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EVALUATION OF DEMONSTRATED BIOSWALE

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EVALUATION OF DEMONSTRATED BIOSWALE

1. Purpose

a. The purpose of this Public Works Technical Bulletin (PWTB) is to document lessons learned during the demonstration of a bioswale design to increase infiltration and decrease stormwater runoff in poorly drained soils. These lessons learned will provide technical information and guidance for public works, natural resources, and environmental personnel responsible for monitoring, developing, and implementing Best Management Practices (BMPs) for managing stormwater and non-point source pollution (NPS).

b. All PWTBs are available electronically in Adobe® Acrobat® portable document format (PDF) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide (WBDG) Web page, which is accessible through this Universal Resource Locator (URL):

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

2. Applicability This PWTB applies to all US Army Continental United States (CONUS) and Outside Continental United States (OCONUS) installations that are actively pursuing options for on-site stormwater management.

3. References

a. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement," 28 August 2007, http://www.apd.army.mil/pdffiles/r200_1.pdf

b. Department of the Army (DA), “Sustainable Design and Development Policy Update,” 16 December 2013, http://www.usace.army.mil/Portals/2/docs/Sustainability/Hydrology_LID/ASAIEE_SDD_Policy_Update_2013-12-16.pdf

c. Unified Facilities Code (UFC) 3-210-1, Low Impact Development, http://wbdg.org/ccb/DOD/UFC/ufc_3_210_10.pdf

d. Clean Water Act of 1972 (CWA) and Amendments of 1987: National Pollution Discharge Elimination System (NPDES) Phase II Stormwater Management Program.

e. Energy Independence and Security Act of 2007 (EISA), Section 438, Stormwater Runoff Requirements for Federal Development Projects, http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf

f. Executive Order 13148, Greening the Government through Leadership in Environmental Management, 21 April 2000, http://www.epa.gov/epp/pubs/eo13148.pdf

g. Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management, 24 January 2007, http://www.wbdg.org/ccb/FED/FMEO/eo13423.pdf

4. Discussion

a. AR 200-1 contains policy for environmental protection and enhancement, pollution prevention, conservation of natural resources, sustainable practices, and compliance with environmental laws.

b. In December of 2013, the DA released “Sustainable Design and Development Policy Update” which contains policy directed towards a series of regulatory requirements impacting stormwater management. The policy applies to all construction activities on Army installation and these “projects must be planned, designed, and constructed to manage any increase in storm water runoff (i.e., the difference between pre- and post-project runoff) within the limit of disturbance.”

c. The Army Low Impact Development Technical User Guide provides guidance for the planning and design of LID on Army construction projects to comply with stormwater requirements and resource protection goals set by the Energy Independence and Security Act (EISA) of 2007. EISA Section 438 establishes strict stormwater runoff requirements for Federal development and redevelopment projects. The provision establishes “stormwater runoff requirements for Federal development projects. The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 sq ft shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow.”

d. The Clean Water Act of 1972 and Amendments of 1987 contain policy for how Army training lands are to be managed concerning the protection of the quality of water resources in the United States. Specific topics concerning stormwater management are: total maximum daily pollutant loads, spill prevention and control, non-point source management, management of wetlands, and the National Pollutant Discharge Elimination System (NPDES).

e. EISA 2007, Section 438 contains policy establishing a set of requirements for stormwater runoff for Federal developments and redevelopments over 5000 sq ft.

f. EO 13148 contains policy for the implementation of sustainable landscapes that aim to reduce negative impacts on the natural environment. It focuses on sustainable management through the inclusion of LID guidelines and principles.

g. EO 13423 contains policy for environmental, transportation, and energy-related activities and how to do them in a conscientiously integrated, efficient, and environmentally and economically sustainable manner.

h. EO 13514 contains policy mandating Federal agencies to maintain and operate sustainable buildings. The goal is for Federal agencies to set an example by reducing potable, industrial, and agricultural water use.

i. This PWTB documents lessons learned from the demonstration project. This PWTB will discuss bioswales and other similar LID practices for stormwater management. The PWTB introduces bioswales and bioretention basins as LID practices and describes their purpose, design considerations, benefits, and implementation. In 2012, a bioswale was installed at Fort Hood, TX to demonstrate installation, maintenance, and stormwater management benefits of the technology when used in areas with low permeability soils. Lessons learned from the demonstration are documented in this PWTB.

j. Appendix A provides information on bioswales, a popular LID technique used for bioretention of stormwater. This appendix defines the term “bioswale,” describes how a bioswale functions, and outlines how its implementation will support LID site design for maintaining sustainable development.

k. Appendix B presents a lessons-learned report on the associated “Demonstration and Implementation of a Bioswale at Fort Hood, TX” project. This appendix details work conducted, materials used, quantities, and lessons learned from the demonstration, including implementation, costs, environmental, and societal benefit.

l. Appendix C contains background and expanded explanations of pertinent laws and regulations relating to how LID is relevant for compliance.

m. Appendix D contains a list of the references cited in the previous appendices.

n. Appendix E provides a list of acronyms and abbreviations along with their expanded form.

5. Points of Contact

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APPENDIX A

LID Option: Bioswale

General Description

Bioswales are wide, shallow, vegetated channels that use bioretention media (sand, gravel, and/or engineered media) beneath the surface to help improve water quality. Bioswales enhance water quality through the capture and infiltration of stormwater from the drainage shed, which also aids in the reduction of stormwater runoff and side-channel erosion. Infiltration is increased through the lengthening of water retention time from surface runoff. Bioswales are generally used in drainage areas less than 5 acres. They use infiltration to retain runoff volume and treats runoff using physical, chemical, and biological processes to reduce pollutant loadings in the water. Because bioswales can reduce the pollutants in water, they can help sites meet the water quality standards set by the Clean Water Act’s National Pollution Discharge Elimination System (NPDES).

The Virginia Department of Conservation and Recreation identifies seven components of a bioretention system (VDEQ 1999), which were reiterated in the USEPA (2000) document, *Low Impact Development: A Literature Review*:

1. **Pretreatment Area.** A pretreatment area is commonly a sedimentation basin or a vegetated buffer strip. It slows surface runoff, thereby providing time for large particles to settle out before water enters the bioretention structure.

2. **Ponding Area.** A ponding area provides runoff storage above the bioretention structure. To encourage aerobic and discourage anaerobic conditions, ponding should not last more than 48 hrs.

3. **Surface Mulch and Organic Layer.** The surface mulch and organic layer increases surface area for infiltration, provides nutrients and moisture retention to vegetation, provides microbial rich media for uptake and degradation of pollutants, and reduces soil erosion. The layer varies in thickness based on design criteria.

4. **Planting Soil.** The planting soil adsorbs pollutants and provides habitat for plant materials and microbial communities

that are key in pollutant degradation. The soil varies in thickness based on design criteria.

5. **Sand Bed (Optional).** A sand bed is placed under the planting soil. It provides exfiltration and positive drainage for the planting layer. A well-drained planting layer maintains aerobic microbial conditions.

6. **Plant Material.** The selected vegetation must be resilient enough to survive periods of extreme wetness and extreme dryness, and should include species capable of phytoremediation and bioaccumulation of pollutants.

7. **Infiltration Chambers.** Infiltration chambers allow ponded water to infiltrate the surface and to exfiltrate below the soil surface. They also encourage aerobic conditions by aerating the soil in between wet periods.

