

Engineering design includes, but is not limited to, assessing the physical condition of the installation site¹, evaluating design hydrology parameters following City and County of Honolulu (CCH) requirements, sizing and designing management practices, preparing construction plans and cost estimates, preparing detailed installation drawings, acquiring permits, and construction management. 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.

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

2.2 Financial Resources

Financial resources required to implement the management practices can vary considerably. Comparing cost between the more complex baffle box and a simple grass swale finds that relatively the baffle box cost is high versus low for the grass swale. In many instances the cost for implementing one practice is relatively high when compared to the net benefit it can provide. Similar to production costs that function by economies of scale, the cost to implement per unit management practice goes down as the number of units installed goes up. The total implementation cost increases as more units are installed, but not linearly. As the number of units installed increases, the net benefit in terms of NPS pollutant reduced increases as a power function.

Costs, including capital, Operations and Maintenance (O&M), and time and training requirements associated with installation and maintenance, influence selection of recommended management practices. Comparison of cost to NPS pollutant reduction potential also affects selection of practices. Another consideration that was used in selecting management practices was initial cost to long-term maintenance cost. In general, costs to implement management practices include the following:

- Engineering design, including all plans, drawings, biddable plans and permit acquisition
- Product purchase, including shipping cost
- Construction installation
- Construction Management
- Annual maintenance

Cost and equations to generate cost estimates to implement selected management practices are shown in Table 1. Costs should be considered provisional and order of magnitude estimates. Relative cost information on capital, O&M, and training for the recommended management practices in Wailupe

¹ Assessing a site’s physical condition could include geotechnical analysis, locating utilities, inspecting structures (if the practice is a retrofit), and hydrologic analysis.

Watershed is expressed qualitatively (high, moderate, and low). Relative cost relates the cost of the practice to its performance in terms of reduction of NPS pollutant the practice can be expected to achieve. “Low” indicates a cost ratio of less than one, meaning the cost of the practice is lower than the expected benefit, resulting in the practices being favorable to implement. A high relative cost would mean it costs more per unit reduction of NPS pollutant.

O&M cost refers to the amount of labor and expense required to maintain proper function of the management practice (relative to other management practices). A rating of “low” indicates that the practice does not require much maintenance, “moderate” implies an average amount of maintenance, and “high” indicates the management practice is labor-intensive or otherwise costly to maintain.

Training cost identifies the costs for time and materials needed to train staff on maintenance protocols to maintain the practices in good, safe and efficient operating condition. Some of the recommended practices are expected to require no post-installation maintenance (e.g., revegetation of upslope areas), while other practices will require ongoing routine maintenance (e.g., baffle boxes). The selection process considered the types of maintenance and equipment that would be necessary to maintain the various practices, and compared that to the current equipment and capacity of CCH and Hawai‘i Department of Transportation (HIDOT) departments responsible for municipal separate storm sewer system (MS4) maintenance. For example, baffle boxes can be cleaned using Vector equipment presently owned by both CCH and HIDOT. Practices that would require the purchase of new maintenance equipment were not recommended.

Funding for implementation of management practices can come from a range of sources including Federal, State, local and private sources. In addition to resources at the local and State level that can be used to identify funding opportunities, the Environmental Protection Agency (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* (www.epa.gov/efinpage/guidbkpdf.htm).

Table 1. Costs Associated with Recommended Management Practices

Implementation Cost					
Management Practice	Calculated Cost ²	Relative Cost	O&M Cost	Training Cost	References
Baffle box	\$40,000/unit	Moderate	Moderate	Moderate	Vendor quote
Coir logs	\$22.50/ft.	Moderate	Low	Low	Vendor quote
Curb inlet baskets	\$1800/unit	Low	Moderate	Low	(LA-SMD 2000; USEPA 2003; Field, Tafuri et al. 2004)
Extended detention basin	$C = 12.4V^{0.76}$; V in ft ³	Low	Moderate	Low	(Brown and Schueler 1997; LA-SMD 2000; Barr 2001)
Good housekeeping practices	N/A	Low	Moderate	High	(LA-SMD 2000)
Grass swale	\$0.25 - \$0.50/ft ²	Moderate	Moderate	Low	(Barr 2001)
Green roof – Green grid	\$14 - \$25/sq. ft.	Moderate	Low	Low	(Greenroof 2010, LA-SMD 2000)
Infiltration trench	$C = 16.9V^{0.69}$; V in ft ³	Moderate	Low	Low	(Brown and Schueler 1997; LA-SMD 2000; Barr 2001)
Invasive species control	N/A	High	High	Low	(LA-SMD 2000)
Modular wetland	\$32,000/unit	Moderate	Moderate	Moderate	Vendor quote
Natural/Native vegetation	N/A	Moderate	Low	Moderate	(LA-SMD 2000)
Porous pavement	\$8 - \$12/ft ²	Moderate	Moderate	Moderate	Vendor quote
Rain barrels	\$60 - \$135 each	Low	Low	Moderate	(Brown and Schueler 1997)
Subsurface storage	$C = 12.4V^{0.71}$; V in ft ³ ; \$400 per cubic yard	High	High	High	(Brown and Schueler 1997)
Turf reinforcement mats	\$22/sq meter	Moderate	Low	Low	Vendor quote

² Includes installation cost unless noted otherwise.

3 Implementation Priority

Sites that are generating the most NPS pollutants and locations that are logistically favorable were given the highest implementation priority for management practices. For most of the recommended treatment practices, benefits are manifested immediately or upon the first rainfall event that generates overland flow. The priority pollutant of concern identified in the Maunalua Bay Strategic Conservation Strategic Plan is land based pollutants, specifically fine terrigenous sediment running off into Maunalua Bay (Mālama Maunalua 2006). As described in the *Pollution Control Strategies Report*, sediments are primarily generated from the upper watershed, adjacent slopes, and stream corridor management units. Priority is given to management practices that are designed to reduce the generation and transport of fine sediments, and elevated when they also capture and reduce other NPS pollutants.

The long-term solution to reducing the amount of land based pollutants reaching Maunalua Bay is to prevent generation or reduce generation to background levels. In most cases this is not feasible, especially in the near future. Reducing sediment generation to background levels would require considerable cost and multiple years. Since Maunalua Bay is in poor ecological health, and marine scientists contend there is not a lot of time to act before the Bay's ecology collapses completely, treatment controls that would result in immediate benefits were assigned high priority for implementation. Although there may be a lag time for prevention controls, such as restoring vegetation, to result in significant reduction of NPS pollutants, they are recommended with a lower implementation priority.

Implementation priority considered sediment "hotspots" locations as priority for treatment. An effort was made to identify installation locations along pathways that sediment are routed into the stream and ocean. Since sediment is generated across diffuse and numerous locations, it is most efficient to treat when it enters the MS4 pipe network. The more management practices that are installed, the more NPS pollution is reduced. The installation of a range of practices is expected to result in complimentary treatment and greater reduction rates along the pollution train.

Management practices for implementation were prioritized within each management unit. Similar to ranking the units for priority, specific areas were evaluated and management practices prioritized. The priority for implementation should not be considered rigid, and if a land owner or entity responsible for a particular parcel has resources to implement a management measure that is lower priority the opportunity should be taken. Any installation of a management measure is a positive gain towards reducing NPS pollution regardless of order. Units that are contributing the most sediment should, to the extent possible, be targeted first in order to reduce the largest contribution of sediment to the ocean in a timely manner. Table 2 presents relative implementation priorities for the recommended management practices based on an evaluation of their load reduction of potential and relative cost. Table 3 presents the management units in order of priority and the implementation priority of management practices within each unit.

The recommended management practices identified in this WBP can each be implemented independently. Due to the lack of quantitative data on the source and amounts of pollutants in the watershed, the prioritization is based on the best estimates of where treatments are possible and which treatments will provide the most effective pollutant removal. The prioritization should be used as a guideline, and if there are opportunities to implement a management practice considered lower priority (i.e. available funding,

volunteer work), that should be done. In general, reduction in NPS pollution is a function of the extent to which management practices are installed, including how many and the spatial area they cover.

