Watershed Management Plan for Hanalei Bay Watershed

Volume 2: Strategies and Implementation

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Prepared for:

Hanalei Watershed Hui
5299C Kuhio Hwy
P. O. Box 1285
Hanalei, Kaua'i, HI 96714
www.hanaleiwatershedhui.org

Prepared by:

SUSTAINABLE RESOURCES GROUP INTN'L, INC.
111 Hekili Street, Ste A373
Kailua, HI 96734
www.srgii.com

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The Watershed Management Plan for Hanalei Bay Watershed has been developed as a two volume document: *Volume 1: Watershed Characterization*, and *Volume 2: Strategies and Implementation* (this document). The complete plan characterizes the project watersheds (Volume 1); recommends pollution control strategies, outlines implementation strategies, provides evaluation and monitoring protocols, and describes education and outreach approaches (Volume 2).

Executive Summary

Healthy water bodies and coral reefs are vital to our culture, way of life, and economy. The Hanalei Bay Region suffers from water quality problems and coral reef degradation that are caused in part by land-based pollutants. Land use in this area over the past century has resulted in export of these pollutants, which adversely impact fresh and ocean water quality and the coral reef ecosystem, and diminish habitat for plants and animals and resource use by people. Land-based pollutants generated across large areas from diffuse sources are commonly referred to as nonpoint source (NPS) pollutants. NPS pollutants are transported off the watersheds in both surface water and groundwater and delivered into the ocean at various locations and rates.

The Hanalei Bay Region is currently targeted by Federal, State, and private efforts for watershed planning efforts with the goals of reducing stressors to and improving the overall health of coral reefs, nearshore waters, and watersheds. Established to promote sustainability and stewardship of the watersheds of Hanalei Bay (Hanalei, Wai‘oli, Waipā, and Waikoko), the Hanalei Watershed Hui plays an essential role in this effort. The *Hawai‘i State Department of Health* funded the Hanalei Watershed Hui to develop this Watershed Management Plan (WMP) as a component of on-going efforts to identify and reduce stressors to, and improve the overall health of coral reefs, nearshore waters, and watersheds. The *Hanalei Bay Watershed Management Plan* (HBWMP) is composed of two volumes: *Volume 1: Watershed Characterization*, and *Volume 2: Strategies and Implementation*. It adheres to the Environmental Protection Agency (EPA) Clean Water Act (CWA) Section 319 guidelines for watershed plan development. These guidelines require use of a holistic, watershed based approach to identify sources and sinks of NPS pollutants, and the remedial actions necessary to reduce their loads to receiving waters.

Volume 1: Watershed Characterization summarizes the current environmental conditions of Hanalei Bay Watershed, with an emphasis on identifying water quality pollutant sources and types. It was developed using existing data and information, field investigations, interviews with a cross-section of people with historic and current knowledge of land uses and activities, and geospatial data analysis using geographic information system (GIS) software. The characterization provides a mechanism to evaluate watershed processes and determine if land uses and activities are generating NPS pollutants, altering the hydrologic regime and ecological processes, and causing adverse impacts to the watershed's ecosystem.

Major NPS pollutant sources within the watersheds are those land uses, activities, and inputs that have the greatest overall adverse impact to water quality and coral reef ecosystem health. The pollutants of primary concern within the Hanalei Bay Watershed, and the main focus of remediation efforts are, in order of priority, (1) sediment and plant detritus and other particulates that comprise Total Suspended Solids (TSS), (2) bacteria, and (3) nutrients. The main manmade pollutant sources are wastewater disposal systems, grazing operations, and taro cultivation. Secondary pollutant sources are a combination of manmade and natural sources, including disturbed upland areas, overgrown and eroding streambanks, and managed wetlands used for waterbird habitat. The HBWMP is focused on water quality issues and does not specifically address: flooding, irrigation water supply, instream flows, or irrigation diversion works. While relevant to water quality, these issues were not scoped to be assessed under this plan.

Volume 2: Strategies and Implementation discusses strategies for management of sources and NPS pollutants in the Hanalei Bay Watershed as identified in *Volume 1*. To refine the discussion of pollutants and their control strategies, the watersheds were delineated into six management units [Built Environment, Taro *Lo'i*, Grazing, Forested Upland, Stream, and U.S. Fish and Wildlife Service (USFWS) Wetlands], three of which are high priority for immediate action (Built Environment, Taro *Lo'i*, and Grazing). Key water quality issues and recommendations by management unit are presented in Table ES-1.

Table ES-1. Major NPS Pollutant Sources and Recommended Management Practices

Pollutants/ Key Issues	Sources	Critical Areas	Management Practices
Built Environment			
Stormwater runoff, nutrients, bacteria, sediment, metals	Individual wastewater systems (cesspools, batch plants, septic tanks), impervious surfaces, land use and drainage systems	Hanalei Town	Baffle Box, Bioretention Cell, Curb Inlet Basket, Good Housekeeping Practices, Grass Swale, Gutter Downspout Disconnection, Permeable Surfaces, Storm Sewer Disconnection, Commercial WWTP Upgrades, Aerobic Treatment Unit, High Efficiency Toilets
Taro *Lo'i*			
Nutrients, sediment, bacteria	Fertilizers, suspension of sediments, animal waste	Taro pondfields	Constructed Wetlands, Lo'i Management (*'auwai outlet gate closure protocol, dry tilling of taro ponds, taro resting period, 'auwai and ditch cleaning*), Fertilizer Management Plan, Pesticide Management Plan
Grazing			
Bacteria, nutrients, sediment	Animal waste, trampling	Pastures used for buffalo and cattle	Grazing Management System (*prescribed grazing, travel ways to facilitate animal movement, livestock fencing, livestock watering*)
Forested Upland			
Erosion/sediment, nutrients, bacteria	Naturally occurring and accelerated due to alien vegetation and feral animals,	All lands within Conservation Zone	Erosion Control Mats and Vegetative Plantings, Feral Ungulate Fencing
Stream			
Sediment	Streambanks, *hau* bush	Dense stands of *hau* bush	Channel Maintenance and Restoration
USFWS Wetland/Hanalei Refuge			
Nutrients, bacteria, sediments	Birds	Wetlands	Erosion Control Mats and Vegetative Plantings, Wetland Pollution Reduction Practices

Major sources of NPS pollution can be remediated through the implementation of management practices. Targeting priority areas and sites, and applying appropriate strategies is expected to decrease generation and transport of NPS pollutants that reach the ocean. Reduction of pollutant loads is a function of both the types and number of management practices installed. The HBWMP identifies a set of management practices for implementation based on the targeted pollutant locations and land use activities. They were chosen based on their expected performance to reduce sediment, nutrient, bacteria, and other NPS pollutants that currently impact water in streams, estuaries and the bay. Selection of practices was also based on practical considerations such as cost to install and maintain, past history on successes and failures of practices installed, and likelihood that land owners and managers would be willing to install and maintain practices.

Replacement of or upgrades to outdated and failing wastewater treatment systems, both at the individual homeowner level (e.g. cesspools and septic tanks) and for the two commercial properties in Hanalei will likely have the most significant positive impact on water quality (primarily nutrients and bacteria). Management practices designed to reduce sediment and nutrient contributions from grazing areas and taro cultivation are also recommended as high priority.

The WMP also discusses elements required for implementation, including responsible entities, legal requirements, and financial resources. In addition, it details resources needed for implementing management practices, including data and analysis requirements, technical resources, and cost. Milestones should be set to track implementation on a programmatic level as well as the pollutant reductions being achieved and the affected change in the health of the ecosystem. It is highly recommended that all solutions be implemented as soon as possible, however it is recognized that this is likely not feasible due to financial and labor constraints. The priorities for implementation should not be considered rigid. If a landowner or entity responsible for a particular parcel has resources to implement a solution that is lower priority, the opportunity should be taken. Any installation of a management practice is a positive gain towards reducing NPS pollution. Adaptive management is necessary to improve management by learning from the outcomes of past activities.

Four types of monitoring are necessary to track management practices: trend, implementation, baseline, and effectiveness. Qualitative and quantitative information about the management practices, water quality, and coral reef ecosystem condition helps determine their effectiveness. The HBWMP identifies site-based effectiveness monitoring for recommended management practices. Long-term trend monitoring of water quality and coral reef ecosystem health will also provide information that can be correlated to implementing solutions to reduce NPS pollutants.

Success of the HBWMP is dependent on stakeholder awareness and involvement. The Hanalei Watershed Hui and other organizations must continue and expand activities to engage the local community in efforts to reduce NPS pollution. Implementation of the solutions recommended in the HBWMP, per the identified priorities, is crucial to reducing the generation and transport of sediments and other NPS pollutants. This will result in improved water quality and ecosystem health within the watersheds and the nearshore coastal waters.

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Acronyms

ATU	Aerobic Treatment Unit
BMP	Best Management Practice
CBT	Cyclic Biological Treatment
CRAMP	Coral Reef Assessment and Monitoring Program
CWA	Clean Water Act
CWB	Clean Water Branch
CWSRF	Clean Water State Revolving Fund
CZARA	Coastal Zone Act Reauthorization Amendments
CZO	Comprehensive Zoning Ordinance
DLNR	Department of Land and Natural Resources
DOH	Department of Health
EPA	Environmental Protection Agency
GIS	Geographic Information System
gpd	Gallons Per Day
HBWMP	Hanalei Bay Watershed Management Plan
HRS	Hawaiʻi Revised Statutes
IWS	Individual Wastewater Systems
LA	Load Allocation
LBSP	Land Based Sources of Pollution
LID	Low Impact Development
MOS	Margin of Safety
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NWR	National Wildlife Refuge
O&M	Operations and Maintenance
QA/QC	Quality Assurance and Quality Control
QAPP	Quality Assurance Project Plan
S4	Separate Storm Sewer System
SWCD	Soil and Water Conservation District
TMDL	Total Daily Maximum Load
TSS	Total Suspended Solids
TVR	Transient Vacation Rentals
UH-CTAHR	University of Hawaii, College of Tropical Agriculture and Human Resources
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WMP	Watershed Management Plan
WWTP	Wastewater Treatment Plant

1. Introduction

The Hanalei Bay Watershed Management Plan is being developed for four watersheds (Hanalei, Waiʻoli, Waipā, and Waikoko) that drain into Hanalei Bay to address the impacts of land-based pollutants to the water quality of the streams, estuaries, and waters of Hanalei Bay. The primary objectives of the HBWMP are to identify sources of land-based pollutants and develop actions to remediate them to reduce water quality problems. If implemented, these remedial actions will reduce potential health risks to humans that come into contact with these waters and improve aquatic ecosystems, including the coral reefs of Hanalei Bay. The HBWMP is focused on water quality issues and does not address instream flows, irrigation allocations, flooding, and the diversion and intake structure on the Hanalei River.

In *Volume 1: Watershed Characterization*, the pollutants and their sources were identified. *Volume 2: Strategies and Implementation* (this document) identifies specific management practices to reduce or prevent NPS pollutant generation, or treat polluted runoff. It also outlines strategies to insure successful implementation and evaluation. Together, Volumes 1 and 2 of the HBWMP address the key components of a watershed-based plan as defined by the EPA (Box 1).

Box 1. EPA's Nine Key Components for Watershed-Based Plans

1. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan.
2. An estimate of the load reductions expected from management measures.
3. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions, and a description of the critical areas in which those measures will be needed to implement this plan.
4. Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.
5. An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.
6. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.
7. A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.
8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.
9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established.

1.1 NPS Pollution Management Hierarchy

Box 2 summarizes the hierarchical set of terms used throughout this document to categorize and discuss management of NPS pollutants: management practice, management measure, and management unit. Additional details are provided in Appendix B.

Box 2. NPS Pollution Management Hierarchy

Management Practice. An individual action (e.g. treatment, strategy, plan) to lessen generation and transport of NPS pollutants. One or more management practices are implemented to satisfy a management measure. Examples include: installation of a baffle box and creation of a fertilizer management plan. The same practice can occur in multiple management units.

Management Measure. Economically achievable measure to control the addition of pollutants to coastal waters through practices, technologies, processes, siting criteria, operating methods, or other alternatives. Examples include: erosion and sediment control, and bacteria. The same measure can occur in multiple management units.

Management Unit. The geographical area, land use, or specific source of pollutant input to which a given set of management measures apply. In this HBWMP, management units are generally delineated based on land use.

1.2 Pollutants Types Generated by Management Unit

Volume 1: Watershed Characterization, characterized the watersheds of Hanalei Bay, and described the types of pollutants generated within them. In *Volume 2*, six distinct management units have been delineated to evaluate pollutant inputs from common land uses within the watersheds: Built Environment, Forested Upland, Grazing, Stream, Taro *Lo'i*, and USFWS Wetland. Each management unit has its own pollutant sources, pollutant types, and land uses.[1] This aids in the analysis of the sources and pathways of NPS pollutants, and allows specific management strategies to be recommended within each unit or for locations and land uses in a unit.

There are several categories of NPS pollutants generated within the project area: sediment; nutrients; organics; bacteria; debris/litter; and hydrocarbons (Table 1).[2] Their presence within each of the units and the amount generated from each depends on the land uses, activities and conditions. These pollutants are generated across all areas of the watersheds both from natural processes (background) and human uses (accelerated). Sampling and data on certain pollutants (i.e. metals, organics) in the four watersheds is limited or does not exist. However, chemical constituents of these classes of pollutants are likely present as the by-product of vehicle use, natural decay of basaltic rock, and from pesticide use.

Table 1. NPS Pollutant Generation Types for Management Units

Pollutant Type	Management Unit					
	Built Environment	Forested Upland	Grazing	Stream	Taro *Lo'i*	USFWS Wetland
Total Suspended Solids[3]	✓	✓	✓	✓	✓	✓
Nutrients	✓	✓	✓	✓	✓	✓
Organics	✓				✓	
Pathogens[4]	✓	✓	✓	✓	✓	✓
Debris/Litter	✓				✓	
Hydrocarbons	✓					
Metals	✓	✓	✓	✓		

[1] See *Volume 1: Watershed Characterization*, Section 3 for additional information on the various landowners, land uses, and geographic characteristics for each of the management units.

[2] Pollutant types are described in detail in *Volume 1: Watershed Characterization*, Table 16.

[3] Total Suspended Solids refers to the total amount of particulates in a water column and is primarily comprised of sediments.

[4] Pathogens include bacteria, viruses, and protozoa.

1.3 Water Quality Goals and Context of Plan under Clean Water Act

The preparation of this HBWMP follows development of two Total Maximum Daily Load (TMDL) studies conducted by the State of Hawai'i Department of Health (DOH) (Tetra Tech and DOH 2008, 2011) (Section 4.2.1.1).[5] This brief summary is provided to put the HBWMP in context with the TMDL reports and the water quality goals they established.

The Phase 1 TMDL established a total of eight TMDLs for the four streams and estuaries of the Hanalei Bay watershed (Tetra Tech and DOH 2008). Past and ongoing water quality monitoring and assessment efforts identified sediments, nutrients, and microbial pathogens as pollutants of concern in the Hanalei Bay watershed. In response to the 2006 List of Impaired Waters in Hawai'i Prepared under CWA §303(d), DOH prepared TMDLs for total suspended solids (TSS is included as a surrogate for turbidity TMDLs) in Hanalei Stream and Hanalei Estuary (together defined as the Hanalei Stream System), Waipa Stream and Estuary (Waipa Stream System), and in the Waioli, Waipa, and Waikoko Estuaries; and for and *enterococci* in the Hanalei Stream System. DOH also calculated Informative TMDLs and Load Targets (both not for EPA approval) for nutrients (nitrogen and phosphorus) in these waterways. Informative TMDLs were generated since repeated water quality samples showed that water quality criteria were not being met for nutrients in the streams, their estuaries, and in Hanalei Bay.

The Phase 2 TMDL was prepared for the marine waters of the Hanalei Bay and established TMDLs for *enterococci* and TSS (Tetra Tech and DOH 2011). The Phase 2 TMDL built upon Phase 1 and confirmed that improvements to water quality in Hanalei Bay would be achieved by meeting the Phase 1 TMDLs for the four estuaries since the water quality criteria for the estuaries are the same as or more stringent than the water quality criteria of the Hanalei Bay. Reductions to the loads delivered to the four estuaries by their streams will aid in achieving TMDLs for the bay.

As the name implies, TMDLs quantify the amount of each assessed pollutant that can be added or loaded into the water bodies per day that does not impair the aquatic ecosystem or exceed water quality standards. Numerical models were used to calculate existing pollutant loads derived off the four subwatersheds and TMDLs for the various streams, estuaries, and Hanalei Bay. For all pollutants assessed, the TMDL was lower than the existing load and load reductions (existing load minus the TMDL) were computed. TMDLs are assigned to a water body as a whole (e.g. Hanalei River), so existing loads and TMDLs are a composite of all surface waters and groundwaters draining into the river.

The TMDLs for TSS, bacteria, and nutrients are the water quality goals set forth by DOH for the various water bodies of the Hanalei Bay watershed. If the TMDLs are achieved, water quality criteria will be met, stressors to aquatic ecosystems will be reduced, and beneficial uses will not be impaired. During preparation of the Phase 1 TMDL the public was concerned that the identified TMDLs and load reductions were not achievable due to uncertainty about how much of the various pollutants were generated at natural or background levels versus above background levels attributed to human use and activities. Although DOH recognized that the TMDLs and load reductions appeared daunting and not realistic to the public, the TMDLs were approved and now should be considered the goal for water quality. In reality, achieving the TMDLs may not be possible or may take considerable time,

[5] See *Volume 1: Watershed Characterization*, Sections 2.1-2.4 for a discussion of the regulatory environment and overview of applicable water quality rules, regulations, and issues.

resources, and a commitment by residents of the watershed with support from government. However, any load reduction of the various pollutants is beneficial.

Table 2 – Table 9 contain the TMDLs for TSS, bacteria, and nutrients for the four streams, their estuaries, and Hanalei Bay.[6] The Hanalei River subwatershed has existing loads for the three pollutants that are greater than loads estimated off the other three subwatersheds. Correspondingly, pollutant load reductions for the Hanalei River subwatershed are largest. This is because the Hanalei subwatershed comprises nearly 77 percent of the land area that drains into Hanalei Bay, and contains the most land area in cultivation, urban, and conservation cover types.

Table 2. Total Suspended Solids TMDL Load Allocations and Load Reductions Required to Achieve TMDLs for Streams and Estuaries

Wet Season Baseflow	Existing Load	TMDL	Reduction Required	
Water Body	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	6550.7	1506.6	5044	77.0%
Hanalei River Estuary	6959.2	1600.6	5358.6	77.0%
Waioli Stream Estuary	1124.9	123.7	1001.1	89.0%
Waipa Stream	452.8	52.1	400.7	88.5%
Waipa Stream Estuary	491.6	56.5	435.1	88.5%
Waikoko Stream Estuary	110.8	2.4	108.4	97.8%

Table 3. Enterococcus TMDL Load Allocations and Load Reductions Required to Achieve TMDLs for Streams and Estuaries

Wet Season Baseflow (Geometric Mean)	Existing Load	TMDL	Reduction Required	
Water Body	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	7.00E+12	4.6E+12	2.50E+12	35.0%
Hanalei River Estuary	7.90E+12	5.1E+12	2.80E+12	35.0%

Table 4. Total Suspended Solids Informative TMDLs and Suggested Reductions for Streams

Wet Season Baseflow	Existing Load	Informative TMDL	Suggested Reduction	
Water Body	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	1073.9	118.1	955.8	89.0%
Waikoko Stream	106.4	2.3	104.1	97.8%

Table 5. Enterococcus Informative TMDLs and Suggested Reductions for Streams and Estuaries

Wet Season Baseflow (Geometric Mean)	Existing Load	Informative TMDL	Reduction Required	
Water Body	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Waioli Stream Estuary	1.80E+12	9.05E+11	8.60E+11	49.0%
Waioli Stream	1.70E+12	8.5E+11	8.20E+11	49.0%
Waipa Stream Estuary	8.30E+11	6.5E+11	1.70E+11	21.0%
Waipa Stream	7.60E+11	6.0E+11	1.60E+11	21.0%
Waikoko Stream Estuary	2.60E+11	9.4E+11	1.70E+11	64.0%
Waikoko Stream	2.50E+11	9.1E+11	1.60E+11	64.0%

[6] Table 2 - Table 7are from the Phase 1 TMDL. Table 8 - Table 9 are from the Phase 2 TMDL.

Table 6. Wet Season Total Nitrogen Informative TMDLs and Suggested Reductions for Streams and Estuaries

Wet Season Baseflow	Existing Load	Informative TMDL	Suggested Reduction	
Water Body	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	367.4	84.5	282.9	77.0%
Hanalei River	315.7	72.6	243.1	77.0%
Waioli Stream Estuary	77	8.5	68.5	89.0%
Waioli Stream	67.8	7.5	60.3	89.0%
Waipa Stream Estuary	30	3.5	26.6	88.5%
Waipa Stream	23.4	2.7	20.7	88.5%
Waikoko Stream Estuary	16.7	0.4	16.3	97.8%
Waikoko Stream	15.6	0.3	15.3	97.8%

Table 7. Wet Season Total Phosphorous Informative TMDLs and Suggested Reductions for Streams and Estuaries

Wet Season Baseflow	Existing Load	Informative TMDL	Suggested Reduction	
Water Body	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	88	20.2	67.7	77.0%
Hanalei River	79.5	18.3	61.3	77.0%
Waioli Stream Estuary	17.8	2.0	15.8	89.0%
Waioli Stream	16.4	1.8	14.6	89.0%
Waipa Stream Estuary	7.1	0.8	6.3	88.5%
Waipa Stream	6.1	0.7	5.4	88.5%
Waikoko Stream Estuary	2.8	0.1	2.7	97.8%
Waikoko Stream	2.6	0.1	2.6	97.8%

Table 8. Total Suspended Solids TMDL Load Allocations and Load Reductions Required to Achieve TMDLs for Hanalei Bay

TMDL Allocations		Total Suspended Solids TMDLs
		Geometric Mean
LA	(kgd)	842.4
MOS	(kgd)	44.3
TMDL	(kgd)	886.8
Existing Load	(kgd)	4,319.5
Reduction Required	(kgd)	3,432.7
	(%)	79.5%

Table 9. Enterococcus TMDL Load Allocations and Load Reductions Required to Achieve TMDLs for Hanalei Bay

TMDL Allocations		Enterococcus TMDL
		Geometric Mean
LA – Surface Water	(CFU/day)	3.10E+12
LA – Groundwater	(CFU/day)	1.40E+11
MOS	(CFU/day)	1.70E+11
TMDL	(CFU/day)	3.40E+12
Existing Load	(CFU/day)	5.30E+12
Reduction Required	(CFU/day)	2.00E+12

1.4 Pollutants of Primary Concern

The pollutants of primary concern within the Hanalei Bay Watershed, and the main focus of remediation efforts are, in order of priority, (1) sediment and plant detritus and other particulates that comprise TSS, (2) bacteria, and (3) nutrients (*Volume 1: Watershed Characterization*, Section 2.2.3). TSS is used as surrogate for turbidity since turbidity is not reported in units of mass and turbidity is considered a component of TSS.[7]

Sediment is one of the largest contributors to land-based NPS pollution (Table 10). Sediment is primarily generated by soil erosion that occurs when bare earth is exposed through natural or anthropogenic processes. Sediments are also sourced to earthwork activities that take place along waterways or in the watersheds that do not utilize practices to control their introduction and movement. This has been the case along the Hanalei River where past unpermitted grading on parcels next to the river exposed deposited alluvial sediments that washed into the river and out to the bay. Within each of the management units, the type, location, and magnitude of sediment generating processes vary and are largely influenced by the intensity of the activities that occur within the unit. Infield observations, stakeholder communications, review of past studies that attempted to quantify erosion rates and sediment runoff, and analysis of high resolution aerial photography were employed to determine areas with the greatest extent of active and potential erosion within the watersheds.

Table 10. Typical Sediment Generating Activities and Land Uses within Hanalei Bay Watershed

Management Unit	Activity / Land Use
Built Environment	Motor vehicle use and tire tracking on unvegetated / bare earth surfaces, road surface breakdown (e.g. asphalt)
Taro *Lo'i*	Mixing of sediments into water during *lo'i* maintenance, from foraging birds, and occasional lack of proper flow controls.
Grazing	Grazing activity of cattle and buffalo, and subsequent tracking of sediment into waterways; trampling of *'auwai*, stream and ditch banks via hooves
Forested Upland	Accelerated erosion from rooting, wallowing, and general disturbance of vegetated areas by feral ungulates. Natural erosion.
Stream	Eroding banks and inputs from ditches.
USFWS Wetland	Mixing of sediments into water from maintenance and birds foraging.

[7] Turbidity is a regulated water quality parameter and is identified as impairing water quality in the Hanalei Bay Watershed.

Bacteria are the second largest contributor to land-based NPS pollution (Table 11). The largest contributors to bacterial presence within Hanalei Bay Watershed are human waste (introduced via subsurface disposal systems) and animal waste (land-based). **Nutrients** (Nitrogen and Phosphorus) are the third largest contributor to land-based NPS pollution (Table 12). Much remains to be discovered concerning the land-based and vadose zone transport of nutrients within the watersheds.[8] Future research may determine nutrient inputs from land-based sources have as significant an adverse impact on the Hanalei Bay environment as sediment. There are several main factors that influence sediment, bacterial and nutrient introduction into the water bodies of Hanalei Bay Watershed (Table 13).

Table 11. Bacterial Sources within Hanalei Bay Watershed

Management Unit	Source
Built Environment	Human waste via residential and commercial Individual Wastewater System (IWS) (introduced into groundwater table)
Taro *Lo'i*	Wildlife waste
Grazing	Cattle, buffalo, and wildlife waste and physical damage
Forested Upland	Feral ungulates, wildlife, and naturally occurring strains in soils
Stream	Eroding streambanks
USFWS Wetland	Wildlife waste

Table 12. Nutrient Sources within Hanalei Bay Watershed

Management Unit	Source
Built Environment	Human waste via residential and commercial IWS (introduced into groundwater table); commercial and residential fertilizers applied to lawns and landscaped areas
Taro *Lo'i*	Wildlife waste; fertilizers introduced into taro ponds
Grazing	Cattle, buffalo, and wildlife waste
Forested Upland	Feral ungulate, wildlife waste
Stream	Eroding banks, vegetative inputs(e.g. leaves)
USFWS Wetland	Wildlife waste

Table 13. Influencing Factors for Transmitting Main Pollutants of Concern into Environment

Factor	Sediment	Nutrient	Bacteria
Travel distance of pollutant-generating source(s) to natural streams, drainage channels, easily transmissible pipe networks, or along surface features (e.g. roads) that can rapidly transport runoff downstream.	✓	✓	✓
Size of contributing drainage area that a pollution-generating source is located in.	✓	✓	✓
Rainfall intensity within the region that a pollution-generating source is located in.	✓	✓	✓
Surface areal coverage of lands with soils that are currently exposed and subject to erosive action and subsequent transport of generated sediment during rainfall events.	✓		
Slope of land topography for the pollution-generating source.	✓		
Vertical distance between an individual IWS and the groundwater table.		✓	✓
Average effluent flow rate of IWS, wastewater characteristics of the IWS, and hydraulic properties of aquifer.		✓	✓

[8] The vadose zone refers to underground water above the water table.

2. Implementation Strategies

Identifying key implementation strategies will ensure that the management practices identified in the HBWMP are developed and implemented with a solid foundation and oversight aimed at measureable reductions in pollutant loads. Management plan implementation depends largely on community and stakeholder support and coordination for success. Implementation strategies must consider both overall WMP implementation (Section 2) and specific projects or management practices (Section 3).

2.1 Implementing A Watershed Management Plan

2.1.1 Responsible Entities

An important component of an implementation strategy is identification of the entities responsible for implementation. The Hanalei Watershed Hui is responsible for coordinating implementation of the HBWMP. The Hui is an on-the-ground resource and facilitator of watershed planning and implementation efforts in the Hanalei Bay Region with a focus on building community networks and promoting actions to improve the environment of the Hanalei Region.

Recommended management practices can be required under a regulatory program or implemented voluntarily. Often, overall implementation of a WMP is accomplished through the joint efforts of private and public entities. Responsibility for implementing management practices will often fall on landowners of the parcel or site where the practices will be installed. In many cases there will be more than one entity involved, particular at different stages of the process, so ongoing coordination will be needed and a lead entity needs to be identified. Entities that may directly or indirectly implement the recommended management practices include, but are not limited to: USFWS, Department of Land and Natural Resources (DLNR), Hawaiʻi Department of Transportation, Kauai County, commercial businesses, private land owners, and community groups/volunteers.

2.1.2 Legal Requirements

As a planning document, the HBWMP is not subject to evaluation under the National Environmental Policy Act (NEPA), Hawaiʻi Revised Statutes (HRS) Chapter 343 (Environmental Impact Statements), the National Historic Preservation Act (Section 106), HRS Chapter 6E (Historic Preservation) (Box 3). Consultation with the public is being conducted as part of the watershed planning process (Box 1).

A review of laws, ordinances, government programs, and plans pertaining to NPS and point source pollutants was conducted to determine if the recommended practices are required to comply with a rule or law and/or program or plan (*Volume 1: Watershed Characterization,* Section 2.3). For many locations identified in the HBWMP where practices should be installed there are no regulations that require installation or implementation. However, installation of the recommended practices is compatible with, and often supported by programs, plans, and regulations addressing and governing NPS pollution control.

In some instances implementation of a management practice will require permits and/or compliance with Federal and State laws designed to protect natural and cultural resources. These may include securing a CWA §404 (*Discharge Dredged or Fill Material*) Permit from U.S. Army Corps of Engineers

(USACE); a CWA §401 Permit (Water Quality Certification) or CWA §402 Individual Permit (*National Pollutant Discharge Elimination System*) from DOH Clean Water Branch (CWB); a County of Kauaʻi Grading or Grubbing Permit; or a Special Management Area Use Permit for construction from Kauaʻi County.

Box 3. When Do Federal and State Statutes Apply?

NEPA establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and it provides a process for implementing these goals within Federal agencies. NEPA requires Federal agencies to consider the potential environmental consequences of their proposals, to consult with other interested agencies, to document the analysis, and to make this information available to the public for comment before the implementation of the proposals. NEPA is only applicable to Federal actions, including projects and programs entirely or partially financed by Federal agencies and that require a Federal permit or other regulatory decision.

HRS Chapter 343 requires an environmental assessment for actions that[9]: Propose the use of state or county lands or the use of state or county funds, other than funds to be used for feasibility or planning studies for possible future programs or projects which the agency has not approved, adopted, or funded, or funds to be used for the acquisition of unimproved real property; provided that the agency shall consider environmental factors and available alternatives in its feasibility or planning studies; Propose any use within any land classified as conservation district by the state land use commission under Chapter 205; Propose any use within the shoreline area as defined in Section 205A-41; Propose any use within any historic site as designated in the National Register or Hawaiʻi Register as provided for in the Historic Preservation Act of 1966, Public Law 89-665, or Chapter 6E; Propose any amendments to existing county general plans where such amendment would result in designations other than agriculture, conservation, or preservation, except actions proposing any new county general plan or amendments to any existing county general plan initiated by a county; and Propose any reclassification of any land classified as conservation district by the state land use commission under Chapter 205.

National Historic Preservation Act, Section 106 requires each Federal agency to identify and assess the effects of its actions on historic resources.[10] The responsible Federal agency must consult with appropriate State and local officials, Indian tribes, applicants for Federal assistance, and members of the public and consider their views and concerns about historic preservation issues when making final project decisions. Section 106 applies when two thresholds are met: there is a Federal or federally licensed action, including grants, licenses, and permits, and that action has the potential to affect properties listed in or eligible for listing in the National Register of Historic Places.

HRS Chapter 6E provides guidance on conserving and developing the historic and cultural property within the State for the public good. §6E-8 requires the review of effect of proposed state projects on historic properties, aviation artifacts, or burial sites, consistent with §6E-43, especially those listed on the Hawaii register of historic places. Before any agency or officer of the State or its political subdivisions commences any project which may affect these items, the State Historic Preservation Division must review of the effect of the proposed project. Similarly, §6E-10 requires private landowners to provide an opportunity for review of any construction, alteration, disposition or improvement of any nature, by, for, or permitted that will affect an historic property on the Hawaiʻi Register of historic places. The proposed project shall not be commenced, or in the event it has already begun, continued, until the department shall have given its concurrence.[11]

2.2 Financing Implementation

Implementing a WMP requires funding for programmatic elements, installation of management practices, monitoring, and education and outreach.

2.2.1 Financial Resources

Funding for watershed management planning efforts (i.e. on-going planning, management practice implementation, monitoring, education, and outreach) can come from a range of sources including Federal, State, local and private entities. Funding mechanisms will include contracts, private funds, community grants, cost-share agreements, and volunteer efforts.

[9] http://www.hawaii.edu/ohelo/statutes/HRS343/HRS_343-5.htm

[10] http://www.achp.gov/nhpp.html

[11] http://www.capitol.hawaii.gov/hrscurrent/Vol01_Ch0001-0042F/HRS0006E/

The Hanalei Bay Region has, and continues to receive priority attention for funding from a range of entities. Specific funding resources that have already been identified to support the HBWMP include:

- **CWA §319 Funding** (administered by DOH and sourced from EPA). Since the watershed has EPA-approved TMDL, will have a WMP that follows EPA guidance (Box 1), and waters are on the CWA Integrated 303(d) List/305(b) Report for Hawai'i, studies or projects aimed at addressing sources and reducing NPS pollutants qualify for this Federal funding. Grant cycles are generally yearly.
- **Natural Resources Conservation Service (NRCS) Conservation Practices**. NRCS works with land owners and land managers to fund implementation of practices that conform to practice standards. Funding reimbursement is generally between 75% and 90% dependent on the parameters established. A Conservation Plan is typically developed for a given land parcel under management and once approved the land owner becomes a partner and can participate in NRCS funding via the Farm Bill.
- **Federal Funds**. Federal funds were provided to replace cesspools between 2005 and 2010 within the Hanalei Bay Watershed. Ten private cesspools were replaced with septic tanks as well as the County-owned cesspool at the Hanalei Pavilion, and upgrade three other systems (two along the beach on County lands and one at the County Maintenance yard).
- **DOH CWB.** Hanalei Bay Watershed monitoring efforts have been ongoing through annual funding agreements. Monitoring is done along rivers and streams, in the estuaries, and in the bay.

Other potential funding resources include:

- **Private Funding**. Private land owners could fund management practices on their lands (e.g. commercial centers, homeowners). In most cases the recommended management practices will benefit the local environment as well as contribute to the health of the larger ecosystem.
- **County of Kauai**. Kauai County is the owner/operator of properties or structures recommended to be addressed. The County could increase fees (e.g. recycled water rates and sewer user fees) or taxes (e.g. property).
- **Visitor Tax/Fee**. A local visitor tax or fee could be levied on 'luxury items and services' or 'occupancy' in the Hanalei Bay Region to fund infrastructure, services and programs related to improving water quality and coral reef health. These environmental initiatives would be beneficial to the tourism industry.[12]
- **Revenue Bond**. Bonds on which the debt service is payable mainly from revenue generated through the operation of the project being financed, or from other non-property tax sources. They may be issued by state and local governments, or by an authority, commission, special district, or other unit created by a legislative body for the purpose of issuing bonds for facility construction.[13] Revenue bonds are usually tax-exempt. State Revolving Fund bonds are revenue bonds.

