NYC Green Infrastructure Plan:

2011 Preliminary Pilot Monitoring Results

UPDATE SUPPLEMENT

NYC Environmental Protection

June 2012

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In the parking lot at Far Rockaway, standard asphalt, porous asphalt, and FilterPave™ (shown here) pilots installed in 2011 are currently being monitored to compare stormwater runoff reduction performance.

Surface stage gauges installed in bioretention facilities at the Bronx River Houses Community Center are used to measure the capacity of the facilities to pond water.

MANAGING RUNOFF THROUGH GREEN INFRASTRUCTURE

DEP has allocated $187 million in capital funds for FY12-FY15 to implement green infrastructure, primarily on city-owned property in combined sewer areas. DEP works with the Green Infrastructure Task Force to identify green infrastructure opportunities within priority tributary areas (Figure 1). Source controls installed at these locations include blue roofs, green roofs, bioswales, bioretention, porous pavement, subsurface detention infrastructure, among other types of structural facilities designed to manage stormwater runoff. Background information on the specific design and monitoring plans for these source controls can be found in *The NYC Green Infrastructure Plan 2011 Update*.

2011 Monitoring Activities

This report summarizes initial monitoring results and preliminary observations made in 2011 for a number of individual source controls (Table 1). In general, the purpose of the monitoring effort is to: a) evaluate the effectiveness of various green infrastructure practices at managing the 1-inch rainfall event, and b) provide data that will allow DEP to extrapolate the runoff reduction benefits on a large scale. Specifically, the stormwater pilot monitoring aims to evaluate the effectiveness of each of these source controls at reducing the volume and/or rate of stormwater runoff from the drainage area through measuring quantitative aspects like source control inflow and outflow rates (Table 2), as well as qualitative issues like maintenance requirements, appearance, and community perception.

Quantitative monitoring was conducted primarily through remote monitoring equipment, such as pressure transducer water level loggers in conjunction with weirs or flumes to measure flows (Figure 2). This equipment monitored aspects of source control performance at a regular interval, typically 5 minutes. Site visits were conducted regularly to download and maintain this equipment, as well as assess qualitative monitoring aspects. Monitoring equipment setups at each site were designed in an attempt to evaluate the major functional elements of each source control. Rain gauges and/or weather stations were installed at some pilot locations to collect more locally-accurate weather data. On-site testing and calibration efforts included infiltration tests and metered discharges (through hydrant testing) to calibrate flow monitoring equipment and assess the validity of assumptions used in pilot performance analysis.

Figure 1. The location of green infrastructure pilots that are currently being monitored in priority CSO watersheds across the City.

Table 1. Pilots and Impervious Area Managed at each Monitoring Site

Green Infrastructure Application	Site	Source Control	Impervious Area Managed (ft²)
Right-of-Way (ROW)	Autumn Avenue	Enhanced Tree Pit	2,250
	Blake Avenue	Enhanced Tree Pit	2,175
	Ridgewood Avenue	Enhanced Tree Pit	4,420
		Street-Side Infiltration Swale	4,420
	Union Street	Enhanced Tree Pit	1,680
		Street-Side Infiltration Swale	2,230
	Eastern Parkway	Street-Side Infiltration Swale	19,880
	Howard Avenue	Street-Side Infiltration Swale	6,630
	99th Avenue	Street-Side Infiltration Swale*	3,300
	North & South Conduit	Bioretention	81,870
	Shoelace Park	Bioretention*	43,000
On-Site	Bronx River Houses	Bioretention (5)	18,570
		Blue Roof: Trays*	1,640
		Subsurface Perforated Pipe System*	13,600
		Subsurface Stormwater Chambers	3,950
	Canarsie Parking Lot	Bioretention (3)*	10,050
	Far Rockaway Parking Lot	Bioretention*	8,900
		Porous Asphalt	6,380
		FilterPave	4,260
	Spring Creek Parking Lot	Wet Meadow	14,000
	Metropolitan Avenue	Blue Roof: Trays	10,680
		Blue Roof: Modified Inlet	5,250
		Blue Roof: Check Dams	5,890
	PS 118	Blue Roof: Check Dams	3,500
		Green Roof	3,500
		Total	**282,025**

* Monitoring data to be included in future updates

Future Monitoring Activities

Construction and installation of monitoring equipment will be completed for five additional pilot installations by Spring 2012, and the monitoring results will be added to future reports. Further analysis of 2011 monitoring data is underway and will also be included in future reports. This effort is expected to help improve designs, develop metrics to better compare source controls, and incorporate detention/retention factors into citywide assessments of CSO reduction alternatives.

In addition, water quality sampling is being conducted at some of the pilot locations to evaluate the ability of these source control practices to remove pollutants of concern. Lastly, performance monitoring will provide an opportunity to evaluate maintenance requirements and design features (e.g., underdrains) and to make adjustments, where necessary, to optimize performance.

Table 2. Summary of Quantitative Monitoring Parameters at Pilot Sites

	Water Quantity					Weather					Water / Soil Quality				
Constructed Pilots	Inflow	Outflow	Infiltr.	Soil Moisture	Stage	Evap.	Rainfall	Wind	Relative Humidity	Solar Rad.	Diesel/ Gas	Nutrients, TSS, TOC, Salts	Metals	Soil Sampling	Infiltrated Water Sampling
Enhanced Tree Pits															
Autumn Ave.			○	●	●		●				●	●	●	●	●
Blake Ave.	○		○	●	●		●				●	●	●	●	●
Ridgewood Ave.	○		○	●	●		●				●	●	●	●	●
Union St.	○		○	●	●		●				●	●	●	●	●
Street-Side Infiltr. Swales															
Eastern Parkway	○		○	●	●		●				●	●	●	●	●
Howard Ave.	○		○	●	●		●				●	●	●	●	●
99th Ave.			○	●	●		●				●	●	●	●	●
Ridgewood Ave.	○		○	●	●		●				●	●	●	●	●
Union Ave.	○		○	●	●		●				●	●	●	●	●
Bioretention (ROW)															
North & South Conduit	●	●	●		●		●				●	●	●	●	●
Shoelace Park	●	●	○				●				●	●	●	●	
Bronx River Houses															
Blue Roof: Trays	○	○			●	●	●	●	●	●					
Bioretention (5)	●/○	●			●		●					●		●	
Sub. Stormwater Chambers	●	●					●				●	●	●		
Sub. Perforated Pipe System	●	●					●				●	●	●		
DOT Parking Lots															
Canarsie Bioretention (3)	●		○	●	●		●				●	●	●	●	●
Far Rockaway Bioretention	●		○	●	●		●				●	●	●	●	●
Far Rockaway Porous Asphalt and FilterPave	○	●					●				●	●	●		
Spring Creek Wet Meadow	●	○	○	●	●		●				●	●	●	●	
Roof Top															
Metropolitan Ave.	○	●				●	●	●	●	●					
PS 118-Green & Blue Roof	●	●				●	●	●	●	●		●	●		

● = Direct Measurement ○ = Calculated Value

Note: Infiltration and evaporation data not used in the analysis for this report. Water quality and soil quality monitoring will start in 2012.

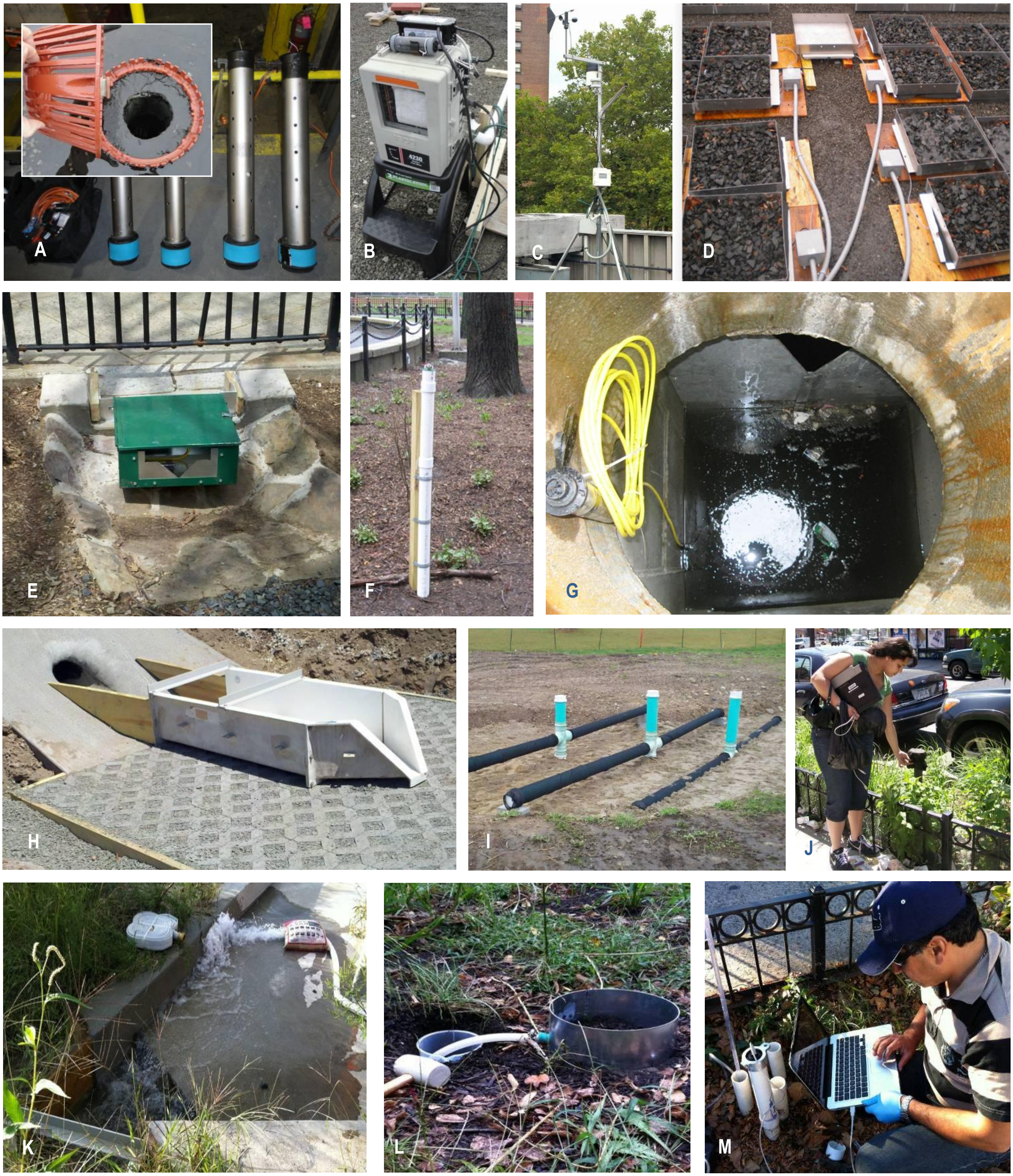


Figure 2. A diversity of equipment and sampling techniques were used at each site including: (A) Roof drain inserts, (B) ISCO 4230 Bubbler Flow Meter**;** (C) weather station; (D) Arlyn Series 320D-CR Scales and Data Logger; (E) V-notch weir and pressure transducer; (F) stage gauge; (G) water level logger and weir plate; (H) H-flume; (I) water quality sampling wells; (J) street side monitoring well; (K) hydrant testing for curb loss estimates and equipment calibration; (L) infiltration tests; and (M) piezometers.

Information Included in this Report

The remainder of this report provides a summary of the available 2011 stormwater monitoring results. The information presented is organized by pilot type and site as follows:

- Jamaica Bay Enhanced Tree Pits and Street-Side Infiltration Swales
- North & South Avenues Conduit Bioretention
- Bronx River Houses Bioretention and Subsurface Storage
- Far Rockaway Park & Ride Facility Porous Pavement
- Spring Creek Wet Meadow
- Metropolitan Avenue Blue Roof
- PS 118 Blue Roof and Green Roof

Each of these summaries is divided into three sections: Pilot Overview, 2011 Monitoring Results, and Summary. The Overview describes the pilot site and basic monitoring design and equipment. A figure illustrating site layout and a table of site metrics and storm characteristics are provided. Both show that a wide range of storm events with varying characteristics have been analyzed. The metrics are defined as follows:

Impervious Area Managed—the square footage of roads, rooftop, and other impervious surfaces draining to each source control.

Drainage Area (DA): Green Infrastructure (GI) Footprint—the ratio between the impervious area managed and the source control's surface area.

# of Storms—the number of individual storm events with a depth greater than 0.1 inch included in the analysis for this report.

Storm Depth—the total amount of rain during an event measured in inches; presented here as a range.

