Green Stormwater Infrastructure Toolbox and Campus Guidelines

July, 2018

The Environmental Cooperative at the Vassar Barns

Vassar College Office of Sustainability

NEW YORK STATE OF OPPORTUNITY. | Department of Environmental Conservation | Hudson River Estuary Program

Acknowledgments

This project has been funded in part by a grant from the New York State Environmental Protection Fund through the Hudson River Estuary Program of the New York State Department of Environmental Conservation. Additional funding from: The Leona M. and Harry B. Helmsley Charitable Trust, The Environmental Cooperative at the Vassar Barns and the Vassar Sustainability Office.

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Executive Summary

This report outlines the benefits of green stormwater management for the campus and the broader Hudson River Estuary. Vassar College is located in the middle of the Casperkill watershed, an urbanized tributary of the Hudson, which and like many such streams has impervious cover that accelerates delivery of contaminants (such as nutrients, sediment, and road salt) to the river. By comparing and contrasting the many GSI practices, this report sheds light on the multiple ways, both small and large, that stakeholders can make a positive difference to our local waterways.

Stormwater management is inherently site-specific, so it is difficult to provide clear broadly applicable recommendations. The purpose of this report is thus to outline options for the Vassar campus and to share a record of those options as a reference for others undertaking similar planning.

This report includes the following resources to guide the integration of GSI practices:

- Goals to guide integration of GSI practices over time on Vassar Campus/Vassar-owned properties
- Green Stormwater Infrastructure Toolbox: GSI Benefits, Application and Common GSI Practices
- Decision support recommendations and
- Maintenance, monitoring and metrics recommendations

Introduction and Campus Watershed Context

In the heart of the Hudson Valley, Vassar College is situated amid and near numerous natural water resources, including the Casperkill, Fonteyn Kill, Vassar Lake, Sunset Lake and the Hudson River. This proximity to water was a purposeful decision on the part of Matthew Vassar so that Vassar students would have a healthy supply of spring water. As the campus and the surrounding communities grew, the health of these water resources diminished.

Colleges and universities have often been in the forefront of the transition from conventional approaches to building and infrastructure design to greener, more sustainable practices. Vassar's green building efforts are evident in the recently completed renovations of both Sanders Physics and New England Buildings as part of Vassar's Integrated Science project, which also included a renovation of Olmsted Hall, the construction of the 'Bridge Building,' and the removal of Mudd Hall. The College is also working toward the goal of becoming carbon neutral by 2030. Green Stormwater Infrastructure (GSI) practices are a natural extension of these efforts.

A variety of Green Stormwater Infrastructure (GSI) measures can improve the health and ecological functions of water and ecological resources on college campuses, as well as within their broader communities and watersheds. The 2011 Vassar Landscape Master Plan, written by Michael Van Valkenburgh and Associates (MVVA), identified the need to improve the ecological health of Vassar's water systems, including both its engineered stormwater management system and the natural system of lakes and streams that run through campus. (Figure 1). The MVVA Plan also noted that Vassar's traditional piped drainage system channels warm, sediment- and pollutant-laden runoff from hardscape into campus waterways. Runoff contributes to the erosion of stream banks and the proliferation of sediment, which blankets stream substrates and streambed ecosystems. Rapid removal of stormwater from the landscape, rather than infiltration, lowers groundwater levels, causing less water in streams during dry weather. As has been noted by the Casperkill Assessment (Menking et. al, 2009) and a study of the Fonteyn Kill (Cunningham et. al, 2013), water quality in the kills that pass through the Vassar campus is quite poor, both chemically and biologically. In the past 50 years a dramatic increase in impervious surfaces on campus has significantly contributed to the increase in pollution and in the rate and amount of water entering the Casperkill after storm events. Runoff from roadways and parking lots is higher in temperature and contains salts and heavy metals, which can damage flora and fauna. Piped runoff also contains high levels of sediments and nutrients, as storm runoff no longer percolates through the soil profile. Without infiltration, groundwater and soil water recharge declines.

By transitioning from conventional or "grey" stormwater infrastructure[1] to green stormwater infrastructure (GSI) techniques over time, Vassar can improve the quality of its water bodies and their ecosystems, as well as the quality of water conveyed offsite, via the Casperkill into the Hudson River. (Figure 2). While Vassar has some GSI practices in place on campus, the vast majority of stormwater runoff generated by campus buildings, pavement and improvements is conveyed via subsurface systems to local waterbodies and streams (Figure 3). Sand traps in the storm drainage lines catch some sediment from roadways, but aside from these, there is generally no filtration or other means to improve the quality of runoff generated from the campus.

1 Grey stormwater infrastructure is conventional pipe and culvert removal of storm runoff to the nearest waterways. This is not to be confused with “grey water,” which is water moderately contaminated by use, for example drainage from sinks, tubs, and washing machines that is normally delivered to sanitary sewer systems. Usually primary contaminants are nutrients (for example, from soap). Toilets, by contrast, produce “black water” contaminated by fecal bacteria and other contaminants hazardous to human health. Sanitary sewers deliver this to water treatment plants, except where aging infrastructure leaks into natural waterways.

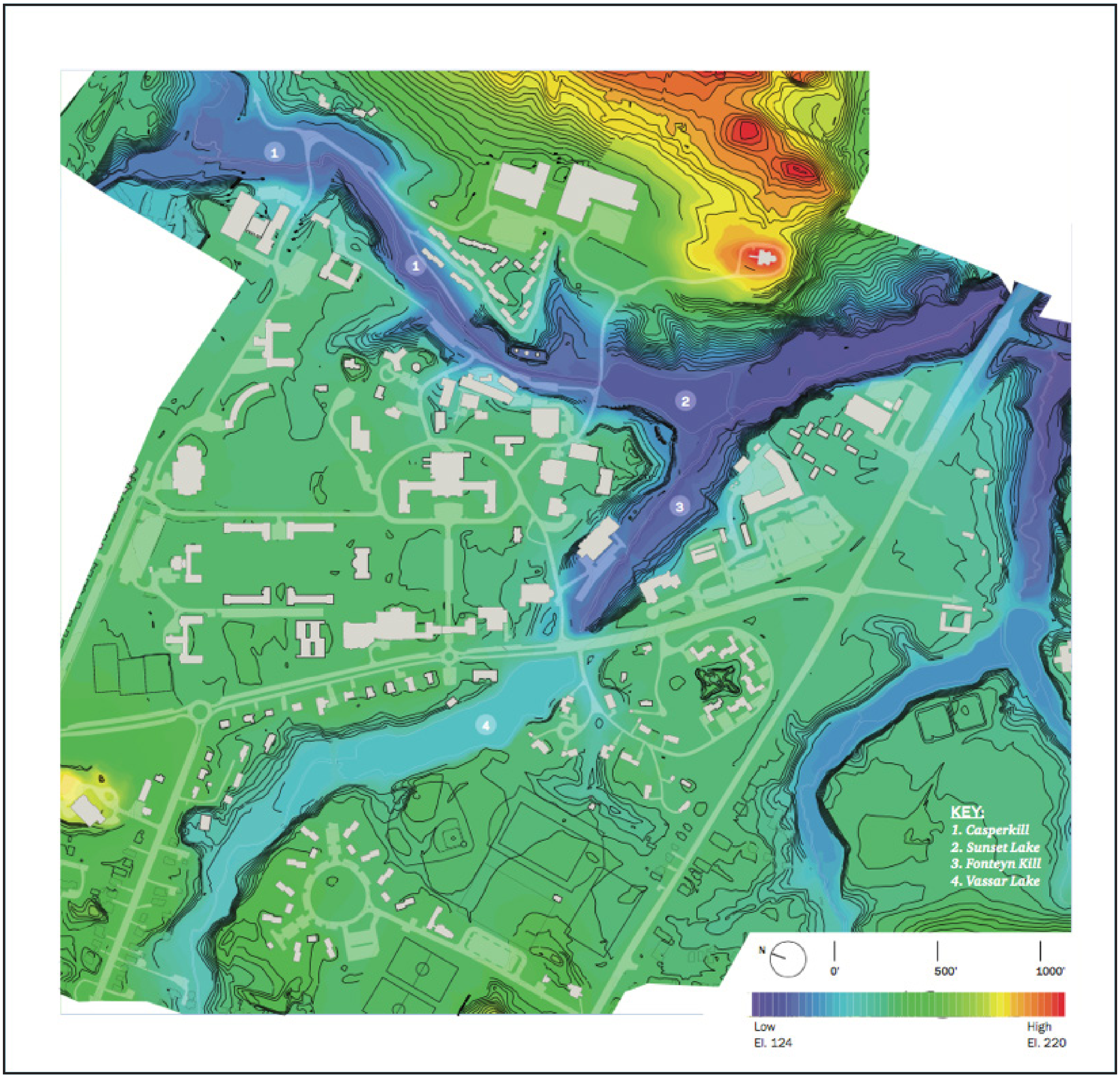


Figure 1 – Vassar campus topography and water resources.
Source: MVVA Landscape master plan

