APPENDIX C
METHODS FOR ESTIMATING URBAN STORMWATER BMP COSTS AND LOAD REDUCTIONS

C.1 Introduction

For the purposes of this study, we assumed that federally regulated urban areas would be sources of demand for nutrient credits. Using the TMDL scenario of the Chesapeake Bay Watershed Model 5.3.2 (CBWM) (USEPA, 2010), we estimated the costs and nutrient reductions associated with urban BMP implementation to achieve the TMDL. Within the optimization model, regulated urban areas are allowed to purchase nutrient credits from significant point sources or agricultural nonpoint sources in lieu of implementing the additional urban BMPs assumed within the TMDL scenario.

The following nine urban stormwater BMPs are included in the study:

- **Dry ponds**—This practice involves creating a depression to temporarily store and slowly release runoff following rain events. These ponds are designed to dry out in between rain events, as opposed to wet ponds.
- **Dry extended detention ponds**—This practice involves creating a depression to store temporarily and release runoff following rain events using a low-flow outlet. Runoff is released more slowly than from dry ponds. These ponds are designed to dry out in between rain events, as opposed to wet ponds.
- **Urban filtering practices**—This practice involves passing runoff through a filter bed for pollutant removal.
- **Urban infiltration practices**—This practice involves creating a trench or basin where water infiltrates the soil with no underdrain.
- **Urban infiltration practices with sand/vegetation**—This practice involves creating a trench or basin where water infiltrates the soil with no underdrain. This practice includes a layer of sand and vegetation in its design.
- **Wet ponds and wetlands**—Wet ponds are permanent manmade pools to intercept runoff and release it at a specified flow rate, while wetlands accomplish similar runoff control with flood or saturated soils and associated vegetation.
- **Urban forest buffers**—This practice involves planting trees adjacent to a stream (at least 35-ft wide) and managing the buffer to maintain stream bank integrity.

- **Urban nutrient management**—This practice involves public outreach and education to reduce fertilizer application on pervious developed areas.

- **Street sweeping**—This practice involves removing debris from streets and cleaning storm drains.

C.2 Estimating Additional Acres of Federally Regulated Urban Stormwater BMPs

We assumed that nutrient credits may substitute only for urban BMPs not currently implemented in federally regulated urban areas (as estimated by the CBWM 2010 Progress scenario). To define regulated urban areas, we included four urban land use classifications: regulated pervious developed, regulated impervious developed, CSS on pervious developed, and CSS on impervious developed.

The spatial delineation of urban BMPs for the 2010 progress and TMDL scenarios are based on data sources provided by the states that may result in slight spatial inconsistencies at more granular scales. For example, acres of nutrient management may be provided at the county level in the 2010 progress scenario and at the state level for the TMDL scenario. The methods used by the CBWM to allocate where the BMP is implemented may result in some areas where BMPs are estimated to be implemented in 2010 and not with the TMDL, even if the state increases BMP implementation overall. To account for these potential inconsistencies, we estimate the percentage of additional implementation of each BMP within each state to achieve the TMDL using total implementation in the 2010 progress and TMDL scenarios.

C.3 Methods for Estimating BMP Cost and Nutrient Load Changes

Several key nutrient loading and cost variables are required to estimate BMP cost and nutrient load reductions. These variables include the following:

- estimates of cost per acre for each BMP,

- delivered per acre nutrient loads (TMDL Scenario of the CBWM), and

- treatment efficiency of each BMP.

Each of these data sources and the methods of estimation are discussed below.

C.3.1 BMP Costs per Acre

For this study, we relied primarily on BMP cost data being developed by EPA to estimate the cost of the Chesapeake Bay TDML (CBPO, 2012, in progress).[1] The annualized total cost of each BMP is comprised of three primary components, which include land, installation, and maintenance costs. Each of these components is defined as follows:

- **Annual Land Rental Costs—**These costs are included to reflect the opportunity costs of using land for urban stormwater BMPs instead of development. This cost is assumed to be $100,000/acre throughout the watershed.
- **Installation Costs—**These costs relate to the actual time, labor, capital, and materials used in designing and constructing the BMP.
- **Annual Maintenance Costs—**These costs are incurred in repairing, maintaining, and monitoring the BMP each year after it is constructed.

An important distinction between these costs is that installation costs are only incurred once in the life of the BMP, whereas land rental and BMP maintenance costs are incurred continually. Therefore, installation costs must be annualized in order to be compared with annual land rental and BMP maintenance costs. Installation costs were annualized using a 7% discount rate over the time periods reported in Table C-1. All costs have been adjusted for inflation and represented in 2010 dollars.

Table C-1. BMP Costs per Acre Treated ($2010)

Best Management Practice	Annualized Total Costs ($/acre/year)	BMP Time Horizon
Dry Ponds	$1,544–$3,256	20
Dry Extended Detention Ponds	$616–$1,298	20
Urban Filtering Practices	$1,680–$5,694	20
Urban Infiltration Practices	$1,776–$3,855	20
Urban Infiltration Practices with Sand/Vegetation	$1,699–$3,855	20
Wet Ponds and Wetlands	$607–$1,279	20
Urban Forest Buffers	$52–$328	15
Urban Nutrient Management	$20	3
Street Sweeping	$1,002	20

[1] We relied on draft cost estimates available December 2011. For three urban BMPs in Maryland—dry extended detention ponds, wet ponds and wetlands, and urban forest buffers—cost estimates were much higher than other states. For these BMPs, we conservatively applied an average of Virginia and Pennsylvania costs.

