Recommendations of the Expert Panel to Define BMP Effectiveness for Urban Tree Canopy Expansion

Karen Cappiella, Sally Claggett, Keith Cline, Susan Day, Michael Galvin, Peter MacDonagh, Jessica Sanders, Thomas Whitlow, Qingfu Xiao

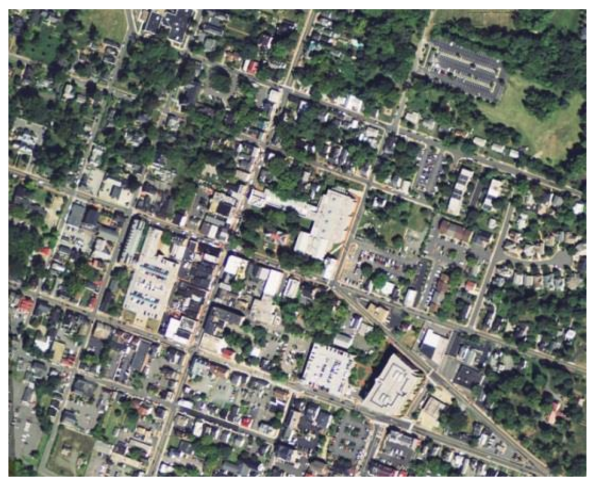

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Table of Contents

LIST OF TABLES (tables in appendices not listed)

LIST OF FIGURES (figures in appendices not listed)

Executive Summary

The report includes (1) recommendations from the Expert Panel for the Urban Tree Canopy Expansion best management practice (BMP) and (2) recommendations for an Urban Forest Planting BMP provided by the Forestry Work Group and supported by the Partnership (Appendix H).

The Forestry Work Group convened an Expert Panel to determine pollution control performance estimates for the best management practice of expanded urban tree canopy as part of the Phase 6 Chesapeake Bay Watershed Model (CBWM). The Expert Panel recommendations are based on review and synthesis of the literature, best professional judgement and the approved tree canopy land use loading rates for nitrogen, phosphorus and sediment. The recommendations include a revised urban tree canopy BMP credit for tree planting. Panel members also strongly recommend the Chesapeake Bay Program (CBP) convene a future expert panel for a new BMP to credit practices that maintain and conserve existing tree canopy in urban areas given the continued net loss of tree canopy throughout the Bay watershed. There was strong agreement among the Panel that the conservation and maintenance of existing tree canopy in developed or developing areas has the potential to have a greater positive impact on local efforts to address water quality than tree planting alone.

Nutrient and sediment reductions for the proposed Phase 6 Urban Tree Canopy Expansion BMP are based on the estimated acres of tree canopy resulting from tree planting that will be simulated as a land use change in the Phase 6 model. The Panel agreed to use a robust modeling approach to estimate the annual projected canopy area for new trees planted based on the number of factors that affect an individual tree's growth summarized in the literature. The creditable area for each tree planted is based on simulations using the i-Tree Forecast model using scenarios and input parameters defined by the Panel. The model scenarios explicitly account for (1) a variety of tree species, (2) mortality and (3) growing conditions. Each tree planted in developed areas is eligible for a creditable area of 144 ft^2 that translates to 300 trees per acre with the average nutrient and sediment reductions summarized in Table E.1. This creditable area is based on an estimated annual growth for a 10-year old tree after planting (assuming an initial diameter at breast height or DBH of 1-inch at planting). This timeframe for growth was selected based on the timeframe for the Bay TMDL for practices "to be in the ground" and growth period for a newly planted tree to achieve sufficient size to be mapped as a land use, as land use datais updated. The relative land use loading rate (percent reduction) would then be applied in the CBP modeling tools as a land use change equal to the reported acreage of tree planting. The total reduction would be automatically calculated through the modeling tools, but can be understood by the following equation:

Edge of Field Load Reduction (lbs/yr) = Planted Tree Canopy (acres) x Tree Canopy Loading Rate Reduction (%) x Base Land Use loading Rate (lbs/ac/yr) **(Eq. ES-1)**

Table E.1. Tree canopy relative land use loading rates based on the underlying land use land cover (Source: Hynicka and Divers 2016)

Land Use	Total Nitrogen Reduction (%)	Total Phosphorus Reduction (%)	Total Sediment Reduction (%)
Canopy over Turfgrass	23.8	23.8	5.8
Canopy over Impervious	8.5	11.0	7.0

The Panel could not identify any unintended consequences of adopting the recommendations for this Urban Tree Canopy Expansion BMP. While the Expert Panel acknowledged the contribution of nutrients in leaf litter to surface waters, the panel members concur with the review of the Street Sweeping and Inlet Cleaning Expert Panel report that a more explicit accounting of this source requires further evaluation given the uptake and storage of nutrients from trees. The Panel has concern that land use updates using high resolution imagery may result in double-counting of urban tree canopy acreage if a decision to distinguish urban tree canopy as a result of the BMP is not provided. However, the specific method to update the land uses is to be determined by the Partnership at a future date. The Expert Panel requests that a decision rule(s) be developed by the Partnership to determine if there will be an issue with double-counting the acreage of tree canopy credited as a BMP (as a result of tree planting) and the acreage of canopy as captured by high resolution imagery in future land use updates. The Expert Panel provides recommendations to advance research and management that address the current limitations of research to comprehensively quantify the effects of urban tree canopy on water quality, other than forests and riparian buffers, along with the need to focus strategies that maintain and conserve existing urban tree canopy.

Acknowledgements

The Panel wishes to acknowledge the contributions to the report from others inside and outside of the CBP partnership structure: Dave Nowak (US Forest Service) and Alexis Ellis (Davey Group) for their generous assistance with operating and interpreting results from i-Tree Forecast; Julie Mawhorter (US Forest Service), Rebecca Hanmer (Chair, Forestry Workgroup) and the Forestry Workgroup ; CBPO staff, particularly the modeling and GIS teams, including Lucinda Power (EPA, CBPO), Peter Claggett (US Geological Survey), Jeff Sweeney (EPA, CBPO), Matt Johnston (UMD, CBPO), and Gary Shenk (US Geological Survey), and; all those – too numerous to list here – who participated in the Panel's June 2015 public stakeholder session or May 2016 webinar and provided their input on the draft report or at any point during the Panel's duration.

Recommendations of the Expert Panel to Define BMP Effectiveness for Urban Tree Canopy

SECTION 1: CHARGE AND MEMBERSHIP OF THE EXPERT PANEL

1.1 Panel Membership

The Forestry Workgroup approved the membership of the Expert Panel in February 2015. The roster for the Urban Tree Canopy BMP Expert Panel is provided in Table 1. A copy of the meeting minutes is provided in Appendix A.

Table 1. Expert Panel Membership.

Name	Affiliation
Panel Members	
Karen Cappiella	Center for Watershed Protection
Sally Claggett	US Forest Service, CBPO
Keith Cline	Fairfax County (VA)
Susan Day*	Virginia Tech
Michael Galvin	SavATree
Peter MacDonagh	Kestrel Design Group
Jessica Sanders	Casey Trees
Thomas Whitlow	Cornell University
Qingfu Xiao	University of California-Davis
Panel Support	
Neely Law (Chair)	Center for Watershed Protection
Jeremy Hanson (Coordinator)	Virginia Tech, CBPO
Brian Benham	Virginia Tech (Project Director)
Marcia Fox	DE DNREC (WTWG rep)
Ken Hendrickson	EPA Region 3 (Regulatory Support)
David Wood	CRC, CBPO (CBP modeling team rep)

* On sabbatical leave starting in September 2015

1.2 Panel Charge

The Expert Panel was convened by the Forestry Work Group (FWG) of the Chesapeake Bay Program's (CBP) Water Quality Goal Implementation Team (WQGIT) to determine pollution control performance estimates for the best management practice (BMP) of expanded urban tree canopy. A literature review and synthesis was completed for the purpose of informing recommendations for this BMP. Best professional judgement and use of models provided additional insight to inform recommendations where gaps in information or understanding existed.

The Expert Panel report also includes the following:

- Identity and expertise of Panel members
- Practice name/title

- Detailed definition of the practice
- Recommended nitrogen, phosphorus, and sediment loading or effectiveness estimates
- Justification for the selected effectiveness estimates, including a list of references used and a detailed discussion of how each reference was considered, or if another source was investigated, but not considered.
- Description of how best professional judgment was used, if applicable
- Land uses to which the BMP is applied
- Load sources the BMP will address and potential interactions with other practices
- Description of pre-BMP and post-BMP circumstances, including the baseline conditions for individual practices
- Conditions under which the BMP works/does not work/or varies in its effectiveness
- Temporal performance of the BMP including lag times between establishment and full functioning (if applicable)
- Unit of measure (e.g., feet, acres)
- Locations within the Chesapeake Bay watershed where this practice is applicable
- Useful life; effectiveness of practice over time
- Cumulative or annual practice
- Description of how the BMP will be tracked, reported, and verified
- Suggestion for a review timeline
- Outstanding issues that need to be resolved in the future and a list of ongoing studies, if any
- Documentation of any dissenting opinion(s) if consensus cannot be reached
- Operation and Maintenance requirements and how neglect alters performance
- Any ancillary benefits or unintended consequences beyond impacts on nitrogen, phosphorus and sediment loads
- A technical appendix that describes changes that will be made to the modeling and reporting tools to accommodate the BMP(s)

The report includes recommendations from the Expert Panel for the **Urban Tree Canopy Expansion BMP, as well as** recommendations for an **Urban Forest Planting BMP** provided by the Forestry Work Group (FWG) and supported by the Partnership that is provided in Appendix H.

During the Expert Panel process, the CBP further requested recommendations for land use loading rates for the newly proposed tree canopy land uses in the Phase 6 Chesapeake Bay Watershed Model (CBWM) in August 2015. However, initial relative land use loading rate recommendations from the Expert Panel were not approved by the Water Quality GIT at their September 2015 meeting. The FWG continued development of the land use loading rates through contract work with Mr. Justin Hynicka (MD DNR) and Dr. Marion Divers (University of Pittsburgh). The Expert Panel Chair and Coordinator worked with the FWG to provide input on the development of the land use loading rates, along with review by the Expert Panel. While the charge of the Expert Panel remained focused on the BMP recommendations for urban tree canopy expansion, the Panel also addressed how to best align the tree canopy land use with an annual tree canopy BMP. The WQGIT approved the relative land use loading rate for tree canopy land uses at the March 14, 2016 meeting. The final report from Hynicka and Divers (2016) is included as Appendix B to this report that provides a full description of how the loading rates for these new tree canopy land uses were derived. An addendum to Appendix B summarizes a list of items for the partnership's future consideration whenever the tree canopy land uses and loading rates are revisited for future updates to the modeling tools.

SECTION 2: DEFINITIONS AND PERFORMANCE MEASURE

Definitions

The definitions for forest and tree canopy land uses are provided by the CBP Partnership as part of the development of the Phase 6 CBWM and were not developed by the Expert Panel. The BMP definitions below describe the BMP for the purposes of this report. The reader should refer to Appendix F or the latest set of Phase 6 modeling documentation for the partnership-approved definitions used for modeling and reporting purposes.

Forest land use: For purposes of this report, the term refers to forest land uses as defined and mapped by the CBP as part of the Phase 6 CBWM. The CBP Partners are mapping all trees at 1-m resolution using some combination of leaf-on, leaf-off, and LiDAR imagery. Generally, trees are identified in the imagery by their spectral and height characteristics with a minimum canopy area of $9m^2$ and minimum height of 5m (Chesapeake Bay Image Interpretation and Mapping Standards, Chesapeake Conservancy, and pers comm J. O'Neil-Dunne, University of Vermont, 1/21/2016). Forests include contiguous patches of trees that are greater than or equal to 1-acre, corresponding to a patch of trees with a minimum internal radius of 36m, and are generally 20m – 30m away from non-road impervious surfaces (e.g., structures, driveways, and parking lots) in developed areas and approximately 10m away from non-road impervious surfaces in rural areas. At times this report may refer to the forest land use as defined in the Phase 5.3.2 CBWM, but if not explicitly specified the report is referring to Phase 6.

Tree canopy land use: The Phase 6 CBWM includes a new set of land uses that describe tree canopy with a managed understory as developed by the CBP Partners. There are two subclasses: i) tree canopy over impervious; and ii) tree canopy over turfgrass. Generally, trees are identified in the imagery by their spectral and height characteristics with a minimum canopy area of $9m^2$ and minimum height of 5m (Chesapeake Bay Image Interpretation and Mapping Standards, Chesapeake Conservancy, and pers comm J. O'Neil-Dunne, University of Vermont, 1/21/2016). Trees are included and mapped in one of these two classes if they overtop roads, driveways, or parking lots or if they are within 20m – 30m of non-road impervious surfaces in developed areas or within 10m of non-road impervious surfaces in rural areas. The two tree canopy land uses include the majority of trees located in developed areas and all trees adjacent to rural structures. The understory is assumed to be either pervious (i.e., turfgrass) or impervious cover. Because there are no Tree Canopy land uses in the Phase 5.3.2 CBWM, this term is only used in reference to Phase 6. A very small percentage of trees are excluded from both the forest and tree canopy definitions because they are in small isolated patches, less than 1-acre after accounting for adjacent water bodies and wetlands. These trees are included in the “mixed open” land use class and are not discussed in this report.

Urban tree canopy BMPs: This refers to a set of BMPs that include actions and/or program elements that result in expanded tree canopy through the maintenance of existing tree canopy and/or an increase in trees for developed land uses in the Chesapeake Bay Watershed Model. Under the Phase 6 CBWM, the actions available for credit under this BMP category include two types of BMPs: 1) Urban Tree Canopy Expansion and 2) Urban Forest Planting. Tree conservation practices that protect existing tree canopy were not considered by the Panel under this BMP, but may be considered by a future expert panel. Tree canopy that is not available for credit as part of this set of BMPs include forest buffers and trees that are planted as part of a structural BMP (e.g. bioretention, tree bioretention/planter).

Urban Tree Canopy Expansion BMP: Tree plantings on developed land (impervious or turfgrass) that result in an increase in tree canopy but are not intended to result in forest-like conditions. The trees are not part of a riparian forest buffer, structural BMP (e.g. bioretention, tree planter), or do not conform to the definition of the Urban Forest Planting BMP. Credit is based on the number of individual trees planted with a conversion to equivalent acres for reporting purposes. A credit of 144 ft^2 per tree planted is equivalent to 300 trees planted per acre; however this is not a planting density requirement. Thus, each newly planted tree converts 1/300 an acre of either pervious or impervious developed area to tree canopy land uses. The relative nitrogen, phosphorus and sediment load reductions are applied to the underlying land use and applied to creditable area (see Table E.1 and Section 5.2.1). This BMP does not require trees to be planted in a contiguous area. The reader should refer to Appendix F or the latest set of Phase 6 modeling documentation for the partnership-approved definition used for modeling and reporting purposes.

Urban Forest Planting BMP: Tree planting projects in urban or suburban areas that are not part of a riparian buffer planting, structural BMP (bioretention, tree planter) or Urban Tree Canopy Expansion BMP. This BMP is implemented with the intent of establishing forest or similar ecosystem processes and function. This requires that urban forest plantings be documented in a planting and maintenance plan that meets state planting density and associated standards for establishing forest conditions, including no fertilization and minimal mowing as needed to aid tree and understory establishment. This is a land use change BMP converting developed turfgrass to forest. The nutrient and sediment reductions will correspond to the unit area loading of converting developed turfgrass to forest in the model segment where the BMP is applied. Under this BMP, the trees are planted in a contiguous area. The reader should refer to Appendix F or the latest set of Phase 6 modeling documentation for the partnership-approved definition used for modeling and reporting purposes.

CBP FWG’s BMP Verification Guidance (2014) defines **expanded tree canopy** as the overall percent of tree cover in a geographically defined locality on developed land.

Performance Measure

Credit for the proposed Phase 6 Urban Tree Canopy Expansion BMP will be the equivalent acres of tree canopy based on number of trees planted that result in a land use conversion to tree canopy land uses. As such, this will be simulated as a land use change. Applicable developed land use classes will be converted to either Tree Canopy over Impervious or Tree Canopy over Turfgrass. More details are provided in Section 3 and Appendix F. The load reduction for a land use change BMP equals the relative, or percent, load reduction of nitrogen, phosphorus and sediment from the underlying pervious or impervious land use for the newly defined tree canopy land uses.

The credit of this BMP is cumulative, which means that the acres reported in a previous year carry over into the next year. As a land use change BMP, the converted acres will be eligible to receive other urban BMPs reported through National Environmental Information Exchange Network (NEIEN). Thus, this BMP may be considered a 'stackable' BMP, where additional BMPs may be applied to the underlying land use. For example, urban nutrient management may be applied to the pervious area under the tree canopy. For more information, see Appendix F.

Credit for the proposed Phase 6 Urban Forest Planting BMP is provided in Appendix H as recommended by the FWG. This BMP is simulated as a land use change from urban pervious to forest land use. The credit for this BMP is cumulative, which means that the acres reported in the previous year carry over into the next year. This BMP is not considered a 'stackable' BMP since there are no urban BMPs eligible for application to the forest land use.

SECTION 3: URBAN TREE CANOPY IN THE CHESAPEAKE BAY

The Panel's recommendations are only applicable to the Phase 6 CBWM, which is currently being reviewed with a final version planned for release in early 2017. To better understand the Panel's recommendations described in this report, however, it is important to understand the previous Urban Tree Planting BMP that was applied in the Phase 5.3.2 Watershed Model. This section provides this context and also provides a basic overview of how the Phase 6.0 Watershed Model is expected to simulate the new Tree Canopy land uses.

3.1 How the Urban Tree Planting BMP is simulated in the Phase 5.3.2 Watershed Model

The Phase 5.3.2 CBWM has a small number of "urban" land use classes: impervious, pervious, construction, and extractive.

The Phase 5.3.2 definition for Urban Tree Planting is as follows (CAST documentation, June 23 2015 version):

> Urban tree planting is planting trees on urban pervious areas at a rate that would produce a forest-like condition over time. The intent of the planting is to eventually convert the urban land use to forest. If the trees are planted as part of the urban landscape, with no intention to convert the area to forest, then this would not count as urban tree planting.

In addition to this definition, the FWG defined the Urban Tree Planting BMP as:

> Planting trees in an urban or residential environment with the intent to increase and sustain the tree canopy. Planting 100 trees is equivalent to converting one acre of urban land to forest. Tree replacement may need to occur but cannot be "counted" as an additional planting.

The Phase 5.3.2 BMP definition in CAST for Urban Tree Planting converts 1 acre of urban pervious land to 1 acre of forest for every 100 trees that are planted. The basis of this definition, as described above, is that the 100 trees will produce a forest-like condition over time. While 100 trees planted in the same one acre plot could eventually produce a forest-like condition, the definition itself led to a number of problems. The interpretation of the definition for this BMP led to difficulties in regard to implementation and credit evaluation. For example, it was difficult, if not impossible, to know that reported trees are indeed planted in a contiguous acre or if those trees are individually planted throughout a local area. The CAST definition was developed specifically to only award a reduction to projects that plant at a certain density (100 trees/acre), whereas in practice there are many planting projects that do not meet that criteria.

Section 5.1 further reviews the current Phase 5.3.2 Urban Tree Planting BMP credit.

3.2 How tree canopy land uses will be represented in the Phase 6 Watershed Model

The Phase 6 CBWM is still under development and review at this time with a final version planned for release in early 2017. A major aspect of the changes from Phase 5.3.2 to Phase 6 is the incorporation of new land uses. These new land uses and their incorporation into the Phase 6 model have been discussed among the various CBP and Water Quality Goal Implementation Team (WQGIT) workgroups, and are not the subject of this report. It is important to note the addition of two particular land uses under the "Developed" category of land use classes: Tree Canopy over Turfgrass and Tree Canopy over Impervious. Like all other Developed land uses, these are split into Regulated (MS4), Non-Regulated, and Combined Sewer System (CSS) categories, to create a total of six land uses. To account for the distribution of Tree Canopy over Roads and Tree Canopy over other impervious non-roads (building parking lots, etc.), in the Phase 6 Beta-1 version, 90% of existing canopy was assumed to be over Roads and the remaining 10% over non-road impervious surfaces (see Table 2). This distribution may change for the final version of the Phase 6 CBWM as additional analysis and calibration is completed.

The Phase 5.3.2 CBWM only accounted for urban trees through the forest land use, so only areas large enough to qualify as Forest, or areas converted to forest through a land use change BMP, were captured. This potentially left many trees not meeting the definition of forested land use unaccounted for across the watershed landscape. However, in practice, the Phase 5.3.2 urban land uses would have implicitly accounted for the benefits of urban trees through the calibration process. The FWG identified the need to simulate urban tree canopy in a more explicit fashion to more fully account for the benefits provided by all trees and as such, credit in the Bay TMDL. Over the course of several months the CBP partnership considered the addition of tree canopy land uses, and the approved land uses included Tree Canopy over Turfgrass and Tree Canopy over Impervious. As noted above, these are then divided into three categories for tracking, reporting and planning purposes: MS4, Non-regulated, and CSS. This results in six tree canopy land uses when the two types of tree canopy are split among those three categories. Altogether, the acres of tree canopy land use in 2013-2014 represents approximately 17% of the developed acres in the Phase 6 CBWM (Beta1, January 2016), or roughly 2% of the total acres in the Chesapeake Bay watershed (Table 2).

Table 2. Preliminary estimates of tree canopy land uses[1] acreage in the Phase 6 CBWM (Beta 1 vers.)

Land Use	CSS (ac)	MS4 (ac)	Non-Regulated (ac)	Total (ac)	Tree Canopy Land use as % of Developed Land uses
Tree Canopy Over Impervious	732	50,589	102,679	154,000	3
Tree Canopy Over Turfgrass	14,051	383,829	344,748	742,628	14

[1] Distribution for tree canopy land uses over impervious developed land is currently set at 90% over roads and 10% over building and other. The acreage and tree canopy proportion will likely change as the Phase 6 model goes through further evaluation prior to finalization.
CSS = acres of Phase 6 developed land uses associated with Combined Sewer System areas
MS4 = acres of Phase 6 developed land uses associated with Municipal Separate Storm Sewer Systems
Non-regulated = acres of Phase 6 developed land uses that are not associated with CSS or MS4 areas

SECTION 4: REVIEW OF THE AVAILABLE SCIENCE

Over 150 publications were reviewed by the Expert Panel and Hynicka and Divers (2016) to describe and quantify the hydrologic and water quality benefits associated with urban tree canopy. Of these publications, 115 publications were reviewed by the Expert Panel to evaluate the research questions defined in the scope of this Expert Panel:

1. What is the effectiveness of urban tree canopy on reducing runoff, nutrient and sediment loads?
2. How does effectiveness vary by species, over time, with differences in planting sites (e.g., distance from impervious cover or other trees, soil conditions, geographic location) and with different maintenance strategies?

Both Hynicka and Divers (2016) and the Expert Panel found a limited number of studies directly addressing the water quality benefits of urban trees. While the processes and mechanisms for reducing runoff and pollutants by trees are well known, the amount by which trees reduce runoff, and by extension improve water quality, is highly variable .Further, the results of individual studies are not directly comparable. For example, the runoff reduction and water quality benefits for urban tree canopy are more challenging to characterize given the:

- Considerable variability by species in the performance of individual trees,
- Change in effective treatment with time due to tree growth
- Ability to define contributing drainage area
- The effect of site specific conditions and climate, and
- Ability of comparison studies is limited based on type of vegetation studied.

As such, Hynicka and Divers (2016) constructed a modeling approach that assesses changes in water yield as the primary method to derive nutrient and sediment pollutant load reduction benefits for urban tree canopy (see Appendix B for full report). The literature review provided by Hynicka and Divers (2016) provides references to parameterize their water balance model and subsequent nitrogen, phosphorus and sediment relative land use loading rates. The following literature review highlights more generally, the hydrologic and water quality benefits of urban tree canopy based on the review by the Expert Panel, supplemented by work by Hynicka and Divers (2016). The data reviewed for this synthesis were not limited to the Chesapeake Bay watershed. The literature review was also extended to include studies on trees planted as a part of an urban stormwater best management practice (e.g., bioretention) to quantify the impact of urban tree canopy on water quality. The Panel also reviewed a number of studies on the water quality and runoff reduction benefits of non-urban forests, which may be considered an upper limit to any credit assigned to urban tree planting, based on the assumption that trees and forests in urban environments do not function as well as natural forests due to factors such as compacted soils, lack of forest understory, availability of nutrients, light and water that impact tree health. Appendix C provides the complete literature synthesis.

As trees planted in the urban riparian zone (i.e., within 100 feet of a waterbody) are currently credited under a separate best management practice (Urban Riparian Forest Buffers), this review focused primarily on the benefits of trees in upland areas.

Urban trees provide a host of other benefits, including air quality improvement, habitat for wildlife, temperature reduction and energy savings. While the focus of the Panel charge is to highlight the water quality benefits, a summary of these additional benefits is provided in Section 4.6 to acknowledge the overall beneficial impact of trees in urban environments.

4.1 Hydrologic and Water Quality Benefits

Urban tree canopy is unlike most other urban BMPs, which have a defined drainage area and are engineered to capture and remove pollutants from stormwater runoff. Trees are living and have a biological lifespan, growing beyond 100 years, with urban trees ranging on average from 19 to 60 years depending on their location (i.e., street vs residential sites) (Roman and Scatena 2011). While the processes and factors affecting the hydrological cycle and water quality are the same for all trees, the quantitative impact from urban trees, specifically, is less well-known. Extensive field-based studies on natural forests have allowed the development of numerous physically and empirically-based computer models to allow broader applicability and understanding of the hydrologic and water quality impact of tree canopy.

The primary impact on water quality is attributed to the prevention of water pollution by reducing the amount of runoff generated from areas where tree canopy is present. Trees also redistribute soil-water and groundwater to the near surface from trees roots accessing water to depths greater than 2-ft (Day et al. 2010). In the absence of tree canopy, rain falling on urban surfaces such as parking lots, streets and lawns picks up various pollutants as it runs off the landscape. Therefore, the cumulative effect of tree canopy is to temporarily detain rainfall and gradually release it, regulating the flow (volume and peak) of stormwater runoff downstream and thereby preventing pollutants in rainfall and on urban surfaces from being transported to local waterways. While trees process nutrients, there are a few permanent or long-term storage pathways as nutrients and sediment from soil, atmosphere and groundwater interact with the tree: for example, long term storage of nutrients in woody biomass, along with permanent removal of nitrogen via denitrification given favorable soil moisture, carbon and nitrogen conditions (e.g., Groffman et al. 2004, Raciti et al. 2011). The formation of insoluble compounds of phosphorus is the primary mechanism for phosphorus removal through associations with metals in the soil (Busman et al. 2002 as cited in Hynicka and Divers 2016).

The specific processes by which urban trees impact runoff are shown in Figure 1 in blue. Additional mechanisms by which trees positively influence water quality are shown in green in Figure 1, while potential contributors to runoff pollution are shown in red. The figure attempts to illustrate that all parts of a tree, its canopy, woody biomass and roots with associated micro-organisms, all contribute to the water quality effects provided by trees. By extension, the characteristics of the soil environment in which it grows will also affect the hydrologic response, or be affected by the tree itself. For example, when it rains, trees capture rainfall in their canopies (**rainfall interception**). Intercepted rainwater is temporarily stored in the canopy before being released by **evaporation** directly into the atmosphere or transmitted to the ground via stems, branches, and the tree trunk (**stemflow**) for root absorption. The water delivered to the base of trees penetrates the soil rapidly (**infiltration**) by following interconnected pathways in the soil formed by large roots and macropores. Rainfall that is not intercepted by the canopy later reaches the underlying ground as **throughfall**. This water can be lost to evaporation, transpiration by the underlying vegetation, or infiltration or it can become **runoff.** Throughfall may carry nutrients and other pollutants and dissolved organic carbon from leaf exudates to the ground surface. If the underlying ground cover is pervious, leaf litter and other organic matter, soil macropores, and small depressions all work to slow runoff, hold water and further promote infiltration. The infiltrated water can feed into local waterways through **interflow** or replenish groundwater supplies (**recharge**). In between storms, trees can also absorb water from the soil by root uptake and release the unused portion back into the atmosphere in the form of water vapor through **transpiration**. Tree roots and their associated microbial and macroinvertebrate communities may also treat infiltrated nutrients in-between storms by a) moving water and nutrients below the surface (vertically and horizontally) at night and b) removing soil water via evapotranspiration in the daytime, making for healthy soils that are better able to infiltrate and percolate rainfall. Evapotranspiration also increases soil water storage potential, effectively lengthening the amount of time before rainfall becomes runoff.

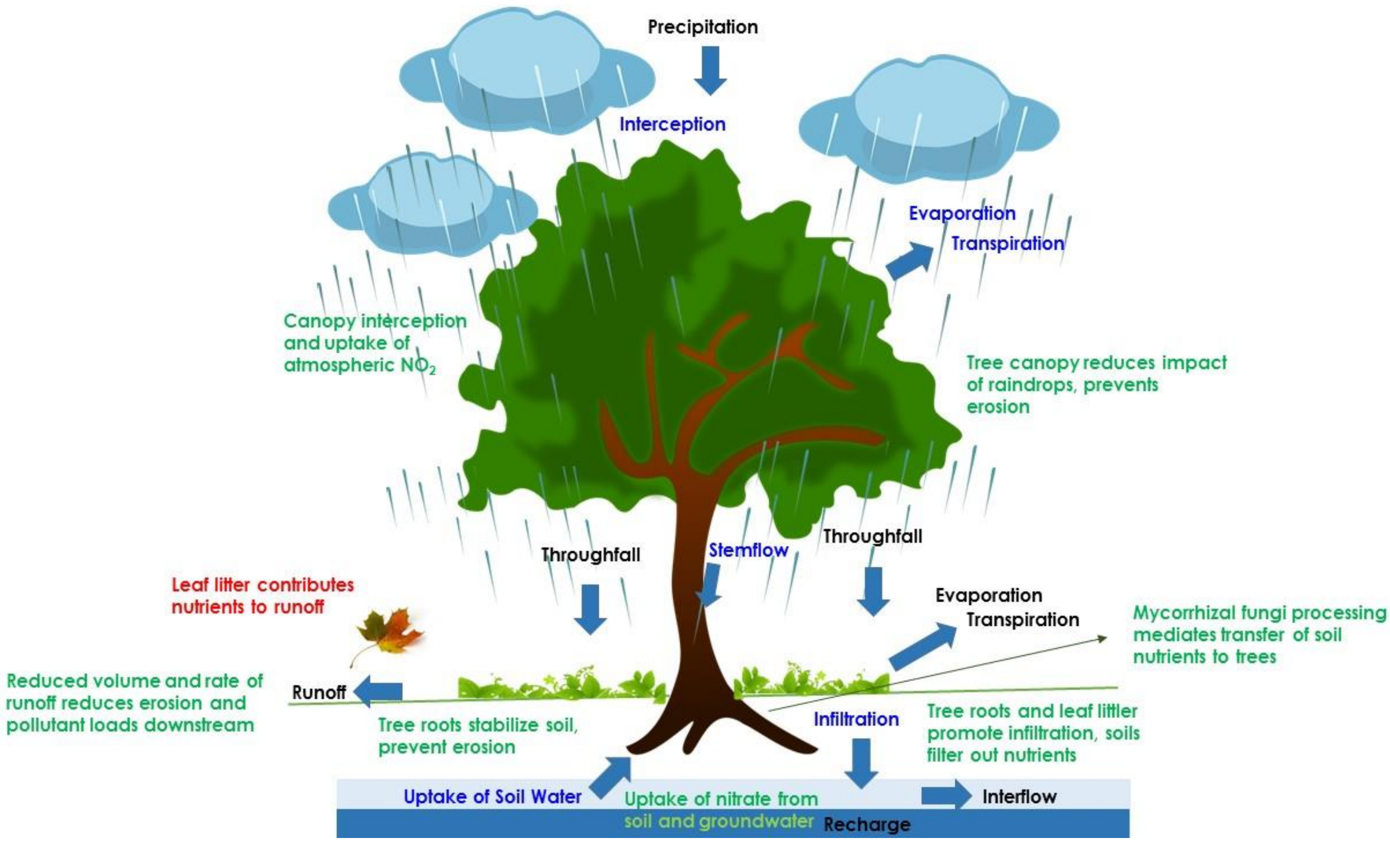

Figure 1. Urban Tree Impacts on Hydrology and Water Quality

Interception

Canopy interception of rainfall is a significant component of the tree water balance but is highly variable as it is influenced by numerous factors. For example, interception losses and storage depend on factors such as leaf area index (LAI) and tree structure, and are largely influenced by storm characteristics such as frequency and intensity (Xiao et al. 2000, Keim et al. 2006). For example, the most critical time for trees to play a role in reducing runoff is during and right after a storm (KDGT 2013). KDGT (2013) suggests that, because of this, continuous simulation modeling may be the best approach for estimating rainfall interception on an annual basis. Studies of interception by urban trees report that trees can intercept 6.5-66.5% of annual rainfall, compared to 10-46% of annual rainfall for natural forests (Table 3). A more narrow range of interception values for modeling studies in the Chesapeake Bay watershed suggests annual interception values between 14.5 to 19.6% for four developed watersheds in the Piedmont, with 17% as the average (Wang et al. 2008, Band et al. 2010) (shown in bold).

Table 3. Rainfall Interception Studies of Urban Trees

Study	Location	Interception (% of annual rainfall)[1]	Species/Condition[2]	Type of Study[3]
Kirnbauer et al. 2013	Hamilton, Ontario, CA	6.5-11 17-27	G. biloba (D), P. acerifolia (D), A. saccharinum (D) L. styraciflua (D)	Modeling
Livesley et al. 2014	Melbourne, Victoria, Aus.	29 44	E. saligna (E) E. nicholii (E)	Measured
Xiao and McPherson 2002	Santa Monica, CA	27.3 15.3 66.5	All park and street trees Small jacaranda mimosifolia (D) Mature tristania conferta (E)	Modeling
Xiao et al. 1998	Sacramento County, CA	11.1	Tree canopy in the County	Modeling
Xiao et al. 2000	Davis, CA	15 27	Pear (D) Oak (E)	Measured
Xiao and McPherson 2011a	Oakland, CA	14.3 25.2 27.0	Sweetgum (D) Gingko (D) Lemon (E)	Measured
Wang et al. 2008	**Baltimore, MD**	**18.4**	**Tree canopy in Dead Run subwatershed (D)**	**Modeling**
Band et al. 2010	**Fairfax, VA**	**14.5**	**Tree canopy in Accotink watershed (D)**	**Modeling**
Band et al. 2010	**Baltimore, MD**	**15.7**	**Tree canopy in Gwynns Falls watershed (D)**	**Modeling**
Band et al. 2010	**Montgomery County, MD**	**19.6**	**Tree canopy in Rock Creek watershed (D)**	**Modeling**
Asadian and Weiler (2009)	Vancouver, BC	49 61	Douglas fir (E) Western red cedar (E)	Measured
Berland and Hopton 2014	Cincinnati, OH	6.7	Average value	Modeling
McPherson and Simpson 2002	Modesto, CA	3.2	Average value	Modeling
McPherson and Simpson 2002	Santa Monica, CA	7.0	Average value	Modeling
McPherson et al. 2011	Los Angeles, CA	0.4 (low) 5.6 (high)	Crapemyrtle Jacaranda (D)	Modeling
Soares et al. 2011	Lisbon, Portugal	4.5	Average value	Modeling
CWP, 2014	Montgomery County, MD	7.57	15-20 year old 9-15" DBH tree	Modeling

[1] represents the % of rain falling on the tree canopy that is captured through interception
[2] D = deciduous, E = evergreen
[3] Measured = studies that infer interception by subtracting measured throughflow and stemflow from measured rainfall; modeled = studies that model interception using models such as i-Tree

Evapotranspiration (ET)

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. There were limited studies that quantified annual ET rates for trees in urban areas (Litvak et al. 2014, Pataki et al. 2011) and the Chesapeake Bay watershed with the exception of a modeling study by Band et al. (2010). Most studies instead evaluate how one or more factors influence ET, develop and test models for estimating ET, or measure ET values for a particular species during the growing season. Hynicka and Divers (2016) report a range of 15-25 inches/year of ET that varies based on tree age, species, canopy health and season (Ford et al. 2001; Penman 1948; Wullschleger et al. 2001; Wullschleger et al. 2000; Wilson et al. 2001; Peters et al. 2010).

In a suburban watershed in Baltimore County, MD, Band et al. (2010) identified the importance of ET on runoff reduction and noted that the major effect of tree canopy on runoff production was the ability to remove soil water by transpiration, allowing more pore space for infiltration. However, Litvak et al. (2014) found that in summer, total plot ET of urban lawns with trees was lower than lawns without trees by 0.9 – 3.9 mm d^{-1} in the Los Angeles metropolitan area. Another study from Los Angeles by Pataki et al. (2011) raised concerns that certain tree species may place too much of a demand on the local water supply because of high ET rates.

Infiltration

Studies on the effects of urban trees on soil infiltration demonstrate that trees can increase soil infiltration rates and soil hydraulic conductivity, even in highly compacted soils such as those typically found in the urban environment. Day et al. (2010) found improved structure of compacted soil by tree roots. Tree roots can increase soil infiltration rates over unplanted controls by 63% and 153% for severely compacted soils, while removal of urban forest understory and leaf litter decreased infiltration rates by 35% (Bartens et al. 2008; Kays 1980). Research findings of a biofilter by Le Coustumer et al. (2012) also suggest the importance of thick roots that help to maintain permeability of the soil over time through the creation of macropores. In non-urban environments, soil infiltration rates under tree canopy were 50% higher than outside the canopy (Mlambo et al. 2005), while deforestation or forest burning decreased infiltration rates by 20-35% (Wondzell and King 2003; Lal 1996).

Runoff Reduction

The combined effect of trees' ability to intercept and evapotranspire rainfall and promote infiltration of water into the soil is that the rate and overall proportion of rainfall that becomes runoff is reduced. Modeling studies show that, as forest cover in a municipality or watershed increases, runoff decreases (and the inverse is also true). Watershed-scale studies of runoff reduction often provide results in terms of the percent of annual runoff reduced by a given percent of tree cover in the watershed (in comparison to the runoff generated if trees were not present). These results can be translated into a percent runoff reduction per unit area of canopy if watershed areas are provided in the studies. However, not all studies are conducted on an annual basis and the results (streamflow measured at the watershed outlet) reflect not just the effect of trees in the watershed but the cumulative effect of all other land cover types and watershed features. As indicated in Table 4, the runoff reduction attributed to urban trees ranges from 2.6 to 88.8% and each study has a unique approach to quantifying runoff reduction – from individual plots or sites to watersheds. Runoff reduction attributed to natural forests is similarly wide-ranging, with values from 8 to 80% from studies of water yield before and after deforestation of forested catchments.

Table 4. Studies of Runoff Reduction by Percent Tree Canopy at the Watershed or Site-Scale.

Study	Results	Description
American Forests (1999)	19% increase in runoff	Modeled increase in runoff associated with loss of 14% forest cover
Armson et al. (2013)	58% reduction in runoff in summer and 62% in winter	Measured reduction from plot containing a tree pit and surrounded by asphalt
Wang et al. (2008)	2.6% runoff reduction	Modeled reduction associated with increasing tree cover over turf from 12 to 40%
	3.4% runoff reduction	Modeled reduction associated with increasing tree cover over impervious surface from 5 to 40%
Xiao and McPherson (2011b)	88.8% runoff reduction	Measured runoff reduction for bioswale integrating structural soils and trees[1]
Page et al. (2014)	80% runoff reduction	Measured runoff volume captured and treated by Silva Cell with tree[1]
Sanders (1986)	7% increase in runoff	Modeled increase in runoff associated with loss of 22% forest cover
	5% reduction in runoff	Modeled reduction associated with increasing tree cover over non-surfaced areas from 37% to 50%

[1] This study did not include unplanted controls

In addition to reducing total runoff volume, tree canopy can delay peak runoff because of its ability to intercept and slowly release rainfall (Asadian and Weiler 2009). Research on the ability of tree canopy to delay throughfall reports a delay in throughfall of 0.17 hours to 3.7 hours after rainfall (Asadian 2010, Xiao 2000).

Water Quality

Only one study (shown in bold) directly addressed the effects of urban trees on the quality of stormwater runoff, Table 5. Nine of the studies reviewed were field studies of the pollutant removal performance of stormwater treatment systems that include trees (e.g., Silva cells). However, only four of these studies (Denman 2006, Denman et al. 2011, Denman et. al 2015, Read et al. 2008) included unplanted controls to separate out the benefits provided by the tree vs. the filter media, and only one of those (Denman 2006) reported results that represent the water quality performance associated with the trees. Read et al. (2008) did not report results for trees versus other types of vegetation. Table 5 summarizes studies of pollutant removal from stormwater runoff by stormwater treatment systems with trees.

Table 5. Pollutant Removal by Stormwater Treatment Systems with Trees.

Study	Treatment System Type	Parameter and % Reduction[3, 4]						
		TN	NOx	DIN	TKN	TP	FRP	TSS
Denman 2006	**Street Tree Bioretention**	**82-95**						
Denman et. al 2011; Denman et al. 2015	Biofiltration		2-78				70-96	
Geronimo et al. 2014	Tree Box Filter							80-98
Page et al. 2014	Silva Cell				71, 84[5]	72		86
Roseen et al. 2009	Street Tree			62		-54[6]		88
UNHSC, 2012	Tree Box Filter (Non-proprietary)	10		8				88
UNHSC, 2012	Filterra	15				52		85
Xiao and McPherson 2011a	Bioswale	95.3[1]						95.5[2]

[1]average of all nutrient species results
[2]average of results from TSS and TDS
[3] values represent pollutant removal associated with the entire treatment system
[4] TN = total nitrogen, NOx = nitrogen oxides/dioxide; DIN = dissolved inorganic nitrogen; TKN = total Kjeldahl nitrogen, TP = total phosphorus; FRP = filterable reactive phosphorus; TSS = total suspended solids
[5] The values represent reductions from two different sites
[6] Authors speculate the contribution from compost affected the results (pers.comm)

Of the other studies on water quality benefits of urban trees, a modeling study by Band et al. (2010) estimated that current tree cover in Baltimore County, MD's Baisman Run watershed reduced TSS by 981 lbs (445kg) over the simulation period, TP by 4.4 lbs (2kg), TKN by 26.5 lbs (12kg) and NO2+NO3 by 8.8 lbs (4 kg). These results were based on modeling using UFORE-Hydro that simulated changes in flow due to changes in watershed land cover, and applied national median event mean concentration (EMC) values to estimate associated changes in pollutant loads; yet, it is difficult to put these values into context because the total pollutant inputs to the watershed are unknown. Groffman et al. (2009) and (2004) illustrates the retentive nature of urban forests compared to grasslands and agricultural lands. For example, Groffman et al. (2009) found that annual nitrate leaching was higher in grass than in forest plots, except for one highly disturbed site that had hydrologic N losses well in excess of atmospheric inputs. Further, data showed an estimated N retention of 95% in a forested basin, compared to 75% for a suburban basin and 77% for an agricultural basin.

Numerous studies have evaluated the water quality benefits of natural forests. Table 6 summarizes measured nutrient and sediment exports from undisturbed forests. It also presents ratios of pollutant loading from forests that have undergone disturbance (e.g., ice damage, insect defoliation, fire) and forests that were harvested (using a range of methods such as cattle grazing, clearcutting, strip cutting, and whole tree removal) compared to the pre-disturbance or control sites for those particular studies. Given the limited amount of data on the water quality benefits of urban trees and forests, the data from undisturbed forests could be applied to establish upper bounds of pollutant removal. The ratios for disturbed and harvested forest could potentially be useful if culled to look only at studies that represent conditions commonly found in urban forest patches or planting sites (e.g., sparse cover, die-off from lack of watering, compacted soils).

Table 6. Nutrient and Sediment Loads from Non-Urban Forests[1].

Type of Forest	**Pollutant Export (lbs/acre/year)[1]** ; number of studies shown in parenthesis		
	Total Nitrogen	Total Phosphorus	Total Suspended Sediment
Forest Land Use (CBWM 5.3.2, edge of stream)[5]	3.92	0.11	78
Undisturbed	2.14[3] (123)	0.16[2] (14)	41.9[2] (17)
	Ratio of Pollutant Export from Harvested/Disturbed Forest:Reference[4]		
Disturbed	3.09	2.04	2.04
Harvested	7.03	3.12	3.05

[1] based on studies of eastern forests compiled by Justin Hynicka from Maryland DNR for urban tree canopy land use recommendations

[2] median value

[3] calculated as the sum of median values for NO3 and TKN

[4] mean ratio of harvested or disturbed pollutant export to pollutant export from reference sites

[5] average edge of stream target

Leaf Litter

An emerging topic in urban stormwater management is the effect of nutrients and carbon from leaf litter on urban streams. Leaf litter represents a major energy source (dissolved organic carbon, DOC) and source of nutrients to streams where water soluble compounds readily leach from the leaves within hours to days following immersion, with macro-invertebrates and bacteria decomposing the leaf material in-stream. In urban-suburban areas, leaf litter collects in curbs and gutters and is flushed through the storm drain system, potentially contributing nutrients to urban streams.

While many urban areas have less than 40% tree canopy, the storm drainage systems provide a steady supply of leaf litter to streams, in addition to leaf fall from riparian areas (Stack et al. 2013). In a Scientific and Technical Advisory Committee (STAC) Workshop report, Sample et al. (2015) report data for Baltimore, MD provided by Nowak (2014) to estimate an urban tree canopy biomass nutrient load of 28.8 lbs/ac/yr and 2.95 lbs/ac/yr of N and P, respectively for the entire canopy. In an outfall netting study in Easton, MD, Stack et al. (2013) found an average of 4.7 TN lb/ac/yr and 0.36 TP lb/ac/yr associated with leaf litter (organic gross solids) in catchments with 24% canopy cover. The difference between these loading rates is attributed in part to the aged leaf litter at the outfall and leaf litter reaching the streams compared to the total canopy used to estimate the biomass by Nowak (2014). Further, research by Hobbie et al. (2013) found rapid decomposition rates for leaves on pavement. While Hobbie et al. (2013) documented an initial loss of the leaf litter mass by 80% within 1-year, there was continual fluctuation (increase and decrease) in phosphorus.

Street sweeping studies have also quantified the potential impact of leaf litter on urban nutrient loadings. Baker et al. (2014) and Berretta et al. (2011) found that organic matter (i.e., leaf litter) comprised 10% of the mass load collected by street sweepers. Baker et al. (2014) and Waschbusch (2003) found that the leaves, or coarse organic material found or collected on the street using field sampling methods or street sweeper, contribute 30% of the collected total phosphorus load. This 'gutter subsidy' was estimated by Baker et al. (2014) to be 2 lbs - 6 lbs P/curb-mile in residential catchments with up to 20% tree canopy. Further, Templer et al. (2015) estimated that up to 52 ± 17% of residential litterfall carbon (C) and nitrogen is exported through yard waste removed from the City of Boston, which is equivalent to more than half of annual N outputs as gas loss (i.e. denitrification) or leaching. The authors questioned the ramifications of the impact of such a substantial export on ecosystem services. While recent studies illustrate the available supply of leaf litter in urban areas, further research is needed to better quantify the fate, transport, and processing of leaf litter in urban watersheds and how to best account for this source as part of an urban nutrient mass balance. For example, significance of tree canopy reducing leachate of nitrogen compared to turfgrass (Nidzgorski and Hobbie 2015) and the predominance of groundwater delivery of inorganic N to streams in urban watersheds (Janke et al. 2014). Therefore, given the state of the science, Hynicka and Divers (2016) assumed a net flux of zero of nutrient from leaf litter based on a simplifying assumption of continuous cycling and distribution of nutrients as trees take up nutrients to support leaf development, through secession and litterfall.

4.2 Additional Benefits of Trees in the Urban Landscape

Trees in the urban environment provide a host of environmental benefits beyond the hydrologic and water quality benefits. Most notably, research demonstrates the impact of tree canopy to improve air quality, reduce temperatures in the urban environment, and mitigate the effects of climate change. Small patches and linear corridors of vegetation in urban areas provide habitat and food resources supporting diverse wildlife.

Trees and their leaf area and structure are effective traps for capturing atmospheric particulates and their dispersal or movement as well. The typical large surface area to volume ratio of the tree canopy provides an extensive area for atmospheric deposition of particulates and associated pollutants. For example, Nowak et al. (2013) demonstrated that urban trees remove large amounts of fine particulate matter ($PM_{2.5}$). This modeling based study estimated that 5.2 to 72.2 tons of $PM_{2.5}$ were removed from the atmosphere in Syracuse and Atlanta, respectively, consequently improving air quality. Janhäll (2015) describes the variable effects of vegetation to disperse or concentrate air flows and pollutants in urban 'canyons", while citing that larger and denser trees greatly reduced the dispersion enhancing its function to act as sink for pollutants. In addition to particulates, trees remove gaseous air pollutants by the leaf stomata as well as surface of the trees (Nowak et al. 2006).

Trees mitigate the urban heat island (UHI) effect as their canopy shades the surface of roads, parking lots and sidewalks as well as sides of buildings. Loughner et al. (2012) for example demonstrated that adding vegetation in metropolitan areas such as Washington, D.C. and Baltimore, MD decreased surface air temperature as a result of tree shading and evapotranspiration. Even relatively sparse parking lot canopies can exert a significant cooling effect on parking lot climate and vehicle temperatures (Scott et al. 1998). Akbari et al. (1997) documented 20–45°F (11–25°C) lower temperatures for tree covered compared to unshaded areas, while trees may reduce peak summer temperatures by 2–9°F (1–5°C) (e.g., Kurn et al. 1994). Also, common to all vegetation, the adsorption of carbon dioxide affects the concentration of carbon dioxide, a notable greenhouse gas.

Trees in urban areas are an important wildlife habitat despite development patterns that leave behind or produce small areas and linear corridors of vegetation. In a study in Central Ohio, Matthew et al. (2010) find that even small patches of urban forests are often key for migrating birds, such as the Swainson's thrush, a species that is declining throughout much of its range. An abundance and diversity of bird species is also present in urban areas in the United States that have the most canopy coverage. As part of a long-term ecological study in Baltimore, MD, Nilon et al. (2011) found at least a third of the total number of bird species known to occur in the region, in the city itself. They expect their survey to under-estimate the number of species as their study did not include urban forested or park areas. The bird species included black-crowned night herons, indigo buntings, scarlet tanagers, white breasted nuthatches and a variety of warblers.

SECTION 5: PROTOCOLS TO DEFINE NUTRIENT AND SEDIMENT REMOVAL RATES FOR URBAN TREE CANOPY EXPANSION BMP

The current Phase 5.3.2 CBWM tree planting BMP definition in CAST converts 1-acre of urban pervious land for every 100 planted trees. This results in a land use conversion from urban pervious to forest land use. In practice, reported trees were converted to acres of the BMP in Phase 5.3.2 using the 100 trees/acre conversion rate. While this approach was reasonable for the Phase 5 modeling tools, significant changes to the modeling tools under the Midpoint Assessment and in development of the Phase 6 CBWM demand an approach that gives a more realistic and scientifically-based credit reduction to tree planting efforts. Further, the resultant credit of planting a single tree or groups of trees on developed land uses would likely not result in a forest-like condition, thus water quality benefit, and therefore the value of credit required to address the range of tree planting projects in urban areas required further revision and development. For these reasons, among others, the Panel determined that protocols to define nutrient and sediment removal rates for the urban tree canopy BMP in Phase 6 need to consider a credit approach and value that better represented the diversity in pattern and distribution of trees (e.g. size, location and density of coverage, as well as underlying soil conditions), mortality, and how trees vary across the urban landscape – from a single tree to a small patch of trees, along a public right-of-way or in a parking lot, or in a residential yard.

In the long-term, tree planting is critical to offset the loss of trees from development throughout the Bay watershed. Collectively, within the Chesapeake Bay, individuals, government and private interests need to take immediate action to expand urban tree canopy through the maintenance and protection of existing tree canopy, including forested lands, in addition to planting. Conservation actions of existing tree canopy are needed as rates of land development in the Bay are such that loss of tree canopy, largely forested lands, is outpacing new urban tree canopy created by planting trees. Nowak (2012) estimated that 1 in every 3 new trees in urban areas is planted, while two-thirds of the gains to existing urban forest results from natural regeneration. However, natural regeneration was found to account for a much greater proportion of the influx of trees in Baltimore, MD compared to other urban areas evaluated. This new tree canopy will therefore take decades of growth to replace mature forest cover. The reality is that in the Bay watershed alone, some 750,000 acres—equivalent to 20 Districts of Columbia—have been developed since the 1980s (Sprague et al , 2006). Over roughly the same time period, the watershed has experienced a net loss of forest land at the rate of 100 acres each day (USFS report 2006, see Figure 1). Specific to the Baltimore area, Nowak and Greenfield (2012) found that city tree cover loss is 0.48% per year, while gains in impervious surface are 0.51% annually. Therefore, efforts to expand tree canopy in the future will depend on continued actions to plant new trees to replace lost canopy and conserve and maintain existing tree canopy that would facilitate natural generation. The protocols described below recommend an approach that recognizes these two critical factors to expand urban tree canopy and provide credit for jurisdictions towards the Bay TMDL.

The Phase 6 CBWM will include a tree canopy land use that includes: 1) tree canopy over impervious and 2) tree canopy over turfgrass land uses on developed (urban) lands. Current estimates of tree canopy land uses are provided in Table 2, although final estimates of this land use acreage are still under review by the Partnership until later in 2016. The current estimates represent approximately 2% of the total Bay Watershed for developed land uses. This estimate is based on methods used by the CBP to classify tree canopy from high resolution imagery. For land use mapping purposes, numerical thresholds were defined by the CBP to classify a tree if the spectral imagery for vegetation has an area of 97 ft^2 ($9m^2$) and is 5 m (16.4 ft) in height (Chesapeake Bay Image Interpretation and Mapping Standards, Chesapeake Conservancy, and pers. comm. J. O'Neil-Dunne, University of Vermont, 1/21/2016). A decision-rule is therefore recommended by the Panel to ensure the tracking and reporting of an annual expanded tree canopy BMP credit does not result in double counting tree canopy classified as a land use (see Section 6).

5.1 The Metric for Reporting the Phase 6 Urban Tree Canopy Expansion BMP and the Derivation of the Credit

Review of Existing Credit

The Expert Panel recommends replacing the current Urban Tree Planting BMP used in Phase 5.3.2 of the CBWM for the Phase 6 CBWM. In addition, the FWG provides recommendations for Urban Forest

Planting BMP as provided in Appendix H. The existing Urban Tree Planting BMP in Phase 5.3.2 equates 1-acre for forested land use for every 100 trees planted. The nitrogen, phosphorus and sediment reductions based on the land use conversion vary according to the calibrated land use loading rates, but the net reduction is approximately 67% for nitrogen, 77% for phosphorus and 57% for sediment based on the median Phase 5.3.2 land use loading rates for urban pervious and forest. The existing tree planting BMP is cumulative, which means that the acres reported in a previous year carry over into the next year.

The Panel found that the 100 newly-planted trees equivalent to one acre conversion was too generous. The canopy cover as a result of planting 100 trees would likely not be large enough to cover one acre and likely did not account for mortality. Typically, in practice, tree planting projects 'overplant' to account for expected mortality, especially in the first few years. The proposed Phase 6 Urban Tree Canopy Expansion BMP credit incorporates mortality into the **creditable acreage of tree canopy** to account for the fact that a proportion of trees will die and urban growing conditions are likely not optimal for the average tree to realize its full growth potential. As such, tree canopy is gained and lost year-to-year. Consequently, the Expert Panel found no basis for equating the per acre nutrient and sediment load from urban land with 100 trees planted to that of forest. Therefore, the Panel concluded that the water quality benefits of urban tree planting should be based upon a projected growth of individual trees planted. This approach to crediting is more representative of urban planting and growing conditions.