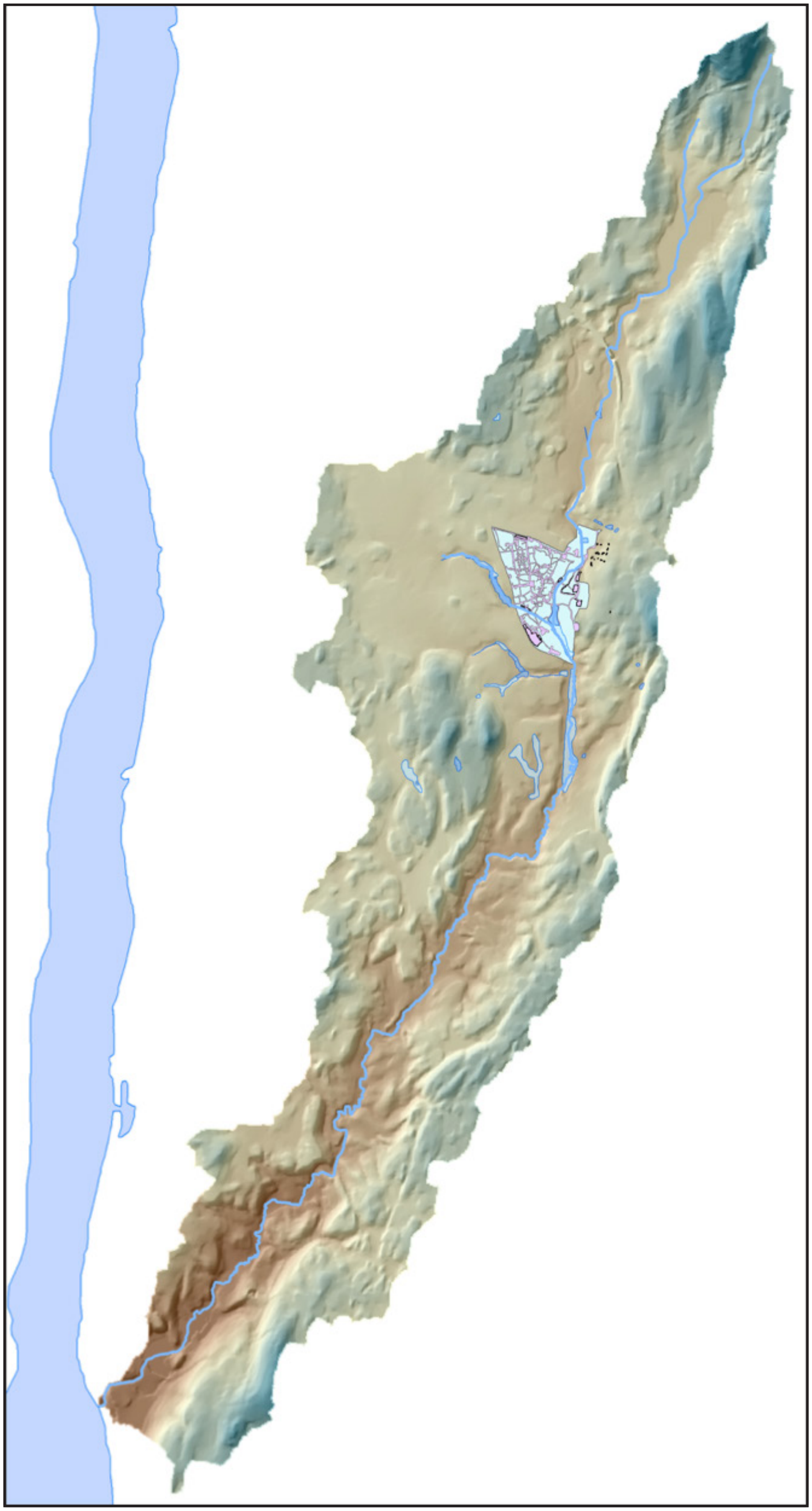


Figure 2 - Map of the Casperkill watershed

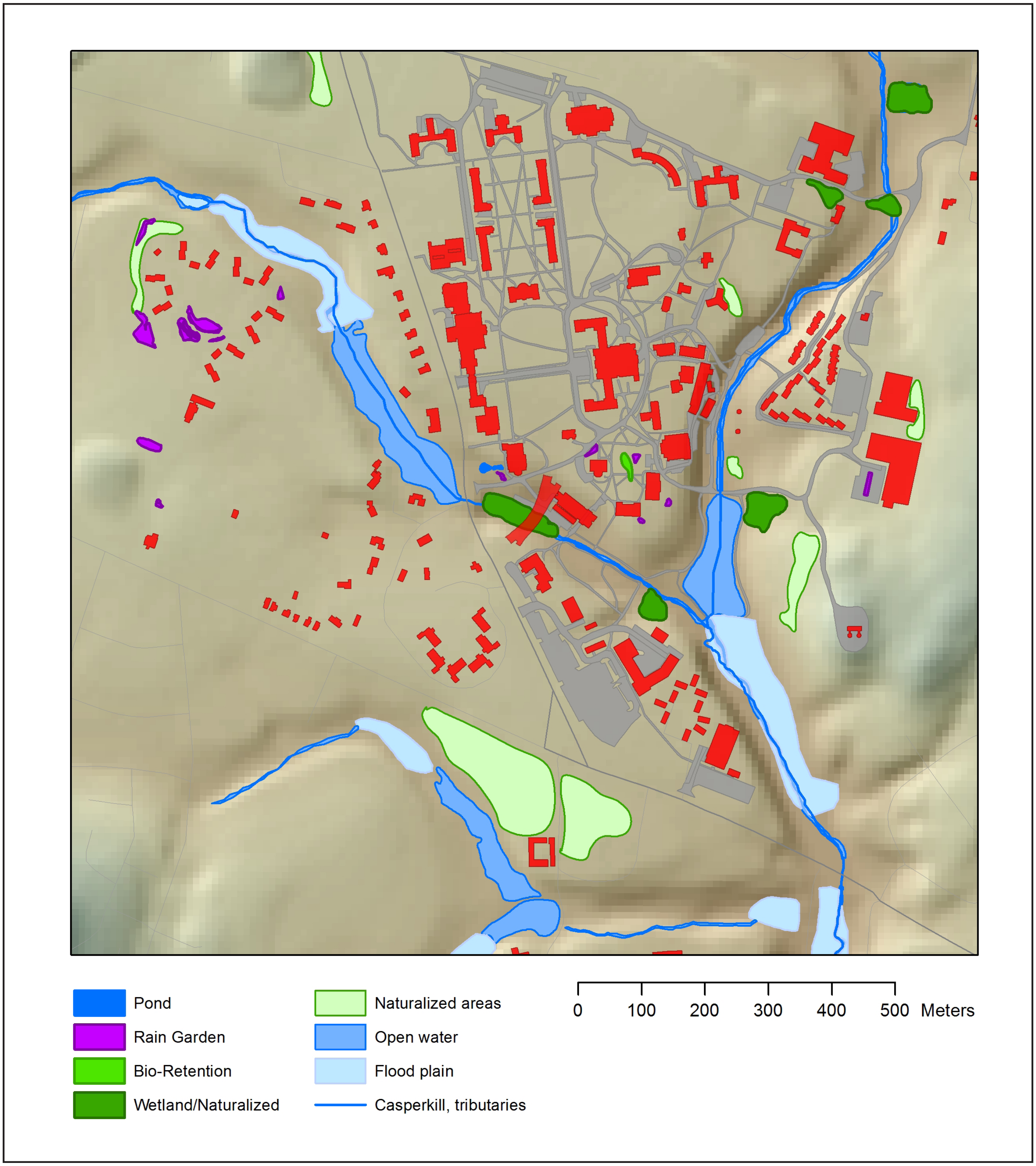


Figure 3 - Impervious coverage and current GSI practices on the Vassar College campus

Vassar College

History of Sustainability Initiatives

Vassar's Early Days

1800s

1865: First Tree Plantings

1868: First Class Tree is planted

1875: Arboretum Founded

1894: Alumna Trustee Ellen Swallow Richards advised the trustees to construct an irrigation plant instead of a costly sewage canal from the college to the Hudson River.

Ecological Lab & Preserve

1900s

1920: Professor Edith Roberts creates Ecological Laboratory

1976: 275 acres set aside as Ecological Preserve (now 530 acres)

1987: 10 Year Plan by Sasaki Associates

1996: Collins Field Station built on Preserve

Programming

2000-09

2000: Environmental Studies Program certified by NY State

2000: Advisory Committee on Recycling & Sustainability formed

2006: Environmental Studies Collins Fellow created

2006: Casperkill Watershed Assessment

2008: Rain Gardens installed at Townhouses

Planning & Planting

2010-13

2010: Student garden (VEG) created

2011: MVVA Campus Landscape Plan

2010: Trees 4 Tribs Planting

2013: Arboretum Committee founded

2013:. First 'naturalized areas'

2013: First Tree Campus USA designation

Environmental Cooperative

2014

2015: Environmental Cooperative founded

2015: Vassar receives Hudson River Estuary Program Grant

Science Project Landscaping

2016

2016: Sustainability features in new Bridge building include bird-friendly glass and a system that collects rainfall and snowmelt to be used in the Olmsted Hall greenhouse.

2016: Raingardens added at former Mudd site and by Chapel as part of project.

2016: The wetlands surrounding the Fontynkill and the Edith Roberts Ecological Lab were restored as part of the project

Sustainability Integration

2017

2017: Trees 4 Tibs plantings at Sunset Lake

2017: Two parking lot medians converted to native gardens

2017: Vassar Barns GSI Master Plan/Pilot Projects

2018: Campus Green Infrastructure Policy & Tools

Figure 4 - History of environmental action and planning at Vassar College

Goals For Integration of Green Stormwater Practices

Vassar College has an opportunity to contribute to community efforts to improve the quality of its watersheds by incorporating green stormwater management on the campus. At the same time, attractive landscape elements can be incorporated into GSI practices to enhance biodiversity and landscape aesthetics, and to provide a living laboratory for both faculty and students

In 2016, the Environmental Cooperative at the Vassar Barns and the Sustainability Office received funding from the New York State Environmental Protection Fund, NYSDEC Hudson River Estuary Program, to broaden the capacity for GSI practices on Vassar's campus. The specific goals of this grant include developing campus standards and tools for GSI to become more fully integrated into Vassar's decision-making processes on both maintenance and capital projects, including creating an inventory of the stormwater practices already in place, creating pilot projects to showcase and study GSI measures in the area around the Vassar Barns and hosting a series of educational trainings for Vassar staff and the community about green infrastructure practices (these training and educational efforts are summarized in a separate document included in the Appendix). These green stormwater practices are not only environmentally beneficial in terms of decreasing pollution and revitalizing the Casperkill, they will also advance the Environmental Cooperative's mission of educating and engaging community members and students with conservation and environmental stewardship in the Hudson Valley.

For the past two years, an interdisciplinary team consisting of members of Vassar's community from the Environmental Cooperative, Facilities Operations and Sustainability, as well as Vassar faculty, design professionals and undergraduate student researchers, has been dedicated to creating this policy guide for implementing GSI practices at Vassar and building a more sustainable future.

