Memorandum

To: Ben Leach – DEQ

Cc: Robert Hare – DETI

From: Alla Flaksman – ERM, Stephen Lindsay – ERM, Doug Beisch – Stantec, Glenn Muckley – Stantec

Date: February 16, 2018

Subject: Virginia ACP Stormwater Quantity Compliance Methodology

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EXECUTIVE SUMMARY

The following is intended to provide background clarity as to the stormwater management compliance strategy for the Atlantic Coast Pipeline (ACP) project and serve as documentation and explanatory information to the Virginia Department of Environmental Quality (DEQ) Water Program's Office of Stormwater Management to demonstrate the compliance approach for the Virginia Stormwater Management Program (VSMP) Part IIB Technical Criteria, specifically with 9VAC25-870-66 for water quantity for the project. The methodology herein has been developed with consideration for the “2017 Annual Standards and Specifications for Erosion and Sediment Control and Stormwater Management for Construction and Maintenance of Gas Transmission Facility Projects in Virginia” for Dominion Energy Transmission, Inc. (DETI), approved July 5, 2017 (DETI AS&S). It is understood that the methodology defined herein shall be appended to the approved DETI AS&S as a special project and utilized to provide additional clarity for the ACP project beyond that which the AS&S provides. This document is generally referred to as the “White Paper” below and in various project support documents.

This White Paper defines a stepwise process for evaluation, calculation, and documentation of water quantity compliance for the ACP, and the below provides additional detail on process refinement for pipeline and access road areas.

As noted under this White Paper, the stormwater management approach centers on maintaining existing sheet flow patterns and converting existing shallow concentrated flows intercepted by the ROW to sheet flow, where practicable. As such, access road compliance with 9VAC25-870-66 is sought primarily through 9VAC25-870-66.D, through an Environmental Site Design (ESD) approach whereby measures (waterbars, flow diffusers, gravel diaphragms, ditches, check dams, etc) are integrated within the right of way (ROW) / roadway construction footprint, where feasible, and restoration practices are employed which minimize changes to runoff parameters. Documentation provided for sheet flow will demonstrate, if practices are installed and maintained properly, that A) areas will leave the practices / ROW in sheet flow, and B) that increased volumes of sheet flow in aggregate from these practices have been evaluated for "impacts on down-gradient properties or resources" and are not anticipated to" cause or contribute to erosion, sedimentation, or flooding of down gradient properties or resources". Where not feasible to maintain sheet flow per the above, concentrated flow outfalls are addressed through satisfaction of 9VAC25-870-66.B and 9VAC25-870-66.C for channel protection and flood protection, respectively.

CERTIFICATION

The Virginia ACP Stormwater Quantity Compliance Methodology, or White Paper, was developed by Environmental Resources Management, Inc. (ERM) and Stantec Consulting Services Inc. (Stantec).

Developed by:	In consultation with:
Environmental Resources Management (ERM) 180 Admiral Cochrane Drive Suite 400 Annapolis, Maryland 21401 (410) 266-0006	Stantec Consulting Services Inc. (Stantec) 1011 Boulder Springs Drive Suite 225 Richmond, Virginia 23225 (804) 267-3474

Stephen Lindsay, PE

Doug Beisch, PE

Glenn Muckley, PE

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1.0 INTRODUCTION

The Atlantic Coast Pipeline (ACP) project consists of approximately 600 miles of interstate natural gas transmission pipeline and associated laterals in West Virginia, Virginia, and North Carolina. Approximately 307 miles of transmission pipeline and over 100 miles of permanent access roads are located in Virginia. A 50-foot wide permanent right-of-way (ROW) will be maintained along the pipeline and a 30-foot wide permanent ROW will be maintained for permanent access roads.

The purpose of this memorandum is to discuss the approach and compliance methodology for the pipeline ROW and permanent access roads for complying with Virginia's water quantity criteria set forth in 9VAC 25-870-66.

The general overview of the process to achieve water quantity compliance is illustrated using a flow chart presented in Attachment 1 and discussed in the following sections.

2.0 WATER QUANTITY FOR PIPELINE RIGHT-OF-WAY

Compliance with the requirements at 9 VAC 25-870-66 for the pipeline ROW and access roads will primarily be achieved by demonstrating that runoff leaves the permanent maintained ROW as sheet flow. Specifically, the mechanism through which compliance is achieved will be 9 VAC 25-870-66.D. The methodology involves the following steps.

1. Delineate the drainage area to each permanent waterbar and culvert, perform hydrologic computations, and size required end treatments to demonstrate that project runoff will leave the permanent maintained ROW as sheet flow at that location. To ensure sheet flow, all waterbars and cross-culverts (those not conveying jurisdictional waters) will be implemented with an end treatment. Specific end treatment sizing and type is dependent on hydraulic loading. See Section 6 below for additional detail.

2. Assess the potential for sheet flow to re-concentrate downgradient of the permanent maintained ROW. If it appears sheet flow re-concentration might occur within 100 feet of the permanent maintained ROW, provide additional intermediate points of analysis to assess the potential for increased volumes of sheet flow and impacts on downgradient properties or resources. If no re-concentration occurs within the 100-foot buffer,

provide a point of analysis were re-concentration occurs at properties downstream.

The evaluation to be performed is discussed in more detail in the following sections.

2.1 Permanent Waterbar Sheet Flow Computations

Permanent waterbars are required to be installed along the pipeline ROW in accordance with the FERC Upland Erosion Control, Revegetation, and Maintenance Plan (FERC Plan) to slow runoff velocity, direct water off the ROW and prevent sediment deposition into sensitive resources. Specifically, permanent waterbars will be installed upgradient of all wetland, waterbody and road crossings (which allows us to isolate project drainage contributions from cross-drainage needed to convey larger streams). At other locations along the ROW and access roads, spacing for permanent waterbars will generally follow the table below.

Recommended Spacing for Permanent Waterbars (FERC Plan V.B.2)

Trench Slope (%)	Spacing (feet)
5 to 15	300
> 15 to 30	200
> 30	100

It is noted that there are over 6,500 permanent waterbars along the pipeline ROW in Virginia.

While this memorandum focuses on permanent waterbars, it should be noted that temporary waterbars will be used during active construction to manage runoff on the temporary and permanent ROW. The transition from temporary to permanent waterbars is discussed in the VA ACP Stormwater Pollution Prevention Plan (SWPPP) and in the construction sequence in the Erosion and Sediment Control Plan Notes sheets. Additionally, maintenance requirements for permanent waterbars and related stormwater best management practices (BMPs) to remain in place once construction is complete and the pipeline is operational are addressed in the VA ACP SWPPP, Section 8.6. Additional waterbar and culvert end treatment maintenance information is provided in the construction plans.

Hydrologic computations will be performed at each permanent waterbar and cross-culvert to demonstrate that runoff will leave the permanent maintained ROW or access road as sheet flow. The specific methodology to be applied is described below.

1. The drainage area to each permanent waterbar or culvert will be delineated.

2. The SCS Runoff Curve Number Method will be used to compute the peak runoff rate for storm events (1, 2 and 10-year events). Industry standard software programs and equations, such as HydroCAD, HEC-HMS or similar, will be used to perform hydrologic computations in accordance with Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) methodology. The time of concentration for each catchment will be computed primarily using the watershed lag method described in Chapter 15 of the Engineering Handbook, Part 630 Hydrology. Where the watershed lag method is not appropriate (curve numbers <50 or >95), the TR-55 flow path segment or similar industry accepted methods may be used as well. Alternatively, a conservative time of concentration of 5 minutes may be utilized.

3. At the terminus of the permanent waterbar or cross-culvert, an end treatment element will be added to transition discharges captured at the waterbar or cross-culvert to a sheet flow condition. The standards and specifications for end treatments are provided on the construction plans and have been adapted from other design references. End treatments shall refer to those features defined under Section 6 of this document, and consist of Standard Stone Aprons (SSA) and Flow Diffusers. See Attachment 4 for additional information regarding SSA, and See Attachments 4 and 5 for design and additional references for Flow Diffuser standards and specifications basis of design. For the purposes of this project, a flow diffuser is defined as a permanent non-erosive outlet for concentrated runoff constructed to diffuse flow uniformly through a stone matrix onto a stabilized area in the form of shallow, low velocity, sheet flow.

For examples of a waterbar calculation see Figure 7.7. Per Section 6.1.2 and relevant references, the slope of the receiving area downgradient of the flow diffuser should not exceed 30 percent. Exceedances of the recommended slope limit are likely to occur in some locations in the western part of the commonwealth. Where the slope of the downgradient receiving area exceeds 30 percent, the allowable discharge rate per foot of flow diffuser will be reduced by 50 percent to 0.125 cubic feet per second (cfs) per foot. Per FERC requirements in areas with slopes greater than 30 percent, reduced permanent waterbar spacing of no more than 100 feet is used, as compared with permanent waterbar spacing of 200 feet in project areas where the slope is less than 30 percent. Given that FERC has determined that permanent waterbar spacing of 100 feet (as opposed to 200 feet) is appropriate for these steep slope areas, the consultant team similarly elected to reduce the allowable hydraulic loading to the flow diffusers to half of the amount normally allowed (i.e., reduction from 0.250 cfs per foot to 0.125 cfs per foot). It should also be noted that, where the pipeline ROW slope exceeds 30 percent, best in class (BIC) steep slope incremental controls will be utilized which will provide further protection. An example of BIC incremental controls that could be applied includes further reduction of the permanent waterbar spacing to less than 100 feet.

The following section presents the methodology for assessing impacts to downgradient property and resources due to potential increases in the volume of sheet flow, as required by 9 VAC 25-870-66.D.

2.2 Downgradient Channel Adequacy Evaluation

At this stage of the pipeline ROW analysis it has been demonstrated that runoff leaving the permanent maintained ROW is in a sheet flow condition (i.e., non-erosive velocity and flow depth less than 0.1 feet). To achieve compliance with 9 VAC 25-870-66.D it is necessary to demonstrate that increased volumes of sheet flow are not expected to adversely impact downgradient property or resources. The analysis includes an evaluation of the anticipated channel velocities in the receiving drainage feature, and an assessment (where manmade channels are present or other improvements adjacent to natural channels, such as structures or land uses, which may be subject to localized flooding) of whether localized flooding is anticipated to occur. The first check on the receiving channels is performed by assessing the potential for the sheet flow leaving the permanent maintained ROW to re-concentrate within 100 feet of the permanent maintained ROW. Sheet flow will be assumed to have the potential to re-concentrate if a drainage feature, identified through inspection of the topographic data, or delineated waterbody is encountered. A point of analysis will be established at the point of flow re-concentration and the pre- and post-construction hydrologic conditions evaluated. The specific methodology to be applied is described below.

1. Firstly, the designer reviews available topographic mapping, land use mapping, flood mapping, and aerial mapping resources to identify if there are manmade receiving channels or manmade improvements (e.g. yards, agricultural fields, structures, roads, trails, etc.) within the potential flood-prone area of natural channels in the immediate vicinity which may experience localized flooding. Localized flooding is flooding which is

likely to cause property damage or unsafe conditions. If localized flooding is of any concern based on the review, flow depths are calculated for the 10-year event in manmade channels and natural channels. Both 2-year velocity and 10-year flow depth (where necessary) comparisons are performed via a single section analysis using best available topography at a downstream point of aggregated sheet flow defined under the analysis. See Attachment 1 – Water Quantity Compliance Flow Chart for additional information. If 10-year flow depths are not expected to be contained (without attenuation) within the stormwater conveyance system (i.e. localized flooding is expected to occur), volume mitigation is provided for the 10-year storm to reduce post-development discharges to pre-development, as necessary. Volume mitigation (as discussed in Section 6) is provided though storage in drainage features such as flow diffusers, gravel diaphragms, check dams, and waterbar storage.

2. Once the area has been screened for localized flooding, those drainage areas with increased sheet flow volumes must be evaluated to determine if receiving channels are adversely impacted. Where there is a low probability for the sheet flow leaving the permanent maintained ROW to re-concentrate downgradient of the ROW (re-concentration is of concern if it occurs within 100 feet of the permanent ROW) it is then necessary to evaluate whether increased volumes of sheet flow will have an impact on downgradient property or resources. If volumes of sheet flow from the drainage area in question have increased, then a representative point of analysis is provided in the receiving channel. Points of analysis are selected where incremental sheet flow releases are aggregated in the receiving channel. If post-development (2-year) channel velocities are expected to increase (without accounting for runoff storage mitigation practices) then the ability to offset the increase in volume, for example by accounting for storage behind the upgradient permanent waterbar/flow diffuser, will be evaluated. Upon demonstrating that any increase in the volume of sheet flow is mitigated by storage in these practices, the team has provided assurance that flows have been mitigated such that there is no anticipated impact on downgradient property or resources and compliance with the requirements at 9 VAC 25-870-66.D is achieved for that drainage area.

3. If a drainage feature exists within 100 feet of the 50-foot wide maintained permanent ROW there is assumed to be potential for the sheet flow to re-concentrate and possibly impact downgradient property or resources. An additional point of analysis will be established at the point of flow re-concentration and the pre- and post-construction hydrologic conditions will be evaluated.

If the post-construction velocity is less than or equal to the pre-construction velocity at the additional point of analysis, there is no anticipated impact on downgradient property or resources and compliance with the requirements at 9 VAC 25-870-66 D is achieved for that drainage area. Velocities will be calculated using 2 significant figures. If post-development (2-year) channel velocities are expected to increase (without accounting for runoff storage mitigation practices) then the ability to offset the increase in volume, for example by accounting for storage behind the upgradient permanent waterbar/flow diffuser, will be evaluated. Upon demonstrating that any increase in the volume of sheet flow is mitigated by storage in these practices, the team has provided assurance that flows have been mitigated such that there is no anticipated impact on downgradient property or resources and compliance with the requirements at 9 VAC 25-870-66.D is achieved for that drainage area.

4. If volume mitigation is not sufficient to demonstrate that localized flooding and impacts to receiving channels are appropriately mitigated, or in instances where project drainage cannot be dispersed as sheet flow, the designer must then default to the energy balance method and size controls (utilizing the appropriate improvements factor) to achieve the point of discharge standard for the concentrated discharge location.

As 9VAC25-870-66.D does not define quantifiable metrics for evaluation of sheet flow by design storm event or a threshold for margin of calculation error, but clearly does anticipate "increased" volumes of sheet flow. If localized flooding is not of concern, the general compliance approach is to mimic pre-development velocities (within the computed accuracy of 2 significant figures) or to provide volumetric mitigation of increases in sheet flow.

For the pipeline ROW itself, in the absence of access roads (or other new impervious cover) the team anticipates that the restoration plan (restoration of the disturbed ROW area back to a "forest/open space" condition) will achieve most of the runoff management compliance objectives. As discussed in Section 2.2.3 of the approved Dominion Energy Transmission, Inc. (DETI) 2017 Standards and Specifications wherein it is stated that for portions of pipeline that traverse prior developed lands, DETI does not expect to provide improvements to existing runoff conditions if pre-development conditions are restored. Where increased volumes of sheet flow are expected from the pipeline ROW, the compliance approach will be the same as that outlined above, with the goal of maintaining sheet flow and volumetric mitigation for increases.

Mitigation options are addressed in Section 6 and include, but are not limited to, reconfiguring permanent waterbars and/or implementation of best management practices (BMPs) to restore the pre-construction flow conditions at the point of analysis. If standard sizing for flow dissipation measures is not sufficient to demonstrate there is no localized flooding for 10-year, 24-hour depth and the channel velocities for 2-year events are mitigated, as necessary, designers will evaluate the potential to add additional practices or increase the size of practices to offset the increase in the volume of sheet flow by accounting for storage behind the upgradient permanent waterbar / flow diffuser elements. Upon demonstrating that any increase in the volume of sheet flow is mitigated, the team has provided reasonable assurance that there is no impact on downgradient property or resources and compliance with the requirements at 9 VAC 25-870-66.D is achieved for that drainage area.

3.0 WATER QUANTITY FOR ACCESS ROADS

Compliance with the requirements at 9 VAC 25-870-66 for access roads will be achieved by demonstrating that runoff leaves the access road ROW as sheet flow where possible (i.e., 9 VAC 25-870-66 D) in the same manner as the ROW. Where it is not feasible to achieve sheet flow leaving the access road ROW, compliance will be achieved using the Energy Balance method (i.e., 9 VAC 25-870-66 B.3).

A discussion of the types of access roads utilized for the ACP project as well as the information to be provided documenting existing and proposed access road conditions is presented in Section 3.1. The methodology for achieving compliance with the water quantity requirements is presented in Sections 3.2 through 3.5.

The water quantity analysis will be performed for only those access roads where there is potential for a material change to the existing stormwater runoff characteristics. The identification of these roads is presented in Section 3.1.

3.1 Access Road Engineering Details

In accordance with the approved DETI 2017 Standards and Specifications Appendix B, access roads will be grouped into four categories based on the extent of improvements required to prepare the road for use to support the project. Depending on the improvements, the impact on stormwater runoff characteristics will range from no expected impact to a material impact. Specifically, the four categories are defined below; all access roads, or access road segments, will be assigned a category that is depicted on the corresponding alignment sheet and access road plans.

1. Existing road with no improvements proposed – includes those existing roads that are in a condition such that no improvements are needed to prepare the road for use to support the project (e.g., asphalt surfaced roads).

2. Existing road with minor improvements proposed – includes those existing roads that contain either a compacted earth or gravel surface and the current road configuration (i.e., width, grade, etc.) is adequate to support the project. Roads in this category may receive supplemental gravel to improve the surface condition; however, the footprint of the road would not be expanded (i.e., no additional impervious surface is proposed).

3. Existing road with major improvements proposed – includes those existing roads that will receive an expanded footprint (i.e., the impervious surface post-construction may exceed that existing pre-construction) in order to prepare the road for use to support the project.

4. New road – includes roads not located within the limits of an existing road.

No post-construction stormwater management criteria will apply to access roads in categories 1 and 2 because the roads are existing and there is no additional impervious surface proposed. Access roads in categories 3 and 4 involve improvements that could potentially result in a material change to the existing stormwater runoff characteristics as a result of the addition of impervious surface, and therefore are the subject of the access road water quantity analysis. However, note that most of the proposed roads are within existing dirt / gravel road footprints. As such, the new versus existing road designation noted herein relates specifically to the nature of impervious cover change. To remain conservative the consultant team deemed many roads new for purposes of stormwater evaluation even though some existing gravel may exist within the footprint. Further, the area outside of the proposed impervious access roads (i.e. the shoulder on both sides of roadway) is utilized with a consistent pre-development land cover for the purpose of pre- to post-development comparison. This is a conservative approach given the siting of proposed roads along existing road traces (whereas most of the roads are deemed new for purposes of stormwater compliance) and conservative assumptions for the addition of impervious cover, and the nature of the proposed post- stabilization approach to establish scrub-shrub conditions for vegetated areas outside of the impervious width (scrub-shrub curve numbers for these residual areas, if used, would be lower than reversion to pre-development land cover). Additional documentation may be provided upon field construction mobilization as to the extent of existing gravel limits, if necessary, should additional analysis and/or plan modification be required to address field constraints.

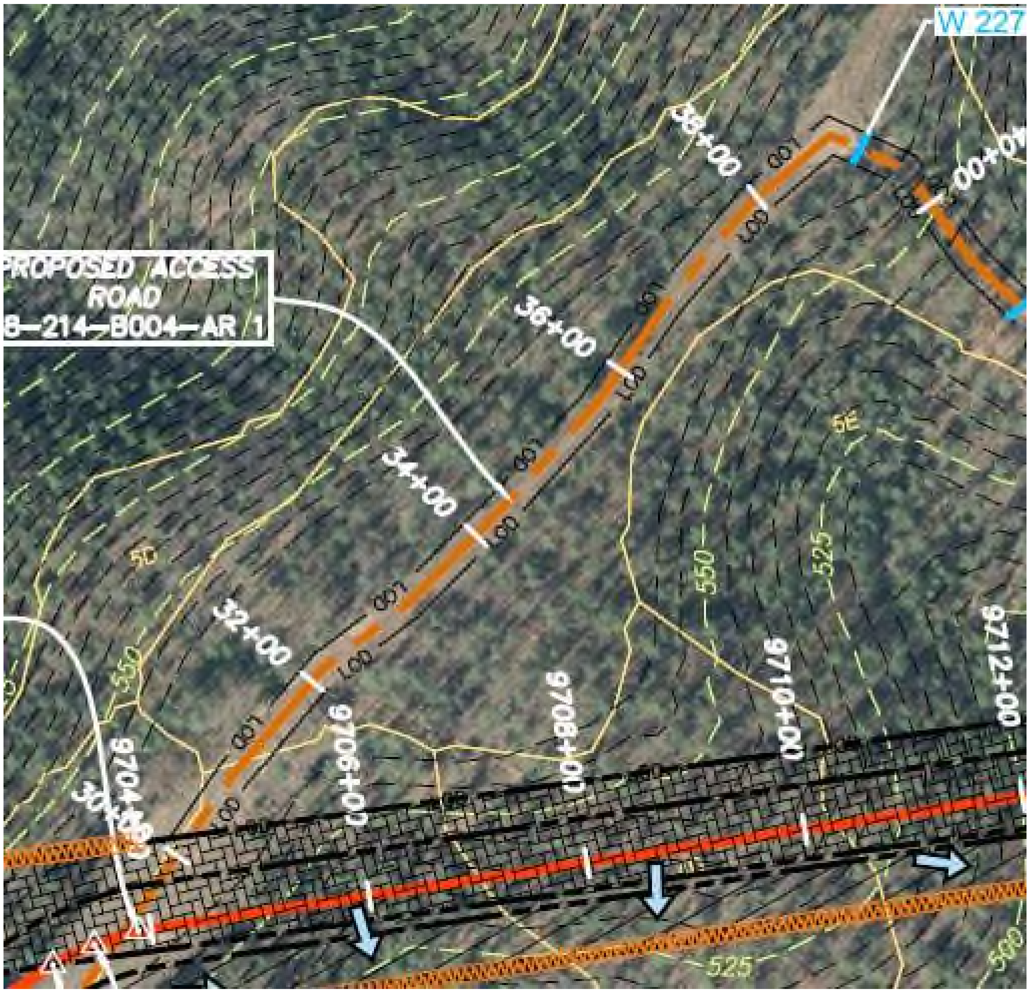
Engineering details will be provided for all permanent access roads, including plan, profile and typical cross-sections depicting the existing and proposed improvements, approximate limits of cut and fill and existing or proposed drainage elements. Engineering details for access roads are depicted on plans associated with the project. For existing permanent access roads, documentation describing the basis for any assumptions as to the extent of existing impervious surfaces will be provided. Documentation that will be evaluated includes the Virginia Geographic Information Network (VGIN) land cover data, aerial photography, field reconnaissance notes and site-specific photographs, where available. For examples of how existing access road conditions forming the basis of the water quantity analysis are documented refer to Section 7.

3.2 Scenario 1 – Ridgetop Conditions

Segments of access roads located along ridgetops have a small drainage area contributing to the downgradient edge of the access road ROW (an example access road ridgetop scenario is presented in the figure below). At these locations runoff will leave the access road ROW as sheet flow since the length of the contributing drainage area will be significantly less than 100 feet, the generally accepted minimum flow path length at which point sheet flow becomes shallow concentrated or channel flow. However, there is likely to be a small increase in runoff volume due to the increase in impervious area. An analysis similar to that described in Section 2.2 will be performed to demonstrate there is no impact on downgradient property or resources. Options for mitigating an increase in runoff volume include installing a gravel diaphragm or flow diffuser at the downgradient edge of the access road ROW and accounting for storage within or behind the element. Other options that may be considered include minimizing the width of the impervious surface or rehabilitation of the access road by infilling the voids in the access road stone with soil to achieve an effective curve number that is lower than that for gravel alone.

Upon demonstrating that any increase in the volume of sheet flow is mitigated, there is assumed to be no impact on downgradient property or resources and compliance with the requirements at 9VAC 25-870-66 D is achieved for that drainage area.

Access Road along Ridgetop



3.3 Scenario 2 – Segments with Waterbars

Access road waterbars are used where an access road is ascending or descending a slope generally perpendicular to the topographic contours such that there is very little to no off-site runoff contribution (see example location in the figure below). At these locations, an analysis similar to that described in Sections 2.1 and 2.2 will be performed for each waterbar to demonstrate that: 1) runoff leaves the access road ROW as sheet flow and 2) any increase in runoff volume as a result of new impervious area and/or change in pre-construction hydrologic conditions will be mitigated through runoff volume reduction strategies. Options for mitigating an increase in runoff volume include accounting for storage behind the upgradient permanent waterbar/flow diffuser elements and accounting for storage within roadside ditches. In some instances, other options that may be considered include minimizing the width of the impervious surface or rehabilitation of the access road by infilling the voids in the access road stone with soil to achieve an effective curve number that is lower than that for gravel alone.

Upon demonstrating that any increase in the volume of sheet flow is mitigated, there is assumed to be no impact on downgradient property or resources and compliance with the requirements at 9 VAC 25-870-66 D is achieved for that drainage area.

Access Road Waterbars

3.4 Scenario 3 – Conversion to Sheet Flow Conditions

Access roads that exist in locations where the surface topography is at an angle to the road will generally be constructed with a roadside ditch and periodic ditch relief culverts. Where feasible (i.e., generally at locations with relatively small contributing watersheds upgradient of the access road ROW), the concentrated flow discharging from the ditch and culvert system will be converted to sheet flow using standard stone aprons and flow diffuser elements prior to leaving the access road ROW. An analysis similar to that described in Section 2.1 will be performed to demonstrate that the runoff leaves the access road ROW as sheet flow. The increase in runoff volume will be assessed in accordance with the methodology identified in Section 2.2 to demonstrate there is no impact on downgradient property or resources. Options for mitigating an increase in runoff volume include accounting for storage within the roadside ditch and behind the flow diffuser at the base of the fill slope. Other options that may be considered include minimizing the width of the impervious surface or removal and rehabilitation/restoration of the access roads to reduce runoff.

Upon demonstrating that any increase in the volume of sheet flow is mitigated, there is assumed to be no impact on downgradient property or resources and compliance with the requirements at 9 VAC 25-870-66 D is achieved for that drainage area.

3.5 Scenario 4 – Segments with Roadside Ditch and Culvert

Where it is not feasible to achieve sheet flow leaving the access road ROW, compliance will be achieved using the Energy Balance method (i.e., 9 VAC 25-870-66 B.3). Software programs, such as HydroCAD, HEC-HMS or similar, will be used to perform hydrologic computations in accordance with NRCS TR-55 methodology using the 1-year, 24-hour storm event.

The Energy Balance method equations, as presented in 9 VAC 25-870-66 B.3.a are provided below.

Equation 1 $$Q_{Developed} \leq IF \times \frac{(Q_{Pre-Developed} \times RV_{Pre-Developed})}{RV_{Developed}}$$

Equation 2 $$Q_{Developed} \leq Q_{Pre-Developed}$$

Where: $Q_{Developed}$ = The allowable peak flow rate of runoff from the developed site

IF = Improvement Factor (0.8 for sites > 1 acre, 0.9 for sites ≤1 acre)

$RV_{Developed}$ = The volume of runoff from the site in the developed condition

$Q_{Pre\text{-}Developed}$ = The peak flow rate of runoff from the site in the pre-developed condition

$RV_{Pre\text{-}Developed}$ = The volume of runoff from the site in the pre-developed condition

$Q_{Developed}$ need never be less than the following:

Equation 3 $$\frac{(Q_{Forest} \times RV_{Forest})}{RV_{Developed}}$$

Where: Q_{Forest} = The peak flow rate of runoff from the site in a forested condition

RV_{Forest} = The volume of runoff from the site in a forested condition

$RV_{Developed}$ = The volume of runoff from the site in the developed condition

Where the Energy Balance is applied stormwater BMPs will be required to reduce the runoff peak flow rate and volume. Options for complying with the Energy Balance include accounting for storage within the roadside ditch; rehabilitation and restoration of access roads to remove impervious cover; and minimizing the width of the impervious surface. In the event access road rehabilitation is applied, supporting computations and details will be provided with the corresponding access road submission.

Upon demonstrating that the Energy Balance is satisfied, compliance with the requirements at 9 VAC 25-870-66 B.3 is achieved for that drainage area.

3.6 Typical Access Road Water Quantity Analysis Package

The access road water quantity analysis is to be presented for each access road or for each group of access roads that connect or are located adjacent to each other as dictated by the topography and hydrography of the local area.

A typical package will include a description of site pre-development and post-development conditions, summary of compliance with water quantity regulations for each segment of the road, and supporting calculations. See Section 7 for additional detail regarding documentation.

4.0 BASIS FOR INPUT DATA

The data to be used in the analysis discussed in Sections 2 and 3 is identified in the following sections.

4.1 Land Cover

The baseline land cover data is obtained as a Land Cover product in a raster and vector data format from the Virginia Land Cover Map Service publicly made available by the VGIN. The VGIN Land Cover product classifies the land cover using the classification scheme developed by VGIN and its partners. The VGIN Land Cover product aims to provide improved land coverage data to assist localities in planning and implementation of stormwater management programs. This evaluation utilizes the categories of the VGIN Land Cover product. The data set used for the pre-development land cover condition in this analysis is the VGIN Land Cover product. Data utilized is sourced from the following: https://vgin.maps.arcgis.com/home/item.html?id=6ae731623ff847df91df767877db0eae.

The data maintained by VGIN is understood to be compiled from sources ranging in dates per the below: "1 meter Land Cover Dataset based on a 12 item classification scheme. This statewide dataset is divided into tiled imagery from the Virginia Base Mapping Program (VBMP) orthophotography between the dates of 2011 and 2015."

The data set for the post-development land cover condition in this analysis is developed using the baseline land cover data and the following assumptions for each new and existing major upgrade permanent access road:

1. the access road is approximately 16 feet wide and surfaced with gravel; and

2. all areas categorized as Forest within the pipeline permanent and temporary ROW will be converted to the scrub-shrub land cover category.

To facilitate the evaluation of water quantity, runoff curve numbers are assigned to each land cover classification using the land cover descriptions presented in the TR-55 manual and the Virginia Stormwater Management Handbook. The correlation of the land cover categories with TR-55 land cover descriptions and the associated curve numbers is presented in Attachment 2.

4.2 Topography

The stormwater analysis utilizes the best consistently-available topography, which is derived from several different sources, including VGIN LiDAR and project-specific LiDAR. Since multiple sources are utilized the contour intervals vary with location. Specific sources are noted within the water quantity analysis packages.

4.3 Soils

The Hydrologic Soil Group (HSG) classification is obtained from the Soil Survey Geographic Database (SSURGO) publicly available from the United States Department of Agriculture (USDA) NRCS. The HSG D is assigned in cases where the HSG is listed as A/D, B/D, or C/D. In cases where HSG was not listed, HSG was assigned as presented in White Paper Attachment 3.

4.4 Storm Events and Precipitation Depths

Runoff volumes and peak flow rates are calculated for the 1-year, 24-hour; 2-year, 24-hour; and 10-year, 24-hour storm events as needed in the water quantity analysis. Precipitation depths are obtained from the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service. The precipitation depths for each storm were obtained from NOAA as iso-contours.

5.0 COMPLIANCE STRATEGIES

Several key aspects to the water quantity compliance strategy are included here.

5.1 Pipeline Area Restoration and Rehabilitation Strategies

Per 2017 DETI AS&S:

"The forestry and vegetative management practices employed by DETI within the right-of-way comply with the VRRM recommendations for open space. Where the right-of-way consists of forest or open space conditions prior to the construction activity, and will remain in a forested or open space condition under post-developed conditions (e.g., undisturbed or restored to a hydrologically functional state and all surfaces will remain as permeable surfaces which are mowed no more than once every three years, in accordance with FERC Plan Guidelines or maintained in accordance with Table 1 referenced above), runoff curve numbers are identical under the Virginia Runoff Reduction Method.

Further the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) provides additional guidance and background on the development of natural scrub-shrub habitat. Per the NRCS Fish and Wildlife Habitat Management Leaflet Number 42 "Scrub-shrub Birds" (January 2007).

Under Natural Regeneration on page six, "The process of natural regeneration is slow, inexpensive, and, where not constrained by other considerations, should be the favored option. A disturbance such as grazing, lightly disking, burning, or mowing, may be necessary to begin this process. After scrub-shrub has been established, periodic management is necessary to maintain it in an early successional stage."

Additionally, on page 6 "Planting should only be done where there is no natural source of regeneration or when a rapid result is required."

As such, it is anticipated that successional regeneration will provide for a long-term scrub-shrub condition in terms of representative species and right-of-way maintenance practices; however, this may take time. As such, given the breadth of activities proposed, it has been discussed that a component of the permanent stabilization be modified to include a seed source of select scrub-shrub species. This would initiate a jumpstart of successional processes and to provide more near-term assurance that scrub-shrub conditions will be established.

As a commitment to this result, Dominion would ensure that the permanent seed mix be adjusted within the permanent right-of-way to incorporate a minimum percentage (e.g., 3-10%) of early successional scrub-shrub species to establish a seed source for scrub-shrub development consistent with the plan for seeding and planting for the adjacent restoration of the temporary right-of-way.

Select species will be identified that promote this land cover consistent with the TR-55 definition for scrub-shrub, and Dominion will incorporate species that are shown for the temporary right-of-way seeding palette under the current Restoration and Rehabilitation (R&R) Plan to be planted within the permanent 50-foot ROW. This is understood to further ensure final stabilization conditions will provide for hydrologic functionality noted under scrub-shrub and are consistent with maintenance practices under DETI AS&S.

Updates will be reflected in the ACP Restoration and Rehabilitation Plan, as necessary. Land cover CN's for permanent ROW consistent with scrub-scrub under TR-55 are provided under Attachment 2.

5.2 Volumetric Offsets Evaluation

In areas where increased volumes of sheet flow may indicate an increase in downstream channel velocity, when increases in velocity are noted (percent increase computed using two significant figures), aggressive pursuit of compliance is sought through assurance that additional detention volumes are provided in offset. To evaluate efficacy of volumetric offsets, the methodology was used as defined under Technical Release 55 Urban Hydrology for Small Watersheds (TR-55), Chapter 6.

In lieu of detailed modeling through a TR-55 modeling interface, an alternative process was utilized to assess aggregate volumes of sheet flow as defined under TR-55 Chapter 6 – Storage Volumes for Detention Basin. This method is also identified under the DEQ Plan Reviewer for Stormwater Management Certification Course, and may be utilized to assess the storage volume required (Vs) in relation to the post-development calculated runoff volume (Vr) with a conservative and reasonable Factor of Safety (FOS) of 1.25. This method is utilized across the project; however, individual practice and structure routings may be applied, if necessary.

Per Chapter 6 (page 6-2), "Use figure 6-1 estimate storage volume (Vs) required or peak outflow discharge (qo). The most frequent application is to estimate Vs, for which the required inputs are runoff volume (Vr), qo, and peak inflow discharge (qi). To estimate qo, the required inputs are Vr, Vs, and qi."

For the purposes of the project, Vs (required storage) was determined utilizing Figure 6-1, for a Type II distribution of the relevant storm event (2-year or 10-year event) and "Worksheet 6a: Detention basin storage, Peak outflow discharge (q_o) known" under TR-55 Appendix D-7. See Section 7 below regarding documentation of this methodology. TR-55 pages 6-2 and D-7 are provided under Attachment 4.

6.0 MITIGATION MEASURES

The following provides discussion regarding treatments and measures used to either maintain sheet flow, address volumes associated with sheet flow areas, or to address energy balance compliance, as applicable.

6.1 Sheet Flow Maintenance and Increased Volumes Evaluation

Per the flow chart under Attachment 1, the primary compliance path is through maintenance of sheet flow leaving the project. The below is intended to provide an overview of the basic components.

6.1.1 Standard Stone Apron – Flow Assessment and Detail Development

The following is intended to provide background to the consulting team's approach to very conservatively demonstrate that waterbar and culvert feature outlet flows discharge in a sheet flow condition. Additionally, this assessment has been used in developing standardized details and flow-based triggers for use in stormwater management plan evaluation Water Quantity Calculations Package.

Modified Apron Evaluation

The consultant team evaluated depth and flow values across the modified apron at the outfall of culverts and waterbars along the access roads and pipeline to ensure sheet flow at the outfall of the apron. This effort utilized the weir equation (Source: Chapter 5, VSWMH,1999), see Equation 6.1 below, to calculate a discharge at the outfall of the apron with varying apron lengths analyzed. Assumptions used in the weir equation include a dimensionless weir coefficient of 3.0, and a constant depth of water over the weir of 0.1 feet (ft), understood as a threshold depth for sheet flow conformance specific to the project.

Equation 6.1: Weir Equation

$$Qw = Cw\ x\ L\ x\ h^{1.5}$$

Where: Qw = weir discharge, cfs

Cw = dimensionless weir coefficient

L = Length of weir, ft

h = hydraulic head, ft

Once flow values were obtained, the design team determined the normal depth within the practice leading to the apron for reference only. The analysis centered on providing a conservative documentation of sheet flow depths (0.1 foot of less) leaving a stone apron weir. The normal depth in a waterbar for reference was determined using Bentley Systems FlowMaster v8i for a representative v-ditch with 2:1 ft/ft (H:V) side slopes, an 8% longitudinal slope, and a manning's n of 0.041. To determine the normal depth of flow through culverts of various sizes, Bentley Systems CulvertMaster v3.3 software was utilized to model each culvert size at each of the specified weir lengths and corresponding discharges for a point of reference. Assumptions used in this assessment include a culvert length of 24 ft, the standard design slope for each culvert size per the project culvert design under Section 6.3, projecting inlet conditions, and a Manning's roughness coefficient for corrugated metal pipe (CMP) of 0.024. See Table 6.1 below.

Table 6.1: Conservative End Treatment Weir Discharges (0.1 feet Deep)

				Depth in Culvert, ft (via CulvertMaster computation)						
	Length of Weir (ft)	**Calculated Weir Discharge (cfs)**	**Corresponding Depth in Waterbar (ft)**	**12"**	**18"**	**24"**	**30"**	**36"**	**42"**	**48"**
SSA Type 1	2	0.190	0.21	0.14	0.12	-	-	-	-	-
SSA Type 1	3	0.285	0.25	0.17	0.15	-	-	-	-	-
SSA Type 2	4	0.379	0.28	0.19	0.17	0.17	-	-	-	-
SSA Type 2	5	0.474	0.30	0.21	0.19	0.19	0.19	-	-	-
SSA Type 2	6	0.569	0.32	0.23	0.21	0.21	0.21	0.22	-	-

Standard Detail Development

This modified apron evaluation and the sheet flow velocity check analysis was utilized to develop standard stone apron details which are then implemented across the project at the lower end of the 10-year flow range. This defines typical apron sizes for 12 to 18-inch diameter culverts and waterbars that receive 10-year flows between 0 cfs and 0.569 cfs. See the estimated flow triggers per the draft SSA under Attachment 4. For flows between 0 cfs and 0.284 cfs, a SSA Type 1 is selected. Once flows exceed 0.284 cfs and remain equal to or less than 0.569 cfs, a SSA Type 2 will be provided. Should flows exceed approximately 0.569 cfs, a flow diffuser (See Section 6.1.2) will be employed unless concentrated flow conditions are understood to apply at the end of feature, such as at concentrated channels and jurisdictional features (areas of energy balance). See construction details for SSA Type 1 and Type 2 (Figures 6.1, 6.2, and 6.3). See the estimated flow ranges used to derive triggers for SSA's under Attachment 4. All SSA's will be designed using the 10-year storm event.

Figure 6.1: Standard Stone Apron (SSA) Type 1 and Type 2 (Detail 1)

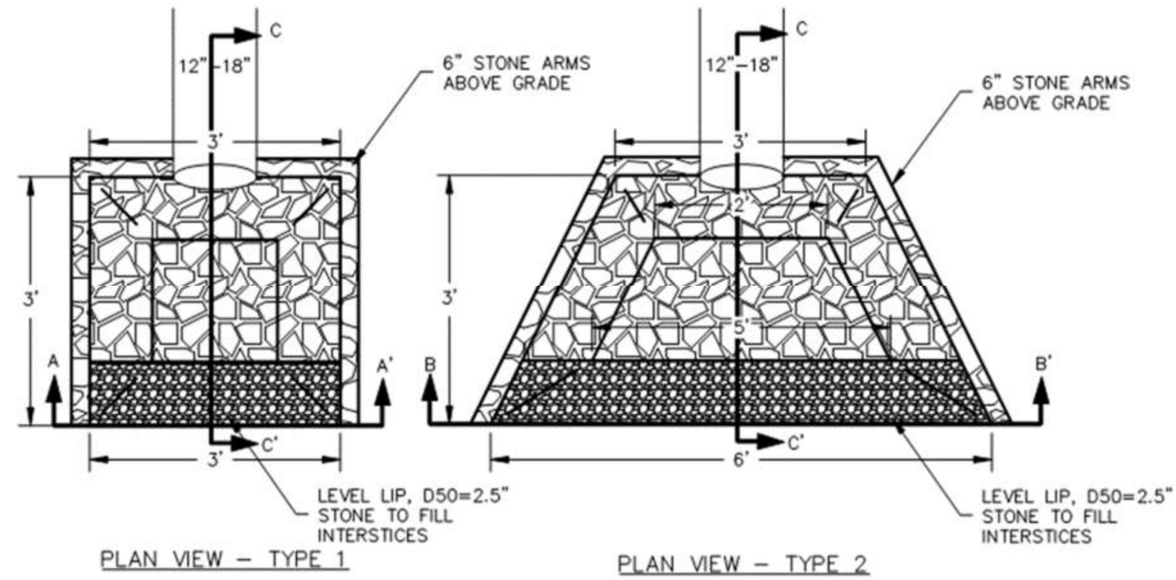


Figure 6.2: Standard Stone Apron (SSA) Type 1 & Type 2 (Detail 2)

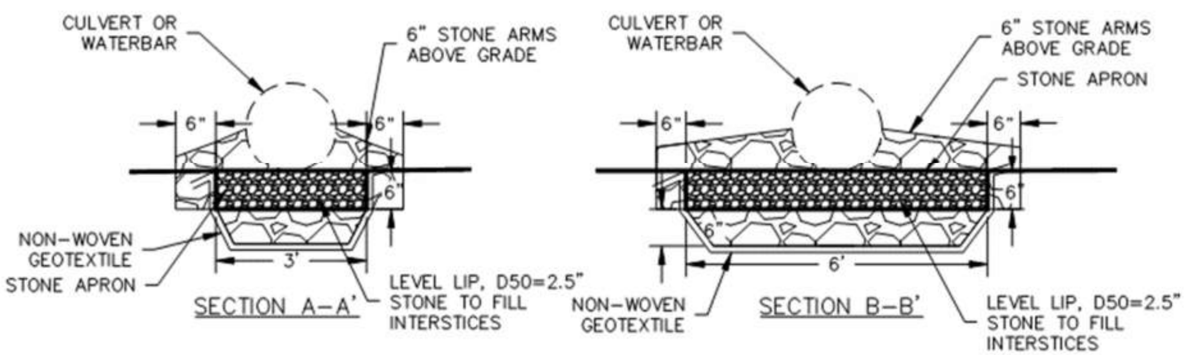
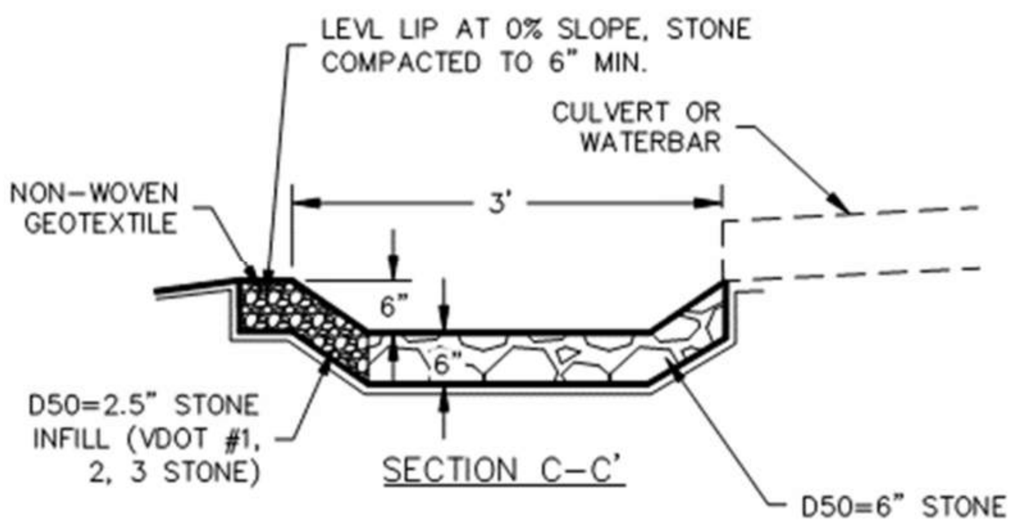


Figure 6.3: Standard Stone Apron (SSA) Type 1 & Type 2 (Detail 3)



6.1.2 Flow Diffuser Basis of Design and Constructability Optimization

As noted above, a Flow Diffuser will be provided as a feature end treatment when flows exceed 0.569 cfs as part of the overall stormwater management water quantity compliance approach. All Flow Diffusers will be designed using the 10-year storm event. Similar water quantity / flow transition standards in Virginia, such as Virginia Standard and Specification 3.21 – Level Spreader (VESCH), designed based on the 10-year storm event, cite a 1.0 cfs per linear foot of weir length; however, in effort to find a more conservative approach the consultant team reviewed similar state standards for maintenance of sheet flow.

