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10 MARCH 2012

GUIDANCE FOR LOW IMPACT DEVELOPMENT (LID) SITE SELECTION AND INTEGRATION ON MILITARY LANDS

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FACILITIES ENGINEERING ENVIRONMENTAL

GUIDANCE FOR LOW-IMPACT DEVELOPMENT (LID) SITE SELECTION AND INTEGRATION ON MILITARY LANDS

1. Purpose.

This Public Works Technical Bulletin (PWTB) provides the following assistance to military installations.

a. Guidance and information on low-impact development (LID) and sustainable stormwater infrastructure site analysis and selection on military lands.

b. An overview of LID for others involved in stormwater (e.g., stormwater maintenance crews) who do not require the detailed technical information required for design and development of sustainable infrastructure (SI).

c. Benefits to organizations that wish to establish and prioritize the costs and benefits within different locations on an installation for a more integrated approach to LID implementation.

d. Suggestions on retrofitting existing stormwater infrastructure with SI such as LID implementation.

e. All PWTBs are available electronically at the National Institute of Building Sciences' Whole Building Design Guide webpage, which is accessible through this link:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability.

a. This PWTB applies to all CONUS U.S. Army facilities engineering activities.

b. It will support installation DPW personnel, installation planners, and other personnel to balance the technical requirements for environmental compliance, sustainability, and operational capability of the installation.

3. References.

a. Army Regulation (AR) 200-1, “Environmental Protection and Enhancement,” 13 December 2007.

b. Executive Order (EO) 13423, “Strengthening Federal Environmental, Energy and Transportation Management,” 24 January 2007.

c. “Sustainable Design and Development Policy Update,” Memorandum from Deputy Assistance Secretary of the Army, Installations and Housing (DASA I&H), 5 January 2006.

d. “Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings” Memorandum of Understanding (MOU), 6 March 2006.

e. “Army LEED Implementation Guide” US Army Corps of Engineers, 15 January 2008.

f. EO 13514, “Federal Leadership in Environmental, Energy and Economic Performance,” 5 October 2009.

g. “Energy Independence and Security Act (EISA),” Title 42, United States Code (USC), Chapter 52, Section 17094, Section 438, 19 December 2007.

NOTE: Highlights of these regulatory and policy references are given below, with more details in Appendix B.

4. Discussion.

a. AR 200-1 implements, federal, state, and local environmental laws and DOD policies for preserving, protecting, conserving, and restoring the quality of the environment. It outlines Army environmental stewardship and defines the framework for the Army Environmental Management System.

b. EO 13423 requires that new construction and major renovation of buildings comply with the five Guiding Principles in the Federal Leadership in High Performance and Sustainable Buildings MOU.

c. The DASA Memorandum requires that the Army transition to the US Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) Rating System to meet sustainability goals for infrastructure development.

d. EO 13514 requires federal agencies to lead the nation by example for improved environmental performance including conserving and protecting water resources through efficiency, reuse, and storm management.

e. Appendix A provides an overview of LID and the stormwater management goals it is designed to meet. This section groups LID practices by their basic functions from a stormwater perspective. General overviews of these functions are given and the affected regulations are listed to illustrate how regulatory integration into comprehensive planning effort is needed.

f. Appendix B focuses on the regulatory and policy requirements that pertain to the implementation of LID on military lands by outlining the current regulatory framework under which LID must operate. Details of the regulations are given to assist the reader in understanding to goals of each regulation and its implication in shaping LID implementation.

g. Appendix C examines the underlying design concepts of LID and how this concept varies from traditional stormwater management approaches. This section presents a methodology that stormwater management personnel could take to integrate LID practices into their existing plans. A general approach is offered along with information regarding acceptable LID practices based on sizing, soil type, ecological region, and stormwater treatment priority.

h. Appendix D discusses the approaches and challenges in integrating LID practices into the overall stormwater system. This section outlines the general issues incurred while developing plans and designs for individual projects that will eventually be managed within a larger stormwater context. Designers and planners are encouraged to be proactive in their understanding in how site development will affect stormwater management goals.

i. Appendix E provides fact sheets for common LID practices. This section lists general LID practices, treatment effectiveness, and the advantages and constraints of these common LID practices. Additionally, a general overview of the construction and maintenance needs of each practice is discussed.

j. Appendix F lists references used in previous appendices and resources for additional investigation.

k. Appendix G defines abbreviations used in this PWTB.

5. Points of Contact.

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APPENDIX A:

LOW-IMPACT DEVELOPMENT OVERVIEW

Introduction

Rethinking the approach to stormwater management is a critical step to improving ecosystems and natural habitats. Released stormwater plays a significant role in contaminating streams and rivers by carrying pollutants (e.g., soils, metals, hydrocarbons) that harm sensitive species and pollute drinking water sources, in addition to. Historically, stormwater management has meant centralized flood control by moving water rapidly away from urban-type areas. While this flood/volume based hydrology approach has worked as intended, its success comes at financial expense and societal cost (e.g., increased water treatment cost, infrastructure maintenance, and pollutant remediation).

As environmental awareness has increased in the last several decades, new rules and regulations have been enacted to address environmental problems. The flood-control approach as the only stormwater management approach is rapidly becoming outdated and increasingly expensive to maintain. Numerous case studies and research have indicated that stormwater management strategies should become decentralized and stormwater controls measures should focus on mimicking the area's pre-development hydrology in an effort to lower downstream pollution, increase water reuse, and improve groundwater recharge (EPA 2007). These stormwater control strategies can be implemented with either structural or non-structural stormwater control measures and are frequently referred to as green infrastructure (GI), sustainable infrastructure (SI), or low-impact development (LID) measures (note that throughout this document these three terms will be used interchangeably). While conventional stormwater management strategies focus on the prevention of flooding, LIDs dominant objective is the management of smaller, frequently occurring storm events (i.e., the 95% percentile storm event). It is during these storm events that the majority of pollutants are washed off impervious surfaces and carried into the stormwater drainage network. Through the management of small storms, LID strategies minimize hydrological and pollutant loading impacts of the site on the storm drainage network and receiving bodies of water.

In recent years, the perspective of stormwater management has shifted to a watershed-based framework as an organizing principle and it is helpful to visualize the stormwater drainage network as part of the watershed even though it is frequently invisible by virtue of being underground. When the watershed is separated into its component parts, installation planners and designers can focus on sites to implement those stormwater control strategies (which can be either above- or below-ground) that optimize water movement and reuse. The practice of LID approaches stormwater and related runoff as a resource to be utilized compared to traditional stormwater practices which treat stormwater as a nuisance (Sarte and Terrell 2008).

Site Considerations and Areas of Practice

Many military installations resemble urban communities in their composition because they contain industrial areas, open spaces, recreational areas, housing, retail, offices, and transportation networks. Furthermore, military installations have unique land use applications due to their training areas, range facilities, maintenance facilities, parking/storage/staging locations, and environmentally sensitive areas which may require unique approaches for SI development and implementation. The constraints imposed on design and implementation in unique military areas, by training doctrine, mission requirements, and human health and safety considerations may limit the range of SI options available to the planners and designers. Thus, adaptation of standard designs and alteration of standard practices may be required to meet all land-use requirements for a military site.

As always, feasibility and cost will be primary constraints on any SI; these constraints are some of the main challenges that installation planners face in considering the placement of LID infrastructure. Fortunately, there is a broad array of both non-structural and structural options available which range in cost. Many LID stormwater measures are comparable to traditional stormwater best management practices (BMPs) and over their lifespan, they will lower the cost of installation stormwater management and maintenance. LID stormwater control measures are frequently implemented on military lands where there is new development and/or redevelopment. Additionally, these BMPs can provide standalone stormwater treatment.

New site development provides the opportunity to fully integrate the building superstructure into the surrounding environment. Site redevelopment frequently does not have the same latitude as a new development to reinvent the site, and implemented LID strategies may be required to compensate for the lack of full infrastructure integration on the site. Such circumstances may increase the implementation and maintenance costs over a fully integrated site. Regardless, those areas that are able to harness LID strategies effectively are able to retain water, reduce peak flow rates, and improve water quality. For the purpose of planning and prioritization of SI development into the existing stormwater system, the stormwater network is functionally categorized in the areas listed below.

- Accumulation Areas
- Conveyance/Transport Areas
- Detention Areas
- Retention Areas
- Pollution Treatment Areas

These five functional areas are interspersed throughout the stormwater network of the installation, and many locations have multiple functions (e.g., a grass channel can accumulate, convey, detain, and treat stormwater). The functions of these five areas are discussed in the following sections, with suggestions given on strategies for SI development. Table A-1 that follows the discussion summarizes the areas and related BMPs.

Accumulation Areas

LID strategies can be used to maximize site infiltration and prevent stormwater from accumulating as surface runoff through the management of soil or surface permeability. Much of the urbanized and built space on military lands is dominated by impermeable areas. During rainstorms, there is a tremendous amount of water runoff accumulated from areas such as buildings, parking lots, and roads or areas with poorly permeable soils. This runoff rapidly flows down gradient into an existing stormwater network or into a nearby adjacent area and the result frequently overwhelms the stormwater system. By improving the permeability in areas of high runoff, stormwater and pollutants entering the stormwater network can be reduced. Thus, increasing infiltration of impervious and semi-pervious elements of the landscape is the most effective means of reducing the need for structural LID BMPs further downstream. LID BMPs that fall under the category include non-structural practices such as reforestation, site soil amending, impermeable structure footprint minimization, and promotion of sheet flow (i.e., drainage disconnects). Structural BMPs include permeable pavements, planter boxes, and rain gardens.

Conveyance Areas

The primary purpose of conveyance areas is water transport from one location to another location downstream. Traditionally, these structures have been built to channel water downstream as quickly as possible to prevent upstream flooding. To accomplish this, the channels are constructed from relatively impermeable materials such as turf grasses, concrete, rock, and underground piping. The drawback of this approach is that along the conveyance corridor, water has relatively little time to be reabsorbed into the surrounding environment through infiltration; furthermore, polluted waters have no opportunity for treatment. The reclamation of these spaces for infiltration and treatment provides additional land area that might not be available prior to water entering the conveyance. The utilization of natural swales and natural channels allows for infiltration of stormwater runoff and reduces the overall volume and rate of water at the receiving end of the conveyance. This reduction is accomplished by purposing vegetation to reduce water flow energy. Use of conveyance area stormwater control measures requires minimal construction effort and maintenance when properly planned and installed. Conveyance treatments can be used as a standalone practice but most are commonly used in conjunction with other practices as part of the overall design scheme. LID BMPs that fall under this category include: vegetated swales, bioswales, rain gardens, and infiltration trenches.

