5 Green Infrastructure Implementation Methods

As discussed in Chapter 2 of this document, one of the most effective ways to reasonably mimic pre-construction runoff conditions in new development is to employ sustainable site design techniques during planning. Both structural and non-structural stormwater control measures can be integrated into a site design to help meet pre-construction runoff conditions and treat pollutants within the runoff. Non-structural stormwater control measures include protecting existing features, slowing runoff, disconnecting impervious surfaces, etc.

Where site conditions make infiltration impracticable, underdrain systems and extended detention may be used to better simulate pre-construction runoff conditions and return runoff to its pre-construction condition. This is also applicable where potential groundwater contamination is a concern.

This chapter further explores sustainable site design using non-structural and structural methods for managing stormwater runoff, while also creating functions and addressing needs outside of stormwater management.

5.1 Sustainable Site Design Principles

Reducing pollutant sources and stormwater volume through non-structural stormwater control measures in strategic combination with structural stormwater control measures can be an effective method of managing runoff. Proper application of sustainable design methods require defining the sources of potential runoff issues so appropriate non-structural and structural stormwater control measures can be selected.

Figure 5.1 Oakbrook development site plan. Source: Shockey Consulting

The following principles are from the *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers* (Southeast Michigan Council of Governments, 2008):

Plan first.
Planning for runoff management in the earliest stages of the development process helps ensure that natural resources are protected and the impacts are minimized.

Prevent, then mitigate.
Minimizing the amount of runoff generated from the site is the most effective way to manage stormwater. This can include preserving natural features, clustering development and minimizing impervious surfaces. Once prevention as a design strategy is maximized, then the site design — using structural stormwater control measures — can be prepared.

Minimize the disturbance.
Limiting the disturbance of a site reduces the amount of stormwater runoff control needed to maintain the natural hydrology.

Manage stormwater as a resource – not a waste.
Designing sites to take advantage of stormwater runoff can create community amenities, reduce watering needs and protect natural resources. Planning a development around naturalized stormwater areas can help attract residents and adds value to lots near them. See Chapter 2 for benefits of green infrastructure.

Mimic the natural water cycle.
Designing the site to control peak rate, annual volume and water quality flows helps manage the full range of precipitation from small, frequent events to large, infrequent flood events.

Disconnect, decentralize, distribute.
Capturing rainfall where it falls is a very effective stormwater management technique. This is accomplished by disconnecting impervious areas from the drainage system, installing stormwater control measures at individual lots and neighborhoods and spreading them throughout the development.

Integrate natural systems.
Protecting and taking advantage of native soils, vegetation and natural resources minimizes the impacts of a development and can increase its value.

Natural resources are effective stormwater systems that provide water quality benefits and reduce flood peaks.

Maximize multiple benefits.
Designing the site to preserve natural resources and incorporate stormwater control measures using native vegetation can add to the social and economic value of a development and community.

Make maintenance a priority.
Stormwater control measures often require different types of maintenance than typical crews are used to performing. Placing priority on training crews to properly care for stormwater control measures and committing to scheduled maintenance programs is important for their long-term function.

More Sustainable Site Design Resources

The Missouri Department of Natural Resources' *Protecting Water Quality: A field guide to erosion, sediment and stormwater best management practices for development sites in Missouri and Kansas*, contains a section on permanent post construction stormwater control measures including information on their design and application. There are multiple additional resources including:

1. The *Maryland Stormwater Design Manual* includes technical guidance on many types of structural and non-structural stormwater control measures, including those that attempt to meet pre-construction runoff conditions. The Maryland manual is currently adopted with some adaptations by some MS4s in Missouri, including the Metropolitan St. Louis Sewer District.

2. The *APWA/MARC BMP Manual* provides guidance for land development practices within the region. It provides developers, engineers and planners with flexible tools to reduce the volume of stormwater discharge while conserving water quality at the same time. The manual provides specific guidance for planning and implementing stormwater control measures, and describes how to assess alternative site-design approaches to maximize the benefits for individual sites. It also defines stormwater control measures, provides performance goals for site development and describes methods for determining development impacts. (Mid-American Regional Council, 2008).

3. The *Minnesota Stormwater Manual* contains site design regulations based on integrated stormwater management accounting for runoff rate, volume, quality and groundwater impacts. The manual also discusses the "treatment train process" where multiple stormwater control measures are placed in sequence to better manage runoff. (Minnesota Stormwater Steering Committee, 2008)

4. The international best management practices database is available at www.bmpdatabase.org. It is a resource for extracting data on structural stormwater control measure performance. It is focused on providing information about the performance of stormwater control measures and the removal of specific pollution by a range of types of stormwater control measures, but does not make recommendations on which type to use.

5. Other post-construction design manuals such as the *Urban Small Sites Best Management Practice Manual* have developed lists of practices that meet certain performance criteria. www.metrocouncil.org/environment/Water/BMP/manual.htm

6. The EPA System for Urban Stormwater Treatment and Analysis INtegration Model, or SUSTAIN, www.epa.gov/nmrl/wswrd/wq/models/sustain, is a decision support system to facilitate selection and placement of stormwater control measures and low impact development techniques at strategic locations in urban watersheds. It was developed to assist stormwater management professionals in developing implementation plans for flow and pollution control to protect source waters and meet water quality goals. SUSTAIN was designed to help users develop, evaluate, and select optimal best management practice combinations at various watershed scales on the basis of cost and effectiveness.

