Landscape Performance Series

Cornell Plantations Brian C. Nevin Welcome Center

Methodology for Landscape Performance Benefits
Cornell University
Case Study Investigation 2014

Research Fellow: Michele A. Palmer, R.L.A., ASLA, LEED Green Associate
Lecturer, Department of Landscape Architecture
Cornell University, Ithaca New York

Research Assistant:
Mujahid D. Powell, Undergraduate Program
Department of Landscape Architecture
Cornell University, Ithaca New York

Cornell University Case Study Partner:
Halvorson Design Partnership, Inc.
Firm Liaison, Tobias Wolf, Wolf Lighthall Inc.

Site Plan, Baird Sampson Neuert Architects Inc.

Introduction:
The Cornell Plantations is a university-based public garden with 4,000 acres of natural and designed landscapes in and around the Cornell campus. Despite its size and stature, "Plantations" had no visitor center, accessible classrooms, or distinct point of arrival, and its 25-acre Botanical Garden was fragmented by ad hoc, driveways, parking areas, and service structures.

The Brian C. Nevin Welcome Center project is part of a comprehensive landscape reorganization of the heart of the Botanical Garden, part of the “Plantations Transformation” fundraising campaign designed to make the project area more attractive as a destination, more effective as a gateway to the Plantations’ other holdings, and more compelling as a model of sustainable practices.

In its 2002 Master Plan, Plantations responded to the need for a more cohesive and welcoming visitor experience with recommendations for the restoration of a historic schoolhouse, the preservation of well-loved gardens, the consolidation of vehicular circulation and parking, the relocation of service structures, the construction of a new visitor center, and the creation of a "Bioswale" Garden that would demonstrate the use of plants to mitigate stormwater impacts. The phased implementation of the Master Plan culminated in the opening of the Nevin Welcome Center in January, 2011.

For “green infrastructure” landscapes to be broadly accepted, they must be perceived as visually appealing and the goal from early in the project was to create a garden that also functioned as a stormwater practice. The garden has been very well received and Don Rakow, Executive Director of Cornell Plantations from 1993 to 2013, has described the bioswale as “one of Plantations’ most popular gardens and a model for other university-based public gardens around the nation.”

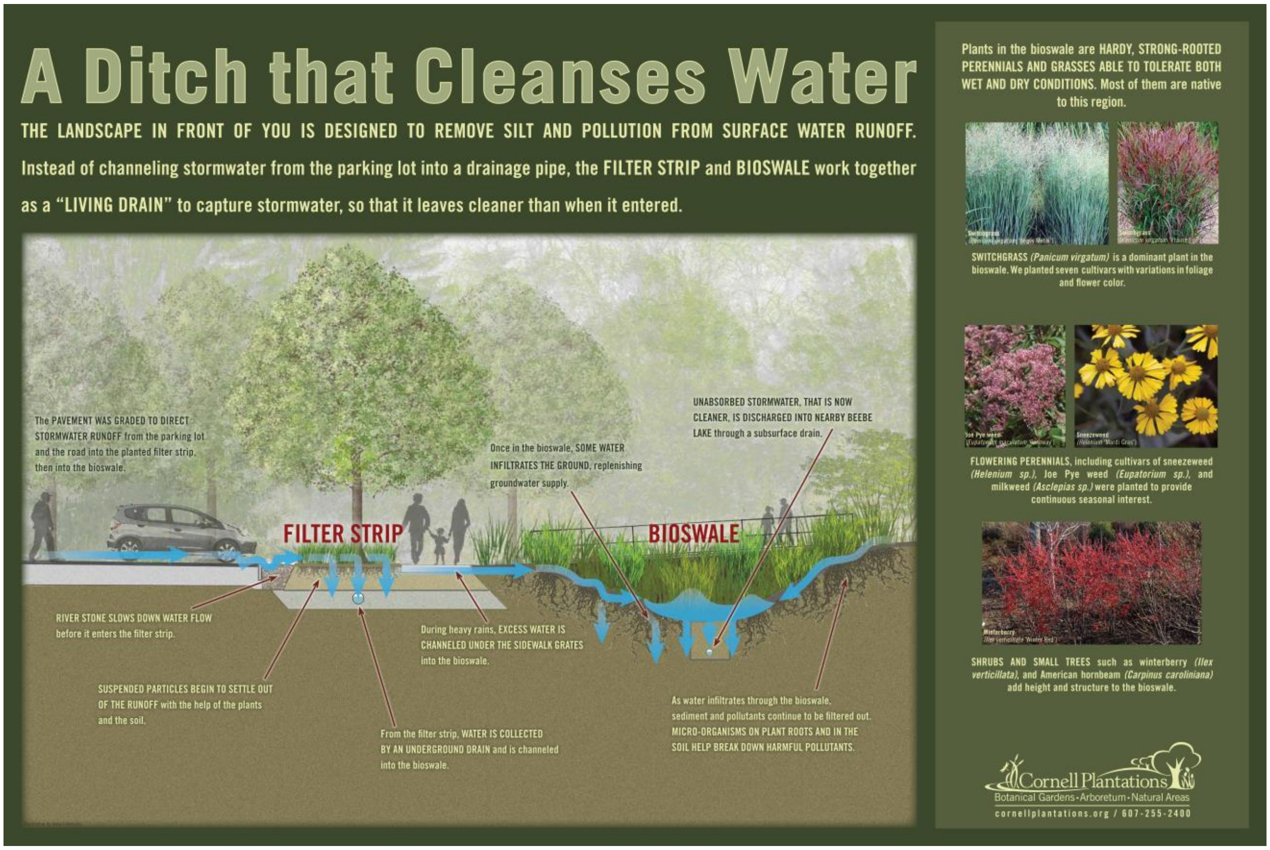
Collaborative Design:

Cornell Plantations’ horticultural, education, and ecological mission and its in-house expertise created unique opportunities for collaboration. Every part of the project – building and landscape alike – reflects interdisciplinary teamwork, none more than the bioswale. There, the landscape architect, architect, civil engineer, and client each made unique and essential contributions, with Plantations’ Landscape Designer, Irene Lekstutis, and Director of Horticulture, Mary Hirshfeld, stepping forward as de facto members of the design team. Their work was especially notable not only in shaping the final design of the plantings and guiding them through establishment, but in their understanding of the land, its microclimate, and its soils, all with a depth of knowledge only attainable through decades of hands-on gardening.

Design Intent and Constraints:

It was the intention of the Landscape Architect Tobias Wolf that the Design express natural processes:

> *An ancient oxbow meander of Fall Creek created the “bowl” that defines the Botanical Garden, carving the slopes around the garden and leaving Comstock Knoll at its core. Today, the periglacial creek is echoed in the bioswale’s function and form. The bioswale receives surface runoff from the gently sloped floor of the bowl; its curve echoes that of the creek and the surrounding escarpments; and its plantings are massed to evoke the movement of water -- with lower grasses and spreading perennials "flowing" around "fixed" clusters of trees, shrubs, and shrub-like perennials towards a bridge-like path that provides a visitor overlook.*
>
> *The bioswale also articulates new functions with new forms, which shape and reveal the movement of water. As visitors move from their cars into the gardens, they follow the course of the water, over a nearly-flush curb that catches sediment, across a river rock strip and walk over a planted 'filter strip" on elevated steel grates, and then down the length of the bioswale to its outlet. Along the way, they may observe the gradation of plants from the most heat- and drought-tolerant nearest the parking lot to the most moisture-loving and immersion-tolerant at the bioswale’s center.*



Interpretive Sign, Cornell Plantations

The practice called the 'Bioswale Garden' at the Plantations is actually a system comprised of sheet flow from lawn areas and the parking lot, a filter strip and a dry swale practice all of which work together to both filter stormwater and attenuate peak flow rates. It has been questioned why porous pavement is not part of this system. Poor soils with low percolation rates make large installations of porous pavement problematic in this area and large amounts of mulch and decaying plant matter were deemed to cause a risk for clogging pavement surfaces. It was decided that having the parking area directly sheet flow to the filter strip was the best option given the conditions.