[12] For example, a resort tax program in Montana has funded a task force conducting community water quality monitoring, watershed resource assessment, community education and watershed restoration. http://www.bigskyresorttax.com/benefits_detail.php?ID=16

[13] Revenue bonds now account for the majority of municipal bonds used to finance water, sewer, and solid waste infrastructure in the US.

- **Clean Water State Revolving Fund (CWSRF)**.[14] The CWSRF provides low interest loans to county and state agencies for the construction of municipal wastewater facilities and implementation of NPS pollution control and estuary protection projects. CWSRF funds could potentially be used for wastewater and stormwater infrastructure projects, and NPS pollution projects eligible under CWA §319 (e.g. agricultural runoff, stormwater runoff).

EPA has developed resources to enable watershed practitioners in the public and private sectors to find appropriate methods to pay for environmental protection efforts. Details are available at www.epa.gov/owow/funding.html and in the *Guidebook of Financial Tools: Paying for Sustainable Systems*.[15]

2.2.2 Implementation Costs

In general, costs to implement constructed management practices include the following:

- Engineering design, including all plans, drawings, biddable construction plans and permit acquisition
- Product purchase, including shipping cost
- Construction installation
- Construction management
- Operation and maintenance

Financial resources required to implement the management practices can vary considerably. Cost is a function of the effort involved in preparing detailed designs and acquiring permits (if necessary); cost of materials and supplies; and the duration and complexity of construction installation. Often the cost for implementing a single practice (e.g. aerobic injection unit) appears relatively high compared to the net reduction of pollutant loads. However economies of scale can be achieved through multiple installations as the cost to implement per unit management practice often decreases as the number of units installed increases. As the number of units installed goes up, the net benefit in terms of NPS pollutants reduced increases not linearly, but as a power function.

Various costs, including capital (equipment), Operations and Maintenance (O&M), and time and training requirements associated with installation and maintenance, will influence the communities' selection of management practices. Comparison of cost to NPS pollutant reduction potential also affects selection of practices. Another consideration is initial cost versus long-term maintenance cost.

For practices that are not constructed (e.g. fertilizer management plans) costs to implement may include the following:

- Site-specific testing and creation management plan by qualified entity
- Cost of materials specified in plan
- Site management
- Annual update / maintenance

[14] http://water.epa.gov/grants_funding/cwsrf/cwsrf_index.cfm; http://hawaii.gov/wastewater/cwsrf.html
[15] www.epa.gov/efinpage/guidbkpdf.htm

2.3 Technical Implementation of Management Practices

Implementation of a given management practice requires gathering supporting design data and assessing technical resources currently available for implementation. The resources required in a given scenario can be determined by factors including complexity of design, site conditions, and regulatory and land owner requirements. Some practices, such as a structurally-based practice (e.g. aerobic injection unit) will require development of engineering plans, specifications, and cost estimates, resulting in a relatively high cost to site. Other practices, such as management plans (e.g. fertilizer) are less resource intensive to prepare.

2.3.1 Data and Analysis Recommendations For Design of Management Practices

Design data relevant to the specific site under consideration is important to ensuring proper construction of the practice; determining realistic operations and maintenance requirements; and establishing monitoring protocols to ensure the practice operates as intended for the duration of its life span. Examples of recommended design data and analysis that could influence the successful implementation of a given practice include size of contributing upstream drainage area, soil infiltration rates, and required treatment efficiency of the practice.

While this HBWMP does not provide details for the recommended management practices, sufficient information about target sites and land use and practices to control or reduce NPS pollutants is delineated. The community will need to secure services of a qualified engineer or government technical personnel to assist in preparation of site specific plans for practices and sites chosen for implementation. Appendix C contains recommendations for design data and analysis considerations for selected management practices. The recommendations should not be taken as a comprehensive list of detailed design parameters, but rather used as a guide to provide general information on the scope of typical data needs for a detailed design to be developed. Additional data may be required for design of management practices, and not all recommendations may be applicable to a given, individual site. Each site has specific characteristics and constraints that must be taken into consideration before a detailed design is developed for a specific management practice location.

2.3.2 Technical Resources

Technical resources necessary to implement management practices are a function of the complexity of the engineering design, land ownership issues, permit requirements, preparation of biddable construction plans and drawings, and development of a post-installation Operation, Maintenance, and Monitoring Plan. Engineering design includes, but is not limited to, assessing the physical condition of the installation site[16], evaluating design hydrology parameters following County of Kauai requirements, sizing and designing management practices, preparing construction plans and cost estimates, preparing detailed installation drawings, acquiring permits, and construction management. These are collectively referred to as 'Plans, Specifications, and Estimates'. In addition to the engineering elements there are logistical issues associated with taking a management practice from the concept design phase to the implementation phase. Addressing logistical issues requires involvement of persons familiar with the technical elements of the design, the regulatory issues, and construction aspects of installation.

[16] Assessing a site's physical condition could include geotechnical analysis, locating utilities, inspecting structures (if the practice is a retrofit), and hydrologic analysis.

Contractors with expertise and knowledge of installing practices are a vital technical resource for the implementation. Since some of the recommended management practices have not been installed or have limited installations in Hawai‘i (e.g. permeable surface installations), it will be important that the design and construction manager articulate the objectives and installation nuances to contracting crews, and provide detailed guidance to facilitate correct and expeditious installations.

2.4 Adaptive Management

Adaptive management is defined as a systematic process for continually improving management policies and practices by learning from the outcomes of past and current management activities. An adaptive management process will be used to implement the HBWMP. Adaptive management recognizes that there is a level of uncertainty about the ‘best’ policy or practice for a particular management issue, and requires that each management decision be revisited in the future to determine if it is providing the desired outcome. The approach builds upon prior results, both positive and negative, and allows managers to continually reassess and incorporate new knowledge into management practices. In addition, water quality sampling continues under funding from DOH. As the data becomes available and analyzed it is expected that the information can aid in determining what types of and where practices should be implemented.

Management actions in a WMP guided by adaptive management can be viewed as hypotheses and their implementation as tests of those hypotheses. *A priori* planning and test design can allow managers to better determine if actions are effective at achieving a management objective. For example, monitoring before and after installation might assess the effectiveness of a pollution control method. Once an action has been completed, the next, equally important, step in an adaptive management protocol is the assessment of the action’s effectiveness (results). A review and evaluation of results allows managers to decide whether to continue the action or to change course. This investigational approach to management means that regular feedback loops guide managers’ decisions and ensure that future strategies better define and approach the objectives of the WMP.

Adaptive management is a powerful way to approach a methodology for effectively achieving load reductions and meeting load targets, but it is also time and personnel intensive. Designing a plan that incorporates adaptive management takes more time initially, but can lead to shorter implementation times and greater efficiency later. An adaptive management plan requires an extensive review of current scientific literature and existing management practices, and consultations with experts in the field. It also requires that the implementation of management practices and evaluation protocols be thoughtfully designed, and it must include feedback mechanisms for reassessing management strategies and changing them, if necessary. As additional information about agents and processes impacting the project area becomes available, priority pollutants of concern could shift, with corresponding adjustments to management practices required. Section 0, *Evaluation and Monitoring*, illustrates how adaptive management will be used in the plan’s implementation.

The HBWMP is a living document that will benefit from regular review and updating, to remain current and to support effective management. Lessons learned from the process of developing the HBWMP can be applied to subsequent watershed management planning efforts in the region.

3. Pollution Control Strategies

The *Pollution Control Strategies* section identifies and locates the management practices applicable to the Hanalei Bay Region, as well as their calculated and/or relative contributions to pollutant load reduction.[17] As part of the planning process the relevant management measures provided a basis for identifying specific management practices. Appendix B provides this background information.

3.1 Management Practices

3.1.1 Definitions

A set of management practices has been identified for implementation based on the targeted pollutant locations and land use activities (Table 14). Management practices were chosen based on their expected performance to reduce sediment, nutrient, bacteria, and other NPS pollutants that currently impact water in streams, estuaries and the bay. Selection of practices was also based on practical considerations such as cost to install and maintain, past history on successes and failures of practices installed, and likelihood that land owners and managers would be willing to install and maintain practices.

Table 14. Definitions of Management Practices

Management Practice	Definition
Individual Waste System: Aerobic Treatment Unit (ATU)	A small-scale sewage treatment system similar to a septic tank system, but which uses an aerobic process for digestion rather than just the anaerobic process used in septic systems.
Baffle Box	Hard treatment device designed to capture runoff pollutants three ways: trapping gross solids using a mesh grate, settling of particles in one of the chambers, and hydrocarbon absorption onto a skimmer boom.
Bioretention Cell (Rain Garden)	Depression consisting of native plant species and soil mixtures that receives stormwater flow and infiltrates to treat pollutants
Channel Maintenance and Restoration	Practices used to control sediment and plant pollution into waterways during earthwork such as stream bank stabilization or habitat enhancement (e.g. *hau* bush removal). Examples include floating booms and silt curtains extended across river and stream banks downstream of work.
Constructed Wetlands	Practice excavated and installed on a small waterway (e.g. *'auwai*) that intercepts outflow of taro *lo'i* or off other lands. Inflow water passes over and through plants so that sediments and particulates are filtered, and nutrients are taken up by plants. Designed to treat baseflow or non-storm event discharges. Also known as wet basin.
Curb Inlet Basket (with Filter)	Mesh grate placed inside curb inlet used to capture gross solids.
Commercial Wastewater Treatment Plant (WWTP) Upgrades	Tertiary (advanced or final) treatment upgrades to existing wastewater treatment plants such as filtration, lagooning (e.g. wetlands), and nutrient removal.

[17] A full discussion of NPS pollutant types, locations of generation, and transportation off the watershed into receiving waters is presented in *Volume 1: Watershed Characterization*.

Management Practice	Definition
Erosion Control Mats and Vegetative Plantings	Erosion control mats are geotextiles that are composed of synthetic fabric and stabilize the ground while initial vegetative growth takes place. Vegetative plantings are hearty native or non-invasive species used to permanently stabilize and protect the ground surface. The practices are used together to discourage erosion and generation of sediment from exposed soil surfaces, including those within drainageways.
Feral Ungulate Fencing	A structural conservation practice that prevents movement of ungulates across a given boundary. Within areas impacted by feral ungulate presence, fences prevent their movement into the forested lands. Ungulate fencing prevents direct contact of fecal matter with waterways, allows for restoration of vegetation, and reduces bacteria and nitrogen loadings and sediment input into waterways.
Fertilizer Management Plan	A conservation practice recommended to be prepared for any activities where fertilizers are actively applied, stored, and present the potential for introduction into the environment. Objective is to provide only amount of fertilizer needed, to minimize loss and export to receiving waters.
Good Housekeeping Practices	Actions and activities conducted by residents that reduce the generation of NPS pollutants and runoff from their properties. Practices that prevent or minimize potential for spills or misuse of fluids and other pollutant sources from activities within the watershed. Includes educational component.
Grass Swale	Engineered vegetated conveyance channel constructed at a gentle grade designed such that water quality treatment can occur for a specific contributing drainage area through infiltration of runoff and pollutants into the soil.
Grazing Management System	Set of strategies implemented to prevent trampling within established riparian buffers by cattle or other livestock. Reduces sediment and fecal matter loadings (bacteria and nitrogen) entering water bodies. *Prescribed Grazing*. Management of vegetation with grazing and/or browsing animals. *Livestock Fencing*. Structural conservation practice that prevents movement of livestock across a given boundary. Within grazing areas, ditches between paddocks are fenced off to limit cattle and buffalo movement. *Livestock Watering*. Practices such as use of a solar-powered system that draws water from ditches and pumps it into troughs for cattle, in lieu of allowing livestock to access ditches, *ʻauwai*, or streams to water.
Gutter Downspout Disconnection	Removal of directly piped, roof-generated stormwater runoff into the Separate Storm Sewer System (S4). Promotes infiltration into landscaped and pervious surfaces and avoids introduction onto impervious surfaces.

Management Practice	Definition
High Efficiency Toilets	*Composting Toilet*: Dry toilet that uses a predominantly aerobic processing system that treats sewage, (typically with no water or small volumes of flush water) via composting or managed aerobic decomposition. Works best with low evaporation rates (non-humid areas) although may be modified to accommodate humid areas such as Hanalei. *Low Flow Toilet:* Toilets and urinals that use small amounts of water for flushing or toilets that have two tanks, one for liquid and one for solid disposal. Results in less wastewater and easy to retrofit to existing facilities. *Waterless Urinal*: Urinals that utilize a trap insert filled with sealant liquid instead of water. The sealant is lighter than water and floats on top of the urine collected in the U-bend, preventing odors from being released into the air. Useful in high-traffic facilities and in situations where providing a water supply may be difficult or where water conservation is desired. Can result in substantial water usage reductions.
Lo'i Management	Protocol for operating *'auwai* outlet that keeps the gate closed during *lo'i* tilling and weed pulling. Promotes settling of sediment and prevents TSS from migrating to receiving waters. Tilling *lo'i* when dry. Prevents stirring up of sediment common to wet tilling practices and promotes the traditional resting period for *lo'i.*[18]
Permeable Surfaces	Pavements and concretes that contain a low percentage of fines, which can be used in areas with light traffic (e.g. parking lots) to promote infiltration and treatment of stormwater runoff within the subsurface environment.
Pesticide Management Plan	A conservation practice recommended to be prepared for any activities where pesticides are actively applied, stored, and present the potential for introduction into the environment.
Storm Sewer Disconnection	Removal of directly piped urban S4 components (e.g. catch basins, drainage pipes) within a developed site and instead promoting onsite retention, infiltration, and treatment of stormwater through natural areas and structural practices.
Wetland Pollution Reduction Practices	Set of protocols implemented to prevent pollutant migration generated by bird presence within wetland areas. Goal is for reduction of nutrients and bacteria introduced downstream into water bodies.

3.2 Recommended Management Practices

Management practices have been identified for sites within Hanalei Bay Watershed. This section describes each of the management units, common pollutant inputs within each, the main sources of these pollutants, and recommended management practices. Management units are presented in alphabetic order, and management practices are presented within applicable management units. Priority practices and their locations for each management unit are identified along with discussion as how the priority and sites were selected. Additional information on selected practices is found in Appendix C. Estimates of pollutant load reductions for selected practices are presented in Section 3.4.

The recommended management practices were selected and prioritized with a ranking based on: (1) ability to either prevent or reduce generation of NPS pollution at its source; (2) ability to treat the pollutant stream that contains them; (3) effectiveness of remediating multiple NPS pollutants

[18] It is recognized that dry tilling may not be possible for all *lo'i*.

through installation of the practice; (4) cost; (5) practical and logistic elements of installation; and (6) link to regulatory or management objectives that either require or promote measures to reduce NPS pollutants.

Practices that are most practical to install or adopt are given the highest priority for implementation. For example, the largest sources of sediment are derived during rainfall and runoff in the steep upland areas of the four watersheds and along the streams. However, it is not realistic to control erosion over such a large area, nor are the natural versus accelerated rates of erosion quantified, and therefore it is not as high a priority as compared to other practices tied directly to manmade activities. On the other hand, cesspools that are located in sandy soils in proximity to Hanalei Bay are sources of pollutants that are more discrete, and addressing them is practical. Of these, locations that are logistically favorable for implementation and are estimated as having high impact in regard to pollutant input, are given the highest implementation priority.

Recommendations of site specific locations for implementing the management practices are based in part on a rationale correlated to the size of the subwatersheds. Per the Phase 1 TMDL, the existing loads of the three pollutants of concern (TSS, nutrients, and bacteria) are positively correlated to the size of the four subwatersheds, with Hanalei as the highest and Waikoko the lowest. The pollutant load per unit acre is also positively correlated to the watershed area. The associated load reductions necessary to achieve the TMDLs for these pollutants are highest in the Hanalei Watershed when compared to the Waipā, Waikoko, and Waiʻoli Watersheds. As a result when selecting locations for the practices, Hanalei Watershed was the priority.

Recommended management practices are targeted for implementation as soon as the necessary resources have been secured to ensure their completion (Table 17). Upon full implementation, these practices will have the greatest positive benefit by either preventing the generation of NPS pollutants at the source, or treating them through filtration or retention once they have entered the watershed stormwater drainage system. Some of these practices will have positive benefit whether all locations have been implemented.

In the long run, the best solution to reducing the amount of land-based pollutants reaching the ocean is to prevent generation and/or reduce generation to background levels. For example, it is more effective to reduce the amounts of pollutants as compared to trying to lower their concentrations once they are applied (e.g. nutrients put onto a taro *loʻi*). An approach that combines both preventative and treatment methods comprises a 'treatment stream' and may be the most effective at reducing pollutants. However in many instances it is not immediately feasible to implement preventative actions due to high costs, long range time commitments, and willingness of users to alter their actions. Therefore, some treatment controls that result in immediate benefits are ranked high priority for implementation. For some of the recommended treatment practices, reduction of NPS pollutants is expected to occur immediately after installation. Although there may be a lag time before certain preventive controls (e.g. ungulate fences), are implemented and begin to show results of significant reduction of NPS pollutants, they too are recommended.

The management units and associated management practices that were determined to be highest priority and should be the focus of initial efforts are[19]:

1. IWS upgrades in the Built Environment Unit
2. Taro *Loʻi* Management Unit
3. Grazing Management Unit

3.2.1 Built Environment Unit

The Built Environment Unit includes areas used for business, residential, recreational, and transportation, which are the primary urban generators of land-based NPS pollution (Table 15). Management practices for this unit are targeted at controlling/reducing stormwater runoff and associated pollutants from commercial sites and roadways; reducing subsurface bacteria and nutrient contributions from commercial and residential property IWS; and reducing chemical, nutrient, and water usage associated with landscaping.

Commercial property parcels within the Built Environment Unit are present in Hanalei and Waiʻoli Watersheds. Generally speaking, commercial properties share several common land-based pollutant inputs associated with the operation and maintenance of their facilities. The largest commercial properties in this unit are Hanalei Center and Ching Young Village, which also contain the largest areas of impervious surface within the Hanalei Bay Watershed. Both the Hanalei Center and Ching Young Village properties' stormwater discharge currently ties into Kuhio Highway's S4 and drains into an *ʻauwai* located east of Aku Road, which ultimately discharges into Hanalei River.

Table 15. Major Land-Based Pollutants and Their Sources

	Land Use/Land Type		
Land-Based Pollutants and their Source(s)	**Commercial**	**Residential**	**Kuhio Highway**
Nutrient inputs to surface water and groundwater from fertilizer application of landscaping and turf surfaces	✓	✓	
Nutrient, bacteria, and other pollutant inputs from IWS and treatment works disposal (e.g. septic and cesspool, package plants)	✓	✓	
Metals (e.g. copper from vehicle brake pads)	✓	✓	✓
Generation of sediments from vehicle traffic and exposed/eroding soils	✓	✓	✓
Hydrocarbons, chemicals, and fluids deposited from the motor vehicles	✓	✓	✓
Hydrocarbon and chemical-based fluids, sediment, and metals/toxins deposited on the highway travel lanes and other impervious surfaces from motor vehicle usage and wear	✓	✓	✓
Trash and debris accumulated on property/roadway edges and other connected properties	✓		✓
Nutrients and sediment generated from vegetation (plants and grass) along edges of paved areas as well as from fertilized landscaped areas of properties draining toward the highway	✓	✓	✓

[19] Opportunities or funding to implement management practices in other management units should also be taken advantage of if presented.

There are approximately 272 single family homes on residential lots within Hanalei Bay Watershed, with numerous single family lots in Hanalei town used as vacation rentals and bed and breakfasts. Many of these residences are in close proximity to the ocean shoreline and other water bodies.

State Highway 560 (Kuhio Highway) runs through Hanalei Bay Watershed, from Princeville to Haena. Within Hanalei town, an S4 runs for a portion of Kuhio Highway's length, capturing stormwater runoff from at least eight curb inlets occurring on both sides of the road. Pollutants discharged into this S4 include those generated on the highway surface as well as roads, driveways, and parking lots contiguously connected that intersect the highway. Ultimately, these pollutants are carried in stormwater runoff to the Hanalei and Wai'oli Rivers via County drains.

Several commercial and residential property parcels have impervious area that is directly connected to Kuhio Highway or ditches and '*auwai*. This directly connected impervious area (e.g. parking lots and driveways providing direct access to Kuhio Highway and other main streets) fosters the transport of stormwater and its associated pollutants, allowing runoff to travel relatively unrestricted downstream along these impervious surfaces until discharging via street drainage systems or into ditches and '*auwai*. Ultimately, discharge is to surface water bodies such as the Hanalei River.

3.2.1.1 Wastewater Management

Priority Practice: Aerobic Treatment Unit

Aerobic treatment units are structural devices (similar to septic tanks) that utilize a second chamber tank for aeration to enhance microbial decomposition of sewage. ATUs are recommended to replace small capacity cesspools and failing or undersized septic residential IWS within the Hanalei Bay Region. A prioritization scheme was developed to identify and prioritize specific properties for upgrade to ATU, with a focus on single family homes that are legally licensed Transient Vacation Rentals (TVR). There are approximately 117 of these, which likely generate higher volumes of wastewater than typical households. Existing IWS units (i.e. septic systems and cesspool systems) on these properties that have not been upgraded or resized to accommodate these increases in waste load are more prone to failure over time (Table 16; Figure 3 and Figure 4).

Properties that currently have cesspool(s) for their IWS and are TVRs were identified. A multiple criteria metric was developed based on several characteristics: soil type, proximity to surface water, depth to water table (if known), and location within floodway. Properties with a metric of 90 percent total points and above were classified as high priority (45 properties) (Figure 3 and Figure 4). Following the replacement of cesspools on priority properties, other TVRs on cesspools and septic systems should be targeted for replacement with ATUs, followed by single family home residential properties with cesspools systems. Lastly, residential properties with failing septic systems should be addressed for replacement. All property owners with cesspools and septic tanks are encouraged to upgrade their units to ATUs to reduce contaminant export to surface waters in the Hanalei Bay Watershed.

Table 16. Existing IWS for Hanalei TVRs[20]

Type	Number
Aerobic Unit (No final approval)[21]	1
Cesspool (Confirmed)[22]	13
Cesspool (DOH Card)[23]	13
Cesspool (Assumed)[24]	19
Cesspools (Confirmed)[25]	2
Septic Tank	57
Septic Tank (No final approval)[26]	12
Total	**117**

A typical ATU suitable for Hanalei single family homes may be Model #DF60-FF, manufactured by Delta Environmental Products, with a capacity of 600 gallons per day (M. Cummings, pers. comm.). The average cost to purchase and install one of these units is approximately $35,000 on the north shore of Kaua'i. However the price fluctuates depending on specific conditions of the subject property and the specific island and location. International Wastewater Technologies, Inc. offers the Cyclic Biological Treatment (CBT) process, an ATU that can be sized for residential homes with a 1,000 gpd capacity (G. Lindbo, pers. comm.). A typical ATU is aerated 24 hrs/day, which causes denitrification issues resulting from the presence of human waste. However the CBT single basin reactor has an anoxic (low oxygen) system state induced by a cycling pattern of 2 hours on/2 hours off, which naturally denitrifies the system. The retail cost for the CBT unit is $10,000 – $12,000 preassembled, and the installing contractor can then tie the unit into the existing wastewater stream in place of an existing septic tank, as well as tying in electrical lines. Installation costs typically range between $5,000 – $10,000, resulting in a total cost of $15,000 – $22,000 for each CBT unit installed. Design of actual unit by an engineer can cost an additional several thousand dollars in fees, depending on the firm (M. Cummings, pers. comm.).

The process involved in upgrading an IWS will require each individual homeowner to retain the services of a State of Hawai'i licensed civil engineer with expertise in subsurface wastewater system design (M. Cummings, pers. comm.). The engineer will complete a site assessment and perform a soil percolation test to determine in-situ soil conditions. A proposed design will be completed, the plans will be stamped by the engineer, and submitted to DOH for review. DOH will either approve the system as designed or cite the necessary changes for approval. An approved system can then be

[20] Data derived from IWS information provided by EPA Region 9 (R9) Pacific Southwest compilation of DOH Wastewater Branch (WWB) IWS database and TVR information provided by County of Kaua'i.

[21] "No final approval" means record on file indicated no date of aerobic unit system final approval by DOH. Unclear if the system was actually installed.

[22] TMK parcel has a single cesspool based upon EPA R9 research related to large capacity cesspool (LCC) voluntary compliance/closure efforts.

[23] Property initially identified based upon a TMK building value greater than $0, where no confirmation of IWS/cesspool exists to assume a cesspool is in place; then cross-referenced property with University of Hawaii compilation of available DOH WWB cesspool card records.

[24] Indicates all remaining TMKs with a building value greater than $0, after IWS data was matched to TMKs.

[25] Multiple cesspools present per TMK parcel based upon EPA R9 research related to LCC voluntary compliance/closure efforts.

[26] Record indicated no date of septic tank system final approval by DOH. Unclear if the system was actually installed.

constructed by a licensed contractor. The reader is referred to a report entitled *Onsite Wastewater Treatment Survey and Assessment* (WRRC and Engineering Solutions, Inc. 2008) for guidance in selection of an appropriate IWS system in Hawai'i, as well as discussing potential IWS options with DOH staff and consulting with a licensed engineer specializing in wastewater treatment. See Appendix C.1.

Commercial WWTP Upgrades

Upgrades to the existing commercial WWTPs are recommended for both Hanalei Center and Ching Young Village, with the priority being the Hanalei Center system. Ching Young Village currently employs an STM Air Rotor Westech system to process wastewater, which uses a partially submerged conveyor belt to rotate media to the surface, and uses ambient air contact with oxygen for aerobic treatment (M. Cummings, pers. comm.). The system has the capacity to process a wastewater flow-rate of approximately 20,000 gpd, however it currently receives and treats between 6,000 and 8,000 gpd. This system replaces the typical blower apparatus found in many WWTPs, and results in increased energy efficiency and lower costs. Within Ching Young Village, there are five restaurants that contribute sewage flow to the unit, and each has its own grease interceptor installed for preliminary treatment prior to contributing flow to the system. Hanalei Center's package plant treats approximately 7,000 gallons per day. This plant does not use aeration to treat waste and is not as efficient as the Ching Young Village package plant. Both plants dispose of the partially treated effluent via gravity force injection wells on site.

Recommended upgrades to the Hanalei Center and Ching Young Village WWTPs include tertiary treatment targeted at reduction of bacteria levels and nutrient concentrations within the final treated effluent. An option for tertiary treatment includes routing effluent treated to the secondary level into a finishing wetland prior to discharge into the subsurface.

A constructed wetland system can be added into the sewage treatment process to function as either the secondary treatment or tertiary treatment phase (e.g. it can be implemented within the treatment stream after the existing primary settling tank, becoming the new secondary treatment process (L. Roth, pers. comm.)). Expected measured concentrations of wastewater constituents attained when utilizing a wetland system for secondary treatment include TSS values less than 10 mg/l; Biological Oxygen Demand values less than 10 mg/l; and TN values less than 5 mg/l.

Similarly, a recirculating sand filter can be added as additional tertiary treatment. With recirculating sand filters, the media (sand, peat, foam, fly ash, or other media) encourages biological growth, allowing effluent to pass slowly through the media multiple times and giving bacteria sufficient time to process the constituents found in the effluent. Wetland and sand filter systems can be used in combination for enhanced treatment.

Additional treatment practices (e.g. new grease interceptors, UV disinfection for tertiary treatment) could potentially process wastewater effluent to the R-2 level, and even the R-1 level for both Hanalei Center and Ching Young Village (the existing system currently meets R-3 requirements) (L. Roth, pers. comm.)). Generally speaking, package wastewater treatment systems require substantial energy costs to operate, particularly when the aeration process is involved. The best overall solution for both properties may be to replace the existing aeration phase of the treatment process with a constructed wetland for aerobic treatment of wastewater, which will require lower long-term operating costs. Another option, primarily for the Hanalei Center, would be installation of a series of

ATUs. Detailed feasibility assessments and engineering studies will need to be prepared to determine the types of upgrades for the Hanalei Center batch plants. For Ching Young Village a feasibility study on the use of a wetland to finish partially treated effluent is recommended.

High Efficiency Toilets

The high visibility and central placement of Hanalei Center and Ching Young Village attracts locals and visitors alike for shopping, dining, and other activities. Restroom usage at these sites by patrons results in heavy wastewater flow rates. Currently the businesses within these properties employ standard plumbing fixtures. It is recommended that the public restrooms within Hanalei Center and Ching Young Village, and businesses at both properties (e.g. restaurants) be retrofitted with low-flush or zero flush toilets to reduce wastewater disposal discharge rates and rates of potable water use.

Additionally, waterless urinals are recommended for all three of the comfort stations (restrooms) at beach parks: (Hanalei Beach Park, Hanalei Pavilion Beach Park, and Waioli Beach Park) as well as the County's Hanalei base yard (including the maintenance facility).

3.2.1.2 Runoff and Pollutant Transport Control

Runoff control is accomplished by implementation of management practices to filter and trap pollutants transported in runoff from semi-pervious and impervious surfaces. A combination of structural and non-structural practices is recommended for Hanalei Center and Ching Young Village properties, and within the highway right-of-way (Figure 1-2).

Baffle Box

A baffle box is a multi-chambered concrete box separated internally with baffles used to settle out pollutants. Chambers can be fitted with absorbent membranes to trap floating pollutants (e.g. hydrocarbons). Effective at removing coarse sediments, TSS, and hydrocarbons, the system is specially designed to capture trash and debris, organics, and gross solids in a raised screening basket that allows these pollutants to be stored in a dry state. See Appendix C.2.

Two baffle boxes are proposed for treatment of the impervious area runoff from Hanalei Center and Ching Young Village that are tied into the Kuhio Highway S4 system, as well as the portion of Kuhio Highway itself draining to the S4. Placement of the baffle boxes is recommended inline within the S4 on the *makai* (ocean) and *mauka* (mountain) sides of the highway, immediately upstream of the two outfall(s) point at the *'auwai* / box culvert east of Aku Road. This stretch of Kuhio Highway has a high potential for NPS pollutants due to its concentration of commercial and residential development. Ultimately, these pollutants are washed into Hanalei River and Hanalei Bay by runoff generated during rain events.

Bioretention Cell (Rain Garden)

A bioretention cell (commonly known as a rain garden) is a constructed depression consisting of native plant species and soil mixtures that receives stormwater flow and functions to retain and treat common pollutants onsite. See Appendix C.3.

Bioretention cells are proposed for treatment of runoff from paved parking lot, access aisle, and driveway runoff on both the Hanalei Center and Ching Young Village properties. Through strategic siting of rain gardens, runoff can be captured onsite and treated, thereby reducing both the concentration of pollutants entering the S4 system as well as the volume of runoff. Rain gardens must be placed where runoff can naturally sheet flow into them via the existing site grading. In some instances, this may involve removal of curbing to break up the concentrated flow of runoff. Exact placement is dependent on site grading and rain garden/screening plantings that collectively satisfy Section 8-5.5, Development Standards for Commercial Development, of the *County of Kauai Current Comprehensive Zoning Ordinance* (CZO).[27]

At Ching Young Village, bioretention cells can potentially be placed at locations within the existing front yard, side yard, or lawn areas to receive sheet flow of runoff. Along the front yard, the rain garden may take the shape of a long swale running between the parking lot and the sidewalk of Kuhio Highway. In other locations, rain gardens may take more circular or other shapes depending on space constraints.

Within the Hanalei Center, the existing vegetated and grassed parking lot islands can be retrofitted with rain gardens to receive sheet flow of parking lot, access aisle, and driveway runoff. Placement of the rain gardens is recommended in existing vegetated islands so that excavation and removal of existing impervious areas is not necessary. Rain gardens can also be placed within the lawn areas between the various buildings. The lawn area east of Harvest Market Hanalei and west of Bubba's Burgers may be an ideally suited location.

Additionally, roof runoff may be directed to the rain gardens in order to further reduce the volume of runoff entering the S4 system. This can be done by rerouting roof gutters or disconnecting the roof gutter drainage system from the S4 system (see Gutter Downspout Disconnection).

In summary, given the high traffic volume to Hanalei Center and Ching Young Village, existing grass and landscaped areas which currently receive or can receive sheet flow runoff, and potential for retaining considerable stormwater runoff volume onsite, installation of bioretention cells on both properties provides an excellent public education opportunity to demonstrate low-impact development (LID) techniques to address land-based NPS pollution. Permanent signage in "plain English" describing the project near the implementation location will help generate community support and promote acceptance of future projects.

Curb Inlet Basket (with Filter)

Mesh curb/grate inlet baskets are typically retrofitted into existing S4 curb inlets in order to trap gross solids, and are ideal for removing large quantities of hydrocarbons, including oils and grease, when fitted with an optional absorbent polymer. Curb inlet baskets are generally not recommended for installation on S4 systems where baffle boxes are installed, due to treatment redundancy. See Appendix 0.

Curb inlet basket retrofits are recommended for retrofitting within each of the approximately eight curb inlets in the Kuhio Highway S4, to trap coarse debris and detritus that enters the pollution stream from contributing commercial and residential impervious, unpaved, and landscaped drainage surfaces. Presently, the S4 curb inlets have no filtration devices, and any debris and pollutants that

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[27] Section 8-5.5(e) of the County of Kauai Current CZO states that all parking lots of commercial developments shall be "screened from public thoroughfares by a fence, wall, or plant screen not less than four (4) feet high…The setback area between the parking area paving and the public right-of-way shall be planted and shall not be paved."

enters them readily flows into the closed piping system and is ultimately discharged into the *'auwai* / box culvert east of Aku Road or carried west and discharged into the Waioli River.

The S4 inlets targeted for retrofit are located in the high traffic segment of the highway between Cin Wai Tai Road and Aku Road, along which the Hanalei Center and Ching Young Village have frontage. The S4 receives runoff from both of these properties through a combination of closed piping and catch basin network on the Ching Young Village property, and sheet/concentrated flows from Hanalei Center. Retrofitting these curb inlets will result in an immediate decrease in pollution discharged to the Aku Road box culvert, and will require regular maintenance to keep them functioning as intended.

Good Housekeeping Practices

Good housekeeping practices are recommended for all residential properties within the Hanalei Bay Watershed. This practice generally applies to the materials and activities associated with irrigation and fertilization of lawns and landscaping, household and automotive fluid / chemical handling and storage, and outdoor storage of materials including motor vehicles and parts. While these activities are not actively regulated, and may be considered a minor contributor to pollution, the combined input from residential properties has the potential for a substantial impact on NPS pollutant loadings. These pollutants are readily conveyed into waterways via runoff sources including irrigation and rainfall. See Appendix C.11.

Grass Swale

A grass swale is a shallow excavation, constructed on a gradually sloped grade, lined with grass along a waterway. The vegetated conveyance channel slows flow, temporarily impounds a portion of flow, filters a portion of pollutants, settles out sediment, encourages infiltration into the underlying soils, and reduces the potential for erosion caused by runoff velocities within the channel. Grass swales can be implemented wherever there is runoff that needs to be conveyed to a natural drainage channel from a treatment device or as a conveyance from a land use that has preventative treatment components incorporated into its design. See Appendix C.12.