As such, the Flow Diffuser details provided herein have been developed following review of similar state standards, such as the Maine Level Spreader in Section 8.3 of the Maine Stormwater Best Management Practices Manual, September 2010, which mirrors the 0.25 cfs per linear feet design value, and the H.R.C Research Series Report No. 10 – Analysis of Flow Through Porous Media as Applied to Gabion Dams Regarding the Storage and Release of Storm Water Runoff, NAHB/NRC Designated Housing Research Center at Penn State, August 1992 (Penn State Analysis). Additionally, several project constraints have been considered, including practical implementation in pursuit of sheet flow maintenance, Virginia-specific needs for conformance under 9VAC25-870-66.D, and Virginia specific constructability, namely downstream sheet flow definition held to 100 feet, Virginia best practice (inclusive of Virginia Department of Conservation and Recreation – *Technical Bulletin No. 2, Hydrologic Modeling and Design in Karst*), and modification of the downstream steep slope limitations per similar standards (e.g. Maine Level Spreader) through mitigation efforts (0.125 cfs / linear foot sizing in areas 30% and greater downstream of the practice).

The structure has two main components, the first being the flow through the stone berm and the second being the weir flow once the berm is crested. To estimate the flow through the stone berm, Darcy's Law / Equation was utilized. The equation was optimized within standard hydraulic conductivity ranges to produce a peak flow rate of 0.25 cfs per linear foot when the headwater condition is at the berm crest height. The rating curve then utilizes the results of Darcy's Equation up to the berm height capped at 0.25 cfs per linear foot of weir length, which is equivalent to the 10-year flow (based on the Penn State study and state references). As such, the 10-year storm is established at the top of the stone berm, and the resultant flow through the berm is maintained in sheet flow. The composite rating curve for the Flow Diffuser complex (stone sump and stone berm) combines the stone berm segment (8 inches of stone) and the weir equation to estimate flows that overtop the berm. The weir equation utilizes a conservative weir coefficient of 3.0. In areas where detailed routing models for the flow diffusers are required this rating curve will be utilized. See White Paper Attachment 4 for rating curve information.

Given some of the project terrain and to augment the BIC approach employed by ACP, the project team has committed to additional design restrictions when downstream slopes exceed 30%. In this instance, the 0.25 cfs per linear foot of weir crest length requirement will be reduced to 0.125 cfs. This effectively doubles standard flow diffuser spacing, ensuring more diffuse distribution of flows, and will theoretically reduce the depths of sheet flows within these more sensitive slope areas.

Further, to address additional constructability, stability, and adaptation for project use, a series of additional diffuser improvements include:

- The addition of a one foot wide level lip at zero percent grade, tying out to existing downstream grade to provide enhanced sheet flow transition (See Figures 6.4 and 6.5 below);
- The incorporation of two types of diffuser practices to accommodate normal construction (side slopes 2:1 or flatter) and more space constrained environments (side slopes steeper than 2:1) such as adjacent to access roads;
- The addition of a woven geotextile fabric on the downstream sump trench face and a non-woven geotextile on the bottom of the

facility in typical facilities as a best practice to promote flow through the level lip with drainage capability through the sump floor (if applicable);

- Weeps are needed in instances where an impermeable liner is used or when HSG C or D soils are encountered in Flow Diffuser construction. Weeps have been proposed to address two concerns, namely:
    - Karst – Where Flow Diffusers are sited within defined limits of Karst geology (whether on plans or as noted under field conditions) or Karst indicative features, "such as rock outcrops, sinkholes, springs, caves, etc." (Technical Bulletin No. 2, Virginia Department of Conservation and Recreation – Hydrologic Modeling and Design in Karst) are identified within the immediate downstream area – a liner is desirable to inhibit exfiltration from the facility. Additionally, underdrains or weeps are needed to drain the facilities in accordance with Technical Bulletin No. 2 where it is desirable in that: "Inlet and outlet structures should be designed to provide diffuse discharge of water; avoid concentration of flows. Under drains are preferred to provide gradual discharge of water and to avoid prolonged ponding of water." The general intention of the development strategy is to maintain existing drainage patterns to the extent practicable. In addition, the Flow Diffusers are intended to provide general attenuative effects, while providing diffuse discharge in pursuit of conditions endorsed by Technical Bulletin No. 2, while meeting the applicable subsection(s) of 9VAC25-870-66.
    - Within HSG C and D – It is understood that sump storage may take longer to exit via exfiltration, evaporation, etc. where Flow Diffuser footprints are sited within identified HSG C and D soils. As such, weeps are proposed where Flow Diffuser footprints are sited within C and D soils. (General Note – Whether in Karst or in C or D HSG soils field engineering will be required to accommodate myriad field conditions and outfall configurations related to weeps.)
- Incorporation of a stone sump area, which may be expanded to allow for flexibility in the field regarding materials and the addition of storage, as the need arises.
- Field adjustment factors for increased length should high groundwater table conditions be found during construction (See Attachment 4.10).

See construction details for Flow Diffusers (Figure 6.4 and 6.5) below.

Figure 6.4: Flow Diffuser (Side Slopes 2:1 or Less Steep)

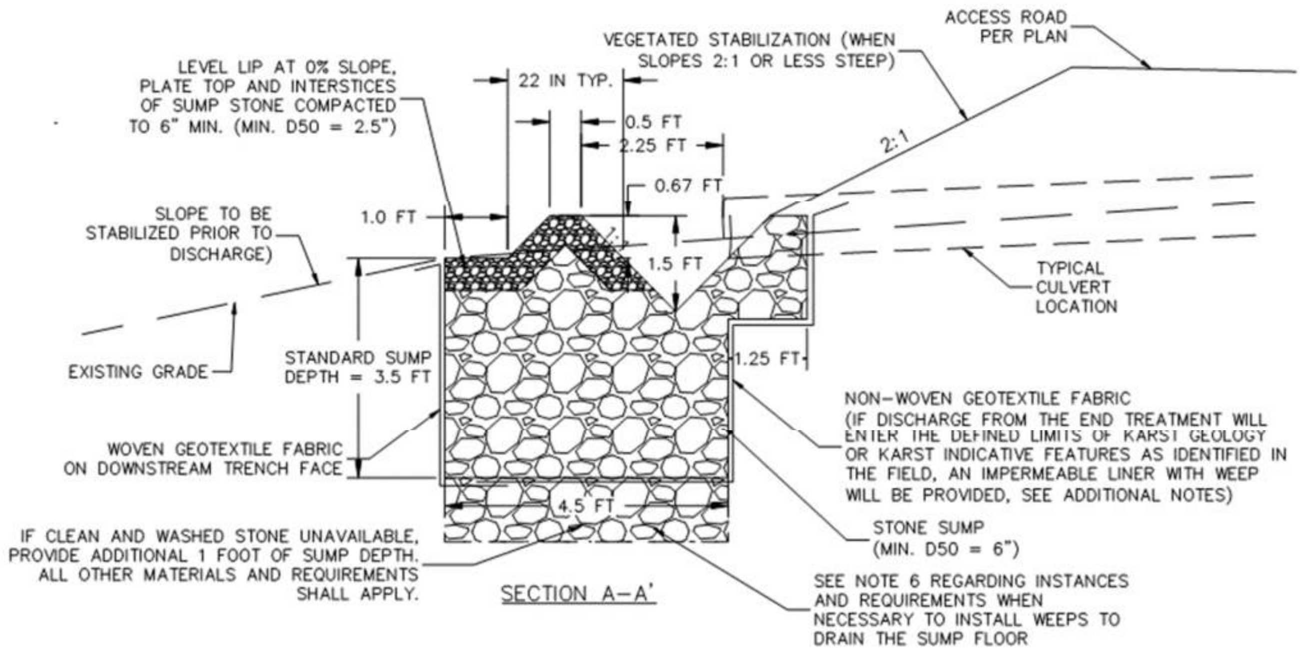
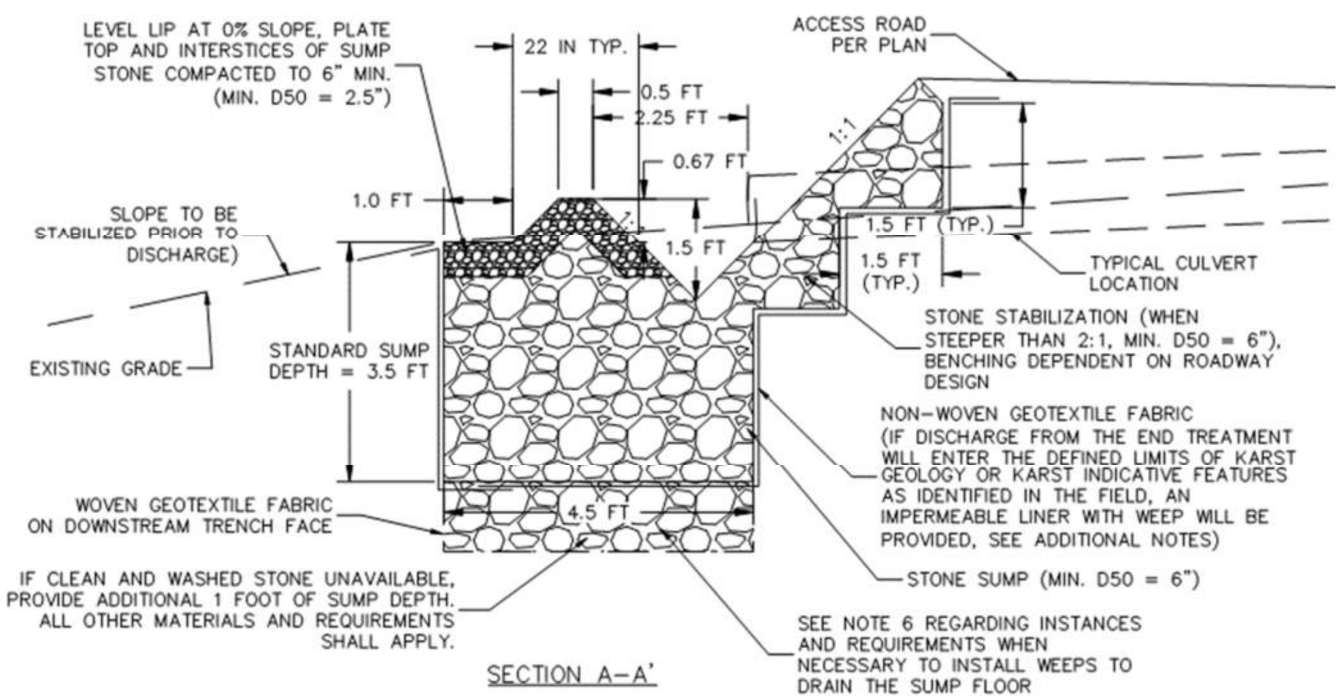


Figure 6.5: Flow Diffuser (Side Slopes Steeper than 2:1)



Flow Diffuser sizing will be provided under the Water Quantity Package per the following:

Sizing standardization, which provides for upsizing of features for standard construction practices in the field will be provided on the construction plans. Generally, the standard sizing will start at a minimum weir length of 6 feet and increase in 2 feet increments. Sizing upgrades for the areas subject to decreased flow (0.125 cfs) sizing criteria will also be upsized per the standard sizing categories.

See Attachment 4 for additional information regarding standard sizing of Flow Diffusers.

As noted, in areas where facilities discharge directly to a Karst feature, and thus receive an impermeable liner, and in areas with HSG C and HSG D soils, the Flow Diffusers will be provided with the ability to weep / drain the sump condition. These instances will be identified on the construction plans. Weeping will be provided in these instances, primarily through a gravel trench (6 inches by 6 inches), or french drain composed of VDOT #57 Stone wrapped in a non-woven geotextile fabric. Modifications to french drains / weeps to address field conditions / constraints will be provided on construction record drawings.

Additional Sump Volume to Address Unwashed Stone

To address the settling of fines through the potential use of unwashed stone, the flow diffuser detail has been enhanced with the option for additional gravel sump storage. To estimate the volume of fines associated with the unwashed stone, it was conservatively estimated that 5% of the total stone weight was made up of fine material. Based on the volume of stone per linear foot of flow diffuser and standard densities for gravel and loose dirt, a fine material volume estimate and corresponding required sump storage were developed. This volume of sediment corresponded to a required sump depth, taking a porosity of 0.4 into account, of 0.86 feet. This depth was conservatively increased to 1 foot and is listed as a requirement if un-washed stone is to be used in the construction of the flow diffuser. Notes requiring these adjustments to provide for field flexibility and long-term improved facility efficacy are provided on the construction plans.

Diffuser Sediment Loading

To estimate the necessary maintenance frequency of the proposed flow diffusers, sediment loading estimates based on guidance from the

Chesapeake Bay TMDL Action Plan Guidance GM15-2005 were analyzed. To conservatively assess the pipeline ROW the Forested TSS loading rates per River Basin were averaged to yield a 60.56 lbs/acre/year loading rate. Assuming maintenance is required once sediment has reached 50% of the total provided storage volume, cleanout would be required approximately once every 160 years. To conservatively assess the access roads the Regulated Urban Impervious loading rates per River Basin were averaged to yield a 682.23 lbs/acre/year loading rate. Assuming maintenance is required once sediment has reached 50% of the total provided storage volume, cleanout would be required approximately once every 14 years. Due to the lifespans noted in both the pipeline ROW and access road sections and with the 1-year inspection frequency as defined in the flow diffuser maintenance specifications, the requirement for clean-out becomes more of an inspection based protocol than a strict yearly mandate.

Maintenance requirements for the Flow Diffusers are provided on the construction plans.

<u>Flow Diffuser Construction in High Groundwater Table Conditions</u>

The Standard Sump Depth as defined per the Flow Diffuser detail (3.5 feet) will need to be adjusted by the contractor in the field in the event that High Groundwater Table (HGWT) conditions are encountered. In these circumstances the contractor shall determine the Effective Sump Depth based on the HGWT influence, and then will increase the sizing of the flow diffuser to be installed by multiplying the Flow Diffuser Length Per Plan by the appropriate Flow Diffuser Length Multiplier, which has been incorporated into the Flow Diffuser detail. These Length Multipliers were developed by estimating the effective volumes on a per linear foot basis and correlating the volume associated with the reduced sump depths to that of the typical Flow Diffuser detail (Attachment 4). Also, see Attachment A4.10 for additional detail.

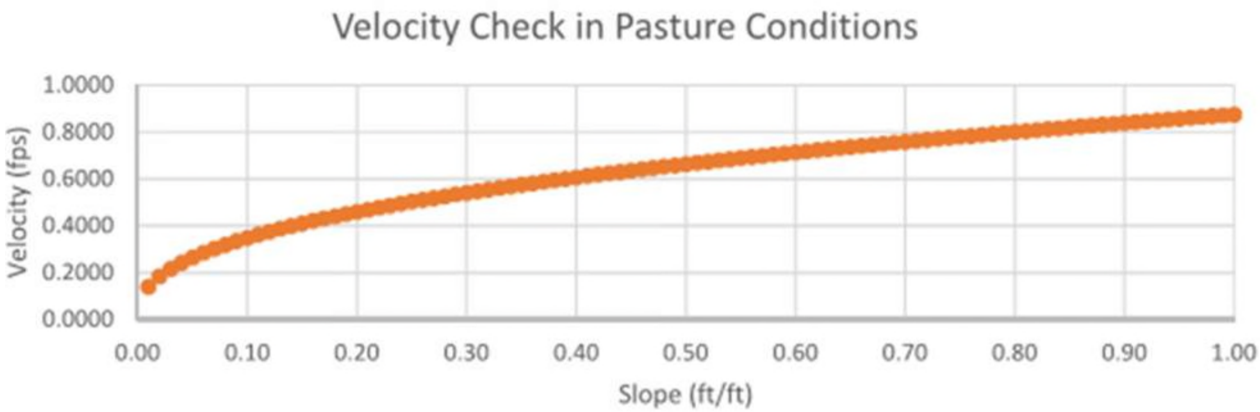
6.1.3 Sheet Flow Downstream Velocity Assessment

Sheet Flow Velocity Check

To address how areas outside the ROW (which are often forested without dense herbaceous cover) will be protected, the team has utilized assumptions of a pasture-like stabilization mix for the slope permissible velocity analysis. The question centers on whether this analysis is sufficiently conservative for downstream areas which may be higher slope and/or may have forested rather than herbaceous land covers. The team evaluated the issue utilizing the travel time equation for sheet flow contained in TR-55 (Equation 3-3). The equation was utilized for sheet flow lengths of 100 ft. to assess the travel time and associated velocity. In these instances, the original assumptions of pasture-like conditions are compared to those for forested conditions (to be conservative, the team utilized the sheet flow Manning's roughness value of 0.4 for Woods with light underbrush). As shown below in Figures 6.6 and 6.7, the increased roughness associated with wooded areas reduces the velocities to well within permissible ranges, even for steeper slope non-pasture areas. Permissible velocity ranges are between 1.9 and 6 fps depending on channel slope, lining material, and soil erodibility as shown in VESCH Chapter 3, Table 3.18-A, attached. For example, whereas a receiving area with a pasture-like land cover originally utilizing a Manning's n of 0.15 on a 20% slope (0.2 ft/ft vertical to horizontal) would yield a velocity of 0.41 fps, the same analysis of sheet flow for discharges to Woods with light underbrush would yield a velocity of 0.19 fps. See Attachment 4 for tabular curve development noted under figures below.

Figure 6.6: Velocity Check in Wooded Conditions

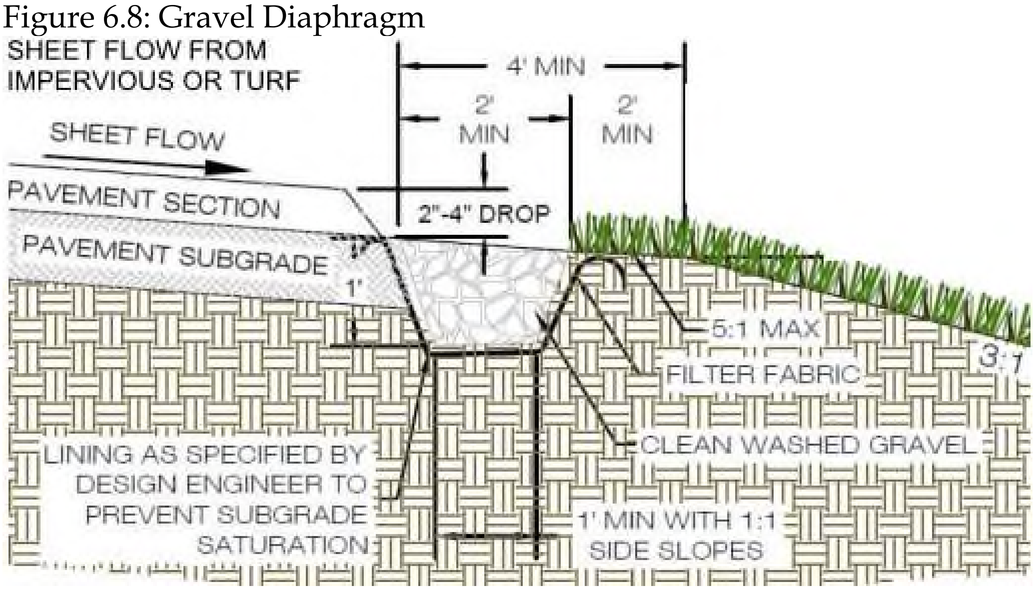
Figure 6.7: Velocity Check in Pasture Conditions



6.1.4 Access Road Ridgetop Condition – Gravel Diaphragm

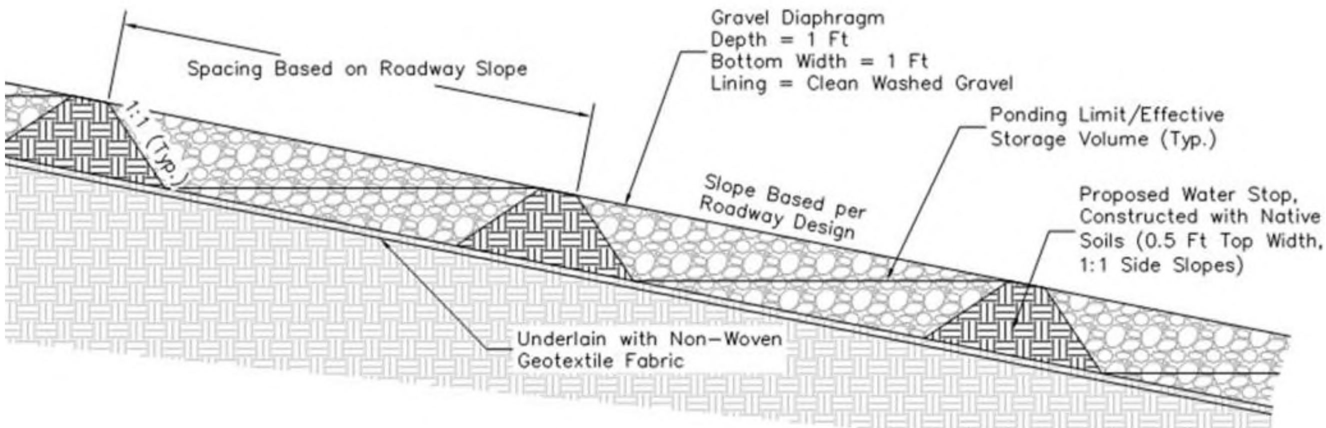
Generally, the minimal impervious area introduced by the access road improvements may be considered sheet flow where the roads are constructed in a ridgetop, or crowned, geometry given the limited flow length and adjacent topography. However, to further ensure sheet flow under water quantity criteria, a Gravel Diaphragm (generally shown under Figure 6.8) will be provided in areas where re-concentration may occur within the 100-foot buffer. As such, these will be identified to accompany road construction in areas, as applicable. Increases in Gravel Diaphragm dimensions to provide additional volumetric offset, if necessary, are understood to be conservative. As such, no deviation or exception from DEQ should apply. Expanded sizes of Gravel Diaphragms, if applicable, will be identified individually within the design packages.

Figure 6.8: Gravel Diaphragm



Because ridgetop road conditions will generally traverse ascending/descending ridgetop roads, it is important to consider A) constructability, B) effectiveness, and C) conservative volumetric quantification for gravel diaphragms utilized for purposes of addressing volumetric offsets. Water stops will be provided in gravel diaphragms to discourage flow through the gravel trench where this is not intended.

Figure 6.9: Gravel Diaphragm with Water Stops



The water stops will be constructed of native soil material per Figure 6.2. The water stops will be provided in gravel diaphragms according to roadway slopes as defined on the construction documents. See Water Stop Spacing in Table 6.3 below.

Table 6.10: Water Stop Construction Cross Section

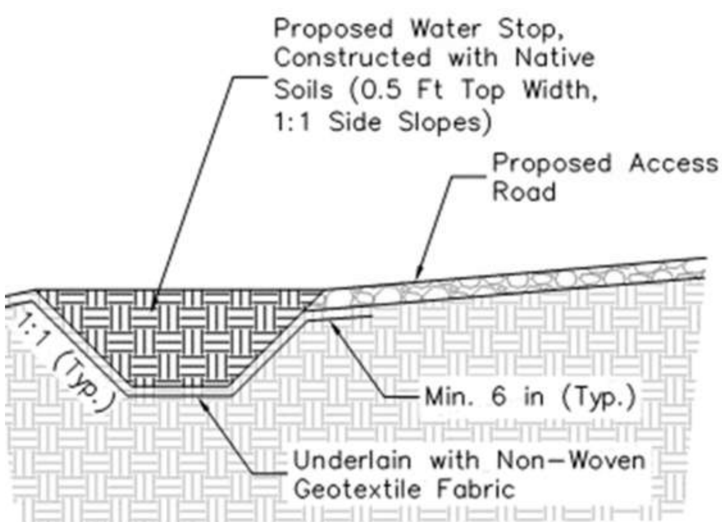


Table 6.2: Gravel Diaphragm Water Stop Spacing

Water Stop Spacing:

Roadway Slope	Water Stop Spacing
0% – 5%	21 FT
+5% – 10%	11 FT
+10% – 15%	8 FT
+15% – 20%	6 FT
+20% – 40%	4 FT

6.2 Concentrated Stormwater Discharges From Project Areas

Where it is not possible for the consultant team to maintain sheet flow, where the complexity of drainage patterns may indicate, or more expeditious and conservative application of the energy balance equation may be more applicable, Channel Protection (9VAC25-870-66.B) and Flood Protection (9VAC25-870-66.C) criteria shall apply. Additionally, where the complexity of drainage patterns may indicate or more expeditious and conservative application of the energy balance equation may be more applicable, satisfaction of water quantity criteria may also be met through Channel Protection (9VAC25-870-66.B) and Flood Protection (9VAC25-870-66.C) criteria at the discretion of the designer. The following provides general discussion as to the compliance approach in these situations; however, further strategy and detail may be provided under individual spread design packages.

6.2.1 Channel Protection – 9VAC25-870-66.B

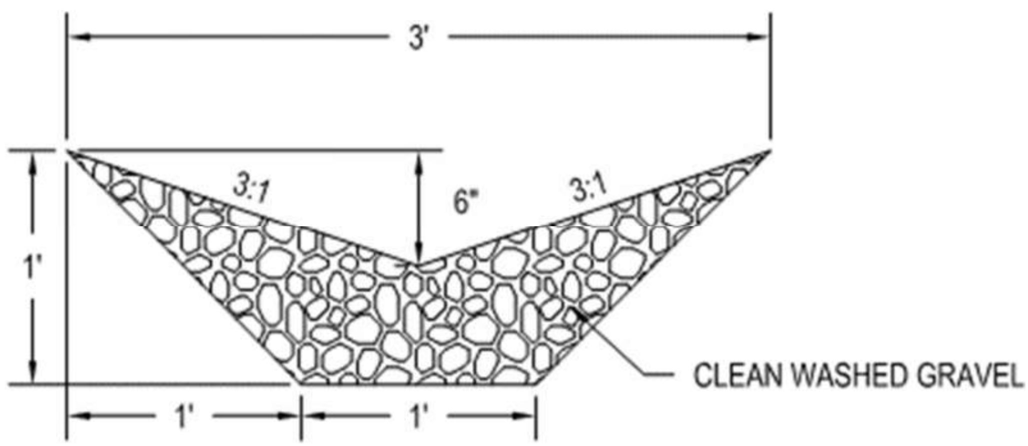
Where concentrated flows leave the site, principally at areas of jurisdictional culvert crossings, 9VAC25-870-66.B will apply. In these instances, the energy balance equation will apply to the area of improvement that drains to the concentrated flow point leaving the site.

Generally, the stormwater management strategy (particularly for access roads) centers on providing separation of runoff from onsite improvements from that of offsite, undisturbed areas. This is addressed through several possible ways generally, or as specifically designed and documented to address nuanced site constraints under the Water Quantity Package, if applicable.

One option generally employed in areas that require energy balance equation satisfaction is the Culvert Flanking Strategy (See Attachment 4), whereby use of cross culverts to Flow Diffusers, ditches, microtopography, or some other conveyance option may be employed to A) contain onsite drainage and provide detention / release control and B) bifurcate onsite flows from offsite flows. This is accomplished by "flanking" a primary cross culvert, which carries offsite bypass flows through the project, with smaller culvert / diffuser complexes just upstream within the roadway section. Flow from these diffusers are still intended to outfall in sheet flow per the Flow Diffuser sizing; however, these areas are generally included in the energy balance applicable area to remain conservative and avoid design /documentation iteration.

Further, there may areas of energy balance that are required where proposed access road improvements are in ridgetop condition. In these instances, options include expanding the size and storage volume of standard Gravel Diaphragms to address volume control locally. Or another option is to provide a Gravel Diversion Trench (see Figure 6.11 below) to control areas of runoff and direct them to downstream storage practices.

Figure 6.11: Gravel Diversion Trench



6.2.2 Flood Protection – 9VAC25-870-66.C

Similarly, where Channel Protection applies, Flood Protection will also be demonstrated in accordance with 9VAC25-870-66.C. In these instances, the 10-year storm requirements will be addressed. Generally, this will be demonstrated with modeling of project improvements, including Flow Diffusers to demonstrate 10-year flow attenuation. Available aerial photography, topography, FEMA Flood Insurance Rate Maps (FIRM), or local digital GIS floodplain mapping will be utilized in review. Documentation will be provided under Spreadsheet Tab / Attachment 14

– Flood Protection. See Section 7 for additional detail regarding template documentation.

6.3 Culvert Design

Standardized culvert sizing is employed for the project in areas of intended sheet flow and concentrated flow discharges. The proposed culverts are sized for the 10-year, 24-hour peak flow rate using design charts for circular pipe flow presented in Appendix 8C-61 of the Virginia Department of Transportation (VDOT) Drainage Manual. The culverts are proposed to be constructed using corrugated metal pipe with approximate Manning's roughness coefficient of 0.024. The design limits the headwater depth to the diameter of the culvert. For example, the design maximum headwater depth for a 12-inch culvert is 12 inches. The design slope and maximum discharge capacity for each culvert size is selected using design charts for circular pipe flow considering headwater depth equivalent to culvert diameter and outlet velocity of six feet per second (fps) for 12-inch diameter culverts and eight fps for all other culverts. Culvert size is selected so that the calculated 10-year, 24-hour post-development peak flow rate is no more than 90 percent of the culvert maximum discharge capacity. The final culvert slope is to be adjusted in the field, as needed, to convey the required peak flow rate and to maintain an acceptable discharge velocity. The table below identifies the design criteria for each size culvert considered under standard sizing. In instances where designs may exceed these standards, such as offsite flow bypass, a site specific culvert design will be provided and documented under detailed submittals.

Table 6.3: Standard Culvert Design

Culvert Design					
Diameter of Culvert (inches)	Maximum Headwater (inches)	Design Velocity (fps)	Design Slope (feet/feet)	Maximum Discharge Capacity (cfs)	Maximum Allowable Peak Flow Rate (cfs)
12	12	6	0.06	4.5	4.1
18	18	8	0.06	14	12.6
24	24	8	0.04	25	22.5
30	30	8	0.03	40	36
36	36	8	0.023	55	49.5
42	42	8	0.019	75	67.5
48	48	8	0.017	100	90

7.0 TEMPLATE DOCUMENTATION

To provide a template for analysis, documentation, and review, the consultant team developed a standardized reporting structure that includes a cover memorandum (Overall Water Quantity Narrative) for the Spread on a pipeline and access road basis. The memo provides general information and reference to Appendices that are provided in a consistent framework that is included here:

A. Water Quantity Compliance Summary Tables
B. Figures: Precipitation Values
C. Figures: Drainage Features
D. Figures: Pre-Development Land Cover
E. Figures: Post-Development Land Cover
F. Figures: FEMA Floodplain Map
G. ACP Water Quantity Calculations Packages
H. TR-55 Modeling Reports
I. Figures: Hydrologic Soil Groups & Geologically Sensitive Features

The key components, Appendix A – Water Quantity Compliance Summary Tables, Appendices C, D, and E – Mapping Components, and Appendix G – ACP Water Quantity Calculations Packages are discussed in more detail below.

7.1 Memo Appendix A – Compliance Summary Tables

The first appendix is intended to provide an overall understanding for key points of analysis (POA's), whether they relate to sheet flow analysis or concentrated flow analysis, and what regulatory section has been satisfied. An example Compliance Summary Table is provided on Figure 7.1 below.

Figure 7.1: Example Water Quantity Compliance Summary Table

Atlantic Coast Pipeline (ACP) Water Quantity Calculations Compliance Summary | Access Road / Pipeline ID: XXXX - XXXXX - XXX

Sheet Flow (9VAC25-870-66.D) Areas - Compliance Summary

Starting Station	Ending Station	D/S Point of Analysis	Aggregate Drainage Areas	Sheet Flow End Treatment Provided?	Initial Sheet Flow Complaince - D/S Aggregate Check			Sheet Flow Compliance with Mitigation Measures - D/S Aggregate Recheck, if necessary		Compliance Achieved Through
					Velocity Evaluation Performed Satisfactorily (per flowchart)?	Localized Flooding Evaluation Performed Satisfactorily (per flowchart)?	Mitigation Measures Required?	Velocity Evaluation Performed Satisfactorily (per flowchart)?	Localized Flooding Evaluation Performed Satisfactorily (per flowchart)?	
3+50	9+50			Yes	Yes	Yes	No	Yes	Yes	9VAC25-870-66.D
0+00	9+50			Yes			Yes	Enter Value	Enter Value	ERROR - RECHECK
				Yes			Yes	Enter Value	Enter Value	ERROR - RECHECK
				Yes			Yes	Enter Value	Enter Value	ERROR - RECHECK
				Yes			Yes	Enter Value	Enter Value	ERROR - RECHECK
				Yes			Yes	Enter Value	Enter Value	ERROR - RECHECK

Concentrated Flow (9VAC25-870-66.B & 9VAC25-870-66.C) Areas - Compliance Summary

Starting Station	Ending Station	Point of Compliance	Aggregate Drainage Areas	Conforms with 1-YR Energy Balance?	Conformance with 10-YR Flood Protection Criteria?	Energy Balance Compliance Achieved Through	Energy Balance Notes	Flood Protection Compliance Achieved Through	Flood Protection Notes
				Yes	Yes	9VAC25-870-66.B	-	9VAC25.870-66.C	No D/S Flooding Apparent, but 10-YR Attenuation Provided
				No	No	No	-	No	
						No	-	No	
						No	-	No	
						No	-	No	

1) Note: Areas cited under this Sheet Flow (9VAC25-870-66.D) Areas - Compliance Summary are consistent with project regulatory compliance approach and maintain sheet via end treatment measures defined.

2) Note: Velocity checks for downstream (d/s) aggregate areas of sheet flow are conservative. Compliance strategy seeks to generally adderess velocity through a net zero change (above and beyond regulatory requirements of 9VAC25-870-66.D) approach when comparing downstream velocities to 2 signficant figures. Note there may be several downstream POAs assessed to remain conservative.

3) Note: Areas cited under this Concentrated Flow (9VAC25-870-66.B & 9VAC25-870-66.C) Areas - Compliance Summary are consistent with project regulatory compliance approach and meet VSMP Regulations 9VAC25-870-66.B and 9VAC25-870-66.C.

4) See individual water quantity compliance packages for additional compliance detail.

5) Flowchart refernces noted refer to Water Quantity Compliance Flow Chart per the White Paper.

7.2 Mapping Components

Several mapping components will be included with each access road and pipeline ROW Water Quantity Package to support the calculations in the Water Quantity Calculations Spreadsheet. Graphics depicting the site topography, identified waterbodies and wetlands, ROW limits, drainage features, delineated watersheds, and access road stationing are included in the cover memorandum (Overall Water Quantity Narrative) Appendix C. Additional mapping displaying the delineated drainage areas in respect to hydrologic soils groups and the pre-development and post-development landcover can be found in Appendices D and E of the cover memorandum (Overall Water Quantity Narrative), respectively.

Figure 7.2: Example Post-Development Conditions Land Cover

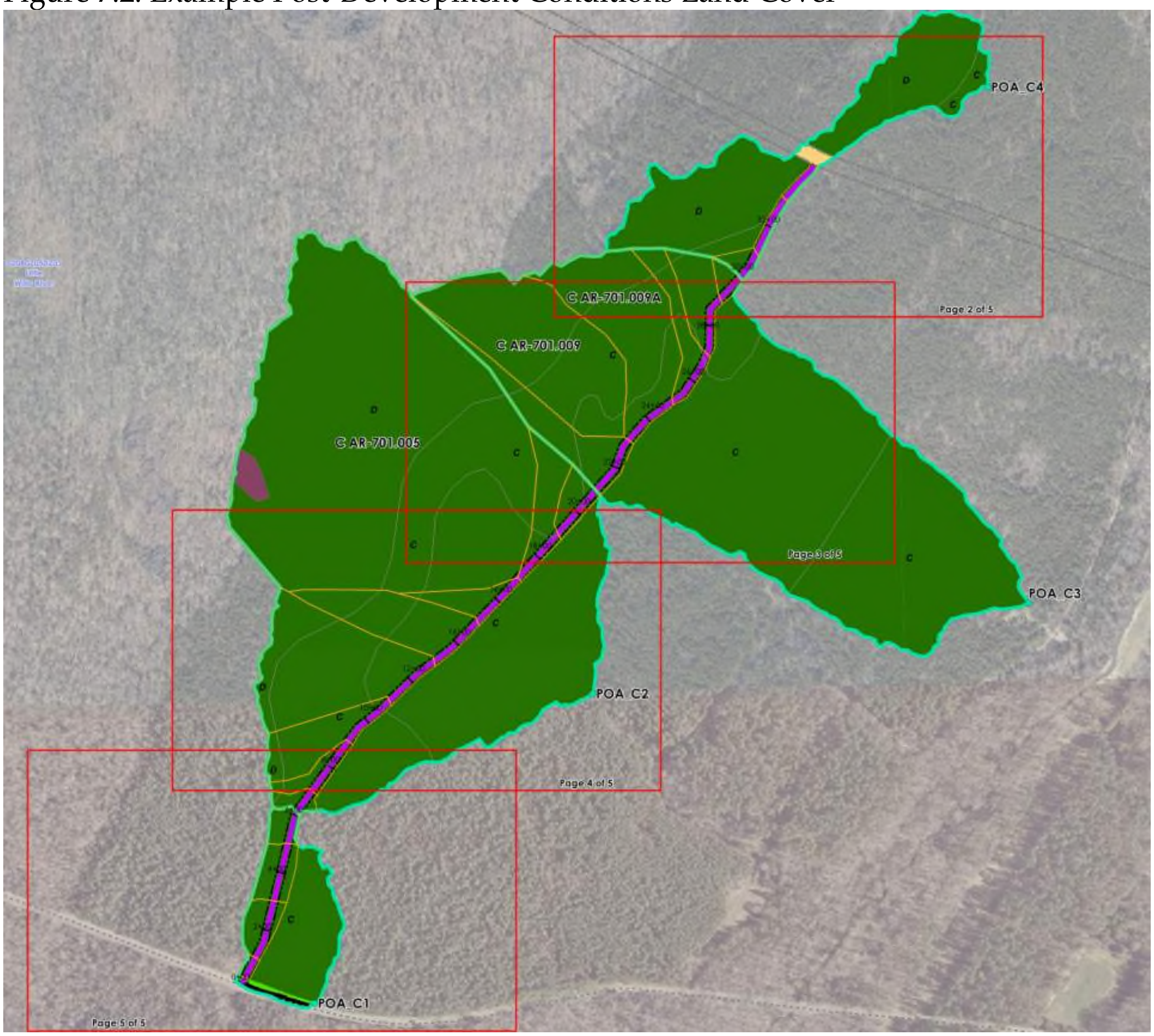


Figure 7.3: Example Drainage Feature Map

7.3 Water Quantity Calculations Package Template

To provide basic, concise reporting across the project, a template was developed in spreadsheet format (Microsoft Excel 2016) for a consistent framework for analysis, documentation, and review. While deviations are necessary dependent on individual access road or pipeline specifics and applicability, the format below is provided in a spreadsheet format.

<u>Project Data and Preliminary Hydrology</u>

The following is intended to provide some background on the process, calculations, and reporting structure utilized for the pipeline and access road water quantity compliance package spreadsheet template. Generally, calculation cells are noted in grey, input cells noted in orange, and modifications to the template / custom notations are highlighted in blue (custom notations are needed in instances where practice sizing is increased beyond standards, and other similar conditions where the spreadsheet is limiting).

Spreadsheet Cover Sheets – Includes project specifics in the orange data input cells.

Spreadsheet Cover Sheet 1 – Includes general information for the specific access road or pipeline. Information includes spread name, County location, access road identification (if applicable), access road category (if applicable), VSMP technical criteria, 12 Digit Watershed Location, and Virginia 6th Order HUC ID. A list of template attachments to be completed and appended are also provided. See the list below for additional information.

Spreadsheet Cover Sheet 2 – Includes Water Quantity Analysis Narrative to highlight aspects of the particular access road or pipeline covered under this review. Additional data sources specific to the review are noted, including topography, land use, soils, wetlands / waters delineation, aerial photography. Space for additional notes is also provided, if necessary.

Water Quantity Calculation Package Spreadsheet Tabs / Attachments to be completed and appended include:

Spreadsheet Tabs / Attachments 1 and 2 – Pre and post-development drainage area and curve number (CN) calculations. These attachments contain feature (waterbars, culverts, etc) drainage areas, as well as aggregated drainage areas for subsequently identified points of analyses through downstream review. These data entries are provided from GIS analyses. Curve number and Manning's n reference tables are documented under the White Paper Attachment 2.

