RECOMMENDATIONS OF THE EXPERT PANEL TO DEFINE REMOVAL RATES FOR DISCONNECTING EXISTING IMPERVIOUS AREA RUNOFF FROM STORMWATER DRAINAGE SYSTEMS

DRAFT REPORT

Presented to USWG, TBD
Revised report presented to and approved by USWG, TBD
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List of common acronyms used throughout the text:

AMC	Antecedent Moisture Condition
BMP	Best Management Practice
C	Clay
CAST	Chesapeake Assessment Scenario Tool
CBP	Chesapeake Bay Program
CBWM	Chesapeake Bay Watershed Model
CDA	Contributing Drainage Area
CF	Compaction Factor
CN	Curve Number
HSG	Hydrologic Soil Group
Ksat	Saturated Hydraulic Conductivity
L_f	Infiltration Depth
MAST	Maryland Assessment Scenario Tool
OM	Organic Matter
RR	Runoff Reduction
Rv	Runoff Volume
Sa	Sand Content
SPAW	Soil-Plant-Air-Water Model
SPS EP	Stormwater Performance Standards Expert Panel
SRP EP	Stormwater Retrofit Projects Expert Panel
ST	Stormwater Treatment
TP	Total Phosphorus
TN	Total Nitrogen
TSS	Total Suspended Solids

UFS EP	Urban Filter Strip Expert Panel
USWG	Urban Stormwater Work Group
VAST	Virginia Assessment Scenario Tool
WQGIT	Water Quality Goal Implementation Team
WQv	Water Quality Volume
ρ	Bulk Density

Executive Summary

The Urban Stormwater Work Group convened an Expert Panel to define and develop nutrient and sediment load reduction recommendations using the disconnection of existing impervious area runoff from stormwater drainage systems as new best management practices (BMP) to be adopted by the Chesapeake Bay Program (CBP). Disconnection of impervious area runoff is not currently defined by the CBP as a BMP available for credit towards Watershed Implementation Plans. The Expert Panel provided representation from the Bay jurisdictions, scientists, and stormwater practitioners to review and evaluate the scientific literature and other data sources, review the Chesapeake Bay Watershed Model assumptions to simulate the impact of impervious area disconnection and make recommendations to quantify and qualify this BMP, as well as review information to verify its performance after implementation.

In its review of the recently approved methods to define removal rates of runoff reduction and stormwater treatment BMPs (SPS EP, 2012 and SRP EP, 2012), research-specific publications and the design of simple disconnection and soil amendments, the Expert Panel determined that a modification to the methods presented in SPS EP (2012) was needed to quantify the nutrient and sediment load reduction from impervious area disconnection to amended soils. A total of 75 publications were reviewed along with the State and District of Columbia stormwater design guidance for simple disconnection and soil amendments to form the basis of the Expert Panel recommendations.

In addition, the Expert Panel reviewed whether the existing drainage network of a site could be retrofitted via the creation of storage facilities within the drainage network or adjacent treatment areas with the option of diverting runoff from disconnected impervious cover into these facilities to achieve full or partial disconnection. Note this practice is described in SRP EP (2012). The purpose of including it here is to provide additional details and examples beyond the information provided in SRP EP (2012) to show how it can be utilized as part of impervious disconnection.

The impervious disconnection recommendations are summarized in Table E - 1 below. The pollutant load reductions are available if the qualifying conditions are met and verified post-construction.

Table E - 1. Recommended nutrient and sediment removal for the disconnection of existing impervious area runoff from stormwater drainage systems.

Protocol	Units[1]	Pollutant Removal
Impervious area disconnection to amended HSG A or B soils[2]	Pounds per year	TN, TP, and TSS removal calculated as simple impervious disconnection following recommendations of the Expert Panel to Define Removal Rates for Urban Filter Strips (UFS EP, 2014).
Impervious area disconnection to amended HSG C or D soils	Pounds per year	TN, TP, and TSS removal calculated based on the runoff reduction from a 1.0 inch rain event, which is used as the water quality volume treated and the RR pollutant removal curves in SRP EP (2012).
Treatment in the conveyance system	Pounds per year	TN, TP, and TSS removal calculated based on the water quality volume treated and the RR and ST pollutant removal curves in SRP EP (2012).

[1]Note that relative reductions from the SRP EP (2012) curves must be multiplied by location specific TN, TP, and TSS yields (i.e. 50% reduction of 10 pounds per acre per year for one acre gives 5 pounds per year reduction).

[2]Amendments or decompaction activities are typically not suggested for A or B soils, as infiltration rates tend to be high for these soil groups. However, the computational method protocols of this Expert Panel report (Section 5.1.2) can be used if measured Ksat is found to be extremely low from compacted urban areas.

In addition to the specific recommendations to define impervious area disconnection as a BMP for the Chesapeake Bay Program, the Expert Panel provides a set of future research and management needs to advance our understanding of this BMP.

Section 1. Charge and Membership of the Panel

The roster for the Impervious Area Disconnection Expert Panel is provided in Table 1. A copy of the meeting minutes are provided in Appendix A.

Table 1. Expert Panel Membership[1]

Name	***Affiliation***
Gregory Evanylo, PhD	Department of Crop and Soil Environmental Sciences, Virginia Tech
Franco Montalto, PhD, PE	Department of Civil, Architectural and Environmental Engineering, Drexel University
Jason Papacosma	Arlington County, VA Department of Environmental Services
David Sample, PhD, PE, D. WRE	Department of Biologic Systems Engineering, Virginia Tech
Justin Shafer	City of Norfolk, VA
Ryan Winston, PhD, PE	Department of Food, Agricultural, and Biological Engineering, Ohio State University
Non-panelists: Bill Stack (Panel Chair, CWP), Jeremy Hanson (Panel Coordinator, VA Tech), Reid Christianson (Technical Support, CWP), Lisa Fraley-McNeal (Technical Support, CWP), Greg Sandi (MDE), Liz Ottinger (EPA Region 3), Jeff Sweeney (CBPO)	

[1]Steve Stewart from the Baltimore County Dept. of Environmental Protection and Sustainability was originally part of the Panel, but withdrew prior to completion of the final draft and was unable to participate in the approval process.

1.1 Background on Panel

This Expert Panel was convened by the Urban Stormwater Work Group to define and develop nutrient and sediment load reduction recommendations for new BMPs that can be used for the disconnection of existing impervious area runoff from stormwater drainage systems. Disconnection of impervious area runoff is not currently defined by the CBP as a BMP available for credit towards Watershed Implementation Plans. However, it has proven to be an excellent strategy to reduce stormwater, sediments, and nutrients generated from urban land. The Chesapeake Bay Partnership has identified numerous practices that effectively disconnect impervious cover through the Expert Panel Process (e.g., urban filtering practices, urban filter strips, runoff reduction practices, etc.). Using soils that have been modified to enhance their runoff reduction capabilities have not been considered among these practices. The Urban Stormwater Workgroup (USWG) has consistently voted this practice as a top priority for launching an expert panel to define its pollutant reduction capability.

The proposed approach for impervious area disconnection is to direct or otherwise spread stormwater from impervious cover of existing development (not new or re-development) to an acceptable area of pervious cover where it may be effectively stored and infiltrated into the soil. Pervious cover consisting of hydrologic soil group (HSG) A or B soils has high to moderate infiltration rates and should follow the approach of simple disconnection using protocols previously developed by the Urban Filter Strip Expert Panel (UFS EP, 2014). In comparison, HSG C or D soils have low infiltration rates and should use the protocols explicitly developed by this Expert Panel to increase the infiltration capacity of the receiving soils. This new set of protocols for treating urban runoff involves changing the existing hydraulic properties of the soils treating runoff. In many cases, this will entail modification to the soils of the pervious cover receiving the runoff, such as soil tilling, compost or other soil amendments, phyto-remediation or special plantings that can increase soil infiltration. These modifications are needed because most urban soils have likely lost their original capacity to infiltrate runoff due to the mass grading and soil compaction that accompanies land development.

1.2 Expert Panel Charge

The initial charge of the panel was to evaluate the nutrient and sediment removal and runoff reduction benefits associated with disconnecting existing acres of impervious cover through several engineering and/or field assessment methods. The Panel considered and modified these approaches based on available science and their best professional judgment.

The panel was specifically requested to evaluate:

- Impervious disconnection to pervious areas amended with compost and/or vegetative plantings.
- The potential to retrofit existing drainage networks on a site to achieve full or partial impervious disconnection.
- Modeling to determine the degree of disconnection based on a disconnection benchmark established by the Panel.
- The existing retrofit adjustor curves and their suitability to assess the sediment and nutrient reduction potential for this new category of stormwater retrofit or whether some other methodology is preferable.

Beyond this specific charge, several types of impervious cover disconnection have already been addressed by previous expert panels, and are therefore, **outside the scope** of this new impervious disconnect expert panel:

- Methods to disconnect impervious cover used to comply with new state stormwater performance standards for new development or redevelopment projects (e.g., multiple structural and non-structural practices to reduce runoff are already established by a previous prior expert panel).

- Homeowner BMPs such as rain gardens, rain barrels, dry wells and downspout disconnections that are used to retrofit existing residential properties (e.g., credits for these on-site retrofit practices have already been established by the retrofit expert panel).

- Urban filter strips, urban filtering practices, urban or agricultural stream buffers, and shoreline management practices that accept stormwater from adjacent impervious areas (e.g., credits and qualifying conditions for these types of runoff disconnection practices have already been established by previous expert panels).

In addition to the practices listed above, other ongoing or existing urban stormwater BMPs approved, or under review, by the Chesapeake Bay Program (CBP) are outside the scope of this expert panel, including bioretention and other infiltration practices as defined by the CBP.

Note that the recommendations of this Expert Panel are for the disconnection of impervious cover to a pervious area and do not apply to pervious area restoration alone (without impervious disconnection). While the methods developed in Section 5 provide an excellent starting point for developing protocols that would allow credits for pervious area restoration, it was outside the Panel's charge to develop them. Additional review of pervious area restoration is recommended as a future research need in Section 7 as there are benefits that can be attributed solely to pervious area restoration

During its deliberations, the panel was expected to be mindful that the disconnection practice is only proposed for Phase 6 of the CBWM, and not the current Phase 5.3.2. This is extremely important because the target sediment and nutrient loads for impervious and/or pervious cover may change as a result of future model calibration during the mid-point assessment, particularly if existing urban loads are shifted to new land use categories.

While conducting its review, the panel followed the procedures and process outlined in the WQGIT BMP review protocol.

Section 2. Definitions and Qualifying Conditions

2.1 Definitions

Compaction Factor: The ratio of the bulk density of compacted soil to the bulk density of "natural" or "normal" soil. The compaction factor ranges from 0.9 to 1.3 with 1.3 being very compacted soil.

Concentrated Flow: Stormwater flowing in a confined feature, such as a ditch or swale.

Conveyance System: The existing drainage network designed to convey stormwater. The conveyance system includes channels and roadside ditches constructed as part of development to transport stormwater. Natural waterways are not considered part of the conveyance system.

Curve Number: A parameter used to predict the amount of runoff from a rainfall event in a particular area. The curve number methodology was developed by the NRCS and is based on hydrologic soil group, land use, treatment, and hydrologic condition.

Impervious Area Disconnection: The redirection or otherwise spread of stormwater from impervious cover to an acceptable area of pervious cover or other BMP to provide filtering and infiltration.

Offline Facilities: BMPs that split flows from the existing drainage network to an adjacent depression or excavated treatment area, such as a constructed wetland or bioretention.

Online Facilities: BMPs installed within the existing drainage network. Examples of these practices include the conversion of a ditch into a dry or swale, creation of linear bioretention treatment cells within the ditch, or the installation of weirs or check dams to provide storage.

Runoff Reduction: The total runoff volume that is reduced through infiltration, canopy interception, or evaporation assessed over a long-term period of record (i.e., not event-based).

Saturated Hydraulic Conductivity: The ability of a saturated soil to transmit water when subjected to a hydraulic gradient. It can be thought of as the ease with which pores of a saturated soil permit water movement.

Simple Disconnection: The redirection of stormwater to existing pervious areas that have not been modified for enhanced runoff reduction. For example, disconnecting a rooftop downspout from the storm sewer system and directing the runoff to an adjacent lawn area.

Soil Amendment: Conditioners and fertilizers that are added to a soil to increase its infiltration capacity. Compost is one of the most commonly used amendments. Other amendments include zeolite, gypsum, and liquid amendments such as ammonium laureth sulfate.

Infiltration Depth (L_f): The depth that water moves into the soil. Also known as the soil wetting front.

Treatment in the Conveyance System: The creation of storage facilities within the existing drainage network or adjacent treatment area, with the option of diverting runoff from disconnected impervious cover into these facilities to achieve full or partial disconnection.

Urban Filter Strip (UFS): A BMP designed to manage stormwater that consists of stable areas with vegetated cover on flat to gently sloping land. They are commonly referred to as filter strips or vegetated filter strips. Water quality benefits from urban filter strips are derived from both load reduction through infiltration and recharge, as well as removal of pollutants through settling and filtration.

2.2 Qualifying Conditions

2.2.1 Qualifying Conditions for Runoff Reduction Associated with Impervious Area Disconnection and Soil Amendments

- This practice is not applicable for areas that are likely to become compacted (e.g., sports fields), unless it can be shown through verification every 2 years that the saturated soil conductivity (Ksat) has not been reduced. Refer to Section 6.1 for additional information.

- This practice is not recommended for sites with greater than 10 percent slope unless non-erosive velocities are verified.

- Water being delivered from impervious to pervious areas must be distributed such that sheet flow dominates across the pervious area. This will prevent the formation of preferential or concentrated flow and erosion. In other words, the entire pervious area being credited must be used for runoff reduction.

- Concentrated flow from a pipe, conveyance system, or impervious cover lengths greater than 75 ft must enter a low flow diversion or forebay and into a combination channel and level spreader (or other appropriate configuration) prior to discharging into the pervious area. These runoff conditions are likely to have runoff velocities that limit infiltration and/or cause erosional channels within the pervious area.

- Level spreader (or other engineered flow dispersion device) length is based on 10ft for every 1 cfs (of the concentrated flow) with a maximum 100 ft length. This sizing criterion is based on basic hydraulic properties of weirs and a maximum desired flow velocity through grass. It is assumed that re-concentration of flow will not occur, or is minimized at flow rates lower than this permissible maximum flow velocity. Most recent research indicates that larger drainage areas cause nuisance conditions in the level spreader channel (sediment build-up, standing water and therefore, it is recommended that the level spreader be limited to 100 feet or less (Winston et al., 2011).

- The maximum allowable drainage area to meet the above condition will vary depending on the percentage of imperviousness in the contributing drainage area and the volume of runoff to be treated. Therefore, the Panel was not able to recommend a universal level spreader sizing criterion for concentrated flow conditions based on drainage area.

- The suggested maximum ratio of impervious area in the drainage area to pervious area available for treatment is 15:1. The panel felt ratios larger than this may lead to stability issues of the receiving area. Higher ratios may be used if the computational method is used (Section 5.1.3).

- Not an applicable practice for hotspots or where groundwater less than 1.5 feet from the surface (Winston et al. 2010).

- Recommended soil classification is Hydrologic Soil Group C or D. Amendments or decompaction activities are typically not suggested for A or B soils, as infiltration rates tend to be high for these soil groups. If disconnecting to A or B soils refer to Simple Disconnection as described in the Urban Filter Strip Expert Panel. However the computational method protocols of this Expert Panel report (Section 5.1.2) can be used if measured Ksat is found to be extremely low from compacted urban areas.

- This practice is not suggested in areas with karst topography where surface soil is less than 1.5 feet.

- Soil surface sealing and crusting can significantly reduce soil infiltration rates and must be limited through establishment of healthy vegetation (>90% coverage) uniformly distributed across the entire pervious area. Region-appropriate turf or low-maintenance plants, such as perennials, woody shrubs, or trees are encouraged. Clumping grasses should be avoided and grass clippings should not be removed to reduce/prevent the need for future fertilization. High maintenance grass or other vegetation is discouraged.

    - If surface sealing due to sodium is a concern (i.e. areas receiving runoff from impervious areas being treated with sodium based road salt), a calcium based additive must be used. The calcium application rate depends on the amount of sodium in the soil. Sonon et al. (2015) and Davis et al. (2012) provide guidelines for calcium application.

    - Surface sealing as a result of sediment deposition or parent material properties can be addressed through appropriate vegetation management.

- This practice requires soil improvement over a minimum depth of 3 inches to 6 inches, depending on the vegetation planted. The minimum depth of 3 inches is generally sufficient for turf, though deeper improvements will have a greater impact on runoff reduction. For non-turf plants which have deeper rooting depths, a minimum depth of improvement of 6 inches is required.

- Tilling or incorporation depths greater than 13 inches are not eligible for additional nutrient and sediment load reductions.

- Tillage should not occur within the root zone of established trees, which may be approximated by the canopy diameter (i.e., tree drip line).

- Application of fertilizer to promote the establishment and maintenance of healthy vegetation must follow these additional best practices:

  - A soil test should be conducted during the establishment of vegetation and every year thereafter to determine fertilization requirements.

  - Phosphorus and potassium fertilizer and lime should be applied at the rates recommended by the soil testing laboratory.

  - Nitrogen fertilizer should be applied at the rates required for healthy plant growth.

  - Fertilizer must be kept off of impervious surfaces, such as sidewalks, driveways, patios, and roads either by the use of specialized application equipment and/or removal by blower, broom, etc.

  - Fertilizer should not be applied before moderate or heavy rain.

  - Fertilizer should not be applied within 20 feet of a waterway (stream, lake, etc.)

- Nutrient testing should be conducted on existing soil by a testing laboratory prior to compost improvement. Existing soil test P results are suggested to be less than 55 mg/kg (Mehlich 1) or 127 mg/kg (Mehlich 3) if compost is to be incorporated. At these levels or below the use of compost will be beneficial due to runoff reduction and improved soil qualities and the comparatively smaller risk for leaching. Above these levels, there is a risk that compost additions will contribute to phosphorus export from the site.

- Compost must meet safety requirements for human contact, have a total nitrogen content of less than 2% (95% in organic form), and a total phosphorus content of less than 3%. Compost must meet the US Composting Council's soil amendment compost specifications found at: http://compostingcouncil.org/specifying-sta/ , which includes a maturity rating of >80%, and be provided by a member of the US Composting Seal of Testing Assurance (STA) program. See www.compostingcouncil.org for a list of local providers.

2.2.2 Qualifying Conditions for Treatment in the Conveyance System

A list of general qualifying conditions for facilities that provide treatment in the conveyance system is included below. The Urban Stormwater Retrofit Manual (Schueler et al., 2007) and individual state stormwater manuals should be consulted for additional qualifying conditions that may be applicable, such as building setbacks.

- In-channel treatment areas should be shown to withstand the erosive velocities associated with the maximum design storm. Velocity control is a significant design consideration with online retrofits to minimize sediment re-suspension and prevent erosion. Velocity may be reduced by further reducing channel slope, increasing the channel width, increasing roughness, or using geotextile reinforcement. Scour analysis may be needed to size the diameter of stone needed to stabilize check dams, biologs or weir walls. In addition, care must be taken to ensure that additional runoff from disconnected impervious cover is introduced to the conveyance system with non-erosive velocities. State stormwater manuals should be consulted for specifications to achieve non-erosive velocities, such as through the use of level spreaders.

- A natural channel should **never** be retrofitted unless it has been previously altered for drainage purposes.

- Since conveyance retrofits rely on vegetation for stability, grass or wetland plant species should be carefully chosen. A vegetation management plan is needed to ensure adequate vegetation growth in future years.

- Inflow should either be sheet flow or concentrated flow with pretreatment as noted in the appropriate state stormwater manual.

Section 3. Background on Impervious Area Disconnection in the Chesapeake Bay

3.1 Application of Impervious Area Disconnection

Disconnected impervious area as a current land use is not available for pollutant load reduction credit from the CBP. The hydrologic connectivity of impervious surfaces is difficult to determine since it is dependent on the physical characteristics (e.g., vegetative cover, flowpath length, topography, soil) of intervening pervious areas. Additionally, hydrologic connectivity is dependent on rainfall duration and intensity and the relative sizes of the impervious and pervious areas (Mueller and Thompson, 2009). During 2014, the USWG evaluated the potential to create a land use category to represent disconnected impervious cover in the Phase 6 Chesapeake Bay Watershed Model (CBWM), but concluded that available mapping and monitoring data could not accurately differentiate between connected and disconnected impervious cover at the scale of the Bay watershed (Sample et al, 2014, Tetra Tech, 2014). Consequently, the USWG did not recommend that a separate land use category be created for disconnected impervious cover in the next phase of the watershed model. This recommendation was subsequently endorsed by the WQGIT and Modeling Workgroup. The preferred approach was to investigate methods to calculate credits for impervious disconnection as a best management practice (BMP).

3.2 Chesapeake Bay Jurisdictions Impervious Disconnection Design Specifications

Impervious area disconnection is defined as a stormwater BMP, predominantly as rooftop disconnection in all of the six Bay States and the District of Columbia. Although the specifications for impervious disconnection vary by jurisdiction, they have some common characteristics:

- Slope – generally less than 5% with caveats like turf reinforcement, sheetflow, and level spreader
- Soil – any hydrologic soil group (A, B, C, or D) with caveats like soil amendments or tillage for HSG C/D or compacted areas
- Size – minimum length and width between 10 and 20 feet
- Vegetation – commonly turf or meadow with a goal of resisting erosion

In addition to impervious disconnection, Virginia, Pennsylvania, and the District of Columbia provide credits for compost soil amendments that meet certain specifications. The Expert Panel considered these specifications in the development of the protocols presented in this report. A summary of the design specifications included in each of the State's and the District of Columbia's stormwater management manuals is provided in Appendix B.

Section 4. Review of the Available Science for Impervious Area Disconnection

Disconnection of impervious cover for the purposes of this Expert Panel involves the direction of stormwater from existing impervious cover to a pervious area that contains soils that have been modified to enhance their runoff reduction capabilities. In comparison, simple disconnection involves the direction of stormwater from impervious cover to an existing pervious area that has not been modified. Simple impervious disconnection follows the Recommendations of the Expert Panel to Define Removal Rates for Urban Filter Strips (UFS EP, 2014). A review of the literature for simple disconnection is provided in the UFS Expert Panel Report. A total of 75 publications were reviewed by this Expert Panel to evaluate the pollutant removal effectiveness of impervious area disconnection, along with its runoff reduction capability.

4.1 Performance of Modified Pervious Areas that Accept Runoff Redirected from Existing Impervious Cover

Any modification to improve the hydraulic properties of existing pervious areas could be considered to fall under the general category of soil reclamation and may cause wholesale changes in hydraulic response (De Wrachien & Chisci, 1999). Soil restoration/conditioning are typically needed to improve the hydraulic characteristics of soils compacted as a result of construction practices. Urban soil compaction reduces infiltration rates and leads to increased stormwater. For example, Gregory et al. (2006) found that compacted sandy soils in North Central Florida had infiltration rates reduced from 70-99% in comparison to non-compacted soils. Schueler (2000) reviewed techniques to reverse soil compaction after construction and the resulting decrease in soil bulk density (Table 2). The following sections provide a review of the available literature for the primary methods of soil restoration/conditioning.

Table 2. Reported activities that restore or decrease soil bulk density. Source: Schueler (2000)

Land Use or Activity	Decrease in Bulk Density (gms/cc)	Source:
Tilling of Soil	0.00 to 0.02	Randrup, 1998, Patterson and Bates, 1994
Specialized Soil Loosening	0.05 to 0.15	Rolf, 1998
Selective Grading	0.00	Randrup, 1998 and Lichter and Lindsey, 1994
Soil Amendments	0.17	Patterson and Bates, 1994
Compost Amendment	0.25 to 0.35	Kolsti *et al.*, 1995
Time	0.20	Legg *et al.*, 1996
Reforestation	0.25 to 0.35	Article 36

Soil Decompaction

There are many methods for tilling (decompacting) soil and the general benefits have been documented (Fite et al, 2011; Kees, 2008); however, not all of the noted benefits are related to increasing infiltration for purposes of stormwater control or water quality enhancement. Since many decompaction and amendment studies are in relation to agriculture, the impact of soil decompaction may focus on the resulting crop yield, water holding capacity, trafficability, etc. Specific soil tillage techniques are quite variable, though surface tillage and subsoiling are the two general categories. Table 3 summarizes a review of studies reporting tillage impacts on soil infiltration.

Table 3. Review of studies reporting tillage impacts on soil infiltration

Study	Finding(s)
Hauser & Taylor, 1964	Chisel plowing increased the amount of water infiltrated in 10 hours by 8%, vertical mulching increased infiltrated volume by 51%, and disk plowing increased infiltration volume by 91%, compared to a control plot.
Balousek, 2003	Chisel plowing done in conjunction with deep tilling reduced runoff volume 36-53% compared to a control plot in Wisconsin that was graded and compacted to simulate construction activity.
Haynes, McLaughlin, & Heitman, 2013	Deep tillage (20 – 30 cm) reduced volume (as a percentage of precipitation) by 98% and core aeration (1-2 cm) reduced volume by 74% for a study site in Raleigh, NC. In comparison, native, compacted soils reduced volume by 83%. The authors hypothesized that the aeration process compacted the soil which is why the native, compacted soil had a higher volume reduction than the aerated soil. The deep tilled infiltration rate at one site was found to be similar to the highest rates found else- where on home lawns for 65 - 70 year old lawns. Only the deep tillage sites showed significant reductions in bulk density among sites of 0.2 and 0.3 g/cm^3.
Jasa and Dickey, 1991	Subsoiling through preplant along the crop row and postplant between crop rows increased the average time for runoff to occur (increased infiltration). The average time to runoff for the subsoiling treatments was twice as long (40 minutes compared to 20 minutes). Ultimately, this translated to roughly a 2/3 reduction in runoff.
Brown, 2012	Shallow (15 cm) and deep (30 cm) tillage was studied on compacted soils in the Piedmont, Coastal, and Mountain regions of NC. Limited infiltration was found on control plots at all three sites (0-10%), while tillage resulted in initial infiltration rates near 100%. After 5 months to a year, bulk density increased for all tillage sites due to soil setting and wheel traffic from riding lawn mowers.

Though tillage frequency likely will not directly factor into soil conditioning, as the practice would likely be a one-time activity, frequency research can inform the expected useful life of a practice, or, alternatively, the long-term benefits. For example, a frequency on paratillage (tillage without decimating soil structure) showed plots tilled annually have statistically significant higher steady-state infiltration rates (7.2 cm/hr) when compared to plots tilled every other year (1.9 cm/hr) or every 3rd year (1.1 cm/hr) (Clark et al, 1993). This paper suggests the immediate improvement of soil decompaction may subside, though no comparison with untreated plots were given.

Addition of Soil Amendments

The addition of soil amendments is also recognized as a suitable method for reducing runoff through increased infiltration. The list of potential amendments for soil is quite extensive. Amendments for the sole purpose of increasing infiltration, however, might be limited to compost or a relatively coarse aggregate like sand. Research into this topic has typically been done to show soil health enhancement and to provide better growing conditions for selected plants. Long-term information is needed to infer benefits on runoff reduction. A few studies focus on hydraulic properties of amendments by themselves, as well as resulting properties of a mix of amendments and soil.

Zeolite

A study by Dung et al. (Dung et al , 2011) estimated hydraulic properties of various zeolite amendments, as well as 60:40 mixes of soil and zeolite. Interestingly, the resulting saturated hydraulic conductivities are only about ¼ the volume weighted estimates of saturated hydraulic conductivities of the components (Figure 1), making testing of the mixes an important part of estimating runoff reduction from an amendment activity. Bulk density was fairly predictable given the mixture components (Figure 2).