Grass swales are recommended as an alternative to bioretention cells within Hanalei Center and Ching Young Village in areas where rain gardens are deemed unfeasible (e.g. vegetation will not be naturally maintained; may be damaged by pedestrian or vehicular use; inadequate filtration capacity). Grass swales are recommended for placement adjacent to pollution-generating impervious surfaces, similar to the recommendations for rain garden siting, particularly in high traffic volume areas. However, unlike bioretention cells, grass swales will most likely not be placed within traffic islands due to space constraints. Ideally, areas of the properties that receive low sediment loads should be selected for placement. Dependent on County of Kauai Current CZO (Section 8-5.5(e)), the existing vegetated front yard buffer setback of Ching Young Village may be an excellent location for a grass swale installation, running adjacent to and paralleling the sideway of Kuhio Highway. Within Hanalei Center, a grass swale can be graded to receive stormwater from parking lot and roof runoff, and fitted into the surrounding landscape.

Gutter Downspout Disconnection

Commercial businesses and residential houses are typically fitted with downspout pipes that discharge stormwater off the property and onto the adjacent sidewalk and/or street, or into the closed drainage system. This practice is likely conducted to reduce ponding that occurs during rainfall events. The funneled runoff adds to the runoff generated on other impervious areas including parking lots, driveways, buildings, and streets. The higher volume of runoff contributed from downspouts increases the frequency and efficiency by which NPS pollutants are carried to the S4 inlets. See Appendix C.14.

Existing gutter downspouts can be disconnected from properties that tie into the existing Kuhio Highway S4 system. Any downspouts that discharge onto pervious surfaces draining to the Ching Young Village parking lot catch basins or Kuhio Highway and its S4 are recommended to be redirected to pervious areas where infiltration into soils can take place. These disconnections can be done in coordination with construction of either bioretention cells or grass swales, promoting onsite treatment and retention of pollutants.

Permeable Surfaces

Porous pavement, pervious concrete, and concrete pavers are three common types of permeable surfaces that incorporate a range of materials and techniques to promote infiltration of stormwater runoff into the subsurface environment. The underlying base and sub-base layers of these surfaces function to reduce runoff volume, as well as effectively trap suspended solids and filter pollutants that would otherwise be transported by runoff into downstream drainageways. Permeable surfaces can be a viable choice in settings where industrial or commercial traffic is in use (i.e. parking lots), with few restrictions regarding axle weight. See Appendix C.16.

Installation of permeable parking surfaces is recommended to replace the conventional paved parking lots and access driveways within Hanalei Center and Ching Young Village. Although costs to construct a full permeable parking surface at both sites may be higher than that of a conventional site, the drainage appurtenances typically constructed for conveyance of stormwater (e.g. catch basins, drainage piping, curbing) would be unnecessary, removing the short and long-term maintenance and replacement costs requirements typically required for such items.

Full replacement of existing impervious surfaces with permeable surfaces would effectively remove stormwater runoff contributions from the parking lot, access aisle, and driveway areas of both developments, and result in full stormwater retention and treatment onsite. Onsite management of stormwater would remove a substantial portion of the drainage flow currently entering the Kuhio Highway S4 and significantly reduce pollutant concentrations discharging into downstream water bodies.

Additionally, roof runoff from both the Hanalei Center and Ching Young Village properties can be readily directed to the permeable surfaces, further reducing runoff flows from the property. There are multiple buildings on the Hanalei Center property, and the reduction in total flow from the site with redirection of runoff from these impervious surfaces can be substantial.

Storm Sewer Disconnection

Ultimately, disconnection of the existing S4 segment (i.e. the closed piping/catch basin network) within the Ching Young parking lot is recommended. This S4 ties into the Kuhio Highway S4 and provides a direct route for stormwater and pollutants concentrated on the parking lot, driveway, and parking stall surfaces to be transported to the Hanalei River. Removing this section of the S4, and replacing it with a combination of permeable parking lot surfaces, or, alternatively outletting runoff from the existing paved surfaces to naturally vegetated areas will promote natural processes of infiltration and treatment. Disconnecting this section of the S4 will promote onsite settling of sediment within the runoff, extend the timing of runoff to more closely mimic pre-development conditions, and remove and retain debris on the ground and typically found in stormwater. This can be done in conjunction with establishing alternate stormwater treatment practices such as bioretention or vegetated swales on the Ching Young Village and Hanalei Center properties to wholly manage treatment of stormwater pollution and runoff volume onsite. See Appendix C.18.

3.2.2 Taro *Lo'i* Management Unit

The Taro *Lo'i* Management Unit consists of the taro growing areas and includes the *'auwai*, ditches, and *lo'i* integral to the cultivation of taro*.* The Unit lies within the Agricultural Land Use District, and is present in all four of the Hanalei Bay watersheds (Figure 5–7). Management practices in this unit are targeted at reducing loads of sediment, bacteria, and nutrients exported in both surface water and groundwater to receiving waters.

Priority Practice: Constructed Wetlands

There are approximately seventy ditches with outlets that discharge surface water draining from taro *lo'i* and waterbird wetlands on the Hanalei National Wildlife Refuge (NWR) into the Hanalei River. Similar outflow ditch outlets exist in the other watersheds that route used *lo'i water* and storm water runoff to streams or estuaries. Outflow water carries dissolved nutrients, bacteria, and suspended sediments that degrade receiving water quality. Review of the Phase 1 TMDL report found that estimated nutrient loads (nitrogen and phosphorus) sourced to cultivated lands resulted in disproportionally high loads compared to other land types. In all four subwatersheds the percentage of land area in cultivation is a small percentage of the total land area and yet the total estimated loads of various forms of nitrogen and phosphorus were highest from the cultivated areas. A constructed wetland planted with a high density of native sedges will treat and improve used *lo'i* water by (1) settling sediments and other solids; and (2) bioremediating nutrients via sedges and soil microbes. Under routine conditions the constructed wetlands shall be installed near the outlet of the ditches and allow water to flow through the wetland before it discharges into the receiving waters. See Appendix C.6

A total of 28 constructed wetlands are recommended to be installed on ditch outlets (Figure 2, Figure 6, and Figure 7). Fifteen of the sites are identified as high priority, with twelve of these located within the Hanalei NWR. The high priority sites were determined based on review of the load estimates for TSS and nutrients prepared for the Phase 1 and Phase 2 TMDLs, and other water quality data sets.

Priority Practice: Fertilizer Management Plan

A fertilizer management plan is a conservation practice recommended to be prepared for any activities where fertilizer is used to promote plant growth. The objective of the plan is to ensure application of fertilizer amounts that minimize losses of nutrients through leaching to groundwater and surface water runoff. A fertilizer management plan is comprised of a soil test to determine existing nutrient amounts, generated estimates of loses from leaching and surface water runoff, crop needs, fertilizer application efficiency, and irrigation scheduling.

Taro cultivation is the dominant crop in the Hanalei Bay Watershed and is assumed to have the largest quantity of fertilizer applied of any land use. A fertilizer management plan should be prepared for taro operations that use fertilizers. See Appendix C.10. To reduce cost to farmers, the development of fertilizer management plans for taro farmers can be done for *lo'i* that are located in proximity to each other, have similar soil types, and share similar cultivation practices.

Lo'i Management

<u>*'Auwai* Outlet Gate Closure Protocol</u>

'Auwai outlet gates are currently installed at the outlets of taro *lo'i*. However, their usage has been reported as inconsistent, leading to transport of suspended pollutants to receiving waters when *lo'i* are disturbed. Farmers should close gates to prevent flow through of suspended pollutants during weeding and tilling of *lo'i*. Gates should remain closed until pollutants settle out and water in *lo'i* is clear. Additionally, outlet gates should be installed for *lo'i* that do not have one.

<u>Dry Tilling of Taro Ponds</u>

Currently, wet tilling operations are employed by several farmers. This involves the sowing of fertilizers into the substrate when *lo'i* are ponded. Dry tilling involves sowing of fertilizer after *lo'i* are dry. During wet tilling sediments are suspended and often remain in the water column for weeks, which increases the probability of turbid and nutrient rich waters flowing out of *lo'i*. Dry tilling is recommended for all actively cultivated taro *lo'i*. Used as a management practice in coordination with closure of the *'auwai* outlet gate, it is expected to reduce sediment and nutrient loads exported in surface water outflows.

<u>Taro Resting Period</u>

After applying fertilizers and flooding *lo'i*, it is recommended that water be held for two weeks before releasing.

<u>*'Auwai* and Ditch Cleaning</u>

'Auwai and drainage ditches should be cleaned at regular intervals. Accumulated mud and sediments should be excavated.

Pesticide Management Plan

A pesticide management plan should be prepared for taro operations that use pesticides. At a minimum, pesticide use should be restricted to regulatory approved products and applications should be compliant with manufacturer recommendations. The goal of pesticide management plans is to reduce migration of applied pesticides to receiving waters. See Appendix C.17.

3.2.3 Grazing Management Unit

The Grazing Management Unit includes all fields currently used for grazing livestock in Hanalei and Waipā Watersheds. A portion of the fields in the Hanalei Watershed lack fencing along waterways to restrict cattle access to water bodies. Management practices in this unit are targeted at reducing bacteria, sediment and nutrients introduced into water bodies. There are two primary targets for grazing management: the Mowry property and Princeville Ranch (Figure 7).

Mowry Property.[28] A herd of 25 adult buffalo, as well as 20 calves, are currently pastured on the Mowry property. The primary issues associated with the presence of these animals are trampling of the *'auwai* banks by animal movement, and generation of animal waste (e.g. bacteria, sediment, nutrients) within these areas. The function of the buffalo on this land is unclear at this time; there is question as to whether their presence is as pets, or whether they are being raised for slaughter and human consumption. It is recommended the buffalo be removed this property. There appears to be very little management of these animals or controls in place to prevent trampling of ditches that are connected to the Hanalei River or prevent their waste from entering the Hanalei River.

Princeville Ranch. Princeville Ranch currently leases nearly 700 acres of land in the Hanalei Watershed to cattle operators who raise approximately 20 steers on 200 acres of usable pasture. The steers feed on grasses and other plants, and use ditches in the pastures for watering. Much of the 700 acres is unusable to the cattle operators due to the abundance of invasive alien vegetation that displaces non-native grasses that the animals need for feed. In addition, stretches of the ditches on the parcel are overgrown and in disrepair, resulting in stagnant water conditions and boggy pastures.

There are no watering troughs provided for the animals, and as a consequence they access ditches or old *'auwai* to drink from. The *'auwai* are heavily overgrown with California grass and other plants. The cattle mostly access the water at few points along the waterways, and in some areas their trampling introduces sediment directly into the water, which is then transported to the Hanalei River. Cattle urine and feces are also input at these watering locations, and other locations near the waterways.

Grazing Management System

Several management practices are used in combination as part of a grazing management system to control erosion (sediment) and direct input of feces and urine (bacteria, nutrient) to waterways.

Priority Practice: Livestock Fencing

1Fences are commonly used by ranchers to group animals and control grazing pressures in paddocks and prevent access to protected resources (e.g. water). Fencing should be installed to control livestock movement and restrict animals from riparian zones (vegetated areas that serve as a transition between land and waterways). Ditches, *'auwai,* and natural channels flowing through pastures should be fenced off to prevent livestock damage to channel banks and introduction of animals waste into waters.[29] By keeping animals at certain distance from the riparian area, physical damage by animals to waterways is minimized and the vegetation can filter and capture pollutants carried by overland flow during storms or floods. Fences set back from waterways will prevent animals from defecating and urinating directly into water. Priority fences are depicted on Figure 7. On the Mowry property this includes fencing along the upper bank of the Hanalei River and fencing both sides of the drainage canal. On Princeville Ranch fencing is recommended along both sides of the ditch/*'auwai* that dissects the center of the parcel and drains into the Hanalei River.

[28] Access to the parcel was not granted during preparation of this plan, and observations of the property were made from helicopter air survey and visual scans using binoculars from several vantage points outside of the property.

[29] During preparation of the HBWMP the cost to fence off the ditches on the Princeville property where cattle pasture was considered prohibitive by the lessees.

Prescribed Grazing

Prescribed grazing is the management of vegetation using grazing and/or browsing animals (NRCS 2011). Prescribed grazing has ecological benefits such as reduced accelerated soil erosion and improved soil condition; improved surface water quality; and improved riparian and watershed functions. Generally speaking, prescribed grazing adjusts the timing, intensity, and duration of grazing to sustain vegetation and the grazing animals while minimizing adverse effects to the environment. Key ingredients of prescribed grazing include:

- Management of grazing animals to maintain adequate vegetative cover on sensitive areas (e.g. water bodies, riparian areas, wetlands);
- Managing animal numbers, grazing distribution, length, browsing periods, and timing of use to provide grazed plants sufficient recovery time to meet planned objectives;
- Providing rest from grazing to ensure the success of seeding and other conservation practices that cause stress or damage to key plants.

Provisions for improving surface water quality and quantity through prescribed grazing include:

- Minimizing concentrated livestock areas in order to enhance nutrient distribution and improve ground cover while reducing soil compaction and excess runoff and erosion;
- Planning the intensity, frequency, timing, and duration of grazing in order to minimize deposition of animal wastes and bacteria into water bodies and impacts on stream bank/shoreline stability;
- Providing adequate vegetative and soil ground cover for infiltration of runoff.

A Grazing Plan may be developed for livestock that identifies periods of grazing, deferment, rest, and other activities within specific areas. Maps showing paddocks, grazing rotations, timing, fencing, water bodies, riparian areas, and other valuable identifiers may be used for support. A Monitoring Plan can be developed to assess the grazing strategy and determine areas for improvement.

Travel Ways to Facilitate Animal Movement

The creation of established animal travel ways to watering areas (e.g. *'auwai*) improves grazing efficiency and distribution, protects ecologically sensitive and erosive sites, and provides access to forage, water, working/handling facilities, and shelter for grazing animals (NRCS 2012). Water bodies, stream banks, and other ecologically sensitive areas will be protected through their proper design and placement. Integral to the construction of animal travel ways is the consideration of in-situ soil characteristics and ensuring that accelerated erosion will not occur. Where necessary, diversions with a stable outlet are necessary and travelways should be crowned where appropriate.

An Operation and Maintenance Plan for animal travel ways can be prepared by NRCS and reviewed with the owner (NRCS 2012). This plan specifies the trails or walkways and associated practices have annual inspections (and after significant storm events) to identify repair and maintenance needs. These maintenance needs can include:

- Periodic grading/re-shaping of trails
- Re-seeding of areas in which the vegetation has been damaged or destroyed
- Mending of fences and replacement of gates
- Periodic removal and management of manure accumulations

For multiple adjacent vegetated walkways, the plan should provide guidance concerning the rotation of walkways to allow for recovery of vegetation and for improvement of animal movement.

Livestock Watering

Currently, livestock migrate into waterways to access drinking water, which readily introduces bacteria, sediment, and nutrients into the water bodies. Use of a system to draw water from ditches, pump it into troughs, and provide water for livestock within grazing fields will help keep cattle out of waterways. Using a photovoltaic power system means that no hardwired electricity is needed to pump the water into the trough. Blackstone Energy Solutions, Inc. produces photovoltaic systems with various pump sizes available to service 250 head of livestock, with water elevation lifts of 5 feet up to 500 feet.[30] Individual pumps are sized taking into consideration both the elevation lift and number of livestock required for watering. Both fixed and skid mounts are available for the watering systems to enable mobility for rotational grazing. Pumps can utilize both solar/wind power, or conventional AC power. Water can be withdrawn directly from the ditches and it is expected to alleviate cattle forays into the waterways.

Another alternative is to construct small water harvesting structures that collect rainfall and direct runoff into a cistern/trough system for watering. The system is essentially comprised of a roof area that is sloped and fitted with gutters that carry rainwater into a tank that feeds a trough. The sizes of the roof area and storage tank are a function of the rainfall amounts and water demands (i.e. amount of water for the number of animals pastured).

3.2.4 Forested Upland Unit

The Forested Upland Unit includes the undeveloped and steeply sloped forested headwater lands that generally extend from the upper boundary of the agricultural areas within each of the four project watersheds several miles into the upper elevations. These forested uplands consist of primarily non-native vegetation, including mainly evergreen forest and scrub/shrub, with small areas of grassland, palustrine wetlands, and bare lands.

The bare lands are the result of two main processes: (1) natural soil loss, brought on by surficial erosion and mass wasting; and (2) accelerated erosion and mass wasting resulting from feral ungulate damage and alien plants. In several reaches along the rivers and streams, the sediment inputs from within the channel itself are increased over background due to feral ungulates that trample and generally destabilize the channel’s bed and banks making them prone to erosion and alien vegetation. Feral ungulates are present in the watershed, and trample and remove native vegetation, create trails and wallows, transmit pathogens, and generally degrade the landscape. Ungulates are vectors and disperse alien plant seeds, which further degrades the native habitat and often replaces it with a monotypic stand. Ungulate and wildlife waste is also responsible for nutrient and pathogen generation.

Management practices in this unit are targeted at reducing natural and anthropogenically-sourced erosion and controlling the introduction of sediment, bacteria, and nutrients into waterways by feral ungulates. Specific locations targeted for soil surface remediation and establishment of permanent

[30] http://www.blackstoneenergysolutions.com/ag-solar-waterpump.html

vegetative stands will need to be prioritized as part of a future watershed inventory assessment and have not been delineated at this time.

Erosion Control Mats and Vegetative Plantings

Existing erosion hotspots that have exposed ground or are eroding at accelerated rates are recommended for treatment with a combination of bioengineering treatments that utilize biodegradable erosion control mats and geotextiles, and vegetation. These hotspots occur on streams and river banks, along trails, and on numerous spots in the forested and lowland areas. Hotspots are spread throughout the watershed and will need to be addressed on a location by location basis using an assessment process that prioritizes sites or remedial actions.

Vegetation planted on exposed or vulnerable surfaces is prescribed where practical. The type of vegetation and feasibility of long-term survival of plantings depends on site conditions, including existing vegetative cover, rainfall amounts, soil conditions, and slope angles. Selection of vegetative species should be based on specific location within the project area where vegetative cover is proposed, rainfall intensities in the area, and associated runoff rates.

Feral Ungulate Fencing

Fences are used throughout Hawaiʻi's forests to protect native plant communities and control and restrict animal movement. With the exception of Waipā Watershed, there are no known fences in the Conservation lands of the Hanalei Bay Watersheds to control feral ungulate movement. The Halelea Forest Reserve that encompasses most of the Conservation land in the Hanalei Watershed is managed by DLNR Division of Forestry and Wildlife. Fencing to protect critical areas and assist in control of feral ungulates is recommended, and should be coordinated with this division. Ultimately, feral ungulate removal is recommended to reduce their population numbers.

3.2.5 Stream Management Unit

The Stream Management Unit contains all rivers and streams within the Hanalei Bay Watershed. *Hau* bush is currently present in all waterways in the four watersheds, however the density of stands varies. These water bodies are vulnerable to streambank erosion and deposition, as well as channel constriction that may result from *hau* bush presence within the channel corridor. *Hau* bush removal is recommended only after plans that include management practices to control sediment and organics inputs during its removal are prepared.

The primary reason for *hau* bush removal is based on its invasive growth into waterways that reduces the channel's conveyance capacity. The slowing of water in and along the *hau* bush areas likely results in sediment deposition as water moves through the channel. As a result, the channel area is reduced and hydraulic variables such as flow direction and speed may be altered, resulting in adverse impacts to portions of the channel that are free of *hau* bush. Sedimentation on the channel bed may also reduce aquatic habitat, create anaerobic areas, and generally degrade the aquatic ecosystem and water quality.

No specific sections of the waterways have been identified for *hau* bush removal. Nor has an inventory and assessment of stream channels been conducted to determine sections of stream banks that are failing and in need of immediate stream channel restoration activities. The management practices are tools that should be used to control sediment during work along waterways.

Channel Maintenance and Restoration

There are two types of practices that are used during stream or river channel work that disturbs the bed and banks: construction management practices to control sediment and vegetative introduction and migration beyond the construction zone; and post-construction management practices to restore the site and stabilize the channel for long term protection.

Silt curtains and floating booms are devices placed in a water course during construction that contain the disturbed sediment associated with earthwork adjacent to and within water bodies. Curtains are designed to control the settling rate of solids (silt) suspended in water by providing a controlled area of containment for the silt. Booms form a floating barrier for debris/waste capture on the surface of water bodies. Suspension of silts in water, otherwise known as turbidity, is a common occurrence when construction or dredging in the marine environment is taking place. Silt curtains are typically manufactured from heavy duty polypropylene geotextile, with floats and ballast that can also be supplied. Curtains can be manufactured to suit specific applications, largely dependent on the location and flows of the specific water course. Standard curtain designs are usually available with a variety of fabric options, lengths, and flotation sizes so that entire areas affected by earthwork can be fully contained. They are typically used for containment under calm water conditions.

Silt curtains / floating booms are recommended at all locations of *hau* bush removal and where channel maintenance activities occur. Such activities are known to occur on properties located on the meander bend of the Hanalei River. Prior to any channel work the operator is responsible for securing all permits and approvals, and are expected to comply with provisions and practices to minimize adverse impacts from their projects on waterways (Appendix C.4).

Following construction, stream banks should be protected using erosion mats and vegetation. In many scenarios the vegetation will be part of the overall project, e.g. habitat enhancement. Timely installation is a key component, and all steps of the work flow must be clearly defined and timelines established.

3.2.6 USFWS Wetland Management Unit

The USFWS Wetland Unit, within the Hanalei NWR in Hanalei Watershed, contains 60 acres (24 ha) of intensively managed wetlands, 141 acres (57 ha) of taro *lo'i*, and 24 acres (10 ha) of dikes and ditches for the recovery of endangered Hawaiian waterbirds and wintering habitat for migratory waterfowl and shorebirds (Figure 7). Similar to the Taro *Lo'i* Unit, the USFWS Wetland Unit is focused on reducing sediment, bacteria, and nutrient generation on and export from wetlands to receiving waters.

Via special use permits issued to taro farmers, the USFWS promulgates regulations and requirements pertaining to taro cultivation practices. For example, pesticides used on the refuge are limited to products approved by USFWS. In addition, USFWS provides guidance and direction to farmers regarding existing or potential issues between farming and waterbirds. The USFWS does not currently require farmers on the refuge to prepare fertilizer or pesticide management plans. Nor is there a written list of management practices for farmers to consider or comply with to minimize potential water quality impacts. USFWS is in the process of preparing a Comprehensive Conservation Plan for the refuge that will most likely include some of the recommendations made in the HBWMP pertaining to water quality. Taro *lo'i* cultivated on the refuge should adhere to the management practices described for the Taro *Lo'i* Unit (Section 3.2.2).

There are two specific water quality issues to be addressed under this management unit: erosion of a section of the China Ditch near the USFWS maintenance complex and discharge of turbid waters from wetland *lo'i*.

Erosion Control Mats and Vegetative Plantings

A section of a bank on the China Ditch that crosses through the USFWS maintenance parcel located along Ohiki Road is bare and shows signs of erosion. The bare banks should be sculpted, to the extent possible, to lower the slope angle and should be stabilized and protected. Erosion mats and vegetation should be installed and planted along the exposed section.

Wetland Pollution Reduction Practices

USFWS manipulates water levels in the wetland cells on the refuge to create and maintain desired habitat conditions. Similar to taro *lo'i*, wetlands used for waterbird habitat have the potential to export turbid waters containing suspended pollutants. During maintenance periods, outlets of the wetland should be closed to minimize export of pollutants. Drainage ditches should be cleaned of accumulated sediments and mud at periodic intervals.

Table 17. Implementation Details for Recommended Management Practices

Management Practice	Estimated Cost[31]	Responsible Entity	Implementation Timeframe[32]	Life Expectancy[33]	Technical Assistance[34]	Financial Assistance[35]
Built Environment						
Aerobic Treatment Unit[36]	$27-$35k/unit	Land owner	Phased installation 2014-2024	25-30 years	Contracted engineer	Land owner
Baffle Box	$50-$90k/unit	Kauai County	Installation by 2017	50 years	Contracted engineer; Kauai County	Kauai County, Land owner
Bioretention Cell (Rain Garden)	$25-$40/cu foot[37]	Land owner	Phased installation 2014-2019	20-50 years	Contracted engineer	Kauai County, Land owner
Curb Inlet Basket	$1800/unit	Kauai County	Installation by 2016	50 years	Contracted engineer; Kauai County	Kauai County
Commercial WWTP Upgrades[38]	$200-$450k	Hanalei Center / Ching Young Village	Design completed by 2015 Installation by 2019	30 years	Contracted engineer	Land owner
Good Housekeeping Practices	$1000[39]	Land owner	2015	10-15 years	HWH	HWH
Grass Swale	$$20-$40/cu foot	Land owner	Phased installation 2014-2024	10 - 20 years	Contracted engineer	Land owner
Gutter Downspout Disconnection	$1000[40]	Land owner	2015	15-25 years	HWH	HWH
High Efficiency Toilets	$500-$1150/unit	Land owner	Phased installation 2014-2016	10-25 years	Contracted engineer	Kauai County
Permeable Surfaces	$8-$12/square foot	Land owner	TBD	15 - 25 years	Contracted engineer	Land owner
Storm Sewer Disconnection	TBD	Land owner	TBD	Indefinite	Contracted engineer	Land owner

[31] Cost estimates are based on RS Means Construction Cost data and actual cost of installations (Hawai‘i and mainland). Actual cost will vary according to site conditions.

[32] The implementation timeframe may be adjusted during updates, following an adaptive management approach.

[33] Life expectancy of the management practices varies and is a function of adherence to maintenance regimes outlined during design.

[34] For most practices the landowner or entity installing will need to prepare detailed designs and acquire permits (if necessary) with the assistance of a contractor. For some practices technical assistance may be provided by the government.

[35] Entities responsible for funding may be able to secure the actual funds to implement management practices through a range of resources (Section 2.2.1).

[36] Unit considered 600 gallon per day system, standard for residential dwelling.

[37] Cubic foot refers to volume of water treated daily under normal flow conditions (e.g. ditch with average discharge of 0.5 cubic feet per second equals 43,200 cu feet per day with a cost range of $300-$600k).

[38] Cost estimate range based on upgraded and new system for Hanalei Center package plant.

[39] Cost for informational flyers to inform homeowners about applicable good housekeeping practices (2000 @ $0.50/ea).

[40] Cost for informational flyers to inform homeowners about how to disconnect gutter downspouts (2000 @ $0.50/ea).

Table 17 cont'd. Implementation Details for Recommended Management Practices

Management Practice	Estimated Cost[41]	Responsible Entity	Implementation Timeframe[42]	Life Expectancy[43]	Technical Assistance[44]	Financial Assistance[45]
Constructed Wetlands	$7-$13/cu foot	USFWS, other land owners/farmers	Phased installation 2014-2017	15-30 years	Contracted engineer	USFWS
Fertilizer Management Plan	$3000 per plot	USFWS, other land owners/farmers	Plans prepared by 2015	Update every 5 years	UH-CTAHR / NRCS-East Kauai SWCD	NRCS, Land owner
Pesticide Management Plan	$3000 per plot	USFWS, other land owners/farmers	Plans prepared by 2015	Update every 5 years	UH-CTAHR / NRCS-East Kauai SWCD	NRCS, Land owner
Grazing						
Grazing Management System						
Livestock Fencing	$50/linear foot	Land owner /Lessee	Installation by 2015	5- 20 years	NRCS-East Kauai SWCD	NRCS, Land owner
Prescribed Grazing	$2000k	Land owner /Lessee	Plans prepared by 2015	N/A	NRCS-East Kauai SWCD	NRCS, Land owner
Livestock Watering	$1200-$2000/unit	Land owner /Lessee	Installation by 2015	10 years	NRCS-East Kauai SWCD	NRCS, Land owner
Forested Upland						
Erosion Control Mats and Vegetative Planting	$15.50/sq foot	DLNR	Phased implementation 2014-2024	2-10 years	DLNR	DLNR
Feral Ungulate Fencing	$195/linear foot	DLNR	Phased implementation 2014-2024	5-25 years	DLNR	DLNR
Stream						
Channel Maintenance and Restoration	TBD	DLNR	Phased implementation 2014-2024	TBD	DLNR, NRCS, Private	TBD
USFWS Wetland						
Erosion Control Mats and Vegetative Planting	$15.50/sq foot	USFWS	Phased installation 2014-2019	2-10 years	USFWS	USFWS
Wetland Pollution Reduction Practices	TBD	USFWS	Begin immediately; ongoing	Varies	University of Hawaii, NRCS, Private	USFWS

[41] Cost estimates are based on RS Means Construction Cost data and actual cost of installations (Hawai'i and mainland). Actual cost will vary according to site conditions.

[42] The implementation timeframe may be adjusted during updates, following an adaptive management approach.

[43] Life expectancy of the management practices varies and is a function of adherence to maintenance regimes outlined during design.

[44] For most practices the landowner or entity installing will need to prepare detailed designs and acquire permits (if necessary) with the assistance of a contractor. For some practices technical assistance may be provided by the government.

[45] Entities responsible for funding may be able to secure the actual funds to implement management practices through a range of resources (Section 2.2.1).

3.3 Low-Impact Development Strategies for Future Development

A low-impact development management practice is a stormwater management strategy concerned with maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection and maintain water quality while meeting environmental regulatory requirements and minimizing a project's impact. LID practices utilize a variety of natural and built features that reduce the rate of runoff, filter out pollutants, and facilitate the infiltration of water into the ground. LID management practices help to improve the overall quality of receiving surface waters and stabilize the flow rates of nearby streams.

For existing developments, management measures and practices serve several purposes:

- Minimize and reduce introduction of pollutants into the environment.
- Control pollutants at their source.
- Reduce pollutant loadings in surface water runoff in developed areas.
- Minimize sediment loadings from stream banks and other natural conveyance features, by reducing volume and velocities of runoff.
- Preserve, enhance, or establish buffers that create benefits to water quality along water bodies and their tributaries.

In most built areas within a watershed, practices to control runoff and land-based pollutants are added as retrofits to conventional storm water systems or onto other features such as parking lots. Management practices can provide these same purposes in future developments, but also have the advantage of incorporating low impact design controls into the design phase, rather than retrofitting a developed site. Addressing water quality and placing controls on pollution generation during the design phase of a project can represent a cost savings over the life of the project, when compared to future retrofits that may be required to address pollutant issues. LID can also represent a significant reduction in disturbed and impervious areas associated with a project (e.g. utilizing natural areas for detention and treatment of stormwater runoff in lieu of standard large detention ponds).

Of the recommendations made in this HBWMP, bioretention cells and vegetated swales are two low impact designs that are cost effective and relative and feasible for use in future developments or on properties that are being redeveloped. The most effective method for ensuring the incorporation of LID strategies into future development is to require their use through policy and regulatory requirements (e.g. building codes, permit requirements), primarily at the County level (Section 5.3.4).

3.4 Pollutant Load Reductions

Suitable management practices for management units will address target parameters. Drawing from multiple guidebooks and engineering judgment, Table 18 presents relative performance of management practices in addressing pollutant loading and stormwater flow (LA-SMD 2000; EPA 2003; Field et al. 2004; EPA 2005; EPA 2007; EPA 2008a; Bio Clean 2009).[46] The table identifies the

[46] The *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, recommends identifying the effectiveness of each management practice in reducing pollutant loading and addressing hydrologic impacts using a scale of high, medium, or low (EPA 2008b).

complimentary benefits of various management practices. The actual reduction depends on the extent of the practice, existing loading levels, and local features like soil and hydrology.

Pollutant load removal efficiency of selected management practices has been the subject of many studies. There are wide discrepancies in methods for evaluating and quantifying the effectiveness of management practices. Management practice performance is best described by how much stormwater runoff is treated and what effluent quality is achieved (Strecker et al. 2001). Stormwater management practices by definition are specific devices, practices, or methods used to support the intensions of the stormwater management measure (Field et al. 2004). However this term lumps widely varying techniques into a single category. There is little scientific literature regarding load reductions of nutrients associated with fertilizer management for taro *lo'i.* Nonetheless, it is logical that applying fertilizers in amounts not in excess of those required to meet plant needs will result in reducing export of fertilizers in surface water and groundwater flows from *lo'i.*

Table 18 illustrates the management practices and their anticipated relative load reductions for the six major pollutant types occurring in the project area.

Table 18. Management Practices and Expected Relative Load Reductions

Management Practice	Nutrients	Sediment	Organics	Bacteria	Debris/ Litter	Hydro-carbons
Aerobic Treatment Unit	H	H	L	H	L	L
Baffle Box	H	H	H	M	H	M
Bioretention Cell (Rain Garden)	H	H	H	H	L	H
Channel Maintenance and Restoration	L	H	L	L	L	L
Curb Inlet Basket (with Filter)	L	H	L	L	H	L
Commercial WWTP Upgrades	H	L	L	H	L	L
Constructed Wetlands	M	M	L	L	H	M
Erosion Control Mats and Vegetative Plantings	M	H	L	L	L	L
Feral Ungulate Fencing	H	H	L	H	L	L
Fertilizer Management Plan	H	L	L	L	L	L
Good Housekeeping Practices	H	H	H	L	H	M
Grass Swale	H	M	H	M	H	H
Grazing Management System	H	H	L	H	L	L
Gutter Downspout Disconnection	L	L	L	L	L	L
High Efficiency Toilets	H	L	L	H	L	L
Lo'i Management	M	H	L	L	L	L
Permeable Surfaces	H	M	H	H	L	H
Pesticide Management Plan	L	L	H	L	L	L
Storm Sewer Disconnection	H	H	M	M	H	H
Wetland Pollution Reduction Practices	H	M	M	M	H	M

3.4.1 Correlating Pollutant Load Reductions to TMDLs

One of the challenges was to ascertain how the estimated load reductions correlate to the applicable TMDL (Section 1.3). It is difficult to quantify the correlation between specific management practices and their estimated pollutant load reductions to a TMDL for nutrients, bacteria and TSS for specific water bodies.

The TMDLs were developed using two models. One model computed pollutant loads delivered off of land areas (subwatersheds) into the receiving water body (Hanalei Estuary). Several of the TMDL land area subwatersheds are not watersheds in the true definition of a watershed, but are land areas with uniform uses and land conditions.[47] For each of the land areas the pollutant load model was used to generate a load estimate for nutrients, bacteria, and TSS. The estimated load of a particular pollutant (e.g. nitrogen) was assigned to the entire land area assessed, and is not for a specific outlet of a stream, *'auwai*, or ditch draining the land area.

The second model is a hydrodynamic water quality model that was used to estimate how much of a particular pollutant can be loaded in water body daily without impairing its water quality. In the Phase 1 TMDL a composite existing daily load for the three pollutants was computed, which is the sum of the land areas draining into the various water bodies, e.g. Hanalei Estuary. The composite TMDL for each of three pollutants was then compared to the existing daily load in order to compute the load reductions necessary to bring the existing load down to the TMDL.

The practices recommended to treat pollutants in the HBWMP (e.g. constructed wetlands) are sited for installation at specific locations along waterways where there are no existing load estimates. This makes it difficult to calculate the site specific pollutant load in relation to the total pollutant load for the land area it is located within. Without this specific date, correlating to the TMDL, which is the total maximum daily load of a pollutant, is not possible.

One approach to developing a robust numeric estimate of load reductions that would be provided by the recommended practices would be to run the first TMDL model (land area load estimate) with the practices. Since the model uses land use, cover, condition, hydrology, and rainfall as input variables, the practices could be used to modify the input variables. This approach is beyond the scope of the HBWMP. The approach used herein (Section 3.4.3) was a best attempt at using relative load estimates for priority practices, and where possible, equating them to actual numeric load reductions and comparing that value to the existing TMDL. Any practice that prevents nutrients, bacteria and TSS from entering into water ways will ultimately reduce the existing daily loads, which in turn means the loads are trending down towards the TMDL.

