Memorandum

To: MIDS Work Group
From: Barr Engineering Company
Subject: MIDS Subtask 2.2(1): Recommend Credits for MIDS Practices
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Project: 23621050.00 MIDS

The goal of MIDS Subtask 2.2(1) is to review, evaluate, and discuss the applicability and pros and cons for structural and non-structural Best Management Practices (BMPs) while devising and defining a volume and pollutant reduction amount for each BMP.

1. Introduction and Summary

Barr reviewed the 32 structural and non-structural BMPs developed by the MIDS subcommittee. First, we defined each of BMP, and then we grouped each BMP by volume and pollutant reduction processes. Based on an extensive literature search of both credit methodologies used by organizations and peer-reviewed research, we summarized the applicability to MIDS and the pros and cons for each individual BMP. We used this information to offer three alternative scenarios to the MIDS Work Group for quantifying stormwater runoff volume and pollution reduction.

"Credit" Assignment Scenarios:

The stormwater runoff volume reductions ("credit") of each BMP could be defined through various processes and used in a "calculator" in various ways, including:

1) Quantifying reductions based on literature-reported values. Volume (and pollution) reduction percentages obtained from literature sources would be used to apply credits. The procedure would be a preliminary test for volume and pollution reduction followed by modeling of the site. The "calculator" could be a screening tool that allows the user to determine how much the BMPs reduce the volume (and possibly pollutants). Or, the "calculator" could be the main design tool.

2) Quantifying reduction amounts of individual BMPs based on devised relationships between BMP parameters and volume reduction. Volume reduction would be determined through multivariate regression analysis between model parameters and volume reduction capacity. Information would be obtained through extensive literature search and deterministic modeling. Pollution reduction would be applied in same manner as Scenario 1. As with Scenario 1, the "calculator" could be a screening tool or the main design tool.
3) Allow currently accepted hydrologic models to quantify the runoff reductions of proposed on-site BMPs. Barr could provide standardized modeling methods for various LID BMPs and develop a bookkeeping system to quantify need volume reduction and track amounts provided by the proposed BMPs.

2. BMP Overview

Tables 1 and 2 list and provide brief definitions for each of the structural and non-structure BMP identified by the MIDS subcommittee. The various BMPs are grouped into three different BMP types:

1) Runoff volume reduction/infiltration – includes practices that reduce some volume of runoff through infiltration. Some practices reduce more volume than others (e.g., bioretention basin vs. filter strips), but all practices are capable of some infiltration to reduce runoff volume.

2) Runoff volume reduction/non-infiltration – includes practices that reduce runoff volume without being dependent on infiltration.

3) Runoff quality treatment/ no infiltration – includes practices whose primary functions are to provide water quality treatment. These practices do not utilize infiltration; however, some may contribute to a small amount of volume reduction through absorption into soils and evapotranspiration.

Table 1. Definitions of Structural BMPs

BMP Type	BMP	Definition
Runoff Volume Reduction/Infiltration	Infiltration basin	A natural or constructed impoundment/bioretention basin with permeable soils that captures, temporarily stores, and infiltrates the design volume of water within 48 hours (24 hours within trout stream watersheds).
	Bioretention basin/ Rainwater garden without drain tile	An infiltration basin (above) that includes vegetation and utilizes the chemical, biological, and physical properties of plants, microbes, and soils for reducing runoff and removing pollutants. Bioretention basins typically have a maximum ponding depth of 6 inches and a maximum pooling depth of 18 inches that ensures survival of planted vegetation.
	Bioretention basin/ Rainwater garden with suspended drain tile	A bioretention basin (above) but modified to include a drain tile that is "suspended" in the underlying media in such a way that allows infiltration at a rate compatible with underlying soils but carries away excess water in the drain tile after it has filtered through the bioretention basin.
	Infiltration trenches	A shallow excavated trench, typically 3 to 12 feet deep, that is backfilled with a coarse stone aggregate allowing for the temporary storage of runoff in the void space of the material. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Trenches are commonly used for drainage areas less than 5 acres in size.
	Infiltration shelves	Area surrounding a detention pond able to infiltrate runoff when pond overflows and/or water is directed to the outflow pipe.
	Pervious pavement without drain tile	Pervious pavements reduce runoff volumes by allowing water to pass through surfaces that would otherwise be impervious. Pervious pavements can be subdivided into three general categories: 1) Porous Pavements – porous surfaces that infiltrate water across the entire surface (i.e., porous asphalt and porous concrete pavements); 2) Permeable Pavers – impermeable modular blocks or grids separated by spaces or joints that water drains through (i.e., block pavers, plastic grids, etc.); 3) Amended Soils - Fiber or artificial media added to soil to maintain soil structure and prevent compaction.
	Pervious pavement with suspended drain tile	Same as pervious pavement (above) but modified to include a drain tile that is "suspended" in the underlying media in such a way that allows infiltration at a rate compatible with underlying soils but carries away excess water in the drain tile after it has filtered through the pervious pavement and base media.
	Dry swale without drain tile	In dry swales, the entire water quality volume is temporarily retained by checkdams during each storm. Unlike the grass channel, the filter bed in the swale is 30 inches of prepared soil, which allows the water to filter through.
	Dry swale with suspended drain tile	Same as dry swale (above) but modified to include a drain tile that is "suspended" in the underlying media in such a way that allows infiltration at a rate compatible with underlying soils but carries away excess water in the drain tile after it has filtered through the pervious pavement and base media.
	Underground Infiltration	Underground storage (including pre-manufactured pipes, vaults, and modular structures) are used to temporarily store and infiltrate the design volume of runoff..

