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Lessons Learned From the Design of a Bioretention Area to Treat Storm Water Runoff

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LESSONS LEARNED FROM THE DESIGN OF A BIORETENTION AREA TO TREAT STORM WATER RUNOFF

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ABSTRACT

The California Department of Transportation (Caltrans) has initiated a number of pilot projects to assess the performance and applicability of various storm water "green" Best Management Practices (BMPs). Green BMPs include vegetated swales and filter strips, constructed treatment wetlands, wet detention basins, and bioretention areas. One pilot project includes a 3-year study to design, construct, and investigate the water quality performance of a bioretention area BMP. In general, bioretention areas are soil and plant-based storm water treatment systems developed in the late 1980s in Prince George's County, Maryland. Pollutants are removed through biological and physical processes. To date, little performance data has been documented.

The pilot site is located in Southern California along State Route 73. The BMP is an on-line system with a drainage area of approximately 1.6 ha (4.0 ac). The BMP includes two pretreatment devices to help remove litter and sediment. Storm water runoff is ponded to a depth of 150 mm (6 in). The ponding area will be planted with Creeping Wildrye, Salt Grass, Mexican Rush, and Clustered Field Sage. The bioretention area consists of a 75 mm (3 in) organic layer, a 1.2 m (4 ft) planting soil layer, a 0.3 m (1 ft) sand layer, and a 0.3 m (1 ft) gravel layer with a PVC underdrain system. The BMP will be installed with automated samplers at influent and effluent points. Water quantity and quality data from flow-composite samples of storm water runoff will be collected and evaluated during representative storms over a 3-year period.

The BMP incorporates design recommendations from available literature on sizing, configuration, and vegetation selection. However, deviations in design were necessary to fit within the existing basin footprint. Additionally, the design included cooperation with U.S. Fish and Wildlife Service, California Department of Fish and Game, California Department of Health Services, and a Native American Tribal Council. This paper describes the siting and design efforts for the bioretention BMP in the Western United States. The discussion focuses on the application of the bioretention concept within the transportation environment and the deviations from standard design guidance required.

INTRODUCTION

Over the past six years, California Department of Transportation (Caltrans) has initiated a number of pilot projects to assess the performance and applicability of various proprietary and non-proprietary storm water BMPs. In the fall of 1998, Caltrans initiated a 3-year pilot project in Southern California that included the design, construction, and monitoring of various storm water "green" BMPs. These green BMPs include vegetated swales and filter strips, and a wet detention basin. In addition to the investigation of these green BMPs, Caltrans has recently initiated a study to design, construct, and investigate the water quality performance of a bioretention area BMP.

The objectives of the pilot study include: documenting the design, construction, and maintenance costs; documenting maintenance requirements; and conducting influent and effluent water quality monitoring to investigate the performance of the BMP.

A bioretention area is a soil and plant-based storm water treatment BMP developed in the late 1980s in Prince George's County, Maryland. In general, the water quality volume (WQV) is ponded to a depth of 6 inches within a basin that contains plants and an organic mulch layer. The ponded water infiltrates through an organic mulch layer and a planting soil layer, and into the in situ material underlying the bioretention area or into an underdrain collection system. Pollutants are removed through biological and physical processes. The soil is designed to adsorb heavy metals, nutrients, and hydrocarbons. The microorganisms in the soil are intended to cycle and assimilate nutrients and metals and degrade petroleum-based solvents and other hydrocarbons. Additionally, the planting soil filters the larger particles that do not settle out in the pretreatment area located upstream of the BMP.