3.4.2 Pollutant Removal Efficiency of Selected Management Practices (Published)

This section describes the pollutant removal efficiencies of structural management practices recommended in this document, with available removal efficiency data listed for a typical installation. Data was available for the following practices: baffle box, bioretention cell, grass swale, and permeable pavement. The remainder of the practices are non-structural in nature (and their

[47] A watershed is a unit of land with surface runoff that drains to a common outlet (e.g. mouth of a stream). Watershed boundaries are delineated based on topography. A large watershed such as the Hanalei River can be further divided into numerous subwatersheds, such as for each stream that flows into the main stem of the Hanalei River. Subwatersheds can also be further subdivided based on local topography.

pollutant removal capabilities are dependent on various factors) or there is no data available to determine their efficiency.

Table 19 illustrates the relationship between various management practices and the removal efficiencies of common pollutants generated within the project area.[48] As shown, all of the practices have significant reductions in the median TSS concentration. The reduction is greatest for bioretention cells, with a median concentration in stormwater effluent reduced from 50 mg/L to 10 mg/L (80% reduction). For Total Phosphorus, grass swales have the greatest reduction, from 0.26 mg/L to 0.21 mg/L median concentration (19% reduction). For Total Nitrogen, bioretention cells again have the greatest reduction from 1.38 mg/L to 1.09 mg/L (21%).

Table 20 illustrates the removal efficiencies expected from a typical baffle box installation, taken from the supplier's brochure.

Pollutant load reductions can be achieved by reducing pollutant concentrations, surface runoff volumes, and/or a combination of both. For bioretention, as an example, the existing Best Management Practices (BMP) Database dataset does not show a statistically significant reduction in nitrate concentrations; however, nitrate loads are expected to be reduced at bioretention sites that effectively reduce volumes discharged to surface waters.

[48] The publically-available International Stormwater BMP Database contains results of stormwater BMP studies independently conducted and provided by researchers throughout the U.S. and other countries. The database provides the median influent and effluent event mean concentrations, for commonly reported constituent and BMP categories (updated November 2011).
http://www.bmpdatabase.org/Docs/BMP%20Database%20Tabular%20Summary%20November%202011.pdf

Table 19. Selected Management Practice Pollutant Removal Efficiency Data

(from International Stormwater BMP Database; Geosyntec Consultants, Inc. and Wright Water Engineers, Inc. 2012)[49]

Management Practice	Grass Strip			Bioretention Cell			Grass Swale			Porous Pavement			Retention Pond[50]			Wetland Basin		
Constituent	In	Out	%Eff	In	Out	%Eff	In	Out	%Eff	In	Out	%Eff	In	Out	%Eff	In	Out	%Eff
TSS (mg/L)	43.1	19.1	56%	37.5	8.3	78%	21.7	13.6	37%	65.3	13.2	80%	70.7	13.5	81%	20.4	9.06	56%
Enterococcus (#/100 mL)	NA	NA	--	605	234	61%	NA	NA	--	NA	NA	--	615	153	75%	NA	NA	--
Fecal Coliform (#/100 mL)	32000	23200	28%	NA	NA	--	4720	5000	-6%	2210	2750	-24%	1350	542	60%	1920	707	63%
Total Phosphorus (mg/L)	0.14	0.18	-29%	0.11	0.09	18%	0.11	0.19	-73%	0.15	0.09	40%	0.30	0.13	57%	0.13	0.08	38%
Total Nitrogen (mg/L)	1.34	1.13	16%	1.25	0.90	28%	0.75	0.71	5%	1.26	1.49	-18%	1.83	1.28	30%	1.14	1.19	-4%
Nitrate + Nitrite (mg/L)	0.41	0.27	34%	0.26	0.22	15%	0.30	0.25	17%	0.42	0.71	-69%	0.43	0.18	58%	0.24	0.08	67%
Total Arsenic (µg/L)	1.04	0.94	10%	NA	NA	--	1.68	1.17	30%	2.50	2.50	0%	1.36	0.85	38%	NA	NA	--
Total Cadminum (µg/L)	0.52	0.18	65%	0.99	0.94	5%	0.50	0.31	38%	0.28	0.25	11%	0.49	0.23	53%	0.31	0.18	42%
Total Chromium (µg/L)	5.49	2.73	50%	NA	NA	--	4.53	2.32	49%	3.60	3.73	-4%	4.09	1.36	67%	NA	NA	--
Total Copper (µg/L)	24.52	7.30	70%	17.00	7.67	55%	10.86	6.54	40%	13.07	7.83	40%	9.57	4.99	48%	5.61	3.57	36%
Total Iron (µg/L)	792	590	26%	515	1032	-100%	151	86	43%	NA	NA	--	1094	280	74%	NA	NA	--
Total Lead (µg/L)	8.83	1.96	78%	3.76	2.53	33%	3.93	2.02	49%	4.30	1.86	57%	8.48	2.76	67%	2.03	1.21	40%
Total Nickel (µg/L)	5.41	2.92	46%	NA	NA	--	9.26	3.19	66%	3.64	1.71	53%	4.46	2.19	51%	NA	NA	--
Total Zinc (µg/L)	103.3	24.3	76%	73.8	18.3	75%	36.2	22.9	37%	57.6	15.0	74%	53.6	21.2	60%	48.0	22.0	54%

Table 20. Baffle Box Pollutant Removal Efficiencies[51]

Constituent	Percent Removal
TSS	76.9 – 93.3
Total Phosphorus	**18 – 70**
Total Nitrogen	**38 – 63**
Metals	Up to 57
Trash and Debris	**99**

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[49] Source document contains additional detail. International Stormwater BMP Database is regularly updated.

[50] In some cases, the retention ponds and wetland basin categories have been combined into a single category to provide more than three studies.

[51] Bio Clean Environmental Services, Inc. Nutrient Separating Baffle Box brochure, available at www.biocleanenvironmental.net.

3.4.3 Pollutant Removal Efficiency of Priority Management Practices (Calculated)

This section provides estimated pollutant load reductions for priority practices including: aerobic treatment units, constructed wetlands, fertilizer management plans, and livestock fencing.

3.4.3.1 Aerobic Treatment Units

Upgrading cesspools to ATUs is a priority management practice. An estimate of the load reduction for TSS and BOD was prepared by comparing disposal effluent concentrations of TSS and BOD for cesspool and ATU using literature values. Table 21 provides values for a single replacement and the scenario of decommissioning 45 priority cesspools and installing ATUs. IWS systems currently in use are not designed to disinfect the partially treated waste water before disposing into the environment, meaning they do not kill or disable bacteria.[52]

Table 21. Priority Upgrade of Cesspools to ATUs: Estimated Pollutant Load Reduction

IWS Type	Number of Units	TSS (mg/l)-day	BOD (mg/l)-day	Load Reduction Cesspool to ATU	
Cesspool	1	250	300	TSS (mg/l)	BOD (mg/l)
ATU	1	85	100	165	200
Cesspool	45	11250	13500	TSS (mg/l)	BOD (mg/l)
ATU	45	3825	4500	7425	9000

A significant pollutant load reduction can be achieved by closing cesspools and upgrading to ATUs on just 45 properties (Table 21). Closing all cesspools and septic units (combined total of 340) in the Hanalei Bay Watershed and upgrading to ATU would result in daily TSS and BOD load reductions of approximately 56,100 mg/l and 68,000 mg/l respectively. On an annual basis the respective load reductions would be approximately 21 kg/l (TSS) and 20 kg/l (BOD).

3.4.3.2 Constructed Wetlands

For each of the high priority constructed wetland sites, Table 22 provides a summary of the estimated annual pollutant load reductions for TSS and nutrients. Pollutant load reduction estimates are the product of existing load estimates (lbs/yr) for the outlets and the constructed wetland performance.[53] Estimates of the existing loads are based on estimates for the Phase 1 TMDL partitioned by subwatersheds.

The load reductions presented in Table 22 are distributed across all four subwatersheds for both streams and estuaries. In order to put the estimated load reductions in context with the TMDLs, the estimated pollutant load reductions and the Phase 1 TMDL estimated existing annual total load were compared to the recommended TMDL annual load for TSS, TN, and TP for the four subwatersheds of Hanalei (Table 23).

[52] In addition to ATUs, there is state of the art system manufactured by Envirocycle for IWS applications that produces treated effluent water that exceeds ATUs effluent water quality and also disinfects the waste stream before disposal. The Envirocycle product for IWS use completed testing in the State of Hawaii in April 2014 and its approval for use in Hawaii by HIDOH is expected by summer 2014.

[53] Performance refers to percent reduction the wetland is estimated to provide for TSS and nutrients.

Table 22. Priority Constructed Wetlands: Estimated Pollutant Load Reduction

Constructed Wetland Unit #	TSS 50% Effective (ton/yr)	TP 35% effective (lb/yr)	TN 30% effective (lb/yr)
1	0.93	28	251
3	0.99	72	530
4	0.99	72	530
5	0.99	72	530
6	0.32	19	127
7	0.32	19	127
9	0.69	79	596
10	0.43	23	154
14	5.33	158	714
17	0.99	72	530
19	0.32	19	127
21	0.32	19	127
22	0.99	72	530
23	0.99	72	530
25	0.44	30	213
Load Reduction Per Year	**15 ton/yr 6.8 kg/yr**	**824 lb/yr 373 kg/yr**	**5,619 lb/yr 2,548 kg/yr**

Table 23. Comparison of Priority Constructed Wetlands Pollutant Load Reduction to Phase 1 TMDL

Scenario	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)
Constructed Wetland Load Reduction	6.6	373	2548
Phase 1 TMDL Existing Load[54]	1.6×10^6	2.1×10^4	9.0×10^4
Phase 1 TMDL Target Load[55]	3.25×10^5	3653	1.5×10^4
Load Reduction as Percent of Existing Load	0.0004	1.77	2.8

Table 22 indicates that 15 recommended constructed wetlands are estimated to reduced TSS and nutrients at appreciable levels. Although when compared to existing and TMDL loads per year, the reductions are a small fraction. However, the reduction of TSS and nutrients *will* provide a measurable reduction in loads, which in turn will assist in approaching the TMDL.

3.4.3.3 Fertilizer Management Plan

It is not possible to derive an estimated load reduction for the priority practice of developing fertilizer management plans since there is no data on current fertilizer application rates. It stands to reason that if less fertilizers are applied on the watersheds, less nitrogen and phosphorus will be delivered into receiving waters and water quality will improve.

[54] TMDL Existing Load is an estimate derived by watershed model for the Phase One TMDL study.

[55] TMDL Target Load refers to the load of pollutant that was derived by water quality modeling, and is the amount of pollutant that can input into water body without impairing its quality.

3.4.3.4 Grazing Management System: Livestock Fencing

Estimates to quantify nutrient load reductions for livestock fencing, the priority practice for the Grazing Unit were prepared (Table 24). The estimates are made based average daily waste load (weight) generated by cattle and buffalo and the concentration of N and P contained in the waste. The waste load and concentrations are sourced to literature values taken from a variety of published reports, including EPA. For both cattle and buffalo the daily N load is 0.141 kg and P load is 0.023 kg. Approximately 60 percent of the N load is from urine. The pathways for nutrient inputs to waterways include: animal defecation and urine directly into water ways, movement through soil, and movement into waterways during flooding or overland flow events. It is unknown how much of the daily waste load from the buffalo and cattle are directly discharged into waterways, or how much of the manure (dried feces) and urine deposited on the ground make it into the surface waters. A review of literature on fencing practices to exclude cattle from water ways found that the load reduction is function of fence distance from the water body, with a minimum of 10 feet. For the estimates presented, a 60 percent reduction of nutrients with fences setback 12 feet from the waterways was used. No attempt was made to quantify bacteria load reductions, though it is known that a reduction will occur. If all the buffalo are removed, as is recommended, the existing total loads for N and P are the values estimated for cattle, as is the load reduction.

Table 24. Priority Livestock Fencing: Estimated Pollutant Load Reduction

Animal and Count[56]	N kg/yr	P kg/yr	N kg/yr	P kg/yr	Load Reductions kg/yr	
	Existing	Existing	w/Fence	w/Fence	N	P
Cattle (40)	2,058	335	1,234	201	824	134
Buffalo (50)	2,573	419	1,543	251	1,030	168
Total	**4,631**	**754**	**2,777**	**452**	**1,854**	**302**

Fencing off the waterways on the two parcels is estimated to reduce existing totals of nitrogen (4,631 kg/yr) and phosphorus (754 kg/yr). When compared to the TMDL total reduction (existing annual load minus TMDL/yr) for the all river and estuaries, the load reduction estimates are N (3%) and P (1.5%). When compared to the TMDL total reduction (existing load minus TMDL/yr) for the Hanalei River and Estuary (both properties drain into the Hanalei River), the load reduction estimates are N (12%) and P (5%). Fencing off waterways will also reduce sediment and bacterial inputs generated by the buffalo and cattle, though it was not possible to derive numeric estimates for these pollutants.

3.4.4 Implementing Management Practice Treatment Chains

Critical to the success of alleviating the heavy pollutant loads is the use of treatment chains, or a sequence of various management practices within a given pollutant stream. These practices integrate the prevention, capture, and filtering of runoff as it makes its way downslope through the watersheds.

Treatment chains allow several management practices to function as a collective whole, utilizing the positive aspects that each provides to benefit watershed health. This eases the burden of relying on one specific management practice to function optimally under all storm event and pollutant loading

[56] The number of animals on each property are estimates based on the best available information.

conditions. If one of the treatment practices within the treatment chain fails, it may impact the other management practices, but they will most likely continue to function to some degree of efficiency. In contrast, malfunction of a single management practice may result in failure of the system to be treated at all. For example, the high sediment loadings from the taro *lo'i* within the Taro *Lo'i* Unit would be greatly reduced by incorporating a treatment chain including both preventive (e.g. dry tilling) and treatment (e.g. '*auwai* outlet gate closure) controls. Treatment chain complexity varies with factors such as varying topography, intensity of land use, proximity to existing natural and manmade drainage channels, and other site specific factors. Treatment chains provide redundancy and a safeguard in the event one practice fails.

4. Evaluation and Monitoring

The *Evaluation and Monitoring* section provides guidance for monitoring and evaluating the effectiveness of the recommended management practices in reducing NPS pollutants. Methodologies for qualitative and quantitative assessments are presented (Table D.1). General guidance on water monitoring to be conducted by volunteers is available in a publication entitled *Taking Care of Hawaiʻi's Waters: A Guidebook for Getting Started in Volunteer Water Quality Monitoring*.[57]

4.1 Measuring Effectiveness of Watershed Management Planning

Evaluating the success of watershed management planning efforts is important. Successful program implementation is demonstrated when management practices are being implemented in areas identified, in a timely fashion, cost-effectively, etc. The effectiveness of management practices is measured by achieving reductions in pollutant loads into the waterways and related improvements to the health of the coral reef environment.

4.1.1 Program Implementation

Development of an implementation strategy requires selecting practices, securing funds, establishing timescales, and planning tasks. EPA suggests outlining tasks and the level of effort for each to establish a baseline for time estimates. It is also necessary to collectively discuss tasks and identify those that are feasible and identify the responsible parties (EPA 2008b). Factors such as funding availability, participation of managing and regulatory entities, and effectiveness of pollutant load reduction will influence feasibility of management practice implementation and the implementation timeline. As the implementation process moves forward, additional work will be needed to fund the efforts and distribute work requirements. An implementation strategy for education and outreach activities is presented in Section 5.

The principles of adaptive management require regular review of the program and revision of management goals, objectives, actions, and techniques, to improve the performance of the program. The HBWMP is a living document that will benefit from regular review and updating, to remain current and to support effective management. The HBWMP should be reviewed (yearly) and updated as needed. Future reporting and results of monitoring activities will be essential to providing information on the pollutant loads in the watershed and the effectiveness of management practices.

4.1.2 Management Practice Performance

To ensure the most effective pollution control strategies for the Hanalei Bay Watershed, the success of management practices to limit generation and transmission of pollutants in the watersheds must be regularly evaluated. Regular monitoring must occur in order to determine if progress is being made towards meeting stated goals. A status report should be developed every year to document progress, challenges, and next steps. Next steps will consist of a list of management practices to occur the next year, along with a realistic schedule that reflects available funding, equipment purchases, and personnel time. Comparison of the projected schedule with the actual schedule will enable better timeline estimates for future projects and will help determine if the scale and scope of the management practices slated for the following year(s) are appropriate.

[57] http://monitoring.coral.org/sites/default/files/documents/Water%20Quality%20Manual_Final_10_2.pdf

Information in the GIS and associated databases will be essential for developing this report so data can be objectively analyzed and compared between years. Notes on problems encountered with management practices, interesting outcomes, successes, and ideas for improving management practices in the future should be kept on a linked document, to allow for easy cross-reference.

4.1.3 Pollution Reduction Targets

Ideally, a WMP should identify specific targets for load reductions of identified pollutants (i.e. TSS). Both the 2008 Phase 1 and 2011 Phase 2 TMDL reports identified target load reductions for the impairing pollutants: TSS, nutrients, and bacteria (Section 1.3). The practical reality is that quantifying exactly how much pollutant loads are reduced after implementing practices is difficult and potentially costly. With this said, DOH and EPA expect that watershed users will each do their parts to reduce generation and transport of pollutants so that loads into the streams, estuaries and Hanalei Bay decrease.

Existing water quality sampling stations distributed across the Hanalei Bay Watershed can be used to evaluate changes of concentrations of impairing pollutants over time. Prior to installation of practices, data from sampling stations located in receiving waters downstream of the installation can be pulled from the appropriate TMDL report or other data source. Samples can then be collected after installation and compared to determine if changes are occurring and to quantify the changes. Pollutant load reduction can also be expressed qualitatively when numerical data is not attainable for existing conditions or sampling is not possible (e.g. documenting improvement in ground cover on a treated erosion site using photographic monitoring over time). It is very important to document efforts taken to reduce pollutants loads so that regulatory agencies recognize actions are being taken to improve water quality.

4.1.4 Performance Metrics

Performance metrics can be used to evaluate progress towards implementation of the HBWMP and meeting the water quality goals (i.e. achievement of the TMDLs for TSS, bacteria, and nutrients) (Table 25). These example metrics can be refined over time.

Table 25. Example Metrics for Evaluating Progress of Implementation of HBWMP

Target	Metric
Achieve water quality goals (meet TMDLs) for various water bodies in the Hanalei Bay Watershed.	- Measured improvements in water quality - Load reductions achieved for TSS, bacteria, nutrients - Number of management practices installed
Provide effective guidance to ensure implementation and long-term success of watershed management efforts in Hanalei Bay Watershed.	- Regular review and update of HBWMP - Use of HBWMP as a model for other WMPs - Establishment and implementation of a monitoring program
Increase education, understanding, and participation by both residents and visitors regarding watersheds, NPS pollution, and coral reef health in Hanalei Bay Watershed.	- Dollars spent on education and outreach - Number of volunteers participating in outreach activities - Number of attendees participating in site visits/workshops to discuss retrofit and other restoration projects - Number of public and private landowners participating in HBWMP efforts

4.2 Monitoring Logistics

4.2.1 Drivers for Monitoring

Monitoring is conducted for both regulatory and non-regulatory purposes, although in many cases it is driven by regulations even if the regulation itself does not "require" monitoring.

4.2.1.1 Water Quality

Section 208 of the 1972 CWA requires every state to establish effective practices to control NPS pollution. Also, under CWA §303(d), the EPA requires that each state develop a list of waters that fail to meet established water quality standards. Waters on the §303(d) list of impaired water bodies are defined as water bodies having beneficial uses but that are impaired by one or more pollutants. The law requires that states establish priority rankings for waters on the list and develop TMDLs for these waters.[58] In many cases, the recognition of CWA §303(d) listing and the subsequent development of TMDLs for that water body triggers a water quality monitoring program.

Water bodies in the Hanalei Watershed have been included on the State's §303(d) list of impaired waters due to continuous exceedance of State water quality standards and impairment to their beneficial uses (*Volume 1: Watershed Characterization*, Section 2.4.1). DOH proposed establishing eight TMDLs for streams and estuaries in the Hanalei Bay Watershed. Phase 1 TMDLs (streams and estuaries) were established for TSS as a surrogate for turbidity and *Enterococcus* for water bodies in the Hanalei Bay Watershed. Phase 2 TMDLs for the Hanalei embayment (marine waters) for the same parameters were approved by EPA in the spring of 2012 (Tetra Tech and DOH 2008, 2011; *Volume 1: Watershed Characterization*, Section 2.4.2).[59]

4.2.1.2 Coral Reef Health

Watershed management efforts in the Hanalei Bay Region are targeted at improving the overall health of coral reefs, nearshore waters, and watersheds. This area is a beneficiary of work conducted as part of the Hawai'i Coral Reef Strategy, particularly the Land Based Sources of Pollution (LBSP) Local Action Strategy. As a key partner in this effort, the National Oceanic and Atmospheric Administration (NOAA) Coral Program uses a set of performance measures to track progress toward reaching on-the-ground outcomes in addressing threats from LBSP (Box 4) (NOAA Coral Reef Conservation Program 2012). Monitoring efforts conducted as part of and in relation to the HBWMP will assist NOAA in gathering the information needed to demonstrate progress. Although the HBWMP does not include monitoring of coral reefs, there are related efforts to assess coral reef health over time (Appendix D.2.1).

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[58] A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive, also known as the loading capacity, so that the water body will meet water quality standards. The TMDL allocates that load to point and non-point sources, which includes both anthropogenic and natural background sources of pollutants. If the TMDL identifies NPS pollutants as a major cause of impairment, states can apply for EPA funded grants, called Section 319 grants. These grants can be used to fund state programs for NPS assessment and control as well as individual projects.

[59] Although Hanalei Bay, streams, and estuaries are not listed on the §303(d) list for nutrients, numerous samples collected from these water bodies show that there have been consistent exceedances of water quality standards over the years. Standards for Ammonia, Nitrite plus Nitrate, and Total Phosphorous are consistently exceeded in all five estuaries and in the streams. In part, nutrients are not listed because samples were collected without an approved quality assurance quality control plan, and because there were not sufficient number of samples in some of the water bodies. Because of these exceedances, unofficial "informative TMDLs" were also calculated for nutrients.

Box 4. NOAA Coral Program's LBSP Performance Measures

1. Number of watersheds with completed and approved integrated WMPs.
2. Number of projects completed from approved WMPs to reduce LBSP in priority coral reef areas.
3. Stable or decreasing total suspended solids (metric tons/year) measured in target watersheds.
4. Stable or improving coral demographics (recruitment, size frequency, mortality) in priority coral reef areas.
5. Number of in-water restoration projects implemented in degraded coral reef ecosystems to reduce accumulated sediments, nutrients, and algae.
6. Number of active partnerships established with local, state/territory, federal and/or non-governmental organizations with a common goal to reduce LBSP impacts in priority coral reefs areas.

4.2.2 Monitoring and Data Collection Responsibility

Water bodies in the Hanalei Bay Watershed have undergone water quality sampling for about two decades by a range of public and private entities including University of Hawaiʻi researchers, State and Federal agencies and non-governmental organizations (*Volume 1: Watershed Characterization*, Section 5.3). Each of these efforts contributes valuable information to support monitoring efforts. Studies that do not have a monitoring component can provide essential baseline information about watershed condition. Past monitoring efforts provide data for comparison and determination of effectiveness.

The HBWMP characterizes the watershed conditions and makes recommendations on how to reduce NPS pollutants generated from the watershed and discharged into the ocean. This is an essential first step towards improving the health of the watershed and its receiving waters. The monitoring program needs to assemble data to evaluate the expected changes of water quality following implementation of some or all of the recommended management practices.

DOH is the primary entity responsible for collecting and storing water quality data. Although DOH does not collect all the water quality data, they have and continue to contract for water quality sampling collection (e.g. Hanalei Watershed Hui, Kauaʻi Chapter of the Surfrider Foundation). Most water quality data collected using funds from EPA or DOH is stored at DOH, and they are responsible for enforcement of water quality standards in the State of Hawaiʻi. Water quality data and information pertaining to watershed processes has also been collected by researchers affiliated with government agencies and universities. In most cases these data are not under the repository of DOH, however much of the data has been reported on in peer reviewed reports. The Hanalei Watershed Hui does outreach to the community to present water quality data so that people are made aware of the status of waters they use for recreation and subsistence. A geo-database would be the most desirable platform for storage of the data collected in the Hanalei Bay Watershed (Appendix D.1.3).

4.2.3 Data Collection, Storage, and Reporting

Identifying specific approaches for accurate collection and analysis of data is essential for determining the effectiveness of implemented management practices. General guidance on water monitoring to be conducted by volunteers is available in *Taking Care of Hawaiʻi's Waters: A Guidebook for Getting Started in Volunteer Water Quality Monitoring*.[60] Monitoring stormwater management practices tends to generate a considerable amount of data and information. A well designed and

[60] http://monitoring.coral.org/sites/default/files/documents/Water%20Quality%20Manual_Final_10_2.pdf

implemented data management program is valuable for the development of comprehensive and ongoing monitoring of management practices (Appendix D.1).

In order to maximize the effectiveness of data and information collected, and to increase its exposure and usefulness to larger stakeholder groups, a central repository should be developed to house the data collected by the various parties. A geo-database for the Hanalei Bay Watershed should be developed and maintained. Collaboration with past efforts and building onto existing databases would be an efficient means for utilizing GIS in monitoring efforts.

4.3 Monitoring in Hanalei Bay Watershed

Monitoring is a process that provides feedback to managers and stakeholders to verify if pollution control strategies are being installed and working as designed, and if water quality is improving. Some level of monitoring is necessary to verify and justify the installation of practices and provide support for future installation of management practices. Of the seven types of monitoring used in watershed management, this plan focuses on four: implementation, baseline, trend, and effectiveness (EPA 1997) (Table 26; Appendix D.2). These four types best address the intent of the *Evaluation and Monitoring* requirements and will provide the necessary information to determine if NPS pollutant reduction is occurring in the Hanalei Bay Watershed. Monitoring also helps to refine future selection of practices for other watersheds.

Table 26. General Characteristics of Monitoring Types

(EPA 1996)

Type of Monitoring	Location of Monitoring	Frequency of Measurements	Duration of Monitoring	Intensity of Data Analysis
Trend	Reference Site	Low	Long	Low to moderate
Baseline	Installation & Reference Site	Low	Short to medium	Low to moderate
Implementation	Installation site	Variable	Duration of project	Low
Effectiveness	Installation & Reference Site	Medium to high	Usually short to medium	Medium
Project	Variable	Medium to high	Greater than project duration	Medium
Validation	Installation & Reference Site	High	Usually medium to long	High
Compliance	Installation Site	Variable	Dependent on project	Moderate to high

The HBWMP is a sequential step in the overall CWA §319 Nonpoint Source Management Program process, and follows the establishment of TMDLs (Section 1.3). The primary goal of the TMDL is to stimulate action through the WMP to control sources of excessive nutrients, sediment and pathogens, and to improve water quality. To achieve this, the TMDLs for the nine water bodies placed daily load limits for the three pollutant types. DOH computed the percent reduction of the existing daily loads necessary in order to meet TMDLs. Monitoring for the pollutants is required to determine if the TMDLs are being met. At the most basic level, monitoring is necessary to verify compliance under the CWA. This monitoring requires dedicated resources over time to conduct the monitoring, compute loads, and compare loads to targets set in the TMDL.

In addition to monitoring for compliance, the HBWMP recommends monitoring implementation of management practices. This will assist in correlating changes in water quality to reductions in land-based sources of pollutants. The HBWMP also recommends repeating, in the future after management practices are installed, the work done by researchers from Stanford University and others using isotope tests and genetic markers to refine source assessments of nutrients and bacteria. This will provide information on whether the signatures have changed and if the management practices are effective in reducing or changing the main pollutant sources.

Other monitoring or studies to help further refine sources, relative contributions, and flow paths of pollutants include groundwater modeling of the Hanalei Bay Watershed. At present it is commonly accepted by scientists that most fresh water inputs to Hanalei Bay are from the surface waters draining the watersheds, and are dominated by the Hanalei River. What is not understood is how much of the various pollutants are carried into the Hanalei Bay in groundwater. Groundwater discharged into the bay occurs as submarine groundwater directly into the bay, or into the fresh water and estuaries that drain to the bay.

4.3.1 Implementation Monitoring

For each management practice installed in the Hanalei Bay Watershed, the following information should be collected and maintained in a GIS database and/or relational database (Appendix D.1.3). Information on implementation should be conveyed to County of Kauai, DOH, Department of Transportation, NOAA, USACE, U.S. Geological Service, Hanalei Watershed Hui, and other entities to be determined.

- Details on specific type of management practice
- Management unit
- Location installed
- Construction start date
- Construction completion date
- Entities involved
- Purpose and targeted pollutants
- Expected performance (if applicable)
- Issues and delays before implementation (if applicable)

4.3.2 Monitoring of Environmental Conditions

In general, there is not sufficient data for the Hanalei Bay Watershed to develop comprehensive numerical estimates on the concentration of pollutants in runoff water across the watershed. Management units were delineated in order to focus on NPS pollutant types and control methods for the predominant pollution-generating land uses. Monitoring methods to collect information that addresses the identified priority NPS pollution parameters in the management units are identified in Table 27. Baseline data is not necessary to evaluate the effectiveness of the management practices that are recommended in the HBWMP, however they can be used as guidance when quantifying a practice's effectiveness. When possible, the use of existing sampling stations will provide data and information that can be used for effectiveness and trend monitoring. Trend monitoring can supplement effectiveness monitoring and can be used to correlate the management practice installation and trends in water quality and watershed conditions.

Table 27. Monitoring Parameters by Management Unit

Monitoring Location	Monitoring Objective	Method
Built Environment Unit		
Storm sewer outfalls along Kuhio Highway	Determine water quality of stormwater runoff by sampling at outfall locations. Results can be used for long term trend analysis and identifying pollutant hotspots to remediate.	Collect grab samples during runoff events and analyze at lab.
Commercial WWTPs	Determine water quality by sampling effluent of WWTP. Results can be used for long term trend analysis.	Continue data collection per permit requirements. As upgrades are made, data can be used to quantify associated pollutant reductions.
Forested Upland Unit		
Exposed surface soils	Document installation of management practices. Quantify effectiveness of management practices when possible (e.g. determine percent ground cover, estimate exposed field surface area, and potential sediment loss).	Establish photo points, establish erosion pins.
Grazing Unit		
Field ditch outlets into rivers	Document installation of management practices. Quantify reductions of pollutants exported from grazing parcels.	Continue or reoccupy stations at outlets of pastures along Hanalei River and collect water quality samples.
Stream Unit		
Eroding streambanks	Document installation of management practices. Measure channel geometry over time and responses to stream channel alterations.	Establish photo points, establish erosion pins, establish cross sections, and measure channel geometry.
Taro *Lo‘i* Unit		
Taro *lo‘i*	Document installation of management practices. Quantify reductions of pollutants exported from *lo‘i.*	Collect water quality samples at outlets and from existing stations. Document changes to amounts of fertilizer and pesticides used.
USFWS Wetland Unit		
Waterbird Wetlands	Document installation of management practices. Quantify reductions of pollutants exported from wetlands.	Collect water quality samples at outlets and from existing stations.

The overall goals of implementing stormwater management practices pertain to preventing pollution at the source, improving stormwater outfall discharge quality, reducing pollutants loads to receiving waters, restoring ecosystem functions for beneficial uses and erosion protection, and complying with water quality standards. The priority parameters for monitoring in the Hanalei Bay Watershed are 1) fine terrigenous sediments (TSS), 2) bacteria, and 3) nutrients. Continuing data acquisition from existing water quality sampling stations and establishing new stations when necessary is expected to provide data that can be used to quantify pollutant load reductions and help refine areas within the watersheds that are generating pollutants.

4.3.3 Effectiveness Monitoring of Management Practices

Once management practices are installed, effectiveness monitoring should be conducted. Information on effectiveness monitoring for each management practice, including the objective(s) of monitoring efforts, basic monitoring protocols, and recommended monitoring frequency, is included in Appendix D.3. Results of effectiveness monitoring should be maintained in a GIS database and/or relational database (Appendix D.1.3).

Although a monitoring frequency of a set interval (for example, every six months or annually) is advantageous with respect to planning and resource efforts, some of the most beneficial data is usually obtained in inclement weather, typically during or after a rainfall event of significant intensity that tests the management practice under conditions for which it was designed. Incorporating a monitoring plan that is flexible with respect to weather patterns is a recommendation to gain insight into which practices require maintenance or replacement with a more suitable management practice (Box 5).

Box 5. Stormwater Quality Monitoring Challenges

Stormwater quality at a given location varies greatly both among storms and during a single storm event. Significant temporal and spatial variability of stormwater flows and pollutant concentrations are challenging to effectively sample. For example, the intensity of Hawai‘i’s rainfall varies seasonally and is often irregular and dramatic. Variations in rainfall affect the rates of runoff, pollutant wash-off, in-channel flow, pollutant transport, sediment deposition and resuspension, channel erosion, and numerous other phenomena that collectively determine the pollutant concentrations, pollutant forms, and stormwater flow rate observed at a given monitoring location at any given moment. In addition, the transitory and unpredictable nature of many pollutant sources and release mechanisms (e.g. spills, leaks, dumping, construction activity, landscape irrigation runoff, vehicle washing runoff) contribute to inter-storm variability (GeoSyntec and ASCE 2002). In general, many measurements (i.e. many samples taken during a single storm event) are necessary to obtain enough data to be confident of actual management practice performance. Available resources, such as budget and staff, should be considered when determining the number of samples required to obtain a statistically valid assessment of water quality. A well-designed monitoring program will need to collect enough stormwater samples to result in a high level of statistical confidence when determining management practice effectiveness. A small number of samples are not likely to provide a reliable indication of stormwater quality at a given site or the effect of a given management practice.

4.4 Meeting Milestones

Milestones are useful for assessing whether management practices are being implemented, operating as intended, and reducing loads as expected. The assessment is both dynamic and circular, as additional management practices are implemented over time, thereby hopefully contributing to improved water quality. It is important to track the monitoring parameters to gather the information needed for determining whether or not milestones are achieved. If they are not, the adaptive nature of watershed management planning calls for changes (e.g. implement more or different management practices; reassess where pollutant loads are coming from).

