PDHonline Course C194 (6 PDH)

Design of Bioretention Systems

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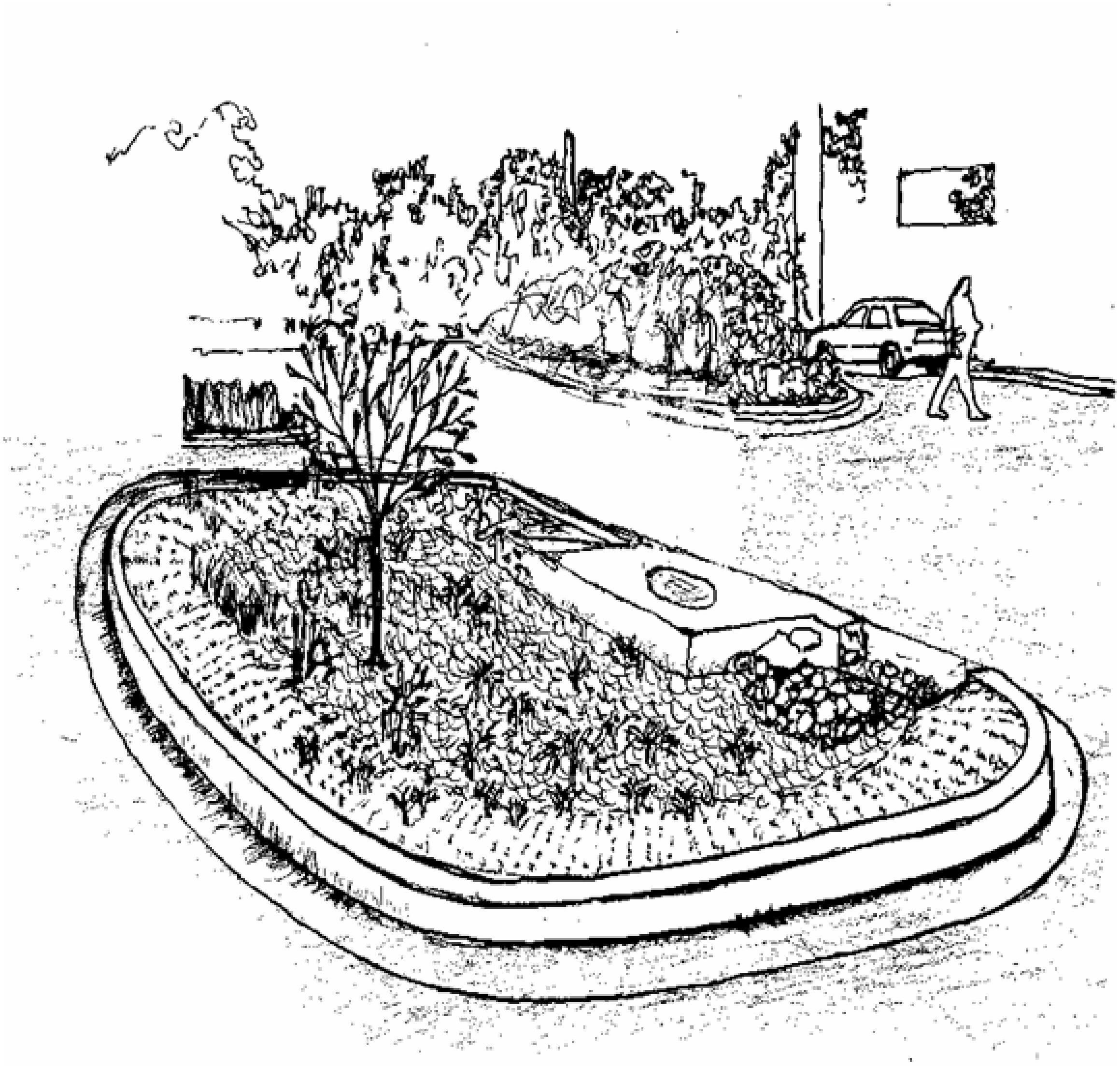
Bioretention Design Specifications and Criteria



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Section 2.0 - Siting and Design Criteria

2.1 Introduction to Bioretention Siting and Design

Bioretention is an acceptable urban BMP option as identified in the Maryland Department of the Environment's "2000 Maryland Stormwater Design Manual Volumes I & II", Section 2.7, BMP Group 3 (Infiltration), and BMP Group 4 (Filtration).

Bioretention is flexible in design, affording many opportunities for the designer to be creative. This design guide first goes into a step by step process of how to size and design bioretention to accommodate the design storm runoff amount. After that, how to integrate the bioretention facility(ies) into the overall site design is explored. Once this is done at a subdivision macro scale, further analysis is performed at the micro or lot scale.

At the micro scale, several related issues are presented. The first issue is how to develop a grading plan, sediment and erosion control plan, and the bioretention plans themselves. In this part of the document, site constraints or restrictions are identified. Several example plans are also presented.

2.2 Bioretention Site Applicability

For various reasons, the application of bioretention may or may not be appropriate for your site. The following general guidelines can assist the designer to determining when to utilize bioretention for stormwater management:

1. Facilities can be placed close to the source of run-off generation.
2. The site permits the dispersion of flows and bioretention facilities can be distributed uniformly.
3. Sub-drainage areas are smaller than 2 acres and preferably less then 1 acre.
4. Available room for installation including setback requirements.
5. SWM site integration is a feasible alternative to end-of-pipe BMP design.
6. Suitable soils availability.

2.3 Site Evaluation

To begin, evaluate the site's existing topography and associated drainage patterns. Potential bioretention facilities should be applied where sub-drainage areas are limited to less than 1-2 acres, and preferably less than 1 acre. Generally, commercial or residential drainage areas exceeding 1-3 acres in size will discharge flows greater than the 5 cfs for a 10year storm event. When flows exceed this level, the designer should evaluate the potential for erosion to stabilized areas. Typically, flows

> **Hint:** By limiting the drainage area to less than 1 acre, and avoiding creating berms > 3', pond approval/review is not required.

greater than 5 cfs for the 10-year storm event will require pipe enclosure across developed lots. However, by employing drainage dispersion techniques and retaining existing contours, concentrated quantities of flow can be reduced below these thresholds, eliminating or reducing the need for a pipe conveyance system. This may be accomplished by dispersing larger drainage areas to multiple bioretention facilities. This dispersion of flow technique can reduce the cost of engineering design and site construction. In Addition to reducing the need for drainage pipe conveyance systems, dispersion techniques can also eliminate the need for surface drainage easements.

Bioretention Design Feature Functions

Design Feature	Water Quality Treatment	Water Quantity Treatment	Groundwater Recharge	Wildlife Habitat	Micro-Climate Alteration	Vegetative Buffering	Natural Area Protection	O&M and Public Safety	Aesthetic Improvements
Siting/Location									
Sizing									
Shape									
Ponding Time/Depth									
Velocity									
Planting Soil									
In-Situ Soil									
Underdrain System									
Mulch Layer									
Plant Material									
Edge Protection									

Table 2.1: Bioretention design feature functions to consider for SWM requirements

2.4 Sizing Bioretention

To size a bioretention facility, the designer has to first determine for what purposes it is intended. For example, what are the site requirements for water quality and quantity control? What design storm is required to meet the stormwater management criteria? Can the bioretention be used for water quality and quantity control? Can the bioretention facility be used independently of other BMP's, or will it be installed along with other practices?

> **Hint:** Where practical, place proposed impervious surfaces on hydrologic soil groups C & D and preserve soil groups A & B to reduce the net change in the CN value.

The above questions may be answered at the stormwater management concept stage. Having determined the design storm, the designer may use the following procedural outlines for sizing bioretention areas for water quality and quantity criteria, adjusting accordingly to the specific site constraints. Designers should pay close attention to the stormwater management criteria and waiver conditions that could help reduce the overall stormwater management control requirements.

2.5 Sizing and Placement Procedure

The following procedure may be followed by designers in order to utilize bioretention within a site:

Step 1: Delineate the development site drainage area in the pre and post development condition. Delineate subdrainage divides for the post development condition, identifying strategic locations for possible bioretention facilities.

Step 2: Using TR-55 methodology, determine the pre and post development CN for the proposed development site. Adjust the CN value by measuring the actual impervious versus pervious areas. Remember to incorporate other LID site design techniques to help reduce the post development CN value. Methods such as increasing the percentage of disconnected impervious areas, preserving wooded areas, and reducing impervious surfaces will minimize the amount of control required.

Step 3: Select the required design storm and design depth for the bioretention facility(ies). The SWM Concept application submission shall identify the intent to utilize an LID approach through the use of bioretention. The design storm used is dependent upon the objectives of the LID approach which can vary from stream & ecosystem protection to load reduction for TMDL requirements. Note: the design storm can vary significantly depending upon the stormwater management objective.

Step 4: Determine the storage volume required to maintain runoff volume or CN. Use Chart Series A: (as provided in the back of this manual) Pre-development Runoff Volume Using Retention Storage.

Step 5: Determine the storage volume required to maintain the pre-development peak runoff volume using 100% retention. Use Chart Series B: Percentage of Site Area Required to Maintain the Predevelopment Peak Runoff Rate Using 100% Retention.

Step 6: Utilize the results from Chart Series A, B, and C to determine the percentage of the site needed to maintain both the predevelopment peak runoff and the runoff volume.

Step 7: Determine appropriate percentage of site available for retention practices. If the percentage of the site available for retention practices is less than the percent determined in step 5, recalculate the amount of BMP required to maintain the peak runoff rate while attenuating some volume.

See the design example that follows. This procedure is used in a design example presented later in this chapter.

2.6 Location Guidelines

Bioretention facilities may be used *anywhere* to achieve a degree of treatment. The location depends in part on the *type* of facility employed. See Chapter 1 for specific bioretention types. The following guidelines present some preferable locations for bioretention:

- ✍On new residential subdivision lots or commercial lots, near the source of the runoff generation from impervious surfaces. Locate facilities near the perimeters and edges to maintain typical use of the property. Avoid locating near building areas (unless the design incorporates adequate waterproofing measures), well heads, and septic systems.

- ✍Areas upland from inlets or outfalls that receive sheet flow from graded areas.

- ✍Areas of the site that are planned to be excavated or cut. Existing wooded areas or other significant natural features should be avoided if possible, for the purposes of installing a bioretention facility.

- ✍When available, areas of USDA sandy, well drained soils should be used for siting the bioretention areas. These soil types comprise the planting soils for bioretention areas, and locating bioretention areas in these soils would minimize or eliminate the cost of importation of planting soil.

- ✍Stormwater Management Retrofit and Redevelopment Opportunities- Even where total stormwater management control is not feasible, the addition of a retrofit bioretention facility will provide some improvement in water quality.

2.7 Integration and Site Distribution of Bioretention Areas

The integration of bioretention areas across the development site is very important to achieve proper stormwater management controls. Each site is unique, necessitating close attention to subdrainage areas when evaluating the net impacts on the hydrologic characteristics. Once the amount of site area to be dedicated to the bioretention area(s) is known, specific facility sizing can be accomplished. To do this, the following steps should be followed in order to distribute the facilities uniformly:

1. Delineate and sub-divide sub-drainage areas (preferably less than 1 acre drainage area). Find local low points for each sub-drainage area and evaluate the location for suitability for bioretention.

2. Using the volume derived from section 2.5 procedure above, (steps 1-7), and the total site area, find applicable weighted area for each sub-drainage area. For example, if a sub-drainage area represents 15% of the total drainage area for the whole development, then 15% of the required volume control should be applied to that same sub-drainage area. Similarly, if only 5% of the total drainage area for the whole development is located in a sub-drainage area, then 5% of the volume requirement should be sited accordingly in the respective sub-drainage area.

3. The allowable pooling depth should be no greater than 6". If pooling depths are less than 6", then the surface area and/or the volume of the facility must be expanded accordingly.

4. When siting bioretention facilities to intercept drainage, the designer should attempt to use the preferred "off-line" facility design. An example of an off-line facility is shown in Figure 2: Offline Bioretention. Off-line facilities are defined by the flow path through the facility. Any facility that utilizes the same entrance and exit flow path upon reaching pooling capacity is considered an off-line facility.

5. Whenever possible, underdrains should be utilized for bioretention discharge. The underdrains may outfall to a suitable location such as: common space area, stream valley, drainage swale, roadside open-section, or an existing enclosed drainage system.

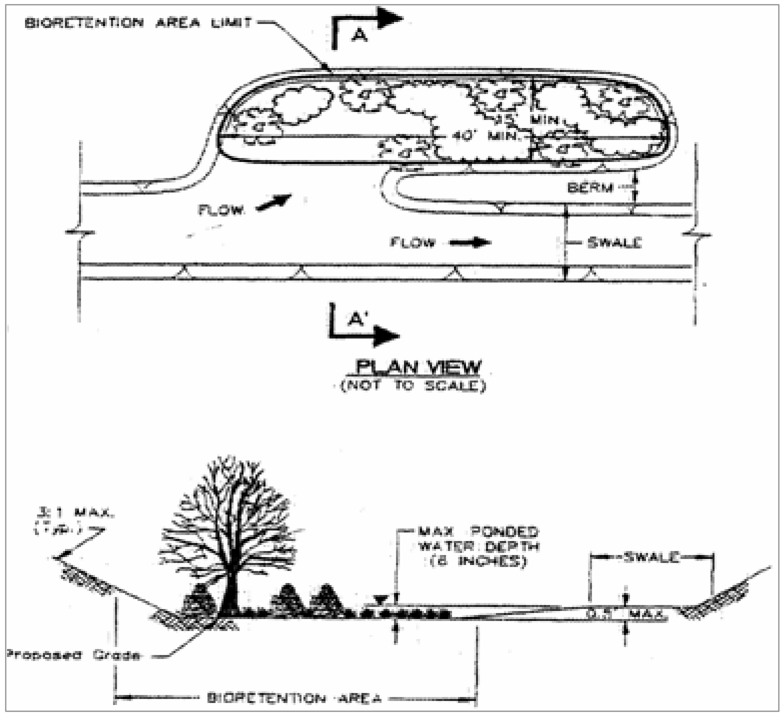


Figure 2.1: Offline Bioretention

2.8 Grading for Bioretention Developments

2.8.1 Site Grading for Bioretention

Siting the bioretention area(s) within a development requires the same information and analysis as conventional site design to determine the existing hydrology. Evaluation of the sub-drainage divides and flow paths will help determine how to best layout the proposed development making best use of the existing contours to minimize grading. Preservation of existing natural features (even within the development envelope) will help maintain existing flow patterns and flow paths and disperse runoff instead of concentrating it in one location.

Clearing and grading operations must be carefully considered when integrating bioretention within lot areas. In the case of a residential community, each lot should be independently designed to ensure drainage from each lot is adequately handled- either by proper overland conveyance to a bioretention facility, or by maintaining the original dispersed drainage patterns.

Once the site is evaluated to determine the flow patterns and soils, lot locations can be plotted to maximize lot yield being careful to allow no more than two lots draining across a third lot. Portions of the lot that are to remain undisturbed do not need to consider stormwater management control for those areas if no new runoff is added and the flow patterns present in the predevelopment condition have not been altered.

After the lots have been positioned to maximize existing contours and to reduce graded areas, attention must be focused to the portion of the lot that is to be developed. This portion of the lot will generate new runoff, particularly from the new imperious areas. It is here that bioretention areas must be located as close to the source as possible to intercept and absorb this new runoff. Typically, placing the bioretention areas on the lowest portion of the individual lot will accomplish this. Be sure to account for proposed improvements such as building footprints and areas that may be used for pools or decks. The key point is to blend the bioretention facility into the lot in such a way so that typical use of the property is not encumbered. The following section provides suggestions for bioretention site grading design.

2.8.2 Site Grading Design Considerations

✍ Locate facilities away from traveled areas such as public pathways to avoid soil compaction. Where facilities are placed near walkways, be sure to delineate boundaries and borders to make pathways clear.

✍ Sloped areas *immediately* adjacent to proposed bioretention areas should be less than 20% but greater than 2% to ensure positive flow at reduced velocities. Weep garden designs (see design example in Chapter 3) can be used where steeper slopes are encountered.

✍ Proposed bioretention facilities may be situated at the same location as an interim sediment control facility. If this is done, several activities must be performed to ensure residual sedimentation does not hamper the effectiveness of bioretention:

1. The invert of the proposed facility must be 1' below the invert of the existing sediment control facility.
2. Bioretention must have an underdrain discharge pipe.
3. During construction of the bioretention facility, sediment and runoff must be diverted.

✍ Cut and fill limitations should conform to existing County grading criteria for developed lots*. Typically, areas that are placed in cut must have sufficient geotechnical investigation to ensure that an adequate minimum distance (2') to the water table is maintained. For fill areas, berms may be used to create depression areas for use in bioretention, but should be minimally used to avoid being defined, classified, and regulated as a dam. Consult with the PGSCD and MD378 for questions regarding dam classification criteria.