Table 2. Relative Implementation Priorities

Management Practice	Load Reduction Potential	Relative Cost	Implementation Priority
Baffle box	High	High	High
Coir logs	Moderate	Moderate	Moderate
Curb inlet baskets	High	Low	High
Extended detention basin	Moderate	High	High
Good housekeeping practices	Moderate	Low	High
Grass swale	Low	Moderate	Low
Green roof – Green grid	Low	High	Low
Infiltration trench	Moderate	Moderate	Moderate
Invasive species control	Moderate	High	Low
Modular wetland	High	Moderate	High
Natural/Native vegetation	Low	Moderate	Low
Porous pavement*	Moderate	Moderate	Moderate
Rain barrels	Low	Low	Moderate
Subsurface storage	High	High	Moderate
Turf reinforcement mats	High	High	Moderate

Table 3. Priority Management Practices by Management Unit

Management Practice	Priority
Upland Forest Management Unit	High
Extended detention basin	High
Invasive species control	Low
Natural/Native vegetation	Low
Steep Slopes Management Unit	High
Baffle box	High
Coir logs	High
Infiltration trench	Moderate
Natural/Native vegetation	Low
Turf reinforcement mats	Moderate
Urban Management Unit	High
Baffle box	High
Curb inlet baskets	High
Good housekeeping practices	Low
Grass swale	Moderate

Management Practice	Priority
Green roof – Green grid	Low
Infiltration trench	Moderate
Modular wetland	High
Natural/Native vegetation	Low
Porous pavement	Moderate
Rain barrels	Low
Subsurface storage	Moderate
Stream Channel Management Unit³	Medium
Coir logs	Moderate
Natural/Native vegetation	Moderate
Turf reinforcement mats	High

4 Responsible Entities

Responsibility for implementing management practices will often fall on landowners of the parcel or site where the practices will be installed. 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. In many locations identified in this report where practices should be installed there are no definitive findings 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 and point source pollution control. There are also legal issues and interpretations of laws governing NPS pollutants that are currently being discussed between regulatory agencies that will have bearing on the responsibility of NPS pollution control.⁴

Recommended management practices can be required under a regulatory program or implemented voluntarily. Table 4 summarizes the multiple Federal, State and county agencies that have responsibility related to implementing activities related to controlling polluted runoff and maintaining water quality. Some of these entities have a role in promoting both regulatory and voluntary approaches. Imposing responsibility to implement practices is most effective through economic incentives or by regulatory drivers. Regulatory approaches work best when adequate mechanisms are in place to provide oversight and enforcement. This section describes existing point source and NPS pollution control methods, including adherence to the National Pollutant Discharge Elimination System (NPDES) permit program and other permit conditions.

³ The USACE is currently working on a flood control project in Wailupe. As part of this project they will be developing detailed designs to control bank erosion and will likely be prioritizing sections of the channel for construction and the types of practices to install.

⁴ CCH submitted a draft NPDES permit to HDOH for review. HDOH is addressing issues including the footprint and contributing area of the MS4, and whether NPS pollutants delivered into the MS4 become point source pollutants.

4.1 Regulating Point Source Pollution

Historically, regulatory approaches focused on storm water management for the purpose of preventing property damage and the loss of life. With the enactment of the Clean Water Act and its subsequent amendments, water quality controls were required for certain types of storm water runoff. Point sources are most often controlled using regulatory approaches. Amendments to the Clean Water Act (CWA) in 1972 (Section 402) introduced a permit system for regulating point sources of pollution and provided the statutory basis for the NPDES permit program for regulating the discharge of pollutants from point sources to waters of the U.S. In 1990, Phase I of the NPDES storm water program was established, requiring a NPDES permit to discharge storm water runoff for large or medium municipalities that had populations of 100,000 or more. A ruling in 1999 expanded the NPDES program to apply to all urbanized MS4 and required the development of a storm Storm Water Management Program (SWMP) for storm water outfalls administered by the State.

Hawai'i Department of Health (DOH) administers and approves NPDES permits in the State of Hawai'i. CCH and HIDOT, through the SWMP, are legally bound to implement the terms of the NPDES permit. In Wailupe Watershed both CCH and HIDOT hold NPDES permits approved by DOH. The CCH permit (No. HI S000002) covers most of the land within the urbanized section of the watershed and specifically addresses water discharge from CCH's MS4 into State waters. The HIDOT permit (No. S000001) authorizes storm water discharge from the Highways Division MS4 into State waters. Both permits mandate that discharge comply with the basic water quality criteria specified in Hawai'i Administrative Rules (HAR) Chapter 11-54-4, that pollutants be reduced to the maximum extent possible, and that the permittee take immediate action to stop, reduce, or modify the discharge of pollutants as needed to stop or prevent a violation. Pollutants include: floating debris, oil, grease, scum, or other floating materials; substances in amounts sufficient to produce turbidity or other conditions in receiving waters; substances or conditions or combination thereof in concentrations that produce undesirable aquatic life; and soil particles resulting from erosion on land involved in earthwork.

The CCH NPDES permit's Pollution Prevention/Good Housekeeping section requires the development and implementation of a system maintenance program. Under this plan, the Debris Control Program Plan includes a frequent scheduled sweeping of major streets and roadside litter pick up and includes a Chemical Application Program Plan to reduce the contribution of pollutants (i.e. pesticides, herbicides, and fertilizers) from municipal areas and activities. Suggested management practices include educational activities, non-chemical solutions, and use of native plantings. While the CCH NPDES permit provides direction for effective preventative measures, there are no provisions that require management practices that could capture or treat pollutants in the MS4.

The HIDOT NPDES permit's Pollution Prevention/Good Housekeeping section (Part D-1-f) describes a Debris Control Program Plan that includes a street sweeping schedule. It also describes a maintenance schedule for catch basin cleaning and removal of green waste and accumulated soil. There are requirements to completely map HIDOT's storm drain structures and establish an asset management system to assist with appropriate maintenance scheduling. There are no requirements for management practices to address nutrient loads or other pollutants and toxins that are commonly found in the MS4 and/or can be attributed to vehicular transportation.

In both permits, Part D (Section f3) requires the implementation of erosion control measures in areas where there is potential for significant water quality impacts (i.e. evidence of rilling, gullyng, and/or evidence of sediment transport). It is unclear if CCH and HIDOT are considering erosion from sources that are conveyed by their MS4s, or if the concern is focused on the outfall locations where the water from their pipes may be causing the erosion.

4.2 Managing NPS Pollution

4.2.1 Federal and State Programs

The Federal Water Pollution Control Act [i.e. Clean Water Act (CWA)] and Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) are the Federal laws that provide the principal guidance for NPS pollution control. The CWA addresses polluting activity in the nation's streams, lakes, and estuaries. In 1987 the CWA was amended to include Sections 305(b), 303(d), and 319, which require States to monitor water quality, identify waterbodies that do not meet water quality standards, and develop NPS pollution control programs. Under CWA Section 319, States may apply for Federal funds to pursue projects aimed at NPS pollution control. In 1990, while reauthorizing the Coastal Zone Management Act (CZMA), Congress enacted Section 6217 of CZARA entitled "Protecting Coastal Waters". Section 6217 requires States with approved Coastal Zone Management (CZM) Programs to develop programs to implement NPS pollution controls. CZM Programs have been developed pursuant to Federal requirements by States with coastal lands in order to manage their coastal and ocean resources. States with approved CZM Programs are eligible for Federal funds.

Section 305(b) of the CWA requires states to submit biennial reports to EPA on the condition of waters within their boundaries. Section 303(d) of the CWA requires states to identify water bodies with impaired water quality and the constituents that are impairing the water quality. Maunalua Bay is listed on the State of Hawai'i's 303(d) list, and therefore any point discharge into the streams or the bay directly are required to comply with State of Hawai'i water quality standards. As part of the 303(d) the State is required to develop a Total Maximum Daily Load (TMDL) for each pollutant causing the impairment. The impairments for Maunalua Bay are: total nitrogen, nitrite-nitrate nitrogen, ammonium and chlorophyll a.⁵

At the Federal level, the CWA is administered by the EPA and the CZM Program is administered by the Office of Ocean and Coastal Resource Management, part of the National Oceanic and Atmospheric Administration. State and local government are responsible for the day-to-day implementation of programs designed to meet the requirements of the CWA and CZARA.