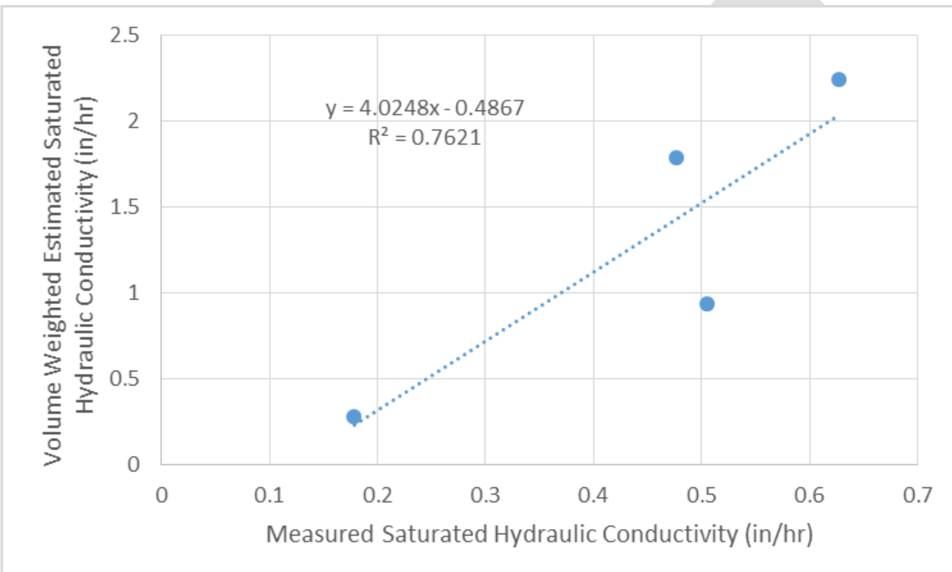

Figure 1. Comparison of component predicted and measured saturated hydraulic conductivity.

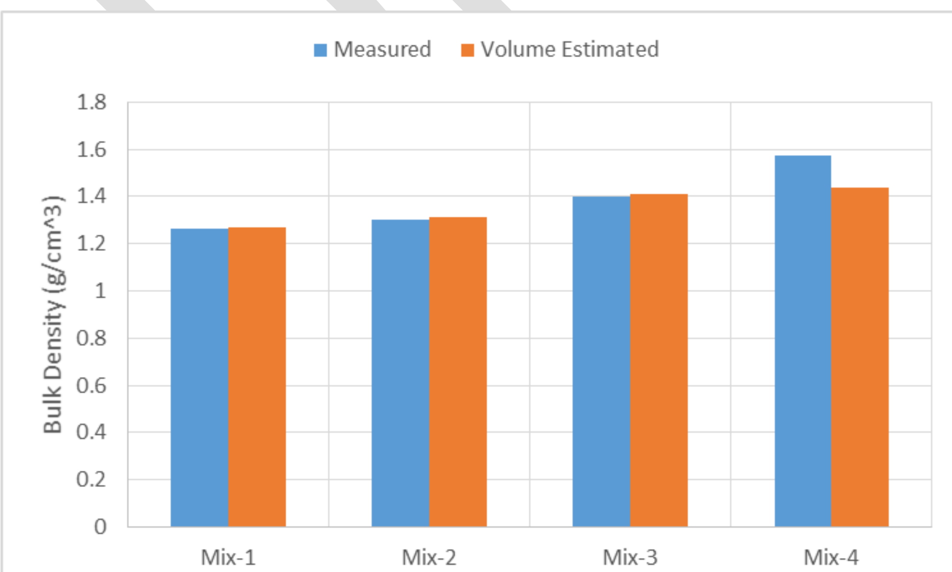

Figure 2. Component estimated and measured bulk density.

Gypsum

Gypsum is routinely used to modify (improve) soil characteristics in agriculture (NRCS, 2015). The draft NRCS standard for gypsum amendments gives recommended rates for site conditions and goals, which may be helpful for use in urban areas as well. Specifically, the amendment is intended to help restore aggregates to the soil, ultimately reducing bulk density. Flanagan et al. (2002) used gypsum applied with polyacrylamide to amend soils. Their results suggested a reduction in runoff by about 1/3rd when compared to the control plot. The polyacrylamide only amendment reduced runoff by about the same amount. The base soil for these experiments was a clay loam with a sand content of 22%, a clay content of ~28%, and an organic matter content of ~1.2%. Using the SPAW model with these soil characteristics predicts a saturated hydraulic conductivity of 0.19 inches per hour. Using the Green-Ampt infiltration model for the first three storm events reported by Flanagan et al. (2002) with default porosity and suction head from Rawls et al. (1983) and saturated hydraulic conductivity from SPAW for the control, these amendments may increase the effective saturated hydraulic conductivity by 1.5 and 1.7 times for the polyacrylamide and gypsum-polyacrylamide treatments, respectively. These treatments aided with vegetation establishment as well (Figure 3).

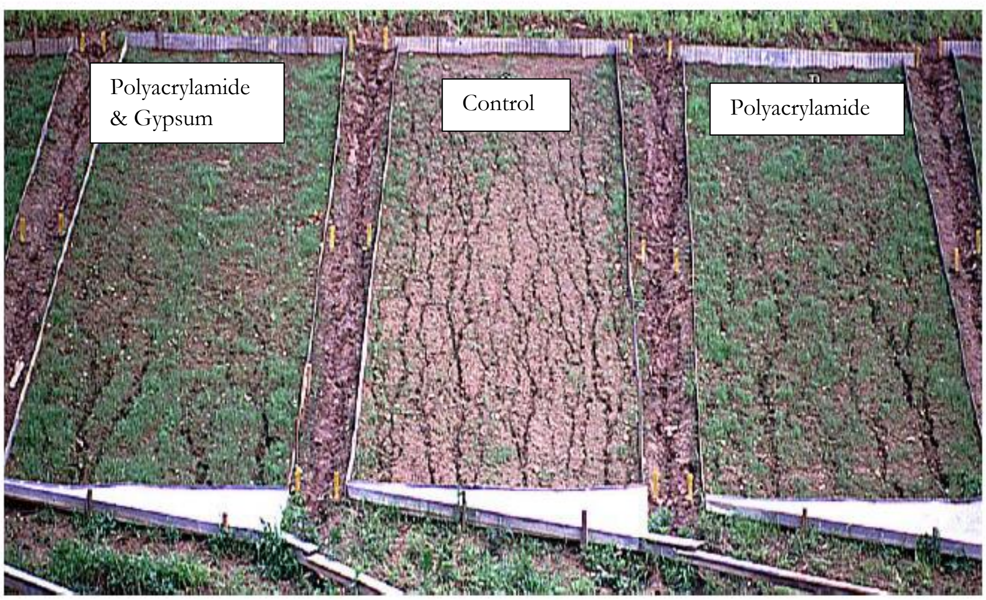

Figure 3. Figure from Flanagan et al. (2002) showing vegetation establishment in amended plots.

Liquid Amendments

Liquid amendments like ammonium laureth sulfate (ALS) applied after a tillage operation have been found to have little effect on infiltration, especially when compared to compaction (Hamlett et al., 1990) (Figure 4). The differences between treatment and control plots over a season were not statistically significant.

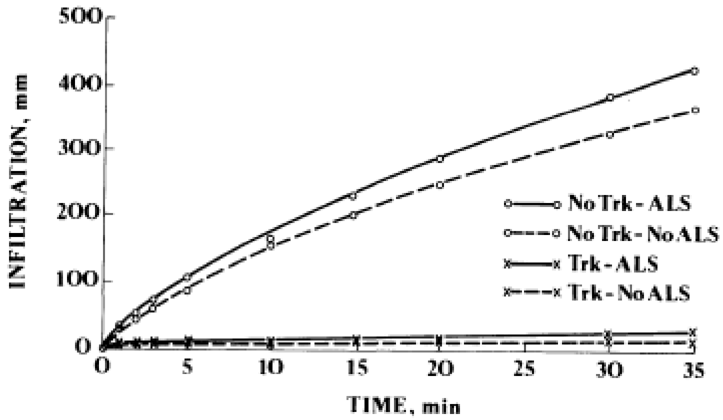

Figure 4. Cumulative infiltration associated with ammonium laureth sulfate soil amendment as well as compaction due to agricultural implements.

<u>Compost</u>

A vast majority of the literature focuses on using compost as a soil amendment. This may be due to availability, as many of the compost sources are waste products (i.e. yard debris, paper mill residuals, wastewater treatment plant biosolids, etc.). Additionally, adding organic materials to soil is often advantageous for crop growth (including lawns). Table 6provides a review of studies that report the effectiveness of using compost as a soil amendment.

Carmen (2015) found that downspout disconnection in conjunction with compost soil amendments in some cases provided additional volume and peak flow reduction than non-amended systems. Plots were established in four residential sites in Durham, NC where paired downspouts were disconnected and the receiving lawn area was amended for one downspout at each site. The amendment consisted of tilling the soil 6-8 inches, applying lime and 1" of plant-based compost (50.3% organic matter, 1.9% N and 1.6%P), and spreading a tall fescue seed blend. After allowing 3 months for the plots to establish, the total volume reduction at the sites ranged from 38 -99% during Phase 2 (Table 4). The mixed results from the study are complicated by (1) the inability to separate out which factor(s) of the amendment process contributed to the reduction in outflow, and (2) the inability to distinguish which site factors limited the effect of the amendment process. It was likely that the lawns being monitored had "good" infiltration capacity to begin with, and therefore had limited opportunity for improvement.

Table 4. Summary of volume reduction from Phase 1 and Phase 2 monitoring periods, pre and post soil amendment for four residential sites in Durham, NC. Source: Carmen (2015)

Site	Volume IN (m^3) Pre	Volume IN (m^3) Post	Volume OUT (m^3) Pre	Volume OUT (m^3) Post	VR (% red) Pre	VR (% red) Post	VR (% red) Total
1A	46.6	46.7	20.2	29.0	57	38	47
1B	22.0	21.7	6.2	8.9	72	59	65
2A	16.7	19.5	3.3	0.2	80	99	90
2B	24.9	25.1	5.9	7.4	76	71	73
3A	14.7	14.0	1.1	0.9	92	94	93
3B	26.5	25.1	7.1	1.4	73	94	84
4A	20.2	19.6	7.8	10.1	62	48	55
4B	21.8	20.7	0.2	0.8	99	96	97

* Sites shown in ***bold italic*** indicate amendment treatment

The following table shows how the results from Carmen (2015) have been incorporated into a draft of the NC BMP Manual for crediting soil amendments.

Table 5. Draft of NC BMP Manual crediting for soil amendments based on Carmen (2015).

	Type 1 DIS		Type 2 DIS		Type 3 DIS
Disconnected Roof: Vegetated Area Size	**6' x 12'**		**12' x 24'**		**12' x 24' & site BUA* < 24%**
Disconnected Paved Area: Vegetated Area Size	**10' width**		**15' width**		**15' width & BUA < 24%**
Hydrologic soil group	A/B	C/D	A/B	C/D	A/B only
Runoff reduction credit	45%	30%	65%	50%	100%
TSS reduction credit	45%	30%	65%	50%	85%
TN reduction credit	30%	30%	30%	30%	30%
TP reduction credit	35%	35%	35%	35%	35%

**Built Upon Area (BUA) is defined as impervious surface and partially impervious surface to the extent that the partially impervious surface does not allow water to infiltrate through the surface and into the subsoil.*

Olson et al. (2013) conducted a study at three locations in Minneapolis, WI with urban soils characterized as loam and clay loam soils to evaluate the effect of soil amendment to increase infiltration rates. The study areas were parks or open fields, with turf health and density varying from site to site. Each site had a control, a till only, and a till + compost plot. Hydraulic conductivities, bulk densities, and soil strength data were collected at each site. Using Green-Ampt infiltration modelling, compost plot runoff volume was 17% of control, and till-only was 33% of control runoff volume. No annualized or long-term runoff reduction calculations were attempted. These involved a range of design storms only (2-year, 1-h to 100-yr, 1-h). Temporal variations were observed (e.g., effects of freeze/thaw; spring saturated hydraulic conductivity (Ksat) different from summer Ksat, etc.) Tillage plus composting was an effective treatment at all three sites, but tillage alone was not effective at two sites (i.e., proposed that tillage destroys macropore structures in soils); the site where tillage alone was effective was relatively new construction. Neither bulk density nor soil strength were good surrogates for K_{sat}.

Table 6. Review of studies reporting the effectiveness of using compost as a soil amendment

Study	Finding(s)
Felton, 1995	The addition of large quantities of composted municipal solid waste (~6.25 and 12.5 tons per acre) increased saturated hydraulic conductivity 318 times untreated conditions, and decreased bulk density about 14% for a site in Kentucky.
Pandey and Shukla, 2006	Yard trimming compost that was applied two years in a row and disc incorporated significantly increased soil organic matter. Increases in soil water content were also found and attributed to increased capillary rise associated with the increased organic matter. The authors did not find any increase in nitrate concentration in the shallow groundwater associated with the compost amended plots.
Balousek, 2003	Chisel-plowed and deep-tilled soil that was amended with compost reduced runoff volume by 74-91% in comparison to 36-53% from the plowed and tilled soil alone.
Harrison et al., 1997	Water holding capacity doubled with a 2:1 compost:soil amendment.
Kolsti et al., 1995	Seven control test plots (with tillage) and variants (tillage plus compost) were monitored during 1 to 2 storms over a 3 month period in Washington State. Percent volume reductions ranged from 26% to 46%. Permeability of the native soils likely moderated additional volume reductions compared to monitoring data collected at sites with more clays and silts.
Weindorf et al., 2006	Seven soils with compost amendments in Dallas, TX were studied with a range of compost depths. In contrast to some of the other studies reviewed, infiltration rate was found to be more strongly affected by soil texture, soil mineralogy, and climatic effects than by the addition of compost.
Risse, et al., 2011	Under medium and large rainfall conditions, a soil amendment plot study in Georgia found that control grass, mulch and surface composted plots (runoff reductions of 83% to 97%) showed significantly higher efficiency of runoff reduction compared to incorporated biochar and control bare soil (runoff reductions of 43% to 79%). Surface composted plots had the highest runoff reduction of 97%, which is most likely due to the high water holding capacity of the compost. Incorporated compost plots on which the same type and rate of compost had been applied showed more runoff than the surface compost plots. The process of incorporation reduced the amount of compost on the plot surface which resulted in reduced capacity to hold water.
Bean and Dukes, 2015	In contrast to other studies, incorporating compost with tillage for two Florida soils significantly reduced soil bulk densities, but did not translate to significantly greater infiltration rates or lower runoff production compared to tillage alone. Due to greater infiltration rates and lower bulk densities, tillage with or without compost at either 10 or 20 cm incorporation depths produced significantly less runoff than compacted soils (mean runoff coefficients, $p<0.005$ and 0.03–0.14 compared to 0.19 and 0.46, respectively; mean effective curve numbers, 62–71 and 40–49, compared to 87 and 75, respectively).

Vegetative Cover Management
Runoff can be reduced through modification of vegetation management. Managing a pervious area as something other than turf/lawn over a sustained period of time may alter soil characteristics and increase the ability of infiltration to occur (Cole & Spildie, 2007). In addition, some vegetative choices may use more nitrogen or phosphorus from the soil profile, which has the potential to reduce nutrient loss even further.

Schueler (2000) suggests reforestation as a long-term approach for restoring compacted urban soils. Trees and shrubs gradually build soil structure through root penetration, leaf fall, macropores and associated soil fauna. However, this process can take decades to occur, and usually requires a helping hand in urban watersheds. For example, establishing trees in compacted urban soils often requires the excavation of larger and deeper tree pits filled with special soil mixes to allow tree roots to flourish.

In relation to tillage, Haynes et al. (2013) found that vigorous vegetation appears to be critical to the success of deep tillage over time. One of their deep tillage study sites found that poor grass troth during a cold, wet winter period resulted in the failure to maintain high infiltration rates. The grass established under more ideal conditions responded to deep tillage with significantly more roots below the 15 cm soil profile, suggesting this as an important factor in maintaining infiltration rates.

4.2 The Effect of Site, Design, and Maintenance Characteristics on Performance

Development Age
Mueller and Thompson (2009) found that infiltration rates for newer lawns (5-10 years) were lower than the infiltration rates for older lawns (50 years). Similarly, Woltemade (2010) found older lawns (>10 years) had higher infiltration rates. The mean infiltration rate in recently built areas is 69% less than that for older neighborhoods. Woltemade (2010) hypothesized that the differences may be due to a combination of recent construction techniques that rely on heavy equipment for delivery of materials and site grading and the limited time for grass and woody vegetation to become established on more recently built lots.

Many natural processes act to loosen up soil, such as freezing/thawing, particle sorting, earth worm activity, root penetration and the gradual buildup of organic matter. Often, however, these processes take decades, and operate primarily within the first foot or so of soil. In addition, many of these natural processes are effectively turned off when soil compaction becomes severe (i.e., bulk density greater than 1.7) because water, plant roots and soil fauna simply cannot penetrate the dense soil matrix (Schueler, 2000).

Soil Amendment Design
Methods for incorporation of amendments into existing soils should be developed to ensure uniformity and reproducibility. Much of this type of work has been done in the agricultural arena. For example, Hart et al. (1995) found better uniformity when a potassium bromide surface applied tracer was incorporated with a tiller traveling at a higher forward ground speed, which caused the tiller tines to, effectively, take larger bites of undisturbed soil with each rotation. Uniformity was measured using an ion chromatography analysis of 1.2 inch soil lifts down to the tillage depths.

Schueler (2000) identified a number of situations where compost amendments are not ideal, including sites with steep slopes, a high water table, wet saturated soils, or on a slope draining toward a foundation.

Existing Soil Phosphorus Content
Soil amendment design needs to consider existing soil phosphorus content and how the soil amendment will affect phosphorus retention. Maryland, for example, uses a P-index tool, which is used to consider whether a soil will contribute to P transport vial leaching or runoff (e.g., stormwater). Furthermore, crediting will need to be associated with maintenance procedures like grass clipping, fertilization, compaction, etc. that affect the mobility or source contributions of P. For example, liming to reduce soil acidity makes soil-bound P available for plant uptake. However, this can cause increased P loss if done on soils with a high background P-index. Iyamuremye and Dick (1996) present a good introduction on phosphorus and lime interactions.

Soil Amendment Composition
One consideration when amending soils with compost is the potential for leaching of nutrients from the compost, especially when the site is newly developed. Pitt et al. (1999) found pollutant concentrations in surface runoff and subsurface flows from a compost amended soil test site increased by 5-10 times. However, when the decreased surface flow quantities were considered in conjunction with the increased surface runoff concentrations, it was found that all of the surface runoff mass discharges were reduced (to 2 to 50 percent of the un-amended discharges). In comparison to surface runoff, many of the subsurface flow mass discharges increased, especially for ammonia, phosphate, total phosphorus, nitrates, and total nitrogen.

Faucette (2004) found that nutrients were exported from most compost-treated research plots (tested poultry residue, wastewater treatment, yard waste organics, biosolids compost, food compost) when compared to mulch or soil-only plots. Total N lost in the runoff (combined from all three storms sampled) as a percent of the total applied by the treatments was 15.3% from the hydroseed with mulch, 12.2% from the hydroseed with silt fence, 3.9% for the biosolids compost, 2% for the MSW compost, and 0.7% for both the yard waste compost and poultry litter compost treatments.

Paus et al. (2014) conducted batch and column experiments to investigate the effects of compost volume fraction (CVF) on bioretention media. Substantial concentrations of P in the compost samples and its release during the batch leaching experiments (i.e., 203 ± 24 mg P per kg compost) suggested that P release from the bioretention media during storm water infiltration is a concern. Columns with 10% CVF effectively filtered out particulate P and leached more dissolved P than was retained. In comparison, columns with 30% and 50% CVF substantially released both total and dissolved P.

Mullane et al. (2015) studied leachate composition of municipal compost from the Seattle–Tacoma region. Results suggest that, in general, leachate concentrations of N and P from mature compost decrease over the course of individual rainstorms, as well as following successive storms. However, this overall decline was not smooth, as the initiation of each storm mobilized a new peak of constituent concentrations in the leachate. Sustained leaching of P was observed at concentrations of several milligrams of P per liter and up to 10 mg/L of N.

When using compost, rather than using a generic specification, Lenhart (2007) suggested properties such as nutrient content, water holding capacity, metals uptake capacity, shrink/swell, product maturity, pathogen and weed seed content require a high level of scrutiny to insure that appropriate composts are being used. There are many feedstock sources of compost and methods of composting which yield very different end products. Feedstocks such as mixed yard debris, manure, and fallen deciduous leaves offer substantial differences in nutrient content. Additionally, the concentration of residual chemicals such as pesticides and herbicides, the presence of woody material and relative percent differences in cellulose or lignistic materials can be vastly different among various compost types. Methods of processing also have a significant impact on the quality of the compost, especially with respect to maturity, content of foreign materials, and biological contaminants such as pathogens and weed seed survival in the feedstock sources of compost (Lenhart, 2007).

Maintenance and Longevity

Long-term research is needed to determine how long the benefits of compost amendments persist. For example, are compost amendments only needed once, or must they be repeated as the compost decomposes? What kind of lawn maintenance practices are needed to maintain the benefits of amended lawns, including increased K_{sat} and decreased bulk density?

Benefits to soil health through the addition of compost has long-term effects as shown in a study by Gilley and Eghball (2002). Four years after compost addition at a rate high enough to satisfy the crops nitrogen needs, soil electrical conductivity and the pH were still higher than the control plot. The limits of effectiveness of compost amendment (i.e., age or decay rate) and a maintenance/reapplication schedule are recommended for further study.

4.3 Existing Methodologies to Assess the Change in Soil Hydraulic Properties from Soil Restoration/Conditioning

NRCS Curve Number

A popular method used in many arenas is the NRCS Curve Number (CN) runoff method (MDE, 2009; NYDEC, 2010; WPWU, 2012). As this method is commonly written into stormwater guidance, designers are familiar with it. Additionally, this method is part of typical hydrology models used to estimate runoff volume and peak flows (TR-55). The standard CN equation as highlighted by various sources (Mockus, 1972; NRCS, 2004) is:

$$\boldsymbol{Q = \frac{(P - I_a)^2}{(P - I_a) + S}}$$

Where Q = total runoff (depth); P = precipitation (depth); I_a = initial abstraction (depth); S = potential retention (depth). For general use, I_a is assumed to be 0.2*S. The actual CN value is used in the calculation of S as (Mockus, 1972):

$$\boldsymbol{CN} = \frac{1000}{\boldsymbol{S + 10}}$$

Where CN is the CN value associated with a given soil and land use/land cover type. In the above equation S is in inches.

The advantages to using this method are simplicity and recognition. However, there is a missing link between on-the-ground activities (i.e. soil amendments) and changes in the curve number. There are various ways around this such as using estimated saturated hydraulic conductivity (K_{Sat}) from SPAW in conjunction with Chong and Teng (1986) (Christianson et al., 2015), though this type of link is not "mainstream".

The EPA Stormwater Calculator is a tool that might also be used to obtain the volumetric reduction due to soil restoration/conditioning. This involves running the Calculator and varying the soil drainage characteristics pre and post-treatment. In addition, the Calculator is capable of generating annual volume reductions. http://www2.epa.gov/water-research/national-stormwater-calculator. A model like this could, effectively, be used as the crediting framework, though the link between each specific activity to reduce runoff and resulting soil drainage characteristics is still needed.

Infiltration & Runoff

Another approach that uses measured infiltration rates instead of estimated KSat is presented by Mueller and Thompson (2009). They developed a stormwater reduction model for urban residential lawns that requires inputs of precipitation intensity and duration, roof-to-lawn ratio, and steady-state infiltration rate. The model was used to estimate annual lawn runoff for Madison, Wisconsin by using a precipitation record that produces stormwater representative of long-term average conditions for the area. The stormwater reduction model can be used to determine the viability of urban lawns as a stormwater management practice and has potential to be implemented into urban runoff models that consider indirect area runoff.

$$D_{\text{runoff}} = i \cdot t\left(1 + \frac{A_{\text{roof}}}{A_{\text{lawn}}}\right) - I \cdot t - I_{\text{a}},$$

i = rainfall intensity (cm/hr)
t = storm duration (hr)
I = lawn infiltration rate (cm/hr)
Ia = abstraction depth (cm)

Figure 5, which is Wisconsin specific, can be used to determine the benefit of the disconnection procedure based on infiltration rate.

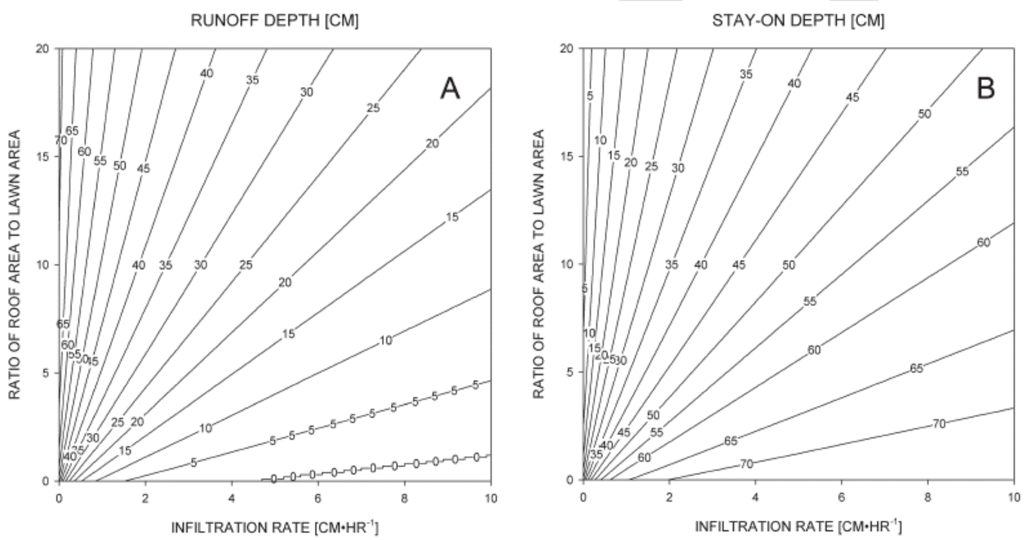

Figure 5. Annual (A) Runoff and (B) Stay-On Depth (cm) for infiltration rates ranging from 0-10 cm/hr and roof to lawn ratios ranging from 0-20. Annual precipitation was 73.2 cm. Source: Mueller and Thompson (2009).

Soil-Plant-Air-Water Model

In the absence of measured infiltration rates, soil textural and compaction information could be used along with the Soil-Plant-Air-Water (SPAW) model (Saxton and Rawls, 2009) to estimate improvements in runoff retention for disconnected impervious surfaces. Resulting parameters may be used in the above methods. The SPAW model has been updated and is now a standalone computer model (available for download from the Agricultural Research Service (ARS) at http://hydrolab.arsusda.gov/SPAW/SPAWDownload.html). Inputs into this model, for purposes of this effort, are sand (%), clay (%) (or, alternatively, textural class), organic matter (% by weight), gravel, and compaction level. Saturated hydraulic conductivity would be output from this model, which is not impacted by salinity or moisture content.

Section 5. Protocols to Define Nutrient and Sediment Removal Rates

The protocols in Section 5.1 are intended to determine the TN, TP, and TSS load reductions from impervious disconnection to amended soil. Simple disconnection (to pervious area without soil amendment) has been previously evaluated by the filter strip panel (http://www.chesapeakebay.net/documents/UFS_SBU_Expert_Panel_Draft_Report_Decision_Draft_FINAL_WQ_GIT_APPROVED_JUNE_9_2014.pdf). Additionally, the protocols in Section 5.2 add detail and specifications for conveyance system treatment techniques, which were previously mentioned in the retrofit expert panel report (http://www.chesapeakebay.net/documents/Final-CBP-Approved-Expert-Panel-Report-on-Stormwater-Retrofits-long_012015.pdf).

5.1 Pollutant Removal for Runoff Reduction Associated with Impervious Area Disconnection Coupled with Soil Amendments

This protocol outlines methods to estimate the benefit of impervious disconnection and soil amendments by estimating the change in hydraulic conductivity resulting from the amendment and consequently runoff reduction. Impervious area disconnection can involve introducing "new" impervious cover onto amended soils or addressing existing impervious cover that drains to these soils. A default rate is presented in Section 5.1.1 to be used for planning purposes and non-conforming projects. Section 5.1.2 provides a simple method that can be used when site-specific soil samples are not available to obtain a conservative estimate of pollutant removal. In comparison, a higher credit can be calculated by using the computational method presented in Section 5.1.3 to obtain a more accurate estimate of pollutant removal based on site-specific characteristics and soil amendments.