Detention Areas

If measures to reduce surface runoff from accumulation areas are insufficient, inappropriate, or infeasible, the use of detention areas may be warranted. By constructing a depression in the landscape for temporary storage of surface runoff, water can be channeled to detention areas to manage excess surface water runoff and to treat pollutants. Water in the detention area is infiltrated and eventually percolates down to the local water table. Historically, the practice of detention has been confined to sizeable downstream basins which require piping, waterway entrances, spillway exits, and rock/concrete in an attempt to keep high energy water flow from eroding the basin banks. Given its size, the detention basin requires substantial maintenance to maintain its function. This maintenance frequently includes debris removal and periodic draining and cleaning. Furthermore, detention basins that are filled with water year round provide a vector for pests and animals at the site and can create moisture issues if used near culturally sensitive or historic sites. By utilizing LID BMPs, detention basins can be located closer to the source of surface runoff and be a smaller in size. These detention areas are frequently dry during most parts of the year, unless site management goals dictate otherwise. Potential structural BMPs include: green roofs, rain gardens, bioswales, infiltration trenches, and wetlands. These structures can be scaled to fit the location’s need.

Retention Areas

Retention areas are created to provide long-term, significant collection and storage of runoff water for later reuse such as irrigation. By doing so, surface runoff water is prevented from entering the stormwater system. Rainwater retention as an LID BMP is frequently chosen as an alternative to reduce energy use because it limits the need to pump or haul water to a site. Potential structural BMPs include: planters, wet ponds, rain barrels, and cisterns.

Pollutant Treatment Areas

During a storm event, pollutants that have accumulated on impervious surfaces are collected and transported down gradient by surface runoff. At the beginning of a storm event, pollutants are at their highest levels (e.g., soils, military unique contaminants, and petroleum, oils, and lubricants [POLs]), but as the storm event progresses, pollutant concentrations decrease dramatically. Pollutants in stormwater systems without SI will require downstream treatment. Pollutants in stormwater systems with SI can be captured and mitigated near the source. LID BMPs are designed to abate and treat the majority (95%) of all rainfall events; furthermore, these practices also can be utilized to treat urban pollutants through decentralized biotreatment that reduces the need for expensive downstream treatment facilities.

Table A-1. Areas of stormwater system and related examples of LID BMPs.

Functional Areas of Stormwater System	Examples of Related LID Best Management Practices
Accumulation Areas	Reforestation, site soil amending, impermeable structure footprint minimization, promotion of sheet flow, permeable pavements, planter boxes, rain gardens
Conveyance Areas	Vegetated swales, bioswales, rain gardens, infiltration trenches
Detention Areas	Detention basins, green roofs, rain gardens, bioswales, infiltration trenches, wetlands
Retention Areas	Planters, wet ponds, rain barrels, and cisterns
Pollutant Treatment Areas	Sand filter system (see Section E), commercial systems (e.g., CDS)

Comprehensive Planning

The successful long-term implementation of LID practices requires that planners, designers, and developers be aware of how a prospective LID site will be viewed from a regulatory, hydrological, and maintenance perspective. Additionally, installations provide the facilities and services to fulfill mission requirements that support troop training and readiness. The various regulatory perspectives for stormwater management are listed below. (For more detailed information, see Appendix B.)

Regulatory

- Clean Water Act
    - Section 402 – National Pollutant Discharge Elimination System (NPDES)
    - Section 303(d) - Total Maximum Daily Load (TMDL) (Impaired Waters)
- EISA Section 438 – requirements for federal development and redevelopment projects.
- NHPA (1966) – National Historic Preservation Act – cultural resources preservation on military lands
- ESA (1973) Endangered Species Act – Threatened and endangered species protections on military lands

- State and municipal laws

Standards, Codes, and Guidelines

- ASHRAE Section 189.1 – American Society of Heating, Refrigerating and Air-Conditioning Engineers - Standard for the Design of High-Performance Green Buildings Except Low Rise Residential Buildings
- LEED™ – Leadership in Energy and Environmental Design – Silver Level or Higher for new constructions or major renovations.
- UFC 3-210-10 - Unified Facilities Code - Low Impact Development
- Installation Design Guide (IDG)
- Installation Master Plan (IMP)
- Range Complex Master Plan (RCMP)
- State and municipal codes

In order to decide which LID BMP to implement at each site, the primary concern is how to address the management of the 95th percentile storm runoff or the pre-development hydrology. Within that context, each location is potentially subject to different land uses, constraints, and requirements. Therefore a “cookie cutter” approach to LID implementation is discouraged. Additionally, considerations for maintenance are crucial. The LID practice selected should fully evaluate a well-developed maintenance plan to keep the BMP performing at top levels. Maintenance is a crucial aspect of the overall project success since a failure of an integrated management practice (IMP) will eventually cascade down through the stormwater system. Another important consideration is that IMPs are all multi-purpose practices that can be combined and used in conjunction with one another to provide a solution for the many regulatory challenges that installations face with their stormwater management plans.

APPENDIX B:

EXPLANATION OF REGULATORY AND POLICY DRIVERS FOR LOW-IMPACT DEVELOPMENT IMPLEMENTATION

This appendix discusses in detail the legislation governing the implementation of LID on federal facilities and additional sources of guidance regarding the technical design and installation of LID infrastructure on military installations.

Regulatory and Policy Guidance

(a) EO 13423, “Strengthening Federal Environmental, Energy, and Transportation Management”, January 2007. EO 13423 requires that new construction and major renovation of buildings comply with the guiding principles set forth in the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (2006) and directs federal agencies to implement sustainable practices.

(b) EISA, Section 438 “Storm Water Runoff Requirements for Federal Development Projects,” December 19, 2007. This Act establishes strict stormwater runoff requirements for federal development and redevelopment projects on projects that exceed 5,000 sq ft.

(c) EO 13514, Section 14, “Federal Leadership in Environmental, Energy and Economic Performance”, October 2009. Goal 2 established targets to improve Water Resources Management and the reduction of Stormwater Runnoff.

(d) LEED™ (Leadership in Energy and Environmental Design) Requirements for Army Installations. On March 2000, the US Green Building Council (USGBC) established a building certification system for identifying and implementing green building design, construction, operations, and maintenance solutions. As of 2008, the US Army Corps of Engineers (USACE) has required LEED™ Silver (minimum building requirements) or higher for new constructions or major renovations. Additionally, the General Services Administration has updated their procurement requirements to LEED™ Gold.

(e) ASHRAE Section 189.1, “Standard for the Design of High-Performance Green Buildings Except Low Rise Residential Buildings.” The purpose of adopting this “green building” code was to shift USACE from a certification-based approach to a code-based approach for renovation and new construction.

Details of Executive Order 13423

EO 13423 was meant to set more challenging goals for the federal government than the Energy Policy Act of 2005 (EPAct 2005), and it superseded EO 13123 and EO 13149. Of particular interest regarding LID practices are the sections in EO 13423 that pertain to reducing energy intensity, reducing water intensity, and designing and operating sustainable buildings. EO 13423 requires federal agencies to reduce energy intensity by 3% each year, leading to 30% overall reduction by the end of fiscal year (FY) 2015 compared to an FY 2003 baseline. This goal was given the weight of law when ratified by EISA 2007. EO 13423 mandates that federal agencies reduce water intensity (gallons per square foot) by 2% each year through FY 2015 for a total of 16% based on water consumption in FY 2007. EO 13423 requires federal agencies to ensure new construction and major renovations comply with the 2006 Federal Leadership in High Performance and Sustainable Buildings MOU, which was signed at the White House Summit on Federal Sustainable Buildings. It also requires that 15% of the existing federal capital asset building inventory of each agency incorporate the sustainable practices in the Guiding Principles by the end of FY 2015. The “Guidance on Sustainability” section in EO 13423 includes revised guiding principles for new construction, new guiding principles for existing buildings, clarification of reporting guidelines for entering information on the sustainability data element (#25) in the Federal Real Property Profile, and an explanation of how to calculate the percentage of buildings and square footage that are compliant with the Guiding Principles for agencies' scorecard input (USDOE 2011).

Details of Section 438 of Energy Independence Security Act

EISA 2007 established energy management goals and requirements while also amending portions of the National Energy Conservation Policy Act (NECPA). Regarding stormwater management, the intent of Section 438 of the EISA is to require federal agencies to develop and/or redevelop applicable facilities in a manner that maintains or restores stormwater runoff to the maximum extent technically feasible. Implementation of Section 438 of the EISA can be achieved through the use of GI/LID infrastructure. The intention of the statute is to maintain or restore the pre-development site hydrology during the development or redevelopment process. To be more specific, this requirement is intended to ensure that receiving waters are not negatively impacted by changes in runoff temperature, volumes, durations, and rates resulting from federal projects. It should also be noted that a performance-based approach was selected in lieu of a prescriptive requirement in order to provide site designers maximum flexibility in selecting control practices appropriate for the site.

Details of Executive Order 13514

EO 13514 Section 14 required the US Environmental Protection Agency (USEPA) to write and issue guidance regarding Section 438 of EISA in coordination with other federal agencies and to establish a timeline to do so. This EO set in motion the efforts to create publications that provide technical guidance on LID implementation.

Technical Guidance for LID Implementation

(a) “Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the

Energy Independence and Security Act" (EPA 841-B-09-001, December 2009).

(b) "Design for Low Impact Development". Department of Defense (DoD) Unified Facilities Criteria (UFC) 3-210-10, October 2010. This recently updated criterion provides instructions for integrating LID into planning, design, construction, and operation on DoD installations.

(c) Army Installation Design Standard and site-specific Installation Design Guides.

(d) National LID Manual, "Low-Impact Development Design Strategies An Integrated Design Approach" (EPA 841-B-00-003, 1999)

(e) State and local LID guidance

Details of EPA 841-B-09-001 and Section 438

In December 2009, the USEPA published this document to outline a framework for meeting the requirement of EISA Section 438, a section intended to remedy the problems with the traditional stormwater management approach. This framework focuses heavily on the implementation of decentralized stormwater management practices which is commonly referred to as GI, SI, and LID infrastructure. The goal of these stormwater management practices is to retain pre-development hydrology and stormwater runoff characteristics of the site to reduce downstream pollutant potential and peak runoff rates. It has been found that traditional stormwater practices provide poor peak runoff rate control for smaller more-frequently occurring storms, proffer negligible downstream water volume reduction, and increase the duration of peak flow events. This ultimately results in storm flow events that exceed pre-development flows and cause erosive stream channel and embankment instabilities (Shaver et al 2007; NAS 2008). This guidance document also further clarifies the technical approaches published in the National LID Manual, "Low-Impact Development Design Strategies an Integrated Design Approach." Section 438 of the EISA 2007 reads as follows:

> Section 438. Storm water runoff requirements for federal development projects. The sponsor of any development or redevelopment project involving a federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the pre-development hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

Section 438 uses several terms that require further clarification to better understand the applicability of this legislation.

