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MEMORANDUM

TO: Kathy Chaston, NOAA; Alyssa Miller, Malama Maunalua; and Robert Irvine Aina Haina Shopping Center

FROM: Anne Kitchell and Michelle West, Horsley Witten Group

DATE: June 17, 2009

RE: Summary of Stormwater Retrofit Options at Aina Haina Shopping Center

This memorandum summarizes ten (10) stormwater retrofit options identified by Horsley Witten Group (HW), Robert Irvine, NOAA, Malama Maunalua, DOH, and others at the site visit to the Aina Haina Shopping Center in Honolulu, Hawaii on May 23, 2009. The retrofit options include the following:

A. Bioretention in grass area at the southwest corner of the site
B. Cistern to collect roof drainage for irrigation
C. Perimeter sand filter at gas station
D. Stormwater planter boxes at shopping center downspouts
E. Perimeter sand filter along retail frontage
F. Bioretention at parking lot inlet
G. Bioretention adjacent to library
H. Bioswale in rear of shopping center
I. Perimeter sand filter in rear of shopping center
J. Cistern to collect rainwater for reuse at shopping center

Table 1 provides additional information on each potential option. Locations of each and the approximate drainage divides across the main parking lot are shown in Figure 1. Attached to this memo are typical schematics for three of the practices described here: bioretention (Attachment A), sand filter (Attachment B), and planter boxes (Attachment C). Adaptations for bioretention design developed by Schueler (2006) specifically for Maui County are also included here.

The intent of this site investigation was to: (1) provide additional hands-on training on conducting a retrofit inventory as a follow-up to NOAA's May 22, 2009 LID/Stormwater workshop; (2) explore alternative stormwater management options with interested owners/managers at a shopping center that is to be redeveloped; and (3) support collaborative partnerships between Malama Maunalua, local businesses, and agency staff. While it was not the intent of this activity to develop detailed concept designs, HW would be pleased to assist in further refinement of potential retrofits opportunities upon request.

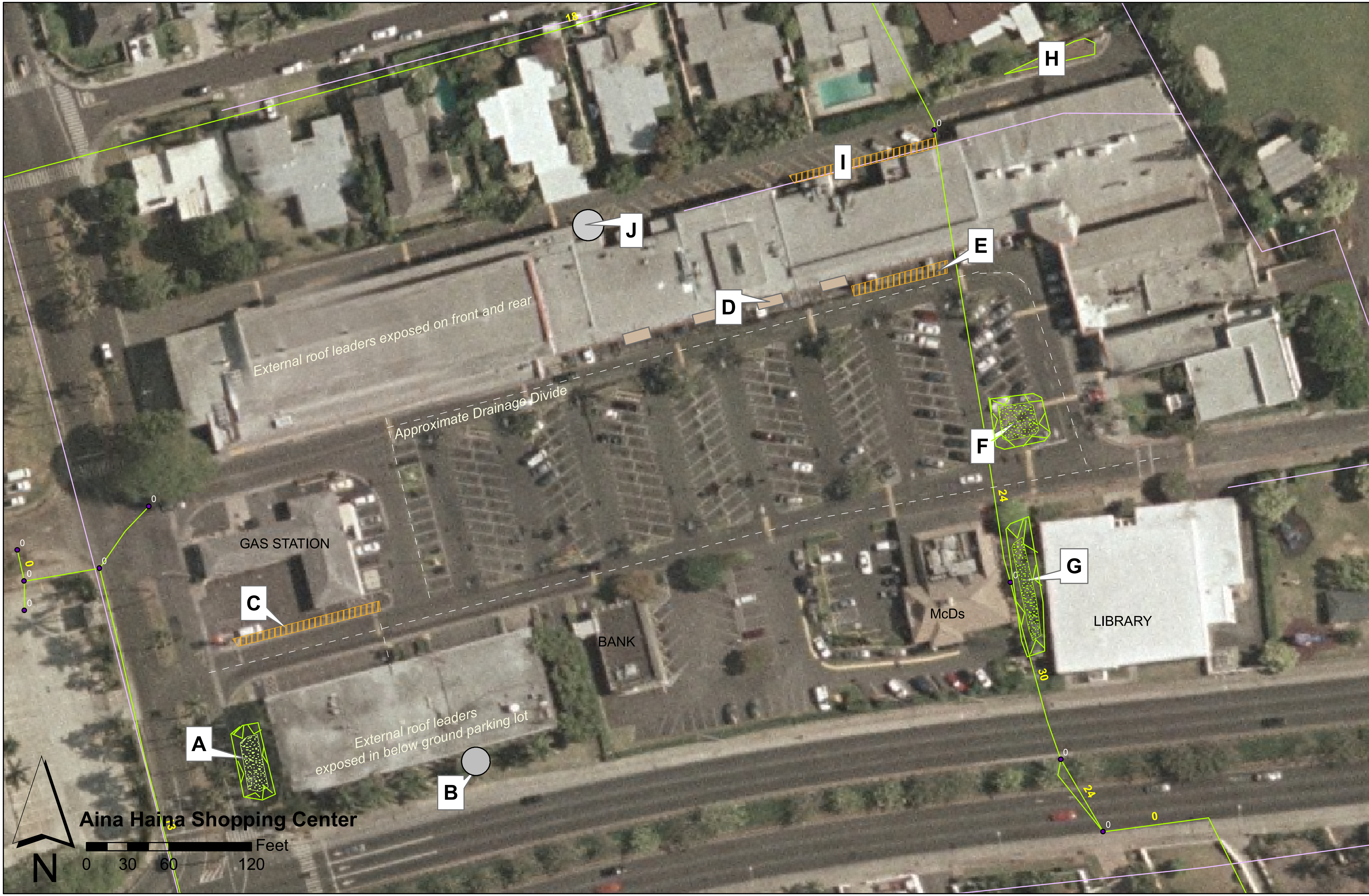
Potential opportunities were identified based on a review of site drainage plans, site-specific soil report, and a four-hour site investigation. Currently, no stormwater treatment exists on site. Annual rainfall average is unclear, but estimates range from 12-20 inches. The majority of the site drains to the 24-inch drain pipe running north to south on the eastern side of the parking lot. Soils on site are not conducive to infiltration, and confirmed pollution hotspots are present (i.e., gas station). Parking is a premium, so loss of spaces is not desirable. <u>At a minimum, designers should evaluate alternative parking lot layout (90 degree parking with minimum stall dimensions).</u>

