Montgomery County Stormwater Management Facility Design Specification

TREES AND TREE CLUSTERS

May 2011

Individual trees and tree clusters can provide significant stormwater volume reduction and pollutant removal. This design specification establishes stormwater volume credit for single trees and small tree clusters that meet the criteria listed below. The Maryland Stormwater Design Manual does not currently include individual trees and small tree clusters as separate stormwater practices. Montgomery County established this tree and tree cluster stormwater specification in order to promote and enable the use of mature trees as stormwater management practices, both through tree protection and tree planting efforts.

A. Facility Description

Single Tree Stormwater Practice

The single tree stormwater practice is a tree that is at least 1.5" diameter at breast height and that has an established root zone that has acclimated to the surrounding native soil, or that is provided sufficient soil volume in a constructed tree box or landscaping panel.

Tree Cluster Stormwater Practice

The tree cluster stormwater practice is a grouping of trees comprised of no less than 2 individual trees that are grouped together densely such that their canopies overlap. **[Needed: determination of whether there is an upper limit to either the number of trees in a tree cluster or to the surface area of the tree cluster.]**

B. System Design Considerations

1. Applicability

The single tree stormwater practice is appropriate for contributing drainage areas of 1000 square feet or less; the tree cluster stormwater practice is appropriate for contributing drainage areas of 2500 square feet or less. Mature trees that are permanently protected on a site, and trees and tree clusters that are planted on a project site, are included as eligible for stormwater volume credit if they meet the specifications given below as documented by the applicant's certified arborist or other qualified professional.

The single tree and tree cluster stormwater practice is applicable to urban, suburban, and rural sites, including sites where the tree or tree cluster is surrounded by unconfined, native soil and subsoil and other vegetation, and more dense suburban or urban sites where the trees are confined in constructed planter boxes and landscaping panels. For trees in confined structures without significant root zone contact with surrounding native soils, the minimum soil volume criterion listed in part C.3 below is required.

2. Design Storm

The single tree and tree cluster stormwater practices must be able to provide reduction through the soil volumes associated with their root zones, plus through their canopy interception, of the runoff from the contributing drainage area for the Water Quality Volume – the first one-inch of each storm**. [or through the first 1.5” of each storm – TBD.]**

3. Single Tree Practice - location

Single trees to be eligible for this practice must be located down-gradient from the contributing impervious source area, and must be a minimum of 10 feet from any building foundation.

4. Tree Cluster Practice - location

Tree clusters to be eligible for this practice must be located down-gradient from the contributing impervious source area, and must be a minimum of 10 feet from any building foundation.

5. Limitations

Not suitable for large contributing impervious areas – single trees are suitable for up to a 1000 square foot contributing impervious area, and tree clusters are suitable for up to a 2500 square foot contributing impervious area.

C. Specifications and Details

1. Documentation of tree size and species

The tree species, Diameter at Breast Height (DBH), and canopy and critical root zone radii of the single tree and/or tree cluster must be documented on the site plan map and stormwater concept, site development and final plans by a qualified professional.

2. Calculation of canopy interception
Canopy interception for a single tree or tree cluster can be calculated using the USDA F.S. i-tree Streets tool; a Maryland DNR tree benefits calculator incorporates this into a larger estimate of benefits. The i-tree calculator yields a total annual number of gallons of stormwater reduced through leaf interception. **Further work is needed in order to enable rapid computation of the canopy interception stormwater volume for a single one-inch or 1.5” storm.**

3. Soil Volume

The need for provision of adequate soil volume is crucial both for stormwater volume capture and for tree survival and longevity. Research demonstrates that trees need 1 to 2 cubic feet of soil volume for every square foot of canopy area.[i] For trees in confined structures without significant root zone contact with surrounding native soils, this minimum soil volume criterion is required.