✍ Minimize grading and limits of disturbance to maintain existing dispersion of flow. The more disperse the flowpaths are, the smaller the resultant sub-drainage areas will be.

✍ Facilities that traverse residential property lines are prohibited. Maintain 2' minimum distance from property lines. For residential cross-lot drainage, a surface drainage easement must be provided.

✍ Where grading and excavation for underdrains or other drainage appurtenances are involved, practice standard utility practices for setback criteria when in the vicinity of other utilities.

Drainage systems designed to service the bioretention area are exempt from the setback criteria. Stormdrain pipe joints in the vicinity of the bioretention area should be sealed to prevent piping and possible subsequent cavitation.

*The Prince George's County Grading Ordinance currently does not have a provision for bioretention. For this reason, it may be necessary to obtain a variance or waiver.

2.9 Developing a Grading Plan for Bioretention

In developing the grading plan, the sediment and erosion control practices used are a function of the size of the drainage area. The drainage area contributing to each bioretention area should be delineated for the site. The Rational Method "c" coefficient should then be determined for the drainage area using the methodology specified in Chapter 4 of the Prince George's County Stormwater Management Manual. Additionally, consult the Prince George's County Grading Ordinance as well as the PGSCD for grading plan specifics.

2.10 Sizing Bioretention for Water Quality utilizing the MDE Unified Stormwater Sizing Criteria

Bioretention may be used as an acceptable BMP in accordance with the MDE 2000 Stormwater Design Manual, Chapter 2, Section 2.7.1, BMP Group 3 (infiltration practices) and BMP Group 4 (filtering practices). To be considered as a stand alone treatment of WQ_v (water quality volume), a bioretention facility must be capable of the following;

1. capturing and treating the required WQv,
2. removing 80% of the TSS,
3. removing 40% of the TP, and
4. having an acceptable longevity rate in the field.

Performance Criteria for Bioretention Design

Critieria	Filtration Design	Infiltration Design	Cpv Storage Design
General Feasibility			
Location	All locations okay with underdrain[1]	Insitu soils to be certified suitable	In-situ soils to be certified suitable[1]
Drainage Area	2 acre max, 1 acre max. impervious	1 acre max, ½ acre max. imperv.	1 acre max, ½ acre max. imperv
Soils Infiltration Rate	See soil mixture specifications	In-situ soils 1"/hr infiltration rate[2]	In-situ soils 1"/hr infiltration rate[2]
Clay Content	< 5%	<5%	<5%
Hotspots	Yes w/liner	No w/o proper pretreatment	No
Water Table	>2 vert. feet from facility invert	>4 vert. feet from facility invert	>2 vert. feet from facility invert
Water Supply Well	Maintain >100' distance		
Building Structures	Setback >10'[3], downgradient	Setback >25'[3], downgradient	Setback >10'[3], downgradient
Septic System	Maintain >50' distance		
Sloped areas	Okay w/ weep garden design	Not recommended greater than 20%	Not recommended
Property line Setback	2' minimum		
Conveyance			
Entrance Flow	Surface sheetflow	Surface sheetflow	Surface sheetflow
Entrance Treatment	Rip-rap, gabion mattress, surge stone,	Rip-rap, gabion mattress, surge stone,	Rip-rap, gabion mattress, surge stone,
Surface Pool Dewater	3-4 Hours	3-4 Hours	3-4 Hours
System dewater	<48 hours	<48 hours	<48 hours
Overflow/ Outlet	Safe overflow path or approp. outlet	Safe overflow path	Safe overflow path or approp. outlet
Flow Path	Off-line preferred; Where not feasible, in-line permissible		
Flow Regulator	Divert WQv		
Media Filter	Non-woven Filter Fabric or pea gravel diaphragm	none	Non-woven Filter Fabric and liner around facilty
Underdrain	4" dia. min.	N/A	4" dia min.
Pretreatment			
Pretreat. BMP	Surface	Required	Required
Grass Filter Strip	Use where space permits. Not always feasible.		
Surface Treatment	Allowable where impervious area >75%		
Pretreatment Vol.	25% of WQv	N/A	25% of WQv
Treatment			

Volume	Entire WQv filtered – pretreat. volume	Entire WQv infiltra. – pretreat. volume	Entire WQv filtered – pretreat. volume
Porosity	n = .25 for soil mix; .40 for stone	n = .25 for soil mix	n = .25 for soil mix; .40 for stone
Landscaping	See Landscaping Chapter		
Maintenance			

2.11 Developing a Landscaping Plan for Bioretention

The designer/landscape architect can develop a landscaping plan for bioretention in similar fashion to conventional site landscaping design. The main difference is essentially the integrated stormwater management control- "functional landscaping" as well as the aesthetic appeal. Even though the facility is being designed to capture and treat stormwater, the designer is cautioned *not* to view bioretention as a wetland, pond, or other water feature. Rather, the designer should utilize plant species that are tolerant to wide fluctuations in soil moisture content.

A landscaping plan developed for the purposes of bioretention should include the following elements:

- ✍ Plan view of the facility showing landscape features
- ✍ Plant and Material Schedules
- ✍ Spot grades and section locations
- ✍ Cross-section view
- ✍ Inflow and discharge points/connections
- ✍ Landscaping specifications

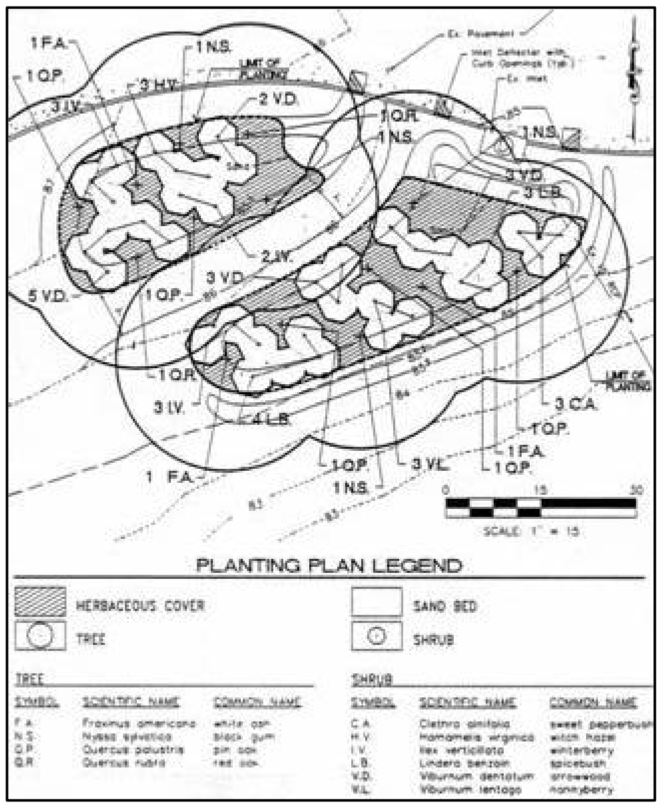


Figure 2.4: Portion of Typical Landscaping Plan for Bioretention

Designers should use planting materials from our planting list in Chapter 3. Chapter 3 also provides other useful information pertaining to landscape issues.

2.12 Bioretention Site Integration

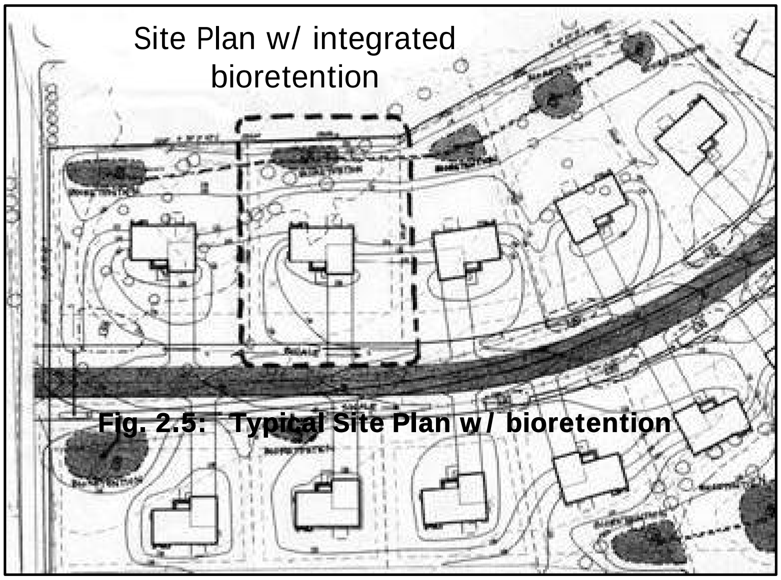


Fig. 2.5: Typical Site Plan w/ bioretention

When using bioretention in new developments, many options exist for designing and integrating bioretention facilities. The design phase of integrating bioretention BMP's should begin early in the land development process. Part of that process involves determining the appropriate development envelope and constraints.

The following sections in this chapter describe the process of utilizing bioretention to meet the requirements of storm water management. Each section relates to the example provided, indicating which issues and information are addressed at that stage. The first issue is site integration and site constraints relative to bioretention.

Site integration is key to the management of stormwater runoff by the use of bioretention. Essentially, this entails locating the facilities close to the source where the runoff is generated and making use of landscaping options. This means strategically placing facilities throughout a community, typically within residential lot areas. To do this, the designer must be aware of various site constraints and setbacks established to prevent possible contamination and seepage problems from occurring. Most of these setback and constraint criteria have been identified in the following text.

2.12.1 Bioretention Site Integration Design Criteria

When attempting to integrate a bioretention facility into the proposed development envelope, the designer must be cognizant of possible impacts to other development features. In particular, setbacks from utilities, property lines, buildings and roadways should be determined. In addition, areas of conservation to preserve trees and existing grading are also of concern when designing or placing a bioretention facility. The following design criteria shall be incorporated into the design technical plans and shown on the plan view (if applicable).

2.12.1.1 County Right-Of-Way

Bioretention is allowed within the County's Right-Of-Way with the prior approval of the Director of Public Works and Transportation.

2.12.1.2 Wellhead

Bioretention areas should be placed at least 100 feet from any source water location. Other restrictions may apply. Consult with the Department of Health, Environmental Health Sanitarians for specific conditions.

2.12.1.3 Septic Field

When siting bioretention facilities, septic areas must be avoided, unless the septic field utilizes a hybrid design specifically designed to accept surface water. Otherwise, maintain a 50' setback from the septic field to avoid cross contamination. It is preferable to locate bioretention facilities upgrade of any septic field and to divert any overflow path away from the field as well.

2.12.1.4 Basement

When siting bioretention facilities on lots that will have a basement, the facility offset requirements include the following:

- ✍ Minimum of a 25' setback down-gradient from the home foundation.
- ✍ If possible, facility invert shall be lower than the proposed basement floor elevation.
- ✍ Facility shall be located down-gradient from the home or building location.

2.12.1.5 Building Foundation

Setback from a foundation or slab shall be 5' or greater. Basement setbacks apply whenever the structure has a basement. Exceptions may be acquired for planter box bioretention facilities located on industrial or commercially zoned property. For planter box bioretention facilities, waterproofing membranes (as a minimum) adjacent to the building wall are required.

2.12.1.6 Property Line

Bioretention facilities can not cross private property lines. Additionally, whenever possible, bioretention areas should be sited on the same lot that generates the runoff. The perimeter of a bioretention area shall be located at least 2' away from any property line. For weep garden designs, locate at least 20' away from any down-gradient property boundary or line.

2.12.1.7 Outlet Drainage

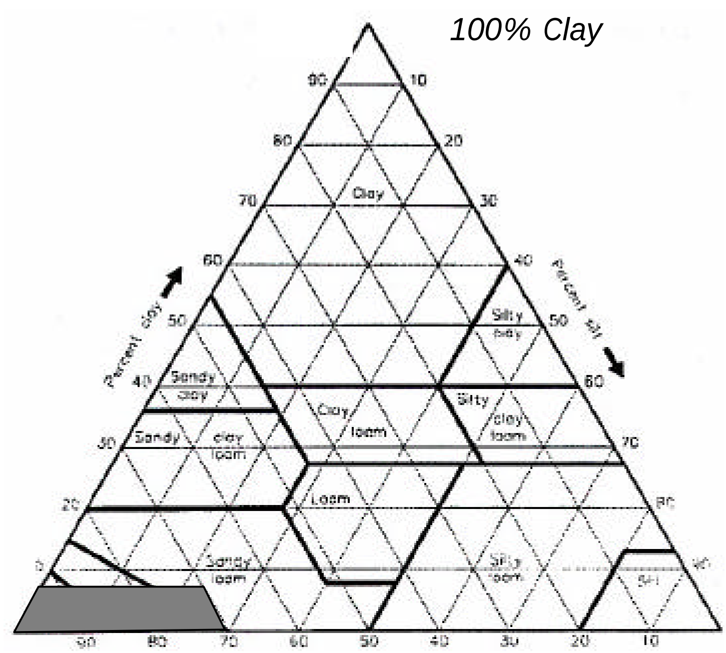
Overflow from bioretention areas must be safely conveyed to a suitable discharge point (stormdrain system, stream channel, or swale). In-line facilities are discouraged due to possible mulch-float problems. Off-line facilities are preferred to control drainage.

2.12.1.8 Underdrain

Underdrains are required for all residential lot facilities and recommended for all facilities in general. Underdrain material shall be of approved material and have a hydraulic capacity greater than the planting soil infiltration rate. Underdrains shall not be located within the groundwater zone of saturation. Underdrains shall be perforated with ¼ - ½ " openings, 6" center to center and a total cross-sectional area of at least (or greater than) 3 times the underdrain pipe hydraulic capacity. Underdrain pipe material may be composed of PVC , rigid Schedule 40 or ADS pipe material.

2.12.1.9 Soil Restrictions

The main soil restriction for use in bioretention facilities is that the soil must have an infiltration rate sufficient enough to draw down any pooled water within 3-4 hours after a storm event. This requires that the soil infiltration rate exceed 1.5 inches/hour (USDA Classification of SAND). For areas with unsuitable soils, this restriction can be overcome by importing the planting soil mix and providing an underdrain system in the facility to help achieve the desired infiltration rate. For in-situ soils, see Appendix B: Bioretention Soil Testing Criteria and Methodology.



100% Sand *100% Silt*

Figure 2.5: USDA Soil Textural Triangle

2.12.1.10 Cross-Lot Drainage

Drainage from bioretention facilities shall not be directed to cross over another developed, private portion of a lot. Drainage from a bioretention area must have a suitable discharge point. Suitable discharge points include dispersing of flows to undeveloped lots, common space areas, or to the County Right-Of-Way (R-O-W). If a site is not conducive for bioretention without affecting another developed lot adversely, then there is the option of conveying the flow. See grading section for example of swale grading between lots to the R-O-W.

2.12.1.11 Groundwater

Depth to groundwater below the facility invert shall be no less than 2'. Determining the depth to groundwater shall be done by performing an actual soil boring or test pit similar to a percolation test. Testing shall be conducted during specific seasonal periods. Contact the Health Department, Division of Environmental Health, to determine the current criteria.

2.12.1.12 Minimum Depth Criteria

Facilities using the specified soil mix can be as shallow as 1.5 feet in depth. For facilities designed using in-situ soils, the minimum facility depth criteria does not apply. Rain Gardens may be very shallow if the drainage area is less than ¼ acre.

2.12.1.13 Slopes & Existing Grades

Generally, sloped areas exceeding 20% shall not be used for bioretention. However, a weep garden design may be used on shallow slope conditions and where no downstream seepage problems will impact buildings.

2.12.1.14 Wooded Areas

Wooded areas should not be cleared to make room for a bioretention facility. If the bioretention facility design incorporates the use of wooded areas as an integral part of the facility and preserves the wooded area, then it is permissible. Design themes such as forest transition zones and ponded wooded areas are examples of permissible designs.

2.12.1.15 Median and Traffic Island Considerations

Any bioretention facilities sited within the County R-O-W must first be approved by the Department of Public Works and Transportation. These facilities shall be approved on a case-by-case basis by the Director of DPW&T. The Maryland State Highway Administration has begun to incorporate bioretention within their roadway right-of-way extensively. When bioretention facilities are located in close proximity to paved areas, curtain drains shall be utilized to prevent lateral drainage under pavement sections. Curtain drain material shall consist of approved linear materials. (see specifications table)

2.12.1.16 Utility Clearance

Utility clearances that apply to storm drainage pipe and structure placement also apply to bioretention. Standard utility clearances for storm drainage pipes have been established at 1' vertical and 5' horizontal. However, bioretention systems are shallow, non-structural IMP's consisting of mostly plant and soil components, with a flexible underdrain discharge pipe. For this reason, other utilities may traverse a bioretention facility without adverse impact. Conduits and other utility lines may cross through the facility but construction and maintenance operations must include safeguard provisions. In some instances, bioretention could be utilized where utility conflicts would make structural BMP applications impractical.