The EPA Stormwater Management Model or SWMM http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/ works with SUSTAIN to help answer:

- How effective are best management practices in reducing runoff and pollutant loadings?
- What are the most cost-effective solutions for meeting water quality and quantity objectives?
- Where, what type of and how big should best management practices be?

7. Loading and Management Model, or SLAMM, was originally developed to better understand the relationships between sources of urban runoff pollutants and runoff quality (Pitt and Voorhees. 2002). Source It has been continually expanded since the late 1970s and now includes a wide variety of source area and outfall control practices (infiltration practices, wet detention ponds, porous pavement, street cleaning, catch basin cleaning and grass swales). SLAMM is strongly based on actual field observations, with minimal reliance on theoretical processes that have not been adequately documented or confirmed in the field. SLAMM is mostly used as a planning tool, to better understand sources of urban runoff pollutants and their control. USGS works with Wisconsin DNR to support SLAMM in their region with their calibration data.

8. EPA's green infrastructure website http://water.epa.gov/infrastructure/greeninfrastructure/gi_modelingtools.cfm has links to additional open source tools and other models. Simp and complex tools exist. The user must decide what tools will meet their needs.

5.2 Defining the Source

Source control requires defining the pollutants of concern. Urban and suburban runoff characteristics are affected by many factors such as rainfall amount, rainfall intensity, land use, geology, season of the year and antecedent condition. Modeling software tools are available to help identify, quantify and address pollutants of concern such as the EPA SUSTAIN Model and SLAMM.

Continuous long-term simulations are needed for stormwater quality analyses. Single event design storms are not effective in covering the wide range of conditions needing attention. Use actual decades of rain data for the area (such as possible with SWMM and WinSLAMM, www.winslamm.com).

1. Design Storms

Selecting a design storm is a critical step. The current standard of practice focuses on small but frequent rain events that account for the great majority of pollutants found in runoff. These small storms generate what is typically defined as a water quality volume. According to the National Research Council, water quality volume (W_{qv}) is the volume needed to capture and treat 90 percent of the average annual stormwater runoff volume equal to 1 inch times the volumetric runoff coefficient (R_v) times the site area. (National Research Council, 2009) Control may also include storms up to 1.5 to 2 inches where channel protection requirements apply. This volume is based on local rainfall data and can vary depending on geographic location.

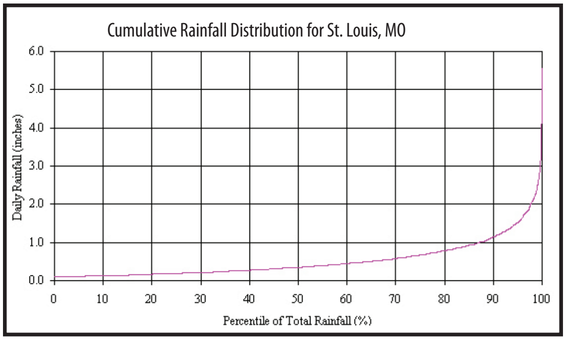


Figure 5.2 Source: Metropolitan St. Louis Sewer District.

Selecting a Design Storm: St. Louis, MO Rainfall Distribution

50 years of rainfall data for St. Louis, indicates that 90 percent of all rainfall events are 1.14 inches or smaller. This value should be determined locally using rainfall records to develop a similar rainfall frequency analysis. Communities with large geographic areas may find it beneficial to obtain data from different areas in a community to account for variability in rainfall patterns. Rainfall data sets and distributions can be derived from weather service organizations such as the United States Geological Survey (http://mo.water.usgs.gov/), National Weather Service, National Oceanic and Atmospheric Administration, or their regional and local affiliates.

2. Land use – Runoff carries pollutants that are primarily a function of land use. For example, commercial parking and dense urban areas can create excess volume and thermal loads, gas stations may contain hydrocarbons and agricultural areas may have high suspended solids loads from dormant croplands.

3. Target Pollutants – In context of source control, regulators and designers need to consider pollutants in context of the receiving streams. According to a recent report completed for EPA, "the rapid conversion of land to urban and suburban area has profoundly altered how water flows during and following storm events, putting higher volumes of water and more pollutants into the nation's rivers, lakes, and estuaries. These changes have degraded water quality and habitat in virtually every urban stream system" (Committee, 2009). Numeric limits for specific pollutants are not common, however target pollutants may include suspended solids, TMDL values, channel protection volumes, or specific pollutants linked to industrial land use.

Summary of Available Stormwater Quality Data Included in NSQD, Version 3.0

Parameter	Residential	Commercial	Industrial	Freeways	Open Space	
Land use and number of samples in the NSQD	TSS (mg/L)	BOD5 (mg/L)	COD (mg/L)	Fecal Coliform (mpn/100 mL)	Fecal Strep. (mpn/100 mL)	Total E. Coli. (mpn/100 mL)
Residential Areas Combined (2,586)	120	15	70	56,000	64,000	6,000
Commercial Areas Combined (916)	120	20	90	26,000	54,000	5,500
Industrial Areas Combined (719)	170	30	100	47,000	63,000	3,100
Freeway Areas Combined (680)	115	15	90	8,500	27,000	6,000
Open Space Areas Combined (79)	40	7	20	7,300		1,550

Table 5.1 Source: National Stormwater Quality Database, version 3, 2007
http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