This report includes the following resources to guide the integration of GSI practices:

- Goals to guide integration of GSI practices over time on Vassar Campus/Vassar-owned properties
- Green Stormwater Infrastructure Toolbox: GSI Benefits, Application and Common GSI Practices
- Decision Support Recommendations
- Maintenance, Monitoring and Metrics Recommendations

The grant project team reviewed relevant green stormwater research and collaborated with the grant's NYSDEC Project Manager to develop the following overarching goals for integrating GSI on the Vassar Campus over time:

Overall goals

- Explore and demonstrate opportunities for runoff mitigation.
- Maximize ecosystem services and benefits of maintenance practices, infrastructure investments and capital projects with an eye toward improving the overall health of waterways and watersheds.
- Leverage educational programming to connect students, faculty, staff, administrators, the community and other stakeholders with learning opportunities about GSI and watershed health.

Strategies

- Minimize impervious surfaces on campus, especially close to waterways and in areas that drain directly to waterways through buried pipes.
- Promote low-cost practices to treat stormwater close to its source rather than at stream outfall.
- Improve decision-making on maintenance projects; retrofit projects and capital projects to explicitly consider including GSI design elements.
- Improve water quality by filtering/infiltrating stormwater, rather than moving stormwater directly to water bodies.
- Avoid over-design and over-sizing of conventional grey infrastructure systems.
- Maintain and expand tree canopy on campus, to provide both water uptake and cooling.
- Match or improve on the cost of traditional piped stormwater strategies.
- Reduce the College's contribution to flooding in the Casperkill per Casperkill Assessment.
- Enhance riparian buffers and edges of existing waterways and wetlands.
- Anticipate the need for, and cost of, training to properly maintain GI elements well before projects are conceptualized and designed.
- Develop holistic strategies for meeting state and municipal stormwater management requirements.
- Develop monitoring and performance metrics, such as tracking the percentage of campus rooftops and impervious coverage captured and treated, and quantifying total runoff reduction as GI practices are implemented over time.
- Consider establishing a campus-wide mitigation bank and performance metrics for stormwater runoff; for example, in exchange for a new building footprint or impervious coverage, create wetland or implement other GSI practices to offset new impacts.

GIS Toolbox: Benefits, Relative Cost, Applicability, And Decision Support Tools

A key component of the HREP Grant is to develop guidance on how GSI techniques can be integrated into campus for a variety of project types, including maintenance, renovation and new capital projects. Central to such guidance is to understand various ecosystem benefits and services offered by common GSI practices, the costs and benefits of common GSI practices compared to "business as usual" (BAU) and the various possibilities for incorporating specific GSI practices within different project types.

In assessing relative costs, it is important to note that we have been unable to gather data on the cumulative costs of installing and maintaining conventional “grey” infrastructure. Buried drainage lines and other infrastructure have substantial and ongoing costs, but these business-as-usual costs are not systematically accounted for or available for comparison. Thus, we are approximate in estimating the costs of GSI relative to costs of grey infrastructure. Previous studies, however (e.g. EPA 2008, Houle et al. 2013) have found that net costs of grey infrastructure are often higher than those of green infrastructure. Further, if the monetary value of ecosystem services associated with GSI were accounted for, compared to ecosystem costs of grey infrastructure, GSI costs could often be significantly lower than those of conventional approaches.

The GSI Ecosystem Services/Benefits analysis in Table 1 was undertaken with student support and considers runoff reduction, carbon sequestration, temperature mitigation, nutrient and pollution retention, wildlife/plant habitat, and aesthetic value. Each GSI practice was ranked from very low to very high relative to installing and maintaining grey infrastructure. This average also appears in Table 2, Summary of GSI Practices Compared to BAU, which includes relative rankings for initial installation cost, opportunities for educational programming/synergy, as well as space, maintenance requirements and long-term costs compared to conventional approaches to managing stormwater

Further, if the public/health value of the ecosystem services provided by GSI were valued in monetary equivalents, costs would be significantly lower than conventional approaches. Lastly, Table 3, the 'Applicability of GSI Practices' summarizes the opportunities for incorporating specific GSI practices into maintenance projects, retrofit projects and capital projects. As noted, while the full range of GSI approaches is relevant for new capital projects, a number of GSI practices can be implemented on a small scale, at relatively low costs with high benefits, such as rain gardens, bioswales, tree canopy, riparian buffers, meadow conversions and downspout disconnection.

Table 1 - Ecosystem Services and Benefits of Common GSI Practices

GI Practice	Runoff Reduction	"Carbon Sequestration	Temperature Mitigation (water or air)	Nutrient and Pollution Retention	Wildlife and Plant Habitat	“Aesthetics” / Beautification
Downspout Disconnection (5)	High - Downspout disconnection directs stormwater away from the buildings towards pervious surfaces. Works best when paired with another practice, such as a rain garden or stormwater planters which absorbs the displaced water.	Low - May indirectly add to carbon sequestration if water is diverted to a permeable area that supports vegetation.	High- Redireciton of water to locations where it can be absorbed by soils helps to cool water.	Very High - Displaces water towards pervious locations that retain nutrients and filter the water.	Low - Redirection of water may support gardens or lawns that create habitat.	Low - Redirection of water may support the growth of vegetated areas such as gardens or lawns.
Meadows (2,5)	Very High -Capture large quantities of stormwater and retain it in the soil allowing for groundwater recharge.	High - Herbaceous vegetation is important for the storage of carbon, however large mature trees are best for carbon sequestration.	Very High - Reduce runoff and provide shade, decreasing the quantity and temperature of water entering storm drains. Increasing vegetated areas increases evapotranspiration reducing urban heat island effects.	Very High - Promote infilitratoin and filtration of water.	Very High - Provide habitat for many plants and animals.	Very High - Meadows that support native wildflowers and grasses help to maintain the natural character of an area.
Rainwater Harvesting (1,5)	Low - Water captured using a cistern can have a large impact on reducing discharge. However, the use of barrels to store captured water provides minimal contribution to flood mitigation. Both rainbarrels and cisterns need to be emptied on a regular basis to be most effective.	Very Low -no impact on carbon sequestration.	High - Reducing the direct input of stormwater into storm drains leads to overall water cooling.	High - Prevents runoff from directly entering waterways or storm drains, giving sediments a chance to settle out.	Very Low - Rainwater harvesting has no direct benefits to wildlife and plant habitats.	Low - Dependant on water storage method (barrel of cistern), painted barrels can be aesthetically pleasing and add to a landscapte design.
Riparian Buffers (5)	Very High - Filter discharge from bodies of water, keep banks stable during a storm event, and reduce discharge rates.	High - Consist of carbon sequestering vegetation, effectiveness dependant upon plant types and tree size, but there is the potential for high carbon sequestration rates.	Very High - Help lower water temperatures by increasing shade and infiltration.	Very High -Act as a barrier between streams and surrounding sources of pollution. They slow floodwater decreasing sediments in the water column.	Very High - Provide shelter/shade for aquatic animals and space for plants to thrive in their natural environment. They provide shade, cooling water, resulting in increased oxygen levels for aquatic organisms.	High - Maintain the natural character of an area.
Rain Gardens, Bioretention, Bioswales (1,3,5)	Very High - Surface runoff is decreased by directing water into vegetated areas.	High - Growth of vegetation results in carbon sequestration. This varies depending on the size of the practice and the types of plants growing in the area.	Very High - Vegetation provides shade and increases infiltration of stormwater, reducing the temperature of water entering stormwater system.	Very High -Capture stormwater within a depression, retaining nutrients and filtering out pollutants.	Very High - When planted with native vegetation these practices increase habitats for a variety of animlas.	Very High - Flowering shrubs, small trees and herbaceous species can help to beautify a location.

Constructed Wetlands and Small Ponds (1,3,5)	High - Constructed wetlands capture and retain stormwater reducing peak runoff, however their connection to groundwater decreases their success at reducing total stormwater volume.	High - Consist of carbon sequestering vegetation, effectiveness dependant upon plant material/tree size.	Very High - Vegetation provides shade and increases infiltration of stormwater, reducing the temperature of water entering stormwater system.	Low - permanently wet areas tend not to capture nitrogen and phosphorus as well as areas that fluctuate between wet and dry.	Very High - Provide habitat to a variety of plants, insects, and wildlife.	High - With intential design and maintenance can improve aesthetics of an area by increasing native vegetation
Tree Canopy, Tree Pits (2,4,5)	High - Intercept rainwater and increase evapotranspiration, slowing down and reducing the amount of runoff during an rain event. Large trees with deep roots increase infiltration rates.	Very High - Trees (especially those exhibiting large canopies) are the best natural carbon sequestration tool.	Very High - mature trees provide shade, reducing urban heat island effects.	Very High - Trees roots allow for an increase in the abosrbtion of excess nutrients and pollutants.	Very High - Trees provide habitats for many animal species.	Very High - Trees are aesthetically pleasing and help to beautify streets and neighborhoods.
Green Roofs (1,3,5)	Very High - with proper design can be very efficient at reducing overall volume of stormwater leaving the site.	High - Replacing traditional roof tops with plant life allows for increased carbon sequestration, although typically green roofs ususally consist of smaller vegeation and no trees.	High - Transform impervious surfaces to pervious, reducing immediate runoff and reducing temperature before entering storm drains	Low - Sediment and fertilizers present in the media of green roofs may leach into runoff	High - Create habitat for animals such as birds and pollinators.	High - Depending on the design, can contribute to the aesthetics of an area.
Permeable Pavement (1,3,5)	Very High - reduces the quantity of storm water runoff when compared to traditional paved surfaces.	Very Low - no impact on carbon sequestration.	High - Water temperature is reduced by preventing runoff from directly entering the stream.	High - Sediment is retained and filtered out of the when properly maintained to prevent clogging.	Very Low - Reduces space for natural vegetation and habitats.	Low - Surfaces can look identical to traditional pavements. Permeable pavers can be aesthetically more pleasing that pervious asphalt.
Pipe to stream conversions/ daylighting (5,6)	Very High - Increases storage capacity of small streams, and slows water by reducing channelization.	Low - Growth of vegetation around stream channel can increase carbon storage.	Low - Daylighted streams must be coupled with riparian trees and herbaceous plantings to help shade water and reduce temperatures.	High - Natural cosystem processes may return to the water system allowing for increased nutrient retention.	Very High - Provides habitats for plant and animal species where previously none existed.	Very High - Transforms previously piped water network into attractive natural systems.

