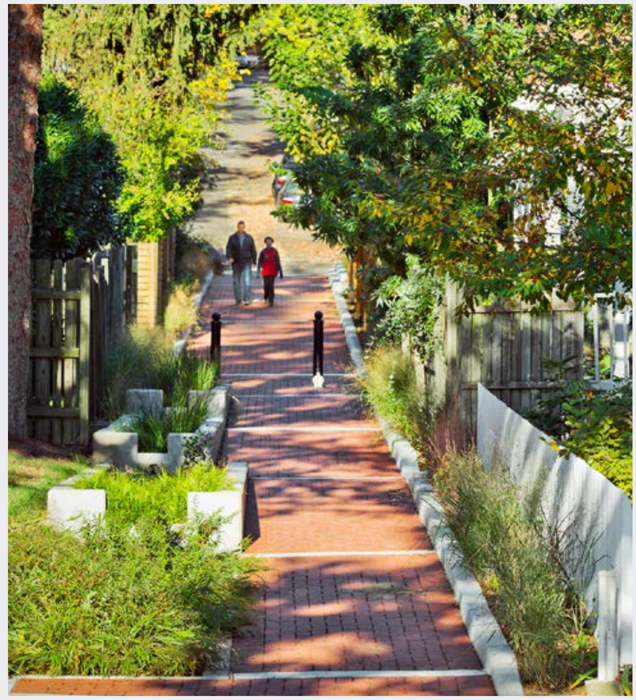
GREEN ALLEYS

Applicable Street Typologies

- Neighborhood connector
- Neighborhood residential
- Parkways
- Shared street
- Alleys

Design Tips

- At a minimum, a green alley could consist of a centered, linear pervious concrete strip.
- Traditional concrete is recommended where garbage trucks or other large vehicle wheel loads are anticipated, such as at alley aprons.
- Pervious concrete works best for alleys with low slopes.
- Bioretention can add aesthetic value as well as treatment value.
- For steep slopes, bioretention can be stepped with weirs, such as in the photo to the left.



From top:
Q STREET ALLEY, WASHINGTON, DC
Source: Allen Russ / Rhodeside Harwell

CLOSE-UP OF PERMEABLE SIDEWALK
Source: Aaron Volkening

MARTHA GARDENS GREEN ALLEYS
Source: City of San Jose, California

2.3 CLOUDBURST STREETS

Source: Ramboll and Ramboll Studio Dreiseitl

Cloudburst streets, which collect water and move it away from vulnerable areas, are not approved for meeting stormwater regulations in Virginia, but they are a green stormwater element that complements the use of green infrastructure in managing stormwater. Green stormwater elements are designed primarily to treat stormwater runoff water quality. Most pollutants get washed off impervious ROW during storms in the “first flush” or the initial runoff. As such, green stormwater elements are generally designed to treat the “water quality volume” or the runoff from a storm (i.e., a precipitation total of an inch).

USE OF CLOUDBURST STREETS

Both green stormwater infrastructure and the storm sewer pipes they generally connect to have a specific capacity, so systems are usually designed with overland relief for larger storms. Overland relief is a safe overflow path for runoff in a larger storm when storm sewers reach capacity. Cloudburst streets provide the overland relief that channels and directs water from flash floods caused by an extreme amount of precipitation in a short time. Cloudburst streets are best used for shared streets with no parking because they are intended to flood during larger storms. Safer pedestrian pathways are designated, and flooding of adjacent buildings is made less frequent and less severe.

SITING FOR FLOOD RESILIENCY

Cloudburst streets should be considered in the right project context to create vibrant community spaces that provide increased flood resiliency. Where green stormwater elements are required, adding blue-green cloudburst design elements can maximize benefits to the project and the community in the face of limited funding and limited opportunity to redevelop our impervious street and sidewalk ROWs.

For projects that incorporate cloudburst streets, the potential for vehicle damage from floodwaters must be carefully considered and communicated. Flood insurance policies do not cover cars.

Design Tips

› Connect to upstream green streets.

› Form streets to channel and direct water with a reverse-crown or V-shape profile and raised curbs to provide positive drainage from buildings and safe pedestrian passageways.

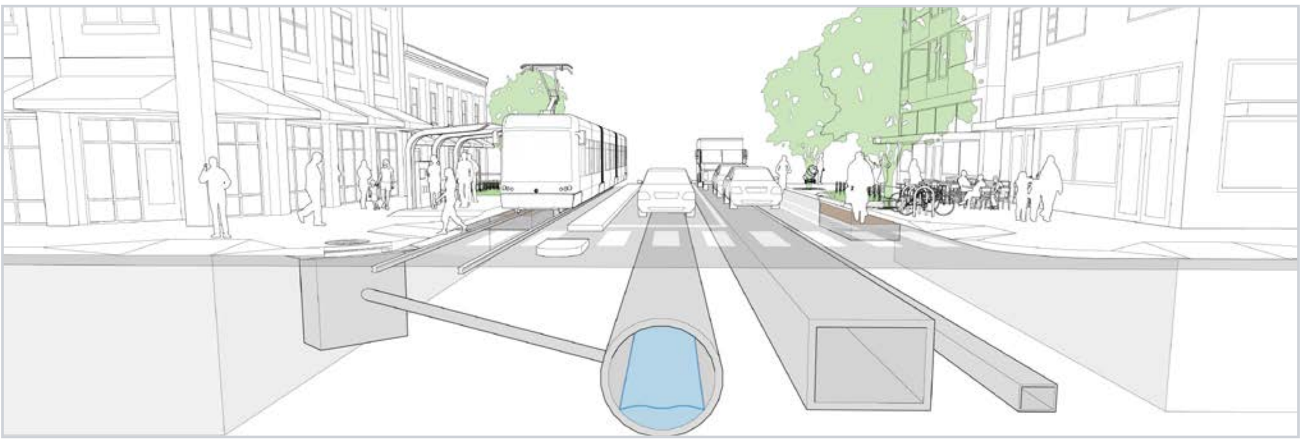
› Incorporate green stormwater elements such as vegetated swales, bioretention, and permeable concrete.

› A raised curb edge treatment with curb cuts between a vegetated swale or bioretention planter and the roadway helps to demarcate the facility for snow plowing.

3 DESIGN CONSIDERATIONS

Q STREET ALLEY, WASHINGTON, DC
Source: Allen Russ

The considerations presented herein include Alexandria-specific context, requirements, and recommendations to supplement the Virginia BMP Clearinghouse for the reference standards and specifications for bioretention and permeable pavement.



Source: NACTO

3.1 PLANNING FOR STORMWATER

One of the first steps required in designing a street or sidewalk stormwater facility or assessing its feasibility is to identify a potential location to tie into the storm sewer system. Generally, urban bioretention and permeable pavement require several feet of elevation difference between the surface elevation to the facility and the invert elevation of the downstream conveyance system to which it discharges.

UTILITIES

A utility survey must be completed before designing stormwater facilities for the street and sidewalks. Early identification and record (including depth) of existing utility locations allow for improved and earlier coordination with utility companies so that utilities can be either relocated or avoided.

Typically, utilities or footings for streetscape elements, such as streetlights, do not compromise the functionality and streetscape appearance. With engineering controls and setbacks, generally based on the utility's preferences, stormwater facilities can be installed with utilities crossing through the facility.

Engineering controls to accommodate utilities may include, but are not limited to:

› Horizontal and/or vertical setbacks

› Relocation of older utility lines outside of the facility footprint

› Waterproof shielding of utility lines, especially sewer and gas lines

› Encasement of electric conduit in concrete, which typically ends up running through the gravel layers of the facilities

Obtain permission to construct over existing utility easements prior to the design of the facility.

SOIL INFILTRATION

For infiltration to be feasible, soil infiltration tests must demonstrate that at least ½ inch of water can percolate into the soil per hour and the bottom of the the soil underneath the proposed bioretention must be at least 2 feet above bedrock or the seasonal high groundwater table.

Soil infiltration rates in Alexandria are typically quite low because of the predominance of clay soils. In Alexandria, a relatively smooth bedrock surface slopes east southeast, above which lies the Potomac Formation, which is the dominant geologic unit in the City. The Potomac Formation is relatively close to the modern land surface nearly everywhere west of Old Town and Del Ray, except in the lower elevations of Holmes Run Gorge in the extreme western section of the City, where it has been stripped off by erosion to expose the underlying bedrock. It is strongly dominated by expandable-lattice (high shrink-swell) clay minerals, which limit the feasibility of permeable pavement and infiltrating urban bioretention designs (City of Alexandria, 2017).

Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups (HSG) based on the soil's runoff potential. Because of the strong dominance of high shrink-swell clay minerals in the predominant Alexandrian soils, all green stormwater infrastructure must be designed assuming HSG D soils unless a soils report from a soil scientist or geotechnical engineer delineates onsite soils otherwise. Green stormwater elements must be designed with an underdrain consistent with the most current Virginia BMP Clearinghouse standards and specifications.

Soil investigations should also consider testing for soil contamination from previous projects, especially at industrial sites, as well as existing compaction and depth to the groundwater table. Soil compaction must be mitigated and avoided prior to installation of infiltrating facilities.

WATER QUALITY SIZING

Notwithstanding the requirements for soil volume to support tree growth, the minimum water quality sizing of a stormwater facility should be per the most current version of the Virginia BMP Clearinghouse standards and specifications as well as any applicable water quality criteria for development or redevelopment projects. Applicable criteria may include:

- Runoff from a storm with the 90th percentile rainfall depth of 1 inch as per the Virginia Stormwater Management Act and the Virginia Stormwater Management Program Regulations.
- The first ½ inch of runoff from the total impervious area of the site as per the City's Water Quality Volume Default.

Per the Virginia BMP Clearinghouse standards and specifications, the feasibility of using bioretention facilities is based in part on having the available space to accommodate the minimum surface area for water quality treatment based on the size and imperviousness of the contributing drainage area. Individual bioretention planters must be sized to handle the runoff from the contributing drainage area calculated per the applicable water quality criteria. Multiple planters may be linked or sequenced to prevent overloading a single planter.

Permeable pavement is typically designed to treat the stormwater that falls on the actual pavement surface areas. Reference the Virginia BMP Clearinghouse standards and specifications for limitations on the external contributing drainage area for permeable pavement.

3.2 URBAN BIORETENTION

Urban bioretention is a popular green technique as it can provide not only stormwater management, but aesthetic improvements and street enhancements.

INFLOW, OUTFLOW, AND UNDERDRAINS

The hydrologic design of the inflow, outflow, and overflow paths depends on many factors, such as the runoff volume to be treated, the longitudinal slope of the street and sidewalk, and site context. For more design recommendations and example inlet configurations, consult the *NACTO Urban Street Stormwater Guide*.

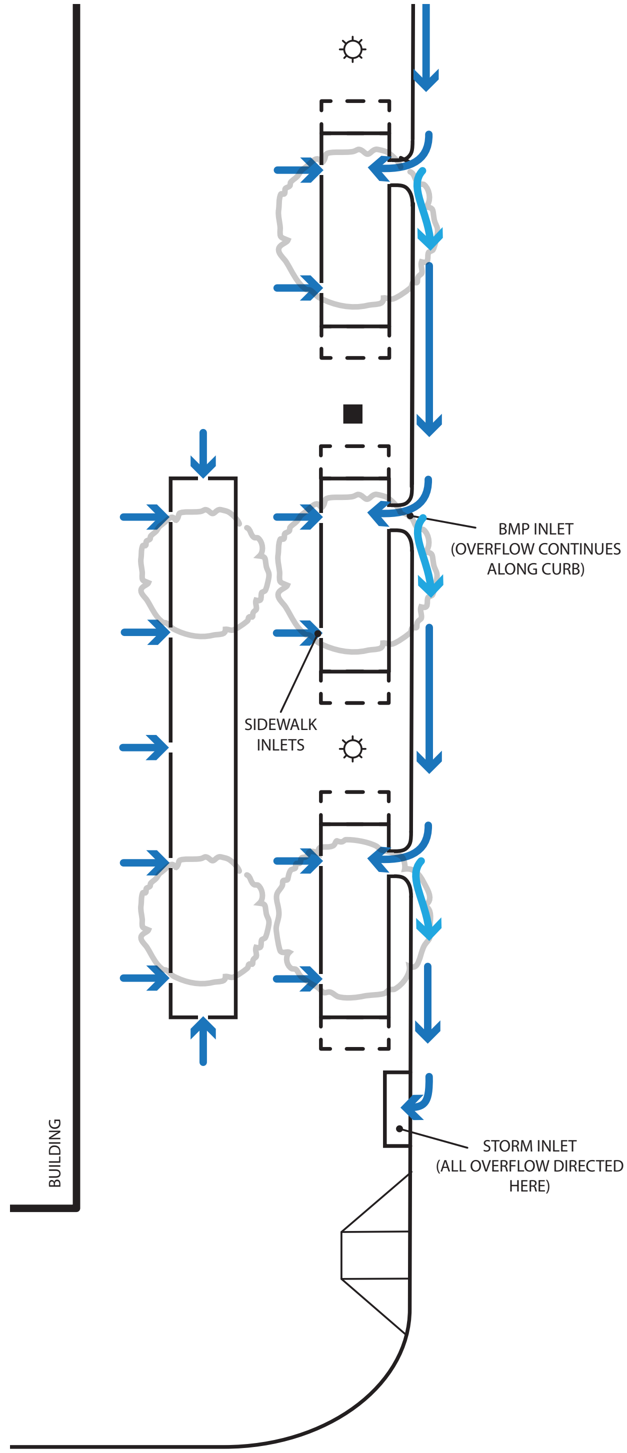
OFF-LINE HYDROLOGIC DESIGNS

In off-line facilities, runoff volumes greater than the treatment volume bypass the facility. Incoming flow from a curb inlet fills the facility up to its ponding level. As the facility fills up, higher flows are diverted past the facility.

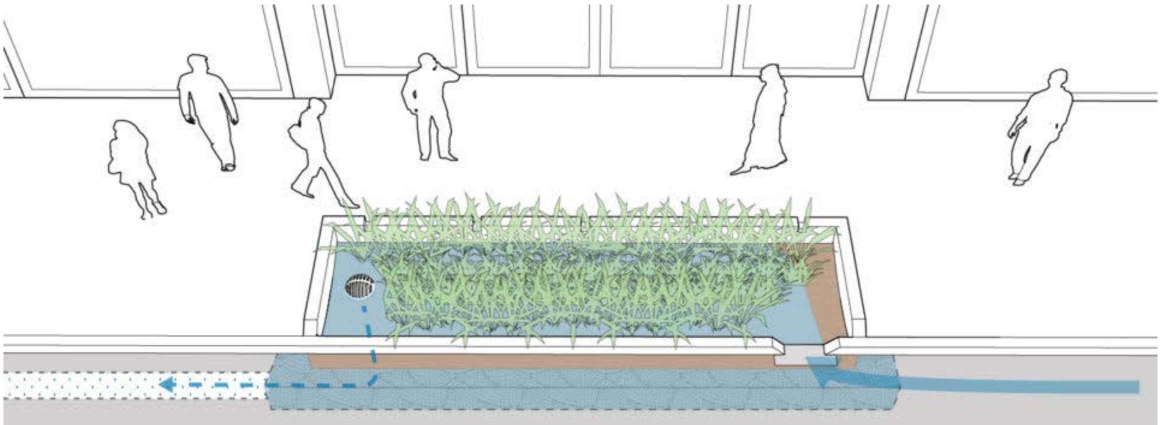
Higher flows do not pass over the filter bed, reducing maintenance required, and additional flow is able to enter as the ponding water infiltrates into the soil media.

Off-line designs that require an underdrain should also provide a raised outlet structure. In this scenario, the raised outlet structure provides redundancy if the filter media has clogged. The riser must be designed such that the filter bed is not bypassed in typical operations.

Because the facilities are designed for only the water quality volume, all overflow in the street is directed to storm inlets. A raised overflow drain or outlet structure does not preclude the need for one or more storm inlets in the ROW where overflow is directed. Storm inlets must safely capture runoff from a 10-year design storm.



OFF-LINE HYDROLOGIC DESIGN



ON-LINE HYDROLOGIC DESIGN Source: NACTO

ON-LINE HYDROLOGIC DESIGNS

On-line designs incorporate an overflow structure to safely capture a 10-year design storm. Overflow risers and underground piping to the storm sewer are larger than in off-line systems with raised outlet structures, because of the need to manage larger runoff volumes.

The riser must be designed such that the filter bed is not bypassed in typical operations and may require an orifice control structure to regulate the rate at which water leaves the system.

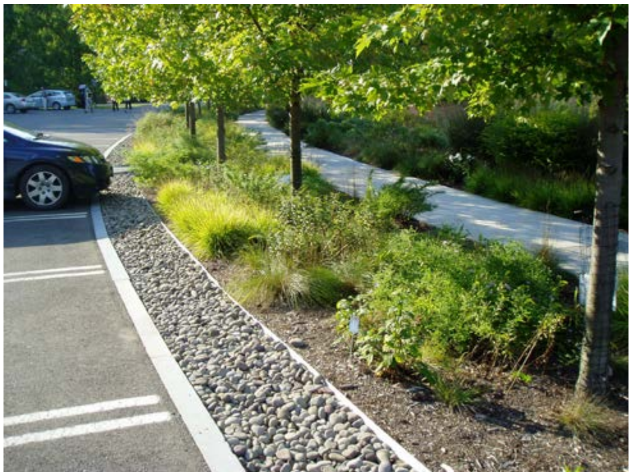
On-line hydrologic designs might be useful to supplement the capacity of downstream storm inlets in managing flow from a 10-year storm. As with storm inlets in the street, raised outlet structures could become clogged. In this case, the infrastructure could be more difficult to access for maintenance and more critical to remedy.

PRETREATMENT ZONE AND SPLASH PAD

A cobble or concrete area is designed at inlets to the bioretention facility to both prevent erosion in the facility and to provide a designated area for maintenance crews to target to collect accumulated sediment and trash. Capture of sediment and trash in inlets reduces the potential for clogging of the filter bed; however, the easiest way for a bioretention facility to stop working is for the inlets to get clogged.

The most current version of the Virginia BMP Clearinghouse standards and specifications permits various materials to be used to accomplish these functions. Several proprietary options may also be appropriate for the site. In any design, there needs to be enough of a drop to the forebay from the gutter elevation to allow the debris to drop out and stay on the splash

PROPRIETARY RAIN GUARDIAN TURRET
Source: www.rainguardian.biz/project-planing/turret



ROCK WEIR
Source: Tompkins County, New York

pad. Alternatively, a rock weir of river jack can be used to trap sediment, debris, and trash at the inlet for easy collection.

In configurations with flush curbing and sheet flow of runoff from the sidewalk into the planter, the pretreatment zone and splash pad should run parallel to the length of the planter along the curb.

In configurations with multiple flow-through cells, the first cell in a series can have the pretreatment zone for targeted maintenance.

SOIL VOLUME FOR TREES

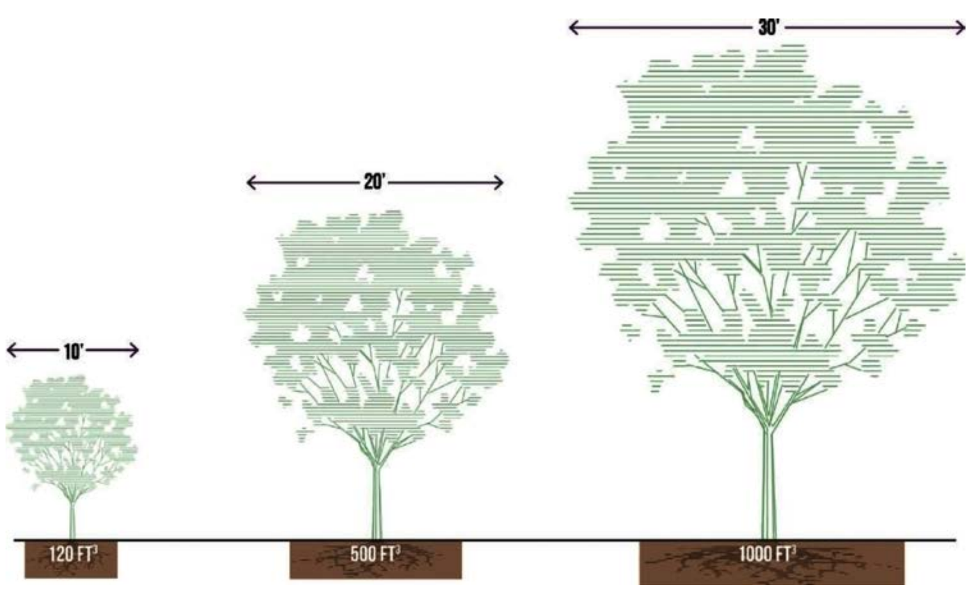
In the constrained urban Alexandrian sidewalk, the soil volume required for a tree well will often drive the design of the stormwater tree well and, in most cases, will require soil panels to extend the length of the soil volume available to the trees in the critical depth within the amenity zone.

MAXIMIZING GROWING CONDITIONS

The soil volume requirements and specifications are intended to maximize the growing conditions for plants and to provide the dual functions needed for stormwater management systems. The size of any street tree is limited not only by the tree species, but by the soil volume provided.

Stormwater tree wells require a minimum volume of 450 cubic feet per each individual, isolated tree planted or a minimum of 300 cubic feet where the shared soil volume root space is continuous and shared by two or more trees.

Soil volume for trees must be calculated with a maximum 3-foot depth. Providing a shallower soil depth over a larger area maximizes the growing conditions of the street trees by providing the soil within the main root zone.



Source: NACTO

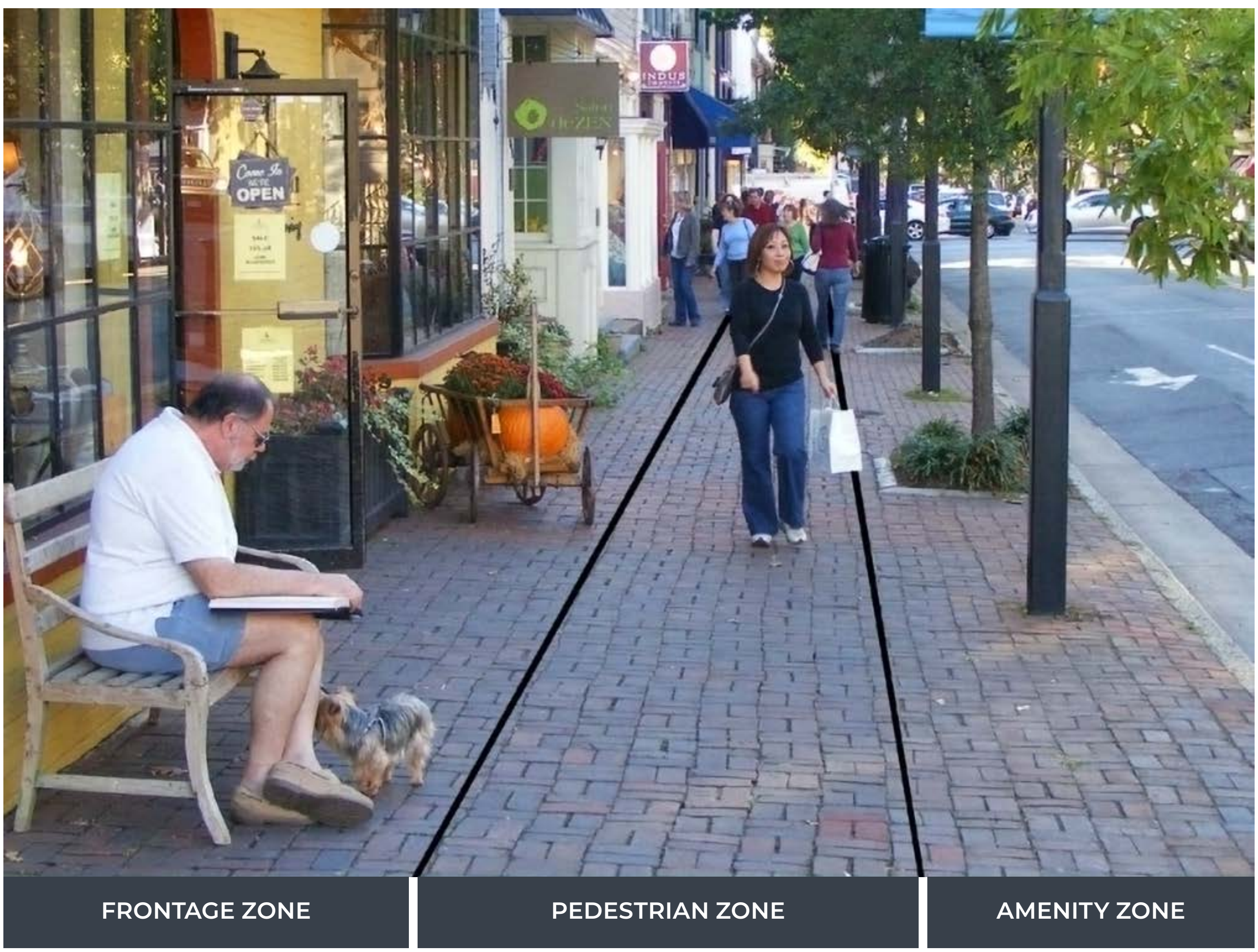
If an underdrain or overflow structure is located within a stormwater tree well, then the volume it occupies is not counted toward the total soil volume required.

