MĀLAMA I KA WAI
DOT - AIRPORTS

Post-Construction
Best Management Practice Manual

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LIST OF ACRONYMS

AC	Advisory Circular
AIR-E	Airports Division Engineering Branch
AIR-EE	Airports Division Engineering Branch, Environmental Section
AIR-OM	Airports Division, Oahu District, Maintenance Section
ALP	Airport Layout Plan
AMS	Asset Management System (Veoci, GIS, or similar)
AOA	Aircraft Operations Area
ATCT	Airport Traffic Control Towers
BMP	Best Management Practice
BRL	Building Restriction Line
CCH	City and County of Honolulu
CCH DPP	City and County of Honolulu, Department of Planning and Permitting
CFR	Code of Federal Regulations
CM	Construction Manager
CWA	Clean Water Act
CWP	Center for Watershed Protection
DOH	State of Hawaii, Department of Health
DOH-CWB	State of Hawaii, Department of Health, Clean Water Branch
DOH-SDWB	State of Hawaii, Department of Health, Safe Drinking Water Branch
DOTA	State of Hawaii, Department of Transportation – Airports Division
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FOG	Fats, oils, and grease
GIS	Geographic Information System
GPS	Global Positioning System
HAR	Hawaii Administrative Rules
HDS	Hydrodynamic Separator
HNL	Daniel K. Inouye International Airport
HRS	Hawaii Revised Statutes
HSG	Hydrologic Soil Group
IWDP	Industrial Wastewater Discharge Permit
LID	Low Impact Development
MDE	Maryland Department of the Environment
MS4	Municipal Separate Storm Sewer System
MTD	Manufactured Treatment Device
NAVAID	Navigational Aid
NGPC	Notice of General Permit Coverage
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
OFA	Object Free Area
OFZ	Obstacle Free Zone
OGG	Kahului Airport
OWS	Oil Water Separator

PBMP	Post-Construction/Permanent Best Management Practice
POFZ	Precision Obstacle Free Zone
ROFA	Runway Object Free Area
ROH	Revised Ordinances of Honolulu
RPZ	Runway Protection Zone
RSA	Runway Safety Area
SPM	State Project Manager
SWMPP	Stormwater Management Program Plan
SWPPP	Stormwater Pollution Prevention Plan
TERPS	Terminal Instrument Procedures
TIP	Tenant Improvement Project
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
UIC	Underground Injection Control
USDA	United States Department of Agriculture
WQV	Water Quality Volume

GLOSSARY

303(d) List - Under *CWA § 303(d)*, States are required to compile a list of impaired and threatened waters that fail to meet any of their applicable water quality standards or cannot support their designated or existing uses. This 303(d) list is required to be submitted for EPA approval every two years. States are required to develop a TMDL for each pollutant causing impairment for water bodies on the list.

Airport Layout Plan or ALP - A scaled drawing (or set of drawings), in either traditional or electronic form, of current and future airport facilities that provides a graphic representation of the existing and long-term development plan for the airport and demonstrates the preservation and continuity of safety, utility, and efficiency of the airport.

Best Management Practices or BMPs - BMPs are stormwater management practices utilized to reduce or eliminate the negative impacts of stormwater runoff.

HAR § 11-54 defines BMPs as schedules of activities, prohibitions or designations of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of State waters. BMPs also include treatment requirements, operatins procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage. BMPs include methods, measures or practices selected by the department to meet nonpoint source pollution control needs. BMPs also include but are not limited to structural and non-structural controls. BMPs can be applied before, during, and after pollution-producing activities to reduce or eliminate the introduction of pollutants into receiving State waters. Please refer to the definitions of the State waters and the receiving water.

This manual addresses the structural BMPs that are intended and designed to reduce the discharge of pollutants, directly or indirectly, to State waters, to the maximum extent practicable.

Biofiltration - The process of improving water quality by filtering water through a biologically influenced media. Stormwater biofiltration systems include biofilters, bioretention systems, and rain gardens.

Building Restriction Line or BRL - According to *FAA AC 150/5300-13 § 210*, BRL is a line that identifies suitable and unsuitable locations for buildings on airports. A BRL is a line indicating where airport buildings must not be located, limiting building proximity to aircraft movement areas. The BRL should encompass the RPZs, the ROFA, the runway visibility zone, NAVAID critical areas, areas required for TERPS, and the ATCT clear line of sight.

Clean Water Act or CWA - (*33 USC 1251 et seq.*) Requirements of the NPDES program are defined under *CWA § 307, 402, 318, and 405*.

Construction Activity - Refer to *HAR § 11-55, Appendix C.*

Detention - The capture and subsequent release of stormwater runoff from a site at a slower rate than it is collected, the difference being held in temporary storage.

Detention Volume - The volume of runoff that is held and treated in a temporary storage structure.

Disturbed Area / Disturbance of Land – Refer to *HAR § 11-55, Appendix C.*

Drainage Area – The specific land area that contributes stormwater runoff into a defined point. Drainage area also refers to the drainage basin or watershed.

Drain or drawdown - Lowering of the water surface resulting from a withdrawal or release of water.

Drain or drawdown time - Time it takes for a PBMP to completely empty the WQV, i.e., there should be no ponded or standing water within the PBMP past the drain or drawdown time after a rain event.

Erosion - The wearing-away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, new development, redevelopment, road building, or timber cutting.

Evapotranspiration - The combined loss of water into the atmosphere by evaporation (water changing from a liquid to vapor from soil, water, or plant surfaces) and transpiration (water taken up by plant roots and transpired through plant tissue and leaves).

Flood or Flooding - The inundation to a depth of 3 inches or more of any property not ordinarily covered by water. The terms do not apply to inundation caused by tsunami wave action.

Grading - Any excavation, leveling, or fill, or combination thereof.

Hydrologic Soil Group or HSG - A measure of soil types ranging from A (lowest runoff potential) to D (highest runoff potential). These parameters can be determined from soil maps prepared by the USDA for any county or using the NRCS Web Soil Survey website. The NRCS Web Soil Survey can be accessed using the webpage below: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Impervious Surface - A surface covering or pavement of a developed parcel of land that prevents the land's natural ability to absorb and infiltrate rainfall/stormwater. Man-made impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, storage areas, impervious concrete, and asphalt; and any other continuous watertight pavement or covering. Landscaped soil and pervious pavement, underlain with pervious soil or pervious storage material, are not impervious surfaces. This definition does not include natural soil and rock that are impervious for the purposes of this Manual.

Infiltration - The downward movement of water from the surface to the subsoil.

Infiltration PBMPs - Practices that capture and temporarily store a design storm volume of water before infiltrating into the soil.

Infiltration Rate - The infiltration rate or permeability (inch/hour) is the rate at which water passes through the soil profile during saturated conditions.

Inlet - A permanent constructed entrance into a DOTA MS4, drainage system, or State waters.

Invert - The lowest point on the inside of a drainage structure or conveyance system.

Low Impact Development or LID - A stormwater and land use management strategy that strives to mimic pre-development hydrologic processes of infiltration, filtration, storage, evaporation, and transpiration by emphasizing conservation, use of on-site natural features, site planning, and distributed stormwater management practices that are integrated into a project design. For purposes of the PBMP Manual, the terms LID and Green Stormwater Infrastructure are used interchangeably since both practices use similar processes of infiltration, filtration, storage, evaporation, and transpiration to manage stormwater runoff naturalistically and in an integrated manner.

LID PBMP - Post-Construction Best Management Practice that seeks to mimic pre-development hydrology by minimizing disturbed areas and impervious cover. LID promotes infiltration, detention, evapotranspiration, and biotreatment of stormwater runoff close to its source. Examples of LID PBMPs include but are not limited to bioretention, rain gardens, permeable pavements, and water reuse.

Maximum Extent Practicable - Economically achievable measures for the control of the addition of pollutants from existing and new categories of non-point sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available non-point source pollution control practices, technologies, processes, siting criteria, operating methods or other alternatives.

Municipal Separate Storm Sewer System or MS4 - Refer to *40 CFR § 122.26 (b)(8)* and the Small MS4 definition.

New Development - Creation or addition of impervious surface undertaken to alter the natural or existing condition of, or improvements to, DOTA property. Projects meeting the definition of redevelopment shall not be considered new development.

National Pollutant Discharge Elimination System or NPDES - According to *40 CFR § 122.2*, NPDES means the national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under the *CWA § 402*.

On-line Facilities - Water quality treatment facilities that receive all of the stormwater runoff from a drainage area. Flows above the water quality design flow rate or volume are passed through at a lower % removal efficiency.

On-site - The entire property that includes the proposed development.

Operational Source Control PBMPs - Operational Source Control PBMPs are schedules of activities, prohibition of practices, and other managerial practices to prevent or reduce pollutants from entering stormwater. Operational BMPs include the formation of a pollution prevention team, good housekeeping, preventive maintenance procedures, spill prevention and clean-up, employee training, inspections of pollutant sources and BMPs, and record keeping. They can also include process changes, raw material/product changes, and recycling wastes.

Overflow - A pipeline or conduit device, together with an outlet pipe that provides for the discharge of portions of runoff flows into the State waters or other points of disposal after a regular device has allowed the portion of the flow which can be handled by treatment facilities.

Permeable Filter Fabric - A non-woven, water-permeable material generally made of synthetic products such as polypropylene and used in stormwater management.

Permeable Pavement - Pervious concrete, porous asphalt, permeable pavers, or other forms of pervious or porous paving material intended to allow passage of water through or between the pavement section. Permeable pavement often includes an aggregate base that provides structural support and acts as a stormwater reservoir.

Pollutant - Any dredge, spoil, solid refuse, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical waste, biological materials, radioactive materials, heat, wrecked or dismantled equipment, rock, sand, soil, sediment, dirt, industrial, municipal, or agricultural waste and substances of similar nature.

Pollution - Contamination or other alteration of the physical, chemical, or biological properties, of State waters, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive or other substance into any State waters that will or is likely to create a nuisance or render such waters harmful, detrimental or injurious to the public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or livestock, wild animals, birds, fish or other aquatic life.

Pollution Prevention - Practices and actions that reduce or eliminate the generation of pollutants.

Post-Construction/Permanent Best Management Practice or PBMP - Specific Best Management Practice designed to reduce the stormwater volume or improve water quality after construction is completed. Subcategories include:

- Low Impact Development PBMP;
- Source Control PBMP; and
- Treatment Control PBMP.

Precipitation - Any liquid or solid form of atmospheric water vapor condensation that falls to the earth's surface. The main form of precipitation observed in Hawaii is rain.

Pretreatment - A practice or device, which treats stormwater prior to entering the PBMP. Pretreatment is important to the design of PBMPs. Properly designed pretreatment systems help to sustain required PBMP function, extend service life, and reduce maintenance costs. The primary goal of most pretreatment systems is to capture sediment, trash, and debris using a variety of methods, but is most commonly achieved by decreasing peak stormwater velocities to allow sediment to settle or by filtering incoming stormwater through vegetation to remove sediment before it reaches a downstream PBMP.

Project Proponent - Project proponents are the designers and tenants responsible for ensuring that new construction and redevelopment project sites are designed in a manner that is protective of the environment and PBMPs are implemented. Contractors can also be considered project proponents since they are responsible for managing new construction and redevelopment project sites to protect the State waters, and ensuring that PBMPs are implemented.

Proprietary PBMP - A commercially available pre-manufactured or partially manufactured PBMP that treats water through filtration, separation, or settling methods. Such examples include catch basin inserts, water quality inlets, oil-grit separators, and hydrodynamic devices.

Receiving Water - The State water that receives discharge from the new development and redevelopment project discharges to. The term "receiving water" is used interchangeably with State water throughout this manual.

Redevelopment - Alteration of the footprint of an existing site or building or replacing impervious surfaces on DOTA property.

Retention - The storage of stormwater to prevent it from leaving the development site.

Retrofit - Retrofits can include new installations and upgrades/alterations to the existing MS4 (including PBMPs) that provide stormwater treatment, pollutant reduction (e.g., improve the quality of stormwater runoff), trash or floatable reduction, runoff volume reduction, and/or address specific objectives at an existing site. Retrofits can also include opportunities that remedy past design and/or performance deficiencies.

Reuse - Planned capture and treated reuse of stormwater runoff that would otherwise be discharged without being put to direct use.

Runoff - Water originating from rainfall and other sources (e.g., sprinkler irrigation) that flows over the land surface to drainage facilities, rivers, streams, springs, seeps, ponds, lakes, and wetlands.

Runoff Coefficient or C - The runoff coefficient is a dimensionless coefficient relating the amount of runoff to the amount of precipitation received. It represents the interaction of multiple factors, including water storage in surface depressions, infiltration, antecedent moisture, ground cover, ground slopes, and soil types. Since the coefficient may vary with respect to prior wetting and seasonal conditions, the use of average values is typically applied to simplify the determination of this coefficient. The runoff coefficient is a larger value for areas with low infiltration and high runoff (pavement, steep gradient) and a lower value for permeable, well-vegetated areas (forest, flat land).

Rainfall Intensity or i - Rainfall intensity is a variable related to rainfall duration and design storm recurrence interval and indicates rainfall severity. Rainfall intensity at a duration equal to the time of concentration or Tc is used to calculate the peak flow in the Rational Method. The rainfall intensity can be selected from the appropriate intensity-duration-recurrence interval (I-D-R) curves.

Run-on - Offsite stormwater surface flow or other surface flow entering onto a project site.

Seasonal High Groundwater - Seasonal high groundwater is the highest annual groundwater elevation as determined by a qualified soil scientist, geohydrologist, or licensed engineer in the State of Hawaii based on monitoring wells or other recognized methods.

Secondary Containment - Structures, usually dikes or berms, surrounding tanks or other storage containers, designed to catch spilled materials from the storage containers.

Sedimentation - The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.

Sediments - Soil, sand, and minerals washed from land into water, usually after rain, that collects in reservoirs, rivers, lagoons and harbors. Accumulated sediments destroy fish nesting areas, and cloud water bodies, thus preventing sunlight from reaching beneficial aquatic plants. Farming, mining, and building activities without proper implementation of BMPs will expose sediment materials, allowing them to be washed off the land during rainfall events.

Sheet Flow - Runoff that flows over the ground surface as a thin, even layer not concentrated in a channel.

Small MS4 - A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) that is designed or used for collecting or conveying stormwater and is owned or operated by a city, county, or other governmental entity (including federal and state entities). The term “MS4” specifically excludes combined sewers and systems that are part of a Publicly Owned Treatment Works.

Soil group, hydrologic - A classification of soils by the Soil Conservation Service into four potential runoff groups. The groups range from A soils, which are very permeable and produce little or no runoff, to D soils, which are not very permeable and produce much more runoff.

Source Control PBMP - Appropriate structural measure that prevents pollutants from contacting stormwater runoff or prevent the discharge of contaminated runoff to the DOTA MS4, drainage system, or State waters. Source Control PBMPs can be categorized as operational or structural, and are further defined individually in this glossary.

Spillway - A passage such as a paved apron or channel for surplus water over or around a dam or similar obstruction. An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

State waters - As defined by *HRS § 342D-1*, State waters means all waters, fresh, brackish, or salt around and within the State, including, but not limited to, coastal waters, stream, rivers, drainage ditches, ponds, reservoirs, canals, groundwaters, and lakes; provided that drainage dicthes, ponds, and reservoirs required as part of a water pollution control system are excluded. *HAR § 11-54* applies to all State waters , including wetlands, subject to the following exceptions:

1. *HAR § 11-54* does not apply to groundwater, except the Director may in the Director’s discretion take appropriate actions when the Director believes that the discharge of

pollutants to the ground or groundwater has adversely affected, is adversely affecting, or will adversely affect the quality of any State water other than groundwater.

2. *HAR § 11-54* does not apply to drainage ditches, flumes, ponds, and reservoirs that are required as part of a water pollution control system.
3. *HAR § 11-54* does not apply to drainage ditches, flumes, ponds, and reservoirs that are are used solely for irrigation and do not overflow into or otherwise adversely affect the quality of any other State waters, unless such ditches, flumes, ponds, and reservoirs are waters of the U.S. as defined in *40 CFR § 122.2.*

The term "receiving water" is indicative of the particular State water that a project discharges to and this term is used throughout this manual. The terms, State waters and receiving waters are used interchangeably in this Manual.

Storm Drains - Above- and below-ground structures for transporting stormwater to streams or outfalls for flood control purposes.

Storm Frequency - The time interval between major storms of predetermined intensity and runoff volumes for which storm sewers and other structures are designed and constructed to hydraulically accommodate flow without surcharging and/or back flooding; e.g., a 2-year, 10-year, or 100-year storm.

Stormwater - According to *40 CFR § 122.26 (b)(13)*, stormwater means stormwater runoff, snow melt runoff, and surface runoff and drainage. Stormwater also means that portion of precipitation that does not naturally percolate into the ground or evaporate but flows via overland flow, interflow, pipes, and other features of a stormwater drainage system into a defined surface water body or a PBMP. Stormwater runoff also includes surface runoff, street wash water, and may include discharges from firefighting activities.

Structural Source Control PBMPs - Physical, structural, or mechanical devices or facilities intended to prevent pollutants from entering stormwater. Structural Source Control PBMPs typically include:

1. Enclosing or covering the pollutant source (building or other enclosure, a roof over storage and working areas, temporary tarp, etc.).
2. Segregating the pollutant source to prevent stormwater run-on and direct only contaminated stormwater to appropriate treatment control PBMPs.

Swale - A shallow drainage conveyance with relatively gentle side slopes.

Time of Concentration or T_c - The time it takes for runoff to travel from the hydraulically most distant point in the watershed to the point of reference downstream.

Treatment Control PBMP - Engineered technology designed to remove pollutants from stormwater runoff prior to discharge to the DOTA storm drain system or receiving waters. Examples of treatment PBMPs are ponds, oil/water separators, and manufactured treatment devices.

Tributary Drainage Area - A geographic area where precipitation collects and runoff drains into a common outlet or a particular PBMP. To size the PBMP, the project proponent should calculate the volume of runoff that will drain to it from the tributary drainage area.

Underdrain - A pipe with holes drilled through the top, installed on the bottom of a PBMP, used to collect and remove captured runoff.

UIC Program - A federal regulatory program established to protect underground sources of drinking water from UIC well discharges. The EPA has granted the State of Hawaii, Department of Health, Safe Drinking Water Branch authority to regulate UIC wells.

UIC Well - According to *HAR § 11-23*, UIC well is defined as "a bored, drilled or driven shaft, or dug hole whose depth is greater than its widest surface dimension." Examples of UIC wells or sub-surface infiltration systems include dry wells, drainage wells, and other similar devices that discharge stormwater to the ground.

Waters of the United States - Refer to the current definition by EPA and the Department of Army. EPA and the Department of Army published the *CWA: Definition of Waters of the U.S. final rule* effective June 2020. On June 9, 2021, EPA and the Department of Army announced their intention to initiate a new rulemaking process to establish a definition of waters of the U.S. Additional information can be obtained from EPA Waters of the United States web page, which can be accessed using the following webpage: https://www.epa.gov/wotus

Wildlife - Any wild animal, including without limitation any wild mammal, bird, reptile, fish, amphibian, mollusk, crustacean, arthropod, coelenterate, or other invertebrates, including any part, product, egg, or offspring thereof.

Wildlife Attractants - Any man-made structure, land-use practice, or man-made or natural geographic feature that can attract or sustain hazardous wildlife within the landing or departure airspace or the airport's aircraft operations area. These attractants can include architectural features, landscaping, waste disposal sites, wastewater treatment facilities, agricultural or aquaculture activities, surface mining, or wetlands.

Wildlife Hazard - A potential for a damaging aircraft collision with wildlife on or near an airport. Species of wildlife (birds, mammals, reptiles), including feral and domesticated animals, not under control that may pose a direct hazard to aviation (i.e., strike risk to aircraft) or an indirect hazard such as an attractant to other wildlife that poses a strike hazard or is causing structural damage to airport facilities (e.g., burrowing, nesting, perching).

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The development of the Post-Construction Best Management Practice Manual incorporated applicable portions of the City and County of Honolulu, *Storm Water BMP Guide for New and Redevelopment* (July 2017) for local consistency. This manual also utilized other agencies' and municipalities' manuals and guidance documents with similar conditions and restraints as the DOTA airports.

DISCLAIMER

The information presented in this Post-Construction BMP Manual was taken from available, and most recent sources deemed to be representative of the acceptable PBMPs and stormwater runoff control measures. This manual has been prepared as a reference guide for PBMP design and is not intended to replace the applicable storm drain design standards. The selection of appropriate PBMPs shall be made in conjunction with best professional judgment and sound engineering principles to assure the proper function and performance of the PBMPs and associated DOTA MS4 or drainage system.

DOTA does not guarantee the accuracy or completeness of this document and will not assume any liability or responsibility for the use of, or for any damages resulting from, any information contained herein. The detail and the wording in this manual will not necessarily result in compliance with any Standard Specifications.

The design criteria in this manual are recommendations and not intended to conflict with federal, state, county, and other regulations that dictate airport operations and safety. The selection and implementation of PBMPs should comply with all applicable regulations.

1. INTRODUCTION

The Post-Construction BMP Manual was developed to provide guidance for assessing the requirements, applicability, and technical feasibility of implementing PBMPs at airports owned or operated by DOTA. DOTA is required to comply with federal, state, and county regulations to protect water resources by treating and controlling flow rates of stormwater runoff for new development and redevelopment projects at its airports. However, airports are different from other industrial, commercial, or MS4 project sites, and DOTA must manage stormwater in a way that will not compromise aircraft safety. Wildlife attractants at airports are a major concern because of the potential for collisions between wildlife and aircraft that threaten human safety. Many traditional PBMPs, such as ponds, may provide wildlife habitat and, thereby, attract wildlife species that can be hazardous to aircraft. As a result, such traditional PBMPs must be individually considered and appropriately selected for use at DOTA airports to reduce or eliminate hazardous wildlife attractants. This manual focuses on the technical and safety issues related to stormwater management within the airport environment.

The Permanent Best Management Practice Program, hereinafter “Post-Construction Program”, is complementary to the Construction Program, and requires that specified new development and redevelopment projects include PBMPs. PBMPs are designed to provide water quantity control and improve water quality after construction is completed. PBMPs are further classified into the following categories based on priority:

1. LID PBMPs;
2. Source Control PBMPs; and
3. Treatment Control PBMPs.

The purpose of PBMPs is to mimic pre-construction hydrologic processes, reduce or prevent stormwater runoff, retain stormwater on-site, control the source of potential pollutants, treat stormwater, or prevent the discharge of pollutants that enter the DOTA MS4, drainage system, or State waters after the Project is completed.

This manual has been developed to prioritize and promote LID PBMPs that favor infiltration, biofiltration, evapotranspiration, or harvesting/reuse of stormwater, followed by other practices that treat and release stormwater. This Manual guides the selection, installation, inspection, and maintenance of PBMPs.

The target audience for this manual includes:

- Project Proponents;
- DOTA Staff (including Planners, Engineers, and Maintenance staff);
- Consultants (including designers and CMs);
- Contractors and subcontractors; and
- DOTA Airport Tenants and users.

Project proponents may also include PBMPs not listed in this Manual, provided it is approved by the DOTA AIR-E and AIR-EE.

1.1 BACKGROUND

The Post-Construction Program requires specified construction projects to include PBMPs and verify that they are in place to prevent or minimize water quality impacts to the maximum extent practicable after construction is completed.

The Post-Construction Program includes training and outreach to clarify requirements; design plan review to verify PBMPs have been included, where required; PBMP standards that include LID; and tracking inspection and maintenance data for PBMPs. When a PBMP is constructed and activated, it requires inspection and maintenance for proper operation to continue to function as designed to provide water quality treatment. PBMP Operation & Maintenance (hereinafter referred to as "PBMP O&M") is necessary and provides for the routine inspection practices based on the type of PBMP installed and the preventive and corrective maintenance needed to properly maintain the PBMP, and should be considered during design (refer to sections 5.1.1 and 6.0 for additional information on the PBMP O&M requirements and DOTA provided information).

1.2 REGULATORY REQUIREMENTS

There are several federal, state, and county requirements, which affect stormwater management and may apply to a given new development and redevelopment project. Potential applicable requirements for DOTA airport projects may include the following:

- 303(d) list *(regulated under CWA § 303(d));*
- NPDES Permits for discharges from Small MS4s and construction activities (regulated under *CWA § 402*, *40 CFR § 122* and *HAR § 11-55, Appendices K* and *C*);
- FAA Regulations *14 CFR § 139* and ACs;
- UIC Authorization (regulated under *HAR § 11-23*); and
- Other - CCH IWDP (regulated under *ROH § 14*), county code related to construction, building permits, fire code, county fire department flammable finishes permits, storm drainage standards, etc.

1.2.1 Clean Water Act § 303(d) List of Impaired Waters

Under *CWA § 303(d)*, the DOH-CWB is required to develop lists of impaired waters. These are waters for which technology-based regulations and other required controls are not stringent enough to meet the water quality standards set by the State. *CWA § 303(d)* requires that the State establish priority rankings for waters on the lists and develop TMDLs for these waters. Within the TMDL, the DOH-CWB allocates a loading capacity among the various point sources and non-point sources. Permits for point sources are issued through the NPDES program.

DOH-CWB is obligated by the *CWA § 303(d) and § 305(b)* to report on the State's water quality on a two year cycle. DOH-CWB develops Integrated Reports and TMDLs; current approved and previous reports can be accessed at the following webpages:

https://health.hawaii.gov/cwb/clean-water-branch-home-page/integrated-report-and-total-maximum-daily-loads/

https://www.epa.gov/tmdl/monitoring-assessment-and-tmdls-hawaii

For State waters on the State *CWA § 303(d)* list or State established and EPA approved TMDLs, DOTA shall target the pollutants of concern to include the parameters causing impairment, and consideration shall be provided for trash reduction techniques for PBMPs (refer to section 1.2.2.1).

1.2.2 Clean Water Act § 402 NPDES Permits

In Hawaii, the discharges from the Small MS4s, construction activities greater than or equal to one acre, hydrotesting, and dewatering activities are required to obtain NPDES permits regulated under *HAR § 11-55, Appendices K* and *C* respectively. DOH-CWB has the delegated authority to manage NPDES permits for EPA in Hawaii.

Additional information on all DOH-CWB general permits and application processing can be accessed using the webpage below:

https://health.hawaii.gov/cwb/permitting/general-permits/

The CWB Notice of Intent Form can be submitted through the e-Permitting Portal, which can be accessed using the webpage below:

https://eha-cloud.doh.hawaii.gov/epermit/

1.2.2.1 HNL Small MS4 Permit

The *HNL MS4 NPDES Permit No. HI S000005* includes the requirements to develop and implement this Post-Construction BMP Manual. *HNL Small MS4 Permit Part D.1.e.* requirements for this Manual are as follows:

- DOTA shall develop, implement, and enforce a program to address stormwater runoff from all new development and redevelopment projects that result in a land disturbance of one acre or more and smaller projects that have the potential to discharge pollutants to the DOTA Small MS4.
- DOTA shall review and update, as necessary, the criteria defining when PBMPs must be included in a project design and the types to be imlemented that address stormwater impacts and pollutants of concern, including LID.
- For State waters on the 303(d) list or State established and EPA approved TMDLs, the pollutants of concern to be targeted shall include the parameters causing impairment. Consideration shall also be provided for trash reduction techniques as required in HNL Small MS4 Permit Part D.1.(f)(1)(v).
- DOTA shall revise its standards for addressing PBMPs, to include LID requirements and reduce its use of exemptions.
- Ensure that the management practices are prioritized to favor infiltration, evapotranspiration, or harvesting/reuse of stormwater followed by other practices that treat and release stormwater.
- This Manual shall be applicable to all construction projects disturbing at least one acre and smaller projects that have the potential to discharge pollutants to the DOTA Small MS4.
- The plan for the implementation of LID provisions shall include, at a minimum, the following:

  - Criteria for requiring implementation;
  - Investigation into the development of quantitative criteria for a specific design storm to be managed by LID techniques;
  - Infeasibility criteria for circumstances in which a waiver could be granted for the LID requirements; and
  - When a LID waiver is granted, alternatives such as offsite mitigation and/or non-LID treatment control BMPs could be required.
- DOTA shall not advertise any construction project nor award any construction contract until the project design has been reviewed and accepted to ensure that appropriate PBMPs (including LID PBMPS) have been included in the project design.
  - PBMPs shall be included in the bid package for design-bid-build projects; and
  - DOTA shall review and approve the project design for design-build projects the same as for design-bid-build projects prior to implementation.
- No project shall proceed without the inclusion of appropriate PBMPs unless DOTA grants a waiver based on specific documentation demonstrating that such PBMPs are not feasible.
- PBMP installation project documents shall also include appropriate requirements for their future continued maintenance.
- DOTA shall track the PBMP inventory, frequency of inspections and maintenance of the PBMPs in its AMS.
- All stormwater treatment and LID PBMPs shall be inspected at least once a year for proper operation; maintenance shall be performed as necessary to ensure proper operation.

1.2.2.2 OGG Small MS4 Permit

Under the *OGG MS4 NPDES Permit No. HI 14KE349*, DOTA shall implement the requirements of *HAR § 11-55 Appendix K, Part 6.(a)(5)*. These requirements, as related to this Manual, are as follows.

- DOTA shall develop, implement, and enforce a program to reduce pollutants in stormwater runoff entering its Small MS4 from new development and redevelopment projects that disturb greater than or equal to one acre of land;
- DOTA shall establish rules, ordinances, or other regulatory mechanisms, including enforcement procedures and actions, that address post-construction runoff from new development and redevelopment projects;
- DOTA shall implement structural and/or non-structural PBMPs to minimize water quality impacts and maintain pre-development runoff conditions; and
- DOTA shall ensure that the procedures for long-term O&M of PBMPs are established and updated as necessary.

1.2.2.3 NGPC for Construction Activities

Any construction project that disturbs one acre or more of total land area, which includes activities that disturb less than one acre of land area and are a part of a larger common plan of development that will ultimately disturb one acre or more of total land area, shall be required to apply for an NGPC for construction activities regulated under *HAR § 11-55 Appendix C.*

Under the NGPC for construction activities, DOTA and the contractor shall implement the *HAR § 11-55 Appendix C* requirements. These requirements as related to this Manual are as follows.

- Ensure that all discharges from the area of earth disturbance to the natural buffer are first treated by the site's erosion and sediment controls, and use velocity dissipation devices if necessary to minimize soil erosion in order to minimize pollutant discharges when directing stormwater to vegetated areas.
- The SWPPP shall include post-construction measures. The SWPPP shall include descriptions of measures that will minimize the discharge of pollutants via stormwater discharges after construction operations have been finished. All projects shall consider PBMPs to minimize the discharge of pollutants via stormwater discharges after construction operations have been completed. Examples of PBMPs include vegetated swales and natural depressions; structures for stormwater retention, detention, or recycle; velocity dissipation devices to be placed at the outfalls of detention structures or along with the length of outfall channels; and other appropriate measures.
- If using any of the following PBMPs at a DOTA site that could be considered Class V UIC wells (if they meet the definition of a well and an injection well), DOTA shall document any contact with the DOH-SDWB:
    - Infiltration trenches (if stormwater is directed to any bored, drilled, driven shaft, or dug hole that is deeper than its widest surface dimension or has a subsurface fluid distribution system);
    - Commercially manufactured precast or pre-built proprietary subsurface detention vaults, chambers, or other devices designed to capture and infiltrate stormwater; and
    - Dry Wells/drainage wells, seepage pits, or improved sinkholes (if stormwater is directed to any bored, drilled, driven shaft, or dug hole that is deeper than its widest surface dimension or has a subsurface fluid distribution system).

1.2.3 Federal Aviation Administration Regulations and Advisory Circulars

DOTA airports must be maintained and operated in a condition that meets all requirements of *14 CFR § 139, Airport Certification*. Modification from the standards without FAA approval is not permitted. The FAA guiding documents that derive from *14 CFR § 139* affecting airport design and operations concerning stormwater management are listed below:

- *FAA AC 150/5300-13A, Airport Design* – This document prescribes airfield layout standards to maintain passenger and aircraft safety around operational surfaces in the various FAA-regulated airport zones;
- *FAA AC 150/5200-33C, Hazardous Wildlife Attractants on or near Airports* – This document provides design limitations on certain land uses that have the potential to attract hazardous wildlife on or near public-use airports;
- *FAA AC 150/5370-10H, Standard Specifications for Construction of Airports* - Prescribes the material requirements and methods used to construct airport operating surfaces and subgrades, including site drainage;
- *FAA AC 150/5320-5D, Airport Drainage Design* - Describes requirements for the design and construction of airport surface and subsurface storm drainage systems for paved runways, taxiways, and aprons;

- *ACRP Report 125: Balancing Airport Stormwater and Bird Hazard Management* – This document provides valuable guidance to help airports identify and evaluate stormwater management and bird mitigation practices including a risk analysis and decision tool; and
- Wildlife Hazard Management Plans – These documents developed for individual airports provide considerations for construction projects, stormwater management measures, and vegetation.

The limitations of the FAA regulations applicable to airports and guidance for PBMP design and implementation are discussed in the section 2.1.2.

1.2.4 Underground Injection Control Authorization

To implement provisions of the Federal Safe Drinking Water Act (refer to *40 CFR § 144*), the DOH-SDWB has adopted *HAR § 11-23* for a UIC program. Additional information can be obtained from the DOH-SDWB UIC Program home page, which can be accessed using the webpage below:

https://health.hawaii.gov/sdwb/underground-injection-control-program/#:~:text=The%20Underground%20Injection%20Control%20(UIC,originate%20from%20injection%20well%20activity

According to *HAR § 11-23*, a UIC well is defined as “a bored, drilled or driven shaft, or dug hole whose depth is greater than its widest surface dimension.” The discharge of stormwater into the ground can be classified as a Class V Subclass C injection well.

Project proponents should review these regulations if designing a dry well or drainage well and apply for a UIC permit if needed. DOTA has developed guidance for preparing the UIC permit application, permit renewal, and abandonment, which can be accessed using the webpage below:

http://hidot.hawaii.gov/airports/files/2021/09/SOP_DOH_UIC_APPLICATION-GUIDE_ePermitting.pdf

A General Application for a UIC Permit to Operate should be submitted to DOH-SDWB at least 6 months before the anticipated date of UIC well construction. DOH-SDWB issues an approval to construct and test the UIC injection well is after the application is satisfactorily processed. Upon receipt of the approval to construct, the contractor shall construct the injection well followed by injection testing. The contractor shall submit a final report including injection test results, geologic logs, and information requested by DOH-SDWB. DOH-SDWB issues a UIC permit to operate the injection well is issued after the final report is satisfactorily completed.

1.2.5 Other

1.2.5.1 City and County of Honolulu Industrial Wastewater Discharge Permit

The CCH Pretreatment Program monitors wastewaters to prevent the discharge of any substance that might harm the environment or cause damage to the sanitary sewer system. The CCH Regulatory Control Branch must approve any commercial or industrial discharge into the sanitary sewer system. If an operation is likely to discharge harmful materials like large amounts of fats, oils, and grease (FOG) into the CCH sanitary sewer system, they must install a pretreatment system to prevent harm to the CCH sanitary sewer system.

Under the *ROH § 14-5.1*, Paragraph (a), “No person shall discharge or cause to be discharged any industrial wastewater into the public sewers or into any private sewer which discharges to the public sewers, without first applying for and obtaining an IWDP.”

The following is a list of commercial or industrial project activities that will require permits from the CCH:

- Projects that require a building permit and have a sanitary sewer connection shall be evaluated for the issuance of an IWDP;
- Entities that need to discharge chlorinated water, gray water, cooling tower water, or any other polluted water (that cannot be disposed of through the storm drain, landscaping, or watering) temporarily into the CCH sewer system will require a Temporary IWDP application;
- Any business that discharges FOG must connect all kitchen fixtures to a Grease Interceptor; and
- Entities that haul and dispose of liquid waste into the CCH sewer system will require a Liquid Wastehaulers IWDP.

Additional information can be obtained from CCH, Department of Environmental Services, Regulatory Control Branch, Pretreatment Program home page, which can be accessed using the webpage below:

http://www.honolulu.gov/cms-env-menu/site-env-sitearticles/1097-wwm_eq_pretreatment_program.html

1.2.5.2 County Codes and Permits

Requirements for site design and planning are governed by applicable standards and specifications of county agencies with jurisdiction. The design requirements may pertain to Building Code, Fire Code, county agency ordinances, and county zoning requirements. The project proponent should design PBMPs consistent with these standards, specifications, codes, and ordinance requirements (examples include building permits, fire code compliance, county fire department flammable finishes permits, county storm drainage standards, etc.).

2. POST-CONSTRUCTION BEST MANAGEMENT PRACTICE APPLICABILITY

2.1 PROJECTS REQUIRING POST-CONSTRUCTION BMPS

DOTA has developed the criteria that documents which new development and redevelopment construction projects need to implement the PBMP program. A review for PBMP implementation is required for the new development and redevelopment construction projects at DOTA airports that meet one or more of the following criteria:

- Construction activities that result in land disturbance of one acre or more.
- Construction projects that result in land disturbance less than one acre but have the potential to discharge pollutants to the DOTA MS4, drainage system, or State waters. Small projects that have or involve any of the following conditions or activities:
    - Steep earthen slopes (i.e., grade of 20% or more);
    - Modifying, replacing, or installing new drainage structures, as appropriate;
    - Parking lots and buildings adding 5,000 square feet or more of impervious area;
    - Aircraft, vehicle, or equipment washing areas; and
    - Aircraft, vehicle, or equipment fueling areas or container and material storage areas.
- Construction projects that do not meet exemption criteria from the Construction Design Review process (refer to section 2.1.1).

2.1.1 Exempt Projects

Projects that do not meet the DOTA's definition of construction activity and certain types of activities are exempt from the Construction Design Review process according to DOTA's Construction Site Runoff Control Program, and therefore, these projects are exempt.

Project proponents must still go through the DOTA Construction Design Review process which requires the submission of drawings or specifications for AIR-EE review and approval. The project proponent shall use AMS to undergo the Construction Design Review process including an exemption from PBMP implementation. AIR-EE will determine whether a project is exempt.

2.1.2 Federal Aviation Administration Limitations and Exclusions on PBMP Implementation

While all non-exempt construction projects require a review of PBMP implementation, PBMP implementation might be limited or prohibited in certain airport areas due to FAA regulation limitations and exclusions related to aircraft safety concerns or safety zones, such as wildlife attractants.

The availability of food source, water source, and cover (shelter) at airports can provide an attractant to the wildlife that can pose a risk to aviation safety (refer to *FAA AC 150/5200-33C*). Effective food source, water source, and shelter management on and near airports to reduce hazards to aviation depends on collaboration among airport managers, engineering staff, consultants, and designers, as well as environmental personnel to develop PBMPs that eliminate or minimize wildlife attractants to meet the complex safety and regulatory requirements facing DOTA airports.

FAA has several regulations and *FAA ACs* that define the specific design standards (e.g., grading, surface, and drainage features) and prescribe airfield layout standards, which result in a high level of passenger and aircraft safety around the runway and taxiway operational surfaces (refer to section 1.2.3).

FAA regulations define several on-airfield operational zones that ensure the safety of airfield operations should aircraft deviate from the defined runway and taxiway surfaces. In addition, FAA mandates protection zones for near-airfield areas, which extend outside of the airfield AOA boundary, and are designed to ensure the protection of aircraft approach and departure airspace.

The FAA specified zones of interest (both on-airfield and near-airfield zones) related to a PBMP implementation strategy include RSA, ROFA, TOFA/TSA, Apron, and AOA. FAA design standards for these zones have direct implications for the design and location of the PBMPs. The following sections describe the specific design standard restrictions related to PBMPs for on-airfield and near-airfield zones.

2.1.2.1 Runway Safety Area (RSA)

The RSA is the most restrictive of all airport zones, and modification of the FAA standards is not permitted. The RSA restrictions can be found at *FAA AC 150/5300-13A.*

2.1.2.2 Runway Object Free Area (ROFA)

The ROFA has similar restrictions as the RSA. The ROFA restrictions can be found at *FAA AC 150/5300-13A.*

2.1.2.3 Runway Protection Zone (RPZ)

The RPZ has similar restrictions as the RSA and ROFA. The protected airspace is a family of related three-dimensional airspace surfaces designed to provide obstacle clearance to arriving and departing aircraft. Examples of these surfaces include the Runway Departure, Arrival, and the *14 CFR § 77* Surfaces. Like the RPZ, these extend from the runway ends to a specified distance beyond. They also extend out in the airport drivelane and parking areas. The RPZ restrictions can be found at *FAA AC 150/5300-13A.*

2.1.2.4 Taxiway Object Free and Taxiway Safety Areas (TOFA/TSA)

The TOFA/TSA have similar restrictions as the RSA and ROFA based on the aircraft serving the airport. The TOFA/TSA restrictions can be found at *FAA AC 150/5300-13A.* Where the TOFA/TSA physically overlap the ROFA and RSA, the more rigorous runway standards apply.

2.1.2.5 Object Free Area (OFA)

The OFA has restrictions related to aboveground structures. The OFA restrictions can be found at *FAA AC 150/5300-13A.*

2.1.2.6 Object Free Zone (OFZ)

The OFZ may be composed of the ROFZ, the POFZ, the inner-approach OFZ, and the inner-transitional OFZ. The OFZ restrictions can be found at *FAA AC 150/5300-13A*.

2.1.2.7 Runway Obstacle Free Zone (ROFZ)

The ROFZ restrictions can be found at *FAA AC 150/5300-13A*.

2.1.2.8 Building Restriction Line (BRL)

The BRL is a restrictive zone set beyond the RPZ, the ROFA, the runway visibility zone, NAVAID critical areas, areas required for TERPS, and ATCT clear line of sight. The BRL restrictions can be found at *FAA AC 150/5300-13A*.

2.1.2.9 Apron

The Apron restrictions can be found at *FAA AC 150/5300-13A*.

2.1.2.10 Airport Operations Area (AOA)

The AOA restrictions can be found at *FAA AC 150/5300-13A*.

2.1.2.11 Wildlife Hazard Areas

The wildlife hazard area restrictions can be found at *FAA AC 150/5200-33C*.

2.1.3 Federal Aviation Administration Exemption Zone for PBMP Installation

DOTA reviewed the ALP to evaluate the above listed FAA restriction zones to understand the limiting factors for PBMP implementation. While the RSA, ROFA, TOFA/TSA were the most restrictive in implementing PBMPs, the BRL was deemed the most restrictive. Additionally, RPZs were also included within this all-encompassing area since RPZs require eliminating or reducing wildlife attractants. The existing and future layers for FAA zones and the property boundary were used to delineate and establish the DOTA defined FAA Exemption Zones for PBMP installation maps.

Figure 2-1 below depicts the FAA Exemption Zone for PBMP installation at HNL. FAA Exemption Zone for PBMP installation maps for all 15 airports Statewide are provided in Appendix I and also provided within the AMS. The project proponent can use the interactive maps within the AMS to review their project location to determine whether they fall within the FAA Exemption Zone.

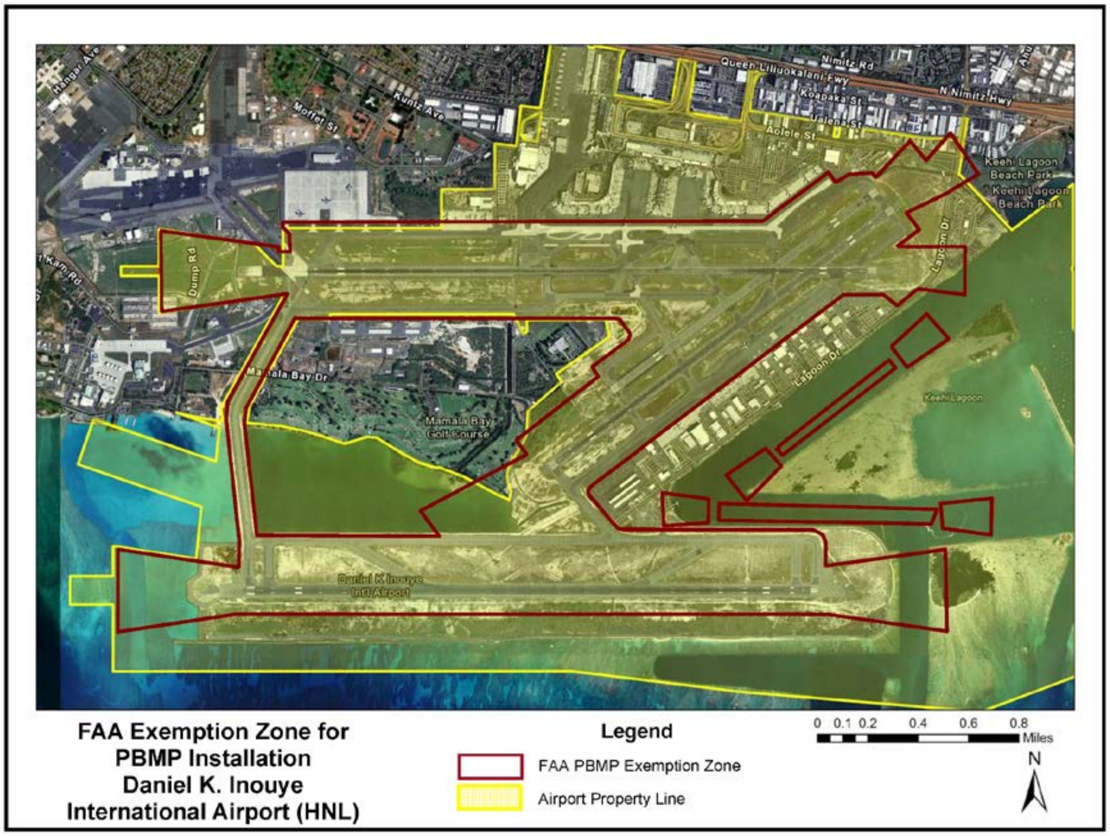


Figure 2-1. Daniel K. Inouye International Airport FAA Exemption Zone for PBMP Installation

2.1.4 Variance

DOTA has developed criteria that documents which new development and redevelopment construction projects may qualify for a PBMP variance. Project proponents may request a PBMP variance that meet one or more DOTA established criteria:

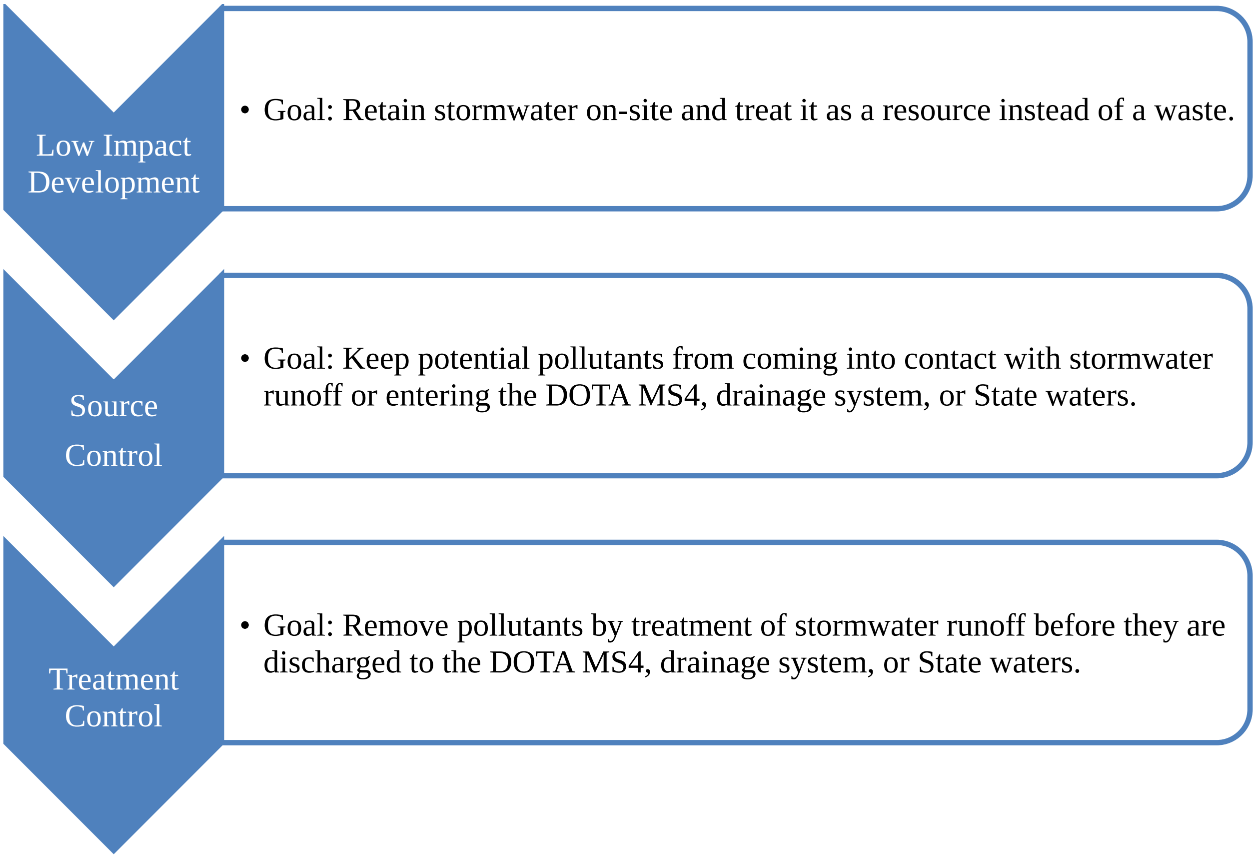
- The project is located within the FAA Exemption Zone for PBMP installation (refer to Appendix I and in the AMS);
- The project returns the area to pre-development runoff conditions;
- The project is solely to address Water Quality Improvement or Preservation (examples include Shoreline Protection, Landscaping, PBMP Installation / Retrofit, and Permanent Erosion Control); and
- The project qualifies for another PBMP variance not listed herein.

PMP variance requests shall be submitted in the AMS as part of the Construction Design Review process. Project proponents shall include drawings, specifications, reasons why PBMP implementation is not feasible due to other airport regulations or safety concerns, or any other pertinent information to AIR-EE. AIR-EE will review each PBMP variance request and determine whether a project qualifies.

3. POST-CONSTRUCTION BEST MANAGEMENT PRACTICE IMPLEMENTATION

3.1 PBMP CATEGORIES AND PREFERENCE

Every construction project at DOTA airports should consider PBMPs based on three priorities: 1) LID, 2) Source Control, and 3) Treatment Control. Figure 3-1 and Table 3-1 establishes DOTA's priority of designing and installing PBMPs for stormwater management at its airports Statewide.



- Goal: Retain stormwater on-site and treat it as a resource instead of a waste.
- Goal: Keep potential pollutants from coming into contact with stormwater runoff or entering the DOTA MS4, drainage system, or State waters.
- Goal: Remove pollutants by treatment of stormwater runoff before they are discharged to the DOTA MS4, drainage system, or State waters.

Figure 3-1. PBMP Categories in the Order of Preference

In addition, the following criteria must be met for projects on DOTA airport property as follows:

1. Retain stormwater on-site by infiltration, evapotranspiration, or harvesting/reuse, as much of the WQV as feasible, with appropriate LID Retention PBMPs or LID Biofiltration PBMPs.
2. If it is demonstrated to be infeasible to retain and/or biofilter the WQV, treat and discharge with appropriate Treatment Control PBMPs. If only a portion of the WQV is retained on-site or biofiltered, appropriate Treatment Control PBMPs can be used to treat and discharge the remaining portion of the WQV.

Table 3-1 and Figure 3-2 present the DOTA PBMP implementation requirements for post-construction in new development and redevelopment projects.

Table 3-1. DOTA PBMP Implementation Requirements

PBMP Category	Applicable Projects
LID	Required for all non-exempt projects that do not qualify for a PBMP variance
Source Control	Required for all non-exempt projects
Treatment Control	Required for all non-exempt projects that do not qualify for a PBMP variance **if LID is infeasible**

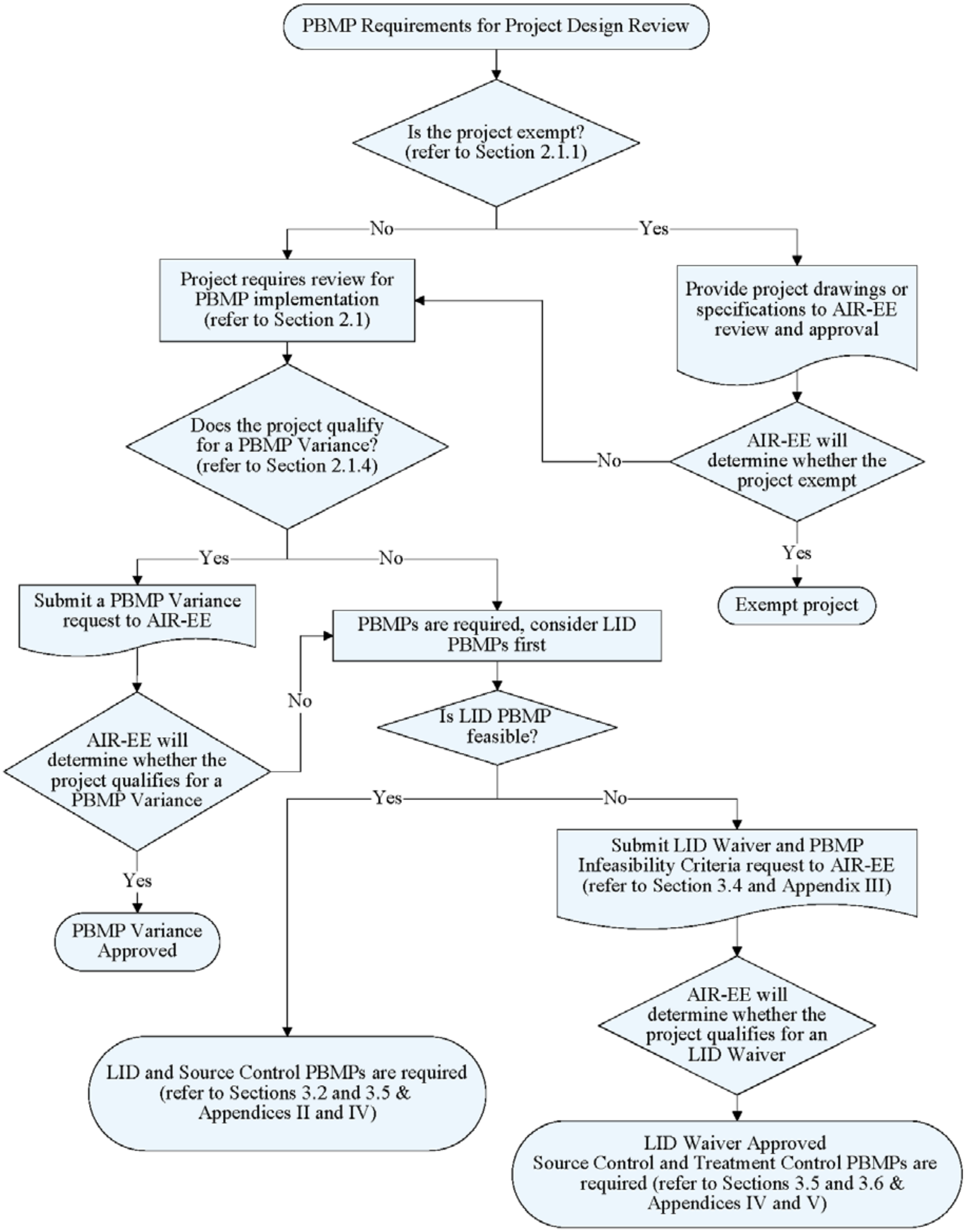


Figure 3-2. Flowchart Depicting DOTA PBMP Implementation Requirements

These considerations will be documented through the DOTA Design Review process. Project proponents shall use the AMS to undergo the Construction Design Review process.

LID, Source Control, and Treatment Control PBMPs are discussed throughout this manual.

3.2 LOW IMPACT DEVELOPMENT PBMP REQUIREMENTS

LID PBMPs seek to mimic pre-development hydrology by minimizing disturbed areas and impervious cover. LID promotes infiltration, detention, evapotranspiration, and biotreatment of stormwater runoff close to its source. Examples of LID PBMPs include, but are not limited to, bioretention, rain gardens, permeable pavements, and harvesting/reuse.

All non-exempt new development or redevelopment projects that do not qualify for a PBMP variance (refer to section 2.1.4) must evaluate the implementation of LID PBMPs for stormwater management unless it is infeasible to implement.

Table 3-2 presents a list of acceptable LID PBMPs, reference to the corresponding LID PBMP Design Fact Sheets provided in Appendix II, and the LID PBMP type. PBMPs not included herein, may be used with DOTA review and approval.

Table 3-2. Low Impact Development PBMPs

LID PBMP Name	PBMP Design Fact Sheet	LID PBMP Type
Biofilter	LC-1	Biofiltration
Bioretention	LC-2	Retention[1]
Bioswale	LC-3	Biofiltration
Harvesting/Reuse	LC-4	Retention
Dry Well/Drainage Well	LC-5	Retention
Infiltration Basin	LC-6	Retention[1]
Infiltration Trench	LC-7	Retention[1]
Permeable Pavement	LC-8	Retention[2]
Subsurface Infiltration	LC-9	Retention[2]
Vegetated Buffer Strip	LC-10	Biofiltration
Vegetated Swale	LC-11	Biofiltration

Notes:

[1] Can be designed as biofiltration PBMP if there are site constraints to capture and infiltrate the entire WQV.

[2] Can be designed as biofiltration PBMP depending on the type and model of the proprietary product selected for the project.

The following information is provided for each of the above-listed LID PBMPs:

- PBMP Category;
- Pollutants Targeted;
- Description;
- Limitations;

- Design Guidelines including general, pretreatment consideration, area requirements, minimum design criteria, and sizing guidelines;
- Construction Considerations; and
- Example Schematics.

3.3 INFILTRATION REQUIREMENTS

LID PBMPs rely on the soil's ability to infiltrate stormwater runoff; these PBMPs use the filtration, adsorption, and biological properties of the soil matrix, with or without amendments, to remove pollutants as stormwater infiltrates into the ground. Infiltration can provide multiple benefits, including pollutant removal, peak flow control, groundwater recharge, and flood control.

This section outlines the design requirements applicable to infiltration PBMPs.

3.3.1 Soil Types and Textures

The USDA NRCS classifies soils into four HSGs (A, B, C, and D) according to their minimum infiltration rate obtained for bare soil after prolonged wetting. The four HSGs are defined as follows:

1. Group A - Soils having a high infiltration rate (low runoff potential) when thoroughly wet. This group consists mainly of deep, well-drained to excessively drained sands or gravelly sands. Group A soils have a high rate of water transmission.
2. Group B - Soils having a moderate infiltration rate when thoroughly wet. This group consists mainly of moderately deep to moderately well-drained soils, with a moderately fine texture to moderately coarse texture. Group B soils have a moderate rate of water transmission.
3. Group C - Soils having a slow infiltration rate when thoroughly wet. This group consists mainly of soils having a layer that impedes the downward movement of water or soils of fine to moderately fine texture. Group C soils have a slow rate of water transmission.
4. Group D - Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. This group consists mainly of clays with a high shrink-swell potential, soils with a high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. Group D soils have a very slow rate of water transmission.

Table 3-3 presents a list of typical infiltration rates for the various soil types and HSG.

Table 3-3. Typical Soil Infiltration Rates Associated with Soil Types

Soil Texture Class	Hydrologic Soil Group	Infiltration Rate (inch/hour)
Sand	A	8
Loamy Sand	A	2
Sandy Loam	B	1
Loam	B	0.50
Silt Loam	C	0.25
Sandy Clay Loam	C	0.15
Clay Loam	D	0.09
Silt Clay Loam	D	<0.09
Clay	D	<0.05

Source:
Storm Water BMP Guide for New and Redevelopment (CCH, July 2017).

Based on the soil textural classes and the corresponding infiltration rates, the feasibility of infiltration can be determined and used to eliminate unsuitable soil conditions for infiltration PBMPs.

Soils acceptable for use with infiltration PBMPs include those with infiltration rates equal to or greater than 0.50 inch/hour. Soil textures with rates less than 0.50 inch/hour are unsuitable since it increases the risk of the PBMP not draining properly and creating localized areas of standing water, which would be detrimental to airport operational safety. Underdrains may be used if the infiltration rate of the underlying soils is less than 0.50 inch/hour. Project proponents should evaluate the use of underdrains based on the site conditions.

Project proponents shall use the USDA Web Soil Survey webpage to obtain the soil information for their project site using the webpage below; however, the infiltration rate or permeability of the soil types within the subsoil profile shall be field test verified, extending a minimum of 3 feet below the bottom of the proposed PBMP.

https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

3.3.2 Determination of Infiltration Rates

Soil lithology and the depth to groundwater are key factors to determine the feasibility of the installation of infiltration PBMPs. A soil investigation performed by project proponents should adequately evaluate soil lithology to determine if there are potential problems in the soil structure that would inhibit infiltration, or if there are potential adverse impacts to structures, slopes, or groundwater. In addition, the identification of the seasonal high groundwater table elevation should be determined using a piezometer or other accepted geotechnical means.

Project proponents can determine the infiltration rates of the soil matrix and the depth to groundwater by conducting field investigations as detailed below.

3.3.2.1 Field Investigations

Project proponents shall conduct soil investigations and perform infiltration tests where no previous data is available in order to accurately determine the local soil characteristics and capacity for infiltration PBMPs.

Infiltration rate tests are used to help estimate the maximum sub-surface vertical infiltration rate of the soil below a proposed infiltration facility (e.g., infiltration trench or infiltration basin). There are various infiltration field test methodologies, the two most common being the Falling Head Percolation Test and the Double-Ring Infiltrometer Test.

DOTA utilizes the CCH recommendation for the minimum number of permeability tests: 1 test per 100 linear feet for an infiltration trench and 1 test per 2,500 square feet for an infiltration basin, subsurface infiltration system, dry well/drainage well, bioretention, and permeable pavement (*City and County of Honolulu, Storm Water BMP Guide for New and Redevelopment, revised July 2017*). A licensed professional engineer with geotechnical expertise should determine the actual testing protocols and methods used for a specific project.

3.3.3 Design Infiltration Rates

DOTA understands that there may be variability with the testing and measurement of infiltration rates. To account for uncertainties and variability in testing and assumptions from previous studies, a correction/safety factor shall be applied to the measured infiltration rate to produce a design infiltration rate for the PBMP sizing calculations. The minimum safety factor for infiltration PBMPs is 2.

3.4 LOW IMPACT DEVELOPMENT WAIVER AND PBMP INFEASIBILITY CRITERIA

LID PBMP implementation may not be feasible at the project site depending on the location suitability constraints, including soil infiltration rate, depth to the seasonal high groundwater table, setbacks, drawdown requirements, depth of bedrock, and the proposed activities on the site.

DOTA has developed site infeasibility screening criteria for various LID PBMPs. The following provides a list of evaluation criteria which can assign a waiver from LID PBMP implementation.

- Infiltration infeasibility;
- Biofiltration infeasibility;
- Harvesting/reuse infeasibility; and
- Other Infeasibility.

Project proponents shall use the LID Waiver and Infeasibility Screening Worksheet provided in Appendix III or go through the PBMP Design Review process within the AMS.

3.4.1 Infiltration Infeasibility Evaluation Criteria

Infiltration PBMPs are infeasible and shall not be used if any of the following conditions exist:

1. Soils beneath the PBMP invert have a measured infiltration rates of less than 0.50 inch/hour;
2. Soils beneath the PBMP invert are classified as HSG "C" or "D" as reported by the USDA NRCS;
3. The seasonal high groundwater table is within 3 feet from the PBMP invert;
4. There is a documented concern that there is potential for soil pollutants, groundwater pollutants, or pollutants associated with industrial activities to be mobilized;
5. The project area is prone to geotechnical hazards such as soil movement, sloughing, etc.;
6. The PBMP is built within the setbacks established in Table 3-4 below:

Table 3-4. Setbacks for Infiltration PBMPs

Set back from nearest:	Distance (feet)
Drinking water well	50
Septic system	35
Property line	10
Building foundation	20
Down-gradient building foundation	100

Source:
Storm Water BMP Guide for New and Redevelopment (CCH, July 2017).

7. There are proposed activities/land uses that pose a high threat to water quality, including a high potential for chemical spills (including oil and grease) or high levels of sand or sediment; and
8. The location of the infiltration PBMP facility/facilities conflict with the location of existing or proposed underground utilities or easements, including their placement or orientation such that they would discharge to utility trenches, restrict access, or cause stability concerns.