Figure 7.4: Example Spreadsheet Tab / Attachment 1 – Pre-development CN Calculations

1 - VGIN Land Cover Data - Pre

Land Cover Classification	11				21				22			
Hydrologic Soil Group	A	B	C	D	A	B	C	D	A	B	C	D
CN Table 1	100	100	100	100	98	98	98	98	98	98	98	98
CN Table 2[1]	100	100	100	100	98	98	98	98	98	98	98	98
DA ID												
07-001-A009-AR1_POA_C1					0.48	0.03			0.29	0.03		
C 157.001					0.04							
C 157.002					0.03							
C 157.003					0.07	0.03				0.03		

91				98				99				100			
A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
30	67	70	77	30	48	65	73	98	98	98	98	72	82	87	89
40	67	70	77	40	48	65	73	98	98	98	98	72	82	87	89

91	98	99	100	DA (acres)	CN Calculated	CN Table	CN Utilized
				48.01	55	1	55
				1.87	51	1	51
				0.09	55	1	55
				15.66	51	1	51

Curve Number Limitations – Note Curve Numbers less than 40 are problematic under the TR-55 framework and will produce unreliable results for flow and volume calculations (essentially, discharges and volumes cannot be relied upon and are indeterminate for CN<40 due to underlying limitations in the compliance methodology). The TR-55 manual notes for a CN of less than 40, another procedure should be used to determine runoff.

Given many of the existing project soils and land uses, many areas of very low CN may be noted. With the large initial abstraction of greater than 3 inches for any CNs less than 40 and the limitations of the TR-55 modeling equations (graphical peak discharge method), alternative approaches were discussed. However due to the Commonwealth's stormwater management compliance framework being reliant on the methodologies outlined in TR-55, an alternative, conservative approach to upward adjust the Curve Numbers was derived if the spreadsheet results are utilized in lieu of more sophisticated hydrologic modeling. To resolve the limitations of the graphical peak discharge method in the spreadsheet, the consultant team is conservatively increasing CNs where composite CN's are below the TR-55 threshold of 40 to produce values that would fit within the modeling parameters and therefore could be analyzed in both the pre- and post-development scenarios.

To address this manual adjustment, while still calculating the CNs per the land use and soil classifications, the consultant team added in additional columns on the VGIN Land Cover Data, Attachments 1 and 2. These changes have been highlighted in blue and are conservatively used throughout the remainder of the spreadsheet for all calculations. The underlying individual land cover/soil constituents which are less than 40 (and create the issue when composited) are upward adjusted to 40 (for both pre and post-development). In this regard, when a predevelopment composite CN (Water Quantity Calculations Package Attachment 1 - VGIN Land Cover Data – Pre, Calculated CN column) is less than 40, a second adjusted CN table (CN Table 2 under Water Quantity Calculations Package Attachments 1 and 2) will be utilized for both the pre-development and post-development CN calculations. This CN Table 2 provides for upward adjustment of all constituent land cover CNs that are less than 40 under TR-55 to CN of 40. The composite curve number will then be generated by this CN Table 2. The exception will be when the post-development CN decreases to below 40 (due to a resultant scrub-shrub land use for instance) from a pre-development CN equal to or greater than 40. In this instance the calculated composite post-development curve number will be raised to a minimum of 40 so that a determinant result may be evaluated in the post-development condition. This has the effect of inflating the curve numbers to allow for determinate results using the TR-55 graphical peak discharge method, while maintaining a similar relative difference between pre and post-development. It should be noted that this adjustment approach has a tendency to overestimate runoff and thusly artificially inflate practice sizing, and as such is conservative. If the conservative peak discharge computations in the spreadsheet are problematic in a given instance, designers are encouraged to model the scenario using unadjusted CNs in a modeling package such as TR-20 to produce results which are not inflated by this workaround due to limitations of TR-55 hydrology for CN less than 40.

Spreadsheet Tab Attachment 2 (cont.) – Tabulation of Land Cover Changes (Percentages of Total Drainage Area). This tab presents the tabulation of land cover changes provided to address 9VAC25-870-55.B.8.h

Spreadsheet Tabs / Attachments 3 and 4 – Pre-development and post-development times of concentration (Tc) definition. These tabs include cells to define NOAA Atlas 14 rainfall amounts for the 1-year, 2-year and 10-year storm events based on Precipitation Figures under each Overall Water Quantity Narrative, areas to demonstrate the manner in which these rainfall values were defined (rainfall contours generated from NOAA rainfall data), the average basin slope cell, and an option cell to allow Tc default to 5 minutes to remain conservative.

In accordance with the United States Department of Agriculture (USDA) – Natural Resources Conservation Service (NRCS) Part 630 Hydrology National Engineering Handbook, Chapter 15 – Time of Concentration (Chapter 15), Tc's are preliminarily estimated using the Watershed lag method (average basin slope). See White Paper Attachment 6 for documentation of the GIS Average Basin Slope method definition procedure for the project. Composite Curve Number information from Spreadsheet Tab Attachments 1 and 2 are utilized for calculations of watershed flow length. The average basin slope from GIS data analysis are entered, and an option for conservatively using a 5 minute Tc is provided for smaller watersheds. This is often generally utilized within the project improvement footprint where drainage areas are less than 5 acres. The inputs then calculate the watershed lag time, which is then converted to

Tc, if the default of 5 minutes is not utilized. Where CNs are below 50 or above 95 and not defaulted to 5 minutes an alternate methodology (flow segment method per TR-55) will be used and documented under the Spreadsheet Tabs / Attachments 3 and 4. See White Paper Attachment 6 for Average Basin Slope Method definition protocols used for the project.

Figure 7.5: Example Spreadsheet Tab / Attachment 4 – Post-development Times of Concentration (Tc) definition

4 - Post - Tc Definition

P2yr (in) = 3.0

P10yr (in) = 4.3

P1yr (in) = 2.5

DA ID	DA (acres)	CN	Flow Length (ft)	Avg. Watershed Slope (%)	Default Tc of 5 min? (Yes / No)	Calc'd Lag (hr)	Calc'd Tc (hr)	Used Tc (hr)	Used Tc (min)
4A_F_POA_C1	122.92	49	3749	35.64	No	0.350	0.584	0.584	35
4A_F_POA_C2	53.20	54	2268	43.78	No	0.186	0.310	0.310	19
4A_F_POA_C3	#####	40	62269	49.05	No	3.583	5.971	5.971	358
4A_F_POA_R1	0.62	49	157	55.75	Yes	0.022	0.037	0.083	5
P 155.073	0.05	48	35	16.60	Yes	0.012	0.021	0.083	5
P 155.075	0.05	48	35	15.69	Yes	0.013	0.021	0.083	5
P 155.077	0.02	48	20	8.44	Yes	0.011	0.019	0.083	5
P 155.079	0.05	48	35	8.45	Yes	0.017	0.029	0.083	5
P 155.081	0.01	48	13	6.56	Yes	0.009	0.015	0.083	5
P 155.083	0.05	48	35	21.16	Yes	0.011	0.018	0.083	5
P 155a.001	0.13	45	61	52.91	Yes	0.012	0.020	0.083	5
P 155a.003	0.10	41	52	57.44	Yes	0.011	0.019	0.083	5
P 155a.004	0.11	62	56	41.66	Yes	0.008	0.013	0.083	5
P 155a.005	0.15	49	67	36.61	Yes	0.014	0.023	0.083	5
P 155a.007	0.08	48	46	17.17	Yes	0.015	0.025	0.083	5

Spreadsheet Tab / Attachment 5 - TR-55 Calculation – This attachment provides documentation of peak flow calculations in accordance with TR-55 Chapter 4, Graphical Peak Discharge Method. The preliminary results will be reviewed for assessment of sheet flow. The Spreadsheet Tab / Attachment 5 utilizes interpolated values from Table F-1 of TR-55 to tabulate the graphical peak discharge calculations, coefficients (C0, C1, and C2) associated with the Ia/P ratio, initial abstraction (Ia) to precipitation ratio (P). These equations are used to assist in the automation of the flow calculations and have been reviewed to be generally consistent with TR-55 modeled flows.

Figure 7.6: Spreadsheet Tab / Attachment 5 – TR-55 Calculation

TR-55 Peak Flow Computations for DA		4A_F_POA_C1		Predevelopment		
		2 yr	10 yr			
qp	Peak Discharge	3.94	25.22	cfs		
qu	Unit Peak Discharge	275.31	336.89	csm/in	TR-55 Equation	
Am	Drainage Area	0.192	0.192	sqmi	122.94	Ac
Q	Runoff Volume	0.07	0.39	in	SCS CN Equation	
		33,230	173,933	cu ft		
		0.763	3.993	ac-ft	3.230	
	Wetland Area	0.0	0.0	sqmi		
Fp	Pond/Swamp Adjst.	1.00	1.00			
	Tc	0.58	0.58	hr		
	Rainfall Distribution	II	II			
	Storm Frequency	2	10	yr		
	24 hr Rainfall, P	3.00	4.30	in		
	Ia	2.08	2.08	in	TR-55 Equation	
	CN	49.0	49.0			
	Ia/P	0.694	0.484			
	C0	2.29219	2.38440	TR-55 Nomograph Interpolation		
	C1	-0.63724	-0.62943	TR-55 Nomograph Interpolation		
	C2	-0.02310	-0.07288	TR-55 Nomograph Interpolation		

Simplified, Conservative Sheet Flow Review – Point of Analysis (POA)

Definition and Screening

The below provides for the process as to review feature outfall conformance to sheet flow and preliminarily review the potential for impacts of increased volumes of sheet flow (on an aggregate basis) to downstream properties. Using the attachments in this section and the process defined under the White Paper, the conservative assumptions herein may screen areas and allow for focusing of more detailed assessment, only on an as needed basis. No modeling, detailed routing, or accounting for storage is provided under this section.

Spreadsheet Tab / Attachment 6 – Waterbar Assessment & Calculations – This attachment preliminarily evaluates waterbars by feature using tabular TR-55 peak flows from Attachment 5. This is intended to demonstrate sheet flow by feature and what end treatments (Standard Stone Apron Type 1, Standard Stone Apron Type 2), or Flow Diffusers) are required. These features will be aggregated in later evaluation steps, starting with Spreadsheet Tab / Attachment 9.

Figure 7.7: Example Spreadsheet Tab / Attachment 6 – Waterbar Assessment & Calculations

DA	Waterbar ID	Length	Drainage Area	2-YR Peak Q	10-YR Peak Q	Ex Slope Leaving Practice	D/S Land Cover	End Treatment Selection	Standard Stone Apron - Type 1 or Type 2: 2-YR Velocity	10-Yr Runoff Depth	Permiss. Velocity	Depth	Velocity
		ft	acres	cfs	cfs	(ft/ft)	Forested or Pasture?	(Type 1 / 2 / Flow Diffuser)	fps	ft	fps	Pass / Fail	Pass / Fail
4A_F_POA_C1	4A_F_POA_C1	16	122.92	3.94	25.22	0.03	Forested	Flow Diffuser	N/A	N/A	N/A	N/A	N/A
4A_F_POA_C2	4A_F_POA_C2	16	53.20	6.43	26.27	0.01	Forested	Flow Diffuser	N/A	N/A	N/A	N/A	N/A
4A_F_POA_C3	4A_F_POA_C3	16	13,290.42	0.00	130.48	0.02	Forested	Flow Diffuser	N/A	N/A	N/A	N/A	N/A
4A_F_POA_R1	4A_F_POA_R1	16	0.62	0.06	0.36	0.03	Forested	Type 2	0.10	0.07	2.25	PASS	PASS
P 155.073	P 155.073	16	0.05	0.00	0.03	0.23	Forested	Type 1	0.22	0.02	2.25	PASS	PASS
P 155.075	P 155.075	16	0.05	0.00	0.03	0.17	Forested	Type 1	0.20	0.02	2.25	PASS	PASS
P 155.077	P 155.077	16	0.02	0.00	0.01	0.22	Forested	Type 1	0.22	0.01	2.25	PASS	PASS
P 155.079	P 155.079	16	0.05	0.00									
P 155.081	P 155.081	16	0.01	0.00									
P 155.083	P 155.083	16	0.05	0.00									
P 155a.001	P 155a.001	16	0.13	0.00									
P 155a.003	P 155a.003	16	0.10	0.00									
P 155a.004	P 155a.004	16	0.11	0.07									
P 155a.005	P 155a.005	16	0.15	0.02									

Flow Diffuser: Flow Diffuser Req'd	Calc'd Diffuser Length	Proposed Diffuser Length	Flow / foot of Weir Crest Length Req'd based on D/S Slope	Flow / ft of Weir Crest	Flow / ft of Weir Crest based on D/S Slope Met?	Less than 0.1 Acre / foot Length of Crest?	D/S Condition Concen-trated w/in 100 FT	Sheet Flow Maintained ?
Yes / No	ft	ft	cfs / ft	cfs / ft	(Yes / No)	(Yes / No)	(Yes / No)	(Yes / No)
Yes	100.9	1229.2	0.250	0.021	Yes	Yes	yes	No
Yes	105.1	532.0	0.250	0.049	Yes	Yes	yes	No
Yes	521.9	132904.2	0.250	0.001	Yes	Yes	yes	No
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes
No	N/A	N/A	N/A	N/A	N/A	N/A	no	Yes

Spreadsheet Tab / Attachment 7 – Documentation of Ridgetop Sheet Flow Condition – This attachment simply documents that the limited lateral flow from roads within the ridgetop sections of road leave the road / ROW in sheet flow, what stations these conditions occur, and whether or not a downstream concentrated condition exists within the 100 foot ROW buffer. Evaluation of aggregate effects of increased volumes of sheet flow will be provided in subsequent steps.

Figure 7.8: Example Spreadsheet Tab / Attachment 6 – Documentation of Ridgetop Sheet Flow Condition

Starting Station	Ending Station	Rd Type	Left Lateral Imperv Flow Length ft	Right Lateral Imperv Flow Length ft	Side of Road	Imperv Flow = Shallow Conc. [3] ft	Imperv Disconnect (Yes/No)	D/S Condition Conc. (Yes/No)	Criteria Satisfied? (Yes/No)	If No, Add'l D/S Measure for Satisfaction ?
0+00	21+50	F	8	8	R	75	Yes	Yes	No	GD
0+00	21+50	F	8	8	L	75	Yes	Yes	No	GD

Spreadsheet Tab / Attachment 8 – Culverts Definition and Outfall Assessment – Similar to Attachment 6, this provides documentation of sheet flow leaving proposed culverts and what end treatments (Standard Stone Apron Type 1, Standard Stone Apron Type 2, or Flow Diffusers) are required.

Figure 7.9: Example Spreadsheet Tab / Attachment 8 – Culverts Definition and Outfall Assessment

DA	Culvert ID	Drainage Area	2-YR Peak Q	10-YR Peak Q	Pipe Material	Pipe n	Pipe Slope	Design Pipe Diameter	Capacity	Ex Slope Leaving Practice	D/S Land Cover	End Treatment Selection
		acres	cfs	cfs			%	in	cfs	(ft/ft)	Forested or Pasture?	(Type 1 / 2 / Flow Diffuser)
C158.015	C158.015	1.23	0.24	1.36	CMP	0.024	6.00%	12	4.73	0.17	Forested	Flow Diffuser
C158.017	C158.017	0.02	0.02	0.05	CMP	0.024	6.00%	12	4.73	0.10	Forested	Type 1
C158.018	C158.018	0.42	0.03	0.22	CMP	0.024	6.00%	12	4.73	0.10	Forested	Type 1
C158.023	C158.023	1.21	0.13	0.87	CMP	0.024	6.00%	12	4.73	0.10	Forested	Flow Diffuser
C158.024	C158.024	0.80	0.09	0.58	CMP	0.024	6.00%	12	4.73	0.10	Forested	Flow Diffuser
C158.025	C158.025	0.68	0.06	0.43	CMP	0.024	6.00%	12	4.73	0.10	Forested	Type 2
C158.026	C158.026	1.21	0.13	0.87	CMP	0.024	6.00%	12	4.73	0.10	Forested	Flow Diffuser
C159.009	C159.009	1.94	0.33	1.95	CMP	0.024	6.00%	12	4.73	0.69	Forested	Flow Diffuser
C159.011	C159.011											
C159.013	C159.013											
C159.015	C159.015											
C159.016	C159.016											
C159.017	C159.017											
C159.019	C159.019											
C159.020	C159.020											

Standard Stone Apron - Type 1 or Type 2					Flow Diffuser							D/S Condition Concen-trated w/in 100 FT	Sheet Flow Maintained ?
2-YR Velocity	10-Yr Runoff Depth	Permiss. Velocity	Depth	Velocity	Flow Diffuser Req'd	Calc'd Diffuser Length	Proposed Diffuser Length	Flow / foot of Weir Crest Length Req'd based on D/S Slope	Flow / ft of Weir Crest	Flow / ft of Weir Crest based on D/S Slope Met?	Less than 0.1 Acre / foot Length of Crest?		
fps	ft	fps	Pass / Fail	Pass / Fail	Yes / No	ft	ft	cfs / ft	cfs / ft	(Yes / No)	(Yes / No)	(Yes / No)	(Yes / No)
N/A	N/A	N/A	N/A	N/A	Yes	5.5	12.3	0.250	0.111	Yes	Yes	Yes	No
0.16	0.03	2.25	PASS	PASS	No	N/A	N/A	N/A	N/A	N/A	N/A	Yes	No
0.16	0.09	2.25	PASS	PASS	No	N/A	N/A	N/A	N/A	N/A	N/A	Yes	No
N/A	N/A	N/A	N/A	N/A	Yes	3.5	12.1	0.250	0.072	Yes	Yes	Yes	No
N/A	N/A	N/A	N/A	N/A	Yes	2.3	8.0	0.250	0.072	Yes	Yes	Yes	No
0.16	0.08	2.25	PASS	PASS	No	N/A	N/A	N/A	N/A	N/A	N/A	Yes	No
N/A	N/A	N/A	N/A	N/A	Yes	3.5	12.1	0.250	0.072	Yes	Yes	Yes	No
N/A	N/A	N/A	N/A	N/A	Yes	15.6	19.4	0.125	0.101	Yes	Yes	No	Yes
N/A	N/A	N/A	N/A	N/A	Yes	32.6	36.8	0.125	0.111	Yes	Yes	No	Yes
N/A	N/A	N/A	N/A	N/A	Yes	34.7	34.7	0.125	0.125	Yes	Yes	No	Yes
N/A	N/A	N/A	N/A	N/A	Yes	12.8	12.8	0.125	0.125	Yes	Yes	No	Yes
N/A	N/A	N/A	N/A	N/A	Yes	15.5	15.5	0.125	0.125	Yes	Yes	No	Yes
N/A	N/A	N/A	N/A	N/A	Yes	33.8	33.8	0.125	0.125	Yes	Yes	No	Yes
N/A	N/A	N/A	N/A	N/A	Yes	20.6	20.6	0.125	0.125	Yes	Yes	No	Yes
N/A	N/A	N/A	N/A	N/A	Yes	9.0	10.2	0.125	0.111	Yes	Yes	No	Yes

Detailed Review and Modeling

To this point, no detailed modeling for further review has been performed, rather only the areas that require further analysis have been identified. The following provides discussion of the steps that are being taken to review these areas for A) sheet flow areas that may require further evaluation, modeling, or mitigation measures to document no apparent impacts to downstream properties due to increased volumes of sheet flow, and B) areas of concentrated flow that may require further evaluation, modeling, or mitigation measures to document conformance with the energy balance equation. POA naming conventions for the project are provided below for both access roads and pipeline segments.

Access road:

Culverts, waterbars naming is based on the sheet No. It uses the same naming convention as shown on the alignment sheets.

- Culvert: C SheetNo.Numerical numbers. For example, C E146.001
- Waterbar: W SheetNo.Numerical numbers. For example, W E146.001
- POA-R: Access road name_POA_R#. For example 07-001-A009-AR 1_POA_R1
- POA-C: Access road name_POA_C#. For example, 07-001-A009-AR 1_POA_C1
- POA: these are for the points further downstream if there are any. For example, 07-001-A009-AR 1_POA_1
- Energy balance drainage area: Access road name_EB#. For example, 07-001-A009-AR 1_EB1.
- Use the same naming ID for the drainage area of the above points

Pipeline:

- Waterbar: Use the naming IDs provided in GIS
- POA-R: Spreadname_letter_POA-R1. For example, staff 1 will use 11_A_POA_R1. Staff B will use 11_B_POA_R1. (Different letter as it involves different groups of people.)
- POA-C: Spreadname_letter_POA-C1. For example, starting with 11_A_POA_C1 for staff 1, starting with 11_B_POA_C1 for staff 2.
- Energy balance drainage area: Spreadname_letter_EB#. For example, starting with 11_A_EB1 for staff 1. starting with 11_B_EB1 for staff 2.

Methodology for Defining Points of Concentrated Flow**:**

1. Utilizing available data, in order of reliability
    a. Streams and Wetlands

   b. Aerial photography
   c. Available Topography
2. Engineering judgement is used to approximate
   a. The existence of a concentrated flow feature
   b. The estimated geometry of the feature
3. The process will generally conform to:
   a. Where a Stream or Wetland exists a concentrated flow feature is confirmed.
   b. In areas outside Streams and Wetlands review/documentation, aerial photography may confirm the existence of a concentrated flow feature (e.g. ditch).
   c. Finally, topography provides for visual assessment of discrete concentrated flow paths. Note that sections of the project exist within steep, often karst, terrain of western Virginia. As such, broad and steep headwater drainages or ravines often do not contain defined concentrated flow paths.
4. Once the concentrated flow feature is identified, the available data is utilized in concert, where practicable to estimate channel geometry. This includes.
   a. Section is pulled if possible from the available topography. Slopes are estimated based on available topography, which may include the averaging of two slopes in areas of transition and large gaps between contours.
   b. Information such as delineation of ordinary high water and bank width metrics are used to approximate near channel features, which are then nested within the section pulled from available topography, to the extent practicable. Where delineation information is not available, aerial photography may be used to estimate approximate channel width.
   c. Finally, if no delineation or aerial information is useful, the topo will be relied on.
5. The following notes may be considered under this process:
   a. Existing flow paths may contain sheet flow and shallow concentrated flow depending on location and terrain characteristics.
   b. Some potential hydrologic benefits of the roadway development approach may include:

i. the elongation of Tc flow paths
ii. incremental storage along ditch lines with substantially lower slopes than existing grade, even prior to implementation of check dams
iii. use of both elongated flow paths and ditch features to break existing shallow concentrated flow paths and return to sheet flow.

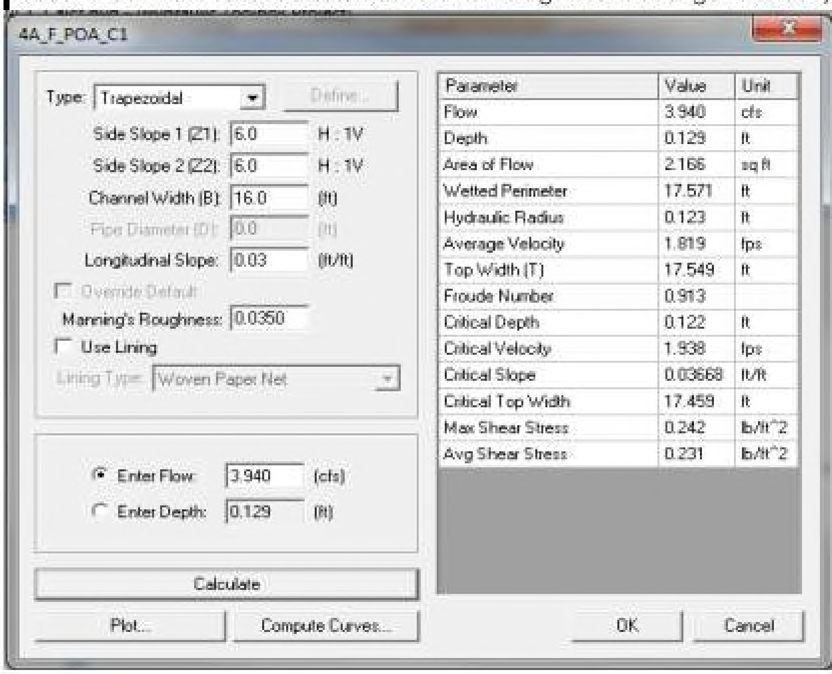
Spreadsheet Tab / Attachment 9 – Sheet Flow Aggregate Downstream Check – Velocity checks are performed for a POA downstream (POA-C) to assess whether the post-development velocity of increased volumes of sheet flow is noted as increased for velocities with two significant figures. Should this be the case and all upstream checks are deemed consistent with the compliance approach, then sheet flow is maintained and conformance with 9VAC25-870-66.D may be satisfied.

Figure 7.10: Example Spreadsheet Tab / Attachment 9 – Sheet Flow Aggregate Downstream Check

Sheet Flow Downstream Velocity Comparison				
Sheet Flow POA	Aggregated Drainage Areas	Pre Velocity (fps)	Post Velocity (fps)	% Velocity Change
ID		2-YR	2-YR	2-YR
4A_F_POA_C1	122.92	1.82	1.82	0.0%
4A_F_POA_C2	53.2	1.40	1.40	0.0%
4A_F_POA_C3	13290.42	4.64	4.64	0.0%

Notes:

1. No accounting for storage of upstream facilities has been included in this unrouted flow comparison.
2. See Attachment 10 for detail on outfalls with a significant change in velocity.



For the purposes of comparing pre-development to post-development velocities in the downstream channel, Manning's roughness coefficients were conservatively selected for each section based upon best available data and engineering judgement. The roughness coefficients remain consistent between the pre- and post-development modeling. The results of this comparative analysis require mitigation measures to contain all volume increases when any velocity increase is noted.

For those areas that an increase is shown due to increased volumes of sheet flow, mitigation steps may be required and further modeling is performed and documented in accordance with the White Paper under further steps below.

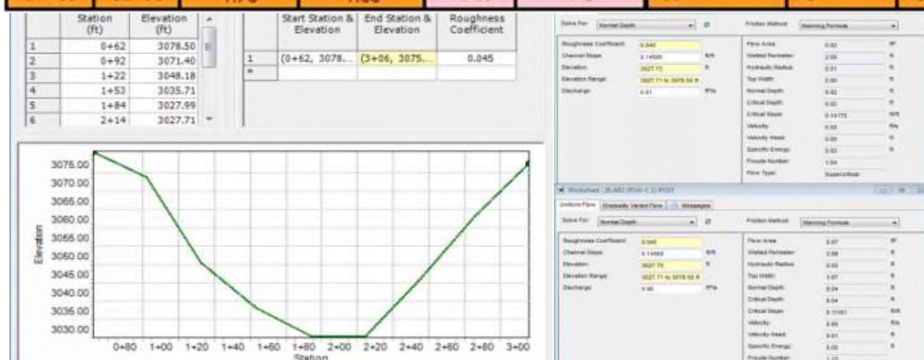
Spreadsheet Tab / Attachment 10A – Mitigation for Sheet Flow – This attachment will provide detail on the modeling that is performed to demonstrate how practices are used collectively to meet either sheet flow or concentrated flow compliance objectives. Velocities are compared for the 2-year storm event, pre-development to post-development unrouted, and flow depths are similarly compared for the 10-year storm event. Documentation of the proposed mitigation strategies are provided and a discussion of the area of concern is included along with any modeling support and additional documentation (i.e. detailed routings, Vs/Vr comparisons, or other modeling results) underneath each table.

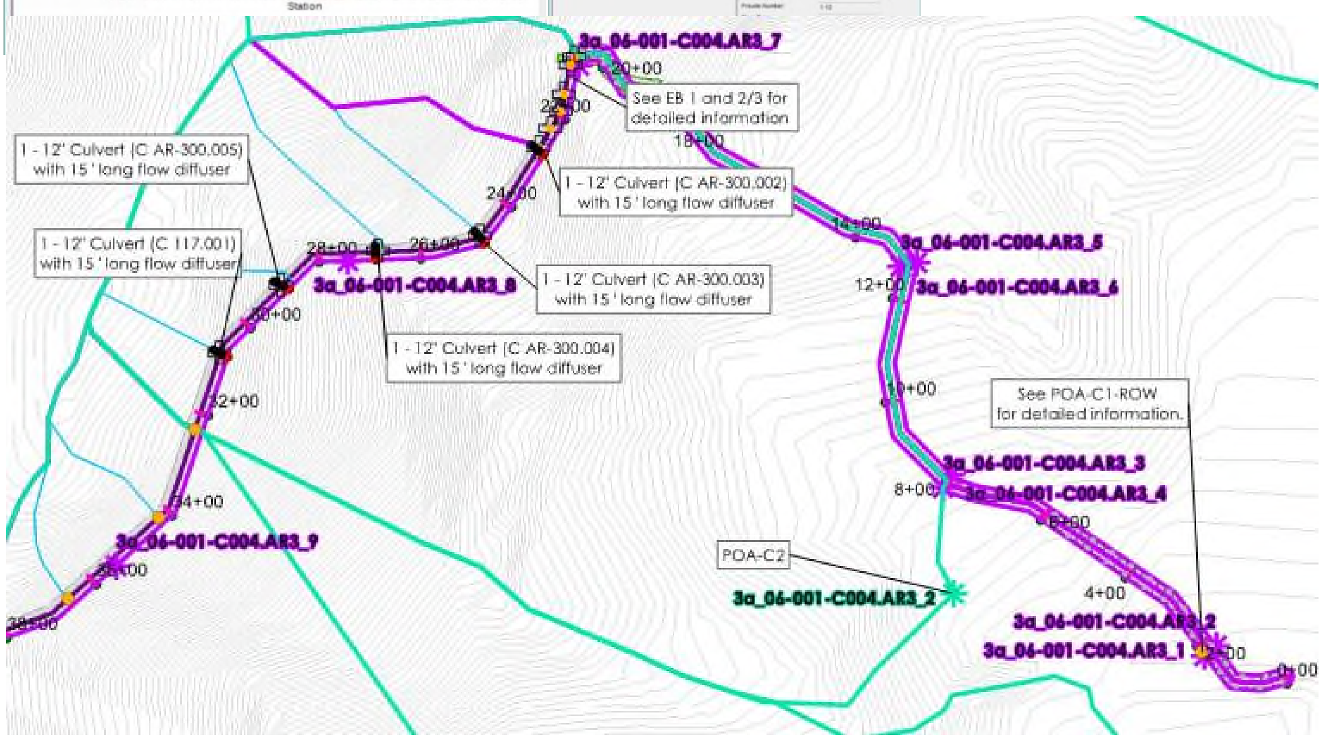
Figure 7.11: Example Spreadsheet Tab / Attachment 10a – Mitigation for Sheet Flow

POA =					C1-ROW				
Starting Station	Ending Station	Existing Vel (fps)	Postdevelopment Vel (fps)	% Vel Change	Change within +1% of Pre	1-Storage Accounting / Modeling	2-Roadway redux to 12 feet	3-Road Rehab	Energy Balance Needed
		2-YR	2-YR (Unrouted)	2-YR	(Yes/No)	(Yes/No)	(Yes/No)	(Yes/No)	(Yes/No)
0+00	18+88	1.08	1.50	38.9%	No	Yes	No	No	No

Note: Upstream C2 aggregate storage (below) criteria satisfied. C1 was evaluated for additional ROW improvements only.

POA =					C2				
Starting Station	Ending Station	Existing Vel (fps)	Postdevelopment Vel (fps)	% Vel Change	Change within +1% of Pre	1-Storage Accounting / Modeling	2-Roadway redux to 12 feet	3-Road Rehab	Energy Balance Needed
		2-YR	2-YR (Unrouted)	2-YR	(Yes/No)	(Yes/No)	(Yes/No)	(Yes/No)	(Yes/No)
21+50	32+35	1.75	1.88	7.4%	No	Yes	No	No	No



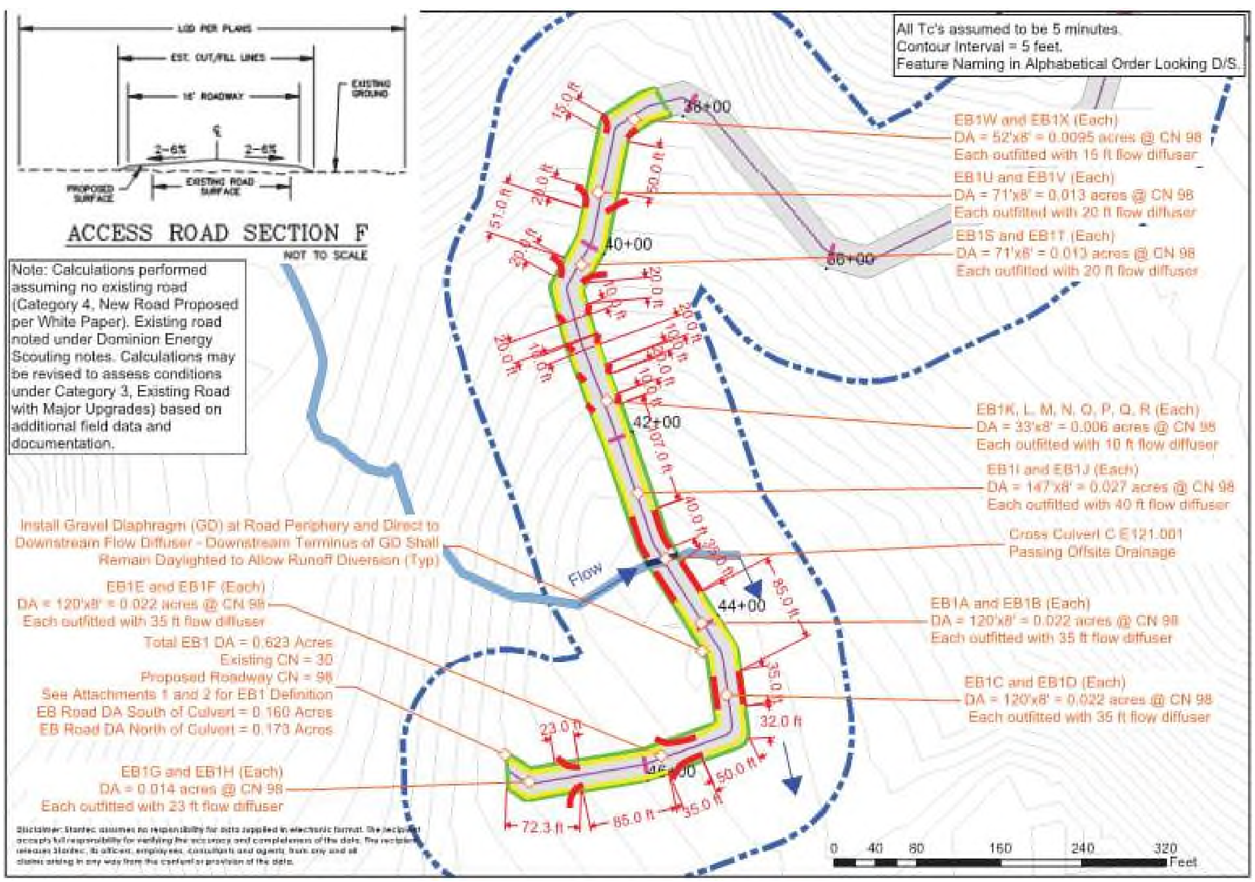


Spreadsheet Tab / Attachment 10B – Mitigation for Concentrated Flow – Similar to Spreadsheet Tab / Attachment 10A this tab includes measures and modeling approach notes to provide compliance with the energy balance requirements, as applicable. Several different types of modeling software are utilized to perform detailed routed modeling, see applicable modeling software under Section 8 below. Energy Balance compliance documentation, with routed peak flows and runoff volumes, is provided under Spreadsheet Tab / Attachment 13.

Figure 7.12: Example Spreadsheet Tab / Attachment 10b – Mitigation for Concentrated Flow

POA =					EB-1				
Starting Station	Ending Station	Existing flow (cfs)	Postdevelopment flow (cfs)	% flow Change	Change within +1% of Pre	1-Storage Accounting / Modeling	2-Roadway redux to 12 feet	3-Road Rehab	Energy Balance Needed
		1-YR	1-YR (Unrouted)	1-YR	(Yes/No)	(Yes/No)	(Yes/No)	(Yes/No)	(Yes/No)
38+00	47+20	0.00	0.90	#DIV/0!	#DIV/0!	Yes	No	No	No

POA =					EB-2				
Starting Station	Ending Station	Existing flow (cfs)	Postdevelopment flow (cfs)	% flow Change	Change within +1% of Pre	1-Storage Accounting / Modeling	2-Roadway redux to 12 feet	3-Road Rehab	Energy Balance Needed
		1-YR	1-YR (Unrouted)	1-YR	(Yes/No)	(Yes/No)	(Yes/No)	(Yes/No)	(Yes/No)
8+25	11+00	0.00	0.13	#DIV/0!	#DIV/0!	Yes	No	No	No



Spreadsheet Tab / Attachment 11 – TR-55 Unrouted Flow – This attachment provides a summary of the unrouted TR-55 flows from mitigation efforts defined under both Overall Water Quantity Narrative Attachments 10a and 10b.

Figure 7.13: Example Spreadsheet Tab / Attachment 11 – TR-55 Unrouted Flow

PEAK FLOW SUMMARY										
Outfall	Concen-trated?	Existing Peak Discharge (cfs)			Postdevelopment Peak Discharge (cfs)			Percent Difference		
ID	(Yes/No)	1-YR	2-YR	10-YR	1-YR	2-YR	10-YR	1-YR	2-YR	10-YR
POA-EB1	Yes	0.00	0.00	0.00	0.11	0.16	0.31	#DIV/0!	#DIV/0!	#DIV/0!
POA-EB2/3	Yes	0.00	0.00	0.01	0.18	0.22	0.32	#DIV/0!	#DIV/0!	3100.0%

Notes:

1. TR-55 Modeling of Mitigation Efforts (Sheet Flow & Concentrated Flow).

Spreadsheet Tab / Attachment 12 – TR-55 Routed Flow and Volume Summary – This attachment provides a summary of the routed TR-55 flows from the mitigation efforts defined under both Overall Water Quantity Narrative Attachments 10 and 10A.

Figure 7.14: Example Spreadsheet Tab / Attachment 12 – TR-55 Routed Flow and Volume Summary

PEAK FLOW SUMMARY										
Outfall	Concen-trated?	Existing Peak Discharge (cfs)			Postdevelopment Peak Discharge (cfs)			Percent Difference		
ID	(Yes/No)	1-YR	2-YR	10-YR	1-YR	2-YR	10-YR	1-YR	2-YR	10-YR
POA-EB1	Yes	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!	#DIV/0!
POA-EB2/3	Yes	0.00	0.00	0.01	0.00	0.00	0.01	#DIV/0!	#DIV/0!	0.0%

RUNOFF VOLUME SUMMARY										
Outfall	Concen-trated?	Existing Volume (ac-ft)			Proposed Volume (ac-ft)			Percent Difference		
ID	(Yes/No)	1-YR	2-YR	10-YR	1-YR	2-YR	10-YR	1-YR	2-YR	10-YR
POA-EB1	Yes	0.000	0.000	0.000	0.000	0.000	0.001	#DIV/0!	#DIV/0!	#DIV/0!
POA-EB2/3	Yes	0.000	0.000	0.003	0.000	0.000	0.005	#DIV/0!	#DIV/0!	66.7%

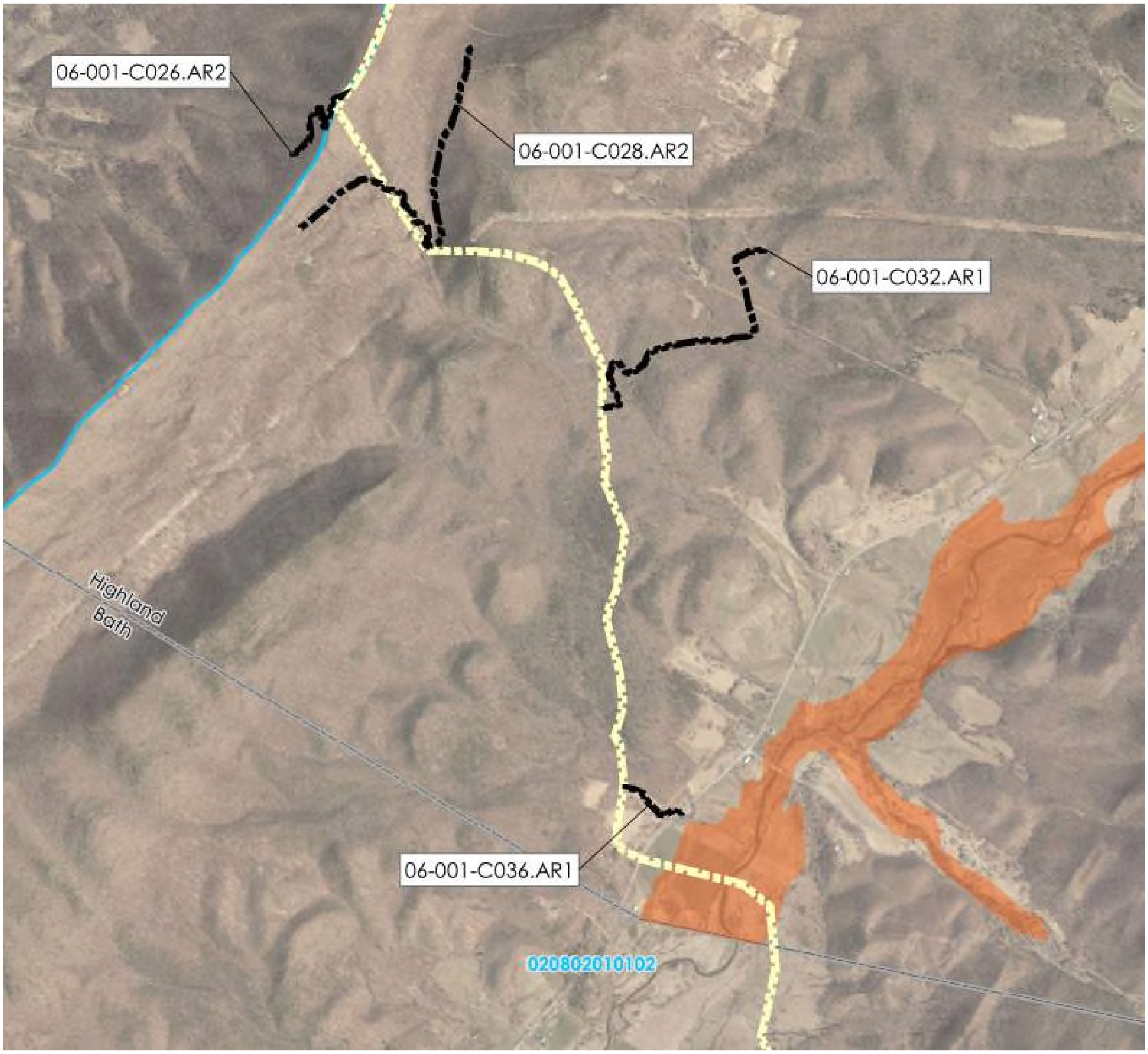
Spreadsheet Tab / Attachment 13 – Flow / Energy Balance Summary – This attachment combines the outfalls and flow information from Overall Water Quantity Narrative Attachments 11 and 12 to further document where energy balance is required, and how it is met in terms of allowable flow.