2.13 Bioretention Facility Performance Types

The following facility performance types have been slightly modified to optimize the expected or anticipated pollutant loadings based on the proposed land use. All of these facilities may be used as high-hydraulic capacity filtration systems. High hydraulic capacity filtration systems are defined as systems that are composed of essentially a shallow sandy soil mix, thick layer of mulch, an underdrain/gravel discharge system, and placed off-line.

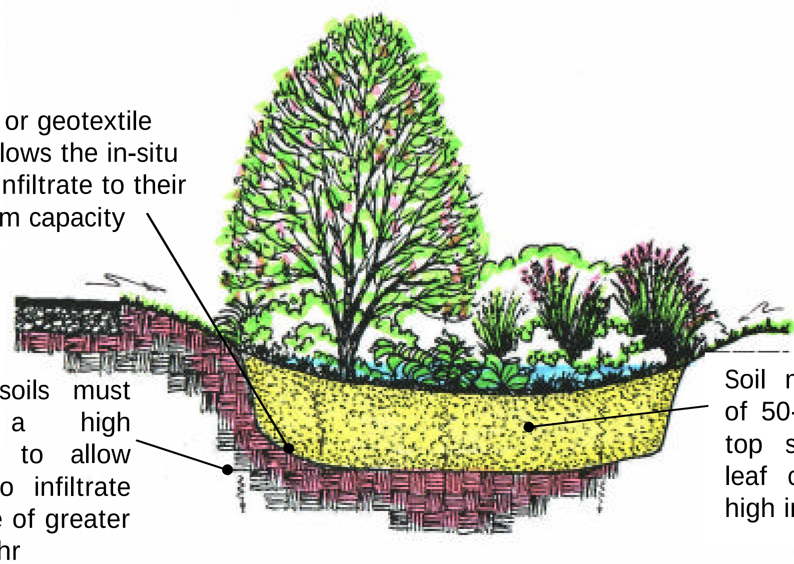


Figure 2.6: Infiltration/Recharge Facility (enhanced infiltration)

This type of facility is recommended for areas where high recharge of groundwater would be beneficial. Because there is no underdrain, the in-situ soils need to have a high infiltration rate to accommodate the inflow levels. The infiltration rate of the in-situ soils must be determined through proper soil testing/diagnostics. Preferably, facilities of this type should have infiltration rates of 1"/hr or greater. Facilities must be at least 2.5 feet deep to allow adequate filtration processes to occur. Siting of these facilities should be in areas where visibility is not a concern because hydraulic overload can cause extended periods of standing water conditions. This facility type is suitable for areas and land uses that are expected to generate nutrient runoff (i.e.; residential and business campuses) that can be infiltrated and captured by the facility. Fresh mulch rather then aged shredded bark mulch can be used to enhance denitrification processes.

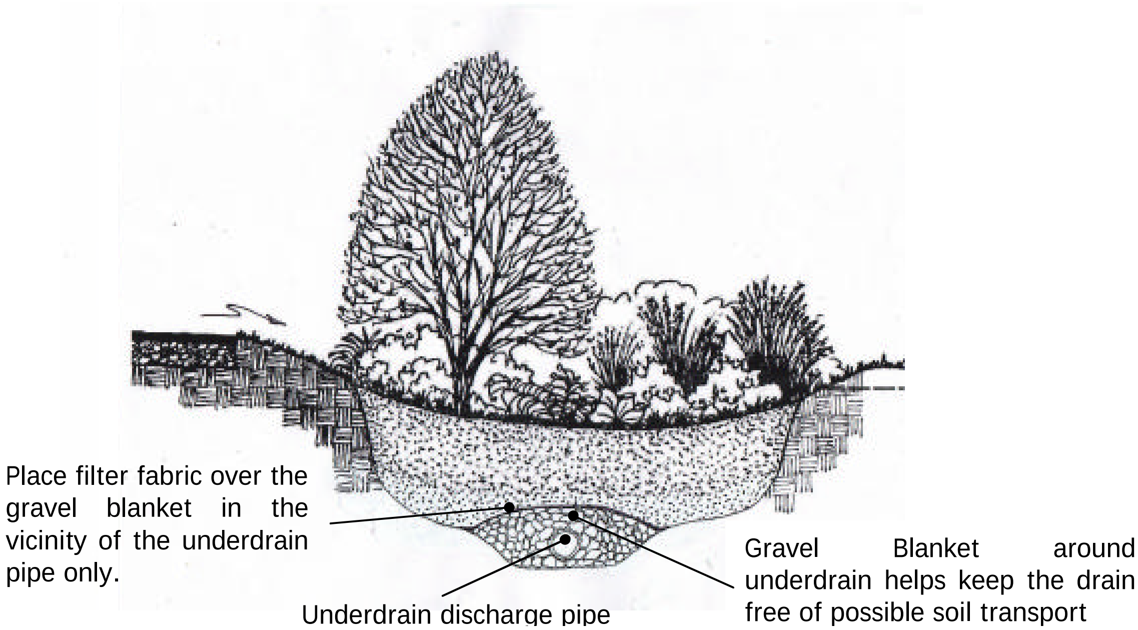


Figure 2.7: Filtration/Partial Recharge Facility

This type of facility is recommended for areas where high filtration and partial recharge of runoff would be beneficial. This facility is designed with an underdrain at the invert of the planting soil mix to ensure that the facility drains at a desired rate. The facility allows for partial recharge, as an impervious liner is not used. The depth is also shallow (2.5') to allow the facility to handle high capacity flows if necessary. Siting of this performance type is suitable for visually prominent or gateway locations in a community. The facility type is suitable for areas and land uses that are expected to generate nutrient and metals loadings (residential, business campus, or parking lots). Attention to mulch type and amount will ensure the adequate treatment of the anticipated loadings.

The facility shown above incorporates a filter material between the gravel blanket around the underdrain and the planting soil above. The filter fabric does not need to extend to the side walls. The filter fabric may be installed horizontally above the gravel blanket- extending just 1-2 feet on either side of the underdrain pipe below. Do ***not*** wrap the underdrain with filter fabric.

Instead of using a filter fabric, the designer may opt to utilize a pea gravel diaphragm over the underdrain gravel blanket.

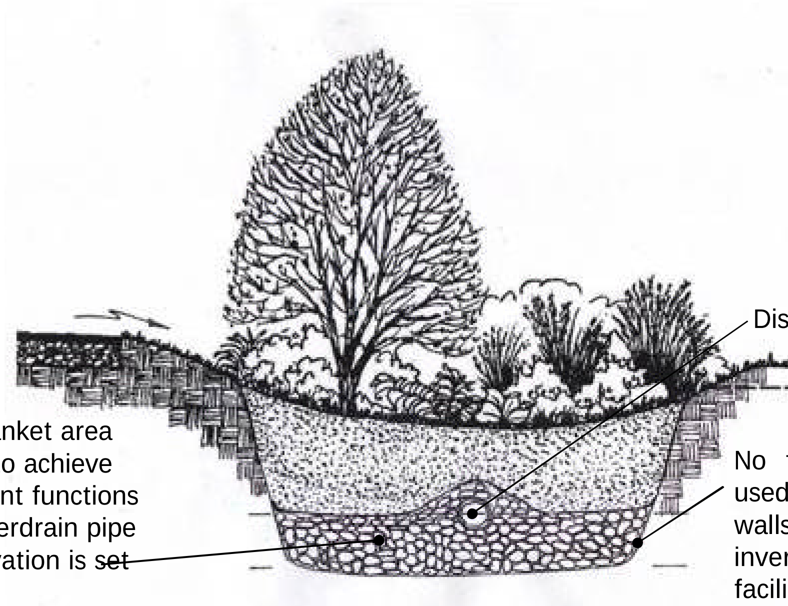


Figure 2.8: Infiltration/Filtration/Recharge

This type of facility is recommended for areas where higher nutrient loadings (particularly nitrates) are anticipated. The facility is designed to incorporate a fluctuating aerobic/anaerobic zone below the raised underdrain discharge pipe. This fluctuation created by saturation and infiltration into the surrounding soils will achieve de-nitrification. With a combination of a fresh mulch covering, nitrates will be mitigated through the enhancement of natural denitrification processes. This type of facility would be suitable for areas where nitrate loadings are typically a problem (residential communities).

The raised underdrain has the effect of providing a storage area below the invert of the underdrain discharge pipe. This area also provides a recharge zone and can be used to meet the Maryland SWM requirements. In addition, quantity control can also be augmented with this storage area. The storage area is equal the void space of the material used. If #57 stone is used, an acceptable void space ratio is 30%.

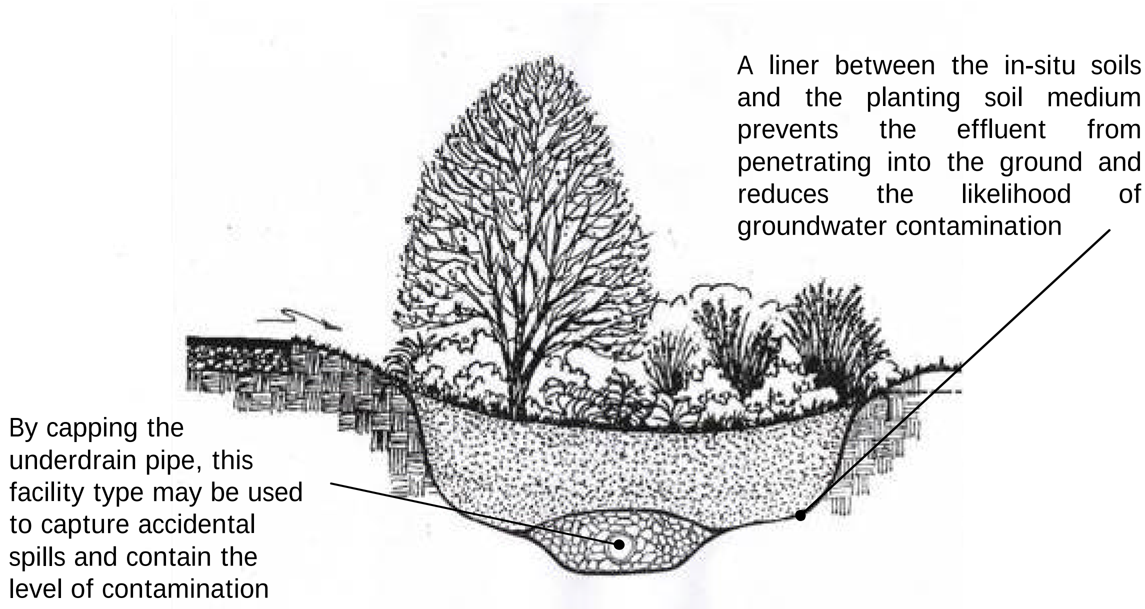
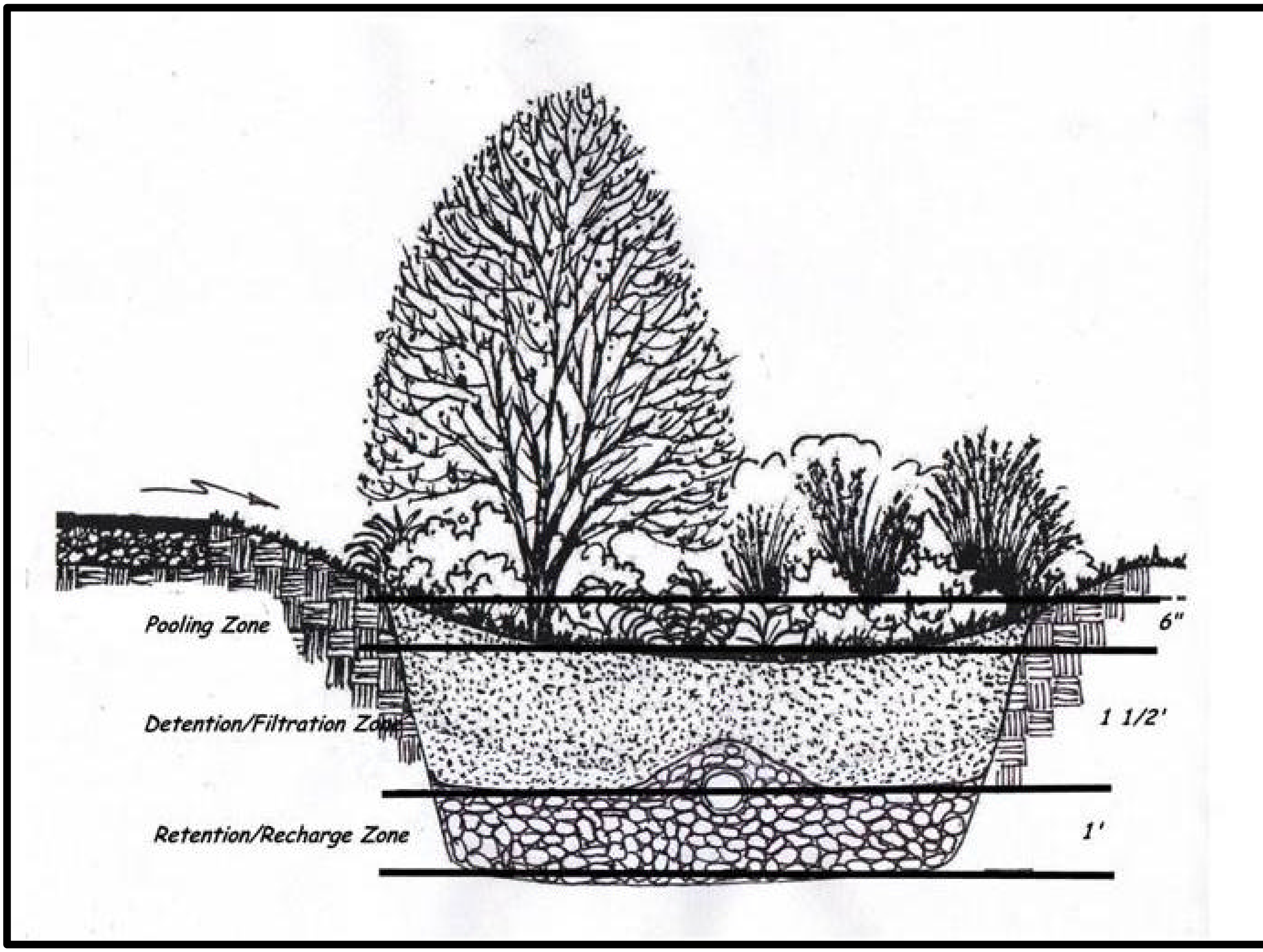


Figure 2.9: Filtration Only

This type of facility is recommended for areas that are known as "hot-spots" (gas stations, transfer sites, and transportation depots). An important feature of this type of facility is the impervious liner designed to reduce or eliminate the possibility of groundwater contamination. The facility provides a level of treatment strictly through filtration processes that occur when the runoff moves through the soil material to the underdrain discharge point. In the event of an accidental spill, the underdrain can be blocked and the objectionable materials siphoned through the observation well and safely contained.

2.14 Hydrologic Analysis For Bioretention Design

The following information provides a step-by-step methodology for determining how large to make a bioretention facility for addressing stormwater management quality and quantity control. A site design example and accompanying hydrologic calculations are provided next to each step of the process.



2.15 Component Design

After the volume of bioretention has been determined, a detailed design of the individual bioretention components can be done. The bioretention components are described in the following section:

2.15.1 Inflow Design

The inflow design is critical to the proper functioning of the facility. There are essentially three key considerations to address for inflow: 1) velocity control to prevent excessive erosion; 2) equal and uniform distribution of inflow across the surface of the facility; and 3) safe overflow or bypass path. Several different inflow entrance designs may be used as shown below:

- Concrete wheel stops along perimeter facility
- Concrete/Macadam curb with curb-cut openings)(Figure 2.9)
- Sheet flow across paving and/or grass area (Figure 2.10)

2.15.2 Discharge Design

For specific design types, see the Bioretention Performance Types section in this chapter.

2.15.3 Underdrain Specification

Where underdrains are specified, the following information provides guidance for underdrain requirements.

2.15.3.1 Underdrain Material Types

Underdrain systems may be composed of a variety of materials, with PVC pipe material being the most commonly used. PVC pipe comes in 8-12' sections. Alternative pipe material may include flexible ADS pipe. Other pipe materials may be substituted at the designer's prerogative and with concurrence of the County.

2.15.3.2 Underdrain Connections

Pipe joints and storm drain structure connections must be adequately sealed to avoid piping conditions (water seeping through pipe or structure joints). Pipe sections shall be coupled using suitable connection rings and flanges. Field connections to stormdrain structures and pipes shall be sealed with polymer grout material that is capable of adhering to surfaces. Underdrain pipe shall be capped (at structure) until completion of site. Underdrains connected directly to a storm drainage structure shall be non-perforated for a distance of at least 5' from the structure interface to avoid possible piping problems.