SITING AND DESIGN

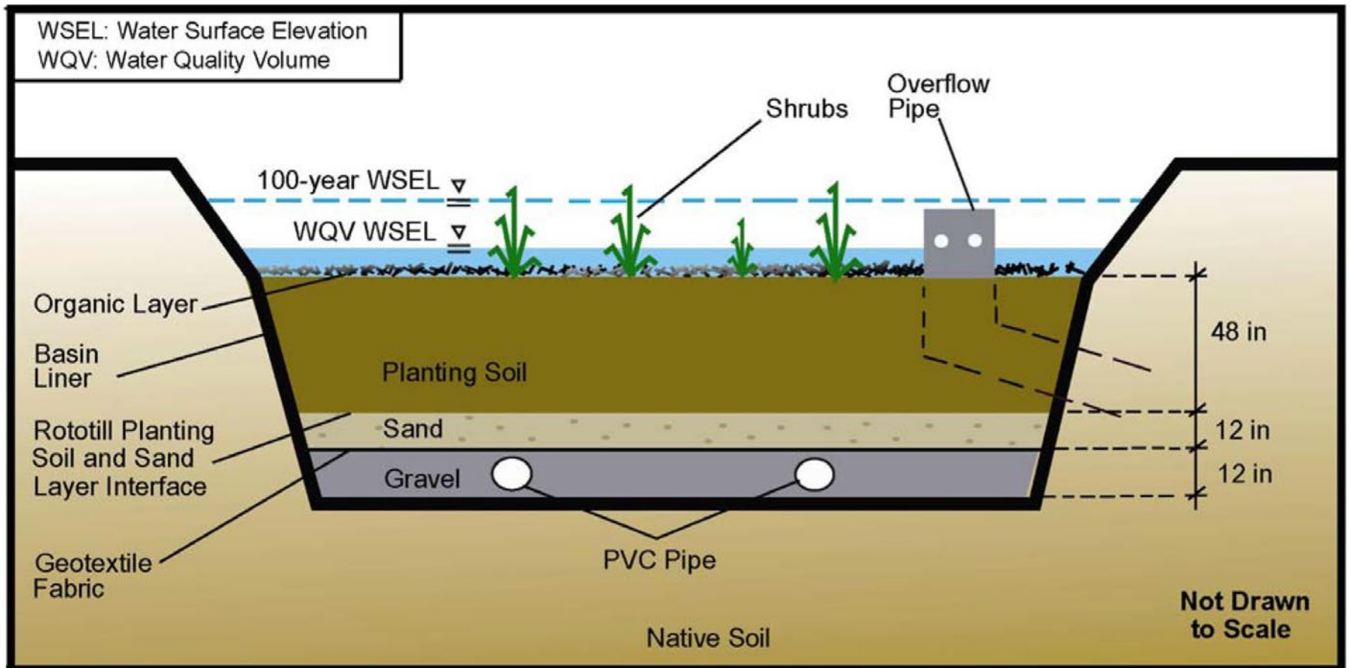
The pilot project included the following four general steps: (1) literature search; (2) siting of the BMP; (3) hydrologic and hydraulic modeling; and (4) design of the BMP. The purpose of the literature search was to identify design guidance in current use by practicing engineers. Design guidance from the Center for Watershed Protection (CWP) was selected for this project (Claytor, 1996). The CWP design guidance was selected because it provides details on the individual design components of the bioretention BMP for storm water treatment. The CWP design guidance was partially adapted from Prince George's County, Maryland (PGCM) Design Manual for the Use of Bioretention in Stormwater Management (PGCMDER, 1993). Siting for the BMP consisted of applying siting criteria from the design guidance to various candidate sites to select a preferred site. Once a preferred site was selected, hydrologic and hydraulic modeling was conducted to simulate peak inflows, inflow hydrographs, peak outflows, and outflow hydrographs. During the modeling process, the design guidance was applied to the preferred site to generate the bioretention BMP design. Plans and specifications were prepared in accordance with Caltrans standard protocols.

Original Design and Revised Design

The original bioretention design consists of the following components: (1) pretreatment, (2) ponding area; (3) organic layer; (4) planting material; (5) planting soil; (6) sand bed; (7) underdrain collection system; and (8) bypass structure (Claytor, 1996). Figure 1 presents a cross-section of the bioretention BMP, designed according to the original design guidance (Claytor, 1996), along with a summary of the design components. Figure 2 presents a plan view of the bioretention BMP, designed according to the original design guidance (Claytor, 1996).

During the completion of the bioretention design, PGCM updated its 1993 design guidance manual for bioretention BMPs (PGCMDER, 2002). There are a number of changes between 1993 design guidance manual and the 2002 design guidance manual. One of the key issues addressed in these updates was premature clogging observed in a number of full-scale installations. After thorough evaluation of the new design criteria and discussion with PGCMDER staff, the decision was made to redesign the Caltrans bioretention BMP to reflect the updated design guidance from

PGCM. Figure 3 presents a cross-section of the redesigned bioretention BMP, designed according to the revised design guidance (PGCMDER, 2002), along with a summary of the changes between the revised design guidance and the original design guidance. In general, the changes involve removing the sand bed, modifying the soil mixture, and reducing the planting soil depth.



