APPENDIX C – Post-Construction Best Management Practices

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C1.1 INTRODUCTION

This Appendix to the City of Killeen DDM was written to provide guidance to developers for the implementation of post-construction Best Management Practices (BMPs) to meet requirements of the City's Post-Construction Ordinance, Chapter 32, Article IV. The BMPs contained in this manual were selected by the City's Drainage Stakeholder Committee and deemed to be the most appropriate for local conditions. A total of 41 different Post-Construction BMPs were considered by the Drainage Stakeholder Committee and were ranked from "most acceptable" to "least acceptable". Based on feedback from local stakeholders on March 10, 2010 and March 28, 2012, the City selected 22 BMPs for inclusion in the Post-Construction Ordinance and this manual. The ordinance does not preclude the use of other BMPs; however, the BMPs outlined in this manual are acceptable for meeting post-construction requirements if designed according to principles outlined in this manual and Construction Standards and Details, if available.

Appendix C is organized based on the type of BMP. Three types of BMPs were selected for inclusion in this Manual:

- Site Design BMPs,
- Source Control BMPs, and
- Treatment Control BMPs.

C1.2 SITE DESIGN BMPS

C1.2.1 Preserve Special Flood Hazard Areas (Riparian Buffer)

A riparian buffer is a conservation area that serves the function of physically protecting and separating a stream, lake, or wetland from future disturbance or encroachment. Water hazard setbacks, vegetative buffers, and engineered buffers are the three types of riparian buffers. Water hazard setbacks are areas that separate a potential pollution hazard from a stream, lake, or pond. By providing setbacks from these areas in the form of a buffer, the potential for pollution can be reduced. Vegetated buffers are native or existing areas used to divide land multiple land uses or additional landscaping. Engineered buffers are areas specifically designed to treat storm water before it enters into a stream, lake, or wetland (USEPA, 2012).

Buffers can be incorporated into new development by establishing specific preservation areas to be managed through established maintenance agreements. For re-developed areas, easements may be required from adjacent property owners.

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	Med
Commercial	Yes	Groundwater Recharge	Med
Industrial	Yes	Peak Rate Reduction	Med
Redevelopment	Yes	BMP Credit	
Highway/Road	Limited	1 (25’) 2 (55’)	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

The riparian buffer must extend a minimum of 55 feet beyond the CBZ on both sides of the creek to receive the full BMP Credit (provided that the full extent of the riparian buffer lies within the proposed development). If the creek borders the property and only one side of the riparian buffer can be established, then a partial BMP Credit of 1 may be granted.

If a riparian buffer of 25 feet beyond the CBZ is preserved then a partial BMP Credit of 1 may be granted. Similarly, if the 25’ riparian buffer can only be established on one side of the CBZ due to the property boundary then a BMP Credit of 0.5 may be granted.

Design Specifications / Considerations

The Environmental Protection Agency (EPA) suggests the following considerations when establishing a riparian buffer.

- Designate minimum total buffer width
- Three-zone buffer system
- Use mature forest as a vegetative target
- Conditions for buffer expansion or contraction

- Physical delineation requirements
- Consideration for buffer crossings
- Integrate storm water and storm water management with buffer
- Buffer limit review
- Public education
- Buffer flexibility

The EPA recommends a minimum buffer width of 100 feet on either side of the Delineated Waters of the U.S or ordinary high water mark. Each should be divided into a stream side, middle and outer zone (see Figure C1.2.1). These zones will be distinguished by function, width, vegetative target, and allowable uses.

The stream side zone should be designed to protect the physical and ecological characteristics of the stream or wetland. For streams, this zone is equivalent to the CBZ as defined in chapter 10. Uses shall be restricted as defined by City ordinance. For wetlands, this zone will extend a minimum of 25 feet outside the natural extents of the wetland. Vegetative targets for this area consist of mature forest. Allowable uses will be restricted to flood control, utility right-of-way, recreational trails, and other minimal invasive uses.

The middle zone should provide distance between the inner zone (i.e., CBZ) and upland development. Typical widths should range between 55 to 100 feet based on stream order, natural grade, and 1 percent annual chance floodplain extents. The vegetative target for the middle zone is managed forest. Allowable uses should be restricted to mild recreational activities, storm water BMPs, and recreational trails.

The outer zone will be the first zone to receive runoff from upland development. It shall be designed to reduce encroachment while filtering and slowing runoff. The minimum width of the outer zone should be 20 feet with a vegetative target of forest or turf-grass. Outer zone uses will be restricted to, utility right-of-way, setback easements, and most storm water BMPs. Depending on development characteristics and landscape requirements, the outer zone may include backyards or publicly maintained open spaces. For optimal performance, the use of vegetated swale areas leading to a grass filter are recommended within the outer zone were practical. The swales should be designed to capture discharges for smaller storm events, while allowing larger flows to discharge directly to the channel. The flows captured by these swales can be spread across an infiltration basin located within the middle or outer zones (USEPA, 2012).

Operation and Maintenance

The buffer management plan should include the establishment, management, and distinction of allowable uses within each buffer zone. The buffer limits should be clearly defined and visible before, during, and after construction. The outer boundary of riparian buffers should be clearly marked. Individual BMPs located within the outer buffer zone will be maintained per their specific requirements.

Recommended Inspection Schedule

Periodic inspections should be conducted to assess areas of erosion, bank stability decline, sedimentation, accumulation of debris, and vegetation. Areas of concern should be documented and addressed in a timely manner.

References

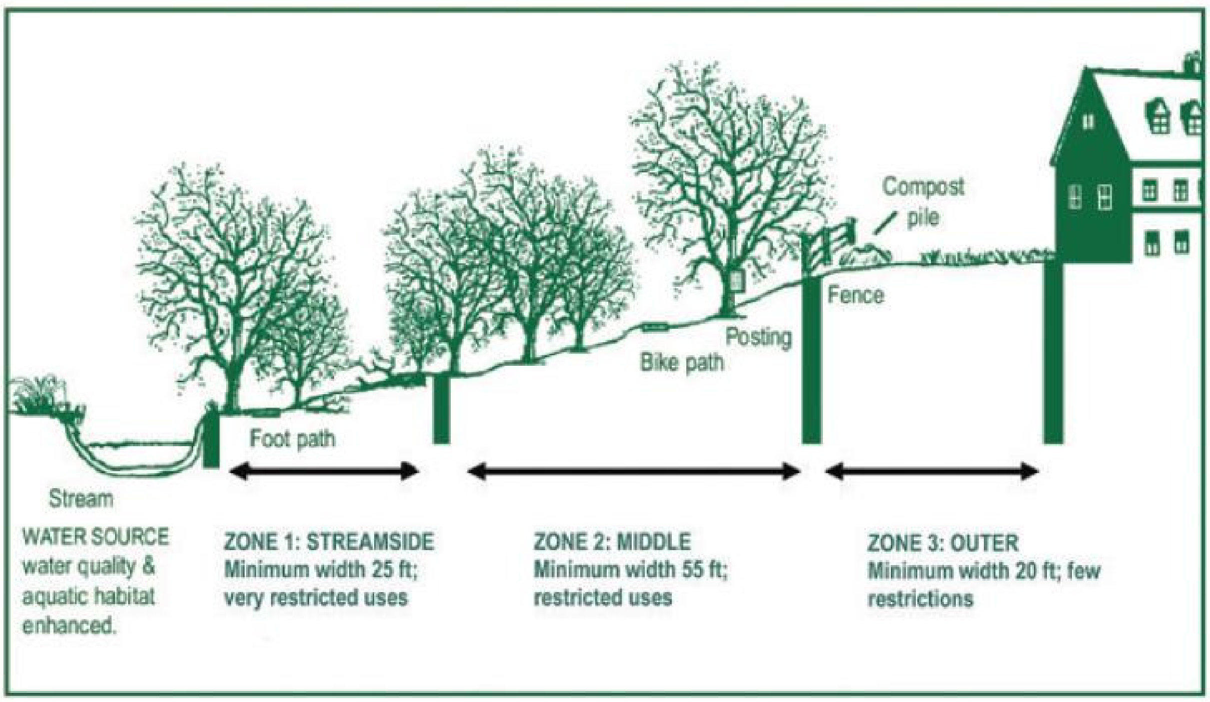
North Central Texas Council of Governments. *iSWM Technical Manual: Planning*. April. 2010. Web. 29 March. 2012. < http://iswm.nctcog.org/Documents/technical_manual/Planning_4-2010b.pdf>.

Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*. SEMCOG 2008.

United States Environmental Protection Agency (USEPA), April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.2.1: Preservation of Special Flood Hazard Areas (Riparian Buffers)

Preservation of Special Flood Hazard Areas Plan View
(Source: iSWM Technical Manual - Planning)



Preservation of Special Flood Hazard Areas Section View
(Source: SEMCOG 2008)

C1.2.2 Protection of Natural Features

The goal of this practice is to minimize the potential impacts that adjacent development may have on natural features or native habitats. By preserving natural areas, vegetation, existing desirable trees, vines, bushes and grasses are protected from disturbance. These features include areas such as wetlands, floodplains, aquifer recharge areas, mature woodlands, and other wildlife habitat within or adjacent to new development. Open spaces within re-development areas should be considered for preservation as natural features early in the planning process (USEPA, 2012).

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	Med
Commercial	Yes	Groundwater Recharge	Med
Industrial	Yes	Peak Rate Reduction	Med
Redevelopment	Yes	BMP Credit	
Highway/Road	Limited	1	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

The natural features to be protected must lie outside the CBZ. A minimum of 10 percent of the developable area (excluding the CBZ) must be protected to receive the BMP Credit.

Design Specifications / Considerations

Protection of natural features and open spaces during and after site construction can be achieved through (1) site planning techniques, (2) construction site BMPs, and (3) other post construction measures.

1. Site planning techniques

Development site plans should attempt to incorporate significant environmental features, which may be marketed as amenities and/or public open spaces. These areas should be designated as possible conservation areas and ranked based on their level of uniqueness, environmental value, historic value, and aesthetics. Proposed protected areas must be designated and approved by the City prior to any site development. Proposed development and re-development should be planned and designed in such a manner that would complement the natural areas. If multiple areas are being protected within a development site, connection should be provided between areas to allow for possible wildlife movement. Setbacks should be established adjacent to protected areas where practical. Size and location of setbacks should be compatible with the protected feature. If a creek or stream is located with the protected area, or the area is within a

SFHA refer to Chapter 10 for delineation of Creek Buffer Zone or *C1.2.1 Preservation of Special Flood Hazard Areas* for setback determination.

2. Best management practices (BMPs) during construction

Once significant environmental features have been identified, they must be protected during construction. Limits of disturbance and location of all protected areas shall be detailed in the construction site Storm Water Pollution Prevention Plan (SWPPP) as well as related construction plans. Selection of appropriate construction BMPs shall consider the type of environmental feature that is being protected. Determination of Environmental Sensitive Areas (ESAs) may be required if the City deems it necessary. Refer to Section *C1.2.7 Locate Development in Less Sensitive Area* for guidelines on protecting ESAs. All construction related activities shall be restricted in these designated areas. Areas shall be inspected periodically to determine if additional BMP measures are necessary during construction and after construction.

3. Post construction measures

Once construction is complete the protected areas shall become amenities for site occupants (e.g. homeowners or commercial tenants) and future maintenance shall be the responsibility of the owners or occupant. The Developer should provide information to owner/occupants detailing each protected area and any activities that are restricted in these areas (USEPA, 2012).

In some cases, the City may assume maintenance responsibilities as defined by city ordinance (See Section 32-49).

Operation and Maintenance

Maintenance procedures shall be provided by the developer to the owner/occupant for each significant feature and/or protected area. Homeowners and maintenance crews shall employ the necessary procedures and precautions to ensure the protected areas are not adversely impacted or destroyed. The City may specify additional BMPs to protect designated areas if determined necessary by city staff.

Recommended Inspections Schedule

Periodic inspections should be conducted to assess areas of erosion, bank stability decline, sedimentation, accumulation of debris, and vegetation. Areas of concern should be document and addressed in a timely manner.

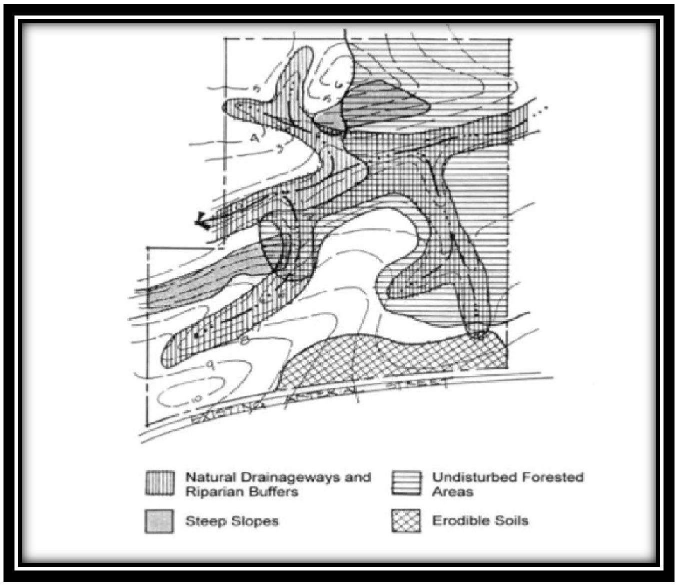
References

North Central Texas Council of Governments. *iSWM Technical Manual: Planning*. April. 2010. Web. 29 March. 2012. < http://iswm.nctcog.org/Documents/technical_manual/Planning_4-2010b.pdf>.

Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*. SEMCOG 2008.

United States Environmental Protection Agency (USEPA), April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.2.2: Protection of Natural Features



(Source: iSWM Technical Manual - Planning)

Delineation of Natural Features

C1.2.3 Dedication and Acceptance of Linear Parks

Development in designated floodplain areas can reduce the floodplain's ability to convey storm flows, while also increasing the flooding, safety, and property damage risk to adjacent developments. Linear parks can be used within a development to dedicate open space that will encompass the unaltered 1 percent annual chance or 0.2 percent annual chance floodplains. Proposed development and redevelopment can use these areas to fulfill post-construction BMP requirements while maintaining the natural condition of the creeks and adjacent floodplains. Linear parks can provide multiple amenities and benefits to both new development and redevelopment. The following are associated with linear parks:

- Creation of open spaces and recreational areas such as hike and bike trails.
- Protection of natural areas and riparian habitat.
- Flood protection, erosion control, and storm water quality improvements. (Arlington, 2005)

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	Low/Med
Commercial	Yes	Groundwater Recharge	Low
Industrial	Yes	Peak Rate Reduction	Med/High
Redevelopment	Yes	BMP Credit	
Highway/Road	Yes	1	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

The linear park must encompass the CBZ and a minimum of 25 feet on one or both sides of the CBZ to receive the BMP Credit.

Design Specifications / Considerations

The City shall evaluate all land proposed to be designated as a linear park per the following criteria:

- Linear park area should be adequate in size, dimension, topography, and accessibility to meet the needs of the adjacent community.
- Consideration should be given to the required floodplain and floodway widths located within the park area to ensure adequate conveyance of flood waters.
- Public access should be made available through the use of public streets.
- Minimum park widths should encompass the CBZ and extend a minimum of 25 linear feet on either side, where practical (measured from the CBZ limit).

- Access to linear park areas should remain outside the 1 percent annual chance floodplain.
- Access shall be provided through a dedicated right-of-way, per city requirements.
- Minimum of two (2) vehicular access locations should be provided per linear park area. The City may require additional access points dependent on park dimensions.
- Storm sewer system design shall be as specified in the Drainage Design Manual.
- Public utilities shall be installed underground within or along linear park areas.
- Over-head utilities must not create any significant hazard to the designated park areas or adjacent community (Arlington, 2005).

Areas dedicated as linear parks must be protected during construction of all land directly adjacent to the park area. This involves allowing areas to remain in a native state where possible. Methods for achieving this include:

- Limiting the use of heavy maintenance equipment and chemical application in native areas.
- Limit maintenance during migratory, breeding, or nesting seasons. (Mid march through June)
- Rotational pruning of woody vegetation (Arlington, 2003).

Platting Requirements:

- Limits of all land designated as linear parks and access should be labeled on the final plat.
- All proposed purchase agreements shall be attached if owner(s) anticipate selling any portion of the linear park to the city or any private group.
- Developer shall propose a participation agreement (City may choose to waive this requirement) (Arlington, 2005).

Operation and Maintenance

Linear parks should provide a low maintenance, natural environment for community use. Trash collection should be available along all trail and picnic areas incorporated within the park. Native grasses, wildflowers, and other herbaceous plants should be maintained along these areas. Regular mowing should be limited to trail, picnic areas, and other designed access points.

Noxious plant and other invasive species shall be identified and removed on a regular basis. Removal shall be performed through non-chemical methods, whenever possible, so as not to impact native vegetation and habitat. Natural vegetation should be managed in order to maintain user security (sight distances, escape routes, etc.) Trail corridors should remain clear of thick, woody vegetation (Arlington, 2003).

Recommended Inspection Schedule

Periodic inspections should be conducted to assess areas of erosion, bank stability decline, sedimentation, accumulation of debris, and vegetation. Areas of concern should be documented and addressed in a timely manner.

References

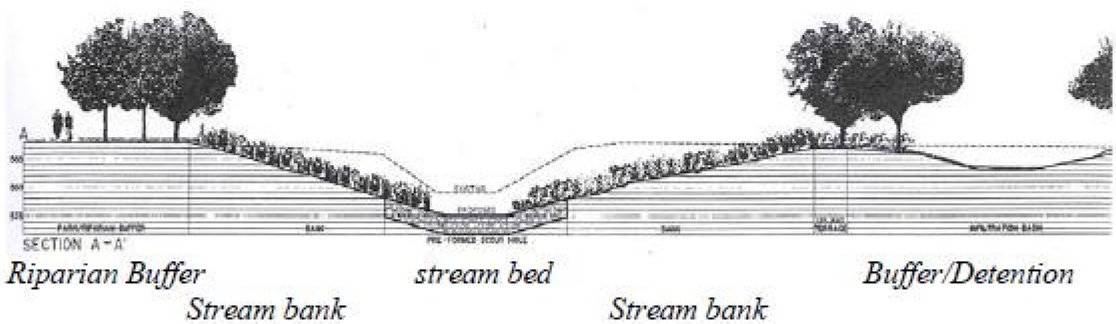
Arlington, City of. *Subdivision Rules and Regulations: Ordinance No. 05-044; Article VII Linear Parks*. June 21, 2005.

Arlington, City of. *Design Criteria Manual; Section 4.7*. August 12, 2003.

Center for Research in Water Resources (CRWR). *Waco LID Guidance Manual*, Lady Bird Johnson Wildflower Center, University of Texas at Austin. August 2011.

U.S. Army Corps of Engineers. *Dallas Floodway Project - Overview*. March 2012. Web. 06 June. 2012. <http://www.swf.usace.army.mil/pubdata/pao/floodway/index.asp> .

Figure C1.2.3: Dedication and Acceptance of Linear Parks



(Source: Arlington Design Criteria Manual, 2003)

Example of Linear Park Designation.
(Dallas Floodway – Balanced Vision Plan)
(Source: USACE, Fort Worth District)

C1.2.4 Reduce Limits of Grading

Clearing and grading for development should be limited to the minimum amount necessary for construction to be completed. A site footprint should be developed to determine the smallest possible land disturbance area for a development site. This will result in the preservation of more undisturbed natural areas throughout the development site, and reduce the amount of erosion and sediment loss that may result from typical construction practices. A common practice used to reduce overall grading limits is to design based on the existing topography by designing roadway alignments to match existing contours. Criteria for roadway design should be flexible enough to achieve optimal alignments while still maintaining the necessary safety requirements.

Conventional residential lot layout practices often result in larger graded areas. Reducing the overall disturbed area of a site can be best applied to lower density residential development. In these developments, grading can be limited to building pads only and can significantly reduce the overall soil disturbance during construction. This practice may also be effective in other residential and commercial developments. However, as site areas decrease and building densities increase this practice becomes more difficult to apply (SEMCOG, 2008).

