VIRGINIA DCR STORMWATER DESIGN SPECIFICATION No. 11

WET SWALE

VERSION 2.0
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SECTION 1: DESCRIPTION

Wet swales can provide runoff filtering and treatment within a conveyance system and are a cross between a wetland and a swale. Linear on-line or off-line wetland cells are formed within the channel to intercept shallow groundwater or retain runoff to create saturated soil or shallow standing water conditions (typically less than 6 inches deep) in order to maintain a wetland plant community. The saturated soil and wetland vegetation provide an ideal environment for gravitational settling, biological uptake, and microbial activity.

Designers should note that a wet swale does not provide a runoff volume reduction credit and is therefore typically the final element in the roof-to-stream pollutant removal sequence, and **should therefore be considered *only* if there is remaining pollutant removal required after all other upland runoff reduction options have been considered and properly credited.**

SECTION 2: PERFORMANCE

While Wet Swales do not provide runoff volume reduction, they do provide moderate pollutant removal depending on their design (see **Table 11.1**). Wet Swales are particularly well suited for the flat terrain and high water table of the coastal plain.

Table 11.1. Summary of Stormwater Functions Provided by Wet Swales

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	0%	0%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	20%	40%
Total Phosphorus (TP) Mass Load Removal	20%	40%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	25%	35%
Total Nitrogen (TN) Mass Load Removal	25%	35%
Channel Protection	Limited – reduced Time of Concentration; and partial detention volume can be provided above the Treatment Volume (*Tv*), within the allowable maximum ponding depth.	
Flood Mitigation	Limited	
[1] Change in event mean concentration (EMC) through the practice.		

Sources: CWP and CSN (2008), CWP, 2007

Leadership in Energy and Environmental Design (LEED®). The LEED® point credit system designed by the U.S. Green Building Council (USGBC) and implemented by the Green Building Certification Institute (GBCI) awards points related to site design and stormwater management. Several categories of points are potentially available for new development and redevelopment projects. **Chapter 6** of the 2013 *Virginia Stormwater Management Handbook* (2nd Edition) provides a more thorough discussion of the site planning process and design considerations as related to Environmental Site Design and potential LEED credits. However, VDCR is not affiliated with the USGBC or GBCI and any information on applicable points provided here is based only on basic compatibility. **Designers should research and verify scoring criteria and applicability of points as related to the specific project being considered through USGBC LEED resources.**

Table 11.2. Potential LEED® Credits for Wet Swales[1]

Credit Category	Credit No.	Credit Description
Sustainable Sites	SS5.1	Site Development: Protect or Restore Habitat
Sustainable Sites	SS5.2	Site Development: Maximize Open Space[2]
Sustainable Sites	SS6.2	Stormwater Design: Quality Control[3]

[1] Actual site design and/or BMP configuration may not qualify for the credits listed. Alternatively, the project may actually qualify for credits not listed here. Designers should consult with a qualified individual (LEED AP) to verify credit applicability.
[2] Applicable to designs with natural form and with side slopes averaging 4:1 or flatter and vegetated.
[3] Must demonstrate that the system is designed for achieving 80% removal of TSS (Level 2).

SECTION 3: DESIGN TABLE

The major design goal for Wet Swales is to maximize nutrient removal. The two levels of design that enable wet swales to maximize nutrient reduction are shown in **Table 11.3** below.

Table 11.3. Wet Swale Design Criteria

Level 1 Design (RR:0; TP:20; TN:25)	Level 2 Design (RR:0; TP:40; TN:35)
Tv = [(1 inch)(R_v)(A)] / 12 – the volume reduced by an upstream RR BMP	Tv = [(1.25 inch)(R_v)(A)] / 12 – the volume reduced by an upstream RR BMP
Swale slopes less than 2% [1]	Swale slopes less than 1% [1]
On-line design	Off-line swale cells
Minimal planting; volunteer vegetation	Wetland planting within swale cells
Turf cover in buffer	Trees, shrubs, and/or ground cover within swale cells and buffer
[1] Wet Swales are generally recommended only for flat coastal plain conditions with a high water table. A linear wetland is always preferred to a wet swale. However, check dams or other design features that lower the effective longitudinal grade of the swale can be applied on steeper sites, to comply with these criteria.	