4. Determination of Soil Water-Holding Capacity based on soil group

Determination of soil porosity is based on the soil type and porosity factor using the table below. **(The values below are guidelines based on experience of site designers and builders; they are consistent with values reported in the technical literature[ii]; further references for this table and improved numbers are requested.)**

Soil Type	Water Capacity Factor
Silt Loam	0.3
Loam	0.25
Clay Loam	0.2
Clay	0.15

5. Stormwater discharge into tree root zone area via sheet flow

The Stormwater discharge into the tree or tree cluster area must be via sheet flow. If the tree or tree cluster is located on a slope, then level spreaders, terracing, or another standard method of ensuring sheet flow into the tree / tree cluster practice are required.

6. **Mulch**

A mulch layer must be provided underneath the tree, that is 2 to 3" thick, comprised of hardwood mulch and spread uniformly over the entire Critical Root Zone. **Quantification of the water holding capacity of various mulches is requested.**

7. Avoidance of soil compaction

Experts estimate that compacted soils only have on average a 5% water storage capacity (compared with his estimate of a 20% water storage capacity for loam soils.) It is crucial that the builder and landowner avoid soil compaction within the CRZ and take steps to reduce compaction if it has already occurred.

8. Determination of stormwater volume capture by the tree or tree cluster

The equation for determining the stormwater volume that is captured by single trees or tree clusters is:

WQV = X + Y, where WQV = The runoff from the contributing source area for the first one-inch [1.5”] of each storm.

X = the volume captured by the tree/ tree cluster’s canopy interception. When combined with an estimate of water storage in the soil volume, the i-Tree Streets calculator tool provides an important part of the total tree stormwater volume capture estimate. To compute the annual volume of water captured through canopy interception by a single tree, or tree cluster, use the Maryland tree benefits calculator. **Further work is needed in order to enable rapid computation of the canopy interception stormwater volume for a single one-inch storm.**

Y = the volume captured by stormwater infiltration into the soil and mulch associated with the tree’s/ tree cluster’s root zone. Stormwater infiltration includes the volume of stormwater captured by the tree/ tree cluster’s mulch layer, plus the soil volume layer that is held within the tree/ tree cluster’s root zone. Y is determined by the combination of water storage in the soil macropores associated with the tree or tree cluster’s root zone, plus the water storage in the mulch layer.

Y = Mulch storage (M) + Root Zone Stormwater storage (RZ)

Y = M + RZ(cubic feet); Where Rz is determined by:

Y = M + [Root Zone Area x Root Zone Depth x Water Capacity Factor]

Root Zone Area: $\pi (CRZ)^2$ = Root Zone Area RZA, (square feet)

CRZ = Diameter of the tree at Breast Height (DBH, inches) x (1.5) = CRZ radius (feet)