Design Summary

Site:	drainage area = 4.0 ac
Pretreatment:	bioswale= 49.2 ft long litter removal device
Ponding Area:	depth = 6 in surface area = 0.2 ac
Organic Layer:	3 in of shreded hardwood mulch or chips
Planting Material:	Creeping wildrye, Salt grass, Clustered field sedge, Tall umbrella sedge, Mexican rush, brown-headed rush
Planting Soil:	depth = 4 ft
Sand Bed:	depth = 12 in
Underdrain Collection system:	gravel depth = 12 in PVC pipe = 6 in diameter, perforated

Figure 1 Cross Section and Summary of Original Bioretention Design

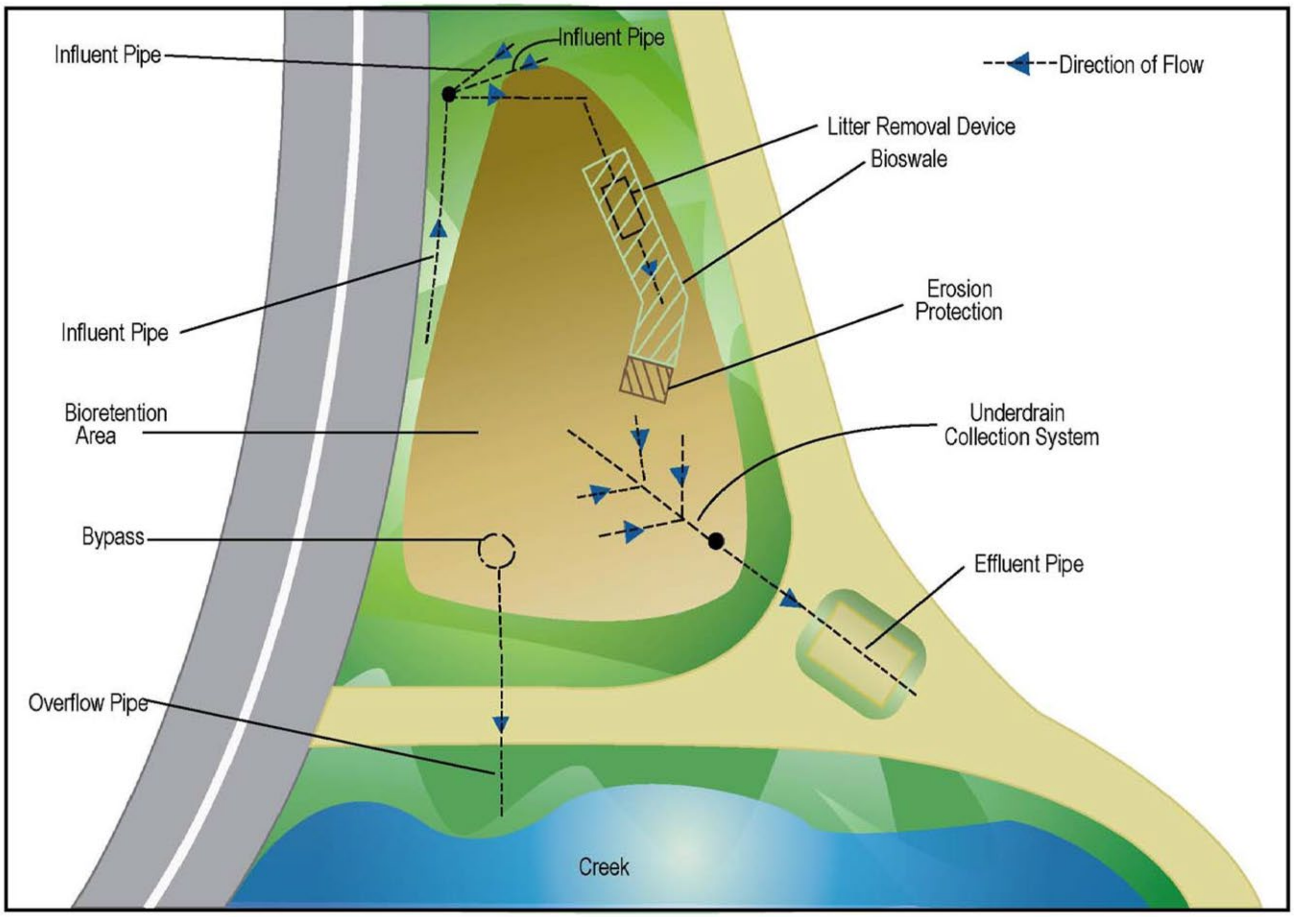
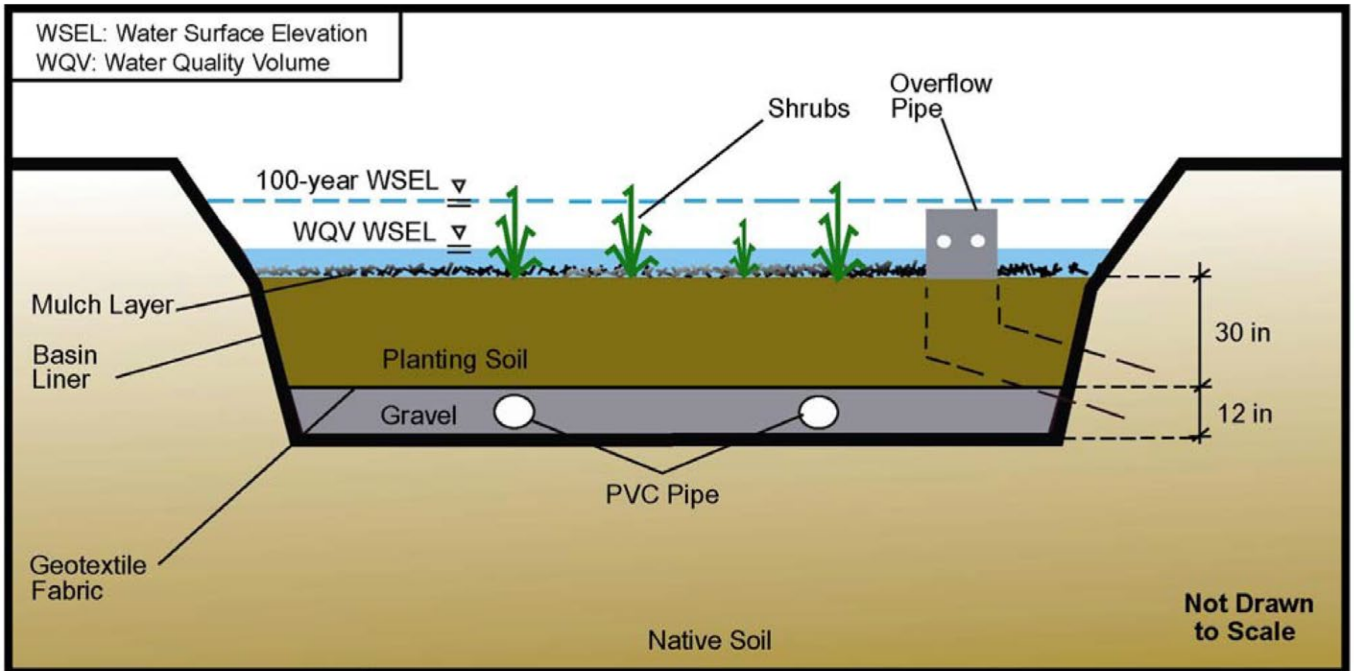