Expandability:

The Plantations continues to develop new gardens and in the near future plans to install a Peony Garden, an Asia Garden and implement pedestrian walkway improvements. Because these projects were considered in the 2002 Master Plan and planned for in the stormwater management, the bioswale will only require a minor expansion to serve these new projects.

Research Strategy and Methods Used:

As is the mandated by the format of the case study program, the performance benefits studied fall under three broad categories: Environmental, Social, and Economic. The primary source of information about the project was the design team and the construction documents for the project. Staff from the Cornell Plantations met on site and consented to interviews and a site tour, sharing their knowledge of the design process and the post-construction functioning of the project. Also, an interesting advantage of the project's location on the Cornell campus was the opportunity to work with researchers and professors at Cornell, who also contributed to our understanding of the project. Detailed information about the performance benefits assessed follow as performance indicators.

Performance Indicators:

Environmental

Performance Indicator 1:

- *Eliminates an estimated 78,000 gallons of runoff per year, reducing annual stormwater runoff from the site by 31%.*

Methods: The Virginia Runoff Reduction Method (RRM) Worksheet developed by the Center for Watershed Protection was used to model the pre and post stormwater conditions of the site. The worksheet is a spreadsheet-based tool designed for users to determine compliance with Virginia stormwater legislation by estimating runoff reduction from the first one inch of rainfall. The spreadsheet is based on the "Runoff Reduction Method" developed by the Center for Watershed Protection (CWP) to estimate changes in site runoff volume and pollutant load as well as the reductions in runoff and pollutant loadings associated with management practices installed on site. The "Runoff Reduction Method" was developed by the CWP in order to provide a new regulatory framework which incentivizes sustainable site design strategies and more accurately accounts for overall management practice effectiveness. The RRM uses current research to isolate pollutant concentration reduction efficiency from previously unaccounted for reductions in runoff by certain management practices. The method assigns efficiency credits for nutrient removal and runoff reduction by each practice based on median efficiency rates reflected in current research.

Site Plan with Flow Lines, Baird Sampson Neuert Architects Inc., Michele Palmer

For the purpose of this case study, the calculator was run twice in order to compare pre-development runoff and pollutant levels to post-development, post-treatment levels. The following steps were used to calculate runoff and pollutant levels in both pre-development and post-development conditions:

1. Determine site conditions including annual rainfall as well as the acreage of forest, turf and impervious cover (broken down by hydrologic soil class) for each drainage area. Values were collected using area takeoffs from aerial photos of the site, construction documents, and the project engineer's calculations. These values are used to calculate the runoff coefficients (Rv) for

each drainage area which are then used to calculate the total quantity of runoff generated, or initial 'treatment volume' (Tv) on the site. This step is competed in both pre-development calculations as well as post-development calculations.

2. Determine the catchment area and connections of each stormwater management practice on the site. These values were collected using area takeoffs from construction documents and are based on calculations provided in the project documentation. This step is only completed for post-development calculations and the input values selected in this study may be found in the flow charts below in the stormwater management summary.
3. Enter local values for 1-year, 2-year and 10-year storm events (2.30 inches, 2.65 inches, and 3.90 inches respectively) and enter average annual rainfall of 37" in Ithaca.
4. Use the final one inch storm event runoff volumes and pollutant loads to estimate annual runoff quantities and loads. Because this runoff calculation only accounts for runoff generating storm events, the equation below only accounts for the 90% of annual rain events which produce runoff. While 10% of the remaining runoff producing rain events are in fact larger than the 1" event used by the Virginia spreadsheet, the RRM accounts for these larger events by using management practice credit values based on efficiency rates reported in a wide variety of existing research, including larger storm events (larger than 1"). With the one inch storm event used by the Virginia spreadsheet, one can approximate annual runoff using the following equation:

Where RVR = Runoff Reduction Volume

$$1"\ Storm\ RVR \times \frac{37"\ runoff}{1"\ runoff} \times 90\% = RVR\ Annual\ Volume$$

Limitations: Area values used in the modeling were calculated by area take-offs from construction documents. This introduces potential for human error in the calculations. The modeling developed by the Center for Watershed Protection was developed for the State of Virginia rather than New York. All of the state specific models developed by the Center are based on the same underlying scientific studies but reflect a particular state's regulations that are all regional implementations of the Federal Clean Water Act. While the spreadsheet is designed to evaluate projects based on Virginia's local WQv rain event size of 1" which is sized to account for 90% of annual runoff producing storm events, this does not affect the final calculation of annual impact used in this study. Also, the CWP notes that the credit values assigned to calculate the nutrient removal efficiencies and runoff reduction efficiencies of certain management practices are based on limited existing research. In these cases, the CWP assigns values based on its best judgment based on the currently available data. Finally, the accuracy of results produced by this methodology requires that the practices studied were designed according to certain 'minimum eligibility criteria', built within the last three years, and maintained properly.