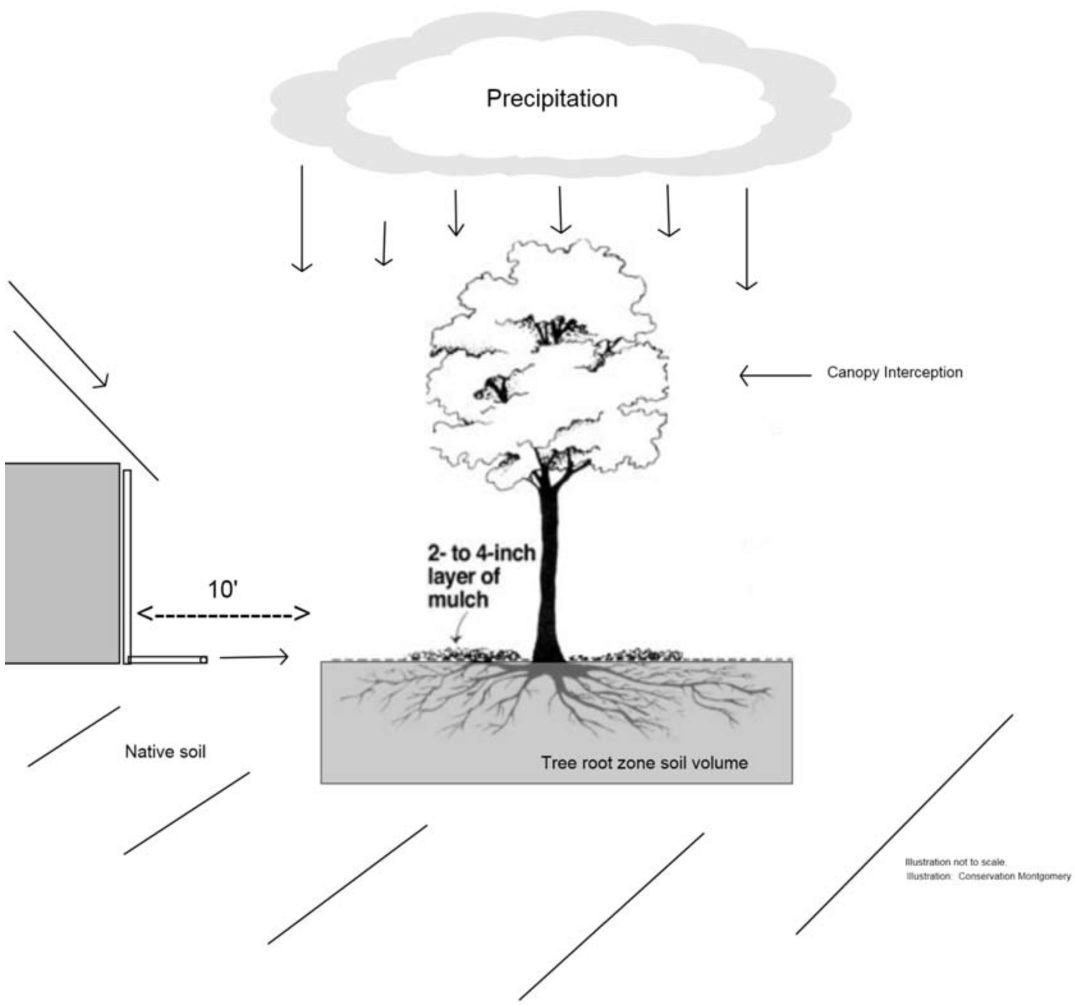
RZA (square feet) * Root Zone Depth (feet) (assumed to be 1.5 feet) =

Rz Volume * Water Capacity Factor from