Urban Tree Canopy Expansion BMP

The Panel recommendation for the Urban Tree Canopy Expansion BMP is intended to broaden the type of management actions that would provide nutrient and sediment credits available for tree planting efforts in urban areas. The Panel supports that 'every tree counts' and provides some level of water quality benefit. A detailed description of the methods used to derive the water quality benefit of the Urban Tree Canopy Expansion BMP and its creditable area for this BMP is provided in Section 5.2.

The **Urban Tree Canopy Expansion BMP** is defined as actions on developed land (impervious or turfgrass) that result in an increase in tree canopy but are not intended to result in forest-like conditions. The trees are not part of a riparian forest buffer, structural BMP, or do not conform to the definition of the Urban Forest Planting BMP. Credit is based on the number of individual trees planted with a conversion to equivalent acres for reporting purposes. A credit of 144 ft^2 per tree planted is equivalent to 300 trees planted per acre; however, this is not a planting density requirement. Thus, each newly planted tree converts 1/300 an acre of either pervious or impervious developed area to tree canopy land uses. The relative nitrogen, phosphorus and sediment load reductions are applied to the underlying land use and applied to creditable area (see Section 5.2.1). This BMP does not require trees to be planted in a contiguous area. There is no double counting between this BMP and the Urban Forest Planting BMP (Appendix H). The reader should refer to Appendix F or the latest set of Phase 6 modeling documentation for the partnership-approved definition used for modeling and reporting purposes.

The Panel recommendations for the creditable area for Urban Tree Canopy Expansion BMP account for expected mortality of newly-planted trees and is a way to provide realistic, yet conservative, estimates on projected tree growth given the numerous factors that affect tree survivability and growth potential across a range of conditions expected in urban and suburban environments. Accounting for the effect of mortality on tree canopy is consistent with crediting approaches used for other urban stormwater BMPs that 'discount' the optimal function of a BMP based on reasonable, real-world factors that are expected to impact performance and longevity. While a 'no tree loss' assumption may provide a strong incentive for tree planting, this would likely lead to an over-estimate of actual tree canopy if the most optimistic 'gains' in tree canopy were awarded for tree planting.

The Panel also considered the actual versus projected or future condition of tree canopy in development of the recommended protocol. Unlike most other stormwater BMPs, the actual water quality benefits of tree canopy are time-dependent. Trees have a biological lifespan. As such, the tree canopy will increase in size until it peaks at maturity, then begins to decline and die. Conversely, traditional structural urban BMPs such as wet ponds will function at their engineered level immediately and if maintained will continue to function as designed for the design lifespan. For this reason, it was necessary to determine the appropriate time horizon for quantifying the benefits of an annual urban tree canopy BMP credit given the TMDL 2025 timeframe and how this additional acreage of tree canopy would affect accounting for the existing tree canopy (vs new BMP) land use acreage.

Lastly, as a result of discussions with the CBP modeling staff and Partnership, the Panel recommendations assumed that the CBWM **tree canopy land use** acreage that accounts for existing urban tree canopy within the Bay watershed, and separately from the BMP, will be updated approximately every five (5) years. The Panel has concern that land use updates using high resolution imagery may result in double-counting of urban tree canopy acreage if a decision rule to distinguish urban tree canopy as a result of the BMP is not provided. However, the specific method to update the land uses is to be determined by the Partnership at a future date. The initial aerial mapping data are based on 2013 high resolution remote sensing imagery with an expected update in 2018/19 and likely in 2023 (pers. comm., P. Claggett). The Expert Panel requests that a decision rule(s) be developed by the Partnership to determine if there will be an issue with double-counting the acreage of tree canopy credited as a BMP (i.e., as a result of tree planting) and the acreage of canopy as captured by high resolution imagery in future land use updates.

5.2 Crediting Approach

The nutrient and sediment reduction credits for the **Urban Tree Canopy Expansion BMP** is based on the approved land use loading rates for the urban tree canopy land uses (Appendix B) and Panel recommendations for a creditable area. The ability to quantify the effect of urban tree planting on urban stormwater loads differs from other urban BMPs as there are not set design specifications to quantify a specific volume of runoff treated and the numerous factors that affect performance of individual trees as described in Section 4. Best professional judgement, along with findings from research, are needed to develop methods that quantify the pollutant load reductions from this BMP. While models exist to quantify the hydrological benefits of tree canopy, specifically runoff reduction, the output is highly dependent on the type of tree species, age class, climate, land use. Therefore, a method to generalize the effect of either 'classes of trees (e.g. broadleaf, evergreen, large, medium or small trees) representative of a Chesapeake Bay default climate or sub-regions is needed for the purposes of Urban Tree Canopy Expansion BMP credit development.

5.2.1 Tree Canopy BMP Nutrient and Sediment Load Reductions

Appendix B provides the full documentation of the methods used to develop the relative land use loading rate for the tree canopy land uses. A general water balance approach (Eq. 1) where input (I) equals output (O) plus any change in storage (ΔS) is used to derive the relative effectiveness of tree canopy over turfgrass and impervious cover. This method provides an estimate of the proportion of precipitation that becomes surface flow (edge of field), or water yield. The water balance approach incorporates key hydrologic processes that affect the movement and fate of nutrients and sediment to include: precipitation (P), runoff (R), evapotranspiration (ET), soil leachate (L) and a change in storage term (ΔS). Hynicka and Divers (2016) describe the water mass balance in the equations below, where the subscripts *g* and *t* refer to parameters specific to turfgrass and tree canopy, respectively. Equations 4 and 5 omit the soil leachate term as this process is not applicable to impervious land cover. Rather, a laterally flowing subsurface water (T) term is introduced to quantify the water moving through the soil. This term is a necessary assumption to meet the basic physiological needs of the tree.

General Mass Balance: $I = O + \Delta S$ **(Eq. 1)**

Turfgrass: $P = R + ET_g + L + \Delta S$ **(Eq. 2)**

Canopy over Turfgrass: $P = R + ET_g + ET_t + L + \Delta S$ **(Eq. 3)**

Impervious $P + T_i = R + E + T_o + \Delta S$ **(Eq. 4)**

Canopy over Impervious: $P + T_i = R + ET_t + T_o + \Delta S$ **(Eq. 5)**

Hynicka and Divers (2016) used daily precipitation data over an 11-year period from eight weather stations throughout the Chesapeake Bay watershed, along with representative values from the literature to parameterize the processes represented in the model (e.g. ET, L, T). The Soil Conservation Service Curve Number (CN) Method was used to estimate runoff for the four land use scenarios (i.e., turfgrass, canopy over turfgrass, impervious and canopy over turfgrass) (USDA 1989). The CN method was modified to account for the amount of precipitation adsorbed to leaves and branches after throughfall stops, effectively reducing the amount of precipitation that reaches the ground, or underlying land cover. The curve numbers used in the model were selected to represent the underlying land cover and potential modifications as a result of tree canopy overlying them.

Table 7. Curve numbers used to derive relative land use loadings rates for tree canopy (from Hynicka and Divers 2016)

Land Cover Land Use	Curve Number Value	Description
Impervious	98	Recommendation in USA Technical Release 55, Urban Hydrology for Small Watersheds
Tree Canopy over Impervious	98	Tree canopy does not modify underlying impervious cover properties
Turfgrass	79	Equivalent to turfgrass in fair conditions, HSG C
Tree Canopy over Turfgrass	74	Account for effects of canopy interception and improve physical structure of compacted soils by tree roots (see Day et al. 2010). Equivalent to turfgrass in good conditions, HSG C

This analysis provides a relative (%) load reduction for tree canopy over pervious of 23.8% for TN and TP and 5.8% for TSS. The relative load reductions for tree canopy over impervious are 8.5%, 11% and 7% for TN, TP, and TSS, respectively. These relative load reductions are applied to the underlying land cover loading rate. For example, tree canopy over turfgrass would modify the TN load reduction of turfgrass by 23.8%, or 8.5% TN load reduction of impervious loading rate where tree canopy is over impervious cover. The average percent N, P and sediment load reductions for this BMP are shown in Table 8. The actual reduction will be calculated in the modeling tools using the calibrated Phase 6 loading rates.

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Table 8. Tree canopy relative land use loading rates based on the underlying land use land cover (Source: Hynicka and Divers 2016)

Land Use	Total Nitrogen Reduction (%)	Total Phosphorus Reduction (%)	Total Sediment Reduction (%)
Canopy over Turfgrass	23.8	23.8	5.8
Canopy over Impervious	8.5	11.0	7.0

The effectiveness value would then be applied to a reported acreage of new tree canopy as a result of tree planting (see next section). The total reduction would be automatically calculated through the modeling tools, but can basically be understood by the following equation:

Edge of Field Load Reduction (lbs/yr) = Planted Tree Canopy (acres) x Tree Canopy Loading Rate Reduction (%) x Base Land Use loading Rate (lbs/ac/yr) **(Eq. 6)**

5.2.2 Derivation of Creditable Area for Urban Tree Canopy Expansion BMP

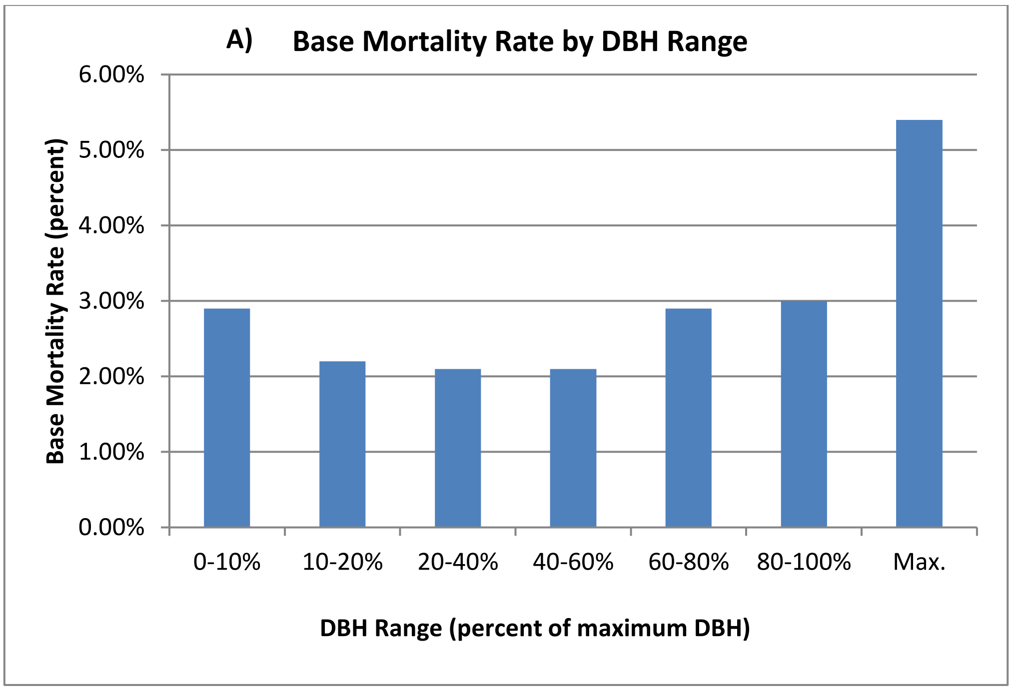
A central consideration by the Expert Panel in developing a method to credit tree canopy acreage for an annual BMP is the ability to translate '*number of trees planted*' to acres of tree canopy and to keep the reporting and tracking simple (e.g. # trees/acre). The crediting method would need to be able to account for a variety of tree planting scenarios (e.g. from single trees to small groups of trees) with the exception of planting projects that meet the criteria of the Urban Forest Planting BMP (Appendix H), where planting is intended to create forest like conditions. This desire for simplicity stems from the relatively small area treated by the Urban Tree Planting BMP compared to other BMPs as reported in the Phase II WIPs progress reports, the non-structural nature of this BMP, and the numerous organizations and individuals that are involved in tree planting efforts throughout the Bay watershed.

There are numerous variables that affect the canopy size of an individual tree, and therefore the Panel sought a method that could characterize these factors to provide a default or representative net tree canopy acreage based on number of trees planted. The method adopted by the Panel to develop a conversion factor for 'number of trees planted' to acres of tree canopy is described below.

Overview of the i-Tree Forecast Modeling Tool

i-Tree Forecast estimates annual tree canopy coverage amounts and growth based on tree population data for an area of interest. It is a part of the i-Tree suite of models developed by the USFS (Nowak et al. 2013a, b). i-Tree Forecast is an empirical model that was released in Spring 2016 as part of the i-Tree ECO model. The USFS provided simulations of i-Tree Forecast based on Panel input using a pre-release version of the model. Documentation of the model can be found in Nowak et al. (2013a, 2013b) with additional documentation expected to be available when i-Tree ECO is released (i.e., https://www.itreetools.org/resources/manuals/Ecov6_ManualsGuides/Ecov6Guide_UsingForecast.pdf).

The area of tree canopy cover is predicted by the following tree characteristics: species (growth rate, height at maturity), diameter at breast height (DBH), crown light exposure (CLE) and dieback. For the purposes of the simulations defined by the Panel, the growth rate is not affected by dieback as the trees planted were assumed to be in good condition. The tree characteristic data used in i-Tree Forecast is based on data published in the literature and field data from areas throughout the United States[1]. The field and published data provide species-specific information on DBH, tree height, crown height, crown width and other variables to derive equations used in the model. The growth rate and other tree parameters of an individual tree (or group of trees) are dependent on DBH for a species, which functions as the primary independent variable in the i-Tree Forecast model. Figure 2a shows how each size class of tree has a unique set of seven diameter ranges to which base mortality rates are assigned. If a user specifies a different mortality rate, a similar distribution of DBH class is used in i-Tree Forecast. A user-defined mortality rate of 5% was selected by the Panel (see next section for more detailed description), with additional model simulations evaluating a 2.5% mortality. This mortality rate is applied in the initial year (at planting) but will vary in subsequent years based on DBH as shown in Figure 2b below.



[1] List of databases include: http://hort.ufl.edu/; http://plants.usda.gov; http://www.backyardgardener.com/; http://www.ces.ncsu.edu/; http://www.floridata.com; http://www.hort.uconn.edu/plants/; http://www.hortpix.com/index.html; http://en.hortipedia.com/wiki/

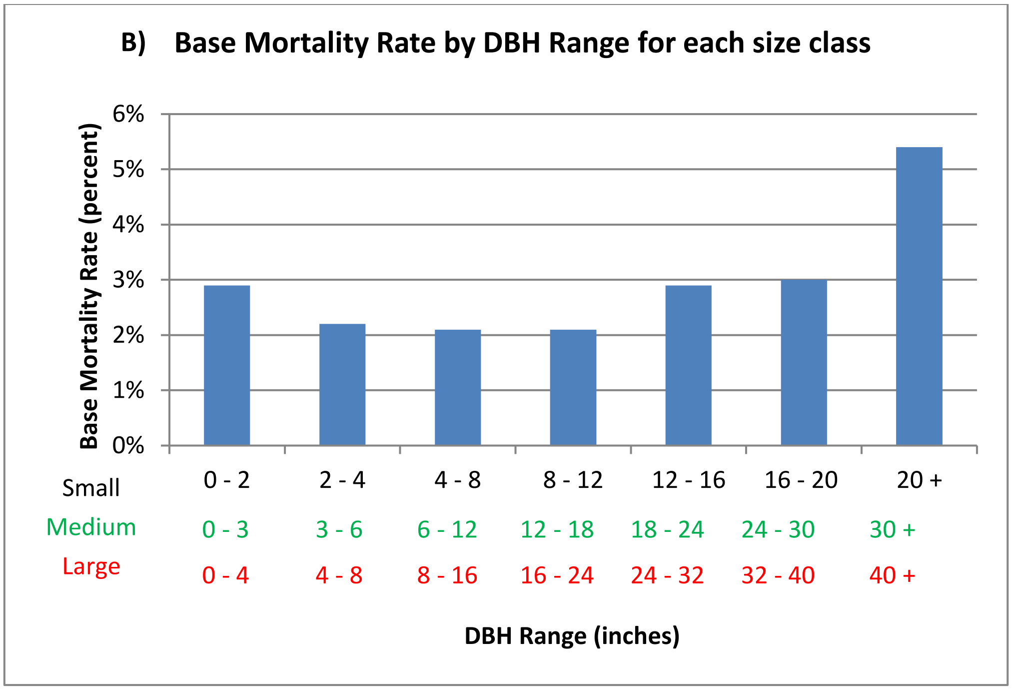


Figure 2. Mortality rate distribution by diameter class with range classified by DBH for the species (A) and for actual DBH classes for small, medium and large tree species (B), (Nowak et al. 2013b)

Description of i-Tree Forecast Simulations Used to Derive Panel Recommendations

Forecast simulations, for the purposes of informing Panel recommendations, were designed to provide **an average annual projected canopy area for a single tree planted**. Input parameters for i-Forecast included: location (growing season length), size of tree at planting, baseline mortality rate, crown light exposure, condition of tree at planting, and tree species. The summary of the Panel input for i-Tree Forecast simulations is provided in Table 9. Twenty tree species were selected by the Panel based on commonly identified species for tree planting, to include large, medium and small broadleaf deciduous, large and small coniferous evergreen and broadleaf evergreen. The number of different species input to Forecast was balanced by a manageable number of 'cohorts' for summary output. A cohort is defined as a group of trees which all have the exact same set of input parameters. The final simulation included 40 cohorts per location (20 species, 2 crown light exposure conditions) for analysis with 10,000 trees per cohort. The high number of trees is used as input for building precision into an average estimate of net tree canopy area for a single tree planted. The location is defined by the growing season length that is represented by the number of frost-free days (FFD) per year. Figure 3 shows the distribution of the four climate regions included in the simulation. The summary output also defines a default Chesapeake Bay-wide climate (166 FFD). A 5% mortality rate was initially selected by the Expert Panel based on a literature review (see Appendix C for summary of studies) and best professional judgement. Additional scenarios used a lower mortality rate of 2.5% to evaluate the effect of average annual, projected canopy growth.

In i-Tree Forecast, the mortality is applied annually to the remaining tree population. For example, if 10,000 trees are planted, one year after planting 9,500 trees would remain after year 1 using a 5% mortality rate. However, the mortality rate is adjusted lower in subsequent years as shown in Figure 2 for a given species and DBH. In general, research finds higher mortality rates are typical in urban compared to natural forest conditions and for newly planted and younger trees. A meta-data analysis by Roman and Scatena (2011) estimated street tree annual survival rates ranged from 94.9% to 96.5% which equates to a mean life expectancy of 19-28 years. The estimated lifespan for an urban tree in Baltimore, MD was estimated to be 15 years (Nowak et al. 2004). Roman (2013) found an overall annual mortality rate of street trees in Oakland CA of 3.7%, with the highest mortality rates found for small/young trees. The same study evaluated survival of trees planted through a residential planting program in Sacramento, CA and found a survival rate of 70.9% at five years post-planting. A study of street trees in New York City found that the highest mortality rates occurred in the first few years after planting (Lu et al. 2010). The canopy area per tree planted is a metric that accounts for remaining canopy of surviving trees, divided by the original number of trees planted. The apparent decrease in canopy area per tree is because eventually the die-off/mortality rate overtakes the canopy growth rate; a modeled tree does not decrease in size, but the number of trees decreases enough that the average remaining canopy area per original tree planted does decrease.

Canopy area per tree planted is given by:

(Canopy area per surviving tree) x (Number of surviving trees) / (Number of trees originally planted) **(Eq. 7)**

The simulations were considered a-spatial as the only geographic reference for the simulations is climate region. Tree planting density was not addressed with the exception of light conditions specified in the simulations. For example, a park or forest-like condition would limit crown light exposure (CLE) similar to higher density planting situations. Land use was not taken into account regarding impacts on tree condition, growth rate, and mortality, as this would require location-specific input parameters at the county-level. Further, land use does not affect the projected tree canopy growth, rather environmental outputs from the model.

Table 9. Summary i-Tree Forecast model simulations.

- 4 Geographic regions and one representative average of the Chesapeake Bay watershed. The geographic region is defined as an area with the same number of frost-free days (FFD)/year as defined in i-Tree Forecast. The FFD is used as a proxy variable to account for climate effect on growth. Other specific factors that affect tree growth explicitly such as precipitation and solar radiation are taken into account as part of modeling environmental outputs in associated hydrological and pollution models. This part of i-Tree Forecast was not used by the Panel as the explicit use of i-Tree Forecast was to provide an estimate for canopy growth based on trees planted. Below is the initial list of regions within the Chesapeake Bay classified by FFD where the numbers indicate the growing season length (in frost-free days). The locations provide examples of locations within each of the regions.
    - 105 FFD: e.g. Cooperstown, NY; Force, PA
    - 150 FFD: e.g. Scranton, PA; Monterey, VA
    - 166 FFD: This is the average across the Chesapeake Bay
    - 210 FFD: e.g. Baltimore, MD; Norfolk, VA; Dames Quarter, MD
    - 255 FFD: e.g. Harborton, VA; Tangier, VA (Eastern Shore, Accomack County)
- The final set of scenarios included 2 climate regions and the Chesapeake Bay default.

- Size of tree at planting
    - 1” DBH planting size was selected to be representative of tree planting projects. This size of tree is generally representative of a 5 year old tree.

- Condition at planting
    - Good condition.

- Mortality
    - Two mortality rates were simulated for analyses; 5% and 2.5% baseline mortality rate, of remaining population based on literature review values (average of 19 studies that evaluated street and/or yard trees across a wide range of geographic locations) and best professional judgement

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- Crown light exposure (2 types).
    - Forecast provides two CLE parameters that differ in the amount of sunlight a crown is exposed to. A park-like setting is similar to a partially closed canopy and growth rate is reduced by 44 percent. An open-space setting received full sunlight. The simulations planted ½ of the trees in park-like setting and ½ in open space. The park-like setting provided reduced light exposure to a tree that would be present when trees are planted near buildings, for example.

• Tree species to represent. A total of 20 species were included in the model simulations to be representative of the different tree types: – Broadleaf large, medium and small species (n=4, 4, 5) – Evergreen large and medium species (n=4, 2) – Broadleaf evergreen small specie (n=1)	**Broadleaf deciduous, large** Platanus acerifolia - London planetree Quercus michauxii - Swamp chestnut oak Quercus phellos - Willow oak Ulmus americana - American elm **Broadleaf deciduous, medium** Acer rubrum - Red maple Betula nigra - River birch Nyssa sylvatica - Black tupelo Ostrya virginiana - Eastern hophornbeam **Broadleaf deciduous, small** Amelanchier arborea - Downy serviceberry Cercis canadensis - Eastern redbud Cornus kousa - Kousa dogwood Prunus yedoensis - Yoshino flowering cherry Styrax japonicus - Japanese snowbell **Coniferous evergreen, large** Cryptomeria japonica - Japanese red cedar Cupressocyparis x leylandii - Leyland cypress Pinus spp - Pine (average of genus) Pinus strobus - Eastern white pine **Coniferous evergreen, medium** Chamaecyparis thyoides -Atlantic white cedar Juniperus virginiana - Eastern red cedar **Broadleaf evergreen, small** Ilex opaca - American holly

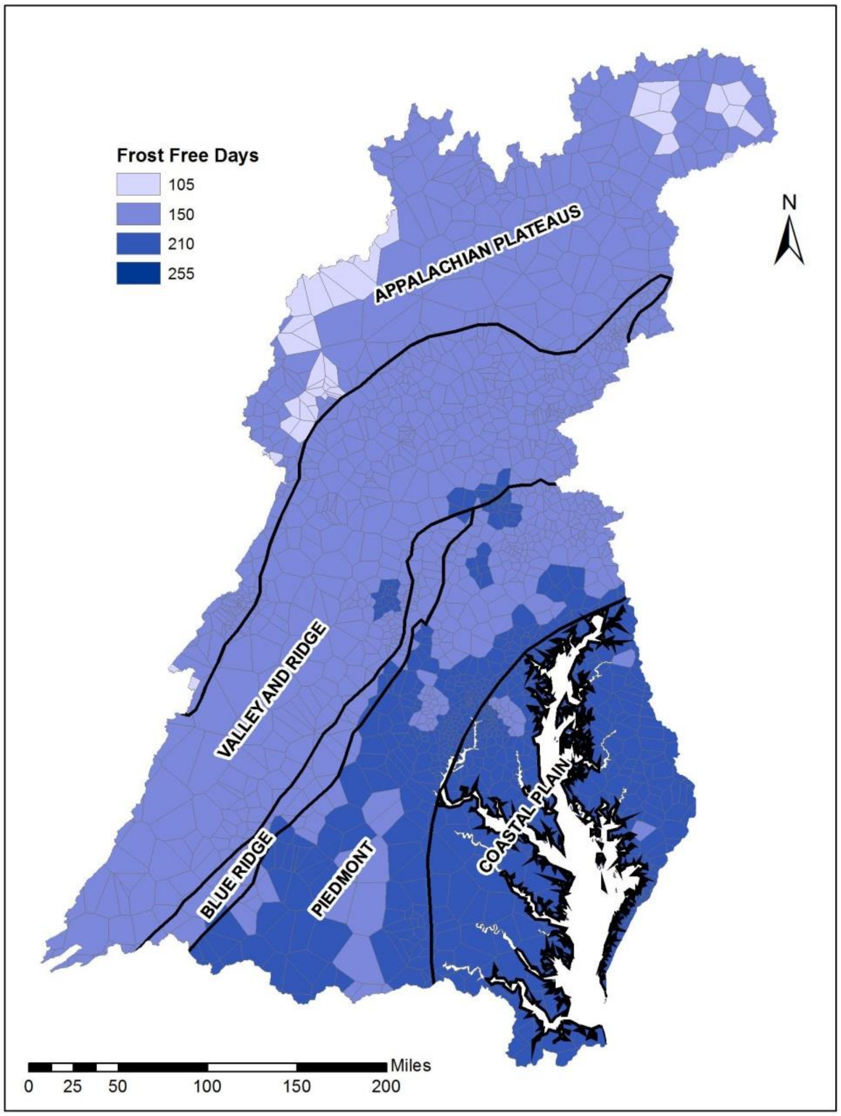

Figure 3. Climate regions used in the i-Tree Forecast model simulations

5.3 Summary of Results

i-Tree Forecast provides an average projected annual growth of tree canopy area for a newly planted tree based on the scenarios described in Table 9. The results of the model were then used to provide an estimated acreage 'credit' for each tree planted. The results are provided for the 150 FFD, 210 FFD and Chesapeake Bay average of 166 FFD. Due to the small area of the 105 FFD and 255 FFD (3.6% of the Bay watershed area), the Panel concluded that projected canopy growth in these areas may be associated with the other two FFD climate areas and a Bay-wide average. The 210 FFD climate area closely approximates the Coastal Plain and Piedmont physiographic provinces, while the 150 FFD is inclusive of the Valley-Ridge and Appalachian physiographic provinces.

Figure 4 illustrates an example set of results for all tree types simulated for the Bay-wide climate area. Additional output from Forecast is provided in Appendix E. While the growth curves for the broadleaf trees are similar, the projected canopy area for the different tree species is apparent, with evergreens and coniferous with the lowest projected canopy area and broadleaf species the greatest area. The average projected canopy area for a single tree also varies by climate, where a longer growing season (i.e., more FFDs) is expected to produce a larger tree canopy.

The Panel recommends a definition of a default or representative tree as a necessary simplification for jurisdictions to report and track this BMP given the numerous factors that affect tree canopy (i.e., growth and survivability of trees planted) and the information typically available for tree planting projects. The Panel's professional experience finds that coniferous evergreen trees are not commonly planted and subsequently not considered as part of the recommended default definition of a tree and credit. The default broadleaf tree is defined as projected growth for both broadleaf large and medium trees. Table 10 provides results for an average, or default broadleaf tree for the three climate scenarios using a 5% and 2.5% mortality rate.

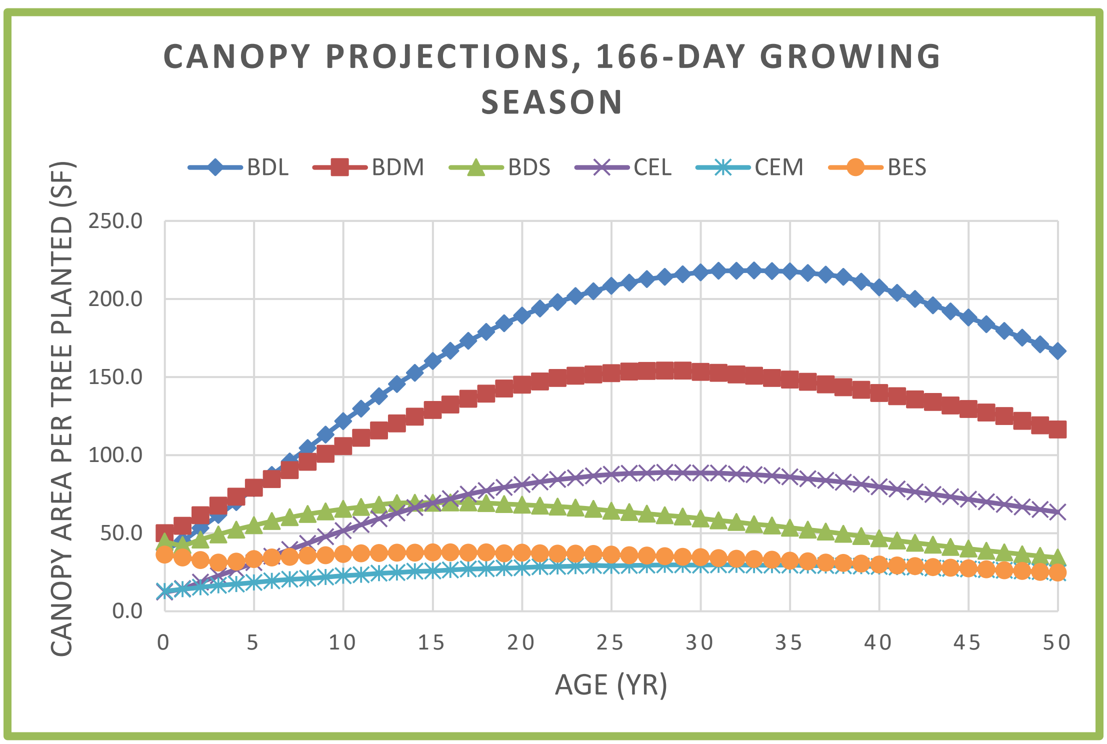

Figure 4. Canopy projections for the Chesapeake Bay-wide (166-day) growing season. (BDL = broadleaf large; BDM = broadleaf medium; BDS = broadleaf small; CEL = coniferous large; CEM = coniferous medium; BES = broadleaf evergreen)

Table 10. Projected average canopy area (ft^2) for a single tree planted for specified growth period using a 5% mortality rate (a) and 2.5% mortality rate (b).

a) Default Broadleaf (ft^2), 5% mortality			
	150 FFD	**166 FFD**	**210 FFD**
Age (yrs)	**Valley Ridge and Appalachian Physiographic Region**	**Chesapeake Bay-wide**	**Coastal and Piedmont Physiographic Region**
5	74	79	92
10	104	114	**144**
25	160	180	239

b) Default Broadleaf(ft^2), 2.5% mortality			
	150 FFD	**166 FFD**	**210 FFD**
Age (yrs)	**Valley Ridge and Appalachian Physiographic Region**	**Chesapeake Bay-wide**	**Coastal and Piedmont Physiographic Region**
5	85	90	105
10	132	**144**	182
25	271	304	399

In its review and discussion of the i-Tree Forecast outputs summarized in Table 10a-b above, the Panel agreed that their "Default Broadleaf" category, which combines Broadleaf-Large and Broadleaf-Medium, was the most representative of trees planted in urban and suburban contexts. This agreement reflected the Panel's experience and best professional judgment that the other categories (broadleaf small, coniferous, and broadleaf evergreen) are rarely selected for planting projects and their lower Forecast results should therefore not be incorporated in the Panel's recommended estimate of average canopy area per tree planted. The Panel also agreed that a canopy area following 10-years of growth after planting represented a good compromise for a creditable area. This was based on the following discussion points:

- An analysis of the i-Tree Forecast results found that, on average, it would take approximately 10-years of growth after planting for the canopy area to be captured by high resolution imagery (i.e., 97 ft^2 minimum area for higher resolution imagery used by Partnership to map urban tree canopy land uses).
- The Panel agreed that crediting canopy growth at a greater expected maturity (>10 years) would over-credit the Urban Tree Canopy Expansion BMP.
- 10-years represented a period that approximated the time at which all BMPs should be implemented for the 2025 target date for the Bay TMDL.

The Panel also agreed that the BMP reporting should be as simple as possible, and that a separate BMP for coniferous or smaller tree species would be unnecessary. With these points in the mind, the Panel chose 144 ft^2 as the best estimate of average canopy per tree planted.

The Panel noticed that the 144 ft^2 appeared in both the 5% and 2.5% mortality scenarios for the 210 FFD and 166 FFD areas, respectively. After discussion there was agreement that one estimate, not multiple estimates based on varying mortality or FFDs, should be used for the Phase 6 BMP, based on 10 years of growth for the reasons explained above. This conclusion from the Panel was later strengthened when the output from i-Tree Forecast was found to compare well with the "Tree Canopy Spread & Coverage in Urban Landscapes" database for 10-year old trees (http://dendro.cnre.vt.edu/predictions/canopy.cfm). Table 11 provides the 10-year minimum and maximum canopy area for the tree species used to define the default tree with a range of canopy area from 46 – 226 ft^2.

Table 11. Comparable Urban Tree Canopy Area for Selected Broadleaf Tree Species from Existing Database ((http://dendro.cnre.vt.edu/predictions/canopy.cfm)

Broadleaf deciduous, large	**10 yr area, min (ft^2)**	**10-yr area ,max (ft^2)**
Platanus acerifolia - London planetree	153	201
Quercus michauxii - Swamp chestnut oak	201	226
Quercus phellos - Willow oak	78	113
Ulmus americana - American elm	176	226
Broadleaf deciduous, medium		
Acer rubrum - Red maple	113	176
Betula nigra - River birch	133	201
Nyssa sylvatica - Black tupelo	50	78
Ostrya virginiana - Eastern hophornbeam	46	66
AVERAGE	**118.8**	**160.9**
GRAND AVERAGE	**139.8**	

Source: http://dendro.cnre.vt.edu/predictions/canopy.cfm

5.4 Final recommendation for BMP credit

The Expert Panel recognizes that new acreage of tree canopy from tree planting activities will make up a small percentage of overall tree canopy and that a net loss of tree canopy in the Chesapeake Bay watershed will continue to occur unless measures are taken to maintain and conserve existing tree canopy. Trees planted for mitigation purposes, as required by existing regulations, are not eligible for TMDL credit.

Recommendation 1: Decision Rule for Tree Canopy as a BMP and as a Land Use

The high resolution imagery used by the Partnership to develop the Phase 6 CBWM land use distribution has a minimum mapping unit for tree canopy land uses of 97-ft^2 in area (Chesapeake Bay Image Interpretation and Mapping Standards, Chesapeake Conservancy, and pers. comm., J. O'Neil-Dunne, University of Vermont, 1/21/2016). In review of the Forecast results, a tree will, on average, meet the 97 sq. ft. threshold 10 years after planting (assuming a DBH of 1" at planting with an assumed mortality of 5%). Therefore, the recommended decision rule be that trees will require a minimum of 10 years growth after planting to reach an area necessary to be captured by high resolution imagery and mapped as a land use. Based on this decision rule, trees planted for BMP credit in 2016 and onward will continue to be tracked as a BMP through 2025.

Recommendation 2: Lifespan of Annual BMP Credit

The lifespan of the BMP credit is based on the time period until it is mapped as a land use based on the high resolution imagery analysis completed by the Partnership and i-Tree Forecast results (i.e., minimum of 10 years of growth after planting). This BMP would not be eligible for renewal in the NEIEN once it is classified as a land use to avoid double counting of tree canopy acreage. Unlike other structural BMPs that have a credit duration due to their expected practice lifespan, urban trees on average have an expected lifespan between 19-28 years, and longer on residential sites (Roman and Scatena 2011).

Recommendation 3: Information for Reporting and Tracking BMP

The Panel recommends using the default broadleaf tree as a representative tree to report and track this BMP since broadleaf large and medium trees are most common for tree planting. While there are many different species planted that are typical of urban tree planting projects, the majority of the trees are either large or medium deciduous based on the Panel's experience and best professional judgement. The species selection was based on Panel input. This recommendation does not limit the type or density of trees planted that are eligible for credit. The credit applies to all tree types, whether planted individually or in a contiguous area (i.e., trees other than broadleaf species may be planted).

While climate region (FFD) is not necessary to report and track the BMP, the Panel used the output from i-Tree Forecast simulations for the Chesapeake Bay-wide climate of 166 days as guidance to determine the tree canopy acreage for credit. An assessment of the FFD shown in Figure 3 and the county jurisdictional boundaries found that many counties, specifically in the Piedmont region, may be subject to more than one FFD area. The Panel concluded that reporting a canopy area credit based on multiple climate regions would be too complex and that the BMP should be as simple as possible for reporting and tracking purposes. The Panel concluded that the Bay-wide FFD of 166 days should be used as guidance to project canopy growth using a default tree to avoid complexities of multiple FFDs within a single county and provide clarity for ease of reporting and tracking.

Recommendation 4: Metric for Translating Trees Planted to Urban Tree Canopy Acreage

The Panel recommends the annual BMP acreage credit be based on 10 years of projected growth after planting. The 10 years of projected growth was chosen not only to assure that trees planted can be identified through high resolution imagery but it also represents a mid-point in the projected lifespan of the tree that best aligns with the planning timeframe for the Phase III WIPs where jurisdictions must identify the BMPs that will be "in the ground" by 2025. That is, the average life expectancy of urban street trees is approximately 19-28 yrs (Roman and Scantena 2014), while Nowak (2004) estimated the average lifespan for urban trees in Baltimore, MD to be 15 years. This means that trees planted in 2016 and after will receive the full BMP credit assuming 10 years of growth whether or not they actually grow large enough by 2025. In this sense these trees are “over-credited.” On the other hand, the trees that continue growing beyond 10 years will be “under-credited.” Both the projected growth and the nutrient and sediment reduction credit are considered to be conservative. While the sediment and nutrient reduction credit is over-estimated during this period, after 10 years the reduction credit is under-estimated assuming proper tree care and in the absence of actions or disease that cause its mortality. This recommendation provides assurance that the continued growth of trees post 2025 will work to maintain the nutrient and sediment caps after the TMDL is met.

The Panel recommends that the credit for the default broadleaf tree for the Bay-wide climate is as follows with number of trees per acre shown in parentheses: 144 ft^2 of tree canopy area for every tree planted (300 trees per acre). This is based on a similar output of i-Tree Forecast for the recommended 10-years of projected growth assuming low and high mortality rates (2.5% and 5% mortality) in both the 166 and 210 FFD areas. This is the Expert Panel’s best professional judgement to provide a realistic, yet conservative canopy area to credit towards the BMP given that this projected canopy area is similar to existing databases and accounts for annual mortality. Simulations represented conditions to simulate growth in urban areas, where there are less than ideal conditions for maximum growth.

An example calculation to illustrate how the credit would apply follows.

The example assumes use for the CBWM Phase 6. As such the land use loading rates used in this example are for illustration purposes only as they are subject to change prior to the release of the model in 2017. A jurisdiction reports 1,000 trees planted in 2017, 800 trees are planted on pervious land uses and 200 trees are planted adjacent to sidewalks or impervious right-of-ways. The effectiveness value applied to the BMP is based on the land use change to tree canopy over turfgrass area or tree canopy over impervious area (Table 8) and Equation 6.

Table 12. Estimate of Total Nitrogen, Total Phosphorus and Total Suspended Sediment Load Reduction Credit as a Result of Urban Tree Canopy Expansion

Numbers Of trees Planted	Dominant underlying Land Use Land Cover (Phase 6)	Equivalent tree canopy (acres)	TN (lbs/ac)	TP (lbs/ac)	TSS (ton/ac)
800	Turfgrass[1]	2.67	7.87	0.35	27.84
200	Impervious	0.67	0.88	0.14	60.67

[1] For this example, the land use classifications for Phase 6 are used, however, the loading rates are based on the pervious land use loading rates from the 5.3.2 model for TN, TP and TSS are: 12.4 lb/ac/yr, 0.55 lb/ac/yr and 0.09 ton/ac; Impervious land use loading rates for TN, TP and TSS are: 15.5 lb/ac/yr, 1.93 lb/ac/yr and 0.65 ton/ac.

(Note the loading rates for impervious and turfgrass (pervious) land use land cover used for this example are based on CBWM version 5.3.2 from Sample et al. 2014[1] and are subject to change based on final CBWM version 6. This is for illustrative purposes only.)

Qualifying Conditions

The qualifying condition for this BMP is to report the number of trees planted. This is consistent with the previous Urban Tree Planting BMP reporting requirements and information typically available given the diversity of project implementation. Jurisdictions may also report the dominant land cover on which the tree is planted (turfgrass or impervious using Phase 6 developed land use classes). This information would be provided based on site conditions at the time of planting. If this information is not provided, the CBP will make assumptions based on the current distribution of land uses in the Phase 6 model. Tree planting projects are encouraged to use a selection of native species.

SECTION 6: ACCOUNTABILITY

Unintended Consequences and Double-Counting

The Panel does not envision any unintended consequences of adopting the recommendations for this Urban Tree Canopy Expansion BMP credit. The recommended pollutant removal efficiencies may be refined as research is further developed to quantify the nutrient impact of tree canopy on water quality, specifically in reference to leaf litter washed off of impervious cover (roads and non-roads). The current assumption applied in the derivation of the nutrient reductions for urban tree canopy is that nutrients generated by trees are transferred from the soil, throughflow, runoff and into biomass. Theoretically, this assumption results in a no net change in load. Recommendations to advance the understanding of nutrient fate from leaf litter are presented in Section 7.

Given the use of high resolution imagery to define the Phase 6 tree canopy land uses and new tree canopy added through implementation of tree planting as a BMP, there is a potential to double-count the water quality benefit. Similar to all acres of land use change BMPs, Urban Tree Canopy Expansion will receive credit between CBWM land use updates (i.e., using for example satellite imagery). Following an update, all historic implementation effort using the Phase 6 model will still be tracked toward milestones set by the jurisdictions and all new implementation will be counted as a land use change. This avoids double-counting in the model simulations while demonstrating implementation and effort toward milestone goals. The Panel also recommends the following decision rule to avoid double-counting of tree canopy acreage.

To avoid double counting with the existing tree canopy land use, annual tracking and reporting new acres of tree canopy will be reported as a land use change BMP and tracked separately from the existing land uses. The assumption of this protocol is that the tree canopy land use as part of the Chesapeake Bay Watershed Model (CBWM) is updated approximately every 5 years using high resolution imagery; however the specific methods to complete this type of analysis is to be determined by the partnership at a future date.

Verification for the Urban Tree Canopy Expansion BMP

The Chesapeake Bay Program adopted verification guidance from the FWG for the existing tree planting BMPs. The guidance was developed based on the BMP used in the Phase 5.3.2 CBWM that does not include a tree canopy land use. Verification is an important process to ensure the BMPs implemented are still functioning as planned in order to provide continued nutrient and sediment reductions towards the Bay TMDL. In review of the existing verification guidance, the Panel determined that the FWG's current verification guidance demands a very high level of assurance that presents challenges to local jurisdictions for reporting and tracking purposes and does not align with the current methods developed to credit tree planting. Further, tree planting is conducted by many different types of organizations and groups that are either volunteer-based or associated with municipal programs, with a range of oversight and post-planting maintenance. The Panel acknowledges that it is critical for tree planting projects to implement measures that ensure the greatest potential survival of trees planted. However, it is well-documented that mortality is typically high in the first few years, on average 4-6% overall. The Panel strongly emphasized that it is unreasonable to assume a replanting of all trees that die in these first few years which the Verification Guidance recommends, as the planting densities in many cases are overplanted to account for expected mortality and the recommended crediting method accounts for a 2.5% to 5% annual mortality.

The Panel acknowledges that specific verification procedures and protocols will be determined by a jurisdiction according to their implementation priorities and programmatic capabilities in accordance with the overall BMP Verification Principles and BMP Verification Framework adopted by the CBP partnership (CBP, 2014). As such, the Panel recommendations are advisory in nature, and are not binding on any State. With that in mind, the Panel asks the Partnership to consider the following for the recommended Phase 6 Urban Tree Canopy Expansion BMP.

- The suggested BMP credit duration is 10 years. At some point in the future, as part of the CBWM land use updates, the creditable area for the Urban Tree Expansion BMP will be captured. It is in the interest of jurisdictions to ensure the survival of trees planted so they contribute to an expanded tree canopy and therefore improved water quality. While planted trees account for a small percentage of overall tree canopy in the Bay watershed, it is a BMP that can be widely implemented in the watershed that has tremendous value in involving multiple stakeholders in the Chesapeake Bay restoration effort. If trees are not maintained and die, then the canopy will not be captured during the land use update and seen as 'credit' lost.
- The land use updates may be used as part of the verification process for this BMP over the long term. The land use updated using for example, high resolution imagery, provides an objective process given the classification rules used by the Bay Program. While periodic updates to the high resolution land use imagery would not verify specific tree planting projects, they would verify the total tree coverage in an aggregate area. This would provide an automated verification of total existing tree canopy and for trees 10 years after planting, although extraneous factors such as development are likely to overwhelm the effect of tree planting.

- Verification efforts by local governments would ideally focus on ensuring that management of trees planted provides for optimal survival. A 2.5% to 5% annual mortality is currently built-into the recommendations for the Urban Tree Canopy Expansion BMP and tree replacement

Throughout its discussions, the Panel acknowledged that a jurisdiction with more rigorous planting, conservation, and verification protocols for its trees will likely see greater overall gains in tree canopy relative to the Panel's recommended BMP credit. Consistent with the existing FWG verification guidance the FWG proposed to provide education to landowners about planting and after care given tree planting efforts on private lands. Put another way, a jurisdiction that better ensures the health and longevity of both its newly planted and existing trees will accrue acres of tree canopy and forest land uses in the long run, which will be beneficial in meeting and maintaining TMDL targets in 2025 and beyond.

SECTION 7: FUTURE RESEARCH AND MANAGEMENT NEEDS

As with every BMP expert panel, there is uncertainty associated with the recommendations presented using currently available research and tools. It is vital that studies providing real-world empirical data and continually improving modeling tools be developed and published for the benefit of the scientific community and future BMP expert panels. With this in mind, the items below were identified and agreed upon by the Panel as items that should be considered by researchers inside and outside the Chesapeake Bay region in the future. The addendum to Appendix B of this report includes additional items specifically related to tree canopy land use loading rates, compiled with CBP partnership input during the review and approval period of the report recommendations. The items in this section are inclusive of research and management needs in a more general sense than land use loading rates alone.

Research

- Evaluate the effect of tree canopy, non-forested lands on water quality. This may be in the form of field research or GIS-based analysis of multiple catchments that could be combined with high resolution imagery and other available data to help isolate the effect of tree canopy changes from factors that usually confound that analysis. Long-term water quality monitoring data are needed to isolate the effect of tree canopy along with advancing model development to simulate changes in urban tree canopy on water quality.
- Support research to characterize and quantify the impact of leaf litter on nutrient contributions to the urban mass balance.
- Continued research on the effect of soils on tree canopy growth in urban watersheds. Recent research suggests that soil volume is a key variable to urban tree growth potential (i.e, Susan Day's), along with the effect of tree canopy on altering soil physical properties such as enhanced infiltration.
- There is a need for collection of multi-year field data that explicitly measure nutrient fluxes associated with areas of tree canopy. The data should be collected in areas representative of applicable conditions within the Chesapeake Bay Watershed. The data can be used to inform future expert panels, new versions of the modeling tools or land use loading rates.

- If new data specific to nutrient fluxes from tree canopy over turf and impervious surfaces in the Chesapeake Bay watershed are not gathered, the Partnership can consider whether to adjust, drop, or keep this land-use/BMP as presently recommended for future model versions.
- This BMP, and others, need to consider how future research findings on land cover/land use and conveyance systems affect material transport to streams and the Bay (e.g. Re-plumbing the Chesapeake Bay Watershed: Improving Roadside Ditch Management to Meet TMDL Water Quality Goals).

Management

- Jurisdictions review and adopt guidance for tree planting and post planting care (i.e., minimum soil volume, mulching, planting depth, appropriate tree species for location) to provide the best possible conditions and promote growth in urban tree canopy and tree health with efforts to provide (disseminate) this guidance to individuals, groups or organizations conducting tree planting.
- Jurisdictions use tools to evaluate the net loss/gain of tree canopy beyond the Chesapeake Bay land use update. It is expected to see a continued net loss despite extensive efforts to replace tree canopy by tree planting given continued development patterns in the Bay watershed
- The Urban Tree Canopy Expansion BMP credit be reevaluated after 2025 to account for the increase in credit post-2025 as trees mature.
- Develop BMP's that address the conservation and maintenance of existing tree canopy. Conservation BMP's will reduce future pollutant loads by reducing the loss of tree canopy in future land use projections. Maintaining tree canopy has the potential to have a greater positive impact on local efforts and actions to address water quality than tree planting alone. A cost-benefit analysis comparing the benefits of planting new trees with tree conservation should be a part of this research.

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Appendix A: Panel Meeting Minutes

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, March 25, 2015, 12:00PM-2:00PM EST
Conference Call

Name	Affiliation	Present? Y/N
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech	Y
Michael Galvin	SavATree	Y
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	Y
Jessica Sanders	Casey Trees	N
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	Y
Marcia Fox	DE DNREC (WTWG rep)	Y
Ken Hendrickson	EPA Region 3 (Regulatory Support)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	Y

Welcome and Introduction

- Neely convened the call and reviewed the agenda. Neely thanked everyone for agreeing to serve on the panel. She looked forward to hearing everyone's input throughout the process as the panel develops and evaluates the nutrient and sediment reductions for urban tree cover and trees. She asked everyone to introduce themselves to the group.
    - Neely Law is the Panel Chair and will be guiding the panel in that role. She has coordinated and served on BMP panels for the CBP before, and will draw on that experience to benefit this group.
    - Jeremy Hanson explained his role as the Panel Coordinator. Since August 2014 he has been Virginia Tech's Project Coordinator for expert panels like this one. He is located at the Chesapeake Bay Program Office in Annapolis, MD.
    - Karen Cappiella noted she has expertise and experience with literature reviews and work related to water quality and urban forestry, including a number of past Center for Watershed Protection (CWP) projects. She noted CWP has a similar project to evaluate the water quality benefits of urban trees at the national level.
    - Brian Benham: Professor and Extension Specialist in the Biological Systems Engineering Department at Virginia Tech. His role as Project Lead is to help this and other panels under the Virginia Tech cooperative agreement as they perform their work. He works closely with Jeremy to ensure the panel has any assistance it needs to perform as effectively as possible. He is located at the Blacksburg campus.
    - Sally Claggett works for the US Forest Service and coordinates forestry activities and efforts at the Chesapeake Bay Program, including the Forestry Workgroup that requested this BMP review panel.

- Keith Cline is the Director of Urban Forestry Management Division in Fairfax County, VA. The division is housed in the stormwater unit for the county, and he will bring his years of government experience and a local perspective to the panel. For previous 10 years worked for US Forest Service in DC and was involved in development of iTree.
- Susan Day helps run the urban forestry programs at Virginia Tech. Research background includes work on urban soils and how it affects tree health and pollution mitigation.
- Mike Galvin: Director at SavATree, formerly with MD Department of Natural Resources. While at DNR he worked extensively with local governments as they began to develop urban tree canopy goals and strategies. He went to CaseyTrees after DNR, and helped DC develop its own UTC strategy.
- Peter MacDonagh: With Kestrel Design Group in Minnesota, and also serve as adjunct faculty at University of Minnesota. Consulting experience as an arborist and general green infrastructure specialist.
- Tom Whitlow is with the horticulture department and a part of the Urban Horticulture Institute there. His research experience covers a range of disciplines and targets, including work to assess air quality reductions around urban tree cover.
- Qingfu Xiao is a research faculty member at UC-Davis. Research background includes urban forestry and urban hydrology. He looks forward to contributing his experience to the panel.
- Marcia Fox is the Chesapeake Bay Nonpoint Source Data Coordinator for Delaware Department of Natural Resources and Environmental Control (DNREC), where she works to report all of the state's nonpoint source BMP data to the CBP. Previously she worked as an urban forester with the Delaware Department of Forestry, so she is excited to be involved as the Watershed Technical Workgroup representative for this panel.
- Ken Hendrickson works as the Green Infrastructure Lead for the Office of State and Watershed Partnerships at EPA Region III in Philadelphia. His background includes hydrology and landscape architecture and he has been with EPA for about 5 years.
- David Wood staffs the Water Quality Goal Implementation Team (WQGIT) and Watershed Technical Workgroup (WTWG) for the CBP, which the panel will learn more about those groups later on. He explained his role as the CBP Modeling Team representative for the panel, serving as a resource on issues relating to the Watershed Model and associated modeling tools.

Review of BMP Protocol, statement of work and panel timeline

- Jeremy described the Chesapeake Bay Program and provided background on the BMP review process. He and Neely noted that the context for these BMP panels is important to be aware of. Jeremy noted that the introductory memo and BMP Protocol provide additional detail about the CBP and the BMP review process, and he encouraged the panelists to read them if they have not already.
- Tom asked if there are any empirical measurements in the context of the model, or if everything is simulated or estimated using the models.
    - Jeremy noted that Watershed Model is calibrated to actual monitoring data over many years, so it is calibrated to those empirical data points. As a management tool it is used to simulate progress for subsequent years.
- There was additional discussion about the model. Susan asked for a clarification of the bar chart that Jeremy had on one of his slides, asking if the loads in that chart were simulated loads from the Watershed Model.

    - Jeremy confirmed she was correct, and that the model simulations are used to track progress over time controlling for factors like precipitation. Actual loads in the watershed will vary from year to year due to precipitation and other variables. The Watershed Model has to make a number of simplifying assumptions to serve as a management tool across a 64,000 square mile watershed, so he thanked Susan for that point.
- Neely reviewed the statement of work with the panel, and focused on the questions and topics raised under task #2. She noted there may be secondary questions that arise, but the panel will focus on the two primary questions described under that task:
    - What is the effectiveness of urban tree canopy on reducing runoff, nutrients and sediment?
    - How does effectiveness vary by species, over time, with differences in planting sites (e.g., distance from impervious cover or other trees, soil conditions, geographic location) and with different maintenance strategies?
- She reviewed tasks #3 and #4, noting that the panel report will need to address the list of items under task #4, which was adapted from the BMP Protocol.
- Sally raised the issue about tree cover as a land use layer in the modeling tools. Susan asked for clarification about double counting issues. Neely explained that the panel does need to be careful about potential double counting issues. For example, the same trees planted for a riparian buffer BMP are not also counted for a tree planting or tree canopy BMP.
    - Keith: For that example if a tree is credited for a riparian buffer credit. What determines when that tree or project is counted as a buffer versus another tree canopy?
        - Neely: As an example, the CBP recently approved urban filter strips as a BMP. Virginia had pointed out that they have vegetated filter strips. In their stormwater manual there are different credits based on the vegetative. These are all great questions that will help us work through important issues that should be discussed and resolved. Jeremy noted that Keith's and Susan's questions illustrate the importance of clear and explicit BMP definitions so that locals and state data analysts are certain about how to label a certain practice when they report it to the CBP.
- Xingfu: what scale are we talking about for this review? Sally noted the panel can look at science or literature at any scale. All the information is useful whether it looks at an individual tree, acres, or a watershed segment.
- Neely reviewed the timeline for the panel. She noted it's an ambitious timeline, but it is doable especially with the support from Virginia Tech and CWP. This panel will also try to pick up where the previous panel left off. She noted that CWP will provide a synthesis of its literature review by June. It will focus on summarizing and highlighting findings and data from the literature. Will try to have a fully-approved report by the end of the year. April will be spent getting more background on the CBP modeling tools.
    - She noted that they would like panelists to travel for a face-to-face meeting in the May timeframe, which will include a public stakeholder session. Travel expenses will be reimbursable through CWP. In June the panel will be discussing crediting approaches based on the review and similar efforts in other states, working to wrap up and finalize a report in the July and August timeframe. Hope to have panel consensus on the report in September and then work through the review process from October to December. Neely and Jeremy will work to draft short pieces and write-ups of the report to solicit specific input from the panel members.