Summary of Available Stormwater Quality Data Included in NSQD, Version 3.0							
	NH3 (mg/L)	NO2+NO3 (mg/L)	Nitrogen, Total Kjel-dahl (mg/L)	Phosphorus, total (mg/L)	Cu, total (µg/L)	Pb, total (µg/L)	Zn, total (µg/L)
Residential Areas Combined (2,586)	0.5	1.0	1.8	0.4	30	20	120
Commercial Areas Combined (916)	0.8	0.8	1.9	0.3	30	30	200
Industrial Areas Combined (719)	0.7	0.9	2.0	0.4	40	60	250
Freeway Areas Combined (680)	1.7	1.9	2.5	0.7	35	75	160
Open Space Areas Combined (79)	0.3	0.6	0.5	0.1	10	50	60

Table 5.2 Source: National Stormwater Quality Database, version 3, 2007 http://www.unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.html

4. Soil Type – Soil type affects both the volume of runoff and type of sediment a watershed may produce. Highly erodible soils may contribute large volumes of post-construction sediment to structural stormwater control measures, making non-structural measures an important preventive maintenance tool. In contrast, cohesive watershed soils may generate less volume of sediment, but contain finer grained sediments that may require filtration based structural stormwater control measures for effective treatment.

Figure 5.3: Theis Park rain garden- Kansas City, MO.
Source: Shockey Consulting.

5.3 Controlling the Source through Sustainable Site Design Methods and Practices

Limiting the volume of runoff and pollutants through site planning is a critical component of green infrastructure. Non-structural stormwater control measures most relevant to source control of volume and other pollutants are minimizing impervious surfaces during design and maintaining good housekeeping practices.

5.3.1 Minimizing Pavement and Direct Connections

Minimizing impervious surface requires designers to evaluate every potential impervious surface and its connection to the stormwater collection system. Roads, curbs, walks, trails, driveways, alleys, rooftops and hardscaped open space all contribute to increased rates and volume of runoff. The impact of each can be minimized through efficient design.

Research in Milwaukee, WI (Pitt, 1999) demonstrates rains between 0.5 and 1.5 inches are responsible for about 75 percent of the runoff pollutant discharges and are key rains when addressing mass pollutant discharges in a given year. The median rainfall depth was about 0.2 inches while 66 percent of all Milwaukee rains were less than 0.5 inches in depth. Pollutant loads closely followed the runoff cumulative probability density function, demonstrating how small but frequent rain events create the majority of the annual runoff volume and the greatest pollutant discharges. Furthermore according to the National Research Council publication Urban Stormwater management in the United States 2009, MS4s have failed to address the more frequent rain events (<2.5 cm). Stormwater control measures designed to address these storms can assist with larger watershed flooding issues.

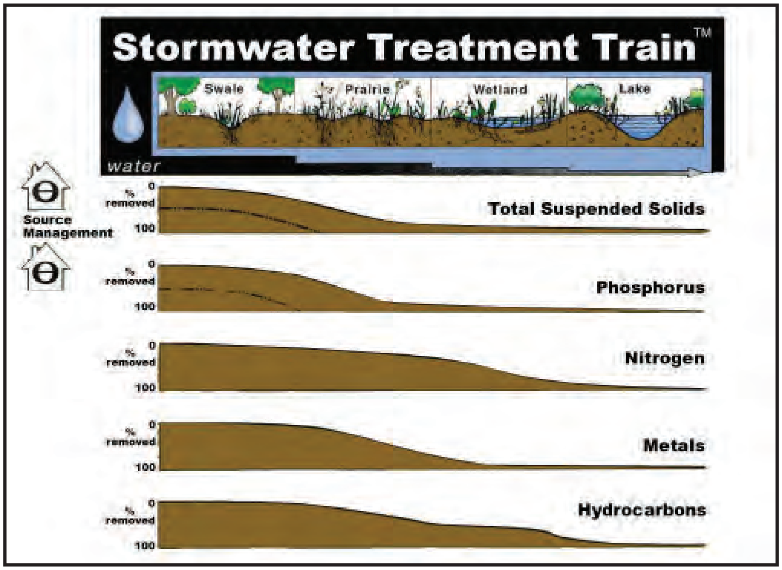
1. Narrowing – Reducing the width of roads create a directly proportional decrease in water quality volumes associated with transportation networks. Narrowing may also create more area for vegetated stormwater control measures within the right of way such as grass swales or rain gardens. Designers may be able to decrease effective road widths through inclusion of pervious pavements in curbs, gutters and shoulders or through adapting some streets and alleys to private drives.

2. Shortening – Concepts should be re-evaluated during design development to help ensure that road lengths cannot be further reduced. Use of cul-de-sacs, clustering homes, or limiting the use of unloaded roads can decrease overall street lengths required in some residential developments.

3. Through streets versus cul-de-sacs – Emergency service chiefs may sometimes negotiate narrower street widths in exchange for through streets versus cul-de-sacs. Narrower streets may be difficult for emergency vehicle drivers to navigate if the street also ends in a cul-de-sac. If cul-de-sacs must be used, they should be designed with functional rain gardens where possible.

4. Walks and trails – Sidewalks can be reduced by using minimum widths (reducing from five to four feet for example) or by substituting a single multi-use trail for streets planned with walks on each side. Pervious concrete may even be used for sidewalks. Trails are not typically directly connected impervious surfaces, so their effect on runoff rates and volumes is not as severe as roads or walks. However, trail networks should be narrowed and shortened where practicable.