table below = RZ (cubic feet)

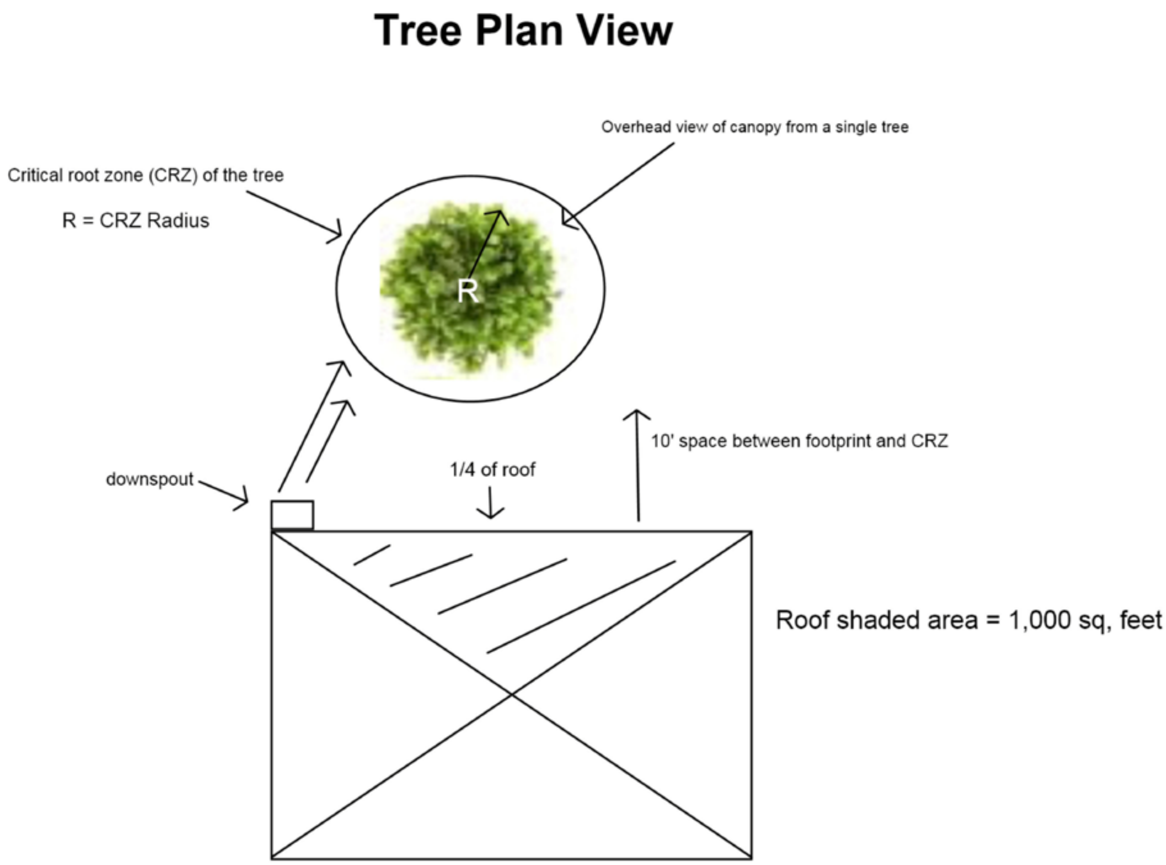
Soil Type	Water Capacity Factor
Silt Loam	0.3
Loam	0.25
Clay Loam	0.2
Clay	0.15