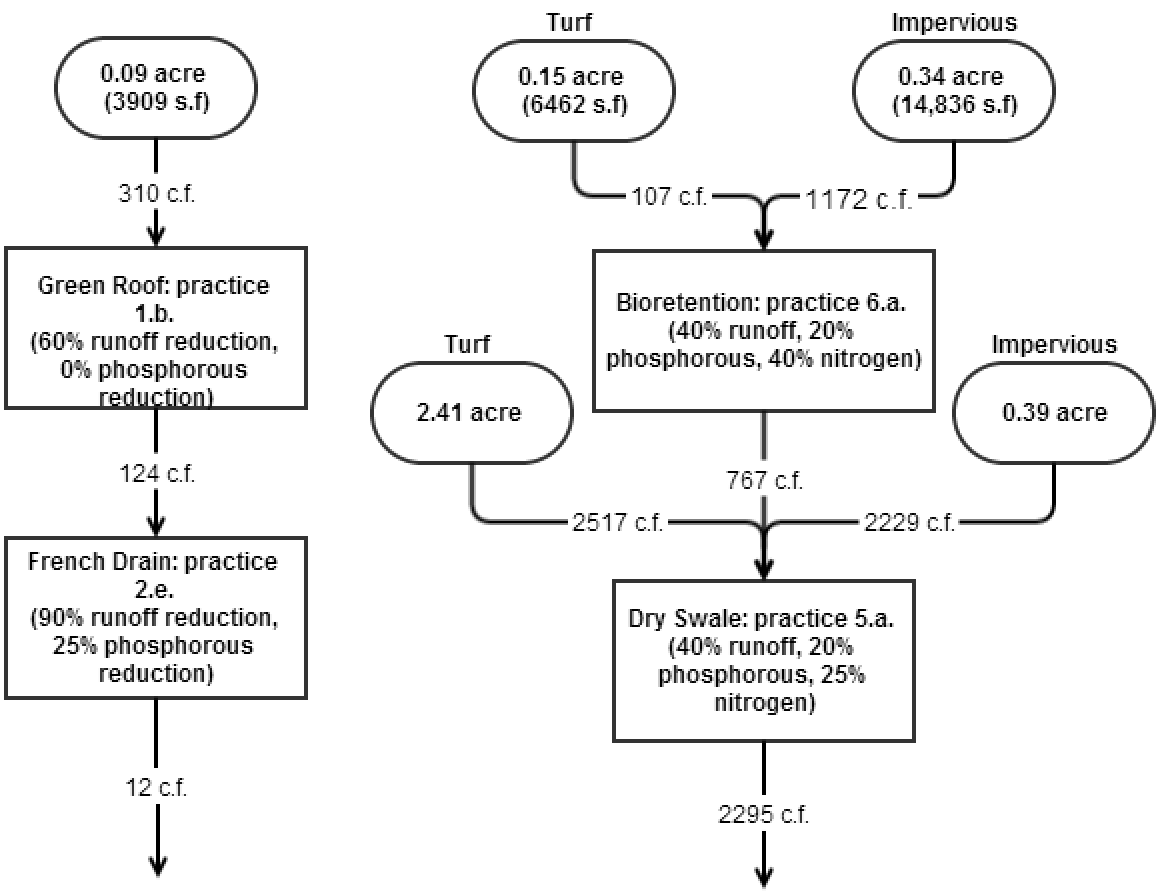
PRE-DEVELOPMENT LAND COVER SUMMARY

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.68	0.37	2.41	0.00	3.46	*30.51*
Turf (acres)	0.76	4.97	0.00	0.00	5.73	*50.53*
Impervious (acres)	0.87	1.22	0.06	0.00	2.15	*18.96*
Site Rv: 0.29					**11.34**	***100.00***

POST-DEVELOPMENT LAND COVER SUMMARY

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.67	0.50	1.91	0.00	3.08	*29.00*
Turf (acres)	0.54	5.24	0.00	0.00	5.78	*54.43*
Impervious (acres)	0.35	1.35	0.06	0.00	1.76	*16.57*
Site Rv: 0.27					**10.62**	***100.00***

STORMWATER MANAGEMENT SUMARY



* Values the above boxes summarize the predicted reduction rates for each practice.

STORMWATER SUMMARY

	Pre-Development	Post-Development	Runoff Reduction	Treated Volume	Pre-Post Change	% Change
One Inch Storm Runoff Volume (ft3)	11,876	10,548	2,297	8,251	-3,625	-31%
Annual Storm Runoff Volume (acre-ft)	9.08	8.06	1.76	6.30	-2.78	-31%

Performance Indicator 2:

- *Reduces peak stormwater flow rates by 81%, 62% and 58% respectively, for 1 year, 10 year, and 100 year storm events.*

Methods: Review of project Stormwater Pollution Prevention Plan (SWPPP) provided by T.G. Miller Engineers and Surveyors, P.C.

Performance Indicator 3:

- *Reduces pollutants in parking lot runoff as measured by increased concentrations of heavy metals in bioswale soils and decreased concentrations in outflow water.*

[Lauren McPhillips contributed to the following text]

It is important to reduce concentrations of metals in runoff from parking lots and buildings, because many of these metals could have adverse effects on biota in downstream water bodies. Nutrients, both nitrate and phosphorus, are a concern because high concentrations can lead to algal blooms in ponds, lakes, and estuaries, which can subsequently cause anoxia and 'dead zones.' In the case of this bioswale, where outflow had an increase in nitrate and dissolved phosphorus and concentrations that are generally considered high, it will be important to better optimize organic amendments to the soils in order to reduce leaching of these nutrients while still maintaining plant health.

Methods: Water quality function was assessed by partners from the Biological & Environmental Engineering Department, Todd Walter and Lauren McPhillips. Their work included collecting soil and water samples in the bioswale to assess whether the bioswale is accumulating contaminants and improving the water quality of incoming runoff.

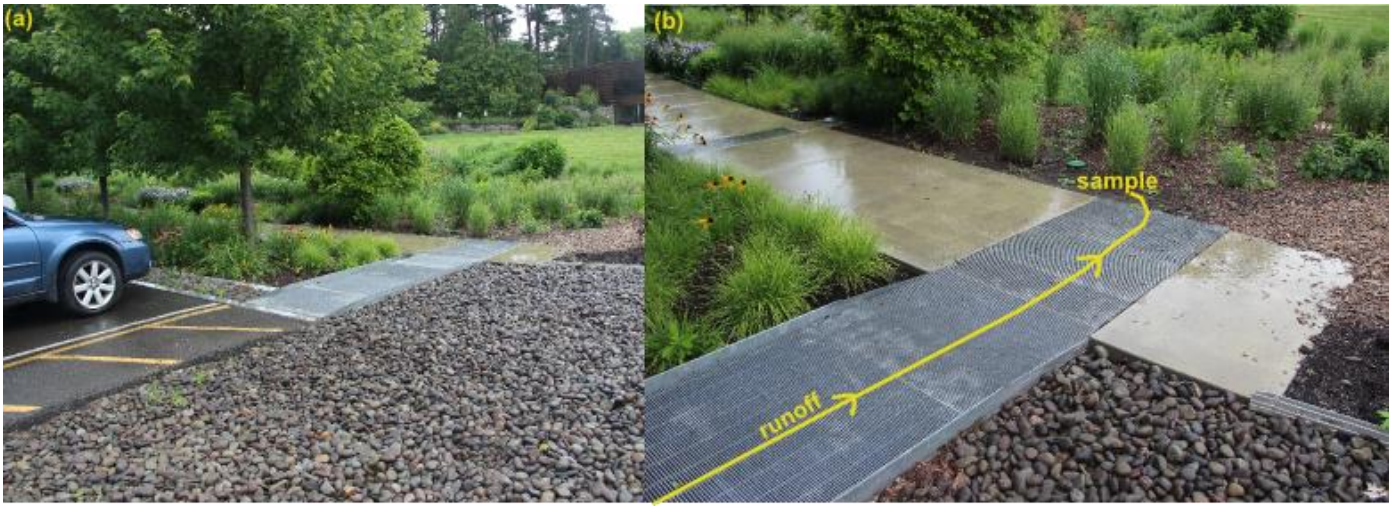
Samples of bioswale inflow runoff and outlet flow from the basin underdrain were taken during two storm events. These samples were analyzed for nitrate (NO_3^-) using ion chromatography, dissolved phosphorus (DP) using a phosphorus colorimetric autoanalyzer, as well as metals and particulate phosphorus (PP) using nitric acid digestion and ICP spectroscopy; concentrations were compared between inlet and outlet samples.

Sampling Locations, Baird Sampson Neuert Architects Inc., Michele Palmer

Soil samples were obtained from three locations inside the basin as well as three locations outside the basin which had the same original soil media but did not receive storm runoff. Samples were analyzed for total metal concentrations using a nitric acid digestion and ICP spectroscopy.

