Impervious Cover Assessment
And Reduction Action Plan
Prepared For

Montgomery Township, Somerset County, New Jersey

by the
Watershed Institute

December 30, 2020

Acknowledgements

Designed as a blueprint for municipalities to take action to reduce impacts of stormwater runoff from impervious surfaces to New Jersey's Waterways, this document was created by The Watershed Institute staff with Water Quality Restoration Grant funding from the New Jersey Department of Environmental Protection under the Federal Clean Water Act, Section 319(h). This study was created with guidance from, and in supplement to, similar work performed by the Rutgers Cooperative Extension Water Resources Program, and we would like to thank them for their input and support.

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Executive Summary

Stormwater runoff occurs when precipitation falls on hard surfaces like roofs, parking lots, and roadways that are impervious to water. Stormwater runoff can cause flooding and pollute waters, and these concerns have grown more pronounced with increasing development and larger storm events that scientists attribute to climate change. The Watershed Institute created this Impervious Cover Assessment (ICA) and Reduction Action Plan (RAP) to 1) assess the extent of impervious cover in Montgomery Township, as well as the amount of the resultant stormwater runoff and associated pollutant loading (i.e. perform an ICA), 2) perform a more detailed ICA and stormwater assessment for a select number of commercial properties within the municipality, 3) provide a select number of preliminary designs that act as examples of possible actions that can be taken to reduce or mitigate the amount or stormwater runoff and associated pollutants (i.e. create an RAP), and 4) review any policies and ordinances that the municipality may have that are relevant to stormwater management and make recommendations for changes in policy that will reduce stormwater runoff and its impacts in the future.

In Summary:

1. Impervious surfaces cover approximately 8.13 percent of Montgomery Township's land area. This is slightly below the 10% threshold above which a subwatershed is considered to be impaired for water quality.
2. The municipality has five subwatersheds which have impervious cover (IC) ranging from 3.6-14.6 % IC; the recommendation of this report is that restorations efforts should be focused in the three subwatersheds with the highest percentages of IC: the Lower Millstone, Pike Run, and the Beden Brook subwatersheds; We recommend limitations on development and incorporation of Green Infrastructure throughout the municipality to limit future increases in IC.
3. Stormwater runoff volume from the municipality IC is over 2.1 billion gallons of stormwater annually.
4. Using Geographical Information Systems, we identified 35 sites where actions could be taken to mitigate stormwater runoff. For 12 of those sites, we conducted more detailed on-site stormwater assessments and prepared Green Infrastructure conceptual designs. Those 12 projects have a total stormwater mitigation potential of more than 39.8 million gallons of runoff.
5. While Montgomery Township has some regulations in place for Tree Protection, Stream Corridor Protection, and Stormwater Management Rules, the creation of new and updating / strengthening of current ordinances for all three of these categories are recommended to help with mitigation and resiliency for both surface water pollution, flooding events, and habitat degradation (See Policy Review).

Introduction

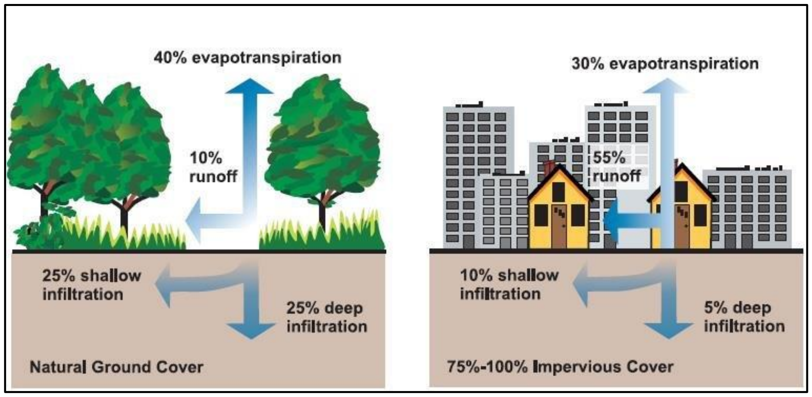


Figure 1: Relationship between impervious surfaces and stormwater runoff.[1]

Pervious and impervious are terms that are used to describe the ability or inability of water to flow through a surface. Pervious surfaces are those which allow stormwater to readily soak into the soil and recharge groundwater. When rainfall drains from a surface, it is called "stormwater runoff". Impervious cover (IC) is any material that has been placed over soil that prevents water from soaking into the ground. Impervious surfaces include paved roadways, parking lots, sidewalks, rooftops, and most aspects of development. As impervious areas increase, so does the volume of stormwater runoff. Impervious surfaces alter the natural hydrologic cycle, causing runoff to increase dramatically from ~ 10% of annual rainfall in an undeveloped watershed to > 50% in a highly urbanized watershed (Figure 1).[2]

As stormwater flows over the ground, it picks up pollutants, including salts, animal waste, sediment, excess fertilizers, pesticides, motor oil, and other toxic substances. It is no surprise then, that impervious cover can be linked to the quality of water in lakes, reservoirs, estuaries, and aquifers, and the amount of impervious cover in a watershed can be used to project the current and future quality of streams.[3] However, there are many other consequences associated with high amounts of runoff.

Problems in New Jersey due to stormwater runoff include:

- Pollution: According to the 2010 New Jersey Water Quality Assessment Report, 90% of the assessed waters in New Jersey are impaired, with urban-related stormwater runoff listed as the most probable source of impairment.[4]
- Flooding: Over the past century, the state has seen an increase in flooding (Figure 2). Communities around the state have been affected by these floods. The amount of damage caused also has increased greatly with this trend, costing billions of dollars over this time span.
- Erosion: Increased stormwater runoff causes an increase in the velocity of flows in our waterways. The increased velocity after storm events erodes stream banks and shorelines,

1 Figure and caption recreated from United States Environmental Protection Agency (USEPA). 2003 Protecting Water Quality from Urban Runoff. National Service Center for Environmental Publications - EPA-841-F-03-003

2 Paul MJ & Meyer JL. 2001. The ecology of urban streams. Annual Review of Ecology & Systematics 32:333-365

3 Caraco, D., et. al. 1998. Rapid Watershed Planning Handbook. A Comprehensive Guide for Managing Urbanizing Watersheds. Prepared by Center For Watershed Protection, Ellicott City, MD. Prepared for U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds and Region V. October 1998.

4 United States Environmental Protection Agency (USEPA). 2013. Watershed Assessment, Tracking, and Environmental Results, New Jersey Water Quality Assessment Report. http://ofmpub.epa.gov/waters10/attains_state.control?p_state=NJ

degrading water quality. This erosion can damage local roads and bridges and cause harm to wildlife.

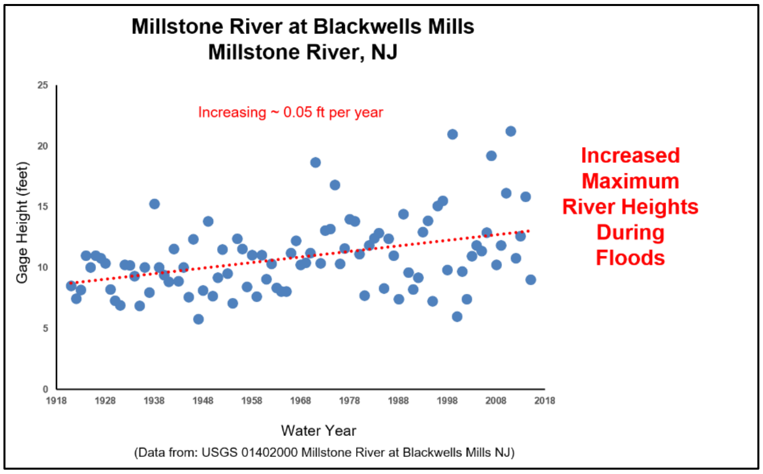


Figure 2: Annual Maximum River Height at Blackwells Mills Dam, Franklin Twp, NJ

The primary cause of the pollution, flooding, and erosion problems is the quantity of impervious surfaces draining directly to local waterways. New Jersey is one of the most developed states in the country, and has the highest percent of impervious cover in the country at 12.1% of its total area.[5] Most of these surfaces are directly connected to local waterways (i.e., every drop of rain that lands on these impervious surfaces and does not evaporate ends up in a local river, lake, or bay without any chance of being treated to remove pollutants or opportunity for it to recharge ground water). To repair our waterways, reduce flooding, recharge groundwater and reduce erosion of streambanks, stormwater runoff from IC has to be better managed. Surfaces need to be disconnected with green infrastructure or other Best Management Practices (BMPs) to restore the natural hydrological cycle by preventing stormwater runoff from flowing directly into New Jersey's waterways.

The first step to reducing the impacts from impervious surfaces is to conduct an impervious cover and stormwater management assessment to determine the sources and volumes of runoff water. Once impervious surface have been delineated, there are three primary actions that can be designed to restore an area's proper hydrology:

1. **Eliminate impervious cover that is not necessary.** For example, a paved courtyard at a public school could be converted to a garden or grassy area.
2. **Reduce or convert impervious surfaces.** There may be surfaces that are required to be hardened, such as roadways or parking lots, but could be reduced in size and/or converted to pervious surface. This can be achieved by reducing car-lanes sizes or replacing hardscaping with permeable paving materials such as porous asphalt, pervious concrete, or permeable paving stones that could be substituted for impermeable paving materials.

[5] Nowak, D. J., and E. J. Greenfield, 2012. Trees and Impervious Cover in the United States. *Landscape and Urban Planning* 107 (2012): 21-30. http://www.nrs.fs.fed.us/pubs/jrnl/2012/nrs_2012_nowak_002.pdf

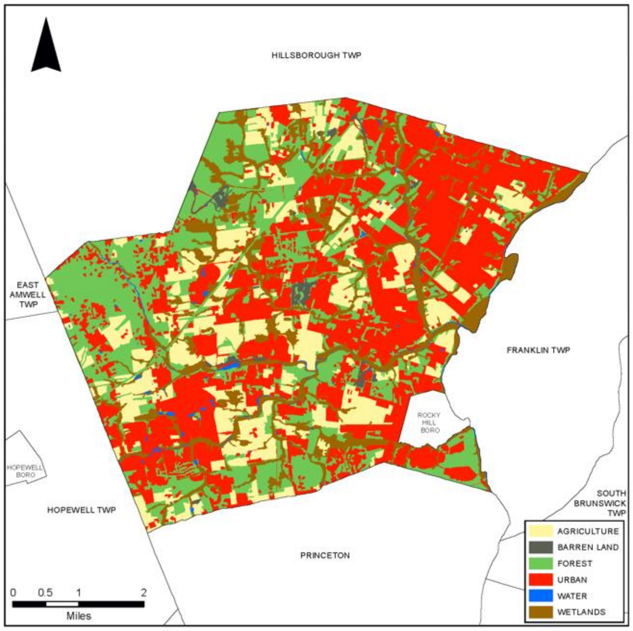


Figure 3: Land-use aerial of Montgomery

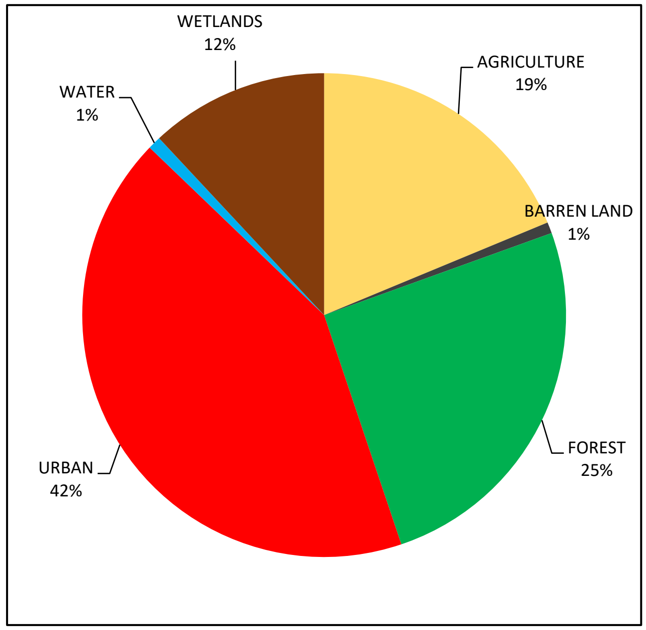


Figure 4: Land-use composition (%) in Montgomery

3. **Disconnect impervious surfaces from flowing directly to local waterways.** There are many ways to capture and treat stormwater runoff from impervious surfaces and subsequently either reuse the water or allow the water to infiltrate into the ground restoring aquifers (See Green Infrastructure & Best Management Practices).