Peak Intensity—the highest rate of rainfall as measured over a 5-minute interval (in/hr) during an event; presented here as a range.

Storm Duration—total time from the beginning to the end of a rain event; presented here as a range.

Performance results are presented in the 2011 Monitoring Results section for each pilot analyzed. A brief narrative is supported by an example hydrograph and one or more pilot performance charts. The hydrographs are presented in two parts. The lower graph generally shows source control inflow and outflow (gallons per minute) for the duration of a single storm event. Outflow is a direct measure of flow in the outlet pipe, which excludes losses via other mechanisms (e.g. infiltration). Water level is shown, in some cases, as an indication of runoff storage within the source control and of overall system performance. The corresponding cumulative rainfall depth and intensity of that event is shown in the upper graph.

The performance charts show the percent volume retained and, in some cases, peak flow reduction by each source control for all storm events including those greater than 1 inch. Each dot represents a single storm event. Volume retention is defined as the portion of inflow into the source control practice that is not discharged to the sewer system. Peak flow reduction is the difference between the highest measured inflow and outflow rates expressed as a percentage.

The last portion of each pilot summary is a listing of findings to date and future monitoring activities for each pilot.

A summary of anticipated future monitoring activities and analysis for all pilot source controls is included at the end of this report.

Enhanced tree pits, like the one installed here at Ridgewood Avenue, are street-side source controls that capture, treat, and infiltrate stormwater at existing curb inlets.

JAMAICA BAY ENHANCED TREE PITS AND STREET-SIDE INFILTRATION SWALES

Pilot Overview

There are two designs for source control pilots installed in the right-of-way: enhanced tree pits (ETP) and street-side infiltration swales (SSIS). Constructed within the sidewalk areas adjacent to the roadway, both designs are similar. ETPs are 20 feet long, with an engineered soil layer underlain by gravel, recycled glass, or storage chambers. SSISs are 40 feet long, and only have an engineered soil substrate. Water is diverted from the gutter into the source controls through newly-constructed inlets, modified inlets, or curb cuts. Water ponds in the system and is taken up by plants, filters through media, infiltrates, or overflows back into the drainage system. Monitoring devices used include pressure transducers, piezometers, soil moisture sensors, and rain gauges.

Example design of a street-side infiltration swale.

Monitoring Site Summary

Green Infrastructure Site	Impervious Area Managed (ft^2)	DA:GI Footprint	# of Storms	Storm Depth (in)	Peak Intensity (in/hr)	Storm Duration (hrs)
Autumn Ave ETP	3,948	39	13	0.14-2.06	0.24-1.80	0.1-52
Blake Ave ETP	2,176	22	17	0.10-3.14	0.24-4.68	0.8-61
Ridgewood ETP	4,420	44	17	0.23-4.13	0.12-1.80	3.5-81
Union Street ETP	1,679	17	17	0.10-3.14	0.24-4.68	0.8-61
Eastern Parkway SSIS	19,883	99	17	0.10-5.11	0.12-2.88	0.08-53
Howard Ave SSIS	6,630	33	17	0.11-5.15	0.24-5.28	0.75-53
Ridgewood SSIS	5,513	28	12	0.23-4.13	0.12-1.80	3.5-81
Union Street SSIS	2,231	11	17	0.10-3.14	0.24-4.68	0.8-61

Data Collection Period: Sept 1- Dec 1, 2011

2011 Monitoring Results

An example hydrograph shows inflow rates and subsurface storage for a 1.5-inch storm event (Chart 1). Volume retention performance of four ETP and three SSIS pilots show a high level of volume retention for most small storm events except for the installations at Eastern Pkwy and Howard Ave. (Chart 2).

Summary

Results show complete capture of runoff for 1-inch or less rain in most cases; however:

- Early 2011 results (not shown here) were not as good as those provided due to frequently observed inlet clogging. This issue was resolved by installing open curb cuts;
- Relatively low Eastern Pkwy ETP performance is likely due to the very large watershed area compared to source control area; and
- Relatively poor capture at the Howard Ave. SSIS site is likely due to the steep, short slope and may be a function of the catch basin design. The installation of small check dams just before the catch basin may improve overall capture rates.

These were the first fully-permitted, first-generation green infrastructure installations in the City. Additional retrofits planned for Spring 2012 will help improve capture rates and allow for greater monitoring capability.

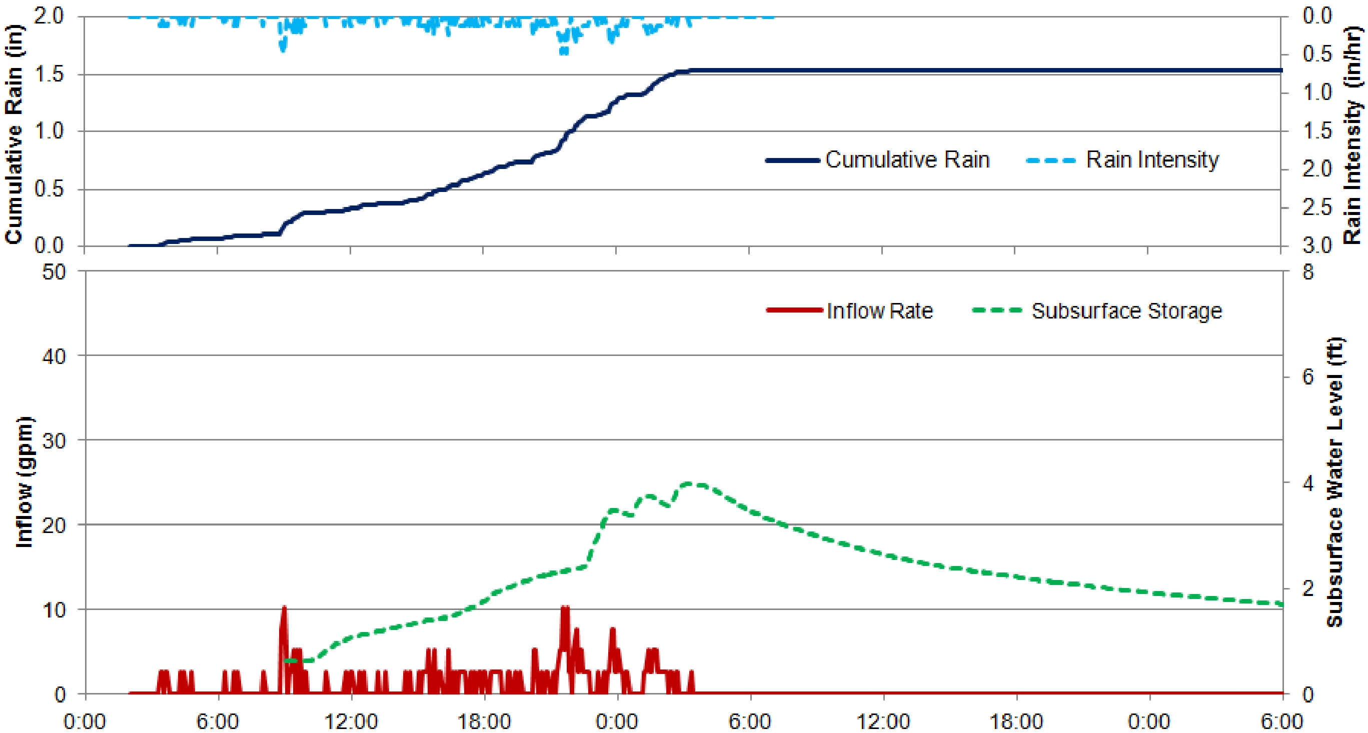
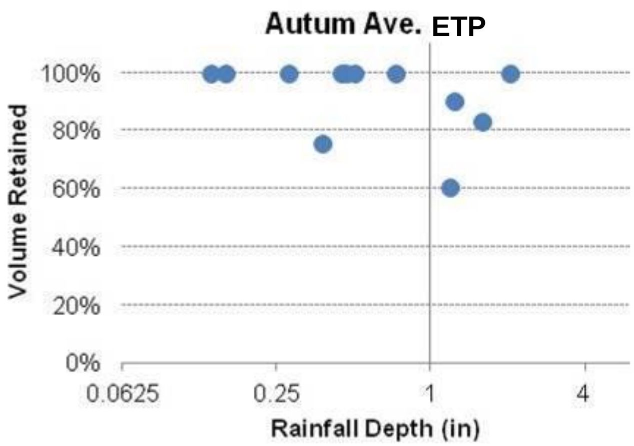
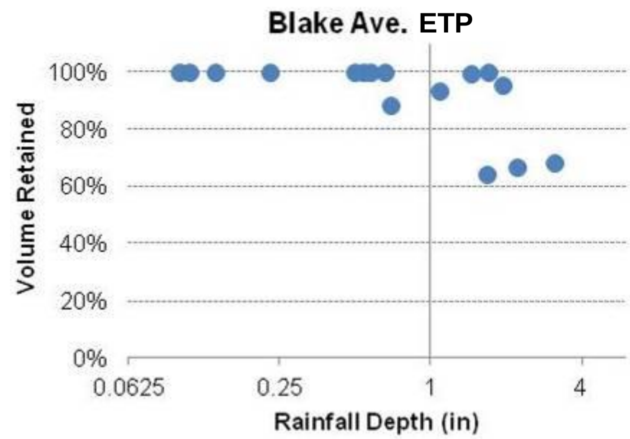
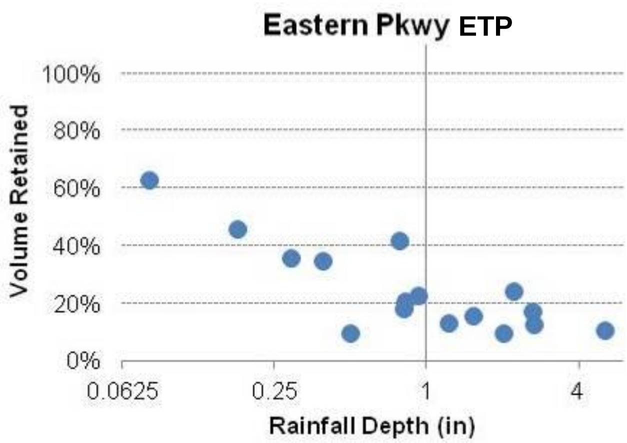
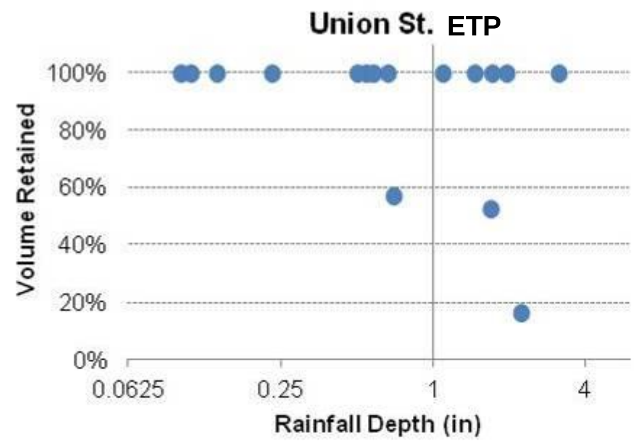


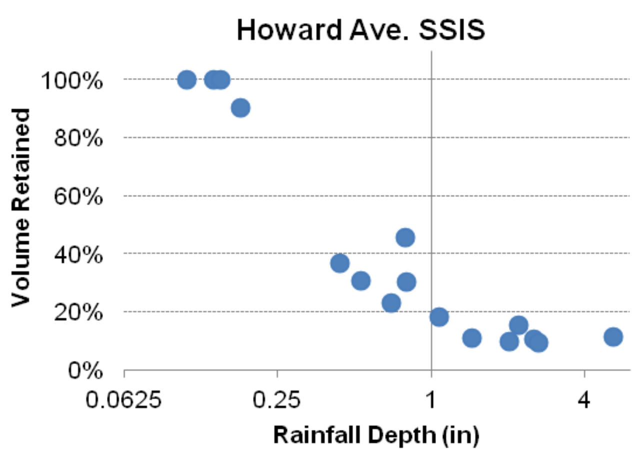
Chart 1. Hydrograph showing enhanced tree pit performance during 1.5–inch storm at Blake Ave on Dec 7, 2011.