2.15.3.3 Underdrain Perforations

Perforated PVC pipe sections are available from local hardware stores. The perforation locations are not too critical for proper function, as long as the total opening area exceeds the expected flow capacity of the underdrain itself. Commonly marketed perforated PVC pipe has ¼ or ½" perforations, 6" center to center, along two or three longitudinal rows. Whether or not the perforations are placed at the invert of pipe or elsewhere, depend upon the design of the facility. Typically, the perforations are placed closest to the invert of the pipe to achieve maximum potential for draining the facility. The perforations can be placed near the top of the pipe if an anaerobic zone is intended. Water below the perforated portion of the underdrain will have a tendency to accumulate during periods of saturation. Otherwise, water will have a tendency to infiltrate into the surrounding insitu soils. See specifications table for specifics relating to underdrain perforations. 4.7.4 No perforations are to be within 5' of where the underdrain system connects to a stormdrain structure.

2.15.3.4 Underdrain Locations

Underdrains are typically located at the invert of the bioretention facility to intercept any filtered water that does not infiltrate into the surrounding soils. Soil and gravel cover over the underdrain shall be at least 2' in depth. Placement of 2-3" gravel bedding is recommended beneath the discharge points- Underdrains must "daylight" or connect to an existing drainage system to achieve positive flow. Suitable discharge points include:

- ✍ Grass swale areas, flush cut with sideslope areas
- ✍ Stormdrain pipe conveyance system

2.15.4 Observation/Cleanout Standpipe

An observation/cleanout standpipe shall be installed in every bioretention facility that has a depth greater than 2' and/or an underdrain system. The standpipe will serve three primary functions: 1) it will indicate how quickly the bioretention facility dewaters following a storm; 2) it provides maintenance cleanout port; and 3) it will be connected to the underdrain system to facilitate cleanout.

The observation well must consist of a rigid non-perforated PVC pipe, 4 to 6 inches in diameter. It should be located in the center of the structure and be capped flush with the ground elevation of the facility. The top of the well shall be capped with a screw, or flange type cover to discourage vandalism and tampering. Lock is not necessary.

2.15.5 Filter Materials

2.15.6 Gravels

Gravel bed materials are sometimes used to protect an underdrain pipe to reduce clogging potential. Placement of the gravel over the underdrain must be done with care. Avoid dropping the gravel high levels from a backhoe or front-end loader bucket. Spill directly over underdrain and spread manually. The construction specifications for gravel used to protect bioretention underdrains follows:

- ✍ Gravel stone size shall be no greater than ½"-1½" in diameter. (Blue stone, double washed, #57 stone)
- ✍ The use of "pea gravel" in place of geotextile fabric is optional, but preferred
- ✍ Depth of the gravel shall not exceed 12"
- ✍ River-run, washed gravel is preferred.

2.15.7 Pea Gravel Diaphragm

Older specifications for bioretention utilized a geotextile fabric to filter water and soil before passing through to the underdrain gravel blanket. The use of a pea gravel diaphragm has gained acceptance because of the reduced likelihood of blockage. If a pea gravel diaphragm is used in this manner, it should have a minimum thickness of 3-4" and a maximum thickness of 8". Where situations permit, a greater depth may be applied. A permeable filter fabric shall be placed over the underdrain gravel blanket and beneath the pea gravel diaphragm- only where the underdrain is located and extending 2' to either side.

2.15.8 Filter Fabric

Filter fabric is needed for two purposes in bioretention facilities: 1. Controlling transport of silt, and 2. Controlling the direction of flow. In some older designs, the filter fabric placed on top of the gravel bed is used to control sediment transport into the gravel bed, which otherwise may become clogged. This filter fabric must meet a minimum permittivity rate of 75 gal/min/ft^2 and shall not impede the infiltration rate of the soil medium. Filter fabric may be placed along the "walls" of the facility to help direct the water flow downward and to reduce lateral flows. Filter fabric must be placed along the sidewalls, (from the subgrade and over the stone) when installing a facility in a median strip or parking lot landscape island to prevent lateral flow under pavement.

2.15.9 Liners

Where bioretention is used for areas that require groundwater protection (stormwater hot spots or source water protection), a liner is employed. The minimum thickness for liners used in bioretention applications shall be 30 mil. Any underdrain systems shall be placed above the liner with a provision to cap the underdrain discharge pipe to confine drainage if needed. Care during placement of the liner is necessary to avoid puncture. Soil medium placed over the liner should be placed by hand shovel rather than construction equipment.

2.16 Soil Installation

2.16.1 Placement

Installation of soils must be done in a manner that will ensure adequate filtration. After scarifying the invert area of the proposed facility, place soil at 8"-12" lifts. Lifts are not to be compacted but are performed in order to reduce the possibility of excessive settlement. Lifts may be lightly watered to encourage natural compaction.

2.16.2 Soil Compaction

Avoid over compaction by allowing time for natural compaction and settlement. No additional manual compaction of soil is necessary. Rake soil material as needed to level out. Overfill above the proposed surface invert to accommodate natural settlement to proper grade. Depending upon the soil material, up to 20% natural compaction may occur. For facilities designed with a liner, no scarification of the invert area is required.

2.17 COMPACTION IN BIORETENTION AREAS

It is very important to minimize compaction of both the base of the bioretention area and the required backfill. When possible, use excavation hoes to remove original soil. If bioretention areas are excavated using a loader, the contractor should use wide track or marsh track equipment, or light equipment with turf-type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction resulting in reducing infiltration rates and storage volumes and is not acceptable. Compaction will significantly contribute to design failure.

Compaction can be alleviated at the base of the bioretention facility by using a primary tilling operation such as a Chisel Plow, Ripper, or Subsoiler. These tilling operations are to refracture the soil profile through the 12 inch compaction zone. Substitute methods must be approved by the engineer. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment.

Rototill 2 to 3 inches of sand into the base of the bioretention facility before back filling the facility and placement of underdrain. Pump any ponded water before preparing (rototilling) base.

When back filling the bioretention facility, place soil in lifts 12" or greater. Do not use heavy equipment within the bioretention basin. Heavy equipment can be used around the perimeter of the basin to supply soils and sand. Grade bioretention materials with light equipment such as a compact loader or a dozer/loader with marsh tracks.

2.18 SOIL PRESOAK

In order to speed up the *natural* compaction process, presoaking the placed soil may be performed. Significant settlement can occur after the first presoak, and additional settlement may occur subsequent to the initial wetting. If time and construction scheduling permits, it is preferable to allow natural settlement to occur with the help of rain events to presoak the soil medium.

BIORETENTION SOIL & MATERIAL REQUIREMENTS:

Soil Texture And Structure:

Topsoil for bioretention shall have a sandy loam, loamy sand, or loam texture per USDA textural triangle. Maximum clay content is <5%; soil mixture shall be 50-60% sand; 20-30% leaf compost*; and 20-30% topsoil. The soil shall be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. No other materials or substances shall be mixed or dumped within the bioretention that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations. The planting soil shall be free of Bermuda Grass, Quackgrass, Johnson Grass, Mugwort, Nutsedge, Poison Ivy, Canadian Thistle, Tearthub, or other noxious weeds.

* Leaf compost is essentially composed of aged leaf mulch and provides added organic matter to improve the health of the soil and ensure adequate soil structure.

Soil Testing:

Planting soil for bioretention areas must be tested prior to installation for PH and organic matter. The soil should meet the following criteria (Landscape Contractors Association, 1986).

PH Range: 5.5 – 6.5
Organic Matter: 1.5 – 3.0%

It is required that a sieve analysis, PH, and organic matter test be performed per each bioretention area.

Soil Placement:

Placement of the planting soil in the bioretention area should be in lifts of 12 to 18 inches and lightly compacted. Minimal compaction effort can be applied to the soil by tamping with a bucket from a dozer or backhoe. Refer also to “compaction”.

Mulch Specifications:

Individual planting shall be mulched (refer to landscaping details, DRWG. C-16). Acceptable mulch shall be shredded hardwood only. Mulch must be well aged, uniform in color, and free of foreign material including plant material. Well aged mulch is defined as mulch that has been stockpiled or stored for at least twelve (12) months.

Sand Specifications:

Provide clean sand, free of deleterious materials. Sand shall meet AASHTO M-6 or ASTM C-33 with grain size of 0.02”- 0.04”.

Geotextile Specifications:

Geotextile fabric shall meet ASTM D-751 (puncture strength - 125 LB)
ASTM D-1117 (Mullen burst strength – 400 PSI)
ASTM D-1682 (Tensile strength – 300 LB)
Fabric shall have 0.08” thick E.O.S. of #80 sieve, and maintain 125 GPM per SQ. FT. flow rate.

Gravel Filter Specifications:

Underdrain gravel blanket shall be double washed, #57 stone, 1-1/2” in size. Pea Gravel shall be washed, river-run, round diameter, ¼ - ½ “ in size.

Inspection Requirements:

- The contractor shall arrange a “preconstruction meeting” with the owner and architect/ engineer prior to beginning work on the bioretention facility.
- At the completion of excavation to inspect sub grade preparation.
- During underdrain and filter installation.
- Back fill of soil into the bioretention areas. Soil certifications for back fill are required.
- The final topsoil layers should be thoroughly wetted achieve settlement of the soil/sand backfill mix.
- Additional soil backfill should be placed as required to achieve the design top surface elevations.
- The work shall be inspected by the owner/architect prior to final stabilization and planting.
- Sediment & erosion control practices may be removed upon approval by the County inspector

4.16 Typical Sequence of Construction for Bioretention

The sequence of construction for bioretention areas is closely tied to the grading plans for the development. Because bioretention is a source control IMP, drainage area catchments are kept relatively small and therefore, manageable during the construction phase for control of sediment. Basic sediment control practices are employed for each lot. For a typical bioretention sediment control plan, see Chapter 2.

A typical sequence of construction with typical construction schedule is provided at the end of this chapter (page 4-17). The sequence of construction will vary for every project but the designer may utilize this sequence of construction as a general guide. Variations to the sequence must be noted and conveyed to the County inspector. The sequence of construction shall be place on the plans.

Sequence of Construction For Bioretention

1. Install sediment control devices as shown on the plans.
   -Construction time: __________ Day(s)

2. Grade site to elevations shown on plan. If applicable, construct curb openings, and/or remove and replace existing concrete as specified on the plan. Curb openings shall be blocked or other measures taken to prohibit drainage from entering construction area. At the end of each workday, all excavations shall be protected by construction safety fencing or temporary backfill as needed.
   -Construction time: __________ Day(s)

3. Stabilize grading within Limit of Disturbance except for Bioretention Area. Bioretention areas may be utilized as sediment traps *if* the proposed invert of the bioretention facility is 1' lower then the sediment trap.
   -Construction time: __________ Day(s)

4. Excavate bioretention area to proposed invert depth and scarify the existing soil surfaces, taking care not to compact the in-situ materials.
   -Construction time: __________ Day(s)

4a. Install underdrain system and observation wells, if specified
   -Construction time: __________ Day(s)

5. Backfill bioretention area with planting soil as shown in the plans and detailed in the specifications. Overfilling is recommended to account for settlement.
   -Construction time: __________ Day(s)

6. Presoak the planting soil prior to planting vegetation to allow for settlement. This can be done by water truck or allowing water to enter the pit from a rain event.
   -Construction time: __________ Day(s)

7. Excavate or fill to achieve proper design grade, leaving space for the upper layer of mulch and/or topsoil that will bring the surface to final grade and ready for planting.
   -Construction time: __________ Day(s)

8. Plant vegetation specified in the planting plan for Bioretention Area.
   -Construction time: __________ Day(s)

9. Mulch and install erosion protection at entrance points; remove sediment control practices or entrance blocks with inspector authorization.
   -Construction time: __________ Day(s)

Total Estimated Construction Time: __________ Day(s)

Note: The times above represent construction time only and not the full duration of the individual activities. For example, activity six (presoak) may be one month long allowing for natural settlement to occur before proceeding to activity 7.

4.17 Inspectors Checklist for Bioretention

The following checklist has been derived and modified from a checklist developed by the Community Standards Division, Site Development Inspection Section for use when evaluating a bioretention facility during different phases:

4.17.1 Bioretention Inspection Checklist

1. Pre-construction Meeting

- ✍ Approved Stormwater Management Plan
- ✍ Disseminate inspection requirements; what needs inspection
- ✍ Ticket and tag requirements & a copy of the geotechnical report (if available)

2. Excavation of Bioretention Area

- ✍ Suitable sub-grade materials
- ✍ Presence of moisture or water
- ✍ Dimensions and placement of excavation conforms with plans
- ✍ Sediment and erosion control devices in place

3. Installation Phase

- ✍ Optional sand layer placed per plan
- ✍ Backfill soil conforms with specifications and placed per details and specifications
- ✍ Correct placement of ground cover or mulch cover
- ✍ Correct placement of underdrains (size, schedule, location) where required
- ✍ Correct placement of filter fabric
- ✍ Proper placement of plant materials (type, size, quantity, tags)
- ✍ Proper grade establishment

4. Final Inspection and As-Built

- ✍ Original signed/sealed Certification Letter (for private facilities) and/or As-Built Plan (for public facilites) from a Maryland Registered Professional Engineer
- ✍ Changes in grading, facility depth, size, soil medium, plant materials, etc., shall require an As-built Plan whether private or public to reflect the changes.
- ✍ Maintenance Agreement/Covenant for bioretention facilities located on private property
- ✍ All landscaping installed/landscape warrantee documentation received
- ✍ Bioretention configuration, size and depth are in accordance with approved plans
- ✍ Landscaping certification documentation for bioretention facility(ies)
- ✍ Drainage area conforms to approved plan
- ✍ Drainage area completely stabilized

2.16 Bioretention Site Submittal Requirements

BIORETENTION PLAN REVIEW CHECKLIST

Project Name: ____ Date Received: ____________
Project Address:____
Case #:_____________________

Accepted - **Not Accepted** - **N/A**

Plan Standard Notes & Specifications

_____ _______ _____ Notes on sediment & erosion controls.
_____ _______ _____ Sequence of Construction.
_____ _______ _____ Sediment control notes for bioretention facilities during construction.
_____ _______ _____ Specifications for construction materials.
_____ _______ _____ Specifications for planting soil medium requirements.
_____ _______ _____ Compaction Notes.
_____ _______ _____ Easements.
_____ _______ _____ Copy of concept letter.
_____ _______ _____ Storm drain notes.
_____ _______ _____ Stormwater management construction specifications.

Plan Layout

_____ _______ _____ Vicinity map.
_____ _______ _____ Owner / developer information.
_____ _______ _____ Approval box.
_____ _______ _____ Plan view of site & facilities.
_____ _______ _____ Cross-section along centerline of bioretention.
_____ _______ _____ Cross-section along stormdrain or flow path.
_____ _______ _____ Existing grades and proposed grades.
_____ _______ _____ Elevation at surface, ponding elevation.
_____ _______ _____ Standard detail for bioretention.
_____ _______ _____ Landscaping plan.
_____ _______ _____ Soil map.
_____ _______ _____ Inflow and discharge points/connections.

Drainage Area to Facilities

_____ _______ _____ DAM delineated to each facility.
_____ _______ _____ Drainage area less than 2 acres max.
_____ _______ _____ Facilities located near source.
_____ _______ _____ Facilities not to be placed where concentrated water discharge exceeds 3 cfs.

Grading

_____ _______ _____ Existing and proposed contours with limits of disturbance.
_____ _______ _____ Spot elevations at entrance invert.
_____ _______ _____ Underdrain invert elevation and facility invert elevation.
_____ _______ _____ ½ inch contours for detail at facility.
_____ _______ _____ Not crossing properties and 2-foot min. from property lines.
_____ _______ _____ Not to be built in public right of ways.
_____ _______ _____ Not to be built where wooded areas would need to be cleared to make room for the facility.
_____ _______ _____ Sloped areas exceeding 20% shall not be used for bioretention except "weep-gardens" designs.
_____ _______ _____ 25 ft. setback from the home foundation.

Facility Components

_____ _______ _____ Pretreatment - Erosion protection: RipRap, Reno mattress, etc.
_____ _______ _____ Flow entrance – Curb cut, curb deflector, pipe outfall, etc.
_____ _______ _____ Ponding area – depth 6 inch max.
_____ _______ _____ Planting soil medium – 50% construction sand, 20-30% organic leaf compost, and 20-30% topsoil with a max. of 5% clay content.
_____ _______ _____ Mulch and/or groundcover
_____ _______ _____ Filtering mechanism

- Gravel & Filter Cloth
- Peagravel
- Other ________________________

_____ _______ _____ Underdrain or outlet - Approved pipe material, pipe size perforation size.
_____ _______ _____ Safe overflow allowance

Design Computations

_____ ______ ____ Facilities designed for water quality and/or water quantity control
_____ ______ ____ Method of Sizing:
MD Unified Sizing Methodolgy __________
Prince George's LID Methodolgy __________
Prince George's % DA Methodology __________
_____ ______ ____ Post Development RCN Value
_____ ______ ____ Geotechnical Report.