D. Cross Section and Plan View Sketches

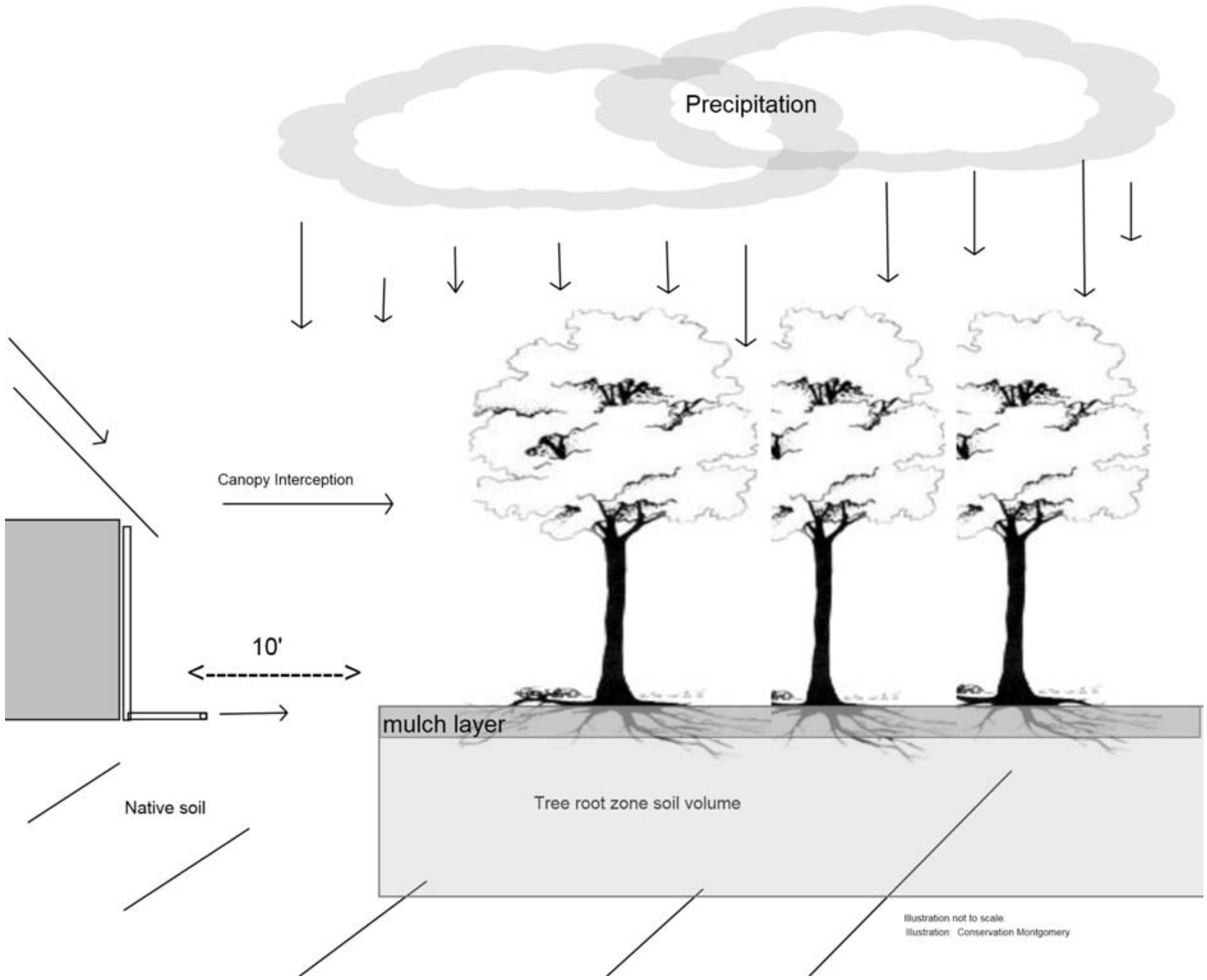
1. Single Tree Cross Section



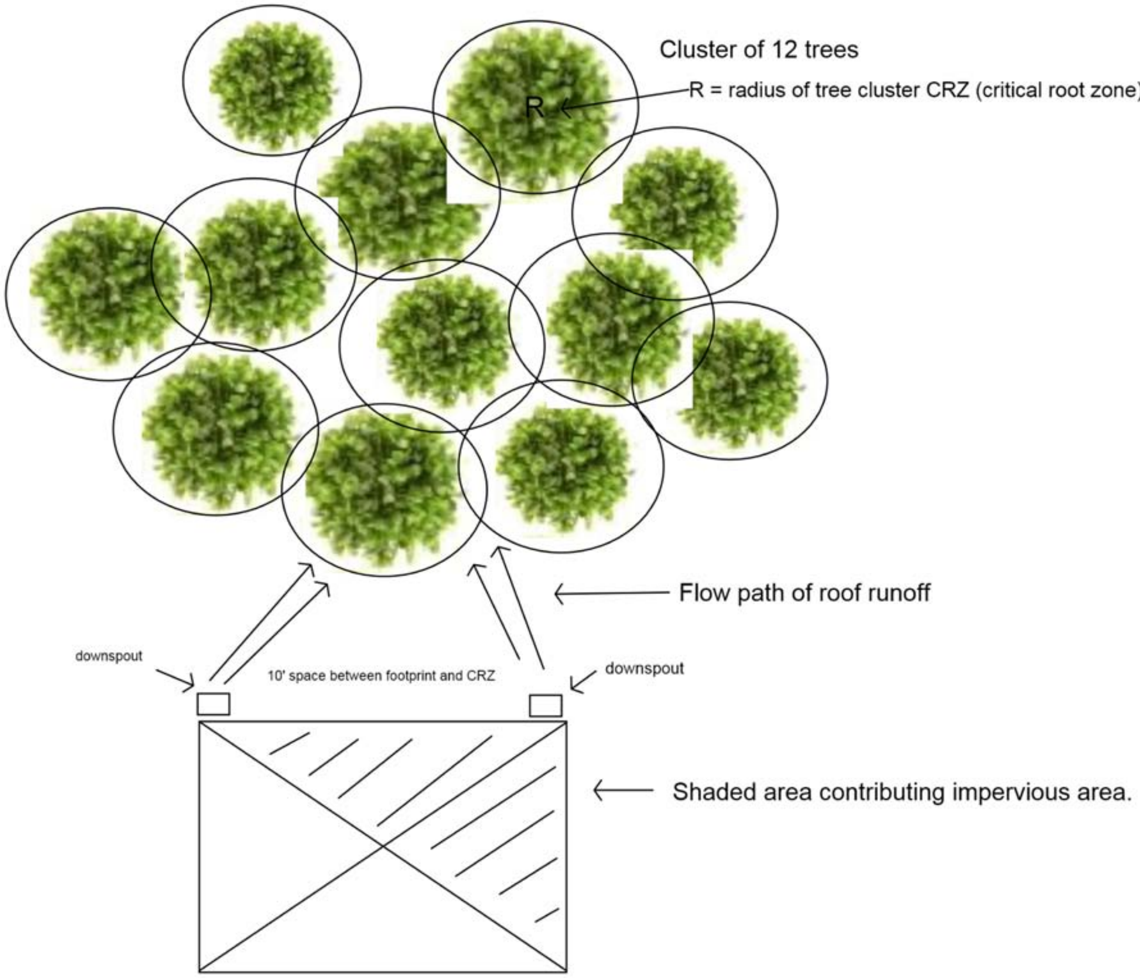
2. Single Tree Plan View



3. Tree Cluster Cross Section



4. Tree Cluster Plan View



Tree Plan Using a Cluster of Trees

E. Sample Calculations

Single Tree in Loam Soil

Assumptions: 1000 square foot contributing impervious area; 24” DBH single tree; 1.5’ root zone depth.

Calculation:

Contributing runoff for a 1.5” rainstorm over 24 hours:

1000 x 0.125 = 125 cubic feet of runoff sheet flows into the tree’s Critical Root Zone area (CRZ), which is covered with mulch.

Y = M + [Root Zone Area x Root Zone Depth x Water Capacity Factor]

M = runoff volume absorbed by the mulch layer (TBD).

Root Zone Area = 24 x 1.5 = 36’ radius; = 4071 square feet.

Root Zone Depth = 1.5’.

Root Zone Volume = 4071 sq. ft. x 1.5’ = 6107 cubic feet.

Water Capacity Factor of Loam = 0.25.

Root Zone Stormwater Storage = RZ = 1526 cubic feet of storage capacity.

Conclusion: this tree’s root zone can absorb all of the incoming runoff from a 1.5” rainstorm for the contributing 1000 square foot impervious area.

Single Tree in Clay Soil

Y = M + [Root Zone Area x Root Zone Depth x Water Capacity Factor]