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	High
Commercial	Yes	Groundwater Recharge	High
Industrial	Yes	Peak Rate Reduction	High
Redevelopment	Limited	BMP Credit	
Highway/Road	Limited	1	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

A minimum of 25 percent of the developed area (excluding CBZ and other preserved natural areas) must be maintained with natural grade to receive the BMP credit.

Design Specifications / Considerations

Minimal disturbance methods should be used to limit the amount of clearing and grading that takes place on a development site, preserving more of the undisturbed vegetation and natural hydrology of the site. The following considerations should be made during the conceptual design phase of the project.

- *Identify Natural and Environmentally Sensitive Areas*. Delineate and avoid areas which can be maintained as natural open space or other conservation areas. These areas may includes creeks and other natural waterways, floodplain, wooded areas, steep slopes, etc. (See BMP C1.2.2 and C1.2.7).

- *Minimize Site Disturbance*. Adjust road alignments, lot plans, phasing, and building locations to fit the existing terrain and reduce mass grading requirements. Municipal code requirements and safety standards should be maintained and may result in additional grading.
- *Concentrate Areas of Development*. Development should be limited to existing open space, when possible. If excessive grading is required, retaining walls may be used to reduce cut/fill volumes.
- *Minimize Grading within Lots*. Grading should be limited to access routes and building pads, whenever possible.
- *Establish a Limit of Disturbance* (LOD). The overall limit of disturbance shall be based on maximum disturbance radii and lengths. Maximum distances should reflect reasonable construction techniques and equipment needs together with the physical characteristics of the development site such as slopes or soil types. LOD distances may vary by type of development and size of lot, site, and/or phase, and by the specific development feature to be constructed. Limits of disturbance should be designated on construction plans and submitted to the City for review.
- *Using Site "Foot Printing".* This involves mapping all grading limits of disturbance to identify the smallest possible land area that requires clearing and land disturbance.
- *Fit Site to Terrain*. Adjust roadway alignments and building layout to match the existing topography.

Operation and Maintenance

Reducing the total site disturbance will decrease the maintenance requirements both during and following construction. All disturbed areas and supporting erosion and sediment controls should be monitored periodically, until permanent soil stabilization has been established.

Natural and undisturbed areas will require minimal maintenance as long as they are allowed to function in a manner consistent with their pre-development conditions. Occasional maintenance may be required for the control of invasive species. This maintenance can often be performed on an "as needed" basis.

Recommended Inspection Schedule

Typical inspection schedules for post-construction erosion control would involve routine assessments every two weeks until vegetation is established and after all rainfall events which exceed 0.5 inches of precipitation within a 24 hour period. Inspections of natural areas should be performed at least once per growing season to assess the overall health of the areas (USEPA, 2012).

References

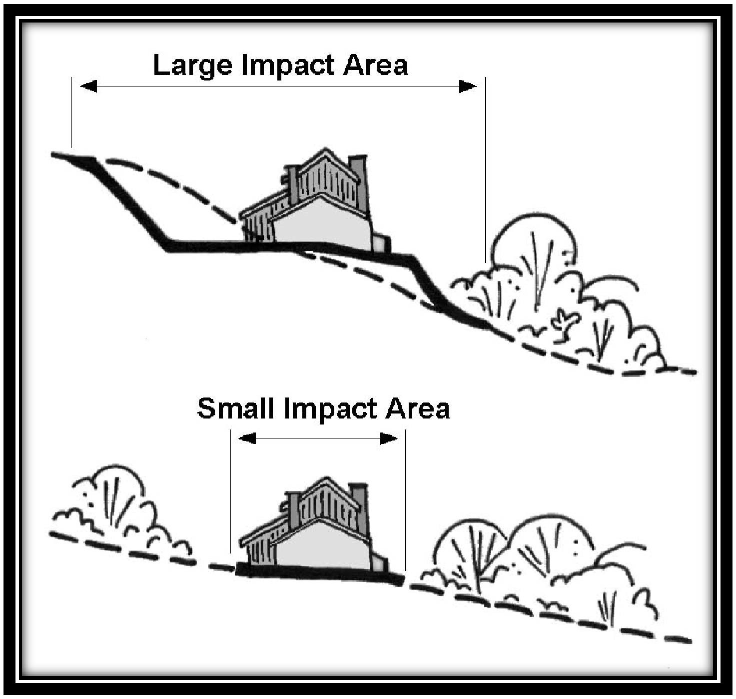
North Central Texas Council of Governments. *iSWM Technical Manual: Planning*. April. 2010. Web. 29 March. 2012. < http://iswm.nctcog.org/Documents/technical_manual/Planning_4-2010b.pdf>.

Low Impact Development Center, Inc. *Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies*. April. 2010. Web. 06 June. 2012. <http://www.casqa.org/LID/SoCalLID/tabid/218/Default.aspx>.

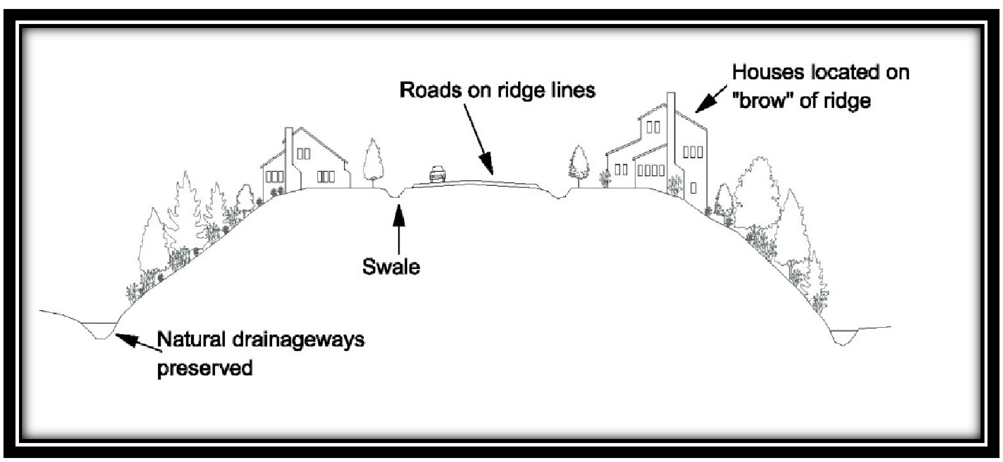
Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*. SEMCOG 2008.

United States Environmental Protection Agency (USEPA), April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.2.4: Reduce Limits of Grading



(Source: iSWM Technical Manual - Planning)



(Source: Low Impact Development Center, Inc. 2010)

C1.2.5 Open Space Design / Cluster Development

Open space design, also known as cluster development, is a practice in which a development is designed to keep all proposed improvements to a dense area within the site property and leave the other areas untouched. Open space design (cluster development) is an effective way to preserve as much land as possible within a development in its natural state. By implementing this type of development, it is possible to preserve wetlands, floodplains, buffers to streams, wildlife habitats and historical features that otherwise would be compromised or lost. With all of the development constrained to a smaller area there are substantial economic benefits gained by open space design (cluster development) by means of less necessary infrastructure. Preserved natural areas will also increase the property value of the development. In addition to the economic advantages of a cluster development, it also helps maintain the natural hydrologic and hydraulic nature of a site. The usable space created by a cluster development is typically used within residential developments but can also be used in commercial applications. The goal of cluster development is to develop less land area while allowing the same number of residential units as a traditional development.

Pollutant Removal / BMP Credit

A BMP Credit of 2 can be taken if the entire development is designed based on this concept.

Design Specifications / Considerations

When considering a cluster development, it is important to determine if there is sufficient land area to dedicate a substantial portion towards open space. In order to be effective it must be determined that the same number of units can be developed in relation to a traditionally planned development. Allowing the same number of units to be developed in a cluster development ensures that the developer is not financially burdened by designing a cluster development. Where there are environmentally sensitive areas to maintain, the use of cluster developments can be a very useful tool to gain BMP credits.

There are limitations for cluster developments. In some cases, there is not enough land to create both a cluster and retain a significant portion of the property as open space and undeveloped. The lot size for residential subdivisions can be limited with a cluster development. Larger lots may cut into the available land for open space. Not all developments contain land that is worth preserving, as well. Examples of pre- and post-development site conditions using cluster development are illustrated in the construction details, PC-46 and PC-47, respectively.

Operation and Maintenance

Cluster developments require the same maintenance as traditional developments though not on as large of a scale since all of the development is limited to a smaller area. Municipal utility providers will need to have access to maintain their utilities within the infrastructure. In addition, the subdivision will most likely need to establish a homeowners association to maintain the preserved open space and educate the community about the cluster development. Since the open space will be preserved in its natural state, the maintenance is not that demanding. Natural waterways need to be inspected to make sure that any additional storm water runoff does not cause any un-natural stream bank erosion or failure. All natural features within the open space must be inspected to ensure that they remain in their natural state.

Recommended Inspection Schedule

Seasonal inspections of open space areas are recommended for cluster developments.

References

United States Environmental Protection Agency (USEPA), April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

C1.2.6 Minimize Directly Connected Impervious Area

Storm water volumes can be reduced for developed areas by avoiding the direct connection of impervious areas such as rooftops, roadways and parking lots. These surfaces contribute to the rapid conveyance of storm flows. Water quality is also reduced as organics, hydrocarbons and other pollutants become concentrated in these areas. Connecting impervious areas to open channels or bioretention areas can provide water quality treatment and reduce peak discharges for developed areas.

Storm water quantity and quality benefits are achieved by routing the runoff from impervious areas to pervious areas such as lawns, landscaping, filter strips, vegetated buffers and channels. Similar to the use of undisturbed buffers and natural areas, vegetated areas such as lawns, engineered filter strips, and vegetated channels can act as bio-filters for storm water runoff and provide infiltration in pervious soils (Hydrologic Soil Groups A and B). In this way, the runoff is "disconnected" from a hydraulically efficient structural conveyance such as a curb and gutter or storm drain system. This helps reduce the time of concentration of storm flow within drainage basins and can in turn reduce overall peak flows for proposed development (SEMCOG, 2008).

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	High
Commercial	Yes	Groundwater Recharge	High
Industrial	Limited	Peak Rate Reduction	High
Redevelopment	Limited	BMP Credit	
Highway/Road	Limited	1	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

A minimum of 25 percent of the impervious area must be disconnected to receive a BMP Credit. This BMP is subject to area weighting based on the percentage of impervious area that is disconnected.

Design Specifications / Considerations

Successful implementation of this BMP often involves directing storm runoff to areas of existing vegetation. Vegetation may vary in type and maturity, but infiltration rates and soil type should be considered in order to reduce excessive ponding in these areas. When designing vegetated areas, consideration should be given to existing water table elevations, soil type and infiltration rates, the possibility of erosion, and the effects of water logged soils. The proper use of structural BMPs such as bioretention, dry wells, and infiltration trenches will limit the potential for ponding and increase the efficiency of these areas. Other considerations for disconnecting impervious areas include:

- Sheet flow runoff from impervious areas to natural conveyance systems such as riparian buffers and vegetated swales.

- Connect roof drains to specifically design BMPs such as bioretention basins or detention basins. Refer to construction detail PC-39 of the DDM for specific roof drain design standards.
- Incorporate vegetated swales and bioretention areas within lot design.
- Maintain gradual slopes in vegetated areas. (less than 5 percent).
- Avoid excess pollutant loading to vegetative areas.
- Avoid concentrating flows from larger impervious areas to allow for on-site treatment of smaller flows. Contributing drainages areas should be limited to 1000 sq. ft. per discharge location. The maximum impervious flow path should not exceed 75 feet (SEMCOG, 2008).
- The length of disconnection should equal the length of impervious flow path. (Minimum 75 feet for concentrated discharges; minimum 25 feet for sheet flow discharges) (SEMCOG, 2008).
- Avoid the direct connection to impervious conveyance systems, such as roof drains discharging onto pavement or storm sewer systems. Instead intercept drain flows using dry wells, rain gardens, or other similar BMP.
- Provide safety overflow outlets for larger storm events.
- Travel velocities through vegetated areas should be reduced below 6 feet per second for smaller storm events (2-year return period).

Operation and Maintenance

Operation and maintenance programs should fulfill the requirements of the individual BMP incorporated within this design practice. Typical maintenance for vegetated areas shall be performed on a biannual or seasonal basis and include the removal of dead or impaired plants and mulch replenishment. This can be incorporated into a regular landscaping plan for the site. Routine trash and debris removal may also be required for vegetated areas located adjacent to parking lots and roadways.

Recommended Inspection Schedule

Biannual or seasonal inspections are necessary to assess the overall vegetation health of previous areas. Areas of erosion or poor plant growth should be noted. Inspections should be documented and any concerns shall be addressed in a timely manner.

References

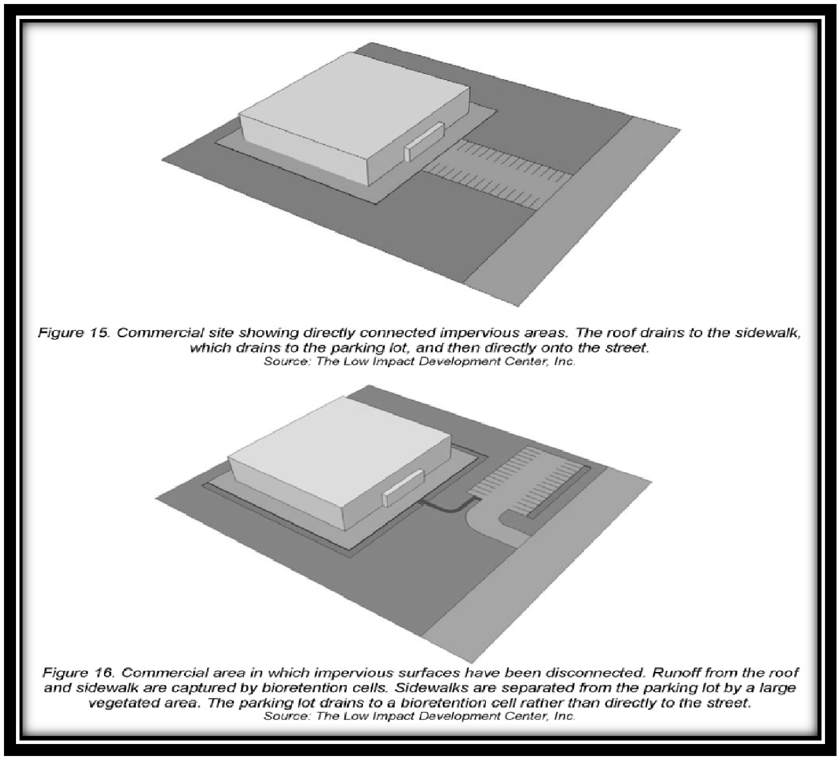
Low Impact Development Center, Inc. *Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies*. April. 2010. Web. 06 June. 2012. <http://www.casqa.org/LID/SoCalLID/tabid/218/Default.aspx>.

Maine Stormwater Best Practices Manual <http://www.state.me.us/dep/land/stormwater/stormwaterbmps>.

Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers,* SEMCOG 2008.

United States Environmental Protection Agency (USEPA), April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.2.6: Minimize Directly Connected Impervious Area



(Source: Low Impact Development Center, Inc. 2010)

"Center for the Arts stormwater disconnection"

(Source: SEMCOG 2008)

C1.2.7 Locate Development in Less Sensitive Area

Protecting environmentally sensitive areas (ESAs) involves indentifying and limiting the impacts to certain natural features during development. These features can then be used to benefit the development through storm water quality, volume reduction in runoff, or as amenities. Protecting ESAs can be achieved at the site level as well as regionally within a community. Prioritization of certain areas can be designated by weighing the functional value of individual areas. ESAs must be preserved in their natural state and shall not be used to construct storm water infrastructure (SEMCOG, 2008).

To minimize the hydrologic impacts on the existing land cover, the area of development should be located on areas of the site which are less sensitive to disturbance or have a lower value in terms of hydrologic function. A site layout should be designed so the areas of development are placed in such a way that will minimize the hydrologic impacts to the overall site. In doing so the natural hydrology and drainage characteristics for these areas shall be preserved and can be utilized to prevent or mitigate for storm water impacts which result from development. Generally such areas may include riparian buffers, wetlands, alluvial plains, floodplain, woodlands, and steep slopes (SEMCOG, 2008).

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	High
Commercial	Yes	Groundwater Recharge	High
Industrial	Yes	Peak Rate Reduction	High
Redevelopment	No	BMP Credit	
Highway/Road	Limited	1	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

A partial BMP Credit of ½ may be given for a certified study of the area that indicates that no ESAs are present on the site. If ESAs are identified, a minimum of 80 percent of those areas must be protected to receive a full BMP Credit of 1.

Design Specifications / Considerations

Protecting ESAs can be achieved across all types of land development projects. As development density and land use requirements increase, the application of this BMP will decrease. For these limited cases, it is important that ESAs be prioritized early in the planning process. The following are some general steps for defining ESAs.

- **Identify, Delineate, and Inventory ESAs.** The maps and data produced will provide information on the possible ESAs which are located within the site. Mapping will enable the developer to define areas of development to avoid encroachment on and disturbance of sensitive areas. The quality of habitat within these areas should also be documented and will be a useful tool in determining where encroachments may have the least impact.

- **Create ESA map to prioritize areas to avoid development.** Overlay environmentally sensitive resource maps to create an integrated map. Areas should then be prioritized based on their level of importance. Criteria for determining such levels may include types of natural features, quality of vegetation, existence of protected wildlife, possible mitigation requirement (local or federal), and connectivity to larger natural features.
- **Delineate and Prioritize Potential Development Areas.** Potential development areas should be prioritized to correlate with ESA prioritization. Thus, if an area is a high priority ESA then it should be a low priority for development. Factors which may influence the prioritization of development included existing terrain, ease of access, proposed infrastructure, cost of development, and local zoning requirements.
- **Federal and Municipal Regulations.** Regulations and mitigation requirements enforced by Federal Emergency Management Act, U.S. Army Corps of Engineers, Texas Commission of Environmental Quality, and local ordinances may prohibit or restrict development in some ESAs. Federal and municipal regulations should be fully understood and disclosed early in the planning process. Once protected ESAs have been established, additional documentation may need to be in place for maintenance of these areas. These documents may include conservation easements, maintenance agreements, platted boundaries, etc.

Once ESAs have been designated they will need to be protected throughout the construction process. General construction guidelines for protecting ESAs include:

- **Conducting Pre-Construction Meetings.** A meeting shall be held prior to the start of construction to educate community officials, contractors and sub-contractors on the natural resources being protected as well as the methods of protection being used.
- **Special Requirements for ESAs.** Document all work requirements to be performed within or adjacent to ESAs. Include specifications for the work to be performed as well as the equipment that will be used. List all activities not allowed with protected areas.
- **Minimizing Construction Staging Areas.** Limit the amount of area used for construction staging and clearly mark all staging areas. All storage of materials and construction activities should be limited to these areas. These areas are not allowed within a protected area.
- **Clearly Marking ESAs.** Install construction fencing around all ESAs to prevent unnecessary encroachment.
- **Limited Excavation.** Limit excavation to only what is necessary to meet engineering and construction requirements. Do not stock pile or place spoil material in protected areas.
- **Routine Monitoring.** Construction activities should be routinely monitored to ensure ESAs are being protected as shown by the construction plans. Post-construction monitoring should be conducted on areas impacted by construction to ensure that such areas receive the appropriate maintenance (SEMCOG, 2008).

Operation and Maintenance

Protecting ESAs can create maintenance concerns over who will be responsible to perform such activities. In most instances, these areas will be owned and maintained by homeowner's associations or private property groups. In some instances, local municipalities or state or federal agencies may have jurisdiction over these areas. Specific maintenance requirements will depend on the natural vegetation within the preserved area. Some areas, such as floodplains and woodlands, may required little to no maintenance. Open space areas may require seasonal mowing and invasive species management.