3.4.2 Biofiltration Infeasibility Evaluation Criteria

Biofiltration PBMPs must be evaluated individually for infeasibility as each has different applications, and must be designed to have an appropriate hydraulic loading.

3.4.2.1 Vegetated Biofilters Infeasibility Evaluation Criteria

Vegetated Biofilters are infeasible and shall not be used if any of the following conditions exist:

1. The invert of the underdrain layer is below the seasonally high groundwater table;
2. The amount of sunlight received by the site is inadequate or irrigation is infeasible to support vegetation;
3. The site lacks a sufficient hydraulic head to support PBMP operation by gravity; and

4. The PBMP is unable to operate off-line with bypass, and unable to operate in-line with a safe overflow mechanism.

3.4.2.2 Bioswales Infeasibility Evaluation Criteria

Bioswales are infeasible and shall not be used if any of the following conditions exist:

1. The invert of the underdrain layer is below the seasonally high groundwater table;
2. The amount of sunlight received by the site is inadequate or irrigation is infeasible to support vegetation;
3. The site lacks a sufficient hydraulic head to support PBMP operation by gravity; and
4. The PBMP is unable to operate off-line with bypass, and unable to operate in-line with a safe overflow mechanism.

3.4.2.3 Vegetated Swale Infeasibility Evaluation Criteria

Vegetated Swales are infeasible and shall not be used if any of the following conditions exist:

1. The amount of sunlight received by the site is inadequate or irrigation is infeasible to support vegetation; and
2. The PBMP is unable to operate off-line with bypass, and unable to operate in-line with a safe overflow mechanism.

3.4.2.4 Vegetated Filter Strip Infeasibility Evaluation Criteria

Vegetated filter strips are infeasible and shall not be used if any of the following conditions exist:

1. The amount of sunlight received by the site is inadequate or irrigation is infeasible to support vegetation; and
2. The PBMP is unable to operate off-line with bypass, and unable to operate in-line with a safe overflow mechanism.

3.4.3 Harvesting/Reuse Infeasibility Evaluation Criteria

Harvesting/reuse PBMPs are infeasible and shall not be used if any of the following conditions exist:

1. The harvested water cannot be reused at the project site (landscape irrigation or other non-potable use);
2. The demand is inadequate to reuse the collected volume of water at the project site;
3. The site constraints, such as a slope above 10% or lack of available space, make it infeasible to locate a cistern of adequate size to collect and reuse the required demand amount of water for the site;
4. The harvesting/reuse of stormwater runoff conflicts with county, state, or federal ordinances and building codes;

5. The cistern is built within the setbacks established in Table 3-5 below:

Table 3-5. Setbacks for Harvesting/Reuse PBMPs

Setback from nearest:	Distance (feet)
Septic system	10
Property line	5
Building foundation	5

Source:
Storm Water BMP Guide for New and Redevelopment (CCH, July 2017).

6. The cistern restricts access to underground utilities or easements; and
7. The harvesting/reuse system conflicts with a reclaimed water system.

3.5 SOURCE CONTROL PBMP REQUIREMENTS

Source Control PBMPs are appropriate structural measures that prevent pollutants from contacting stormwater runoff or prevent discharge of contaminated runoff to the DOTA MS4, drainage system, or State waters. While Source Control PBMPs are categorized as either "operational" or "structural," this manual only includes a discussion on Structural Source Control PBMPs.

Structural Source Control PBMPs are physical, structural, or mechanical devices or facilities intended to prevent stormwater from contacting surfaces, work areas, and activities that can generate pollutants. Examples of structural Source Control PBMPs include creating enclosures or roofs covering work areas where pollutants are present, providing secondary containment, or installing devices that direct contaminated stormwater to appropriate LID or Treatment Control PBMPs.

Table 3-6 presents a list of acceptable Source Control PBMPs and reference to the corresponding Source Control PBMP Design Fact Sheets provided in Appendix IV. PBMPs not included herein, may be used with DOTA review and approval.

Table 3-6. Source Control PBMPs

Source Control PBMP Name	PBMP Design Fact Sheet
Dispersion	SC-1
Fueling Area Design	SC-2
Loading Area Design	SC-3
Maintenance Area Design	SC-4
Material Storage Area Design	SC-5
Triturator Facility Design	SC-6
Washing Area Design	SC-7
Waste Management Area Design	SC-8

The following information is provided for each of the above-listed PBMPs:

- PBMP Category;
- Pollutants Targeted;
- Description;
- Approach;
- Suitable Applications;
- Limitations;
- Design Considerations;
- Construction Considerations; and
- O&M Recommendations.

Structural Source Control PBMPs such as enclosures, roofs, secondary containment, etc., while permanent, are not subject to the PBMP inspections and maintenance requirements. However, Structural Source Control PBMPs may be subject to inspections under the DOTA Tenant Inspection and Enforcement program or the DOTA Facility Inspection program.

At sites that maintain an Industrial Stormwater General Permit, project proponents should take special care to review this section to verify that all applicable Source Control PBMPs and PBMPs are included within their Industrial SWPPP.

3.6 TREATMENT CONTROL PBMP REQUIREMENTS

Treatment Control PBMPs are engineered technologies designed to remove pollutants from stormwater runoff prior to discharge to the DOTA MS4, drainage system, or State waters. Examples of treatment PBMPs are ponds, OWSs, and manufactured treatment devices.

Table 3-7 presents a list of acceptable Treatment Control PBMPs and reference to the corresponding Treatment Control PBMP Design Fact Sheets provided in Appendix V. PBMPs not included herein, may be used with DOTA review and approval.

Table 3-7. Treatment Control PBMPs

Treatment Control PBMP Name	PBMP Design Fact Sheet
Alternative Wetland	TC-1
Dry Detention Basin	TC-2
Evaporation Pond	TC-3
Hydrodynamic Separator or HDS Unit	TC-4
Manufactured Treatment Device or MTD	TC-5
Oil Water Separator or OWS	TC-6
Sand Filter	TC-7
Subsurface Detention	TC-8

The following information is provided for each of the above-listed Treatment Control PBMPs:

- PBMP Category;
- Pollutants Targeted;
- Description;
- Limitations;
- Design Guidelines including general, pretreatment consideration, area requirements, minimum design criteria, and sizing guidelines;
- Construction Considerations; and
- Example Schematics.

4. PBMP DESIGN CRITERIA

To effectively address DOTA's stormwater management objectives, the consideration of PBMPs should be integrated into the site planning and design process. In addition to standard engineering design practices, project proponents should evaluate the project site conditions and planned future use to determine which PBMPs would be the most effective. The basic steps in the PBMP planning, decision-making, and design processes are presented in Figure 4-1.

Figure 4-1. PBMP Design Process

4.1 POLLUTANTS OF CONCERN

Project proponents should identify anticipated pollutants of concern in accordance with the following:

- Planned activities;
- Planned site design;
- Land use type of the project and associated potential pollutants;
- Legacy pollutants that may potentially be present on the site;
- Changes in stormwater discharge flow rates, velocities, durations, and volumes resulting from the new development or redevelopment project;
- Sensitivity of receiving waters to changes in stormwater discharge flow rates, velocities, durations, and volumes; and
- Receiving water quality [303(d) list of receiving water impairments].

4.1.1 Typical Pollutants Associated with Projects at DOTA Airports

Typical pollutants of concern associated with projects at DOTA airports include:

- Chlorophyll a;
- Bacteria (*Enterococci*);
- Metals (Copper, Zinc, Lead, Aluminum, Cadmium, Chromium, Nickel, Silver);
- Nutrients (total nitrogen, nitrate + nitrite, ammonia nitrogen, total phosphorus);
- Oil & Grease;
- Organic Compounds (hydrocarbons, jet fuel, aviation fuel);
- Pathogens;
- Pesticides;
- Sediment (turbidity, TSS); and

- Trash.

4.1.2 Pollutants from 303(d) List of Impaired Waters

Project proponents shall target all pollutants of concern while selecting the PBMPs and use their best judgment to evaluate potential pollutants of concern that may discharge from the project site. In addition, project proponents shall also consider pollutants of concern based on the project site's receiving water quality based on impairments listed in the 303(d) list of receiving waters.

Project proponents shall identify the nearest and first receiving water body that has the potential to receive a discharge from the project site. The receiving water bodies are designated by Hawaii's Water Quality Standards as described in *HAR § 11-54*, which categorizes surface waters as inland or marine waters. Inland waters are comprised of water body types such as streams, estuaries, lakes and reservoirs, wetlands, and anchialine pools. Marine water body types are comprised of embayments, coastal, and oceanic waters. The receiving water body at certain DOTA airports can also include a dry well/drainage well (underground injection).

The minimum pollutants of concern are listed as impairments in the latest Water Quality Monitoring and Assessment Report from the DOH-CWB. Additional information can be obtained from DOH-CWB and accessed using the webpage below:

https://health.hawaii.gov/cwb/clean-water-branch-home-page/integrated-report-and-total-maximum-daily-loads/

Project proponents can also target the pollutants of concern beyond those listed in sections 4.1.1 and 4.1.2. Although trash is not on the 303(d) list, it shall be considered a pollutant of concern for all DOTA airports that discharge to State waters. New development and redevelopment constrution projects discharging to a dry well/drainage well may request an exemption from targeting trash.

4.2 ACCEPTABLE PBMPS

Project proponents should select PBMPs based on the identified pollutants of concern, the site restrictions, PBMP pollutant removal performance, and other requirements including MS4 permits, TMDLs, etc.

Table 4-1 summarizes the PBMP categories, pollutants of concern, and pollutant removal performance for LID and Treatment Control PBMPs.

Table 4-1. LID and Treatment Control PBMP Pollutant Removals

PBMP # and Name	Bacteria	Metals	Nutrients	Oil & Grease	Organic Compounds	Pathogens	Pesticides	Sediment	Trash
LC-1 Biofilter*	L	H	M	H	H	M	U	M/H	H
LC-2 Bioretention	L	H	H	H	H	H	H	H	H
LC-3 Bioswale	L	M	M	M	L/M	U	U	H	H
LC-4 Collection and Reuse	U	H	H	H	H	H	H	H	L
LC-5 Dry Well/Drainage Well	U	H	H	H	H	H	H	H	H
LC-6 Infiltration Basin	U	H	H	H	H	H	H	H	H
LC-7 Infiltration Trench	U	H	H	H	H	H	H	H	H
LC-8 Permeable Pavement	U	H	H	H	H	H	H	H	H
LC-9 Subsurface Infiltration	U	H	H	H	H	H	H	H	H
LC-10 Vegetated Buffer Strip	L	M	L	M	M	L	U	M	M
LC-11 Vegetated Swale	L	M	L	M	L	L	U	M	L
TC-1 Alternative Wetland*	L/M	H	L	U	U	L	U	H	H
TC-2 Dry Detention Basin	U	L/M	L	M	U	L	U	M	H
TC-3 Evaporation Pond	U	L	L	M	U	L	U	M	H
TC-4 Hydrodynamic Separator (HDS)*	U	L	L	M/H	L	L	L	M/H	H
TC-5 Manufactured Treatment Device*	L	L	L	M/H	L	L	L	M/H	H
TC-6 Oil Water Separator*	U	L	L	H	L	L	L	M/H	H
TC-7 Sand Filter	M/H	M/H	L/M	H	M/H	M	U	H	H
TC-8 Subsurface Detention*	U	L/M	L	M	U	L	U	M	H

Notes:

H = High

L = Low

M - Medium

U = Unknown

* The pollutant removal performance may vary depending on the type and model of the product selected.

Sources:

Storm Water BMP Guide for New and Redevelopment (CCH, July 2017).

Preliminary Data Summary of Urban Storm Water Best Management Practices, EPA-821-R-99-012 (EPA, August 1999).

Minnesota Stormwater Manual (Minnesota Pollution Control Agency, February 17, 2021).

Project proponents may also propose PBMPs not listed in this Manual, provided that sufficient information about the design, performance, requirements, and maintenance is included with the Construction Design Review process.

4.3 SIZING CRITERIA

While the basic hydrology and hydraulic principles are the same when designing a storm drain system or a PBMP, these two principles have very different design goals and philosophies that must be recognized in order to meet performance objectives.

1. The design goal for storm drain systems is to protect human health and property from flooding. In order to accomplish this goal, the design must have the capacity to convey runoff from a large storm, such as a 25-year recurrence interval storm (hydrology). Furthermore, storm drain systems are predominantly engineered to handle a specified flow rate instead of a runoff volume.
2. The design goal for PBMPs is to treat the many small storms that collectively transport the majority of the runoff pollutants. In order to accomplish this goal, the design must have the capacity to convey runoff from a small storm (hydraulic), such as a 24 hour, 85th percentile storm event. Furthermore, PBMPs are predominantly engineered to handle a specified runoff volume.

DOTA requires specific criteria for PBMP sizing using both volume-based and flow-based PBMP design (i.e., Volume-Based = 1 inch and Flow-Based = 0.4 inch/hour). This criteria aligns with the *Storm Water BMP Guide for New and Redevelopment* (CCH, July 2017).

4.3.1 Volume-Based Designs

Volume-based designs include PBMPs that will hold a set volume of runoff, such as dry detention pond, infiltration basin, infiltration trench, dry well/drainage well, harvesting/reuse, permeable pavement, vegetated biofilter, bioretention, bioswale, and sand filter.

This Manual includes quantitative design criteria including a 24 hour, 85th percentile storm event, which is 0.961 inches for HNL; and therefore, a 1-inch runoff depth was selected to be the design storm for volume-based PBMP designs. A 1-inch design depth is widely used throughout the U.S. (EPA, 2018) and was selected to be applied at DOTA airports statewide.

The TR-55 curve number method commonly used for estimating runoff from small urban watersheds (USDA NRCS, 1986) is not appropriate for small rainfall events. The Curve Number method underestimates the runoff volume for small storms less than 2 inches (Claytor and Schueler, 1996).

Since DOTA's design depth is small (1-inch) and airports typically have one predominant type of cover and smaller drainage areas, the Short-Cut Method (Claytor and Schueler, 1996) can be used to estimate the volumetric runoff coefficient, C, and the WQV. The design must hold **1-inch of runoff** and shall be sized based on the following equation:

WQV = PCA x 3630

where WQV = Water Quality Volume (cubic feet)
P = Design Storm Runoff Depth (inch)
C = Volumetric Runoff Coefficient
A = Drainage Area (acre)

C is an empirically derived value that indicates the fraction of rainfall converted into runoff for that land use. Using data from the Nationwide Urban Runoff Program (EPA, 1983) data collected at 44 monitored development sites with various percentages of impervious area, it was concluded that primary influence on the C can be determined as a function of the impervious area within the contributing drainage area (Schueler, 1987). Schueler used simple linear regression to derive an equation to calculate the C based on the percent impervious cover. The volumetric runoff coefficient shall be calculated using the following equation for smaller storms in urban areas (Schueler, 1987):

C = 0.05 + 0.009(I)

Where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

The WQV shall be based on the impervious cover of the project site. Offsite existing impervious areas may be excluded from the calculation of the WQV. Project proponents should plan to divert any offsite flows to minimize the offsite runoff contribution to the new development or redevelopment construction project.

When a new development or redevelopment construction project contains or is divided by multiple drainage areas, the WQV volume shall be addressed for each drainage area.

4.3.2 Flow-Based Designs

Flow-based designs include those that will move stormwater through a system that also removes potential pollutants. Examples of flow-based designs include vegetated buffer strips, vegetated swale, subsurface infiltration devices, alternative wetlands, evaporation ponds, HDS units, MTDs, OWSs, and subsurface detention facilities.

The design must be able to accommodate a peak rainfall intensity of **0.4 inch/hour**, based on the following equations:

$$\mathbf{WQF = CiA}$$

where WQF = Water Quality Flow Rate (cubic feet per second)
C = Runoff Coefficient
I = Peak Rainfall Intensity (inch/hour)
A = Drainage Area (acre)

The peak rainfall intensity is 0.4 inch/hour based on the *City and County of Honolulu Water Quality Rules* and will be used statewide at all DOTA airports.

For drainage areas containing multiple land uses, compute the composite weighted runoff coefficient using the following equation:

$$\mathbf{C_C = [(\sum_{i=1}^{n} C_i A_i)/A_t]}$$

where C_C = Composite Weighted Runoff Coefficient
$C_{1,2,..n}$ = Runoff Coefficient for each Land Use Cover Type
$A_{1,2,..n}$ = Drainage Area to each Land Use Cover Type (acre)
n = Number of Land Use Cover Types within the Drainage Area
A_t = Total Drainage Area (acre)

Table 4-2 provides the runoff coefficients for various drainage surface areas. Project proponents should use best professional judgment to select the appropriate C value within the range. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have the lower C values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should have higher C values.

Table 4-2. Runoff Coefficients

Type of Drainage Surface Area	Runoff Coefficient
Roofs	0.75 – 0.95
Concrete	0.80 – 0.95
Asphalt	0.70 – 0.95
Stone, brick, or concrete pavers with mortared joints and bedding	0.80
Stone, brick, or concrete pavers with sand joints and bedding	0.70
Pervious Concrete	0.10
Porous Asphalt	0.10
Permeable interlocking concrete pavement	0.10
Grid pavements with grass or aggregate surface	0.10
Crushed aggregate	0.10
Grass	0.10
Grass over Porous Plastic	0.05
Gravel over Porous Plastic	0.05
Light industrial	0.50 - 0.80
Heavy Industrial	0.60 - 0.90
Unimproved areas	0.10 - 0.30

Sources:
Storm Water BMP Guide for New and Redevelopment (CCH, July 2017).
Storm Drainage Standards (CCH DPP, 2017).
Storm Water Runoff System Manual (County of Kauai, Department of Public Works, July 2001).
MC-15, Chapter 4 Rules for the Design of Storm Drainage Facilities in the County of Maui (County of Maui, Department of Public Works and Waste Management, November 2, 1995).

4.3.3 Combined Volume-Based and Flow-Based Designs

Volume-based and flow-based PBMP designs do not necessarily treat precisely the same stormwater runoff quantity. For example, an on-line volume-based PBMP, such as a detention basin will treat the design runoff volume and is not greatly affected by runoff entering the basin at a high rate, say from a short but intense storm that produces the design volume of runoff. However, a flow-based PBMP might be overwhelmed by the same short but intense storm if the storm intensity results in runoff rates that exceed the flow-based PBMP design flow rate. Additionally, a flow-based PBMP such as a swale will treat the design flow rate of runoff and is not greatly affected by the duration of the design flow, say from a long, low-intensity storm; however, a volume-based PBMP such as a detention basin subjected to this same rainfall runoff event will begin to provide less treatment or will go into bypass or overflow mode after the design runoff volume is received.

Therefore, there may be situations where project proponents need to consider both volume-based and flow-based PBMP design criteria. An example of where both types of criteria might apply is an off-line detention basin where the capacity of the diversion structure could be designed to comply with the flow-based criteria, while the detention basin itself could be designed to comply with the volume-based criteria.

When both volume-based and flow-based criteria apply, project proponents should determine which of the criteria apply to each element of the PBMP system and then size the elements accordingly.

4.3.4 Pan Evaporation Rate Data

Pan evaporation rate data are used to determine the potential evapotranspiration of a project area. The potential evapotranspiration directly influences soil moisture conditions and runoff. Pan evaporation is not highly variable like rainfall. *Pan Evaporation: State of Hawaii 1894-1983* (Ekern, P.C. and Chang, J.H., 1985) was used as the source for the pan evaporation data. The monthly pan evaporation data for all 15 DOTA airports statewide are provided in Appendix VI.

To convert the pan evaporation values to potential evapotranspiration values, the pan evaporation values need to be multiplied by a correction factor or the Pan Evaporation Coefficient, K_p. Project proponents can use site-specific data where available for the K_p. If site-specific data is unavailable, a K_p value of 0.80 can be used (for the Hawaiian climate).

4.3.5 Rainfall Data

The rainfall data source for the State of Hawaii was obtained from *Online Rainfall Atlas of Hawaii Pan Evaporation* (Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013). The monthly rainfall data for all 15 DOTA airports statewide are provided in Appendix VI.

4.3.6 Other Data and Coefficients

4.3.6.1 Drain or Drawdown Time

DOTA has set the drain or drawdown time for the PBMPs to drain the WQV, t, to 48 hours or less; this was selected to minimize the wilflife attractant and address aircraft safety requirements in accordance with the *FAA AC 150/5200-33C*. Flows that cannot be infiltrated or biofiltered in 48 hours or less should be routed to bypass the PBMP through a stabilized discharge point with the exception of subsurface detention PBMPs where a value of 48 hours to 72 hours for t can be used. Project proponents should note that when the drawdown time is reduced to 24 hours, the maximum ponding depth is reduced by a factor of 2.

4.3.6.2 Permeability Coefficients

Project proponents can use site-specific data where available or conduct in-situ measurements to determine the coefficient of permeability for the planting soil or media, k_m. If specific data is unavailable, a value of 1 foot/day for k_m can be used (CCH, 2017).

Project proponents can use site-specific data where available or conduct in-situ measurements to determine the coefficient of permeability for the sand, k_s. If specific data is unavailable, a value of 3.50 feet/day for k_s can be used (CCH, 2017).

4.3.6.3 Porosity Values

Project proponents can use site-specific data where available for the porosity values of various media, n. If site-specific data is unavailable, the following values of n provided in **Table 4-3** can be used.

Table 4-3. Porosity Values

Type of Media	Porosity Abbreviation	Porosity
Backfill Material	n_{bf}	0.30 – 0.95
Backfill Material – trench rock for infiltration trenches	n_{bf}	0.35
Drainage Layer	n_d	0.40
Gravel Layer	n_g	0.30
Media Layer	n_m	0.25
Pavement Course	n_p	0.15
Reservoir Course	n_r	0.35
Sand	n_s	0.40

Source:
Storm Water BMP Guide for New and Redevelopment (CCH, July 2017).

4.3.6.4 Landscape Coefficient

The landscape coefficient, K_l, was derived specifically to estimate water loss from landscape plantings. The following factors are used to determine K_l:

- Species;
- Density; and
- Microclimate.

Project proponents can use site-specific data where available for K_l. If site-specific data is unavailable, a value of 0.60 for K_l can be used. This value is for turfgrass in the warm season and was obtained from *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California* (University of California Cooperative Extension, California Department of Water Resources, 2000).

4.3.6.5 Irrigation Efficiency

Irrigation efficiency, e, can be defined as the beneficial use of applied water (by landscaping). An e value of 100% would mean that all applied water was used by the planting. This rarely occurs in real project conditions. Consequently, the e value is generally less than 100% and additional water should be applied to account for efficiency losses.

Irrigation efficiency values can be obtained by three approaches: calculated, estimated, or goal setting. All three of these methods are highly approximate. Therefore, project proponents can use site-specific data where available for the e value. If site-specific data is unavailable, a value of 0.90 for e can be used assuming the new landscape can achieve 90% irrigation efficiency obtained from *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California* (University of California Cooperative Extension, California Department of Water Resources, 2000).

4.3.6.6 Fill Time

The *Maryland Stormwater Design Manual Volumes I & II* (CWP and the MDE, 2000) states that the effective fill time for most infiltration trenches and infiltration basins will generally be less than 2 hours and, therefore, uses 2 hours. Unless another value can be justified, project proponents should use a fill time value of 2 hours for sizing bioretention facilities, dry wells/drainage wells, infiltration basins, infiltration trenches, and permeable pavements.

4.3.6.7 Manning's n Values

The roughness coefficient, Manning's n value, varies with the type of vegetative cover and flow depth. Unless another value can be justified, project proponents should use a Manning's n value of 0.25 and 0.20 for vegetated buffer strip and vegetated swale sizing calculations respectively; these values are consistent with the *Storm Water BMP Guide for New and Redevelopment* (CCH, July 2017).

4.3.6.8 Freeboard

Project proponents should typically use a freeboard of 1-foot with the exception of evaporation ponds. For evaporation ponds, DOTA suggests using 2 feet since there is no outlet structure.

4.4 PBMP DESIGN FACT SHEETS

A PBMP Design Fact Sheet provides specific information about the design of a particular PBMP containing information on the PBMP design considerations, targeted pollutants of concern, limitations, design criteria, and sizing calculation procedures. Refer to sections 3.2, 3.5, and 3.6 for the specific information included within the LID PBMP Design Fact Sheets, Source Control PBMP Fact Sheets, and Treatment Control PBMP Design Fact Sheets respectively.

The sizing procedures provided within the PBMP Design Fact Sheets for LID and Treatment Control PBMPs are based on simple dynamic and static principles and, therefore, may result in larger PBMPs than are necessary. Other sizing methods (such as detailed routing methods or continuous simulation models) may be used with DOTA approval. PBMP sizing calculation worksheets can be requested from AIR-EE.

4.5 RETROFITS

Retrofits include upgrades/alterations to the existing DOTA MS4 or drainage system that provide stormwater treatment, pollutant reduction (e.g., improve the quality of stormwater runoff), trash or floatable reduction, etc. Where possible, project proponents should identify opportunities to upgrade the existing DOTA MS4, drainage system, or PBMPs in their redevelopment projects.

4.6 PRELIMINARY DESIGN

The primary objectives of the preliminary design phase are to gather key information and develop a preliminary site layout that considers all the site characteristics and constraints for PBMP design.

4.6.1 Site Assessment

The site assessment provides information about the site and its surroundings, forming the basis to make decisions about PBMP location and selection. The site assessment should include an inventory and analysis of natural and developed conditions that would affect the project design. Information typically collected during the site assessment includes:

- Topography;
- Hydrologic patterns and features;
- Soils information and geotechnical assessment;
- Native vegetation and soil protection areas;
- Environmentally sensitive features;
- Site access;
- Land use controls; and
- Utility availability and conflicts.

4.6.2 Identify Stormwater Standards and Requirements

Project proponents should identify and review the DOTA engineering standards and any applicable state and federal requirements that can influence the PBMP design. This typically involves coordination with AIR-E and AIR-EE to discuss the proposed project and approach to meeting the standards and requirements. DOTA standards and requirements that may influence site design include:

- Stormwater requirements, including PBMP requirements;
- Infeasibility criteria for LID PBMPs;
- Setback requirements for structures, drinking wells, foundations, etc.;
- Soil and subsurface hydrology evaluation and reporting requirements;
- PBMP sizing methodologies to be used;
- DOTA engineering design standards;
- Maintenance agreement requirements for DOTA MS4 or drainage system including PBMPs; and
- FAA regulations and design standards.

4.6.3 Preliminary Site Layout

Developing the preliminary site layout is an iterative process intended to optimize site development and consider the site requirements and constraints, including PBMPs. This process typically takes place after the site assessment has occurred.

4.6.4 Pre-Design Meeting

After the preliminary site layout is determined, project proponents should request a pre-design meeting with AIR-EE to discuss the preliminary PBMP design, the O&M required for long-term effectiveness, accessibility, and options for any innovative PBMP design. Project proponents can also provide information on the potential for PBMP variance, LID waivers, or other site constraints that limit PBMP implementation.

The goal of the pre-design meeting is to establish a collaboration between project proponents and AIR-EE to design PBMPs effectively, communicate any issues early, and consider PBMPs that serve the best interest of DOTA over time.

4.7 PBMP SELECTION AND SIZING

Every construction project has unique design goals and constraints. As such, there is no one-size-fits-all PBMP which meets the DOTA stormwater requirement. Preliminary sizing of PBMPs will be necessary to determine if the post-construction performance can be achieved with a single PBMP or if several PBMPs need to be applied in series, using a “treatment train” approach. The selection and sizing process will likely be iterative as multiple options may need to be considered to determine the most efficient and effective PBMP(s) for the site. Refer to section 4.3 for PBMP sizing criteria.

4.8 FINAL PBMP DESIGN

Coordination with AIR-EE is recommended prior to beginning the final design phase to verify that the preliminary site layout and proposed PBMPs adequately address the DOTA stormwater requirements.

4.9 PBMP MAINTENANCE

Project proponents must account for PBMP maintenance during the design phase. Documentation of the PBMP maintenance requirements can be provided either by developing and submitting a PBMP O&M Plan or utilizing the PBMP O&M Fact Sheets within this Manual (refer to Appendix VII). The O&M costs for the designed PBMPs shall be provided.

For DOTA projects, DOTA will be responsible for long-term maintenance. For TIPs, tenants will be responsible for long-term maintenance.

4.10 PBMP INFORMATION NEEDED PRIOR TO CONSTRUCTION FINAL ACCEPTANCE

Prior to construction final acceptance, DOTA shall verify/inspect that all PBMPs have been installed in accordance with the approved designs (from the Construction Design Review process).

The contractor shall submit drawings, product sheets, maintenance requirements, specifications if applicable, and the O&M Plan to the DOTA SPM.

Additionally, DOTA will need the following information:

- GPS coordinates or GIS location data;
- Contractor responsible O&M end date;
- Warranty information, if applicable; and
- PBMP turnover date.

5. INSPECTIONS, OPERATIONS, AND MAINTENANCE

After installation, PBMPs require perpetual inspection and maintenance to continue to function as designed (i.e., meeting the criteria for stormwater flow rate, volume and water quality). PBMPs need to be properly maintained such that the effectiveness of the PBMP does not decrease. Routine and timely scheduled maintenance of PBMPs will also help avoid more costly rehabilitative maintenance to repair damages that may occur due to deferred maintenance or when PBMPs have not been maintained regularly.

All LID and Treatment Control PBMPs will be inspected annually to verify that they are functioning properly and maintenance is performed as necessary. These inspections will verify proper operation in accordance with the Project's PBMP O&M Plans and/or the PBMP O&M Fact Sheets provided in Appendix VII.

5.1 PBMP INSPECTION, OPERATIONS & MAINTENANCE

Every PBMP constructed shall have a PBMP O&M Plan or use the DOTA PBMP O&M Fact. O&M Fact Sheets can be utilized to conduct inspections of DOTA owned PBMPs and can be used as a resource to conduct inspections of tenant PBMPs.

DOTA is responsible for the maintenance of PBMPs on DOTA owned and operated spaces. Tenants are responsible for the maintenance of PBMPs on tenant leased spaces.

For DOTA-owned PBMPs, AIR-OM has a Statewide service contract for inspection and maintenance of LID and Treatment Control PBMPs (i.e., OWSs, HDS units, drain inlet inserts, etc.) with the exception of certain vegetated PBMPs, such as bioswales, etc. The service contractors are allowed to use their own inspection/maintenance forms which are provided to DOTA; data from these reports is entered into the PBMP Database.

Maintenance of vegetated PBMPs is conducted by DOTA Maintenance personnel on a regular schedule or through Work Orders requested by AIR-EE personnel. Additionally, Work Orders may be generated when DOTA receives complaints on PBMP maintenance or landscaping issues.

For tenant-owned PBMPs, mechanisms used to assign responsibility for maintenance may include:

- Lease language;
- Covenants;
- Maintenance agreements;
- Conditional Use Permits; or
- Other legal agreements.

AIR-EE and DOTA Maintenance personnel tracks all inspections and maintenance of PBMPs (DOTA-owned and tenant-owned).

5.2 PBMP DATABASE

All inspections and maintenance of PBMPs are tracked in the AMS, in addition to the standard identification information. The following information is tracked:

- PBMP Category (i.e., LID, Source Control, Treatment Control);
- Latitude and longitude coordinates;
- Photographs;
- PBMP O&M Plan;
- Date of inspection and/or maintenance;
- Inspection frequency; and
- Maintenance frequency.

5.3 ENFORCEMENT AND RESPONSE PLAN FOR PBMPS

When tenant-owned PBMP inspections reveal a lack of maintenance or if PBMPs are not performing as intended, DOTA will undertake appropriate enforcement actions. The levels of enforcement and associated penalties are typically issued at the discretion of the DOTA inspector, with consideration of relevant circumstances regarding the violation. This escalation of enforcement may include verbal warnings and written notifications to the tenant in accordance with the Tenant Inspection and Enforcement Manual.

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Appendix I

FAA Exemption Zone for PBMP Installation - Maps for Airports Statewide

FAA Exemption Zone for
PBMP Installation
Dillingham Air Field (HDH)

Legend

🟥 FAA PBMP Exemption Zone

🟨 Airport Property Line

FAA Exemption Zone for PBMP Installation Daniel K. Inouye International Airport (HNL)

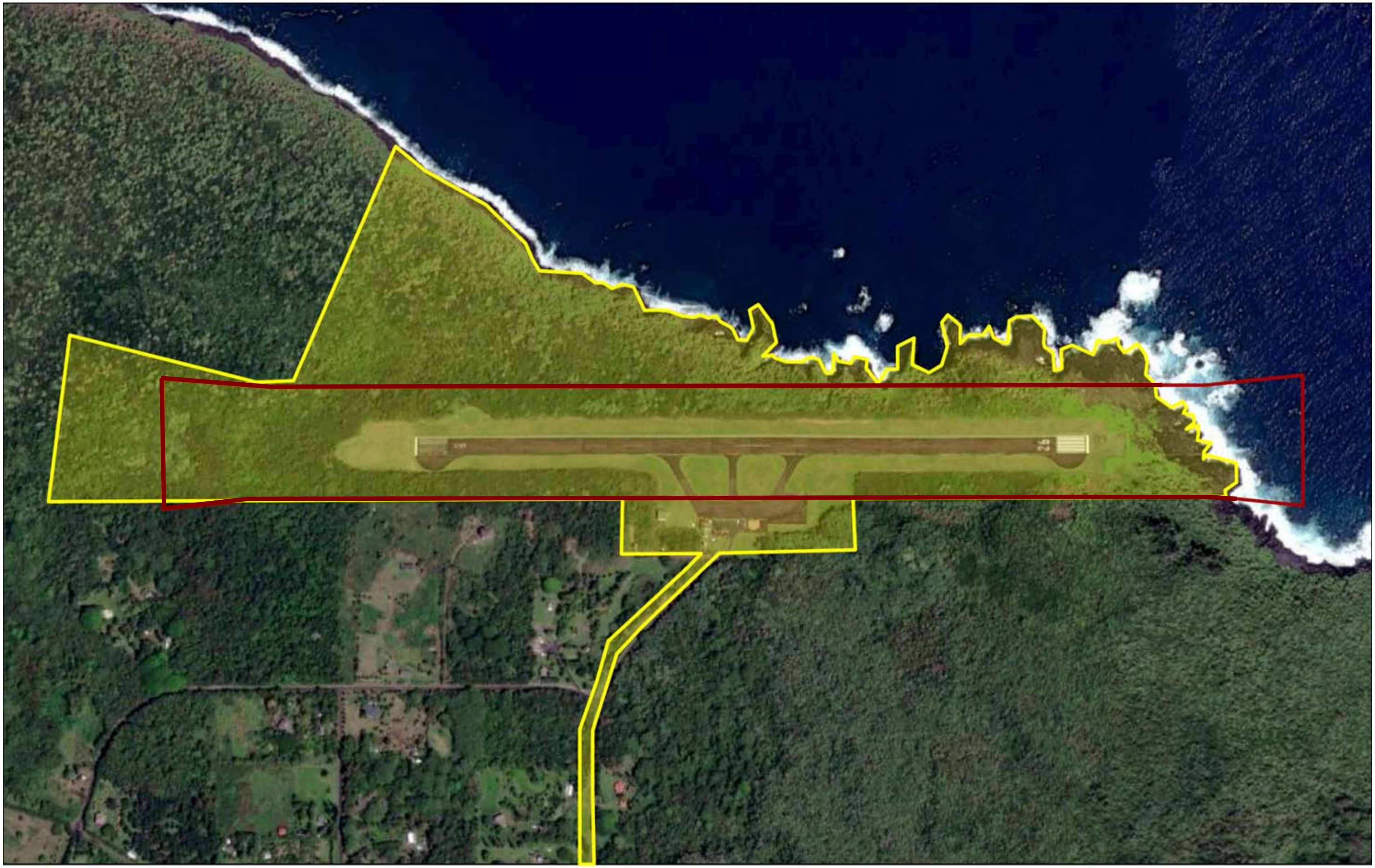
Legend

🟥 FAA PBMP Exemption Zone

🟨 Airport Property Line

0 0.1 0.2 0.4 0.6 0.8 Miles

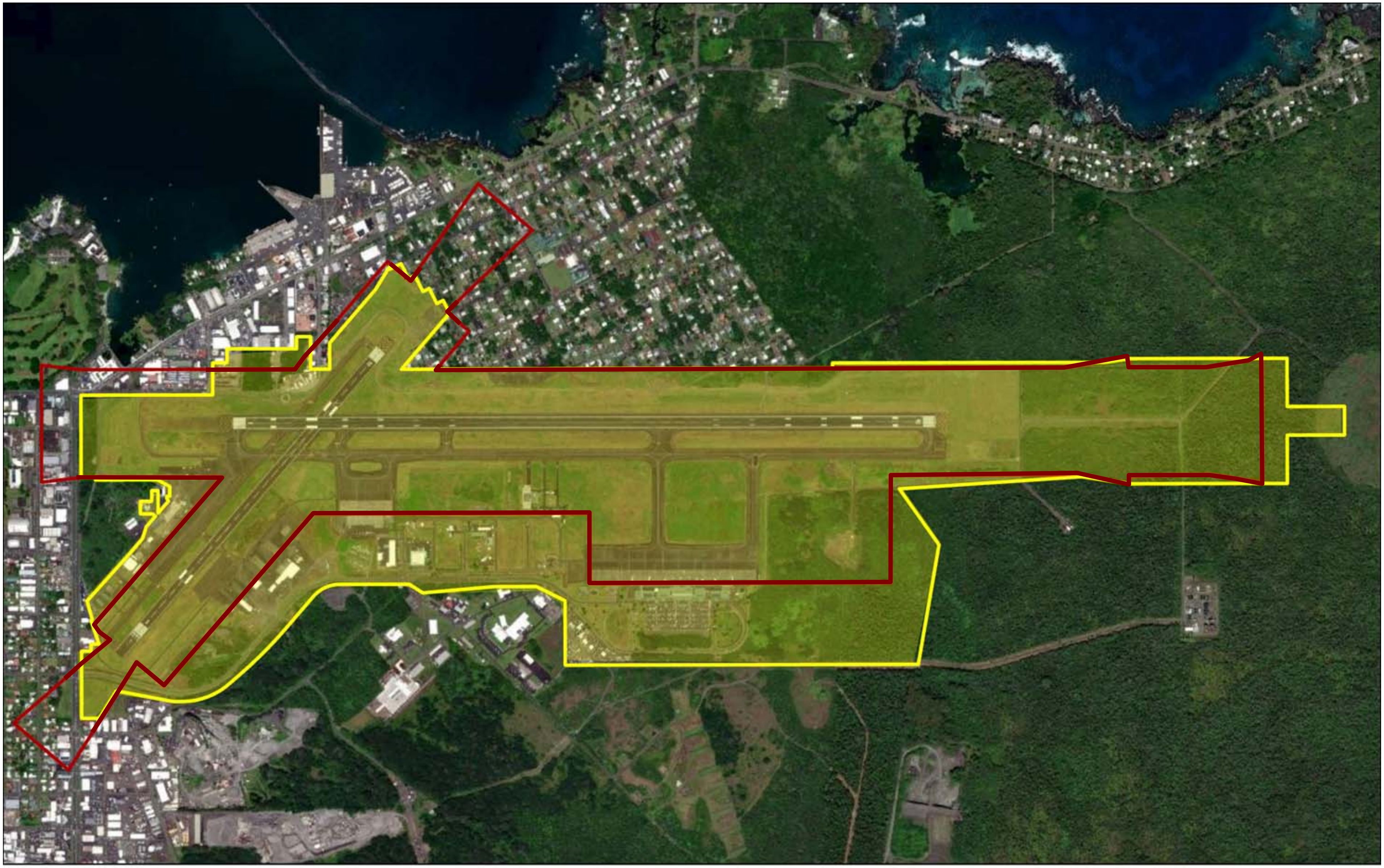
N



FAA Exemption Zone for PBMP Installation Hana Airport (HNM)

Legend

🟥	FAA PBMP Exemption Zone
🟨	Airport Property Line



FAA Exemption Zone for PBMP Installation Hilo International Airport (ITO)

Legend

🟥 FAA PBMP Exemption Zone

🟨 Airport Property Line

FAA Exemption Zone for PBMP Installation Kapalau Airport (JHM)

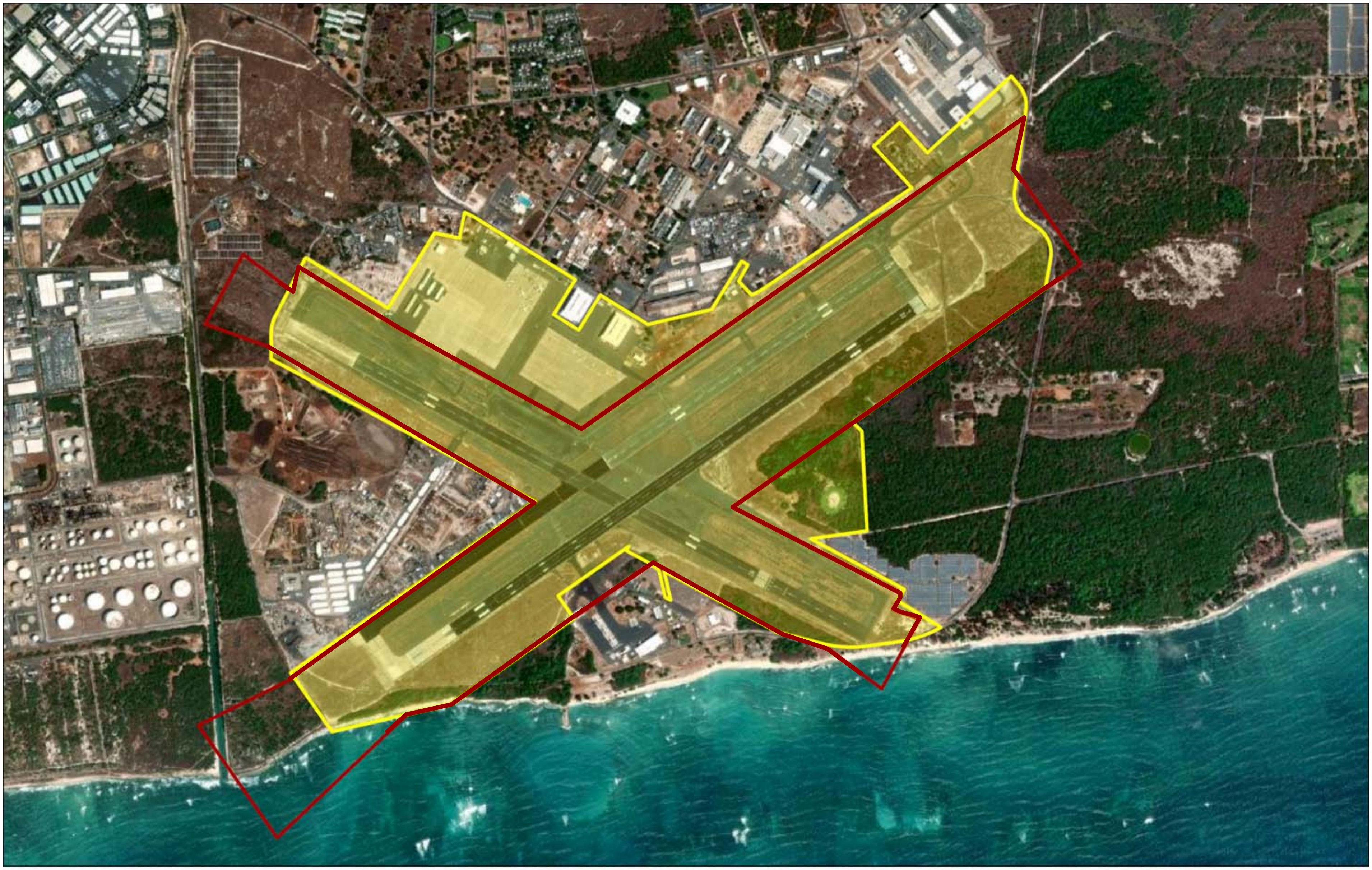
Legend

▭ FAA PBMP Exemption Zone

🟨 Airport Property Line

0 0.05 0.1 0.2 0.3 0.4 Miles

N



FAA Exemption Zone for PBMP Installation Kalaeloa Airport (JRF)

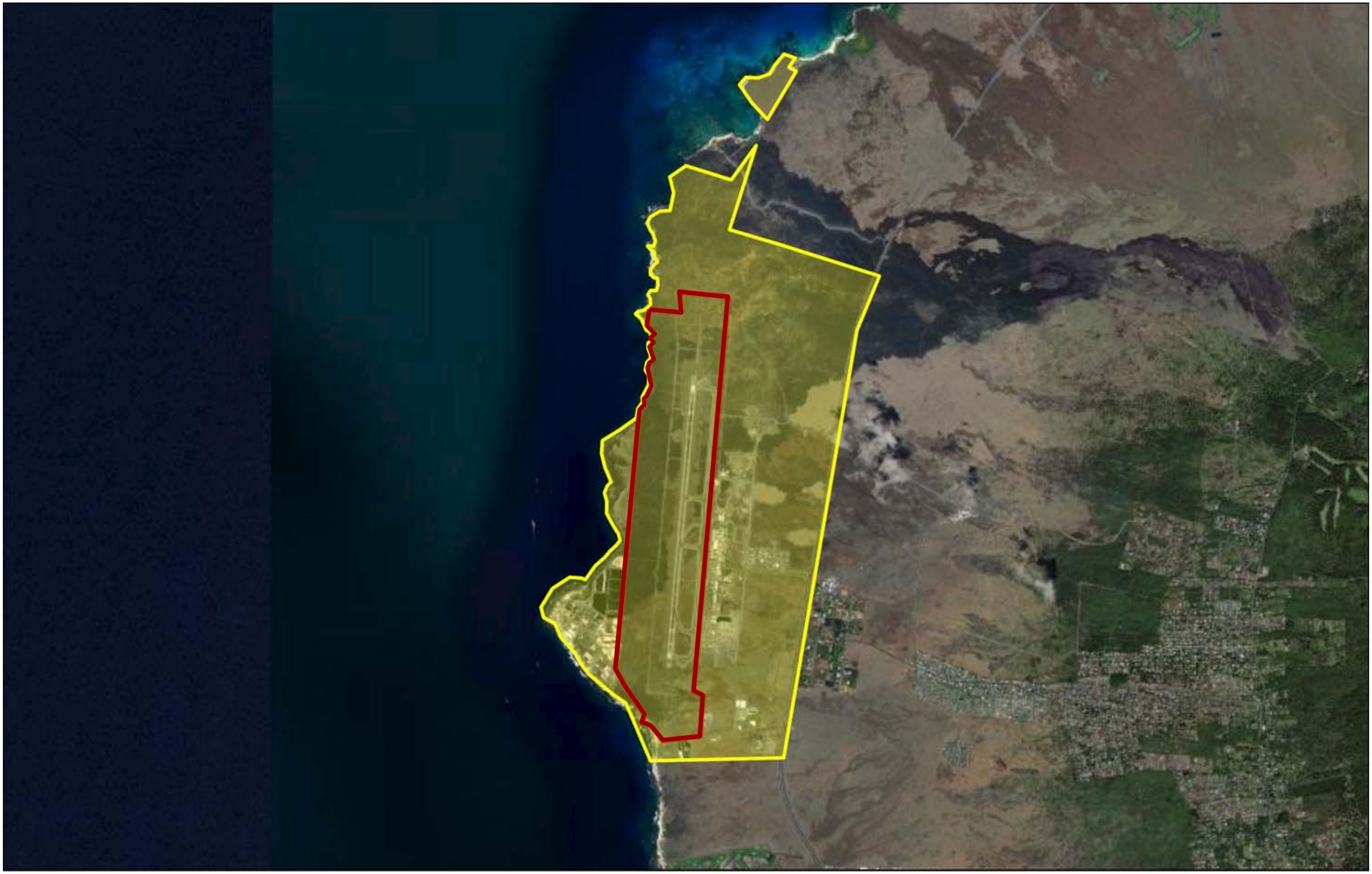
Legend

☐ FAA PBMP Exemption Zone

▨ Airport Property Line

0 0.1 0.2 0.4 0.6 0.8 Miles

N

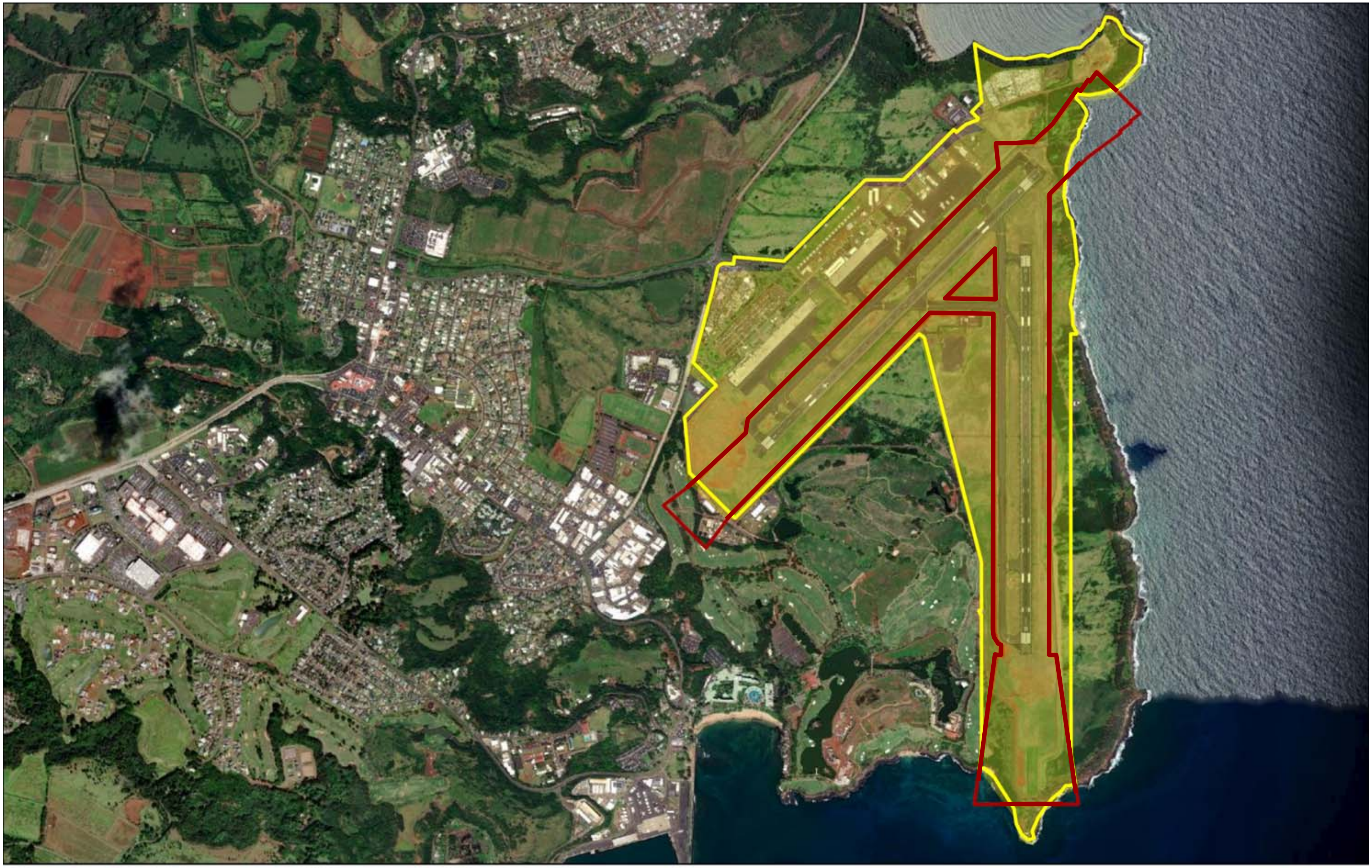


FAA Exemption Zone for PBMP Installation International Airport at Keahole (KOA)

Legend

▭ FAA PBMP Exemption Zone

▨ Airport Property Line

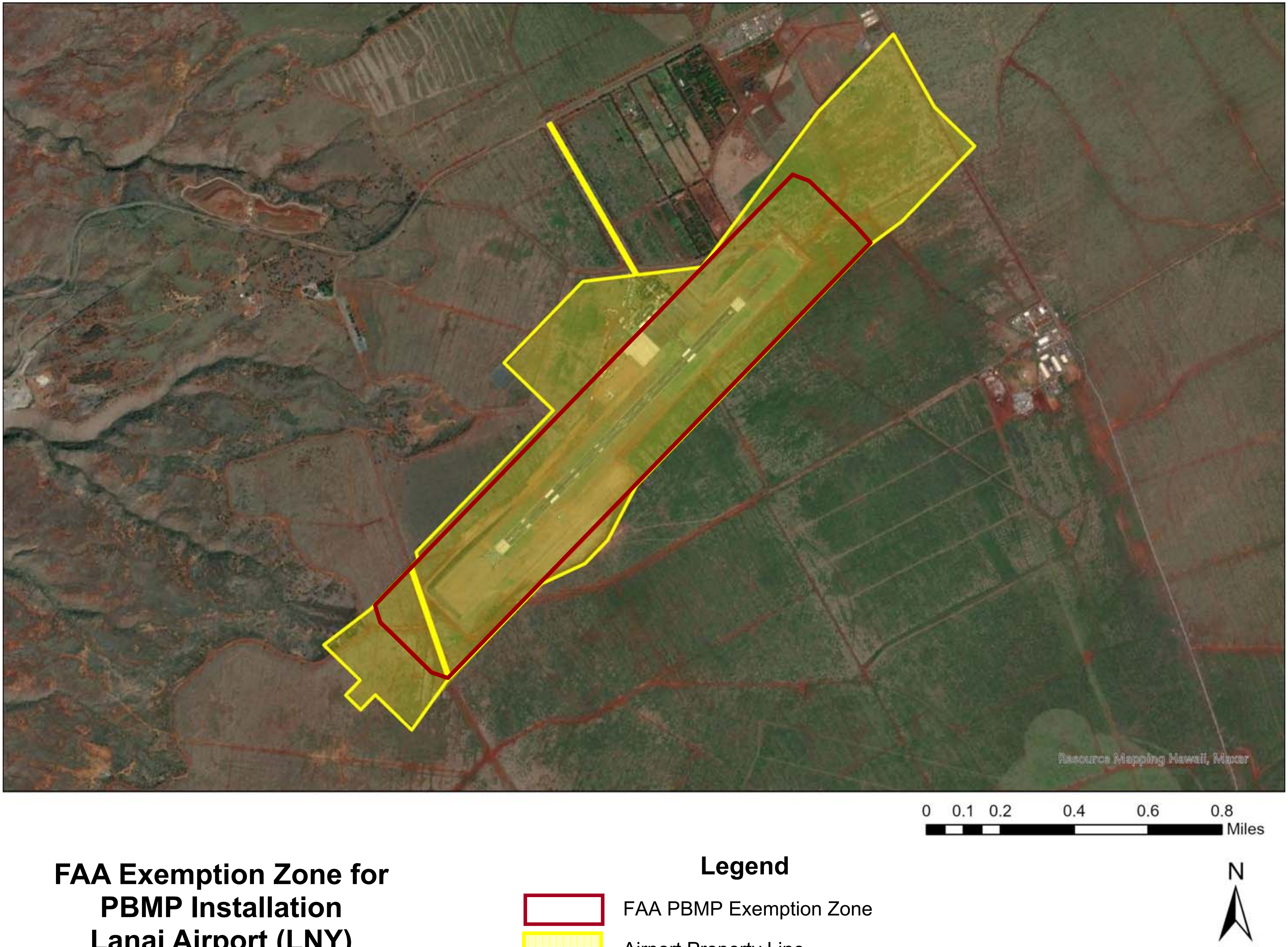


FAA Exemption Zone for PBMP Installation Lihue Airport (LIH)

Legend

□ FAA PBMP Exemption Zone

▨ Airport Property Line

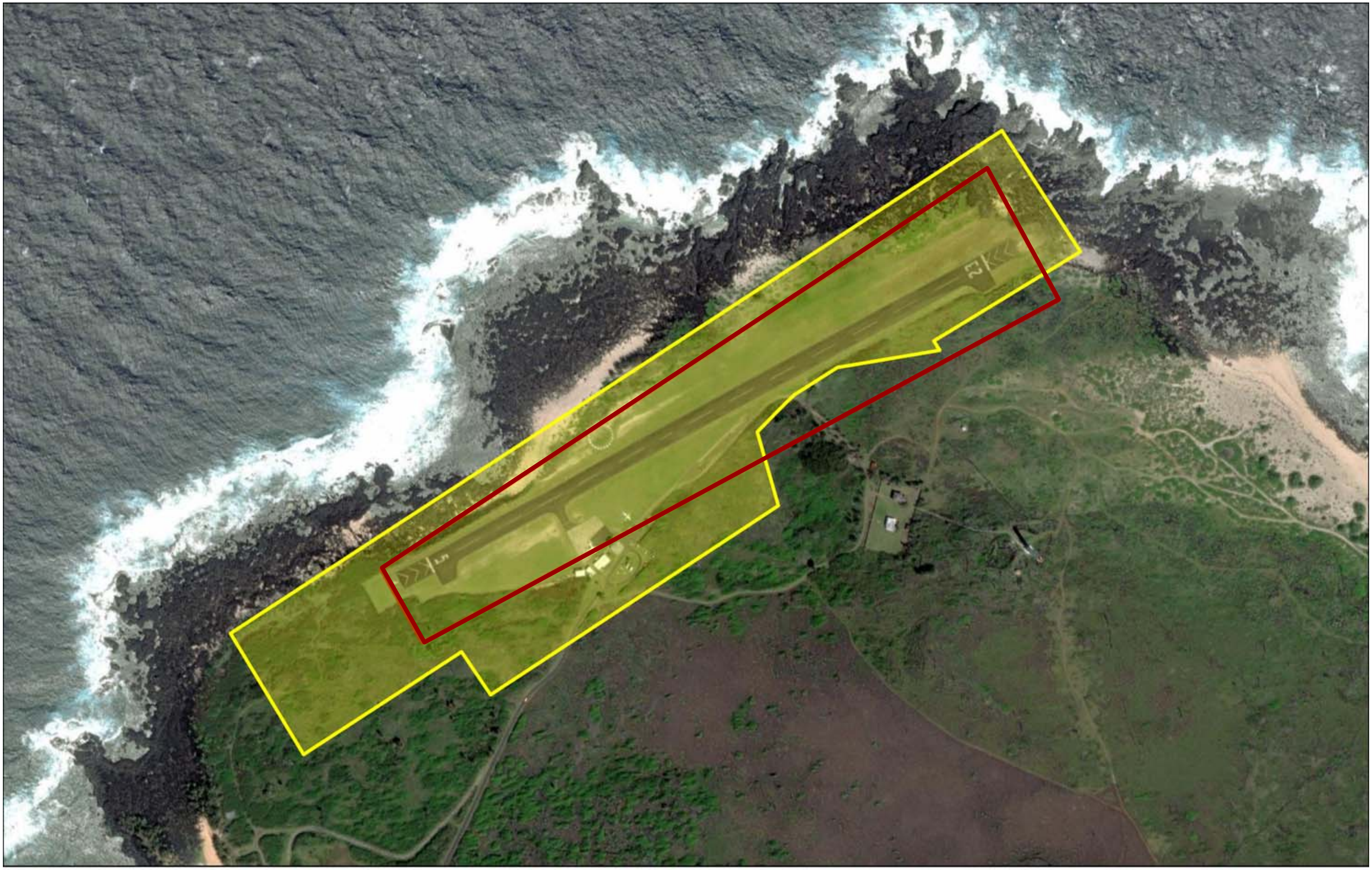


FAA Exemption Zone for PBMP Installation Lanai Airport (LNY)

Legend

▭ FAA PBMP Exemption Zone

▨ Airport Property Line

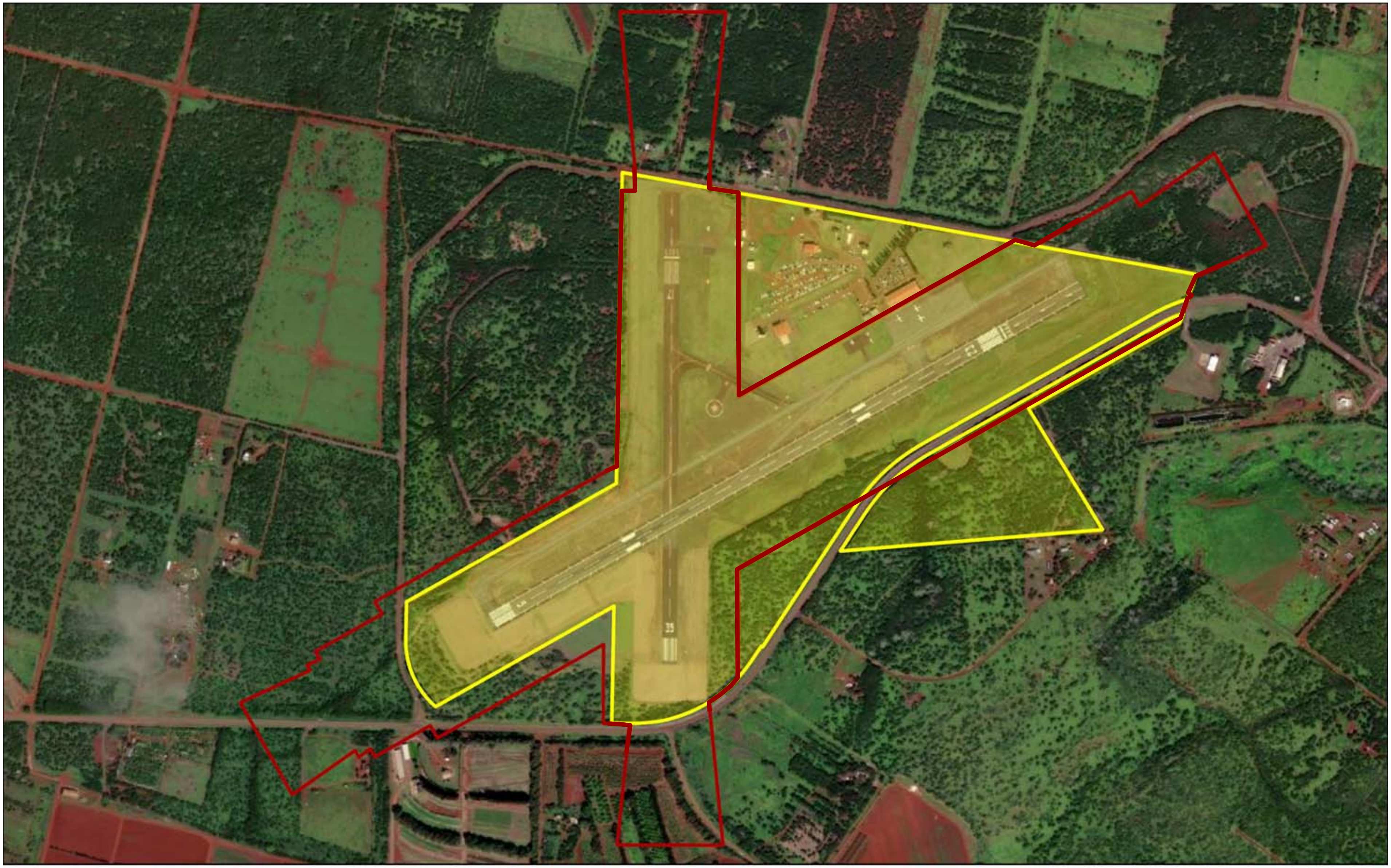


FAA Exemption Zone for PBMP Installation Kalaupapa Airport (LUP)