- A "sponsor" is generally regarded as the federal department or agency that owns, operates, occupies, or is the primary user of the facility and has initiated a development and/or redevelopment project. Regardless of whether the federal agency hires another entity to perform any development or redevelopment activities the agency will still be regarded as the sponsor.

- A "federal facility" means any building that is constructed renovated, leased, or purchased for use in part or whole by the federal Government.
- "Development/redevelopment" includes any activities that change the landscape during the project and includes other infrastructure (e.g., roads and parking lots) where changes affect runoff volume, rates, duration, and temperature.
- The "footprint" includes all land that is disturbed as part of project.
- The "property" has been interpreted to mean that the land surrounding the project site is available for GI/LID implementation even if that implementation exceeds the "footprint" of the property.

EISA Section 438 is intended to ensure not only that the hydrology remains similar to pre-development conditions, but also that the ecological conditions, channel geomorphology and aquifer recharge rates are similar. To meet this goal requires a systematic approach. To maintain flexibility, however, two options for achieving a pre-development hydrologic regime are presented.

Option 1: Retain the 95th Percentile Rain Event

One approach to establishing the performance objectives is to design, construct, and maintain stormwater management practices that manage rainfall onsite and prevent the offsite discharge of precipitation from all rainfall events less than or equal to the 95th percentile rainfall event, to the maximum extent technically feasible (METF).

For purposes of this guidance, retaining all storms up to and including the 95th percentile storm event is analogous to maintaining or restoring the pre-development hydrology with respect to the volume, flow rate, duration, and temperature of the runoff for most sites. This 95th percentile approach was identified and recommended because this storm size appears to best represent the volume that is fully infiltrated in a natural condition and thus should be managed onsite to restore and maintain this pre-development hydrology for duration, rate, and volume of stormwater flows.

Option 2: Site-Specific Hydrologic Analysis

In this option, pre-development hydrology would be based on site-specific conditions and local meteorology by using continuous simulation modeling techniques, published data, studies, or other established tools. If the designer elects to use Option 2, the designer would then identify the pre-development condition of the site and quantify the post-development runoff volume and peak-flow discharges that are equivalent to pre-development conditions.

Defensible and consistent hydrological assessment tools should be used and documented.

APPENDIX C

LOW-IMPACT DEVELOPMENT DESIGN INTEGRATION WITH STORMWATER MANAGEMENT PLANS

Introduction

The practice of seamlessly incorporating LID practices into stormwater management systems is referred to as an Integrated Management Practice (IMP). Since IMPs are site-specific and completely customizable, they are easily implemented into any existing stormwater management plan (SMP) or new development. The design and evaluation processes outlined in the following pages provide a potential framework for IMP placement and allow the entire SMP to be the most effective plan possible for the cantonment area in question. This framework can be achieved by taking the factors listed below into consideration.

- climate (precipitation and evapotranspiration)
- drainage area infiltration potential
- pollution reduction potential
- cost per area of the implementation
- runoff volume reductions

The initial step in creating LID-based IMP approaches for an updated SMP is to locate and categorize the areas that require stormwater treatment practices. Areas directly included are impervious surfaces that create surface runoff and transport pollutants into the natural environment and areas that contribute to surface runoff. LID IMPs are designed to ameliorate stormwater runoff concerns for a particular location of the watershed hydrology. However, when designing LID for specific sites it is important to consider how such LID practices will affect stormwater movement at the watershed scale. Since the implementation a complete LID-based design for the watershed takes a number of years to achieve, it is crucial to optimize the placement of LID BMPs within the watershed context. A potential tool for use in this planning and development that was developed for the USEPA is the System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN) model, as explained on the agency's website.*

> SUSTAIN is a decision support system to facilitate selection and placement of Best Management Practices (BMPs) and Low Impact

* SUSTAIN was developed by Tetra Tech, an environmental engineering and consulting service. Details are available online at http://www.epa.gov/nrmrl/wswrd/wq/models/sustain/.

Development (LID) 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. From an understanding of the needs of the user community, SUSTAIN was designed for use by watershed and stormwater practitioners to develop, evaluate, and select optimal BMP combinations at various watershed scales on the basis of cost and effectiveness.

It is important to note that the use of SUSTAIN requires access to Geographic Information Systems (GIS) software and access to all the necessary data layers to run model analyses successfully. In addition, expert users of GIS software who are familiar with hydrological processes are needed to use the model to the full extent of its capabilities.

After identifying and prioritizing the critical areas an IMP may be selected for each site. The process for selecting the best IMP for a specific site is a key element of integrating LID practices into stormwater management plans. As an example, the County of Contra Costa in California has developed a comprehensive approach to integrating LID into stormwater infrastructure for both new and existing development. This section outlines the approach the Contra Costa Clean Water Program has adopted, but refers the reader to the website for exact details of the process.*

Contra Costa County is representative of a major metropolitan area with both urban and rural components on moderate-to-steep terrain. It is located near a major body of water with substantial shipping activity. It has a history of agricultural use of the land and some agriculture still exists in the county. Additionally, the county is located on a major fault line so seismic activity has been incorporated into elements of planning and design. The program considers a majority of the elements that military installations would need to consider to adopt a similar strategy. However, it is important to note that the reader should only utilize the Contra Costa approach using hydrologic and design factors appropriate to their specific region.

Figure C-1 outlines the process of developing planning and preliminary designs for integrating LID into existing stormwater infrastructure to achieve stormwater management goals. Step 1 requires that the users separate the area of interest (e.g., cantonment area) into separate watersheds (e.g., drainage management areas). This is done to identify

* Details of the Contra Costa Clean Water Program are available at http://www.cccleanwater.org/Publications/Guidebook/Stormwater_C3_Guidebook_5th_Edition.pdf

potential treatment areas, inflow and outflow, and upper and lower catchments for a particular site.

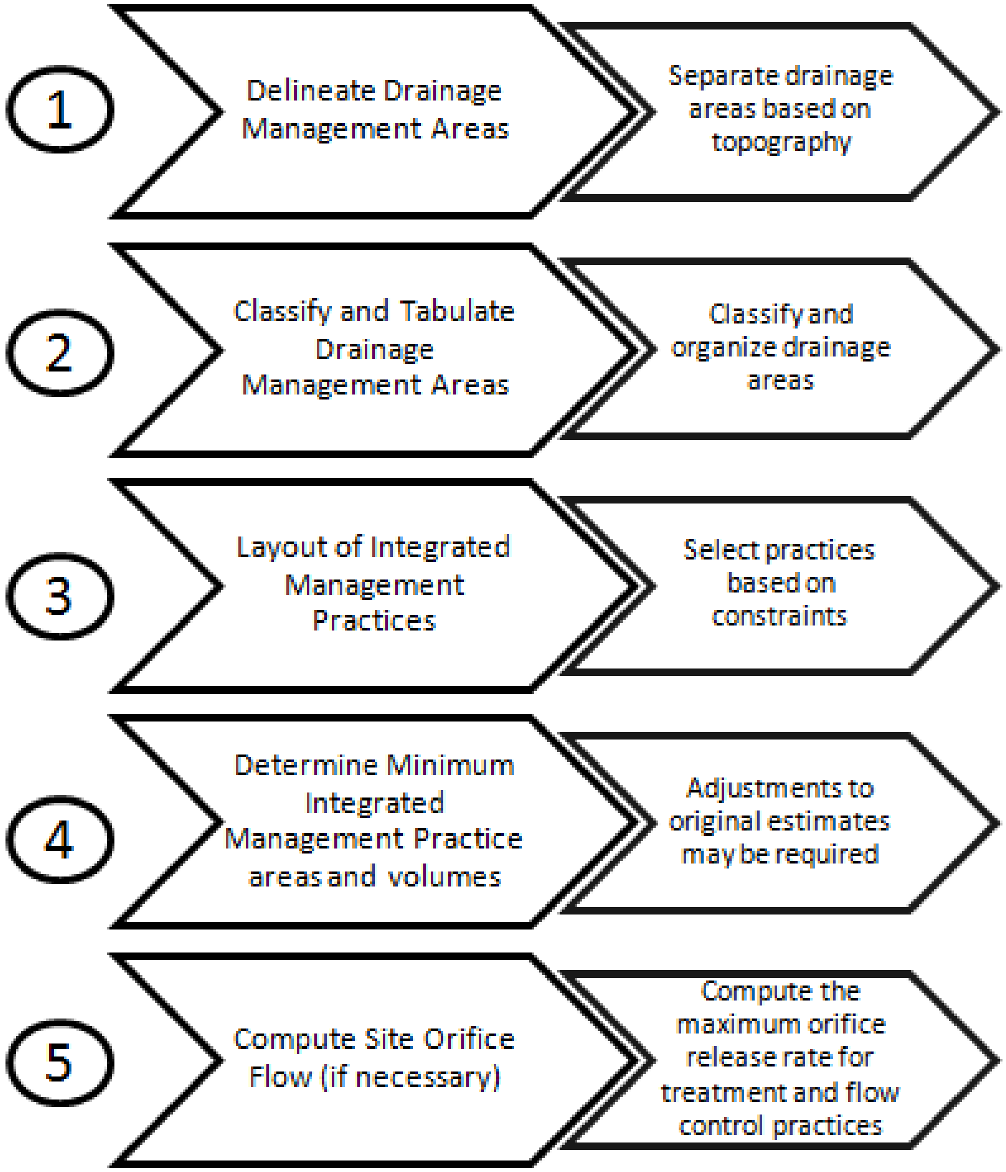


Figure C-1. Steps to design LID-based stormwater management plans (Contra Costa Clean Water Program 2010).

Step 2 separates drainage management areas (DMAs) into four functionally classified types: self-retaining areas, self-treating areas, areas draining to self-retaining areas, and areas draining to integrated management practices. This classification of areas allows the designer/planner to focus on meeting the hydrologic and treatment requirements of the site. Additionally, this classification is useful for planning and project prioritization based on monetary limitations and/or treatment requirements.