Panel roles and responsibilities

- Neely noted the time and asked for questions or comments from the panel about their roles or responsibilities.
- Jeremy noted that the handout describes the general roles and that the introductions touched on this issue, but it is an evolving process so people will probably adapt their contributions to fit the needs of the group.
- Tom noted he has a good database of literature atmospheric deposition sources and sinks, primarily with particulate matter and atmospheric nitrogen. Jeremy and Neely asked Tom to discuss the database offline in more detail with Karen and Neely.

Discussion: Public stakeholder forum

- Neely and Jeremy explained that the panel will need to host an open session where outside stakeholders are invited and welcome to attend. The general goal is to interact with the wider stakeholder community, including private firms, federal/state/local agencies, academic researchers, or nonprofits. Similar to National Academies of Science panels, other meetings and calls are closed for deliberation among the panelists only, or invited guests. The panel has some leeway in crafting the forum agenda, which will ideally allow for extended discussion and mutual information exchange between the panelists and stakeholders.
- The open session would be for a morning or afternoon, and could coincide with another half-day or full day of panel-only meetings. The extended meeting would allow for
- **ACTION**: Jeremy will distribute a Doodle poll to help schedule the face-to-face meeting in late May or the first week of June.

Demo: Virginia Tech Scholar

- Jeremy demonstrated basic use of the Scholar site.
- **ACTION**: Jeremy will add the panelists to the Scholar site. Panelists should expect an automated email by COB 3/26 with instructions on how to log-in to the site. If they do not receive this email by the end of the week (3/27), they should contact him so he can ensure they gain access.

Next steps and confirm next call date/time

- It was pointed out that April 22 is Earth Day, so there will be conflicts for multiple panel members.
    - **Post-meeting note:** The next panel call is now scheduled for Wednesday, April 29th, 12:00PM-2:00PM EST.
- Neely noted that panelists should expect to receive a preliminary literature review database with the set of materials for the April call, so the panelists can provide additional studies or sources for the list.

Wrap-up and review action items

- Neely noted that the Chesapeake Bay Program and the Forestry Workgroup has a management strategy out for public comment and review. Jeremy will provide a link to draft management strategy when he distributes the minutes to the panel.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, April 29, 2015, 12:00PM-2:00PM EST
Conference Call

Name	**Affiliation**	**Present? Y/N**
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech	Y
Michael Galvin	SavATree	Y
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	N
Jessica Sanders	Casey Trees	Y
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	Y
Marcia Fox	DE DNREC (WTWG rep)	N
Ken Hendrickson	EPA Region 3 (Regulatory Support)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	N
Ari Daniels	CWP	Y
Invited guests: Matt Johnston (UMD, CBPO modeling team), Peter Claggett (USGS, CBPO)		

Welcome and Introduction

- Neely and Jeremy convened the call and verified participants. Neely asked for any corrections or comments on the minutes for the March call; none were raised.
- **DECISION**: The March conference call minutes were accepted as written.

Overview of the Chesapeake Bay Modeling Framework, land uses and BMPs

- Neely explained the bulk of the call would cover background about the Watershed Model and how urban tree canopy fits in as a land use and BMP for the current (Phase 5.3.2) and future (Phase 6) Chesapeake Bay Watershed Model (Model). (Presentation provided)
- Jeremy described how the current Model simulates BMPs and land uses in general, and how a land use change like the current tree planting BMP is simulated. When 100 trees are planted and reported for an area, one acre of urban-pervious land is converted to forest. He noted that the average loading rate for urban pervious is significantly higher than forest, which is the lowest loading land use in the Model. So the current reduction is very large.
    - Susan asked how the current BMP might apply to areas with different understories like impervious surfaces. Jeremy explained that the current definition only allows for a conversion from urban-pervious to forest, but the next Model will likely include different land uses that could be modified or changed by tree planting, as will be discussed later.
- Neely reviewed the proposed Phase 6 land uses for tree canopy. She explained how the Watershed Model uses satellite imagery and other data (e.g., Ag Census) to generate land cover

and land uses for the watershed to create a digital landscape at a county scale. She noted the digital landscape of land uses is calibrated to monitored loads to create the Model.

- Neely described the proposed tree canopy land use for the Phase 6 Model, which are still pending approval, but may include separate land uses or categories for tree canopy over a variety of land uses, including 3 land uses for developed (i.e. urban) areas: turf/herbaceous, impervious roads, or impervious non-roads. Each tree canopy land use could potentially be given its own unique loading rate, or a reduction factor applied to modify the loading rate of the understory land use land cover (e.g. pervious, impervious).
    - **ACTION**: Add Tetra Tech 2014 analysis of urban land use loading rates to the Scholar site in reference to higher EMC from impervious transportation land use
- Tom: Looking forward to model development post Phase 6; additional consideration may be given to BMPs installed under tree cover. For example, in Montgomery County there is a lot of work being done with bioretention, permeable pavers, and other practices that are installed under tree cover.
- Peter mentioned that the data currently used for a baseline land use for the next version of the Model represents 2012 land uses and imagery. Next year the CBP will get new data that represents 2013-2014 that will be used for the final calibration of the Model.
- Susan: It seems we are asking if we are capturing trees planted as a land use change BMP or as canopy that is mapped through imagery data.
    - Neely: Correct. We still have to decide what the best way to capture, track and report tree canopy is.
    - Jessica: To clarify, it doesn't matter what the size of the project is? If I plant 200 larger trees it is the same as 200 trees of a smaller or different set of species?
        - Neely explained the panel can consider qualifying conditions and differences that could affect the reduction or benefit, e.g. density or size of the trees.
        - Matt thanked Neely for the point about qualifying conditions. He explained that the Model is used to evaluate what the cumulative estimated benefit is from the sum of implemented BMPs reported by the states. In that way it is a management tool.
    - Peter agreed with Mike's interpretation of how fine-scale data from high resolution imagery (1-m) is aggregated to CBWM, where the finer scale data is essentially represented as a fraction of land cover within a larger grid cell
- Neely directed panelists' to one of the discussion questions. How does a tree canopy land use affect the implementation of an urban tree canopy BMP? Are they the same or are they separate? By same, we mean the methods to estimate their water quality benefits and reporting their extent in the model (e.g. acreages).
    - Peter explained the way the CBP distinguish forest from tree canopy is using the size of the clump of trees, and whether it is an acre or larger clump, or a line of trees in a median or along a road. If the trees are not clumped together in a large enough clump or they are spread in a line or along a street, then they will be captured as tree canopy. One acre, or larger, clumps can be represented as forest.
        - Peter also noted they may not detect planted trees in the imagery for 5 or 10 years. At that time we would want to make sure we aren't double counting between the trees reported as a BMP and the added tree canopy based on imagery.
    - Keith: in our county we have a table that developers can use to estimate their canopy after 10 years. That might be a pertinent way to capture or estimate canopy coverage.

- Neely: the CBP has been developing a verification process with the jurisdictions. The overarching goal of the verification effort it to ensure that BMPs reported for credit are actually installed and functioning as intended.
- There was discussion about the need to have estimated tree canopy. Matt noted that from the modeling perspective, the Model needs to know what the tree canopy coverage was in 1985 and through time.
- Peter: we don’t have a grip on the rate of change for tree canopy is over time to date. Moving forward, with high resolution data every 3-5 years, we will be able to track and understand the rates of change for tree canopy over time, not just forest.
- Tom noted he sent a couple images to the panel to illustrate the small scale complexity issue he mentioned earlier, specifically in Montgomery County.
  - Neely pointed out the image seems to show a proprietary practice or technology where the tree is planted in a system that has an underdrain and other features installed under the canopy. The tree, when it grows, could be captured by imagery but how would this be credited? Important for recommendations to be clear what is or is not counted as tree canopy for jurisdictions to report
- Mike liked the idea of the tree canopy modifier that would be applied to the land uses. Neely asked the rest of the panelists for their thoughts on that approach, noting that the panel can always change its mind or make adjustments down the road. No commitments at this time.
  - Susan: it makes sense, but it is predicated that we are making sufficient distinctions in the landscape when we are actually lumping a lot of things together, e.g. managed and unmanaged lawns, hedgerows, compacted soils and well drained soils, etc. That’s the only caveat at this time.
    - Matt: Those many flavors of BMPs can easily be reflected as individual BMP efficiencies, but not as individual land uses. For example, maybe trees planted on road medians reduce runoff by 5% and trees planted on managed turf reduce the runoff load by 10%. There could be a large number of BMPs in that way, which would be reported and applied to appropriate land uses.
  - Neely: After we review the literature there may be gaps or areas where the panel explore the use of models to help supplement or inform the panel’s analysis in cases where the literature is very limited.
    - Sally: There is a lot of work involved with tracking and reporting practices like this, so we need to consider what will be required of people who will report these practices into the Model.
    - Mike: I like the approach because it lets a tree be a tree. Land cover is a big factor and trees are a modifier, but it doesn’t necessarily make a night-and-day difference like changing an acre into forest.
    - Susan: if we look at this in 2-phases, a BMP phase and a land use phase, then after a tree matures it is captured by imagery and transitions from BMP phase to the land use phase. That seems fair and reasonable.
  - Mike: There are a lot of variables and details that can affect the water quality impact of a tree or set of trees, but at the end of the day someone has to set rules of the road. Having clear and simple rules will help ensure programmatic success.

        - Qingfu suggested that looking longer term the panel may need to consider changes in water volume or precipitation. Matt and Jeremy noted that the CBP partnership is looking at longer term effects of climate change on things like precipitation, but those questions and considerations are outside the scope of this panel.
- Neely summarized that the panel was not quite at consensus, but there seems to be some general support for having tree canopy as its own land use, or modifier. Also some support for having it as a BMP and then transitioning it to a land use or modifier after a certain amount of time, perhaps 5-10 years. We'll continue to discuss these approaches going forward.

Catalogue of research studies

- Karen described the database that the CWP had compiled so far, noting that Jeremy had previously distributed the spreadsheet of studies to the panelists. It is also uploaded to the Scholar site. They have two worksheets, one for Tree Benefits (65 studies so far) and one for Urban Tree Health and Longevity (44 studies). She explained the organization and fields in the spreadsheet.
- Karen explained some of the factors used to evaluate the studies, based on Table 1 in the BMP Protocol, e.g. year published, applicability, variability, references, etc. She reviewed some of the (preliminary) key findings:
    - Majority of studies are from 2000 or later. 42 of Benefits studies focus on urban.
    - Most (32) document hydrologic benefits, most commonly interception
    - Some (13) evaluate water quality
        - 7 field studies; only 3 of these use unplanted controls and only 1 provides useable results. Variable in terms of N and P species and methods used to calculate removal.
        - Other studies not as applicable because of difficulty scaling results because of their scale, focus or methods.
- Karen described some of the gaps in the literature so far. Need more studies specific to nutrient and sediment reduction of urban trees/forests. Given this gap the panel could potentially use hydrologic studies to develop credit if we can document the link between runoff and pollutant reduction. The CWP will also include review of current crediting systems as models
- Karen: The database is on the Scholar site. She asked panelists to download the spreadsheet on their own computer, add new studies, and upload a new version of the spreadsheet with their name added to the file. Neely pointed out that she uploaded a newer version of the spreadsheet earlier that day, along with a blank version that panelists could use to add new studies to the list.
- **ACTION**: Panel members should upload studies or references not listed in the database to the Scholar folder. Populate the blank version of the spreadsheet for each study or article added. Leave green columns blank, they will be filled out by the CWP (note the CWP will need the full text article uploaded to Scholar to review it).
- **ACTION**: Request for panel members to review the database and add & upload publications to the Scholar site. Neely will contact panel members the week of May 15th to identify what 1-2 papers panelists will present at the June 3rd meeting
- **ACTION**: Neely and Jeremy will provide additional guidance to panel members about presentations for the June meeting.

Travel plan for June 3rd meeting

- Neely: It will be a full day meeting in Annapolis. Funds are available to reimburse panel members for travel. Forms and instructions were sent to the panel. Contact Neely or Jeremy with questions about the meeting.

Wrap-up and review action items and next steps

- Neely noted the panel will have its June 3rd meeting and a conference call later in June. No call in May.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, June 3, 2015, 8:30AM-12:00PM EST
Meeting in Annapolis, MD

Name	Affiliation	Present? Y/N
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech	Y
Michael Galvin	SavATree	Y
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	Y
Jessica Sanders	Casey Trees (remotely)	Y
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	N
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep) (remotely)	Y
Ken Hendrickson	EPA Region 3 (Regulatory Support) (remotely)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	Y
Ari Daniels	CWP	Y

Welcome and Introduction

- Neely convened the meeting and reviewed the day's agenda.
- **DECISION**: April minutes were accepted as written.

Literature review synthesis and discussion

- Neely asked panelists to consider how complete the write up and review is and where are the gaps. What are the initial thoughts on how it can inform the BMP crediting.
- Karen: Review the draft literature synthesis with participants. Reviewed 73 studies, only a handful looked at explicit water quality benefits and urban trees. Most of the studies were in semiarid regions or areas that may not be transferrable to the Chesapeake Bay watershed.
    - Most interception studies looked at stormwater volume. No explicit link to nutrients, but we can make that link.
    - Continuous simulation modeling would be most applicable modeling approach.
    - Most evapotranspiration studies looked at various monitoring or modeling approaches. Hard to transfer those results.
    - Runoff reduction studies are at the municipal scale and normally look at tree cover over time, using models or tools like CITYgreen or iTree. Some studies also looked at runoff reduction for non-urban areas.
    - Only 10 studies looked at water quality. Only Denman 2006 included unplanted controls to compare with tree planted areas. There was a study that measured nitrate leaching from urban forest and urban turf and found higher nitrate leaching from the grassed areas than the forest plots. There is also the issue of leaf litter and leaves as a potential

  - nutrient source in the urban landscape. Neely will present some research on that in the afternoon.
  - Jessica: there are some localities that have weekly sweeping
  - Neely explained the street sweeping panel is considering some different scenarios for seasonal sweeping that would capture more leaves or other material.
- Discussion of the credit and clarification of who would benefit from the BMP credit, and how local and state jurisdictions meet their nutrient targets.
  - Jeremy clarified that the term "credit" can be applied in a number of contexts at a local or state level, e.g. stormwater utilities may credit volume reduction, rain barrels, etc. This panel and BMPs approved by the CBP are strictly concerned with credit for pounds of nitrogen, phosphorus and sediment that are applied toward the states' TMDL targets.
  - David and Jeremy explained that BMP data is reported from the locasl to the state, and reported by the state to the CBP. Tools like CAST, MAST and VAST help the locals for planning purposes. So Fairfax can use VAST to get an idea of the reductions they can achieve through various BMP implementation scenarios.
  - There are a lot of gaps in the BMP implementation data, e.g. NGOs or homeowners are doing a lot of implementation but we still have to develop mechanisms to track and verify those practices

Literature reports from panel members

- Each panel member gave a brief 10 minute presentation about their selected study followed by a couple quick follow up questions, with discussion following all the presentations.
- Tom looked at 4 studies that were all natural experiments, with no active manipulation. Replication for multiple locations over multiple years. Try to account for impervious and canopy cover.
  - He discussed nitrogen fluxes illustrated by P.H. Templar et al (2015) who compares the fluxes in rural and urban settings. He ran some regressions between impervious cover and N yields using data reported by Groffman, and pointed out that the developed areas showed quite a bit of variation, while the natural Pond Branch area had virtually no interannual variation in N yields. If you remove Pond Branch the slope in the regression basically disappears. The regression for forest cover and N yields has a negative slope with largely the same effect when Pond Branch is removed.
  - Nowak and Greenfield (2012) of 20 US cities, including Baltimore. Perhaps increasing urban tree cover probably cannot reduce N yield below ~7 kg per hectare-year. Perhaps 1% tree cover increase can translate to about 1% in N reduction? Forest cover is a relatively crude factor for estimating since it can be overwhelmed by other factors even in suburban areas, e.g. septics, precipitation, etc. (Note: 6.7 kg N /ha = 6 lbs N/year).
  - 2007 National Engineering Handbook. Section on disturbed soils. One possible limitation of UFORE or iTree-Hydro may be they do not fully account for soil disturbance or compaction, and hydrologic properties of soils.
- Susan discussed infiltration in urban soils. Yang & Zhang (2011). 30 sites with soil samples and measurements for each site (Nanjing, China). It does look at a spectrum of what occurs in different parts of a city, so it gives a sense of the variation can be when you change vegetation type and management. Is it trees, or trees + soil? Suggest we have to consider both, not just trees alone. Soils at old developments are less compacted compared to new developments. There is a very dramatic difference in the infiltration rates of old developments compared to new ones, with more compacted soils. So if management actions can transition the soils from compacted to non-compacted it can have a very significant impact. Development practices

continue to change rapidly, so it's difficult to say if tree planting or development today will provide high-infiltration soils in 20-30 years.

- Neely: good points to raise about considering soils as a factor for the

- Mike discussed some results of the Baltimore Ecosystem Study (BES). Trees very likely help, but how much does one tree do for nitrogen? Always have to weigh the value of resources for verification versus restoration. Need a balance.
- Keith verbally discussed Pataki et al (year?). He noted Tom was a co-author. It was very helpful as a theoretical and conceptual paper, with a focus on understanding biogeochemical processes in urban areas and how to quantify green infrastructure benefits. Discusses possible costs and disservices for green infrastructure to better understand the net benefits.
    - There has been more discussion of disservices in recent years. It will help when we discuss leaf litter in more detail.
    - Mike: by planting trees we are adding more areas where natural processes like denitrification can occur.
    - Neely: the modeling team has asked previous panels to look at other forms of nitrogen, but to express the net benefit in terms of TN. There are many ways to look at the overall effect.
- Peter discussed results from a study of over 1,000 parking lot trees on Walt Disney World property. Found 81% were in good condition.Soil volume and canopy coverage. 21.5 inches biggest dbh. 1000 cubic feet seemed to be threshold, with 95% rate of "good" trees. 100% at 1500 cubic feet. The trees will resize themselves based on the soil volume they are planted in. There is a lot of resistance to increase the soil volume due to cost, so there is a question of what the optimal soil volume would be to achieve most "good" or healthy trees with least cost or soil volume. The study does not cover soil conditions or soil chemistry in detail.
    - How feasible is it to assess or evaluate tree health without on-site assessment? Nowak and others do imagery assessments using non-leafed images to get better estimates of impervious cover, but then it may not capture tree health.
        - Peter agreed that an on-site assessment of tree health may be a reasonable condition for credit.
    - Peter: for MN stormwater manual if you want a tree with expected canopy of 800 square feet, then you would need 1600 cubic feet of soil volume (1:2 ratio). It's like with rain gardens, where the soils and media are
- Sally: we need to be able to measure and track these tree plantings and tree canopy. A lot of the potential is in people's back yard. We may not know all the specifics about species, soil volume, etc. The practice is not a big-hitter in terms of what is currently tracked or reported by the jurisdictions. Want to bring practical side of how to track, report and credit these trees over time.
    - How it might look is a locality would report the trees they plant and they would get credit for a time. Every 5 years we will update the land use based on 1-m data and some BMPs like tree planting would be wiped clean in favor of the accurate and updated land use. So from a verification perspective this is a useful way to credit, but verify. The panel can weigh in on what it recommends in terms of the methods for when or what to wipe clean based on updated imagery and land use.
    - This would give a more complete picture of what is going on and would account for other impacts, such as emerald ash borer.
    - Keith: we are looking at overall canopy for the county, not going to the parcel level. Using the imagery, in a sense we are losing canopy at the county scale.

- Part of the charge of the panel is how to quantify or credit the tree canopy, or perhaps individual trees.
- Loading target for Forest land use will be going down for Phase 6 of the Model.
- There was discussion of the current Phase 5.3.2 Watershed Model and the Phase 6 Watershed Model. Currently the intent is to have Tree Canopy as a separate land use in the P6 Model. Areas of canopy >1 acre (with unmanaged pervious understory) are classified as forest, but tree cover <1 acre in area are treated as tree canopy. Tree canopy can be over pervious or impervious land uses, so canopy would modify the load from that understory.
- There was a subgroup of people that developed the report, but it can be referenced as a Forestry Workgroup product.

Discussion of BMP definition and crediting approach

- Neely led further discussion about how to define/credit the BMP
    - The proposed 25% reduction/modifier is set relative to urban pervious. That relative benefit would hold and translate to a higher % reduction relative to urban impervious.
    - The 25% is based on primarily on evapotranspiration (ET) information.
    - There was discussion about longer term trends and the effect of management actions and wastewater treatment. Neely mentioned a recent USGS study and will share the reference with the group.
    - Tree planting may not be able to keep up or cancel the effects of other changes or disturbances, but maintaining existing tree canopy is critical for the overall water quality and trends.
    - We can recommend the conditions that would be ideal to have, but would need to discuss whether those should be qualifying conditions or not. Can rely on 5 year updates of imagery and the land use.

Wrap-up and review action items and next steps

- **ACTION**: Jeremy will add all slides to the Scholar site; Keith will provide some summary bullets points for uploading.

Panel session adjourned; convened for Open Session following lunch:
http://www.chesapeakebay.net/calendar/event/22656/

SUMMARY OF ACTIONS AND DECISIONS
Open Session: Urban Tree Canopy Expert Panel Stakeholder Forum
Wednesday, June 3, 2015, 1:00PM-4:00PM
http://www.chesapeakebay.net/calendar/event/22656/

Welcome and Introduction

- Jeremy Hanson (Virginia Tech, Chesapeake Bay Program; Panel Coordinator) welcomed participants and reviewed the agenda. He and Neely Law (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.

Stakeholder Presentations

Dave Nowak, US Forest Service (remotely)

- Dave discussed urban hydrology and how iTree tools (including iTree-Canopy and iTree-Hydro) can be used to estimate the stormwater volume reduction or other benefits associated with green infrastructure and tree cover.
- View the presentation for more details.
- Frank Rodgers (Cacapon Institute): How does iTree-Canopy or iTree-Hydro differentiate between tree canopy (TC) over impervious or TC over pervious?
    - Nowak: based on averages for land uses from field information we have.
- Mike Galvin (SavATree): how do impervious vs. pervious compare?
    - Nowak: Best recollection, roughly 10:1. For every 1% of impervious cover you add, you have to plant about 10-12% of tree cover to offset the increase. Depends on other factors, especially rainfall intensities and depths (large vs. small storms).
- Anne Hairston-Strang (MD DNR Forest Service): Role of infiltration. Does the iTree model account for soil types?
    - Nowak: iTree-Hydro does include infiltration and we are working to add or improve routines for infiltration and evapotranspiration. The best place to plant trees over pervious is over the least infiltrating soils. Andretti at SUNY-ESF is working on the different soil types for iTree.
- Barbara Brumbaugh (City of Chesapeake): Why do you believe there was such a difference in the Durham data? Do you have any coastal plain data for the amount of runoff reduced?
    - Nowak: Probably precipitation, but would have to revisit data. Drivers are…We are working to expand and include Coastal Plain. We are trying to build up the database and include other cities or areas to see if the curves and trends hold.
        - Barbara White: Would like to have a similar study in the tidewater area and coastal plain of VA
- Mark Symborski: How much N, P, and sediments, if eventually washed off trees over impervious cover, will end up in the stream system anyway? And how does that affect the pollutant reduction rates for canopy over impervious cover?
    - Nowak: Don't know the answer for certain. That would depend on a number of factors; couple deposition and the canopy models. N will dissolve and wash off, but this all depends on event mean concentration (EMC).

- Keith Cline (Fairfax County): determining canopy over impervious, have an idea for how easy it is to estimate that using the imagery and iTree-Canopy?
    - Nowak: Sometimes it is easy if you know where the roads are and you can make pretty good guesses. It becomes tougher in heavily canopied areas, but it is possible with aerial imagery.
- Sally Claggett (USFS): when you look at the Durham curve the reduced runoff curve starts fairly high, which may be an indication of evapotranspiration. At high impervious cover percentages, they are doing poorly due to soil capacity. Do you concur?
    - Nowak: Need to explore the data more. Could also depend on the amount of precipitation. Could be that Durham receives less rainfall.
- Neely Law (CWP): work we've done in older areas of Baltimore suggests that the texture of the soil allows for greater infiltration than would be expected based on hydrologic grouping.
    - Nowak: Could be partly that, but also several other reasons. Also depends on precipitation intensity.
- Mark Symborski (Montgomery County, MD): Are tree leaves that end up in the storm drain system taken into account by the models?
    - Nowak: No. We are estimating the leave drop and nutrients/carbon that would be associated with those leaves, but we do not know where they end up in the overall system so we do not model where they go.
- Justin Hynicka (MD DNR Forest Service): Does the range of calibration data cover the full range of 1-100% or how much of that is extrapolated
    - Nowak: We calibrate to the actual conditions of the watershed based on actual data. Once calibrated the range of 1-100% impervious or 1-100% tree canopy is simulated with all modeling.
- Dave encouraged anyone to share suggestions or thoughts on new needs or applications for the iTree tools. Always welcome thoughts on how to improve or expand the tools.
    - Claggett: As we've been talking, we'd like to know more about the type of urban forest in terms of physical site conditions – what type of understory, age, associated physical characteristics of surrounding area and the associated benefits/modeling outputs.
        - Nowak: difficult to break up by biological data. All they have is cover, not age, etc., which is difficult.
        - Claggett: we are starting to have hi-res imagery for whole watershed to differentiate whatever is possible at that scale.
        - Nowak: if we could break them out by height classes that would help (age distribution).
    - Hairston-Strang: It won't be available for Baltimore for a while, but generally is there a role for the plots?
        - Nowak: probably want to go to LIDAR map, which will help tease out the structural differences. Baltimore is data-rich, but outside is weaker. In the interim, we can use existing iTree plots.
- Law thanked Nowak for taking time to present and respond to questions remotely.

Neely Law, Center for Watershed Protection

- Law reviewed some studies that investigated the potential contribution that fallen leaves may have for nutrients in urban catchments. She emphasized that trees are good and more trees are even better. She noted that there have been questions about how important leaf litter may be in the urban nutrient context and how to perhaps consider or address it while evaluating the

overall benefits of urban tree cover. There are major data gaps, but a rough estimate comparing upland number from Nowak (2014) in Baltimore City to an outfall number from a recent CWP (2013) study in Easton, there may be an 85% reduction from upland to outfall. Very rough estimate, but it does demonstrate very large losses and transformations along and within the urban drainage network.
    - View [the presentation] for more information.
- Law: Comparing phosphorus loads to percent tree cover in catchment area, and tying that to frequency of street sweeping – more trees, more P; more sweeping, more P captured; also seasonal pulse in P conc. of leachate – Spring pulse is probably pollen and seeds, Fall pulse is leaf fall
    - Peter MacDonagh (Kestrel Design Group): Another Minnesota study looked at cost per pound of phosphorus removal \$50-70/lb-P and found that street sweeping was actually extremely cost effective for collecting phosphorus (usually \$350-\$400/lb-P).
- Hairston-Strang: research question relates to benefit of leaf litter organic matter versus detriment – don't want to starve the streams.
- Steve Saari (DDOE): many jurisdictions have leaf litter pickup, and associated compost production – anyone quantify this?
    - Law: trying to quantify, but it is difficult.
- Ted Brown (Biohabitats): can we look at the load differential between runoff reduction benefits of planting trees over impervious cover vs. potential for leaf litter loading with and without street sweeping. In other words could the expert panel show higher removal credit when planting is coupled with street sweeping or would that be double counting?
    - Hanson: Both this UTC and the street cleaning panels have to ensure their definitions do not lead to double counting any part of the credit, leaf litter or otherwise.
    - Law: this accounting question is fundamental to the debate. Leaf litter could be a reduction in the benefit of tree planting, or there are other ways to account for it.
- Eric Sprague (Alliance for the Chesapeake Bay): Forest is not a zero load – urban tree planting may already account for leaf litter since forest cover is the calibration point.
    - Hanson: The info is there, it's a great point, but it's very difficult to parse. It is a known factor, but not a known quantity.
- Saari: Steve Saari: the ultimate question regarding a factor or datum is "what would we do with this?" At programmatic level, the nutrients can't really drive a BMP like street sweeping.
- Claggett: we're basically saying that trees can't keep up with our developed landscape, and how do we manage trees to account for this?
- Rodgers: hard to account, because due to deposition, a tree in Maryland may be collecting and depositing nutrients from Ohio, for example.

Craig Carson, Montgomery County (MD) Department of Environmental Protection

- Craig described the county's MS4 program and related aspects of their role in managing stormwater, which includes planting trees and maintaining canopy. The county has adopted UTC goals and has its own tree canopy law. He reviewed MDE's criteria for MS4 credit for reforestation or for individual trees. He noted that the county collects planting date, species, size of tree at installation, location and minimum survival rate for its own records.
    - View [the presentation] for more information.
- Claggett: are any of those county credits related to the CBP BMP credit for 100 trees/acre?

- Carson: WE've only been using the programs we handle in house, so cannot say how they relate to the CBP BMP credits. The canopy law is fairly new and we are still developing the details.
- Saari: are 2 inch DBH (diameter at breast height) trees for stream restoration as well?
  - We usually plant 1.5 inch caliper and continue to measure them while they become fully established. When they reach 2" we count them for credit.
- Law: with the new tree canopy law will there be a mechanism for reporting and tracking the data?
  - Carson: Laura Miller is working on tracking trees planted and developing the new program. Still in early stages. Right now anything we currently have is largely based on what we have established in the restoration credit.
- Galvin described a recent experience with a client and the roadside tree law. Would have been easiest to cut down the trees in a situation, but because of the law they remained as a result of the importance the law places on existing trees. Are you seeing any effort really incentivizing preserving trees versus planting?
  - Carson: recognizing resources is important, and all other benefits of trees.
- Saari talked about tracking mortality in projects they're planting. Are there other mortality tracking efforts in other areas? DC is not tracking mortality in existing and untouched tree stands. There are other activities going on so what we ultimately track and report is not a net increase. Unable to track or report the net change because we don't have mechanisms to capture all the various activities that remove or add trees.
  - Carson: we do monitor trees and track health, but there's a data-intensive threshold that is difficult to overcome.
- Claggett noted the CBP will be compiling high resolution (1m) data for land use and land cover which would include tree canopy across the entire Bay Watershed.

Discussion

- Law noted there is a dichotomy for tree canopy and tree planting. On one hand it is considered a very cost-effective practice, but on the other hand it is considered as very difficult from a tracking perspective. She asked for participants for their thoughts about how they would like to see tree planting or tree canopy as a BMP for nutrient and sediment credit, knowing that it has to be tracked, reported and verified.
  - Lou Etgen (Alliance for the Chesapeake Bay): in the agriculture sector there is a credit for nutrient management plans, and maybe a similar approach could apply here where incentives or credit is given for management or maintenance when we know that certain actions are beneficial.
- Hairston-Strang: the tree canopy assessment is the periodic gut-check since it's impossible to account for and track all the trees dying or being removed.
- MacDonagh: the trajectory for basically every urban area is a continuous loss of trees or green space.
- Galvin: part of this is a learning exercise. It helps to know how many trees are being planted compared to the overall trends or losses.
- Cline: a lot of this is state specific. Maryland has its Forest Conservation Act, but Virginia doesn't have anything like that. Think we should be careful because the specific requirements or implementation issues can vary widely across the jurisdictions.
- Saari: DC planting trees to outrun the mortality, knowing not all new trees will survive. Perhaps we should report a more conservative number to have that buffer in place.

- Etgen: if we had the money to gather the high resolution data every year then we wouldn't have these concerns about tracking these trees annually, but we do not have the money and have to rely on less frequent updates, like every 5 years.
    - Rodgers: what about just using iTree Canopy, take 1-2 days, and any municipality or jurisdiction could handle this level of reporting.
    - Having the land imagery data available in combination with the BMP reporting is useful.
- Law: the BMPs are reported annually. Would it be amenable to only update the tree canopy only every 5 years when the land use is updated with high resolution data?
- Hanson: land use data are updated as often as data are available. The years in between, there must be extrapolations to model/account for the year-to-year changes. Therefore, it's still important to report the BMPs in order to fill in the gaps. Both pieces of info are important so that 5 years from now, we can calibrate the reported data with the actual data, and identify the differences based on location, etc.
- Julie Mawhorter (USFS): The tracking is important for short-term crediting, and also to manage the trees planted.
- Carson: different entities might be competing for the same space – a rain garden in the right of way might be battling the same root space for a tree.
- Hairston-Strang: how can we best improve the Bay? i-Tree Hydro doesn't have the geospatial differentiation. It may be beneficial to somehow allow inclusion of soil type or infiltration rates.
- MacDonagh: Increased soil volume for trees helps increase the success of those trees. We have used up some of the best trees (e.g. elms) and have to increasingly rely on species that may require more specific conditions or may not be as successful in their survival.
- Law: if you look at crediting for runoff reduction practices vs stormwater treatment, the credits are developed based on infiltration and the associated processes even if the reductions are not quantified in terms of the specific mechanisms.
- MacDonagh: first 30 inches of soil depth is where ~80% of nutrient processing occurs.
- Law: We have a lot of people here involved with tree planting projects in some way. Does every tree count?
    - It was noted that UTC assessments sometimes include non-native species.
    - Galvin: Every tree counts, but you can't count every tree. It is a tracking and reporting issue.
    - MacDonagh: question to me is not should every tree count, but should every tree count equally? If someone is planting trees properly with plenty of soil volume and at a high survival rate, then that is better than improperly planting more trees that won't succeed or live.
    - Rodgers: Cacapon collects the same data as Montgomery County: location, date planted, species, stock size. A lot of data is from volunteers. We are going to these plantings and finding that the volunteers are infilling dead trees with new trees, eliminating the direct data-reality connection. Trying to count every planted tree can become a very difficult process.
    - Chris Brosch (Virginia Tech, VA DCR): the agriculture nutrient management panel has relied on values from literature to estimate an effectiveness value that we can discount according to other factors that we cannot measure. Could give tree planting a base condition credit, and based on certain program components, apply discounts. If those programs do certain things, the discount can be removed later on, making the credit modular, or "plug and play".

    - Hairston-Strang agreed. Suggest having some simple rate or estimate and build from there.

Wrap up and next steps

- Hanson asked each Panel member to share their biggest take-away messages or lessons learned from the day.
- Galvin: The big eye opener is to think about how much of the overall land cover and land use is really at issue here, i.e. only a percent of urban areas. Take away all agriculture, forest, and parse out everything, and everything else, this BMP is very small.
- Tom Whitlow (Cornell): Seconded Galvin's point – largely supported by the panel's literature synthesis. Makes putting specific credit values on this BMP very difficult.
- Claggett: runoff reduction is something we can sort of measure, but it is just a piece of the nutrient/sediment benefits attributable to canopy. There may be uncertainty in the range, focus should be on additional pieces.
- Cline: Building on what Mike said, we are looking at a small overall piece of the watershed. The amount of planting is a very small component of the larger picture for tree canopy and water quality. It's more about preserving our larger trees and existing canopy. The management of our existing canopy is the truly important piece.
- Susan Day (Virginia Tech): Agree with Keith, but noted that tree planting may not occur or be reported if there isn't a nutrient and sediment credit associated with it.
- MacDonagh: Preserving the canopy and incentivizing the maintenance of that canopy is a more important piece overall. See this as a two-pronged thing, with the focus on preserving existing canopy, with tree planting being a smaller supporting measure.
- Karen Cappiella (CWP): We all seem to be on the same page, and personally like the simplicity of the top-down approach that would be based on periodic updates to hi-res tree canopy and land imagery.
- Day: concern that relying too much on imagery may miss some on-the-ground issues such as the forest health. A future discussion point would be that aerial imagery may not pick up dying forest until it's too late.
- Some of the panelists felt that Urban Forest Management Plan could be a good idea and there are examples of that. Cline noted that for Fairfax County they have many different plans that cover different pieces of their overall tree and forestry management.
    - MacDonagh suggested that penalties for loss of existing canopy may be more effective overall approach.
    - Whitlow: management of forest may include removing largest trees on rotational basis, as part of best management.
    - Galvin: take a logic model format – what are inputs and outputs – canopy in, ecosystem services out.
- Law and Hanson thanked everyone for their time and participation.

Adjourned

Participants

Name	**Affiliation**
Panel members and support	
Neely Law	CWP
Karen Cappiella	CWP
Peter MacDonagh	Kestrel Design Group
Susan Day	Virginia Tech
Tom Whitlow	Cornell University
Keith Cline	Fairfax County (VA)
Sally Claggett	USFS
Mike Galvin	SavATree
Jeremy Hanson	Virginia Tech, CBPO
Ari Daniels	CWP
Other in-person participants	
Anne Hairston-Strang	MD DNR Forest Service
Chris Brosch	Virginia Tech, DCR
Eric Sprague	Alliance for the Chesapeake Bay
Frank Rodgers	Cacapon Institute
Jenny McGarvey	Alliance for the Chesapeake Bay
Julie Mawhorter	US Forest Service
Justin Hynicka	MD DNR Forest Service
Lou Etgen	Alliance for the Chesapeake Bay
Rick Fisher	Anne Arundel County DPW
Steve Saari	District of Columbia Department of the Environment
Tuana Phillips	CRC
Kate Baker	Chesapeake Conservancy
Jeff Sweeney	EPA, CBPO
Craig Carson	Montgomery County DEP
Webinar participants	
Dave Nowak	USFS
Barbara White	VA Dept. of Forestry
Barbara Brumbaugh	City of Chesapeake
Barbara Duke	City of Virginia Beach
Bob Goumas	City of Suffolk
Casey Kellner	City of Springfield, MO
Claire Jones	City of Suffolk
Mark Hockley	PA DEP
Chuck Mills	California ReLeaf
Colin Jones	MDA
David gasper	NYS DEC
Dana Coelho	USFS
Dona M Foster	USFS
David	City of Suffolk
Earl Bradley	

Ed Heide	City of Suffolk
Ellen Mussman	Baltimore County, MD
George Onyullo	DDOE
Robert Goo	EPA
Jacob Dorman	City of Suffolk
Jeff White	MDE
Jill Sunderland	HRPDC
Jenny Tribo	HRPDC
Julia Bartens	Davey Resource Group
Justin Shafer	City of Norfolk
Karen Coffman	MD SHA
Kelsey Brooks	VA DEQ
Kate Gordon	MD SHA
Lara Kling	VA DEQ
Marcia Fox	DE DNREC
Mark Symborski	Montgomery County, MD
Markku McGlynn	DDOE
Mary Gattis	Alliance for the Chesapeake Bay, LGAC
Michael Knapp	Montgomery County, MD
Michael Nentwich	City of Norfolk
Nicholai Francis-Lau	MDE
Liz Ottinger	EPA
Ginger Ellis	Anne Arundel County, MD
Robbie Coville	Davey Resource Group
Robin Pellicano	MDE
Sarah Davis	Springfield, MO
Shoshana Risman	George Washington University
Ted Brown	Biohabitats
Tomas Jordan	City of Suffolk
Rob MacPherson	City of Virginia Beach
Chris Kennedy	City of Virginia Beach

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, June 24, 2015, 12:00PM-2:00PM EST
Conference Call

Name	**Affiliation**	**Present? Y/N**
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech	Y
Michael Galvin	SavATree	Y
Neely Law (Chair)	Center for Watershed Protection	N
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	Y
Jessica Sanders	Casey Trees	N
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	N
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep)	N
Ken Hendrickson	EPA Region 3 (Regulatory Support)	N
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	N
Ari Daniels	CWP	Y

Welcome and Introduction

- Jeremy convened the meeting and reviewed the day's agenda.
- **DECISION**: June face-to-face meeting minutes were accepted as written.

BMP definition discussion

- Karen recalled the current definition for tree planting and reviewed the preliminary proposed definition for panel discussion. She explained the rationale for the preliminary definition, which is based on the panel's conversations at its June 3rd meeting. Tree canopy is more than tree planting and involves protecting/maintaining existing canopy. Forest canopy as a whole is important. WQ benefits for individual trees is likely minimal.
    - She asked if the panel members agree with the definition to include maintenance of, and increase in tree canopy.
        - Tom asked what kind of units would be measured or reported for something like maintenance.
            - Susan asked for clarification about the radius mentioned in the draft definition. The 120-ft minimum radius is the threshold for an area of trees to count as forest (1 acre) in the model. Karen noted that might not be needed in the final definition, but wanted to include that detail for discussion.
        - Sally suggested the group better define what we are calling the practice. Right now it is "urban tree planting/urban tree canopy" or just "tree planting in urban

areas." The verification guidance from the FWG moves away from that term and refers to it as "expanded tree canopy."

        - There was discussion and general agreement to keep "urban" in the name. May need to clarify what is meant by "urban," but for our purposes, urban means areas that are developed or not included in other land uses by the Bay Program (agriculture, forest, etc.).
        - Susan and Mike suggested simply calling it Urban Tree Canopy.
        - Keith did not see a problem including "protection" or "maintenance" in the BMP name because it implies an action by the jurisdiction.
        - Ari noted the "M" in BMP would encompass protection, maintenance, etc.
    - There was some general discussion of BMP crediting as a part of the definition discussion.
        - Jeff: for the TMDL there isn't awarding of "credits" in the sense of a water quality trading program. We track the progress that the jurisdictions make towards their numeric targets using estimated reductions from the various BMPs included in Model scenarios. In addition EPA also looks at programmatic goals stated in the jurisdictions' WIPs. For the purposes of this group, suggest being careful with the term "credit."
            - Tom asked about the units being considered and there was discussion. There are lots of different units, depending on the specific element under discussion. Locals/states will report the number of trees planted or acres, while the Model estimates the water quality benefits of the practice in terms of lbs of TN, TP, TSS.
                - **Post-meeting note:** Panels are encouraged to use English units in their reports (Fahrenheit, acres, feet, lbs, etc.)
    - There was additional discussion about the definition, verification, and the use of the hi-res land cover data.
        - Sally: Protecting and maintaining canopy is a part of verification, but do not see it as a part of the definition.
        - Susan: I thought that we were leaning towards programmatic elements as a part of the BMP.
        - Karen: We can include programmatic elements in a number of ways, e.g. qualifying conditions.
        - Jeff: There are about 175 BMPs available for reporting. They all require some form of appropriate maintenance. If it is not maintained then the BMP will no longer receive credit once its "credit duration" expires. What we're really reporting is the planting or actions that produce an expected increase in acres of canopy.
        - Susan: Protecting your existing canopy can be considered a management action because it reduces the baseline of continual canopy loss.
        - Sally: all the programmatic elements are important, but this panel needs to focus on the science and the effects that changes in canopy coverage have on water quality. I.e., what is the benefit for TN, TP and TSS associated with one additional acre of tree canopy?
        - Susan: do not see the programmatic aspects as something that would require units (e.g. urban forester on staff). The acres or trees planted would be the only units for reporting practices.

        - Keith and Susan commented that while there may continue to be losses of tree canopy, there is still a management action involved. There could have been more loss without certain programs or other efforts.
        - Sally: some of the jurisdictions will gain tree canopy. Expect tree planting to continue to be reported.
        - It was reiterated that BMPs should be focused on actions on-the-ground that produce water quality benefits.
    - Karen recalled the proposed definition. The UTC BMP includes actions and/or program elements that result in the maintenance of and/or increase in tree canopy in the urban landscape.
        - Keith noted there are a number of different ordinances in place that can increase the amount of protected areas under those easement mechanisms. Think that would be important and should be reported on. There may be a decrease in overall canopy but they increased the acres of protected areas.
        - If the panel develops a credit based on preserved acres then jurisdictions would then need to report the number of preserved area.
    - Keith: there are sometimes state legislative limits to what we can require in terms of tree preservation for development. The Dillon Rule. Some tools in Maryland, for example, are not available in other states like Virginia.

Minnesota crediting method

- Peter discussed the way trees are addressed as a BMP in Minnesota's stormwater BMP manual. He pointed out the Wiki website is continuously updated. The tree credits are used for new development or areas along linear corridor. He encouraged the panel to visit the website: http://stormwater.pca.state.mn.us/index.php/Trees
    - Peter noted there has been some push back on the requirement for 2 cu ft of soil volume per 1 sq ft of projected mature canopy. Susan commented that science doesn't support necessarily projected mature canopy rather than something better correlated with tree biomass, like DBH.

Crediting methods – Chesapeake Bay jurisdictions

- Ari noted the time and summarized how the various Bay jurisdictions address trees as a stormwater BMP for their purposes. The CWP wanted to know if the states have existing requirements or programs that could be affected by the panel's recommendations.
    - NY, PA and DC give credit at the site level in the context of new or redevelopment requirements.
        - There are approved BMP panel reports for retrofits and new state performance standards, so Jeremy mentioned that trees in the context of these requirements may already be addressed.
    - Ari described Maryland's impervious acre reduction equivalence used for their MS4 retrofit requirements.
        - BMP reduction efficiency (%) OR difference in land use loading rates, divided by difference between forest and impervious loading rate.
        - At the municipal level, they track the amount of impervious acres treated by retrofits. MDE uses that information to track the MS4 areas' progress towards the state's 20% retrofit goal.

Discussion of crediting methods

- **ACTION:** Jeremy, Karen and Neely will chat offline and make revisions to the proposed definition and crediting approach based on today's discussion. The panel will revisit the issue and discuss the revised proposed definition at its next call on Wednesday, July 22, 12:00PM-2:00PM EST.
- Jeremy noted the panel may select a new standing monthly time for August and beyond, and he asked panelists to be ready to discuss their Fall teaching schedule on the next call.

Wrap-up, review action items and next steps

- Karen and Jeremy noted the time. They thanked everyone for their time and engaged discussion.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, July 22, 2015, 12:00PM-2:00PM EST
Conference Call

Name	Affiliation	Present? Y/N
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	N
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech	Y
Michael Galvin	SavATree	N
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	Y
Jessica Sanders	Casey Trees	N
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep)	N
Ken Hendrickson	EPA Region 3 (Regulatory Support)	Y
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	N
Ari Daniels	CWP	Y
Peter Claggett	USGS, CBPO	Y

Welcome and Introduction

- Neely convened the meeting and reviewed the day's agenda.
- **DECISION**: June 24th call minutes were accepted with one edit from Susan.

Updates to BMP Protocol

- Jeremy summarized changes to the BMP Protocol, which was approved by the WQGIT on July 13th. He described that the review/approval process for panel reports was revised, and that panel members will need to complete the new conflict of interest (COI) disclosure form. He agreed to split it into a separate document and share it with the panel for their review and completion. Since it is a new form, he asked panel members to contact him with any questions as they complete the form.
- **ACTION**: Jeremy will provide the COI form for the panel members. Panel members will review and complete the form and submit to Jeremy. They should contact Jeremy with any questions or comments about the form.

General Points of agreement

- Neely recapped the write-up, survey and conversations shared with panelists since the June conference call. Neely noted that she, Karen and Jeremy also spoke with CBPO staff on issues related to an annual tree canopy BMP. Jeremy and Neely explained CBPO staff's concerns about the panel's direction that relies on updated land cover imagery that would only be updated periodically (e.g., every 5 years). For TMDL tracking and reporting purposes, that approach would pose a number of problems. The high-resolution data is not guaranteed to continue in the future for unknowable budgetary reasons. Also, periodic updates may not coincide with major checkpoints such as 2017 and 2025, when EPA and the jurisdictions need an understanding of the estimated water quality effect of all implemented management actions like tree planting.

- Neely and Peter explained how the land uses are updated every year. Peter noted that tree canopy is a new land use for the next version of the model. Data of county level housing trends is main way to help estimate and forecast changes in development (and thus tree canopy coverage) on a short-term or annual basis. For now we are only forecasting tree canopy in developed (urban/suburban) areas. With only 30-meter NLCD data it is more difficult to forecast or predict changes in tree canopy. Need high resolution imagery to better understand changes or trends in tree canopy.
- High resolution imagery will give us a detailed baseline of tree canopy in the watershed. If high resolution imagery is not available, then we need to consider other options for how to track estimated changes in tree canopy over time.
- Jeremy recalled Peter's explanation of how annual projections/updates are made. He explained how assumptions and best available data determine the annual changes in the land uses (the delta). Every so often there is a new NLCD, Ag Census, or other major data source that becomes available and there is a substantive update.
- Jeff and Neely explained that an annual tree canopy BMP would ultimately be the net change (gain or loss) of tree canopy over time in a given area. Boils down to tree coverage over time, so moving more towards how to estimate or track canopy from year-to-year, while every 5 years there will ideally be high resolution data to confirm/verify the canopy coverage. So we are
- Peter clarified that tree canopy in the Phase 6 model will be any patches of trees (urban or non-urban) that don't meet the criteria for forest (patches of trees >1 acre).
- Neely directed panelists' attention to decision point 1, statement 1 on her slides.
  - Susan felt TC should include all tree coverage, not just the smaller patches. It was clarified that forest is tracked as a separate land use with extremely low loading rates. The existence of that forest is essentially a BMP given the low loading rates compared to other land uses. Tree canopy is areas of tree coverage that are too small to be considered "forest" by the CBPO. Susan suggested calling it "tree canopy" and not "urban tree canopy."
  - Peter mentioned that based on recent analysis he did, 18% of all roads in the watershed appear to be covered by trees, so the load from the road land use would be significantly reduced
  - After discussion and clarification there was agreement on the following statement: measuring the WQ benefits of tree canopy should be tracked as a land use and not as an annually reported BMP. Can refine the language and phrasing in the final report.
    - **DECISION**: Measuring the WQ benefits of tree canopy should be tracked as a land use and not as an annually reported BMP.
- Decision point 1, question/statement 2:
  - There was discussion about a possible disconnect between the preceding statement and the 2nd one. Jeremy explained that the issue seems to be how a county or state could use data or information of planting or conservation to modify the estimated annual change in the land use. Tom noted in that case there would still be a need for some element of local/state reporting for actions like tree planting.

        - Neely summarized that based on feedback from the jurisdictions and stakeholders, and following the literature, an annual credit based on overall canopy is the best method.
        - Keith agreed and added that just because tree planting can be tracked, it should not necessarily be tracked. Tree planting is a very small overall piece of canopy. Planting trees is very important, but we should move away from that old approach and focus on the overall tree coverage. The total inventory of canopy, not just inventory of individual trees.
        - Peter M asked if trees or tree canopy under an easement is credited or accounted for differently
            - Jeff noted that this issue has been discussed with engaged foresters in the region before. The trees under an easement are counted because they remain in the land imagery and land use every year.
            - The panel could mention various tools available for maintaining existing canopy, which is a critical part
    - Neely noted the time and reserved the discussion for continued discussion on the next call.
- There was agreement from the panel on decision point 2: Do the water quality benefits for tree canopy land uses vary by pervious and impervious land uses [under the canopy].
    - **DECISION**: The panel agrees that the water quality benefits for tree canopy land uses vary by pervious and impervious land uses under the canopy.

Wrap-up, review action items and next steps

- Jeremy noted the next call is scheduled for August 26th and asked if anyone's fall semester schedule requires a change in the meeting time; none were raised though the August call will need to be moved up one hour to avoid a conflict with Neely and Jeremy. Jeremy will note this change in an email to the group along with the dates for September and October calls. If anyone has conflicts given a new semester schedule the panel can work to find a new regular time. Neely thanked everyone for their time and engaged discussion.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, August 26, 2015, 11:00AM-1:00PM EST
Conference Call

Name	Affiliation	Present? Y/N
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech	Y
Michael Galvin	SavATree	Y
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	Y
Jessica Sanders	Casey Trees	N
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	
Marcia Fox	DE DNREC (WTWG rep)	Y
Ken Hendrickson	EPA Region 3 (Regulatory Support)	N
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	N
Ari Daniels	CWP	Y
Peter Claggett	USGS, CBPO	Y

Welcome and Introduction

- Neely convened the meeting and reviewed the day's agenda.
- **DECISION**: July 22nd call minutes were accepted.

Methods to estimate water quality benefits of tree canopy

- Neely explained that the panel is being asked to provide its recommendations for relative loading rates, or water quality benefits associated with tree canopy over impervious and tree canopy over pervious. The WQGIT needs to approve any new Phase 6 land uses (including tree canopy) at its 9/14 conference call, so they've asked for additional information from the panel to explain why more than one tree canopy land use is needed, and what the relative loading rates would be.
- Karen reviewed methods and assumptions to derive the proposed relative loading rate reductions of 8% reduction for TC over pervious and 21% for TC over impervious. She asked for questions.
    - Sally: Transpiration value of 5% seems low. A study in Hubbard Brook had much higher transpiration rate, but that was not an urban area. Range of 23-32%.
    - Susan asked for clarification about turf and open space in the Phase 6 Watershed Model. Would expect tree canopy to be over open space or meadow or something other than turf grass.

        - Neely: That's a good point and it reinforces our approach to define set a relative loading rate.
    - Neely discussed sources for the numbers used. For interception, initially had a 13% figure that was an average based on a handful of studies that were scattered around and were not necessarily urban areas. After further consideration, went with the 18% interception value which reported in a study in the Chesapeake Bay.
    - For transpiration, may be able to get a refined value from iTree analysis, but want to know if the panel is comfortable with the conservative 5% value.
    - Jeremy asked for clarification about the factors that can affect transpiration. He encouraged the panel to use a conservative value since the tree canopy may be quite variable and a conservative value would be the safest approach.
    - Susan mentioned that transpiration may not be directly relatable to throughfall, so may need to adjust that in the methods. Tom agreed linking it to throughfall may also be confusing; rainfall is a better parameter.
    - Qingfu and Susan noted that transpiration is very dependent on location, climate, etc. The 5% appears to be based on California data, so is probably too low.
    - Karen: The majority of studies reported results as rates for an individual tree or a volume of what was transpired. So it was hard to find a value that could be applied as a % of rainfall or throughfall. Transpiration in particular is extremely variable for a number of reasons. Do not recall any studies that provided a transpiration value for an urban tree as a % of annual rainfall.
    - The panel can proceed with 5% or some other value and recommend that the transpiration value may need to be adjusted in the future, and that adjustment could be made in the next calibration of the Model in 2016.
        - Peter: if the panel takes that approach it would help if they provide information about the potential range or variability so the modeling team has a sense of how much or how little the transpiration or runoff reduction might change.
    - Mike: we're basing this runoff reduction on what is on the ground at the end, but if the tree wasn't there then the transpiration and those other processes would not have occurred. Want to be sure we are properly crediting those activities to the tree.
    - Karen: we are calculating runoff reduction by taking difference between the runoff reduction from a site with and without a tree.
    - Sally commented that the calculations are still very conservative.
    - Neely summarized that there was agreement on the modified calculations/methods
        - Would need to bring something back to panel with a quick turnaround and perhaps have another brief call before the 9/14 WQGIT to get the panel's sign off.
    - Neely recapped that there was no agreement on calculation results or numbers at this time. She asked the panel to provide any information about any of the parameter values (transpiration, etc.) soon. At this point, continue to focus on the current values and revised calculation steps.
    - **ACTION**: Panel members with any relevant studies or information about parameter values (transpiration, etc.) should provide those sources to Karen and Neely by COB Friday, 8/28.
    - **ACTION**: Updated calculations and results will be shared with the panel early next week (week of 8/31) and the panel will have a 30-minute call on Thursday, 9/2, at 1:00PM EST.