Legend

🟥 FAA PBMP Exemption Zone

🟨 Airport Property Line

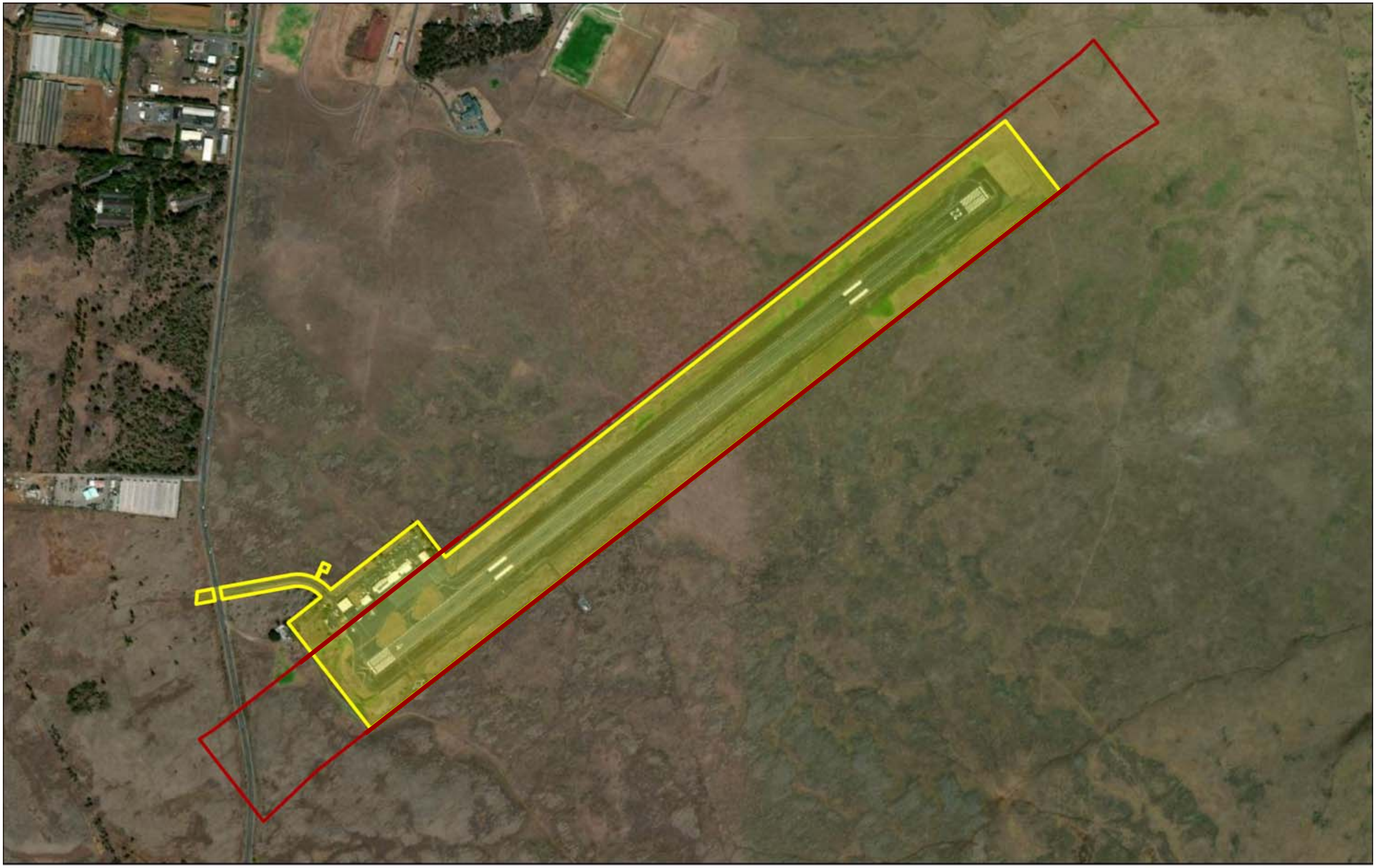


FAA Exemption Zone for PBMP Installation Molokai Airport (MKK)

Legend

▢ FAA PBMP Exemption Zone

▨ Airport Property Line

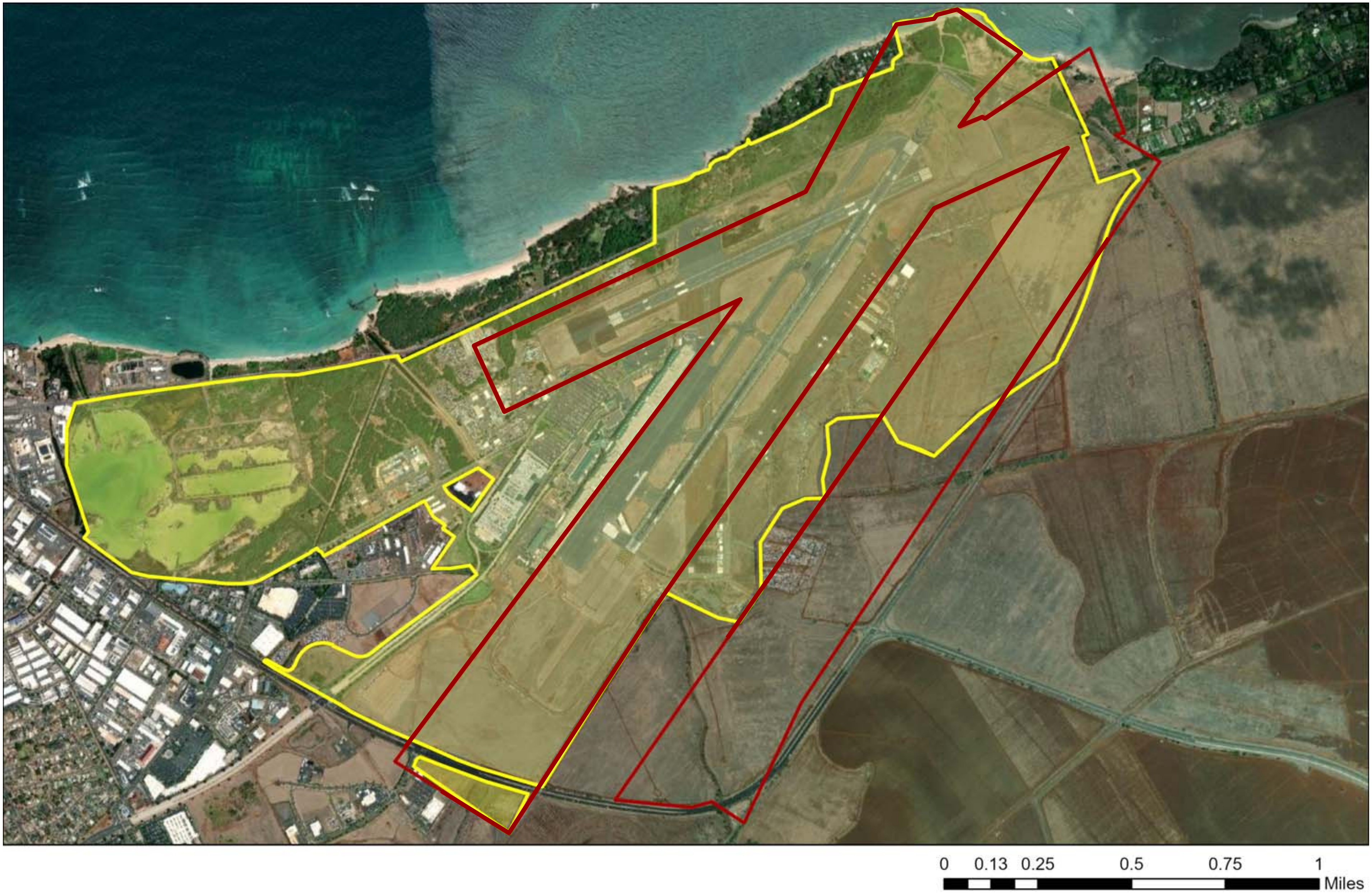


FAA Exemption Zone for PBMP Installation Waimea-Kohala Airport (MUE)

Legend

🟥 FAA PBMP Exemption Zone

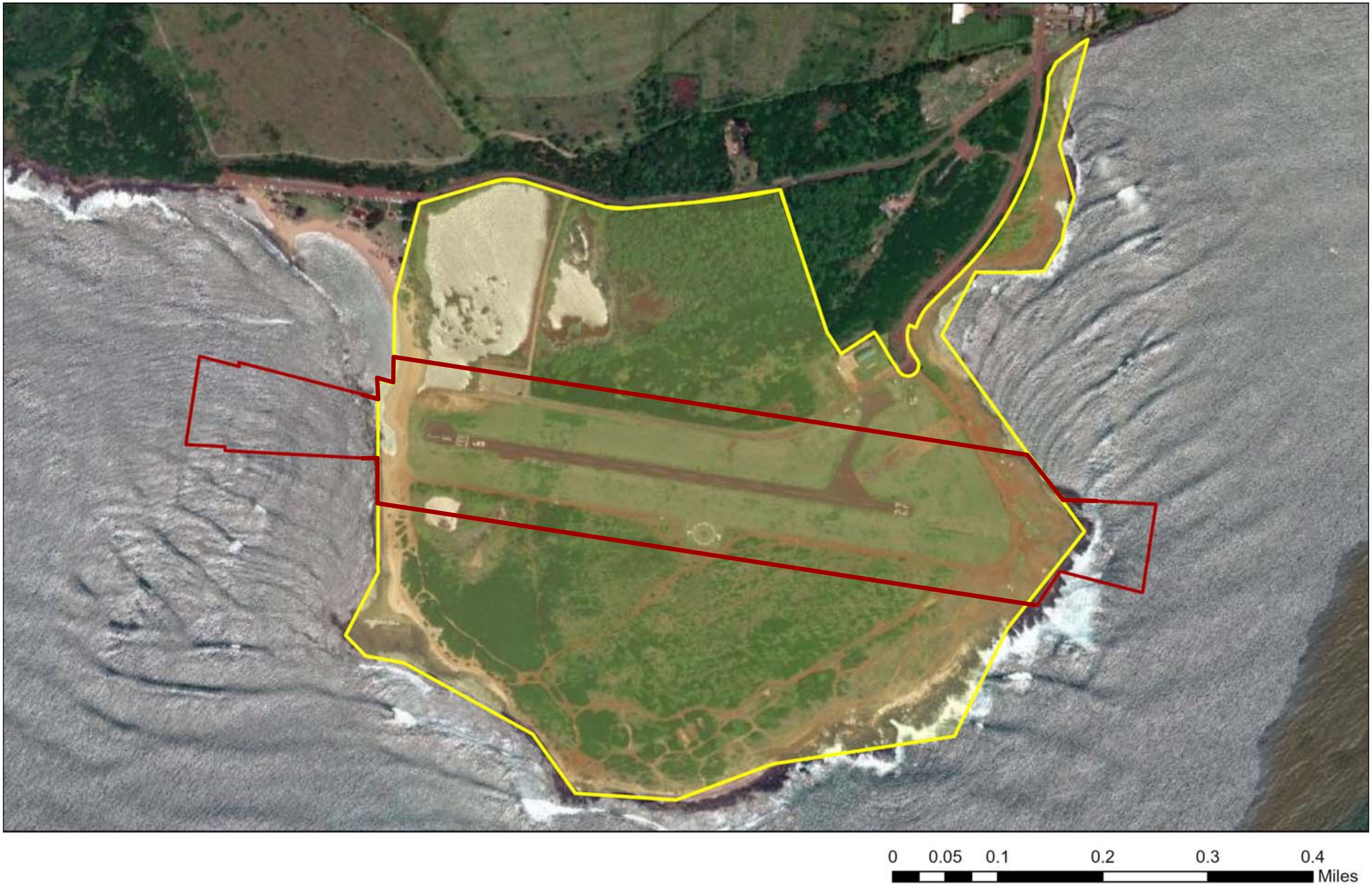
🟨 Airport Property Line



FAA Exemption Zone for PBMP Installation Kahului Airport (OGG)

Legend

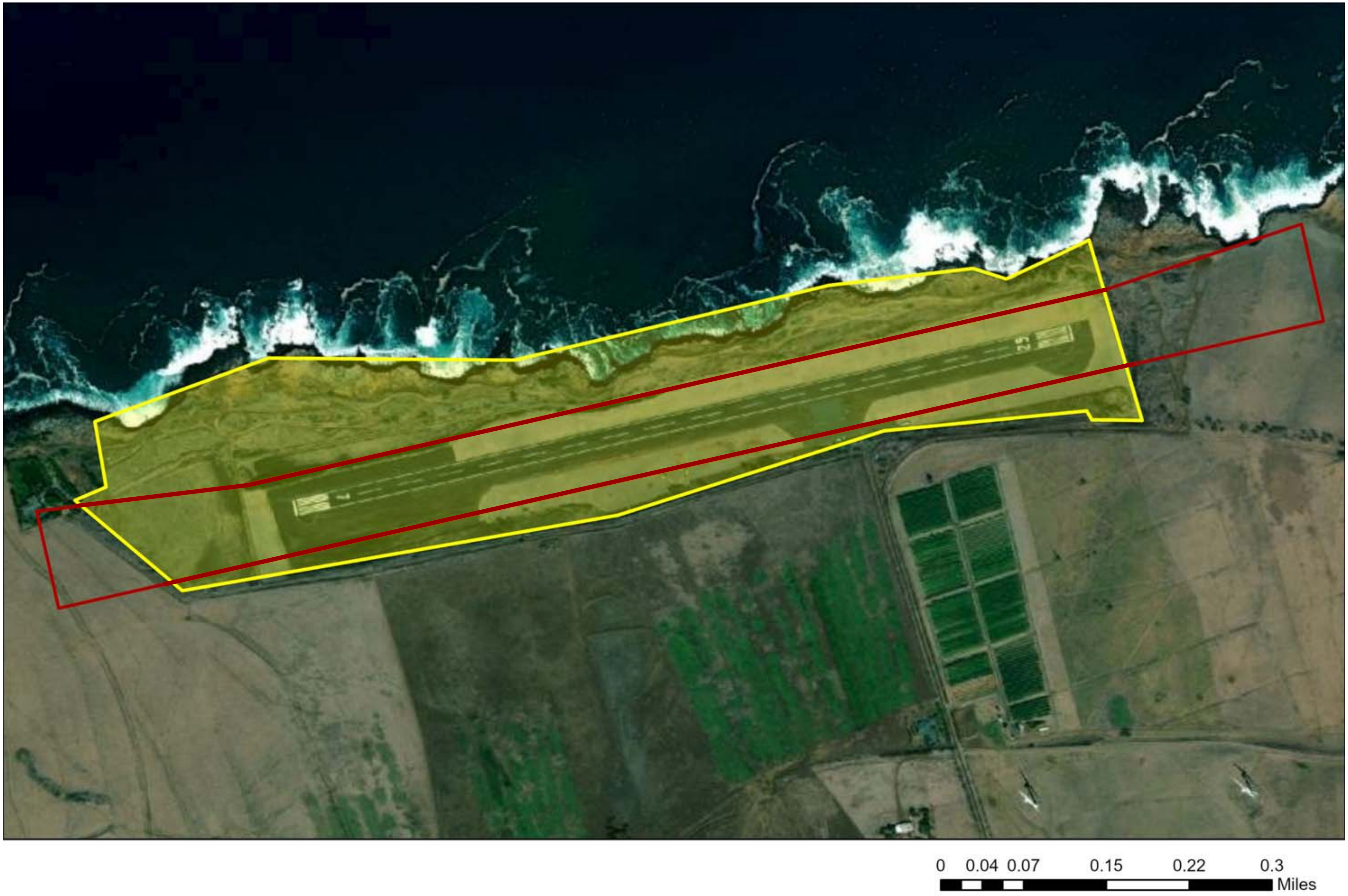
▭	FAA PBMP Exemption Zone
▨	Airport Property Line



FAA Exemption Zone for PBMP Installation Port Allen Airport (PAK)

Legend

- □ FAA PBMP Exemption Zone
- ▨ Airport Property Line



FAA Exemption Zone for PBMP Installation Upolu Airport (UPP)

Legend

▭	FAA PBMP Exemption Zone
🟨	Airport Property Line

N

Appendix II

LID PBMP Design Fact Sheets

Appendix II
LID PBMP Design Fact Sheets

This Appendix describes specific LID PBMPs to be considered for incorporation into new development and redevelopment projects at DOTA airports including retrofit projects to meet stormwater management objectives.

LID PBMPs are required for all non-exempt projects that do not qualify for a PBMP Variance with site conditions where LID PBMPs are feasible. LID PBMPs should be considered first before implementing Treatment Control PBMPs.

The following lists the various LID PBMP types to be considered, and may include the use of more than one depending on site specific conditions:

- LC-1: Biofilter
- LC-2: Bioretention
- LC-3: Bioswale
- LC-4: Harvesting/Reuse
- LC-5: Dry Well/Drainage Well
- LC-6: Infiltration Basin
- LC-7: Infiltration Trench
- LC-8: Permeable Pavement
- LC-9: Subsurface Infiltration
- LC-10: Vegetated Buffer Strip
- LC-11: Vegetated Swale

The following information is provided for each of the above-listed LID PBMP Fact Sheets:

- PBMP Category
- Pollutants Targeted
- Description
- Limitations
- Design Guidelines
- Construction Considerations
- Example Schematics

Please refer to Appendix VII for the corresponding O&M Fact Sheets.

LC-1: Biofilter

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☒Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☐Pesticides
☒Sediment
☒Trash
☐Other:

Stormwater Planter
Source: Bureau of Environmental Services
Stormwater planter at Epler Hall at Portland State University, Oregon

DESCRIPTION

A biofilter is an engineered shallow depression or above ground facility that collects and filters stormwater runoff using specialized soil media and planting. Filtered runoff discharges to an underdrain and returns to the DOTA MS4 or drainage system.

This category of PBMPs include vegetated biofilters, stormwater curb extensions, tree box filters, planter boxes, or similar proprietary devices.

Stormwater curb extensions are landscaped areas within the street parking zone that collect and filter stormwater runoff. There are stormwater curb extensions such as intersection, mid-block, transit stop, bend-out, etc. They can be planted with groundcover, grasses, shrubs, or trees, depending on the site conditions, costs, and design context.

Tree box filters and planter boxes are proprietary biotreatment devices designed to mimic natural systems such as biofilter cells by incorporating plants, soil, and microbes. Tree box filters and planter boxes are used adjacent to areas of impervious surfaces in highly urbanized settings to collect and filter stormwater runoff.

LIMITATIONS

Biofilters are considered infeasible if any of the following conditions are met.

- A site where biofiltration is determined to be infeasible (refer to the Biofiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).
- Removal of mature trees for the construction of the biofilter may be infeasible and requires additional review and approval by DOTA on a case-by-case basis.

VEGETATED BIOFILTER

Vegetated biofilters are considered infeasible if any of the following conditions are met in addition to the general limitations listed above.

- Unstable surrounding soil stratum and soils with clay content greater than 25%.
- A site with slopes greater than 20%.
- There is a documented concern that there is a potential on-site for soil pollutants, groundwater pollutants, or pollutants associated with industrial activities to be mobilized.
- The media layer depth of the biofilter is less than 2 ft.

STORMWATER CURB EXTENSION

Stormwater curb extensions are considered infeasible if any of the following conditions are met in addition to the general limitations listed above.

- Sites where on-street parking may be removed or reduced to incorporate stormwater curb extensions.
- Location conflicts where utility and fire hydrants will need to be accessed by emergency responders.
- Sites where existing catch basins cannot be moved.
- There is a documented concern of a potential for soil pollutants, groundwater pollutants, or pollutants associated with industrial activities on-site to be mobilized.
- Excessive sediment sources (e.g., dirt roads, gravel shoulders, gravel driveways) are located within the drainage area.

TREE BOX FILTER OR PLANTER BOX

Tree box filters and planter boxes are considered infeasible if any of the following conditions are met in addition to the general limitations listed above.

- Sites where on-street parking may be removed or reduced to incorporate tree box filters or planter boxes.

- Location conflicts where utility and fire hydrants will need to be accessed by emergency responders.
- Excessive sediment sources (e.g., dirt roads, gravel shoulders, gravel driveways) are located within the drainage area.
- Following the manufacturer's instructions for placement and installation causes limitations.

DESIGN GUIDELINES

GENERAL

- The ponding depth should be 12-in or less.
- An overflow device (e.g., riser, spillway) or bypass should be included to safely convey runoff from significant storm events when the surface/subsurface capacity is exceeded.
- Overflow for the 10-yr storm event should be directed to an outlet point with energy dissipators designed to prevent erosion from the 10-yr storm velocity.
- A flow regulator may be provided to divert runoff from large drainage areas if needed.
- Landscaping is critical to the function and performance of biofilters. Vegetation in or around biofilter that provides food or cover for hazardous wildlife should be eliminated.
- The plantings selected should consider the local climate, expected water depth in the biofilter, expected tolerances to pollutant loads, and varying soil moistures. Trees selected should be small in stature, similar to those found nearby, and have non-invasive root systems. Ground cover, such as grasses, should be planted after the trees and shrubs are in place.
- Irrigation may be required to maintain the vegetation during dry periods.

VEGETATED BIOFILTER

- The biofilter should include a 2 to 4 ft deep media layer and a 2-in to 4-in surface mulch layer; it may include a gravel layer at the bottom for the underdrain.
- If a mulch layer is used on the surface of the planting bed, consideration should be given to dispersion caused by flotation during storm events.
- Observation wells are recommended. The observation wells indicate how quickly the biofilter dewaters following a storm event and provides an insight into whether the biofilter is functioning as intended (i.e., clogged with sediment, etc.).
- Permeable filter fabric should be placed between the media layer and the gravel layer.
- The biofilters should have a 6-in perforated underdrain pipe in a gravel layer.
- A cleanout pipe should be tied into the end of all underdrain pipe runs.

STORMWATER CURB EXTENSION

- Stormwater curb extensions can be used at a roadway intersection, midblock, or along the length or block of the roadway and can be combined with pedestrian crosswalks to increase safety along the roadway.
- Stormwater curb extensions can be sited immediately upstream of storm drains to intercept as much runoff as possible. Consider the maximum potential drainage area by selecting the topographically lowest point of the curb/flow line.
- Stormwater curb extensions are typically recessed 1–2 ft from the outside edge of the right-most travel lane. However, the width may be tailored to accommodate emergency or large vehicle access or other existing conditions.

- Stormwater curb extensions should be designed to capture drainage of stormwater from the gutter and not cause ponding. Depending on site-specific grading conditions, the design may include properly locating or relocating catch basins or utilizing design treatments that convey water through, around, or between the stormwater curb extension and the curb line.
- Stormwater curb extensions should be designed to allow street sweepers to clean the street area around it adequately. The curb return from the bump-out edge to the original curb line should be designed to enable street sweeping along the curb edge, typically angled between 30 and 60 degrees relative to the curb line. Steeper return angles will usually require hand-sweeping.
- Design inlets and outlets to resist incursions by vehicles and bicycles, as motor vehicle wheels may be prone to enter, especially during parking maneuvers.
- The biofilter cell should be designed using the vegetated biofilter design guidelines above.
- Use low plantings in biofilter cells of the stormwater curb extensions near intersections to maintain sight clearance; plants should grow no higher than 24-in above the sidewalk grade.

TREE BOX FILTER OR PLANTER BOX

- Tree box filters or planter boxes can also be engineered for enhanced pollutant removal and hydraulic performance, allowing for a smaller footprint and ease of construction and maintenance.
- Follow the manufacturer's instructions for the design guidelines.
- Tree box filters or planter boxes can be used as a pretreatment for other LID and Treatment Control PBMPs.

PRETREATMENT CONSIDERATIONS

- Biofilters are susceptible to clogging and premature failure from sediment, trash, and other contaminants. Pretreatment should be provided where sediments, debris, or trash may cause concern or decreased PBMP functionality and when space permits.

VEGETATED BIOFILTER

- Pretreatment may be achieved with sedimentation basins, forebays, or manufactured treatment devices.

STORMWATER CURB EXTENSION

- None.

TREE BOX FILTER OR PLANTER BOX

- Follow the manufacturer's instructions for any pretreatment considerations.

AREA REQUIREMENTS

VEGETATED BIOFILTER

- A biofilter requires a footprint equivalent to 3.3% - 3.8% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects the minimum planting media depth and maximum ponding depth, while the upper value reflects the maximum planting media depth and minimum ponding depth.

STORMWATER CURB EXTENSION

- The area requirements of a biofilter cell within a curb extension should follow the area requirements provided for the vegetated biofilter above.

TREE BOX FILTER OR PLANTER BOX

- Follow the manufacturer’s instructions for area requirements.

MINIMUM DESIGN CRITERIA

VEGETATED BIOFILTER

Design Parameter	**Units**	**Value**
Planting Media coefficient of Permeability	ft/day	1
Mulch Thickness	in	2 - 4
Planting Media Depth	ft	2 - 4
Drawdown (drain) Time	hrs	48 or less
Maximum Ponding Depth	in	12
Minimum Underdrain Diameter	in	6

STORMWATER CURB EXTENSION

- The minimum design criteria for the biofilter cell should follow the minimum design criteria provided for the vegetated biofilter above.

TREE BOX FILTER OR PLANTER BOX

- Follow the manufacturer’s instructions for minimum design criteria.

SIZING GUIDELINES

VEGETATED BIOFILTER

Step 1: Use the procedure presented below to compute the volumetric runoff coefficient and WQV.

The volumetric runoff coefficient should be calculated using the following equation:

$$\mathbf{C = 0.05 + 0.009I}$$

where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

The WQV is calculated using the following equation:

$$\mathbf{WQV = PCA \times 3630}$$

where WQV = Water Quality Design Volume (ft^3)
P = Design Storm Runoff Depth (in) (refer to section 4.3.1)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ac)

Step 2: Select initial values for the planting media depth (l_m) and allowable maximum ponding depth (d_p).

Step 3: Calculate the filter bed surface area (A_b):

$$\mathbf{A_b = (WQV \times l_m) / (k_m (l_m + d_p/24) (t/24))}$$

where A_b = Filter Bed Bottom Surface Area (ft^2)
WQV = Water Quality Design Volume from Step 1 (ft^3)
l_m = Planting Media Depth from Step 2 (ft)
k_m = Planting Media Permeability Coefficient (ft/day) (refer to section 4.3.6.2)
d_p = Maximum Ponding Depth from Step 2 (ft)
t = Filter Bed Drain Time (hrs) (refer to section 4.3.6.1)

Step 4: Select a filter bed width (w_b), and calculate the filter bed length (l_b):

$$\mathbf{l_b = A_b / w_b}$$

where l_b = Filter Bed Length (ft)
A_b = Filter Bed Bottom Surface Area from Step 3 (ft^2)
w_b = Filter Bed Width (ft)

Step 5: Calculate the total area occupied by the PBMP excluding pretreatment (A_{PBMP}) using the filter bed dimensions, embankment side slopes, and freeboard:

$$\mathbf{A_{PBMP} = [w_b + 2z(d_p + f)] \times [l_b + 2z(d_p + f)]}$$

where A_{PBMP} = Area Occupied by PBMP Excluding Pretreatment (ft^2)
w_b = Filter Bed Width from Step 4 (ft)

z = Filter Bed Interior Side Slope (length per unit height)
d_p = Maximum Ponding Depth from Step 2 (ft)
f = Freeboard (ft)
l_b = Filter Bed Length from Step 4 (ft)

If the calculated area does not fit in the available space, either reduce the drainage area, increase the planting media depth (if it is not already equal to the maximum depth), and repeat the calculations.

STORMWATER CURB EXTENSION

- The sizing guidelines for the curb extension biofilter cell should follow the sizing guidelines provided for the vegetated biofilter above.

TREE BOX FILTER OR PLANTER BOX

- Follow the manufacturer's instructions for sizing guidelines.

CONSTRUCTION CONSIDERATIONS

UNDERDRAINS

- Underdrains are to be placed on a 3 ft wide section of the permeable filter fabric. The pipe is placed next, followed by the gravel bedding. The ends of underdrain pipes not terminating in an observation well should be capped.
- The main collector pipe for underdrain systems should be constructed at a minimum slope of 0.5%. Observation wells or cleanout pipes should be provided (1 minimum per every 1,000 ft^2 of surface area).

PLANTING

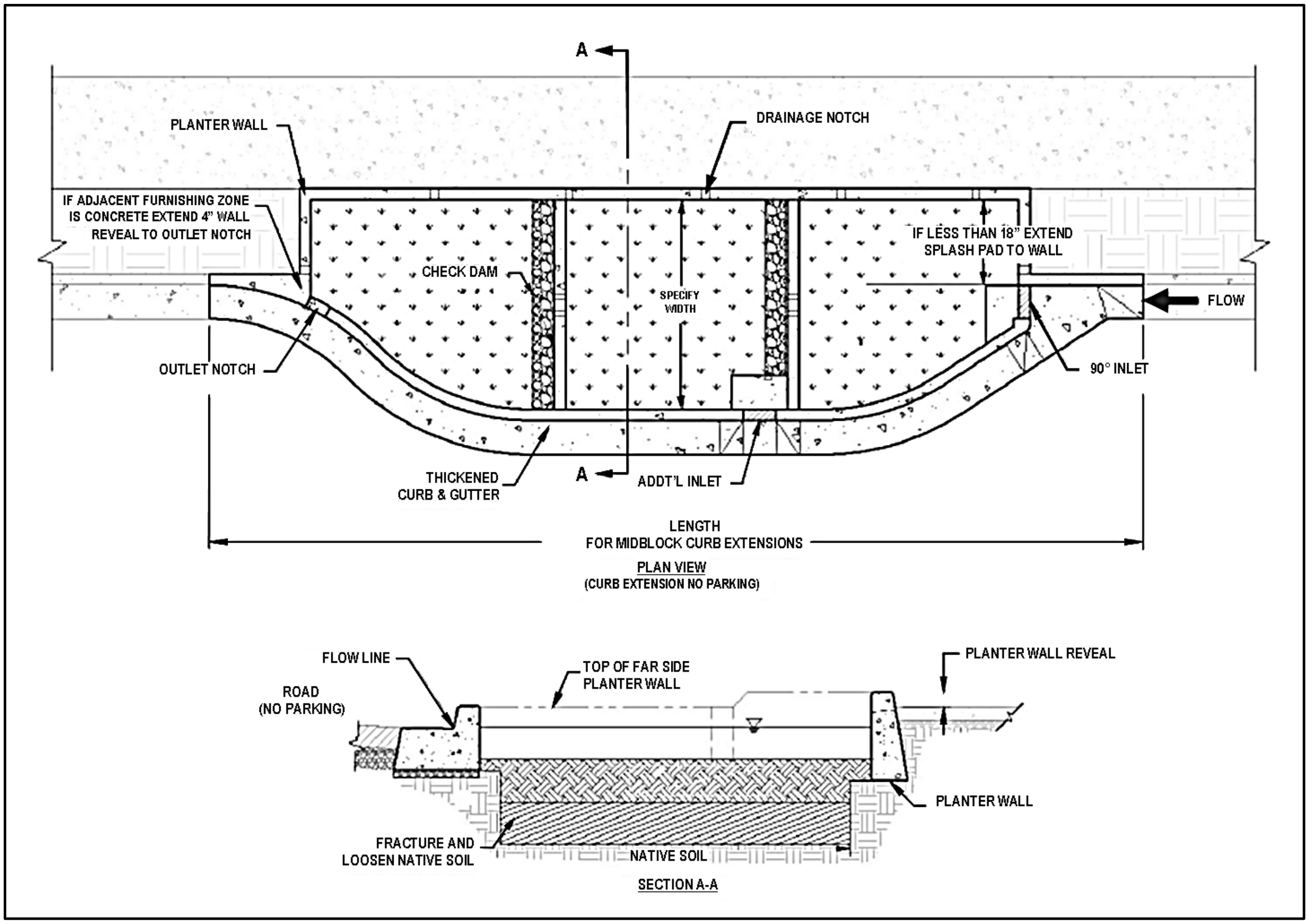
- Plant as soon as possible after the area has been graded. Sod should be protected with tarps or other protective covers during delivery and should not be allowed to dry out between harvesting and placement.
- The rootstock of the plant material should be kept moist during transport and on-site storage. The plant root ball should be planted such that 1/8 of the ball is above the final grade surface. The diameter of the planting pit should be at least 6-in larger than the diameter of the planting ball. Set and maintain the plant straight during the entire planting process. Thoroughly water ground bed cover after installation.
- Mulch should be placed in the surrounding area to a uniform thickness of 2-in to 3-in. Compost is a heavier organic material and is less likely to float; place on the surface and in the low areas of the biofilter. Mulch and wood chips that will float and move to the perimeter of the biofilter during a storm event are not preferred.

MISCELLANEOUS

- Install biofilters at the time of the year when there is a reasonable chance of successfully establishing vegetation without irrigation; however, it is recognized that rainfall in a given year may not be sufficient and temporary irrigation may be used.
- Biofilter areas should not serve as sediment control measures during the construction.
- Biofilters should not be established until the contributing drainage area is stabilized.

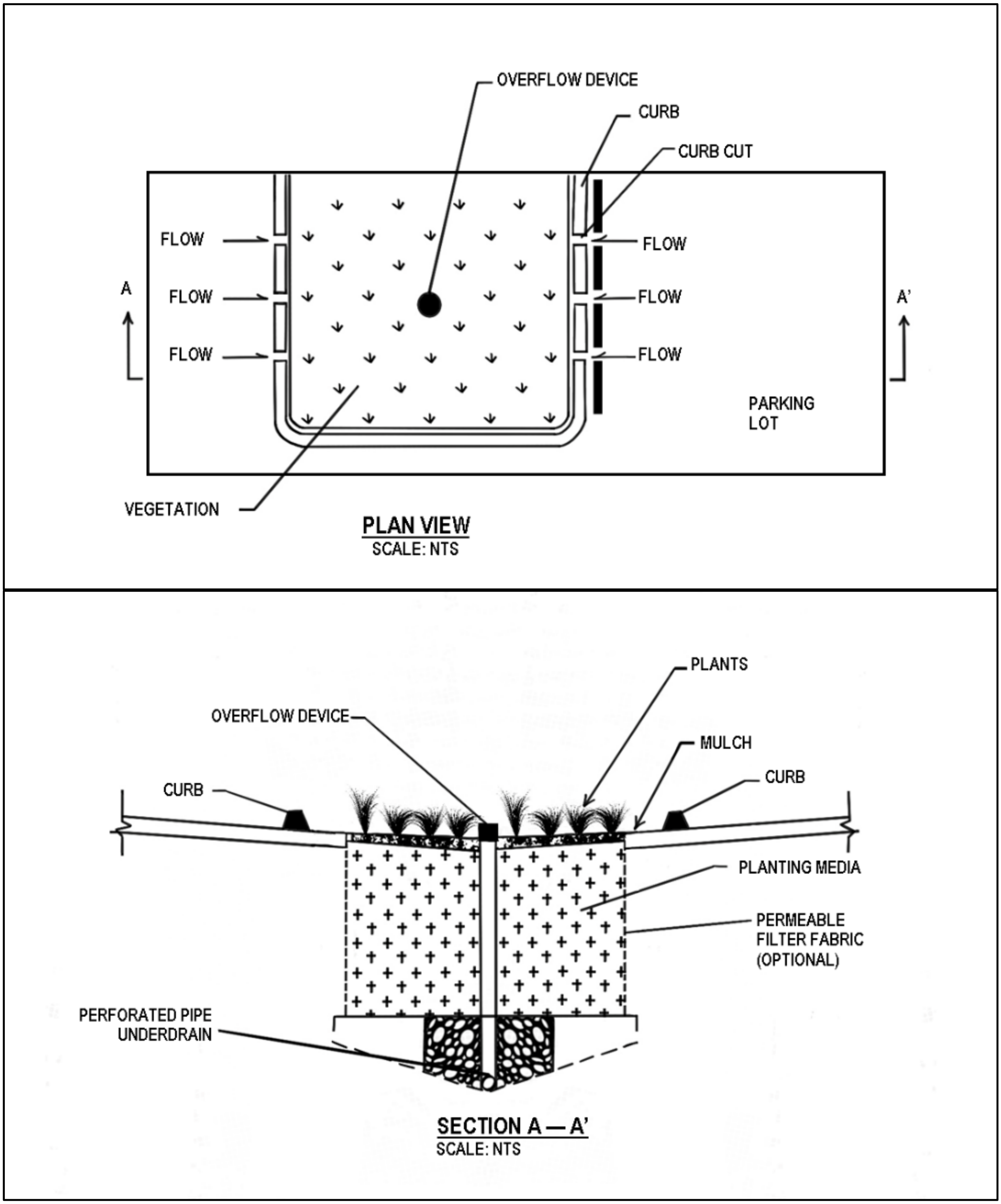
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



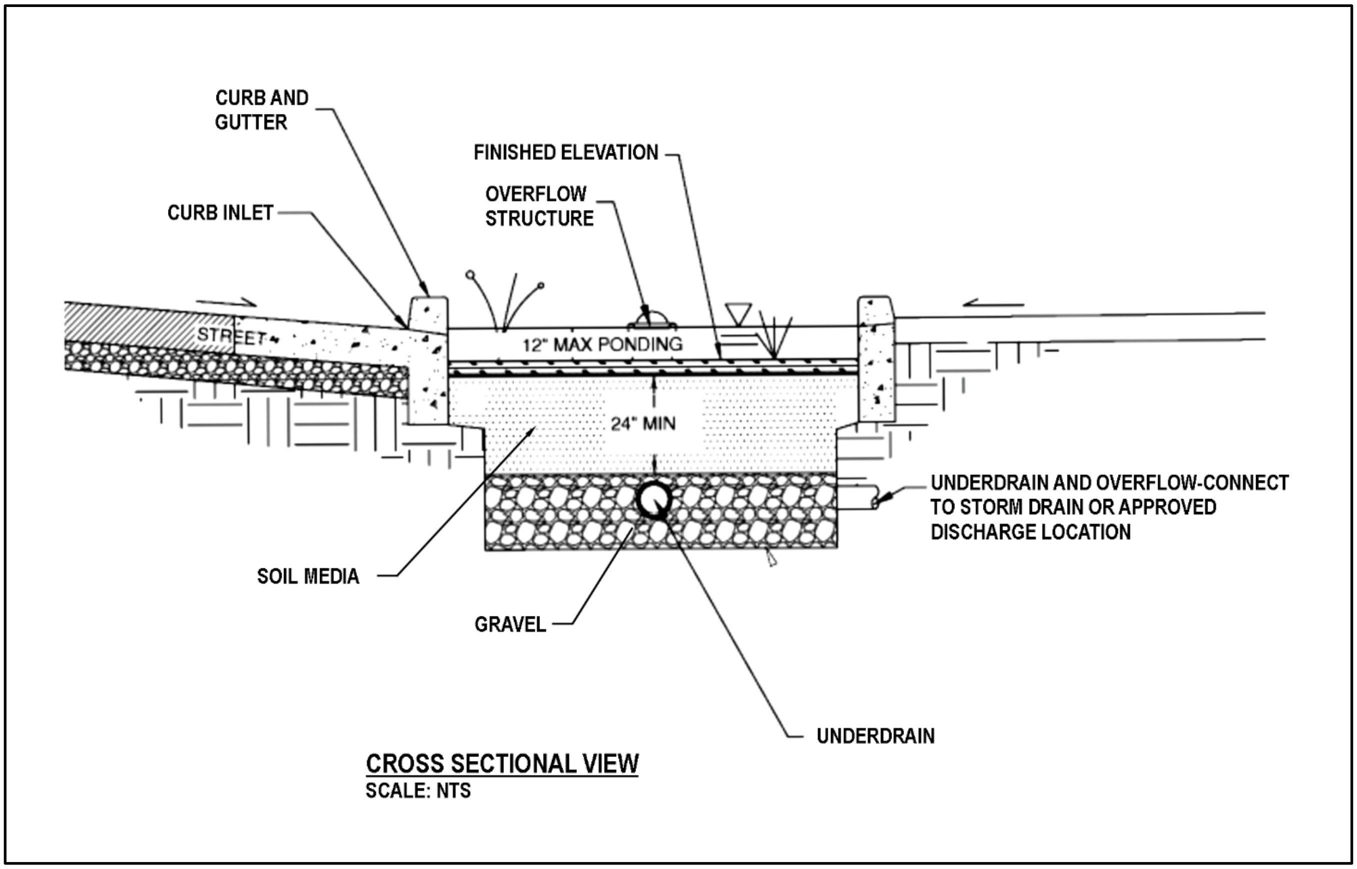
Example Schematic of a Stormwater Curb Extension

Source: *2020 Stormwater Management Manual*, *SWMM Details* (City of Portland, Oregon, Bureau of Environmental Services, December 2020). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Vegetated Biofilter

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Planter Box with underdrain

Source: *Low Impact Development Initiative, Low Impact Development Stormwater Management Standard Details* (California Stormwater Quality Association (CASQA), August 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

LC-2: Bioretention

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☒Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☐Other:

Bioretention at the Kakoi Baseyard, Oahu
Source: HDOT Highways Division

DESCRIPTION

Bioretention is an engineered excavated facility that collects and filters stormwater runoff using specialized soil media and planting. It captures and temporarily stores the water quality volume and passes it through layers of sand, organic matter, soil, or other media. Filtered runoff infiltrates through the bioretention facility invert and into the soil matrix and collects and returns to the DOTA MS4 or drainage system.

LIMITATIONS

Bioretention facilities are considered infeasible if any of the following conditions are met.

- A site where infiltration is determined to be infeasible (refer to the Infiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).
- Unstable surrounding soil stratum and soils with clay content greater than 25%.
- A site with slopes greater than 20%.

- Removal of mature trees for the construction of the bioretention facility may be infeasible and requires additional review and approval by DOTA on a case-by-case basis.
- The media layer depth of the bioretention facility is less than 2 ft.

DESIGN GUIDELINES

GENERAL

- The bioretention facility should include a minimum of 2 to 4 ft media layer and a 2-in to 4-in surface mulch layer; it may include a gravel layer at the bottom.
- If a mulch layer is used on the surface of the planting bed, consideration should be given to problems caused by dispersion during storm events.
- The ponding depth should be 12-in or less.
- An overflow device (e.g., riser, spillway) should be included to safely convey runoff from significant storm events when the surface/subsurface capacity is exceeded.
- Overflow for the 10-yr storm event should be directed to an outlet point with energy dissipators designed to prevent erosion from the 10-yr storm velocity.
- A flow regulator may be utilized to divert runoff from large drainage areas if needed.
- Observation wells are recommended. The observation wells indicate how quickly the bioretention facility dewaters following a storm event and provides an insight into whether the bioretention facility is functioning as intended (i.e., clogged with sediment, etc.).
- Permeable filter fabric should be placed between the media layer and the gravel layer.
- DOTA prefers bioretention facilities without underdrains; however, underdrains can be used if the site conditions warrant the use. If using an underdrain, the bioretention facility should have a minimum of 6-in perforated underdrain pipe in a gravel layer.
- A cleanout pipe should be tied into the end of all underdrain pipe runs.
- Landscaping is critical to the function and performance of the bioretention facilities. Vegetation in or around bioretention facilities that provide food (seeds) or habitat for wildlife that could be hazardous to airport operations should not be considered.
- The plantings selected should consider the local climate, expected water depth in the bioretention facility, and expected tolerances to pollutant loads and varying soil moistures. Trees selected should be small in stature, similar to those found in the local area, and have non-invasive root systems. Ground cover, such as grasses, should be planted after the trees and shrubs are in place.
- Irrigation may be required to maintain the vegetation during dry periods.

PRETREATMENT CONSIDERATIONS

- Bioretention facilities are susceptible to clogging and premature failure from sediment, trash, and other contaminants. Suitable pretreatment systems maintain the infiltration rate of the device without frequent and intensive maintenance.
    - For soil infiltration rates below 3 in/hr, pretreatment is strongly recommended, and the pretreatment device should be sized for at least 25% of the WQV.
    - For soil infiltration rates greater than 3 in/hr, pretreatment is mandatory to minimize groundwater contamination risks. The pretreatment device should be sized for at least 50% of the WQV if the soil infiltration rate is below 5 in/hr and 100% of the WQV if the soil infiltration rate is above 5 in/hr.
- Pretreatment may be achieved with vegetated swales, vegetated buffer strips, sedimentation basins, forebays, or manufactured treatment devices.

- Forebays should be 18-30 in deep and used only in locations where standing water is not considered a safety concern. The forebay should be lined such that water will not flow into the underdrain without first flowing through the treatment area of the bioretention facility. Lining material should allow for the removal of sediment and debris with a shovel or vac truck.

AREA REQUIREMENTS

- A bioretention facility requires a footprint equivalent to 4% - 13% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects the maximum allowable infiltration rate and minimum allowable factor of safety, while the upper value reflects the minimum allowable infiltration rate and maximum allowable factor of safety.

MINIMUM DESIGN CRITERIA

Design Parameter	Units	Value
Mulch Thickness	in	2 - 4
Media Layer Depth	ft	2 - 4
Drawdown (drain) Time	hrs	48 or less
Maximum Interior Side Slope (length per unit height)	ft/ft	3:1
Maximum Ponding Depth	in	12
Minimum Depth from Basin Invert to Groundwater Table	ft	3
Minimum Freeboard Above Overflow Device	ft	1
Minimum Soil Infiltration Rate	in/hr	0.50

SIZING GUIDELINES

Step 1: Use the procedure below to compute the volumetric runoff coefficient and WQV.

The volumetric runoff coefficient should be calculated using the following equation:

$$\mathbf{C = 0.05 + 0.009I}$$

where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

The WQV is calculated using the following equation:

$$\mathbf{WQV = PCA \times 3630}$$

where WQV = Water Quality Design Volume (ft^3)
P = Design Storm Runoff Depth (in) (refer to section 4.3.1)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ac)

Step 2: Calculate the maximum water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$$\mathbf{d_{max} = kt / (F_s \times 12)}$$

where d_{max} = Maximum Storage Depth (ft)
k = Soil Infiltration Rate (in/hr)
t = Drawdown (drain) Time (hrs) (refer to section 4.3.6.1)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

Step 3: Select a ponding depth (d_p), media layer thickness depth (l_m), and gravel layer thickness depth (l_g; this is optional) such that the total effective storage depth (d_t) is no greater than the maximum water storage depth (d_{max}) calculated in Step 2:

$$\mathbf{d_t = d_p + l_m n_m + l_g n_g \leq d_{max}}$$

where d_t = Total Effective Water Storage Depth (ft)
d_p = Ponding Depth (ft)
l_m = Media Layer Depth (ft)
n_m = Media Layer Porosity (refer to section 4.3.6.3)
l_g = Gravel Layer Depth (ft)
n_g = Gravel Layer Porosity (refer to section 4.3.6.3)
d_{max} = Maximum Storage Depth from Step 2 (ft)

Step 4: Calculate the bioretention facility bottom surface area (A_b):

$$\mathbf{A_b = WQV / (d_t + (kT / 12F_s))}$$

where A_b = Bottom Surface Area (ft^2)
WQV = WQV from Step 1 (ft^3)
d_t = Total Effective Water Storage Depth from Step 3 (ft)
k = Soil Infiltration Rate (in/hr)
T = Fill Time (time for the PBMP to fill with water [hrs]) (refer to section 4.3.6.6)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

Step 5: Select a bioretention facility bottom or invert width (w_b), and calculate the bioretention facility bottom or invert length (l_b) using the surface area (A_b) calculated from Step 4:

$$\mathbf{l_b = A_b / w_b}$$

where l_b = Bottom or Invert Length (ft)
A_b = Bottom Surface Area from Step 4 (ft^2)
w_b = Bottom or Invert Width (ft)

Step 6: Calculate the total area occupied by the PBMP excluding pretreatment (A_{PBMP}) using the bioretention facility bottom dimensions, embankment side slopes, and freeboard:

$$\mathbf{A_{PBMP} = [w_b + 2z\ (d_p + f)] \times [l_b + 2z\ (d_p + f)]}$$

where A_{PBMP} = Area Occupied by PBMP Excluding Pretreatment (ft^2)
w_b = Bottom Width from Step 5 (ft)
z = Bioretention facility Interior Side Slope (length per unit height)
d_p = Design Ponding Depth from Step 3 (ft)
f = Freeboard (ft)
l_b = Bottom Length from Step 5 (ft)

If the calculated area does not fit in the available space, either reduce the drainage area or increase the ponding depth, media layer depth, or gravel layer depth (if the total effective depth is not already equal to the maximum depth), and repeat the calculations. If that does not work and the calculated area does not fit in the available space, reduce the Infiltration rate factor of safety (if the minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

CONSTRUCTION CONSIDERATIONS

COMPACTION

- It is vital to minimize compaction of both the base of the bioretention facility and the required backfill. When possible, use excavation hoes to remove the original soil. If bioretention facilities are excavated using a loader, the contractor should use wide track or marsh track equipment or light equipment with turf-type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high-pressure tires is unacceptable as it may cause excessive compaction resulting in reduced infiltration rates. Compaction could significantly contribute to design failure.
- Compaction can be minimized at the base of the bioretention facility by using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12-in compaction zone.
- Place soil in lifts of 12-in to 18-in when backfilling the bioretention facility. Do not use heavy equipment within the bioretention facility. Heavy equipment can be used around the perimeter of the bioretention facility to supply media materials. Grade bioretention facility materials with light equipment such as a compact loader, a dozer, or a loader with marsh tracks.

UNDERDRAINS

- Underdrains are to be placed on a 3 ft wide section of the permeable filter fabric. The pipe is placed next, followed by the gravel bedding. The ends of underdrain pipes not terminating in an observation well should be capped.
- The main collector pipe for underdrain systems should be constructed at a minimum slope of 0.5%. Observation wells or cleanout pipes should be provided (1 minimum per every 1,000 ft^2 of surface area).

PLANTING

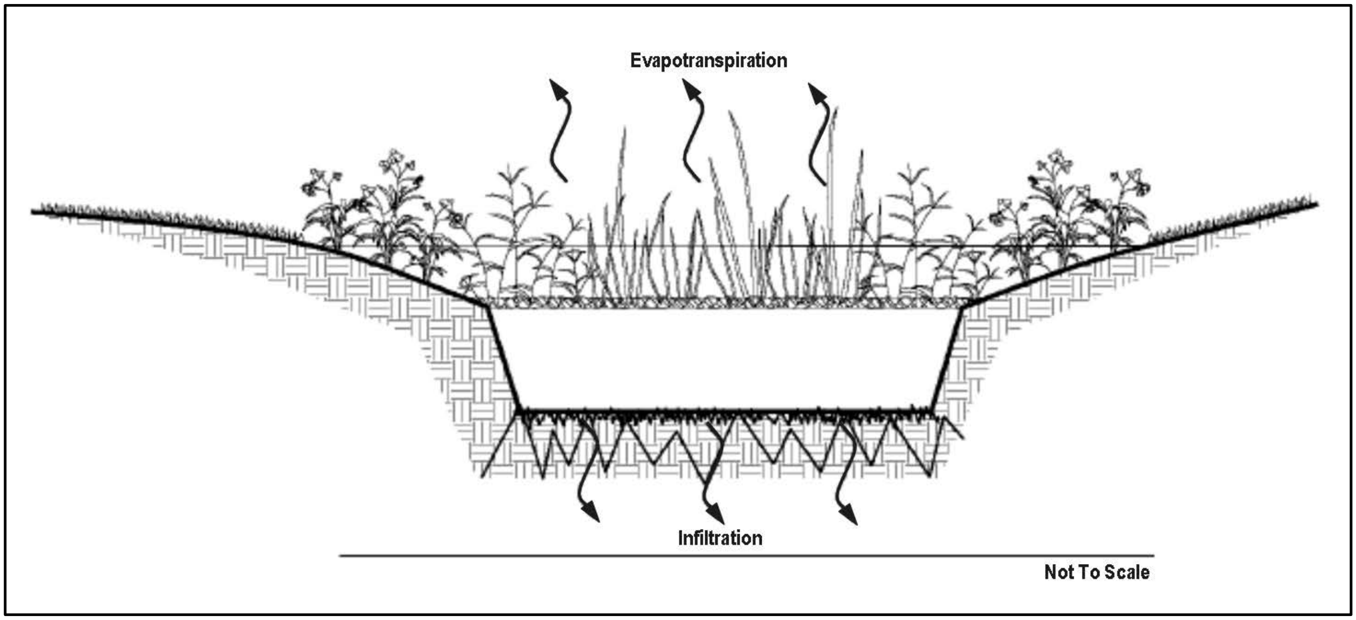
- Plant as soon as possible after the area has been graded.
- The rootstock of the plant material should be kept moist during transport and on-site storage. The plant root ball should be planted such that 1/8 of the ball is above the final grade surface. The diameter of the planting pit should be at least 6-in larger than the diameter of the planting ball. Set and maintain the plant straight during the entire planting process. Thoroughly water ground bed cover after installation.
- Place a uniform thickness of 2-in to 3-in of mulch on the surface. Compost is a heavier organic material and is less likely to float; place on the surface and in the low areas of the bioretention facility. Mulch and wood chips that will disperse and move to the perimeter of the bioretention facility during a storm event are not preferred.

MISCELLANEOUS

- Install bioretention facilities at the time of the year when there is a reasonable chance of successfully establishing vegetation without irrigation; however, it is recognized that rainfall in a given year may not be sufficient, and temporary irrigation may be used.
- The bioretention facility area should not serve as a sediment control measure during construction.
- Bioretention facilities should not be established until the contributing drainage area is stabilized.

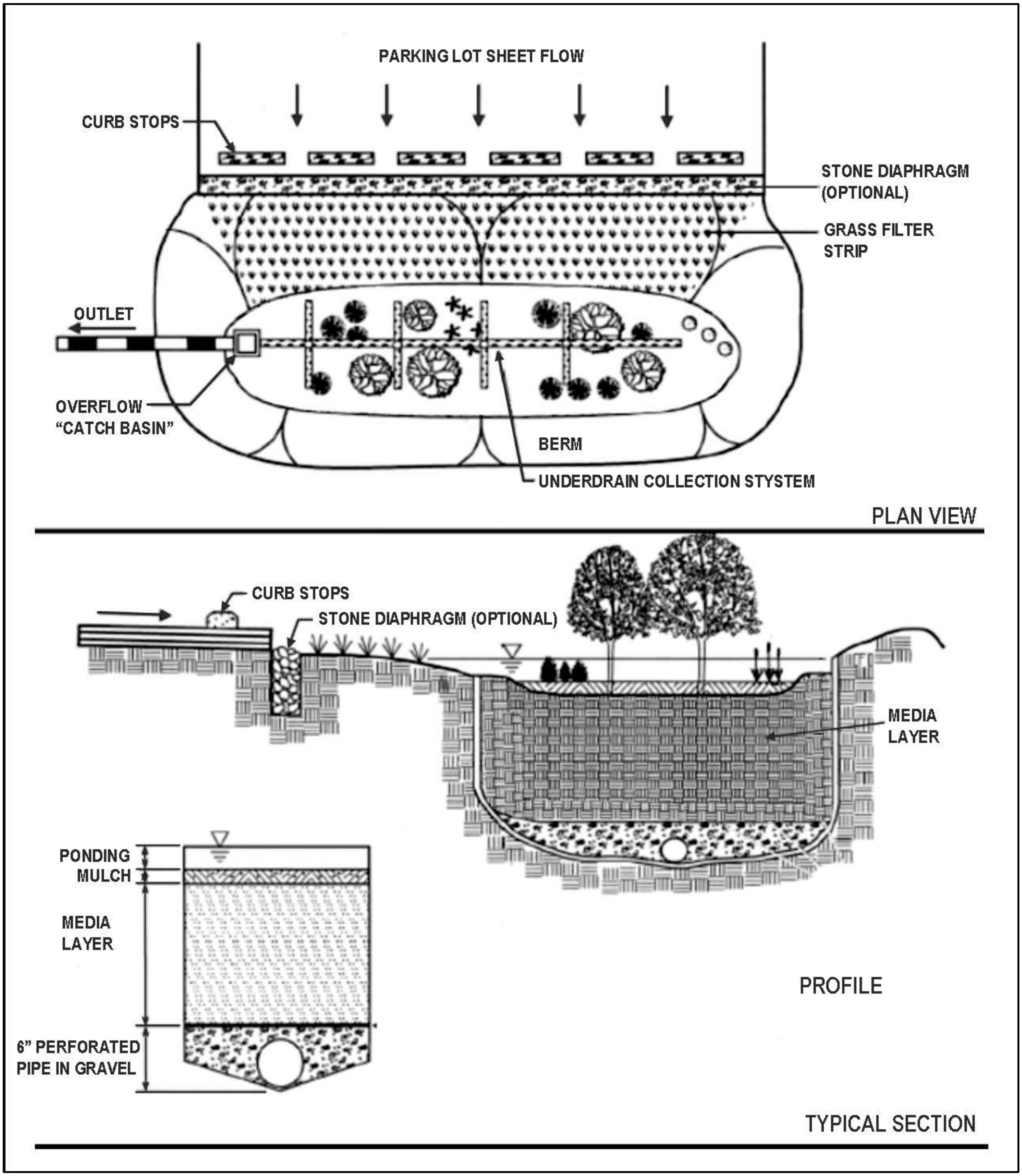
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of a Bioretention Facility with no underdrain

Source: *Minnesota Stormwater Manual* (Minnesota Pollution Control Agency, February 17, 2021). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Bioretention Facility with an underdrain

Source: *2000 Maryland Stormwater Design Manual Volumes I & II* (CWP and MDE, May 2009). The source schematic was modified to remove design details that are not consistent with this Fact Sheet. The sand filter layer and the gravel curtain drain shown above are not needed.

LC-3: Bioswale

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☒Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☐Pathogens
☐Pesticides
☒Sediment
☒Trash
☐Other:

Bioswale at Terminal 3 Parking Lot, Daniel K. Inouye International Airport

DESCRIPTION

A bioswale, sometimes referred to as a bioretention swale or an enhanced swale, is a shallow linear channel with a media layer covered with turf or other surface material (other than mulch or plants). Runoff is captured in the cells formed by check dams, filters through a media layer, and discharges at the downstream end of the swale; the filtered runoff can also collect and return to the DOTA MS4 or drainage system via underdrains.

LIMITATIONS

A bioswale is considered infeasible if any of the following conditions are met.

- A site where biofiltration is determined to be infeasible (refer to the Biofiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).
- Unstable surrounding soil stratum and soils with clay content greater than 25%.

- A site with slopes greater than 5%.
- Removal of mature trees for the bioswale construction may be infeasible and requires additional review and approval by DOTA on a case-by-case basis.
- There is a documented concern that there is a potential on the site for soil pollutants, groundwater pollutants, or pollutants associated with industrial activities to be mobilized.
- The media layer depth of a bioswale is less than 18-in.

DESIGN GUIDELINES

GENERAL

- Bioswale should have a contributing drainage area of 5 ac or less.
- Bioswale should include an 18-in to 36-in media layer and a drainage layer at the bottom.
- The ponding depth should be 18-in or less.
- Inlets and outlets to bioswales should be provided with energy dissipators such as riprap to prevent erosion and scour.
- An overflow device (e.g., riser, spillway) should be included to safely convey runoff from significant storm events when the surface/subsurface capacity is exceeded.
- A flow regulator may be provided to divert runoff from large drainage areas if needed.
- Check dams should be used for bioswales on longitudinal slopes exceeding 2%.
- Check dams should be installed perpendicular to the flow. A v-notch weir, weep hole, or similar drainage feature should be provided within the check dam to direct low flow volumes.
- Permeable filter fabric should be placed between the media layer and the drainage layer.
- Bioswale should have a minimum of 6-in perforated underdrain pipe in a drainage layer.
- A cleanout pipe should be tied into the end of all underdrain pipe runs.
- Vegetation in or around bioswales that provide food (seeds) or habitat for wildlife that could be hazardous to airport operations should not be considered.
- Landscaping design should specify proper grass species or plantings based on the site-specific soils and hydric conditions present along the channel. Grass should be designed like a typical lawn for regular mowing. The plantings selected should consider the local climate, expected water depth in the bioretention facility, and expected tolerances to pollutant loads and varying soil moistures.
- Irrigation may be required to maintain the grass during extended dry periods.

PRETREATMENT CONSIDERATIONS

- Pretreatment may be achieved with sedimentation basins, forebays, pea gravel diaphragm, or manufactured treatment devices.
- A pea gravel diaphragm can be used along the top of the channel to provide pretreatment for lateral sheet flows entering the bioswale.
- The volume of the forebay should be equal to at least 0.05-in per impervious ac of drainage area.
- Forebays should be used only in locations where standing water is not considered a safety concern. The forebay should be lined such that water will not flow into the underdrain without first flowing through the treatment area of the bioswale. Lining material should allow for the removal of sediment and debris with a shovel or vac truck.

AREA REQUIREMENTS

- A bioswale requires a footprint equivalent to 8% - 40% of its contributing impervious drainage area. The lower value reflects the maximum allowable values for the specified dependent variables, while the upper value reflects the minimum allowable values for all specified parameters.

MINIMUM DESIGN CRITERIA

Design Parameter	**Units**	**Value**
Maximum Interior Side Slope (length per unit height)	ft/ft	3:1
Bottom Width	ft	2 - 8
Maximum Longitudinal Slope without Check Dams	%	2
Maximum Longitudinal Slope with Check Dams	%	5
Maximum Check Dam Height	in	12
Maximum Ponding Depth at downstream end	in	18
Media Layer Depth	in	18 - 36
Minimum Freeboard	ft	0.50
Minimum Underdrain Diameter	in	6

SIZING GUIDELINES

Step 1: Use the procedure below to compute the volumetric runoff coefficient and WQV.

The volumetric runoff coefficient should be calculated using the following equation:

$$\mathbf{C = 0.05 + 0.009I}$$

where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

The WQV is calculated using the following equation:

$$\mathbf{WQV = PCA \times 3630}$$

where WQV = Water Quality Design Volume (ft^3)
P = Design Storm Runoff Depth (in) (refer to section 4.3.1)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ac)

Step 2: Select values for the media layer depth (l_m), drainage layer depth (l_d), media layer porosity (n_m), drainage layer porosity (n_d), maximum surface ponding depth (d_p, if check dams are used), bottom width (w_b), and interior side slope (z, length per unit height).

Step 3: Calculate the total effective storage depth (d_t) based on the instantaneous storage capacity using the average ponding depth (assumed to be one-half the maximum ponding depth) and the void space in the media layer and drainage layer:

$$\mathbf{d_t = [(d_p/2) + l_m n_m + l_d n_d]/12}$$

where d_t = Total Effective Water Storage Depth (ft)
d_p = Maximum Ponding Depth from Step 2 (ft)
l_m = Media Depth from Step 2 (ft)
n_m = Media Layer Porosity (refer to section 4.3.6.3)
l_d = Drainage Layer Depth from Step 2 (ft)
n_d = Drainage Layer Porosity (refer to section 4.3.6.3)

Step 4: Calculate the swale invert area required (A_b) based on the instantaneous storage capacity (neglecting the additional ponding capacity due to the shape of the swale sides):

$$\mathbf{A_b = WQV / d_t}$$

where A_b = Swale Invert Surface Area (ft^2)
WQV = WQV from Step 1 (ft^3)
d_t = Total Effective Water Storage Depth from Step 3 (ft)

Step 5: Calculate the total area required (A_{PBMP}) taking into account the side slopes along the length of the swale:

$$\mathbf{A_{PBMP} = [w_b + 2z\,(f + d_p / 12)] \times (A_b / w_b)}$$

where A_{PBMP} = Total Surface Area (ft^2)
w_b = Bioswale Bottom Width from Step 2 (ft)
z = Interior Bioswale Side Slope (length per unit height) from Step 2
d_p = Design Ponding Depth from Step 3 (ft)
f = Freeboard (ft)
A_b = Bottom Surface Area from Step 4 (ft)

If the minimum surface area is larger than the available space, reduce the tributary drainage area or increase one or more design depths (media, drainage, ponding), and repeat the calculations.

CONSTRUCTION CONSIDERATIONS

COMPACTION

- It is vital to minimize compaction of both the base of the bioswale and the required backfill. When possible, use excavation hoes to remove the original soil. If the bioswale is excavated using a loader, the contractor should use wide track or marsh track equipment or light equipment with turf-type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high-pressure tires is unacceptable as it may cause excessive compaction resulting in reduced infiltration rates. Compaction could significantly contribute to design failure.
- Compaction can be minimized at the base of the bioswale by using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12-in compaction zone.

- Place soil in lifts of 12-in to 18-in when backfilling the bioswale. Do not use heavy equipment within the bioswale. Heavy equipment can be used around the perimeter of the bioswale to supply media materials. Grade bioswale materials with light equipment such as a compact loader or a dozer/loader with marsh tracks.

CHECK DAMS

- Check dams should be constructed using concrete, stone, or other non-erodible material.
- Check dams should be appropriately anchored into the bottom and side slopes of the bioswale.

UNDERDRAINS

- Underdrains are to be placed on a 3 ft wide section of the permeable filter fabric. The pipe is placed next, followed by the gravel bedding. The ends of underdrain pipes not terminating in an observation well should be capped.
- The main collector pipe for underdrain systems should be constructed at a minimum slope of 0.50%. Observation wells or cleanout pipes should be provided (1 minimum per every 1,000 ft^2 of surface area).

PLANTING

- Plant as soon as possible after the area has been graded.
- The rootstock of the plant material should be kept moist during transport and on-site storage. The plant root ball should be planted such that 1/8 of the ball is above the final grade surface. The diameter of the planting pit should be at least 6-in larger than the diameter of the planting ball. Set and maintain the plant straight during the entire planting process. Thoroughly water ground bed cover after installation.
- Place a uniform thickness of 2-in to 3-in of mulch on the surface. Compost is a heavier organic material and is less likely to float; place on the surface and in the low areas of the bioretention facility. Mulch and wood chips that will disperse and move to the perimeter of the bioretention facility during a storm event are not preferred.