Step 3 is used to broadly select IMPs based on the physical and size constraints of the site (see Table C-1,Table C-2,Table C-3, Table C-4, and Table C-5 for guidance adapted from the County of Contra Costa Clean Water Program).

Step 4 involves the hydrologic calculations to adjust IMP selections determined in Step 3.Step 4 is an iterative process outlined in Figure C-2 and uses Table C-1, Table C-2, Table C-3, and the hydrologic calculations (flow and volume) specific to the site to determine IMP size and flow handling needs.

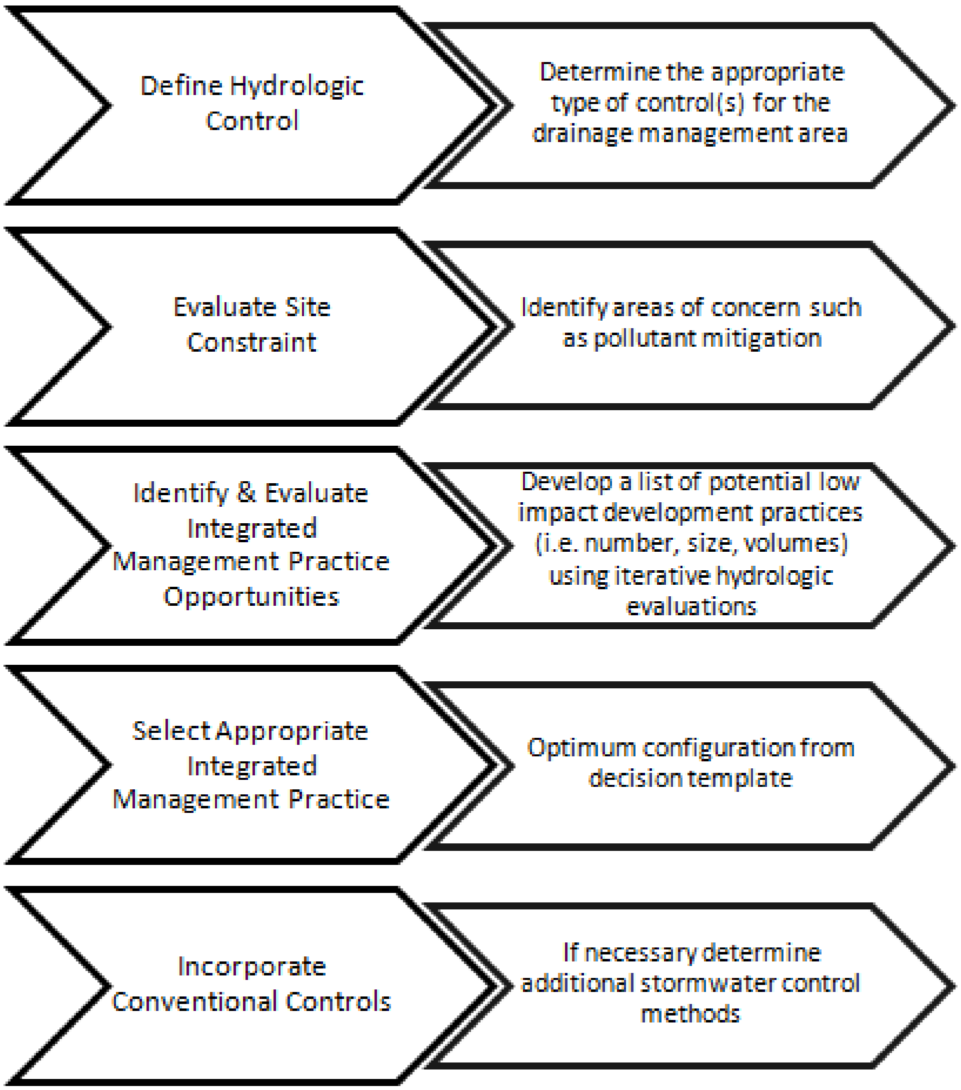


Figure C-2. Site-specific design approach for a stormwater management LID site (applicable to Figure C.1, Step 4; Prince George's County 1999a).

Step 5 uses orifice equations, if necessary, to determine the release rate of water from the system for any excess flow.

Table C-1. IMP physical design constraints (Figure C-1, Steps 3 and 4).

	Bioretention	Infiltration Trench	Rain Garden	Swales	Tree Box Filter	Sand Filter	Porous Pavement
Space Required	Minimum Surface Area 5m^2, width 1.5m, length 3m, depth 0.6m	Maximum drainage area 4 ha	Minumum area of 12m^2	Bottom Width: 0.6-1.8m	2.1m X 2.1m (typ.)	maximum 0.8 Ha of drainage area	Not applicable
Soils	Permeable soils, infiltration rate > 10.2 cm/hr *limitations can be eliminated with the use of underdrains	Permeable, limited silt and clay content, Infiltration Rate > 1.3 cm/hr	Permeable soils, infiltration rate > 1.3 cm/hr *limitations can be eliminated with the use of underdrains	Soil is not a limiting factor, it determines which type of swale will be used	Not applicable; Engineered filter soils are provided with unit purchase	Not to be used in areas with silt/clay in drainage vicinity	Permeable soils, infiltration rate > 1.3 cm/hr
Slopes	Not typically a limitation, but a design consideration	Max. ungradient slope of 20:1, Max. downgradient slope of 5:1	8:1 Slope	Side of Swale: 3:1 or flatter Longitudinal slope: 100:1 min Max.: based on allowable velocities	Gentle is recommended toward unit intake	10:1 maximum slope	Gentle or none
Water Table/Bedrock	1.2m clearance above is recommended	Min. depth of 1.2m required	0.6-1.2m clearance above is recommended	Generally not a constraint	Min 0.6m clearance above; needs to be at least 1m deep	Min. 0.6m clearance above; Min. 1m deep	At least 1.2m clearance
Proximity to build foundation	Min. distance of 3m downgradient	Min. distance of 30m away	Min. distance of 3m downgradient	Min. distance of 3m downgradient	Min. distance of 3m downgradient	Min. distance of 3m downgradient	Min. distance of 3m downgradient
Depth	0.6-1.2m, depending on soil type	Depth range of 0.9-3.7m	0.6-1.2m, depending on soil type	Not applicable	Dependant on size of unit and manufacturers design	2m head clearance	Not applicable
Maintenance	Low: weed, replace vegetation, debris removal, apply mulch	Moderate-High: weed, replace vegetation, debris /sediment removal	Low: weed, replace vegetation, debris removal, apply mulch	Low: weed, mow, debris removal	Low-Moderate:Pruning and sediment removal	High: Raking and soil removal	Moderate: Vacuum

Table C-2. Runoff Management IMPs based on site requirements (Figure C-1, Steps 3 and 4)

Site Features/Issues	Pervious Pavement	Green Roof	Disperse Runoff to Landscape	Storage for Later Use	Bioretention Facility	Flow-through Planter	Dry Well	Cistern + Bioretention	Bioretention + Vault
Clayey native soils		X	X	X	X	X		X	X
Permeable native soils	X	X	X	X	X	X	X		
Very steep slopes		X		X		X			
Shallow depth to groundwater		X		X		X			
Roof drainage			X	X	X	X	X	X	
Parking Lots	X		X	X	X		X		X
Extensive Landscaping			X	X	X				
Densely developed sites with limited space	X	X		X		X	X	X	X

Table C-3. Climate considerations and constraints for IMPs (Figure C-1, Steps 3 and 4).

CONUS Category 1 and 2 Fort Climate Classification (Koppen-Geiger)

B	C	D
Arid	Temperate	Continental
Carson Bliss Lewis/Yakima Irwin	Hood Bragg Campbell Stewart Polk Benning	Alaska Drum Riley

LID Technology Compatibility

		A	B	C	D	E
		Tropical	Arid	Temperate	Continental	Polar
1	Bioretention Cells	●	▲	●	▲	○
2	Bioswales	●	▲	●	▲	○
3	Vegetated/Grassy Swales	●	▲	●	▲	○
4	Compost Amendments	●	▲	▲	▲	○
5	Selective Grading	●	▲	●	▲	○
6	Downspout Disconnection	●	▲	▲	▲	○
7	Permeable Pavement	●	▲	▲	○	○

Key

●	High Effectiveness (Recommended)
▲	Medium Effectiveness (Recommended with Reservation)
○	Low Effectiveness (Not Recommended)

The template outlined below in Table C-4 is designed to help the developer decide which LID practice is the best fit for the given site situation based on the stormwater priorities of the installation.

Table C-4. Template for LID IMP best fit (Figure C-1, Step 3).

Criteria	Relative Weight	LID 1		LID 2		LID N	
		marking	weighted marking	marking	weighted marking	marking	weighted marking
Regulatory Compliance	TBD						
Construction Cost	TBD						
Pollution Control	TBD						
Hydraulic Control	TBD						
Construction Impact & Duration	TBD						
O&M	TBD						
Resource Conservation	TBD						
Total	100%						

Various weights can be placed on the criteria given in Table C-4. This ensures the proper factors are being weighted for the circumstances given.

1. Once the relative weight is determined for each criterion, place its decimal form in the “marking” box for each row.

2. Determine the “weighted marking” value for each LID and its criteria (see Table C-5).

3. Place these values in the appropriate box. For each LID practice, multiply the “weighted marking” by its corresponding “marking” value.

4. Continue down the column, summing the total of each multiplication pair at the bottom.

5. The highest total in the bottom row is the best practice for the site given the weighted criterion.

The approach outlined above can be modified to suit the needs of the installation. Regardless, it is important develop a process to cost-effectively integrate LID practice into stormwater management plans. The timeframe for this process is long and will generally span several decades because the cost to rapidly implement such a plan would be prohibitively expensive and difficult to justify.

Table C-5. Marking criteria.