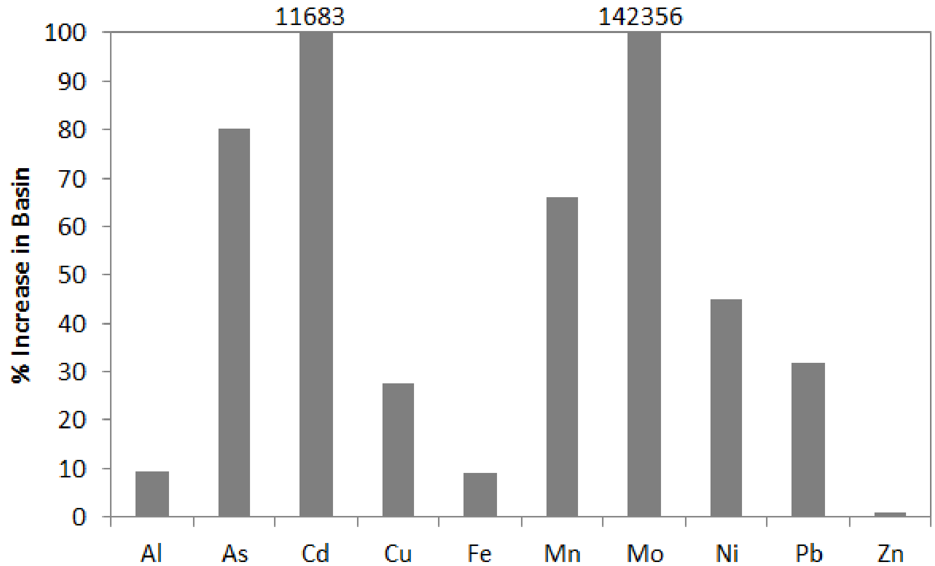
Limitations: The water samples only provide a snapshot of pollutant concentrations in site runoff from two dates when we could access bioswale outlet flow; these 'snapshots' are complemented by analysis of pollutants in basin soils, which provides a more integrated assessment of basin water quality function over its lifetime. There is no way to sample only the outflow from the bio-retention practice tree strip. Sheet flows from the lawn as well as water filtered by the bio-retention practice are combined in the bioswale. Deborah Caraco, P.E. from the Center for Watershed Protection mentioned that the results of the water analyses may under-estimate the efficacy of the bioswale as they do not account for runoff reduction due to infiltration or evaporation; both of these processes reduce the flow volume and thus could increase concentration of pollutants. In the future, having data on flow volumes entering and leaving the basin could allow calculation of total pollutant loads.

Lauren McPhillips Setting Up Water Sampling, Mujahid Powell

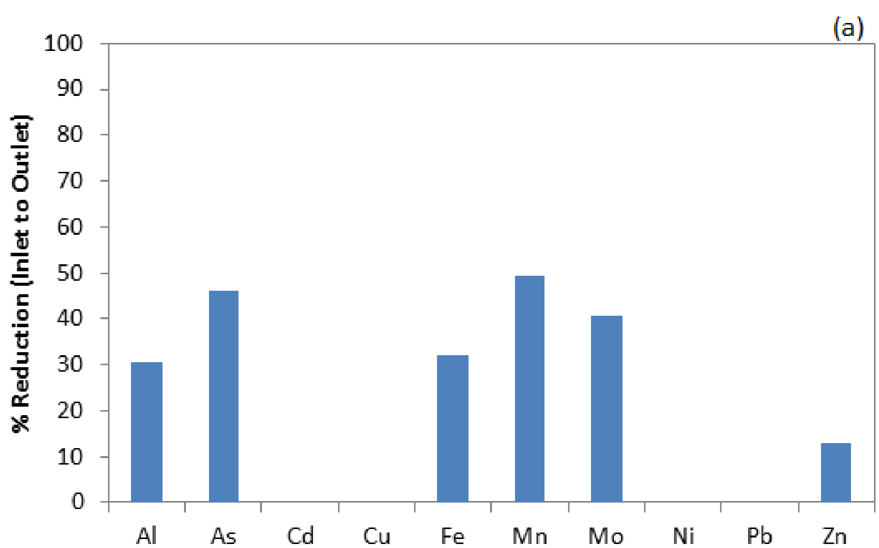


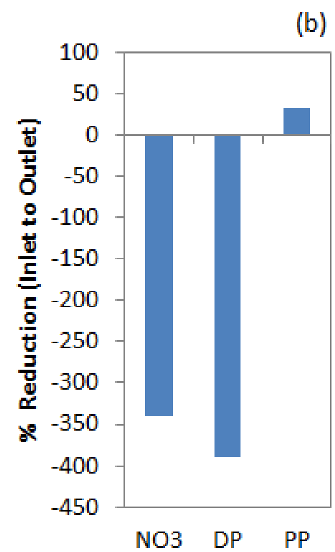
Photos of inlet sampling location for bioswale, with (a) showing where runoff from the parking lot drains into the stone diaphragm and then through the grate to the bioswale, where we sampled (b), Lauren McPhillips

Graphs:



Results of soil metals analysis averaged for the two sample events, comparing concentrations in soil inside the basin with a control soil outside of the basin. Analyzed metals include aluminum (Al), arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), and zinc (Zn). All metals demonstrate increases in concentration, or accumulation of metal, within the basin. Cadmium (Cd) and molybdenum (Mo) show very high percentage increases because control soils had concentrations very close to zero.





Results of water analysis, comparing concentrations of nutrients and metals in inflow with outflow. Analyzed metals (a) demonstrate no change between inflow and outflow (primarily because levels were overall very low) or reduction in concentration between inflow and outflow. Dissolved nutrients, nitrate (NO_3^-) and dissolved phosphorus (DP) (b) demonstrate an increase in concentration between the inflow and outflow, whereas particulate phosphorus (PP) shows a decrease in concentration.

Performance Indicator 4:

- *Increases biodiversity. The bioswale contains over 50 plant species, giving it a Reciprocal Simpson Index of 11.5, which is 26.3 more than that of a turf grass seed mix typically used for dry swales.*

The Reciprocal Simpson Index is a common variation of the Simpson's Index of Diversity which is used to measure biodiversity. Biodiversity encompasses both species richness and species evenness which reflect the total number of species in a sample as well as the balance between the populations of each species respectively. The value of this index starts with one as the lowest possible figure, where higher values equal greater diversity. The value one would represent a community containing only one species. The maximum value possible is equal to the total number of species in the sample, meaning that the populations of each species in the bioswale are equally abundant.

Methods: The Reciprocal Simpson Index was used to compare biodiversity between the current plantings in the Bioswale Garden and a typical turfgrass seed mix which is an acceptable treatment for a dry-swale practice in the State of New York. This index was determined by counting the number of individuals of each species present in the bioswale and entering the data into a spreadsheet using the following formula to calculate the Reciprocal Simpson Index. Similarly for the turfgrass, the biodiversity value was calculated using the species proportions of a typical seed mix in place of actual quantities. This is an acceptable way of calculating the Reciprocal Simpson Index.

$$D = \frac{1}{\left(\frac{\sum n_i(n_i - 1)}{N(N-1)}\right)}$$

D= Diversity, n_i =*population of an individual species,* *N=Total number of individuals*

BIOSWALE:

$$\mathbf{11.530} = \frac{1}{\left(\frac{180{,}222}{1442(1442-1)}\right)}$$

Totals:	**1442**	**180222**
Species (52 total)	**n**	**n(n-1)**
Achillea millefolium	12	132
Agastache foeniculum	3	6
Amsonia rigida	10	90
Amsonia hubrichtii	23	506
Asclepias speciosa	7	42
Baptisia x bicolor	12	132
Baptisia x variicolor	12	132
Baptisia alba	13	156
Baptisia megacarpa	6	30
Baptisia sphaerocarpa	6	30
Caltha palustris	6	30

TURFGRASS:

$$\mathbf{0.439} = \frac{1}{\left(\frac{4350}{100(100-1)}\right)}$$

Totals:	**100**	**4350**
Species (3 total)	**n**	**n(n-1)**
Poa pratensis	60	3540
Lolium perenne	25	600
Festuca ovina	15	210