In Hawai'i, two programs exist specifically to implement polluted runoff controls. The Polluted Runoff Control Program⁶ is administered by the DOH Environmental Management Division, Clean Water Branch. The Coastal Nonpoint Pollution Control Program is part of the State CZM Program and is administered by the Hawai'i Department of Business, Economic Development and Tourism (DBEDT), Office of Planning. These agencies work in coordination with other Federal, State and county agencies. DOH and the DBEDT maintain separate programs because they have different responsibilities and Federal funding sources, CWA Section 319 and CZARA Section 6217, respectively. To meet the program

⁵ Impaired constituents on 2006 303(d) list are available from DOH: http://hawaii.gov/health/environmental/env-planning/wqm/wqm.html/2006_Integrated_Report/2006_Chapter_IV_Assessment_of_Waters.pdf

⁶ Formerly known as the Nonpoint Source Pollution Control Program.

components required under Section 6217, the State developed *Hawai'i's Coastal Nonpoint Pollution Control Program Management Plan* in 1996. In an effort to guide coordination between the DOH and CZM pollution control programs, the State established a single plan entitled *Hawai'i's Implementation Plan for Polluted Runoff Control* (2000).

4.2.2 Voluntary Initiatives

Parallel to Federal and State programs, and often supported by available funding, voluntary initiatives are an important mechanism for both preventative and treatment control of NPS pollution. There are numerous stakeholders that are affected by NPS pollutants since ultimately they impact water quality of ocean waters. Mālama Maunalua has taken a leadership role in the watersheds that drain into Maunalua Bay, and has identified actions and strategies to reduce NPS pollutants. Community engagement, education, and volunteer programs are an integral part of a comprehensive solution to reduce NPS pollution.

Table 4. Agencies with Responsibilities Related to Controlling Polluted Runoff and Maintaining Water Quality

Federal Agencies
<p>U.S. Environmental Protection Agency (EPA) (Region 9)</p> <p>Responsible for providing clean and safe surface water, ground water, and drinking water and protecting and restoring aquatic ecosystems (Office of Water). Provides funding for Section 319 projects. For Hawai'i, permitting activities have been delegated to the State.</p>
<p>USDA Natural Resources Conservation Service</p> <p>Provides technical assistance for conservation activities. Works closely with the 16 Soil and Water Conservation Districts (SWCD) in Hawai'i. Provides permitting expertise and coordination with permitting agencies.</p>
<p>USDA Farm Services Agency</p> <p>Responsible for most of the Federal financial support regarding farming activities such as farm plans to reduce erosion or control animal impacts on water.</p>
<p>U.S. Army Corps of Engineers (USACE)</p> <p>Charged with protection of the Nation's aquatic resources which is accomplished by: implementing the Nationwide Permits system for certain activities; regulating construction activities in navigable waters and dredging of harbors; regulating the discharge of fill material in wetlands and other U.S. waters; and conducting ecosystem restoration, flood damage reduction, water control projects and various water quality studies. Administers CWA Section 404.</p>
<p>U.S. Coast Guard</p> <p>Responsible for administration of a maritime protection program to prevent and control pollution in U.S. navigable waters. Enforces laws against individuals and companies that pollute marine waters.</p>

State Agencies
<p>DOH Clean Water Branch</p> <p>Responsible for enforcing and revising water quality standards. Water quality standards are maintained through monitoring and enforcement, sponsorship of polluted runoff control projects, review of permit issuance and public education. Administers Section 319 grants programs and NPDES permit process, regulates sewage treatment and disposal, hazardous waste and solid waste, and reviews and issues permits for industrial storm water discharge, construction storm water discharge, MS4 permits and NPDES.</p>
<p>DOH Environmental Planning Office</p> <p>Water Quality Management Program: Responsible for setting the State's water quality goals (Water Quality Standards), evaluating the progress in achieving these goals, and long-range planning to solve water quality problems.</p> <p>Planning Review Program: Reviews development projects with potential environmental impacts and coordinates departmental evaluations on mitigative measures. Implements environmental policies and standards at the earliest stages of the planning process for statewide project developments.</p>
<p>Department of Transportation</p> <p>Responsible for the developing and implementing strategies to control polluted runoff from transportation facilities (i.e. public highways and trails, airports, and commercial harbors). Authorized to enforce polluted runoff control mechanisms for commercial harbors, highways, roads and bridges, including through NPDES permits.</p>
<p>DBEDT Office of Planning</p> <p>Oversees the Hawai'i CZM Program. This program guides appropriate land and water uses and activities through coordination of State and county agencies and ensuring compliance with laws, regulations and management policies, including the requirements of the CZMA. The CZM Program employs a variety of regulatory and non-regulatory techniques to address coastal issues and uphold environmental laws.</p>
<p>Department of Land and Natural Resources (DLNR)</p> <p>Manages State-owned terrestrial and submerged lands and regulates uses in the designated conservation districts. Administers the State's designated marine life conservation districts, marine and freshwater fisheries management areas, wildlife sanctuaries, and natural area reserves. Provides funding to the 16 local SWCDs through the Hawai'i Association of Conservation Districts.</p>
<p>DLNR Commission of Water Resource Management</p> <p>The Commission's staff is comprised of the Surveying, Planning, Ground-Water Regulation, and Stream Protection and Management Branches. Oversees the instream use protection program, which recommends appropriate interim and final instream flow standards. Issues permits for well construction, modification of existing well or pump installation, and alterations of stream channels and diversions.</p>
<p>DLNR Engineering Division</p> <p>Oversees the flood and dam safety program. Provides for the inspection and regulation of construction, enlargement, repair, alteration, maintenance, operation, and removal of dams or reservoirs to protect the health, safety, and welfare of the citizens of the State by reducing the risk of failure of the dams or reservoirs.</p>

<p>DLNR Division of Aquatic Resources</p> <p>Manages the state’s aquatic resources and ecosystems through programs in commercial fisheries and resource enhancement; aquatic resources protection, habitat enhancement, and education; and recreational fisheries. Sets overall water conservation, quality and use policies; defines beneficial and reasonable uses; protects ground and surface water resources, watersheds and natural stream environments; establishes criteria for water use priorities while assuring appurtenant rights and existing correlative and riparian uses and establishes procedures for regulating all uses of Hawai‘i’s water resources.</p>
<p>Department of Agriculture</p> <p>Regulates activities to protect agricultural industries and natural resources against insects, diseases and pests. Controls all eradication services directed against weed and insect pests, and controls the sale and use of pesticides.</p>
<p>County Agencies</p>
<p>City and County of Honolulu</p> <p>Responsible for planning and zoning in urban districts, local transportation, solid waste disposal, subdivision and grading regulation, recreation, and water supply development. Manages state-mandated county regulatory programs dealing with erosion control, urban design, beach access, and park dedication. Legally bound, through the SWMP, to take action per the conditions of the NPDES permit.</p>
<p>CCH Department of Public Works</p> <p>Responsible for planning, designing, inspecting and managing construction projects, facilitating quality control, contracting, construction management, and equipping facilities and other improvements for State agencies. Each project undertaken by the department requires consideration of erosion and sediment control, nutrient management and road construction/ reconstruction.</p>
<p>CCH Department of Environmental Services</p> <p>Issues permits and implements ordinances that address polluted runoff controls. Responsible for the collection and treatment of wastewater, storm water and green debris. Responsible for enforcement of illegal discharges and drain connections to the City’s drain system, water quality monitoring and spill response and prevention. Administers the provisions of the City’s NPDES storm water permit through the Storm Water Quality Branch.</p>
<p>CCH Department of Planning and Permitting</p> <p>Responsible for issuing and administering zoning and land use changes. Issues permits: building, clearing, stockpiling, grading, and construction dewatering. Issues private drain connection licenses to the MS4 and assesses the need for construction of permanent detention/retention and other engineering control structures in developments. Takes enforcement action against illegal grading or construction.</p>
<p>CCH Department of Design and Construction</p> <p>Manages authorized improvements to the City’s public buildings, streets, roads, bridges and walkways, wastewater facilities, parks and recreational facilities, transportation systems, and drainage improvements and flood control. Provides technical assistance when needed.</p>
<p>CCH Department of Facility Maintenance</p> <p>Owns, operates, and maintains the MS4, which includes street sweeping, storm drain cleaning, roadside litter pickup, and maintenance of City-owned streams, channels, debris basins, and other structural practices.</p>
<p>CCH Department of Water Supply and the Board of Water Supply</p> <p>Manages municipal water resources and distribution system. Develops Watershed Management Plans that are used to meet the requirements of preparing a county water use and development plan under the State Water Code and City and County ordinances.</p>