Other Stormwater Management Basins

Bioswales, also referred to as “bioretention basins” or, in urban settings, as “rain gardens” are effective at managing and treating stormwater. Bioswales share some similarities with other stormwater management basins. However, they are unique and very adaptable in design. Some stormwater management basins are designed to be wet even between storm events. Others focus solely on infiltration. Some common forms of stormwater management basins are retention basins, detention basins, infiltration basins, and sedimentation basins. Each form of basin is engineered to perform a different function that should be implemented according to a site’s unique needs.

Retention Basin

A “retention basin” is a stormwater management structure that permanently obstructs a specific volume of water, even between storm events. Retention basin inflow may be stored above the permanent pool and released through a control structure. This feature helps to prevent flash flooding and storm drain overloading. A retention basin can be used to significantly improve the quality of stormwater runoff. Sediment, chemicals, and nutrients are removed from the basin through physical, biological, and chemical processes. Enhancements in retention basin design can be made to improve pollutant removal in the permanent pool (VDEQ 1999).

Infiltration in retention basins is assumed negligible. For this reason, design should be based on permeability tests and subsurface analysis. If the infiltration rate is too high or the subsurface is unsuited, e.g., karst topography, then basin liners or other special designs may need to be implemented. These factors should be considered during the planning phase, as they might influence best management practice (BMP) selection, design, and cost (VDEQ 1999). When designing a retention system, it is important to consider flow impacts. Upstream flow must be considered, especially when large amounts of erosion occur upstream. Large amounts of sedimentation from upstream flow could drastically increase maintenance requirements. If sedimentation is expected, retention basin design should include some form of pretreatment, e.g., sediment forebay. A retention basin will also disrupt natural flow conditions and water quality downstream (VDEQ 1999). Safety, maintenance, and health issues must also be taken into consideration when considering contained water (Fifield 2011). Despite these challenges, a retention basin is often considered one of the most common and reliable BMPs in use today. A well-maintained retention basin can also prove to be an attractive landscaping feature.

Detention Basin

Detention basins are among the most common stormwater management faculties and are often found on construction sites. Detention basins only temporarily detain runoff water. They differ from a retention basin in that they do not have permanent pool of water and are generally dry between rainfall events. Detention basins are typically designed to contain runoff from a 2-year, 24-hr rainfall event and take a minimum of 48 hrs to drain (Fifield 2011). A 2-year, 24-hr storm event is defined as the maximum 24-hr precipitation event with a probable recurrence interval of once in 2 years, as defined by the National Weather Service. Since detention basins are designed to drain within a short period and there is no permanent pool, there is little opportunity for stormwater treatment beyond sedimentation. As a result, these structures are typically designed for channel protection and flood control only (City of Indianapolis 2009). According to UFC 3-210-10, “DOD discourages the construction of detention ponds.”

Pretreatment is recommended for detention basins to encourage drop-out of sediments, or in some cases, infiltration. Grassed swales, sediment forebays, and filter strips are a few acceptable options. In the absence of a permanent pool, detention basins are meant to be vegetated. Vegetation stabilizes soils in the basin, encourages sedimentation, and provides aesthetic value. Planting should be designed in a way that minimizes the need for mowing, irrigation, or pruning (City of Indianapolis 2009) Infiltration is likely to occur in detention basins that are not lined. As with retention basins, potential impacts upstream and downstream must be considered in the design of a detention basin. In anticipation of sedimentation, over-excavation can increase the design life (City of Indianapolis 2009).

Infiltration Basin

An infiltration basin is a stormwater impoundment that retains water until it infiltrates into the soil. Infiltration basins are typically built over highly permeable soils. Infiltration basins are suited for removing pollutants. Infiltration basins are not suited for managing channel erosion or controlling flooding. As a result, they are commonly designed to control the water from a 2-year design storm. Infiltration basins assist in groundwater recharge and help to reduce peak discharge (VDEQ 1999). Sediment forebays or other pretreatments options are a necessity for infiltration basins. If provisions are not made to prevent sediment, grease, and oil intrusion, infiltration basins can easily become clogged. Clogging reduces infiltration basin efficiency and eventually leads to complete failure.

Soils must have infiltration rates ranging from 0.52 in/hr up to 8.27 in/hr. Soil textures of loam, sandy-loam, and loamy-sand are typically acceptable, generally Hydrologic Soil Group (HSG) A and B soils. The bottom of the infiltration basin must also be at least 2 to 4 ft above the seasonal high water table or bedrock layer to be effective (VDEQ 1999). Infiltration basin vegetation should stabilize the basin soil and be able to survive extended periods of submergence. Since infiltration basins assist in groundwater recharge, pollutants should be monitored to minimize contamination to the water table. Additional pretreatment may be necessary to remove pollutants if contamination is a concern.

Sedimentation Basin

A sedimentation basin is a basin that is solely intended for collection of sediment. Sediment basins are often used in conjunction with other BMPs as a pretreatment to remove large particles. In this case, sedimentation basins are often referred to as sediment forebays. Sedimentation basins allow sediment to settle in an isolated accessible area (VDEQ 1999). Sediments can accumulate rapidly and require frequent clean outs. Maintenance crews should make cleaning of sediment basins and associated sediment control structures a routine task. Recommended maintenance practices that pertain to sediment basins are:

1. Sedimentation basins should be kept clear of debris.

2. Vegetation should be maintained on a monthly schedule.

3. Inspections should be done after significant rain events to determine if a major cleanout or repair is required.

4. Sediment basins should be cleaned to half their design volume to maintain effectiveness.

The size and shape of the sediment basin is determined based on conventional sediment theory. This theory uses Stokes Law to determine settling velocity for different sized particles. The size and shape is then determined based on a desired trap efficiency. Trap efficiency, the percentage of particles retained, can vary with the size of the storm. A sediment basin will retain less sediment during a large storm, which will in turn lower its trap efficiency. Proper siting, construction, and geometric characteristics should always be taken into consideration in the design process (Davis and Mccuen 2005, 274-278).

Location

The LID philosophy depends on the implementation of many small systems. This makes it important for LID practices to be applicable for both small- and large- scale projects. Bioswales and other bioretention structures are suitable for many types of developments ranging from large extensively paved areas to small single residences. In general, a bioswale will be used for contributing drainage areas of 5 acres or less and are designed to retain the first inch (or first flush) of stormwater runoff to treat. Bioswales and other bioretention structures should be placed close to the source of runoff or area of development. This reduces energy of the runoff and limits the potential for channel erosion and peak flow. There should also be ample room for maneuvering during installation and maintenance on a bioretention basin. In general, the bioretention structure should be placed over soils that are highly permeable and well drained, to encourage infiltration. If the soil is not suitable for infiltration and exhibits low permeability, further precautions should be taken, e.g., by installing an underdrain system or vertical trenching, or by modifying the soil media.

Existing topography should always be considered when placing and selecting bioretention structures. If natural grades are too steep, bioretention may not be a feasible option. Bioswales should be kept to 3:1 or gentler side slopes. The amount of flood control that a bioswale can provide depends on the volume of the bioretention structure, porosity of the media, and the permeability or infiltration rate of the native soils underlying the bioswale. If the structure is undersized, much of the runoff will bypass the structure. To increase the amount of water detained in the basin, one can increase the amount of ponding area or subsurface storage. Voids in the soil layers, such as plastic catchment systems, also provide additional storage capacity. If one were to increase the depth or cross section of the bioswale, the water storage space would increase.