This report details the results of an Impervious Cover Assessment (ICA) performed during 2016/2017 for Montgomery Township at several different scales: by municipality, subwatershed, and individual lots. In addition, a concept design to reduce or mitigate stormwater runoff, here called a Reduction Action Plan or RAP, was created for a subset of the individual lots that were assessed. Finally, a review of the municipality's ordinances and/or Master Plan sections that are relevant to the control of stormwater runoff was completed, with suggestions for making changes towards resiliency for flooding and improved water quality.

Impervious Cover Analysis: Montgomery Township

Municipal Subwatershed Assessment

Located in Somerset County in central New Jersey, Montgomery Township covers about 32 square miles. The primary land-use type was determined to be urban at 42% of the total town (Figures 3 & 4), with rural residential as the dominant type of urban land at 58% (Figure 5). Impervious surfaces were estimated to cover 8.13% of Montgomery Township's land area (Figure 6). The municipality is divided into five individual subwatershed units (Figure 7, colored areas), all of which drain to the Millstone River.

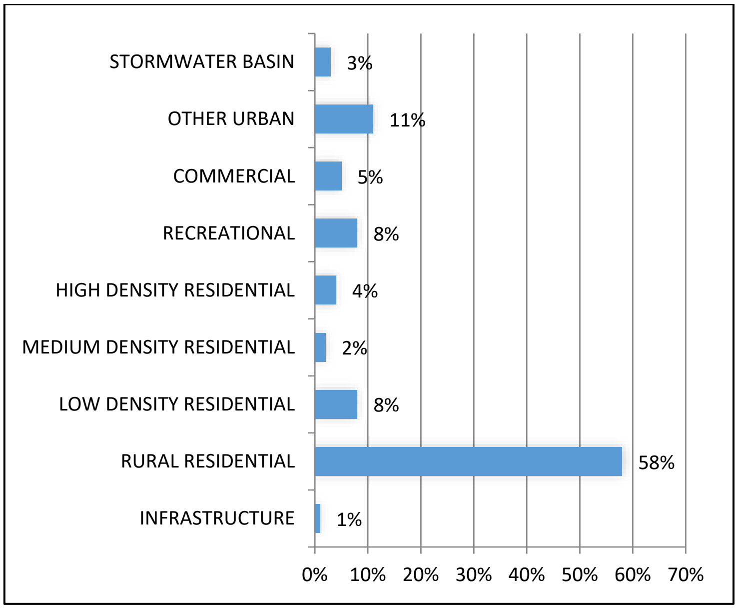


Figure 5: Urban land-use composition in Montgomery

Analysis of the sections of those drainage areas that fall within the municipality's boundaries showed a variable amount of IC, ranging from 3.63% in the Cruser Brook/Roaring Brook subwatershed to 14.56% in the Lower Millstone River subwatershed (Table 1).

Runoff volumes caused by impervious surfaces was modeled for the entire municipality as well as for each of the subwatersheds for the following categories of rainfall events: 1) The New Jersey's water quality design storm (the storm event used to analyze and design stormwater management systems (equal to 1.25 inches of rain over a 2 hour period), 2) the 2-year design storm (3.30 inches in 24 hours), 3) the 10-year design storm (4.96 inches in 24 hours), 4) the 100-year design storm (8.12 inches in 24 hours), and 5) New Jersey's total average annual rainfall of 46.94 inches (Table 2).[6,7] Impervious surfaces in Montgomery Township result in over 2.1 billion gallons of annual stormwater runoff. The Water Quality Design storm would produce 56.9 million gallons in just a two hour period, while the 2, 10, and 100 year storms would generate 150.1, 225.6, and 369.3 million gallons within a 24 hour period respectively.

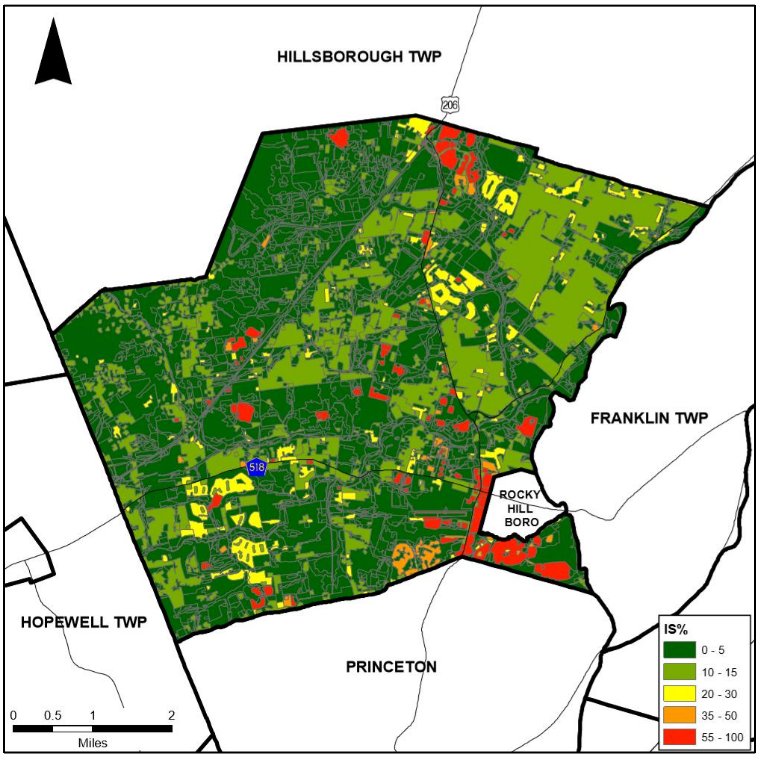


Figure 6: Amount of Impervious Surfaces (% IS) by parcel in Montgomery

The 5 main subwatersheds within Montgomery Township are further composed of 8 tributary subwatersheds, or HUC 14 basins (delineated by yellow perimeters, Figure 7). Existing conditions for impervious cover and runoff calculations for the entirety of each HUC 14 (which includes the areas outside of the

[6] NJ Stormwater Best Management Practices Manual – see https://www.njstormwater.org/bmp_manual2.htm
[7] Based on New Jersey's average annual rainfall as of 2017 – Office of the NJ State Climatologist, Rutgers University

Table 1: Impervious cover analysis by subwatershed for Montgomery

Subwatershed	Total Area		Land Area		Water Area		Impervious Cover		
	(ac)	(mi²)	(ac)	(mi²)	(ac)	(mi²)	(ac)	(mi²)	(%)
Beden Brook	5,437.33	8.50	5,370.33	8.39	67	0.10	430.39	0.67	8.01%
Cruser Bk / Roaring Bk	2424.72	3.79	2,421.93	3.78	2.79	0.00	87.95	0.14	3.63%
Lower Millstone River	2,303.66	3.60	2,263.28	3.54	40.38	0.06	329.58	0.51	14.56%
Pike Run	7,107.40	11.11	7,070.94	11.05	36.46	0.06	660.71	1.03	9.34%
Rock Brook	3,515.36	5.49	3,479.22	5.44	36.14	0.06	166.42	0.26	4.78%
Total	20,788.47	32.48	20,605.70	32.20	182.77	0.29	1,675.05	2.62	8.13%

Table 2: Stormwater runoff volumes (million gallons) from impervious surfaces by subwatershed in Montgomery

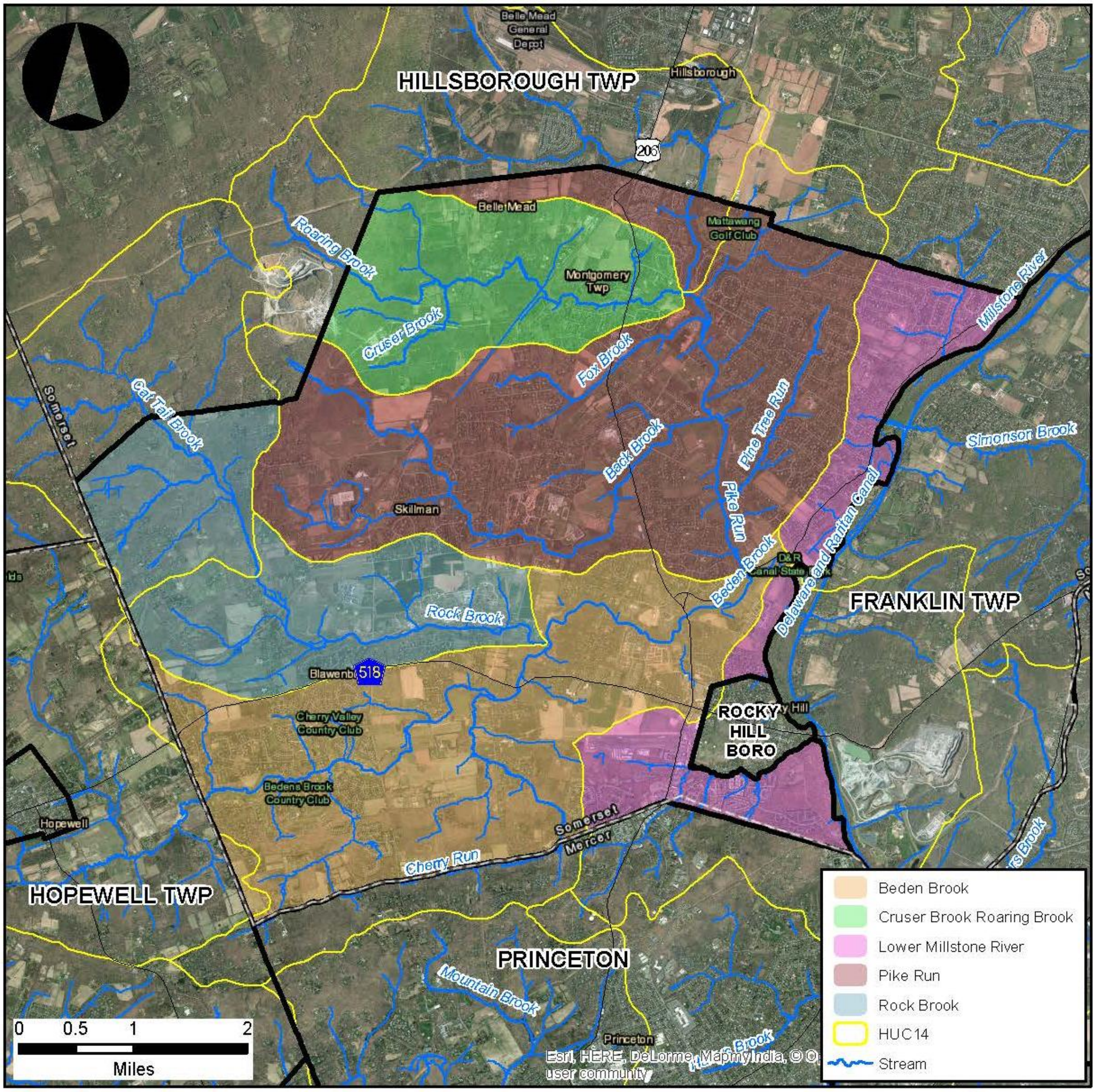
Subwatershed	Total Runoff Volume for the 1.25" NJ Water Quality Storm (MGal)	Total Runoff Volume for the NJ Annual Rainfall of 46.94" (MGal)	Total Runoff Volume for the 2-Year Design Storm (3.30") (MGal)	Total Runoff Volume for the 10-Year Design Storm (4.96") (MGal)	Total Runoff Volume for the 100-Year Design Storm (8.12") (MGal)
Beden Brook	14.6	548.5	38.6	58.0	94.9
Cruser Bk / Roaring Bk	3.0	112.1	7.9	11.8	19.4
Lower Millstone River	11.2	420.1	29.5	44.4	72.7
Pike Run	22.4	842.1	59.2	89.0	145.7
Rock Brook	5.6	212.1	14.9	22.4	36.7
Total	56.9	2,134.9	150.1	225.6	369.3

municipal boundaries) were also calculated. Results for land and water area as well as impervious cover can be found in Appendix A. Runoff values for the different rain event categories were also modeled for each HUC 14 basin and can be found in Appendix B.