Milestone: Implement management practices in Built Environment Management Unit (high priority)

Target:

By 2017, Close all 45 cesspools on TVR properties and upgrade
By 2019, upgrade 50% of the remaining cesspools
By 2019, complete installation of commercial WWTP upgrades
By 2024, upgrade 100% of the remaining cesspools and septic tanks

Milestone: Implement management practices in Taro Lo‘i Management Unit (high priority)

Target:

By 2016, ensure 50% of the priority constructed wetlands are built and 50% of the taro farmers are employing recommended management practices
By 2017, ensure 100% of the priority constructed wetlands are built and 100% of the taro farmers are employing recommended management practices

Milestone: Implement management practices in Grazing Management Unit (high priority)

Target:

By 2016, install fences on Mowry property and Princeville Ranch pastures
By 2016, ensure Princeville Ranch is employing 50% of the recommended management practices
By 2019, remove buffalo from Mowry property
By 2019, ensure Princeville Ranch is employing 100% of the recommended management practices

Milestone: Implement management practices in Built Environment Management Unit

Target:

By 2016, complete installation of 25% of the recommended practices
By 2019, complete installation of 75% of the recommended practices

Milestone: Implement management practices in Forested Upland Management Unit

Target:

By 2016, inventory and assess Conservation Lands to identify sites eroding at accelerated rates and prepare erosion control practices to remediate (DLNR).
By 2019, complete erosion control, revegetation, and fencing at 25% of identified sites
By 2024, complete erosion control, revegetation, and fencing at 100% of identified sites

Milestone: Implement management practices in Stream Management Unit

Target:

By 2015, complete inventory and assessment of stream channels to identify sites for *hau* bush removal and restoration (DLNR, USFWS)
By 2019, complete removal and restoration of 25% of identified sites
By 2024, complete removal and restoration of 100% of identified sites

Milestone: Implement management practices in USFWS Wetland Management Unit

Target:

By 2015, require taro *lo‘i* farmers to employ recommended management practices
By 2015, conduct erosion control and revegetation on affected sections of the China Ditch
By 2015, implement wetland pollution reduction practices

Milestone: Achieve pollutant load reductions as outlined in the TMDL

As implementations are undertaken and completed, water quality data should continue to be collected, evaluated and compared to the TMDL to determine if the implementations are achieving the desired results (Section 1.3).

Target:

By 2019, reduce pollutant loads across the watersheds to meet 30% of the TMDL targets
By 2024, reduce pollutant loads across the watersheds to meet 30% of the TMDL targets
By 2029, reduce pollutant loads across the watersheds to meet 80% of the TMDL targets
By 2034, reduce pollutant loads across the watersheds to meet 100% of the TMDL targets

5. Education and Outreach

Lack of education or awareness of water quality impacts is a root cause of many NPS pollution issues. The *Education and Outreach* section describes strategies to educate and engage people in reducing LBSP in Hanalei Bay Watershed including: building public awareness and support, supporting implementation, engaging the community, and changing policy. In addition, this section includes an explanation of the organizational structure in place to assist in finding, funding, and synergizing on education and outreach initiatives. On-going efforts of the Hanalei Watershed Hui have additional direction from the HBWMP on specific implementation projects, which will benefit from associated education and outreach.

Successful implementation of the HBWMP, including the recommended management practices, is dependent on stakeholder awareness and involvement. Some landowners exposed to information and education campaigns will change their practices based on a greater awareness of water quality issues. This can be expected to improve and/or maintain water quality and coral reef health. Education and outreach programs should:

- Increase stakeholder awareness about the link between land-based NPS pollutants and coral reef ecosystem health.
- Increase stakeholders' level of knowledge about nutrient and sediment loading and the health of the off-shore waters.
- Educate land use decision makers.
- Increase agency support for, and participation in, actions to reduce NPS pollution.
- Engage the community in installation, monitoring, and maintenance of projects.
- Convey information about monitoring activities and results.
- Involve partnering with other local groups to develop and implement a comprehensive education and outreach program addressing water quality and watershed management issues.
- Develop targeted outreach activities and materials.
- Affect policy change.

5.1 Public Awareness and Support

An education and outreach strategy needs to build community support for a holistic approach to planning for the Hanalei Bay Region. This includes developing general public awareness about polluted runoff, including its negative effects on coastal and marine environments including coral reefs. Educational outreach on pollution prevention should be conducted to inform stakeholders how they can reduce generation of NPS pollutants and discharges to the receiving ocean waters. Efforts also need to target implementation of structural and nonstructural management practices identified in the HBWMP. Watershed awareness and active stewardship among residents, community associations, businesses, and visitors can be promoted through education programs, recreational opportunities, and participatory watershed activities (Section 5.3).

5.2 Organizational Support for Implementation and Outreach

As a result of on-going efforts in the region, there is a broad base of support for the HBWMP. These components are described in more detail below, and among other functions, provide the structure to support educational and outreach activities.

5.2.1 Hanalei Watershed Hui

The Hanalei Watershed Hui's on-going efforts support implementation of the HBWMP. The Hui works toward comprehensive planning for the Hanalei Bay Region with a focus on building community networks and educating stakeholders. The Hui plays a key role in gathering public input and communicating the findings of the HBWMP. The Hui facilitates this process by providing technical assistance in developing partnerships and projects that align with needs identified in the HBWMP. The Hui is engaging with groups and individuals throughout the plan development and implementation process. This may take the form of one-on-one consultations, or attending meetings, functions, trainings or events involving interested/relevant stakeholders.

5.2.2 Agency Support

Agency support for, and participation in, actions to reduce NPS pollution in the Hanalei Bay Watershed is essential. This includes cooperative agency partnerships to address regional and watershed management needs and expand community and government interest in improving watershed health in the Hanalei Bay Region. The HBWMP provides technical guidance and a set of priority implementable actions that can be taken to reduce NPS pollution inputs in the offshore waters. Since these actions do not fall within the responsibility of any single agency, implementation will require collaborative efforts among multiple entities. The community can act as intermediary to build essential networks and partnerships among NOAA, USACE, EPA, DOH, DLNR, County of Kauai, and others, and facilitate integration of improved water quality management practices into existing agency management plans and practices. Key to these efforts will be the ability to raise funds for implementing management solutions. Funding partners are needed to address long-range funding needs for land-based pollution reduction across the region (Section 2.2).

5.2.3 Partnering

Other entities (e.g. Waipā Foundation, Hanalei to Haʻena Community Association, NOAA National Marine Sanctuaries, and other local organizations) conduct activities related to this watershed-based management planning effort in the Hanalei Bay Region. Education and outreach efforts may be specific to the HBWMP or may address a broader effort. Where possible, efforts should be coordinated to develop and implement a comprehensive education and outreach program addressing water quality and watershed management issues.

The Hui anticipates a full partnership with the Hawaiian Islands Humpback Whale National Marine Sanctuary, which may support water quality monitoring. The Hui has initiated planning with the Pacific Islands Ocean Observing System for water quality and other monitoring support for the Hanalei Bay and environs.[61] The Hui will continue its focus on the fishery and reef health of Hanalei Bay, thus encouraging fisherfolk and recreational users of the Bay to engage in learning about potential sources of water pollution and implementing management practices. The Hui anticipates the continuation of a positive partnership with USFWS that has supported the installation of management practices and upgraded IWS in recent years. The Hui will actively encourage inclusion of WMP recommendations in the forthcoming USFWS Comprehensive Conservation Plan, which will serve as an example to other farmers in the area.

[61] Based at the University of Hawaii: http://oos.soest.hawaii.edu/pacioos/

5.3 Community Engagement

Community engagement focuses education, enforcement, and technical resources on changing behaviors that cause pollution. Specific resources applied to different target audiences are selected based on major pollutant source areas identified in a watershed. Pollution prevention and source control education is a broad restoration practice that seeks to prevent pollution by targeting stakeholders. Public engagement is key to success as implementation of recommendations will, in part, be accomplished through community projects.

5.3.1 Planning Process

Input during the HBWMP process was considered essential to obtaining stakeholder support. The Hanalei Watershed Hui and SRGII worked together to identify key stakeholders in the Hanalei Region representing government policy makers, major land owners, managers of the two shopping centers, farmers, ranchers, the Hanalei to Ha‘ena Community Association, the USFWS Hanalei Refuge leadership, and residents with specific experience or expertise and resources.

Individual conversations with stakeholders were initiated in June 2011. Individuals were contacted and the WMP process was described. Information, questions and concerns were elicited. Focused discussions with these stakeholders consisted of anticipated HBWMP content areas, visual maps and data of the area, specific issues related to individual concerns, and expected timelines. The Hui and SRGII maintained contact (e.g. personal correspondence or conversation) with those who expressed interest. Throughout the WMP process, stakeholders were encouraged to describe their particular issues and concerns, some were invited to correspond privately on sensitive issues and all were asked to suggest solutions.

5.3.2 Outreach Tools

A range of stakeholder interaction methods and tools are typically needed to reach and engage the full range of stakeholders as effectively as possible. Recognizing that the values and interests of project stakeholders may vary, different methods are needed to meet the needs of the stakeholders, as well as to facilitate the flow of information back and forth between the stakeholders and the project team. The range of methods that will be utilized in the Hanalei Bay Region is outlined in Box 6, including those already being used by the Hui. In addition, EPA has developed a *NPS Outreach Toolbox*, which contains a variety of resources to help develop an effective and targeted outreach campaign to educate the public on NPS pollution or stormwater runoff.[62] Examples from Hawai‘i and the mainland can be adapted for use in the Hanalei Bay Region.

Box 6. Watershed Management Outreach Tools

Website. The Hanalei Watershed Hui website is an existing outlet for community outreach and education. It can be used to inform stakeholders about the HBWMP and key findings, and provide a mechanism for receiving input on watershed planning efforts (http://www.hanaleiwatershedhui.org/). This website could also support implementation efforts (e.g. list of resources, volunteer opportunities, monitoring information).

Social Media. A social media presence (i.e. Facebook, Twitter) can help engage a cross-section of the population by providing regular updates, information, and opportunities. The Hui’s existing social media outlets can be used to support implementation efforts.

[62] http://cfpub.epa.gov/npstbx/index.html

Public Access Television. Hoʻike Public Access television can be used to broadcast educational programming and public presentations. The Hui will facilitate broadcasts describing various management practices and potential opportunities for citizen involvement.

Photographs. Pictures are a powerful way of sharing information about problems and solutions. Stakeholders can be asked to share images that can then be posted publically.

Geospatial Information. Maps are essential for watershed management planning. They can be used to convey information to stakeholders at a regional or site-specific level.

Signage. On-site interpretive signage in high visibility locations can include information on how the management practice works and describe the project's environmental benefits.

Workshops. Landowners who attend targeted workshops (e.g. pollution control strategies) can be expected to come away with increased awareness of how their land management decisions impact water quality and many will change their current practices.

Speakers. Guest speakers who have been successful with watershed restoration efforts in other areas can be invited to speak, sharing their stories and lessons learned (e.g. Michael Cummings, a student at the University of Hawaiʻi, who completed an assessment of existing commercial and residential septic system conditions within the Hanalei region as part of his coursework in 2012).

Community Events. The Hui will continue engaging in public presentations and participating in community events to share information about management practices and opportunities for projects to reduce the pollutants entering Hanalei storm drains, rivers and Bay. A bulletin board is also used for community outreach and education.

Education. The Hui will continue its work with the public and private education sector to teach watershed science and encourage individual use of management practices.

Talk Story. Hawaiian practitioners can teach traditional management techniques based on an *ahupuaʻa* system.

5.3.3 Suggested Educational Topics for Increasing Community Watershed Stewardship

Pollution prevention and source control education is about more than just raising awareness, although this is an important component. In the Hanalei Bay Region, opportunities exist to help stakeholders practice better stewardship. Much of the region is privately owned and effective private stewardship of those watershed areas is an integral part of watershed protection. Efforts should focus on discouraging pollution-producing behaviors and implementing practices or programs that will help to reduce pollution. Specific behaviors and activities that can be targeted across the watershed include:

- Reporting water quality sampling and analysis results to the community.
- Understanding the links between reef and fishery health and water quality, with specific emphasis on nutrient pollution and new emerging information.
- Updating IWS (to include assisting with funding support)
  - Replace outdated cesspools with ATU-type septic systems to improve waste water treatment.
- Improving control of erosion
- Provide better guidance and enforcement of on-site erosion and illicit grading and grubbing.
- Improving taro cultivation methods
  - Educate and incentivize Hanalei taro farmers to optimize fertilizer use and employ management practices related to the preparation, maintenance, and harvest of taro.
- Improving lawn care and landscaping practices
  - Educate land owners on practices to reduce fertilizer and pesticide use on their lawns.
  - Encourage an increase in native plant landscaping and edible organic gardening
- Disconnecting rooftops

    - Install rain barrels, rain gardens, and naturally vegetated depression areas that accept rooftop drainage.
    - Encourage smaller lawn area, rain gardens, and catchment barrels.
- Increasing watershed awareness
    - Continue with the storm drain stenciling throughout the Urban District, so the public understands "All drains lead to the ocean". Stenciling the drains can be expected to result in increased awareness of landowner impacts to surface water. This should result in a change in practices that will improve and maintain water quality.
- Managing recreational activities
    - Educate visitors about potential for damaging coral reefs (i.e. humans can easily damage delicate corals by standing on, kicking, or coming in contact with them).
- Improving municipal responsibility
    - Local governments maintain much of the physical infrastructure in the watersheds, including roads, sewers, and storm drain systems. In many cases, communities can reduce or prevent pollutants from entering the watershed by changing their infrastructure maintenance policies.

5.3.4 Continued Engagement

The HBWMP provides guidance for implementing a set of management practices targeted at improving the water quality of the Hanalei Bay Watershed. The implementation will need to result from the combined efforts of multiple stakeholders. The Hui will use the HBWMP, along with other data and information, to continue to educate stakeholders on both problems and potential solutions. Engagement during the planning process appears to have raised the commitment level of some stakeholders to implement recommended management practices. Securing funding for some of the more expensive projects will continue to be a challenge. The Hui will use implementation monitoring (Section 4.3.1) to monitor success over time.

5.4 Changes in Policy

Most, if not all, of the recommendations presented in the HBWMP will be implemented on a voluntary basis; they are not required by rules or regulations. Adoption of new policies at the County or State level provides developers and landowners with a standard set of guidelines designed to address limiting production of stormwater or treating NPS pollutants.

Incorporation of stormwater quality devices and LID technologies will promote reduction of land-based pollution generation and alteration of hydrology across the watersheds. The use of LID practices is recommended to address the management of stormwater quality and quantity within the County of Kauaʻi. An integral step toward widespread use of LID is the adoption of rules at the county level governing the management of stormwater for new and redeveloped lands that require use of LID practices. Several of the practices recommended in this HBWMP (e.g. bioretention cells, grass swales, permeable surfaces) are LID approaches toward stormwater management (quality and quantity). It is suggested that the County of Kauaʻi move toward a future where residential, commercial, and industrial developments of all sizes and scope utilize LID approaches.

Individual lot homeowners, regardless whether their property is included in a subdivision with a master drainage plan, should be encouraged to adopt LID practices on their parcels. The goal of this would be to reduce runoff generated on individual parcels, reduce use of potable water for irrigation of landscaped areas, and promote green practices throughout the County of Kauaʻi. Homeowners are also encouraged to adopt practices that reduce their use and disposal of potable water. Techniques to facilitate this include low flush toilets and reuse of grey water (sink and shower water) instead of disposal down standard plumbing drains and subsequent introduction into the subsurface environment through IWS.

In addition, the following development practices are recommended for incorporation at the County level:

- To the maximum extent possible, include native plants into the design of low impact development practices, and include as a requirement for obtaining a building permit within Kauaʻi County.
- Revise County of Kauaʻi building code to include section of green roof design.
- Provide incentives for incorporating green roof design into subdivisions.
- Encourage pervious surfaces for treatment and storage of stormwater runoff in lieu of paved roadways and standard detention ponds.
- Require new developments to evaluate and compare LID subdivision/commercial development vs. standard development layout: area of development impact, runoff quality at outlet point; area of impervious required.

Appendix A. Figures

1 

Figure 1.
Built Environment Management Unit:
Recommended Managment Practices - Wai'oli Watershed
Hanalei Bay Watershed Management Plan
April 2014

Figure 2.
Built Environment Management Unit:
Recommended Managment Practices - Hanalei Watershed

Hanalei Bay Watershed Management Plan
April 2014

Source: State of Hawaii Data Repository
Satellite image, 1.10.2010

N

0 0.0175 0.035 0.07 Miles

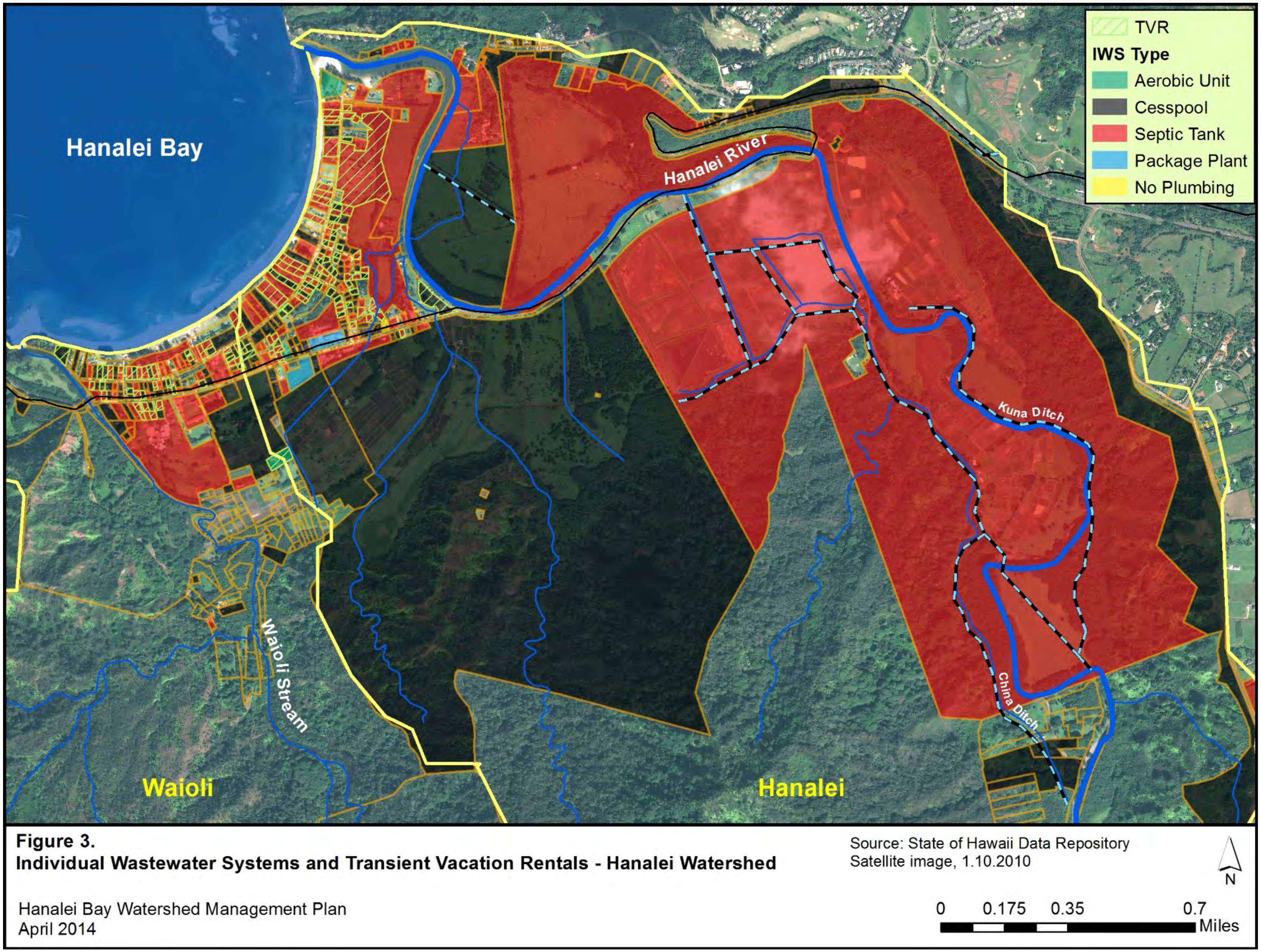


Figure 3.
Individual Wastewater Systems and Transient Vacation Rentals - Hanalei Watershed

Figure 4.
Individual Wastewater Systems and Transient Vacation Rentals - Hanalei Town

Source: State of Hawaii Data Repository
Satellite image, 1.10.2010

N

Hanalei Bay Watershed Management Plan
April 2014

0 0.05 0.1 0.2 Miles

Figure 5.
Taro Lo'i and Recommended Practices - Waikoko and Waipā Watersheds

Hanalei Bay Watershed Management Plan
April 2014

Source: State of Hawaii Data Repository
Satellite image, 1.10.2010

N

0 0.05 0.1 0.2 Miles

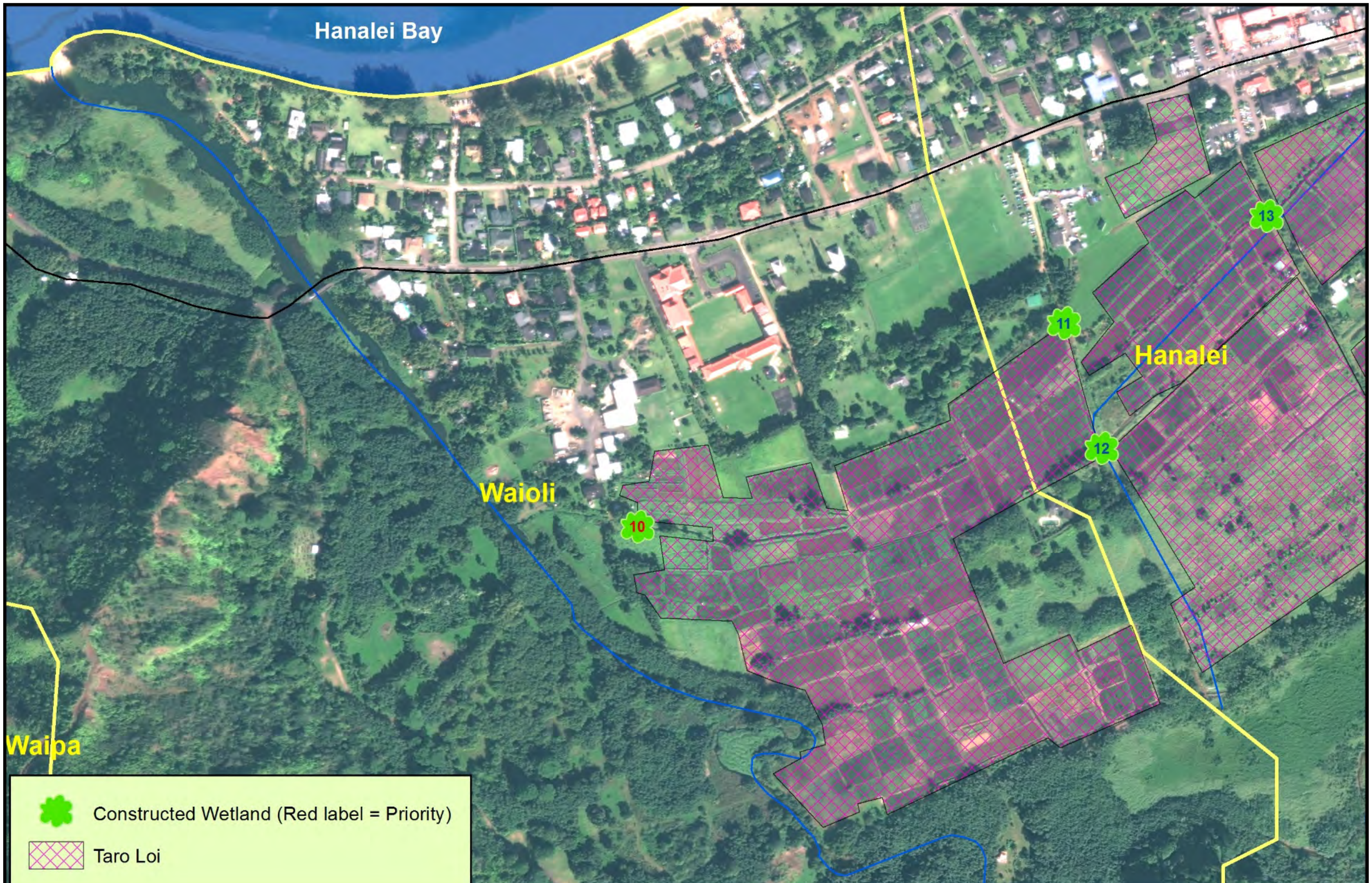


Figure 6.
Taro Lo'i and Recommended Practices - Wai'oli Watershed

Hanalei Bay Watershed Management Plan
April 2014

Source: State of Hawaii Data Repository
Satellite image, 1.10.2010

N

0 0.05 0.1 0.2 Miles

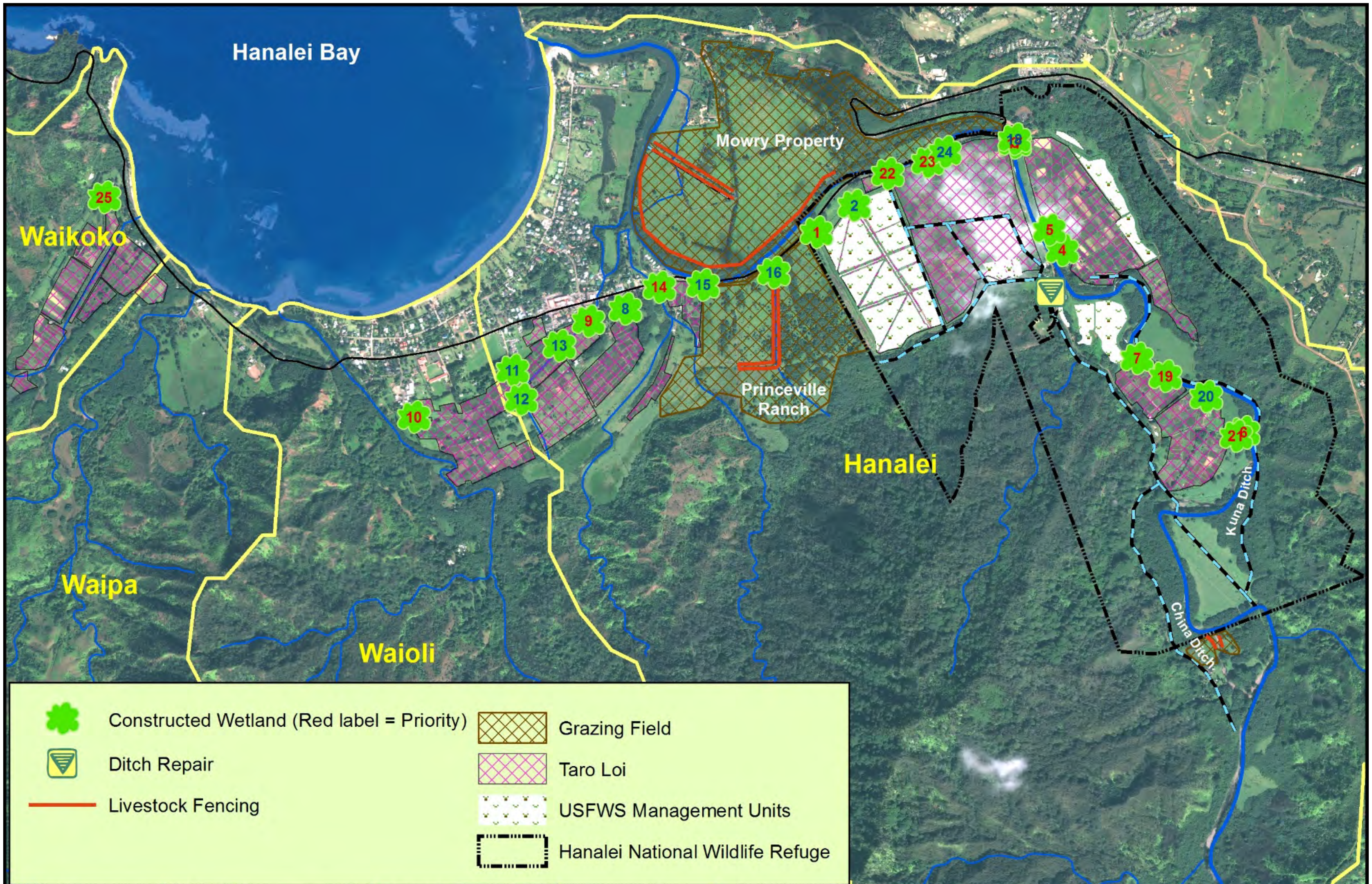


Figure 7.
Grazing, Taro Lo'i, USFWS Management Units and Recommended Practices - Hanalei Watershed

Hanalei Bay Watershed Management Plan
April 2014

Source: State of Hawaii Data Repository
Satellite image, 1.10.2010

0 0.25 0.5 1 Miles

N

Appendix B. NPS Pollution Management Hierarchy

Watershed management uses a hierarchy to address planning at different scales. By delineating management measures and practices within the context of management units, it is possible to focus pollution control activities on achieving specific goals.

B.1. What are Management Measures?

The Coastal Zone Management Act of 1972 created a program for U.S. states and territories to voluntarily develop programs to manage and protect coastal resources. Although the protection of water quality is a key component of these programs, it was not specifically cited in the original statute. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) specifically charged State coastal programs and State NPS programs with addressing NPS pollution that affects coastal water quality.

Management measures are defined in Section 6217 of CZARA as "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives."[63] In general, management measures are groups or categories of cost-effective management practices implemented to achieve a comprehensive goal, such as reducing NPS pollutant loads.[64]

Management measures can be used to guide the implementation of a comprehensive NPS pollutant and runoff management program. Some examples of HBWMP management measures that can help control the delivery of pollutant loads to receiving waters are: erosion and sediment control (e.g. reduce the load of sediment delivered to a water body) and fertilizer management (e.g. apply fertilizers based on specific plant needs in order to lessen excess nutrient inputs to surface and ground waters). Management measures and practices can be implemented for other related purposes, such as:

- Protecting water resources and downstream areas from increased land-based and subsurface pollutants, and protect these resources against flood risks.
- Conserving, protecting, and restoring stream habitat.
- Setting aside permanent riparian buffers for flow reduction and increased infiltration.

Management measures can be implemented using two different approaches. The most desirable approach is to implement practices that prevent NPS pollutant generation. Known as a *preventive* approach, this focuses on controlling or eliminating a specific pollutant at its source before it enters the ecosystem and causes harm. Conversely, a *treatment* approach is focused on treating a specific

[63] http://www.epa.gov/owow/NPS/MMGI/Chapter1/ch1-1.html#Act

[64] This report follows the lead of EPA and uses the term management practice instead of the more familiar term best management practice. The word "best" has been dropped for the purpose of this report, as it was in the *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (EPA 1993) and the *National Management Measures to Control Nonpoint Source Pollution from Hydromodification* (EPA 2007) because the adjective is too subjective. A "best" practice in one region or situation might be entirely inappropriate in another region or situation.

NPS pollutant along its entire pollution stream after it has entered the environment.[65] The two approaches can be implemented individually or combined. From a watershed science perspective, a preventive approach is usually the best way to address NPS pollutants, because it reduces the need for greater resources to manage pollutants once released into the environment. However, preventive measures are not always technically feasible, lack necessary resources, or are cost-prohibitive to implement, and it may take considerable time after they are installed for benefits to be realized.

B.2. What are Management Practices?

A management practice is a specific action that can be implemented to achieve a management measure. Practices include individual treatments, strategies, and plans to lessen generation and transport of NPS pollutants. Management measures are typically implemented by applying one or more management practices according to the source, location, and climate (EPA 1993).

Similar to management measures, management practices can be grouped according to preventive and treatment approaches and combined as necessary. Preventive management practices (preventive practices) focus on reducing or eliminating the generation of a pollutant at its source (e.g. limiting tilling of taro ponds to during dry periods only, in order to minimize sediment generation associated with wet tilling). Conversely, treatment management practices (treatment practices) involve treating or controlling a particular NPS pollutant once it has left its source and entered the environment. Treatment practices are typically engineered designs that function either independently, or within an integrated group of practices. An example of a treatment practice is a baffle box, which is a precast concrete box that utilizes baffles to settle out pollutants contained in stormwater flowing within a separate storm sewer system (S4). When combined with one or more other treatment practices (such as permeable parking lot/driveway surfaces that infiltrate and treat stormwater when it first enters the S4 pollution stream), a higher percentage of efficiency in pollutant removal can occur.

Treatment practices can be hard or soft: hard practices generally use structures made of concrete or synthetic materials (e.g. baffle box); while soft engineering practices are designed based on ecological practices, and use natural vegetation and materials. Some situations can call for both hard and soft engineering practices to maximize the best elements of each approach. For example, if a desired management measure is erosion and sediment control, then a grass swale (soft practice) could be constructed at the entrance to a baffle box (hard practice) upstream of the entrance to an S4 and both could help achieve the management measure prior to stormwater entering the S4.

B.3. Choosing Pollution Control Strategies

Pollution control strategies for the project area were selected based on established guidelines for the adoption of management measures and management practices. In addition, a large volume of research has been developed by researchers in the Hanalei Bay Region with respect to various pollutants generated, their sources, and the effects they have on the coastal environment.

[65] Pollution stream refers to the pathway a pollutant follows across a watershed from its source to its sink. Within the Hanalei Bay Watershed, this pathway is generally dictated by the course taken by rainfall-generated runoff, as the majority of NPS pollutants migrate downstream intermixed within runoff water.

Several published documents, other data sources, as well as common engineering practices used for pollution remediation, were consulted during the selection of management strategies:

- *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (EPA 1993)*;*
- *Hawai'i's Management Measures for the Coastal Nonpoint Pollution Control Program* (Stewart 2010a);
- *Responsible Agencies and Authorities - A Supplemental for Hawai'i Management Measures* (Stewart 2010b), a comprehensive document that covers the various agencies that can aid in the implementation of management measures within watersheds;
- NRCS Hawai'i Field Office Technical Guide[66] conservation practice standards for use in the Pacific Islands Area
- *National Management Measures to Control Nonpoint Source Pollution from Urban Areas* (EPA 2005)
- Historic sources of NPS pollution within the management units, obtained through interviews with stakeholders;
- Observations conducted infield in order to identify current NPS pollutant hotspots presenting a hazard to the health of the ecosystem;
- Analysis of high intensity aerial photography in order to identify NPS pollutant hotspots covering significant surface area within the watersheds.

B.4. Management Practices

A set of management practices have been identified for implementation in Hanalei Bay Watershed based on the targeted pollutants and hotspots. Management practices were chosen based on their expected performance to reduce sediment, nutrient, bacteria, and other types of NPS pollutants that currently impact water quality. Practices selected were based on those most appropriate and effective to address the NPS pollutant site, NPS pollutant type, and/or the land use and activity that generates the NPS pollutant. Using best professional judgment, management practices were also assessed and prioritized based on a number of criterion, including pollutant load reduction potential, land acreage affected, landowner "buy-in," cost, ease of implementation, and potential for educational outreach and exposure to the community. Management practices were prioritized for locating in the Hanalei Watershed since this watershed generates most of the pollutant loads and the Phase 1 TMDL calls for the largest reduction in pollutants.

Management practices can be classified as either preventive or treatment. Preventive practices can be considered a proactive approach toward NPS pollution management in that they anticipate and prevent issues before they develop. There may be a lag time between when preventive controls are implemented and significant reduction of NPS pollutants is achieved. Treatment practices are focused on the need to treat NPS pollution after a specific pollutant source or sources have begun to cause detriment to the environment. They are expected to provide immediate NPS load reductions. In the long term, the best solution to reducing the amount of land-based pollutants reaching the ocean is to prevent generation and/or reduce generation to background levels. However in some instances this is not immediately feasible due to high costs, land management constraints, and long range time

[66] http://efotg.sc.egov.usda.gov/treemenuFS.aspx

commitments. The use of preventative and treatment practices depends on the type of NPS pollutant, land use and activity, and flow paths transporting the NPS pollutant. At many sites a combination of preventative and treatment practices will be employed.