The Environmental Services Division of the Department of Environmental Resources of Prince George’s County, Maryland Stormwater Management Design Manual provides guidance to bioretention site evaluation and location. Bioretention structures can easily be incorporated into both new and existing areas of development. Grading for the bioretention can be completed during construction reducing the cost of implementation. Locations receiving sheet flow upland of inlets or outfalls are also highly applicable. These include locations such as roofs, roadways, and parking lots. Natural conditions should generally not be altered, so that mature trees and other natural undulations in the topography are maintained.

Bioretention

Bioretention allows for stormwater to be treated where it is produced, as opposed to traditional end-of-the-pipe stormwater management. This is achieved by setting aside areas for stormwater to be treated naturally by a combination of vegetation, mulch, and soil. Runoff is treated by physical, chemical, and biological processes commonly associated with plants, micro-organisms, and soils (Prince George's County, Maryland 2007) These control measures are commonly known as rain gardens or bioswales. This is the most cost effective option if the site conditions, such as water table, soil, vegetation are suitable (NAVFAC 2004).

Bioretention structures, which can vary in size, can be designed to collect and treat runoff from a very large impermeable area. Natural low permeability soils can be amended with porous media and planted with various grasses, shrubs, and trees. Vegetation is a key element to the concept of bioretention. Vegetation promotes evapotranspiration, soil porosity, biological activity, and pollutant uptake (Davis 2005). Bioretention structures have two basic designs, systems with and without underdrains. An underdrain is installed in a bioretention structure when the base soil has a low rate of infiltration, when the water is to be collected for reuse, or if required, to meet high levels of stormwater runoff rates.

Design Options

Use of the Army's new LID Planning Tool (January 2013) or the Environmental Services Division of the Department of Environmental Resources of Prince George's County, Maryland would result in several different applications of bioretention structures (Prince George's County, Maryland 2007)

Developed Areas

1. **Curbless Parking Lot Perimeter**. This low cost design is located adjacent to shallow graded parking lots. Runoff flows directly into the structure. Grass buffer is recommended to dissipate sheet flow.

2. **Curbed Parking Lot Perimeter.** In this area, water is diverted into bioretention structure by curb and gutter. When entering the bioretention structure, concentrated flow must be dissipated through buffer or other options.

3. **Parking Lot Island and Median**. Stormwater here is diverted into medians or parking islands for bioretention.

4. **Swale-side**. Water flowing in a ditch or swale is diverted into this bioretention structure. When the structure is full, water bypasses the system and drains directed into the swale invert. This system is typically designed with an underdrain connected to the swale invert. This is the design approach used for the Fort Hood Demonstration

Small-scale Bioretention

1. **Landscaped Garden.** Landscaped Gardens, typically referred to as "rain gardens," are areas planted in a depressed area to collect flow and allow ponding.

2. **Shallow-Dish Design**. This scalloped area in a small graded lot may include an underdrain for enhanced hydraulic capabilities.

3. **Tree and Shrub Pits**. These “pits” are actually depressed areas around trees or shrubs that allow for ponding. Mulch is built up around plants, but is cut away in unoccupied areas. Care should be taken with this approach to reduce potential for “smothering” tree roots and associated root girdling of the tree.

4. **Sloped Weep Garden**. In sloped areas, sheet flow that comes down the slope is intercepted and infiltrated by the weep garden. On the downhill side, filtered flows slowly seep out of a retaining wall.

Bioswale Benefits: Water Quality

Water quality is enhanced in a bioswale through physical, chemical, and biological processes. Some of these key processes are:

1. **Sedimentation.** Sedimentation occurs when particles settle out of the water, reducing the amount of suspended pollutants and improving water clarity. This process often occurs in pretreatment structures where the velocity is greatly decreased.

2. **Filtration.** Pollutant-laden runoff percolates through a filter medium, where pollutants adhere to the medium and are made biologically available to microbial community within the mulch layer. This encourages bioremediation of the pollutants through assimilation.

3. **Adsorption.** Adsorption refers to the adhesion of pollutants to surfaces inside of the bioswale.

4. **Ion Exchange.** Ion exchange is a process in which an ion in a solution is exchanged with a similarly charged ion bonded to a solid surface.

5. **Volatilization.** Volatilization converts a liquid or a solid to a gaseous phase by applying heat or reducing pressure.

6. **Assimilation.** Pollutant uptake by soil flora or soil fauna is called “Assimilation.”

7. **Chemical Degradation.** The breakdown of chemical compounds by soil flora or soil fauna is termed “chemical degradation.”

8. **Organic Decomposition.** The breakdown of organic compounds by soil flora or soil fauna is termed “organic decomposition.”

Bioswale Benefits: Water Quantity

Water Quantity is managed in bioswales by controlling peak flow and reducing runoff volume. Some key processes for managing water quantity are:

1. **Infiltration.** Infiltration refers to the process of water moving into the soil.

2. **Percolation.** The process of water passing through pervious media, which occurs after infiltration, is called "percolation."

3. **Groundwater Recharge.** Groundwater Recharge refers to the addition of water to the saturated zone.

4. **Evaporation.** The process of evaporation occurs when liquid water is converted to water vapor.

5. **Transpiration.** Water vapor is released into the atmosphere by living organisms by transpiration.

6. **Evapotranspiration.** Evapotranspiration refers to the sum of evaporation and transpiration.

7. **Drainage.** The systematic withdrawal of water from the surface or subsurface is called "drainage."

8. **Ponding.** Ponding occurs when water is temporarily detained above the bioswale awaiting infiltration or drainage.