GRASSING

- Include directions in the specifications for the use of the appropriate fertilizer and soil amendments based on soil properties determined through testing compared to the needs of the grassing requirements.
- Grassing should be done as soon as possible after the area has been graded.
- If sod tiles are used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the bioswale.
- Use a roller on the sod to verify no air pockets form between the sod and the soil.
- Per FAA Regulations, seeds are not to be scattered or applied through hydroseeding.

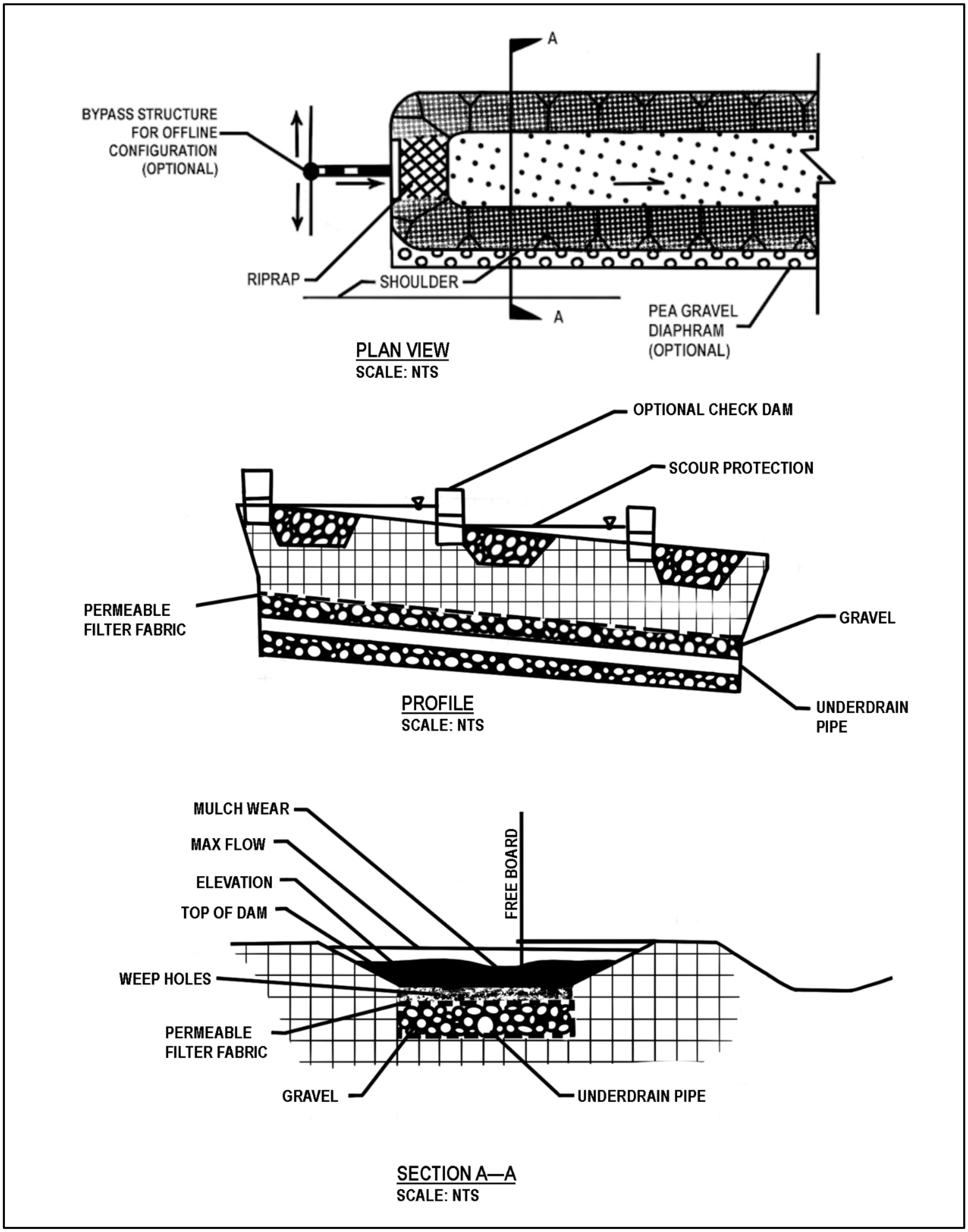
MISCELLANEOUS

- Install bioswales at the time of the year when there is a reasonable chance of successfully establishing grass without irrigation; however, it is recognized that rainfall in a given year may not be sufficient, and temporary irrigation may be used.
- The bioswale area should not serve as a sediment control measure during the construction.

- Bioswales should not be established until the contributing drainage area is stabilized.

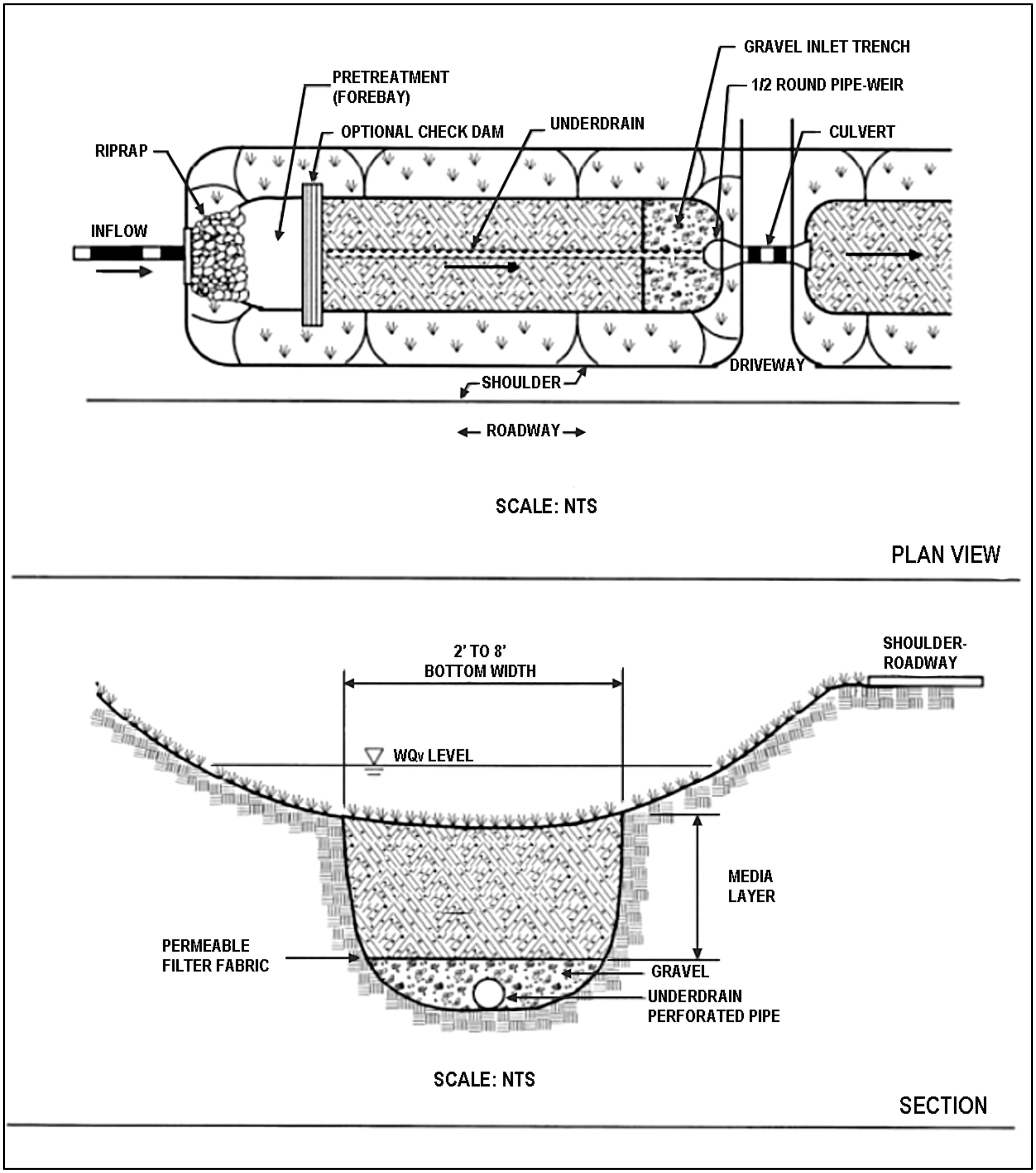
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of a Bioswale

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Bioswale

Source: *2000 Maryland Stormwater Design Manual Volumes I & II* (CWP and MDE, May 2009). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

LC-4: Harvesting/Reuse

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☐Other:

Cistern, Maui
Source: Sea Grant, University of Hawaii

DESCRIPTION

Harvesting/Reuse is the harvesting and temporary storage of roof runoff in rain barrels or cisterns for subsequent non-potable use, including landscape irrigation or vehicle washing. Rain barrels are small containers with capacity ranging from 50 to 100 gal, whereas cisterns are larger containers with capacity of 100 gal and above.

LIMITATIONS

Harvesting/reuse is considered infeasible if any of the following conditions are met.

- A site where harvesting/reuse is determined to be infeasible (refer to the Harvesting/Reuse Infeasibility Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).

DESIGN GUIDELINES

GENERAL

- Local pan evaporation and rainfall data may be used if available.
- Cisterns and rain barrels should have tight-fitting covers to exclude contaminants and animals.
- Cisterns and rain barrels should not allow penetration of sunlight to limit algae growth.
- Direct downspouts and facility storm drains to the cisterns and rain barrels.
- For the cisterns and rain barrels, spigot or hose bibb for drawing water should be at least 2-in from the ground and marked “Caution: Non-potable Water, Do Not Drink.”
- In areas where the cistern or rain barrel needs to be buried partially below the water table, special design features should be employed to keep it from floating. Also, observation risers should be provided.
- Design shall keep reused stormwater piping systems separate from other potable water piping systems. Plumbing materials shall be selected appropriate to the use and meet the requirements of the County code.
- Pipes, cisterns, and rain barrels should be marked “Caution: Non-potable Water, Do Not Drink.”
- A high flow bypass may be necessary for the cisterns and rain barrels. The bypass should be located so that overflow discharges will not impact downstream structures.

PRETREATMENT CONSIDERATIONS

- Pretreatment may be achieved with roof gutter guards or leaf gutter screens for roof runoff. Screens may be used to filter debris.

AREA REQUIREMENTS

- A cistern or rain barrel size can vary greatly depending on the project area, roof size, and irrigation area. The size can be anywhere from less than 1,000 gal to more than 10,000 gal per 1,000 ft^2 of roof area.

MINIMUM DESIGN CRITERIA

One of two equivalent performance standards should be met:

1. Harvesting/reuse PBMPs are designed to capture at least 80% of the average annual (long-term) runoff volume and meet 80% of the overall annual demand.
2. Harvesting/reuse PBMPs are sized to drain the tank in 48 hrs following the end of rainfall. The size of the PBMP is dependent on the demand at the site.

When using the LID Waiver and Infeasibility Screening Worksheet provided in Appendix III or AMS, if it is determined that harvesting/reuse is feasible, then the PBMP should be sized to the estimated 48-hr demand, if feasible.

SIZING GUIDELINES

Step 1: Define the reuse (irrigation) demand by selecting the values for the irrigation area (A_i), pan evaporation coefficient (K_p), landscape coefficient (K_l), and irrigation system efficiency (e). Use specific data if available; if specific data is unavailable, use values of 0.80 for K_p, 0.60 for K_l, and 0.90 for e (refer to sections 4.3.4, 4.3.6.4, and 4.3.6.5).

Step 2: Define the non-irrigation demand (D_o), which may include other non-potable uses.

Step 3: Define the runoff available for reuse by selecting values for the drainage area (i.e., roof area) (A), % of impervious cover (I), and cistern capacity (C_v).

Step 4: Identify the project's nearest reference point and use the corresponding monthly rainfall rates and monthly pan evaporation rates (E_{pan}).

Step 5: Perform a month-to-month analysis, starting with January and ending with December. Set the beginning cistern volume in January to 0.

Step 5a: Calculate the reference evapotranspiration rate for the month (ET_o) using the pan evaporation rate (E_{pan}) and the pan evaporation coefficient (K_p):

$$\mathbf{ET_o = E_{pan} \times K_p}$$

where ET_o = Reference Evapotranspiration Rate for the month (in)
E_{pan} = Pan Evaporation Rate for the month (in) from Step 4
K_p = Pan Evaporation Coefficient from Step 1 (refer to section 4.3.4)

Step 5b: Calculate the actual evapotranspiration rate for the month (ET_a) using the reference evapotranspiration rate (ET_o) and the landscape coefficient (K_l):

$$\mathbf{ET_a = ET_o \times K_l}$$

where ET_a = Actual Evapotranspiration Rate for the month (in)
E_{pan} = Reference Evaporation Rate for the month (in) from Step 5a
K_l = Landscape Coefficient from Step 1 (refer to section 4.3.6.4)

Step 5c: Calculate the total demand for the month (D_t) by multiplying the irrigation area (A_i) by the difference between the actual evapotranspiration rate (ET_a) and the rainfall (r), and adding the non-irrigation demand (D_o):

$$\mathbf{D_t = 7.48 \times A_i \times (ET_a - r)/(12e) + D_o}$$

where D_t = Total Demand for the month (gal)
A_i = Irrigation Area from Step 1 (ft^2)
ET_a = Actual Evapotranspiration Rate from Step 5b
r = Total Rainfall for the month (in) from Step 4
e = Irrigation System Efficiency from Step 1 (refer to section 4.3.6.5)
D_o = Other Non-Irrigation Demand for the month (gal) from Step 2

If the total demand for the month is negative (because the rainfall amount exceeds the evapotranspiration rate), set the total demand to 0.

Step 5d: Calculate the amount of runoff generated for the month by multiplying the drainage area by the rainfall by the volumetric runoff coefficient:

$$\mathbf{R_g = 7.48 \times A \times r \times (0.05 + 0.009 \times I)/12}$$

where R_g = Runoff Generated for the month (gal)
A = Drainage Area from Step 3 (ft^2)
r = Total Rainfall for the month (in) from Step 4
I = Impervious Cover (%) from Step 3

Step 5e: Compare the total demand (D_t) to the cistern capacity (amount of runoff in the cistern) at the beginning of the month (C_b) plus the runoff generated during the month (R). If the monthly demand is greater, set the amount of runoff reused (R_u) to the sum of C_b and R. If the monthly demand is less, set the amount of runoff reused to D_t.

Step 5f. Compare the Cistern capacity (C_v) to the cistern capacity at the beginning of the month (C_b) plus the runoff generated during the month (R_g) minus the amount of runoff used (R_u). Set the amount of runoff in the cistern at the end of the month (C_e) to the lower of the two values.

$$\mathbf{C_e = \min (C_b + R_g - R_u, C_v)}$$

where C_e = Cistern Capacity at the End of the month (gal)
C_b = Cistern Capacity at the Beginning of the month (gal)
R_g = Runoff Generated for the month (gal)
R_u = Runoff Used for the month (gal)
C_v = Cistern Capacity (gal)

Step 5g: Compare the sum of runoff generated during the month (R_g) and the amount in the cistern at the beginning of the month (C_b) to the total demand (D_t). Set the amount of runoff used (R_u) to the lower of the two values.

$$\mathbf{R_u = \min (R_g + C_b, D_t)}$$

where R_u = Runoff Used for the month (gal)
R_g = Runoff Generated for the month (gal)
C_b = Amount of Runoff in Cistern at the beginning of the month (gal)
D_t = Total Demand for the month (gal)

Step 5h: Calculate the amount of cistern overflow by the following:

$$\mathbf{O = C_b + R_g - D_t - C_e}$$

where O = Total Cistern Overflow for the month (gal)
C_b = Cistern Capacity at the Beginning of the month (gal)
R_g = Runoff Generated for the month (gal)
D_t = Total Demand for the month (gal)
C_e = Cistern Capacity at the End of the month (gal)

If the overflow is negative (because the amount of runoff in the cistern at the end of the month is less than the cistern capacity), set the overflow to 0.

Step 5i: Calculate the amount of runoff captured in the cistern by subtracting the overflow from the amount of runoff generated:

$$\mathbf{R_c = R_g - O}$$

where Rc = Runoff Capture in the cistern for the month (gal)
R_g = Runoff Generated for the month (gal)
O = Total Cistern Overflow for the month (gal)

Step 5j: Set the beginning cistern amount for the next month equal to the ending cistern amount for the current month. Repeat Steps 5 through 13 for each subsequent month. Continue to Step 5 after Steps 4a through 4i have been performed for all 12 months.

Step 6: Calculate the overall runoff capture efficiency by dividing the cumulative runoff captured by the cumulative runoff generated:

$$\mathbf{E_c = 100 \times \sum_{n=1}^{12} Rc \;/\; \sum_{n=1}^{12} Rg}$$

where Ec = Overall Runoff Capture Efficiency (%)
R_c = Runoff Capture from each month (gal)
R_g = Runoff Generated from each month (gal)

If the calculated efficiency is below the minimum design criteria value, revise one or more of the following parameters and return to Step 1: drainage area (A), cistern size (C), irrigation area (A_i), and other non-irrigation demand (D_o).

Step 7: Calculate the overall demand met efficiency by dividing the cumulative runoff used by the cumulative demand:

$$\mathbf{E_d = 100 \times \sum_{n=1}^{12} Ru \;/\; \sum_{n=1}^{12} Dt}$$

where Ed = Overall Demand Met Efficiency (%)
R_u = Runoff Used from each month (gal)
D_t = Total Demand from each month (gal)

If the calculated efficiency is below the minimum design criteria value, revise one or more of the following parameters and return to Step 1: drainage area (A), cistern size (C), irrigation area (A_i), and other non-irrigation demand (D_o).

Step 8: Calculate the WQV credit:

$$\mathbf{WQV = PCA /12}$$

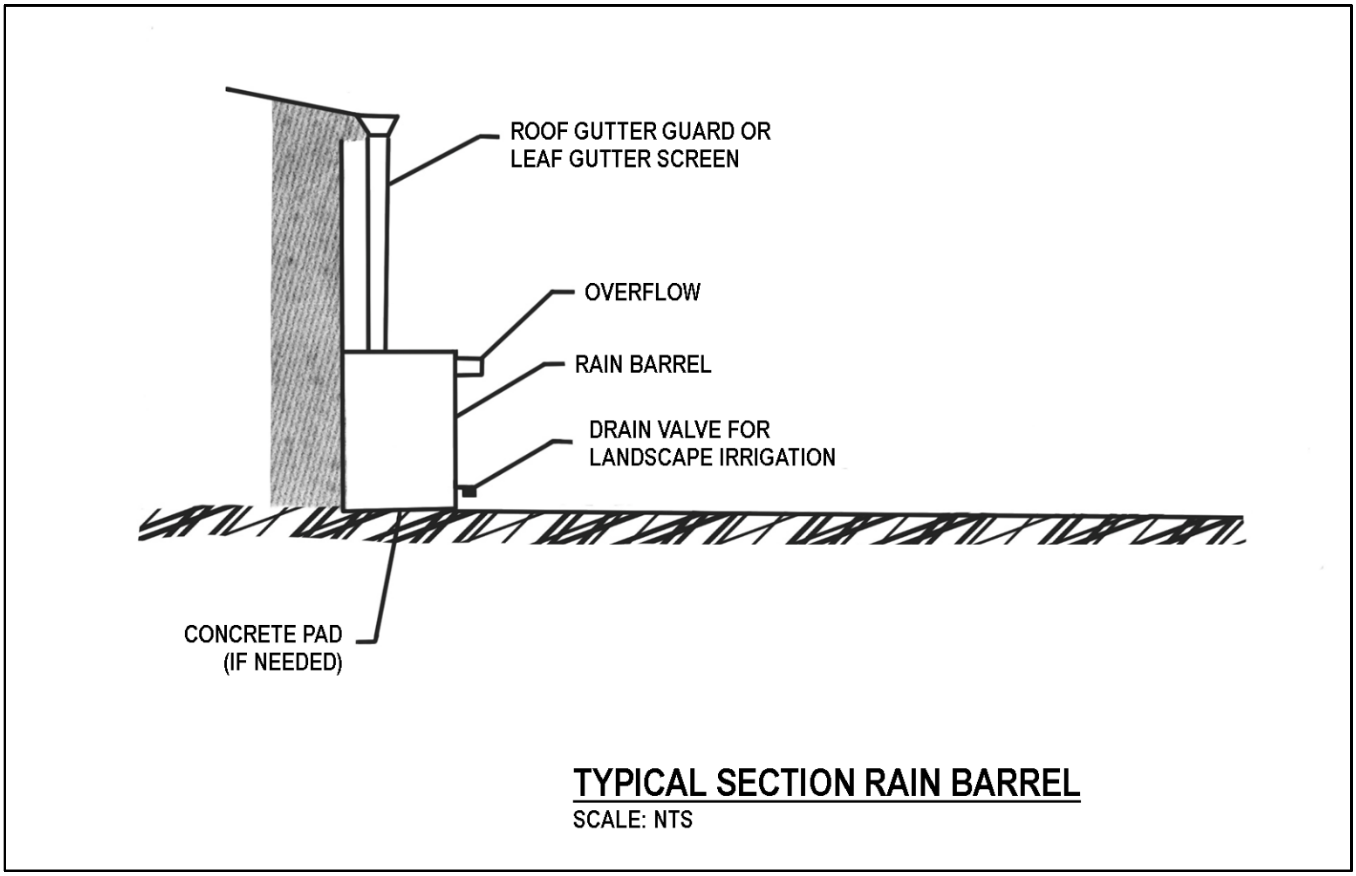
where WQV = Water Quality Volume (ft^3)
P = Design Storm Runoff Depth (in) (refer to section 4.3.1)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ft^2)

CONSTRUCTION CONSIDERATIONS

- Do not connect the piping to a potable water system.
- Prior to collecting the stormwater runoff from a roof, the roof should be cleaned.
- Refer to manufacturer guidelines if using manufactured systems.

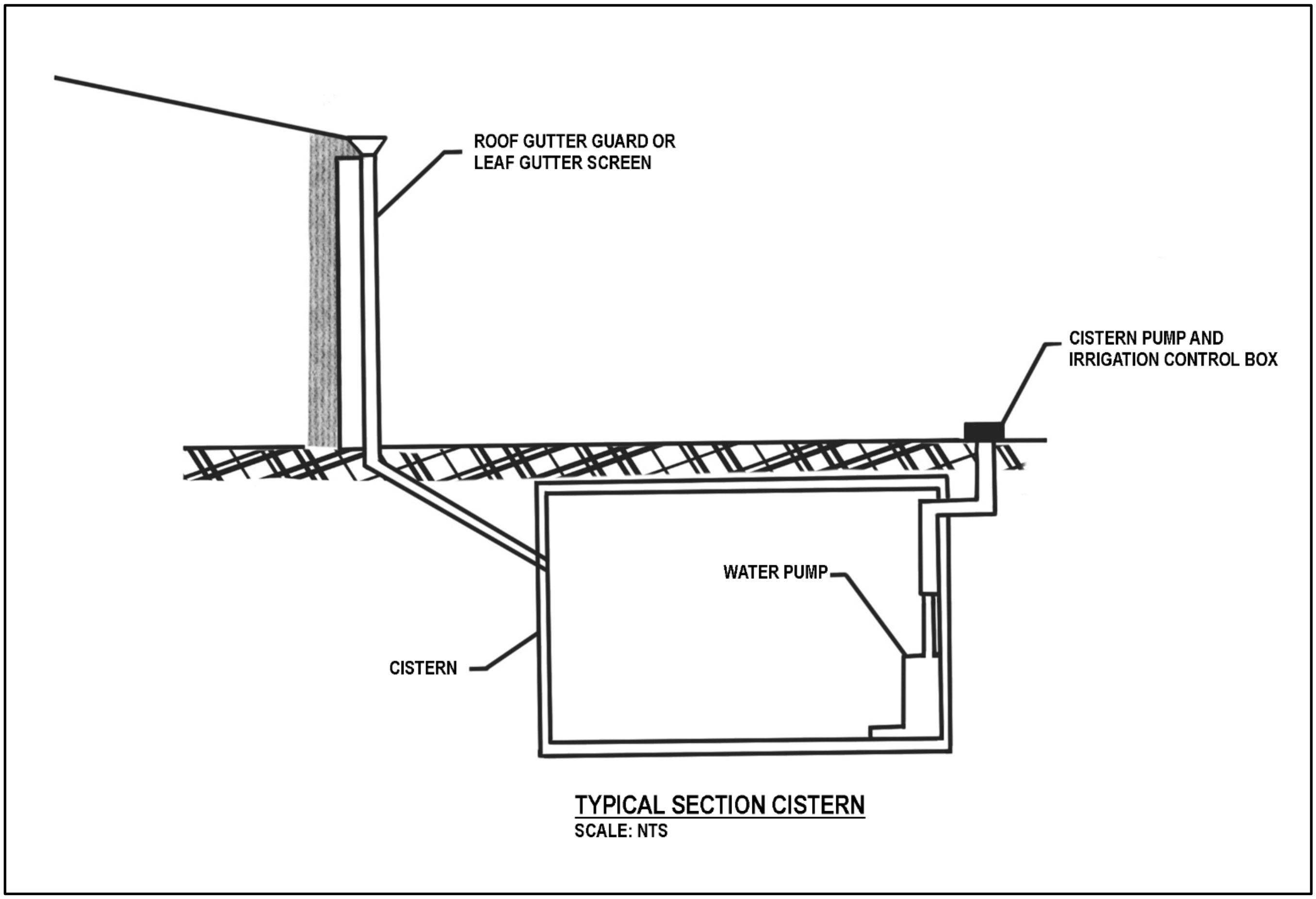
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of a Harvesting/Reuse System

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Harvesting/Reuse System

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

LC-5: Dry Well/Drainage Well

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☐Other:

Dry Well, Daniel K. Inouye International Airport

DESCRIPTION

A dry well/drainage well is a subsurface aggregate-filled or prefabricated perforated storage facility, where stormwater or roof runoff is stored and infiltrates into the soil matrix.

A dry well/drainage well is constructed by excavating a pit in the ground and filling it with aggregate. A connection from the stormwater or roof downspout conveys water into the dry well/drainage well, allowing it to be stored in the voids. To minimize sedimentation from lateral soil movement, the sides and top of the stone matrix can be wrapped in permeable filter fabric, though the bottom should remain open.

According to the State and Federal UIC Program regulations, a dry well/drainage well can be considered a Class V stormwater drainage well if it meets the definition of a well and an injection well (i.e., deeper than wide). Dry wells/drainage wells that fall under the Class V injection well category shall apply for a UIC permit (refer to Federal UIC regulations, *40 CFR § 144* and State of Hawaii UIC regulations, *HAR § 11-23*).

All UIC permitted stormwater drainage wells will be considered PBMPs to satisfy the Post-Construction Program requirements but will be inspected and maintained under the UIC or Post-Construction Program, whichever is more stringent.

LIMITATIONS

Dry wells/drainage wells are considered infeasible if any of the following conditions are met.

- A site where infiltration is determined to be infeasible (refer to the Infiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).
- A site with slopes greater than 20%.
- Removal of mature trees for the construction of a dry well/drainage well may be infeasible and requires additional review and approval by DOTA on a case-by-case basis.
- The depth of the dry well/drainage well is less than 2 ft.

DESIGN GUIDELINES

GENERAL

- Dry wells/drainage wells should be designed for small drainage areas with low pollutant loading, such as rooftops.
- The bottom of the dry well/drainage well should remain open to maximize infiltration.
- The dry well/drainage well should be backfilled with double-washed locally available rock with a diameter range of 1-in to 3-in.
- The dry well/drainage well may be subject to applicable federal and state UIC regulations; refer to Federal UIC regulations, *40 CFR § 144* and State of Hawaii UIC regulations, *HAR § 11-23*.

PRETREATMENT CONSIDERATIONS

- Dry wells/drainage wells are susceptible to clogging from sediment, leaves, and other organic material.
- Pretreatment may be achieved with roof gutter guards or leaf gutter screens for roof runoff. If the dry well/drainage well receives non-roof runoff, pretreatment should be provided using vegetated swales, vegetated buffer strips, mesh screens, or manufactured treatment devices.
- The dry well/drainage well design may also include an intermediate box with an outflow higher to allow sediment to settle. Water would then flow through a mesh screen and into the dry well/drainage well.

AREA REQUIREMENTS

- A dry well/drainage well requires a footprint equivalent to 2% - 20% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects the maximum allowable infiltration rate and minimum allowable factor of safety, while the upper value reflects the minimum allowable infiltration rate and maximum allowable factor of safety and no ponding.

MINIMUM DESIGN CRITERIA

Design Parameter	**Units**	**Value**
Drawdown (drain) Time	hrs	48 or less
Minimum Depth from basin invert to groundwater table	ft	3
Minimum Soil Infiltration Rate	in/hr	0.50
Aggregate Size	in	1 – 3

SIZING GUIDELINES

Step 1: Use the procedure presented below to compute the volumetric runoff coefficient and WQV.

The volumetric runoff coefficient should be calculated using the following equation:

$$\mathbf{C = 0.05 + 0.009I}$$

where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

The WQV is calculated using the following equation:

$$\mathbf{WQV = PCA \times 3630}$$

where WQV = Water Quality Design Volume (ft^3)
P = Design Storm Runoff Depth (in) (refer to section 4.3.1)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ac)

Step 2: Calculate the maximum water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$$\mathbf{d_{max} = kt/(F_s \times 12)}$$

where d_{max} = Maximum Storage Depth (ft)
k = Soil Infiltration Rate (in/hr)
t = Drawdown (drain) Time (hrs) (refer to section 4.3.6.1)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

Step 3: Select a ponding depth and dry well/drainage well backfill material depth (l_{bf}) such that the total effective storage depth is no greater than the maximum storage depth (d_{max}) calculated in Step 2:

$$\mathbf{d_t = d_p + l_{bf}n_{bf} \leq d_{max}}$$

where d_t = Total Effective Water Storage Depth (ft)
d_p = Ponding Depth (ft)
l_{bf} = Backfill Material Depth (ft)
n_{bf} = Backfill Material Porosity (refer to section 4.3.6.3)
d_{max} = Maximum Storage Depth from Step 2 (ft)

Step 4: Calculate the PBMP surface area (**A_{PBMP}**):

$$\mathbf{A_{PBMP} = WQV/(d_t + kT/12F_s)}$$

where A_{PBMP} = PBMP Surface Area (ft^2)
WQV = WQV from Step 1 (ft^3)
d_t = Total Effective Water Storage Depth from Step 3 (ft)
k = Soil Infiltration Rate (in/hr)
T = Fill Time (time for the PBMP to fill with water [hrs]) (refer to section 4.3.6.6)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

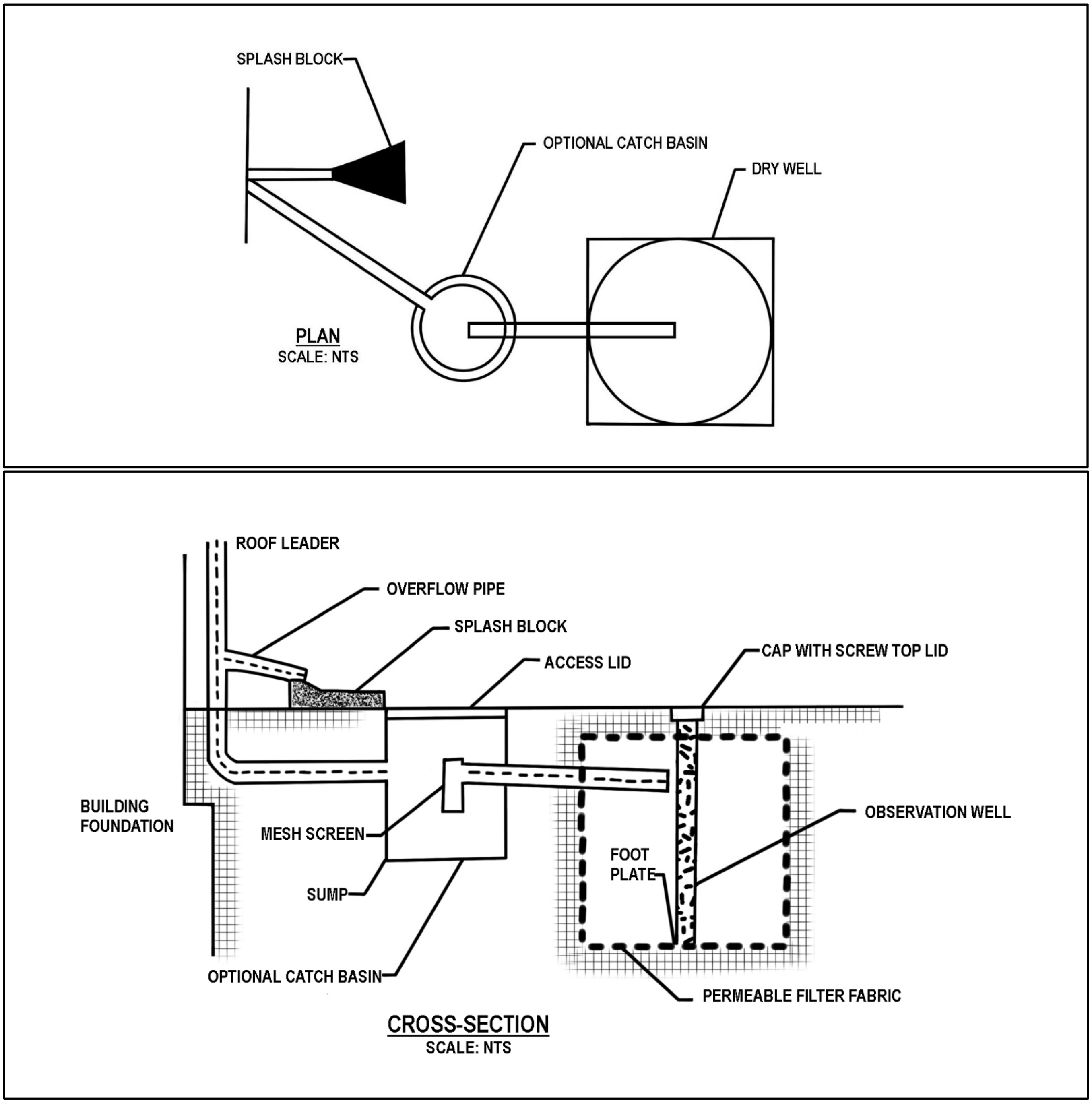
If the calculated area does not fit in the available space, either reduce the drainage area, increase the ponding depth, or backfill material depth (if the total effective depth is not already equal to the maximum depth) and repeat the calculations. If this does not work and the calculated area does not fit in the available space, reduce the infiltration rate factor of safety (if the minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

CONSTRUCTION CONSIDERATIONS

- Dry well/drainage well should be excavated in soil matrix, uncompacted by heavy equipment.
- Refer to manufacturer guidelines if using any manufactured treatment devices.
- Trees and other large vegetation should be planted away from dry wells/drainage wells such that roots may not penetrate the dry well/drainage well and the drip lines do not overhang the dry wells.
- Access should be provided for dry well/drainage well maintenance via a secured manhole or cleanout.
- A General Application for a UIC Permit to Operate should be submitted to DOH-SDWB at least 6 months before the anticipated date of UIC well construction.

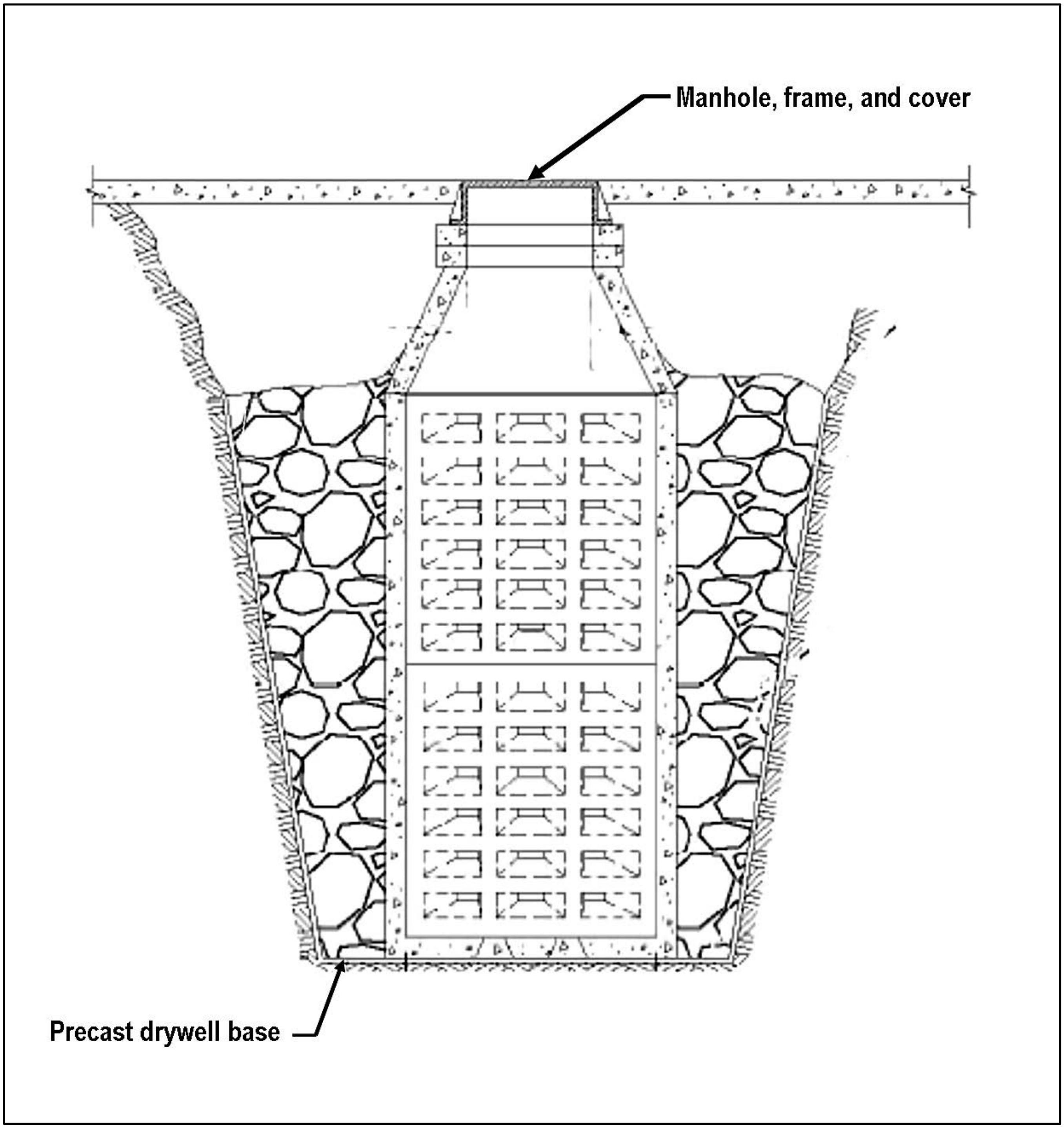
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of a Dry Well/Drainage Well

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Dry Well/Drainage Well
Source: *Stormwater Management Manual for Western Washington* (State of Washington, Department of Ecology, 2019). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

LC-6: Infiltration Basin

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☐Other:

Infiltration Basin, Kahului Airport

DESCRIPTION

An infiltration basin is a shallow impoundment over permeable soils, where stormwater runoff is stored and infiltrates through the basin bottom and into the soil matrix.

LIMITATIONS

Infiltration basins are considered infeasible if any of the following conditions are met.

- A site where infiltration is determined to be infeasible (refer to the Infiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).
- Unstable surrounding soil stratum and soils with clay content greater than 25%.
- A site with slopes greater than 20%.

DESIGN GUIDELINES

GENERAL

- The bottom of the infiltration basin should be graded as flat as possible to provide uniform ponding and infiltration across the basin bottom.
- A 6-in layer of sand may be placed on the bottom of an infiltration basin to sustain the design permeability rate over time.
- Infiltration basins should have side slopes equal to or less than 3:1 (length per unit height) to provide bank stability and allow for mowing.
- The infiltration basin should be designed with an outlet structure to convey peak flows exceeding the design capacity and an overflow spillway to convey peak flows that exceed the combined infiltration capacity and outlet structure capacity of the basin.
- Overflow for the 10-yr storm event should be directed to an outlet point with energy dissipators designed to prevent erosion from the 10-yr storm velocity.
- If the embankment falls under the jurisdiction of the State of Hawaii, Department of Land and Natural Resources (DLNR), Engineering Division, Dam Safety Program, it shall be designed to meet the applicable requirements.
- A flow regulator may be provided to divert runoff from large drainage areas if needed.
- Observation wells are recommended. The observation wells indicate how quickly the infiltration basin dewaters following a storm event and provide an insight into whether the infiltration basin is functioning as intended (i.e., clogged with sediment, etc.).
- DOTA prefers infiltration basins without underdrains; however, underdrains can be used if the site conditions warrant the use. If using an underdrain, the infiltration basins should have a minimum 6-in perforated underdrain pipe in a gravel layer.
- Permeable filter fabric should be placed between the infiltration basin media and the gravel layer.
- A cleanout pipe should be tied into the end of all underdrain pipe runs.
- Consider including vehicle access to the infiltration basin invert for maintenance.
- Landscaping could be critical to the function and performance of the infiltration basin. Establishing vegetation on the basin side slopes and floor can provide a natural means of maintaining relatively high infiltration rates.
- Vegetation in or around infiltration basins that provide food (seeds) or habitat for wildlife that could be hazardous to airport operations should be eliminated.
- Landscaping design should specify proper grass species based on site-specific soils and hydric conditions present along the channel. Vegetation should be designed like a typical lawn for regular mowing.
- Irrigation may be required to maintain the vegetation during dry periods.

PRETREATMENT CONSIDERATIONS

- Infiltration basins are susceptible to clogging and premature failure from sediment, trash, and other contaminants. Suitable pretreatment systems maintain the infiltrate rate of the device without frequent and intensive maintenance.
    - For soil infiltration rates below 3 in/hr, pretreatment is strongly recommended, and the pretreatment device should be sized for at least 25% of the WQV.
    - For soil infiltration rates greater than 3 in/hr, pretreatment is mandatory to minimize groundwater contamination risks. The pretreatment device should be sized for at least 50%

of the WQV if the soil infiltration rate is below 5 in/hr and 100% of the WQV if the soil infiltration rate is above 5 in/hr.

- Pretreatment may be achieved with vegetated swales, vegetated buffer strips, sedimentation basins, forebays, or manufactured treatment devices.
- Forebays should be used only in locations where standing water is not considered a safety concern. The forebay should be lined such that water will not flow into the underdrain without first flowing through the infiltration basin. Lining material should allow for the removal of sediment and debris with a shovel or vac truck.

AREA REQUIREMENTS

- An infiltration basin requires a footprint equivalent to 7% - 20% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects the maximum allowable infiltration rate and minimum allowable factor of safety, while the upper value reflects the minimum allowable infiltration rate and maximum allowable factor of safety.

MINIMUM DESIGN CRITERIA

Design Parameter	**Units**	**Value**
Invert Slope	%	0
Maximum Interior Side Slope (length per unit height)	ft/ft	3:1
Drawdown (drain) Time	hrs	48 or less
Minimum Soil Infiltration Rate	in/hr	0.50
Minimum Freeboard Above Overflow Device	ft	1
Minimum Depth from Basin Invert to Groundwater Table	ft	3

SIZING GUIDELINES

Step 1: Use the procedure below to compute the volumetric runoff coefficient and WQV.

The volumetric runoff coefficient should be calculated using the following equation:

$$\mathbf{C = 0.05 + 0.009I}$$

where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

The WQV is calculated using the following equation:

$$\mathbf{WQV = PCA \times 3630}$$

where WQV = Water Quality Design Volume (ft^3)
P = Design Storm Runoff Depth (in) (refer to section 4.3.1)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ac)

Step 2: Calculate the maximum allowable water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$$\mathbf{d_{max} = kt / (F_s \times 12)}$$

where d_{max} = Maximum Storage Depth (ft)
k = Soil Infiltration Rate (in/hr)
t = Drawdown (drain) Time (hrs) (refer to section 4.3.6.1)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

Step 3: Select a design ponding depth no greater than the maximum allowable depth calculated in Step 2:

$$\mathbf{d_p \leq d_{max}}$$

where d_p = Design Ponding Depth (ft)
d_{max} = Maximum Storage Depth (ft) from Step 2

Step 4: Calculate the infiltration basin bottom surface area (A_b):

$$\mathbf{A_b = WQV / (d_p + (kT / 12F_s))}$$

where A_b = Bottom Surface Area (ft^2)
WQV = WQV from Step 1 (ft^3)
d_p = Design Ponding Depth (ft) from Step 3
k = Soil Infiltration Rate (in/hr)
T = Fill Time (time for the PBMP to fill with water [hrs]) (refer to section 4.3.6.6)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

Step 5: Select an infiltration basin bottom width (w_b), and calculate the basin bottom length (l_b) using the surface area (A_b) calculated from Step 4:

$$\mathbf{l_b = A_b / w_b}$$

where l_b = Bottom Length (ft)
A_b = Bottom Surface Area (ft^2) from Step 4
w_b = Bottom Width (ft)

Step 6: Calculate the total area occupied by the PBMP excluding pretreatment (A_{PBMP}) using the infiltration basin bottom dimensions, embankment side slopes, and freeboard:

$$\mathbf{A_{PBMP} = [w_b + 2z\,(d_p + f)] \times [l_b + 2z\,(d_p + f)]}$$

where A_{PBMP} = Area Occupied by PBMP Excluding Pretreatment (ft^2)
w_b = Bottom Width (ft) from Step 5
z = Basin Interior Side Slope (length per unit height)
d_p = Design Ponding Depth (ft) from Step 3
f = Freeboard (ft)
l_b = Bottom Length (ft) from Step 5

If the calculated area does not fit in the available space, reduce the drainage area, increase the ponding depth (if it is not already set to the maximum depth), or reduce the infiltration rate factor of safety (if the minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

CONSTRUCTION CONSIDERATIONS

COMPACTION

- It is vital to minimize compaction of both the base of the infiltration basin and the required backfill. When possible, use excavation hoes to remove the original soil. If infiltration basins are excavated using a loader, the contractor should use wide track or marsh track equipment or light equipment with turf-type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high-pressure tires is unacceptable as it may cause excessive compaction resulting in reduced infiltration rates. Compaction could significantly contribute to design failure.
- Compaction can be minimized at the base of the infiltration basin using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12-in compaction zone.
- Do not use heavy equipment within the infiltration basin. Heavy equipment can be used around the perimeter of the infiltration basin to supply media materials. Grade infiltration basin materials with light equipment such as a compact loader or a dozer/loader with marsh tracks.

UNDERDRAINS

- Underdrains are to be placed on a 3 ft wide section of the permeable filter fabric. The pipe is placed next, followed by the gravel bedding. The ends of underdrain pipes not terminating in an observation well should be capped.
- The main collector pipe for underdrain systems should be constructed at a minimum slope of 0.50%. Observation wells or cleanout pipes should be provided (1 minimum per every 1,000 ft^2 of surface area).

GRASSING

- Include directions in the specifications for using the appropriate fertilizer and soil amendments based on soil properties determined through testing and compared to the needs of the grassing requirements.
- Grassing should be done as soon as possible after the area has been graded.
- If sod tiles are used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the bioswale.
- Use a roller on the sod to verify no air pockets form between the sod and the soil.
- Per FAA Regulations, seeds are not to be scattered or applied through hydroseeding.

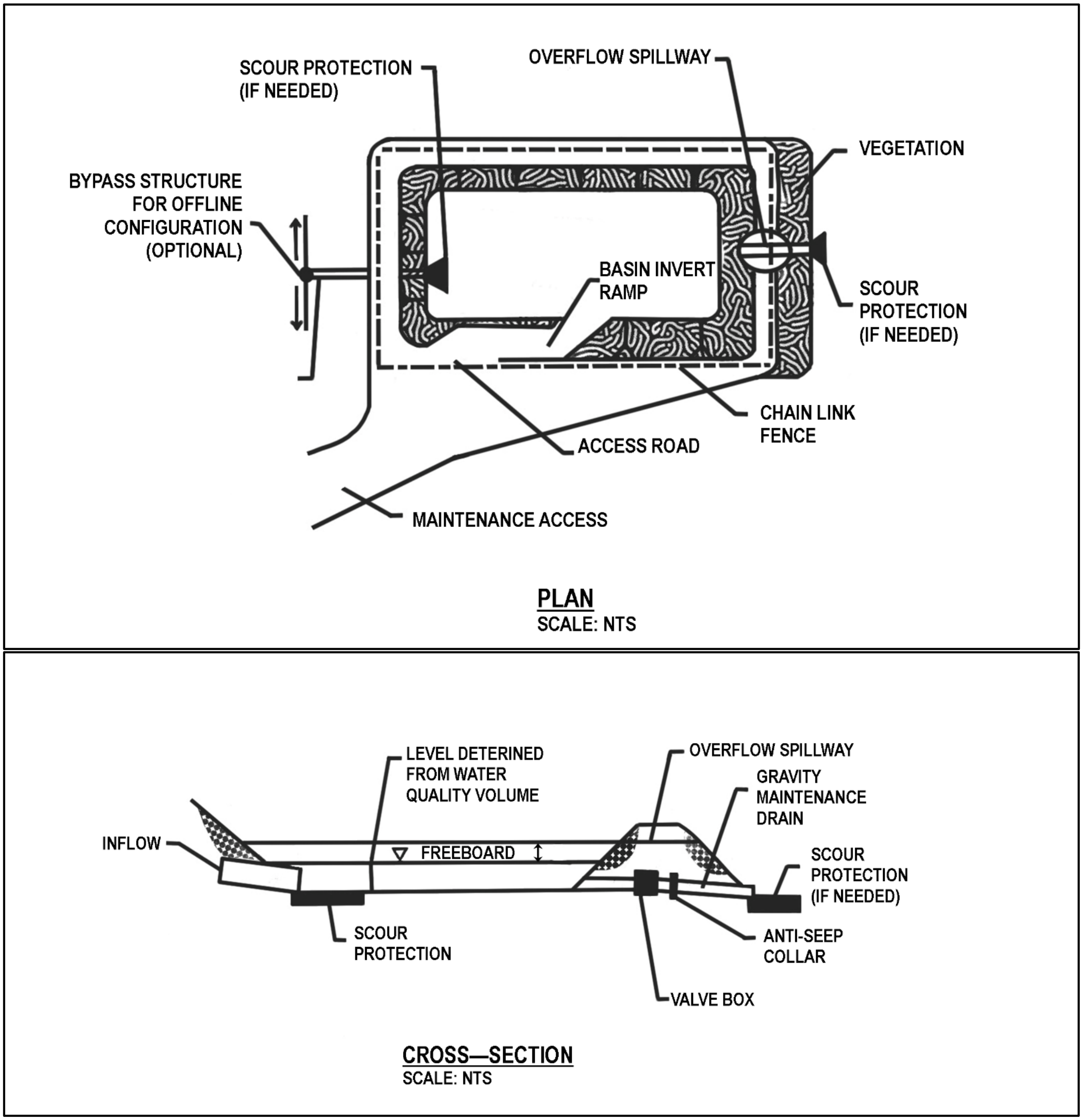
MISCELLANEOUS

- Care should be exercised to prevent natural or fill soils from intermixing with the stone aggregate.
- Install infiltration basins at the time of the year when there is a reasonable chance of successfully establishing vegetation without irrigation; however, it is recognized that rainfall in a given year may not be sufficient and temporary irrigation may be used.
- The infiltration basin area should not serve as a sediment control measure during construction.

- Place excavated material such that it cannot be washed back into the basin if a storm occurs during the construction of the basin.
- Vertically excavated walls may be difficult to maintain in areas where soil moisture is high or where soft cohesive or cohesionless soils are dominant. These conditions may require laying back the side slopes to maintain stability.
- Infiltration basins should not be established until the contributing drainage area is stabilized.

EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of an Infiltration Basin with no underdrain

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

LC-7: Infiltration Trench

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☐Other:

Infiltration Trench, Kauai
Source:HDOT Harbors Division, Kauai Federal Credit Union

DESCRIPTION

An infiltration trench is a long, narrow rock-filled trench with no outlet, where stormwater runoff is stored in the void space between the rocks and infiltrates through the trench bottom and into the soil matrix.

According to State and Federal UIC Program regulations, an infiltration trench can be considered a Class V stormwater drainage well if it meets the definition of a well and an injection well (i.e., deeper than wide). Infiltration trenches that fall under the Class V injection well category shall apply for a UIC permit (refer to Federal UIC regulations, *40 CFR § 144* and State of Hawaii UIC regulations, *HAR § 11-23*).

All UIC permitted infiltration trenches will be considered PBMPs to satisfy any Post-Construction Program requirements but will be inspected and maintained under the UIC or Post-Construction Program, whichever is more stringent.

LIMITATIONS

Infiltration trenches are considered infeasible if any of the following conditions are met.

- A site where infiltration is determined to be infeasible (refer to the Infiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).
- Unstable surrounding soil stratum and soils with clay content greater than 25%.
- A site with slopes greater than 20%.

DESIGN GUIDELINES

GENERAL

- Infiltration trenches should be between 2 - 8 ft deep and 2 – 25 ft wide.
- The infiltration trench should include a minimum of 2 ft trench rock or alternative backfill layer; it may include an optional sand layer at the bottom and an optional filter media layer at the top.
- A 6-in layer of sand may be placed on the bottom of an infiltration trench to sustain the design permeability rate over time.
- A 2-in layer of pea gravel or alternative filter material layer may be placed on the surface of an infiltration trench; this optional layer can help prevent clogging of the trench rock or alternative backfill layer.
- Permeable filter fabric should be placed between the trench rock or alternative backfill layer and the sand layer.
- The bottom of the infiltration trench should be graded as flat as possible to provide uniform ponding and infiltration across the trench bottom.
- The sides of infiltration trench should be lined with a permeable filter fabric that prevents soil piping but has greater permeability than the parent soil.
- The infiltration trench should be designed with an outlet structure to convey peak flows exceeding the design capacity and a bypass to convey peak flows that exceed the trench's combined infiltration capacity and outlet structure capacity.
- The outlet should include energy dissipators designed to prevent erosion from the 10-yr storm velocity.
- A flow regulator may be provided to divert runoff from large drainage areas if needed.
- Observation wells are recommended at 50 ft intervals over the length of the infiltration trench. The observation wells indicate how quickly the infiltration trench dewaters following a storm event and provide an insight into whether the infiltration trench is functioning as intended (i.e., clogged with sediment, etc.).
- DOTA prefers infiltration trenches without underdrains; however, underdrains can be used if the site conditions warrant the use. If using an underdrain, the infiltration trenches should have a minimum of 6-in perforated underdrain pipe in a gravel layer.
- A cleanout pipe should be tied into the end of all underdrain pipe runs.
- Consider including vehicle access to the infiltration trench invert for maintenance.
- An infiltration trench may be subject to applicable federal and state UIC regulations; refer to Federal UIC regulations, *40 CFR § 144* and State of Hawaii UIC regulations, *HAR § 11-23*.

PRETREATMENT CONSIDERATIONS

- Infiltration trenches are susceptible to clogging and premature failure from sediment, trash, and other contaminants. Suitable pretreatment systems maintain the infiltration rate of the device without frequent and intensive maintenance.
  - For soil infiltration rates below 3 in/hr, pretreatment is strongly recommended, and the pretreatment device should be sized for at least 25% of the WQV.
  - For soil infiltration rates greater than 3 in/hr, pretreatment is mandatory to minimize groundwater contamination risks. The pretreatment device should be sized for at least 50% of the WQV if the soil infiltration rate is below 5 in/hr and 100% of the WQV if the soil infiltration rate is above 5 in/hr.
- Pretreatment may be achieved with vegetated swales, vegetated buffer strips, sedimentation basins, forebays, or manufactured treatment devices.
- Forebays should be used only in locations where standing water is not considered a safety concern. The forebay should be lined such that water will not flow into the underdrain without first flowing through the infiltration trench. Lining material should allow for the removal of sediment and debris with a shovel or vac truck.

AREA REQUIREMENTS

- An infiltration trench requires a footprint equivalent to 2% - 20% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects the maximum allowable infiltration rate, the minimum allowable factor of safety, and minimal ponding, while the upper value reflects the minimum allowable infiltration rate, the maximum allowable factor of safety, and no ponding.

MINIMUM DESIGN CRITERIA

Design Parameter	**Units**	**Value**
Trench Depth	ft	2 - 8
Trench Width	ft	2 - 25
Maximum Top Backfill Layer Thickness	in	6
Maximum Bottom Sand Layer Thickness	in	12
Drawdown (drain) Time	hrs	48 or less
Minimum Soil Infiltration Rate	in/hr	0.50
Trench Rock Size	in	1.50 – 3
Minimum Depth from Trench Invert to Groundwater Table	ft	3

SIZING GUIDELINES

Step 1: Use the procedure below to compute the volumetric runoff coefficient and WQV.

The volumetric runoff coefficient should be calculated using the following equation:

$$\mathbf{C = 0.05 + 0.009I}$$

where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

The WQV is calculated using the following equation:

$WQV = PCA \times 3630$

where WQV = Water Quality Design Volume (ft^3)
P = Design Storm Runoff Depth (in) (refer to section 4.3.1)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ac)

Step 2: Calculate the maximum allowable water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$d_{max} = kt / (F_s \times 12)$

where d_{max} = Maximum Storage Depth (ft)
k = Soil Infiltration Rate (in/hr)
t = Drawdown (drain) Time (hrs) (refer to section 4.3.6.1)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

Step 3: Select a design ponding depth (d_p) (optional), trench rock or alternative backfill layer depth (l_{bf}), and sand layer depth (l_s) (optional) such that the total effective storage depth (d_t) is no greater than the maximum allowable depth (d_{max}) calculated in Step 2:

$d_t = d_p + l_{bf}n_{bf} + l_s n_s \leq d_{max}$

where d_t = Total Effective Water Storage Depth (ft)
d_p = Ponding Depth (ft)
l_{bf} = Backfill Layer Depth (ft)
n_{bf} = Backfill Material Porosity (refer to section 4.3.6.3)
l_s = Sand Layer Depth (ft)
n_s = Sand Porosity (refer to section 4.3.6.3)
d_{max} = Maximum Storage Depth (ft) from Step 2

Step 4: Calculate the infiltration trench surface area (A_{PBMP}):

$A_{PBMP} = WQV / (d_t + (kT / 12F_s))$

where A_{PBMP} = Surface Area excluding Pretreatment (ft^2)
WQV = WQV from Step 1 (ft^3)
d_t = Total Effective Water Storage Depth (ft) from Step 3
k = Soil Infiltration Rate (in/hr)
T = Fill Time (time for the PBMP to fill with water [hrs]) (refer to section 4.3.6.6)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

If the calculated area does not fit in the available space, reduce the drainage area or increase the ponding depth or trench backfill layer depth or sand layer depth (if the total effective water storage depth is not already set to the maximum depth), and repeat the calculations. If this does not work and the calculated area does not fit in the available space, reduce the infiltration rate factor of safety (if the minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

CONSTRUCTION CONSIDERATIONS

COMPACTION

- It is vital to minimize compaction of both the base of the infiltration trench and the required backfill. When possible, use excavation hoes to remove the original soil. If infiltration trenches are excavated using a loader, the contractor should use wide track or marsh track equipment or light equipment with turf-type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high-pressure tires is unacceptable as it may cause excessive compaction resulting in reduced infiltration rates. Compaction could significantly contribute to design failure.
- Compaction can be minimized at the base of the infiltration trench using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12-in compaction zone.
- Do not use heavy equipment within the infiltration trench. Heavy equipment can be used around the perimeter of the infiltration trench to supply media materials. Grade infiltration trench backfill with light equipment such as a compact loader or a dozer/loader with marsh tracks.

UNDERDRAINS

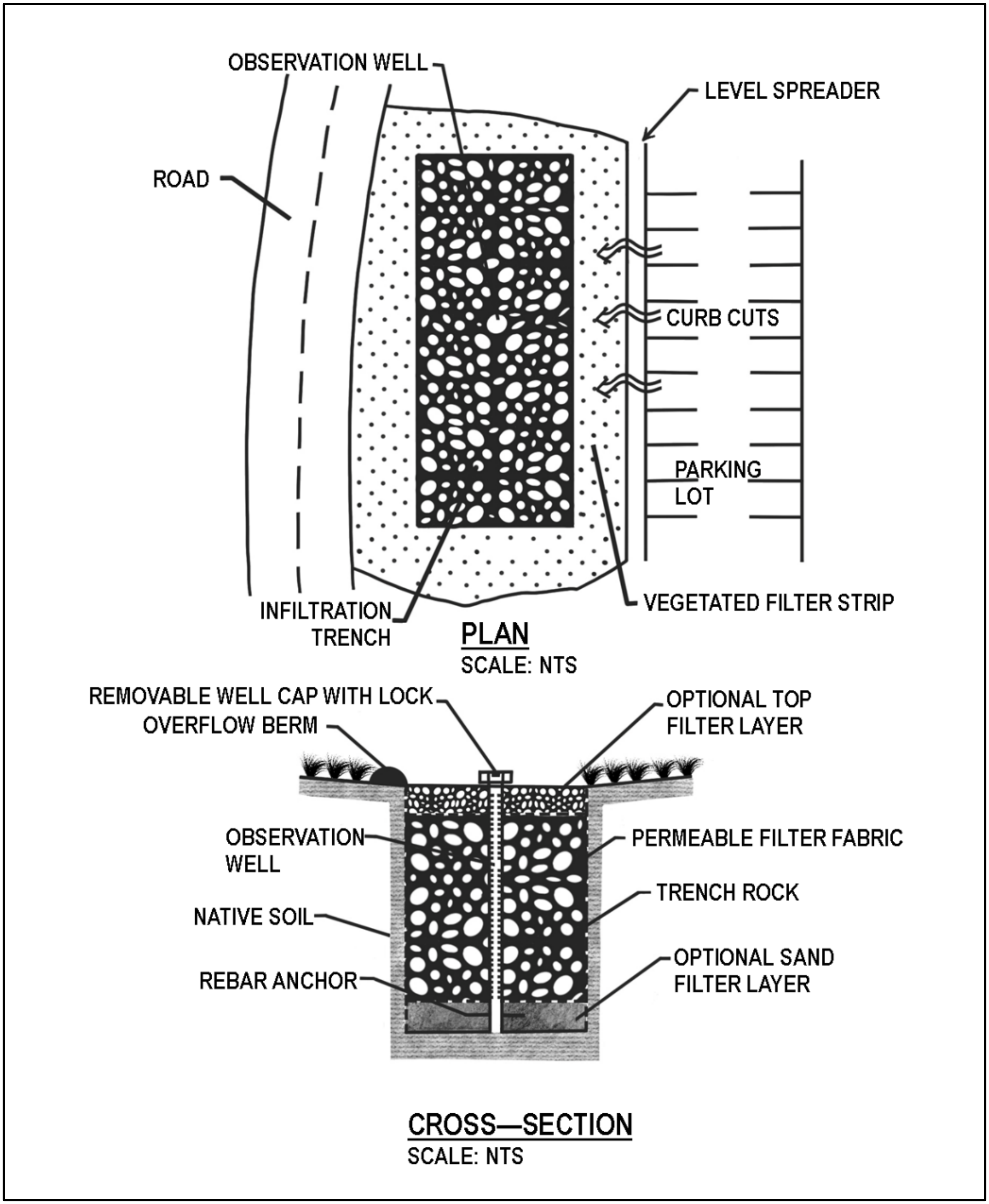
- Underdrains are to be placed on a 3 ft wide section of filter cloth. The pipe is placed next, followed by the gravel bedding. The ends of underdrain pipes not terminating in an observation well should be capped.
- The main collector pipe for underdrain systems should be constructed at a minimum slope of 0.50%. Observation wells or cleanout pipes should be provided (at 50 ft intervals).