Chelone lyonii	7	42
Echinacea purpurea	75	5550
Echinacea pallida	10	90
Echinacea paradoxa	33	1056
Eupatorium dubium	21	420
Eupatorium maculatum	20	380
Filipendula camtschatica	5	20
Filipendula rubra	15	210
Gillenia trifoliata	14	182
Helenium automnale	12	132
Helianthus angustifolius	4	12
Hibiscus moscheutos	7	42
Inula orientalis	10	90
Iris x robusta	15	210
Iris ensata	25	600
Iris laevigata	11	110
Iris versicolor	10	90
Kalimeris incisa	31	930
Lialis spicata	13	156
Monarda didyma	54	2862
Plox paniculata	4	12
Rudbeckia subtomentosa	12	132
Solidago rugosa	218	47306
Stachys byzantina	5	20
Veronia lettermannii	22	462
Veronicastrum virginicum	26	650
Betula nigra	5	20
Rhus glabra	6	30
Carpinus caroliniana	6	30
Aronia arbutifolia	10	90
Cotinus coggygria	8	56
Cercidiphyllum japonicum	15	210
Ilex verticullata	25	600
Lindera benzoin	4	12
Ostrya virginiana	4	12
Panicum virgatum	297	87912
Pennisteum alopecuroides	2	2
Schizachyrium scoparium	37	1332
Sesleria autumnalis	77	5852
Sporobolus heterolepis	145	20880
Acer x freemanii	12	132

Limitations: The species of some plants may have been misidentified because of similarities between plants of the same cultivar or genus when they are not in bloom. As a result, some species may have been over-counted or under-counted. Also, any limitations inherent to the Reciprocal Simpson Index while the Simpson Index in its pure form is considered a dominance index because it weights towards the abundance of the most common species, the Reciprocal Simpson Index corrects for this bias producing a true biodiversity measure.

Performance Indicator 5:

- *Increased overall soil health in the bioswale by 28% according to the Cornell Soil Health Assessment Training Manual. Soil amendments increased soil organic matter by 74% and active carbon by 37% as compared to the adjacent turf.*

During construction, soil was stripped and stockpiled and then placed back onto the site. Topsoil used for lawn areas was not amended. The topsoil for the bioswale was amended with compost and sand to make a well-drained soil for the filter practice. While the water holding capacity was lower for the bioswale soil, it should be understood that the soil mix is intended to be well drained to function as a filter practice so the lower test result in this case is desired and expected.

Dr. Bassuk and Prof. Peter Trowbridge have been studying the benefits of soil amendment on the Cornell campus for nearly a decade and they have found that a simple process of amending with 1/3 compost by volume and annual mulching thereafter continues to improve soil health over time. Organic matter in soil increases water holding capacity and provides nutrients and energy to plants. Research shows that active carbon is a "leading indicator" of soil health, correlating with percent organic matter and biological activity in soil. While soil health may seem like a less tangible benefit, there are two aspects to the amendment process that are key to understanding the benefit.

1. A poor soil can be amended at a low cost with good result, thereby avoiding the cost and environmental impact (stripping another site) of importing soil.
2. A healthy soil produces healthy plants, allowing them to provide the visual and ecosystem benefits expected with fewer replacements required.

Overall, the bioswale soil was healthier in key ways, especially evident in the penetrometer reading. If a soil is too dense for plants to grow in, then the other indicators such as moisture and nutrition are irrelevant if plants' roots can't reach them.

Methods: Soil samples and penetrometer readings were collected in the bioswale and the adjacent turf with research partner Dr. Nina Bassuk in order to conduct a full soil health analysis at Cornell University's soil lab. Test results may be found below:

Soil Health Assessment Results

Indicator	Turf		Bioswale		% Change Value	% Change Rating
	Value	Rating	Value	Rating		
Available Water Capacity (m/m)	0.26	97	0.15	63	-42%	-35%

Aggregate Stability (%)	22.7	26	51.6	81	111%	211%
Organic Matter (5)	5.1	89	8.9	100	74%	12%
ACE Soil Protein Index	7.1	40	19	100	167%	150%
Root Pathogen Pressure (1-9)	4.0	63	5.0	50	25%	-20%
Respiration	0.78	12	0.81	45	38%	275%
Active Carbon (ppm) [Permangate Oxidizable]	551	37	759	81	38%	119%
pH	7.1	100	7.3	89	2%	-11%
Phosphorous	36.4	19 High, potential impact risk	179	0 High, potential impact risk	391%	100%
Potassium	211.9	100	138.6	100	-35%	0%
Minor Elements Mg, Fe, Mn, Zn	182, 1.8, 13.8, 0.2	56, Zinc Deficient	442, 2.0, 45.2, 3.1	100	142%, 11%, 228%, 1450%	79%
Penetrometer Depth	1”	N/A	18”	N/A	94%	N/A
Overall Quality Score (Out of 100)	58	Medium	74	High	28%	N/A

Limitations: The soil health test was originally developed for agricultural applications and so underlying assumptions about the soil health are focused on crop production rather than landscape plants. Generally all plants require moisture, oxygen and nutrition, all of which are evaluated as part of the test. The indicator ratings need to be understood in relation to each other rather than as individual values. For example, while the turf soil has a higher water holding capacity, it is a dense soil with a high clay content. Since it is too dense to allow healthy root growth, the water present would not actually be available to individual plants.

For a detailed description of all of the tests and relative value assessments, see the entire soil test reports in the appendix.

Social

Performance Indicator 6-8:

- *Provides recreational and educational opportunities for an estimated 50,000 visitors per year based on 2013 counts. 68% of 71 survey respondents achieved the bioswale learning objectives, answering 7 out of 9 questions correctly.*

- *Helps galvanize visitor interest and support for green infrastructure. 92% of the 71 survey participants said they were interested in seeing green infrastructure in their communities, and 52% report that they are likely to install smaller scale practices in their home landscape.*
- *Provides a variety of learning experiences to approximately 12,460 people per year at low or no cost, including exhibits, lectures, youth programs, tours, internships, and a volunteer program.*

Methods: Visitor counts and participant counts were provided by the Cornell Plantations education and outreach staff. Program statistics include programs throughout the Plantations and the Welcome Center sponsored activities are not tracked separately.

Preparing Survey Collection near Interpretive Sign, Michele Palmer

In 2013 the Plantations' education programs served:

- 9433 Participants in Adult Education
- 2095 Participants in Youth Education
- 933 Cornell Students

Plantations staff participated in the development of a survey to assess visitors' understanding and support for green infrastructure. This is an important measure of success for this project, as the client is an educational organization. As part of the project, the Cornell Plantations established a set of learning objectives for visitors and developed an interpretive sign which explains the function of the green infrastructure system around the parking lot:

- Most visitors will:
  - Realize that water is much cleaner when it leaves the bioswale than when it entered.
  - Recognize that a bioswale is a more sustainable alternative to a conventional drainage culvert system.
- Some visitors will:
  - Describe where the water comes from that enters the bioswale and where it goes from there.
  - Describe in their own words how water is filtered by the filter strip and bioswale.
  - Name one plant in the bioswale and briefly explain why it was selected.
  - Appreciate that Cornell Plantations constructed a bioswale rather than a conventional drainage system.
  - Recognize that smaller scale bioswales can be created for home landscapes.

In order to gauge a visitor's understanding of green infrastructure practices in the botanical garden, the survey uses a standard Likert scale questions which allow respondents to self-report their level of understanding, as well as a short quiz using true or false questions to assess whether or not the project's learning objectives are being achieved. In addition to understanding, the survey asked participants to report their support for green infrastructure being constructed in their community, as well as the likelihood that the participant will install green infrastructure in their home landscape.