APPENDIX B

Demonstration and Implementation of a Bioswale at Fort Hood, TX

Background

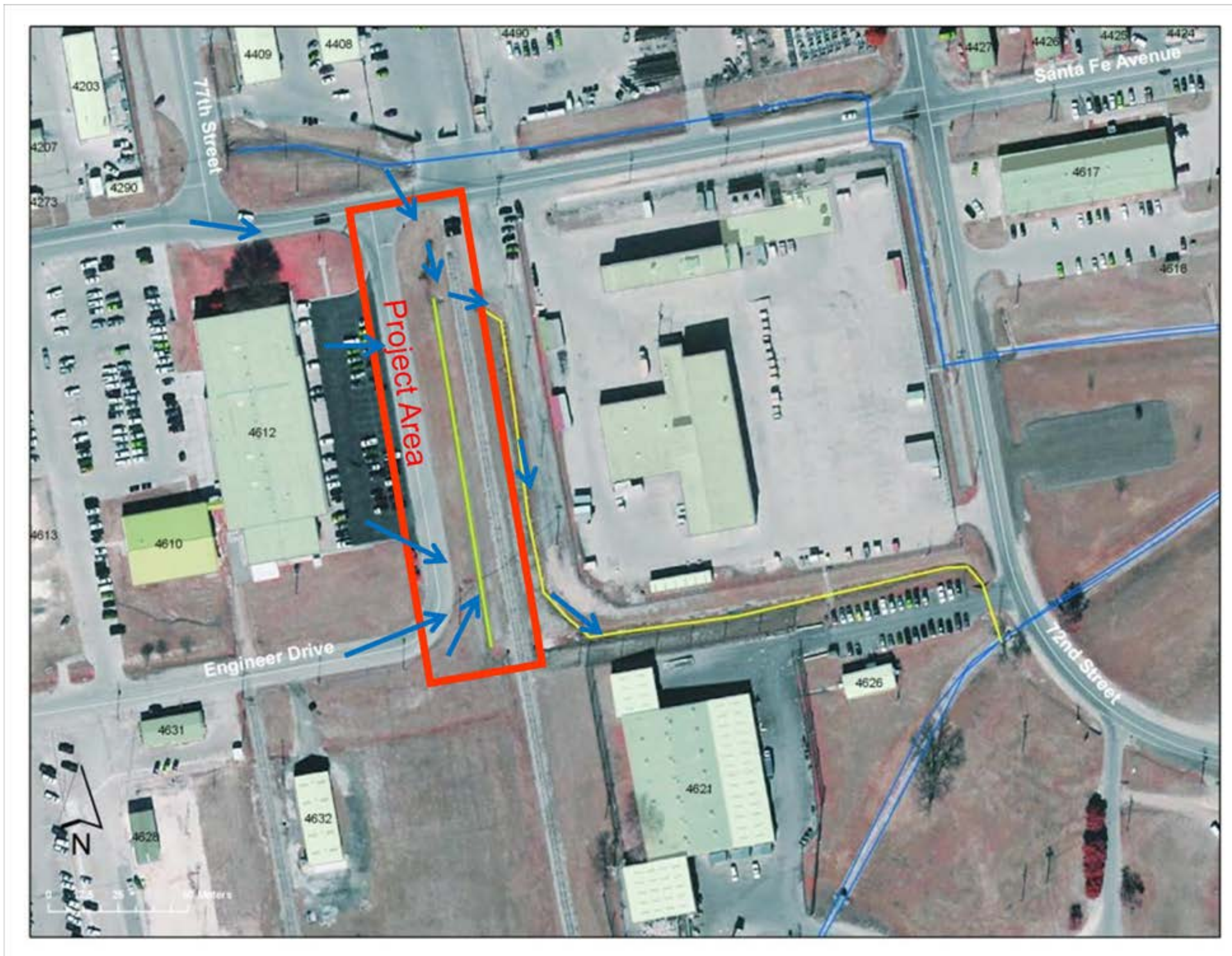
The Fort Hood Directorate of Public Works Office (DPW) expressed interest in demonstrating stormwater quality retrofits to an existing traditional drainage system. Due to the nature of Fort Hood's scope of activities, scale of operations, overall footprint, and native soils, they have many unique challenges for stormwater management. Historically, detention basins and extensive drainage conveyance systems have been used to control and remove stormwater. However, the benefits of these systems reach little beyond the temporary containment or relocation of stormwater. An alternative is the use of bioswales or bioretention structures. These structures are a site design strategy using biological and physical systems to achieve maximum infiltration to reduce flooding and to help meet water quality standards.

Bioswales are designed to mimic natural hydraulic conditions that maximize infiltration and reduce peak flow. Bioswales, if strategically implemented, can facilitate infiltration of stormwater into the soil, help replenish groundwater, AND reduce total stormwater runoff while meeting the requirements of Executive Orders 13418, 13423, 13514, DOD Directive 4700.4, and/or NPDES permits. Additionally, they have been shown to decrease the effects of urban heating and to provide remediation/reduction of pollutants.

ERDC-CERL and Fort Hood demonstrated the use of a designed bioswale in 2012, to assess the implementation, cost, performance, and environmental benefits of the structure. The project provided DPW staff a tangible demonstration of the BMP installation and maintenance, and of the cost benefits of using bioswales as a stormwater management practice. This effort used an area located near the DPW-Environmental and Engineering Offices at Fort Hood. By implementing and adopting the latest stormwater management technologies at this site, the participants aimed to develop and transmit a better understanding of a LID bioswale to encourage and facilitate their use at Fort Hood and other Army installations with low permeability soils.

Site Description

Figure B-1 shows the location of the demonstration. The site used an existing large grass drainage ditch, east of the DPW-Engineering parking lot, and located between a railroad spur and Engineer Drive. The grass drainage ditch was the outfall for a 5-acre drainage area consisted of asphalt parking lots, paved streets, and stormwater ditches. Runoff from the west parking lots and streets drained first into a system of two curb inlets, then through two 24 in concrete culverts. Runoff from the streets and drainage ditches, which ran along the north side of the site, was conveyed through two 18-in culverts system to the grass drainage ditch outfall.



Source: Google Earth

Figure B-1. Project Area (blue arrows delineate original flows).

The DPW office is located in an approximate 11-acre sub-basin with downstream discharges located on the west side of the railroad embankment. The existing ditch received drainage from approximately 5 acres of the 11-acre sub-basin. Most of the

5 acres are impermeable parking lots, streets, and buildings with limited permeable areas. Traditional methods to improve existing stormwater structures would significantly affect parking space. Therefore, it was important that the stormwater management systems not reduce parking space after installation. To maintain parking space, any new stormwater management faculties would need to be located underground or at an off-site location. Underground systems are generally expensive. An off-site system was selected to reduce costs and to avoid potential impacts on existing parking lots. A vegetated bioswale was chosen as an appropriate management method.

Soil boring data from a 2007 geotechnical investigation (Westin 2007) at geothermal fields 100 yds from the proposed site were used to describe the soil at the demonstration site. Boring logs indicated that the site is dominated by sandy lean clay. Sandy lean clays have minimal hydraulic conductivity in the range of 1.19×10^{-2} to 2.0×10^{-2} in/hr. Since soils with low hydraulic conductivity do not provide a sufficient infiltration rate, the demonstration bioswale was equipped with a subsurface drainage system. The bioswale media requirement was also specified to be at least 1.51 in/hr and not to exceed 5.0 in/hr of infiltration. These requirements meant that significant testing of an engineered filter media before and after installment were required in the bioswale.

Installation Overview

The project successfully demonstrated the feasibility of a bioswale at Fort Hood. The following sections describe the general process used to install the bioswale.

Erosion Control

Erosion control plans were developed before work began. The purpose of these plans was to comply with all environmental laws and regulations, and Fort Hood programs. BMPs included such practices as phasing work to reduce the potential for off-site runoff and installing temporary diversion pipes for contributing culverts, riprap check dams at outfalls, silt fencing, and fiber coir sediment logs around soil stockpiles. Additionally, safety barriers and safety fencing were used. Care was taken to ensure that nearby property was not damaged and impacts from the installation were limited to only the area of concern.

Site Development

Using standard BMPs, the site was cleared and graded to remove existing debris and vegetation. Top soil was stored for final dressing of the bioswale to ensure quality soil for successful vegetation establishment. Subsoil was tested for infiltration rate and failed to meet the requirements. The subsoil was removed and used at another site on Fort Hood. Excavation depths in bioretention Basin 1 (North) ranged from 3-3.5 ft while they ranged from 5 to 8.25 ft in bioretention Basin 2 (South) (Figure B-2). Overflow outlets and spillways were adjusted to 3.5 ft above the final grade of each basin to prevent safety hazards and to reduce the potential for plant death due to standing water during extensive periods of rainfall.

