Villa Park Police Station Urban BMP Demonstration Project

A Project to Demonstrate Integration of Green Roof, Permeable Paving, and Bioswale Urban Runoff Systems

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Introduction

The Village of Villa Park constructed a new police station east of the previous station and south of Village Hall in the heart of Villa Park and on the site of a former asphalt parking lot. The site is 0.72 acres in size and is covered mostly by the building footprint and parking lot. Despite this small size, runoff volumes and rates are expected to be reduced to undeveloped conditions using green roofs, permeable paving, and bioretention. The project is also expected to reduce pollutant loads by more than 90%.

Villa Park is in the Salt Creek watershed (WSID ILGL09) along segment GL09. This segment of the Creek is rated as "partial support" for overall use and aquatic life and "nonsupport" for swimming according to the 2000 Illinois Water Quality Report. The impairments are reported to be caused by priority organics, PCBs, excess nutrients including phosphorus, nitrogen and nitrates, salinity/TDS/chlorides, flow alteration, and excessive algal growth/chlorophyll a. The sources of pollutants are listed as municipal point sources including combined sewer overflows, collection system failures, urban runoff/storm-sewers, hydrologic/habitat modifications, upstream impoundment, flow regulation and modification, and contaminated sediments.

Many of the causes and sources listed above are related to urban runoff, which is largely unregulated at this time. Thus, implementing and providing examples of best management practices to cleanse and reduce volumes of urban stormwater runoff is greatly needed in this largely built out watershed.

Also, the DuPage County Department of Environmental Concerns encourages the use of best management practices to address storm water management water quality issues. However, detention is virtually the only BMP implemented under DEC's stormwater ordinance and detention basins are difficult to implement on small sites and do little to control the volume of runoff reaching area waterways.

One of the obstacles to greater implementation of green roofs, permeable paving, bioswales, and similar strategies is lack of understanding by local regulators (municipal and county) on the runoff rate and volume reduction performance of these BMPs in relation to stormwater release rate standards. Thus, runoff rates are being measured as part of this project to provide hydrologic performance data.

This project addresses pollutant loadings as well as storm runoff induced water level fluctuations within Salt Creek. The green roof on the new police facility will reduce runoff and pollutant loading and provide a prototype green roof that we can easily display to communities and businesses in the Salt Creek and other watersheds. The site outside the building demonstrates innovative, infiltration based storm water management approaches that can be used throughout the watershed to help address nonpoint source pollution.

Project Location and Pre-Project Conditions
The project is located as shown in Figure 1 at the intersection of Ardmore Avenue and Home Avenue, south of Village Hall. The site is a block south of St. Charles Road and just north of the Prairie Path.

The site was previously an asphalt paved parking lot with no detention. The runoff from the parking lot drained offsite via storm sewers and surface runoff. (See photos at the end of the document for pre-project condition.)

Project Purpose and Goals
The purpose of this project was to address urban runoff impacts to Salt Creek, to provide an example of a "green building" for the Village, County, and the general public, and to demonstrate innovative, retention-based stormwater management approaches for highly impervious areas. To achieve these purposes, the following BMP design and performance objectives were used to guide design of the system.

- **Improve water quality:** Salt Creek is an impaired water body and urban runoff is a significant contribution to that impairment.
- **Reduce Runoff Volumes:** Most BMPs do little to control runoff volumes and therefore urban streams continue to be impacted despite improvements in water quality. Control of runoff volumes is necessary to prevent increases in streambank erosion and other impacts resulting from the "flashiness" of urban streams.
- **Provide Demonstration of Advanced Urban Runoff BMPs on Tight Urban Sites:** As many urban areas are experiencing a resurgence in development interest, significant opportunity exists to retrofit our urban areas as redevelopment occurs. The Village of Villa Park and Illinois EPA were interested in providing demonstrations on how these small urban sites can be retrofit to address runoff rates, volumes, and water quality.
- **Meet County Stormwater Release Rate Standards:** Although the County ordinance has a threshold of 1 acre, the Village wished to meet the standard for this 0.72 acre site.
- **Ensure Long Term Performance of BMP Systems:** Many BMPs receive very little maintenance. Thus, to ensure long term performance, the system needed to be designed for minimal maintenance.

Project Description
The Villa Park Police Station project includes a green roof, two bioswales with underground storage, and a permeable paving parking lot. These features are shown on the Site Plan in Figure 2 and the construction drawings in Appendix 1. Virtually all runoff from the site is filtered by the various features to improve water quality and the entire parking and bioswale area remains available for infiltration. The green roof and bioswale soils also serve to retain water to allow for slow evaporation between events.

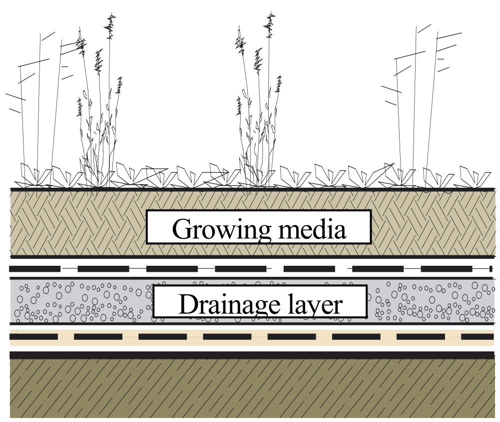
The general operation of the system is described below, followed by detailed descriptions of each of the BMPs used on the project.