MISCELLANEOUS

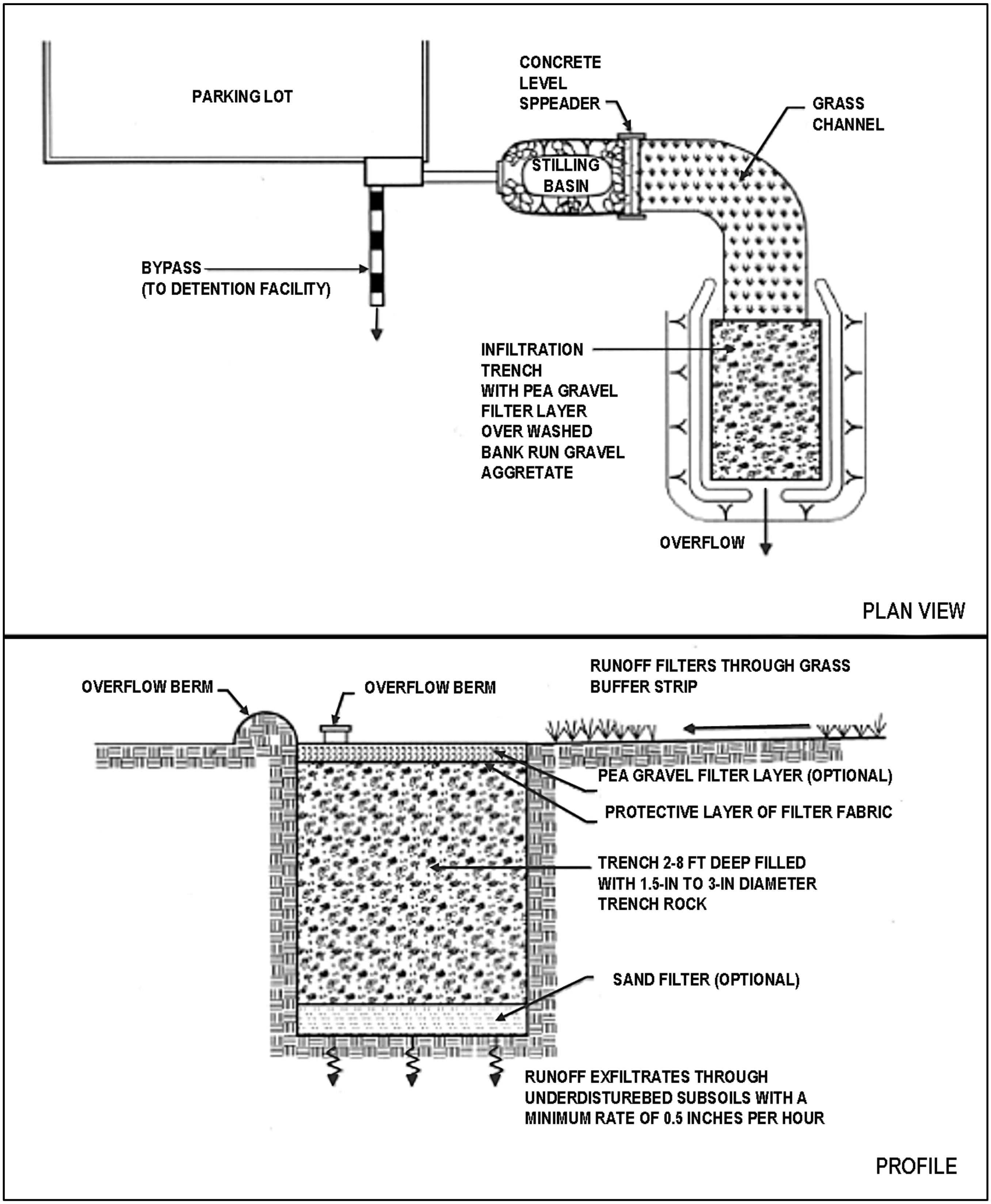
- Care should be exercised to prevent natural or fill soils from intermixing with the trench rock.
- The infiltration trench area should not serve as a sediment control measure during the construction.
- Place excavated material such that it cannot be washed back into the trench if a storm occurs during the construction of the trench.
- Place the trench rock or alternative backfill layer in a maximum loose lift thickness of 12-in.
- The trench rock should be washed prior to placement.
- Vertically excavated walls may be difficult to maintain in areas where soil moisture is high or where soft cohesive or cohesionless soils are dominant. These conditions may require laying back of the side slopes to maintain stability.
- Infiltration trenches should not be established until the contributing drainage area is stabilized.
- A General Application for a UIC Permit to Operate should be submitted to DOH-SDWB at least 6 months before the anticipated date of UIC well construction.

EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of an Infiltration Trench
Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of an Infiltration Trench

Source: *2000 Maryland Stormwater Design Manual Volumes I & II* (CWP and MDE, May 2009). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

LC-8 Permeable Pavement

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☐Other:

Elliott Street Parking Lot Permeable Pavement, Daniel K. Inouye International Airport

DESCRIPTION

Permeable pavement, sometimes referred to as pervious pavement or porous pavement, is a porous, load-bearing surface that allows for the temporary storage of runoff in an underlying aggregate reservoir layer until it infiltrates into the soil matrix. Permeable pavement includes pervious concrete, porous asphalt, interlocking pavers, and reinforced and gravel-filled grids.

LIMITATIONS

Permeable pavement is considered infeasible if any of the following conditions are met.

- A site where infiltration is determined to be infeasible (refer to the Infiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).
- Unstable surrounding soil stratum and soils with clay content greater than 25%.
- A site with slopes greater than 20%.

- A site is receiving runoff from non-impervious surfaces.

DESIGN GUIDELINES

GENERAL

- Permeable pavement systems are appropriate in areas with light to medium-duty loads, such as parking lots, parking areas, driveways, sidewalks, bike paths, etc.
- Permeable pavement systems generally have up to 4 material layers that make up the system: 1) permeable pavement surface material, 2) filter layer or choker coarse (optional), 3) reservoir layer (can be combined base coarse and subbase reservoir layers), and 4) subgrade (soil matrix).
- Permeable pavement reservoir layer depth should be sufficient to store the water quality volume. The underlying soil matrix should drain the stored stormwater in less than 48 hrs unless an underdrain is provided.
- Permeable pavement should include measures that will allow runoff from the design storm to enter the reservoir layer if the permeable pavement surface course becomes clogged or otherwise incapable of conveying the maximum design storm runoff to the subgrade.
- Additional design details on specific permeable pavement systems are provided by the National Asphalt Pavement Association, the National Ready Mix Concrete Association, the Interlocking Concrete Pavement Institute, and the American Association of State Highway and Transportation Officials.
- Perforated pipes along the bottom of the bed may be used to distribute runoff evenly over the entire bottom of the reservoir layer. Pipes should lay flat along the bottom of the reservoir layer and provide uniform distribution of water. Depending on the size, these pipes may provide additional storage volume.
- Flows exceeding the design capacity of the permeable pavement will require an overflow system connected to a downstream conveyance or other PBMP.
- Permeable filter fabric should be placed between the reservoir layer and the underlying subgrade.

PRETREATMENT CONSIDERATIONS

- Pretreatment is not required as long as the permeable pavement does not receive run-on from non-impervious surfaces due to sediment potentially clogging the surface material.
- Pretreatment, if needed, can be achieved with gravel filter strips, vegetated swales, or vegetated buffer strips.

AREA REQUIREMENTS

- Permeable pavement requires a footprint equivalent to 5% - 18% of its contributing impervious drainage area. The lower value reflects the maximum allowable infiltration rate and minimum allowable factor of safety, while the upper value reflects the minimum allowable infiltration rate and maximum allowable factor of safety.

MINIMUM DESIGN CRITERIA

Design Parameter	**Units**	**Value**
Maximum Depth of Reservoir Layer	ft	3
Drawdown (drain) Time	hrs	48 or less
Minimum Soil Infiltration Rate	in/hr	0.50
Minimum Depth from Reservoir Invert to Groundwater Table	ft	3

SIZING GUIDELINES

Step 1: Use the procedure below to compute the volumetric runoff coefficient and WQV.

The volumetric runoff coefficient should be calculated using the following equation:

$$\mathbf{C = 0.05 + 0.009I}$$

where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

The WQV is calculated using the following equation:

$$\mathbf{WQV = PCA \times 3630}$$

where WQV = Water Quality Design Volume (ft^3)
P = Design Storm Runoff Depth (in) (refer to section 4.3.1)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ac)

Step 2: Calculate the maximum allowable water storage depth (d_{max}) using the underlying soil infiltration rate (k) and the required drawdown time (t):

$$\mathbf{d_{max} = kt / (F_s \times 12)}$$

where d_{max} = Maximum Storage Depth (ft)
k = Soil Infiltration Rate (in/hr)
t = Drawdown (drain) Time (hrs) (refer to section 4.3.6.1)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

Step 3: Select a pavement course depth (l_p) and the reservoir depth (l_r) such that the total effective storage depth (d_t) is no greater than the maximum allowable depth (d_{max}) calculated in Step 2:

$$\mathbf{d_t = l_p n_p + l_r n_r \leq d_{max}}$$

where d_t = Total Effective Water Storage Depth (ft)
l_p = Pavement Course Depth (ft)
n_p = Pavement Course Porosity (refer to section 4.3.6.3)
l_r = Reservoir Layer Depth (ft)
n_r = Reservoir Layer Porosity (refer to section 4.3.6.3)
d_{max} = Maximum Storage Depth (ft) from Step 2

Step 4: Calculate the permeable pavement surface area (A_{PBMP}):

$$\mathbf{A_{PBMP} = WQV / (d_t + (kT / 12F_s))}$$

where A_{PBMP} = PBMP Surface Area (ft^2)
WQV = WQV (ft^3) from Step 1
d_t = Total Effective Water Storage Depth (ft) from Step 3
k = Soil Infiltration Rate (in/hr)
T = Fill Time (time for the PBMP to fill with water [hrs]) (refer to section 4.3.6.6)
F_s = Infiltration Rate Factor of Safety (refer to section 3.3.3)

If the calculated area does not fit in the available space, either reduce the drainage area, increase the pavement course depth or reservoir course depth (if the total effective depth is not already set to the maximum depth), and repeat the calculations. If this does not work and the calculated area does not fit in the available space, reduce the infiltration rate factor of safety (if the minimum number of test pits and permeability tests have not been performed) and repeat the calculations.

CONSTRUCTION CONSIDERATIONS

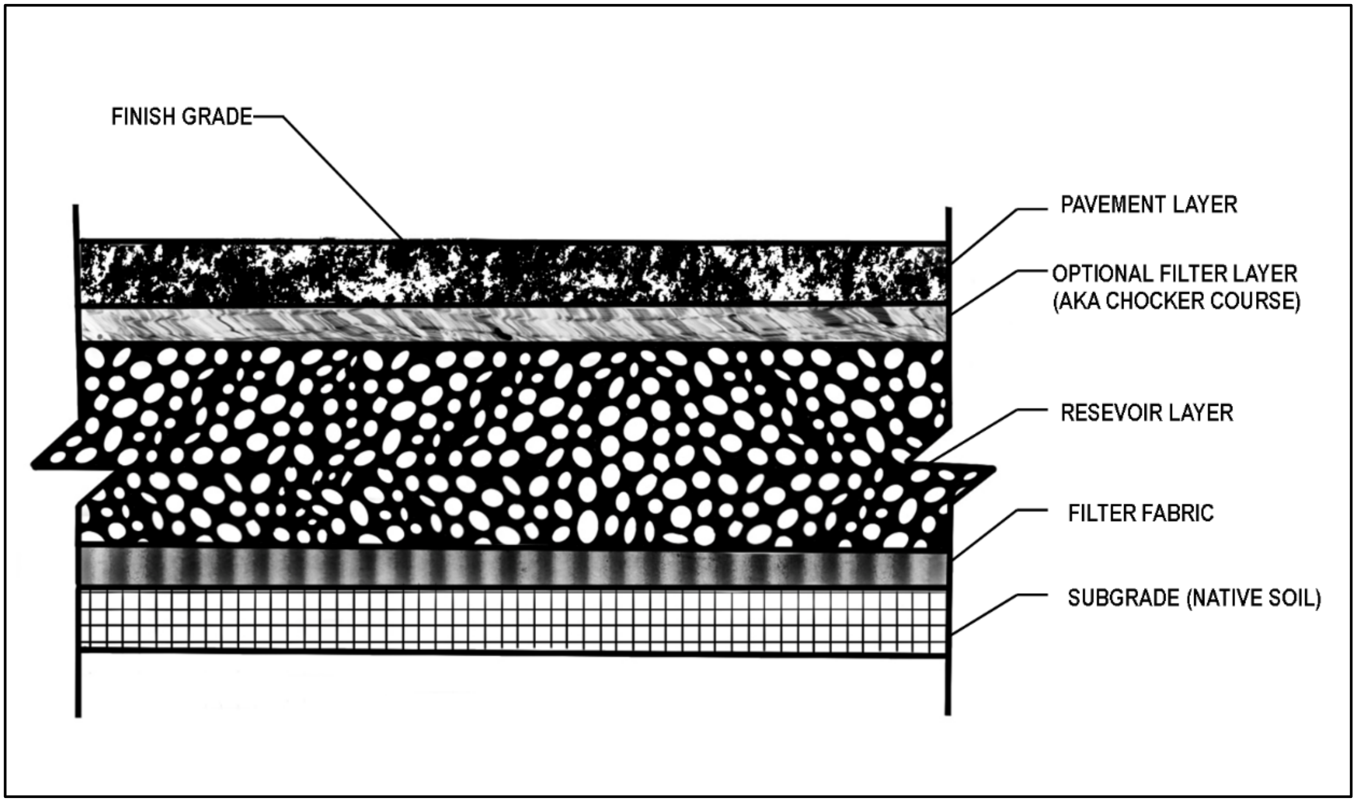
- Prior to installation, a preconstruction meeting should be scheduled with the superintendent, foremen, permeable pavement manufacturer representative, testing lab representative, and the engineer or owner’s representative to discuss logistical considerations. Logistical considerations may include scope and schedule, test locations, site access plans including staging and construction areas, quality control plans (prevention of sedimentation and compaction, material testing protocols and frequency, site inspection procedures and frequency), and documentation protocols and procedures.
- It is vital to minimize compaction of the permeable pavement subgrade soil and the required backfill. When possible, use excavation hoes to remove the original soil. If permeable pavements are excavated using a loader, the contractor should use wide track or marsh track equipment or light equipment with turf-type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high-pressure tires is unacceptable as it may cause excessive compaction resulting in reduced infiltration rates. In addition, compaction could significantly contribute to design failure.
- Compaction of the permeable pavement can be minimized by using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12-in compaction zone.
- Do not use heavy equipment within the permeable pavement. Heavy equipment can be used around the perimeter of the permeable pavement to supply media materials. Grade permeable pavement backfill with light equipment such as a compact loader or a dozer/loader with marsh tracks
- Permeable pavement surfaces can be laid without cross-falls or longitudinal gradients.
- Permeable pavement surfaces should not be used to store site materials unless the surface is well protected from the deposition of silt and other spillages.
- The pavement should be constructed in a single operation, as one of the last items to be built, on a development site. Landscape development should be completed before pavement construction to avoid contamination by silt or soil from this source.
- Surfaces draining to the permeable pavement should be stabilized before the construction of the pavement.
- Inappropriate construction equipment should be kept away from the pavement to prevent damage to the surface, sub-base, or sub-grade.
- Including signage on-site is another way to educate airport users, visitors, and maintenance crews about the permeable pavement system. Signage can also help readers understand how the system functions and

the consequences of different activities on-site. Signage should be resilient to environmental conditions to prevent frequent replacement.

- Access to maintain the permeable pavement should be considered.

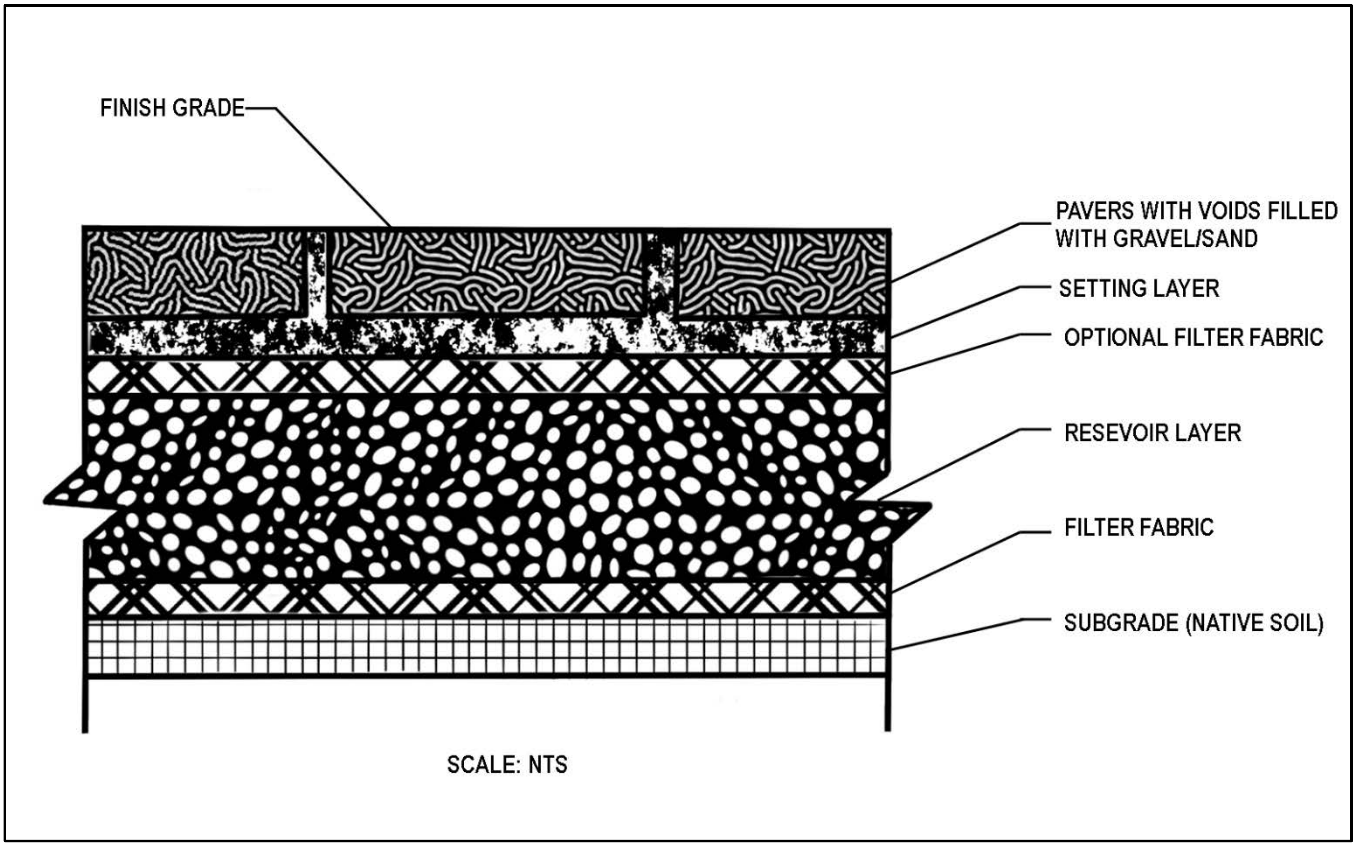
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic showing Typical Section of Pervious Concrete or Porous Asphalt

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic showing Typical Section of Permeable Pavers

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

LC-9: Subsurface Infiltration

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☐Other:

Subsurface Infiltration
Source: *Philadelphia Stormwater Management Guidance Manual, Version 3.2*

DESCRIPTION

A subsurface infiltration system is a rock storage (or alternative pre-manufactured material) bed below surfaces such as parking lots, lawns, and playfields for temporary storage and infiltration of runoff. Subsurface infiltration systems, including pre-manufactured pipes, vaults, modular structures, etc., have been developed as alternatives to infiltration basins and trenches for space-limited sites and stormwater retrofit applications. Proprietary subsurface infiltration systems can also be referred to as Manufactured Treatment Devices or MTDs.

According to the State and Federal UIC Program regulations, a subsurface infiltration system can be considered a Class V stormwater drainage well if it meets the definition of a well and an injection well (i.e., deeper than wide). Subsurface infiltration systems that fall under the Class V injection well category shall apply for a UIC permit (refer to Federal UIC regulations, *40 CFR § 144* and State of Hawaii UIC regulations, *HAR § 11-23*).

All UIC permitted subsurface infiltration systems will be considered PBMPs to satisfy any Post-Construction Program Requirements but will be inspected and maintained under the UIC or Post-Construction Program, whichever is more stringent.

LIMITATIONS

A subsurface infiltration system is considered infeasible if any of the following conditions are met.

- A site where infiltration is determined to be infeasible (refer to the Infiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).
- Unstable surrounding soil stratum and soils with clay content greater than 25%.
- A site with slopes greater than 20%.

DESIGN GUIDELINES

GENERAL

- Subsurface infiltration systems are generally applicable to small sites (typically less than 10 ac) and should be installed in areas that are easily accessible to maintain.
- Consider using subsurface infiltration systems certified for general use by the Washington State Department of Ecology Technology Assessment Protocol (TAPE) or certified by the New Jersey Department of Environmental Planning (NJDEP).
- Follow the manufacturer's guidelines for design considerations based on the site conditions.
- Subsurface infiltration systems should safely overflow or bypass flows in excess of the stormwater quality design storm to downstream drainage systems.
- The bottom of the subsurface infiltration system should be graded as flat as possible to provide uniform ponding and infiltration across the subsurface infiltration system bottom.
- Permeable filter fabric should be placed between the rock or alternative material layer and the subsurface infiltration system invert.
- Observation wells/inspection ports are recommended. The observation wells/inspection ports indicate how quickly the subsurface infiltration system dewaters following a storm event and provide an insight into whether the subsurface infiltration system is functioning as intended (i.e., clogged with sediment, etc.).
- Manholes should be included for cleaning access. Some designs include an isolated row, a row of the system that incorporates strategically located inspection ports, and manholes for maintenance.
- Subsurface infiltration systems may be subject to applicable federal and state UIC regulations; refer to Federal UIC regulations, *40 CFR § 144* and State of Hawaii UIC regulations, *HAR § 11-23*.

PRETREATMENT CONSIDERATIONS

- Pretreatment may be achieved with vegetated swales, vegetated buffer strips, sedimentation basins, forebays, or manufactured treatment devices.
- Subsurface infiltration systems are susceptible to clogging and premature failure from sediment, trash, and other contaminants. Suitable pretreatment systems maintain the infiltrate rate of the device without frequent and intensive maintenance.
    - For soil infiltration rates below 3 in/hr, pretreatment is strongly recommended, and the pretreatment device should be sized for at least 25% of the WQV.
    - For soil infiltration rates greater than 3 in/hr, pretreatment is mandatory to minimize groundwater contamination risks, and the pretreatment device should be sized for at least

50% of the WQV if the soil infiltration rate is below 5 in/hr and 100% of the WQV if the soil infiltration rate is greater than 5 in/hr.

- Forebays should be used only in locations where standing water is not considered a safety concern. The forebay should be lined such that water will first flow through the subsurface infiltration system. Lining material should allow for the removal of sediment and debris with a shovel or vac truck.

AREA REQUIREMENTS

- The below-grade footprint requirements for commercially available infiltration chambers vary by manufacturer. However, similar to above-grade non-proprietary systems, space will be minimized for sites with higher infiltration rates and lower infiltration rate factors of safety.
- Follow the manufacturer’s guidelines for appropriate area requirements and selection of appropriate configurations.

MINIMUM DESIGN CRITERIA

Design Parameter	**Units**	**Value**
Follow manufacturer's guidelines for the minimum design criteria.		
Drawdown (drain) Time	hrs	48 or less
Minimum Soil Infiltration Rate	in/hr	0.50
Minimum Depth from System Invert to Groundwater Table	ft	3

SIZING GUIDELINES

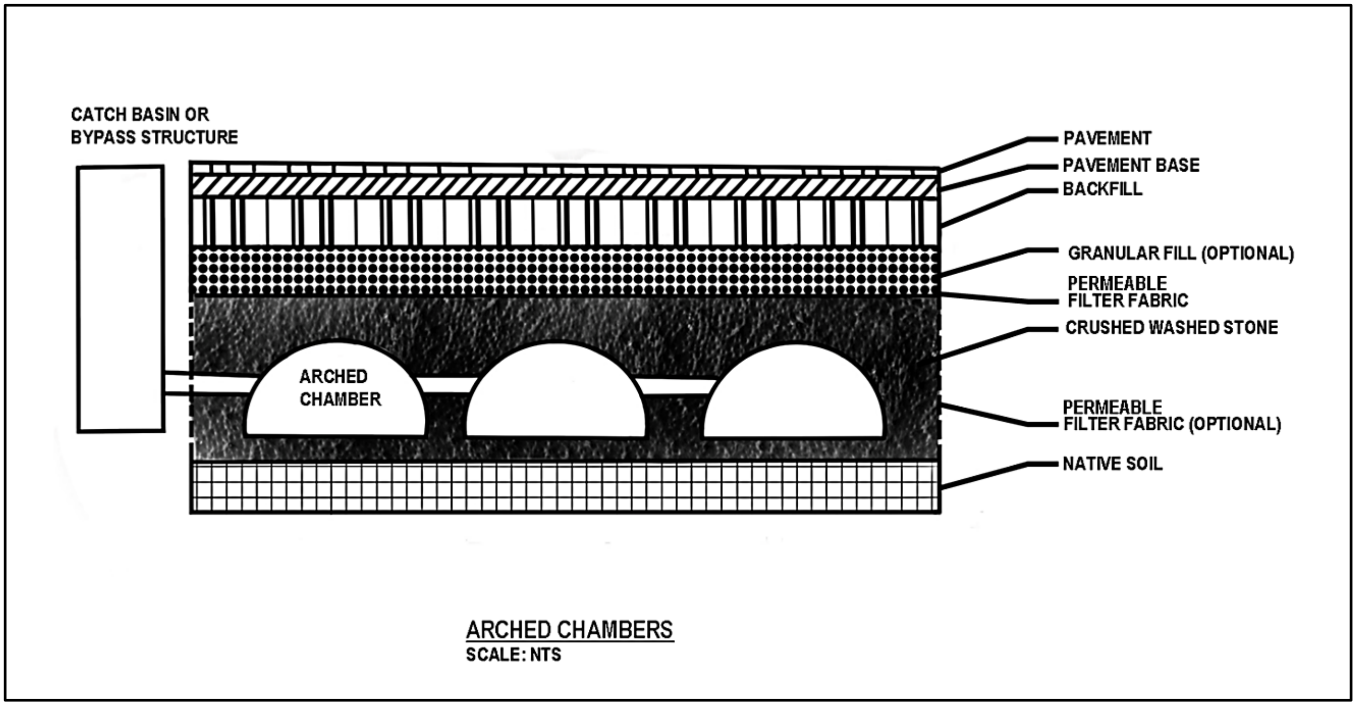
- DOTA sizing guidelines are not provided as sizing procedures will vary by manufacturer.
- Follow the manufacturer’s guidelines for appropriate sizing calculations and selection of appropriate device/model.
- Every unit requires detailed hydraulic analysis before installation to verify optimum infiltration is achieved.

CONSTRUCTION CONSIDERATIONS

- Follow the manufacturer’s recommendations.
- A General Application for a UIC Permit to Operate should be submitted to DOH-SDWB at least 6 months before the anticipated date of UIC well construction.

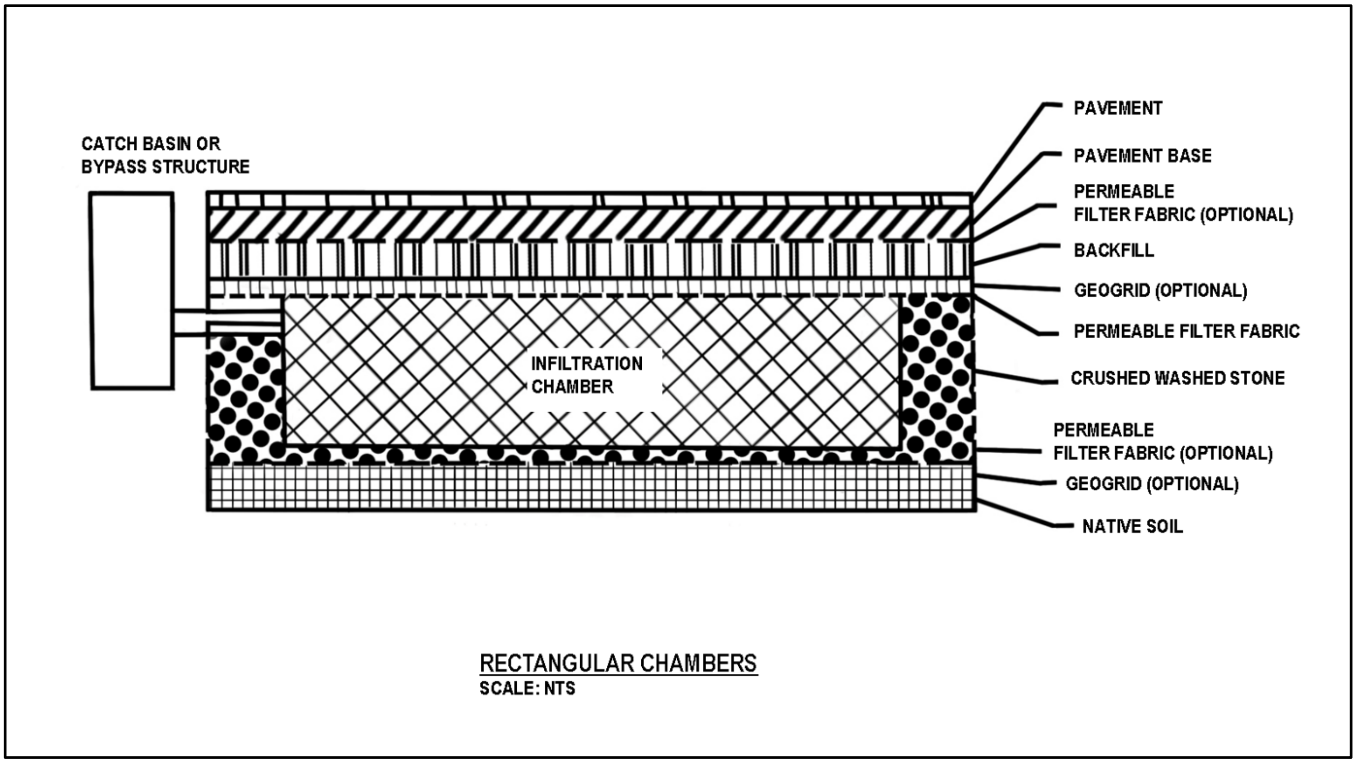
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



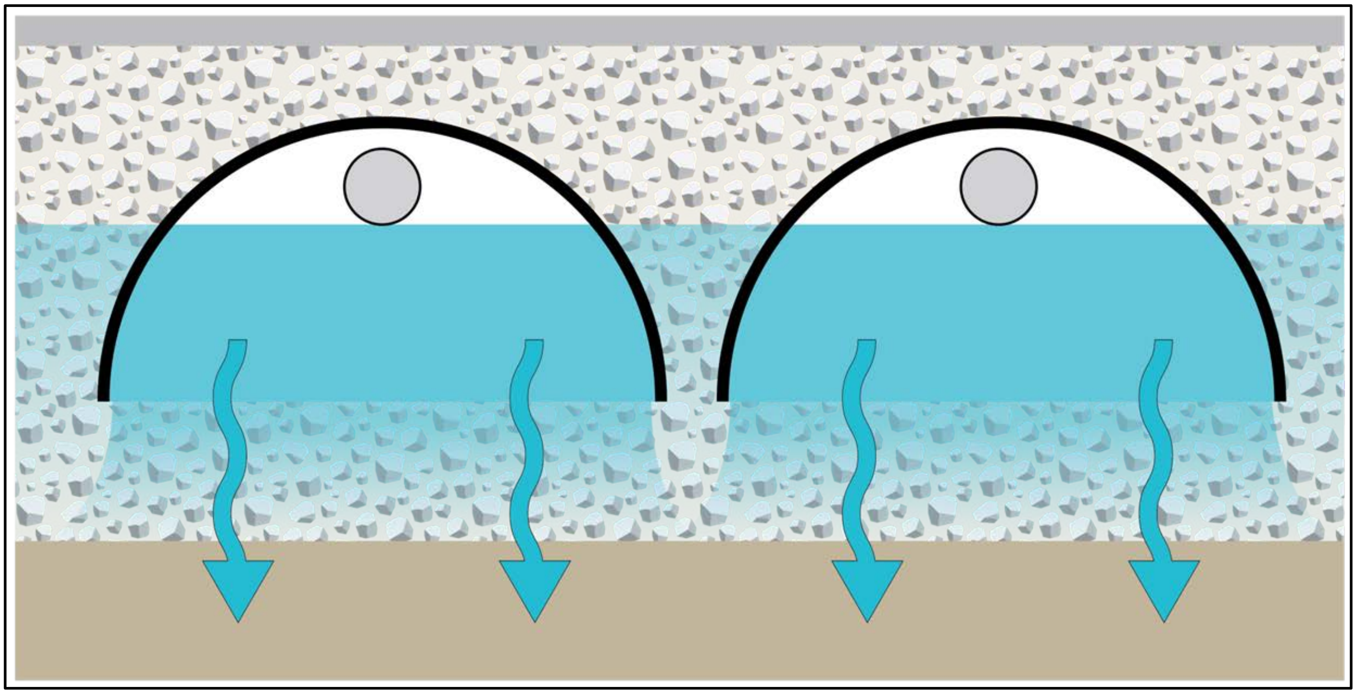
Example Schematic of a Subsurface Infiltration Systems

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Subsurface Infiltration Systems

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of an Infiltration System

Source: *Minnesota Stormwater Manual* (Minnesota Pollution Control Agency, February 17, 2021).

LID PBMP Design Fact Sheets

LC-10: Vegetated Buffer Strip

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☒Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☐Pesticides
☒Sediment
☒Trash
☐Other:

Vegetated Buffer Strip, Oahu
Source: HDOT Highways Division

DESCRIPTION

A vegetated buffer strip is a strip of land parallel to and adjacent to the edge of the contributing impervious surface and designed to accommodate sheet flow. A vegetated buffer strip is typically vegetated with turfgrass. Vegetated buffer strips provide filtration, reduce flow velocity, and prevent erosion.

LIMITATIONS

Vegetated buffer strips are considered infeasible if any of the following conditions are met.

- A site where biofiltration is determined to be infeasible (refer to the Biofiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).

- Removal of mature trees for the vegetated buffer strip construction may be infeasible and requires additional review and approval by DOTA on a case-by-case basis.
- Unstable surrounding soil stratum and soils with clay content greater than 25%.
- A site with slopes greater than 5%.
- There is a documented concern that there is a potential on the site for soil pollutants, groundwater pollutants, or pollutants associated with industrial activities to be mobilized.

DESIGN GUIDELINES

GENERAL

- Vegetated buffer strips are most economical when existing vegetation can be retained to serve as the buffer strip or when a landscaped area serves as a buffer strip incorporated into the site design.
- Vegetated buffer strips should be used to treat runoff from small drainage areas. The maximum length (in the direction of flow towards the buffer strip) of the tributary area should be 75 ft.
- The width of the vegetated buffer strip should be the same as the length of the tributary area (in the direction of flow towards the buffer strip). If a vegetated buffer strip width selected is not the same as the length of the tributary area, a transition structure will be necessary to capture all the runoff and establish uniform sheet flow across the entire strip width.
- The flow should enter the vegetated buffer strip as sheet flow spread out over the width of the strip.
- A pea gravel diaphragm or engineered level spreader should be provided at the upper edge of the PBMP when the width of the contributing drainage area is greater than that of the filter. Level spreader options include porous pavement strips, stabilized turf strips, slotted curbing, rock-filled trench, or concrete sills.
- Landscaping is critical to the function and performance of the vegetated buffer strips. Vegetate the buffer strips with dense turf grass to promote sediment capture, filtration, nutrient uptake, and lower flow velocity, limiting erosion.
- Landscaping design should specify proper grass species based on site-specific soils and hydric conditions present along the channel. Grass should be designed like a typical lawn for regular mowing.
- Vegetation in or around the vegetated buffer strips that provide food (seeds) or habitat for wildlife that could be hazardous to airport operations should not be considered.
- Irrigation may be required to maintain the grass during extended dry periods.

PRETREATMENT CONSIDERATIONS

- None.

AREA REQUIREMENTS

- A vegetated buffer strip requires a footprint of no less than 0.40% of its contributing impervious drainage area. While there is no upper value because there is no maximum design width or design length, the minimum footprint corresponds to the minimum length and the maximum slope and minimum width combination that provide the maximum allowable design depth.

MINIMUM DESIGN CRITERIA

Design Parameter	Units	Value
Maximum Flow Velocity	fps	1
Maximum Upstream Area Flow Length	ft	75
Minimum Length	ft	15
Maximum Flow Depth	in	1

SIZING GUIDELINES

Step 1: Use the procedure presented below to compute a composite weighted runoff coefficient and the water quality design flow rate.

For drainage areas containing multiple land uses, a composite runoff coefficient is calculated using the following equation:

$$\mathbf{C_C = [(\sum_{i=1}^{n} C_i A_i)/A_t]}$$

where C_C = Composite Weighted Runoff Coefficient
$C_{1,2,..n}$ = Runoff Coefficient for each Land Use Cover Type
$A_{1,2,..n}$ = Drainage Area to each Land Use Cover Type (ac)
n = Number of Land Use Cover Types within the Drainage Area
A_t = Total Drainage Area (ac)

Compute the peak inflow rate using the Rational method:

$$\mathbf{Q = CiA}$$

where Q = Water Quality Design Flow Rate (cfs)
C = Runoff Coefficient
i = Peak Rainfall Intensity (in/hr) (refer to section 4.3.2)
A = Tributary Drainage Area (ac)

Step 2: Select initial values for the buffer strip width (w) and buffer longitudinal slope (s).

Step 3: Compute the design flow depth for the water quality flow rate using a simplified form of Manning's Equation assuming a shallow flow depth:

$$\mathbf{y = 12 \times [nQ/1.49\sqrt{(s/100)}]^{0.6}}$$

where y = Design Flow Depth for water quality flow rate (in)
n = Manning's n value (refer to section 4.3.6.7)
Q = Water Quality Flow Rate (cfs) from Step 1
w = Design Width (ft) from Step 2
s = Longitudinal Slope (%) from Step 2

Step 4: Calculate the design flow velocity using the flow continuity equation:

$$\mathbf{V = 12Q/wy}$$

where V = Design Flow Velocity (fps)
Q = Water Quality Flow Rate (cfs) from Step 1
w = Design Width (ft) from Step 2
y = Design Flow Depth (ft) from Step 3

If the design flow velocity is greater than the maximum allowed velocity, revise one of the parameters and repeat the calculations.

Step 5: Select a design buffer strip length (L) equal to or greater than the minimum length, and calculate the total PBMP area required (A_{PBMP}):

$$\mathbf{A_{PBMP} = L \times w}$$

where A_{PBMP} = Total Area (ft^2)
L = Design Length (ft) from Step 6
w = Design Width (ft) from Step 2

CONSTRUCTION CONSIDERATIONS

GRASSING

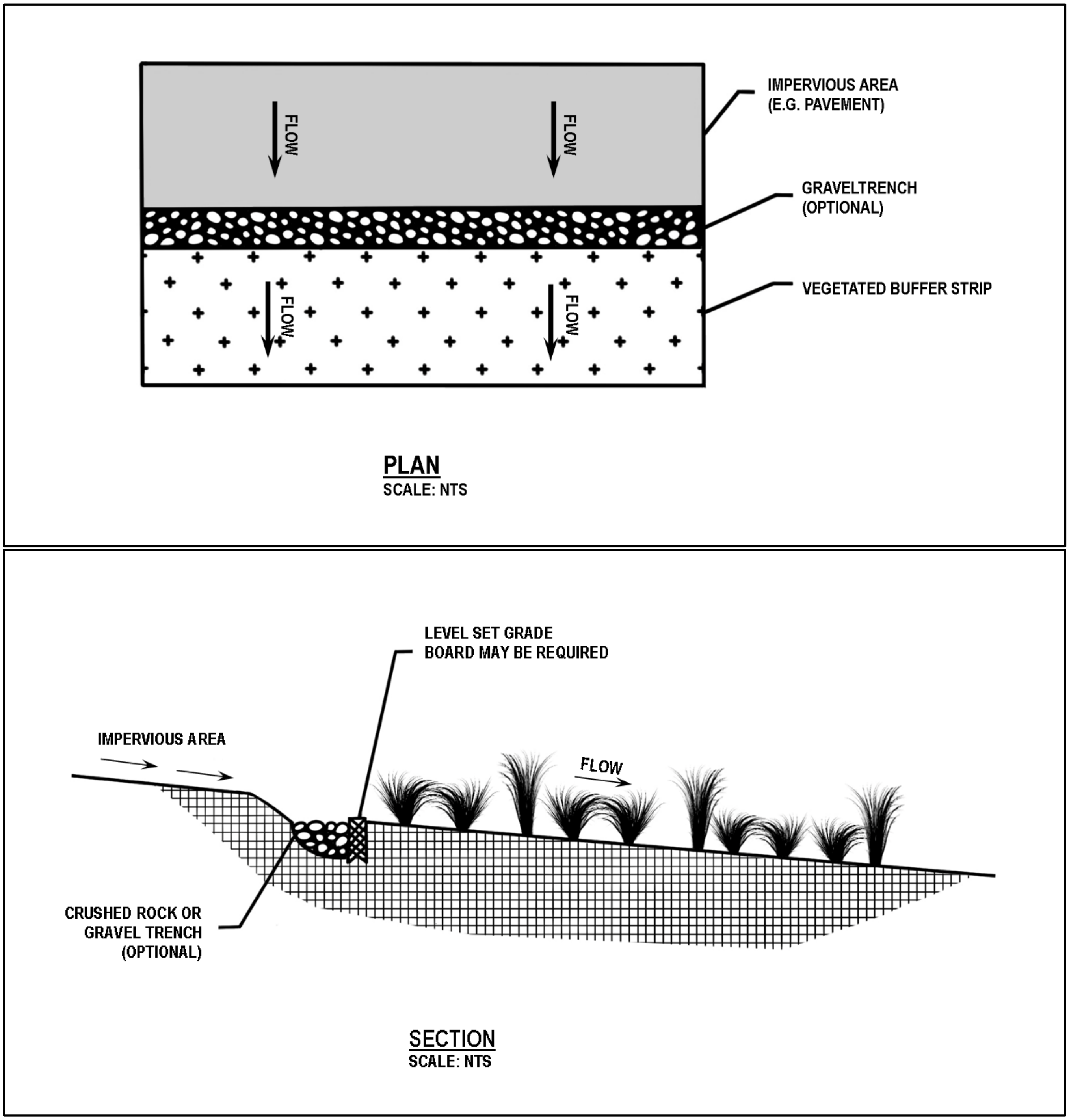
- Include directions in the specifications for using the appropriate fertilizer and soil amendments based on soil properties determined through testing and compared to the needs of the grassing requirements.
- Grassing should be done as soon as possible after the area has been graded.
- If sod tiles are used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the vegetated buffer strip.
- Use a roller on the sod to verify no air pockets form between the sod and the soil.
- Per FAA Regulations, seeds are not to be scattered or applied through hydroseeding.

MISCELLANEOUS

- Install vegetated buffer strips at the time of the year when there is a reasonable chance of successfully establishing grass without irrigation; however, it is recognized that rainfall in a given year may not be sufficient and temporary irrigation may be used.
- Strip and stockpile good topsoil during construction for use in surface preparation prior to planting.
- Avoid using the buffer strip or vegetated channel for vehicular traffic, this can be damaging to the vegetation and reduce its effectiveness.
- A vegetated buffer strip should not be established until the contributing drainage area is stabilized.

EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of a Vegetated Buffer Strip

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

LID PBMP Design Fact Sheets

LC-11: Vegetated Swale

PBMP Category

☒LID
☐Source Control
☐Treatment Control

Pollutants Targeted

☒Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☐Pesticides
☒Sediment
☒Trash
☐Other:

Vegetated Swale along H-3, Oahu
Source: HDOT Highways Division

DESCRIPTION

A vegetated swale is a broad, open, shallow earthen channel designed to treat the water quality volume within dry or wet cells formed using check dams or other means. Vegetated swales are typically vegetated with flood-tolerant grasses that can provide filtration, reduce flow velocity, and prevent erosion. Stormwater runoff typically enters at one end of the vegetated swale and exits at the other end.

LIMITATIONS

Vegetated swales are considered infeasible if any of the following conditions are met.

- A site where biofiltration is determined to be infeasible (refer to the Biofiltration Infeasibility Evaluation Criteria within the LID Waiver and PBMP Infeasibility Screening Criteria (section 3.4)).

- Removal of mature trees for the vegetated swale construction may be infeasible and requires additional review and approval by DOTA on a case-by-case basis.
- Unstable surrounding soil stratum and soils with clay content greater than 25%.
- A site with slopes greater than 5%.
- There is a documented concern that there is a potential on the site for soil pollutants, groundwater pollutants, or pollutants associated with industrial activities to be mobilized.

DESIGN GUIDELINES

GENERAL

- Vegetated swales should be used to treat runoff from small drainage areas of less than 5 ac.
- Vegetated swales should generally have a trapezoidal shape with a flat bottom (in the direction perpendicular to flow) to promote even flow across the whole width of the swale.
- A vegetated swale width should be between 2 -10 ft and will have a flow depth of no greater than 4-in; the hydraulic grade line is no greater than 2% between check dam structures.
- Longitudinal slopes should be less than 5% to qualify for water quality volume treatment.
- A high flow bypass should be included to safely convey runoff from significant storm events when the flow velocity exceeds 1 fps.
- Overflow for the 10-yr storm event should be directed to an outlet point with energy dissipators designed to prevent erosion from the 10-yr storm velocity.
- Check dams may be used for vegetated swales on longitudinal slopes exceeding 2% to reduce the velocity and increase ponding and infiltration.
- Check dams, if installed, should be perpendicular to the flow. A v-notch weir, weep hole, or similar drainage feature should be provided within the check dam to direct low flow volumes.
- Landscaping is critical to the function and performance of the vegetated swales. Vegetate the swale with dense turf grass to promote sedimentation, filtration, nutrient uptake, and to lower flow velocity, limiting erosion.
- Landscaping design should specify proper grass species based on site-specific soils and hydric conditions present along the channel. Grass should be designed like a typical lawn for regular mowing.
- Vegetation in or around the vegetated swale that provides food (seeds) or habitat for wildlife that could be hazardous to airport operations should not be considered.
- Irrigation may be required to maintain the grass during extended dry periods.

PRETREATMENT CONSIDERATIONS

- None.

AREA REQUIREMENTS

- A vegetated swale requires a footprint equivalent to 2% - 4% of its contributing impervious drainage area. The lower value corresponds to maximizing the flow depth and slope, while the upper value corresponds to maximizing the bottom width and slope.

MINIMUM DESIGN CRITERIA

Design Parameter	Units	Value
Maximum Interior Side Slope (length per unit height)	ft/ft	3:1
Maximum Flow Velocity	fps	1
Maximum Water Depth	in	4
Minimum Hydraulic Residence Time	min	7
Maximum Bottom Width	ft	10
Maximum Longitudinal Slope without Check Dams	%	2
Maximum Longitudinal Slope with Check Dams	%	5
Maximum Check Dam Height	in	12
Minimum Freeboard	ft	0.50

SIZING GUIDELINES

Step 1: Use the procedure presented below to compute a composite weighted runoff coefficient and the water quality design flow rate.

For drainage areas containing multiple land uses, a composite runoff coefficient is calculated using the following equation:

$$\mathbf{C_C = [(\sum_{i=1}^{n} C_i A_i)/A_t]}$$

where C_C = Composite Weighted Runoff Coefficient
$C_{1,2,..n}$ = Runoff Coefficient for each Land Use Cover Type
$A_{1,2,..n}$ = Drainage Area to each Land Use Cover Type (ac)
n = Number of Land Use Cover Types within the Drainage Area
A_t = Total Drainage Area (ac)

Compute the peak inflow rate using the Rational method:

$$\mathbf{Q = CiA}$$

where Q = Water Quality Design Flow Rate (cfs)
C = Runoff Coefficient
i = Peak Rainfall Intensity (in/hr) (refer to section 4.3.2)
A = Tributary Drainage Area (ac)

Step 2: Select initial values for the swale bottom width (b), depth of flow (y), swale side slope (z), and swale longitudinal slope (s).

Step 3: Calculate the cross-sectional area (A_c), wetted perimeter (WP), and hydraulic radius (R) using the dimensions established in Step 2:

$$\mathbf{A_c = (by/12) + (zy^2/144)}$$

$$\mathbf{WP = b + (2y/12)\sqrt{(1+z^2)}}$$

$$\mathbf{R = A_c/WP}$$

where A_c = Cross-sectional Area (ft^2)
WP = Wetted Perimeter (ft)
R = Hydraulic Radius (ft)
b = Swale Bottom Width (ft) from Step 2
y = Depth of Flow (in) from Step 2
z = Swale Side Slope (length per unit height) from Step 2

Step 4: Compute the calculated flow rate in the swale using the selected dimensions and Manning's Equation:

$$\mathbf{Q = (1.49A_cR^{2/3}s^{1/2})/n}$$

Where Q = Calculated Flow Rate (cfs)
A_c = Cross-sectional Area (ft^2) from Step 3
R = Hydraulic Radius (ft)
s = Longitudinal Slope (%) from Step 2
n = Manning's n value (refer to section 4.3.6.7)

Step 5: Once an appropriate design flow rate is achieved, calculate the design flow velocity using the flow continuity equation:

$$\mathbf{V = Q/A_c}$$

where V = Design Flow Velocity (fps)
Q = Design Flow Rate (cfs) from Step 4
A_c = Cross Sectional Area (ft^2) from Step 3

If the design flow velocity is greater than the maximum allowed velocity, either include check dams with vertical drops of no more than 12-in or revise one or more swale dimensions and repeat the calculations.

Step 6: Select an initial value for the hydraulic residence time (T) to compute the swale length (L). Multiply the velocity by the hydraulic residence time to determine the length:

$$\mathbf{L = 60VT_h}$$

where L = Swale Length (ft)
T_h = Hydraulic Resistance Time (min)
V = Design Flow Velocity from Step 5 (fps)

Step 7: Calculate the total area required (A_{PBMP}) taking into account the side slopes along the length of the swale and the freeboard:

$$\mathbf{A_{PBMP} = [b + 2z(f + y/12)] \times L}$$

where A_{PBMP} = Total Surface Area (ft^2)
b = Swale Bottom Width (ft) from Step 2
z = Swale Side Slope (length per unit height) from Step 2
f = Freeboard (ft)
y = Depth of Flow (in) from Step 2
L = Swale Length (ft) from Step 6

If the calculated area does not fit in the available space, either reduce the drainage area, reduce the hydraulic residence time (if it is longer than the minimum), or revise one or more swale dimensions and repeat the calculations.

CONSTRUCTION CONSIDERATIONS

CHECK DAMS

- Check dams should be constructed using wood, concrete, stone, or other non-erodible material.
- Check dams should be appropriately anchored into the bottom and side slopes of the vegetated swale.

GRASSING

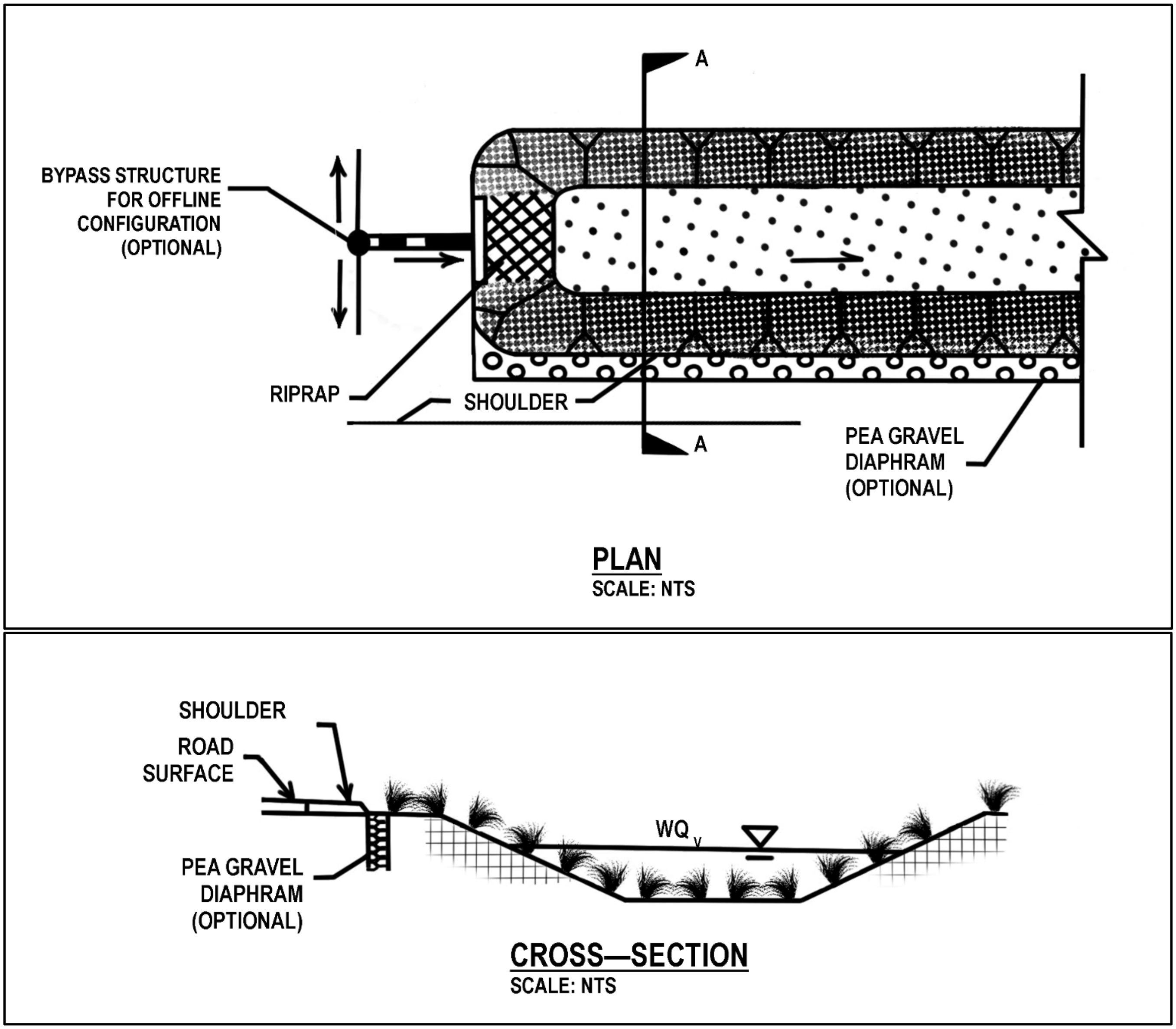
- Include directions in the specifications for using the appropriate fertilizer and soil amendments based on soil properties determined through testing and compared to the needs of the grassing requirements.
- Grassing should be done as soon as possible after the area has been graded.
- If sod tiles are used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the vegetated swale.
- Use a roller on the sod to verify no air pockets form between the sod and the soil.
- Per FAA Regulations, seeds are not to be scattered or applied through hydroseeding.

MISCELLANEOUS

- The inflow should be directed towards the upstream end of the swale but should occur evenly over the swale.
- Install vegetated swales at the time of the year when there is a reasonable chance of successfully establishing grass without irrigation; however, it is recognized that rainfall in a given year may not be sufficient, and temporary irrigation may be used.
- Vegetated swale areas should not serve as sediment control measures during construction.
- A vegetated swale should not be established until the contributing drainage area is stabilized.

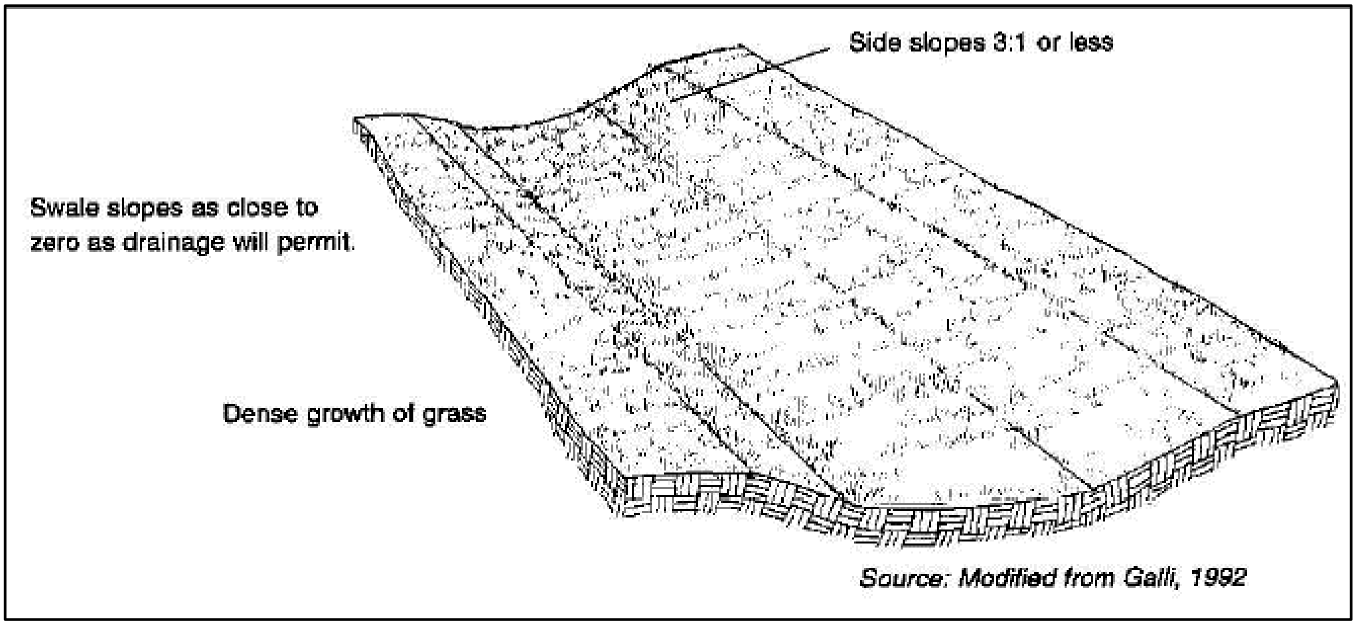
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of a Vegetated Swale

Source: *Storm Water BMP Guide for New and Redevelopment* (CCH, 2017). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Typical Vegetated Swale

Source: *Integrated Stormwater Management, iSWM Technical Manual, Site Development Controls* (North Central Texas Council of Governments, November 2020). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

Appendix III

LID Waiver and Infeasibility Screening Worksheet

LID Waiver and Infeasibility Screening Worksheet

This worksheet is used to evaluate and document the infeasibility screening of various LID PBMPs and provides a waiver for LID based on the following:

- Infiltration Infeasibility
- Biofiltration Infeasibility
- Harvesting/Reuse Infeasibility
- Other Infeasibility.

Project proponents shall use Veoci to go through the PBMP design process and provide all pertinent documentation associated with the questions below.

Infiltration Infeasibility Evaluation

<table>
<tr><th>No.</th><th>Infiltration Infeasibility Evaluation Criteria
<i>Based on the answers to the questions below, infiltration is feasible or infeasible. If “Yes” is checked for any criteria, then infiltration is infeasible. You must provide evidence for each infeasibility condition claimed.</i></th><th>Response (Yes/No)</th></tr>
<tr><td>1.</td><td>Do soils beneath the PBMP invert have measured boring and infiltration rates less than 0.50 in/hr?</td><td></td></tr>
<tr><td>2.</td><td>Are soils beneath the PBMP invert classified as HSG “C” or “D” as reported by the USDA NRCS?</td><td></td></tr>
<tr><td>3.</td><td>Is the seasonal high groundwater table within 3 ft from PBMP invert?</td><td></td></tr>
<tr><td>4.</td><td>Is there a documented concern that there is a potential for soil pollutants, groundwater pollutants, or pollutants associated with industrial activities to be mobilized?</td><td></td></tr>
<tr><td>5.</td><td>Is the project area prone to geotechnical hazards such as soil movement, sloughing, etc.?</td><td></td></tr>
<tr><td>6.</td><td>Is the PBMP built within the setbacks listed below?
<table>
<tr><th>Setback from nearest:</th><th>Distance (ft)</th></tr>
<tr><td>Drinking water well</td><td>50</td></tr>
<tr><td>Septic system</td><td>35</td></tr>
<tr><td>Property line</td><td>10</td></tr>
<tr><td>Building foundation</td><td>20</td></tr>
<tr><td>Down-gradient building foundation</td><td>100</td></tr>
</table></td><td></td></tr>
<tr><td>7.</td><td>Are there proposed activities/land uses that pose a high threat to water quality, including high potential for chemical spills (including oil and grease) or high levels of sand or sediment?</td><td></td></tr>
<tr><td>8.</td><td>Does the location of the infiltration PBMP facility/facilities conflict with the location of existing or proposed underground utilities or easements, including their placement or orientation such that they would discharge to the utility trench, restrict access, or cause stability concerns?</td><td></td></tr>
<tr><td>9.</td><td>Other (Refer to the Limitations in Appendix II):</td><td></td></tr>
<tr><td></td><td>Infiltration Infeasibility Evaluation Results:
<i>Is infiltration feasible?</i></td><td></td></tr>
</table>

If feasible, you may design infiltration PBMPs and proceed to the Biofiltration Infeasibility Evaluation Criteria section.

LID Waiver and Infeasibility Screening Worksheet

Biofiltration PBMP Infeasibility Evaluation

Biofiltration PBMPs must be evaluated individually for infeasibility. The table below provides infeasibility guidelines. If "Yes" is checked for any criteria, then biofiltration is infeasible for that PBMP. You must provide evidence for each infeasibility condition claimed.

No.	**Vegetated Biofilter Infeasibility Evaluation Criteria** *Based on the answers to the questions below, Biofilter is feasible (if all answers are no) or infeasible (if one answer is yes).*	**Response (Yes/No)**
1.	Is the invert of the underdrain layer below the seasonally high groundwater table?	
2.	Is the amount of sunlight received by the site inadequate or irrigation infeasible to support vegetation?	
3.	Does the site lack a sufficient hydraulic head to support PBMP operation by gravity?	
4.	Is the PBMP unable to operate off-line with bypass and unable to operate in-line with a safe overflow mechanism?	
5.	Other (Refer to the Limitations in Appendix II):	
	Vegetated Biofilter Infeasibility Evaluation Results: *Is a vegetated biofilter feasible?*	

No.	**Bioswale Infeasibility Evaluation Criteria** *Based on the answers to the questions below, Bioswale is feasible (if all answers are no) or infeasible (if one answer is yes).*	**Response (Yes/No)**
1.	Is the invert of the underdrain layer below the seasonally high groundwater table?	
2.	Is the amount of sunlight received by the site inadequate or irrigation infeasible to support vegetation?	
3.	Does the site lack a sufficient hydraulic head to support PBMP operation by gravity?	
4.	Is the PBMP unable to operate off-line with bypass and unable to operate in-line with a safe overflow mechanism?	
5.	Other (Refer to the Limitations in Appendix II):	
	Bioswale Infeasibility Evaluation Results: *Is a bioswale feasible?*	

No.	**Vegetated Swale Infeasibility Evaluation Criteria:** *Based on the answers to the questions below, Vegetated Swale is feasible (if all answers are no) or infeasible (if one answer is yes).*	**Response (Yes/No)**
1.	Is the amount of sunlight received by the site inadequate or irrigation infeasible to support vegetation?	
2.	Is the PBMP unable to operate off-line with bypass and unable to operate in-line with a safe overflow mechanism?	
3.	Other (Refer to the Limitations in Appendix II):	
	Vegetated Swale Infeasibility Evaluation Results: *Is a vegetated swale feasible?*	

LID Waiver and Infeasibility Screening Worksheet

No.	**Vegetated Buffer Strip Infeasibility Evaluation Criteria:** *Based on the answers to the questions below, Vegetated Buffer Strip is feasible or infeasible. Vegetated Buffer Strip is feasible (if all answers are no) or infeasible (if one answer is yes).*	**Response (Yes/No)**
1.	Is the amount of sunlight received by the site inadequate or irrigation infeasible to support vegetation?	
2.	Is the PBMP unable to operate off-line with bypass and unable to operate in-line with a safe overflow mechanism?	
3.	Other (Refer to the Limitations in Appendix II):	
	Vegetated Buffer Strip Infeasibility Evaluation Results: *Is a vegetated buffer strip feasible?*	

If feasible, you may design biofiltration PBMPs and proceed Harvesting/Reuse Infeasibility Evaluation Criteria section.