Table 1. Summary of Retrofit Alternatives at Aina Haina Shopping Center

Retrofit	Description
A. Bioretention in grass area at corner 	Excavate bioretention facility in existing grassed area (30 ft x 50 ft); currently does not receive runoff, but if drainage pulled from curb using trench drain (or similar) under sidewalk may be able to capture a small portion of W. Hind Street and a portion of shopping center egress lane. Minor constraints include existing irrigation lines and mature palm trees. Tie overflow into 18 inch drain pipe across W. Hind Street. See bioretention schematics in Attachment A for more detail.
B. Cistern to collect roof drainage for irrigation 	~ 6-10 cast iron roof leaders exposed along outside edge of below ground parking deck. Existing yard inlet in adjacent grassed area ties into drainage system. Concept is to remove elbows and redirect to either (1) planters; (2) linear swale; or (3) storage cistern with pump that ties into irrigation system. Excess volume can discharge back into drain system. Water reuse is one of the areas where you can get points for LEED certification.
C. Perimeter sand filter at gas station 	¾ of the gas station (high point midway at pumps) and majority of area in rear drains towards shopping center egress and is collected/conveyed towards W. Hind Street in concrete curb/channel. This gas station is also a service station with potential to contribute contaminants such as oil, gas, coolant, brake, and transmission fluid. Concept for this location includes (1) installation of (~40 ft) perimeter sand filter in concrete curbing along entrance to gas station, and (2) regrade/repave so entire site drains to practice (when renovated). Tie overflow into 18 inch drain pipe across W. Hind Street. See schematics for sand filter in Attachment B.

D. Stormwater planter boxes at downspouts 	External roof drains inside columns spaced ~ every 20 feet across store fronts discharge directly onto parking surface and into concrete curb/channel. During renovation activities, consider "greening" entrances with stormwater planter boxes at downspouts to: (1) enhance aesthetics, and (2) capture and treat stormwater runoff from rooftop. Planters can be narrow and low to ground and can wrap around columns or extend to either side depending on pedestrian access needs. Sizing of each planter could be roughly 2' by 5' and 2-3' tall, but actual dimensions should be based on how much flow will be entering each one. See Attachment C for planter details.
E. Perimeter sand filter on frontage 	This concrete channel conveys drainage from rooftop, the parking adjacent to stores, and half of drive aisle for most of the length of the storefront (~400 ft) into grated inlet. Concept is to install dual chamber perimeter sand filter in section of channel and tie into existing inlet. Advantage of sand filters is that they remove oils, no parking spaces are lost, and maintenance access is easy. Actual length of practice to be determined based on actual drainage area and rainfall information. See Attachment B for sand filter details.
F. Bioretention at parking lot inlet 	This is the major inlet along the existing drain pipe that collects majority of runoff from parking lot. We recommend constructing a bioretention facility as part of a parking lot landscape island. Rule of thumb is that you need 2-5% of drainage area for a bioretention practice, so you would likely lose ~8 parking spaces (these spaces could be recovered by altering the parking space layout). An added benefit of a parking lot bioretention is that you can gain shade trees. See Attachment A for bioretention details.
G. Bioretention adjacent to Library 	An alternative to option F (or in addition) is to construct a bioretention facility in the landscaped area between McDonald's and the library at last inlet above main drain pipe. There is potential as part of the redevelopment plan for the site to leave enough space here for a stormwater management practice. A feasibility assessment is needed to determine sizing of practice – may be able to simply block inlet and redirect runoff into bioretention. Tie overflow back into drain pipe. This would be highly visible location to incorporate educational signage about watershed/stormwater issues.

H. Bioswale in rear of shopping center 	Grassed area in rear (northeast side) of shopping center could accept drainage from portion of rooftop and drive aisle if curb was removed. Consider constructing a vegetated swale (tie overflow into existing inlet). This area is also going to be redone to incorporate a designated trash collection and shared grease trap. At minimum, be sure to consider measures to prevent dumpster juice and other waste materials from coming into direct contact with drainage inlet.
I. Perimeter sand filter in rear of shopping center 	Rooftop runoff, wash water, and other discharges from restaurants and retail businesses are draining along curb to inlet (east side) in rear of shopping center. Consider installing a perimeter sand filter along this area. See Attachment B for more detail on sand filter.
J. Cistern to collect rainwater for reuse 	Numerous external downspouts are exposed along the rear of the shopping plaza. Consider potential to harvest rainwater in large tank or cistern to potentially provide water for flushing toilets and/or landscaping.