BMP Type	BMP	Definition
Runoff Volume Reduction/Non-infiltration	Green roofs	Green roofs consist of a series of media layers that create an environment suitable for plant growth without damaging the underlying roof system. Green roofs create green space for public benefit, energy efficiency, and stormwater retention/ detention.
	Harvested and re-use	Rain water harvesting is the practice of collecting rain water from impermeable surfaces, such as rooftops, and storing for future use. There are a number of systems used for the collection, storage and distribution of rain water including rain barrels, cisterns, evaporative control systems, and irrigation. Harvested rainwater can be reused in irrigation or even treated water to be used for drinking, laundry, sanitation or irrigation
Runoff Quality Treatment / No or Minor Runoff Volume Reduction	Biofiltration basin/ Rainwater garden with drain tile and impermeable layer	Nearly identical to bioretention basins with the addition of a drain tile at an impervious layer or slow-draining soil horizon. This type of biofiltration basin is often used in areas of potential stormwater “hot-spots” (e.g., gas stations, transfer sites, transportation depots, etc.), areas where groundwater recharge is undesirable, or areas with less optimal infiltration rates in the underlying soil.
	Pervious pavement with drain tile and impermeable layer	Pervious pavement with the addition of a drain tile at an impervious layer or slow-draining soil horizon below the designed filtration media. This design modification for pervious pavement is often used in areas of potential stormwater “hot-spots” (e.g., gas stations, transfer sites, transportation depots, etc.), areas where groundwater recharge is undesirable, or areas with less optimal infiltration rates in the underlying soil.
	Grass channel	Grass channels are designed to convey stormwater runoff. Typical specifications include a runoff velocity target of 1 foot per second and the ability to handle the peak discharge from a 2-year design storm and pass larger storms. Grass channels do not provide adequate pollutant removal benefits to act as a stand-alone BMP. Stormwater volume reductions can be created by placing checkdams across the channel.
	Dry swale with drain tile and impermeable layer	Dry swale with the addition of a drain tile at an impervious layer or slow-draining soil horizon. This design modification for a dry swale is often used in areas of potential stormwater “hot-spots” (e.g., gas stations, transfer sites, transportation depots, etc.), areas where groundwater recharge is undesirable, or areas with less optimal infiltration rates in the underlying soil.
	Wet swale	Wet swales occur when the water table is located very close to the surface. This wet swale acts as a very long and linear shallow wetland treatment system. Like the dry swale, the entire water quality treatment volume is stored within a series of cells created by checkdams. Cells may be planted with emergent wetland plant species to improve pollutant removal.
	Wet pond	Constructed basins placed in the landscape to capture stormwater runoff. The pond is graded and outlet structures are designed in such a way that specified volumes of water are either held until displaced by future runoff or detained for a specified period of time. While the runoff is being held in the pond, sediment and associated pollutants settle to the bottom. Pollutants can also be removed from the stormwater through microbial, plant and algal biological uptake.

BMP Type	BMP	Definition
	Filter strips	Filter strips rely on vegetation and sheet flow across the entire strip to slow runoff velocities and filter out sediment and other pollutants from urban stormwater.
	Sand filters	Sand filters utilize a porous media (usually sand) to filter pollutants from runoff. These BMPs typically include an on-line or off-line sedimentation chamber; a layer of filter media separated from a gravel bed by a geotextile fabric; and a series of drain tile is also often included to collect runoff after passing through the sand filter and discharge it to the outflow point. Sand filters can be divided into three sub-classes: surface sand filter, underground sand filter; and perimeter sand filter.
	Enhanced sand filters	Incorporates a media, such as iron and alum, into a sand filter BMP. These enhancements can increase the removal of phosphorus and/or other pollutants from normal sand filters.
	Underground storage/ detention	Storage tanks either incorporated directly into or before the storm sewer system. Stormwater is released at a controlled rate to a sewer system or open water course. If the storage systems are bottomless or perforated, they will allow infiltration.
	Pretreatment	Stormwater is pretreated before it is infiltrated to filter pollutants and/or remove contaminates that might impair the performance of a downstream BMP.
	Optimized stormwater flow network	Manual or technical operations that optimize treatment of stormwater. For example, the water level of a wet detention pond could be controlled and lowered after stormwater has been treated to release cleaner water and provide storage for the next runoff event.
	Enhanced sedimentation operations	Chemical and biological treatment of stormwater enhances settling of suspended sediment by encouraging flocculation. Variations include aluminum sulfate, ferric chloride, chitosan, and polyacrylamide. Chemical and biological treatments are typically used as a final or polishing step in the treatment train.

