Impervious Cover Assessment
And Reduction Action Plan
Prepared For

Hopewell Township, Mercer 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 Hopewell 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 4.85 percent of Hopewell Township's land area. This is below the 10% threshold above which a subwatershed is considered to be impaired for water quality.
2. The municipality has eleven subwatersheds which have impervious cover (IC) ranging from 0.04-18.81 % IC; the recommendation of this report is that restorations efforts should be focused in the subwatersheds with the highest percentages of IC: the Shabakunk, Little Shabakunk, and Jacob's Creek 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 nearly 2.3 billion gallons of stormwater annually.
4. Using Geographical Information Systems, we identified 26 sites where actions could be taken to mitigate stormwater runoff. For 10 of those sites, we conducted more detailed on-site stormwater assessments and prepared Green Infrastructure conceptual designs. Those 10 projects have a total stormwater mitigation potential of more than 21.5 million gallons of runoff.
5. While Hopewell 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

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]

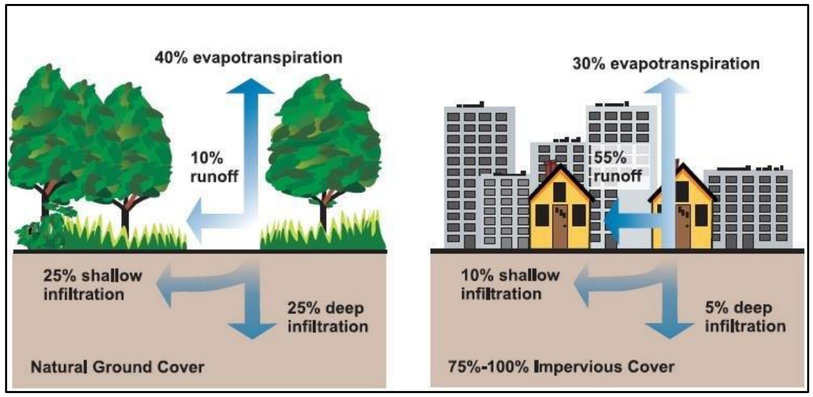

Figure 1: Relationship between impervious surfaces and stormwater runoff.[1]

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,

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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.

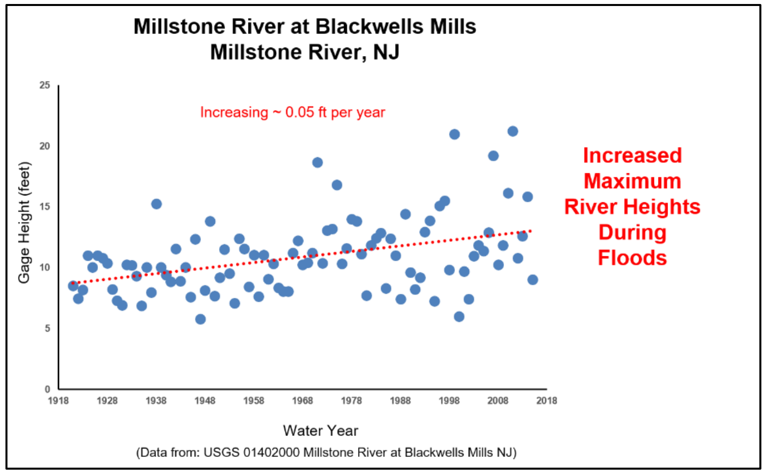


Figure 2: Annual Maximum River Height at Blackwells Mills Dam, Franklin Twp, NJ

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

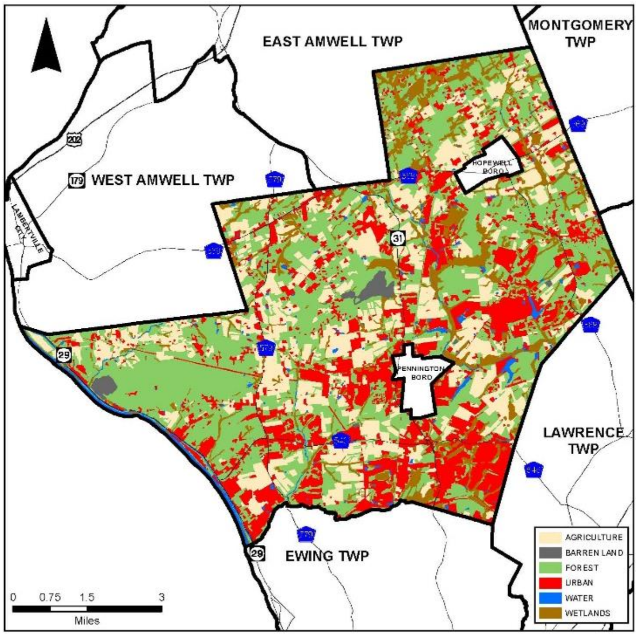


Figure 3: Land-use aerial of Hopewell Township

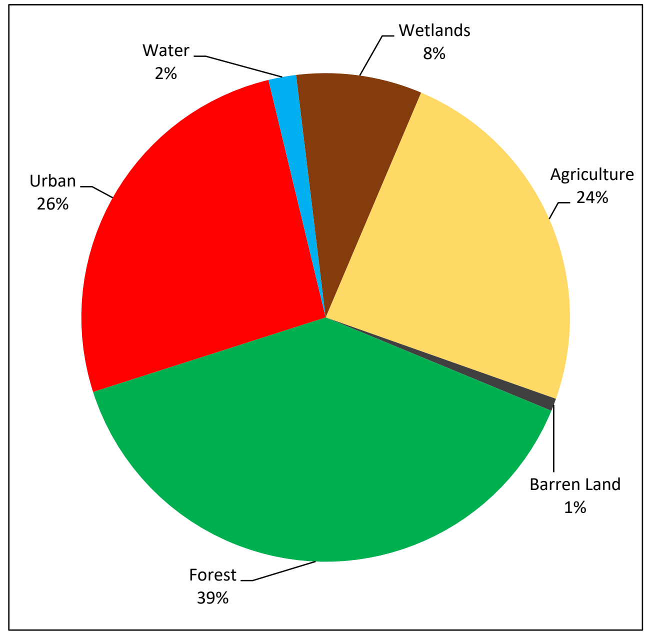


Figure 4: Land-use composition (%) in Hopewell Township

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 Hopewell 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: Hopewell Township

Municipal Subwatershed Assessment

Located in Mercer County in central New Jersey, Hopewell Township covers slightly less than 59 square miles. The primary land-use type was determined to be forest. Urban land use was calculated at 26% of the total town (Figures 3 & 4), with rural residential as the dominant type of urban land at 54% (Figure 5). Impervious surfaces were estimated to cover 4.85% of Hopewell Township's land area (Figure 6). The municipality is divided into 11 individual subwatershed units (Figure 7, colored areas), with some draining to the Millstone River and the remaining areas draining to the Delaware River.

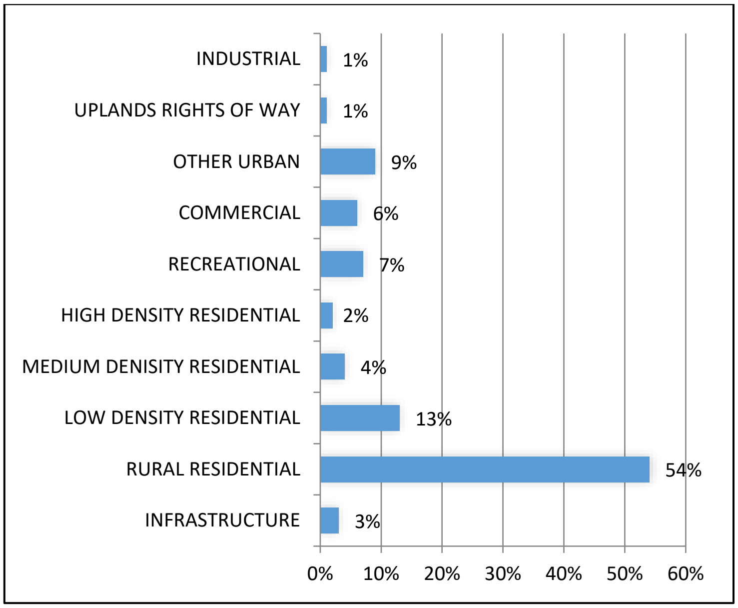


Figure 5: Urban land-use composition in Hopewell Township

Analysis of the sections of those drainage areas that fall within the municipality's boundaries showed a variable amount of IC, ranging from 0.04% in the Rock Brook subwatershed to 18.81% in the Shabakunk Creek 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 (3.32 inches in 24 hours), 3) the 10-year design storm (4.98 inches in 24 hours), 4) the 100-year design storm (8.14 inches in 24 hours), and 5) New Jersey's total average annual rainfall of 46.94 inches (Table 2).[6,7] Impervious surfaces in Hopewell Township result in over 2.2 billion gallons of annual stormwater runoff. The Water Quality Design storm would produce 60.9 million gallons in just a two hour period, while the 2, 10, and 100 year storms would generate 161.7, 242.6, and 396.6 million gallons within a 24 hour period respectively.