5. Disconnection - Conventional designs often include direct connection of runoff to the collection system via downspout connections to sewers, area inlets within paved parking areas and gutter inlets along roadways. Disconnecting this runoff from the impervious surface prior to entering the collection system can effectively reduce impact from these areas on the hydrologic regime. Effective disconnection examples include downspout disconnection or redirection, moving parking area inlets into rain gardens, placing roadway inlets within roadside swales or bioretention areas, or using pervious pavements in gutters in advance of inlets.



The Stormwater Treatment Train,™ or STT, graphic was created by Applied Ecological Services Inc. in the early 1980's. It was developed after working on a study of the Des Plaines river and to study how discharge in the river has changed since mid-1800's. This STT graphic shows the elements developed for the Prairie Crossing project, Grayslake, IL. The dashed line in the graphic is expected reductions in nutrients, road de-icing salts, fertilizers and other contaminant constituents from source control. This aids changing landowner behavior to reduce home lawn fertilizer, herbicide, and pesticide uses. This graphic is stylized modeling output from the USGS HSPF model. Any questions about this graphic or the studies behind it can be directed to Steven I. Apfelbaum (steve@appliedeco.com) at Applied Ecological Services, Inc.

Figure 5.4 Stormwater Treatment Train. Source: Applied Ecological Services. See www.appliedeco.com for more STT information and project examples.

5.3.2 Good Housekeeping

Basic maintenance of pavements, landscapes and stormwater control measures is needed to ensure long-term stormwater control measures performance and help prevent unnecessary pollutants in runoff. Site designers should include specific operation and maintenance manuals for all stormwater control measures and landscape areas. These practices will help the municipality with stormwater compliance. Some good housekeeping strategies may include:

- Regular street sweeping using mechanical or vacuum sweepers to protect downstream stormwater control measures from filling or clogging, The cost effectiveness of street sweeping for stormwater management alone may be low, but is strongly suggested for maintenance of pervious pavements.
- Minimizing material volumes during deicing material applications.
- Prompt pavement repairs.
- Quick cleanup of chemical or other pollutant spills.
- Nuisance geese prevention practices including fencing or vegetated barriers, no feeding signs or ordinances, chemical repellent applications to lawn areas. Dog patrols, capture and relocation and addling eggs may also be used but may require permits or other special permission.
- Vector (mosquito) control.
- Pet waste regulations.
- Trimming vegetation and removing accumulated sediments, floatables and other debris.
- Proper, limited or prohibited application of fertilizers and pesticides.
- Use of moisture sensors in irrigated turf areas.

GOOD HOUSEKEEPING STRATEGY: MODEL MAINTENANCE AGREEMENT

To help ensure maintenance of stormwater control measures, MS4s can provide model maintenance agreements. Example language below is taken from St. Louis Metropolitan Sewer District:

KNOW ALL MEN BY THESE PRESENTS, that, ___________ a Missouri Corporation, for and in consideration of the approval of sewer plans and of the issuance of a sewer permit by The Metropolitan St. Louis Sewer District for stormwater management facilities according to plans to be approved by said District for a development known as ___________ in St. Louis ___________, Missouri, at ___________, and other good and valuable considerations, do hereby agree and promise, as follows:

1. To build and construct stormwater management facilities, including Best Management Practices (BMP), basins, drainage facilities, appurtenances and sewer lines, in accordance with the design, plans and report, submitted to and approved by The Metropolitan St. Louis Sewer District. The stormwater management facilities are to be perpetually located within the dimensioned and reserved area, as shown hachured on the exhibit "A" as attached hereto and made a part hereof.

2. To maintain and operate the stormwater management facilities in conformity with the approved Stormwater Management Facilities Report.

3. To maintain all pipes and drains in good working order and maintain all walls, dikes, vegetation, filter media, and any other requisite appurtenances and improvements for the retention and management of stormwater in good repair.

4. That in the event ____ or its successor in title to said property shall fail to maintain the stormwater management facilities, BMP, basins, drainage facilities, appurtenances and sewer lines in accordance with this agreement, The Metropolitan St. Louis Sewer District shall be permitted to enter onto the property and make the repairs and corrections and perform such maintenance as it deems necessary and bill the owners of said property for the services performed. It is further agreed that in the event said bill or charge for the services performed shall not be paid within a period of 30 days said sum shall become a lien on the real property and shall accrue interest at a rate of eight percent (8 percent) until paid in full.

5. This agreement is irrevocable and shall continue forever.

5.4 Green Infrastructure and Structural Stormwater Control Measures.

Many stormwater control measures are a potential element of green infrastructure if applied in an integrated manner with other necessary infrastructure. Where possible, green infrastructure should be integrated to help meet non-stormwater needs such as landscaping requirements, habitat improvement, pedestrian connectivity, overflow parking surfaces and rooftop improvements. Integration examples include:

- Permeable pavements can be used to minimize the volume of runoff and can also be designed to help control peak rates.
- Green roofs or rainwater harvesting for re-use.
- Rain gardens or bioretention in place of elevated parking islands.
- Infiltration trenches below pervious parking or curb and gutter sections (where site conditions do not pose significant threats to groundwater contamination).
- Vegetated filter strips and flush or "ribbon" curbs adjacent to pavement sections.
- Wetland areas may be used to manage stormwater provided that runoff has been treated prior to entering. This can help maintain wetland hydrology while minimizing the risk of infill to the wetland.