BMP System Overview (See Figure 2)

- Excess rainfall that is not retained by the green roof system and runoff from the non-vegetated roof area is discharged to the surface of the eastern bioswale.
- Surface runoff from the permeable paving parking area that cannot percolate through the openings in the pavement, drains to the surface of the southern bioswale.
- Subsurface runoff from the permeable paving parking area (water that percolates into the aggregate base under the paver parking surface) can either infiltrate into the subgrade below the parking lot or drain laterally to the underground storage trenches beneath the surface bioswales.
- Runoff to the surface of the bioswales percolates through an amended topsoil down to the storage trench below. A portion of the runoff within the bioswale infiltrates into the subgrade below the bioswale and a portion is temporarily detained by a restrictor sized to meet the DuPage County and Villa Park detention release rate standards.

BMP System Components

- **Green Roof** – The green roof of the Police station is a Hydrotech system. Over most of the roof, the system is composed of a 3-inch rooting matrix and a gravel filled plastic drain board. In the area of the roof devoted to mechanicals (heating, cooling, etc), the gravel is overlain by concrete pavers that allow runoff to pass through to the drainage media. (This area is denoted as "non-vegetated roof" in Figure 2). The growing media is a lightweight, engineered soil composed of expanded clay or slate mixed with organic matter. The drainage layer is also expanded clay or slate with a larger particle size. The exact mix of the materials is proprietary. The expanded clay or slate material is designed to be light weight and have high permeability as well as high water holding capacity. The approximate properties of the growing media are as indicated below. (Information provided by Midwest Trading Company – one provider of green roof soil and drainage media.)



Green Roof Section

    - Dry Unit Weight - approximately 30 - 45 lbs per cubic foot (water is 62 lbs per cubic foot).
    - Saturated Unit weight – approximately 75 – 80 lbs per cubic foot.
    - Porosity - 70% to 80% (conventional angular gravel is approximately 40%).
    - Water holding capacity – approximately 25 - 35%.
    - Permeability – approximately 30 inches per hour.

  The runoff coefficient or runoff curve number of green roofs varies with green roof thickness and drainage layer type. Information from Germany (where green roofs have been in place for decades) report runoff coefficients as low as 0.1 to as high as 0.8. However, it appears that event-based coefficients are mixed with annual runoff-based coefficients, making the reliability of these numbers for stormwater design uncertain. Recent paired rainfall and runoff data from University of North Carolina suggests runoff coefficients of 0.55 to 0.60 with an initial abstraction of approximately 0.3 inches for small 3- to 4-inch thick green roofs. Runoff monitoring data from this project will provide additional data for determining runoff characteristics. However, for purposes of design for this project, a runoff Curve Number (CN) of 74 (similar to turf on C soils) was used. The discharge from the green roof drains to the surface of the bioswales. Because both the vegetated and unvegetated portions of the roof are covered with green roof media, the entire roof was represented as one surface when estimating runoff.

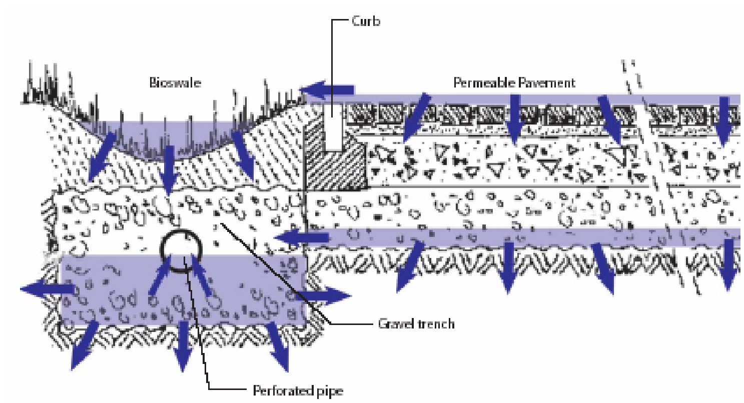
- **Permeable Paving** – There are a range of permeable paving strategies suitable for year round, continuous use. These include porous asphalt, porous concrete and interlocking permeable pavers. Unlike rigid concrete pavement (poured concrete), porous asphalt and interlocking pavers are flexible pavement systems and therefore are tolerant of modest amounts of frost heave. Asphalt is a relatively short-lived pavement that requires resurfacing from time to time. Also, seal coating that is often part of maintenance would render porous asphalt impermeable. Finally, interlocking paver systems are extremely long lasting yet flexible, combining the benefits of asphalt and poured concrete without the negatives. Partially due to this and other IEPA funded projects, interlocking permeable paving systems are becoming increasingly popular. As a result, installation costs are dropping, making interlocking paver system installation costs more competitive.

  The selected Unilock Ecoloc permeable paver system has an approximately 10% open area that is filled with a medium gravel material. Because of the chamfers designed into the pavers, all runoff is routed to the open areas. Thus, all runoff has the potential to infiltrate through the openings. At installation, the net infiltration capacity is very high but tends to decrease over time, leveling off after a period of approximately 5 years. German studies have demonstrated initial infiltration rates of 9 in/hr and higher and two four year old installations indicated rates of 3 in/hr. In another study of two and five year old parking lot installations, infiltration rates were found to be approximately 6 and 5 in/hr, respectively. These rates are sufficiently high to capture the runoff from all but the most intense rainfalls. If the pavement surface clogs, the infiltration can be restored by removing and replacing the top 1 to 2 inches of crevice fill material. (See Maintenance Section.)