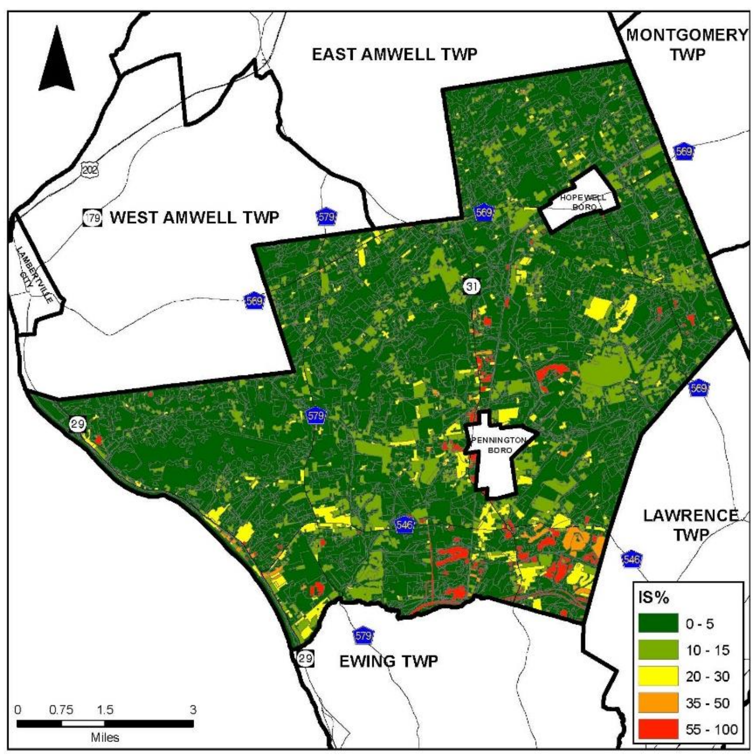


Figure 6: Amount of Impervious Surfaces (% IS) by parcel in Hopewell Twp.

The 11 main subwatersheds within Hopewell Township are further composed of 18 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 municipal boundaries) were also calculated.

[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 Hopewell Township

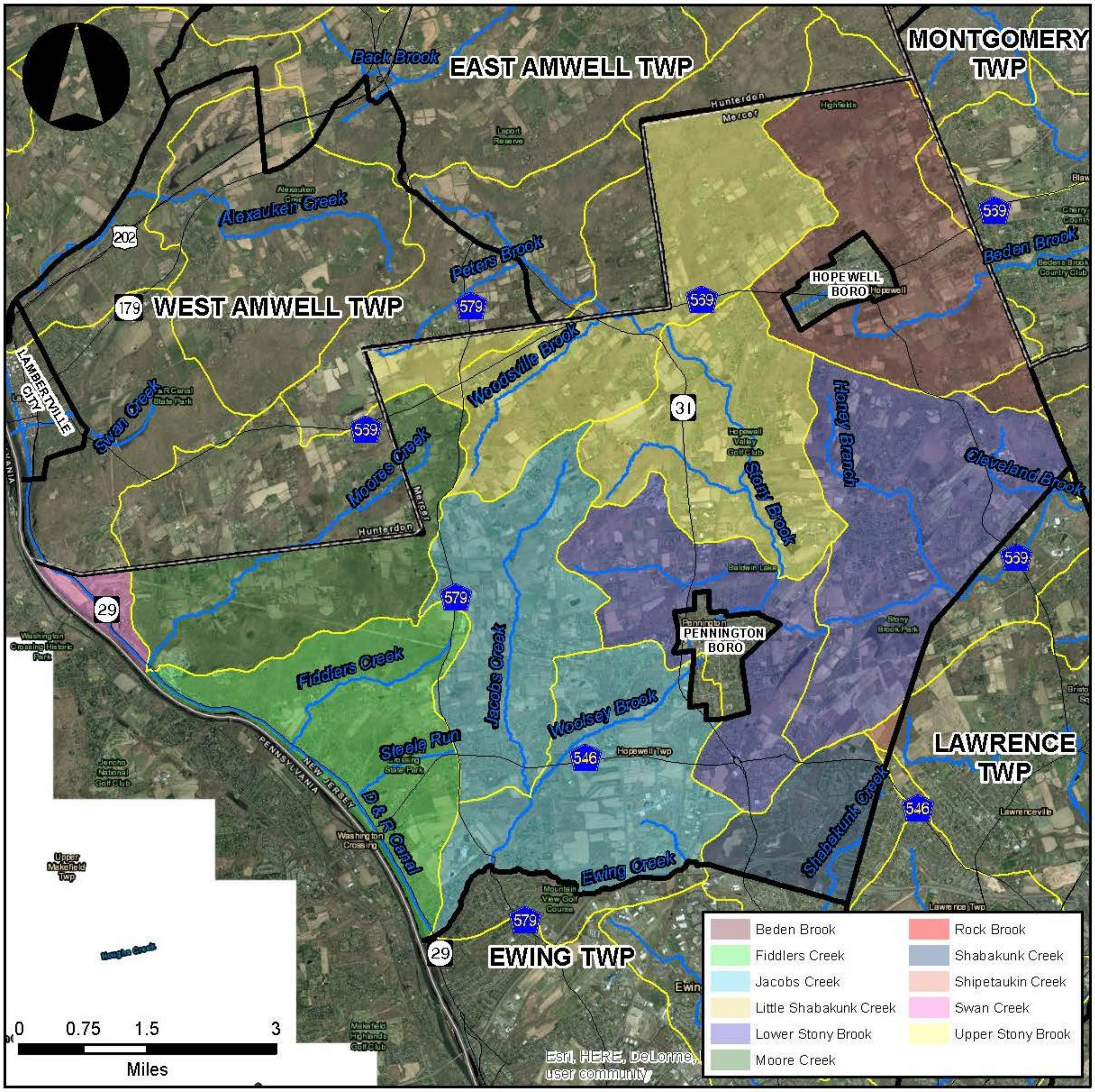
Subwatershed	Total Area		Land Use Area		Water Area		Impervious Cover		
	(ac)	(mi²)	(ac)	(mi²)	(ac)	(mi²)	(ac)	(mi²)	(%)
Beden Brook	4,468.38	6.98	4,439.07	6.94	29.31	0.05	111.92	0.17	2.52%
Fiddler's Creek	3717.92	5.81	3,467.20	5.42	250.72	0.39	126.35	0.20	3.64%
Jacob's Creek	7,441.02	11.63	7,380.76	11.53	60.26	0.09	456.32	0.71	6.18%
Little Shabakunk Creek	11.38	0.02	11.38	0.02	0.00	0.00	1.21	0.00	10.63%
Lower Stony Brook	8,251.94	12.89	8,097.87	12.65	154.07	0.24	469.57	0.73	5.80%
Moore Creek	3192.93	4.99	3,170.93	4.95	22	0.03	46.87	0.07	1.48%
Rock Brook	22.58	0.04	22.58	0.04	0.00	0.00	0.01	0.00	0.04%
Shabakunk Creek	1,496.50	2.34	1,490.73	2.33	5.77	0.01	280.43	0.44	18.81%
Shipetaukin Creek	73.14	0.11	73.14	0.11	0.00	0.00	0.73	0.00	1.00%
Swan Creek	453.35	0.71	359.84	0.56	93.51	0.15	15.2	0.02	4.22%
Upper Stony Brook	8,587.10	13.42	8,505.04	13.29	82.06	0.13	285.61	0.45	3.36%
Total	37,716.24	58.93	37,018.54	57.84	697.70	1.09	1,794.22	2.80	4.85%