4.3 Implementing Management Practices

An important component of an implementation strategy is identification of the entities responsible for implementing the range of management practices. Often, overall implementation of a WBP is accomplished through the joint efforts of private and public entities. 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. Table 5 identifies the primary entities responsible for implementing the recommended management practices in Wailupe Watershed.

Table 5. Entities Responsible for Implementing and Maintaining Management Practices

Management Practice	Responsible Entities
Baffle box	– CCH – HIDOT
Coir logs	– CCH
Curb inlet baskets	– CCH – HIDOT – Commercial
Extended detention basin	– CCH – Private
Good housekeeping practices	– Community groups – Residents/Volunteers
Grass swale	– CCH – Private – Commercial
Green roof – green grid	– Commercial/business owners
Infiltration trench	– CCH – Private – Commercial
Invasive species control	– Various
Modular wetland	– Private
Natural/native vegetation	– DLNR – Volunteers
Porous pavement	– CCH – Private – Commercial
Rain barrels	– Residents/Volunteers
Retention pond	– CCH
Subsurface storage	– Private
Turf reinforcement mats	– USACE

5 Measurable Milestones

There are two types of milestones that can be used to evaluate whether pollution control measures are being implemented, and if load reductions and load targets are being achieved. The former relates to measuring the success of program implementation – are identified management practices being implemented in areas identified, in a timely fashion, cost-effectively, etc. The latter specifically addresses

the effectiveness of the management practices in achieving reductions in identified pollutant loads, and related improvements to the overall health of the system. In the WBP for Wailupe Watershed, this refers to reducing sediment loading and discharge into the waterways, and improved health of Maunalua Bay.

5.1 Program Implementation

Factors such as funding availability, participation of responsible entities, and pollutant load reduction efficacy will influence feasibility of management measure implementation and the implementation timeline. Milestones for Wailupe Watershed implementation can be assigned to management measures as a means to support scheduling and track tasks (see Table 6). EPA gives three examples of times scales:

- Short-term (1 to 2 years)
- Mid-term (3 to 5 years)
- Long-term (5 to 10 years or longer)

Table 6. Implementation Timeframe for Management Measures

Management Measure	Implementation Timeframe
Bioengineered filtering system	Mid-term
Capture and filter sediment	Short-term
Channel stabilization	Short-term
Detention/retention	Long-term
Erosion protection of bare or exposed areas	Short-term
Flow restrictors/regulators	Long-term
Household generation	Short-term
Identify, prioritize, schedule retrofit opportunities	Short-term
Infiltration	Mid-term
Instream sediment load control	Long-term
Operation and Maintenance	Short-term
Restore natural systems	Long-term
Run-off interception/control	Mid-term
Slope energy	Short-term
Streambank preservation/enhancement	Mid-term

With selected practices, and given available funds and time-scales accounted for, an implementation strategy can be developed. EPA suggests outlining subtasks and the level of effort for each milestone to establish a baseline for time estimates. It is also necessary to collectively discuss milestones and identify those that are feasible and identify the responsible parties (USEPA 2008). Table 7 identifies some of the required subtasks for each of the recommended management practices. As the implementation process moves forward, additional work will be needed to fund the efforts and distribute work requirements.

Table 7. Management Practice Subtasks

Management Practice	Subtasks
Baffle Box	<ul style="list-style-type: none"> - Location logistics - Drainage size - O&M
Coir logs	<ul style="list-style-type: none"> - Available material - Installation - O&M
Curb inlet baskets,	<ul style="list-style-type: none"> - Location logistics - O&M
Extended detention basin	<ul style="list-style-type: none"> - Drainage size - Permits - Construction - O&M
Good housekeeping practices	<ul style="list-style-type: none"> - Education/Outreach - Community acceptance
Grass swale	<ul style="list-style-type: none"> - Location logistics - Community acceptance - O&M
Green roof – green grid	<ul style="list-style-type: none"> - Location logistics - O&M
Infiltration trench	<ul style="list-style-type: none"> - Location logistics - Community acceptance - O&M
Invasive species control	<ul style="list-style-type: none"> - Develop and Implement plans
Modular wetland	<ul style="list-style-type: none"> - Location logistics - O&M
Natural/native vegetation	<ul style="list-style-type: none"> - Location logistics - Irrigation - O&M
Porous pavement	<ul style="list-style-type: none"> - Commercial/business support - Community acceptance - O&M
Rain barrels	<ul style="list-style-type: none"> - Education/Outreach - Distribution
Retention pond	<ul style="list-style-type: none"> - Location logistics - Community acceptance - O&M
Subsurface storage	<ul style="list-style-type: none"> - Location logistics - O&M
Turf reinforcement mats	<ul style="list-style-type: none"> - Available material - Installation - O&M

5.2 Pollution Reduction Targets

Ideally, a WBP should identify specific targets for load reductions of identified pollutants (i.e., sediment). The practical reality of this WBP is that there is no baseline water quality data for use in establishing specific reduction targets. Monitoring efforts to evaluate whether management practices are reducing NPS pollutants are included in the *Evaluation and Monitoring Plan*. An example indicator for measuring pollutant reductions by the management practices is the presence of sediments captured by the installed structures. It will be difficult to quantify specific pollution reduction targets for Wailupe Watershed since there is limited information on baseline conditions. The *Evaluation and Monitoring Plan* addresses both the current lack of available information and the need for ongoing monitoring to both set targets and measure progress towards reducing pollutant loads. Indicators will provide quantitative measurements of progress toward meeting goals and will be easily communicated to target audiences. The indicators and associated targets will serve as triggers to indicate whether progress is being made and whether the implementation approach needs to be reevaluated (see Section 6). It is important to note that often, long and uncertain lag times occur between implementation and response at the watershed level. This timing is accounted for in the evaluation and monitoring framework.

6 Adaptive Management

Adaptive management can be used to address recommendations should the load reductions and load targets not be achieved. 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. 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. Adaptive management builds upon prior results, both positive and negative, and allows managers to continually reassess and incorporate new knowledge into their management practices.

Management actions in a WBP 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 the results allows managers to decide whether to continue the action or to change course. This experimental approach to management means that regular feedback loops guide managers’ decisions and ensure that future strategies better define and approach the objectives of the WBP.

Adaptive management is a powerful way to approach the 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. 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 what is impacting Maunalua Bay becomes available, priorities

pollutants of concern may shift, and management practices would need to be adjusted. The WBP is a living document that will benefit from regular review and updating, to remain current and to support effective management. The *Evaluation and Monitoring Plan* illustrates how adaptive management will be used.

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Watershed Based Plan for Reduction of Nonpoint Source Pollution in Wailupe Stream Watershed

Evaluation and Monitoring Plan

Draft

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1 Introduction

The goal of the *Wailupe Watershed Based Plan* is to characterize and assess the condition of the watershed and to identify management objectives and pollutant control strategies to reduce generation and discharge of non-point source (NPS) pollutants into the receiving waters of Wailupe Stream and Maunalua Bay. A watershed characterization is presented in the *Watershed Characterization Report*, while management practices to address priority problems are presented in the *Pollution Control Strategies Report*. The objective of this *Evaluation and Monitoring Plan* is to provide guidance for monitoring and evaluating the effectiveness of the recommended management practices in reducing NPS pollutants once they are installed. This document presents guidelines and methodologies that will provide both qualitative and quantitative assessments that can be used to determine effectiveness of the practices and adaptively apply the findings to other watersheds.