SECTION 4: TYPICAL DETAILS

Figure 11.1 provides a typical plan for an on-line Wet Swale with an off-line wetland cell providing additional storage. **Figure 11.2** shows a typical plan for a Wet Swale with check dams. **Figure 11.3** provides a typical profile and section.

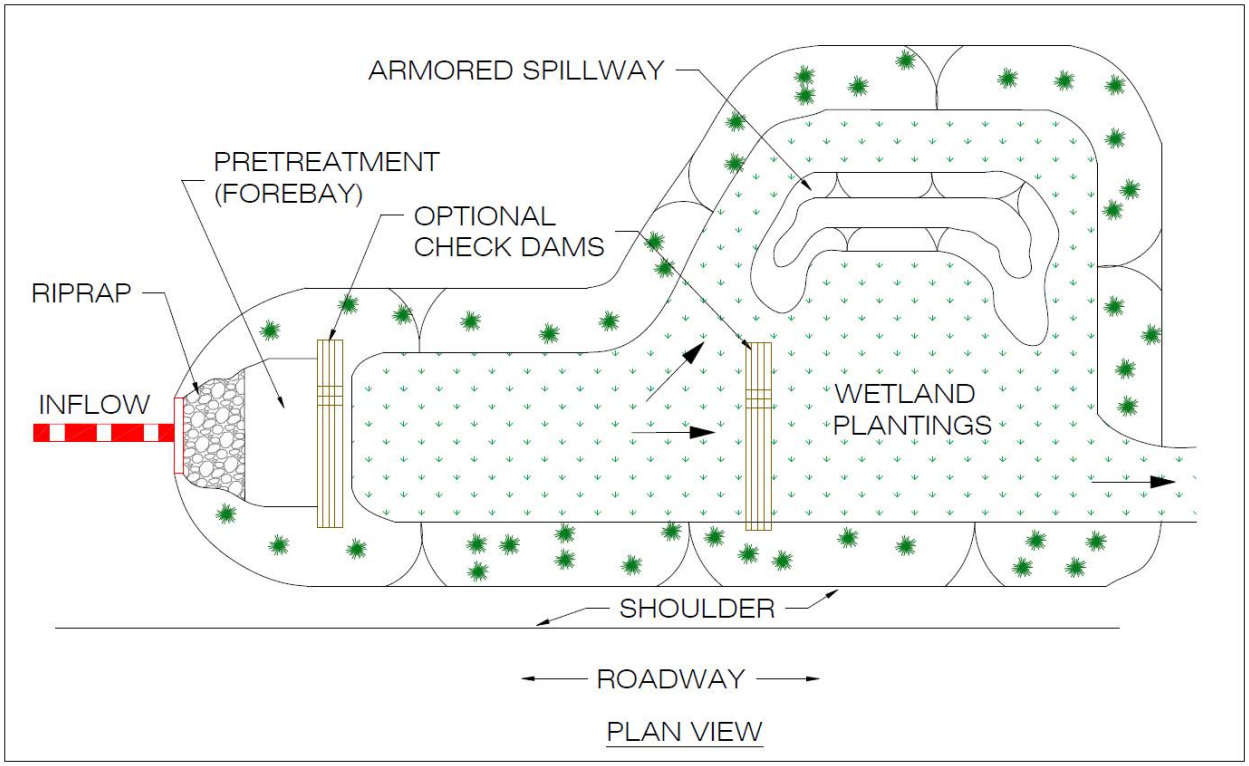

Figure 11.1. Wet Swale with Additional Storage on the Side

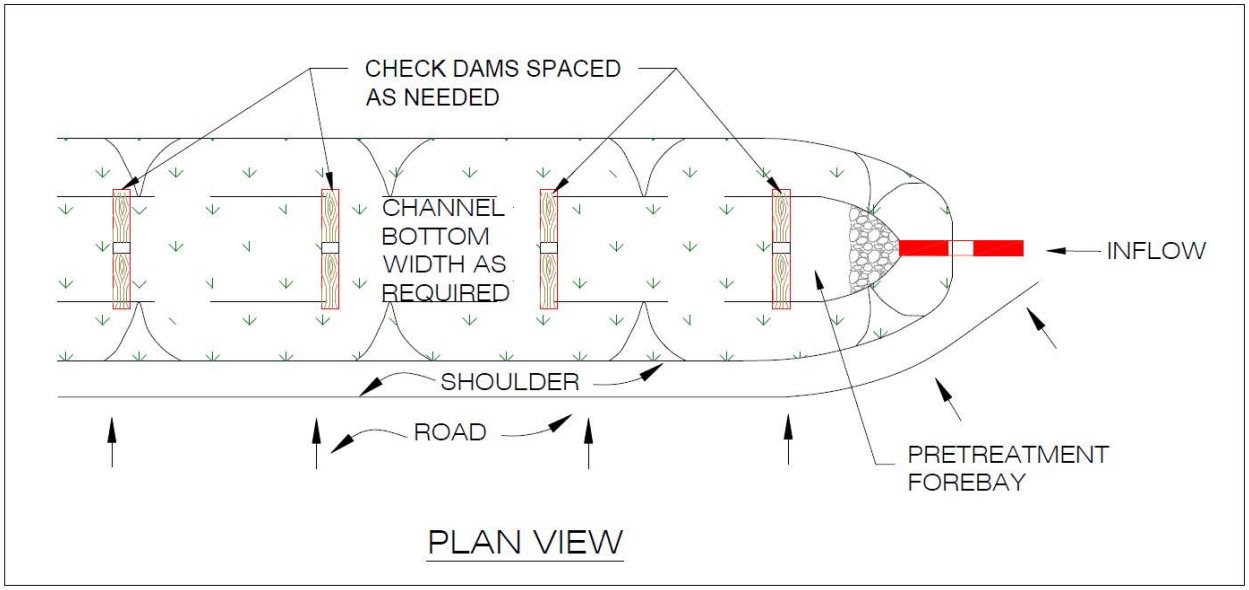

Figure 11.2. Wet Swale with Check Dams

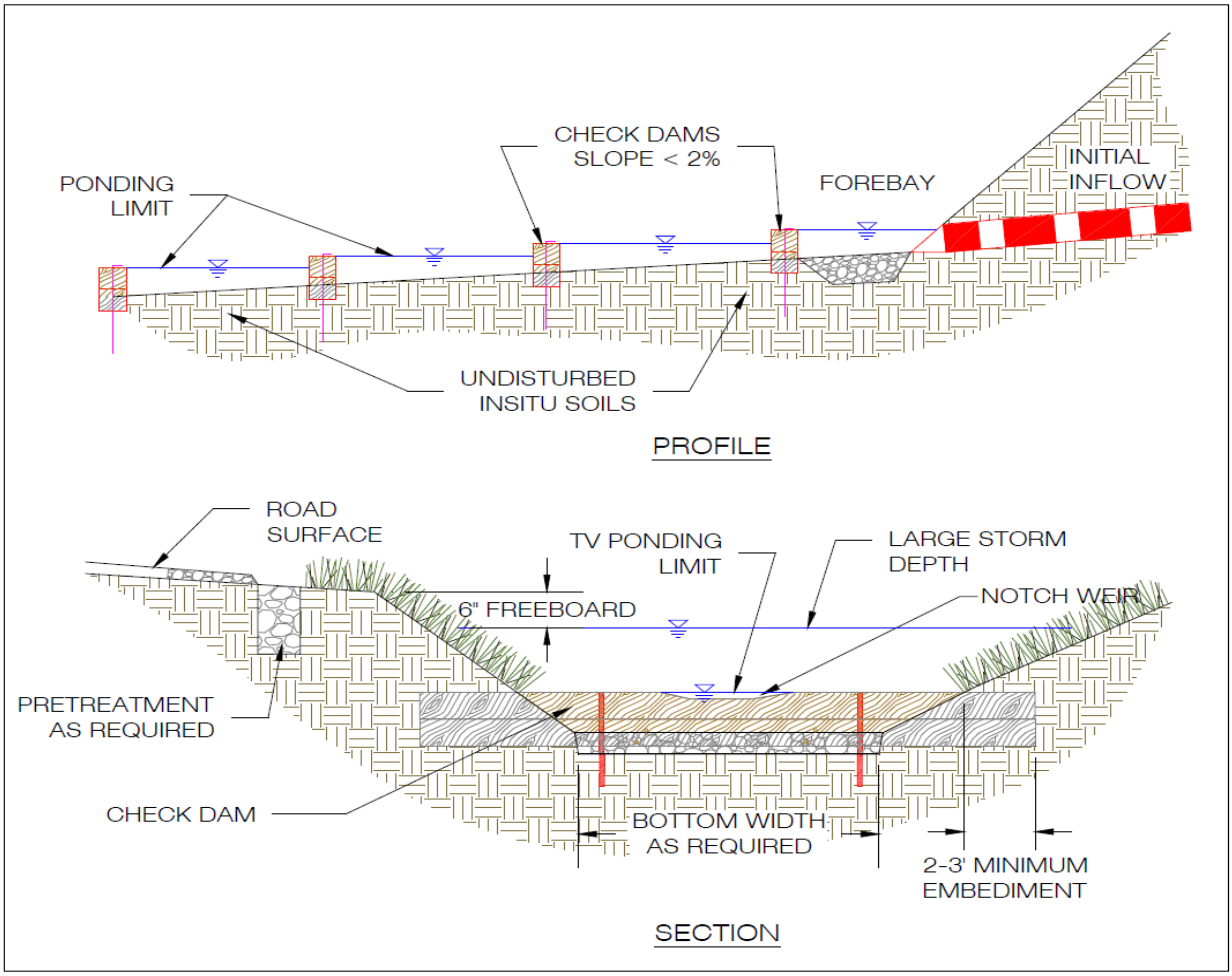

Figure 11.3. Typical Wet Profile and Section

SECTION 5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

The following feasibility criteria should be evaluated when designing a wet swale:

Contributing Drainage Area. The maximum contributing drainage area (CDA) to a Wet Swale should not exceed 5 acres, and preferably be less to avoid excessive flow rates.