SOIL PANELS

Both stormwater tree wells and standard tree wells are installed within the sidewalk amenity zone. Soil panels are also placed within the amenity zone to reduce the potential for differential settling of the surrounding sidewalk in the pedestrian zone.

The City's *Landscape Guidelines* require that for standard street tree wells, tree well trenches / soil panels shall be continuous between tree wells beneath the surface of the sidewalk. Because the coping curbing required for stormwater tree wells reduces the soil volume within the amenity zone, the designer can anticipate a similar need for soil panels underneath the surface of the sidewalk between stormwater tree wells unless calculations demonstrate that the required soil volume has been provided at the required calculation depth. Continuous soil panels are most likely to be needed between stormwater tree wells where sidewalk amenity zones are narrow and there is no shared soil volume (an individual tree well configuration is used).

If an open well or continuous planting strip cannot accommodate the required soil volume, alternative methods for increasing available soil volume below street and sidewalk structures may



be acceptable, subject to review as part of the Final Site Plan process. Alternative methods for increasing available soil volume may include, but are not limited to, modular suspended pavement systems and structural soils and will be considered by the City on a case-by-case basis.

Tree trenches with access to adjacent uncompacted soil that provides arable soil volume, adequate moisture, and space for rooting of individual trees may account for up to 20 percent of the total required soil volume. Calculations shall be provided for any alternative method indicating effective soil volume provided per tree, with volume dedicated to structural components vs. soil available to the root structure delineated.

Refer also to the City's BMP typical details for supported and suspended sidewalk soil panels for tree wells in Section 5.

COMPACTION

In all cases, the soil volume requirement relates only to uncompacted soil suitable for root growth and shall not include compacted subgrade, such as that adjacent to wells or trenches.

SOIL MEDIA AND PLANTINGS

Specification of the specific materials used in a bioretention system shall conform to the most current version of the Virginia BMP Clearinghouse standards and specifications for bioretention.

PLANTINGS

Planting plan requirements are stipulated in the Virginia Stormwater BMP Clearinghouse standards. Plant palettes for the City's urban bioretention and BMP tree well facilities should, as a best practice, consider:

- Diversity
- Persistent foliage
- Canopy spread
- Longevity
- Growth rate
- Drought tolerance
- Tolerance to saturated soils
- Tolerance to poor soils
- Resistance to urban pollutants (air and water), especially by forebays
- Bark texture
- Foliage texture
- Branching structure
- Canopy density

Aesthetically pleasing plantings are recommended for high-traffic areas. Plant pallets must follow the Native Species Standards in Section 2.b of the *Landscape Guidelines*. Use of species on the *Landscape Guidelines* invasive plant lists is prohibited. A list of recommended plantings is maintained on the City's website.

Planting design and layout should comply with Virginia Stormwater BMP Clearinghouse standards. Plantings should not be placed in forebays. Shrubs, groundcovers, and grasses shall be installed:

- To provide a continuous and vigorous cover for the planting ground plane. Two to three species maximum shall be used per 50 linear feet of planting strip, and two species maximum within a well. Supplemental herbaceous material may be inter-planted to provide additional seasonal interest.
- In large swathes of the same species to provide a simple aesthetic and maintenance program.
- To provide full seasonal interest.

The ultimate height of the planting material shall be carefully considered and in accordance with the *Landscape Guidelines* Plant Material Standards, especially in relation to the adjacent sidewalk level.

- In stormwater tree wells where the soil level is sunken below the sidewalk level, underplanting shall be chosen to ultimately grow above the adjacent sidewalk level.
- In stormwater curb extensions, plantings should grow no higher than 24 inches above the sidewalk grade. Shrubs are prohibited.
- Planting selections for sloped soil profiles shall be cognizant of the plant sizes relative to the adjacent sidewalk.

PLANTS AND WATER REQUIREMENTS

Plants shall be located to maximize their vigor and health with regards to their water requirements. Careful consideration shall be given to the placement of plants and whether they can tolerate inundation or periods of drought. This is particularly pertinent to facilities that have a sloped soil profile and to plants located in/around water inlets.

INSTALLATION

Installation of plant material shall follow the procedures established in the City's *Landscape Guidelines*, unless otherwise specified. If conflicting requirements and procedures with the *Landscape Guidelines* are in evidence, the procedures and requirements outlined in these guidelines shall be adhered to.

Trees in stormwater tree wells should be staked in a manner that avoids penetrating the underdrain, such as guying or use of a duck bill anchor.

PLANTING ESTABLISHMENT

- During the planting establishment period and during prolonged spells of dry weather, regular watering will be required to maintain plant vigor.
- No permanent ground-set irrigation system shall be installed.
- Reduction and curtailment of water use may be required in a water supply emergence per City Code section 5.6 Article A, Division 2.

EXPERIENCE FROM NEIGHBORING LOCALITIES HAS SHOWN THAT PLANTINGS THAT GROW TOO TALL MAY PRESENT SAFETY AND AESTHETIC CONCERNS IF THEY BLOCK SIGHT LINES, ESPECIALLY AROUND BUSINESSES.

ADJACENT CURBS AND EDGE TREATMENTS

Structural footings may be needed for adjacent curbs and edge treatments given sidewalk or street conditions to prevent lateral movement of the walls of the bioretention facilities.

Concrete edge treatments surrounding bioretention facilities shall be standard except where the Board of Architectural Review has the authority to and approves a certificate of appropriateness within historic districts, in which case granite edge treatments shall be used adjacent to City Standard Brick sidewalks. Refer to the City of Alexandria Sidewalk Materials Staff Guidance Map for more information.

The side walls of the facilities shall be designed to support the edge of the well or trench, structurally support the coping curb, and in many cases provide a root barrier. Excavations for bioretention facilities may be feasible with cuts resulting in vertical walls in Alexandria's clay soils and when concrete coping curbing is used. However, the side walls of the bioretention facility may require a 30 degree slope from the top of the subgrade and narrowing to the bottom of the excavation and/or additional structural footings, such as when additional strength is required to support the heavier granite curbing structure.

The design of the side walls may include alternatives that meet these requirements, and may include full depth concrete walls, benched walls, and battered walls. All structural elements shall be certified by a structural engineer.

FENCING

A short, 18-inch decorative wrought iron fence is required around the bioretention facility on all sides adjacent to the sidewalk where the total drop from the top of the curb to the top of the mulch is greater than 8.25 inches. A three-sided fence should be considered where the open side is adjacent to the roadway or a parking lane. See Section 5 Typical Standards and Details for fencing applications and specifications.

STEP-OUT ZONES AND WALKWAYS

Step-out zones accommodate the mobility of people walking, biking, and using transit as well as to provide access to sidewalks for people entering or exiting vehicles in adjacent on-street parking. In urban settings, step-out zones are based on clear zone principals and goals of providing space for recovery of an errant vehicle.

Depending on the length of urban bioretention facilities and the street uses, step-out zone widths will vary. A bioretention facility 20 feet or less in length with regular access paths between the curb and sidewalk should enable narrower step-out widths on constrained sidewalks. Step-out zones must have a minimum lateral offset of 1.5 feet provided beyond the back of the curb. Clear zones of at least 3 feet beyond the face of the curb are typical. In any case, a clear zone should be provided according to the Virginia Department of Transportation *Road Design Manual*, Appendix A-2.

Regular access paths or walkways at least 5 feet wide must be provided between the curb and the pedestrian sidewalk zone to provide increased connectivity for pedestrians and motorists. Consider siting them in the locations of existing walkways, lead walks to building entryways, and in other locations where there is a regular need for loading and unloading for deliveries, moving vehicles, or disability parking. Walkways may not be required where there is no curb-side parking.

Walkways are one option for facilitating mobility of street and sidewalk users; however, the designer should carefully consider whether the bioretention facility with or without a walkway is appropriate for the site. Accessible paths and clearances for people using mobility devices should take priority in high-traffic intersections and major destinations, and potentially in other areas where pedestrian paths are more varied, such as where a diagonal path to a bus or transit stop would be the preferred choice for pedestrians.

3.3 PERMEABLE PAVEMENT

Permeable pavement installations in the City streets and sidewalks should be limited to pervious concrete, especially in applications where the City will assume maintenance responsibility. Alternative designs using porous asphalt will be considered on a case-by-case basis. Permeable pavers are prohibited. For this reason, this document may refer to permeable pavement and pervious concrete interchangeably.

In addition to other design considerations limiting the placement of permeable pavement materials, the use of permeable pavement within Alexandria's sidewalks is limited by requirements for historic districts and some small area plans. Refer to the City's Sidewalk Materials Staff Guidance Map for additional information; this map is used by City staff to summarize the multitude of zoning requirements for sidewalk materials. Consider pervious concrete where City-standard concrete or brick/concrete hybrid sidewalks are recommended as denoted on the map.

Other localities have demonstrated success with both pre-cast and cast-in-place pervious concrete. Pre-cast pervious concrete is more difficult to place in areas with turns or slope changes such as some alleys and many intersections; these areas may be paved with traditional impervious materials when pre-cast materials are otherwise used.

Specification of the specific materials used in a permeable pavement system shall conform to the most current version of the Virginia BMP Clearinghouse standards and specification for bioretention. Additionally, the designer must carefully consider the expected traffic load at the proposed site and the consequent structural requirements.

PAVEMENT SLOPE

Designers must mitigate the potential for stormwater to run downhill and out of the surface when permeable pavement is installed. Additionally, steep slopes may cause shifting of the pavement surface and base materials. Tiered subgrades and/or check dams within the reservoir and extending to the subgrade are commonly used to slow the flow of water within the pavement system.

Permeable pavement is prohibited where longitudinal slopes exceed 5%. The engineer should design the system to achieve storage, draw-down, and structural requirements. For facilities lined with a waterproof membrane, the minimum bottom slope shall be 2 % to drain dry.

HYDRAULIC CONSIDERATIONS

Permeable pavement should not be hydraulically connected to structure foundations to avoid harmful seepage. Install a concrete curb between pervious pavement and asphalt pavement. The concrete curb shall extend into the subgrade below the aggregate sub-base for the asphalt pavement, as well as the subgrade below the permeable pavement reservoir. The size of the reservoir under the pavement should be designed based on water quality treatment criteria, the water quantity/flood protection considerations, and freeze-thaw considerations.

FREEZE-THAW

Freeze-thaw cycles pose a risk of cracking permeable pavement, especially in areas such as Alexandria that do not drain readily and experience hard wet freezes where the ground stays frozen as a result of long continuous periods of average daily temperatures below freezing.

The stone reservoir underneath the pavement surface must be designed so that the depth of water within the stone layer stays below the pervious concrete layer. Piping consisting of a minimum 8-inch PVC with cleanouts for maintenance may be placed under sidewalks to store the water within the reservoir to avoid freeze-thaw. In Alexandria, the frost penetration depth per the building code is 24 inches. For extra protection, design for a 25-year or 100-year storm. See the current Virginia BMP Clearinghouse standards and specification for bioretention for more information.

Maintenance of permeable pavements is also critical to prevent pavement failure due to freeze-thaw, as accumulated sediment can prevent water in the pavement from draining into the reservoir layer.

SITING FOR SNOW OPERATIONS

Permeable pavement is not recommended on snow emergency routes, primary routes, or secondary routes and is prohibited in travel lanes. Alleys and sidewalks may be better suited for avoiding impacts from snow operations.

Pervious concrete can be plowed similar to traditional pavements using similar equipment and settings. There are several impacts to snow operations may have on pervious concrete, including where and how they are plowed.

To the extent possible, siting and design of pervious concrete surfaces should be prioritized outside of areas where heavy plowing or brining is anticipated.

EDGE RESTRAINTS

Permeable pavement should be installed with standard concrete edge restraints on sides to facilitate identification for maintenance and to address hydraulic considerations in Section 3.3.3. Where permeable pavement abuts a driveway apron, edge restraints may not be necessary.

THE AIR LAYER WITHIN THE VOIDS OF THE SURFACE AND BASE LAYERS KEEPS THE PERVIOUS PAVEMENT SYSTEM (ON THE LEFT) WARMER IN COLDER WEATHER THAN TRADITIONAL PAVEMENTS (RIGHT) WHICH PROVIDES A SAFER SURFACE FOR VEHICLES AND PEDESTRIANS.

Source: John Kevern

A CLEAN PLOWED PERVIOUS CONCRETE SURFACE (ON THE LEFT) RETAINS SOME SNOW IN THE SURFACE PORE SPACE COMPARED TO A TRADITIONAL CONCRETE SURFACE (RIGHT).

Source: John Kevern

3.4 ALIGNING WITH COMPLETE STREETS

The City's *Complete Streets Design Guidelines* aim to ensure that Alexandria's streets meet the needs of all users. Green stormwater infrastructure helps meet the need for stormwater management while providing additional benefits to users. The following tables summarize the local street contexts that are most appropriate for each green stormwater configuration.

URBAN BIORETENTION

Cells highlighted in blue indicate a preferred use of the bioretention configuration.

Bioretention	Commercial Connector	Main Street	Mixed-Use Boulevard	Neighborhood Residential	Parkways	Neighborhood connector	Industrial	Shared street	Other
Continuous Planters	yes			yes		yes	yes		
Individual Tree Wells	yes	yes	yes				yes	yes	
Mid-Sidewalk BMPs	yes		yes					yes	
Back of Sidewalk BMP		yes	yes	yes	yes			yes	
Curb Extension		yes	yes	yes	yes	yes		yes	
Median	yes		yes	yes		yes	yes	yes	
Bus Bulb	yes	yes	yes						yes – transit vision
Protected Bike Lane	yes		yes	yes		yes	yes		yes – bike overlay

PERMEABLE PAVEMENT

Cells highlighted in blue indicate a preferred use of the permeable pavement configuration. All recommended permeable pavements are to be pervious concrete.

Permeable Pavement	Commercial Connector	Main Street	Mixed-Use Boulevard	Neighborhood Residential	Parkways	Neighborhood connector	Industrial	Shared street	Other
Permeable Bike Lane	yes		yes	yes	yes	yes			yes – bike overlay
Permeable Sidewalk		yes	yes	yes	yes	yes		yes	
Permeable Parking Spots		yes	yes	yes	yes	yes		yes	
Permeable Alley				yes	yes	yes		yes	yes – alleys

4 IMPLEMENTATION

HUMBOLDT STREET, SAN MATEO, CALIFORNIA
Source: San Mateo County

4.1 PERMITTING AND CONSTRUCTION

Virginia Stormwater Management Regulations specify water quality and water quantity criteria on all major development and redevelopment projects, as well as on projects with a total land disturbance of greater than 2,500 square feet. The design and construction of stormwater BMPs for treatment of stormwater runoff from the public ROW are required in areas of new development or redevelopment that include either the construction of new public roads and sidewalks, or significant rehabilitation of the existing ROW facility per "Memorandum to Industry No. 03-2014," dated June 11, 2014.

Property owners, developers, and applicants seeking approvals of plans such as Development Site Plans, Development Special Use Permits, and/or Special Use Permits within the City where stormwater quality BMPs will be installed in the public ROW should consult these guidelines in the design of BMP systems that are suitable in both function and streetscape context. In any given development application, the City may require additional information or improvements beyond the guidelines set forth herein.

LOCAL POLICIES AND ORDINANCES

"Memorandum to Industry No. 04-2014*" (sic), dated June 1, 2014. Defines the requirement that any stormwater quality BMP in the public ROW shall follow the design guidelines established by the City and be subject to approval by the Director of T&ES.

Article XIII of the City's Zoning Ordinance - the Environmental Management Ordinance. Adopted by the City in 1992, and later revised in 2014 to comply with the Virginia Chesapeake Bay Preservation Area Designation and Management Regulations and the Virginia Stormwater Management Program regulations. The purpose of this ordinance is to protect local streams, the Potomac River, and the Chesapeake Bay. Land development projects in the City are subject to these requirements to protect environmentally sensitive lands, minimize potential pollution from stormwater runoff, minimize potential erosion and sedimentation, reduce the introduction of harmful nutrients and toxins into state waters, maximize rainwater infiltration while protecting groundwater, and ensure the long-term performance of the measures employed to accomplish the statutory purpose.

AUTHORITY

The Environmental Management Ordinance is issued under the authority of Section 62.1-44.15:73 of the Code of Virginia (the Chesapeake Bay Preservation Act), 62.1-44.15:24 et seq. of the Code of Virginia (the Virginia Stormwater Management Act), and attendant regulations as adopted by the Virginia State Water Control Board. Code of Virginia Section 62.1-44.15:27 specifically requires the City to adopt a Virginia Stormwater Management Program. Authority to protect water quality is also provided by Section 15.2-2283 (Purpose of zoning ordinances) of the Code of Virginia. Authority to establish more stringent water quality design criteria is described in Section 62.1-44.15:33 of the Code of Virginia.

4.2 MAINTENANCE

Maintenance considerations are an integral part of continued, successful treatment of stormwater runoff from the City's public streets and sidewalks. Since 2014, when developers were first required to treat public ROW in development and redevelopment projects to help the City meet unfunded state and federal stormwater mandates, the capital costs of the BMPs in the ROW have been fronted largely by developers. The life-cycle costs for green infrastructure that becomes the continued responsibility of the

City are thus wholly dependent on the costs of maintenance.

Everyone throughout the value chain who participates in the ultimate installation and upkeep of these street and sidewalk stormwater BMPs has the opportunity and responsibility to be a good steward of public funds. The designer influences how the BMP will function and what access maintenance staff will have to do their work. The construction crews will influence the successful implementation of the design. The developer has control over plant establishment and the initial maintenance during the warranty periods before maintenance responsibilities are accepted by the City at the time of bond release. In this way, many stakeholders influence the ultimate costs of annual maintenance to the City long before the City begins routine maintenance.

During design and permitting, any BMP in the ROW may be subject to approval by the Director of T&ES or his/her designee because of the ultimate maintenance responsibilities assumed by the City. Additionally, as time goes on, the City may amend these design guidelines to provide more specific recommendations on design criteria that reduce the required level or cost of service.

Section 4.2.1 describes maintenance responsibilities. Section 4.2.2 describes typical maintenance tasks to inform expectations of the developer during the bond period, and Section 4.2.3 identifies common maintenance problems.

RESPONSIBILITIES

"Memorandum to Industry No. 04-2014" (or subsequent revisions) forms the basis for maintenance responsibilities between the developer or permit applicant and the City, although agreements for specific projects shall be made on an individual basis, either as part of the master planning or development site plan process.

In terms of maintenance responsibility, two scenarios are likely:

1. The developer/permit applicant shall be responsible for maintaining the street and sidewalk BMPs until acceptance by the City for maintenance.

   The City shall accept the structural elements of the sidewalk BMPs constructed and installed in the ROW for maintenance upon passing inspection and termination of the maintenance bond for public improvements. If any plantings are installed as part of the BMP system, the requirements of Section 11-413 (6) (b) of the Zoning Ordinance apply, and the plantings must be maintained by the developer/applicant for 3 years. Planting shall remain healthy and showing signs of vigor and growth. The City shall accept the plantings installed in street and sidewalk BMPs located in the ROW upon passing inspection and termination of the maintenance bond for landscaping.

2. In some cases, the developer, Business Improvement District, or Homeowners Association / Master Association will be responsible for the maintenance of ROW street and sidewalk BMPs.

   In such cases, a legal mechanism providing for maintenance access must be executed and recorded, such as an easement, a maintenance agreement, deed language, etc.

Per the terms of "Memo to Industry No. 2014-04*," in most cases when BMPs are installed in the public ROW, the City will maintain the BMP after the bond period (Performance and/or Maintenance, as applicable). In these situations:

› T&ES maintains the hardscape and drainage elements of each installation and plants, except for trees, but including the replacement of trees.

› RPCA maintains all trees.

TYPICAL MAINTENANCE OPERATIONS

First year and subsequent routine and some non-routine maintenance activities shall be considered anytime BMPs are designed and installed. This section presents a brief guide to help stakeholders responsible for maintenance to understand general maintenance expectations for successful implementation of BMP facilities. Nothing in this section shall be interpreted to release the developer of maintenance activities determined by regulation or otherwise required by the City.

First-Year Maintenance Operations. Successful establishment of BMP facilities will require maintenance tasks be undertaken in the first year following installation with proper permits from the City.

Initial inspections. For the first 6 months following construction, the facilities should be inspected at least twice after storm events that exceed ½ inch of rainfall.

Maintenance Inspections. Conducting a spring maintenance inspection and cleanup is highly recommended at each stormwater management facility.

Routine and Non-Routine Maintenance. Maintenance of BMPs requires integration into the routine operations for both landscaping and more traditional stormwater facilities (i.e., catch basin maintenance).

COMMON MAINTENANCE PROBLEMS

BIORETENTION FACILITIES

Bioretention facilities have unique landscaping maintenance needs, such as maintaining elevation differences needed for ponding, proper mulching, sediment and trash removal, and limited use of fertilizers and pesticides.

The most common non-routine maintenance problem for urban bioretention involves standing water. If water remains on the surface for more than 48 hours after a storm, adjustments to the grading may be needed or underdrain repairs may be needed. The surface can also be checked for accumulated sediment or a fine crust that builds up after the first several storm events. Several methods can be used to rehabilitate the filter (try the easiest things first, as described below).

Determine Presence of Standing Water. Open the underdrain observation well or cleanout and pour in water to verify that the underdrains are functioning and not clogged or otherwise in need of repair. The purpose of this check is to see if there is standing water all the way down through the soil.

- If there is standing water on top, but not in the underdrain, then there is a clogged soil layer.
- If the underdrain and standpipe have standing water, then the underdrain must be clogged and will need to be snaked.
- Remove accumulated sediment

Amend Soil. By hand, add 2 to 3 inches of sand into the upper 8 to 12 inches of soil at very selective locations only and without damaging the root system of the tree planting. Shrub and grass under-planting may need to be replaced to allow for soil amendments. A careful assessment of the location of the tree roots shall be performed prior to selecting the locations for sand amendment.

Install Sand Wicks. Install sand wicks from 3 inches below the surface to the underdrain layer. This reduces the average concentration of fines in the media bed and promotes quicker drawdown times. Sand wicks can be installed by excavating or augering (using a tree auger or similar tool) down to the gravel storage zone to create vertical columns, which are then filled with a clean open-graded coarse sand material (ASTM C-33 concrete sand or similar approved sand mix for bioretention media). Enough wick drains of sufficient dimension should be installed to meet the design dewatering time for the facility without damaging the root system of the planting. A careful assessment of the location of the tree roots shall be performed prior to selecting the locations for sand wicks.

PERMEABLE PAVEMENT

Both routine and non-routine maintenance may be required for permeable pavement. Permeable pavement has unique routine maintenance needs compared to traditional pavements or stormwater structures, in particular, maintaining infiltration rates. Non-routine maintenance problems include raveling and clogging or sealing of the pavement surface.

Routine Maintenance. Routine maintenance involves maintaining infiltration rates. Ideally, there should be no more than 10 percent infiltration blockage. Blockage by sedimentation or debris might be considered moderate with between 10 to 30 percent blockage and severe when there is more than 30 percent blockage caused by sediment or debris.

› Field infiltration testing using ASTM C1701 can be performed on a case-by-case basis to identify clogged areas or to determine an optimized plan for cleaning the pavement. However, studies have shown that visual inspection of the surface pavement usually matches testing of impaired surface draining, especially when caused by observable storm impacts or sedimentation onto the surface.

› Weeds should not be present in permeable pavement. The presence of weeds indicates an accumulation of sediment and a reduction of infiltration.

Non-Routine Maintenance. The most common non-routine maintenance problems for permeable pavement involve raveling and clogging or sealing of the pavement surface. Abrasion can also occur in locations with turning traffic or snow plowing.

Raveling is when the aggregate mixture comes loose after the concrete has set and is often related to design or installation. Design and installation must be performed by installers trained and experienced in pervious concrete installation. Requiring satisfactory completion of test panels before starting work is also a good practice. Surface raveling might be considered moderate when there is 25% loss of surface particles with no rutting and severe when there is 50% or greater loss of surface particles with localized rutting.