Individual Lot Assessment

More specific impacts of runoff due to impervious surfaces can be modeled on a lot by lot basis once priorities have been identified through municipal and subwatershed scale assessments. An ICA was performed for 35 individual lots in Montgomery Township that contained particularly high levels of impervious cover (see colored lots, Figure 8 or visit https://thewatershed.org/**impervious-cover-assessments**/). Existing runoff volumes caused only by the sites' IC were modeled for the Water Quality Design Storm, the 2 year storm, and for the state's total annual rainfall (See Appendix C). Estimates for the annual amount of

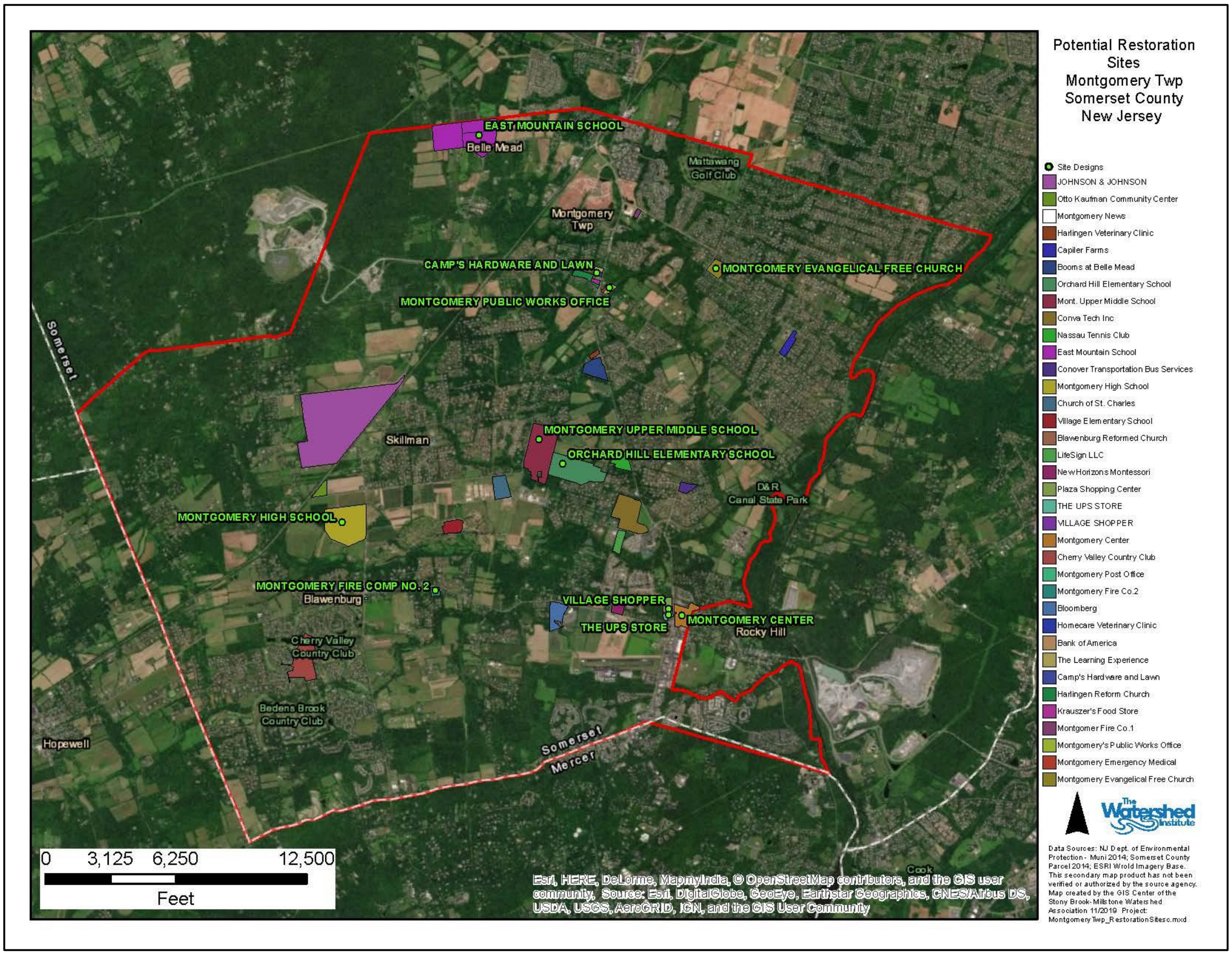
Figure 7: Map of subwatersheds in Montgomery



select pollutants (lb/year) that will runoff with the stormwater into waterways were also generated, including total nitrogen (TN), total phosphorous (TP), and total suspended solids (TSS).

Those 35 properties alone accounted for nearly 164 acres of impervious cover and over 343 million gallons of the town's annual stormwater runoff. This volume of runoff from impervious surfaces carries an estimated 428 lb of total phosphorous, 4,393 lb of total nitrogen, and 45,353 lb of total suspended solids into the streams of Montgomery Township, and downstream to the Millstone River. The summary of existing individual lot conditions can be found in Appendix C or online at https://thewatershed.org/**impervious-cover-assessments**/.

Figure 8: Map of individual lots that received an ICA in Montgomery



Reduction Action Plans: Montgomery Township

Of the 35 individual ICAs performed at the single lot scale, 12 were selected for RAP designs (see Fig 8, green labels). For each RAP, we analyzed close up maps of the sites (Figure 9a) with ArcGIS to calculate the total impervious cover (Figure 9b). Site visits were then conducted to survey for precise slope, drainage and existing stormwater management features, and to determine the sites' potential to host a stormwater management project (see Appendix D for example Site Assessment Template). Drainage areas, defined as any area that drains to a similar point on-site, were then delineated, and non-structural stormwater management features were then designed to capture select drainage areas (Figure 9c). These stormwater features were designed to either remove and/or convert impervious surfaces to pervious surfaces, or otherwise disconnect drainage areas from the local waterways by creating bioretention systems or other Green Infrastructure/Best Management Practices (BMPs) (See Green Infrastructure and Best Management Practices section below).

A summary of BMP designs, the impacts of the proposed BMPs for the site, along with an overview map of each RAP can be found in Appendix E. Wherever possible BMPs were designed with the intent to capture the volume of runoff equivalent to that of the 2 Year Storm for the intended drainage area, however this was not always possible. The modeled runoff reduction for individual and combined

BMPs for each site is expressed here in two ways. First, the Maximum Volume Reduction Potential of the green infrastructure expressed as gallons per storm, i.e. the instantaneous capacity of all BMPs installed. The second value is the total annual Recharge Potential (gallons / year), or the total amount of average annual rainfall that is estimated to be infiltrated into the ground to recharge groundwater and is therefore intercepted before reaching local waterways.

A summary of individual and combined BMPs for all Montgomery RAPs by subwatershed is found in Appendix F. Combined the RAP designs are estimated to have a Maximum Volume Reduction Potential of over 2.9 million gallons/storm, and a Recharge Potential greater than 39.8 million gallons/year. This will mitigate over 31% of a 2 Year Storm event, and infiltrate slightly under 30% of the annual rainfall that runs off of the IC from these 12 sites combined. The potential for pollution removals was also estimated, and the RAPs for these sites will collectively intercept more than 6 lb of TP, 36 lb of TN, and 1,055 lb of TSS, preventing these pollutants from entering local waterways. Finally, we provide a robust cost estimate for each feature based on previous experience and professional conversations.

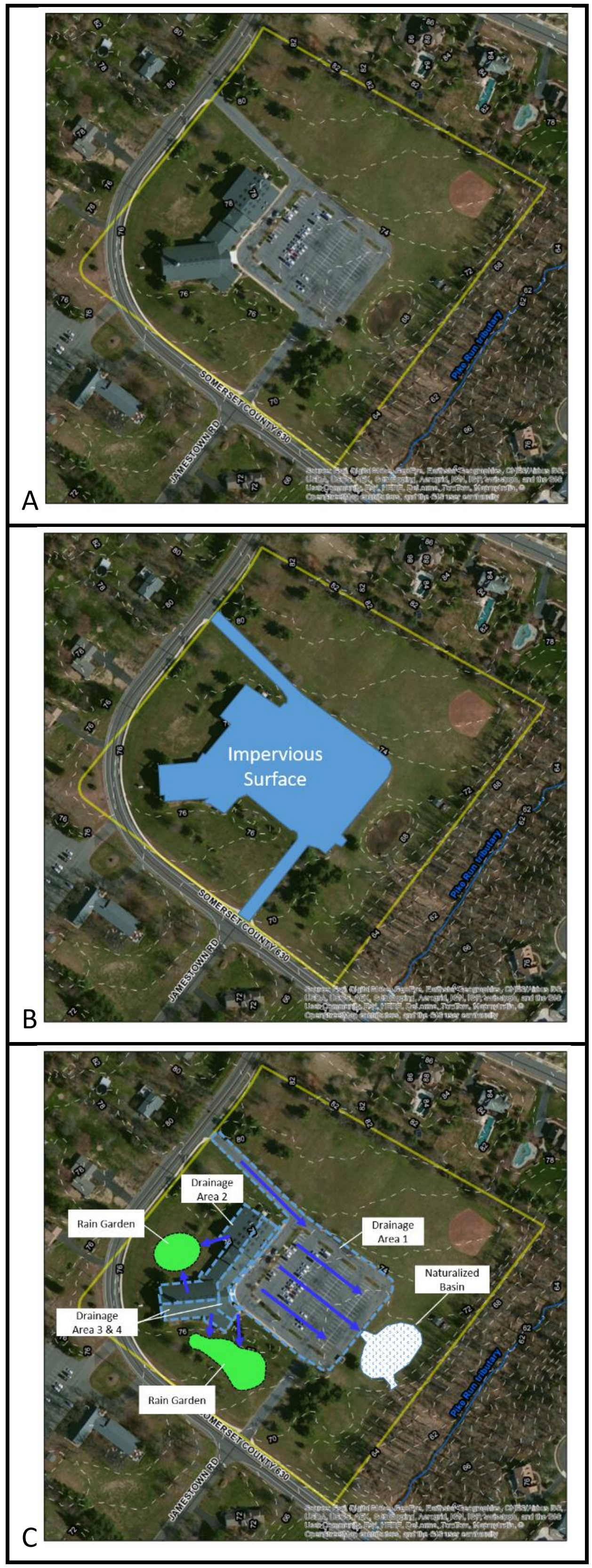


Figure 9: Example site-specific ICA & RAP process

Policy Review: Montgomery Township

Montgomery Township has a history of "node"-oriented development planning, which has served to limit sprawl to some extent and facilitated the preservation of open space. As of the last Master Plan Update in August 2017, 37 percent of the land in Montgomery Township was preserved open space. However, as development pressures increase, there are opportunities to increase protections for natural resources within the municipal code.

Tree Protection

Trees and forests play an important part in reducing flooding and soil erosion. Fewer trees compound the effects of impervious cover on flooding and pollution, especially when trees are removed and replaced with hardscapes. Strengthening protections for trees is important to both limit the spread of impervious cover and to reduce its impacts.

Current Policy: The Montgomery municipal code addresses tree protection in Chapter XVI, Section 5.6, Natural Features; and Chapter XIV, Section 3, Clearing and Removal of Trees. A permit is required from the municipality to:
1) Clear forested areas that are more than 50% of an individual residential lot that cannot be subdivided under the municipal code or are otherwise more than 40,000 square feet,
2) Clear more than 20,000 square feet of forest on a non-residential lot or a residential lot than can be further subdivided under the municipal code, or
3) Remove individual "public" trees (defined as trees located on municipally owned property; on common property owned by a homeowners', condominium or townhouse association; or on property that is encumbered by a conservation-purpose deed restriction or easement) .
The municipality's Enforcement Officer is authorized to issue permits to applicants seeking to clear forests and remove public trees based on his or her evaluation of the negative environmental impacts of such clearing, the positive impacts from any proposed tree replacement or reforestation plan, and whether a public purpose is furthered by the proposed removal or clearing

Should someone remove a public tree without a permit or in violation of a permit, then replacements are required at a two to one ratio in terms of size. The example provided is that if a 30 inch diameter tree is removed, the total amount of replacement trees must be equal to 60 inches. Any person who clears a forested area without having first obtained a permit, or does so in violation of any condition of such permit, is required to restore the cleared area to a forested area by the planting of new trees,
For land development projects, a minimum of 14 trees per acre must be planted on single-family residential lots, nonresidential and multifamily development.

Recommendation: While requiring the replacement of public trees and the protection of forested areas is a good start, we recommend the following actions to strengthen tree protection in Montgomery Township:

1. **Enact a tree protection ordinance** that requires a permit for removal of any tree in the municipality, whether it is a public tree, forested area, or related to a subdivision or site plan approval or is part of a private activity. Such an ordinance should prohibit the removal of healthy trees over 3 inches in diameter, limit the number of trees that can be removed on any lot per year (outside of an approved development application), and specify a replacement plan that does not result in significant canopy loss.
2. Reduce the discretion of the Enforcement Officer to issue permits for clearing forests or removing individual trees without preparation and implementation of a reforestation or tree replacement plan that fully mitigates the environmental damage.
3. In situations where there is a conservation easement or deed restriction on existing woodlands or farmland, the Board may reduce the total number of required trees on the remaining property or require forest enhancement so as to compensation for the loss of trees, increase in forest edge or other negative impacts from the development.