Space Required. Wet swale footprints typically cover approximately 5% of their contributing drainage area depending on the contributing drainage area's impervious cover.

Site Topography. Site topography constrains wet swales; while some gradient is needed to provide positive drainage through the system, wet swales generally work best on sites with relatively flat slopes (i.e., less than 2% gradient).

A modification of the wet swale is the Regenerative Conveyance System (RCS). The RCS can be used to bring stormwater down steeper grades through a series of step pools. Refer to **Section 7**: Regional and Special Case Design Adaptations.

Depth to Water Table. It *is* permissible for wet swales to intersect the water table.

Soils. Wet Swales work best on the more impermeable Hydrologic Soil Group (HSG) C or D soils.

Hydraulic Capacity. When a Wet Swale is used as an on-line practice (Level 1 design), it must be designed with enough capacity to convey peak runoff from the 1, 2, and 10-year design storms . This means that the surface dimensions are largely determined by the need to pass these larger storm events.

When a wet swale is used as an off-line practice (Level 2 design), a bypass or diversion structure must be designed to divert the large storm (e.g., when the flow rate and/or volume exceeds the Treatment Volume (*Tv)* to an adequate channel or conveyance system. The Wet Swale is then designed to provide the required volume and meet the velocity and residence time criteria for the *Tv*.