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

Subwatershed	Total Runoff Volume for the 1.25" NJ Water Quality Storm	Total Runoff Volume for the NJ Annual Rainfall (46.94")	Total Runoff Volume for the 2-Year Design Storm (3.32")	Total Runoff Volume for the 10-Year Design Storm (4.98")	Total Runoff Volume for the 100-Year Design Storm (8.14")
	(MGal)	(MGal)	(MGal)	(MGal)	(MGal)
Beden Brook	3.8	142.6	10.1	15.1	24.7
Fiddlers Creek	4.3	161.0	11.4	17.1	27.9
Jacobs Creek	15.5	581.6	41.1	61.7	100.9
Little Shabakunk Creek	0.0	1.5	0.1	0.2	0.3
Lower Stony Brook	15.9	598.5	42.3	63.5	103.8
Moore Creek	1.6	59.7	4.2	6.3	10.4
Rock Brook	0.0	0.0	0.0	0.0	0.0
Shabakunk Creek	9.5	357.4	25.3	37.9	62.0
Shipetaukin Creek	0.0	0.9	0.1	0.1	0.2
Swan Creek	0.5	19.4	1.4	2.1	3.4
Upper Stony Brook	9.7	364.0	25.7	38.6	63.1
Total	60.9	2,286.8	161.7	242.6	396.6

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.

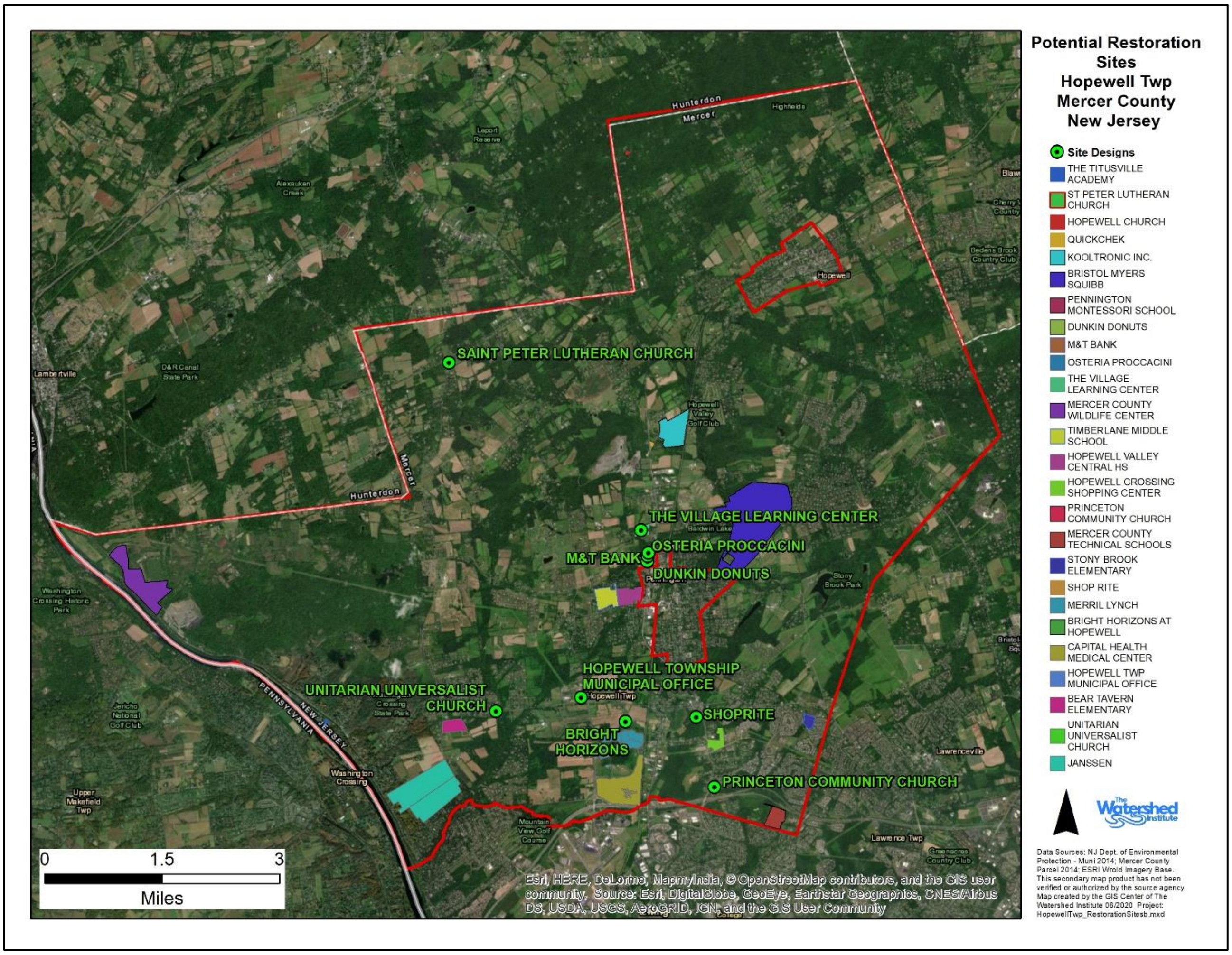
Figure 7: Map of subwatersheds in Hopewell Township



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 26 individual lots in Hopewell 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 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).

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



Those 26 properties alone accounted for over 241 acres of impervious cover and nearly 320 million gallons of the town's annual stormwater runoff. This volume of runoff from impervious surfaces carries an estimated 405 lb of total phosphorous, 4,227 lb of total nitrogen, and 41,088 lb of total suspended solids into the streams of Hopewell 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**/.

Reduction Action Plans: Hopewell Township

Of the 26 individual ICAs performed at the single lot scale, 10 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 Hopewell RAPs by subwatershed is found in Appendix F. Combined the RAP designs are estimated to have a Maximum Volume Reduction Potential of over 1.6 million gallons/storm, and a Recharge Potential greater than 21.5 million gallons/year. This will mitigate over 90% of a 2 Year Storm event, and infiltrate greater than 85% of the annual rainfall that runs off of the IC from these 10 sites combined. The potential for pollution removals was also estimated, and the RAPs for these sites will collectively intercept more than 2.9 lb of TP, 21 lb of TN, and 618 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.