5.1.1 Default Rate for Impervious Area Disconnection Coupled with Soil Amendments

A conservative default rate was developed to be used solely for planning purposes and non-conforming projects. The conditions used to generate the default rate are: impervious to pervious ratio (I:P) of 1 or lower, at least 1 inch of compost (at 50% organic matter) is added, at least 3 inches of incorporation into the native soil occurs, and all qualifying conditions are met. These conditions result in a water treatment value of 0.1 inches per impervious acre that is used with the RR curves in the Retrofit Expert Panel recommended protocols, further discussed in section 5.3. The default nutrient and sediment removal rates derived from this process are presented in Table 7 below. The default does not apply to soils classified as clay or sandy clay at any initial organic matter or to silty clay loam, clay loam, or silty clay when initial organic matter is 1% or less.

Table 7. Default Nutrient and Sediment Removal for Impervious Area Disconnection Coupled with Soil Amendments

TN	TP	TSS
12.3%	14.6%	15.6%

Default rates are from the RR curves in the Retrofit Expert Panel recommended protocols, using a value of 0.1 inches per impervious acre treated.

5.1.2 Simple Method for Impervious Area Disconnection Coupled with Soil Amendments

For planning purposes, or in areas where site specific soil samples are unavailable, the following simplified curves (Figure 6 to Figure 8) are suitable for use. These curves are conservative in that they assume minimal compost amendment addition of 1 inch and an incorporation depth of 3 inches into the existing soil. These curves also assume the initial soil has a compaction factor of 1:1 and the compost used has at least 50% organic matter (OM). See subsequent discussion and Appendix E for a description of the compaction factor and how the compost OM can influence the amendment process. For ease, each curve has been aggregated into three groups: loose, medium, and tight existing conditions. Due to the impact OM has on infiltration, three sets of curves were developed to represent differences in beginning OM. A list of soil types associated with each OM curve is provided in Table 8 and were grouped based on natural breaks in data. See Appendix E Part 5 for individual soil type information. The computational method, as outlined in Section 5.1.3 is recommended when initial soils have 1% or less organic matter and are clay loam or silty loam.

Table 8. Soil types grouped by a site's existing organic matter and loose, medium, and tight existing soil conditions.

	Initial Soil Condition		
Organic Matter	**Loose**	**Medium**	**Tight**
1% or less	Loam	Silt Silt loam Sandy clay loam	Silty clay loam
greater than 1%	Loam Silt Silt loam	Sandy clay loam Silty clay loam	Clay loam Silty clay

Step 1. Identify whether the initial soil conditions are loose, medium, or tight.
Identify soil type and % OM for the top 12 inches of your site based on Soil Survey Geographic (SSURGO) soils data. These data are available online via the Web Soil Survey (http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Local or other more refined data are also suitable, if available. Use Table 8 to determine whether the initial soil conditions are loose, medium, or tight. Pervious areas consisting of a sandy clay are, generally, not recommended for amendment or for receiving runoff from disconnected impervious because they are tight soils with limited infiltration capacity. If a site contains this soil type, use the computational method outlined in Section 5.1.3, below that incorporates measurements of soil bulk density and compaction to estimate the potential benefits of soil amendments and whether they are worthwhile to pursue.

Step 2. Determine runoff depth treated (inches) per impervious acre.
Based on the initial soil conditions and OM obtained from Table 8, use the appropriate curve from Figure 6 to Figure 8 to determine water treated (inches) per impervious acre. Water treated is a representation of runoff reduction associated with the soil amendment and disconnection. For a description of water treated, see Section 5.1.3, Step 4 and Step 5 as well as Section 5.3. If OM is greater than 3%, use the 3% curves (Figure 8). If OM is less than 1%, use the 1% curves (Figure 6). For OM values between 1% and 3% use the 2% curve (Figure 7). Note, at low I:P ratios, the full benefit of amending a loose existing soil may be limited due to minimal runoff (i.e. the site conditions cannot get appreciably better). Values are also shown in Table 9 for convenience.

The runoff depth treated per impervious acre, along with the drainage area, is reported to the states for crediting purposes. Refer to Appendix D for the technical reporting requirements. Computation of the annual TN, TP, and TSS load reductions is not required for reporting. However, load reduction estimates can be obtained by either: 1) entering the water treated per impervious acre directly into MAST, CAST, or VAST; or 2) following the procedures in Section 5.3.

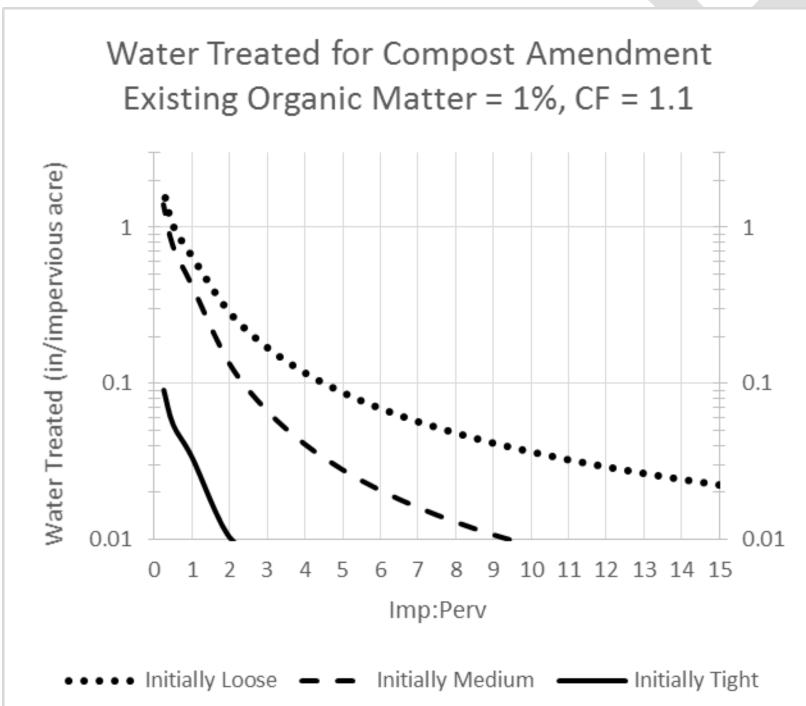

Figure 6. Simple water treatment curve representing an existing organic matter of 1%. Results represent the simple case where 1 inch of compost is added and incorporated 3 inches into the existing soil. Water treated is a representation of runoff reduction.

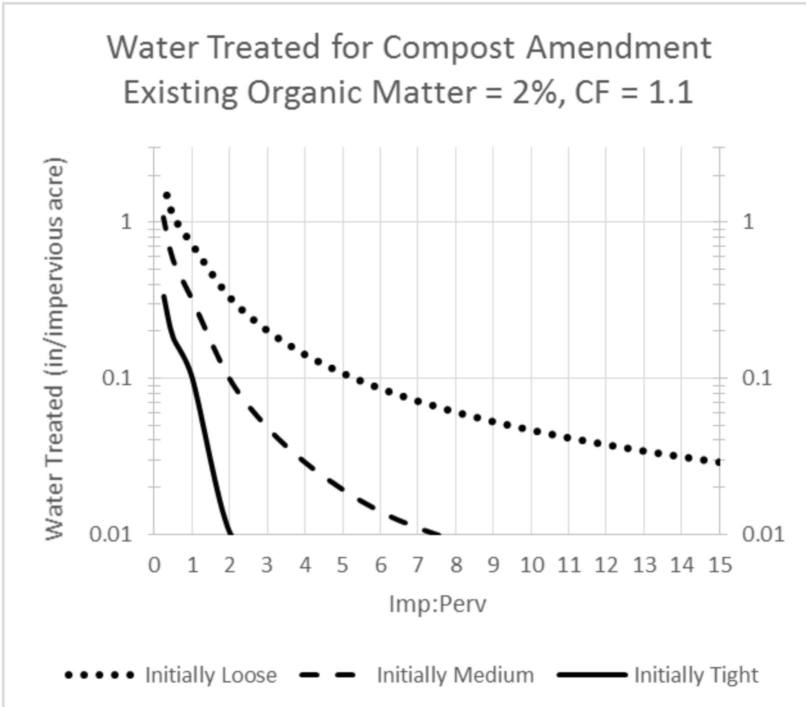

Figure 7. Simple water treatment curve representing an existing organic matter of 2%. Results represent the simple case where 1 inch of compost is added and incorporated 3 inches into the existing soil. Water treated is a representation of runoff reduction.

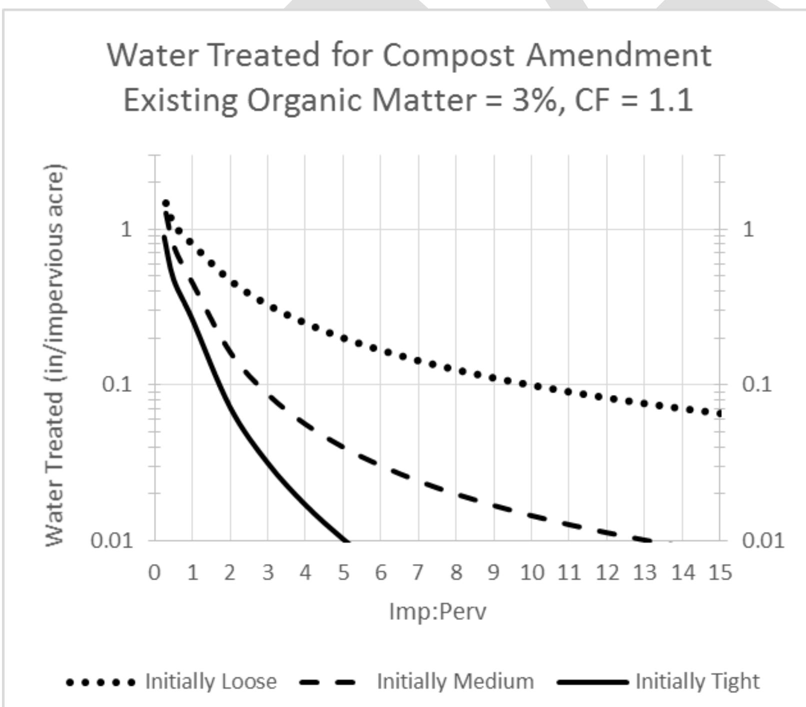

Figure 8. Simple water treatment curve representing an existing organic matter of 3%. Results represent the simple case where 1 inch of compost is added and incorporated 3 inches into the existing soil. Water treated is a representation of runoff reduction.

Table 9. Water treated (in) per impervious acre based on initial soil conditions and organic matter content. Water treated is a representation of runoff reduction.

	Initial Organic Matter = 1.0			Initial Organic Matter = 2.0			Initial Organic Matter = 3.0		
I:P*	Loose	Medium	Tight	Loose	Medium	Tight	Loose	Medium	Tight
15	0.022	0.005	0.002	0.029	0.004	0.002	0.066	0.008	0.002
14	0.024	0.005	0.002	0.032	0.004	0.002	0.071	0.009	0.002
13	0.026	0.006	0.002	0.034	0.005	0.002	0.077	0.010	0.002
12	0.029	0.007	0.003	0.038	0.005	0.003	0.083	0.011	0.003
11	0.032	0.008	0.003	0.042	0.006	0.003	0.091	0.013	0.003
10	0.036	0.009	0.003	0.047	0.007	0.003	0.100	0.014	0.003
9	0.042	0.011	0.003	0.053	0.008	0.003	0.111	0.017	0.003
8	0.048	0.013	0.004	0.061	0.009	0.004	0.126	0.020	0.004
7	0.057	0.016	0.004	0.072	0.011	0.004	0.144	0.024	0.005
6	0.069	0.021	0.005	0.087	0.014	0.005	0.168	0.030	0.007
5	0.088	0.028	0.006	0.108	0.019	0.006	0.201	0.040	0.010
4	0.117	0.041	0.007	0.142	0.029	0.007	0.249	0.056	0.017
3	0.171	0.067	0.008	0.203	0.049	0.008	0.326	0.087	0.032
2	0.287	0.134	0.010	0.331	0.100	0.010	0.466	0.161	0.072
1	0.659	0.428	0.034	0.723	0.323	0.102	0.793	0.447	0.262
0.5	1.039	0.765	0.054	1.106	0.580	0.182	1.067	0.775	0.477
0.25	1.737	1.409	0.091	1.805	1.070	0.335	1.542	1.395	0.890

**I:P = Impervious to pervious area ratio*

5.1.3 Computational Method for Impervious Area Disconnection Coupled with Soil Amendments

The Simple Method in Section 5.1.2 above is based on just one inch of compost and is inherently conservative. The more detailed protocols in this section allow for the calculation of water quality benefits associated with decompaction, sand additives, compost, or some combination. Use of these protocols is recommended to calculate a more accurate estimate of pollutant removal based on site-specific characteristics and soil amendments, and therefore obtain a higher level of credit than can be achieved with the Simple Method.

Step 1. Estimate Impact of Soil Amendments and Decompaction on Hydraulic Properties of Soils

Estimating the hydraulic properties of soils before and after the incorporation of soil amendments and decompaction may be the most challenging step in this protocol, as the literature is limited on broadly relating soil conditioning activities with specific and predictable changes in resulting soil hydraulic properties (i.e. bulk density, effective saturated hydraulic conductivity, water holding capacity, etc.). Estimated soil properties using predictive equations from Saxton and Rawls (2006) are the basis for the method described and utilized here. For details on this method, see the original publication, Appendix E Part 1 or see the SPAW Soil Water Characteristic Model (Saxton & Rawls,

2009) at http://hydrolab.arsusda.gov/soilwater/Index.htm. Implementing these predictive equations allows for an estimation of existing soil properties, while modifying the compaction factor and/or the organic matter percentage can model decompaction, tillage activities, and/or soil amendments.

Determine pre-amendment sand content (Sa), clay (C), organic matter (OM), and bulk density (ρ) by collecting soil samples on-site.

Collect soil samples from the surface down to a depth of 12 inches for laboratory analysis of sand, clay, and organic matter. A minimum of five soil samples are required for each site less than 0.75 acres and 10 samples per acre for larger sites. Samples should be collected in a random pattern within the proposed amendment area with the goal of providing the best representation of the site. All soil cores taken should be mixed together well for collection of a subsample for laboratory analysis. Amount of soil required from a subsample will vary depending on the laboratory analyzing for sand, clay, and organic matter. Note, this collection method assumes soil samples collected to a depth of 12 inches from the surface are representative of the underlying soil profile extending further below this depth. For I:P larger than 10, it is recommended soil sampling to 24 inches occurs, due to the potential presence of restrictive soil layers.

Bulk density samples should also be taken with a core of known volume and dried at 105 Celsius. A minimum of two samples are required for each site less than 0.75 acres and three samples per acre for larger sites. Again, samples should be collected in a random pattern with the goal of providing the best representation of the site. Cone penetrometer measurements to a depth of 12 inches from the surface should also be done to estimate pre-amendment soil compaction and establish a baseline for periodic future verification. A minimum of ten measurements are required for sites less than 0.75 acres and 20 measurements per acre for larger sites. Follow penetrometer manufacturers' recommendations for measurement procedures.

Use parameters collected above to estimate saturated hydraulic conductivity, K_{Sat}, of the existing soil using methods provided in Appendix E Part 1 or the SPAW model.

Depending on the OM, general soil textures of silt loam, silt, loam, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, or clay could be considered HSG C or D. Since amendments or decompaction activities are only suggested on HSG C or D equivalent soils, others are not considered here.

Decompaction or tillage activities could, effectively, bring the compaction factor down to 1.0 for those areas where excess compaction is present and subsequent recompaction is avoided. For example (see Table E- 1 for more bulk density and compaction factor combinations), if a clay loam was decompacted from a bulk density of 1.54 g/cm3 (CF = 1.1) to 1.40 g/cm3 (CF = 1.0), you would expect the K_{Sat} of the decompacted zone to change from 0.05 in/hr to 0.18 in/hr (Table E-2), an increase of ~3.5 times.

Soil volume changes associated with decompaction (change in bulk density) must, ultimately, be taken into account to preserve soil mass for subsequent calculations. This adjustment can be simply done by adding the change on top of the tillage depth. For example, if a soil with an initial compaction factor of 1.1 is tilled to 4 inches, the resulting compaction factor is 1.0 and the resulting soil would be 0.4 inches "deeper" (1.1-1.0=0.1; 0.1*4.0"=0.4"). See Appendix E Part 2 for more details.

Determine amendment details, including OM content of compost (or characteristics of some other sand based amendment), depth to be applied (i.e. 2 inches over the site), and depth to incorporate into existing soil.

The amendment supplier should be able to supply this information. If they cannot, request they have the material analyzed, as this information is required to estimate the effect of amendments on the existing soil, as described below. Additionally, the OM used should be the long-term average.

Estimate the effect of amendments on the existing soil.

Adding soil amendments (for example, one inch of compost), would add material to the soil column. As many of the common soil amendments are likely organic in nature, resulting change in soil characteristics will be an increase in the fraction of OM. These amendments would likely be incorporated or tilled into the soil. Again, tillage would serve to decrease the compaction factor. The OM added and a reduction in the CF both add volume to the soil column. If a bulk density of compost of 0.5 g cm^{-3} is assumed, the resulting soil column depth can be calculated. The addition of OM will increase the OM in the soil being amended. These changes to the pervious area soil characteristics can be used in the Saxton and Rawls predictive equations to estimate the "benefit" of soil amendments in terms of a change in K_{Sat}. See Appendix E Part 2 for suggested equations to make these adjustments. For example, adding 3 inches of compost with 50% OM (by volume) to a clay loam soil with 2.5% OM (by mass) and incorporating 6 inches into the native soil (tilling) would increase the OM content of the original soil to 5.7% (by mass).

For amendments with particle sizes in the sand range, amendments can be assumed to have a bulk density of 1.42 g/cm^3 (uncompacted sand). The material added effectively increases resulting sand content and decreases resulting clay content, which allows for a recalculation of the "new" soil hydraulic properties. This adjustment in no way accounts for any chemical changes in the soil that might alter soil structure. See Appendix E Part 2 for suggested equations to make these adjustments. Finally, in some cases, the addition of sand to a soil with heavy clay can cause hardening and negatively impact K_{Sat}. Consulting with a soil scientist before additions of sand is highly recommended.

Both organic and sand sized amendments may be added in conjunction.

Re-estimate the K_{Sat} using the same process as above. The purpose of this step is to quantify the changes in pervious area conditioning (amendment and decompaction) activities. Resulting K_{Sat} is, subsequently used in Step 2 for development of an effective K_{Sat}.

Step 2. Determine Effective Ksat

Another important piece of information before determining the CN value for a site is how far into the soil water will infiltrate. This is called the infiltration depth (L_f), and is used to calculate an effective K_{Sat}. The L_f value depends on the impervious to pervious ratio (I:P) or the area of impervious cover being disconnected to a given pervious area because the higher the amount of impervious cover, the more runoff that is generated and delivered to the pervious area. See Appendix E Part 4 for more information on the development of this parameter. Values for L_f range from 6 inches to 34 inches and are presented in Table 10. The general relationship when working with I:P ratios of 1 or larger is 2 times the I:P ratio plus 4 gives L_f. The L_f identified in Table 10 is used with Equation 5.1.3.1 below to determine $K_{SatEffective}$.

Table 10. Infiltration depth for determining $K_{SatEffective}$.

I:P	Infiltration Depth (L_f) (inches)
0.25	6
0.5	6
1	6
2	8
3	10
4	12
5	14
6	16
7	18
8	20
9	22
10	24
11	26
12	28
13	30
14	32
15	34

Effective Saturated Hydraulic Conductivity (resistance to flow) can be calculated after Oosterbaan and Nijland (1994) (as reported in Christianson et al., 2012) as:

$$K_{SatEffective} = \frac{L_f}{\frac{D_{Cond}}{K_{SatCond}} + \frac{L_f - D_{Cond}}{K_{SatNative}}} \qquad (5.1.3.1)$$

where L_f is the infiltration depth (Table 10), D_{Cond} is the depth of conditioned soil, and $K_{SatCond}$ and $K_{SatNative}$, are the saturated hydraulic conductivities of the conditioned and native soil, respectively. The K_{Sat} values come from the Saxton and Rawls equations mentioned above. If the difference between L_f and D_{Cond}. Is less than zero, use zero for the $L_f - D_{Cond}$ term in the above equation.

Step 3. Convert Saturated Hydraulic Conductivity to a Curve Number

Here, the NRCS Curve Number (CN) method is used for estimating runoff. Since benefits from decompaction and soil amendments are in terms of $K_{SatEffective}$, a conversion is required between $K_{SatEffective}$ and CN. A relationship proposed by Chong and Teng (1986) will be used to relate $K_{SatEffective}$ to CN with:

$$CN = \frac{1000}{4.345 * K_{SatEffective}^{1.208} + 10} \qquad (5.1.3.2)$$

Where $K_{SatEffective}$ is in inches per hour.

Though this method does not consider vegetation, Christianson et al. (2015) found this model was likely better in the disturbed soil of urban landscapes than relying on the SSURGO hydrologic soil group (HSG). Plotting equation 5.1.3.2 for various K_{Sat} values gives the suggested grey curve in Figure 9. Though this method takes the vegetation component out of the CN estimate, the results are reproducible given soil characteristics, which very well may be the limiting factor to urban infiltration.

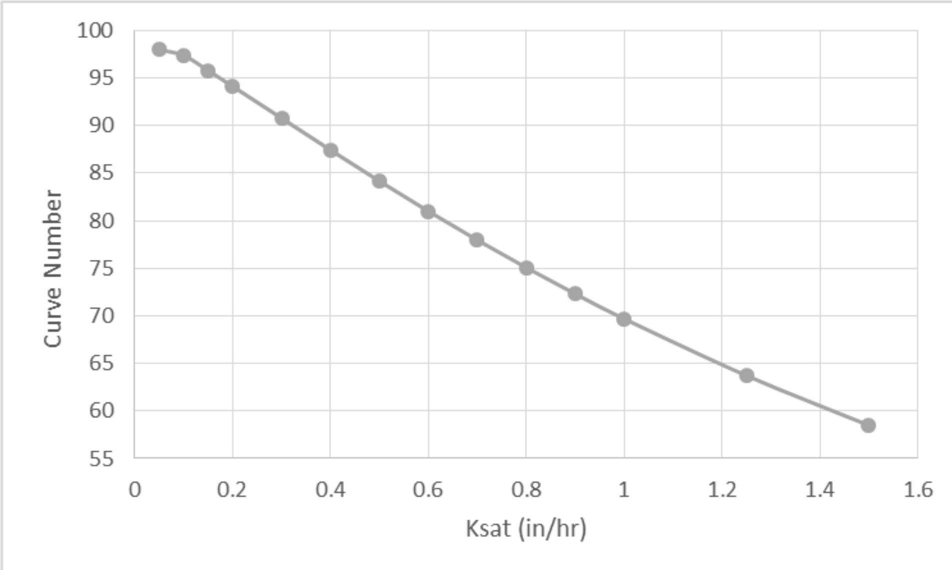

Figure 9. Curve Number as a function of effective saturated hydraulic conductivity. This relationship is from Chong and Teng (1986).

This conversion is done for pervious areas and has an upper CN bound of 98, which is equal to that of impervious cover. Since the above methods do not consider moisture, the resulting CN values are assumed to be "normal" antecedent moisture conditions (AMC) (also referred to as antecedent runoff conditions – ARC). An analysis of rainfall at Reagan National Airport shows ~80% of rain events occur when the AMC is dry. Since the majority of storms occur during the dry AMC category (defined by less than 0.5 inches or 1.4 inches of rain in the preceding 5 days during the dormant and growing seasons, respectively), using normal conditions makes runoff reduction estimates inherently conservative (i.e. less calculated runoff reduction than is likely to occur).

Step 4. Estimate Curve Number and Water Treated Due to Amended Pervious Area and Disconnected Impervious Area

In this step, a "weighted" Curve Number is computed for the amended pervious area and the impervious area that drains to it, which includes any additional impervious area through disconnection. When estimating runoff volume at a site where impervious disconnection is to be implemented, using the Natural Resource Conservation Service (NRCS) Curve Number (CN) method may be the easiest approach. This method was implemented here, though more complex models such as a rainfall-runoff model using the Green-Ampt infiltration approach are also appropriate for use.

A 1.0 inch rain event is used in this calculation to determine runoff before and after amendments (the difference is the water treated – see Step 5), as this has been shown to best represent relative long-term annual average runoff reductions. See Appendix E Part 3 for justification of this assumption and suggested calculation methods.

Step 5. Compute the Runoff Depth Treated per Impervious Acre

The water volume treated (as runoff reduction) (RR) is simply the difference between the runoff from existing/beginning site conditions and runoff from the site once soil amendments have been done, as described in Appendix E Part 3. The runoff depth treated per impervious acre, along with the drainage area, is reported to the states for crediting purposes. Refer to Appendix D for the technical reporting requirements. Computation of the annual TN, TP, and TSS load reductions is not required for reporting. However, load reduction estimates can be obtained by either: 1) entering the water treated per impervious acre directly into MAST, CAST, or VAST; or 2) following the procedures in Section 5.3.

5.2 Pollutant Removal for Treatment in the Conveyance System

These protocols evaluate the drainage network to determine if it can be effectively "retrofitted" via the creation of storage facilities within the existing drainage network or adjacent treatment area, with the option of diverting runoff from disconnected impervious cover into these facilities to achieve full or partial disconnection. Note this practice is described in the "Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects." Storage facilities can be online or offline and are typically associated with the runoff reduction and stormwater treatment retrofits described in the report (e.g., bioretention, constructed wetlands). The purpose of including them here is to provide additional details and examples beyond the information provided in the Retrofit Panel Report to show how they can be utilized as part of impervious disconnection.

5.2.1 Protocol for Online Facilities

This protocol provides credit for Stormwater Treatment (ST) or Runoff Reduction (RR) within the existing drainage network following the "Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects." RR practices include: conversion of a ditch into a dry swale, creation of linear bioretention treatment cells within the ditch, or extension of the existing flow path. ST practices include the installation of weirs or check dams to provide storage, or conversion of a ditch into a wet swale. Additional details about these practices and examples are included in Table 11 below. We use the Virginia Stormwater Management Handbook for the following examples. Users should consult local state manuals for appropriate specifications.

Several feet of head is needed for online facilities to filter runoff and collect it in an underdrain. Extremely low-gradient channels are poor candidates for retrofits unless they are designed as wet swales. On the other hand, steep gradient channels often preclude inline retrofits due to erosive forces. Ideal gradients range between 0.5 and 2.0%. In addition, less than three feet of elevation difference is preferred between the top of bank and the channel bottom.

Table 11. Options for online treatment within the existing drainage network.