2 Types of Monitoring

Monitoring is a process that provides feed back 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. Measureable 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 a practice installation location 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 (see Table 1) (USEPA 1996). There can be considerable overlap and some redundancy between the seven and there is no strict definition or standards that define them.

Box 1. Types of Monitoring

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.

Table 1. General Characteristics of Monitoring Types
(USEPA 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	Dependant on project	Moderate to high

This plan focuses on three types of monitoring: implementation, baseline and effectiveness. These three monitoring types best meet the intention of the *Evaluation and Monitoring Plan* requirements and will provide the necessary information to determine if NPS pollutant reduction is occurring and to help refine future selection of practices for other watersheds.

2.1 Implementation Monitoring

Implementation monitoring documents 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. 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 USEPA report *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures - Urban* (USEPA 2001).

2.2 Baseline Monitoring

Baseline and effectiveness monitoring are temporally linked by pre- and post-implementation of a practice. Baseline monitoring is the initial collection of data and information, and transitions to

effectiveness monitoring following installation of a practice or beginning of an activity. Baseline monitoring documents existing conditions of 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 characterization 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.¹ 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 implemented management practice effectiveness.

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.

2.3 Effectiveness Monitoring

2.3.1 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 USEPA guidance document *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (USEPA 1996).

¹ 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.

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 Wailupe Watershed impacted by both point and non-point sources, 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.

2.3.2 Sampling Locations

Effectiveness monitoring is primarily conducted at the location where the pollutant control management practice is installed. This 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 Section 4.3 and Table 3 are focused on monitoring effectiveness at the installation locations of the management practices.

2.3.3 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 and protocols should minimize opportunities for subjective analysis during the monitoring activities. When utilizing volunteers to conduct monitoring sufficient subject matter background should be provided to minimize bias and subjectivity during monitoring.

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 computation of the amount of sediment that was removed from storm water that entered the baffle box, and would equate to a reduction of sediment 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. This scheme 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 a baffle box 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 (EMC). 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, but rather presented as specific examples of rigorous numeric methods that could be conducted by the entity installing the various management practices, or others.

- Concentration measured at individual points in time can be useful to determine concentration as a function of time or if the "first flush" phenomenon occurred during a specific storm event. This type of monitoring is best when focusing on outflow monitoring.
- Contaminant loads are typically calculated by using an average concentration multiplied by the total 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.
- EMC 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 operation and maintenance (O&M) of a management practice is as important as the proper design and installation. Regular maintenance and inspection of a management practice 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 practices 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.

3 Monitoring Logistics

3.1 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. Section 208 of the 1972 Clean Water Act (CWA) requires every state to establish effective practices to control NPS pollution. Urban areas must meet requirements of municipal separate storm sewer system (MS4) permits, and many industries and institutions such as state departments of transportation must also meet National Pollutant Discharge Elimination System (NPDES) storm water permit requirements. Even if monitoring is not required under the NPDES permit, operators of regulated MS4s are required to develop a Storm Water Management Plan (SWMP) that includes measurable goals and states their intention to implement needed storm water management controls (management practices). MS4 operators are also required to assess controls and the effectiveness of their storm water programs and reduce the discharge of pollutants to the “maximum extent practicable.”

In many cases, the recognition of CWA Section 303(d) listing and the subsequent development of Total Maximum Daily Loads (TMDL) for that water body triggers a water quality monitoring program. Under CWA Section 303(d), the EPA requires that each state develop a list of waters that fail to meet established water quality standards. Water bodies that are 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. 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 nonpoint sources, which includes both anthropogenic and natural background sources of pollutants. If the TMDL identifies nonpoint sources of 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 nonpoint source assessment and control as well as individual projects.

3.2 Monitoring Program Administration

The City and County of Honolulu (CCH) and the Hawai‘i Department of Transportation (HIDOT) are required to undertake a comprehensive water quality monitoring and activity tracking/reporting program to comply with NPDES Permits No. HI S000002 and HI S000001, respectively. Both permits describe in Part E the preparation of an Annual Monitoring Plan, the development of a Waste Load Allocation (WLA) Implementation and Monitoring Plan, and development of Implementation and Monitoring Plans for additional WLA’s as adopted by DOH. These requirements are addressed in the SWMPs developed by CCH and HIDOT (CCH-ENV 2007; HIDOT 2007). There are no monitoring requirements or WLAs for Wailupe Stream or the nine other streams that drain into Maunaloa Bay.

Focus in both the CCH and HIDOT WLA Monitoring Plans is on actions in the Ala Wai Canal, Kawa Stream, and Waimanalo Stream; all of which are currently on the 303(d) list of impaired waters and have established TMDLs. In response to waste load reduction goals set by USEPA and HDOH, HIDOT worked jointly with CCH to propose implementation and monitoring plans for each of these water bodies (found in Oahu SWMP Appendices M.2, M.3, M.4). The WLA Monitoring Plans are specific to water quality monitoring and activity tracking to demonstrate efforts towards compliance. The scope of work

outlined in these plans includes drainage area characterization and water quality monitoring to develop a monitoring approach and configure monitoring locations. The U.S. Geological Survey (USGS) is also involved in the program through a separate contract with HIDOT Highways to conduct in-stream and outfall monitoring. The SWMP includes the development of baseline data and a database to record field collection and sampling. HIDOT and CCH will use the databases to estimate the reduction of pollutants once permanent management practices are installed.

Wailupe Stream is not currently listed on the 303(d) list of impaired water bodies and therefore no TMDL has been developed for it. TMDL monitoring is only done after the water body is 303(d) listed and daily loads of the impairing water constituents are established. This is relevant to Wailupe Stream since it means that routine monitoring will not occur under CWA unless there is a specific compliance reason to conduct the monitoring (e.g. spill of pollutant that requires post clean up monitoring). All water bodies in the State are required to adhere to water quality standards, however, most streams are not routinely sampled and determining if a stream is compliant with standards is difficult. It is likely that Wailupe Stream is not compliant during moderate to high discharge events, due to elevated levels of sediments. Maunalua Bay is listed on the 303(d) impaired water body list, but the streams terminating in the Bay are not listed.

3.3 Monitoring and Data Collection Responsibility

3.3.1 Existing Monitoring Efforts in Wailupe Watershed

Currently the USGS, the National Weather Service (NWS), and Mālama Maunalua are the only entities that are routinely and systematically collecting hydrologic data in Wailupe Watershed. The USGS maintains a stream flow gage on Wailupe Stream that continuously records stream flow and a suspended sediment sampler to collect samples during moderate to high flows. There is no water quality sampling program for other parameters in the watershed, and as a result there is very little available data to characterize baseline water quality conditions. The NWS maintains a weather station at Wailupe Valley School, collecting data on a variety of meteorological variables including rainfall and temperature. Mālama Maunalua recently installed two rain gages in Wailupe Watershed along the headwater ridgeline on top of the pali and Wiliwilinui ridge above Aina Haina neighborhood.

3.3.2 Management of Wailupe Watershed Monitoring

At present there is no single entity responsible for collecting and maintaining data and information on water quality and/or watershed conditions in Wailupe Watershed. This WBP has characterized the watershed conditions and made recommendations to on how to reduce NPS pollutants generated from the watershed and discharged into Wailupe Stream and the ocean. This has been an important step towards improving the health of the watershed and its receiving waters, Maunalua Bay. However, there is still a need to develop a water quality monitoring program that can be used to provide baseline data and provide numeric criteria to evaluate the expected changes of water quality following implementation of some or all of the management practices recommended in the *Pollution Control Strategies Report* of this WBP. There needs to be an identified entity conducting baseline monitoring in the watershed, even if not required. Similarly, monitoring the effectiveness of the practices once they are installed is not necessarily required under the CWA, but should be conducted. It is recommended that Mālama Maunalua take the lead on managing, collecting and analyzing the information recommended as part of implementation, baseline and effectiveness monitoring for Wailupe Watershed. Their relationships and collaborations with

various government agencies and private and public partners makes them uniquely qualified to spearhead this effort.