Aina Haina Shopping Center
Feet
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External roof leaders exposed on front and rear
Approximate Drainage Divide
External roof leaders exposed in below ground parking lot
GAS STATION
BANK
McDs
LIBRARY
18
24
30
24
0

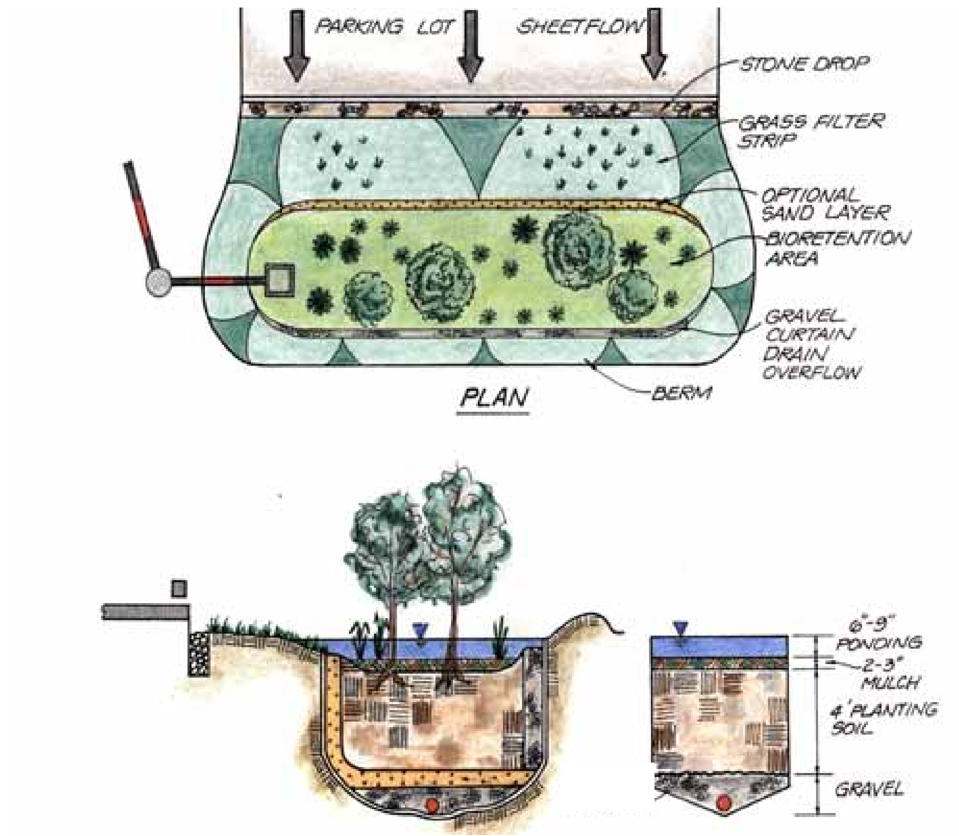
Attachments

A. Bioretention
B. Perimeter Sand Filters
C. Stormwater Planters

Attachment A - Bioretention

The bioretention system (also referred to as a "rain garden" or a "biofilter") is a stormwater management practice to manage and treat stormwater runoff using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression. The pollutant removal method combines physical filtering and adsorption with bio-geochemical processes. The system consists of an inflow component, a pretreatment element, an overflow structure, a shallow ponding area (less than 9" deep), a surface organic layer of mulch, a planting soil bed, plant materials, and an underdrain system to convey treated runoff to a downstream facility (Figure 1).

Figure 1: Schematic of a Bioretention System (Claytor & Schueler, 1996)



Bioretention facility surface areas are typically sized at a ratio of 5% of the impervious area draining to the facility to capture, manage, and treat runoff from the 1-inch precipitation event (Claytor & Schueler, 1996). Pretreatment for bioretention consists of a grass channel or grass filter strip, a gravel diaphragm / stone drop, and a mulch layer. In addition, there are several physical geometry recommendations that should be considered in the layout and design of bioretention facilities. The following design guidance is suggested (Table 1):

Table 1: General Design Guidance for a Bioretention System

Minimum width	10 feet
Minimum length	15 feet
Length to width ratio	2:1
Maximum ponding depth	6-9 inches
Planting soil depth	2-4 feet, 1’ minimum
Underdrain system	6" pipe in 8" gravel bed
Plant spacing	trees at 10-foot centers; shrubs at 5-foot centers; herbaceous materials at 1- to 2-foot centers

Bioretention facilities are cost-effective measures designed to help meet many of the management objectives of watershed protection. Pollutant removal rates for bioretention systems are similar to filtering or infiltrating systems. Potential removal rates for total suspended solids (TSS), metals, and bacteria can exceed 90%. The removal rates for nutrients (nitrogen and phosphorus) are in the range of 70%. Like most LID systems, maintenance is required to ensure proper performance of a bioretention system. General landscaping maintenance such as mulching, weeding and irrigation is required to maintain the healthy vegetation. Occasional clean up of trash or litter and sediment removal would be required to prevent clogging of the soil medium.

Inspections are an integral part of system maintenance. During the six months immediately after construction, bioretention facilities should be inspected at least twice, or more, following precipitation events of at least 0.5 inch to ensure that the system is functioning properly. Thereafter, inspections should be conducted on an annual basis and after storm events of greater than or equal the 1-year precipitation event. Minor soil erosion gullies should be repaired when they occur. Pruning or replacement of woody vegetation should occur when dead or dying vegetation is observed. Separation of herbaceous vegetation root shock should occur when over-crowding is observed, or approximately once every 3 years. The mulch layer should also be replenished (to the original design depth) every other year as directed by inspection reports. The previous mulch layer would be removed, and properly disposed of, or roto-tilled into the soil surface. If at least 50 percent vegetation coverage is not established after two years, a reinforcement planting should be performed. If the surface of the bioretention system becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the surface should be roto-tilled or cultivated to breakup any hard-packed sediment, and then revegetated.