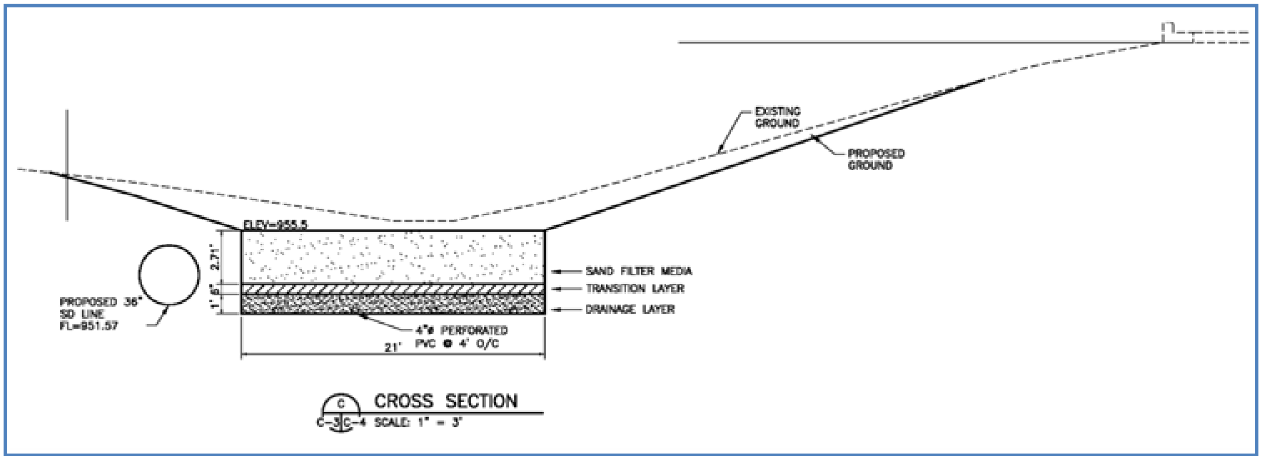


Figure B-2. Cross section of bioswale showing subsurface drainage and filter media layers.

For both bioretention basins within the bioswale area, netted wood fiber erosion control blankets were used on slopes with turf reinforcement mats at each of the contributing inlets. Additionally, scour pads were installed at the base of the north Santa Fe inlet and on the inlet from the DPW parking lot and Engineer Drive. Wire-wrapped riprap check dams at the top (north end) of each bioretention basin floor were installed. The scour pads, turf reinforcement mats, and riprap check dams were installed to reduce stormwater velocity, to provide minimal settling time to drop suspended materials from stormwater, and finally, to reduce potential for erosion of the bioswale media and side walls.

Drainage

A storm drainage, underdrain system was installed per bioswale design (See Figures B-3 and B-4). A series of drainage pipes (perforated PVC) were installed within the base of the bioretention basins with a 1-1.5% pitch and placed on non-woven geotextile with a sand base to ensure long-term drainage. The geotextile limits soil migration and prevents soil entering into the under-drainage system and filter media (Figure B-5). Each underdrain system had a level control device installed to allow for control of the water levels within each bioretention basin.

Figure B-3. Bioswale trench excavation.

Figure B-4. Subsurface drainage system of perforated pipe installed.

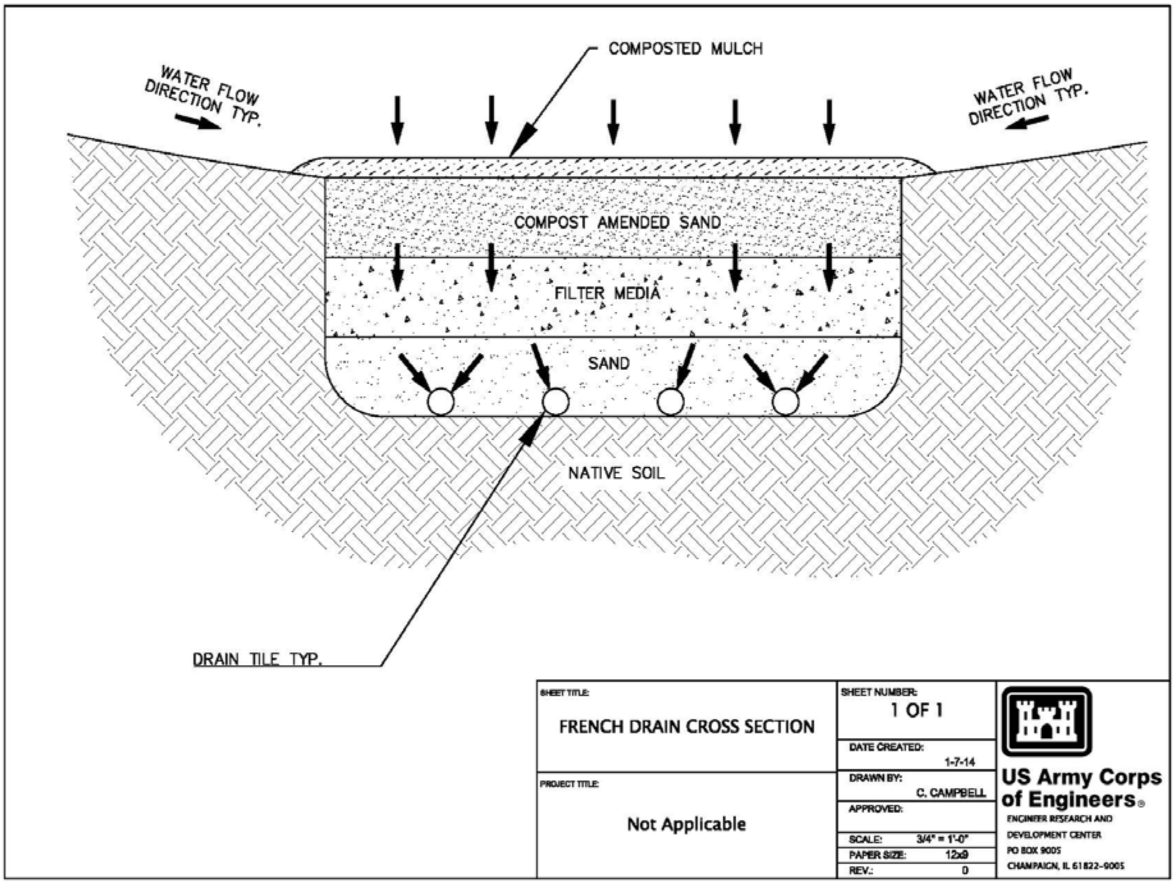


Figure B-5. Cross section of subsurface drainage system.

Filtration Media

New infiltration media, sand, was brought in to meet the minimal 1.51 in/hr hydraulic conductivity requirements and averaged 4.5 in/hr when tested. The filter media was installed over the underdrain systems at a depth of 24 in. Once installation of the filter media was complete, the demonstration area was finish-graded to create a smooth condition for planting and landscaping. A temporary, non-woven geotextile was installed as a cover of the filter media between the final grade and installation of compost, mulch, and final landscaping.

For final landscaping, nutrient rich compost was added and worked into the top 8 in of the infiltration media. The compost was added to amend the high sand infiltration media. Compost will provide increased nutrients, water retention, microbial activity, and enhanced bioremediation of contaminants. The compost amended sand was then topped with an 18- to 24-in layer of high quality composted shredded hardwood mulch. Species native to Fort Hood were transplanted in 1- and 3-gallon transplants, set in groupings of 3-15 with 18 in offset spacing.