Criteria	5	4	3	2	1
Regulatory Compliance	Option is fully acceptable from a regulatory standpoint	Option is fully acceptable from a regulatory standpoint, but permitting renewal is needed	Option is acceptable from a regulatory standpoint but new permitting is needed	Option is hardly acceptable from a regulatory standpoint	Option is not acceptable from a regulatory standpoint
Construction Cost(ranked)	Lowest cost		Average		Highest Cost
Pollution Control	Relevant discharge quality benefit	Limited discharge quality benefit	No discharge quality benefit	Limited discharge quality worsening	Relevant discharge quality worsening
Hydraulic Control	Relevant decrease of flooding risk	Limited decrease of flooding risk	No risk of flooding risk	Limited increase of flooding risk	Relevant increase of flooding risk
Construction Impact/Duration	No impact on mission activity	Limited impact on ancillary base mission	Relevant impact on ancillary base mission	Limited impact on critical base mission	Relevant impact on critical base mission
O&M(None-Extreme)	None	Low	Moderate	High	Extreme
Resource Conservation	Relevant benefit on resource conservation	Limited benefit on resource conservation	No impact on resource conservation	Limited impact on resource conservation	Relevant impact on resource conservation

APPENDIX D:

LID INTEGRATION WITH STORMWATER MANAGEMENT PLANS: CHALLENGES

Until recently, stormwater programs established to address water quality objectives have been designed to control traditional pollutants that are commonly associated with municipal and industrial discharges (e.g., nutrients, sediment, and metals). Increases in runoff volume and peak discharge rates have been regulated through state and local flood control programs. Although these programs have merit, knowledge accumulated during the past 20 years has led stormwater experts to conclude that conventional approaches to control runoff are not fully adequate to protect the nation's water resources (National Research Council 2008).

Moving ahead with large-scale implementation of sustainable stormwater infrastructure presents unique challenges. New developments, renovations, and retrofits that integrate sustainable stormwater infrastructure will encounter obstacles that include those listed below.

- institutional resistance to change
- installation mission requirements
- code, guidelines and standards conflicts
- economics
- implementation timeframe
- facilities breadth
- water quality requirements

As with any project, it is especially important to integrate efforts between the various planning documents. There are several planning documents that stormwater managers should consider. In the case of Fort Hood, those documents were the Real Property Master Plan's Long-Range Component (LRC), the IDG, the INRMP's Historic Properties Component, the Endangered Species Management Plan, the Range Development Master Plan, and the Land Sustainment Management Plan. As an example of the need for such integration, the Stormwater Management Plan for Fort Hood states that the installation will develop and implement an LID program to provide both required and recommended strategies and BMPs to better manage post-construction stormwater flows. Fort Hood's IDG is used to aide engineers, contractors, and designers in construction projects on post. The IDG designates the minimum requirements that need to be met in order to construct projects on Fort Hood; it incorporates construction techniques such as LID, green buildings, and energy-efficient construction designs. The challenge that designers and planners face is ensuring that different policy requirements do not conflict with or duplicate one another as installation infrastructure is developed. Thus, it is important to develop a written integration that includes strategies and BMPs appropriate for the installation.

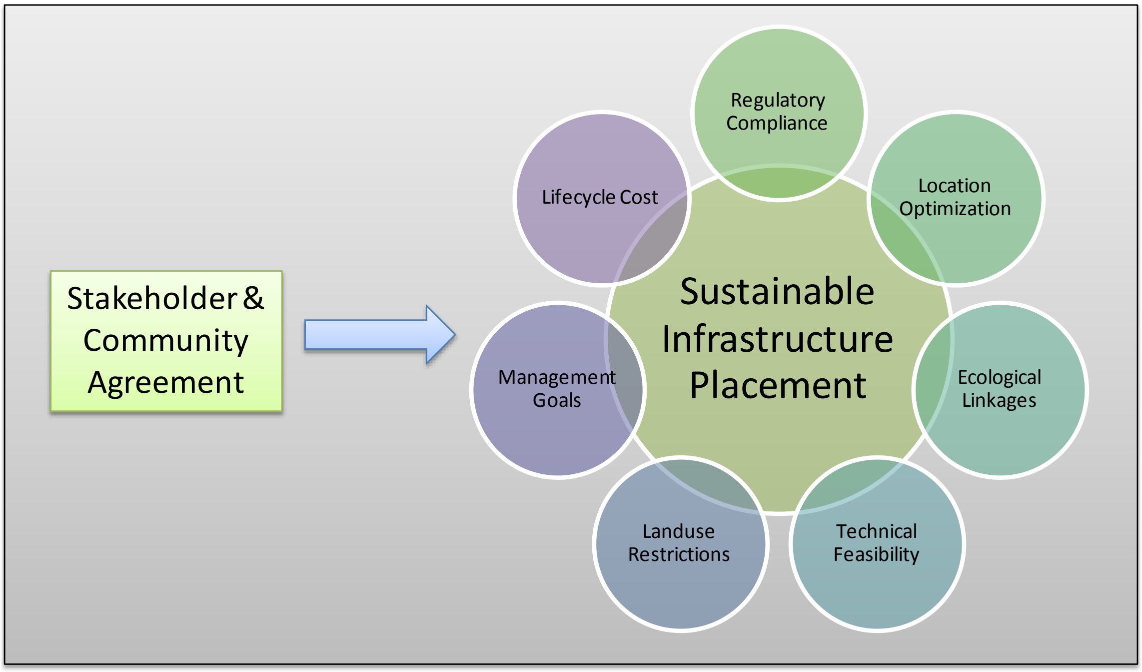


Figure D-1. Considerations impacting sustainable infrastructure placement.

Figure D-1 illustrates the multiple and sometimes conflicting requirements that impact SI placement. While incorporating an integrated LID approach, it is important to consider the following key points for optimum site assessment and planning.

- Proper site assessment begins with identifying the scale at which you will be working (regional, large watershed, site-based) and using a multi-disciplinary approach that includes planners, engineers, architects, and landscape architects.

- It is also important to identify environmental, stakeholder, and community needs early in the process so that those needs can be incorporated into the site design. Selecting the right technology at the right location is critical to the program.

One of the greatest challenges with implementing green technologies such as LID is selecting the control measure. Measures that include better site design, downspout disconnection, conservation of natural areas, watershed, and land-use planning can dramatically reduce runoff and the pollutant load. Assessing the benefits of the variety of control strategies consistent with the TMDL and Municipal Separate Stormwater Sewer Systems (MS4) programs is also a challenge. Conducting these assessments is often labor- and time-intensive, with no real guarantee of complete accuracy. Utilizing decision-support modeling tools helps with this process.

Selecting the right technology at the right location requires an understanding of watershed management issues at a site within the context of the management area and comprehensive stormwater management approaches. Watershed management is not a new concept; frequently, it is being coupled with collaborative planning and outside agency plan integration to effectively achieve environmental management. In 1996, the USEPA established its Watershed Protection Approach (WPA) which was based on the premise that water quality and ecosystem problems can be best addressed at the watershed level and not at the individual water body or discharge levels.

Furthermore, managing a water body requires managing the land in its watershed (EPA 1996). There are four basic principles to the WPA.

1. Targeting priority problems
2. Promoting a high level of stakeholder involvement
3. Integrating solutions from multiple agencies and private parties
4. Measuring success through monitoring and other data gathering

Choosing the right technology also requires the engineer to incorporate the basic concepts of watershed planning into the process of site assessment and planning.

- Identify the critical ecological linkages throughout the site and maximize the retention of native forest cover or revegetate with native species if already cleared. This includes protecting topographic site features that slow, store and infiltrate stormwater. Other examples include existing tracks of habitat, watercourses, greenways, urban parks, steep slopes, etc.
- Gain understanding of the critical interaction between the land use and the physical environment within the desired scale.
- Ensure identification of the role of GI throughout the watershed (TMDL, pollution reduction, peak flow). Minimize impervious surfaces and completely disconnect them. Place buildings and roads away from critical areas and on well-draining soils.
- Evaluate which GI or LID technology is best during the site-suitability phase, given the environmental requirements (biogeophysical parameters such as soil type, gradient, and location); determine if the soil onsite can handle increased flow rates from development within the network.
- Develop a stormwater management plan for the site to treat suspended solids runoff and meet USEPA guidelines. Review potential eligible structural or non-structural strategies to treat stormwater runoff. Propose BMPs for the project and clearly articulate those BMPs in the project's drawings, specifications, and narrative.

- Review the stormwater management plan in relation to the entire project and the sustainability goals, especially stormwater efficiency goals.

The long-term sustainability of the project is affected by maintenance, pollution prevention, and education. It is important to develop reliable, long-term maintenance programs with clear, enforceable guidelines and to educate homeowners, building operators, local government staff, contractors, and others on proper operation and maintenance of SI. Involvement programs are also useful; they can educate the public about stormwater management problems and BMPs while stressing what preventive steps the individual can take.

Land planning and pollution source prevention are important first steps in controlling runoff and nonpoint source pollution but they will not achieve stormwater management objectives alone. SMPs must also be considered with the basic principles of watershed management.

APPENDIX E:

LOW-IMPACT DEVELOPMENT PRACTICES – FACT SHEETS

Disclaimer: The names of vendors and their products that appear here are for information only. The vendor products listed are NOT APPROVED FOR USE by the U.S Army Corps of Engineers and their appearance here is NOT AN ENDORSEMENT by the Corps.

The following pages illustrate various commonly installed LID BMPs found across CONUS. The fact sheets are for information purposes only and are not intended to be used as design aids.

LID Fact Sheet

Retention: Bio-retention cells

Description

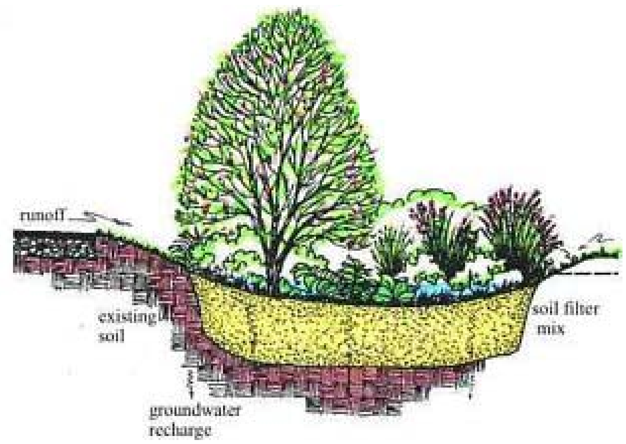
Used as an alternative to concrete waterways, grass swales are used to decrease the flow rate of rainwater runoff and therefore improve infiltration. Note that grass swales are also a low-impact form of retention as well. This practice is particularly site specific, meaning that it is dependent upon site related variables such as soil type and slope.

Constituent Removal

Pollutant	Reported Removal Rate
Sediment(TSS)	29-96%
Chemical Oxygen Demand	**
Total Nitrogen	32-40%
Total Phosphorous	4-85%

** Not found in source
Source: USACE 2008 (PWTB 200-1-62).

Schematic



Source: Prince George’s County Dept. of Environmental Resources 1999a.