Figure 2 Plan View of the Original Bioretention Design

APPLICATION OF THE BIORETENTION CONCEPT TO THE TRANSPORTATION ENVIRONMENT

Bioretention BMPs have been frequently used in the Eastern United States to treat storm water runoff from small impervious areas, such as parking lots, or to treat storm water runoff from small residential lots. The purpose of this project is to apply the bioretention concept: (1) in the Southern California climate, i.e., a short wet season and dry summers and (2) to the transportation environment, i.e., slightly larger drainage areas adjacent to freeways. In the application of the bioretention concept, several challenges were encountered. These challenges are discussed in the following section.



Design Summary Changes		
Design Parameter	**Design Guidance (PGCMDER, 1993)**	**Design Guidance (PGCMDER, 2002)**
Sand Bed	Utilizes 12 in sand layer	No sand layer
Planting Soil	35-60% sand 30-55% silt 10-25% clay	50-60% sand 20-30% topsoil with <5% clay content 20-30% leaf compost
Planting Soil Depth	4 feet	2.5 feet

Figure 3 Design Summary Changes between Revised Design and Original Design

Bioretention Siting

In general, a project site is normally given and a practitioner assesses which BMP can be applied to the project site. For the various Caltrans pilot studies, a BMP type is given and the practitioner assesses which site within an area can be utilized for that BMP. The original design guidance (Claytor, 1996) applied to this project during the siting phase required 6.5 ft of available head for the bioretention BMP to operate by gravity. Additionally, the bioretention BMP had to be located within the Caltrans right-ofway (ROW) along a freeway. The siting criteria made the selection of a site for a bioretention BMP difficult. The revised design guidance (PGCMDER, 2002) requires only 3.5 ft of available head for the bioretention BMP to operate by gravity. The reduced head requirement would increase the number of sites in which the bioretention concept can be applied.