Table 2. Definitions of Non-Structural BMPs

BMP Family	BMP	Definition
Landscape management	Cluster development/ conservation design	Residential development that concentrates lots in a compact area of the site to allow for greater conservation of natural. Minimum lot sizes, setbacks and frontage distances are relaxed so as to maintain the same number of dwelling units at the site.
	Urban forestry	Reforestation. Planting trees on existing turf or barren ground with the goal of establishing a mature forest canopy that can intercept rainfall and maximize infiltration.
	Soil protection and amendments	Areas not being developed are left undisturbed. Soil compaction due to heavy equipment during construction is minimized. Compacted soils can be amended through ripping or tilling or the addition of conditioners such as compost, top soil, lime or gypsum to the soil for the goal of increasing the infiltration capacity of the soils.

BMP Family	BMP	Definition
Impervious surface design/ management	Linear projects	Reducing the amount of impervious surfaces in a development by reducing street/sidewalk/trail widths and cul-de-sac radii.
	Parking lot design	Designing parking lots to reduce the amount of impervious surface area constructed.
	Impervious surface disconnection	Eliminating direct impervious surface to storm sewer pathways by including buffers of pervious area between systems.
Operations and maintenance		Practices designed to eliminate pollutants before they are transported through runoff. For example, • managing impervious surfaces for buildup and wash off, seasonal operations, dry/wet cycles through street sweeping or other methods, or • managing turf and landscapes to encourage health, stormwater infiltration, and pollution reduction.

2.1 Stormwater Runoff Volume Reduction

The MIDS legislation calls for the runoff from developed sites to mimic native hydrology. As shown through modeling of various potential MIDS performance goals, stormwater volume reduction BMPs are needed to mimic native runoff volumes.

The BMPs examined through this task handle runoff reduction differently, and depending on design details and site conditions, the same BMP will handle runoff differently. To highlight these differences, each of the BMPs was grouped into five categories based on how runoff volume is reduced.

Practices that provide infiltration: These BMPs utilize naturally high infiltration rates or change the infiltration rates of an area either through changes in soils properties or routing stormwater over pervious areas.

Practices that provide stormwater runoff storage: These BMPs collect runoff for reuse in some other capacity, slowly releasing the runoff into a stormwater system or removing the collected runoff volume through evapo-transpiration.

Practices that provide evapo-transpiration: These BMPs have a significant vegetation component that reduces stormwater runoff by reducing soil moisture and enhancing the ability of the soil to absorb moisture during the next runoff event.

Practices that reduce the production of stormwater runoff/impervious surface reduction: These BMPs reduce the amount of impervious surface in the development; thus, reducing the stormwater runoff volume compared to the non-reduced situation.

Practices that do not reduce stormwater runoff volumes: These BMPs do not provide runoff volume reduction, but are useful in reducing pollutant loads. Disconnecting impervious surfaces is included in this no volume reduction group, but it is considered as a special case and will be discussed separately in a later section of this memorandum.

Table 3 groups the BMPs by these stormwater runoff volume reduction categories.

Table 3. BMPs Grouped by Stormwater Volume Reduction Mechanism

Key: ● = Major attribute; ○ = Minor attribute; Blank = Not applicable or unknown **BMP (see Tables 1 and 2 for definitions)**	**Infiltration**	**Storage**	**Evapo-transpiration**	**Impervious Reduction**	**No Direct Volume Reduction**
Infiltration basin	●	●	●		
Bioretention/Rainwater garden without drain tile	●	●	●		
Bioretention/Rainwater garden with suspended drain tile	○	●	●		
Infiltration trenches	●	●			
Infiltration shelves	●		●		
Pervious pavement without drain tile	●			○	
Pervious pavement with suspended drain tile	○			○	
Dry swale without drain tile	●	●	●		
Dry swale with suspended drain tile	○	●	●		
Underground infiltration	●	●			
Green roofs		●	●		
Harvested and re-use	○	●			
Biofiltration basin/Rainwater garden with drain tile at impermeable layer		●	●		●
Pervious pavement with drain tile and impermeable layer		○			●
Grass channel	○		○		

Key: ● = Major attribute; ○ = Minor attribute; Blank = Not applicable or unknown **BMP (see Tables 1 and 2 for definitions)**	**Infiltration**	**Storage**	**Evapo-transpiration**	**Impervious Reduction**	**No Direct Volume Reduction**
Dry swale with drain tile at impermeable layer	○	●	●		●
Wet swale		●	●		●
Wet pond		●	●		●
Filter strips	○		○		
Sand filters	○	●			●
Enhanced sand filters	○	●			●
Underground storage/detention		●			●
Pretreatment		●			●
Optimized stormwater flow network	○	●			●
Enhanced sedimentation operations					●
Cluster development/Conservation design				●	●
Urban forestry	○	○	●		
Soil protection and amendments	○		○		
Linear projects				●	
Parking lot design				●	
Impervious surface disconnection	○			●	●
Operations and maintenance	○				●

2.2 Pollution Reduction

While not specified within the MIDS legislation, developing consistent and agreed upon values for pollutant (total phosphorus and total suspended solids) removals from MIDS practices is a MIDS Work Group goal. Most of the BMPs evaluated contain a pollution reduction mechanism. To help quantify the pollution reduction capabilities, each BMP was placed into categories based on its pollution reduction mechanism (Table 4). Each mechanism is able to remove certain pollutants from the water column.

- **Adsorption:** The attachment of particles to soils media. Pollutants removed typically included metals and nutrients that have a net positive charge.