Advantages

- Low cost
- Low maintenance
- Reduces runoff volume
- Added aesthetic value
- Reduction of toxins
- Decrease costs for constructing

Key Design Elements

- Bioretention area and depth
- Vegetation
- Bioretention media
- Liner, if deemed necessary

Constraints

- Environments with dry periods may need to implement irrigation for vegetation
- Vegetation may require additional care

LID Fact Sheet

Retention: Bio-retention cells (cont'd)

Additional Tools and Materials Needed

- Soils
  - Topsoil (less than 20% clay)
  - Course Sand(less than 10% clay)
- Perforated drain pipe
- 10-cm outfall pipe made of high-density polyethylene (HDPE)
- Gravel
- Native plants
- Drainage fabric
- Shredded hardwood mulch
- Sediment fencing and installation equipment
- Underdrain pipe made of perforated HDPE

Construction Process Overview

1. Orient the area so that it is parallel to the natural flow of runoff

2. If measurable contaminants are in the soil, place a liner and connection to existing stormwater pipe system, excavate area as required.

3. Install sediment fence

4. Add bedding layer once well mixed, in 33-cm increments; water each layer after it is placed.

Inspection, Review, and Estimated Construction Cost

Inspection/Review: After rainstorms inspect cell, make sure drainage paths are clear, and water is dissipated within 4–6 hr. Note: this time may fluctuate depending on the season.

Construction Cost Range: $107-$430 per square meter

Maintenance and Upkeep

First year: Water plants weekly in periods of no precipitation.
Monthly: Remove debris and any undesired vegetation.
Biannually: Reapply mulch to a depth of about 7.5 cm.
Annually:
- Remove any accumulated sediment in cell and pretreatment area.
- Prune plants as necessary.
- Replace any dead vegetation.
- Inspect system for possible clog.
- Flush underdrain system if a clog is found.

Average Annual Cost: $ .77 per impervious square meter

Available Vendor Products (Not Inclusive)

DeepRoot® Silva Cell

TreePod® Biofilter

Filterra® Bioretention System

UrbanGreen™ Biofilter

LID Fact Sheet

Retention: Rain Gardens

Description

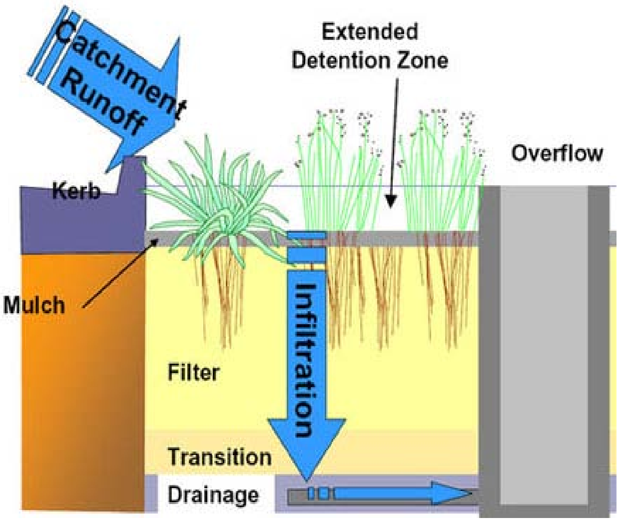
The goal of a rain garden is to effectively use vegetation to detain stormwater while infiltrating and recharging groundwater supply. The attractiveness found by the addition of a rain garden to a LID design is present in multiple forms. Not only is the garden scalable, and able to be implemented in residential settings as well as open areas, it is almost self-sustaining.

Constituent Removal

Pollutant	Reported Removal Rate
Sediment(TSS)	29-96%
Chemical Oxygen Demand	**
Total Nitrogen	32-40%
Total Phosphorous	4-85%

** Not found in source
Source: USACE 2008 (PWTB 200-1-62).

Schematic



Source: Monash City Council website.

Advantages

- Low cost
- Low maintenance
- Reduces toxins
- Added aesthetic value
- Low impact on environment

Key Design Elements

- Bioretention area and depth
- Vegetation
- Infiltration rate
- Bioretention media
- Liner, if deemed necessary

Constraints

- Environments with dry periods may need to implement irrigation for vegetation
- Vegetation may require additional care

LID Fact Sheet

Retention: Rain Gardens

Additional Tools and Materials Needed

- Soils
  - Clean, organic compost
  - Sand, only if soil is not very permeable
- Drainage fabric
- Native plants
- Shredded hardwood mulch
- Rock infiltration sump
- Filter fabric: Felt type
- "Toothed" backhoe

Construction Process Overview

1. Grade garden area to the necessary topography, allowing an additional 20cm to be excavated
2. Place rock infiltration sump that is wrapped in the filter fabric below the surface. Note: the depth of placement is determined based on soil conditions
3. Using the toothed backhoe, scarify the entire garden
4. Fill bed with 50% in situ top soil and 50% compost. Note: a layer of sand may be used as a base layer if local soil is not very permeable.
5. Place mulch over bedding and add vegetation

Inspection, Review, and Estimated Construction Cost

Inspection/Review: After rainstorms inspect cell, make sure drainage paths are clear and water is dissipated between 4-6 hours.
Note: this time may fluctuate depending on the season.

Construction costs (Residential): $32.30 to $43.06 per square meter

Maintenance and Upkeep

First year: Water plants weekly in periods of no precipitation
Monthly: Remove debris and any undesired vegetation
Biannually: Reapply mulch to a depth of about 7.5cm
Annually:
- Remove any accumulated sediment in cell and pretreatment area
- Prune plants as necessary
- Replace any dead vegetation

Average Annual Cost: $.77 per impervious meter squared each year*
**same as bioretention cell*

Available Vendor Products (Not Inclusive)

Smiling Sun LLC.

Ion Exchange, Inc.

Agrecol®

LID Fact Sheet

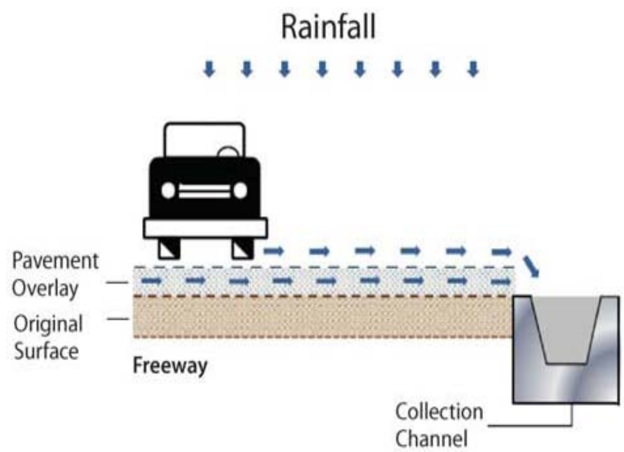
Retention: Permeable Pavement

Description

The main allure of permeable pavement is the flood reduction factor. By replacing impermeable surfaces with this measure, the runoff is significantly decreased as more water is able to be absorbed in the immediate area. Other benefits include water quality improvements and decreased flow rate. Aesthetic value can be increased by the addition of color pavers and textured pavements.

This practice is optimally placed on sites with sandy soils for increased infiltration. While permeable pavement is not recommended for heavy traffic or excess weight load, it has proven an effective alternative in parking lots and driveways. Although initial installation costs may be increased, the added value that permeable pavement delivers in its effectiveness, durability, and aesthetics makes it an attractive practice to prevent flooding.

Schematic



Source: Caltrans 2010.

Constituent Removal

Pollutant	Reported Removal Rate
Sediment(TSS)	82-95%
Chemical Oxygen Demand	82%
Total Nitrogen	80-85%
Total Phosphorous	65%

** Not found in source
Source: USACE 2008 (PWTB 200-1-62).

Advantages

- Reduces toxins
- Flood reduction
- Improve water quality
- Decreased flow rate
- Low impact on environment
- Added aesthetic value

Key Design Elements

- Load requirements
- Thickness of porous layer
- Media type

Constraints

- More costly than asphalt concrete
- Not feasible where sand is applied for traction
- Durability due to weather and traffic
- Special maintenance machinery required

LID Fact Sheet

Retention: Permeable Pavement

Additional Tools and Materials Needed

Gravel
Sand
Geotextile fabric

Construction Process Overview

1. Excavate to design depth of reservoir system
2. Add gravel layer
3. Cover with permeable geotextile fabric; install sand layer
4. Wet sand and level with hand tools
5. Place pavement layer, compact pavers(if used)
6. Fill voids with material such as pea gravel or loamy sand

Inspection, Review, and Estimated Construction Cost

Inspection/Review: Check final elevation for conformance to the design drawings

Construction Costs: $50-$70 per square meter

Maintenance and Upkeep

First year: Inspect on a monthly basis
Monthly: Low-pressure washing and vacuuming should be done regularly
Biannually:
  Street sweep the area using vacuum, brush, and water to clean
  Add aggregate as needed after cleaning
  Repair cracks and settlement in asphalt or concrete

Operational and Maintenance costs: $.59 per impervious meter squared each year

Available Vendor Products (Not Inclusive)

TemPark®	Permapave USA Corp.
Boddingtons®	Aqua-Loc®

LID Fact Sheet

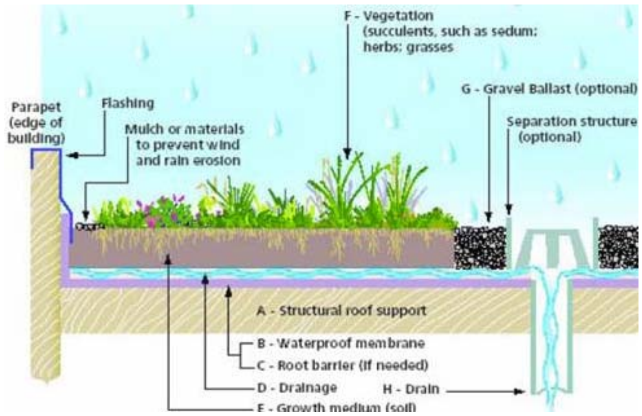
Retention: Vegetated Roofs

Description

In contrast to the traditional practice of tar and shingles or other impervious materials, having a grass roof overhead has a multitude of benefits not touched on by common practices today. Not only does it reduce stormwater runoff and add insulation, but also it adds longevity to the roof and a creative space. Furthermore, green roof tops are also recognized by LEED.

Roofs that are ideal candidates for vegetated roofs have little or no pitch. Construction can be tedious and cumbersome; refer to construction checklist for details. The various layers within the green roof all contribute towards its effectiveness.

Schematic



Source: City of Sandy website.