C.3.2 Delivered Nutrient Load Changes from Not Implementing Additional Urban Stormwater BMPs

To include urban stormwater BMPs in this study, we assumed that nutrient reductions from additional urban stormwater BMPs to meet the TMDL may instead be met by other nutrient source reductions. To estimate the change in nutrient loads from *not* implementing these additional BMPs, we first calculated the baseline total nutrient loads for each regulated urban land use category for each land-river segment using the CBWM TMDL scenario. We then estimated baseline per-acre nutrient loads (by land-river segment) for the acres with different combinations of existing urban stormwater BMPs based on their nutrient reduction effectiveness (Table C-2).

Table C-2. Nutrient Reduction Effectiveness

Best Management Practice	Nitrogen Reduction Effectiveness	Phosphorus Reduction Effectiveness
Dry Ponds	5%	10%
Dry Extended Detention Ponds	20%	20%
Urban Filtering Practices	40%	60%
Urban Infiltration Practices	80%	85%
Urban Infiltration Practices with Sand/Vegetation	85%	85%
Wet Ponds and Wetlands	20%	45%
Urban Forest Buffers	25%	50%
Urban Nutrient Management	17%	22%
Street Sweeping	3%	3%

$$\text{Loading}_{\text{NoBMP}}/\text{Acre} = \text{Loading}_{\text{LRSeg}}/[\text{Acres}_{\text{NoBMP}} + \sum_{i=1}^{N}(\text{AcresBMP}_{\text{i}} \text{ x } (1\text{-Eff}_{\text{BMPi}}))] \quad \text{(C.1)}$$

where

$\text{Loading}_{\text{NoBMP}}/\text{Acre}$ Per acre loading (lbs. per year) of nitrogen or phosphorus (by land–river segment) on acres where no BMPs are current being applied

$\text{Loading}_{\text{LRSeg}}$ Total loading (lbs per year) of nitrogen or phosphorus within a land–river segment.

$\text{Acres}_{\text{NoBMP}}$ Acres not treated by a BMP within a land–river segment.

$Acres_{BMPi}$	Acres treated by BMP type (i) within the land–river segment.
Eff_{BMPi}	Effectiveness of BMP type (i) within the land–river segment.(i.e., fraction of pollutant load removed on acres where the BMP is applied)

For acres currently applying BMP type a, we estimated per-acre loads as:

$$Loading_{BMPi}/Acre = (Loading_{NoBMP}/Acre) \times (1-Eff_{BMPi}) \qquad (C.2)$$

where

$Loading_{BMPi}/Acre$	Per acre loading of nitrogen or phosphorus within a land-river segment when BMP type (i) is applied.

This equation was repeated for all BMPs and combinations of BMPs available in our study, allowing the estimation of different delivered loadings within land–river segments according to BMP treatment.

We then estimated the change in delivered load that would occur if the additional acre of BMP was not implemented as:

$$\Delta Load_{BMPi}/Acre = (Eff_{BMPi}/(1-Eff_{BMPi})) \times (Loading_{BMPi}/Acre) \qquad (C.3)$$

where

$\Delta Load_{BMPi}/Acre$	Per acre change in loading of nitrogen or phosphorus within a land-river segment from not implementing BMP type (i).

C.3.2 Overlapping Urban Stormwater BMPs

We assumed that certain combinations of BMPs are also applicable on developed land. For instance, impervious areas being treated by detention ponds may also be treated by street sweeping. The nine BMPs included have an additional 25 possible combinations of BMPs. We estimated the change in delivered load that would occur if the additional acre of two overlapping BMPs was not implemented as:

$$\Delta LoadBMPi,j/Acre = [(1-(1-EffBMPi) \times (1-EffBMPj))/((1-EffBMPi) \times (1-EffBMPj))] \times (LoadingBMPi,j/Acre) \qquad (C.4)$$

where

$\Delta Load_{BMPi,j}/Acre$	Per-acre change in loading of nitrogen or phosphorus within a land–river segment from not implementing overlapping BMP types (i) and (j).
Eff_{BMPj}	Effectiveness of BMP type (i) within the land–river segment (i.e., fraction of pollutant load removed on acres where the BMP is applied)
$Loading_{BMPi,j}/Acre$	Per-acre loading of nitrogen or phosphorus within a land–river segment when overlapping BMP types (i) and (j) are applied.

References

Chesapeake Bay Program Office (CBPO). 2012 (in progress). *Chesapeake Bay Cost Model (Draft).*

U.S. Environmental Protection Agency (USEPA). 2010. *Chesapeake Bay Phase 5.3 Community Watershed Model*. EPA 903S10002–CBP/TRS-303-10. USEPA: U.S. Environmental Protection Agency, Chesapeake Bay Program Office, Annapolis, MD.