Recommended Inspection Schedule

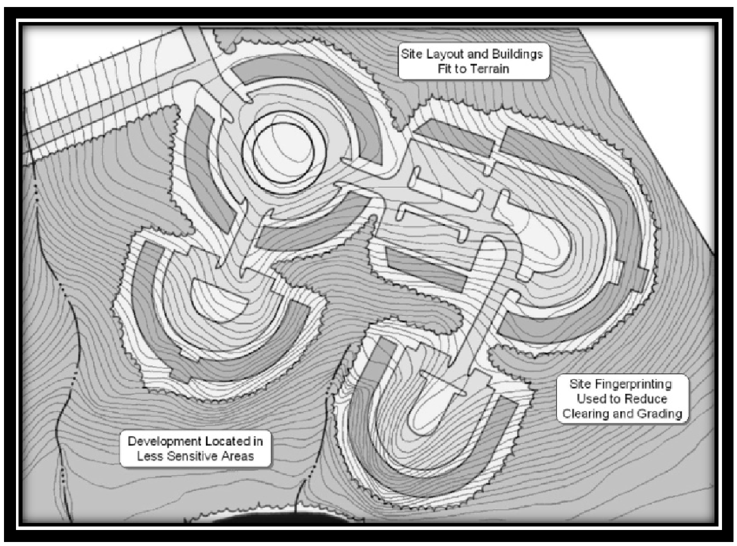
Biannual or seasonal inspections are necessary to assess the overall vegetation health and to control the threat of invasive species. Inspections should be documented and any concerns shall be addressed in a timely manner.

References

North Central Texas Council of Governments. i*SWM Technical Manual: Planning*. April. 2010. Web. 29 March. 2012. < http://iswm.nctcog.org/Documents/technical_manual/Planning_4-2010b.pdf>.

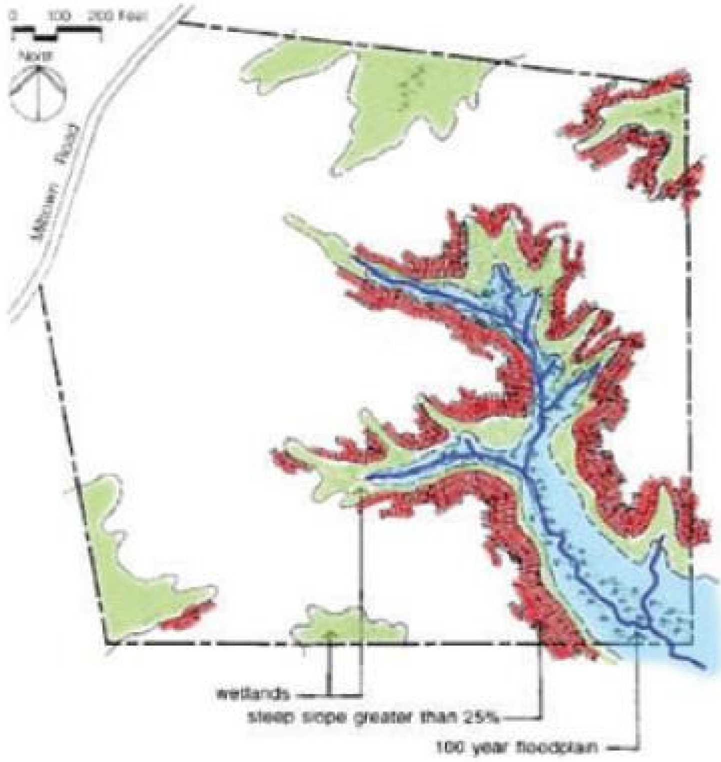
Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers,* SEMCOG 2008.

Figure C1.2.7: Locate Development in Less Sensitive Area



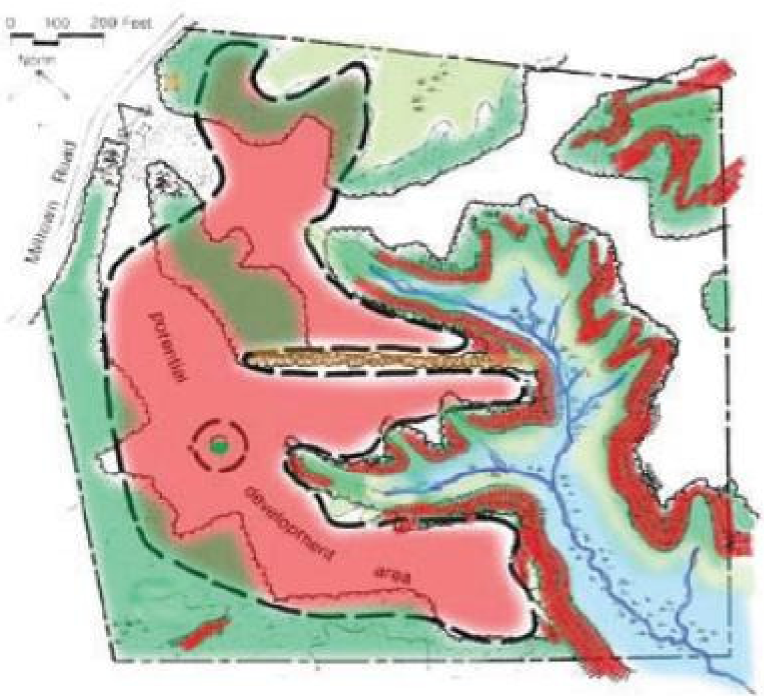
(Source: iSWM Technical Manual - Planning)

Example of Sensitive Area Map



(Source: SEMCOG 2008)

Example of Potential Developable Areas Map



(Source: SEMCOG 2008)

C1.2.8 Minimize Siting on Erodible Soils

Permeable soils such as sand and gravel provide an opportunity for storm water infiltration and groundwater recharge. Conversely, once disturbed these soil types can exhibit unstable and erosive characteristics. Development and the disturbance of areas consisting of erodible soils should be avoided due to the greater risk of erosion.

Variables that affect soil erosion are climate, soil classification, vegetation, and topography. Of these climate is the least controllable factor. Climatic changes involving temperature, wind, precipitation, and humidity can all have an effect on soil erodibility. The geometry of soil particles and their interaction with one another will also have an effect on the erosive nature. This interaction between particles relates the textual qualities of gradation and plasticity, as the primary engineering interest for soils to be used as a construction material. Gradation of a soil is the particle size distribution, as determined by dry weight, sieve testing for particles greater than 0.075 mm in diameter and hydrometer analysis for particles smaller than 0.075 mm in diameter. The terms clay, silt, sand and gravel describe different gradation ranges of soils particles. Particle distributions and sieve designations are listed in the table below:

Table C1.2.8: Standard Sieve Designation and Corresponding Grain Size (ASTM E-11 ; ASTM D-2487)

Standard Sieve Size (mm)	Alternative	Description
125 - 90	5 in. - 3.5 in.	Cobbles
75 - 22.4	3 in. - 7/8 in.	Coarse Gravel
19 - 5.6	3/4 in. - No. 3 1/2	Fine Gravel
4.75 - 2.36	No. 4 - No.8	Coarse Sand
2.00 - 1.18	No. 10 - No. 16	Medium Sand
1.00 - 0.500	No. 18 - No. 35	
0.425 - 0.212	No. 40 - No. 70	Fine Sand
0.180 - 0.090	No. 80 - No. 170	
0.075 - 0.038	No. 200 - No. 400	Fines
0.032 - 0.020	No. 450 - No. 635	

(Source: Dewberry and Davis 1996)

The plasticity of a soil is a measure of how a soil will behave once it is combined with water molecules. Soils with a particle size less than 0.002 mm will exhibit high degrees of plasticity or cohesion. These particles are usually flaky in shape and have a high degree of workability once they reach optimal moisture content. The point at which a soil will begin to exhibit plastic characteristics is known as the plastic limit (PL). As the moisture content continues to increase, a soil will begin to behave as a liquid, at which point the liquid limit (LL) is established. The difference between the plastic limit and the liquid limit equals the plasticity index (PI) for that soil and defines the range at which a given soil remains plastic in nature (Dewberry and Davis, 1996).

Topography can also influence the erosive nature of soil. Generally, erosive soils exhibit slopes between 2 and 15 percent, with highly erosive soils having slopes greater than 15 percent. Vegetation plays an integral role in reducing erosion. Established vegetation can help reduce surface runoff velocities, hold soils in place, strengthen soil structure through root systems and plant residues, increase biological activity, and increase transpiration rates. The effectiveness of vegetation varies with plant species, maturity, and climate. Trees and well established grasslands are effective in reducing erosion due to their well established root systems.

Pollutant Removal / BMP Credit

A partial BMP Credit of ½ may be given for a certified study of the area that indicates that no erodible soils are present on the site. If erodible soils are identified, a minimum of 80 percent of those areas must be protected to receive a full BMP Credit of 1.

Design Specifications / Considerations

Two of the most widely used soil classification methods are the Unified Soil Classification System (USC) and the American Association of State Highway and Transportation Officials (AASHTO) method.

A complete description of the USC method is provided by ASTM D-2487. The main principle of the USC method is that the engineering properties of coarse-grained soils are defined by gradation, while the engineering properties of fine-grained soils are defined by plasticity. In general, soils are defined as either coarse-grained or fine-grained. The textural qualities of gravel, sand, silt, and clay are designated by the letters G, S, M, and C, respectively. The gradation of soils is defined as either well graded (W) or poorly graded (P), and plasticity is defined as either high (H) or Low (L).

The AASHTO classification system is described in ASTM D-3282 or AASHTO M65. This system uses laboratory testing to classify soils. AASHTO designates seven groups, A-1 thru A-7, to classify soils. Each group classification is based on gradation, liquid limit (LL), and plasticity limit (PL). Sieve testing is used to determine particle size. Groups A-1 through A-3 are used to classify sandy soils, while A-4 through A-7 classify silt and clay materials (Dewberry and Davis, 1996).

Either of these methods are acceptable for determining the engineering soil characteristics for a site prior to development. Testing should be performed by a geo-technical specialist or licensed geologist. A detailed map of the soil type distribution should be produced to determine areas of the site that are more favorable for grading. Areas with “problem soils” should also be labeled and avoided when possible. Problem soils are those which require additional engineering due to their irregular characteristics. They are often indigenous to selected regions of the country, and can exist in isolated pockets throughout a project site. Such soils include *expansive clays*, *metastable soils*, *organic soils*, *dispersive soils*, *normally consolidated clays*, and *limestone*. Locating these soils early in the planning and design process can reduce costly delays, additional excavation, and the likelihood of future design failures.

Expansive Clays. Various clays exhibit the ability to shrink and swell as the moisture content changes. These soils typically have a high plasticity index (PI) and are commonly found in south and southern United States. Common soil names include *gumbo, adobe,* and *black cotton.* The environmental factors as hydrology, slope, vegetation, and underlying soils may affect the behavior of these clays.

Metastable Soils. Collapsing soils decrease in volume as moisture content increases or when subjected to vibration. Typically fine sand, silt, and clay materials will exhibit these qualities. Such soils are commonly deposited in alluvial fans, at the base of cliffs or mountains, or in semiarid regions. Loess soils, commonly found in the midwest and western United States, are the most common type of metastable soils. Compacted loess can be used as a foundation as long as the dry unit weight is around 99#/cf or greater. Compaction is required the full depth for lifts less that 6 inches.

Organic Soils. Organic soils exhibit very little cohesion and are highly compressible, even under lighter loading. Commonly found in estuaries, wetlands, and floodplains, these soils should not be used for construction. Peat consists of fibrous, partially decomposed organic matter and high porosity.

Normally Consolidated Clays. Clay is considered normally consolidated if the existing compression state is directly related to the overburden weight. Normally, these soils will be subject to long-term settling under loads that exceed to the overburden weight. Estimates for this settlement can be obtained from sample testing.

Limestone. Limestone and other sedimentary minerals are highly erodible due to their solubility. Sink holes can occur for soils that overlay sedimentary deposits. Voids in bedrock enable ground water to transfer of overlaying soil particles. Particles are deposited at the bedrock surface until the weight of the sedimentation creates a sink hole (Dewberry and Davis, 1996).

Operation and Maintenance

The Natural Resources Conservation Service (formerly the Soil Conservation Service) has produced soil surveys detailing information useful in landplaning and engineering design. Field exploration should be carefully planned for development site based on the characteristics of the development. The number of boring locations will be dependent on prevailing soil conditions, variability of soils, and project details. The following guidelines can be helpful in determining boring locations.

- For commercial and retail development, boring should be locations near building corners and one in the middle. Larger building groups may place boring in a gridded layout to establish a subsurface cross section.
- For dams and other structural fill, boring locations should be places to create a geological profile across the valley, upstream and downstream toe, and all major hydraulic structures. Borings located in the impoundment area can help locate suitable structural fill material.
- For roadway design, boring locations are used to obtain data bases on the following criteria:
    1) Shallow borings along the road alignment are used to confirm the presence of anticipated soils.
    2) Borings in the vicinity of major structures (bridge abutments, piers, and retaining walls) are used to create a subsurface profile for foundation integrity.
    3) Borings within cut areas help determine the difficulty of excavation and slope stability.

4) Borings in borrow areas help determine the soils suitable for fill material. Borings should be made at 200 to 400 feet grid intervals depending the site size.

References

Dewberry and Davis. *Land Development Handbook; Planning, Engineering, and Surveying.* 1996.

Ward, Andy D. and Trimble, Stanley W. *Environmental Hydrology.* Chapter 9 Soil Conservation and Sediment Budgets, 2004.

C1.2.9 Dedication and Acceptance of Conservation Easements

Conservation easements are voluntary agreements which allow an individual property owner or company to set aside private property for the use of limited development. Conservation easements can cover all or portion of a property and can be permanent or temporary per a documented agreement. Easements shall typically describe the resources they are intended to protect (e.g. forest, agriculture, historic, or private open space) as well as give an explanation of the restricted uses for the property. These easements can relieve the property owners from the burden of maintaining these areas by shifting such responsibilities to private organizations or local, state, or federal governmental agencies.

Conservation easements are thought to contribute to the protection of water quality. Typical uses for conservation easements involve preserving natural areas being threatened by urban development. In rapidly developing areas, conservation easements provided a method of preserving open space and natural features.

Pollutant Removal / BMP Credit

The pollutant removal efficiency of these areas is depended on the amount of area preserved, conservation techniques, and specific nature of the easement.

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	High
Commercial	Yes	Groundwater Recharge	High
Industrial	Yes	Peak Rate Reduction	High
Redevelopment	No	BMP Credit	
Highway/Road	Limited	0.5	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

Design Specifications / Considerations

Conservation easements shall be designated in such a manner that preserves the current state regardless of changes in ownership. In doing so, landowners can ensure that the property will remain in prescribed condition for perpetuity. Often governing agencies and private land trusts have determined specific criteria for the designation of such easements. The following is an example of such criteria:

Criteria	Details
Natural Resource Value	Does the property provide a critical habitat or important environmental aspects worth preserving?
Uniqueness of the Property	Does the property have unique traits worth preserving?
Size Distinction	Is the land area enough to have a natural resource or conservation value?
Financial Requirements	Are funds available to meet all financial obligations?
Perpetuity	Has a perpetual conservation agreement been established?
Easement Holder's Criteria	Does the property align with the easement holder's mission and specific conservation criteria?

Source: USEPA, 2006

Operation and Maintenance

Prior to the dedication of an easement, a management agreement must be documented detailing the responsibilities of the easement holder. These management duties shall include:

- Easement language shall be stated clearly and in a manner that is enforceable by the governing agency,
- Limits and legal description of easements shall be documented by final plat,
- Land use should be regularly monitored,
- A review and approval process shall be established for all restricted uses,
- Easement restrictions shall be enforceable by law,
- Development records shall be maintained for all allowable uses.

Maintenance responsibilities for all conservation easements will be determine through the management agreement.

Recommended Inspection Schedule

Biannual or seasonal inspections are necessary to assess the overall vegetation health and to control the threat of invasive species. Inspections should be documented and any concerns shall be addressed in a timely manner.

References

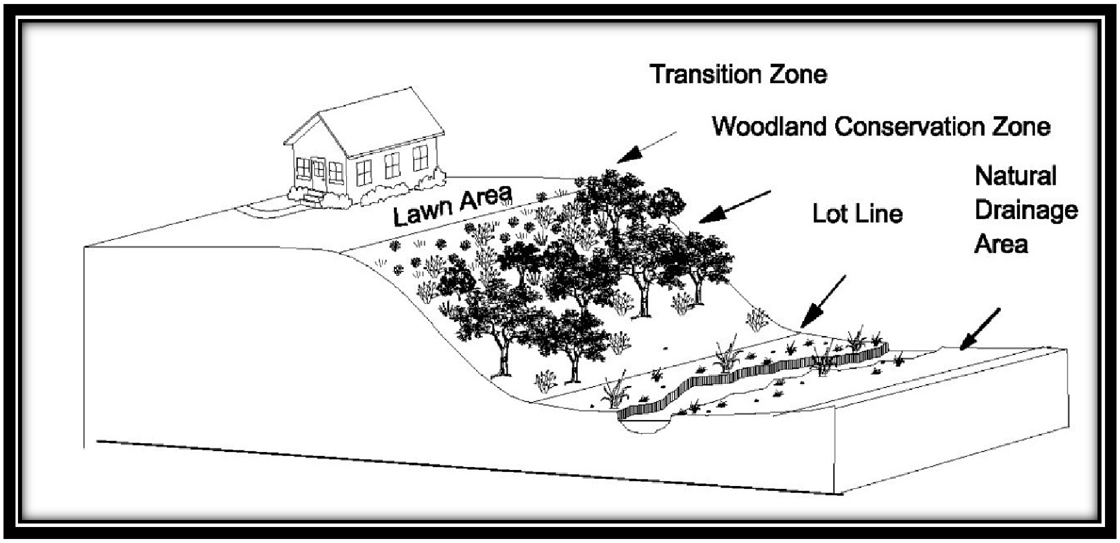
Low Impact Development Center, Inc. *Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies*. April. 2010. Web. 06 June. 2012. <http://www.casqa.org/LID/SoCalLID/tabid/218/Default.aspx>.

North Central Texas Council of Governments. *iSWM Technical Manual: Planning*. April. 2010. Web. 29 March. 2012. < http://iswm.nctcog.org/Documents/technical_manual/Planning_4-2010b.pdf>.

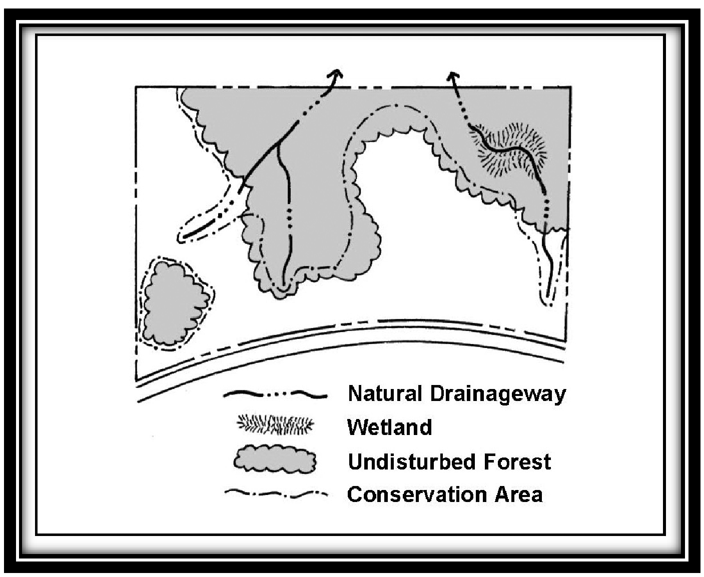
Southeast Michigan Council of Government. Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers. SEMCOG 2008.

United States Environmental Protection Agency (USEPA), April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.2.9: Dedication and Acceptance of Conservation Easements



(Source: Low Impact Development Center, Inc. 2010)



(Source: iSWM Technical Manual - Planning)

C1.3 SOURCE CONTROL BMPS

C1.3.1 Urban Forestry

Urban forestry is a BMP that utilizes landscaping in an urban setting to help reduce the amount of runoff generated by rainfall. Urban forestry not only utilizes trees to accomplish the goals of the BMP but also shrubs and turf. Urban forestry enhances the urban setting by providing aesthetics which otherwise may not be provided. Trees cool urban areas, save energy, improve air quality, improve social connections and create walkable environments. Trees and other plants have the capacity to absorb water and when placed in carefully planned locations can provide necessary storm water treatment. Not only do these plants absorb water, fallen leaves from the plants will also absorb water and slow down storm water runoff. The root systems of the plants help keep soils loose and less compacted and allows the soil to retain more water.