Grass species used included:

- Indian Grass (*Sorghastrum nutans*)
- Upland Switchgrass (*Panicum virgatum*)
- Big Muhly (*Mulenbegia lindheimeri*)
- Little Bluestem (*Schizachyrium scoparium*)

Forb species used included:

- Firewheel (*Gaillardia pulchella*)
- Blackfoot Daisy (*Melamcodium leucanthum*)
- Engelmann Daisy (*Engelmannia peristenia*)
- Victoria Blue Sage (*Salvia farinacea* ‘Victoria’)
- Black Sampson Echinacea (*Echinacea angustifolia*)

Biologic Filter Media

Key features of Bioretention Basin 1 (shown in Appendix E) are:

1. Fourteen linear feet (LF) of existing 24-in reinforced concrete pipe (RCP) were removed. A 4x4-ft drop inlet was installed to serve as an emergency spillway.

2. A 77 LF, 12-in PVC line, Line A, was installed at 0.7% gradient. This line passed under the railroad tracks and required boring. Seven 4-in slotted PVC underdrains were connected to the 12-in line on 4-ft centers with length as noted in the design plan.

3. Two (2) 4x4-ft scour mats were placed at each of the two existing headwalls. This was accompanied by 192 SF of turf reinforcement matting and 15 yd^3 of washed gravel and riprap filter berm as shown in design plans.

Key features of Bioretention Basin 2 (shown in Appendix E) are:

1. An existing headwall structure and drop structure were removed. A 4x4-ft junction box was installed.

2. An 85 LF, 36-in High Density Polyethylene (HDPE) line, Line B, was installed at a 1.7% gradient connecting to the new 4x4-ft junction box and drop inlet.

3. A 34 LF, 12-in PVC was installed at a grade of 1% and connected to the new junction box. Seven 4-in slotted PVC underdrains were connected to the 12-in line on 4-ft centers with length as noted in the design plan.

4. Bioretention Basin 2 also included the installation of a 5-ft curb inlet and box, 27 ft of 24-in RCP and headwall (and removal of 11-ft of existing 24-in RCP and headwall as described in the design plans).

5. Sixty-five SF of inlet scour protection was placed at outlet of RCP and headwall, accompanied by 505 SF of turf reinforcement matting and 14 CY of washed gravel and riprap filter berm as shown in design plan.

6. The 4-in underdrain was covered with a 12-in layer of pea gravel to serve as a drainage layer followed by a layer of geotextile. Next, a layer of washed sand was put down to serve as a transition layer with a 6-in maximum thickness tapering at 0.5% to 0-in thickness at the upstream north end of the filter media.

Filter Media Design and Testing Overview

Since the soil excavated from the site did not meet the minimum soil characteristics for infiltration rates, the contractor amended the soil so that the final amended soil met the following criteria:

1. Filter media should have a hydraulic conductivity of no less than 1.51 in/hr and to not exceed 5.0 in/hr. Final test results averaged 4.5 in/hr infiltration rate.

2. Soil pH should be between 6 and 7, and salt content less than 19 mg/kg.

3. Filter media should have combined clay and silt fraction of less than 12% to ensure soil strength to reduce potential for collapse.

4. Filter media should be capable of supporting vegetation, i.e., they should not be composed of a pure washed sand.

5. Filter media must be free of fire ants and other invasive species.

Lessons Learned

After the bioswale was installed and allowed to properly operate for over a year, it was evaluated and a detailed list of the lessons learned on a project of this scope were compiled:

1. On projects that include the evaluation of the current infiltration media, soil borings and laboratory analysis will be required. It is recommended that this effort employ a contractor with the proper boring equipment and skills, who will perform laboratory testing of soil characteristics (sieve analysis, Atterberg Limits, etc.), and who will submit a full geotechnical report of hydraulic conductivity, soil type, and particle size per COE specifications(Figure B-6). This evaluation should be done to identify the amount of soil mixing and the type of soil that must be used before a contractor is awarded the project. For bidding and award purposes, it is also valuable to note where unsuitable material could or must be disposed. In a high-plastic clay environment, the contractor might have to bid for the removal of that material from the site, or from the Base/Post.

2. Before awarding the project to a contractor, it is important to identify the biofiltration media to be used. This is essential to the performance of the bioswale. It is also important that the contractor be notified how much outside material will be required on the project site, so that an appropriate bid can be made.

3. To supplement the biofiltration media it is recommended that a top dress of mulch should be used. It is important to use quality mulch, which may cost more initially, but will be beneficial in the long-term. Mulch also plays an important role in retaining moisture for the newly planted vegetation, limiting the growth of unwanted plant species, as well as remediating contaminants such as petroleum, oils, and lubricants. A minimum mulch depth of 12 to 18 in should be used. This demonstration placed 18 to 24 in of top-dressed mulch.

4. Installation Landscape Managers are cautioned to instruct contractors NOT to mulch the bioretention area when they are mulching other base areas. Low quality mulch added on top of the existing mulch will seriously compromise the beneficial effects of the biofiltration media system.

5. On a project that involves increasing infiltration, it is also important to reduce compaction caused by heavy equipment. Equipment such as bulldozers and hydraulic excavators are typically large and heavy and can remove a great many air voids. Loss of air voids significantly decreases hydraulic conductivity and reduces bioswale performance. It is important to train heavy equipment operators on the need to reduce compaction by keeping the amount of earthwork to a minimum. This will benefit the project by reducing the amount of tracking, which will in turn reduce compaction.

Figure B-6. Bioswale infiltration testing.

6. It is also important to keep the design of a bioswale as simple as possible. This not only keeps the cost low, but also minimizes the amount of earthwork and reduces long-term maintenance.

7. Erosion control practices will sometimes need to be adjusted. Significant rainfall events will likely occur before the bioswale vegetation is well established, and may cause erosion control BMPs that have not had sufficient time to “settle in” to fail. Heavy rainfall may create problems with newly installed features that may then require replacement and/or repair. For example, after a storm at this site that exceeded the 25-year, 24-hour precipitation event, riprap check dams

had to be adjusted by adding larger stone and extensions to the front apron and the tail ends. Additionally, the riprap aprons at the outlets and inlets needed additional riprap and replacement of erosion control blankets.

8. Establishment of vegetation is essential in a project of this scope. First, it is critical to select appropriate plant species. Species should be:

   a. Adapted to the environment in which they are to be placed.

   b. Capable of tolerating long periods of submersion (24 hrs) and extended periods of drought work best in bioswales.

   c. Able to remediate contaminated stormwater runoff. Species that can phytoaccumulate or phytoremediate are desirable.

   d. Characterized by their extensive rooting systems. Such rooting systems increase plant uptake and evapotranspiration, and help with stormwater infiltration.

   e. Identified with the proper growth habitat to avoid overcrowding, and excessive maintenance.

   f. Selected for their visual appeal, functionality, and low maintenance.

   g. Selected to avoid non-native invasive species, which should not be planted per the DA SDD policy memo (December 2013)

9. Maintenance is very important when establishing a bioswale. It is important that the maintenance crew be aware of the function of the bioswale. The maintenance crew should ensure a bioswale’s function by keeping out debris and undesirable plant species, and by monitoring the system for clogs. The most critical maintenance period is during the first 2 years of implementation. During the first year of implementation, it is important to have a supplemental watering system to help establish desired plant species. Also, the site should not be mowed for the first year. Mowing encourages undesirable species and stresses newly planted species. Place “No Mowing” signs around the site where mowing should not occur short-term and long-term. Weed control is important to the maintenance of this structure to control unwanted plant species, which may compete with desired species. It is important to “work” the mulch yearly to keep it from becoming compacted or crusted over by sediment, which will allow undesirable species to grow in the mulch. During the establishment of the bioswale, it is

also important to re-seed the area surrounding the bioswale to reduce potential side-wall erosion.