Assumptions: 1000 square foot contributing impervious area; 24” DBH single tree; 1.5’ root zone depth.

Calculation:

Contributing runoff for a 1.5” rainstorm over 24 hours:

1000 x 0.125 = 125 cubic feet of runoff sheet flows into the tree's Critical Root Zone area (CRZ), which is covered with mulch.

Y = M + [Root Zone Area x Root Zone Depth x Water Capacity Factor]

M = runoff volume absorbed by the mulch layer (TBD).

Root Zone Area = 24 x 1.5 = 36' radius; = 4071 square feet.

Root Zone Depth = 1.5'.

Root Zone Volume = 4071 sq. ft. x 1.5' = 6107 cubic feet.

Water Capacity Factor of Clay soil = 0.15.

Root Zone Stormwater Storage = RZ = 916 cubic feet of storage capacity.

Therefore this tree's root zone can absorb all of the incoming runoff from a 1.5" rainstorm for the contributing 1000 square foot impervious area.

<u>Tree Cluster in Loam Soil</u>

Y = M + [Root Zone Area x Root Zone Depth x Water Capacity Factor]

Assumptions: 2500 square foot contributing impervious area; 12 mature trees of average 24" DBH; spaced 5 feet apart; total cluster radius including the outside CRZ = 72'; 1.5' root zone depth.

Calculation:

Contributing runoff for a 1.5" rainstorm over 24 hours:

2500 x 0.125 = 312 cubic feet of runoff which sheet flows into the tree cluster's Critical Root Zone area (CRZ), which is covered with mulch.