    - Tom asked Karen and Neely to provide the primary references for the current assumption values.
    - **ACTION**: Karen/Neely will post the referenced studies on the Scholar site and message the group when they are available.
        - Post-meeting note: the files are posted in the Scholar folder for the 8/26 call.

Panel schedule for remainder of 2015

- Jeremy noted the proposed schedule described in the agenda. Will push back the regular September conference call one week to Wednesday, September 30th. A face-to-face on 10/21 is problematic for Tom.
- **ACTION**: Jeremy will distribute a Doodle for the October Face-to-Face to see if there's a better option available.
    - Will schedule a short (1-hour) conference call one week after the face-to-face to resolve any lingering items.
- Jeremy and Neely noted the time, recapped the next steps, and thanked everyone for their participation and engaged discussion.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Thursday, September 3, 2015, 1:00PM-2:00PM EST
Conference Call

Name	**Affiliation**	**Present? Y/N**
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech	N
Michael Galvin	SavATree	Y
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	N
Jessica Sanders	Casey Trees	Y
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep)	Y
Ken Hendrickson	EPA Region 3 (Regulatory Support)	Y
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	N
David Wood	CRC, CBPO (CBP modeling team rep)	N
Ari Daniels	CWP	N
Peter Claggett	USGS, CBPO	N
Bill Stack	CWP	Y

Welcome and Introduction

- Neely convened the meeting and verified participants.

Finalizing methods and estimates of water quality benefits of tree canopy

- Neely summarized some changes in the past week to the method following comments from panel members. She described three options the panel has in terms of confirming its methods and estimates for the WQGIT. #1 includes transpiration and is the same method that was discussed the previous week; #2 excludes transpiration; #3 excludes transpiration but includes an adjustment for interflow. Sally wanted clarification about the interflow assumptions and preferred option 3. Keith also preferred 3. Qingfu noted interception amount is mostly evaporated. He also supported option 3. Neely clarified that the interflow benefit in option 3 does not treat TP or TSS, but does provide additional TN reduction, so for option 3 it's 18.5% TN reduction, and 17% reduction for TP and TSS. For option 2 it's 17% for TN, TP and TSS. This assumes that a 5% transpiration rate translates to a 5% reduction of interflow. Sally expressed concern that 5% is too low or conservative. Tree canopy as a land use is primarily capturing existing canopy, and newly planted trees are only a very small piece.
- Neely and Jeremy noted the time and asked each panel member: yay or nay? Option 3, as described during the call with 5% transpiration.
    - Karen, Keith and Jess: yay

- Tom: Yay, as first iteration.
- Sally, Peter: yay, with reservations that 5% is too low
- Qingfu: yay, but there could be other estimate(s) to make improvements
- Mike had left call, but responded yay to option 3 via email
- Susan was on travel.
- **DECISION**: The panel approved recommending Option 3 in its technical memo to the WQGIT.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, September 30, 2015, 12:00PM-2:00PM EST
Conference Call

Name	Affiliation	Present? Y/N
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech	N
Michael Galvin	SavATree	Y
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	Y
Jessica Sanders	Casey Trees	Y
Thomas Whitlow	Cornell University	N
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep)	N
Ken Hendrickson	EPA Region 3 (Regulatory Support)	Y
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	N
Ari Daniels	CWP	Y
Peter Claggett	USGS, CBPO	N
Bill Stack	CWP	Y
Invited guests--Dave Nowak, USFS; Alexis Ellis, Davey		

Welcome and Introduction

- Neely convened the meeting and verified participants. She noted the primary focus of the call would be to learn about a potential tool to help the panel formulate its annual BMP reduction estimates.
- She updated the panel on the status of the tree canopy land use recommendations for the Phase 6 watershed model. The land uses were approved by the WQGIT on 9/28, but the loading rates are currently set equal to the underlying land use instead of the panel's recommended (reduced) loading rates. The rates can be adjusted in subsequent versions of the beta model based on input from the panel or workgroups.
    - There was discussion about the panel's role in refining the loading rates for CBP approval in the future. It was noted that the modelers and various workgroups will also have a role in adjusting or refining the methods or loading rates. The panel does not have the entire burden from a loading rate perspective. The panel can focus on its work to estimate the annual BMP reductions and the loading rate issue will be clarified moving forward. Will know more in coming weeks.

Discuss UTC BMP annual credit

- Keith felt excited about the tool. Suggested perhaps we could not just limit the analysis to trees planted, but simulate other management actions too. Curious if we could use Landscape for that.
- Neely introduced Alexis and Dave. They presented about i-Tree Forecast and how it operates. Built off iTree Eco. Loads into forecast to run the simulation. Can start with a base population of at least one tree and add information for a project or additional trees. Dave discussed how to operate the tool, its parameters, options and assumptions.
    - They noted that hydrological effects won't be in first version of Forecast. Working to figure out how to incorporate that large database into the tool without breaking it. (Sitoshi?) Have hydrologic benefits by county (lower 48 states) and could calculate/provide those manually. Hydrologic benefits were developed with grant from EPA. Have a table with all that information, including evaporation, evapotranspiration, avoided runoff, vegetation uptake, etc.
        - Neely asked how the area gets defined/set up in the model.
            - Would be done in the Eco portion. Would enter that area and information. Default is the area in the database, but can be overridden with personal data.
        - Neely noted the phase 6 land uses include tree canopy over turf and tree canopy over impervious. Is there a way to distinguish the understory in the tools?
            - Dave: Not in forecast. Could do that in Hydro to look at impacts. That would allow you to change the level of impervious cover.
        - Karen: what format are the hydrologic benefits provided?
            - Cubic meters per year. Separate numbers for each of the variables.
                - Neely: If we had area of county could we convert it to a depth of runoff?
                    - Dave: Yes, but have to consider if extrapolation is done properly to that given area.
        - Sally: who is the intended user for Forecast?
            - Dave: County planners, managers, consultants, or anyone who uses Eco and wants to understand the population of their trees going forward. This is just the first piece. It is a dynamic tool. Want to add climate change or other factors in the future.
        - Sally: how might we determine a watershed-wide average?
            - Dave: Could do it for all the counties using the Hydro outputs.
        - Jeremy asked about how the tool(s) may account for development now or in the future. Dave mentioned they are waiting for new data coming out next year and will build that into Landscape. Would be tough to account for anthropogenic effects in Forecast.
        - Bill: What's the basic hydrologic model component? Curious about the typical size of storms it would be based on.
            - Dave: TOPMODEL and green-ampt
            - Alexis: Based on the weather data, so whatever has occurred in the timeframe.
- Ari discussed some possible variables and trial scenarios that could help inform the panel's annual BMP estimates.
    - Variables (see Ari's slides for more info):

        - Number and species distribution
        - Size
        - Mortality rate
            - Pest events
            - Extreme weather events
        - Planting area distribution
        - Location
    - Jeremy asked how the species composition may affect the end results in terms of hydrologic benefits
        - Dave explained the tool won't respond directly to the species per se, but the size of the tree over time, leaf area index for that county/region, etc. Depends on characteristics.
        - Jeremy: So looking at the first 5-10 years of a tree's life, the estimated hydrologic differences would not vary widely based on the assumed species composition.
    - Neely asked what is most important in terms of model sensitivity. Want to narrow down the scenarios to a manageable number and knowing the most important variables would help.
    - Dave responded to a question from Mike: if you have an inventory or plot-based information that would be your base population. Think what Ari is interested in is planting scenarios that aren't currently available. I.e., what is the estimated effect of planting trees, based on the average effect from those scenarios.
        - Alexis noted she can pinpoint the effect of newly added trees.
    - Keith: Forecast will take your existing population and estimate what happens to it over time. Will need to look at the planting scenarios and compare. Have to think in certain terms from a BMP perspective.
        - Alexis clarified she can separate out the starting population from new trees, but the current forthcoming version of Forecast itself does not include those new cohorts in the calculation.
    - Keith felt that Landscape may be the tool of interest for purposes of understanding the effects of planted trees or other management actions.
        - Landscape has those hydrologic tables built in.
    - Mike asked for clarification of what the intended use of the Forecast is for the panel.
        - Neely: Alexis will run scenarios for us in Forecast to provide a baseline or estimated trends over time. So we would have an idea of what happens to a population of trees annually over time.
        - Keith: preservation or other actions reduce the die off or mortality rates. Trees planted is just one practice or action.
            - Neely: we'll include discussion of this on 10/21 agenda.
        - Peter agreed the tool would be really helpful. He asked if jurisdictions could track and report trees that are cut like they do for trees planted.
            - Jeremy felt the data may be available in some jurisdictions and areas, but would not be available or reported in many other areas.
            - Keith: depends on the jurisdictions and their role in planting, maintaining and removing trees. Many other entities (nonprofits, etc.) are involved in both planting and cutting.

        - Peter: Suggested that question because it may be an important part of the picture and could potentially overwhelm planting effort in some cases.
        - Sally: Agree it is a very important issue, but it also something that is already credited in a sense. If they lose forest as a land use it affects their overall progress towards their target reductions. Our initial charge includes suggestions on how the practice will be tracked, reported and verified.
    - Ari asked for any immediate reactions to the table and scenario construction. Noting the time, Jeremy asked panelists to provide their feedback. Alexis noted that the scenarios described on Ari's slide would be a relatively quick turnaround, but she noted she starts maternity leave on October 26.

Wrap-up, review action items and next steps

- **ACTION**: Comments and feedback on the proposed scenario construction to Ari by COB October 7th so he can provide updated scenarios to Alexis shortly after that.
- Jeremy to provide minutes from the call and previous calls to panelists.
- **ACTION**: Panel members that would need overnight travel funds or reimbursement for the 10/21 meeting in Ellicott City should contact Neely immediately to confirm funds are available before they make reservations or travel plans (Tom/Peter/Qingfu). A conference line and webinar will be provided for anyone that cannot attend in person.
- Jeremy thanked everyone for their time and engaged discussion.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, October 21, 2015, 9:00AM-4:00PM EST
Meeting

Name	Affiliation	Present? Y/N
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	N
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech (sabbatical)	N
Michael Galvin	SavATree	N
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	Y
Jessica Sanders	Casey Trees	N
Thomas Whitlow	Cornell University	N
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep)	N
Ken Hendrickson	EPA Region 3 (Regulatory Support)	N
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	N
Ari Daniels	CWP	Y
Peter Claggett	USGS, CBPO	N
Bill Stack	CWP	N
Invited guests-- Alexis Ellis, Davey; Rebecca Hanmer, Forestry Workgroup		

Welcome and Introduction

- Neely welcomed everyone and verified participants.
  - **DECISION**: The 9/30 conference call minutes were accepted as written.

Discussion of CBP partnership comments on proposed land uses and loading rates

- Jeremy explained that the WQ Science document was provided by Sally Claggett and Julie Mawhorter. It summarizes technical and scientific questions from the USWG and WQGIT regarding the panel's recommended land use loading rates and methods. Jeremy pointed out that he and Neely provided draft responses for the panel's feedback. The goal is to get a sense of the panel's response and thoughts on the comments so Neely and Jeremy can accurately communicate the panel's consensus back to the commenters.
- Rebecca thanked the panel for all their hard work so far and in the coming months.
- Neely mentioned the panel's timeline is being extended into February-March 2016 due to the additional task of the loading rate recommendations and the time it took to deal with that.
- Neely reviewed the comments, primarily from MD SHA and VA DEQ, and the draft responses.
  - Neely recalled previous discussion of transpiration and interflow, which led the panel to provide the "bump up" to account for the transpiration of the tree. There were concerns about applying that transpiration for trees over impervious cover. Impervious

surfaces in the model do not have interflow or subflow, but in reality there is some or else the trees would not live. The panel would need to discuss this in more detail moving forward with the modeling team.

- Neely also pointed to the comments regarding the one-to-one reduction and leaf litter issues.
  - Neely explained the street sweeping panel also looked at the leaf litter issue. She had looked into all of that same literature for this tree canopy panel. The street sweeping panel determined that it didn't have the information necessary to make any recommendations to address leaf litter at this time. There isn't any new science from what has been reviewed.
    - Jeremy described that the load from leaf fall of trees is one of many "sources" that is implicitly captured in the calibration. For new trees planted over impervious perhaps the panel can figure out if the leaf fall should have an effect on the overall effectiveness, but for trees planted in pervious settings there probably is no water quality concern. Leaves falling into a gutter are a potential concern, not necessarily leaves that fall in a field. Trees have always lost their leaves.
    - Jeff encouraged the panel to continue to consider and address the issue as best they can with the available information. Helps to document all of that in the report.
  - The panel will continue to discuss the one-to-one assumption that was part of its initial recommendations.
- Neely noted questions raised about the Herrera citation. She clarified that the Herrera approach and methods were used, but values from studies in the Chesapeake Bay were substituted. This was documented in the memo.
- Neely pointed to infiltration comments. She recalled previous comments Susan Day had made regarding potential impacts of trees on soils' infiltration ability and need for additional research to document this effect of tree canopy on the surround soil environment and effect on runoff and pollutants
  - Peter noted a study in Canada looking at shelter belts and the infiltration on both sides. However those trees were planted back in the 1930s so we can't know when those effects were realized.
- Neely reiterated that the panel will be able to more fully explain its reasoning in the full report.
  - Rebecca: if interception is such a large part of the equation, but perhaps a recommendation could be made for additional information gathering or research to measure runoff factors for areas with tree canopy. Neely mentioned that research recommendations are a standard component of panel reports, so the panel will certainly define the data gaps and research needs. She also noted that differences in definitions also matters. Given the CBP definition of tree canopy, it can be more difficult to get the kind of information a future panel would need. Most studies and tools look at tree coverage in an urban forest or forest perspective.
- **ACTION**: Panel members should email Jeremy and Neely any thoughts or comments on the proposed responses (red text) by COB Thursday October 29.

Review and discuss crediting methods for BMP

- Neely recapped where the panel had left off in its BMP discussions back in July, before the panel's time was monopolized with the land use recommendations.
    - She asked if the panel members still agreed with the approach that an annual BMP reduction credit would be replaced by the tree canopy land use every five years. I.e. the annual reduction would be available until the land use is re-mapped to avoid double counting. Continued discussions needed with CBP to better understand expected methods to update/adjust tree canopy land uses on an annual basis.
        - Peter noted the 50 sq ft threshold is a good one. Gives them more information and incentive to improve the way they plant trees.
        - There was discussion about potential crediting or double counting issues and options for addressing them.
            - Peter asked if the ash borer has already done the bulk of its damage or if more damage is expected. Keith noted that the ash borer is just getting started in Northern Virginia, but ash is roughly only 5% of the canopy, but there are major concerns about the loss of that canopy. Ash is a common landscaping tree though, so entire plantings are at risk in some contexts. Expect that signal would be strong enough to show up in the land use updates.
    - Neely recalled the panel's discussion about actions that protect and maintain existing canopy. The issue is how to define and quantify those effects on an annual basis. It involves actions different than tree planting. Protecting and maintaining existing canopy would be the most effective action to offset loss rates There was discussion of potential options for how to define or quantify
        - Primary purpose of the model is to help develop WIPs …EPA is considering developing the Phase III WIPs on a future 2025 condition. The Phase I and Phase II WIPs were developed based on existing conditions. Basing them on future conditions would place much more importance on conservation programs. That will be a partnership decision so EPA is just one of parties involved. The decision would be made after the panel has completed its work, however.
            - Issues to consider:
                - Time lag between planting and mapped land use
                    - May not be depending on how credit is developed (i.e. project TC vs. annual change)
                - Model: track and report credit as BMP and replaced with land use approx. every 5 years
                - 3 approaches to address conservation
                    - Inform model annual TC projection
                    - BMP
                    - Local conservation programs
                - Note: 2017 WIP address future 2025 conditions to include jurisdictional conservation programs
        - Keith asked for clarification of how forest/timber harvest is factored into the current model.
            - Jeff explained the Phase 6 model: true forest, disturbed, and harvested. There is a "forest harvesting practices" BMP that includes the various best practices involved with minimizing the potential water quality impacts.

- Neely reviewed the panel's previous proposed definitions for the BMP and land use. She noted the land use definition had been approved by the WQGIT. The panel still needs to discuss and refine its definition for the BMP(s).
    - Neely suggested:
        - Planting, converting
        - Maintaining, would apply to existing TC land use.
    - She reviewed some additional elements for a revised definition for the panel to consider:
        - Represents "net" acreage of tree canopy (net = existing - loss + replacement)
        - Every tree counts
        - Less than 1 acre
        - Trees over pervious and over impervious
        - Trees planted as part of BMPs excluded
        - Trees must be planted in good condition and maintained to ensure survival
        - Need to address how trees in BMPs are not counted as this (tree canopy) BMP
    - Keith asked for clarification about how to account for trees that are planted in another BMP like a rain garden. There was discussion and the group agreed that it is an inconsequential issue, though it is something that will need to be mentioned and addressed in the report. If the tree(s) is large enough it will be captured in the land use through the high res imagery, but do not expect that to be an issue. It is highly unlikely that anyone would undergo effort to report the planted trees as a BMP in addition to the primary BMP associated with those trees.
- There was discussion of possible crediting approach and things to consider. Want to make it as easy as possible to report given information available to jurisdictions. There are a number of factors to consider for credit development (e.g., size and species of tree, growth/loss rate, understory land cover, planting conditions, etc.). Need to document and mention the various factors and demonstrate that the panel considered the factors when developing its recommendations.
    - Peter noted there were pretty clear thresholds in that Disney study between tree survival and soil volume. Over 1500 ft3 was 100%, a little over 80% for 500 ft3, and only around 50% for 100 ft3.
    - Neely noted that the panels and the CBP cannot set explicit design criteria, but the panel can provide its suggestions about what factors and criteria can help ensure the survival and performance of the BMP.
    - Factors to consider:
        - Tree species: small, medium, large (later revised to just large and small)
        - Tree species general category
            - Broadleaf/deciduous
            - Evergreen
        - Also "default" average tree to account for jurisdictions not reporting other information
        - Growth and loss rate
        - Understory land cover

            - Planting conditions

- Neely recapped that iForecast can help the panel understand how canopy changes/expands annually. Initial scenario focused on tree planting. Ari and Neely summarized results from the initial iForecast scenarios that were run by Alexis. Ari and Neely thanked Alexis for running the scenarios.
    - Initial scenarios designed to give a general sense of results for various locations in the watershed. Selected mortality rate of 5%. A lit review provided where N>81,500 indicated overall average mortality was 4.2% (post meeting note: Lit review conducted by Jenny McGarvey and shared with CWP via pers. communication). Conversations with panel and landscape architects indicates that mortality rate ranges from 4-6%. So 5% is reasonable starting point.
        - The average starts at 5% and varies by DBH after first year. First year all mortality is 5%, but can go up or down in subsequent years based on DBH and it may not average out to 5% overall in the long run.
        - Ari explained that a cohort is any single group of trees that have all common variables assigned to them. He clarified that a single scenario was run though it included about 40 cohorts that each describe different paths/outcomes based on the programmed variables.
    - They reviewed outputs. Canopy area per tree planted vs. time. This answers "how much canopy did you get for every tree planted?" As opposed to per tree remaining. If you look only at remaining trees then the canopy is much higher. Looked at overall averages for the simulated areas over 30 years. Also reviewed breakdowns by species. 40 cohorts over the 4 locations and 5 species. So 25,000 of each tree in each location for each light exposure, etc. Geographic location in Forecast only determines the number of frost free days per year, so Baltimore and Norfolk have overlapping curves by location and increased from 50 sq ft to over 200; Cooperstown only increases from 50 sq ft to a little over 100. Jeremy asked if Forecast is entirely annualized or if planting date/month can be differentiated in the model. Alexis explained that it is annualized so there are no assumptions or differences based on planting date.
        - Jeremy asked if the total available area for the trees is specified. Curious if we can get a sense of density in Forecast. Alexis explained that the total area was not specified for these general simulations, but it could be. She noted that the model can account for changes in CLE as the trees grow, but did not build that in for these particular simulations.
        - iForecast can accept general categories such as "broadleaf, large," but some calculations (e.g. crown width or height) need to know the species. Could perhaps look for representative species within the groups.
        - Neely asked for a better idea of the average longevity for urban trees
            - Peter noted that Chicago did a survey and found 7 years was average life for street trees. Other studies have found around 13 years, or as high as 23 years for street trees. Street trees have highest mortality rates.
                - Keith clarified that many urban trees are on private property or planted away from the street. Not all urban trees are street trees that have those low lifespans.
        - Keith noted that the geographic location and the light exposure were two factors that seemed to have a significant effect on the canopy coverage within a five year period.

- Neely asked how the panel could best explore the effect of land us within iForecast. Alexis noted that the land use tends to affect the mortality most directly. The CLE could also be affected or tweaked in that context. With some research could maybe adjust the growth rates as well. By default iForecast only currently presents results broken out by land use.
    - Ari: could define a “transit” land use for our purposes and specify different mortality rates or other variables. Could make a comparison to the standard/average cohorts. Would need data to support those different assumptions though.
    - Could maybe use the number of frost free days as a starting point.
    - The assumption is that you are getting credit for trees that are planted properly under the right conditions to ensure greater chance of survival.
    - Peter noted a study by Tom Smiley for Charlotte, NC. In the downtown area. After 30 years of tree growth there was an exceptionally high survival rate. The soil volume was 700 cu ft for each tree.
        - It was pointed out that 2” caliper is most likely 1” DBH for trees being planted.
    - Jeremy suggested some comparison cohorts could be simulated with different density assumptions. There was discussion about how to approach the BMP credit, what to report, how to factor in density, the existing BMP definition, etc. The iForecast results seem to imply that the current definition of 100 trees planted per acre falls far short of the intended one acre of canopy coverage at both 10 and 30 year marks.
    - Change in tree canopy equals (net) growth in existing tree canopy plus new trees planted
        - Existing TC is known and it is mapped (at distinct points in time)
            - CBWM projected change in land use on annual basis in between imagery updates
        - If we know an average age of urban trees we could use iForecast results for estimated canopy area per tree at that age.
        - Jeremy suggested the panel look for representative surveys or data that the panel can use to better understand representative species/groups of trees in the CB watershed, particularly in developed areas. Same for any other assumptions we may use about the typical age of existing within developed tree canopy areas.
    - There was extensive discussion of how the annual BMP would be simulated in the watershed model as either a land use change BMP or an “efficiency” (i.e. a percent reduction). The reductions could be simulated in an equivalent way, but the accounting within the model is different.
- Groups of trees that represent small, medium and large. It was suggested to use a weighted-average for frost free days for the entire watershed, instead of various locations. Alternatively, could proportion the trees based on relative area of climactic zones within the watershed.

                - Soil volume is a major factor, so it was suggested that spacing could be a useful mechanism to ensure adequate spacing. Peter mentioned that spacing of at least 25 feet is good, but 35 feet is recommended.
            - The light exposure did not have as great an impact in the first 5 years, but over the 30 years it has a significant effect. Again, spacing and soil volume helps ensure that the tree has the necessary light exposure to grow well and live longer.
                - Keith mentioned that in reality most of these trees will be planted in open space, not in shade of existing forests or trees.
                - Peter mentioned that 180 sq ft of canopy coverage (at 30 years from the averaged iForecast results) would have diameter of 15 feet. So that would be the closest you could plant trees.
                - Peter also noted that in urban areas trees are often planted in the shade of buildings so it may make sense to keep the 50/50 split after all
                - Will keep half-half split for CLE assumptions.
                - Keeping 1 million trees constant for these additional cohorts. Divide them based on distribution of climatic zones.
                - There was discussion of the distribution of species. It was suggested that the different between small trees and the mid/large trees is of more interest.
                    - **ACTION**: Keith will provide some suggestions for potentially representative species to select for cohorts.
                - Will also add conifer and deciduous.
                - Neely: to recap discussion the differences in tree growth are more a function of the planting conditions (soil volume, spacing, etc.) than a function of the underlying land use. This will need to be conveyed in the final report, depending on recommendations Expert Panel provides
    - Participants went through Ari's modified version of the spreadsheet results from iForecast. They looked at different breakdowns and graphs of the results, focusing on the first five years of the simulations, the runoff avoided, and other results of interest.
    - Neely asked Alexis for additional documentation from Satoshi that explains how the runoff avoided was calculated. Alexis will put Satoshi in touch with Neely/CWP and Jeremy so the group can discuss some of the estimated WQ benefits in more detail in November.

Wrap-up, review action items and next steps

- **ACTION**: Panel members should email Jeremy and Neely any thoughts or comments on the proposed responses (red text) by COB Thursday October 29.
- **ACTION**: Keith to provide suggested species for modified cohorts.
- **ACTION**: Panelists will be asked to weigh in on modified iForecast cohorts. Neely and Ari will send out summary of modifications following Keith's suggested species.
- **ACTION**: Neely and Jeremy will work with Sitoshi and plan a discussion
- Neely and Ari recapped some additional discussion items and analysis that
    - Projected land use changes…work with CBPO modelers
    - Newly planted tree vs preserved or existing tree of an older age tree (~20" DBH or 30 yrs old)
    - Newly planted tree vs standard BMP like bioretention

    - Number of trees that actually make an acre based on Forecast results
- **ACTION**:
- Neely and Jeremy thanked everyone for their time and engaged discussion.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, December 9, 2015, 1:00PM-4:00PM EST
Conference Call

Name	**Affiliation**	**Present? Y/N**
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech (sabbatical)	N
Michael Galvin	SavATree	N
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	N
Jessica Sanders	Casey Trees	Y
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep)	N
Ken Hendrickson	EPA Region 3 (Regulatory Support)	Y
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	N
Ari Daniels	CWP	Y
Peter Claggett	USGS, CBPO	N
Bill Stack	CWP	Y
Invited guests-- Alexis Ellis, Davey;		

Welcome and Introduction

- Neely welcomed everyone and verified participants.
    - **DECISION**: The October minutes were accepted as written.

Discussion of options

- Neely explained two options for how the panel can recommend the BMP reduction is simulated in the annual progress runs, as a land use change or as an effectiveness value (aka a % efficiency). She recalled the panel's working definition for the urban tree canopy BMP. The focus of today's discussion is on tree planting, with other actions to be later discussed in January. She and Jeremy clarified how the two approaches are different even if the reduction is the same. Either way the reported acres would be taken out whenever the land use imagery is updated, so the differences only apply for the years in between the imagery and land use updates. They asked for panelists' input or thoughts on their preference.
    - Sally: initially liked the land use change approach but the effectiveness value does seem easier programmatically and for reporting. Prefer the effectiveness value for that reason.
    - Keith agreed with Sally. The reporting elements would be the same, but the accounting seems easier.

- Tom was curious how the effectiveness value may change over time in the real world and what empirical data would be used to support or explain that change. Prefer something quantifiable and verifiable.
    - Neely responded the data is currently not available in a format or scale that would enable this analysis and panel can discuss this further as part of 3rd agenda item for discussion (Supplementary analysis). Expert Panels are convened to review existing credits to refine assumptions and values. Panel will be asked to provide research-based recommendations that would improve the load reduction credit (effectiveness of relative loading rate) as part of the Expert Panel report.
- Jess agreed with Tom
- Neely noted the balance in favor of simulating it as an effectiveness value over as a land use change.
    - Qingfu was okay with that approach and pointed out that "land use" is usually used in a different context.
- Sally suggested that the panel proceed with treating tree planting as an effectiveness BMP instead of as a land use change. Jeremy and Neely asked if there were any objections to that, noting it wouldn't be a fully final recommendation until the panel's report is completed. No objections were raised.
- **DECISION**: The panel will proceed with treating the annual BMP (the tree planting component) as an effectiveness value rather than a land use change BMP.

Discussion of panel's use of iTree Forecast

- Neely recalled the CBP's current definition for the tree planting BMP, which is simulated as a land use change where 100 trees equals one acre that is converted from urban pervious to the forest land use. She explained the discussion at hand is limited to how we can translate the trees planted into an area of tree canopy to help quantify the BMP for Phase 6. The water quality benefit associated with that canopy is the next step, but first the panel needs methods to determine how much canopy area is gained by planting a tree(s).
    - Neely mentioned that one point that was made repeatedly back in June and in other discussions is that the current BMP reporting needs to be as simple as possible.
        - Sally added that the BMP represents a very small amount of reduction in the overall WIPs so that is another reason to keep it simple for the annual progress submissions.
- Neely recapped that the goal of using iTree Forecast is to estimate the canopy gained associated with tree planting. She summarized the cohorts that were used in Forecast, thanks to the assistance and work from Alexis.
    - Ari explained that Alexis averaged the frost-free days (FFD) associated with all the municipalities within the Chesapeake Bay watershed and arrived with 172 FFD. Most fall between 150 and 210 FFD in the watershed. 105 and 255 are outliers.
- Neely and Ari described one hypothetical approach to use the panel's Forecast outputs and information and provide a simple way for a jurisdiction to determine the amount of canopy based on the number of trees planted. Ari reviewed options for the panel to consider for determining how much canopy to credit for each planted tree. He summarized some potential pros/cons for each option.
    - Option 1, the canopy would be based on the current canopy coverage, i.e. it would change annually for the duration of the BMP.

- Option 2, the canopy would be based on projected canopy area at the time of the next land use update (i.e., 5 years).
  - Sally mentioned that it might be better to talk about the canopy in terms of the tree's age rather than the caliper at time of planting. Keith commented that the imagery tends to pick up a tree once it is 9 feet tall. Ari explained that CBP staff indicate that the tree is expected to be detected in the imagery once its canopy is ~50 square feet.
  - Neely noted the canopy area will vary by tree type. The outputs are based on the assumption that on average the tree is 1" caliper at the time of planting.
- Option 3 would be based on projected canopy in 2025.
- Jeremy noted that the panel is not limited to only those 3 options. He suggested a fourth option where the canopy is averaged based on a certain (TBD) number of years (e.g., 2.5, 5, or 10) and the canopy would then be equal each of the years. While a tree's canopy does change year to year in the real world, it is important for the modeling tools and the BMPs to be consistent.

- Neely asked for the panelists' input on the options and described the decisions.
  - Sally pointed out that the land uses based on imagery will not distinguish the canopy based on tree size or type, etc. The tree canopy land use will be updated every five years. She preferred option 2 or some version of it.
  - Qingfu preferred option 1.
  - Keith: the Forecast tool has much more science and information behind it, so the information from the tool is much better than the existing BMP. Seems that the canopy would have to be consistent each year though. Much more difficult if we try to deal with variable canopy credits. Suggest that the credit is given at time of planting based on project canopy that accounts for mortality, etc. So then it is just a matter of what year you choose.
  - Karen: leaning toward option 2 since it seems like more of a middle ground looking at the 5 year, or maybe the fourth option. Since we agreed to simulate it as an efficiency that may affect the panel's choice.
  - Keith asked if the periodic land use update affects how the panel should approach this. Unclear if the 5 year distinction is arbitrary or if they should coincide. Perhaps the fourth option could have longer timeframe like option 3.
    - Ari felt that looking at an average would be a reasonable way to consolidate and address some of the pros/cons from the other three options.
  - Tom suggested using smaller numbers of trees in the example scenario to illustrate how the credit would work; may be more realistic. The land cover is the most solid approach and most verifiable. Mildly in favor of the second option.
- Bill: in the real world as the canopy grows beyond 2025 it becomes a very large benefit in terms of those longer term loads. The benefit continues to grow beyond the life of the practice. Need to emphasize that. Sally agreed.
- Jeremy explained that the Watershed Model is used for simulating and tracking the cumulative effect of management actions and changes on the ground.
- Jeremy noted the time and that there seemed to be a preference for Option 2, but more discussion was needed at the next call. Neely and Jeremy will prepare some refined options for January with side by side comparisons of what the canopy would be based on a set of different ages/average (e.g., 2.5, 5 years, 10 years). Will need a panel recommendation at that time.

Discussion of potential supplementary analysis

- Neely summarized a request from Tom to investigate available datasets that could be used to estimate a change in water quality or runoff response from a watershed based on a change in canopy cover. After discussing the analysis with leaders of the CBPO modeling team, we determined that it is not possible to conduct this analysis for the panel's benefit with available data. The data required is not currently available and cannot be derived or developed at this time. While there are available land use and land cover data over the timeframes of interest, the water quality monitoring stations with the necessary nutrient and sediment data are associated with drainage areas that are too large to effectively isolate the effects of tree canopy over those timeframes, whether it's 10, 15 or 30 years.
- Tom suggested someone might be able to do something better in the next cycle of BMP review. Could suggest a certain number or size of catchments that could be combined with high resolution imagery and other available data to help isolate the effect of tree canopy changes from factors that usually confound that analysis.
- Jeremy mentioned that every panel includes a section that outlines future research recommendations identified by the panel. Every panel stumbles upon research gaps or issues that would ideally be addressed in the future to improve the science the next time the BMP is revisited by the CBP or others.
- Sally mentioned the tree canopy land use is brand new so the Forestry Workgroup and the partnership will continue to explore what insights that new information and high resolution imagery may offer.

Wrap-up, review action items and next steps

- Neely and Jeremy thanked everyone for their time and engaged discussion. They will circulate a Doodle for mid to late January and will also work to put out a little survey about some options/numbers to consider in the meantime.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Friday, January 29, 2016, 1:00PM-4:00PM EST
Conference Call

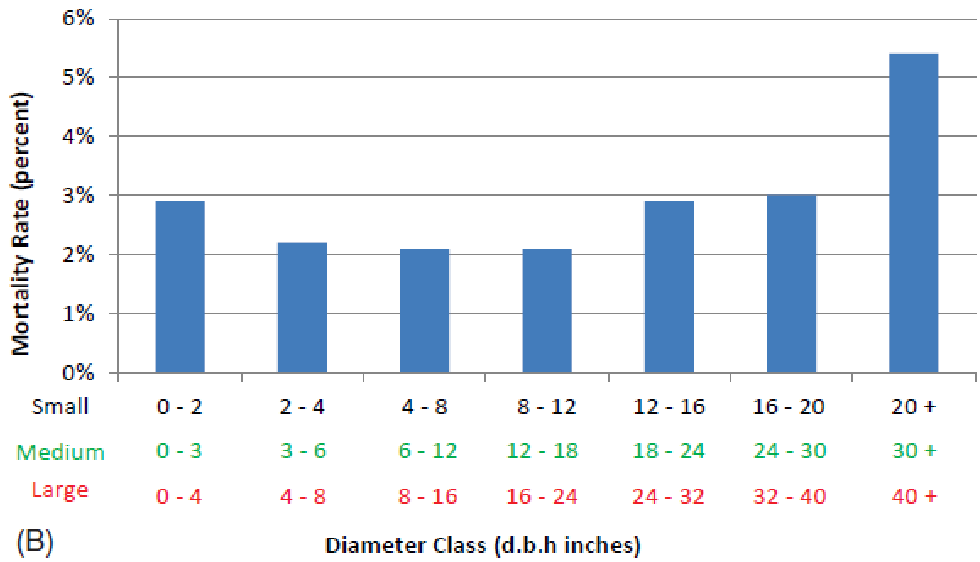
Name	Affiliation	Present? Y/N
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech (sabbatical)	N
Michael Galvin	SavATree	Y
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	Y
Jessica Sanders	Casey Trees	N
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep)	N
Ken Hendrickson	EPA Region 3 (Regulatory Support)	N
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	Y
David Wood	CRC, CBPO (CBP modeling team rep)	N
Ari Daniels	CWP	Y
Peter Claggett	USGS, CBPO	Y
Bill Stack	CWP	Y
Invited guests—Justin Hynicka, MD DNR; Marion Divers		

Welcome and Introduction

- Neely and Jeremy welcomed participants to the call. Neely reviewed the day's objectives.
- Jeremy noted the busy agenda and asked for any comments or edits to the December minutes should be sent to him.

Discussion of revised options for expanding tree canopy as a BMP

- Neely recapped that the panel agreed to credit the BMP annually as an effectiveness value rather than as a land use change. Neely noted that some representatives of the Forestry Workgroup (FWG) asked the panel to consider Forecast output for projected canopy growth at 0% mortality in comparison to the 5% assumption the panel has currently input into Forecast.
    - Sally understood the 5% is applied in Forecast each year, and that was one reason for concern from the FWG since it may overestimate the mortality. Ari noted that the mortality calculation could be overridden in Forecast to simulate it that one-time instead of annually, but that the panel had previously discussed and decided to apply it annually. Neely further clarified that the 5% is the overall mortality but the actual % mortality applied each year varies based on trees species and DBH relative to height at maturity. *For panel's reference added after the meeting:*



- Neely offered one potential option for the panel to consider, i.e. to offer two credit options: one based on a 0% mortality and one based on the 5% mortality. For the former, there would be stricter qualifying conditions that would provide assurance that trees planted have the greatest survival and growth rates to include replacing trees that are lost.
  - Keith: the assumption or condition that every tree lost will be replaced is false and does not exist. The fact that mortality was built in was a strength of using Forecast to help construct the credit because it would account for that realistic loss of trees. No jurisdiction can achieve that 0%. Since it's not a single entity or structure like a stormwater pond it is impossible to check and replace every tree that is lost. The verification of health/survival would be prohibitive for almost any jurisdiction, and would not be done. There's a big difference between a living tree and other types of BMPs.
  - Mike concurred with Keith that the 0% scenario would be unreasonable and that the 5% makes more sense.
  - Sally noted the partnership had already endorsed BMP verification guidance that instructs jurisdictions to replant lost trees.
    - Ari mentioned that this tree planting BMP is different than some of the other tree-based BMPs. Whereas BMPs like riparian forest buffers are larger contiguous areas of trees, the tree planting BMP could be individual trees reported at an aggregate scale.
    - Bill pointed out that the verification documents and protocols from the workgroups are guidance that sets a bar for the jurisdictions. Jurisdictions will not always be able to adhere to every aspect of the guidance, depending how high the bar is. Past expert panels have provided recommendations for BMP verification that must be followed to obtain and keep the credit.
- Neely explained the mapping threshold based on the high-resolution imagery is $9m^2$, or 97 sq ft. She pointed out that the various cohorts (except for coniferous) tend to hit or pass that threshold approx. 10 years after planting.
    - Neely: there is such a wide level of variability with site conditions that the 5% mortality is effectively a way to build conservatism into the credit. We aren't distinguishing red buds from oaks, or soil volume, soil types, etc. Those factors

        can have a dramatic effect on the growth of a tree and its ability to meet its growth potential.
    - Sally was concerned that the annual application of mortality in Forecast perhaps lowered the expected canopy per tree too much.
    - Mike: these credits and incentives are low per tree, and water quality credit should not be a driver for tree planting, Incentives come from jurisdiction for all of the other benefits provided by trees. The benefits of trees really add up when they are planted in large numbers and when they exist in larger continuous areas.
    - Keith: The accumulation of all your trees is what matters and provides the benefits, so not hung up on looking at the individual tree.
    - Sally: even with the current Phase 5 reduction it is a relatively small BMP. Want the panel to be aware of that.
- Neely asked the panel: Does the 100 trees/acre need to be revised: Consensus: Yes, it needs to be revised.
    - **DECISION**: The Phase 5.3.2 conversion of 100 trees/acre needs to be revised for Phase 6.
- Given the minimum mapping unit for tree canopy (97 sq ft) and review of Forecast output, does the panel agree:
    - A tree will, on average, meet the 97 sq ft threshold after 10 years. Therefore, the tree will receive credit as a BMP for 10 years, but will be credited as a land use after that (when the imagery will be able to detect it).
        - Sally: At least 10 years.
        - Keith and others agreed with 10 years.
    - **DECISION**: A tree will, on average, meet the 97 sq ft threshold after 10 years. Therefore, the tree will receive credit as a BMP for 10 years, but will be credited as a land use after that (when the imagery will be able to detect it).
- Provide a default tree?
    - Sally and Mike: Yes.
    - Mike noted that coniferous is only planted in reforestation contexts, and the vast majority of planting is broadleaf.
    - Neely noted that over the first 10 years there is not much difference between the large and medium broadleaf growth projection.
    - Exclude coniferous from default?
        - Keith and Mike: yes.
        - Sally noted that coniferous will still be tracked and counted under the land uses. Jeremy pointed out coniferous would still be tracked and reported through the BMP and the land uses, but the decision is to exclude it from the calculated default tree.
    - **DECISION**: The panel will recommend a default tree, which will be calculated based on broadleaf only.
- Default should be based on broadleaf medium, large, or both ("default broadleaf")?
    - Keith: Medium broadleaf
    - Mike: default broadleaf (med and large)
    - Tom: default broadleaf. In final report, include a disclaimer that we recognize it is a simplification but it will balance out in the end.

        - Jeff: the modeling tools can have as many BMPs as the panel wants. Other BMPs have various categories like that, and if the jurisdiction doesn't specify one, then it gets credited at the lowest effectiveness value from those categories.
        - Peter: Broadleaf medium
        - Sally: broadleaf default (Large and Medium)
        - Karen: broad default of Medium and large (post meeting input)
    - Geographic: have different canopy credits based on FFD or not?
        - Mike: agree with having two. No additional work from the jurisdictions in terms of reporting and there is a wide discrepancy between New York and southern parts of Virginia.
        - Peter: average (166).
        - Sally: use the average.
        - Keith: use two.
        - Jeremy noted that the map for FFD is not a north-south division.
        - Neely determined the panel can revisit this decision later. She noted the difference is rather small until after year 10 of growth. Once we determine our chosen year of projected growth then we can make a more informed choice about how to account for FFD.
    - Mortality
        - Peter: 5% is more realistic and accounts for real world conditions.
        - Keith: the 5% is a safety estimate and would account for mortality and in a sense build verification into the BMP reduction. The science brought us to the 5%
        - Sally: it is a very little amount of credit for 10 years anyway. Tree planting itself is a very small piece of the pie, which is far outweighed by other factors such as development.
        - Sally: 0% mortality or apply mortality one-time instead of annually.
            - Jeremy suggested the panel could present the 0% mortality canopy projections in the report to demonstrate the potential yield a jurisdiction could see in its imagery after 10 or more yearsif they provide the right soil conditions, etc. That way the panel can communicate the potential longer term gains if the jurisdictions take the right steps, but still provide a more realistic BMP credit.
        - Tom: 5% sounds reasonable acknowledging what the conditions are
        - Mike: prefer the 5% approach. Our role should be based on what we can justify with the science and 0% just does not seem reasonable based on our role as a panel.
        - Karen: we can justify the 5% whereas 0% isn't realistic, but maybe some other value in between would make sense. We don't have time to run more Forecast scenarios but maybe there's some other way to provide a bump-up. Agreed with Jeremy's suggestion to use the 0% to illustrate potential growth given proper maintenance, planting techniques etc
    - Neely will send email laying out issue for panel's growth period of choice (2.5, 5, 10, etc.)

Land use loading rates for tree canopy

- Justin reviewed his and Marion's work to assess the runoff benefits of tree canopy. He walked through their conceptual models and asked for input from the panel.

- Justin noted there is not a lot of direct data to support a loading rate, but there is a wealth of information about the underlying processes that we can put together in a modeling approach. He reviewed analysis about the reduction in water volume by tree canopy relative to impervious and pervious land covers. Initial results using 2015 precipitation and soil type characterized by HSG D properties. Looking at the water balance you have 18% reduction for canopy over impervious and a 26.3% reduction for TC over turf.
- Tom mentioned hydraulic lift. Trees with deeper roots redistribute water across different strata. Probably more detail than is needed for the task at hand, but there will be different ETs. Mentioned some recent studies from Stu Schwartz that may be useful.
- Justin: still looking at how to adjust the nutrient values based on the water balance reductions.
- Justin: For tree canopy over impervious, can vary the throughflow term. Right now it is the max amount of ET you can get; it is a very important term in the model overall. The analysis done for HSG D. For tree canopy over turfgrass, if you improve infiltration you might not improve the reduction from canopy because the soils are already doing the work at that point.
- Panel to review material provided by Justin and provided comments to Neely or Jeremy; in general panel found modeling approach reasonable.
- Jeremy noted there is a webinar scheduled on 2/11 when Justin and Marion will present their recommended loading rates to the partnership. Panel can review/discuss Justin and Marion's nutrient findings during our next call in February.
    - Information for the 2/11 webinar is available on the CBP calendar: http://www.chesapeakebay.net/calendar/event/23466/
- Neely noted the time and thanked everyone for their time and participation.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Wednesday, March 2, 2016, 2:00PM-4:00PM EST
Conference Call

Name	**Affiliation**	**Present? Y/N**
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech (sabbatical)	N
Michael Galvin	SavATree	Y
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	N
Jessica Sanders	Casey Trees	N
Thomas Whitlow	Cornell University	N
Qingfu Xiao	University of California-Davis	N
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep)	Y
Ken Hendrickson	EPA Region 3 (Regulatory Support)	Y
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	Y
Ari Daniels	CWP	Y
Peter Claggett	USGS, CBPO	N
Bill Stack	CWP	Y
Invited guests—N/A		

Welcome and Introduction

- Neely and Jeremy welcomed participants to the call. Neely reviewed the day's objectives.
- Neely pointed that Qingfu did participate on 1/29. No other comments raised for the 1/29 minutes; they were accepted as amended.

General overview of draft report

- Neely noted the distributed draft is the first full draft. Some sections still need to be updated (Sections 3 and 4, based on land use loading rate recommendations).. Focus today will be on recommendations highlighted in section 5.4 of draft.
- Neely noted that she and Jeremy had discussion with Matt Johnston from CBPO modeling team, who recommended the panel credit the annual BMP as a land use change. This does not affect methods used to develop panel recommendations. There would be no difference in the credited reductions, but accounting for it as a land use change would be consistent with other BMPs that are also land uses. She noted this will require some edits in the draft report to reflect this.
- Neely recapped points of agreement from the January conference call. Agreed to default tree on broadleaf only. Panel agreed the 100 trees per acre needs to be updated, support for different values arise from Expert Panel discussions and Forecast output, along with FWG analysis recommending 200-300 trees/acre. Forecast analyses range from 182-420 trees/acre as presented in the draft report.

- Neely explained the consensus-based approach for the panel and subsequent CBP workgroups approval process. Currently plan for panel approval in April. Report would then be released for a comment period by CBP partnership
- **ACTION**: Panelists to provide any final comments, edits or input by COB Friday March 11th. Use track changes and comments feature in the Word file. Send feedback to Neely and Jeremy.
- Neely reviewed the outline of the report and highlighted some of the areas that will be updated and expanded in next version. She asked panelists to review and provide comments on all definitions (Section 2) and asked if there are additional terms that should be defined.
- Keith commented that the report should clearly explain that the panel's recommendations will only address tree planting, not conservation
  - Need additional text to explain that "every tree planted counts." Previous Phase 5 BMP may have also counted every tree, but it wasn't explicit in the definition.

Discussion: BMP recommendations and options

- Neely summarized the five recommendations identified in Section 5.4 of the draft report. She noted that recommendations 1 and 2 may be incorporated together in the next draft, given the land use change approach suggested by Matt Johnston. Panel agreed trees planted after 10-yrs of projected growth would be captured by high resolution imagery. Once classified as a land use using high resolution imagery, the BMP credit would no longer exist.
- DECISION: Panel agreed with Recommendations #2 with clarifications requested. Will review revised recommendation in next draft. Panel had previously agreed to 10 year lifespan for Recommendation #1; the combination of these recommendations will be clarified based on panel's discussion and input.
- Sally requested clarification in the recommendation describing the lifespan of the credit vs the transition from BMP to land use acreages.
- Neely and Jeremy will work with the CBP modeling staff to develop the technical appendix that will explain how the BMP will be implemented and report and tracked. There are technical issues beyond the expert panel that need to be resolved by the Bay Program as the model transitions from version 5.3.2 and version 6 (e.g. acreages of tree planted based on existing credit and recommendations of the expert panel). Neely recalled that for recommendation 3, there were differences of opinions on whether to have two climate areas (150 FFD and 210 FFD) or one climate area (166 FFD). She explained that many counties will have areas with both climate areas.
  - Keith: looking at the map and information now, 166 FFD does seem like the most reasonable approach.
  - Marcia: Agree with that as a reporting agency, that would greatly simplify the tracking and reporting.
  - Mike: does seem like one climate area is preferable, would otherwise have to specify which counties are associated with one or the other climate zone.
  - Sally: agreed. id note that most of the larger urban areas in the watershed, that would most likely claim this type of BMP credit, would fall in the 210 FFD zone, so may want to consider that or explain that in the report. Using a 166 FFD average, would therefore be considered conservative for this area.
  - Karen: agreed that one climate is preferable to avoid confusion of having one number for planning purposes that is different from the actual credit
  - **DECISION**: The panel agreed to set its recommendations based on one representative Baywide climate zone (166 FFD).

- For recommendation #4, tree type eligible for credit. Neely recalled the panel previously agreed on broadleaf default as a necessary simplification for reporting and tracking given available information typically available for this practice. A combined broadleaf large and medium species is used in the example that uses 10 tree species. Panel agreed.
- Neely described some possible options for setting the BMP credit. Option 1 is a basic credit. Option 2 is one example of an enhanced credit based on 2.5% reduced mortality. Option 3 is a second example of an enhanced credit based on 25-yr expected growth.
- Bill commented that the panel may not want to base the enhanced credit on 25-yr expected growth given the timeline of the Bay TMDL and reconciling this potential additional canopy growth that is credited vs 10 yrs
    - Sally: trees per acre decision should be separated from the BMP credit duration issue.
    - Mike agreed with having one basic credit.
    - Marcia agreed with sticking with one basic credit.
    - Keith: agree with one basic credit.
    - Karen liked the enhanced credit idea, but understood the reasoning for having one credit.
    - Marcia noted that a number of the qualifying conditions criteria are already built into the Forestry Workgroup's verification guidance and the jurisdictions' verification plans. Jeremy and Sally agreed that keeping it simple is preferable. The partnership's verification framework acknowledges that verification rigor should be based on the relative priority or reduction associated with a BMP.
    - Keith: want to be conservative, but not too conservative. Keep it simple to minimize the hoops that the jurisdiction would need to jump through for tracking and reporting.
    - Mike: Share Keith's concern that we never addressed protection and conservation of trees from a BMP perspective. Would like to keep the expected growth in a reasonable timeframe, did not agree with a credit based on 25 years of projected growth
    - It was noted that 144 sq ft per tree planted, or 300 trees/acre.
    - Looking at all these scenarios and range of variables, we can agree that a certain value is best representative of a reasonable "average tree."
    - Sally: the value selected should be guided, not taken explicitly, from Forecast results. The results show quite an increase from the current credit.
    - Neely: The value recommended by the panel needs to have documentation and rationale along with best professional judgement the recommendation
    - Mike: when we agreed to use this tool as basis to inform our recommendations, feel we should choose from among the values presented from the outputs. The science and modeling tool got us here. 200 trees/acre seems to be at fringe of the results.
    - Neely: Based on the panel discussions, the following recommendations was put forward: One credit with basic qualifying conditions, number of trees planted and some other basic guidance, using 144 sq ft as per tree value.
        - Sally: do not suggest including planting guidance.
        - No objections were raised by those present. 144 sq ft.
        - **DECISION**: Panelists agreed with 144 sq ft average canopy per tree planted.

Update: tree canopy land use loading rates

- Jeremy recalled that Justin Hynicka presented his methods to the panel at their 1/29 call. Justin presented on a webinar on February 11th, and there were some adjustments to the methods and assumptions based on feedback from the partnership during and following the webinar. Jeremy noted the updated documentation will be ready soon. The Urban Stormwater

Workgroup, Modeling Workgroup, and Water Quality Goal Implementation Team will consider the updated relative loading rates in the next couple weeks.

- Sally added that she felt Justin did a really good job of teasing out differences between nitrogen, phosphorus and sediment in the latest proposed rates.

Wrap-up and review of next steps

- Neely: verification discussion in section 6 is written in context of panel's own perspective and input in light of verification guidance and Phase 6 watershed model. Marcia noted that DE received a conditional approval of its verification plan and will be submitting updated plan soon. Lots of moving parts.
- Next call: TBD. Jeremy will distribute a Doodle for early April.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Urban Tree Canopy Expert Panel
Friday, April 8, 2016, 12:00PM-2:00PM EST
Conference Call

Name	Affiliation	Present? Y/N
Karen Cappiella	Center for Watershed Protection	Y
Sally Claggett	US Forest Service, CBPO	Y
Keith Cline	Fairfax County (VA)	Y
Susan Day	Virginia Tech (sabbatical)	N
Michael Galvin	SavATree	N
Neely Law (Chair)	Center for Watershed Protection	Y
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Peter MacDonagh	Kestrel Design Group	Y
Jessica Sanders	Casey Trees	Y
Thomas Whitlow	Cornell University	Y
Qingfu Xiao	University of California-Davis	Y
Non-panelists/Support		
Brian Benham	Virginia Tech (Project Director)	N
Marcia Fox	DE DNREC (WTWG rep)	N
Ken Hendrickson	EPA Region 3 (Regulatory Support)	N
Jeff Sweeney	EPA, CBPO (CBP modeling team rep)	Y
Ari Daniels	CWP	Y
Bill Stack	CWP	Y
Invited guests—N/A		

Welcome and Introduction

- Neely welcomed participants to the call. Neely explained that the primary objective for the call is to ask the panel for approval on the decision draft of their report.
- Jeremy asked for comments or edits on minutes from the March 2nd conference call; none were raised. **DECISION**: The March 2nd minutes were approved as written.

Land use loading rate approval

- Neely explained the relative land use loading rates developed by Justin Hynicka and Marion Divers were approved by the WQGIT on March 14th. The panel previously discussed and reviewed Justin and Marion's work. No additional comments from participants were raised.

Approval of decision draft

- Neely described the CBP review/comment process. Once the panel approves its report for release, it will be released to the various workgroups and the WQGIT. There is an initial 30 day comment period before seeking approval from the sector workgroup, followed by the WTWG, and finally the WQGIT. Once the WQGIT has accepted the report the panel is officially disbanded and thanked for all its work. Until then Neely and Jeremy will be primary contacts for handling and responding to comments, and they will contact specific panelists or the full panel as needed based on the comment or issue.

- Neely reviewed the major recommendations and revisions in the decision draft. She mentioned that a clarification was added to explain the recommended BMP only covers urban tree planting at this time, while conservation practices may be considered by a future panel. Sally noted that conservation practices do not necessarily "expand" canopy. Jeremy suggested "protect" as a better term.
- Neely walked through additions and clarifications to sections 3 and 4; no comments were raised. She reviewed section 5 in more detail with participants.
    - Neely explained that some text was added to section 5.2 to address how the panel's methods and iTree Forecast were applied in more detail.
    - Sally asked for clarification about the edits for recommendation 2 in section 5.4. Keith noted that the focus is on total acres of canopy credited, not just acres planted like it used to be.
    - Qingfu noted that tree species can vary significantly in their water quality performance. Neely agreed but explained that the panel, like others, did not want to be too prescriptive in terms of what species should be planted or credited. Those types of decisions are jurisdiction specific and panels need to build their recommendations accordingly.
    - Neely noted that section 5.4 will likely draw most of the attention when the report is released.
- Sally: Should explain or mention somewhere in the report that while tree planting is a good thing, it's recognized that those gains are likely to be overwhelmed by other factors. Tree planting is just one small piece of a small piece. Neely pointed to a paragraph toward the beginning of section 5 that makes some of these points. She asked Sally or others to provide suggested language for that place, or for insertion or emphasis in other parts of the report. Peter agreed that it could be helpful to emphasize those points in the recommendations part of the report. Keith recalled the panel had discussed the importance of conservation and perhaps the language for future research could be expanded to emphasize the vital role of conservation.
- Neely described the text in the verification section. She noted that the language was crafted carefully since the FWG has developed its sector guidance that was accepted as a part of the CBP's BMP verification framework. There was discussion about the relation of the panel's verification recommendations to the existing guidance and the state's current verification plans. Jeff and Jeremy explained that when a new BMP is approved/added, then the states update their QAPP accordingly. The state and EPA would consider the panel's recommendations in addition to, not in place of, the guidance from the FWG and their current verification plans. The state and EPA would work together to set procedures that are rigorous enough and satisfy the protocols for the given BMPs.
- Prior to leaving the call, Keith suggested to add to management needs that jurisdictions use tools to evaluate net loss/gain of tree canopy beyond Chesapeake Bay land use updates. It is expected to see a continued net loss of tree despite extensive efforts to replace tree canopy by tree planting given continued development patterns in the Bay watershed
- Neely noted that Tom and Keith needed to leave the call soon and she asked for approval of the report through the verification section, pending final review and editorial comments/changes.
    - Sally noted that the 380 trees/acre conversion may be an issue with the FWG. Jeremy agreed it's likely to be a focal point in the forthcoming months when the report is being reviewed.
        - **POST-MEETING CORRECTION:** There was a typo in the slides that incorrectly stated 114 sq. ft of canopy per tree planted (or ~380 trees per acre). After the

meeting this error was pointed out and corrected to the panel, since they previously agreed to 144 sq. ft (or ~300 trees/acre).