The following is an excerpt from the Working Draft of "Design Guidelines for Stormwater Treatment Practices To Protect Water Quality in Maui County, Hawaii"

Prepared by:

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Date: April 13, 2006

Section 2.0
Design Guidelines for Bioretention Areas on Islands

Key Island Adaptations:

- Three different designs proposed that are adapted to different annual rainfall regimes on island
- Thinner filter media depths recommended due to local soils and bedrock concerns
- Hi ET rates make it difficult to attain a vigorous plant cover without irrigation (which is not a wise use of scarce island freshwater resources
- Need a two cell design to capture sediments prior to treatment in the bioretention area
- Bioretention areas must be fully protected during construction, and only installed after entire contributing drainage areas are stabilized (which is not the current practice in Maui County).

Bioretention areas are suitable for all land uses, so long as the contributing drainage area is limited to a maximum of about five acres. Common bioretention opportunities include landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, and streetscapes (i.e., between the curb and sidewalk). Bioretention, when designed with an underdrain and liner is also a good design option for treating potential stormwater hotspots. Bioretention is extremely versatile because of its ability to be incorporated into landscaped areas.

Water Quality- Bioretention is an excellent stormwater treatment practice since it utilizes due to a variety of pollutant removal mechanisms including vegetative filtering, settling, evaporation, infiltration, transpiration, biological and microbiological uptake, and soil adsorption. Bioretention can also be designed as an effective infiltration/recharge practice, particularly when soil tests indicate an infiltration rate exceeding one inch per hour.

Peak Discharge Control- To meet peak discharge criteria, another structural control (e.g., detention) will be necessary in conjunction with a bioretention area. Bioretention can help reduce detention requirements for a site by providing elongated flow paths, longer times of concentration, and volumetric losses from infiltration and evapotranspiration. While bioretention is not recommended to provide peak discharge control, although it can be used to treat the quality of runoff on the surface before it is discharged to an underground perforated pipe used for infiltration of peak discharges. Therefore, bioretention areas should either be designed "off-line" using a flow diversion or be designed to safely pass large storm flows while still protecting the ponding area, mulch layer and vegetation.

Site Feasibility Factors

- Drainage Area – 5 acres maximum recommended; 0.5 to 2 acres is preferred. For larger sites, multiple bioretention areas can be used to treat runoff provided appropriate site grading is accurately direct flows to each facility.
- Space Required – Approximately 7-10% of the tributary impervious area is required for practice footprint; minimum 200 ft^2 area for small sites (10 feet x 20 feet)
- Site Slope – Sloped areas immediately adjacent to practice should be less than 20% but greater than 0.5 – 1% to promote positive flow towards the practice.
- Practice Slope – The slope of the practice surface should not exceed 1% to promote even distribution of flow throughout practice.
- Minimum Head – A minimum of 3 to 4 feet of elevation difference is needed at a site from the inflow to the outflow, when an underdrain is used.
- Minimum Depth to Water Table – A separation distance of 2 feet recommended between the bottom of the bioretention area and the elevation of the seasonally high water table.
- Soils – No restrictions; engineered media required; underdrain is required where parent soils are classified as Hydrologic Soil Group (HSG) C or D.
- Soil Infiltration rate – In some cases, an on-site test within the proposed infiltration area is needed to establish the infiltration rate below the infiltration area. One test pit per 200 sf of filter bed. See Appendix A for simplified infiltration testing procedures.
- Groundwater Protection – Do not allow infiltration of runoff from stormwater hotspot into groundwater.
- Aesthetics - Bioretention area locations should be integrated into the site planning process, and aesthetic considerations should be taken into account in their siting and design.

Three Basic Bioretention Designs

The basic bioretention design is modified to account for different levels of annual rainfall (AR) on the island, as shown in Table 2.1 below:

Table 2.1: Three Design Variants for Island Bioretention			
Design Factor	**Design No. 1** AR > 25 inches	**Design No. 2** AR 26 to 74 inches	**Design No. 3** AR < 75 inches
Water Quality Volume	RO from 0.8 inch storm	RO from 1.0 inch storm	RO from 1.5 inch storm
Cells	Two	Two	Two
Pretreatment	25% of SA	35% of SA	50% of SA
Underdrain	Not required	Recommended	Required
Surface Cover	Coral rock or pumice stone	Pumice	Organic mulch
Vegetation	A few planting holes	Trees 15' o.c.	Native trees/shrubs
Irrigation	Only to planting holes	Short-term to establish growth	Not recommended
Infiltration	Yes, six inch rock sump below underdrain	Where soil testing indicates it is feasible	Where soil testing indicates it is feasible
Surface Overflow?	Elevated drop inlet above max ponding height	Yes, safely direct excess runoff to surface or SD pipe	Yes, safely direct excess runoff to surface or SD pipe
Depth of Media Filter	Min. 2 feet	Min. 3 feet	Min 4 feet
Connection to Underground Perforated Pipes	OK, after full surface WQv treatment in Bioretention area. No peak discharge credit given for water quality volume		
RO= Volumetric runoff SA: Surface area of bioretention oc: on center SD: storm drain pipe WQv = water quality volume			

Conveyance

- A flow splitter or diversion structure should be provided to divert the WQ_v to the bioretention area and allow larger flows to bypass the practice.
- Where a flow splitter is not used, contributing drainage areas should be limited to about 0.5 acres and an overflow should be provided within the practice to pass a percentage of the WQ_v to a stabilized water course or storm drain.
- The overflow associated with the 10- or 25-year storm should be controlled so that velocities are non-erosive at the outlet point (i.e., prevent downstream slope erosion). Common overflow systems within the structure consist of a yard drain inlet, where the top of the yard drain inlet is placed at the elevation of the shallow ponding area.
- A stone drop of about six inches or small stilling basin should be provided at the inlet of bioretention areas where flow enters the practice through curb cuts.
- Bioretention areas with underdrains should be equipped with a minimum 6" underdrain diameter in a 1' gravel bed. Increasing the diameter of the underdrain provides a greater capacity to drain standing water from the filter. The porous gravel bed prevents standing water in the system by promoting drainage.