- **Filtration:** A physical process of removing solids from the runoff by trapping particles in a soil/sand media or through the use of a screen. This process is effective in removing suspended soils and pollutants attached to suspended solid, such as nutrients and metals.
- **Sedimentation:** Removal of solids from a water column by settling the particles in a basin.
- **Biological uptake:** The active removal of pollutants, typically nutrients, from the water column accomplished by vegetation or microbes located within the BMP.
- **Pre-runoff removal:** The active removal of pollutants in the watershed before a storm event occurs. This includes street sweeping, leaf removal, and other operational techniques used to eliminate pollutants as well as the reduction of impervious surfaces in the watershed which reduce pollutant sources.
- **No removal:** This category includes BMPs that have no pollutant removal mechanism.

Table 4. Pollutant Reduction Mechanism

BMP	Adsorption	Filtration	Sedimentation	Biological/ Microbe uptake	Pre - runoff removal	No removal
Infiltration basin	X	X		X		
Bioretention/Rainwater garden without drain tile	X	X		X		
Bioretention/Rainwater garden with suspended drain tile	X	X		X		
Infiltration trenches	X	X		X		
Infiltration shelves	X	X		X		
Pervious pavement without drain tile	X	X				
Pervious pavement with suspended drain tile	X	X				
Dry swale without drain tile	X	X	X	X		
Dry swale with suspended drain tile	X	X	X	X		
Underground infiltration	X	X		X		
Green roofs	X	X		X		
Harvested and re-use						X
Biofiltration basin/Rainwater garden with drain tile at impermeable layer	X	X		X		

BMP	Adsorption	Filtration	Sedimentation	Biological/ Microbe uptake	Pre - runoff removal	No removal
Pervious pavement with drain tile and impermeable layer	X	X				
Grass channel			X			
Dry swale with drain tile at impermeable layer	X	X		X		
Wet swale			X			
Wet pond	X		X	X		
Filter strips		X				
Sand filters		X				
Enhanced sand filters	X	X				
Underground storage/detention			X			
Pretreatment	X	X	X	X	X	
Optimized stormwater flow network						X
Enhanced sedimentation operations	X		X	X		
Cluster development/Conservation design					X	
Urban forestry	X	X		X		
Soil protection and amendments	X	X	X	X		
Linear projects					X	
Parking lot design					X	
Impervious surface disconnection					X	X
Operations and maintenance					X	

2.3 BMP Pros and Cons

The use of BMPs can provide many advantages to a stormwater management plan. These practices also have their limitations. Barr has provided a list of pros and cons for the BMPs identified by the MIDS Work Group. Descriptions of basic pros and cons are listed and described below. Table 5 provides a summary of the pros and cons of each BMP.

Pros

- **Decrease surface runoff:** All BMPs that have a volume reduction mechanism will decrease surface runoff in a watershed.
- **Increase groundwater recharge:** All BMPs that increase infiltration will increase groundwater recharge in a watershed.
- **Reduce peak discharge rates:** All BMPs that have a volume reduction mechanism will reduce peak discharge rates from some storms. This includes BMPs that promote infiltration and/or storage
- **Reduced construction costs:** Many of the BMPs cost less than conventional curb and gutter systems. They can also decrease the demand and needed capacity of municipal storm sewer systems and reduce flooding events.
- **Pollutant removal:** Many of the evaluated BMPs can remove pollutants from stormwater runoff. By infiltrating the stormwater, soils, plants, and microbes can filter or break down many pollutants found in stormwater runoff. Pollutants are also removed close to the source, reducing the transport to other waterbodies.
- **Reduce pollutant application:** Certain BMPs can limit the amount of pollutants applied to the landscape. For example, by preventing stormwater runoff from ponding and then freezing, pervious pavement can dramatically reduce the need for road salt. A study at the University of New Hampshire concluded that road salt applications can be reduced by between 75% and 100% in areas using pervious pavements while obtaining the same roadway traction. Covering a landscape with natural vegetation that also increases stormwater infiltration can limit the need for fertilizers used on conventional lawns.
- **Improve air quality:** The increased use of trees and other vegetation in urban areas can improve air quality through leaf uptake, contact removal and the absorption of air pollutants to the vegetation.
- **Urban heat island mitigation:** The use of trees and other vegetation can shade impervious areas reducing temperature in urban areas. Also, narrow streets and tall buildings can trap heat and concentrate waste heat from building and cars. The inclusion of green areas in the city design can limit the amount of trapped heat through the inclusion of a more open design.

- **Reduce runoff temperature:** Many BMPs can reduce the temperature of runoff before it reaches receiving waters. This feature is especially important for watersheds with trout streams or other cold water ecosystems that are impacted by relatively warm runoff. Practices that infiltrate, filtrate, shade, or reduce impervious areas typically help reduce runoff temperatures.
- **Compatible with all soil types:** Compatibility with all soil types provides flexibility for installing a particular BMP in any location where site design allows for sufficient space.
- **Flexible design parameters:** Some BMPs can achieve identical functions with a variety of different shapes and configurations.
- **Small surface area:** For developments with a small overall area, BMPs that require a smaller amount of surface area can help optimize usage of the space.