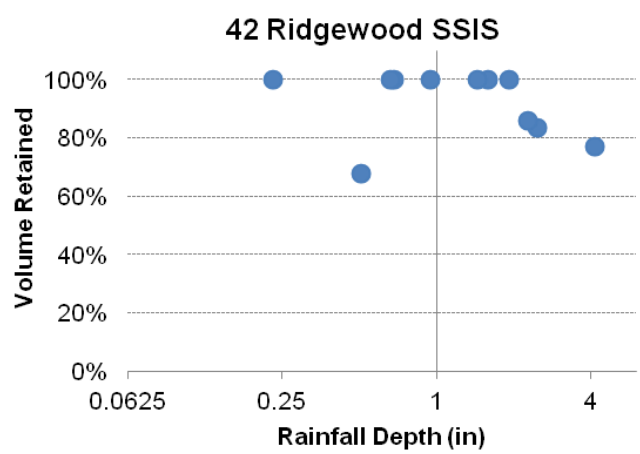












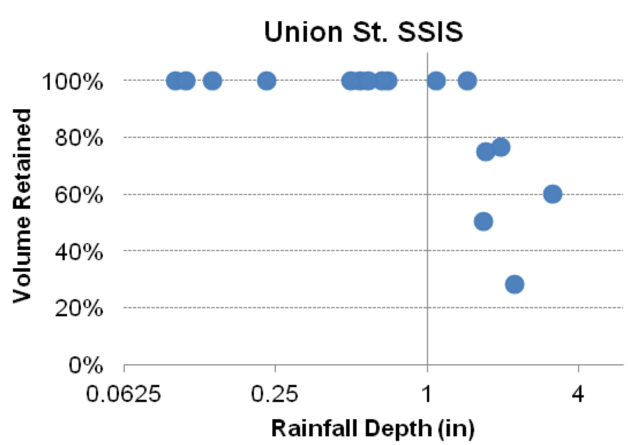


Chart 2. Comparison of enhanced tree pit and street-side infiltration swale performance across all sites monitored in 2011 (each dot represents a single storm event; however, overlap may occur for storms with similar depths).

The bioretention facility at North and South Conduit Avenues receives stormwater runoff from curb inlets and curb cuts on surrounding roadways. To measure the amount of flow entering the pilot, temporary H-flumes were installed at inlet locations.

NORTH & SOUTH CONDUIT AVENUES BIORETENTION

Pilot Overview

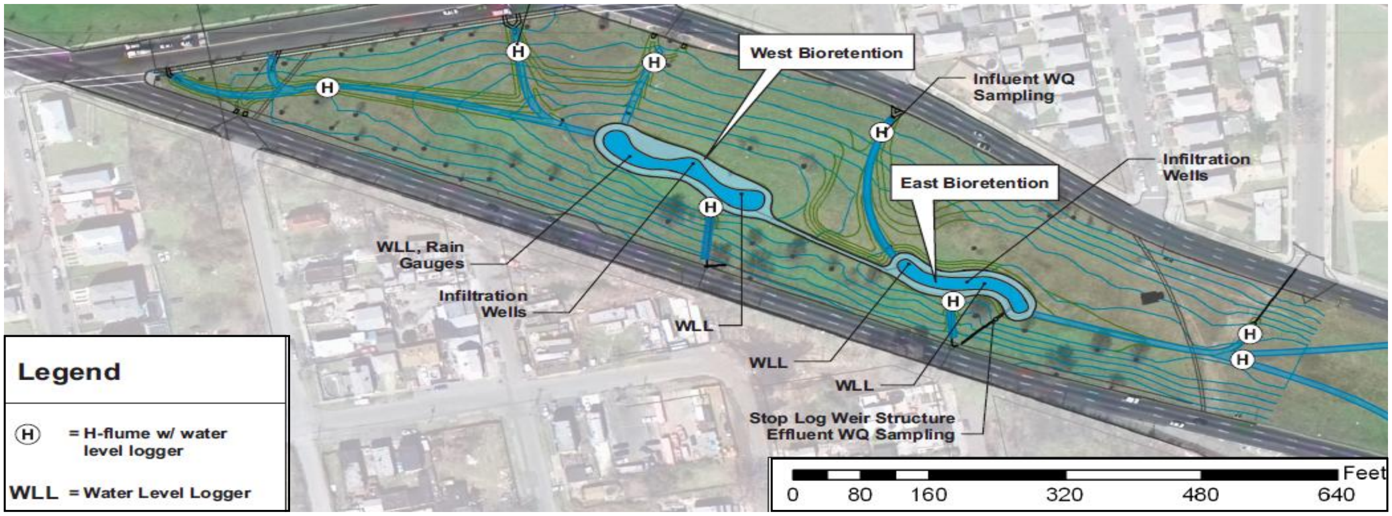
This pilot includes a pair of connected, vegetated bioretention areas located within the median of the North and South Conduit Avenues. Modifications to the road drainage system (i.e., curb cuts, inlet modifications, and catch basin modifications) were required to direct runoff into the facilities via pipes or vegetated swales. Inflow is measured using H-flumes at each of the inlet channels. The bioretention areas are connected via a surface overflow channel and a subsurface underdrain. A grated outlet structure serves as a surface overflow for the entire system. Combined underdrain and surface overflow leaving the system in a single pipe is measured with a pressure transducer, water level logger, and weir plate.

Unique to this pilot is the installation of a stop log weir structure along the outlet pipe used to investigate the effect of an underdrain on system performance.

Monitoring Site Summary

Metric	Site Data
Impervious Area Managed (ft²)	81,870
DA:GI Footprint	7:1
# of Storms	20
Storm Depth (in)	0.1-7.8
Peak Intensity (in/hr)	0.2-4.9
Storm Duration (hrs)	0.2-53

Data Collection Period: Aug 2011- Dec 2011.



Map showing monitoring locations at the North and South Conduit pilot.

2011 Monitoring Results

An example hydrograph comparison of inflow and outflow rates and surface storage is shown in Chart 3 for a 1.1-inch storm event. A significant amount of storage occurred on the surface of this facility during this event, and no outflows were observed following this event. Preliminary data indicate that for storm events less than two inches, the bioretention facility is providing 100% volume retention (Chart 4).

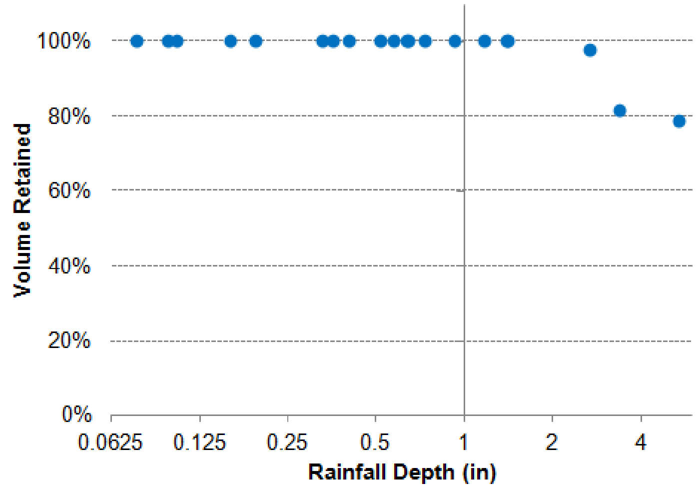


Chart 4. Bioretention performance across all storms monitored (each dot represents a single storm event; however, overlap may occur for storms with similar depths).

Summary

The bioretention appears to provide 100% retention for small storms. The median amount of time needed for the surface ponding to drain after a storm, or draw down duration, was approximately 7 hours. Of particular note:

- Monitoring and onsite tests show apparent infiltration losses along the conveyance swales; and
- Flow bypass at curb cuts has been observed, and modifications to minimize these losses are anticipated in 2012.

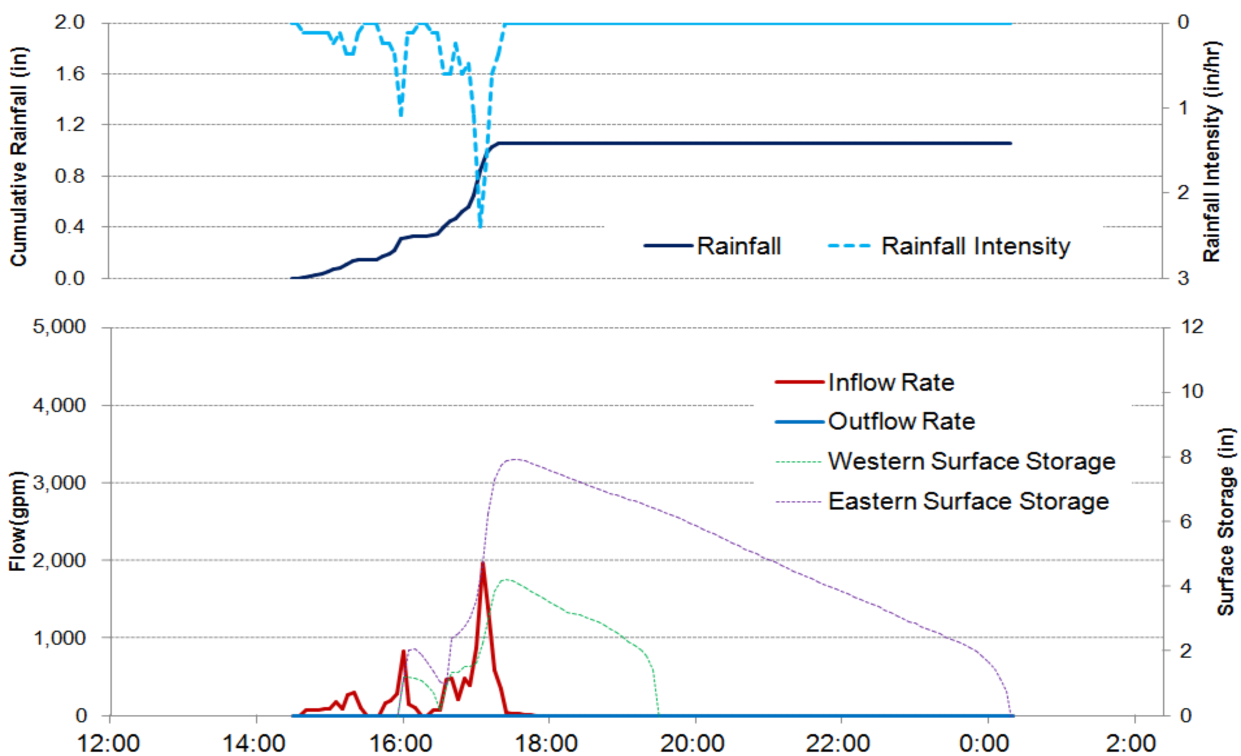
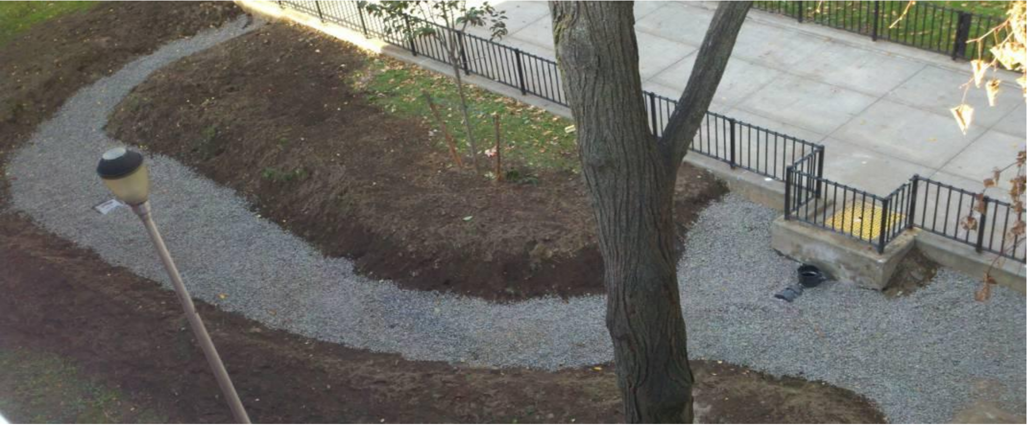


Chart 3. Hydrograph showing bioretention performance during 1.1– inch storm at North & South Conduit on Aug 9, 2011.



A view from the Bronx River Houses Community Center roof overlooks the installation of the gravel subsurface layer below one of the five bioretention facilties. The discharge from underdrains within the gravel is monitored in catch basins using water level loggers and weir plates.