Urban forestry can be used in most types of urban development including residential and commercial developments. Urban forestry can be limited when the pervious cover within a development is extremely limited or non-existent, like an industrial development. In addition to providing an environmental benefit, urban forestry can also provide shade, beauty and privacy. Urban forestry can be provided by either maintaining existing vegetation on sites or by creating an urban forest environment within a proposed development. In both cases, it is imperative that once the urban forest is established, a maintenance and conservation plan be adopted to preserve and maintain its function. An example of urban forestry that can be accomplished by the preservation of existing tree canopy is depicted in the Construction Detail PC-48.

Pollutant Removal / BMP Credit

To receive credit for preservation of tree canopy, the existing tree canopy must cover at least 50 percent of the site. At least 25 percent of the existing tree canopy must be preserved to receive a BMP Credit of 1. The following number of BMP Credit points will be awarded based on the percentage of existing tree canopy that is preserved.

10% - 24.9%	0.5 Credit
25% - 49.9%	1 Credit
50% - 65%	2 Credits
>65%	3 Credits

If the pre-development tree canopy is less than 50 percent of the site, one credit will be awarded if sufficient trees are planted to bring the projected mature canopy cover for the entire site to at least 25 percent. This may be achieved through a combination of preservation of existing tree canopy and restoration/creation of new tree canopy. The recommended tree plantings list found in Article VI, Subdivision A of the City’s Landscaping Regulations, Section 8-530 may be used for restoring tree canopy. Those trees that are listed as Medium or Canopy Types may be used. The mature canopy for Medium Type trees may be assumed to be 700 square feet. The mature canopy for Canopy Type trees may be assumed to be 2000 square feet. These assumptions shall be used for the computation of tree canopy upon maturity based on the tree species planted.

Design Specifications / Considerations

One of the main factors to consider when designing an urban forest is to determine if enough area is available to maintain the functions of forest. The critical root zones of trees must be preserved while conserving an existing urban forest or to provide enough room for a critical root zone of a fully developed tree. A minimum of 10 feet clearance should be maintained between roads and parking lots and the forest canopy. A minimum of 15 feet should be maintained between structures and the forest canopy (see Detail PC-48). When preserving an existing urban forest, it is beneficial to eliminate invasive species from the setting. Only native species should be maintained and introduced to the urban forest. It is also important to direct storm water runoff to the urban forest. If rainfall and storm water runoff is not sufficient to meet the trees water needs then it may be necessary to provide supplemental irrigation in order to maintain the plants. Urban forests require the correct amount of sunlight and shade to prosper. Any surrounding development must be designed to allow the proper amount of sunlight and shade.

Urban forestry may be limited by the area available for plantings and root systems. Poor soil can also limit the use of this BMP. Urban forestry may introduce unwanted wildlife and pests to the environment. The use of native species may limit the diversity of the urban forest. Poor tree care practices by citizens and untrained arborists can also present problems with maintaining the urban forest.

Operation and Maintenance

To maintain the function of an urban forest it must be properly cared for. All trees must be pruned and cared for based on their needs. Improper care and maintenance of the trees could lead to failure of the urban forest. Dead plants must be replaced to ensure proper density. Litter control within the urban forest should be maintained. The use of native vegetation and the preservation of a site as close to its natural state as possible will minimize the required maintenance for the site. It may be necessary to use an easement to better preserve the urban forest.

Recommended Inspection Schedule

Monthly inspections are necessary until an urban forest becomes well established. Seasonal inspections are necessary for the urban forest once it is established.

References

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

U.S. Department of Agriculture Forest Service (USDA Forest Services) April 2012, Urban and Community Forestry, 25 Jun. 2012, <http://www.fs.fed.us/ucf/>.

C1.3.2 Xeriscaping

Xeriscape is a landscaping approach which focuses on the use of native, drought tolerant plants. Water conservation is the primary goal of xeriscape landscapes. A well-designed landscape can decrease maintenance by as much as 50 percent though reduced mowing and mulching, elimination of weak, unadaptable plants, and more efficient watering techniques. It is estimated that Texas urban areas use about 25 percent of the water supply for lawn and garden watering. Much of the landscaping used requires relatively high amounts of watering in order to survive. By reducing the overall watering requirement, xeriscaping may also reduce the need for insecticide and the use of other chemicals, while ultimately improving the quality of storm water runoff (Texas Xeriscape).

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	Med
Commercial	Yes	Groundwater Recharge	Low
Industrial	Limited	Peak Rate Reduction	Med
Redevelopment	Yes	BMP Credit	
Highway/Road	No	0.5	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

A minimum of 50 percent of the managed landscape must be xeriscaped to receive the BMP Credit.

Design Specifications / Considerations

Exposure. When planning xeriscape landscape it is important to consider the sun exposure of the site. Sites with a southern and western exposure will experience the greatest amount of water loss. Plants located near buildings and paved areas will also have an increased water loss. Extensive use of rock or gravel around plants can increase the overall temperature and runoff characteristics of the landscapes. Using organic rich top soils and mulch will increase the infiltration and moisture holding capacity of the soil. Using larger trees to shade the areas during peak exposure periods will help reduce soil temperatures and evaporation.

Slope or Grade. Steep slopes greatly increase the runoff and evaporation characteristics of soils. Terracing can be used to minimize slopes where allowable. Using low profile plants (generally less than 24 inches in height) will help reduce runoff and soil temperatures in these areas.

Reduce Irrigated Turf. Xeriscaping should be used to reduce or replace smaller turf areas that are isolated and hard to maintain. Turf in these areas often result in increased water waste.

Ornamental grasses and meadow mixes can be substituted in these areas to reduce the overall maintenance requirement.

Soil Preparation. Proper soil preparation is instrumental for water conservation. Sandy soils can allow water and nutrients to leach out of the root zone, while tight clay soils have a propensity to produce runoff. The ideal soil should consist of a combination of aggregates, sand, silt and porous material. Fifty percent (50 percent) of the overall volume should be pore space. Organic material can be used to increase the pore space in tight clay soils. Organic matter should be added annually to landscaped areas. For sodded or seeded areas, a thorough layer of organic matter should be incorporated into the soil prior to planting.

Xerigation. Sprinkler systems should be checked for overall coverage and adjusted to ensure complete coverage and reduce watering of impervious areas. Irrigation amounts and times should be consistent with exposure durations. Areas with north and easterly exposures will typically require less water than south and western exposure areas. Drip line systems are an efficient means of irrigating raised beds, shrub borders, and other isolated areas. To avoid over watering, only irrigate areas that show visible signs of stress. If possible, trees and shrubs should be irrigated with deep root watering devices.

Xerimulch. Using mulch in flower beds and shrubbed areas will reduce water use and soil temperature, while also protecting the soil from wind erosion. There are two basic types of mulches. *Organic Mulches* consist of straw, compost, wood chips, bark, and natural materials. *Inorganic Mulches* use plastic film, gravel, and woven fabrics to increase the porosity of soils. Organic mulches are necessary to improve the nutrient load of soils. These materials will decompose and be naturally incorporated into the soils. Inorganic mulches are effective in excluding weeds, but can also exclude water and limit the aeration of the soil (Wilson and Feucht, 2007).

Operation and Maintenance

A properly applied xeriscape design can decrease maintenance as much as 50 percent. Yearly maintenance should be performed to replenished mulch layers and remove weak or dead plants. Insect control rarely reaches problem levels. Biological pest controls are recommended when necessary. Chemical controls should be used as a last resort. Proper mowing of grasses will help reduce water and energy requirements. Grass should not be cut no more than 1/3 of the leaf length per mowing. Clippings should be left on the lawn as they will act as mulch. Small weeds should be removed by hand before they establish mature root depths. Regular pruning may be required to maintain plant shape and health (Texas Xeriscape).

Recommended Inspection Schedule

Xeriscapes should be inspected once a year to replenish mulch layers and remove weak or dead plants. Irrigation equipment should be inspected monthly to ensure proper coverage and irrigation amounts (Texas Xeriscape).

References

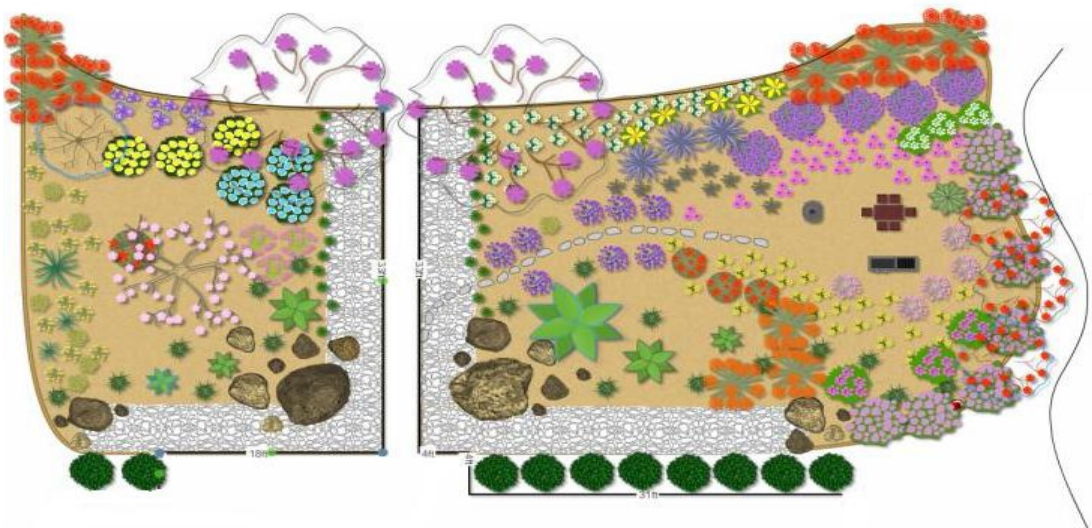
Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*, SEMCOG 2008.

Texas Xeriscape website: www.texasxerscapes.com.

Wilson, C. and Feucht, J.R. *Xeriscaping: Creative Landscaping*. Colorado State University Extension, October 2007.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.3.2: Xeriscaping



Example of Xeriscape Landscape Plan.
(Source: http://austinnativelandscaping.com)

Xeriscape
(Source: WWW.daveshoes.com)

C1.3.3 Parking Lot / Storm Water Islands

Storm water islands provide treatment of runoff from parking lots and other impervious areas prior to discharges reaching the storm sewer system or natural channels. Additional structural control features such as filter strips, and vegetated swales can be incorporated into parking lot islands. Storm water is directed into these areas and temporarily detained. The runoff then flows through the beds or infiltrates into an underlying collection basin and is discharged into the storm sewer system. These areas can be integrated into the site's overall landscape plan and can be maintained by commercial landscaping contractors. Storm water islands are typically used within small drainage basins, and are able to be utilized in various soil conditions. They are adequate at removing a variety of pollutants, including total suspended solids and nutrients.

This BMP is a specialized form of bioretention (see BMP C1.3.6) intended for use in parking lots.

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	N/A	Volume Reduction	Med / High
Commercial	Yes	Groundwater Recharge	Med / High
Industrial	Yes	Peak Rate Reduction	Med / High
Redevelopment	Yes	BMP Credit	
Highway/Road	Yes	2	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

A minimum of 80 percent of the parking areas must be treated though one or more storm water islands to receive the BMP Credit.

Design Specifications / Considerations

Storm water islands should be designed to collect and treat the first ½ inch of rainfall runoff from paved surfaces. The combined island area should be between 5 percent and 10 percent of the total impervious area it is receiving. Underlying planting beds should be designed using a mixture of sand and soil to allow for infiltration with a layer of mulch at the surface. Ponding is typical at the surface of the beds often to a depth of 6 to 9 inches.

Plant selection is important to both the function and appearance of storm water islands. Native plant species should be incorporated when possible. A mixture of warm and cool season plants should be used to help ensure active plant growth throughout the year. Plant selection should include a combination of trees, woody shrubs, and herbaceous plants. Specimen plants in plug or gallon-potted form shall be planted at approximately 1 to 2 foot centers.

Soil pH should range between 5.5 and 6.5. Ideally, the content of fines (clay) should be less than 10 percent. Small amounts are beneficial for pollutant adsorption while large amounts can decrease the soils infiltration capacity. Soils should also be free of pollutants and unwanted plant material. Organic content should range between 5 and 10 percent. Additional organics may be added to increase the cumulative water holding capacity.

Mulch should be applied to a depth of 2 to 3 inches immediately following the planting of trees and shrubs. Shredded and composted materials should be used for mulching. Mulch depths shall not exceed 3 inches and should not be placed directly against plant stems in order to allow adequate oxygen flow.

If underlying soil has a low infiltration rate, an under-drain system may be required (see BMP C1.3.6).

Operation and Maintenance

After plants have been established, landscape maintenance shall occur on a seasonal basis. Maintenance schedules should be integrated within the overall site landscaping plan. Properly designed storm water islands will require regular maintenance within the first 1 to 2 years after installation. Less maintenance will be required once perennial and native vegetation is established. Watering should occur daily for the initial 2 to 3 weeks following installation. Newly established specimens should be watered at a rate of 1 inch per week throughout the first season. Watering schedules should be established as part of the landscape plan. Pruning and weed removal should be done as needed while plants are being established. Weeds should be removed by hand. Organic material should be removed as needed (typically twice a year and by hand). Mulch should be evened out if erosion takes place, and replenished every 1 to 2 years (SEMCOG, 2008).

Recommended Inspection Schedule

Islands should be inspected monthly until plants are adequately established. Seasonal inspections should continue throughout the life of the facilities.

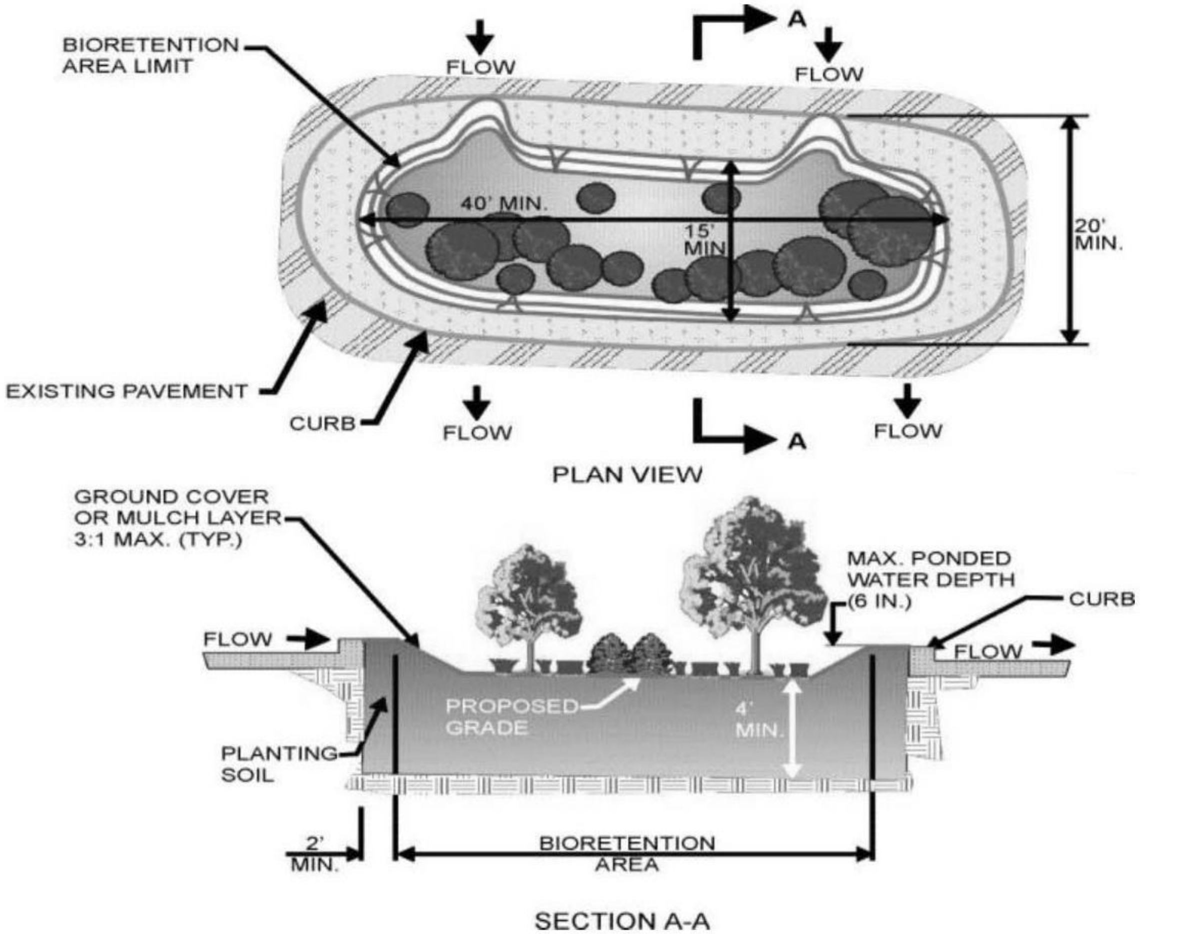
References

North Central Texas Council of Governments. *iSWM Technical Manual: Landscape*. April. 2010. Web. 29 March. 2012. <http://iswm.nctcog.org/Documents/technical_manual/Landscape_4-2010b.pdf>.

Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*. SEMCOG 2008.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.3.3: Parking Lot / Storm Water Islands



(Source: iSWM Technical Manual; Landscaping)

C1.3.4 Pervious Concrete / Asphalt

Pervious concrete, also known as porous, gap-graded, or enhanced porosity concrete, is concrete with reduced sand or fines and allows water to drain through it. Pervious concrete over an aggregate storage bed will reduce storm water runoff volume, rate, and pollutants. The reduced fines leave stable air pockets in the concrete and a total void space of between 15 and 35 percent, with an average of 20 percent. The void space allows storm water to flow through the concrete, and enter a crushed stone aggregate bedding layer and base that supports the concrete while providing storage and runoff treatment. When properly constructed, pervious concrete is durable, low maintenance, and has a low life cycle cost.

Pervious concrete can be used for storm water management programs. The runoff volume and rate control, plus pollutant reductions, allows the users to improve the quality of storm water discharges. Pervious concrete can be used to reduce stress to the storm sewer and minimize localized flooding by infiltrating and treating storm water on site. Developments can use pervious concrete to meet post-construction storm water quantity and quality requirements. The use of pervious concrete can potentially reduce additional expenditures and land consumption for conventional collection, conveyance, and detention storm water infrastructure.

Pervious concrete can replace traditional impervious pavement for most pedestrian and vehicular applications except high-volume/high-speed roadways. Pervious concrete can be designed to handle heavy loads, but surface abrasion from constant traffic will cause the pavement to deteriorate more quickly than conventional concrete. Pervious concrete can be used for pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways. The environmental benefits from pervious concrete allow it to be incorporated into green infrastructure and low impact development programs. In addition to providing storm water volume and quality management, the light color of concrete is cooler than conventional asphalt and helps to reduce urban temperatures and improve air quality. Unlike the smoothed surface of conventional concrete, the surface texture of pervious concrete is slightly rougher, providing more traction to vehicles and pedestrians.

Pervious / porous asphalt works in the same manner as pervious concrete, however, applications of pervious asphalt are typically limited to parking lots. Like pervious concrete the fines in the asphalt aggregate are removed to create voids in the finished product to allow storm water to infiltrate through the asphalt paving. Pervious asphalt appears slightly coarser than traditional asphalt but is still attractive and smooth enough to meet the requirements of the Americans with Disabilities Act.

Pervious concrete and asphalt do not require any proprietary ingredients and therefore can be provided by any concrete or asphalt distributor. Pervious concrete and porous asphalt are shown in Construction Details PC-37 and PC-38, respectively.

Pollutant Removal / BMP Credit

For residential developments, at least 50 percent of the sidewalks and driveways must include porous concrete or porous asphalt to receive the BMP Credit of 0.5. For non-residential sites, at least 50 percent of the parking areas must be porous concrete or asphalt to receive the BMP Credit of 0.5.