B.4.1. Management Practices and Pollutant Types

Table B.1 illustrates the relationship between management practices and pollutant types generated within the project area. Each of the practices applies to at least one of the six major pollutant types, while several of the practices apply to multiple types. Association with more than one pollutant does not necessarily imply that the practice is more effective at removal of each of the types. Practices that are concentrated on one main pollutant, such as creating and adhering to an effective fertilizer management plan to reduce nutrient-related pollutants, can also be highly successful.

TableB.1. Management Practices and their Applicability to Pollutant Type

Management Practice	Pollutant Type					
	Sediment	Nutrients	Organics	Bacteria	Debris / Litter	Hydrocarbons
Aerobic Treatment Unit		✓		✓		
Baffle Box	✓	✓			✓	✓
Bioretention Cell (Rain Garden)		✓	✓			✓
Channel Maintenance and Restoration	✓				✓	
Curb Inlet Basket (with Filter)	✓				✓	
Commercial WWTP Upgrades		✓		✓		
Constructed Wetlands	✓	✓		✓		
Erosion Control Mats and Vegetative Plantings	✓					
Feral Ungulate Fencing	✓			✓		
Fertilizer Management Plan		✓				
Good Housekeeping Practices	✓	✓	✓	✓	✓	✓
Grass Swale	✓	✓	✓			✓
Grazing Management System	✓			✓		
Gutter Downspout Disconnection	✓					✓
High Efficiency Toilets		✓		✓		
Loʻi Management	✓	✓		✓	✓	
Permeable Surfaces		✓	✓	✓		✓
Pesticide Management Plan			✓			
Storm Sewer Disconnection	✓	✓	✓	✓	✓	✓
Wetland Pollution Reduction Practices		✓		✓		

Appendix C. Management Practices

Management practices should be implemented as soon as funding and resources are available. These practices will prevent and treat NPS pollutants, and reduce pollutant loadings to the coral reef environment. Prior to implementation, some of the recommended management practices will require detailed design work based on the complexity of the measure, site physiographic conditions, and land ownership and regulatory considerations. Other practices will be straightforward and easily implemented once any regulatory considerations have been addressed. The HBWMP is not intended to be a design manual for management practices. There are numerous publications and resources to guide land managers and designers in the selection, acquisition, and installation of management practices.

Resources

A Handbook for Stormwater Reclamation and Reuse Best Management Practices in Hawaii, December 2008
www.state.hi.us/dlnr/cwrm/planning/hsrar_handbook.pdf

Low Impact Development, A Practitioner's Guide, June 2006
http://hawaii.gov/dbedt/czm/initiative/lid/lid_guide_2006.pdf

EPA's National Pollution Discharge Elimination System Stormwater Program
http://cfpub.epa.gov/npdes/home.cfm?program_id=6

International Stormwater BMP Database
http://www.bmpdatabase.org/

Center for Stormwater Protection
http://www.cwp.org/your-watershed-101/stormwater-management.html

Installation Tasks

Table C.1 identifies some of the required tasks for each of the management practices.

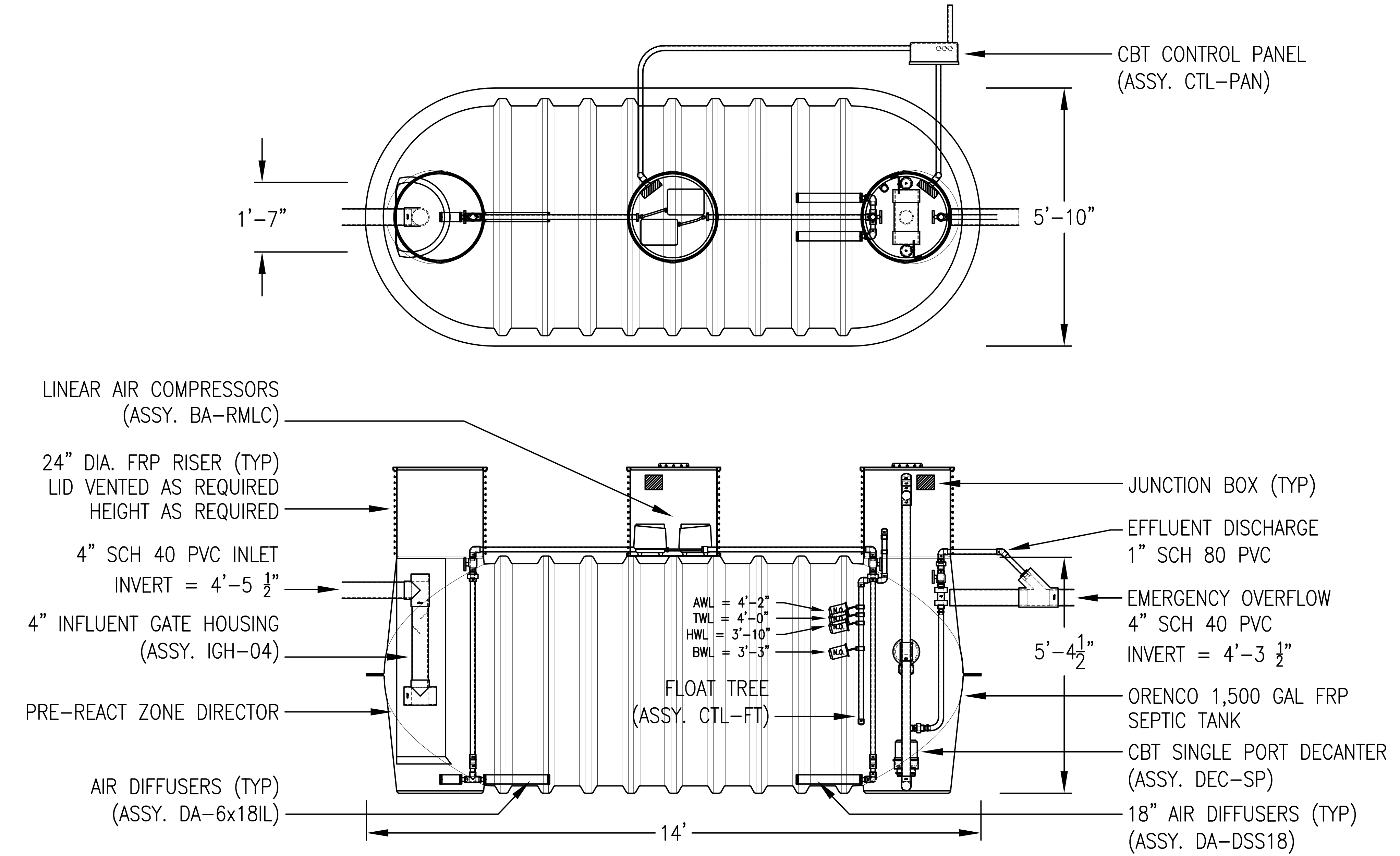
Table C.1. Management Practice Installation Tasks

Management Practice	Location Logistics	Drainage size	Construction	Community Acceptance	O&M	Permits	Land Owner / Manager Support	Education / Outreach	Municipal Support
Aerobic Treatment Unit			X	X	X	X	X	X	X
Baffle Box	X	X	X		X		X		X
Bioretention Cell (Rain Garden)		X	X		X		X		
Channel Maintenance and Restoration	X	X	X	X	X	X	X		
Curb Inlet Basket (with Filter)	X		X		X		X		
Commercial WWTP Upgrades			X		X	X	X		X
Constructed Wetlands	X	X	X	X	X	X	X	X	
Erosion Control Mats and Vegetative Plantings	X		X				X		
Feral Ungulate Fencing	X		X		X		X		
Fertilizer Management Plan				X	X		X		
Good Housekeeping Practices							X	X	
Grass Swale		X	X				X		
Grazing Management System	X		X		X		X		
Gutter Downspout Disconnection							X		
High Efficiency Toilets			X		X				X
Lo'i Management					X		X		
Permeable Surfaces		X	X		X		X		
Pesticide Management Plan				X	X		X		
Storm Sewer Disconnection							X		
Wetland Pollution Reduction Practices	X	X	X		X		X		

C.1. Aerobic Treatment Unit

Description

An ATU is a small-scale sewage treatment system similar to a septic tank system, but which uses an aerobic (oxygen present) process for digestion rather than just the anaerobic process used in septic systems. Compared to conventional septic tanks, ATUs break down organic matter more efficiently, achieve quicker decomposition of organic solids, and reduce the concentration of pathogens in the wastewater.



CBT™ INTERNATIONAL WASTEWATER TECHNOLOGIES, LLC.

2632-B Kilihau Street
Honolulu, Hawaii 96819
Phone - 808-833-2298
Fax - 808-833-2322
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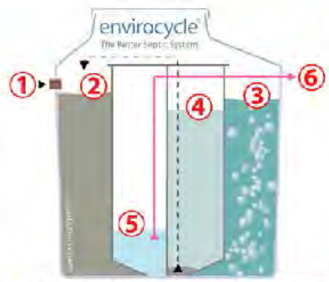
Envirocycle® provides state-of-the-art wastewater treatment and 100% water recycling in one compact, self contained, easy to install and service unit with no extra septic tanks or complicated plumbing.



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Every Envirocycle® brand unit includes our exclusive EnviroSentry® Remote Monitoring and Control Unit Service. If any abnormal operating condition should occur, 24 hours a day, 7 days a week, the system will alert your local Envirocycle® factory service center with information that will allow them to pinpoint the reason for the alarm. This exclusive Envirocycle®-only wireless RMCU system not only can monitor critical functions of the unit in real time, but potential problems can be discovered and fixed before a problem even occurs.

Exclusive Power Failure Protection.

In the event of a power outage, the Envirocycle® unit has a reserve storage capacity to hold at least a day's worth of wastewater. Plus, a battery backup keeps the monitoring system operating so everyone is aware hourly of the unit status.

No Preventative Maintenance.

Every other competitive system sold today requires routine preventative adjustment, cleaning, or pumping to keep it working. Envirocycle® is the no preventative maintenance, virtually trouble-free septic solution. Why settle for anything less, when you can have the superior performance, savings, and best-of-class service with an Envirocycle® Wastewater Treatment System?

Professional Design & Installation.

From start to finish Envirocycle® tracks and manages every step of the design, installation, and service process for you. Why? To ensure that you get the best overall treatment system and value for your money. Only Envirocycle® pre-selects Registered Civil Engineers and certifies them to design Envirocycle® systems. And, only select factory-trained, licensed & insured Contractors are allowed to install and service Envirocycle® treatment systems. You can be sure that when you buy an Envirocycle® you get the long-lasting treatment system and the long-lasting courteous professional service you deserve.

Envirocycle® Treated Wastewater is TWICE as Clean as the ANSI/NSF-40 National Standard Requires:

	Septic Tank	ANSI/ NSF 40	EC Unit
BOD	286	30	14
TSS	330	30	7
TKN	75	10	7
Fecal	20,000,000	N/A	1387

C.2. Baffle Box

Description

The Nutrient Separating Baffle Box is a multi-chambered concrete box separated with baffles used to settle out pollutants. Chambers can be fitted with absorbent membranes to trap floating pollutants, e.g. hydrocarbons. Effective at removing sediments, TSS, and hydrocarbons, this system is specially designed to capture trash, debris, organics, and gross solids in a raised screening basket that allows these pollutants to be stored in a dry state.

Baffle boxes are a treatment practice that can provide water quality benefits to stormwater runoff that has entered the Urban Unit's S4. This is accomplished through filtering and trapping of sediments and other NPS pollutants contained in the runoff within the baffle box, prior to runoff exiting the system into manmade or natural channels. This includes hardlined concrete channels that convey runoff from basins or have replaced the natural stream channels that once flowed through the region. Baffle boxes are essentially a retro-fit to the S4 and are expected to significantly and immediately reduce the concentration of fine sediments, nutrients, and other NPS pollutants.

Design Considerations

Retrofits to the S4 inlets and pipe network are recommended to reduce NPS pollutants conveyed in the S4. Baffle boxes should be installed in S4's that receive elevated levels of sediment and nutrient laden runoff from contributing drainage areas. Priority should be given to installations where an S4 discharges directly to the coastal environment or water bodies without any treatment practices in place to treat the runoff discharge. The location of baffle box installation within an S4 system should be at an accessible point above the stormwater outfall.

The use of curb/grate inlets and baffles boxes on the same pipe network is somewhat redundant and not necessary. When a baffle box is placed near the outfall of a pipe network it will treat all the runoff entering the curb/grate inlets on the same pipe network and will essentially render the inlet structures obsolete. If baffle boxes are not installed, then it is strongly recommend that curb/grate inlets be installed (Appendix 0).

Recommended baffle boxes are manufactured by Bio Clean Environmental Services, Inc. (Bio Clean), a company that has worked with municipal entities on installations in Hawai'i. The Bio Clean baffle box can be customized to trap up to 95% of the sediment routed into its three chamber design. Based on the documented performance of this manufacturer's product, baffle boxes from Bio Clean are recommended.[67] The Bio Clean baffle box is designed to trap both coarse and fine sediments, filter nutrients, and capture hydrocarbons, and is relatively easy to maintain using conventional vactor equipment.

[67] Details can be found at http://www. biocleanenvironmental.com/product/ns_baffle_box.

BIO CLEAN
ENVIRONMENTAL SERVICES, INC.

Nutrient Separating Baffle Box

A Superior Stormwater Treatment System Separated from the Rest.

The Nutrient Separating Baffle Box (NSBB) is a widely accepted and desired stormwater solution chosen by civil engineers, municipalities and developers nationwide because of its superior characteristics. The NSBB is easy to install and maintain and is the only systems with a two stage maintenance option, which minimizes maintenance costs.

Hundreds of Nutrient Separating Baffle Boxes have been installed nation wide, from Florida to California because of its superior and proven design. The NSBB efficiently removes TSS, hydrocarbons, nutrients, metals and debris/organics from stormwater runoff. The patented filtration screen system captures and stores trash and organics in a dry state, which prevents nutrient leaching and bacterial build up.

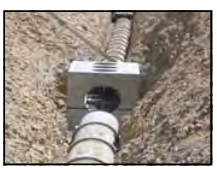
System Characteristics

Traps Oil & Grease
The skimmer and hydrocarbon booms captures all forms of hydrocarbons.

High TSS Removal
The three chambered design maximizes capture of large and fine TSS.

89.8% TSS Removal
Pandit - 1996
86.3% TSS Removal
Harvey's Lake - 2004
93.3% TSS Removal
Dillard - 2006

Low Installation Cost
Bottom of structure less than 4 feet from invert of pipe.



Separates Nutrients & Trash
The patented filtration screen system captures and stores trash and organics in a dry state which prevents nutrient

Low Head Loss
Allows for easy retrofit and inline installation. Eliminates the need for expensive diversion structures.

Easy Maintenance
Unobstructed Manhole Access

POLLUTANT	REMOVAL EFFICIENCY
Trash & Debris	99%[1]
TSS	76.9%[2] to 93.3%[3]
Fine TSS (d_{50} 63 µm)	67.3%[4]
Metals	Up to 57%[5]
Total Nitrogen	38% to 63%[5]
Total Phosphorus	18% to 70%[2,5]

1. Rockledge Baffle Box Independent Field Report. Applied Environmental Technology. 2007.
2. Brevard County (Micco & Indialantic). St. Johns River Water Management District. 1994.
3. Field Test for Suntree Nutrient Separating Baffle Box. Dillard & Associates. 2005.
4. New Jersey Corporation for Advanced Technology. 2008.
5. Atlantic Beach Field Report. Blue Water Environmental. 2004.

Setting a New Standard for Hydrodynamic Separators.

The Nutrient Separating Baffle Box is designed to do more than most systems. This system is effective at removing not only TSS, but also fine TSS and gross solids making it, overall, a more effective treatment system compared to traditional swirl type separators. This system has been proven to provide the following benefits:

System Benefits

- **Can Treat 100% of the Flow.**
  Offline Configuration is Not Required.
- **Inexpensive Maintenance.**
  Patented screen system allows gross solids to be removed without vacuuming out the water.
- **Minimal Head Loss.**
  Hydraulically efficient design generates less head loss than diversion structures.
- **Custom Designs Available.**
  Can be modified to meet your needs.
- **Easy to Install.**
  Delivered in a top & bottom half to minimize weight. Shallow profile minimizes installation costs.
- **5 Year Warranty.**
  Made of precast concrete, fiberglass, aluminum & stainless steel. No cheap plastics!

BIO CLEAN
ENVIRONMENTAL SERVICES, INC.

P O Box 869, Oceanside, CA 92049
(760) 433-7640 • Fax (760) 433-3176
www.biocleanenvironmental.net

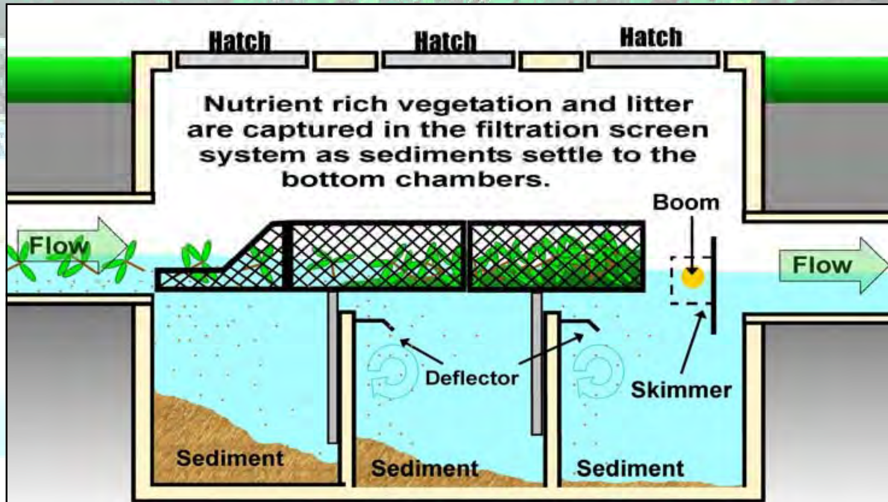
"The Stormwater Standard"

Functional Description

Captures:

- Trash & Debris D
- Oxygen Demanding Substances/Organic Compounds D
- Hydrocarbons, Oils & Grease
- TSS (including fines)
- Nutrients (particulates)
- Heavy Metals (particulates)

"Pollutants with this symbol D are stored in a dry state".



The Filtration Screen System is Patented

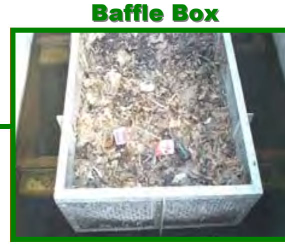
During Storm Event

Why Dry State Storage? D

Storing Trash, Debris, Organics, and Oxygen Demanding Substances in a Dry State Prevents:

- **Prevent Nutrient Leaching**
- **Eliminate Septic Conditions**
- **Minimize Bacteria Growth**
- **Eliminate Bad Odors**

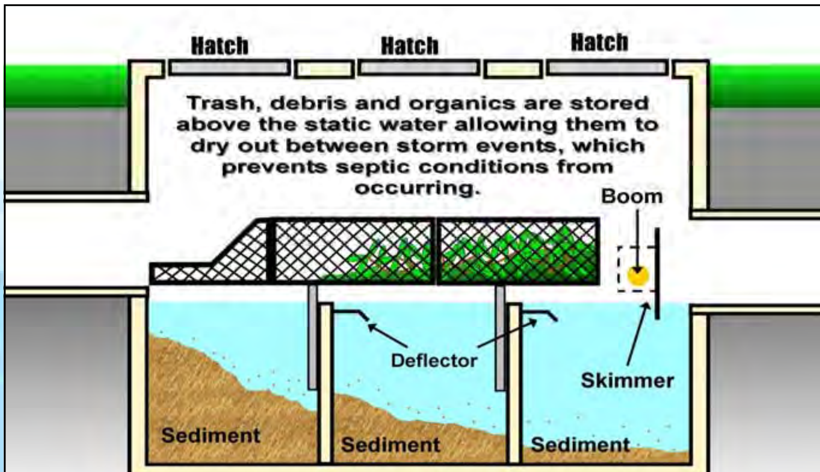
Nutrient Separating Baffle Box



Standing Water is Clear & No Bacteria Growth Visible.

Other Systems

Standing Water is Not Clear & Bacteria Growth Visible.



After Storm Event

Operation:

Skimmer & Boom
Collects hydrocarbons & controls flow velocity which improves removal efficiency.

Deflectors
Prevents re-suspension of captured pollutants at higher flows by directing water currents above sediment chambers.

Filtration Screen System
Collects and stores trash, debris, organics, and oxygen demanding substances in a dry state above the standing water. As mentioned above this has many performance benefits along with simplifying maintenance.

Multiple Sediment Chambers
Maximizes TSS removal and eliminates scouring during extreme flow rates.

BIO CLEAN ENVIRONMENTAL SERVICES, INC.

P O Box 869, Oceanside, CA 92049
(760) 433-7640 • Fax (760) 433-3176
www.biocleanenvironmental.net

"The Stormwater Standard"

C.3. Bioretention Cell (Rain Garden)

Description

A bioretention cell, or rain garden, is a low-impact development measure that is placed along the flow path of storm water runoff where it captures and treats stormwater containing pollutants. It is comprised of shallow depression excavated and backfilled with media used to promote infiltration and support plants that are installed to both physically trap and bioremediate pollutants. This system detains the volume of stormwater runoff that typically contains high pollutant loadings. Known as the "first flush," this portion of rainfall generated on impervious and other areas of reduced infiltration is treated within the bioretention cell through chemical processes that include plant root uptake and soil retention.

Bioretention cells can be installed alone or as part of a treatment chain of management practices within the Built Environment Unit. They help to break up the directly connected impervious area that is associated with the impervious areas of shopping plazas and roadways. They also will function to disconnect the S4 network at specific locations within the Built Environment Unit and promote infiltration of stormwater runoff into pervious soils present on the developed properties. They also create strategic S4 disconnection points, which results in reductions of runoff volume, peak flow, and pollutant loadings to the coastline.

Incorporating bioretention into a site development project can be more cost effective over the lifetime of the project when compared to the traditional method of S4 drainage construction.

Design Considerations

Bioretention cells typically have a grass filter strip running along the edge of their width to trap sediment generated on the surface of the drainage area that contributes runoff to the system. Runoff should sheet flow over a grass filter strip area into bioretention areas without the use of catch basins or closed system piping networks, reducing both construction and maintenance costs associated with stormwater infrastructure over the life of the project. This will allow sediment suspended in the stormwater to settle out and avoid clogging of the system. When properly sited and constructed, bioretention can require little maintenance over an extended service life, resulting in reductions to pollutant loadings that would otherwise be conveyed downstream through traditional closed drainage piping networks and natural stream channels.

The cell includes a surface layer of mulch (typically 2 to 3 inches in depth) underlain by a compost-amended soil layer (typically 12 to 18 inches in depth, consisting of a mixture of compost and sandy soils) to receive and infiltrate runoff. The surface of the cell is depressed below the surrounding ground surface between 6 and 12 inches deep, so that stormwater can be captured and ponded for several hours along the full length of the cell while it infiltrates into the underlying soils for treatment. The cell's surface depression is lined with native and non-invasive plants, and the plant root systems extend into the underlying compost/sand, where uptake of stormwater pollutants occurs.

Depth to Groundwater Table

Bioretention is most appropriate for use as a management practice in locations where the groundwater table is several feet below the ground surface to avoid stagnant ponding of runoff on the ground surface and to ensure infiltration into the bioretention soil mixture and underlying site soils. An excavated test pit may be necessary to determine the high water table if data is not already available for the site. Groundwater depths can vary significantly across large parcels based on a number of factors including topography and proximity to coastal waters.

Soil Infiltration Rate

A soil infiltration test must be performed at each proposed bioretention location to determine suitability of the management practice for that location, as well as design details for the installation. While general soil types and corresponding infiltration rates can be obtained from a variety of sources for a given geographical area, insitu conditions vary greatly, often within just a few feet on a particular site.

Suitable Plantings

Suitable planting selection must be made based on the rainfall for each specific bioretention placement location. Within the Built Environment Unit, bioretention cells may be best planted with species that can easily assimilate into the existing landscape.

Use of Underdrain and Overflow Control Structure

Depending on presence of underground utilities, underlying soil characteristics, and other site constraints, it may be necessary to install an underdrain below the bioretention soil mix to convey infiltrated water from the cell to a suitable outlet point. If an underdrain is used, it should be properly sized for the contributing volume of runoff predicted at the design storm event to the bioretention cell. A soil analysis should be performed at each bioretention cell location, to determine whether the underlying soils can naturally infiltrate the runoff that will percolate through the bioretention soil mix, or if an underdrain should be utilized to direct stormwater into a closed drainage system or stabilized outlet.

If an underdrain is used, the bioretention cell must discharge the treated runoff to either the existing closed drainage system within the site, or daylight into an existing drainage course or natural channel. Depending on the location of the bioretention cell, this may necessitate construction of a piping network to convey the stormwater to the suitable location. Cells that do not utilize underdrains are fully infiltrating and do not require a piped outlet. If daylighting into a drainage course is possible, incorporation of a vegetated swale prior to connection into the system will provide further treatment of runoff.

An overflow control structure can convey flow at larger storm events directly into the closed drainage system that the bioretention cell is connected to if an underdrain is used. This structure can be a raised catch basin with grate located above the level of ponding required to handle the infiltration of the first flush runoff event. If an underdrain is not incorporated into the design, an overflow structure may still be required to convey runoff offsite in the event of flooding or compromise to the infiltration capacity of the cell.

Grading

Bioretention is recommended for placement in areas where existing grades are as close to level as possible. While cells can be constructed in moderately sloped areas, care should be taken to orient the bioretention cell so that its longitudinal length runs along the contour, and the surface of the cell is level across its length to promote sheet flow of runoff into the cell and discourage channelization. Runoff should enter the cell along its width, and not from the ends.

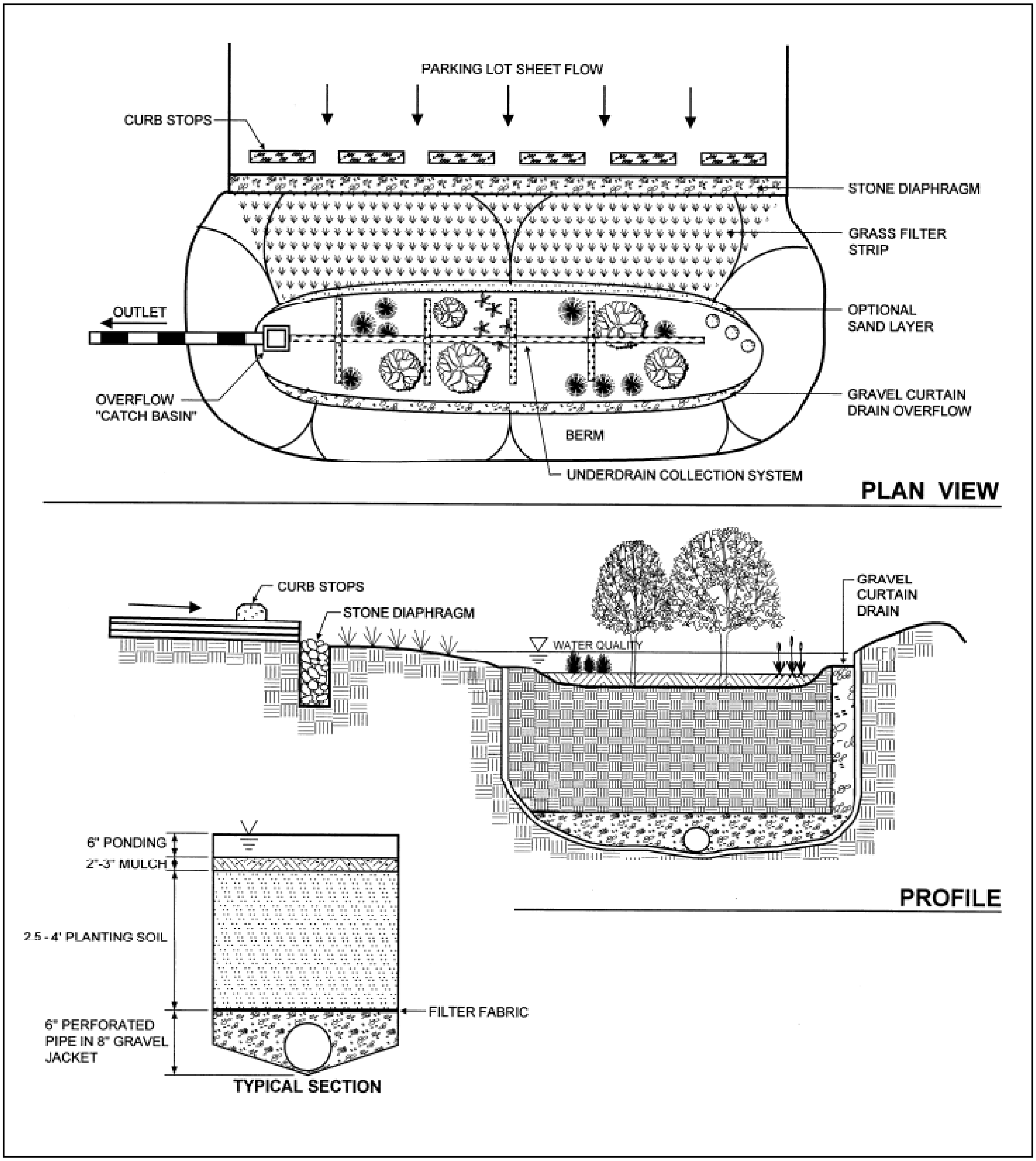
Contributing Drainage Area

Bioretention cells should be sized and located on the site to handle the volume and rate of stormwater runoff generated on the contributing drainage area. Cover types within the project area have varying infiltration and runoff generation characteristics that factor into the calculations for proper sizing of bioretention areas. Bioretention relies on infiltration of runoff through its surface into the underlying soil mix below, and as such it is critical that the drainage areas contributing runoff to the cells not be subject to activities that could release sediment into the cell via rainfall, irrigation, or other runoff events. Clogging of the bioretention cell can cause ponding, loss of infiltration capacity, and reduction of water quality treatment.

Available Land Area for Construction

Sufficient land must be available for construction that allows for placement of both the bioretention area and grass filter strips without removal of mature trees and avoiding potential impact from vehicular or pedestrian impacts, and the associated sediment generation associated with these impacts. Within the Built Environment Unit, bioretention is suited well for placement between impervious parking lots and adjacent to paved roadways where there are currently areas of landscape plantings, turf, or unstabilized soils. Areas at shopping centers or parks where there are high levels of vehicle egress are recommended for bioretention siting. The majority of oils and grease from vehicles parked and traveling within these areas can be captured and contained within the bioretention cells onsite for treatment.

Bioretention Cell Detail

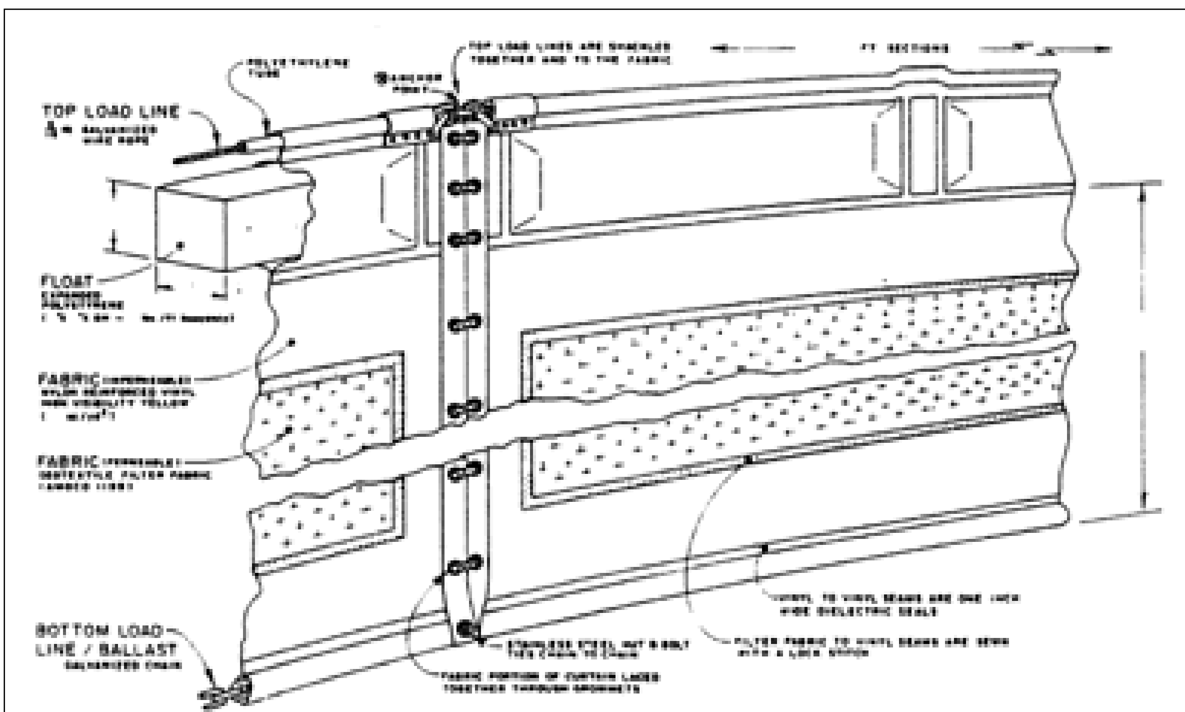


Note: Graphical representation only; not actual design.
(from Vermont Stormwater Treatment Manual, http://www.vtwaterquality.org/cfm/ref/ref_stormwater.cfm)

C.4. Channel Maintenance and Restoration

Description

Channel maintenance and restoration is accomplished using practices that control movement of sediment and plant pollution into waterways during earthwork such as stream bank stabilization or habitat enhancement (e.g. *hau* bush removal). Examples include floating booms and silt curtains extended across river and stream banks downstream of work.