Hotspot Land Uses. Wet Swales are not recommended to treat stormwater hotspots, due to the potential interaction with the water table and the risk that hydrocarbons, trace metals, and other toxic pollutants could migrate into the groundwater. For a list of designated stormwater hotspots, consult Stormwater Design Specification No. 8 (Infiltration).

Highway Runoff. The linear nature of Wet Swales makes them well suited to treat highway or low- and medium-density residential road runoff, if there is adequate right-of-way width and distance between driveways.

SECTION 6: DESIGN CRITERIA

6.1. Sizing of Wet Swales

Wet swales should be designed to capture and treat the *Tv* remaining from the upstream runoff reduction practices. Runoff treatment credit can be taken for any temporary or permanent storage created within each wet swale cell. This includes the permanent wet storage below the normal pool level and up to 12 inches of temporary storage created by check dams or other design features. Designers must also demonstrate that *on-line* wet swales also have sufficient capacity above the *Tv* to safely convey the larger design storm events. Refer to the hydraulic design methods outlined in Stormwater Design Specification No. 3 (Grass Channels).

6.2. Swale Pretreatment and Geometry

The wet swale should follow the general design guidance contained in Sections 6.1 and 6.2 of Stormwater Design Specification No. 3 (Grass Channels).

6.3. Other Design Issues for Wet Swales

- The average normal pool depth (dry weather) throughout the swale should be 6 inches or less.
- The maximum temporary ponding depth in any single wet swale cell should not exceed 12 inches at the most downstream point (e.g., at a check dam or driveway culvert). Nominal additional flow depth is acceptable during storm events to pass the larger storms.
- Check dams should be spaced as needed to maintain the effective longitudinal slope identified for the Level 1 or Level 2 design, as appropriate. A typical plan and profile for the check dams is provided in **Figure 11.2** above. Refer to Section 6.4 of Stormwater Design Specification No. 3 (Grass Channels) for additional information on check dams.
- Individual wet swale segments formed by check dams or driveways should generally be at least 25 to 40 feet in length.
- Wet swale side slopes should be no steeper than 4H:1V to enable wetland plant growth. Flatter slopes are encouraged where adequate space is available, to enhance pre-treatment of sheet flows entering the channel.

6.4. Planting Wet Swales

Designers should choose grass and wetland plant species that can withstand both wet and dry periods as well as relatively high velocity flows within the channel. For a list of wetland plant species suitable for use in Wet Swales, refer to the wetland panting guidance and plant lists provided in Stormwater Design Specification No. 13 (Constructed Wetlands). If roadway salt will be applied to the contributing drainage area, swales should be planted with salt-tolerant non-woody plant species.

6.5. Material Specifications

Consult **Section 6.7** of Stormwater Design Specification No. 3 (Grass Channels) for criteria pertaining to suitable materials for check dams and other swale features.

SECTION 7: REGIONAL & SPECIAL CASE DESIGN ADAPTATIONS

7.1. Karst Terrain

Wet swales are generally *not* feasible in karst terrain, since the water table rarely reaches the land surface**.**

7.2. Coastal Plain

Wet Swales work well in areas of high water table, and consist of a series of on-line or off-line storage cells. Designers should design cells such that the underlying soils are typically saturated, but do not cause standing water between storm events. It may also be advisable to incorporate sand or compost into surface soils to promote a better growing environment. Wet Swales should be planted with wet-footed species, such as sedges or wet meadows. Wet Swales are not recommended in residential areas, due to concerns about mosquito breeding.