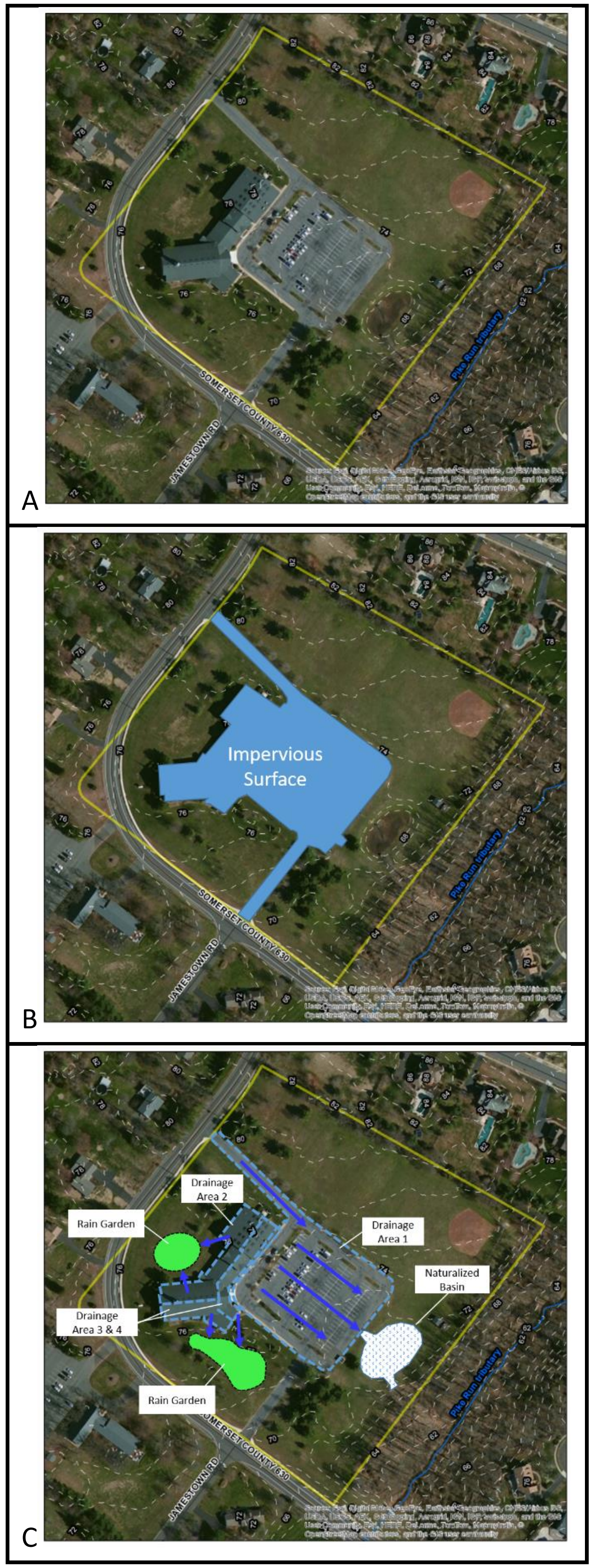


Figure 9: Example site-specific ICA & RAP process

Policy Review: Hopewell Township

Hopewell Township is a mostly rural community with a significant amount of farmland and large tracts of open space that include Washington Crossing State Park, Baldpate Mountain, Mercer Meadows, Curliss Lake Woods, and the Watershed Reserve. Hopewell has taken many steps to preserve and protect environmental resources; however, further protections will be needed to offset future planned development.

Tree Protection

Trees and forestlands play an important part in reducing flooding and soil erosion. Having fewer trees compounds the effects of impervious cover on flooding and pollution, especially when trees are removed and replaced with impervious cover. Strengthening protections for trees is important in limiting the spread of impervious cover as well as reducing its impacts.

Current Policy: Hopewell Township's current tree removal ordinance, which only applies to trees 10 inches dbh or larger, allows removal of trees up to a cumulative total of 150 inches of diameter at breast height over a period of ten years without requiring a permit (Chapter XII, Section 4, Forest Management and Tree Removal). In order to obtain a permit, a tree protection and removal plan must be submitted to the town and reviewed by the Administrative Officer. Trees removed with a permit are required to be replaced, with sizing and quantities provided by ordinance. If replacement of trees on the tax lot they were removed from is not feasible, then monetary compensation can be made to the town.

The municipality also had a Community Forestry Management Plan approved through 2015.

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

1. **Enact a tree protection ordinance that tracks cumulative totals**. While the current ordinance is a good start, the lack of ability to track the cumulative totals of residents to ensure compliance with its provisions is a concern. Requiring a permit for the removal of any trees would be a better way to ensure compliance. The town could issue permits "by right" to property owners for a limited number of trees per year. Other revisions to the ordinance should require the replacement of healthy trees over 3 inches in diameter, limit the number and size of trees (measured by cumulative diameter) 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. The ordinance should apply to all trees, not just those larger than 10 inches dbh.

2. **Review and update the Community Forestry Management Plan,** and renew approval through the New Jersey Forest Service.

Stream Corridors

A stream corridor is composed of several essential elements including the stream channel itself, floodplains, and forests. Where stream corridors are maintained in their natural condition with minimum disturbance, they are instrumental in removing sediment, nutrients, and pollutants by providing opportunities for filtration, absorption and decomposition by slowing stormwater velocity, which aids in allowing 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, 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: Hopewell Township's stream corridor ordinance is found in Chapter XII, Section 3, Stream Corridor Protection, and Chapter XVII, Section 115 Stream Corridors in the municipal code. Hopewell Township places a 150 ft buffer on all streams delineated on a map entitled "Hopewell Township Stream Centerlines and 150 Foot Buffer" or that have 50 acres of drainage or more. Hopewell Township allows for stream corridor averaging along the perimeter of detention basins.

Recommendation: The Hopewell Township ordinance leaves some ambiguity as to the relation between the prepared map and the ordinance's determination of what receives the 150 ft protections. It should be clarified that any stream is to be protected by extending their 150 ft buffer to all surface water bodies, not just streams appearing on the map. In certain situations this lack of buffer could create encroachment on water bodies that flow into streams that otherwise would have protections. Hialeah Pond in an example of this.

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 only required to comply with the state standards as described in N.J.A.C. 7:8-5, Design and Performance Standards for Stormwater Management, and applies only to major developments. Additional stormwater management requirements can be found in Chapter XVII, Section 95 of the municipal code, Off-Street Parking and Loading, which specifies that:

> "All parking and loading areas shall have drainage facilities installed in accordance with good engineering practice and in accordance with the "drainage" provisions of section 17-82. The design of all drainage for parking facilities shall address water quality, flooding and groundwater recharge and shall incorporate the use of nonstructural stormwater management strategies to the maximum extent practicable. All parking and loading areas shall be designed to minimize impervious surfaces by use of permeable materials where appropriate, and use of multi-level parking where appropriate."

Additionally, Chapter XII, Section 4.6, Forest Management and Tree Removal notes that a tree removal permit will not be granted if the removal of the tree in question will result in additional stormwater runoff onto adjacent lots.

Recommendation: Given the plans for future development in Hopewell Township, its current stormwater requirements are likely to prove inadequate in addressing the stormwater issues of the town. Our recommendation is to craft a specific stormwater ordinance that meets the state minimums, but includes additional protections. Such an ordinance would ideally:

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.

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 nearly 5% suggests that streams in Hopewell Township are not likely to be highly impaired, but may be 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 Jacob's Creek (6.18% IC), Little Shabakunk Creek (10.63% IC) and Shabakunk Creek (18.81% IC) subwatersheds would have the greatest effect at lowering the municipality's overall impact to watershed health.

The recommended green infrastructure practices 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 90% of the 2 Year Storm, they do account for 239% 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 Hopewell was harvested and purified, it could supply water to 556 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 projects not considered by this report that may be implemented at public/commercial organizations, schools, faith-based and nonprofit organizations, and other community locations. 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 Hopewell 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

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[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

to provide Hopewell 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, Hopewell 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:

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

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

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[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

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.

Figure 10: Rapid Infiltration of water through pervious pavement

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]

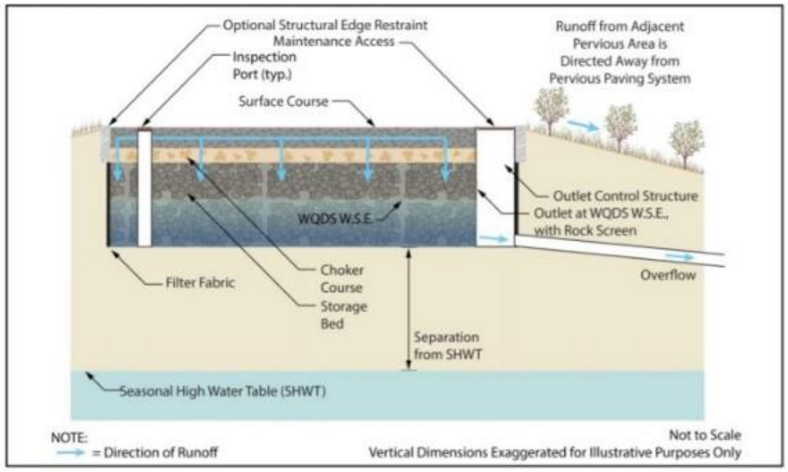

Figure 12: Basic components diagram common to a variety of pervious pavement systems.
Image Credit – NJ-BMP Manual

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.