Pretreatment

- Adequate pretreatment cells for bioretention area will consist of a minimum one foot deep surface cell connected to bioretention area with an impermeable filter fabric on the bottom and a two inch layer of sand or crushed rock. The cell shall be at least six inches higher in elevation than the main bioretention

- Bioretention should not be used to treat runoff from dirt parking lot or roads due to a high potential for clogging from sediment.

Treatment

- Bioretention should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- Bioretention systems shall consist of the following treatment components: A minimum two foot deep planting soil bed (i.e., “filter bed”), a surface cover layer, and a 9 to 12 inch deep surface ponding area (see Table 2.1).
- The filter bed shall be a made soil mixed on-site with the characteristics as shown in Table 2.2.
- Elevations must be carefully worked out to ensure that the desired runoff flow enters the facility with no more than the maximum design depth.
- The bioretention area should be sized based on the simplified sizing procedures set forth by Hirschman (2005):

For Bioretention Areas with Underdrains

WQv = 1.0 ft * SA of bioretention area (sf)

For Bioretention Areas without Underdrains (Infiltration)

WQv = 1.4 ft * SA of bioretention area (sf)
Where WQv = is required water quality volume in cubic feet
SA= surface area of bioretention area in square feet

Table 2.2. Construction Specifications for Island Bioretention Areas	
Pea Gravel	Clean, double washed stone (#7 or #8)
Underdrain Gravel	3” min clean, double washed # 57 stone over underdrain; 3” addl of pea gravel on top for filter.
Underdrain Pipe	6” rigid schedule 40 PVC pipe, with 3/8” perforations @ 6” oc, each underdrain on 1% slope located 20 feet oc from next pipe
Soil Media	50% sand, 30% acceptable topsoil, 20% aged organic leaf compost derived on island..
Surface Cover	Layer of 1 to 3” pumice stone or crushed coral, OR 2” layer of shredded tangantangan brush, coconut fronds or banana leaves, aged at least six months.
Bottom Geotextile	Bottom only. Non-woven polyprene geotextile w/ flow rate of > 110 gallons/minutes/square foot (e.g., Geotext 351 or equivalent)

Top Soil	Testing to ensure that it has loamy sand or sandy loam texture, with less than 5% clay content, corrected pH 6 to 7, and organic matter of at least 2%
Trees*	12 feet oc, 1" minimum caliper
Shrubs*	8 feet oc
Ground Cover*	Buffalograss or kiligrass anchored in erosion control fabric
Species selection dependent on design, drought tolerance and commercial availability	

Landscaping

- A dense, healthy vegetative cover should be established over the contributing pervious drainage areas before runoff can be accepted into the practice.
- Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan must be provided for bioretention areas.
- General planting recommendations for bioretention areas are as follows:
  - Native plant species should be specified over non-native species.
  - Vegetation should be selected based on a specified zone of hydric tolerance. For example, Design No. 1 should emphasize just a few trees or shrubs that can tolerate dry conditions (Xeriscapes), and will generally lack surface cover of turf or vegetation. Design No. 2 also emphasizes a few planting holes for larger trees and shrubs. Design No. 3 features trees, shrubs and groundcovers.
  - Woody vegetation should not be located at points of inflow.
  - Trees should not be planted directly overtop of underdrains and may be best located along the perimeter of the practice.
  - A tree density of approximately one tree per 300 square feet (i.e., 15 feet on-center) is recommended. Shrubs and herbaceous vegetation should generally be planted at higher densities (10 feet on-center and 5.0 feet on center, respectively), if they can be sustained without supplemental irrigation.

- Bioretention areas do not pose any major safety hazards, and fencing is generally not needed or desirable.

Construction Sequence

1. Bioretention areas must be fully protected by silt fence or construction fencing to prevent compaction by heavy equipment during construction, and can only be installed after entire contributing drainage areas has been vegetatively stabilized.

2. The pretreatment cell should be excavated first and sealed until full construction is completed

3. Excavators or backhoes working adjacent to the proposed bioretention area should excavate it to the appropriate design depth.

4. It may be necessary to rip the bottom soils to promote greater infiltration

5. Place the filter fabric on the bed of the bioretention area with six inch overlap on sides. Place six inches of stone on bed (for infiltration chamber design) and then lay the

perforated pipe, Pack #57 stone to three inches above top of underdrain, and then add three inches of pea gravel as filter.

6. Mix soil media on-site in adjacent impervious area or plastic sheeting. Apply in 12" inch lifts until desired top elevation of bioretention area is achieved. Wait a few days to check for settlement, and add additional media as needed.

7. Prepare planting holes for any trees and shrubs, install vegetation, and water accordingly. Install any temporary irrigation.

8. Lay down surface cover in both cells (pumice stone, shredded vegetation, piligrass plugs or coral stone, depending on design).

9. Conduct final construction inspection, checking inlet, pretreatment cell, bioretention cell and outlet elevations.

Maintenance

Some general bioretention maintenance considerations are provided below, and a more detailed checklist of maintenance activities and associated timetables is provided in Table 2.3.