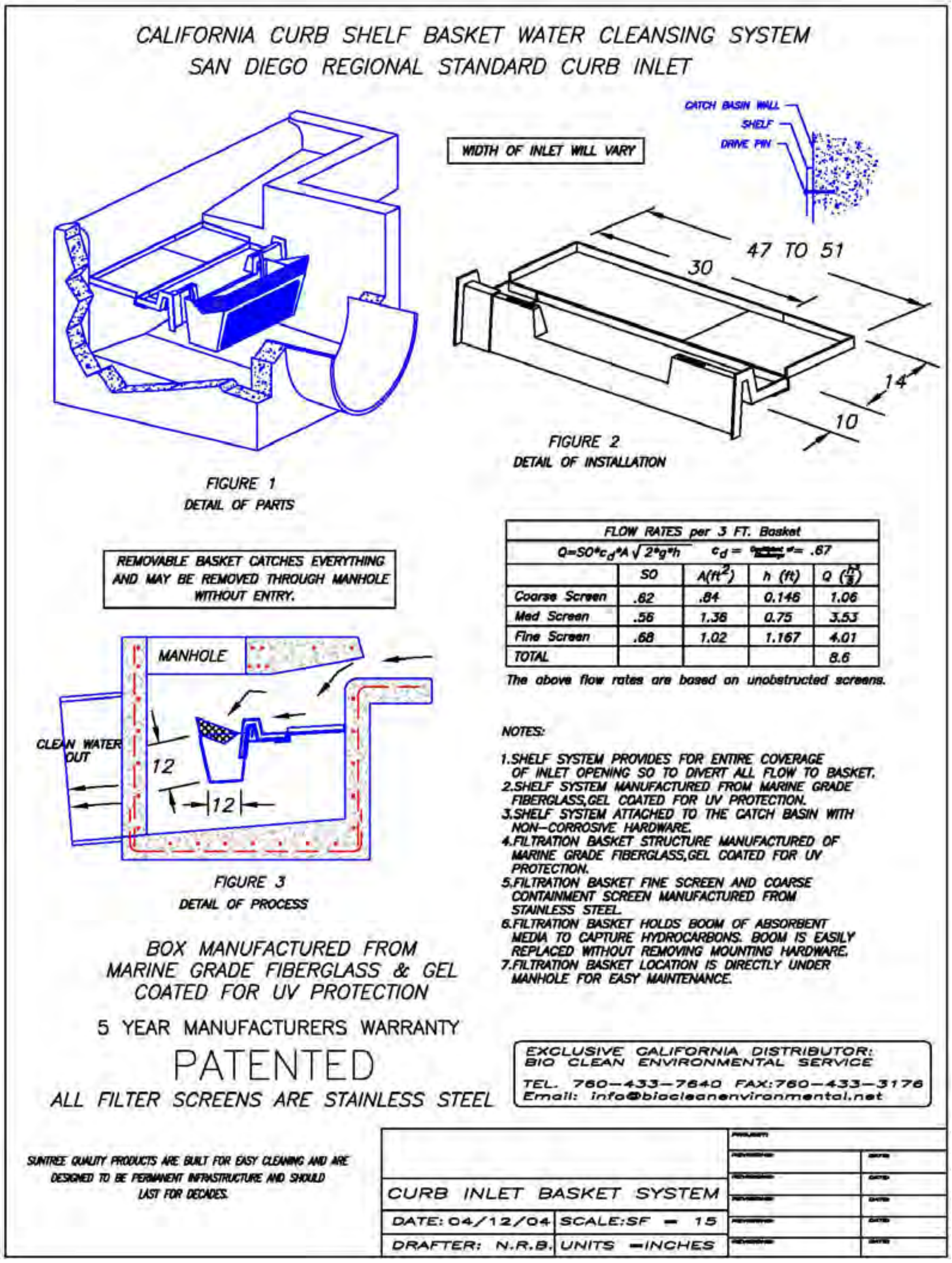


C.5. Curb Inlet Basket (with Filter)

Description

Mesh curb/grate inlet baskets trap gross solids and are ideal for removing large quantities of hydrocarbons, including oils and grease when fitted with an optional absorbent polymer. Bio Clean has tested their curb inlet basket system in Hawai'i and reports having the lowest installation time and highest rated catch basin insert for performance and maintenance (Bio Clean 2009).

Curb Inlet Basket with Shelf System



C.6. Constructed Wetlands

Description

A constructed wetland is an excavated basin that is planted with native wetland plants. The wetland is usually fitted with a spillway to allow for water to be drawn down when the wetland reaches its water holding capacity. The recommended design for the Hanalei Watershed is to design a wetland that allows water to flow through it on a continuous basis. Plants in the wetland will slow the flow, which allow solids to settle and for nutrients in suspension to be taken up by plants and reduced by micro-organisms living in the wetland soils.

Design Considerations

Constructed wetlands should be installed in line of ditches and ‘*auwai* immediately upstream of their outlets. The wetlands will be disproportionately longer than they are wide to facilitate through flow conditions. The bed slope of the wetland along its long axis will be set to a positive grade. Plants will be installed at a density that will balance flows and bioremediation.

C.8. Erosion Control Mats and Vegetative Plantings

C.8.1. Erosion Control Blanket / Turf Reinforcement Mat

Turf reinforcement mats are made of synthetic fabric and are used to line bare soil areas both within the landscape and within channels to protect the channel bed and bank from erosion due to natural wasting of the banks and drainage flow through the channel. They allow a long-term solution for erosion control. Turf reinforcement mats maintain intimate contact with the subgrade, resulting in rapid seedling emergence and minimal soil loss. They allow water to infiltrate in substrate and provide for hydraulic connectivity to groundwater. Mats should be made of non-degradable fabric to ensure long-term protection of ground soils.

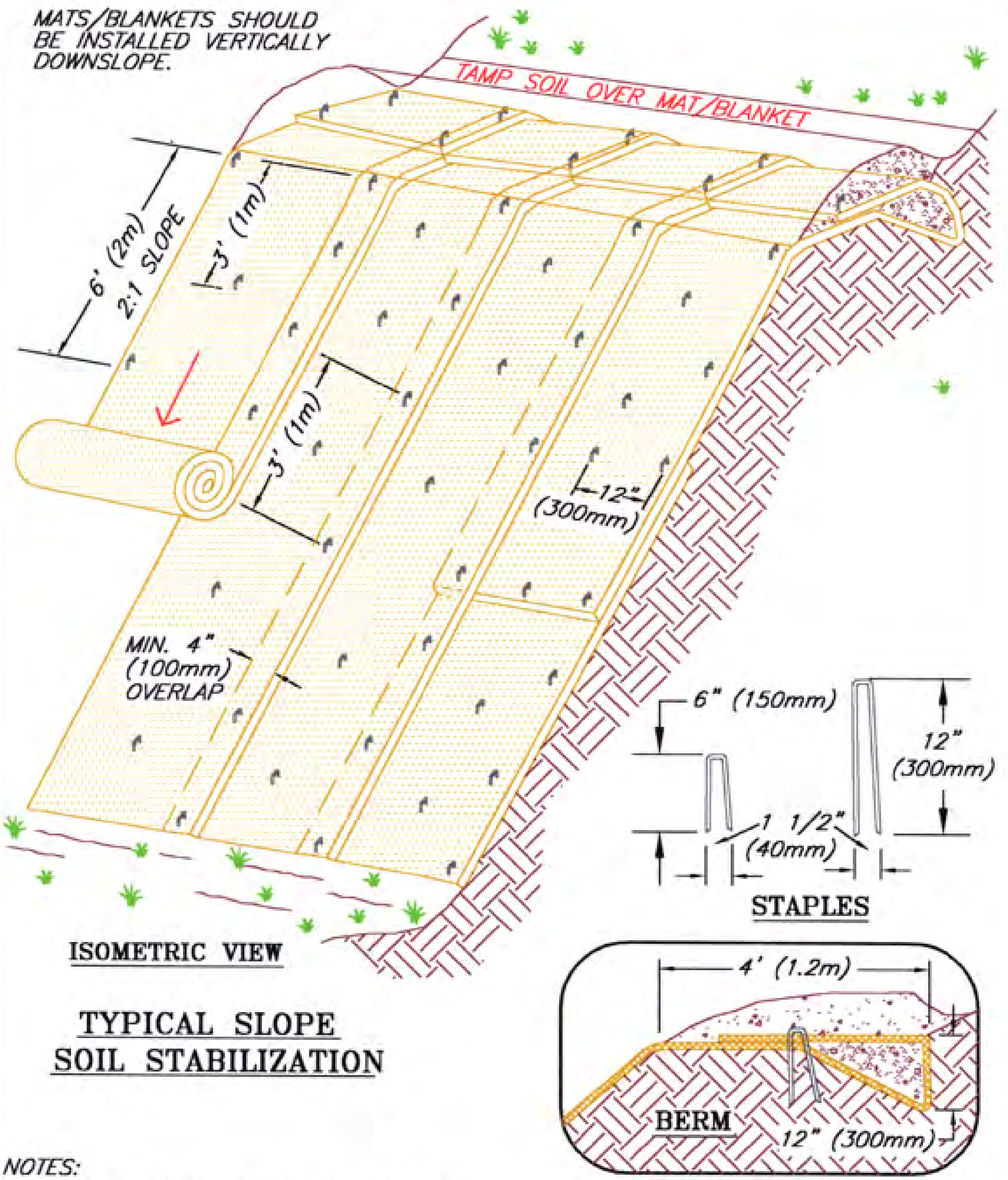
Stream bank stabilization is defined as the stabilization of an eroding stream bank using practices that consist primarily of 'hard' engineering such as, but not limited to, turf reinforcement matting, concrete lining, rip-rap or other rock, and gabions. The use of 'hard' engineering techniques is not considered a restoration or enhancement strategy but may be necessary in certain location where erosion threatens adjacent properties and the probability of success using soft engineering practices is low. Other sections along the channel banks can be treated with bioengineering and soft engineering practices, which can be expected to reduce bank erosion, increase site aesthetics, enhance instream habitat, and be less costly compared to hardened structures.

C.8.2. Natural/Native Vegetation

Native vegetative cover provides a permanent, stabilized surface for soils that are highly subject to erosion. Vegetation will decrease the rate of overland flow and amount of erosion generated from exposed soil areas. The type of vegetation and feasibility of long-term survival of plantings depends on site conditions, including existing vegetative cover and slope angles. Selection of vegetative species should be based on specific location within the project area where vegetative cover is proposed, rainfall intensities in the area, and associated runoff rates.

Design Considerations

Vegetative cover provides a natural, soft practice for stabilizing soil surfaces that are currently exposed and have high erosion potential, and is best implemented with erosion control mats. This practice remediates these areas and protects the ground surface from rainfall and overland flow. It also provides a micro-habitat for plant growth. Biodegradable erosion control blankets provide ground cover on exposed areas, decrease slope length, and trap sediments.



TYPICAL SLOPE SOIL STABILIZATION

NOTES:

1. SLOPE SURFACE SHALL BE FREE OF ROCKS, CLODS, STICKS AND GRASS. MATS/BLANKETS SHALL HAVE GOOD SOIL CONTACT.
2. APPLY PERMANENT SEEDING BEFORE PLACING BLANKETS.
3. LAY BLANKETS LOOSELY AND STAKE OR STAPLE TO MAINTAIN DIRECT CONTACT WITH THE SOIL. DO NOT STRETCH.

NOT TO SCALE

EROSION BLANKETS & TURF REINFORCEMENT MATS SLOPE INSTALLATION

FILE: BLNKTSLP

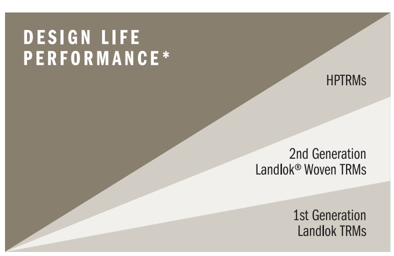
LANDLOK® TURF REINFORCEMENT MATS

Our Landlok® Turf Reinforcement Mats (TRMs) are the industry's most advanced solutions for applications requiring immediate, long-term erosion protection, vegetative reinforcement and water quality enhancement capabilities. Our first generation TRMs are constructed of a dense web of 100% polypropylene fibers positioned between two biaxially oriented nets. When vegetated, they provide twice the erosion protection of vegetation alone.

Now we've taken the same woven technology in our High Performance Turf Reinforcement Mats (HPTRMs) and used it to design the next generation of TRMs. These netless, composite-free three-dimensional second generation TRMs feature a rugged material construction that combines superior tensile strength, flexibility and UV stability. This allows them to deliver better, long-term performance over traditional methods like rock riprap and concrete paving and increased design life over first generation netted, fused, glued or stitch-bonded TRMs. All Landlok TRMs feature our patented X3® fiber technology, which provides 40% greater surface area for trapping and protecting seed and soil.

1ST GENERATION LANDLOK® TRMs FEATURES & BENEFITS

- Provides permanent turf reinforcement to enhance vegetation's natural ability to filter soil particles and prevent soil loss during storm events
- 100% synthetic and UV-stabilized components
- Utilizes X3 fiber technology for up to 40% greater surface area to protect emerging seedlings and sediment retention
- Promotes infiltration which leads to groundwater recharge
- More aesthetically pleasing than conventional methods (i.e. rock riprap and concrete paving)
- Superior product testing and performance
- Easier installation than conventional solutions (no heavy equipment required)



*Design life performance may vary depending upon field conditions and applications.

2ND GENERATION LANDLOK® WOVEN TRMs FEATURES & BENEFITS

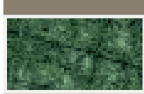
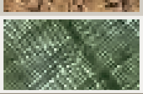
All the features and benefits of first generation Landlok TRMs, plus:

- A unique, patented matrix of pyramids formed with X3 fibers that gridlocks soil in place under high-flow conditions
- 3-D woven material with superior tensile strength for loading and/or survivability requirements
- Greater flexibility to maintain intimate contact with subgrade, resulting in rapid seedling emergence and minimal soil loss
- Completely interconnected yarns that provide superior UV resistance throughout the TRM
- A combination of superior characteristics for long-term performance and a longer design life than first generation Landlok TRMs
- Meets requirement of 5 mm^2 or less mesh size to prevent wildlife entanglement in any sensitive habitats

Outperforms and is more cost-effective than conventional erosion control methods, including:

- **Rock riprap**
- **Concrete paving**
- **Erosion Control Blankets (ECBs)**

LANDLOK® TURF REINFORCEMENT MATS PRODUCT FAMILY TABLE

PRODUCT		DESCRIPTION	FUNCTIONAL LONGEVITY	COLOR	FIBER TYPE	# OF NETS	FHWA FP-03, SECTION 713 COMPLIANCE
	LANDLOK® 450	1ST GENERATION TRM	PERMANENT	TAN OR GREEN	POLYPROPYLENE X3® FIBER TECHNOLOGY	2	TYPE 5A, 5B, 5C
	LANDLOK 1051	1ST GENERATION TRM	PERMANENT	TAN	POLYPROPYLENE X3 FIBER TECHNOLOGY (GEOTEXTILE BACKING)	1	TYPE 5A, 5B, 5C
	LANDLOK 300	2ND GENERATION TRM	PERMANENT	TAN OR GREEN	POLYPROPYLENE X3 FIBER TECHNOLOGY	0 (WOVEN)	TYPE 5A, 5B, 5C

PROPEX® | THE ADVANTAGE CREATORS.™
GEOSYNTHETICS

LANDLOK® TURF REINFORCEMENT MATS

APPLICATION SUGGESTIONS FOR LANDLOK® TURF REINFORCEMENT MATS

	APPLICATION	FUNCTIONAL LONGEVITY	PRODUCT STYLE	INSTALLED COST[1]	ANCHOR SUGGESTIONS[5]
SLOPES[2]	UP TO 1H:1V	PERMANENT	LANDLOK® 300	\$10.00 - 15.00/yd² \$11.96 - 17.94/m²	2.5 ANCHORS/yd² 3 ANCHORS/m²
SLOPES[2]	UP TO 1.5H:1V UP TO 2H:1V	PERMANENT	LANDLOK 450	\$9.00 - 14.00/yd² \$10.77 - 16.75/m²	2 ANCHORS/yd² 2.5 ANCHORS/m²
CHANNELS[3]	SHEAR STRESS UP TO 10 lb/ft² (479 N/m²) VELOCITY UP TO 18 ft/sec (5.5 m/sec)	PERMANENT	LANDLOK 450	\$9.00 - 14.00/yd² \$10.77 - 16.75/m²	2.5 ANCHORS/yd² 3 ANCHORS/m²
CHANNELS[3]	SHEAR STRESS UP TO 12 lb/ft² (576 N/m²) VELOCITY UP TO 20 ft/sec (6.1 m/sec)	PERMANENT	LANDLOK 300	\$10.00 - 15.00/yd² \$11.96 - 17.94/m²	2.5 ANCHORS/yd² 3 ANCHORS/m²
BANKS[4]	WAVE ACTION < 1 ft (30 cm)	PERMANENT	LANDLOK 1051	\$10.00 - 15.00/yd² \$11.96 - 17.94/m²	2.5 ANCHORS/yd² 3 ANCHORS/m²

NOTES: 1. Installed cost estimates range from large to small projects according to material quantity. The estimates include material, seed, labor and equipment. Note that costs vary greatly in different regions of the country. 2. For slopes steeper than 1H:1V, please see our Pyramat® HPTRM product brochure. 3. Values shown are short-term fully vegetated maximums. For channels with a shear stress greater than 12 lb/ft² (576 N/m²) and velocity greater than 20 ft/sec (6.1 m/sec), please see our Pyramat HPTRM product brochure. 4. For wave action greater than 1 ft (30 cm), please see our Pyramat HPTRM product brochure. 5. For anchor size and style, please see our TRM Installation Guidelines.

KEY PHYSICAL PROPERTIES OF LANDLOK® TURF REINFORCEMENT MATS

- Tensile Strength: High-strength and low-strain minimizes seed, root damage and material under heavy loads.
- Flexibility: Greater flexibility allows our TRMs to conform and maintain intimate contact with the prepared grade, increasing the ease of successful installation.
- Seedling Emergence: Landlok TRMs, now with X3® fiber technology, offer 40% more fiber surface area to capture the critical sediment and moisture needed to increase seed germination within the first 21 days.
- UV Resistance: All Landlok TRM components are constructed with the top-tested UV stabilizers, such as carbon black and hindered amine light stabilizers (HALS).

SEVEN STEPS FOR SUCCESSFUL TRM SELECTIONS*

1. SELECT APPLICATIONS
2. DETERMINE FUNCTIONAL LONGEVITY
3. ANTICIPATE CLIMATE (ARID, SEMI-ARID OR TEMPERATE)
4. UNDERSTAND TRADITIONAL SOLUTION
5. PREDICT NON-HYDRAULIC STRESSES (MAINTENANCE STRESSES)
6. KNOW VEGETATION TYPE
7. CALCULATE HYDRAULIC STRESSES

*See Propex Engineering Bulletin or EC-DESIGN® software for more information.

LANDLOK® TURF REINFORCEMENT MAT PROPERTY TABLE[1] ENGLISH & METRIC UNITS

	PROPERTY	TEST METHOD	VALUE[2]	LANDLOK® 450	LANDLOK® 1051	LANDLOK® 300
PHYSICAL	MASS PER UNIT AREA	ASTM D-6566	MARV	10.0 oz/yd^2 340 g/m^2	14 oz/yd^2 475 g/m^2	8.3 oz/yd^2 281 g/m^2
PHYSICAL	THICKNESS	ASTM D-6525	MARV	0.4 in 10.1 mm	0.4 in 10.1 mm	0.3 in 7.6 mm
PHYSICAL	LIGHT PENETRATION	ASTM D-6567	TYPICAL	20%	5%	50%
PHYSICAL	COLOR	VISUAL	–	GREEN, TAN	TAN	GREEN, TAN
MECHANICAL	TENSILE STRENGTH	ASTM D-6818	MARV	400 x 300 lb/ft 5.8 x 4.3 kN/m	300 x 225 lb/ft 4.3 x 3.2 kN/m	2400 x 2000 lb/ft 35.0 x 29.2 kN/m
MECHANICAL	TENSILE ELONGATION	ASTM D-6818	MAXIMUM	50%	85%	50%
MECHANICAL	RESILIENCY	ASTM D-6524	MARV	90%	80%	75%
MECHANICAL	FLEXIBILITY	ASTM D-6575	TYPICAL	0.026 in-lbs 30000 mg-cm	0.022 in-lbs 25000 mg-cm	0.195 in-lbs 225000 mg-cm
ENDURANCE	FUNCTIONAL LONGEVITY	OBSERVED	TYPICAL	PERMANENT	PERMANENT	PERMANENT
DURABILITY	UV RESISTANCE	ASTM D-4355	MINIMUM	80% @ 1000 HOURS	80% @ 1000 HOURS	90% @ 3000 HOURS
PERFORMANCE	SEEDLING EMERGENCE[3]	ECTC DRAFT METHOD #4	TYPICAL	409%	220%	296%
PACKAGING	ROLL WIDTH	MEASURED	TYPICAL	6.5 ft 2.0 m	6.5 ft 2.0 m	8.5 ft 2.6 m
PACKAGING	ROLL LENGTH	MEASURED	TYPICAL	138.5 ft 42.2 m	138.5 ft 42.2 m	106 ft 32.3 m
PACKAGING	ROLL WEIGHT	CALCULATED	TYPICAL	75 lb 34 kg	101 lb 46 kg	51 lb 23 kg
PACKAGING	ROLL AREA	MEASURED	TYPICAL	100 yd^2 84 m^2	100 yd^2 84 m^2	100 yd^2 84 m^2

NOTES: 1. The listed property values are effective 06/2009 and are subject to change without notice. 2. MARV indicates Minimum Average Roll Value calculated as the typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any sample taken during quality assurance testing will exceed the reported value. 3. Calculated as percent increase in average plant biomass with tall fescue grass seed in sand 14 days after seeding versus traditional monofilament TRMs and HPTRMs.

LANDLOK® TURF REINFORCEMENT MAT PERFORMANCE VALUES ENGLISH & METRIC UNITS

MATERIAL	FUNCTIONAL LONGEVITY	SHORT-TERM MAXIMUM SHEAR STRESS AND VELOCITY						MANNING'S "n"		
		VEGETATED[4, 7]		PARTIALLY[5]		UNVEGETATED[6]		0"-6"	6"-12"	12"-24"
LANDLOK® 450	PERMANENT	10 lb/ft^2 479 N/m^2	18 ft/sec 5.5 m/sec	8 lb/ft^2 383 N/m^2	15 ft/sec 4.6 m/sec	5 lb/ft^2 239 N/m^2	12 ft/sec 3.7 m/sec	0.035	0.025	0.021
LANDLOK 1051	PERMANENT	10 lb/ft^2 479 N/m^2	18 ft/sec 5.5 m/sec	n/a	n/a	5 lb/ft^2 239 N/m^2	12 ft/sec 3.7 m/sec	0.036	0.026	0.020
LANDLOK 300	PERMANENT	12 lb/ft^2 576 N/m^2	20 ft/sec 6.1 m/sec	–	–	–	–	0.030	0.028	0.018

NOTES: 4. Maximum permissible shear stress has been obtained through fully vegetated (70% to 100% density) testing programs featuring specific soil types, vegetation classes, flow conditions and failure criteria. These conditions may not be relevant to every project nor are they replicated by other manufacturers. Please contact Propex for further information. 5. Maximum permissible shear stress has been obtained through partially vegetated (30% to 70% density) testing programs featuring specific soil types, vegetation classes, flow conditions and failure criteria. These conditions may not be relevant to every project nor are they replicated by other manufacturers. Please contact Propex for further information. 6. Maximum permissible shear stress has been obtained through unvegetated (0% to 30% density) testing programs featuring specific soil types, vegetation classes, flow conditions and failure criteria. These conditions may not be relevant to every project nor are they replicated by other manufacturers. Please contact Propex for further information. 7. Maximum permissible shear stress achieved after only 14 weeks of vegetative establishment versus the industry standard of two full growing seasons.

C.9. Feral Ungulate Fencing

Description

Feral ungulate fencing is a structural conservation practice that prevents movement of ungulates across a given boundary. Within areas impacted by feral ungulate presence, fences prevent their movement into the forested lands. Ungulate fencing prevents direct contact of fecal matter with waterways, allows for restoration of vegetation, and reduces bacteria and nitrogen loadings and sediment input into waterways.

Gregory Koob

C.10. Fertilizer Management Plan

Description

A fertilizer management plan is a conservation practice recommended to be prepared for taro cultivation. A fertilizer management plan includes information on crop nutrient requirements, soil fertility, irrigation application, types of fertilizers, and other pertinent information that results in providing the crop adequate nutrients while at the same time minimizing excess fertilizer application and potential loss from *lo'i* in surface water and groundwater. Fertilizer management plans should be created if not already in place, and reviewed on a regular basis for efficiency and incorporation of changes in practices.

Key Components

- Maps depicting *lo'i* acreage and location, and water works structures (gates, dikes, *auwai*, outlets to receiving waters)
- Yield expectations per *lo'i*.
- Summary of existing conditions
    - Soil
        - Soil fertility via soil sampling and nutrient assessment
        - Cation exchange potential
        - Soil physical parameters, infiltration rate, texture
    - Irrigation water
        - Water quality analysis, sampling assessment for nutrient concentrations with forms of biologically available nitrogen, e.g. nitrate ammonium
        - Water quality samples collected from *lo'i*
    - Plant
        - Taro needs
        - Taro tissue samples
    - Fertilizer
        - Fertilizer analysis, type and source of nitrogen
        - Estimated fertilizer application rates
    - Yields
        - Analysis of fertilizer applied on *lo'i*
        - Other sources of nutrients (e.g. waterfowl).
        - The best available information for creating recommendations for fertilizer sources and crop requirements.

C.11. Good Housekeeping Practices

Description

Good housekeeping practices include actions and activities that reduce the generation of NPS pollutants and runoff. Good housekeeping practices within the Built Environment Unit are generally associated with the impervious areas of residential and commercial land uses. Activities in these areas affect the types and amounts of contaminants that are generated, which impacts pollutant concentrations mobilized in runoff. Stakeholders should be educated and encouraged to engage in good housekeeping practices. Implementation of a good housekeeping program to reduce the generation of by-products associated with normal human activities is recommended for residents, employees, and business owners in the Hanalei Bay Watersheds.

Box C.1. Good Housekeeping Practices

Know the property boundaries, and where storm water from the property goes.
Use biodegradable and recyclable cleaners when possible.
Carefully select and control inventory. Having fewer materials on hand simplifies operations, reduces inventory cost, more effectively uses available roofed storage space, and lessens the opportunities for spills or leaks.
Use good material storage practices (avoid toxic materials to the extent possible, store containers of liquids in a way they are unlikely be knocked over, cover stockpiled materials, consider the best place to conduct specific activities.)
Conduct property maintenance (clean up the site, but not by washing grit and grime into the storm drainage system).
Eliminate improper discharges to storm drains - only rainwater should run off the site.
Clean up spills of materials or from equipment now, not later.
Practice waste management (pick up litter, sweep areas and dispose of sweepings in the garbage (unless they are hazardous and require special disposal)
Use good waste storage practices (keep dumpsters and other containers closed; store containers under cover)
Dispose of mop water to a sanitary sewer.
Maintain equipment and vehicles regularly. Check for and fix leaks.
Wash cars over grass patches, use phosphorus free soaps
Capture rainfall using rain barrels, placing downspouts on vegetated areas, install rain gardens.

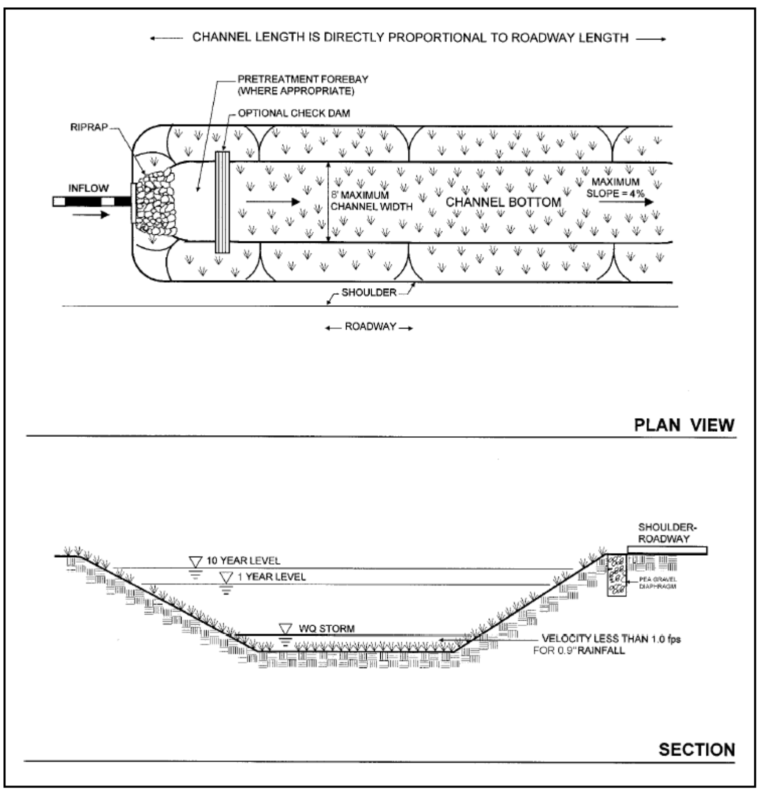
C.12. Grass Swale

Description

A grass swale is a shallow excavation, constructed on a gradually sloped grade, lined with grass along a waterway. The vegetated conveyance channel slows flow, temporarily impounds a portion of flow, filters a portion of pollutants, settles out sediment, encourages infiltration into the underlying soils, and reduces the potential for erosion caused by runoff velocities within the channel. Grass swales can be implemented wherever there is runoff that needs to be conveyed to a natural drainage channel from a treatment device, or as a conveyance from a land use that has preventative treatment measures incorporated into its design. Grass swales can be especially effective when constructed at grades approaching level because they slow water to the maximum extent possible while still maintaining positive grade. Ponding may occur in swales, which will aid in additional settling and treatment of the runoff.

Design Considerations

Grass swales are recommended to reduce NPS pollutants and attenuate runoff generated off public and commercial parking areas and other impervious surfaces. Grass swales temporarily store runoff and remove fine sediments, are useful for controlling higher frequency flood events (generally less than the 2-year), and can be designed with a spillway outlet to handle large rainfall events. They should be constructed along and adjacent to parking lots where there is room and non-impervious surfaces.



Note: Graphical representation only; not actual design.
(from Vermont Stormwater Treatment Manual, http://www.vtwaterquality.org/cfm/ref/ref_stormwater.cfm)

C.13. Grazing Management System

Description

A grazing management system consists of a set of strategies to prevent trampling within established riparian buffers by cattle or other livestock. Working together, these strategies reduce sediment and fecal matter loadings (bacteria and nitrogen) entering water bodies. Additional strategies may be available from NRCS (www.pb.nrcs.usda.gov and www.hi.nrcs.usda.gov).

Prescribed Grazing. Management of vegetation with grazing and/or browsing animals. For more information see “Prescribed Grazing for Pacific Island Farms” (USDA NRCS Conservation Practice Standard 528).

Livestock Fencing. Structural conservation practice that prevents movement of livestock across a given boundary. Within grazing areas, ditches between paddocks are fenced off to limit cattle and buffalo movement. (USDA NRCS Conservation Practice Standard 382).

Livestock Watering. Practices such as (1) use of a solar-powered system that draws water from ditches and pumps it into troughs for cattle, in lieu of allowing livestock to access ditches, *‘auwai*, or streams to water; or (2) use of a low tech water harvesting system to fill watering trough.

C.14. Gutter Downspout Disconnection

Description

Existing gutter downspouts can be disconnected from residential and commercial buildings that tie into closed drainage systems or discharge onto pervious surfaces, and be directed to stabilized areas where infiltration into soils can take place.

Commercial businesses and residential houses are typically fitted with downspout pipes that discharge storm water off the property and onto the adjacent sidewalk and/or street, or into the closed drainage system. This practice is likely being conducted to reduce ponding that occurs during rainfall events. The funneled runoff adds to the runoff generated from County of Kauaʻi owned and private impervious areas including streets, sidewalks, and buildings. The higher volume of runoff increases the frequency and efficiency by which NPS pollutants are carried to S4 inlets. Rain falling on commercial and residential lots is lost as source water for the landscaped areas and adds to the disruptions of the hydrologic regime.

Disconnection of gutter downspouts attenuates runoff, and directing the outlets to areas that are stabilized and/or can accommodate temporary ponding means that some contaminants generated off the roof areas are treated via infiltration. This more closely mimics the natural hydrologic regime. Individually, capture of rainwater at the individual house level will not significantly reduce runoff volume reaching the S4, nor will it increase the time of peak flows. However when adopted on a mass scale across the Built Environment Unit, benefits derived in terms of reduced water costs and increased awareness are real. Programs to disconnect downspouts should be scaled up across watersheds in order to increase the number of homeowners that participate and the volume of water captured, and correspondingly decrease runoff.

C.15. High Efficiency Toilets

Description

Composting Toilet: Dry toilet that uses a predominantly aerobic processing system that treats sewage, (typically with no water or small volumes of flush water) via composting or managed aerobic decomposition. Works best with low evaporation rates (non-humid areas) although may be modified to accommodate humid areas such as Hanalei.

Waterless Urinal: Urinals that utilize a trap insert filled with sealant liquid instead of water. The sealant is lighter than water and floats on top of the urine collected in the U-bend, preventing odors from being released into the air. Useful in high-traffic facilities and in situations where providing a water supply may be difficult or where water conservation is desired. Can result in substantial water usage reductions.

C.16. Permeable Surfaces

Description of Common Permeable Surface Installation Options

Porous pavement, pervious concrete, and concrete pavers are three common types of permeable surfaces that incorporate a range of sustainable materials and techniques to promote infiltration of stormwater runoff into the subsurface environment. The underlying base and sub-base layers of these surfaces function to reduce runoff volume, as well as effectively trap suspended solids and filter pollutants that would otherwise be transported by runoff into downstream drainageways. Permeable surfaces can be a viable choice in settings where industrial or commercial traffic is in use (i.e. parking lots), with few restrictions regarding axle weight.

Porous Pavement

Porous pavement surfaces are designed to accommodate pedestrian, bicycle, and vehicle traffic while allowing infiltration, treatment, and storage of stormwater. Porous pavement systems utilize hot-mix asphalt pavement, and are similar to standard pavement. However, porous pavement contains reduced or eliminated fine materials (sands and finer material), resulting in channels between aggregates within the surface layer that allow stormwater to infiltrate into the subsurface. A porous pavement system design life can be up to 20 years.

Generally, there is an underdrain installed below the pavement and aggregate courses, because long-term infiltration rates will likely decrease over time. Underdrains ensure that storm drainage will be routed away from the system and will not be deleterious to its long term structural integrity. Underdrains can daylight (safely discharge to the ground surface) in proximity to nearby existing ditches for flow conveyance downstream.

If installed properly, porous pavements can virtually eliminate surface flows from low intensity storms, as well as store subsurface flows and provide water quality treatment for hydrocarbons, metals, and nutrients. The main concern with porous pavement is that excessive sediment, directed onto the system’s surface or migrated up from the subsurface, will clog the surface pores and channels between the mix aggregate. For this reason, sediment generation needs to be strictly controlled during and after construction. One way to ensure the long-term integrity of the system is to place filter fabric between the subgrade and the bottom of the gravel’s base material to prevent sands and finer materials from migrating upward into the system.

Typical costs for porous pavement range between $2.80 and $3.50 per square foot, with additional costs typically added on for handling and installation (contractors are generally unfamiliar with the process of installation itself). Base aggregates are another cost and are dependent on the depth required, since the base aggregates function as a pond with the void ratio between the rocks varying to the degree necessary.

Pervious Concrete

Similar to porous pavements, pervious concrete systems can also encourage the infiltration, treatment, and storage of stormwater while accommodating vehicular traffic requirements. Pervious concretes utilize Portland cement concrete, similar to conventional concrete, but without the fine aggregate (sand) component. Typically, the mixture includes washed coarse aggregate, hydraulic cement, optional admixtures, and water. This yields a surface containing a matrix of pores that allow stormwater to infiltrate into the subsurface below. A pervious concrete system design life can be 20 years or more.

Like porous pavement, these systems typically have underdrains installed below to ensure the long-term integrity of the system. Pervious concrete is vulnerable to sediment accumulation within the system for the same reasons as porous pavements and similar actions should be taken to ensure the system's stability.

Typical costs for pervious concrete can be significantly more expensive than pavement ($10 - $15 per square foot on average), with additional costs typically added on for handling and installation (many contractors are generally unfamiliar with the process of installation itself). Base aggregate costs vary similarly to pervious pavement.