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

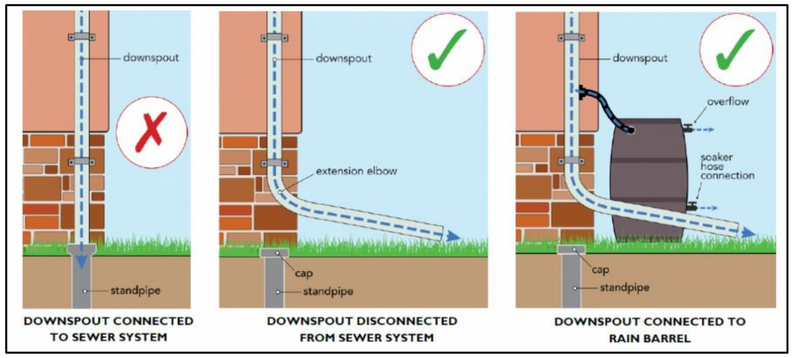

Figure 13: Downspout disconnection
Image credit: DC-Water

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.

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.

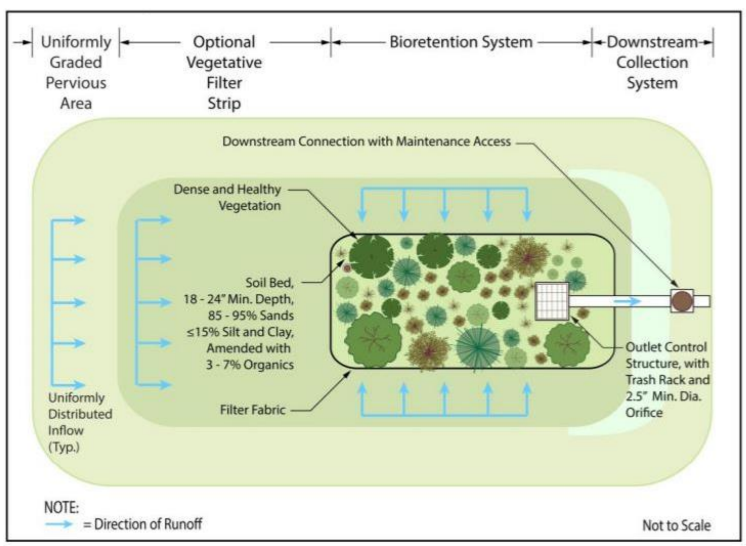

Figure 14: Basic bioretention system design.
Image credit: NJ-BMP Manual

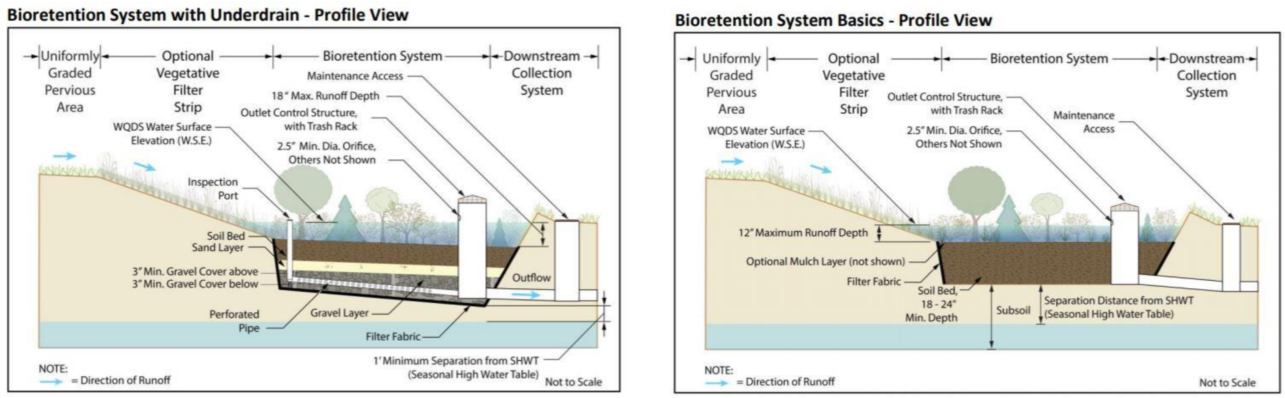

Figure 15: Bioretention facility cross section with underdrains.
Image credit: NJ-BMP Manua

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.

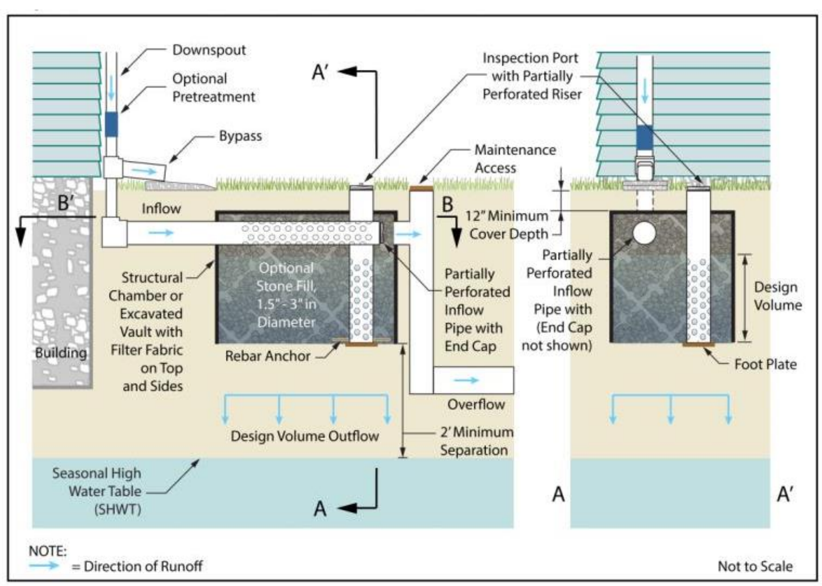

Figure 16: Dry well basics diagram.
Image credit: NJ-BMP Manual

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]

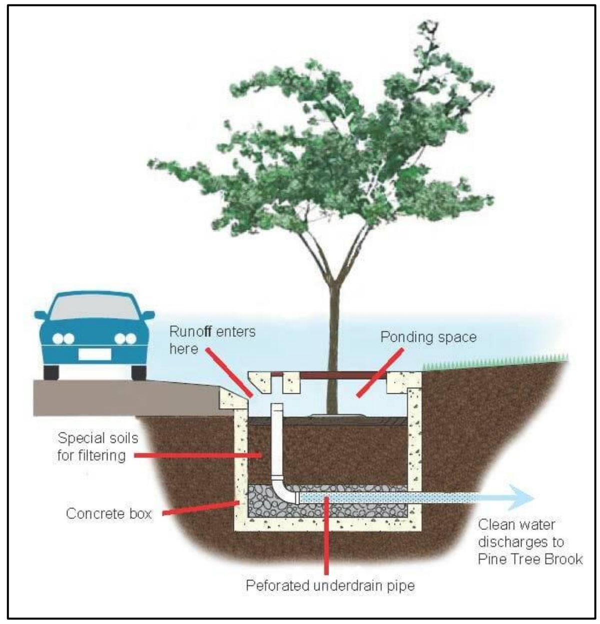

Figure 17: Basic tree filter box diagram
Image credit: Town of Milton, MA Dept. of public works stormwater

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]

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

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

[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

and sizes. Cisterns must be sized based upon on-site water needs; an under-sized cistern 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.