- A legally binding and enforceable maintenance agreement should be executed between the practice owner and the local review authority.
- Adequate access must be provided for all bioretention facilities for inspection, maintenance, and landscaping upkeep.
- The surface of the ponding area may become clogged with fine sediment over time. Core aeration or cultivating of unvegetated areas may be required to ensure adequate filtration.
- All bioretention areas must be covered by a drainage easement to allow inspection and maintenance. If bioretention area is located in a residential area, the existence and purpose of the bioretention area shall be noted on the deed of record.

- The most frequently cited maintenance concern for bioretention is surface and underdrain clogging caused by vegetation, organic matter, sediment, hydrocarbons, and algal matter. Common operational problems include:

    - standing water
    - clogged filter surface
    - broken observation wells
    - inlet, outlet or underdrains clogged

- Effective long-term operation of bioretention practices requires dedicated and routine maintenance tasks performed on consistent timetable.

Table 2.3 Recommended Maintenance Activities for Bioretention Areas

Activity	Schedule
• Pruning and weeding to maintain appearance. • Mulch replacement when erosion is evident. • Remove trash and debris.	As needed
• Inspect inflow points for clogging (off-line systems). Remove any sediment from pretreatment cell. • Inspect trees and shrubs for survival and replace any dead or severely diseased vegetation.	Semi-annually
• Inspect and remove any sediment and debris build-up in pretreatment areas. • Inspect inflow points and bioretention surface for build up of sediments	Annually
• Replace mulch if used for surface cover area. • Replace pea gravel diaphragm or filter fabric if warranted. • The planting soils should be tested for pH to establish acidic levels. If the pH is below 5.2, limestone should be applied. If the pH is above 7.0 to 8.0, then iron sulfate plus sulfur can be added to reduce the pH.	2 to 3 years

Many design features can minimize the maintenance burden and maintain pollutant removal efficiency. Key examples include: limiting drainage area, providing easy site access, providing pretreatment, and utilizing native plantings.

The construction phase is another critical step where many maintenance problems can be minimized or avoided. The most important maintenance guideline to follow during construction is to make sure that the contributing drainage area has been fully stabilized prior to bringing the practice "on line".

Construction and Maintenance Inspections

Inspections during construction are needed to ensure that the bioretention practice is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is acceptable to the professional designer.

Attachment B – Perimeter Sand Filter

Description

The perimeter sand filter is an enclosed filter system designed to treat the water quality storm (first flush) in two underground chambers. This BMP captures and temporarily stores stormwater runoff, filtering it through a bed of sand. The system consists of a wet sedimentation chamber and a sand bed (filtration) chamber. Runoff flows into the structure through inlet grates located along the top of the first chamber. This chamber is equipped with a shallow permanent pool of water, which provides pretreatment, i.e., removing floatables and heavy sediments. The second is the sand bed or filtration chamber, which removes additional pollutants such as finer sediments, nutrients, and hydrocarbons in the filtering media (1-2' deep sand layer). After treatment, the filtered runoff is collected by underdrains and returned to the conveyance system. Storms greater than the water quality event with fill both chambers to capacity until excess runoff is routed to a bypass chamber, which will overflow to the conveyance system.

Benefits and Limitations

Perimeter sand filter systems can be relatively expensive to construct and install, and they have high maintenance requirements. However, because they have few site constraints beside head requirements and provide a high level of treatment, sand filters can be used on a variety of development and redevelopment sites where the use of other structural controls may be precluded. If used at a hotspot, an impermeable liner is required to prevent contaminants from entering groundwater. In addition, because sand filters have a permanent pool of standing water, they present potential mosquito concerns if not properly designed. Their use is limited to situations in which they can be inspected and maintained frequently enough to control mosquito breeding.

Sizing and Design Guidelines

Perimeter sand filters should be sized to satisfy the WQv requirements for the impervious surface area draining to the practice. The basis for the sizing guidance relies on the principles of Darcy's Law, where liquid is passed through porous media with a given head, a given hydraulic conductivity, over a given timeframe (Flinker, 2005). The equation for sizing a sand filter is as follows:

$$WQv = \frac{A_f \text{ x } [k \text{ x } (h_f + d_f)(t_f)]}{d_f}$$

where:

