Watershed Based Management Plan for Honouliuli Watershed:

A Guide for Erosion and Sediment Control on Agricultural and Forest Reserve Lands

View of the Honouliuli Watershed from the base of the Waianae Mountains.

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Honouliuli Watershed Plan - Executive Summary

The Watershed Based Management Plan for the upper portion of the Honouliuli Watershed (aka the Honouliuli Watershed Plan, or the Plan) is an overview of a strategic approach to address non-point source (NPS) pollution from a defined project area within the Honouliuli watershed. The Oʻahu Resource Conservation and Development (Oahu RC&D) Council recognized the project area as a high priority area to apply conservation management measures that would reduce erosion and sediment and nutrient delivery to the Honouliuli Stream and the receiving waters of Pearl Harbor.

The Honouliuli Watershed Plan is intended to provide guidance to stakeholders in the project area, interested community stewardship groups, and local, state, and federal agencies that are interested in the protection or restoration of surface water quality. The plan identifies strategic approaches to address non-point source (NPS) pollution and has three main objectives:

1. to identify the causes and sources of NPS pollution in the project area;
2. to strategically identify and prioritize conservation practices that will control NPS pollution and minimize their delivery to receiving waterbodies;
3. to provide information and support for stakeholders to implement conservation practices into their management activities.

The project area consists largely of agricultural and forest reserve land that typifies much of the land in the upper elevations of the Pearl Harbor watershed region. The Plan focuses on these major land use types and associated activities to identify primary pollutant types and their causes. Agricultural land use includes row crop production, for corn and truck crops, and grazing. The Honouliuli forest reserve is recognized as a refuge for rare and endangered plants and animals, and as an area for research and education, community service and cultural preservation. Known and perceived concerns in these land use types that could potentially lead to water quality impairments were identified by gathering and summarizing existing data such as climate conditions, land use and land cover, current management methods, stakeholder concerns and observations, and existing management plans.

The watershed and project area characterization section summarizes the general environmental conditions of the watershed and was developed through field investigations and geospatial data analysis using geographic information system (GIS) software. Along with on-going consultation by experts and stakeholders, Oahu RC&D utilized available Natural Resources Conservation Service (NRCS) technical resources to identify natural resource concerns, quantify load reduction potential, and to distinguish priority areas for management practice installation. As part of this program, an implementation schedule with milestones and evaluation components was included. The Plan is also intended to provide support to maintain and conduct educational activities and outreach that will increase implementation, tracking, and evaluation of management practices.

A pollution control strategy included management measures for addressing resource concerns in the major land use types. Recommended measures for agricultural areas include managing for erosion and sediment control, nutrients, pesticides, irrigation water, and grazing. Management measures for the Honouliuli forest reserve include management of access roads, fire, pre-harvest planning, streamside management zones, and re-vegetation of disturbed areas. Specific practices to achieve load reductions were identified using NRCS's Field Office Technical Guides (FOTGs). The FOTG database provides in depth information on a large number of conservation practices, including guidelines and standards for implementation and maintenance.

The NRCS has standardized computer programs and models that were utilized to quantify sediment delivery and yield reduction from the project site to receiving waterways. Estimated results for load reduction serve as a valuable qualitative reference for selecting and implementing recommended management practices. The Revised Universal Soil Loss Equation Version 2.0 (RUSLE2) model provided estimates of the average annual soil erosion and delivery from selected areas. Value inputs for the RUSLE2 model were based on climate, soil, topography, and land use within varying regions of the project area. An input value for implemented practices, or combination of practices, was included to show effects from varying levels of conservation management systems. Results from the RUSLE2 indicated that installing a progressive management system that focused either on soil loss or delivery rate will in turn reduce the other; however reduction rates were magnified when both were implemented in a comprehensive system. Additionally, the WinTR-55 sediment yield reduction model was used to simulate runoff from storm events for the entire project area. Results showed that improving vegetative conditions in the lower and mid project areas significantly reduce erosion and sediment delivery.

The implementation strategy recognizes the economic impacts of implementing management measures by analyzing the cost to install and maintain conservation practices. Further GIS analysis and groundtruthing was utilized for quantification purposes and for prioritizing the implementation of conservation practices based on land use category and the propensity of the soil at the site to water erosion. A schedule for implementing NPS management measures is included in the Plan, and identifies five years of activities that begin in years previous (2011) to the Plan completion, and extends beyond its publication. An outreach strategy for continued participation from stakeholders in the project area aimed at garnering support from the local community is also proposed that includes an information, education, and public participation component.

The Honouliuli Watershed Plan provides a framework for addressing erosion and sediment delivery from the project area. Implementation of the management measures presented in the Plan is expected to reduce generation and transport of land-based pollutants, resulting in improved water quality and ecosystem health in receiving waterways in the watershed and ultimately Pearl Harbor Bay. The Plan provides a framework that can be used for other watersheds in the Pearl Harbor region and will offer guidance for future planning initiatives and voluntary conservation efforts in the watershed.

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Acronyms

ATFS	American Tree Farm System
CN	Curve Number
CMS	Conservation Management System
CN	Curve Number
CPPE	Conservation Practice Physical Effects
CSG	Crest stage-gage
CTAHR	College of Tropical Agriculture and Human Resources
CWA	Clean Water Act
CZM	Coastal Zone Management
DAR	Division of Aquatic Resources
DLNR	Department of Land and Natural Resources
DoD	Department of Defense
DOH	Department of Health
DOFAW	Division of Forestry and Wildlife
DRG	Digital Raster Graphics
EPA	Environmental Protection Agency
EQUIP	Environmental Quality Incentives Program
FOTG	Field Office Technical Guide
FSA	Farm Service Agency
HAPPI	Hawaii's Pollution Prevention Information
HAR	Hawai‘i Administrative Rules
HEL	Highly Erodible Land
HMEP	High Moderate Erosion Potential
HSG	Hydrologic Soil Group
HSVAP	Hawai‘i Stream Visual Assessment Protocol
MEP	Moderate Erosion Potential
MLRA	Major Land Resource Areas
NIFA	National Institute of Food and Agriculture
NOAA	National Oceanic and Atmospheric Administration
NPS	Non-Point Source
NRCS	National Resources and Conservation Service
OM	Organic Matter
ORCD	O‘ahu Resource Conservation and Development
PCB	Polychlorinated Biphenyls
RUSLE2	Revised Universal Soil Loss Equation Version 2.0
SWCD	Soil and Water Conservation Districts
TMDL	Total Daily Maximum Load
T&E	Threatened and Endangered
UH	University of Hawai‘i
USDA	United States Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S Geological Service

1 Honouliuli Watershed Plan Overview

1.1 Introduction

“The name Honouliuli, literally ‘dark bay”, perhaps gets its name from the waters of ‘West Loch of Pearl Harbor”. –M. K. Pukui, 1974

The State of Hawai’i Department of Health identified Pearl Harbor as an impaired water body where existing water quality does not meet applicable water quality standards. The Honouliuli watershed, which makes up a part of the larger Pearl Harbor watershed, was identified by the O‘ahu Resource Conservation and Development (ORCD) Council as a high priority area to apply conservation management measures that would reduce erosion and sediment runoff. Once implemented, these management measures will decrease erosion and sediment delivery and subsequently improve water quality in the Honouliuli watershed and its runoff that ultimately discharges into the West Loch of Pearl Harbor. This watershed plan focuses on addressing water-related issues associated with existing land use types; specifically, the identification and management of *Non -Point Source* (NPS) pollution originating from the project area that encompasses the upstream segment of the Honouliuli stream. Developing a plan for Honouliuli’s project area represents a significant step towards achieving water quality standards in the entire Honouliuli watershed. This plan will provide a framework that can be used for other watersheds in the Pearl Harbor region and will offer guidance for other planning initiatives and voluntary conservation efforts in this and other watersheds.