Design Specifications / Considerations

The load-bearing and infiltration capacities of the subgrade soil, the infiltration capacity of the pervious concrete / asphalt, and the storage capacity of the stone base/subbase are key storm water design parameters. To compensate for the lower structural support capacity of clay soils, additional subbase depth is often required. The increased depth also provides additional storage volume to compensate for the lower infiltration rate if a clay subgrade is present. Underdrains are often used when permeable pavements are installed over clay. In addition, an impermeable liner may be installed between the subbase and the subgrade to limit water infiltration when clay soils have a high shrink-swell potential, or are in close proximity to the water table.

Measures should be taken to protect pervious concrete from high sediment loads, particularly fine sediment. Appropriate pretreatment BMPs for run-on to permeable pavement include filter strips and vegetated swales. Preventing sediment from entering the base of permeable pavement during construction is critical. Runoff from disturbed areas should be diverted away from the permeable pavement until they are stabilized.

Several factors may limit permeable pavement use. Pervious concrete has reduced strength compared to conventional concrete and will not be appropriate for applications with high volumes and extreme loads. It is not appropriate for storm water hotspots where hazardous materials are loaded, unloaded, and stored, or where there is a potential for spills and fuel leakage. For slopes greater than 2 percent, terracing of the soil subgrade base may be needed to slow runoff from flowing through the pavement structure. Another approach for using pervious concrete on slopes, lined trenches with underdrains can be dug across slope to intercept flow through the subbase.

Operation and Maintenance

One of the main maintenance concerns is the potential clogging of the pervious concrete pores. Fine particles that can clog the pores are deposited on the surface from vehicles, the atmosphere, and runoff from adjacent land surfaces. Clogging will increase with age and use. While more particles become entrained in the pavement surface, it does not become impermeable. Studies of the long-term surface permeability of pervious concrete and other permeable pavements have found high infiltration rates initially, followed by a decrease, and then leveling off with time. With initial infiltration rates of hundreds of inches per hour, the long-term infiltration capacity remains high even with clogging. Permeability can be increased with vacuum sweeping. In areas where extreme clogging has occurred, half inch holes can be drilled through the pavement surface every few feet to allow storm water to drain to the aggregate base. Many large cuts and patches in the pavement will weaken the concrete structure.

Recommended Inspection Schedule

Pervious concrete / asphalt should be inspected annually for clogging and cracks.

References

Pervious Pavement. 2011, National Ready Mix Concrete Association, 25 Jun. 2012, <http://www.perviouspavement.org/>.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

C1.3.5 Modular Porous Pavement System

Modular porous pavement systems are an alternative to traditional asphalt or concrete paving systems. The use of these systems can decrease the total impervious cover proposed for a site and also can offer both peak runoff control and water quality benefits. Modular porous pavement systems are typically constructed with cast or prestressed concrete pavers.

Cast or prestressed concrete pavers are solid blocks set on a surface with joints that leave open space between each unit. These joints can be filled with loose aggregate or pervious material such as pea gravel, sand, or soil. Another option is to plant grass in the joints. These pavers are typically built on an open graded crushed aggregate base, but can also be built on synthetic materials such as rain tanks. The base offers infiltration and partial treatment of storm water pollution. The material and depth of the base can be designed to accommodate almost any storage requirements. Concrete pavers may be dyed and stamped during the manufacturing process to create multi-colored patterns that can simulate more expensive materials such as brick, stone or wood.

Concrete pavers can be used in most places where concrete would be used in both vehicular and pedestrian facilities. These pavers with a sufficiently designed base course can withstand heavy vehicular loads. Also, these systems are ready for vehicular traffic immediately after installation. They do not require time for curing.

These systems can be designed to infiltrate up to 100 inches of rain per hour, so even if the joints become 90 percent clogged, the porous pavers would still be able to capture all but the most major storms. These systems provide benefit for both peak flow attenuation if underground storage is provided and water quality treatment in the form of filtration through the joints and base course. The sub-base of these systems can be used to store storm water runoff. This volume of water can either be stored for future use or can be released through exfiltration into the ground or a storm sewer system.

Another type of modular porous pavement consists of pavers with void spaces in the middle of each unit and resembles a “honeycomb” pattern. This system allows for vegetation to grow through it and eventually these pavers will blend into the landscaping and essentially disappear once the turf is established. These pavers are typically constructed on top of an engineered base course that provides structural support and also allows infiltration. This system will reduce the total impervious cover compared to a traditional system.

Pollutant Removal / BMP Credit

For residential developments, at least 50 percent of the sidewalks and driveways must include modular porous pavement to receive the BMP Credit of 0.5. For non-residential sites, at least 50 percent of the parking areas must be modular porous pavement to receive the BMP Credit of 0.5.

Design Specifications / Considerations

Modular porous pavement systems provide many benefits some of which include:

- Conservation of space on site and reduction of impervious cover,
- Reduction of runoff by as much as 100 percent from frequent, low-intensity and short duration storms,
- Reduction or elimination of retention basins in other parts of the drainage system,
- Promotes tree survival by providing air and water to root,
- Reduces pollutants and improves water quality,
- Reduces peak discharges and stress on storm sewers,
- Increases recharge of groundwater,
- Reduces overall project cost due to reduction in storm sewer and drainage appurtenances,
- Eliminates ponding and flooding in parking lots, and
- Can be eligible for LEED credits.

Some limitations of the modular porous pavement systems are:

- Overall cost compared to other BMPs,
- Requires a greater site evaluation and design effort,
- Requires a higher level of construction skill, inspection and attention to detail, and
- Requires more intensive surface maintenance to minimize clogging to ensure long-term performance.

There is not a single way to design and construct modular porous pavement systems. These products are supplied by multiple vendors and each product will have their own unique design criteria. It is imperative to work with the supplier to design a system that is suitable for its specific location and purpose. Some of the aspects of design to consider are loads it will encounter. A sidewalk with pedestrian loads will have a different design than a road surface that will see heavy vehicular traffic. It is important to consider the design storm for which the system will be responsible for treating. This will affect the joint spacing and base material design. It must also be decided if this system will provide peak flow attenuation, water quality treatment or both.

Operation and Maintenance

Modular porous pavement systems can become clogged with sediment over time, thereby slowing their infiltration rate and decreasing storage capacity. Clogged surface openings are a major cause of hydraulic failure. The rate of sedimentation depends on the amount of traffic and other sources that wash sediment into the joints, base and soil. Since the pavement is detaining runoff that contains sediment, there may be a need to eventually remove and replace the base material when the infiltration is reduced to such a degree that the pavement is no longer performing its job in storing and exfiltrating water. Periodic removal of sediment in the openings will increase the surface infiltration rates. Vacuum type street cleaning equipment without brooms and water spray action are the most effective at loosening and removing sediment from the openings. Typical mowing is necessary for the systems with grass planting in the joints of honeycomb systems.

Recommended Inspection Schedule

The frequency of vacuum cleaning will depend on the use and sources of sediment brought to the pavement openings. Vacuuming should be performed at least twice annually and sediment depositions should be monitored for more frequent vacuuming. Vacuuming will have the best results when the sediment is dry, which means vacuuming during warm, dry weather.

References

Smith, David, Permeable Interlocking Concrete Pavements Manual – Design, Specification, Construction, Maintenance 4th Ed., Virginia, Interlocking Concrete Pavement Institute, 2011.

Low, Thomas E. Light Imprint Handbook, Integrating Sustainability and Community Design, Charlotte, North Carolina: Civic by Design, 2010.

C1.3.6 Bioretention (Rain Garden)

Bioretention areas or rain gardens are shallow vegetated basins landscaped with natural vegetation. They are typically small areas which are designed to handle extremes in moisture and nutrient concentrations. Rain gardens are designed to incorporate many of the pollutant removal mechanisms that are found within natural ecosystems. Plant selection should be diverse and utilize native species which are more tolerant to insects, disease, pollutants, and climate changes. Aesthetically, bioretention areas have the appeal of an attractive garden, and can support habitat for birds, butterflies and other local wildlife.

Bioretention can be effective in small residential areas and as part of larger storm water management systems. Vegetation acts as both a filter and detention mechanism. Plants absorb pollutants while the subsurface materials break them down. Detention volumes are created in the infiltration zone beneath the gardens. Properly designed infiltration areas will act as a sponge and absorb runoff volumes. Rain gardens can either be under-drained or self-contained depending on the sub-surface media characteristics. Both types are effective at improving storm water quality, reducing peak runoff volumes, and facilitating infiltration. Determining which type of rain garden to use for a given application depends on the volume of runoff to be treated, existing soil conditions, available space, and budget.

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	Med / High
Commercial	Yes	Groundwater Recharge	Med / High
Industrial	Yes	Peak Rate Reduction	Med / High
Redevelopment	Yes	BMP Credit	
Highway/Road	Yes	2	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

This BMP is subject to area weighting based on the percentage of area treated through bioretention. See Chapter 10 for example calculations for area weighting.

Design Specifications / Considerations

Bioretention areas are most effective when used to treat relatively small volumes of storm water runoff. A typical ratio of impervious drainage area to bioretention is 5:1. Drainage areas should not exceed one acre in total size. Bioretention design should be altered to fit varying site requirements for infiltration, filtration, or a combination. General components of a bioretention area include: Pretreatment, Flow Inlet, Ponding, Plant Material, Organic Material, Volume Storage Beds, and Positive Outflow (SEMCOG, 2008). Flexibility in design allows bioretention to be used for varying runoff volumes and site conditions. Infiltration zones should be designed in such a way not to impact existing groundwater quality or threaten existing subsurface structures. **Table C1.3.6** provides typical setback distances for various lot elements.

Table C1.3.6: Setback Distances for Bioretention	
Setback from	Minimum distance (feet)
Property Line	10
Building Foundation*	10
Private well	50
Public water supply well**	50
Septic system drain field***	100
*Minimum with slopes directed away from building **Minimum 200 ft from potable water wells ***50 ft for septic systems with a design flow of less than 1,000 gallons per day	

(Source: SEMCOG 2008)

Typical infiltration rates should be greater than 0.5 inches per hour. For areas were existing subsurface infiltration rates are less than 0.5 inches per hour, additional subsurface materials (mulches, permeable soils, or under-drains) may be required. The following design considerations should be utilized for bioretention areas.

- **Flow Entrance.** Design should prevent soil erosion. Structural BMPs such as rip rap, erosion control mats, and level spreaders should be used if necessary.
- **Positive Outflow System.** Design should safely divert excess runoff. Overflow should be routed in a non-erosive manner or into an existing storm sewer system.
- **Surface Area.** Storage requirements should not exceed a ratio of 5:1 impervious area to bioretention area. Maximum drainage areas should not exceed 1 acre and the total volume from the area should be utilized by the bioretention area. Side slopes within the areas should be gradual (3:1 maximum).
- **Ponding Area.** Areas need to provide sufficient storage volumes while maintaining ponding depth requirements. Maximum ponding depth range from 6 to 18 inches, dependent on vegetation characteristics.
- **Planting Soil Depth.** Design depth should range between 18 and 48 inches for herbaceous plant species. Soil depth will be increase for larger vegetation such as trees and large woody shrubs. Existing soil should be used when possible, but may required modification to increase porosity.
- **Soils Type.** Soil pH should range between 5.5 and 6.5. Ideal content of fines (clay) should be less than 10 percent. Small amounts are beneficial for pollutant absorption. Soils should also be free of pollutants and unwanted plant material. Organic content should range between 5 to 10 percent. Additional organics may be added to increase the cumulative water holding capacity.
- **Plant Selection.** Proper plant selection is essential for the success of the bioretention area. Native wetland and floodplain plants will be well suited for these areas. Specimen plants in plug or gallon-potted form shall be planted at approximately 1 to 2 foot centers. Tree and shrubs should also be incorporated within the areas.
- **Planting Seasons.** Generally trees, shrubs, and other woody species should be planted in the spring (April – June) or fall (September - November). Native seeding should be

executed from October to June. Live specimens should be planted from April through June. Landscape contractors should be used whenever available.

- **Mulch.** Mulch should be applied to a depth of 2 to 3 inches immediately following the planting of trees and shrubs. Shredded and composted materials should be used for mulching. Mulch depths shall not exceed 3 inches and should not be placed directly against plant stems in order to allow adequate oxygen flow.
- **Storage, Infiltration, and Under-drains.** If subsurface storage or infiltration beds are used, they shall contain a minimum of 6 inches of clean gravel material. Void space ratios shall be approximately 40 percent. Gravel should be contained in geotextile fabric. If under-drains are used, diameters should be between 6 and 12 inches and pipes must be perforated, and encased in clean, well graded gravel. Pipe flow capacities shall be sufficient to handle total infiltration rates with minimum soil coverage of 18 inches. Drain pipes should daylight to the surface or be connected to a storm sewer system.

Operation and Maintenance

Properly design bioretention areas will require regular maintenance within the first 1 to 2 years after installation. Less maintenance will be required once perennial and native vegetation is established. Watering should occur daily for the initial 2 to 3 weeks following installation. Newly established specimens should be watered at a rate of 1 inch per week throughout the first season. Watering schedules should be established as part of the landscape plan. Pruning and weed removal should be done as needed while plants are being established. Weeds should be removed by hand. Organic material should be removed as needed (typically twice a year and by hand). Mulch should be evened out if erosion takes place, and replenished every 1 to 2 years (SEMCOG, 2008).

If drain time exceeds 48 hrs, clogged filter media should be replaced.

Recommended Inspection Schedule

Activity	Schedule
Replenish mulch, remove diseased and dead plants	Twice annually
Daily watering	Initial 2 weeks following completion
Mowing of turf grasses	Monthly
Inspect soil and repair eroded areas	Monthly
Remove trash and debris	Monthly
Replace tree stakes and supports	Annually

(Source: SEMCOG 2008)

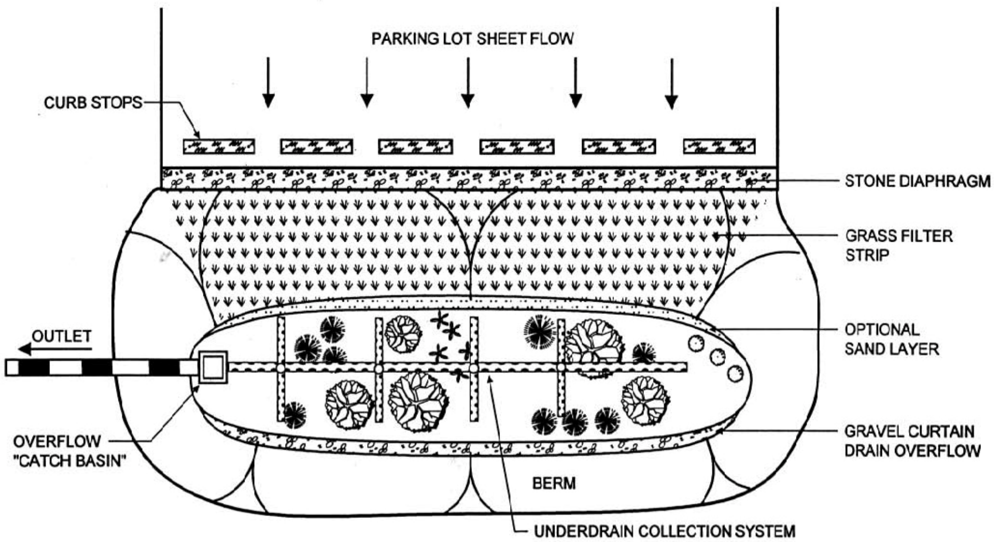
References

Center for Research in Water Resources (CRWR). *Waco LID Guidance Manual*, Lady Bird Johnson Wildflower Center, University of Texas at Austin, August 2011.

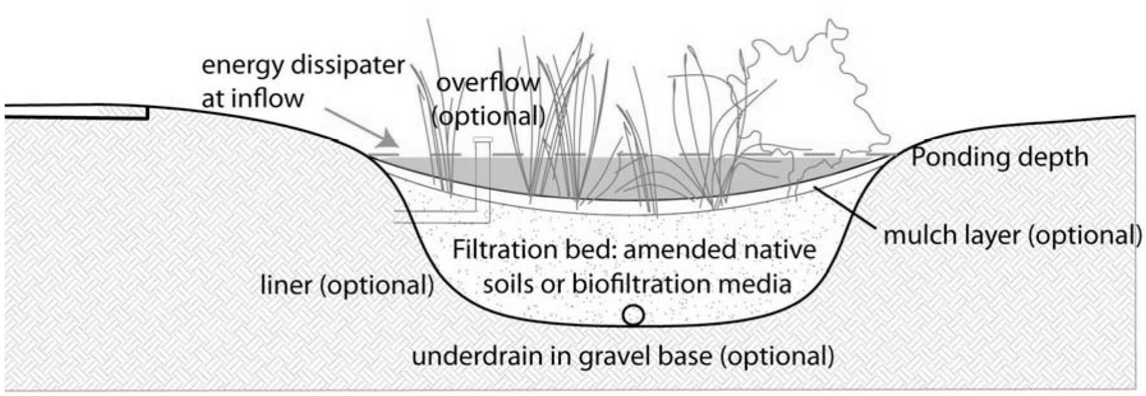
Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*, SEMCOG 2008.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.3.6: Bioretention (Rain-Garden)



Plan View (NTS)
(Source: CRWR, 2011)



Section View (NTS)
(Source: CRWR, 2011)

C1.4 TREATMENT CONTROL BMPS

C1.4.1 Dry Extended Detention Basin

Extended detention basins capture and temporarily detain storm water runoff. They are intended to serve primarily as settling basins for the solids fraction, nutrients attached to solids, and as a means of limiting downstream erosion by managing storm water. Extended detention basins may be constructed either online or offline. Extended detention basins are typically depressed basins that temporarily store storm water runoff following a storm event and do not have a permanent water pool between storm events. The outlet of a dry extended detention basin is typically constricted to control the outlet from these ponds. These basins must drain in no less than 24 hours to ensure proper sediment removal and no more than 48 hours to prevent odor and mosquito breeding.

The water quality benefits are the removal of sediment and buoyant materials. Furthermore, nutrients, heavy metals, toxic materials, and oxygen-demanding materials associated with the particles are also removed. Control of maximum runoff rates serves to protect drainage channels below the basin from erosion and to reduce downstream flooding.

An extended detention basin can be used as a standalone BMP but can also be combined with a secondary BMP such as a vegetative filter strip, an infiltration basin/trench or a bioretention basin to provide additional pollutant removal and receive a greater BMP credit. One of the main advantages of extended detention basins is their adaptability. They can be used on areas with thin soils, high evaporation rates, low-soil infiltration rates, in limited space areas, and where groundwater is to be protected. Dry extended detention basins are relatively easy and inexpensive to construct and operate. These basins require an extended draw down time and are controlled by an outlet orifice. If this orifice gets too small, it can get easily clogged and effect the performance of the BMP. Therefore, it is not recommended that these basins be designed to handle drainage areas less than three acres. If necessary, these basins can also provide flood control. Refer to Construction Detail PC-43 for a schematic layout of a dry extended detention basin.

Pollutant Removal / BMP Credit

This BMP is subject to area weighting based on the percentage of area treated through dry extended detention basins. A maximum BMP Credit of 1.5 may be awarded for this BMP. See Chapter 10 for example calculations for area weighting.

Design Specifications / Considerations

Dry extended detention basins work great to control the runoff for drainage basins larger than three acres. Site constraints may limit the use of dry extended detention basins for sites larger than 100 acres. They are very versatile and can be used in most situations where land is available. Dry extended detention basins are one of the most cost effective structural post-construction BMP. Dry extended detention basins can be used where insufficient land area and runoff prevents the use of a wet pond. These basins provide great runoff control as the first part of a treatment train. In most cases, it is possible to modify these basins to accommodate future development by either lowering the bottom of the basin or modifying the outlet structure.