Landscaping Detail

_____ ______ ____ Plan view of landscaping.
_____ ______ ____ Plant list.
_____ ______ ____ Planting notes.
_____ ______ ____ Planting schedule and specifications.
_____ ______ ____ Standard detail for planting.
_____ ______ ____ Use bioretention plant list – (No exotic or invasive plants).

Permitting

_____ ______ ____ Sediment / Erosion Control.
_____ ______ ____ Stormdrain permit for construction.
_____ ______ ____ Easement or Maintenance Covenant

COMMENTS:____
____
____
____
____
____

First Review: **Reviewer**____ **Date**__________
Please complete all items checked "Not Accept" and return with corrections.

Second Review: **Reviewer**_______________________________________ **Date**__________
Please complete all items checked "Not Accept" and return with corrections.

✍ I hereby approve all items listed above being completed as per County specifications.

Reviewer'sSignature____ Date__________

BIORENTENTION INSPECTION CHECKLIST

Sign and date each phase of construction, as each one is completed. This is to confirm that each phase was completed in compliance with County approved plans and specifications. Refer to the Bioretention Guidelines located in The Bioretention Manual for any questions on bioretention installation and specifications.

---

1) Arrange a pre-construction meeting with the County Inspector. Review sequence of construction, dimensions and location of the facility, soil specifications and landscaping, and required inspections and certifications.

   ✍ ***Required Inspections**: Site engineer shall be present during the construction of the facility in order for the engineer to certify the installation and completion of the facility. The following inspections shall be approved in writing by the County inspector prior to proceeding to next activity.*

_______________________________ _______________________________

Contractor/Developer **Inspector**

Excavation of Bioretention Area

1) Inspect the subgrade for proper depth, permeability, and presence of water. Also inspect the dimensions and location of the area for conformity with the approved stormdrain plan.

_______________________________ _______________________________

Contractor/Developer **Inspector**

Installation

1) Scarify the bottom and sides of the facility before installation of any materials. Inspect correct placement of the underdrain system, which includes pipe size, perforations, pipe schedule, gravel bedding, filter cloth, and location of system.

   * ***Inspectors must obtain tickets for materials used in the installation of the underdrain.***

2) Inspect the planting soil medium for conformity with specifications and placed per details and specifications. Avoid compaction of the soil.

   * ***A soil certification for the planting soil medium will be required by the inspector.***

3) Inspect for proper placement of mulch layer. Also inspect for proper placement of landscaping, including type, size, and quantity of plants.
   * ***Inspectors must obtain tags for planting materials to verify plantings.***

4) Inspect proper pooling depth of the facility.

_______________________________ _______________________________

Contractor/Developer **Inspector**

Final Inspection

1) Inspect the bioretention configuration, size, and depth are in accordance with approved plans.

2) Inspect the landscaping to verify compliance with approved plans.

3) Drainage area must conform to approved plan. Drainage area must be permanently stabilized. Sediment controls devices shall remain in place until the contributing drainage area to the bioretention facilities is permanently stabilized.

? For final inspection of a private facility, submit a copy of the Maintenance Agreement/Covenant and an original signed/sealed certification letter from a Maryland registered professional engineer for the completed facility. If any changes to the facility (location, size, etc.), approved As-Builts are required.

- OR -

? For final inspection of a public facility, submit a certified As-Built plan, original landscaping certification, and release of liens.

_______________________________ _______________________________

Contractor/Developer **Inspector**

COMMENTS:

2.17 Bioretention Design Specifications

The following chart itemizes the design specification standards that may be utilized in the development of a bioretention facility. The specifications are to be used as a guideline only, and may be substituted with an approved equal.

Component	Specification	Dimensions/Size	Reference Notes
Underdrain Pipe	Rigid Schedule 40	6-8" Diameter	Slope @ ½%
Underdrain Perforations		1/2", 6" c to c, top & sides	Smaller perforation sizes allowed
Underdrain Gravel Bed	AASHTO M-43	1/2"-1" Diameter	Washed Stone preferred #57
Pea Gravel Diaphragm	ASTM D 448	1/4"-1/2" diameter pebbles	
Soil Medium - Sand - Top Soil - Leaf Compost	Construction Sand; PGCODER Grading Ordinance	.02" - .04" diameter	Coarse Sand, less than 5% clay
Impervious Liner		30 mil. minimum	
Geotextile Fabric	See SWM Design Manual	Non-woven	ASTMD 4491
Mulch Material	Raw Hardwood	Varies	-
Plant Material	See Plant Listing	Varies	-
Observation well/cleanout stand pipe	Rigid Shield (no perforations)	4” or 6” Diameter	Open at bottom or attached to underdrain with standard “T” connection

Bioretention Design Example Utilizing the Prince George's County Stormwater Management Sizing Criteria

The Prince George's County Bioretention design criteria is based upon the Low Impact Development hydrologic analysis presented in the "Low-Impact Development Hydrologic Analysis 2000" companion document. The following example assumes the reader is familiar with LID methodology. For a more detailed description and additional sizing examples, consult that LID document.

LID Bioretention Design Example - Background Information

Several assumptions are made about the example site being presented:

1. 100% of the proposed site condition will have disconnected impervious surfaces with uniformly distributed bioretention facilities, open section roadway, and grass swale conveyance.

2. Site predevelopment condition is almost entirely wooded. Some wooded areas will be preserved in the proposed condition. For our example, 0.54 acres of woods in good condition will be preserved.

3. All other pervious surfaces are presumed to have a CN equal to grass in good condition.

4. Dispersed drainage patterns and pre-existing flow paths will be preserved. Site topography will also be preserved as much as possible.

5. For our example, a portion (one sub-drainage area) of the entire site is being analyzed. The hydrologic analysis of this portion will be used as a representative sample for the entire site. The portion represents a typical "cross-section" of the proposed development conditions.

6. The T_c remains the same for both the pre and post condition.

Given Data for portion of entire site:

Existing Condition					
Land Cover Type	Soil (HSG)	CN	Area (Ac)	CN x Area	% of site
Woods (good condition)	"B"	55	3.36	184.8	100
Proposed Condition					
Impervious Area	"B"	98	0.6	58.8	18
Woods (good condition)	"B"	55	0.54	29.7	16
Grass	"B"	61	2.22	135.42	66
T_c = 15 minutes (both)					

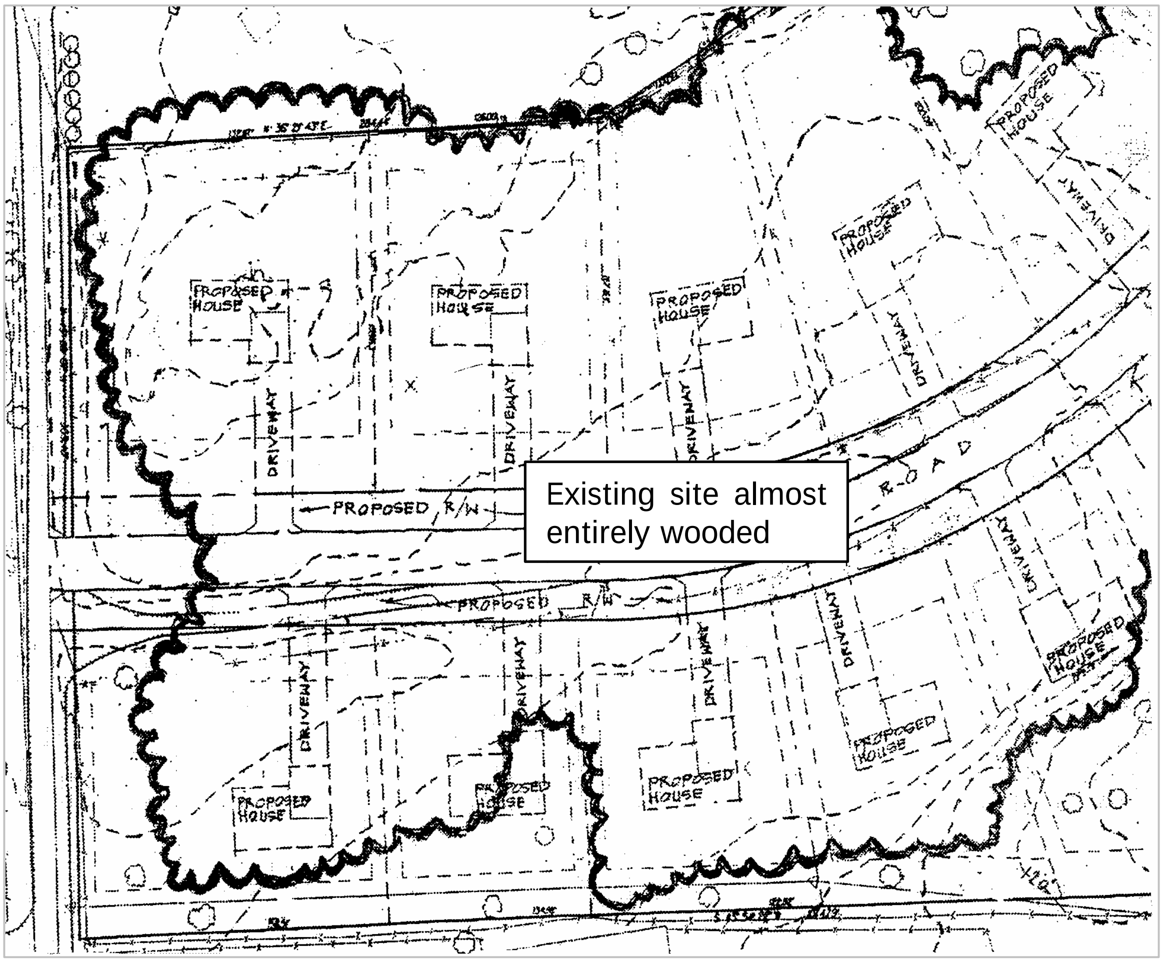


Figure 2.12: Site Plan - Existing

Site Information:

½ Acre Residential Zoning, 25 Lots, open section roadway, swale conveyance. See site plan for details of layout. We need only analyze a portion of the whole site if proposed conditions are typical throughout.

Procedure and Solution

Step 1 Determine the percentage of each land cover occurring on site:

For our example, this information is provided in the table above.

Step 2 Calculate the custom composite Curve Number for pre and post condition:

For conventional site design, the designer would refer to Figure 2.2a of the Technical Release #55 (SCS 1986). The conventional CN for our site would be 68.

Using the background information presented above, the custom predevelopment composite CN = 55 and the post development composite CN_c = 67. (See Equation 4.2 in Chapter 4 of the LID Hydrologic Analysis manual.)

Step 3 Calculate LID CN based on connectivity of the site imperviousness:

For our example, we will adjust that curve number to account for the disconnected imperviousness. Remember, one of our assumptions when using uniformly distributed bioretention facilities is that there is essentially 100% disconnected impervious surfaces. Therefore;

$CN_p = (55 \times 0.54) + (61 \times 2.22)/0.54 + 2.22) = 59.8$

$CN_c = CN_p + (P_{imp}/100) \times (98 – CN_p) \times (1 – 0.5R)$, *where* $R = 1.0$

$CN_c = 59.8 + 0.179 \times (98 – 59.8) \times 0.5$

$CN_c = 59.8 + 3.41 = 63.2$; *Use 63*

> Note: For bioretention, *R* (the ratio of disconnectivity) will always equal *1.0* because once the water is intercepted, that portion of the drainage area is disconnected. This is true for any BMP that intercepts runoff from impervious areas before the runoff enters a stream channel directly.

Step 4 Determination of Design Storm:

Determine the amount of rainfall (*P*) needed to initiate direct runoff by using the following equation –

$P_{24} = 0.2 \times [(1000/CN_{pre}) – 10]$ (use CN_{pre} for woods in good condition)

$P_{24} = 0.2 \times 8.18 = 1.64$ *inches*

Step 5 Account for variation in land cover:
Multiply P_{24} by a factor of *1.5*

1.64” x 1.5 = 2.46” ; compare the one-year storm event (2.7”) and use the higher value. Therefore, use P_{24} = 2.7”.

Step 6 Determine storage volume required to maintain Predevelopment Runoff Volume using retention storage using Chart Series A:

In Prince George’s County, the proper storm to use is the SCS Type II Rainfall Distribution for a 24 Hour Storm. Therefore; Chart Series A, Type II should be used for this example.

In our example, 2.7” falls between the 2 and 3 inch storm charts, so both charts will be used to find the solution through interpolation.

Using Chart A, Type II, 2” Storm, we get 0.09”.
Using Chart A, Type II, 3” Storm, we get 0.22”.

Through interpolation, we find the storage volume required to maintain the predevelopment runoff volume using retention storage is 0.18”.

Applying the 0.18” to our site portion as shown in figure 2.11, *(0.18” x 3.36Ac)/12 = 0.00504 ac-ft*; Use 0.051 ac-ft

Step 7 Determine Volume for Water Quality Control:

In Prince George’s County, a minimum requirement for water quality control is equivalent to the first ½ inch of runoff from impervious surfaces.

For our site, we have 18% impervious areas, therefore, the water quality requirement is: *(3.36 acres x .18) x 0.5”/ 3.36 = 0.09*. This is less than *0.18*”. Therefore, use storage for runoff volume control to meet water quality requirement.

Step 8 Determine storage volume required to maintain predevelopment peak runoff rate using 100% retention.

Use Chart Series B Type II, 2’ and 3” storm charts

From 2 inch chart = *0.08”*
From 3 inch chart = *0.25”*

Interpolating, we get *0.20* inches (approximately 0.056 ac-ft).

Since this storage *(0.056 ac-ft)* is larger than the storage needed to maintain the pre-development runoff volume *(0.051 ac-ft)*, additional detention storage is needed to maintain pre-development peak discharge.

Use chart Series C, Type II, 2” and 3” storm chart.

From 2 inch chart = 0.06”
From 3 inch chart = 0.17”
Interpolating, we get 0.14 inches. Therefore; use hybrid facility design procedure to determine the additional detention storage.

$X = (50/(0.20 – 0.14)) (-0.14 + \text{squareroot of } [(0.14)^2 + 4(0.20 – 0.14) \times 0.18]$

$= 92.2\%$

Therefore, the required retention storage (0.18”) is 92.2% of the total storage. Therefore, the total storage is

$= 0.18/0.922 = 0.195”$

Applied to our site = *0.195” x 3.36 acre/12 = 0.055 ac-ft (0.11 acres if 6”* storage is used).

In order to reduce the surface area of the bioretention areas, the storage within soil layers in the bioretention facilities is calculated. The additional volume is derived based on the following assumptions:

1. The soil medium is comprised chiefly of minimally compacted sand/leaf compost mixture and the void ratio is 30%.

2. The depth of soil medium available below the underdrain is 2 ft. This volume is used for recharge and extended detention.

= 0.11 acres x 2.0 ft x 0.30 = 0.066 ac-ft

Therefore, the total storage is

Total = 0.055 + 0.066 = 0.121 ac-ft

Step 9 Determine bioretention sizing needed to accommodate volume requirements.

Use 6” maximum surface ponding depth, and at least one facility per lot.
0.05 Ac-ft/.5ft = 0.1acres needed for bioretention.
0.1 acres = 4356 sqft / 6 lots = 726 sqft per lot

Typical bioretention configuration = *25’ x 29’* on average.