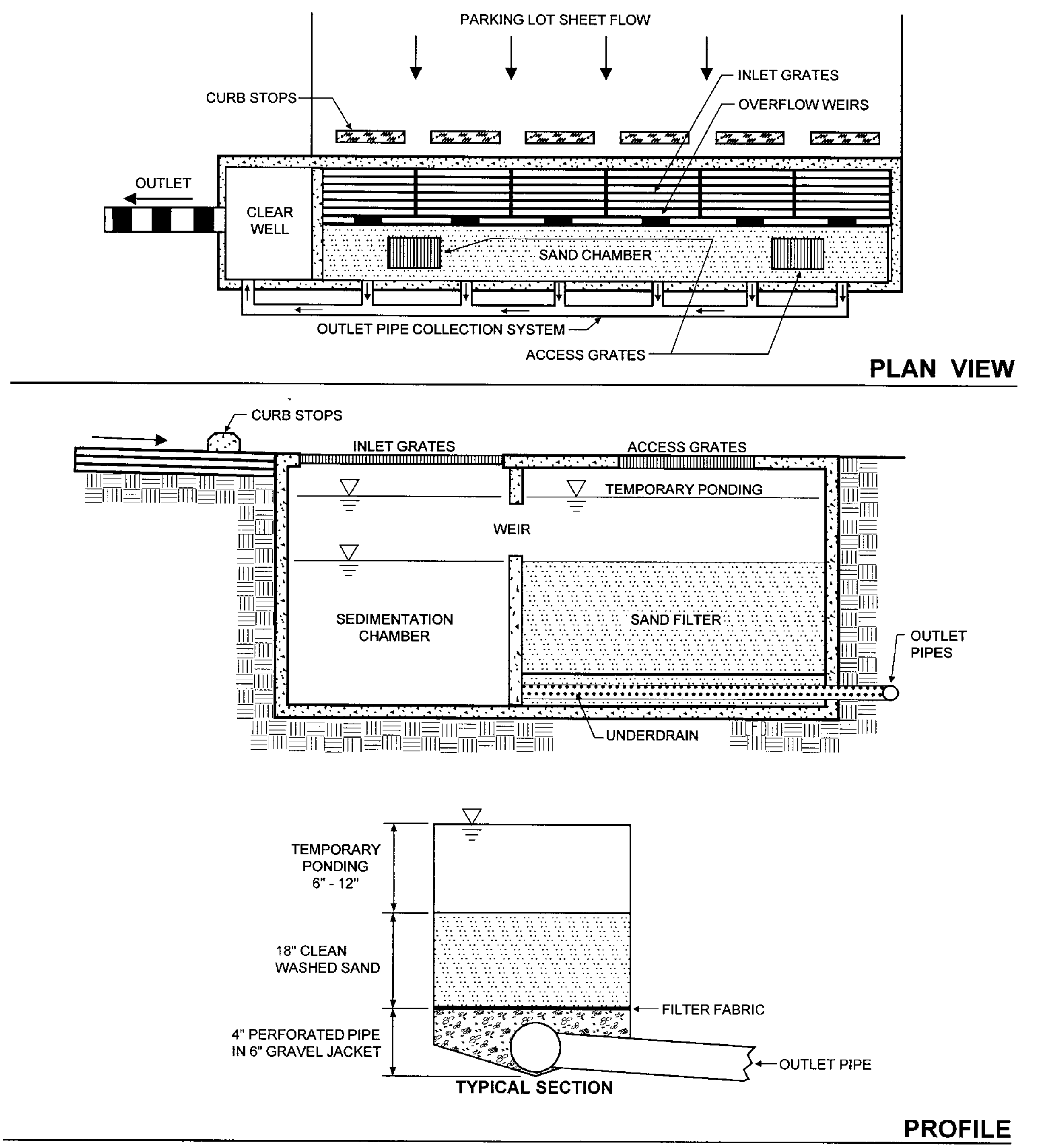
- A_f = the required surface area [square feet]
- d_f = depth of the soil medium [feet, recommended 18", 12" min]
- k = the hydraulic conductivity [in ft/day, usually set at 3.5 ft/day for sand, conservative to take into account clogging over time]
- h_f = average height of water above the planter bed [feet]
- t_f = the design time to filter the treatment volume through the filter media
- WQv = water quality volume [cubic feet], usually based on 0.5 – 1' of runoff from impervious surfaces

Maintenance

Specific maintenance requirements are as follows:

- Sediment should be removed from the wet sedimentation chamber when it accumulates to a depth of more than ½ the design depth.
- Inspect and replace damaged inlet/outlet structures and/or grates as needed.
- Remove trash and debris away from inlet grates as necessary.
- When the filtering capacity of the filter diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 48 hours after a storm event), the top few inches of discolored material shall be removed and replaced with fresh material.
- For unique installations in extremely tight sites or redevelopment projects where recommended dimensions have been reduced, more frequent maintenance should be performed.

Figure 1. Schematic of Perimeter Sand Filter (Source: Center for Watershed Protection)



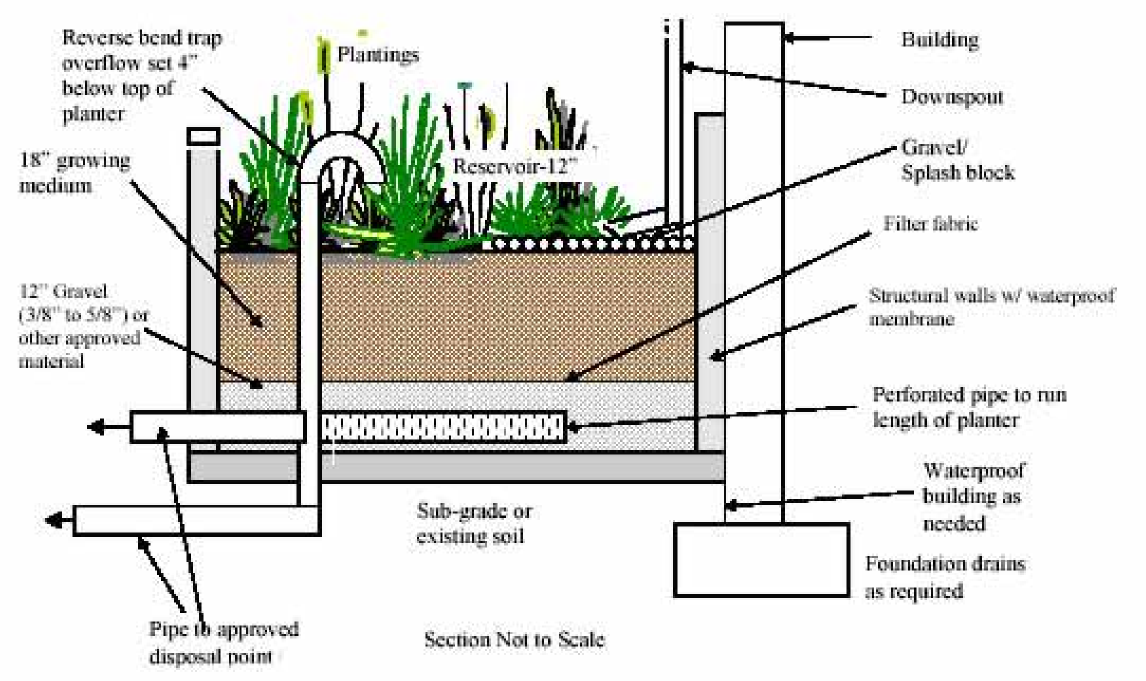
Attachment C - Stormwater Planter

Description

Stormwater planters are small-scale, stormwater treatment systems comprised of sandy/organic soil media and plants in a confined planter box. Stormwater planters are simply "bioretention in a box." Planters generally look like large vaulted plant boxes and can contain anything from basic wildflower communities to complex arrangements of trees and flowering shrubs. The method combines physical filtering and adsorption with bio-geochemical processes to remove pollutants.