Cons

- **Vertical separation from groundwater:** Infiltration practiced need to have vertical separation of at least three feet from the seasonal high water table.
- **Possible groundwater contamination:** Groundwater contamination could occur with any of the infiltration practices. Pollutants not removed from runoff would be given a direct path to groundwater. One example includes chloride from de-icing chemicals. All infiltration BMPs should not be constructed near stormwater pollution hotspots or groundwater wells to reduce groundwater contamination. (See MIDS memorandum: Identify Restrictions for MIDS Practices to Protect Groundwater and Prevent Sinkholes (Work Plan 3, Item 2; MIDS Subtask 2.3).)
- **Restrictive in high slope terrain:** Many infiltration practices need mild slopes to effectively infiltrate runoff. These include pervious pavements (only constructed on slopes < 5%), bioretention basins (may require terraces for slopes >20%), vegetative swales, green roofs (require a wooden lath grid or other retention system for slopes >15%), and filter strips.
- **Restrictive in low permeable soils:** Infiltration BMPs will be limited in areas where underlying soils have low permeability, such as type D soils.
- **Restricted by city policies:** BMPs designed to limit impervious surface areas such as linear projects, parking lot designs, or even density increases, may be restricted based on city policies. These policies include cul-de-sac radii, street or sidewalk widths.

- **Require continued maintenance:** To keep BMP effectiveness, infiltration rates need to be maintained. This includes preventing soil compaction in bioretention areas or clogging caused by sand and silt in pervious pavements or other infiltration BMPs.
- **Higher construction costs:** Some BMPs require significantly higher construction costs compared to conventional construction practices.
- **Space consumption:** Some BMPs require a relatively large surface area to be effective.

Table 5. BMP Pros and Cons

Key:
● = Strongly/usually applicable
◑ = Moderately/occasionally applicable
○ = Poorly/rarely applicable
Blank = Not applicable or unknown

BMP	Pros													Cons								Notes
	Decreases runoff volume	Recharges groundwater	Reduces peak discharge rates	Reduces construction costs	Removes pollutants	Reduces pollutant application	Improves air quality	Mitigates urban heat island	Reduces runoff temperature	Compatible with all soil types	Flexible design parameters	Small surface area at site		Separation from groundwater	Groundwater contamination	Restrictive for high slopes	Poor for low permeable soils	Restricted by city policies	Maintenance intensive	Higher construction costs	Space consumption	
Infiltration basin	●	●	●		●				●		◑			●	◑	●	●	◑	●	◑	●	
Bioretention basin/Rainwater garden without drain tile	●	●	●		●				●		◑			●	◑	●	●	◑	●	◑	●	
Bioretention basin/Rainwater garden with suspended drain tile	◑	●	●		●				●		◑			◑	◑	●	◑	◑	●	◑	●	
Infiltration trenches	●	●	●		●				●					●	◑	◑	●					
Infiltration shelves	●	●	●		○				●		◑			●	○	●	●		◑	◑	◑	
Pervious pavement without drain tile	●	●	●	○	●				●			●		●	◑		●		◑	◑		
Pervious pavement with suspended drain tile	◑	●	●	○	●				●	◑		●		◑	◑		●		◑	◑		
Dry swale without drain tile	●	●	◑		●				●		◑			●	◑	●	●		○			
Dry swale with suspended drain tile	◑	●	◑		●				●	◑	◑			◑	◑	●	●		○			
Underground infiltration	●	●	●		●				●		●	●		●	◑	◑	●		●	●		
Green roofs	●	○	◑		●		○	●			○	●							◑	●		Reduces heating/cooling costs and extends roof life.
Harvested and re-use	●	◑	●		●				◑	◑	●	●					◑		◑	◑		Reduces water use for summer watering
Biofiltration basin/Rainwater garden with drain tile at impermeable layer	○		●		●					●	◑					●		◑	●	◑	●	
Pervious pavement with drain tile and impermeable layer	○		●	○	●				●	●		●					●		◑	◑		
Grass channel	◑	◑	○	◑	●				◑	●	◑					●			○			Can reduce runoff volumes for small runoff events
Dry swale with drain tile at impermeable layer	○		●		●				●	●	◑					●			○			
Wet swale	◑		●		●						◑					●						
Wet pond	◑		●		●					●	◑					●			○		●	
Filter strips	◑	◑			●											◑						Can reduce runoff volumes for small runoff events
Sand filters	○	○	◑		●							●			○	●			●	◑	◑	
Enhanced sand filters			◑		●							●										
Underground storage/detention			●		●				●	●	●	●										
Pretreatment			◑		●														◑			
Optimized stormwater flow network	●		●		●														●			
Enhanced sedimentation operations					●														●		●	Can help meet strict water quality goals. May require additional permitting
Cluster development/Conservation design	◑	◑	◑	◑	◑	◑		◑	◑	●	●							●				
Urban forestry	◑	◑	◑				●	●	●	●	●	●										Provides shading and wind breaks to reduce heating and cooling costs.
Soil protection and amendments	◑	◑	○	◑	◑	●			○	●		●			○					○		
Linear projects	●	◑	●	●		●		●			●	●						●				
Parking lot design	●	◑	●	●		●		●			●	●						●				
Impervious surface disconnection	◑	◑	●	◑	●					●	●	●										
Operations and maintenance						●													●			

2.4 Special Case: Impervious Disconnection

Impervious disconnection is an important and effective tool to be used in the reduction of stormwater runoff. However, impervious disconnection alone does not provide stormwater volume and pollutant reduction. The volume and loading reduction are instead obtained by routing the runoff to a BMP. For example, the most common form of impervious disconnection is routing runoff from a roof or driveway over a grass lawn. In this capacity, the grass lawn is considered a filter strip. Any stormwater volume or pollutant reduction is provided by the filter strip and the amount will depend on the features (size, soils, vegetation, etc) of the filter strip. Therefore, calculating stormwater runoff volume and pollutant reduction amount for impervious disconnection alone is not needed.