As the selection of stormwater control measures are considered, the potential for groundwater contamination pollution post-construction should also be considered. Overall contamination potential (the combination of the subfactors of mobility,

Primary and Secondary Removal Mechanisms

Best Management Practices Group	Pollutant Removal Mechanisms									
	Water Quality					Water Quantity				
	Screening Filtration	Infiltration/ Recharge	Settling	Biological Uptake	Temperature Control	Soil Adsorption	Volume Control	Rate Control	Velocity Control	Evapotranspiration
Pollution Prevention	Not applicable - pollutants not exposed to stormwater									
Better Site Design/ Low Impact Development	1	2	2	2	2	2	1	2	2	2
Runoff Volume Minimization		2			2		1	2		
Temporary Construction Sediment Control			1					1	2	
Bioretention	1	2	2	2	2	2	2	2		2
Filtration	1	2		2		2		2		2
Infiltration	2	1		2	1	2	2	2		
Stormwater Ponds		2	1	2				1	1	2
Stormwater Wetlands	2	2	1	1		2		1	1	2
Supplemental Treatment	Each supplemental and proprietary device should be carefully studied to learn the primary and secondary pollutant removal functions.									

1 = Primary Pollutant Removal
2 = Secondary Pollutant Removal Mechanism

Table 5.3 Source: Minnesota Stormwater Control Manual (2008) abundance, and filterable fraction) is the critical influencing factor in determining whether to use infiltration at a site. The ranking of these three subfactors in assessing contamination potential depends on the type of treatment planned, if any, prior to infiltration. See Table 5.3 for groundwater contamination potential.

Creating a series of stormwater control measures in sequence has a cumulative effect that can be used to meet water quality goals, even where each individual stormwater control measure in the series may be undersized relative to water quality volume.

Groundwater Contamination Potential for Stormwater Pollutants Post-Treatment.

Compound Class	Compounds	Surface Infiltration and No Pretreatment*	Surface Infiltration with Sedimentation*	Subsurface Injection with Minimal Pretreatment
Nutrients	Nitrates	Low/moderate	Low/moderate	Low/moderate
Pesticides	2,4-D	Low	Low	Low
	*-BHC (lindane)	Moderate	Low	Moderate
	Atrazine	Low	Low	Low
	Chlordane	Moderate	Low	Moderate
	Diazinon	Low	Low	Low
Other organics	VOCs	Low	Low	Low
	1,3-dichlorobenzene	Low	Low	High
	Benzo(a) anthracene	Moderate	Low	Moderate
	Bis (2-ethyl-hexyl) phthalate	Moderate	Low	Moderate
	Fluoranthene	Moderate	Moderate	High
	Naphthalene	Low	Low	Low
	Phenanthrene	Moderate	Low	Moderate
	Pyrene	Moderate	Moderate	High
Pathogens	Enteroviruses	High	High	High
	Shigella	Low/moderate	Low/moderate	High
	P. aeruginosa	Low/moderate	Low/moderate	High
	Protozoa	Low	Low	High
Heavy metals	Cadmium	Low	Low	Low
	Chromium	Low/moderate	Low	Moderate
	Lead	Low	Low	Moderate
	Zinc	Low	Low	High
Salts	Chloride	High	High	High

Table 5.4 Source: Dr. Robert Pitt. (Modified from Pitt, R. et al. 1994.)

* Even for those compounds with low contamination potential from surface infiltration, the depth to the groundwater must be considered if it is shallow (1 m or less in a sandy soil). Infiltration may be appropriate in an area with a shallow groundwater table if maintenance is sufficiently frequent to replace contaminated vadose zone soils.

A typical green infrastructure "treatment train" could include:

- Water quality volume rain gardens or subsurface infiltration in advance of the collection system to better distribute infiltration practices throughout a site.
- Surface flow, linear vegetated features to allow infiltration and treatment during conveyance, but also provide pedestrian connectivity.
- Larger stormwater basins to manage larger storm events. These larger basins may be located in ball fields, parks and other common green space areas.

Which stormwater control measure is selected may be a function of where they fit into a development, rather than altering the development to make them fit. General types of structural stormwater control measures include:

1. Bioretention typically includes amended soils to provide improved filtration and increased storage capacity. Bioretention areas can be small streetscape islands or large and extensive parking lot medians. Where site conditions are poorly drained or impermeable, bioretention areas may have underdrains.

Site Level Constraints and Opportunities	
Site Feature	**Constraint or Opportunity**
Floodplains, riparian areas, wetlands, natural and man-made drainage ways	To the extent possible, development should be avoided in floodplain areas, riparian areas, wetlands, and drainage ways. A stream buffer ordinance or other regulations may be in place to limit development in these areas.
Soils and topography	Impact the amount of runoff and infiltration of precipitation that will occur.
Geology, groundwater conditions	Might create limitations on where development can occur if the area is underlain by limestone with fractures and solutions cavities or if the water table is near the ground surface.
Vegetation	Opportunities to eliminate invasive species, improve or restore habitat, and enhance landscaping aesthetics. Use selected vegetation for water quality and quantity controls.
Existing land use	Redevelopment projects may already be paved, have buildings, and buried infrastructure that make implementation of structural stormwater control measures problematic. Opportunities to disconnect downspouts, use existing infrastructure, and decrease impervious surface may all provide low cost stormwater improvements.
Roadways	Stormwater management in the right of way may be prohibited by regulatory agencies. If not, street landscapes, curbs and gutters, and sidewalks all provide potential areas for distributed storage outside the street boundaries. Over widened streets can be narrowed or otherwise redesigned to include less impervious areas.