5

TYPICAL STANDARDS AND DETAILS

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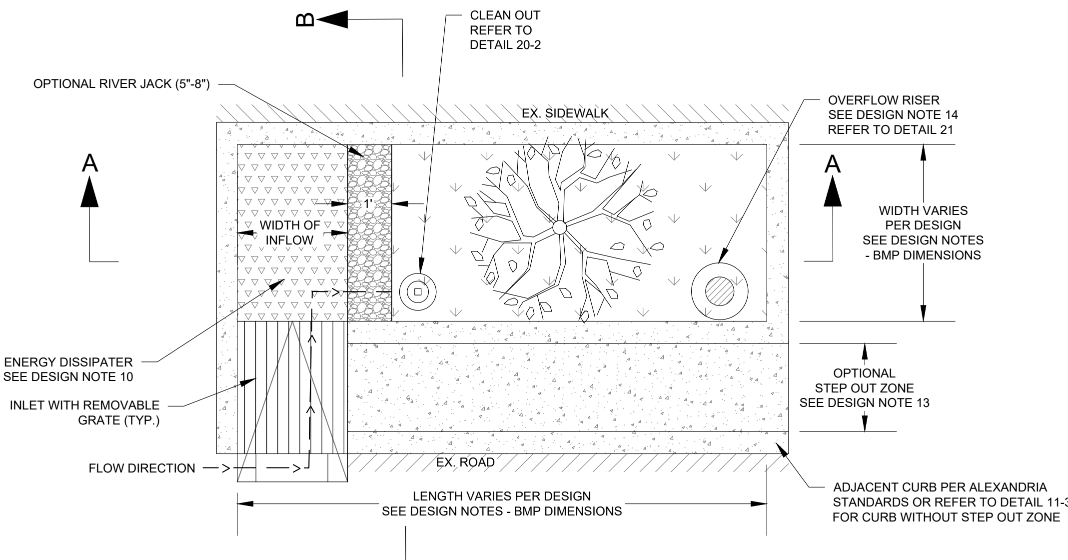
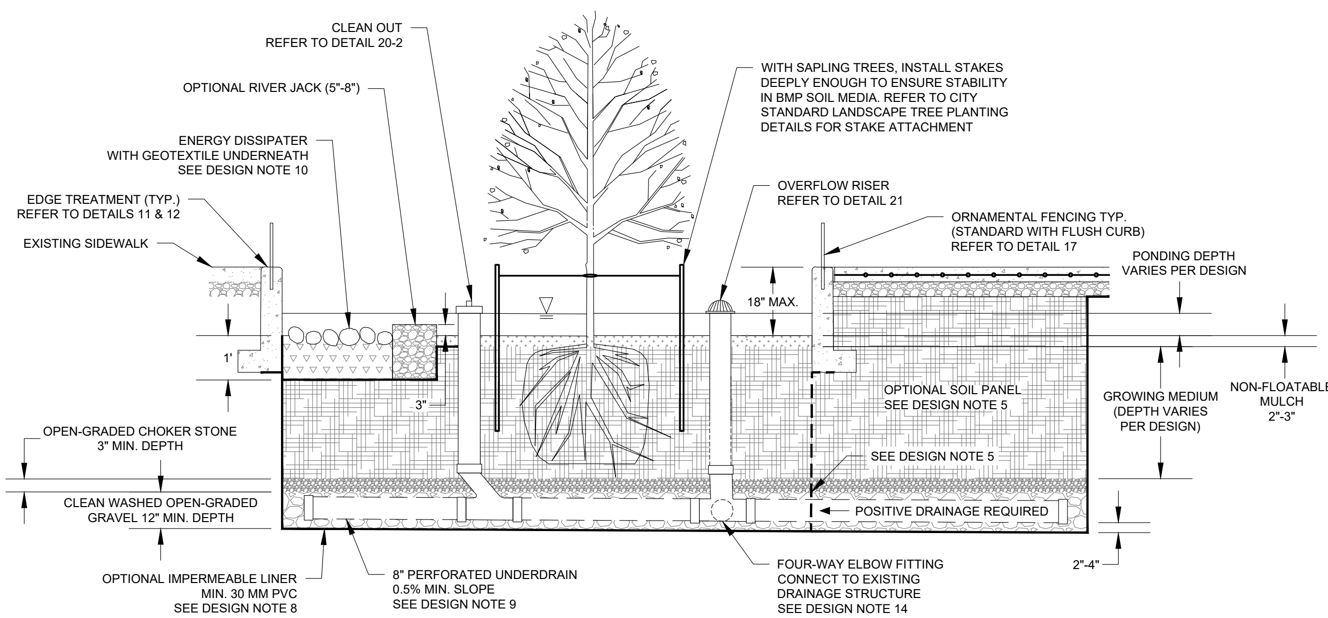


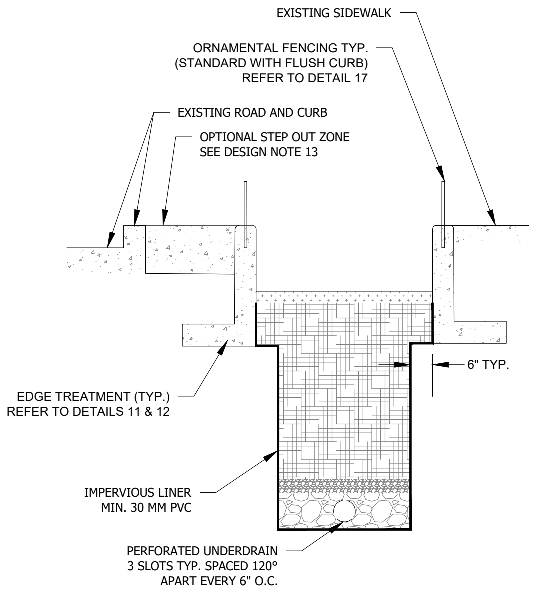
PLAN VIEW



PROFILE A-A

DETAIL 1

INDIVIDUAL TREE WELL



SECTION B-B

DESIGN NOTES

BMP DIMENSIONS

1. THE RATIO OF THE LENGTH OF THE SHORTEST FLOW PATH TO THE OVERALL LENGTH OF THE BMP SHOULD BE AT LEAST 0.3 FT/FT.
2. LONGITUDINAL SLOPE OF THE BMP SURFACE SHALL BE LEVEL TO PROVIDE A CONSISTENT PONDING DEPTH.
3. WEIR ELEVATION(S) SHALL BE DESIGNED SUCH THAT WATER FROM A 10-YR STORM CANNOT REACH THE SIDEWALK AND THE PONDING DEPTH OF THE DOWNSTREAM SIDE OF THE BIORETENTION CANNOT EXCEED 1 FOOT.
4. CLEAN OUTS SHOULD BE A MIN. OF 2' AWAY FROM THE EDGE OF THE TREE'S ROOT BALL.
5. PROVIDE MIN. 450 CUBIC FEET OF SOIL FOR EACH INDIVIDUAL, ISOLATED TREE WITHIN A MAXIMUM 3 FOOT DEPTH. CONTINUOUS UNCOMPACTED SOIL PANELS UNDER SUSPENDED, REINFORCED SIDEWALK MAY BE USED TO MEET SOIL VOLUME REQUIREMENTS FOR TREES IN ACCORDANCE WITH THE BMP DESIGN GUIDELINES (REFER TO DETAIL 23). ALTERNATIVE METHODS SUCH AS MODULAR SUSPENDED PAVEMENT SYSTEMS WILL BE CONSIDERED ON A CASE-BY-CASE BASIS (REFER TO DETAIL 24). IF A SOIL PANEL WILL NOT BE CONSTRUCTED, TIE IN IMPERVIOUS LINER AS SHOWN BY DASHED LINE.
6. IF NO CHECK DAM IS USED, DESIGNER MUST ENSURE THAT ROAD SLOPES ALLOW FOR CONSTRUCTABILITY OF TREE WELLS. TREE WELLS MAY NOT BE FEASIBLE ON ROAD SLOPES GREATER THAN 8%.

BMP MATERIALS

7. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 9 (BIORETENTION) FOR DESIGN AND MATERIAL SPECIFICATIONS.
8. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.
9. UNDERDRAIN PIPE SHALL BE PERFORATED HDPE OR PVC SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER.
10. ACCEPTABLE ENERGY DISSIPATERS MAY INCLUDE:
    - A GRAVEL DIAPHRAGM WITH AN OPTIONAL TOP LAYER OF DECORATIVE RIVER ROCK
    - VDOT #3 STONE
    - SPLASH BLOCK BORDERED BY 5"-8" RIVER JACK; OR
    - AN ACCEPTABLE ALTERNATIVE PER THE VIRGINIA BMP CLEARINGHOUSE.
11. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING

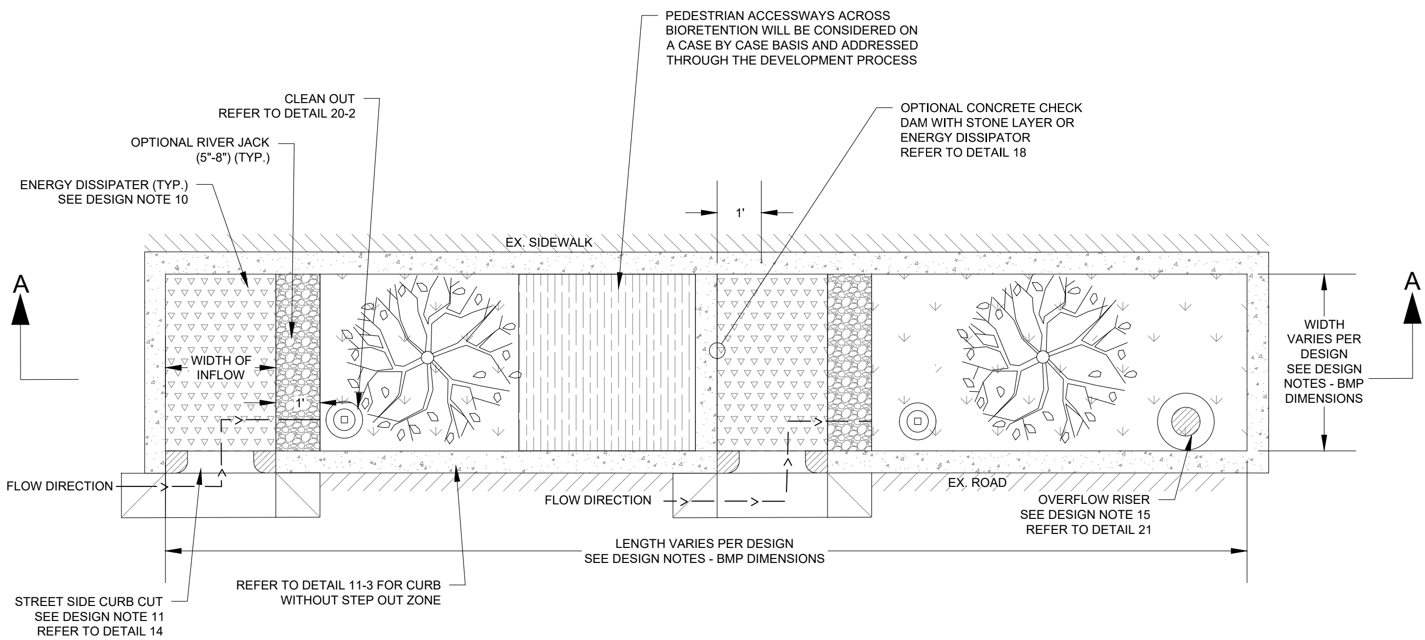
12. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.
13. WHEN STEP OUT ZONE IS INCLUDED, MINIMUM WIDTH OF STEP OUT ZONE IS 1.5'. PREFERRED WIDTH IS 3'. IF NO STEP OUT ZONE IS USED, THE TRENCH DRAIN INLET MAY BE REPLACED WITH A CURB CUT INLET.
14. THE OUTLET PIPE FROM THE OVERFLOW RISER SHALL BE SIZED TO CONVEY THE 10-YR STORM WITH A MINIMUM DEPTH OF COVER OF 2 FEET. THE OUTLET PIPE SHALL BE 8-INCH MINIMUM DIAMETER SCHEDULE 40 PVC WITH A MINIMUM SLOPE OF 0.5%. IF A LARGER OUTLET PIPE IS REQUIRED, CONNECT UNDERDRAIN AND OUTLET PIPE THROUGH A DRAINAGE STRUCTURE.
15. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.
16. LATERAL BRACINGS SHALL BE INCLUDED TO WITHSTAND ANTICIPATED LOADING. REFER TO DETAIL 25.

CONSTRUCTION INFORMATION

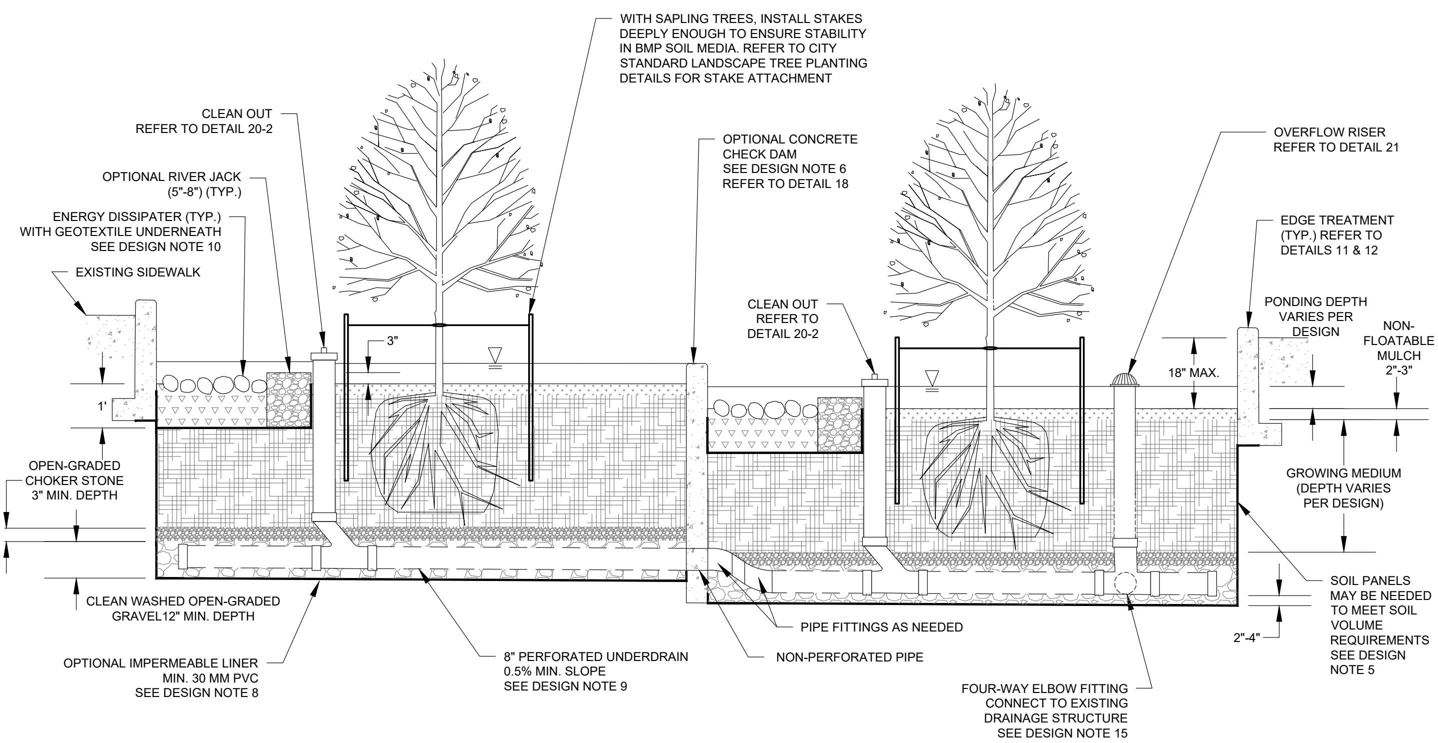
1. BACKFILL SOIL MIXTURE BENEATH ROOTBALL MUST BE COMPACTED SUCH THAT ROOT BALL DOES NOT SINK.

DETAIL 1

INDIVIDUAL TREE WELL (continued)



PLAN VIEW



PROFILE A-A

DETAIL 2

CONTINUOUS TREE WELL

DESIGN NOTES

BMP DIMENSIONS

1. THE RATIO OF THE LENGTH OF THE SHORTEST FLOW PATH TO THE OVERALL LENGTH OF THE BMP SHOULD BE AT LEAST 0.3 FT/FT.

2. LONGITUDINAL SLOPE OF THE BMP SURFACE SHALL BE LEVEL TO PROVIDE A CONSISTENT PONDING DEPTH.

3. WEIR ELEVATION(S) SHALL BE DESIGNED SUCH THAT WATER FROM A 10-YR STORM CANNOT REACH THE SIDEWALK AND THE PONDING DEPTH OF THE DOWNSTREAM SIDE OF THE BIORETENTION CANNOT EXCEED 1 FOOT.

4. CLEAN OUTS SHOULD BE A MIN. OF 2' AWAY FROM THE EDGE OF THE TREE'S ROOT BALL.

5. PROVIDE 450 MIN. CUBIC FEET OF SOIL FOR EACH INDIVIDUAL, ISOLATED TREE OR PROVIDE 300 CUBIC FEET OF SHARED SOIL VOLUME PER TREE WITHIN A MAXIMUM 3 FOOT DEPTH IN ACCORDANCE WITH THE BMP DESIGN GUIDELINES. CONTINUOUS UNCOMPACTED SOIL PANELS UNDER SUSPENDED, REINFORCED SIDEWALK MAY BE USED TO MEET SOIL VOLUME REQUIREMENTS FOR TREES IN ACCORDANCE WITH THE BMP DESIGN GUIDELINES (REFER TO DETAIL 23). ALTERNATIVE METHODS SUCH AS MODULAR SUSPENDED PAVEMENT SYSTEMS WILL BE CONSIDERED ON A CASE-BY-CASE BASIS (REFER TO DETAIL 24).

6. IF NO CHECK DAM IS USED, DESIGNER MUST ENSURE THAT ROAD SLOPES ALLOW FOR CONSTRUCTABILITY OF TREE WELLS. TREE WELLS MAY NOT BE FEASIBLE ON ROAD SLOPES GREATER THAN 8%.

BMP MATERIALS

7. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 9 (BIORETENTION) FOR DESIGN AND MATERIAL SPECIFICATIONS.

8. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.

9. UNDERDRAIN PIPE SHALL BE PERFORATED HDPE OR PVC SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER.

10. ACCEPTABLE ENERGY DISSIPATERS MAY INCLUDE:
    - A GRAVEL DIAPHRAGM WITH AN OPTIONAL TOP LAYER OF DECORATIVE RIVER ROCK
    - VDOT #3 STONE
    - SPLASH BLOCK BORDERED BY 5"-8" RIVER JACK; OR
    - AN ACCEPTABLE ALTERNATIVE PER THE VIRGINIA BMP CLEARINGHOUSE.

11. THE TRENCH DRAIN INLET MAY BE USED IN PLACE OF THE CURB CUT INLET IN AREAS WHERE THE CONTINUOUS TREE WELL WILL BE OFFSET FROM THE CURB.

12. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING

13. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.

14. WHEN STEP OUT ZONE IS INCLUDED, MINIMUM WIDTH OF STEP OUT ZONE IS 1.5'. PREFERRED WIDTH IS 3'. IF NO STEP OUT ZONE IS USED, THE TRENCH DRAIN INLET MAY BE REPLACED WITH A CURB CUT INLET.

15. THE OUTLET PIPE FROM THE OVERFLOW RISER SHALL BE SIZED TO CONVEY THE 10-YR STORM WITH A MINIMUM DEPTH OF COVER OF 2 FEET. THE OUTLET PIPE SHALL BE 8-INCH MINIMUM DIAMETER SCHEDULE 40 PVC WITH A MINIMUM SLOPE OF 0.5%. IF A LARGER OUTLET PIPE IS REQUIRED, CONNECT UNDERDRAIN AND OUTLET PIPE THROUGH A DRAINAGE STRUCTURE.

16. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.

17. LATERAL BRACINGS SHALL BE INCLUDED TO WITHSTAND ANTICIPATED LOADING. REFER TO DETAIL 25.

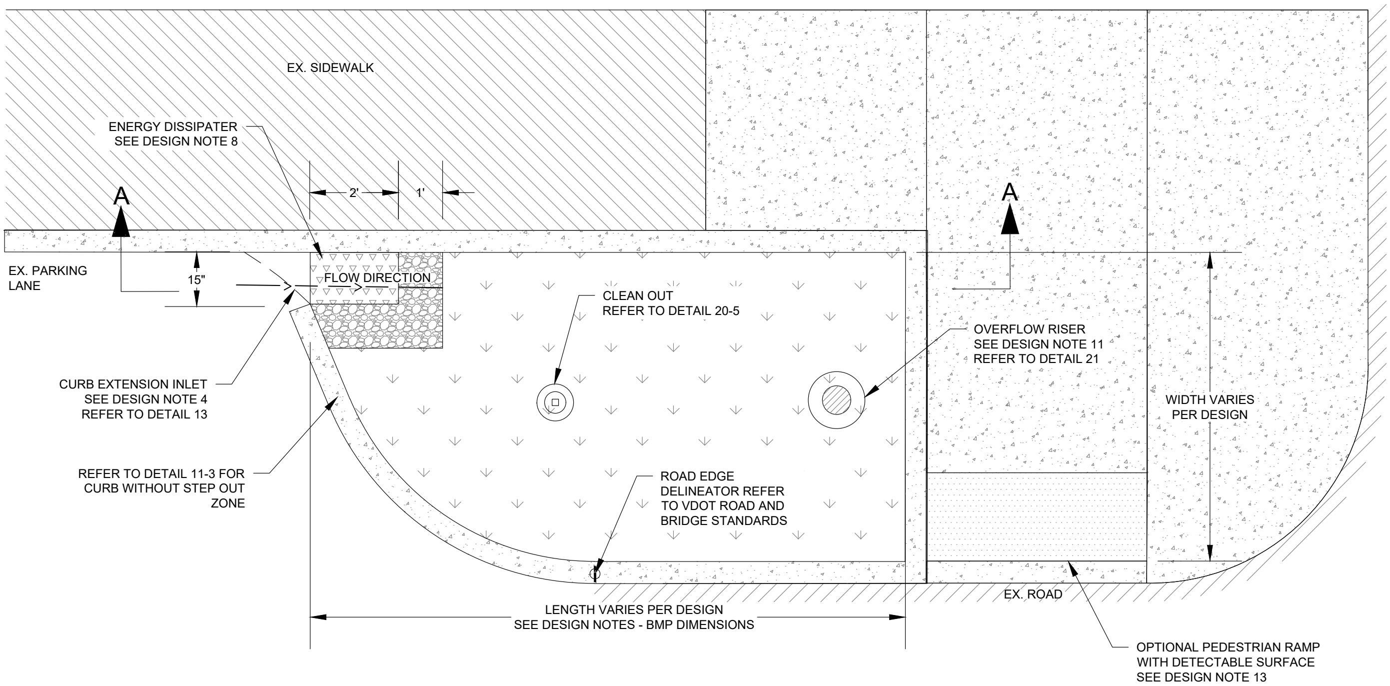
18. CONTINUOUS TREE WELLS MUST NOT OVERLAP WITH OR BLOCK ACCESS TO BUS STOPS, INTERSECTIONS, OR CROSSWALKS.

CONSTRUCTION INFORMATION

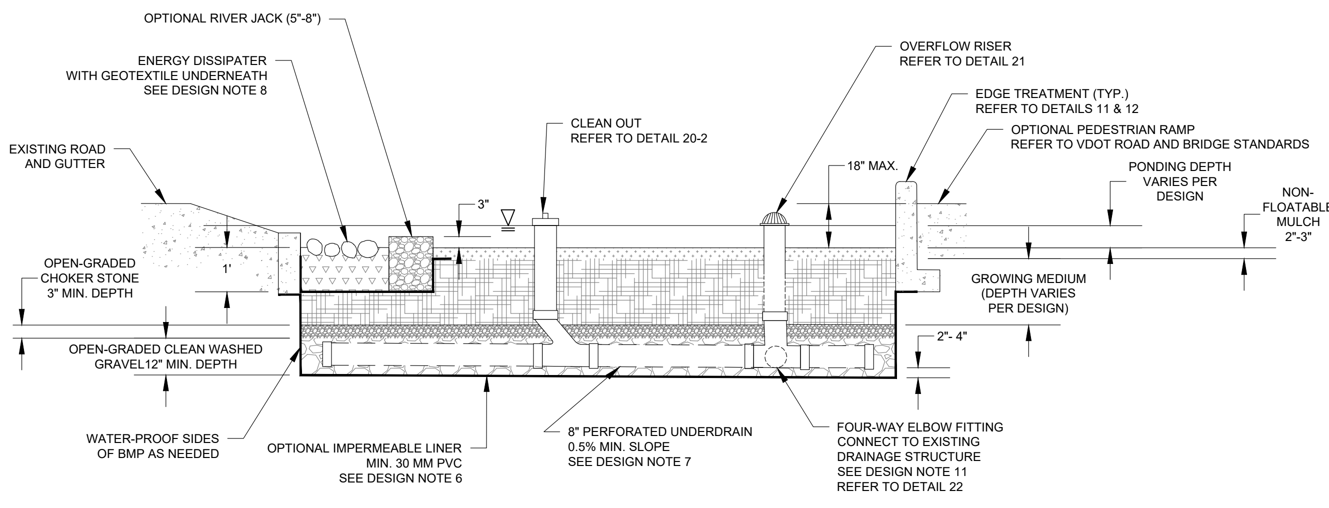
1. BACKFILL SOIL MIXTURE BENEATH ROOTBALL MUST BE COMPACTED SUCH THAT ROOT BALL DOES NOT SINK.