Number of Correct Answers	1	2	3	4	5	6	7	8	9	*Total
Number of Respondents	1	1	3	1	5	8	14	21	13	71
Percent of Respondents	1.4%	1.4%	4.2%	1.4%	7%	11.3%	19.7%	29.6%	18.3%	100%

* Total includes respondents who answered all questions incorrectly. (4 respondents)

- 78.9% (56) of respondents agreed that their visit to the Cornell Plantations increased their understanding of green infrastructure including bioswales and green roofs. (49.3% strongly agree and two respondents chose not to answer the question)
- 91.5% (65) of respondents described themselves as interested in seeing sustainable features such as rain gardens, bioswales and green roofs. (23.9% very interested)
- 52.1% (37) of respondents stated that they likely would install sustainable features such as rain gardens, bioswales and/or natural filters at their home. (26.8% very likely)

The survey was administered to visitors on an ongoing basis between mid-June and mid-July in both paper and digital form as well as through in-person surveys recorded by the researchers on two occasions. Paper surveys and a collection box will be provided near visitor information in the visitor center. A digital version of the survey was created using “Qualtrics” online survey software, and publicized by posting QR codes and URLs to the survey around the Nevin Center site. The in-person survey occurred on two occasions, first in early June, and the second time on July 19, to compare responses in early summer to responses late in summer when plantings are lusher.

Survey Notes: 71 Cornell Plantations visitors responded to the survey between early June and late July 2014. 68 responses were collected in person, 3 responses were submitted in paper form to the visitor center welcome desk, and none were collected online due to problems with the online survey form. The survey also collected the following visitor demographic profile:

- AGE: 7.0% aged 18-24, 28.2% aged 25-44, 46.5% aged 45-64 and 18.3% 65 years or older.
- TRAVEL DISTANCE: 7.0% less than one mile, 26.8% 1-10 miles, 8.5% 11-50 miles, 14.1% 51-100 miles, 43.7% more than 100 miles.
- TRAVEL METHOD: 12.7% walking, 0.0% biking, 85.9% car, 0.0% public transportation, 0.0% Other.
- VISIT FREQUENCY: 50.7% first visit, 31.0% less than once per month, 5.6% once a month, 8.5% once a week, 2.8% Daily.

Limitations: The survey was only administered over a short period of time over summer months while students are not on campus and survey recruitment may have been more successful among certain population groups, therefore not representing the full visitor body accurately. In addition, it was noted that asking questions to visitors prompted them to observe and think more than they may have otherwise.

Economic

Performance Indicator 9:

- *Saves $316 or 14% of the building's predicted annual heating and cooling costs by using a green roof instead of a white roof.*

Methods: Green roofs act as insulators for buildings, reducing energy needed to provide cooling and heating. Review of LEED documentation provided by Cornell University Plantations which states that 68% of the roof is vegetated. The project specifications were reviewed and Bioroof Systems, the installer of the green roof was contacted about specifics of the installation and provided a depth of media installed. The GBRL Green Roof Energy Calculator (v 2.0), was used to calculate potential savings. This calculator interpolates the simulation results to determine a predicted energy and cost savings based on the user input values for building type, location, green roof leaf area index, soil depth and area.

The following information was used in the calculator:

- New Office Building in Albany, NY
- Total roof area of 3517 ft2
- Growing Media Depth of 6 inches
- Leaf Area Index of 4.5
- Covers approximately 68% of the total roof area (the rest categorized as a dark roof i.e. solar panels)
- Not irrigated

For reference, the annual whole building electricity consumption for the specified green roof was calculated by the GBRL Green Roof Energy at 145259 kWh and the annual gas consumption at 474 Therms.

Annual Energy Savings compared to a Dark Roof (albedo = 0.15)

Electrical Savings: 1120.4 kWh

Gas Savings: 5.9 Therms

Total Energy Cost Savings (1): $-5.12

Annual Energy Savings compared to a White Roof (albedo = 0.65)

Electrical Savings: 517.5 kWh

Gas Savings: 27.5 Therms

Total Energy Cost Savings (1): $316.07

Limitations: The nearest city available to input was Albany, New York, which has a similar climate but may vary from the project location. Heating and cooling costs predictions are extracted from the LEED documentation for the 5,082 sf interior space of the building. Predicted base line costs for the natural gas heating are $1,911 and electrical cooling $281.79 for a total of $2,192.79 annually. This may not represent actual costs.

Performance Indicators 10:

- *Stimulated Cornell Plantations' fundraising with $4.8 million in a project-specific donation to the Nevin Welcome Center and $13.5 million raised for the "Plantations Transformation" campaign. Naming rights for garden areas are expected to raise at least an additional $1 million.*

  Methods: Development staff at the Plantations was consulted to understand the funding of the Nevin Welcome Center. Since the Plantations is a botanical garden, the focus is on its landscapes and the buildings would theoretically not be in existence. To serve the botanical garden mission, building and service improvements were needed to make the landscapes more accessible and appealing to visitors. 13.5 million dollars was raised in a campaign called 'Plantations Transformation' which partially funded the Nevin Welcome Center as well as other improvements to the landscape and other service buildings. While the Welcome Center building was one focus for fundraising, the surrounding landscape and Bioswale Garden were strong contributing factors in the efforts. Included in the total 13.5 million was a single large donation by Madolyn M. Dallas and Glenn Dallas which funded the Tree Plaza which transitions the visitor experience from the parking area to the main walk to the Nevin Center building.

'Naming rights' continue to create funding opportunities. There are minimum donation amounts for specific naming opportunities but there is no set maximum. Two large opportunities are still open:

- $550k for the Bioswale Garden
- $500k for the patio, terrace garden and tropical plantings, all at the entrance to the Nevin Center.

Limitations: There is no set monetary value for the 'naming rights' opportunities, so the impact of donations cannot fully be projected. The value of the donations towards landscape cannot be separated from the building as both were part of the same fundraising campaign.

Lessons Learned:

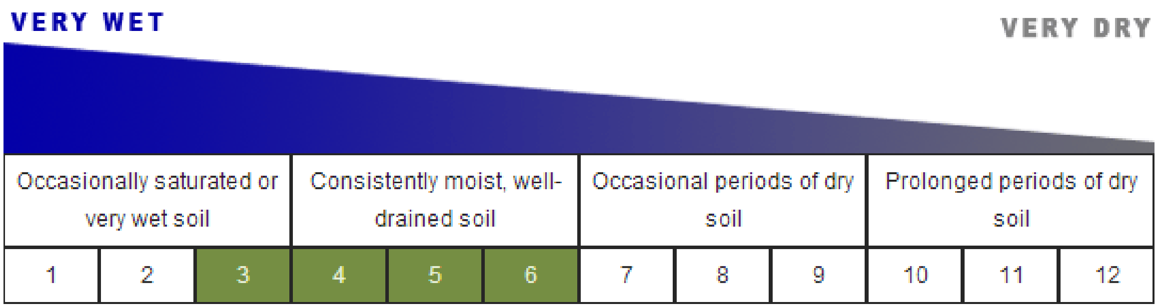
C.U. Structural Soil Tree Health:

- *Several Katsura (Cercidiphyllum japonicum) trees planted in structural soil have not been thriving, with explanations varying from pH intolerance to inadequate soil volume and poor species selection. Tests and calculations show that at 7.4-7.6, pH is within tolerable levels for Katsura trees. While soil volume is minimally adequate for trees of this size to survive 90% of dry periods in Ithaca, the species selected has poor tolerance for occasional periods of dry conditions and scrutiny of the site grading shows little water being directed to the tree openings in the pavement. While the species has the landscape qualities desired, a better selection could have been made based on research on CU Structural Soil.*

Methods: Several Katsura (Cercidiphyllum japonicum) trees planted in CU structural soil have not been thriving. Review of construction documents, pH tests and soil volume calculations were used to verify the likely cause of stress on the Katsura trees. Nina Bassuk, one of the developers of C.U. Structural Soil, suggests that the Katsura trees are not an appropriate selection for Structural Soil. Indeed, the species is not included in the list of appropriate species in the guide to "Using CU Structural Soil in the Urban Environment" handbook. The handbook states that the criteria for appropriate trees is moderate to high drought tolerance, and alkaline soil tolerance.