Stream Corridors

A stream corridor is composed of several essential elements, including the stream channel itself, floodplains, and adjacent forests. Where stream corridors are maintained in their natural condition with minimum disturbance, they are instrumental in removing sediment, nutrients, and pollutants from runoff. Vegetated stream buffers provide opportunities for filtration, absorption and decomposition of such pollutants by slowing stormwater velocity, which helps stormwater to be absorbed in the soil and taken up by vegetation. They also reduce stream bank erosion, displace potential sources of non-point source pollution from the water's edge, provide shading of water bodies that keeps the water cooler than streams exposed to direct sunlight, and prevent flood-related damage and associated costs to surrounding communities. Impervious cover does the opposite of these things, so prohibiting the placement of impervious cover near streams is an important goal.

Current Policy: Montgomery currently has protections for stream corridors as described in Chapter XVI, Section 6.4, Critical Areas:

> "Stream corridor shall mean and include the area within a floodway, flood plain, flood hazard area, special flood hazard area, buffer strips one hundred (100) feet from the top of the channel banks of the stream, intermittent stream and/or State open water, and the area that extends one hundred (100) feet from the flood hazard area or special flood hazard area line on both sides of the stream. If there is no flood hazard area or special flood hazard area line delineated, the distance of one hundred (100) feet shall be measured outward from the top of the banks of the stream channel on both sides of the stream, intermittent stream and/or State

open water. If slopes greater than fifteen (15%) percent abut the outer boundary of the stream corridor, the area of such slopes shall also be included as the stream corridor. If the flood plain, flood hazard area or special flood hazard area extends for more than one hundred (100) feet from the top of the channel bank, said larger area shall be the stream corridor." (Subsection C, 42.)

For stream corridors that are not in the Flood Hazard Area or Special Flood Hazard Area, building additions of up to 500 square feet and decks of up to 750 square feet are allowed. "Pools, and pool related appurtenances, such as walkways, patios, decks and fences" are also allowed.

Montgomery also has a Special Water Resource Protection Areas provision within in stormwater management rules (Chapter XVI, Section 5.2) that provides a 300-foot protected buffer on all "waters designated as Category One … and all perennial or intermittent streams that drain into or upstream of the Category One waters… within the associated HUC14 drainage area". The New Jersey Department of Environmental Protection designated a stretch of Rock Brook as Category one in Montgomery Township in April 2020.

Stream corridors are identified by the Montgomery Township Hydrography Map.

Recommendation: We recommend taking the following steps to improve the stream corridor ordinances in Montgomery:

1. **Increase the minimum buffer width to 150 ft**. The 100' buffer should be increased to 150' which will provide a larger and more effective buffer for the waterways within the municipality.
2. **Include all surface water bodies in the ordinance**. Ponds and lakes can also benefit from buffer protection.
3. **Reduce the amount of building allowable in stream corridors not in Flood Hazard Areas or Special Flood Hazard Areas.** Stream corridors are important to help prevent flooding along the entire length of a waterway, not just in areas already prone to flooding. Protecting the streams along their entire course is important.

In addition, we agree with the recommendation, included in Montgomery's recently completed Natural Resources Inventory, to review Montgomery's existing floodplain development ordinances and regulations and amend them as necessary to provide added protections.

Stormwater Management

Impervious cover creates more stormwater run-off as the rain is unable to infiltrate into the ground. Impervious cover also speeds the runoff of rain water from the property, which carries with it whatever litter and chemicals are on the surface. Proper stormwater management can mitigate the worst impacts of impervious cover on the environment.

Current Policy: Currently, stormwater management is required of any new major developments and redevelopments in Montgomery Township that disturbs one acre or more of vegetation, soil and/or bedrock or adds ¼ acre or more of impervious surface (Chapter XVI, Section 5.2, Stormwater Management and Grading). Minor development is any development not considered major. In addition to requiring stormwater management for major development, Montgomery Township also requires it for minor development in certain circumstances where ¼ acre of impervious surface is being added or "the applicant is seeking subdivision or minor or major site plan approval or approval for "d" variances pursuant to N.J.S.A. 40:55D-70d or for "c" variances for lot coverage".

Montgomery Township requires the use of the Nonstructural Stormwater Management Strategies Point System to demonstrate the use of non-structural stormwater management and low impact development strategies have been used in the plans.

Recommendation: The current ordinance does not address the collective impact of smaller developments in Montgomery Township, nor does it account for current impairments to waterways affected by stormwater runoff from sites within the municipality. Our recommendations are to:

1. **Decrease the threshold for a development to be considered "major"** to half an acre of soil disturbance or 5,000 sq. ft. of new or replacement impervious cover. Disturbance should also include repaving activities that do not necessarily disturb bare soil as well as other redevelopment activities.
2. Require the retention and treatment of the 95th percentile storm on site.
3. **Amend the definition of "minor development" and require stormwater management for all such developments**. Specifically, require stormwater mitigation for 250 sq. ft. or greater of any new development or new impervious cover. Along with the change in definition, minor development should require stormwater management that would treat on site 2 gallons of stormwater per square foot of impervious cover predominantly through the use of green infrastructure and non-structural stormwater management best practices. Of the 2 gallons per square foot, the 95th percentile storm should be retained onsite.
4. **The regulatory thresholds for major and minor development should be evaluated** for the total cumulative earth disturbance and/or additional impervious cover.
5. **The stormwater management design must recognize the existence of a TMDL** or impaired waters in the watershed and enhance the stormwater management requirements to meet the reductions set out in the TMDL or to reduce pollution in impaired waters.
6. **Porous pavement should be required** in any reconstruction project, except where heavy sediment loading, traffic, or truck weight is expected.
7. **A strict adherence to the non-structural requirements** should be met and enforced.

8. **Require stormwater management for the replacement of existing impervious cover that was constructed without stormwater management features.** Although the ordinance indicates that stormwater requirements apply to redevelopment projects, this is only true for such projects that add ¼ acre or more of impervious surface or disturb one acre or more of vegetation, soil and/or bedrock. Many older buildings, parking lots, driveways, and other developments were constructed with little or no attention or mitigation of the stormwater runoff that they generate. Stormwater mitigation measures should be required when such developments are **replaced** with new impervious surfaces during redevelopment.

Discussion and Conclusions

The literature suggests a link between impervious cover and stream ecosystem impairment starting at approximately 10% impervious cover, but has also been seen to impact water quality at 5% or lower depending on the parameter and conditions being studied.[8,9,10] Having a collective level of impervious cover of over 8% suggests that streams in Montgomery Township are likely either impaired, or on the verge of becoming so, due to impacts associated with stormwater runoff. However, evaluating impervious cover on a subwatershed basis reveals that certain areas are near or above the 10 % criteria for impaired watersheds (see Table 1), and allows mitigation efforts to be focused in areas with the highest amounts of runoff, flooding, and likelihood of impairment. For instance, concentrating efforts in the Lower Millstone (14.56 % IC) and Pike Run (9.34 % IC) subwatersheds would have the greatest effect at lowering the municipality's overall impact to watershed health.

The recommended green infrastructure practice and the drainage area that the practice will treat are identified for each site in Appendix E. While the designs reported here account for approximately 31% of the 2 Year Storm, they do account for 83% of a Water Quality Design Storm, for which precipitation rate is much higher and flooding much more likely. For context, if the stormwater runoff from one Water Quality Design Storm (1.25 inches of rain) in Montgomery was harvested and purified, it could supply water to 526 homes for one year.[11] Additionally, the calculations herein consider instantaneous capacity which does not account for infiltration into the ground, when in reality each BMP will infiltrate water at rates that are geology-dependent. This can be interpreted as providing a robust *underestimate* of feature capability. Consequently, capacity of each BMP should be higher than estimated in this report, and will increase with higher soil infiltration rates.

This report contains information on specific *potential* project sites where *potential* green infrastructure practices could be installed to provide examples of steps that can be taken towards stormwater runoff mitigation. They do not represent the only possibilities on each site. Variations, subsets, or alternatives to each design exist and this report is not exhaustive. There are also many other

[8] Schueler, T. 1994. The Importance of Imperviousness. Watershed Protection Techniques1(3): 100-111.
[9] Arnold, C.L. Jr. and C.J. Gibbons. 1996. Impervious Surface Coverage The Emergence of a Key Environmental Indicator. Journal of the American Planning Association 62(2): 243-258.
[10] Walsh CJ, Roy AH, Feminella JW, Cottingham PD, Groffman PM, Morgan RP II (2005) The urban stream syndrome: Current knowledge and the search for a cure. Journal of the North American Benthological Society 24(3):706-723.
[11] Assuming 300 gallons per day per home

projects not considered by this report that may be implemented at public/commercial organizations, schools, faith-based and nonprofit organizations, and other community locations not included in this report. Robust cost estimates have also been included which may not be representative of actual project costs, and likely will be lower depending on the contractor, materials, and methods.

Here we report on the state of impervious cover and resultant runoff impacts for Montgomery Township, and provide examples of how the municipality can reduce flooding and improve its waterways by better managing stormwater runoff from impervious surfaces. Assessing impervious cover is the first step toward better managing stormwater runoff. The impervious cover reduction action plans are meant to provide Montgomery with a blueprint for implementing green infrastructure practices that will reduce the impact of stormwater runoff. These practices can be implemented in other public spaces including along roadways and throughout the entire community. Furthermore, development projects that cannot satisfy the New Jersey stormwater management requirements for major development can also use these plans or others like them to provide off-site compensation from stormwater impacts to offset a stormwater management deficit.[12] Finally, Montgomery can quickly convert this impervious cover reduction action plan into a stormwater mitigation plan and incorporate it into the municipal stormwater control ordinance.

[12] New Jersey Administrative Code, N.J.A.C. 7:8, Stormwater Management, Statutory Authority: N.J.S.A. 12:5-3,13:1D-1 et seq., 13:9A-1 et seq., 13:19-1 et seq., 40:55D-93 to 99, 58:4-1 et seq., 58:10A-1 et seq., 58:11A-1 et seq. and 58:16A-50 et seq., *Date last amended: April 19, 2010*.

Methodology

Municipal Impervious Cover Assessments:

Watersheds were delineated, and land-use types, composition, and impervious cover percentages for the entire municipality and for each of the subwatersheds was determined using ArcGIS.[13] Runoff volume caused by impervious cover was modeled for the entire municipality as well as for each subwatershed for the following categories of rainfall events: 1) The New Jersey's water quality design storm (the storm event used to analyze and design stormwater management systems: equal to 1.25 inches of rain over a 2 hour period), 2) the 2-year design storm, 3) the 10-year design storm, 4) the 100-year design storm, and 5) New Jersey's total average annual rainfall of 46.94 inches.[14,15]

Runoff volume was modeled using equation 1:

$$Eq\ 1: Runoff\ Volume\ \ (gal) = \left[IC\ Area\ (ft^2) \times \left(Rainfall\ (in) \times \frac{1\ (ft)}{12\ (in)}\right)\right] \times \frac{7.48052\ (gal)}{1\ (ft^3)}$$

Where IC is impervious cover. Rain volumes for each storm event used for each municipality can be found in Table 3. These values were determined by the precipitation values for a municipality's dominant subwatershed, and were taken from NOAA's Atlas 14 Point Precipitation Frequency Estimates for New Jersey.[16]

Individual Lot Impervious Cover Assessments:

Public or commercial sites were selected based on the following primary criteria: amount of impervious cover; proximity to and/or potential impact to a stream; and where practicable, the nature of the commercial or public property (e.g. ease of access, potential for partnerships or project implementation, etc.). Percent area of impervious cover for lots was taken from NJ-GeoWeb's 2012 aerial imagery. Total impervious cover for each site was estimated as the percent IC (as determined in the Land Use/Land Cover 2012 data layer) times the lot size.