Constituent Removal

Pollutant	Reported Removal Rate
Sediment(TSS)	85%
Chemical Oxygen Demand	**
Total Nitrogen	30%
Total Phosphorous	85%

** Not found in source
Source: PDEP 2006.

Advantages

- LEED recognized
- Save on utility costs
- Reduction of toxins
- Runoff reduction
- Added aesthetic value
- Low impact on environment
- Water quality improvement

Key Design Elements

- Structural considerations
- Accessibility
- Desired volume reduction
- Vegetation
- Area of project
- Intensive or extensive design

Constraints

- Flat or gently sloping roof
- High installation costs
- May require irrigation

LID Fact Sheet

Retention: Vegetated Roofs (cont'd)

Additional Tools and Materials Needed

Native mosses, sedums, and shrubs
Soil
Drainage, aeration, water storage and root barrier
Insulation
Membrane protection
Roofing membrane

Construction Process Overview

1. Clear the entirety of the area that is to be used in the system
2. Place roofing membrane, membrane protective layer and root barrier
3. Add the drainage, aeration, water storage, and root barrier in that order, respectively
4. Place the designated soil mix used for the bedding
5. Add vegetation, may be in the form of mats to reduce costs

Inspection, Review, and Estimated Construction Cost

Inspection/Review: Leakage detection systems can be installed to easily locate breaches to be repaired

Estimated Construction Cost: $161 to $215 per square meter

Maintenance and Upkeep

First year: Regularly water plants until well established
Monthly: Weed and remove debris
Annually: Inspection of roof membrane, and care of drainage layer flow paths

Available Vendor Products (Not Inclusive)

American Hydrotech,Inc.
Express Blower,Inc.
ZinCo USA
Tremco Inc.
Green Roof Blocks™

LID Fact Sheet

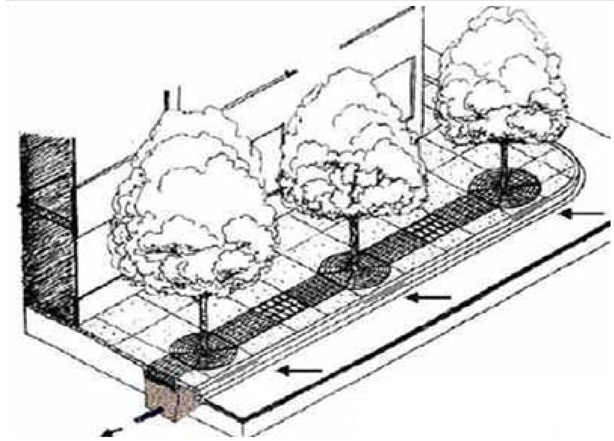
Redirection and Runoff Water Quality Assurance: Tree Box Filter

Description

Due to their compact size, tree filters are able to be implemented easily into new development as well as retrofitted into existing development. By collecting, naturally filtering, and redirecting water to a catch basin, tree box filters have gained popularity in stormwater management.

The flow is directed from the paved surface, over to the various inlets for the tree box filter. Upon its entrance, the water is filtered through the various layers and then redirected to the desired location.

Schematic



Source: Virginia Dept. of Conservation and Recreation.

Constituent Removal

Pollutant	Reported Removal Rate
Sediment(TSS)	85%
Chemical Oxygen Demand	**
Total Nitrogen	68%
Total Phosphorous	74%

** Not found in source
Source: Virginia Dept. of Conservation and Recreation.

Advantages

- Reduces toxins
- Flood reduction
- Improve water quality
- Low impact on environment
- Added aesthetic value

Key Design Elements

- Gentle slopes, if any present
- Ideally placed next to an impervious surface such as a road.
- Site placement
- Vegetation
- Area of site

Constraints

- Drainage area constraints depend on size of unit
- Max. depth of unit is dependent on unit size and manufacturer’s guidelines

LID Fact Sheet

Redirection and Runoff Water Quality Assurance: Tree Box Filter (cont'd)

Additional Tools and Materials Needed

Filltera® Stormwater Bioretention Filtration System or other comparable model

Construction Process Overview

Professional installation will be provided by Filterra® or other manufacturer

Inspection, Review, and Estimated Construction Cost

Inspection/Review: Inspect that water is drained in a timely manner after a significant rainstorm

Estimated construction cost: $6,000 per unit per .1 ha of impervious surface

Maintenance and Upkeep

First year: Replacement of mulch, occasional watering of trees
Monthly: Removal of debris and weeds
Annually: Inspection, pruning, replacing plants as necessary and adding mulch

Estimated Maintenance Cost: $100-$500 annually per unit

Available Vendor Products (Not Inclusive)

DeepRoot® Silva Cell

TreePod® Biofilter

Filterra® Bioretention System

UrbanGreen™ Biofilter

LID Fact Sheet

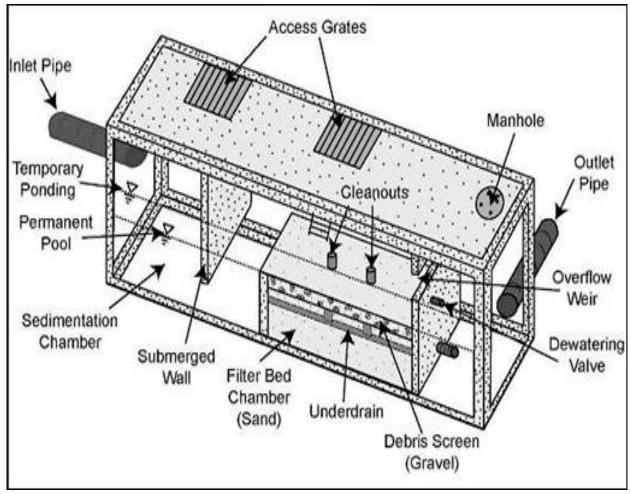
Redirection and Runoff Water Quality Assurance: Sand Filter

Description

Gaining popularity in urban areas is the more costly sand box filter. A perk to this filter is that it is extensively useful in separating oil from runoff, which is a major concern for military installations. Depending on the specific covering over the filter, have the added benefit of being able to be driven over which saves on space used as well as decreases permeable areas.

The filter works by having runoff into its box; the sand then allows the water to infiltrate and captures the oil and other debris. The filtered water is then redirected elsewhere to be retained further.

Schematic



Source: Virginia Dept. of Conservation & Recreation website.

Constituent Removal

Pollutant	Reported Removal Rate
Sediment(TSS)	80%
Chemical Oxygen Demand	**
Total Nitrogen	30%
Total Phosphorous	50%

** Not found in source
Source: Knox County, TN 2008.

Advantages

- Reduces toxins, especially oil
- Flood reduction
- Improve water quality
- Low impact on environment

Key Design Elements

- Gentle slopes toward intake of filter
- Maintenance access
- Ideally placed next to an impervious surface such as a road.
- Area and depth
- Placement in conjunction with existing drainage pipes

Constraints

- High maintenance
- High construction cost
- No more than .81 ha of drainage area
- Not to be used in areas with silt/clay in drainage vicinity
- 2 m of head clearance

LID Fact Sheet

Redirection and Runoff Water Quality Assurance: Sand Filter (cont'd)

Additional Tools and Materials Needed

Gravel
Sand
Concrete
Grates
Curb Stops
Outlet pipes

Construction Process Overview

Professional installation will be provided by manufacturer

Inspection, Review, and Estimated Construction Cost

Inspection/Review: After a significant rainfall, check to see that the water is drained in a sufficient amount of time

Construction Cost Estimate: $176.57 per cubic meter of stormwater treated

Maintenance and Upkeep

Monthly:
- Check that inlets and outlets are clear of debris and filter is unclogged.
- If a permanent pool is present, ensure that the chamber does not leak, and normal pool level is retained.

Annually:
Check sediment level; if chamber is more than half full, clean out.
- Check and repair any damaged grates, inlets, outlets, and spillways.

Maintenance Cost Estimate: 5% of construction costs ($8.83 per cubic meter of stormwater treated)

Available Vendor Products (Not Inclusive)

Oldcastle Precast®

Kristner Concrete Products, Inc.

Gillespie Precast LLC

MC Pipe & Precast

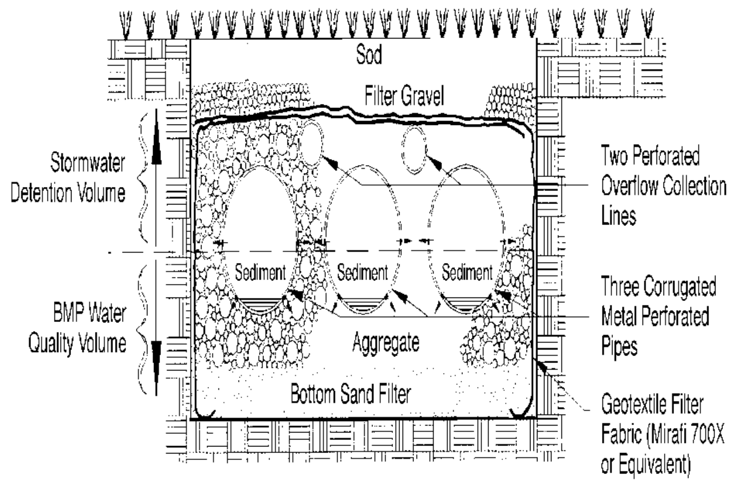
LID Fact Sheet

Infiltration: Infiltration Trench

Description

Capturing the first flush and the pollutants contained within it is the primary goal for an infiltration trench. Once the stormwater is directed into it, it begins to filter the sediments, toxins, and various forms of organic matter through its layers. This practice can typically be found in arid climates, but it is successful in colder climates so long as the site's surface remains unfrozen. This form of trench is best used in areas that have low silt and clay content; it may have to be reconstructed every ten years or as needed, due to the load of trapped sediments within. However, it does perform excellently at removing these pollutants.

Schematic



Source: Prince George's County 1999a.

Constituent Removal

Pollutant	Reported Removal Rate
Sediment(TSS)	90%
Chemical Oxygen Demand	70-80%
Total Nitrogen	60%
Total Phosphorous	60%

Source: Prince George's County 1999b.