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 would be the most desirable platform for storage of the various data collected in Wailupe Watershed (see Section 5.3).

4 Monitoring in Wailupe Watershed

4.1 Implementation Monitoring for Wailupe Watershed

For each management practice installed in Wailupe Watershed, the following information should be collected. The information should be maintained in a GIS database and/or relational database (see Section 6.3). Information on implementation should be conveyed to DOH, USGS, U.S. Army Corps of Engineers, 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)

4.2 Monitoring of Environmental Conditions in Wailupe Watershed

4.2.1 Baseline Data for Wailupe Watershed

Previous sections of the Wailupe WBP compiled existing data and identified data gaps for Wailupe Watershed. In general, there is a lack of quantitative data for Wailupe Watershed to develop numerical estimates on the concentration of pollutants in runoff water across the watershed. There is sufficient qualitative information to make informed inferences regarding where pollutants loads are generated, what types of pollutants are being generated, and the flows paths that the pollutants use as they are transported off the watershed and into Wailupe Stream and the ocean (see *Inventory of Existing Data and Determination of Data Gaps Report* and *Watershed Characterization Report*). In addition, there are data sets generated from water quality samples collected in Maunalua Bay that support the hypothesis that land based pollutants are the source of pollutants found in the Bay. Baseline data collected in all ten of the watersheds that drain into the Bay would be extremely useful in narrowing down the pollutant constituents that each watershed is generating, as well as the watersheds that are contributing the highest pollutant loads.

Four management units have been delineated in Wailupe Watershed for focusing NPS pollutant types and control methods (see *Pollution Control Strategies Report*). A baseline data monitoring plan is needed for each of these management units. Monitoring methods to collect baseline information that address the

identified priority NPS pollution parameters are identified in Table 2. Sampling of baseline data is not necessary to evaluate the effectiveness of the management practices that are recommended for installation in this WBP. However, establishing baseline sampling sites across the four management units will provide data and information that can be used to implement 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.

Establishment of and data acquisition from baseline sampling locations is expected to provide information that can be used to refine or identify new locations to install practices. A better understanding of the condition of the watershed through acquisition of baseline data will lead to better decision-making regarding the type and locations to install practices. Two types of baseline monitoring sampling stations should be installed: (1) at specific NPS pollutant generating sites; and (2) at reference locations along Wailupe Stream and in the ocean near the stream's mouth.

The overall goals of implementing storm water management practices pertain to preventing pollution at the source, improving storm water 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 that monitoring of Wailupe Watershed will focus upon are 1) fine terrigenous sediments and 2) other NPS pollutants (see *Watershed Characterization Report* and *Pollution Control Strategies Report*).

Table 2. Baseline Monitoring Parameters

Monitoring Location	Monitoring Objective	Method
Upland Forest		
Exposed faces beneath ridgelines	Estimate exposed surface area and potential sediment loss.	Measure surface area, establish photo points, establish erosion pins
Ridge line utility access road, and upland trails	Inventory condition to determine specific locations for BMPs to reduce sediment production.	Ground based survey of road and trails
Upland forested plots (to be determined)	Determine percent ground cover and vegetation types for use in erosion models and assessing ungulate impacts.	Vegetation transect to compute percent cover and species composition
Confluence of three major tributaries of Wailupe Stream above the detention basin	Determine baseline water quality, use for long term trend monitoring	Collect and analyze water samples at routine intervals.
Steep Slopes		
Upper, middle and toe area of slope on west side of Aina Haina below Wiliwilinui ridge.	Determine percent ground cover, erosion rates; identify erosion hotspots locations for coir log or other erosion control structure installation.	Establish transects parallel to slope, measure vegetation density, install erosion pins, establish photo points, and assess condition of gulches draining slopes for erosion hotspot inventory.

Table 2. cont.

Monitoring Location	Monitoring Objective	Method
Urban		
Collect water samples at four storm water pipe outfalls along Wailupe Stream and four at ocean.	Determine baseline water quality of storm water runoff, can be used for long term trend analysis and identifying pollutant hotspots to remediate.	Collect grab samples during runoff events and analyze at lab.
Throughout residential and commercial areas.	Determine attitudes and views of stakeholders; assess willingness to alter behavior to reduce generation of NPSP.	Survey a subset of residents to determine activities and uses that generate NPSP.
Stream Channel		
Establish 6 reference monitoring locations on Wailupe Stream 1. Stream mouth (0+00) 2. + 600 ft. upstream 3. + 1800 ft. upstream 4. + 4330 ft upstream 5. + 6110 ft. upstream 6. + 8550ft. upstream	Determine baseline water quality, geomorphic, vegetation conditions that can be used to evaluate trends in variables following installation of practices, and to identify locations for installing future practices	Establish water quality stations collecting water samples concurrently at routine intervals, establish flow rating curves, establish cross section and longitude profiles, install erosion pins, install vegetation transects, establish photo points, conduct pebble counts, survey aquatic invertebrates

4.3 Monitoring Effectiveness of Management Practices in Wailupe Watershed

This section provides information and guidance on monitoring the effectiveness of management practices once they are installed. Guidance is provided in the form of basic protocols. Results of effectiveness monitoring efforts should be maintained in a GIS database and/or relational database (see Section 6.3).

Table 3 summarizes information on effectiveness monitoring parameters for management practices in Wailupe Watershed. The protocols were developed based on the assumption that members of the Mālama Maunaloa volunteer program would be conducting the effectiveness monitoring.

- **Analysis Type:** Specifies whether analysis will be quantitative or qualitative.
- **Protocol:** Identifies the type of protocol to be used for sampling
- **Target NPS:** Identifies the NPS pollutants being addressed by the management practice
- **Frequency:** Recommended frequency of monitoring efforts
- **Entity:** Persons or organization responsible for monitoring

Table 3. Effectiveness Monitoring for Management Practices

Practice	Monitoring Objective	Protocol	Target NPS Pollutants								Frequency
			Sediments	Nutrients	ODS	Pathogens	Metals	Hydrocarbons	Organics	Storm water flow	
Baffle box	Qualitative/ Quantitative	Visual assessment; sediment volume; grab sample	X	X	X	X	X	X	X		Biennially or prior to vault cleanout
Coir logs	Qualitative/ Quantitative	Photo point; sediment volume	X							X	Biennially
Curb inlet baskets	Qualitative	Debris type and volume	X	X	X	X	X	X	X		Concurrent with routine or as needed maintenance
Extended detention basin	Qualitative/ Quantitative	Visual assessment; sediment volume	X	X			X			X	Storm/runoff event; concurrent with routine maintenance
Good housekeeping practices	Qualitative	Survey		X	X					X	Annually
Grass swale	Qualitative	Visual assessment	X				X			X	Annually; storm event
Green roof – Green grid	Quantitative	Storm water volume								X	N/A
Infiltration trench	Qualitative	Visual assessment	X	X	X	X	X			X	Annually; storm event
Invasive species control	Qualitative/ Quantitative	Collaboration	X	X		X					N/A
Modular wetland	Qualitative/ Quantitative	Visual assessment; grab sample	X	X	X	X	X		X	X	Quarterly; storm events
Natural/Native vegetation	Qualitative/ Quantitative	Vegetation survey	X	X		X					Annually
Porous pavement	Qualitative	Visual assessment	X			X				X	Annually; storm event
Rain barrels	Quantitative	Interview								X	Annually
Subsurface storage	Quantitative	Storm water volume	X	X	X	X	X	X	X	X	Annually; storm event
Turf reinforcement mats	Quantitative	Visual assessment	X								Biennially; storm event

4.3.1 Protocols for Effectiveness Monitoring

This section identifies the type of practice, the objective(s) of monitoring efforts, monitoring protocols, and recommended monitoring frequency for each management practice.