Existing runoff volumes caused only by the sites' impervious cover were modeled for the Water Quality Design Storm, the 2 year storm, and for the state's total annual rainfall as described above. Annual loading estimates for the associated select pollutants (lb/year), including total nitrogen (TN), total phosphorous (TP), and total suspended solids (TSS) were calculated for each site after the NJDEP method for calculating Total Maximum Daily Loads. The specific aerial loading coefficients were taken

[13] Land Use/Land Cover 2012 [New Jersey Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information Systems (BGIS)]; HUC14 2011 [Department of Environmental Protection (NJDEP), New Jersey Geological Survey (NJGS)]; Municipality 2014 [New Jersey Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS)]
[14] NJ Stormwater Best Management Practices Manual – see https://www.njstormwater.org/bmp_manual2.htm
[15] Based on New Jersey's average annual rainfall as of 2017 – Office of the NJ State Climatologist, Rutgers University
[16] NOAA Precipitation Frequency Data Severs: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nj

from the NJ Stormwater Best Management Practices Manual, are determined by Land Cover and can be found in Table 4.[17]

Table 3: Stormwater volumes by storm event

HUC-13 Watershed	2-Year Storm *(in/24 hrs)*	10-Year Storm *(in/24 hrs)*	100-Year Storm *(in/24 hrs)*
Cranbury Twp	3.31	5.07	8.57
East Windsor Twp	3.31	5.07	8.57
Hightstown Bor	3.31	5.07	8.57
Hopewell Bor	3.30	4.96	8.12
Hopewell Twp	3.32	4.98	8.14
Lawrence Twp	3.32	4.98	8.14
Millstone Bor	3.32	5.07	8.54
Montgomery Twp	3.30	4.96	8.12
Pennington Bor	3.32	4.98	8.14
Plainsboro Twp	3.30	5.01	8.32
Princeton	3.30	5.01	8.32
Robbinsville Twp	3.32	5.07	8.54
Rocky Hill Bor	3.30	5.01	8.32
Roosevelt Bor	3.32	5.07	8.54
West Amwell Twp	3.33	4.94	7.92
West Windsor Twp	3.30	5.01	8.32

<u>Reduction Action Plans (RAPs):</u>

A select number of lots were chosen for RAPs from the individual ICA list using the criteria described above. For each RAP, we analyzed close up maps of the sites and performed hand-drawn calculations for total impervious cover using ArcGIS measurement tools. Preliminary soil assessments were conducted for each potential project site identified using the U.S. Department of Agriculture Natural Resources Conservation Service GIS soil layer, which utilizes regional soil data to predict soil types in an area. Several key soil parameters were examined (e.g., hydrologic soil group, drainage class, depth to water table) to evaluate the suitability of each site's soil for type of green infrastructure practices. Site visits were then conducted to survey for precise slope, drainage and existing stormwater management features, and to determine the sites' potential to host, and placement of, stormwater management features (see Appendix D for example Site Assessment Template).

Table 4: Nutrient loading coefficients by Land Cover type

Land Cover	TP load (lbs/acre/yr)	TN load (lbs/acre/yr)	TSS load (lbs/acre/yr)
High, Medium Density residential	1.4	15	140
Low Density, Rural Residential	0.6	5	100
Commercial	2.1	22	200
Industrial	1.5	16	200
Urban, Mixed Urban, Other Urban	1	10	120
Agriculture	1.3	10	300
Forest, Water, Wetlands	0.1	3	40
Barrenland/Transitional Area	0.5	5	60

[17] NJ Stormwater Best Management Practices Manual – see https://www.njstormwater.org/bmp_manual2.htm

Non-structural stormwater Green Infrastructure, or Best Management Practice (BMP), features were then designed to capture select drainage areas based on the above assessments and with respect to the two year storm event.

The BMP area required for each identified drainage area was calculated using equation 2:

$$Eq\ 2: BMP\ Area\ (ft^2) = \left[Drainage\ Area\ (ft^2) \times \left(2\ year\ storm\ (in) \times \frac{1\ (ft)}{12\ (in)}\right)\right] \div BMP\ Capacity\ (ft)$$

The Maximum Volume Reduction Potential for each individual BMP, or the volume of runoff captured per storm event (gal), was then calculated using equation 3:

$$Eq\ 3: Maximum\ Volume\ Reduction\ Potential\ (gal) = \left(Drainage\ Area\ (ft^2) \times 2\ Year\ Storm (ft)\right) \times \frac{7.48052\ (gal)}{1\ (ft^3)}$$

Annual Recharge Potential (gallons / year), or the total amount of average annual rainfall that is estimated to be captured by individual BMPs was calculated using equation 4:

$$Eq\ 4: Recharge\ Potential\ (gal) = \left\{\left[Drainage\ Area\ (ft^2) \times \left(Annual\ Rainfall\ (in) \times \frac{1\ (ft)}{12\ (in)}\right) \times\right] 0.95\right\} \times \frac{7.48052\ (gal)}{1\ (ft^3)}$$

Finally, the potential for each BMP to remove TSS, TP, and TN was estimated using BMP-dependent removal coefficients (Table 5), and calculated using equation 5:

$$Eq\ 5: Removal\ Potential\ \left({}^{lb}/_{yr}\right) = \left(Area\ of\ BMP\ (ft^2) \times \frac{1\ (acre)}{43560\ (ft^2)}\right) \times Loading\ Coefficent\ \left(\frac{{}^{lb}/_{acre}}{year}\right) \times Removal\ Coefficient$$

Table 5: BMP-specific nutrient removal potential coefficients.

BMP Practice	TSS Removal Potential	TP Removal Potential	TN Removal Potential
Pervious Pavement	0.8	0.6	0.5
Bioretention system	0.9	0.6	0.3
Downspout planter boxes	ND*	ND*	ND*
Rainwater harvesting system	ND*	ND*	ND*
Curb Cuts	ND*	ND*	ND*
Dry well	ND*	ND*	ND*
Extended Detention Basin	0.5	0.2	0.2
Infiltration Structure	0.8	0.6	0.5
Sand Filter	0.8	0.5	0.35
Vegetative Filter	0.7	0.3	0.3
Wet Pond	0.7	0.5	0.3

*No Data

Green Infrastructure & Best Management Practices

Figure 10: Rapid Infiltration of water through pervious pavement

Section 502 of the Clean Water Act defines green infrastructure as "...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters." Whereas gray infrastructure is a conventional piped drainage system that quickly moves urban stormwater downstream and away from the built environment.

Stormwater runoff is a major cause of water pollution in urban areas. The concern with the conventional system is that it does not allow water to soak into the ground and instead sends it flowing off hardscaped surfaces such as parking lots, roads and roofs, to gutters and storm sewers and other engineered collection systems where it is discharged into local streams. These stormwater flows carry with it nutrients, bacteria, trash, and other contaminants. Larger storms result in higher stormwater volumes, which cause erosion and flooding in streams, damaging property, infrastructure and habitat. However when rain falls in natural, undeveloped areas, water is absorbed and filtered by soil and plants.

Green infrastructure mimics these natural systems and treats runoff as a resource by capturing, filtering, and absorbing stormwater. As a general principal, green infrastructure practices use soil and vegetation to recycle stormwater runoff through infiltration and evapotranspiration. When used as components of a stormwater management system, green infrastructure practices such as bioretention, porous pavement, rain gardens, and vegetated swales can produce a variety of environmental benefits. In addition to effectively retaining and infiltrating rainfall, these practices can simultaneously help filter

Figure 11: Example of Depaving project
Image credit: Habitat Network, yardmap.org

air pollutants, reduce energy demands, mitigate urban heat islands, and sequester carbon while also providing communities with aesthetic and natural resource benefits.[18]

Elimination of Impervious Surfaces (De-paving)

One method to reduce impervious cover is to "depave" (Figure 11). Depaving is the act of removing paved impervious surfaces and replacing them with pervious soil and vegetation that will allow for the infiltration of rainwater. Depaving leads to the re-creation of natural space that will help reduce flooding, increase wildlife habitat, and positively enhance water quality as well as beautify neighborhoods. Depaving can also bring communities together around a shared vision to work together to reconnect their neighborhood to the natural environment.

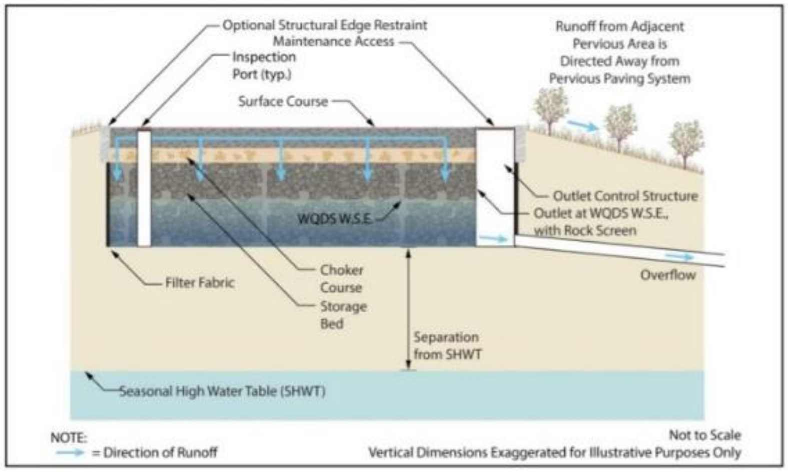


Figure 12: Basic components diagram common to a variety of pervious pavement systems.
Image Credit – NJ-BMP Manual

Pervious Pavements

A pervious paving system (Figure 10 & 12) is a stormwater management facility that filters stormwater runoff as it moves vertically through the system by either infiltrating through the void spaces in the hardscaped surface course or infiltrating through the joints in paver units. The system consists of a surface course, a transition layer and a storage bed of open-graded aggregate, where runoff is temporarily stored. Discharge of runoff from pervious paving systems is either through an underdrain or through infiltration into the subsoil. In order to receive a TSS removal rate for Water Quality, these systems must be designed to treat the entire Water Quality Design Storm volume without overflow; the adopted total suspended solids (TSS) removal rate is 80%. [19]

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[18] United States Environmental Protection Agency (USEPA), 2013. Watershed Assessment, Tracking, and Environmental Results, New Jersey Water Quality Assessment Report. http://ofmpub.epa.gov/waters10/attains_state.control?p_state=NJ

[19] New Jersey Stormwater Best Management Practices Manual, Chapter 9.7 Pervious Paving Systems, p. 2, https://www.njstormwater.org/pdf/2016-11-07-pervious-paving-final.pdf

Disconnected Downspouts

Often referred to simply as disconnection, this is the easiest and least costly method to reduce stormwater runoff for smaller storm events. Rather than flowing out toward the street, and then into the sewer system, a downspout is redirected over a grassed area to allow the water to be filtered by the grass and soaked into the ground (Figure 13). A healthy lawn can typically absorb the first inch of stormwater runoff from a rooftop in a slow rain event. Alternatively, downspouts can also be diverted to a vessel such as a rainbarrel in order to harvest and reuse the rainwater.

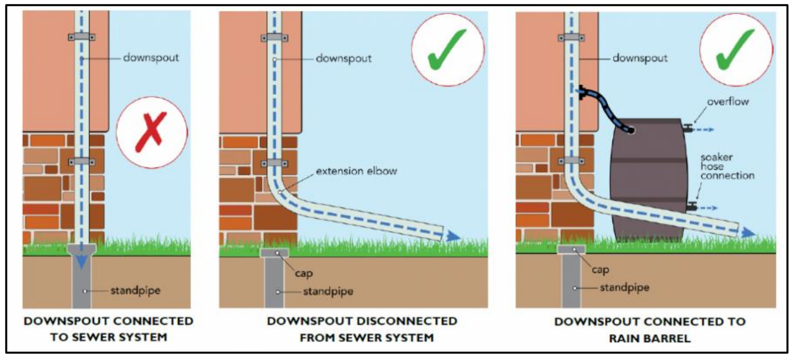

Figure 13: Downspout disconnection
Image credit: DC-Water

Bioretention Systems

Bioretention systems are vegetated stormwater management facilities that are used to address the stormwater quality and quantity impacts of land development. They filter a wide range of pollutants from land development sites through both the native vegetation and the soil bed, including suspended solids, nutrients, metals, hydrocarbons and bacteria. Vegetation provides uptake of pollutants and runoff, and the root system helps maintain the infiltration rate in the soil bed before discharging excess downstream through an underdrain or infiltrating into the subsoil.

The total suspended solids (TSS) removal rate is 80 - 90%; this rate will depend on the depth of the soil bed and the type of vegetation selected. These systems provide an opportunity to intercept and slow stormwater, as well as filter and cool the water that has flowed off of a hot, polluted surface before it enters the sewer system.