Figure 7.15: Example Spreadsheet Tab / Attachment 13 – Flow / Energy Balance Summary

Outfall	Concen-trated? (Yes/No)	Storm Event	I.F.	Storm Flow Summary			RV Pre (ac-ft)	RV Post (ac-ft)	Q Allowable (cfs)	Meets E.B. (Yes / No)	Flow Attenuation (Yes/No)
				Ex Peak (CFS)	Prop Peak (CFS)	Change in Flow (%)					
4A_F_POA_C1	yes	1	0.8	0.00	0.00	#DIV/0!	0.000	0.000	#DIV/0!	#DIV/0!	Yes
		2	0.8	0.00	0.00	#DIV/0!	N/A	N/A	N/A	N/A	Yes
		10	0.8	0.00	0.00	#DIV/0!	N/A	N/A	N/A	N/A	Yes
4A_F_POA_C2	yes	1	0.8	0.00	0.00	#DIV/0!	0.000	0.000	#DIV/0!	#DIV/0!	Yes
		2	0.8	0.00	0.00	#DIV/0!	N/A	N/A	N/A	N/A	Yes
		10	0.8	0.00	0.00	#DIV/0!	N/A	N/A	N/A	N/A	Yes
4A_F_POA_C3	yes	1	0.8	0.00	0.00	#DIV/0!	0.000	0.000	#DIV/0!	#DIV/0!	Yes
		2	0.8	0.00	0.00	#DIV/0!	N/A	N/A	N/A	N/A	Yes
		10	0.8	0.03	0.03	0.00	N/A	N/A	N/A	N/A	Yes

Spreadsheet Tab / Attachment 14 – Flood Protection – For those concentrated flow areas, a demonstration of Flood Protection is provided here. Documentation will be provided to address Flood Protection criteria (9VAC25-870-66.C). FEMA Flood Insurance Rate Maps (FIRM) or local digital GIS floodplain mapping will be provided/depicted, if applicable. Note that some areas of access road improvements may be through existing regulated floodplains. The construction of these access roads is understood to be of limited footprint, no net fill, work to be performed at or near existing grade, and the topdressing of stone in areas of existing gravel. As such, no impact to the existing regulated floodplain is intended. See the individual cover memo (Overall Water Quantity Narrative) for specific information or exceptions.

Figure 7.16: Example Spreadsheet Tab / Attachment 14 – Flood Protection



Spreadsheet Tab / Attachment 15 – Modeling Summaries – This provides detailed modeling results for review as necessary, including CulvertMaster, or other programs, as applicable. Given their significant size, TR-55 modeling results (PondPack, HydroCAD, etc) are combined under the cover memorandum (Overall Water Quantity Narrative) Appendix H for reference, as necessary.

Spreadsheet Tab / Attachment 16 – Roadside Channel Design – Each access road has been designed utilizing an array of typical sections established for the project. Several of these sections involve the implementation of roadside channels. Spreadsheet Tab / Attachment 16 utilizes the flows developed on Tab / Attachment 5 along with proposed slopes and single section modeling runs to define minimum channel depths, average shear stress, and proposed channel linings. The majority of the analysis on this tab is performed outside of the spreadsheet and compiled in this location for documentation.

Figure 7.17: Example Spreadsheet Tab / Attachment 16 – Roadside Channel Design

Spread	Access Road	Station Start	Station Stop	Channel Slope (ft/ft)	Channel Sizing				Channel Lining				
					10-Yr Flow (cfs)[1]	Channel Type	10-Yr Flow Depth (ft)	Min. Channel Depth (ft)	2-Yr Flow (cfs)[1]	2-Yr Flow Area (sf)	2-Yr Wetted Perimeter (ft)	2-Yr Average Shear Stress (lb/sf)	Channel Lining
3A	06-001-C004.AR3	21+50	22+74	0.138	0.00	Type I	0.00	1.00	0.00	0.00	0.00	#DIV/0!	Grass Lined
3A	06-001-C004.AR3	22+74	24+74	0.105	0.00	Type I	0.00	1.00	0.00	0.00	0.00	#DIV/0!	Grass Lined
3A	06-001-C004.AR3	24+74	26+75	0.281	0.00	Type I	0.00	1.00	0.00	0.00	0.00	#DIV/0!	Grass Lined
3A	06-001-C004.AR3	26+75	28+75	0.378	0.00	Type I	0.00	1.00	0.00	0.00	0.00	#DIV/0!	Grass Lined
3A	06-001-C004.AR3	28+75	30+77	0.407	0.00	Type I	0.00	1.00	0.00	0.00	0.00	#DIV/0!	Grass Lined
3A	06-001-C004.AR3	30+77	32+32	0.143	0.00	Type I	0.00	1.00	0.00	0.00	0.00	#DIV/0!	Grass Lined
3A	06-001-C004.AR3	32+32	34+22	0.213	0.00	Type I	0.00	1.00	0.00	0.00	0.00	#DIV/0!	Grass Lined
3A	06-001-C004.AR3	34+22	36+58	0.063	0.00	Type I	0.00	1.00	0.00	0.00	0.00	#DIV/0!	Grass Lined
3A	06-001-C004.AR3	36+58	38+18	0.194	0.00	Type I	0.00	1.00	0.00	0.00	0.00	#DIV/0!	Grass Lined

Notes:

1. Flows taken from Water Quantity Spreadsheet Attachment 5 "TR-55 Flow Calculation"
2. Average Shear Stress Calculated using the following equation: $\tau = 62.4*slope*(flow\ area/wetted\ perimeter)$
3. Flow Depths, Areas, and Wetted Perimeters taken from Flowmaster Modeling Results
4. Minimum Freeboard of 0.1 feet is provided in the 10-Yr Storm Event
5. Slope for each roadside ditch section was estimated by taking the approximate elevation at the starting and ending stations and dividing the change in elevation by the length of the section.
6. All blue cells were manually entered because the points of analyses generate no flow up to the 10-year storm event and are beyond the computational limits of the TR-55 methodology.
7. Typical channel geometries and permissible shear stress values noted below per previous ERM plan submittal package.

Reference 1. Typical Channel Geometry

Roadside Ditch Geometry	Bottom Width (feet)	Side Slope (run/rise)
Type I	0	2
Type II	2	2
Type III	4	2

Reference 2. Allowable Shear Stress

Lining Type	Manning's roughness coefficient, n	Permissible Shear Stress (lbs/ft²)
Grass Lined	0.035	0.398
Riprap (D_{50} - 6 in)	0.069	2.4
Riprap (D_{50} - 12 in)	0.08	4.8

Generally, note that changes to standard spreadsheet columns and calculations will be made in blue text and noted, where applicable for additional clarity.

Storage Volume Estimation

Outside of the overall Water Quantity Calculation Spreadsheet, an additional spreadsheet was developed to assist in estimating the volume attenuation provided by the proposed practices. This spreadsheet is utilized when assessing the storage volume to runoff volume relationship described herein and documented in TR-55. The spreadsheet also provides an outlet structure cross section for the flow diffuser that can be utilized if detailed routed modeling efforts are required. Additional discussion on how the stage storage curves and associated volumes per practice were developed is provided below.

Flow Diffuser – The flow diffuser stage storage curve was developed utilizing a cross sectional area subdivision of the proposed flow diffuser geometry. Areas of open storage and stone void space storage were differentiated and a porosity of 0.4 was assigned to all void storage areas. The stage storage curve was then developed utilizing these areas and unitized volumes along with an inputted flow diffuser length to estimate the overall diffuser storage volume. A rectangular weir section is similarly populated based on the inputted flow diffuser length assuming that the weir crest is located at the base of the stone berm where the structure ties-out to existing grade.

Waterbar – The waterbar stage storage curve was developed utilizing a conservative trapezoidal section with a 0.17 ft bottom width, typical 2:1 side slopes, and a standard depth of 6 inches. The stage storage curve was then developed utilizing this geometry along with a standard waterbar length of 16 feet for the access roads and a modified length for the pipeline ROW applications.

Check Dam – The check dam stage storage curve was developed utilizing a conservative v-ditch section with typical 2:1 side slopes and a standard depth of 6 inches. The stage storage curve was then developed utilizing this geometry along with a standard ponding length of 5 feet, per a conservative 20% roadway slope.

Gravel Diaphragm – The gravel diaphragm stage storage curve was developed utilizing a trapezoidal section with a 1 ft depth, 1 ft bottom width and typical 2:1 side slopes. The stage storage curve was then developed utilizing this geometry along with an effective length, a porosity of 0.4, and a percent usable volume estimate of 33% to remain conservative in most situations. The 33 percent usable volume reduces the storage volume of the diaphragm conservatively based on an estimated cross sectional area reduction for a roadway slope of 40%. Should it be necessary to credit volumes in excess of this conservative level, this will be documented specifically under the Water Quantity Calculations Package.

Project specific checklists are included under Attachment 7

8.0 SOFTWARE MODELING PACKAGES

Software programs utilized in this White Paper and water quantity analysis packages include:

Bentley Systems FlowMaster v8i

Bentley Systems CulvertMaster v3.3

Bentley Systems PondPack v8i

Federal Highways Administration, Hydraulic Toolbox 4.1 or Later

NRCS, Win TR-55, Version 1.00.10

Autodesk Inc., Hydraflow Hydrographs Extension for AutoCAD Civil 3D 2011, Version 8

HydroCAD Software Solutions LLC, HydroCAD Stormwater Modeling 10.0 or Later

HEC-HMS Version 4.0 or Later

Esri ArcGIS Desktop (Versions 10.3 & 10.4)

Esri ArcGIS Spatial Analyst Extension (Versions 10.3 & 10.4)

Esri Arc Hydro Tools (Versions 10.3 & 10.4)

9.0 REFERENCES

Chapter 4 and Chapter 5– Hydrologic Methods, Virginia Stormwater Management Handbook (VSWMH), Volume II. Virginia Department of Conversation and Recreation, 1999.

Chapter 8 - Culverts, Drainage Manual. Virginia Department of Transportation, 2017.

Chapter 15 – Time of Concentration. Engineering Handbook, Part 630 Hydrology. United States Department of Agriculture. 2010.

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Technical Release 55 Urban Hydrology for Small Watersheds (TR-55). United States Department of Agriculture and Natural Resources Conservation Service. 1986.

Watershed Boundary Dataset (WBD). Coordinated effort between the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), the United States Geological Survey (USGS), and the Environmental Protection Agency (EPA). Available online at https://nhd.usgs.gov/wbd.html. Accessed January 2017.

Maine Stormwater Best Management Practices Manual, Volume III. BMP Technical Design Manual Chapter 8.3 Level Spreaders http://www.maine.gov/dep/land/stormwater/stormwaterbmps/

United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) Wildlife Habitat Council Fish and Wildlife Habitat Management Leaflet Number 42 “Scrub-shrub Birds”, January 2007.

Virginia Erosion & Sediment Control Handbook, Virginia Department of Environmental Quality, Third Edition, 1992.

ATTACHMENTS

Attachment 5 – References: Standards and Specifications for Flow Diffusers

A5.1: H.R.C Research Series Report No. 10 – Analysis of Flow Through Porous Media as Applied to Gabion Dams Regarding the Storage and Release of Storm Water Runoff, NAHB/NRC Designated Housing Research Center at Penn State, August 1992

A5.2: Maine Level Spreader – Section 8.3, Maine Stormwater Best Management Practices Manual, September 2010

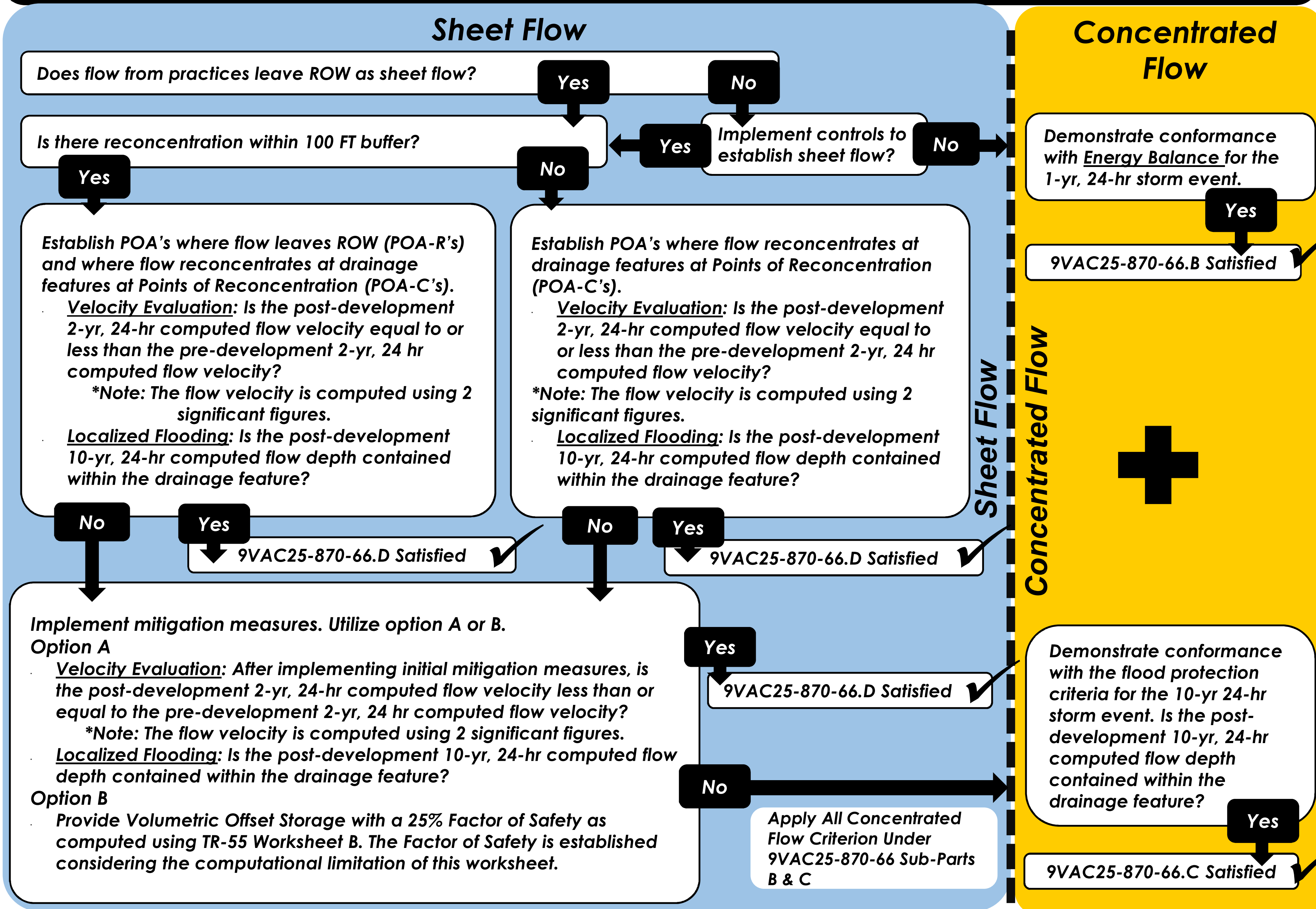
Attachment 6 – Procedure: Calculating Average Basin Slope

ATTACHMENTS

Attachment 1 – Water Quantity Compliance Flow Chart

Water Quantity Compliance Flow Chart

Rev. 12/20/2017



Notes: ROW (Right-of-Way); POA (Point of Analysis) CN (Curve Number)

Attachment 2 – Curve Number Assignments

Table A2.1: Land cover and associated classifications (descriptions, Curve Numbers, roughness coefficients, shallow and concentrated flow surface conditions)

Table A2.2: Pre-Development and Post-Development Land Cover Categories

Attachment A2.3: TR-55 Curve Number Limitation Evaluation

Table A2.1: Land cover and associated classifications (descriptions, Curve Numbers, roughness coefficients, shallow and concentrated flow surface conditions)

					Curve Number (CN) (See Note 2 and 3)					Roughness Coefficient (Manning's n) for Sheet Flow (See Note 4)		
					Hydrologic Soil Group				TR-55 Land Cover Description			
Land Cover Category	**VGIN Classification**	**VGIN Classification #**	**Land Cover Description**	**VGIN Reference Section (See Note 1)**	**A**	**B**	**C**	**D**		**n**	**Surface Description**	**Shallow Concentrated Flow Surface Condition (See Note 5)**
Turf Grass	Turf Grass	71	The Turf Grass classification includes vegetation (primarily grasses) planted in developed settings for erosion control or aesthetic purposes, as well as natural herbaceous vegetation and undeveloped land, including upland grasses and forbs. Examples include but are not limited to recreational areas, lawns, and vacant lands. Any grasses or managed turf that fall into this description will be included if the land is less than 1 acre in size, or visually determined to be recreational from the imagery.	2.3.4.1	39	61	74	80	TR-55, Table 2-2a, Open Space (lawns, parks, golf courses, cemeteries, etc.), good condition (grass cover > 75%)	0.15	Short grass, prairie	Unpaved
Impervious	Extracted Buildings, driveways, parking lots, roads, etc.; External Local & Statewide Impervious data	21/22	The Extracted and External classification includes areas characterized by a high percentage of constructed materials such as asphalt and concrete, buildings and parking lots, and infrastructure such as roads and rail-roads. Buildings features are represent residential and commercial building foot-prints. Roads features represent automotive thoroughfares. The information was derived from statewide data such as linear roadway centerline features, roadway classification (interstate, highway, or secondary roadway), specific VDOT (Virginia Department of Transportation) attribution such as number of lanes, lane width and hard shoulder width. Ancillary roads features are linear features that were not considered to be roadway centerlines or streams, but were visible on the aerial photography. These features may be driveways, wide hiking or ATV trails, logging roads, jeep trails, private roadways, or other similar features. Railroads features represent locomotive railway centerlines and are represented as linear features. Other Impervious surface features are polygonal features representing other potential impervious surfaces (e.g., large parking lots).	2.3.6.1	98	98	98	98	TR-55, Table 2-2a, Paved parking lots, roofs, driveways, etc.	0.01	Smooth surfaces (concrete, asphalt, gravel, or bare soil)	Paved
Forest	Forest	41	The Forest classification includes areas characterized by tree cover of natural or semi-natural woody vegetation, including deciduous, ever-green, and mixed foliage types. Any area that is not encompassed by a 1 acre circle is characterized as Tree. The Deciduous Forest class includes all band spectrums for the leaf-off trees and those with browning leaves. The Coniferous Forest class includes mixed foliage and evergreen trees. The Forest Shadow class includes the darker color bands associated with the shadows produced in more mountainous or hilly forested areas.	2.3.7.1	30	55	70	77	TR-55, Table 2-2c, Woods. Good hydrologic condition.	0.8	Woods, dense underbrush	Unpaved
Forest	Tree	42	The Tree classification includes areas characterized by tree cover of natural or semi-natural woody vegetation, less than or equal to an acre in size. This class includes deciduous, evergreen, and mixed foliage types.	2.3.8.1	30	55	70	77	TR-55, Table 2-2c, Woods. Good hydrologic condition.	0.8	Woods, dense underbrush	Unpaved
Wood/Grass	Harvested/ Disturbed Forest	61	The Harvested/Disturbed Forest classification includes areas of forest clear-cut, temporary clearing of vegetation, and other dynamically changing land cover due to land use activities. These features are categorized where there is 30% canopy cover or less.	2.3.9.1	32	58	72	79	TR-55, Table 2-2c, Woods-grass combination (orchard or tree farm. Good hydrologic condition.	0.4	Woods, light underbrush	Unpaved
Shrub/Scrub	Shrub / Scrub	51	The Shrub/Scrub classification is characterized by natural or semi-natural woody vegetation with aerial stems generally less than 6 meters tall as well as evergreen and deciduous species of true shrubs, young trees, and those that are small or stunted due to environmental conditions. This feature includes easement fields, stunted tree growth around wetland features, and any additional patches of stunted trees and turf that do not fit into the other classifications.	2.3.10.1	30	48	65	73	TR-55, Table 2-2c, Brush. Good hydrologic condition.	0.8	Woods, dense underbrush	Unpaved
Agriculture	Pastureland	81	The Pastureland classification includes areas of grasses, legumes, or grass-legume mixtures planted for live-stock grazing or the production of seed or hay crops. The land may be used only for pasture in rotation with crops, or more or less permanently used for this purpose. Any grasses or managed turf that fall into this description, or otherwise cannot be categorized as cropland or recreational will be included here if the land is greater than 1 acre in size.	2.3.3.1	39	61	74	80	TR-55, Table 2-2c, Pasture, grassland, or range - continuous forage for grazing. Good hydrologic condition.	0.17	Cultivated soils, residue cover >20%	Unpaved

Table A2.1 Continued: Land cover and associated classifications (descriptions, Curve Numbers, roughness coefficients, shallow concentrated flow surface conditions, and VRRM Land Cover)

					Curve Number (CN) (See Note 2 and 3)							
					Hydrologic Soil Group					Roughness Coefficient		
Land Cover Category	**VGIN Classification**	**VGIN Classification #**	**Land Cover Description**	**VGIN Reference Section (See Note 1)**	**A**	**B**	**C**	**D**	**TR-55 Land Cover Description**	**n**	**Surface Description**	**Shallow Concentrated Flow Surface Condition (See Note 5)**
Agriculture	Cropland	82	The Cropland classification includes areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber, or is maintained in developed settings for specific purposes. Examples include row crops, small grain, fallow (tilled with sparse vegetative cover), feeding operations, orchards, groves, vineyards, nurseries, and other horticultural areas. Any grasses or managed turf that fall into this description, or otherwise cannot be categorized as pastureland will be included here if the land is less than 1 acre in size.	2.3.2.1	67	78	85	89	TR-55, Table 2-2b, Row crops, straight row. Good hydrologic condition.	0.17	Cultivated soils, residue cover >20%	Unpaved
Wetlands	NWI/Other	91	The NWI/Other classification includes all NWI (National Wetlands Inventory) Woody Wetland areas where forest or shrub land vegetation accounts for 25% to 100% of the cover and the soil or substrate is periodically saturated with or covered with water. This classification also includes all NWI Emergent Wetland features where perennial herbaceous vegetation accounts for 25% to 100% of the cover and the soil or substrate is periodically saturated with or covered with water.	2.3.11.1	30	55	70	77	TR-55, Table 2-2c, Woods. Good hydrologic condition.	0.4	Woods, light underbrush	Unpaved
Barren	Barren	31	The Barren classification includes areas with little or no vegetation characterized by bedrock, desert pavement, beach and other sand/rock/clay accumulations, as well as areas of extractive mining activities with significant surface expression. Example features include but are not limited to beaches, volcanic material, slides, quarries, strip mines, and gravel pits. Vegetation, if present, would be more widely spaced than that of the Scrub/Shrub category, and would have limited ability to support life (such as clearing due natural fire, flood, etc.). Disturbed Forest is defined as land that is in a transitional state where barren characteristics may be inferred, but there are no sizable areas that are purely barren.	2.3.5.1	77	86	91	94	TR-55, Table 2-2b, Fallow, bare soil.	0.01	Smooth surfaces (concrete, asphalt, gravel, or bare soil)	Paved
Water	Water	11	The Water classification includes all areas of open water; typically 25% or greater pixel cover of water, and all areas characterized by perennial cover of ice/snow and includes drainage network and basins such as rivers, streams, lakes, canals, waterways, reservoirs, ponds, bays, estuaries, and ocean as defined by the NHD (National Hydrography Dataset).	2.3.1.1	100	100	100	100	No capture of stormwater.	n/a	n/a	n/a
Permanent ROW	Shrub / Scrub	98	The Permanent ROW is being treated as Shrub/Scrub which is characterized by natural or semi-natural woody vegetation with aerial stems generally less than 6 meters tall as well as evergreen and deciduous species of true shrubs, young trees, and those that are small or stunted due to environmental conditions. This feature includes easement fields, stunted tree growth around wetland features, and any additional patches of stunted trees and turf that do not fit into the other classifications.	2.3.10.1	30	48	65	73	TR-55, Table 2-2c, Brush. Good hydrologic condition.	0.8	Woods, dense underbrush	Unpaved
Gravel	n/a	99	The Gravel classification represents the post-development road surface associated with Major Upgrade and Proposed New access roads. The estimated road width is no more than 16 feet in the Post-Development condition.	n/a	98	98	98	98	TR-55, Table 2-2a, Paved parking lots, roofs, driveways, etc.	0.01	Smooth surfaces (concrete, asphalt, gravel, or bare soil)	Paved

Notes:

1. VGIN Reference: Technical Plan of Operations. Virginia Statewide Land Cover Data Development. WorldView Solutions Inc. Prepared for Virginia Information Technologies Agency and Virginia Department of Environmental Quality. May 6, 2016. Version 7.0. Accessed September 2017. <http://www.vita.virginia.gov/uploadedFiles/VITA_Main_Public/ISP/VGIN/Land_Cover/LandCover_TechnicalPlanOfOperations_v7_20160506.pdf>
2. TR 55: Technical Release 55 Urban Hydrology for Small Watersheds (TR-55). United States Department of Agriculture and Natural Resources Conservation Service. 1986.
3. The Curve Numbers are derived from TR-55 (see Note 2), referenced by the Virginia Stormwater Management Handbook, 4-4.4.3, C.
4. The Curve Numbers associated with gravel have been conservatively estimated as impervious area. The design team may request modification of these values upon future design guidance and agency approval.
5. The Roughness coefficients (Manning's n) for Sheet Flow is derived from TR-55 (see Note 2), Table 3-1 that is also presented in the Virginia Stormwater Management Handbook, Table 4-9a.
6. The surface condition associated with Shallow Concentrated Flow is presented in both in TR-55 (see Note 2), Figure 3-1 and the Virginia Stormwater Management Handbook, 4-4.3.3.E.2.b.
7. VRRM: Guidance Memo No. 16-2011- Updated Virginia Runoff Reduction Method Compliance Spreadsheets - Version 3.0, May 2, 2016.

Table A2.2: Pre-Development and Post-Development Land Cover Categories

Pre-Development Condition Land Cover Category	Post-Development Condition Land Cover Category
Turf Grass	Turf Grass, unless access road surface;Gravel for access road surfaces only
Impervious	Impervious
Forest, Tree	Shrub/Scrub, unless access road surface;Gravel for access road surfaces only
Wood/Grass	Shrub/Scrub, unless access road surface;Gravel for access road surfaces only
Shrub/Scrub	Shrub/Scrub, unless access road surface;Gravel for access road surfaces only
Agriculture (Cropland)	Agriculture (Cropland) unless access road surface;Gravel for access road surfaces only
Agriculture (Pastureland)	Agriculture (Pastureland) unless access road surface;Gravel for access road surfaces only
Wetlands	Wetlands, unless access road surface;Gravel for access road surfaces only
Barren	Barren, unless access road surface;Gravel for access road surfaces only
Water	Water

Attachment A.2.3 – TR-55 Curve Number Limitation Evaluation

The following is provided for additional support of the TR-55 Curve Number procedure noted under the White Paper Section 7.3 for the purposes of producing a conservative determinant flow for evaluations for curve numbers less than 40. The following is excerpted from White Paper comment response provided by ACP to DEQ on 2/16/2018.

From Section 7.3 (page 46) of the Virginia ACP Stormwater Quantity Compliance Methodology, or White Paper, submitted to DEQ on February 7, 2018:

> *Curve Number Limitations – Note Curve Numbers less than 40 are problematic under the TR-55 framework and will produce unreliable results for flow and volume calculations (essentially, discharges and volumes cannot be relied upon and are indeterminate for CN<40 due to underlying limitations in the compliance methodology). The TR-55 manual notes for a CN of less than 40, another procedure should be used to determine runoff.*
>
> *Given many of the existing project soils and land uses, many areas of very low CN may be noted. With the large initial abstraction of greater than 3 inches for any CNs less than 40 and the limitations of the TR-55 modeling equations (graphical peak discharge method), alternative approaches were discussed. However due to the Commonwealth's stormwater management compliance framework being reliant on the methodologies outlined in TR-55, an alternative, conservative approach to upward adjust the Curve Numbers was derived if the spreadsheet results are utilized in lieu of more sophisticated hydrologic modeling. To resolve the limitations of the graphical peak discharge method in the spreadsheet, the consultant team is conservatively increasing CNs where composite CN's are below the TR-55 threshold of 40 to produce values that would fit within the modeling parameters and therefore could be analyzed in both the pre- and post-development scenarios.*
>
> *To address this manual adjustment, while still calculating the CNs per the land use and soil classifications, the consultant team added in additional columns on the VGIN Land Cover Data, Attachments 1 and 2. These changes have been highlighted in blue and are conservatively used throughout the remainder of the spreadsheet for all calculations. The underlying individual land cover/soil constituents which are less than 40 (and create the issue when composited) are upward adjusted to 40 (for both pre and post-development). In this regard, when a predevelopment composite CN (Water Quantity Calculations Package Attachment 1 - VGIN Land Cover Data – Pre, Calculated CN column) is less than 40, a second adjusted CN table (CN Table 2 under Water Quantity Calculations Package Attachments 1 and 2) will be utilized for both the pre-development and post-development CN calculations. This CN Table 2 provides for upward adjustment of all constituent land cover CNs that are less than 40 under TR-55 to CN of 40. The composite curve number will then be generated by this CN Table 2. The exception will be when the post-development CN decreases to below 40 (due to a resultant scrub-shrub land use for instance) from a pre-development CN equal to or greater than 40. In this instance the*

calculated composite post-development curve number will be raised to a minimum of 40 so that a determinant result may be evaluated in the post-development condition. This has the effect of inflating the curve numbers to allow for determinate results using the TR-55 graphical peak discharge method, while maintaining a similar relative difference between pre and post-development. It should be noted that this adjustment approach has a tendency to overestimate runoff and thusly artificially inflate practice sizing, and as such is conservative. If the conservative peak discharge computations in the spreadsheet are problematic in a given instance, designers are encouraged to model the scenario using unadjusted CNs in a modeling package such as TR-20 to produce results which are not inflated by this workaround due to limitations of TR-55 hydrology for CN less than 40.

In doing this CN adjustment, it is noted by DEQ that there are some instances and anomalies whereby the differential from predevelopment to postdevelopment curve numbers are altered and may go down from traditional TR-55 CN calculations. This generally occurs in areas of very low existing CNs, or A Hydrologic Group (HSG) Soils.

Even though the feature sizing would remain conservative with the methodology described above, we understand the concern may be that the relative change in pre to postdevelopment peak flow and volume may be low in these instances. To aid in communications DEQ provided spreadsheet examples of the identified areas for ACP review.

Stantec Consulting Services Inc. (Stantec) reviewed the spreadsheet information provided by DEQ and performed additional hydrologic modeling in Bentley Systems PondPack v8i (PondPack). Because of the TR-55 limitations noted above, Stantec utilized the TR-20 Method Unit Hydrograph Simulation setting under PondPack to run the actual computed modeling pre and postdevelopment flow results. The actual modeled flow differential was compared against conservative spreadsheet TR-55 model results. Note the information provided by DEQ follows two drainage areas identified by DEQ previously that were discussed on 1/15/18. Stantec provided a prior TR20 evaluation of those previously via email on 1/16/18, and for completeness these two areas are shown in the first two lines of Attachment 1 - Drainage Area TR-20 Assessment Summary. Modeling summaries are provided under Attachment 2.

Note in all forty cases reviewed, the spreadsheet calculations provided:

1. conservatively high flows that would be used for feature sizing over TR-20 flows and
2. flow differentials (pre to post) that equal (1) or exceed (39) the actual TR-20 modeled flow differentials.

Based on the above, the calculations remain conservative for purpose of regulatory compliance. As such, no changes to either the calculations or methodology are proposed. If DEQ needs more specific assurances for some particular subwatershed which is submitted with the detailed design packages, we suggest that you request similar TR-20 based flow comparisons at that time.

Attachment 1 - Drainage Area TR-20 Assessment Summary
Attachment 2 – PondPack Modeling Results

Attachment 1 - Drainage Area TR-20 Assessment Summary

Drainage Area Data									10-Year Flow (cfs)						Spreadsheet Conservative and Compliance Assessment Summary		
									PondPack			Sprdsht Adjusted ↑					
DA ID	DA Pre (ac)	DA Post (ac)	Tc Pre (hrs)	Tc Post (hrs)	Sprdsht Pre CN	Sprdsht Post CN	Actual Pre CN[1]	Actual Post CN[1]	Pre	Post	PondPack Δ (cfs)	Pre	Post	Sprdsht Δ (cfs)	Sprdsht Conservative for Feature Sizing?	Sprdsht Δ > PondPack Δ > 0 = Conservative?	Regulatory Compliance Met?
C AR_304.10	1.12	1.12	0.083	0.083	40	44	30	35	0.000	0.003	0.003	0.090	0.200	0.110	Yes	Yes	Yes
C AR_304.13	2.64	2.64	0.083	0.083	44	45	36	38	0.009	0.015	0.006	0.460	0.530	0.070	Yes	Yes	Yes
36-014-AR2-POA_R001	0.04	0.04	0.083	0.083	40	72	30	67	0.000	0.086	0.086	0.004	0.121	0.117	Yes	Yes	Yes
36-014-AR2-POA_R002	0.32	0.32	0.083	0.083	40	56	30	49	0.000	0.110	0.110	0.028	0.324	0.296	Yes	Yes	Yes
36-014-AR2-POA_R003	0.4	0.4	0.083	0.083	40	51	30	43	0.000	0.013	0.013	0.036	0.225	0.189	Yes	Yes	Yes
36-014-AR2-POA_R004	1.16	1.16	0.117	0.100	40	46	30	37	0.000	0.005	0.005	0.089	0.257	0.169	Yes	Yes	Yes
36-014-AR2-POA_R005	0.35	0.35	0.083	0.083	40	57	30	50	0.000	0.146	0.146	0.031	0.391	0.360	Yes	Yes	Yes
36-014-AR2-POA_R006	1.62	1.62	0.181	0.136	40	51	30	42	0.000	0.034	0.034	0.100	0.712	0.613	Yes	Yes	Yes
36-014-AR2-POA_R007	0.81	0.81	0.086	0.083	40	55	30	47	0.000	0.169	0.169	0.072	0.885	0.813	Yes	Yes	Yes
C AR305.001	1.77	1.77	0.083	0.083	40	46	30	37	0.000	0.008	0.008	0.160	0.429	0.269	Yes	Yes	Yes
C AR305.002	2.05	2.05	0.149	0.130	40	45	30	36	0.000	0.007	0.007	0.139	0.350	0.211	Yes	Yes	Yes
C AR305.002A	2.87	2.87	0.214	0.192	40	44	30	35	0.000	0.007	0.007	0.162	0.351	0.189	Yes	Yes	Yes
C AR305.003	6.18	6.18	0.287	0.251	40	45	30	36	0.000	0.021	0.021	0.166	0.391	0.225	Yes	Yes	Yes
C AR305.003A	1.55	1.55	0.088	0.083	40	47	30	38	0.000	0.009	0.009	0.135	0.448	0.313	Yes	Yes	Yes
06_001_C037.AR2_AOA_C15	4.21	4.22	0.120	0.117	40	41	30	32	0.000	0.000	0.000	0.317	0.397	0.080	Yes	Yes	Yes
06_001_C037.AR2_AOA_C2	1.82	1.82	0.083	0.083	40	45	30	36	0.000	0.006	0.006	0.164	0.387	0.223	Yes	Yes	Yes
06_001_C037.AR2_AOA_R1	10.8	10.8	0.133	0.133	40	42	30	33	0.000	0.009	0.009	0.770	1.145	0.375	Yes	Yes	Yes
C AR_304.1	0.87	0.88	0.083	0.083	40	45	30	36	0.000	0.003	0.003	0.078	0.187	0.109	Yes	Yes	Yes
C AR_304.10*	1.7	1.7	0.083	0.083	40	41	30	32	0.000	0.000	0.000	0.153	0.189	0.036	Yes	Yes	Yes
C AR_304.11	2.41	2.41	0.084	0.083	40	42	30	33	0.000	0.002	0.002	0.217	0.323	0.106	Yes	Yes	Yes
C AR_304.15	1.09	1.09	0.083	0.083	40	44	30	35	0.000	0.003	0.003	0.098	0.202	0.103	Yes	Yes	Yes
C AR_304.16	2.04	2.04	0.083	0.083	40	40	30	31	0.000	0.000	*0.000*	0.183	0.183	*0.000*	Yes	Equal	Yes
C AR_304.19	0.76	0.76	0.083	0.083	40	48	30	40	0.000	0.008	0.008	0.068	0.230	0.162	Yes	Yes	Yes
C AR_304.2	0.44	0.44	0.083	0.083	40	47	30	38	0.000	0.003	0.003	0.040	0.120	0.080	Yes	Yes	Yes
C AR_304.22	2.41	2.41	0.093	0.090	40	41	30	32	0.000	0.000	0.000	0.206	0.258	0.052	Yes	Yes	Yes
C AR_304.22a	2.32	2.32	0.096	0.093	40	41	30	32	0.000	0.000	0.000	0.195	0.244	0.049	Yes	Yes	Yes
C AR_304.24	1.2	1.2	0.083	0.083	40	41	30	32	0.000	0.000	0.000	0.108	0.134	0.025	Yes	Yes	Yes
C AR_304.24a	1.98	1.98	0.092	0.087	40	42	30	33	0.000	0.002	0.002	0.170	0.260	0.090	Yes	Yes	Yes
C AR_304.25	0.37	0.37	0.083	0.083	40	49	30	41	0.000	0.005	0.005	0.033	0.138	0.104	Yes	Yes	Yes
C AR_304.26a	0.06	0.06	0.083	0.083	40	96	30	95	0.000	0.313	0.313	0.005	0.384	0.379	Yes	Yes	Yes
C AR_304.26b	0.05	0.05	0.083	0.083	40	54	30	47	0.000	0.010	0.010	0.004	0.040	0.036	Yes	Yes	Yes
C AR_304.28c	0.92	0.92	0.083	0.083	43	45	35	38	0.002	0.005	0.003	0.145	0.195	0.050	Yes	Yes	Yes
C AR_304.4	1.24	1.24	0.083	0.083	40	44	30	35	0.000	0.003	0.003	0.112	0.229	0.117	Yes	Yes	Yes
C AR_304.47a	0.16	0.16	0.083	0.083	40	42	30	33	0.000	0.000	0.000	0.014	0.021	0.007	Yes	Yes	Yes
C AR_304.47b	0.12	0.12	0.083	0.083	40	98	30	98	0.000	0.634	0.634	0.011	0.787	0.776	Yes	Yes	Yes
C AR_304.48	0.46	0.46	0.083	0.083	40	47	30	38	0.000	0.003	0.003	0.041	0.125	0.083	Yes	Yes	Yes
C AR_304.49	2.34	2.33	0.105	0.094	40	44	30	35	0.000	0.006	0.006	0.188	0.405	0.217	Yes	Yes	Yes
C AR_304.5	1.01	1.01	0.083	0.083	40	44	30	35	0.000	0.003	0.003	0.091	0.187	0.096	Yes	Yes	Yes
C AR_304.8	2.4	2.4	0.083	0.083	40	46	30	37	0.000	0.011	0.011	0.216	0.580	0.364	Yes	Yes	Yes
C AR_304.9	1.99	1.98	0.083	0.083	40	41	30	32	0.000	0.000	0.000	0.179	0.220	0.041	Yes	Yes	Yes

Notes:

1) TR20 flows from PondPack are based on actual CN information.

2) Spreadsheet conservative flows as noted per White Paper that are below 40 are adjusted updward so as to compute a determinant flow value.

3) P1yr=2.5 inches, P2yr=3.0 inches, P10yr=4.3 inches

4) The following Tc's were adjusted conservatively based on assessment of 3e review files: 36-014-AR2-POA_R007, C AR305.003, C AR305.003A

5) Only one reviewed DA ID (C AR_304.16) is not represented conservatively; however, the flow differential is equal to that of the TR-20 model results.

6) Regulatory Compliance = Flows are conservatively high / features conservatively sized, and flow deltas from pre to post in spreadsheet are >= TR20 actual results.