Runoff Reduction Practices		
Conversion of a Ditch into a Dry Swale		
	**Description:** Dry swales are linear soil filter systems that temporarily store and filter stormwater. Typical dry swale design references a trapezoidal channel. Existing soils are replaced with a sand/soil mix that meets minimum permeability requirements. Stormwater treated by the soil bed typically flows into an underdrain, which conveys treated runoff back to the conveyance system further downstream.	**Feasibility and Design Applications[1]:** ▪ Size: 3-5% of the CDA[2] ▪ CDA: <5 acres ▪ Slope: <4% (<2% preferable) ▪ Hydraulic head: 3-4 ft ▪ Depth to water table: >2 ft (>1 ft in coastal plain) ▪ Soils: Infiltration rate <1/2 in/hr require an underdrain ▪ Ponding depth: <12 inches at most downstream point
Creation of Linear Bioretention Treatment Cells within a Ditch		
	**Description:** Surface runoff is directed into a linear series of bioretention treatment cells within a swale. The primary component is the filter bed, which has a mixture of sand, soil, and organic material as the filtering media. Normally, the filtered runoff is collected in an underdrain and returned to the storm drain system.	**Feasibility and Design Applications:** Size: 3-6% of the CDA CDA: <2.5 acres for each individual treatment cell ▪ Slope: 0.5-2% ▪ Hydraulic head: 4-5 ft ▪ Depth to water table: >2 ft (>1 ft in coastal plain) ▪ Soils: Infiltration rate <1/2 in/hr require an underdrain ▪ Ponding depth: 6-12 inches
Extending the Flow Path of an Existing Ditch		
	**Description:** The length of an existing ditch can be extended to provide additional area for runoff reduction through infiltration. Note that runoff reduction for this practice is highly dependent on the underlying soil permeability. Compared to the other practices for treatment in the conveyance system, credit is minimal because this practice lacks the storage volume and filtering capabilities associated with engineered soil media.	**Feasibility and Design Applications:** ▪ Size: based on peak rate of flow ▪ CDA: <5 acres ▪ Slope: <2% ▪ Bottom of the channel should not intercept the high water table ▪ Soils: works best with HSG A or B soils
Stormwater Treatment Practices		
Installation of Weirs or Check Dams to Provide Storage (Stormwater Treatment)		

	**Description:** Weirs or check dams can be added to existing ditches or swales to provide storage of runoff. Under low-flow conditions, water ponds behind the structures and then infiltrates, evaporates, or seeps through the structure. Under high-flow conditions, water flows over, and/or through the structure.	**Feasibility and Design Applications:** ▪ Size: 3-5% of the CDA ▪ CDA: <5 acres ▪ Slope: <4% (<2% preferable) ▪ Depth to water table: >2 ft (>1 ft in coastal plain) ▪ Ponding depth: <12 inches
Conversion of a Ditch into a Wet Swale/Wetland (Stormwater Treatment)		
	**Description:** Wet swales are linear wetland cells that intercept shallow groundwater to maintain a wetland plant community. Saturated soils support wetland vegetation, which provides an ideal environment for gravitational settling, biological uptake, and microbial activity.	**Feasibility and Design Applications:** ▪ Size: 5% of the CDA ▪ CDA: <5 acres ▪ Slope: <2% ▪ Depth to water table: wet swales can intersect the water table ▪ Soils: works best with HSG C or D soils ▪ Ponding depth: <6 inches

[1]Note that the individual state stormwater manuals should be consulted for the specifications that apply to each practice type.
[2]CDA = Contributing Drainage Area

The steps to calculate credit for online facilities include:

Step 1: Estimate the Runoff Volume (R_v) for the drainage area, which should include any additional disconnected impervious cover draining to the facility. This step is important to ensure that the additional runoff generated from impervious disconnection can be safely conveyed in the drainage network (Step 3) and that minimum residence time is achieved (Step 4).

Step 2: Estimate the Water Quality Volume (WQv) available within the online facility. Water quality storage can be created above the existing surface of the channel or below the existing channel in underlying engineered soil media. Storage below the channel is obtained through RR practices, such as dry swales or bioretention cells, none of which alter the hydraulic capacity of the channel. Storage above the channel is obtained using ST practices, such as weirs, berms or checkdams that do alter channel hydraulic capacity.

Step 3: Determine whether the proposed online facility can safely convey the required design storm for the conveyance system (e.g., 10 yr. storm) through hydrologic modeling based on the revised Rv from Step 1. Refer to the individual state stormwater manuals for design storm requirements.

Step 4: Use Manning equation to estimate flow velocity. Divide the length of the channel providing treatment by this velocity to ensure that minimum residence time is achieved for the water quality design storm within the channel treatment area based on the revised Rv from Step 1. Refer to the individual state stormwater manuals for residence time requirements. Evaluate the channel geometry to ensure that flow spreads evenly over the bottom of the channel.

Step 5: Compute the runoff depth treated per impervious acre. First, divide the WQv of the online facility by the impervious cover within the drainage area. The results should be in the units of runoff depth in inches captured per impervious acre. The runoff depth treated per impervious acre, along with the drainage area, is reported to the states for crediting purposes. Refer to Appendix D for the technical reporting requirements. Computation of the annual TN, TP, and TSS load reductions is not required for reporting. However, load reduction estimates can be obtained by either: 1) entering the water treated per impervious acre directly into MAST, CAST, or VAST; or 2) following the procedures in Section 5.3.

5.2.2 Protocol for Offline Facilities

Offline facilities split storm flows from the existing drainage network to an adjacent depression or excavated treatment area. Constructed wetlands (ST) and bioretention (RR) are preferred for offline applications since they minimize the need for major excavation and embankments. Offline designs are generally preferred when the contributing drainage area is large (>5 acres). They will require an effective flow splitter across the channel that can handle sediment deposition and clogging by trash and woody debris. In addition, at least three to four feet of head is needed for offline facilities to divert runoff from the conveyance system to the proposed treatment area and then bring it back to the conveyance system. As in the above example, we use the Virginia Stormwater Management Handbook for the following examples. Users should consult local state manuals for appropriate specifications.

Step 1: Estimate the Runoff Volume (R_v) for the drainage area, which should include any additional disconnected impervious cover draining to the facility. This step is important to ensure that the additional runoff generated from impervious disconnection can be safely conveyed (Step 3) and that minimum residence time is achieved (Step 4) in the existing drainage network.

Step 2: Estimate the WQv available within the offline facility.

Step 3: Determine whether the existing drainage network can safely convey the required design storm (e.g., 10 yr. storm) to and from the offline facility through hydrologic modeling based on the revised Rv from Step 1. Refer to the individual state stormwater manuals for design storm requirements.

Step 4: Use Manning equation to estimate flow velocity. Divide the length of the existing drainage network by this velocity to ensure that minimum residence time is achieved for the water quality design storm based on the revised Rv from Step 1. Refer to the individual state stormwater manuals for residence time requirements. Evaluate the channel geometry to ensure that flow spreads evenly over the bottom of the channel.

Step 5: Compute the runoff depth treated per impervious acre. First, divide the WQv of the offline facility by the impervious surface within the drainage area. The results should be in the units of runoff depth in inches captured per impervious acre. The runoff depth treated per impervious acre, along with the drainage area, is reported to the states for crediting purposes. Refer to Appendix D for the technical reporting requirements. Computation of the annual TN, TP, and TSS load reductions is not required for reporting. However, load reduction estimates can be obtained by either: 1) entering the water treated per impervious acre directly into MAST, CAST, or VAST; or 2) following the procedures in Section 5.3.

5.3 Retrofit Expert Panel Adjustor Curves for Calculating Load Reduction

The Retrofit Expert Panel developed a series of retrofit adjustor curves that return a percentage of TN, TP, and TSS reduced based on the volume (inches) of water treated per impervious acre in the drainage area. These curves can be presented graphically, but are represented mathematically in Table 12 below for reference so that loading reductions can be estimated for planning purposes without having to input the runoff depth per impervious cover into MAST, CAST or VAST to determine load reduction. Region specific land use loading rates (lbs/ac/yr) for TN, TP, and TSS can used along with these equations to determine the total pounds of reduction.

Table 12. Polynomial equations for the pollutant removal curves in the Stormwater Retrofit Expert Panel

TP	RR	$y = 0.0304x^5 - 0.2619x^4 + 0.9161x^3 - 1.6837x^2 + 1.7072x - 0.0091$
	ST	$y = 0.0239x^5 - 0.2058x^4 + 0.7198x^3 - 1.3229x^2 + 1.3414x - 0.0072$
TN	RR	$y = 0.0308x^5 - 0.2562x^4 + 0.8634x^3 - 1.5285x^2 + 1.501x - 0.013$
	ST	$y = 0.0152x^5 - 0.131x^4 + 0.4581x^3 - 0.8418x^2 + 0.8536x - 0.0046$
TSS	RR	$y = 0.0326x^5 - 0.2806x^4 + 0.9816x^3 - 1.8039x^2 + 1.8292x - 0.0098$
	ST	$y = 0.0304x^5 - 0.2619x^4 + 0.9161x^3 - 1.6837x^2 + 1.7072x - 0.0091$

5.4 Design Examples

5.4.1 Disconnecting Impervious to Amended Pervious Example (Simple Method)

This example is intended to illustrate how to use the simple curves for determining the nutrient and sediment benefits for disconnecting impervious areas to amended soils.

A public building is being considered for a stormwater management effort. Impervious surface disconnection to an amended pervious area is one of the BMPs being considered and the simple curves will be used since no soil samples are being collected. The impervious to pervious ratio (I:P) for the site is 3:1, which consists of 0.75 acre of roof draining to 0.25 acres of pervious. Based on the SSURGO soil data, the site has a silty clay loam soil at 2% organic matter. With 2% organic matter, a silty clay loam is considered a "Medium" soil for purposes of the simple method and would use Table 9. The resulting water treated is roughly 0.05 inches per impervious acre, which translates to 6% TN reduction, 4% TP reduction, and 7% TSS reduction using the retrofit curves in Section 5.3. The resulting TN reduction is plotted on the TN retrofit curve in Figure 10, for reference.

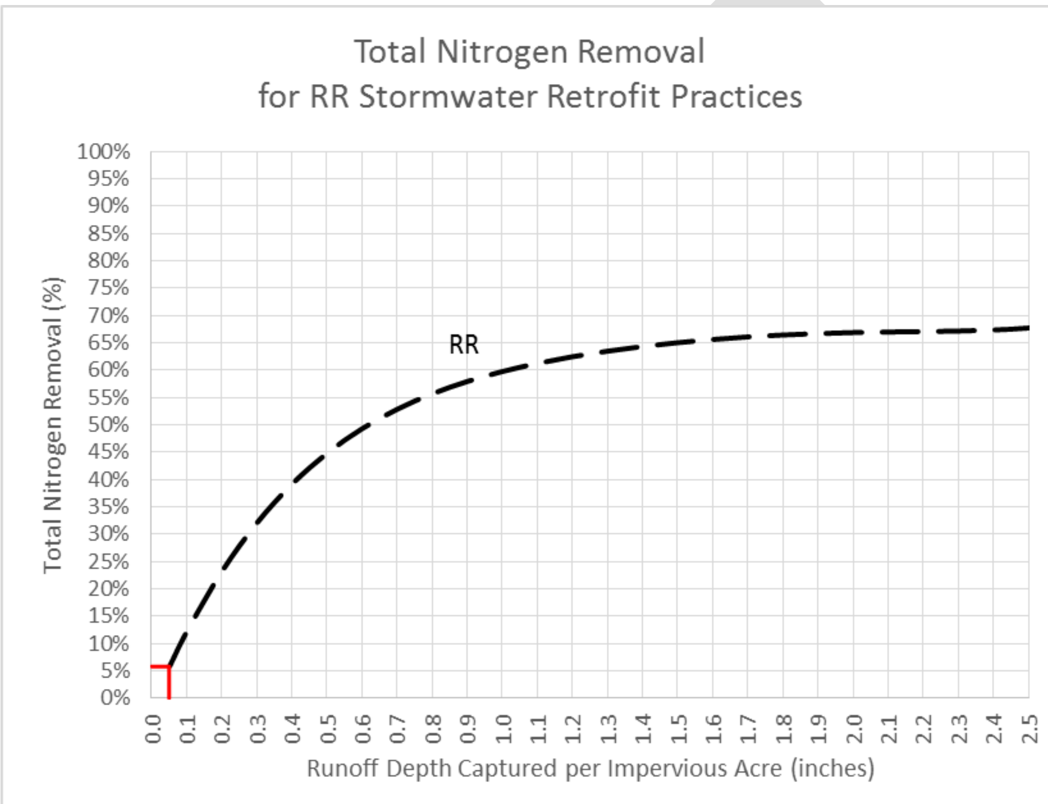

Figure 10. Resulting TN reduction from the soil amendment and disconnection example using simple method.

5.4.2 Disconnecting Impervious to Amended Pervious Example (Computational Method)

This example is intended to illustrate how to walk through a site evaluation and determine the runoff reduction and nutrient benefit expected due to soil amendment activities.

You're interested in getting nutrient reduction credit at a school that has a total of 1 acre of managed turf grass not actively used for sporting activities. As the majority of the building rooftop is not conducive to disconnection, only 0.25 acres are available to disconnect giving an impervious to pervious ratio (I:P) of 0.25.

Soil test results show the soil is a clay loam soil type with a sand content of 33% (by mass), a clay content of 34% (by mass), and an organic matter content of 2.5% (by mass). The bulk density is 1.40 g/cm^3, which corresponds to a compaction factor of 1.0 (i.e. the soil is not overly compacted).

Entering this information into the equations highlighted in Appendix E Part 1 (or using SPAW) to determine the soil hydraulic properties, one estimates a saturated hydraulic conductivity of ~0.180 inches per hour. Using this K_{Sat} value in equation 5.1.3.2, the resulting CN is 94.8, which is quite high.

Compost addition will consist of 2 inches over the 1 acre site due to donated material limitations. Compost will be incorporated into native soil to a depth of 5 inches. Knowing the compost characteristics (50% organic material) and the incorporation depth, you use the methods in Appendix E Part 2 to estimate a new organic matter content. At this point, amended soil characteristics can be determined using Appendix E Part 1 (or SPAW) with increased organic matter. The resulting K_{Sat} value is 0.48 in/hr, more than twice the original.

Using Step 2 in section 5.1.3, you determine the infiltration depth is 6 inches and the resulting $K_{SatEffective}$ is 0.48 in/hr. This $K_{SatEffective}$ is subsequently used in equation 5.1.3.2 to estimate a new CN for the pervious area (84.9).

The next step is to determine site runoff from the existing and the amended site conditions. The methods in Appendix E Part 3 (equations 22 to 25) are used here to determine both runoff and an effective site CN value. The difference between existing and amended runoff volume is the water treated, though this result must be divided by the impervious area for use with the retrofit curves in section 5.3.

So, the resulting 0.38 inches of runoff reduction over the entire 1.25 acres is 0.48 ac-inches, which is divided by 0.25 acres of disconnected roof to give 1.92 inches of treatment per impervious acre. This value is then used in the retrofit curves to get relative TN, TP, and TSS reductions (see Figure 11 for the resulting TN curve). TN reduction for this example is around 67%.

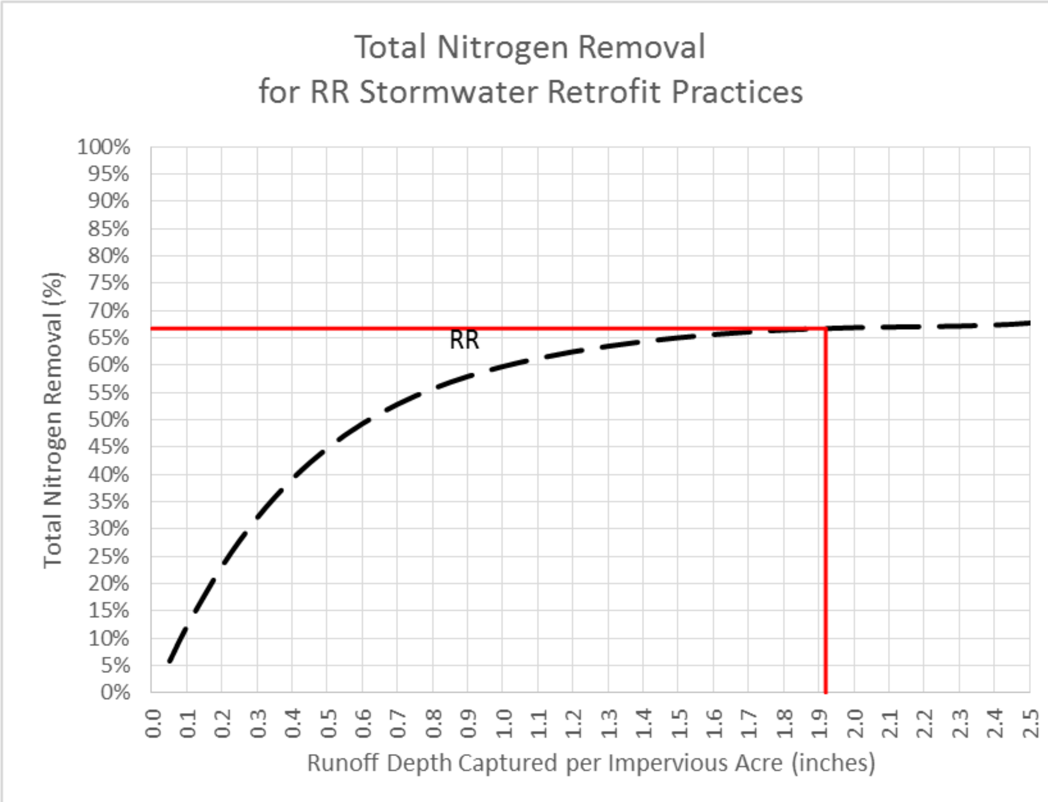

Figure 11. Resulting TN reduction from the soil amendment and disconnection example using the computational method.

5.4.3 Treatment in the Conveyance System Design Examples

The following examples have been created to show the proper application of the protocols for treatment in the conveyance system to determine the nutrient and sediment reductions. We use the Virginia Stormwater Management Handbook for the following examples. Users should consult local state manuals for appropriate specifications.

All of the examples are for an elementary school site in Ditchville, VA, with two existing grass channels. The first 200 ft grass channel currently drains runoff from sidewalks and pervious areas adjacent to the school building and has a slope of 1.0%. Rooftop drains will be disconnected from the storm drain and diverted to this channel, resulting in a total drainage area of 3 acres, 50% of which is impervious (Design Example 2). The second grass channel is 150 ft and has a slope of 0.5%. Rooftop drains will not be diverted to this channel, as it is located further away from the school building and drains recreational fields and a portion of an adjacent neighborhood. The total drainage area for the second grass channel is 5 acres, 5% of which is impervious (Design Example 1). Both grass channels currently drain to inlets connected to the storm drain system underneath the ballfields.

Design Example 1: Installation of Check Dams to Provide Storage

The existing 150 ft grass channel that drains the ballfields and adjacent neighborhood is proposed to be retrofit with 5 check dams spaced 30 ft apart.

Step 1. Estimate the Runoff Volume (R_v)

Rooftop drains are not being diverted to this grass channel because it is not located near the school building. Instead, the retrofit will provide additional treatment for runoff from the existing drainage area of 5 acres, 5% of which is impervious. The Rv for the water quality design storm is found to be 1,724 ft^3.

Step 2. Estimate water quality volume

The volume of water stored behind each of the check dams is added together and found to be 450 ft^3. Note that even though the WQv for the facility is less than the Rv, credit is still received as part of this protocol, as calculated in Step 5 using the pollutant removal curves from the Stormwater Retrofit Expert Panel.

Step 3. Determine whether the proposed online facility can safely convey the required design storm

Virginia regulations require that on-line facilities be designed with enough capacity to (1) convey runoff from the 2-year at a non-erosive velocity, and (2) contain the 10-year flow within the banks of the swale. A hydrologic routing model was used to confirm that the channel could safely convey the 10 year storm.

Step 4. Ensure that minimum residence time is achieved for the water quality design storm within the channel treatment area

Manning's equation was used to ensure that the minimum residence time specified in the Virginia Stormwater Management Handbook was achieved.

Step 5. Compute the runoff depth treated per impervious acre

The drainage area for this grass channel is 5 acres and 5% impervious, which means there are 0.25 acres of impervious cover. The 450 ft^3 WQv divided by 0.25 acres of impervious cover in the drainage area results in 0.5 inches captured per impervious acre.

Since this is a stormwater treatment practice, use the ST curves from the Retrofit Expert Panel to determine the percentages of TN, TP, and TSS reduction. Figure 12 below shows that for 0.5 inches captured per impervious acre, the removal rate for TN is 26%. Similarly, the TP and TSS curves result in removal rates of 41% TP and 52% TSS.

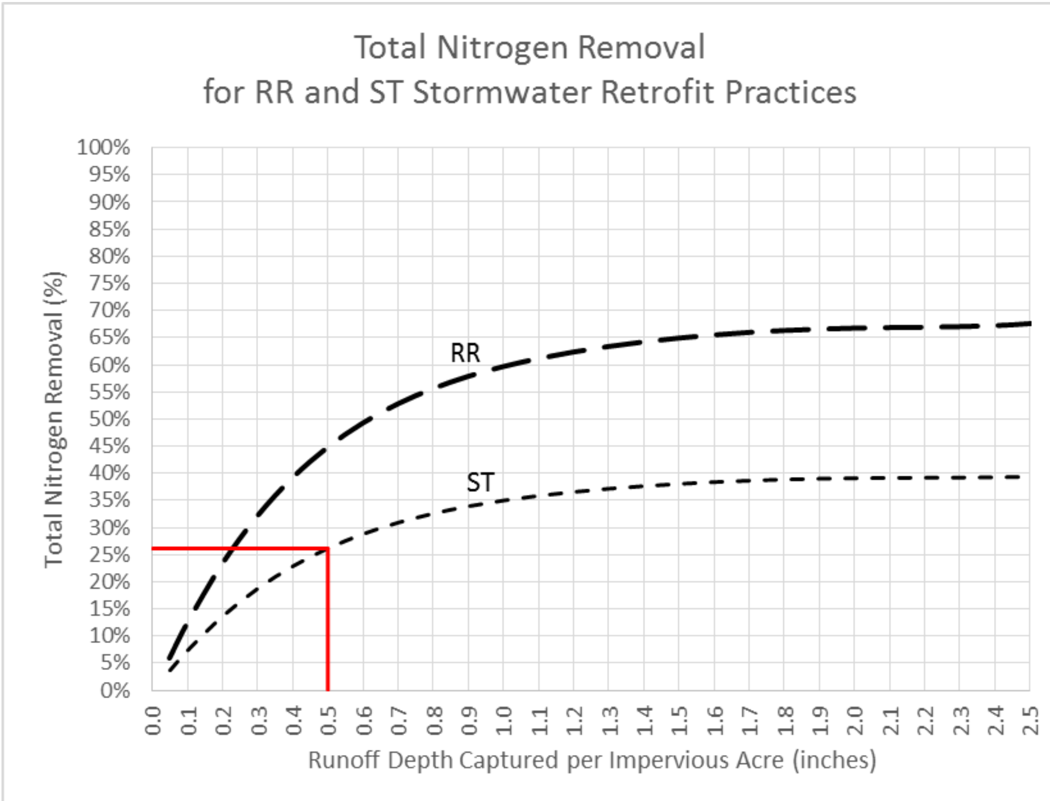

Figure 12. Total nitrogen removal curve from the Stormwater Retrofit Expert Panel. The red line indicates that for 0.5 inches captured per impervious acre, the TN removal is approximately 26% for ST practices.

The efficiencies from the Retrofit Expert Panel pollutant reduction curves are then multiplied by the locally derived loading rates from MAST, CAST, or VAST to obtain the pollutant reduction credits.

<u>Design Example 2: Extending the Flow Path</u>

The existing storm drain is proposed to be replaced with a 400 ft grass channel that will connect the existing 200 ft and 150 ft grass channels.

Step 1. Estimate the Runoff Volume (R_v)

Impervious cover from the school rooftop will be disconnected from the storm drain and diverted to this channel. The revised drainage area based on this impervious disconnection is 3 acres, 50% of which is impervious. The Rv for the water quality design storm is found to be 5,445 ft^3.

Step 2. Estimate water quality volume

Numerous models are available to calculate the infiltration rate. For this example, we use the multi-layer Green Ampt model to calculate infiltration along the proposed 400 ft grass channel, assuming the underlying soil has greater than 15 inches of silt loam, with clay loam beneath. For a 1.0 inch rainfall, the model found that the grass channel is able to infiltrate 442 ft^3. Note that even though the WQv for the facility is less than the Rv, credit is still received as part of this protocol, as calculated in Step 5 using the pollutant removal curves from the Stormwater Retrofit Expert Panel.

Step 3. Determine whether the proposed online facility can safely convey the required design storm
Virginia regulations require that on-line facilities be designed with enough capacity to (1) convey runoff from the 2-year at a non-erosive velocity, and (2) contain the 10-year flow within the banks of the swale. A hydrologic routing model was used to confirm that the channel could safely convey the 10 year storm.

Step 4. Ensure that minimum residence time is achieved for the water quality design storm within the channel treatment area
Manning's equation was used to ensure that the minimum residence time specified in the Virginia Stormwater Management Handbook was achieved.

Step 5. Compute the runoff depth treated per impervious acre
The drainage area for this grass channel is 4.8 acres and 31% impervious, which means there are 1.5 acres of impervious cover. The 442 ft^3 WQv divided by 1.5 acres of impervious cover in the drainage area results in 0.08 inches captured per impervious acre.

Since this is a runoff reduction practice, use the RR curves from the Retrofit Expert Panel to determine the percentages of TN, TP, and TSS reduction. Figure 13 below shows that for 0.08 inches captured per impervious acre, the removal rate for TN is 10%. Similarly, the TP and TSS curves result in removal rates of 12% TP and 13% TSS.

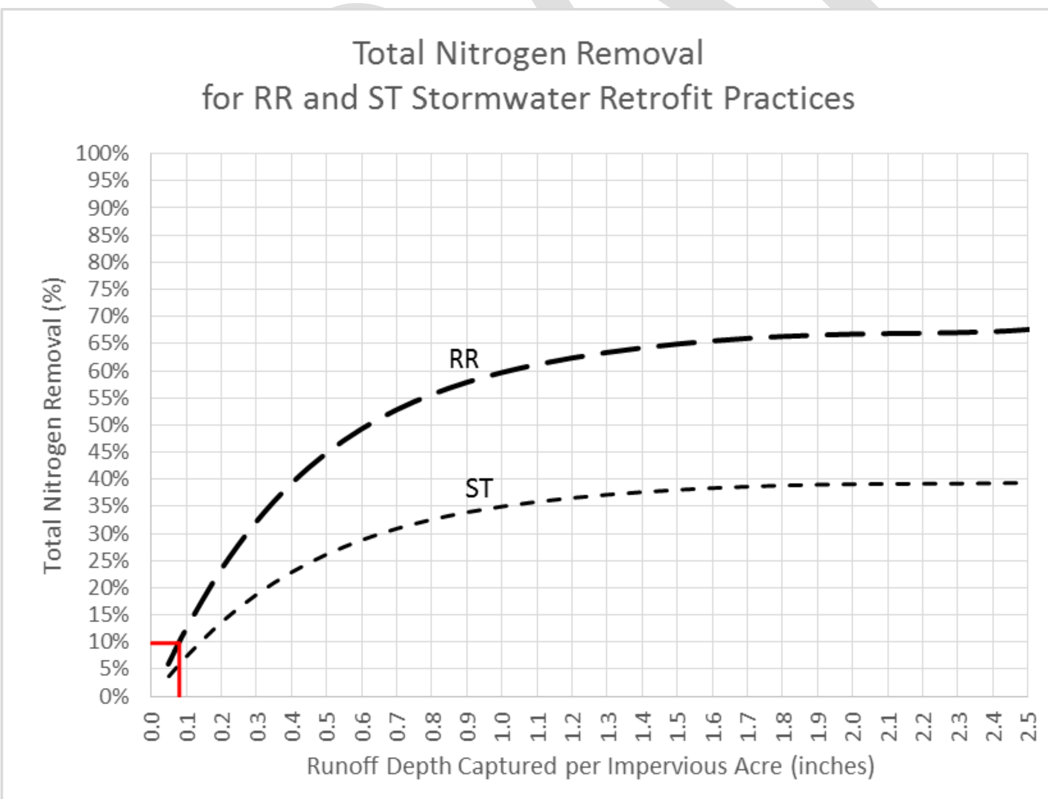

Figure 13. Total nitrogen removal curve from the Stormwater Retrofit Expert Panel. The red line indicates that for 0.08 inches captured per impervious acre, the TN removal is approximately 12% for RR practices.

The efficiencies from the Retrofit Expert Panel pollutant reduction curves are then multiplied by the locally derived loading rates from MAST, CAST, or VAST to obtain the pollutant reduction credits.

<u>Design Example 3: Offline Facility</u>
Space is available adjacent to the ballfields to install an offline 50 ft x 25 ft bioretention facility. Runoff conveyed by the 200 ft grass channel that drains the sidewalks and pervious areas by the school, as well as the proposed rooftop to be disconnected from the stormdrain will be redirected to the bioretention facility via a flow splitter.

Step 1. Estimate the Runoff Volume (R_v)
Similar to Design Example 2, impervious cover from the school rooftop will be disconnected from the storm drain and diverted to the existing channel. The revised drainage area based on this impervious disconnection is 3 acres, 50% of which is impervious. The Rv for the water quality design storm is found to be 5,445 ft^3.

Step 2. Estimate water quality volume
The water quality volume of the bioretention facility is estimated to be 1,500 ft^3. Note that even though the WQv for the facility is less than the Rv, credit is still received as part of this protocol, as calculated in Step 5 using the pollutant removal curves from the Stormwater Retrofit Expert Panel.