Harvesting/Reuse Infeasibility Evaluation

<table>
<tr><th>No.</th><th>Harvesting/Reuse Infeasibility Evaluation Criteria
<i>Based on the answers to the questions below, stormwater harvesting/reuse is feasible or infeasible. If “Yes” is checked for any criteria, then harvesting/reuse is infeasible. You must provide evidence for each infeasibility condition claimed.</i></th><th>Response (Yes/No)</th></tr>
<tr><td>1.</td><td>Is it infeasible for the harvested water to be reused at the project site (landscape irrigation or other non-potable use)?</td><td></td></tr>
<tr><td>2.</td><td>Is the 48 hr demand less than 0.25 WQV?
[<i>Estimate the anticipated average demand over a period of 48 hours. Guidance for calculating irrigation demand is provided in the Harvesting/Reuse fact sheet in the Post-Construction BMP Manual.]</i></td><td></td></tr>
<tr><td>3.</td><td>Do site constraints, such as a slope above 10% or lack of available space, make it infeasible to locate a cistern of adequate size to harvest and reuse the required demand amount of water for the site?</td><td></td></tr>
<tr><td>4.</td><td>Does the requirement for harvesting/reuse of stormwater runoff conflict with local, state, or federal ordinances and building codes?</td><td></td></tr>
<tr><td>5.</td><td>Is the cistern built within the setbacks listed below or does it restrict access to underground utilities?
<table>
<tr><th>Setback from nearest:</th><th>Distance (ft)</th></tr>
<tr><td>Septic system</td><td>10</td></tr>
<tr><td>Property line</td><td>5</td></tr>
<tr><td>Building foundation</td><td>5</td></tr>
</table></td><td></td></tr>
<tr><td>6.</td><td>Does a harvesting/reuse system conflict with a reclaimed wastewater system?</td><td></td></tr>
<tr><td>7.</td><td>Other (Refer to the Limitations in Appendix II):</td><td></td></tr>
<tr><td></td><td>Harvesting/Reuse Infeasibility Evaluation Results:
<i>Is harvesting/reuse feasible?</i></td><td></td></tr>
</table>

If feasible, you may design a harvesting/reuse system. If it is infeasible, you must include Treatment Control PBMPs in the design.

LID Waiver and Infeasibility Screening Worksheet

Other Infeasibility Evaluation

No.	**Other Infeasibility Evaluation Criteria** *Provide LID Waiver Explanation and Documentation*	Response (Yes/No)
1.	Other Criteria (please explain):	
	Other Infeasibility Evaluation Results: *Does the Project qualify for an LID waiver based on the other infeasibility criteria?*	

If it is infeasible, you must include Treatment Control PBMPs in the design.

LID WAIVER APPROVED?

No.	**LID Waiver Evaluation Criteria** *Based on all the above criteria*	Response (Yes/No)
	LID Waiver Evaluation Results: Does the Project qualify for an LID waiver based on all the above criteria?	
	Is the LID Waiver Approved?	

You must include Source Control and Treatment Control PBMPs in the design.

Appendix IV

Source Control PBMP Design Fact Sheets

Appendix IV

Source Control PBMP Design Fact Sheets

This Appendix describes specific Source Control PBMPs to be considered for incorporation into new development and redevelopment projects at DOTA airports including retrofit projects to meet stormwater management objectives.

Source Control PBMPs are required for all non-exempt projects for the following activities and areas:

- SC-1: Dispersion for landscaped areas and velocity dissipation
- SC-2: Fueling Area Design for aircraft, vehicle, and equipment fueling
- SC-3: Loading Area Design for outdoor loading operations related to aircraft, vehicle, and equipment
- SC-4: Maintenance Area Design for aircraft, vehicle, and equipment maintenance and repair
- SC-5: Material Storage Area Design for material storage
- SC-6: Triturator Facility Design for triturator facilities
- SC-7: Washing Area Design for aircraft, vehicle, and equipment washing
- SC-8: Waste Management Area Design for outdoor waste storage

Source Control PBMP Design Fact Sheets are designed differently from the LID PBMP Design Fact Sheets and Treatment Control PBMP Design Fact Sheets since the Fact Sheets provide measures

The following information is provided for each of the above-listed Source Control PBMP Fact Sheets:

- Description
- Approach
- Suitable Applications
- Limitations
- Design Considerations
- Construction Considerations
- Operations & Maintenance (O&M) Recommendations

Please note that O&M Recommendations within these Fact Sheets pertain to the O&M of Source Control PBMPs immediately after construction i.e., to be implemented after the project is turned over to DOTA or tenant; the O&M Recommendations are not operational. The operational BMPs can be found under the DOTA Tenant Inspection and Enforcement program or the DOTA Facility Inspection program.

SC-1: Dispersion

PBMP Category

☐LID
☒Source Control
☐Treatment Control

Pollutants Targeted

☒Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☐Pathogens
☐Pesticides
☒Sediment
☒Trash
☐Other:

Splashblock located along HART, Daniel K. Inouye International Airport

DESCRIPTION

Dispersion PBMPs operate by dispersing stormwater runoff through vegetation or other media, which provides varying levels of runoff reduction and attenuation. Dispersion attenuates peak flows by slowing the runoff entering the DOTA MS4 or drainage system, impeding the velocity of stormwater runoff, allowing some infiltration, and providing some water quality benefits. Dispersion can be classified as concentrated flow dispersion, sheet flow dispersion, and downspout dispersion systems.

1. Concentrated flow dispersion from driveways or other pavement attenuates peak flows, slows the runoff into the DOTA MS4 or drainage system, allows for some infiltration, and provides some water quality benefits. Examples of concentrated flow dispersion include landscaped areas, level spreaders, etc.
2. Sheet flow dispersion can be used for any impervious or pervious graded surfaces to reduce concentrated flows. Because flows are already dispersed as they leave the surface, they need only traverse a narrow band of adjacent vegetation for effective on-site stormwater management. Examples of sheet flow dispersion include landscaped areas, level spreaders, etc.

3. Downspout dispersion can be used for urban lots located in less permeable soils, where infiltration is not feasible. Examples of downspout dispersion are level spreaders, perforated stub-out connections, or splashblocks, spreading roof runoff over vegetated areas.

Each project site possesses unique topographic, hydrologic, and vegetative features, some of which are more suitable for development than others. This Fact Sheet discusses landscaped areas, level spreaders, perforated stub-out connections, and splashblocks.

APPROACH

Integrating and incorporating appropriate landscaped areas, level spreaders, perforated stub-out connections, and splashblocks into the project design is effective PBMP that can be utilized to reduce runoff velocity, minimize erosion, and provide stormwater runoff reduction and attenuation.

SUITABLE APPLICATIONS

LANDSCAPED AREAS

- Applications include areas planned for development or redevelopment which include landscaped areas.

LEVEL SPREADER

- A level spreader is a device used to spread out stormwater runoff uniformly over the ground surface as sheet flow (i.e., not through channels). The purpose of level spreaders is to reduce the erosive energy of concentrated flows by distributing runoff as sheet flow onto stabilized vegetative surfaces, thereby increasing infiltration and improving water quality.
- Flows collected in a pipe or ditch require energy dissipation and dispersal at the end of these systems before entering the dispersion area.
- A level spreader can be the top of a channel, an earthen berm, or a rigid weir-like structure that distributes flow evenly across its length at non-erosive velocities onto stabilized dispersal areas.
- A level spreader can be an outlet for dikes and diversions that disperses the runoff from the slope.

SPLASHBLOCKS

- A splashblock is a device manufactured from concrete, plastic, or other material that works to channel water away from the foundation. The splashblock is typically rectangular and has a close-ended side positioned underneath a downspout. It also has an open-ended side that works to direct water safely away from the foundation.
- Downspout dispersion should be used when the ground is sloped away from the foundation and there is adequate vegetation and area for effective dispersion.
- Splashblocks with downspout extensions can be a good option to disperse roof runoff away from the foundation, buildings, etc.

PERFORATED STUB-OUT CONNECTIONS

- A perforated stub-out connection is a length of perforated pipe within a gravel-filled trench placed between roof downspouts and a stub-out to the DOTA MS4 or drainage system. These systems are intended to provide infiltration during dry periods.
- Downspout dispersion should be used when the ground is sloped away from the foundation and there is adequate vegetation and area for effective dispersion.
- Perforated stub-out connections can also be a good option to disperse roof runoff away from the foundation, buildings, etc.

LIMITATIONS

LANDSCAPED AREAS

- If the site is susceptible to erosion, additional control measures may be necessary during landscaping.

LEVEL SPREADER

- The maximum flow into a level spreader should not exceed 30 ft^3/s.
- The level spreader lip should have a zero slope for proper operation, allowing the discharged water to flow evenly onto the stabilized dispersion area.
- A level spreader is not a sediment trapping or filtering device. Water flowing into the level spreader should be free of sediment.
- Level spreaders are not applicable in areas with easily erodible soils or little vegetation.

SPLASHBLOCKS

- Splashblocks cannot be placed on slopes greater than 20%.

PERFORATED STUB-OUT CONNECTIONS

- Perforated stub-out connections cannot be placed on slopes greater than 20%.
- The seasonal groundwater table should not be less than 1 ft below the stub-out connection bottom.
- During the wet winter months, perforated stub-out connections may provide little or no flow control.

DESIGN CONSIDERATIONS

Design requirements for site design and landscape planning are governed by applicable standards and specifications of federal, state, and county agencies with jurisdiction. The design requirements may pertain to DOT, airport, FAA, Building Code, Fire Code, county agency ordinances, and county zoning requirements. Design requirements described in this fact sheet are meant to enhance and be consistent with these standards, specifications, codes, and ordinance requirements.

LANDSCAPED AREAS

- Vegetation should be selected based on the soil type, soil condition, site topography, climate, seasonal variation, maintenance concerns, aesthetic considerations, water, fertilizer, and pesticide usage.
- Strip and stockpile topsoil. Use stockpiles of topsoil for landscaped areas.
- Roughen the slope or area to be planted by plowing, disking, or raking to a depth of 6-in, with the furrows trending along the contours.
- Plant the grass using sprigs, plugs, or sod, as appropriate.
- Per FAA Regulations, seeds are not to be scattered or applied through hydroseeding.
- If sod tiles are used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels within the dispersion area.
- Roll or compact the sod immediately after installation to verify firm contact with the underlying soil. Tamp down the plugs immediately after installation to provide firm contact with the underlying soil.
- The vegetated flow path should consist of well-established lawn or pasture, landscaping with well-established groundcover, native vegetation with natural groundcover.
- The groundcover should be dense enough to help disperse and infiltrate flows to prevent erosion.
- Apply fertilizer, lime, other soil amendments as indicated by soil testing.
- Irrigate until the vegetation is established and during extended dry periods.

LEVEL SPREADER

- Construct a level spreader on undisturbed soil and not on fill material since undisturbed soil is more resistant to erosion than fill.
- Level spreaders should be level.
- Runoff water containing high sediment loads should use a pretreatment device before being released to a level spreader.
- The length of level spreaders is dependent on inflow rate, pipe diameter (if applicable), number and size of perforations (if applicable), and downhill cover type.
- The level spreader should be long enough to discharge the calculated peak flow rate. At a minimum, the peak flow rate should be from a 10-yr, 24-hr design storm.
- The slope below the level spreader should be relatively smooth in the direction of flow to discourage channelization.
- A perforated pipe level spreader diameter may range in size from 4-in to 12-in.
- The pipe should be laid in an envelope of aggregate (AASHTO #57 or equivalent).
- The thickness of the aggregate envelope is based upon the desired volume reduction.
- Non-woven geotextile should be placed below the aggregate to discourage clogging by sediment.
- Use a rigid outlet lip design (concrete or metal) for high discharge flow conditions (flow greater than the design flow).
- The outlet area below the level spreader should be uniform and well vegetated, having a slope of 10% or less.
- Follow the standards under the Landscaped Areas section above for the vegetated portions.

SPLASHBLOCKS

- Splashblocks should be used for downspouts discharging to a vegetated flow path at least 50 ft in length; the vegetated flow path is measured from the downspout to the downstream property line, stream, wetland, or another impervious surface. Sensitive area buffers may count toward flow path lengths.
- For the purpose of maintaining adequate separation of flows discharged from adjacent dispersion devices, the vegetated flow path segment for the splashblock (or the outer edge of the vegetated flow path segment for the dispersion trench) should not overlap with other flow path segments, except those associated with sheet flow from a non-native pervious surface.
- A maximum of 700 ft^2 of roof area may drain to each splashblock.
- Place a splashblock at each downspout discharge point.
- The downspout should empty onto a splash block, and the splashblock should carry water away from the foundation and prevent erosion.

PERFORATED STUB-OUT CONNECTIONS

- Perforated stub-out connections consist of at least 10 ft of perforated pipe per 5,000 ft^2 of roof area laid in a level 2 ft wide trench backfilled with washed drain rock with a diameter range of ¾-in to 1.50-in.
- Extend the drain rock to a depth of at least 8-in below the bottom of the pipe and cover the pipe.
- Lay the pipe level and cover the rock trench with filter fabric and 6-in of drain rock.

CONSTRUCTION CONSIDERATIONS

- All upstream areas should be stabilized before diverting runoff to any dispersion PBMPs.
- All contributing DOTA MS4 or drainage system elements (inlets, outlets, pipes, storm drains, other PBMPs, etc.) should be installed before installing the dispersion PBMPs.

LANDSCAPED AREAS

- Inspect the grassed areas frequently after the first installation, especially after large storm events, until it is established as permanent cover.

LEVEL SPREADER

- When the level spreader is used as an erosion and sediment control measure, it should be reconfigured (flush perforated pipe and clean out all sediment) to its original state before using it as a dispersion PBMP.
- The perforated pipe should be installed along a contour, with care taken to construct a level bottom.
- Do not allow discharge flow to pond below the level spreader outlet.
- Do not operate vehicles and heavy equipment in the level spreader because they can create surface indentations that can impede flow.

SPLASHBLOCKS

- Splashblocks should be secured and positioned to receive the downspout flow.

PERFORATED STUB-OUT CONNECTIONS

- None.

O&M RECOMMENDATIONS

LANDSCAPED AREAS

- Inspect for dead or diseased vegetation; replant, fertilize and irrigate as needed
- Provide irrigation during extended dry periods, if feasible.
- Cutting or mowing grass will encourage the establishment and spread of grass.

LEVEL SPREADER

- Conduct inspections for debris and sediment accumulation in the level spreader channel. Remove accumulated debris and sediment as needed.
- Maintaining a vigorous vegetative cover on the areas below a level spreader is critical for maximizing pollutant removal efficiency and erosion prevention. The vegetative cover should be sustained at 85% and replaced if damage greater than 50% is observed.

SPLASHBLOCKS

- Inspect for debris and sediment accumulation in the splashblock.

PERFORATED STUB-OUT CONNECTIONS

- Inspect for ponding of water over the perforated stub-out connections. If the water ponds for more than 48 hrs after a rain event, clear the outlet of sediment or trash blockages. If this does not help with the infiltration, the media may be clogged; replace the media.

SC2: Fueling Area Design

PBMP Category

☐ LID
☒ Source Control
☐ Treatment Control

Pollutants Targeted

☐ Bacteria
☒ Metals
☐ Nutrients
☒ Oil & Grease
☒ Organic Compounds
☐ Pathogens
☐ Pesticides
☐ Sediment
☒ Trash
☒ Other: PAHs

Jet Fuel Loading Rack at a Fueling Facility, Kahului Airport

DESCRIPTION

Fueling areas can discharge pollutants such as jet fuel, aviation fuel, diesel, and gasoline to the DOTA MS4, drainage system, or State waters. Spills or releases are a common occurrence at fueling areas due to the nature of the activity and the stored materials. This PBMP includes design recommendations to mitigate those potential impacts.

APPROACH

Project plans should be developed for containment, leak prevention, emergency spill cleanup, and cleaning near fuel dispensers.

SUITABLE APPLICATIONS

Applications include areas planned to have fuel dispensing equipment, including airfield fueling areas, jet fuel dispensing areas, gasoline outlets, and car rental facilities.

LIMITATIONS

None.

DESIGN CONSIDERATIONS

Design requirements for fueling areas are governed by applicable standards and specifications of federal, state, and county agencies with jurisdiction. The design requirements may pertain to DOT, airport, FAA, Building Code, Fire Code, county agency ordinances, and county zoning requirements. Design requirements described in this fact sheet are meant to enhance and be consistent with these standards, specifications, code, and ordinance requirements.

GENERAL

COVERING

- Include an overhanging roof structure or canopy over fuel dispensing areas.
- The fuel dispensing area should be covered, and the cover's minimum dimensions should be equal to or greater than the area within the grade break or the fuel dispensing area, as defined below.
- The cover should not drain onto the fuel dispensing area, and downspouts should be routed to prevent drainage across the fueling area.
- If fueling large equipment or vehicles that prohibit the use of covers or roofs, the fueling island should be designed to accommodate the larger vehicles and equipment and prevent stormwater run-on and runoff.

SURFACING

- Pave fuel dispensing areas with non-porous Portland cement concrete (or equivalent smooth impervious surface) to prevent leaks and spills from seeping into the ground.
- Extend the paved area a minimum of 6.5 ft from the corner of each fuel dispenser, or the length at which the hose and nozzle assembly may be operated plus 1 ft, whichever is greater.
- The use of asphalt concrete or permeable pavement is prohibited.
- Use asphalt sealant to protect asphalt paved areas surrounding the fueling area.

GRADING/CONTOURING

- Dispensing areas should have an appropriate slope to prevent ponding and be separated from the rest of the site by a grade break that prevents run-on of stormwater.
- Grade the fueling areas to drain toward a dead-end sump or vegetated/landscaped area.

DRAINS

- Do not locate storm drains near the fueling area.
- Direct runoff from downspouts/roofs away from fueling and dispensing areas toward vegetated/landscaped areas if possible.

SPILL RESPONSE

- For emergency conditions, provide storm drain seals such as isolation valves, etc., to prevent spills from commingling with stormwater.
- Provide signage for tank operations and emergency shutoff, if applicable.

DESIGNING NEW INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” section of this Fact Sheet.

FUEL CONTAINERS

- Provide secondary containment to the fuel containers and piping. Follow all federal, state, and county regulations are followed.
- Designate an appropriate location for the emergency shutoff in an easily accessible area but a sufficient distance from the fuel pumps for safety purposes. Provide signage indicating the location of the emergency shutoff.

COVERING

- Fuel dispensing areas should provide an overhanging roof structure or canopy.
- The cover’s minimum dimensions should be equal to or greater than the area within the grade break.
- The cover should not drain onto the fuel dispensing area, and the downspouts should be routed to prevent drainage across the fueling area.
- The fueling area should drain to the treatment control PBMP(s) prior to discharging to the DOTA MS4 or drainage system.
- Note: If fueling large vehicles or equipment that would prohibit the use of covers or roofs, the fueling island should be designed to sufficiently accommodate the large vehicles or equipment and prevent stormwater run-on and runoff.
- Grade the fueling areas to direct stormwater to a dead-end sump.

SURFACING

- Use asphalt sealant to protect asphalt paved areas surrounding the fueling area at sites that have existing asphalt surfaces.

GRADING/CONTOURING

- Consider providing a berm around the fueling area such that any spills can be contained. Berms may be utilized in areas where vehicles need to enter and exit the fueling area. Include a discharge drain that may be locked for the bermed area to allow for the release of accumulated, uncontaminated stormwater.

DRAINS

- Route downspouts and storm drains such that runoff will not flow through the dispensing area.

REDEVELOPING EXISTING INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” and the “Design Considerations, Designing New Installation” sections of this Fact Sheet.

CONSTRUCTION CONSIDERATIONS

- None.

O&M RECOMMENDATIONS

- Develop an operations plan that describes procedures for fueling.
- Employ safeguards against accidental releases.
- Protect fueling areas from rainfall, stormwater run-on, and runoff.
- Perform inspections to verify secondary containment devices or systems are water tight.
- Specify all regular and preventive maintenance.
- Maintain the berms or other containment systems such that they have adequate capacity to hold a spill.
- Post signs warning vehicle owners/operators against "topping off" at the fuel dispenser or fuel island.
- Post signs with information on how and to whom spills or releases are to be reported.

SC3: Loading Area Design

PBMP Category

☐ LID
☒ Source Control
☐ Treatment Control

Pollutants Targeted

☐ Bacteria
☒ Metals
☒ Nutrients
☒ Oil & Grease
☒ Organic Compounds
☐ Pathogens
☐ Pesticides
☒ Sediment
☒ Trash
☒ Other: PAHs

Loading Area at a Cargo Facility,
Daniel K. Inouye International Airport

DESCRIPTION

Several measures can be implemented at loading docks to prevent contribution of various pollutants such as oil and grease, heavy metals, nutrients, suspended solids, and trash to the DOTA MS4, drainage system, or State waters. The loading and unloading of materials might result in the discharge of various potential pollutants if the materials were to spill. This PBMP includes design recommendations to mitigate impacts from potential pollutants.

APPROACH

Project plans should be developed for preventative measures to include overflow containment structures and dead-end sumps. Engineered infiltration or other treatment systems may also be considered.

SUITABLE APPLICATIONS

Applications include areas planned for development and redevelopment.

LIMITATIONS

Implementation of covers may be limited depending on the size of the aircraft, vehicle, or equipment that may be loaded or unloaded.

DESIGN CONSIDERATIONS

Design requirements for loading areas are governed by applicable standards and specifications of federal, state, and county agencies with jurisdiction. The design requirements may pertain to DOT, airport, FAA, Building Code, Fire Code, county agency ordinances, and county zoning requirements. Design requirements described in this fact sheet are meant to enhance and be consistent with these standards, specifications, code, and ordinance requirements.

GENERAL

- Designate an area of loading.
- Cover all loading dock areas or design them to preclude stormwater run-on and runoff.
- Do not allow runoff from depressed loading docks (truck wells) to discharge into DOTA MS4, drainage system, or State waters.
- Drain below-grade loading docks from warehouse/distribution centers of fresh food items through water quality inlets, engineered infiltration system, or similar.
- Direct downspouts such that runoff does not flow through the loading areas.
- Grade or berm the loading/unloading area to a drain that is connected to a dead-end.
- Pave loading areas with non-porous Portland cement concrete (or equivalent smooth impervious surface) instead of asphalt.
- Provide containment areas and sumps with impervious surfaces for accumulation of stormwater and non-stormwater since accumulated water can be contaminated. Contaminated stormwater should be disposed of following applicable laws and cannot be discharged directly to the DOTA MS4, drainage system, or State waters.

DESIGNING NEW INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” section of this Fact Sheet.
- Loading dock areas should be covered and drainage should be designed to preclude stormwater run-on and runoff.
- Pretreatment may be required.
- Other features such as impermeable berms, overflow containment structures, etc., may be comparable and equally effective.

REDEVELOPING EXISTING INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” and the “Design Considerations, Designing New Installation” sections of this Fact Sheet.

CONSTRUCTION CONSIDERATIONS

- None.

O&M RECOMMENDATIONS

- Develop an operations plan that describes procedures for loading and unloading.
- Employ safeguards against accidental releases.
- Protect loading areas from rainfall, stormwater run-on, and runoff.
- Perform inspections to verify containment devices or systems are water tight.
- Specify all regular and preventive maintenance.
- Maintain the loading area grade to be sloped or recessed to direct flow toward a drain with a shutoff valve, or toward a dead-end sump.
- Maintain the drain with a shutoff valve or dead-end sump such that they have enough capacity to hold a spill.
- Post signs with information on how and whom spills or releases are to be reported.

SC4: Maintenance Area Design

PBMP Category

☐ LID
☒ Source Control
☐ Treatment Control

Pollutants Targeted

☐ Bacteria
☒ Metals
☐ Nutrients
☒ Oil & Grease
☒ Organic Compounds
☐ Pathogens
☐ Pesticides
☒ Sediment
☒ Trash
☒ Other: PAHs, Solvents, Antifreeze, Paint, etc.

Aircraft Maintenance Hangar,
Daniel K. Inouye International Airport

DESCRIPTION

Aircraft, vehicle, and equipment maintenance/repair may contribute various potential pollutants such as petroleum products, solvents, paints, antifreeze, other vehicle fluids, oil and grease, heavy metals, suspended solids, and trash to the DOTA MS4, drainage system, or State waters. The maintenance/repair activities may result in the discharge of various pollutants in the event of spills or leaks. This PBMP includes design recommendations to mitigate impacts from potential pollutants.

APPROACH

Project plans should be developed for preventative measures to include overflow containment structures and dead-end sumps. Engineered infiltration or other treatment systems may also be considered.

SUITABLE APPLICATIONS

Applications include areas planned for development and redevelopment.

LIMITATIONS

Implementation of covers may be limited depending on the size of the aircraft, vehicle, or equipment that may be maintained.

DESIGN CONSIDERATIONS

Design requirements for the maintenance areas are governed by applicable standards and specifications of federal, state, and county agencies with jurisdiction. The design requirements may pertain to DOT, airport, FAA, Building Code, Fire Code, county agency ordinances, and county zoning requirements. Design requirements described in this fact sheet are meant to enhance and be consistent with these standards, specifications, code, and ordinance requirements.

GENERAL

- Locate maintenance/repair areas indoors or undercover where possible.
- Pave maintenance area/bay floors with non-porous Portland cement or equivalent to prevent leaks and spills from seeping into the ground.
- Provide impermeable berms, trench drains, or other containment systems around the maintenance/repair area to prevent any spilled materials or wash down waters from entering the DOTA MS4, drainage system, or State waters.
- Connect trench drains to sumps or the sanitary sewer through OWSs or other treatment PBMPs.
- Grade or berm the maintenance/repair area to a drain that is connected to a dead-end.
- Provide containment areas and sumps with impervious surfaces for accumulation of stormwater and non-stormwater since accumulated water can be contaminated. Contaminated stormwater should be disposed of following applicable laws and cannot be discharged directly to the DOTA MS4, drainage system, or State waters.
- Collected spilled materials or wash-down waters from the maintenance/repair areas should be directed to OWSs or other treatment devices.
- Designate locations for material and waste storage.
- Provide secondary containment for liquids and batteries. Follow all federal, state, and county regulations are followed.

DRAINS

- Direct connection from maintenance bays into the DOTA MS4, drainage system, or State waters is prohibited.
- Do not allow runoff or wash-down waters from the maintenance/repair area to discharge into DOTA MS4, drainage system, or State waters.
- Route downspouts and storm drains such that runoff will not flow through the maintenance/repair area.

SPILL RESPONSE

- For emergency conditions, provide storm drain seals such as isolation valves, etc., to prevent spills from commingling with stormwater.

DESIGNING NEW INSTALLATIONS

- Implement the applicable PBMPs from the "Design Considerations, General" section of this Fact Sheet.
- Maintenance/repair areas should be covered, or drainage should be designed to preclude stormwater run-on and runoff.
- Pretreatment may be required.

REDEVELOPING EXISTING INSTALLATIONS

- Implement the applicable PBMPs from the "Design Considerations, General" and the "Design Considerations, Designing New Installation" sections of this Fact Sheet.

CONSTRUCTION CONSIDERATIONS

- None.

O&M RECOMMENDATIONS

- Develop an operations plan that describes procedures for conducting maintenance/repair activities.
- Employ safeguards against accidental releases.
- Protect maintenance areas from rainfall, stormwater run-on, and runoff.
- Perform inspections to verify containment devices or systems are water tight.
- Specify all regular and preventive maintenance.
- Maintain the maintenance area grade to be sloped or recessed to direct flow toward a drain with a shutoff valve, or toward a dead-end sump.
- Maintain the drain with a shutoff valve, dead-end sump, impermeable berms, trench drains, or other containment systems such that they have adequate capacity to hold a spill.
- Protect the area such that if maintenance/repair areas are washed, the wash water is collected and directed to the sanitary sewer if allowable.
- Post signs with information on how and to whom spills or releases are to be reported.

SC5: Material Storage Area Design

PBMP Category

☐ LID
☒ Source Control
☐ Treatment Control

Pollutants Targeted

☐ Bacteria
☒ Metals
☒ Nutrients
☒ Oil & Grease
☒ Organic Compounds
☐ Pathogens
☒ Pesticides
☒ Sediment
☒ Trash
☒ Other: Depending on type of material stored

Material Storage Area with a Containment Berm at a Hangar, Daniel K. Inouye International Airport

DESCRIPTION

The proper design of a material storage location will reduce the potential for pollutants to impact the DOTA MS4, drainage system, or State waters. Since material spills may occur in these areas, PBMPs should center on containment and cover.

The material storage may result in a pollutant discharge to the to the DOTA MS4, drainage system, or State waters in the event of spills or leaks and will be dependent upon the type of material stored.

Accumulated material on an impervious surface could result in a significant impact on the DOTA MS4, drainage system, or State waters. This PBMP includes design recommendations to mitigate impacts from potential pollutants.

APPROACH

Outdoor material storage areas require a drainage approach different from the typical infiltration or detention strategy. Containment and preventative measures such as enclosures, secondary containment structures, and impervious surfaces are considered best practices and are encouraged.

SUITABLE APPLICATIONS

Applications include areas planned for development and redevelopment.

LIMITATIONS

Implementation of covers may be limited depending on the materials being stored and the timeframe for storage.

DESIGN CONSIDERATIONS

Material may be stored in various ways, including bulk piles, containers, shelving, stacking, and tanks. Stormwater contamination may be prevented by reducing the possibility of stormwater contact with the material storage areas either through diversion, cover, or capture of the stormwater. Control measures may also include minimizing the storage area.

Design requirements for the material storage areas are governed by applicable standards and specifications of federal, state, and county agencies with jurisdiction. The design requirements may pertain to DOT, airport, FAA, Building Code, Fire Code, county agency ordinances, and county zoning requirements. Design requirements described in this fact sheet are meant to enhance and be consistent with these standards, specifications, code, and ordinance requirements.

GENERAL

- Design material storage areas to be indoors or undercover, if feasible. Cover all material storage areas, or design them to preclude stormwater run-on and runoff. For areas that should be uncovered (e.g., material stockpile), contain the site with berms, trench drains, or other systems.
- Pave the material storage area with non-porous Portland cement or equivalent to prevent leaks and spills from seeping into the ground.
- Provide secondary containment for materials with the potential to contaminate stormwater; secondary containment can include structures such as berms, dikes, curbs, etc., or an enclosure that prevents contact with stormwater runoff. Secondary containment for liquids and batteries may include spill pallets, double-walled tanks, or other appropriate methods.
- Provide containment for outdoor materials (e.g., stockpile kept on-site for longer periods) using berms, concrete walls, trench drains or other containment systems around the material storage area to prevent any spilled liquids from entering the DOTA MS4, drainage system, or State waters.
- Provide containment areas and sumps with impervious surfaces for accumulation of stormwater and non-stormwater since accumulated water can be contaminated. Contaminated stormwater should be disposed of following applicable laws and cannot be discharged directly to the DOTA MS4, drainage system, or State waters.
- Connect trench drains to sumps or the sanitary sewer through OWSs or other treatment devices.

DRAINS

- Direct connection from material storage areas into DOTA MS4, drainage system, or State waters is prohibited.
- Route downspouts and storm drains such that runoff will not flow through the material storage areas.

SPILL RESPONSE

- For emergency conditions, provide storm drain seals such as isolation valves, etc., to prevent spills from commingling with stormwater.

DESIGNING NEW INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” section of this Fact Sheet.
- Material storage areas should be covered and drainage should be designed to preclude stormwater run-on and runoff.
- The storage area should have a roof or awning that extends beyond the storage area to minimize stormwater collection within the secondary containment area. A manufactured storage shed may be used for small containers.
- Pretreatment may also be required.

REDEVELOPING EXISTING INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” and the “Design Considerations, Designing New Installation” sections of this Fact Sheet.

CONSTRUCTION CONSIDERATIONS

- None.

O&M RECOMMENDATIONS

- Develop an operations plan that describes procedures for material storage.
- Employ safeguards against accidental releases.
- Protect material storage areas from rainfall, stormwater run-on, runoff, and wind dispersal.
- Perform inspections to verify containment devices or systems are water tight.
- Specify all regular and preventive maintenance.
- Maintain the sumps, impermeable berms, trench drains, or other containment systems such that they have adequate capacity to hold a spill.
- Protect the area such that if material storage areas are washed, the wash water is collected and directed to the sanitary sewer if allowable.
- Post signs with information on how and whom spills or releases are to be reported.

SC6: Trituator Facility Design

PBMP Category

☐ LID
☒ Source Control
☐ Treatment Control

Pollutants Targeted

☒ Bacteria
☐ Metals
☒ Nutrients
☐ Oil & Grease
☒ Organic Compounds
☒ Pathogens
☐ Pesticides
☐ Sediment
☒ Trash
☒ Other: Lavatory waste

Triturator Facility at Kahului Airport

DESCRIPTION

The proper design of a triturator facility will reduce the potential for pollutants associated with servicing of aircraft lavatory facilities that may impact DOTA MS4, drainage system, or State waters. The sanitary sewage and associated rinse waters produced during the servicing of aircraft lavatory facilities should pass through a special grinder known as a triturator, which grinds the contents into small enough pieces to enter the sanitary sewer system safely. Due to the potential of spills at the triturator facilities, PBMPs focus on containment and pollution prevention.

APPROACH

The lavatory waste removed from the aircraft is transported to a triturator facility, generally located airside, near airline operations, for pretreatment prior to discharge to the sanitary sewage system. Triturator facilities require containment and preventative measures such as enclosures, impervious surfaces, etc.

SUITABLE APPLICATIONS

Applications include areas planned for development and redevelopment.

LIMITATIONS

Implementation of berms at the triturator facilities may be limited depending on the size of the trucks or trailers equipped with bulk storage containers used to service lavatory facilities.

DESIGN CONSIDERATIONS

Design requirements for triturator facilities are governed by applicable standards and specifications of federal, state, and county agencies with jurisdiction. The design requirements may pertain to DOT, airport, FAA, Building Code, Fire Code, county agency ordinances, and county zoning requirements. Design requirements described in this fact sheet are meant to enhance and be consistent with these standards, specifications, code, and ordinance requirements.

GENERAL

- Triturator facilities should be designed with low roll-over type berming.
- A water source should be included at the triturator facility to conduct cleanout and backflushing of the lavatory service equipment.
- Pave the triturator facility area with non-porous Portland cement or equivalent to prevent leaks and spills from seeping into ground.
- A triturator facility should be designed away from storm drains to preclude stormwater run-on and runoff.
- Direct downspouts such that runoff does not flow through the triturator facility.
- Triturator facilities should be designed to provide the required volume disposal from aircraft bulk tanks into the sanitary sewer system.
- Slope the triturator facility towards the floor drain leading to the triturator to capture the lavatory wastes.
- Provide signage indicating how to conduct operations at the triturator facility.

DRAINS

- Route downspouts and storm drains such that runoff will not flow through the triturator area.

SPILL RESPONSE

- For emergency conditions, provide storm drain seals such as isolation valves, etc., to prevent spills from commingling with stormwater.

DESIGNING NEW INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” section of this Fact Sheet.
- The triturator facility should include a cover and low roll-over type berming.
- A triturator facility should be designed away from storm drains to preclude stormwater run-on and runoff and dragout after disposal.
- The triturator (grinder) should be a closed, self-contained, below-grade, automated station designed to allow for the simple, clean, and efficient disposal of sewage pumped from airplane lavatories.
- A water flush system should be provided at the facility to conduct cleanout and backflushing of the lavatory service equipment.
- The triturator (grinder) and water flush system can be designed to start automatically when the lavatory vehicle enters the facility and turns off when the vehicle exits.
- The triturator facility can be designed to have vehicle stops or signage to verify the lavatory service equipment parks right on top of the floor drain leading to the triturator.
- Slope the triturator facility towards a floor drain leading to the triturator.
- Pretreatment may be required.

REDEVELOPING EXISTING INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” and the “Design Considerations, Designing New Installation” sections of this Fact Sheet.

CONSTRUCTION CONSIDERATIONS

- None.

O&M RECOMMENDATIONS

- Develop an operations plan that describes procedures for triturator operations.
- Employ safeguards against accidental releases.
- Protect triturator facility from rainfall, run-on, runoff, and wind dispersal.
- Perform inspections to verify containment devices or systems are water tight.
- Specify all regular and preventive maintenance.
- Maintain the triturator facility grade to be sloped to direct flow toward floor drain capturing the lavatory waste.
- Provide a method for inspection of the triturator facility containment and clean up/discharge of spill material.
- Post signs with information on how and whom spills or releases are to be reported.

SC7: Washing Area Design

PBMP Category

☐ LID
☒ Source Control
☐ Treatment Control

Pollutants Targeted

☐ Bacteria
☒ Metals
☒ Nutrients
☒ Oil & Grease
☒ Organic Compounds
☐ Pathogens
☐ Pesticides
☒ Sediment
☐ Trash
☒ Other: Surfactants, paints, etc.

East Wash Rack, Daniel K. Inouye International Airport

DESCRIPTION

Aircraft, vehicle, and equipment washing may result in various pollutants associated with washing activities such as surfactants, sediment, and petroleum products. This PBMP includes design recommendations to mitigate those potential impacts.

APPROACH

Project plans should include appropriately designed area(s) for washing aircraft, vehicles, and equipment. Depending on the size and other parameters of the facility, wash water may be conveyed to a sewer, an infiltration system, a recycling system, or another alternative. Pretreatment may be required for a discharge to a sanitary sewer.

SUITABLE APPLICATIONS

Applications include areas planned for development and redevelopment.

LIMITATIONS

Implementation of covers may be limited by the size of aircraft, vehicle, or equipment that requires washing.

DESIGN CONSIDERATIONS

Design requirements for the washing areas are governed by applicable standards and specifications of federal, state, and county agencies with jurisdiction. The design requirements may pertain to DOT, airport, FAA, Building Code, Fire Code, county agency ordinances, and county zoning requirements. Design requirements described in this fact sheet are meant to enhance and be consistent with these standards, specifications, code, and ordinance requirements.

GENERAL

- Design the washing area to be contained and to prevent dragout of wash water. The design should include grading the site to a central drain, placing berms around the perimeter, locating it indoors or under cover (if feasible), or some other containment method.
- Discharge wash water to the sanitary sewer, a holding tank, process treatment system, or an enclosed recycling system.
  - Include a wash water treatment device or pretreatment device such as an OWS.
  - Consider recycling the water after filtration or direct excess to the sanitary sewer, where county ordinances allow.
  - Install sumps or drain lines to collect wash water. Divert wash water to the sanitary sewer or an equally effective alternative.
  - Slope the washing area towards a dead-end sump to contain spills.
  - Provide containment areas and sumps with impervious surfaces for accumulation of stormwater and non-stormwater since accumulated water can be contaminated. Contaminated stormwater, should be disposed of following applicable laws and cannot be discharged directly to the DOTA MS4, drainage system, or State waters.
- Provide identification for the wash area and signage about approved washing practices.

DRAINS

- Prevent stormwater runoff from flowing through the washing area.
- Route downspouts and storm drains such that runoff will not flow through the washing area.
- Direct and divert stormwater runoff away from the washing area and the exposed area around the washing area to alternatives other than the sanitary sewer.

DESIGNING NEW INSTALLATIONS

- Implement the applicable PBMPs from the "Design Considerations, General" section of this Fact Sheet.
- The washing area should be self-contained and include a roof or an overhang.
- Pretreatment may be required.
- The washing area should have a proper connection to a sanitary sewer, where county regulations allow.

REDEVELOPING EXISTING INSTALLATIONS

  - Implement the applicable PBMPs from the “Design Considerations, General” and the “Design Considerations, Designing New Installation” sections of this Fact Sheet.

CONSTRUCTION CONSIDERATIONS

- None.

O&M RECOMMENDATIONS

- Develop an operations plan that describes procedures for washing.
- Mark the area clearly as a wash area.
- Protect wash area from rainfall, run-on, runoff, and wind dispersal.
- Perform inspections to verify containment devices or systems are water tight.
- Specify all regular and preventive maintenance.
- Maintain the wash area grade to be sloped or recessed to direct flow to the sanitary sewer, a holding tank, process treatment system, or an enclosed recycling system.
- Maintain the containment areas and sumps such that they have adequate capacity to hold a spill.
- Post signs stating that washing is only allowed in the wash area.

SC8: Waste Management Area Design

PBMP Category

☐ LID
☒ Source Control
☐ Treatment Control

Pollutants Targeted

☐ Bacteria
☒ Metals
☐ Nutrients
☐ Oil & Grease
☐ Organic Compounds
☐ Pathogens
☐ Pesticides
☒ Sediment
☒ Trash
☒ Other: Depending on the waste

Waste Management Area, Daniel K. Inouye International Airport

DESCRIPTION

Improper waste management can result in various contaminants being discharged by stormwater runoff. Specifically, pollution may occur when loose trash and debris are dispersed by the wind, comes in contact with stormwater runoff or when waste containment devices leak. Additional contaminants may be discharged to the stormwater dependent upon the waste being stored or handled. This PBMP includes designs to mitigate the impact of outdoor waste storage and disposal.

APPROACH

Project plans should include preventive measures such as enclosures, containment structures, and impervious pavements to mitigate spills and reduce the likelihood of contamination.

SUITABLE APPLICATIONS

Applications include areas planned for development and redevelopment.

LIMITATIONS

None.

DESIGN CONSIDERATIONS

Design requirements for waste management areas are governed by applicable standards and specifications of federal, state, and county agencies with jurisdiction. The design requirements may pertain to DOT, airport, FAA, Building Code, Fire Code, county agency ordinances, and county zoning requirements. Design requirements described in this fact sheet are meant to enhance and be consistent with these standards, specifications, code, and ordinance requirements.

Wastes from airports are typically hauled by commercial carriers that may have design or access needs for waste storage areas. The design criteria in this fact sheet are recommendations and not intended to conflict with the needs of the waste hauler. The waste hauler should be contacted prior to the design of the project site trash collection areas. Any conflicts should be discussed with the DOTA.

GENERAL

- Designate a waste area that is out of the path of stormwater flow.
- Berm trash storage areas to prevent run-on from adjoining roofs and pavement or grade areas towards vegetated/landscaped areas.
- Prevent rainfall from entering containers with roofs, awnings, or attached lids.
- Pave waste storage areas with an impervious surface to prevent leaks and spills from seeping into ground and allow for easier cleanup of spills.
- Provide signage to indicate the types of wastes that can be disposed of within the areas.
- Provide secondary containment for materials with the potential to contaminate stormwater; secondary containment can include structures such as berms, dikes, curbs, etc., or an enclosure that prevents contact with stormwater runoff. Secondary containment for liquids and batteries may include spill pallets, double-walled tanks, or other appropriate methods.

DRAINS

- Do not locate waste storage areas near storm drains.
- Route downspouts and storm drains such that runoff will not flow through the waste management areas.

DESIGNING NEW INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” section of this Fact Sheet.
- Design waste container areas so that drainage from adjoining roofs and pavement is diverted around the area(s) to avoid run-on. The design should include berming or grading the waste handling area to prevent run-on of stormwater.
- Make sure waste container areas are screened or walled to prevent off-site transport of trash by wind dispersion.
- Provide roofs, awnings, or attached lids on all trash containers to minimize direct precipitation and prevent rainfall from entering containers.

REDEVELOPING EXISTING INSTALLATIONS

- Implement the applicable PBMPs from the “Design Considerations, General” and the “Design Considerations, Designing New Installation” sections of this Fact Sheet

CONSTRUCTION CONSIDERATIONS

- None.

O&M RECOMMENDATIONS

- Develop an operations plan that describes procedures for waste management.
- Employ safeguards against accidental releases.
- Protect the waste area from rainfall, run-on, runoff, and wind dispersal.
- Perform inspections to verify containment devices or systems are water tight.
- Specify all regular and preventive maintenance.
- Maintain the berms, dikes, curbs, or other containment systems such that they have adequate capacity to hold a spill.
- Protect the area such that if waste storage areas are washed, the wash water is collected and directed to the sanitary sewer if allowable.
- Do not permit any discharges from the waste storage area to enter the DOTA MS4, drainage system, or State waters.
- Post signs with information on how and to whom spills or releases are to be reported.

Appendix V

Treatment Control PBMP Design Fact Sheets

Appendix V

Treatment Control PBMP Design Fact Sheets

This Appendix describes specific Treatment Control PBMPs to be considered for incorporation into new development and redevelopment projects at DOTA airports including retrofit projects to meet stormwater management objectives.

Treatment Control PBMPs are required for all non-exempt projects that do not qualify for a PBMP Variance with site conditions where LID PBMPs are infeasible. LID PBMPs should be considered first before implementing Treatment Control PBMPs.

The following lists the various Treatment Control PBMP types to be considered, and may include the use of more than one depending on site specific conditions:

- TC-1: Alternative Wetland
- TC-2: Dry Detention Basin
- TC-3: Evaporation Pond
- TC-4: Hydrodynamic Separator Unit
- TC-5: Manufactured Treatment Device
- TC-6: Oil Water Separator
- TC-7: Sand Filter
- TC-8: Subsurface Detention

The following information is provided for each of the above-listed Treatment Control PBMP Fact Sheets:

- PBMP Category
- Pollutants Targeted
- Description
- Limitations
- Design Guidelines
- Construction Considerations
- Example Schematics

Please refer to Appendix VII for the corresponding O&M Fact Sheets.

TC-1: Alternative Wetland

PBMP Category

☐LID
☐Source Control
☒Treatment Control

Pollutants Targeted*

☒Bacteria
☒Metals
☒Nutrients
☐Oil & Grease
☐Organic Compounds
☒Pathogens
☐Pesticides
☒Sediment
☒Trash
☒Other: Varies

*Pollutant removal may vary based on modular wetland type.

Floating wetland in Kaanapali Lagoon, Maui
Source: West Maui Ridge 3 Reef Initiative

DESCRIPTION

Alternative wetlands considered at airports may include floating wetland (also known as floating treatment wetland or FTW) or modular wetland.

The FTW is constructed of a buoyant artificial floating raft and consists of a suspended matrix with aquatic wetland plants. A raft is placed in a polluted body of waterways (such as a canal) or ponds, and the plants draw pollutants out of the water. Depending on the type of plant, the pollutant will either be stored in the plant or metabolized. The floating treatment wetland technology is an emerging approach used for treating stormwater containing nutrients with various aquatic plants. FTW can be considered retrofit.

Modular wetlands are proprietary biotreatment devices approved by the Washington State University TAPE, NJDEP, California Water Resources Control Board, Virginia Department of Environmental Quality, etc. This is a small wetland that can be created adjacent to storm drains for basic stormwater treatment and enhanced treatment, including sediment, nutrients, and heavy metals uptake. The modular wetland functions differently than an FTW; the modular wetland includes various components and provides water quality by removing various pollutants depending proprietary biotreatment device. The pollutant removal performance may vary depending on the type and model of the proprietary modular wetland selected for the project. Therefore, project proponents need to review the manufacturer's specifications for modular wetlands to determine pollutants targeted for removal.

Wildlife deterrence should be a top priority to assure that the alternative wetlands do not pose a safety hazard to aircraft.

LIMITATIONS

- FAA requires that wildlife attractants be limited within the airport due to the safety threat they pose to aircraft. As such, the wetlands shall be designed such that they do not pose this risk.
- Vegetation disposal may also need to be considered.

FLOATING TREATMENT WETLANDS

- FTWs can only be installed as a retrofit on an existing waterway (such as a canal) or pond (wet pond).
- Anchoring FTWs can be a challenge due to wind shock, hydraulic flow, and float material integrity.
- FTWs occupy open water surfaces and block access or reduces available area for a waterway or pond recreational use.
- For maximum nutrient-removal efficiency, FTWs need to be harvested or removed seasonally.
- FTWs are infeasible if the depth from FTW raft to waterway or pond bottom is 3.50 ft or less.

MODULAR WETLANDS

- Follow the manufacturer's instructions for any limitations.

DESIGN GUIDELINES

GENERAL

- Determine the type of alternative wetland needed and the size of the area to be treated.
- Pick hardy plants common to Hawaii to limit the watering and landscaping requirements.
- Design the storm drain so that the water will be directed through the plant bed before entering the DOTA MS4, drainage system, or State waters.
- Provide a bypass valve for heavy stormwater flows.
- Consider including a trap to collect large debris items to prevent the vegetation bed from clogging.
- Perform a water balance to demonstrate that a wetland can withstand a 30-day drought at summer evaporation rates without completely drawing down if needed.

FLOATING TREATMENT WETLANDS

- FTWs can be located in existing waterways or ponds primarily as retrofits.
- FTW units are placed perpendicular to the flow path.
- FTWs located near the shoreline attenuate wave action and reduce undercutting and bank/shoreline erosion.
- Anchoring should allow the FTW to rise and fall with changes in water level.
- FTWs should be adequately anchored or tethered in the waterway or pond to protect its flood control function during major storms and enable retrieval for periodic maintenance, yet anchoring should not be too taut to inundate the surface and flood the raft.
- Pre-plant the vegetation and anchor it in the water (canal or stream).
- Construct the FTW by pinning potted plants or using coir or other compatible substance for the base.
- The raft should be placed perpendicular to the stormwater flow path and be at least 3.50 ft above the bottom of the waterway or pond.
- There can be modular FTWs that can be used independently or connected. Follow the manufacturer's instructions for design guidelines.

MODULAR WETLANDS

- Follow the manufacturer's instructions for design guidelines.

PRETREATMENT CONSIDERATIONS

FLOATING TREATMENT WETLANDS

- None.

MODULAR WETLANDS

- Some models may incorporate advanced pretreatment chambers that include separation and pre-filter cartridges.

AREA REQUIREMENTS

FLOATING TREATMENT WETLANDS

- FTW should achieve a minimum waterway or pond surface coverage of 10 % and a maximum waterway or pond surface coverage of no more than 50 %.
- Follow the manufacturer's instructions for any other type of modular FTW.

MODULAR WETLANDS

- The modular wetland can be designed in several configurations depending on the location, space availability, site conditions, and treatment requirements. Follow the manufacturer's instructions for any other type of modular wetland.

MINIMUM DESIGN CRITERIA

FLOATING TREATMENT WETLANDS

- The minimum design criteria for the FTW required to treat a drainage area is not well documented. Currently, FTWs are used as retrofits to either increase the performance or function of an existing waterway or pond.
- Follow the manufacturer's instructions for minimum design criteria for any other type of modular FTW.

MODULAR WETLANDS

- Follow the manufacturer's instructions for minimum design criteria.

SIZING GUIDELINES

FLOATING TREATMENT WETLANDS

- Most FTW are implemented as a retrofit and can be expanded if results indicate more footprint is required to achieve the discharge criteria within existing waterways or ponds (based on the targeted pollutants of concern).
- Follow the manufacturer's instructions for sizing guidelines to size any other type of modular FTW.

MODULAR WETLANDS

- Follow the manufacturer's instructions for sizing guidelines.

CONSTRUCTION CONSIDERATIONS

FLOATING TREATMENT WETLANDS

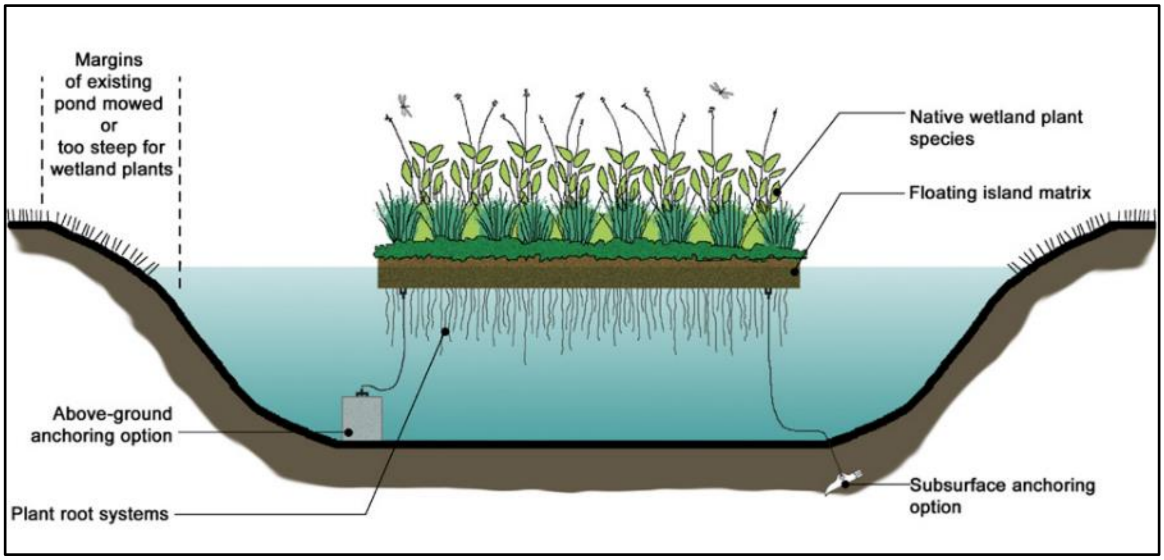
- The floating matrix is usually manufactured off-site and assembled at the desired location.
- The establishment of the plants may require 6-12 months, depending on location and weather conditions.
- Follow the manufacturer's instructions for construction considerations for any other type of modular FTW.

MODULAR WETLANDS

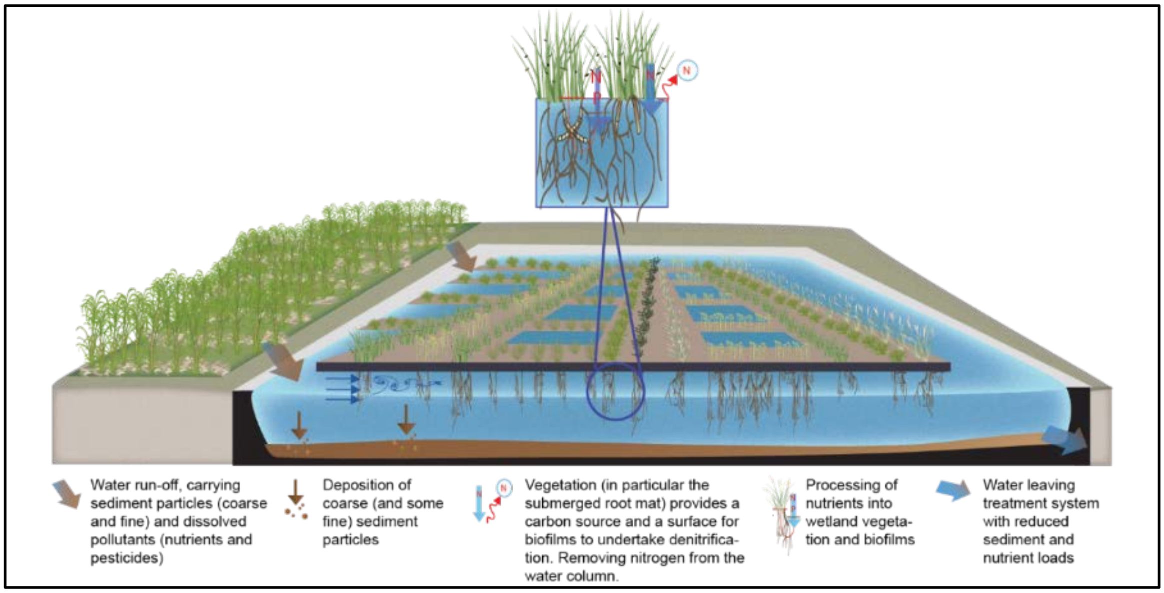
- Follow the manufacturer's instructions for construction considerations.

EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Schematic of a Floating Treatment Wetland
Source: Texas Community Watershed Partners



Schematic of a Floating Treatment Wetland Processes
Source: Texas Community Watershed Partners

TC-2: Dry Detention Basin

PBMP Category

☐LID
☐Source Control
☒Treatment Control

Pollutants Targeted

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☐Organic Compounds
☒Pathogens
☐Pesticides
☒Sediment
☒Trash
☐Other:

Detention Basin at Kahului Airport

DESCRIPTION

Dry detention basins can provide stormwater quantity control and improve water quality using shallow man-made impoundment that provides for the temporary storage of stormwater runoff to allow particles to settle. Dry detention basins contain stormwater flow and retain the water until it can be released slowly over time. Dry detention basins can also be used to provide flood control by including flood detention storage. Dry detention basins do not have a permanent pool and are designed to drain completely between storm events.

Wildlife deterrence should be a top priority to assure that the dry detention basin does not pose a safety hazard to aircraft.

LIMITATIONS

- Dry detention basins are ineffective at removing soluble pollutants.
- Dry detention basins are considered infeasible if any of the following conditions are met.
  - Basins with standing water for a duration longer than 48 hrs.
  - Basin invert would be below the seasonally high groundwater table.
  - Unable to operate with a safe overflow mechanism.
  - The FAA recommends that airports avoid detention basins with standing water.
  - Sited within the required setback distance from the AOA.
  - Basin includes wildlife attractants.
  - Sited within 20 ft of any building foundation.
  - Located within 35 ft from a drinking water well.
- Dry detention basins may not be suitable near septic tanks, drain fields, fill sites, or steep, unstable slopes.

DESIGN GUIDELINES

- Dry detention basins should be designed, engineered, constructed, and maintained for a maximum 48–hr detention period after the design storm event and remain completely dry between storm events per *FAA AC 150/5200-33B*.
- Dry detention basins should have enough available storage so that they perform adequately in multiple-day rain events.
- Dry detention basins can also include a two-cell design: the upper cell that remains dry and the lower cell of the detention basin detains water for an extended period following consecutive storm events but should need to be designed with additional wildlife deterrent measures.
- When dry detention basins do not draw down completely, project proponents may use physical barriers, bird balls, wire grids, floating covers, vegetation barriers (bottom liners), pillows, or netting, to prevent access to hazardous wildlife to open water thereby preventing aircraft-wildlife interactions.
- When physical barriers are proposed, project proponents should evaluate their use, effectiveness, and maintenance requirements. Project proponents must assure physical barriers do not adversely affect water rescue. Before installing any physical barriers over detention basins according to *14 CFR § 139* airports, project proponents should obtain approval from DOTA and the appropriate FAA Regional Airports Division Office.
- Use steep-sided, riprap or concrete-lined, narrow, linear-shaped water detention basins to facilitate the control of hazardous wildlife.
- Where a constant water flow is anticipated through the basin, or where any portion of the basin bottom may remain wet, the detention basin should include a concrete or paved pad or ditch/swale in the bottom to prevent vegetation propagation that may provide nesting habitat.
- Basin bottoms should have a gradient such that the outlet/control structure is at the absolute lowest point (so that the basin drains down) and located in the enclosed or covered downstream cell of the basin.
- All vegetation in or around detention basins that provide food or cover for hazardous wildlife should be eliminated.
- The general design of detention basins should consist of the following elements:
  - An outlet control structure;
  - An overflow spillway; and
  - Maintenance access.
- Outlet control structures can be catch basins or manholes with a restrictor device to control the discharge from a detention basin, and may consist of an orifice, weir, outlet pipe, etc. Stage is the depth of water, as defined by the absolute distance from the water surface to the bottom of the water body when it has certain volume of water. Combinations of orifices, weirs, and pipes can provide multi-stage outlet control

for different control volumes (i.e., water quality protection volume, streambank protection volume, and flood control volume).

- Provide a low flow orifice capable of discharging the water quality volume over 48 hrs.
- Provide weirs for overflow of the streambank protection volume and flood control volume. Overflow weirs can also be of different heights and configurations, including sharp-crested weirs, broad-crested weirs, v-notch weirs, etc., to maintain control of multiple design flows.
- Design an overflow spillway to contain or pass the 100-yr storm event depending on the project requirements.
- Routing calculations should demonstrate that the storage volume is adequate.
- Water should not be discharged from the detention basins in an erosive manner. Riprap, plunge pools or pads, or other energy dissipaters should be placed at the end of the outlet to prevent scouring and erosion.
- A high flow bypass should be included in the detention basin design to address instances of significant rainfall, outlet structure blockage, or mechanical failure. The bypass should be located so that high flow discharges will not impact downstream structures.
- Maintenance access should be provided over the inlet pipe and outflow structure. Maintenance access openings can consist of a standard frame, grate and solid cover, or a removable panel.
- If the embankment falls under the jurisdiction of the State of Hawaii, DLNR Engineering Division, Dam Safety Program, it shall be designed to meet the applicable requirements, or these requirements, whichever are more stringent.

Pretreatment Considerations

If significant amounts of sediment or sand are anticipated at the site, pretreatment can be accomplished using a vegetated filter strip, biofiltration swale, or manufactured treatment device.

A sediment forebay can be used where it does not pose as a wildlife attractant. A sediment forebay should be located at each major inlet to provide pretreatment, preserve the basin’s capacity, and reduce maintenance requirements in the basin. The forebay consists of a separate cell that drains into the main basin, formed with an acceptable barrier, such as an earthen berm or gabion baskets, etc.). If used, the total volume of all forebays should be at least 5% of the total WQV.

Area Requirements

A detention basin requires a footprint equivalent to 1% - 9% of its contributing impervious drainage area. The actual value depends on several variables, including the drainage area, pre-project and post-project runoff coefficients, and basin depth. Footprints at the lower range reflect deep basins (e.g., 8 ft) serving large drainage areas (e.g., 50 ac), while footprints at the upper range reflect shallow basins (e.g., 1 ft) serving small drainage areas (e.g., 1 ac).

MINIMUM DESIGN CRITERIA

Design Parameter	Units	Value
Maximum Interior Side Slope (length per unit height)	ft/ft	2:1
Maximum length to width ratio		3:1
Maximum depth	ft	8
Drawdown (drain) time for WQV	hrs	48 or less
Drawdown (drain) time for 50% of WQV	hrs	24
Basin invert slope	%	1 - 2
Minimum Depth from Basin Invert to Groundwater	ft	3
Minimum Outlet Size	in	4
Minimum Freeboard	ft	1

SIZING GUIDELINES

Dry detention basins must be sized to provide adequate capacity to capture the WQV and a complete drawdown within 48 hrs. The following is a simplified method for sizing a trapezoidal dry detention basin (assuming the same side and end slopes). Other design methods or modeling procedures may be used at project proponent's discretion but are subject to approval by the DOTA.

Step 1: Use the procedure presented below to compute the pre-project (i.e., undeveloped) and post-project (i.e., developed) weighted runoff coefficients. For drainage areas containing multiple land uses, the following formula may be used to compute a composite weighted runoff coefficient (refer to section 4.3.2):

$$\mathbf{C_C = [(\sum_{i=1}^{n} C_i A_i)/A_t]}$$

where C_C = Composite Weighted Runoff Coefficient
$C_{1,2,..n}$ = Runoff Coefficient for each Land Use Cover Type
$A_{1,2,..n}$ = Drainage Area to each Land Use Cover Type (ac)
n = Number of Land Use Cover Types within the Drainage Area
A_t = Total Drainage Area (ac)

Compute the peak flow rate into the basin using the Rational method:

$$\mathbf{q_i = C_{post} i A}$$

where q_i = Peak Flow Rate into the Basin (cfs)
C_{post} = Post-project Weighted Runoff Coefficient
i = Peak Rainfall Intensity (in/hr) (refer to section 4.3.2)
A = Tributary Drainage Area (ac)

Step 2: Compute the peak flow rate leaving the basin using the pre-project runoff coefficient, which effectively requires the detention basin to maintain the pre-project discharge rates:

$$\mathbf{q_o = C_{pre}iA}$$

where q_o = Peak Flow Rate leaving Basin (cfs)
C_{pre} = Pre-project Weighted Runoff Coefficient
i = Peak Rainfall Intensity (in/hr)
A = Tributary Drainage Area (ac)

Step 3: Calculate the basin storage volume required:

$$\mathbf{SV_{reqd} = 3{,}630 \times PA\ [1- (q_o/q_i)]}$$

where SV_{reqd} = Storage Volume Required (ft^3)
P = Design Storm Runoff Depth (in)
A = Tributary Drainage Area (ac)
q_o = Peak Flow Rate leaving the Basin (ft^3) from Step 2
q_i = Peak Flow Rate into the Basin (ft^3) from Step 1

Step 4: Select initial values for the detention basin total width (w_t), total length (l_t), and depth (d) based on space availability, topography and existing drainage facilities. Also select values for the interior side slope (z) and required freeboard (f). Calculate the basin invert width and invert length:

$$\mathbf{w_b = w_t - 2z(d+f)}$$

$$\mathbf{l_b = l_t - 2z(d+f)}$$

where w_b = Basin Bottom Width (ft)
l_b = Basin Bottom Length (ft)
w_t = Basin Total Width (ft)
l_t = Basin Total Length (ft)
z = Basin Interior Side Slope (ft/ft)
d = Depth of Flow for Storage Volume (ft)
f = Freeboard (ft)

Step 5: Calculate the resulting storage volume using the prismoidal formula for trapezoidal basins:

$$\mathbf{SV_{calc} = (w_bl_bd + (w_b+l_b)zd^2 + 4z^2d^3/3}$$

where SV_{calc} = Volume of Trapezoidal Basin (ft^3)
w_b = Basin Bottom Width (ft) from Step 4
l_b = Basin Bottom Length (ft) from Step 4
d = Depth of Flow for Storage Volume (ft) from Step 4
z = Basin Interior Side Slope from Step 4

If the dry detention basin is a different shape (not a trapezoidal basin), the resulting storage volume should be used instead of using the formula above.