Attachment 2 – PondPack Modeling Results

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Subsection: Master Network Summary

Catchments Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ft³)	Time to Peak (hours)	Peak Flow (ft³/s)
06_001_C037.AR2_AOA_C15Post	10-YR	10	0.000	0.000	0.00000
06_001_C037.AR2_AOA_C15Pre	10-YR	10	0.000	0.000	0.00000
06_001_C037.AR2_AOA_C2Post	10-YR	10	171.000	24.000	0.00635
06_001_C037.AR2_AOA_C2Pre	10-YR	10	0.000	0.000	0.00000
06_001_C037.AR2_AOA_R1Post	10-YR	10	65.000	24.000	0.00914
06_001_C037.AR2_AOA_R1Pre	10-YR	10	0.000	0.000	0.00000
36-014-AR2-POA_R001 Post	10-YR	10	212.000	11.950	0.08615
36-014-AR2-POA_R001 Pre	10-YR	10	0.000	0.000	0.00000
36-014-AR2-POA_R002 Post	10-YR	10	427.000	12.000	0.10955
36-014-AR2-POA_R002 Pre	10-YR	10	0.000	0.000	0.00000
36-014-AR2-POA_R003 Post	10-YR	10	247.000	12.050	0.01281
36-014-AR2-POA_R003 Pre	10-YR	10	0.000	0.000	0.00000
36-014-AR2-POA_R004 Post	10-YR	10	167.000	18.150	0.00512
36-014-AR2-POA_R004 Pre	10-YR	10	0.000	0.000	0.00000
36-014-AR2-POA_R005 Post	10-YR	10	520.000	12.000	0.14592
36-014-AR2-POA_R005 Pre	10-YR	10	0.000	0.000	0.00000
36-014-AR2-POA_R006Post	10-YR	10	848.000	12.450	0.03433
36-014-AR2-POA_R006Pre	10-YR	10	0.000	0.000	0.00000
36-014-AR2-POA_R007Post	10-YR	10	881.000	12.000	0.16912
36-014-AR2-POA_R007Pre	10-YR	10	0.000	0.000	0.00000
C AR305.001Post	10-YR	10	255.000	18.100	0.00783
C AR305.001Pre	10-YR	10	0.000	0.000	0.00000
C AR305.002APost	10-YR	10	152.000	23.950	0.00743
C AR305.002APre	10-YR	10	0.000	0.000	0.00000
C AR305.002Post	10-YR	10	192.000	23.950	0.00712
C AR305.002Pre	10-YR	10	0.000	0.000	0.00000
C AR305.003APost	10-YR	10	314.000	17.500	0.00905
C AR305.003APre	10-YR	10	0.000	0.000	0.00000

Subsection: Master Network Summary

Catchments Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ft³)	Time to Peak (hours)	Peak Flow (ft³/s)
C AR305.003Post	10-YR	10	570.000	24.000	0.02140
C AR305.003Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.10 Post	10-YR	10	60.000	24.000	0.00292
C AR_304.10 Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.10*Post	10-YR	10	0.000	0.000	0.00000
C AR_304.10*Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.11Post	10-YR	10	15.000	24.000	0.00207
C AR_304.11Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.13 Post	10-YR	10	536.000	17.500	0.01545
C AR_304.13 Pre	10-YR	10	248.000	24.000	0.00921
C AR_304.15Post	10-YR	10	59.000	24.000	0.00285
C AR_304.15Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.16Post	10-YR	10	0.000	0.000	0.00000
C AR_304.16Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.19Post	10-YR	10	262.000	13.450	0.00775
C AR_304.19Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.1Post	10-YR	10	83.000	24.000	0.00307
C AR_304.1Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.22Post	10-YR	10	0.000	0.000	0.00000
C AR_304.22Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.22aPost	10-YR	10	0.000	0.000	0.00000
C AR_304.22aPre	10-YR	10	0.000	0.000	0.00000
C AR_304.24Post	10-YR	10	0.000	0.000	0.00000
C AR_304.24Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.24aPost	10-YR	10	12.000	24.000	0.00170
C AR_304.24aPre	10-YR	10	0.000	0.000	0.00000
C AR_304.25Post	10-YR	10	159.000	12.950	0.00524
C AR_304.25Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.26aPost	10-YR	10	800.000	11.900	0.31305
C AR_304.26aPre	10-YR	10	0.000	0.000	0.00000
C AR_304.26bPost	10-YR	10	51.000	12.000	0.00978
C AR_304.26bPre	10-YR	10	0.000	0.000	0.00000
C AR_304.28cPost	10-YR	10	186.000	17.500	0.00537
C AR_304.28cPre	10-YR	10	49.000	24.000	0.00240
C AR_304.2Post	10-YR	10	89.000	17.500	0.00258
C AR_304.2Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.47aPost	10-YR	10	1.000	24.000	0.00014
C AR_304.47aPre	10-YR	10	0.000	0.000	0.00000
C AR_304.47bPost	10-YR	10	1,702.000	11.900	0.63406
C AR_304.47bPre	10-YR	10	0.000	0.000	0.00000
C AR_304.48Post	10-YR	10	93.000	17.500	0.00267
C AR_304.48Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.49Post	10-YR	10	125.000	24.000	0.00608
C AR_304.49Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.4Post	10-YR	10	67.000	24.000	0.00324

Subsection: Master Network Summary

Catchments Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ft³)	Time to Peak (hours)	Peak Flow (ft³/s)
C AR_304.4Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.5Post	10-YR	10	54.000	24.000	0.00264
C AR_304.5Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.8Post	10-YR	10	345.000	18.100	0.01059
C AR_304.8Pre	10-YR	10	0.000	0.000	0.00000
C AR_304.9Post	10-YR	10	0.000	0.000	0.00000
C AR_304.9Pre	10-YR	10	0.000	0.000	0.00000

Node Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ft³)	Time to Peak (hours)	Peak Flow (ft³/s)
10 Post	10-YR	10	60.000	24.000	0.00292
10 Pre	10-YR	10	0.000	0.000	0.00000
13 Post	10-YR	10	536.000	17.500	0.01545
13 Pre	10-YR	10	248.000	24.000	0.00921
O-100	10-YR	10	12.000	24.000	0.00170
O-101	10-YR	10	0.000	0.000	0.00000
O-102	10-YR	10	159.000	12.950	0.00524
O-103	10-YR	10	0.000	0.000	0.00000
O-104	10-YR	10	800.000	11.900	0.31305
O-105	10-YR	10	0.000	0.000	0.00000
O-106	10-YR	10	51.000	12.000	0.00978
O-107	10-YR	10	49.000	24.000	0.00240
O-108	10-YR	10	186.000	17.500	0.00537
O-109	10-YR	10	0.000	0.000	0.00000
O-110	10-YR	10	67.000	24.000	0.00324
O-111	10-YR	10	0.000	0.000	0.00000
O-112	10-YR	10	1.000	24.000	0.00014
O-113	10-YR	10	0.000	0.000	0.00000
O-114	10-YR	10	1,702.000	11.900	0.63406
O-115	10-YR	10	0.000	0.000	0.00000
O-116	10-YR	10	93.000	17.500	0.00267
O-117	10-YR	10	0.000	0.000	0.00000
O-118	10-YR	10	125.000	24.000	0.00608
O-119	10-YR	10	0.000	0.000	0.00000
O-120	10-YR	10	54.000	24.000	0.00264
O-121	10-YR	10	0.000	0.000	0.00000
O-122	10-YR	10	345.000	18.100	0.01059
O-123	10-YR	10	0.000	0.000	0.00000
O-124	10-YR	10	0.000	0.000	0.00000
O-49	10-YR	10	0.000	0.000	0.00000
O-50	10-YR	10	212.000	11.950	0.08615
O-51	10-YR	10	0.000	0.000	0.00000

Subsection: Master Network Summary

Node Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ft³)	Time to Peak (hours)	Peak Flow (ft³/s)
O-52	10-YR	10	427.000	12.000	0.10955
O-53	10-YR	10	0.000	0.000	0.00000
O-54	10-YR	10	247.000	12.050	0.01281
O-55	10-YR	10	0.000	0.000	0.00000
O-56	10-YR	10	167.000	18.150	0.00512
O-57	10-YR	10	0.000	0.000	0.00000
O-58	10-YR	10	520.000	12.000	0.14592
O-59	10-YR	10	0.000	0.000	0.00000
O-60	10-YR	10	848.000	12.450	0.03433
O-61	10-YR	10	0.000	0.000	0.00000
O-62	10-YR	10	881.000	12.000	0.16912
O-63	10-YR	10	0.000	0.000	0.00000
O-64	10-YR	10	255.000	18.100	0.00783
O-65	10-YR	10	0.000	0.000	0.00000
O-66	10-YR	10	192.000	23.950	0.00712
O-67	10-YR	10	0.000	0.000	0.00000
O-68	10-YR	10	152.000	23.950	0.00743
O-69	10-YR	10	0.000	0.000	0.00000
O-70	10-YR	10	570.000	24.000	0.02140
O-71	10-YR	10	0.000	0.000	0.00000
O-72	10-YR	10	314.000	17.500	0.00905
O-73	10-YR	10	0.000	0.000	0.00000
O-74	10-YR	10	0.000	0.000	0.00000
O-75	10-YR	10	0.000	0.000	0.00000
O-76	10-YR	10	171.000	24.000	0.00635
O-77	10-YR	10	0.000	0.000	0.00000
O-78	10-YR	10	65.000	24.000	0.00914
O-79	10-YR	10	0.000	0.000	0.00000
O-80	10-YR	10	83.000	24.000	0.00307
O-81	10-YR	10	0.000	0.000	0.00000
O-82	10-YR	10	0.000	0.000	0.00000
O-83	10-YR	10	0.000	0.000	0.00000
O-84	10-YR	10	15.000	24.000	0.00207
O-85	10-YR	10	0.000	0.000	0.00000
O-86	10-YR	10	59.000	24.000	0.00285
O-87	10-YR	10	0.000	0.000	0.00000
O-88	10-YR	10	0.000	0.000	0.00000
O-89	10-YR	10	0.000	0.000	0.00000
O-90	10-YR	10	262.000	13.450	0.00775
O-91	10-YR	10	0.000	0.000	0.00000
O-92	10-YR	10	89.000	17.500	0.00258
O-93	10-YR	10	0.000	0.000	0.00000
O-94	10-YR	10	0.000	0.000	0.00000
O-95	10-YR	10	0.000	0.000	0.00000
O-96	10-YR	10	0.000	0.000	0.00000

Subsection: Master Network Summary

Node Summary

Label	Scenario	Return Event (years)	Hydrograph Volume (ft³)	Time to Peak (hours)	Peak Flow (ft³/s)
O-97	10-YR	10	0.000	0.000	0.00000
O-98	10-YR	10	0.000	0.000	0.00000
O-99	10-YR	10	0.000	0.000	0.00000

Time-Depth Curve: 10-YR	
Label	10-YR
Start Time	0.000 hours
Increment	0.100 hours
End Time	24.000 hours
Return Event	10 years

CUMULATIVE RAINFALL (in)
Output Time Increment = 0.100 hours
Time on left represents time for first value in each row.

Time (hours)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
0.000	0.0	0.0	0.0	0.0	0.0
0.500	0.0	0.0	0.0	0.0	0.0
1.000	0.0	0.0	0.1	0.1	0.1
1.500	0.1	0.1	0.1	0.1	0.1
2.000	0.1	0.1	0.1	0.1	0.1
2.500	0.1	0.1	0.1	0.1	0.1
3.000	0.1	0.2	0.2	0.2	0.2
3.500	0.2	0.2	0.2	0.2	0.2
4.000	0.2	0.2	0.2	0.2	0.2
4.500	0.2	0.2	0.2	0.3	0.3
5.000	0.3	0.3	0.3	0.3	0.3
5.500	0.3	0.3	0.3	0.3	0.3
6.000	0.3	0.3	0.4	0.4	0.4
6.500	0.4	0.4	0.4	0.4	0.4
7.000	0.4	0.4	0.4	0.4	0.5
7.500	0.5	0.5	0.5	0.5	0.5
8.000	0.5	0.5	0.5	0.5	0.6
8.500	0.6	0.6	0.6	0.6	0.6
9.000	0.6	0.6	0.7	0.7	0.7
9.500	0.7	0.7	0.7	0.7	0.8
10.000	0.8	0.8	0.8	0.8	0.8
10.500	0.9	0.9	0.9	0.9	1.0
11.000	1.0	1.0	1.1	1.1	1.2
11.500	1.2	1.3	1.5	1.8	2.4
12.000	2.8	2.9	3.0	3.0	3.1
12.500	3.1	3.2	3.2	3.2	3.3
13.000	3.3	3.3	3.3	3.4	3.4
13.500	3.4	3.4	3.4	3.5	3.5
14.000	3.5	3.5	3.5	3.5	3.5
14.500	3.6	3.6	3.6	3.6	3.6
15.000	3.6	3.6	3.7	3.7	3.7
15.500	3.7	3.7	3.7	3.7	3.7
16.000	3.7	3.7	3.8	3.8	3.8
16.500	3.8	3.8	3.8	3.8	3.8
17.000	3.8	3.8	3.8	3.9	3.9
17.500	3.9	3.9	3.9	3.9	3.9

CUMULATIVE RAINFALL (in)
Output Time Increment = 0.100 hours
Time on left represents time for first value in each row.

Time (hours)	Depth (in)	Depth (in)	Depth (in)	Depth (in)	Depth (in)
18.000	3.9	3.9	3.9	3.9	3.9
18.500	4.0	4.0	4.0	4.0	4.0
19.000	4.0	4.0	4.0	4.0	4.0
19.500	4.0	4.0	4.0	4.0	4.0
20.000	4.0	4.1	4.1	4.1	4.1
20.500	4.1	4.1	4.1	4.1	4.1
21.000	4.1	4.1	4.1	4.1	4.1
21.500	4.1	4.1	4.1	4.1	4.1
22.000	4.2	4.2	4.2	4.2	4.2
22.500	4.2	4.2	4.2	4.2	4.2
23.000	4.2	4.2	4.2	4.2	4.2
23.500	4.2	4.2	4.2	4.2	4.2
24.000	4.3	(N/A)	(N/A)	(N/A)	(N/A)

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.117 hours
Area (User Defined)	4.220 acres

Computational Time Increment	0.016 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	32.000
Area (User Defined)	4.220 acres
Maximum Retention (Pervious)	21.3 in
Maximum Retention (Pervious, 20 percent)	4.3 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.117 hours
Computational Time Increment	0.016 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	40.86805 ft³/s
Unit peak time, Tp	0.078 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.312 hours
Total unit time, Tb	0.390 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.120 hours
Area (User Defined)	4.210 acres

Computational Time Increment	0.016 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	4.210 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.120 hours
Computational Time Increment	0.016 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	39.75192 ft³/s
Unit peak time, Tp	0.080 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.320 hours
Total unit time, Tb	0.400 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.820 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00635 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00635 ft³/s

Drainage Area	
SCS CN (Composite)	36.000
Area (User Defined)	1.820 acres
Maximum Retention (Pervious)	17.8 in
Maximum Retention (Pervious, 20 percent)	3.6 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	172.486 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	171.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	24.74628 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.820 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	1.820 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	24.74628 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.133 hours
Area (User Defined)	10.770 acres

Computational Time Increment	0.018 hours
Time to Peak (Computed)	23.993 hours
Flow (Peak, Computed)	0.00916 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00914 ft³/s

Drainage Area	
SCS CN (Composite)	33.000
Area (User Defined)	10.770 acres
Maximum Retention (Pervious)	20.3 in
Maximum Retention (Pervious, 20 percent)	4.1 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	68.239 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	65.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.133 hours
Computational Time Increment	0.018 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	91.75323 ft³/s
Unit peak time, Tp	0.089 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.355 hours
Total unit time, Tb	0.443 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.133 hours
Area (User Defined)	10.770 acres

Computational Time Increment	0.018 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	10.770 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.133 hours
Computational Time Increment	0.018 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	91.75323 ft³/s
Unit peak time, Tp	0.089 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.355 hours
Total unit time, Tb	0.443 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.045 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	11.933 hours
Flow (Peak, Computed)	0.08802 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	11.950 hours
Flow (Peak Interpolated Output)	0.08615 ft³/s

Drainage Area	
SCS CN (Composite)	67.000
Area (User Defined)	0.045 acres
Maximum Retention (Pervious)	4.9 in
Maximum Retention (Pervious, 20 percent)	1.0 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	1.3 in
Runoff Volume (Pervious)	212.606 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	212.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	0.61186 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.045 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.045 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	0.61186 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.316 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	12.022 hours
Flow (Peak, Computed)	0.11943 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	12.000 hours
Flow (Peak Interpolated Output)	0.10955 ft³/s

Drainage Area

SCS CN (Composite)	49.000
Area (User Defined)	0.316 acres
Maximum Retention (Pervious)	10.4 in
Maximum Retention (Pervious, 20 percent)	2.1 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.4 in
Runoff Volume (Pervious)	428.859 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	427.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	4.29661 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.316 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.316 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	4.29661 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.397 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	12.044 hours
Flow (Peak, Computed)	0.01282 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	12.050 hours
Flow (Peak Interpolated Output)	0.01281 ft³/s

Drainage Area	
SCS CN (Composite)	43.000
Area (User Defined)	0.397 acres
Maximum Retention (Pervious)	13.3 in
Maximum Retention (Pervious, 20 percent)	2.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.2 in
Runoff Volume (Pervious)	248.008 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	247.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	5.39795 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.397 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	0.397 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	5.39795 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.100 hours
Area (User Defined)	1.161 acres

Computational Time Increment	0.013 hours
Time to Peak (Computed)	18.133 hours
Flow (Peak, Computed)	0.00513 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	18.150 hours
Flow (Peak Interpolated Output)	0.00512 ft³/s

Drainage Area	
SCS CN (Composite)	37.000
Area (User Defined)	1.161 acres
Maximum Retention (Pervious)	17.0 in
Maximum Retention (Pervious, 20 percent)	3.4 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	168.233 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	167.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.100 hours
Computational Time Increment	0.013 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	13.15496 ft³/s
Unit peak time, Tp	0.067 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.267 hours
Total unit time, Tb	0.333 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.117 hours
Area (User Defined)	1.161 acres

Computational Time Increment	0.016 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	1.161 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.117 hours
Computational Time Increment	0.016 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	11.24355 ft³/s
Unit peak time, Tp	0.078 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.312 hours
Total unit time, Tb	0.390 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.348 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	12.022 hours
Flow (Peak, Computed)	0.15544 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	12.000 hours
Flow (Peak Interpolated Output)	0.14592 ft³/s

Drainage Area	
SCS CN (Composite)	50.000
Area (User Defined)	0.348 acres
Maximum Retention (Pervious)	10.0 in
Maximum Retention (Pervious, 20 percent)	2.0 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.4 in
Runoff Volume (Pervious)	522.071 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	520.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	4.73171 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.348 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.348 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	4.73171 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.136 hours
Area (User Defined)	1.625 acres

Computational Time Increment	0.018 hours
Time to Peak (Computed)	12.439 hours
Flow (Peak, Computed)	0.03437 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	12.450 hours
Flow (Peak Interpolated Output)	0.03433 ft³/s

Drainage Area	
SCS CN (Composite)	42.000
Area (User Defined)	1.625 acres
Maximum Retention (Pervious)	13.8 in
Maximum Retention (Pervious, 20 percent)	2.8 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.1 in
Runoff Volume (Pervious)	853.928 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	848.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.136 hours
Computational Time Increment	0.018 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	13.53854 ft³/s
Unit peak time, Tp	0.091 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.363 hours
Total unit time, Tb	0.453 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.181 hours
Area (User Defined)	1.625 acres

Computational Time Increment	0.024 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	1.625 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.181 hours
Computational Time Increment	0.024 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	10.17260 ft³/s
Unit peak time, Tp	0.121 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.483 hours
Total unit time, Tb	0.603 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.813 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	12.022 hours
Flow (Peak, Computed)	0.19900 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	12.000 hours
Flow (Peak Interpolated Output)	0.16912 ft³/s

Drainage Area	
SCS CN (Composite)	47.000
Area (User Defined)	0.813 acres
Maximum Retention (Pervious)	11.3 in
Maximum Retention (Pervious, 20 percent)	2.3 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.3 in
Runoff Volume (Pervious)	884.807 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	881.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	11.05424 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.086 hours
Area (User Defined)	0.813 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.813 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.086 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	10.71148 ft³/s
Unit peak time, Tp	0.057 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.229 hours
Total unit time, Tb	0.287 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.120 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00293 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00292 ft³/s

Drainage Area

SCS CN (Composite)	35.000
Area (User Defined)	1.120 acres
Maximum Retention (Pervious)	18.6 in
Maximum Retention (Pervious, 20 percent)	3.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	61.062 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	60.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	15.22848 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.120 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	1.120 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	15.22848 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.700 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	32.000
Area (User Defined)	1.700 acres
Maximum Retention (Pervious)	21.3 in
Maximum Retention (Pervious, 20 percent)	4.3 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	23.11466 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.700 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	1.700 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	23.11466 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	2.410 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00207 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00207 ft³/s

Drainage Area	
SCS CN (Composite)	33.000
Area (User Defined)	2.410 acres
Maximum Retention (Pervious)	20.3 in
Maximum Retention (Pervious, 20 percent)	4.1 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	15.196 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	15.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	32.76843 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.084 hours
Area (User Defined)	2.410 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	2.410 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.084 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	32.50836 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.224 hours
Total unit time, Tb	0.280 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	2.640 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	17.522 hours
Flow (Peak, Computed)	0.01547 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	17.500 hours
Flow (Peak Interpolated Output)	0.01545 ft³/s

Drainage Area	
SCS CN (Composite)	38.000
Area (User Defined)	2.640 acres
Maximum Retention (Pervious)	16.3 in
Maximum Retention (Pervious, 20 percent)	3.3 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.1 in
Runoff Volume (Pervious)	539.419 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	536.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	35.89570 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	2.640 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00922 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00921 ft³/s

Drainage Area	
SCS CN (Composite)	36.000
Area (User Defined)	2.640 acres
Maximum Retention (Pervious)	17.8 in
Maximum Retention (Pervious, 20 percent)	3.6 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	250.199 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	248.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	35.89570 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.093 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00286 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00285 ft³/s

Drainage Area

SCS CN (Composite)	35.000
Area (User Defined)	1.093 acres
Maximum Retention (Pervious)	18.6 in
Maximum Retention (Pervious, 20 percent)	3.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	59.590 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	59.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	14.86136 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.093 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	1.093 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	14.86136 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	2.036 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	31.000
Area (User Defined)	2.036 acres
Maximum Retention (Pervious)	22.3 in
Maximum Retention (Pervious, 20 percent)	4.5 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	27.68320 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	2.036 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	2.036 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	27.68320 ft³/s
Unit peak time, Tp	0.056 hours

Subsection: Unit Hydrograph Summary

Label: C AR_304.16Pre

Return Event: 10 years

Storm Event: 10-YR

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.755 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	13.422 hours
Flow (Peak, Computed)	0.00779 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	13.450 hours
Flow (Peak Interpolated Output)	0.00775 ft³/s

Drainage Area	
SCS CN (Composite)	40.000
Area (User Defined)	0.755 acres
Maximum Retention (Pervious)	15.0 in
Maximum Retention (Pervious, 20 percent)	3.0 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.1 in
Runoff Volume (Pervious)	263.540 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	262.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	10.26563 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.755 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.755 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	10.26563 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.880 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00307 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00307 ft³/s

Drainage Area	
SCS CN (Composite)	36.000
Area (User Defined)	0.880 acres
Maximum Retention (Pervious)	17.8 in
Maximum Retention (Pervious, 20 percent)	3.6 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	83.400 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	83.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	11.96523 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.870 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	0.870 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	11.82927 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.093 hours
Area (User Defined)	2.322 acres

Computational Time Increment	0.012 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	32.000
Area (User Defined)	2.322 acres
Maximum Retention (Pervious)	21.3 in
Maximum Retention (Pervious, 20 percent)	4.3 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.093 hours
Computational Time Increment	0.012 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	28.29023 ft³/s
Unit peak time, Tp	0.062 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.248 hours
Total unit time, Tb	0.310 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.096 hours
Area (User Defined)	2.322 acres

Computational Time Increment	0.013 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	2.322 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.096 hours
Computational Time Increment	0.013 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	27.40616 ft³/s
Unit peak time, Tp	0.064 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.256 hours
Total unit time, Tb	0.320 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.090 hours
Area (User Defined)	2.413 acres

Computational Time Increment	0.012 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	32.000
Area (User Defined)	2.413 acres
Maximum Retention (Pervious)	21.3 in
Maximum Retention (Pervious, 20 percent)	4.3 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.090 hours
Computational Time Increment	0.012 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	30.37890 ft³/s
Unit peak time, Tp	0.060 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.240 hours
Total unit time, Tb	0.300 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.093 hours
Area (User Defined)	2.413 acres

Computational Time Increment	0.012 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	2.413 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.093 hours
Computational Time Increment	0.012 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	29.39894 ft³/s
Unit peak time, Tp	0.062 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.248 hours
Total unit time, Tb	0.310 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.087 hours
Area (User Defined)	1.983 acres

Computational Time Increment	0.012 hours
Time to Peak (Computed)	24.000 hours
Flow (Peak, Computed)	0.00170 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00170 ft³/s

Drainage Area	
SCS CN (Composite)	33.000
Area (User Defined)	1.983 acres
Maximum Retention (Pervious)	20.3 in
Maximum Retention (Pervious, 20 percent)	4.1 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	12.511 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	12.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.087 hours
Computational Time Increment	0.012 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	25.82621 ft³/s
Unit peak time, Tp	0.058 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.232 hours
Total unit time, Tb	0.290 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.092 hours
Area (User Defined)	1.983 acres

Computational Time Increment	0.012 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	1.983 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.092 hours
Computational Time Increment	0.012 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	24.42262 ft³/s
Unit peak time, Tp	0.061 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.245 hours
Total unit time, Tb	0.307 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.202 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	32.000
Area (User Defined)	1.202 acres
Maximum Retention (Pervious)	21.3 in
Maximum Retention (Pervious, 20 percent)	4.3 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	16.34342 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.202 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	1.202 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	16.34342 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.368 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	12.922 hours
Flow (Peak, Computed)	0.00527 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	12.950 hours
Flow (Peak Interpolated Output)	0.00524 ft³/s

Drainage Area	
SCS CN (Composite)	41.000
Area (User Defined)	0.368 acres
Maximum Retention (Pervious)	14.4 in
Maximum Retention (Pervious, 20 percent)	2.9 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.1 in
Runoff Volume (Pervious)	159.529 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	159.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	5.00364 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.368 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	0.368 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	5.00364 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.060 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	11.922 hours
Flow (Peak, Computed)	0.31919 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	11.900 hours
Flow (Peak Interpolated Output)	0.31305 ft³/s

Drainage Area	
SCS CN (Composite)	95.000
Area (User Defined)	0.060 acres
Maximum Retention (Pervious)	0.5 in
Maximum Retention (Pervious, 20 percent)	0.1 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	3.7 in
Runoff Volume (Pervious)	801.017 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	800.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	0.81581 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.060 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.060 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	0.81581 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.047 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	12.022 hours
Flow (Peak, Computed)	0.01150 ft^3/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	12.000 hours
Flow (Peak Interpolated Output)	0.00978 ft^3/s

Drainage Area	
SCS CN (Composite)	47.000
Area (User Defined)	0.047 acres
Maximum Retention (Pervious)	11.3 in
Maximum Retention (Pervious, 20 percent)	2.3 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.3 in
Runoff Volume (Pervious)	51.151 ft^3

Hydrograph Volume (Area under Hydrograph curve)	
Volume	51.000 ft^3

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	0.63905 ft^3/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.047 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.047 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	0.63905 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.918 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	17.522 hours
Flow (Peak, Computed)	0.00538 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	17.500 hours
Flow (Peak Interpolated Output)	0.00537 ft³/s

Drainage Area	
SCS CN (Composite)	38.000
Area (User Defined)	0.918 acres
Maximum Retention (Pervious)	16.3 in
Maximum Retention (Pervious, 20 percent)	3.3 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.1 in
Runoff Volume (Pervious)	187.571 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	186.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	12.48191 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.918 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00240 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00240 ft³/s

Drainage Area

SCS CN (Composite)	35.000
Area (User Defined)	0.918 acres
Maximum Retention (Pervious)	18.6 in
Maximum Retention (Pervious, 20 percent)	3.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	50.049 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	49.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	12.48191 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.440 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	17.522 hours
Flow (Peak, Computed)	0.00258 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	17.500 hours
Flow (Peak Interpolated Output)	0.00258 ft³/s

Drainage Area	
SCS CN (Composite)	38.000
Area (User Defined)	0.440 acres
Maximum Retention (Pervious)	16.3 in
Maximum Retention (Pervious, 20 percent)	3.3 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.1 in
Runoff Volume (Pervious)	89.903 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	89.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	5.98262 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.440 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.440 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	5.98262 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.160 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00014 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00014 ft³/s

Drainage Area	
SCS CN (Composite)	33.000
Area (User Defined)	0.160 acres
Maximum Retention (Pervious)	20.3 in
Maximum Retention (Pervious, 20 percent)	4.1 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	1.009 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	1.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	2.17550 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.160 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.160 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	2.17550 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.117 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	11.922 hours
Flow (Peak, Computed)	0.64452 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	11.900 hours
Flow (Peak Interpolated Output)	0.63406 ft³/s

Drainage Area	
SCS CN (Composite)	98.000
Area (User Defined)	0.117 acres
Maximum Retention (Pervious)	0.2 in
Maximum Retention (Pervious, 20 percent)	0.0 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	4.0 in
Runoff Volume (Pervious)	1,705.033 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	1,702.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	1.59083 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.117 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	0.117 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	1.59083 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.457 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	17.522 hours
Flow (Peak, Computed)	0.00268 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	17.500 hours
Flow (Peak Interpolated Output)	0.00267 ft³/s

Drainage Area	
SCS CN (Composite)	38.000
Area (User Defined)	0.457 acres
Maximum Retention (Pervious)	16.3 in
Maximum Retention (Pervious, 20 percent)	3.3 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.1 in
Runoff Volume (Pervious)	93.377 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	93.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	6.21376 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	0.457 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	0.457 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	6.21376 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.094 hours
Area (User Defined)	2.330 acres

Computational Time Increment	0.013 hours
Time to Peak (Computed)	24.001 hours
Flow (Peak, Computed)	0.00608 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00608 ft³/s

Drainage Area

SCS CN (Composite)	35.000
Area (User Defined)	2.330 acres
Maximum Retention (Pervious)	18.6 in
Maximum Retention (Pervious, 20 percent)	3.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	127.034 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	125.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.094 hours
Computational Time Increment	0.013 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	28.08571 ft³/s
Unit peak time, Tp	0.063 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.251 hours
Total unit time, Tb	0.313 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.105 hours
Area (User Defined)	2.340 acres

Computational Time Increment	0.014 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	2.340 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.105 hours
Computational Time Increment	0.014 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	25.25131 ft³/s
Unit peak time, Tp	0.070 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.280 hours
Total unit time, Tb	0.350 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.240 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00324 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00324 ft³/s

Drainage Area	
SCS CN (Composite)	35.000
Area (User Defined)	1.240 acres
Maximum Retention (Pervious)	18.6 in
Maximum Retention (Pervious, 20 percent)	3.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	67.604 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	67.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	16.86010 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.240 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	1.240 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	16.86010 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.010 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	23.999 hours
Flow (Peak, Computed)	0.00264 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.00264 ft³/s

Drainage Area	
SCS CN (Composite)	35.000
Area (User Defined)	1.010 acres
Maximum Retention (Pervious)	18.6 in
Maximum Retention (Pervious, 20 percent)	3.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	55.065 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	54.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	13.73283 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.010 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	1.010 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	13.73283 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	2.400 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	18.122 hours
Flow (Peak, Computed)	0.01060 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	18.100 hours
Flow (Peak Interpolated Output)	0.01059 ft³/s

Drainage Area	
SCS CN (Composite)	37.000
Area (User Defined)	2.400 acres
Maximum Retention (Pervious)	17.0 in
Maximum Retention (Pervious, 20 percent)	3.4 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	347.765 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	345.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	32.63246 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	2.400 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	2.400 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	32.63246 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.980 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	32.000
Area (User Defined)	1.980 acres
Maximum Retention (Pervious)	21.3 in
Maximum Retention (Pervious, 20 percent)	4.3 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	26.92178 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.990 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	1.990 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	27.05775 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.774 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	18.122 hours
Flow (Peak, Computed)	0.00784 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	18.100 hours
Flow (Peak Interpolated Output)	0.00783 ft³/s

Drainage Area	
SCS CN (Composite)	37.000
Area (User Defined)	1.774 acres
Maximum Retention (Pervious)	17.0 in
Maximum Retention (Pervious, 20 percent)	3.4 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	257.057 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	255.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	24.12082 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.774 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	1.774 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	24.12082 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.192 hours
Area (User Defined)	2.874 acres

Computational Time Increment	0.026 hours
Time to Peak (Computed)	23.987 hours
Flow (Peak, Computed)	0.00745 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	23.950 hours
Flow (Peak Interpolated Output)	0.00743 ft³/s

Drainage Area	
SCS CN (Composite)	35.000
Area (User Defined)	2.874 acres
Maximum Retention (Pervious)	18.6 in
Maximum Retention (Pervious, 20 percent)	3.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	156.720 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	152.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.192 hours
Computational Time Increment	0.026 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	16.96066 ft³/s
Unit peak time, Tp	0.128 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.512 hours
Total unit time, Tb	0.640 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.214 hours
Area (User Defined)	2.874 acres

Computational Time Increment	0.029 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	2.874 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.214 hours
Computational Time Increment	0.029 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	15.21704 ft³/s
Unit peak time, Tp	0.143 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.571 hours
Total unit time, Tb	0.713 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.130 hours
Area (User Defined)	2.051 acres

Computational Time Increment	0.017 hours
Time to Peak (Computed)	23.989 hours
Flow (Peak, Computed)	0.00714 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	23.950 hours
Flow (Peak Interpolated Output)	0.00712 ft³/s

Drainage Area

SCS CN (Composite)	36.000
Area (User Defined)	2.051 acres
Maximum Retention (Pervious)	17.8 in
Maximum Retention (Pervious, 20 percent)	3.6 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	194.389 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	192.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.130 hours
Computational Time Increment	0.017 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	17.87638 ft³/s
Unit peak time, Tp	0.087 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.347 hours
Total unit time, Tb	0.433 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.149 hours
Area (User Defined)	2.051 acres

Computational Time Increment	0.020 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	2.051 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.149 hours
Computational Time Increment	0.020 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	15.59684 ft³/s
Unit peak time, Tp	0.099 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.397 hours
Total unit time, Tb	0.497 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.083 hours
Area (User Defined)	1.546 acres

Computational Time Increment	0.011 hours
Time to Peak (Computed)	17.522 hours
Flow (Peak, Computed)	0.00906 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	17.500 hours
Flow (Peak Interpolated Output)	0.00905 ft³/s

Drainage Area

SCS CN (Composite)	38.000
Area (User Defined)	1.546 acres
Maximum Retention (Pervious)	16.3 in
Maximum Retention (Pervious, 20 percent)	3.3 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.1 in
Runoff Volume (Pervious)	315.887 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	314.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.083 hours
Computational Time Increment	0.011 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	21.02074 ft³/s
Unit peak time, Tp	0.056 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.222 hours
Total unit time, Tb	0.278 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.088 hours
Area (User Defined)	1.546 acres

Computational Time Increment	0.012 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area	
SCS CN (Composite)	30.000
Area (User Defined)	1.546 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	0.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.088 hours
Computational Time Increment	0.012 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	19.90600 ft³/s
Unit peak time, Tp	0.059 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.235 hours
Total unit time, Tb	0.293 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.251 hours
Area (User Defined)	6.185 acres

Computational Time Increment	0.033 hours
Time to Peak (Computed)	23.995 hours
Flow (Peak, Computed)	0.02144 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	24.000 hours
Flow (Peak Interpolated Output)	0.02140 ft³/s

Drainage Area	
SCS CN (Composite)	36.000
Area (User Defined)	6.185 acres
Maximum Retention (Pervious)	17.8 in
Maximum Retention (Pervious, 20 percent)	3.6 in

Cumulative Runoff	
Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	586.200 ft³

Hydrograph Volume (Area under Hydrograph curve)	
Volume	570.000 ft³

SCS Unit Hydrograph Parameters	
Time of Concentration (Composite)	0.251 hours
Computational Time Increment	0.033 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	27.92050 ft³/s
Unit peak time, Tp	0.167 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.669 hours
Total unit time, Tb	0.837 hours

Storm Event	10-YR
Return Event	10 years
Duration	24.000 hours
Depth	4.3 in
Time of Concentration (Composite)	0.287 hours
Area (User Defined)	6.185 acres

Computational Time Increment	0.038 hours
Time to Peak (Computed)	0.000 hours
Flow (Peak, Computed)	0.00000 ft³/s
Output Increment	0.050 hours
Time to Flow (Peak Interpolated Output)	0.000 hours
Flow (Peak Interpolated Output)	0.00000 ft³/s

Drainage Area

SCS CN (Composite)	30.000
Area (User Defined)	6.185 acres
Maximum Retention (Pervious)	23.3 in
Maximum Retention (Pervious, 20 percent)	4.7 in

Cumulative Runoff

Cumulative Runoff Depth (Pervious)	0.0 in
Runoff Volume (Pervious)	0.000 ft³

Hydrograph Volume (Area under Hydrograph curve)

Volume	0.000 ft³

SCS Unit Hydrograph Parameters

Time of Concentration (Composite)	0.287 hours
Computational Time Increment	0.038 hours
Unit Hydrograph Shape Factor	483.432
K Factor	0.749
Receding/Rising, Tr/Tp	1.670
Unit peak, qp	24.41828 ft³/s
Unit peak time, Tp	0.191 hours

SCS Unit Hydrograph Parameters	
Unit receding limb, Tr	0.765 hours
Total unit time, Tb	0.957 hours

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Attachment 3 – Hydrologic Soil Group Assignments for Soils without a SSURGO Classification

Soil Name	HSG Assignment
Aquents, 0 to 2 percent slopes, frequently ponded	D
Dam	D
Gullied land	D
Industrial waste pond	D
Made Land	D
Mixed alluvial land	B
Mixed alluvium, poorly drained	B
Mixed alluvium, well drained	B
Pits and dumps	D
Pits, quarry	D
Rock land	D
Rock outcrop-Chilhowie complex, steep	D
Rock outcrop-Drall complex, steep	D
Rock outcrop-Frederick complex, sloping	D
Rock outcrop-Frederick complex, steep	D
Rock outcrop-Opequon complex, 55 to 100 percent slopes	D
Rubble land	D
Stony land	D
Udorthents, bouldery	D
Udorthents, dams	D
Udorthents, loamy	D
Udorthents, sandy	D
Udorthents, shaly	D
Udorthents, smoothed	D
Udorthents, smoothed, 0 to 25 percent slopes	D
Udorthents, smoothed, 3 to 35 percent slopes	D
Udorthents, smoothed-Urban land complex	D
Udorthents-Dumps complex	D
Udorthents-Rock outcrop complex, 15 to 100 percent slopes	D
Udorthents-Urban land complex, 0 to 45 percent slopes	D
Urban land	D
Urban land, 0 to 5 percent slopes	D
Urban land-Conetoe-Chesapeake-Tetotum complex, 2 to 40 percent slopes	D
Urban Land-Udorthents complex, 0 to 2 percent slopes	D

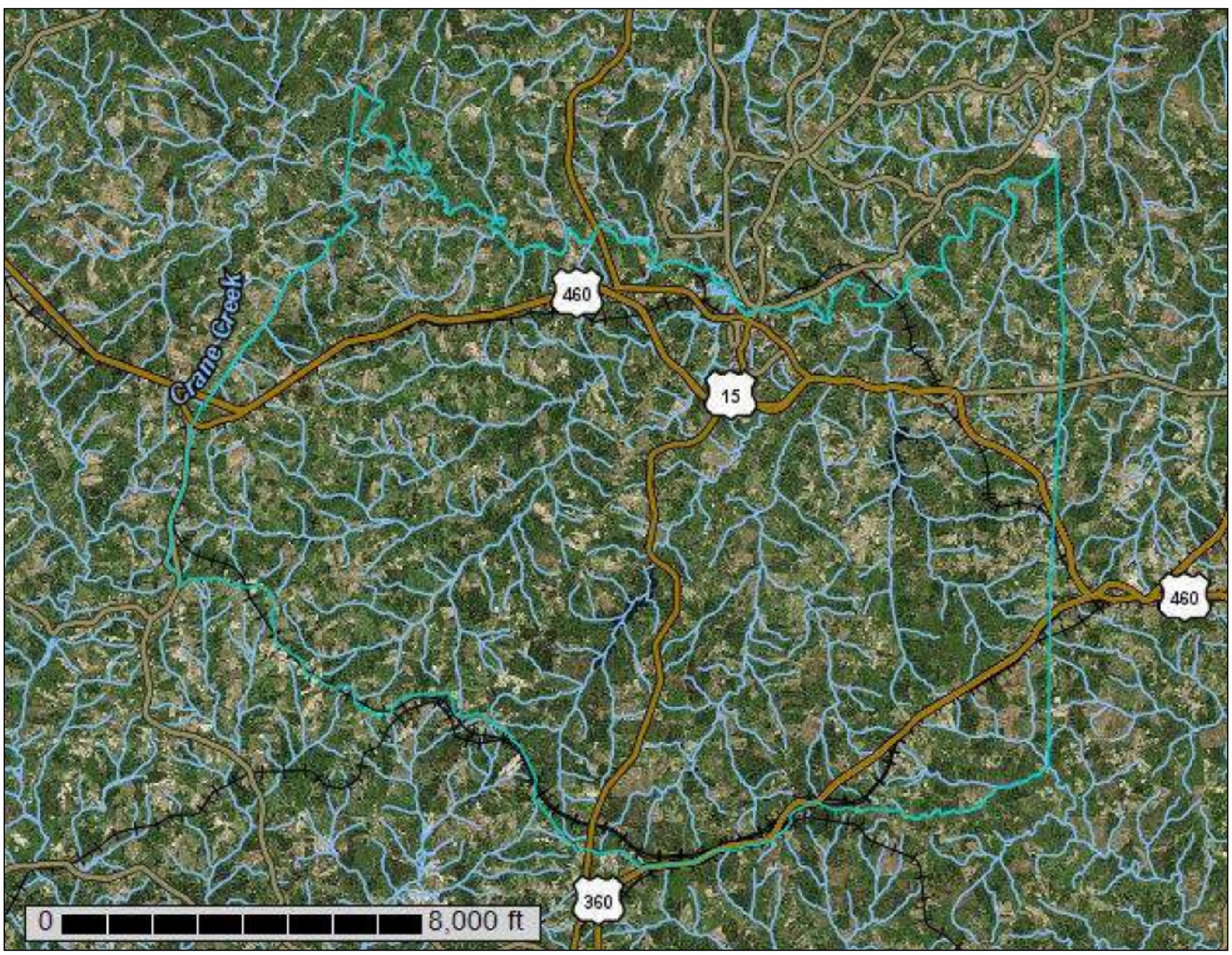
Note regarding Soils without Assigned HSGs: To facilitate computations of Curve Numbers (CNs) using the TR-55 methodology, Hydrologic Soil Groups (HSG) were assigned in cases where HSGs were not listed in the Soil Survey Geographic Database (SSURGO). The HSG assignment was determined using guidance from Appendix A of the TR-55 (Appendix A, Technical Release 55 Urban Hydrology for Small Watersheds, TR-55, United States Department of Agriculture and Natural Resources Conservation Service. 1986). Project specific field investigations were not considered to determine HSG assignments for soils. The majority of the soils were conservatively assigned HSG D based on the map unit name, which in most cases points to urban and industrial land use. To identify the appropriate HSG for mixed alluvial lands, the USDA Web Soil Survey was consulted to obtain more information. The mixed alluvial lands, both poorly and well drained, intersect the project areas primarily in Prince Edward County. (The Soil Resource Report is attached.) The typical profiles of both soils are silt loam. Therefore, the soil profile corresponds best to soil texture of HSG B - silt loam or loam, as listed in Appendix A of the TR-55. The typical capacity of the most limiting layer to transmit water is moderately high to high (0.57 to 1.98 in/hr) for both soils. The capacity to transmit water of both soils is greater than that noted to be typical for group B soils (0.15-0.30 in/hr) and group A soils (greater than 0.30 in/hr) as noted in Appendix A of the TR-55. The difference in the natural drainage class does not appear to be differentiating characteristic for association with Hydrologic Soil Groups as defined by the TR-55. Consequently, HSG B is an appropriate classification for all mixed alluvial lands.