DETAIL 2

CONTINUOUS TREE WELL (continued)



PLAN VIEW



PROFILE A-A

DETAIL 3

CURB EXTENSION

DESIGN NOTES

BMP DIMENSIONS

1. THE RATIO OF THE LENGTH OF THE SHORTEST FLOW PATH TO THE OVERALL LENGTH OF THE BMP SHOULD BE AT LEAST 0.3 FT/FT.

2. LONGITUDINAL SLOPE OF THE BMP SURFACE SHALL BE LEVEL TO PROVIDE A CONSISTENT PONDING DEPTH.

3. WEIR ELEVATION(S) SHALL BE DESIGNED SUCH THAT WATER FROM A 10-YR STORM CANNOT REACH THE SIDEWALK AND THE PONDING DEPTH OF THE DOWNSTREAM SIDE OF THE BIORETENTION CANNOT EXCEED 1 FOOT.

4. THE RADIUS OF THE CURB FOR CURB EXTENSION BIORETENTIONS SHALL BE CONDUCIVE TO THE TURNING RADIUS OF STREET SWEEPERS AND OTHER VEHICLES.

BMP MATERIALS

5. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 9 (BIORETENTION) FOR DESIGN AND MATERIAL SPECIFICATIONS.

6. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.

7. UNDERDRAIN PIPE SHALL BE PERFORATED HDPE PVC SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER.

8. ACCEPTABLE ENERGY DISSIPATERS MAY INCLUDE:
   - A GRAVEL DIAPHRAGM WITH AN OPTIONAL TOP LAYER OF DECORATIVE RIVER ROCK
   - SPLASH BLOCK BORDERED BY 5"-8" RIVER JACK; OR
   - AN ACCEPTABLE ALTERNATIVE PER THE VIRGINIA BMP CLEARINGHOUSE.

9. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING

10. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.

11. THE OUTLET PIPE FROM THE OVERFLOW RISER SHALL BE SIZED TO CONVEY THE 10-YR STORM WITH A MINIMUM DEPTH OF COVER OF 2 FEET. THE OUTLET PIPE SHALL BE 8-INCH MINIMUM DIAMETER SCHEDULE 40 PVC WITH A MINIMUM SLOPE OF 0.5%. IF A LARGER OUTLET PIPE IS REQUIRED, CONNECT UNDERDRAIN AND OUTLET PIPE THROUGH A DRAINAGE STRUCTURE.

12. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.

13. CURB RAMP SHALL BE IN ACCORDANCE WITH CURRENT VDOT ROAD AND BRIDGE STANDARDS.

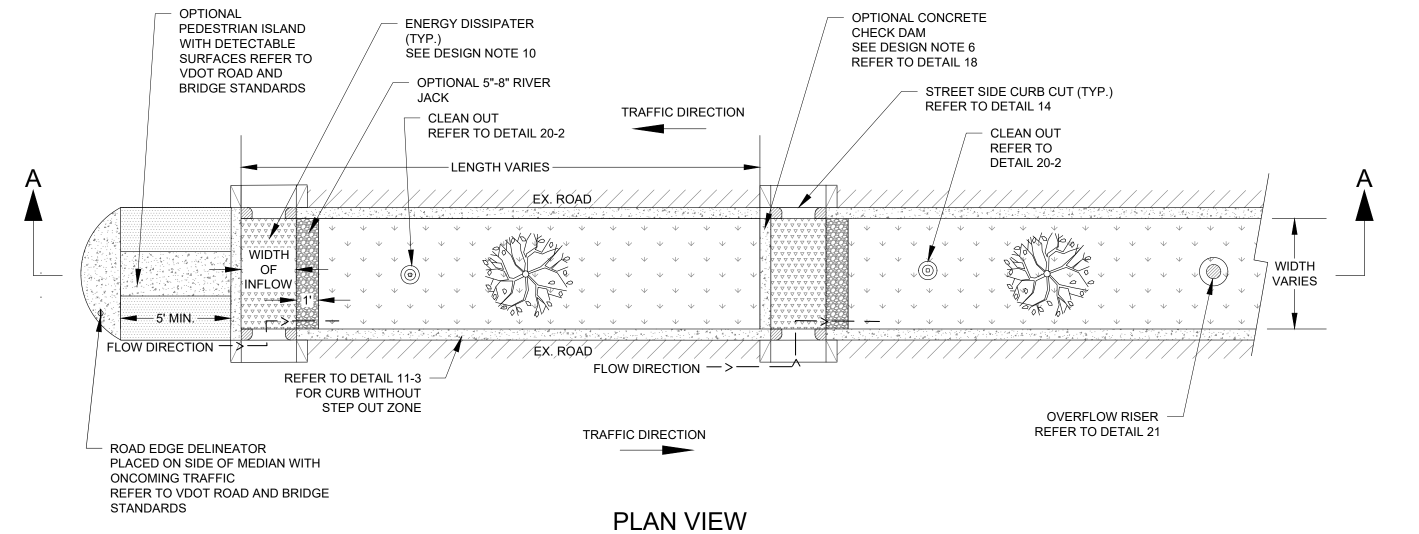
14. LATERAL BRACINGS SHALL BE INCLUDED TO WITHSTAND ANTICIPATED LOADING. REFER TO DETAIL 25.

CONSTRUCTION INFORMATION

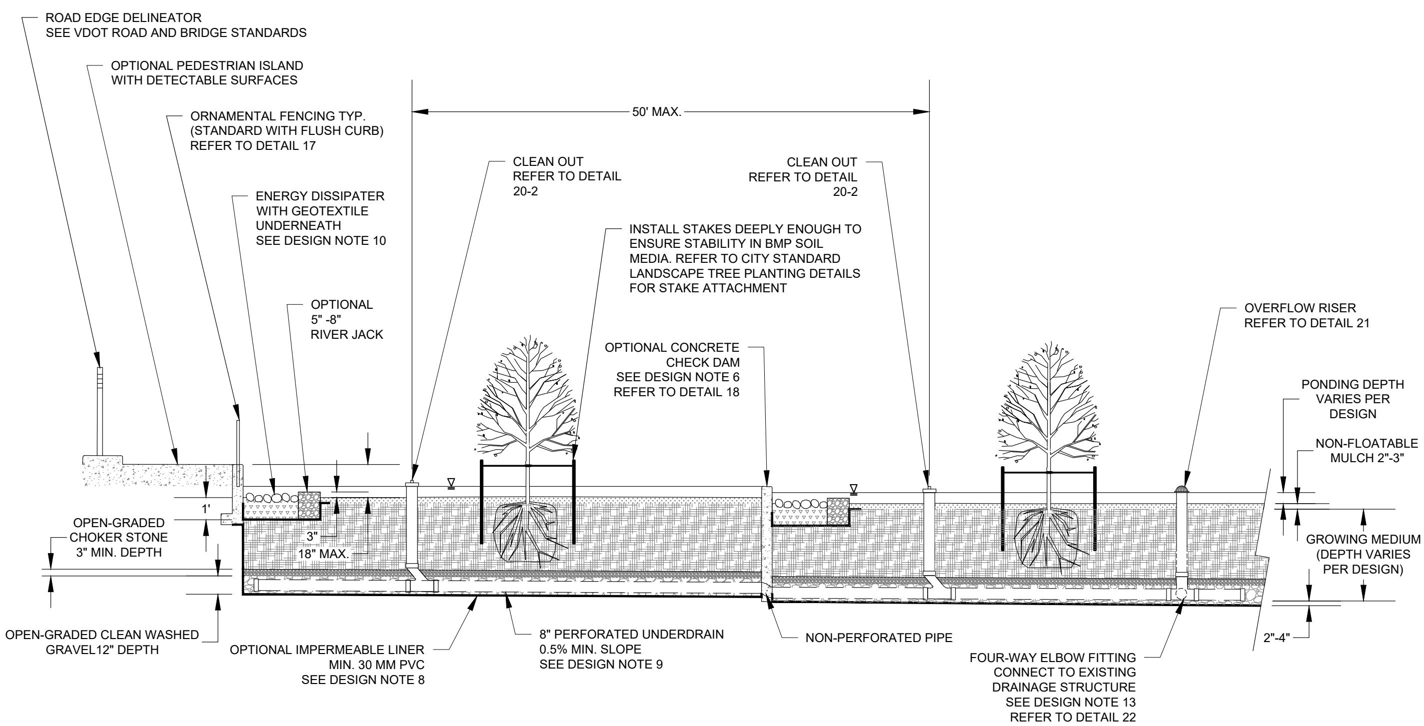
1. BACKFILL SOIL MIXTURE BENEATH ROOTBALL MUST BE COMPACTED SUCH THAT ROOT BALL DOES NOT SINK.

DETAIL 3

CURB EXTENSION (continued)



PLAN VIEW



PROFILE A-A

DETAIL 4

MEDIAN

DESIGN NOTES

BMP DIMENSIONS

1. THE RATIO OF THE LENGTH OF THE SHORTEST FLOW PATH TO THE OVERALL LENGTH OF THE BMP SHOULD BE AT LEAST 0.3 FT/FT.

2. LONGITUDINAL SLOPE OF THE BMP SURFACE SHALL BE LEVEL TO PROVIDE A CONSISTENT PONDING DEPTH.

3. WEIR ELEVATION(S) SHALL BE DESIGNED SUCH THAT WATER FROM A 10-YR STORM CANNOT REACH THE SIDEWALK AND THE PONDING DEPTH OF THE DOWNSTREAM SIDE OF THE BIORETENTION CANNOT EXCEED 1 FOOT.

4. CLEAN OUTS SHOULD BE A MIN. OF 2' AWAY FROM THE EDGE OF THE TREE'S ROOT BALL.

5. PROVIDE 450 MIN. CUBIC FEET OF SOIL FOR EACH INDIVIDUAL, ISOLATED TREE OR PROVIDE 300 CUBIC FEET OF SHARED SOIL VOLUME PER TREE WITHIN A MAXIMUM 3 FOOT DEPTH IN ACCORDANCE WITH THE BMP DESIGN GUIDELINES.

6. IF NO CHECK DAM IS USED, DESIGNER MUST ENSURE THAT ROAD SLOPES ALLOW FOR CONSTRUCTABILITY OF TREE WELLS. TREE WELLS MAY NOT BE FEASIBLE ON ROAD SLOPES GREATER THAN 8%.

BMP MATERIALS

7. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 9 (BIORETENTION) FOR DESIGN AND MATERIAL SPECIFICATIONS.

8. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.

9. UNDERDRAIN PIPE SHALL BE PERFORATED HDPE OR PVC SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER.

10. ACCEPTABLE ENERGY DISSIPATERS MAY INCLUDE:
    - A GRAVEL DIAPHRAGM WITH AN OPTIONAL TOP LAYER OF DECORATIVE RIVER ROCK
    - SPLASH BLOCK BORDERED BY 5"-8" RIVER JACK; OR
    - AN ACCEPTABLE ALTERNATIVE PER THE VIRGINIA BMP CLEARINGHOUSE.

11. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING

12. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.

13. THE OUTLET PIPE FROM THE OVERFLOW RISER SHALL BE SIZED TO CONVEY THE 10-YR STORM WITH A MINIMUM DEPTH OF COVER OF 2 FEET. THE OUTLET PIPE SHALL BE 8-INCH MINIMUM DIAMETER SCHEDULE 40 PVC WITH A MINIMUM SLOPE OF 0.5%. IF A LARGER OUTLET PIPE IS REQUIRED, CONNECT UNDERDRAIN AND OUTLET PIPE THROUGH A DRAINAGE STRUCTURE.

14. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.

15. CROSS WALK SHALL BE IN ACCORDANCE WITH CURRENT VDOT ROAD AND BRIDGE STANDARDS.

16. IF MEDIAN BIORETENTION IS USED ON ROADS THAT ARE NOT CROWNED TO ALLOW RUNOFF TO DRAIN TOWARD THEM, THEY WILL NOT REQUIRE CURB CUTS OR ENERGY DISSIPATION. THEY WILL ONLY TREAT STORMWATER THAT FALLS DIRECTLY ONTO THE BMP SURFACE.

17. TREE BRANCHES SHALL NOT OBSTRUCT THE VISIBILITY OF PEDESTRIANS OR VEHICLES. TREE BRANCHES SHALL BE MAINTAINED TO PROVIDE CLEAR SPACE TO A MINIMUM HEIGHT OF 7'.

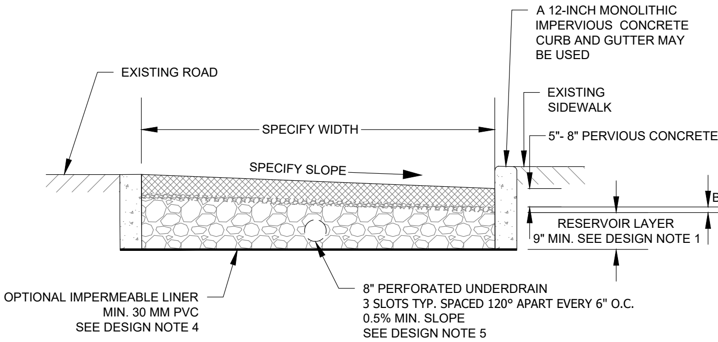
18. LATERAL BRACINGS SHALL BE INCLUDED TO WITHSTAND ANTICIPATED LOADING. REFER TO DETAIL 25.

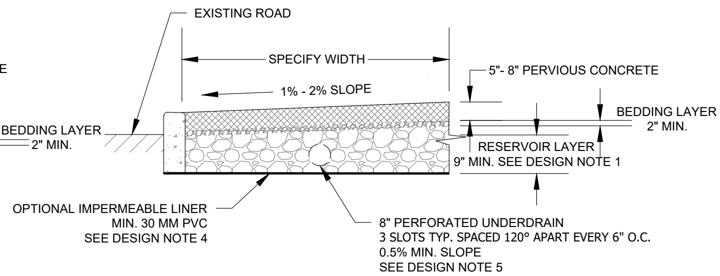
CONSTRUCTION INFORMATION

1. BACKFILL SOIL MIXTURE BENEATH ROOTBALL MUST BE COMPACTED SUCH THAT ROOT BALL DOES NOT SINK.

DETAIL 4

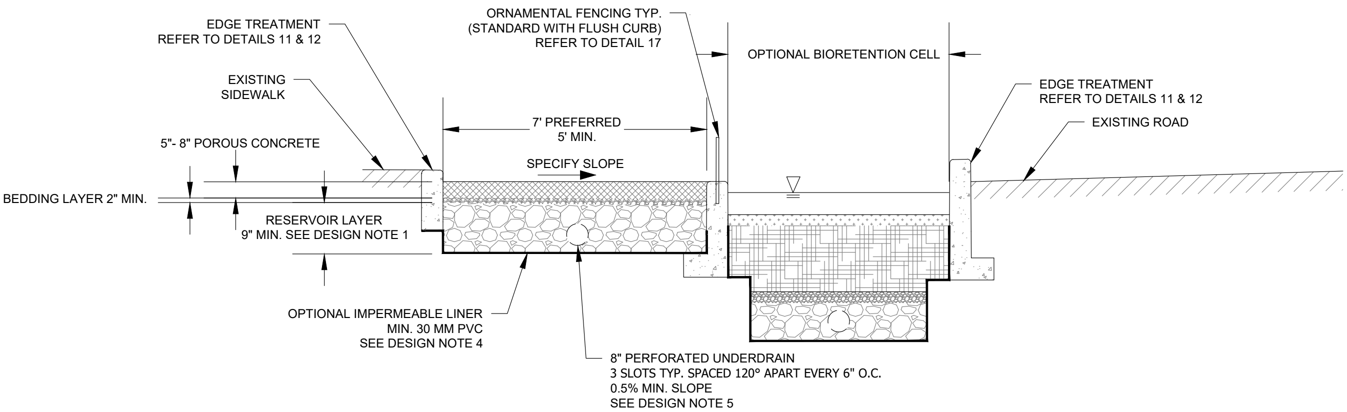
MEDIAN (continued)



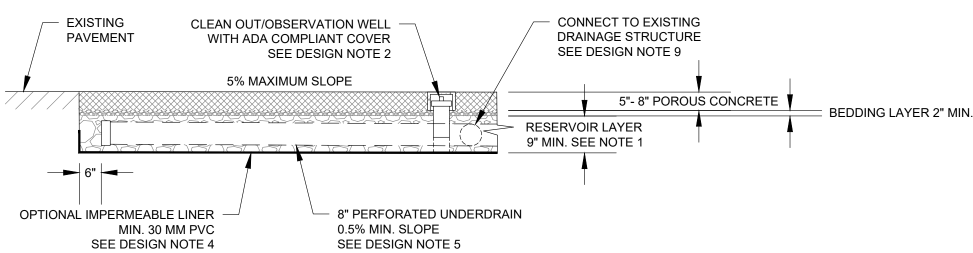


5-1 PERVIOUS CONCRETE PARKING LANE SECTION

5-2 PERVIOUS CONCRETE SIDEWALK SECTION



5-3 PERVIOUS CONCRETE BIKE LANE SECTION



TYPICAL PERVIOUS CONCRETE PROFILE

DESIGN NOTES

BMP DIMENSIONS

1. RESERVOIR LAYER WILL BE OPEN-GRADED AND SIZED TO HOLD THE TREATMENT VOLUME AND CHANNEL PROTECTION VOLUME. DEPTH DEPENDS ON GEOTECHNICAL CONSIDERATIONS AND STRUCTURAL DESIGN COMPUTATIONS.

2. THE MAXIMUM SPACING BETWEEN OBSERVATION WELLS IN A CONTINUOUS SECTION OF PERMEABLE PAVEMENT WILL BE 100'.

BMP MATERIALS

3. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 7 (PERMEABLE PAVEMENT) FOR DESIGN AND MATERIAL SPECIFICATIONS.

4. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.

5. UNDERDRAIN PIPE SHALL BE PERFORATED HDPE OR PVC SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER AND A MINIMUM SLOPE OF 0.5%.

6. ALTERNATIVE DESIGNS USING POROUS ASPHALT MAY BE CONSIDERED ON A CASE-BY-CASE BASIS. PERMEABLE PAVERS ARE PROHIBITED.

7. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING

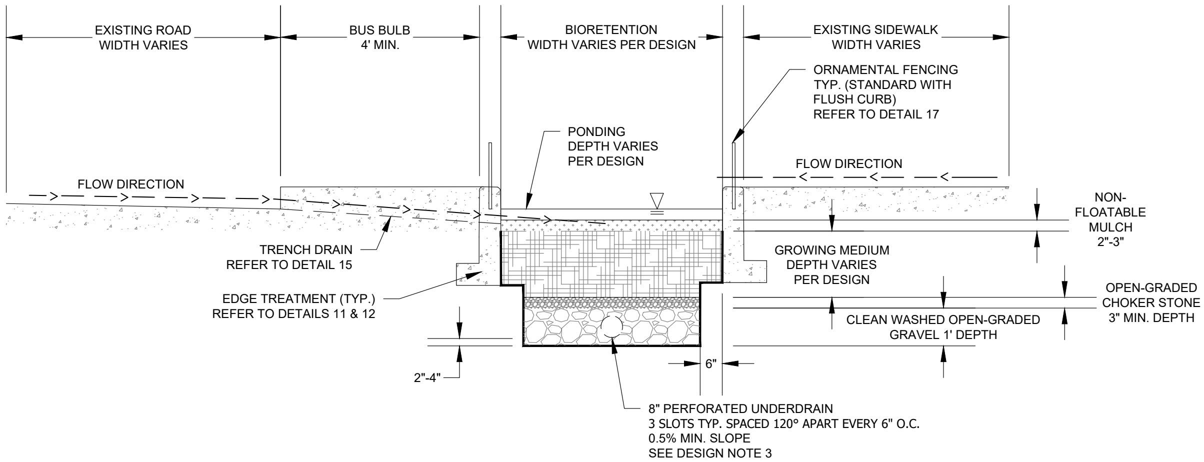
8. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.

9. THE OUTLET PIPE SHALL BE SIZED BASED ON THE VA DEQ STORMWATER DESIGN SPECIFICATION NO.7 PERMEABLE PAVEMENT WITH A MINIMUM DEPTH OF COVER OF 1 FOOT.

10. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.

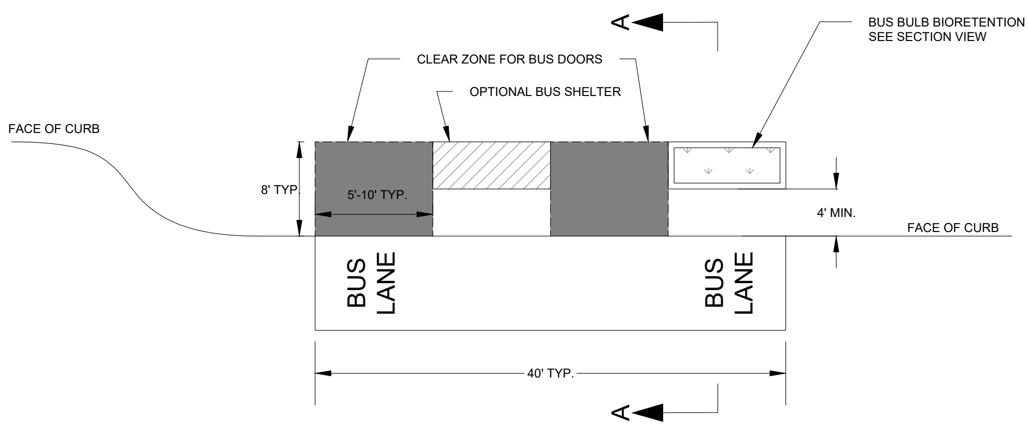
DETAIL 5

PERMEABLE PAVEMENT



TYPICAL BUS BULB SECTION A-A

Scale: 1" = 4'



PLAN VIEW

Scale: 1" = 15'

DESIGN NOTES

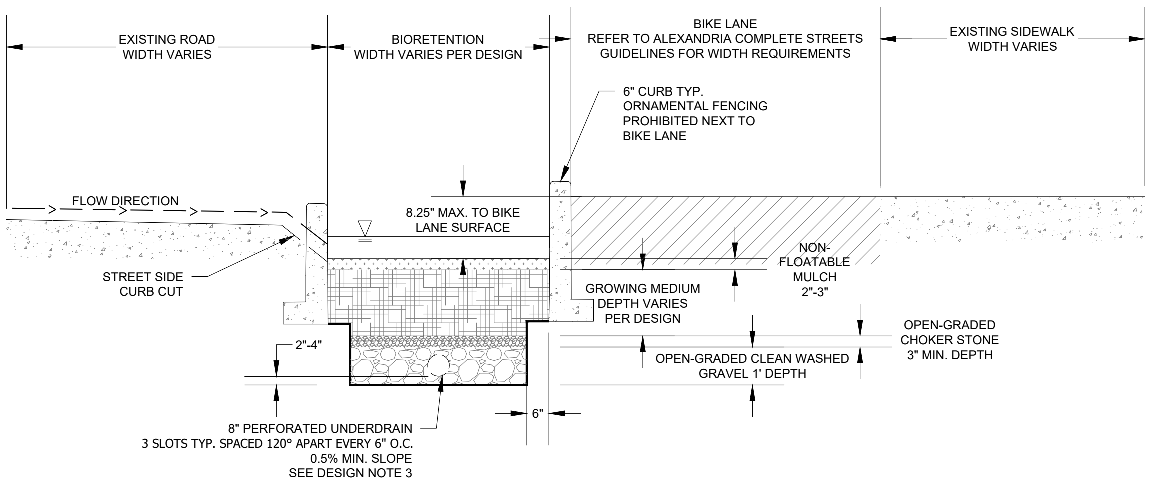
BMP DIMENSIONS
1. WEIR ELEVATION(S) SHALL BE DESIGNED SUCH THAT WATER FROM A 10-YR STORM CANNOT REACH THE SIDEWALK AND THE PONDING DEPTH OF THE DOWNSTREAM SIDE OF THE BIORETENTION CANNOT EXCEED 1 FOOT.

BMP MATERIALS
2. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 9 (BIORETENTION) FOR DESIGN AND MATERIAL SPECIFICATIONS.
3. UNDERDRAIN PIPE SHALL BE PERFORATED HDPE OR PVC SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER.
4. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.
5. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING
6. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.
7. THE OUTLET PIPE FROM THE OVERFLOW RISER SHALL BE SIZED TO CONVEY THE 10-YR STORM WITH A MINIMUM DEPTH OF COVER OF 2 FEET. THE OUTLET PIPE SHALL BE 8-INCH MINIMUM DIAMETER SCHEDULE 40 PVC WITH A MINIMUM SLOPE OF 0.5%. IF A LARGER OUTLET PIPE IS REQUIRED, CONNECT UNDERDRAIN AND OUTLET PIPE THROUGH A DRAINAGE STRUCTURE.
8. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.
9. LATERAL BRACINGS SHALL BE INCLUDED TO WITHSTAND ANTICIPATED LOADING. REFER TO DETAIL 25.