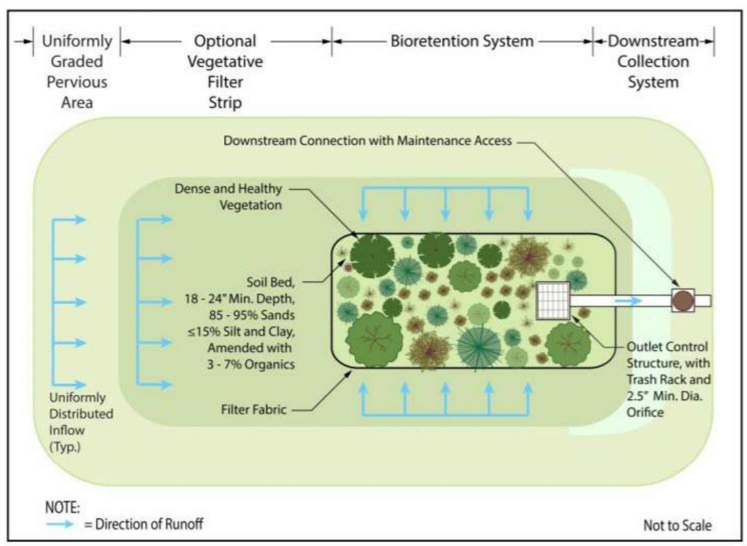

Figure 14: Basic bioretention system design.
Image credit: NJ-BMP Manual

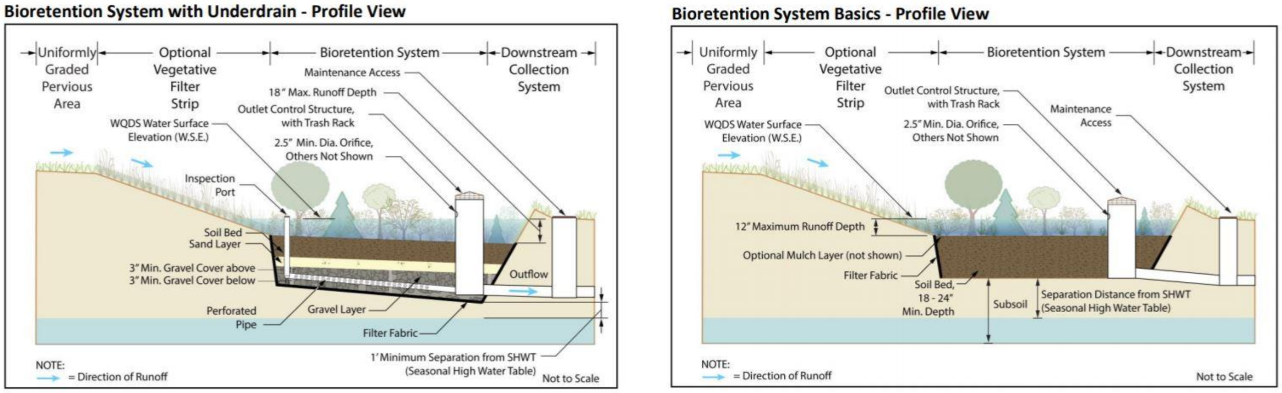

Figure 15: Bioretention facility cross sections with and without an underdrain.
Image credit: NJ-BMP Manual

Dry Wells

A dry well is an underground chamber that is used to collect and store stormwater runoff from rooftops while allowing it to infiltrate into the soil. Dry wells are limited to the collection of roof runoff and is prohibited in areas where there is high pollution or sediments are anticipated. Treatment from all other surfaces is not allowed. Dry wells are mainly used in areas where stormwater quality is not a concern, as this type of structure will not remove pollutants from stormwater.

Tree Filter Boxes

Tree box filters are in-ground containers typically containing street trees in urban areas. Runoff is directed to the tree box, where it is filtered by vegetation and soil before entering a catch basin. Tree box filters adapt bioretention principles used in rain gardens to enhance pollutant removal, improve reliability, standardize and increase ease of construction, and reduce maintenance costs. Individual tree box filters hold a relatively small volume of stormwater (100 - 300 gallons), but concerted use throughout a stormwater drainage area will decrease the total volume of discharged stormwater.

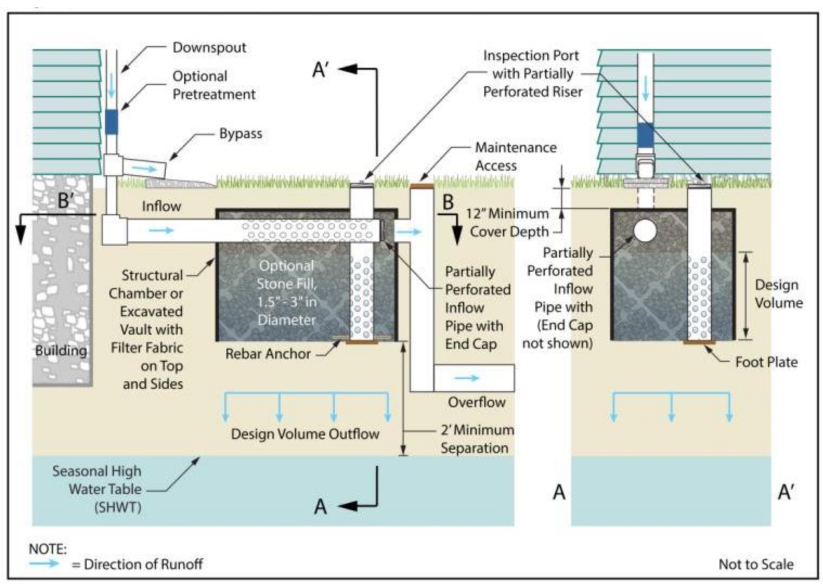

Figure 16: Dry well basics diagram.
Image credit: NJ-BMP Manual

Tree box filters decrease peak discharge by detaining stormwater volume and by increasing discharge duration. Use of numerous tree box filters in a stormwater drainage area can have an impact on total discharge energy and flow rates. Tree box filters have a high removal rate of pollutants in stormwater, as they have similar mechanisms and pollutant removal capabilities as rain gardens and vegetated roofs. They also provide the added value of aesthetics while making efficient use of available land for stormwater management.[20]

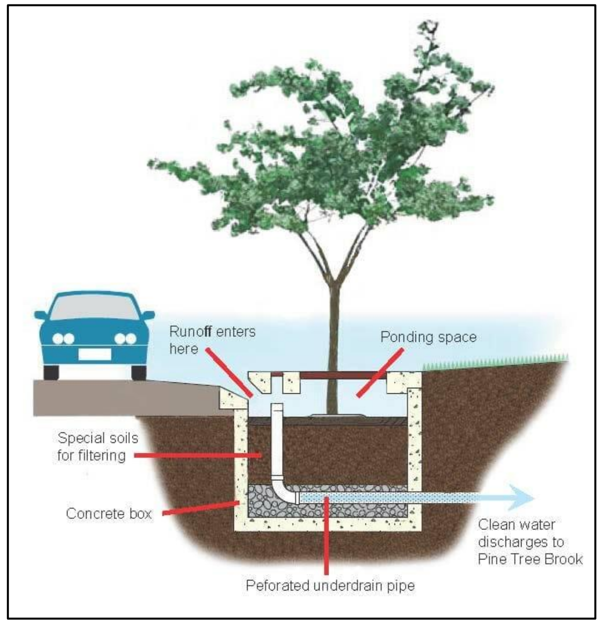

Figure 17: Basic tree filter box diagram
Image credit: Town of Milton, MA Dept. of public works

Stormwater Planters

A stormwater planter is a specialized planter installed in the sidewalk area that is designed to manage street and sidewalk runoff. It is normally rectangular, with four concrete sides providing structure and curbs for the planter. The planter is lined with a permeable fabric, filled with gravel or stone, and topped off with soil, plants, and sometimes trees. The top of the soil in the planter is lower in elevation than the sidewalk, allowing for runoff to flow into the planter through an inlet at street level. These planters manage stormwater by providing storage, infiltration and evapotranspiration of runoff. Excess runoff is directed into an overflow pipe connected to the existing combined sewer pipe.[21]

Rainwater Harvesting Systems

Cisterns are stormwater management practices used to capture similar to rain barrels, but collect and reuse roof runoff on a much larger scale. Cisterns are ideal for harvesting rainwater for non-potable uses including vehicle washing or toilet flushing. Cisterns are extremely versatile and may be used on a variety of sites ranging from small-scale residential sites to large-scale industrial or commercial sites; they may be placed either indoors or outdoors and above, at, or below grade. They can also be found in various shapes and sizes. Cisterns must be sized based upon on-site water needs; an under-sized cistern

Figure 18:Street-side stormwater planter diagram
Image credit: Philly Water

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[20] Water Environment Research Foundation, Tree Box Filters, 12/2019
https://www.werf.org/liveablecommunities/toolbox/treebox.htm
[21] Phillywatershed.org, Stormwater Planter, 12/2019,
http://archive.phillywatersheds.org/what_were_doing/green_infrastructure/tools/stormwater-planter

may not store sufficient water for site demands, and an over-sized cistern may remain full or near-full most of the time, and thus be unable to provide storage during rain events.

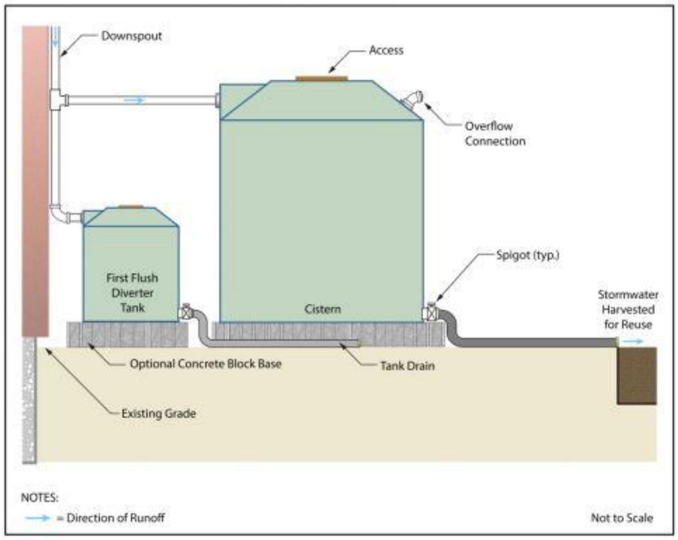

Figure 19: Example of above ground cistern including first flush diverter. Image credit: NJ BMP Manual

Appendix A – Municipality’s HUC 14 Existing Impervious Surface Conditions

HUC 14 NAME	HUC13 NAME	HUC14 CODE	Total Area		Land Area		Water Area		Impervious Cover		
			(ac)	(mi^2)	(ac)	(mi^2)	(ac)	(mi^2)	(ac)	(mi^2)	(%)
Millstone R (Beden Bk to Heathcote Bk)	Lower Millstone River	02030105110030	5,135.94	8.02	5,009.17	7.83	126.76	0.20	511.05	0.80	10.20%
Beden Brook (above Province Line Rd)	Beden Brook	02030105110040	5037.53	7.87	5,010.10	7.83	27.43	0.04	212.08	0.33	4.23%
Beden Brook (below Province Line Rd)	Beden Brook	02030105110050	6,492.60	10.14	6,421.47	10.03	71.13	0.11	492.87	0.77	7.68%
Rock Brook (above Camp Meeting Ave)	Rock Brook	02030105110060	3,875.71	6.06	3,860.22	6.03	15.49	0.02	67.63	0.11	1.75%
Rock Brook (below Camp Meeting Ave)	Rock Brook	02030105110070	2,224.10	3.48	2,197.75	3.43	26.35	0.04	126.69	0.20	5.76%
Pike Run (above Cruser Brook)	Pike Run	02030105110080	3,709.43	5.80	3,694.41	5.77	15.02	0.02	335.83	0.52	9.09%
Cruser Brook / Roaring Brook	Cruser Brook Roaring Brook	02030105110090	3,337.62	5.22	3,334.83	5.21	2.79	0.00	92.64	0.14	2.78%
Pike Run (below Cruser Brook)	Pike Run	02030105110100	7,134.71	11.15	7,102.21	11.10	32.50	0.05	584.72	0.91	8.23%
Millstone R (BlackwellsMills to BedenBk)	Lower Millstone River	02030105110110	8,829.76	13.80	8,691.87	13.58	137.89	0.22	818.82	1.28	9.42%
		Total	45,777.40	71.53	45,322.03	70.82	455.36	0.71	3,242.34	5.07	7.15%

Appendix B – Municipality's HUC 14 Existing Runoff Conditions

HUC 14 NAME	HUC13 NAME	HUC14 CODE	Total Runoff Volume (MGal)				
			NJ Water Quality Storm (1.25"/2h)	NJ Annual Rainfall of 46.94"	2-Year Design Storm (3.30-3.33"/24h)	10-Year Design Storm (4.94-5.07"/24h)	100-Year Design Storm (7.92-8.57"/24)
Millstone R (Beden Bk to Heathcote Bk)	Lower Millstone River	02030105110030	17.3	651.4	45.8	69.5	115.5
Beden Brook (above Province Line Rd)	Beden Brook	02030105110040	7.2	270.3	19.0	28.6	47.9
Beden Brook (below Province Line Rd)	Beden Brook	02030105110050	16.7	628.2	44.2	66.4	111.3
Rock Brook (above Camp Meeting Ave)	Rock Brook	02030105110060	2.3	86.2	6.1	9.1	14.9
Rock Brook (below Camp Meeting Ave)	Rock Brook	02030105110070	4.3	161.5	11.4	17.1	27.9
Pike Run (above Cruser Brook)	Pike Run	02030105110080	11.4	428.0	30.1	45.2	74.0
Cruser Brook / Roaring Brook	Cruser Brook Roaring Brook	02030105110090	3.1	118.1	8.3	12.5	20.4
Pike Run (below Cruser Brook)	Pike Run	02030105110100	19.8	745.2	52.4	78.7	128.9
Millstone R (BlackwellsMills to BedenBk)	Lower Millstone River	02030105110110	27.8	1,043.6	73.4	111.4	185.0
		Total	110.0	4,132.5	290.5	438.5	725.9