Step 3. Determine whether the existing drainage network can safely convey the required design storm to and from the offline facility
Virginia regulations require that grass channels be designed with enough capacity to (1) convey runoff from the 2-year flow at a non-erosive velocity, and (2) contain the 10-year flow within the banks of the swale. A hydrologic routing model was used to confirm that the channel could safely convey the 10 year storm.

Step 4. Ensure that minimum residence time is achieved for the water quality design storm within the existing drainage network
Manning's equation was used to ensure that the minimum residence time specified in the Virginia Stormwater Management Handbook was achieved within the existing drainage network leading to and from the offline facility.

Step 5. Compute the runoff depth treated per impervious acre
The drainage area for the bioretention is 3 acres and 50% impervious, which means there are 1.5 acres of impervious cover. The 1,500 ft^3 WQv divided by 1.5 acres of impervious cover in the drainage area results in 0.28 inches captured per impervious acre.

Since this is a runoff reduction practice, use the RR curves from the Retrofit Expert Panel to determine the removal efficiencies of 30% TN, 35% TP, and 38% TSS. These efficiencies are then multiplied by the locally derived loading rates from MAST, CAST, or VAST to obtain the pollutant reduction credits.

Section 6. Accountability Mechanisms

The verification of individual BMPs is a critical element to ensure that BMPs continue to reduce pollutants as designed following implementation and for the expected life of that BMP. The guidance for verification is based on SPSEP (2012) and SRP (2012) for new development, redevelopment and retrofits, USWG (2014) with additional information specific to design elements that may affect impervious area disconnection performance.

6.1 Basic Reporting, Tracking, and Verification Requirements

Basic Reporting Unit. Reporting entities will track the following information for practices that fully meet the expert panel impervious area disconnection and treatment in the conveyance system BMP definitions:

1. Impervious Area Treated (acres)
2. Total Area Treated (acres)
3. RR or ST type of practice. Note that impervious area disconnection to amended soils is only a RR practice. Treatment in the conveyance system can be either a RR or ST practice (Refer to Section 5.2 for additional information).
4. Runoff Depth (inches treated) or Volume treated (Acre-Feet)

Credit Duration.

- <u>Impervious Area Disconnection to Amended Soils:</u> The maximum duration for the impervious area disconnection to amended soils removal rate will be 5 years. The removal rate can be extended if a field inspection verifies the BMP(s) are still performing using testing described in Section 5.1.3. Areas that are heavily used will require soil testing using penetrometers or measurements of bulk density every 2 years.

- <u>Treatment in the Conveyance System</u>: The maximum duration for the removal rate will be 10 years, although it can be renewed based on a field performance inspection that verifies the retrofit still exists, is adequately maintained and operating as designed. The duration of the removal rate will be 5 years for retrofits installed on private property, and can only be renewed based on visual inspection that the on-site retrofit still exists.

State BMP Reporting Systems. Each state has a unique system to report BMPs. In some cases states have incorporated these reporting requirements into their MS4 Permit annual reporting, while the reporting process for non-MS4 jurisdictions and other entities are still being developed. To get credit for load reductions in the context of CBWM progress runs, states will need to report BMP implementation data using CBP-approved rates or methods, reporting units and geographic location (consistent with the National Environmental Information Exchange Network, NEIEN standards), and periodically update data based on the local field verification of BMPs.

Reporting to the State. The reporting entities will need to submit documentation to the state on the basic reporting units provided above. To be eligible for the removal rates in the model, localities or other data providers need to check with their state stormwater agency on the specific BMP data to report, and follow the BMP reporting and tracking procedures established by their state. The Panel recommends that the following information be reported for impervious area disconnection and treatment in the conveyance system (in addition to the basic reporting units listed above):

- Date of Implementation: Year the practice was installed
- Geographic Unit: Qualifying NEIEN geographies including: Latitude/Longitude; or County; or Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); or State

Initial Verification of BMP Installation. Localities or other data providers, will need to verify that urban BMPs are installed properly, meet or exceed the design standards for its BMP classification, and are functioning hydrologically as designed prior to submitting the BMP for load reduction credit in the state tracking database. This initial verification is provided either by the BMP designer or the local inspector as a condition of project acceptance as part of the normal local stormwater BMP plan review process. From a reporting standpoint, the data provider would simply indicate in its annual report whether or not it has BMP review and inspection procedures in place and adequate staff to implement them.

BMP Record-Keeping. Localities, or other data providers, should maintain a project file for each retrofit project. This may include a low impact development (LID) locator map showing all LID and site design practices employed, construction drawings, as-built survey (for larger practices), digital photos, inspection records, and maintenance agreement. The file should be maintained for the lifetime for which the BMP removal rate will be claimed. Localities are encouraged to develop a GIS-based BMP tracking system in order to schedule routine inspections and maintenance activities over time.

Non-Conforming Projects.

- <u>Impervious Area Disconnection to Amended Soils</u>: Past projects and projects that do not conform to these reporting requirements can receive credit using the Default Rate as described in Section 5.1.1 as long as minimum amendments and incorporation depth have been met. The new protocols (simple and computational methods described in Sections 5.1.2 and 5.1.3) can be applied to projects that have been installed less than 5 years ago to receive credit.

- <u>Treatment in the Conveyance System</u>: There is no treatment in the conveyance system default rate for non-conforming projects. The pollutant reduction rate is determined by calculating the runoff treatment volume per impervious acre, whether the BMPs achieve RR or ST, and entering the appropriate removal rate from the retrofit expert panel adjustor curves.

Periodic BMP Inspections. Routine maintenance inspections should be conducted to verify that the system of practices still exists, is adequately maintained and is operating as designed.

- Inspections for Impervious Disconnection to Amended Soil: ensure: 1) the absence of any erosional channels, 2) the vegetative cover is in condition according to the qualifying conditions for this BMP and 3) the site has not been compacted – obvious wear/trail patterns, significant variations in vegetation health, apparent dips holding water, etc. A record of a soil test to determine the amount of nitrogen and phosphorus applied from fertilizer application is recommended and should be noted on the inspection form, or as a separate follow-up action according to State or District guidance. To verify that the site has not become recompacted, refer to Section 5.1.3 for soil testing procedures. Depending on the results of the soil testing, additional amendments may be necessary to maintain the current credit.

- Inspections for Treatment in the Conveyance System: ensure: 1) the continued safe conveyance of the design storm, 2) the practice is still capable of removing nutrients/sediment, and 3) the practice is performing to its original design. It is recommended that these rapid investigations be conducted as part of every other routine stormwater BMP inspection (e.g. 6 to 10 years), or as mandated in their MS4 permit, to assure that individual LID and site design practices are still capable of removing nutrients/sediments.

Suggested Process for BMP Downgrades.

- Impervious Area Disconnection to Amended Soils: If the field inspection indicates that the amended soil is not performing to its original design, the responsible party can opt to re-run the computations using revised soil test data to determine an adjusted credit.
- Treatment in the Conveyance System: If the field inspection indicates that a BMP system is not performing to its original design, the responsible party would have up to one year to take corrective maintenance or rehabilitation actions to bring it back into compliance. If the facility is not fixed after one year, this would be reported to the state BMP tracking entity and the pollutant reduction rate for the BMP would be eliminated. If corrective maintenance actions were verified for the BMP system at a later date, the reporting entity could take credit for the load reduction at that time.

Special Procedures for BMPs Installed in Non-Regulated Areas. Development is expected to occur in non-regulated communities, which tend to be very small in size and fairly new to stormwater BMP review. It is acknowledged that these non-regulated communities may not currently have the budget and/or regulatory authority to fully meet the new BMP verification protocol. The Urban Stormwater Work Group has recommended alternative verification procedures (USWG, 2014) for these communities. Data providers are encouraged to check with their state stormwater agency on the specific BMP data to report, and follow the BMP reporting and tracking procedures established by their state.

6.2 Un-Intended Consequences and Double-Counting

The Expert Panel does not foresee any unintended consequences of the implementation of the recommendations for impervious area disconnection and treatment in the conveyance system. The specific qualifying conditions provide the States and DC clear guidance for their application and pollutant removal.

Given the sequential implementation of BMPs in the CBWM, the Expert Panel does not foresee any double counting related to impervious area disconnection or treatment in the conveyance system. Impervious area disconnection and treatment in the conveyance system may be used as part of a treatment train approach to urban stormwater management and as such is discounted accordingly in the CBWM. Given the qualifying conditions for fertilizer management for impervious area disconnection, pollutant load reductions for Urban Nutrient Management (UNM) may not be applied to the area of an impervious area disconnection, however, any pervious areas draining to the disconnection may be eligible for UNM.

Section 7. Future Research and Management Needs

1. The Urban Stormwater Work Group should review and update the New State Stormwater Performance Standards and Stormwater Retrofit Expert Panel reports to reference the nutrient and sediment crediting recommendations of this Impervious Disconnection Expert Panel report.
2. Monitoring studies to evaluate the fate of nitrogen and phosphorus treated by impervious area disconnection, especially when soils are amended with compost.
3. Fate of soil amendments over the long-term – how long do the improvements that they provide to soil hydraulics last? For example, are compost amendments only needed once, or must they be repeated as the compost decomposes? What kind of lawn maintenance practices are needed to maintain the benefits of amended lawns, including increased K_{sat} and decreased bulk density?
4. Several questions were brought up during the Expert Panel process. One was how to credit the restoration of existing ditches that include soil amendments. Another was how to credit restoration of just the pervious area (without impervious disconnection). While the protocols developed as part of this Panel can estimate runoff reduction for the pervious area restoration, it was outside the Panel's charge to develop a methodology to calculate nutrient and sediment load reductions. An agricultural ditch expert panel is currently in the process of being formed. However, the formation of a joint sector (urban/agriculture) expert panel is also recommended to review such topics as the addition of soil amendments to existing ditches and nutrient and sediment load reductions from pervious area restoration alone.
5. The use of water treatment residuals as a surface application to retain soluble P.

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Appendix A: Expert Panel Meeting Minutes

SUMMARY OF ACTIONS AND DECISIONS
Impervious Cover Disconnection Expert Panel
Friday, August 21, 2015, 10:00AM-12:00PM
Conference Call

Name	Affiliation	Present? Y/N
Bill Stack (Chair)	Center for Watershed Protection	Y
Joe Battiata	Center for Watershed Protection	Y
Greg Evanylo	Virginia Tech	Y
Jason Papacosma	Arlington County (VA) DES	Y
Steve Stewart	Baltimore County (MD) DEPS	Y
Ryan Winston	North Carolina State University	N
David Sample	Virginia Tech	Y
Franco Montalto	Drexel University	Y
Justin Shafer	City of Norfolk (VA)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Brian Benham	Virginia Tech	N
Greg Sandi	MD Dept. of Environment	Y
Jeff Sweeney	EPA, CBPO	Y
Liz Ottinger	EPA Region 3	Y
Reid Christianson	Center for Watershed Protection	Y

Welcome and introductions

- Jeremy verified participants and welcomed everyone to the panel's first call. Everyone introduced themselves to the group.

Review of BMP Protocol, statement of work and panel timeline; panel roles and responsibilities

- Jeremy gave a brief overview of the Chesapeake Bay Program (CBP) and the Water Quality Goal Implementation Team (WQGIT). He noted the BMP Protocol was revised in July 2015, so everyone on the panel should read through that version, which was provided via email and is on the Scholar site. He explained the Protocol now includes a Conflict of Interest form that the panelists will need to complete and sign. Jeremy will upload a Word version of the form to Scholar for the panelists to complete.
    - **ACTION:** Panelists to submit signed COI forms to Jeremy.
- Bill discussed the panel's charge and scope of work
    - There was discussion about the specific practice or practices the panel will be evaluating, since various "disconnection" or similar practices have been defined by other BMP panels and the CBP, including new state performance standards, homeowner BMPs such as rain gardens, urban filter strips, urban filtering

practices, etc. The panel will need to keep in mind that they want to identify and define new and distinct practices for recommendation to the CBP. When drafting the charge and scope of work Bill and Jeremy did not want to restrict the practices to only sub-soil tillage or soil treatment practices, so the general "impervious cover disconnection" name was kept, but the panel has leeway to refine and adjust the details as it gathers information moving forward. This may be a point of confusion for the panel and others, but Jeff, Bill, are Jeremy are familiar with existing CBP BMPs and will help guide the panel on this.

  - **ACTION**: Jeremy/Jeff/Bill will put together a list of related existing BMPs and their CBP definitions.
  - Greg E. noted there are quite a few other practices that could be looked and that would be distinct from existing CBP practices.
  - Jeremy noted the panel will be given more background and detail about the watershed model and other modeling tools at its September meeting.
  - Greg E. mentioned a relevant symposium that may be a beneficial resource for the panel. He provided the link to the group: https://scisoc.confex.com/scisoc/2015am/webprogram/Session14672.html

- Bill reviewed the panel's timeline. Following September meeting the panel will hold conference calls, likely monthly, to discuss issues and literature to develop its recommendations. Plan to hold a second face to face to review the draft report in detail early next year, potentially having a report ready for partnership review as early as February 2016.

Discussion of 9/15 public stakeholder forum

- Jeremy reviewed the agenda for the afternoon public stakeholder session agenda. He encouraged the panelists to suggest researchers or colleagues that could present relevant information at the public session, or future panel calls. The panel members are also welcome to present if they are interested. Given the timeline, he asked for recommendations by the end of next week (COB Friday 8/28).
  - **ACTION**: By COB 8/28, panelists should send Bill and Jeremy any suggested researchers or colleagues that could present relevant data or research at the 9/15 public session.

Demo of VT Scholar site

- Jeremy demonstrated the panel's Scholar site that the panel can use to access or share files for panel purposes.

Wrap-up and review of next steps

- Bill and Jeremy reviewed the actions and next steps. They thanked the panel again for their time and discussion.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Impervious Cover Disconnection Expert Panel
Tuesday, September 15, 2015, 9:00AM-12:00PM
Conference Call

Name	Affiliation	Present? Y/N
Bill Stack (Chair)	Center for Watershed Protection	Y
Greg Evanylo	Virginia Tech	Y
Jason Papacosma	Arlington County (VA) DES	N
Steve Stewart	Baltimore County (MD) DEPS	Y
Ryan Winston	North Carolina State University	Y
David Sample	Virginia Tech	Y
Franco Montalto	Drexel University	Y
Justin Shafer	City of Norfolk (VA) (via teleconference)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Brian Benham	Virginia Tech	N
Greg Sandi	MD Dept. of Environment	Y
Jeff Sweeney	EPA, CBPO	Y
Liz Ottinger	EPA Region 3 (via teleconference)	Y
Reid Christianson	Center for Watershed Protection	Y

Welcome and introductions

- Jeremy and Bill welcomed everyone in the room and on the phone and reviewed the day's agenda.

Introduction to CBP modeling tools

- Jeremy gave an overview of the modeling tools and how BMPs are simulated in the model. BMPs are typically applied at a county level in Scenario Builder, which generates a comprehensive scenario that includes all the land uses, BMPs and other inputs applied in the watershed. The Watershed Model then simulates the delivery of N, P and S loads to the tributaries and waterways. He asked panel members to avoid getting lost in the weeds about any of the specific processes in the Watershed Model.
- Jeff noted the primary purpose of the modeling tools is for local and state governments to help develop an implementation plan. There was discussion that other models used in a research context, and in the literature can be used to inform the panel's recommendations.

Open discussion of literature review

- Reid reviewed the major research questions.
    - What are the primary methodologies?

- What does research tell us about observed runoff reduction?
- How do site, design or other characteristics affect performance?
- There was discussion about potential overlap with other existing CBP-approved BMPs. Some similar practices like rooftop disconnection are already covered when that rooftop disconnection redirects the runoff to another practice such as a rain garden or bioretention area. This panel will explicitly carve out disconnection practices that are not currently covered in existing CBP BMPs.
- Reid reviewed various soil conditioning and soil amendment studies.

- Bill reviewed some literature review guidelines
  - Was the data generated consistent with what is found in the CB Watershed?
  - How does the duration of the experiment compare to the intended timeline of the BMP? If the experiment is substantially shorter, how might that influence its operational effectiveness?
  - Do results reflect changes in pollution reduction benefits over the lifetime of the practice?
  - Whether factors that could affect pollution reduction benefits are adequately addressed (location w.r.t. pollution sources and pollution content of sources treated)?
  - What parameters were sampled and monitored (paired watershed, grab samples, ground water, etc.)?
  - What, if any, assumptions were made during the experiment and conclusion?
- It was noted that the preference is for studies conducted in the CB watershed, but studies from outside the watershed that are elsewhere in the US or international can still be useful in some cases, but the panel should be careful on what information or lessons they adapt from the non-CB watershed studies.
- Bill noted that panels also provide future research recommendations for future BMP panels or future research needs.

Discussion of BMP definition and crediting approach

- Bill summarized that the panel was gradually narrowing its focus and explained how the panel can continue to make progress towards its eventual recommendations report. He reviewed and discussed components of the report that the panel will need to consider to develop that report.

<u>Activities/practices to include</u>

1. Soil amendments
   a. Compost
   b. Water treatment residuals
   c. Different residuals or products
   d. Other(s)
2. Decompaction
3. Vegetation management
   a. Franco noted he has a grad student doing research on the subject of vegetation and its effect on surface-sealing, etc.
   b. Use literature to distinguish between types of vegetation
   c. Use of forest as a specific vegetation; Disconnection to forested areas (tentative)

4. Disconnection to forest and possibly wetlands
5. Soil conservation
    a. Redirecting impervious to a pervious area may degrade the soil resource
    b. Cover becomes important (i.e. 90% coverage)
    c. This would factor into
6. Define design components (maybe borrow from new development design specification)
    a. Could/would these components be tied to the retrofits curves?
7. Enhance filter strips? This could include water treatment residuals
8. Urban agriculture/gardening?
    a. May fall into another (existing) BMP
    b. Is literature available to estimate these benefits?
9. Apply this to general pervious (i.e. no need for disconnection – get benefits simply for making pervious "better")
10. Brownfield reclamation with the above activities?

<u>Activities/practices to exclude</u>

1) Filter strips (which excludes soil amendments)
2) Disconnection to another CBP-approved practice (rain garden, bioretention, etc.)

<u>Qualifying conditions</u>

1) There must be some treatment of the soil
    a. Some measure of this
    b. Define "treatment"
2) Make sure "treatment" is going to make things better (i.e. does the site "need" some help?)
3) Must be poor soils to begin with
4) Look at the qualifying conditions for filter strip
    a. L:W ratio
    b. Imp to pervious ratio
    c. Level spreader
    d. 90% vegetative (turf) cover

Do we want to consider differentiation of source areas? At the end we will suggest which land uses these protocols/practices will be applied to.

Wrap-up and review of next steps

- ACTION: The CWP will share its first draft of the lit review. Panel members will provide feedback, including specific studies that should be added, in preparation for the next call (date/time TBD).
- ACTION: A Doodle poll will be distributed to schedule the next call.
- ACTION: Jeremy, Bill and Jeff to develop the list of existing CBP-approved BMPs that are closely related to the panel's work
- Future discussion topic: The panel will revisit and continue to build on the list of practice categories developed during the morning's discussion.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Open Session: Impervious Cover Disconnection Expert Panel Stakeholder Forum
Tuesday, September 15, 2015, 1:00PM-4:00PM
http://www.chesapeakebay.net/calendar/event/22967/

Welcome and Introduction

- Jeremy Hanson (Virginia Tech, Chesapeake Bay Program; Panel Coordinator) welcomed participants and reviewed the agenda. He and Bill Stack (Center for Watershed Protection; Panel Chair) summarized the Chesapeake Bay Program's BMP review process that the Urban Tree Canopy (UTC) expert panel will be following. View the slides, the BMP Protocol, and the panel's statement of work for more information.

Panel Introductions

- Each panel member present briefly introduced themselves.

Presentations

Reid Christianson, Center for Watershed Protection

- Reid reviewed various types of practices related to impervious disconnection found in the literature and that may be considered by the panel.
- View his slides for more details. No questions were raised following his presentation.

Ryan Winston, North Carolina State University

- Ryan described some research conducted by NCSU on downspout disconnection in Durham, NC. He mentioned that the research has been used to inform a new chapter for Disconnected Impervious Surfaces to North Carolina's stormwater BMP manual. Phase I of the project looked at design elements such as slope and ratio of contributed area to treatment/infiltration area: max 7% slope (except A soils where 15% is allowed), dense lawn, all sites built within the past 50 years shall be tilled to 8 inches. Phase II looked at soil amendments applied to the same plot areas from Phase I: tilled soil 6-8 inches, applied compost and lime, and seeded to establish grass. Durham is roughly in the center of North Carolina's Piedmont region, so there are similarities to the Chesapeake Bay; Durham is all considered soil group D and some of the infiltration rates observed did seem unusually high. All of the sites were homes that were in older neighborhoods with well-established top soils.
- View his presentation for more details.
- In response to questions that were asked, Ryan explained that topsoil removal during construction is a more recent occurrence. Older neighborhoods typically left topsoil in place. Downspout disconnection benefit will be recognized more in newer neighborhoods. He was also asked for ideas as to why infiltration rates were higher on some of the D soils in the study. He speculated that it's because topsoil can transmit a lot of water laterally in some instances.

Greg Evanylo, Virginia Tech

- Greg reviewed some studies looking at compost products (e.g. compost blankets) that can be applied in a disconnection context. He described soil effects and benefits of compost applications observed in a number of studies.
- At least one rainfall simulation study found that compost applications reduced total phosphorus export compared to the control or other applications (poultry litter and fertilizer).
- View his slides for more information.
- Julie Winters asked if the source of the compost matters.
    - Greg explained it does matter in terms of N- and P-availability. Do not want to overapply soluble N or P into the top soil. Yard waste is probably the most benign source of compost in most contexts. Animal manure composts would depend on specific properties of the compost, so can't make a judgment without more information about the specific compost. Studies discussed including yard waste and paper mill sludge.
- Jeremy noted there is an agriculture BMP panel evaluating manure treatment technologies including composting.
    - Greg mentioned that composting does not reduce the overall available P, but can reduce the available N due to microbial processing.

David Sample, Virginia Tech

- David discussed some modeling approaches and studies that looked into the effects of disconnection practices, including a study in Virginia Beach using the SWMM model.
- View his presentation for more information.
- Franco mentioned a study modeling yards in Manhattan at the fine disaggregation level – one block. However, fine disaggregation did not necessarily provide better results – more variables to specify. It could also be a function of lag and the aggregated effect of all the smaller pieces. Would need to have monitoring data to calibrate the lag.

Additional Discussion

- Bill asked Ryan about some of the unusually high infiltration rates observed in the Durham study.
    - There may be an unknown issue with some of the highest values, but even some of the 1-in/hr rates were also quite high for D soils. Even disconnecting the runoff to a half inch of top soil can yield an annual runoff reduction over 50%.
- Julienne: we have an impervious disconnection standard in DC. Is there a way to have a standard/spec for the use of compost blankets to treat road runoff as its own BMP?
    - Greg Evanylo: There are a number states that already have such standards and specs in their manuals. Many state Departments of Transportation have standards for compost applications, but the cost is sometimes higher than the Departments may prefer to spend.
    - David: There can be other factors such as lead in the soil that could constrain soil treatment or disconnection options.
- Reid: Based on the discussion there appears to be a number of modeling tools and established methods that the panel could use to inform its recommendations. He asked the panel members to discuss what specific factors or elements would be most critical for determining the reduction or water quality benefits.

- Greg Evanylo: If you are able to crack through that top level surface seal that is a great start. Disconnection practices can't change the overall hydrologic connectivity of the site, but they can allow for greater infiltration and other benefits.
- Franco noted that cold season performance and warm season performance could affect the soil amendment or disconnection practices that can be applied in New York versus Virginia, e.g. frozen soils. That will be something the panel will have to consider. Traver has some studies that look at the effect of temperature in a similar context for bioretention.

Wrap up and next steps

- There was discussion about the panel's intended next steps. The CWP will share its preliminary literature review with the panel for their feedback and to identify studies or sources that can be added. From there the panel can begin to develop a strawman of various recommendations and move to develop consensus over the coming months. Could have a rough idea of the various recommendations by the end of the year.
- Hanson asked each Panel member to share their biggest take-away messages or lessons learned from the day.
    - Greg E: the big disconnect is between available models and the on-site data. There's a lot of individual data of what occurs on a specific site. Need a better understanding of how information and individual models might be able to inform our discussions.
    - David: expect that we will need to take what we learn from the more specific or local models and translate it to the 64,000 square mile watershed scale.
    - Franco: after today we are seeing that there are a lot of options and practices that could fall within the scope of the panel.
    - Ryan: might want to look at the urban filter strip panel's approach because there are similarities in the concept of the practices, so it could be a useful reference.
    - Steve: if we have sufficient empirical data then we don't have to rely on models. If we look at models think they have to be calibrated to monitoring data to be useful for our purposes. To use the modeling studies to validate our empirical information, the models need that calibrated point of reference.
        - Ryan noted there are few, if any, published studies on downspout disconnection. There may not be enough published empirical data for the panel to rely on unless we include the filter strips literature and modeling studies.
        - Franco commented that monitoring practices like this is extremely expensive from a research perspective, which is what makes it so difficult to get the kind of empirical data we want.
        - Steve: using wet ponds as an example, there is a large amount of studies with phosphorus reductions that can range from a 90% reduction to a 10% net contribution. Have to consider the mean or median of that range as our best
        - Ryan: think we have to control for certain factors, e.g. a minimum distance for the disconnected runoff or other minimum factors that could

help constrain the range or give us a better idea of what the benefits will be.

- Sandi: from a reporting perspective, expect that what gets reported, or what the reduction is, will be based on the existing reduction curves or efficiency rates the panel develops. The information the state receives from the locals has to be translated into the parameters or elements that get reported through NEIEN.
- Stack: there might be data or studies out there that will tell us what factors may be most important for determining what the reduction is, not just the volume treated that the current runoff reduction curves are based on. The panel is off to a great start and is pretty far along for its second.

- Stack and Hanson thanked everyone for their time and participation.

Adjourned

Participants

Name	Affiliation
Panel members and support in attendance or on the phone	
Bill Stack (Chair)	Center for Watershed Protection
Reid Christianson	Center for Watershed Protection
Greg Evanylo	Virginia Tech
Steve Stewart	Baltimore County (MD) DEPS
Ryan Winston	North Carolina State University
David Sample	Virginia Tech
Franco Montalto	Drexel University
Justin Shafer	City of Norfolk (VA)
Jeremy Hanson (Coord.)	Virginia Tech, CBPO
Greg Sandi	MD Dept. of Environment
Jeff Sweeney	EPA, CBPO
Liz Ottinger	EPA Region 3
Lisa Fraley-McNeal	CWP
Other participants in attendance or on the phone	
Julienne Bawtista	DDOE
Julie Winters	EPA CBPO
Norm Goulet	NVRC
Lisa Fraley-McNeal	CWP
Sarah Lane	UMCES, MD DNR
Lindsay Thompson	
Robin Pellicano	MDE
Kelsey Brooks	VA DEQ
Dinorah Delmasy	MDE
Karen McJunkin	Citizens Advisory Committee
Beau Croll	
Lindsay Thompson	
Jeanna Henry	EPA Region 3
Jenny Tribo	HRPDC
Sarah Bradbury	DDOE
Edward Heide	
Gina Snyder	EPA Region 1

SUMMARY OF ACTIONS AND DECISIONS
Impervious Cover Disconnection Expert Panel
Friday, October 30, 2015, 10:00AM-12:00PM
Conference Call

Name	Affiliation	Present? Y/N
Bill Stack (Chair)	Center for Watershed Protection	Y
Reid Christianson	Center for Watershed Protection	Y
Greg Evanylo	Virginia Tech	Y
Jason Papacosma	Arlington County (VA) DES	Y
Steve Stewart	Baltimore County (MD) DEPS	N
Ryan Winston	North Carolina State University	Y
David Sample	Virginia Tech	Y
Franco Montalto	Drexel University	Y
Justin Shafer	City of Norfolk (VA)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Brian Benham	Virginia Tech	N
Greg Sandi	MD Dept. of Environment	Y
Jeff Sweeney	EPA, CBPO	Y
Liz Ottinger	EPA Region 3	Y
Lisa Fraley-McNeal	CWP	Y

Welcome and introductions

- Bill welcomed participants and reviewed the day's agenda.
- Jeremy mentioned the September meeting minutes would soon be posted to Scholar. Will confirm their approval after that.