It was hypothesized that that the lighter green leaves were due to a nutrient deficiency caused by high pH. In order to verify whether or not pH is a factor in the Katsura trees' stress, pH tests were taken in the structural soil planting (from the structural soil layer), and from a non-structural soil planting elsewhere on campus with healthy trees. Field tests conducted by Dr. Nina Bassuk show that at 7.4-7.6, pH, well within tolerable levels (pH 5.0-8.0) for species based on the Cornell University Woody Plants Database.

While soil volume is adequate for trees of this size to survive, this species is not tolerant of dry conditions and scrutiny of the site grading shows little water being directed to the tree openings in the pavement. While the species has the landscape qualities desired, a better selection could have been made based on research on CU Structural Soil. Dr. Bassuk has recommended a program of watering to ensure their survival, which is being implemented. While the species has the landscape qualities desired, a better selection could have been made based on experience with CU structural soil. Trees that thrive in CU soil include those tolerant of both of a variety of moisture conditions and periods of dryness and higher than average pH that resulting from the use of Ithaca's local limestone.



Water Tolerance for Katsura, Cornell Woody Plants Online Database

Nutrient Removal - Modelled Predictions vs. Testing:

- *Bioswales are generally predicted to remove a variety of contaminants including nutrients, metals and suspended solids. This prediction was verified for the Bioswale Garden at the Nevin Welcome Center by the Center for Watershed Protection runoff reduction spreadsheet modeling, however input-output water sampling and tests by Lauren McPhillips have found that despite the practice's success removing metals from runoff, it appears to be a net source of dissolved Nitrogen and Phosphorous. There are no definitive answers at this point, however there are two hypotheses: Despite the lack of institutional memory of this, excess nutrients leaving the bioswale could be coming from stripped and stockpiled topsoil which may have originated in gardens which were historically fertilized through either compost or chemical fertilizers. Also, the enriched mulch made of bark and compost used in the bioswale may be contributing excess nutrients to the bioswale.*

Runoff Reduction Spreadsheet Modeling Results: (See Performance Indicators 1-2 for methodology and limitations)

	Pre-Development	Post-Development	Runoff Reduction	Treated Volume	Pre-Post Change	% Change
Total Phosphorous Load (lbs/yr)	6.42	5.70	1.98	4.00	-3.00	-42%
Total Nitrogen Load (lbs/yr)	45.93	40.80	18.94	22	-24	-52%

*** See Performance Indicator 3 for Sampling Results, Methodology and Limitations ***

Cost Comparison:

Capital Cost Comparison:

The educational and horticultural elements of the Bio-swale Garden increased installation costs by $121,500 or 92% as compared to standard turf. The increased cost for the decorative elements of the project can be seen as the cost of providing an educational landscape, meant to encourage an appreciation of the possibilities for creating a sustainable stormwater solution in the context of a botanical garden. Visitors also learn that they can create a similar garden at a different scale in their home landscapes.

A cost comparison was developed to understand the cost of creating stormwater management that is also a garden as compared to the cost of a standard stormwater practice. Standard practice for a dry swale would have been turf with mulch over the filter components of the system. The basic costs for the treatment and storage practices are the same. The increase in cost is due the open grate foot paths that reveal the movement of water and the cost of the garden plantings that provide its horticultural display.

Key Elements

- Create a showcase display of native plants
- Reveal through decorative elements making the movement of water clear to visitors
- Educate and encourage visitor support for sustainable practices

Methods: Review and recreation of cost estimates for bioswale and a conventional detention pond using local unit costs provided by T.G. Miller Engineers and Surveyors, P.C. and Vermeulens Cost Consultants dated October of 2008.

See the below summary for a comparison of the major elements of the cost estimates.

Category	**Standard Practice**	**Nevin Welcome Center**	**% Cost Difference**
Filter Strip	$87,308	$87,308	0%
Drainage and Walkways Between Filter Strip and Bioswale	$3,670	$50,100	1265%
Dry Swale and Filter Practice	$21,360	$52,400	145%
Plantings	$2,100	$30,305	1343%
General Conditions	$17,165.70	$33,016	92%

TOTALS	$131,604	$253,130	92%

Limitations: Costs were developed through design team estimates and may not reflect actual costs. For hypothetical costs, values were derived from R.S. Means.

Acknowledgments:

We would like to thank everyone who generously shared their time with us, helping to strengthen the study methods and collect the information necessary to complete this case study. In particular, Irene Lekstutis, Landscape Designer for the Plantation met with us and facilitated our contact with others at the plantations including Sonja Skelly and Justin Kondrat. David Cutter, University Landscape Architect was also helpful in providing documents and facilitating introductions with researchers at Cornell.

Dr. Nina Bassuk and Lauren McPhillips were of great assistance in taking on-site field tests and interpreting those results for us. We would not have been able to discover important lessons learned without their generous participation.

We would also like to acknowledge the assistance of Deborah Caraco P.E. of the Center for Watershed Protection in Ellicott City, Maryland. She helped us select the best worksheet to model the conditions on the site and critiqued our process for inputting the data in order to have the most accurate result. We believe that the tools developed by the Center could be more widely used in the LAF's Case Study program as they are relatively straightforward and are based on widely accepted underlying studies in the science of stormwater.

Resources:

Baird Sampson Neuert Architects Inc, Project Architect, 317 Adelaide St W, Toronto, ON M5V 1P9, Canada, http://www.bsnarchitects.com/

Dr. Nina Bassuk and Prof. Peter Trowbridge, Woody Plants Database, Cornell University, http://woodyplants.cals.cornell.edu/home

Battiata, J., Collins, K., Hirschman, D., and Hoffmann, G. "The Runoff Reduction Method." *Journal of Contemporary Water Research & Education*, ISSN 1936-7031, 12/2010, Volume 146.

Bioroof Systems Inc. , 1550 Yorkton Court, Unit 17,Burlington, Ontario, supplier of green roof, http://www.bioroof.com/BR_systems_home.html

The Center for Watershed Protection, 3290 North Ridge Road, Suite 290, Ellicott City, MD 21043 http://www.cwp.org/

http://www.cwp.org/online-watershed-library/cat_view/65-tools/91-watershed-treatment-model

Cornell Soil Health http://soilhealth.cals.cornell.edu/

Gugino, B.K., Idowu, O.J., Schindelbeck, R.R., van Es, H.M., Wolfe, D.W., Moebius-Clune, B.N., Thies, J.E., and Abawi, G.S. "Cornell Soil Health Assessment Training Manual", Second Ed, Cornell, CALS, 2009.