Advantages

- Removal of toxins
- Recharge surrounding groundwater
- Used in conjunction with other practices
- Does not act as a breeding ground for mosquitoes

Key Design Elements

- Soil should have a low silt and low clay content
- Infiltration rate >1.3 cm/hr
- Maintenance access

Constraints

- High rehabilitation costs when clogging occurs
- Avoid areas prone spills that would contaminate groundwater
- High rate of failure when not maintained
- Higher construction costs

LID Fact Sheet

Infiltration: Infiltration Trench

Additional Tools and Materials Needed

- Filter fabric
- Sand
- Stone or gravel
- Pipe
- Screen for covering overflow pipe

Construction Process Overview

1. Orient area so it is parallel to the natural flow of runoff.
2. Excavate the trench to desired dimensions.
3. Line sides of trench with filter fabric.
4. Add layer of sand to the bottom for filtering.
5. Add layer of cleaned stone or gravel.
6. Add screen-covered pipe for overflow precautions.
7. Once constructed, establish a recommended 6m Grass Filter Strip to each side of the filter.

Inspection, Review, and Estimated Construction Cost

Inspection/Review: Drainage time should be at least 6 hr to ensure pollutant removal.

Estimated Construction Cost: $95.50 per square meter

Maintenance and Upkeep

First Year: Hydroseed weekly and when necessary as grass matures; avoid use of fertilizers.
Monthly:
Remove weeds and debris.
Cut grass to a height of 15-20 cm.
Remove sedimentation left on stones.
Annually:
Remove any sediment deposits and oil/grease from pretreatment area.
Add seed during growing season if necessary.
Estimated Annual Maintenance Cost: $4.78-9.55 per impervious square meter, or 5-10% of construction costs

Available Vendor Products (Not Inclusive)

N/A

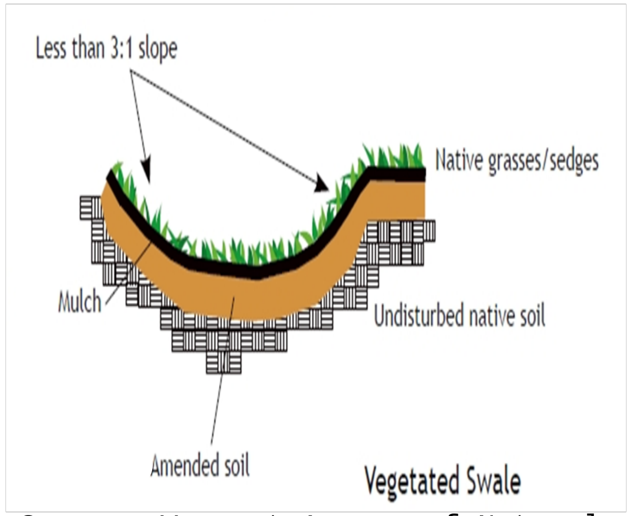
LID Fact Sheet

Conveyance: Grass Swales

Description

Used as an alternative to concrete waterways, grass swales are used to decrease the flow rate of rainwater runoff and therefore improve infiltration. Note that grass swales are also a low-impact form of retention. This practice is particularly site specific, meaning that it is dependent upon site related variables such as soil type and slope.

Schematic



Source: Vermont Agency of Natural Resources website.

Constituent Removal

Pollutant	Reported Removal Rate
Sediment(TSS)	22-94%
Chemical Oxygen Demand	34-63%
Total Nitrogen	14-45%
Total Phosphorous	29-99%

Source: USACE 2008 (PWTB 200-1-62).

Advantages

- Low cost
- Low impact
- Low maintenance
- Effective
- Reduces toxins

Key Design Elements

- Soil type; determines which type of swale is appropriate
- Drainage area
- Slope
- Vegetation

Constraints

- Bottom Width Required:
  Min.: .61 m
  Max.: 1.83 m
- Slope:
  Side of Swale:
  3:1 or flatter
  Longitudinal slope:
  100:1 min
  Max.: based on allowable

LID Fact Sheet

Conveyance: Grass Swales (cont'd)

Additional Tools and Materials Needed

- Erosion netting
- Installation equipment

Construction Process Overview

1. Orientate area so it is parallel to the natural flow of runoff.
2. If measurable contaminants are in the soil, place a liner connection to existing stormwater pipe system; excavate area as required.
3. Install sediment fence.
4. Scrape and prepare surface to be seeded.
5. Apply seed – hydroseeding may be the desired technique.

Inspection, Review, and Estimated Construction Cost

Inspection/Review: The water should move through the system within a 24-hr timeframe.

Estimated Construction Cost: $2.70 per square meter

Maintenance and Upkeep

First Year: Water seed weekly and when necessary as grass matures, avoid use of fertilizers.

Monthly:

Remove weeds and debris.

Cut grass to a height of 15-20 cm.

Annually:

Remove any sediment deposits from swale.

Available Vendor Products (Not Inclusive)

N/A

LID Fact Sheet

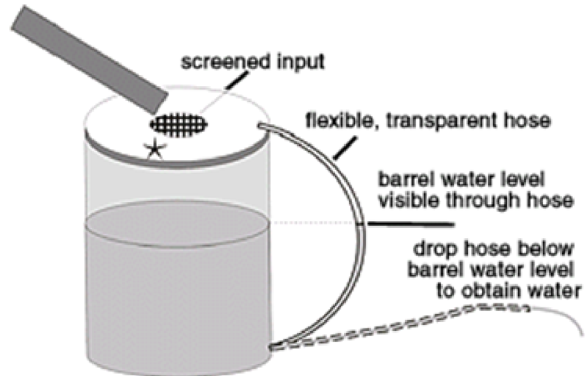
Runoff Repurposing: Cistern/Rain Barrel

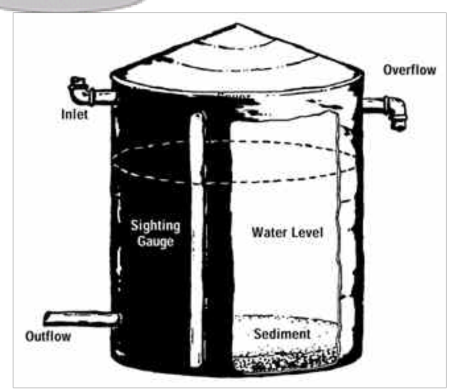
Description

The idea behind these practices is to retain the water running off buildings roofs that can be repurposed for non-potable water usage at a later time. This is not only environmentally sound, but can help to save on annual water bills when practiced correctly.

The main difference between cisterns and rain barrels is building size; for larger, commercial buildings it may require large cisterns. These can be stored underground and require a pump to redistribute the rainwater, whereas the rain barrel is typically used in residential situations and is commonly used to water gardens.

Schematic





Source: (top) Maryland DNR Green Building Program; (bottom) TWDB 2005.

Constituent Removal

Note: No pollutant removal unless a filter is employed

Advantages

- Reduce Water Costs
- Public Involvement
- Reuse of water
- Low impact on environment
- Low construction costs
- Minimal maintenance required

Key Design Elements

- Near roof fitted with gutters for rainwater collection
- Desired amount of rainwater captured

Constraints

- May freeze if not insulated during the winter in colder climates

LID Fact Sheet

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Runoff Repurposing: Cistern/Rain Barrel (cont'd)

Additional Tools and Materials Needed

Downspouts
Roof washer
Cleanout plug
Pump
Cistern/ plastic barrel
Overflow pipe
Locking Pliers
Adjustable hole saw
Pump Container's screen and cover
Concrete blocks

Construction Process Overview

Rain Barrel:

1. Level area where barrel is to be placed; place blocks.
2. Cut downspout tube to appropriate length; place barrel on top of blocks.
3. Connect downspout from gutter to barrel, using proper fittings and drilled hole size to fit.
4. Add an overflow line near the top; be sure to cover end with screen.

Cistern:

1. Place cistern on concrete base.
2. Connect inlet, outlet, and overflow to separate lines; add fittings to ensure seal.

Inspection, Review, and Estimated Construction Cost

Inspection/Review: Check for any leak or clogs
Estimated construction costs:
Rain Barrel: $20
Cistern: $2,000

Maintenance and Upkeep *

Cistern:
Monthly: Inspect components; address leaks/clogs; keep gutters free of leaves
Annually: Replace broken parts; clean out completely during dry season
Estimated Annual Cost: $100/unit/year*
Rain Barrel:
Monthly: Inspect components, address leaks and clogs, keep gutters free of leaves
Annually: Replace broken parts as necessary
Estimated Operational and Maintenance cost:$3.2/unit/year

*LID Center, Fairfax County, BMP fact sheet: http://www.lowimpactdevelopment.org/ffxcty/7-1_rainbarrel_draft.pdf and TWDB http://www.twdb.state.tx.us/innovativewater/rainwater/raincatcher/archived/spring_2008.asp

Available Vendor Products (Not Inclusive)

Eagle Peak Containers, Inc.
Aquabarrel®

APPENDIX F:

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A comprehensive overview of LID, published by the Puget Sound Action Team is online at: http:/www.psat.wa.gov/Publications/LID_tech_manual05/lid_index.

Additional information is available at a website funded by the USEPA: http://www.lid-stormwater.net.

A literature review conducted in 2005 is available from the USEPA at the agency's Low Impact Development website: http://www.epa.gov/owow/nps/lid/.

Information pertaining to LEED can be found at US Green Building Council website: http://www.usgbc.org.

APPENDIX G:

ACRONYMS AND ABBREVIATIONS

Term	**Spellout**
ASHRAE	American Society of Heating, Refrigeration and Air-conditioning Engineers
BMP	Best Management Practices
CERL	Construction Engineering Research Laboratory
CONUS	Continental United States
DA	Department of the Army
DASA I&H	Deputy Assistant Secretary of the Army, Installations and Housing
DMA	drainage management areas
DoD	Department of Defense
DNR	Department of Natural Resources
EISA	Energy Independence and Security Act
EO	Executive Order
EPA	Environmental Protection Agency (also USEPA)
EPAct	Energy Policy Act of 2005
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
FY	fiscal year
GI	green infrastructure
HPDE	high-density polyethylene
HQUSACE	Headquarters, U.S. Army Corps of Engineers
IDG	Installation Design Guide
IMP	integrated management practice
LEED	Leadership in Energy and Environmental Design
LID	Low-Impact Development
METF	maximum extent technically feasible
MOU	memorandum of understanding
MS4	municipal separate stormwater sewer system
NECPA	National Energy Conservation Policy Act
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
POC	point of contact
POLS	petroleum, oils, and lubricants
PWTB	Public Works Technical Bulletin
SI	sustainable infrastructure
SMP	Stormwater Management Plan
TMDL	total maximum daily load
TSS	total suspended solids
TWDB	Texas Water Development Board
UFC	Unified Facility Criteria
USACE	US Army Corps of Engineers
USC	US Code
USDOE	US Department of Energy
USEPA	US Environmental Protection Agency
USGBC	US Green Building Council
WPA	Watershed Protection Approach