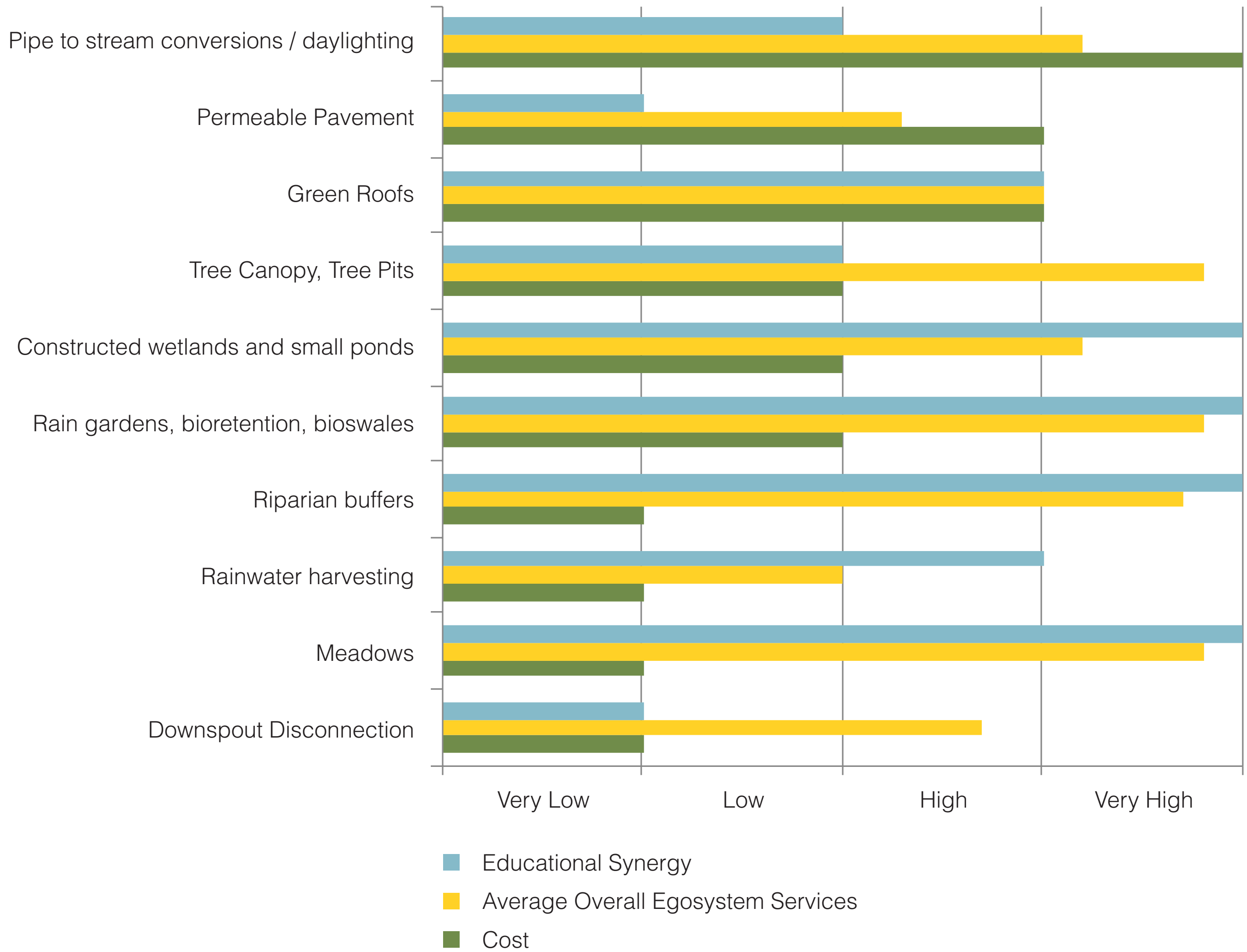
Relative Ranking: Very Low, Low, High, Very High (Based on review of current literature; may require modification as new information becomes available over time).
For easy reference, the sources cited in this chart are listed here as well as in the Reference section:

1. Alves, A., Gomez, J.P., Vojinovic, Z., Sanchez, A., and Weesakul, S. 2018. Combining Co-Benefits and Stakeholder Perceptions into Green Infrastructure Selection for Flood Risk Reduction. Environments, 5:29.
2. Coutts, C., and Hahn, M. 2015. Green Infrastructure, Ecosystem Services and Human Health. International Journal of Environmental Research and Public Health 12: 9768-9798.
3. Driscoll, C.T., Eger, C.G., Chandler, D.G., Davidson, C.I., Roodsari, B.K., Flynn, C.D., Lambert, K.f., Bettez, N.D., Groffman, P.M. 2015. Green Infrastructure: Lessons from Science and Practice.
   A Publication of the Science Policy Exchange. 32 pages.
4. Nowak, D.J. and Crane, D.E., 2001. Carbon Storage and Sequestration by Urban Trees in the USA. Environmental Pollution, 116: 381-389.
5. NYSDEC Stormwater management design manual
6. Trice, Amy. 2017. Daylighting Streams: Breathing Life into Urban Streams and Communities. American Rivers.org/DaylightingReport

Table 2 - Summary of GSI Practices Compared to Business as Usual (BAU)

	Install Cost	Ecosystem Services	Educational Synergy	Space Requirements (BAU)	Maintenance Requirements (BAU)	Long Term Costs (BAU)	Traditional Infrastructure
Downspout Disconnection	Very Low	High	Very Low	Small	Minor monitoring	None	Gutters
Meadows	Very Low	Very High	Very High	Meadows	Annual mowing	Low	Lawns
Rainwater Harvesting	Very Low	Low	High	Small	Cistern management	Low	Gutters
Riparian Buffers	Very Low	Very High	Very High	Moderate	Vine removal	Low	Lawns, pavement
Rain Gardens, Bioretention, Bioswales	Low	Very High	Very High	Small	Debris removal; veg maintenance	Low	Lawn
Constructed Wetlands and Small Ponds	Low	High	Very High	High	Debris removal; veg maintenance	Moderate	Culvert
Tree Canopy, Tree Pits	Low	Very High	Low	None, Small	Tree maintenance	None, Low	Lawns, Sidewalk
Green Roofs	High	High	High	None	Veg maintenance	Moderate	Traditional roof
Permeable Pavement	High	Low	Very Low	None	Similar maintenance effort to traditional surfaces	Similar/lower	Impermeable pavement
Pipe to stream conversions/ daylighting	Very High	High	Low	Moderate	Debris removal; veg maintenance	Low	Buried Pipe

Figure 4 – Educational Synergy, Ecosystem Benefits, & Installation Cost by GSI Practice



Higher ranking for Educational Synergy reflects greater opportunities to integrate educational programming and research into implementation, monitoring, or management. Higher numbers for Ecosystem Services correlate with higher benefits. Higher installation cost numbers represent higher costs.

Table 3 - Opportunities for Implementing GSI

GI Practice	Maintenance (Building, Parking Lot, Paths, Landscape)	Retrofit (Building/Parking Lot, Landscape)	Capital Project (New Buildings, Parking, Paths, Driveways, Landscapes)
Downspout Disconnection	X	X	X
Meadows	X	X	X
Rainwater Harvesting	X (Rain Barrel)	X	X (Cistern)
Riparian Buffers		X	X
Rain Gardens, Bioretention, Bioswales		X	X
Constructed Wetlands and Small Ponds			X
Tree Canopy, Tree Pits	X	X	X
Green Roofs			X
Permeable Pavement	X	X	X
Pipe to stream conversions/ daylighting		X	X

Decision-Support Recommendations

Understanding internal decision-making processes is essential to rethinking long-standing approaches to conceptualizing maintenance, retrofit and capital projects and opportunities for incorporating GSI. How are stormwater projects and landscape improvements undertaken on campus? Most educational institutions do not have clear decision-making processes for when and how GSI should be considered nor designated budgets for stormwater improvements. Improvements generally occur as part of larger retrofit projects or capital projects for new buildings and associated landscaping. Maintenance typically occurs on an as-needed basis. On occasion, a major stormwater project is undertaken, such as the Kenyon trunk line, a large drainage pipe that redirects runoff from the dorms directly to the Casperkill.

Several shifts are required to institutionalize GSI as the College's primary approach for stormwater management:

1. Formal support from the Administration and Board of Trustees for improving the health of campus waterways and their watersheds via integration of GSI over time.
2. Explicit integration of GSI consideration early in project scoping and development for retrofit and capital projects (including changes to the Project Initiation Form and associated training to address consideration of GSI).
3. Strong collaboration and coordination among Facilities, the Master Plan Committee and Sustainability Office to pilot integration of small GSI practices into maintenance upgrades to showcase the possibilities for GSI in maintenance projects and to provide training opportunities for maintaining these practices on a small scale. Such pilot projects would also be used to develop and test a process and procedure for integrating GSI into maintenance upgrades.
4. A more integrated approach to campus tree management via coordination among Facilities, the Sustainability Office, the Master Plan Committee and the Arboretum Committee in regard to stormwater management planning.

Common Green Stormwater Infrastructure Practices

GSI is designed to mimic natural processes that have been altered by development projects and the consequent increase in impervious surfaces by finding creative ways for stormwater to be retained, filtered and treated close to its source. For a complete overview of GSI practices please see the NYSDEC Stormwater Design Manual (NYSDEC, 2015).

Downspout disconnection: This practice disconnects downspouts that convey roof runoff directly to storm drains with no treatment or filtration. Runoff can instead be directed to vegetated rain gardens, lawn areas or downspout planters that provide some filtering and treatment of runoff while promoting infiltration. When a connected impervious surface is disconnected so that stormwater flows onto a permeable surface such as a lawn, it is called "simple disconnection." Simple disconnection is often the least expensive option for treating stormwater runoff. Lawn areas usually can absorb the first inch of runoff from these impervious surfaces, provided the area is large enough. Other means of disconnection involve diverting a connected impervious surface to a green infrastructure installation such as a rain garden, bio-retention system or stormwater planter. These green infrastructure practices can be designed to capture larger runoff volumes than simple disconnection to a lawn area or downspout planter.