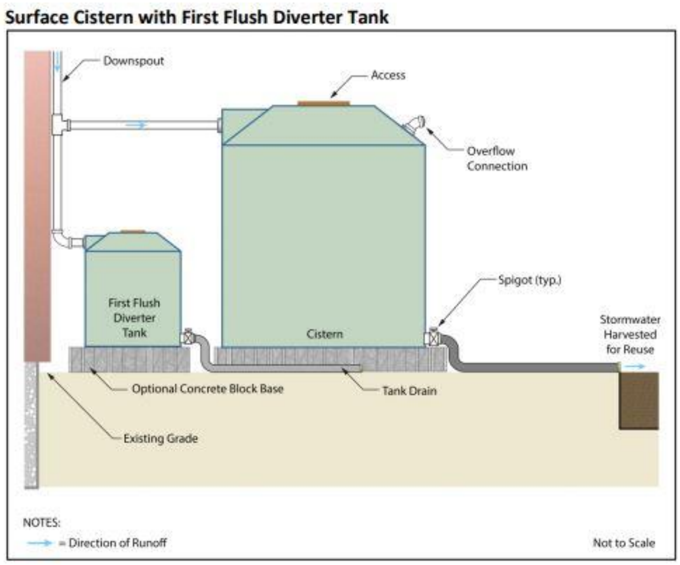

Figure 19: Example of above ground cistern including first flush diverter. Image credit: NJ BMP Manual

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

HUC 14 NAME	HUC13 NAME	HUC14 CODE	Total Area		Land Use Area		Water Area		Impervious Cover		
			(ac)	(mi²)	(ac)	(mi²)	(ac)	(mi²)	(ac)	(mi²)	(%)
Stony Bk (above 74d 49m 15s)	Upper Stony Brook	02030105090010	4,090.52	6.39	4,058.27	6.34	32.25	0.05	79.90	0.12	1.97%
Stony Bk (74d 48m 10s to 74d 49m 15s)	Upper Stony Brook	02030105090020	6,174.30	9.65	6,137.52	9.59	36.78	0.06	128.08	0.20	2.09%
Stony Bk (Baldwins Ck to 74d 48m 10s)	Upper Stony Brook	02030105090030	3,664.13	5.73	3,611.40	5.64	52.73	0.08	176.81	0.28	4.90%
Stony Bk(74d46m dam to/incl Baldwins Ck)	Lower Stony Brook	02030105090040	3,647.22	5.70	3,589.60	5.61	57.62	0.09	398.67	0.62	11.11%
Stony Bk(Province Line Rd to 74d46m dam)	Lower Stony Brook	02030105090050	6,272.07	9.80	6,143.52	9.60	128.55	0.20	301.26	0.47	4.90%
Stony Bk (Rt 206 to Province Line Rd)	Lower Stony Brook	02030105090060	5,153.93	8.05	5,085.95	7.95	67.98	0.11	520.68	0.81	10.24%
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%
Swan Creek (Moore Ck to Alexauken Ck)	Swan Creek	02040105210030	4,046.02	6.32	3,769.69	5.89	276.33	0.43	287.10	0.45	7.62%
Moore Creek	Moore Creek	02040105210040	6,030.06	9.42	6,001.26	9.38	28.80	0.05	95.27	0.15	1.59%
Fiddlers Creek (Jacobs Ck to Moore Ck)	Fiddlers Creek	02040105210050	3,731.69	5.83	3,467.20	5.42	264.49	0.41	126.35	0.20	3.64%
Jacobs Creek (above Woolsey Brook)	Jacobs Creek	02040105210060	3,543.48	5.54	3,519.77	5.50	23.71	0.04	130.36	0.20	3.70%
Jacobs Creek (below/incl Woolsey Brook)	Jacobs Creek	02040105210070	4,870.98	7.61	4,824.91	7.54	46.07	0.07	532.37	0.83	11.03%

Appendix A Continued – Municipality's HUC 14 Existing Impervious Surface Conditions

HUC 14 NAME	HUC13 NAME	HUC14 CODE	Total Area		Land Use Area		Water Area		Impervious Cover		
			(ac)	(mi²)	(ac)	(mi²)	(ac)	(mi²)	(ac)	(mi²)	(%)
Shipetaukin Creek	Shipetaukin Creek	02040105230060	6905.67	10.79	6,808.93	10.64	96.74	0.15	1003.33	1.57	14.74%
Shabakunk Creek	Shabakunk Creek	02040105240010	5,400.59	8.44	5,340.05	8.34	60.54	0.09	1422.16	2.22	26.63%
Little Shabakunk Creek	Little Shabakunk Creek	02040105240050	2,785.76	4.35	2,767.76	4.32	18.00	0.03	701.84	1.10	25.36%
		Total	83,946.36	131.17	82,615.36	129.09	1330.9974	2.08	6,803.46	10.63	8.24%

Appendix B – Municipality's HUC 14 Existing Runoff Conditions

HUC 14 NAME	HUC13 NAME	HUC14 CODE	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 (3.30-3.33") (MGal)	Total Runoff Volume for the 10-Year Design Storm (4.94-5.07") (MGal)	Total Runoff Volume for the 100-Year Design Storm (7.92-8.57") (MGal)
Stony Bk (above 74d 49m 15s)	Upper Stony Brook	02030105090010	2.7	101.8	7.2	10.8	17.7
Stony Bk (74d 48m 10s to 74d 49m 15s)	Upper Stony Brook	02030105090020	4.3	163.2	11.5	17.3	28.3
Stony Bk (Baldwins Ck to 74d 48m 10s)	Upper Stony Brook	02030105090030	6.0	225.4	15.9	23.9	39.1
Stony Bk(74d46m dam to/incl Baldwins Ck)	Lower Stony Brook	02030105090040	13.5	508.1	35.7	54.2	90.1
Stony Bk(Province Line Rd to 74d46m dam)	Lower Stony Brook	02030105090050	10.2	384.0	27.0	41.0	68.1
Stony Bk (Rt 206 to Province Line Rd)	Lower Stony Brook	02030105090060	17.7	663.6	46.7	70.8	117.6
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
Swan Creek (Moore Ck to Alexauken Ck)	Swan Creek	02040105210030	9.7	365.9	26.0	38.5	61.7
Moore Creek	Moore Creek	02040105210040	3.2	121.4	8.6	12.9	21.1
Fiddlers Creek (Jacobs Ck to Moore Ck)	Fiddlers Creek	02040105210050	4.3	161.0	11.4	17.1	27.9
Jacobs Creek (above Woolsey Brook)	Jacobs Creek	02040105210060	4.4	166.1	11.8	17.6	28.8
Jacobs Creek (below/incl Woolsey Brook)	Jacobs Creek	02040105210070	18.1	678.5	48.0	72.0	117.7
Shipetaukin Creek	Shipetaukin Creek	02040105230060	34.1	1,278.8	90.4	135.7	221.8
Shabakunk Creek	Shabakunk Creek	02040105240010	48.3	1,812.6	128.2	192.3	314.3
Little Shabakunk Creek	Little Shabakunk Creek	02040105240050	23.8	894.5	63.3	94.9	155.1
		Total	230.9	8,671.2	612.2	920.2	1,511.3