1.2 Purpose

“Erosion is a process of detachment and transport of soil particles by erosive agents”.

W.D. Ellison, 1944

This report was developed to provide an assessment and comprehensive plan for managing NPS water quality-related issues and subsequently minimize the Honouliuli watershed’s potential of being listed as an impaired water body within Pearl Harbor’s 303(d) listing. To be specific, this report characterizes the project area’s natural resources and land use types to identify NPS pollutant types, manage and control them to enhance existing conditions, and provide appropriate recommendations for implementing conservation practices. Cooperation and participation of landowners and stakeholders was imperative in completing this report.

Terrigenous sediments and nutrients are land-based pollutants causing significant adverse impacts to the water quality within the Pearl Harbor watershed. Anthropogenic influences on land use, both urban and agricultural, can adversely impact stream ecosystems and ultimately the water quality entering into the Harbor. Erosion and runoff from agricultural, urban, and industrial activities (e.g. farming, road building, logging, construction, etc.) are transported via stormwater runoff and introduce sediment and nutrient yields into the Honouliuli stream and encompassing Pearl Harbor watershed. Although erosion is a natural process in this area, it becomes an issue when it is accelerated beyond natural rates due to external conditions such as land run-off, precipitation, and hydrologic modifications. Sediment particles can act as a transport agent for chemicals present in upland soils through adsorption of metals, nutrients, oil, pesticides, and other potentially toxic chemicals (Oki and Brashner 2003). The problems associated with sedimentation and NPS pollution is further exacerbated by stormwater runoff into conveyance systems where NPS pollution becomes concentrated and may then be treated as a point source discharge, subject to permit requirements of the Clean Water Act (CWA). Land in the project area is managed primarily for agriculture and forest reserve that are both likely to contribute to NPS sediment and nutrient loads deposited into the coastal waters of Pearl Harbor.

While water quality issues remain the focus of this plan, it is worth noting concerns related to conditions of water quantity as they relate to water quality. To be specific, there are approximately 45 additional linear miles of ditches/ drains that move water into and out of agricultural fields. The Waiahole Ditch System runs through Honouliuli's project area and across the ʻEwa plain carrying surface waters to and from the Waikele and Kaloi watersheds. These ditches and drains may become overwhelmed with stormwater runoff during intense rain events. The West Loch Golf Course, located in the lower region of the watershed, acts additionally as flood protection for the watershed during storm events but at a cost to the golf course as it gets inundated with high yields of sediment during flood events. Sediment deposited during past and recent flooding events has resulted in a loss in income for the golf course due to temporary closures needed to clean up and restore the golf course to recreational use.

Figure 1. Photo of Sedimentation at West Loch Golf Course after December 2008 Storm Event.

1.3 Objective

The objectives of this report are threefold: 1) to identify the causes and sources of NPS pollution in the project area; 2) to strategically identify and prioritize conservation practices that will control NPS pollution and minimize their delivery to receiving waterbodies; and 3) to provide information and support for stakeholders to implement conservation practices into their management activities.

1.4 Methodology

The following documents were used in the development of this report: the State of Hawai‘i’s (2010) Watershed Guidance, the Environmental Protection Agency’s (EPA) Handbook for Developing Watershed Plans to Restore and Protect Our Waters (USEPA 2008) and Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters (USEPA 1993).

The Hawaii Watershed Guidance includes six Guiding Principles for Watershed Management that were incorporated into this plan. These principles include:

1. Risk Based: integrates risk reduction measures based on existing hazards and projected future impacts of climate change
2. Community-based: engages communities in plan development and implementation
3. Place-based: considers unique social, economic, and environmental characteristics of the watershed
4. Integrated: considers connections between land and sea as well as cumulative impacts of planned actions and other planning efforts
5. Culture-based: builds on Native Hawaiian knowledge, principles, and practices
6. Collaborative: promotes collaboration among stakeholders at all stages

The first four steps of a six-step planning and implementation process, following the EPA handbook, served as a framework for the preparation of this plan. The six steps in the recommended planning and implementation process are:

1. Build partnerships
2. Characterize the watershed
3. Set goals and identify solutions
4. Design the implementation program
5. Implement the plan
6. Measure progress and make adjustments

The EPA has identified nine key elements of successful watershed plans to achieve water quality improvements.

1. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan.
2. An estimate of the load reductions expected from management measures.
3. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions and a description of the critical areas in which those measures will be needed to implement the plan.
4. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement the plan.
5. An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

6. Schedule for implementing the nonpoint source management measures identified in the plan that is reasonably expeditious.
7. A description of the interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.
8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.
9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under the previous element.

Additionally, this study implements components of Hawaii's Coastal Nonpoint Pollution Control Program Management Plan (prepared June 2006 by the Hawaiʻi Coastal Zone Management (CZM) Program under Section 6217, Coastal Zone Act Reauthorization Amendments). In Chapter 2 of this plan (titled "Management Measures for Hawaiʻi"), the means of implementing management measures with recommended conservation practices for erosion and sediment control are described for agriculture and forestry land use types, specifically.

2 Water Quality Standards

Streams or coastal waters are considered impaired if they do not meet Hawaii's water quality standards that support its designated use. Standards and regulations are listed in the Water Quality Management Plan for the State of Hawaii, Hawaiʻi Administrative Rules (HAR) Chapter 11-54. This Plan assesses the basic criteria for identifying elevated levels of toxic pollutant standards that would be cause for 303(d) listing as an impaired water body. Intermittent and perennial streams are considered for the following specific water quality criteria: basic criteria (narrative 'free of' and numeric standards for toxic pollutants; HAR §11-54-4), inland recreational waters (HAR §11-54-8.a), water column (HAR §11-54-5.2.b) and stream bottom (HAR §11-54-5.2.b.2) (HDOH 2006).

Specific water column criteria for Hawaiʻi streams (HAR §11-54-5.2) were first established in 1979 and were last revised in 2004. Four parameters (temperature, pH, dissolved oxygen, salinity) have designated limits defined by specific upper or lower bounds. Five other parameters (turbidity, total nitrogen, nitrate+nitrite nitrogen, total phosphorus, and total suspended solids) are defined by three numeric criteria – a geometric mean and two exceedance values (10% and 2%) for each of the two seasons (wet and dry). The given numeric water quality criteria for these parameters are referenced in Table 1, where the following terms are defined:

1. The geometric mean (GM) is calculated as the *n*th root of the product of *n* sample values, where *n* is the total number of samples. The GM of all time-averaged samples should not exceed the given value.
2. 10% exceedance value. No more than 10% of all time-averaged samples should exceed this value.
3. 2% exceedance value. No more than 2% of all time-averaged samples should exceed this value.