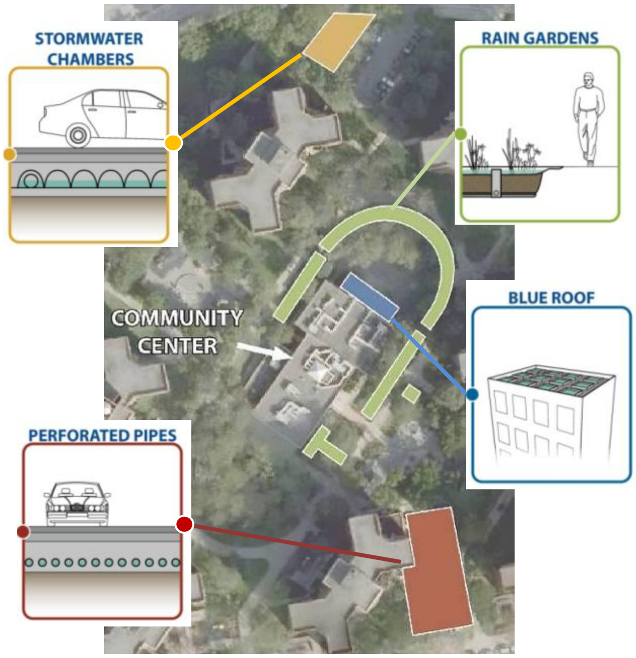
BRONX RIVER HOUSES BIORETENTION AND SUBSURFACE STORAGE

Pilot Overview

This site contains five bioretention facilities (referred to on-site as rain gardens) installed within the existing landscaping around the Community Center; a blue roof tray system installed at the Community Center; as well as two subsurface systems-stormwater chambers and perforated pipes-installed beneath the north and south parking lots, respectively. Monitoring analyses for this report include data from only the bioretention and stormwater chamber pilots.

Bioretention facilities constructed in open lawn areas provide surface, soil, and gravel storage for retention and detention, subsoil contact to promote infiltration, vegetation to increase evapo-transpiration, and an underdrain to prevent standing water. Inflow is measured with a weir box at one inlet and is calculated for the other inlets based upon rainfall, drainage area, and weir box measurements. Outflow is measured at the outlet of the underdrain system.

Catch basins direct runoff to the two subsurface pilots constructed under parking lots. These chambers and perforated pipe systems embedded in gravel provide storage capacity for detention and subsoil contact for seepage losses. Both systems discharge to the combined sewer system. Monitoring equipment in catch basins and at manholes measures inflow and outflow, respectively.



Green infrastructure installations at the Bronx River Houses.

Monitoring Site Summary

Metric	Site Data
Impervious Area Managed (ft^2)	Bioretention (5): 18,570 Chambers: 3,950
DA:GI Footprint	Bioretention: 6:1 to 20:1 Chambers: 5:1
# of Storms	Bioretention: 45 Chambers:43
Storm Depth (in)	0.1-4.9
Peak Intensity (in/hr)	0.1-5.4
Storm Duration (hrs)	0.3-122

Data Collection Period: May- Dec 2011

2011 Monitoring Results

Hydrograph comparisons of inflow and outflow rates indicate little to no outflow from bioretention facilities during small storm events (Chart 5). Occasional outflow was observed during deep or intense rainfall events.

All of the bioretention facilities, while variable in performance, have shown 80-100% volume reduction for most storms less than 1 inch (Chart 6). This indicates a relatively high percentage of soil retention with subsequent evapotranspiration and/or infiltration. Surface storage in each bioretention allows for slow seepage.

The subsurface stormwater chambers show little to no outflow during large events, as shown in Chart 7, for a 4.8-inch storm.

For most events less than 1-inch, the stormwater chambers have shown 100% volume reduction (Chart 8). For events larger than 1 inch, some outflows are observed; although peak outflows are reduced compared to rate of inflow or rate of runoff without controls (Chart 9).

Further monitoring of vegetative performance and evaluation of maintenance activities for the bioretention practices is anticipated in 2012, particularly related to the removal of vegetative debris and mulch. The performance evaluation of the second subsurface storage system, the perforated pipe system, is ongoing. In addition, monitoring data comparing different drainage layer types from the blue roof system are currently being evaluated.

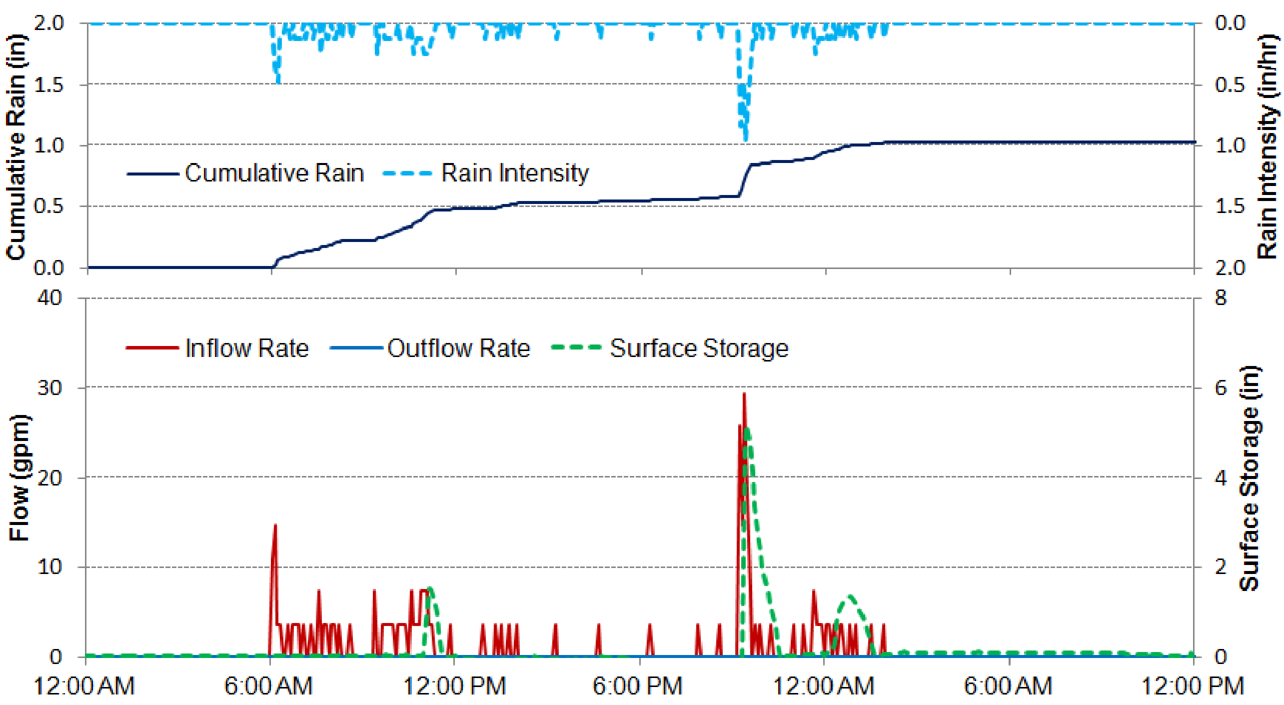


Chart 5. Example hydrograph showing performance of Bioretention #3 at the Bronx River Houses during a 1-inch storm event on Oct 19, 2011.

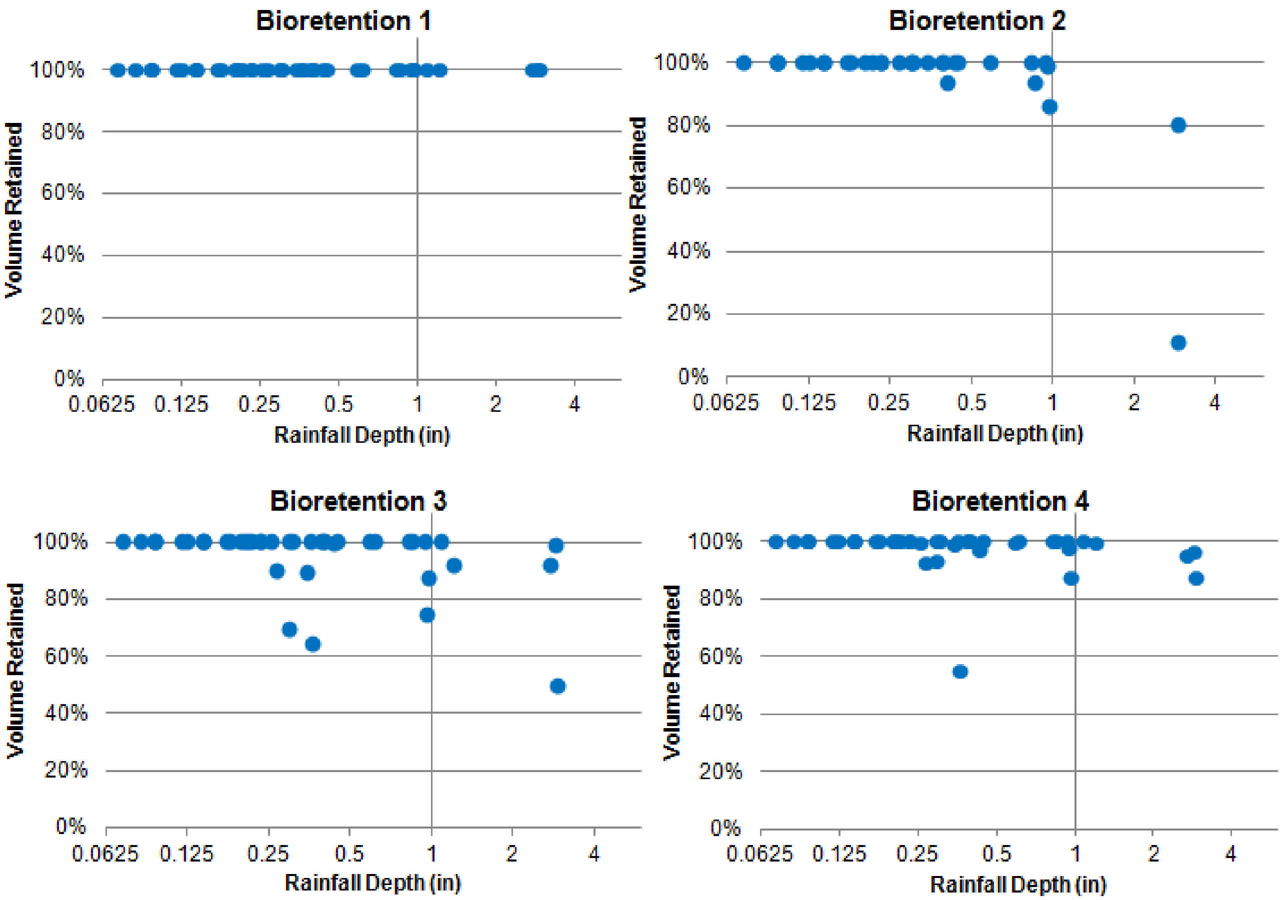


Chart 6. Retention performance at four of five bioretention installations at the Bronx River Houses for all storms monitored (each dot represents a single storm event; however, overlap may occur for storms with similar depths).

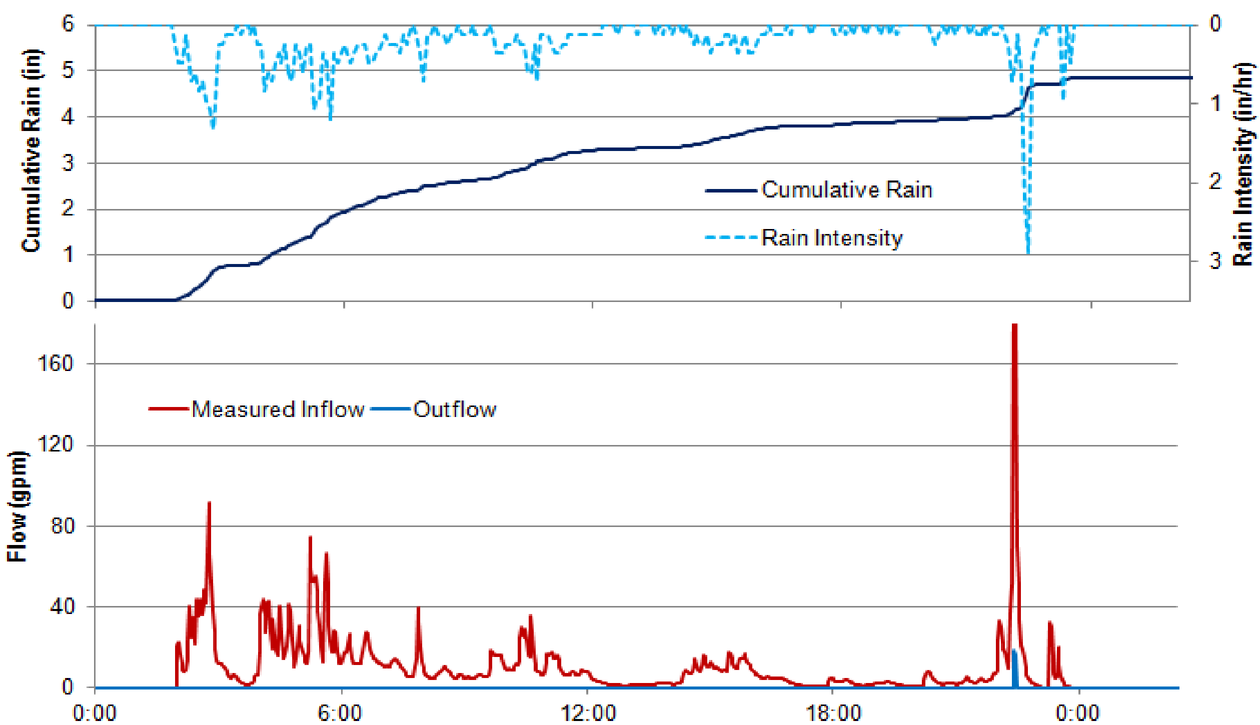


Chart 7. Example hydrograph showing performance of subsurface stormwater chambers at the Bronx River Houses during a 4.8-inch storm on Aug 15, 2011.