Table 5.5 Source: Michigan (2008)

Figure 5.5 Wetland Swale. Source: Olsson Associates

2. Subsurface infiltration is an engineered, subsurface trench similar to a septic leach field. It may be placed at the perimeter of paved areas, beneath pervious concrete curb and gutter sections, pervious sidewalk or trail systems, or in pervious parking, drives or alleys.

3. Bioswales may contain engineered backfill that can improve performance, but also increase cost. Wetland swales can be used in zero-slope conditions to help ensure long-term survivability of vegetation.

4. Swales with native vegetation can provide improved long term infiltration, but may not be aesthetically appropriate for some settings.

5. Rain gardens are small, landscaped areas designed to receive and manage small storms. They typically need to be a depressed landscape area planted with vegetation that tolerate flooded as well as dry conditions. They can be placed near downspouts, intersections, or intermittently along streets where space allows.

6. Turf swales with shade trees may be more aesthetically pleasing but require more frequent mowing and provide less effective long-term infiltration and treatment than deeper rooted native or adaptive plants.

7. Linear dry detention allows for the swale to serve both a conveyance and rate control function.

8. Stormwater parks can include a variety of control measures but generally will have a small frequently inundated water quality area (if no stormwater control measures address this upstream) and a large, normally dry, offline detention shelf area that is used as a park.

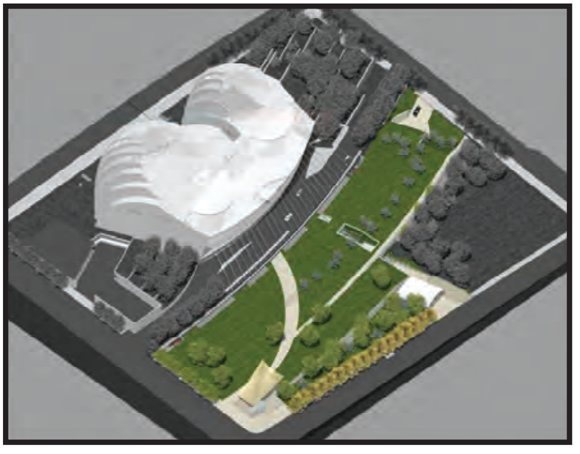
9. Green roofs can offer a combination of benefits, including stormwater management, urban heat island moderation, improved air quality, building energy savings and useable green space.

Figure 5.6 Intensive Rain Garden - Olsson family garden, St. Louis Children's Hospital. Source: www.stlouischildrens.org

Introduction to Case Studies

Throughout the U.S., there is a growing recognition of the benefits green infrastructure provides to communities. Many municipalities and other jurisdictions have begun to effectively incorporate these practices. The following case studies were selected to showcase both site and landscape scale GI projects which have successfully been implemented. Additional case studies are included in Chapter 6. Readers are encouraged to follow the links or titles provided for each case study to learn more about these projects.

Case Study: Kansas City Performing Arts Center Garage Kansas City, MO



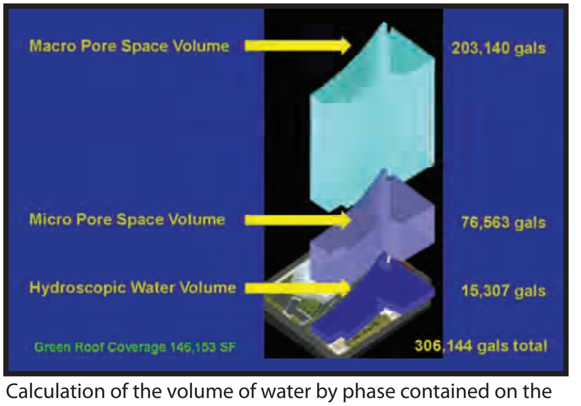
Kansas City Performing Arts Center Garage Green Roof boundary is shown in color.
Source: Jeffrey L. Bruce & Company, Landscape Architects

The Arts District Garage is a $32 million, 1000 car underground parking structure attached to the new Kauffman Performing Arts Center in downtown Kansas City, Missouri. The green roof atop the structure is designed as a 2.63 acre open space park. The 146,000 square foot green roof component of the garage serves as a stormwater collection and detention system with the capability of collecting and detaining 50 percent of a 100 year storm event for the first 24 hours and the system will continue to detain 25 percent of the stormwater for up to the next 66 hours before release into the water harvesting cisterns.