At Vassar, a cistern collects rainwater from the roof of the Bridge for Laboratory Sciences and Olmsted Hall, which is then used to water plants in the Olmstead greenhouse.

Meadows: Protecting natural meadow areas from development and transitioning traditional lawns or concrete surfaces into unmown areas helps to improve soil organic matter and infiltration and maintains natural hydrology and ecological functioning (NYS DEC, 2015). Naturalized areas, especially those hosting native plant species, provide important habitat for many beneficial animals such as pollinators and birds.

Rainwater harvesting: Rainwater may be collected, mainly from rooftops, in systems such as cisterns or rain barrels. Rain barrels are smaller than cisterns and installed above ground, whereas cisterns may be installed above ground or below grade. Rain barrels tend to be used in more residential settings while cisterns are more common in institutional settings. Water harvested in either system can be used for watering gardens, lawns, flower beds, or for other, non-potable uses. Rainwater harvesting systems come in all shapes and sizes and are suitable for harvesting rainwater in the spring, summer, and fall, but must be winterized during the colder months. Cisterns and rain barrels are often paired with other green infrastructure practices to increase their storage capacity or efficiency. Cistern or rain barrel systems can be paired with a vegetative practice (e.g., rain garden, bioswale, stormwater planter) to capture the overflow from the rainwater harvesting system when it has reached full capacity. Both systems are most effective when emptied regularly by using up the stored water.

Riparian buffer restoration: A healthy vegetated stream or lakeshore buffer helps improve water quality by filtering and slowing runoff, reducing soil erosion, providing upland habitat, capturing nutrients and providing shade to lower water temperatures. Maintaining natural areas around local streams and lakes is an important planning practice. These areas can be used as natural filters and buffers by directing sheet flow toward them. In addition, restoration of riparian buffers is an important practice in maintaining the health of streams. Naturalization and planting of native trees and shrubs along stream banks on campus can help improve the water quality of the Casperkill and Sunset Lake.

Direct Impact on Problems Identified in the Casperkill Assessment

A major issue discussed in the assessment is erosion. Riparian buffers can alleviate preexisting erosion while also filtering out excess nutrients. Currently, many of the tributaries of the Casperkill, such as the Fonteyn kill, do not have adequate buffers. As a result, the banks erode, increasing the amount of sediment in the stream channel and harming the various species living in the water.

Rain gardens, bio-retention and bioswales: Rain gardens, bio-retention areas and bioswales are open, vegetated stormwater storage areas that slow runoff and filter pollutants, improving water quality and creating habitat beneficial to a variety of species. All three practices may be strategically placed to treat storm-water runoff close to its source, and are easy to install and maintain. Rain gardens generally refer to smaller systems, which include a modest depression to collect water and are vegetated with native plants that can withstand moisture regimes ranging from flooded to dry. Bio-retention areas are usually larger than rain gardens and typically designed with an underdrain that connects to the storm drain system. Bioswales, also known as dry swales, are natural drainage paths or vegetated channels used to transport water, replacing underground storm sewers or open concrete channels. Bioswales increase the time of concentration, reduce discharge, provide infiltration, and are generally one of the cheapest options to install. These gardens generally include a modest depression to collect water and are vegetated with native plants that can withstand moisture regimes ranging from flooded to dry. Bio-retention areas are usually larger than rain gardens and typically designed with an underdrain that connects to the storm drain system.

Figure 5 - Bio retention area near the Bridge Building at the former site of Mudd Laboratory

Vassar College recently installed rain gardens and bio-retention areas on campus. Seven small rain gardens were installed to filter drainage at the Townhouses. The Bridge for Laboratory Sciences project encompasses the bio-retention area constructed at the former location of Mudd Chemistry Building in addition to the rain gardens and restored stream corridor of the Fonteyn kill near Olmsted and around Skinner Hall and the new Bridge Building.

Direct Impact on Problems Identified in the Casperkill Assessment

The implementation of enhancing vegetated areas through installation of green roofs and rain gardens would drastically decrease the amount of stormwater runoff from impervious surfaces – a main issue discussed in the Casperkill Assessment. By transitioning traditional hardscaping such as pavement, mulched areas and roofs into lush vegetated spaces, polluted stormwater runoff from these surfaces would be greatly decreased.

Constructed Wetlands and Small Ponds: Constructed wetlands mimic the functions of natural wetlands to capture stormwater, reduce nutrient loads and create diverse wildlife habitat. They are often created in engineered growth media in trenches, small islands and pools. They are designed to contain water at all times—either standing water on the surface or water saturated just below the soil surface. Constructed wetlands may be built expressly for capturing and filtering stormwater. Plants can be chosen for specific performance goals. Small wet ponds can be paired with aesthetic improvements and habitat creation to treat and store stormwater runoff. Water is treated through sedimentation and nutrient uptake. The storage and treatment of water reduces the overall quantity and quality of stormwater runoff, reducing the impact on surrounding water bodies.

At Vassar, the ponds in front of the Chapel function to retain and hold runoff. The establishment of native wetland plants and the addition of a walking path circling them add aesthetic and recreational value.

Tree canopy and Tree Pits (also known as tree filter boxes): Tree planting is perhaps one of the most cost effective GSI practices. Trees intercept rainwater to reduce runoff, increase infiltration of water, increase evapotranspiration, cool air temperatures and provide important habitat. Planting trees in locations, at sizes and with methods designed to retain stormwater can augment existing stormwater management systems and improve water quality while enhancing forest canopy. Tree-planting approaches that incorporate the largest trees possible will increase their stormwater utility function. Incorporating tree pits where street trees or trees in parking areas are desirable allows runoff to be directed to smaller underground storage systems that feed the tree root zone and enhance root space, improving the health and longevity of trees planted in hardscape environments.

Vassar has received Tree Campus USA status for the past 5 years and has an active arboretum committee. This committee ensures the health and maintenance of the current tree population and plans for new tree plantings each year.

Green roofs: Vegetated roofs capture and filter rain, reducing the amount of stormwater that flows from roofs to the conventional storm sewer system. Green roofs also provide cooling effects, resulting in lower energy costs and better air quality.

Figure 6 - Permeable concrete pavers on the residential quad

Permeable pavement: Permeable pavement includes porous asphalt, porous concrete, and permeable concrete pavers and crushed stone walkways. All allow water to infiltrate into the ground, reducing runoff. Applications include sidewalks and paths, parking aisles and roads. Permeable paving reduces puddles and freezing (making surfaces safer in winter) which decreases the need for salt and ice-melting chemicals.

Direct Impact on Problems Identified in the Casperkill Assessment

A main impairment to the Casperkill is stormwater runoff from paved surfaces like roads and parking lots. Replacing these impervious paved surfaces with pervious surfaces would drastically reduce runoff and improve the health of the watershed.

Pipe to stream conversions/daylighting: Uncovering and eliminating stretches of buried stormwater pipes and creating intermittent stream systems improves aquatic system health, reduces flooding and creates new opportunities for plant and wildlife habitat. In addition, these conversions have aesthetic value that adds natural components to landscape designs.

Campus Opportunities

At a number of sites on the Vassar campus where GSI practices can be implemented, we can highlight the potential and opportunity to address environmental degradation. While Vassar has used GSI practices at the Townhouses and the Science Project, as well as at some smaller sites, numerous stormwater and drainage problem areas remain; they warrant future attention via both short-term and long-term projects. While the short-term opportunities are attractive and productive on a number of levels, long-term solutions should also be incorporated into future plans to improve the overall health and well-being of the watershed.

To date, Vassar's approach to GSI has been project-by-project. To achieve more effective implementation, Vassar should develop a more holistic strategy that takes account of all Vassar's institutional property holdings. Through comprehensive analysis of these holdings we can map out opportunities that will achieve two goals: reduce Vassar's contribution to the impairment of the Casperkill and demonstrate methods others can follow, in order to encourage reductions elsewhere so that together we may preserve, restore and regenerate the ecological integrity of the watershed.

Short-Term Opportunities for Integrating GSI Practices

Tree Canopy

Tree planting is a cost-effective method to reduce stormwater runoff. Much of the tree canopy on campus is composed of trees that are more than 70 years old; not enough periodic planting has occurred over time to assure that, when these trees die, there will be younger trees to take over. Vassar should invest in tree planting in numerous locations, such as the area by Noyes Lawn, the area between the lower new Terrace Apartments (TAs) and the Casperkill, by the Orchard and Observatory, by the path from Cushing to the TA bridge and more. Since tree saplings are fairly inexpensive, there is adequate incentive for alumni or other community members to sponsor trees relatively easily. In the 2011 Master Landscape Plan prepared by MVVA, reforestation is highlighted as an important future project. The specific recommendation is, "Commit to replanting at least fifteen trees each year to plan for the eventual losses of the aging tree canopy" (pg. 54). In our estimation, fifteen is too few trees and should be restated as "replant fifteen 3"-trunk-diameter canopy shade trees and 30 saplings per year…" to offset the die-off of trees in wild areas of the campus that is linked to climate change.

Reforestation

Reforestation adds significant aesthetic value to the campus in addition to promoting cooler and healthier air to breathe, without triggering permitting or other outside approvals. Reforestation can be done in multiple ways. For example:

- Stand-alone, large-caliper tree plantings in prominent locations where instant aesthetic impact is desired;
- Designed grove or copse plantings where medium-sized plant material is located and the design intent is achieved within a few years; and/or,
- Ecological-restoration-style plantings where specific areas are designated (at different scales) and planted densely with inexpensive saplings.

Meadows

Another fairly simple project is the naturalization of specific mown fields on campus. Naturalizing underused mown fields and turning them into meadows filled with flowers and grasses for pollinators and other native species would decrease gas and labor costs of mowing, while helping capture stormwater. If overall budgets do not allow the restoration of a native species, non-native "weeds" can be allowed to naturalize into the areas. Annual mowing should occur to inhibit the growth of vines, shrubs and trees. Even a meadow that is a mix of native and invasive species still retains stormwater runoff better than lawn or pavement.