  Because of the high surface infiltration capacity and due to the relatively low soil infiltration capacities in northeastern Illinois, the infiltration of the subgrade and the drainage characteristics of the base material control the runoff characteristics rather than the surface. Thus, a permeable paving system behaves hydraulically like a detention system with the detention located in the gravel base under the paving surface. The release from the "detention" can be controlled either by the hydraulic conductivity of the gravel or by the capacity of perforated drains within the gravel base. In some cases, a restrictor can be installed in the drain to meet stormwater release rate requirements. The porosity of the open graded gravel base of the pavement systems is approximately 40% (IDOT CA1 and CA7 aggregate porosities were both measured to be 42% at one local quarry). Thus, the available detention volume is equal to 40% of the gravel volume under the pavement surface. For this project no restrictor was used to control the release of the pavement and instead the aggregate hydraulic conductivity controls. The drainage from the 12-inch gravel base discharges to the gravel beneath the bioswale soil. In addition to lateral release from the aggregate, water is released via infiltration into the subgrade. The measured infiltration capacity of the subgrade soils under the previous parking lot was 0.75 in/hour. Due to additional compaction that likely occurred during construction, a conservatively low infiltration capacity of 0.1 in/hour for the permeable paver subgrade was assumed. Virtually all the rainfall falling onto the permeable pavers drains through to the gravel base below. Thus, a CN of 98 was used, consistent with typical paving surfaces. The runoff is assumed to immediately enter the gravel base.

The runoff into the gravel base was routed through the base using conventional storage routing techniques. The discharge rate from the base was computed based on Darcy's law with a hydraulic conductivity of 3500 in/hr and a subgrade slope of 1%. The discharge from the gravel base is to the gravel under the bioswales. See the following section on hydrologic analysis for further discussion on storage routing of the permeable paving.

- **Bioretention Swales** – Bioswales are composed of a surface topsoil underlain by a gravel drainage/storage layer. The topsoil was amended with sand and organic matter to achieve a design infiltration capacity of 2 to 5 inches per hour. The design mix of the eight inch soil layer was as listed below:
    - 70% - 80% coarse sand
    - 8% - 10% organic content
    - 10% maximum clay content.



Bioretention swale adjacent to permeable paving

Because of the water holding capacity of the bioswale topsoil, a CN of 74 was used, consistent with turf on hydrologic soil group C soils.

As with the permeable paving, runoff was also storage routed through the bioswales. The above ground and underground storage both function as detention. The release from the system is controlled by a restrictor to meet the county release rate of 0.1 cfs/acre. The depth of gravel drainage/soil layer is 3 feet.

BMP System Hydrologic Analysis

The Villa Park system was evaluated using standard NRCS runoff curve number and routing methods contained within "HydroCAD".

Runoff Analysis

Runoff from permeable paving, green roofs and the other site surfaces (walks, landscaping, etc.) were modeled independently to produce runoff hydrographs and the sum of the individual hydrographs were routed through the detention (bioswale) system. The green roof and permeable pavement descriptions above discussed the runoff characteristics of these surfaces and Table 1 below summarizes the runoff parameters.

Table 1: Runoff Parameters

Location	Area (ac)	CN	Time of Concen. (hours)	Notes
Green Roof	0.0874	74	0.1	Runoff assumed similar to lawn on "C" soils
Permeable Paving	0.215	98	0.1	Permeable paving runoff also routed through gravel storage beneath pavement. Discharge controlled by hydraulic conductivity of gravel. Infiltration through bottom at 0.1 inches per hour
Impervious Paving	0.111	95	0.1	
Landscape	0.138	65	0.1	Native landscaping beds
Bioswale	0.134	74	0.1	Turf over top of gravel infiltration bed
Total Area	**0.72**			

Detention Analysis

Detention occurs in both the surface of the bioswales and the underground coarse aggregate material of the bioswales and permeable paving. All runoff is either filtered through the surface soils of the bioswale or through the permeable paving before being discharged to the underground storage. This is done to improve water quality and to prevent clogging of the permeable paving and bioswale subgrade soils. The bottom six inches of the bioswale underground storage is reserved for infiltration storage. Once the stage exceeds six inches, runoff begins to discharge through the restrictor. The following paragraphs describe analysis of the various components.

- **Permeable Paving Underground Storage** – Detention storage is provided within the 12-inch base of the permeable paving. The base material is IDOT CA-7 coarse aggregate with a size range from 0.2- to 1-inch. The total volume of storage in the gravel layer is approximately 3750 ft^3 (0.086 ac-ft). The discharge from the base is controlled by the hydraulic conductivity of the

CA-7 aggregate and the slope of the subgrade. Based on information in the drainage design guidelines prepared for the Uni-Group (Texas A&M, 1998), the hydraulic conductivity of the aggregate was assumed to be 0.08 feet per second. The slope of the subgrade is 1%. The drainage from the 12-inch gravel base discharges to the gravel beneath the bioswale soil. In addition to lateral release from the aggregate, water is released via infiltration into the subgrade. The measured infiltration capacity of the subgrade soils under the previous parking lot was 0.75 in/hour. Due to additional compaction that likely occurred during construction, a conservatively low infiltration capacity of 0.1 in/hour for the permeable paver subgrade was assumed. All the rainfall falling onto the permeable pavers was assumed to drain through to the gravel base below. However, if surface runoff occurs on the permeable pavers, the runoff is directed to the surface of the bioswales where it can be treated and detained.