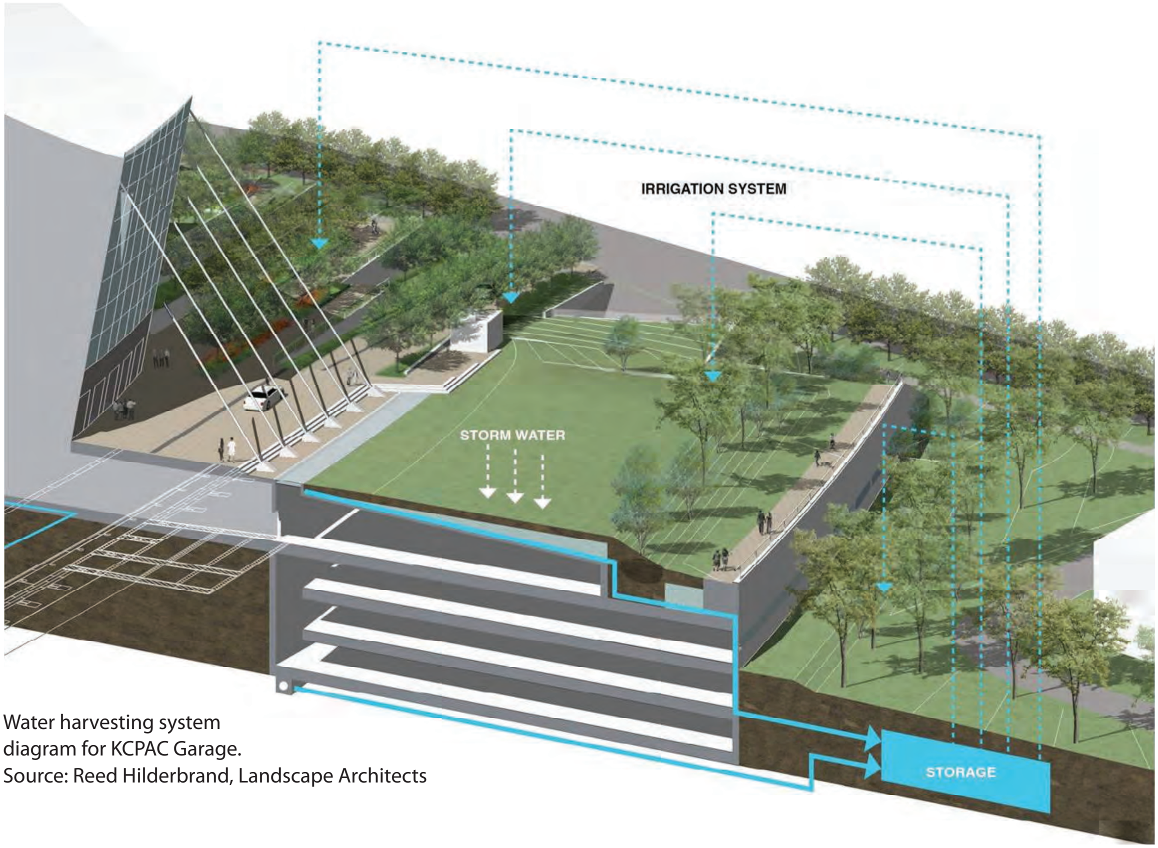
The system captures excess stormwater which exceeds storage capacity of the green roof soils and routes it into underground cistern storage where it is then recycled as irrigation water for the vegetated roof. The Arts District Garage is the first permitted green roof stormwater detention facility in Kansas City, MO.

Green Roof Design

The primary objective for this rooftop park is to provide a grand lawn for the new KCPAC building. The green roof designed as a multipurpose space for events and public gatherings helps to blur the edges of the parking garage by projecting the landforms



Calculation of the volume of water by phase contained on the green roof. Source: Jeffrey L. Bruce & Company, Landscape Architects.



Water harvesting system
diagram for KCPAC Garage.
Source: Reed Hilderbrand, Landscape Architects

of the surrounding park onto the parking garage. The unique aspect of this case study is the soil profile design that allows the green roof to replace the mandated stormwater detention facility. The soil profiles were specifically designed to meet the diverse needs of this demanding site. The use of the site by hundreds of thousands of visitors per year required considerable agronomic innovation to ensure sustainability of the landscape under such physical loading and abuse.

Using the sand based media mix designed for the green roof a mock-up of the green roof profile was created to mimic as built conditions so that the designers could gain a precise understanding of water movement and detention in the soil profile.

This experiment was conducted under two scenarios; one with the sand-based soil in a saturated condition and the second with the soil in an unsaturated condition. Using the Kansas City stormwater design parameters that mandate retention of the first 25 percent of a 100 year storm event, the lab simulated a 3" storm event within a 25 minute time period, thus exceeding the city requirements. The measurements were documented over a 120 hour period with the following results:

- 50 percent of the storm event was retained within the soil profile for the first 24 hours.
- 25 percent of the storm event was retained within the soil profile for 66 hours before the soil moisture content returned to an unsaturated condition.

The test results indicated the green roof for the KCPAC Garage contained a total of 306,144 gallons of water storage.

Local ordinances mandated a stormwater detention facility for the garage, but did not mandate a green roof. This component of the design was envisioned by the landscape architect who provided the research data to determine the retention and flow characteristics of the growing media and demonstrated meeting the stormwater ordinance requirements with alternative means.

Based on this data, storm events such as the 2, 10, and 25 year storm events would be retained in the soil making the water available to the plant material or slowly draining to the collection system when the soil profile is in an unsaturated condition thus eliminating runoff. Having the alternative compliance method of meeting the local stormwater ordinance approved the design team was able to remove from the project a $348,000 traditional detention system and replace them with two 50,000 gallon cisterns for $290,000. With the addition of the 2 cisterns the stormwater would be collected and returned to the green roof for reuse as irrigation water further reducing stormwater runoff from the site.

The Arts District Garage green roof is the first green roof project in Missouri to be permitted as a stormwater detention facility. It provides life cycle cost savings by increasing the life of the waterproofing membrane, reducing water cost for the irrigation system and provides a pristine open space within the urban landscape. The creation of this green roof open space also provides a stormwater detention facility that greatly exceeds the local stormwater requirements and serves as part of the structure's infrastructure.