- Keith agreed with releasing the report as-is. Agree with making the verification a suggested recommendation for the jurisdictions to consider, not a requirement or condition for the jurisdictions (e.g. 2 years after planting visit subsample of planting sites). Want to see that sort of decision left up to the locality to use the method or approach they prefer.
- Tom explained the importance for being able to modify the model going forward as data to characterize the impact of tree canopy on water quality is provided. Need to continue to make a case for on-ground empirical data collection for improvements to the model in the future. Neely noted that the future research needs section hopefully captures that point, which has also been made by MDE and others.
- Peter: No objections. It is important to make the points about conservation throughout the report, including the executive summary. The credit may be minimal for the tree planting, and they'll see the most benefits by protecting their existing canopy. Important to make that point up front because the planting credit will draw some scrutiny but it's such a small part of the canopy.

- Neely walked through recommendations from the future research and management needs section.
  - Jeremy explained two new bullets based on comments from MDE when the loading rates were discussed and approved by the WQGIT on 3/14. There were some follow-up emails to get to the suggested bullets; he asked panel members for thoughts about the language and if there were any objections to including them in the section 7 list.
    - Qingfu: okay with adding this in, since there's always a need for more data collection like that.
    - No objections were raised to adding the bullets.
    - Peter commented that a general struggle is incentivizing "doing more good" rather than looking at it in terms of "doing less harm." Jeremy pointed out that there is a part of the report that explains some of the panel's rationale that if a locality is prudent and has good conservation statutes, sites trees carefully with good soil volume and other conditions, etc., then in the long run they will see more gains in their canopy than the suggested 380 trees/acre.
      - **POST-MEETING CORRECTION:** There was a typo in the slides that incorrectly stated 114 sq. ft of canopy per tree planted (or ~380 trees per acre). After the meeting this error was pointed out and corrected to the panel, since they previously agreed to 144 sq. ft (or ~300 trees/acre).
- Neely noted that final clarifications from today will be made. She asked if anyone else had objections or final input on approving the report.
  - All members approved the report as discussed with final amendments.
- Neely and Jeremy described the next steps after the call.
  - **ACTION**: Panel members should send Neely any further comments by COB 4/15.
  - **ACTION**: Neely will distribute updated final version by Friday 4/22. Panelists will be given one week to provide any final thoughts (by COB Friday 4/29), and if nothing is received that is the version that will be sent out to the partnership for comment.
- Jeremy did note that the report is not strictly locked down when it is sent to the partnership, so if panel members do overlook something or have additional thoughts after the 29th they can be addressed along with the rest of the partnership's comments.

Wrap-up and review of next steps

- Neely and Jeremy thanked all of the panel participants for their contributions and engagement over the past year. They noted this will likely be the panel's last conference call, but it was a tremendous pleasure working with everyone.

Adjourned

Appendix B: Relative Reductions in non-point source pollution loads by urban trees.

Relative reductions in non-point source pollution loads by urban trees

Justin Hynicka[1] and Marion Divers[2]

1 – Maryland Department of Natural Resources – Forest Service

2 – University of Pittsburgh – Department of Geology and Environmental Science

Background

Trees modify the fate and transport of water, nutrients, and sediment in natural and developed landscapes due to their unique physical structure compared to other plant species, basic physiological processes, and long lifespan. Since 2003, it has been the policy of the Chesapeake Bay Program (CBP) partners to increase tree canopy cover for water quality and other benefits. While tree planting best management practices (BMPs) provide opportunities to account for the water quality benefits of new trees, the benefits of existing urban trees that do not meet the definition of forest are not directly accounted for in the CBP model land uses. Advances in remote mapping technology now allow tree canopy to be mapped and total cover quantified at small spatial scales (O'Neil-Dunne et al. 2014), providing the basic information needed to ascribe water quality benefits to all urban trees of a minimum canopy size.

As the spatial resolution of tree canopy mapping increases, the land use characteristics and management decisions beneath the canopy of a tree broaden. In particular, many urban trees likely lack an understory of herbaceous and woody plants, lack a distinct organic soil horizon, are surrounded by soils affected by urban development and compaction, and have an increased probability of fertilization. For these reasons, it is not appropriate to apply the loading rate of forests – the lowest non-point source pollution loading rate among CBP land uses – to urban trees. Here we describe how trees attenuate and store non-point source pollution and describe a method for estimating unique relative pollution loading rates for two new CBP land uses: tree canopy over turfgrass and tree canopy over impervious surfaces.

Attenuation and removal of non-point source pollution by trees

It is well known that nitrogen and phosphorus are essential plant nutrients, and there is strong evidence that organic matter containing nitrogen accumulates in soils beneath trees over time. On a per-hectare basis forests store more carbon annually than urban open space due to higher tree densities. Yet, on a per tree basis urban trees may fare better, the same, or slightly worse than trees in a forest due to the release of competition for resources and/or different environmental stresses (McHale et al. 2009).

Later we show that average annual uptake of N and P per tree ranges from ~ 0.31 to 1.20 lbs. and 0.17 to 0.60 lbs., respectively. Trees, and in particular the root system, increase soil organic matter contents by physically incorporating organic matter, adding plant litter to carbon stores, exuding carbon from the roots, and root die-off (Day, Wiseman et al. 2010). Soil under urban trees has been shown to have a higher carbon content than bare soil or soil under grass (Takahashi et al. 2008; Huyler et al. 2014), therefore allowing greater potential for nutrient uptake and cycling (Jo and McPherson 1995). Carbon cycling, in turn, drives N retention via uptake and microbial utilization (Lovett, Weathers et al. 2002).

In addition to storing nitrogen in biomass and soils, trees promote biogeochemical processes that convert biologically active nitrogen to inactive forms. Nitrogen inputs include organic nitrogen, nitrogen oxide gases, and ammonium nitrate particles that can be deposited as both wet and dry deposition. These inputs of nitrogen can be transformed through biological processes in soil into nitrate-N, a highly soluble form that leaches from through soils and easily transported by groundwater flowpaths (Wakida and Lerner 2005). Conversely, nitrate-N can undergo denitrification in urban systems (Groffman et al. 2004), a microbial process that transforms nitrate-N into inert dinitrogen gas and returns nitrogen to the atmosphere.

Removal of nitrate-N via denitrification is strongly influenced by soil moisture (Groffman et al. 2004; Kaushal et al. 2008). Trees promote greater soil moisture by creating preferential hydrologic flow paths and absorbing water via root systems (Day, Wiseman et al. 2010). In urban areas, turfgrass roots are likely not reaching groundwater, while deeper-rooted trees may uptake and re-distribute soil moisture from farther belowground upwards toward the surface (Day, Wiseman et al. 2010). This assists the plant community by promoting growth and ultimately increasing nutrient utilization. Greater soil moisture near the land surface, where carbon and nitrogen are also concentrated, may also promote greater rates of denitrification (Gift et al. 2010; Groffman et al. 2004; Raciti et al. 2011; Zhu, Dillard, and Grimm 2005).

In contrast to nitrogen-N, the primary form of phosphorus (orthophosphate) is less soluble and primary transported from landscapes to surface water in overland flow. Phosphorus losses from landscapes have been shown to be strongly dependent on runoff, which can transport phosphorus in particulate and dissolved forms (Staver and Brinsfield 2001). Phosphorus is generally not a major component in groundwater because it is in forms that will be bound to soil particles (Correll 1998) and most P has been shown to remain in the top three feet of soil (Daniels et al. 2010).

The primary retention mechanism for phosphorus is from irreversible binding of phosphorus to soil clay minerals. Over time, orthophosphate forms insoluble compounds through associations with metals such as iron, aluminum, and calcium in the soil (Busman, Lamb et al. 2002). These fixed forms of phosphorus are generally unavailable to plants. Therefore, retention of P is best achieved by increasing infiltration of water, bringing the nutrients in that water into contact with soil, and the formation of insoluble compounds in the soil. Tree roots reduce soil compaction and create soil macropores that increase water infiltration. Increased infiltration leads to greater pollutant/soil interaction. Additionally, trees remove soil water through evapotranspiration, thereby increasing storage capacity of soil water for future precipitation (Day, Wiseman et al. 2010).

Lastly, sediment sources in urban areas include the particles from regional and local atmospheric deposition. Trees have been shown to increase trapping of particles when compared to grass, a difference attributed to reduced overland flow, allowing particles to settle out via sedimentation (Leguedois, Ellis et al. 2008). As more water is retained beneath urban trees, the majority of sediments that would otherwise be transported by that water are likely to be retained and added to soil stores via adsorption onto organic matter and soil surfaces (Leguedois, Ellis et al. 2008).

Absolute versus relative loading rate calculations

Despite strong evidence that trees promote the attenuation and removal of non-point source pollution, we know of no studies that have quantified absolute loading rates for urban tree canopy land uses. There is very limited pollution concentration data available for runoff and subsurface flow beneath urban tree canopies that can be used to calculate representative, statistical, edge of field (EOF) loading rates for nitrogen, phosphorus, and/or sediment. This is in contrast to forested watersheds where surface water quantity and quality can be more easily evaluated (for example see: Campbell et al. 2004). Furthermore, pollution fluxes determined from streams in uniform watersheds integrates many biotic and abiotic processes from upland to riparian areas (Vannote et al. 1980). Because urban tree canopy land uses are small by definition, it is unlikely that non-point source pollution in surface water can be traced back to them in complex urban watersheds especially where larger patches of forest may also exist.

Spatial and temporal variation of inputs also makes quantifying absolute loading rates challenging among all CBP land uses. Atmospheric deposition and fertilizer are the primary inputs of nitrogen, phosphorus, and sediment to developed areas. Total atmospheric deposition (i.e., wet and dry deposition) is well documented and varies regionally over the Chesapeake Bay watershed (Linker, Dennis et al. 2013), and is often elevated in densely developed areas, relative to agricultural, forested, and suburban areas (Lovett, Traynor et al. 2000). Atmospherically sourced phosphorus is generally deposited as dust or aerosol (Correll 1998), while fertilizer includes orthophosphate and polyphosphate (which readily converts to orthophosphate when in contact with water). Variation in turfgrass fertilization rates have been documented (Aveni, Berger et al. 2013), but are extremely difficult to predict spatially. Fertilization is one of the primary reasons that nutrient loads from turfgrass are elevated in the Chesapeake Bay model relative to open space (~ 5x and 2x for N and P, respectively) and forests (~7x and 12x for N and P, respectively).

No matter whether the source of nutrients is from atmospheric deposition or fertilizer, hydrologic processes ultimately govern the fate and transport of non-point source pollution to surface waters. Therefore, given (1) the lack of data needed to estimate absolute pollution loads of tree canopy land uses and (2) high spatial variability in pollution inputs, we choose to estimate reductions in non-point source pollutant loads by trees by modeling changes in water yield relative to turfgrass and impervious surfaces – the land cover types beneath tree canopy. While we have already described how trees store and aid in pollution removal, this approach nevertheless relies on our best professional judgment that changes in water quality are proportional to changes in water yield.

Methods

We used fundamental principles in watershed hydrology to estimate the relative reduction in water yield by tree canopy compared to two underlying land uses – turfgrass and impervious surfaces – over which tree canopy extends and can be mapped using remote sensing technology. A general water balance equation (Eq. 1) is shown below where I is inputs, O is outputs, and ΔS is the change in water stored in soils. For comparison, water balance equations (Eq. 2 to 5) for two existing CBP land uses and those land uses with tree canopy are also shown. In these equations, inputs include precipitation (P), and/or laterally flowing subsurface water (T_i, throughflow), and outputs include runoff (R), evapotranspiration (ET), gravitational soil water that drains beneath the plant rooting zone (i.e., leaching, L), evaporation (E), and throughflow (T_o). The subscripts g and t refer to parameters specific to turfgrass and tree canopy, respectively.

General Mass Balance: $$I = O + \Delta S$$ **(Eq. 1)**

Turfgrass: $$P = R + ET_g + L + \Delta S \quad \textbf{(Eq. 2)}$$

Canopy over Turfgrass: $$P = R + ET_g + ET_t + L + \Delta S \quad \textbf{(Eq. 3)}$$

Impervious $$P + T_i = R + E + T_o + \Delta S \quad \textbf{(Eq. 4)}$$

Canopy over Impervious: $$P + T_i = R + ET_t + T_o + \Delta S \quad \textbf{(Eq. 5)}$$

For water quality purposes, we are ultimately interested in the proportion of precipitation that becomes stream/surface flow, also known as *water yield*. Equation 6 describes the relative reduction in water yield from turfgrass with tree canopy relative to turfgrass without canopy, and Eq. 7 describes the relative reduction in water yield from impervious surfaces with tree canopy relative to impervious surfaces without canopy. The subscripts in equations 6 and 7 are used simply to identify the underlying land use (*g* is turfgrass and *i* is impervious) and whether or not that land use is covered by tree canopy (*c*). The role of tree canopy in modifying water yield varies with the severity of precipitation and the quality of vegetation (Keim, Skaugset, and Weiler 2006). To account for spatial and temporal variation in precipitation, we used eleven years (2005 to 2015) of daily weather data (National Climatic Data Center 2016) from each of eight regional locations spanning the Chesapeake Bay Watershed (Figure 1). The ∑ symbol in equations 6 and 7 indicates that the volume of runoff, soil leachate, and change in throughflow will be estimated from daily weather data (unless otherwise noted), and the final results based on the mean annual cumulative total across all sites and years.

$$f_r = \left(1 - \frac{\sum R_{gc} + \sum L_{gc}}{\sum R_g + \sum L_g}\right) \times 100 \quad \textbf{(Eq. 6)}$$

$$f_r = \left(1 - \frac{\sum R_{ic} + \sum T_{ic}}{\sum R_i + \sum T_i}\right) \times 100 \quad \textbf{(Eq. 7)}$$

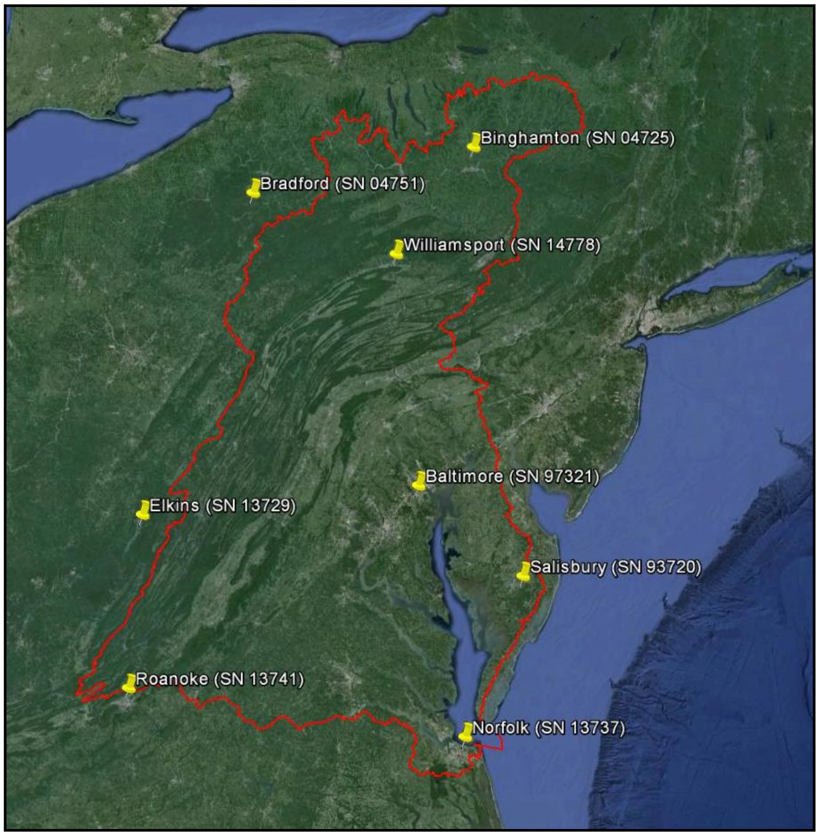


Figure 1: Weather station locations used in this analysis

Precipitation is assumed to be the only input of water to areas mapped as tree canopy over turfgrass. In CBP reporting, riparian forest buffers are a stand alone BMP. This restricts areas mapped as tree canopy over turfgrass to upland sites where the water table is likely below the plant-rooting zone (~2 ft. deep). This assumption likely underestimates the hydrologic benefit of trees in developed areas as trees on residential property have been shown to access water below this depth, uplift, and redistribute it in shallow soil horizons at night (Day, Wiseman et al. 2010). For tree canopy over impervious surfaces, we include a source of shallow, subsurface water (T, throughflow) that trees can access and use to meet basic physiological needs. Throughflow originates from other pervious urban land uses and can be taken up and transpired by trees. The throughflow element is necessary because water and nutrients required for plant growth and function cannot infiltrate through impervious surfaces.

Calculating Runoff

For each of the four land use types, we estimated runoff using the Soil Conservation Service Curve Number Method (Eq. 8), where *R* is runoff, *P* is precipitation, I_a is the initial abstraction, and *S* is the potential maximum retention after runoff begins (all units in inches, USDA 1989).

$$R = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \textbf{(Eq. 8)}$$

In order to isolate the effects of tree canopy interception beyond the water retaining properties of the underlying land use (i.e., turfgrass and impervious surfaces), we introduced a tree canopy interception term, C_i (units also in inches), into the basic curve number equation (Eq. 9). This term accounts for the amount of precipitation adsorbed to leaves and branches after throughfall stops and, effectively, reduces the amount of precipitation that reaches the ground before initial abstractions occur.

$$R = \frac{(P - C_i - I_a)^2}{(P - C_i - I_a) + S} \qquad \textbf{(Eq. 9)}$$

The amount of precipitation retained in the canopy varies with tree age, species, canopy health, and season. Tree canopy land uses are identified and mapped using satellite imagery with a resolution of one square meter and minimum height of two meters (O'Neil-Dunne et al. 2014), and therefore likely include trees that are ten years old at a minimum. For young to mature deciduous trees, interception capacity ranges from 0.02 to 0.11 inches per storm, whereas interception capacity for coniferous trees of similar age ranges from 0.02 to 0.18 inches per storm (Breuer, Eckhardt, and Frede 2003). For deciduous trees, most but not all interception capacity is lost during the winter as the branches and trunk still provide some interception capacity, whereas conifers retain full interception capacity year round. Because the current mapping methodology only indicates the presence of a tree and provides no other information on tree species or quality of the canopy, C_i in our model was set at 0.05 inches per storm during the growing season (April through October) – below the mean range of interception capacity – and zero during the dormant season. This amount of credit is similar to that given by a state agency for canopy interception in structural BMPs (0.043 in per storm; Minnesota Pollution Control Agency 2016), which likely includes a younger population of trees from new installations rather than a well established tree canopy.

The curve number method was originally designed to estimate stormflow following large precipitation events with flood planning as the most obvious application (Garen and Moore 2005). During the development of this method, observations of precipitation and runoff volume at the watershed scale revealed that the ratio of initial abstractions to potential maximum water retention (I_a/S) was approximately equal to 0.2 (USDA 1989). However, more recent research has demonstrated that this assumption significantly underestimates runoff at smaller scales, and that $I_a/S = 0.05$ is a more appropriate assumption for small urban areas (Woodward et al. 2003). Substituting 0.05 S for I_a in Equation 9 yields the following:

$$R = \frac{\left(P - C_i - 0.05 \times S\right)^2}{P - C_i + 0.95 \times S} \qquad \textbf{(Eq. 10)}$$

In the curve number method, the total maximum water retaining capacity (S) is further simplified to a dimensionless 'curve number' factor, CN, ranging from 0 to 100 (Eq. 11). The curve number accounts for the physical attributes of the land surface as well as the hydrologic properties of the underlying soil that affect infiltration. Following recommendations in the USDA Technical Release 55, *Urban Hydrology for Small Watersheds*, we set CN = 98 for all impervious surfaces (with and without tree canopy), CN = 79 for turfgrass, and CN = 74 for tree canopy over turfgrass. The difference between a CN value of 79 and 74 is modest, and is equivalent to turfgrass in fair versus good condition with hydrologic soil group C (HSG). We used a slightly lower curve number (i.e., less runoff) for canopy over turfgrass to account for the *temporal* effects of canopy interception and improved physical structure of compacted soils by tree roots (Day et al. 2010). Equation 12 is the final equation that we used to calculate runoff.

$$S = \frac{1000}{CN} - 10 \qquad \textbf{(Eq. 11)}$$

$$R = \frac{\left(P - C_i - 0.05 \cdot \left(\frac{1000}{CN} - 10\right)\right)^2}{P - C_i + 0.95 \cdot \left(\frac{1000}{CN} - 10\right)} \qquad \textbf{(Eq. 12)}$$

Runoff is also influenced by the amount of precipitation and Figure 2 shows how runoff depth varies with precipitation depth based on Equation 12; forested land (*CN* = 55; HSG B) is also shown for reference. As previously mentioned, we used eleven years (2005 to 2015) of daily weather data from each of eight regional locations spanning the Chesapeake Bay Watershed to account for spatial and temporal variation in precipitation.

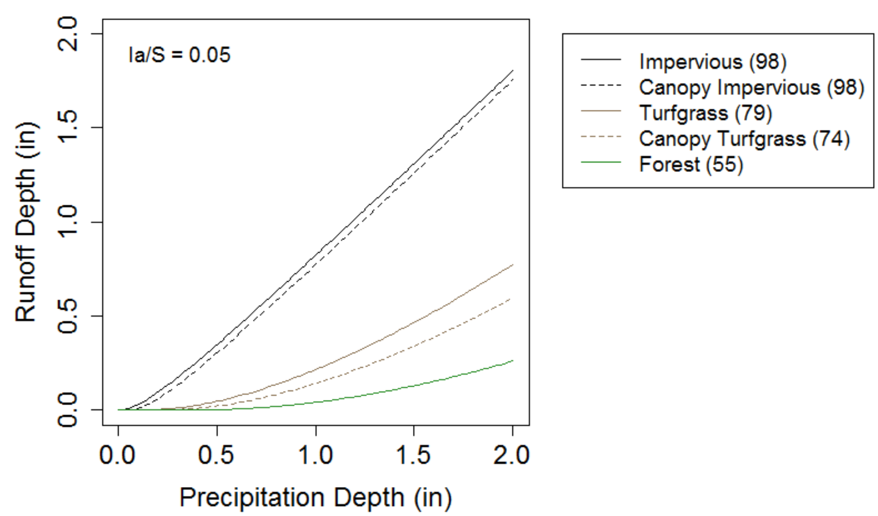
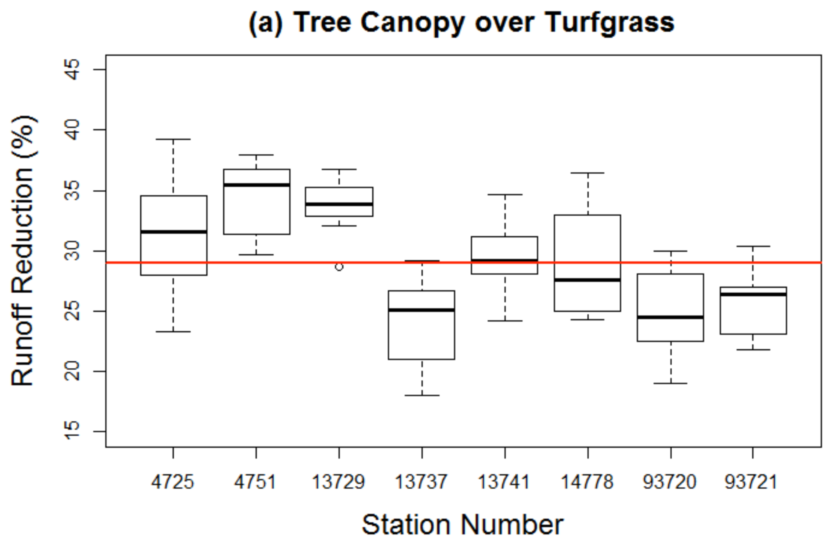


Figure 2: Precipitation vs. runoff depth estimated using the SCS Curve Number Method

For water quality purposes, it is important to note that ‘runoff’ estimated using the CN method from pervious areas is not the same as ‘runoff’ from impervious surfaces. In pervious upland areas, runoff includes both infiltration excess overland flow and macro-pore shallow subsurface flow (Garen and Moore 2005). In contrast, runoff from impervious surfaces is exclusively overland flow that is highly connected to surface waters by storm drains and pipes. This implies that on-site retention drives the water quality benefits of tree canopy over turfgrass, where as minimizing downstream erosion drives the water quality benefits of tree canopy over impervious surfaces. While we have no way of quantifying how tree canopy over turfgrass alters the balance between the two components of runoff (i.e., infiltration excess overland flow vs. shallow subsurface flow), it is highly likely that trees reduce infiltration excess overland flow (Asadian and Weiler 2009; Leguédois et al. 2008).

Runoff from impervious and other highly compacted surfaces is particularly problematic in developed areas because water is delivered over shorter periods of time to surface waters that erode stream banks (Walsh, Roy et al. 2005). Water quality can be impaired both by infrequent, large storm events as well as by more frequent, smaller events that deliver quick pulses of nutrients and sediments to receiving waters (Walsh, Fletcher et al. 2005). Trees reduce rainfall intensity and volume, and decrease runoff rates by intercepting precipitation on leaves and branches even when limited by surrounding impervious surfaces (Asadian and Weiler 2009; Nowak, Wang, and Endreny 2007; Wang, Endreny, and Nowak 2008; Xiao et al. 1998).

The results of our runoff calculation are shown in Figure 3. Across all sites and years, annual relative runoff reduction by tree canopy over turfgrass ranged from 18.0 to 39.2 % with a mean value of 29.0 %. Annual runoff reduction by tree canopy over impervious surfaces ranged from 3.5 to 10.6 % with a mean value of 7.0 %. Because sediment does not have a dissolved form, we assumed that sediment retention beneath tree canopy over turfgrass had an efficiency factor of 0.20, resulting in a recommended relative reduction for sediment of 5.8% (29.0% relative reduction in runoff x 0.2).



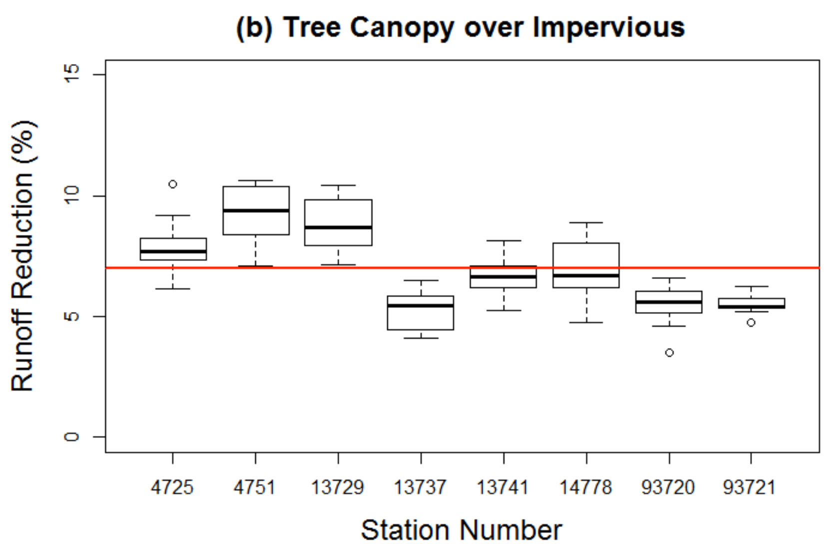


Figure 3: Relative reduction in runoff volume by tree canopy compared to (a) turfgrass and (b) impervious surfaces. Red line indicates the mean relative reduction in runoff across all sites and years.

Calculating Leaching

For pervious urban areas including turfgrass and tree canopy over turfgrass, the precipitation remaining after interception and runoff infiltrates (*I*) into soil (Equation 13). All or a portion of this water is temporarily stored in the soil, and in well-drained areas the maximum amount of soil water storage that is available for evapotranspiration (S_{max}) is equal to the soil's water holding capacity. Water holding capacity varies with soil texture (lowest in both very sandy and very clayey soils) and ranges from ~1 to 2 inches per foot of soil (Brady and Weil 1996). For this analysis, we used a soil water holding capacity of 2 inches per foot, and a total soil volume based on the typical rooting depth of trees (2 ft) and one square meter of land – the minimum mapping unit of tree canopy.

The actual volume of soil water (S_t) will vary over time as a function of the initial soil water volume after rainfall (S_{t-1}) minus the amount of water evaporated and transpired (ET) in between precipitation events. Tracking changes in soil water over time also has the advantage of placing an upper limit on ET. During initial model testing, the soil water volume at the end of the year was almost always equal to the maximum water holding capacity. For this reason, the water holding capacity at the beginning of each year was set to zero ($S_t = S_{max}$). Any rainfall that is infiltrated in excess of the available water holding capacity was assumed to leach (L) below the rooting zone and lost as groundwater (Equation 14).

$$I = P - C_i - R \qquad \textbf{(Eq. 13)}$$

$$L = I - S_{\max} + S_t \qquad \textbf{(Eq. 14)}$$

In between precipitation events, evapotranspiration (ET) by turfgrass and trees reduces the volume of water in soil allowing more infiltrated water to be stored the next time it rains (Equation 15). In the same way that interception varies with tree age, species, canopy health, and season, ET also varies with these factors. Total annual ET rates are similar between turfgrass, trees in natural forest settings, and urban trees ranging from ~15 to 24 inches per year, or 0.04 to 0.064 inches per day (Ford et al. 2011; Penman 1948; Wullschleger et al. 2001; Wullschleger et al. 2000; Wilson et al. 2001; Peters et al. 2010). Again, because the current mapping methodology only indicates the presence of a tree and provides no other information on tree species or quality of the canopy, ET in our model was set at 0.05 inches per day for trees and turfgrass without trees during the growing season (April through October). We assumed that ET of shaded turfgrass was approximately half as effective as non-shaded turfgrass. Therefore, daily rates of ET for turfgrass and canopy over turfgrass were set to 0.05 and 0.08 inches per day during the growing season, respectively. During the dormant season (November through March), ET was only attributed to turfgrass at a rate of 0.025 inches per day.

$$S_t = S_{t-1} - ET \qquad \textbf{(Eq. 15)}$$

The results of our leaching calculation are shown in Figure 4. Across all sites and years, annual relative leaching reduction by tree canopy over turfgrass ranged from 10.0 to 42.5 % with a mean value of 22.5 %.

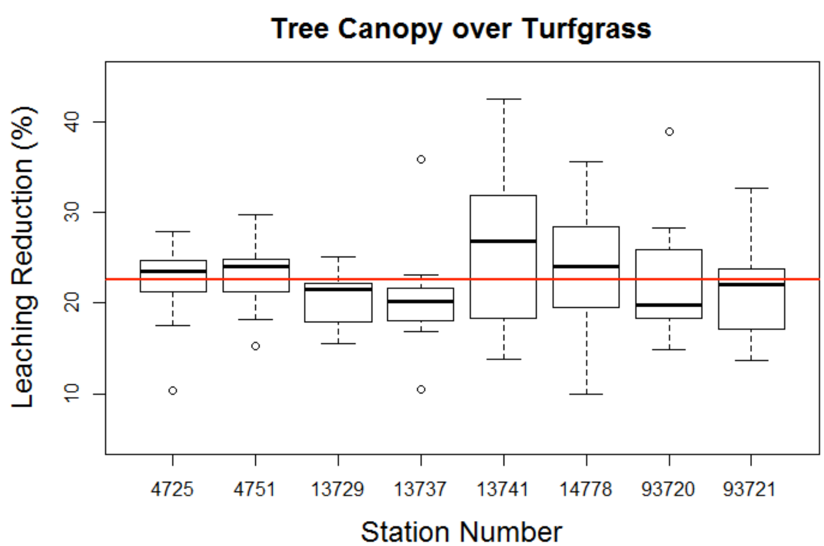


Figure 4: Relative reduction in leaching volume by trees compared to turfgrass

Calculating Throughflow

We know of no straightforward way to estimate the mean daily flux of subsurface throughflow, and subsequent nutrient flux, beneath impervious surfaces. Tree roots are highly advantageous, often growing into broken stormwater pipes and culverts, and there is likely a high degree of spatial variation. In addition, a large portion of dissolved nitrogen and phosphorus taken up through roots with water and incorporated in tree tissues is later deposited as leaf litter on impervious surfaces that are highly connected to surface waters. While it is true that decomposing leaf litter contributes nitrogen and phosphorus to road runoff in autumn (Hobbie et al. 2014; Kaushal and Belt 2012), it is entirely possible that the net flux of N and P in litterfall over the course of a year is zero simply by transforming, concentrating, and redistributing base flow (Janke et al. 2014).

However, a small proportion of N and P are incorporated into woody plant tissues (i.e., branches, bark, heartwood, and sapwood) that represent a long-term store of non-point source pollution. Rather than rely on poorly constrained estimates of throughflow (Eqs. 4 and 5), we choose to estimate relative on-site pollution reduction based on the result of nutrient uptake – biomass growth – and the proportion of N and P stored in wood versus total annual uptake (wood + leaf production) and atmospheric deposition (Eq. 16).

$$R = \left(\frac{W}{W + L + A} \right) \times 100 \qquad \textbf{(Eq. 16)}$$

We estimated annual storage of N and P in tree wood by combining estimates of average annual wood production of urban trees (4.5 to 9.7 kg of C per tree per year, Nowak and Crane 2002) with C, N, and P concentration data in wood from the literature (molar C/N and C/P in wood ~ 300 and 500, respectively; Rastetter et al. 1991; Pettersen 1984; Martin et al. 1998). Based on our calculations (see Appendix 1 for full calculations), 0.038 to 0.083 lbs of N and 0.051 to 0.11 lbs of P are stored in new wood tissues per tree per year. Similarly, we estimated the annual flux of N and P in tree litterfall by combining estimates of annual leaf production (~5 to 20 kg leaf mass per tree per year; Olson 1963; Chapin et al. 2011; Abelho 2001; Martin et al. 1998) with N and P concentration data in tree leaves (~ 25 ppm N and molar N/P ~ 5; Martin et al. 1998; Schaller 1968; McGroddy et al. 2004). These calculations indicate that ~ 0.27 to 1.10 lbs of N and 0.12 to 0.49 lbs of P are taken up each year by trees and used to build leaves. Finally, we used established atmospheric deposition rates (14 kg N ha^{-1} yr^{-1}; National Atmospheric Deposition Program) or precipitation concentration data combined with annual rainfall data (63 ppb inorganic + organic P ; Smullen et al. 1982) to estimate the amount of atmospheric N and P deposited on the canopy of a mature tree (~ 10 m^2). Table 1 shows the fluxes of N and P used to estimate storage in wood relative to total uptake and atmospheric deposition.

Table 1. Average annual nutrient uptake and atmospheric deposition of N and P

Elemental Fluxes	Woody Biomass (lbs. $tree^{-1}$ yr^{-1})	Litterfall (lbs. $tree^{-1}$ yr^{-1})	Atmos. Dep. (lbs. $tree^{-1}$ yr^{-1})	N and P in wood relative to total uptake and atm. Dep. (%)
Nitrogen	0.038	0.69	0.031	5.0 %
Phosphorus	0.051	0.31	0.0013	14 %

To make these results comparable to water yield, we must still make some assumption about the efficiency of nutrient uptake over the course of a year. For this conversion we used a simple assumption based on the proportion of time that trees are transpiring over the course of a year (7/12 months x ½ day = 0.29). Therefore, we estimate that the relative reduction in N and P by trees from throughflow to be 1.5 and 4.0 % respectively.

Summary of results and recommendations

The results of our water yield calculations are summarized in Table 2. Relative reduction in total yield for tree canopy over turfgrass is closer to the relative reduction in leaching due to the greater volume of water exported in soil leachates compared to runoff. Table 3 displays the final recommended relative reductions for N, P, and sediment for tree canopy land uses after adding in the small proportion of N and P stored in woody biomass.

Table 2. Estimated annual reductions in water yield by tree canopy relative to impervious and pervious land covers

Land Use	Precip. (in)	Runoff Red. (%)	Leaching Red. (%)	Total Yield (%)

Canopy over Turfgrass	39.9	29.0	22.5	23.8
Canopy over Impervious	39.9	7.0	NA	7.0

Table 3. Recommended relative reductions in N, P, and sediment for tree canopy land uses

Land Use	**Total Nitrogen Red. (%)**	**Total Phos. Red. (%)**	**Total Sed. Red. (%)**
Canopy over Turfgrass	23.8	23.8	5.8
Canopy over Impervious	8.5	11.0	7.0

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Appendix 2: Biomass Calculations

Woody Biomass

4.5 to 9.7 kg of C per tree per year (Nowak and Crane 2002)

x 1000 g/kg conversion factor

x 1 mol C / 12.01 g of C conversion factor

x 1 mol N / 300 mol C references listed below

x 14.01 g N / mol N

x 1 lb / 454 g

= 0.038 to 0.083 lbs N per tree per year

mass ratio C/N approximately 300:1 (Rastetter et al. 1991), C is 50% of wood (so 500 mg/g) (Pettersen 1984), 0.2 to 4.0 mg N / g wood for heartwood, sapwood, and branches (Martin et al. 1998)

4.5 to 9.7 kg of C per tree per year (Nowak and Crane 2002)

x 1000 g/kg conversion factor

x 1 mol C / 12.01 g of C

x 1 mol P / 500 mol C (ROGER C. PETTERSEN 1984)

x 30.97 g P / mol P

x 1 lb / 454 g

= 0.051 to 0.11 lbs P per tree per year

Litterfall

5 to 20 kg per tree per yr (Olson 1963; Chapin III, Matson, and Vitousek 2011; Abelho 2001) (Martin et al. 1998)

x 1000 g / kg unit conversion factor

x 25 mg N / 1 g of litter (Martin et al. 1998)

x 1 g / 1000 mg unit conversion factor

x 1 lb / 454 g unit conversion factor

= 0.27 to 1.10 lbs N per tree per year

5 to 20 kg per tree per yr (Olson 1963; Chapin III, Matson, and Vitousek 2011; Abelho 2001) (Martin et al. 1998)

x 1000 g / kg unit conversion factor

x 25 mg N / 1 g of litter (Martin et al. 1998; Schaller 1968)

x 1 g / 1000 mg unit conversion factor

x 1 mol N / 14.01 g N unit conversion factor

x 1 mol P / 5 mol N (McGroddy, Daufresne, and Hedin 2004)

x 30.97 g P / mol P unit conversion factor

x 1 lb / 454 g unit conversion factor

= 0.12 to 0.49 lbs P per tree per year

Atmospheric Deposition

14 kg N ha^{-1} yr^{-1} (NADP via Marion)

x 1000 g / 1 kg unit conversion factor

x 1 lb. / 454 g unit conversion factor

x 1 ha / 10000 m^2 unit conversion factor

x 10 m^2 canopy area of single tree

= 0.031 lb. N per tree per year

Appendix 2, continued

Atmospheric Deposition

TP = 63 ug/L in atmospheric dep. (Smullen, Taft, and Macknis 1982)

x 1 g / 10^6 ug

x 1 lb. / 454 g

x 1000 L / m^3

x 39.9 in of rainfall

x 1 m / 39.37 in

x 10 m^2

= 0.0013 lbs P per tree per year

Addendum for Appendix B: Considerations and research needs when tree canopy land use loading rates are revisited in the future

Though the USWG and WQGIT approved the Phase 6 land use loading rates for tree canopy over turfgrass and tree canopy over impervious in March 2016, it is important to acknowledge that significant concerns and uncertainty remain for the loading rate recommendations developed by Hynicka and Divers on behalf of the Forestry Workgroup (provided as Appendix B in this report). To that end, the following is a list of items for the partnership's future consideration whenever the tree canopy land uses and loading rates are revisited for future updates to the modeling tools. The list includes some elements also identified in the UTC Expert Panel's report, but also other items that are specific to land use loading rates identified in the review and comment process.

- There is a need for collection of multi-year field data that explicitly measures nutrient fluxes associated with areas of urban tree canopy as it relates to the BMPs defined for Phase 6. The data should be collected in areas representative of applicable conditions within the Chesapeake Bay Watershed. The data may be derived from field research or GIS-based analysis of multiple catchments that could be combined with high resolution imagery and other available data to help isolate the effect of tree canopy changes from factors that usually confound that analysis. The data can be used to inform future expert panels, new versions of the modeling tools or land use loading rates.
- If new data specific to nutrient fluxes from tree canopy over turf and impervious surfaces in the Chesapeake Bay watershed is not gathered, the CBP partnership can consider whether to adjust, drop, or keep the tree canopy land uses and loading rates as presently recommended for future model versions.
- Use available published data and revisit assumptions of seasonal variations pertaining to trees and associated nutrient fluxes – including the effects of tree pollen, leaf litter and detritus – to assess the net overall effect for setting an annualized loading rate. The seasonal variations would need to be accounted for in the annual loading rates used in the modeling tools.
- When considering potential increases in infiltration, there should be consistency with the latest set of model assumptions and methods for groundwater and nitrogen transport, broken down by species if possible. Incorporate available research on the effect of tree canopy to alter soil physical properties such as enhanced infiltration.
- If applicable empirical data is still lacking and a conceptual model is necessary to develop loading rates for tree canopy land use(s) then, the direct and indirect impacts to sediment loads from trees in a watershed should be characterized carefully in coordination with other urban land use loading rates and assumptions.

Appendix C: Urban Tree Canopy Literature Synthesis

Review of the Available Science for Urban Tree Planting and Canopy

A total of 115 publications were reviewed by the Expert Panel to evaluate the research questions defined in the scope of this Expert Panel:

1. What is the effectiveness of urban tree canopy on reducing runoff, nutrient and sediment?
2. How does effectiveness vary by species, over time, with differences in planting sites (e.g., distance from impervious cover or other trees, soil conditions, geographic location) and with different maintenance strategies?

A limited number of studies directly address the water quality benefits of urban trees, and an even smaller subset provide results that can be used to develop effectiveness values for urban tree planting. Consequently, the data reviewed were not limited to the Chesapeake Bay watershed. Of greater applicability were the 49 studies on the hydrologic benefits of urban trees. These studies attempt to quantify one or more components of the tree's hydrologic cycle, which, combined, can inform estimates of runoff reduction provided by urban trees. The literature was also extended to include studies on trees planted as a part of an urban stormwater best management practice to quantify the impact of urban tree canopy on water quality. We also reviewed a number of studies on the water quality and runoff reduction benefits of non-urban forests, which may be considered an upper limit to any credit assigned to urban tree planting, based on the assumption that trees and forests in urban environments do not function as well as natural forests due to factors such as compacted soils, lack of understory, open-grown trees and numerous impacts on tree health.

Because trees planted in the urban riparian zone (i.e., within 100 feet of a waterbody) will be credited under a separate best management practice (Urban Forest Buffers), this review focused primarily on the benefits of trees in upland areas. Urban trees provide a host of other benefits, including air quality improvement, habitat for wildlife, temperature reduction and energy savings. While some of these ancillary benefits were also addressed in the literature reviewed, this synthesis focuses solely on nutrient, sediment and runoff reduction.

Hydrologic Benefits

Trees affect water quality primarily by reducing the amount of stormwater runoff that reaches surface waters. Trees reduce runoff through rainfall interception by the tree canopy, by releasing water into the atmosphere through evapotranspiration (ET), and by promoting infiltration of water through the soil and storage of water in the soil and forest litter. Major findings from the literature review for each of these processes are summarized below.

Interception

Canopy interception of rainfall is an important and significant component of the tree water balance. Interception losses depend on factors such as leaf area index (LAI), tree structure, and notably storm characteristics (Xiao et al. 2000). The most critical time for trees to play a role in reducing runoff is during and right after a storm (KDGT 2013). KDGT (2013) suggests that, because of this, continuous simulation modeling may be the best approach for estimating rainfall interception on an annual basis. Quantifying interception on an annual timescale allows for development of an average value across differing rainfall conditions and also accounts for interception during both leaf-on and leaf-off periods. Therefore, the synthesis of studies in this section focuses primarily on those reporting results over an annual timeframe.

Table 1 summarizes the values found in the literature on annual rainfall interception by urban trees and forests, which range from 6.5 to 66.5% for all trees, 6.5 to 27% for deciduous trees and 27-66% for evergreen species, as a percent of annual rainfall. Some of the studies only reported interception as a volume per tree per year and these results range from 106 to 2,000 gallons/tree/year. Note that most of the studies in Table 1 are from semi-arid climates, so further analysis will be needed to adapt them to the Chesapeake Bay region.

More studies are available on rainfall interception by natural forests, and these results are summarized in Table 2 for comparison to the urban tree results. Even in the natural environment, rainfall interception by forests is extremely variable and difficult to measure, as noted by Crockford and Richardson (2000) in a review of interception studies. The range of annual interception by deciduous forests shown in Table 2 is 10-22% and 15-46% for evergreen forests. Both sets of data generally agree that evergreen intercept more rainwater than deciduous trees (more than double in some cases) since they have leaves year-round.

Table 1. Rainfall Interception Studies of Urban Trees				
Study	Location	Interception (% of annual rainfall)[1]	Species/Condition[2]	Type of Study[3]
Kirnbauer et al. 2013	Hamilton, Ontario, CA	6.5-11 17-27	G. biloba (D), P. acerifolia (D), A. saccharinum (D) L. styraciflua (D)	Modeling
Livesley et al. 2014	Melbourne, Victoria, Aus.	29 44	E. saligna (E) E. nicholii (E)	Measured
Xiao and McPherson 2002	Santa Monica, CA	27.3 15.3 66.5	All park and street trees Small jacaranda mimosifolia (D) Mature tristania conferta (E)	Modeling
Xiao et al. 1998	Sacramento County, CA	11.1	Tree canopy in the County	Modeling
Xiao et al. 2000	Davis, CA	15 27	Pear (D) Oak (E)	Measured
Xiao and McPherson 2011a	Oakland, CA	14.3 25.2 27.0	Sweetgum (D) Gingko (D) Lemon (E)	Measured
Wang et al. 2008	Baltimore, MD	18.4	Tree canopy in Dead Run subwatershed (D)	Modeling
Band et al. 2010	Fairfax, VA	14.5	Tree canopy in Accotink watershed (D)	Modeling
Band et al. 2010	Baltimore, MD	15.7	Tree canopy in Gwynns Falls watershed (D)	Modeling
Band et al. 2010	Montgomery County, MD	19.6	Tree canopy in Rock Creek watershed (D)	Modeling
Asadian and Weiler (2009)	Vancouver, BC	49 61	Douglas fir (E) Western red cedar (E)	Measured
Study	Location	Interception (gallons/ tree/yr)[4]	Species/Condition	Type of Study

Table 1. Rainfall Interception Studies of Urban Trees				
Berland and Hopton 2014	Cincinnati, OH	1,770 (6.7)	Average value	Modeling
McPherson and Simpson 2002	Modesto, CA	845 (3.2)	Average value	Modeling
McPherson and Simpson 2002	Santa Monica, CA	1,849 (7.0)	Average value	Modeling
McPherson et al. 2011	Los Angeles, CA	106 (0.4) (low) 1,479 (5.6 (high)	Crapemyrtle Jacaranda (D)	Modeling
Soares et al. 2011	Lisbon, Portugal	1,189 (4.5)	Average value	Modeling
CWP, 2014	Montgomery County, MD	2,000 (7.57)	15-20 year old 9-15" DBH tree	Modeling

[1] represents the % of rain falling on the tree canopy that is captured through interception
[2] D = deciduous, E = evergreen
[3] Measured = studies that infer interception by subtracting measured throughflow and stemflow from measured rainfall; modeled = studies that model interception using models such as i-tree
[4] Units of m^3/tree/yr are noted in parentheses

Table 2. Rainfall Interception by Natural Forests			
Study	**Interception (% of annual rainfall)**	**Type of Forest/Location**	**Type of Study**
Zinke (1967), cited in Xiao et al. (2000)	15-40	Conifer stands	Compilation of 39 Studies
	10-20	Hardwood stands	
Baldwin (1938), cited in Xiao et al. (2000)	59	Old growth forests	Unknown
Dunne and Leopold (1978) cited in Herrera Environmental Consultants (2008)	13[1]	Deciduous trees	Compilation of measured studies
	28[1]	Conifers	
Molchanov (1960) cited in Reynolds et al. (1988)	34-46	Spruce forest/USSR	Measured
	24-27	Pine forest/USSR	
	24	Birch forest/USSR	
	22	Oak forest/USSR	
Heal et al. (2004)	44	Conifers/UK	Measured
Link et al. (2004)	22.8-25	Old-growth Douglas fir forest/Western Cascades, WA	Measured
Deguchi et al. (2006)	16.8	Deciduous forest/Japan	Measured

[1] these studies were unavailable so it is unknown whether these values represent percent of annual rainfall versus storm event or study period rainfall

Evapotranspiration

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. When vegetation is small, water is predominately lost by soil evaporation, but once the vegetation is well developed, transpiration becomes the main process. As described in KDGT (2013), rainfall interception, advection, turbulent transport, total leaf surface area and available water capacity are all factors that combine to control ET rates, and the relative importance of each variable can fluctuate due to climate, soils and vegetative conditions.

Given the complexity of quantifying ET, no studies were found that quantify annual ET rates for trees in urban areas. Most studies instead evaluate how one or more factors influence ET, develop and test models for estimating ET, or measure ET values for a particular species during the growing season. KDGT (2013) describe the different methods of estimating ET, as well as the advantages and limitations of each.

Sinclair et al. (2005) documented the influence of soil moisture on ET and found that ET is highest when soil moisture is highest, and decreases as soil moisture decreases. Wang et al. (2011) found that transpiration rates were highest during a summer day and lowest during a winter night because of the great influence of the evaporative demand index, consisting of air temperature, soil temperature, total radiation, vapor pressure deficit, and atmospheric ozone. Guidi et al (2008) concluded that ET was strongly correlated to plant development and mainly dependent on its nutritional status rather than on the differences between species. A modeling study by Band et al. (2010) in suburban watershed in Baltimore County, MD, identified the importance of ET on runoff reduction and noted that the major effect of tree canopy on runoff production was the ability to remove soil water by transpiration, allowing more pore space for infiltration. However, Litvak et al (2014) found that in summer, total plot ET of urban lawns with trees was lower than lawns without trees by 0.9–3.9 mm d^{-1} in the Los Angeles metropolitan area. Another study from Los Angeles by Pataki et. al (2011) raised concerns that certain tree species may place too much of a demand on the local water supply because of high ET rates.

Tables 3 and 4 present a summary of transpiration studies for urban trees while Table 5 summarizes similar data from natural forests. These studies quantify transpiration during the growing season or some portion of it, rather than on an annual basis. There is quite a wide range of results for the average daily volume of water an urban tree can transpire, from 0.2 gallons to 46.7 gallons per tree per day. Studies that report rates of transpiration show a more narrow range of results, from 0.1 to 2.39 mm/day for urban trees. These rates are comparable to that of natural forests, which range from 0.5 to 3.0 mm/day.

Table 3. Transpiration Rates by Urban Trees During the Growing Season				
Study	**Location**	**Average Daily Transpiration Rate (mm/day)**	**Species / Condition[1]**	**Type of Study**
Wang (2012)	Beijing, China	1.47	Horse Chestnut - *Aesculus chinensis* (D), 10.5-19.2 DBH	Measured
Chen et al. (2011)	Liaoning Province, China	1.51	*Cedrus deodara, Zelkova schneideriana, Metasequoia glyptostroboides, Euonymus bungeanus*	Measured
Peters et al. (2010)	Minneapolis St. Paul, Minnesota	1.1[2]	*Fraxinus Pennsylvanica, Quercus rubra, Juglans nigra, Tilia Americana, Ulmus pumila, Ulmus thomasii* (D)	Measured
		1.9[2]	*Picea glauca, Picea pungens, Pinus strobes, Picea abies, Pinus nigra, Pinus sylvestris* (E)	Measured
Cermak et al. (2000)	City of Brno, Czech Republic	2.17	Red Maple - *Acer campestre L* (D), roots covered by asphalt, 18” DBH, shaded	Measured
		2.39	Red Maple - *Acer campestre L* (D), roots covered by asphalt, 50” DBH, exposed to sunlight	
Pataki et a. (2011)	Los Angeles, CA	0.1-2.2	Urban forest plots with mixed species	Measured

[1]D = deciduous, E = evergreen

[2] Converted from $kg/m^2/day$ assuming $1kg = 0.0010m^3$

Table 4. Gallons of Water Transpired by Urban Trees During the Growing Season				
Study	**Location**	**Average Daily Transpiration Volume (gal/tree/day)**	**Species / Condition[2]**	**Type of Study**
Pataki et al. (2011)	Los Angeles, CA	0.2[3]	Laurel Sumac - *Malosma laurina*, unirrigated	Measured
		0.8[3]	*Pinus canariensis*, unirrigated	
		2.3[3]	Blue Jacaranda - *Jacaranda mimosifolia*, irrigated	

Table 4. Gallons of Water Transpired by Urban Trees During the Growing Season				
Study	**Location**	**Average Daily Transpiration Volume (gal/tree/day)**	**Species / Condition[2]**	**Type of Study**
		3.4[3]	Kurrajong - *Brachychiton populneus*	
		3.4[3]	Redwood - *Sequoia sempervirens*	
		5.0[3]	Lacebark –*Brachychiton discolor*	
		11.3[3]	Grand Eucalyptus - *Eucalyptus grandis*	
		12.0[3]	Crape Myrtle - *Lagerstroemia indica*	
		12.5[3]	California Sycamore - *Platanus racemosa*, campus	
		13.0[3]	Canary Island Pine - *Pinus canariensis*,	
		13.4[3]	Goldenrain tree - *Koelreuteria paniculata*	
		17.9[3]	Chinese elm - *Ulmus parvifolia*	
		19.4[3]	*Pinus canariensis*, campus	
		23.7[3]	Laurel Fig - *Ficus microcarpa*	
		23.7[3]	Honey Locust - *Gleditsia triacanthos*	
		26.2[3]	Jacaranda - *Jacaranda chelonia*	
		27.1[3]	*Platanus racemosa*, street	
		46.7[3]	London Planetree - *Platanus hybrida*, street	
Green (1993)	Palmerston North, New Zealand	10.5[1]	10 year old isolated walnut (D)	Measured
Cermak et al. (2000)	City of Brno, Czech Republic	17[1]	Red Maple - *Acer campestre L* (D), roots covered by asphalt, 18” DBH, shaded	Measured
		37[1]	Red Maple - *Acer campestre L* (D), roots covered by asphalt, 50” DBH, exposed to sunlight	

[1] Converted from liters/tree/day

[2]D = deciduous, E = evergreen

[3]Converted from kg/tree/day assuming 1 gallon = 3.79 kg of water

Table 5. Transpiration Rates by Natural Forests During the Growing Season				
Study	**Location**	**Average Daily Transpiration Rate (mm/day)**	**Type of Forest/Location**	**Type of Study**
Wullschleger et al. (2000)	Eastern TN	1.1-3.0[1]	Large red maples in a upland oak forest	Measured
Wullschleger et al. (2001)	Eastern TN	1.1 (average) 2.2 (maximum)	Upland oak forest (white and red oak, black gum, red maple, yellow poplar)	Measured / Modeled[2]
Cienciala et al. (1997)	Central Sweden	0.5[3]	100 year old stand sub-boreal forest (pine and spruce)	Measured
		0.9[3]	50 year old stand sub-boreal forest (pine and spruce)	
Ford et al. (2011)	Coweeta Basin, Western NC	1.1	Mixed deciduous hardwood forest	Measured
		2.4	White pine forest	

[1]Measurements are for individual trees

[2]Sap flow measurements for individual trees were used to model stand transpiration

[3]Measurements taken during a dry period in July

Because of the difficulty in measuring ET by trees over annual timeframes, some studies use a water balance approach to estimate ET for a watershed by subtracting discharge from precipitation. Table 6 summarizes these studies, which estimated annual ET rates for forested watersheds of 24% to 77%. Hibbert (1969) found that water yield from a 22-acre catchment in the southern Appalachians increased over 5 inches annually when the catchment was converted from hardwood forest to grass. During years when grass production was high, water yield from the catchment was about the same as or less than the expected yield from the original forest. As grass productivity declined, water yield gradually increased. Hibbert (1969) attributes the changes in water yield to changes in ET.