One study translated impervious disconnection to effective impervious (Wagner, 2010). Wagner used models in SWMM to simulate runoff from a 100% impervious watershed being routed over a pervious area (filter strip) using the four soil types. The results of this analysis are given in terms of effective imperviousness. Effective imperviousness represents the amount of impervious area that is still effective in producing runoff after being routed over the previous section. For example, for a ratio of impervious to pervious area of one and a soil type of A, the effective impervious area was 33%. This means that the impervious section can now be treated as 33% impervious (67% pervious) instead of 100% impervious. Other values calculated using the model are given in Table 6.

Table 6. Effective impervious values for various soil groups and ratios of impervious runoff source area and adjacent pervious area

Ratio of impervious to pervious area	Soil group			
	A	B	C	D
0.2	19%	31%	42%	54%
1	33%	50%	64%	70%
2	49%	65%	76%	80%
5	72%	83%	88%	90%

3. Assigning Reduction Amounts (Credits)

The MIDS legislation is to enable and promote Low Impact Development (LID) BMPs. One challenge to overcome with LID BMPs is to build agreement between developers and regulators on how much stormwater volume and pollutants are reduced by LID BMPs. Calculation methods can be very detailed and robust with several parameters based on the specific site, but can also be subjective. Developing a standardized approach to have consistency between developers and regulators would be helpful. The following sections discuss three possible scenarios for quantifying stormwater volume reductions.

3.1 Scenario 1: Literature-Based with Specifications Method

Volume and pollution credits are assigned to an individual BMP based on a percent reduction in either runoff volume or event mean pollution (EMC) concentration reported in literature. Research reports on existing monitored BMPs typically provide percent reduction capabilities. By compiling and analyzing these studies for each of the BMPs, average percent volume reduction values can be calculated. This is the process used in the development of the Virginia Calculator. Up to as many as 17 studies (bioretention) were analyzed for each BMP. Each publication reported a percent runoff reduction value for an existing BMP. The values were compiled to obtain runoff reduction rates. Professional judgment was used for BMPs where sufficient data did not exist. The Virginia calculator also provides design criteria needed to achieve the percent reduction potential. All values were reported as conservative estimates for the specific BMP. Pollution EMC reduction percentages were obtained using the same procedure. Each percentage value reported is a conservative estimate based on value reported in the literature. The percent reduction values are listed in Table 7. Design parameters can be found in (CWP & CSN, 2008).

Also listed in Table 7 are similar values provided by other sources and calculators. A second set of volume reduction percentages were provided by the International Stormwater BMP database (http://www.bmpdatabase.org/), which collects monitoring information from existing BMPs throughout the world. The International Stormwater BMP database values reported in Table 7 are average runoff reduction percentages obtained through an analysis of every BMP monitored through their database. The 25^{th} to 75^{th} percentile ranges are given in Table 7 along with the median values for this analysis. Unlike the Virginia calculator specific design parameters are not provided, instead these values are a range of possible percent reduction percentages obtained by the BMPs. Other sources for EMC pollutant reductions include values used by the Pennsylvania and New Hampshire calculators as well as values reported in the Minnesota Stormwater Manual. These values were based on literature results.

Table 7. Runoff and pollution reduction percentages

	Volume Reduction		TP EMC reduction				TSS EMC reduction			
BMP	Virginia[a]	BMP database[b] (IQR (median))	Virginia[a]	New Hampshire[c]	Pennsylvania[d]	Minnesota Stormwater Manual and other sources	Virginia[a]	New Hampshire[c]	Pennsylvania[d]	Minnesota Stormwater Manual and other sources
Infiltration basin										
Bioretention basin/Rainwater garden without drain tile	80%			65%		100%[e]	90%	90%		
Biofiltration basin/Rainwater garden with suspended drain tile					85%				85%	85%[e]
Biofiltration basin/Rainwater garden with drain tile at impermeable layer	40%	45 -74% (57%)	25-50%			50%[e]	60%	73%		
Infiltration trenches	90%		25%	60%	85%	100%[e]		90%	85%	100%[e]
Infiltration shelves			25%							
Pervious pavement without drain tile	75%			65%						
Pervious pavement with suspended drain tile	45%		25%	45%	85%	80%[e]	75%	90%	85%	
Pervious pavement with drain tile and impermeable layer										
Grass channel	10 - 20%		15%	25%	50%		69-87%	65%	50%	
Dry swale without drain tile	60%									
Dry swale with suspended drain tile		35 - 65% (42%)	20 - 40%	25%	50%	0%[e]	69-87%	65%	50%	
Dry swale with drain tile at impermeable layer	40%									
Wet swale	0%	--	20 - 40%	25%	50%	0%[e]	69-87%			
Wet pond										
Filter strips	25 - 50%	18 - 54% (34%)	0%	45%	20%			73%	30%	
Sand filters	0%		60 - 65%	65%		0-50%[e]	80-92%	85%		70-85%[e]
Enhanced sedimentation operations										
Pretreatment										
Enhanced sand filters	0%					85-90%[f]				
Optimized stormwater flow network										
Harvested and re-use			0%			100%[e]	0%			100%[e]
Green roofs	45 - 60%		0%		85%	100%[e]	0%		85%	90%[e]
Underground storage/detention			0%				0%			
Density increases with set aside lands										
Urban forestry			15%		85%				85%	
Soil protection and amendments	50%		0%		0%				30%	
Linear projects										
Parking lot design										