7.3 Regenerative Conveyance System (Coastal Plain Outfalls)

Regenerative stormwater conveyance (RSC) systems are open-channel, sand seepage filtering systems that utilize a series of shallow aquatic pools, riffle weir grade controls, native vegetation and underlying sand channel to treat and safely detain and convey storm flow, and convert stormwater to groundwater via infiltration at coastal plain outfalls and other areas where grades make traditional practices difficult to implement. RSC systems combine features and treatment benefits of swales, infiltration, filtering and wetland practices. In addition, they are designed to convey flows associated with extreme floods (i.e., 100 year return frequency event) in a non-erosive manner, which results in a reduction of channel erosion impacts commonly encountered at conventional stormwater outfalls and headwater stream channels.

RCS systems are referred to as Step Pool Storm Conveyance (SPSC) channels in Ann Arundel County, MD where systems have been installed and observed. The physical characteristics of the SPSC channel are best characterized by the Rosgen A or B stream classification types, where “bedform” occurs as a step/pool cascading channel which often stores large amounts of sediment in the pools associated with debris dams” (Rosgen, 1996). Due to their ability to safely convey large flood events, RSC systems do not require flow splitters to divert smaller events for water quality treatment, and reduce the need for storm drain infrastructure in the conveyance system.

These structures feature surface/subsurface runoff storage seams and an energy dissipation design that is aimed at attenuating the flow to a desired level through energy and hydraulic power equivalency principles. RSC systems have the added benefit of creating dynamic and diverse ecosystems for a range of plants, animals, amphibians and insects. These ecosystems enhance pollutant uptake and assimilation and provide a natural and native aesthetic at sites. RSC systems are unique in that they can be located on the front or tail end of a treatment system and still provide water quality and groundwater recharge benefits. Where located on the front end of a treatment train, they provide water quality, groundwater recharge, and channel protection, while also providing non-erosive flow conveyance that delivers flow to the stormwater quantity practice - a constructed wetland, wet pond, ED Pond, or combination.

The Ann Arundel County design specification can be found at:
http://www.aacounty.org/DPW/Watershed/StepPoolStormConveyance.cfm

SECTION 8: CONSTRUCTION

Consult the construction criteria outlined in Section 8 of both Stormwater Design Specification No. 3 (Grass Channels) and Stormwater Design Specification No. 13 (Constructed Wetlands). An example construction phase inspection checklist for Wet Swales can be accessed at the end of this specification.
Upon final inspection and acceptance, the GPS coordinates should be logged for all wet swales and submitted for entry into the local BMP maintenance tracking database.

SECTION 9: MAINTENANCE

The Virginia Stormwater Management regulations (4 VAC 50-60) specify the circumstances under which a maintenance agreement must be executed between the owner and the VSMP authority, and sets forth inspection requirements, compliance procedures if maintenance is neglected, notification of the local program upon transfer of ownership, and right-of-entry for local program personnel.

- All wet swales must include a long term maintenance agreement consistent with the provisions of the VSMP regulations, and must include the recommended maintenance tasks and a copy of an annual inspection checklist.
- When wet swales are located on individual private residential lots, homeowners will need to be educated regarding their routine maintenance needs.
- A deed restriction, drainage easement or other mechanism enforceable by the VSMP authority must be in place to help ensure that wet swales are maintained, as well as to pass the knowledge along to any subsequent owners.
- The mechanism should, if possible, grant authority for local agencies to access the property for inspection or corrective action. Where wet swales are designed to convey runoff from multiple lots or properties, a drainage easement that ensures the access for purposes of inspections and corrective actions must be provided.

Wet swales have maintenance needs similar to dry swales, although woody wetland vegetation may need to be removed periodically. Please consult the maintenance criteria outlined in Section 9 of Stormwater Design Specification No. 3 (Grass Channels), Stormwater Design Specification No. 10 (Dry Swales), and Stormwater Design Specification No. 13 (Constructed Wetlands). Example maintenance inspection checklists for Wet Swales can be accessed in Appendix C of Chapter 9 of the *Virginia Stormwater Management Handbook* (2010).