Simple, low-cost alterations to existing campus lawns can significantly increase stormwater infiltration. Regularly overseeding white clover and rye into existing lawns and incorporating these species into future new lawns has been shown to increase infiltration rates. In addition to its role in stormwater runoff improvements, clover fixes carbon in the soil, and its small white flowers offer excellent pollinator forage.

Rain Water Harvesting

Installing rain barrels at all of the TAs to help forestall hillside erosion is another short-term opportunity. The stormwater outlet between the TAs and Ballantine Field is heavily eroded due to

Recent GSI Educational Outreach Initiatives

Rain barrel building workshop: In 2009-2010 Vassar held a series of rain barrel building workshops that served over 100 community members. More recently in July of 2017, The Environmental Cooperative held a rain barrel building workshop in collaboration with the Cornell Cooperative Extension of Dutchess County at the Vassar Barns. The workshop offered barrels and supplies at one fourth the normal cost to 29 participants from the local community. Participants were guided through the steps to build their own rain barrel. The workshop was a huge success, and many participants sent photos afterward of their newly installed rain barrels. The Cooperative also conducted a mini rain barrel workshop with 15 local teachers and educators on how to use similar workshops to teach students about teamwork, helping the community and making a difference.

the large amount runoff from Walker Field House. When the field house is rebuilt in the next few years, it could include a cistern to collect water for re-use in landscape management. At the TAs .... Water collected in rain barrels could be used for watering lawns or small gardens near the apartments. Rain barrels or cisterns would also be feasible for campus dorms. Installing a form of rainwater harvesting in addition to a small community pollinator garden would not only help stormwater management, but also create visually attractive, educational spaces to learn about the environment. House Teams could be responsible for maintaining the gardens as an aspect of team bonding; they might even build and install rain barrels themselves. House Fellow groups might also each build a rain barrel, decorate it, and donate it to an organization in the community, helping to foster good relations between students and community members.

Rain Gardens and Downspout Disconnection
(Smaller Lots on Raymond Avenue & College Avenue)

It's important to remember that Vassar College owns not only the immediate campus, but also numerous lots along Raymond Avenue and College Avenue. Individual homeowner-sized rain gardens along Raymond Avenue would help engage more of the community with green stormwater management and raise awareness of the impact of stormwater runoff on the Casperkill. On College Avenue, downspout disconnection could be installed in various locations.

Daylighting

In many cases, existing buried stormwater pipes can be daylighted over time. Many pipes that discharge directly into the Casperkill can be shortened so they spill into the riparian zone around the creek through a controlled system of check dams or even wetlands. Exposing rainwater runoff would have many benefits such as, but not limited to:

- Heightened campus aesthetics
- New habitat for plants and animals
- Reduced sediment transport to the Casperkill
- Moderation of stormwater temperature
- Flood mitigation
- Educational opportunities

Long-Term GSI Opportunities

Sunset Lake

Sunset Lake is one of Vassar's most visible landmarks, and summer algae growth makes its ailing condition highly visible to the campus community. Primary impairments of the lake include constant influx of sediment and nutrients, making the lake increasingly shallow and eutrophic. Primary sources of sediment and nutrients are 1) upstream urban development in the Town of Poughkeepsie, 2) impervious surfaces on campus; 3) stream-channel and lake-bank erosion on campus. Among these, this plan aims to address the second and third sources by reducing direct runoff to the stream.
In recent decades, the solution to sediment accumulation has been periodic flushing by lowering the dam on the lake—a process that also aims to reduce aquatic weeds by freezing the substrate. Flushing helps to reduce sediment, but opinions on weed reduction are mixed, and impacts on the stream ecosystem can be profound. As an alternative, upstream sediment traps should be considered to reduce sediment influx into the lake. Other steps can also help reduce sediment influx: in particular, establishing a vegetated buffer around the lake will help protect shorelines and reduce bank erosion, and reducing storm discharge will shrink channel erosion and delivery of sediment to the lake. Both strategies should contribute to an overall increase in water quality.

Vines, storm events, and other causes of mortality have steadily reduced the number of mature trees in the Sunset Lake drainage area. Effects of this include more runoff and less stream shading. The tree canopy should be replaced as trees are lost, and maintenance to control vines should occur annually or semi-annually.

Because Sunset Lake is one of the signature landscape features of the Vassar campus, especially as the scenic backdrop for Commencement, there are multiple co-benefits to improving the health of the lake.

Doubleday Parking Lot/Casperkill Banks Revegetation

The Doubleday parking lot by the TA Bridge offers another opportunity to use natural drainage to assist with runoff, flooding, erosion and pollution filtration. This parking lot is one of the less attractive features on campus. Stormwater collects and pools in the parking lot, before discharging to the stream, delivering pollutants and sediment directly to the Casperkill. Changing this landscape by reducing or removing parking and creating a naturalized drainage way, while leaving a path for bikes, pedestrians and emergency vehicles, would offer students and visitors a beautiful streamside natural area to enjoy. This transformation, in tandem with revegetating the banks of the Casperkill, would improve infiltration, water quality, biodiversity, and aesthetics.

Joss Beach, the Quad and Noyes Circle

A few other areas of opportunity include Joss Beach, the Quad and Noyes Circle. These are very visible campus locations that could be turned into beautifully landscaped fields that not only assist stormwater management, but also add aesthetic value. Currently, Joss Beach is used for student recreation and occasional events, in addition to Quidditch practice. This area holds great potential. Naturalized edges could increase infiltration. Vegetated swales could line the margins of the lawn, reducing runoff from adjacent buildings, filtering parking lot pollutants, and creating a more attractive landscape for student events, such as fall harvest festivals, concerts, and Reunion events.

One of the most widely valued views of the Vassar campus is from the 8th floor of Jewett, over the residential quad lawn. Especially gorgeous in fall and winter, this view is a highlight for many students. While the vast green, dotted with trees and intersected by sidewalks, is well loved, there exists the potential to make environmental and aesthetic improvements without sacrificing its historic, iconic identity. For example, quads need not be perfectly flat for their entire expanse to best serve students. A varied topography could entice students to use the space for different purposes. Areas could be sloped to act more as amphitheaters, and small rain gardens could splash the green to add vibrant colors, sounds and textures. A mix of picnic tables and benches would add varied seating for students and guests. Community gardens or pollinator gardens, planted with native plants by dorm residents, would be great educational tools and also naturally attractive.

South Parking Lot

A final long-term solution that could significantly improve stormwater management on the Vassar campus is renovating the South Parking Lot to include permeable pavers, tree pits and a bioswale down the middle and around the perimeter. One of the goals of the Campus Master Plan is to make the campus a more pedestrian-friendly environment, restricting cars to campus margins. With this in mind, the South Lot could be expanded to accommodate additional parking. Such an expansion is another opportunity to transform an impervious surface into a GSI practice that can help manage stormwater and improve the visual character of surface parking. The inclusion of solar carports/charging areas where cars would be protected from weather and electric vehicles could charge would add another sustainability dimension to this concept.

Recent GSI Educational Outreach Initiatives

Youth Outreach: The Environmental Cooperative did youth outreach through events in the Poughkeepsie community. At the Unity and Hope camp in late July, the Cooperative led activities to teach youth about stormwater, natural resources, watersheds and pollination. Children decorated a rain barrel, went on walks to the Casperkill, made plant presses and learned about the Vassar Farm and Preserve. At each activity, there were approximately 15-25 elementary age children and their guardians

Maintenance, Monitoring and Metrics

Using the Vassar campus as a laboratory, the Casperkill Assessment Project represents an excellent model for future collaborations among faculty, students, local organizations and local individuals to assist with installing, maintaining and monitoring GSI installations on campus and in the community. As GSI practice expands on Vassar's campus, other water-related research and teaching might include constructed wetlands research, water quality and stream bank erosion monitoring and habitat studies. Beyond classroom-related work, student volunteers could participate in removing invasive species, planting new species, and generally cleaning and maintaining GSI installations with training and support from Facilities Operations and the Environmental Cooperative. Students and community members can also play an important role in helping to install and maintain the landscape improvements developed for the Vassar Barns as part of this project (See Appendix), as well as in monitoring changes in water quality and habitat at the Barns.

Beyond student- and community-supported maintenance, the training needed to properly maintain GSI practices should be identified early in any major retrofit or capital project. While specific GSI techniques and landscape approaches will be new when first integrated into the campus, these features will become more common parts of the campus landscape over time and more integrated into the skills of Facilities staff. While some GSI practices may involve greater labor time to maintain than current practices, others, such as low-mow areas and meadows, involve substantially less maintenance.

Monitoring

Monitoring and maintenance are closely tied to metrics for stormwater management and watershed health. One recent effort —the Vassar Campus Stormwater Monitoring App— well illustrates this relationship. Facilities Operations is responsible for monitoring stormwater infrastructure on campus in compliance with the Town of Poughkeepsie site plan approval process and NYSDEC stormwater regulations. Inspections are required periodically (currently twice per year). After paper forms were created for the inspections, Facilities Operations managers asked whether an app that could be used in the field would be more efficient and allow more frequent inspections. Two apps were ultimately developed; one for periodic inspection data that can be stored with existing mapped features, such as rain gardens, and a second app to document stormwater problems observed in areas that do not trigger required inspections, but where common problems such as erosion, sedimentation or ponding occur. Over time, the density of points at locations where problems are frequently reported should indicate priority sites for managers to address. Using these apps, the collection of data to monitor stormwater practices on campus will be more efficient and more frequent.

Metrics

Metrics are also an important tool in evaluating changes in campus conditions and waterway health over time. Key campus metrics that can be tracked on either by individual project or annually include:

1. Change in area (acres or percentage) of impervious coverage on campus and on Vassar-owned properties
2. Change in area (acres or percentage) of tree canopy
3. Change in area (acres or square footage) of rooftop runoff being directly conveyed to subsurface stormwater system.