There are limitations to where a dry extended detention basin can be used. The contributing area must be large enough to prevent the outlet orifice from becoming too small and potentially clog. Also once a contributing area gets too large, the detention basin starts to lose functionality. These basins require adequate drop from the inlet to the outlet. In situations where the land is too flat, it may not be possible to grade in a detention basin. Although these basins are relatively simple, it does require proper construction to prevent ponding on the bottom of the basin and side bank erosion. Land constraints can also limit the applicability of a dry extended detention basin.

It is essential that not only the required water quality volume is provided in the basin but also that it is configured correctly. A correct configuration of the basin will create a long flow path across the basin. This is established by maintaining a 2:1 length to width ratio for the basin. To ensure that low velocities are maintained across the basin while avoiding stagnate areas, all flows must enter the basin at the opposite end as the outlet structure. This long flow path and low velocities will promote settling of debris and pollutants contained within the storm water runoff. The water quality volume will consist of runoff from all impervious surfaces including roadways, parking areas, rooftops and all developed pervious areas within the contributing drainage area. For the purpose of design, water quality volume shall be calculated as the first one-half (0.5) inch of runoff plus one-tenth (0.1) inch for each ten (10) percent increase of impervious cover over twenty (20) percent within the contributing drainage area. It is important to increase the size of the detention facility by 20 percent of the required water quality volume to accommodate the reduction in volume due to the accumulation of debris between maintenance activities. Outlet design should be such that the entire water quality volume is released over a minimum duration of forty-eight (48) hours. The detention capacity for dry extended detention basins shall be calculated per the requirements stated in Section 1.2.8 of the City of Killeen Drainage Design Manual. The typical depth of a detention basin is between 2 and 5 feet but may be as deep as 8 feet.

A dry extended detention basin is comprised of two separate but connected basins. The first basin is the sediment forebay and is where all flows should enter the basin. If the detention basin is designed as an offline facility it may be necessary to design a splitter structure at the basin inlet to isolate the water quality volume and divert additional flows around the basin. Flows that enter the basin should pass over or through an energy dissipater to prevent scour and erosion at the inlet to the basin. This will also prevent re-suspension of accumulated sediment. This forebay helps capture the larger sediment particles and is separated from the rest of the basin by either a rock berm or a gabion wall. The sediment forebay should be sized to capture 20 percent of the water quality volume. The main basin should be planted with vegetation that is adaptable to periodic inundation. The main basin provides additional sediment removal and some nutrient removal. The main basin should be designed with a low flow channel to help facilitate low flows. This basin should also be sloped at 2 to 5 percent from the rock berm to the outlet to prevent ponding water between storm events. It is beneficial to provide a vertical marker in the basin to indicate when 10 percent of the design volume is lost due to sedimentation, signaling time for maintenance. Side slopes of the basin should not exceed 4:1 horizontal to vertical slopes.

The outlet of the basin should be controlled with an orifice device that ensures proper drawdown time. A typical outlet structure for an extended detention basin is a perforated riser pipe wrapped in a filter fabric. The riser pipe should be enclosed in a trash rack to prevent clogging.

The extended detention basin should be vegetated for both aesthetic and performance measures. As stated earlier, the plantings should be suitable for periodic inundation. It is also recommended that a 6 to 8 inch layer of topsoil be part of the basin design. Top soil will promote healthy vegetation growth and also enhance infiltration and water storage within the basin. A native sod is recommended as a primary ground cover. Trees and shrubs can be used to screen structural aspects of the basin and will aid evapotranspiration and basin floor drying.

Operation and Maintenance

Dry extended detention basins require periodic maintenance. The frequency of maintenance depends on the frequency and depth of storms. These basins are composed of many components and each has specific maintenance requirements.

All grass in the detention basin should be mowed at least twice annually and should be limited to a height of 18 inches. More frequent mowing may be necessary for aesthetic purposes. Debris and litter should be removed prior to all mowing operations. The vegetation and ground cover must be maintained within the basin. Bare spots must be immediately revegetated upon discovery and all apparent erosion within the basin and surrounding the inlet and outlet of the basin must be corrected. All structural elements must be repaired or replaced if found damaged. Standing water in the bottom of the basin creates habitat for nuisances such as mosquitoes, odor and litter accumulation. These problems usually only occur if regular maintenance and inspections are not performed. Dry extended detention basins are designed to capture sediment. Sediment must be removed from the pond when it either reaches a designated level or starts to inhibit vegetation growth within the basin. Sediment also tends to accumulate around the inlets and outlets of the basin. If not removed regularly, the function of the basin may be compromised.

Recommended Inspection Schedule

Inspections to dry extended detention basins should be conducted at least twice annually and one inspection should occur after a rain event to ensure proper functioning of the outlet structure.

References

Barrett, Michael E. Ph.D., P.E. Texas Commission on Environmental Quality, Field Operations Division, *Complying With the Edwards Aquifer Rules: Technical Guidance for Best Management Practices* RG-348, Texas, 2005.

Lower Colorado River Authority, Water Resource Protection, *Highland Lakes Watershed Ordinance, Water Quality Management Technical Manual*, 5th ed., 2007.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

C1.4.2 Stream Restoration

Stream restoration is the rehabilitation of degraded stream reaches to a close approximation of its natural potential. Successful stream restoration requires an understanding of the causes of degradation; specific knowledge of the stream's current condition; and an understanding of the stream's most stable condition based on its valley type and flow characteristics. Knowledge of stable stream characteristics is necessary to develop an effective design. Ideal design characteristics should be determined through inspection of reference stream reaches within the watershed or from smaller reaches in the region.

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	Low
Commercial	Yes	Groundwater Recharge	Low
Industrial	Yes	Peak Rate Reduction	Low
Redevelopment	Limited	BMP Credit	
Highway/Road	Limited	2.0 (soft techniques) 1 (hard techniques)	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

The total length of degraded stream within the proposed development must be restored to receive credit for this BMP. The assessment of stream condition must be prepared and certified by a licensed professional. A BMP Credit of 2.0 may be awarded when "soft techniques" are used for restoration. A BMP of 1 may be granted when using "hard techniques". Soft and hard techniques are described below.

Design Specifications / Considerations

Natural "soft" restoration techniques should be used for streams that are set back from urban areas. These techniques use natural materials (rock, vegetation, logs, etc.) to stabilized stream banks, prevent streambed cutting, and restore a more natural, meandering pattern (S-curve) characteristic of stable streams. Long-term protection can be provided through the improvement of the buffer zone adjacent to the stream or river.

Areas where streambeds are bordering or within urbanized development may require engineered "hard" restoration techniques. These techniques use engineered structures to establish a secure stream bank and reduce velocities, where applicable. Hard techniques typically consist of rock walls, rip rap, and concrete reinforcement. Example specific "Soft" and "Hard" techniques are listed below (Maryland DEP).

Soft Techniques

Stone Toe Protection. Stone is installed along the base of the stream banks to protection against heavy flows eroding the existing stream banks.

J-Hook. Rock is placed within the channel in a J-shape to divert water away from eroding stream banks. Slots are placed in the hook portion to allow faster flows to pass through and dissipate energy by forming scour pools.

Cross Vane. Lines of large stone or logs are strategically placed at an angle to direct flows toward the center of the stream. Vanes prevent fast-flowing water from eroding existing banks and maintain channel elevation. Scour pools form below the vane, creating pool habitat.

Grading and Planting. Stream banks are graded to create gentle sloping steps to accommodate flow events. Vegetation helps stabilize the sloped banks.

Step Pools. Large rocks are used to create a series of stepped pools at outfall structures. These pools dissipate high velocity storm flows prior to entering a stream.

Brush Layering. Layers of live branch cuttings are installed linearly along the stream bank. Cuttings sprout new growth and the root systems stabilize the bank slopes.

Root Wads. Tree root clusters are anchored within stream banks to provide habitat for fish, aquatic insects, and other wildlife. Root masses reduce stream flows, armor existing stream banks, deflect high energy flows, form scour pools, and provide aquatic habitat.

Woody Debris. Logs and dead trees are used to create habitat for fish to reproduce and live. Debris is anchored along stream banks to provide protection from erosion.

Mulch Planting. Selected reaches of stream banks are planted with vegetation to stabilize and hold sediment in place.

Shallow Wetlands. Creation of shallow wetlands below storm water outfalls allow for water quality treatment and provide natural habitat.

Coir logs. Constructed from biodegradable coconut fibers, coir logs provide a medium for vegetation. They should only be used to protect less erosive stream reaches (Maryland DEP).

Hard Techniques

Gabion Walls. Stacked wire mesh baskets filled with smaller rock material, generally 5 to 8 inches in diameter. Typical basket dimensions are 36 inches by 36 inches and can be stacked and connected as needed to achieve the design length and heights.

Gabion Mattress. Wire meshed baskets range in depth from 6 inches to 18 inches. Mattresses are filled will smaller rock material, generally 4 – 6 inches in diameter.

Rock Pack and Flush Cuts. Rocks are packed in areas where stream flows have undercut trees. (Maryland DEP)

Imbricated Rip Rap. Loose rip rap is stacked to create a stone wall protecting stream banks from further erosion. For high flow areas, rip rap may require grouting (Maryland DEP).

Articulating Concrete Blocks. A flexible concrete block revetment system which provides erosion control and can be installed above or below normal pool elevations (NCMA).

Operation and Maintenance

Routine maintenance should be performed based on the BMP and techniques implemented. Repairs to bank failures should be performed as needed. Most practices are ineffective at bank stabilization unless maintained in proper working order (SEMCOG, 2008).

Recommended Inspection Schedule

Inspection of BMP should be performed by persons familiar with the overall BMP function, location, design specifications, and performance. Inspections shall be performed annually at a minimum. Documentation of inspection should record the date of inspection, findings, and any maintenance and repairs, if required.

References

Maryland Department of Environmental Protection (DEP). http://www.montgomerycountymd.gov/department/DEPhome/water/streamrestorationtechniques. Montgomery County.

National Concrete Masonry Association (NCMA). http://www.ncma.org/Articulatingconcreteblock.

Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*. SEMCOG 2008.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 http://cfpub.epa.gov/npdes/stormwater/menuofbmps.

Figure C1.4.2: Stream Restoration

Soft Techniques

Stone Toe Protection (Maryland DEP)

J-hook (Maryland DEP)

Cross Vane (Maryland DEP)

Grading and Planting (Maryland DEP*)*

Log Vane (Maryland DEP)

Step Pools (Maryland DEP)

Brush Layering (Maryland DEP)

Root Wads (Maryland DEP)

Woody Debris (Maryland DEP)

Mulch Planting (Maryland DEP)

Shallow Wetlands (Maryland DEP)

Coir Logs (Maryland DEP)

Hard Techniques

Gabion Walls (Jacobs, 2011)

Gabion Mattress (Jacobs, SNC 2011)

Rock Pack and Flush Cut (Maryland DEP)

Imbricated Rip Rap (Maryland DEP)

Articulating Concrete Blocks (NCMA)

C1.4.3 Storm Water Wetland

Storm water or constructed wetlands are engineered systems that incorporate characteristics of a wetland ecosystem. As storm water travels through the wetland, pollutants and other organic materials are removed by settling and biological processes. Wetlands can be very effective at removing pollutants from storm water discharges while providing natural wildlife habitat and aesthetic appeal.

Storm water wetlands are applicable for flood control, erosion protection, and pollutant removal. They can be applied in most regions throughout the United States, with the exception being arid and semi-arid climates.

Storm water wetlands differ from natural wetlands in that they are specifically designed to treat storm water discharges, and generally have less biodiversity. Natural wetlands shall not be used as a substitute for storm water or constructed wetlands. Altering the hydrology of an existing natural wetland can disrupt the natural ecosystem and biological processes that are integral to wetlands survival. Natural wetlands should always be protected from adverse effects of development, including increases in storm water discharges (SEMCOG, 2008).

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Industrial	Yes	Peak Rate Reduction	Low/Med
Redevelopment	Yes	BMP Credit	
Highway/Road	Limited	2	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

This BMP is subject to area weighting based on the percentage of area treated through the Storm Water Wetland. A maximum BMP Credit of 2 may be awarded for this BMP. See Chapter 10 for example calculations for area weighting.

Design Specifications / Considerations

Constructed wetland design is largely dependent on site constraints as well as developer or community preference. However, the following considerations should be incorporated in all wetland design.

Pretreatment

Pretreatment is used to remove larger, coarse sediment particles typically through settling. Removing these particles prior to them reaching the permanent pool can significantly reduce the maintenance requirements of the system. Typically, the sedimentation pond should be about 10 percent of the volume of the permanent pool. Sediment deposits will need to be removed periodically to ensure the sedimentation pond functions properly.

Treatment
Treatment design features can enhance the ability of the wetland to remove pollutants. The purpose of most treatment features is to decrease the discharges through the wetland. Typical treatment features include:

- Large surface area. The surface area of a wetland should be at least 1 percent of the contributing drainage area.
- Length-to-width ratio equal to or greater than 1.5:1.0. This will help prevent "short circuiting".
- Variable water depths. Wetlands should consist of very shallow (less than 6 inches) to moderately shallow (less than 18 inches) water zones. Varying the water depths throughout the wetland will increase the travel time, allow for further settling of particles and plant diversity.

Conveyance
Storm water should be safely conveyed into and from a wetland such that the potential for erosion is minimized. All outfalls should be stabilized to prevent scour. An emergency spillway may be required for larger storm events.

Maintenance Reduction
Wetlands should be designed to incorporate techniques which will reduce the overall maintenance burden. For example, reverse-slope pipes or weir structures can be used for outlets to reduce clogging from debris. "Micro pools" can also be used at the outlet to prevent clogging. A drain should also be installed on the permanent pool for periodic dredging. Design features can also be used to reduce maintenance of the sedimentation area and main pool. Maintenance access should be designed for all features within the wetland.

Landscaping
Landscaping within wetlands can create aesthetic appeal for communities and adjacent development, while enhancing the pollutant removal capacity. Detailed landscaping plans should provide information on plant species, planting schedules, and maintenance requirements. Plans should detail wetland plants as well as vegetation for adjacent areas. Native plants should be used when possible. Soils from constructed wetlands can be used to supplement live potted plants and create a natural seed bank. Mulch can also be used to establish wetland vegetation, as the native wetland plant seeds can be incorporated within the mulch (USEPA, 2012).

Operation and Maintenance

Regular maintenance and inspection will be needed in addition to permanent incorporated features. Table C1.4.3 outlines these practices.

Recommended Inspection Schedule

Table 1.4.3: Regular Maintenance Recommendations for Constructed Wetlands	
Activity	**Schedule**
Replace wetland Vegetation after 2nd growing season, maintain a minimum of 50% of surface area coverage.	One-Time
Remove invasive vegetation where possible	Semi-Annual Inspection
Inspect outlet/ inlet structures for damage and debris	Annually
Inspect for signs of hydrocarbon contamination	Annually
Monitor for sediment accumulation	Annually
Repair erosion, undercut, and short circuit areas	As Necessary
Mowing of adjacent side slopes	3-4 times/year
Supplement areas if plant are have not established	Annually (if needed)
Remove pretreatment debris and sedimentation	Annually (if needed)
Removed sediment form main pool when volume is significantly reduced and wetland becomes eutrophic.	20 to 50-year maintenance

(Source: EPA, 2012)

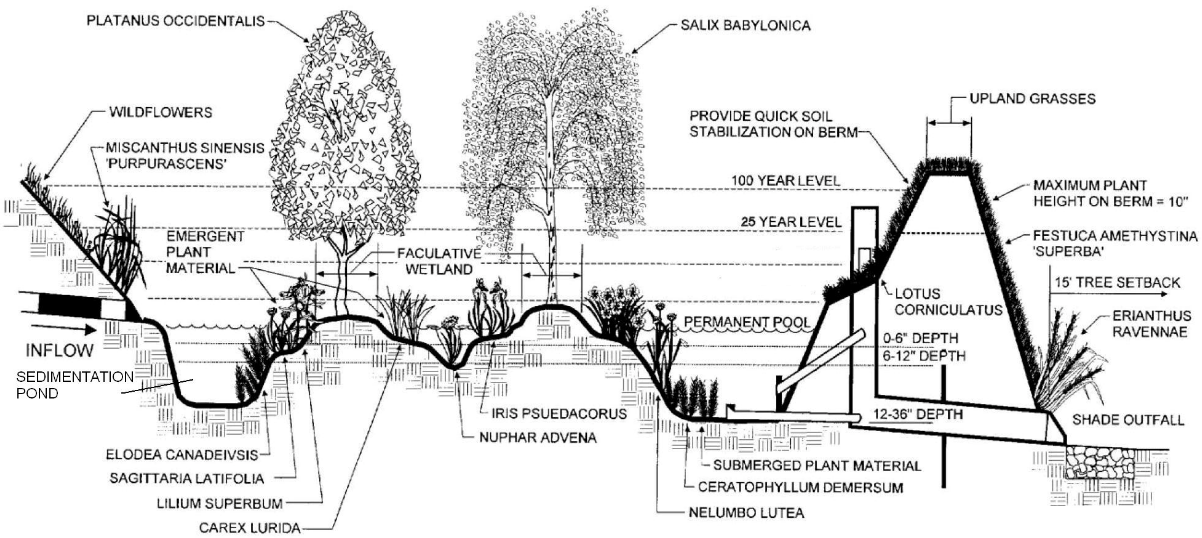
References

North Central Texas Council of Governments. *iSWM Technical Manual: Landscape*. April. 2010. Web. 29 March. 2012. <http://iswm.nctcog.org/Documents/technical_manual/Landscape_4-2010b.pdf>.

Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*. SEMCOG 2008.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012 <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.4.3: Storm Water Wetland



Section View for Typical Storm Water Wetland
(Source: iSWM Technical Manual, Landscape)

C1.4.4 Vegetated Swales

Vegetated swales are grass lined channels that convey storm water and remove pollutants by filtration through grass and infiltration through soil. They require shallow slopes and soils that are well drained. Pollutant removal capability is related to channel dimensions, longitudinal slope, and type of vegetation. Design of these components should promote an extended contact time of runoff through the swale to improve pollutant removal rates.

Although vegetated swales are primarily used as storm water conveyance systems, they can provide a water quality benefit for smaller storms, but their ability to control large storms is limited. Therefore, they are most applicable in low to moderate sloped areas or along highway medians as an alternative to ditches and curb and gutter drainage. Their performance diminishes sharply in highly urbanized settings, and they are generally not effective and suitable to control construction runoff. Grassy swales can be used as a pretreatment measure for other downstream BMPs, such as extended detention basins. Vegetated swales can utilize check dams and wide depressions to increase runoff storage capacity, hydraulic retention time and promote greater settling of pollutants. A cross-section of a vegetated swale is presented in the Killeen Construction Detail PC-35.

Vegetated swales are more aesthetically pleasing than concrete or rock-lined drainage systems and are generally less expensive to construct and maintain. Swales can reduce impervious area and reduce the pollutant accumulation and delivery associated with curb and gutters. The disadvantages of this technique include the possibility of erosion and channelization over time, and the need for more right-of-way as compared to a storm drain system. When properly constructed, inspected, and maintained, the life expectancy of a swale is estimated to be 20 years.

Pollutant Removal / BMP Credit

This BMP is subject to area weighting based on the percentage of area treated through Vegetated Swales. A maximum BMP Credit of 1 may be awarded for this BMP. See Chapter 10 for example calculations for area weighting.

Design Specifications / Considerations

Swales have a comparable performance to wet basins but are limited to treating a few acres. The suitability of a swale at a site will depend on land use, size of the area serviced, soil type, slope, imperviousness of the contributing watershed, and dimensions and slope of the swale system. In general, swales can be used to serve areas of less than 10 acres, with slopes no greater than 2.5 percent. The seasonal high water table should be at least 4 feet below the surface. Use of natural topography is encouraged and natural drainage courses should be regarded as significant local resources to be kept in use. Research indicates that vegetated controls are effective at removing pollutants even when dormant. Therefore, irrigation is not required to maintain growth during dry periods, but may be necessary only to prevent the vegetation from dying.

Swales make it difficult to avoid channelization where unwanted. They cannot be placed on steep slopes, and the area required may make swales impractical in densely populated areas.