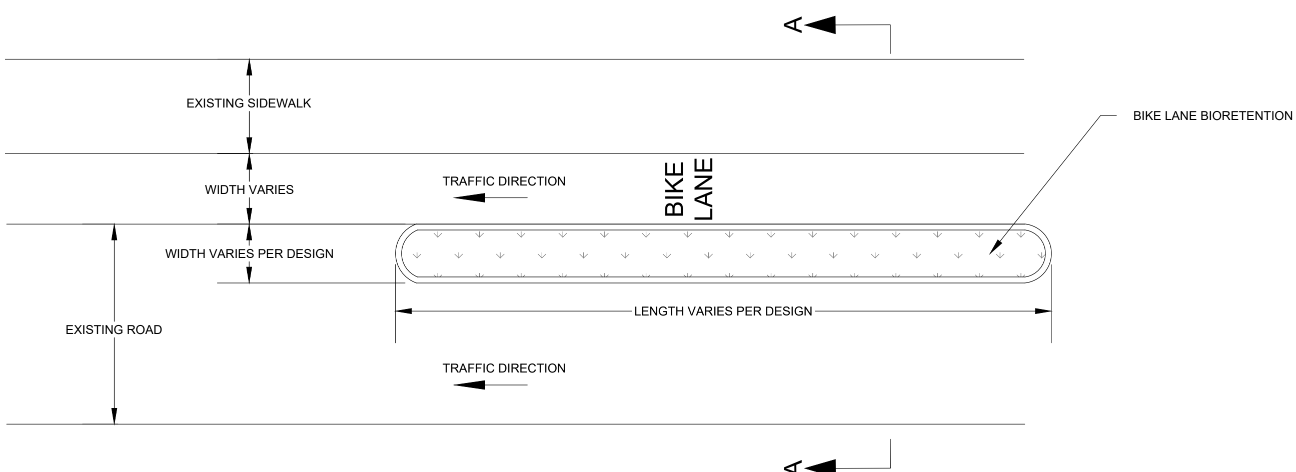
DETAIL 6

BUS BULB BIORETENTION



TYPICAL PROTECTED BIKE LANE SECTION A-A

Scale: 1" = 4'



PLAN VIEW

Scale: 1" = 15'

DESIGN NOTES

BMP DIMENSIONS

1. WEIR ELEVATION(S) SHALL BE DESIGNED SUCH THAT WATER FROM A 10-YR STORM CANNOT REACH THE SIDEWALK AND THE PONDING DEPTH OF THE DOWNSTREAM SIDE OF THE BIORETENTION CANNOT EXCEED 1 FOOT.

BMP MATERIALS

2. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 9 (BIORETENTION) FOR DESIGN AND MATERIAL SPECIFICATIONS.

3. UNDERDRAIN PIPE SHALL BE PERFORATED HDPE OR PVC SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER.

4. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.

5. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING

6. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.

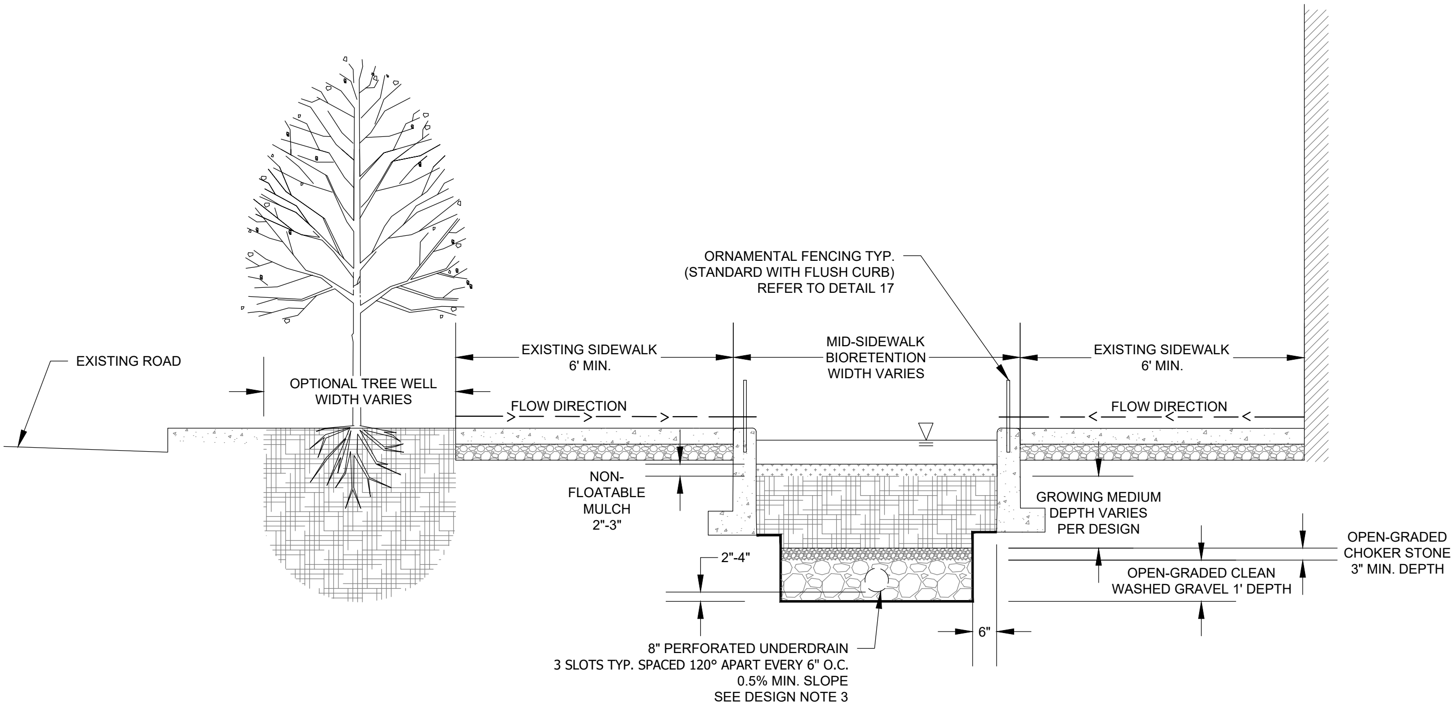
7. THE OUTLET PIPE FROM THE OVERFLOW RISER SHALL BE SIZED TO CONVEY THE 10-YR STORM WITH A MINIMUM DEPTH OF COVER OF 2 FEET. THE OUTLET PIPE SHALL BE 8-INCH MINIMUM DIAMETER SCHEDULE 40 PVC WITH A MINIMUM SLOPE OF 0.5%. IF A LARGER OUTLET PIPE IS REQUIRED, CONNECT UNDERDRAIN AND OUTLET PIPE THROUGH A DRAINAGE STRUCTURE.

8. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.

9. LATERAL BRACINGS SHALL BE INCLUDED TO WITHSTAND ANTICIPATED LOADING. REFER TO DETAIL 25.

DETAIL 7

BIKE LANE BIORETENTION



SECTION VIEW

Scale: 1" = 4'

DESIGN NOTES

BMP DIMENSIONS

1. WEIR ELEVATION(S) SHALL BE DESIGNED SUCH THAT WATER FROM A 10-YR STORM CANNOT REACH THE SIDEWALK AND THE PONDING DEPTH OF THE DOWNSTREAM SIDE OF THE BIORETENTION CANNOT EXCEED 1 FOOT.

BMP MATERIALS

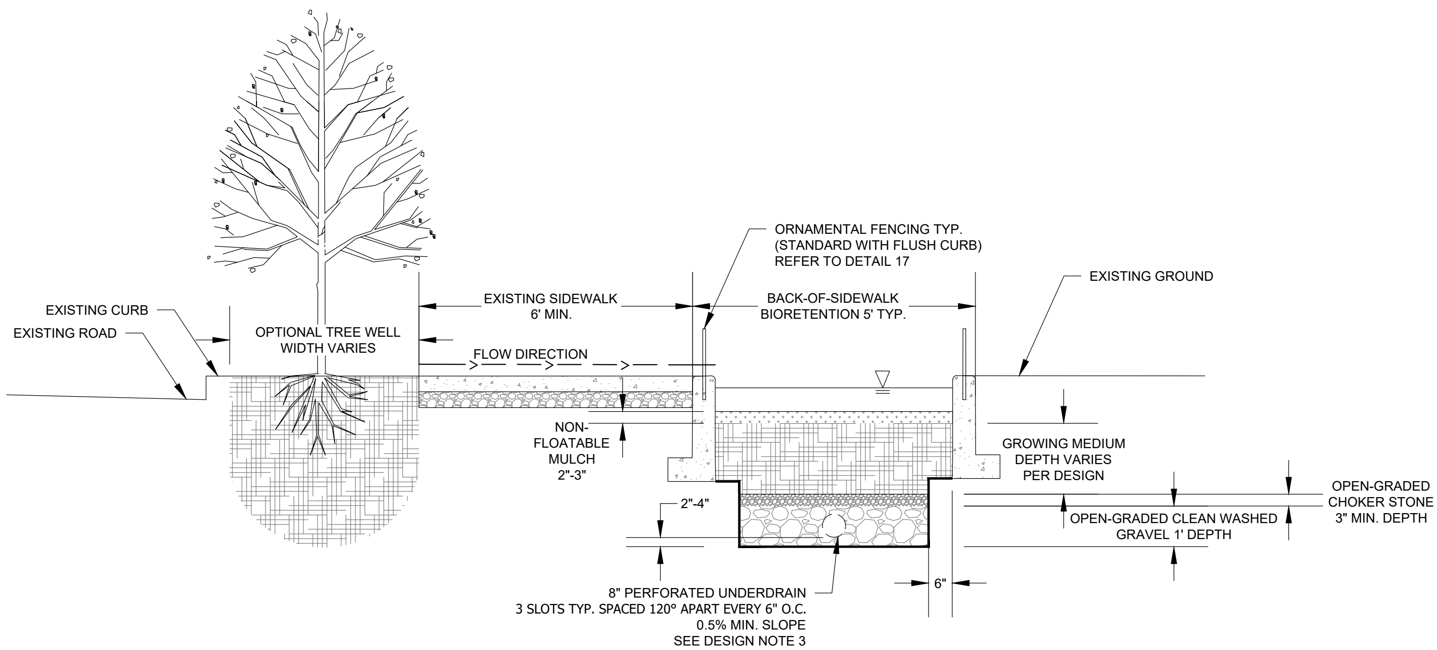
2. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 9 (BIORETENTION) FOR DESIGN AND MATERIAL SPECIFICATIONS.
3. UNDERDRAIN PIPE SHALL BE PERFORATED HDPE OR PVC SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER.
4. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.
5. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING

6. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.
7. THE OUTLET PIPE FROM THE OVERFLOW RISER SHALL BE SIZED TO CONVEY THE 10-YR STORM WITH A MINIMUM DEPTH OF COVER OF 2 FEET. THE OUTLET PIPE SHALL BE 8-INCH MINIMUM DIAMETER SCHEDULE 40 PVC WITH A MINIMUM SLOPE OF 0.5%. IF A LARGER OUTLET PIPE IS REQUIRED, CONNECT UNDERDRAIN AND OUTLET PIPE THROUGH A DRAINAGE STRUCTURE.
8. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.
9. LATERAL BRACINGS SHALL BE INCLUDED TO WITHSTAND ANTICIPATED LOADING. REFER TO DETAIL 25.

DETAIL 8

MID-SIDEWALK BIORETENTION



SECTION VIEW
Scale: 1" = 4'

DESIGN NOTES

BMP DIMENSIONS
1. WEIR ELEVATION(S) SHALL BE DESIGNED SUCH THAT WATER FROM A 10-YR STORM CANNOT REACH THE SIDEWALK AND THE PONDING DEPTH OF THE DOWNSTREAM SIDE OF THE BIORETENTION CANNOT EXCEED 1 FOOT.

BMP MATERIALS
2. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 9 (BIORETENTION) FOR DESIGN AND MATERIAL SPECIFICATIONS.

3. UNDERDRAIN PIPE SHALL BE PERFORATED HDPE OR PVC SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER.

4. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.

5. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING
6. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.

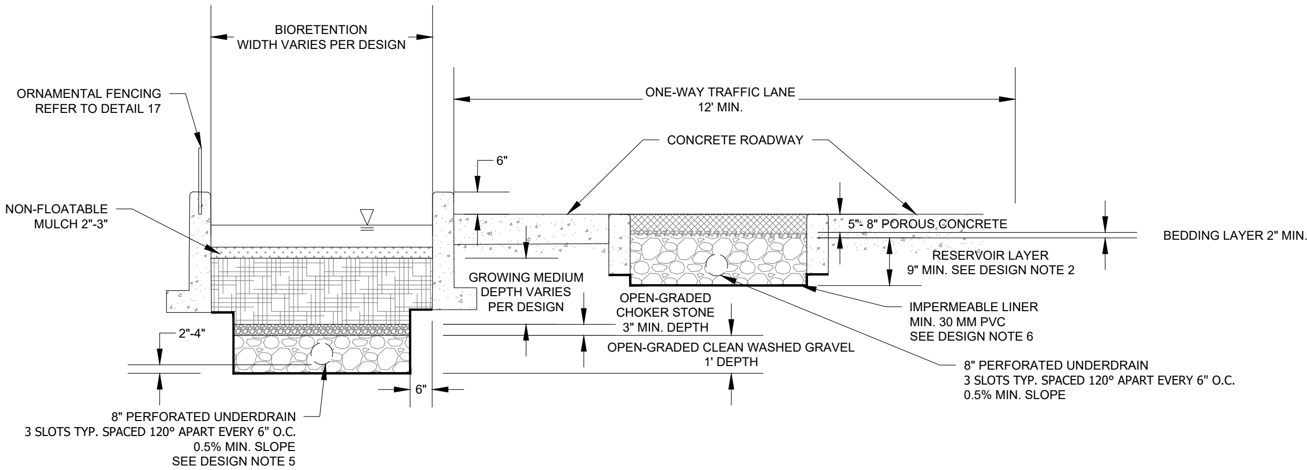
7. THE OUTLET PIPE FROM THE OVERFLOW RISER SHALL BE SIZED TO CONVEY THE 10-YR STORM WITH A MINIMUM DEPTH OF COVER OF 2 FEET. THE OUTLET PIPE SHALL BE 8-INCH MINIMUM DIAMETER SCHEDULE 40 PVC WITH A MINIMUM SLOPE OF 0.5%. IF A LARGER OUTLET PIPE IS REQUIRED, CONNECT UNDERDRAIN AND OUTLET PIPE THROUGH A DRAINAGE STRUCTURE.

8. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.

9. LATERAL BRACINGS SHALL BE INCLUDED TO WITHSTAND ANTICIPATED LOADING. REFER TO DETAIL 25.

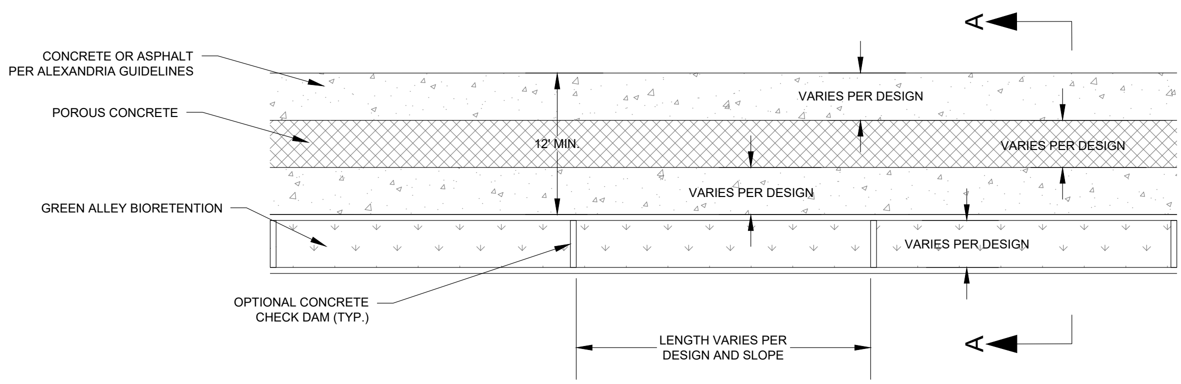
DETAIL 9

BACK-OF-SIDEWALK BIORETENTION



TYPICAL GREEN ALLEY SECTION A-A

Scale: 1" = 4'



PLAN VIEW

Scale: 1" = 15'

DESIGN NOTES

BMP DIMENSIONS

1. SIDEWALK ELEVATION MUST BE SET ABOVE TOP ELEVATION OF INLET/OUTLET SUCH THAT WATER FROM A 10-YEAR STORM DOES NOT OVERFLOW ONTO THE SIDEWALK AND PONDING DEPTH DOES NOT EXCEED 1 FOOT.

2. DEPTH OF RESERVOIR LAYER WILL BE SIZED TO HOLD THE TREATMENT VOLUME AND CHANNEL PROTECTION VOLUME, AND DEPENDS ON GEOTECHNICAL CONSIDERATIONS AND STRUCTURAL DESIGN COMPUTATIONS.

3. THE MAXIMUM SPACING BETWEEN OBSERVATION WELLS IN A CONTINUOUS SECTION OF PERMEABLE PAVEMENT WILL BE 100'.

BMP MATERIALS

4. REFER TO VA DEQ STORMWATER DESIGN SPECIFICATION NO. 7 (PERMEABLE PAVEMENT) AND NO. 9 (BIORETENTION) FOR DESIGN AND MATERIAL SPECIFICATIONS.

5. UNDERDRAIN PIPE SHALL BE PERFORATED PVC OR HDPE SCHEDULE 40 WITH $\frac{3}{8}$" PERFORATIONS AT 6" ON CENTER.

6. THE IMPERMEABLE LAYER SHALL BE MIN. 30 MM THICK. IF INFILTRATION PRACTICES ARE USED, CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS. WHERE INFILTRATION IS DESIRED, AN IMPERMEABLE LAYER WILL NOT BE REQUIRED.

7. MATERIAL SHALL BE AT MINIMUM 95% OF THE AVERAGE DRY DENSITY FOR COMPACTION IN ACCORDANCE WITH APPENDIX D OF VIRGINIA TEST METHODS FOR SOILS AND AGGREGATE COMPACTION STANDARDS.

SITE PLANNING

8. MINIMUM SET BACKS TO BMPS FROM EXISTING INFRASTRUCTURE WILL APPLY.

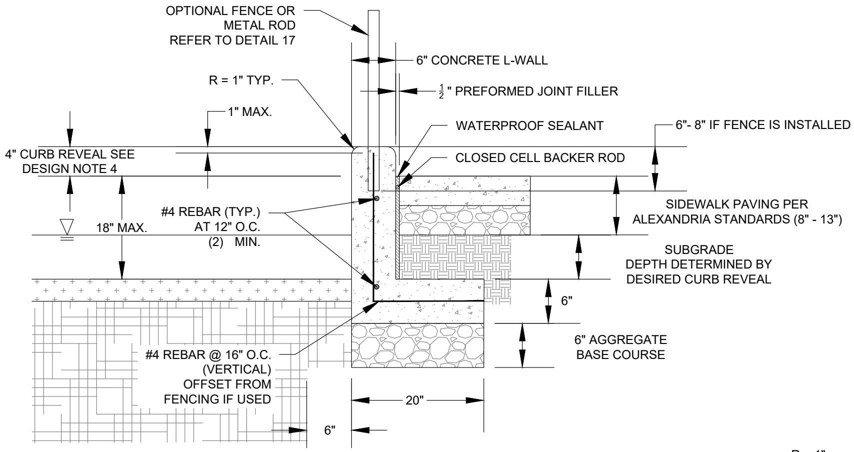
9. THE OUTLET PIPE FROM THE OVERFLOW RISER SHALL BE SIZED TO CONVEY THE 10-YR STORM WITH A MINIMUM DEPTH OF COVER OF 2 FEET. THE OUTLET PIPE SHALL BE 8-INCH MINIMUM DIAMETER SCHEDULE 40 PVC WITH A MINIMUM SLOPE OF 0.5%. IF A LARGER OUTLET PIPE IS REQUIRED, CONNECT UNDERDRAIN AND OUTLET PIPE THROUGH A DRAINAGE STRUCTURE.

10. PLACE A CLEANOUT WHEREVER THE UNDERDRAIN CONNECTS TO THE EXISTING STORM DRAIN TO FACILITATE MAINTENANCE.

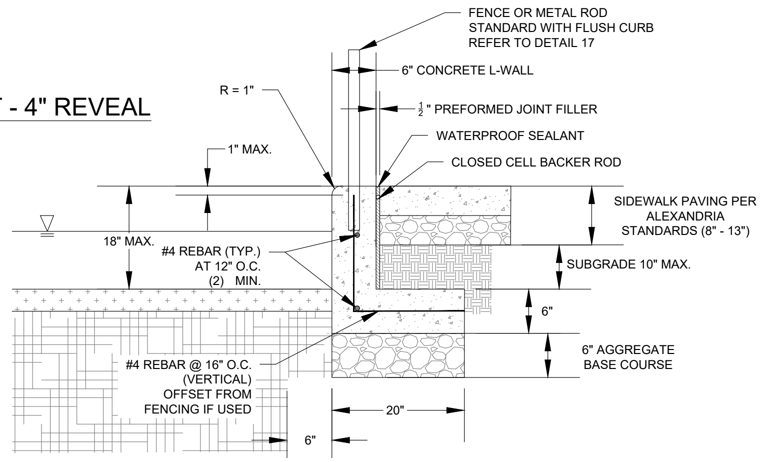
11. LATERAL BRACINGS SHALL BE INCLUDED TO WITHSTAND ANTICIPATED LOADING. REFER TO DETAIL 25.