Compare the calculated storage volume (SV_{calc}) to the required volume (SV_{reqd}) from Step 3. If the calculated volume is greater than or equal to the required volume, the selected dimensions (w_t and l_t) and depth (d) are adequate for preliminary design. If the calculated volume is less than the required volume, increase the dimensions or the depth (d) and repeat Steps 4 and 5. If the footprint area and depth are set to maximum allowable values based on site characteristics and the calculated volume is still less than the required volume, reduce the drainage area (A) and repeat Steps 1 through 5.

Alternatively, a stage-storage curve can be analyzed to check whether the basin has adequate storage. A stage-storage curve defines the relationship between the depth of water and storage volume in a basin. The estimated peak stage occurs for the estimated volume from Step 3 (depth of water for the storage volume required) or at the 100-yr storm event (check the County requirements). Compare the depth of the basin to the peak stage. If the depth of the basin is less than the peak stage accommodating freeboard, set the depth to maximum allowable value or reduce the drainage area and repeat Steps 1 through 5.

Step 6: Select the type and size of the outlet structure for both water quality and water quantity control. The outlet structure should be sized to convey the allowable discharge at the stage from Step 3 (depth of water for the storage volume required) and at the stage from 100-yr storm event depending on the project requirements. A stage-discharge curve can provide the discharge that the outlet structure should convey at the peak stages. The outlet structure can be designed as a multi-stage control.

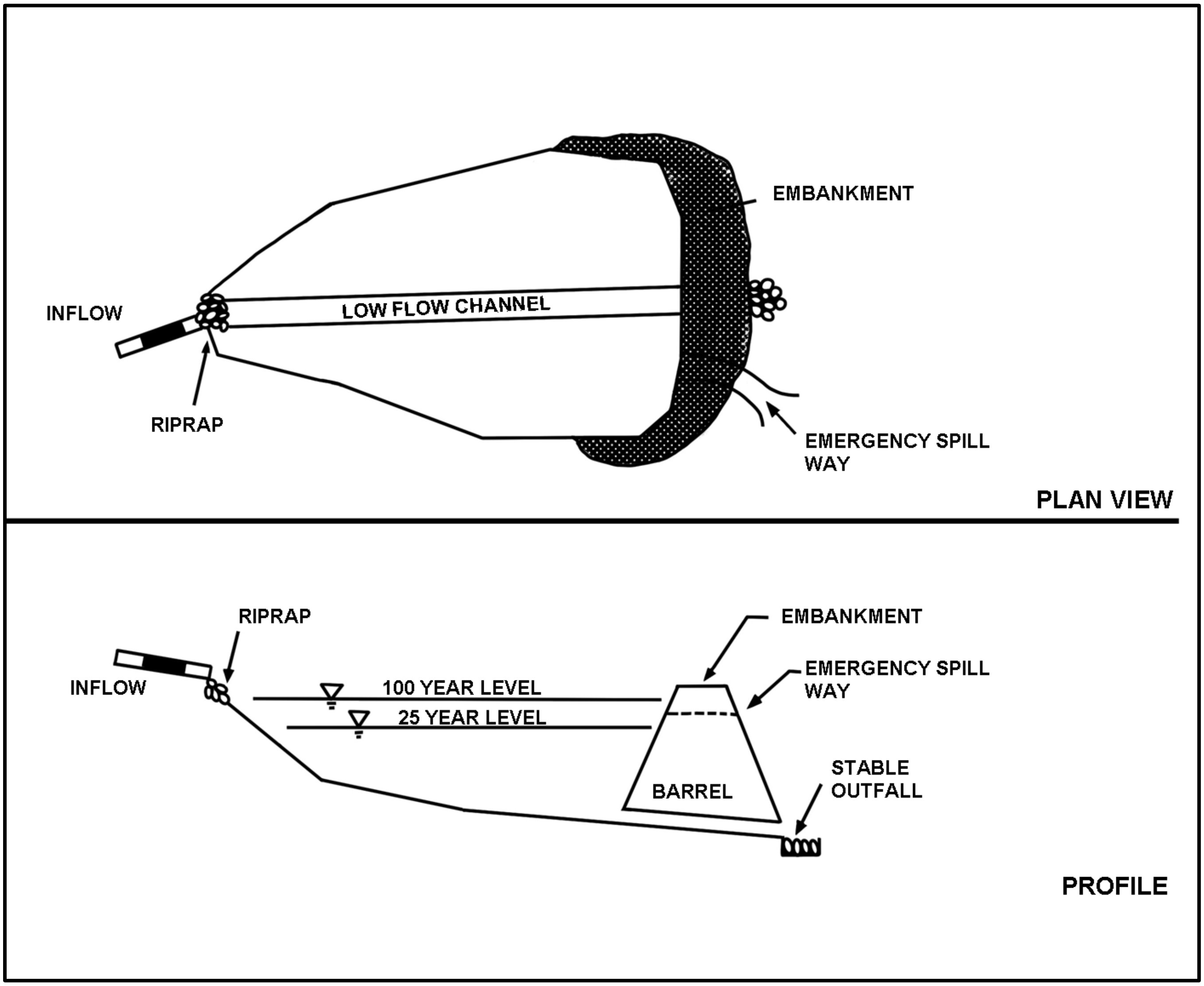
Step 7: Perform routing calculations using inflow hydrographs to check the preliminary design using a storage routing computer model. If the routed developed (post-development) peak discharges from the design storm exceed the undeveloped (existing) peak discharges, revise the available storage volume, outlet structure, etc., and return to Step 6.

CONSTRUCTION CONSIDERATIONS

- Inspect the facility after the first large storm to determine whether the desired residence time has been achieved.
- When constructed with a small drainage area, orifice sizing is critical, and inspections should verify that flow through additional openings such as bolt holes does not occur.

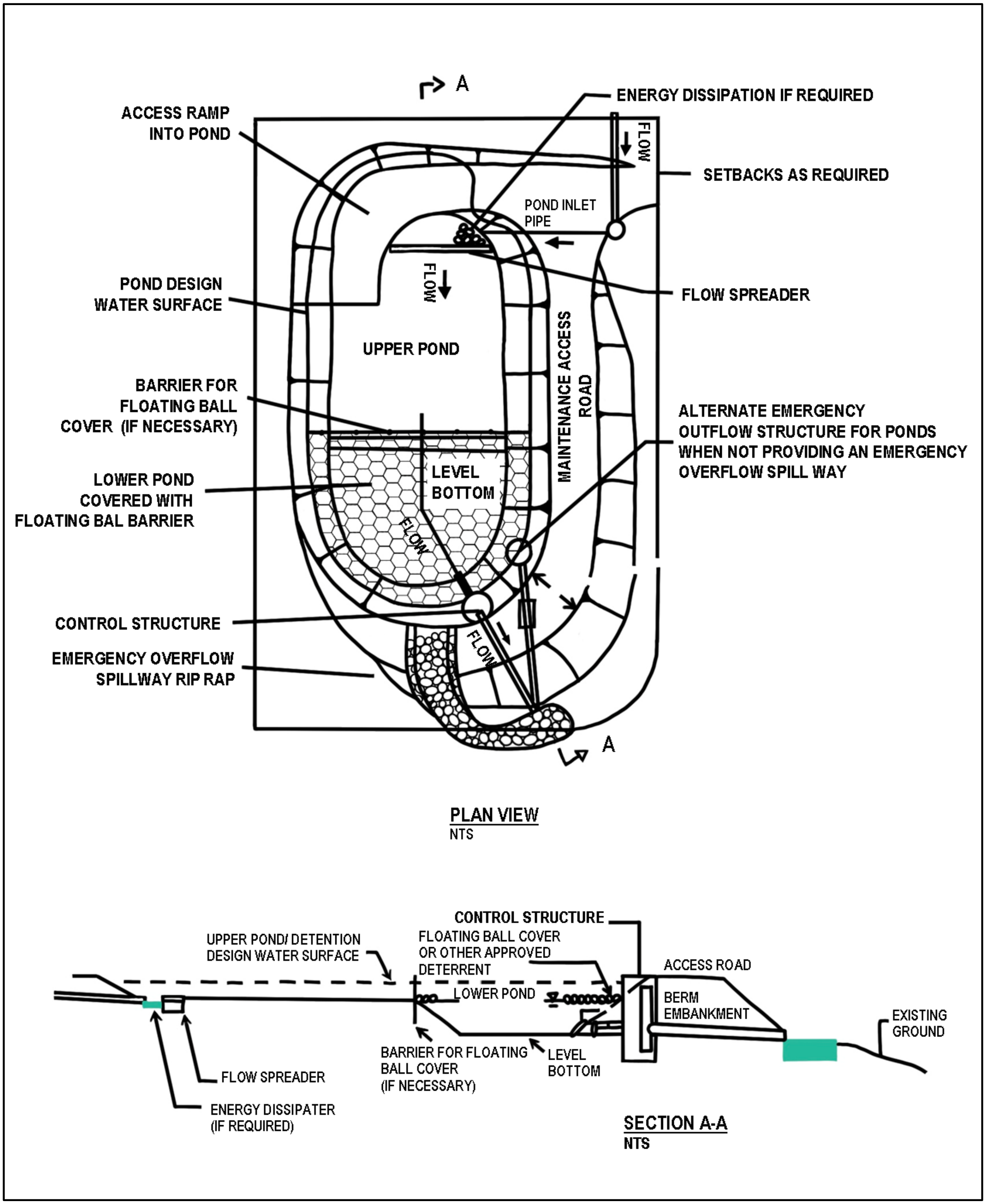
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of a Detention Basin

Source: *Iowa Storm Water Management Manual* (Iowa Department of Natural Resources, 2009). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Detention Basin with Two Cell Design
Source: *Aviation Stormwater Design Manual, Managing Wildlife Hazards Near Airports, M 3041.00* (Washington DOT, 2008). The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

TC-3: Evaporation Pond

PBMP Category

☐LID
☐Source Control
☒Treatment Control

Pollutants Targeted

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☐Organic Compounds
☒Pathogens
☐Pesticides
☒Sediment
☒Trash
☐Other:

Evaporation Pond at Kahului Airport

DESCRIPTION

Evaporation ponds are shallow man-made ponds with large surface areas designed to hold a set volume of runoff and allow for evaporation by sunlight and exposure to ambient temperatures, wind, and humidity with no outlet structure. Evaporation ponds are constructed in relatively impervious soils or with a liner to retain stormwater and reduce the risk of contaminants being discharged to the DOTA MS4, drainage system, or State waters during a significant storm event exceeding the design capacity. In addition, evaporation ponds can significantly reduce total annual surface runoff volume, stream bank erosion, and other adverse impacts to the DOTA MS4, drainage system, or State waters.

DOTA has implemented evaporation ponds in areas where stormwater infiltration is not allowed due to risk of groundwater contamination or where discharges from activities into the sanitary sewer are prohibited (e.g., Maui County does not allow for OWS connection to sanitary sewer), and where there is significant potential for hazardous chemical spills.

DOTA discourages the use of evaporation ponds since the FAA recommends that airports avoid ponds with standing water, which can attract various waterfowl and increase the risk of bird strikes. However, they are included in this manual as an option for unique cases in which other alternatives may be infeasible or cost-prohibitive.

DOTA should be consulted prior to the implementation of an evaporation pond in a project design.

LIMITATIONS

- Evaporation ponds are considered infeasible for any of the following conditions:
  - Ponds with standing water for a duration longer than 48 hrs.
  - The pond invert would be below the seasonally high groundwater table.
  - Located within 20 ft of any building foundation.
- Evaporation ponds may not be suitable near drinking water wells, septic tanks, drain fields, fill sites, or steep, unstable slopes.

DESIGN GUIDELINES

GENERAL

- Evaporation ponds should be used only where stormwater infiltration is not allowed due to the risk of groundwater contamination, where discharges from activities into the sanitary sewer are prohibited, or where there is significant potential for hazardous chemical spills.
- Evaporation ponds do not include an outlet structure. Thus, consideration should be given to surrounding drainage patterns or additional storage capacity to accommodate larger storm events that exceed the design rainfall.
- Evaporation ponds should be designed and maintained to prevent any discharge into the DOTA MS4, drainage system, or State waters. Additionally, evaporation ponds should be designed to prevent any discharge into the sanitary sewer system.
- Evaporation ponds should be designed to include a minimum of 2 ft of freeboard.
- Evaporation ponds typically include liners, which prevent infiltration.
  - Liners may include compacted till liners, clay liners, synthetic liners, and concrete liners; longevity should be considered in selecting the pond liner. Exposed liners should be manufactured out of material resistant to ozone or ultraviolet deterioration. Otherwise, the liner should be covered with a protective layer of soil of at least 6-in or other suitable material.
  - The synthetic liner should be fabricated out of polyethylene or rubber with a minimum thickness of 40 mils for higher resistance to tears and punctures.
  - The use of a geotextile underlayment beneath the membrane liner should also be considered for increased durability.
  - Evaporation ponds that utilize a membrane liner must include an underdrain with a leak detection device and collection system.
- Provide top anchor trenches along liner edge in accordance with manufacturer's recommendations to prevent liner slippage.
- Adjoining liner sheets required for larger-sized evaporation ponds may be welded in the field. Seams should be tested in accordance with applicable industry standards for quality control.
- Evaporation ponds can be effectively used only where the evapotranspiration capacity is adequate to drawdown the required quantity of stormwater within a reasonable time, typically considered to

be not more than 48 hrs. The 48-hr drawdown time allows the evaporation pond's capacity to be re-established and reduces the potential for unsanitary conditions, such as mosquito breeding, associated with stagnant water. This requirement is consistent with the FAA requirement for ponds per *FAA AC 150/5200-33B*.

- If the embankment falls under the jurisdiction of the DLNR Engineering Division, Dam Safety Program, it shall be designed to meet the applicable requirements, or these requirements, whichever are more stringent.

PRETREATMENT CONSIDERATIONS

- If significant amounts of sediment or sand are anticipated at the site, a sediment forebay should be located at each major inlet to provide pretreatment, preserve the capacity of the pond, and reduce maintenance requirements in the pond. The forebay should consist of a separate cell that drains into the main pond and is formed by an acceptable barrier, such as an earthen berm or gabion baskets. If used, the total volume of all forebays should be at least 5% of the total WQV.

AREA REQUIREMENTS

- None.

MINIMUM DESIGN CRITERIA

Design Parameter	**Units**	**Value**
Maximum End Slope (length per unit height)	ft/ft	3:1
Maximum Side Slope (length per unit height)	ft/ft	3:1
Drawdown (pond evaporation) Time	hrs	48 or less
Maximum Depth	ft	8
Minimum Clearance from basin invert to the groundwater table	ft	3
Minimum Freeboard	ft	2

SIZING GUIDELINES

Evaporation ponds must be sized to provide adequate capacity to capture the WQV and a surface area to allow evaporation within 48 hrs and assuming no annual accumulation. The following is a simplified method for determining the approximate size of a trapezoidal evaporation pond. Other design methods or modeling procedures may be used at project proponent's discretion but subject to approval by the DOTA.

Step 1: Identify the project's nearest reference point and use the corresponding Monthly Rainfall (r) (refer to section 4.3.5 and Appendix VI) and Monthly Pan Evaporation Rates (E_{pan}) (refer to section 4.3.4 and Appendix VI).

Step 2: Calculate the contributing Tributary Drainage Area (A) into the evaporation pond. Since evaporation ponds do not allow for infiltration, the WQV is based on the total rainfall depth compared to a design storm runoff depth typically used to size other treatment control BMPs.

Step 2a. Calculate the Tributary Drainage Area (A) that generates runoff to the evaporation pond. The Tributary Drainage Area (A) should also include the pond area.

Step 2b. Enter the design Freeboard (f).

Step 2c and 2d. Enter assumed Top Length (L) and Top Width (W) for the Pond Structure based on available space at the site.

Step 2e and 2f. Enter assumed End Slope (z_e) and Side Slope (z_s) values.

Step 2g. Calculate the % impervious cover (I) of the Tributary Drainage Area (A). Please note that the evaporation pond surface area should be counted towards the impervious cover % to account for the imperviousness from the liner.

Step 2h. The Pan Evaporation Coefficient (K_p) is a regionally defined parameter (refer to section 4.3.4).

Step 3: Calculate the Volumetric Runoff Coefficient using the following equation developed by the EPA for smaller storms in urban areas:

$$\mathbf{C = 0.05 + 0.009I}$$

where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

Step 4: Calculate the dimensions of the pond at freeboard depth.

$$\mathbf{P_L = L - 2z_e f}$$

$$\mathbf{P_W = W - 2z_s f}$$

where P_L = Design Peak Evaporation Pond Surface Length (ft)
P_W = Design Peak Evaporation Pond Surface Width (ft)
L = Top Length (ft)
W = Top Width (ft)
z_e = End Slope (ft/ft)
z_s = Side Slope (ft/ft)
f = Freeboard (ft)

Step 5: Perform a month-to-month analysis, starting with January and ending with December, and calculate the monthly WQV based on Monthly Rainfall (r) from Step 1 using the following equation:

$$\mathbf{WQV = 3630 \times rCA}$$

where WQV = Monthly Water Quality Design Volume (ft^3)
r = Monthly Rainfall (in)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ac)

Calculate the Monthly Evaporation Volume (E) using the Monthly Pan Evaporation Rates (E_{pan}), Evaporation Pan coefficient (K_p), and the Evaporation Pond Surface Area (A_p).

While the Evaporation Pond Surface Area (A_p) depends on the depth of water in the trapezoidal pond, the pond depth is not yet known; therefore, it is initially estimated to be the area of the pond at freeboard depth. Calculate the Evaporation Pond Surface Area (A_p) based on the values for P_L and P_W and then calculate the Monthly Evaporation Volume (E).

$$\mathbf{A_p = P_L P_W / 43{,}560}$$

where A_p = Evaporation Pond Surface Area (ac)
P_L = Design Peak Evaporation Pond Surface Length (ft)
P_W = Design Peak Evaporation Pond Surface Width (ft)

$$\mathbf{E = 3630 \times E_{pan} K_p A_p}$$

where E = Monthly Evaporation Volume (ft^3)
E_{pan} = Monthly Pan Evaporation Rate (in) from Step 1
K_p = Pan Evaporation Coefficient (refer to section 4.3.4)
A_p = Evaporation Pond Surface Area (ac)

After Step 5, repeat steps 4 and 5 several times, to obtain the most precise estimate, through iteration, of the Evaporation Pond Surface Area (A_p) for each month. After the first estimate, subsequent iterations use the following calculation for Ap that involves solving for the Water Depth in the pond at the end of the month (D) and then calculating the Evaporation Pond Surface Area (A_p) at that depth.

$$\mathbf{S_e = \frac{1}{6} D\,(l_b w_b + (l_b+2z_e D)(\,w_b+2z_s D) + 4(l_b+z_e D)(\,w_b+z_s D)) \text{ – SOLVE FOR D}}$$

$$\mathbf{A_p = (l_b+2z_e D)(\,w_b+2z_s D)/43{,}560}$$

where S_e = Storage Capacity at the end of the month (ft^3)
l_b = Bottom Length (ft)
w_b = Bottom Width (ft)
D = Water Depth in the pond at the end of each month (ft)
z_e = End Slope (ft/ft)
z_s = Side Slope (ft/ft)
A_p = Evaporation Pond Surface Area (ac)

Compare the monthly inflow (WQV) to the monthly outflow (Evaporation Volume, E).

The storage capacity at the beginning of the month (S_b) is the same as the storage capacity at the end of the previous month (S_e). For the first month of the analysis (January), S_b is set to 0.

If WQV exceeds E for a given month, the difference is added to the storage capacity at the beginning of the month (S_b), and the storage capacity at the end of the month (S_e) is computed.

$$\mathbf{S_e = S_b + WQV - E}$$

where S_e = Storage Capacity at the end of the month (ft^3)
S_b = Storage Capacity at the beginning of the month (ft^3)
WQV = Monthly Water Quality Design Volume (ft^3)
E = Monthly Evaporation Volume (ft^3)

If E exceeds WQV for a given month, the difference is subtracted from the storage capacity at the beginning of the month (S_b), and the storage capacity at the end of the month (S_e) is computed. The process is continued for the remaining months until December. If the computed storage capacity at the end of the month is negative, a value of 0 is shown for S_e.

Step 6: Calculate the remaining required pond dimensions. Calculate the Required Storage Capacity (S_R) as the maximum computed Storage Capacity at the end of the month (S_e).

$S_R = MAX(S_e)$ for S_e from January through December

where S_R = Required Storage Capacity (ft^3)
S_e = Storage Capacity at the end of the month (ft^3)

Calculate the Required Pond Depth (D_R) as the depth below the freeboard required to contain the Required Storage Capacity (S_R).

$$\mathbf{S_R = \frac{1}{6} D_R \left(P_L P_W + (P_L - 2z_e D_R)(P_W - 2z_s D_R) + 4(P_L - z_e D_R)(P_W - z_s D_R)\right)} \textbf{ - SOLVE FOR } \mathbf{D_R}$$

where S_R = Required Storage Capacity (ft^3)
D_R = Required Pond Depth (ft)
P_L = Design Peak Evaporation Pond Surface Length (ft)
P_W = Design Peak Evaporation Pond Surface Width (ft)
z_e = End Slope (ft/ft)
z_s = Side Slope (ft/ft)

Calculate the Overall Pond Structure Depth (D_T) as the summation of the Required Depth (D_R) and the Freeboard Depth (f).

$$\mathbf{D_T = D_R + f}$$

where D_T = Overall Pond Structure Depth (ft)
D_R = Required Pond Depth (ft)
f = Freeboard Depth (ft) (refer to section 4.3.6.8)

Calculate the bottom Length (l_b) and Bottom Width (w_b) of the Pond Structure from the Overall Pond Structure Depth (D_T), Top Length (L), Top Width (W), Side Slope (z_s), and End Slope (z_e).

$$\mathbf{l_b = L - 2z_e D_T}$$

$$\mathbf{w_b = W - 2z_s D_T}$$

where l_b = Bottom Length (ft)
w_b = Bottom Width (ft)
D_T = Overall Pond Structure Depth (ft)
L = Top Length (ft)
W = Top Width (ft)
z_e = End Slope (ft/ft)
z_s = Side Slope (ft/ft)

Step 7: Calculate the Maximum Pond Storage Capacity Available (S_A) as the total volume of the overall pond structure based on the Overall Pond Structure Depth (D_T) from Step 6 and the Top Length (L) and Width (W) of the pond structure from Step 2c and 2d.

$$\mathbf{S_A = \frac{1}{6}\ D_T\ (LW + l_b w_b + 4(L\text{-}z_e D_T)(W\text{-}z_s D_T))}$$

where S_A = Maximum Pond Storage Capacity Available (ft^3)
D_T = Overall Pond Structure Depth (ft)
L = Top Length (ft)
W = Top Width (ft)
l_b = Bottom Length (ft)
w_b = Bottom Width (ft)
z_e = End Slope (ft/ft)
z_s = Side Slope (ft/ft)

The difference between the Maximum Pond Storage Capacity Available (S_A) and the Required Storage Capacity (S_R) is the amount of Excess Pond Storage Capacity (S_X). The excess capacity provides a factor of safety during larger storm events or periods of lower-than-expected evaporation rates.

$$\mathbf{S_X = S_A - S_R}$$

where S_A = Maximum Pond Storage Capacity Available (ft^3)
S_R = Required Storage Capacity (ft^3)
S_X = Excess Pond Storage Capacity (ft^3)

Step 8: If the Required Depth (D_R) is greater than what is possible with the pond dimensions entered in Step 2, increase the size of the evaporation pond by increasing the Top Length (L) or Top Width (W) and recalculate.

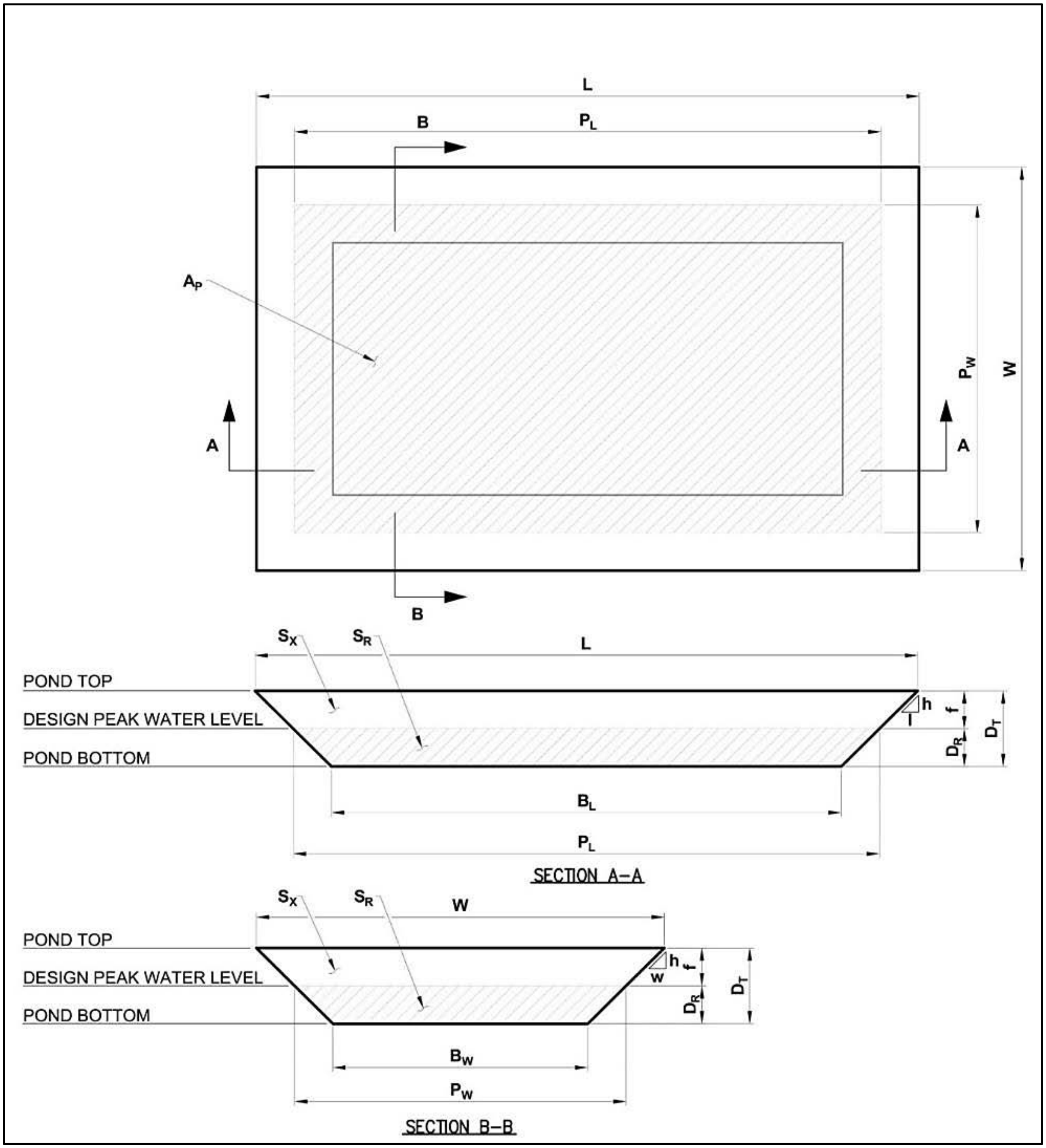
Use the lowest Monthly Pan Evaporation Rate (E_{pan}) to calculate the maximum allowable depth of water that can drawdown (evaporate) in 48 hrs. For example, if the lowest Monthly Pan Evaporation Rate (E_{pan}) is 5-in per month, the maximum allowable depth of water that can evaporate in 48 hrs is 0.03 ft (assuming 30 days in a month). If the maximum allowable depth is not feasible to design, consider a different PBMP or contact DOTA to discuss an exception from the 48-hr drawdown criteria based on the proposed pond site conditions.

CONSTRUCTION CONSIDERATIONS

- Pond liners need to be protected from sharp objects (for example, stones) below the liner and punctured by any objects in the pond.
- Stormwater should not be allowed to enter the evaporation pond until all construction is completed and the contributing drainage area to the basin is adequately stabilized. If this prohibition is not feasible, do not excavate the evaporation pond to the final grade until the contributing drainage area has been stabilized.

EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



Example Schematic of an Evaporation Pond

TC-4: Hydrodynamic Separator Unit

PBMP Category

☐LID
☐Source Control
☒Treatment Control

Pollutants Targeted*

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☒Other: Varies

*Pollutant removal may vary based on type of HDS Unit.

Continuous Deflective Separator Unit
Daniel K. Inouye International Airport

DESCRIPTION

A hydrodynamic separator or HDS unit is also known as a vortex separator, a swirl separator, a swirl concentrator, or a continuous deflective separator unit. Vortex separators are gravity separators and essentially wet vaults. Vortex separators, swirl separators, or swirl concentrators are flow-through structures that use a vortex action to separate coarse sediment and floatables (trash, debris, etc.) from stormwater.

HDS units are flow-through structures with a settling or separation unit to remove sediments and other pollutants. No outside power source is required because the energy of the flowing water allows the sediments to separate efficiently. Depending on the type of unit, this separation may be achieved using swirl action or indirect filtration.

The continuous deflective hydrodynamic separators use swirl concentration and continuous deflective separation to screen, separate and trap trash, debris, sediment, and hydrocarbons from stormwater runoff. The continuous deflective separator technologies direct solid pollutants into the lower catchment chamber and the floatables to the surface of the upper chamber using a non-mechanical, non-blocking screen technology.

Manufacturers have developed several proprietary versions of HDS units for stormwater treatment. These HDS units function differently, include various components, and provide water quality by removing coarse sediment and floatables; some models may also remove oil and grease. The pollutant removal performance may vary depending on the type and model of the proprietary HDS unit selected for the project. Therefore, project proponents need to review the manufacturer's specifications to determine pollutants targeted for removal.

LIMITATIONS

- Some HDS units have standing water that remains between storms which could be a mosquito breeding concern.
- The drainage area served is limited by the capacity of the largest models available.
- HDS units are not effective for the removal of dissolved pollutants, fine sediments, and pollutants that adhere to fine sediments.
- HDS units are considered infeasible for any of the following conditions:
    - The bottom of the PBMP is below the seasonally high groundwater table.
    - Unable to operate off-line and unable to operate in line with a safe overflow mechanism.

DESIGN GUIDELINES

GENERAL

- All HDS units should safely overflow, or bypass flows in excess of the stormwater quality design storm to downstream drainage systems.
- Consider using HDS unit models certified for general use by the Washington State Department of Ecology TAPE or certified by the NJDEP.
- Follow the manufacturer's guidelines for design considerations based on the site conditions.
- There are no specific landscaping requirements. However, areas around these units should be clear at the surface and accessible for maintenance and inspection purposes.
- Aggressive maintenance plans are required to reduce the risk of re-suspension of sediment during large storm events.
- Manholes should be included in each chamber for cleaning access.
- OWSs may be used in conjunction with these units to remove oils.

PRETREATMENT CONSIDERATIONS

- No pretreatment is required. Project proponents may consider a treatment train in conjunction with OWS or manufactured treatment devices if targeting various pollutants.

AREA REQUIREMENTS

- The footprint requirements for proprietary manufactured treatment devices vary by manufacturer. Follow the manufacturer’s guidelines for appropriate sizing calculations and selection of appropriate device/model.

MINIMUM DESIGN CRITERIA

- Follow manufacturer’s guidelines for the minimum design criteria.

SIZING GUIDELINES

- Follow the manufacturer’s guidelines for appropriate sizing calculations and selection of appropriate device/model.
- Every unit requires detailed hydraulic analysis before installation to verify optimum solids separation is achieved.

CONSTRUCTION CONSIDERATIONS

- Follow manufacturer’s recommendations.

EXAMPLE SCHEMATICS

- None provided since presenting any specific product might be interpreted as an endorsement.

Treatment Control PBMP Design Fact Sheets

TC-5: Manufactured Treatment Device

PBMP Category

☐LID
☐Source Control
☒Treatment Control

Pollutants Targeted*

☒Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☒Other: Varies

*Pollutant removal may vary based on type of MTD.

Drain Inlet Insert at Maintenance Baseyard (left) and Drain Inlet Insert at Elliott Street Parking Lot (right), Daniel K. Inouye International Airport

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DESCRIPTION

Manufactured treatment devices or MTDs are proprietary water quality structures utilizing settling, filtration, adsorptive materials, vortex separation, vegetative components, or other appropriate technology to remove pollutants from stormwater runoff.

DOTA has several HDS units and OWSs in their current PBMP inventory, and therefore, those two types are covered under separate design fact sheets and excluded from the MTD PBMP category. Please refer to the respective design fact sheets for information on designing HDS units and OWSs.

Manufacturers have developed several proprietary versions of MTDs for stormwater treatment. These MTDs function differently, include various components, and provide water quality by removing various pollutants such as coarse sediment, metals, nutrients, floatables, organic compounds, oil & grease, etc. The pollutant removal performance may vary depending on the type and model of the proprietary MTD selected for the project. Therefore, project proponents need to review the manufacturer's specifications to determine pollutants targeted for removal.

According to the State and Federal UIC Program regulations, an MTD designed to capture and infiltrate stormwater can be considered a Class V stormwater drainage well if it meets the definition of a well and an injection well. MTDs that fall under the Class V injection well category shall apply for a UIC permit (refer to Federal UIC regulations, *40 CFR § 144* and State of Hawaii UIC regulations, *HAR § 11-23*).

All UIC permitted MTDs will be considered PBMPs to satisfy any Post-Construction Program requirements but will be inspected and maintained under the UIC or Post-Construction Program, whichever is more stringent.

LIMITATIONS

- The drainage area served is limited by the capacity of the largest models available.
- Not effective for removal of dissolved pollutants, fine sediments, and pollutants that adhere to fine sediments.
- MTDs are considered infeasible for any of the following conditions:
    - The bottom of the PBMP is below the seasonally high groundwater table.
    - Unable to operate off-line and unable to operate in line with a safe overflow mechanism.
    - Requires a flat site and hydraulic gradient to support gravity flow.
- Each type of device has specific design constraints and limitations for use.
- Certain models have standing water that remains between storms which could be a mosquito breeding concern.
- Performance standard for targeted pollutant removal, high initial implementation cost, and maintainability could limit the implementation of MTDs.

DESIGN GUIDELINES

GENERAL

- Select MTDs capable of treating the potential pollutants of concern at the project site based on the documented performance standards. The performance standard documentation should include independent third-party scientific verification of the ability of the MTD to meet the stormwater objectives (water quality treatment and water quantity control) of the project.
- All MTDs should safely overflow or bypass flows in excess of the stormwater quality design storm to downstream drainage systems.
- Consider using MTD models certified for general use by the Washington State Department of Ecology TAPE or certified by the NJDEP.
- Follow the manufacturer's guidelines for design considerations based on the site conditions.
- There are no specific landscaping requirements. However, areas around these units should be clear at the surface and accessible for maintenance and inspection purposes.

- Aggressive maintenance plans are required to reduce the risk of re-suspension of sediment during large storm events.
- Maintenance access should be included in each chamber.
- Project proponents should review the maintainability of the MTDs, including access, equipment needed to conduct maintenance, and local availability of replacement media, media filters, other parts, etc.
- MTDs designed to capture and infiltrate stormwater may be subject to applicable federal and state UIC regulations; refer to Federal UIC regulations, *40 CFR § 144* and State of Hawaii UIC regulations, *HAR § 11-23*.

PRETREATMENT CONSIDERATIONS

- No pretreatment is required.

AREA REQUIREMENTS

- The footprint requirements for proprietary manufactured treatment devices vary by manufacturer. Follow the manufacturer's guidelines for appropriate sizing calculations and selection of appropriate device/model.

MINIMUM DESIGN CRITERIA

- Follow manufacturer's guidelines for the minimum design criteria.
- A General Application for a UIC Permit to Operate should be submitted to DOH-SDWB at least 6 months before the anticipated date of UIC well construction.

SIZING GUIDELINES

- No example is provided as sizing procedures vary by manufacturer.
- Follow the manufacturer's guidelines for appropriate sizing calculations and selection of appropriate device/model.

CONSTRUCTION CONSIDERATIONS

- Follow manufacturer's recommendations.

EXAMPLE SCHEMATICS

- None provided since presenting any specific product might be interpreted as an endorsement.

TC-6: Oil Water Separator

PBMP Category

☐LID
☐Source Control
☒Treatment Control

Pollutants Targeted*

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☒Pesticides
☒Sediment
☒Trash
☒Other: Varies

*Pollutant removal may vary based on type of OWS.

Oil water separator at the DOTA Wash Rack, Kahului Airport

DESCRIPTION

OWSs are treatment control devices designed to remove water-insoluble hydrocarbons and settleable solids from stormwater runoff. The primary function of OWSs is to specifically remove oil, jet fuel, gasoline, diesel, other water-insoluble hydrocarbons, floatable debris, and settleable solids.

The two commonly used OWSs are the conventional American Petroleum Institute or API separator (also known as the baffle type) and the coalescing plate separator. Both use gravity to remove floating and dispersed oil.

- Conventional API OWSs are composed of three bays separated by baffles. The efficiency of the API OWSs is dependent on the detention time in the oil separator bay and on droplet size. These are typically designed to protect from spills.

- Coalescing plate OWSs are composed of parallel plates in the separator bay, which improves efficiency by providing more surface area. In addition, coalescing plate OWSs need considerably less space to separate the floating oil due to shorter travel distances between the parallel plates. So, coalescing plate OWSs are typically used for small drainage areas such as fueling stations, maintenance shops, etc.

OWS includes three compartments: a forebay, an oil separator bay, and an afterbay.

- The forebay is designed primarily to trap and collect sediment, support plug flow conditions and reduce turbulence.
- The oil separator bay traps and holds oil as it rises from the water column, and it serves as a secondary sediment collection area.
- The afterbay provides a relatively oil-free cell before the outlet and provides a secondary oil separation area.

Manufacturers have developed several proprietary versions of OWSs for stormwater treatment. These OWSs function differently, include various components, and provide water quality by removing pollutants such as coarse sediment, oil & grease, jet fuel, gasoline, diesel, other water-insoluble hydrocarbons, floatables, etc. The pollutant removal performance may vary depending on the type and model of the proprietary OWS selected for the project. Therefore, project proponents need to review the manufacturer’s specifications to determine pollutants targeted for removal.

While the OWSs connected to the sanitary sewer are not considered PBMPs, they shall be considered for maintenance areas, material storage areas, and washing areas to meet the requirements of the county Pretreatment Programs.

LIMITATIONS

- The drainage area served is limited by the capacity of the largest models available.
- May not be effective for removal of dissolved pollutants, fine sediments, and pollutants that adhere to fine sediments depending on the model of the proprietary OWS selected for the project.
- The design loading rate for OWSs is low; therefore, they can only be cost-effectively sized to detail and treat nuisance and low flows (small storm or first flush events). Conversely, sizing to accommodate an average to large storm results in a large-sized facility and is not economical.
- The typically low concentrations of oil in stormwater result in considerable performance uncertainty.
- OWSs are considered infeasible for any of the following conditions:
    - The bottom of the PBMP is below the seasonally high groundwater table.
    - Unable to operate off-line and unable to operate in line with a safe overflow mechanism.
    - Requires a flat site and hydraulic gradient to support gravity flow.
- Each type of OWS has specific design constraints and limitations for use.
- Certain models have standing water that remains between storms which could be a mosquito breeding concern.
- OWSs require frequent inspection and routine maintenance for the life of the structure.

- OWSs cannot be used to remove dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols; however, this depends on the model of the proprietary OWS selected for the project.

DESIGN GUIDELINES

GENERAL

- DOTA recommends that OWSs be installed off-line when used for the treatment of stormwater.
- OWSs should be installed upstream of any other stormwater treatment PBMPs, and any pumps to prevent oil from emulsifying.
- All OWSs should safely overflow or bypass flows in excess of the stormwater quality design storm to the DOTA MS4, drainage system, or State waters.
- OWSs should have a shutoff mechanism on the outlet pipe to prevent oil discharges during maintenance and emergency shutoff capability in the event of a spill.
- Storm drain pipes or impervious conveyances should be used for routing oil-contaminated stormwater to the OWS.
- Select OWSs capable of treating the potential pollutants of concern at the project site based on the documented performance standards. The performance standard documentation should include independent third-party scientific verification of the ability of the OWS to meet the stormwater objectives (water quality treatment and water quantity control) of the project.
- Determine the type of OWS: API or coalescing plate.
- A submerged inlet pipe with a turned-down elbow should be included in the forebay at least 2 ft from the bottom. The outlet pipe should be a Tee, sized to pass the Water Quality Design Flow Rate and placed at least 12-in below the water surface.
- Absorbents or skimmers should be used in the afterbay as needed.
- Follow the manufacturer’s guidelines for design considerations based on the site conditions.
- There are no specific landscaping requirements. However, areas around these units should be clear at the surface and accessible for maintenance and inspection purposes.
- Regularly scheduled maintenance plans are required to reduce the risk of re-suspension of sediment during large storm events.
- Maintenance access should be included in each chamber.
- Project proponents should review the maintainability of the OWSs, including access, equipment needed to conduct maintenance, and local availability of replacement media, media filters, other parts, etc.

PRETREATMENT CONSIDERATIONS

- Pretreatment should be considered if the level of sediment in the inflow would cause clogging or otherwise impair the long-term efficiency of the OWS.

AREA REQUIREMENTS

- The footprint requirements for OWSs vary by manufacturer. Follow the manufacturer’s guidelines for appropriate sizing calculations and selection of appropriate device/model.

MINIMUM DESIGN CRITERIA

- Follow manufacturer’s guidelines for the minimum design criteria.

SIZING GUIDELINES

- Determine the size of separators based on the rate of runoff (treatment flow rate), the rise-rate velocity of the oil droplets, and the settling rate of solids to be removed. Sizing an OWS should also consider spill capacity and applicable codes and regulations.
- The following forebay design criteria should be followed:
  - To collect floatables and settleable solids, design the surface area of the forebay (the first bay) at ≥ 20 ft^2 per 10,000 ft^2 of the area draining to the OWS.
  - The length of the forebay should be 1/3-1/2 of the length of all three bays combined. Include roughing screens for the forebay or upstream of the OWS to remove debris, if needed.
  - Screen openings should be about ¾-in.
- The following baffle design criteria should be followed:
  - Oil retaining baffles (top baffles) should be located at least at 1/4 of the length of all three bays from the outlet and should extend down at least 50% of the water depth and at least 1 ft from the OWS bottom.
  - The baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.
- General sizing guidelines for API OWSs include the following:
  - Horizontal velocity: 3 ft/min.
  - Depth of 3 to 8 ft.
  - Depth-to-width ratio of 0.30 to 0.50.
  - Width of 6 to 16 ft.
  - Baffle height-to-depth ratios of 0.85 for top baffles and 0.15 for bottom baffles.
- Coalescing plate OWSs sizing is more complex; sizing calculations require information such as packing plate surface areas and plate angles.
- Follow the 2019 Stormwater Management Manual for Western Washington sizing criteria for API and coalescing plate OWSs sizing. Alternatively, follow manufacturer's guidelines for appropriate sizing calculations and selection of appropriate device/model.

CONSTRUCTION CONSIDERATIONS

- Follow manufacturer's recommendations.
- OWS vaults should be watertight. Pipes entering and exiting a vault below the water surface should be sealed using a non-porous, non-shrinking sealant or concrete mastic.

EXAMPLE SCHEMATICS

- None provided since presenting any specific product might be interpreted as an endorsement.

TC-7: Sand Filter

PBMP Category

☐LID
☐Source Control
☒Treatment Control

Pollutants Targeted

☒Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☒Organic Compounds
☒Pathogens
☐Pesticides
☒Sediment
☒Trash
☐Other:

Oak Manor Surface Sand Filter, Maryland
Source: Montgomery County, Maryland

DESCRIPTION

A sand filter is a basin or chambered structure that captures, temporarily stores, and treats stormwater runoff by passing it through sand, organic matter, soil, or other media. Sand filter design can include the surface sand filter, perimeter sand filter, and underground sand filter.

- A surface sand filter is a ground-level open-air structure that consists of a pretreatment sediment forebay and a filter bed chamber. Surface sand filters can treat the largest drainage area of all the sand filtering systems.
- The perimeter sand filter is an enclosed filter system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot. The perimeter sand filter is most practical for small sites with flat terrain.
- An underground sand filter is similar to the sand filter, but instead the sand layer and underdrains are installed below grade in a vault. An underground sand filter is an option when space is limited.

Wildlife deterrence should be a top priority to assure that the sand filters do not pose a safety hazard to aircraft.

LIMITATIONS

- Sand filters are considered infeasible for any of the following conditions:
    - The bottom of the PBMP is below the seasonally high groundwater table.
    - Unable to operate off-line and unable to operate in line with a safe overflow mechanism.
    - Requires a flat site and hydraulic gradient to support gravity flow.
- Sand filters require frequent inspection and routine maintenance for the life of the structure. Underground and perimeter versions of these practices are easily forgotten because they are out of sight.

DESIGN GUIDELINES

GENERAL

- Sand filters are usually designed as two-chambered stormwater practices; the first is a settling chamber (pretreatment), and the second is a filter bed filled with sand or other filtering media.
- As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the filtering medium.
- Sand filters are best applied on relatively small sites (up to 10 ac for surface sand filters and up to 2 ac for perimeter or underground filters).
- Sand filters require an elevation drop, or head (about 5 to 8 ft), to allow flow through the system.
- Provide at least 2 ft of separation between the bottom of the filter and the seasonally high groundwater table to prevent damage to the filter and groundwater contamination.
- Construct an underdrain, a perforated pipe system in a gravel bed installed on the bottom of filtering practices and used to collect and remove filtered runoff.
- Permeable filter fabric should be placed between the gravel bed and the filter media.
- Use a flow splitter, which is a structure that bypasses larger flows to DOTA MS4, drainage system, or a stabilized channel during larger storms.
- A flow spreader should be installed at the inlet along one side of the filter to distribute incoming runoff across the filter evenly and prevent erosion.
- A cleanout pipe should be tied into the end of all underdrain pipe runs.
- Underground sand filters should be constructed with a gate valve located just above the top of the filter bed for dewatering if clogging occurs.
- Underground sand filter beds should be protected from trash accumulation by a wide mesh geotextile screen to be placed on the surface of the sand bed; the screen is to be rolled up, removed, cleaned, and reinstalled during maintenance operations.

PRETREATMENT CONSIDERATIONS

- Pretreatment is required for sand filters to reduce the sediment load entering the sand bed, prevent clogging, and provide filter longevity.
- Pretreatment can be achieved with vegetated swales, vegetated filter strips, sedimentation basins, forebays, sedimentation manholes, manufactured treatment devices, or a sedimentation chamber that precedes the filter bed.

- Provide at least 25 % of the WQV as pretreatment to the sand filter.
- The typical method is a sedimentation basin with a length to width ratio of 2:1 and should be sized using the Camp-Hazen equation.

AREA REQUIREMENTS

- A sand filter requires a footprint equivalent to 1.50% - 3% of its contributing impervious drainage area, excluding pretreatment. The lower value reflects minimum filter media and ponding depths, while the upper value reflects higher filter media and ponding depths.

MINIMUM DESIGN CRITERIA

Design Parameter	**Units**	**Value**
Sand Coefficient of Permeability	ft/day	3.50
Filter Media Depth	in	18
Drawdown (drain) Time	hrs	48 or less
Maximum Ponding Depth	in	12
Maximum Interior Side Slope if earthen (length per unit height)	ft/ft	3:1
Minimum Underdrain Diameter	in	6

SIZING GUIDELINES

Step 1: Use the procedure below to compute the volumetric runoff coefficient and WQV.

The volumetric runoff coefficient should be calculated using the following equation developed by the EPA for smaller storms in urban areas:

$$\mathbf{C = 0.05 + 0.009I}$$

where C = Volumetric Runoff Coefficient
I = Impervious Cover (%)

The WQV is calculated using the following equation:

$$\mathbf{WQV = PCA \times 3630}$$

where WQV = Water Quality Design Volume (ft^3)
P = Design Storm Runoff Depth (in) (refer to section 4.3.1)
C = Volumetric Runoff Coefficient
A = Tributary Drainage Area (ac)

Step 2: Select sand filter depth (l_m) and maximum ponding depth (d_p). Use Darcy's Law to calculate the required sand filter bed surface area (A_{fb}):

$$\mathbf{A_{fb} = (WQV \times l_s)/[k_s(l_s + d_p/24)(t/24)]}$$

where A_{fb} = Filter Bed Surface Area (ft^2)
WQV = WQV from Step 1 (ft^3)
l_s = Sand Filter Depth from Step 2 (ft)
k_s = Sand Coefficient of Permeability (ft/day) (refer to section 4.3.6.2)
d_p = Maximum Ponding Depth from Step 2 (in)

t = Filter Bed Drain Time (hr) (refer to section 4.3.6.1)

Step 3: Select a filter bed width (w_b), and calculate the filter bed length (l_b):

$$\mathbf{l_b = A_b / w_b}$$

where l_b = Filter Bed Length (ft)
A_b = Filter Bed Surface Area from Step 3 (ft^2)
w_b = Filter Bed Width (ft)

Step 4: Select the side slope (z) and freeboard (f). Calculate the total area occupied by the PBMP (A_{PBMP}) using the filter bed interior side slopes and assuming a rectangular basin:

$$\mathbf{A_{PBMP} = [w_b + 2z(d_p + f)] \times [l_b + 2z(d_p + f)]}$$

where A_{PBMP} = Area Occupied by PBMP Excluding Pretreatment (ft^2)
w_b = Filter Bed Width (ft)
z = Filter Bed Interior Side Slope (length per unit height)
d_p = Maximum Ponding Depth from Step 2 (ft)
f = Freeboard (ft)
l_b = Filter Bed Length from Step 3 (ft)

If the calculated area does not fit in the available space, either reduce the drainage area, increase the ponding depth, or increase the interior side slope (if it's not already set to the maximum) and repeat the calculations.

CONSTRUCTION CONSIDERATIONS

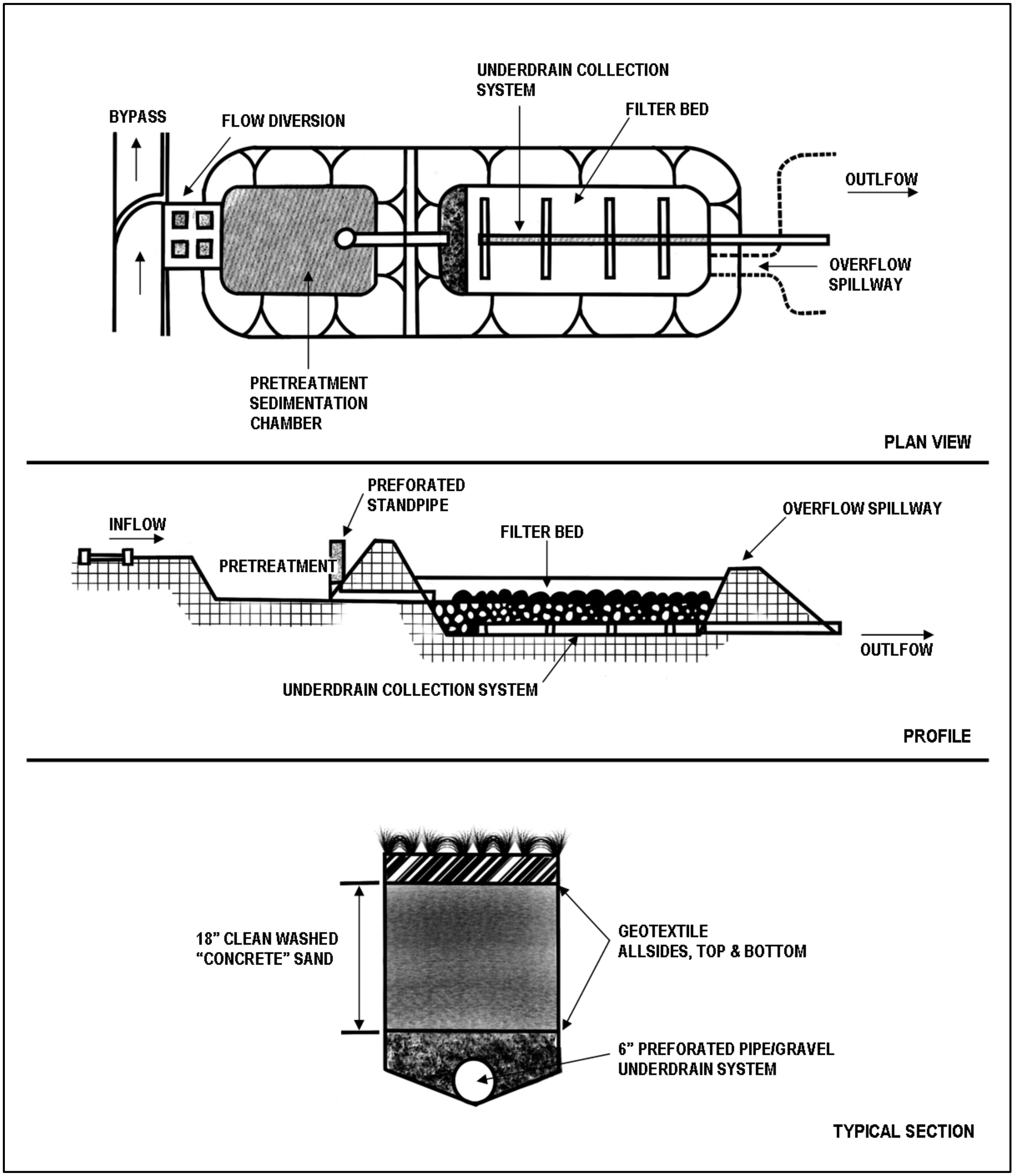
- The tributary area should be completely stabilized before media is installed to prevent premature clogging.
- Careful level placement of the sand is necessary to avoid the formation of voids within the sand filter that could lead to short-circuiting (particularly around penetrations for underdrain cleanouts) and prevent damage to the underlying geomembranes and underdrain system.
- Over-compaction should be avoided to provide adequate filtration capacity. Sand is best placed with a low ground pressure bulldozer. After the sand layer is placed, water settling is recommended. Flood the sand with 10-15 gal of water per ft3 of sand.
- Avoid driving heavy equipment on the sand filter to prevent compaction and rut formation.
- The surface of the filter bed is to be level.
- All underground sand filters should be delineated with signs to be located nearby, and include on it when maintenance is due.

UNDERDRAINS

- Underdrains are to be placed on a 3 ft wide section of the permeable filter fabric. The pipe is placed next, followed by the gravel bedding. The ends of underdrain pipes not terminating in an observation well should be capped.
- The main collector pipe for underdrain systems should be constructed at a minimum slope of 0.50%.
- Observation wells or cleanout pipes should be provided (1 minimum per every 1,000 ft^2 of surface area).

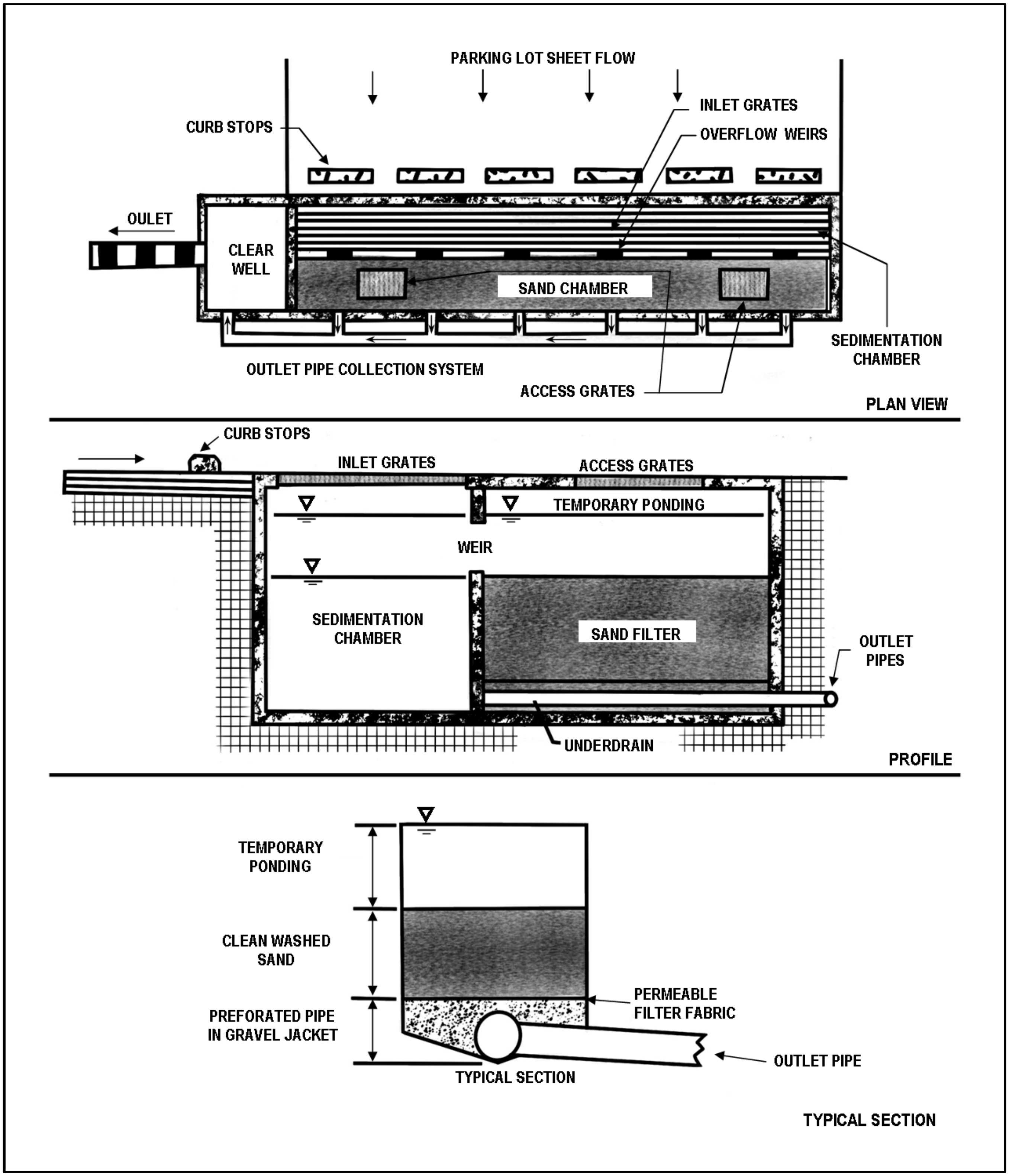
EXAMPLE SCHEMATICS

Disclaimer: The example schematics provided below are intended for visual aid purposes only and not for design purposes. The example schematics are not intended to be used as a design guide for the items, descriptions, and details (depths, etc.). The actual configuration will vary depending on specific site constraints and the design criteria of this fact sheet. Refer to the information provided above for details on the design.



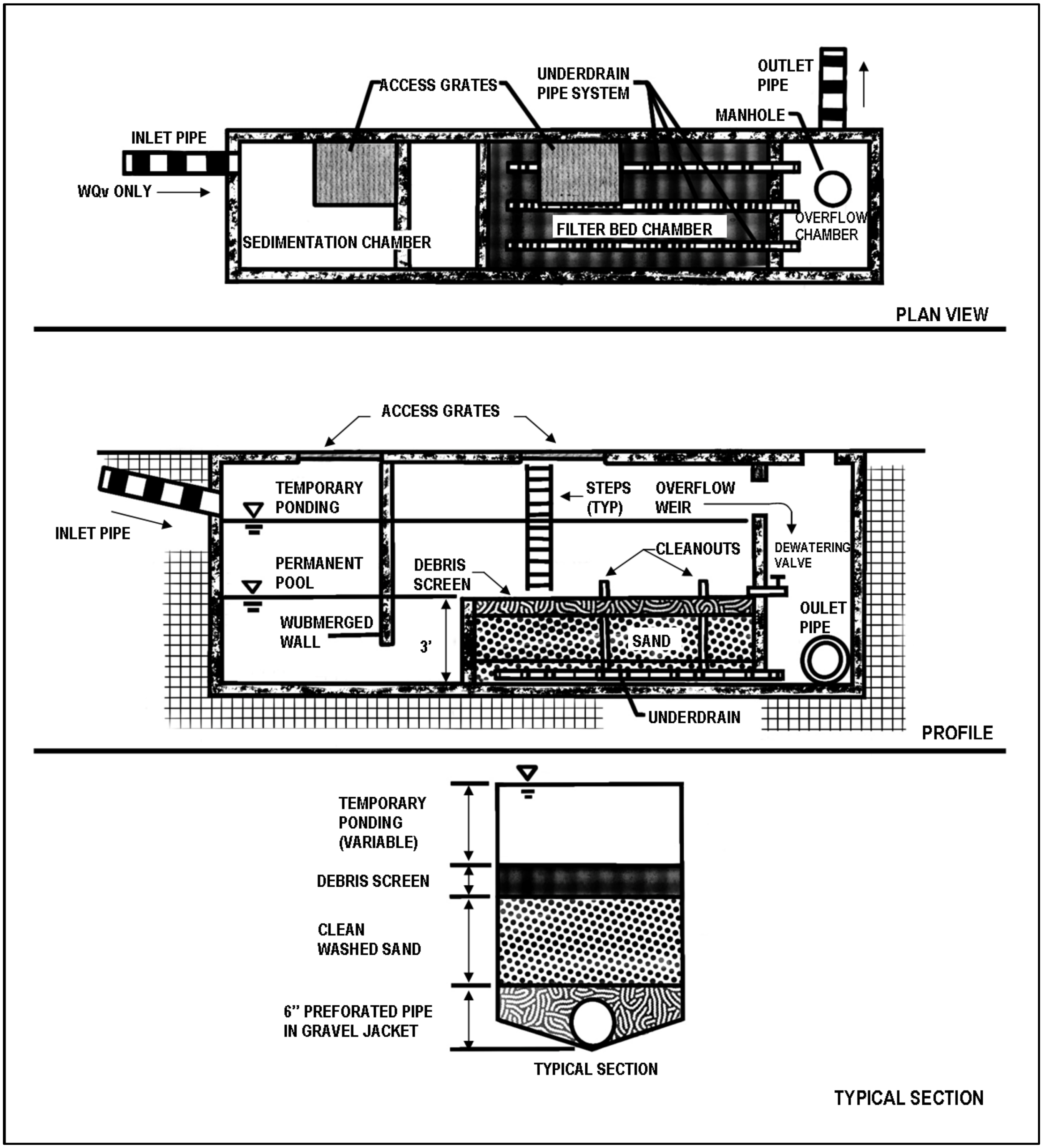
Example Schematic of a Surface Sand Filter

Source: Center for Watershed Protection and the Maryland Department of the Environment, 2000 Maryland Stormwater Design Manual Volumes I & II, Revised May 2009. The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of a Perimeter Sand Filter

Source: Center for Watershed Protection and the Maryland Department of the Environment, 2000 Maryland Stormwater Design Manual Volumes I & II, Revised May 2009. The source schematic was modified to remove design details that are not consistent with this Fact Sheet.



Example Schematic of an Underground Sand Filter

Source: Center for Watershed Protection and the Maryland Department of the Environment, 2000 Maryland Stormwater Design Manual Volumes I & II, Revised May 2009. The source schematic was modified to remove design details that are not consistent with this Fact Sheet.

TC-8: Subsurface Detention

PBMP Category

☐LID
☐Source Control
☒Treatment Control

Pollutants Targeted*

☐Bacteria
☒Metals
☒Nutrients
☒Oil & Grease
☐Organic Compounds
☒Pathogens
☐Pesticides
☒Sediment
☒Trash
☒Other: Varies

* Pollutant removal may vary based on subsurface detention PBMP type.

Subsurface Detention Installation, Philadelphia
Source: *Philadelphia Stormwater Management Guidance Manual, Version 3.2*

DESCRIPTION

Subsurface detention PBMPs are underground structures that temporarily detain stormwater and then release it to the DOTA MS4 or drainage system. Subsurface detention PBMPs are suitable on sites where infiltration has been deemed infeasible, and space constraints prevent the use of surface-level PBMPs. Subsurface detention storage can be designed in various ways and is identified in the following categories:

- Underground storage vaults consist of buried concrete, fiberglass, or polyethylene chambers that temporarily store and release stormwater.
- Underground stone storage consists of buried stone beds wrapped in geotextile that temporarily store and release stormwater.