Appendix C – Page 1 of 2 – Summary of Existing Conditions for Individual Lot ICAs

	SITE NAME	LOCATION				EVALUATED AREA		IMPERVIOIUS COVER			EXISTING ANNUAL LOADS (lb/yr)			RUNOFF VOLUME (gal)		
		ADDRESS	BLOCK	LOT	HUC-14	(ac)	(sq ft)	(ac)	(sq ft)	Percent	TP	TN	TSS	Water Quality Storm	Two Year Storm	Annual Rainfall
	BEDEN BROOK SUBWATERSHED															
	Bank of America	1 Washington Street	35005	4	Beden Brook (below Province Line Rd)	0.89	38,680	0.60	25,916	67.0%	0.59	5.95	71.39	20,194	53,313	758,342
	Bloomberg	100 Business Park Drive	34001	38.01	Beden Brook (below Province Line Rd)	79.24	3,451,747	28.097	1,223,893	35.5%	59.00	618.13	5,619.34	953,683	2,517,722	35,812,718
	Cherry Valley Country Club	125 Country Club Drive	30003	1.03	Beden Brook (below Province Line Rd)	43.19	1,881,186	13.33	580,849	30.9%	28.00	293.36	2,666.89	452,610	1,194,889	16,996,408
	Conva Tech Incorporated	200 Headquarters Park Drive	20001	10.05	Beden Brook (below Province Line Rd)	44.75	1,949,153	10.93	476,087	24.4%	22.95	240.45	2,185.89	370,977	979,379	13,930,937
	Homecare Veterinary Clinic	1015 Georgetown Franklin Turnpike	35005	2	Beden Brook (below Province Line Rd)	0.51	22,408	0.204	8,906	39.7%	0.20	2.04	24.54	6,940	18,322	260,613
	LifeSign LLC	85 Orchard Road	28001	4	Beden Brook (below Province Line Rd)	18.93	824,697	5.72	248,937	30.2%	12.00	125.73	1,142.96	193,977	512,099	7,284,228
*	Montgomery Center	1325 Route 206	29002	46	Beden Brook (below Province Line Rd)	19.22	837,091	13.97	608,594	72.7%	29.34	307.37	2,794.28	474,229	1,251,965	17,808,281
*	Montgomery Fire Company No. 2	529 Route 518	33001	15	Beden Brook (below Province Line Rd)	3.92	170,745	1.87	81,395	47.7%	1.87	18.69	224.23	63,424	167,440	2,381,712
	New Horizons Montessori	12 Vreeland Drive	28004	44.01	Beden Brook (below Province Line Rd)	5.85	254,948	1.88	81,674	32.0%	1.87	18.75	225.00	63,642	168,014	2,389,881
*	Village Shopper	1340 Route 206	28005	69	Beden Brook (below Province Line Rd)	2.34	101,915	1.53	66,620	65.4%	3.21	33.65	305.88	51,911	137,046	1,949,381
*	The UPS Store	1330 Route 206	28005	68	Beden Brook (below Province Line Rd)	2.47	107,778	1.15	50,130	46.5%	2.42	25.32	230.17	39,063	103,126	1,466,883
	Beden Brook Subwatershed Total					**221.31**	**9,640,347**	**50.97**	**3,453,001**	**35.8%**	**161.47**	**1,689.42**	**15,490.56**	**2,690,650**	**7,103,316**	**101,039,383**
	CRUSER / ROARING BROOK SUBWATERSHED															
	Montgomery Fire Company No.1	35 Belle Mead-Griggstown Road	6001	1.01	Cruser Brook / Roaring Brook	2.38	103,736	1.10	47,864	46.1%	1.10	10.99	131.86	37,296	98,462	1,400,553
*	Montgomery Township Municipal Building	2261 Route 206	6001	12	Cruser Brook / Roaring Brook	18.59	809,710	4.73	206,218	25.5%	4.73	47.34	568.09	160,689	424,220	6,034,216
	Cruser Brook Subwatershed Total					**20.97**	**913,445**	**5.83**	**254,082**	**27.8%**	**5.83**	**58.33**	**699.95**	**197,986**	**522,682**	**7,434,768**
	LOWER MILLSTONE RIVER SUBWATERSHED															
	Harlingen Reform Church	34 Dutchtown Harlingen Road	4070	41		0.73	31,945	0.07	2,812	8.8%	0.06	0.65	7.75	2,191	5,785	82,283
	Lower Millstone River Subwatershed Total					**0.73**	**31,945**	**0.07**	**2,812**	**8.8%**	**0.06**	**0.65**	**7.75**	**2,191**	**5,785**	**82,283**
	PIKE RUN SUBWATERSHED															
	Booms at Belle Mead	1980 Route 206	19001	1	Pike Run	18.60	810,369	10.55	459,634	56.7%	10.55	105.52	1,266.21	358,156	945,532	13,449,495
*	Camp's Hardware and Lawn	2168 Route 206	4070	38.02	Pike Run	2.07	90,346	1.05	45,947	50.9%	2.22	23.21	210.96	35,803	94,519	1,344,459
	Capiler Farms	447 Belle Mead-Griggstown Road	18001	16	Pike Run (below Cruser Brook)	8.71	379,583	3.03	132,000	34.8%	3.94	30.30	909.09	102,857	271,544	3,862,504
	Church of Saint Charles	47 Skillman Road	26001	1.01	Pike Run	17.85	777,359	5.476	238,547	30.7%	7.12	54.76	1,642.88	185,881	490,725	6,980,197
	Conover Transportation Bus Services	103 Bridgepoint Road	22030	8	Pike Run	6.85	298,296	0.864	37,652	12.6%	1.12	8.64	259.31	29,339	77,455	1,101,744
*	East Mountain School	252 County Road 601	2001	1,2,3,4	Pike Run	33.04	1,439,120	16.01	697,105	48.4%	16.00	160.03	1,920.40	543,198	1,434,044	20,398,203
	Harlingen Veterinary Clinic	10 Sunset Road	15001	34.02	Pike Run	2.60	113,289	0.50	21,821	19.3%	0.50	5.01	60.11	17,003	44,889	638,513
	Johnson & Johnson	111 Grandview Road	14001	2	Pike Run (below Cruser Brook)	250.26	10,901,457	65.692	2,861,561	26.2%	137.95	1,445.23	13,138.48	2,229,788	5,886,639	83,733,058
	Krauszer's Food Store	2162 Route 206	4070	43	Pike Run	1.87	81,457	1.21	52,492	64.4%	1.21	12.05	144.61	40,903	107,983	1,535,977
	Montgomery Emergency Medical	8 Harlingen Road	6002	5	Pike Run	0.90	39,314	0.650	28,305	72.0%	0.65	6.50	77.98	22,056	58,228	828,243
*	Montgomery Evangelical Free Church	246 Belle Mead-Griggstown Road	7033	24	Pike Run	10.85	472,607	3.10	135,159	28.6%	3.10	31.03	372.34	105,319	278,042	3,954,942
	Montgomery News	2106 Route 206	15001	31.01	Pike Run	0.34	14,880	0.217	9,435	63.4%	0.22	2.17	25.99	7,352	19,408	276,069
*	Montgomery Public Works Office	12 Harlingen Road	6002	4	Pike Run	14.12	614,781	2.11	92,002	15.0%	2.11	21.12	253.45	71,690	189,261	2,692,093
*	Montgomery Upper Middle School	375 Burnt Hill Road	19001	8.34	Pike Run (below Cruser Brook)	58.14	2,532,241	14.25	620,818	24.5%	14.25	142.52	1,710.24	483,754	1,277,111	18,165,947
	Nassau Tennis Club	1800 Route 206	20001	6	Pike Run	12.69	552,790	4.435	193,202	35.0%	4.44	44.35	532.24	150,547	397,445	5,653,354

Appendix C – Page 2 of 2 – Summary of Existing Conditions for Individual Lot ICAs

	SITE NAME	LOCATION				EVALUATED AREA		IMPERVIOIUS COVER			EXISTING ANNUAL LOADS (lb/yr)			RUNOFF VOLUME (gal)		
		ADDRESS	BLOCK	LOT	HUC-14	(ac)	(sq ft)	(ac)	(sq ft)	Percent	TP	TN	TSS	Water Quality Storm	Two Year Storm	Annual Rainfall
*	Orchard Hill Elementary School	269-281 Burnt Hill Road	19001	12	Pike Run	58.92	2,566,233	8.61	375,122	14.6%	8.61	86.12	1,033.39	292,303	771,679	10,976,559
	The Learning Experience	2176 Route 206	4070	38.01	Pike Run	1.60	69,617	0.84	36,501	52.4%	0.84	8.38	100.55	28,443	75,088	1,068,076
	Pike Run Subwatershed Total					**499.42**	**21,753,740**	**61.27**	**6,037,301**	**27.8%**	**214.83**	**2,186.94**	**23,658.24**	**4,704,391**	**12,419,593**	**176,659,432**
	ROCK BROOK SUBWATERSHED															
	Blawenburg Reformed Church	424 Route 518	26001	32	Rock Brook (below Camp Meeting Ave)	1.61	70,165	0.45	19,459	27.7%	0.45	4.47	53.61	15,163	40,029	569,388
*	Montgomery High School	1016 County Road 601	25001	27.02	Rock Brook (below Camp Meeting Ave)	73.29	3,192,147	36.16	1,574,941	49.3%	36.16	361.56	4,338.68	1,227,227	3,239,879	46,084,862
	Otto Kaufman Community Center	356 Skillman Road	14001	38	Rock Brook	7.03	306,116	1.53	66,792	21.8%	1.53	15.33	184.00	52,046	137,401	1,954,424
	Village Elementary School	100 Main Boulevard	26001	1.06	Rock Brook	12.17	530,137	7.67	334,130	63.0%	7.67	76.71	920.47	260,361	687,353	9,777,089
	Rock Brook Subwatershed Total					**94.10**	**4,098,565**	**45.81**	**1,995,322**	**48.7%**	**45.81**	**458.06**	**5,496.75**	**1,554,796**	**4,104,662**	**58,385,763**
	Montgomery Township Total					**836.54**	**36,438,042**	**163.95**	**11,742,518**	**32.2%**	**428.00**	**4,393.40**	**45,353.25**	**9,150,014**	**24,156,038**	**343,601,630**

***Denotes a site that a Reduction Action Plan was created for; see Appendix E & F**

IMPERVIOUS COVER ASSESSMENT AND REDUCTION
SITE ASSESSMENT FORM

Name of person(s) completing assessment: **Assessment date:**

SITE INFORMATION

Site ID:	Site Name:
Site address:	
Block/Lot:	Property owner:
Size of site:	Percent impervious coverage:
Proximity to waterway:	Name of nearest waterway:
Subwatershed (HUC-14):	
Soil type(s) on-site: (Indicate drainage capability)	

AERIAL MAP KEY (Write in additional symbols as needed) Note: Use silver pen for existing infrastructure, other color for potential new installations	
Stormwater flow (arrows): →	Sedimentation (dots): ∙ ∙ ∙ ∙
Erosion (hatched lines): \\\\\\\\	Existing curb cuts (oval circling cuts): ⬭
Storm drain (box with vertical lines):	Ponding (concentric circles): ◎
Downspouts (small filled-in circle): ●	

EXISTING STORMWATER FLOW	OBSERVATIONS	COMMENTS
What is the source of stormwater runoff?	☐ Rooftop ☐ Parking lot ☐ Sidewalk ☐ Compacted grass	
Is the site sloped? (Indicate stormwater flow direction on aerial map with arrows)	☐ Yes, there is a defined slope ☐ Yes, somewhat ☐ No, the site is flat	
Are there areas of pronounced erosion? (Indicate stormwater erosion on aerial map with hatched lines)	☐ Yes, there is serious erosion ☐ Yes, there is mild erosion ☐ There is evidence of healed erosion ☐ No	
Are there areas of pronounced sedimentation? (Indicate sedimentation on aerial map with dots)	☐ Yes ☐ No	

Is there evidence of ponding? Are these low-lying areas on impervious or grassy surfaces? (Indicate areas of ponding on aerial map with concentric circles)	☐ Yes, ponding visible on grassy area ☐ Yes, ponding visible on asphalt/concrete ☐ No	
Does stormwater runoff flow directly into sewer system? (Indicate storm sewers on aerial map with hatched boxes)	☐ Yes, downspouts connected to sewer ☐ Yes, downspouts directed toward sewers ☐ Yes, stormwater flows toward sewers ☐ No, stormwater flows away from sewers OR there are no sewers nearby	
Are there existing curb cuts to direct stormwater flow? (Indicate curb cuts on aerial map with ovals)	☐ Yes, there are existing curb cuts ☐ No, there are no curb cuts ☐ N/A	
Are there existing stormwater BMPs on site? (Write in BMP types on aerial map)	☐ Yes, indicate type and number in comments ☐ No	