- **Bioswale Underground Storage** - The underground storage is created with a 3 foot layer of IDOT CA-7 coarse aggregate below the bioswale topsoil. The total volume of the subsurface storage is approximately 4370 ft^3 (0.100 ac-ft). The discharge from the underground storage is controlled by an orifice restrictor as described under "Bioswale Release Rate" below.
- **Bioswale Surface Storage** – The surface storage is separated from the underground storage with 8-inches of amended topsoil. Surface runoff from all areas discharges to the surface of the bioswale where it filters through the amended topsoil to the underground storage layer. If the depth in the surface storage exceeds 6 inches, excess runoff can discharge down to the underground storage through a surface structure. The underground storage can also bubble up into the surface storage as needed. The total volume of the surface storage is approximately 4520 ft^3 (0.104 ac-ft) at the overflow elevation of 93.4 feet. Overflow from the bioswale (for events exceeding 100-year event) is to the street (Ardmore).
- **Bioswale Release Rate** – For the site area of approximately 0.72 acres, the allowable release rate is 0.072 cfs (0.10 cfs/acre). The restrictor for the site is located in a manhole and the controlling elevation is 6 inches above the bottom of the underground aggregate storage. Runoff access to the restrictor is via an 8-inch perforated pipe that runs the length of the bioswales. The inflow capacity of the 124-foot perforated pipe is more than 30 cfs when the detention area is full. Thus, the perforated pipe does not control the discharge of the basin and the only control is the restrictor. Because the site is small, the restrictor size required to achieve the allowable release rate is 1-inch. Although the restrictor size is small, clogging should not be a concern since runoff must discharge through the perforated pipe for most events prior to reaching the orifice.

  The assumed infiltration capacity of 0.3 in/hr of the bioswale subsoils was based on a percolation test indicating a capacity of 0.75 inches/hour. This infiltration rate over the 3640 ft2 of infiltration bed translates into a discharge rate of 0.025 cfs out the bottom of the bioswale.

BMP System Performance

Runoff Rates and Volumes

Using the model parameters of Table 1and the methods described above, the proposed system was modeled to estimate runoff volumes and flow rates for a range of events. The system was modeled using HydroCAD with the NRCS Type II rainfall distribution and 24-hour duration events.

Table 2: Estimated Flow Rates and Runoff Volumes

Event	24-hour rainfall	Existing Conditions (24-hr runoff & 15-minute flow)	Proposed Conditions	Notes
1-year discharge (cfs)	-	1.7 cfs	0.02 cfs	
2-year discharge (cfs)	-	2.2 cfs	0.02 cfs	
100-year discharge (cfs)	-	5.8 cfs	0.07 cfs	Allowable rate = 0.072
2-inch runoff	2.00 inches	1.48 inches	0.00 inches	Threshold of zero runoff
1-year runoff (inches)	2.51 inches	1.97 inches	0.18 inches*	
2-year runoff (inches)	3.04 inches	2.49 inches	0.41 inches*	
100-year runoff (inches)	7.58 inches	6.98 inches	3.13 inches*	

* Comparing the proposed conditions runoff volumes to the rainfall, the equivalent curve number for the site is approximately 61.

Table 2 shows that the system not only meets the runoff rate requirements of DuPage County but should also significantly reduce runoff volumes. The 100-year runoff volume is reduced by more than 50% and the 1-year runoff volume is reduced by more than 90%. No runoff is produced for approximately 2-inch and small events.

Water Quality

Water quality is improved in two ways. First, all runoff is filtered by green roof media, by permeable paving aggregate, and/or by bioswale amended topsoil. For purposes of estimating pollutant reductions, IEPA pollutant removal rates for sand filters were used to represent the expected pollutant removal rates for the various media of this project. The filtered runoff then has an opportunity to be infiltrated through the subgrade of the permeable pavement and bioswales. For estimating the total load reduction, it was assumed that the infiltrated runoff releases no constituents. To estimate the average annual runoff volume reduction, NIPC's chart showing the distribution of storm rainfall volumes was used (Northeastern Illinois Planning Commission, 1998). The chart indicates that 2-inch and smaller rainfall events (the threshold of zero runoff for the Villa Park BMP system) represents 85% of the average annual rainfall volume.

Table 3: Estimate Average Annual Pollutant Removal Rates

		Constituent				
		TSS	TN	TP	COD	Notes
1	Filter removal rate	80%	35%	50%	55%	Removal rate based on IEPA load reduction worksheet assuming removal rate similar to sand filter
2	Remaining load after filter	20%	65%	50%	45%	One minus the removal rate
3	% of infiltrated water	85%	85%	85%	85%	Percent of annual runoff volume infiltrated based on NIPC "Storm Rainfall Volume Distribution" Chart (Figure 3.1)
4	Remaining runoff after infiltration	15%	15%	15%	15%	One minus the infiltrated percent
5	Remaining load after infiltration	3%	10%	8%	7%	Load from the runoff that is not infiltrated (Row 4 * Row 2)
6	**Total Percent Removal**	**97%**	**90%**	**93%**	**93%**	One minus the remaining load

Table 3 shows that average annual pollutant loads should be reduced 90% to 97%, depending on constituent. These removal rates are significantly higher than virtually any single BMP system, largely due to the volume of runoff infiltrated.