Baffle Box

Practice Description: A baffle box is designed to capture pollutants three ways: trapping gross solids using a mesh grate, settling of particles in one of the chambers, or absorption onto a skimmer boom.

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. These samples should only be collected by persons with the proper training (see Section 5.4.2).

Frequency: Biennially or prior to vault cleanout.

Coir Logs

Practice Description: Coir logs are used to reduce slope length and are installed on the ground perpendicular to the slope. Runoff and material carried is dammed when it encounters the log; water eventually passes through the porous log while particles settle on the upslope side of it.

Monitoring Objective: Evaluate if the coir log is trapping sediment.

Protocol: Qualitative evaluation is conducted by establishing photo points and taking periodic pictures of the upslope face of coir log to visually assess presence of deposited sediment. Quantitative evaluation requires measurements of the volume of sediment on the upslope side of sediment. Volume is computed as the product of the thickness of deposit and its length and width along the face of the coir log.

Frequency: Biennially

Curb Inlet Baskets

Practice Description: Mesh grates placed inside curb inlets used to capture gross solids.

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: Concurrent with routine or as needed maintenance.

Extended Detention Basin

Practice Description: An excavated basin along a waterway fitted with a dam structure is used to temporarily impound runoff and allow particles in the water to settle out of suspension. Extended detention basins attenuate flow out of the basin and trap sediments entering into the basin.

Monitoring Objective: (1) Validate that storm water runoff is being retained. (2) Quantify amount of sediment trapped either per unit time or per storm event. Objective 2 requires surveillance of storm events and rapid mobilization of crews.

Protocol: (1) Visually inspect the basin during stormwater runoff to confirm basin fills. (2) The volume of sediment is the product of the average sediment layer thickness in the basin and its area. Measure the thickness and area of sediment deposits to compute total volume of sediment trapped.

Frequency: Validation of the design to store water can be made during periodic storms that generate overland flow. Quantification of sediment amounts trapped can be done concurrent with routine maintenance to compute a quantity per unit time, or can be conducted immediately after a runoff event to compute quantity per unit time, and quantity per runoff event.

Good Housekeeping Practices

Practice Description: Actions and activities conducted by watershed dwellers that reduce the generation of NPS pollutants and runoff from their properties.

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

Grass Swale

Practice Description: A shallow excavation lined with grass along a waterway that slows flow, temporarily impounds a portion of flow, and filters a portion of pollutants.

Monitoring Objective: To validate 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 for one rain event

Green Roof – Green Grid

Practice Description: A multi layered assembly covered with plants that is used to reduce roof temperature, retain rainfall, and reduce runoff volume and contaminants in it from the roof area.

Monitoring Objective: Quantify the amount of runoff attenuated on roof area.

Protocol: An estimate of the amount of rain water that can be held in the grow medium of the structure is made as part of a green roof design. This estimate can be used to quantify the volume of rainfall can be sequestered on the roof.

Frequency: N/A

Infiltration Trench

Practice Description: A shallow trench that is backfilled with high rock or sand installed along an overland flow path used to promote runoff infiltration. Design is used to reduce overland flow concentration and capture pollutants into the subsurface.

Objective: To validate design is working.

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

Frequency: Annually for one rain event

Invasive Species Control

Practice Description: Program that identifies actions and activities to prevent, reduce and remove invasive species from the ecosystem in order to enhance native ecological systems.

Monitoring Objective: To validate program implementation.

Protocol: The scope of evaluating an invasive species program is extensive and would be best approached by collaborating with University researchers and/or other entities exploring invasive species management programs and assessments.

Frequency: N/A

Modular Wetland

Practice Description: A close-contained structure that mimics a natural wetland and uses natural processes to treat runoff generated from impervious surfaces in a watershed. The wetland is used to attenuate runoff and reduce pollutant loads.

Monitoring Objective: Evaluate the wetland during runoff event to verify it is sized and working properly.

Protocol: During runoff events a sample of water entering and exiting the wetland should be collected. Samples should be analyzed to determine the concentration of target pollutants and the percent reduction of each. The structure should be evaluated to determine that over flow is not occurring and the system is functioning per its design. Plants growing in the wetland should be inspected to evaluate vigor and growth.

Frequency: Quarterly, for four separate rain events

Natural/Native Vegetation

Practice Description: Installation of native plant species along runoff paths, on exposed surfaces, or on areas following restoration activities (i.e. stream channel modifications).

Monitoring Objective: Determine success and survival rates of plants.

Protocol: Vegetation surveys can be conducted for small plots in which each plant is counted at periodic intervals in order to get a value of percent survival. Vegetation transects should be established for large plots.

Frequency: Annually

Porous Pavement

Practice Description: Pavement supporting high usage by pedestrian and vehicular traffic that allows for rainfall infiltration into the subsurface.

Monitoring Objective: Verify that rain water infiltrates into the subsurface and runoff is minimized.

Protocol: Observe the porous pavement site during rainfall event and confirm rainfall infiltration into ground.

Frequency: Annually for one rain event

Rain Barrels

Practice Description: A device used to capture and store runoff generated from roof, slabs, and other impervious surfaces around residential and commercial buildings.

Monitoring Objective: Verify use by building owners and verify storage capacity of barrel.

Protocol: Interview property owners.

Frequency: Annual

Subsurface Storage

Practice Description: These are water storage devices that are installed in an excavated trench below ground and normally covered with fill. Most common uses are to incorporate the storage tank into surface landscaping or place beneath an area such as a parking lot. Water is removed either by gravity (flowing out openings in the base of the reservoir or out an overflow pipe), or by pumping. Subsurface storage reduces overland flow generated from impervious surfaces for use as irrigation water or for slow release into ground water.

Monitoring Objective: Verify installation and operation.

Protocol: Measure depth of water inside tank at access port immediately after rain event that generates overland flow. The volume stored and reduced as overland flow is the product of the depth of the water and the inside area of reservoir.

Frequency: Annually for one rain event

Turf Reinforcement Mats

Practice Description: Turf reinforcement mats are made of synthetic fabric and are used to line a channel to protect the channel bed and bank from erosion. They allow water to infiltrate in substrate and provide for hydraulic connectivity to ground water.

Monitoring Objective: Verify installation is functioning.

Protocol: Following rain events that generate runoff, visually assess the stream reach with the mat to determine if cloth is intact.

Frequency: Biennially, for two separate rain events

4.3.2 Restrictions on Sediment Sampling

Stormwater runoff is generated when water from rainfall events flows over land or impervious surfaces (paved streets, parking lots, and building rooftops) and does not percolate into the ground. As it travels, runoff accumulates debris, chemicals, sediment or other pollutants. During this process, some of the chemicals and pollutants can become adsorbed or deposited into sediments and concentrated in areas where settling occurs (i.e. streambed or ocean) or where a management practice has been implemented. For example, a baffle box installed in a storm drain within the urban area may retain sediments contaminated with chemicals or other pollutants. These pollutants (or contaminants) can include heavy metals, petroleum hydrocarbons, pesticides, herbicides, and polychlorinated biphenyls (Field, Tafuri et al. 2004). Many of these contaminants are known to pose a human health risk at elevated concentrations.

Tier 1 Environmental Action Levels (Tier 1 EALs) are concentrations of over 150 contaminants in soil, soil gas and groundwater below which the contaminants are assumed to not pose a significant threat to human health or the environment (State of Hawaii 2009). During the sampling or handling of sediments, a human health risk can result from direct exposure to contaminants via incidental ingestion, dermal absorption and inhalation of vapors or dust in outdoor air. Exceeding the Tier 1 EAL does not necessarily indicate that contamination poses environmental hazards; however, it does indicate that additional evaluation is warranted (State of Hawaii 2009). This can include additional site investigation and a more detailed evaluation of the tentatively identified environmental hazards. State of Hawaii (2009a), accessible at <http://hawaii.gov/health/environmental/hazard/eal2005.html>, and Section 13 of State of Hawaii (2009b), accessible at <http://www.hawaiidoh.com/>, provide a detailed discussion of the development of the Tier 1 EALs and their use.