DETAIL 10

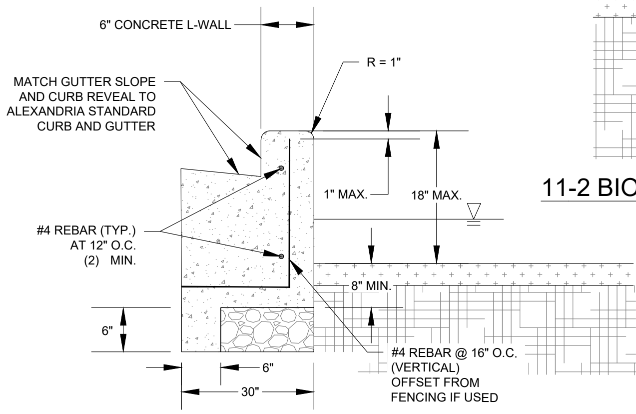
GREEN ALLEY



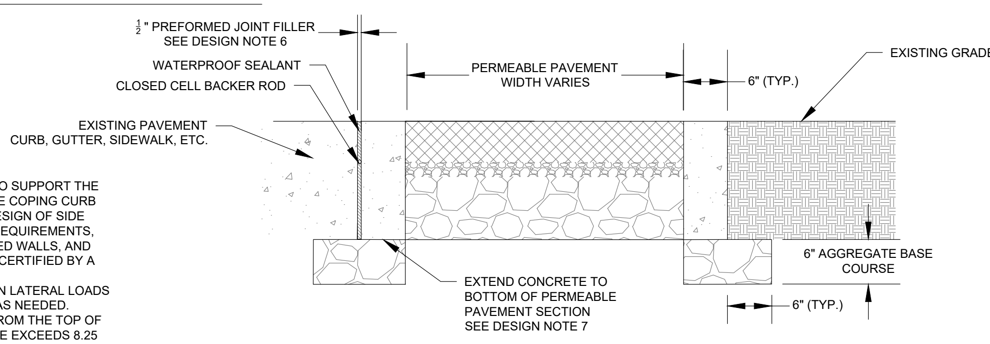
11-1 BIORETENTION SIDEWALK EDGE TREATMENT - 4" REVEAL



11-2 BIORETENTION SIDEWALK EDGE TREATMENT - NO REVEAL



11-3 BIORETENTION ROADSIDE EDGE TREATMENT



11-4 PERMEABLE PAVEMENT EDGE TREATMENT

DESIGN NOTES

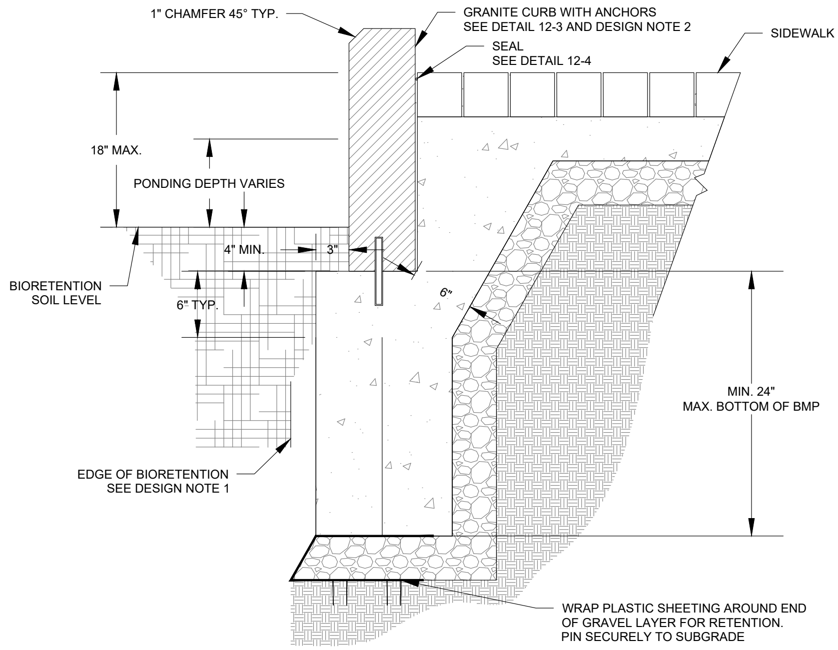
1. THE SIDE WALLS OF BMP FACILITIES SHALL BE DESIGNED TO SUPPORT THE EDGE OF THE WELL/TRENCH, STRUCTURALLY SUPPORT THE COPING CURB AND IN MANY CASES TO PROVIDE A ROOT BARRIER. THE DESIGN OF SIDE WALLS MAY INCLUDE ALTERNATIVES WHICH MEET THESE REQUIREMENTS, AND MAY INCLUDE FULL DEPTH CONCRETE WALLS, BENCHED WALLS, AND BATTERED WALLS. ALL STRUCTURED ELEMENTS SHALL BE CERTIFIED BY A STRUCTURAL ENGINEER.
2. DESIGNER/CONTRACTOR SHALL TAKE INTO CONSIDERATION LATERAL LOADS FROM VEHICLE IMPACTS AND PROVIDE LATERAL BRACING AS NEEDED.
3. METAL FENCING SHALL BE REQUIRED WHEN THE HEIGHT FROM THE TOP OF THE EDGE TREATMENT TO TO THE BIORETENTION SURFACE EXCEEDS 8.25 INCHES.
4. CURB CUTS IN SIDEWALK EDGE TREATMENTS ARE NOT RECOMMENDED FOR EASE OF MAINTENANCE. THE BMP MUST BE POSITIONED AND DESIGNED IN A MANNER THAT ALLOWS POSITIVE DRAINAGE THROUGH OTHER INFLOW POINTS IF A CURB REVEAL IS DESIRED.
5. EDGE TREATMENTS EXTENDING MORE THAN 36 INCHES BELOW ADJACENT LOAD-BEARING SURFACE MUST HAVE FOOTING OR LATERAL BRACING. COORDINATE WITH ENGINEER.
6. SEALANT TO BE USED BETWEEN PERMEABLE PAVEMENT EDGE TREATMENT AND EXISTING CONCRETE STRUCTURES SUCH AS CURBS, GUTTERS, SIDEWALKS, OR ROADS AS NEEDED.
7. MINIMUM EMBEDMENT KEY DEPTHS FOR PERMEABLE PAVEMENT EDGE TREATMENTS ARE SPECIFIED TO PREVENT LATERAL SEEPAGE UNDER THE EDGE TREATMENT AND INTO ADJACENT PAVEMENT SECTIONS. DEEPER EMBEDMENT MAY BE REQUIRED UNDER SOME CONDITIONS.

CONSTRUCTION INFORMATION

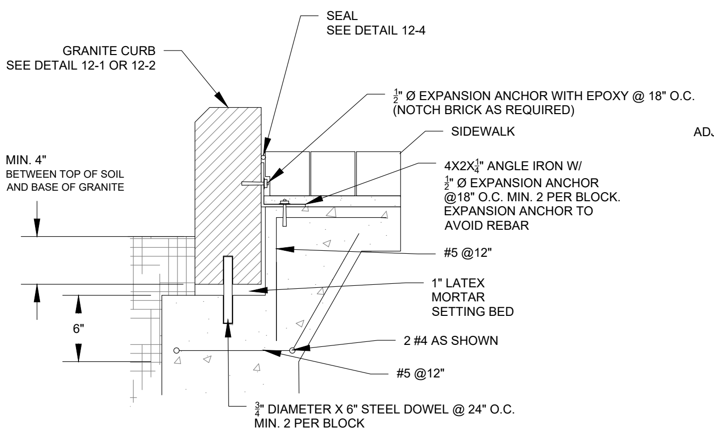
1. INFORMATIONAL PLAQUE MAY BE INSTALLED ON THE TOP FACE OF EDGE RESTRAINT.
2. EXPANSION AND CONTRACTION JOINTS SHALL BE PLACED ACCORDING TO STANDARD ALEXANDRIA CONCRETE CURB REQUIREMENTS.

DETAIL 11

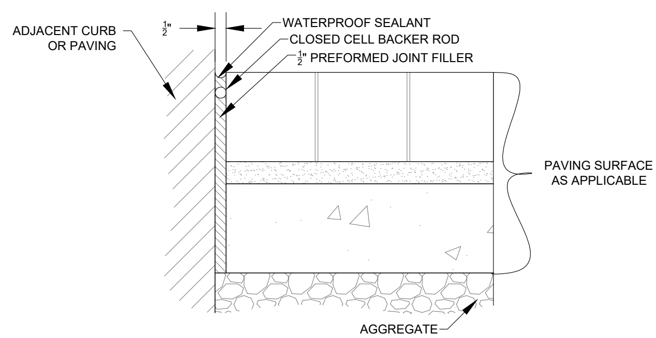
EDGE TREATMENTS



12-1 GRANITE CURB



12-2 ANCHOR DETAIL



12-3 SEAL DETAIL

DESIGN NOTES

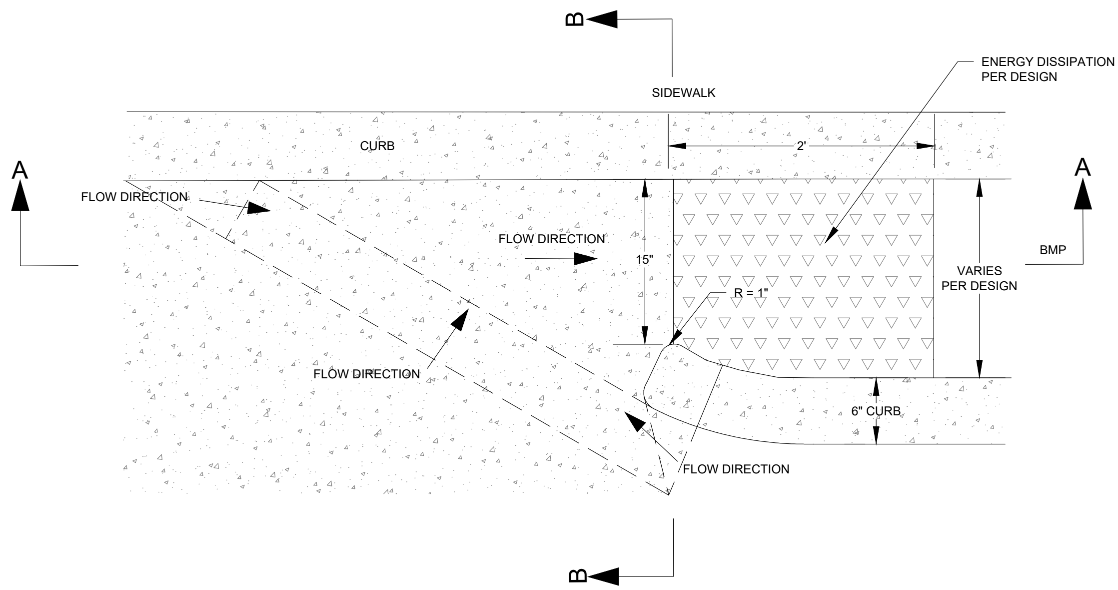
1. THE SIDE WALLS OF THE BMP FACILITIES SHALL BE DESIGNED TO SUPPORT THE EDGE OF THE BMP, STRUCTURALLY SUPPORT THE COPING CURB AND IN MANY CASES TO PROVIDE A ROOT BARRIER. THE DESIGN OF SIDE WALLS MAY INCLUDE ALTERNATIVES WHICH MEET THESE REQUIREMENTS, AND MAY INCLUDE FULL DEPTH CONCRETE WALLS, BENCHED WALLS AND BATTERED WALLS. ALL STRUCTURED ELEMENTS SHALL BE CERTIFIED BY A STRUCTURAL ENGINEER.
2. SHALLOW ALTERNATIVE DETAIL MAY BE USED WHERE EITHER A SLOPED PROFILE OR A SHALLOW PONDING DEPTH ALLOWS.
3. JOINTS SHALL BE SPACED 2' O.C.

CONSTRUCTION INFORMATION

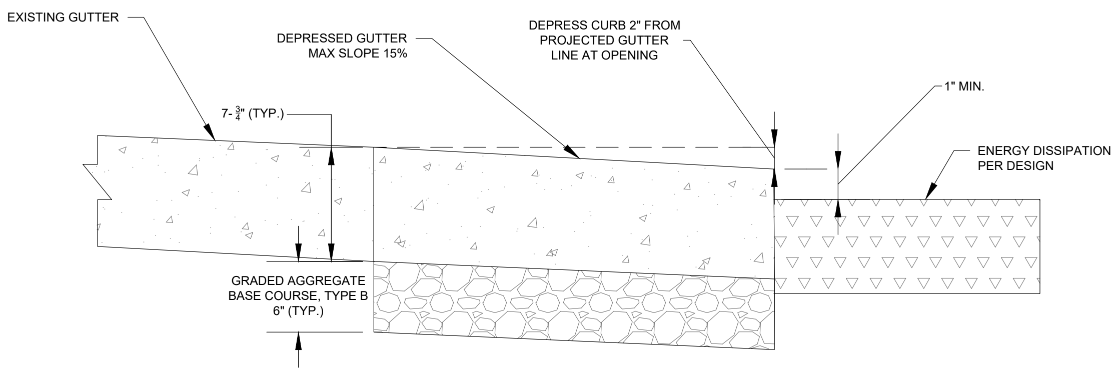
1. ALL STRUCTURAL SHAPES AND PLATES SHALL BE ASTM A36.
2. STRUCTURAL STEEL SHALL BE GALVANIZED IN ACCORDANCE WITH ASTM123. HARDWARE SHALL BE GALVANIZED IN ACCORDANCE WITH ASTM A153.
3. AN INFORMATIONAL PLAQUE MAY BE INSTALLED ON THE TOP FACE OF EDGE RESTRAINT.

DETAIL 12

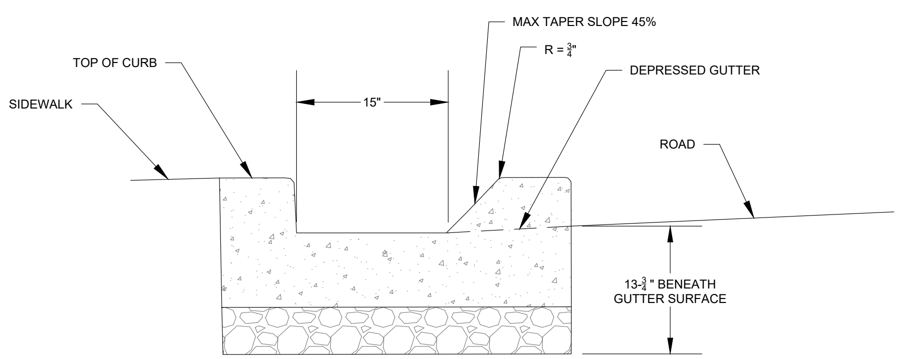
EDGE TREATMENTS



PLAN



SECTION A-A



SECTION B-B

DESIGN NOTES

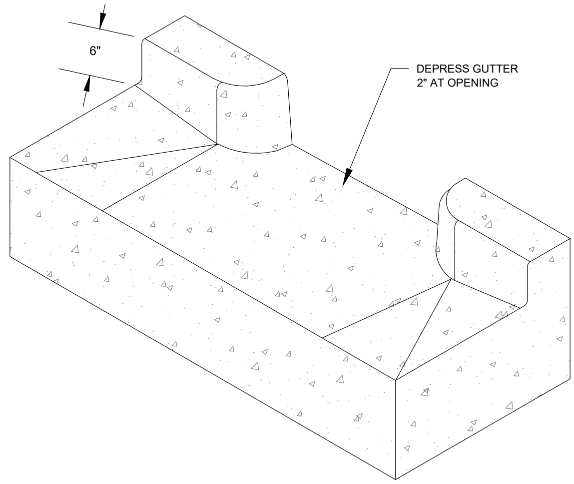
1. MODIFY CURB CUT AND APRON DESIGN AS NEEDED TO INTEGRATE WITH EXISTING CONDITIONS OR APPROVED ROADWAY DESIGN.

CONSTRUCTION INFORMATION

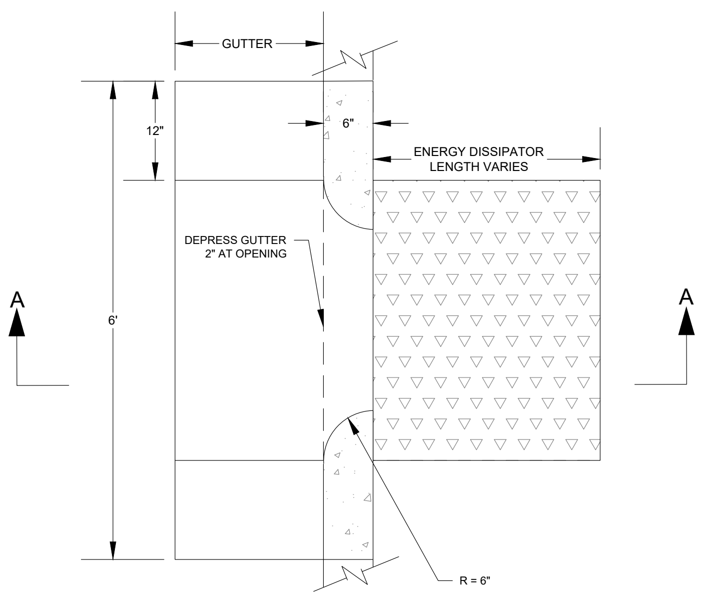
1. THE CONCRETE CURB SHALL BE CONSTRUCTED OF 4" THICK CLASS A3 CONCRETE.

DETAIL 13

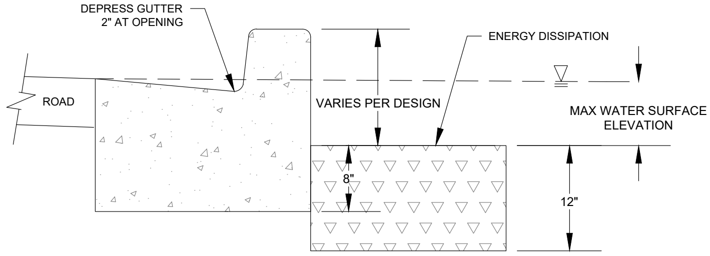
CURB EXTENSION BIORETENTION INLET



PERSPECTIVE



PLAN



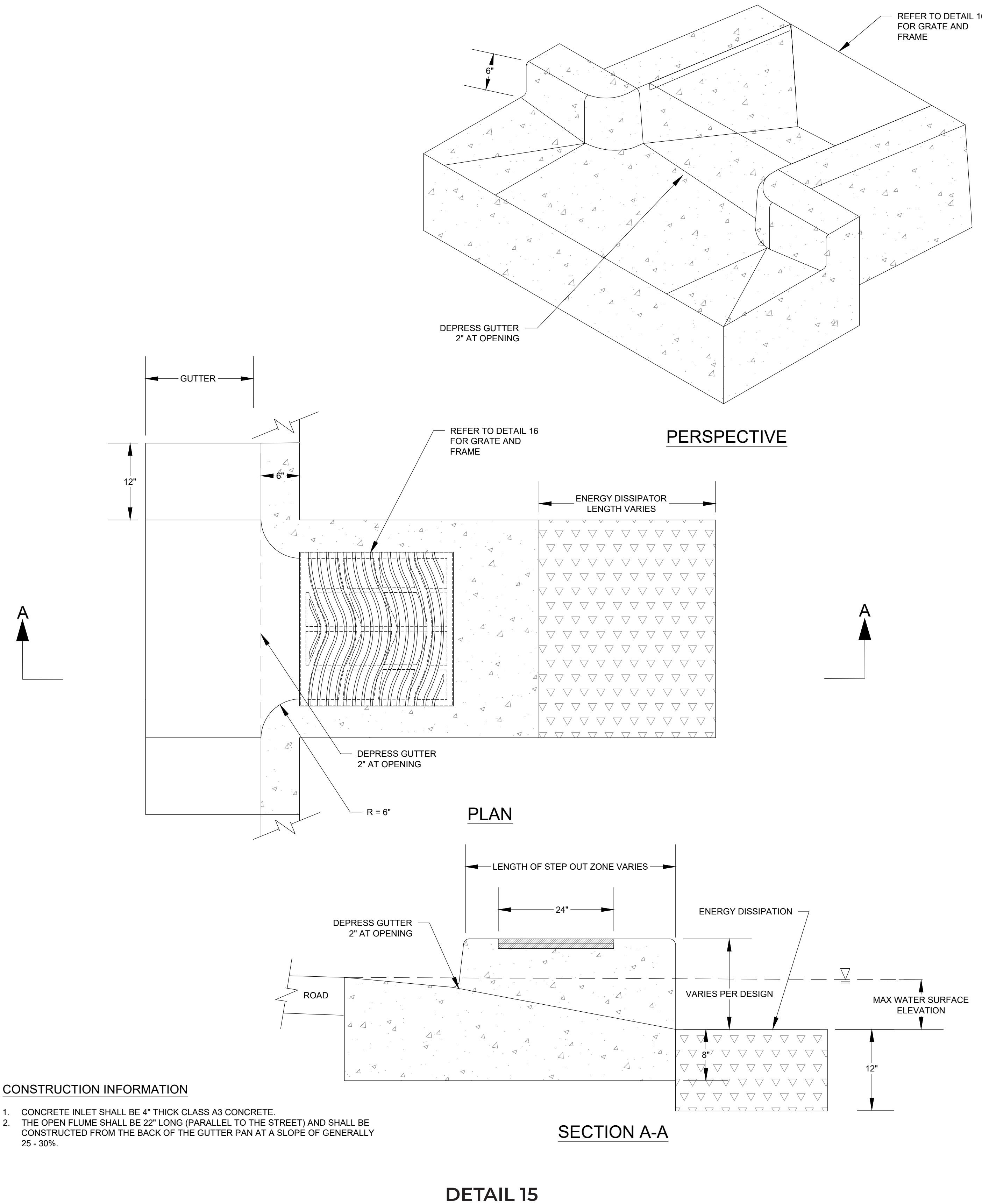
SECTION A-A

CONSTRUCTION INFORMATION

1. CONCRETE INLET SHALL BE 4" THICK CLASS A3 CONCRETE.
2. THE OPEN FLUME SHALL BE 22" LONG (PARALLEL TO THE STREET) AND SHALL BE CONSTRUCTED FROM THE BACK OF THE GUTTER PAN AT A SLOPE OF GENERALLY 25 - 30%.

DETAIL 14

CURB CUT INLET

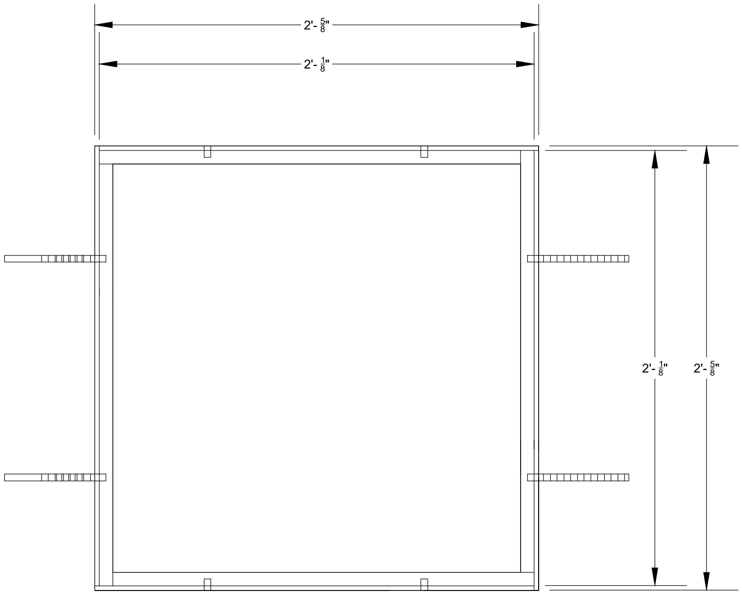


CONSTRUCTION INFORMATION

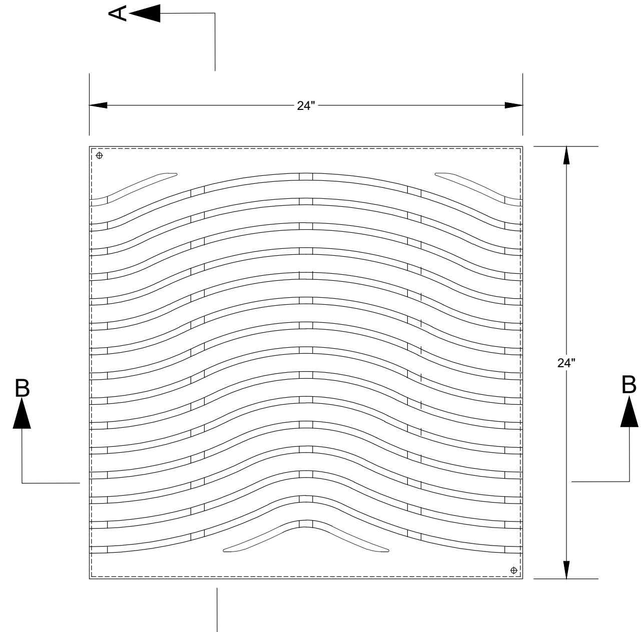
1. CONCRETE INLET SHALL BE 4" THICK CLASS A3 CONCRETE.
2. THE OPEN FLUME SHALL BE 22" LONG (PARALLEL TO THE STREET) AND SHALL BE CONSTRUCTED FROM THE BACK OF THE GUTTER PAN AT A SLOPE OF GENERALLY 25 - 30%.