Table 6. Annual ET by Natural Forests

Study	Location	Results	Description
Boggs and Sun (2011)	Central North Carolina piedmont	Forested watershed retained 77% of annual rainfall, compared to 58% for an urban watershed with 44% impervious cover	ET was estimated by subtracting measured streamflow from precipitation.
Post and Jones (2001)	Oregon, New Hampshire, North Carolina and Puerto Rico	Deciduous forested basins retain 24-54% of rainfall and evergreen forests retain 43-50% of rainfall	ET was estimated by subtracting measured streamflow from precipitation.

Infiltration

Studies on the effects of urban trees on soil infiltration are limited. The studies reviewed demonstrate that trees can increase soil infiltration rates, even in highly compacted soils such as those typically found in the urban environment. Only two studies quantified this increase, with Bartens et al. (2008) showing that tree roots increased soil infiltration rates by an average of 63% over unplanted controls and 153% for severely compacted soils. This same study demonstrated that trees can also increase infiltration rates in structural soils, with green ash grown in CU Soil having an infiltration rate 27 times greater than the unplanted CU Soil control sites (Bartens et al 2008). Kays (1980) showed a 35% decrease in suburban forest infiltration rates with removal of the understory and leaf litter. Chen et al (2014) identified soil rehabilitation with compost to be an important practice for mitigating urban soil compaction and also found the presence of trees contributes to an increase in soil hydraulic conductivity.

In a study of a stormwater biofilter, Le Coustumer et al. (2012) found that hydraulic conductivity declined over time for both vegetated and unvegetated biofilters, except those planted with the tree *Melaleuca ericifolia*. Hydraulic conductivity for the biofilter planted with *M. ericifolia* initially decreased from 155 to 100 mm/h over the first 40 weeks, but then increased to 295 mm/h after 60 weeks, finishing at around 240 mm/h at the end of testing (72 weeks). The authors hypothesize this is due to the importance of thick roots that help to maintain permeability of the soil over time through the creation of macropores.

Three other studies were reviewed that quantify the impact of trees on infiltration rates in non-urban environments. Mlambo et al. (2005) found that soil infiltration rates under tree canopy (0.12 +/- 0.02 mm/s) were 50% higher than outside the canopy (0.06 +/- 0.03 mm/s), and that infiltration rates were significantly higher under large trees than medium or small trees. Lal (1996) found that after the deforestation of a Nigerian forest, infiltration rates decreased by 20 to 30 percent. Wondzell and King (2003) summarized the literature on infiltration rates in burned and unburned forests of the Pacific Northwest and Rocky Mountain regions and showed that infiltration rates were around 35% lower in burned forests than unburned ones (value estimated from chart).

Runoff Reduction

The combined effect of trees' ability to intercept and evapotranspire rainfall and promote infiltration of water into the soil is that the rate and overall proportion of rainfall that becomes runoff is reduced. Most studies on runoff reduction provided by urban forests use hydrologic models to estimate the impact of trees on reducing stormwater runoff. The most commonly used models are American Forest's CITYgreen software, which is based on TR-55 (USDA SCS, 1986) and uses runoff curve numbers that predict runoff based on land use type, and the US Forest Service's i-tree (formerly known as UFORE), which is based on hydrodynamic canopy models. These modeling studies show that, as forest cover in a municipality or watershed increases, runoff decreases (and the inverse is also true).

Table 7 summarizes the results from the studies reviewed on runoff reduction by urban trees and forests. As indicated in the description in Table 7, each study has a unique approach to quantifying runoff reduction.

Table 7. Studies of Runoff Reduction by Urban Trees

Study	**Results**	**Description**
American Forests (1999)	19% increase in runoff	Modeled increase in runoff associated with loss of 14% forest cover
Armson et al. (2013)	58% reduction in runoff in summer and 62% in winter	Measured reduction from plot containing a tree pit and surrounded by asphalt
Wang et al. (2008)	2.6% runoff reduction	Modeled reduction associated with increasing tree cover over turf from 12 to 40%
	3.4% runoff reduction	Modeled reduction associated with increasing tree cover over impervious surface from 5 to 40%
Xiao and McPherson (2011b)	88.8% runoff reduction	Measured runoff reduction for bioswale integrating structural soils and trees[1]

Table 7. Studies of Runoff Reduction by Urban Trees

Study	Results	Description
Page et al. (2014)	80% runoff reduction	Measured runoff volume captured and treated by Silva Cell with tree[1]
Sanders (1986)	7% increase in runoff	Modeled increase in runoff associated with loss of 22% forest cover during a single storm
	5% reduction in runoff	Modeled reduction associated with increasing tree cover over non-surfaced areas from 37% to 50% during a single storm

[1] study did not include unplanted controls

Watershed-scale studies of runoff reduction often provide results in terms of the percent of annual runoff reduced by a given percent of tree cover in the watershed (in comparison to the runoff generated if trees were not present). These results can be translated into a percent runoff reduction per unit area of canopy if watershed areas are provided in the studies. However, not all studies are conducted on an annual basis and the results (streamflow measured at the watershed outlet) reflect not just the effect of trees in the watershed but the cumulative effect of all other land cover types and watershed features.

For both the CITYgreen and i-Tree models, analyses identical to those described in Table 6 have been conducted for dozens of municipalities across the US. Only the Chesapeake Bay region CITYgreen study was reviewed for this synthesis because the methodology is the same in all studies and this paper provides results that are most relevant to the Bay. The runoff curve number method upon which CITYgreen is based was developed for agricultural watersheds and has been shown to be relatively inaccurate in estimating runoff from forest (Tedela et a. 2012). Wang et al. (2008), Armson et al. (2013) and Herrera Environmental Consultants (2008) all found that runoff reduction was more pronounced when trees were planted over/near impervious cover. This is likely attributable to the greater amount of stormwater runoff generated on impervious surfaces, compared to turfgrass or other pervious areas.

In addition to reducing total runoff volume, tree canopy can delay peak runoff because of its ability to intercept and slowly release rainfall (Asadian and Weiler 2009). Research on the ability of tree canopy to delay throughfall reports a delay in throughfall of 0.17 hours to 3.7 hours after rainfall (Asadian 2010, Xiao 2000).

Studies of natural forests infer runoff reduction by measuring changes in runoff from streams draining forested basins before and after clearcutting. Table 8 summarizes these studies, which show a reduction in annual water yield of 8% to 80% after forest harvesting. In the Hornbeck et al. (1997) study, increases in annual water yield diminished rapidly as forests regenerated and were undetectable within 7-9 years after treatment. Douglas and Swank (1972) summarized 23 experiments from mixed deciduous hardwood forests in the Appalachian Highlands. They found a linear relationship between streamflow increase during the first year after forest removal and the percentage reduction of the forest stand, where first year increase = -1.43 + 0.13(% basal area reduction). Bosch and Hewlett (1982) conducted a review of 94 catchment experiments across the world as an update to a review by Hibbert (1967). Pine and eucalypt forest types were found to cause on average 40 mm change in water yield per 10% change in forest cover and deciduous hardwood and scrub ~25 and 10 mm, respectively.

Table 8. Runoff Reduction by Natural Forests

Study	Location	Results	Description
Hornbeck et al. (1997)	Hubbard Brook, New Hampshire	Annual water yields increased by an average of 32% after forest clearing in forested watersheds.	Measured by comparing streamflow in forested basins before and after deforestation.
Moore and Wondzell 2005	Oregon Cascades, Oregon Coast and South Coastal British Columbia	Mean changes in annual water yields after forest harvesting ranged from 8-43% in the Oregon Cascades, 14-26% in the Oregon Coast and South Coastal British Columbia and 15-80% in snow dominated small catchments.	Measured by comparing streamflow in forested basins before and after deforestation.

Water Quality

The primary way that urban trees affect water quality is by reducing the amount of stormwater runoff that reaches surface waters. Trees also improve soil and water quality through uptake of soil nutrients by plants and soil microbes. Tree roots stabilize the soil and tree canopies reduce the impact of raindrops, both of which reduce soil erosion. Trees, specifically the leaf litter produced by trees, are also a needed source of nutrients and carbon to support stream ecology and are deposited to stream from adjacent riparian areas, or through delivery of leaf litter from the urban drainage system. As discussed below, the research to quantify the excessive nutrient load delivered by leaf litter in urban watersheds is incomplete. Most of the studies reviewed focused on the effects of urban trees on the quality of stormwater runoff.

Effects of Trees on the Quality of Stormwater Runoff

Only one study directly addresses the effects of urban trees on the quality of stormwater runoff. Nine of the studies reviewed were field studies of the pollutant removal performance of stormwater treatment systems that include trees (e.g., Silva cells). However, only four of these studies (Denman 2006, Denman et al. 2011, Denman et. al 2015, Read et al. 2008) included unplanted controls to separate out the benefits provided by the tree vs. the filter media, and only one of those (Denman 2006) reported results that represent the water quality performance associated with the trees. Read et al. (2008) did not report results for trees versus other types of vegetation. In addition, the studies, which are summarized in Table 9, evaluate different species of nutrients and/or use varying methods to calculate percent pollutant removal.

Table 9. Pollutant Removal by Stormwater Treatment Systems with Trees *(note: the pollutant reductions are for the practice and not the effect of trees in the practice).*

Study	Treatment System Type	Parameter and % Reduction						
		TN	NOx	DIN	TKN	TP	FRP	TSS
Denman 2006	Street Tree Bioretention	82-95						
Denman et. al 2011; Denman et al. 2015	Biofiltration		2-78				70-96	
Geronimo et al. 2014	Tree Box Filter							80-98
Page et al 2014	Silva Cell				71, 84	72		86
Roseen et al. 2009	Street Tree			62		-54		88
UNHSC, 2012	Tree Box Filter (Non-proprietary)	10		8				88
UNHSC, 2012	Filterra	15				52		85
Xiao and McPherson 2011a	Bioswale	95.3[1]						95.5[2]

[1]average of all nutrient species results
[2]average of results from TSS and TDS

The values shown in Table 9 represent the percent removal of each pollutant provided by stormwater treatment systems with trees. Note that even where studies incorporated unplanted controls, the results reflect the pollutant removal of the entire system. Only the Denman (2006) study provides sufficient data to separate out the pollutant removal associated with just the trees. For the aforementioned study, the results show 82%, 85% and 95% removal of TN by the three bioretention systems with trees, compared to of -7%, 0%, and 36% removal by their respective unplanted controls. The difference between pollutant removal effectiveness of these planted and unplanted systems can be assumed to represent the enhanced TN reductions provided by the trees, with values of 59%, 85% and 89%.

Of the other studies on water quality benefits of urban trees, a modeling study by Band et al. (2010) estimated that current tree cover in Baltimore County, MD's Baisman Run watershed reduced TSS by 981 lbs (445kg) over the simulation period, TP by 4.4 lbs (2kg), TKN by 26.5 lbs (12kg) and NO2+NO3 by 8.8 lbs (4 kg). These results were based on modeling using UFORE-Hydro that simulated changes in flow due to changes in watershed land cover, and applied national median EMC values to estimate associated changes in pollutant loads; yet, it is difficult to put these values into context because the total pollutant inputs to the watershed are unknown. Matteo et al. (2006) ran a watershed-scale model of the water quality impacts of roadside and riparian buffers, but did not provide enough information about the area of the forested buffers to scale the results down to an individual tree planting site or forest plot. This is similar to the results presented by Goetz et al. (2003) and by the CITYgreen and i-Tree studies reviewed in the previous section in that the results are only applicable if the urban tree canopy credit is based on a percent tree canopy for a given watershed or municipality.

Groffman et al. (2009) measured nitrate leaching from urban forest and grasslands and found that annual nitrate leaching was higher in grass than in forest plots, except for one highly disturbed site that had hydrologic N losses well in excess of atmospheric inputs. Nitrate losses from forest plots in this study were 0.05 to 0.79 g N/m/yr; however, nitrogen inputs to the system were not measured. Another study by Groffman et al. (2004) found nitrate yields of 0.11 to 0.14 kg N/ha/yr and TN yields of 0.48 to 0.58 kg N/ha/yr from a forested basin, and estimated N retention of 95% by this basin, compared to 75% for a suburban basin and 77% for an agricultural basin.

Two studies were reviewed that address urban trees and water quality but do not specifically deal with stormwater runoff. Zhang et al. (2011) measured organochlorine pesticides in rainfall, canopy throughfall and runoff and found that the canopy was able to intercept 40% of the wet and dry deposited pollutants compared to a site with no trees, but further research is needed to determine the ultimate fate of the pollutants. Conversely, Xiao and McPherson (2011a) found that nutrients were added as rainfall passed through the tree canopy due to canopy leaching of pollutants that were previously deposited from atmospheric sources. The washoff of atmospheric deposition from leaves would not be considered an additional source of nutrients; however, tree canopy may delay the delivery of these nutrients to the stream.

Numerous studies have evaluated the water quality benefits of natural forests. Table 10 summarizes measured nutrient and sediment exports from undisturbed forests. It also presents ratios of pollutant loading from forests that have undergone disturbance (e.g., ice damage, insect defoliation, fire) and forests that were harvested (using a range of methods such as cattle grazing, clearcutting, strip cutting, and whole tree removal) compared to the pre-disturbance or control sites for those particular studies. Given the limited amount of data on the water quality benefits of urban trees and forests, the data from undisturbed forests could be applied to establish upper bounds of pollutant removal. The ratios for disturbed and harvested forest could potentially be useful if culled to look only at studies that represent conditions commonly found in urban forest patches or planting sites (e.g., sparse cover, die-off from lack of watering, compacted soils).

Table 10. Nutrient and Sediment Loads from Non-Urban Forests[1]

Type of Forest	Pollutant Export (lbs/acre/year)[1] (n)		
	TN	TP	TSS
Undisturbed	2.14[3] (123)	0.16[2] (14)	41.9[2] (17)
	Ratio of Pollutant Export from Harvested/Disturbed Forest:Reference[4]		
Disturbed	3.09	2.04	2.04
Harvested	7.03	3.12	3.05

[1] based on studies of eastern forests compiled by Justin Hynicka from Maryland DNR for urban tree canopy land use recommendations

[2] median value

[3] calculated as the sum of median values for NO3 and TKN

[4] mean ratio of harvested or disturbed pollutant export to pollutant export from reference sites

Pollutant Uptake

Most studies on pollutant uptake by trees focus on nutrient uptake by trees in the riparian zone. These studies were not included in the literature review because the focus of this work is on the benefits of upland urban trees. That is, processes such as nitrate removal from shallow groundwater and denitrification hotspots along the soil water interface are more prominent processes in riparian areas compared to tree in the upland area (Johnson et al 2013). A few studies were available from the field of phytoremediation—the process of using plants to remove contamination from soil and water— which show trees' potential to remove pollutants through plant uptake, adsorption and microbial activity. Phytoremediation has mainly been applied to remove metals, pesticides, and organic compounds from soil and groundwater but could potentially be applied to nutrients in stormwater runoff. Tree species typically used for phytoremediation include willow, poplar (cottonwood hybrids), and mulberry, because they have deep root systems, fast growth, a high tolerance to moisture, and are able to control migration of pollutants by consuming large amounts of water (Metro, 2002; IRTC, 2001; Shaw and Schmidt, 2007). Once pollutants are taken up by plants, one or more activities may occur. Pollutants can be moved into the above-ground portions of the plants, accumulate in the root zone, be broken down through natural processes of plant growth, or be transformed into inert material and discharged through plant leaves or shoots. Biological uptake is seen as only a temporary removal process because the pollutants may be returned to the system when the plant dies, unless it is harvested.

Leaf Litter

An emerging topic in urban stormwater management is the effect of nutrients and carbon from leaf litter on urban streams. Leaf litter represents a major energy source (DOC) and source of nutrients to streams where water soluble compounds readily leach from the leaves within hours to days following immersion, with macro-invertebrates and bacteria decompose the leaf material in-stream. In urban-suburban areas, leaf litter collects in curbs and gutters that is flushed through the storm drain system, contributing nutrients to urban streams that are generally already impaired for excessive nutrients, or impaired biota.

While many urban areas have less than 40% tree canopy, leaf litter input to streams from riparian and upland areas does occur. This results in a large and steady supply of leaves to streams (aka the "gutter subsidy"). In a recent Scientific and Technical Advisory Committee workshop report (Sample et al 2015) and Nowak (2014) provided data for Baltimore, MD estimating an urban tree canopy biomass nutrient load of 28.8 lbs/ac/yr and 2.95 lbs/ac/yr of N and P, respectively if all the leaves were accounted for in the load. However, it is known trees sequester nitrogen prior to leaf fall in trunks, roots and branches leaving low amount of nitrogen in leaf litter. In an outfall netting study in Easton, MD, Stack et al (2013) found an average of 4.7 TN lb/ac/yr and 0.36 TP lb/ac/yr associated with leaf litter in catchments with 24% canopy cover. The difference between these loading rates is attributed in part to the aged leaf litter at the outfall and leaf litter reaching the streams compared to the total canopy used to estimate the biomass by Nowak (2014). Street sweeping studies have also quantified the potential impact of leaf litter on urban nutrient loadings. Baker et al (2014) and Berretta et al. (2011) found that organic matter comprised 10% of the load collected by street sweepers. Waschbusch (2003) also found a similar estimate from a street sweeping study and this contributed to 30% of the total phosphorus load. This 'gutter subsidy' was estimated by Baker et al (2014) to be 2 lbs - 6 lbs P/curb-mile in residential catchments with up to 20% tree canopy. Templer et al (2015) found that up to 52 ± 17% of residential litterfall carbon (C) and nitrogen is exported through yard waste removed from the City of Boston, which is equivalent to more than half of annual N outputs as gas loss (i.e. denitrification) or leaching. While, recent studies illustrate the available supply of leaf litter in urban areas, further research is needed to better quantify the fate, transport, and processing of leaf litter in urban watersheds and how to best account for this source as part of an urban nutrient mass balance. While the nutrients, specifically phosphorus is likely a source to urban streams, it is unknown how much of this soluble load is represented in current monitoring of urban outfalls.

Summary

Urban tree canopy has great potential for helping to meet nutrient and sediment load reductions for the Chesapeake Bay TMDL. However, trees are unlike most other urban BMPs, which have a defined drainage area and are engineered to capture and remove pollutants from stormwater runoff. While trees affect processing of nutrients from the soil, atmosphere and groundwater, their primary impact on water quality is attributed to the prevention of water pollution by reducing the amount of runoff generated from areas where tree canopy is present. In the absence of tree canopy, rain falling on urban surfaces such as parking lots, streets and lawns picks up various pollutants as it runs off the landscape. Therefore, the cumulative effect of tree canopy is to temporarily detain rainfall and gradually release it, regulating the flow (volume and peak) of stormwater runoff downstream and thereby preventing pollutants in rainfall and on urban surfaces from being transported to local waterways.

The ability of an urban tree to reduce runoff is determined by how much rainfall is intercepted and evaporated in the canopy or infiltrated into the soil. The removal of soil water by trees through transpiration also affects runoff by increasing soil water storage potential, effectively lengthening the amount of time before rainfall becomes runoff. By preventing rain from becoming runoff, trees decrease the volume of runoff that is available to pick up sediment and nutrients from the urban landscape. This correlation between runoff and water quality is widely accepted and many stormwater runoff models—including i-tree HYDRO, the Simple Method (Schueler 1987) and the Runoff Reduction Method (Hirschman et al. 2008)—-calculate pollutant loads as a product of runoff volume and pollutant concentration. Trees provide additional water quality benefits through uptake of pollutants from the atmosphere, soil and groundwater, and may contribute nutrients to surface waters through leaf litter, but these components are more challenging to quantify given the available data and its variability. Since the literature on hydrologic benefits of urban trees is much more plentiful than studies of water quality benefits, a possible avenue to explore for a credit is to model the connection between runoff reduction and pollutant reduction.

While these processes and mechanisms for reducing runoff and pollutants are well known, the amount by which trees reduce runoff is highly variable, and by extension water quality as well. For example, interception alone is influenced by numerous factors, including the intensity, duration and frequency of rainfall; canopy architecture, leaf area, leaf angle distribution, leaf surface characteristics; and meteorological factors such as wind speed and vapor pressure deficits. Evapotranspiration is similarly influenced by a number of environmental and structural factors. Studies that quantify these processes offer results that are often site-specific or event-specific. All of these factors present a challenge with translating these results into water quality credits that reflect the “average” condition. Best professional judgement is needed to develop recommendations that reflect the best available science while accounting for this variability as well as the average operational condition of the entire watershed.

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Annotated Bibliography

American Forests, 1999 (Runoff reduction)

Using CityGreen software, forest loss from 1973-1999 was calculated for a 1.5 million acre portion of the Chesapeake Bay region near the Baltimore-Washington corridor. During the study time period, average tree cover went from 51% to 37% and areas with heavy tree cover declined from 55% to 37%. Tree loss resulted in a 19% increase in runoff (for each 2 year peak storm event), an estimated 540 million ft^3 of water. In the study area, the existing tree canopy reduces the need for retention storage by 540 million cubic feet. The model relies on modified formulas from TR-55 to estimate stormwater runoff.

Armson et al. 2013 (Runoff reduction)

This study assessed the impact of trees upon urban surface water runoff by measuring the runoff from $9m^2$ plots covered by 1) grass, 2) asphalt, and 3) asphalt with a tree planted in the center. It was found that, while grass almost totally eliminated surface runoff, the tree plots significantly reduced runoff, with 26% runoff in winter and 20% in summer (as a percentage of rainfall). The trees and their associated tree pits reduced runoff from asphalt by 58% in the summer and 62% in winter. The reduction was attributed primarily to infiltration into the tree pit and canopy interception, although the tree's canopy covered about 35% of the plot. Relative to its canopy crown, the runoff reduction by the tree was estimated to be 170% in summer and 145% in winter.

Bartens et al. 2008 ((Infiltration)

This study examined whether tree roots can penetrate compacted subsoils and increase infiltration rates in the context of an infiltration BMP that uses structural soils and includes large canopy trees. One goal of the study was to determine if tree roots would grow into the compacted subsoils typically found under/adjacent to such a practice. The study found that tree roots increased soil infiltration rates by an average of 63%, and as much as 153%, over unplanted controls.

Bartens et al. 2009 (ET)

In this study, two trees were grown in structural soil mixes and were subject to three simulated infiltration rates for two growing seasons. Reduced infiltration rates were correlated with lower transpiration rates. Transpiration rates for one growing season were reported to be 0.80 to 1.14 $\mu g/cm^2/s$ for the green ash (depending on soil treatment) and 0.76 to 1.39 $\mu g/cm^2/s$ for the swamp white oak. The study also found that larger trees can take up more total water than smaller trees with higher transpiration rates.

Berland and Hopton, 2014

This study estimated canopy interception by street trees along geographic and demographic gradients in Cincinnati. Using i-tree, interception ranged from 59.2 to 214.3 m3 per km of effective street length. The mean interception value used in the model was 6.7m3 per tree, which the researchers note may overestimate runoff reduction.

CWP, 2014

Data from i-tree STREETS was used to plot the volume of rainfall intercepted per year versus trunk diameter and the trunk diameter versus age of the tree. Polynomial regressions were generated from these plots. Regression functions all had R^2 values of at least 0.999. The functions were tied and plotted for 3 tree species found in Montgomery County, MD and for the average “Broadleaf Deciduous Large” value from the i-Tree database for the Piedmont south climate region. I-tree uses a computer model described in Xiao et al. (1998) to generate rainfall interception. The statistical analysis showed an average annual interception volume of 2,000 gallons per tree for a 15-20 year old tree that is 9-15” DBH.

Denman 2006

Study of the performance of a pilot scale street tree bioretention system in reducing nitrogen loads in urban stormwater. Three tree species were planted in three soils of different hydraulic conductivity and irrigated with synthetic stormwater, along with 3 unplanted soil profiles used as controls and irrigated with tap water. The trees grew well in the irrigated soil. Nitrogen content (ammonium, oxidized nitrogen and organic nitrogen) of leach water was measured. Leached nitrogen loads were significantly reduced in systems with a tree. Compared to the total nitrogen input, the load leached in December 2004 from the L. confertus profiles following a 5 hour collection period was 95% less for the low SHC, 85% for the medium SHC and 82% for the high SHC soils. In the unplanted profiles the low SHC soil reduced nitrogen by 36%, whereas the medium (0%) and high SHC soils (-7%) did not remove nitrogen. This study does not appear to be peer reviewed.

Denman et al. 2011

Similar study design as above but this study measured soluble N and P in leachate. Some seasonal variability was found, with higher leaching of N and P in the warmer months. Again, tree growth was good. No significant differences in evergreen versus the one deciduous species planted. P removal did not occur until after the first summer. This study showed greater variability than the previous one. The NOx reduction provided by soils with trees, averaged over time, ranged from 2% to 78%. Reduction of filterable reactive phosphorus ranged from 70% to 96%. No specific values were provided for the unplanted controls for comparison. This study does not appear to be peer reviewed.

Geronimo et al. 2014

This study evaluated pollutant removal and runoff reduction by a tree box filter. The system reduced runoff by 40% for a hydraulic loading rate of 1m/day. It was found out that the hydraulic loading rate was dependent on the total runoff volume received by the system. TSS removal ranged from 80% to 98% at varying hydraulic loading rates. No unplanted control site was tested to evaluate the effects of the tree versus other mechanisms; however the study states that the filtration capacity of the tree box filter was presumed to be the main pollutant removal mechanism.

Groffman et al. 2009

This study measured nitrate (NO3) leaching and soil:atmosphere nitrous oxide (N2O) flux in four urban grassland and eight forested long-term study plots with a range of disturbance, soil type and landscape position in the Baltimore, Maryland metropolitan area from 2002-2005. Annual NO3 leaching ranged from 0.05 to 0.79 g N m yr for the forest plots and was lower than in grass plots, except in a very dry year and when a disturbed forest plot was included in the analysis. Although NO3 leaching was higher in urban grasslands than in forest plots, the difference was not as large or consistent as expected, and the most intensively fertilized plots did not have the highest leaching losses. The N2O results were even more surprising because there were few differences between forest and grass plots, and, again, the more intensively fertilized grasslands did not have greater fluxes. These results suggest that N cycling in urban grasslands is complex and that there is significant potential for N retention in these ecosystems. Grass plots consistently produced less leachate volume than forest plots. It is suspected that the difference was due to higher evapotranspiration on the grass plots due to higher soil temperatures and the longer growing season in urban grassland versus forest ecosystems. A complication in the leaching comparisons was the fact that one of our forest plots was extensively disturbed and had very high N losses. Although leaching from most of the forest plots was very low, consistent with many previous studies of forest ecosystems, data from our highly disturbed forest plot showed that forests can have hydrologic N losses well in excess of atmospheric inputs. Likely causes of the high N losses from the highly disturbed forest plot include soil disturbance and invasion by exotic plant and earthworm species. These results suggest that not all forest components of urban landscapes are functioning as strong N sinks.

Guevara-Escobar et al 2007

This work evaluated rainfall interception and distribution patterns of gross precipitation around the canopy of a single evergreen tree Ficus benjamina (L.) in Queretaro City, Mexico. Nineteen individual storms occurring from July to October, 2005, were analyzed. Interception loss was 59.5% of gross rainfall and was primarily attributed to evaporation, which was not limited due to the low relative humidity and high temperatures. The study showed a screen effect of the tree crown on gross precipitation and if not accounted for in study designs, will lead to underestimation of interception losses. The screen effect was important and accounted for 18.7% of the interception losses by the tree canopy alone.

Herrera Environmental Consultants 2008

This report reviews the literature on the effects of trees on stormwater runoff and make recommendations for applying the available research to develop a stormwater credit for urban trees in the City of Seattle. The review found that evergreen trees in the Pacific Northwest can intercept on average 20% of annual rainfall (18-25%, depending on season) and can transpire 10% of precipitation. Modeling two scenarios of an evergreen tree planted over 1)an impervious surface and 2) a lawn, and based on the value identified above, the authors estimate that planting a tree over impervious cover results in a 27% reduction in the amount of rainfall that becomes runoff (95% runoff coefficient assumed for impervious cover) and planting a tree over turf results in a 12% reduction in the amount of rainfall that becomes runoff (20% for turf). The result for tree planted near impervious cover approach 30%, a value also suggested in the literature on runoff reduction. The same exercise was repeated for deciduous trees using values of 10% for interception and 5% for transpiration. The authors recommend a credit of 30% of the canopy footprint for evergreens and 15% for deciduous trees, if the tree is located within 10 feet of an impervious surface. Trees located more than 10 feet from an impervious surface would receive half this credit.

Inkiläinen et al 2013

To quantify the amount of rainfall interception by vegetation in a residential urban forest this study measured throughfall in Raleigh, NC, USA between July and November 2010. Throughfall comprised 78.1–88.9% of gross precipitation, indicating 9.1–21.4% rainfall interception. Cumulative rainfall interception over the study period ranged from 9.1- 10.6 and the storm based values ranged from 19.9-21.4. Canopy cover and coniferous trees were the most influential vegetation variables explaining throughfall whereas variables such as leaf area index were not found significant in our models. The results do not appear to reflect interception by trees but are for the entire residential parcel which includes other land cover types.

Kays 1980

Infiltration tests conducted across a North Carolina watershed on various land use types found that a medium aged pine-mixed hardwood forest had a mean final constant infiltration rate of 31.56 inches per hour. When the forest understory and leaf litter were removed, the resultant lawn had a mean infiltration rate of 11.20 inches per hour.

Kirnbauer et al. 2013

i-Tree Hydro was used to derive a simplified Microsoft Excel-based water balance model to quantify the canopy interception potential and evaporation for four monoculture planting schemes on urban vacant lots, based on 7 years (2002–2008) of historical hourly rainfall and mean temperature data in Hamilton, Ontario, Canada. The results demonstrate that the tree canopy layer was able to intercept and evaporate approximately 6.5%–11% of the total rainfall that falls onto the crown across the 7 years studied, for the G. biloba, P.×acerifolia and A. saccharinum tree stands and 17%–27% for the L. styraciflua tree stand. This study revealed that the rate at which a species grows, the leaf area index of the species as it matures, and the total number of trees to be planted need to be determined to truly understand the behavior and potential benefits of different planting schemes.

Kjelgren and Montague 1998

The study used a two-layer canopy model to study transpiration of tree species as affected by energy-balance properties of a vegetated (turf) and paved surface. Trees over asphalt had consistently higher leaf temperature, than those over turf, apparently due to interception of the greater upwards long-wave radiation flux from higher asphalt surface temperatures. In one study flowering pear over asphalt in a humid environment had higher leaf temp resulting in one-third more total water loss compared to trees over turf. In other studies, however, water loss of green ash and Norway maple over asphalt in an arid environment was either equal to or less than that over turf. Less water loss was due to higher leaf temp over asphalt causing prolonged stomatal closure. Model manipulation indicated that tree water loss over asphalt will depend on the degree of stomatal closure resulting from how interception of increased energy-fluxes and ambient humidity affect leaf-to-air vapor pressure differences.

Livesley et al. 2014

This study measured canopy throughfall and stemflow under two eucalypt tree species in an urban street setting over a continuous five month period. The species with the greater plant area index intercepted more of the smaller rainfall events, such that 44% of annual rainfall was intercepted as compared to 29% for the less dense E. saligna canopy. Stemflow was less in amount and frequency for the roughbarked E. nicholii as compared to the smooth barked species. However, annual estimates of stemflow to the ground surface for even the smoothbarked E. saligna would only offset approximately 10mm of the 200mm intercepted by its canopy. This study provides an evidence base for tree canopy impacts upon urban catchment hydrology, and suggests that rainfall and runoff reductions of up to 20% are quite possible in impervious streetscapes.

Matteo et al. 2006

This study used the generalized watershed loading function model to evaluate watershed-wide impacts of best management practices (BMPs) scenarios representing riparian and street buffers on water quality, quantity, and open space in rural, suburban, and urbanized environments. The proportion of urban forest cover reduced sediment and nutrient loading, decreased stormwater runoff, and increased groundwater recharge in urbanizing watersheds. The model simulated runoff, groundwater recharge, ET, and TN and TP loads for 4 scenarios in each of the 3 settings: 1) baseline, 2) 10 foot roadside tree buffers, 3) 200 foot riparian buffers, and 4) both the riparian and roadside buffers. Results for the suburban catchment were: TSS reduction of 1.83% from baseline, TN 0.06% reduction, TP 2.75% reduction, runoff 5.24% reduction, ET increase of 0.06% and increase in groundwater recharge of 1.67%. Results for the urban catchment were: TSS reduction of 4.24% from baseline, TN 6.59% reduction, TP 6.57% reduction, runoff 8.75% reduction, ET increase of 2.74% and increase in groundwater recharge of 33.84%. However, the total area of forest associated with each scenario was not reported, making it difficult to apply the result to the individual tree planting site scale. There is also a question about the CNs used in the model for forest (46 for rural forest, 65 for suburban forest and 30 for urban forest), which were taken from TR-55 but the value used for urban forest is for A soils and woods in good condition, and produces less runoff than the suburban and rural sites.

McPherson and Simpson 2002

This paper presents a comparison of the structure, function, and value of street and park tree populations in two California cities. Modesto is covered by 31% trees, while Santa Monica has 15% tree cover. A numerical interception model accounted for the amount of annual rainfall intercepted by trees, as well as throughfall and stem flow (Xiao et al. 1998). The volume of water stored in tree crowns (m3/tree) was calculated from crown projection areas (area under tree dripline), leaf areas, and water depths on canopy surfaces. Hourly meteorological and rainfall data for 1995 (Modesto) and 1996 (Santa Monica) were used as input. Urban forests in Modesto were estimated to reduce stormwater runoff by 3.2m2 per tree, and by 7.0 m2/tree in Santa Monica. Interception differed between cities because of variables such as annual rainfall pattern and tree foliation periods.

McPherson et al 2011

The purpose of this study was to measure Los Angeles's existing tree canopy cover (TCC), determine if space exists for 1 million additional trees, and estimate future benefits from the planting using i-tree. A numerical interception model accounted for the amount of annual rainfall intercepted by trees, as well as throughfall and stem flow (Xiao et al. 1998). The volume of water stored in tree crowns (m3/tree) was calculated from crown projection areas (area under tree dripline), leaf areas, and water depths on canopy surfaces. Hourly meteorological and rainfall data for 1995 (Modesto) and 1996 (Santa Monica) were used as input. Over the 35-year span of the project, planting of 1 million trees was estimated to reduce runoff by approximately 51 to 80 million m3. The average annual interception rate per tree ranged from a low of 0.4m3 for the crapemyrtle (representative of small trees in the inland zone) to a high of 5.6m3 for the jacaranda (representative of medium trees in the inland zone). The difference is related to tree size and foliation period. The crapemyrtle is small at maturity and is deciduous during the rainy winter season, whereas the jacaranda develops a broad spreading crown and is in-leaf during the rainy season.

Page et al 2104

This study evaluated the hydrologic and water quality performance of two suspended pavement systems using Silva cells in North Carolina. Both were planted with a crepe myrtle but no controls were used to test the influence of the trees on results. Pollutant concentrations were significantly reduced, including TP, TN and TSS. TP reductions were at least 72% and TSS reductions were greater than 86%. TN results were not reported but TKN reductions were 71% and 84%. 80% of runoff at the inlet was captured and treated by the practices. Peak flow was mitigated by 62% for stormwater not generating bypass.

Read et al. 2008

Study authors used a pot trial of 20 Australian species to investigate how species vary in the removal of pollutants from semisynthetic stormwater passing through a soil filter medium. Unplanted controls were used that were irrigated with tap water. Five tree species were included in the mix. While plant species improved pollutant removal compared to unvegetated systems (especially for N and P), the study did not provide specific removal values for tree species versus non tree species.

Roseen et al. 2009

This study monitored pollutant removal performance of 6 LID systems from 2004-2006 to evaluate seasonal variations in performance and the influence of cold climates on performance. These were contrasted with data from conventional and manufactured systems. One of the systems was a street tree/filter. Parameters monitored included TSS, TP, dissolved inorganic N, total Zinc and total petroleum hydrocarbons- diesel range. Seasonal performance evaluations indicate that LID filtration designs differ minimally from summer to winter, while smaller systems dependent largely on particle settling time demonstrated a marked winter performance decline. Frozen filter media did not reduce performance. Reported results for the street tree: efficiency ratios of 88% for TSS, 62% for DIN, and -54% for TP. The efficiency ratio was determined to be a more stable estimate of pollutant removal than removal efficiency because it weighs all storms equally and reflects overall influent and effluent concentrations across the entire dataset.

Sivyer et al. 1997

This study used a pan evaporation model to develop a method for predicting irrigation amount and frequency for street trees and tested it on two newly planted deciduous tree species in Norfolk, VA. The calculated daily transpiration rate for a 3” caliper tree during the growing season was estimated at 2.7 gallons per day.

Soares et al. 2011

This study used i-tree to quantify the value of street trees in Lisbon, Portugal. A numerical interception model accounted for the amount of annual rainfall intercepted by trees, as well as through fall and stem flow. The model estimated that Lisbon’s street trees intercepted approximately 186,773m3 of rainfall annually. On average, each tree intercepted 4.5m3 annually. This estimate was considered to be conservative because the rainfall data used were from a year with lower than normal rainfall.

The Kestrel Design Group 2013

In this paper, literature on ET and rainfall interception are reviewed to provide a basis for quantifying these functions as they relate to stormwater BMPs in the State of Minnesota’s stormwater crediting calculator. The paper reviews the various methods for quantifying ET, including direct versus indirect measure approaches, hydrological, micrometeorological and plant physiology approaches, as well as analytical versus empirical approaches. The authors review the advantages and disadvantages of each approach and recommend use of the Lindsey-Bassuk single whole tree water use equation for estimating ET and crediting trees for associated reductions in runoff. The Lindsey-Bassuk equation requires canopy diameter, leaf area index, evaporation rate per unit of time and evaporation rate as inputs and sources of information for each input are identified.

Wang et al. 2008

This study used the UFORE model, which simulates hydrological processes of precipitation, interception, evaporation, infiltration, and runoff using data inputs of weather, elevation, and land cover along with nine channel, soil, and vegetation parameters. The model was tested in the urban Dead Run catchment of Baltimore, Maryland. Total predicted tree canopy interception was 18.4% of precipitation. Key findings included: trees significantly reduce runoff for low intensity and short duration precipitation events; as LAI increases, interception rate increases as well; trees over impervious cover have a greater runoff reduction effect than trees over turf; as potential evaporation increases, interception increases; greater relative interception was seen with lower intensity storms; increasing tree cover over turf from 12% to 40% resulted in 2.6% runoff reduction; and increasing tree cover over IC from 5% to 40% resulted in 3.4% runoff reduction.

Xiao and McPherson 2003

A mass and energy balance rainfall interception model was used to simulate rainfall interception processes for street and park trees in Santa Monica, CA. Annual rainfall interception by the 29,299 trees was 193,168 m3 (6.6 m3/tree), or 1.6% of total precipitation. Rainfall interception ranged from 15.3% (0.8 m3/tree) for a small *Jacaranda mimosifolia* (3.5 cm diameter at breast height) to 66.5% (20.8 m3/tree) for a mature *Tristania conferta* (38.1 cm). In a 25-year storm, interception by all street and park trees was 12,139.5 m3 (0.4%), or 0.4 m3/tree. Rainfall interception varied seasonally, averaging 14.8% during a 21.7 mm winter storm and 79.5% during a 20.3 mm summer storm for a large, deciduous *Platanus acerifolia* tree.

Xiao and McPherson 2011a

A rainfall interception study was conducted in Oakland, California to determine the partitioning of rainfall and the chemical composition of precipitation, throughfall, and stemflow. Rainfall interception measurements were conducted on a gingko (Ginkgo biloba) (13.5 m tall deciduous tree), sweet gum (Liquidambar styraciflua) (8.8 m tall deciduous), and lemon tree (Citrus limon) (2.9 m tall broadleaf evergreen). The lemon, ginkgo, and sweet gum intercepted 27.0%, 25.2% and 14.3% of gross precipitation, respectively. The lemon tree was most effective because it retained its foliage year-round, storing more winter rainfall than the leafless ginkgo and sweet gum trees. Stemflow was more important for the leafless sweet gum. Because of its excurrent growth habit and smooth bark, 4.1% of annual rainfall flowed to the ground as stemflow, compared to less than 2.1% for the lemon and 1.0% for the ginkgo.

Xiao and McPherson 2011b

A bioswale integrating structural soil and trees was installed in a parking lot to evaluate its ability to reduce storm runoff, pollutant loading, and support tree growth. The adjacent control and treatment sites each received runoff from eight parking spaces and were identical except the control used native soils. A tree was planted at both sites. Storm runoff, pollutant loading, and tree growth were measured. The bioswale reduced runoff by 88.8% and reduced solids (TSS, TDS) by 95.5% and minerals (TP, TKN, NH4, NO3)) by 95.3%. It appears the reductions were calculated based on comparison to that of a control. No runoff was generated at the treatment site for storm events less than 9 mm (70% of events). The engineered soil provided better aeration and drainage for tree growth than did the control's compacted urban soil.

Xiao et al 1998

A one-dimensional mass and energy balance model was developed to simulate rainfall interception in Sacramento County, California. Annual interception was 6% and 13% of precipitation falling on the urban forest canopy for the City of Sacramento and suburbs, respectively. Summer interception at the urban forest canopy level was 36% for an urban forest stand dominated by large, broadleaf evergreens and conifers (leaf area index = 6.1) and 18% for a stand dominated by medium-sized conifers and broadleaf deciduous trees (leaf area index = 3.7). For 5 precipitation events with return frequencies ranging from 2 to 200 years, interception was greatest for small storms and least for large storms.

Xiao et al 2000

A rainfall interception measuring system was developed and tested for open-grown trees. The system was tested on a 9-year-old broadleaf deciduous tree (pear, Pyrus calleryana `Bradford') and an 8-year-old broadleaf evergreen tree (cork oak, Quercus suber) representing trees having divergent canopy distributions of foliage and stems. Interception losses accounted for about 15% of gross precipitation for the pear tree and 27% for the oak tree. Interception losses were attributed primarily to canopy storage. The results also showed that interception losses relative to rainfall decreased with increasing rainfall depth. The analysis of temporal patterns in interception indicates that it was greatest at the beginning of each rainfall event. Rainfall frequency is more significant than rainfall rate and duration in determining interception losses.

Yang and Zhang 2011

In this study the physical and chemical properties of urban soils were characterized for 30 urban sites representing a mix of land cover types and age of development. Three of the site types contained trees and were also the oldest sites (20-30 years) with the least amount of compaction (normal to light). Lawns with trees had the highest final infiltration rate, followed by trees with shrubs but the infiltration rate for these two categories was not significantly different. The highest final infiltration rate was comparable to that of a forest. Measured infiltration rate values for these two land cover types were not provided in the paper.

Zhang et al. 2011

This study was conducted to estimate the fluxes of organochlorine pesticides in rain and canopy throughfall and their contributions to runoff in Beijing. Runoff, rain and canopy throughfall sampling was conducted over a two year period at 3 sites, two of which were completely paved and one of which had a canopy area of 54m2 from landscaping trees. At the impervious sites, the contribution of hexachlorobenzene (HCB) and hexachlorocyclohexanes (HCH)s from rainfall accounted for approximately 50% of the mass in runoff. At the site with significant coverage of landscaping trees, the HCB, HCHs, and DDTs from the net canopy throughfall accounted for approximately 10% of the mass in the runoff. The pollutant concentrations in canopy throughfall represent a combination of wet deposition and the portion of dry deposition that is washed from the canopy during a storm. For some sampling dates, concentrations were higher in rainfall than throughfall, indicating that the leaves may have been relatively clean prior to the storm event and the canopy was therefore able to intercept the pollutants, at least temporarily. Further research is needed to evaluate the effects of retention capacity of leaves, antecedent dry days, and storm characteristics on pollutant concentrations in throughfall.

Appendix D: Tree Mortality Rate Literature Review

(database provided by J. Mawhorter)

Source	State	City	Annual Mortality Rate	Survey period	Sample Size	Tree type
McPherson, G. 2014.	CA	Los Angeles	0.044	2006 - 2010	98	Street
McPherson, G. 2014.	CA	Los Angeles	0.046	2006 - 2010	96	Yard
Roman, L., J. Battles, J. McBride. 2014.	CA	Sacramento	0.066	2007-2012	436	Yard
Ko, Y., J. Lee, G. McPherson, L. Roman. 2015.	CA	Sacramento	0.041	1991-1994	254	Yard
Ko, Y., J. Lee, G. McPherson, L. Roman. 2015.	CA	Sacramento	0.038	1994-2013	92	Yard
Roman, L., J. Battles, J. McBride. 2014.	CA	West Oakland	0.037	2007-2011	995	Street
Koeser, A., E. Gilman, M. Paz, C. Harchick. 2014.	Florida	NA	0.013	2005-2010	2354	NA
Jack-Scott, E., M. Piana, B. Troxel, C. Murphy-Dunning, M. Ashton. 2013.	Connecticut	New Haven	0.025	1995-2011	NA	Street
Jack-Scott, E., M. Piana, B. Troxel, C. Murphy-Dunning, M. Ashton. 2013.	Connecticut	New Haven	0.041	1995-2011	NA	Yard
Jack-Scott, E., M. Piana, B. Troxel, C. Murphy-Dunning, M. Ashton. 2013.	CT	New Haven	0.025	1995-2011	NA	Park
Jack-Scott, E., M. Piana, B. Troxel, C. Murphy-Dunning, M. Ashton. 2013.	CT	New Haven	0.027	1995-2011	NA	Vacant lot
Koeser, A., R. Hauer, K. Norris, R. Krouse. 2013.	WI	Milwaukee	0.011	1989-2005	793	Street
Koeser, A., R. Hauer, K. Norris, R. Krouse. 2013.	WI	Milwaukee	0.019	1979-1989	895	Street
Mincey, S. and J. Vogt. 2014.	IN	Indiana	0.017	2006-2012	6366	NA
Roman, L. and F. Scatena. 2011.	PA	Philadelphia	0.034	1995-2005	151	Street
Nowak, D., J. McBride, R. Beatty. 1990.	CA	Oakland	0.188	1985-1988	480	Street
Sullivan, M. 2004.	CA	San Francisco	0.029	5	1987	Street
Foster, R. and J. Blaine. 1978.	MA	Boston/Beacon Hill	0.061	10	215	Street
Foster, R. and J. Blaine. 1978.	MA	Boston/Bolyston St.	0.140	4	136	Street
Gates, S. and J. Lubar. 2007.	PA	Philadelphia	0.029	2	50	Street
Gates, S. and J. Lubar. 2007.	PA	Philadelphia	0.044	1.5	571	Street
Gates, S. and J. Lubar. 2007.	PA	Philadelphia	0.067	1	705	Street
Miller, R.H. and R.W. Miller. 1991.	WI	Milwaukee	0.124	6	1003	Street
Miller, R.H. and R.W. Miller. 1991.	WI	Waukesha	0.065	6	677	Street
Miller, R.H. and R.W. Miller. 1991.	WI	Stevens Point	0.070	9	368	Street

Lu, J., E. Svendsen, L. Campbell, J. Greenfeld, J. Braden, K. King, N. Raymond. 2010.	NY	New York	0.044	2	45094	Street
Lu, J., E. Svendsen, L. Campbell, J. Greenfeld, J. Braden, K. King, N. Raymond. 2010.	NY	New York	0.036	6	2417	Street
Lu, J., E. Svendsen, L. Campbell, J. Greenfeld, J. Braden, K. King, N. Raymond. 2010.	NY	New York	0.034	8	5053	Street
Lu, J., E. Svendsen, L. Campbell, J. Greenfeld, J. Braden, K. King, N. Raymond. 2010.	NY	New York	0.029	9	5935	Street
Sklar, F. and R. Ames. 1985.	CA	Oakland	0.175	1978-1980	1500	Street
Boyce, S. 2010.	NY	New York City/TriBeCa	0.016	2005-2009	503	Street
Thompson et al 2004	IA	NA	0.023	4	932	NA

Appendix E: Summary of i-Tree Forecast Results for Development of Urban Tree Canopy BMP Credit Development

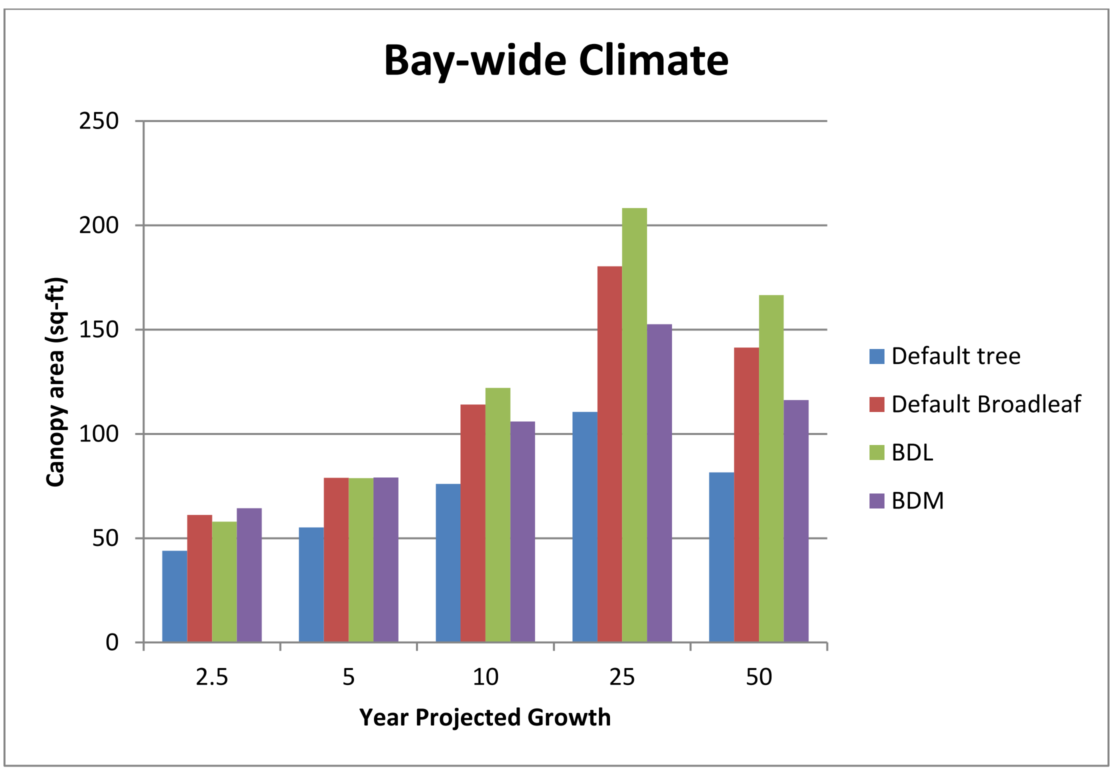
Tree canopy acreage (ft^2) for a single tree planted given a Bay-wide climate (166 FFD).