There is currently no data to confirm or deny the presence of contaminants in sediments from urban runoff in Wailupe Valley or whether their respective concentrations exceed the Tier 1 EALs. Given the lack of data and the potential presence of listed contaminants in sediments, sampling and chemical analysis of retained sediments for practice effectiveness monitoring should be conducted by personnel with proper training and expertise in handling these materials. This training may include Hazardous Waste Operations and Emergency Response (HAZWOPER) training as required by the Occupation Safety and Health Administration. The need for HAZWOPER-trained personnel may be reevaluated once analytical data is available to support easing the restriction on sampling and handling of sediments. If and when analytical data becomes available, Tier 1 EALs should be used as a screening mechanism to determine whether sediments pose a human health risk for sampling personnel.

The HAZWOPER standard applies to five distinct groups of employers and their employees. This includes any employees who are exposed or potentially exposed to hazardous substances -- including hazardous waste -- and who are engaged in one of the following operations as specified by 29 CFR 1910.120(a)(1)(i-v) and 1926.65(a)(1)(i-v). Individuals in any of the groups described below should receive HAZWOPER training:

- clean-up operations — required by a governmental body, whether federal, state, local, or other involving hazardous substances — that are conducted at uncontrolled hazardous waste sites;

- corrective actions involving clean-up operations at sites covered by the Resource Conservation and Recovery Act of 1976 (RCRA) as amended (42 U.S.C. 6901 et seq.);
- voluntary clean-up operations at sites recognized by Federal, State, local, or other governmental body as uncontrolled hazardous waste sites;
- operations involving hazardous wastes that are conducted at treatment, storage, and disposal facilities regulated by Title 40 Code of Federal Regulations Parts 264 and 265 pursuant to RCRA, or by agencies under agreement with USEPA to implement RCRA regulations; and
- emergency response operations for releases of, or substantial threats of releases of, hazardous substances regardless of the location of the hazard.

5 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 storm water 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.

5.1 Quality Assurance and Quality Control

An integral part of any monitoring program is quality assurance and quality control (QA/QC). Development of a quality assurance project plan (QAPP) is the first step in incorporating QA/QC into monitoring. 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 (i.e. Mālama Maunaloa) and provides details on project-specific data collection and data management procedures designed to ensure that these requirements are met. A thorough discussion of QA/QC is provided in Chapter 5 of USEPA's *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (USEPA 1996). 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 a QAPP according to the guidance provided in *EPA Requirements for Quality Assurance Project Plans for Environmental Data Objectives* (USEPA 1994). Additional information can be found at www.epa.gov/quality/qapps.html. EPA requires four types of elements in a QAPP that include (with some examples):

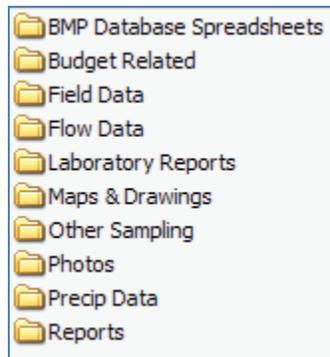
1. Project Objectives and Management
 - Project/task organization
 - Problem definition/background
 - Project/task description
 - Quality objectives and criteria for measurement data
 - Special training requirements/certification
2. Measurements and Acquisition

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

5.2 Data Management

A central data management system should be maintained by Mālama Maunalua 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 (see Figure 1), field forms, electronic database, contractor instructions, and computer backup guidelines. The International Storm Water Best Management Practice Database uses a combination of data entry spreadsheets in Microsoft Excel and a master database in Microsoft Access (WWE and Geosyntec 2009). Both the spreadsheets and the master database can be downloaded from www.bmpdatabase.org.

Figure 1. Example File Directory for Management Practice Monitoring
(GeoSyntec and ASCE 2002)



5.3 Geographic Information Systems

Geographic Information Systems (GIS) are useful for characterizing the features of watersheds 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 storm water inlets, materials used in infrastructure, dates of inspections, and water quality results) can be incorporated into the GIS database and layer attribute tables.² 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 a valuable tool for the 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. A central GIS database for Wailupe Watershed should be developed and maintained. Mālama Maunalua has contracted a consulting group (Geospatial Consulting Group International, LLC) to develop a geodatabase and protocols for data entry to house geospatial data for projects in the Maunalua Bay region. Collaboration with past efforts and building onto existing databases would be an efficient means for utilizing GIS in monitoring efforts in Wailupe Watershed.

5.4 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 statistically relevant experimental design for data collection is strongly recommended and would benefit from consultation with a statistician during the design phase. Statistical analysis and sampling designs are addressed in detail in Chapter 3 of USEPA'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* (USEPA 1996; 2001).

5.5 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 decision making for management decisions for evaluating the effectiveness of installed management practices. Techniques and recommendations for quality presentations can be found in Chapter 6 of USEPA's report, *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures – Urban* (USEPA 2001).

² 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.

6 Evaluating Program Effectiveness

To ensure the most effective pollution control strategies for Wailupe Watershed, the success of management practices to limit generation and transmission of pollutants in the watershed must be regularly evaluated. This section describes challenges to monitoring storm water quality and methods that can be used to ensure that management practices are achieving stated goals and objectives.

6.1 Storm Water Quality Monitoring Challenges

Storm water quality at a given location varies greatly both among storms and during a single storm event. Significant temporal and spatial variability of storm water 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 storm water 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 storm water 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 storm water quality at a given site or the effect of a given management practice.

6.2 Monitoring Program Progress

Regular monitoring must occur in order to determine if progress is being made towards meeting stated goals and objectives. A status report should be developed every year to document progress, challenges, and next steps. Next steps will consist of a list of priority 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.

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.

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 Wailupe WBP should be reviewed (yearly) and updated (as needed) regularly. 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.

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Geospatial Data

Geospatial data was obtained primarily from public data sources (government agencies) and non-profit groups (Mālama Maunalua).

City and County of Honolulu (CCH), Dept of Planning and Permitting (DPP), Honolulu Land Information System (HoLIS) files, NGA 1 Ft Imagery (Oahu) and associated metadata are available for download at <http://gis.hicentral.com/>. HoLIS files are in the following projection: Universal Trans Mercator, Zone 4, NAD 83. State Plane Hawai'i, Zone 3, NAD 83 HARN.

Department of Business, Economic Development & Tourism (DBEDT) files and associated metadata are available for download at <http://www.Hawaii.gov/dbedt/gis/download.htm>. DBEDT files are in the following projection: Universal Trans Mercator, Zone 4, NAD 83.

Hawai'i Gap Analysis Program (HI-GAP) files and associated metadata were from HI-GAP at <ftp://ftp.gap.uidaho.edu/products/Hawaii/>. HI-GAP files are in the following projection: Universal Trans Mercator, Zone 4, NAD 83.

Natural Resources Conservation Service (NRCS) files and associated metadata are available for download at <http://soildatamart.nrcs.usda.gov/>. Zipped file (containing all files for the soil shapefile for the Island of Oahu, including metadata) is current as of April 2010. NRCS files are in the following projection: State Plane Hawai'i, Zone 3, NAD 83.

NOAA/DOC/NOS/NCCOS/CSC files and associated metadata are available for download from *National Oceanic and Atmospheric Administration* (NOAA) (See shapefile and associate .txt file for contact information for source; More information can be found at <http://www.csc.noaa.gov/ccap/pacific/honolulu/index.html> and <http://www.sanctuaries.noaa.gov/>). NOAA files are in the following projection: State Plane Hawai'i, Zone 3, NAD 83.

Mālama Maunalua files and associated metadata were obtained from their GIS database. Mālama Maunalua files are in the following projection: Universal Trans Mercator, Zone 4, NAD 83.

U.S. Geological Survey (USGS) files and associated metadata are available for download at <http://hawaii.wr.usgs.gov/oahu/data.html>. Zipped file (containing .jpg and metadata) is current as of April 2010. USGS files are in the following projection: Universal Trans Mercator, Zone 4, NAD 83.