Table 1: Hawai‘i Inland Water Quality Criteria for Streams (HAR §11-54-5.2)

Parameter	Geometric mean not to exceed the given value		Not to exceed the given value more than 10 percent of the time		Not to exceed the given value more than 2 percent of the time	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
Total Suspended Solids (TSS) (mg/L)	20	10	50	30	80	55
Nitrate + Nitrite as Nitrogen (µg/L)	70	30	180	90	300	170
Total Nitrogen (µg/L)	250	180	520	380	800	600
Total Phosphorus (µg/L)	50	30	100	60	150	80
Turbidity (NTU)	5.0	2.0	15	5.5	25.0	10.0

Source: DOH Hawai‘i Administrative Rules Section 11-54-5.2(2)(b)
Wet Season (November 1 through April 30); Dry Season (May 1 through October 31).
Micrograms per liter (µg/L); Milligrams per liter (mg/L); Nephelometric turbidity units (NTU)

3 Knowledge Base

3.1 Other Studies and Reports

Watershed and stream resources in Hawai‘i have been studied by a range of public and private entities including University research departments, State and Federal agencies and community organizations. Extensive historical data can be found regarding land use and water transport and have provided a rich illustration into human settlement and the temporal transitioning of natural resources on O‘ahu. Management systems and conservation practices suggested for the project area will be supplementary to previous work and management plans that have addressed the primary causes and sources of impairments and dominant land use types. Information regarding the current regulations for the navigable waters of Honouliuli stream and the larger Pearl Harbor watershed and its designated uses were gathered from several sources including the State water standards and quality reports (i.e. Hawai‘i Administrative Rules and under Sections 303(d) and 305(b) of the CWA).

Sources of suspended sediment in the Waikele watershed, O‘ahu, Hawai‘i (Izuka 2012)

The purpose of this study is to identify sources of suspended sediment in the Waikele watershed. The study was conducted by the U.S. Geological Survey (USGS) in cooperation with the City and County of Honolulu, Department of Environmental Services. Data from stream flow/ sediment gages and measurements of changes in channel-bed sediment storage were gathered between October 1, 2007, and September 30, 2010, to assess the sources of suspended sediment in the Waikele watershed, O‘ahu, Hawai‘i. Suspended-sediment yield from the Waikele watershed during the study period averaged 82,500 tons per year, which is 2.7 times higher than the long-term average. More than 90 percent of the yield during the study period was discharged during the December 11, 2008, storm. The study-period results are consistent with long-term records that show that the vast majority of suspended-sediment transport occurs during a few large storms. Results of this study also show that all but a small percentage of the suspended-sediment yield came from hillslopes (areas between stream channels). Of the three land uses considered, agriculture had by far the highest normalized suspended-sediment yield during this study—about an order of magnitude higher than forests and two orders of magnitude higher than urban areas.

Central O‘ahu Watershed Study (Oceanit 2007)

The Central O‘ahu Watershed Study is an overview of watershed information pertinent to the Central O‘ahu and ‘Ewa Districts; including all of the streams and their related lands that drain into the larger Pearl Harbor watershed. Resource problems and issues were identified and potential projects and programs to remediate these issues were investigated and outlined (Oceanit 2007). This important report serves as an extensive inventory of background research and information for the entire region, compiling and identifying critical problems, issues and needs relating to man-made and natural water systems. In relation to Honouliuli watershed's agricultural lands, the study recognized the community concern over future losses of agricultural lands to urban land use. Plans for future development support an Urban Growth Boundary that protects and minimizes agricultural lands from being developed. Development of the management and control plan for decreased sedimentation efforts identified the following needs:

A. Identification of sediment sources,
B. Incentives to increase the use of conservation practices, and
C. Reduction in sediment volume.

Terrestrial degradation was identified as a priority issue occurring in the undeveloped lands. Resource planning to address terrestrial degradation included increasing wildfire prevention and response to protect the hundreds of acres of forest, native species and critical habitat. Also, protection of undeveloped lands, such as in the Honouliuli Forest Reserve, would help to maintain permeability, reduce soil compaction and preserve vegetation and potential habitat for native species. Other needs identified in the Central O‘ahu Watershed study included watershed education and partnerships to build awareness and improve natural resource management.

The Nature Conservancy's Honouliuli Preserve Master Plan (TNC 2000)

The purpose of the Honouliuli Preserve Master Plan is to direct strategies and actions related to resource management and public involvement (TNC 2000). The Key Natural Resources Management Strategies of the plan are: 1) threat control (wildfire, invasive alien plants and invasive alien animals); 2) habitat restoration; 3) rare species protection and recovery; 4) promote research; and 5) safety and preservation maintenance. Although there is no direct mention for the need for sediment and erosion control as it relates to runoff from the reserve, strategies that increase biodiversity and promote the establishment of natives species, seek to control invasive ungulates, and provide maintenance for human disturbances, all directly impact the causes and sources of NPS pollution and erosion.

Farm Conservation Plans

Conservation Plans for individual farms are developed using guidance from the United States Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) in cooperation with the local Soil and Water Conservation Districts (SWCD) (see Appendix 1 for a sample Conservation Plan). Conservation Plans evaluate resource concerns in five broad areas: soil, water, air, plant and animal; and recommendations are made based upon these resource concerns. Conservation Plans typically cover a 3–5 year timeframe, but can be relevant beyond this period as long as production styles and management remain the same. In the Honouliuli Watershed, soil erosion is a primary concern, and therefore Conservation Plans developed for farms in the project area include conservation practices like terraces and diversions, cover crops, field borders, vegetative barriers and other practices that reduce erosion and runoff.

The Division of Aquatic Resources Biological survey

The Division of Aquatic Resources (DAR) has surveyed streams, estuaries, lakes, ponds, reservoirs, ditches, and diversions throughout the Hawaiian Islands to provide a database of critical information for monitoring, assessing, managing and protecting freshwater resources (DAR 2008). Watershed and stream features, biota information and historical information were compiled for each watershed in Hawaiʻi. The Honouliuli watershed survey identified the dominant land use types as agriculture and conservation. Biotic sampling found the endemic *Megalagrion xanthomelas* in the middle reach of the Honouliuli stream; therefore, meeting the DAR's decision criteria to be considered a stream of biotic importance. Furthermore, in 1994, the U.S. Fish and Wildlife Service (USFWS) proposed that *M. xanthomelas* be listed as a threatened species and given protection under the Endangered Species Act where it remains as a candidate species (Polhemus 1996).

NRCS Field Office Technical Guide Pacific Islands Area

The NRCS has provided scientific technical guides, referred to as electronic Field Office Technical Guide (FOTG) that are numerically identified and are publically available[1]. They contain technical information about the conservation of soil, water, air, and related plant and animal resources. Technical guides used in each field office are localized so that they apply specifically to the geographic area for which they are prepared. Content is organized electronically providing easy-access for users to search and display FOTG's and other important technical and financial information needed.

4 Honouliuli Project Area Profile

4.1 Location of Honouliuli Watershed and Project Area

The Honouliuli watershed (hydrologic unit code 20060000) covers a total of 12,640 acres (ac) in the southwest region of the Island of Oʻahu. The watershed extends from its headwaters located in the Waianae Mountain range through the Ewa Plain to Pearl Harbor (see Figure 2). The primary water body in the Honouliuli watershed is the Honouliuli Stream. This perennial/ intermittent stream and its tributaries have a total stream length of 32.5 miles and discharges into the West Loch of Pearl Harbor. Honouliuli Stream is flashy in nature, characteristic of many of Hawaii's streams, due to the small steep watershed and intense rainfall rates. The Honouliuli Watershed is located within the Honouliuli Ahupuaʻa which is the western portion of the ʻEwa Moku.

The Honouliuli project area consists of approximately 7,256 ac of the upper portion of the Honouliuli watershed and is bounded by the Waiʻanae mountain range to the northwest, H-1 freeway at the south, and Kunia Road along the eastern boundary (see Figure 3). The elevation in the project area ranges from 160 ft to 3,080 ft.