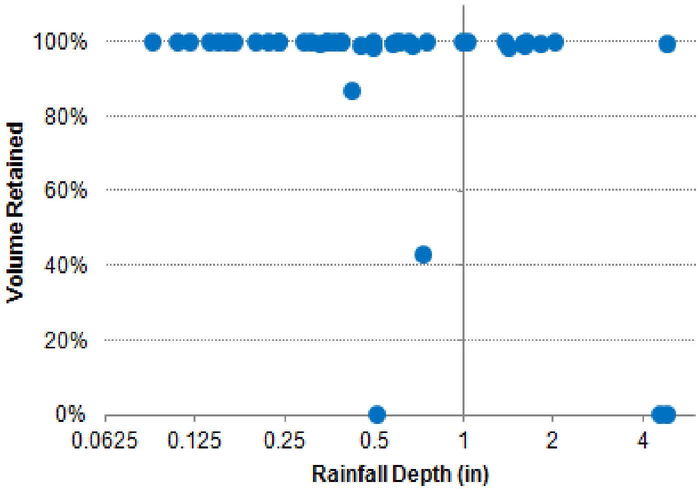


Chart 8. Subsurface stormwater chamber retention performance for all storms monitored (each dot represents a single storm event; however overlap may occur for storms with similar depths).

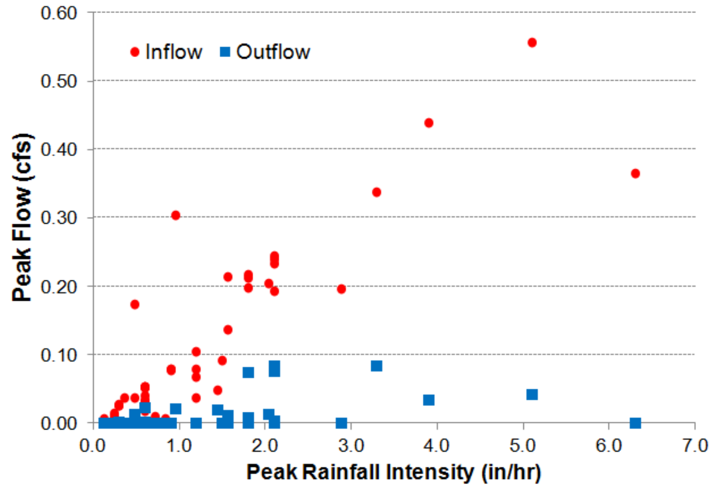


Chart 9. Storage chamber peak control performance for all storms monitored (each point represents a single storm event; however overlap may occur for storms with similar depths).

Summary

Key observations on bioretention performance to date include:

- Bioretention areas are retaining much of the water they receive;
- Most outflow is associated with storms that are greater than 1 inch;
- For storms greater than 1 inch, bioretention has demonstrated significant retention up to 4 inches;
- The median surface drawdown duration is approximately 5 minutes;
- Curb cuts are not 100% effective at runoff capture; in fact, up to 40% by-pass is estimated under certain conditions; and
- Leaf and litter pickup can be challenging. Leaf litter can impede inflow and reduce runoff capture to a source control.

Initial monitoring results for the subsurface stormwater chamber system indicate:

- The subsurface system at this location is effective at capturing the runoff and there appears to be no bypass of the system;
- The system does not generate consistent outflow; and
- Outflow rates have been below design target (0.25 cfs) and outflow is typically ending before the storm ends (median drawdown duration is equivalent to 0 hours).

Designed specifically for monitoring, vertical barriers were installed between adjacent installations of pavement at the Far Rockaway pilot in order to isolate subsurface flows. Asphalt berms were used on the surface to separate runoff between each of the pavement areas.

FAR ROCKAWAY PARK & RIDE FACILITY POROUS PAVEMENT

Pilot Overview

Constructed in a Department of Transportation (DOT) Park & Ride parking lot, this porous pavement pilot contains adjacent, but separate, sections of standard asphalt, porous asphalt, and FilterPave^{TM} (a proprietary porous material). The subsurface of the porous asphalt and FilterPave^{TM} sections are designed with 18 inches of gravel storage and an underdrain pipe. The native soils below are predominately sand with permeability rates of 6-7 inches per hour.

Monitoring equipment has been installed at the outlet of each underdrain pipe to quantify outflows for each section of porous pavement. Equipment has also been installed inside a manhole of the standard asphalt section to quantify its surface runoff contributions. Standard asphalt is being monitored for comparison, but is not intended to manage runoff. A bioretention facility was also installed at this site; although, monitoring of that pilot did not occur during 2011.

Arrangement of pavement types in the Far Rockaway parking lot.

Monitoring Site Summary

Metric	Site Data
Impervious Area Managed (ft^2)	Porous asphalt: 6,400 FilterPave^{TM}: 4,250
DA:GI Footprint	1:1
# of Storms	13
Storm Depth (in)	0.1-2.06
Peak Intensity (in/hr)	0.24-0.84
Storm Duration (hrs)	1.0-44.6

Data Collection Period: Oct - Dec 2011

2011 Monitoring Results

A comparative hydrograph of measured outflow from an example storm event for each of the pavement sections illustrates no outflow at underdrains from the porous asphalt and FilterPave™ sections while considerable outflow is observed from the standard pavement (Chart 10).

The porous asphalt and FilterPave™ sections have shown apparent 100% volume retention for all monitored storms (Chart 11). This suggests that the subsurface storage volume and underlying soil infiltration rates are able to capture all precipitation without discharging to the combined sewer. Monitoring of the standard asphalt also shows volume retention through surface ponding; further quality control of the accuracy of this data and potential sources of observed storage is being conducted.

Durability of each pavement pilot has been visually monitored. Surface wear, chipping, and rutting of the FilterPave™ surface have been observed and are under further investigation. No noticeable signs of wear have been observed in the porous asphalt section.

Closer inspection of the FilterPave™ surface during the monitoring period has revealed rutting and surface wear.

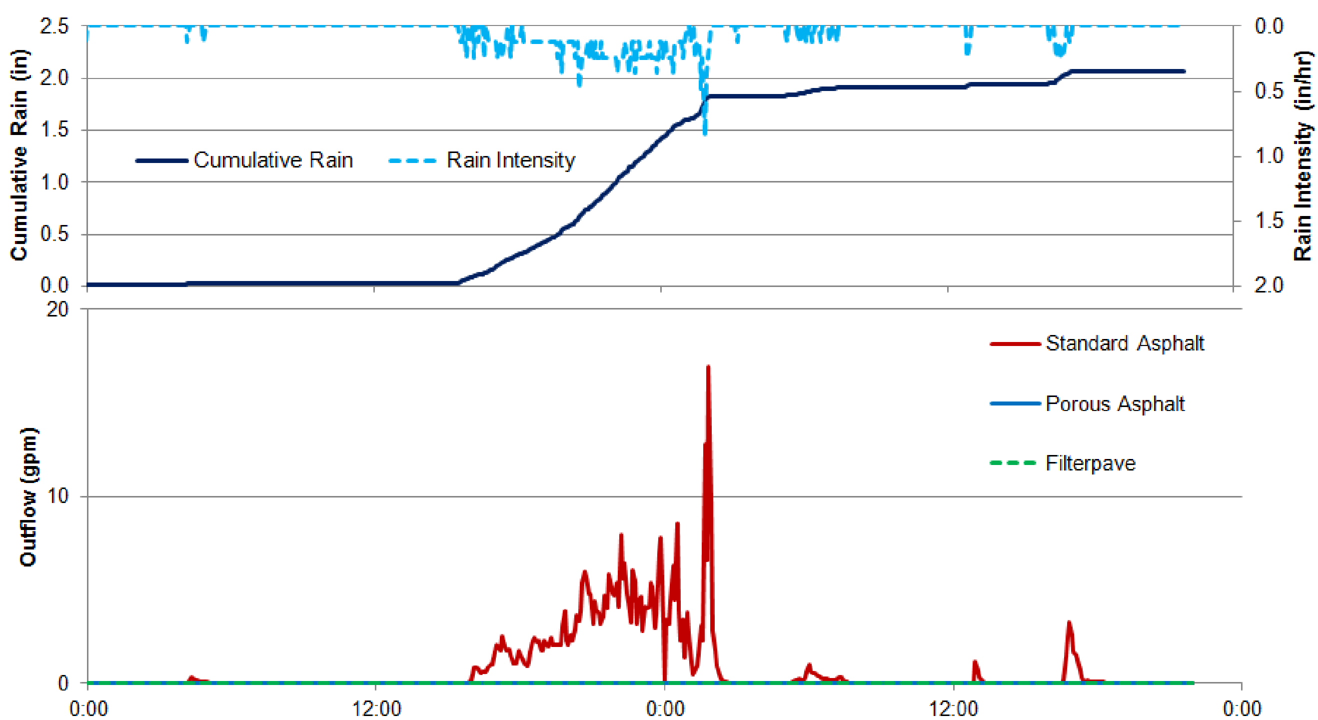


Chart 10. Example hydrograph comparing storm outflow by pavement type during a 2.1-inch storm at Far Rockaway on Nov 22, 2011.

Summary

Key observations to date include:

- The porous asphalt and FilterPave™ pavement pilots have apparently been able to retain and infiltrate all stormwater runoff volume of all monitored storms;
- To date, there has been no measured flow from the FilterPave™ and porous asphalt underdrain systems;
- On-site tests suggest porous asphalt may be generating some surface runoff under certain conditions. 2011 monitoring equipment only measured the underdrain flow and did not measure surface runoff. As a result, additional monitoring equipment was installed in January 2012 to quantify surface runoff from the porous asphalt section during larger storms, if any. Similar field tests do not indicate that surface runoff is occurring from the FilterPave™ section.

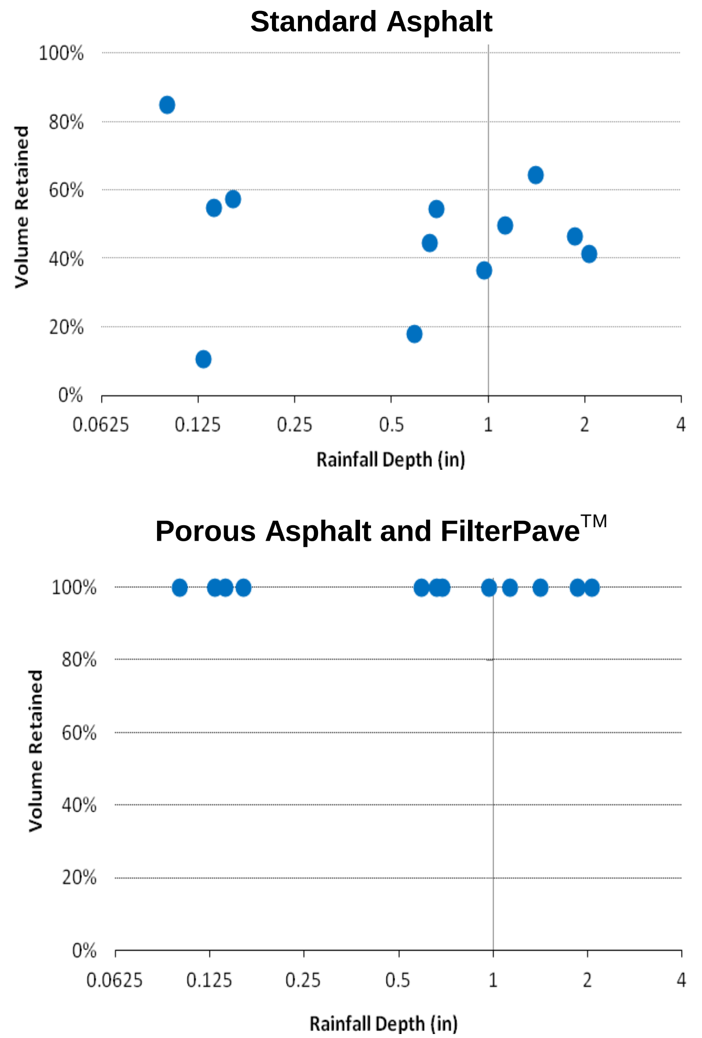


Chart 11. Runoff retention performance for specified pavement types (each dot represents a single storm event; however, overlap may occur for storms with similar depths).