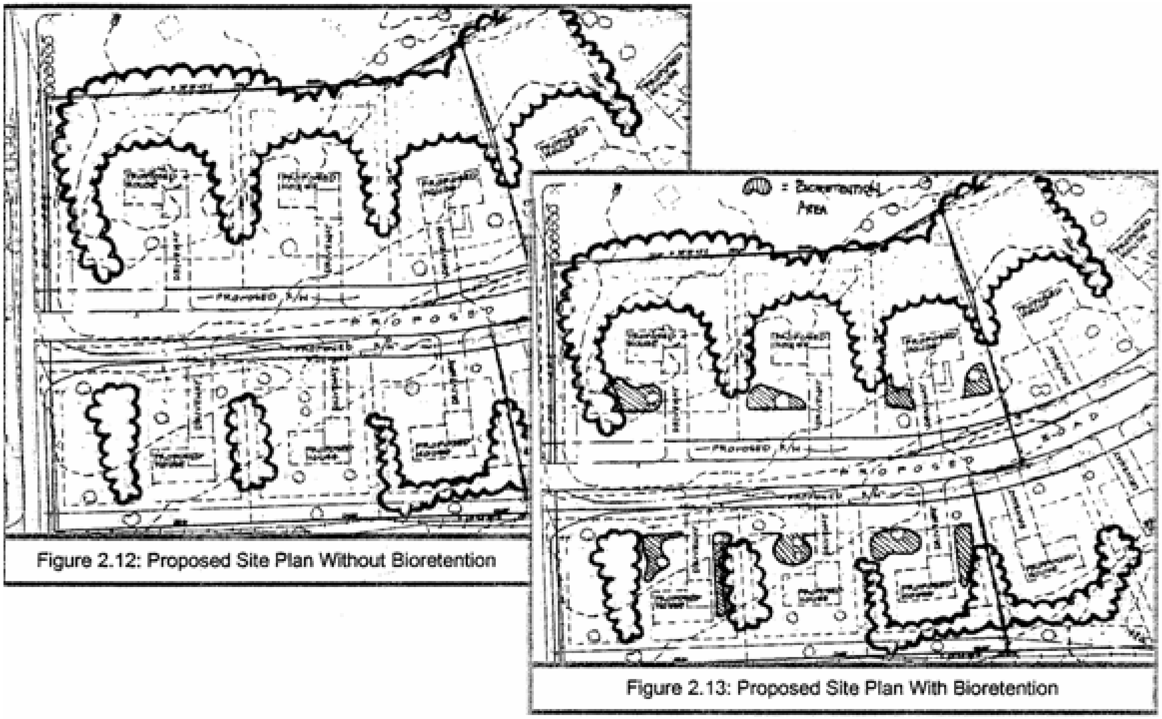


Figure 2.12: Proposed Site Plan Without Bioretention

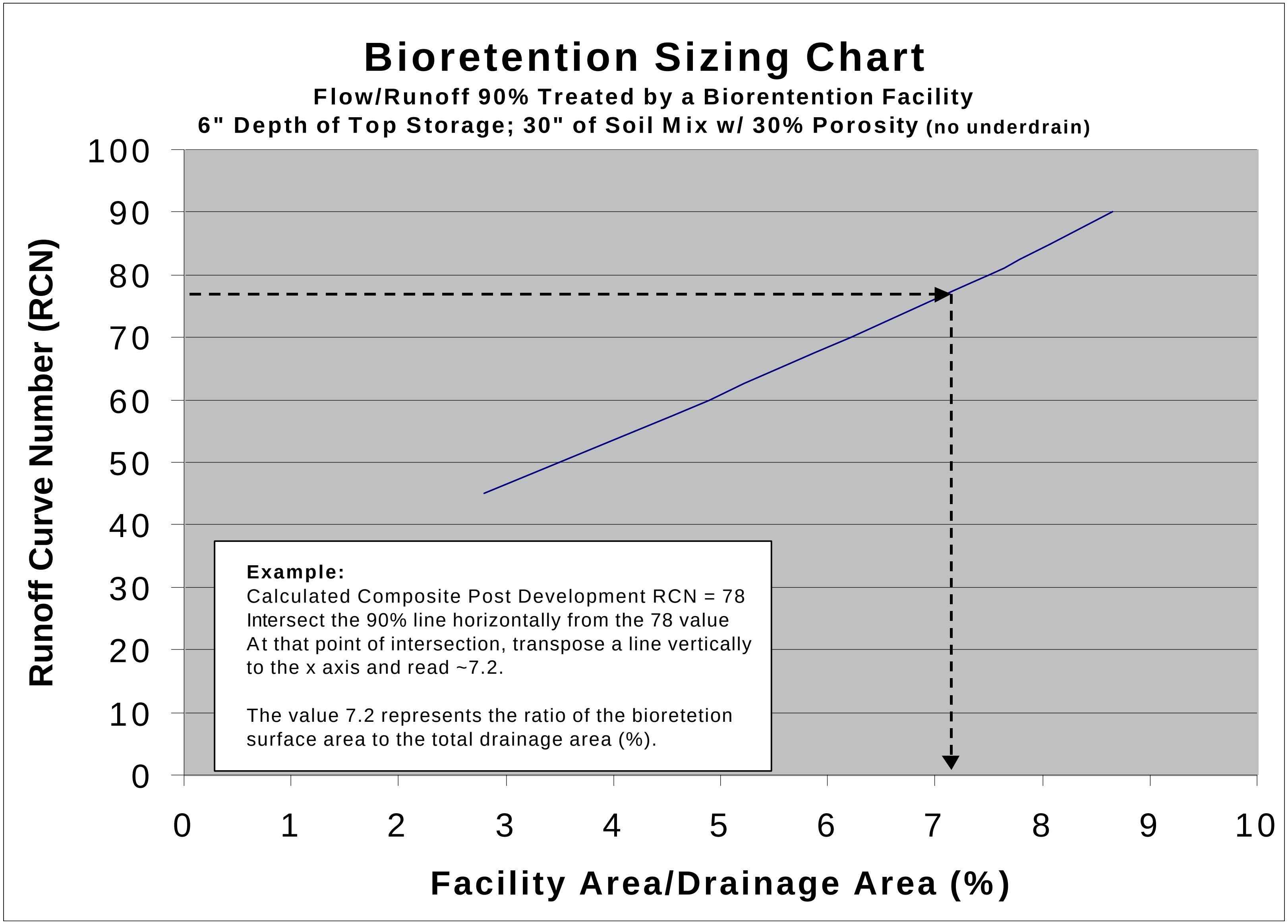
Figure 2.13: Proposed Site Plan With Bioretention

Figure 2.12 and Figure 2.13 above show the proposed site plan for the example provided. By calculating the total volume needed to meet the stormwater requirements, the total bioretention surface area is calculated based on the depth available. The facilities are uniformly distributed throughout the site and placed at locations that can maximize each of the facilities efficiency. Note that some areas go uncontrolled, while other areas will be controlled at a higher level to compensate. In addition, portions of the site where the land cover has not changed from a preexisting natural state, no control is required unless a flooding or erosion problem must be addressed.

Bioretention Sizing Chart

In order to simply the above bioretention sizing process, a chart has been developed. Known as the Bioretention Sizing Chart (see next page), the post development runoff curve number is compared the surface area of the facility as a percent of the contributing drainage area. Therefore, the designer only needs to determine the post development RCN and the drainage area to use the chart to come up with the surface area of a bioretention facility which is based upon the following assumptions: 1. The surface storage depth is 6”.

2. Soil storage capacity is equal to 2 ½‘ of depth with a 30% void ratio, and no underdrain.


Bioretention Sizing Chart
Flow/Runoff 90% Treated by a Biorentention Facility
6" Depth of Top Storage; 30" of Soil Mix w/ 30% Porosity (no underdrain)
Runoff Curve Number (RCN)
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
Facility Area/Drainage Area (%)
Example:
Calculated Composite Post Development RCN = 78
Intersect the 90% line horizontally from the 78 value
At that point of intersection, transpose a line vertically
to the x axis and read ~7.2.
The value 7.2 represents the ratio of the bioretetion
surface area to the total drainage area (%).

Bioretention Design Example

Utilizing the MDE Unified Stormwater Management Sizing Criteria

The Maryland Department of Environment is in the process of developing new stormwater management regulations that are more comprehensive and integrate stormwater management controls into the site design. This approach follows a similar approach to LID. In fact, LID is recognized by the MDE as meeting the new state criteria for stormwater management. Bioretention is just one of the components of LID. However, as this example presents, utilizing just distributed bioretention facilities throughout a site design, the designer can achieve adequate stormwater management controls that meet the State's criteria.

For this example, excerpts have been taken from the Maryland Department of Environment's 1999 Draft Stormwater Management Regulations and from the Soil Conservation Service's Technical Release #55, Second Edition, June 1986. Additionally, the example presented is specific to Prince George's County Maryland. A copy of the State Stormwater Management Regulations may be found on the internet at URL: http://www.mde.state.md.us.

As presented in the Table 2.1 below, the State stormwater criteria attempts to have stormwater management controls that are implemented to do five things:

1. Provide an element of water quality control through filtration/infiltration of stormwater runoff.

2. Provide groundwater recharge for areas that are not considered hot spots, or where the recharge will not compromise groundwater quality.

3. Channel Protection Volume Storage to help reduce stream degradation.

4. Overbank Flood Protection Volume to help control conveyance flooding problems.

5. Extreme Flood Volume for areas that do not regulate floodplain construction activities.

In Prince George's County, when a development proposal incorporates LID methodology with distributed bioretention controls, disbursed drainage, disconnected impervious areas and flow paths, several of the above criteria are not required. This is possible because bioretention practices that are distributed throughout a watershed reduce or eliminate downstream conveyance problems and channel degradation problems. Also, the extreme flood control requirement is not required in Prince George's County because the County regulates all floodplains and prohibits new construction activities within the 100 year ultimate 100 year flood plain area.

Table 2.1 Summary of the Statewide Stormwater Criteria

Sizing Criteria	Description of Stormwater Sizing Criteria
Water Quality Volume (WQ_v) (acre-feet)	$WQ_v = [(P)(R_v)(A)]/12$ P= rainfall depth in inches and is equal to 1.0" in the Eastern Rainfall Zone and 0.9" in the Western Rainfall Zone (Fig. 2.1), R_v = volumetric runoff coefficient, and A = area in acres.
Recharge Volume (Re_v) (acre-feet)	Fraction of WQ_v, depending on pre development soil hydrologic group. $Re_v = [(S)(R_v)(A)]/12$ S = soil specific recharge factor in inches.
Channel Protection Storage Volume (Cp_v)	Cp_v = 24 hour (12 hour in USE III and IV watersheds) extended detention of post-developed one-year, 24 hour storm event. Not required for direct discharges to tidal waters and the Eastern Shore of Maryland. (See Figure 2.4.)
Overbank Flood Protection Volume (Q_p)	Controlling the peak discharge rate from the ten-year storm event to the pre development rate (Q_{p10}) is optional; consult the appropriate review authority. For Eastern Shore: Provide peak discharge control for the two-year storm event (Q_{p2}). Control of the ten-year storm event is not required (Q_{p10}).
Extreme Flood Volume (Q_f)	Consult with the appropriate reviewing authority. Normally, no control is needed if development is excluded from 100-year floodplain and downstream conveyance is adequate.

MDE Bioretention Design Example - Background Information

Note: Utilize the same background information provided in the previous example that utilizes LID methodology developed by Dr. Mow-Soung Cheng.

(1) Water Quality Volume Calculations

- Utilize the MDE Water Quality Volume Equation:

$$WQ_v = [(P)(R_v)(A)]/12$$

- For P, use 1.0" (Prince George's County is in the Eastern Rainfall Zone)

- For R_v, use equation: $R_v = 0.05 + 0.009(I)$

  - Our Example has 18% impervious surfaces, therefore;
  $R_v = 0.05 + 0.009(18) = 0.21$

- For A, use site area in acres

Our example has an area of 3.36 acres

- The Water Quality Volume Equation now equals:

  WQ_v = [(1.0) (0.21) (3.36)]/12 = 0.06 Acft

(2) Recharge Volume Requirements (Re_v)

The Recharge Volume Requirement is a fractional part of the total Water Quality Volume and may be calculated by the following methodology and using the Specific Soil Recharge Factor from the chart below:

Section 2.2 Recharge Volume Requirements (Re_v)

The criteria for maintaining recharge is based on the average annual recharge rate of the hydrologic soil group(s) (HSG) present at a site as determined from USDA, NRCS Soil Surveys. More specifically, each specific recharge factor is based on the USDA average annual recharge volume per soil type divided by the annual rainfall in Maryland (42 inches per year) and multiplied by 90%. This keeps the recharge calculation consistent with the WQ_v methodology. Thus, an annual recharge volume requirement is specified for a site as follows:

Site Recharge Volume Requirement

$Re_v = [(S)(R_v)(A)]/12$ (percent volume method)

where: R_v = 0.05 + 0.009(I) where I is percent impervious cover

A = site area in acres

$Re_v = (S)(A_i)$ (percent area method)

where: A_i = the measured impervious cover

Hydrologic Soil Group	Soil Specific Recharge Factor (S)
A	0.38
B	0.26
C	0.13
D	0.07

The recharge volume is considered part of the total WQ_v that must be provided at a site and can be achieved either by a structural practice (e.g., infiltration, bioretention), a non-structural practice (e.g., buffers, disconnection of rooftops), or a combination of both.

Drainage areas having no impervious cover and no proposed disturbance during development may be excluded from the Re_v calculations. Designers are encouraged to use these areas as non-structural practices for Re_v treatment (see Chapter 5, "Stormwater Credits for Innovative Site Planning").

Note: Re_v and WQ_v are inclusive. When treated separately, the Re_v may be subtracted from the WQ_v when sizing the water quality BMP (see page 2.4, 'Subtraction for Structural Practices).

From equation and table above, $Re_v = [(S) (R_v) (A)]/12$ = site recharge requirement.

For S, (Soil Specific Recharge Factor) use HSG B. Our example has all "B" soils and the S = 0.26.

For our example, we found that R_V was equal to 0.21 and so...

Re_v = [(0.26) (0.21) (3.36)]/12 = 0.015 Ac-ft

- The recharge volume criteria does not apply to any portion of a site designated as a stormwater hotspot nor any project considered as redevelopment. In addition, the appropriate local review authority may alter or eliminate the recharge volume requirement if the site is situated on unsuitable soils (e.g., marine clays), karst or in an urban redevelopment area.

(3) Channel Protection Storage Requirements

When utilizing bioretention and integrated LID techniques to address stormwater management, channel protection storage requirements need to be calculated to meet MDE criteria. The following excepts from the State manual have been included for comparison.

Section 2.3 Channel Protection Storage Volume Requirements (Cp_v)

To protect channels from erosion, **24 hour extended detention of the one-year, 24 hour storm event** (MDE, 1987) shall be provided. In Use III and IV watersheds, only 12 hours of extended detention shall be provided. The rationale for this criterion is that runoff will be stored and released in such a gradual manner that critical erosive velocities during bankfull and near-bankfull events will seldom be exceeded in downstream channels.

The Cp_v requirement does not apply to direct discharges to tidal water or Maryland's Eastern Shore (as defined in Figure 2.4) unless specified by an appropriate review authority on a case by case basis. Local governments may wish to use alternative methods to provide equivalent stream channel protection such as the Distributed Runoff Control method or bankfull capacity/duration criteria (MacRae, 1993).

In our example, The Time of Concentration (T_c) from the site is 15 minutes or 0.25 hr. With distributed bioretention facilities, and dispersed drainage, the T_c remains the same as the pre-developed T_c. Time of concentration, T_c = 15 min. = 0.25 hr

Initial Abstraction, $I_a = 200/cn - 2$

$= 200/63 - 2 = 1.17$

$I_a/P = 1.17/2.7 = 0.43$

From Figure D-11.1, unit peak factor, $q_u = 460\ csm/in$

From Figure D-11.2, with T=24 hr, $q_o/q_i = 0.040$

$V_s/V_r = 0.683 - 1.43\,(q_o/q_i) + 1.64\,(q_o/q_i)^2 - 0.804\,(q_o/q_i)^3$

= 0.628

Where $V_r = Qa = 0.3''$ (2.7" rainfall with RCN = 63);

Therefore, $Vs = 0.3'' \times 0.628 = 0.188''$

$= 0.188 \times 3.36/12 = 0.053\ ac\text{-}ft$

Therefore, the total storage required

$$= 0.06 + 0.053 = 0.113\ ac - ft$$

Compare it with the storage needed for LID = 0.121 ac-ft

(4) Overbank Flood Protection Volume Requirements

According to the State criteria stated below, if a jurisdiction has no control of conveyance, flood plain area, or downstream flooding will occur, Overbank Protection Volume is required. In Prince George's County, the Ultimate 100 year flood plain is regulated. Additionally, where needed, conveyance system improvements may be required offsite. Therefore, Overbank Protection Volume is not required for developments utilizing bioretention for stormwater management controls.

Section 2.4 Overbank Flood Protection Volume Requirements (Q_p)

The primary purpose of the overbank flood protection volume sizing criteria is to prevent an increase in the frequency and magnitude of out-of-bank flooding generated by development (e.g., flow events that exceed the bankfull capacity of the channel and therefore must spill over into the floodplain). Overbank flood protection for the ten-year storm shall only be required if local approval authorities have no control of floodplain development, no control over infrastructure and conveyance system capacity design, or determine that downstream flooding will occur as a result of the proposed development.

For most regions of the State, the overbank flood control criteria translates to preventing the post development ten-year, 24 hour storm peak discharge rate (Q_{p10}) from exceeding the pre development peak discharge rate.

On the Eastern Shore of Maryland, the overbank flood control criteria is defined as preventing the post development two-year, 24 hour storm peak discharge rate (Q_{p2}) from exceeding the pre development peak discharge rate. The rainfall depths associated with the two and ten-year, 24 hour storm events are shown in Table 2.2.

(5) Extreme Flood Volume Requirement

Extreme Flooding Volume is not required for developments in Prince George's County except under extenuating circumstances. Extreme flood volume does not apply for developments that have been approved for LID and/or bioretention installations.

In cases where required, follow the State requirements or the County requirements, whichever are more stringent (conservative).

Total Stormwater Management Volume Requirement

In the final analysis, utilizing the State sizing methodology, the amount of Acre-feet required for stormwater storage is 0.113 ac-ft. This compares favorably with the 0.121

Ac-ft achieved by utilizing the LID sizing criteria. Therefore, for our example, the area needed for bioretention facilities is about 725 sqft per lot, (25' by 29').