The topography of the site should permit the design of a channel with appropriate slope and cross-sectional area as depicted in Construction Detail PC-35. Site topography may also dictate a need for additional structural controls. Recommendations for longitudinal slopes range between 0.5 and 2.5 percent. Flatter slopes can be used, if sufficient to provide adequate conveyance. Steep slopes increase flow velocity, decrease detention time, and may require energy dissipating devices and grade checks. Steep slopes can be managed using a series of check dams to terrace the swale and reduce the slope to within acceptable limits. The use of check dams within swales promotes infiltration.

Swales are one of the least expensive storm water treatment options and cost less to construct than curb and gutter drainage systems.

The swale should have a length that provides a minimum hydraulic residence time of at least 9 minutes. The maximum bottom width is 10 feet. The depth of flow should not exceed 4 inches during a 1 inch/hour storm. The channel slope should be at least 0.5 percent and no greater than 2.5 percent. The swale can be sized as both a treatment facility for the design storm and as a conveyance system to pass the peak hydraulic flows of the 100-year storm if it is located "on-line." Typically swales should be a trapezoidal shape with a bottom width between 4 and 10 feet and side slopes no steeper than 4:1 (H:V). Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible. If flow is to be introduced through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging. Swales must be vegetated in order to provide adequate treatment of runoff. It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing, water-resistant grasses such as Bermuda grass. Swales should be designed to not receive construction runoff unless first routed through a sedimentation basin. If a swale must receive untreated construction runoff then it may be necessary to remove the accumulated sediment immediately after construction and vegetation is established.

Operation and Maintenance

Maintenance for vegetated swales is minimal and is largely aimed at keeping the grass cover dense and vigorous. A minimum of 80 percent vegetated cover is recommended. Maintenance practices and schedules should be developed and included as part of the original plans to alleviate maintenance problems in the future. Recommended practices include:

- *Pest Management*. A Pest Management Plan should be developed for vegetated areas. This plan should specify how problem insects and weeds will be controlled with minimal or no use of insecticides and herbicides.
- *Seasonal Mowing and Lawn Care*. Lawn mowing should be performed routinely, as needed, throughout the growing season. Grass height should be maintained at 2 inches above the design water depth. Grass cuttings should be collected and disposed offsite, or a mulching mower can be used. Regular mowing should also include weed control practices; however, herbicide use should be kept to a minimum. Healthy grass can be maintained without using fertilizers because runoff usually contains sufficient nutrients.
- *Debris and Litter Removal*. Trash tends to accumulate in swale areas, particularly along highways. Any swale structure (i.e. check dam) should be kept free of obstructions to reduce floatables being flushed downstream, and for aesthetic reasons. The need for litter removal is determined through periodic inspection, but should be performed no less than two times per year.

- *Sediment Removal*. Sediment accumulation near culverts and in channels should be removed when they build up to 3 inches at any spot, or cover vegetation. Excess sediment should be removed by hand or with flat-bottomed shovels. If areas are eroded, they should be filled, compacted, and reseeded so that the final grade is level with the bottom of the swale. Sediment removal should be performed periodically, as determined through inspection. Depending on the type of pollutants accumulated, some sediment may be considered hazardous waste or toxic material, and are therefore subject to restrictions for disposal.
- *Grass Reseeding and Mulching*. A healthy dense grass should be maintained in the channel and side slopes. Grass damaged during the sediment removal process should be promptly replaced using the same seed mix used during swale establishment. If possible, flow should be diverted from the damaged areas until the grass is firmly established.
- *Public Education*. Private homeowners are often responsible for roadside swale maintenance. Unfortunately, overzealous lawn care on the part of homeowners can present some problems. For example, mowing the swale too close to the ground, or excessive application of fertilizer and pesticides will be detrimental to the performance of the swale. Pet waste can also be a problem in swales, and should be removed to avoid contamination from fecal coliform and other waste-associated bacteria. The delegation of maintenance responsibilities to individual landowners is a cost benefit to the municipality. However, the city should provide an active educational program to encourage the recommended practices.

Recommended Inspection Schedule

Inspect swales at least twice annually for erosion or damage to vegetation; however, additional inspection after periods of heavy runoff is most desirable. The swale should be checked for uniformity of grass cover, debris and litter, and areas of sediment accumulation. More frequent inspections of the grass cover during the first few years after establishment will help to determine if any problems are developing, and to plan for long-term restorative maintenance needs. Bare spots and areas of erosion identified during semi-annual inspections should be replanted and restored to meet specifications. Construction of a level spreader device may be necessary to reestablish shallow overland flow.

References

Barrett, Michael E. Ph.D., P.E. Texas Commission on Environmental Quality, Field Operations Division, Complying With the Edwards Aquifer Rules: Technical Guidance for Best Management Practices RG-348, Texas, 2005.

City of Austin, Environmental Criteria Manual, American Legal Publishing Corporation, Cincinnati, Ohio, 2012.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012. <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

C1.4.5 Multi-Purpose Detention Areas

Multi-purpose detention areas are storage areas which have been designated for multiple uses in addition to storm water detention. Typically these detention structures are not designed to directly improve water quality, however, the detention they provide can lead to water quality improvements downstream in the watershed. Multi-purpose detention areas are commonly used as parking lots, athletic fields, public parks, and recessed common space areas. These areas will normally be dry between storm events and should be designed in a way that allows normal use the majority of the time. Detention areas should not be used for extended detention and will require connections to other structural controls if water quality improvement is desired. Basins have the ability to be located upstream and downstream of other water quality controls (SEMCOG, 2008).

Pollutant Removal / BMP Credit

Application		Storm Water Quality Function	
Residential	Yes	Volume Reduction	Moderate
Commercial	Yes	Groundwater Recharge	Moderate
Industrial	Limited	Peak Rate Reduction	Moderate
Redevelopment	Yes	BMP Credit	
Highway/Road	No	1.5	
Recreational	Yes		

(Sources: SEMCOG, 2008, iSWM, 2010, and ASCE, 2011)

This BMP is subject to area weighting based on the percentage of area treated through Multi-Purpose Detention Areas. A maximum BMP Credit of 1.5 may be awarded for this BMP. See Chapter 10 for example calculations for area weighting.

Design Specifications / Considerations

Generally, multi-purpose detention areas should be designed to provide temporary storage of a portion or possibly all of the peak design discharge. In many cases, they should adequately reduce post-project peak discharges to pre-project conditions. Routing calculations should be used to determine the storage volume achieved by a given detention basin. In addition to detention requirements, multi-purposed detention should produce other community or regional benefits such as reduced public safety risks and reduced potential of property damage while minimizing the inconvenience to the facility's primary use. Emergency spillways should be installed to handle peak discharges produced by larger events. Care should be taken to ensure spillways do not adversely impact downstream property owners or the receiving conveyance system.

Parking lot detention areas are implemented in areas where a significant portion of the drainage basin is paved or impervious. Parking lot detention is primarily used in two different ways: 1) using ponding areas along raised curbs to create storage volume, and 2) through depressions created around drop inlet locations. Maximum storage depths for parking lot basins should be no more than 12 inches for the 1 percent annual chance storm event. Fire lanes and emergency access should be elevated above the maximum ponding elevation. Ponding depths are typically achieved using raised inlets.

Athletic fields, usually football, soccer, or track and field facilities, can be used to provide greater volumes of storm water detention. Volumes can be created by constructing berms or dikes around the perimeter of the fields and discharges can be controlled through the use of weirs, culverts, or storm sewer inlets. Fields should be graded in such a way to provide positive drainage towards the outfall structure(s).

Public parks and common space areas are most effective in high-density developments. Public plazas and parks can be recessed to provide detention of peak discharges for local areas. These areas should be designed to flood no more frequently than twice per year (ARC 2001).

Operation and Maintenance

Operation and maintenance requirements for multi-purpose detention areas are largely dependent on the normal use of the facility. Regular mowing and landscaping should be maintained according to the facility's maintenance schedule. Debris should be removed from ponding areas to reduce the risk of clogging outlets and improve overall aesthetics. Sediment deposits will need to be removed, and any erosion that takes place during storm events should be repaired immediately. All structural controls should be maintained regularly (ARC 2001).

Recommended Inspection Schedule

Activity	Schedule
Clear trash and debris from ponding areas	Annually; Following large storm events
Remove sediment deposits	As needed per inspection
Repair and re-vegetate eroded areas	As needed per inspection
Repairs to structural controls	As needed per inspection
Routine facility maintenance	As required

Based on Georgia Stormwater Management Manual (Volume 2), ARC 2001

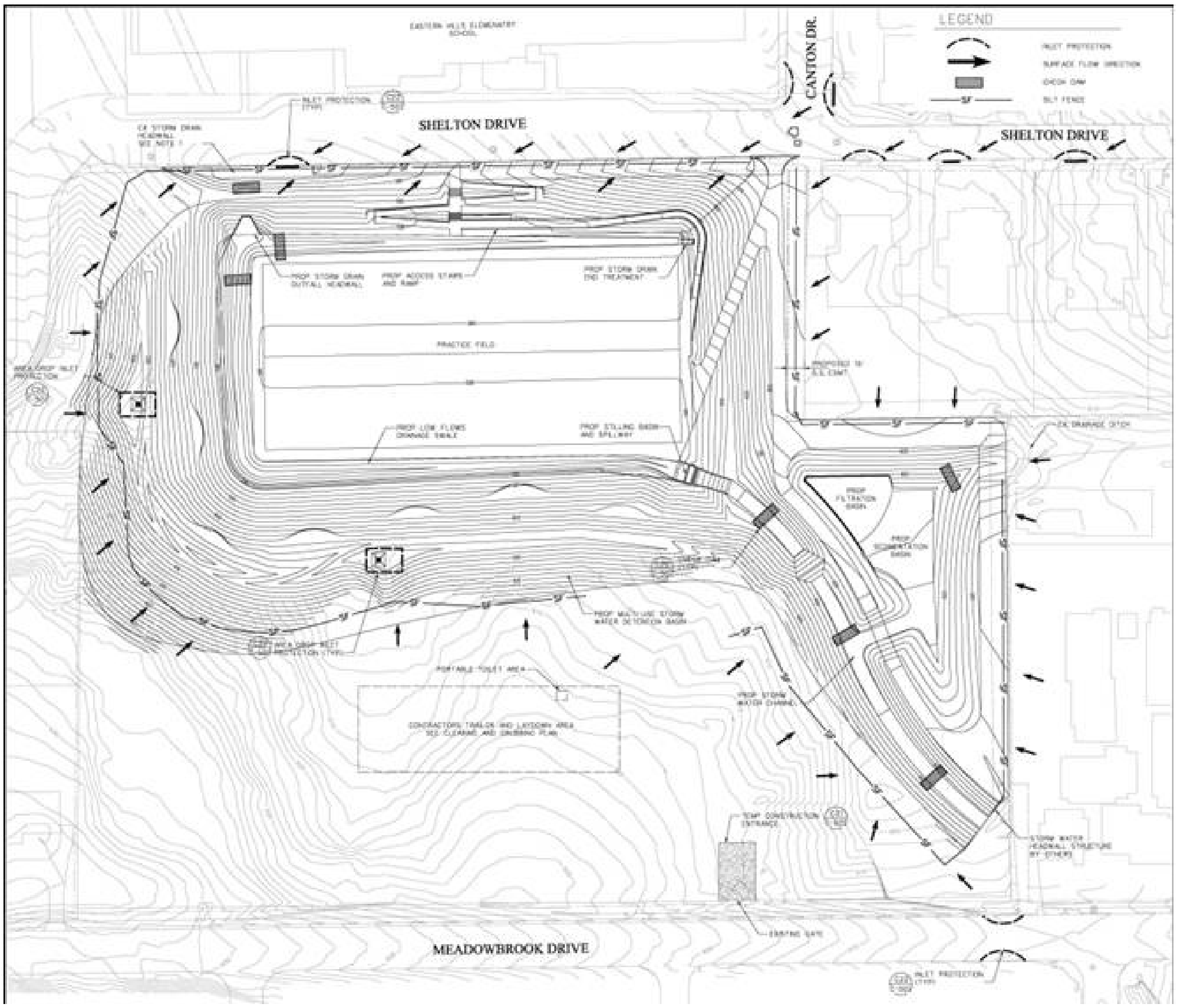
References

Atlanta Regional Commission (ARC). *Georgia Stormwater Management Manual, Technical Handbook.* Vol. 2. 2001. http://www.georgiastormwater.com.

Southeast Michigan Council of Government. *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*, SEMCOG 2008.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012. <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

Figure C1.4.5: Multi-Purpose Detention Areas



Athletic Practice Facility Multi-Purpose Detention Area
(Source: Jacobs 2010)

C1.4.6 Enhanced Swales

Enhanced swales are vegetated open channels that are designed to capture, treat and convey storm water runoff. Enhanced swales differ from vegetated swales in regard to the subsurface of the swale bottom. An enhanced swale provides a subsurface filter media layer in which filtration and infiltration is promoted. Enhanced swales have an increased capacity compared to vegetated swales. There are two types of enhanced swales. The first type uses a soil amendment to increase the absorption rate of the soil and promote biological activity. This type of enhanced swale is called a dry swale. The soil amendments can include rice hulls or other recycled agricultural products, tumbled glass that has been recycled and crushed to a sand consistency, or a compost tea (mycorrhiza) that will promote biological activity. This media layer within an enhanced swale is similar to those in rain gardens and bioretention basins but is typically shallower. The second type of enhanced swale uses wetland plants to increase water absorption and filtration within the swale. The goal of an enhanced swale is to allow the soils to soak up more runoff than native soils. An enhanced swale not only provides water quality treatment for storm water runoff, but also provides minimal flood control because of the increased capacity in the swale for water absorption. Enhanced swales have the ability to remove sediment, nutrients and metals from storm water runoff.

Pollutant Removal / BMP Credit

This BMP is subject to area weighting based on the percentage of area treated through Enhanced Swales. A maximum BMP Credit of 2 may be awarded for this BMP. See Chapter 10 for example calculations for area weighting.

Design Specifications / Considerations

Enhanced swales can be used in a variety of situations. An advantage of an enhanced swale is that they offer both storm water conveyance and treatment. Velocities within the swale must be kept to a minimum so the slopes within the swale must keep to less than 4 percent. These limited slopes and low velocities promote debris and sediment to settle. Check dams can also be included in the swale design to further decrease velocities and promote infiltration. Because of the low velocities, the potential for erosion and scour can be limited. In steeper environments, it may not be possible to design a swale. Swales are typically less expensive to construct than curb and gutter but also have greater maintenance requirements than curb and gutter. Wet swales have a potential for odors and mosquitoes and a nuisance control plan must be developed with a wet swale. Swales do not provide flood control and other measures must be included to reduce the post developed peak flows.

Enhanced swales should be designed to capture the entire water quality volume calculated for the site. The water quality volume will consist of runoff from all impervious surfaces including roadways, parking areas, rooftops and all developed pervious areas within the contributing drainage area. For the purpose of design, water quality volume shall be calculated as the first one-half (0.5) inch of runoff plus one-tenth (0.1) inch for each ten (10) percent increase of impervious cover over twenty (20) percent within the contributing drainage area. Outlet design should be such that the entire water quality volume is released over a minimum duration of twenty-four (24) hours. Over flow outlets should be designed to accommodate for larger storm event discharges. Offsite contributing drainage areas should be routed around the enhanced swales to avoid overloading. Swales have a maximum capacity to treat a drainage area of 10 acres. The bottom width of enhanced swales should be between 4 and 10 feet.

Dry Swales can be designed to work with existing landscaping. Dry swales required minimal maintenance. Dry swales discourage long standing water between storms. The bottom of a dry swale should be at least three feet above the groundwater levels. Dry swales should not be placed within 10 feet of any structure. Ponding in the swale should be limited to 18 inches. If necessary a dry swale can incorporate an under-drain beneath the permeable soil to promote drainage.

Wet swales are designed to retain water and support wetland vegetation and therefore need to be constructed in an area with a high water table or poorly drained soils. Since the areas within the wet swale remain wet there is a higher potential for erosion during higher storm events. Wet swales should not be placed within 10 feet of any structure.

Operation and Maintenance

Enhanced swales need to be mowed at least twice a year to keep the grass within the swale to less than 18 inches. Swales need to be kept free of weeds. In a wet swale all plantings must be maintained and replaced if necessary. All swales must be inspected for signs of erosion and scouring and be corrected if found. Sediment and debris should be removed from the swales.

Recommended Inspection Schedule

Enhanced swales should be inspected at least twice annually and one inspection should occur after a storm event to determine if the swales are functioning properly.

References

North Central Texas Council of Governments. *iSWM Technical Manual: Site Development Controls*. April. 2010. Web. 29 March. 2012. <http://iswm.nctcog.org/Documents/technical_manual/Site_Development_Controls_4-2010b.pdf>.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012. <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

C1.4.7 Wet Pond

Wet ponds are basins that have a permanent pool that provide water quality controls in the form of sediment, biological oxygen demand, organic nutrients and trace metal removal from storm water runoff. They are typically designed as on-line systems and if desired can also provide storm water detention and flood control. City of Killeen Construction Detail PC-44 illustrates a typical system. Wet ponds can also provide recreational and aesthetic benefits since they are designed with a permanent pool.

It is important to maintain the permanent water surface elevation within the wet pond to maintain vegetation along the bank and keep the functionality of the pond. For all sites, a water balance study with local rainfall data must be performed to determine if the typical storms throughout the year will maintain the permanent pool water surface elevation. It has been found that wet ponds are not suitable for drainage areas of less than 10 acres or possibly more depending on site conditions. If storm water runoff will not be sufficient to maintain the permanent pool, an additional source of water must be used. Although evaporation is a major component in water loss, another key element is infiltration and seepage into the ground. For this reason, it is recommended that an impermeable liner be used around the banks of the pond. Two common types of liners are clay and geomembrane. Vegetation is an integral part of a wet pond. The vegetation around the banks of the pond must be maintained to ensure proper function. An improperly maintained wet pond can lead to stagnant water, floating debris, odors and insects.

Pollutant Removal / BMP Credit

This BMP is subject to area weighting based on the percentage of area treated through Wet Ponds. A maximum BMP Credit of 2 may be awarded for this BMP. See Chapter 10 for example calculations for area weighting.

Design Specifications / Considerations

Considerations
Wet ponds have a high capacity for sediment and nutrient removal. They also have the capacity to treat large contributing basins. Wet ponds provide the benefits of both passive (bird watching) and active recreation (fishing, boating) if desired.

Whenever standing water is present in this climate, there is a concern about mosquitoes. Wet ponds are typically stocked with gambusia to help control this potential nuisance. Wet ponds cannot be constructed on steep slopes. In some cases, where there is no available makeup water, the more arid regions cannot sustain a pond with a permanent water surface elevation. In dense development areas there may not be enough land to accommodate a wet pond.

Wet ponds are one of the more expensive post-construction BMPs to construct and maintain. This cost may be offset if the basin is also used for detention and eliminates the needs for a separate detention basin. Maintenance operation can also be expensive. Since the pond must be drained for sediment removal, the wetland vegetation could be lost in that process and must be replaced.

Design Specifications
The pond must be sized properly for proper function. The wet pond needs to be designed for two or three different water volumes depending on whether the pond will provide flood control.

First, the water quality volume for the treatment basin must be calculated. The water quality volume will consist of runoff from all impervious surfaces including roadways, parking areas, rooftops and all developed pervious areas within the contributing drainage area. For the purpose of design, water quality volume shall be calculated as the first one-half (0.5) inch of runoff plus one-tenth (0.1) inch for each ten (10) percent increase of impervious cover over twenty (20) percent within the contributing drainage area. Outlet design should be such that the entire water quality volume is detained above the permanent pool and released over a minimum duration of forty-eight (48) hours. Offsite contributing drainage areas should be routed around the wet ponds to avoid overloading. The total volume of the permanent pool shall equal the calculated water quality volume plus an additional twenty (20) percent of volume to accommodate sediment accumulation. If the wet pond is to be used for flood control, that required volume must be stored above the water quality volume surface elevation. The detention capacity for wet ponds shall be calculated per the requirements stated in Section 1.2.8 of the City of Killeen Drainage Design Manual.
A wet pond needs to be configured with two separate but connected stages, a sediment forebay and a main pool. The pond must not have a length to width ration of less than 1:1. The basin should also be wedge shaped being narrowest at the inlet and widest at the outlet. This configuration will help prevent short-circuiting of the pond. The sediment forebay and the main pool are to be separated by a berm or wall with a top elevation 0.5 feet below the permanent pool elevation. An equalizer pipe must also be designed in the separator wall at the mid-height of the permanent pool. This will allow the water surface between the sediment forebay and the main pool to remain the same even if the permanent pool elevation drops below the top elevation of the separator wall. All flows into the pond must enter into the sediment forebay. This sediment forebay must be designed to capture 20 percent of the water quality volume and be at least three feet deep. The main pool should be between 4 and 6 feet deep and no greater than 8 feet deep. Since the wet pond will impound a large amount of water, the pond embankments should be designed to applicable dam design standards.