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[1] Public access to the eFOTG is available through the NRCS National website: http://www.nrcs.usda.gov/technical/efotg/index.html

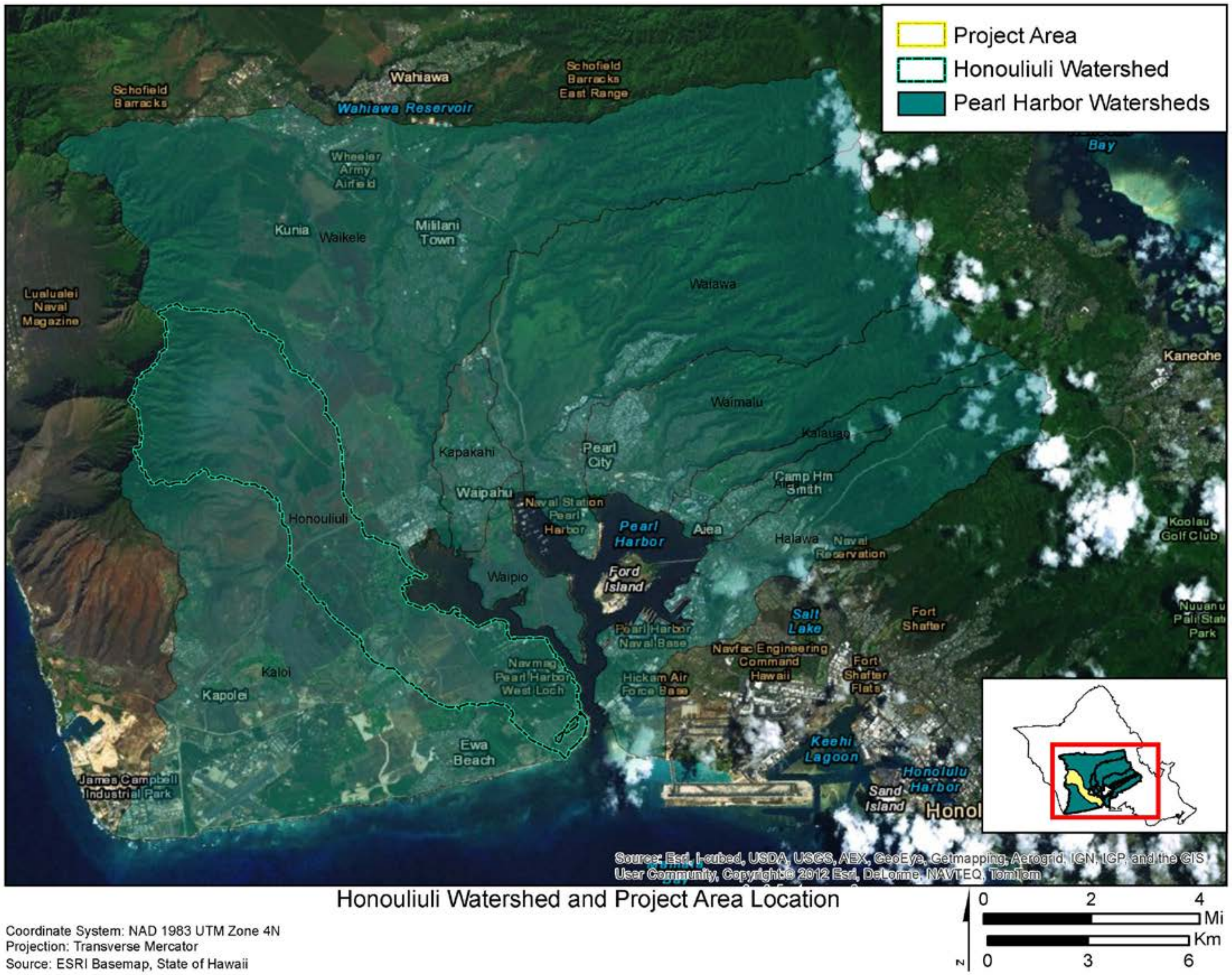


Figure 2. The Honouliuli Watershed Location

The Honouliuli Watershed is part of the larger Pearl Harbor Watershed located on the southwest part of the island of O‘ahu. The Honouliuli Watershed Plan was created for the mauka (upper) portion of the watershed. See Figure 3 for a detailed view of the project area.

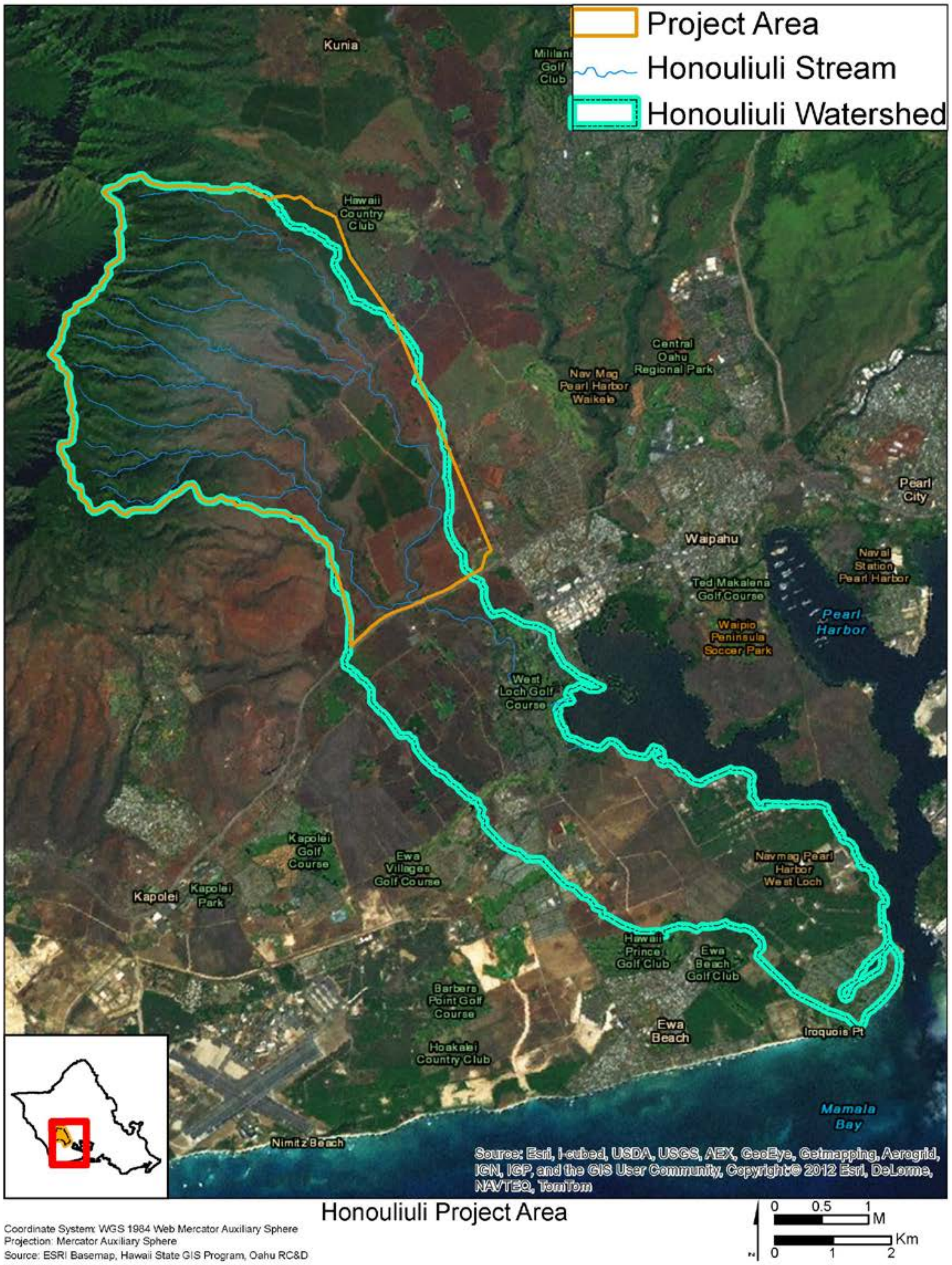


Figure 3. Honouliuli Project Area.