Review of existing CBP-approved BMPs related to Impervious Cover Disconnection

- Jeremy reviewed the list of Chesapeake Bay Program-approved BMPs that are conceptually related to impervious disconnection. He pointed out that the recent retrofits definition was not included, but Reid would describe those definitions later in his presentation.
- Franco asked about impervious surface removal as a BMP. Jeremy noted the "impervious surface reduction" BMP definition would include removal of impervious surfaces and is simulated as a land use change in the modeling tools. Jeff noted that the ISR BMP is also used by jurisdictions for future projection scenarios to simulate effects of smart growth, for example.

Literature review report out

- Greg E. First study (Shiralipour et al. 1992) looked at effects of MSW compost as a soil amendment. Changes in retention capacity and bulk density. Anywhere from 8 to 330 mega grams per hectare were applied,15-40% range change in capacity. Decreases in bulk density ranged from 4% incorporated ¼" and up to 30% when incorporated 1" depth. Second study (Curtis et al. 2009) looked at compost blankets and incorporated compost. Runoff and nutrient losses were measured from natural rainfall events. No statistical differences in terms of runoff, but some sediment, nitrogen and phosphorus benefits from some treatments. Incorporated composts do not lose as much N and P as surface applied compost. Third paper (Avnimelech et al. 1993) reviewed some lab and field studies to find conditions when certain treatments could potentially improve soil properties. Only relevance is if incorporation of compost in applied in soil that is kept aerobic. Fourth paper (Spargo et al) found applications of yard waste compost tended to do better than control and fertilizer control. Concentrations from compost amended soils were higher but mass loss of nutrients were lower because of runoff amount.

  - Reid: all those points seem to strengthen everything that was found in the lit review.
    - Bill asked if any of the studies would suggest any qualifying conditions to help protect against runoff. Greg E agreed they would suggest certain conditions or factors
  - Only first study used MSW compost. 4th study, Spargo was yard waste compost, would need to check what material Curtis study used. MSW compost will tend to be lower N and P than manure compost but fairly similar in composition to YW compost. The physical effects to runoff and capacity should be similar regardless of compost source, but the nutrients may vary.

- Franco discussed three articles. Two about soil sealing and third one about improving soil quality of yards. Not necessarily new information but likely reinforces aspects of the lit review so far.
  - Maulen et al reviewed studies of soil sealing dating as far back as the 50s. Highlights of findings included an increased presence of salt can reduce infiltration and increase bulk density. Might want to think of that in context of disconnecting surfaces that may be treated with salt. Polymers can potentially increase soil's adhesive properties. If not properly treated, sealing could potentially work against the disconnection practices the panel is considering. The authors published a second paper that seemed less relevant to the panel's purposes but will revisit it to be sure.
  - Franco noted he was a co-author for the third paper. There were a suite of studies looking at the ecosystem services of various practices/species applicable to backyards in an urban context such as NYC. Explored potential effects of increasing infiltration of the backyard soils. By altering the soils from 98 to 66 RCN would effectively offset the expected runoff increase from climate change. Done with SWIMM modeling behind it.
  - Greg E. noted that some products like gypsum are better than salt treatments to help counteract the sealing effects. Bill pointed out that an increasing number of salt related TMDLs are being developed, so it will be important to acknowledge that and point to other alternatives.

    - Franco…we've been doing some studies to better understand the role of vegetation in protecting against sealing. Dissipation caused by leaves helps reduce the sealing and soil treatment plays a role too.
- Bill noted he would be following up with panel members for additional lit reviews as needed.

Discussion of draft strawman protocols

- Bill noted that the panel was charged with looking at disconnection as well as practices that modify the hydrologic conductivity or pathway.
- Reid discussed two different methods.
    - First method: Soil characteristics (Saxton and Rawls 2006). Uses soil information in predictive equations to estimate runoff with Curve Number method. Augmentation activities (decompaction, compost or other amendment addition) would change soil characteristics that are plugged into predictive equations(?). Compare initial runoff estimate to augmented runoff estimate. Initial minus Augmented = Runoff reduction.
        - Greg E commented that many composts do not have 80% organic matter. Expecting 50% is more realistic. Also have to expect mineralization of the organic matter over time.
        - Reid discussed potential weak points with the approach. The compaction factor is relative, would require soil testing, etc.
    - Reid reviewed the second approach
        - Greg E. pointed out the larger deeper horizon will remain unchanged. Treatments and amendments will only be applied to the very top layer. Reid fully agreed and mentioned the method is adjusted to account for that fact.
        - Weak points include it is compost only, need to do subsequent calculation to determine runoff reduction amount, and no measure of compaction.
    - Reid compared the two methods. Method 2: Amended area/impervious area = 1. On D soil, compost depth needed to match predevelopment would be 2.08in. Runoff reduction of 25%.
        - Franco commented that applying compost does not necessarily change the HSG. Might help raise the curve number from poor to good or fair.
        - Method 1 would be an average annual runoff reduction of 16% using similar starting points.
        - Franco: Compost amendment could have major impact on sealing effects and the surface properties, but what happens below the surface remains mostly unchanged.
            - Greg E. agreed with Franco, but noted that for smaller storms there is a noticeable difference by treating the top layer. He commented that he was personally unclear about exact assumptions and information goes into changes in the Curve Number.
        - Ryan: Potentially serious issues with using a composite curve number. A composite curve number could really dampen the effect of impercious surface on runoff. Could potentially keep the curve numbers for treated and impervious areas discrete so the impervious area CN is unchanged

after treatment. Also curious how we as a team look at compaction pre-treatment.
    - Ryan noted the initial abstraction equation has been subject of some recent questions in the literature (0.2 may not be the best, recent research shows 0.5). So if we use the curve number approach we may want to discuss want number to use for that.
    - Franco: would want to consider the treatment of the receiving area differently than the rest of the area. Want to keep it simple. Not sure if we would want to consider an upper bound for this.
- Bill noted the time. Bill and Reid will follow up with some panelists individually on how to make adjustments to methods before next meeting. At our next call we'll reserve a larger block of time to discuss the methods. We'll be back in touch to plan another time prior to or following Thanksgiving.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Impervious Cover Disconnection Expert Panel
Thursday, December 3, 2015, 1:00PM-4:00PM
Conference Call

Name	Affiliation	Present? Y/N
Bill Stack (Chair)	Center for Watershed Protection	Y
Reid Christianson	Center for Watershed Protection	Y
Greg Evanylo	Virginia Tech	Y
Jason Papacosma	Arlington County (VA) DES	Y
Ryan Winston	North Carolina State University	N
David Sample	Virginia Tech	Y
Franco Montalto	Drexel University	N
Justin Shafer	City of Norfolk (VA)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Brian Benham	Virginia Tech	N
Greg Sandi	MD Dept. of Environment	Y
Jeff Sweeney	EPA, CBPO	N
Liz Ottinger	EPA Region 3	Y
Lisa Fraley-McNeal	CWP	Y

Welcome and introductions

- Bill welcomed participants and reviewed the day's agenda.
- Jeremy noted that the October minutes had not yet been distributed so he committed to providing those along with the December minutes.

- Bill explained that Steve Stewart had to withdraw from the panel going forward. Bill recalled where the group had left off with its discussion in October.

Review of strawman on runoff reduction related to altering the soil hydraulic properties

- Reid recapped the panel's previous discussion about the strawman approach. Saturated hydraulic conductivity, can change surface layer characteristics but cannot change the Hydrologic Soil Group. Potential to use the NRCS Runoff Curve Number approach. Qualifying conditions.
- Bill and Reid explained the Curve Number approach. The NRCS has defined standard lookup tables based on the HSG and runoff. The lower the CN value, the lower the surface runoff. You can change the curve number (CN) by modifying the top layer…trying to determine how soil amendments can modify the CN, but there are some gaps the panel will need to discuss when trying to make that link between the amendment and the runoff volume reduction.
- David mentioned that Green-Ampt are quantities that you can physically measure. Curve Number approach lumps variability into one parameter. Bill and Reid will follow-up with panel members to discuss if the RCN or another standard model such as Green-Ampt would be better to use.
- Reid discussed the potential link between CN and runoff reduction, in one example a change from CN of 98 to a CN of 60 would give a runoff reduction of ~60%.
- There was discussion about how the runoff reduction estimates might be connected the TN, TP and TSS reduction curves developed by the retrofits panel. David raised some questions and asked to follow-up with Bill offline. Bill noted that the curves have been vetted through other panels and the CBP workgroups, so that is one advantage to using them if the panel determines they are applicable for soil amendments.
    - Greg E. asked if the retrofit curves take into account additional factors beyond concentration and volume. Bill explained they do account for other factors such as groundwater loss, bioretention media processes, etc. The retrofit curves are a simplified assumption of the processes in different stormwater practices. The retrofits panel decided it would be too difficult to take into account all the processes involved in the different types of practices. The curves err on the side of being conservative.
- There was discussion of compost applications. Greg E. suggested that for the panel's runoff reduction purposes the panel could provide certain specs for compost characteristics. There can be differences in terms of compost for healthy vegetation vs compost for runoff reduction. There is a limit in the nutrient concentrations of compost and the amount applied for what can be used by vegetation. Specifications never call for a specific amount of TN or TP – instead focus on amount of organic matter, electrical conductivity, etc. TN and TP specifications would only be important if you are going to specify the rate. Specifications would not change by physiographic province. They are for good quality compost and would be applicable across the entire Chesapeake Bay region.
    - Bill asked if the specs would include the incorporation depth for the compost.
    - Greg E. indicated that for plant growth, typically the recommendation is for the tillage zone (up to 6" with some roto-tillers). Recommendations are typically 20-30% by volume. Tilling any deeper has no real effect for plant growth, but tilling deeper might improve hydraulic connectivity or porosity. Deeper tillage up to 1 m

depth is possible, but most people won't have the equipment needed to do that. There could be some guidelines in the panel recommendations for incorporating to deeper depths.

- **ACTION**: Bill to set up meeting with David and other panel members during the week of Dec 14th to discuss what is the better model to use – RCN or other standard model that can be used with the curves developed from Reagan airport. Also need to further discuss whether those curves are appropriate.

Discussion of protocols for estimating nutrient reductions associated with changes in flow path and retention in drainage network

- Bill recapped that much of the focus had been on "protocol 1" for soil amendments, but the panel has also been asked to consider the effects of disconnecting impervious cover by changing the flow path and retention in drainage network. He noted they had some recent discussions with Tom Schueler (Chesapeake Stormwater Network; USWG Coordinator) about how these types of practices might be addressed in two additional protocols by the panel.
- Lisa discussed some hypothetical examples for these types of practices and how the retrofit curves could be applied.
    - Jason felt it did seem like the approach would be simple enough to use and calculate reductions. He suggested it might be useful to try and give the method a reality check by comparing to results from bioretention.
    - Bill asked Justin if this approach would address his previous suggestion about ditches. Justin noted that the idea was to have a protocol like this for check dams, amendments, or other practices that could be implemented in existing ditches that already capture a lot of runoff in some areas. Bill asked Justin to follow up and provide some initial thoughts about what types of qualifying conditions might apply.
        - Jason suggested the group may want to consider soil types for the examples presented by Lisa, since these types of practices are not as engineered. That may affect the performance. Perhaps using the ST curve would be conservative enough. Don't want to be too conservative though. Bill agreed the panel should continue to consider this issue. He noted the retrofits report references the states' manuals. Might be able to see how they factor in soil based on how they consider the BMPs.
        - Bill: For the soil amendment protocol may use slightly more complex methods that use soil characteristics, tillage depth, etc., to get to estimates of runoff. Not locked into using the curves at this time. Once we determine how to link the soil amendments and changes into a runoff reduction, then we should definitely have a thorough discussion about the appropriateness of the retrofit panel's adjustor curves.
        - Justin suggested the panel may want to use VA's grass swale standards/specs as a reference into differences by HSG. Jason mentioned Virginia's standards/specs for soil amendments, which Bill and Reid confirmed they already looked at. After looking closely at how those specs were developed, it would be very difficult to make the same jumps that

    were made in the CBP context. This panel has more time and expertise and has opportunity to develop a more robust protocol.
    - Jeremy asked if there is a default rate for the adjustor curves, noting the panel will be asked to provide a default rate if possible, for planning purposes or for practices reported without all the requested information.
        - Post-meeting note: CBPO modelers confirmed that there is no default rate for the current retrofit curves. The jurisdictions must provide the information needed for the curves into NEIEN or CAST/MAST/VAST (volume depth). Otherwise they need to report the individual practice under the other CBP-approved reduction values.
    - Will follow up with David for that smaller group call on the model…prior to Christmas?
- ACTION: Doodle poll for another panel meeting in early January.
- Bill noted the time. He summarized plans for the follow up call and mentioned the panel will plan for its next full call in January. He thanked everyone for their time and participation.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Impervious Cover Disconnection Expert Panel
Thursday, January 14, 2016, 1:00PM-3:00PM
Conference Call

Name	Affiliation	Present? Y/N
Bill Stack (Chair)	Center for Watershed Protection	Y
Reid Christianson	Center for Watershed Protection	Y
Greg Evanylo	Virginia Tech	Y
Jason Papacosma	Arlington County (VA) DES	N
Ryan Winston	North Carolina State University	Y
David Sample	Virginia Tech	Y
Franco Montalto	Drexel University	Y
Justin Shafer	City of Norfolk (VA)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Greg Sandi	MD Dept. of Environment	Y
Jeff Sweeney	EPA, CBPO	N
Liz Ottinger	EPA Region 3	N
Lisa Fraley-McNeal	CWP	Y

Welcome and introductions

- Bill welcomed participants and reviewed the day's agenda.
- Jeremy noted that minutes from the previous December and October calls, and September meeting, were distributed. He asked for any comments or edits to them. None were raised; the minutes were accepted as written.

Review of follow-up December modeling call and discussion of comments on the strawman

- Reid recalled a few discussion points from previous calls: saturated hydraulic conductivity, surface sealing, the NRCS runoff curve number (CN), and qualifying conditions.
  - He reviewed the CN method and some of the comments raised by panelists since the December call.
  - Ryan asked if the precipitation conditions for different cities is something the panel should consider. Bill mentioned that other expert panels have used Reagan National as a representative basis for precipitation data used to build their recommendations.
  - Reid described another option looking at porosity instead of the CN.
  - Franco mentioned an existing technique to calculate called the Thornthwaite-Mather approach that uses the wilting point, soil moisture, and field capacity.. Can get the equivalent of the CN using that approach. People are more familiar and used to the CN method, so that is probably simpler. The other approach is not as widely used. It is only as accurate as your measurements of soil moisture parameters. For purposes of planning, a new set of assumptions would need to be developed.
  - Dave suggested keeping it open for people to use alternative approaches or techniques like the one Franco mentioned. Bill mentioned that the stream restoration panel did something similar, but provided the caveat that they would need to check with the appropriate state agency first.

- Reid discussed how to connect soil amendments to the RCN. The panel had previously discussed and agreed that changing the hydrologic soil group (HSG) due to surface layer amendments would be hard to justify. Alternatively we can estimate a new CN based on saturated hydraulic conductivity (Ksat) as opposed to HSG. Could perhaps add qualifying conditions for surface cover or vegetation. Saxton and Rawls evaluated Ksat of native soils based on sand, clay, organic matter and compaction. This could also be used to evaluate Ksat of amended soil. Effective Ksat (of amended soil on top of native soil), if needed for evaluation, could be determined using pre-defined evaluation depths – see Lf discussion below. Could use an Lf (depth of the infiltration wetting front and representing effective Ksat evaluation depth) based on the impervious:pervious ratio. Reid noted that using a higher Lf would put more weight on the native soil (i.e. be more conservative).
  - Lf is the depth that moisture would penetrate. Franco was concerned about simplifying the Lf value to a single number based on I:P ratio. Would largely ignore the temporal factors of these precipitation events, which seems very important.

- Franco: it does seem intuitive that more effort would spent on amendments for a smaller area to treat a larger impervious area. So accounting for that ratio somehow would make sense. Reid: may need to set a cap on the hydraulic loading ratio (HLR). A HLR of 90:1 would be an extreme urban case somewhere like New York City. An HLR of 15:1 could be a very urban setting as well or maybe a roadside ditch for a 4 lane highway. At higher HLR a different type of practice would be considered. Franco suggested that if we cap HLR around 4:1 or 5:1 and assume that we're planning for 1" storm, then at 4:1 we are assuming there are 5 inches of runoff to infiltrate into the soil. Would need to till down to about 12" (5" x 0.4 porosity). So then Ksat effective would be an average based on that 1 foot of soil. If a 2:1 HLR and tilled down to 6" then would calculate Ksat effective based on those 6 inches of soil.

Discussion on compost specs

- Greg elaborated on some aspects of the VA DEQ soil compost amendment specs, including the compost quality specifications for stability, organic matter content (35-65%), C:N ratio <25:1, etc. The U.S. Composting Council and various DOTs had come to agreement on these specifications.
  - Bill noted that the USWG has had concern about phosphorus leaching from compost in the past. Greg responded that Virginia decided it was important to use vegetative-based compost material so phosphorus leaching would be limited. Generally, we may not want to limit to only plant-based – biosolids-based compost from waste water treatment plants may be high in iron or aluminum and can become P sinks.
  - Ryan: Think that compost can be a concern for soil test P sometimes, but also think compost can be an important add-in for bioretention and other practices if it is about 10% or less of the mix. If it's much higher than that then you will probably see an increase in your soil test P.
  - Jeremy noted there is an Ag BMP panel looking at manure injection and incorporation, which includes application of manure compost. He will follow-up with Mark Dubin (AgWG coordinator) offline to see if there are any notable points of crossover to consider between the two panels.

Update on BMPs within the conveyance system

- Bill noted the time. Lisa will present the update at the next call.

Plans for next call, wrap-up and next steps

- Jeremy noted that the face-to-face would be best held later than February so the panel will ideally have a draft set of chapters to discuss at the meeting. The panel can have a call in February to follow-up on any lingering issues before the face-to-face.
- Jeremy will distribute Doodle polls for a February conference call and a meeting in March.
- Reid will update options and protocol. Simplify equations and approach for discussion at next call.
- Bill will follow up with Greg E. on soil specs.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Impervious Cover Disconnection Expert Panel
Thursday, February 25, 2016, 10:00AM-12:00PM
Conference Call

Name	Affiliation	Present? Y/N
Bill Stack (Chair)	Center for Watershed Protection	Y
Reid Christianson	Center for Watershed Protection	Y
Greg Evanylo	Virginia Tech	N
Jason Papacosma	Arlington County (VA) DES	N
Ryan Winston	Ohio State University	Y
David Sample	Virginia Tech	Y
Franco Montalto	Drexel University	Y
Justin Shafer	City of Norfolk (VA)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Greg Sandi	MD Dept. of Environment	Y
Jeff Sweeney	EPA, CBPO	N
Liz Ottinger	EPA Region 3	Y
Lisa Fraley-McNeal	CWP	Y

Welcome and introductions

- Bill welcomed participants and introduced the agenda.

Review of minutes highlighting points of consensus from last call

- Bill recapped points of agreement from the last call and asked if there were any comments or questions for the minutes. None were raised; the minutes were approved as written. **DECISION**: The January 14th minutes were approved.

Discussion on draft expert panel report

- Lisa reviewed the draft report table of contents, giving a brief summary and noting the status for each of the sections.
- Bill recalled that the USWG requested examples of….
- Reid walked through section 5, which describes steps for quantifying changes in soil characteristics and other steps to determine the runoff reduction benefits. He pointed out the piece about evaluation depth still needs some additional work and input from the panel.
- Bill recalled that the panel had previously agreed to using the steps Reid described in order to estimate the runoff reduction for the disconnection practices. He noted the panel had previously discussed the runoff adjustor curves, developed by the Retrofits expert panel, which could potentially translate the panel's methods into nutrient and sediment reductions.
- Reid discussed the link between the Curve Number and Runoff Reduction approaches. The CN was paired to the longterm precipitation and runoff record. The relative runoff

from CN values is nearly a 1:1 line. He explained how to relate runoff reduction to treatment volume and the runoff adjustor curves. He gave an example, 1 ac impervious, 0.2 ac pervious, initial site CN of 97, with treated CN of 86 for the amended area, an overall site CN of 95, which translates to a water treatment depth of 0.16 inches, or 0.19 inches per impervious acre. Or that is the example with the current methods and approach.

  - Franco and Ryan commented that the result seemed reasonable and was pretty straightforward overall. Ryan noted the example made sense for a 5:1 ratio site (impervious: pervious).
    - Franco noted Reid's slides had I:P ratios of 1.0, 2.5, 5 and 10. Is 10 the upper limit?
      - Reid noted that you would have to work extra hard if the ratio is over 10. Franco pointed out that there could be sites with fairly good soils in the pervious area.
  - Reid clarified that any I:P ratio or initial CN could be used under the current methods.
  - Jeremy asked for clarification on how the methods account for larger and smaller storms, since the steps refer to a 1.0 inch storm. Want to make sure that the annual reductions derived from the methods holds and logically applies on annual basis when there are many smaller events and some larger events.
    - Reid reiterated some of the connections between average annual runoff and the CN approach. He also pointed out that the adjustor curves also account for the fact that most events are smaller and there are diminishing returns as you increase the volume along those curves.
  - Franco suggested presenting some of the curves in different manner. X axis existing CN and Y axis amended CN. That point in the contour would be the water treated, and would have contours for the different I:P ratios. That would allow us to efficiently depict the relationships between all the CNs at once.
- Lisa walked through protocols for estimating removal for treatment in conveyance systems. She explained that online facilities are within the existing drainage network, while offline facilities split storm flows from existing drainage network to adjacent depression or excavated treatment area.
  - Lisa described an example for calculating the reduction that uses the adjustor curves.
- Bill noted the panel will need to consider a default rate for planning and reporting purposes. Jeremy commented that default rates have two primary purposes: to give an estimated reduction for the BMP in planning scenarios when the site specific details are unknown, only very basic elements such as the acres treated, and; to give a default reduction to reported practices that don't have the full suite of data that would be needed to do the complete set of reduction calculations.
  - Greg noted that there is a discrepancy in capacity to track and report more detailed information. Phase I MS4s with more resources can more easily track and provide the kind of information needed for the complete protocols, while Phase II communities or unregulated areas may only be able to track and report much more simplified or basic data. That's something to consider while setting a default rate that can work for jurisdictions.

- Reid reviewed an example of the soil amendment protocol and how to generate the load reductions.
- **ACTION**: Panel members should send comments on the draft report to Bill and Reid by COB March 9th.
- Bill requested that panelists provide their thoughts on how to establish a potential default rate, on what qualifying conditions should be for these practices, future research and management needs, or any other thoughts on the draft.

Additional needs and next steps

- Bill and Jeremy reminded everyone that the next meeting will be on Wednesday, April 6th at the CWP offices in Ellicott City, MD. Conference line will be available for those who need to call in. They thanked everyone for their time and discussion.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Impervious Cover Disconnection Expert Panel
Wednesday, April 6, 2016, 9:00AM-3:00PM
Meeting

Name	Affiliation	Present? Y/N
Bill Stack (Chair)	Center for Watershed Protection	Y
Reid Christianson	Center for Watershed Protection	Y
Greg Evanylo	Virginia Tech	Y
Jason Papacosma	Arlington County (VA) DES	N
Ryan Winston	Ohio State University	Y
David Sample	Virginia Tech	Y
Franco Montalto	Drexel University	Y
Justin Shafer	City of Norfolk (VA)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Greg Sandi	MD Dept. of Environment	Y
Jeff Sweeney	EPA, CBPO	Y
Liz Ottinger	EPA Region 3	Y
Lisa Fraley-McNeal	CWP	Y

Welcome and introductions

- Bill welcomed participants and introduced the agenda.

Review of IC panel approval process and schedule

- Jeremy gave an overview of what the panel might expect for the schedule. Following today's meeting and subsequent final revisions, expect a release in early or mid-May of the full report. That starts a 30 day comment period from the CBP partnership, and most panels now schedule a webinar a week or two after the release of the report. Bill and others provide a detailed walkthrough of the recommendations of the recommendations during that webinar, and record it for anyone who misses it. Bill and Jeremy work to respond to the comments received, looping in the panel or specific panelists as needed. Then they would go to the USWG for approval, then the WTWG and finally the WQGIT. Following WQGIT approval the panel is officially dismissed.

Discussion of qualifying conditions

- Lisa walked through the qualifying conditions described in the draft report and some of the feedback from the panelists, asking for additional thoughts. Lisa tracked the changes in the draft as discussion progressed.
- There was discussion of high use areas such as athletic fields, grass parking lots, etc. Panel felt that there may be cases where such areas are applicable, remove the "high use" label.
- Panel felt that the practice shouldn't be strictly limited to HSG C or D soils. The practice is not suggested for A or B soils which would be better off following UFS panel recommendations. Greg E. noted that areas with Karst topography would be problematic that may have surface soil less than 1.5 feet.
- Ryan will look into references regarding calcium based additives and share it with Greg E.
- There was discussion about N and P concentrations for compost used in the disconnection and amendment practices. Greg E. provided some specific thoughts at end of the meeting.
- Greg E. pointed out the soil test "less than 30" was missing a label unit or methods. Need to clarify what's being measured and how.
- There was discussion about nutrient concentrations in compost and the existing soils. After some discussion, Reid pointed out that if the initial soil is already rich in P then practitioners need to be careful that they don't add large amounts of new P in compost that may lead to leaching or export from the treated area.
- Jeremy noted the time and Lisa mentioned that there weren't any comments received on the qualifying conditions for practices in existing conveyance system.

Accountability and BMP verification

- Bill walked through the reporting, tracking and verification aspects of the draft report. Lisa tracked comments and changes directly in the report as the discussion progressed.
- It was pointed out that some of the text was carried over from UFS report, which likely built on language from the stormwater sector verification guidance. Jeremy will refer to the final stormwater verification guidance to double check some of the verification language.
- Greg E. noted that county or local staff could easily use a penetrometer in the field to take measurements and quickly get a sense of the compaction. They would want to test down to the depth that was initially treated, but if using a penetrometer you want to be representative of the site, not just one spot. E.g., would want to probably do at least 5 penetrometer measurements on a small site, probably no more than 20 for a large site.
- There was discussion about how the initial sampling/testing may be related to procedures for follow-up inspections of the site. Soil testing to include bulk density measurements

for comparison to pre-amendment and disconnection conditions. Need to clarify the sampling sites and depth. Would need to sample to depth that was amended, and possibly deeper if there's a need to verify restricting conditions down to one foot depth.

Research needs

- Lisa asked for additional input on the future research and management needs described in the draft report. She tracked some edits and comments directly in the document during the discussion. Jeremy noted there is an agricultural BMP panel getting ready to launch that will be looking at practices applied to ditches in agricultural areas, especially on the Delmarva Peninsula. When this panel's report is out we can work with that panel's leadership to identify areas that need clarification in one or both of the reports.

Default methods

- Reid walked through the protocols for calculating the reductions, based on feedback from previous discussions. He asked for additional thoughts or input from participants to see if there were needs for further clarification before finalizing the report and protocols, including a default, a simplified, and the full detailed protocols.
- Reid explained some of the steps taken to derive the recommended method to use I:P ratio to set the evaluation depth (L_f) which is used for determining $K_{SatEffective}$. Jeremy asked Reid and CWP to take the tables/graphs from the slides and add some narrative text to turn the explanation into an Appendix for the report. It is likely that the methods for deriving Table 11 in the report will be scrutinized if there isn't a discussion of how those values were developed. There was some discussion about whether the term "evaluation depth" might cause confusion and how the evaluation depth from the methods relates back to the real soil conditions of a given project. The term "infiltration depth" may be more accurate to describe the Lf value in the steps for the detailed protocols.
- Greg E. asked if Reid had done some sensitivity analysis of the methods and how the Lf methods influenced CN. Reid explained that the graphs he included serve as a measure of the sensitivity between the recommended methods and the iterative approach in terms of water treated, which is what matters for this particular step in the protocols. The CN mid-step was just not shown.
- Ryan, Franco and Greg E. agreed that the method can be used for the panel's needs.
- Franco suggested including a justification based on field capacity, depth, porosity, storage, etc...Could add a third column for available porosity, and as long as that column is < than the second column, that addresses the issue.
- Reid walked through the simplified and default approaches. There was discussion about the simplified approach and potentially cutting off the curves for runoff depth at a reasonable point such as 0.01 or 0.05 inches. After discussion it was agreed that there may be some small scale projects that could potentially go to those lower values, so the panel felt the RR adjustor curves could be used to the point the TN, TP or TSS value reaches zero. The CWP and Jeremy can work offline to simplify looking up the values instead of guessing the value based on the curves.