Additionally, faculty-led research will also be important to establish and quantify baseline data and periodic monitoring of waterway health. As suggested in the 2011 MVVA Plan, the quantification of water quality variables is complex and involves regional watershed modeling, including the Casperkill watershed and the stretch of the Casperkill and Fonteyn Kill that pass through Vassar. This quantification should be paired with an evaluation of variables in the campus landscape that affect water quality, including percentages of permeable and impermeable surfaces, volume of water discharged to the lake during peak flood events, the quality of water discharged on a periodic basis, and the quality of plant and animal habitat sustained by the water bodies. This assessment would establish a baseline level of performance against which future improvements and their impacts on the watershed can be evaluated. The Casperkill Assessment provides good baseline data from 2007-2009 on many of these metrics. Follow-up studies would be beneficial and informative in assessing changes over time.

Conclusion

The future health of water resources on and off campus depends, in part, on Vassar's commitment to managing stormwater as close to its source as possible. The conventional approach to piping unfiltered stormwater directly to waterbodies (and ultimately the Hudson River) increases storm flow, flashiness, and erosion in waterways. This conventional approach degrades aquatic systems and misses opportunities to enhance ecosystem services and educational synergy for faculty and students. While several GSI practices entail high upfront costs (without factoring in the monetary value of ecosystem benefits), not all do. Moreover, it is often difficult to know the cost relative to conventional approaches, until better business-as-usual accounting is implemented. A number of relatively small, less costly GSI practices can occur across the campus with significant cumulative effects over time. New capital projects can incorporate more robust GSI approaches. For this to happen, and for green approaches to become part of the default decision process in addressing stormwater on campus, more explicit and integrated decision-making structures are needed. This report can serve as the roadmap to embark upon these necessary changes.

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Appendices

Green Infrastructure Education And Outreach Efforts

Over the lifespan of this grant, the Environmental Cooperative participated in numerous outreach efforts to educate and engage the community with GSI practices and the wide range of benefits they can offer. Seven outreach events were held, as follows:

Event: Green Solutions for Stormwater Management - Green Infrastructure Conference
Date: December 8, 2016
Audience: Municipal Officials, Vassar Facilities Operations Staff, students, general public
Attendance: 50
Description: This full-day event focused on the pros and cons of green infrastructure, including management, costs and best practices. Presentations included: The co-benefits of green infrastructure for health and energy efficiency, economics of GI, the importance of soils for GI, maintenance and cost of pervious pavement and restoration ecology as green infrastructure (see attached agenda).

Event: Trees for Tribs planting at Sunset Lake
Date: May 3, 2017
Audience: Vassar Students
Attendance: 65
Description: Working with the NYS DEC Trees for Tribs program, native trees and shrubs were planted on campus near Sunset Lake and the Casperkill as a form of stormwater control in this area. Students were directly involved in planting these trees.

Event: Rainbarrel Building Workshop (co-sponsored with CCEDC)
Date: July 26, 2017
Audience: Community Members
Attendance: 29
Description: Partnering with Cornell Cooperative Extension, Dutchess County, twenty-five 55-gallon barrels were purchased along with all materials needed to build a rain barrel. Additional donations were received to purchase supplies from Page Lumber, Home Depot and Lowe's. Participants were instructed on how to build their rain barrel as well as discussing what Green Infrastructure is, and how practices such as rainwater capture are activities that homeowners can do to capture stormwater on-site at their homes.

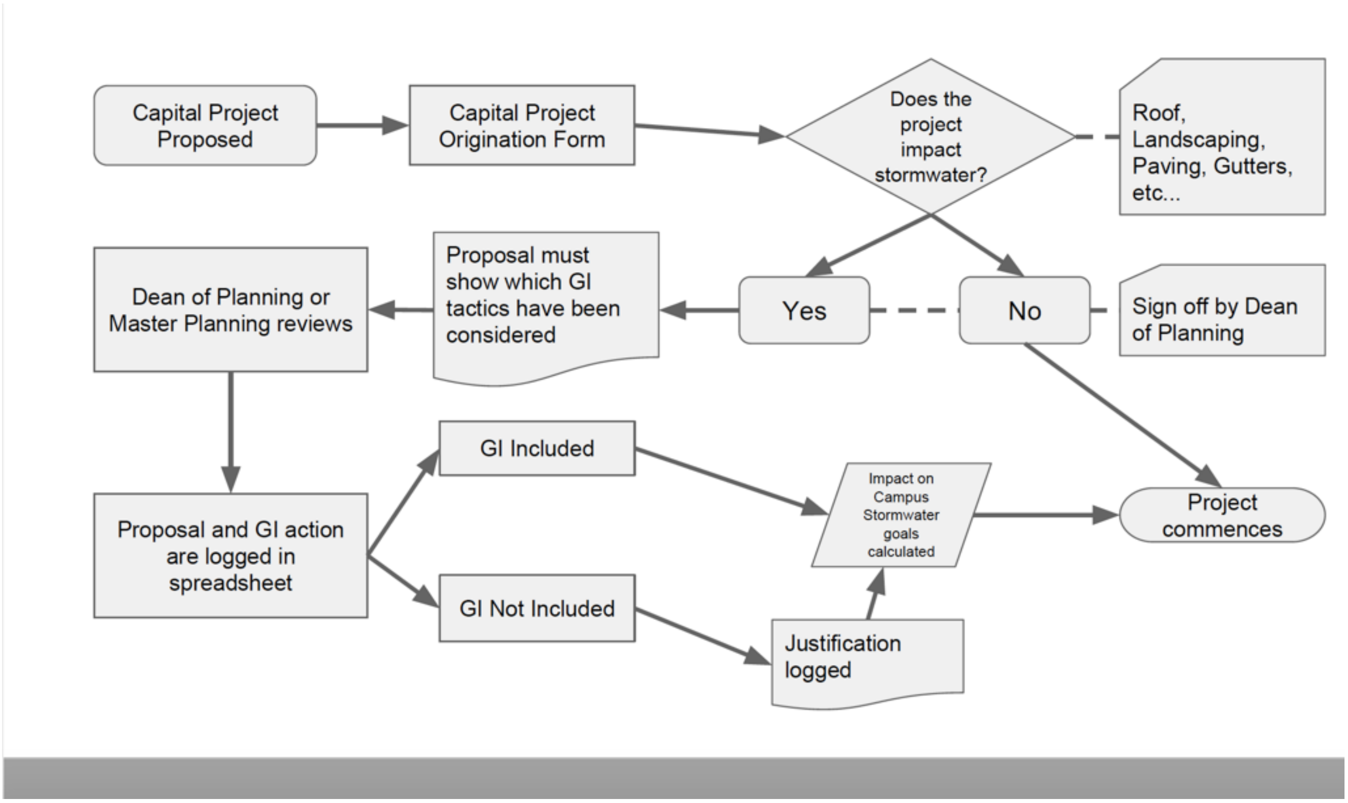
Event: Unity and Hope Summer Program – Rain Barrel Painting
Date: July 27, 2017
Audience: Children ages 5-13
Attendance: 15 (plus some parents)
Description: The Unity and Hope Program is a free ½ day summer program hosted by the Hispanic Heritage Committee in the City of Poughkeepsie from July 24- Aug 4th. The Environmental Cooperative hosted a different one-hour workshop each day during the program. These workshops focused on environmental and conservation efforts locally. On July 27th children were taught about flooding and stormwater and things that they could do on a local level. They decorated a rainbarrel which was then brought back to Vassar and installed at the Collins Field Station on the Vassar Farm and Ecological Preserve.

Event: Vacant Lots to Pop Up Parks – Bryan Quinn
Date: August 2, 2017
Audience: Community Members (at the PUF)
Attendance: 39
Description: In this talk, Bryan Quinn, founder and principal of One Nature LLC (http://www.onenaturellc.com/) based in Beacon, NY described several built examples of vacant lots that his company has transformed to ecologically productive places. Much of his work focuses on how ecological restoration can act as green infrastructure. One Nature uses regenerative design principles to change the future of vacant and underused lots by turning them into better appreciated community gardens, pollinator gardens, stormwater retention areas or public parks. This event was co-sponsored by Hudson River Housing and the Poughkeepsie Farm Project.

Event: Teacher Workshop – Building Community by Building Rainbarrels
Date: August 17, 2017
Audience: local teachers and educators
Attendance: 20
Description: As part of the Poughkeepsie Farm Project's Summer Institute for Educators we presented information about Green Infrastructure, its benefits to the community and ways to engage students in an 1-½ hour workshop. Educators also worked in teams to build a rainbarrel, five rainbarrels were assembled which were donated to a local school. 20 local educators including both teachers and informal educators participated in the event.

Event: Unearthing Green Infrastructure –GI Forum (co-sponsored with CCEDC)
Date: October 10, 2017
Audience: Municipal Officials, Vassar Facilities Operations Staff, students, general public
Attendance: 50
Description: Cornell Cooperative Extension Dutchess County, the Environmental Cooperative at the Vassar Barns, the Dutchess County MS4 Committee and the Dutchess County Soil and Water Conservation District co-sponsored a forum focusing on tools and techniques to maintain and monitor green infrastructure practices. The morning included presentations and case studies about green infrastructure maintenance and a green infrastructure tool kit developed by the Environmental Cooperative. The afternoon session included a bus tour of green infrastructure practices in the Poughkeepsie and La Grange area led by the Dutchess County MS4 Committee and Soil & Water Conservation District.