A project area was identified for purposes of developing this watershed plan. The project area covers the uppor portion of the watershed.

4.2 Physical and Natural Characterization

The project area includes some of O‘ahu’s richest agricultural lands. Sugarcane and pineapple production dominated the project area’s management until 1996, and in recent years has been converted to seed corn and vegetable row crop agriculture. The higher elevations are used for grazing and forest reserve.

MLRA Characterization

The NRCS has described the land resources in the United States for farming, ranching and other uses in the USDA Handbook 296 – Land Resource Regions and Major Land Resource Areas (MLRA) of the United States, the Caribbean, and the Pacific Basin (NRCS 2006). The Honouliuli Watershed contains three MLRA types.

The lower watershed surrounding Pearl Harbor is MLRA 167- Alluvial Fans and Coastal Plains. The area is nearly level or gently sloping and at low elevations (< 200 feet). Alluvial deposits of basalt and ash products sit upon or are mixed with marine products such as coral limestone and calcareous sand deposits. Most of the land use in MLRA 167 on O‘ahu is urban, although in the past, sugarcane production was a major use. Some agriculture persists in the lower Honouliuli Watershed. In undeveloped areas away from the shoreline the naturalized vegetation includes kiawe (*Prosopis pallida)*, haole koa (*Leucaena leucocephala*), and bermudagrass (*Cynodon* species). Wetlands in the coastal areas provide habitat for important native water bird species.

The middle watershed, generally in the agricultural zone, is MLRA 158 – Semiarid and Sub-humid Low Mountain Slopes. This area is on the drier slopes on the leeward side of older islands. General land slopes range from nearly flat to moderately steep. The areas are typically plains dissected by gulches. Most of the surface geology is highly weathered volcanic ash underlain by basalt. Alluvium derived from basalt also occurs. Farms and ranches make up the major land use in this MLRA throughout the islands. Naturalized plants include koa haole (*Leucaena leucocephala*), bermudagrass (*Cynodon* species) and guinea grass (*Megathyrsus maximus*). The major wildlife species include non-native game birds.

The mountainous area in the upper watershed is MLRA 165 – Subhumid Intermediate Mountain Slopes. These are the leeward, drier, slopes on the older Hawaiian Islands. The mountain slopes are dissected by steep sided gulches. These areas are exposed basaltic rock and weathered basalt. This MLRA supports forest, shrubs, scrub, and grasslands. The highest number of native plant species is found in this MLRA in the Honouliuli Watershed. While pineapple was cultivated in the lower areas of this MLRA on O‘ahu, most of the land has remained in forest. The major resource problems are invasive species, feral animals and water erosion.

4.3 Soils

The geology of the Hawaiian Islands is part of a partially exposed volcanic mountain range in which the characterization of soil is mostly from volcanic origin with some coralline origin or a mixture of both. The USDS-NRCS classifies soils within the United States and prepares maps indicating the soil types present in all states including Hawai‘i. Map unit delineation on a NRCS soil map represents an area dominated by one or more major kinds of soil. A map unit is identified and named according to the taxonomic classification of the dominant soils. Multiple soil types are present within the footprint of the Honouliuli project area (see Figure 4 and Table 2).

The project area is characterized by oxisol and inceptisol soils. Oxisol soils are highly weathered, heavy textured (high-clay) and have a moderately low erodibility. Oxisols are characterized by extremely low native fertility, resulting in very low nutrient reserves, high phosphorous retention attributed to their high content of iron and aluminum oxides and low cation exchange capacity. Oxisols have physical properties that are stable and thus resistant to deterioration under intensive mechanized agriculture and allow for heavy, wheeled vehicles to transport on unpaved roads shortly after heavy rain. Stable aggregates allow for less erodibility by enabling rainwater to seep into the soil surface rather than flow over it as runoff (Uehara and Ikawa 1997). Inceptisol soils are young, reddish-brown soils that have a moderate erodibility. Inceptisols often occur on mountain slopes where newly exposed, unweathered materials are actively exposed by erosional processes, or river valleys where sediment deposition readily occurs. Inceptisols are good for crops like pineapple and sugar cane, although fertilizer and irrigation are necessary.

The upper portion of the watershed is characterized by very steep, well-drained soils, where the parent soil material includes basaltic lava (or colluvium) that makes up the narrow ridges and side slopes of the watershed. The soils in Honouliuli Forest Reserve are an association of Tropohumults-Dystrandepts soils. Tropohumults soils have a surface layer and subsoil of reddish-brown silty clay and Dystrandepts were derived dominantly from volcanic ash mixed with colluvium.

The major factors that contribute to rates of soil erosion on unprotected fields are soil texture, ground slope, rainfall intensity, and runoff. The NRCS has already conducted an analysis of erodibility for all soil map units in the United States with their Highly Erodible Lands (HEL) determination program. The HEL determination is used by NRCS and Farm Service Agency (FSA) to govern eligibility for USDA programs. HEL fields must be protected from erosion through conservation practices or put into conservation reserve for the farm to be eligible for certain USDA assistance programs. This report will use the three categories that have been developed by the HEL determinations for Honouliuli watershed’s project area soils – Highly Erodible Land, Potentially Highly Erodible Land, and Not Highly Erodible Land – as a surrogate classification of the erosion hazard of the soils. The use of the HEL categories is not intended to reflect on the eligibility of the fields or farms for USDA programs. The three HEL categories will be called – High Erosion Potential (HEP), High-Moderate Erosion Potential (HMEP), and Moderate Erosion Potential (MEP).