General discussion of lingering issues, additional revisions needed to finalize report, etc.

- Greg E. elaborated on some earlier comments about P-testing for soils. You typically test for either Mehlich-3 (M3), or Mehlich-1 (M1), to see where you fall in a qualitative category (Low, medium, high, very high). If you get to “very high” then P will never be a limiting factor for plant growth. Greg suggested using the threshold values for the “very high” values for M3 and M1 as the cutoff for using compost for a site. At those values or below the use of compost will be beneficial due to the runoff reduction and improved soil qualities and the comparatively smaller risk for leaching. Above that “very high” threshold there is a risk of compost additions adding to P export. He provided values based on Virginia DCR criterion standards for nutrient management.

Mehlich-3 P (of existing soil, ppm)	Mehlich-1 P (of existing soil, ppm)	
60	24	High (H)
127	55	Very High (VH)

- It was suggested that the panel can suggest those M3 and M1 values as a threshold, but the states will ultimately decide what their own threshold should be for allowing compost amendments in areas with relatively high soil-P levels.
- **ACTION**: Bill, Reid and Lisa will make updates and distribute updated version of the report to the panel by COB April 22, asking for final confirmation by May 6. If nothing is raised then that will be the version that is released for CBP partnership review and comment, pending any final polishing changes.
- Bill and Jeremy noted this will likely be the panel’s last call or meeting. They thanked everyone for their engagement, contributions and effort throughout the process.

Adjourned

Appendix B: State and District of Columbia Stormwater Manual Design Specifications and Performance for Impervious Disconnection and Soil Amendments

Table B- 1. State Stormwater Manual Specifications for Impervious Disconnection

State	Specific Practice	Slope	Soils	Geometry	Contributing Drainage Area	Vegetation
MD	Rooftop Disconnection	5% or less or terraces or berms needed if >5%; must be conveyed as sheetflow	HSG A, B, or C. HSG D or soils that are compacted may need to be tilled and/or amended	A pervious area at least 15 ft and no greater than 75 ft long (12 feet for Eastern Shore projects) shall be available down gradient of disconnected downspouts. Disconnected downspouts shall be at least 10 ft from the nearest impervious surface of similar or lower elevation to prevent reconnection.	500 ft^2 or less	Groundcover should be provided. Turf is common, but trees/shrubs and other herbaceous plants will enhance runoff reduction.
MD	Non-Rooftop Disconnection	5% or less or terraces or berms needed if >5%; must be conveyed as sheetflow	HSG A, B, or C. HSG D or soils that are compacted may need to be tilled and/or amended	Flow path through vegetated area should be a minimum of 10 ft and not exceed 75 ft. Disconnections shall be at least 10 ft from the nearest impervious surface of similar or lower elevation to prevent reconnection.	1000 ft^2 or less. The maximum contributing impervious flow path length shall be 75 feet, and the maximum contributing pervious flow path shall be 150 feet.	Groundcover should be provided. Turf is common, but trees/shrubs and other herbaceous plants will enhance runoff reduction.
MD	Sheetflow to Conservation	Contributing drainage area slope is 5% or less or a level	Not specified	Conservation areas shall be 20,000 ft^2 or larger with a	Not specified	Plants native or adapted to MD. Managed turf is not

State	Specific Practice	Slope	Soils	Geometry	Contributing Drainage Area	Vegetation
		spreading device is needed. Conservation area slope not specified.		minimum width of 50 ft.		acceptable vegetation.
VA	Simple Rooftop Disconnection	< 2%, or < 5% with turf reinforcement; flows should be spread evenly across disconnection	Any soil group. Erodibility must be considered	Width ≥ 10 feet; Length equal to longest flow path, but no less than 40 ft^2	1,000 ft^2; longest flow path per disconnection is 75 ft	Not specified
PA	Rooftop Disconnection	5% or less	Not specified	75 ft or greater disconnection length; lot size >6000 ft2; must drain continuously through a vegetated **swale or filter strip**; downspouts must be at least 10 ft away from nearest impervious surface	500 ft^2 or less/ downspout;	Lawn and turf grass are acceptable; meadow is encouraged
DC	Simple Disconnection to Pervious Compacted Cover	< 2%, or < 5% with turf reinforcement	Any soil group	Minimum of 150 ft^2 at least 10 feet wide and 15 feet long; maximum disconnection width is 25 ft unless the contributing runoff is conveyed via sheetflow or a level spreader; maximum disconnection length is 100 ft	1000 ft^2/ rooftop disconnection or maximum impervious flow path of 75 ft for non-rooftop disconnection	Turf vegetation is recommended. If using other vegetation, documentation to ensure erosion will not occur is required.
DC	Simple Disconnection to Conservation Area (Natural Area)	Maximum slope of the receiving area is 6%. (2% for the first 10 ft). Inflow must be conveyed via sheet flow or via a level spreader.	Any soil group	Same criteria as for disconnection to pervious compacted cover, with the addition that the minimum	1000 ft^2/ rooftop disconnection or maximum impervious flow path of 75 ft for non-rooftop disconnection. If	Turf vegetation is recommended. If using other vegetation, documentation to ensure erosion will

State	Specific Practice	Slope	Soils	Geometry	Contributing Drainage Area	Vegetation
				disconnection length is 40 ft.	inflow is conveyed via sheet flow, the maximum flow path is 75 ft when the runoff is conveyed from an impervious area and 150 ft when the runoff is conveyed from a pervious area or level spreader.	not occur is required.
DC	Simple Disconnection to Conservation Area (Amended Soil)	Flow spreading device is required and downspout outlet	For compost-amended filter paths, use 2 to 4 in of compost and till to a depth of 6 to 10 in within the filter path	Minimum of 150 ft^2 at least 10 feet wide and 15 feet long	Maximum of 1000 ft^2/ rooftop disconnection or maximum impervious flow path of 75 ft for non-rooftop disconnection	Turf vegetation is recommended. If using other vegetation, documentation to ensure erosion will not occur is required.
NY	Rooftop Disconnection	Average slope <5%	Encouraged on HSG A or B; for HSG C or D soil enhancements and/or a level spreading device may be needed	Downspouts shall be at least 10 ft away from the nearest impervious surface to discourage "re-connections"; The disconnected, contributing impervious area shall drain through a **vegetated channel, swale, or filter strip (filtration/ infiltration areas)** for a distance equal to or greater than the disconnected, contributing impervious area length.	500 ft^2 or less/ downspout; larger rooftops up to 2,000 ft^2 may be acceptable with a suitable flow dispersion technique such as a level spreader; maximum contributing flow path length from impervious areas shall be 75 feet	Not specified

State	Specific Practice	Slope	Soils	Geometry	Contributing Drainage Area	Vegetation
WV	Impervious Surface Disconnection	2% or less; 5% or less with turf reinforcing; sheetflow with level spreader required	Any soil group; minimum soil infiltration rate of 0.5 in/hr; for compost-amended filter paths use 2 to 4 in of compost and till to a depth of 6 to 10 in within the filter path	Width = 15-25 ft; Length = minimum of 40ft; compost-amended filter paths should be at least 10 ft in width and 20 ft in length within the larger disconnection pervious area	Maximum of 1,000 ft^2 or less/ downspout; For non-rooftop impervious areas, the longest contributing impervious area flow path cannot exceed 75 feet.	Grass species should have the following characteristics: a deep root system to resist scouring; a high stem density with well branched top growth; water-tolerance; resistance to being flattened by runoff; an ability to recover growth following inundation; and, if receiving runoff from roadways, salt-tolerance.

Table B- 2. State Stormwater Manual Performance for Impervious Disconnection

State	Runoff Reduction	Pollutant Removal
MD	PE values (in) are applied to the ESD sizing criteria depending on the disconnection flow path length (rooftop disconnection), ratio of disconnection length to contributing length (non-rooftop disconnection), and the minimum width (conservation areas).	
VA	50% runoff reduction (A/B soils); 25% runoff reduction (C/D soils)	50% TN/TP mass load removal (A/B soils); 25% TN/TP mass load removal (C/D soils); No EMC reduction provided
PA	Volume Reduction (ft3) = Contributing Impervious Area (ft2) x 1/4" / 12	
DC	15 gallons/ 100 ft^2 of receiving pervious area (compacted cover); 45 gallons / 100 ft^2 conservation area (natural cover); 30 gallons / 100 ft^2 conservation area (soil amended)	
NY	If impervious areas are adequately disconnected, they can be deducted from the site's impervious total (Rv calculation) when computing WQv.	
WV	4 $ft^3/100ft^2$ on receiving pervious area (A/B soils); 2 $ft^3/100ft^2$ on receiving pervious area (C/D soils); 4 $ft^3/100ft^2$ on receiving pervious area (C/D amended soils); premise of the credit is the minimum theoretical permeability or infiltration rate of 0.5 in./hr. for HSG A & B soils.	75% TSS, 50% TN/TP (A/B soils); 63% TSS, 25% TN/TP (C/D soils). Note that these %s are the total pollutant load reduction and represent the combined runoff reduction and pollutant removal. TN/TP do not receive any nutrient removal credit - only runoff reduction.

Table B- 3. State Stormwater Manual Design Specification and Crediting for Soil Amendments

State	Performance Credit	Compost Depth	Method	Compost Specs	Regional Adaptations	Additional Considerations
VA	50% runoff reduction for compost amended soils on HSG C/D soils in conjunction with simple disconnection	Varies from 6-24 inches depending on the contributing impervious cover to soil amendment ratio	Rototiller and tiller for lower compost depths and subsoiler for depths >15 in	Must meet general criteria of U.S. Composting Seal of Testing Assurance	Ensure entire depth of soil will not become saturated in coastal plain; terracing for slopes >5%; should not be used in snow storage areas	Soil testing – first test is required to a depth of 1ft for bulk density, pH, salts, and nutrients (every 5,000 ft2); second test is taken one week after compost has been incorporated into the soil
PA	Volume Reduction (ft3) = Area of Min. Soil Compaction (ft2) x ¼" / 12 For Meadow Areas: Volume Reduction (ft3) = Area of Min. Soil Compaction (ft2) x 1/3" / 12 Greater volume credit if calculations support a greater numerical value to Minimizing Soil Compaction.	6 in (till to 8 in) for minor compaction; 10 in (till up to 20 in) for major compaction	Rototill, or rip the subgrade, remove rocks, distribute the compost, spread the nutrients, rototill again.	Compost, but could also be mulch, manure, sand, and manufactured microbial solutions; 2:1 soil:compost	Should not be used on slopes >30%	Should not be used within a tree drip line to avoid damaging the root system
DC	30 gallons / 100 ft^2 of amended soils in conjunction with simple disconnection to a conservation area	Varies from 3-10 in (compost depth) and 8-24 in (incorp. depth) depending on the contributing impervious cover to soil amendment ratio	Tiller for lower compost depths and subsoiler for depths >15 in	Must meet general criteria of U.S. Composting Seal of Testing Assurance	Not Specified	Soil testing – first test is required to a depth of 1ft for bulk density, pH, salts, and nutrients (every 5,000 ft2); second test is taken one week after compost has been incorporated into the soil

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Appendix C: Conformity of Report with BMP Protocol

The BMP review protocol established by the Water Quality Goal Implementation Team (WQGIT, 2014) outlines the expectations for the content of expert panel reports. This appendix references the specific sections within the report where panel addressed the requested protocol criteria.

1. **Identity and expertise of panel members***: See table in Section 1.*

2. **Practice name or title:** *Impervious Area Disconnection Coupled with Soil Amendments is one practice. The other is Treatment in the Conveyance System.*

3. **Detailed definition of the practice***: See Section 2.1 for detailed definitions.*

4. **Recommended N, P and TSS loading or effectiveness estimates:** *See Sections 5.1 and 5.2 for recommended removal rates.*

5. **Justification of selected effectiveness estimates***: See Sections 5.1 and 5.2, with supporting information provided in Appendix E to understand how the panel derived the effectiveness estimates.*
    a. **List of data sources considered and description of how each data source was considered:** *Data sources were discussed in the literature review as well as throughout the description of the protocol. Primary sources include information on soil characteristics, described in Appendix E and previous expert panel reports.*
    b. **Identify data sources that were considered, but not used in determining practice effectiveness estimates:** *Much of the literature sources were not directly used in protocol development, though the general theme of decompaction or the addition of compost reducing runoff, as shown in these sources was used.*
    c. **Documentation of uncertainties in the published literature:** *During protocol development, the conservative methods were largely chosen to insure any uncertainty would yield a "better" result than expected.*
    d. **Documentation of how the Panel addressed negative results or no pollution reduction as a result of implementation of a specific practice:** *Due to the conservative nature of the protocols developed here, situations where no pollution reduction might occur likely overlap with an exceedingly low credit. Additionally, alternative BMPs would likely be more cost effective as well as better performing in these situations.*

6. **Description of how best professional judgment was used, if applicable, to determine effectiveness estimates:** *Best professional judgement was used when making decisions about*

conservative options. For example, when considering pore space available to hold water, assuming the soil is already at field capacity would yield a lower storage estimate than assuming dry (i.e. wilting point) conditions.

7. **Land uses to which BMP is applied:** *Land uses in the Phase 6 model that are equivalent to the current urban land uses in the Phase 5.3.2 model.*

8. **Load sources that the BMP will address and potential interactions with other practices:** *These practices will address runoff from impervious surfaces. The report recommendations provide qualifying conditions to report these practices as stand-alone BMPs as retrofits (not new development or redevelopment).*

9. **Description of pre-practice and post-practice circumstances, including the baseline conditions for individual practices:** *These are new practices and there are no practice baselines.*

10. **Conditions under which the practice performs as intended/designed:** *Section 2.2 describes conditions under which these practices would not apply.*

11. **Temporal performance of BMP including lag times between establishment and full functioning:** *No lag time I assumed.*

12. **Unit of measure:** *Refer to Section 6.1 for basic reporting units.*

13. **Locations in CB watershed where the practice applies:** *Urban*

14. **Useful life; practice performance over time**: *See Section 6.1 for credit duration.*

15. **Cumulative or annual practice:** *Annual*

16. **Recommended description of how practice could be tracked, reported, and verified:** *See Section 6.1 for how state governments can track and report to the Bay Program.*

17. **Guidance on BMP verification***: See Section 6.1 for guidance on BMP verification.*

18. **Description of how the practice may be used to relocate pollutants to a different location** *Not applicable*

19. **Suggestion for review timeline; when will additional information be available that may warrant a re-evaluation of the practice effectiveness estimates**

20. **Outstanding issues that need to be resolved in the future and a list of ongoing studies, if any:** *See Section 7 for a discussion of future research needs.*

21. **Documentation of dissenting opinion(s) if consensus cannot be reached:** *Not applicable*

22. **Operation and Maintenance requirements and how neglect alters the practice effectiveness estimates:** *Refer to Section 6.1 for information on maintenance inspections and the suggested process for BMP downgrades.*

23. **A brief summary of BMP implementation and maintenance costs estimates, when this data is available through existing literature:** *Implementation and maintenance costs are not available in the reviewed literature.*

24. **Technical appendix:** *See Appendix A*

Appendix D: Technical Requirements for Reporting and Crediting of Impervious Area Disconnection in Scenario Builder and the Phase 6.0 Watershed Model

Appendix D is provided as a separate document for CBP review. It will be incorporated into the full report following WQGIT approval.

Appendix E: Runoff Reduction Protocol Development

The following methods were used to develop the simplified curves and the default rates and should be followed for the computational method described in Section 5.1.3.

Part 1: Soil Hydraulic Characteristics

The following set of equations were adapted from Saxton and Rawls (2006). These predictive equations use a “first solution” denoted with a lowercase “t” and a final solution. Working through these equations, whether using these equations or the SPAW Soil Water Characteristic model (K. E. Saxton & Rawls, 2009), for the initial site conditions as well as amended or decompacted conditions will allow for runoff reduction estimates due to the soil conditioning activity.

Information needed to start this process includes pre conditioned sand content (Sa), clay content (C), organic matter content (OM), and bulk density ρ by collecting soil samples on-site. The ρ parameter can be used as ρ_{adj} in equation 10. The measured ρ is used in place of ρ_{adj} as the soil conditions are being compared to “normal” conditions as defined by equation 8. Measured ρ can also be converted into a compaction factor using equation 9 for comparison to simple curves in Section 5.1.2. If in the planning phase, where rough comparisons are needed to compare this practice to other BMPs, soil survey data can be used. Equations 1 through 14 below are used for the pre conditioned AND the post conditioned soil, as a comparison between the two cases is needed. The resulting parameter used for subsequent calculations is the saturated hydraulic conductivity (K_{Sat}) (Equation 13, below), which is used in equation 5.1.3.1 for the calculation of effective saturated hydraulic conductivity ($K_{SatEffective}$).

$$\theta_{1500t} = -0.024 * Sa + 0.487 * C + 0.006 * OM + 0.005 * (Sa * OM) - 0.013 * (C * OM) + 0.068 * (Sa * C) + 0.031 \quad (1)$$

Where, θ_{1500t} is the first solution of moisture content (percent by volume) at 1500 kPa, Sa is the sand content **fraction** by weight, C is the clay content **fraction** by weight, and OM is the organic matter content in **percent** by weight. Note, OM does not compete with Sa or C. The final solution of the moisture content at 1500 kPa is:

$$\theta_{1500} = \theta_{1500t} + (0.14 * \theta_{1500t} - 0.02) \qquad (2)$$

Likewise, the moisture content (percent by volume) at 33 kPa has a first solution:

$$\theta_{33t} = -0.251 * Sa + 0.195 * C + 0.011 * OM + 0.006 * (Sa * OM) - 0.027 * (C * OM) + 0.452 * (Sa * C) + 0.299 \quad (3)$$

Where parameters are as defined above. The final solution for moisture content at 33 kPa is:

$$\theta_{33} = \theta_{33t} + (1.283 * \theta_{33t}^2 - 0.374 * \theta_{33t} - 0.015) \qquad (4)$$

The difference in moisture content (percent by volume) between saturation and 33 kPa can be estimated using a first solution of:

$$\theta_{(S-33)t} = 0.278 * Sa + 0.034 * C + 0.022 * OM - 0.018 * (Sa * OM) - 0.027 * (C * OM) - 0.584 * (Sa * C) + 0.078 \qquad (5)$$

Where parameters are as defined above. The final solution for the difference in moisture content between saturation and 33 kPa is:

$$\theta_{(S-33)} = \theta_{(S-33)t} + \left(0.636 * \theta_{(S-33)t} - 0.107\right) \qquad (6)$$

The moisture content at saturation (0 kPa), θ_S, is:

$$\theta_S = \theta_{33} + \theta_{(S-33)} - 0.097 * Sa + 0.043 \qquad (7)$$

The bulk density associated with a "normal" soil with Sa, C, and OM as used above, in g/cm^3, is estimated as:

$$\rho_N = (1 - \theta_S) * 2.65 \qquad (8)$$

Of course, urban soils can be highly compacted so density effects can be taken into account with a density adjustment factor, or compaction factor (CF), which Saxton and Rawls (2006) suggest should range between 0.9 and 1.3. The bulk density correction is a simple multiplication of ρ_N by the compaction factor, or:

$$\rho_{adj} = \rho_N * CF \qquad (9)$$

Any adjustments of ρ_N, through the implementation of CF or using measured bulk density to give ρ_{adj}, has a subsequent impact on θ_S, θ_{33}, and $\theta_{(S-33)}$ as follows.

$$\theta_{Sadj} = 1 - \frac{\rho_{adj}}{2.65} \qquad (10)$$

$$\theta_{33adj} = \theta_{33} - 0.2 * \left(\theta_S - \theta_{Sadj}\right) \qquad (11)$$

$$\theta_{(S-33)adj} = \theta_{Sadj} - \theta_{33adj} \qquad (12)$$

Adjusted parameters are used in the calculation of the saturated hydraulic conductivity (K_{Sat}) with:

$$K_{Sat} = 1930 * \theta_{(S-33)adj}^{3-\lambda} \qquad (13)$$

Where λ is the slope of a logarithmic tension-moisture curve and can be calculated with:

$$\lambda = \frac{ln(\theta_{33adj}) - ln(\theta_{1500})}{ln(1500) - ln(33)} \qquad (14)$$

To give a general sense of the impact of the compaction factor, CF, for a given soil, Table E- 1 highlights the resulting bulk density of soil textures given the CF. Table E- 2 shows the resulting K_{Sat} values in inches per hour.

Table E- 1. Resulting bulk density, in g/cm3, using 2.5% OM, by weight, and Saxton and Rawls (2006) predictive equations and a compaction factor.

			CF				
Soil Textures	**% Sand**	**% Clay**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**
Silt loam	20	20	1.24	1.37	1.51	1.65	1.78
Silt	7	6	1.23	1.37	1.51	1.65	1.78
Loam	42	18	1.29	1.44	1.58	1.72	1.87
Sandy clay loam	60	28	1.36	1.51	1.66	1.81	1.96
Clay loam	33	34	1.26	1.40	1.54	1.68	*
Silty clay loam	10	34	1.17	1.30	1.43	1.56	1.69
Sandy clay	52	42	1.34	1.48	1.63	*	*
Silty clay	7	47	1.12	1.24	1.36	1.49	1.61
Clay	30	50	1.22	1.36	1.49	*	*
*this compaction factor is unlikely for this soil texture							

Table E- 2. Resulting saturated hydraulic conductivity, in in/hr, using 2.5% OM, by weight, and Saxton and Rawls (2006) predictive equations and a compaction factor.

			CF				
Soil Textures	**% Sand**	**% Clay**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**
Silt loam	20	20	0.92	0.48	0.21	0.06	0.01

Silt	7	6	1.34	0.74	0.35	0.12	0.02
Loam	42	18	1.32	0.73	0.35	0.13	0.03
Sandy clay loam	60	28	0.68	0.31	0.10	0.02	0.00
Clay loam	33	34	0.43	0.18	0.05	0.01	*
Silty clay loam	10	34	0.50	0.23	0.08	0.02	0.00
Sandy clay	52	42	0.14	0.03	0.00	*	*
Silty clay	7	47	0.34	0.15	0.05	0.01	0.00
Clay	30	50	0.12	0.03	0.00	*	*
*this compaction factor is unlikely for this soil texture							

Part 2: Soil Conditioning Adjustments

Conditioned soil can be considered by adjusting Sa, C, OM, and ρ based on the conditioning activity. For example, decompaction through tillage would, effectively, change the compaction factor to 1.0 (i.e. ρ_{adj} goes to ρ_N) and adding compost would increase the OM content. Increasing the OM content is an exercise in mass and volume balance, where adding, for example, 3 inches of compost will increase the elevation of the area you are working with by 3 inches, and tillage to reduce compaction will also increase the elevation of the area. The following set of equations could be used to accomplish this task.

$$D_{Result} = D_{Till} + D_{Till} * (CF_{Initial} - 1.0) + D_{Compost} + D_{Other} \quad (15)$$

Here, D_{Result} is the resulting amended soil depth, D_{Till} is the depth of tillage or incorporation, $CF_{Initial}$ is the compaction factor of the initial soil (see equation 9, above), $D_{Compost}$ is the depth of compost added, and D_{Other} is the depth of other amendments (i.e. sand). If no sand is being added, the Sa and C values (as they are based on weight and are not competitive with OM in the Saxton and Rawls methods), are the same as initial soil conditions. If sand is being added, a bulk density of 1.42 g/cm^3 can be assumed for the added material (use actual value if known) and adjust the Sa values up and C values down. The following equations can be used.

$$Sa_{adj} = \frac{1.42 * D_{Other} + \rho_{adj} * D_{Till} * Sa}{\rho_{adj} * D_{Till} + 1.42 * D_{Other}} \quad (16)$$

$$C_{adj} = \frac{\rho_{adj} * D_{Till} * C}{\rho_{adj} * D_{Till} + 1.42 * D_{Other}} \quad (17)$$

Where, Sa_{adj} and C_{adj} are adjusted sand and clay content. To estimate the impact of changes to the Sa and C values on the resulting K_{Sat} of the amended soil, use Sa_{adj} and C_{adj} in equations 1 through 7, above. Similar to adding sand, adding compost will change the volume of OM in the amended soil. This change can be accounted for by:

$$OM_{adj} = \frac{D_{Compost} * OM_{Compost} + D_{Till} * OM_{Vol}}{D_{Result}} \tag{18}$$

Where, $OM_{Compost}$ is the volumetric fraction of OM in the compost being added, OM_{Vol} is the volumetric fraction of OM in the un-amended soil, which was assumed to be:

$$OM_{Vol} = \frac{OM * \rho_{adj}}{\rho_{OM}} \tag{19}$$

Where $\rho_{OM} = 0.5\ g/cm^3$.

The new OM value is used to re-calculate equations 1 through 13, which will allow quantification of soil hydraulic property changes. Ultimately, changes in K_{Sat} are used with the infiltration depth (L_f) in Table 10, equation 5.1.3.1, and, subsequently, equation 5.1.3.2 to quantify changes for the entire site.

Part 3: Curve Number Weighting

Due to the nature of disconnection, the impervious and pervious areas should remain segregated for purposes of analysis. Runoff from the impervious area becomes effective rainfall, and is used, along with actual rainfall, when determining pervious area runoff. Ultimately, the difference in site runoff for existing (before) and amended site conditions (after) is used with the impervious to pervious ratio (I:P) to determine water treated (in) per impervious acre.

The general form of the CN equation is represented in Equation 20.

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{20}$$

Where Q is runoff in inches, P is rainfall amount in inches, and S is potential retention in inches. Potential retention is related to curve number with equation 21.

$$S = \frac{1000}{CN} - 10 \tag{21}$$

For purposes of this protocol, the precipitation (P) value to be used in 1.0 inches, which allows for the best representation of average annual conditions (Figure E- 1).

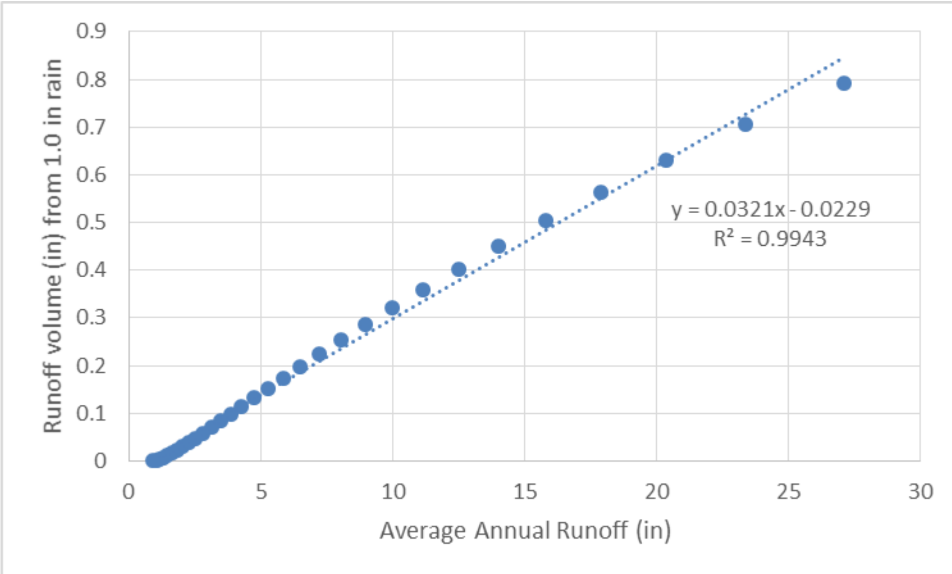

Figure E- 1. High correlation between average annual runoff from Regan National Airport and runoff from a single 1.0 rain event. These data are resulting runoff from CN values between 98 (upper end) and 68 (i.e. each point on the graph represents a CN, so a CN of 98 has a long term annual average runoff of 27 inches, and the runoff from a 1.0 inch rain storm using a CN of 98 is 0.8 inches.