	Volume Reduction		TP EMC reduction				TSS EMC reduction			
BMP	**Virginia[a]**	**BMP database[b] (IQR (median))**	**Virginia[a]**	**New Hampshire[c]**	**Pennsylvania[d]**	**Minnesota Stormwater Manual and other sources**	**Virginia[a]**	**New Hampshire[c]**	**Pennsylvania[d]**	**Minnesota Stormwater Manual and other sources**
Impervious surface disconnection										
Operations and maintenance									85%	

Key
a = (CWP & CSN, 2008) b = (International Stormwater BMP database, 2011) c = (NHDES, 2008)
d = (PDEP, 2006) e = (MPCA, 2008) f = (Erickson et al. 2007)

The values reported by each of the organizations vary. All values were based on literature sources yet the interpretation of the sources by each of the organizations provided diverging reduction percentages. For example, infiltration trenches have a percent EMC pollution reduction percentage ranging from 25% for the Virginia calculator to 100% for the Minnesota Stormwater Manual.

Values listed in Table 7 are estimations within published ranges. In the Virginia calculator, a value of 40% is given for a bioretention basin with a drain tile. However, when examining the sources used by Virginia to develop the 40% value, runoff reduction percentages ranged between 20 and 65%.

The implementation of this scenario for quantifying volume (and pollutant) reductions would also include modeling to confirm results and provide more site-specific analysis. The calculator would be used state-wide, providing an initial screening for possible pollution and volume reduction potential of a development. Once initial screening is conducted, additional modeling using widely-accepted modeling programs and techniques could be implemented.

Volume Credits Scenario 1: Pros

- Easy to implement: a framework already exists (Virginia Calculator) that can be applied to the creation of a calculator
- Standardized process for developers to follow
- Can provided volume reduction potential for a site design using state-wide standards
- Can be used as a tool in areas where resources may not be available for detailed modeling

Volume Credits Scenario 1: Cons

- Oversimplification: runoff reduction percentages are composite values for multiple BMP design scenarios. The values listed may not accurately represent the hydrology of the development. Therefore, some on-site BMPs might not get “full credit” for the volume they are reducing, while others might be getting “more credit” than they should.
- Not all BMPs have literature-reported values.
- Extremely limits the designer if pre-defined BMP specifications are used.
- The wide range of reduction percentages for each BMP could lead to high subjectivity in determining what specific value should be applied to a specific BMP design.
- Percent runoff reduction rates do not take into account soil type of development.

3.2 Credits Scenario 2: Modeling-Based with Detailed Inputs

Under this scenario, Barr with quantify volume reduction amounts for each BMP. Barr will use information gathered through all MIDs subtasks and conduct an extensive literature search to fill in information gaps in order to obtain relationships between specific BMP parameters and volume reduction abilities. Modeling will also be used to fill in any remaining holes in information. Barr will then run a multivariate regression analysis to determine relationships between specific BMP parameters and a reduction in volume.

In this scenario the user would estimate each parameter based on their design and enter the parameters into the calculator. The calculator would use those parameters to calculate a volume reduction percentage. Pollution reduction percentages would be estimated using literature values as described in Scenario 1. The following are examples of input parameters needed to apply this method.

Volume/infiltration

Bioretention

Input parameters: Calculating a volume reduction in a bioretention basin is based on the surface storage volume, the storage volume in the filtering media, the infiltration rate of the filter media, the infiltration rate of the underling soils, the percent vegetative cover, whether a under drain is used or not and the drainage area or drainage volume routed to the bioretention basin. At a minimum these seven parameters would need to be estimated by the developer and entered into to the spreadsheet. Each of these parameters could be estimated using a number of design parameters adding to the complexity. For example surface storage could be based on storage depth, surface area, vegetation cover fraction, surface roughness, and surface slope. Media storage could be based on media height, surface area, and void ratio (voids/solids).

Infiltration trench

Input parameters: An infiltration trench would be analyzed with many of the same parameters as a bioretention basin. These include surface storage, media storage volume, infiltration rates of the media and underlying soils and finally drainage area or drainage volume. The main difference between an infiltration trench and a bioretention basin is the lack of a vegetative cover and the type of media used.

Pervious pavements

Input parameters: Parameters used to calculate volume reduction would include infiltration rates through the pavement, storage capacity under pavement, and infiltration rate into underlying soils. The presence of an underdrain would also be an important parameter; however, the inclusion of an underdrain would limit the storage capacity of the pervious pavement system. Therefore, if an underdrain is present, the storage capacity would be reduced to the appropriate level (i.e., equal to the surface area multiplied by the height of the drainage pipe above the underlying soils). A simpler option for a volume reduction credit would be to remove the impervious surface area from developed runoff calculation.