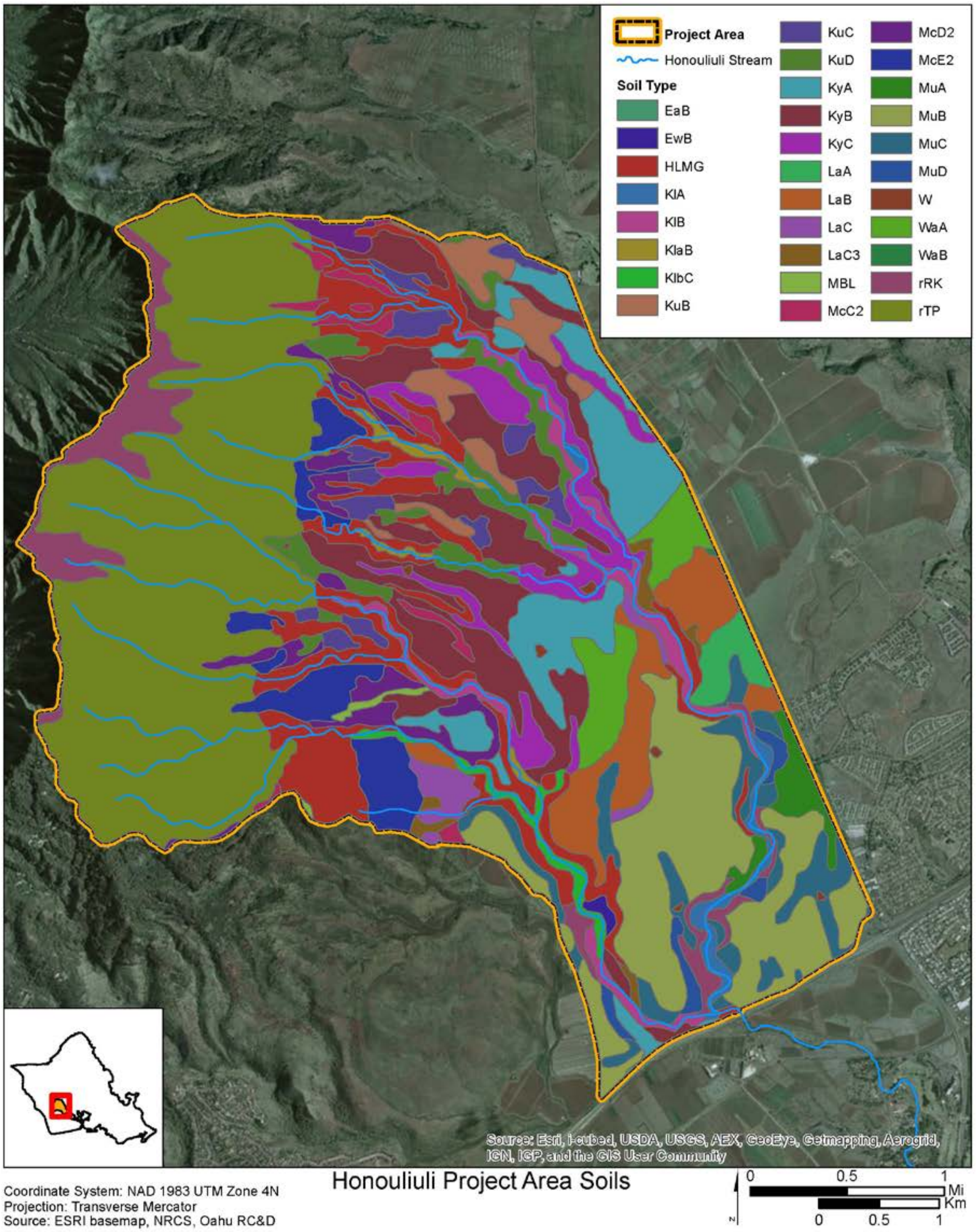


Figure 4. Soil types in the Project Area.
A variety of soil types are found in the project area. See Table 2 for brief descriptions.

Table 2. Summary of Soil Types Found in the Honouliuli Project Area

Map Unit Symbol	Map Unit Name	K-Factor Rating[2]	Erosion Potential[3]
EaB	Ewa silty clay loam, 3 to 6 percent slopes	0.17	Moderate
EwB	Ewa silty clay loam, 6 to 12 percent slopes	0.17	Moderate
HLMG	Helemano silty clay, 30 to 90 percent slopes	0.17	High
KlA	Kawaihapai clay loam, 0 to 2 percent slopes	0.17	Moderate
KlB	Kawaihapai clay loam, 2 to 6 percent slopes	0.17	High-Moderate
KlaB	Kawaihapai stony clay loam, 2 to 6 percent slopes	0.15	High-Moderate
KlbC	Kawaihapai very stony clay loam, 0 to 15 percent slopes	0.10	High-Moderate
KuB	Kolekole silty clay loam, 1 to 6 percent slopes	0.17	High-Moderate
KuC	Kolekole silty clay loam, 6 to 12 percent slopes	0.17	High-Moderate
KuD	Kolekole silty clay loam, 12 to 25 percent slopes	0.17	High
KyA	Kunia silty clay, 0 to 3 percent slopes	0.17	Moderate
KyB	Kunia silty clay, 3 to 8 percent slopes	0.17	High-Moderate
KyC	Kunia silty clay, 8 to 15 percent slopes	0.17	High-Moderate
LaA	Lahaina silty clay, 0 to 3 percent slopes	0.17	Moderate
LaB	Lahaina silty clay, 3 to 7 percent slopes	0.17	High-Moderate
LaC	Lahaina silty clay, 7 to 15 percent slopes	0.17	High-Moderate
LaC3	Lahaina silty clay, 7 to 15 percent slopes, severely eroded	0.17	High-Moderate
MBL	Mahana-Badland complex	0.43	High
McC2	Mahana silty clay loam, 6 to 12 percent slopes, eroded	0.43	High
McD2	Mahana silty clay loam, 12 to 20 percent slopes, eroded	0.43	High
McE2	Mahana silty clay loam, 20 to 35 percent slopes, eroded	0.43	High
MuA	Molokai silty clay loam, 0 to 3 percent slopes	0.20	Moderate
MuB	Molokai silty clay loam, 3 to 7 percent slopes	0.20	High-Moderate
MuC	Molokai silty clay loam, 7 to 15 percent slopes	0.20	High-Moderate
MuD	Molokai silty clay loam, 15 to 25 percent slopes	0.20	High
rRK	Rock land	0.10	High-Moderate
rTP	Tropohumults-Dystrandepts association	0.10	High
W	Water > 40 acres	-	-
WaA	Wahiawa silty clay, 0 to 3 percent slopes	0.15	Moderate
WaB	Wahiawa silty clay, 3 to 8 percent slopes	0.15	High-Moderate

[2] Refer to the Revised Universal Soil Loss Equation (RUSLE) section, Page 38 for details on soil K factor.
[3] Erosion potential is further defined in section 7.3.1 and shown in Figure 11.

4.4 Land Ownership

Land ownership and operations in the project area consist primarily of three seed corn operations, a large-scale fruit and vegetable farm, a private agricultural park with small farmlots, a grazing operation, a research center and the Honouliuli Forest Reserve. The Honouliuli Forest Reserve consists of 3,592 ac (2,061 ac within the project area) that was acquired by Division of Forestry and Wildlife (DOFAW) in 2010 to be managed as a State Forest Reserve for the protection of forest, watershed, and wildlife habitat.

4.5 Land Use

Land use is defined as human uses of the landscape. Aerial imagery and groundtruthing were used to delineate the project area into five categories that will assist in the subsequent RUSLE analysis (see Table 3 and Figure 5).

Table 3. Major Land Use Types in the Honouliuli Project Area (Brokish Survey 2011).

Land Use Type	Acres	% of Project Area
Forest Reserve Most of the forest land is in the Honouliuli Forest Reserve, located in the upper part of the project area.	2061	28%
Grazing Cattle grazing traditionally and currently takes place on lands that are too rugged for row crop production, primarily the gulches and steep areas.	795	11%
Cultivated row crops: seed corn Production of seed corn occurs on the gently sloping soils located in the central and lower parts of the project area.	2252	31%
Cultivated row crops: truck crop Mixed vegetable and fruit production occurs in both small and large scale in the project area.	1193	17%
Gulch Gulches run from the Forest Reserve to the stream outlet. The gulches are used for farming, grazing, and idle lands.	912	13%
Urban/ Major Roads This small portion of the project area includes public infrastructure such as major roads and water storage tanks.	42	1%