Installation of the water harvesting cisterns.
Source: Jeffrey L. Bruce & Company, Landscape Architects

The benefits to the community will be the addition of a vibrant new open space park within Kansas City's downtown area. It will provide a new venue for patrons of the arts by providing landscaped lawn areas for arts and crafts events and well as outdoor on the lawn concerts. Additionally, the reduction in stormwater runoff to an aging city stormwater system helps to improve the capacity of the existing combine sewer system.

Maroney Commons
Source: Rural Learning Center, Howard, South Dakota

Rural Smart Growth

Maroney Commons at the Rural Learning Center in Howard, South Dakota

With just over 850 residents, Howard is reimagining what it means to be rural with Maroney Commons. The Commons, built with green building techniques, is a mixed-use complex with a hotel, a conference center, a restaurant, and offices that will help rural residents learn about green jobs and technology.

A model for other rural towns

Maroney Commons serves as a model for other rural towns looking to create vibrant community places that strengthen Main Streets, help residents learn new skills to compete in the 21st-century economy, and demonstrate environmentally responsible, energy efficient design. Its message that "Rural is a good investment!" can inspire other towns around the nation.

The story behind Maroney Commons began over a decade ago, when Howard High School students launched a successful "buy local" campaign to increase sales tax revenue in Miner County. The effort generated nearly $16 million in additional gross sales for Howard, the county seat, in its first year and inspired Miner County's residents to engage in a community visioning process. The visioning process, combined with the growth of the wind energy industry in Miner County, led to the development of the Maroney Commons.

Although the town could have built the new facility on 40 acres of donated land outside of town, Howard residents instead chose to reinvest in their downtown by demolishing — and salvaging materials from — dilapidated buildings on Main Street, putting Maroney Commons at the center of the community. Intensive workshops gathered citizens' input throughout the design process.

Maroney Commons
Source: Rural Learning Center, Howard, South Dakota

Roof top garden

The roof top garden is a favorite feature with stormwater consideration. This is located just off the wind turbine tower and just off the elevator on the second floor. The garden is a trench that holds two feet of soil and contains plantings that are indigenous to the state of South Dakota; this feature also helps collect rain water as well as supporting the need to "move" if you have been at meetings or training all day.

Cistern

The building features an underground cistern that holds up to 16,500 gallons of rainwater and snowmelt collected from the roof. This water is used to flush toilets throughout the facility. As a part of the learning corridor, the water from the roof flows through a clear plastic pipe on its way to the cistern to help illustrate this feature. Even a slight rain shower will cause people to stop in the corridor and watch this water moving through the pipe; provides an excellent teaching opportunity!

The building also features a rain collection pond (located next to the parking lot which covers the 44 geothermal wells connected to the project!). This pond holds water during a significant rain storm, etc. which then also moves into the rainwater cistern.

Pail of Reference

Many aspects of the construction and design of the Maroney Rural Learning Center are not obvious as you drive past. Some amazing features of the building are now almost out of sight but continue to serve their purpose in conservation and energy efficiency. One of these is the underground water storage cistern located on the west side of the new building. Rain water and snow melt will be

Cistern Pail of Reference with 8-year old Lane Miller, son of Ryan and Sara Miller. Source: Rural Learning Center, Howard, South Dakota

collected and stored in the underground cement cistern which has a capacity of 16,000 gallons. This water is then reused to flush toilets throughout the building.

It is hard for most of us to imagine what 16,000 gallons looks like. But farm kids think in terms of 5-gallon pails. Lane Miller (aged 8) pointed out that more than 3000 of the 5-gallon pails would fit into the cistern. (He went on to calculate that it's actually 3,200 pails – thanks, Lane!). That's a lot of water saved from the roof and from the roof top garden and adds efficiency and renewal points to the building's "green" certification.

"We've hosted tours for young and not so young visitors and each time we've learned something new, too!" reports the Rural Learning Center staff.

With the community's input, Maroney Commons contains a restaurant, a community kitchen, a fitness center, retail space, a hotel, and meeting space. This multi-use community facility will provide educational, social, and business opportunities for not just Miner County residents, but rural communities all across the region. The facility is expected to create 13 full-time jobs and bring the local economy more than $6 million per year. Profits will likely allow the building to be self-sustaining within three years.

The conference center, which holds up to 300 people, was designed for training in green energy jobs and rural health care. The facility also hosts design: South Dakota, a team of architects and community development experts who travel statewide helping residents reimagine their rural communities through design workshops. Eighty percent of South Dakota's population lives within 100 miles of Howard, making the center accessible to many small-town residents.

Maroney Commons has raised the bar — both through its innovative design and construction and its educational opportunities for rural residents. One of the first LEED Platinum-certified buildings in South Dakota, the building has solar panels, a wind turbine, geothermal heating and cooling, porous outdoor pavement, rainwater capture and storage, and native landscaping. Materials gathered from demolished Main Street buildings were recycled and reused during construction; the wood floor from an old gymnasium is now the floor of the restaurant, and Maroney Commons' siding came from an old American Legion hall. Real-time, touch-screen displays of the wind and solar energy produced at the building help visitors understand these technologies.

Partners include City of Howard; Miner County; U.S. Department of Agriculture; American Institute of Architects South Dakota; and Citi Foundation. Contact the Rural Learning Center at 605-772-5153 to set up a tour or visit http://rurallearningcenter.org/