Swales

Input parameters: Parameters for determining volume reductions from swales would include surface storage volume, type of vegetative cover (grass or natural vegetation), surface roughness, surface slope, if it's a dry or wet swale, if it has an underdrain or not, and finally the drainage area or volume contributing to the BMP.

Tree Canopy

Input parameters: These parameters would at minimum include a ratio between drainage area and area covered with trees. This BMP could be analyzed through modeling of various ratios between impervious areas draining into a forested area.

Storage only

Green roofs

Input parameters: Input parameters for green roofs would include vegetation cover fraction, Manning's n, roof slope, media thickness, and media storage capacity.

Harvested/reuse and underground storage

Input parameters: Input parameter would be volume storage capacity of storage tank. Estimates would be made based on typical rainfall patterns in region. For storm events producing rainfall amounts less than the storage capacity, the volume reduction would equal the rainfall volume. For storm events producing rainfall amounts greater than the storage capacity, the volume reduction would equal storage capacity. Regional rainfall patterns would be analyzed to determine and annual average volume reduction amount. Through applying this credit it is assumed that the retained water is used in some capacity before the next storm event.

Infiltration only

Soil protection and amendment

Input parameters: The parameters used for soils protection and/or soil amendments would only include the surface area protected or amended.

Barr could conduct modeling scenarios to determine how this BMP reduces runoff volumes for different soil types. A simple credit assignment could be applied by changing soils classification from poor to good/excellent in initial development runoff calculation.

Filter Strips

Input parameters: Filter strip input parameters include length and width of filter strip, drainage area or volume routed over filter strip.

Barr could conduct modeling of impervious surface sections routed to grass areas at various ratios and all soils types. Barr could also consolidate literature sources of existing filter strip data to obtain a relationship between filter strip and drainage area parameters with volume reduction capacity.

Indirect Credits

Density increases with set aside lands, linear projects, parking lot design

No credits would be given for these BMPs because the BMP sizes would be directly related to amount of impervious surfaces created. If land is set aside, road are narrower, parking lots are smaller, the BMPs would also be smaller. Credit is already given in calculation of developed runoff volume. Less impervious surface equals less developed runoff volume to manage.

Impervious disconnection

No volume reduction credit would be given for impervious disconnection. Instead credits would be given and based on the reduction capacity of the BMP that the impervious area is routed.

Credits Scenario 2: Pros

- Specific volume amounts would be calculated for each BMP
- Values would be based on detailed modeling or extensive literature search
- Design parameters would define volume reduction amounts
- Flexible in design configurations of BMPs to obtain volume reduction credits
- Promotes LID
- Calculator could be used in design situation where resources are not available for using current modeling approaches

Credits Scenario 2: Cons

- Extensive modeling would be required for BMPs where literature analysis is not sufficient
- For more accurate results, the designer would need to input more parameters, which could be open to subjectivity between the designer and regulatory
- Simple addition of individual BMP volume reductions may be an oversimplification of actual hydrology for the whole development (more inputs would be necessary to increase accuracy)
- Models exist that can already calculate the volume reduction for these BMPs and building a new calculator would require designers and regulators to learn a new tool

3.3 Volume Credits Scenario 3: Standards for Modeling BMPs in Models

In this scenario, developers would continue to use currently accepted hydrologic models, such as XP-SWMM, HydroCAD and P8, to model pollution and volume reduction in a development. Barr would provide standardized methods for modeling various LID BMPs. While no specific credits would be assigned because the volume reductions would be quantified in the models, a “bookkeeping” worksheet could be developed to assist regulators in reviewing models and verify that the required volume is reduced.

Volume Credits Scenario 3: Pros

- Flexibility in BMP construction: developer would not be restricted to set design parameters to receive credit
- More accurate representation of developed hydrology: defining credits at the BMP level would require generalizations and averaging; therefore, reducing the accuracy of the final volume

outcome. By using available models that are widely accepted and focusing on the overall development, volume control results would be more reliable. The use of an Excel spreadsheet as in Scenario 1 and 2 could over-simplify watershed hydrology providing results that do not mimic actual conditions.

- Promotes LID: By emphasizing volume reduction and the ability to mimic native hydrology as a design requirement, LID BMPs would be required to reach those goals
- Multiple weather scenarios and regional weather patterns could be applied to a development
- Standardizes the most subjective modeling inputs for LID BMPs and reduces disputes between designer and regulator
- Doesn't require designer and regulator to learn new tool
- "Bookkeeping" spreadsheet would help designer and regulator clearly list the volume control requirements, track the reductions of various BMPs, and summarize whether project conforms to volume control requirements

Volume Credits Scenario 3: Cons

- Requires technical knowledge of the designer and regulator to make, run and review models
- Some modeling inputs would likely still be disputed between the designer and regulator
- Doesn't contribute to the use of a spreadsheet calculator of credits

3.4 Rate Control

Because designers and regulators are already comfortable with the existing tools to evaluate whether the stormwater runoff rates leaving a site are controlled, we did not evaluate the use of new tools. However, a "bookkeeping" spreadsheet could be developed to summarize the stormwater rates leaving a site.

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