Concrete Pavers

Concrete pavers utilize high-density precast concrete placed in a grid pattern that allows infiltration of stormwater through a pattern of openings filled with aggregate. When properly installed, pavers work very well under heavy loads, however vehicle speeds must be regulated as the pavers may become dislodged. A paver system design life can be up to 25 years.

Sand or sediment accumulation is a potential problem and needs to be avoided on paver surfaces. Typically, the base materials are gravels with voids. A choker course is applied that prevents migration of fines up from the subbase into the surface (generally ASTM No.8 aggregate).

A typical installation cost for pavers can be around $3.50 per square foot and includes the pavers themselves, leveling layer below, and installation. Like the others permeable surface options, base aggregate cost depends on depth and void ratio necessary to attenuate flow.

Design Considerations

Site Slope

The topography (ground surface slopes) of a site should be evaluated when considering permeable surface system installation. In general, slopes steeper than 5 - 10% will encourage rapid velocities of stormwater and lessen the infiltration tendency for all of these practices. However, parking lot surfaces are typically graded at less than 5% slopes to allow ease of mobility for customers and pedestrians.

Maintenance

Sediment clogging is a potential issue for the life of any permeable surface system. Sediment trapped in asphalt, concrete, and pavers can be removed using high pressure washing and suction. The biggest maintenance issue typically occurs when facilities attempt to sweep without suctioning out the sediment. If an area becomes clogged irreparably, that area can simply be cut out and replaced with conventional asphalt without a significant impact on the infiltration capacity of the overall area (since the underlying base layers will still provide detention capability and treatment).

Filtration/Treatment

In general, permeable surface options achieve high 90th percentile removal of the common constituents found in stormwater runoff in urban environments.

C.17. Pesticide Management Plan

Decscription

A pesticide management plan is a conservation practice recommended for preparation in areas where pesticides are actively applied, stored, and present the potential for introduction into the drainage system. This includes taro operations that generate pesticide loadings during the normal course of operations that are detrimental to watershed health. A pesticide management plan can include an updated list of pesticides currently applied on the subject parcel, known effects to groundwater and surface water, application rates, and other pertinent site specific information that results in the most effective use of pesticides. NRCS should be contacted for information related to creating and maintaining an effective pesticide management plan.

Key Components

- Maps depicting *lo'i* acreage, pond locations, berm locations, existing gates, existing soil data, proximity to impaired or vulnerable water bodies.
- Yield expectations per *lo'i*.
- Summary of onsite soil conditions and pesticide resources available, including:
  - Soil and/or plant tissue testing or historic crop yield response data.
  - Analysis of pesticides applied on *lo'i*.
  - Historic pesticide application rates.
  - An inventory of hazards / concerns to incorporate into evaluation of field limitations.
    - Lava tubes.
    - Shallow soils over fractured bedrock.
    - Soils with high potential for leaching or runoff.
    - Linear distance to surface water bodies.
    - Soils with high erodibility.
    - Shallow aquifers.
  - The best available information for creating recommendations for pesticide sources and crop requirements.
  - Identification of effective application methods and timing rates for pesticides, including:
    - Pesticide rates necessary for realistic pest control.
    - A reduction in pesticide losses to the environment.
    - Avoidance of pesticide application during leaching and runoff periods.
    - Proper calibration and operation provisions for the equipment used.
    - Educational component / training.

C.18. Storm Sewer Disconnection

Description

Storm sewer disconnection involves the removal of strategic sections of existing closed piping networks that transport stormwater through the watershed. Removing sections of the system, and alternatively outletting runoff to open vegetated areas will promote natural system processes. These processes include promoting settling of sediment within runoff, extending the timing of runoff to more closely mimic pre-development conditions, and removal and retention of debris from transport into the nearshore zone.

Disconnecting storm sewer connections is a joint practice that is coordinated with bioretention cell construction, vegetated swales, or other low impact development practices to reduce the closed drainage system service area. Disconnection can be done at any area that has catch basins installed that direct runoff away from the site in lieu of concentrating runoff into depressed areas for treatment. Commercial properties with landscaped areas can utilize the potential for storm sewer disconnection, and implement low impact design practices.

The transition from disconnected stormwater piping outlets to new landscaped, bioretention treatment areas can potentially be softened through the use of native vegetative plantings. This can be accomplished by lining the outlet of the pipe outlet with plantings, as well as the zone between the pipe outlet and bioretention area, resulting in an aesthetically pleasing and environmentally beneficial design.

Appendix D. Designing a Monitoring Program

D.1. Data Management, Evaluation, and Reporting

Identifying specific approaches for accurate collection and analysis of data is essential for determining the effectiveness of implemented management practices. Monitoring stormwater management practices tends to generate a considerable amount of data and information. A well designed and implemented data management program is valuable for the development of comprehensive and ongoing monitoring of management practices.

D.1.1. Quality Assurance and Quality Control

An integral part of any monitoring program is quality assurance and quality control (QA/QC).[68] Development of a quality assurance project plan (QAPP) is the first step in incorporating QA/QC into monitoring (EPA 2002). The QAPP is a critical document for the data collection effort as it integrates the technical and quality aspects of the planning, implementation, and assessment phases of the project. The QAPP documents how QA/QC elements will be implemented during sample collection, data management, and data analysis. It contains statements about the expectations and requirements of those for whom the data is being collected and provides details on project-specific data collection and data management procedures designed to ensure that these requirements are met. Many of the elements and aspects of a QA/QC program are similar across program types, and the elements listed below are general in nature. The implementation of each management practice that will involve the collection and analysis of environmental data should be accompanied by the development of a QAPP.[69] EPA requires four types of elements in a QAPP that include (with some examples):

1. Project Objectives and Management
    - Project/task organization
    - Problem definition/background
    - Project/task description
    - Quality objectives and criteria for measurement data
    - Special training requirements/certification
2. Measurements and Acquisition
    - Sampling process design
    - Sampling handling and custody requirements
    - Analytical methods requirement
    - Quality control requirements
    - Instrument/equipment testing, inspection, maintenance requirements
    - Instrument calibration and frequency
3. Assessment/Oversight
    - Assessment and response action
    - Reports to management

[68] A thorough discussion of QA/QC is provided in Chapter 5 of EPA's *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (EPA 1996).

[69] QAPP should be developed according to the guidance provided in *EPA Requirements for Quality Assurance Project Plans for Environmental Data Objectives* (EPA 1994). Additional information can be found at www.epa.gov/quality/qapps.html.

4. Data Validity and Usability
   - Data review, validation, and verification requirements
   - Validation and verification methods
   - Reconciliation and user requirements

D.1.2. Data Management

A central data management system should be maintained by primary stakeholders with careful consideration for what level of quality control the data should be held to, where and how the data will be held, who will maintain the database, and how much will data management cost. Before initiating monitoring, it is important to establish data management procedures to enable efficient storage, retrieval, and transfer of monitoring data. These procedures should be identified in the QAPP with specifications related to a central filing system, field forms, electronic database, contractor instructions, and computer backup guidelines.[70]

D.1.3. Geographic Information Systems

Geographic Information Systems are useful for characterizing the features of watersheds, documenting changes in land use, and maintaining data on management practice implementation. The spatial relationships among the locations of pollutant sources, land uses, water quality data, trends in land cover and development, installed management practices, and many other features can be represented graphically. Non-graphical data on characteristics of management practices (e.g. sizing of pipes and stormwater inlets, materials used in infrastructure, dates of inspections, and water quality results) can be incorporated into the GIS database and layer attribute tables.[71] A GIS database can be an extremely useful tool for management practice tracking and for detecting trends in implementation, land use changes, and virtually any data related to management practices and water quality. It is also valuable for communicating data to a wider audience. In order to guarantee data integrity and availability, as well as security, guidance for access and control should be laid out in the QAPP.

Hanalei Watershed Hui maintains a central GIS database for Hanalei Bay Watershed. This database contains important past and present information, and should be regularly maintained and updated with new information. Collaboration with past efforts and building onto existing databases would be an efficient means for utilizing GIS in monitoring efforts.

D.1.4. Data Evaluation

Evaluation of management practices includes statistically summarizing and analyzing collected data. Data analysis begins in the monitoring design phase and QAPP when the goals and objectives for monitoring and the methods to be used for analyzing the collected data are identified. Data analysis typically begins with screening and graphical methods, followed by evaluating statistical assumptions, computing summary statistics, and comparing groups of data. The development of a

[70] The International Storm Water Best Management Practice (BMP) Database uses a combination of data entry spreadsheets in Microsoft Excel and a master database in Microsoft Access (Wright Water Engineers and Geosyntec Consultants Inc. 2009). Both the spreadsheets and the master database can be downloaded from www.bmpdatabase.org.

[71] The attribute table of a GIS mapping layer is a relational database that is linked to a geographic feature and stores characteristics of that feature in tabular format.

statistically relevant experimental design for data collection is strongly recommended and would benefit from consultation with a statistician during the design phase.[72]

D.1.5. Presentation of Monitoring Results

Management practice monitoring results should be presented in a practical and comprehensible form. The target audience(s) (scientists, school groups, policy makers, etc.), format (written or oral), and style (graphics, table, etc.) are factors in the selecting the appropriate means for presentation. Presentation of results will be built around the information that was collected, the statistical findings, and the process of the data collection (i.e. experimental design). Technical quality and completeness of results will ensure adequate information for making management decisions related to evaluating the effectiveness of installed management practices.[73]

D.2. Types of Monitoring

Measurable progress is critical to ensuring continued support of watershed management efforts, and progress is best demonstrated through monitoring data that accurately reflects improved water quality conditions relevant to the identified problems. Other applications of monitoring data include: analyzing long-term trends; documenting changes in management and pollutant source activities; measuring performance of specific management practices; calibrating or validating models; filling data gaps; tracking compliance; and providing information to educate stakeholders.

Monitoring includes quantitative and qualitative methods that can range from visual verification of a practice in the field to complex statistical approaches requiring experimental designs. Quantitative monitoring methods are used to quantify pollutant responses to installed management practices and could include sampling of water quality, measurements of solids sequestered, vegetation density, channel morphology, and hydrology. Qualitative approaches often utilize repeated visits to the location of a practice installation or reference area that the practice is designed to improve and taking photographs that show the practices in use or changes to the reference area over time. The level of effort for monitoring can vary significantly, and practical considerations such as availability of funds and the training and background of the persons conducting the monitoring need to be considered when designing the monitoring program. In many instances implementation monitoring is the minimum level of effort that can be performed. This level is often is all that is needed to ensure that some level of pollutant reduction is occurring by simply documenting the pollution control practices are installed.

There are seven types of monitoring used in watershed management (Box D.1 and Table 26) (EPA 1996). There can be considerable overlap and some redundancy between the types and there is no strict definition or standards that define them.

[72] Statistical analysis and sampling designs are addressed in detail in Chapter 3 of EPA's report, *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures – Urban*, and data analysis and interpretation are addressed in detail in Chapter 4 of EPA's *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (EPA 1996; 2001).

[73] Techniques and recommendations for quality presentations can be found in Chapter 6 of EPA's report, *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures – Urban* (EPA 2001).

Box D.1. Types of Monitoring Used in Watershed Management

Trend monitoring. Use of the adjective "*trend*" implies that measurements will be made at regular, well-spaced time intervals in order to determine the long-term trend in a particular parameter. Typically the observations are not taken specifically to evaluate management practices (as in effectiveness monitoring), management activities (as in project monitoring), water quality models (as in validation monitoring), or water quality standards (as in compliance monitoring), although trend data may be utilized for one or all of these other purposes.

Baseline monitoring is used to characterize existing water quality and watershed conditions, and to establish a database for planning or future comparisons. The intent of baseline monitoring is to capture much of the temporal variability of the constituent(s) of interest, but there is no explicit end point at which continued baseline monitoring becomes trend or effectiveness monitoring.

Implementation monitoring assesses whether activities, actions or installation of practices were carried out as planned. The most common use of implementation monitoring is to determine whether management practices were implemented as recommended. Typically, this is carried out as an administrative review and does not involve any water quality measurements. Many believe that implementation monitoring is the most cost-effective means to reduce NPS pollution because it provides immediate feedback to the managers on whether the practices installation are being carried out as intended.

Effectiveness monitoring. While implementation monitoring is used to assess whether a particular activity was carried out as planned, effectiveness monitoring is used to evaluate whether the specified practice activities had the desired effect. Confusion arises over whether effectiveness monitoring should be limited to evaluating individual practices or whether it also can be used to evaluate the total effect of an entire set of practices on water quality and watershed condition.

Monitoring the effectiveness of individual practices, such as the capture of fine sediments by a baffle box, is an important part of the overall process of controlling NPS pollution. However, in most cases the monitoring of individual practices is quite different from monitoring to determine whether the cumulative effect of all or portion of the practices result in reducing the generation and transport of NPS pollutant to receiving waters. Evaluating individual practices may require detailed and specialized measurements best made at the site of, or immediately adjacent to, the management practice. In contrast, monitoring the overall effectiveness of practices is usually done at reference locations along the stream channel or in the ocean. Thus, it may be difficult to relate the measurements at reference locations to the effectiveness of individual practices.

Project monitoring assesses the impact of a particular activity or project, such as good housekeeping practices.

Validation monitoring refers to the quantitative evaluation of a model that is used to estimate pollutant load reductions or achieve some other objective. The intensity and type of sampling for validation monitoring should be consistent with the output of the model being validated.

Compliance monitoring is used to determine whether specified water-quality criteria are being met. The criteria can be numerical or descriptive. Usually the regulations associated with individual criterion specify the location, frequency, and method of measurement.

D.2.1. Trend Monitoring

Trend monitoring is used to measure improvements in water quality and coral reef health over time. As practices to reduce land-based pollutants are implemented, it is expected that marine life will respond positively, resulting a positive trend. While the HBWMP does not specifically call out parameters for trend *monitoring*, on-going activities will provide information to assess water quality and coral reef health. Trend monitoring is being conducted for shoreline water quality (DOH-CWB Beach Monitoring Program, with comparisons to State water quality standards) and coral reef health (DLNR Coral Reef Assessment and Monitoring Program (CRAMP) Surveys). The CRAMP long-term monitoring is conducted to describe the spatial and temporal variation in Hawaiian coral reef communities in relation to natural and anthropogenic forcing functions. CRAMP surveys have and will continue to be conducted in the Hanalei Bay Region.

Long-term trend monitoring of water quality and coral reef health can be used in conjunction with the efforts to monitoring implementation and effectiveness of the management practices recommended in the HBWMP, with the idea that installation and maintenance of management practices will, over time, reduce NPS pollutant loading to streams and off-shore systems, resulting in improved quality. This type of monitoring aligns with NOAA Coral Program's LBSP Performance Measures 3 and 4 (Box 4).

D.2.2. Implementation Monitoring

Implementation monitoring documents and records information about the installation of management practices including: which management practices are being implemented; where they were installed; when they were installed; the entity that installed them; and what pollutants they are targeting. An implementation monitoring program is a mechanism to track progress and provide verification that a recommended practice was installed successfully. Implementation monitoring is probably the most beneficial type of monitoring recommended in the HBWMP since the implementation of strategies to reduce land-based pollutants and adverse impacts to the coral reefs is vital to achieve ecosystem restoration.

The normal sequence of events leading up to implementation monitoring is that a need for a practice to reduce NPS pollutant(s) and the entity responsible for its implementation are identified. The responsible entity then develops detailed engineering designs, generates a cost estimate to install the design and installs the design. In reality, this "normal" sequence often involves a considerable amount of time between the identification of the need and installation of the practice. The biggest reason for this lag time is the lack of funding to design and install the practice. An implementation monitoring plan can be used to document and identify the phases of the process that result in delays to installation to help develop solutions to expedite the process. Implementation monitoring is described in detail in the EPA report *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures - Urban* (EPA 2001). This type of monitoring aligns with NOAA Coral Program's LBSP Performance Measure 2 (Box 4).

D.2.3. Baseline Monitoring

Baseline and effectiveness monitoring are temporally linked by pre- and post-implementation of a practice. Baseline monitoring is the initial pre-project collection of data and information. It transitions to effectiveness monitoring following installation of a practice or beginning of an activity. Baseline monitoring documents existing water quality and watershed conditions and is used to compare changes to a parameter being sampled following implementation of a practice. Water quality baseline data is usually collected at representative locations such as confluence of channels, stormwater outfall locations and at the mouth of streams.

The main objectives of baseline monitoring are to document existing conditions in a watershed by: identifying locations where pollutants are generated; sampling water quality in surface runoff, streams and ocean waters; and mapping flow transport pathways of pollutants. This allows a characterization of the extent of NPS pollution problems in the watershed and its water bodies that can be used to determine the stressors to the aquatic system and assess changes (i.e. post-implementation of management practices). This can be used to tailor the management practice design and identify pollutants that are impairing water quality and to identify location to install practices. Before new data are collected, available historical data, as well as data currently being collected should be identified and consolidated and have their validity and usability assessed.[74] Existing data can help in deciding what other data sets need to be collected, and how to expand the original data set by either continuing with existing protocols or developing new ones that can utilize the existing data. Pooling individual studies assists in identifying trends in environmental conditions and comparing effectiveness of implemented management practices.

Baseline measurements of pollutants in water bodies are often collected to determine whether violations of water quality standards are occurring. Once a problem is identified, determining its spatial scale and geographical and temporal extent helps to focus management efforts. Determining the causes and sources of the impairments are often more difficult than determining its presence because there are often many potential sources with overlapping influences.

Controlling for influencing factors such as climate is necessary if baseline monitoring is to be used as a reference point for trend analysis and management decisions. The ability to relate water quality responses to land management depends on the quality and quantity of data collected prior to any changes of land management practices.

D.2.4. Effectiveness Monitoring

D.2.4.1. Definition and Purpose

Effectiveness monitoring is used to determine whether management practices, as designed and implemented, are functioning as planned and improving water quality. This type of monitoring is essential for determining how effective the practices are once they are installed. The information obtained from effectiveness monitoring can be used to adjust design of the practices, change the types of practices if the installed practices are not effective, identify locations for future installations, and document reductions of NPS pollutants. Effectiveness monitoring is the subject of the EPA guidance document *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (EPA 1996).

Water quality monitoring is an integrated activity for evaluating the physical, chemical, and biological character of water in relation to human health, ecological conditions, and designated water uses (ITFM 1995). An important water quality monitoring element for NPS pollutants is relating the physical, chemical, and biological characteristics of receiving waters to land use characteristics. The most desirable scenario for conducting effectiveness monitoring is to have a robust set of water quality baseline data to compare to the post-practice installation water quality. This scenario will allow a statistical analysis on post-practice load reductions and water quality improvement. When baseline data is unavailable the probability of computing load reductions is low, making load monitoring difficult. Load monitoring requires considerable effort and should follow protocols documented in *Urban Storm Water BMP Performance Monitoring: A Guidance Manual for Meeting the National Storm Water BMP Database Requirements* (GeoSyntec and ASCE 2002). Due to potentially high variability of discharge and pollutant concentrations in the Hanalei Bay Watershed, collecting accurate and sufficient data from a significant number of storm events and base flows over a range of conditions (e.g. season, land cover) is important.

[74] Data validity implies that individual data points are considered accurate and precise with known field and laboratory methods. Data usability implies that a database demonstrates an overall temporal or spatial pattern.

D.2.4.2. Sampling Locations

Effectiveness monitoring is primarily conducted at the location where the pollutant control management practice is installed and on areas along the flow pathway down gradient. Baseline data collected prior to the installation of a practice will provide a reference condition for which to make post installation comparisons against and compute NPS pollutant load reductions. Selection of reference sampling sites that are representative of the flow network is an important step in the monitoring system design. Effectiveness monitoring is the easiest and most accurate way to evaluate if the practice is working as designed. Effectiveness monitoring can also be conducted at representative locations on the water bodies or surface areas located down the flow gradient from the installed practice. However, it is often difficult to correlate the changes measured at sites located away from the practice installation due to unknown inputs and outputs that occur between the installed and sampling sites. In addition, when multiple practices are installed, ascribing changes to one practice becomes difficult and usually the reference sample value is representative of the cumulative impacts derived from all the practices. For this reason some watershed scientists divide monitoring into two categories based on the sampling location following installation of management practices. Samples collected at the installation site are defined as effectiveness monitoring and those collected at reference locations are classified as trend monitoring. In general the monitoring output of these two monitoring types are positively correlated: if a practice is effective (i.e. shown to be trapping fine sediment), then the trend in water quality at a down gradient stream sampling reference site will likely show a decrease in turbidity. The effectiveness monitoring methods identified in Table D.1 are focused on monitoring effectiveness at the installation locations of the management practices.

D.2.4.3. Methods

Effectiveness monitoring can be carried out using quantitative and/or qualitative methods. Qualitative methods are generally easy to conduct, less costly, and do not require significant training to carry out compared to quantitative methods. Qualitative methods are however prone to subjective analysis. Protocols should minimize opportunities for bias and subjectivity during monitoring activities. When utilizing volunteers to conduct monitoring providing sufficient subject matter background is recommended.

Quantitative methods range in complexity, level of effort to carry out, and cost. Selection of the quantitative method should in part be based on the minimum level of effort needed to determine if the installed practice is functioning effectively and meeting regulatory compliance requirements. For example, it may be sufficient to measure the amount of sediment trapped in a baffle box periodically to determine how much sediment was captured per unit time. This would allow calculation of the amount of sediment removed from stormwater that entered the baffle box, and would equate to a reduction of sediment delivered to the receiving waters. The baffle box would be considered 'effective' since it captured sediment. A more involved monitoring scheme would be needed to determine the efficiency of a baffle box and compute the load reduction for a storm event. For example, measurements of flow into and out of the baffle box during a storm event would need to be collected and the concentration of sediment in each measured. This sampling approach allows computation of the efficiency of the baffle box and the pollutant load reduction. It requires more equipment, labor, and total cost to implement compared to simply measuring the sediment in the baffle box.

The reduction in pollutant concentration that an IWS or other installed treatment device provides can be quantified by sampling water entering and leaving the device and comparing the change. The three commonly used measures are concentration grab samples, total contaminant load conveyed over a specified duration (i.e. storm event), or event mean concentration. An understanding of how the monitoring data will be analyzed and evaluated is essential to determine the collection methods. Methods of estimating water quality concentration for various pollutants require significant time, persons with technical skills and adequate funds. They are not recommended as part of the effectiveness monitoring presented in Section 4.3.3, but rather presented as specific examples of rigorous numeric methods that could be conducted.

- Pollutant concentration measured at individual points in time can be useful in determining concentration as a function of time. This type of monitoring is well established at numerous sampling stations in the Hanalei Bay Watershed.
- Pollutant loads are typically calculated by using an average concentration multiplied by the total water volume over the averaging period. Accurate flow measurement or modeling is essential for load estimation. This method can be used to determine dry weather flows that can contribute substantially to long-term loading.
- Event mean concentration is a method for characterizing pollutant concentrations in receiving water from a runoff event. The value is determined by compositing (in proportion to flow rate) a set of samples, taken at various points in time during a runoff event, into a single sample for analysis. The primary aim is to analyze rain storm events at a site. It often provides the most useful means to quantify the pollution level resulting from a runoff event.

In many instances the proper O&M of a management practice is as important as the proper design and installation. Regular maintenance and inspection insures the practice is functioning at full effectiveness. Deferred maintenance can adversely affect a practices' performance and can result in pollutants bypassing or moving through the structure without reduction. Inspections can also identify repair needs or retrofits, as well as areas that require additional management resources. Effectiveness monitoring can be coordinated with routine maintenance schedules and if possible personnel performing maintenance can be enlisted to conduct the effectiveness monitoring.

D.3. Effectiveness Monitoring Protocols

Table D.1. Effectiveness Monitoring for Management Practices[75]

Management Practice	Objective	Protocol	Target Pollutants								Frequency	Location
			Sediments	Nutrients	ODS	Bacteria	Metals	Hydrocarbons	Organics	Stormwater flow		
Aerobic Treatment Unit	Quantitative	Effluent sampling		X		X					As required by permit	
Baffle Box	Qualitative/ Quantitative	Visual assessment; assessment of sediment volume; grab sample	X	X	X	X	X	X	X		Biannually or prior to vault cleanout	
Bioretention Cell (Rain Garden)	Qualitative/ Quantitative	Visual assessment; assessment of sediment volume		X		X	X	X		X	Annually; or after large volume/intensity storm event	
Channel Maintenance and Restoration	Qualitative/ Quantitative	Visual assessment; assessment of sediment volume of affected streambanks	X	X							After removal of *hau* bush from subject area	
Curb Inlet Basket (with Filter)	Quantitative	Visual assessment of debris volume	X								Biannually and after large volume/intensity storm event	
Commercial WWTP Upgrades	Quantitative	Effluent sampling		X		X					As required by permit	
Constructed Wetlands	Qualitative	Visual assessment , assessment of nutrient budget	X	X		X	X	X	X		As required by designer	
Erosion Control Mats and Vegetative Plantings	Qualitative	Visual assessment; vegetation survey	X	X		X					Biannually	
Feral Ungulate Fencing	Qualitative	Visual assessment	X			X					Annually	
Fertilizer Management Plan	Qualitative/ Quantitative	In house review; technical assessment of fertilizer usage		X							Annually, and when new personnel hold responsible charge of fertilizer application practices	
Good Housekeeping Practices	Qualitative	Facility survey		X	X				X		Annually	

[75] Monitoring Objective: Specifies whether analysis is quantitative or qualitative. Protocol: Identifies type of protocol to be used for sampling. Target NPS Pollutants: Identifies NPS pollutants being addressed by the management practice. Frequency: Recommended frequency of monitoring efforts.

Management Practice	Objective	Protocol	Target Pollutants								Frequency	Location
			Sediments	Nutrients	ODS	Bacteria	Metals	Hydrocarbons	Organics	Stormwater flow		
Grass Swale	Qualitative/ Quantitative	Visual assessment; assessment of sediment volume	X			X	X	X		X	Annually and during large volume/intensity storm event	
Grazing Management System	Qualitative	Visual assessment of condition (e.g. riparian buffer, fencing)	X	X		X					Annually	
Gutter Downspout Disconnection	Qualitative	Visual assessment of condition								X	Annually	
High Efficiency Toilets	Qualitative	Visual assessment of condition		X		X					Annually	
Lo'i Management	Qualitative/ Quantitative	Visual assessment; assessment of sediment volume generated	X								Annually	
Permeable Surfaces	Qualitative/ Quantitative	Visual assessment; stormwater outflow sampling	X	X		X	X	X	X	X	After large volume/intensity storm event; minimum biannually	
Pesticide Management Plan	Qualitative/ Quantitative	In house Review; technical assessment of pesticide use							X		Annually; and when new personnel hold responsible charge of application practices	
Storm Sewer Disconnection	Qualitative	Visual assessment	X	X	X	X	X	X	X	X	Annually	
Wetland Pollution Reduction Practices	Qualitative/ Quantitative	Collect soil, water and plant samples for analysis,	X	X	X	X	X	X	X	X	Biannually	

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D.3.1. Aerobic Treatment Unit

Target Pollutants*:* Nutrients, Bacteria measured as TSS and BOD

Monitoring Objective: To verify that cesspools and septic tanks have been closed and upgraded. *DOH Waste Water Branch does not require IWS operators to sample disposed waste water, and it is not realistic to assume owners will sample.*

Protocol: One time upon closure and upgrade.

Frequency: Verification will be in form DOH Waste Water Branch approval.

D.3.2. Baffle Box

Target Pollutants*:* Sediments, Nutrients, ODS, Bacteria, Metals, Hydrocarbons, Organics

Monitoring Objective: (1) Qualitatively assess the amount of vegetation and rubbish trapped in the entry grate. (2) Quantify the amount of sediment deposited per unit time in the boxes' chambers. (3) Identify the chemical makeup of the substances contained in the deposited sediments.

Protocol: Access to the inside of a baffle box is obtained via ports or manholes located above each of the boxes' chambers. (1) Visual assessment of the type and quantity of gross solids (e.g., vegetation, rubbish, and other materials) should be made and recorded. (2) The volume of sediment particles in each of the chambers is the product of the average sediment layer thickness in each chamber and its area. The volumetric measure can be converted to mass by multiplying the volume times an average particle density. Thickness of the deposition layers can be determined using a graduate rod or other measuring instrument. To account for variability of the thickness of the deposition layer, four samples located at middle point along each of the chamber's walls should be collected and a mean thickness computed. (3) Sediment grab samples can be collected and sent to a laboratory to determine composition.

Frequency: Biannually or prior to vault cleanout.

D.3.3. Bioretention Cell (Rain Garden)

Target Pollutants*:* Nutrients, Bacteria, Metals, Hydrocarbons, Stormwater flow

Monitoring Objective: Verify sediment volume within rain garden and verify vegetative/mulch coverage on surface.

Protocol: Estimate sediment volume after determining if upstream contributions are inhibiting the infiltration capacity of the rain garden.

Maintenance: (1) Remove accumulated sediment and dispose of in landfill. (2) Verify presence of mulch layer and replace as necessary if mulch has dislodged and exposed underlying soil layers.

Frequency: Annually, or after large volume/intensity storm event.

D.3.4. Channel Maintenance and Restoration

Target Pollutants*:* Sediments, Nutrients

Monitoring Objective: Function of project intent. For example, if intent is to remove *hau* bush to open up channel, then monitoring objective would be to quantify area treated.

Protocol: Protocol will be a function of the project actions and will be prepared on project by project basis as required by permits.

Frequency: After project completion. Annually until area is stabilized.

D.3.5. Curb Inlet Basket (with Filter)

Target Pollutants*:* Sediments

Monitoring Objective: Evaluate if gross solids are being captured.

Protocol: Document type and estimate volume of gross solids contained on mesh grate during cleaning inspections. Record composition of debris and estimate the dominant debris type.

Frequency: Biannually and after large volume/intensity storm event. Also, concurrent with routine maintenance.

D.3.6. Constructed Wetlands

Target Pollutants: Nutrients, Suspended Sediments, Bacteria, Metals, and Pesticides

Monitoring Objective*:* Quantification of pollutants remediated, and assurance hydraulics are not being impaired.

Protocol*:* Plants and soil samples collected post-installation and then periodically, assayed for pollutants to quantify loads.

Frequency*:* Variable.

D.3.7. Erosion Control Mats and Vegetative Plantings

D.3.7.1. Erosion Control Blanket / Turf Reinforcement Mat

Target Pollutants*:* Sediments, Nutrients, Bacteria

Monitoring Objective**:** Assess existing blanket/mat locations for evidence of scouring or erosion, assess overall condition of practices, and determine if repair actions, or additional corrective practice implementation is necessary.

Protocol**:** (1) Visually assess condition of blankets/mats. (2) Determine whether repair action is necessary. (3) Repair existing blankets/mats as necessary. (4) If additional blankets/mats are required, install by hand methods. (5) Determine other areas in need of repair or practice implementation.

Frequency**:** Biannually.

D.3.7.2. Natural/Native Vegetation

Target Pollutants*:* Sediments, Nutrients, Bacteria

Monitoring Objective: Validate through visual estimation that full vegetative cover is established on former exposed areas.

Protocol: (1) Validate that the location has a minimum of 75% vegetative cover over its areal extent, and blends evenly into the existing vegetation surrounding the hotspot. (2) Validate that vegetation has a healthy appearance and that there are no sparse or dead areas of vegetation that could develop into erosion hotspots.

Frequency**:** Biannually.

D.3.8. Feral Ungulate Fencing

Target Pollutants*:* Sediments, Bacteria

Monitoring Objective: Validate system components are intact and design is working.

Protocol: (1) Walk length of fence to visually assess condition. (2) Determine whether repair is necessary (e.g. breaks, gaps). (3) Repair fence as necessary.

Frequency: Annually

D.3.9. Fertilizer Management Plan

Target Pollutants*:* Nutrients

Monitoring Objective: To verify proper storage, application, timing, disposal, and other factors related to implementation of fertilizers.

Protocol: (1) Review management plans with facility personnel and conduct frequent trainings to ensure proper use. (2) Amend applicable management plans as necessary to reflect changes in application and usage as new data is introduced that results in improved efficiency.

Frequency: Annually; and when new personnel hold responsible charge of application methods.

D.3.10. Good Housekeeping Practices

Target Pollutants*:* Nutrients, ODS, Organics

Monitoring Objective: To determine if behavioral changes are occurring, to what level, and if they are reducing the generation of NPS pollutants.

Protocol: Conduct survey to document type, location, perceived effectiveness of implemented good housekeeping practices, and effectiveness of educational and outreach methods.

Frequency: Annually

D.3.11. Grass Swale

Target Pollutants: Sediments, Bacteria, Metals, Hydrocarbons, Stormwater flow

Monitoring Objective: Validate system components are intact and design is working.

Protocol: Visually inspect swales during runoff events to assess if water is retained and following event to verify that stagnant water conditions do not occur.

Frequency: Annually, or during large volume/intensity storm event.

D.3.12. Grazing Management System

Target Pollutants: Sediments, Nutrients, Bacteria

Monitoring Objective: Validate system components are intact and design is working.

Protocol: (1) Visually assess condition. (2) Determine whether repair is necessary. (3) Repair components as necessary.

Frequency: Annually

D.3.13. Gutter Downspout Disconnection

Target Pollutants: Stormwater flow

Monitoring Objective: Validate system components are intact and design is working.

Protocol: Visually inspect gutter discharge area during storm event to verify outlet is stabilized and there is no evidence of erosion.

Frequency: Annually.

D.3.14. High Efficiency Toilets

Target Pollutants: Nutrients, Bacteria and reduce use of potable water

Monitoring Objective: Validate system components are intact and design is working.

Protocol: (1) Visually assess condition. (2) Determine whether repair is necessary. (3) Repair components as necessary.

Frequency: Annually

D.3.15. Lo‘i Management

Target Pollutants: Sediments

Monitoring Objective: To verify practices are functioning and, to the extent possible, quantify pollutant load reductions.

Protocol: To be developed by installer of practice.

Frequency: Annually

D.3.16. Permeable Surfaces

Target Pollutants: Sediments, Nutrients, Bacteria, Metals, Hydrocarbons, Organics, Stormwater flow

Monitoring Objective: Validate system components are intact and design is working.

Protocol: (1) Visually assess condition for indicators of clogging. (2) Determine whether repair is necessary. (3) Repair components as necessary.

Frequency: Biannually, or during or immediately after storm event.

D.3.17. Pesticide Management Plan

Target Pollutants: Organics

Monitoring Objective: To verify proper storage, application, timing, disposal, and other factors related to implementation of pesticides.

Protocol: (1) Review management plans with facility personnel and conduct frequent trainings to ensure proper use. (2) Amend applicable management plans as necessary to reflect changes in application and usage as new data is introduced that results in improved efficiency.

Frequency: Annually and when new personnel hold responsible charge of application methods.

D.3.18. Storm Sewer Disconnection

Target Pollutants: Sediments, Nutrients, ODS, Bacteria, Metals, Hydrocarbons, Organics, Stormwater flow

Monitoring Objective: Validate system components are intact and design is working.

Protocol: Visually inspect discharge area during storm event to verify outlet is stabilized and there is no evidence of erosion or discharge of pollutants

Frequency: Annually.

D.3.19. Wetland Pollution Reduction Practices

Target Pollutants: Sediments, Nutrients, ODS, Bacteria, Metals, Hydrocarbons, Organics, Stormwater flow

Monitoring Objective: Verify practices have been installed and, to the extent possible, quantify pollutant load reductions.

Protocol: Varies depending on the design and monitoring budget. To be developed on a project by project basis.

Frequency: Biannually.

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