Bioretention Applicability with State Criteria

Designers intending on implementing a site design employing bioretention facilities are strongly encouraged to use this Bioretention Manual in place of the MDE regulations and standards that are applicable to bioretention. Many of the specifications detailed in the MDE Manual have been based on our 1993 edition of the Bioretention Manual. Prince George's County has been modifying that criteria over the last 10 years to help ensure successful installations. Those modifications have been itemized in the beginning of this manual under the heading "Notice to Manual Users".

As stated previously, the MDE has endorsed the use of bioretention and LID techniques to meet the new State Stormwater Management Regulations. Within the State Manual, bioretention is listed as an acceptable BMP for infiltration and filtration.

The following excepts from the State Manual are provided for convenience:

BMP Group 3. Infiltration Practices

Practices that capture and temporarily store the WQ_v before allowing it to infiltrate into the soil over a two day period include:

- I-1 infiltration trench
- I-2 infiltration basin

BMP Group 4. Filtering Practices

Practices that capture and temporarily store the WQ_v and pass it through a filter bed of sand, organic matter, soil or other media are considered to be filtering practices. Filtered runoff may be collected and returned to the conveyance system. Design variants include:

- F-1 surface sand filter
- F-2 underground sand filter
- F-3 perimeter sand filter
- F-4 organic filter
- F-5 pocket sand filter
- F-6 bioretention*

* may also be used for infiltration.

Used in conjunction with Non-Structural BMP's, bioretention can easily meet the State's stormwater management criteria.

BMP Group 6. Non-Structural BMPs

Non-structural BMPs are increasingly recognized as a critical feature of stormwater BMP plans, particularly with respect to site design. In most cases, non-structural BMPs shall be combined with structural BMPs to meet all stormwater requirements. The key benefit of non-structural BMPs is that they can reduce the generation of stormwater from the site; thereby reducing the size and cost of structural BMPs. In addition, they can provide partial removal of many pollutants. The non-structural BMPs have been classified into seven broad categories. To promote greater use of non-structural BMPs, a series of credits and incentives are provided for developments that use these progressive site planning techniques in Chapter 5.

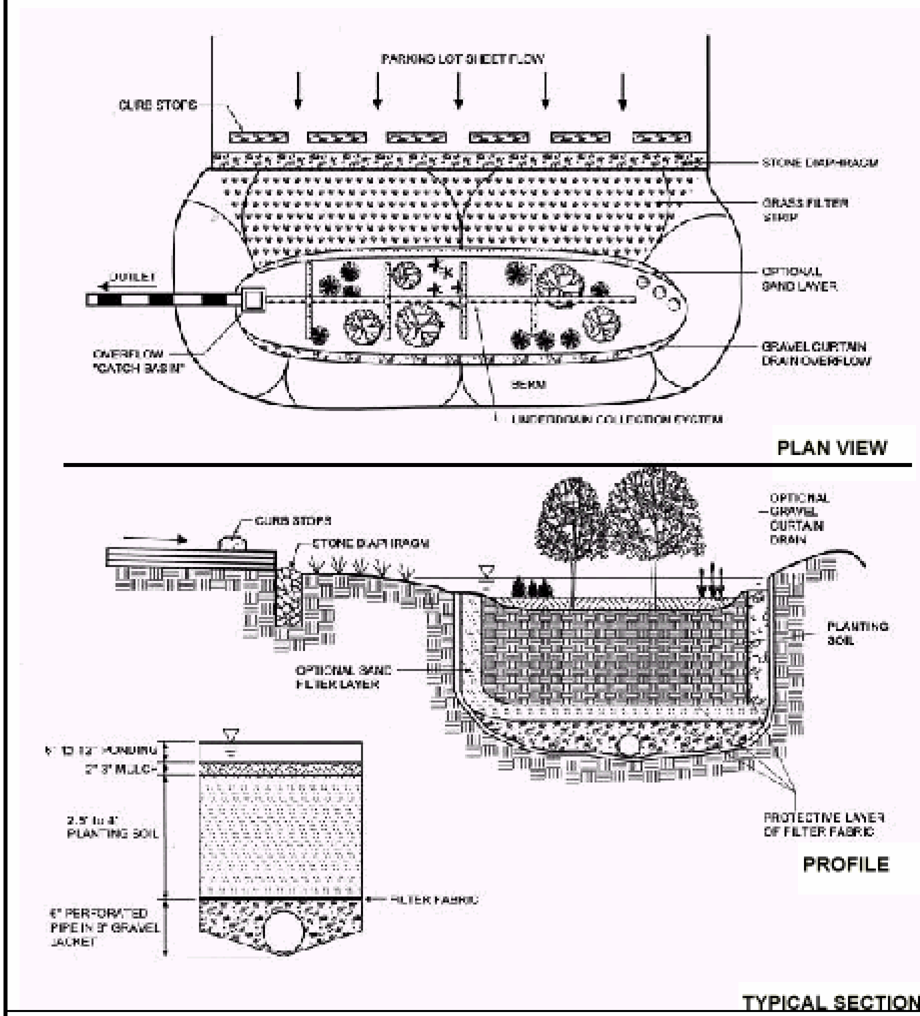
- natural area conservation
- disconnection of rooftop runoff
- disconnection of non-rooftop impervious area
- sheet flow to buffers
- open channel use
- environmentally sensitive development
- impervious cover reduction

Important Note:

The applicability of utilizing bioretention to meet the MDE stormwater management criteria in the example provided above *does not* consider the credits that could be achieved by environmentally friendly site development practices and principles. Therefore, the designer could conceivably get additional storage volume reductions by following the credit application portion of the State Manual in addition to the above.

Example of Bioretention from the State Manual

F-6	**Figure 3.17** Example of Bioretention	F-6



Bioretention combines open space with stormwater treatment.

3.4.4 Filtering Treatment Criteria

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQ_v prior to filtration.

The filter bed typically has a minimum depth of 18". *The perimeter sand filter shall have a minimum filter bed depth of 12".*

Filtering practices typically cannot provide Cp_v or Q_p under most site conditions.

The filter media shall conform to the specifications listed in Table B-3.1 (Appendix B-3).

Comparison Examples Sizing Bioretention

The following examples show the results obtained by following the same methodology detailed in the preceding pages of this chapter. Three example results are shown, comparing the MDE Unified SWM Sizing methodology to the LID Sizing methodology. The LID charts used in the examples have also been included at the end of this chapter for ease of review and analysis by the designer.

EXAMPLE No. 1	**MDE & LID SIZING COMPARISON**
1/2 ACRE RESIDENTIAL - 18% IMPERVIOUS AREA	
SITE INFORMATION:	
1/2 Acre Residential Development (18% Impervious Area)	
Site Are, A = 3.36 acres	
Hydrologic Soil Group = B	
Existing Runoff Curve Number = 55 (Woods, Good Conditions)	
Proposed Runoff Curve Number = 68 (TR-55)	
Using LID approaches w/ impervious area disconnection, RCN = 63	
Time of Concentration, Tc = 10 minutes	
LID Design Storm, P = 2.7 inches (one-year storm, Factor = 1.5)	
Storage Requirement (Maryland Design Manual)	
Water Quality Volume =	0.060 acre-ft
Groundwater Recharge Volume =	0.015 acre-ft (part of WQ volume)
Channel Protection Volume =	0.053 acre-ft
TOTAL VOLUME =	0.060 + 0.053 = 0.113 acre-ft
Storage Requirement (Low-Impact Development)	
6" Bioretention Storage =	0.051 acre-ft. (0.102 acre area)
Additional Detention Storage =	0.004 acre-ft
2' Soil Layer in Bioretention=	0.066 acre-ft
TOTAL VOLUME = 0.051+0.004+0.066	= **0.121 acre-ft**

In the above example, the 2' layer in the bioretention facility is equal to the void area (30%) below the invert of a raised underdrain.

EXAMPLE No. 2 MDE & LID SIZING COMPARISON

1/2 ACRE RESIDENTIAL - 22% IMPERVIOUS AREA

SITE INFORMATION:

1/2 Acre Residential Development (22% Impervious Area)
Site Area, A = 21.0 acres
Hydrologic Soil Group = B
Existing Runoff Curve Number = 55 (Woods, Good Conditions)
Proposed Runoff Curve Number = 69 (higher impervious area)
Time of Concentration, Tc = 0.21 hr.
LID Design Storm, P = 3.0 inches (greater than one-year storm, Factor = 1.8)

Storage Requirement (Maryland Design Manual)

Water Quality Volume = 0.434 acre-ft
Groundwater Recharge Volume = 0.109 acre-ft (part of WQ volume)
Channel Protection Volume = 0.584 acre-ft
TOTAL VOLUME = 0.434 + 0.584 = **1.018 acre-ft**

Storage Requirement (Low-Impact Development)

6" Bioretention Storage = 0.788 acre-ft. (1.576 acres area)
Additional Detention Storage = 0.000 acre-ft (not needed)
1 Soil Layer in Bioretention = 0.475 acre-ft
TOTAL VOLUME = 0.788+0.950 = **1.238 acre-ft**

EXAMPLE No. 3

COMMERCIAL AREA - 63.3% IMPERVIOUS AREA

SITE INFORMATION:

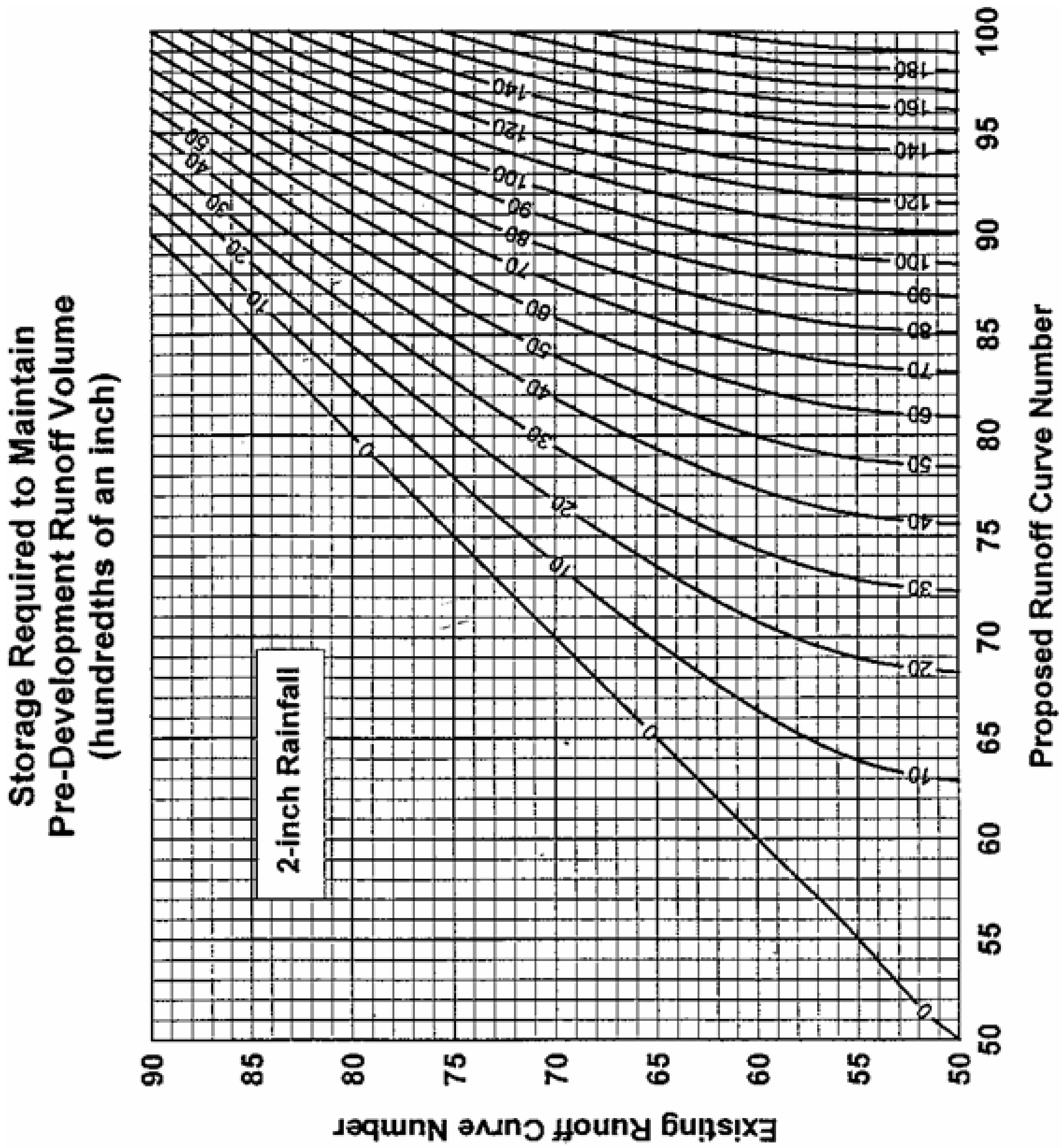
Commercial Area (63.3% Impervious Area)
Site Area, A = 3.00 acres
Hydrologic Soil Group = B
Existing Runoff Curve Number = 55 (Woods, Good Conditions)
Proposed Runoff Curve Number = 87
Time of Concentration, Tc = 0.16 hr.
LID Design Storm, P = 3.0 inches (greater than one-year storm, Factor 1.8)

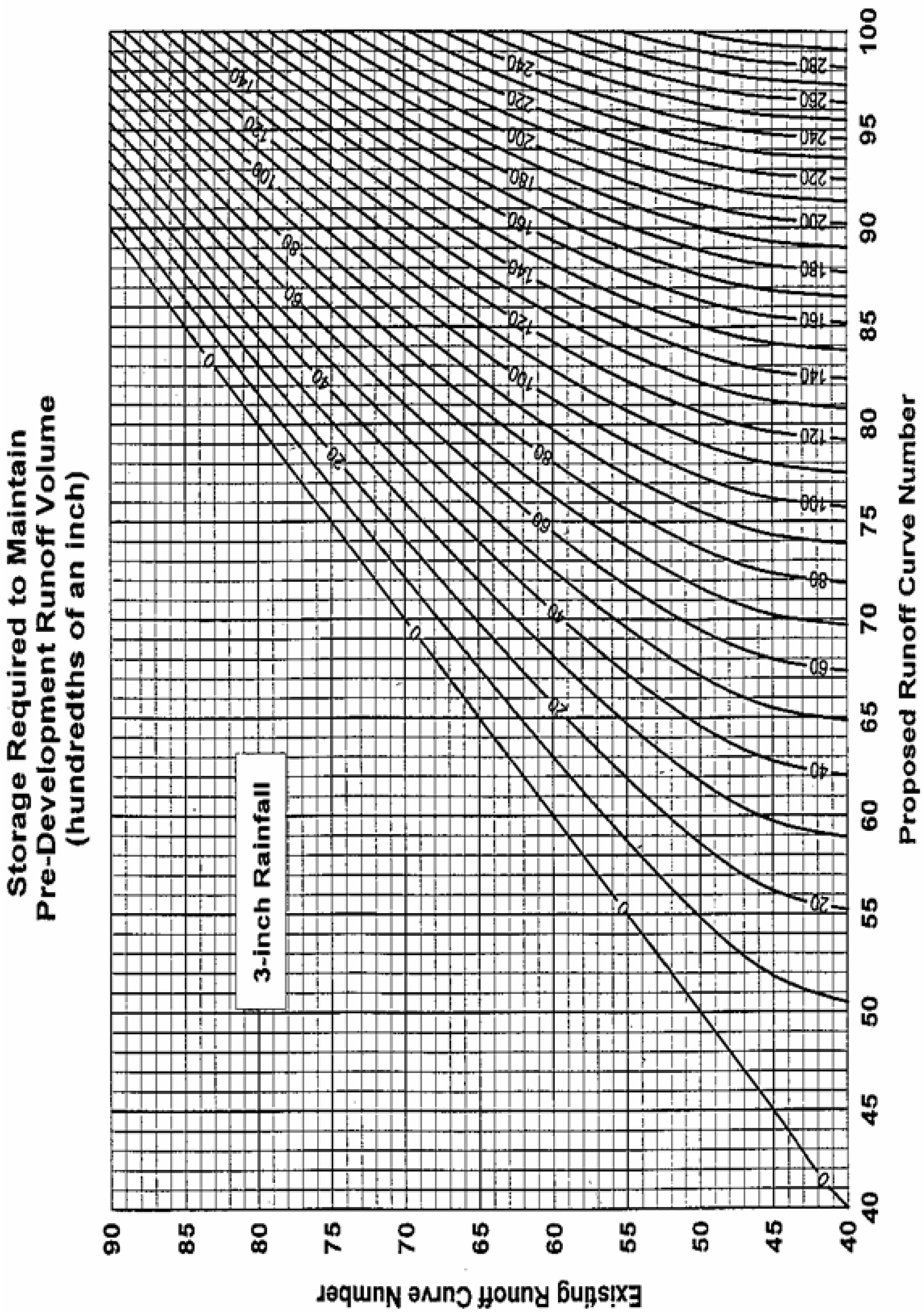
Storage Requirement (Maryland Design Manual)