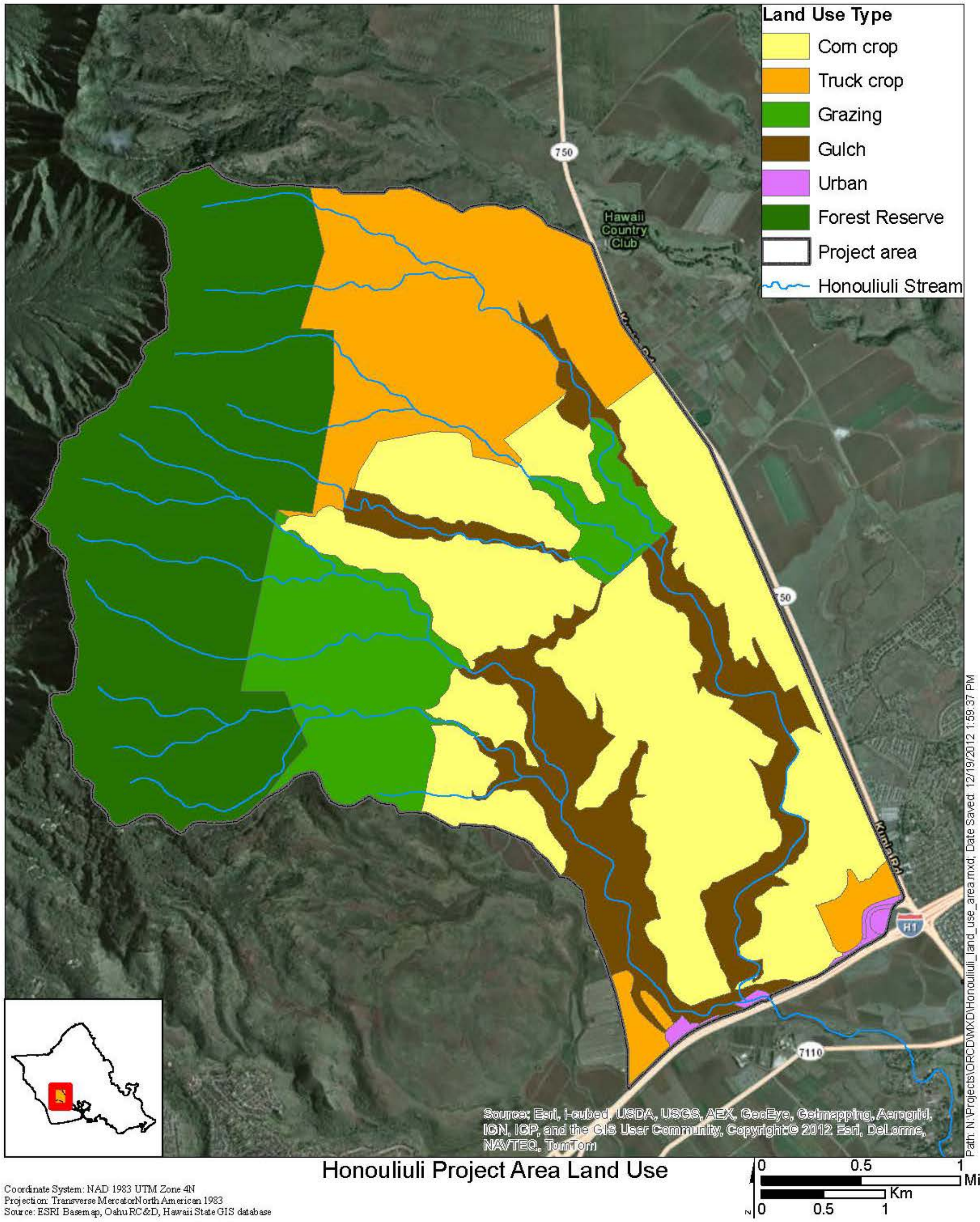


Figure 5. Land Use in the project area.

4.6 Biological and Cultural Resources

There is growing recognition that environmental issues can and should be addressed in ways connected to traditional values and practices; therefore understanding the cultural and biological significance of the Honouliuli Watershed should be considered when making land and water management decisions. Honouliuli means dark harbor, for the dark fertile lands that stretch from the waters of Pearl Harbor to the summit of the Waianae mountain range. The area around Pearl Harbor held the second highest density of population after Honolulu in ancient Hawaiʻi (Oceanit 2007). The history of the Honouliuli watershed includes biologically and culturally significant aspects associated with traditional Hawaiian practices. And, as with all other aspects of Hawaiian culture, agricultural practices closely interfaced with religion, traditions, and customs.

This watershed plan recognizes that the Honouliuli watersheds biological and cultural resources are integrally linked with management decisions, however it is beyond the scope of this report to go into detail regarding the settlement history of the area which includes manipulations to the landscape and its natural resources. Information regarding Honouliuli's rich history can be found in the following documents: Central Oʻahu Watershed Study (Oceanit 2007), Honouliuli Land Tenure in the Māhele ʻĀina (1847-1855) (Hoakalei Cultural Foundation 2012), and The Honouliuli Forest Reserve Master Plan (TNC 2000).

4.7 Surface Water Quality

Honouliuli Stream is classified as State waters, as this inland freshwater stream flows perennially or intermittently (depending on its location within the watershed). The water quality of Honouliuli Stream has not been fully assessed, and is therefore not included on the Hawaii's DOH 303(d) list of impaired waterbodies. Also, because Honouliuli Stream is not currently listed on the 303(d) list of impaired water bodies, Total Daily Maximum Loads (TMDL) have not been determined. TMDL monitoring is only completed after the waterbody is 303(d) listed and daily loads of the impairing water constituents are established. Designated categories are applied to all "Surface Waters" of the State. Honouliuli Stream was rated Category 3, meaning that there was insufficient data for determining a designated use attainment and water quality impairment. On the other hand, Honouliuli Stream is part of the larger Pearl Harbor watershed that was listed in the 2006 Final Report of Impaired Waters in Hawaiʻi, prepared under the CWA 303(d) for excessive sediment and nutrients (HDOH 2006). In particular, the State water quality standards were not attained for total nitrogen (Total N), total phosphorus (Total P), turbidity, and from the previous listing, total suspended solids (TSS) and nitrate+nitrite nitrogen (NO_3+NO_2). Pearl Harbor is also listed for Polychlorinated Biphenyls (PCBs) and chlorophyll-a, and has a fish consumption advisory (see Table 4). Data from these 2006 assessments indicate that Pearl Harbor and many of its tributary watersheds were not attaining water quality standards for total nitrogen, phosphorus, turbidity and total suspended solids. A TMDL report is required for Pearl Harbor as a result of its inclusion on the 303(d) list. At this time, TMDL data and reports are not complete, and the source(s) of these pollutants have not yet been defined.

Table 4: Section 303(d) List Status For Honouliuli Stream and Pearl Harbor. Extracted from the Final Report of Impaired Waters in Hawai'i (HDOH 2006).

Assessed Waterbody	Scope of Assessment	Geocode ID	Enterococci	Total N	NO_3+NO_2	Total P	Turbidity	Other Pollutants	Category	TMDL Priority
Honouliuli Stream	Entire Network	3/4/2011		?	?	?	?	TSS (?)	3	
Pearl Harbor		HIW00006	?	N	N	N	N	chl-a(N)	3, 5	High
Pearl Harbor*		HIW00119	?	L	L	L	N	nutrients, susp. Solids (L); PCBs, fish consumption advisory	3, 5	High

*Waters and nearshore waters to 30 feet from Keehi Lagoon to Oneula Beach

Decision Codes: ? = unknown, N = not attained, L = previous listing from 1998 or earlier.

Parameter Codes: Total N = total nitrogen; NO3+NO2 = nitrite+nitrate nitrogen; PCB = Polychlorinated Biphenyls; Total P = total phosphorus; TURB = turbidity; TSS = total suspended solids; chl-a = chlorophyll a; NH4 = ammonium nitrogen.