Figures B-7 and B-8, respectively, show swales before and after improvement.

Figure B-7. Swale before improvement.

Figure B-8. Swale after improvement.

APPENDIX C

Regulation Background

Many regulations do not necessitate the implementation of LIDs specifically, but regulatory bodies have understood the importance of preserving the pre-construction hydrology. Many regulations aim to control pollutants carried by stormwater, while others are intended to change the rate at which conveyance systems discharge stormwater. Some LID options have been chosen to assist in achieving both of these goals. The following sections discuss regulations that installations across the nation must follow. Note that each installation will have its respective state and local regulations in addition to those described in the following sections.

Clean Water Act

The CWA is the Federal policy pertaining to how Army training lands are to be managed with regard to the protection of US water quality. The following paragraphs describe CWA Sections that specifically concern stormwater management.

Section 303: Water Quality Standards and Implementation Plans

Section 303 contains regulations stating that states shall identify waters within its borders for which effluent limitations are not stringent enough to implement water quality standards. The state must establish a priority ranking in accordance with the severity of the pollution and the waters intended use (CWA 2002).

Section 311: Oil and Hazardous Substance Liability

It is the policy of the United States that there should be no discharges of oil or other hazardous substances into or upon navigable waters. Section 311 also provides the authority to generate a program that teaches how to prevent, contain, and respond to pollution that could contaminate US waters. The goal is to ensure that structures provide a place for containment, or that they take other countermeasures to ensure that oil does not reach navigable waters.

Section 319: Non-point Source Management Program

The regulation of NPS is delegated to the states. The Governor of each state must submit a State Assessment Report and must develop a State Management Plan. This program also provides grants to states for the implementation of the management plans.

Section 402: National Pollutant Discharge Elimination System Program

The discharge of contaminants from point sources is forbidden unless authorized by a NPDES permit. Permits can be attained by the NPDES by implementing BMPs to reduce or prevent discharge into navigable waters. Under the CWA Stormwater Phase II rule, many DoD structures are required to receive a NPDES permit for stormwater (NAVFAC 2004).

Army Regulation 200-1

AR 200-1 outlines environmental policies and designates program requirements to comply with Federal policies. Chapter 4, Section 2, subsection e. ("Wastewater and stormwater*")* outlines the policy for water resource management. One policy delineated in this section is to control or eliminate sources of pollution to avoid contamination of water bodies or groundwater. Another policy is to employ abatement measures for non-point source runoff from structures, construction, and land management activities. Program requirements include obtaining specified permits and creating a Stormwater Management Plan and a Stormwater Pollution Prevention Plan (HQDA 2007).

Department of the Navy "LID Policy"

The DoN wrote a "Low Impact Development Policy" that recognized that construction leads to erosion, loss of natural vegetation and drainage, and an increase in stormwater runoff. The DoN also recognized the failure of conventional stormwater collection and conveyance units to replicate natural systems. Conventional stormwater units such as retention basins lack natural ground infiltration, which leads to an increase in stormwater and nutrient loadings in streams and wetlands. In 2007, the DoN set a policy with the goal to eliminate any increase in stormwater runoff and nutrient and sediment loading due to renovation and construction projects. The policy recommended LID as a way to achieve this goal (DoN 2007). If a site is deemed inappropriate for the implementation of LID, it must go through a waiver process where the site will be reviewed and approved by a regional engineer (DoN 2007).

EISA 2007

EISA 2007, Section 438 ("Stormwater Runoff Requirements for Federal Development Projects") contains policy establishing a set of requirements for stormwater runoff for Federal developments and redevelopments. The act states that “[t]he sponsor of any development or redevelopment project involving a Federal structure with a footprint that exceeds 5,000 sq ft shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow” (EISA 2007).

EO 13148

Section 204 of EO 13148 aims to lessen the amount of pollutant released from various Army agencies. The goal is for agencies to reduce their Toxic Release Inventory (TRI) by 10% annually, or 40% overall. Section 304 mandates that each agency must develop a pollution prevention program at their structures that would compare the lifespan costs of traditional waste removal to an alternative option’s lifespan cost where the reduction of chemicals and pollutants happens at the source. To execute these goals, EO 13148 requires each agency to write an environmental management strategy showing that the goals and requirements of this order are incorporated into their environmental directives, policies, and documents (White House 2000).

EO 13423

Section 2 of EO 13423 states that one goal for the agency is to reduce water consumption by the year 2008 to the baseline level of water consumption in the year 2007. After 2007, the goal is to reduce the consumption by 2% annually by the year 2015, or by an overall 16% reduction by the year 2015. Another goal is to ensure that agencies reduce toxic and hazardous chemicals in terms of use and disposal (White House 2007).

EO 13514

EO 13514 mandates Federal agencies to maintain and operate high performance sustainable buildings following the Guiding Principles for Federal Leadership. Federal agencies are required to reduce potable water consumption (relative to 2007) 2% annually though the end of 2020 or 26% by the end of 2020. They must also reduce industrial and agricultural water consumption (relative to 2010) by 2% annually through 2020, or 20% by the end of 2020 (Young Undated).