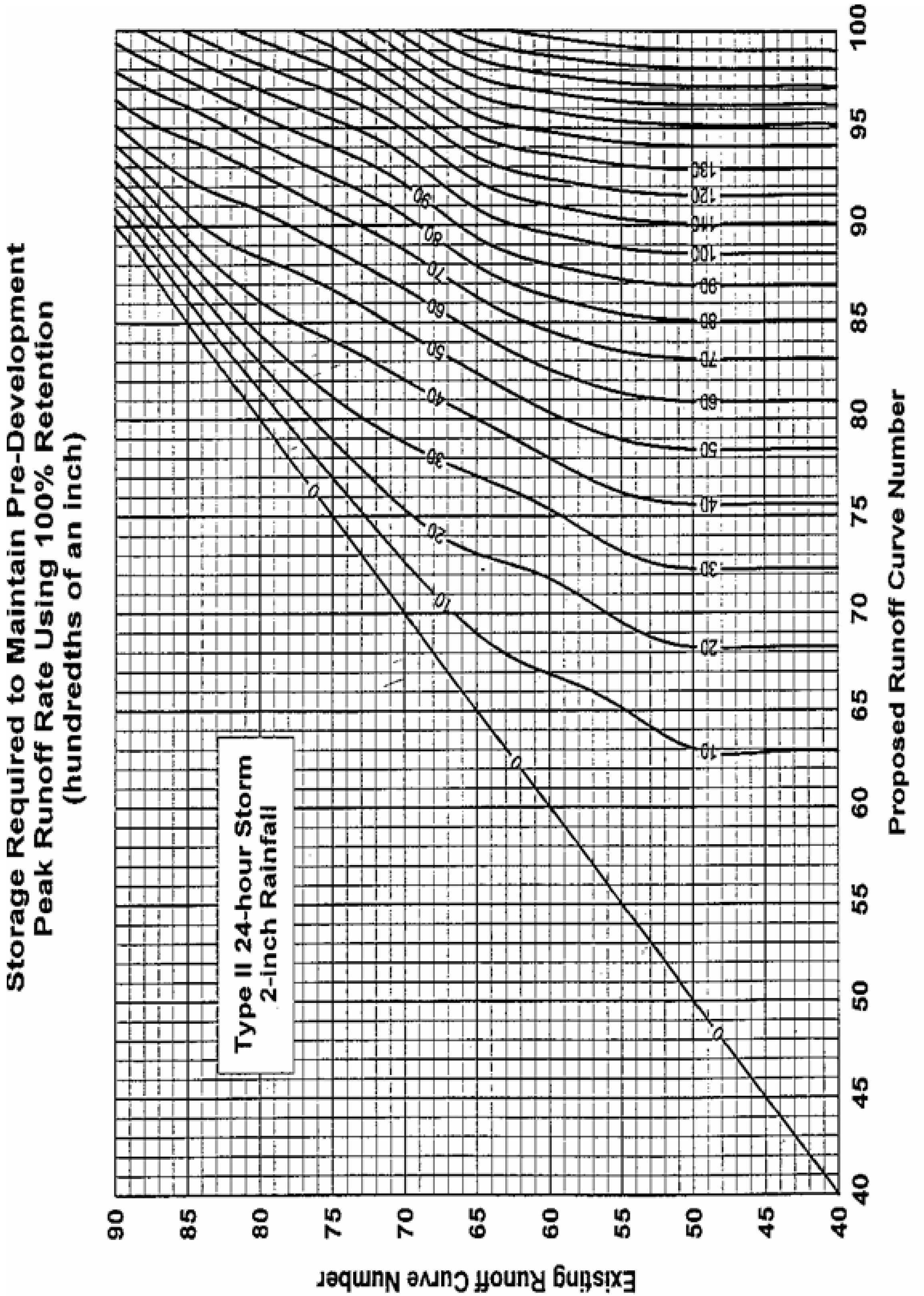
Water Quality Volume = 0.155 acre-ft
Groundwater Recharge Volume = 0.109 acre-ft (part of WQ volume)
Channel Protection Volume = 0.246 acre-ft
TOTAL VOLUME = 0.155 + 0.246 = **0.401 acre-ft**

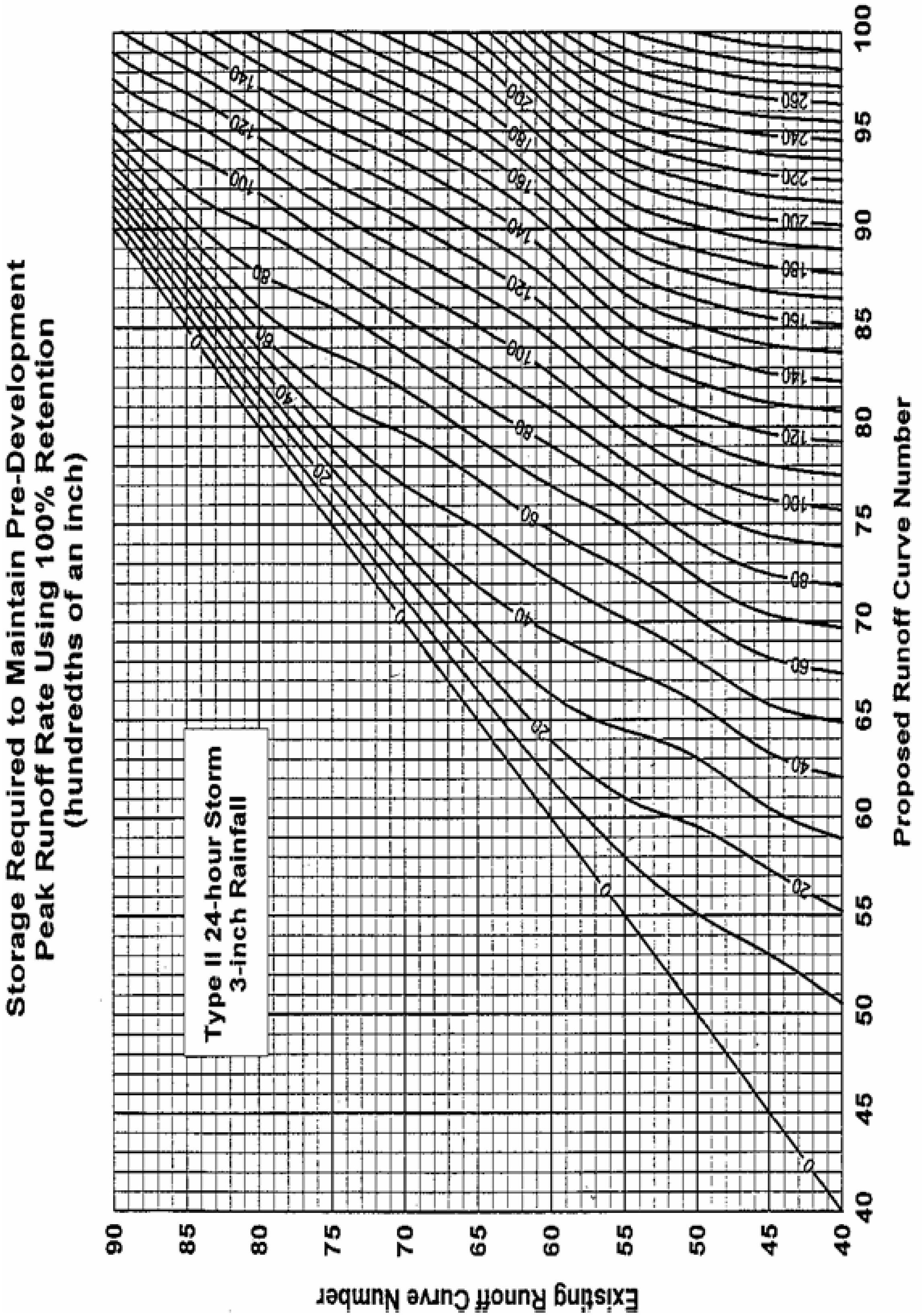
Storage Requirement (Low-Impact Development)

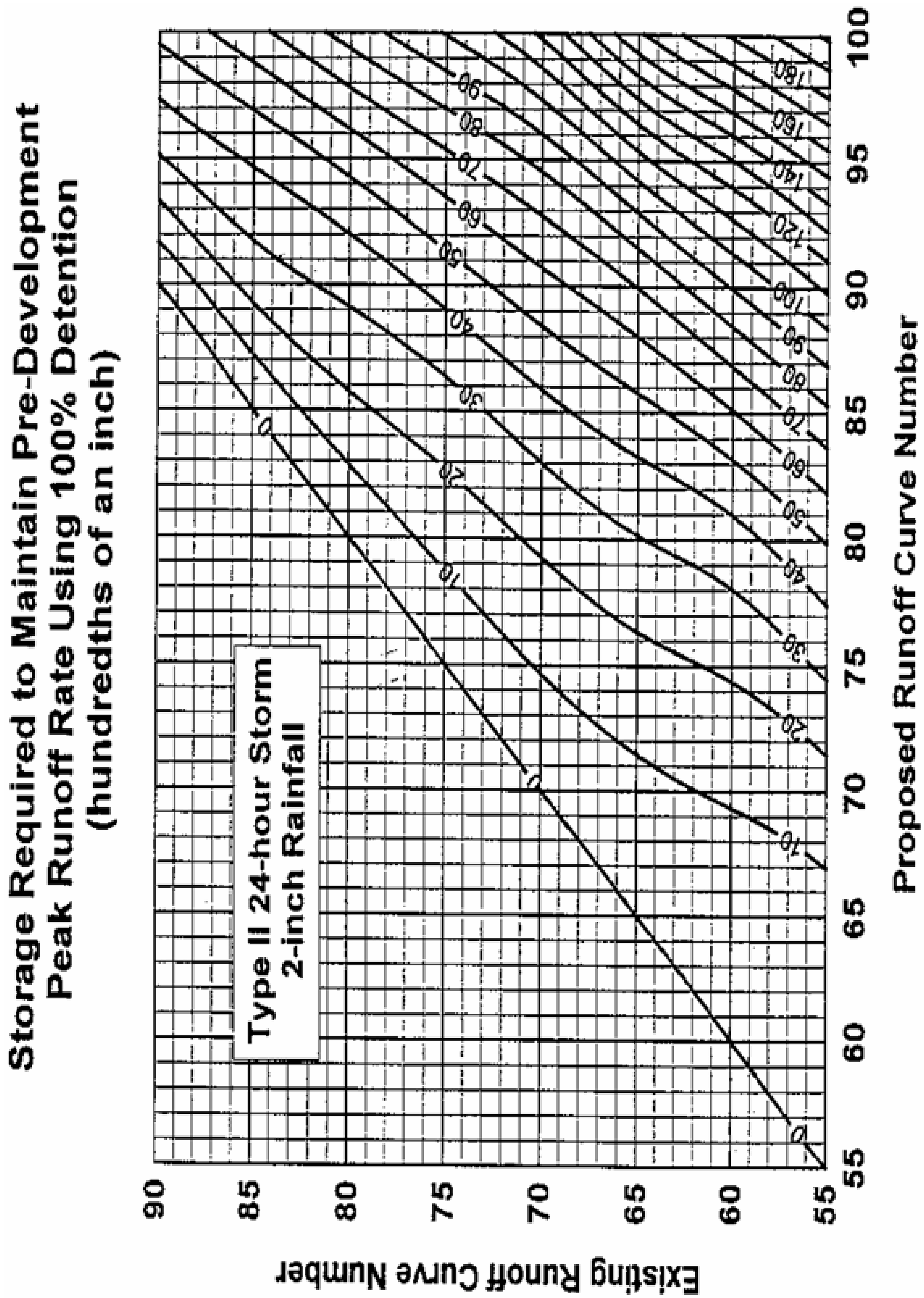
12" Bioretention Storage = 0.375 acre-ft. (0.375 acres area)
Additional Detention Storage = 0.000 acre-ft (not needed)
2' Soil Layer Layer in Bioretention = 0.225 acre-ft
TOTAL VOLUME = 0.375+0.000+0.225 = **0.600 acre-ft**

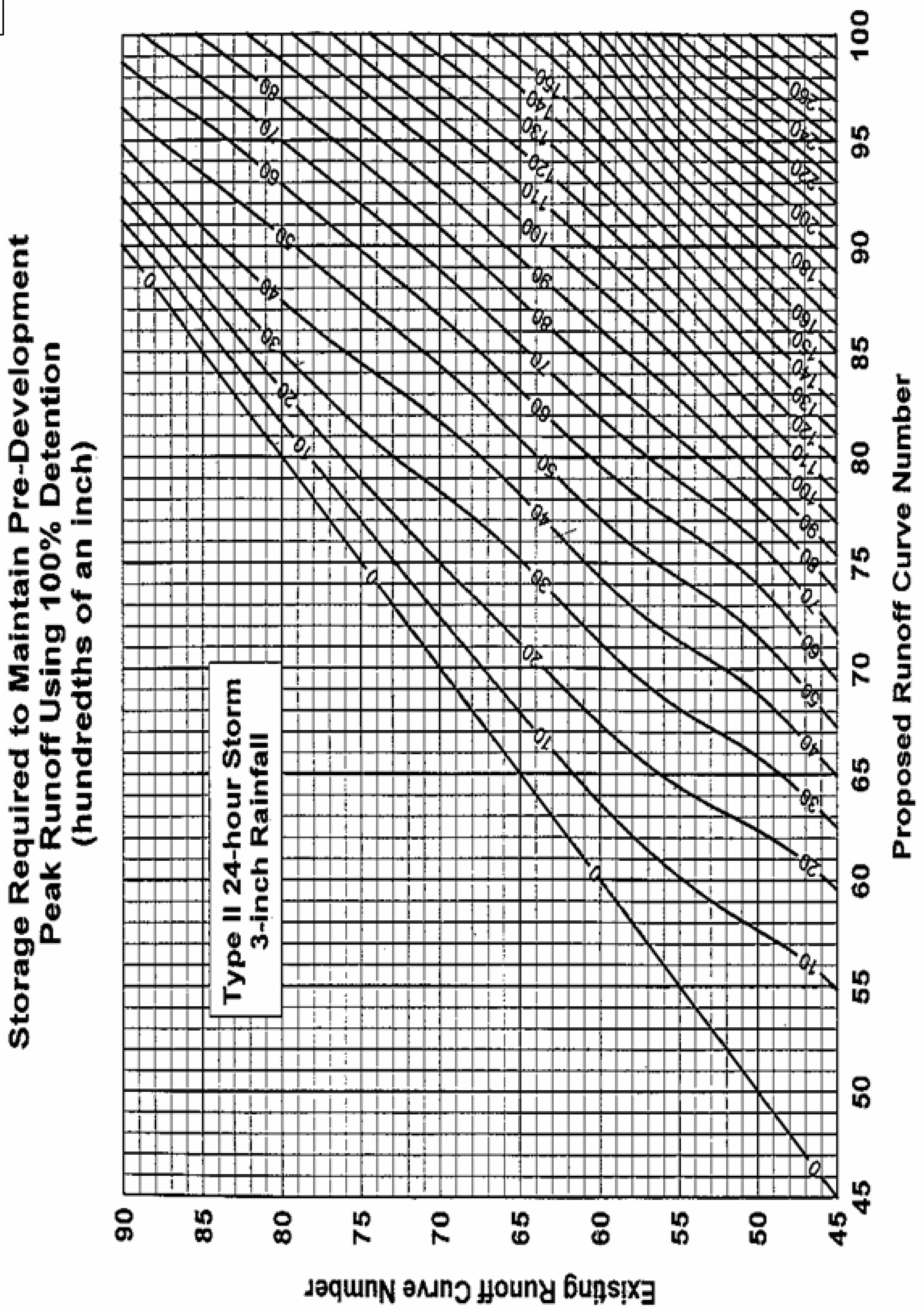

Storage Required to Maintain
Pre-Development Runoff Volume
(hundreths of an inch)
2-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number


Storage Required to Maintain
Pre-Development Runoff Volume
(hundreds of an inch)
3-inch Rainfall
Proposed Runoff Curve Number
Existing Runoff Curve Number


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Type II 24-hour Storm
2-inch Rainfall
Proposed Runoff Curve Number
Existing Runoff Curve Number


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Type II 24-hour Storm
3-inch Rainfall
Proposed Runoff Curve Number
Existing Runoff Curve Number


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
2-inch Rainfall
Proposed Runoff Curve Number
Existing Runoff Curve Number
55
60
65
70
75
80
85
90
95
100


Storage Required to Maintain Pre-Development
Peak Runoff Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
3-inch Rainfall
Proposed Runoff Curve Number
Existing Runoff Curve Number