Runoff Monitoring System

Rainfall and runoff rates are being monitored to verify the assumptions within the modeling of the system and to provide data for municipal and county stormwater agencies that must approve these systems to meet local stormwater ordinances. This is intended to address one obstacle to implementation of green roof and permeable paving systems. The monitoring locations are shown in Figure 3.

Rainfall is measured on the roof using a tipping bucker rainfall gage. Discharge rates from the upper green roof are measured using an ultrasonic sensor within the internal drain of the roof. Discharge leaving the site is measured in the pipe downstream of the detention restrictor using a compound weir and depth sensor placed in the pipe. There is a small amount of offsite runoff draining to the site and this runoff is measured using the same equipment as the runoff leaving the site. The difference between the offsite runoff entering the site and the runoff leaving the site is the runoff generated by the site.

Monitoring data is not yet available but will be provided over the next year as data is collected.

Maintenance and Management

The following paragraphs describe maintenance requirements for the various systems used in the Villa Park Police Station project. Inspection and maintenance activities are described in detail in Appendix 2.

Permeable Paving

Two levels of maintenance are required for permeable paving – routine maintenance and remedial maintenance.

- **Routine Maintenance:** Routine maintenance involves normal street sweeping, similar to that used on standard asphalt and concrete paving. While high efficiency vacuum sweepers are more effective at capturing and removing fine sediment than mechanical broom sweepers, mechanical sweeper equipment is sufficient to dislodge surface encrusted sediment. Permeable paving surfaces should be dry-swept (water should be turned off) in dry weather to remove encrusted sediment that appears as small curled "potato chips". When vacuum equipment is used, vacuum settings should be adjusted to prevent uptake of aggregate from the pavement openings and joints.

- **Snow Plowing:** As with any pavement, snow plowing is required after snow storms. Use of rubber or nylon rather than steel is recommended for the replaceable snowplow tip. However, steel tips are used for plowing many installations, particularly where plowing speeds are low. Manufacturers of interlocking pavement blocks state that the chamfered top edges minimize chipping and allows for normal plowing procedures. Shoes at the edges of the blade and rubber or nylon tipped blades are recommended for all pavements to protect the equipment and driver from impact at manholes, pavement joints, etc that are common to asphalt and poured concrete roads.

  Due to the short flow distance from the paver surface to a joint opening, the opportunity for ice formation is greatly reduced. Also, researchers state that the underlying stone bed tends to absorb and retain heat, further reducing ice formation. For these reasons, regular deicing should not be necessary and is not recommended for water quality protection reasons. However, for occasions when icing does occur, a mild application of deicing salt may be used. If abrasives are necessary, stone chips should be used rather than sand. If sand is used, it will tend to clog the openings and lead to the premature need for remedial maintenance.

- **Remedial Maintenance:** As discussed previously, there is a high initial infiltration capacity (9+ inches/hour net infiltration capacity over the area of the pavement surface) with a decrease and leveling off over time. The decrease in infiltration capacity over time is due to deposition of fine material such as silt and vegetation in the joint aggregate. In a study of two four-year old parking lots, infiltration capacities were found to be approximately 3 in/hr. In another study of two- and five-year old parking lots, the infiltration rates were found to be 6 in/hr and 5 in/hr, respectively (Borgwardt, 1994). Clogging has been found to be limited to a depth of 0.5 to 1 inch, well confined within the joint depth of 3 inches.

  The need for remedial maintenance can be determined by visual inspection. Areas that pond water in the openings between pavers will require remedial maintenance. Remediation can be achieved using a vacuum sweeper with water jets, sweeper, and vacuum bar attachment to evacuate clogged joint material. The evacuated joint material can either be washed and replaced or new joint material can be used to refill the joints. Private contractors are often used to provide remedial maintenance and a Chicago area contractor has indicated that remedial maintenance costs have come in at about $0.25 per square foot of permeable pavement. This cost included both sweeping and recharge of the joints with aggregate. The frequency of required remedial maintenance depends on the degree of sediment and debris loading as well as the level of routine maintenance. However, there are many five to ten year and older installations that have never been maintained and continue to function well.

Bioswales

Maintenance of the bioswales includes inspections to ensure that the amended topsoil is not clogged, inspection of the outlet control, and vegetative management. Specific maintenance activities are described in Appendix 2. Inspections should occur twice annually and after large rainfall events as indicated. Each inspection of the entire system should not require more than approximately four man-hours.

Clogging of outlet structures is not expected to occur since stormwater entering the system must pass through bioswale amended topsoil or through permeable paving for most all events. However, should clogging occur, the orifices may be cleared by simply sweeping away the obstruction.

Clogging of the amended topsoil within the rain gardens and bioswales is not expected to occur provided the vegetation is maintained in a vigorous condition. Should clogging occur, it is unlikely that the entire bioswale will clog but more likely that isolated locations will clog. The cost to remove and replace clogged amended topsoil should not exceed $1 per square foot for small areas. Replacement for large areas (i.e., the entire bioswale) should not exceed $0.25 to $0.50 per square foot. These costs do not include replacement of vegetation.