Y = M + [Root Zone Area x Root Zone Depth x Water Capacity Factor]

M = runoff volume absorbed by the mulch layer (TBD).

Root Zone Area = 72' radius; = 16286 square feet.

Root Zone Depth = 1.5'.

Root Zone Volume = 16286 sq. ft. x 1.5' = 24,429 cubic feet.

Water Capacity Factor of Loam = 0.25.

Root Zone Stormwater Storage = RZ = 24,429 x 0.25 = 6107 cubic feet of storage capacity.

Conclusion: this tree cluster's root zone can absorb all of the incoming runoff from a 1.5" rainstorm for the contributing 2500 square foot impervious area.

<u>Tree Cluster in Clay Soil</u>

Y = M + [Root Zone Area x Root Zone Depth x Water Capacity Factor]

Assumptions: 2500 square foot contributing impervious area; 12 mature trees of average 24" DBH; spaced 5 feet apart; total cluster radius including the outside CRZ = 72'; 1.5' root zone depth.

Calculation:

Contributing runoff for a 1.5" rainstorm over 24 hours:

2500 x 0.125 = 312 cubic feet of runoff which sheet flows into the tree cluster's Critical Root Zone area (CRZ), which is covered with mulch.

Y = M + [Root Zone Area x Root Zone Depth x Water Capacity Factor]

M = runoff volume absorbed by the mulch layer (TBD).

Root Zone Area = 72' radius; = 16286 square feet.

Root Zone Depth = 1.5'.

Root Zone Volume = 16286 sq. ft. x 1.5' = 24,429 cubic feet.

Water Capacity Factor of Clay Soil = 0.15.

Root Zone Stormwater Storage = RZ = 24,429 x 0.15 = 3664 cubic feet of storage capacity.

Conclusion: this tree cluster's root zone can absorb all of the incoming runoff from a 1.5" rainstorm for the contributing 2500 square foot impervious area.

Typical Cross Section

Background Documentation – Technical Basis for the Tree and Tree Cluster Stormwater Practice

I. MDE Stormwater Design Manual Chapter 5 – ESD Chapter

The Maryland Department of the Environment (MDE) in 2009 published revisions to its stormwater manual in order to implement the Stormwater Management Act of 2007 and its Environmental Site Design (ESD) mandates and policies. The major change to the manual was the upgrade of Chapter 5 into an expanded set of ESD practices that enable on-site reduction of runoff. Several practices, including Sheet Flow to Conservation Areas, and Disconnection of Rooftop and Non-Rooftop Runoff, can use trees and tree clusters to receive runoff. However, none of the practices in Chapter 5 focus on single trees or small tree clusters per se as stormwater practices, and the non-structural practices now in Chapter 5 present obstacles to the use of trees for runoff reduction, especially for small residential, commercial, or institutional lots, and rights-of-way, due to the following needs of these constrained sites:

- Minimize the surface area required by the ESD practice
- Avoid use of underdrains
- Avoid need to emplace gravel lenses below the soil layer

The practices listed above from Chapter 5, all have one or more of these drawbacks: they either require a relatively large surface area; or they require the use of underdrains, or they require the excavation and placement of a gravel lens below the practice. In contrast, single trees and tree clusters are able to capture (reduce) considerable runoff volumes in a compact manner that minimizes surface area; and their roots provide vertical channels for infiltration and recharge thus obviating the need for underdrains or gravel lenses.

Single trees in particular, when used as stormwater practices, would be considered as “micro practices” designed to accept runoff from small contributing impervious areas, this also avoids the need for underdrains and other structural components.