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
	FIDDLER'S CREEK SUBWATERSHED															
	The Titusville Academy	86 River Drive	135	38	Fiddlers Creek (Jacobs Ck to Moore Ck)	2.25	98,142	0.77	33,635	34.3%	0.77	7.72	92.66	26,209	69,611	984,204
	Fiddler's Creek Subwatershed Total					**2.25**	**98,142**	**0.77**	**33,635**	**34.3%**	**0.77**	**7.72**	**92.66**	**26,209**	**69,611**	**984,204**
	JACOB'S CREEK SUBWATERSHED															
	Bear Tavern Elementary School	1162 Bear Tavern Road	95	31	Jacobs Creek (above Woolsey Brook)	27.05	1,178,180	4.80	208,869	17.7%	4.79	47.95	575.40	162,755	432,277	6,111,778
*	Bright Horizons	800 North Road	91	3.15	Jacobs Creek (above Woolsey Brook)	6.17	268,660	2.41	105,054	39.1%	2.41	24.12	289.40	81,860	217,420	3,074,006
	Capital Health Medical Center	1 Capital Way	91	3.961	Jacobs Creek (above Woolsey Brook)	132.13	5,755,575	28.35	1,235,019	21.5%	28.35	283.52	3,402.26	962,353	2,556,009	36,138,298
*	Hopewell Township Municipal Office	201 Washington Crossing-Pennington Road	92	46	Jacobs Creek (above Woolsey Brook)	8.96	390,245	3.33	144,916	37.1%	3.33	33.27	399.22	112,922	299,920	4,240,433
	Janssen	1125 Bear Tavern Road	98	17,37	Jacobs Creek (above Woolsey Brook)	247.57	10,784,128	27.56	1,200,531	11.1%	57.88	606.33	5,512.08	935,479	2,484,631	35,129,125
	Merril Lynch	1100 American Boulevard	91	3.01-3.08	Jacobs Creek (below/incl Woolsey Brook)	93.96	4,092,725	46.60	2,029,745	49.6%	97.85	1,025.12	9,319.31	1,581,619	4,200,781	59,393,020
*	Unitarian Universalist Church	268 Washington Crossing-Pennington Road	95	32	Jacobs Creek (above Woolsey Brook)	4.43	193,063	0.94	40,729	21.1%	0.94	9.35	112.20	31,737	84,293	1,191,786
	Jacob's Creek Subwatershed Total					**520.26**	**22,662,576**	**113.98**	**4,964,862**	**21.9%**	**195.55**	**2,029.66**	**19,609.86**	**3,868,724**	**10,275,331**	**145,278,447**
	LOWER STONY BROOK SUBWATERSHED															
*	Dunkin Donuts	1 Tree Farm Road	48.02	1	Stony Bk(74d46m dam to/incl Baldwins Ck)	1.80	78,210	1.40	61,083	78.1%	1.40	14.02	168.27	47,597	126,418	1,787,372
	Hopewell Valley Central High School	259 Pennington-Titusville Road	63.01	1	Stony Bk(74d46m dam to/incl Baldwins Ck)	36.96	1,609,762	10.81	470,922	29.3%	10.81	108.11	1,297.30	366,952	974,624	13,779,792
*	M&T Bank	3 Tree Farm Road	48.02	2	Stony Bk(74d46m dam to/incl Baldwins Ck)	1.35	58,624	0.91	39,459	67.3%	0.91	9.06	108.70	30,747	81,665	1,154,628
*	Osteria Proccacini	7 Tree Farm Road	48.02	3	Stony Bk(74d46m dam to/incl Baldwins Ck)	3.40	148,202	1.98	86,029	58.0%	1.97	19.75	236.99	67,036	178,047	2,517,324
	Pennington Montessori School	4 Tree Farm Road	48	8.03	Stony Bk(74d46m dam to/incl Baldwins Ck)	2.83	123,138	1.03	44,909	36.5%	1.03	10.31	123.72	34,994	92,944	1,314,099
*	The Village Learning Center	15 Yard Road	49	6.03	Stony Bk(74d46m dam to/incl Baldwins Ck)	14.73	641,671	1.03	44,716	7.0%	1.03	10.27	123.19	34,844	92,546	1,308,463
	Timberlane Middle School	51 Timberlane Drive South	63	27	Stony Bk(74d46m dam to/incl Baldwins Ck)	43.59	1,898,757	8.97	390,643	20.6%	8.97	89.68	1,076.15	304,397	808,479	11,430,735
	Lower Stony Brook Subwatershed Total					**104.65**	**4,558,364**	**26.12**	**1,137,762**	**25.0%**	**26.12**	**261.19**	**3,134.33**	**886,568**	**2,354,723**	**33,292,412**
	SHABAKUNK CREEK SUBWATERSHED															
	Mercer County Technical Schools	129 Bull Run Road	78.09	118	Assunpink Creek (below Shipetaukin Ck)	34.42	1,499,333	6.89	300,069	20.0%	6.89	68.89	826.64	233,820	621,026	8,780,420
*	Princeton Community Church	4 Brigham Way	78.04	1.01	Assunpink Creek (below Shipetaukin Ck)	5.16	224,550	1.27	55,374	24.7%	1.27	12.71	152.54	43,148	114,602	1,620,306
	Stony Brook Elementary School	20 Stephenson Road	78.31	62	Assunpink Creek (below Shipetaukin Ck)	12.39	539,720	3.65	158,901	29.4%	3.65	36.48	437.74	123,819	328,863	4,649,654
	Shabakunk Creek Subwatershed Total					**51.97**	**2,263,604**	**11.81**	**514,344**	**22.7%**	**11.81**	**118.08**	**1,416.92**	**400,787**	**1,064,491**	**15,050,381**
	SWAN CREEK SUBWATERSHED															
	Mercer County Wildlife Center	1748 River Road	59	1	Swan Creek (Moore Ck to Alexauken Ck)	139.67	6,084,020	14.23	619,895	10.2%	1.42	42.69	569.23	483,035	1,282,941	18,138,949
	Swan Creek Subwatershed Total					**139.67**	**6,084,020**	**14.23**	**619,895**	**10.2%**	**1.42**	**42.69**	**569.23**	**483,035**	**1,282,941**	**18,138,949**

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
	UPPER STONY BROOK SUBWATERSHED															
	Bristol Myers Squibb	311 Pennington-Rocky Hill Road	46	8.01	Stony Bk (Baldwins Ck to 74d 48m 10s)	429.54	18,710,794	55.53	2,418,828	12.9%	116.61	1,221.63	11,105.73	1,884,801	5,006,032	70,778,118
	Hopewell Church	11 Mount Church Road	3	10	Stony Bk (74d 48m 10s to 74d 49m 15s)	1.50	65,205	0.20	8,895	13.6%	0.20	2.04	24.50	6,931	18,409	260,274
	Hopewell Crossing Shopping Center	800 Denow Road	78	15.99	Stony Bk(74d46m dam to/incl Baldwins Ck)	20.41	889,100	11.06	481,722	54.2%	23.22	243.29	2,211.76	375,368	996,977	14,095,821
	Kooltronic, Incorporated	30 Pennington-Hopewell Road	37	17.011	Stony Bk (Baldwins Ck to 74d 48m 10s)	80.51	3,506,969	9.750	424,691	12.1%	20.47	214.49	1,949.91	330,928	878,945	12,427,024
	QuickChek	129-131 Route 31 North	33	1.01	Stony Bk (Baldwins Ck to 74d 48m 10s)	1.54	67,244	0.96	41,958	62.4%	2.02	21.19	192.65	32,695	86,837	1,227,755
*	Shop Rite	2555 Pennington Road	85	5.01	Stony Bk(74d46m dam to/incl Baldwins Ck)	10.27	447,241	5.43	236,562	52.9%	5.43	54.31	651.69	184,334	489,591	6,922,120
*	Saint Peter Lutheran Church	1608 Harbourton Rocktown Road	29	47	Stony Bk (74d 48m 10s to 74d 49m 15s)	6.72	292,566	1.07	46,738	16.0%	1.07	10.73	128.75	36,419	96,729	1,367,615
	Upper Stony Brook Subwatershed Total					**550.49**	**23,979,120**	**74.26**	**3,659,394**	**15.3%**	**169.04**	**1,767.68**	**16,265.00**	**2,851,476**	**7,573,521**	**107,078,727**
	HOPEWELL TOWNSHIP TOTAL					**1,369.29**	**59,645,825**	**241.17**	**10,929,892**	**18.3%**	**404.71**	**4,227.03**	**41,088.00**	**8,516,799**	**22,620,619**	**319,823,119**

***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)	

Appendix D – Example Site assessment Form – Page 2 of 5

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 ☐ OTHER ______________________	☐ Depaving ☐ Cistern ☐ Downspout planter ☐ Bioswale ☐ Tree filter box	☐ Sand/Gravel Filter Pit/Strip ☐ Discontinuous pavement (partial depaving)