SECTION 10: COMMUNITY & ENVIRONMENTAL CONCERNS

The main concerns of adjacent residents are perceptions that wet swales will create nuisance conditions or will be hard to maintain. Common concerns include the continued ability to mow

grass, landscaping preferences, and the risks of unsightly weeds, standing water, and mosquitoes breeding. For these reasons, wet swales are not recommended in residential settings, because the shallow, standing water in the swale is often viewed as a potential nuisance by homeowners.

Sample Construction Inspection Checklist for Wet Swales: The following checklist provides a basic outline of the anticipated items for the construction inspection of Wet Swales. Many inspection elements will mirror those of constructed wetlands. Inspectors should review the plans carefully, and adjust these items and the timing of inspection verification as needed to ensure the intent of the design and the inspection is met. Finally, users of this information may wish to incorporate these items into a VSMP Authority Construction Checklist format consistent with the format used for erosion and sediment control and BMP construction inspections.

Pre-Construction Meeting

☐ Pre-construction meeting with the contractor designated to install the wet swale practice has been conducted.

☐ Identify the tentative schedule for construction and verify the requirements and schedule for interim inspections and sign-off.

☐ Subsurface investigation and soils report supports the placement of a wet swale practice in the proposed location.

☐ Impervious cover has been constructed/installed and area is free of construction equipment, vehicles, material storage, etc.

☐ All pervious areas of the contributing drainage areas have been adequately stabilized with a thick layer of vegetation and erosion control measures have been removed.

☐ **Certification of Stabilization Inspection:** Inspector certifies that the drainage areas are adequately stabilized in order to convert the drainage conveyance feature (if used for sediment control or diversion) into a wet swale.

Excavation of Wet Swale

☐ Stormwater has been diverted around the area of the wet swale to a stabilized conveyance and perimeter erosion control measures to protect the facility during construction have been installed.

☐ Materials (wetland soils and plants, erosion control materials such as stone, soil stabilization matting, etc.) are available.

☐ Construction of the wet swale geometry (including bottom width, side slopes, check dams, weir overflow and outlet protection, etc.) in accordance with approved plans.

☐ Excavation of internal micro-topographic features: earthen check dams, tree check dams, forebays, etc., in accordance with approved plans.

☐ Installation of pretreatment, including forebays, gravel diaphragms, energy dissipators, etc., is in accordance with the approved plans.

☐ Impermeable liner, when required, meets project specifications and is placed in accordance with manufacturers specifications.

☐ Placement of wetland soils and amendments in accordance with approved plans.

☐ **Certification of Excavation Inspection:** Inspector certifies that the excavation has achieved all the appropriate grades, grade transitions, and wet swale geometry as shown on the approved plans.

Wetland Plantings and Stabilization

☐ Exposed soils on swale bottom and side slopes are stabilized with seed mixtures, stabilization matting, mulch, etc., in accordance with approved plans.

☐ External bypass structure is built in accordance with the approved plans.

☐ Appropriate number and spacing of plants are installed and protected in accordance with the approved plans.

☐ All erosion and sediment control practices have been removed.

☐ Follow-up inspection and as-built survey/certification has been scheduled.

☐ GPS coordinates have been documented for all wet swale installations on the parcel.

SECTION 11: REFERENCES

Anne Arundel County Watershed Ecosystems and Restoration Services, *Step Pool Conveyance Systems,* Annapolis, MD. Available online at: http://www.aacounty.org/DPW/Watershed/StepPoolStormConveyance.cfm

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Center for Watershed Protection (CWP). 2007. *National Pollutant Removal Performance Database Version 3.0*. Ellicott City, MD.

Maryland Department of Environment (MDE). 2000. *Maryland Stormwater Design Manual*. Baltimore, MD. Available online at: http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp

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Schueler, T. 2008. Technical Support for the Baywide Runoff Reduction Method. Chesapeake Stormwater Network. Baltimore, MD. www.chesapeakestormwater.net

Virginia Department of Conservation and Recreation (DCR). 1999. *Virginia Stormwater Management Handbook. Volumes 1 and 2*. Division of Soil and Water Conservation. Richmond, VA.