Vegetation in the wet meadow pilot at the Spring Creek MTA Bus Terminal was specifically selected for tolerance to staturated conditions.

SPRING CREEK WET MEADOW

Pilot Overview

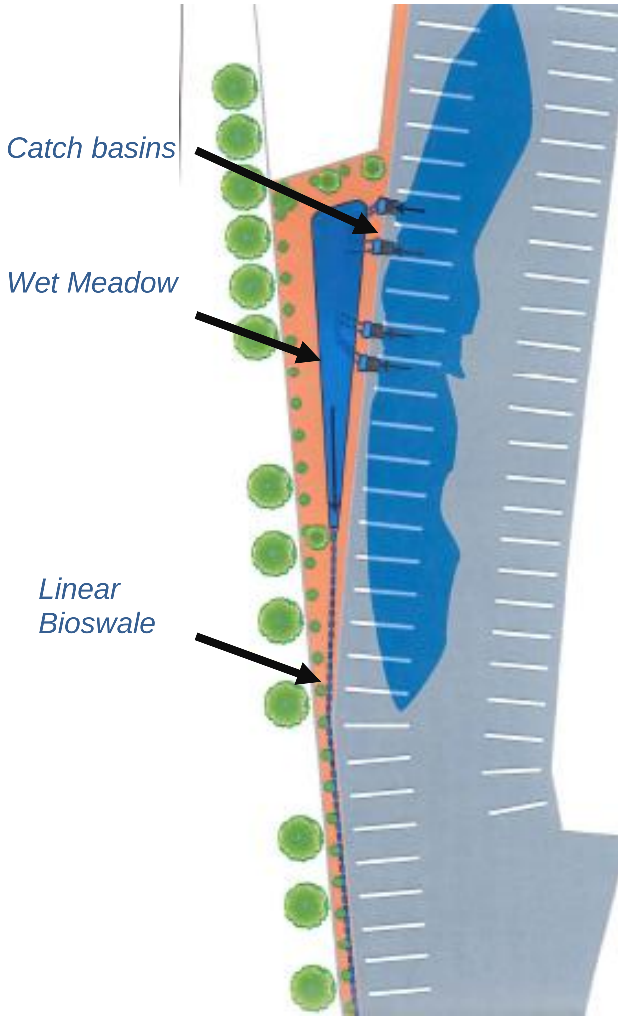
At the Spring Creek Metropolitan Transit Authority (MTA) bus terminal, a stormwater wetland (wet meadow), was constructed to manage runoff from the parking lot, which is conveyed to the source control through catch basins. A solar-powered groundwater pump maintains a permanent 1-foot deep pool to support indigenous wetland plants. Overflow from the wetland is directed into a linear bioswale designed to promote infiltration into the soil (e.g., sand and recycled glass subsurface layers).

Pressure transducers and v-notch weirs were installed to measure inflow and outflow conditions. On-site rain gauges and piezometers have also been deployed at this site to measure local rainfall and wetland storage volume. A sap flow meter was installed to monitor tree transpiration capacity.

Monitoring Site Summary

Metric	Site Data
Impervious Area Managed (ft^2)	14,000
DA:GI Footprint	5.4:1
# of Storms	13
Storm Depth (in)	0.14-2.06
Peak Intensity (in/hr)	0.24-1.80
Storm Duration (hrs)	0.1-52

Data Collection Period: Aug - Dec 2011



Stormwater runoff from the MTA parking lot is diverted to the wet meadow via perimeter catch basins. Excess water in the wet meadow overflows into an infiltrating bioswale.

2011 Monitoring Results

Chart 12 shows an example hydrograph comparing inflow and surface storage of the wet meadow during a 1.1-inch storm. Performance monitoring of the wet meadow shows apparent volume retention ranging between 30% and 100% for all storms (Chart 13).

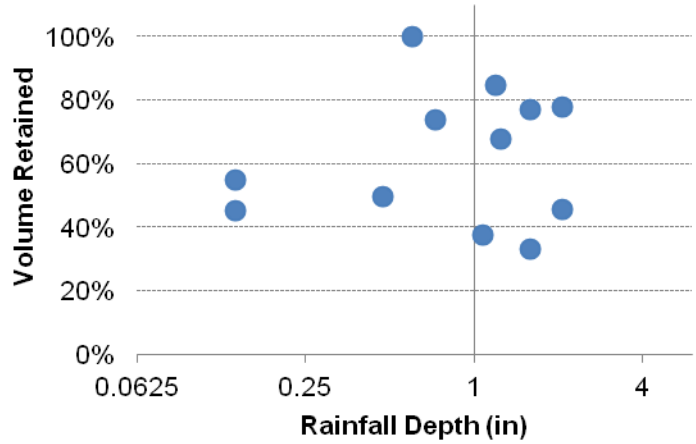


Chart 13. Volume retention performance at the MTA wet meadow pilot (each dot represents a single storm event; however, overlap may occur for storms with similar depths).

Summary

DEP is planning minor retrofitting at this site for 2012, which should result in a measurable increase in source control performance, as follows:

- The occasional, relatively low volume retention percentage at this site is likely due to parking lot topography, which directs runoff into existing dry wells. Additional effort is anticipated in 2012 to better define the drainage area to the practice and to address issues with the monitoring equipment. For example, the installation of check dams may reduce flows to the dry wells and siltation of overflow channels.
- The v-notch weir was often submerged due to consistently high water tables, which is partially a function of the solar-powered pump. A float sensor will be installed to regulate the pump and maintain a one foot water depth.

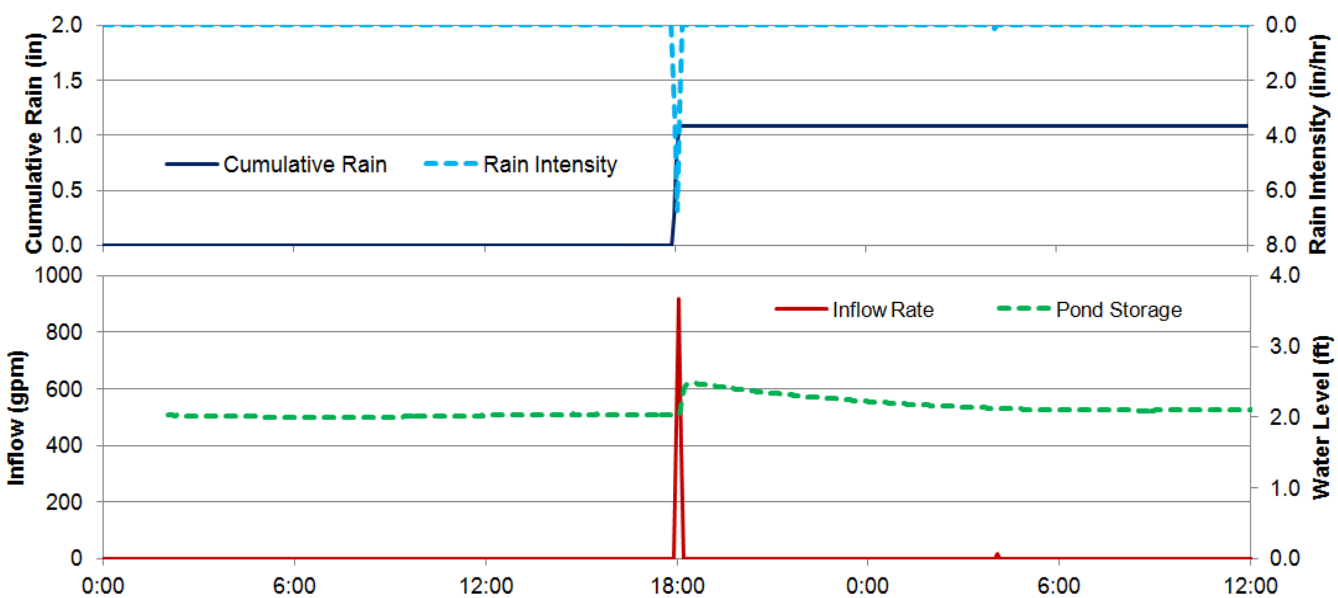


Chart 12. Example hydrograph showing wet meadow storage during a 1.1- inch storm on Aug 18, 2011.

At the Metropolitan Avenue pilot, three variations on blue roof designs are being monitored: modified outlet, check dams, and tray systems. Specially designed inserts were installed inside existing drain pipes in order to measure outflow.

METROPOLITAN AVENUE BLUE ROOF

Pilot Overview

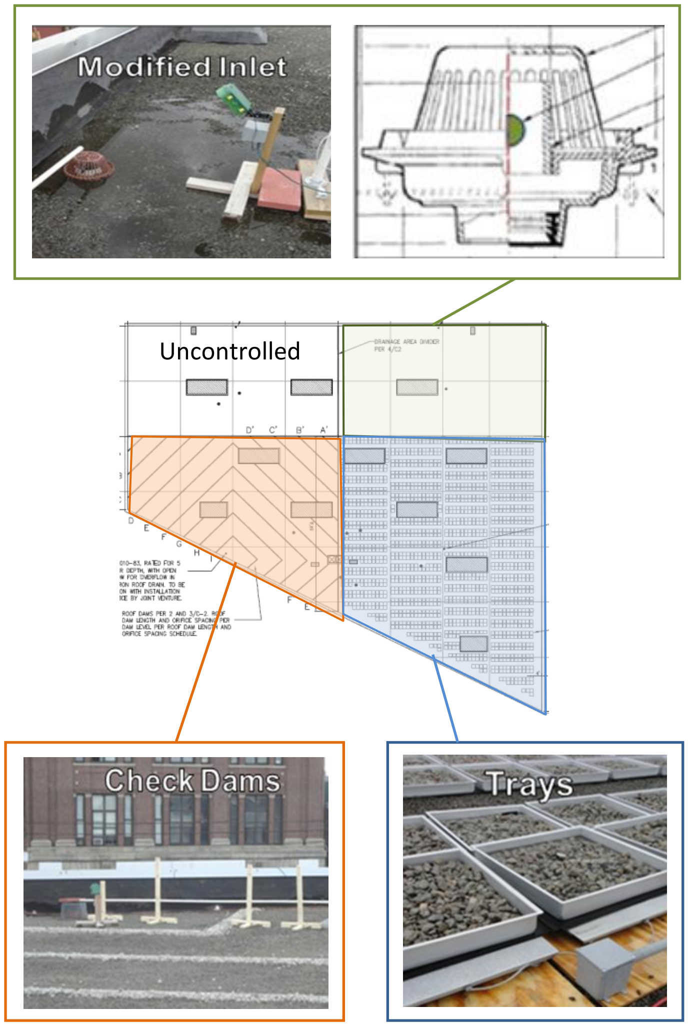
Three blue roof pilots were installed and are being monitored at a DEP storage facility on Metropolitan Avenue. The roof was segmented into four regions to test a modified inlet application (e.g., a roof drain providing flow restriction); a series of check dams installed around an existing inlet; a system of modular trays; and a comparable non-controlled area. Each variant design variant provides for temporary storage capacity during and immediately after rain events, as well as some opportunity for ultimate volume reduction through depression storage and evaporation.

In each monitored section, drain inserts are used to measure outflow rates. In addition, a weather station was installed to measure site-specific rainfall, wind, evaporation, and solar radiation.

Monitoring Site Summary

Metric	Site Data
Impervious Area Managed (ft^2)	Modified inlet:5,250 Check Dams:5,890 Trays:10,680
DA:GI Footprint	1:1
# of Storms	38
Storm Depth (in)	0.1-7.4
Peak Intensity (in/hr)	0.1-6.0
Storm Duration (hrs)	0.5-55

Data Collection Period: Apr - Dec 2011



The roof was divided into three pilot areas and a comparable uncontrolled reference area.