United States Department of Agriculture

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for
Prince Edward County, Virginia



January 30, 2018

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ml	Mixed alluvium, poorly drained	0.0	0.0%
Mm	Mixed alluvium, well drained	0.0	0.0%
Totals for Area of Interest		**226,377.9**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Prince Edward County, Virginia

Ml—Mixed alluvium, poorly drained

Map Unit Setting

National map unit symbol: 4153
Mean annual precipitation: 37 to 62 inches
Mean annual air temperature: 45 to 70 degrees F
Frost-free period: 144 to 226 days
Farmland classification: Not prime farmland

Map Unit Composition

Mixed alluvium: 85 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Mixed Alluvium

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

H1 - 0 to 9 inches: silt loam
H2 - 9 to 30 inches: loam
H3 - 30 to 62 inches: loamy sand

Properties and qualities

Slope: 0 to 2 percent
Natural drainage class: Poorly drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 2 to 8 inches
Frequency of flooding: Frequent
Available water storage in profile: Moderate (about 7.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4w
Hydric soil rating: Yes

Mm—Mixed alluvium, well drained

Map Unit Setting

National map unit symbol: 4154
Mean annual precipitation: 37 to 62 inches
Mean annual air temperature: 45 to 70 degrees F
Frost-free period: 144 to 226 days
Farmland classification: Not prime farmland

Map Unit Composition

Mixed alluvium: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Mixed Alluvium

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

H1 - 0 to 5 inches: silt loam
H2 - 5 to 27 inches: silt loam
H3 - 27 to 79 inches: silt loam

Properties and qualities

Slope: 0 to 2 percent
Natural drainage class: Well drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 48 to 79 inches
Frequency of flooding: Frequent
Available water storage in profile: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydric soil rating: No

Attachment 4 – Mitigation Measures Assessment Computations

Table A4.1: TR-55 Sheet Flow Velocity Assessment (Wooded & Pasture)

Sheet Flow Equation		**= 0.007 * [((nL)^0.8) / (P2^0.5 * s^0.4)]**
Where:	Tt =	travel time (hr)
	L =	Length of overland flow (ft)
	n =	Mannings Roughness coefficient
	P2 =	2 year, 24 hour rainfall in inches
	s =	slope (ft/ft)

Assumptions:
L = 100
n = 0.4 for woods
n = 0.15 for pasture (short grass)
P2 = 3.7

Velocity Check in Wooded Conditions

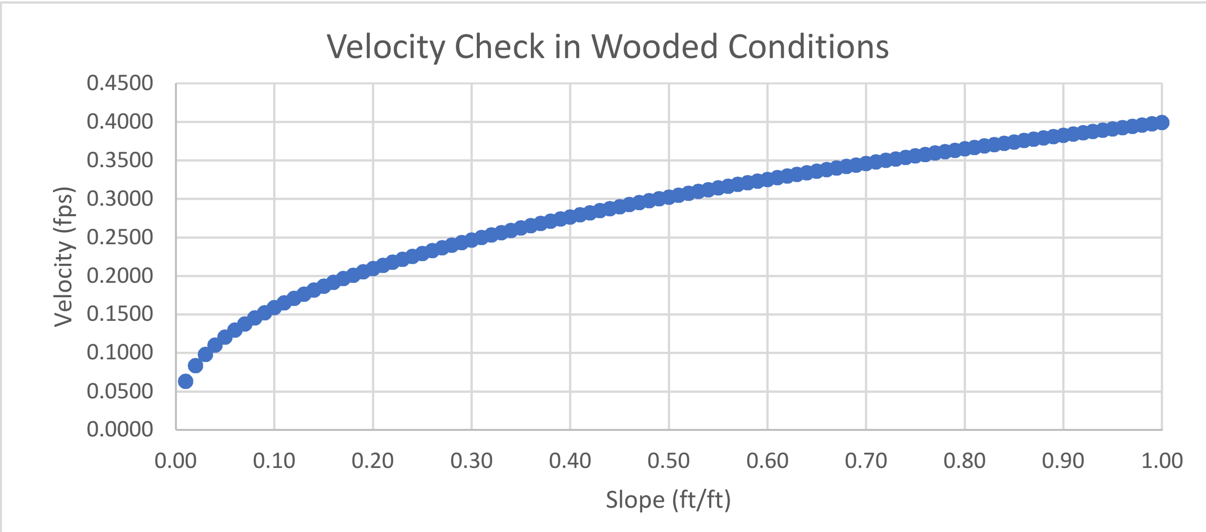
Slope (ft/ft)	Tt (hr)	Tt (s)	Length/Tt (fps)
0.01	0.4392	1581.06	0.0632
0.02	0.3328	1198.22	0.0835
0.03	0.2830	1018.82	0.0982
0.04	0.2522	908.08	0.1101
0.05	0.2307	830.54	0.1204
0.06	0.2145	772.12	0.1295
0.07	0.2017	725.95	0.1377
0.08	0.1912	688.20	0.1453
0.09	0.1824	656.52	0.1523
0.10	0.1748	629.43	0.1589
0.11	0.1683	605.89	0.1650
0.12	0.1625	585.16	0.1709
0.13	0.1574	566.72	0.1765
0.14	0.1528	550.17	0.1818
0.15	0.1487	535.19	0.1868
0.16	0.1449	521.55	0.1917
0.17	0.1414	509.06	0.1964
0.18	0.1382	497.55	0.2010
0.19	0.1353	486.91	0.2054
0.20	0.1325	477.02	0.2096
0.21	0.1299	467.80	0.2138
0.22	0.1275	459.18	0.2178
0.23	0.1253	451.08	0.2217
0.24	0.1232	443.47	0.2255
0.25	0.1212	436.29	0.2292
0.26	0.1193	429.50	0.2328
0.27	0.1175	423.06	0.2364
0.28	0.1158	416.95	0.2398
0.29	0.1142	411.14	0.2432
0.30	0.1127	405.60	0.2465
0.31	0.1112	400.32	0.2498
0.32	0.1098	395.26	0.2530
0.33	0.1085	390.43	0.2561
0.34	0.1072	385.79	0.2592
0.35	0.1059	381.35	0.2622
0.36	0.1047	377.07	0.2652
0.37	0.1036	372.96	0.2681
0.38	0.1025	369.01	0.2710
0.39	0.1014	365.19	0.2738
0.40	0.1004	361.51	0.2766
0.41	0.0994	357.96	0.2794
0.42	0.0985	354.53	0.2821
0.43	0.0976	351.20	0.2847
0.44	0.0967	347.99	0.2874

Velocity Check in Pasture Conditions

Slope (ft/ft)	Tt (hr)	Tt (s)	Length/Tt (fps)
0.01	0.2004	721.3943	0.1386
0.02	0.1519	546.7146	0.1829
0.03	0.1291	464.8621	0.2151
0.04	0.1151	414.3322	0.2414
0.05	0.1053	378.9524	0.2639
0.06	0.0979	352.2996	0.2838
0.07	0.0920	331.2329	0.3019
0.08	0.0872	314.0051	0.3185
0.09	0.0832	299.5544	0.3338
0.10	0.0798	287.1922	0.3482
0.11	0.0768	276.4494	0.3617
0.12	0.0742	266.9932	0.3745
0.13	0.0718	258.5802	0.3867
0.14	0.0697	251.0276	0.3984
0.15	0.0678	244.1947	0.4095
0.16	0.0661	237.9714	0.4202
0.17	0.0645	232.2700	0.4305
0.18	0.0631	227.0198	0.4405
0.19	0.0617	222.1628	0.4501
0.20	0.0605	217.6510	0.4595
0.21	0.0593	213.4445	0.4685
0.22	0.0582	209.5094	0.4773
0.23	0.0572	205.8171	0.4859
0.24	0.0562	202.3430	0.4942
0.25	0.0553	199.0658	0.5023
0.26	0.0544	195.9672	0.5103
0.27	0.0536	193.0311	0.5181
0.28	0.0528	190.2433	0.5256
0.29	0.0521	187.5916	0.5331
0.30	0.0514	185.0650	0.5404
0.31	0.0507	182.6535	0.5475
0.32	0.0501	180.3486	0.5545
0.33	0.0495	178.1423	0.5613
0.34	0.0489	176.0277	0.5681
0.35	0.0483	173.9985	0.5747
0.36	0.0478	172.0488	0.5812
0.37	0.0473	170.1735	0.5876
0.38	0.0468	168.3679	0.5939
0.39	0.0463	166.6276	0.6001
0.40	0.0458	164.9486	0.6062
0.41	0.0454	163.3274	0.6123
0.42	0.0449	161.7607	0.6182
0.43	0.0445	160.2453	0.6240
0.44	0.0441	158.7785	0.6298

0.45	0.0958	344.88	0.2900	0.45	0.0437	157.3576	0.6355
0.46	0.0950	341.86	0.2925	0.46	0.0433	155.9802	0.6411
0.47	0.0941	338.93	0.2950	0.47	0.0430	154.6442	0.6466
0.48	0.0934	336.09	0.2975	0.48	0.0426	153.3473	0.6521
0.49	0.0926	333.33	0.3000	0.49	0.0422	152.0878	0.6575
0.50	0.0918	330.64	0.3024	0.50	0.0419	150.8637	0.6629
0.51	0.0911	328.03	0.3048	0.51	0.0416	149.6734	0.6681
0.52	0.0904	325.50	0.3072	0.52	0.0413	148.5154	0.6733
0.53	0.0897	323.03	0.3096	0.53	0.0409	147.3881	0.6785
0.54	0.0891	320.62	0.3119	0.54	0.0406	146.2902	0.6836
0.55	0.0884	318.28	0.3142	0.55	0.0403	145.2204	0.6886
0.56	0.0878	315.99	0.3165	0.56	0.0400	144.1775	0.6936
0.57	0.0872	313.76	0.3187	0.57	0.0398	143.1603	0.6985
0.58	0.0866	311.58	0.3209	0.58	0.0395	142.1679	0.7034
0.59	0.0860	309.46	0.3231	0.59	0.0392	141.1991	0.7082
0.60	0.0854	307.39	0.3253	0.60	0.0390	140.2530	0.7130
0.61	0.0848	305.36	0.3275	0.61	0.0387	139.3288	0.7177
0.62	0.0843	303.38	0.3296	0.62	0.0385	138.4255	0.7224
0.63	0.0837	301.45	0.3317	0.63	0.0382	137.5424	0.7270
0.64	0.0832	299.55	0.3338	0.64	0.0380	136.6787	0.7316
0.65	0.0827	297.70	0.3359	0.65	0.0377	135.8336	0.7362
0.66	0.0822	295.89	0.3380	0.66	0.0375	135.0066	0.7407
0.67	0.0817	294.12	0.3400	0.67	0.0373	134.1970	0.7452
0.68	0.0812	292.38	0.3420	0.68	0.0371	133.4041	0.7496
0.69	0.0807	290.68	0.3440	0.69	0.0368	132.6273	0.7540
0.70	0.0803	289.01	0.3460	0.70	0.0366	131.8662	0.7583
0.71	0.0798	287.37	0.3480	0.71	0.0364	131.1201	0.7627
0.72	0.0794	285.77	0.3499	0.72	0.0362	130.3886	0.7669
0.73	0.0789	284.20	0.3519	0.73	0.0360	129.6712	0.7712
0.74	0.0785	282.65	0.3538	0.74	0.0358	128.9674	0.7754
0.75	0.0781	281.14	0.3557	0.75	0.0356	128.2768	0.7796
0.76	0.0777	279.65	0.3576	0.76	0.0354	127.5990	0.7837
0.77	0.0773	278.20	0.3595	0.77	0.0353	126.9335	0.7878
0.78	0.0769	276.76	0.3613	0.78	0.0351	126.2801	0.7919
0.79	0.0765	275.36	0.3632	0.79	0.0349	125.6382	0.7959
0.80	0.0761	273.98	0.3650	0.80	0.0347	125.0077	0.8000
0.81	0.0757	272.62	0.3668	0.81	0.0346	124.3881	0.8039
0.82	0.0754	271.28	0.3686	0.82	0.0344	123.7790	0.8079
0.83	0.0750	269.97	0.3704	0.83	0.0342	123.1804	0.8118
0.84	0.0746	268.68	0.3722	0.84	0.0341	122.5917	0.8157
0.85	0.0743	267.41	0.3740	0.85	0.0339	122.0127	0.8196
0.86	0.0739	266.16	0.3757	0.86	0.0337	121.4432	0.8234
0.87	0.0736	264.94	0.3775	0.87	0.0336	120.8829	0.8272
0.88	0.0733	263.73	0.3792	0.88	0.0334	120.3316	0.8310
0.89	0.0729	262.54	0.3809	0.89	0.0333	119.7889	0.8348
0.90	0.0726	261.37	0.3826	0.90	0.0331	119.2547	0.8385
0.91	0.0723	260.21	0.3843	0.91	0.0330	118.7288	0.8423
0.92	0.0720	259.08	0.3860	0.92	0.0328	118.2109	0.8459
0.93	0.0717	257.96	0.3877	0.93	0.0327	117.7008	0.8496
0.94	0.0714	256.86	0.3893	0.94	0.0326	117.1984	0.8533
0.95	0.0710	255.78	0.3910	0.95	0.0324	116.7033	0.8569
0.96	0.0708	254.71	0.3926	0.96	0.0323	116.2155	0.8605
0.97	0.0705	253.65	0.3942	0.97	0.0321	115.7348	0.8640
0.98	0.0702	252.61	0.3959	0.98	0.0320	115.2610	0.8676
0.99	0.0699	251.59	0.3975	0.99	0.0319	114.7938	0.8711

1.00	0.0696	250.58	0.3991	1.00	0.0318	114.3333	0.8746



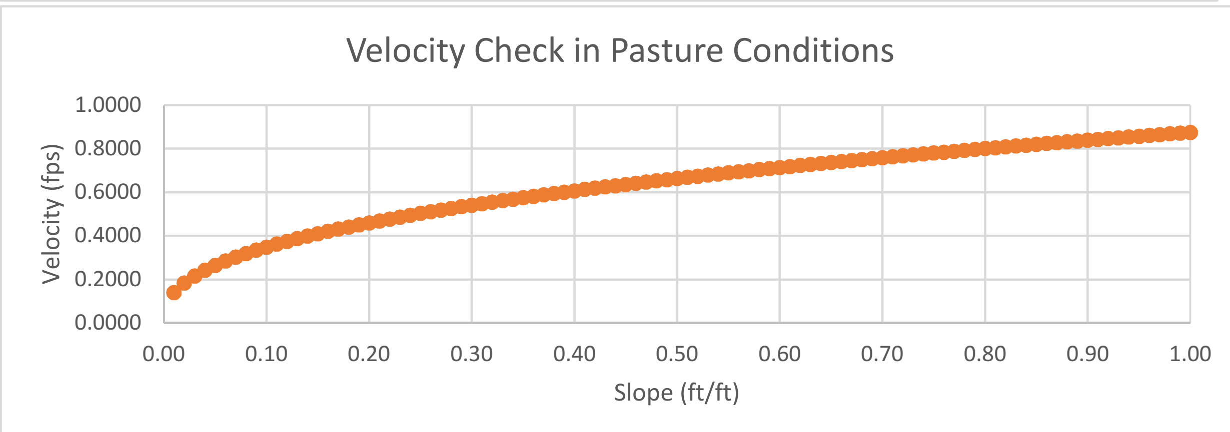


Table A4.2: Diffuser Sedimentation Estimates

Gravel Weight	105.00	lbs/CF	Gravel, Dry: https://www.engineeringtoolbox.com/dirt-mud-densities-d_1727.html
Area of Gravel Below Berm	22.32	SF	
Width	1.00	Ft	
Weight of Gravel per Linear foot of Diffuser	2343.60	LBS	
Percent of Fines in Unwashed Stones	5.00	%	
Weight of Fines per Linear Foot	117.18	LBS	
Density of Fines	76.00	LBS/CF	Dirt, Loose Dry: https://www.engineeringtoolbox.com/dirt-mud-densities-d_1727.html
Volume of Fines	1.54	CF	
Area of Fines per Linear Foot	1.54	SF	
Gravel Sump Porosity	0.40		
Required Sump Storage Area	3.85	SF	
Sump Width	4.50	Ft	
Required Sump Depth	0.86	Ft	

Table A4.2 continued: Diffuser Sedimentation Estimates

Drainage Area	1 AC	2 AC	5 AC	
CN	98	98	98	
Tc	5 min	5 min	5 min	
Diffuser Size	27.7 Ft	55.3 Ft	138.4 Ft	
TSS Loading	60.56 lbs/ac/yr	60.56 lbs/ac/yr	60.56 lbs/ac/yr	Estimated as the Average of the Forested Basin TSS Loadings (CBPA Guidance Doc)
Yearly Sediment Input	60.56 Lbs	121.12 Lbs	302.8 Lbs	
Density of Sediment	76.00 LBS/CF	76.00 LBS/CF	76.00 LBS/CF	Dirt, Loose Dry: https://www.engineeringtoolbox.com/dirt-mud-densities-d_1727.html
Volume of Sediment	0.79684 CF	1.5936842 CF	3.984211 CF	
Volume of Sediment per Linear Foot	0.02877 CF/FT	0.0288189 CF/FT	0.028788 CF/FT	
Area of Gravel Below Berm (no sump)	17.82 SF	17.82 SF	17.82 SF	
Open Storage Area	2.25 SF	2.25 SF	2.25 SF	
Volume of Storage per Linear Foot	9.378 CF	9.378 CF	9.378 CF	The stone storage with 0.4 porosity and full open storage to berm height
Total Storage Volume	259.771 CF	518.6034 CF	1297.915 CF	Diffuser Length times the storage per linear foot
Maintenance Required when Sediment Reaches X% of Total Storage	50 %	50 %	50 %	BMP Clearinghouse Rec's for Ext. Detention - Forebay to be excavated when 50% capacity is filled in
Cleanout Req'd Every X Years	163 Years	162.70582 Years	162.8824 Years	

Table III.1 - Forested loading rates by basin:

River Basin	TN (lbs/ac/yr)	TP (lbs/ac/yr)	TSS (lbs/ac/yr)
James	2.36	0.13	77.38
Potomac	5.29	0.13	79.91
Rappahannock	4.03	0.13	57.35
York	2.13	0.07	27.61

James	77.38 lbs/acre/yr
Potomac	79.91 lbs/acre/yr
Rappahannock	57.35 lbs/acre/yr
York	27.61 lbs/acre/yr
Average	60.5625 lbs/acre/yr

Table A4.2 continued: Diffuser Sedimentation Estimates

Drainage Area	1 AC	2 AC	5 AC	
CN	98	98	98	
Tc	5 min	5 min	5 min	
Diffuser Size	27.7 Ft	55.3 Ft	138.4 Ft	
TSS Loading	682.23 lbs/ac/yr	682.23 lbs/ac/yr	682.23 lbs/ac/yr	Estimated as the Average of the Major basin TSS Loadings for Regulated Urban Impervious Areas (CBPA Guidance Doc)
Yearly Sediment Input	682.23 Lbs	1364.46 Lbs	3411.15 Lbs	
Density of Sediment	76.00 LBS/CF	76.00 LBS/CF	76.00 LBS/CF	Dirt, Loose Dry: https://www.engineeringtoolbox.com/dirt-mud-densities-d_1727.html
Volume of Sediment	8.97671 CF	17.95342 CF	44.88355 CF	
Volume of Sediment per Linear Foot	0.32407 CF/FT	0.324655 CF/FT	0.324303 CF/FT	
Area of Gravel Below Berm (no sump)	17.82 SF	17.82 SF	17.82 SF	
Open Storage Area	2.25 SF	2.25 SF	2.25 SF	
Volume of Storage per Linear Foot	9.378 CF	9.378 CF	9.378 CF	The stone storage with 0.4 porosity and full open storage to berm height
Total Storage Volume	259.771 CF	518.6034 CF	1297.915 CF	Diffuser Length times the storage per linear foot
Maintenance Required when Sediment Reaches X% of Total Storage	50 %	50 %	50 %	BMP Clearinghouse Rec's for Ext. Detention - Forebay to be excavated when 50% capacity is filled in
Cleanout Req'd Every X Years	14.4691 Years	14.44302 Years	14.4587 Years	

Regulated Urban Impervious TSS Loadings

James	676.94	lbs/acre/yr
Potomac	1171.32	lbs/acre/yr
Rappahannock	423.97	lbs/acre/yr
York	456.68	lbs/acre/yr
Average	682.228	lbs/acre/yr

Table 2 b: Calculation Sheet for Estimating Existing Source Loads for the Potomac River Basin (* Based on Chesapeake Bay Program Watershed Model Phase 5.3.2)

Subsource	Pollutant	Total Existing Acres Served by MS4 (06/30/09)	2009 EOS Loading Rate (lbs/acre/yr)	Estimated Total POC Load Based on 2009 Progress Run (lbs/yr)
Regulated Urban Impervious	Nitrogen		16.86	
Regulated Urban Pervious			10.07	
Regulated Urban Impervious	Phosphorus		1.62	
Regulated Urban Pervious			0.41	
Regulated Urban Impervious	Total Suspended Solids		1,171.32	
Regulated Urban Pervious			175.8	

Table 2 b: Calculation Sheet for Estimating Existing Source Loads for the Potomac River Basin (* Based on Chesapeake Bay Program Watershed Model Phase 5.3.2)

Subsource	Pollutant	Total Existing Acres Served by MS4 (06/30/09)	2009 EOS Loading Rate (lbs/acre/yr)	Estimated Total POC Load Based on 2009 Progress Run (lbs/yr)
Regulated Urban Impervious	Nitrogen		16.86	
Regulated Urban Pervious			10.07	
Regulated Urban Impervious	Phosphorus		1.62	
Regulated Urban Pervious			0.41	
Regulated Urban Impervious	Total Suspended Solids		1,171.32	
Regulated Urban Pervious			175.8	

Table 2 d: Calculation Sheet for Estimating Existing Source Loads for the York River Basin (* Based on Chesapeake Bay Program Watershed Model Phase 5.3.2)

Subsource	Pollutant	Total Existing Acres Served by MS4 (06/30/09)	2009 EOS Loading Rate (lbs/acre/yr)	Estimated Total POC Load Based on 2009 Progress Run (lbs/yr)
Regulated Urban Impervious	Nitrogen		7.31	
Regulated Urban Pervious			7.65	
Regulated Urban Impervious	Phosphorus		1.01	
Regulated Urban Pervious			0.51	
Regulated Urban Impervious	Total Suspended Solids		456.68	
Regulated Urban Pervious			72.28	

Table 2 c: Calculation Sheet for Estimating Existing Source Loads for the Rappahannock River Basin (* Based on Chesapeake Bay Program Watershed Model Phase 5.3.2)

Subsource	Pollutant	Total Existing Acres Served by MS4 (06/30/09)	2009 EOS Loading Rate (lbs/acre/yr)	Estimated Total POC Load Based on 2009 Progress Run (lbs/yr)
Regulated Urban Impervious	Nitrogen		9.36	
Regulated Urban Pervious			5.34	
Regulated Urban Impervious	Phosphorus		1.41	
Regulated Urban Pervious			0.38	
Regulated Urban Impervious	Total Suspended Solids		423.97	
Regulated Urban Pervious			56.01	

Table A4.3: Storage Volume Calculator

STORMWATER PRACTICE STORAGE VOLUMES

Access Road or Pipeline ROW ID

POA ID

Flow Diffusers:

Total Number of Diffusers =	1		(Total Number of Diffusers within POA)
Total Diffuser Length =	6	ft	(Includes all diffusers associated with POA)
Outlet Structure Dimensions:			
Weir Length =	6	ft	
Outlet Elevation =	0	ft	
Berm Elevation =	0.6667	ft	
Side Slopes =	Vertical		

Outlet Structure XS

Length (ft)	Elev. (ft)
0	2
0	0
6	0
6	2

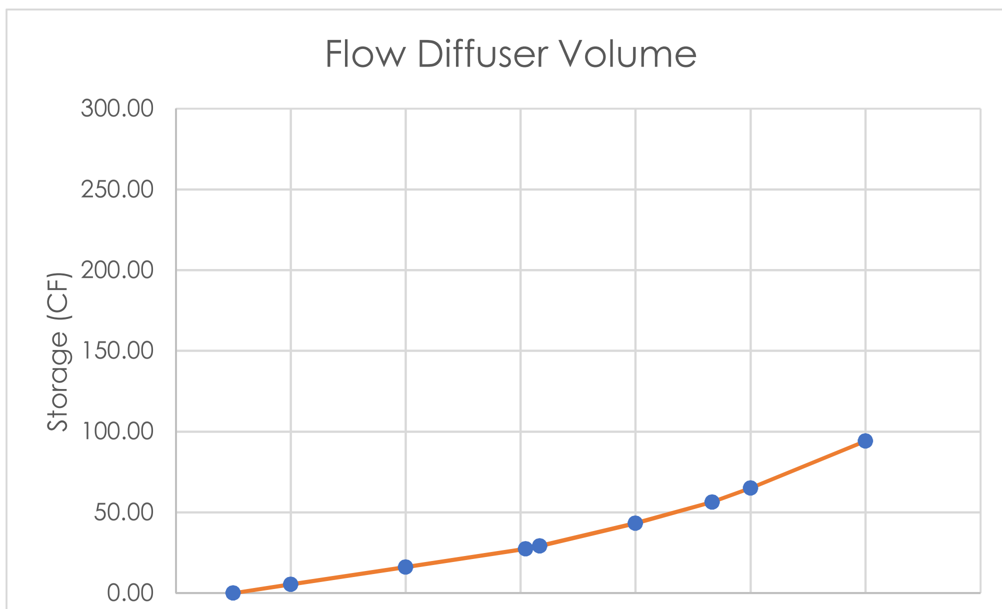
*Only Used in Detailed Routings

Total Flow Diffuser Volume 56.28 CF

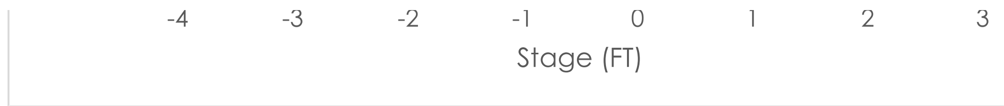
Flow Diffuser Volume Curve

Stage (FT)	Cumulative Storage (CF)
-3.5	0.00
-3	5.40
-2	16.20
-0.9573	27.46
-0.8333	29.17
0	43.17
0.6667	56.28
1	65.15
2	94.15

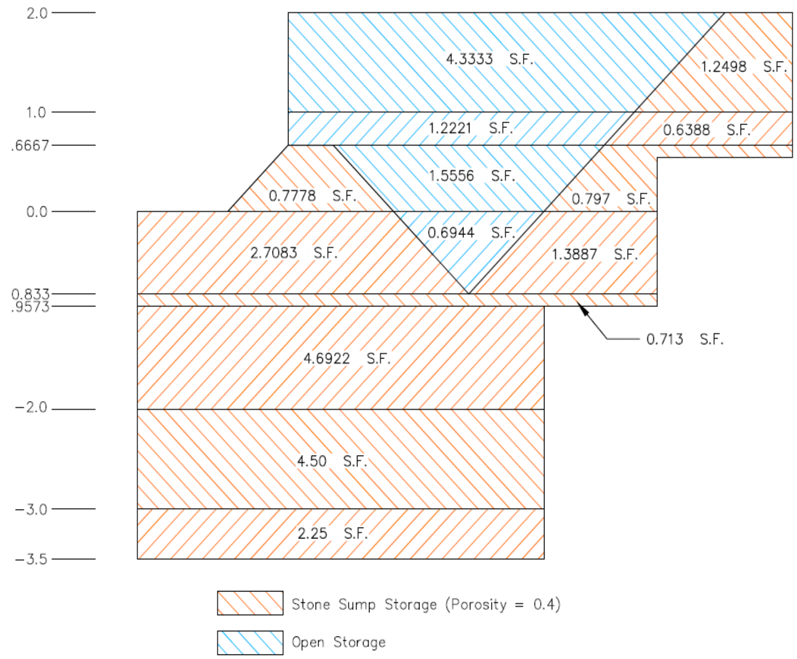
Red Text = Proposed Storage Volume



*Volume Shown Above Proposed Storage for Detailed Routings Only, if Applicable



Elevation Area Diagram: Elevation Area Depiction based upon Provided Flow Diffuser Detail. Areas and Relative Elevations shown were utilized to develop the storage curve above.



Waterbars:

Total Number of Waterbars =	1		(Total Number of Waterbars within POA)
Single Waterbar Length =	16	ft	(Length of one (1) Waterbar)
Outlet Structure Dimensions:			
Total Weir Length =	2.17	ft	
Weir Elevation =	0.5	ft	
Side Slopes =	2:1		

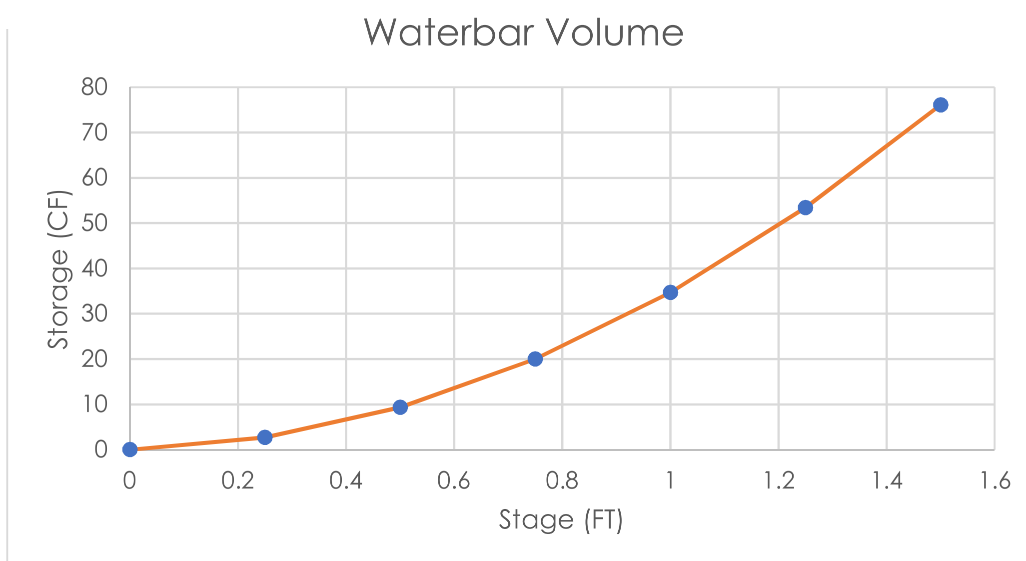
Total Waterbar Volume 9 CF

Waterbar Volume Curve

Stage (FT)	Cumulative Storage (CF)
0	0
0.25	2.68
0.5	9.36
0.75	20.04
1	34.72
1.25	53.4
1.5	76.08

Red Text = Proposed Storage Volume

*Volume Shown Above Proposed Storage for Detailed Routings Only, if Applicable



*Waterbar has a Storage Depth of 0.5 FT with an estimated Trapezoidal Section (Bottom Width of 0.17 FT, 2:1 Side Slopes)

Check Dams*:

Total Number of Check Dams = 1 (Total Number of Check Dams within POA)

Check Dam Ponding Length = 5 ft (Assumes a channel slope of 20%)

Outlet Structure Dimensions:

Total Weir Length = 2 ft

Weir Elevation = 0.5 ft

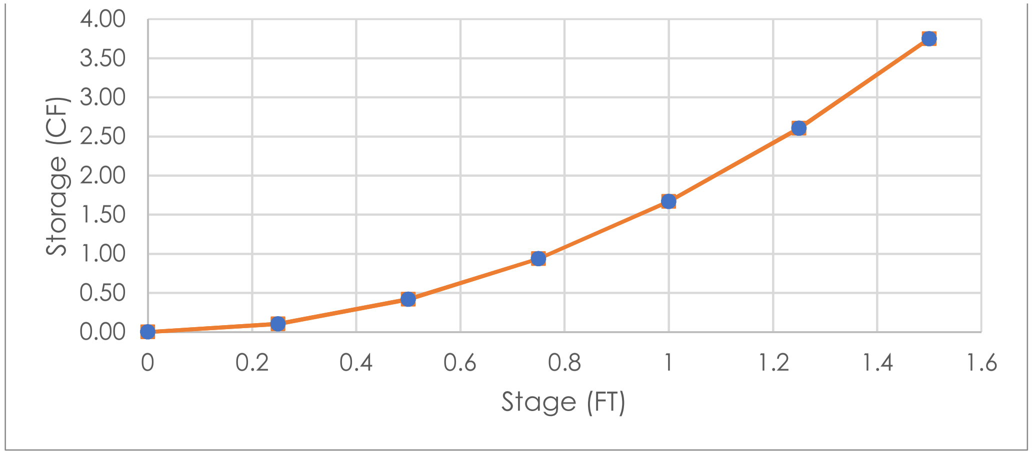
Side Slopes = 2:1

Total Check Dam Volume 0 CF

Check Dam Volume Curve

Stage (FT)	Cumulative Storage (CF)
0	0.00

0.25	0.10
0.5	0.42
0.75	0.94
1	1.67
1.25	2.60
1.5	3.75



Red Text = Proposed Storage Volume

*Volume Shown Above Proposed Storage for Detailed Routings Only, if Applicable

*Conservatively estimated all ditches as Type 1 (V-ditch) with 2:1 Side Slopes

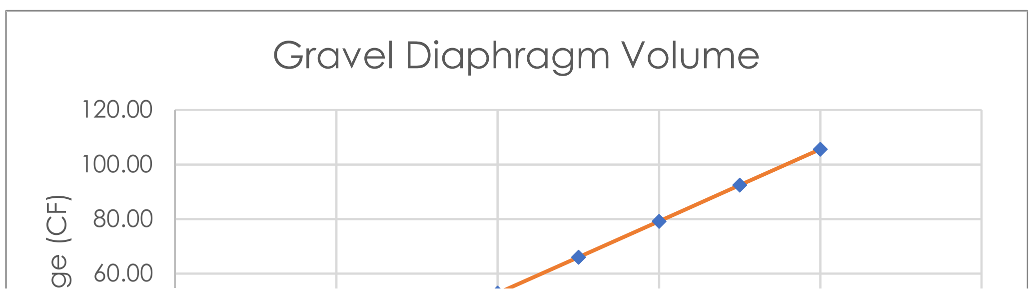
Gravel Diaphragm:

Length of Roadway =	100		(Centerline Length of Road)
Effective Length of Diaphragm =	200	ft	(Assumes a channel slope of 20%)
Outlet Structure Dimensions:			
Total Weir Length =	200	ft	
Weir Elevation =	1	ft	
Side Slopes =	2:1		
Percent Usable Volume =	33	%	

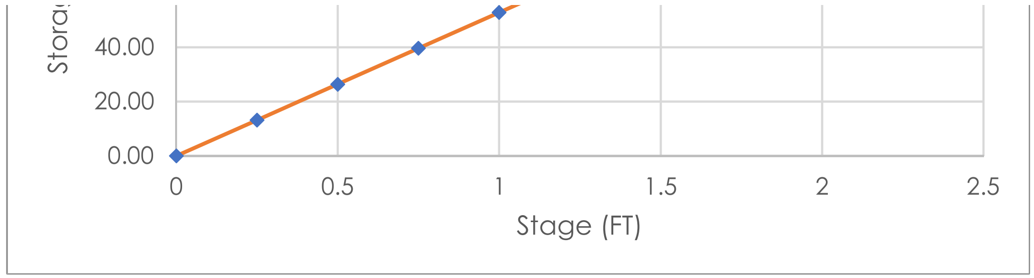
Total Gravel Diaphragm Volume 53 CF

Gravel Diaphragm Volume Curve

Stage (FT)	Cumulative Storage (CF)
0	0.00
0.25	13.20
0.5	26.40
0.75	39.60
1	52.80



1.25	66.00
1.5	79.20
1.75	92.40
2	105.60



Red Text = Proposed Storage Volume

*Volume Shown Above Proposed Storage for Detailed Routings Only, if Applicable

*Diaphragm has 1 FT Depth and Bottom Width, 1:1 Side Slopes, and a Pore Space of 0.4. Roadway Slope Percent Usable Volume conservatively estimated at 33% unless otherwise documented.

Cumulative Storage Volume **119 CF**

*For use in Vs/Vr Storage Volume Comparisons Only. Cumulative Practice Volumes shall not be used for detailed modeling/routings.

Table A4.4: Standard Diffuser Sizing

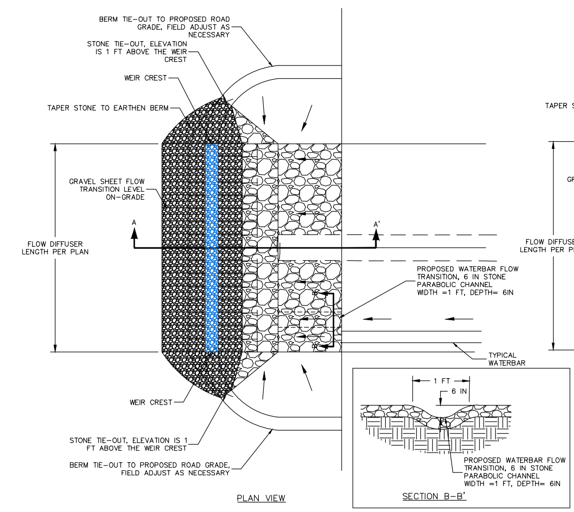
Discharge (cfs)	NYS Diffuser Sizing (FT @ 0.25cfs)	Standard Diffuser Size (FT)
0.100	0.40	-
0.200	0.80	-
0.300	1.20	-
0.400	1.60	-
0.500	2.00	-
0.600	2.40	6.00
0.700	2.80	6.00
0.800	3.20	6.00
0.900	3.60	6.00
1.000	4.00	6.00
1.100	4.40	6.00
1.200	4.80	6.00
1.300	5.20	6.00
1.400	5.60	6.00
1.500	6.00	6.00
1.600	6.40	8.00
1.700	6.80	8.00
1.800	7.20	8.00
1.900	7.60	8.00
2.000	8.00	8.00
2.100	8.40	10.00
2.200	8.80	10.00
2.300	9.20	10.00
2.400	9.60	10.00
2.500	10.00	10.00
2.600	10.40	12.00
2.700	10.80	12.00
2.800	11.20	12.00
2.900	11.60	12.00
3.000	12.00	12.00
3.100	12.40	14.00
3.200	12.80	14.00
3.300	13.20	14.00
3.400	13.60	14.00
3.500	14.00	14.00
3.600	14.40	16.00
3.700	14.80	16.00
3.800	15.20	16.00
3.900	15.60	16.00
4.000	16.00	16.00
4.100	16.40	18.00
4.200	16.80	18.00
4.300	17.20	18.00

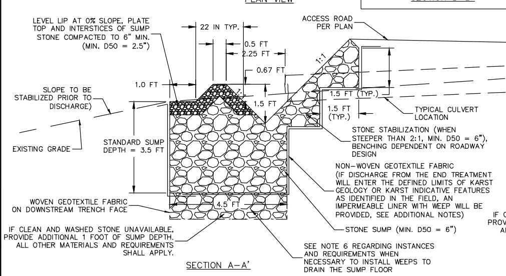
4.400	17.60	18.00
4.500	18.00	18.00
4.600	18.40	20.00
4.700	18.80	20.00
4.800	19.20	20.00
4.900	19.60	20.00
5.000	20.00	20.00
5.100	20.40	22.00
5.200	20.80	22.00
5.300	21.20	22.00
5.400	21.60	22.00
5.500	22.00	22.00
5.600	22.40	24.00
5.700	22.80	24.00
5.800	23.20	24.00
5.900	23.60	24.00
6.000	24.00	24.00
6.100	24.40	26.00
6.200	24.80	26.00
6.300	25.20	26.00
6.400	25.60	26.00
6.500	26.00	26.00
6.600	26.40	28.00
6.700	26.80	28.00
6.800	27.20	28.00
6.900	27.60	28.00
7.000	28.00	28.00
7.100	28.40	30.00
7.200	28.80	30.00
7.300	29.20	30.00
7.400	29.60	30.00
7.500	30.00	30.00
7.600	30.40	32.00
7.700	30.80	32.00
7.800	31.20	32.00
7.900	31.60	32.00
8.000	32.00	32.00
8.100	32.40	34.00
8.200	32.80	34.00
8.300	33.20	34.00
8.400	33.60	34.00
8.500	34.00	34.00
8.600	34.40	36.00
8.700	34.80	36.00
8.800	35.20	36.00
8.900	35.60	36.00
9.000	36.00	36.00

9.100	36.40	38.00
9.200	36.80	38.00
9.300	37.20	38.00
9.400	37.60	38.00
9.500	38.00	38.00
9.600	38.40	40.00
9.700	38.80	40.00
9.800	39.20	40.00
9.900	39.60	40.00
10.000	40.00	40.00

MODIFIED FLOW DIFFUSER DETAIL (SIDE SLOPES STEEPER THAN 2:1)

NOT TO SCALE





NOTES:

1. WEIR SIZING IN ACCORDANCE WITH WHITE PAPER, 0.25 CFS PER LF OF WEIR LENGTH (10-YR STORM), UNLESS DOWNSTREAM SLOPE EQUALS 30% OR GREATER (0.125 CFS/LF).
2. NON-WOVEN GEOTEXTILE FABRIC SHALL BE NON-WOVEN POLYPROPYLENE GEOTEXTILE, SUCH AS MIRAFI 700X, MIRAFI 70/20, N060, OR OWNER APPROVED EQUAL. THE FABRIC SHALL HAVE PUNCTURE RESISTANCE GREATER THAN 100 LBS, APPARENT OPENING SIZE GREATER THAN U.S. 70 SIEVE, AND 30 LBS. OF TENSILE STRENGTH AT 20% (MAXIMUM). ALL GEOTEXTILE FABRICS BEING INSTALLED ON A VERTICAL SLOPE SHALL BE CUT FLUSH WITH GRADE, SO AS NO GEOTEXTILE FABRIC SHALL BE VISIBLE.
3. WOVEN GEOTEXTILE FABRIC SHALL BE WOVEN HIGH-TENACITY POLYPROPYLENE GEOTEXTILE, SUCH AS MIRAFI 500X, ACF S300N, OR OWNER APPROVED EQUAL. THE FABRIC SHALL HAVE PUNCTURE RESISTANCE GREATER THAN 700 LBS, APPARENT OPENING SIZE GREATER THAN U.S. 40 SIEVE, AND 315 LBS. OF TENSILE STRENGTH AT 10% (MAXIMUM).
4. IMPERMEABLE LINER (IF APPLICABLE) SHALL BE 30 MIL PVC INSTALLED IN ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATIONS.
5. STONE MATERIAL SIZE AS SPECIFIED PER DETAILS SHALL BE CLEAN AND WASHED (IF NATIVE MATERIAL, CLEAN AND WASHED SHALL, AT MINIMUM, MEAN POWERWASHING STONE ONSITE TO REMOVE FINES). ALTERNATIVELY, SHOULD CLEAN AND WASHED STONE NOT BE AVAILABLE AT THE FIELD LOCATION, AN ADDITIONAL SUMP STONE AREA MAY BE PROVIDED IN THE BOTTOM OF THE TRENCH PROFILE TO ACCOMMODATE POTENTIAL SEDIMENTATION.
6. IN AREAS WHERE FACILITIES DISCHARGE DIRECTLY WITHIN DEFINED LIMITS OF KARST GEOLOGY OR KARST INDICATIVE FEATURES AND IN AREAS WITH HSG C AND HSG D SOILS, THE FLOW DIFFUSERS WILL BE PROVIDED WITH THE ABILITY TO WEEP / DRAIN THE BOTTOM OF THE SUMP FLOOR. WEEPING WILL BE PROVIDED IN THESE INSTANCES, PRIMARILY THROUGH A GRAVEL TRENCH (6 INCHES BY 6 INCHES), OR FRENCH DRAIN COMPOSED OF VDOT #57 STONE WRAPPED IN A NON-WOVEN GEOTEXTILE FABRIC.
7. IN AREAS WHERE WATERBARS OUTLET TO A FLOW DIFFUSER, A FLOW TRANSITION IS REQUIRED TO TRANSFER FLOWS DOWN THE ROAD EMBANKMENT INTO THE DIFFUSER. THESE TRANSITIONS SHALL BE 6 INCH STONE WITH A GENERAL PARABOLIC SECTION (DEPTH = 6 IN, WIDTH = 1 FT.)
8. FLOW DIFFUSERS SHALL BE INSTALLED TO OUTFALL PARALLEL TO THE DOWN GRADIENT CONTOURS WITH THE LEVEL LIP ON GRADE WITH EXISTING GRADE AT A 0% SLOPE.
9. ALL DOWNSTREAM SLOPES SHALL REMAIN UNDISTURBED TO THE GREATEST EXTENT PRACTICABLE.
10. INSTALLATION SHALL BE PER ALIGNMENT SHEET PLAN AND DETAIL PLAN AND INSTALLATION SHALL BE APPROVED BY OWNER (ACP).
11. CONTRACTOR SHALL NOTIFY OWNER (ACP) IF FIELD CONDITIONS THREATEN OR PROHIBIT THE INSTALLATION OF THE FLOW DIFFUSER MEASURES PER DETAIL AND PLAN. SHOULD FIELD ALTERATION BE REQUIRED, CONTRACTOR SHALL OBTAIN OWNER (ACP) APPROVAL AND CAPTURE CHANGES UNDER CONSTRUCTION RECORD DRAWINGS. BASED ON COORDINATION WITH THE DEQ REPRESENTATIVE, SHOULD CUSTOM FIELD SOLUTIONS BE REQUIRED THAT SIGNIFICANTLY ALTER THE DRAINAGE AREA, FLOW DISCHARGE LOCATIONS OR AFFECTS OVERALL REGULATORY COMPLIANCE, THE CONTRACTOR SHALL BE RESPONSIBLE FOR COMMUNICATIONS TO FACILITATE APPROVAL OF THE ADJUSTMENTS BY THE OWNER (ACP) AND ITS REPRESENTATIVES AND COORDINATION AND APPROVAL BY DEQ.
12. CONTRACTOR SHALL BE RESPONSIBLE FOR ADJUSTMENTS AND/OR CORRECTIVE ACTIONS TO ADDRESS FIELD INSPECTIONS AND RECORD DRAWING CERTIFICATION.
13. CONTRACTOR RESPONSIBLE FOR COORDINATING INDIVIDUAL FACILITY ACCEPTANCE WITH OWNER (ACP) AT RECORD DRAWING COMPLETION.