Green Roofs

Very little maintenance is required for green roofs except vegetative maintenance to control weeds. The sedums used to vegetate the green roof are very drought tolerant and will go dormant under extreme dry conditions. However, the roof can be irrigated if desired to prevent dormancy and improve aesthetics during dry periods.

Summary

The Villa Park police station Urban BMP demonstration project utilizes advanced runoff management techniques that minimize generation of runoff and associated urban pollutants using green roof and permeable paving technology. Runoff that does occur is directed to biofiltration swales that filter the runoff and provide temporary storage for infiltration and runoff rate control.

The system was designed to restore pre-development hydrologic conditions as well as water quality while also meeting local stormwater flood control standards. The system has been estimated to remove 90% to 97% of urban runoff pollutants and reduce runoff volumes to less than produced by a typical park area (the expected equivalent curve number for the site is approximately 61), despite 65% coverage by surfaces normally considered to be impervious (roofs, parking, and walks). Runoff volumes are being monitored to verify the hydrologic analysis and to assist local designers and regulators in designing and evaluating these systems.

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Figure 1: Project Location

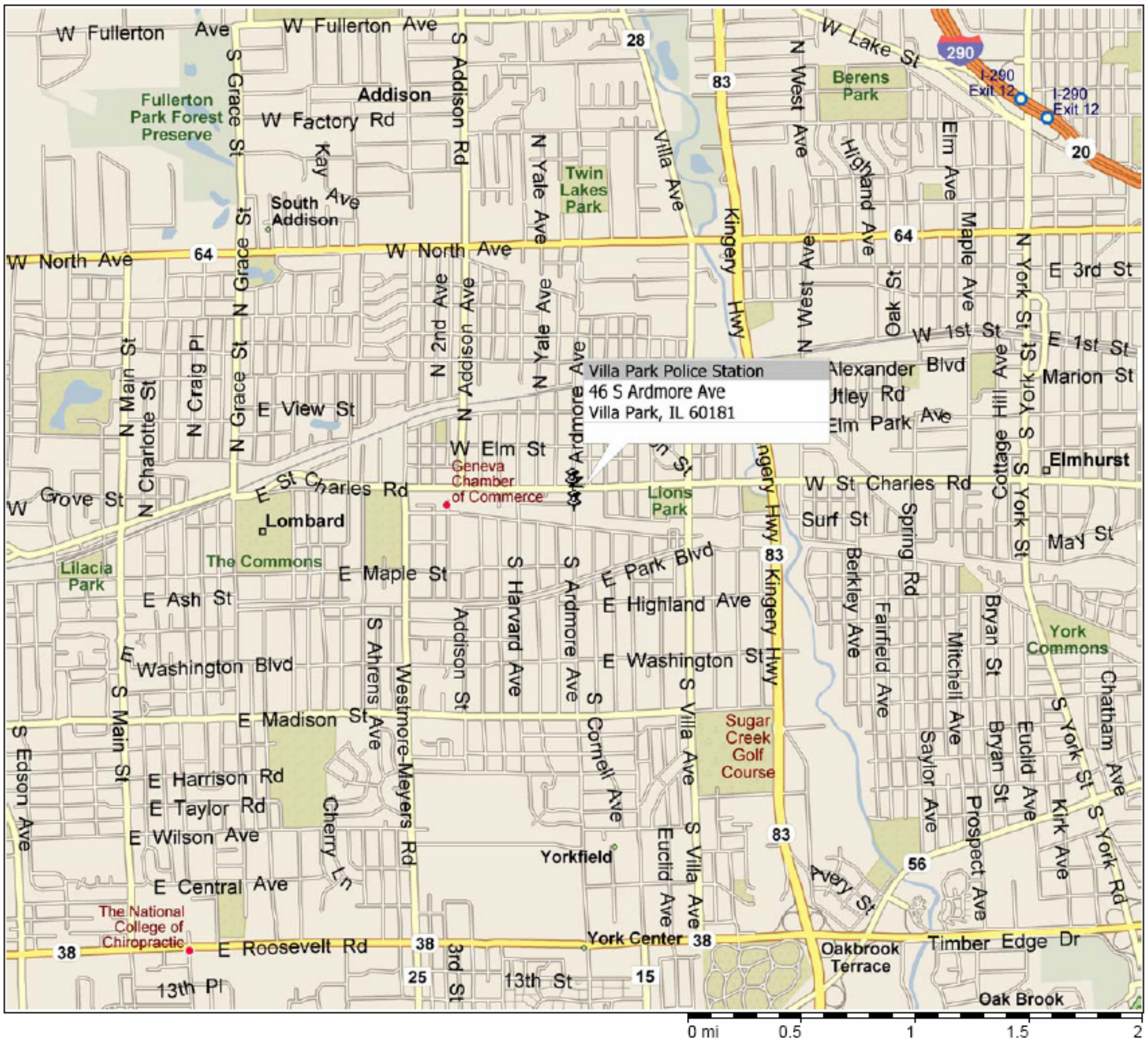


Figure 2: Site Plan

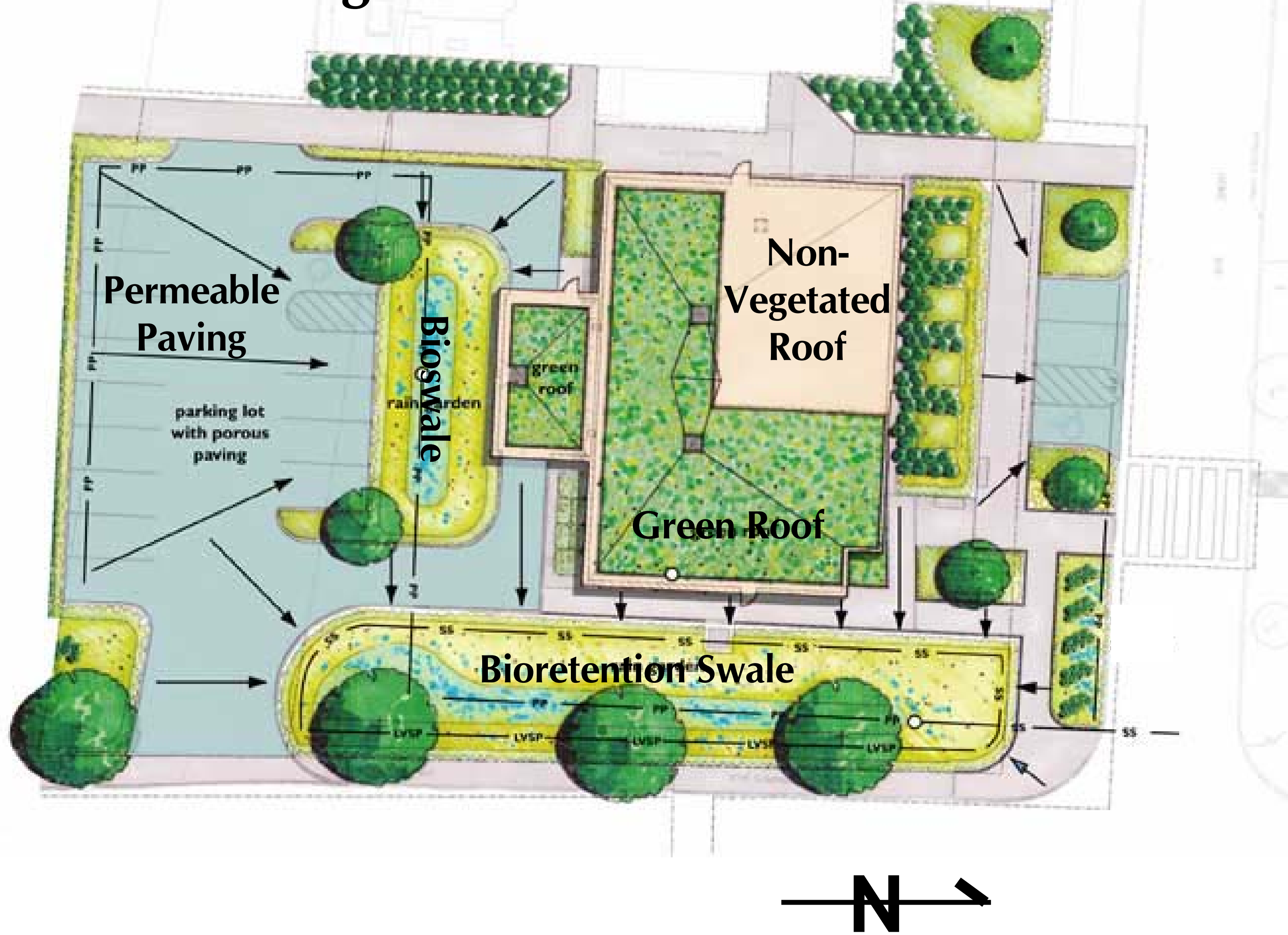
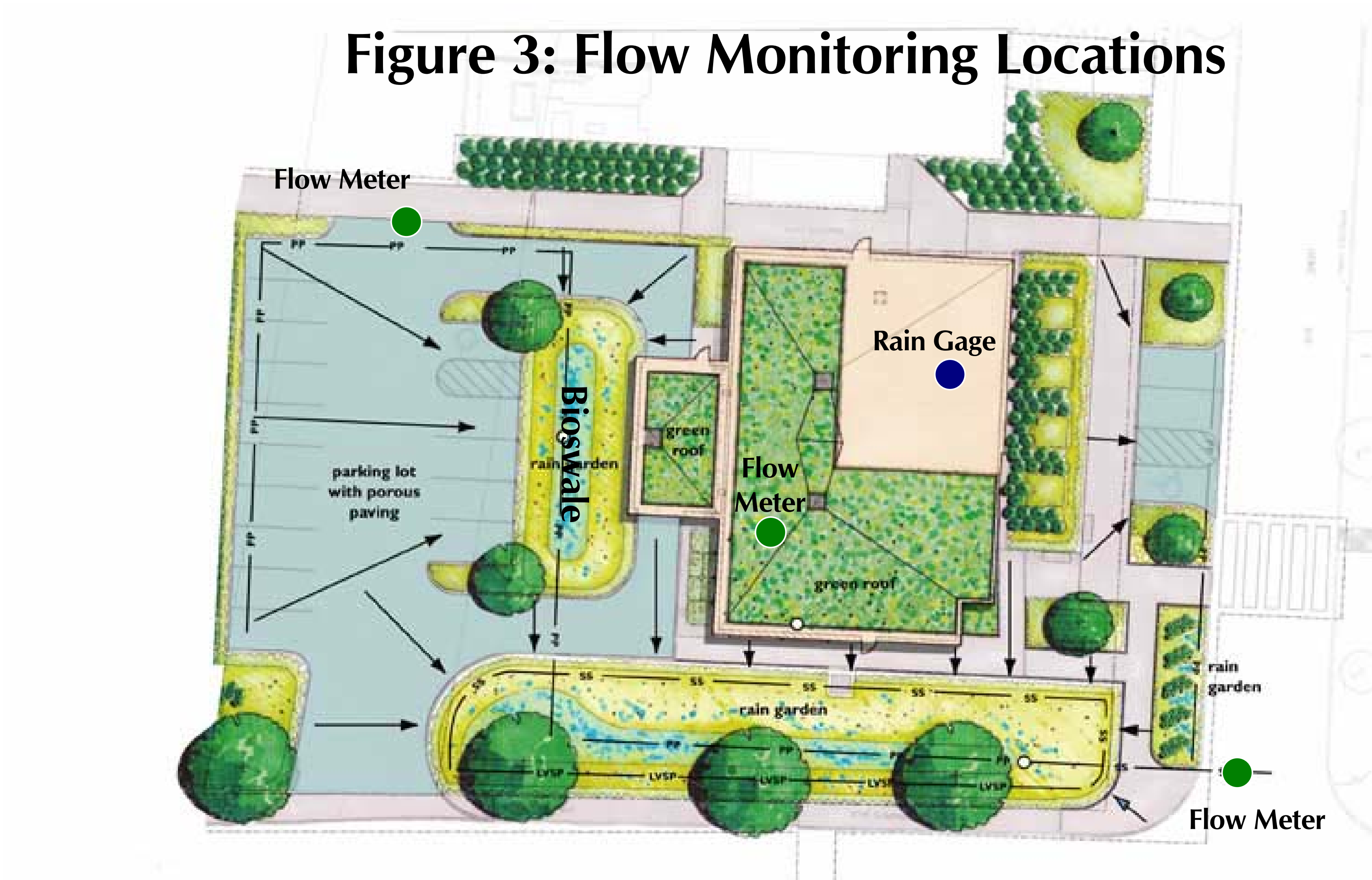