LEED Building Rating System, http://www.usgbc.org/leed

GBRL Green Roof Energy Calculator (v 2.0), Green Building Research Lab, Green Roofs for Healthy Cities, Portland State University, University of Toronto, http://greenbuilding.pdx.edu/GR_CALC_v2/grcalc_v2.php#retain

Brian C. McCarthy, Lecture on Species Diversity Concepts. http://www.ohio.edu/plantbio/staff/mccarthy/dendro/LEC5.pdf

Reed Construction Data 2014, R.S. Means Online, cost estimating figures. http://rsmeansonline.com/

T. G. Miller P.C., prepared the Stormwater Pollution Prevention Plan (SWPPP), http://www.tgmillerpc.com/

Vermeulens Cost Consultants, 9835 Leslie, Richmond Hill, ON L4B 3Y4, Canada, prepared the cost estimate dated October of 2008, http://www.vermeulens.com/

Wolf Lighthall Landscape Architecture + Planning, http://wolflighthall.com/

Appendices:

Summary Data from CWP Virginia Runoff Reduction Method Worksheet

Virginia Runoff Reduction Method Worksheet -- Revised 1/25/12

Site Data Summary

Total Rainfall = 37 inches

Site Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.67	0.50	1.91	0.00	3.08	*29.00*
Turf (acres)	0.54	5.24	0.00	0.00	5.78	*54.43*
Impervious (acres)	0.35	1.35	0.06	0.00	1.76	*16.57*
					10.62	*100.00*

Site Rv	0.27
Post Development Treatment Volume (ft3)	10548
Post Development TP Load (lb/yr)	5.70
Post Development TN Load (lb/yr)	40.80
Total TP Load Reduction Required (lb/yr)	1.35

Total Runoff Volume Reduction (ft^3)	2297
Total TP Load Reduction Achieved (lb/yr)	2
Total TN Load Reduction Achieved (lb/yr)	18.53
Adjusted Post Development TP Load (lb/yr)	3.76
Remaining Phosphorous Load Reduction (Lb/yr) Required	0.00

Drainage Area Summary

	D.A. A	D.A. B	D.A. C	D.A. D	D.A. E	Total
Forest (acres)	0.26	0.50	0.44	1.88	0.00	*3.08*
Turf (acres)	1.21	2.41	1.57	0.59	0.00	*5.78*
Impervious (acres)	0.39	0.73	0.42	0.22	0.00	*1.76*
						10.62

Drainage Area Compliance Summary

	D.A. A	D.A. B	D.A. C	D.A. D	D.A. E	Total
TP Load Red. (lb/yr)	0.00	1.78	0.16	0.00	0.00	*1.95*
TN Load Red. (lb/yr)	0.00	17.33	1.20	0.00	0.00	*18.53*

Drainage Area A Summary

Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.26	0.00	0.00	0.00	0.26	*13.98*
Turf (acres)	0.16	1.05	0.00	0.00	1.21	*65.05*
Impervious (acres)	0.01	0.38	0.00	0.00	0.39	*20.97*
					1.86	

BMP Selections

Practice	Credit Area (acres)	Downstream Practice

Total Impervious Cover Treated (acres)	0.00
Total Turf Area Treated (acres)	0.00
Total TP Load Reduction Achieved in D.A. A (lb/yr)	0.00
Total TN Load Reduction Achieved in D.A. A (lb/yr)	0.00

Drainage Area B Summary

Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.12	0.00	0.38	0.00	0.50	*26.88*
Turf (acres)	0.20	2.21	0.00	0.00	2.41	*129.57*
Impervious (acres)	0.13	0.56	0.04	0.00	0.73	*39.25*
					3.64	

BMP Selections

Practice	Credit Area (acres)		Downstream Practice
5.a. Dry Swale #1 (Spec #10)	**Impervious:**	**0.39**	**None**
	Turf (Pervious):	**2.26**	**None**
6.a. Bioretention #1 or Urban Bioretention (Spec #9)	**Impervious:**	**0.34**	**5.a. Dry Swale #1**
	Turf (Pervious):	**0.15**	**5.a. Dry Swale #1**
11.a.Filtering Practice #1 (Spec #12)	**Impervious:**	**0.34**	**None**
	Turf (Pervious):	**0.15**	**None**

Total Impervious Cover Treated (acres)	1.07
Total Turf Area Treated (acres)	2.56
Total TP Load Reduction Achieved in D.A. A (lb/yr)	1.78
Total TN Load Reduction Achieved in D.A. A (lb/yr)	17.33

Drainage Area C Summary

Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.29	0.00	0.15	0.00	0.44	*23.66*
Turf (acres)	0.17	1.40	0.00	0.00	1.57	*84.41*
Impervious (acres)	0.22	0.20	0.00	0.00	0.42	*22.58*
					2.43	

BMP Selections

Practice	Credit Area (acres)		Downstream Practice
1.b. Vegetated Roof #2 (Spec #5)	acres of green roof	0.09	2.e. To Dry Well or French Drain #2 (Micro-Infiltration #2)
2.e. To Dry Well or French Drain #2 (Micro-Infiltration #2) (Spec #8)	impervious acres disconnected	0	

Total Impervious Cover Treated (acres)	0.09
Total Turf Area Treated (acres)	0.00
Total TP Load Reduction Achieved in D.A. A (lb/yr)	0.16
Total TN Load Reduction Achieved in D.A. A (lb/yr)	1.20

Drainage Area D Summary

Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.00	0.50	1.38	0.00	1.88	*101.08*
Turf (acres)	0.00	0.59	0.00	0.00	0.59	*31.72*
Impervious (acres)	0.00	0.20	0.02	0.00	0.22	*11.83*
					2.69	

BMP Selections

Practice	Credit Area (acres)	Downstream Practice

Total Impervious Cover Treated (acres)	0.00
Total Turf Area Treated (acres)	0.00
Total TP Load Reduction Achieved in D.A. A (lb/yr)	0.00
Total TN Load Reduction Achieved in D.A. A (lb/yr)	0.00

Channel and Flood Protection

	Weighted CN	1-year storm Adjusted CN	2-year storm Adjusted CN	10-year storm Adjusted CN
Target Rainfall Event (in)		2.30	2.65	3.90
D.A. A CN	63	63	63	63
D.A. B CN	67	60	62	64
D.A. C CN	63	61	61	62
D.A. D CN	68	68	68	68
D.A. E CN	0	47	43	#N/A

Summary from Cornell Soil Health Testing

Measured Soil Health Indicators

The Cornell Soil Health Test measures several indicators of soil physical, biological and chemical health. These are listed on the left side of the report summary, on the first page. The "value" column shows each result as a value, measured in the laboratory or in the field, in units of measure as described in the indicator summaries below. The "rating" column interprets that measured value on a scale of 0 to 100, where higher scores are better. Ratings in red are particularly important to take note of, but any in yellow, particularly those that are close to a rating of 30 are also important in addressing soil health problems.

- A rating of 30 or less indicates a Constraint and is color-coded red. This indicates a problem that is likely limiting yields, crop quality, and long-term sustainability of the agro-ecosystem. In several cases this indicates risks of environmental loss as well. The "constraint" column provides a short list of soil processes that are not functioning optimally when an indicator rating is red. It is particularly important to take advantage of any opportunities to improve management that will address these constraints.
- A rating between 30 and 70 indicates Sub-optimal functioning and is color-coded yellow. This indicates that soil health could be better, and yield and sustainability could decrease over time if this is not addressed. This is especially so if the condition is being caused, or not being alleviated, by current management. Pay attention particularly to those indicators rated in yellow and close to 30.
- A rating of 70 or greater indicates Optimal or near-optimal functioning and is color-coded green. Past management has been effective at maintaining soil health. It can be useful to note which particular aspects of management have likely maintained soil health, so that such management can be continued. Note that soil health is often high, when first converting from a permanent sod or forest. In these situations, intensive management quickly damages soil health when it includes intensive tillage, low organic matter inputs, bare soils for significant parts of the year, or excessive traffic, especially during wet times.
- The Overall Quality Score at the bottom of the report is an average of all ratings, and provides an indication of the soil's overall health status. However, the important part is to know which particular soil processes are constrained or suboptimal so that these issues can be addressed through appropriate management. Therefore the ratings for each indicator are more important information.

The Indicators measured in the Cornell Soil Health Assessment are important soil properties and characteristics in themselves, but also are representative of key soil processes, necessary for the proper functioning of the soil.