2011 Monitoring Results

An example hydrograph comparison of outflow rates for a 1.9-inch storm between the uncontrolled and three pilot sites show some detention of rainfall using check dams and trays (Chart 14). Retention performance charts show scattered results with trays providing 50% volume reduction for most storms while check dams and modified inlets are similar to uncontrolled conditions (Chart 15). Chart 16 shows the performance of the pilot to reduce peak flows across a range of rainfall intensities; trays and check dams appear to perform the best for low intensity storms. Median drawdown durations were as follows: 1.2 hrs (uncontrolled); 2.7 hrs (modified inlet); 5.8 hrs (check dams); and 7.8 hrs (trays).

Summary

Initial monitoring results indicate the following:

- All roof types (including uncontrolled) provide some level of retention and detention due to depression storage;
- Trays and check dams appear to be providing more detention than the uncontrolled and modified inlet;
- It is likely that the performance of the modified inlet is impacted by the lack of available rooftop storage due to a 2% roof slope; and
- All roof types drain to avoid nuisance ponding and make capacity available for next storm.

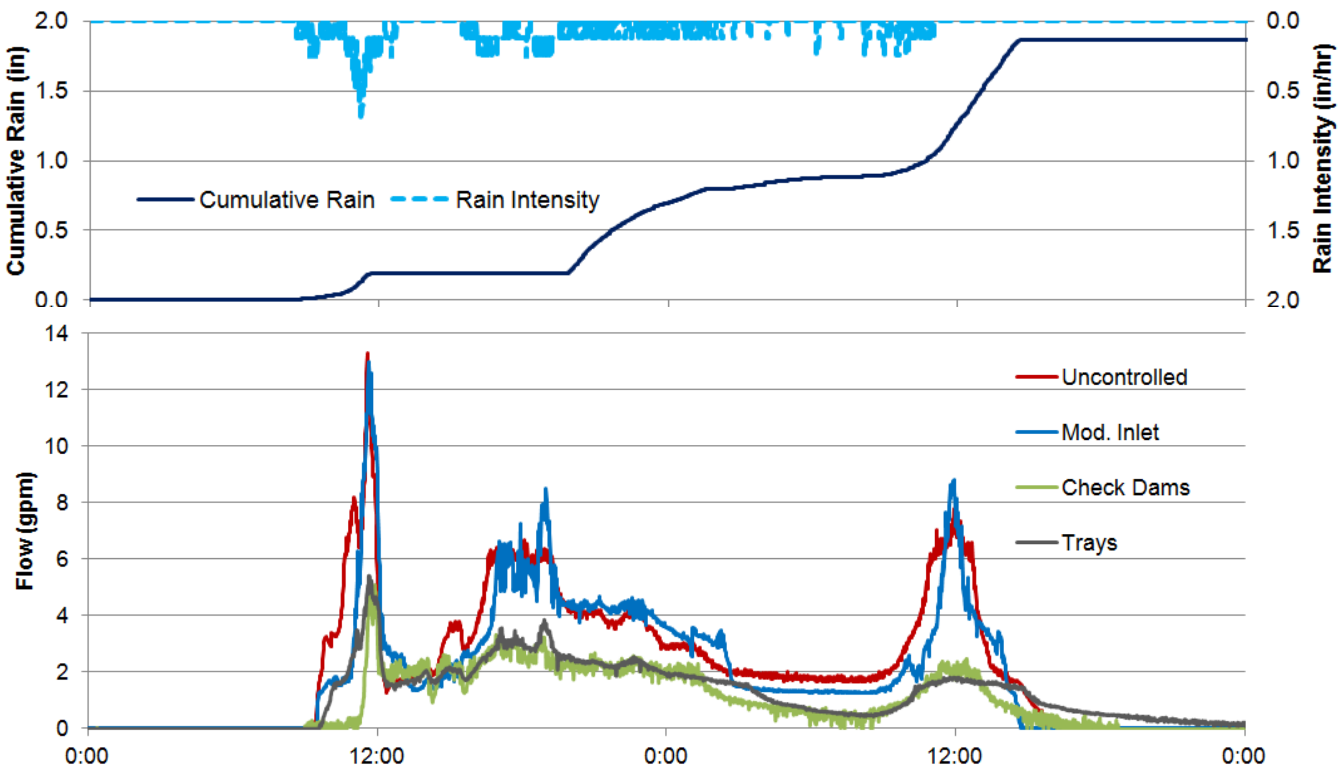


Chart 14. Example hydrographs from a 1.9-inch storm comparing three blue roof pilots against an uncontrolled area on Oct 29, 2011.

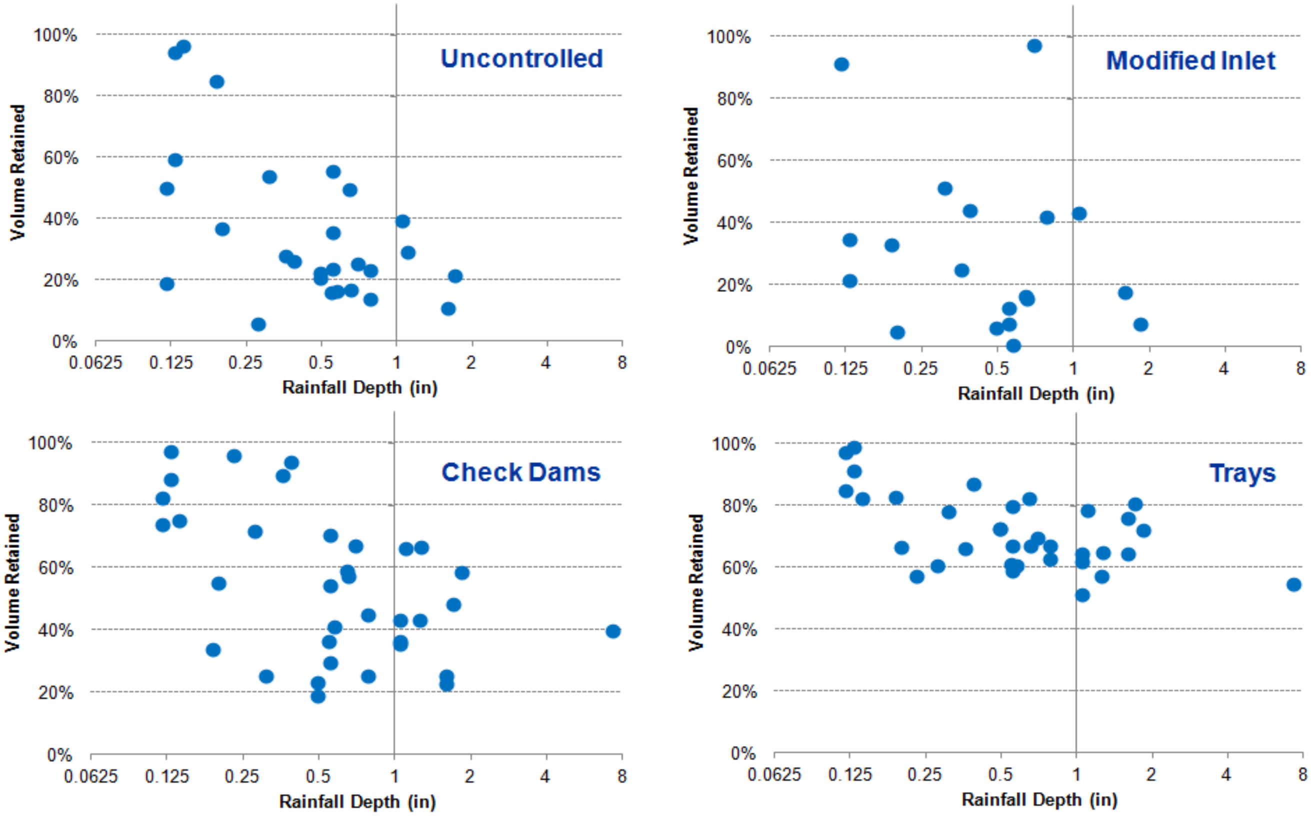


Chart 15. Volume retention performance of rooftop pilots (each dot represents a single storm event).

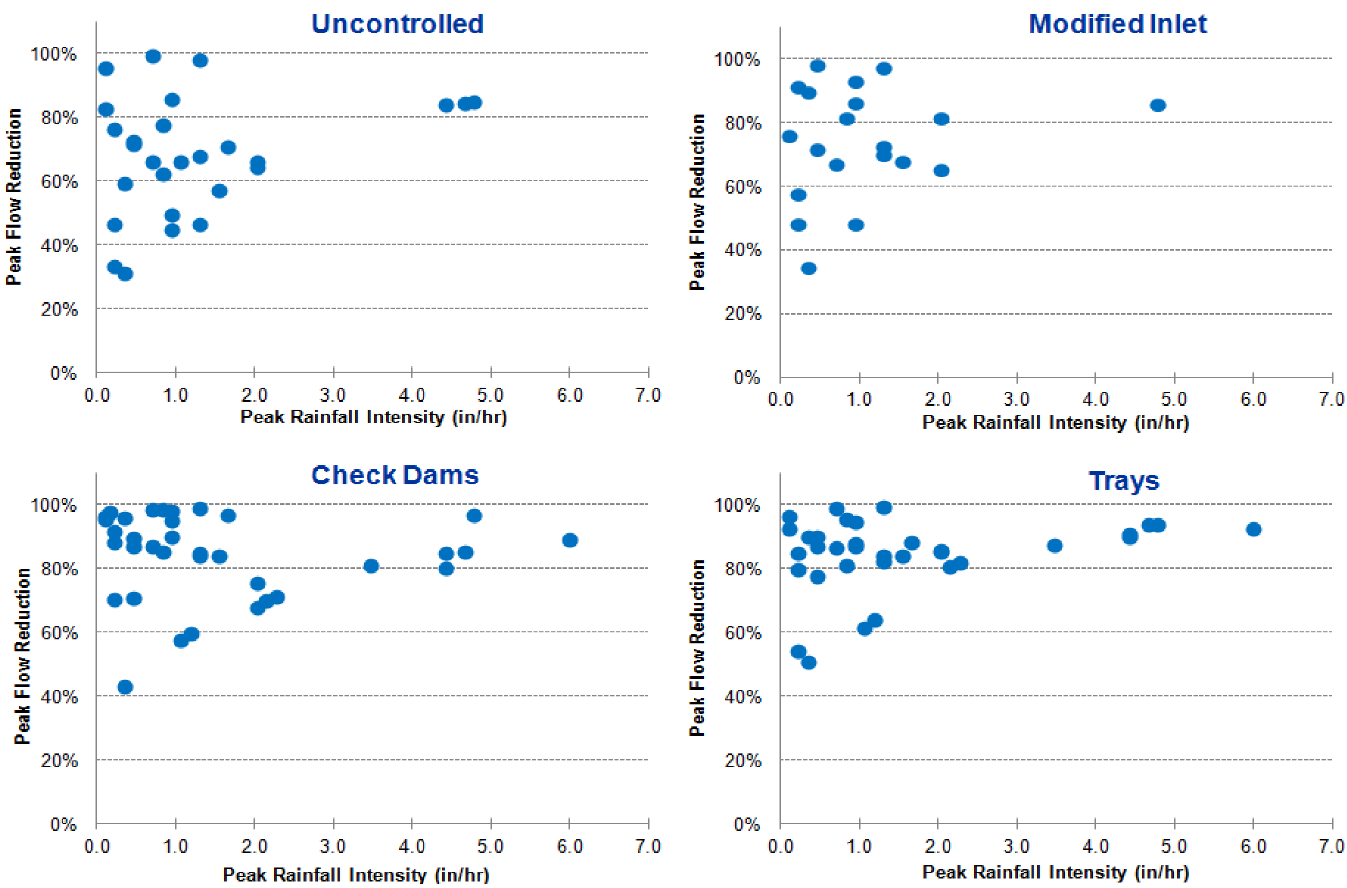


Chart 16. Peak flow reduction performance of rooftop pilots (each dot represents a single storm event).

At PS 118, two rooftop source controls—a green roof and blue roof—were installed and are currently being monitored.