BDL = broadleaf large; BDM = broadleaf medium; CEL = coniferous evergreen large; CEM = coniferous evergreen medium

A1	Bay-wide (166 FFD)
Age	**Default tree**
2.5	44
5	55
10	76
25	111
50	82

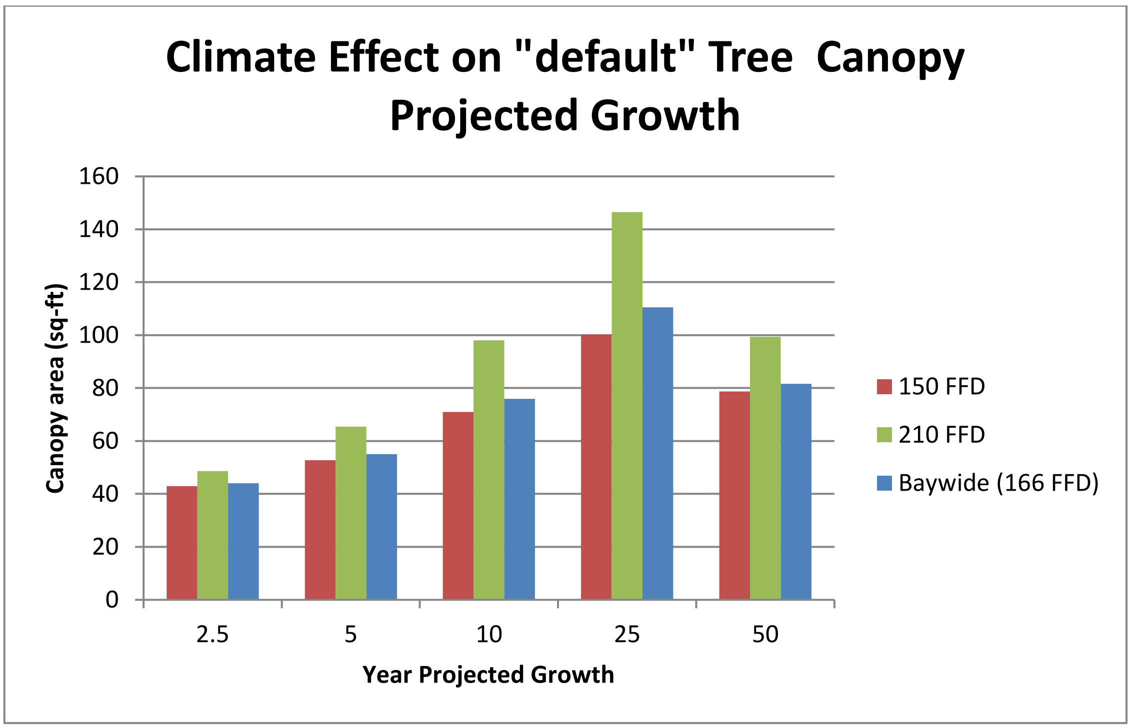
A2	Bay-wide	
Age	**BDL/BDM**	**CEL/CEM**
2.5	61	18
5	79	25
10	114	37
25	180	58
50	141	44

A3	Bay-wide	
Age	**BDL**	**BDM**
2.5	58	64
5	79	79
10	122	106
25	208	153
50	167	116



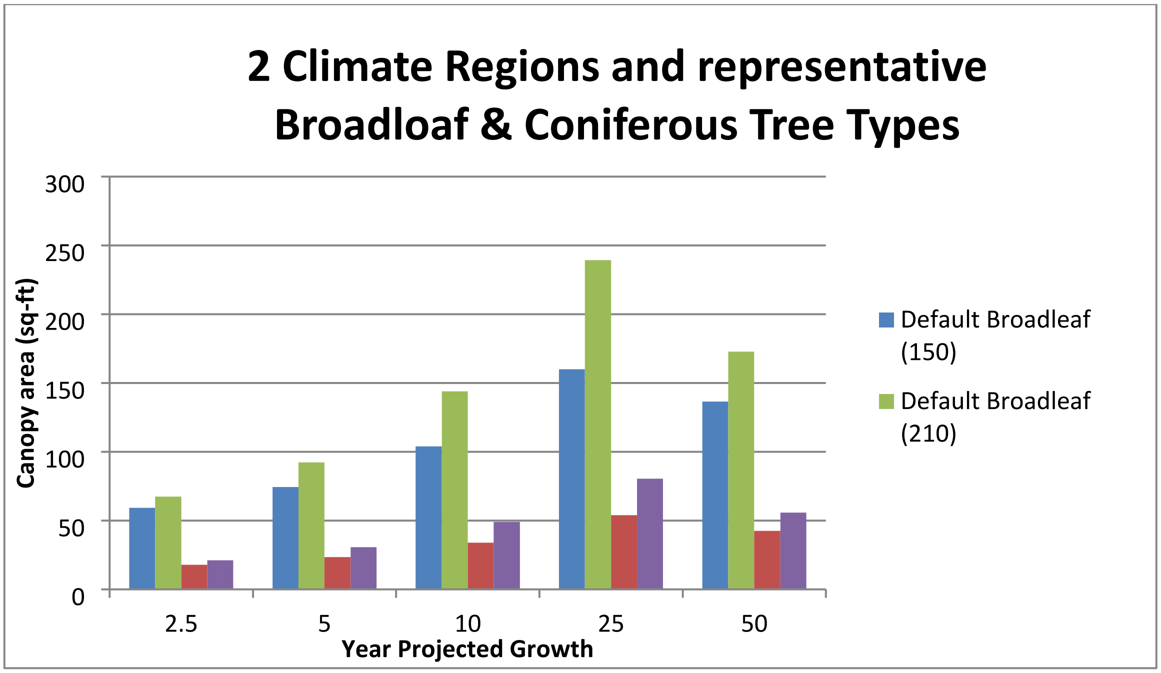
Tree canopy acreage (ft^2) for a single tree planted given two climate regions representative of the Bay Watershed (150 FFD and 210 FFD) for a 'default' tree

B1	150 FFD	210 FFD
Age	**Default tree**	**Default tree**
2.5	43	49
5	53	65
10	71	98
25	100	147
50	79	99



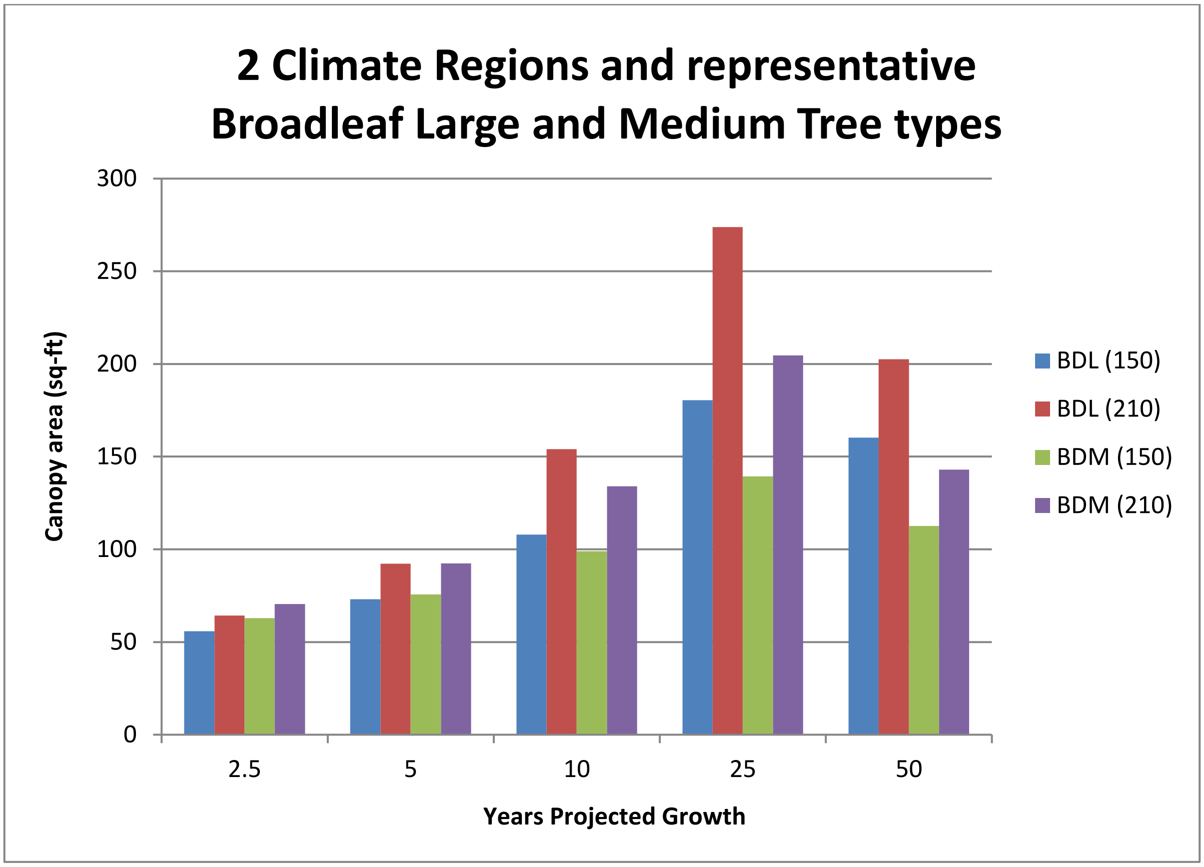
Tree canopy acreage (ft^2) for a single tree planted given two climate regions representative of the Bay Watershed (150 FFD and 210 FFD) for a representative broadleaf tree and coniferous tree. These are based on the average tree canopy of the large and medium tree species for both broadleaf and coniferous trees simulated in i-Tree Forecast.

B2	150		210	
Age	BDL/BDM	CEL/CEM	BDL/BDM	CEL/CEM
2.5	59	18	67	21
5	74	24	92	31
10	104	34	144	49
25	160	54	239	80
50	136	42	173	56



Tree canopy acreage (ft^2) for a single tree planted given two climate regions representative of the Bay Watershed (150 FFD and 210 FFD) for BDL and BDM tree types

B3	150		210	
Age	BDL	BDM	BDL	BDM
2.5	56	63	64	71
5	73	76	92	92
10	108	99	154	134
25	180	139	274	205
50	160	113	202	143


2 Climate Regions and representative
Broadleaf Large and Medium Tree types
Canopy area (sq-ft)
300
250
200
150
100
50
0
2.5
5
10
25
50
Years Projected Growth
BDL (150)
BDL (210)
BDM (150)
BDM (210)

Appendix F: Technical Requirements to Enter Phase 6 Urban Tree Canopy Expansion and Urban Forest Planting BMPs into Scenario Builder

Version: Final (last updated August 31, 2016)

Background: In accordance with the *Protocol for the Development, Review, and Approval of Loading and Effectiveness Estimates for Nutrient and Sediment Controls in the Chesapeake Bay Watershed Model* (WQGIT, 2015) each BMP expert panel must work with CBP staff and the Watershed Technical Workgroup (WTWG) to develop a technical appendix for each expert panel report. The purpose of this technical appendix is to describe how the recommendations of the Urban Tree Canopy Expert Panel and the FWG will be integrated into the Chesapeake Bay Program's modeling tools including NEIEN, Scenario Builder and the CBWM.

Part 1. Technical Requirements for Reporting and Crediting Phase 6 Urban Tree Canopy Expansion BMP

Q1. How is the Urban Tree Canopy Expansion BMP defined in the Phase 6 Chesapeake Bay Watershed Model?

A1. The Urban Tree Canopy Expansion BMP is defined as the planting of trees in an urban area that are not part of a riparian forest buffer, structural BMP (e.g. bioretention, tree planter), or do not conform to the definition of the Urban Forest Planting BMP. The land use area conversion factor is based on the panel's recommendation of 144 sq ft average of canopy per tree planted. Thus, 300 newly planted trees are equivalent to 1 acre of tree canopy land use; however, this is not a planting density requirement and each tree converts 1/300 an acre of either pervious or impervious developed area to tree canopy land uses. This BMP does not require trees to be planted in a contiguous area.

Q2. What are the nutrient and sediment reductions a jurisdiction can claim for Urban Tree Canopy Expansion in the Watershed Model?

A2. The expert panel recommended that the Phase 6 Model treat Urban Tree Canopy Expansion BMP as a land use change to either "tree canopy over impervious" or "tree canopy over turfgrass". The nutrient and sediment reduction credit for a land use change BMP equals the relative, or percent change in nitrogen, phosphorus and sediment load achieved by converting the underlying pervious or impervious land use to the appropriate tree canopy land use. No additional upland reduction will be applied.

Q3. What should jurisdictions submit to NEIEN to receive credit for Urban Tree Canopy Expansion in the Phase 6 Model?

A3. For urban tree plantings, jurisdictions should report the following information to NEIEN:

- *BMP Name:* Urban Tree Canopy Expansion
- *Measurement Name:* Number of Trees Planted

- *Geographic Unit:* Qualifying NEIEN geographies including: Latitude/Longitude; *or* County; *or* Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); *or* State
- *Date of Implementation:* Year the trees were planted
- *Land Uses:* Turfgrass, Roads, Buildings and Other

Q4. Is Urban Tree Canopy Expansion an annual or cumulative BMP?

A4. The credit of this BMP is cumulative, which means that the acres reported in a previous year carry over into the next year.

Q5. Is Urban Tree Canopy Expansion a stackable BMP?

A5. This BMP may be considered a 'stackable' BMP, where additional BMPs may be applied to the underlying land use. For example, urban nutrient management may be applied to the pervious area under the tree canopy. As a land use change BMP, the converted acres will be eligible to receive other urban BMPs reported through NEIEN.

Q6. What is the credit duration for the Urban Tree Canopy Expansion BMP in the Model?

A6. The suggested BMP credit duration is 10 years. Once new high resolution imagery is updated in the model, the trees will be captured through the tree canopy land uses rather than annual BMP submissions. The area of the reported canopy projects within the period of credit duration will continue to be tracked through the BMP history since these projects represent management actions. Once new high resolution imagery is available, changes in the aerial extent of tree canopy will be captured through these data.

Q7. How does the Urban Tree Canopy Expansion BMP avoid the double counting of reductions caused by overlap with the tree canopy land uses or the Urban Forest Planting BMP?

A7. To avoid double counting with existing tree canopy, new acres through Urban Tree Canopy Expansion projects will be tracked and reported as BMPs since they represent on-the-ground management actions. It's assumed that the expansion of canopy through these projects is part of the net change in canopy tracked at different points of time by the high resolution imagery. The environmental models simulate this net change. If there's an overall reduction in canopy between the two points of time, the nutrient and sediment loads will increase because of the changing conditions. If there's a net gain in canopy, nutrient loads will decrease. Again, reported canopy project are part of the overall net change. If there's a net reduction in existing canopy over time through deforestation due to development, the urban tree planting project can be thought of as lessening the degree of the reduction.

Urban Tree Canopy Expansion is reported when planting does not meet the criteria of the Urban Forest Planting BMP. All Urban Forest Planting acres that meet the BMP requirements will be modeled as forest, which is a separate land use than the tree canopy land uses. Urban Tree Canopy Expansion converts either developed turfgrass or developed impervious land uses to tree canopy land uses. Therefore, there is no double counting between these BMPs.

Q8. How do the panel's recommendations for Urban Tree Canopy Expansion affect ongoing historical BMP data cleanup efforts of the jurisdictions?

A8. Jurisdictions should report tree canopy expansion projects with the associated planting date going back to 1985 – for which they have data. Jurisdictions should not report overall net changes in canopy since these are captured through changes in imagery data with prescribed methods. Jurisdictions should consult the BMP definitions to determine which historical BMP acres align with the Phase 6 definitions for Urban Tree Canopy Expansion or Urban Forest Planting.

Part 2. Technical Requirements for Reporting and Crediting Phase 6 Urban Forest Planting BMP

Q9. How is the Urban Forest Planting BMP defined in the Phase 6 Chesapeake Bay Watershed Model?

A9. The Urban Forest Planting BMP is defined as tree planting projects in urban or suburban areas that are not part of a riparian buffer, structural BMP, or Urban Tree Canopy Expansion BMP, with the intent of establishing forest ecosystem processes and function. This requires that urban forest plantings be documented in a planting and maintenance plan that meets state planting density and associated standards for establishing forest conditions, including no fertilization and minimal mowing as needed to aid tree and understory establishment. Under this BMP, trees are planted in a contiguous area as documented in the planting plan and the acreage of this BMP is converted from the developed turfgrass land use into forest in the modeling tools.

Q10. What are the nutrient and sediment reductions a jurisdiction can claim for Urban Forest Planting in the Watershed Model?

A10. Urban Forest Planting is a land use change BMP converting developed turfgrass to forest. The nutrient and sediment reductions will correspond to the unit area loading of converting the developed turfgrass land use to forest land use in the model segment the BMP is applied.

Q11. What should jurisdictions submit to NEIEN to receive credit for Urban Forest Planting in the Phase 6 Model?

A11. For urban forest plantings, jurisdictions should report the following information to NEIEN:

- *BMP Name:* Urban Forest Planting
- *Measurement Name:* Acres Planted
- *Geographic Unit:* Qualifying NEIEN geographies including: Latitude/Longitude; *or* County; *or* Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); *or* State
- *Date of Implementation:* Year the trees were planted
- *Land Uses:* Turfgrass

Q12. Is Urban Forest Planting an annual or cumulative BMP?

A12. The credit of this BMP is cumulative, which means that the acres reported in a previous year carry over into the next year.

Q13. Is Urban Forest Planting a stackable BMP?

A13. No. Since this BMP is a conversion to the forest land use, additional urban BMPs are not applicable.

Q14. What is the credit duration for the Urban Forest Planting BMP in the Model?

A14. The suggested BMP credit duration is 15 years. Once new high resolution imagery is updated in the model, the trees will be captured through the forest land use rather than annual BMP submissions.

Q15. How does the Urban Forest Planting BMP avoid the double counting of reductions caused by overlap with the forest land use or the Urban Tree Canopy Expansion BMP?

A15. To avoid double counting with existing tree canopy or forest, new acres through Urban Forest Planting projects will be tracked and reported as BMPs since they represent on-the-ground management actions. It's assumed that the expansion of forest through these projects is part of the net change in forest tracked at different points of time by the high resolution imagery. The environmental models simulate this net change. If there's an overall reduction in forest between the two points of time, the nutrient and sediment loads will increase because of the changing conditions. If there's a net gain in forest, nutrient loads will decrease. Again, reported forestry projects are part of the overall net change. If there's a net reduction in forest over time due to deforestation or fragmentation from development, the urban forest planting project can be thought of as lessening the degree of the reduction.

Urban Tree Canopy Expansion is reported when planting does not meet the criteria of the Urban Forest Planting BMP. All Urban Forest Planting acres that meet the BMP requirements will be modeled as forest, which is a separate land use than the tree canopy land uses. Urban Tree Canopy Expansion converts either developed turfgrass or developed impervious to tree canopy land uses. Therefore, there is no double counting between these BMPs.

Q16: How does the recommended Phase 6 Urban Forest Planting BMP affect ongoing historical BMP data cleanup efforts of the jurisdictions?

A16. Jurisdictions should report forest planting projects with the associated planting date going back to 1985 – for which they have data. Jurisdictions should not report overall net changes in forest since these are captured through changes in imagery data with prescribed methods. Jurisdictions should consult the BMP definitions to determine which historical BMP acres align with the Phase 6 definitions for Urban Tree Planting or Urban Forest Planting.

Appendix G: Conformity with BMP Review Protocol

The BMP review protocol established by the Water Quality Goal Implementation Team (WQGIT, 2015) outlines the expectations for the content of expert panel reports. This appendix references the specific sections within the report where the panel addressed the requested protocol criteria.

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

2. **Practice name or title:** *Urban Tree Canopy Expansion and Urban Forest Planting*

   Detailed definition of the practice: *See Section 2 for detailed definition Urban Tree Canopy Expansion and Urban Forest Plan BMPs.*

3. **Recommended N, P and TSS loading or effectiveness estimates:** *See Table 8 in Section 5.2.1 and Appendix B for Urban Tree Canopy Expansion BMP and Appendix F (Q10) for Urban Forest Planting BMP*

4. **Justification of selected effectiveness estimates:** *See Appendix B for the Urban Tree Canopy Expansion BMP and Appendix H for Urban Forest Planting BMP*

5. **Description of how best professional judgement was used, if applicable to determine effectiveness estimates:** *See Appendix A, with additional information in Sections 5.2 and 5.3 related to the creditable area of this BMP for the Urban Tree Expansion BMP and Appendix H for the Urban Forest Planting BMP.*

6. **Land uses to which BMP is applied:** *Impervious and Turfgrass land uses in the future Phase 6 CBWM.*

7. **Load sources that the BMP will address and potential interactions with other practices:** *The Urban Tree Canopy Expansion BMP will address pollutant loadings from Impervious and Turfgrass land uses in the Bay watershed. The report recommendations provide qualifying conditions to report the BMP as a BMP as part of new development, redevelopment and/or retrofit. Tree planting will convert impervious and turfgrass land uses to Tree Canopy over Impervious and Tree Canopy over Turfgrass land uses. Urban nutrient management may be applied to Tree Canopy Over Turfgrass Land uses.*

   The Urban Forest Planting BMP will address pollutant loadings from Turfgrass land uses in the Bay watershed. The Urban Forest Planting BMP will convert turfgrass land uses to forest in Phase 6. No *urban BMPs are applicable to the forest land use and would not be applied to the acreage of converted turfgrass*.

8. **Description of pre-BMP and post-BMP circumstances and individual practice baseline:** *See Appendix B for Urban Tree Canopy Expansion BMP and Appendix H for Urban Forest Planting BMP.*

9. **Conditions under which the BMP works/not works:** *Section2 describes conditions under which the Urban Tree Expansion BMP would not apply and Appendix H describes conditions under which the Urban Forest Planting BMP would not apply.*

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

11. Unit of measure: *Acres*

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

13. Useful life of the BMP: *For the purposes of this report, the useful life, or duration, of the Urban Tree Canopy Expansion BMP is a minimum of 10 years but may be longer based on the Chesapeake Bay Program update of the Tree Canopy over Impervious and Tree Canopy over Impervious land uses. The Urban Forest Planting has a minimum lifespan, or duration, of 15 years.*

14. **Cumulative or annual practice:** Cumulative

15. Recommended description of how BMP will be tracked and reported: *See Section 6 for discussion of how state governments can track and report to the Bay Program for the Urban Tree Canopy Expansion BMP. See Appendix F (Q11) for the Urban Forest Planting BMP.*

16. Guidance on BMP Verification: *See Section 6 for the Urban Tree Canopy Expansion BMP and Appendix H for Urban Forest Planting BMP.*

17. **Description of how the practice may be used to relocate pollutants to a different location.** *See Appendix B for Urban Tree Canopy Expansion BMP and Appendix H for Urban Forest Planting BMP.*

18. **Suggestion for review timeline; when will additional information be available that may warrant re-evaluation of the practice effectiveness estimates:** *It is recommended that the Urban Tree Canopy Expansion BMP be re-evaluated in 2025, or sooner pending outcome of research needs identified in Section 7. A recommendation to re-evaluate the Urban Forest Planting BMP is not provided in this report beyond the expectation of periodic evaluation stated in the BMP Protocol.*

19. **Outstanding issues:** *See Section 7 for a discussion of future research needs to address outstanding issues related to the Urban Tree Canopy Expansion BMP.*

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

21. **Operation and Maintenance requirements and how neglect alters the practice effectiveness estimates.** *The method used to derive the creditable area for this BMP accounts for mortality that would result if proper maintenance is not provided. Therefore, not other alterations in practice effectiveness is provided.*

22. **A brief summary of BMP implementation and maintenance costs estimates, when this data is available through current literature:** *Not applicable*

23. **Technical Appendix:** *See Appendix F*

Appendix H: Response to the Urban Tree Canopy BMP Expert Panel Report – Forestry Workgroup proposal to add Urban Forest Planting BMP

Prepared by Justin Hynicka for the CBP Forestry Workgroup, edited by Marian Honeczy and Anne Hairston-Strang, MD DNR Forest Service

Version: August 3, 2016

[Editor's Note: The Forestry Work Group submitted the following recommendation to the Expert Panel for consideration in June 2016 as part of the response to comments received by the Partnership. Subsequent discussions with the Partnership resulted in the modifications to this initial recommendation that are reflected in Appendix F of the report]

<u>Background</u>

Buildings, impervious surfaces, and overhead and underground utility lines often restrict tree planting opportunities in urban areas. Due to these physical restrictions, tree plantings in urban areas routinely feature isolated trees (e.g. street trees) that have high air quality and aesthetic value among other benefits, but lower water quality function compared to more extensive forests. The recommendations by the CBP Urban Tree Canopy Expert Panel advance the accuracy of CBP nutrient load estimates, particularly within the first ten years after planting, by defining and creating a new BMP for tree planting activities in developed areas with lower nutrient reduction credit than forested lands. However, this BMP does not reflect the wide range of tree planting activities in developed areas. Some tree planting programs have and will continue to be designed to restore forest or forest-like conditions. For example, in Maryland, the state's Lawn to Woodland program, as well as similar county-level programs, is designed to convert larger turf grass areas back to forest.

The Phase 6 Urban Tree Planting BMP, as recommended by the Expert Panel, relies on the nutrient loading rates of the Tree Canopy Land Use. Yet, the scale and common maintenance practices of reforestation-focused programs in developed areas distinguish them from this BMP. Tree Canopy loading rates are intended to be used for areas with trees where the land-management activities are unknown and therefore assumed to be managed in a manicured fashion similar to turf grass. Turf grass management includes weekly mowing and a moderate probability of fertilization, whereas maintenance of a reforestation-focused planting site typically includes infrequent mowing (e.g., three or fewer times per year) and no fertilization. Therefore, the higher level of nutrient reduction credit is reasonable and justified given more rigorous standards for forest-planting without fertilization, and maintenance to enhance tree survival and mimic meadow like conditions early in the establishment period. Moreover, a two-tiered credit system matches the Chesapeake Bay Program's Phase 6 land use mapping scenarios expected every five years (both forest and tree canopy areas exist in developed areas), and helps harmonize tree cover and water quality goals at the local level.

The Forestry Work Group recommends crediting the urban forest planting with the credit of a conversion to Forest. Young reforestation plantings in rural areas are also considered to be Forest in the Bay Model. But because it can be more difficult to re-establish forests in the developed sector, these plantings must adhere to certain criteria to ensure the likelihood that they will survive and function as a forest. These criteria, developed by foresters and approved by the Forestry Workgroup, are listed below. Furthermore, these forest-plantings are likely to qualify as Forests when the Land Use model is updated because they adhere more closely to the definition of Forest Land Use and less similar to the definition of Tree Canopy Land Use in Phase 6.0.

<u>Summary of existing and proposed urban tree planting BMPs:</u>

Note: *Please refer to Urban Tree Canopy Expert Panel Report for a complete explanation of recommended changes to the Urban Tree Planting BMP credit for Phase 6 of the Chesapeake Bay Watershed Model. (latest report documents posted here:* *http://www.chesapeakebay.net/calendar/event/24041/)*

Existing credit system (Phase 5.3.2): Urban Tree Planting BMP

- 100 trees planted = 1 acre of land use change to *forest*

Proposed credit systems:

1. Expert Panel recommended credit (Phase 6): Urban Tree Planting BMP
    - 300 trees planted = 1 acre of land use change to *tree canopy*
    - equal to ~10% of existing credit
    - replaces existing credit system

2. Forestry Workgroup's recommended two-tiered system (Phase 6):
    - Tier 1: Urban Tree Planting BMP - 1 acre of land use change to *tree canopy* (default) *[same as Expert Panel recommendation]*
        - 300 trees planted = 1 acre of land use change to *tree canopy*
        - ~10% of existing Phase 5 credit
        - Report: trees planted (to convert to acres for the model)
        - BMP name: Urban Tree Planting

- BMP credit duration: 10-years (after which, credit is assumed to be captured in high resolution land cover data)

- Tier 2: Urban Forest Planting BMP - 1:1 acres of land use change to *Forest* (see eligibility below)
    - Credited as land use conversion from urban turf land use to Forest
    - Report: acres planted
    - BMP name: Urban Forest Planting
    - BMP credit duration: 15-years (after which, credit is assumed to be captured in high resolution land cover data)

The Urban Forest Planting BMP is reserved for projects in urban or suburban areas designed to re-establish forest ecosystem processes (e.g., nutrient cycling), which require a contiguous community of native trees, shrubs, herbaceous plants, and other organisms. We define these types of projects as: tree planting projects in urban or suburban areas of at least ¼ acre in size and minimum width of 50 ft and having little to no disturbance of the understory except to aid tree establishment, manage for conditions that improve forest health, and natural causes that may impact understory conditions. This management does not include the occasional maintaining or mowing of grass lawn or turf.

To be eligible for the higher tier of credit, an urban forest planting project must be documented in a PLANTING PLAN containing the following information:

A contiguous planting area of 1/4 acre or greater AND minimum width of 50 ft (this prevents the planting from being picked-up as Tree Canopy in the next iteration of the Land Use Model).

- A map of the planting area and a vicinity map or other means of locating the planting area
- A nursery order form, list or receipt of the number and species of trees to be planted
    - The majority of trees must be native trees that are medium or large overstory species (e.g. oaks, elms, willows, sycamore)
    - Planting standards, including stocking density and survival rates, should follow state recommendations.
- A post-planting maintenance schedule, plan, or program including elements such as:
    - Years 1-5: identify methods to suppress weed competition, protect from deer and other herbivores, control invasive species, and re-plant as necessary
    - Years 7-10: evaluate survival and the need for thinning or re-planting of trees
    - Years 10+: thin forest stand as necessary and seed for understory species if not present

Pending approval of this recommended crediting approach, a planting plan template and guidelines for BMP review/reporting will be developed by the Forestry Workgroup for consideration by the jurisdictions' in their Verification/Quality Assurance Project Plan (QAPP) procedures.

Appendix I: Compilation of comments and responses received during Partnership review and approval process

Source	Comment	Response	Label
	Comments are verbatim from email or the attachment sent to the panel coordinator. Comments may be separated into different rows for providing a response. Comments are organized by the source. Order is not a statement of significance, it was simpler to organize by the source and separate the statements/comments by topic within that source.		Land Use loading rate; mapping; reporting and tracking; modeling; BMP verification; future research needs; FWG proposal; edits
Marian Honeczy, MD DNR	1) The document doesn't address the different types of tree planting. Will mitigation planting be eligible as well as voluntary planting? Will WIP plantings be eligible as these are for mitigation purposes? If mitigation plantings are not to be included, I would argue that there is a misconception that all mitigation tree planting is to mitigate for tree loss. The MD Forest Conservation Act requires forest mitigation for land use change or ground disturbance - not only forest impact. Mitigation can be for ground disturbance (afforestation) as well as for forest impact (reforestation). Afforestation should be allowed to be used for UTC purposes.	The panel's recommendations do not affect the existing Forest Conservation Act BMP that is currently tracked and reported in the Phase 5.3.2 Watershed Model. Generally, credit toward TMDL nutrient and sediment targets are not applicable for practices installed for regulatory mitigation purposes (e.g. wetland mitigation). The partnership followed this approach for Urban Tree Planting BMP in Phase 5.3.2 and the panel's Phase 6 recommendations do not change it. Edits made to clarify the non-applicability of tree planting for mitigation purposes. (Section 5.4)	Tracking and reporting; modeling
Marian Honeczy, MD DNR	2) There appears to be an underlying theme in the document that UTC is an urban activity. Urban meaning Baltimore City - highly paved, low forest canopy. The CB Agreement applies to almost all of Maryland including urban, urban-suburban, suburban and rural land use classifications. In order to accomplish the CB Agreement goals all areas will need to increase canopy coverage. This document should reflect that. See comment for Section 5 pg 18.	The panel was formed to look at areas that are considered "urban" or "developed" for CBP modeling purposes. This includes urban and suburban areas or any "developed" land uses in the Phase 6 Watershed Model as determined by the partnership's Phase 6 mapping and imagery procedures outside this panel's purview. Generally, these "developed" areas coincide with Urban Area Urban Cluster (UAUC) boundaries, which were most recently set by the 2010 Census. Areas classified under agricultural land uses in Phase 6 will continue to be covered under the existing Tree Planting BMP for that sector. Edits will be made to Section 2 prior to finalizing the report to clarify the applicability of the BMP for Phase 6.	Edit

Marian Honeczy, MD DNR	3) The document doesn't specify who will be reporting. Will the entity (town, state or non profit) planting the trees input the data or will the state? Will those planting the trees be responsible to verify the survival rate either through field work or via mapping or will that responsibility fall to the states?	The state ultimately reports the BMP implementation to the CBP, but other entities will report their data accordingly to the state. The details of the process will vary by jurisdiction. Details about verification and the role for the implementing agencies are described in the Forestry Workgroup's BMP Verification Guidance. The procedures and protocols for BMP verification are determined by the state and documented in their Quality Assurance Project Plan (QAPP) submitted to EPA for the BMP data that they report to EPA. The collection and application of the hi-resolution mapping is yet to be determined, but will likely be a joint effort between CBP staff and state partners.	Tracking and reporting; BMP verification Modeling
Marian Honeczy, MD DNR	4) The CB goal is to plant x acres by 2025 but the trees planted in 2016 won't appear or count as land use by 2025 as the 2017/2018 and 2022/23 mapping cycle won't capture the planting. So aren't we just tracking the planting as a BMP credit ?	All acres of land use change BMPs like Urban Tree Planting receive credit between updates to satellite imagery-based land use data. Since tree canopy is updated based on annual BMP submissions and periodic land use updates there is a potential risk for double counting the benefits in the model simulations. This double counting can be avoided or minimized by applying the same model procedures that are applied to all land use change BMPs. Specifically, all acres of land use change BMPs such as Urban Tree Planting receive an annual credit between updates to satellite imagery-based land use data. Following an update all historic implementation effort will still be tracked toward milestones set by the jurisdictions and all new implementation will be counted as a land use change. This avoids double-counting in the model simulations while demonstrating implementation and effort toward milestone goals Text added to report (Section 6)	Tracking and reporting

Marian Honeczy, MD DNR	5) There are references to CBP, CBP Partners and CB partnership and Partnership throughout the document. If these reference the same entity, revise to reflect one name.	CBP refers to the Chesapeake Bay Program itself or its staff, whereas CBP Partnership or Partnership refer to the wider organization that includes signatory members and other non-governmental partners, and CBP partners refers to those partners, which includes the federal and academic staff located at the CBP in Annapolis, MD.	No Edit
Marian Honeczy, MD DNR	6) Section 2: Definitions pg 3. The definition of forest land use states that it is "defined and mapped" and includes the definition or how the area is identified. The definition of tree canopy land use states how these areas are defined or identified but is missing the "mapped" or recordation aspect as stated in forest land use. Is this mapped areas or acres collected by database or "see section x for data collection by CBP".	Will add the word “mapped” to the tree canopy land use definition	Mapping and imagery Edit
Marian Honeczy, MD DNR	7) Section 2: Performance Measure pg 4. There is mention of the BMP being a "stackable" BMP. Does this include only other non forest BMP or any BMP? A twist to this, could the BMP be "counted" for other purposes after it is included in the BMP database/mapping? A suggestion that the first sentence second paragraph be expanded to explain the carryover. My understanding is that this accounts for the continuing tree growth and continuing effect on loading rates. (The hint that tree replacement and maintenance is beneficial.)	“Stackable” means that other BMPs can be applied in addition to this BMP in the model. Urban BMPs could be applied to the same acres as the Urban Tree Planting land use change BMP in Phase 6. Non-urban BMPs, such as cover crops, would not be applicable. For example, the same acre that is converted to Tree Canopy over Turfgrass can then be treated by Urban Nutrient Management, and could also be treated by a stormwater wet pond. To clarify, the BMP is cumulative for annual progress report purposes and is counted towards the jurisdictions’ implementation milestones; this “database” of BMP implementation is different from the land use data that is mapped using hi-resolution imagery. The annual BMP submissions would be credited based on expected average canopy growth per tree planted, as described in the panel’s report. The hi-resolution imagery will capture net changes in tree canopy. Together the annual BMP data and the periodic imagery data provide the partnership with information about implementation and changes on the ground.	Modeling

Marian Honeczy, MD DNR	8) Section 3.2: .... Represented in Phase 6 Watershed Model pg 6. Found the description of the 90% versus 10% confusing / unclear. Paragraph over table is confusing. Does the entire paragraph refer to Phase 6 or Phase 5.3.2? Got confusing in the middle. Table 2 column titles need a key for CSS and MS4 so abbreviations are clearly understood by all.	Edits made to the paragraph noted to clarify this is in reference to Phase 6.	Edits
Marian Honeczy, MD DNR	9) pg 13 Table 5. Column titles need a key so abbreviations are clearly understood by all.	Edits made to the column headers.	Edits
Marian Honeczy, MD DNR	10) pg 14 Table 5. Page et al 2014. Should it state 71, 84 or 71 - 84?	The values represents results of a study from two different sites. Edits made in Table 5.	Edits
Marian Honeczy, MD DNR	11) pg 15 Table 6. See previous Key comment.	Edits made to headers	Edits
Marian Honeczy, MD DNR	12) pg 15 Leaf Litter second paragraph. Second sentence, reference to Scientific and Technical .... does not make sense.	The Science and Technical Advisory Committee is a body of the Chesapeake Bay Program Partnership. The report is based on a workshop they supported.	Edits
Marian Honeczy, MD DNR	13) Section 5: Protocols pg 18 top paragraph. Development throughout the Chesapeake Bay area is not the same as development or forest loss in Baltimore City as implied by referencing Nowak and Greenfield's research.	Edit made to the text clarifying 'city tree cover' in reference to work by Nowak and Greenfield (2012)	Edits
Marian Honeczy, MD DNR	14) Section 5.1 The Metric pg 18 - 19. The results should be highlighted to reflect the importance - here's is how it will be counted.	This section provides a review of the Phase 5.3.2 credit with information on the recommended credit in later sections after new method is described. No edits made.	Edit s
Marian Honeczy, MD DNR	15) Section 5.2 Table 8. Column titles are written out and not abbreviations as per the previous tables. I like it written out but am fine with a key. Need consistency.	No edits needed	Edits

Marian Honeczy, MD DNR	16) Section 5.2 unknown table pg 23. Is this Figure 2 in addition to Figure 2 on pg 24?	I cannot locate this "unknown table". Yes, it is the same Figure 2. Edits made to specify "2a" and "2b"	Edits
Marian Honeczy, MD DNR	17) Section 5.4 Final Recommendations pg 30. The CB goal is to plant x acres by 2025 but the trees planted in 2016 won't appear or count as land use by 2025 as the 2017/2018 and 2022/23 mapping cycle won't capture the planting. So aren't we just tracking the planting as a BMP credit ? Regarding qualifying conditions, guidance on the acceptable methods of determining existing land cover (impervious vs turfgrass) should be included in the reporting guidance document.	The mapping cycle will be determined and the dates provided in the report are our best estimate. As currently stated, the BMP will be tracked as acres of land use change to tree canopy over impervious or pervious. The determination of underlying land use would be observational and reported as optional given the feedback we received from the FWG to keep the information reported very basic from partners for tree planting. Text added "This information would be provided based on site conditions at the time of planting."	Tracking and reporting
Marian Honeczy, MD DNR	18) Section 6 Accountability pg 32: The last paragraph should be highlighted such as "recommendation" as it explains an important rule to the credit.	In review of the text, the paragraph referenced is redundant and will be deleted.	Edits
Marian Honeczy, MD DNR	19) Section 6 Verification pg 33 second paragraph. After (CBP, 2014), the sentence uses term "commendations" should this be "recommendations"? The verification process does not require field work or counting of trees yearly or after 10 years but verification via the mapping is acceptable. Will this verification be required of the local or state governments or by the entity that did the planting?	Spelling error corrected. Defer to FWG verification guidance and that being developed by States and District. The FWG has already written verification guidance and the jurisdictions have submitted their initial verification plans as a part of their QAPP to EPA for BMP data submissions.	Edits; BMP verification
Marian Honeczy, MD DNR	20) Appendix E. Should there be a table for default broadleaf CEL/CEM? These categories are included at the top of the page. Do the A1, A2, A3, B1,etc have a meaning? B1 default tree column headers refers to what tree? Title 2 Climate Regions for last tow charts refers to what? Maybe Climate 2 Regions is better reference	Appendix E provides the full set of i-Tree Forecast output that was used to inform the Expert Panel recommendations. The Expert Panel decided to recommend a single credit for any tree planted.	Edits
Marian Honeczy, MD DNR	21) pg 115 #4 spelling error. #7 Need to capital titles similar to #8.	Spelling and capitalization corrected	Edits
Arlington Co (VA) Dept. Parks & Rec	Throughout, but particularly the finding of no unintended consequences on page IV:	The proposed addition of an Urban Forest Planting BMP is associated with an unmanaged understory in order to	FWG proposal

	The use of "turfgrass" as the only alternative for understory underneath tree canopy is insufficient. While trees over turfgrass should be credited, this does not reflect the natural state of our forests. Our natural forest understory has shrubs, herbaceous cover, and a duff/leaf layer, providing significantly higher value than trees over turfgrass. I suggest adding a category for trees over herbaceous/shrub, or not specifying turfgrass at all. If no stormwater benefit research exists on the value of these complete vertical forests, this needs to be performed. Not including this option could be very counter-productive, with requirements to maintain turfgrass, where a forest can provide a wider range of benefits, including, potentially, higher stormwater benefit (the research mentioned on page 12 shows the value of leaf litter and understory on stormwater infiltration (Bartens et al.; Kays 1980)). Additionally, turfgrass often competes strongly with our native forest, as it prefers higher pH ranges, which explicitly excludes whole groups of tree species from succeeding with this BMP. The explanation on page 46 is not sufficient to exclude these multi-story plantings, as many communities explore planting understory plants with the trees planted, to provide a fuller spectrum of benefits. Even properly-applied mulch and compost can be a sufficient groundcover for water retention, as research has shown.	mimic forest-like conditions that are distinct from managed turfgrass or compacted urban soils. A summary of the Expert Panel response to the proposal and recommendation is provided above. However, there was not consensus amongst the panel to accept the proposal. The underlying land cover is prescribed by the two new land uses for the Phase 6 model. The literature and research on urban tree canopy, with managed or unmanaged, understory is very limited. Therefore, quantification of the water quality benefit recommended by the BMP is limited to the two tree canopy land uses.	Research
Arlington Co (VA) Dept. Parks & Rec	General: Consider encouraging native planting, where appropriate, for greater added benefit to the Chesapeake Bay. Invasive non-native tree species, while not currently counted as stormwater pollution, do cause similar damage to our ecosystems, affecting the Chesapeake Bay in a broad way.	Text added in "Qualifying Conditions". "Tree planting projects are encouraged to represent a selection of native species. "	edit

Arlington Co (VA) Dept. Parks & Rec	Page 29: Not crediting evergreen trees because they tend to be planted less is not enough justification not to provide credit. Evergreen trees are an important part of our forest ecosystems, and can provide year-round stormwater interception.	Coniferous trees can be planted and reported under the recommended BMP. See text on page 31 as part of Recommendation 3, "…This recommendation does not limit the type or density of trees planted that are eligible for credit. The credit applies to all tree types, whether planted individually or in a contiguous area (i.e., trees other than broadleaf species may be planted)."	Tracking and reporting
Arlington Co (VA) Dept. Parks & Rec	General: Research should be performed on the cost of growing plantable trees. There is an explicit cost and stormwater pollution impact from the facilities needed to grow the trees for these BMPs, which needs to be factored into comparing planting Vs. Preservation of tree canopy.	Added the following text to 4th bullet future management research needs " ..A cost-benefit analysis comparing the benefits of planting new trees with tree conservation should be a part of this research."	Edit
Arlington Co (VA) Dept. Parks & Rec	General: Continue research on conservation over planting. Conservation of existing forestland, soils, and hydrology is critical to the survival of the Bay's ecosystem, and planting, while an important aspect of forestry, often does not fully replace a lost forest and its function.	The panel agrees that the conservation and protection of existing tree canopy and forested areas is critical to the overall Bay ecosystem as well as to water quality. Please see Sections 5 (p. 17) and 7 (p. 35) of the report	No edits
Arlington Co (VA) Dept. Of Env Services	General: Need a detailed calculation example of how to claim the credit in year 1 of the tree planting, what to do in years 2-10, and then after year 10.	The nutrient and sediment reductions from the land use change are the same in years 1-10. An example calculation will be added.	Edit
Arlington Co (VA) Dept. Of Env Services	General: Consider providing a general default computational method, regardless of tree type, dbh, etc. With jurisdictions planting hundreds and even thousands of trees per year, the database accounting will get very complicated. The intent here is to account for 'every tree' in a way that captures the benefits for regulatory compliance accounting purposes, without creating excessive accounting complexity.	This is what the panel strove to do with the proposed Urban Tree Planting BMP for the Phase 6 Watershed Model. The panel's methods and the use of the i-Tree Forecast tool provide a reasonable estimate of the average tree canopy that can be expected per tree planted (144 sq ft.) accounting for a range of variables (mortality, common species, light exposure, etc.) that apply in urban and suburban areas.	Edit (to provide example calculation for clarification)
Arlington Co (VA) Dept. Of Env Services	Page 22, Table 8: For street trees in residential areas (and some other areas) the underlying surface will often be a combination of turf and impervious. Can you consider providing ''blended' % reduction rates explicitly in the table?	The benefits of all BMPs are often "blended". If a jurisdiction does not know the specific type of land use the BMP treats, e.g., whether it's pervious or imperious or, in this case, "blended", the BMP is reported by a more-general land use category (e.g., urban) and the modeling tools proportion the treated acres among all land use types	Modeling

		in the larger category according to the relative proportion of acres among the land use types.	
Arlington Co (VA) Dept. Of Env Services	Page 31, recommendation #4: This section is confusing re pre vs post 10 year timeframe and crediting. Earlier in the report it suggests the Land Use updates by the Bay program will take on the ground tree canopy into account, suggesting that any tree at or beyond 10 years from planting will no longer be credited as an individual tree but instead will be accounted for as 'tree canopy' land use. Please clarify.	All acres of land use change BMPs like Urban Tree Planting receive credit between updates to satellite imagery-based land use data. Following an update all historic implementation effort will still be tracked toward milestones set by the jurisdictions and all new implementation will be counted as a land use change. This avoids double-counting in the model simulations while demonstrating implementation and effort toward milestone goals.	Tracking and reporting; modeling
Baltimore County	1. **Baltimore County is concerned with the 10 year growth/mortality analysis, and timing of the new aerials and LiDAR as it pertains to verification.**		
Baltimore County	a. **We recognize that the model is based on good information derived from i-Tree tools, but has the model been tested to support the conclusion that "on average, a 10 year old tree will appear in tree canopy land use data"? Baltimore County has many years of experience with reforestations and many of our plantings show up on aerial imagery, two years after planting.** What percentage of plantings might be healthy and growing but don't show up or are too small at the 10 year mark, resulting in a loss of BMP credit with no land use credit?	All acres of land use change BMPs like Urban Tree Planting receive credit between updates to satellite imagery-based land use data. Following an update all historic implementation effort will still be tracked toward milestones set by the jurisdictions and all new implementation will be counted as a land use change. This avoids double-counting in the model simulations while demonstrating implementation and effort toward milestone goals.	Tracking and reporting; modeling
Baltimore County	b. **Dates of tree plantings and aerial/LiDAR acquisition will not line up neatly and there will be gaps when a planting provides 0 credit.** IF BMP credit is lost 10 years after planting, and tree canopy credit cannot be taken until tree canopy land cover data is available, plantings will receive 0 credit during this gap. Baltimore County is concerned that the timing of new aerials and LiDAR will not match up and there will be a gap	All acres of land use change BMPs like Urban Tree Planting receive credit between updates to satellite imagery-based land use data. Following an update all historic implementation effort will still be tracked toward milestones set by the jurisdictions and all new implementation will be counted as a land use change. This avoids double-counting in the model simulations while demonstrating implementation and effort toward milestone goals.	Tracking and reporting; modeling

		between losing the UTC BMP Credit and receiving the land use conversion. This gap will be largest for plantings done immediately after aerials/LiDAR are acquired, and will shrink to a minimum for plantings done immediately before aerials/LiDAR are acquired. ***<u>We recommend that jurisdictions do not lose the UTC BMP until they receive the land use conversion. Aerial photography can be used to verify that the reforestation are surviving and growing, even if the trees are not yet 144 square feet in size.</u>*** ***<u>If this is not acceptable, we recommend that the BMP credit last until tree canopy land cover data is available with a ground condition date 10 or more years after the date of planting.</u>*** We would be happy to share aerial photographs of our projects where trees are detected.	The criteria to map urban tree canopy were defined by the CBP Partnership. This decision making was outside of the scope of the Expert Panel. However, the Expert Panel accounted for this criteria developed for the tree canopy land use to ensure consistency across the Bay watershed and multiple methods for tracking and reporting.	
Baltimore County	c.	**If a planting grows particularly quickly, and new land cover becomes available before the 10 year lifespan has ended, there will be double-counting.** For example, if trees planted 5 years ago appear in land cover data, the BMP credit will be provided, and some amount of land conversion credit will also be provided.	This is the reason for modeling procedures summarized above.	
Baltimore County	d.	**What date will be assigned to the land cover derived from the non-coincident aerials and LiDAR data?** Usually, LiDAR and aerials are acquired together. However, leaf-on aerials (4-band or more) are needed for this classification work, and LiDAR is usually acquired at leaf-off. Unless some program begins flying leaf-on	This recommendation will be shared with the CBP's GIS and Modeling staff as it applies to specific modeling issues outside of the expert panel's purview.	Modeling

	aerials and LiDAR at the same time, there will be a date difference between the aerials and the LiDAR. ***<u>We recommend that, when aerials and LiDAR are non-coincident, the more recent date be used as the date of the tree canopy data. This way, the BMP credit period lasts longer and you are unlikely to eliminate BMP credit for a tree planting before it is detectable via remote sensing/land use classification.</u>***		
Baltimore County	e. **Is there a way that high survival rates and improved infill planting practices can be credited more immediately?** Reserving credit for better planting practices/maintenance until 10 years after planting discounts the value of this work. With our many years of reforestation experience, Baltimore County has evolved our planting practices to a method that is more successful and cost effective. We knew early on the importance of tree survival and have included maintenance and survivability guarantees into our planting contracts. Maintenance and tree survival is most important in the first few years after planting. Baltimore County's tree planting program is backed by contracts that lay out our approach for reforestations and landscape style plantings. We have survival guarantees of 90% survival for the first three years after planting for reforestation projects and 100% survival for the first year after planting for large caliper (landscape) trees. We are currently working on an extended	The FWG has proposed a second Phase 6 BMP – Urban Forest Planting that was reviewed by the Expert Panel. A summary of the Expert Panel response to the proposal and recommendation is provided above. However, there was not consensus amongst the panel to accept the proposal. The Expert Panel recognized the many factors that affect the growth of trees and programmatic conditions that affect survivability as well. The Expert Panel sought to provide a credit that would uniformly be applicable across the entire watershed as the Partnership (FWG and WTWG representatives on the Panel) emphasized the need to limit the reporting requirements given information typically reported for tree planting projects (i.e.,number of trees). Thus a balance was sought to reflect the science, the numerous factors affecting tree canopy area (tree growth and survivability) and complexity of reporting and tracking given the (historical) land area reported to be treated by tree planting BMPs.	FWG Proposal

	maintenance and replacement planting contract that will extend maintenance up to 10 years after planting. We are concerned that the proposed credit will discourage local governments from spending time and resources on good planting practices and maintenance. ***<u>While we appreciate that the Panel was charged with determining pollution control performance estimates for BMPs of expanded urban tree canopy (UTC) for the entire Chesapeake Bay Watershed, we recommend crediting tree planting based on established programs and good planting practices.</u>*** We further recommend an automatic credit for the UTC BMP for local government planting programs that provide enhanced reforestation projects. Our approach involves planting 3 gallon saplings of native canopy species with survival guarantees.		
Baltimore County	**2. Baltimore County strongly recommends that crediting 300 trees as an acre for the UTC BMP does not become the crediting mechanism as the Panel Recommendations do not take into account constraints of planting in urban areas.** Due to the characteristics of developed areas, "single tree" plantings are often more appropriate. In addition, limited space and utility conflicts make planting a continuous acre very difficult. Due to these constraints, expanding the UTC requires more resources, including time and money than planting in rural areas. Though there are real constraints associated with planting trees in developed areas, the environmental benefits that urban tree canopies provide are very important, including lowering urban	This is an excellent point that highlights the difficulties of urban tree planting. The panel's consideration of factors such as mortality and planting conditions were made to reflect these difficulties that are typical in urban and suburban areas. It must be emphasized that maintaining and expanding both the Forest and Tree Canopy land uses will be very important in the long run. The more Forest and Tree Canopy that a county or jurisdiction has relative to higher loading developed land uses (e.g., impervious surfaces), the lower their total loads will be. The panel's methods provide a reasonable short-term credit for urban tree planting, but the long term benefits for protecting and expanding Forest and Tree Canopy offer the largest incentives and will reward the jurisdictions that invest the time and resources in their trees. It is likely the Partnership will continue to track and report post 2025, where as such	

	air temperatures, reducing carbon dioxide, and intercepting rainfall. While we understand that the Expert Panel is not recommending planting 300 trees per acre, we are concerned that crediting the UTC BMP at 300/acre will disincentivize jurisdictions from planting trees in developed areas. It is already more costly and time consuming to plant street trees, urban forests, and landscape style trees.	the credit for tree canopy would be captured by continued mapping assessments. There are multiple benefits for tree planting in developed areas, that while the credit for water quality benefits is relatively small relative to other BMPs, a rationale and credit explicitly providing credit for street and/or landscaping trees is available. While trees planted for this purpose were likely given the tree planting credit for CBWM vers 5.3.2. , these types of plantings will not likely to achieve the water quality benefit associated with a forested land use as previously credited	
Baltimore County	**3. We are concerned that the UTC BMP is based on planting location and not on planting style and will not provide adequate crediting for traditional reforestations in developed areas.** We appreciate that there were limitations in the Phase 5.3.2 Watershed Model, specifically on how the CAST definition was developed to only award a reduction to projects that plant a certain density (100 trees/acre), whereas in practice this does not always happen. We also realize that the Expert Panel was tasked with recommending how to address this issue and capture all tree canopy. We are concerned that in the process of addressing "single tree" plantings like street trees, there was too much focus placed on where trees are planted (developed areas) and not on the different types of planting styles. Through policy and planting projects, Baltimore County has developed standards for two planting styles, traditional reforestations and landscape style plantings. Traditional reforestations include planting 110, 3 gallon containerized trees per acre with 3 to 10 years of maintenance and a 90% survival guarantee for the duration of the maintenance period. These areas are typically converted from turf to meadows	The Expert Panel report weighed the benefits of developing a credit that would be applicable and provide realistic growth expectations given the numerous factors affecting the growth of trees and their information typically available for reporting tree planting projects, historically to the Bay Program for TMDL credit.	FWG proposal; mapping

	and herbicide application and mowing is used to address competing vegetation only. Landscape plantings include planting 1.5-2” dbh street trees and a dozen or more of “single tree” plantings on “managed grounds” (e.g. schools, condominiums, business parks). Landscape style trees come with one year of maintenance and a 100% survivability guarantee. Both planting styles are used throughout the County; inside and outside of developed areas. As mentioned previously, we believe that reserving credit for better planting practices/maintenance until 10 years out discounts the value of this work. We are also concerned that this crediting method will incentivize poor planting practices in these areas. Jurisdictions may look at short-term compliance and “on-paper” restoration vs long-term compliance and real water quality restoration. If jurisdictions receive 1/3 acre credit for 100 trees planted in a contiguous acre, we are concerned that they will increase their planting density to 300 trees/acre which is not sustainable in the long-term and will cause overcrowding of the canopy. While our landscape style trees fall into the UTC BMP, we believe that traditional reforestations within developed areas should have their own category, especially when a jurisdiction has an expectation of what their mortality will be based on current planting practices and established contracts.		
	In addition, Baltimore County is concerned with defining a forest as “a contiguous patches of trees that are greater than or equal to 1-acre, corresponding to a patch of trees with a minimum internal radius of 36m, and are generally 20m-30m away from non-road impervious surfaces (e.g., structures, driveways, and	The definition for the Phase 6 forest land use is not set by this expert panel.	

	parking lots) in developed areas and approximately 10m away from non-road impervious surfaces in rural areas." Due to the structure of Baltimore County, many of our reforestations are within 20m-30m of non-road impervious structures in developed areas and 10m away from non-road impervious surfaces in rural areas. These reforestations are still functioning as a forest with ecological and environmental benefits. ***<u>In addition to the Forest Classification outside of developed areas, we support two tiers of tree planting classifications in developed areas, the UTC Classification and an Urban Forest Classification that includes any traditional reforestation within developed areas of 0.25 acre or more</u>***, no matter how close they are to non-road impervious structures. We further recommend an automatic credit for the UTC BMP for local government planting programs that provide enhanced reforestation projects.	Enhanced reforestation projects may qualify depending on planting location; otherwise a new BMP may be required	
Baltimore County	4. **<u>Please clarify how tree plantings that occur beneath existing tree canopy should be handled.</u>** Planting canopy trees beneath existing tree canopy is not a good forestry practice, and Baltimore County does not condone it. However, we are aware that some plantings like this have occurred. It would be useful to have clear guidance from the expert panel on this topic. For example, should a tree planted under existing tree canopy receive urban tree canopy BMP credit? That would be double counting, and shouldn't be allowed? But what if the tree is at the edge of a well establish canopy (e.g. near a road), and the new tree is expected to extend the existing tree canopy outward? Should a BMP credit be provided, perhaps a reduced credit?	Replacement tree planting within a forested area or an area that was reported as an Urban Forest Planting BMP should not be reported as that area would already be receiving credit as a Forest and it would be double-counting to get Urban Tree Planting credit on top of that. However, areas that are not forested (e.g., a row of street trees) could count replacement tree planting under the Urban Tree Planting BMP since the panel's recommendations account for mortality and the replacement trees would not be double-counting.	Reporting and tracking