There are three basic variations of the stormwater planters: the contained system, the infiltration system, and the flow-through system. Contained planters are typical large self-contained planters found on terraces, decks, and sidewalks. Infiltration planter boxes are designed to allow runoff to filter through the planter soils and then infiltrate into the native soils. Flow-through planter boxes are designed with impervious bottoms or placed on impervious surfaces. This flow-through system consists of an inflow component (usually a downspout), a treatment element (soil medium), an overflow structure, plant materials, and an underdrain collection system to divert treated runoff back into the downstream drainage system (Figure 1). Most likely, a flow-through planter box design will work best for the Aina Haina Shopping Center.

Figure 1: Flow-Through Planter (City of Portland, Stormwater Management Manual, 2002)



Stormwater planters are ideally adapted for non-residential and multifamily development as well as urban redevelopment projects (Figure 2). Roof runoff can be directed from the downspout directly into the planters. Runoff from rooftop areas contains nutrients carried in rainwater, sediments and dust from rooftops, and bacteria from bird traffic. These pollutants can all be attenuated to a significant degree during small rain events.

Figure 2: Photo of Stormwater Planter. (City of Portland, Stormwater Management Manual, 2002)

Figure 3: Photo of Stormwater Planter. (Center for Watershed Protection)

Benefits and Limitations

Benefits:

- Planters can be effective in reducing the velocity and volume of stormwater discharge from rooftops areas.
- Stormwater planters are relatively low in cost. These are small self-contained units that can be easily constructed without heavy-duty excavation that accompanies other BMPs.
- Stormwater planters add aesthetic elements by improving the surrounding streetscape.
- Multiple planter units can be used to treat large-scale commercial developments.

Limitations:
The primary limiting factor on the use of stormwater planters is sizing. They are by definition small-scale stormwater treatment cells that are not well-suited to treat runoff from large storm events, or large surface areas. They can however be used in series or to augment alternative stormwater treatment practices. Other limitations include:

- Stormwater planters are not designed to treat runoff from roadways or parking lots and are ideally suited for treating rooftop runoff. Flow-through stormwater planters should not receive drainage from impervious areas greater than 15,000 square feet.
- If the infiltration capacity of the planting media is exceeded, the planter will overflow. Excess stormwater needs to be directed to a secondary treatment system or released untreated to the storm drain system.

Selection and Locations

A few things to consider when selecting this practice:

- Facility dimensions and setbacks from property lines and structures.
- Profile view of facility, including typical cross-sections with dimensions.
- Planter wall material and waterproofing membrane specification.
- Growing medium specification.
- Drain rock specification.
- Filter fabric specification.
- All stormwater piping associated with the facility, including pipe materials, sizes, slopes, and invert elevations at every bend or connection.
- Landscaping plan.

Sizing and Design Guidelines

Stormwater planters should be sized to satisfy the WQv requirements for the impervious surface area draining to the practice. The basis for the sizing guidance relies on the principles of Darcy's Law, where liquid is passed through porous media with a given head, a given hydraulic conductivity, over a given timeframe (Flinker, 2005). The equation for sizing a stormwater planter is as follows:

$$WQv = \frac{A_f \times [k \times (h_f + d_f)(t_f)]}{d_f}$$

where:

A_f	= the required surface area [square feet]
d_f	= depth of the soil medium [feet]
k	= the hydraulic conductivity [in ft/day, usually set at 1 ft/day, but can be varied depending on the properties of the soil media]
h_f	= average height of water above the planter bed [maximum 6 inches]
t_f	= the design time to filter the treatment volume through the filter media
WQv	= water quality volume [cubic feet], usually based on 0.5 – 1' of runoff from impervious surfaces

Costs

Stormwater planters are generally considered cost effective stormwater treatment practices. For one redevelopment project where detailed project records exist stormwater planter costs tallied $2.10 per square foot of managed impervious area or approximately $32.70 per square foot of the practice. For this project, management, design, and permitting costs comprised 25% of the total budget, and construction the remaining 75% (PBES, 2004). The cost of proprietary stormwater planters, or tree box filters, is approximately $24,000 per acre ($0.55 per square foot) of impervious surface. Annual maintenance cost is approximately 2% to 8% of the system cost or in the range of $200 to $2,000 per impervious acre treated (Flinker, 2005).

Maintenance

In well designed stormwater planters, maintenance is generally limited to landscaping duties such as occasional irrigation, weeding and mulching. Periodic maintenance can also include any clogging that may occur in underground piping or overflow structures. Specific maintenance duties suggested by the City of Portland, Oregon are as follows:

As needed:

- Remove any debris or garbage caught in the planter facility.
- Inspect and replace damaged downspout and overflow pipe.
- Remove sediment built up in the planter.
- Inspect and replace any damaged, diseased, or dead plants.
- Inspect and replace damaged splash guards/erosion control measures.

Annually:

- Inspect for structural integrity and proper function and repair any deficiencies.