APPENDIX D

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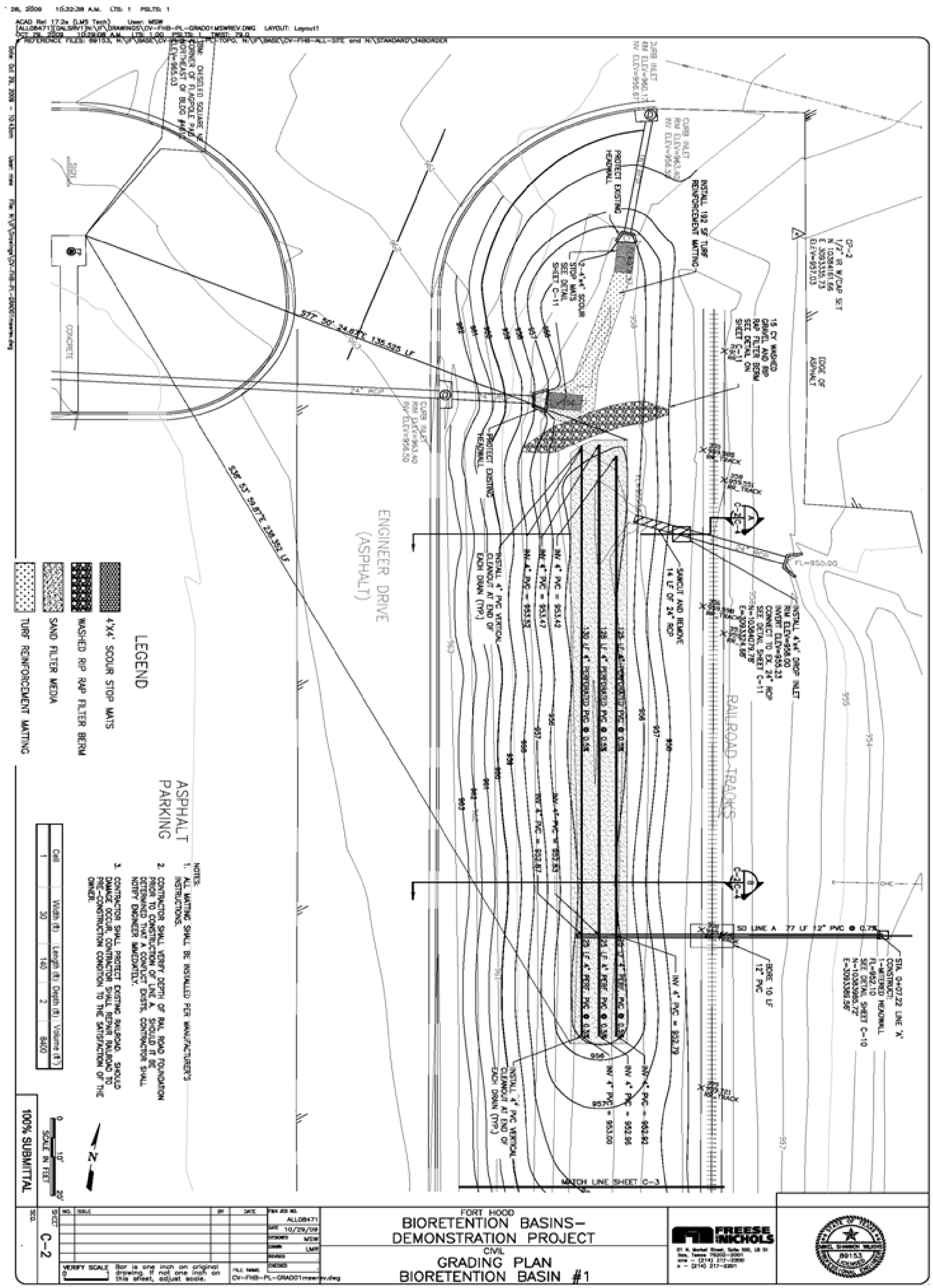
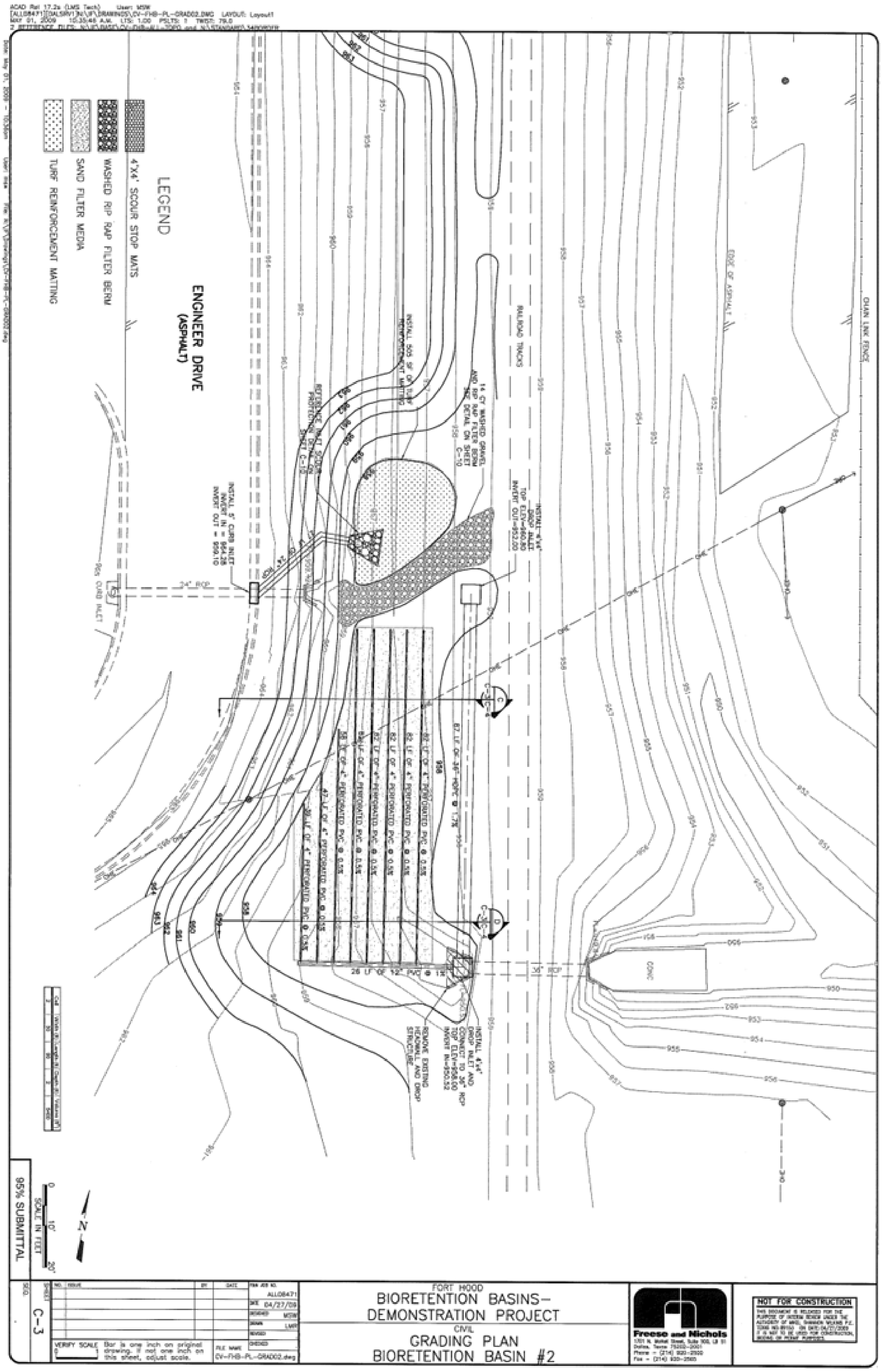
APPENDIX E

Grading Plans and Layouts




LEGEND
4'X4' SCOUR STOP MATS
WASHED RIP RAP FILTER BERM
SAND FILTER MEDIA
TURF REINFORCEMENT MATING
ENGINEER DRIVE
(ASPHALT)
RAILROAD TRACKS
EDGE OF ASPHALT
CHAIN LINK FENCE
SCALE IN FEET
95% SUBMITTAL
NOT FOR CONSTRUCTION
Freese and Nichols
FORT HOOD
BIORETENTION BASINS–
DEMONSTRATION PROJECT
CIVIL
GRADING PLAN
BIORETENTION BASIN #2
C-3

APPENDIX F

Acronyms and Abbreviations

Term	**Definition**
AR	Army Regulation
BMP	Best Management Practice
CECW	Directorate of Civil Works, US Army Corps of Engineers
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CEMP	Directorate of Military Programs, US Army Corps of Engineers
CERL	Construction Engineering Research Laboratory
CONUS	Continental United States
CWA	Clean Water Act
DA	Department of the Army
DoD	US Department of Defense
DoN	Department of the Navy
DPW	Directorate of Public Works
EISA	US Energy Independence and Security Act of 2007
EO	Executive Order
ERDC	Engineer Research and Development Center
HDPE	High Density Polyethylene
HQUSACE	Headquarters, US Army Corps of Engineers
HSG	Hydrologic Soil Group
LID	Low Impact Development
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
OCONUS	outside continental United States
PDF	Portable Document Format
POC	Point of Contact
PWTB	Public Works Technical Bulletin
RCP	Reinforced Concrete Pipe
SES	Senior Executive Service
URL	Universal Resource Locator
US	United States
WBDG	Whole Building Design Guide
WWW	World Wide Web