GI Decision Making - Process & Sample Metrics/Log



Campus Stormwater Project Log

Project	Year	GI tactics Considered	Moving forward with GI? Y/N	Justification?	Date of sign off	Rooftop area (sqft added or Subtracted	Impervious coverage (acreage added or subtracted)	Trees (planted or removed)	Lawn area (acres added or removed)

Sample Costs of GSI Practices

Project	Property	Install Cost	Area Size	Description	Cost sq/ft	Source
Commencement Plaza	Vassar College	$1,003,000.00	60,000	Native plantings, blue stone, outdoor ck	$16.67	Facility Operations, Vassar
Sciences Quad	Vassar College	$2,128,000.00	203,000	Rain gardens, native plantings, sidewalk	$10.48	Facility Operations, Vassar
Swift Hall	Vassar College	$52,000.00	4,400	Ada walkways, native plantings	$11.82	Facility Operations, Vassar
Blodgett Hall Turnaround	Vassar College	$1,142,005.00	64,000	Roadway, sidewalk, native plantings	$17.84	Facility Operations, Vassar
Vassar Barn Option 1	Vassar College	$275,800.00	29,850	Rain garden, constructed wetland, par	$9.24	One Nature LLC
Vassar Barn Option 2	Vassar College	$98,000.00	20,300	Rain garden, constructed wetland	$4.83	One Nature LLC
SUNY Orange Rain Garden	SUNY Orange	$10,000.00	8,300	Rain garden	$1.20	dec.ny.gov/lands773046.html
Poughkeepsie Underwear Factory Wetland and Bioswale	Poughkeepsie Underwear Factory	$126,000.00	3,600	Bioswale	$35.00	dec.ny.gov/lands/100923.htm
Scenic Hudson RiverWalk Park Bioretention	Scenic Hudson Riverwalk Park at Tarrytown	$4,000,000.00	226,512	Bioretention	$17.66	dec.ny.govllands/100872.htm
Village of Greenwood Lake Vegetated Swale	Village Hall, Greenwood Lake	$380,000.00	6,200	Vegetated swale	$61.29	dec.ny.gov/lands/73096.html
Logan Gardens Green Roof	Logan Gardens Housing Development Finance Corp	$75,500.00	1,050	Green roof	$71.90	dec.ny.gov/lands/101086.htm
Columbia County SWCD Porous Pavement	Columbia County Soil and Water Conservation District	$14,000.00	10,000	Permeable paver	$1.40	dec.ny.gov/lands/73104.html
Stewart Airport Pervious Asphalt Pavement	Stewart International Airport	$9,000,000.00	261,360	Permeable asphalt	$34.44	dec.ny.gov/lands/73105.html
Verrazano Blvd. Poughkeepsie Pervious Pavement	37 Verrazano Blvd.	$750,000.00	7,000	Permeable asphalt	$107.14	decony.gov/lands/76844.html
Ardsley Bus Sher Stormwater Planter	Ardsley Bus Shelter	$150.00	10	Other: stormwater planter	$15.00	dec.ny.gov/lands774996.html
Cornell Cooperative Extension Orange County Tree Filter	Orange County Office Building	$5,030.00	250	Other: retrofit of existing catch basin	$20.00	dec.ny.govllands/101085.htm
Rosendale Library & Ulster County Master Gardeners	Rosendale Library	$10,000.00	250	Rain garden	$40.00	dec.ny.gov/lands/79019.html
Greenwood Lake, Village Hall	Greenwood Lake Municipal Building	$380,000.00	8,000	Rain garden, native plantings, sidewalks	$47.50	dec.ny.gov/lands/73047.html
Ashford Park Rain Garden	Ashford Park 638 Ashford Ave. Ardsley, NY 10502	$250.00	100	Rain garden	$2.50	dec.ny.gov/lands/59337.html
Rensselaer Master Gardeners Green Roof	Demonstration Garden at the Robert C. Parker School	$4,500.00	100	Green roof on shed	$45.00	dec.ny.gov/lands/73089.html
CCE Orange County Stormwater Planter	Orange County Office Building	$5,000.00	450	Raised bed/stormwater planter	$11.11	dec.ny.govllands/101087.htm

Vassar Barns Green Infrastructure Master Plan / Pilot Projects (January 2018)

The green infrastructure plan developed around the Vassar Barn is an important component of the Cooperative's education initiative about watershed health and the impacts of stormwater. Having a working system that is adjacent to the Environmental Cooperative will help to facilitate education programs focused on healthy watersheds. With the Vassar Barn acting as a demonstration site, education and outreach programs can utilize the space to not only demonstrate green infrastructure practices but to illustrate concepts such as: the water cycle, runoff and evapotranspiration, and the use and value of native plantings for pollinator conservation, aesthetic value, and habitat sustainability.

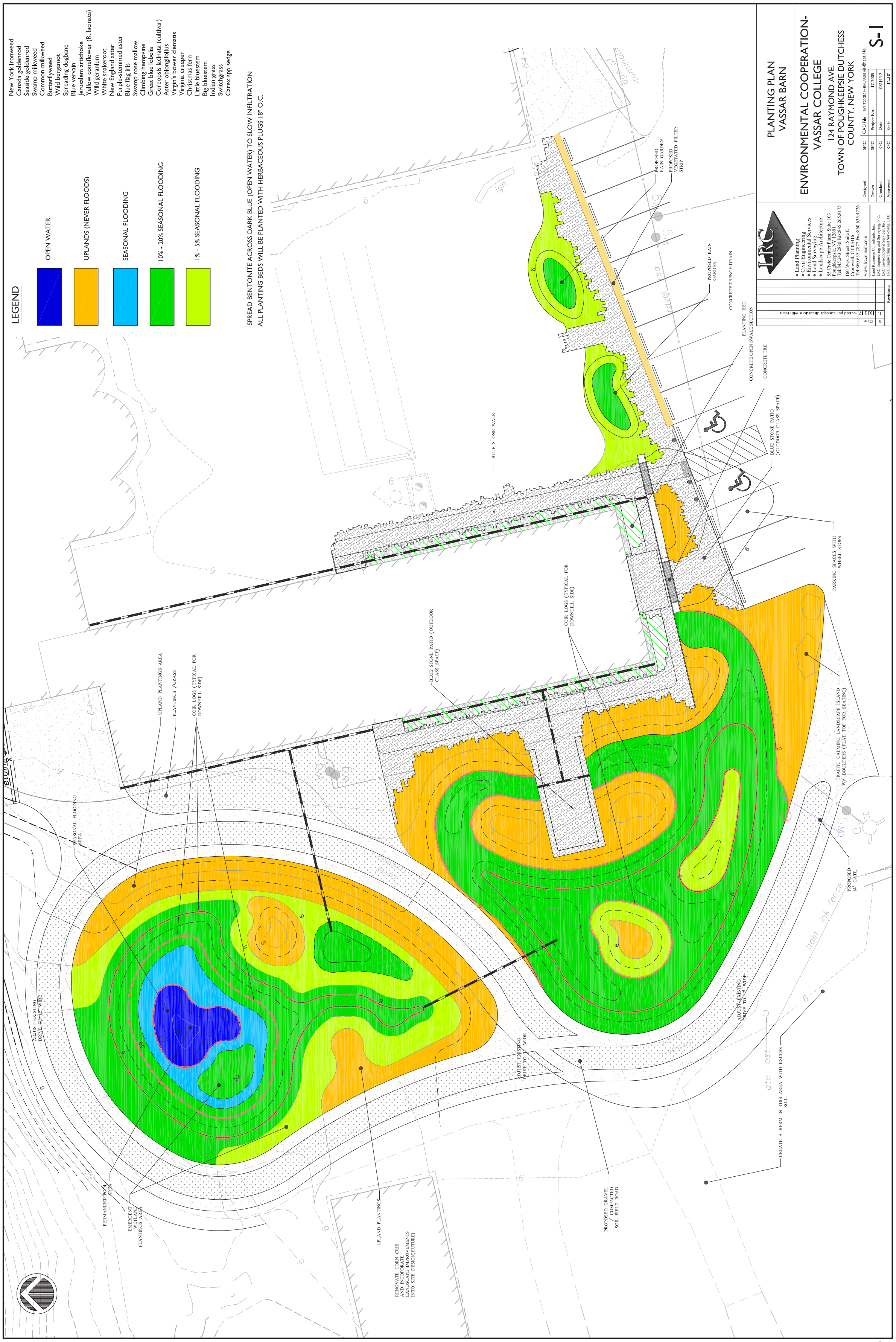
The design team collaborated in a series of internal workshops, including several site visits/field walks, to develop the green stormwater Master Plan using the following overarching criteria to guide development of pilot projects for the Vassar Barns site:

1. Complement and expand on the improvements to the visitor experience created by the architectural restoration of the barn.
2. Promote ties to/synergy with educational programming mission of Vassar Barns.
3. Ensure ease of permitting/shovel-ready potential.
4. Minimize future disruption/extend life of pilot projects based on potential future improvements around the Barns.
5. Maximize ability to replicate pilot measures elsewhere on campus, including affordability of implementation and maintenance.
6. Provide opportunities for Vassar Facilities and others to learn from implementation successes and challenges.
7. Maximize ecosystem services/benefits, in accordance with Casperkill Assessment Report.
8. Fit contextually with the cultural heritage of the land.

The green stormwater Master Plan for the Barns is illustrated in the following concept drawing and has been advanced via engineering and development of cost estimates. Depending on the timing and availability of funding sources, the design components may be constructed as a single phase or as a series of smaller projects.

Please review the full Vassar Barns Green Infrasture Master Plan for additional details.


GREEN INFRASTRUCTURE MASTER PLAN
THE ENVIRONMENTAL COOPERATIVE AT VASSAR BARNS
MEADOW
VEGETATED FILTER STRIP
RAIN GARDEN
DECOMPACTED LAWN
CONSTRUCTED WETLANDS
500 YEAR STORM OVERFLOW
OneNature


LEGEND
OPEN WATER
UPLANDS (NEVER FLOODS)
SEASONAL FLOODING
10% - 20% SEASONAL FLOODING
1% - 5% SEASONAL FLOODING
SPREAD BENTONITE ACROSS DARK BLUE (OPEN WATER) TO SLOW INFILTRATION
ALL PLANTING BEDS WILL BE PLANTED WITH HERBACEOUS PLUGS 18" O.C.
New York Ironweed
Canada goldenrod
Seaside goldenrod
Swamp milkweed
Common milkweed
Butterflyweed
Wild bergamot
Spreading dogbane
Blue vervain
Jerusalem artichoke
Yellow coneflower (R. laciniata)
Wild geranium
White snakeroot
New England aster
Purple-stemmed aster
Blue flag iris
Swamp rose mallow
Climbing hempvine
Great blue lobelia
Coreopsis lanceolata
Aster oblongifolius
Virgin's bower clematis
Virginia creeper
Christmas fern
Little bluestem
Big bluestem
Indian grass
Switchgrass
Carex spp sedge
PLANTING PLAN
VASSAR BARN
ENVIRONMENTAL COOPERATION-
VASSAR COLLEGE
124 RAYMOND AVE.
TOWN OF POUGHKEEPSIE DUTCHESS
COUNTY, NEW YORK
S-1