Deviations from the Original Design Guidance

While applying the original design guidance (Claytor, 1996) to the project, a few deviations were required to fit the bioretention BMP into the project site. These deviations are summarized below:

Claytor, 1996	Recommends that a bioretention BMP be used as a water quality control practice only.
Bioretention BMP	Due to space constraints, a separate flood control basin could not be constructed in parallel to the bioretention BMP to detain flows greater than the design storm. As a result, the bioretention BMP will be used as a water quality control practice and for flood control.
Claytor, 1996	Recommends the bioretention BMP be constructed as an off-line device, with the following exceptions: • drainage area is less than 0.20 ha (0.5 ac); and • insufficient room to divert runoff in excess of the WQV.
Bioretention BMP	As stated above, a separate flood control basin could not be constructed. As a result, the bioretention BMP will be constructed as an on-line device.
Claytor, 1996	Recommends the use of a Pea Gravel Overflow Curtain Drain for overflow and to slow the velocity of the storm water runoff
Bioretention BMP	The Caltrans bioretention design does not utilize a Pea Gravel Overflow Curtain Drain for overflow. Runoff in excess of the WQV is routed through a bypass stand-pipe. A Caltrans developed litter removal device is utilized in this design. This litter removal device slows the velocity of the storm water runoff before entering the bioretention.
Claytor, 1996	Recommends a maximum ponding depth of 6 in.
Bioretention BMP	The WQV is designed to pond to a depth of 6 in. However, because the BMP is constructed as an on-line device, storm events larger than the design storm will result in ponding depths greater than 6 in for short periods of time.
Claytor, 1996	Recommends that the plant material selection should be based on the goal of simulating a terrestrial forested community of native species. The intent is to establish a diverse, dense plant cover to treat storm water runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and exposure.
Bioretention BMP	For the climate in this region, the project would utilize plants that could withstand periods of drought and periods of inundation. The selection of plants for this project focuses on native species.

Agency Coordination

The design effort required cooperation with U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Game (CDFG), California Department of Health Services (DHS), and a Native American Tribal Council. Primary cooperation took place with the CDFG due to the presence of an endangered species, the Gnatcatcher. The Gnatcatcher utilizes Coastal Sage Scrub (CSS) as its primary nesting area. Due to the presence of CSS at the pilot site, mitigation was necessary to account for the loss of habitat required for the retrofit. The CSS area was not identified until mid way through the design phase. As a result, the mitigation area was negotiated and lands purchased offsite. The construction schedule was also dramatically shortened, from September 1 to March 1, to avoid interfering with the nesting season for the Gnatcatcher. The USFWS protocol for nesting birds was followed to ensure survival.

Additional negations took place with the Native American Tribal Council when the pilot area was determined to contain ancestral remains. Archeological monitoring is scheduled during the construction process. Any remains or artifacts unearthed will be removed from the site and reburied according to the Tribal Council's protocols.

Negotiations were also made with the DHS to ensure that the bioretention area does not contain standing water long enough to breed mosquitoes. DHS considers mosquitoes a serious health risk due to the recent California outbreak of West Nile Virus. The agency was consulted and allowed to review the design plans for the bioretention basin to ensure the design would provide for a basin which drained within 72 hours. Once the bioretention BMP is constructed, the local vector control district will provide vector monitoring of the BMP for one year.

NEXT STEPS

Now that a final design has been prepared, the plan for the bioretention basin will move into the construction phase. The construction schedule is dramatically shortened due to the bird nesting season, which makes construction during the wet season necessary. Once construction is complete, a plant establishment period will be necessary. Influent and effluent water quality monitoring will be performed for a period of three years. Constituents to be monitored include: hardness, total dissolved solids, total suspended solids, conductivity, total organic carbon, dissolved organic carbon, nitrate, total kjeldah nitrogen, total phosphorous, dissolved ortho-phosphate, and total recoverable and dissolved metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc). Observational monitoring will also be performed. Notable observations will include plant survivability and die off, erosion, maintenance concerns, and vigor of the bioswale.

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