- Underground pipe and chamber storage consists of perforated plastic or metal pipes or pipe-like linear chambers, placed in a stone bed to provide more storage per unit volume and temporarily store and release stormwater.
- Underground plastic grid storage consists of buried plastic structures stacked and inter-connected to form various shapes and sizes.

Manufacturers have developed several proprietary versions of subsurface detention PBMPs for stormwater treatment. These PBMPs function differently, include various components, and provide water quality benefits by removing various pollutants such as coarse sediment, oil & grease, jet fuel, gasoline, diesel, other water-insoluble hydrocarbons, floatables, etc. The pollutant removal performance may vary depending on the type and model of the proprietary subsurface detention PBMP selected for the project. Therefore, project proponents need to review the manufacturer's specifications to determine pollutants targeted for removal.

LIMITATIONS

- The drainage area served is limited by the capacity of the largest models available.
- Subsurface detention PBMPs are considered infeasible for any of the following conditions:
  - The bottom of the PBMP is below the seasonally high groundwater table.
  - Unable to operate off-line or unable to operate in line with a safe overflow mechanism.
  - Requires a flat site and hydraulic gradient to support gravity flow.
  - Located within 20 ft of any building foundation.
  - Located within 35 ft from a drinking water well.
  - Unstable surrounding soil stratum and soils with clay content greater than 25%.
  - A site with slopes greater than 20%.
  - There is a documented concern that there is a potential on the site for soil pollutants, groundwater pollutants, or pollutants associated with industrial activities to be mobilized.
- Each type of subsurface detention PBMP has specific design constraints and limitations for use.
- Certain models have standing water that remains between storms which could be a mosquito breeding concern.
- Subsurface detention PBMPs may require more excavation than ponds and basins.
- Subsurface detention PBMPs can be more costly and difficult to install and maintain than surface PBMPs.
- Require strict adherence to regularly scheduled inspections because the maintenance needs are not easily visible.

DESIGN GUIDELINES

GENERAL

- The maximum contributing drainage area to be served by a single underground detention vault or tank is 25 ac.
- Subsurface detention PBMPs can be located beneath landscaped areas, parking lots, buildings, or other impervious areas when space constraints allow.

- The general design should consist of the following elements:
    - Underground storage vault;
    - An outlet structure;
    - An overflow spillway; and
    - Maintenance access.
- Routing calculations must be used to demonstrate that the storage volume is adequate.
- The maximum allowable drawdown time is 72 hrs after a 24-hr storm event.
- Subsurface detention vaults and tanks must meet structural requirements for overburden support and traffic loading.
- Flood protection controls for peak discharges should be designed as final controls for on-site stormwater.
- Water should not be discharged from subsurface detention PBMPs in an erosive manner. Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the end of the outlet to prevent scouring and erosion.
- A high flow bypass should be included in the subsurface detention PBMP design to address instances of significant rainfall, outlet structure blockage, or mechanical failure. The bypass should be located so that high flow discharges will not impact downstream structures.
- Select subsurface detention PBMPs capable of storing and settling the potential pollutants of concern at the project site based on the documented performance standards. The performance standard documentation should include independent third-party scientific verification of the subsurface detention PBMP to meet the project's stormwater objectives (water quality treatment and water quantity control).
- All subsurface detention PBMPs should safely overflow or bypass flows in excess of the stormwater quality design storm to the DOTA MS4, drainage system, or State waters.
- Consider using subsurface detention PBMP models certified for general use by the Washington State Department of Ecology TAPE or certified by the NJDEP.
- Follow the manufacturer's guidelines for design considerations based on the site conditions.
- There are no specific landscaping requirements. However, areas around these units should be clear at the surface and accessible for maintenance and inspection purposes.
- Strict adherence to regularly scheduled maintenance plans is required to reduce the risk of re-suspension of sediment during large storm events.
- Adequate maintenance access must be provided for all subsurface detention PBMPs. In addition, access must be provided over each chamber, inlet pipe, and outflow structure. Access openings can consist of a standard frame, grate and solid cover, or a removable panel.
- Project proponents should review the maintainability of the subsurface detention PBMPs, including access, equipment needed to conduct maintenance, and local availability of replacement media, media filters, other parts, etc.

PRETREATMENT CONSIDERATIONS

- Pretreatment should be considered if the level of sediment in the inflow would cause clogging or otherwise impair the long-term efficiency of the subsurface detention.
- A separate sediment sump or vault chamber sized to 0.10-in per impervious ac of contributing drainage should be provided at the inlet for underground detention systems that are in a treatment train with off-line water quality treatment structural controls

AREA REQUIREMENTS

- The footprint requirements for proprietary manufactured treatment devices vary by manufacturer. Follow the manufacturer's guidelines for appropriate sizing calculations and selection of appropriate device/model.

MINIMUM DESIGN CRITERIA

- Follow manufacturer's guidelines for the minimum design criteria.

SIZING GUIDELINES

- Follow the manufacturer's guidelines for appropriate sizing calculations and selection of appropriate device/model.

CONSTRUCTION CONSIDERATIONS

- Follow manufacturer's recommendations.
- Subsurface detention vaults and components should be watertight. Pipes entering and exiting a vault below the design water surface should be sealed using a sealant or concrete mastic.
- All construction joints must be provided with water stops.
- Cast-in-place wall sections must be designed as retaining walls.

EXAMPLE SCHEMATICS

- None provided since presenting any specific product might be interpreted as an endorsement.

Appendix VI

Evaporation Rates and Rainfall Data for Statewide Airports

Pan Evaporation Rate (E_{pan}) Data for Statewide Airports

Island	OAHU	OAHU	MAUI	HAWAII	MAUI	OAHU	HAWAII	KAUAI	LANAI	MOLOKAI	MOLOKAI	HAWAII	MAUI	KAUAI	HAWAII
Airport Name	Dillingham Airfield	Daniel K. Inouye International Airport	Hana Airport	Hilo International Airport	Kapalua Airport	Kalaeloa Airport	Ellison Onizuka Kona International Airport at Keahole	Lihue Airport	Lanai Airport	Kalaupapa Airport	Molokai Airport	Waimea-Kohala Airport	Kahului Airport	Port Allen Airport	Upolu Airport
Airport Code	**HDH**	**HNL**	**HNM**	**ITO**	**JHM**	**JRF**	**KOA**	**LIH**	**LNY**	**LUP**	**MKK**	**MUE**	**OGG**	**PAK**	**UPP**
Units	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**
January	4.36	5.10	^{*1}	5.05	4.61	4.85	^{*1}	5.36	2.16	7.78	5.73	4.21	5.10	5.84	5.72
February	4.36	5.34	^{*1}	4.92	5.28	4.93	^{*1}	5.66	1.83	7.70	6.43	4.12	5.44	5.38	0^{*2}
March	4.80	6.70	^{*1}	5.24	6.23	5.91	^{*1}	6.46	2.55	9.63	7.36	5.32	6.80	6.56	0^{*2}
April	5.36	7.36	^{*1}	5.61	6.77	6.72	^{*1}	7.19	2.64	9.91	7.84	5.38	7.59	7.64	0^{*2}
May	6.48	8.13	^{*1}	5.96	7.86	7.53	^{*1}	7.76	2.06	10.70	10.63	5.78	8.90	8.35	0^{*2}
June	7.20	8.73	^{*1}	6.54	7.91	7.78	^{*1}	8.09	2.07	11.56	10.75	6.22	9.86	8.90	0^{*2}
July	7.47	9.44	^{*1}	6.59	9.07	7.90	^{*1}	8.72	3.91	11.87	11.01	6.13	10.67	9.87	0^{*2}
August	7.09	9.24	^{*1}	6.20	9.17	8.17	^{*1}	8.56	2.35	11.79	12.38	7.08	10.39	8.88	0^{*2}
September	6.26	7.96	^{*1}	5.73	7.92	6.73	^{*1}	7.52	2.11	10.67	10.29	6.41	9.44	8.18	9.36
October	5.54	7.03	^{*1}	5.50	6.98	6.12	^{*1}	6.83	2.67	9.73	9.98	5.63	8.07	7.63	5.92
November	4.45	5.94	^{*1}	4.22	5.42	4.44	^{*1}	5.56	1.00	8.62	7.74	4.25	6.46	6.39	6.09
December	3.64	5.12	^{*1}	4.33	5.13	3.48	^{*1}	5.12	1.50	8.14	6.32	3.88	5.31	5.49	6.33
Station #	*O-1 (841.00)*	*O-10 (751.20)*	*M-16 x*	*H-67 (87.00)*	*M-1 (458.10)*	*O-6 (702.00)*	*H-2 x*	*K-11 (1020.40)*	*687*	*Mo-2 (531.10) not super close*	*Mo-2 (528.30) white dot*	*H-25 (191.10)*	*M-7 (396.00)*	*K-5 (927.00) or 925.00 white dot*	*H-13 (160.30)*

Notes:

^{*1} indicates data not available.

0^{*2} indicates data reported as zero.

Source: *Pan Evaporation: State of Hawaii 1894-1983. State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development* (Ekern, P.C. and Chang, J.H., 1985).

Rainfall Data for Statewide Airports

Island	OAHU	OAHU	MAUI	HAWAII	MAUI	OAHU	HAWAII	KAUAI	LANAI	MOLOKAI	MOLOKAI	HAWAII	MAUI	KAUAI	HAWAII
Airport Name	Dillingham Airfield	Daniel K. Inouye International Airport	Hana Airport	Hilo International Airport	Kapalua Airport	Kalaeloa Airport	Ellison Onizuka Kona International Airport at Keahole	Lihue Airport	Lanai Airport	Kalaupapa Airport	Molokai Airport	Waimea-Kohala Airport	Kahului Airport	Port Allen Airport	Upolu Airport
Airport Code	**HDH**	**HNL**	**HNM**	**ITO**	**JHM**	**JRF**	**KOA**	**LIH**	**LNY**	**LUP**	**MKK**	**MUE**	**OGG**	**PAK**	**UPP**
Units	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**	**(in)**
January	5.23	2.89	8.98	9.64	4.94	3.63	1.89	4.44	3.05	6.08	4.02	5.98	3.40	3.80	5.05
February	4.13	2.53	6.56	9.73	3.59	2.15	1.13	3.49	2.69	4.26	2.94	4.24	2.38	2.61	3.23
March	3.50	2.36	11.36	14.02	4.14	1.87	1.38	4.26	1.66	5.80	2.97	5.80	2.13	3.35	5.84
April	2.34	0.98	8.43	12.45	2.72	1.26	0.73	2.34	1.10	4.49	2.00	5.51	1.16	1.46	3.44
May	1.93	0.79	7.11	8.74	2.07	0.90	1.16	2.46	1.05	3.28	1.27	4.02	0.71	1.29	2.22
June	0.89	0.66	4.62	7.81	1.28	0.29	0.72	1.74	0.87	1.80	0.67	2.95	0.35	0.81	2.77
July	1.90	0.80	6.76	10.97	1.49	0.31	0.71	1.88	0.70	2.22	0.40	4.13	0.35	0.89	3.12
August	2.05	1.42	6.15	10.09	1.39	1.27	0.86	1.96	0.41	2.24	0.46	3.19	0.42	0.88	2.86
September	2.44	1.35	6.70	10.20	1.17	1.36	0.85	2.42	1.19	1.60	0.29	2.06	0.29	1.13	2.13
October	3.04	2.17	7.85	10.13	1.88	2.44	0.75	4.26	1.52	3.33	1.47	4.43	0.82	2.72	2.39
November	4.09	2.97	8.78	15.62	4.04	2.98	1.13	5.18	2.62	4.78	2.88	4.08	2.34	3.28	4.11
December	4.51	3.27	7.51	10.65	5.04	2.99	1.66	4.81	3.05	5.50	3.35	5.11	3.22	3.70	3.95
Station #	*843.7*	*759*	*353*	*87*	*462*	*702.5*	*68.13*	*1020.1*	*656*	*563*	*524*	*192.7*	*398*	*926*	*160.3*
Additional Information on Station	*Dillingham - Other Stations*				*Field 32a No station at airport*	*702.5 Campbel Ind Pk*						*Kamuela Upper (Other Station)*	*Kahului Ap*		

Source: http://rainfall.geography.hawaii.edu/interactivemap.html

Appendix VII

PBMP O&M Fact Sheets

Appendix VII
PBMP O&M Fact Sheets

This Appendix describes specific O&M to be considered for PBMPs. O&M is required for all LID PBMPs and Treatment Control PBMPs after installation is completed and the PBMPs have been turned over to DOTA or tenant.

The following lists the O&M Fact Sheets for LID and Treatment Control PBMPs (named with corresponding design fact sheets):

- LC-1: Biofilter
- LC-2: Bioretention
- LC-3: Bioswale
- LC-4: Collection/Reuse
- LC-5: Dry Well/Drainage Well
- LC-6: Infiltration Basin
- LC-7: Infiltration Trench
- LC-8: Permeable Pavement
- LC-9: Subsurface Infiltration
- LC-10: Vegetated Buffer Strip
- LC-11: Vegetated Swale
- TC-1: Alternative Wetland
- TC-2: Dry Detention Basin
- TC-3: Evaporation Pond
- TC-4: Hydrodynamic Separator Unit
- TC-5: Manufactured Treatment Device
- TC-6: Oil Water Separator
- TC-7: Sand Filter
- TC-8: Subsurface Detention

Note that the O&M required for Source Control PBMPs is provided within Appendix IV. For additional information on the operational Source Control measures, refer to the BMPs provided within the Tenant Program and DOTA Facility Program.

The following information is provided for each of the above-listed O&M Fact Sheets:

- BMP Category
- PBMP Name
- Inspection procedures
- Conditions that warrant maintenance
- Maintenance procedures

Refer to Appendices II and V for the corresponding PBMP Design Fact Sheets.

PBMP O&M Fact Sheet

LC-1: Biofilter

Biofilters detain and filter runoff through internal media and returns treated runoff to the stormwater system (i.e., vegetated biofilter) or detain and treat runoff by infiltrating into the underlying soil (i.e., stormwater curb extension, tree box, planter box, etc.). Maintenance is primarily focused on maintaining healthy vegetation, avoiding clogging, and proper functioning of inlets, outlets, and high-low bypasses.

Stormwater Planter
Source: Bureau of Environmental Services
Stormwater planter at Epler Hall at Portland State University, Oregon

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Monitor observation wells, if present, to determine how quickly the system is draining after a storm and condition of the filter media.
- Inspect the biofilter for ponded water, i.e., standing water in the biofilter after inflow has ceased.
- Inspect surfaces for damage by erosion, rodents, vehicles, or other reasons. Walk around the biofilter, and note the locations of erosion or drainage changes.
- Note landscaping changes that need to be addressed (e.g., grass cutting, vegetation pruning, etc.).
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect the irrigation system for proper operation and distribution.
- Use AMS for PBMP inspection and tracking.

STORMWATER CURB EXTENSION

In addition to the above items, inspect the curb extension for the following:

- Inspect for curb damage or other structural damage.
- Inspect for accumulation of sediment, trash, debris, litter, and leaves surrounding the stormwater curb extensions.

TREE BOX FILTER OR PLANTER BOX

In addition to the above items, inspect the tree box filter or planter box for the following:

- Inspect for structural damage to the box.
- Refer to the manufacturer's inspection requirements for more detailed information.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- Significantly overgrown areas that require landscape maintenance.
- Vegetation is dead or diseased; note that vegetation can be dormant during dry seasons.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from the PBMP or is bypassed).
- Water ponding in a biofilter suggests that sediment or trash blockages may be present, soil infiltration rate may have been reduced due to compaction, media layer may be clogged, or the underdrain/permeable filter fabric may be clogged.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Structural damage.

STORMWATER CURB EXTENSION

In addition to the above items, the following conditions may warrant maintenance of the curb extension:

- Curb damage or other structural damage.
- Accumulation of sediment, trash, debris, litter, and leaves surrounding the stormwater curb extensions.

TREE BOX FILTER OR PLANTER BOX

- In addition to the above items, refer to the manufacturer's maintenance requirements for more detailed information on conditions that may warrant maintenance of the tree box filter or planter box.

MAINTENANCE PROCEDURES

- Conduct regular plant maintenance, including mowing, pruning, and weeding.
- Avoid or minimize the use of fertilizers and herbicides.
- Replace dead and diseased vegetation.
- Remove vegetation clippings and leaves.
- Irrigation may be required during prolonged dry periods.
- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the biofilter, immediately determine the source, remove sediment deposits, and correct the problem.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within biofilters.
- Schedule the repair of biofilters in advance of the first seasonal rains.
- Stabilize eroded areas, replace dead vegetation, repair erosion, and replenish mulch.
- Re-grade to reshape the biofilter cross-section as sediment collects and form pools. Remove and properly dispose of the sediments.
- If water ponds after inflow has ceased, clear the outlet of sediment or trash blockages and remove the top layer of material and replace them with fresh material. If this does not help with the bio-filtration, the media layer, underdrain, or permeable filter fabric may be clogged; replace the media layer, unclog the underdrain, or replace the permeable filter fabric, whichever is applicable.
- Repair structural damage.
- Maintenance can be tracked using work orders, maintenance personnel, landscaping contracts, and AMS.

STORMWATER CURB EXTENSION

In addition to the above items, conduct the following maintenance on the curb extension:

- Repair curb damage or other structural damage.
- Remove accumulated sediment, trash, debris, litter, and leaves surrounding the stormwater curb extensions.

TREE BOX FILTER OR PLANTER BOX

- In addition to the above items, refer to the manufacturer's maintenance requirements for more detailed information on maintenance equipment needed and activities.

PBMP O&M Fact Sheet

LC-2: Bioretention

Bioretention facilities use landscaping features to treat stormwater runoff through infiltration. Runoff filters through the vegetation, prepared soil mix, and gravel in the landscaped area, thereby removing pollutants.

Bioretention facilities have various components, such as an underdrain, monitoring wells, and native plants.

Regular inspections and maintenance are needed to verify flow is unobstructed, erosion is prevented, and soils are biologically active.

Bioretention at Kakoi Baseyard, Oahu
Source: HDOT Highways Division

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Monitor observation wells, if present, to determine how quickly the system is draining after a storm and condition of the filter media.
- Inspect the bioretention for ponded water (i.e., standing water in the bioretention that does not drain after 48 hrs of the storm event).
- Inspect surfaces for damage caused by erosion, rodents, vehicles, or other reasons. Walk around the bioretention facility and note the locations of erosion or drainage changes.
- Note landscaping changes on-site that need to be addressed (e.g., grass cutting, vegetation pruning, etc.).
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect the irrigation system for proper operation and distribution.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- Significantly overgrown areas that require landscape maintenance.
- Vegetation is dead or diseased; note that vegetation can be dormant during dry seasons.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from the PBMP or is bypassed).
- Water ponding in a bioretention facility for longer than 48 hrs suggests sediment or trash blockages may be present, soil infiltration rate may have been reduced due to compaction, media layer may be clogged, or the underdrain/permeable filter fabric may be clogged.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.

MAINTENANCE PROCEDURES

- Conduct regular plant maintenance, including mowing, pruning, and weeding.
- Avoid or minimize the use of fertilizers and herbicides.
- Replace dead and diseased vegetation.
- Remove vegetation clippings and leaves.
- Irrigation may be required during prolonged dry periods.
- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the bioretention facility, immediately determine the source, remove sediment deposits, and correct the problem.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within bioretention facilities.
- Schedule the repair of bioretention facilities in advance of the first seasonal rains.
- Stabilize eroded areas, replace dead vegetation, repair erosion, and replenish mulch.
- Re-grade to reshape the bioretention facility cross-section as sediments collect and form pools, and remove and properly dispose of the sediments.
- If water ponds for more than 48 hrs, clear the outlet and bioretention facility surface of sediment or trash blockages and remove the top layer of material to replace it with fresh material. If this does not help with the infiltration, the media layer, underdrain, or permeable filter fabric may be clogged; replace the media layer, unclog the underdrain, or replace the permeable filter fabric, whichever is applicable.
- Repair structural damage.
- Note that bioretention maintenance can be tracked using work orders, maintenance personnel, landscaping contracts, and AMS.

PBMP O&M Fact Sheet

LC-3: Bioswale

Bioswale at Terminal 3 Parking Lot

Bioswales are vegetated open channels explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means. Maintenance primarily focuses on maintaining healthy vegetation, avoiding clogging, and the proper functioning of inlets and outlets.

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Monitor observation wells, if present, to determine how quickly the system is draining after a storm.
- Inspect the bioswale for ponded water, i.e., standing water in the bioswale after inflow has ceased.
- Inspect inlets, outlets, and check dam structures for evidence of undercutting and erosion.
- Inspect surfaces for damage caused by erosion, rodents, vehicles, or other reasons. Walk around the bioswale, and note locations of erosion or drainage changes.
- Note landscaping changes that need to be addressed (e.g., grass cutting).
- Observe discharge, if present, and the origin of a discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect the irrigation system for proper operation and distribution.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- Significantly overgrown areas that require landscape maintenance; grass should be maintained at least 3-in of height.
- Vegetation is dead or diseased; note that vegetation can be dormant during dry seasons.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from the PBMP or is bypassed).
- Water ponding in a bioswale suggests that sediment or trash blockages may be present, soil infiltration rate may have been reduced due to compaction, media layer may be clogged, or the underdrain/permeable filter fabric may be clogged.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.

MAINTENANCE PROCEDURES

- Conduct regular vegetative maintenance, including mowing and weeding.
- Avoid or minimize the use of fertilizers and herbicides.
- Replace dead vegetation to maintain 90% grass.
- Irrigation may be required during prolonged dry periods.
- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the bioswale, immediately determine the source, remove sediment deposits, and correct the problem.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within bioswales.
- Schedule the repair of bioswales in advance of the first seasonal rains.
- Stabilize undercuts and eroded areas at the bioswale inflow, outflow, and check dam structures.
- Re-grade to reshape the bioswale cross-section as sediments collect and form pools. Remove and properly dispose of the sediments.
- If water ponds after inflow has ceased, clear the outlet and bioswale surface of sediment or trash blockages or remove the top layer of material and replace it with fresh material. If this does not help, the media layer, underdrain, or permeable filter fabric may be clogged; replace the media layer, unclog the underdrain, or replace the permeable filter fabric, whichever is applicable.
- Repair structural damage.
- Note that bioswale maintenance can be tracked using work orders, maintenance personnel, landscaping contracts, and AMS.

PBMP O&M Fact Sheet

LC-4: Collection/Reuse

Collection/reuse is the collection and temporary storage of roof runoff in rain barrels or cisterns for subsequent non-potable use, including landscape irrigation, vehicle washing, or other non-potable use. Maintenance is primarily focused on preventing sediment build-up and clogging, which reduces the capacity of the system.

Cistern, Maui
Source: Sea Grant, University of Hawaii

INSPECTION PROCEDURES

- Inspect filters, screens, gutters, downspouts, first flush devices, roof washers, cisterns, rain barrels, and flow entrances for sediment, trash, and debris accumulation.
- Monitor observation wells, if present, to determine how quickly the system is draining after a storm.
- Inspect for water leaking from the system or outlet, allowing excessive flows.
- Verify that the collection systems are functioning and operational if present.
- Inspect the irrigation system, if present.
- Use AMS for PBMP inspections and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- First flush devices are clogged, or diverter valves need cleaning.
- The collection system is not working as intended.
- Clogging or structural damage of the cisterns and rain barrels.
- The outlet is clogged.
- Cistern leaks or outlets are allowing excessive flows.

MAINTENANCE PROCEDURES

- Remove accumulated sediment, trash, debris, litter, and leaves.
- Cisterns and rain barrels may need to be flushed to remove sediment. If flushing the cistern or rain barrel, clean the inside surfaces thoroughly and disinfect (if needed).
- Clear obstructions at the first flush devices and diverter valves.
- Schedule the repair of the treatment systems as needed.
- Repair leaks and structural damage to the cisterns and rain barrels.
- If the cisterns or rain barrels are not completely drained in 48 hrs, clear the outlet of sediment or trash blockages.
- Note that maintenance can be tracked using work orders, maintenance personnel, service contracts, and AMS.

LC-5: Dry Well/Drainage Well

A dry well/drainage well is a subsurface aggregate-filled or prefabricated perforated storage facility, where stormwater or roof runoff is stored and infiltrates into the soil matrix. Maintenance is primarily focused on avoiding clogging.

Dry Well, Daniel K. Inouye Airport

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Inspect the dry well/drainage well for ponded water (i.e., standing water in the dry well/drainage well that does not drain after 48 hrs of the storm event).
- Inspect the surrounding area for waterlogged soils, indicating dry well/drainage well failure.
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Water ponding in the dry well/drainage well for longer than 48 hrs suggests the sediment or trash blockages may be present, soil infiltration rate may have been reduced due to compaction, or the media layer may be clogged.
- Recent oil spill or fuel spill.
- Significant odors.

MAINTENANCE PROCEDURES

- Remove accumulated sediment, trash, and debris from the DOTA MS4 or drainage system leading to and within dry wells/drainage wells.
- If excessive sediment is deposited in the dry well/drainage well, immediately determine the source, remove sediment deposits, and correct the problem.
- Clear obstructions.
- If water ponds for more than 48 hrs, clear the outlet of sediment or trash blockages and remove the top layer of material to replace it with fresh material. If this does not help with the infiltration, the media may be clogged; replace the media.
- Repair structural damage.
- Note that dry well/drainage well maintenance can be tracked using work orders, maintenance personnel, service contracts, and AMS.

PBMP O&M Fact Sheet

LC-6: Infiltration Basin

An infiltration basin is a shallow impoundment with no outlet, where stormwater runoff is stored and infiltrates through the basin invert and into the soil matrix. Maintenance is primarily focused on preventing sediment build-up and clogging, which reduces the capacity of the system.

Infiltration Basin, Kahului Airport

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Monitor observation wells, if present, to determine how quickly the system is draining after a storm.
- Inspect the infiltration basin for ponded water (i.e., standing water in the infiltration basin that does not drain after 48 hrs of the storm event).
- Inspect surfaces and embankments for damage caused by erosion, rodents, vehicles, or other reasons. Walk around the infiltration basin and note the locations of erosion or drainage changes.
- Note landscaping changes that need to be addressed (e.g., grass cutting).
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- Significantly overgrown areas that require landscape maintenance; grass should be maintained at least 3 in of height.
- Vegetation is dead or diseased; note that vegetation can be dormant during dry seasons.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Water ponding in an infiltration basin for longer than 48 hrs suggests the presence of sediment or trash blockages, reduction of soil infiltration rate due to compaction, or clogging of media layer or the underdrain/permeable filter fabric.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.

MAINTENANCE PROCEDURES

- Conduct regular vegetative maintenance, including mowing and weeding.
- Avoid or minimize the use of fertilizers and herbicides.
- Replace dead vegetation to maintain 90% grass.
- Remove vegetation clippings and leaves.
- Irrigation may be required during prolonged dry periods.
- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the infiltration basin, immediately determine the source, remove sediment deposits, and correct the problem.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within the infiltration basins.
- Schedule the repair of infiltration facilities in advance of the first seasonal rains.
- Stabilize undercuts and eroded areas at the infiltration basin inflow, outflow, overflow structures, and embankments.
- Re-grade to reshape the infiltration basin cross-section as sediments collect and form pools. Remove and properly dispose of the sediments.
- If water ponds for more than 48 hrs, clear the outlet and the infiltration basin surface of sediment or trash blockages and remove the top layer of material to replace it with fresh material. If this does not help with the infiltration, the media layer, underdrain, or permeable filter fabric may be clogged; replace the media layer, unclog the underdrain, or replace the permeable filter fabric, whichever is applicable.
- Repair structural damage.
- Maintenance can be tracked using work orders, maintenance personnel, landscaping contracts, and AMS.

PBMP O&M Fact Sheet

LC-7: Infiltration Trench

An infiltration trench is a long narrow rock-filled PBMP with no outlet, where stormwater runoff is stored in the void space between the rocks and infiltrates through the bottom and into the soil matrix. Maintenance is primarily focused on preventing sediment build-up and clogging, which reduces the capacity of the system.

Infiltration Trench, Kauai
Source: HDOT Harbors Division, Kauai Federal Credit Union

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Monitor observation wells, if present, to determine how quickly the system is draining after a storm.
- Inspect the infiltration trench for ponded water (i.e., standing water in the infiltration trench that does not drain after 48 hrs of the storm event).
- Inspect surfaces for damage caused by erosion, rodents, vehicles, or other reasons. Walk around the infiltration trench and note the locations of erosion or drainage changes.
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from the PBMP or is bypassed).
- Water ponding in an infiltration trench for longer than 48 hrs suggests the presence of sediment or trash blockages, reduction of soil infiltration rate due to compaction, or clogging of media layer, the underdrain, or permeable filter fabric.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.

MAINTENANCE PROCEDURES

- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the infiltration trench, immediately determine the source, remove sediment deposits, and correct the problem.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within the infiltration trenches.

- Schedule the repair of infiltration facilities in advance of the first seasonal rains, as needed.
- Stabilize undercuts and eroded areas at the infiltration trench inflow and outflow structures.
- Re-grade to reshape the infiltration trench cross-section as sediments collect and form pools. Remove and properly dispose of the sediments.
- If water ponds for more than 48 hrs, clear the outlet and infiltration trench surface of sediment or trash blockages and remove the top layer of trench rock and replace it with fresh material. If this does not help, the trench rock or alternative backfill layer, underdrain, or permeable filter fabric may be clogged; replace the trench rock or alternative backfill layer, unclog the underdrain, or replace the permeable filter fabric, whichever is applicable.
- Repair structural damage.
- Maintenance can be tracked using work orders, maintenance personnel, and service contracts.

PBMP O&M Fact Sheet

LC-8: Permeable Pavement

Elliott Street Parking Lot Permeable Pavement, Daniel K. Inouye International Airport

Permeable pavement is a permeable surface that allows stormwater runoff to move through surface voids into an underlying aggregate reservoir for temporary storage and infiltration. Maintenance primarily focuses on preventing sediment build-up and clogging, which reduces the capacity of the system.

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for sediment, trash, and debris accumulation.
- Inspect permeable pavement for accumulation of sediment, trash, and debris.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect for signs of pavement structural damage such as deformations, cracked pavers, etc.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, and debris.
- The area exhibits significant changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Recent significant oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.

MAINTENANCE PROCEDURES

- Remove accumulated sediment, trash, and debris.
- Use commercially available regenerative air or vacuum sweeper to remove sediment and debris from the surface regularly.
- If excessive sediment is deposited in the permeable pavement, immediately determine the source, remove sediment deposits, and correct the problem.
- Schedule the repair of the damaged permeable pavement in advance of the first seasonal rains.
- Repair structural damage.
- Cleanup any fresh petroleum spills immediately with absorbent pads. Do not use clay absorbents as they may clog permeable pavement.
- Maintenance can be tracked using work orders, maintenance personnel, and service contracts.

PBMP O&M Fact Sheet

LC-9: Subsurface Infiltration

Subsurface infiltration is a below surface rock-filled bed with no outlet, where stormwater runoff is stored in the void space between the rocks and infiltrates through the bottom and into the soil matrix. Maintenance is primarily focused on preventing sediment build-up and clogging, which reduces the capacity of the system.

Subsurface Infiltration
Source: *Philadelphia Stormwater Management Guidance Manual, Version 3.2*

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Monitor observation wells, if present, to determine how quickly the system is draining after a storm.
- Inspect the subsurface infiltration system for ponded water (i.e., standing water in the subsurface infiltration system that does not drain after 48 hrs of the storm event). Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Refer to the manufacturer’s inspection requirements for more detailed information.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- The area exhibits significant changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Water ponding in a subsurface infiltration system for longer than 48 hrs suggests the presence of sediment or trash blockages, reduction of soil infiltration rate due to compaction, or clogging of native soil or the permeable filter fabric.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Refer to the manufacturer’s maintenance requirements for more detailed information.

MAINTENANCE PROCEDURES

- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the subsurface infiltration system, immediately determine the source, remove sediment deposits, and correct the problem. Sediment removal may need to be accomplished with a JetVac or a similar process.
- Strict adherence to a regularly scheduled maintenance frequency may be needed to reduce the risk of re-suspension of sediment during significant storm events.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within the subsurface infiltration systems.
- Schedule the repair of subsurface infiltration systems in advance of the first seasonal rains.
- If water ponds for more than 48 hrs, clear the outlet and subsurface infiltration system invert of sediment or trash blockages. If this does not help, the rock or alternative material layer or permeable filter fabric may be clogged; unclog the rock or alternative material layer using a JetVac or a similar process or replace the permeable filter fabric, whichever is applicable.
- Repair structural damage.
- Refer to the manufacturer's maintenance requirements for more detailed information on maintenance equipment needed and activities.
- Maintenance can be tracked using work orders, maintenance personnel, service contracts, and AMS.

PBMP O&M Fact Sheet

LC-10: Vegetated Buffer Strip

Vegetated buffer strips are designed to remove pollutants by physically straining and filtering water through vegetation. Maintenance is primarily focused on maintaining healthy vegetation and avoiding clogging.

Vegetated Buffer Strip, Oahu
Source: HDOT Highways Division

INSPECTION PROCEDURES

- Inspect inlets and sheet flow areas for impoundments for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect the vegetated buffer strip for ponded water, i.e., standing water after inflow has ceased.
- Inspect inlets and outlets for evidence of undercutting and erosion.
- Inspect surfaces for damage caused by erosion, rodents, vehicles, or other reasons. Walk around the vegetated buffer strip, and note locations of erosion or drainage changes.
- Note landscaping changes that need to be addressed (e.g., grass cutting).
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect the irrigation system for proper operation and distribution.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- Significantly overgrown areas that require landscape maintenance; grass should be maintained at least 3 in of height.
- Vegetation is dead or diseased; note that vegetation can be dormant during dry seasons.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Water ponding in a vegetated buffer strip suggests the presence of sediment or trash blockages or the bottom of the vegetated buffer strip needs regrading.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.

MAINTENANCE PROCEDURES

- Conduct regular vegetative maintenance, including mowing and weeding.
- Avoid or minimize use of fertilizers and herbicides.
- Replace dead vegetation to maintain 90% grass.
- Irrigation may be required during prolonged dry periods.
- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the vegetated buffer strip, immediately determine the source, remove sediment deposits, and correct the problem.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within vegetated buffer strips.
- Schedule the repair of vegetated buffer strips in advance of the first seasonal rains.
- Stabilize undercuts and eroded areas at the buffer strip inflow and outflow structures.
- Re-grade to reshape the vegetated buffer strip cross-section as sediments collect and form pools. Remove and properly dispose of the sediments.
- If water ponds after inflow has ceased, clear the outlet and vegetated buffer strip surface of sediment or trash blockages. If this does not help, regrade to surface match the design geometry, revegetate, or investigate the source of sediment.
- Repair structural damage.
- Maintenance can be tracked using work orders, maintenance personnel, landscaping contracts, and AMS.

PBMP O&M Fact Sheet

LC-11: Vegetated Swale

Vegetated swales are designed to remove pollutants by physically straining and filtering water through vegetation. Maintenance is primarily focused on maintaining healthy vegetation and avoiding clogging.

Vegetated Sawle along H-3, Oahu
Source: HDOT Highways Division

INSPECTION PROCEDURES

- Inspect inlets and sheet flow areas for impoundments and accumulation of sediment, trash, debris, litter, and leaves.
- Inspect the vegetated swale for ponded water, i.e., standing water after inflow has ceased.
- Inspect inlets, outlets, and check dam structures for evidence of undercutting and erosion.
- Inspect surfaces for damage caused by erosion, rodents, vehicles, or other reasons. Walk around the vegetated swale, and note locations of erosion or drainage changes.
- Note landscaping changes that need to be addressed (e.g., grass cutting).
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect the irrigation system.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- Significantly overgrown areas that require landscape maintenance; grass should be maintained at least 3 in of height.
- Vegetation is dead or diseased; note that vegetation can be dormant during dry seasons.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from the PBMP or is bypassed).
- Water ponding in a vegetated swale suggests the presence of sediment or trash blockages or the bottom of the vegetated swale needs regrading.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.

MAINTENANCE PROCEDURES

- Conduct regular vegetative maintenance, including mowing and weeding.
- Avoid or minimize the use of fertilizers and herbicides.
- Replace dead vegetation to maintain 90% grass.
- Irrigation may be required during prolonged dry periods.
- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the vegetated swale, immediately determine the source, remove sediment deposits, and correct the problem.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within vegetated swales.
- Schedule the repair of vegetated swales in advance of the first seasonal rains.
- Stabilize undercuts and eroded areas at the swale inflow, outflow, and check dam structures.
- Re-grade to reshape the vegetated swale cross-section as sediments collect and form pools. Remove and properly dispose of the sediments.
- If water ponds after inflow has ceased, clear the outlet and the vegetated swale surface of sediment or trash blockages. If this does not help, regrade to surface match the design geometry, revegetate, or investigate the source of sediment.
- Repair structural damage.
- Maintenance can be tracked using work orders, maintenance personnel, landscaping contracts, and AMS.

PBMP O&M Fact Sheet

TC-1: Alternative Wetlands

Alternative wetlands filter runoff through a floating matrix or prefabricated modular system that mimics the wetland ecosystem prior to returning to the DOTA MS4, drainage system, or State waters. Maintenance is primarily focused on maintaining healthy vegetation, accumulation of trash and debris, proper anchoring of the FTW, mosquito abatement, and proper functioning of inlets, outlets, and high-low bypasses.

Floating wetland in Kaanapali Lagoon, Maui
Source: West Maui Ridge 3 Reef Initiative

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Inspect the alternative wetland system to check that the vegetation is viable and that water is flowing through the wetland system.
- Note landscaping changes that need to be addressed (e.g., grass cutting, vegetation pruning, etc.).
- Inspect for wildlife issues and evidence of mosquitoes or mosquito larvae in the wetlands.
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Use AMS for PBMP inspection and tracking.

FLOATING TREATMENT WETLANDS

In addition to the above items, inspect the FTW for the following:

- Inspect for FTW raft and matrix damage or other structural damage.
- Inspect the anchors or tethers to verify the FTW rises and falls with the stormwater fluctuations, and it is protected from flooding (no inundation of the FTW matrix). Additionally, the anchors or tethers should be functional to retrieve the FTW for maintenance.
- Refer to the manufacturer's inspection requirements for more detailed information.

MODULAR WETLANDS

In addition to the above items, inspect the modular wetland for the following:

- Inspect for structural damage to the prefabricated modular wetland box.
- Inspect surfaces for damage caused by erosion, rodents, vehicles, or other reasons. Walk around the modular wetland, and note locations of erosion or drainage changes.
- Refer to the manufacturer's inspection requirements for more detailed information.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- Significantly overgrown areas that require landscape maintenance.
- Vegetation is dead or diseased; note that vegetation can be dormant during dry seasons.
- Vegetation that is attracting wildlife.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Observed evidence of mosquitoes or mosquito larvae.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Structural damage.

FLOATING TREATMENT WETLANDS

- In addition to the above items, refer to the manufacturer's maintenance requirements for more detailed information on conditions that may warrant the maintenance of FTW.

MODULAR WETLANDS

- In addition to the above items, refer to the manufacturer's maintenance requirements for more detailed information on conditions that may warrant the maintenance of modular wetlands.

MAINTENANCE PROCEDURES

- Conduct regular plant maintenance, including mowing, pruning, and weeding.
- Avoid or minimize the use of fertilizers and herbicides.
- Replace dead, diseased, and wildlife attractant vegetation.
- Remove vegetation clippings and leaves.
- Irrigation may be required during prolonged dry periods.
- Remove accumulated sediment, trash, and debris.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within wetlands.
- Schedule the repair of wetlands in advance of the first seasonal rains, as needed.
- Conduct mosquito abatement using a bubbler, mosquito fish, or other means.
- Repair structural damage.
- Maintenance can be tracked using work orders, maintenance personnel, service contracts, and AMS.

FLOATING TREATMENT WETLANDS

- Repair anchors or tethers as needed.
- Refer to the manufacturer's maintenance requirements for more detailed information on maintenance equipment needed and activities.

MODULAR WETLANDS

In addition to the above regular items, inspect the modular wetland for the following:

- Refer to the manufacturer's maintenance requirements for more detailed information on maintenance equipment needed and activities.
- Maintenance could include periodic replacement of media or filter cartridges.

PBMP O&M Fact Sheet

TC-2: Dry Detention Basin

Dry detention basins can provide stormwater quantity control and water quality using shallow man-made impoundment that provides for the temporary storage of stormwater runoff to allow particles to settle. Dry detention basins do not have a permanent pool and are designed to drain completely between storm events. Maintenance is primarily focused on sediment removal, maintaining healthy vegetation, and mosquito abatement.

Detention Basin at Kahului Airport

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Inspect the outlet, embankment, dikes, berms, and side slopes for structural integrity and signs of erosion or rodent burrows.
- Inspect inlets, control structures, overflow structures, and piping for clogging and signs of erosion.
- Inspect for structural damage of structures.
- Inspect the dry detention basin for ponded water, i.e., standing water in the basin after inflow has ceased.
- Monitor how quickly the dry detention basin is draining after a storm.
- Note landscaping changes that need to be addressed (e.g., grass cutting, vegetation pruning, etc.).
- Inspect for wildlife issues and evidence of mosquitoes or mosquito larvae within the PBMP.
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- Significantly overgrown areas that require landscape maintenance.
- Vegetation is dead or diseased; note that vegetation can be dormant during dry seasons.
- Observed vegetation is attracting wildlife.
- Observed evidence of mosquitoes or mosquito larvae in the basin.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from the PBMP or is bypassed).
- Water ponding in a dry detention basin suggests that sediment or trash blockages may be present, the outflow structures may be clogged, the low flow orifice may be clogged, or the bottom of the basin needs regrading.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Structural damage.

MAINTENANCE PROCEDURES

- Conduct regular plant maintenance, including mowing, pruning, and weeding.
- Avoid or minimize the use of fertilizers and herbicides.
- Replace dead, diseased, and wildlife attractant vegetation.
- Remove vegetation clippings and leaves.
- Irrigation may be required during prolonged dry periods.
- Remove accumulated sediment, trash, and debris.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within the dry detention basin.
- Schedule the repair of the dry detention basin in advance of the first seasonal rains.
- Stabilize eroded areas, replace dead vegetation, and repair erosion.
- Re-grade to reshape the dry detention basin bottom as sediments collect and form pools. Remove and properly dispose of the sediments.
- If water ponds after inflow has ceased, clear the control structure of sediment or trash blockages. If this does not help with the release of runoff, unclog the low flow orifice or regrade the bottom of the basin.
- Repair structural damage.
- Conduct mosquito abatement using a bubbler, mosquito fish, or other means.
- Maintenance can be tracked using work orders, maintenance personnel, landscaping contracts, and AMS.

PBMP O&M Fact Sheet

TC-3: Evaporation Pond

Evaporation ponds are shallow man-made ponds with large surface areas designed to hold a set volume of stormwater runoff and allow for evaporation by sunlight and exposure to the ambient temperatures, wind, and humidity with no outlet structure. Maintenance is primarily focused on sediment removal and mosquito abatement.

Evaporation Pond at Kahului Airport

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, and litter.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Inspect the embankment, dikes, berms, and side slopes for structural integrity and signs of erosion or rodent burrows.
- Inspect inlets, piping, and overflow structures/emergency spillways for clogging and signs of erosion.
- Walk around the entire perimeter of the pond.
- Inspect for structural damage of structures.
- Inspect the evaporation pond for ponded water, i.e., standing water in the pond for longer than the design drawdown time, 48hrs.
- Monitor how quickly the pond is evaporating after a storm.
- Inspect for wildlife issues and evidence of mosquitoes or mosquito larvae.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, and litter.
- Water ponding in an evaporation pond suggests that sediment or trash blockages may be present or the bottom of the basin needs regrading.
- Observed evidence of mosquitoes or mosquito larvae.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Structural damage.

MAINTENANCE PROCEDURES

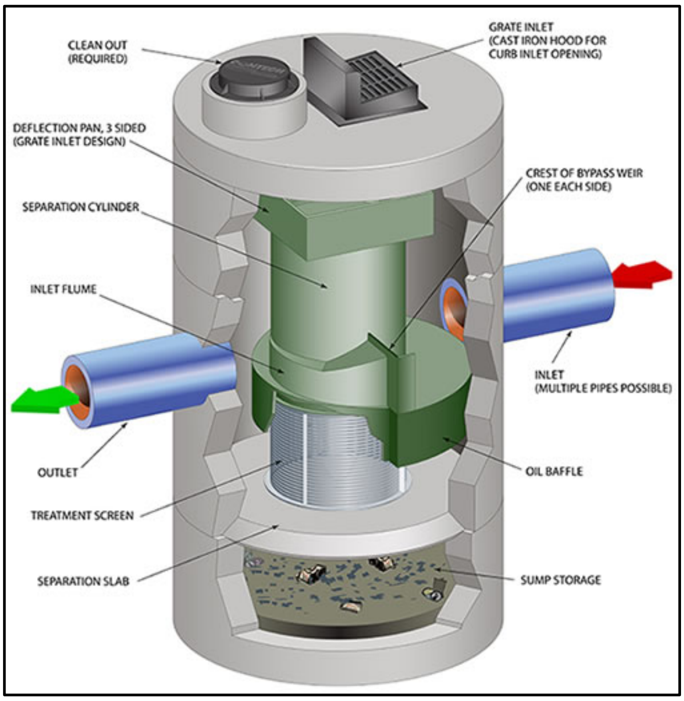
- Remove accumulated sediment, trash, and debris.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within the evaporation pond.
- If water ponds for longer than 48 hrs, clear the sediment or trash blockages. If this does not help, regrade the bottom of the pond.
- Schedule the repair of evaporation ponds in advance of the first seasonal rains.
- Stabilize eroded areas and repair erosion.
- Re-grade to reshape the evaporation pond bottom as sediments collect and form pools. Remove and properly dispose of the sediments.
- Repair structural damage.
- Conduct mosquito abatement using a bubbler, mosquito fish, or other means.
- Maintenance can be tracked using work orders, maintenance personnel, service contracts, and AMS.

PBMP O&M Fact Sheet

TC-4: Hydrodynamic Separator Unit

HDS units are flow-through structures with a settling or separation unit to remove sediments and other pollutants. An HDS unit is also known as a vortex separator, a swirl separator, a swirl concentrator, or a continuous deflective separator unit.

A continuous deflective separator unit is a flow-through structure installed underground as part of the DOTA MS4 or drainage system, with a settling or separation unit to remove sediments, floatables (trash, debris, etc.), and other pollutants. The continuous deflective separator unit is used to remove settleable particles and employs phase separation to remove buoyant materials (free oils and grease) from the water matrix. Common design features include bypass, swirl action, screening action, and coalescence action. The bypass feature allows only low flows to be treated while high flows bypass the treatment chamber. The swirl action feature allows stormwater to enter the unit on a tangent to the chamber, promoting a swirling motion. Sediments are removed by gravity and deposited at the bottom of the chamber. Maintenance is primarily focused on sediment removal, trash and debris removal, unclogging outlet structures, screen cleaning, and mosquito abatement.



Common design features of a CDS® unit
Source: Contech Engineered Solutions

The following details general guidelines for inspection and maintenance of an HDS unit or continuous deflective separator unit currently installed at DOTA airports. Refer to the manufacturer's inspection and maintenance requirements for additional information.

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances.
- Inspect sediment depth with a calibrated dipstick, tape measure or other measuring instrument to determine if cleaning is needed based on the specified unit cleaning depth.
- Inspect for accumulation of trash, floatables, debris, and litter.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Open the separation chamber manhole cover or grate to inspect the vault.
- Inspect inlets, piping, and outflow for clogging.
- Inspect the HDS unit for collected water, i.e., standing water in the HDS unit after inflow has ceased.
- Inspect the unit for structural damages.
- Remove access covers and visually inspect the internal components for broken or missing parts.
- Inspect for evidence of mosquitoes or mosquito larvae in the HDS unit.
- Inspect the color of the absorbent material, if used in the HDS Unit.

- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, and litter.
- Water ponding within the HDS unit suggests that sediment or trash blockages may be present, or the overflow pipe may be clogged. While it is recommended to completely drain the HDS unit to remove sediment, note that certain models of HDS unit may contain water within the separation chamber or the sump (located below the outlet invert); the inspector should assess the ponding conditions that warrant maintenance based on the O&M recommended by the manufacturer for the specific unit.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Structural damage is observed.
- Observed evidence of mosquitoes or mosquito larvae in the HDS unit.
- Significant discoloration of the absorbent material is observed.

MAINTENANCE PROCEDURES

- Remove accumulated sediment and floating trash, and debris with a scoop net or an extension on the end of the boom hose of the vacuum truck. It is recommended to clean HDS units using a vacuum truck.
- Remove the sediment from the bottom of the sump with a vacuum truck.
- There may be a need to dewater the structure through the vortex tubes and evacuate all accumulated sediment from the sediment sump. Water from the dewatering process needs to be disposed of properly.
- Some jetting may be required to loosen up sediment from the sump. The jetting can be achieved by inserting a jet hose through the vortex tube opposite the tube used for vacuum hose access; follow manufacturers O&M procedures.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within the HDS unit.
- Maintenance should be conducted during dry weather when no flow is entering the HDS unit.
- If water ponds after inflow has ceased, clear the outlet of sediment or trash blockages. If this does not help, unclog the overflow drain. However, as noted above, the inspector should assess the ponding conditions that warrant maintenance based on the O&M recommended by the manufacturer for the specific HDS unit.
- Brush the screen clean and, if needed, follow up with a wash (if applicable).
- Schedule the repair of HDS units in advance of the first seasonal rains.
- Repair structural damage.
- Conduct mosquito abatement using a bubbler, mosquito fish, or other means.
- Replace the absorbent material if damage or discoloration is observed. For example, if absorbent pads are tethered to the HDS unit, only OSHA Confined Space Entry trained and certified personnel may enter the structure to remove and replace the spent material.
- Maintenance can be tracked using service contracts.

PBMP O&M Fact Sheet

TC-5: Manufactured Treatment Device

MTDs are proprietary water quality structures utilizing settling, filtration, adsorptive materials, vortex separation, vegetative components, or other appropriate technology to remove pollutants from stormwater runoff. DOTA has separate O&M Fact Sheets for HDS units and OWSs. Maintenance is primarily focused on filter media (including cartridges) replacement, sediment, and trash removal, unclogging outlet structures, and mosquito abatement.

The following details the general guidelines for inspection and maintenance of MTDs. Refer to the manufacturer’s inspection and maintenance requirements for additional information.

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances.
- Inspect sediment depth with a calibrated dipstick, tape measure or other measuring instrument to determine if cleaning is needed based on the specified unit cleaning depth.
- Inspect for accumulation of trash, floatables, debris, and litter.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Open the separation chamber manhole cover or grate to inspect the vault.
- Inspect inlets, piping, and outflow for clogging.
- Inspect the MTD for ponded water, i.e., standing water in the MTD after inflow has ceased.
- Inspect for structural damage of structures.
- Remove access covers and visually inspect the internal components for broken or missing parts.
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect for evidence of mosquitoes or mosquito larvae in the MTD.
- Inspect the color of the absorbent material used in the MTD.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, and litter.
- The area exhibits significant changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Water ponding within the MTD suggests that filter media needs replacement, sediment or trash blockages may be present, or the overflow pipe may be clogged.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Structural damage is observed.
- Observed evidence of mosquitoes or mosquito larvae in the MTD.
- Significant discoloration of the absorbent material is observed.

MAINTENANCE PROCEDURES

- Remove accumulated trash and debris with a scoop net or an extension on the end of the boom hose of the vacuum truck.
- Remove the sediment from the bottom of the sump with a vacuum truck. Some jetting may be required to loosen up sediment from the sump; follow manufacturers O&M procedures.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within the MTD.
- Maintenance should be conducted during dry weather when no flow is entering the MTD.
- If water ponds after inflow has ceased, clear the outlet of sediment or trash blockages. If this does not help, replace the filter media or cartridges or unclog the overflow drain, whichever is applicable. Consider a higher frequency of inspection and maintenance if this problem persists.
- Schedule the repair of MTDs in advance of the first seasonal rains.
- Repair structural damage.
- Conduct mosquito abatement using a bubbler, mosquito fish, or other means.
- Replace the absorbent material if damage or discoloration is observed. For example, if absorbent pads are tethered to the MTD, only OSHA Confined Space Entry trained and certified personnel may enter the structure to remove and replace the spent material.
- Maintenance can be tracked using work orders, maintenance personnel, and service contracts.

A subset of MTDs are inlet inserts. An example of an MTD is a drain inlet insert or catch basin insert. There are several drain inlet inserts and catch basin inserts at DOTA airports.

Drain inlet or catch basin inserts are filters designed to remove the trash, sediment, and contaminants such as hydrocarbons and metals from stormwater runoff. A metal frame with a filter screen is the primary method for pollutant removal. A non-leaching absorbent material in a pouch can be placed with the insert to remove hydrocarbons or metals.

The drain inlet inserts are systems designed to capture fine to coarse sediments, floatable trash, debris, TSS, nutrients, metals, and hydrocarbons conveyed in stormwater runoff. The components may include insertable trash collectors, filter media, cartridges, and absorbents.

Example of Bio Clean Grate Inlet Media Filter at Daniel K. Inouye Airport Maintenance Baseyard

The catch basin inserts are designed to capture sediment, debris, trash, and oils and grease from low (first flush) flows. The components may include insertable trash collectors, filter media, cartridges, and absorbents.

Inlet and catch basin inserts should be visually inspected for damage, conditions found, and obstructions. Inspection of the surrounding area should also be performed and documented. Maintenance is primarily focused on filter media (including cartridges) replacement, sediment, and trash removal, unclogging outlet structures, and mosquito abatement.

The following details general guidelines for inspection and maintenance of inserts currently installed at DOTA airports. Refer to the manufacturer's inspection and maintenance requirements for additional information.

Example FloGard® Insert
Source: Old Castle Infrastructure Company

INSPECTION PROCEDURES

- Open storm drain inlet grated lid or catch basin manhole.
- Inspect sediment depth to determine if cleaning is needed based on the specified unit cleaning depth. If the unit is more than 35% full, recommend cleaning.
- Inspect the insert and screens for accumulation of trash, floatables, debris, and litter.
- Inspect inlets, piping, and outflow for clogging.
- Inspect the inlet insert for ponded water, i.e., standing water in the inlet insert after inflow has ceased.
- Inspect for structural damage of structures.
- Remove access covers and visually inspect the internal components for broken or missing parts.
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect for evidence of mosquitoes or mosquito larvae in the inlet insert.
- Inspect the color of the absorbent material used in the inlet insert.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, and litter.
- The area exhibits significant changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Water ponding within the inlet insert suggests that filter media needs replacement, or sediment or trash blockages may be present.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Structural damage is observed.
- Observed evidence of mosquitoes or mosquito larvae in the inlet insert.
- Significant discoloration of the absorbent material is observed.

MAINTENANCE PROCEDURES

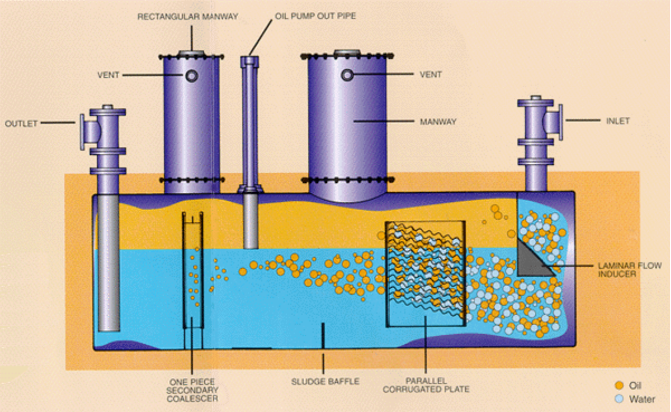
- Remove accumulated trash and debris from the upper portion of the filter/insert by removing the insert or an extension on the end of the boom hose of the vacuum truck.
- Remove all debris from the interior of the insert and dispose of trash and floatable debris as solid waste.
- Remove the sediment from the bottom of the unit with a vacuum truck.
- Some jetting may be required to loosen up sediment from the unit. The jetting can be achieved by inserting a jet hose through the vortex tube opposite the tube used for vacuum hose access.
- Replace filter media by removing the bolts of the screens, removing and replacing the filter media, including absorption media, filter pads, etc. The absorption media, if loose, will need to be removed with a vacuum truck.
- Brush the screen clean and, if needed, follow up with a wash (if applicable).
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within the inlet insert.
- Maintenance should be conducted during dry weather when no flow is entering the inlet insert.
- If water ponds after inflow has ceased, clear the insert of sediment or trash blockages. If this does not help, replace the filter media or cartridges, whichever is applicable. Consider a higher frequency of inspection and maintenance if this problem persists.
- Schedule the repair of inlet inserts in advance of the first seasonal rains.
- Repair structural damage.
- Conduct mosquito abatement using a bubbler, mosquito fish, or other means.
- Replace the absorbent material if damage or discoloration is observed. For example, if absorbent pads are tethered to the inlet insert, only OSHA Confined Space Entry trained and certified personnel may enter the structure to remove and replace the spent material.
- Reinstall the insert into the inlet and replace the grate or manhole cover.
- Maintenance can be tracked using work orders, maintenance personnel, service contracts, and AMS.

PBMP O&M Fact Sheet

TC-6: Oil Water Separator

OWSs are treatment control devices designed to remove non-aqueous phase liquids (hydrocarbons) and settleable solids from stormwater runoff. The primary function of OWSs is to specifically remove oil, jet fuel, gasoline, diesel, other water-insoluble hydrocarbons, floatable debris, and settleable solids. Maintenance is primarily focused on oil removal, sediment, and trash removal, unclogging outlet structures, and mosquito abatement.

The following details the general guidelines for inspection and maintenance of OWSs at DOTA airports. Refer to the manufacturer's inspection and maintenance requirements for additional information.



Example Schematic of an Oil Water Separator, Oahu
Source: Tenant Project , Daniel K. Inouye International Airport

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances.
- Inspect for accumulation of oil, grease, trash, floatables, debris, and litter.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Open the separation chamber manhole cover or grate to inspect the vault.
- Inspect inlets, piping, and outflow for clogging.
- Inspect the OWS for ponded water, i.e., standing water in the OWS after inflow has ceased.
- Inspect for structural damage of structures.
- Remove access covers and visually inspect the internal components for broken or missing parts.
- Inspect OWS after significant storm events.
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect for evidence of mosquitoes or mosquito larvae in the OWS.
- Inspect the hydrocarbon boom used in the OWS.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, and litter.
- The area exhibits significant changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Water ponding within the OWS suggests that filter media needs replacement, sediment or trash blockages may be present, or the overflow pipe may be clogged.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Structural damage is observed.
- Observed evidence of mosquitoes or mosquito larvae in the OWS.

- Significant discoloration of the hydrocarbon boom is observed.

MAINTENANCE PROCEDURES

- Remove accumulated oil, grease, sediment, trash, and debris with a scoop net or an extension on the end of the boom hose of the vacuum truck.
- Transport and dispose of liquid removed from OWS. Test and dispose of sediment removed from the OWS.
- Clear obstructions.
- Remove the floatable trash and debris from the DOTA MS4 or drainage system leading to and within the OWS.
- Maintenance should be conducted during dry weather when no flow is entering the OWS.
- If water ponds after inflow has ceased, clear the outlet and OWS of sediment or trash blockages. Consider a higher frequency of inspection and maintenance if this problem persists.
- Schedule the repair of OWSs in advance of the first seasonal rains.
- Repair structural damage.
- Conduct mosquito abatement using a bubbler, mosquito fish, or other means.
- At any time, the inspector should smell or see fuel in OWS, stop work and notify the appropriate manager, who will report it to the Airports contract administrator for immediate maintenance.
- After spill events, pressure wash the interior and exterior of the OWS with an airport-approved degreaser.
- Maintenance can be tracked using work orders, maintenance personnel, service contracts, and AMS.

PBMP O&M Fact Sheet

TC-7: Sand Filter

A sand filter is a chambered structure that captures, temporarily stores, and treats stormwater runoff by passing it through sand, organic matter, soil, or other media. Maintenance is primarily focused on sediment build-up, avoiding clogging, and proper functioning of inlets, outlets, and high-low bypasses.

Oak Manor Surface Sand Filter, Maryland
Source: Montgomery County, Maryland

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, and litter.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Monitor observation wells, if present, to determine how quickly the system is draining after a storm.
- Inspect the sand filter for ponded water, i.e., standing water in the sand filter after inflow has ceased.
- Inspect surfaces for damage caused by erosion, rodents, vehicles, or other reasons. Walk around the sand filter, and note locations of erosion or drainage changes.
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Inspect the irrigation system for proper operation and distribution.
- Inspect the underground sand filter for structural damage to the vault.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, and litter.
- The area exhibits significant erosion or changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Water ponding in a sand filter suggests that sediment or trash blockages may be present, the sand media layer may be clogged, or the underdrain/permeable filter fabric may be clogged.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- Structural damage.

MAINTENANCE PROCEDURES

- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the sand filter, immediately determine the source, remove sediment deposits, and correct the problem.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within sand filters.
- Schedule the repair of sand filters in advance of the first seasonal rains.
- Stabilize eroded areas and repair erosion.
- Re-grade to reshape the sand filter cross-section as sediments collect and form pools. Remove and properly dispose of the sediments.
- If water ponds after inflow has ceased, clear the outlet and sand filter surface of sediment or trash blockages and scarify the sand media surface. If this does not help with the filtration, the media layer, underdrain, or permeable filter fabric may be clogged; replace the top layer of material with fresh material, unclog the underdrain, or replace the permeable filter fabric, whichever is applicable.
- Repair structural damage.
- Maintenance can be tracked using work orders, maintenance personnel, service contracts, and AMS.

PBMP O&M Fact Sheet

TC-8: Subsurface Detention

Subsurface detention PBMPs are underground structures that temporarily detain stormwater and release it to the DOTA MS4, drainage system, or State waters. Maintenance is primarily focused on preventing sediment build-up and clogging, which reduces the capacity of the system.

The following details general guidelines for inspection and maintenance of a subsurface detention system. Refer to the manufacturer's inspection and maintenance requirements for additional information.

Subsurface Detention Installation, Philadelphia
Source: *Philadelphia Stormwater Management Guidance Manual, Version 3.2*

INSPECTION PROCEDURES

- Inspect surface drainage systems and flow entrances for accumulation of sediment, trash, debris, litter, and leaves.
- Inspect pretreatment measures for sediment, trash, and debris accumulation.
- Monitor observation wells, if present, to determine how quickly the system is draining after a storm.
- Inspect the subsurface detention system for ponded water (i.e., standing water in the subsurface detention system that does not drain after 48 hrs or 72 hrs of the storm event depending on design).
- Observe discharge, if present, and the origin of discharge if it can be viewed. Note if alternate drainage patterns have developed.
- Refer to the manufacturer's inspection requirements for more detailed information.
- Use AMS for PBMP inspection and tracking.

CONDITIONS THAT WARRANT MAINTENANCE

- Accumulation of sediment, trash, debris, litter, and leaves.
- The area exhibits significant changes to the drainage pattern (water drains away from PBMP or is bypassed).
- Water ponding in a subsurface detention system suggests the presence of sediment or trash blockages or clogging of the media layer, the underdrain, or the permeable filter fabric.
- Recent oil spill or fuel spill.
- Output flow is significantly dirty or contains significant odors.
- In addition to the above items, each subsurface detention PBMP is designed differently to treat stormwater and has different maintenance needs. Refer to the manufacturer's maintenance requirements for more detailed information.

MAINTENANCE PROCEDURES

- Remove accumulated sediment, trash, and debris.
- If excessive sediment is deposited in the subsurface detention system, immediately determine the source, remove sediment deposits, and correct the problem. Sediment removal may need to be accomplished with a JetVac or a similar process.
- Strict adherence to regularly scheduled maintenance frequency may be needed to reduce the risk of re-suspension of sediment during significant storm events.
- Clear obstructions.
- Remove trash and debris from the DOTA MS4 or drainage system leading to and within the subsurface detention PBMP.
- Schedule the repair of subsurface detention systems in advance of the first seasonal rains.
- If water ponds after the drawdown time (typically less than 48 hrs but maximum allowable is 72 hrs after rain event depending on the design), clear the outlet of sediment or trash blockages.
- Repair structural damage.
- Refer to the manufacturer's maintenance requirements for more detailed information on maintenance equipment needed and activities.
- Maintenance can be tracked using work orders, maintenance personnel, service contracts, and AMS.