Appendix E – Site-Specific Reduction Action Plans

ATTACHED SEPERATELY

Appendix F – Summary of Reduction Action Plans for Hopewell Township

STORMWATER BMP BY SITE	POTENTIAL MANAGEMENT AREA		SIZE OF BMP		PERCENTAGE OF IMPERVIOUS COVER TREATED	REMOVAL POTENTIAL			MAX VOLUME REDUCTION POTENTIAL (gal/storm)	RECHARGE POTENTIAL (gal/year)	ESTIMATED COST
	(ac)	(sq ft)	(ac)	(sq ft)		TP	TN	TSS			
JACOBS CREEK SUBWATERSHED											
Bright Horizons											
Vegetated Filter	0.29	12,823.97	0.40	17,613	12.2%	0.12	1.21	33.96	26,541	356,483	$88,064.85
Bioswale	0.70	30,486.27	0.11	4,926	29.0%	0.07	0.34	12.21	63,095	847,464	$24,628.72
Site Total	**0.99**	**43,310**	**0.52**	**22,539**	**41.2%**	**0.19**	**1.55**	**46.18**	**89,635**	**1,203,947**	**$112,693.57**
Hopewell Township Municipal Office											
Bioswale 1	0.38	16,464.72	0.07	3,233	11.4%	0.04	0.22	8.01	34,076	457,690	$16,162.50
Bioswale 2	1.08	47,100.55	0.18	7,656	32.5%	0.11	0.53	18.98	97,480	1,309,311	$38,282.20
Bioswale 3	0.86	37,437.71	0.14	6,202	25.8%	0.09	0.43	15.38	77,481	1,040,701	$31,009.60
Cistern	0.47	20,489.65	0.98	42,500	14.1%	0.00	0.00	0.00	42,406	569,576	$212,500.00
Site Total	**2.79**	**121,493**	**1.37**	**59,591**	**83.8%**	**0.24**	**1.18**	**42.37**	**251,442**	**3,377,278**	**$297,954.30**
Unitarian Universalist Church											
Bioswale	0.38	16,483.89	0.06	2,646	40.5%	0.04	0.18	6.56	34,115	458,223	$13,231.75
Rain Garden 1	0.12	5,232.85	0.06	2,646	12.8%	0.04	0.18	6.56	10,830	145,464	$13,229.55
Rain Garden 2	0.16	7,013.96	0.06	2,683	17.2%	0.04	0.18	6.65	14,516	194,976	$13,413.80
Porous Pavement	0.15	6,594.15	0.13	5,462	16.2%	0.10	0.75	7.52	13,647	183,306	$65,540.52
Site Total	**0.81**	**35,325**	**0.31**	**13,437**	**86.7%**	**0.21**	**1.30**	**27.30**	**73,109**	**981,968**	**$105,415.62**
Jacobs Creek Subwatershed Total	**4.59**	**200,128**	**2.19**	**95,566**		**0.63**	**4.03**	**115.85**	**414,186**	**5,563,193**	**$516,063.49**
LOWER STONY BROOK SUBWATERSHED											
Dunkin Donuts											
Rain Garden	0.14	6,142.13	0.06	2,524	10.1%	0.03	0.17	6.26	12,712	170,740	$12,618.40
Bioswale	0.15	6,411.04	0.02	1,080	10.5%	0.01	0.07	2.68	13,268	178,215	$5,399.15
Porous Pavement	0.21	9,011.73	0.05	2,290	14.8%	0.03	0.26	5.05	18,651	250,510	$27,475.08
Site Total	**0.50**	**21,565**	**0.14**	**5,893**	**35.3%**	**0.08**	**0.51**	**13.98**	**44,631**	**599,466**	**$45,492.63**
M&T Bank											
Porous Pavement	0.24	10,484.94	0.04	1,560	26.6%	0.02	0.18	3.44	21,700	291,463	$18,719.28
Rain Garden	0.08	3,398.54	0.02	668	8.6%	0.01	0.05	1.66	7,034	94,473	$3,341.05
Site Total	**0.32**	**13,883**	**0.05**	**2,228**	**35.2%**	**0.03**	**0.23**	**5.09**	**28,733**	**385,936**	**$22,060.33**

Appendix F – Summary of Reduction Action Plans for Hopewell Township

STORMWATER BMP BY SITE	POTENTIAL MANAGEMENT AREA		SIZE OF BMP		PERCENTAGE OF IMPERVIOUS COVER TREATED	REMOVAL POTENTIAL			MAX VOLUME REDUCTION POTENTIAL (gal/storm)	RECHARGE POTENTIAL (gal/year)	ESTIMATED COST
	(ac)	(sq ft)	(ac)	(sq ft)		TP	TN	TSS			
Osteria Proccacini											
Porous Pavement 1	0.72	31,518.03	0.13	5,813	36.6%	0.08	0.67	12.81	65,230	876,145	$69,759.36
Porous Pavement 2	0.53	23,112.70	0.10	4,168	26.9%	0.06	0.48	9.19	47,834	642,492	$50,014.44
Porous Pavement 3	0.25	10,817.15	0.05	2,014	12.6%	0.03	0.23	4.44	22,387	300,697	$24,163.80
Site Total	**1.50**	**65,448**	**0.28**	**11,995**	**76.1%**	**0.17**	**1.38**	**26.43**	**135,452**	**1,819,334**	**$143,937.60**
The Village Learning Center											
Stormwater Basin Naturalization	0.81	35,446	0.34	14,898	79.3%	0.21	1.03	36.94	73,360	985,348	$74,488.55
Site Total	**0.81**	**35,446**	**0.34**	**14,898**	**79.3%**	**0.21**	**1.03**	**36.94**	**73,360**	**985,348**	**$74,488.55**
Lower Stony Brook Subwatershed Total	**3.13**	**136,343**	**0.80**	**35,014**		**0.48**	**3.14**	**82.45**	**282,176**	**3,790,084**	**$285,979.11**
SHABAKUNK CREEK SUBWATERSHED											
Princeton Community Church											
Stormwater Basin Naturalization	1.18	51,524	0.21	9,077	93.0%	0.13	0.63	22.50	106,635	1,432,284	$45,383.90
Site Total	**1.18**	**51,524**	**0.21**	**9,077**	**93.0%**	**0.13**	**0.63**	**22.50**	**106,635**	**1,432,284**	**$45,383.90**
Shabakunk Creek Subwatershed Total	**1.18**	**51,524**	**0.21**	**9,077**		**0.13**	**0.63**	**22.50**	**106,635**	**1,432,284**	**$45,383.90**
UPPER STONY BROOK SUBWATERSHED											
Saint Peter Lutheran Church											
Bioswale	1.06	45,973.70	0.19	8,454	98.4%	0.12	0.58	20.96	95,148	1,277,987	$42,267.50
Vegetated Filter	2.32	100,960.56	2.32	100,961	216.0%	0.70	6.95	194.69	208,949	2,806,523	$302,881.68
Site Total	**3.37**	**146,934**	**2.51**	**109,414**	**314.4%**	**0.81**	**7.54**	**215.65**	**304,097**	**4,084,510**	**$345,149.18**
Shop Rite											
Bioswale	1.38	60,004	0.45	19,666	25.4%	0.27	1.35	48.76	124,185	1,667,999	$98,329.00
Stormwater Basin Naturalization	3.40	147,920	0.51	22,113	62.5%	0.30	1.52	54.83	306,138	4,111,924	$110,566.15
Vegetated Filter 1	0.35	15,155	0.44	19,184	6.4%	0.13	1.32	36.99	31,366	421,296	$57,551.28
Vegetated Filter 2	0.39	17,094	0.49	21,362	7.2%	0.15	1.47	41.19	35,377	475,175	$64,084.74
Site Total	**5.51**	**240,173**	**1.89**	**82,324**	**101.5%**	**0.85**	**5.67**	**181.77**	**497,066**	**6,676,393**	**$330,531.17**
Upper Stony Brook Subwatershed Total	**8.89**	**387,108**	**4.40**	**191,738**		**1.67**	**13.21**	**397.42**	**801,162**	**10,760,903**	**$675,680.35**
HOPEWELL TOWNSHIP TOTAL	**17.80**	**775,103**	**7.61**	**331,395**		**2.91**	**21.00**	**618.22**	**1,604,160**	**21,546,463**	**$1,523,106.85**