The pond should have maximum side slopes of 4:1 (H:V). A vegetated bench should be provided around the perimeter of the permanent pool. The maximum slope of the vegetated bench should be a 5:1 (H:V) slope and extend inward from the permanent pool elevation 10 feet. For safety purposes, flat benches with no greater than 3 percent slope and 10 feet wide should be provided at the maximum pool elevation outward. An emergency spillway must also be provided in the pond to pass flows if the outflow structure gets clogged.

Separate outflow structures must be designed for the water quality volume and the detention volume if the pond provides flood control. The outlet structure for the water quality volume must be designed to drain the pond to the permanent pool in 24 hours. The outflow can be controlled with an orifice plate. A typical configuration for an outlet structure can be seen in City of Killeen Construction Detail PC-44.

A separate drain should be provided in order to drain the pond for maintenance. This drain should have a valve that can be accessed during storm events. If a drain cannot be provided in the pond configuration because of site constraints, a pump will have to be used to drain the pond.

If the wet pond will be used for water quality and not flood control, a splitter box will be necessary at the inlet to the pond to isolate the water quality volume and bypass any flows greater than the water quality volume.

As stated previously, vegetation is an integral part of a wet pond. Vegetation is used both to stabilize the slopes of the pond and to create a wetland habitat along the vegetative bench. This bench provides both filtration and nutrient absorption. Suitable plants should be used for this application based on the depth of water in which it will reside. The City of Austin Environmental Criteria Manual provides a thorough plant list and planting schedule that can be easily translated to the Killeen climate.

It is important to provide erosion protection at the inlet and outlet of the ponds to reduce local scour and erosion. Most wet ponds drain directly into natural channels and the outlet of the pond should be protected to the intersection of the outlet and the channel.

Operation and Maintenance

In order to provide for maintenance activities, site access must be provided to both the sediment forebay and main pool. Maintenance ramps must be provided at a slope of no greater than 4:1. A majority of the access ramp will be underwater at most times so they must be constructed of a material that will withstand a submerged condition. Staging areas are needed for maintenance activities.

All side slopes within the pond embankments should be mowed at least twice annually and the height of the turf should not exceed 18 inches. More frequent mowing may be necessary for aesthetic purposes. There are many aspects of the wet basin that require regular inspections. The embankments must be checked for erosion, cracking, leaking and unwanted vegetation growth. Both the inlet and outlet must be checked for clogging and structural damage. Clogging must be corrected and structural damage must be repaired to prevent further damage. The vegetation within the pond must be checked for bare areas and dead specimens. All bare areas must be reestablished and all dead plants should be replaced. All debris and litter should be removed from the basin. Floating debris must be removed from the inlet and outlet areas. Once the sediment at the bottom of the pond accumulates to displace 20 percent of the permanent pool volume, the sediment must be removed. This requires draining the pond and is typically not necessary more than every 10 years. Nuisance control is a component of wet pond maintenance.

Recommended Inspection Schedule

Inspections should occur at least twice per year. One of these inspections should occur after a storm event to ensure pond and outlet structures are functioning properly.

References

Barrett, Michael E. Ph.D., P.E. Texas Commission on Environmental Quality, Field Operations Division, *Complying With the Edwards Aquifer Rules: Technical Guidance for Best Management Practices* RG-348, Texas, 2005.

United States Environmental Protection Agency (USEPA). April 2012. National Pollution Discharge Elimination System (NPDES), Office of Water, 25 Jun. 2012. <http://cfpub.epa.gov/npdes/stormwater/menuofbmps>.

DEFINITIONS

ACCEPTABLE OUTLET - That point where storm water runoff can be released into a watercourse or drainage way of adequate capacity without causing scour or erosion.

ALLUVIAL FAN - A sloping, fan-shaped mass of sediment deposited by a stream where it emerges from an upland onto a plain.

ALLUVIUM - A general term for all detrimental material deposited or in transit by streams, including gravel, sand, silt, clay and all variations and mixtures of these. Unless otherwise noted, alluvium is unconsolidated.

ALTERATIONS - Cutting, filling, widening, bypassing, channelizing, stabilizing or clearing vegetation in a floodplain.

ANNUAL -A plant that lives and grows for only one (1) year or season, during which the life cycle is completed.

APRON - A floor or lining to protect a surface from erosion; for example, for the pavement below chutes, spillways or at the toes of dams.

BASE FLOW - The stream discharge from ground water accretion.

BERM - A shelf that breaks the continuity of a slope.

BUFFER AREA - A landscape area on a lot, situated between all street views and all vehicles, structures and areas to be buffered from those views.

BUFFERING - The use of landscaping (other than mere grass on flat terrain) or the use of landscaping along with berms, walls or decorative fences that at least partially and periodically obstruct the view from the street, in a continuous manner, of vehicular use areas, parking lots and their parked cars and detention ponds.

CALIPER - The diameter of an installed tree measured six (6) inches above ground level for small trees (four (4) inches diameter or less) at time of planting; measured at 12 inches above ground level for large trees (greater than four (4) inches diameter). The caliper of installed multi-stemmed trees is determined by adding the full diameter of the largest stem to half the diameter of each additional stem.

CANOPY COVER - That geographic area covered by the vertical projection of the drip line or outer branches of a tree or group of trees in a woodland tract, which may be measured directly from aerial photography and/or measured for all trees at least 30 feet in height.

CATCHMENT AREA - The area, defined by topographic relief, which drains to a point recharge or critical environmental feature.

CHANNEL - An existing natural water course or a manmade water course designed to meet specifications contained in the City of Killeen Current Drainage Design Manual Appendix C.

CHANNEL IMPROVEMENT - The improvement of the flow characteristics of a channel by clearing, excavation, realignment, lining or other means in order to increase its water carrying capacity.

CHANNEL STABILIZATION - Erosion prevention and stabilization of distribution in a channel using jetties, drops, revetments, structural linings, vegetation and other measures.

CHECK DAM - A small dam constructed in a gully or other small watercourse to decrease the stream flow velocity (by reducing the channel gradient), minimize channel scour and promote deposition of sediment.

CLAY (SOILS)

a. A mineral soil separate consisting of particles less than 0.002 millimeter in equivalent diameter.

b. A soil texture class.

c. (Engineering) A fine grained soil (more than 50 percent passing the Number 200 sieve) that has a high plasticity index in relation to the liquid limit (Unified Soil Classification System).

COMPACTION - To unite firmly. With respect to construction work with soils, engineering compaction is any process by which the soil grains are rearranged to decrease void space and bring them into closer contact with one another, thereby increasing the weight of solid material per unit of volume, increasing the shear and bearing strength and reducing permeability.

COMPOST - A mixture of vegetable refuse, manure or other organic matter which has gone through a decaying process.

CONDUIT - Any channel intended for the conveyance of water, whether open or closed.

CONTOUR

a. An imaginary line on the surface of the earth connecting points of the elevation.

b. A line drawn on a map connecting points of the same elevation.

CREST

a. The top of a dam, dike, spillway or weir, frequently restricted to the overflow portion.

b. The summit of a wave or peak of a flood.

CROWN - Branch structure of a tree.

CROWN (OF SLOPE) - Top of slope, apex.

CRUSHED STONE - Aggregate consisting of angular particles produced by mechanically crushing rock.

CUT - Portion of land surface or area from which earth has been removed or will be removed by excavation; the depth below original ground surface to excavated surface.

CUT-AND-FILL - Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

DAM - A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion or for retention of soil, sediment or other debris.

DEBRIS - Broken remains of plants, objects and rocks that form trash or remains.

DECIDUOUS - Plants that shed their leaves annually, as opposed to evergreen.

DEPOSITION - The accumulation of material dropped because of a slackening movement of the transporting agent, water or wind.

DETENTION DAM - A dam constructed for the purpose of temporary storage of stream flow or surface runoff which releases the stored water at controlled rates.

DRAIN (VERB)

a. To provide channels, such as open ditches or closed drains, so that excess water can be removed by surface flow or internal flow.

b. To lose water (from the soil) by percolation.

DRAINAGE

a. The removal of excess surface water or ground water from land by means of surface or subsurface drains.

b. Soil characteristics that affect natural drainage.

DRAINAGE AREA (WATERSHED) - All land and water from which runoff may run to a common (design) point.

EMERGENCY SPILLWAY - A dam spillway designed and constructed to discharge flow in excess of the principal spillway design discharge.

ENERGY DISSIPATER - A designed device, such as an apron of riprap or a concrete structure, placed at the end of a water-transmitting apparatus, such as a pipe, paved ditch or paved chute, for the purpose of reducing the velocity, energy and turbulence of the discharged water.

EROSION

a. The wearing away of land surface by running water, wind, ice or other geological agents, including such processes as gravitational creep.

b. Detachment and movement of soil or rock fragments by water, wind, ice or gravity. The following terms are used to describe different types of water erosion:

Accelerated erosion - Erosion much more rapid than normal, natural or geologic erosion, primarily as a result of the influence of the activities of man or in some cases of other animals or natural catastrophes that expose base surfaces; for example, fires.

Gully erosion - The erosion process whereby water accumulates in narrow channels and over short periods removes the soil from this narrow area to considerable depths, ranging from one (1) or two (2) feet to as much as 75 to 100 feet (see gully).

Rill erosion - An erosion process in which numerous small channels only several inches deep are formed (see rill).

Sheet erosion - The removal of a fairly uniform layer of soil from the land surface by runoff water.

Splash erosion - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surfaces runoff.

ESTHETIC (AESTHETIC) - Pleasing to look at.

EXISTING TREE - A tree which exists on a site or easement prior to any development or disturbance.

FACILITY - A building or buildings, appurtenant structures and surrounding land area used by a person at a single location or site.

FILTER STRIP - A strip of permanent vegetation above ponds, diversions and other structures to retard flow of runoff water, causing deposition of transported material, thereby reducing sediment flow.

FLOODPLAIN - The land area adjacent to a waterway necessary to contain a 1 percent annual chance flood under fully developed conditions in accordance with City of Killeen Current Drainage Design Manual.

FREEBOARD (HYDRAULICS) - The vertical distance between the maximum water surface elevation anticipated in design and the top of retaining banks or structures. Freeboard is provided to prevent overtopping due to unforeseen conditions.

GABION - A flexible, woven wire basket composed of two (2) to six (6) rectangular cells filled with small stones. Gabions may be assembled into many types of structures, such as revetments, retaining walls, channel liners, drop structures and groins.

GABION MATTRESS - A thin gabion, usually six (6) or nine (9) inches thick, used to line channels for erosion control.

GRADE

a. The slope of a road, channel or natural ground.

b. The finished surface of a canal bed, roadbed, top of embankment or bottom of excavation; any surface prepared for the support of construction, like paving or laying a conduit.

c. To finish the surface of a canal bed, road bed, top of embankment or bottom of excavation.

HEAD (HYDRAULICS) -

a. The height of water above any plane or reference.

b. The energy, either kinetic or potential, possessed by each weight of a liquid expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various compound terms such as pressure head, velocity head and head loss.

HYDRAULIC GRADE LINE - In a closed conduit, a line joining the elevations to which water could stand in risers or vertical pipes connected to the conduit at their lower end and open at their upper end. In open channel flow, the hydraulic grade lien is the free water surface.

HYDRAULIC GRADIENT - The slope of the hydraulic grade line. The slope of the free surface of water flowing in an open channel.

HYDRAULIC JUMP - The sudden turbulent rise in water level from a flow stage below critical depth to flow stage above critical depth, during which the velocity passes from super critical to subcritical.

HYDRAULIC RADIUS - The cross-sectional area of a channel divided by its wetted perimeter. The "r" in Manning's Formula.

HYDROGRAPH - A graph showing variation in stage (depth) or discharge of a stream of water over a period of time.

HYDROSEEDER - A machine designed to apply seed, fertilizer, lime and short fiber wood or paper mulch to the soil surface.

HYDROSEEDING - Seeding with a hydroseeder.

INLET (HYDRAULICS) -

a. A surface connection to a closed drain.

b. A structure at the entrance end of a conduit.

c. The upstream end of any structure through which water may flow.

IN-CHANNEL DETENTION - Detention accomplished by channel storage or on-stream storage, as opposed to off stream or upland detention.

INSTALLED TREE - A tree which is planted on a site after development occurs.

INTERCEPTOR DRAIN - A surface or subsurface drain or a combination of designed and installed to intercept flowing water.

IRRIGATION - Providing water to plants in an amount and frequency adequate to sustain growth of the plants on a permanent basis.

LANDSCAPE AREA - Any area within the boundaries of a given lot which is devoted to and consists of living plant material and other landscape material, including but not limited to grass, trees, shrubs, flowers, vines, groundcover, native plant materials, existing native vegetation areas, planters, brick, stone, natural forms, water forms and other landscape features, but not including the use of smooth concrete, asphalt or aggregate. Provided, however that the use of nonliving landscape materials shall not predominate over the use of organic living plant material within any single landscape area.

LANDSCAPE ISLAND - A landscape area completely surrounded by a parking area and/or a vehicular use area.

LANDSCAPE MEDIAN - A linear landscape area between two (2) rows of parking, between two (2) drives or between a row of parking and a drive.

LIME - Basic calcareous materials used to raise pH of acid soils for benefit of plants being grown. May be either ground limestone or hydrated lime.

LIMITS OF CONSTRUCTION - The outer limits of the area which will be disturbed by a proposed development activity including the area of all proposed cuts, fills, regrading, structures, ancillary facilities, temporary utilities, temporary or permanent spoil storage areas, access roads, storage areas, staging areas and any other activities or facilities which may cause temporary or permanent loss or damage of vegetation or disruption of the soil surface.

LINEAR DEVELOPMENT - Development which is typically not confined to one site and is linear in nature such as a utility or waterway alteration project.

MULCH - Covering on surface of soil to protect and enhance certain characteristics, such as water retention qualities.

NATIVE PLANTS - Plants native to the area which are compatible with environmental conditions of a site or portions of a site. The standard reference for this criterion shall be the Manual of Vascular Plants of Texas by Correll and Johnston, published by the University of Texas at Dallas (1970).

NATURAL AREA - Area of a site existing in a natural state.

NATURAL GROUND - Ground surface which has not been disturbed by man.

NATURAL GROUND COVER - Any organic material either existing prior to construction or installed after construction.

OUTFALL - The point where water flows from a conduit, stream or drain.

OUTLET - The point at which water discharges from such things as a stream, river, lake, tidal basin, pipe, channel or drainage area.

OUTLET CHANNEL - A waterway constructed or altered primarily to carry water from manmade structures, such as terraces, subsurface drains, diversions and impoundments.

OVERBANK - The area outside the immediate natural stream channel or outside the pilot channel of a new channel which contains the 1 percent annual chance floodplain.

PERMANENT SEEDING - Results in establishing perennial vegetation which may remain on the area for many years.

PERMISSIBLE VELOCITY (HYDRAULICS) - The highest average velocity at which water may be carried safely in a channel or other conduit. The highest velocity that can exist through a substantial length of a conduit and not cause scour of the channel. Safe, nonerosive or allowable velocity.

PIPES OR PIPING - Any pipeline system which is used for the transfer of hazardous materials in connection with an underground storage tank within the confines of a facility.

PIPING - Removal of soil material through subsurface flow channels or "pipes" developed by seepage water.

PLANT MATERIALS - Living plants which are part of an installed landscape.

RETENTION - The amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff.

REVEGETATION - The installation of native trees, shrubs, grasses and wildflowers in an area after its disturbance, along with subsequent maintenance, intended to restore the area to a natural state.

REVETMENT - Facing of stone or other materials, either permanent or temporary, placed along the edge of a stream or shoreline to stabilize the bank and to protect it from the erosive action of water.

RIPRAP - Broken rock, cobbles or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves); also applies to brush or pole mattresses or brush and stone or similar materials used for soil erosion control.

ROUGHNESS COEFFICIENT (HYDRAULICS) - A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.

RUNOFF (HYDRAULICS) - That portion of the precipitation on a drainage area that is discharged from the area in stream channels. Types include surface runoff, ground water runoff or seepage.

SEDIMENT - Solid material, both mineral and organic, that is in suspension, is being transported or has been moved from its site of origin by air, water, gravity or ice and has come to rest on the earth's surface either above or below sea level.

SEDIMENTATION - Deposition of detached soil particles.

SEDIMENT DISCHARGE (SEDIMENT LOAD) - The quantity of sediment, measured in dry weight or by volume, transported through a stream cross section in a given time. Sediment discharge consists of both suspended load and bedload.

SHEET FLOW - Water, usually storm runoff, flowing in a thin layer over the ground surfaces.

SIDE SLOPES (ENGINEERING) - The slope of the sides of a canal, dam or embankment. It is customary to name the horizontal distance first, as 1.5:1 meaning a horizontal distance of 1.5

SILT -

a. (Agronomy) A soil separate consisting of particles between 0.05 and 0.002 millimeter in equivalent diameter.

b. A soil textural class.

c. (Engineering) According to the Unified Soil Classification System, a fine grained soil (more than 50 percent passing the Number 200 sieve) that has a low plasticity index in relation to the liquid limit.

SOIL

a. (Agronomy) The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

b. (Engineering) Earth and rock particles resulting from the physical and chemical disintegration of rocks and may or may not contain organic matter. It includes fine material (silts and clays), sand and gravel.

SPILLWAY - An open or closed channel or both, used to convey excess water from reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

STABILIZATION - Providing adequate measures, vegetative and/or structural, that will prevent erosion from occurring.

STABILIZED AREA - An area sufficiently covered by erosion resistant material, such as a good cover of grass or paving by asphalt, concrete or stone, in order that erosion of the underlying soil does not occur.

STABILIZED GRADE - The slope of a channel at which neither erosion nor deposition occurs.

STILLING BASIN - An open structure or excavation at the foot of an overfall, conduit, chute, drop or spillway to reduce the energy of the descending stream of water.

TEMPORARY SEEDING - A seeding which is made to provide temporary cover from the soil while waiting for further construction or other activity to take place.

TIME OF CONCENTRATION - Time required for water to flow from the most remote point of a watershed in a hydraulic sense to the outlet.

TOE (OF SLOPE) - Where the slope stops or levels out. The bottom of the slope.

TOPSOIL - The topsoil shall be composed of 4 parts of soil mixed with 1 part compost, by volume. The compost shall meet the definition of compost as defined by TxDOT Specification Item 161. The soil shall be locally available native soil that meets the following specifications:

Shall be free of trash, weeds, deleterious materials, rocks, and debris.

100 percent shall pass through a 1.5-inch (38-mm) screen.

Soil to be a loamy material that meets the requirements of the table below in accordance with the USDA textural triangle. Soil known locally as “red death” is not allowable soil. Textural composition shall meet the following criteria:

Textural Class	Minimum	Maximum
Clay	5%	50%
Silt	10%	50%
Sand	15%	67%

TREE REMOVAL - The uprooting or severing of the main trunk of a tree or any act which causes or may reasonably be expected to cause a tree to die, including, but not limited to, damage inflicted upon the root system by machinery, storage of materials or soil compaction; substantially changing the natural grade above the root system or around the trunk; excessive pruning or paving with concrete, asphalt or other impervious materials in a manner which may reasonably be expected to kill a tree.

WINTERKILL - Killed by low temperatures during winter months.

WOOD FIBER - A short fiber mulch material, usually applied with a hydroseeder in an aqueous mixture.

XERISCAPE - A method of landscaping using certain principles of design and installation which conserve water and energy.