II. Typical Water Balance for a single tree or small tree cluster – To be provided.

III. Existing tree – stormwater volume estimation methodologies and related technical literature

Casey Trees’ report, Tree Space Design was published in 2008 through a collaborative effort of four tree and design experts on the Casey Trees staff, combined with a panel of twelve expert advisors including Jim Urban. The main contribution of this report is to establish the need for significantly larger soil volumes for urban trees (target ranges between 500 and 1000 cubic feet per tree) and especially for street trees. These are up to ten times more soil volume per tree than has typically been provided by municipalities. *Tree Space Design* also defines quantitative criteria for minimum soil volumes and root space structures that will provide tree canopies of target sizes and will vastly improve tree longevity.

The USDA Forest Service i-Tree tool contains both street tree and whole-watershed hydrologic estimation components. The Streets (street tree) tool only uses canopy interception[iii], while the whole-watershed Hydro tool uses a broader array of stormwater management functions, but is not applicable to single trees or small tree clusters on single sites. A Maryland version is available for estimating tree benefits across a wide spectrum including stormwater, but again the stormwater element is limited to canopy (leaf) interception and does not include soil water storage. When combined with an estimate of water storage in the soil volume, the i-Tree Streets calculator tool can provide an important part of the total tree stormwater volume capture estimate.

Casey Trees – Limnotech Green Build Out Model (GBOM) (published as version I in 2007 and version II in 2009) is an extremely important modeling effort by a consortium that included, in addition to Casey Trees and Limnotech, US EPA, NRDC, and other organizations. The GBOM used canopy interception through a detailed modeling exercise that assumed each leaf acts as a shallow cup to hold and evaporate a certain quantity of precipitation. Although it remains a highly beneficial and important model for District of Columbia green infrastructure planning, it remains for future versions to incorporate a more complete model of tree-related stormwater management functions.

The 2010 **American Rivers – Center for Neighborhood Technology report, The Value of Green Infrastructure,** used the US Forest Service STRATUM methodology to make sample estimates of urban tree stormwater volume reductions. This model is limited to the estimation of rainfall interception by a tree's canopy. This benefits methodology, though extremely important and useful, significantly underestimates the total volume reduction provided by trees with ample soil volumes.

Bonestroo and Associates in September 2010 hosted a Trees and Stormwater Symposium. Several presentations given during this symposium are useful background material for preparation of a tree and tree cluster stormwater specification, including that of Dr. Peter McDonagh, Director of Science and Design for Kestrel Design Group in Minneapolis. Dr. McDonagh's presentation at this symposium is the source of the estimate that compacted soils have on average a 5% water storage capacity. In addition, Dr. McDonagh's review of the technical literature found that characterization of static water storage in the soil media is that of "abundant, mature research; accepted volumetric quantities, and reliable modeling criteria."[iv]

Endnotes

---

[i] Casey Trees (2008) ***Tree Space Design: Growing the Tree Out of the Box*** (pg.3); Urban, Jim (2008) ***Up By Roots.***

[ii] For instance, see: Dunne, T. and Leopold, L. (1978) ***Water in Environmental Planning***, page 175 regarding estimation of available water-holding capacity of various soil types (Figure 6-9). Using Dunne and Leopold's method of estimating available water-holding capacity of various soils by calculating the difference between porosity and field capacity, an eyeball best-fit estimation for the sands, loams, clay loams, and clays depicted in Figure 6-9 yielded the water-holding capacity factors as follows:

Soil Type	Sands	Loams	Clays
Available Water-Holding Capacity:			
Range	**0.25-0.3**	**0.21-0.25**	**0.18-0.20**
Average	**0.28**	**0.24**	**0.19**

[iii] ***Reference Cities – the Science Behind i-Tree (Streets) STRATUM –*** This background paper on the components of the i-Tree Streets calculator tool, indicates that the street tree input data is for the purpose of determining tree canopy and total leaf area for the purpose of estimating total annual gallons of stormwater that is intercepted by tree leaves and canopies. In other words, the i-Tree Streets tool does not currently incorporate stormwater storage in the trees' associated soil volumes.

[iv] McDonagh, Dr. Peter (2010) presentation at the Bonestroo Trees and Stormwater Symposium:
Big Trees in the City: *Suspended Pavement, Urban Trees, Urban Soils, Stormwater Management*. See esp. slide #13.