DETAIL 15

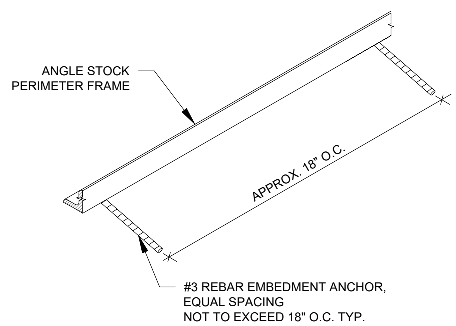
TRENCH DRAIN INLET



FRAME PLAN VIEW



COVER PLAN VIEW



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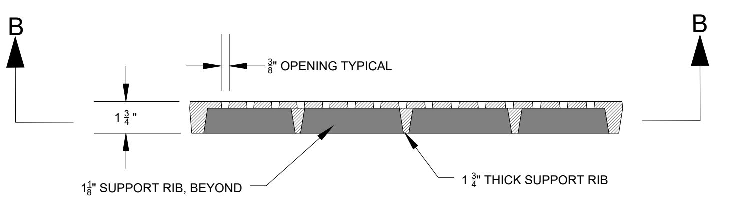
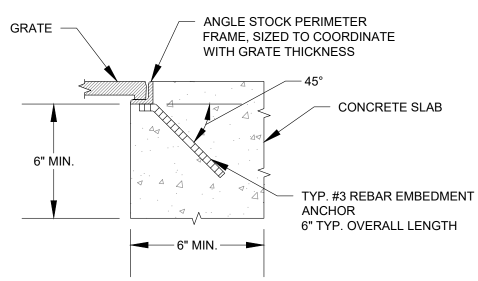
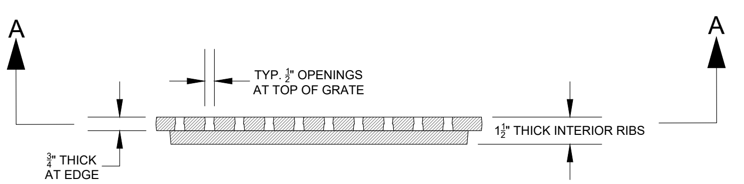


SECTION B-B



ELEVATION



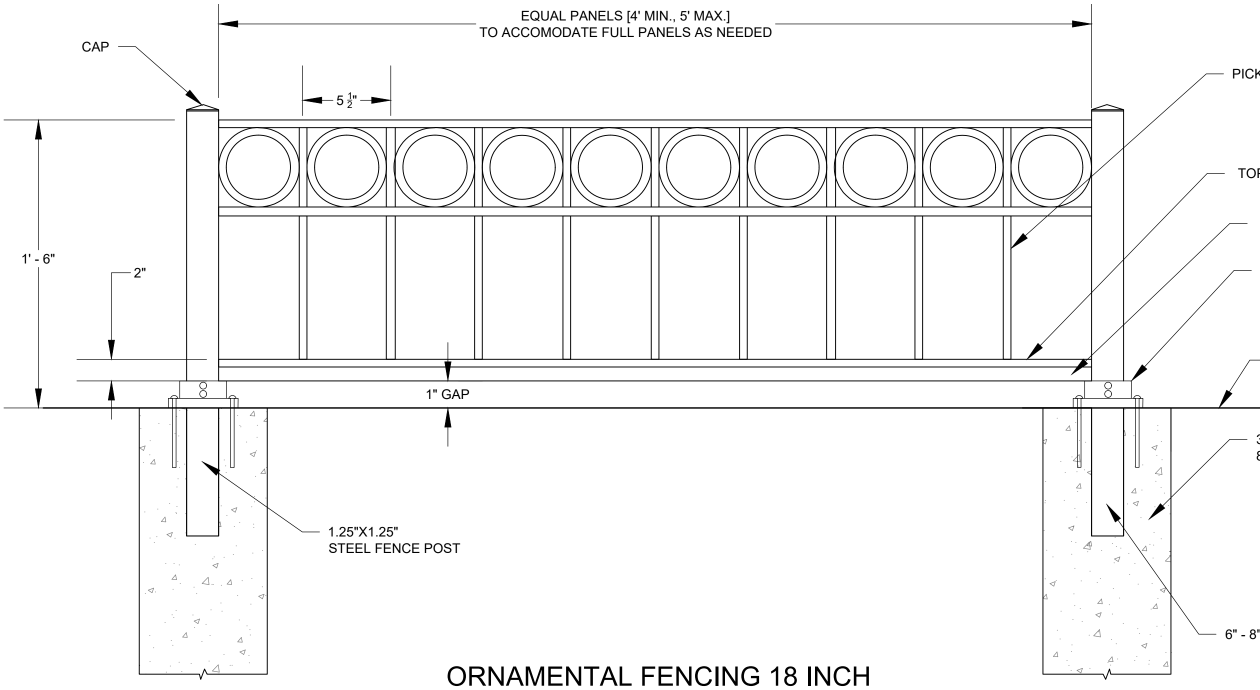
SECTION A-A

CONSTRUCTION INFORMATION

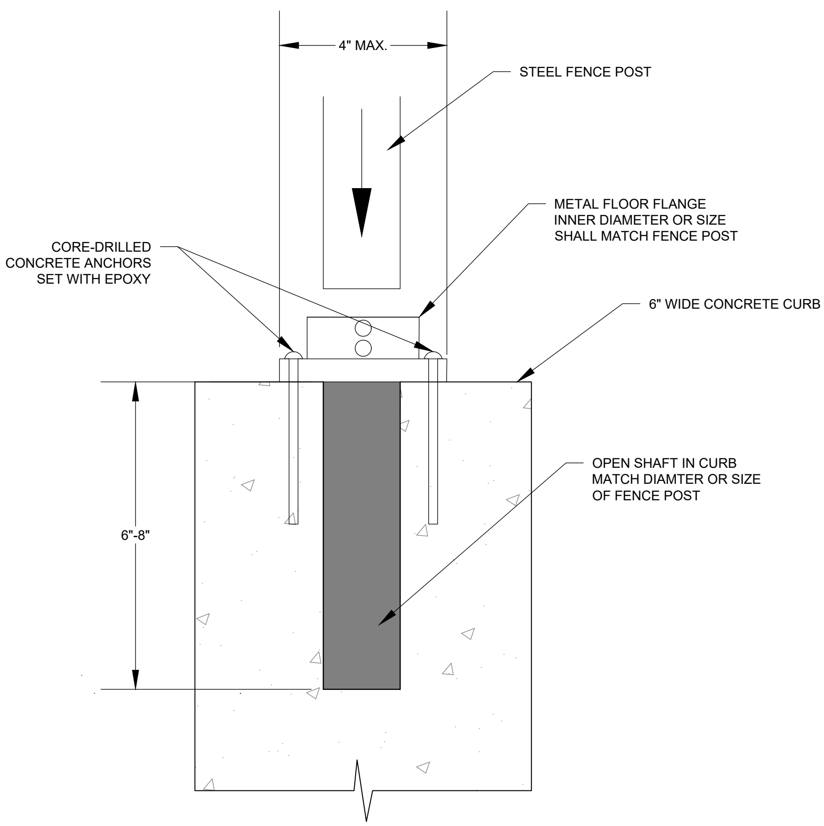
1. FRAME MATERIAL SHALL BE MILD STEEL ASTM A36 ANGLE IRON. ALL WELDS SHALL BE GROUND SMOOTH ON THE OUTSIDE EDGES. THE FINISH SHALL BE NATURAL PATINA OF RAW STEEL.
2. THE GRATE MATERIAL SHALL BE HIGH QUALITY, DUCTILE IRON, ASTM A536 CLASS 65-45-12. THE FINISH SHALL BE NATURAL WEATHERED DUCTILE IRON.
3. THE GAP BETWEEN THE GRATE AND FRAME SHALL BE 1/8 INCH.
4. THE GRATE AND FRAME SHALL BE RATED FOR H2O LOADING WITH A NON-SLIP SURFACE HAVING A STATIC COEFFICIENT OF FRICTION BETWEEN 0.6 - 1.0 PER ASTM C1020. GRATES ON INCLINES SHALL HAVE A COEFFICIENT OF 0.8 - 10.
5. THE GRATE AND FRAME SHALL BE ADA COMPLIANT. FRAMES WILL BE TRUE TO SQUARE, AND THE TOP OF THE GRATE WILL BE FLUSH WITH THE GRADE OF THE ADJACENT PAVEMENT.
6. ALL STRUCTURAL SHAPES AND PLATES SHALL BE ASTM A36.
7. STRUCTURAL STEEL SHALL BE GALVANIZED IN ACCORDANCE WITH ASTM123. HARDWARE SHALL BE GALVANIZED IN ACCORDANCE WITH ASTM A153.

DETAIL 16

GRATE AND FRAME



ORNAMENTAL FENCING 18 INCH



FLANGE DETAIL

DESIGN NOTES

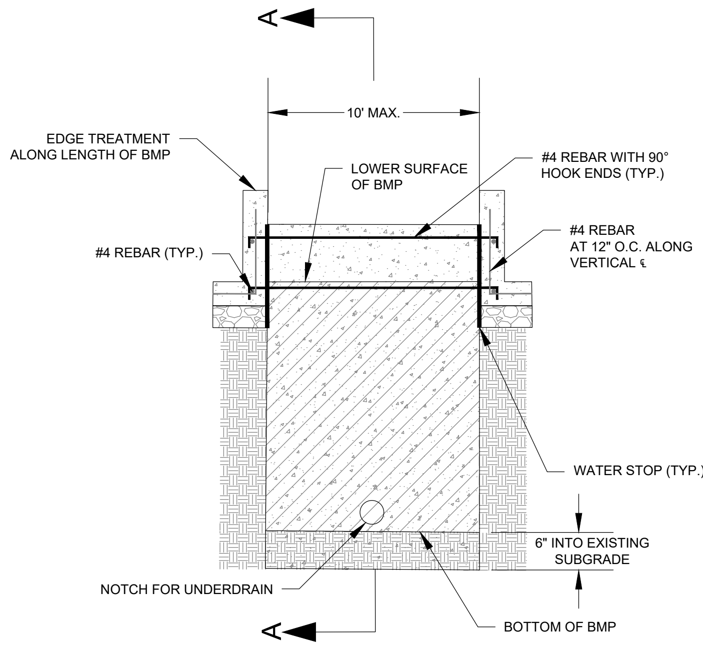
1. METAL FENCING SHALL BE REQUIRED WHEN THE HEIGHT FROM THE TOP OF THE EDGE TREATMENT TO TO THE BIORETENTION SURFACE EXCEEDS 8.25 INCHES.
2. FENCE POSTS MAY BE ROUND OR SQUARE. THE FLOOR FLANGE MUST MATCH THE DIAMETER OR SIZE OF THE FENCE POST.
3. THE CITY MAINTENANCE DEPARTMENT MAY UTILIZE AN ALTERNATIVE DECORATIVE FENCE PATTERN UPON CITY APPROVAL.

CONSTRUCTION INFORMATION

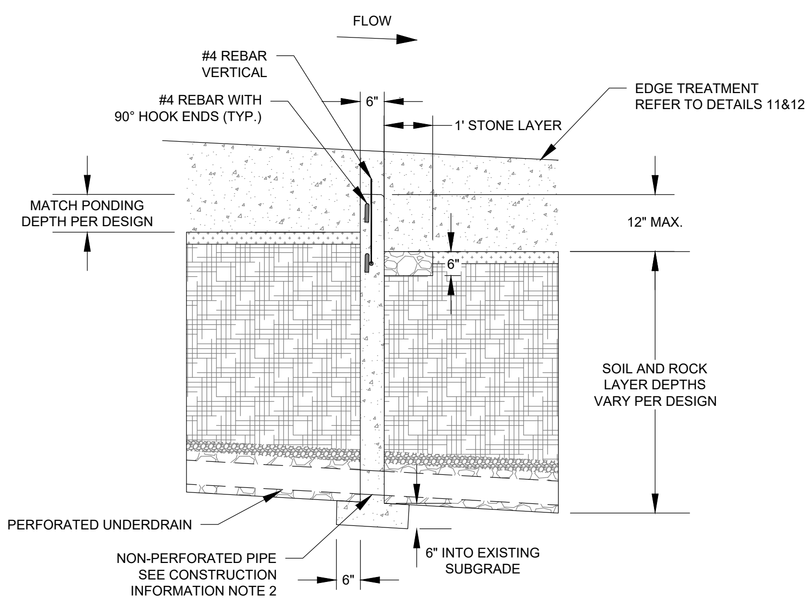
1. FIELD MEASUREMENTS MUST BE TAKEN PRIOR TO FABRICATION.
2. ALL JOINTS TO BE WELDED UNLESS NOTED OTHERWISE.
3. RAILS TO FOLLOW LINE OF GRADE.
4. ALL STEEL TO BE SOLID STEEL.

DETAIL 17

FENCING



ELEVATION VIEW



SECTION VIEW A-A

DESIGN NOTES

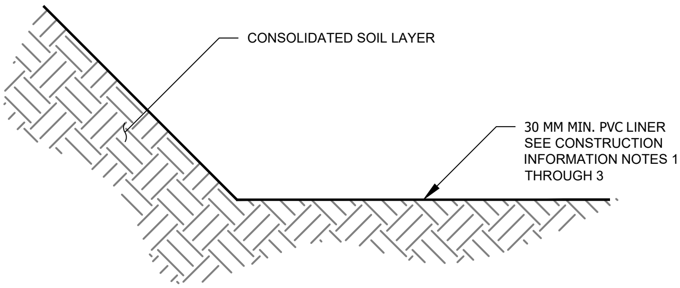
1. CONCRETE CHECK DAM SHALL MEET STRUCTURAL REQUIREMENTS FOR LATERAL BRACING WHEN USED AS LATERAL BRACING. COORDINATE WITH ENGINEER.
2. CHECK DAM MAY BE MODIFIED TO FIT HYDRAULIC DESIGN WITH DIFFERENT WEIR CONFIGURATIONS.

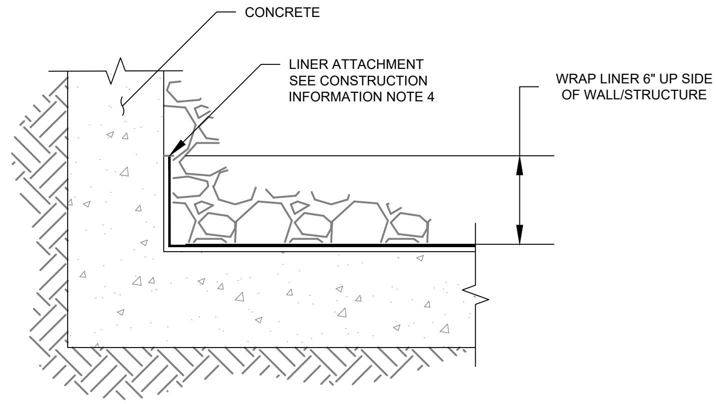
CONSTRUCTION INFORMATION

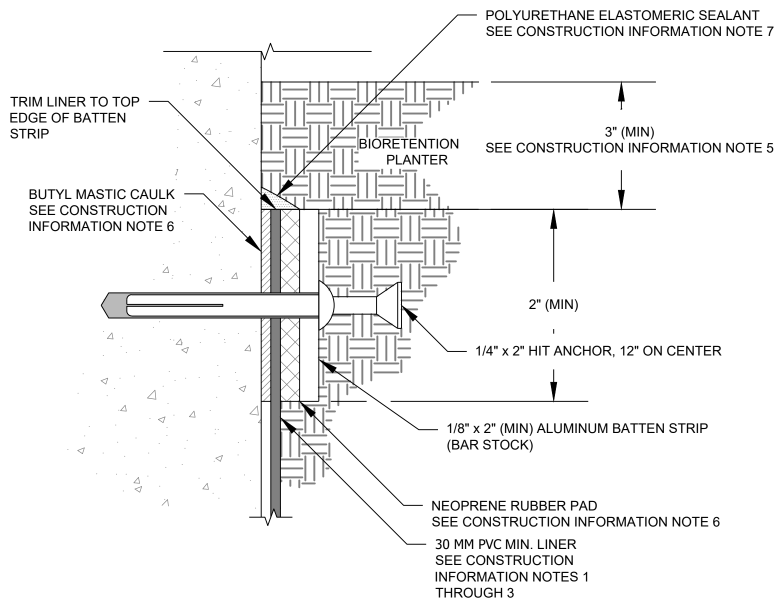
1. ALL CONSTRUCTION COLD JOINTS SHALL INCORPORATE EPOXY, DOWEL/TIE BAR, KEYWAY, AND WATER STOP.
2. PIPE FITTINGS SHALL BE USED TO ACCOMMODATE CHANGES IN GRADE, AS NEEDED.
3. CONCRETE CHECK DAM SHALL BE CONTINUOUS (NO JOINTS) AND REINFORCED WITH #4 BAR, PLACED AT 18 INCHES ON CENTER, EACH WAY.

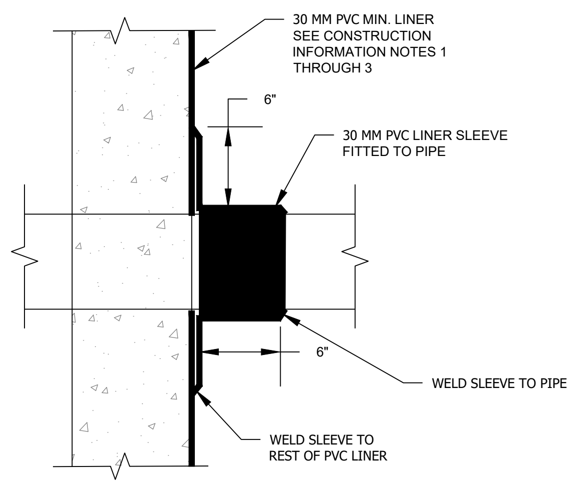
DETAIL 18

CONCRETE CHECK DAM







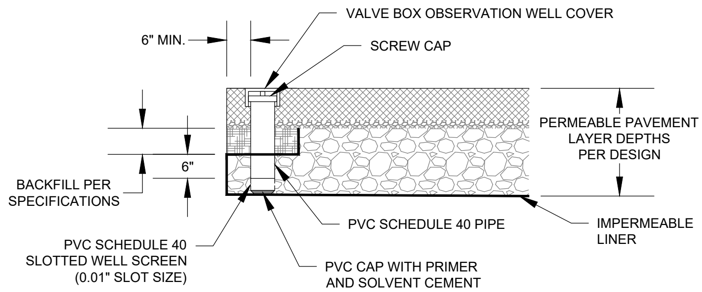


CONSTRUCTION INFORMATION

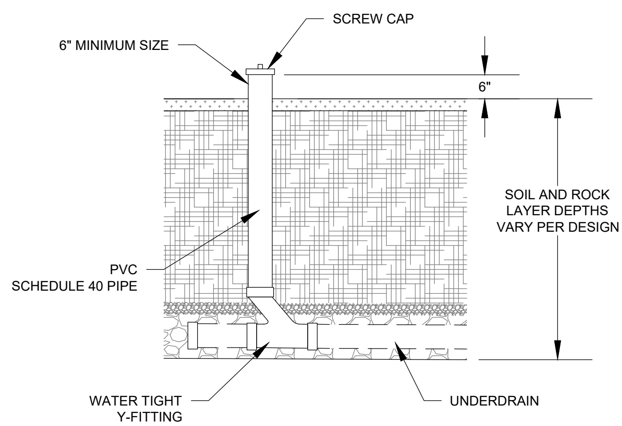
1. LINER SHALL LAY FLUSH WITH GROUND WITH NO AIR VOIDS BELOW THE LINER PRIOR TO BACKFILLING MATERIAL ABOVE THE LINER. CONTOUR THE SUBGRADE AS NEEDED TO ENSURE LINER LAYS FLUSH WITH GROUND.
2. OVERLAP LINER PER MANUFACTURER'S RECOMMENDATIONS.
3. ALL SEAMS SHALL BE WELDED PER MANUFACTURER'S RECOMMENDATIONS UNLESS OTHERWISE SPECIFIED.
4. SECURE LINER CONTINUOUSLY WITH DOUBLE-SIDED TAPE ALONG LINER EDGE AND SINGLE SIDED TAPE ALONG THE TOP EDGE OF LINER TO HOLD LINER IN PLACE DURING BACKFILLING.
5. TOP OF LINER TO BE AT LEAST 3" BELOW FINISH GRADE OF BIORETENTION SOIL EXCEPT WHEN ADJACENT TO BUILDING WALL. WHEN ADJACENT TO BUILDING WALL, LINER OR EQUAL WATERPROOFING SHALL EXTEND TO TOP OF FREEBOARD ELEVATION.
6. APPLY BUTYL MASTIC CAULK, BATTEN STRIP, AND NEOPRENE RUBBER PAD CONTINUOUSLY ALONG TOP EDGE OF LINER.
7. APPLY BEAD OF POLYURETHANE ELASTOMERIC SEALANT CONTINUOUSLY ALONG TOP EDGE OF BATTEN STRIP ASSEMBLY.

DETAIL 19

IMPERVIOUS LINER ATTACHMENT



20-1 OBSERVATION WELL IN PERMEABLE PAVED SURFACE



20-2 CLEAN OUT

DESIGN NOTES

1. AN IMPERMEABLE LINER WILL NOT UNIVERSALLY BE REQUIRED. CONSULT THE VIRGINIA DRAINAGE MANUAL FOR STRUCTURAL SPECIFICATIONS.
2. CLEANOUTS MAY BE USED AS OBSERVATION WELLS.