Additionally, this protocol requires the segregation of impervious and pervious areas, which can be calculated with the following equations. As to not mute the impact of impervious runoff, the impervious area is segregated and the standard CN of 98 is assigned.

$$Q_{imp} = \frac{(P-0.2S)^2}{P+0.8S} \tag{22}$$

Where Q_{imp} is runoff volume (in) from impervious area, P is rainfall (1.0 in), and S is potential retention (in) from equation 24 (S = 0.204 inches when CN = 98. The resulting runoff is directed towards the pervious area and effectively changes the rainfall amount "seen" by pervious.

$$Q_{pervious} = \frac{\left(P_{eff}-0.2S_{pervious}\right)^2}{P_{eff}+0.8S_{pervious}} \tag{23}$$

Here $S_{pervious}$ is calculated with equation 21 using the CN value from equation 5.1.3.1, which is calculated with site specific $K_{SatEffective}$. The P_{eff} variable is effective rainfall (in) and is equal to $Q_{imp} + P$. Additionally, if an overall analysis of the site is preferred, runoff can be spread over the site using equation 24.

$$Q_{Site} = \frac{Q_{pervious} * A_{pervious}}{A_{Site}} \quad (24)$$

Where Q_{Site} is runoff volume (in) from the site after disconnection, $A_{pervious}$ is the area of pervious land being used for the disconnect and A_{Site} is the total area of the site.

Again, if preferred, the overall CN_{Site} value can be calculated by using Q_{Site} in equation 25.

$$CN_{Site} = \frac{1000}{5\left[P + 2Q_{Site} - \sqrt{Q_{Site}(4Q_{Site} + 5P)}\right] + 10} \quad (25)$$

All parameters in equation 25 are as defined above.

This approach was used over simple area weighting since the impervious runoff was being explicitly directed towards the pervious area. This approach is done for both existing (before or initial) and amended (after) conditions. The difference in site runoff between these two conditions is the water treated for the site. For purposes of reporting this can easily be converted into a total volume (cubic feet) by dividing by 12, and by multiplying by the site area in square feet. The difference in site runoff between before and after conditions can also be quantified in terms of inches per impervious acre by dividing the difference by the impervious area in acres. The result can be used with Section 5.3.

Part 4: Infiltration Depth

Using an effective saturated hydraulic conductivity ($K_{SatEffective}$) to estimate the curve number (CN) of pervious area with equation 5.1.3.2 is an iterative process. The resulting $K_{SatEffective}$ is dependent on infiltration depth (L_f), which is dependent on how much water runs off the site, which is dependent on the CN, which is, again, dependent on $K_{SatEffective}$. In order to get around the need for this iterative process, a generalized and largely conservative set of L_f values has been developed based on the impervious to pervious ratio (I:P) (Table 10).

The need for iteration can be shown with this example:
A pervious area of 0.25 acres is receiving runoff from an impervious area of 1.25 acres (I:P = 5). Soil type in the pervious area is a sandy clay loam with a compaction factor of 1.1 (bulk density = 1.63 g/cm^3). The soil amendment is 1 inch of compost (assumed to have 50% organic matter and a bulk density of 0.5 g/cm^3). The compost is incorporated 3 inches into the existing soil. Initial guess on L_f is 4 inches, which roughly corresponds with the amendment/incorporation depth. The resulting CN is 86.25, which results in a runoff volume of 0.57 inches (given the I:P and a 1.0 inch rain event). The difference between 1.0 inches and 0.57 inches (0.43 inches) is the amount of water staying on-site and is assumed to be largely infiltration. When considering available pore space, which is assumed to be the difference between saturated moisture content and moisture at field

capacity (0.17, in this case), L_f can be calculated as the infiltration amount of 0.43 inches over the entire site or 2.55 inches on the pervious area divided by the available porosity of 0.17, which gives 15.27 inches (L_f = 15.27 inches). This "new" L_f would replace the initial guess of 4 inches and the calculations would be repeated, which gives a CN of 95.8 and another "new" L_f of 9.16 inches to be plugged in again to give a CN of 94.8 and another "new" L_f of 9.86 inches. This scenario finally settles with a CN of 95.0 and an L_f of 9.74 inches and a water treated value of 0.054 inches per impervious acre. When using the simplified approach, the L_f for an I:P of 5 is 14 inches, which results in a CN of 95.7 and a water treated value of 0.038 inches per impervious acre.

For initial evaluation, a matrix with 1,989 scenarios was developed. A total of 17 I:P ratios were used, ranging from 0.25 to 15, sand content ranged from 7% to 60%, clay content ranged from 6% to 47%, and organic matter ranged from 1% to 3%. Sand and clay content ranges were based on suggested sand and clay contents of silt loam, silt, loam, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay from the SPAW Soil Water Characteristic Model (Saxton & Rawls, 2009). Combinations of sand and clay exceeding 100% were removed from the analysis. These scenarios were used with an iterative L_f approach to develop an "actual" L_f (Figure E- 2), which, in turn, was used to calculate an "actual" water treated value. As a, generally, conservative as well as user friendly approach was a goal, the best fit line was not used for Table 10 development, rather, an upper infiltration depth of 34 inches was used with a minimum of 6 inches. The 6 inch minimum is applied to I:P of 1 or less to insure conservative estimates of water treated.

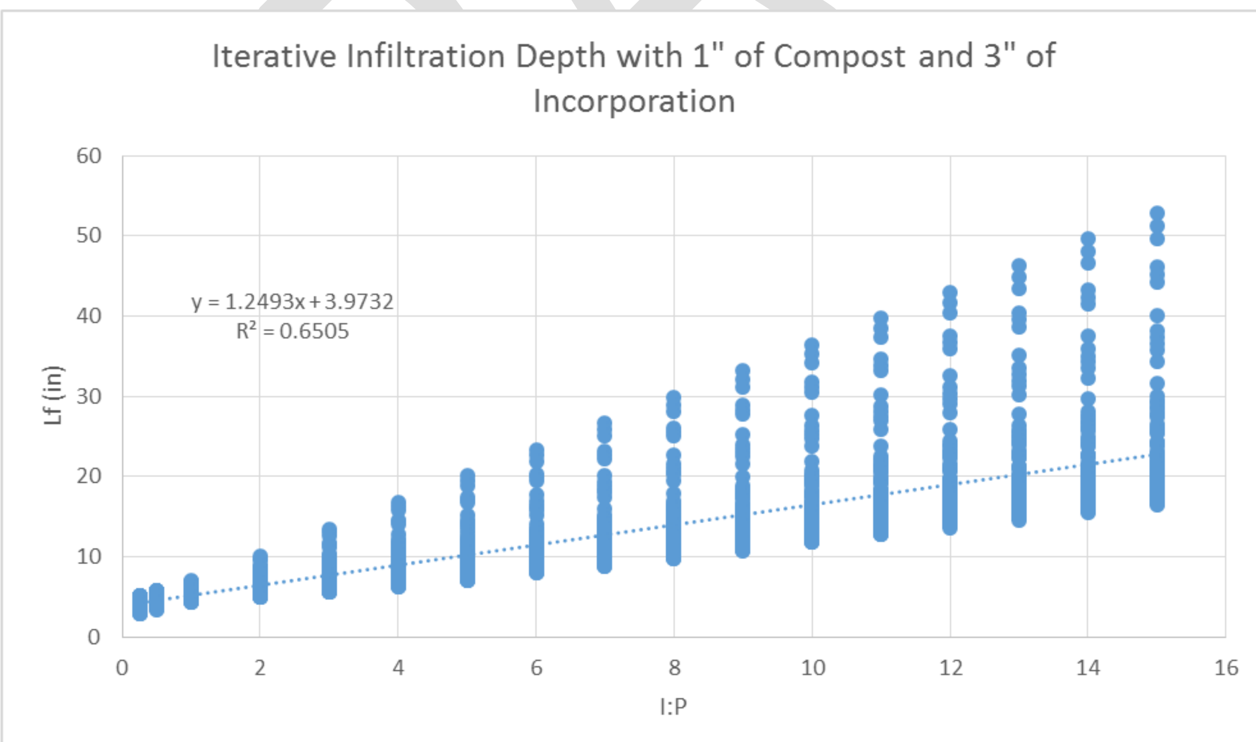

Figure E- 2. "Actual" infiltration depth as a function of impervious to pervious ratio (I:P). Variation is due to differing value of sand, clay, and organic matter. Scenario shown is for a minimal amendment and incorporation effort of 1 inches of compost and 3 inches of incorporation.

The "actual" values of water treated served as a comparator to the resulting water treated using newly developed L_f. For the scenario with 1 inch of compost and 3 inches of incorporation and an initial compaction factor (CF) of 1.1 (Figure E- 3), roughly 98% of the scenarios were predicting water treated less than "actual" values (conservative). When applied to other scenarios, the newly developed L_f also works well. The following figures show the results of "actual" and predicted water treated as a result of the newly developed L_f values for various scenarios including 3 inches of compost with 6 inches of incorporation and a CF of 1.1 (Figure E- 4) (90% conservative), no compost amendment but decompaction to 3 inches from a CF of 1.1 to a CF of 1.0 (Figure E- 5) (95% conservative), 1 inch of sand with incorporation depth of 3 inches and a CF of 1.1 (Figure E- 6) (96% conservative), 1 inch of compost with incorporation depth of 3 inches and a CF of 1.0 (Figure E- 7) (90% conservative), and finally, 1 inch of compost with incorporation depth of 3 inches and a CF of 1.2 (Figure E- 8) (99% conservative). Again, accuracy in all scenarios was secondary to providing conservative estimates of performance.

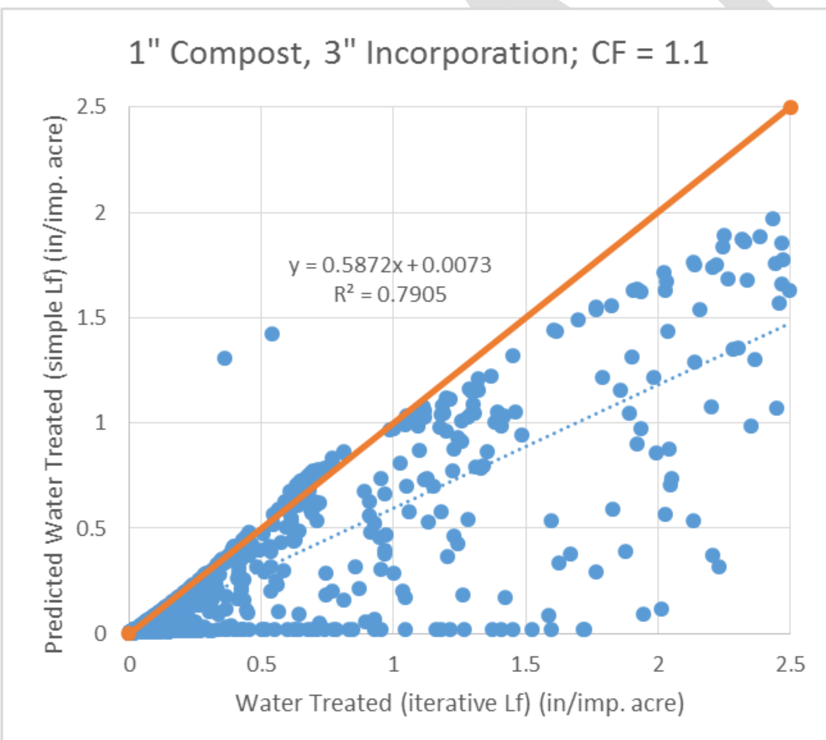

Figure E- 3. . Predicted water treated using conservative infiltration depth estimates resulting from 1 inch of compost with 3 inches of incorporation and a compaction factor of 1.1. Data to the right of the straight line is under predicting, or conservative.

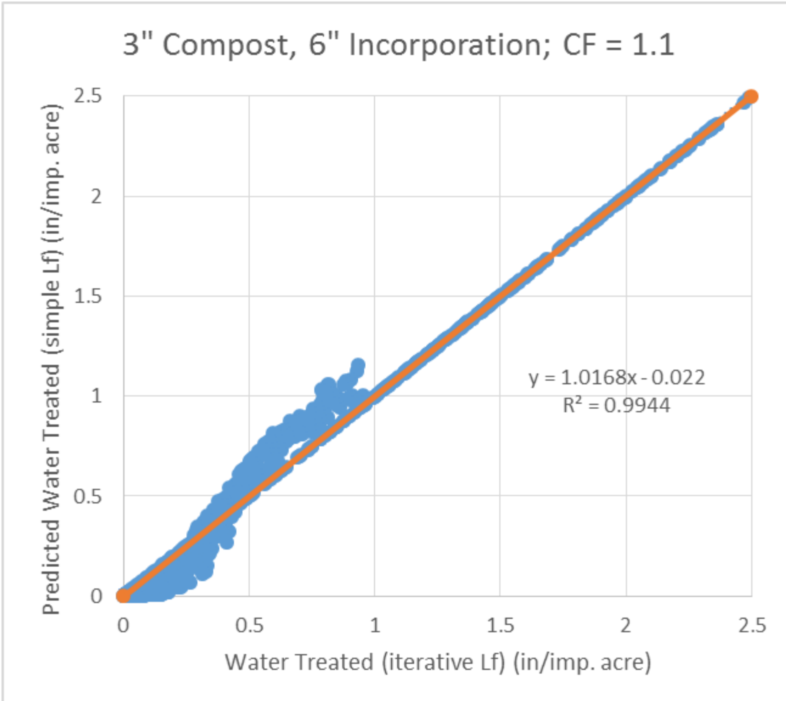

Figure E- 4. Predicted water treated using conservative infiltration depth estimates resulting from 3 inches of compost with 6 inches of incorporation and a compaction factor of 1.1. Data to the right of the straight line is under predicting, or conservative.

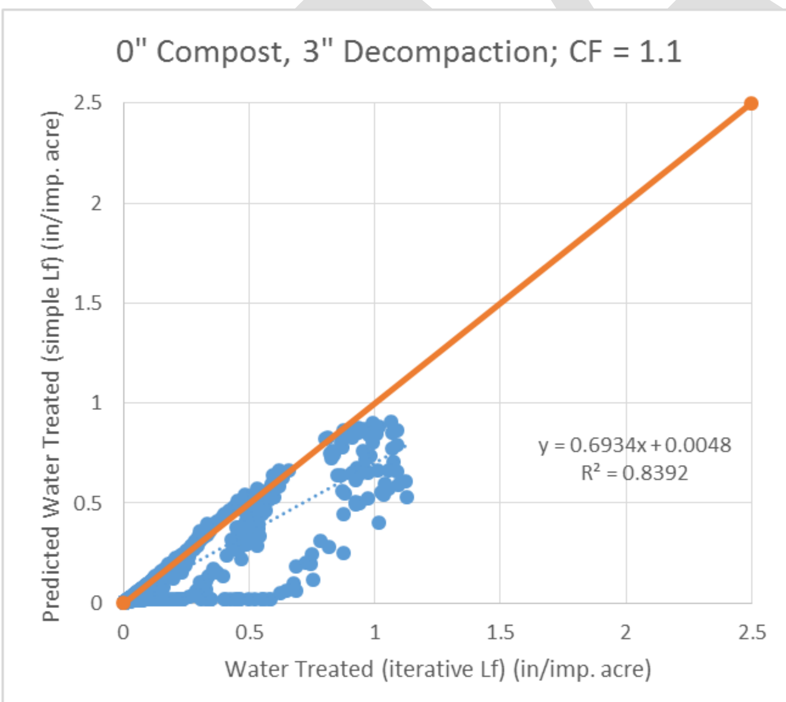

Figure E- 5. Predicted water treated using conservative infiltration depth estimates resulting from 0 inches of compost with 3 inches of decompaction and a compaction factor of 1.1. Data to the right of the straight line is under predicting, or conservative.

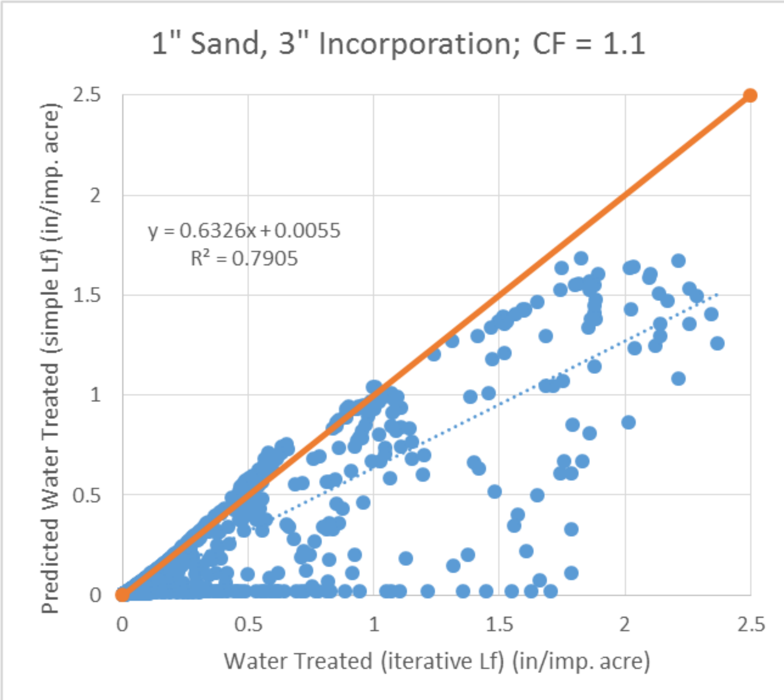

Figure E- 6. Predicted water treated using conservative infiltration depth estimates resulting from 1 inch of sand with 3 inches of incorporation and a compaction factor of 1.1. Data to the right of the straight line is under predicting, or conservative.

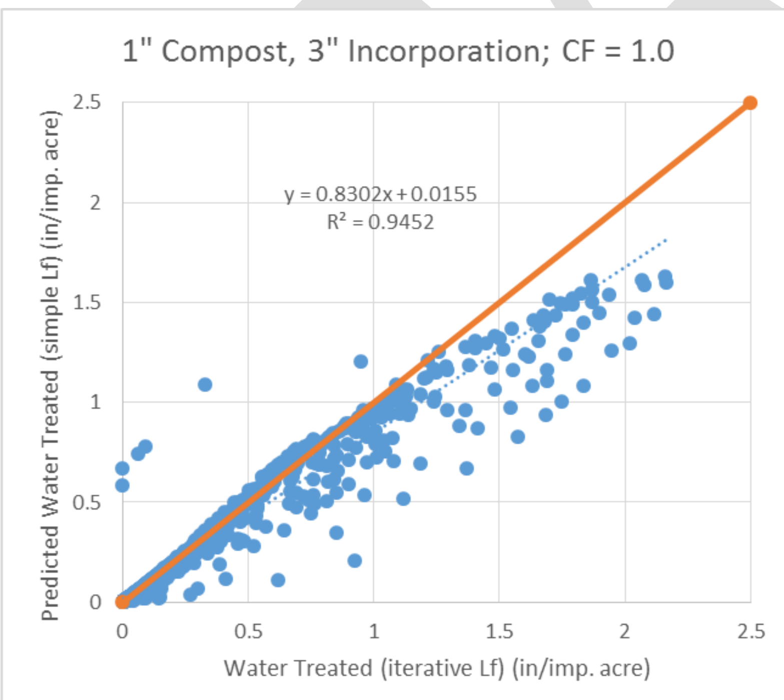

Figure E- 7. Predicted water treated using conservative infiltration depth estimates resulting from 1 inch of compost with 3 inches of incorporation and a compaction factor of 1.0. Data to the right of the straight line is under predicting, or conservative.

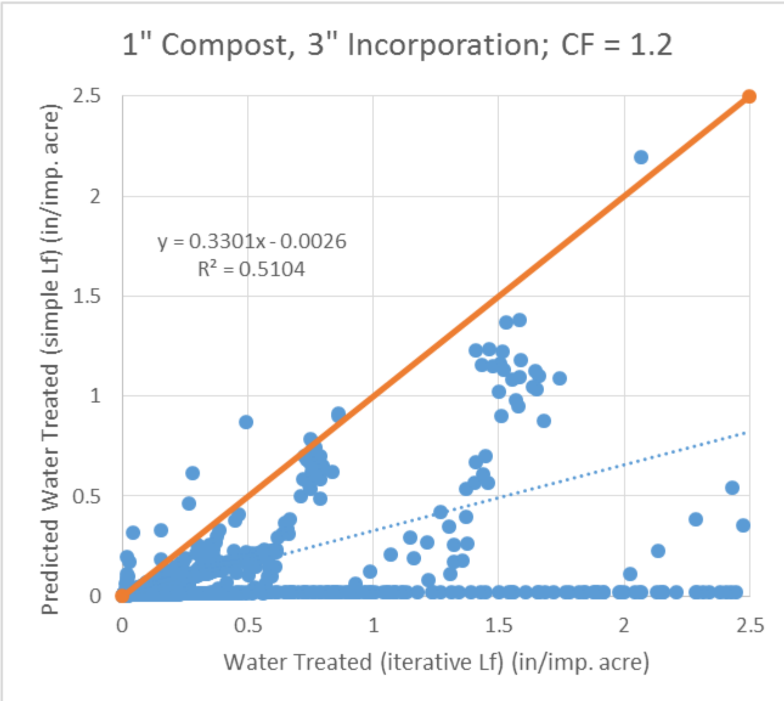

Figure E- 8. Predicted water treated using conservative infiltration depth estimates resulting from 1 inch of compost with 3 inches of incorporation and a compaction factor of 1.2. Data to the right of the straight line is under predicting, or conservative.

Part 5: Simplified Curve Development

Using the simplified L_f values (Table 10), curves can be developed for soil classifications falling in the hydrologic soil group (HSG) C or D range. These curves were the basis for simplified versions presented in Figure 6 to Figure 8 of Section 5.1.2, where averages of initially loose, medium, and tight soils (Table 8) are shown. Individual soil trends are provided in Figure E- 9 to Figure E- 11 for reference. Sandy clay was not included in any of the simplified curves – please use the computational method (Section 5.1.3) if considering amending this type of soil. The computational method should also be used when initial organic matter is low (1% or less) with sandy clay, clay loam and silty clay soils. Sand and clay content for these soils are provided in Table E- 3, and are consistent with the SPAW model.

Table E- 3. General soil characteristics after Saxton and Rawls (2006).

Soil Type	Sand Content (% by volume)	Clay Content (% by volume)
Silt loam	20%	20%
Silt	7%	6%
Loam	42%	18%
Sandy clay loam	60%	28%
Clay loam	33%	34%
Silty clay loam	10%	34%
Sandy clay	52%	42%
Silty clay	7%	47%

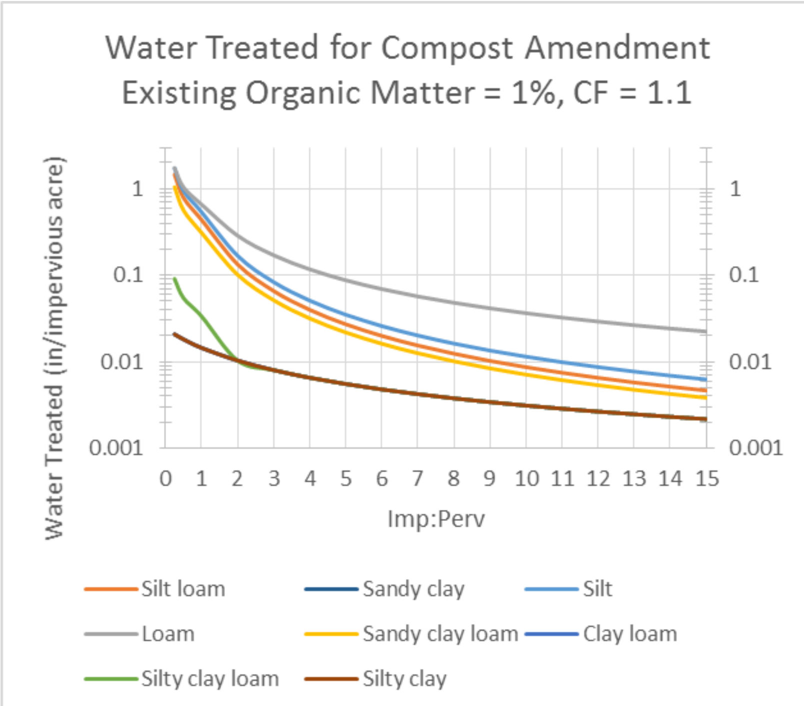

Figure E- 9. Basis for simplified treatment curves. Note that sandy clay, clay loam, and silty clay are not suitable when initial organic matter is 1% or less.

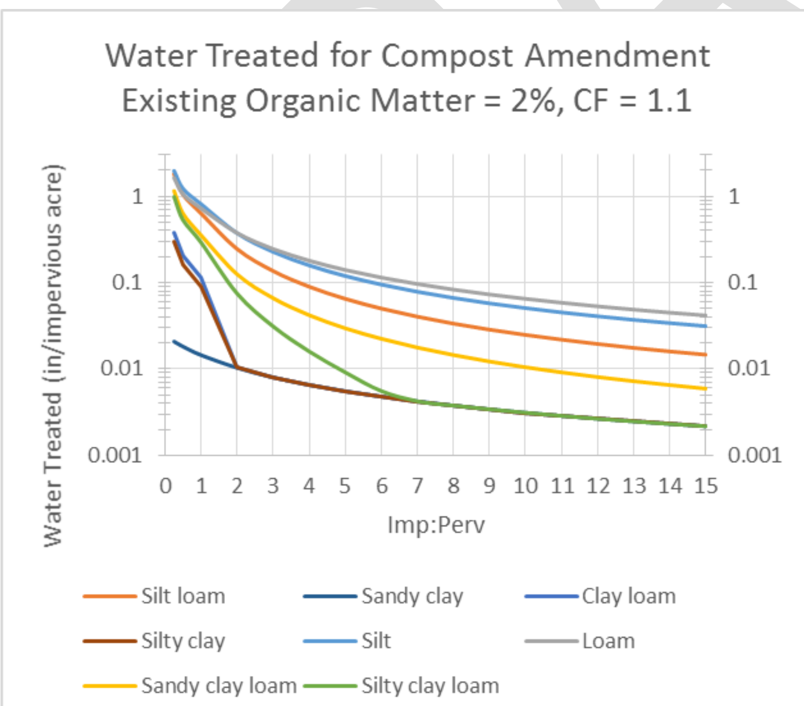

Figure E- 10. Basis for simplified treatment curves. Note that sandy clay is not suitable when initial organic matter is between 1% and 2%.

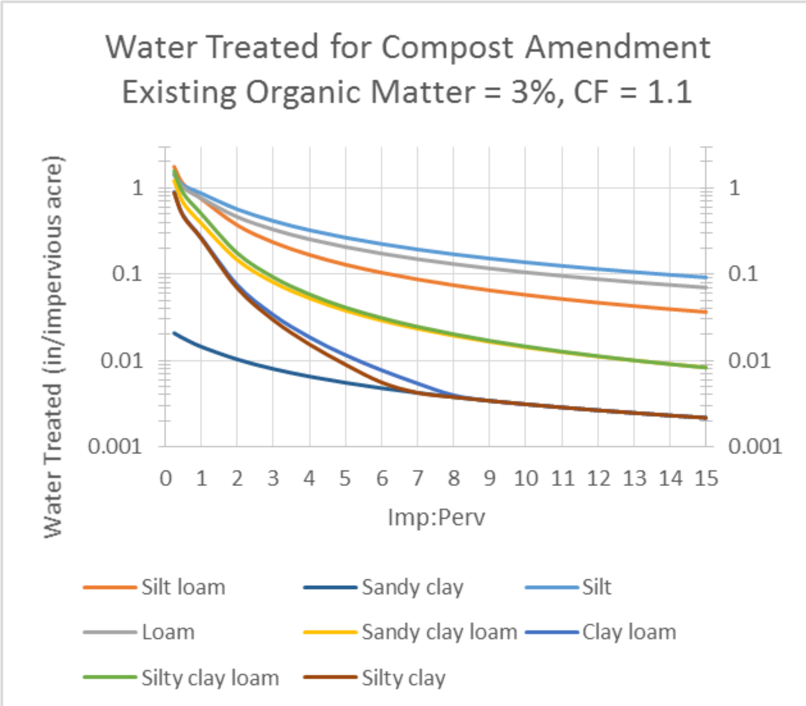

Figure E- 11. Basis for simplified treatment curves. Note that sandy clay is not suitable when initial organic matter is 3% or more.