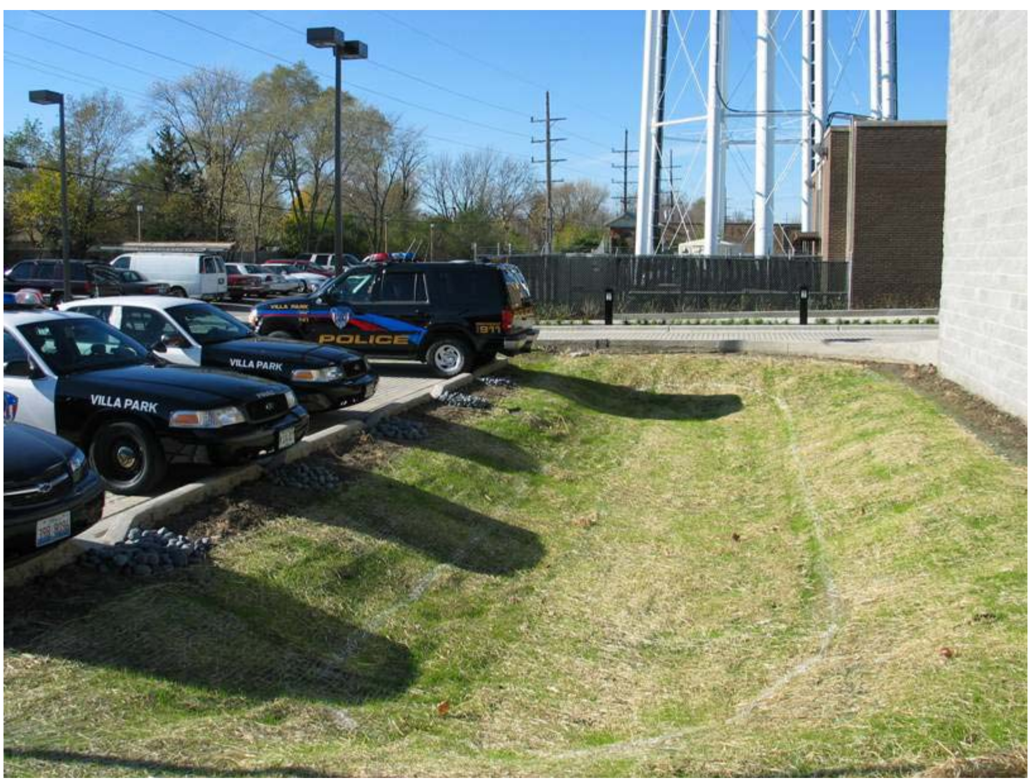
Figure 3: Flow Monitoring Locations



Parking Lot Prior to Construction of Police Station

Installation of South Bioswale

South Bioswale curbs and curb cuts



Completed South Bioswale with Initial Cover Crop Growth

Compaction of Permeable Paving Base

Completed Permeable Paving

Upper Green Roof Prior to Planting

Lower Green Roof Beginning of First Growing Season