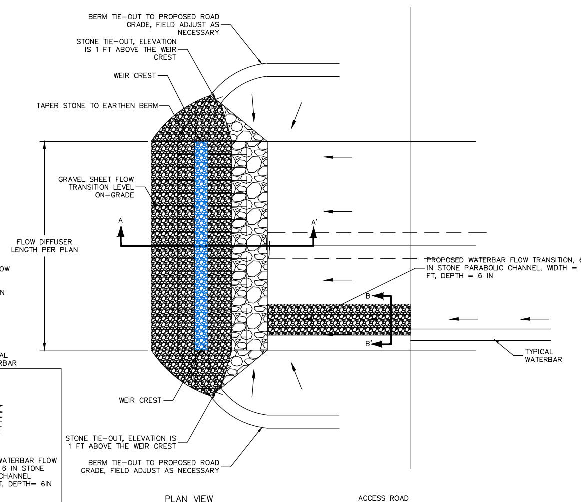
MAINTENANCE:

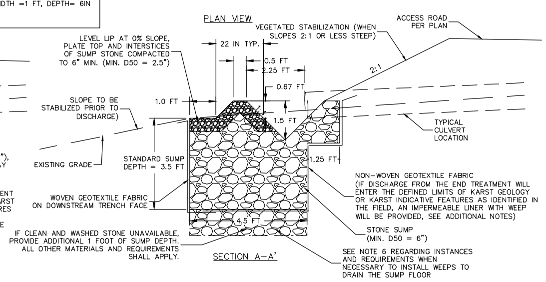
LONG TERM MAINTENANCE OF THE FLOW DIFFUSER IS ESSENTIAL TO ENSURE ITS CONTINUED EFFECTIVENESS. THE FOLLOWING PROVISIONS SHOULD BE FOLLOWED. ANNUAL INSPECTION SHOULD BE PERFORMED, ANY SIGNS OF CHANNELIZATION AND DEFICIENCY SHOULD BE IMMEDIATELY REPAIRED.

1. INSPECTIONS: ONCE A YEAR, THE FLOW DIFFUSER POOL SHOULD BE INSPECTED FOR SEDIMENT ACCUMULATION AND DEBRIS THAT MAY REDUCE ITS CAPACITY. GENERAL STRUCTURAL INTEGRITY SHOULD BE REVIEWED AT THIS TIME. SHOULD STONE DISPLACEMENT OR EROSION BE NOTED, IT SHOULD BE REPAIRED IMMEDIATELY, AS APPLICABLE.
2. SEDIMENT REMOVAL: SEDIMENT BUILD UP WITHIN THE DRY STORAGE SUMP SHOULD BE REMOVED WHEN ANY ACCUMULATION IS NOTED. DISPOSE OF THE SEDIMENTS APPROPRIATELY.
3. DEBRIS: AS NEEDED REMOVE DEBRIS SUCH AS LEAF LITTER, BRANCHES AND TREE GROWTH FROM THE FLOW DIFFUSER.
4. MOWING: MOWING SHALL BE IN ACCORDANCE WITH ROW MAINTENANCE PROTOCOLS.

MODIFIED FLOW DIFFUSER DETAIL (SIDE SLOPES 2:1 OR LESS STEEP)

NOT TO SCALE





FLOW DIFFUSER CONSTRUCTION IN HIGH GROUNDWATER TABLE CONDITIONS

THE STANDARD SUMP DEPTH AS DEFINED PER THE FLOW DIFFUSER DETAIL SHALL BE 3.5 FEET UNLESS SPECIFICALLY NOTED OTHERWISE ON THE CONSTRUCTION PLANS OR IN THE EVENT THAT HIGH GROUNDWATER TABLE (HGWT) CONDITIONS ARE ENCOUNTERED IN THE FIELD. SHOULD HGWT CONDITIONS BE ENCOUNTERED WITHIN THE FOOTPRINT OF A PROPOSED FLOW DIFFUSER, THE CONTRACTOR SHALL NOTE THE DEPTH OF GROUNDWATER ENCOUNTERED AND DETERMINE THE EFFECTIVE SUMP DEPTH, OR THE DEPTH OF THE STONE THAT MAY BE CONSTRUCTED WITHOUT BEING EFFECTED BY THE GROUNDWATER ELEVATION. UPON DETERMINATION OF THE EFFECTIVE SUMP DEPTH BASED ON HGWT INFLUENCE, THE CONTRACTOR SHALL INCREASE THE SIZING OF THE FLOW DIFFUSER TO BE INSTALLED BY MULTIPLYING THE FLOW DIFFUSER LENGTH PER PLAN BY THE APPROPRIATE FLOW DIFFUSER LENGTH MULTIPLIER IN ACCORDANCE WITH THE TABLE 1 BELOW (FLOW DIFFUSER LENGTH MULTIPLIERS IN AREAS OF HGWT). CONTRACTOR SHALL BE RESPONSIBLE FOR NOTING THE SIZE, ORIENTATION, AND STANDARD DEPTHS ACHIEVED ON THE CONSTRUCTION RECORD DRAWINGS FOR ALL FLOW DIFFUSERS INSTALLED. SHOULD HGWT BE ENCOUNTERED, THE CONTRACTOR SHALL ALSO PROVIDE NOTATION REFERENCING THE EFFECTIVE SUMP DEPTH BASED ON HGWT, THE ASSOCIATED FLOW DIFFUSER LENGTH MULTIPLIER, AND THE FINAL DIFFUSER LENGTH BASED ON HGWT ON THE RECORD DRAWINGS.

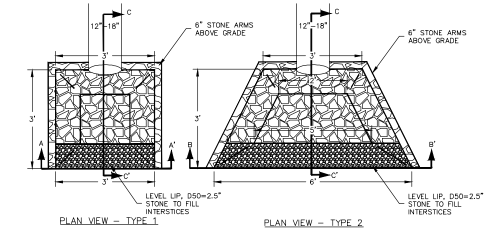
TABLE 1: FLOW DIFFUSER LENGTH MULTIPLIERS IN AREAS OF HGWT

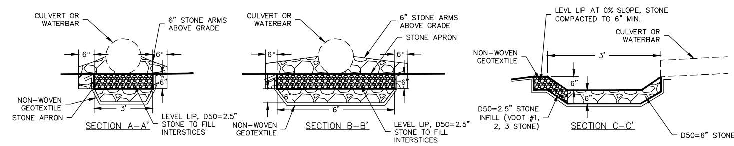
	FLOW DIFFUSER LENGTH MULTIPLIER						
EFFECTIVE SUMP DEPTH BASED ON HGWT	3.5 FT SUMP	3 FT SUMP	2.5 FT SUMP	2 FT SUMP	1.5 FT SUMP	1 FT SUMP	0.5 FT SUMP
	1	1.11	1.25	1.42	1.64	1.95	1.98

CONTRACTOR SHALL BE RESPONSIBLE FOR INSTALLING FLOW DIFFUSERS PER PLAN LOCATIONS AND IN AN ORIENTATION THAT ALLOWS FOR THE ACHIEVEMENT OF SHEET FLOW DISCHARGE PERPENDICULAR TO THE EXISTING DOWNSTREAM GRADE. LIMITED ADJUSTMENTS FOR FIELD OPTIMIZATION (ADJUSTING ORIENTATION WITHIN THE ROW, ARCING OF THE FLOW DIFFUSER LENGTH, BREAKING ONE FLOW DIFFUSER INTO TWO OR MORE TO ACHIEVE THE SAME CAPTURE AND DIFFUSION PRACTICE, ETC) SHALL BE MADE ONLY UPON APPROVAL BY THE OWNER. SHOULD THE CONTRACTOR FAIL TO MEET THE DIFFUSER DIMENSIONS NOTED UNDER PLAN, FAIL TO MEET DIFFUSER LENGTHS ACHIEVED THROUGH THE ROUTINE IMPLEMENTATION OF TABLE 1, FAIL TO ORIENT A FLOW DIFFUSER APPROPRIATELY, OR FAIL TO PROVIDE LIMITED FEATURE ADJUSTMENT TO ADDRESS FIELD CONSTRAINTS WITH THE SAME VOLUMETRIC GOALS; A PLAN MODIFICATION WILL BE REQUIRED WHICH SHALL INCLUDE THE REVIEW AND APPROVAL OF ALTERNATE COMPLIANCE STRATEGIES BY DEQ.

STANDARD STONE APRON DETAILS

NOT TO SCALE





NOTES:

1. THE TYPE 1 STANDARD STONE APRON WILL BE USED WHERE THE 10-YEAR, 24-HOUR PEAK FLOW IS LESS THAN OR EQUAL TO 0.29 CFS.
2. THE TYPE 2 STANDARD STONE APRON WILL BE USED WHERE THE 10-YEAR, 24-HOUR PEAK FLOW IS BETWEEN 0.29 AND 0.57 CFS.
3. STANDARD STONE APRONS SHALL BE INSTALLED PARALLEL TO THE DOWN GRADIENT CONTOURS WITH THE LEVEL LIP ON GRADE WITH EXISTING GRADE AT A 0% SLOPE.
4. IN SOME LOCATIONS IT MAY BE NECESSARY FOR THE PIPE OR WATERBAR TO ENTER THE STANDARD STONE APRON FROM THE SIDE SUCH THAT THE LEVEL LIP IS ORIENTED PARALLEL TO THE DOWNGRADIENT CONTOURS.
5. IN AREAS WHERE WATERBARS OUTLET TO A STANDARD STONE APRON, A FLOW TRANSITION IS REQUIRED TO TRANSFER FLOWS DOWN THE ROAD EMBANKMENT INTO THE STONE APRON DIFFUSER. THESE TRANSITIONS SHALL BE 6 INCH STONE WITH A GENERAL PARABOLIC SECTION (DEPTH = 6 IN, WIDTH = 1 FT.)
6. ALL DOWNSTREAM SLOPES SHALL REMAIN UNDISTURBED TO THE GREATEST EXTENT PRACTICABLE.
7. CONTRACTOR SHALL NOTIFY OWNER IF ANY FIELD CONDITIONS THREATEN OR PROHIBIT THE INSTALLATION OF THE SSA MEASURES PER DETAIL AND PLAN
8. INSTALLATION SHALL BE PER ESC ALIGNMENT SHEET PLAN AND DETAIL PLAN AND INSTALLATION SHALL BE APPROVED BY THE OWNER.
9. CONTRACTOR SHALL BE RESPONSIBLE FOR ADJUSTMENTS AND/OR CORRECTIVE ACTIONS TO ADDRESS FIELD INSPECTIONS AND RECORD DRAWING CERTIFICATION.
10. CONTRACTOR RESPONSIBLE FOR COORDINATING INDIVIDUAL FACILITY ACCEPTANCE WITH OWNER AT RECORD DRAWING COMPLETION.

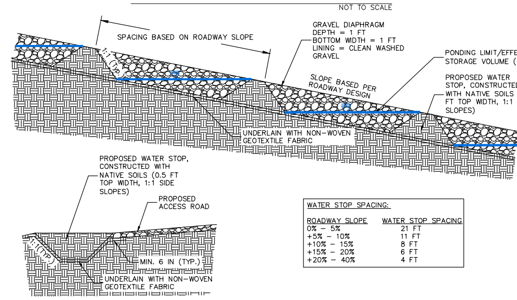
MAINTENANCE:

LONG TERM MAINTENANCE OF THE STONE APRON IS ESSENTIAL TO ENSURE ITS CONTINUED EFFECTIVENESS. THE FOLLOWING PROVISIONS SHOULD BE FOLLOWED. ANNUAL INSPECTION SHOULD BE PERFORMED, ANY SIGNS OF CHANNELIZATION AND DEFICIENCY SHOULD BE IMMEDIATELY REPAIRED.

1. INSPECTIONS: ONCE A YEAR, THE STONE APRON POOL SHOULD BE INSPECTED FOR SEDIMENT ACCUMULATION AND DEBRIS THAT MAY REDUCE ITS CAPACITY. GENERAL STRUCTURAL INTEGRITY SHOULD BE REVIEWED AT THIS TIME. SHOULD STONE DISPLACEMENT OR EROSION BE NOTED, IT SHOULD BE REPAIRED IMMEDIATELY, AS APPLICABLE.
2. SEDIMENT REMOVAL: SEDIMENT BUILD UP WITHIN THE DRY STORAGE SUMP SHOULD BE REMOVED WHEN ANY ACCUMULATION IS NOTED. DISPOSE OF THE SEDIMENTS APPROPRIATELY.
3. DEBRIS: AS NEEDED REMOVE DEBRIS SUCH AS LEAF LITTER, BRANCHES AND TREE GROWTH FROM THE STONE APRON.
4. MOWING: MOWING SHALL BE IN ACCORDANCE WITH ROW MAINTENANCE PROTOCOLS.

GRAVEL DIAPHRAGM WATER STOP DETAILS

NOT TO SCALE

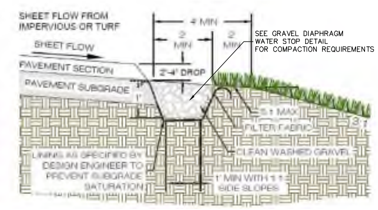


WATER STOP SPACING:

ROADWAY SLOPE	WATER STOP SPACING
0% - 5%	21 FT
+5% - 10%	11 FT
+10% - 15%	8 FT
+15% - 20%	6 FT
+20% - 40%	4 FT

GRAVEL DIAPHRAGM

NOT TO SCALE



NOTES:

1. IF SPRINGS, SEEPS OR OTHER GROUNDWATER IS ENCOUNTERED DURING THE INSTALLATION OF A GRAVEL DIAPHRAGM, PLAN MODIFICATIONS MUST BE PROVIDED AND COORDINATED WITH THE DEQ FIELD REPRESENTATIVE.

SYM.	DATE	BY	REVISION INFORMATION	PROJECT/TASK	APP.
3	02/08/18	JEY	VDEQ COMMENT RESPONSE	-	SL
2	01/22/18	JEY	VDEQ COMMENT RESPONSE	-	SL
1	11/10/17	JEY	VA DEQ COMMENT RESPONSE	-	-
0	05/22/17	JEY	ISSUED FOR PERMITTING	-	-

COMMONWEALTH OF VIRGINIA — Stephen L. Lindsay — Lic. No. 057734 — 02-12-18 — PROFESSIONAL ENGINEER

ERM Environmental Resources Management

DRAWN:	EJB	05/22/2017
CHECKED:	JEY	05/22/2017
APP. FOR BID:		
APP. FOR CONST.:		
SCALE:	AS NOTED	

Atlantic Coast Pipeline, LLC

925 White Oaks Blvd. Bridgeport, West Virginia 26330 / 681-842-8000

TITLE: **ATLANTIC COAST PIPELINE — EROSION AND SEDIMENT CONTROL DETAILS**

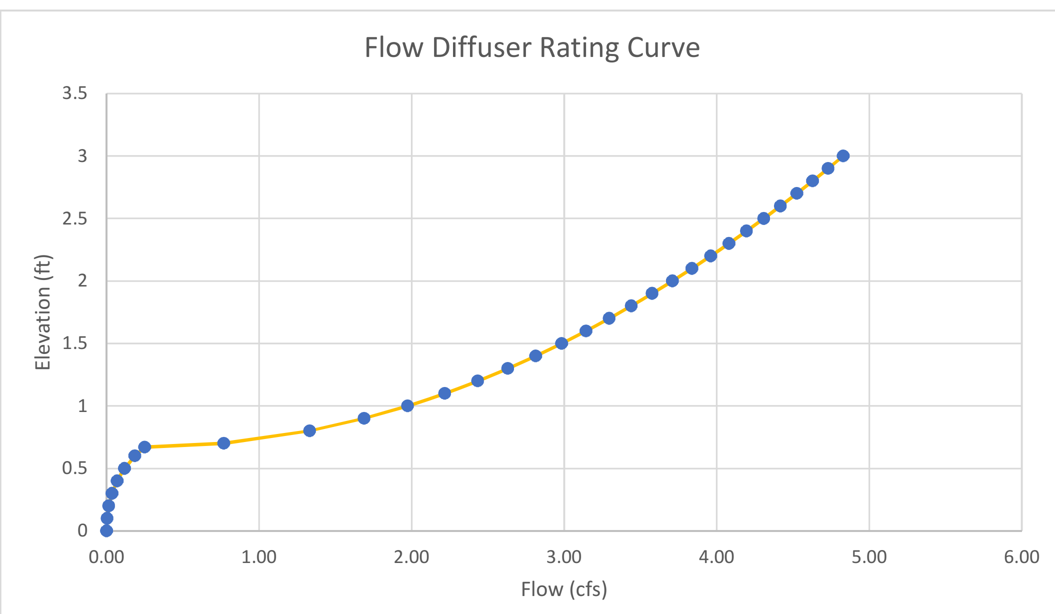
DISTRICT:	COUNTY:	STATE:	GROUP	DWG. NO.	REV.
-	-	VA	-	3 of 13	3

DIR/FILE: ACP\Virginia\Details

Table A4.5: Diffuser Unit Rating Curve

Length of Flow Diffuser 1 ft

Elevation	Flow Through Berm (cfs)	Flow Over Berm (cfs)	Total Flow (cfs)
0	0.00	0.00	0.00
0.1	0.00	0.00	0.00
0.2	0.01	0.00	0.01
0.3	0.04	0.00	0.04
0.4	0.07	0.00	0.07
0.5	0.12	0.00	0.12
0.6	0.19	0.00	0.19
0.67	0.25	0.00	0.25
0.7	0.25	0.52	0.77
0.8	0.25	1.08	1.33
0.9	0.25	1.44	1.69
1	0.25	1.72	1.97
1.1	0.25	1.97	2.22
1.2	0.25	2.18	2.43
1.3	0.25	2.38	2.63
1.4	0.25	2.56	2.81
1.5	0.25	2.73	2.98
1.6	0.25	2.89	3.14
1.7	0.25	3.04	3.29
1.8	0.25	3.19	3.44
1.9	0.25	3.33	3.58
2	0.25	3.46	3.71
2.1	0.25	3.59	3.84
2.2	0.25	3.71	3.96
2.3	0.25	3.83	4.08
2.4	0.25	3.95	4.20
2.5	0.25	4.06	4.31
2.6	0.25	4.17	4.42
2.7	0.25	4.27	4.52
2.8	0.25	4.38	4.63
2.9	0.25	4.48	4.73
3	0.25	4.58	4.83



q=k*i*A
q= Flow (CFS)
i=hydraulic gradient
A=Area Normal to Flow (SF)
k= hydraulic conductivity (ft/s)

i=(h1-h2)/l
h1=Depth Behind Berm (FT)
h2=Depth D/S of Berm (FT)
l=flow length through berm (FT)

Hydraulic Conductivity Range

Natural Wastewater Treatment Systems, Second Edition

By Ronald W. Crites, E. Joe Middlebrooks, Robert Bastian

TABLE 7.1
Typical Media Characteristics for Subsurface Flow Wetlands

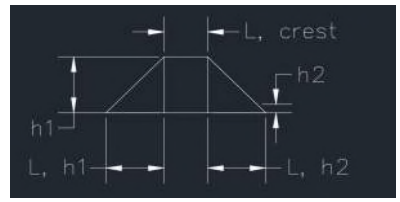
Media Type	Effective Size (D_{10}) (mm)	Porosity (n) (%)	Hydraulic Conductivity (K_s) (ft/d)
Coarse sand	2	28–32	328–3280
Gravelly sand	8	30–35	1640–16,400
Fine gravel	16	35–38	3280–32,800
Medium gravel	32	36–40	32,800–164,000
Coarse rock	128	38–45	164,000–820,000

Note: ft/d × 0.305 = m/d.

k
60500 ft/day   Assumed Medium Gravel
2520.8333 ft/hr
42.013889 ft/min
0.7002315 ft/s

Darcy's Law

h1 (ft)	h2 (ft)	l, h1 (ft)	l, h2 (ft)	l crest (ft)	l (ft)	i	k (ft/s)	A (sf)	q (cfs)
0.000	0.000	0.670	0.670	0.500	1.840	0.000	0.7000	0.000	0.000
0.100	0.015	0.570	0.655	0.500	1.725	0.049	0.7000	0.100	0.003
0.200	0.030	0.470	0.640	0.500	1.610	0.106	0.7000	0.200	0.015
0.300	0.045	0.370	0.625	0.500	1.495	0.171	0.7000	0.300	0.036
0.400	0.060	0.270	0.610	0.500	1.380	0.247	0.7000	0.400	0.069
0.500	0.075	0.170	0.595	0.500	1.265	0.336	0.7000	0.500	0.118
0.600	0.090	0.070	0.580	0.500	1.150	0.444	0.7000	0.600	0.186
0.670	0.100	0.000	0.570	0.500	1.070	0.533	0.7000	0.670	0.250



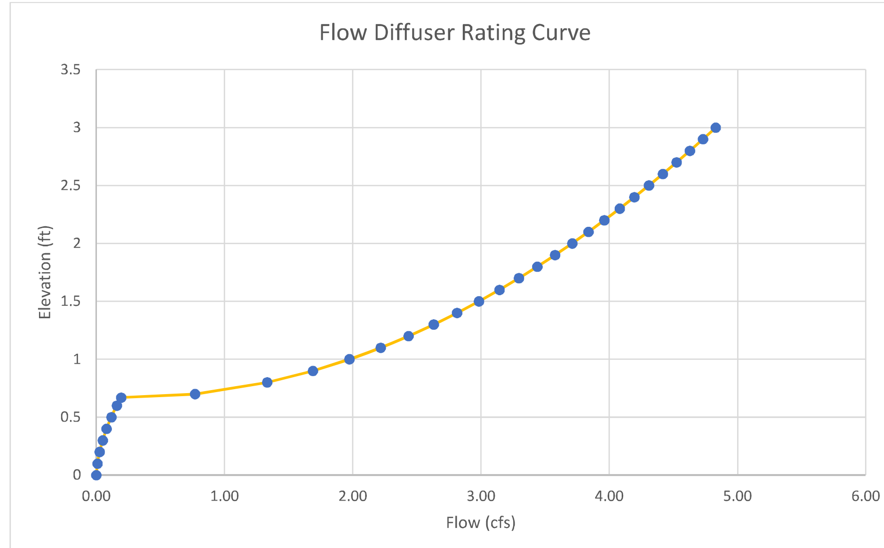
Weir Equation	Q=C*L*(h^.5)		
	Q	-	Flow (cfs)
	C	3	Weir Coefficient
	L	1	Length of Diffuser (ft)
	h	-	Height above weir (ft)

Elevation (ft)	Flow (cfs)
0.67	0.000
0.7	0.520
0.8	1.082
0.9	1.439
1	1.723
1.1	1.967
1.2	2.184
1.3	2.381
1.4	2.563
1.5	2.733
1.6	2.893
1.7	3.045
1.8	3.189
1.9	3.327
2	3.460
2.1	3.587
2.2	3.711
2.3	3.830
2.4	3.946
2.5	4.058
2.6	4.168
2.7	4.274
2.8	4.378
2.9	4.480
3	4.579

Figure A4.5: Gabion Flow Rating Curve (per Penn State)

Length of Flow Diffuser 1 ft

Elevation	Flow Through Berm (cfs)	Flow Over Berm (cfs)	Total Flow (cfs)
0	0.00	0.00	0.00
0.1	0.01	0.00	0.01
0.2	0.03	0.00	0.03
0.3	0.05	0.00	0.05
0.4	0.08	0.00	0.08
0.5	0.12	0.00	0.12
0.6	0.16	0.00	0.16
0.67	0.19	0.00	0.19
0.7	0.25	0.52	0.77
0.8	0.25	1.08	1.33
0.9	0.25	1.44	1.69
1	0.25	1.72	1.97
1.1	0.25	1.97	2.22
1.2	0.25	2.18	2.43
1.3	0.25	2.38	2.63
1.4	0.25	2.56	2.81
1.5	0.25	2.73	2.98
1.6	0.25	2.89	3.14
1.7	0.25	3.04	3.29
1.8	0.25	3.19	3.44
1.9	0.25	3.33	3.58
2	0.25	3.46	3.71
2.1	0.25	3.59	3.84
2.2	0.25	3.71	3.96
2.3	0.25	3.83	4.08
2.4	0.25	3.95	4.20
2.5	0.25	4.06	4.31
2.6	0.25	4.17	4.42
2.7	0.25	4.27	4.52
2.8	0.25	4.38	4.63
2.9	0.25	4.48	4.73
3	0.25	4.58	4.83



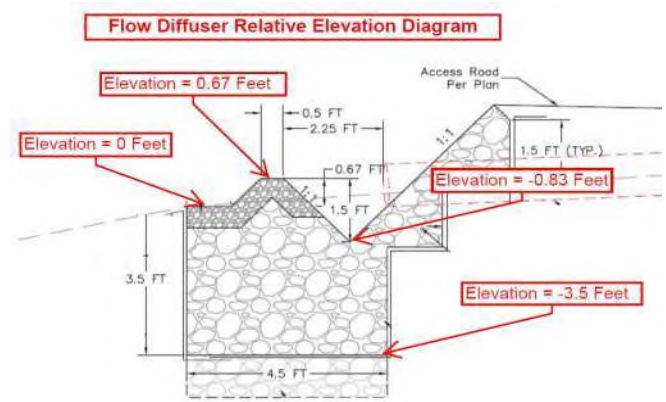
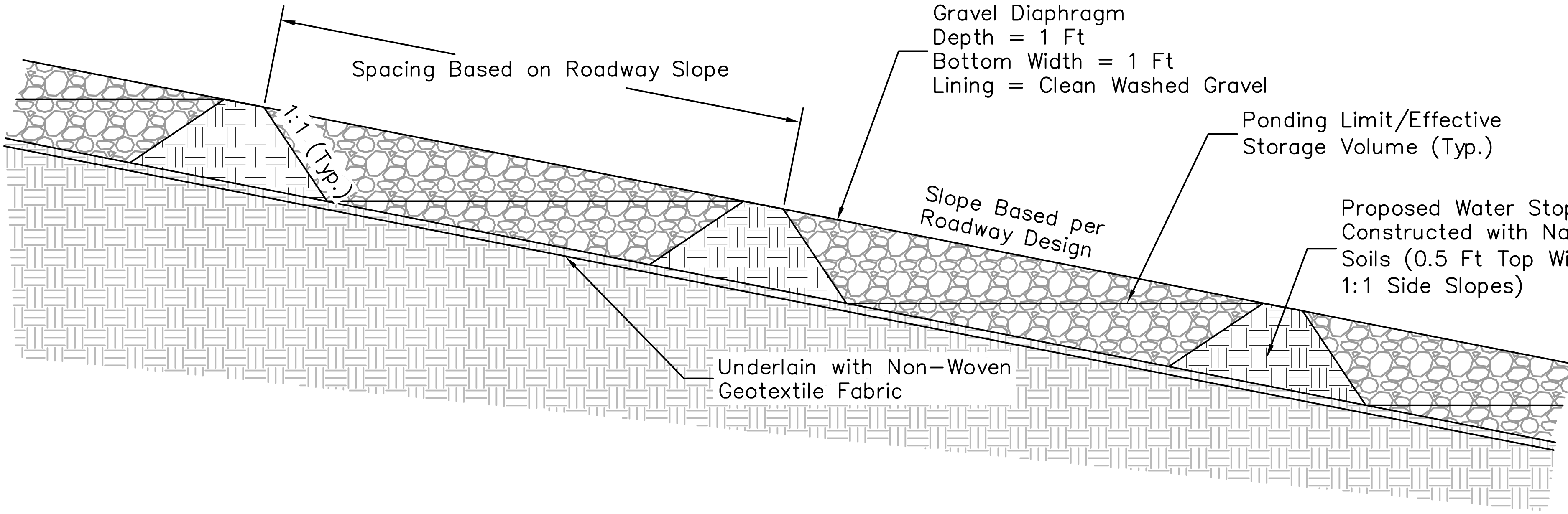
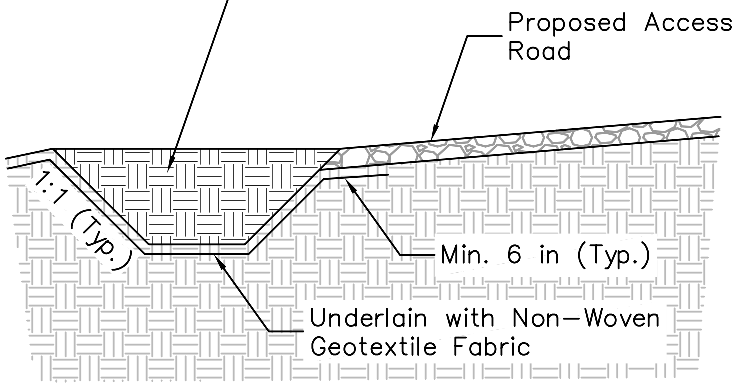


Figure A4.6: Gravel Diaphragm Water Stop

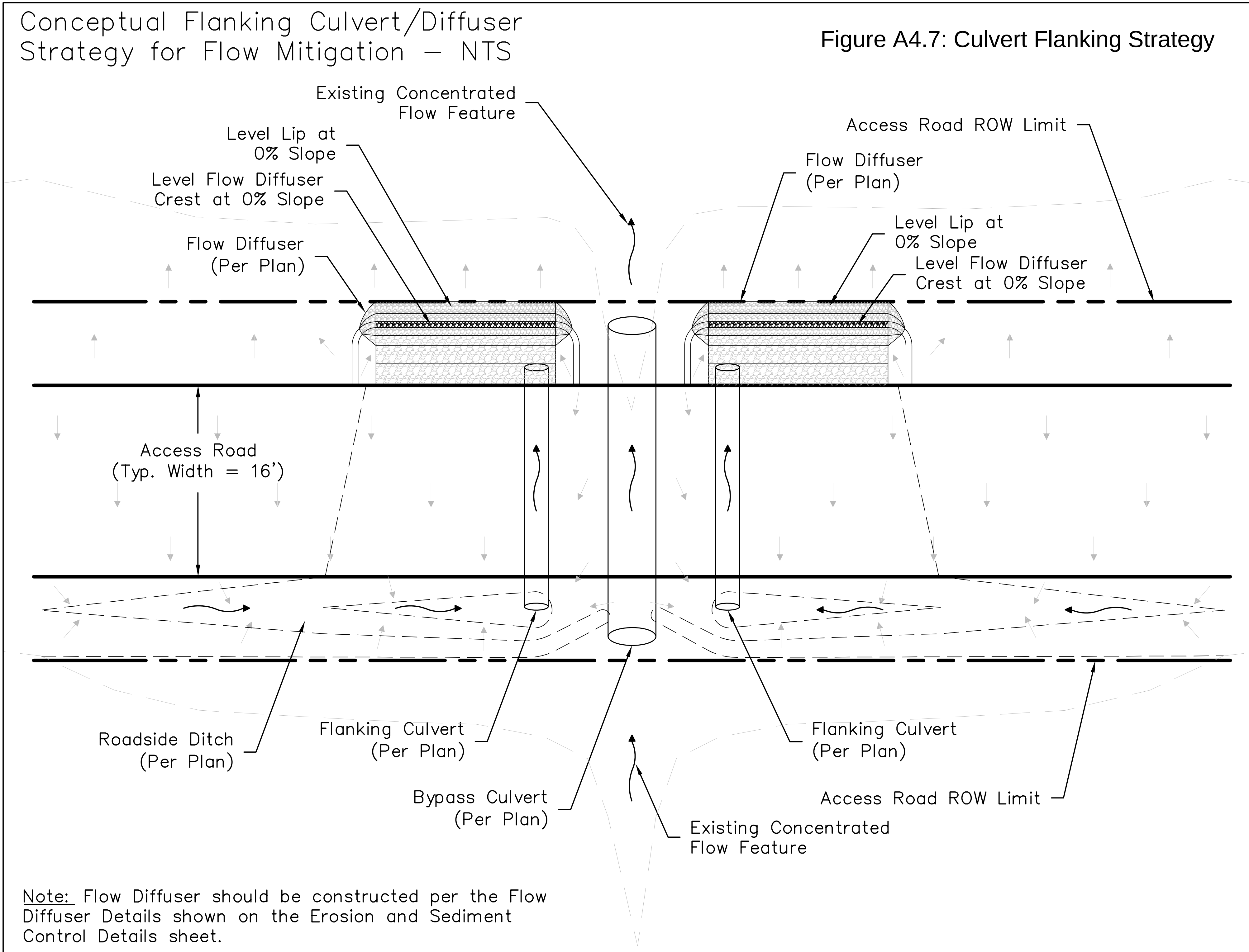




Water Stop Spacing:

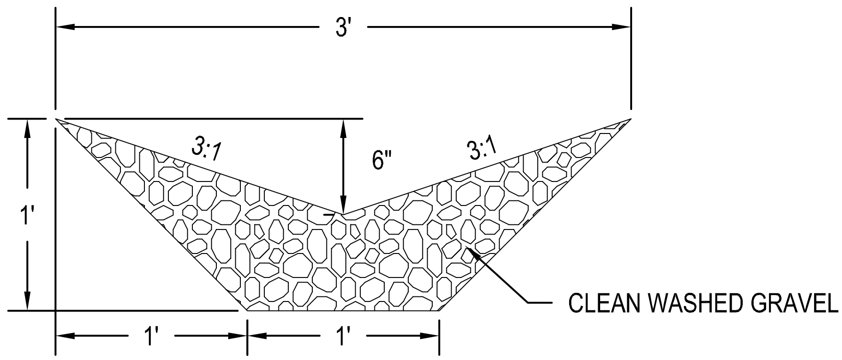
Roadway Slope	Water Stop Spacing
0% – 5%	21 FT
+5% – 10%	11 FT
+10% – 15%	8 FT
+15% – 20%	6 FT
+20% – 40%	4 FT

Figure A4.7: Culvert Flanking Strategy

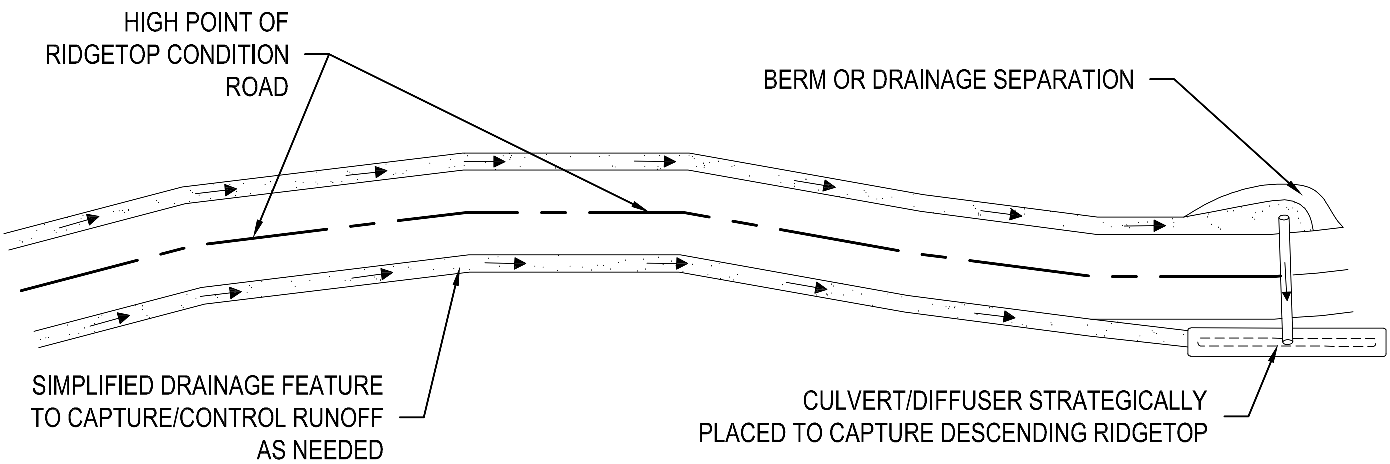


Note: Flow Diffuser should be constructed per the Flow Diffuser Details shown on the Erosion and Sediment Control Details sheet.

Figure A4.8: Gravel Diversion Trench and Ridgetop Runoff Collection and Diffuser Strategy



Detail: Gravel Diversion Trench and Ridgetop Runoff Collection and Diffuser Strategy



NOTES:

1. GRAVEL DIVERSION TRENCH (GDT) PROVIDED AS NECESSARY TO ENSURE SEGREGATION OF ONSITE RUNOFF FROM OFFSITE RUNOFF.
2. ADDITIONAL ACCEPTABLE CONTAINMENT AND DIVERSION PRACTICES MAY BE PROVIDED AS SPECIFIED UNDER THE WATER QUALITY COMPLIANCE CALCULATIONS PACKAGES, IF NECESSARY.

Detail: Ridgetop Runoff Collection and Diffuser Strategy

Input requirements and procedures

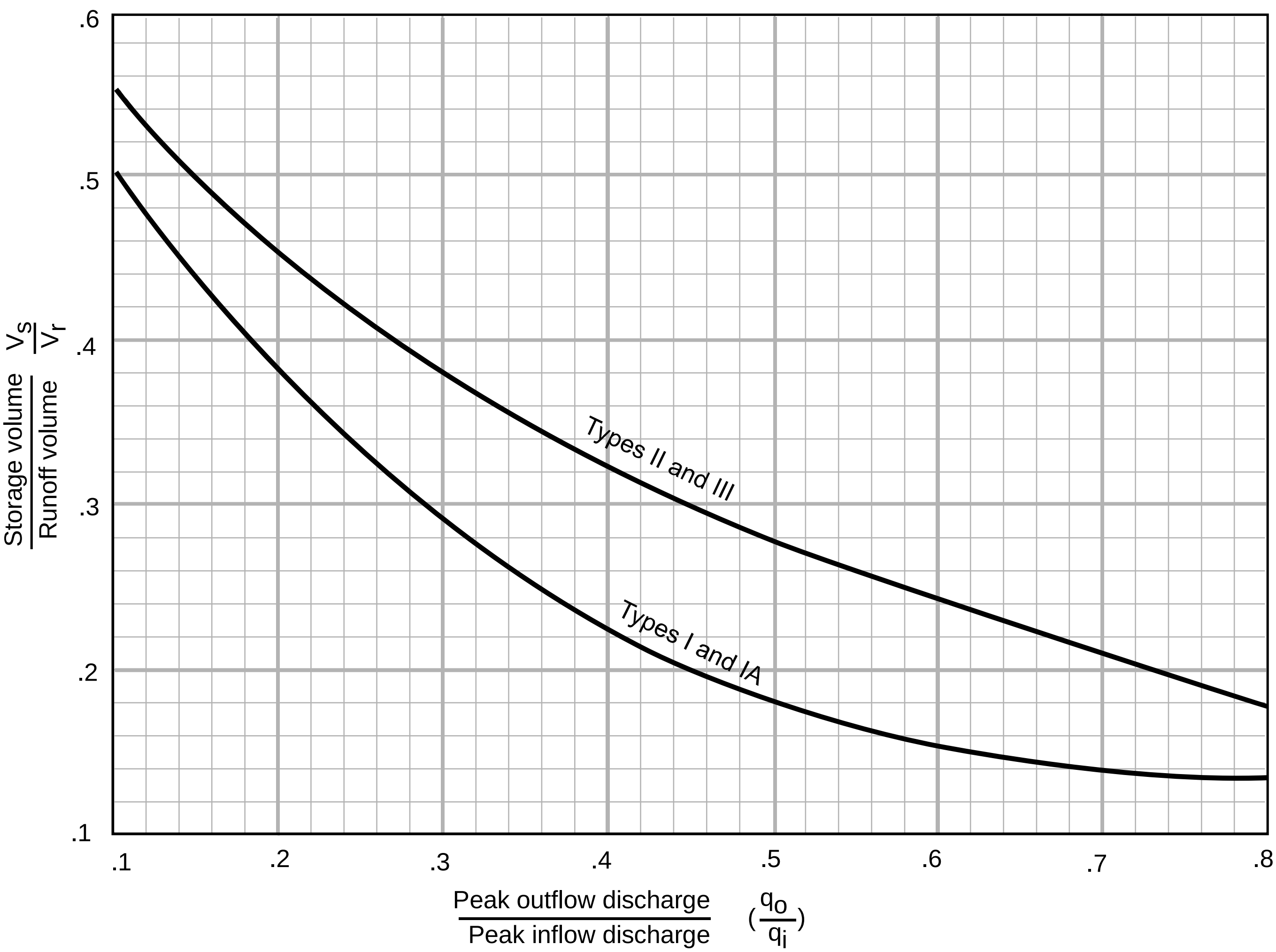
Use figure 6-1 estimate storage volume (V_s) required or peak outflow discharge (q_o). The most frequent application is to estimate V_s, for which the required inputs are runoff volume (V_r), q_o, and peak inflow discharge (q_i). To estimate q_o, the required inputs are V_r, V_s, and q_i.

Estimating V_s

Use worksheet 6a to estimate V_s, storage volume required, by the following procedure.

1. Determine q_o. Many factors may dictate the selection of peak outflow discharge. The most common is to limit downstream discharges to a desired level, such as predevelopment discharge. Another factor may be that the outflow device has already been selected.
2. Estimate q_i by procedures in chapters 4 or 5. Do not use peak discharges developed by other procedure. When using the Tabular Hydrograph method to estimate q_i for a subarea, only use peak discharge associated with $T_t = 0$.