PS 118 BLUE ROOF AND GREEN ROOF

Pilot Overview

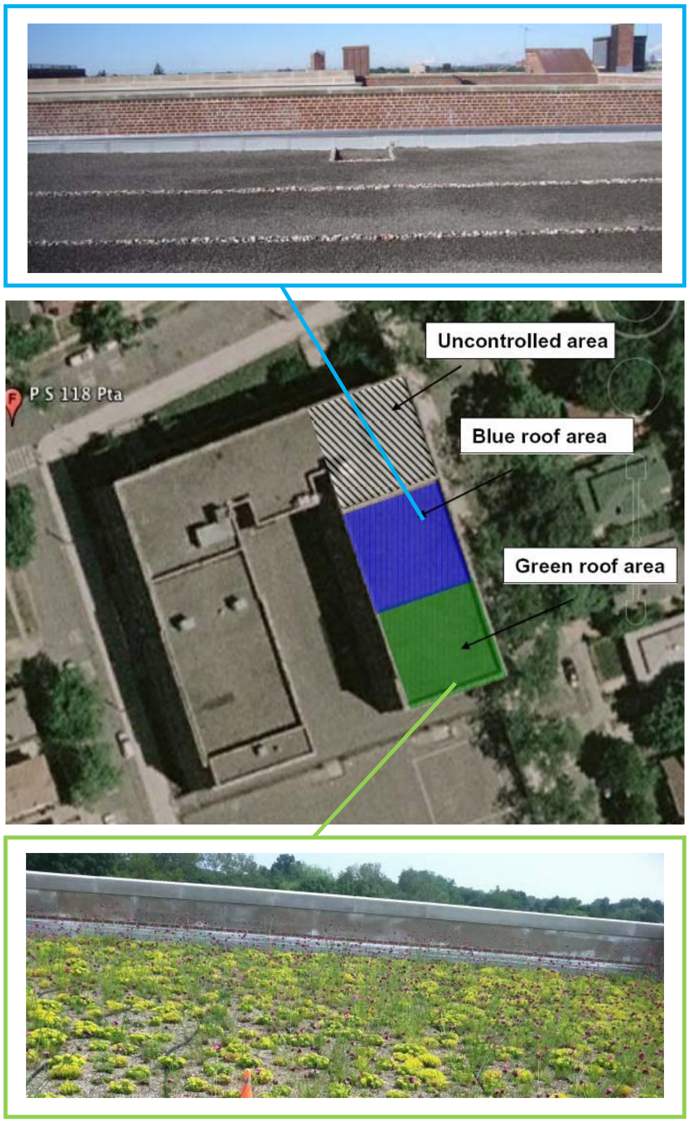
The roof at PS 118 was divided into three sections--a blue roof, a green roof, and an uncontrolled reference section—each approximately 3,200 square feet in size. The green roof is designed to detain precipitation in the 4-inch thick soil layer and to promote evapotranspiration through plant uptake and sun exposure. The blue roof consists of check dams made from perforated aluminum T-section dams that are designed to slow the flow of runoff to existing drains. The uncontrolled area was not modified.

Similar to the monitoring setup at Metropolitan Avenue, a full weather station, water level loggers, v-notch weirs, and drain inserts were used to monitor conditions for both the green and blue roof pilots.

Monitoring Site Summary

Metric	Site Data
Impervious Area Managed (ft^2)	Green roof:3,500 Blue roof (check dams):3,500
DA:GI Footprint	1:1
# of Storms	22
Storm Depth (in)	0.19-6.63
Peak Intensity (in/hr)	0.24-3.60
Storm Duration (hrs)	0.5-60

Data Collection Period: July - Dec 2011



Arrangement of the blue roof, green roof, and uncontrolled areas at the PS 118 pilot site.

2011 Monitoring Results

An example hydrograph comparison of outflow rates between the green and blue roof pilots shows less overall outflow from the green roof than in the blue roof system (Chart 17). Performance comparisons of volume retention and peak flow reduction for the green and blue roofs are shown in Chart 18. The green roof pilot captures at least 60% runoff for 1-inch or smaller storms. The blue roof system of check dams was not as efficient with volume retention measured between 0% and 80%.

Summary

Initial monitoring results indicate the following:

- Both source control types provided significant peak runoff reduction, for low intensity storms;
- Preliminary observations indicate that the green roof may provide slightly better runoff control benefits than the blue roof.
- For larger storms, both systems can also offer significant rate reduction and modest volume reduction.

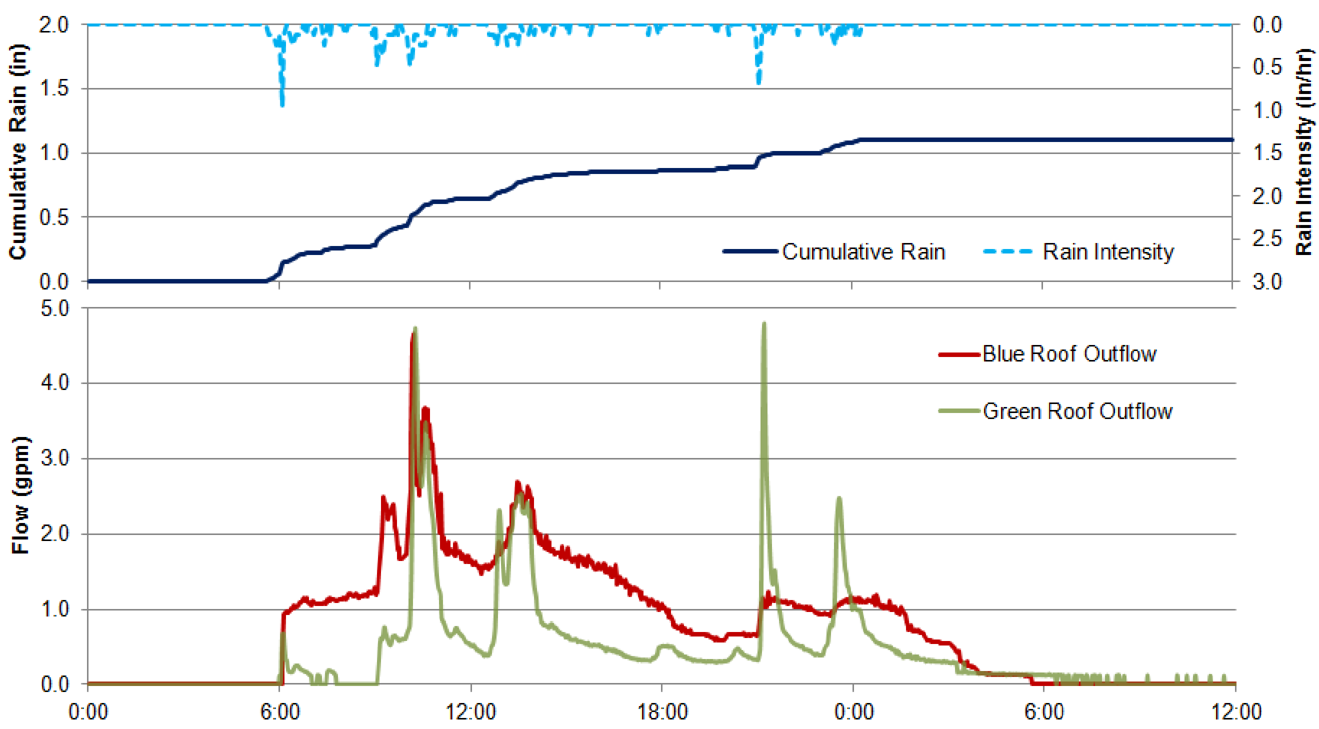


Chart 17. Example hydrograph comparing outflow from rooftop pilots at PS 118 during a 1.1-inch storm on Oct 19, 2011.

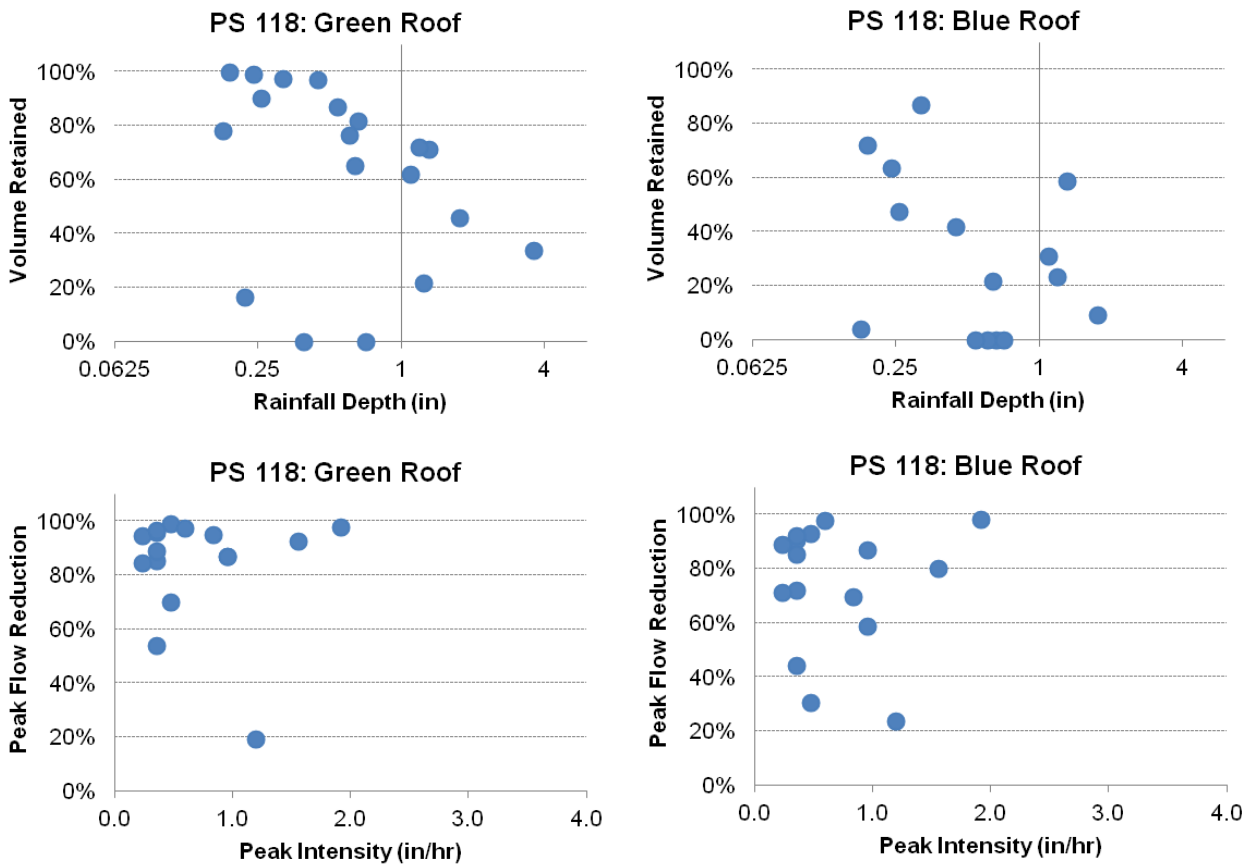


Chart 18. Volume retention (left) and peak flow reduction (right) performance of PS 118 blue and green roofs (each dot represents a single storm; however, overlap may occur for storms with similar depths).

MONITORING SUMMARY AND NEXT STEPS

This 2011 Preliminary Pilot Monitoring Results Update Supplement summarized volume retention and peak flow reduction results from a number of the stormwater pilots. In general:

- Preliminary observations indicate that all green infrastructure source controls are providing stormwater management benefits;
- Overall, bioretention source controls appear to come close to fully managing the 1-inch rainfall. Preliminary data indicate that benefits are realized for storms greater than 1 inch; however, more data are required to fully evaluate effectiveness;
- Findings will be validated and expanded upon through further data collection and analysis in 2012;
- Performance monitoring is showing that curb cuts/bypasses and the sources of other losses need to be further investigated; and
- Further data analysis and development of metrics will provide greater insight into potential CSO reduction and green infrastructure planning. For example, as more data are collected, DEP will be better able to understand how to quantify green infrastructure benefits in development of CSO Long Term Control Plans (e.g., the runoff rate and volume reductions they provide).

The following monitoring and analysis activities are anticipated for inclusion in future monitoring reports:

- Additional calibration of monitoring equipment and initiation of data collection at newly constructed pilots;
- Initial results of water and soil quality sampling;
- Collection and review of co-benefits monitoring data (i.e., urban heat island and energy impacts);
- Further analysis of infiltration and evapotranspiration rates, curb cut bypasses, and other runoff losses;
- Further evaluation of data outliers and poor performance of source controls during certain rain events to better understand deviations in monitoring results;
- Continued evaluation of ongoing maintenance practices/requirements;
- Evaluation of Bronx River Houses roof tray monitoring data; and
- An assessment of seasonal performance for different source controls.

Current and future monitoring results for each year will be cumulatively compared to previous results to assess performance of source controls over time.

Water level logger used to measure outflow in a monitoring manhole for subsurface system.