DETAIL 20

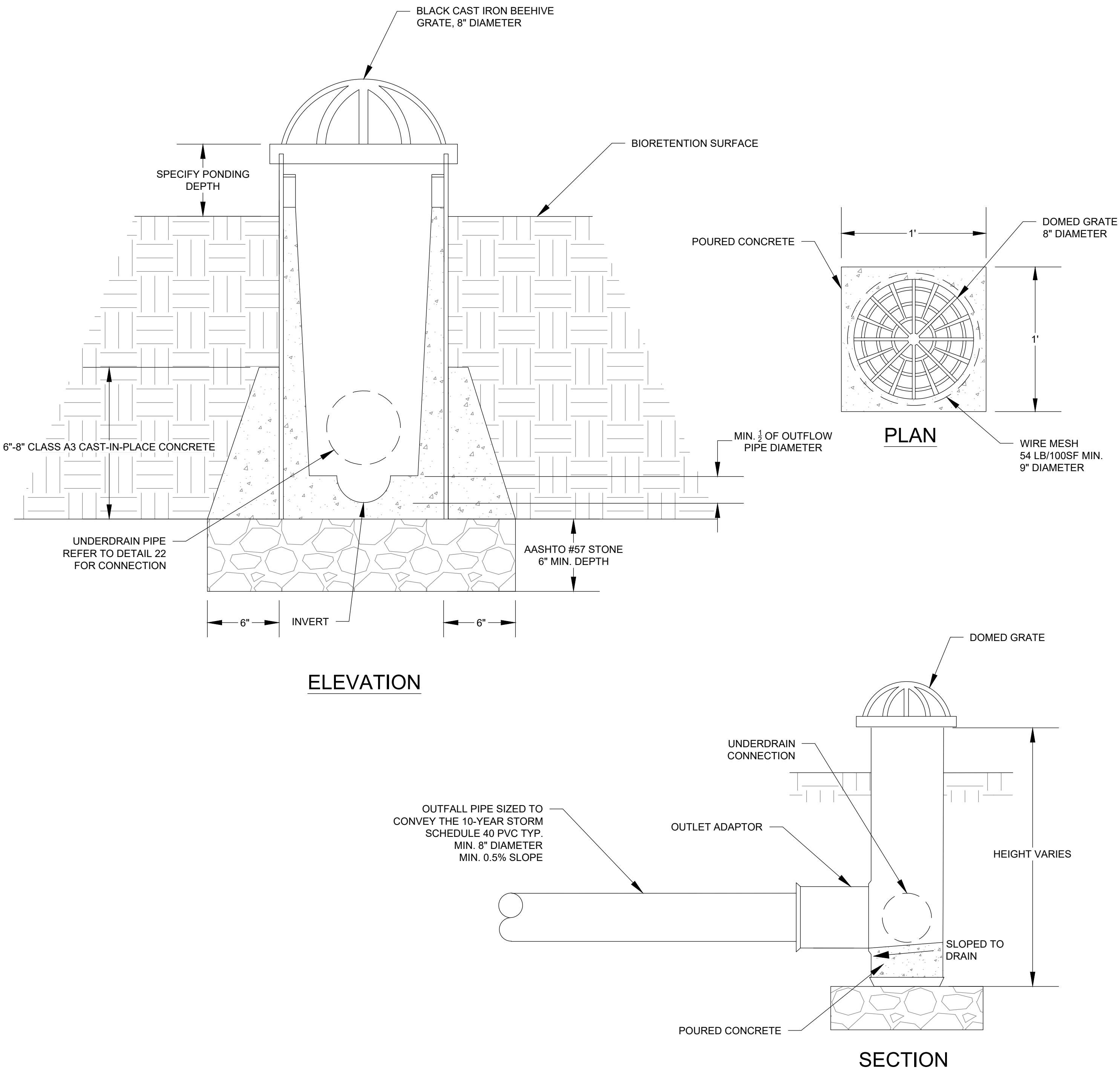
OBSERVATION WELL AND CLEAN OUT

DESIGN NOTES

1. RISER AND DISTRIBUTION PIPE SIZES MAY VARY BASED ON PROJECT SPECIFIC DESIGN. MINIMUM DIAMETERS SHOWN HERE.

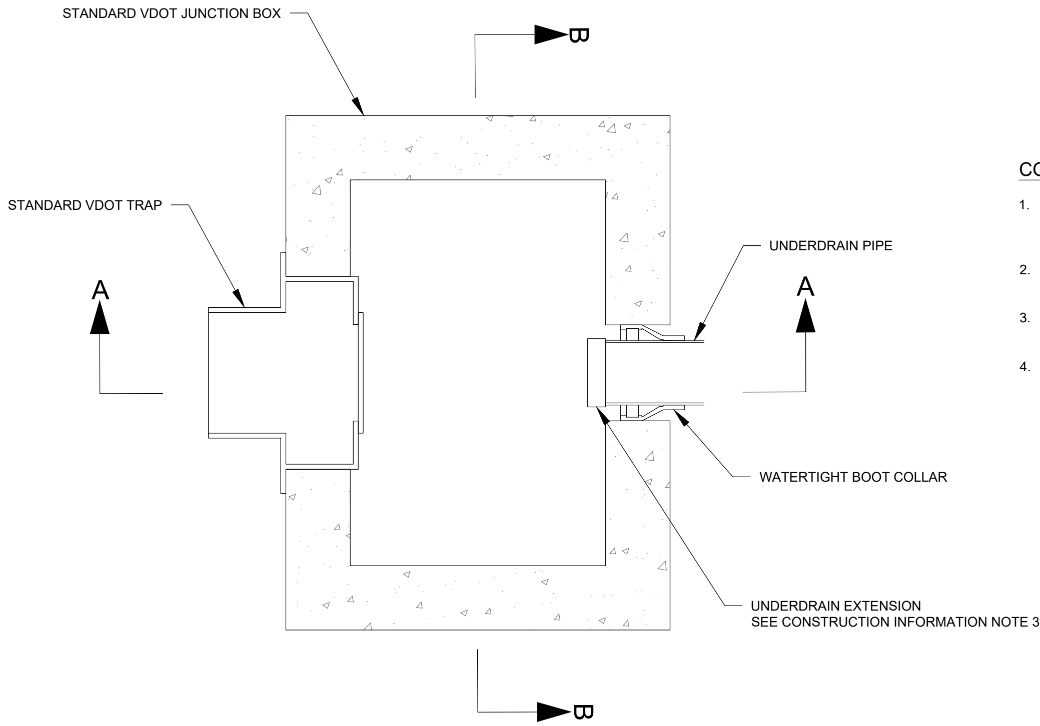
CONSTRUCTION INFORMATION

2. ALL JOINTS, ADJUSTMENTS, AND PIPE CONNECTIONS MUST BE WATERTIGHT.



DETAIL 21

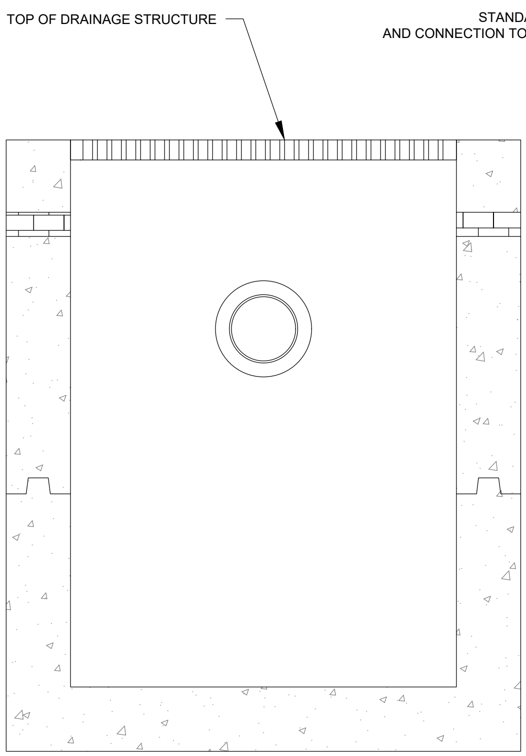
OVERFLOW RISER



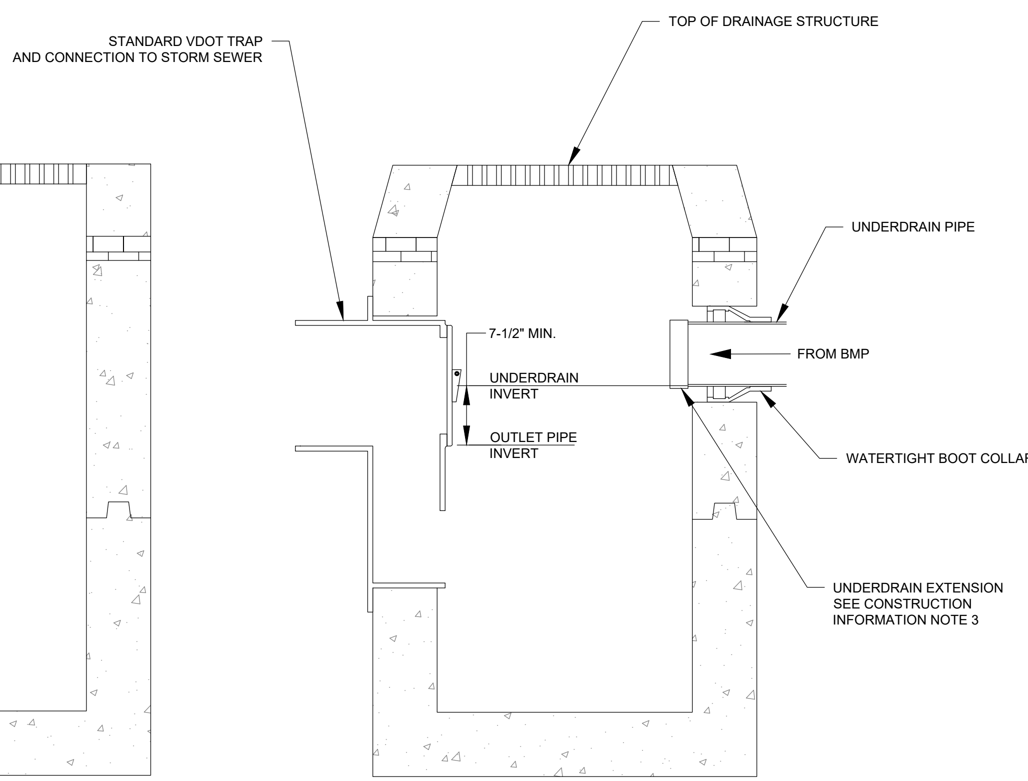
PLAN

CONSTRUCTION INFORMATION

1. ALL CONCRETE COMPONENTS, INLET GRATE AND FRAME, INLET TRAP, AND CONNECTION TO SEWER SHALL BE VDOT STANDARD CONSTRUCTION.
2. HIGHWAY INLET DEPICTED; DESIGN IS GENERALLY APPLICABLE TO ALL VDOT STANDARD INLETS AND MANHOLES.
3. TOTAL EXTENSION OF UNDERDRAIN AND CAP ASSEMBLY INTO INLET TO BE 2" FROM INLET WALL TO END OF CAP.
4. ALL JOINTS, ADJUSTMENTS, AND PIPE CONNECTIONS MUST BE WATERTIGHT.



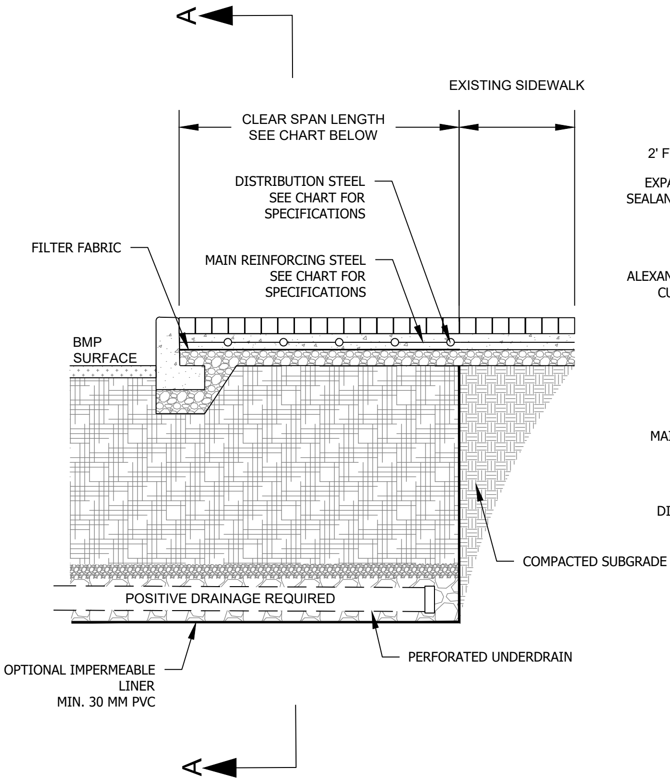
SECTION B-B



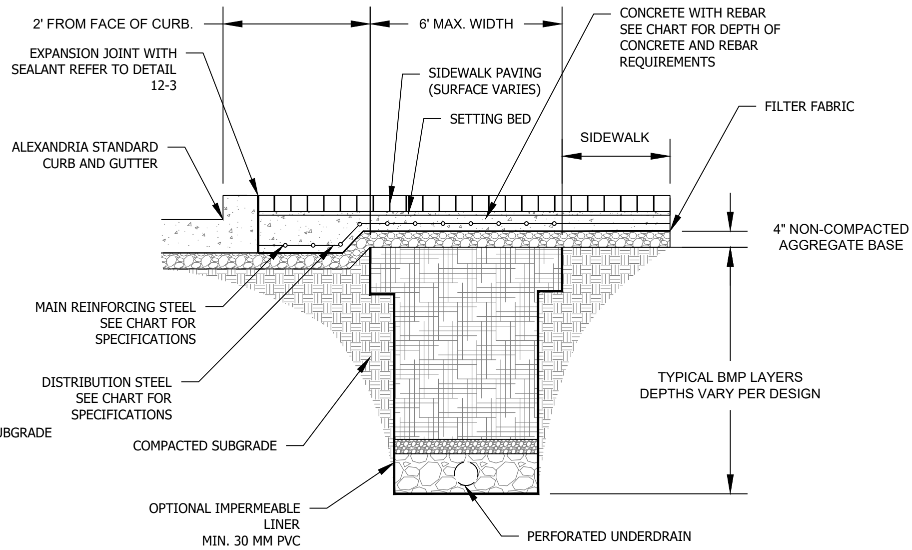
SECTION A-A

DETAIL 22

UNDERDRAIN STORM SEWER CONNECTION



PROFILE VIEW



SECTION A-A

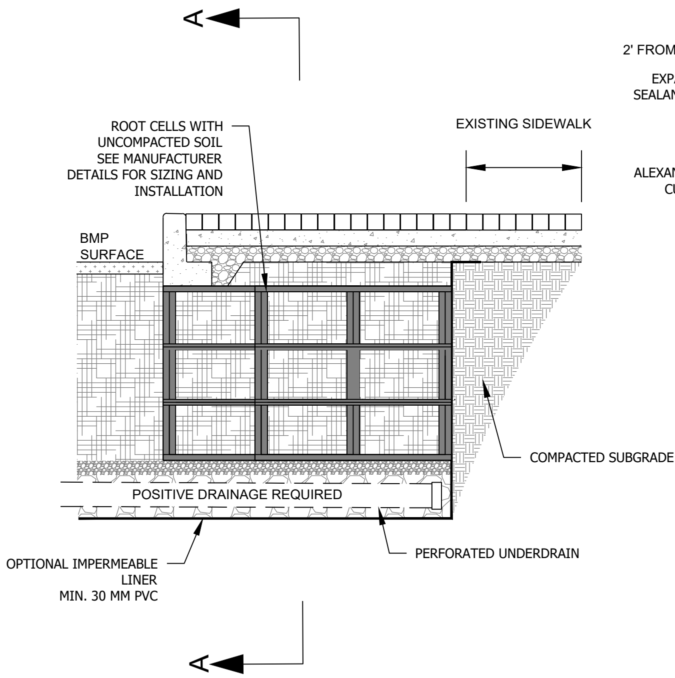
SUSPENDED SIDEWALK CONCRETE BASE DESIGN SPECIFICATIONS				
CLEAR SPAN LENGTH	DESIGN LOAD	SLAB THICKNESS	MAIN REINFORCING STEEL	DISTRIBUTION STEEL
6 Ft	H 20	6 IN.	#8 @ 6 IN. O.C.	#4 @ 12 IN. O.C.
6 Ft	H 20	8 IN.	#5 @ 6 IN. O.C.	#4 @ 12 IN. O.C.
6 Ft	85 PSF; PEDESTRIAN LL	6 IN.	#4 @ 6 IN. O.C.	#4 @ 12 IN. O.C.
8 Ft	H 20	7 IN.	#7 @6 IN. O.C.	#4 @ 12 IN. O.C.
8 Ft	H 20	8 IN.	#6 @ 6 IN. O.C.	#4 @ 12 IN. O.C.
8 Ft	85 PSF; PEDESTRIAN LL	6 IN.	#4 @ 6 IN. O.C.	#4 @ 12 IN. O.C.

DESIGN NOTES

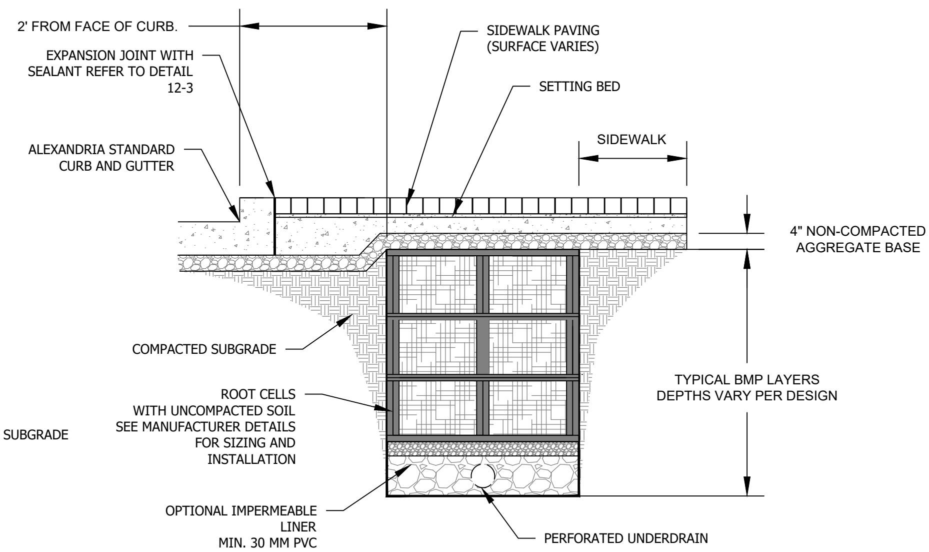
1. THE SIDE WALLS OF BMP FACILITIES SHALL BE DESIGNED TO SUPPORT THE EDGE OF THE WELL/TRENCH, STRUCTURALLY SUPPORT THE COPING CURB, AND IN MANY CASES TO PROVIDE A ROOT BARRIER. THE DESIGN OF SIDE WALLS MAY INCLUDE ALTERNATIVES WHICH MEET THESE REQUIREMENTS AND MAY INCLUDE FULL DEPTH CONCRETE WALLS, BENCHED WALLS, AND BATTERED WALLS. ALL STRUCTURED ELEMENTS SHALL BE CERTIFIED BY A STRUCTURAL ENGINEER.
2. PEDESTRIAN LOADING SHALL BE USED ONLY IN CASES WHERE SIDEWALK IS NOT ACCESSIBLE TO ANY FORM OF VEHICULAR TRAFFIC.
3. SOIL PANELS SHALL BE USED TO MEET SOIL VOLUME REQUIREMENTS FOR VEGETATION PLANTED IN A BMP, PARTICULARLY FOR TREE PLANTINGS. REFER TO ALEXANDRIA'S MOST RECENT LANDSCAPE GUIDELINES FOR SOIL VOLUME REQUIREMENTS.
4. EXISTING UTILITY LINES IN PROXIMITY TO THE BMP MUST BE SLEEVED OR RELOCATED. PROPOSED UTILITY LINES SHALL BE LOCATED OUTSIDE THE BMP.

DETAIL 23

SUSPENDED SIDEWALK



PROFILE VIEW



SECTION A-A

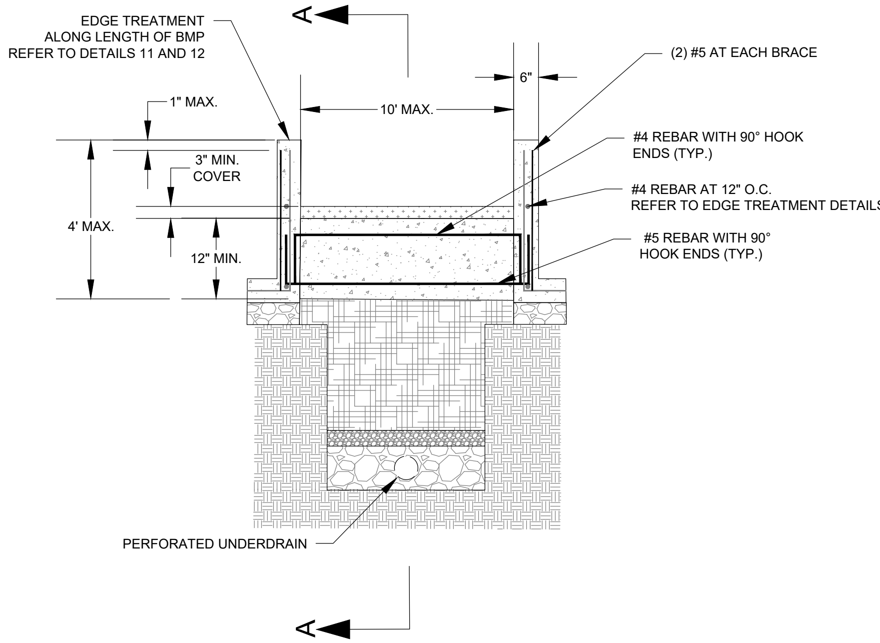
DESIGN NOTES

1. SOIL PANELS SHALL BE USED TO MEET SOIL VOLUME REQUIREMENTS FOR VEGETATION PLANTED IN A BMP, PARTICULARLY FOR TREE PLANTINGS. REFER TO ALEXANDRIA'S MOST RECENT LANDSCAPE GUIDELINES FOR SOIL VOLUME REQUIREMENTS.

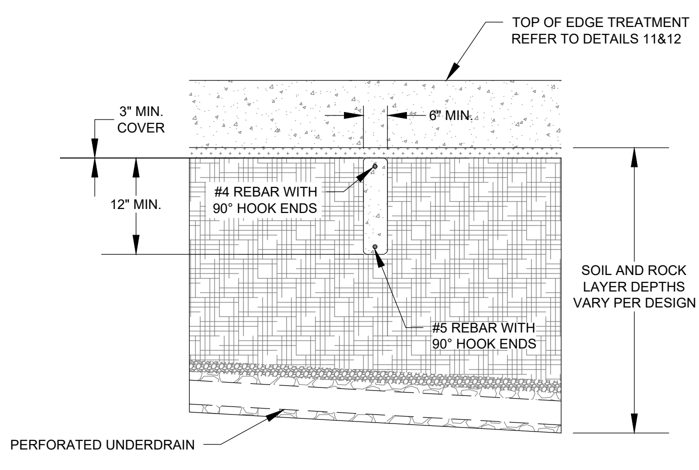
2. EXISTING UTILITY LINES IN PROXIMITY TO THE BMP MUST BE SLEEVED OR RELOCATED. PROPOSED UTILITY LINES SHALL BE LOCATED OUTSIDE THE BMP.

DETAIL 24

SOIL PANEL SUPPORTED SIDEWALK



ELEVATION VIEW



SECTION VIEW A-A

DESIGN NOTES

1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. FOOTINGS AND LATERAL BRACING SHALL BE DESIGNED TO WITHSTAND ANTICIPATED LOADING ASSUMING NO REACTIVE FORCES FROM THE UNCOMPACTED BIORETENTION SOIL WITHIN THE FACILITY.
3. LATERAL BRACING SHALL BE PROVIDED EVERY 6 FEET (MAX) FOR WALLS UP TO 4 FEET IN HEIGHT AND EVERY 4 FEET (MAX) FOR WALLS BETWEEN 4 AND 6 FEET IN HEIGHT.

CONSTRUCTION INFORMATION

1. ALL CONSTRUCTION COLD JOINTS SHALL INCORPORATE EPOXY, DOWEL/TIE BAR, AND KEYWAY.
2. PIPE FITTINGS SHALL BE USED TO ACCOMMODATE CHANGES IN GRADE, AS NEEDED.
3. CONCRETE LATERAL BRACING SHALL BE CONTINUOUS (NO JOINTS).

DETAIL 25

LATERAL BRACING

Appendix A:
Online Resources

Details, references, and other information are provided via the following links. External documents may be updated regularly. For the most current version of the information listed below, visit: www.alexandriava.gov/117278.

› Typical Stormwater Details for Streets & Sidewalks

› Reference Standards

› BMP Plant Lists

› Tree Planting Notes

› City Plans and Standards Links

› Development and Redevelopment Links

Appendix B: Glossary

Many of the terms used in this document have no singular or common definition from city to city or state to state. Other terms that are also known as (aka) or generally used to mean the same thing are listed after the term, with an acknowledgement that sometimes they are used interchangeably, whereas other times they are differentiated with precise definitions for the given context.

Best Management Practice (BMP)
(aka stormwater management facility)
A practice that is an effective and practicable means of controlling stormwater point or nonpoint source pollutants at levels compatible with environmental quality goals. In Virginia, the term BMP is commonly used to refer to specific structural stormwater management facilities on the Virginia BMP Clearinghouse website at swbmp.vwrrc.vt.edu.

Bioretention
The process of capturing stormwater runoff, absorbing and retaining pollutants, and then infiltrating, transpiring, or evaporating the water.

Bioretention facility *(aka rain garden)*
BMP treatment areas that capture stormwater runoff and treat it near its source through the process of bioretention.

BMP Tree Well *(aka urban bioretention facility)*
A landscape feature in the street that allows for tree planting and treatment of stormwater run-off. These systems are installed in a series, with drains connecting the series. At the street level, they appear to be a continuous feature with a large area of visible landscape planting and are occasionally separated by sections of sidewalk.

Check dam
An obstruction placed across the width of a swale or continuous bioretention area to reduce velocity, limit erosion, and promote infiltration into the underlying media.

Curb inlet
A stormwater structure designed to capture stormwater runoff in the roadway and/or gutter pan and deliver it to the BMP underground stormwater piping system.

Curb extension *(aka bump-out, curb bulb, neckdown)*
An expansion of the curb line into a portion of the roadway where the curb-to-curb roadway width is reduced. Curb extensions can enhance pedestrian safety by reducing crossing distances or provide additional sidewalk amenities.

Edge restraint
A manufactured unit (usually composed of stainless steel) installed at the edge of a field of paving or at a curb face to prevent horizontal movement of paving, curbs, or aggregate base courses.

Impervious area
A surface composed of any material that significantly impedes or prevents natural infiltration of water into the soil. Impervious surfaces include, but are not limited to, roofs, buildings, streets, parking areas, and any concrete, asphalt, or compacted gravel surface.

Infiltration
The downward movement of water from the land surface into the soil.

Liner / membrane
A thin pliable sheet or geotechnical fabric to provide separation between filter media and/or to prevent water seepage.

Modular suspended pavement systems
(aka root cell)
Manufactured unit that is designed to allow maximum root growth under a sidewalk. The unit is installed as a system and provides structural support for the sidewalk and void space for uncompacted planting medium.

Right-of-way (ROW)
Generally considered of as a publicly owned street, alley, lane, etc. The public ROW unless otherwise identified.

Runoff
Precipitation that is discharged across the land surface or through conveyances to one or more waterways and that may include stormwater runoff, snow melt runoff, and surface runoff and drainage.

Soil matrix/planting medium
(aka bioretention soil media [BSM])
Uncompacted soil of specific physical, chemical, and biological characteristics designed to support maximum phosphorus removal and enhance plant health and growth.

Soil panel
Uncompacted soil beneath a supported or suspended sidewalk that is designed to meet soil volume requirements for trees.

Stormwater management facility
(aka best management practice)
A structural control measure that controls stormwater runoff and changes the characteristics of that runoff, including, but not limited to, the quantity and quality, the period of release, or the velocity of flow. A stormwater management facility is a type of stormwater BMP.

Supported sidewalk
Sidewalk installation that is designed to allow maximum root growth. The sidewalk is structurally supported by modular suspended pavement systems creating voids beneath, with the voids filled by uncompacted growing medium (soil) for the street trees.

Suspended sidewalk
Sidewalk installation that is designed to allow maximum root growth. The sidewalk is structurally supported to span a void beneath, with the void filled by uncompacted growing medium (soil) for the street trees.

Total Maximum Daily Load (TMDL)
A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant.

Urban bioretention facility *(aka bioretention facility)*
These are structural stormwater facilities or BMPs are bioretention facilities that are adapted to fit into “containers” within urban landscapes. Examples include BMP tree wells, curb extension bioretention facilities, and median bioretention facilities.

Weir
A dam in a swale or bioretention area to raise water levels or divert flow.

Appendix C: References

Alexandria Snow Emergency Routes. *alexandriava.gov/40384*

American Society of Landscape Architects (ASLA). 2016 ASLA Professional Awards. The Copenhagen Cloudburst Formula: A Strategic Process for Planning and Designing Blue-Green Interventions. *https://www.asla.org/2016awards/171784.html*

City of Alexandria. 2017. *Geologic Atlas of the City of Alexandria, Virginia and Vicinity.* https://www.alexandriava.gov/recreation/info/default.aspx?id=89974

City of San Jose. Green Stormwater Infrastructure Maintenance Field Guide. *https://www.sanjoseca.gov/your-government/environment/our-creeks-rivers-bay/green-infrastructure*

IPCC (Intergovernmental Panel on Climate Change), 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

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National Association of City Transportation Officials (NACTO). 2017. Urban Street Stormwater Guide. *https://nacto.org/publication/urban-street-stormwater-guide/*

Virginia DCR Stormwater Design Specification No. 7 Permeable Pavement Version 2.0, January 1, 2013. *https://www.swbmp.vwrrc.vt.edu/*

Virginia DCR Stormwater Design Specification No. 9 Bioretention Version 2.0, January 1, 2013. *https://www.swbmp.vwrrc.vt.edu/*

Washington, DC Department of Energy & Environment (DOEE). 2020. Blue Green Infrastructure: Cloudburst Management Strategies for the District of Columbia. *https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/BGI_Workshop_Final.pdf*

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