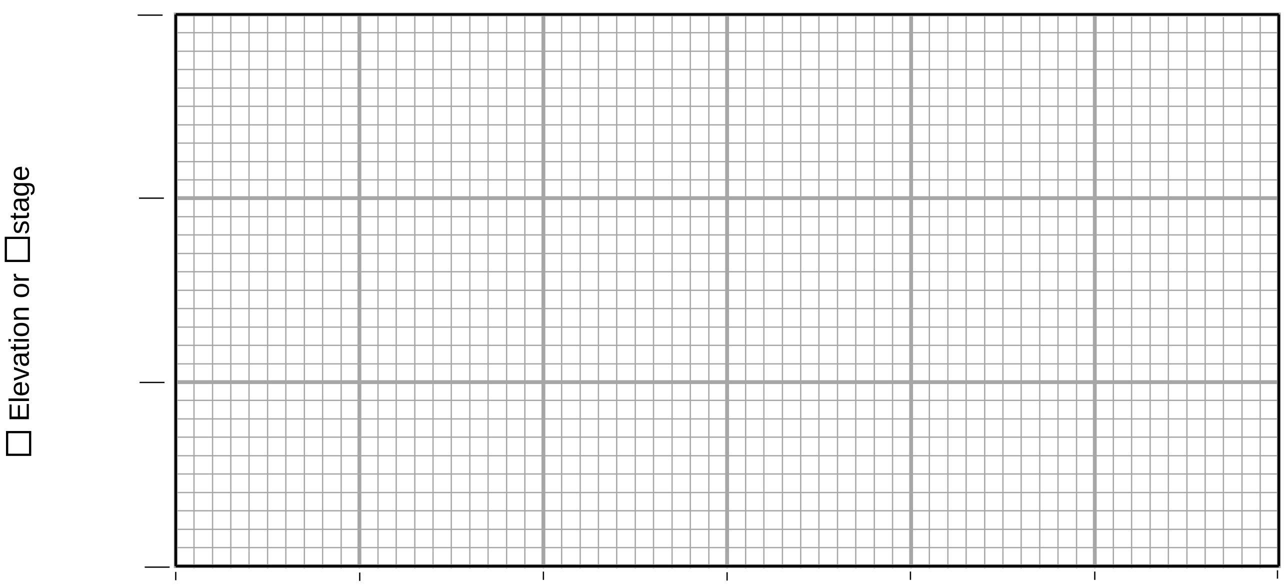
Figure 6-1 Approximate detention basin routing for rainfall types I, IA, II, and III



Worksheet 6a: Detention basin storage, peak outflow discharge (q_o) known

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed



1. Data:
   Drainage area .... A_m = ________ mi^2
   Rainfall distribution type (I, IA, II, III) = ________

	1st Stage	2nd Stage
2. Frequency .... yr		
3. Peak inflow discharge q_i .... ft^3/s (from worksheet 4 or 5b)		
4. Peak outflow discharge q_u .... ft^3/s 1/		
5. Compute $\frac{q_o}{q_i}$		
6. $\frac{V_s}{V_r}$ .... (Use $\frac{q_o}{q_i}$ with figure 6-1)		
7. Runoff, Q .... in (From worksheet 2)		
8. Runoff volume V_r.................. ac ft ($V_r = QA_m$ 53.33)		
9. Storage volume, V_s .... ac-ft ($V_s = V_r$ ($\frac{V_s}{V_r}$))		
10. Maximum storage E_{max} (from plot)		

1/ 2nd stage q_o includes 1st stage q_o.

Attachment A4.10: Flow Diffuser Construction in High Groundwater Table

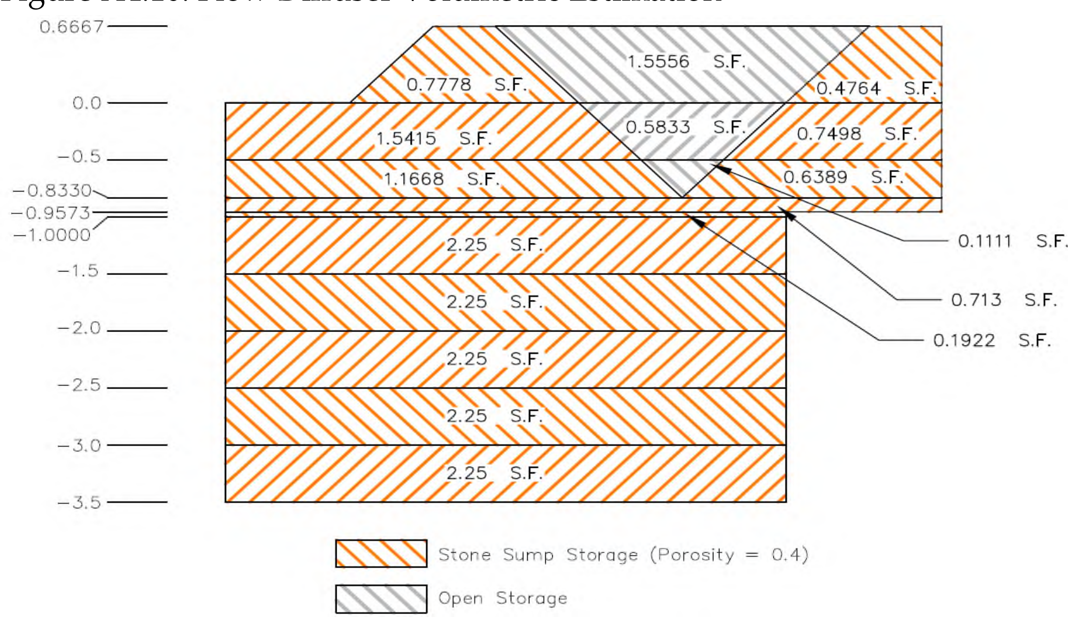
The Standard Sump Depth as defined per the Flow Diffuser detail (3.5 feet) will need to be adjusted by the contractor in the field in the event that High Groundwater Table (HGWT) conditions are encountered. In these circumstances the contractor shall determine the Effective Sump Depth based on the HGWT influence, and then will increase the sizing of the flow diffuser to be installed by multiplying the Flow Diffuser Length Per Plan by the appropriate Flow Diffuser Length Multiplier in accordance with the table below.

Table A4.10: Flow Diffuser Length Multipliers in Areas of HGWT

Effective Sump Depth (FT)	3.5	3.0	2.5	2.0	1.5	1.0	0.5
Storage Volume per Linear Foot based on Influence of HGWT (CF)	9.38	8.48	7.58	6.68	5.78	4.88	4.80
Flow Diffuser Length Multiplier to Accommodate HGWT	**1.00**	**1.11**	**1.25**	**1.42**	**1.64**	**1.95**	**1.98**

These Length Multipliers were developed by estimating the effective volumes on a per linear foot basis and correlating the volume associated with the reduced sump depths to that of the typical Flow Diffuser detail. All volumes were conservatively estimated based on the flow diffuser cross section with the less steep entry slope. The table shows the reduced volumes however, with the increase in length the overall required storage volume will be provided. The figure below depicts the effective storage area, both void space and open storage, for the respective relative elevations depicted. For purposes of this analysis, a porosity of 0.4 was utilized for all void space estimations and volumes depicted in the table above are shown capped at a maximum relative elevation of 0.6667 feet, which corresponds to the crest of the flow diffuser weir.

Figure A4.10: Flow Diffuser Volumetric Estimation



Attachment 5 – Standards and Specifications for Flow Diffusers

A5.1: H.R.C Research Series Report No. 10 – Analysis of Flow Through Porous Media as Applied to Gabion Dams Regarding the Storage and Release of Storm Water Runoff, NAHB/NRC Designated Housing Research Center at Penn State, August 1992

A5.2: Maine Level Spreader – Section 8.3, Maine Stormwater Best Management Practices Manual, September 2010

A5.1: H.R.C Research Series Report No. 10 – Analysis of Flow Through Porous Media as Applied to Gabion Dams Regarding the Storage and Release of Storm Water Runoff, NAHB/NRC Designated Housing Research Center at Penn State, August 1992

H.R.C. Research Series

NAHB/NRC Designated Housing Research Center at Penn State

Report No. 10

ANALYSIS OF FLOW THROUGH POROUS MEDIA AS APPLIED TO GABION DAMS REGARDING THE STORAGE AND RELEASE OF STORM WATER RUNOFF

by

C. McIntyre, Department of Civil and Environmental Engineering
G. Aron, Department of Civil and Environmental Engineering
Jack H. Willenbrock, Department of Civil and Environmental Engineering
M. Deimler, Department of Civil and Environmental Engineering

PENNSTATE

1855

NAHB/RC Designated Housing Research Center
Department of Civil Engineering
The Pennsylvania State University
212 Sackett Building
University Park, PA 16802
(814)863-0623
FAX (814)863-7304

August 1992

Chapter 1

INTRODUCTION

The scope of this research effort is focused on flow through large-size porous media. This media is actually angular limestone rock, typically used in gabion dam structures. A gabion is basically a "basket of rocks." Typical applications of gabions include use in the construction of dikes and dams, underwater scour prevention around bridge piers, and as erosion stabilizers along river banks and coastlines. Within the past few years, innovative engineers have experimented with gabion dams as they relate to storm water management. The idea is to use these structures to detain and release storm water runoff. The concept is to design the gabion dam in such a way that the flow through the structure will meet the specified target release rates, typically predevelopment runoff rates.

The major concern with the use of gabions as outlet control structures is that their design is based upon practical experience and sound engineering judgement. The hydraulic flow-through properties of gabions have never been evaluated in a laboratory setting. This research effort attempts to (1) evaluate the flow through large-size porous media, (2) develop a gabion design equation(s), (3) route a design storm through a detention basin and gabion structure to validate the equation, and (4) formulate recommendations and conclusions.

Chapter 2

PRELIMINARY INFORMATION

2.1 Background Information

The term "gabion" can be traced back to the times of the Roman Empire. Derived from the Latin word for cage, a gabion is actually a hollow basket frame, constructed of metal strapping or wire mesh and filled with earth or stone. Originally gabions were used as barricades or ramparts designed to protect soldiers or as defensive fortifications.

Gabions have evolved to become an integral part of the water resources and hydraulic engineering fields. Figure 2.1 illustrates various gabion configurations. Gabion mattresses are used for scour prevention, for coastline protection, and for lining channels, as shown in Figures 2.2 through 2.4.

Recently gabions have been used in the control of storm water runoff. Their intended purpose was to retain the runoff and then release it at pre-specified rates. Gabion dams have several advantages over traditional dikes and outlet structures used in storm water management that make them a viable alternative approach: their base width is much smaller, they are virtually maintenance free, and some would say that they are aesthetically more pleasing.

Figures 2.5 and 2.6 show some gabion structures designed by Mr. Charles Weir, P.E., of Weir Associates, Inc., to control storm water flows. Mr. Weir used sound engineering principles, practices, and judgement in the design of these dams. The structures shown in these figures are located in Ambler, Pennsylvania, just north of Philadelphia, have been in place for over 15 years and seem to be functioning as intended. Figure 2.5 depicts the use of gabions in the control of residential storm water runoff. The structure is approximately 24 feet long, 3 feet wide, and a maximum of 3 feet in height. Figure 2.6 is a much larger dam measuring approximately 250 feet long, 9 feet wide at the base, and a maximum of 11 feet in height. This structure is particularly well adapted for this wooded site. Only three large-size trees had to be removed during its construction. A traditional earthen dam with 4:1 side slopes and a 10 foot width at crest elevation would have a base width of about 100 feet. This would necessitate the removal of dozens of trees, not to mention the cost of construction and fill material requirements.

One of the major drawbacks to the use of gabions is that the hydraulic flow-through characteristics of their large-size porous media have apparently never been tested in the laboratory. Further investigation was necessary. The authors visited Maccaferri Gabions Inc. in Williamsport, Maryland, the nation's largest producer and supplier of gabions. It was discovered that a great deal of research has been done on gabion structures; however, it has focused only on their hydraulic properties as related to soil stabilization in channels and on slopes. No documented research work has been performed on their flow-through characteristics. At this point it became evident that some laboratory flow tests and analyses were needed. The authors decided to conduct some preliminary flow tests on porous media. The Hydraulics Laboratory of the Department of Civil and Environmental Engineering at The Pennsylvania State University was selected as the test site.

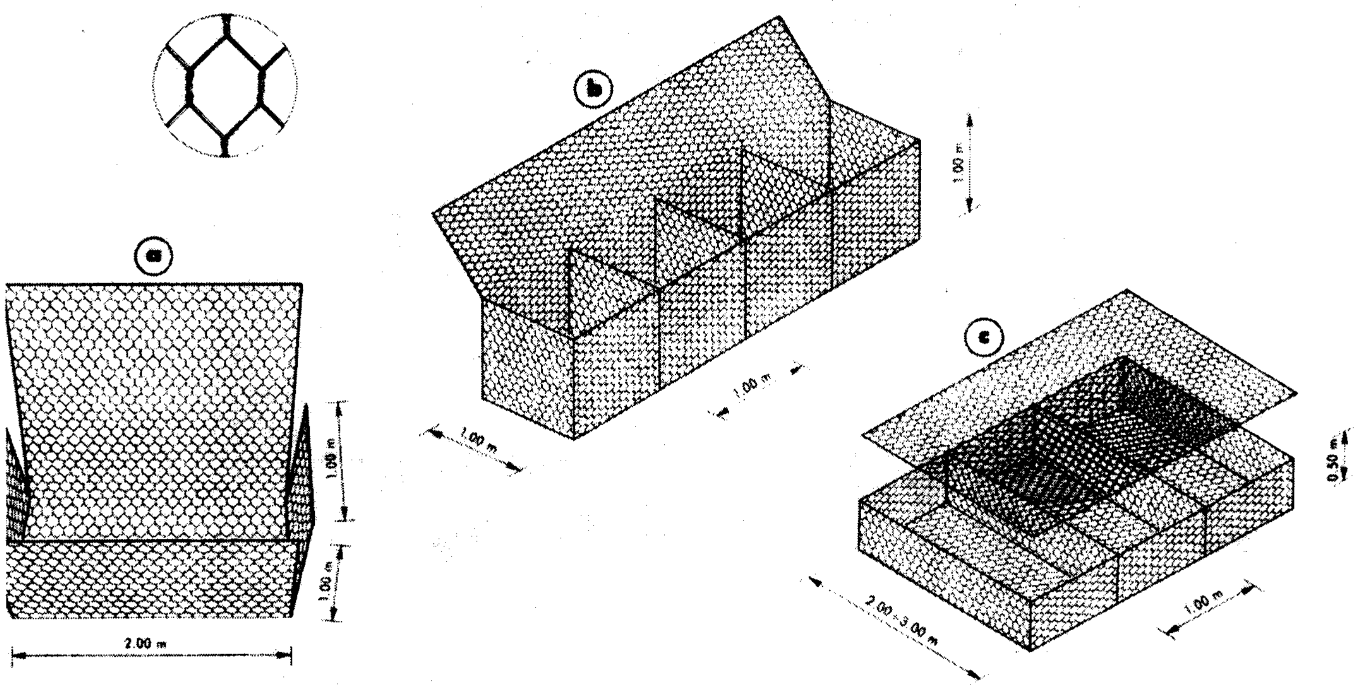


Figure 2.1. Examples of a Gabion: (a) without a diaphragm, (b) with a diaphragm, (c) with multiple cells. Courtesy of Maccaferri Gabion Inc.

Figure 2.2. Gabions Used to Protect Bridge Piers from Scour.
Courtesy of Maccaferri Gabion Inc.

Figure 2.3. Gabion Protected Coastline.
Courtesy of Maccaferric Gabion Inc.

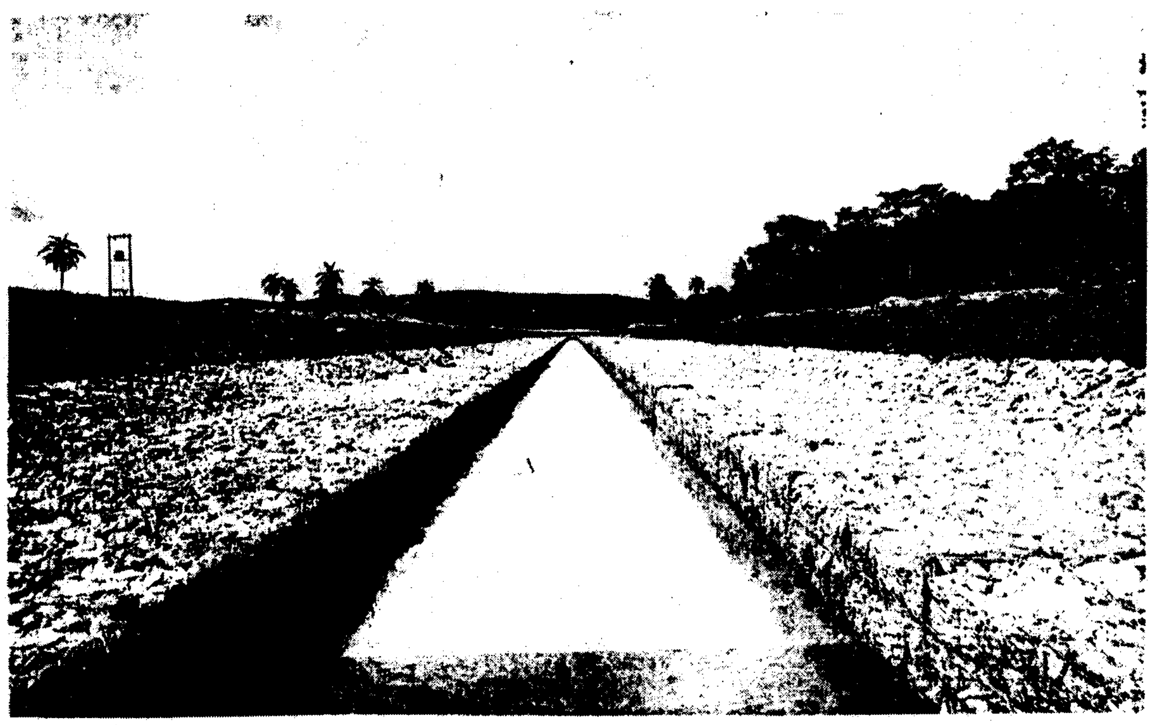


Figure 2.4. Gabion Lined Channel.
Courtesy of Maccaferric Gabion Inc.

Figure 2.5. Gabions Used in a Residential Development.

Figure 2.6. Large-Size Gabion Dam in a Wooded Area.

2.2 Laboratory Set Up: Phase I

The existing hydraulic flumes in the lab proved inadequate for the gabion research effort. The flumes were constructed of plexiglass, which would become severely scratched when in contact with the rock media, and were also too narrow. A minimum flume width of two feet was required to effectively negate the effects of side wall flow which could bypass the media. Therefore, a flume had to be constructed. Plywood was the material of choice since it was readily available at a minimum cost. An 8 foot long flume with a cross section of 24" x 22" was constructed from the plywood sheets. All joints were sealed with silicone compound. Figure 2.7 illustrates the partially constructed gabion flume.

One-half inch wire mesh was selected for the gabion basket framework. The basket width represents the flow path length. Widths of one foot and two feet were selected for these preliminary tests. The baskets were positioned in the flume approximately four feet from the PVC inflow piping to reduce turbulent effects. The flume was then raised into position above a weighing tank so that the outflow from the flume discharged directly into the tank and an accurate measure of the flow could be obtained. Two large piezometers were installed on the flume, one upstream and one downstream of the baskets, to read the upstream and downstream head. Nine smaller piezometer tubes were installed at the basket structure to provide a profile of the water surface. Water was then run through the flume to check for leaks and so that the weighing tank could be calibrated and checked for accuracy. Figure 2.8 shows the fully constructed flume, while Figure 2.9 is a close-up of the piezometer nest.

The angular limestone rock was obtained from a local quarry. Three different rock sizes were collected: 3-5" stone, 1-2" stone, and 3/4" stone. Approximately four cubic feet of each size was collected and transported to the laboratory. Samples of the three rock sizes are shown in Figure 2.10. Additionally, thousands of golf balls were borrowed from the Penn State Golf Course for use in this study, since some data concerning spherical media might prove useful.

With all the apparatus and material in place and in proper working order in the laboratory, flow tests could begin.

Figure 2.7. Partially Constructed Gabion Flume.

Figure 2.8. Finished Gabion Flume.

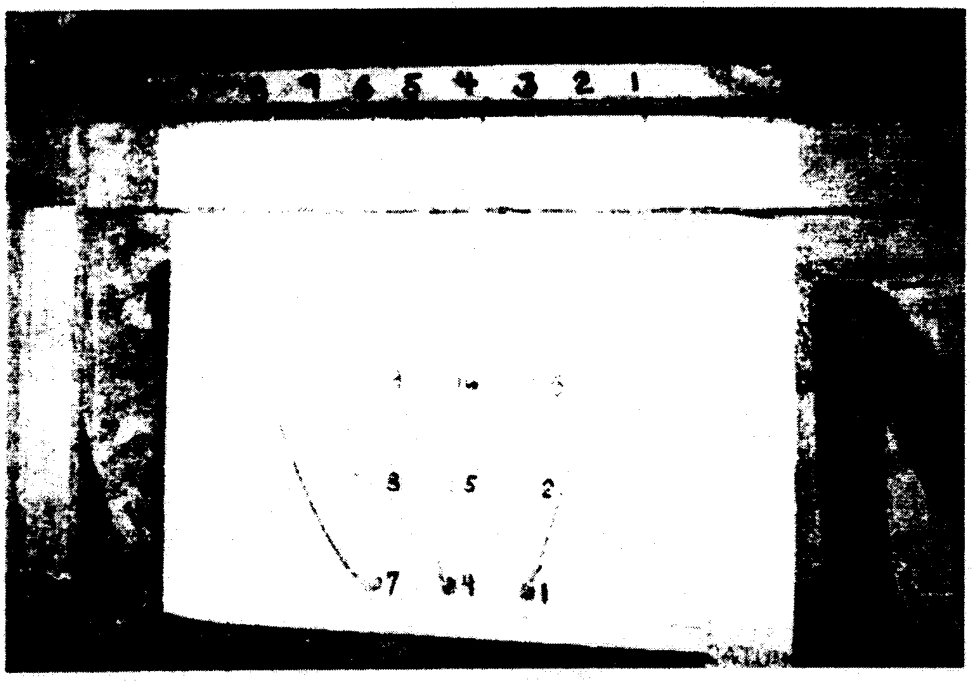


Figure 2.9. Piezometer Nest.

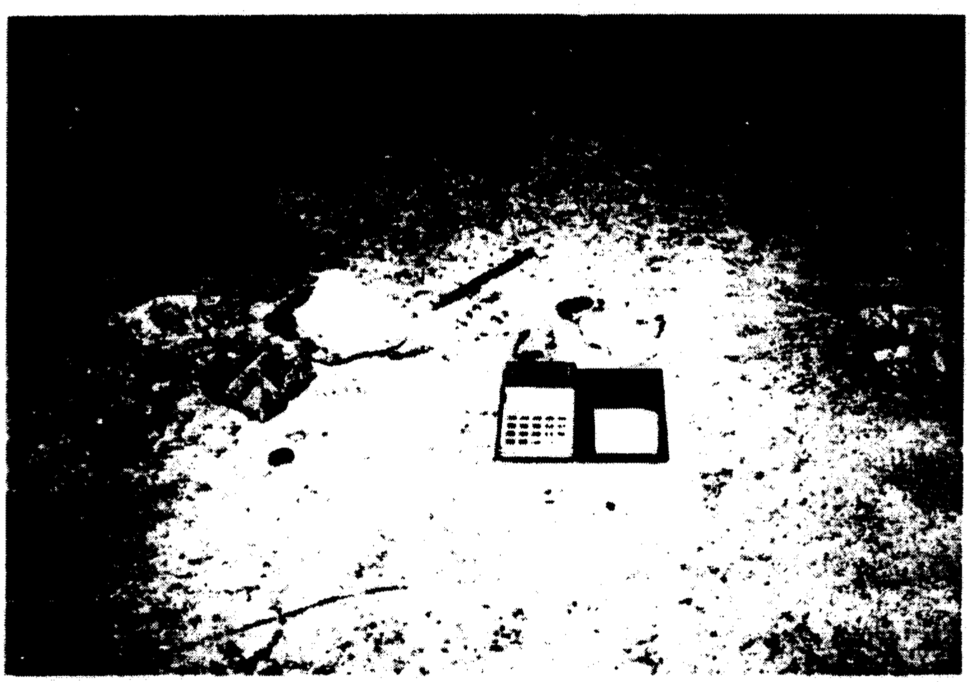


Figure 2.10. Various Rock Sizes Used as Porous Media (from left to right -- large stone, medium stone, small stone).

Chapter 6

SUMMARY AND CONCLUSIONS

6.1. Summary

A series of laboratory flow tests was conducted on angular limestone rock. The purpose of these tests was to determine if a rock-filled gabion dam could be used in storm water management facilities to store and properly release storm water runoff at the predevelopment "target" rates.

The results of the gradation and flow-through tests were applied to the Forchheimer [5,6] relationship for flow through large-size media. The equation was modified to fit the observed data. A single design equation was developed, which is a function of rock diameter, flow path length, ponding depth, and width. The equation is

$$Q = \frac{h^{3/2}W}{\left[\frac{L}{D} + 2.5 + L^2\right]^{1/2}}$$

where

Q = total flow through the gabion dam (cfs)
h = ponding depth in the basin (ft)
W = total length of the gabion dam (ft)
L = horizontal flow path length (or width of the gabion dam) (ft)
D = average rock diameter (ft)

The design equation was checked against the observed values, and then used in a routing sequence in a sample detention basin. The design and routing results yielded reasonable values using a gabion dam to store and release storm water runoff.

6.2 Conclusions

The results of this study indicate that properly sized and configured gabion dams can store significant amounts of storm water runoff and release it at or below the predevelopment "target" discharge rates. However, several key questions remain:

1. How are gabion dams constructed, and is it a very labor-intensive effort?

2. Where are these types of structures applicable, and what advantages do they offer?

3. Do they eventually clog up with leaves, grit, and debris?

4. Will review boards and municipal engineers accept these types of structures as a viable alternative to more traditional methods?

5. How do gabion dams respond in the field to actual storm events?

Question 1:

The construction of a gabion is not a terribly labor-intensive effort; however, a reasonable amount of care should be taken to preserve the integrity of the structure. The rock should be placed in the baskets in layers and then moved (or kicked) into place to minimize void space and to prevent future settlement. Cross-tie wires should be installed to prevent "bulging" of the baskets. Rock may be flat-faced against all sides of the baskets for aesthetic purposes. Adjacent baskets should be wired together to prevent possible future movement. Considering that, on average, relatively few gabion baskets will be required in the construction of the dam, the labor effort is minimal.

Question 2:

A gabion dam can be used almost anywhere; however, they are most applicable on heavily wooded sites, or on sites where excess fill is not available for the construction of traditional dikes. In some instances they may prove to be the most cost-effective means of constructing an outlet structure. They also dissipate the energy of the flow and can discharge the collected runoff as shallow overland flow, as opposed to concentrated swale or pipe flow. A gabion dam inherently constitutes its own spillway. Some may argue that these structures are actually more appealing and tend to blend into a residential setting much better than traditional structures, such as a concrete riser box or a perforated corrugated steel pipe riser in a detention basin.

Question 3:

Some clogging of gabion baskets may occur, especially if using smaller-sized rock media. Leaves and other organic material decompose quickly and are washed through along with fine grit and sand during the next substantial storm. Gabion dams are actually a self-cleansing structure. However, if clogging is of major concern, additional freeboard could be added to the height of the structure. The gabion dams designed by C. Weir (Ambler, PA) have been in operation for over 15 years in a variety of settings and show no apparent clogging of the void spaces. In fact, they seem to be functioning as intended.

Question 4:

Most municipal storm water management ordinances have a section which addresses alternative measures of control and release of runoff. While the term "gabion dam" may not be written out, the phrase " . . . or other alternative designs are permitted as determined by the Municipal Engineer." The Model Storm Water Management Ordinance for Municipalities in the Centre Region of Pennsylvania does have a provision for the use of rock-filled gabions. In other regions, the design engineer and/or project owner may have to "sell" this concept to the review boards and municipal engineers. The findings of this report and any other information the HRC at Penn State can provide may be used as credible evidence during negotiations.

Question 5:

There is no documented research available on the storage and release of storm water runoff from gabion dams in actual field conditions, although existing structures appear to be doing their intended job. A logical extension to this study would involve the design, construction, monitoring, and evaluation of gabion dams in field conditions during actual storm events to determine their effectiveness.

Section 8.3
LEVEL SPREADER

September 2 010

A level spreader is a vegetated or mechanical structure used to disperse or "spread" concentrated flow thinly over a receiving area. Level spreaders reduce erosion and movement of sediment and also assist to filter sediment, soluble pollutants, and sediment-attached pollutants. They are generally used where concentrated flows are discharged to the ground and serve to convert the concentrated flow to sheet flow to prevent erosion of the downstream receiving area. They are generally used to disperse flows over a relatively flat receiving area such as a buffer or swale to ensure uniform distribution of flow and minimize the channelization of water. Level spreaders are not designed to remove pollutants from stormwater; however, some suspended sediment and associated phosphorus, nitrogen, metals and hydrocarbons will settle out of the runoff by settlement filtration, infiltration, absorption, decomposition and volatilization.

8.3.1 Site Suitability Criteria

1. Drainage area: The maximum drainage area to the spreader may not exceed 0.10 acre per foot length of level spreader lip if the level spreader is not discharging directly to a buffer and is only used to dissipate flow volume and velocity. The drainage area served by the spreader discharging directly cannot be more than half the size of the receiving buffer area.

2. Slope: The maximum slope of the receiving area below a level spreader should be no more than 30%. If the slope is greater than 30%, the discharge will need to be brought by a conduit and velocity dissipator to an area that is suitable.

IMPORTANT

This section discusses the design of a level spreader to convert concentrated flow to sheet flow to prevent erosion of downstream receiving areas and to lengthen time of concentration to reduce peak flows. The use of level spreaders with buffers for water quality purposes must follow the design criteria in Chapter 5 Buffers.

8.3.2 Design and Construction Criteria

These standards are not applicable for level spreaders discharging runoff to buffers used to meet the Department's General BMP Standards. Requirements for these level spreaders can be found in Chapter 5 for buffers.

1. Discharge to a Level Spreader: The peak stormwater flow rate to a level spreader due to runoff from a 10-year, 24-hour storm must be less than 0.25

cubic feet per second (0.25 cfs) per foot length of level spreader lip.

2. Length of Level Spreader: The level spreader length may not be more than 25 feet unless approved by the department.

3. Sitting of Level Spreader: The level spreader must be sited so that flow from the level spreader will remain in sheet flow until entering a natural or man-made receiving channel.

4. Capacity: The capacity of each level spreader shall be based on the allowable velocity of the receiving soil. The flow area upstream of the level spreader shall be sufficient to ensure low approach velocities to the level "lip". The minimum flow area shall be equal to the flow area of the delivery channel.

5. Buffer: Each level spreader shall have a vegetated receiving area with the capacity to pass the flow without erosion. The receiving area shall be stable prior to the construction of the level spreader. The receiving area shall have topography regular enough to prevent undue flow concentration before entering a stable watercourse but it shall have a slope that is less than 30%. If the receiving area is not presently stable, then the receiving area shall be stabilized prior to construction of the level spreader. This will limit construction to the growing season.

6. Berm: The berm of the level lip should consist of crushed rock with a three-quarter to three inches in diameter size gradation that will allow flows to slowly seep through the berm, a minimum of 18 inch high and 3 feet wide. The berm should have a 6 to 12 inch deep header channel with a 3-foot bottom width to trap sediments and reduce lateral flow velocities behind the berm. The bottom and back of the spreader channel should be lined with erosion control matting.

7. Installation: A level spreader must be installed correctly with 0% grade on the spreader base and lip to ensure a uniform distribution of flow; otherwise the structure may fail and become a source of erosion.

8. Upstream Velocity: The flow area upstream of the level spreader shall be controlled to ensure low approach velocities to the level "lip." The minimum flow area of level spreader shall be equal to the flow area of the delivery channel. The base and lip shall be installed at a 0% grade (level).

9. Receiving Area: Level spreaders shall blend smoothly into the downstream receiving area without any sharp drops or irregularities to avoid channelization, turbulence and hydraulic jumps. The receiving area below the level spreader shall be protected from harm during construction. Sodding and/or netting in combination with vegetative measures shall stabilize disturbed areas. The receiving area shall not be used by the level spreader until stabilization has been accomplished. A temporary diversion may be necessary in this case.

10. Undisturbed Soils: Level spreaders shall be constructed on undisturbed soil where possible.

11. Entrance Drainage Channel Design: The entrance channel to the level spreader is constructed across the slope and consists of a combination of stone and existing natural vegetation used to disperse, filter and lower the runoff velocity into the level spreader. The entrance channel shall blend smoothly into the downstream receiving area without any sharp drops or irregularities, so to avoid turbulence and hydraulic jumps.

a. Shape: The entrance channel is typically trapezoidal in cross section, but may be parabolic as long as the soil bed design width is equivalent to the design bottom width for a trapezoidal section and is no more than 2 feet deep. Trenches shall be constructed along the existing contour and shall be 15-20 feet long and at least 7 feet wide across the top.

b. Bottom Width: Bottom width for a trapezoidal cross section of the entrance channel should be a minimum of two feet.

c. Side Slopes: Side slopes of the entrance channel shall be 2:1 or flatter to provide pretreatment of runoff entering the level spreader.

d. Longitudinal Slope: The longitudinal slope of the entrance channel should be 1% grade or less in order to avoid excessive velocity and deep water at the downstream end when ponding. If topography dictates a steeper net channel slope, the swale can be broken into relatively flat sections by check dams placed at no closer than 50 feet intervals.

e. Depth and Capacity: The swale should be designed to safely convey the 2 year storm with design velocities less than 4.0 to 5.0 feet per second. The swale should have sufficient total depth to convey the 10-year storm with 6 inches of freeboard.

8.3.3 Maintenance

Long term maintenance of the level spreader is essential to ensure its continued effectiveness. The following provisions should be followed. In the first year the level spreader should be inspected semi annually and following major storm events for any signs of channelization and should be immediately repaired. After the first year, annual inspection should be sufficient. Vegetated level spreaders may require periodic mowing. Spreaders constructed of wood, asphalt, stone or concrete curbing also require periodic inspection to check for damage and to be repaired as needed.

1. **Inspections:** At least once a year, the level spreader pool should be inspected for sand accumulation and debris that may reduce its capacity.

2. **Maintenance Access:** Level spreaders should be sited to provide easy access for removal of accumulated sediment and rehabilitation of the berm.

3. **Sediment Removal:** Sediment build-up within the swale should be removed when it has accumulated to approximately 25% of design volume or channel capacity. Dispose of the sediments appropriately.

4. **Debris:** As needed remove debris such as leaf litter, branches and tree growth from the spreader.

5. **Mowing:** Vegetated spreaders may require mowing.

6. **Snow Storage:** Do not store snow removed from the street and parking lot within the area of the level spreader.

7. **Level Spreader Replacement:** The reconstruction of the level spreader may be necessary when sheet flow from the spreader becomes channeled into the buffer.

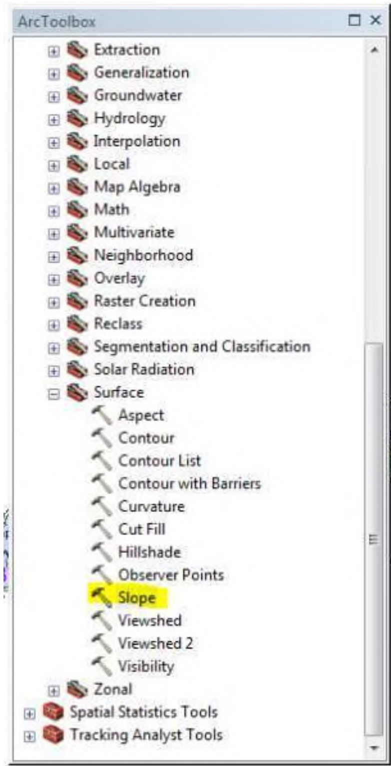
Attachment 6 – Procedure: Calculating Average Basin Slope

Procedure: Calculating Average Basin Slope

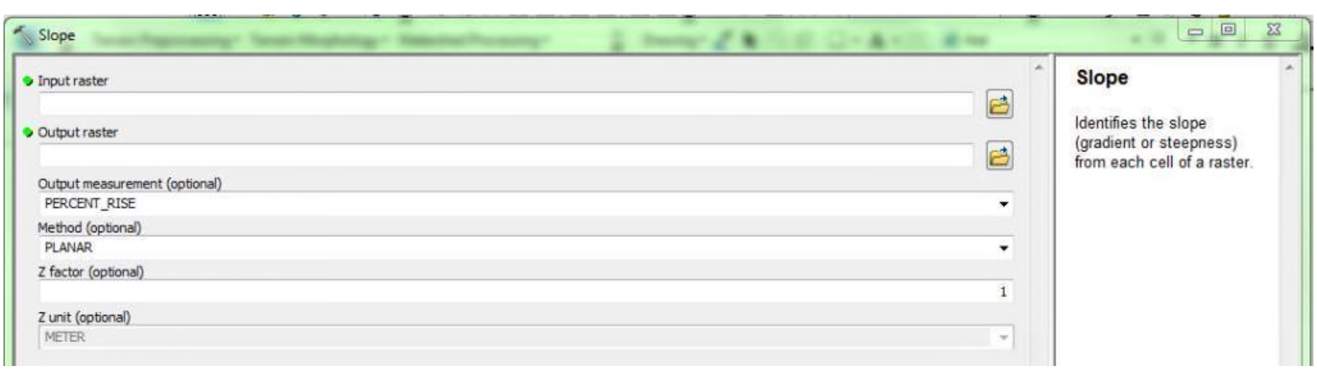
Necessary data: Slope raster (or DEM if slope raster is not available), drainage area polygons.

If slope raster is not available, begin from step 1. If slope raster is available, Skip to step 4.

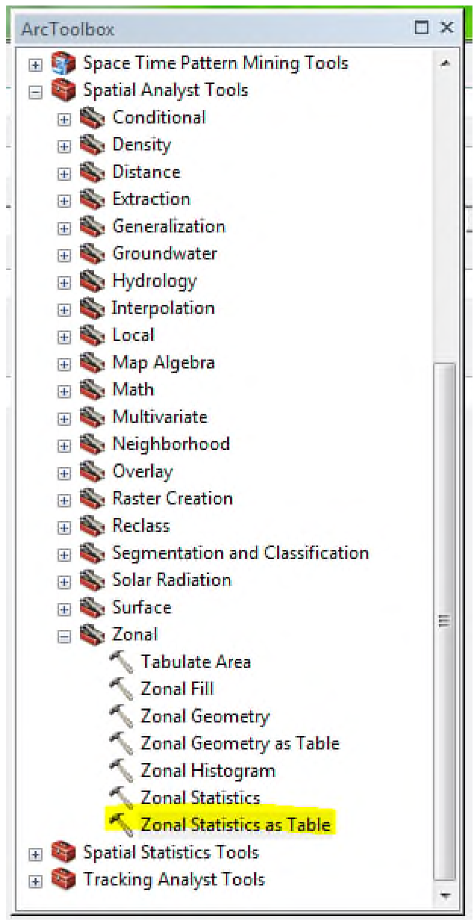
1. Generate slope raster: Add DEM to Map document
2. Select Slope (spatial analyst) tool from Arc Toolbox:



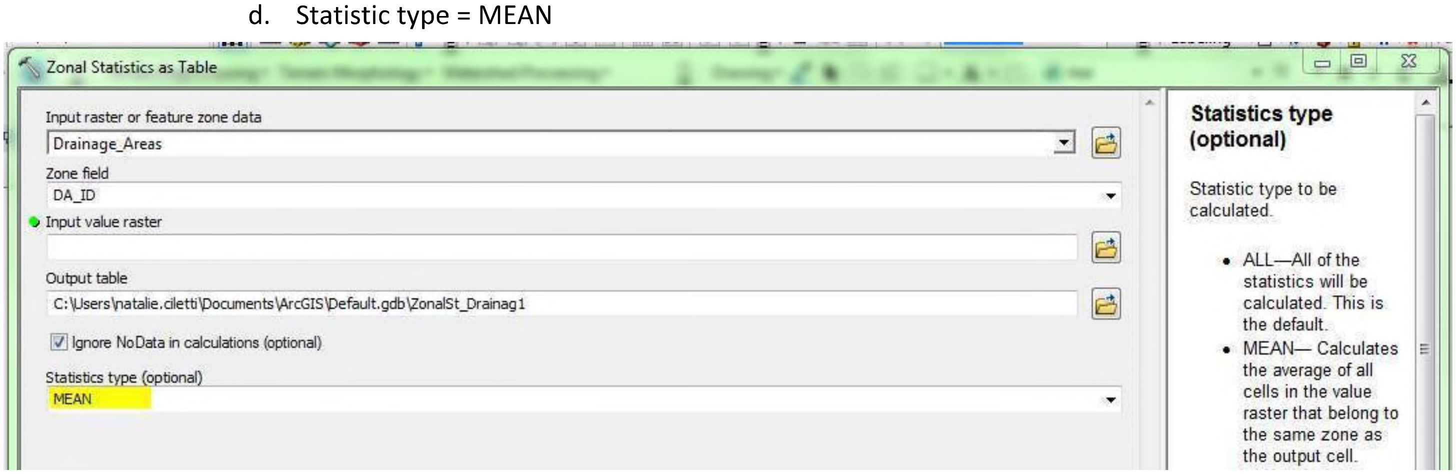
3. Enter the following parameter into the Slope dialog box below
    a. DEM into "Input raster"
    b. select the location for your output slope raster
    c. "Output measurement" = Percent rise
    d. Method = PLANAR,
    e. Z factor =1



4. Add average slope raster dataset to Map document (the average slope raster will automatically add to map if previously completed steps (1-3)
5. Add finalized drainage areas to map document (make sure they all have unique IDs)
6. ***Note Zonal statistics as Table will return the mean slope for the largest extent of overlapping polygons. In order to run on smaller sub drainage areas, select or query drainage polygons to just those smaller DA.
7. Open processing tool Zonal Statistics as Table:



8. Enter the following parameters into the Zonal statistics as Table dialog box below:
    a. "The Input raster or feature zone data" = Drainage Areas;
    b. Zone field" = DA_ID (all DA_IDs must be unique for calculation to work properly)
    c. Enter Slope Raster into "Input raster"; select the location for your output table.
    d. Statistic type = MEAN



9. If needed, repeat #6-8 for any areas with overlapping drainage for the smaller drainage areas.
10. Export/Copy the table(s) to excel spread sheet and save for engineering. They will need a drainage ID and mean slope for each drainage area.

If overlapping drainage areas are problematic, a tool for zonal statistics for overlapping polygons should be utilized, which may be found at:

https://www.arcgis.com/home/item.html?id=b859b33c616a47d2b99b5e133942db02