DEPAVING/DISCONTINUOUS PAVING/GRAVEL FILTER	OBSERVATIONS	COMMENTS
Is there a potential to remove existing paved areas?	☐ Yes ☐ Portions of pavement can be removed ☐ No	

PERVIOUS PAVEMENT	OBSERVATIONS	COMMENTS
Is any asphalt or other paved area in disrepair?	☐ Yes ☐ No ☐ N/A, there is no paved area	

Are there areas of asphalt that are lightly used, like parking spaces or fire lanes?	☐ Yes ☐ No	

RAINWATER HARVESTING/STORAGE	OBSERVATIONS	COMMENTS
Are there downspouts visible on the building? Do they direct onto the ground or into a pipe underground? (Indicate downspouts on aerial map with circles)	☐ Yes, external downspouts ☐ Yes, internal downspouts ☐ No ☐ N/A, there is no building on-site	
Is there a garden or athletic field nearby that may use collected rainwater?	☐ Yes ☐ No	
Is there space next to the downspout for a BMP placement?	☐ Yes, enough space for a cistern ☐ Yes, enough space for a rain barrel or downspout planter ☐ No ☐ N/A, there are no downspouts	

STORMWATER BASIN NATURALIZATION	OBSERVATIONS	COMMENTS
Is there an existing stormwater detention basin?	☐ Yes, with short mowed grass ☐ Yes, with concrete low-flow channel ☐ No	

RAIN GARDEN	OBSERVATIONS	COMMENTS
Are there unpaved areas on-site suitable and large enough for landscaping?	☐ Yes, grassy areas can be landscaped ☐ No, grassy areas cannot be landscaped ☐ No, no grassy areas on-site	

Appendix D – Example Site assessment Form – Page 5 of 5

What type(s) of plants would be appropriate in these areas?	☐ Full sun ☐ Shade ☐ Mix of sun and shade	

TREE FILTER BOX (recommended for more urban areas)	OBSERVATIONS	COMMENTS
Does stormwater flow across sidewalks, curbs, or along the street?	☐ Yes ☐ No	
Is there a sufficient amount of space to install a tree filter box along the sidewalk or road?	☐ Yes ☐ No	
Are there existing trees along the sidewalk or road that could be used in a filter box design?	☐ Yes ☐ No	

BIOSWALE	OBSERVATIONS	COMMENTS
Does stormwater need to travel from its source to the selected BMP?	☐ Yes ☐ No	

GI RECOMMENDATIONS	
Based on your observations, what GI practices would you recommend for this site? (Indicate placement of these practices on the aerial map using alternate pen color)	☐ Rooftop disconnection ☐ Pervious pavement ☐ Rain barrel ☐ Rain garden ☐ Basin naturalization ☐ Depaving ☐ Cistern ☐ Downspout planter ☐ Bioswale ☐ Tree filter box ☐ Sand/Gravel Filter Pit/Strip ☐ Discontinuous pavement (partial depaving) ☐ OTHER ______________________

Appendix E – Site-Specific Reduction Action Plans

ATTACHED SEPERATELY

Appendix F – Summary of Reduction Action Plans for Montgomery Township

STORMWATER BMP BY SITE	POTENTIAL MANAGEMENT AREA		SIZE OF BMP		PERCENTAGE OF IMPERVIOUS COVER TREATED	REMOVAL POTENTIAL			MAXIMUM VOLUME REDUCTION POTENTIAL (gal/storm)	RECHARGE POTENTIAL (gal/year)	ESTIMATED COST
	(ac)	(sq ft)	(ac)	(sq ft)		TP	TN	TSS			
BEDEN BROOK SUBWATERSHED											
Montgomery Center											
Stormwater Basin Naturalization	5.86	255,337	0.63	27,302	42.0%	0.79	4.14	112.82	525,264	7,097,899	$136,511.60
Bioswale 1	0.56	24,304	0.13	5,669	4.0%	0.16	0.86	23.43	49,998	675,618	$28,344.50
Bioswale 2	0.60	26,260	0.11	4,722	4.3%	0.14	0.72	19.51	54,020	729,968	$23,609.30
Site Total	**7.02**	**305,900**	**0.87**	**37,693**	**50.3%**	**1.09**	**5.71**	**155.76**	**629,281**	**8,503,485**	**$188,465.40**
Montgomery Fire Company No. 2											
Porous Pavement	0.88	38,404	0.17	7,587	47.2%	0.10	0.87	16.72	79,003	1,067,566	$91,038.24
Site Total	**0.88**	**38,404**	**0.17**	**7,587**	**47.2%**	**0.10**	**0.87**	**16.72**	**79,003**	**1,067,566**	**$91,038.24**
The UPS Store											
Bioswale	0.32	13,837	0.06	2,502	27.6%	0.07	0.38	10.34	28,465	384,646	$12,510.20
Rain Garden	0.19	8,110	0.07	3,108	16.2%	0.09	0.47	12.84	16,684	225,452	$15,541.50
Vegetated Filter	0.09	4,061	0.09	4,061	8.1%	0.06	0.62	13.05	8,354	112,887	$12,182.88
Site Total	**0.60**	**26,008**	**0.22**	**9,671**	**51.9%**	**0.22**	**1.47**	**36.23**	**53,503**	**722,985**	**$40,234.58**
The Village Shopper											
Vegetated Filter	0.14	6,168	0.19	8,274	9.3%	0.12	1.25	26.59	12,688	171,452	$24,823.17
Bioswale	0.55	23,929	0.10	4,559	35.9%	0.13	0.69	18.84	49,225	665,175	$22,793.45
Site Total	**0.69**	**30,096**	**0.29**	**12,833**	**45.2%**	**0.25**	**1.94**	**45.43**	**61,913**	**836,627**	**$47,616.62**
Beden Brook Subwatershed Total	**9.19**	**400,409**	**1.56**	**67,784**		**1.67**	**9.99**	**254.14**	**823,699**	**11,130,663**	**$367,354.84**
CRUSER BROOK SUBWATERSHED											
Montgomery Township Municipal Building											
Vegetated Filter	0.44	19,357	1.08	46,874	9.4%	0.32	3.23	90.39	39,820	538,092	$140,621.46
Rain Garden	0.16	7,009	0.07	2,868	3.4%	0.04	0.20	7.11	14,418	194,828	$14,340.80
Porous Pavement	1.12	48,743	0.24	10,257	23.6%	0.14	1.18	22.60	100,271	1,354,962	$123,084.12
Site Total	**1.72**	**75,108**	**1.38**	**59,999**	**36.4%**	**0.50**	**4.60**	**120.11**	**154,509**	**2,087,882**	**$278,046.38**
Cruser Brook Subwatershed Total	**1.72**	**75,108**	**1.38**	**59,999**		**0.50**	**4.60**	**120.11**	**154,509**	**2,087,882**	**$278,046.38**

Appendix F – Summary of Reduction Action Plans for Montgomery Township

STORMWATER BMP BY SITE	POTENTIAL MANAGEMENT AREA		SIZE OF BMP		PERCENTAGE OF IMPERVIOUS COVER TREATED	REMOVAL POTENTIAL			MAXIMUM VOLUME REDUCTION POTENTIAL (gal/storm)	RECHARGE POTENTIAL (gal/year)	ESTIMATED COST
	(ac)	(sq ft)	(ac)	(sq ft)		TP	TN	TSS			
PIKE RUN SUBWATERSHED											
Camp's Hardware and Lawn											
Stormwater Basin Naturalization	1.05	45,629	0.30	13,041	99.3%	0.38	1.98	53.89	93,865	1,268,400	$65,203.95
Site Total	**1.05**	**45,629**	**0.30**	**13,041**	**99.3%**	**0.38**	**1.98**	**53.89**	**93,865**	**1,268,400**	**$65,203.95**
East Mountain School											
Porous Pavement 1	0.91	39,612	0.15	6,708	5.7%	0.09	0.77	14.78	81,488	1,101,155	$80,500.20
Porous Pavement 2	0.93	40,499	0.17	7,461	5.8%	0.10	0.86	16.44	83,313	1,125,808	$89,531.76
Rain Garden	0.30	12,948	0.12	5,165	1.9%	0.07	0.36	12.81	26,636	359,933	$25,825.25
Site Total	**2.14**	**93,060**	**0.44**	**19,334**	**13.3%**	**0.27**	**1.98**	**44.03**	**191,437**	**2,586,896**	**$195,857.21**
Montgomery Evangelical Free Church											
Stormwater Basin Naturalization	1.75	76,332	0.37	15,990	56.5%	0.22	1.10	39.64	157,025	2,121,882	$79,949.35
Rain Garden 1	0.34	14,599	0.21	9,039	10.8%	0.12	0.62	22.41	30,032	405,824	$45,196.20
Rain Garden 2	0.29	12,698	0.17	7,445	9.4%	0.10	0.51	18.46	26,121	352,980	$37,225.05
Site Total	**2.38**	**103,628**	**0.75**	**32,474**	**76.7%**	**0.45**	**2.24**	**80.51**	**213,179**	**2,880,686**	**$162,370.60**
Montgomery Public Works Office											
Bioswale	2.57	111,830	0.53	23,140	121.6%	0.32	1.59	57.37	230,051	3,108,680	$115,698.86
Site Total	**2.57**	**111,830**	**0.53**	**23,140**	**121.6%**	**0.32**	**1.59**	**57.37**	**230,051**	**3,108,680**	**$115,698.86**
Montgomery Upper Middle School											
Stormwater Basin Naturalization	6.49	282,632	1.45	63,334	45.5%	0.87	4.36	157.03	581,415	7,856,675	$316,672.15
Rain Garden	0.64	27,816	0.51	22,111	4.5%	0.30	1.52	54.82	57,222	773,238	$110,555.49
Porous Pavmeent	1.82	79,069	0.31	13,415	12.7%	0.18	1.54	29.56	162,656	2,197,973	$160,980.36
Site Total	**8.94**	**389,517**	**2.27**	**98,861**	**62.7%**	**1.36**	**7.42**	**241.41**	**801,293**	**10,827,886**	**$588,208.00**
Orchard Hill Elementary School											
Bioswale 1	3.04	132,538	0.75	32,681	35.3%	0.45	2.25	81.03	272,649	3,684,318	$163,403.50
Bioswale 2	0.14	5,926	0.03	1,410	1.6%	0.02	0.10	3.50	12,190	164,719	$7,050.70
Bioswale 3	0.14	6,006	0.03	1,228	1.6%	0.02	0.08	3.04	12,355	166,953	$6,137.85
Bioswale 4	0.14	6,291	0.03	1,402	1.7%	0.02	0.10	3.48	12,940	174,865	$7,008.57
Site Total	**3.46**	**150,760**	**0.84**	**36,720**	**40.2%**	**0.51**	**2.53**	**91.04**	**310,135**	**4,190,855**	**$183,600.62**
Pike Run Subwatershed Total	**20.54**	**894,425**	**5.13**	**223,570**		**3.28**	**17.74**	**568.26**	**1,839,959**	**24,863,404**	**$1,310,939.23**

Appendix F – Summary of Reduction Action Plans for Montgomery Township

STORMWATER BMP BY SITE	POTENTIAL MANAGEMENT AREA		SIZE OF BMP		PERCENTAGE OF IMPERVIOUS COVER TREATED	REMOVAL POTENTIAL			MAXIMUM VOLUME REDUCTION POTENTIAL (gal/storm)	RECHARGE POTENTIAL (gal/year)	ESTIMATED COST
	(ac)	(sq ft)	(ac)	(sq ft)		TP	TN	TSS			
ROCK BROOK SUBWATERSHED											
Montgomery High School											
Bioswale	0.20	8,632	0.48	20,715	0.5%	0.29	1.43	51.36	17,758	239,962	$103,574.00
Vegetated Filter	0.30	13,233	0.39	16,900	0.8%	0.12	1.16	32.59	27,222	367,856	$50,700.66
Porous Pavement	0.93	40,540	0.30	12,991	2.6%	0.18	1.49	28.63	83,396	1,126,934	$155,888.64
Site Total	**1.43**	**62,405**	**1.16**	**50,606**	**4.0%**	**0.58**	**4.08**	**112.58**	**128,376**	**1,734,752**	**$310,163.30**
Rock Brook Subwatershed Total	**1.43**	**62,405**	**1.16**	**50,606**		**0.58**	**4.08**	**112.58**	**128,376**	**1,734,752**	**$310,163.30**
MONTGOMERY TOWNSHIP TOTAL RAP	**32.89**	**1,432,348**	**9.23**	**401,958**		**6.03**	**36.42**	**1,055.09**	**2,946,544**	**39,816,700**	**$2,266,503.75**