MDE and DNR	**Comment 1.** Replacement of the Urban Tree Planting BMP Section 2 of the report states that, "[t]his BMP will only apply starting with Phase 6 of the CBWM, replacing the Phase 5.3.2 BMP for Tree Planting (Urban)." Maryland does not agree with the elimination of the Urban Tree Planting BMP in Phase 6. The January 12, 2016, memo from Peter Claggett to the WQGIT , *Mapping Adjustments to Forest and Tree Canopy Land Uses for Phase 6*, states of the forest land use that it is, "[a]ssumed to have an unmanaged and pervious understory." Maryland agrees with this assumption, and maintains, that where trees are planted in a manner that is intended to comply with this assumption, that credit should continue to be applied based on a land use change to forest. This position will be described more clearly in the memo from Justin Hynicka of Maryland DNR, *Response to the Urban Tree Canopy BMP Expert Panel Report*.	The Urban Tree Planting BMP will still be available in Phase 6, but it will be a conversion to Tree Canopy in place of forest, per the panel's recommendations.	FWG proposal
MDE and DNR	**Comment 2.** Credit based on 10-year growth projection The report describes a logical approach for crediting the BMP, whereby it is handled as a BMP until the point where it is subsumed into the UTC land use through mapping tools—a time period estimated to be ten years. Based on this analysis, the panel recommends areal credit for the BMP (1 planted tree= 96 square feet) using the predicted canopy coverage that will exist in ten years. While this approach makes sense, it seems like a departure from how other land use change BMPs are credited. Previously, land use change BMPs, such as Urban Forest Buffers, Wetland Restoration and Tree Planting, have been fully credited immediately based on *full* growth potential. It is our understanding that this maintains an assessment framework consistent with the expectation that all pollution control measures needed to restore the Bay be *in place* by 2025. We interpret *in place* to mean installed, rather than fully mature or operational. Following the	As described in the report and considering the range of conditions that exist in urban and suburban areas, the panel recommended crediting Urban Tree Planting based on 10-years of growth is reasonable. The only factor determined based on this 10 years of growth is the estimated average area of canopy per tree planted. This allows conversion from number of trees planted into acres	Modeling

	precedent set by other BMPs, we would expect the UTC credit to be based on the full, or long-term average, canopy level rather than a 10-year growth prediction. As a practical matter, we understand the underlying logic and benefits of the panel's approach, and we are not advocating for or against the full, immediate crediting of land use change BMPs. Rather, we believe that it is important to maintain consistency between how BMPs are credited. We ask the panel to weigh in on whether this approach is consistent with how other land use change BMPs have been credited. If it is not consistent—or if consistency cannot be determined—we request that it either be adjusted to match the other BMPs, or that a formal review of land use change BMP crediting be undertaken by the WQGIT.	for the Watershed Model. Other land use change BMPs like forest buffers or wetland restoration are already reported in terms of area (e.g., acres). The nutrient and sediment reduction is applied in full when the BMP is credited, I.e. the relative land use loading rate is applied immediately in the model. There is no inconsistency in the approach compared to other land use change BMPs it is just an extra step that other land use change BMPs do not need.	
MDE and DNR	**Comment 3. Tree Canopy Landuse Method** Section 2 of the report describes the definition of forest as, "contiguous patches of trees that are greater than or equal to 1-acre, corresponding to a patch of trees with a minimum internal radius of 36m, and are generally 20m – 30m away from non-road impervious surfaces." Please ensure that the forest definition is consistent with the Partnership's latest approved forest land use definition, or clarify whether it is consistent with a proposed revision to the definition.	It should be emphasized that the Phase 6 land use definition for the Forest land use is not defined by this expert panel, but by other groups within the Partnership. The Land Use Workgroup defines forest as "trees farther than 30'-80' from non-road impervious surfaces and forming contiguous patches greater than 1-acre in extent. The variable distance is a result of filtering algorithms (e.g., focal moving windows) applied to the high-resolution non-road impervious surface class."	Mapping and imagery
MDE and DNR	**Comment 4. Reporting Trees or Acres** On page 17 the report states "In practice, reported trees were converted to acres of the BMP in Phase 5.3.2 using the 100 trees/acre conversion rate." It is not clear where or if this statement has a reference. On page 32, the report states "The qualifying condition for this BMP is to report the number of trees planted. This is consistent with the previous urban tree planting BMP reporting requirements and information typically available given the diversity of project implementation."	It is correct that the Phase 5.3.2 Urban Tree Planting BMP can be reported in acres, but it can also be reported as number of trees planted. The number of trees planted could be used to convert to acres (100 trees to one acre in Phase 5.3.2). The Phase 5.3.2 BMP would treat all acres as a conversion to Forest, but there was no explicit requirement that the trees needed to be planted in a contiguous area, so 100 trees planted over 100 different front yards could be reported as 1 acre of UTP in Phase 5.3.2.	Tracking and reporting

	This is not consistent with the current urban tree planting reporting requirements. NEIEN accepts acres of trees planted. Jurisdictions have developed tracking mechanisms based on acres of trees planted that meet the requirements. Maryland currently report acres of trees planted rather than the number of trees planted. To change to trees planted with no acres would mean the assumption that all of the trees reported are 300 trees to 1 acre which may not be the case.	For historical acres the jurisdictions will need to determine which acres should be counted as Urban Tree Planting or Urban Forest Planting.	
MDE and DNR	**Comment 6. Appendix G** The land uses to which the Urban Tree Canopy BMP is applied are incorrect. The land uses that urban tree canopy BMP will be applied to are Impervious and Pervious/Turfgrass.	We will correct Appendix G and Appendix F so they are consistent and have the proper Phase 6 land use names.	Edits
Ken Belt	You, Neely and the panel should be congratulated; this was a tough assignment and I think they did good work here that will make a valuable contribution to our ability to manage the CBay watersheds. It is no easy matter to take the science here, which is in reality highly complex, and use it in what has to be a highly generalized and simplified context. Thanks is due, considering the many months of work you all went through!	Commentary; no response provided	-
Ken Belt	There are a number of small "editing" kinds of things (flow, grammar, flow, etc.) that need attention but I have avoided commenting on them here to focus on more overarching or larger things. So there are below some thoughts, in no particular order that I hope are helpful to you all.	We intend to fix lingering small edits when the report is approved by the WQGIT.	-
Ken Belt	It is probably worth underscoring that much of this work is exploring new territory, and that even though really good specific data is extremely sparse, we know enough to get started here. After all we already know very well that the land use everyone wants in their drinking water reservoir is a nice stable forest… and there are decades of many publications to back that up!	The tree canopy land use loading rates were approved by the Water Quality GIT in March 2016.	Land use loading rates

	The work of Hynicka and Divers is central to the UTC, but I had a great deal of difficulty understanding what the methodology and approach was by reading the main body of the report. For example, there seemed to be quite a jump to how they arrived at loading reductions from a few simple equations. Also there was a basic unease regarding using a CN approach to quantify what are really small scale hydrological processes without new field data to support the process. The NRCS urban hydrology model was never meant to do this kind of work, and is not particularly equipped to handle small but frequent storms (its use is primarily in avoiding flooding related problems. You may want to consult someone who is familiar with the model development to weigh in here (the NRCS still supports the model so they would be a good choice). It may be best to publish the Appendix B separately and get some peer review done by modelers who are familiar with the development of CN based modeling at small scales to insure the validity of the approach? It is likely a bit too late in the process but I did wonder if other models could have been used or adapted?	The methods and the CN approach described in Appendix B were previously reviewed and approved by the partnership. As a part of that process Randy Greer (DE DNREC) did note that the CN approach can underestimate the contribution of smaller events. Based on that feedback Hynicka adjusted some assumptions to better account for smaller events (see page 53, Appendix B; I_a/S was changed to 0.05 instead of 0.2).	
Ken Belt	Care should be taken when using measured vs. modeled hydrologic processes. Each approach has strengths but you should be clear in how these were used in this process. For example, in tables 3 and 4, there were what seemed to be big differences between the modeled and the measured ranges of values. The models may also represent the used of measured hydrologic processes that may, depending on the model and context, simply reflect other measured processes.	The summary of the literature was not applied directly to the land use loading rates or water quality benefits attributed to tree canopy. The information, in the end, was used to illustrate the multiple processes by which urban trees impact runoff. Hynicka and Divers used the literature as guidance and selected median or average values in the development of the land use loading rates, that are applied to the BMP as a land use change.	No edit
Ken Belt	In a number of places I had trouble visualizing exactly how the trees in the UTC BMP are working here. It may be worth emphasizing how the UTC BMP is different than a “normal” stormwater BMP. How is the output handled (i.e., transport to deeper groundwater, surface runoff). Is part of the function avoided erosion from the under canopy surface?	The water quality benefit for the BMP is a land use change BMP, therefore the processes taken into consideration are those described by Hynicka and Divers (Appendix B). While there is potential for tree canopy to reduce the effects of stream erosion, the method is not explicit to this extent. Rather, page 10 of the land use loading rate documentation includes a description of the derivation of the sediment	No edit

		reductions attributed to tree canopy that is separate from lessening the downstream stream impact on streams. A sediment retention factor was assigned to relative reduction in water yields summarized in Table 1.	
Ken Belt	The UTC BMP does not address the treatment of any runoff, right? It sometimes seems that these are only intercepting rainfall and air depositional pollutants. It would be helpful to make this clear with a figure comparing the two kinds of BMPs, especially since comparative statements are made in the document.	Awaiting clarification for this comment.	
Ken Belt	It is worth considering that it is not the canopy that does most of the work here, so we are dealing with not just the effectiveness of the canopy but of it and the soil surface layers and the entire root ecosystem (which is typically as large as the canopy). For example a planted tree that has poor soils and has a stunted root system wont develop a full canopy and so cannot adequately transpire and take up nutrients.. etc.	The literature review attempts to describe the many factors that affect the growth and consequently water quality benefits provided by trees. Will add text to Section 4. Edits beyond those provided will require additional references that unless provided with respect to 'poor soils' the literature review is considered complete.	edit
Ken Belt	I love figure 1! To emphasize the larger, integrated nature of the above and belowground ecosystems, however, I would create the root zone below the tree (as large as the canopy), with all the ecohydrologic processes that go with it (root channels, mycorrhizal communities, macroinvertebrate burrows, hydraulic redistribution, etc.)	We appreciate the comment and given the space and legibility for the graphic, it will not be revised.	Edit
Ken Belt	Table 3 (interception) is very nice; I would separate it into modeled and measured sections though, and give more information of climate and season. Make it clear that Interception depends on may things (eg conifer needles intercept more P than broad leaves do). The canopy is simply a temporary storage area where, the larger or more intense the rainfall event, the more quickly the precip starts to exit as throughfall. Even though most estimate are described as percentage of annual rainfall, it this context it is the storm event viewpoint that is more relevant to UTC as a BMP, making climate, morphology, event frequency and many other characteristics important.	Table 3 currently identifies modeling vs measured studies. The geographic locations are provided to infer climate areas (e.g. SW, arid, humid regions). We included text that references the effect of storm characteristics. We will edit the text to add an 'e.g. frequency, intensity"	Edit

Ken Belt	Be sure to talk about throughfall (i.e., P that makes it through the canopy). It is the vehicle for significant pollutants (air pollutants washed from leaves, insect and animal excretions, etc). In terms of DOC, e.g., leaf exudates create huge DOC loads via the throughfall, even in pristine forests. Treatment happens when this hits the ground, so It is worth remembering that tree roots and their associated microbial and macroinvertebrate communities can work in-between storms by a) moving water and nutrients around below the surface (vertically and horizontally) at night and b) removing soil water via ET in the daytime, making for healthy soils that are better able to infiltrate and percolate rainfall.	Section 4 references the role of throughfall. The literature review focused on urban tree canopy, and includes summary of references provided. However, Hynicka and Divers discuss throughfall. See Appendix C. We will add text to Section 4 noting throughfall processes.	Edit
Ken Belt	Table 4 has a lot of potential; I cannot help but wonder why there are not more published field and plot studies that say something about tree cover and runoff flow magnitudes?	The literature review did not find additional work on this topic. No edit made.	Edit
Ken Belt	Leaf litter is an emerging area for research and I am glad it was mentioned here. Be sure to mention that it is highly dynamic with respect to pollutants… We have little data because it falls as greenfall as well as in the autumn and immediately breaks down, leaving a wide range of small partials that defy sampling and have complicated leaching characteristics. In terms of particulates and dissolved constituents we only suspect that they interact greatly with typical urban gutter contaminants.	Current text captures this comment, "While recent studies illustrate the available supply of leaf litter in urban areas, further research is needed to better quantify the fate, transport, and processing of leaf litter in urban watersheds and how to best account for this source as part of an urban nutrient mass balance." No edit made.	Edit
Ken Belt	I wondered about what we mean by tree planting. Since we are using projected growth as a central process here, should we talk about preparing and amending soils as part of the planting, in at least the areal projection of a full canopy status?	The Expert Panel noted the importance of soil conditions and media (depth, volume etc) that affects tree growth. The planting specifications, much like design specifications for other urban BMPs, are specific to local and state stormwater manuals and beyond the 'level of detail' to provide as part of recommendations. The Panel provides a recommendation for continued research on this topic. This may be modified, or another recommendation added to include a Soil Amendment BMP for a future expert panel. No edit made.	Edit

Ken Belt	In considering future research it may be worth not prognosticating the future using yesterday's lenses. Just as hi resolution imagery allows us to do so much more here, I cannot help but think that technology will make much more possible in the future, allowing us to do things at smaller spatial and temporal scales to measure and account for hydrologic tree functions in the landscape. Look at how we assess stormwater BMPs now (paperless, wireless, digital.. etc.)… lots of associated possibilities, and I think it is ok to put them out there, to inspire innovation?	As of 6/21 follow-up with commenter still needed to clarify specific addition or edits.	
Ken Belt	Think about sustainability. As we maintain and replace UTC BMPs, are we thinking about wood products, reuse, and nutrient sequestration… instead of simply landfilling? Since we don't simply leave dead trees to decompose in urban landscapes it is worth putting these ideas out there, to promote innovation for the next round?	Awaiting clarification for any specific addition or edits from commenter.	
VA DEQ	The charge of the panel as stated in the report (section 1.2) was "to determine pollution control performance estimates for the best management practice (BMP) of expanded urban tree canopy (UTC)." It was not to evaluate the existing approved BMP of Urban Tree Planting. However, it seems the UTC panel is doing more than that by eliminating the urban tree planting BMP entirely (Recommendation 4). This completely eliminates the urban tree planting BMP or a method to credit actual forest creation in the urban sector. Urban tree planting is a land use change BMP converting urban lands (pervious urban) to forest. The UTC panel is recommending elimination of the urban tree planting BMP and replacing it with UTC with a minimum of 300 stems per acre. This has implications for the historical BMP record in phase 6. What urban tree planting that has been reported would have met the definition of that BMP as currently approved. To accept this proposed change by the UTC panel would mean most of the reported urban tree planting would not meet the new required definition (stems per acre) so would need to be excluded from the historical record. VA	Tree planting is a key management action associated with tree canopy. Tree planting was always a component of the panel's charge and this includes the assessment of the existing Phase 5.3.2 Urban Tree Planting BMP. The FWG has proposed a second Phase 6 BMP – Urban Forest Planting. A summary of the Expert Panel response to the proposal is provided in the Technical Memo response to comments. The jurisdictions can consider which of the two Phase 6 BMPs describe their historical data. The new definitions do not necessitate the removal of previously reported acres from historical BMP data. The panel's recommendations should not be interpreted as a density requirement for stems or trees planted. Rather, the panel's methods and the use of the i-Tree Forecast tool provide a reasonable estimate of the average tree canopy that can be expected per tree planted (144 sq ft.) accounting for a range of variables that apply in urban and suburban areas. Without the ability to meet other qualifying conditions associated with the Urban Forest	

	DEQ does not support re-defining urban tree planting or replacing it with UTC acres. A method to allow both conversion to forest (urban tree planting) and expansion of UTC land uses is required. And one that does not require re-defining what has already been approved and included in the phase 6 BMP history. There is a concern that if one needs a contiguous acre with a minimum number of stems at planting to equal forest conditions that the historical BMP representation of riparian forested buffers would need to be examined for instances where less than a contiguous acre is reported. Point is redefinition of what constitutes a forested acre has impacts beyond just UTC forest differentiation. Or if one plants at a 400 stems per acre rate on a riparian ½ acre spot can one report it as a forested buffer or should it be reported as tree canopy?	Planting BMP, there is no assurance that the planted tree is part of a larger project and not a single tree planted in a residential front yard or parking lot. **Every tree should count, but not every tree creates forest-like conditions**. A flaw of the Phase 5.3.2 definition for Urban Tree Planting is that it did not clearly distinguish or define differences between individual or smaller scale tree plantings from the projects that seek to establish forest-like conditions. If a planting project is managed to create forest-like conditions then the density of trees planted, or the density of existing trees not lost to mortality, to attain forest-like conditions is determined by the applicable local, state or federal guidelines and not prescribed by the CBP or the panel. This panel's recommendations have no effect on the existing definitions for Riparian Forest Buffer BMP as defined by the CBP.	
VA DEQ	The executive summary indicates "The Expert Panel recommendations are based on review and synthesis of the literature, best professional judgement and the approved tree canopy land use loading rates for nitrogen, phosphorus and sediment." Consideration and approval of the land use loading rates by the WQGIT does not seem warranted considering there were significant technical concerns raised at the Modeling WG that have not been addressed. Since the BMP aspect is a land use change BMP in that pervious urban or impervious urban including transportation impervious will be converted to tree canopy over these land uses the loading rate difference between these land uses are part of the BMP panel recommendations and subject to comment.	The land use loading rates for Tree Canopy over Impervious and Tree Canopy over Pervious/Turf Grass were reviewed by the Urban Stormwater Workgroup, Modeling Workgroup and Water Quality Goal Implementation Team. None of the groups identified fatal flaws with the proposed loading rates or methods. Following the USWG approval (3/8/16) the WQGIT approved the loading rates on 3/14/16 and the loading rates were incorporated in the second beta version of the Phase 6 Watershed Model. As such, the tree canopy loading rates are not subject to further partnership review unless the commenter feels that this issue represents a fatal flaw and is able to document the fatal flaw with supporting data and references for consideration by the partnership.	Land use loading rates
VA DEQ	Assuming a straight 1 to 1 ratio between percentage runoff reduced and loading reductions for both TN and TP does not seem conservative. In fact it seems that most of the literature cited was modeling studies and not actual	The land use loading rates for Tree Canopy over Impervious and Tree Canopy over Pervious/Turf Grass were reviewed by the Urban Stormwater Workgroup, Modeling Workgroup and Water Quality Goal Implementation Team.	Land use loading rates

	measured results. In addition it seems a majority of the studies examined were from locations significantly outside the CB watershed to include much more arid locations. Since so much of the proposed benefits are from model estimates and or best professional judgement it would seem prudent to reduce the proposed TN and TP loadings assumed to be provided by tree canopy as indicated by the BMP Protocol? Or to increase the proposed loadings of these land uses by some factor to cover the large amounts of uncertainty in the proposed UTC land use loading rates. Considering the report indicates almost 900,000 acres of tree canopy in the Bay watershed it would seem more prudent to assume a lesser benefit for lands affected by tree canopy considering the dearth of measured studies east of the Mississippi. In terms of the modeling and loading impacts it is better to assume a 10% benefit and find out later it should have been 20% than the reverse situation.	None of the groups identified fatal flaws with the proposed loading rates or methods. Following the USWG approval (3/8/16) the WQGIT approved the loading rates on 3/14/16 and the loading rates were incorporated in the second beta version of the Phase 6 Watershed Model. As such, the tree canopy loading rates are not subject to further partnership review unless the commenter feels that this issue represents a fatal flaw and is able to document the fatal flaw with supporting data and references for consideration by the partnership.	
VA DEQ	One of the reasons cited for runoff reduction was increased infiltration under tree canopy. For other BMP's where infiltration is increased the estimated total nitrogen reductions were lessened because of the potential for increase leaching losses of nitrate nitrogen. The CBP WSM simulates NHx, NO23, and Organic forms of nitrogen. It would likewise seem conservative to limit the amount of reductions to the NO23 component of total nitrogen simulated in phase 6 WSM in a similar fashion as done with other BMPs that increase infiltration. In phase 5.x hydrogeomorphic regional factors were applied to limit the amount of NO23 reduced when the BMP panel estimated the overall TN benefit. This resulted in an overall lower TN reduction estimate but was considered conservative since leaching losses of nitrate are real and simulated within the model and with increased infiltration increased leaching losses are a distinct possibility. VA DEQ supports a TN reduction that is modified to account for increased potential leaching losses of nitrate.	The land use loading rates for Tree Canopy over Impervious and Tree Canopy over Pervious/Turf Grass were reviewed by the Urban Stormwater Workgroup, Modeling Workgroup and Water Quality Goal Implementation Team. None of the groups identified fatal flaws with the proposed loading rates or methods. Following the USWG approval (3/8/16) the WQGIT approved the loading rates on 3/14/16 and the loading rates were incorporated in the second beta version of the Phase 6 Watershed Model. As such, the tree canopy loading rates are not subject to further partnership review unless the commenter feels that this issue represents a fatal flaw and is able to document the fatal flaw with supporting data and references for consideration by the partnership.	Land use loading rates

VA DEQ	HSPF will be used to simulate hydrologic and sediment processes in phase 6. The panel recommendation for sediment benefits on canopy over impervious are based on potential downstream benefits perceived from reduced runoff not what sediment is simulated as reduced under the acre of tree canopy. It is not clear if the HSPF simulation will reduce the sediment loadings on the acre of tree canopy over impervious or reduce stream bank erosion being lessened. What is needed from the panel is the amount of sediment prevented from being transported under the tree canopy acre. Not what a reduction in runoff in one location might mean for sediment to some stream downhill of the acre of tree canopy. Between that tree canopy area and the stream the panel seems to assume that there is always a hydrologic connection. What about intervening areas were both run-on and run-off both to and from pervious areas and other impervious areas occurs before reaching a stream? What about impervious areas without canopy uphill of canopy areas where runoff from upland areas is crossing areas with canopy (run-on to UTC land use)? How does UTC reduce run-on from non-UTC impervious areas? HSPF will simulate a single acre of tree canopy land use and route flows and loadings to the edge of stream. Then multiply that by all available acers of that land use to estimate the overall loadings from a given segment. It will simulate the other land uses similarly as separate entities without the real world interactions of run-on/run-off from intervening land uses. Basically there are other process occurring in the model and real world between other impervious areas, the tree canopy areas, and streams downhill that preclude a sediment benefit based on perceived downstream impacts from runoff reduced on an acre UTC uphill of a receiving stream. At this time VA DEQ cannot support the proposed sediment reduction for tree canopy over impervious or tree canopy over transportation.	The land use loading rates for Tree Canopy over Impervious and Tree Canopy over Pervious/Turf Grass were reviewed by the Urban Stormwater Workgroup, Modeling Workgroup and Water Quality Goal Implementation Team. None of the groups identified fatal flaws with the proposed loading rates or methods. Following the USWG approval (3/8/16) the WQGIT approved the loading rates on 3/14/16 and the loading rates were incorporated in the second beta version of the Phase 6 Watershed Model. As such, the tree canopy loading rates are not subject to further partnership review unless the commenter feels that this issue represents a fatal flaw and is able to document the fatal flaw with supporting data and references for consideration by the partnership.	Land use loading rates

VA DEQ	The subject of leaf litter, tree detritus, and pollen loadings seems to be essentially disregarded by the panel. These are sources of nutrients that are a particular concern on impervious land uses. A quick internet search found pollen contains significant amounts of nitrogen and phosphorus. In fact a study was found indicating a lake in Ontario Canada had over 9% of annual TP loadings from tree pollen alone. And that sediment core studies indicated even higher TP loadings from pollen than the 9+% cited. For part of the year leaf litter and other detritus is a major concern and for other parts of the year pollen is a concern. However, there is no seasonal variation to the benefit of tree canopy. So during periods of significant rainfall, low ET, and little to no canopy the same reduction is applied as seasons where there is high interception and ET. This does not seem to be a conservative assumption. VA DEQ would be more comfortable with an acknowledgement of these seasonal issues and an adjustment to the perceived benefits for periods where there is limited to no canopy or when the streets are running yellow from pollen. It seems a double credit to get a tree canopy credit and street sweeping or catch basin clean out when much of what is swept or cleaned out seasonally is leaf litter and tree detritus. It would seem that one or the other BMP should be applied to the same acre but not both.	The loading rates and methods described by Hynicka and Divers in Appendix B are annual loading rates that do account for seasonal differences in the runoff reduction, leaching and throughflow calculations. As noted in the report, the Street Sweeping expert panel looked into the leaf litter issue quite extensively and concluded there is insufficient data to make a definitive adjustment for loads associated with litterfall. The tree absorbs nutrients to form the leaves come from another source in the soil and more research is needed to determine if this transformation and redistribution of nutrients represents a net difference on an annual basis.	
VA DEQ	Besides the already identified issue with the established and approved urban tree planting BMP concern has been expressed regarding application of other BMPs to the UTC land uses. If a state does not know the exact land use(s) a BMP is treating other than urban acres CBP will proportion that BMP reporting to all available urban land uses including UTC. It is foreseen that this will create considerable confusion between reported and credited BMPs and verification requirements. Will states be allowed an option in NEIEN to report urban BMPs as urban without them being applied to the UTC land uses? For example there are land use codes available for reporting via NEIEN protocols that allow urban BMPs to be reported on land	These specific NEIEN issues are the purview of the WTWG and can be clarified in Appendix F.	Tracking and reporting

	uses without CSO or with CSO. Without knowing the extent of UTC and that relationship to reported BMPs it may be preferred to report urban installations on non-UTC land uses or if known on UTC land uses. It is recommended the NEIEN codes list be amended to include land uses with and without UTC so that a reporting partner jurisdiction can specify the extent to which other BMPs are applied to UTC land uses. Please provide a listing or table of approved BMPs can be reported in conjunction with UTC land use change BMP?		
VA DEQ	The report seems confused on the BMP verses the land use of UTC. The BMP is a land use conversion from pervious urban or impervious urban to UTC over pervious or impervious. The benefit of the BMP is the difference in land use loadings between for example pervious urban and UTC over pervious. Therefore, there is no difference between the BMP and the land use as the BMP is the creation of the land use and conversion from another higher loading land use. Recommendation 1 on page 30 is confusing in that the 97 square feet per tree needed for effective canopy (canopy threshold needed to provide the canopy benefit) with the ability to estimate canopy via remote sensing efforts. Remote sensing may well indicate tree canopy areas that do not meet a 97 square foot threshold per tree needed to produce the recommended benefit. It seems the 97 square feet is what is needed for a single tree to provide canopy benefits not needed for detection via remote sensing. The current land use classification effort in VA is utilizing a mosaic of imagery over multiple years and resolutions (12, 6, and 3 inch) aggregated up to 1 meter. According to the GIS experts developing Virginia's high resolution land use 1 meter resolution equates to differentiating an object 4 square meters in size or slightly under 20 square feet or much less than the 97 or 144 square foot threshold for canopy benefits. Therefore the assumption that future remote sensing will capture plantings in a 10 year period is faulty and contradicted later in section 6 of the report. Remote	Comments or concerns over specific mapping procedures and classifications based on imagery are not the purview of this expert panel and should be directed to the CBP modeling and GIS staff. All land uses are simulated through the entire calibration period and it is false to characterize those carefully developed methods for forecasting back through time as "fabricated" since they are based on the best available historical data. However, these methods are not the purview of this expert panel. The 97 square feet is a threshold defined by the Bay Program as part of the land use mapping for tree canopy land uses. This threshold was used as guidance for the Expert Panel to develop its recommendations but mapping and imagery procedures are outside the panel's purview. That is, a credit based on a projected growth of a tree 10-years after planting. The current Phase 5.3.2 credit is based on a mature tree, at time of planting and the equivalent acreage credit as forest land use. The Expert Panel for reasons described in the report Section 5.1 did not support applying a credit based on a longer expected growth period, nor as a conversion to a forested land use.	Mapping and imagery

	sensing will capture things as tree canopy based on the decision rules and algorithms employed at the time. And have as much to do with the definition that a contiguous acre of trees is forest and any group of trees less than that size are part of UTC. In fact that single factor seems the biggest determinant of the extent of UTC. Assume ½ acre of contiguous trees equates to forest and UTC acres will be significantly lessened. Assume 1.5 contiguous acres of trees if forest and UTC acres swell. So the extent of UTC seems more related to what is assumed forest and less on what is remotely detected as canopy over some other land use. Remote sensing may include buffer and other tree planting BMPs and canopy areas less than 97 square feet per stem and include these in the remote sensed totals of UTC. We are also unaware of any other land use or major input factor like a land use in CBP modeling that is based on a single measurement point. The entire historical representation of the UTC simulated land uses must be fabricated because there is insufficient high resolution imagery over time to make predictions or trends in these land uses on actual measured or surveyed results.		
VA DEQ	Recommendation 2 on page 30 and 31 is confusing. Is the BMP credit duration 10 years or annual as it says Recommendation 2: **Lifespan of Annual BMP Credit**. Also unless specific location information is provided to NEIEN such as coordinate pairs but only X stems or acres within a city or 12-digit hydrologic unit or larger area how will we know which NEIEN reported acres of UTC are being captured by the remote sensing efforts assumed to be done at some intervals in the future? This section also indicated that unlike other structural BMPs urban trees on average have an expected 19-28 year lifespan. So is the BMP an annual BMP needing annual accounting, a 10 year credit duration, or something much longer? It would seem that if one follows recommendation 3 and does plant coniferous trees it is unlikely they will ever reach the 97 square foot threshold or possible detection from remote	The reported trees planted or acres for the Urban Tree Planting or Urban Forest Planting BMPs will be tracked for the recommended credit durations of 10 and 15 years, respectively. All acres of land use change BMPs like Urban Tree Planting receive credit between updates to satellite imagery-based land use data. Following an update all historic implementation effort will still be tracked toward milestones set by the jurisdictions and all new implementation will be counted as a land use change. This avoids double-counting in the model simulations while demonstrating implementation and effort toward milestone goals.	Tracking and reporting; modeling

	sensing efforts. Yet acres of UTC would have been reported and simulated with all assumed benefits.		
VA DEQ	The panel is proposing that we report in recommendation 4 of the report 300 stems per acre with tree canopy area of 144 square feet per tree equals 1 acre of UTC. Yet on page 31 Recommendation 3: Information for Reporting and Tracking BMP "This recommendation does not limit the type or density of trees planted that are eligible for credit. The credit applies to all tree types, whether planted individually or in a contiguous area (i.e., trees other than broadleaf species may be planted)." So in one place in the report it indicates 300 stems and 144 square feet per tree is needed and another section a single tree with 97 square feet of canopy is all that is needed. Which is it 97 square feet or 144 square feet of canopy area? Is it a single tree or 300 trees at one or the other square footage of canopy per tree?	The 97 square feet and 144 square feet refer to different things. Based on personal communication with GIS staff the imagery and mapping classification captures trees that are 97 square feet or larger. It has been pointed out that there may be variation in the exact size or area of a tree that is detectable, but such specific imagery issues are outside the scope of this panel. The panel's method for estimating canopy area for a planted tree is based on 10 years of growth for a variety of species and accounts for numerous factors (mortality, light exposure, etc.), and sets the estimated average canopy area of a planted tree at 144 square feet. Based on that area, it would take ~300 trees to equal one acre, but this is NOT a density requirement. Any tree that is planted, reported and credited under the Phase 6 Urban Tree Planting BMP converts 144 square feet, or 1/300 of an acre, from the previous land use to a Tree Canopy land use.	Tracking and reporting; modeling
VA DEQ	This seems a contradiction where the report indicates the panel's BPJ is that coniferous evergreen trees are not commonly planted and subsequently not considered as part of the recommended credit. And the following graphic on page 29 clearly shows the canopy projections from 6 classes of trees based on broadleaf or coniferous and leaf size. That graphic indicates only 2 of the 6 classes produce the needed 97 square feet of canopy area within 10 years that produced the exposed loading rate difference. Yet recommendation 3 would seem to indicate explicitly coniferous trees are acceptable for reporting even those which seem to never reach the 97 or 144 square foot threshold. It seems clear from the report that only broadleaf large and broadleaf medium meet the 10 years 97 square feet criteria and only broadleaf large meets the 144 square feet within 15 years. It would seem a qualifying condition of this BMP would be a type (only broadleaf large and broadleaf medium tree types planted can receive UTC credit) and density requirement (minimum 300 stems	The canopy projections in Figure 4 represent the average canopy per tree planted. So, it is not suggested to assume based on that graph that coniferous trees will not reach the size needed to be captured in high resolution imagery, but rather that the average area per coniferous tree planted will not reach that area threshold. The estimated projections per tree also assumes annual mortality. The actual canopy area, while dependent in part on tree species, will also be affected by a number of other factors. Consequently, the panel feels that given the relative impact of the Urban Tree Planting BMP it is unnecessary to set prescriptive qualifying conditions. Local, state or federal agencies will have established rules or guidance to determine what types or species of trees to plant in specific areas and the panel did not want to dictate that coniferous trees are less valuable to water quality strictly because they provide less canopy coverage on average.	Tracking and reporting;

	per acre at planting). Recommendation 3 and 4 seem to be at odds with each other suggest elimination of recommendation 3 and include tree type requirements (only broadleaf large and broadleaf medium) be a qualifying condition for recommendation 4 assuming clarity between recommendation 4 and the current urban tree planting BMP can be achieved. Without elimination or modification to specify tree type an unintended consequence of recommendation 3 would be wide spread planting of coniferous trees and the reporting of stems per acre planted. This would lead to a situation where a tree type identified by the panel as never reaching the square footage threshold (97 or 144) needed to produce the canopy benefit but is credited in the modeling as providing such benefit.		
VA DEQ	There seems a large disconnect between reporting as few as a single stem planted of any tree type (recommendation 3), 300 stems per acre (recommendation 4) and the expectation that these will be captured via remote sensing at some future date. It seems highly unlikely the imagery processing remote sensing effort will match reported planted acreages. Thus setting up conflicts between what the jurisdiction has reported and what can be verified via an objective process as stated in the report using remote sensing with high resolution imagery provides. And if as the report indicates (Section 6 pages 33 and 34) periodic updates to the high resolution imagery would not verify specific tree planting projects and extraneous factors are likely to overwhelm the effect of tree planting. How using remote sensing processes will we differentiate the tree plantings credited in the model (increased UTC land use area) with what most likely not be detected or overwhelmed according to the report? This seems a direct contradiction to the assumption in Recommendation 1. In terms of verification the panel minutes indicated discussion on the need for adequate soil area at planting to ensure survival and optimum growth (canopy cover). Yet the panel is silent on this as a consideration or	As noted above, all acres of land use change BMPs like Urban Tree Planting receive credit between updates to satellite imagery-based land use data. Following an update all historic implementation effort will still be tracked toward milestones set by the jurisdictions and all new implementation will be counted as a land use change. This avoids double-counting in the model simulations while demonstrating implementation and effort toward milestone goals. The 144 square feet average canopy per tree planted is not a density requirement. It represents a reasonable average that can be applied to the aggregate of all individual or smaller scale tree planting projects in an area. Planting projects that are larger in scale and seek to create forest-like would be tracked under the Urban Forest Planting BMP proposed by the FWG, if that proposal is adopted by the partnership. Since the BMP will only be simulated in the model runs between updates to the high resolution imagery, this essentially acts as a built in verification mechanism for these BMPs in model simulations.	Tracking and reporting; modeling; BMP verification

	condition of the BMP. And if the canopy area is the primary determinant on interception and associated benefits should there also be a method to estimate canopy area by stem to verify reported installations are meeting the minimum canopy area needed to produce the estimated benefits? As is it seems the panel is saying as long as it is a tree and alive it passes verification. If specific actions on maintenance are needed to ensure the canopy area and function are meeting minimum requirements the panel should provide them or at least a listing of the types of actions/equipment that are needed to verify the BMP is functioning properly. Based on the report as is there is great confusion as to what constitutes verification of the BMP and how VA would amend our existing Verification documentation to include UTC in annual reporting. Without the ability to clearly provide local governments with what the state considers needed for verification including maintenance of this BMP it is doubtful to be collected or reported annually.	As with all BMPs, the jurisdictions consider and determine how to verify their reported BMPs based on the BMPs' relative contribution to overall reductions, the state's priorities, programs, and other factors. Considering the scale and scope of urban tree planting and urban forest planting it is not expected that they will contribute large relative reductions in the model simulations compared to other urban BMPs.	
VA DEQ	The panel indicates that if not maintained and UTC plantings die, then the canopy will not be captured by the remote sensing updates. Since maintenance is important to the survival of the BMP and producing a verifiable BMP it is imperative that the experts provide guidance on what constitutes maintenance. How does one verify a BMP is properly functioning without knowing if the BMP is getting proper maintenance?	The Forestry Workgroup has provided extensive BMP verification guidance. Maintenance procedures should follow applicable local, state or federal guidance for trees in that given area.	BMP verification
VA DEQ	If tree canopy has such benefits on impervious and pervious urban it should have similar benefits to non-urban impervious and previous areas so should not be limited to just the urban sector.	This expert panel was not asked to make recommendations for non-urban sectors.	
WV DEP	*1. This sentence in section 3.2 confused me because you can't tell right away (although maybe it's obvious to others?) that you're talking about the tree canopy over impervious:*	Edit made to read, "To account for the distribution of Tree Canopy over Roads and Tree Canopy over other impervious non-roads (building parking lots, etc.), in the Phase 6 Beta-1 version, 90% of existing canopy was assumed to be over Roads and the remaining 10% over non-road impervious surfaces (see **Table 2**)"	Edits

	To account for the distribution of Tree Canopy over Roads and Tree Canopy over other impervious non-roads (building parking lots, etc.), 90% of existing canopy was assumed to be over Roads and the remaining 10% over non-road impervious surfaces for the Beta-1 version. This distribution may change for the final version of the Phase 6 CBWM as additional analysis and calibration is completed. *But it appears again worded more clearly in the footnote to table 2.*		
	2. Should this sentence in section 5.2 "i-Tree forecast" have the word "each" deleted? This mortality rate is applied in the initial each year (at planting) but will vary in subsequent years based on DBH as shown in Figure 2 below.	"each" deleted	Edits
	3. This sentence from the first paragraph under "Verification" seems to need a comma after "recommends" if I am understanding it correctly from the context of the rest of the paragraph: The Expert Panel strongly emphasized that it is unreasonable to assume a replanting of all trees that die in these first few years which the Verification Guidance recommends as the planting density in many cases are overplanted to account for expected mortality and the recommended crediting method accounts for a 2.5% to 5% annual mortality. *Thanks! Great report!* *-Alana*	Comma added	Edits
DC DOEE	This email is to inform you that the District Department of Energy and Environment has reviewed the report from the BMP expert panel for Urban Tree Canopy and we do not have any comments. Thank you for the opportunity to review the report.		

Summary of Partnership Comments and Panel Responses to Draft Report of Recommendations from the Urban Tree Canopy Best Management Practice (BMP) Expert Panel

The Urban Tree Canopy (UTC) panel's report was first released for review and comment by the Chesapeake Bay Program (CBP) partnership on May 3, 2016. This document is provided in accordance with the BMP Protocol, which instructs the Panel Chair and Panel Coordinator to develop a "response to comments" document that provides a response to comments received.

Comments were submitted to the Panel Coordinator from nine individuals or entities between May 3 and June 9. These comments ranged from one or two sentences, to multiple pages of written comments. Comments or suggested edits that pertain to grammar, spelling or formatting of the report are not included or addressed here, but the Coordinator has noted those comments for direct revisions to the report.

This document summarizes major or recurring comments of interest to the partnership and is divided by topic, which are categorized as follows:

I. Proposal by MDE and MD DNR recommending a second type of tree planting BMP credit
II. Tracking and Report BMP credit
III. Modeling
IV. Land Use Loading Rate
V. Future Research and Management Needs

A separate table is provided with a complete list of comments submitted through June 9 along with responses from the Panel Chair and Coordinator.

The order of comments or responses in this document is neither a reflection of their importance or impact in any way, nor is their order necessarily chronological. They are arranged in a way that is intended to be more convenient to the reader, i.e. according to their relation or overlap to one another or their general frequency in received comments. Additional comments received following the June 9th comment deadline will be appended to the third section of this document as needed.

I. Proposal by MDE and MD DNR recommending a second type of tree planting BMP credit

General issue: During the May 20 webinar and the 30-day comment period some partners expressed concern that the recommended Phase 6 urban tree planting credit does not adequately address reforestation-focused programs in developed areas where there is an unmanaged understory (i.e., not turfgrass, not fertilized).

MDE and MD DNR coordinated their response to comments and submitted a proposal that was supported and updated by the Forestry Workgroup (FWG). Additional input provided by Arlington (VA) Department of Parks and Recreation, and Baltimore County suggest support of a credit recognizing the benefits of forest-like plantings where the understory is not impervious surface or managed turfgrass, or programs that have measures to ensure the trees' survival. An example was provided where local tree planting programs specify survivability rates of 90% or 100% depending on the type of planting. The proposal is attached as an appendix to this document.

Raised by: MDE, MD DNR, Arlington VA Parks and Rec, Baltimore County. See attached table for specific comments and responses.

General Response to the Proposal: The Chair of the Expert Panel convened conference calls with the Expert Panel members June 17 and 20 to receive their input and recommendations on the proposal. The panel was asked if they supported the proposal "as-is", "with modifications," or "did not support the proposal". There was not consensus amongst the Expert Panel members, however the majority did not support the proposal. One expert panel supported the proposal "as-is"; one expert panel member was amenable to support the proposal from a programmatic but not technical perspective, while four panel members did not support the proposal even with modifications. Three panel members were not available for comments (no response from two; one is on sabbatical).

Overall, with the exception of one panel member, the Expert Panel found that assigning new reforestation projects of ¼ acre or greater the same pollutant loading rate as that of a mature forest was not supported by the literature nor by any technical documentation at this time. A summary of the panel's input is provided below.

<u>Viewpoint of panelist in support of the proposal</u>
The proposal provides additional incentive to existing tree planting programs that strive to re-create forest-like conditions. The eligibility requirements are consistent with existing programs, such as the MD Forest Conservation Act and local ordinances. It is believed that the impact of this additional incentive would address a small area within the Bay watershed, while the potential to make programmatic gains is far greater. The eligibility requirements differentiate the proposed '2nd-tier' credit relative to the CBWM 5.3.2 tree planting credit that provides a land use conversion credit to forested land use given the qualifying conditions (i.e., contiguous planting areas and other eligibility requirements, such as a planting plan). Further, there is no acreage threshold for tree planted as defined for forest land use.

The expert panel member also commented that a land use conversion to a '"<u>mixed open</u>" land use may be a reasonable alternative to forest. "Mixed open" provides a land use loading rate higher than Tree Canopy over Turfgrass, but lower than forests. It was thought that early successional reforestation efforts throughout the watershed tend to come out classed as shrub-scrub, which is a component of the Mixed Open land use in Phase 6.

<u>Viewpoint of panelists not in support of the proposal</u>
The major concern noted by the Expert Panel rejecting the proposal was the lack of technical basis and rational for the '2nd-tier' credit and awarding a much greater water quality benefit than recommended in the report (one tree planted receives a 144 square feet of canopy coverage, or 300 trees converts one acre to tree canopy applied to the relative tree canopy land use loading rates). While there is potential support to credit this type of planting from a couple of panel members, they did not support conversion to the forest land use as a basis for credit. The proposal is seen as 'status quo' to the Phase 5.3.2 urban tree planting credit, and as discussed in the report, the conversion to forest land use over-credits planting projects as a result. Panel members acknowledged there were a variety of planting projects, from street trees to contiguous planting areas, however, and that the water quality science is insufficient to confidently distinguish their benefits in urban or developed areas. The land use loading rates derived applies the best available science to derive the water quality benefit for trees planted.

Further, it was stated that the loading rates were assigned to the land cover and the BMP was created to provide implementation credit due to the long interval between land cover imagery assessments now that tree canopy land uses exist in the modeling tools. Creating 1-acre minimum for a forest in the land cover and 0.25 acre minimum in the BMP inappropriately decouples the BMP from the land cover and unnecessarily complicates and introduces inconsistencies of what is forest and what is tree planting. There was no technical basis provided in the proposed Urban Forest Planting proposal for 0.25 acre as the threshold to provide greater water quality benefit. A review of the i-Tree Forecast results suggest that on average, broadleaf-medium and broadleaf large trees at 15 years (the BMP duration for the proposal), will have a projected crown diameter of 20-ft, or 314 sq ft in area. This is equivalent to ~32 trees per 0.25 acre, assuming no mortality or 100% replacement.

Proposed path forward: The Expert Panel discussed a number of possible options to address the proposal for a 2nd-tier credit that would be more in-line with the methods and rationale recommended by the Panel.

1. An option would be to simulate the 2nd-tier BMP as a land-use change to another Phase 6 land use with a greater loading rate than forest, but a lower loading rate than tree canopy over turfgrass. Mixed Open appears to be the most reasonable land use that could be applied for this option, but as noted above, there would need to be more documented technical justification for applying the selected Phase 6 land use than is provided in the current FWG proposal. A more detailed justification of the 0.25 acre or other selected threshold for contiguous planting area would also need to be provided.

A second and third option were also suggested by the Expert Panel, however, there are issues moving forward with them that would preclude adoption of the Expert Panel Recommendation in the proposed timeframe.

2. The model to derive the relative land use load rate for “tree canopy over pervious” used a runoff coefficient representative of turfgrass with an assumed impact from trees potential to increase infiltration (CN= 0.74). As such, modeling the water quality benefit could be done by modifying assumptions of the underlying land cover. However, this would essentially create a new loading rate and is not a feasible option at this time considering that land uses and loading rates have already been established for Phase 6. This is a recommendation for a future expert panel, or a time when the land use loading rates for tree canopy are revisited.
3. A recommendation may be added for jurisdictions to use i-Tree Forecast in some form to run specific tree planting scenarios that may provide a higher canopy area credit. The land use loading rate would remain the same, but a potentially larger area would be converted for qualifying projects. However, this would not address differences in the understory and would require time and resources to perform simulations through Forecast. This is a recommendations for a future expert panel, or a time when the urban tree canopy (tree planting) BMP is revisited.

The Phase 6 definition for Mixed Open and preliminary draft loading rates from the second beta Phase 6 Watershed Model are provided below for discussion purposes. The loading rates in the table are subject to change as they are preliminary results from a beta calibration and will change in future calibrations, but there is no anticipated change in the relative differences among the land uses (i.e. their export ratios which are provided in parentheses).

> Mixed Open (MO) – All scrub-shrub and herbaceous and barren lands that have been minimally disturbed (e.g., periodically bush hogged, meadows, etc.), reclaimed, or that have internal

and/or regulated drainage. These include active, abandoned and reclaimed mines, landfills, beaches, waterbody margins, natural grasslands, utility right-of-ways and a portion of herbaceous lands within industrial, transitional (early stages of construction), and warehousing land uses. Also included are potential agricultural lands that were not mapped as either cropland or pasture in the NASS Cropland Data Layers (2008 through 2015).

Table 1. Summary of draft preliminary Phase 6 TN and TP export rates. Source: Draft Phase 6 (second beta) Watershed Model documentation, Section 2. **Draft, for discussion purposes only.** April 19, 2016.

Phase 6 land use	**Average TN export rate** lbs/ac-year (export rate ratio)	**Average TP export rate** lbs/ac-year (export rate ratio)
Mixed Open (Natural)	4.52 (1.46)	0.82 (5.69)
True Forest (Natural)	3.1 (1.0)	0.14 (1.0)
Tree Canopy over Turfgrass (Developed)	16.79 (0.38)	1.32 (0.79)
Tree Canopy over Impervious (Developed)	40.36 (0.91)	1.51 (0.91)

II. Tracking and Report BMP credit

General issue: The tracking and reporting of the BMP and the tree canopy land uses was not sufficiently clear in the report. Concerns were identified about the how the BMP would be reported in time periods between the mapping assessments to update the land use, or how the BMP would be reported following a land use update. There was concern that credit would require specific planting density (300 trees/acre) or some species would be eligible for credit.

Raised by: M. Honeczy (MD DNR), Arlington VA Dept Env Services, Baltimore County, MDE and MD DNR. See attached table for specific comments and responses.

General Response: The Urban Tree Planting BMP for Phase 6 will receive credit between updates to satellite imagery-based land use data. Following an imagery update all historic implementation effort will still be tracked toward milestones set by the jurisdictions and all new implementation will be counted as a land use change. This avoids double-counting in the model simulations while demonstrating implementation and effort toward milestone goals. A single credit is provided that is applicable to all trees planted and does not differentiate between species nor type of planting scenario. The Expert Panel recommendations considered the criteria used to map and classify tree canopy land uses developed the CBP Partnership to address the double-counting issue that was part of the Panel scope.

Next steps: Edits will be made to the final report for added clarification to specify the annual reporting and tracking for BMP credit, to include specific NEIEN issues that are the purview of the WTWG and can be clarified in Appendix F.

III. Modeling

General Issue: Comments were raised to ensure there was consistency with the definitions for the Phase 6 land uses mentioned in the report, the creditable area for tree planting BMPs versus the land use, and in general, how land use change BMPs are credited in the model (i.e., full growth).

Raised by: M. Honeczy (MD DNR), Arlington VA Dept Env Services, Baltimore County, MDE and DNR. See attached table for specific comments and responses.

General Response: The definitions provided in the final report were up-to-date at the time the draft report was released. Revisions to the definitions will be made to the final report as needed, though it should be emphasized that specific mapping definitions or procedures are not the purview of the Expert Panel and are included for the reader's benefit, not as recommendations. As described in the report and considering the range of conditions that exist in urban and suburban areas, the panel credited Urban Tree Planting based on 10-years of growth is reasonable. The only factor determined based on this 10 years of projected growth is the estimated average area of canopy per tree planted. This allows conversion from number of trees planted into acres for the Watershed Model and annual BMP credit. Other land use change BMPs like forest buffers or wetland restoration are already reported in terms of area (e.g., acres). The nutrient and sediment reduction is applied in full when the BMP is credited, i.e. the relative land use loading rate is applied immediately in the model. There is no inconsistency in the approach compared to other land use change BMPs it is just an extra step that other land use change BMPs do not need.

Next steps: Clarifying edits will be made to ensure that the definitions are current and that the identified aspects of the panel's recommendations are more clearly stated. If commenters have specific edits in mind they are encouraged to offer specific edits to the Chair and Coordinator.

IV. Land Use Loading Rate

General issue: Comments received noted issues with methods to derive the land use loading rates for the tree canopy land uses. The Expert Panel adopted these loading rates as the water quality benefit (credit) for the urban tree planting BMP.

Raised by: VA DEQ, Ken Belt. See attached table for specific comments and responses.

General response: The land use loading rates for Tree Canopy over Impervious and Tree Canopy over Pervious/Turf Grass were reviewed by the Urban Stormwater Workgroup, Modeling Workgroup and Water Quality Goal Implementation Team. None of the groups identified fatal flaws with the proposed loading rates or methods. Following the USWG approval (3/8/16) the WQGIT approved the loading rates on 3/14/16 and the loading rates were incorporated in the second beta version of the Phase 6 Watershed Model.

Next steps: The tree canopy loading rates are not subject to further partnership review unless the commenter feels that this issue represents a fatal flaw and is able to document the fatal flaw with supporting data and references for consideration by the partnership. Pending any further documentation to identify fatal flaws, no edits are planned.

V. Future Research and Management Needs

General Issue: A few comments identified additional research and management needs as it pertains to quantifying the water quality benefits of urban tree planting and cost-benefit analysis of the practice.

Raised by: M. Honeczy (MD DNR), Arlington (VA) Parks and Rec

General Response and next steps: The final report will be revised to reflect these additional recommendations.

VI. Summary of All Comments and Responses

The attached table includes responses for all comments that were received.

Summary of Major Revisions to the Urban Tree Canopy Expert Panel Report Based on Comments Received During the Public Comment Period and Subsequent Review by Work Groups (08/18/16)

The Urban Tree Canopy (UTC) panel's report was first released for review and comment by the Chesapeake Bay Program (CBP) partnership on May 3, 2016. A Technical Memo, "Summary of Partnership Comments and Panel Responses to Draft Report of Recommendations from the Best Management Practice (BMP) Expert Panel for Urban Tree Canopy" was submitted to the Forestry Work Group and Partnership on June 23, 2016 summarizing the comments and responses received during the review period. That document was provided in accordance with the BMP Protocol, which instructs the Panel Chair and Panel Coordinator to develop a "response to comments" document that provides a response to comments received. A detailed table listing all the comments verbatim was also developed. Subsequent feedback from partners, including additional comments from VA DEQ were received requesting further clarification on issues such as the land use loading rates, rationale for the credit, definitions and applicability of the BMP, and verification process given future land use updates for the model. This document summarizes updates that have been made in response to this latest round of feedback following the initial revisions that were made in June.

Comments or suggested edits that pertain to grammar, spelling or formatting of the report are not included or addressed here, but the Coordinator has noted those comments for direct revisions to the report. Revisions already summarized in the June summary memo and response to comments table are not included here.

If there are any new or lingering comments or questions that could impact your ability to approve the recommendations for submission to the WQGIT, please email them to Jeremy Hanson, Ted Tesler, Matt Johnston and David Wood one business day or more in advance of the 9/1/16 conference call (i.e. by COB 8/29/16). This will help us prepare for and manage the workgroup's discussion more effectively.

Summary of Major Changes to the Expert Panel Report

- Change of the recommended Phase 6 BMP name from "Urban Tree Planting" to "Urban Tree Canopy Expansion." The name of, and references to, the Phase 5 "Urban Tree Planting" BMP are unchanged.
- Recommendation from the FWG (with Partnership support) for a second (tier 2) BMP called Urban Forest Planting has been incorporated in the report and technical appendix (Appendix F). The definition of the panel's recommended BMP for Urban Tree Canopy Expansion, and various references to the Phase 6 BMP(s) have been adjusted accordingly throughout the report.
    - The report's recommendations from the Expert Panel as written pertain to the Urban Tree Canopy Expansion BMP and recommendations for an Urban Forest Planting BMP is provided as Appendix H to the report.
- An addendum to Appendix B (Derivation of the tree canopy land use loading rates) is provided that summarizes a list of items for the partnership's future consideration whenever the tree canopy land uses and loading rates are revisited for future updates to the modeling tools. Note: As of August 18 we are still waiting for internal feedback on the addendum before discussing it with VA DEQ and subsequently posting it. These future considerations are in direct response to feedback from VA DEQ and pertain specifically to future updates to the tree canopy land use loading rates and have no substantive effect on the currently proposed BMP(s) for Phase 6.
- Updated definitions for the Urban Tree Canopy Expansion and Urban Forest Planting BMPs (Section 2) per feedback from FWG and VA DEQ colleagues.

- Removed text that provides superfluous explanation of methods of updating the tree canopy land uses in the future. The specific method to update the land uses is to be determined by the Partnership at a future date. The text was replaced with more generic language that requests the Partnership to define a decision rule(s) to avoid double-counting of acres of tree canopy as an existing land use defined by satellite imagery and that the acres from reported BMPs (see Section 5.1 and Section 6)
- A more complete description of the panel's rationale and justification for the recommended canopy area credit of 144 ft^2 per tree planted as informed by i-Tree Forecast.
    - Data from *http://dendro.cnre.vt.edu/predictions/canopy.cfm* was added to the report to compare the i-Tree Forecast results with other databases
- Added an example calculation for Recommendation #4 (Section 5.4) that illustrates how the credit for Urban Tree Canopy Expansion can be estimated. It is pointed out that this calculation for land use change BMPs is for illustrative purposes only as the land use loading rates used in the example will differ in the calibrated modeling tools.

- An additional future research recommendation is added to section 7:
    - "This BMP, and others, need to consider how future research findings on land cover land use and conveyance systems affect material transport to streams and the Bay (e.g. Re-plumbing the Chesapeake Bay Watershed: Improving Roadside Ditch Management to Meet TMDL Water Quality Goals)"
- Expanded upon a management recommendation in section 7 as shown in **bold**, 'Develop BMP's that address the conservation and maintenance of existing tree canopy. Conservation BMP's will reduce future pollutant loads by reducing the loss of tree canopy in future land use projections. Maintaining tree canopy has the potential to have a greater positive impact on local efforts and actions to address water quality than tree planting alone. **A cost-benefit analysis comparing the benefits of planting new trees with tree conservation should be a part of this research."**