The Pearl Harbor watershed's main water quality issue is a result of the accumulation of NPS pollution generated from the entire Harbor's watershed region. In general, water quality at the head of Hawai'i's streams is often very good, but has been known to significantly decrease in quality as you move towards the ocean (Tetra Tech 2010). A 1993 analysis of sediment loads into Pearl Harbor indicated that sediments were almost entirely (74%) from streams and derived from the upper watershed areas (i.e. forest reserve lands), the remainder mean annual NPS loads were estimated to be largely from agricultural activities (17%) (Oceanit 2007). In 2000, the USGS testing of 105 sediment samples from Pearl Harbor (including offshore from the Honouliuli Stream) indicated that 148 of 252 chemicals (59%) were present and of that number, significant portions appeared to be agriculture or termiticide related chemicals.

Honouliuli Stream Monitoring

Honouliuli Stream is vulnerable to flash flooding due to heavy rainfall events; therefore, a flood control program exists that includes regulating land use for buffer zones and decreasing flood runoff (Oceanit 2007). On December 11, 2008, a local news station (KITV) reported that, "Honouliuli turned into a river of muddy water as the stream overflowed damaging properties, trapping residents and killing animals" (KITV 2008). On April 20, 2011, a Senate resolution measure was adopted that recognized flooding to be a major problem for various parts of the state and requested the State Hazard Mitigation Forum to study measures that would mitigate risks associated with identified flood hazards. Specifically, this resolution identified that "flash flooding along the Honouliuli Stream in December of 2008 and January of 2011 resulted in water and debris sweeping through farms, ranches, and neighborhoods" (USCS 2011). Mitigation efforts will benefit from data from accurate and real-time stream gages along the Honouliuli Stream, as well as upper elevation rain gages to spatially recognize stormwater runoff potential and for prioritizing areas for management practice installation. Rainfall data are currently collected in gages located only in the lower elevations of the watershed.

The Honouliuli watershed has a USGS crest–stage gage (CSG) (#16212500) that is located at the Honouliuli Stream bridge on Farrington Highway and 1.8 mi west of Waipahu Post Office. This CSG data is available through the USGS National Water Information System (NWIS) database website (*http://waterdata.usgs.gov/ nwis*). A crest stage gage is a non-continuous device that records the highest level of the stream stage at the gage location. The gage is read only after a storm discharge. Channel geometry and hydraulic relationships are used to estimate the peak discharge correlated to the flood crest elevation. This gage was installed in 1956. USGS has calculated the drainage area to be 11.09 square miles or 7097.6 acres. The highest discharge at the gage was estimated to be 3,500 cfs on January 6, 1982. Grab samples for water quality are taken by USGS employees and are collected when the CSG is serviced during periods of active streamflow (R. Rickman, personal communication, May 9, 2011). Water quality sampling of the Honouliuli Stream has been inconsistent; with the first sample taken in 1976 and the subsequent sample taken in 2008. Efforts have been made since the 2008 sampling to increase the frequency of sample data collection every year (Table 5).

Table 5: Suspended Sediment Data from the Honouliuli Stream (USGS 16212500) Water Quality Grab Samples (USGS 2012)

Sample Date/Time HST	Suspended Sediment Concentration mg/L	Suspended Sediment Discharge (tons)/day
10/23/2008 9:40	15	
12/11/2008 10:10	10800	
12/16/2008 13:08	61	
1/30/2009 9:45	48	
3/14/2009 14:04	712	
8/12/2009 14:40	603	
2/2/2010 14:10	228	2.8
2/4/2010 10:54	30	0.25
4/9/2010 15:35	22	0.12
12/20/2010 12:35	3500	
1/13/2011 12:30	4040	
1/20/2011 11:37	4300	
5/9/2011 12:35	156	
3/5/201214:46	142	

Two new continuous recording gages with water quality sampling capacity were installed by USGS, in partnership with the C&C of Honolulu’s Department of Environmental Services, in the Honouliuli watershed’s project area in 2012. City funding for these gages is guaranteed for four years. A new gage, USGS 16212480, was activated on August 30, 2012 on the southern tributary of Honouliuli Stream at a location just upstream of its crossing of the Waiahole Ditch. The gage is located 629 feet above sea level with a drainage area of 1.86 square miles. Most of the land use above the gage is grazing and forest reserve. Real time monitoring in 15 minute time increments is available on the USGS National Water Information System (NWIS) website. Another new gage will be installed adjacent to the Board of Water Supply pumping station just north of the H-1 freeway bridge. This gage location will include all of the

Honouliuli project area, including the cropland. This gage is expected to replace the Honouliuli Stream crest gage near Farrington Hwy. Description of this gage has not yet been published. Real time data from the gage should also be available on the USGS NWIS website.

Continuous water quality sampling and data is limited for nutrient and suspended sediment loads and is not well characterized for NPS pollutants entering the Honouliuli watershed waterways during the wet and dry seasons. Available track records of water quality grab samples in the Honouliuli stream showed suspended sediment concentrations ranged from 15 mg/L to 10,800 mg/L in 2008. The December 11, 2008, flooding event produced an extremely high sediment load that dropped to 61 mg/L after 5 days. Regulations for Hawaii's inland streams maintain numeric water quality criteria for suspended sediment to be lower than those recorded during high flow events; however, samples taken during lower flows have data values that are only slightly higher or within range of the regulated criteria. Over time, smaller storm events that do not trigger high flow may cumulatively result in the transport of high quantities of stormwater runoff and NPS pollutants into receiving waterways. Implementing practices that address these more frequent and smaller storm events may prove efficient in meeting State regulated water quality criteria and targets set in the forthcoming TMDL for Pearl Harbor. Implementation may also significantly reduce overall NPS pollutant loading into Pearl Harbor.

4.8 Hydrology

4.8.1 Rainfall

The Honouliuli watershed is located in the southwestern portion of the island of O‘ahu and is considered to be in the hot and dry region characteristic of the leeward side of the island. Much of the moisture in the usually blowing tradewinds is extracted as orographic rainfall by the Koolau Mountains before reaching Honouliuli. Central and leeward O‘ahu typically receive most of their annual rainfall during the winter season when Kona storms and cold fronts disrupt the trade winds and bring moisture from other directions (Juvik 1998).

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service has two rainfall gages that are placed in the lower elevations of the Honouliuli watershed. The "Honouliuli PHB" (HOFH1) rainfall gage is located approximately 0.5 miles (mi) south of the endpoint of Honouliuli Stream where it terminates into the West Loch of Pearl Harbor; and the Kunia Substation (KUNH1) rainfall gage is located 0.3 mi north of the intersection of Highway 1 and Kunia Road, near the Village Park. The USGS-operated network included only the Poamoho Rain Gage in central O‘ahu in their 2005 listing of their rain gage network. Other agency or private gages exist in and near the project area, but records are not correlated regionally. Fortunately, earlier, more extensive records have been incorporated into average rainfall and storm rainfall tools that are used to project rainfall for this study. Unfortunately, the uncertainties of global climate change reduce the confidence in the projections based on historical data.

The average annual rainfall ranges from 47 inches at the Waianae mountain peaks to 24 inches near the H-1 freeway (UH 2012). Representative storm rainfall for the project are, using the NOAA Atlas 14 Point Precipitation Estimate tool is shown on Table 6 for the centroid of the project area (NOAA 2012). Variability in storm rainfall within the project area was not significant with the mountain tops receiving just 25 percent more rain during some storms than the lower elevations near the H-1 freeway.

Table 6. Storm Rainfall in Honouliuli Project Area (inches)

Storm	Recurrence Interval						
Duration	1-year	2-year	5-year	10-year	25-year	50-year	100-year
1-hour	1.24	1.63	2.13	2.52	3.04	3.44	3.85
6-hour	2.47	3.27	4.37	5.19	6.26	7.07	7.86
24-hour	3.6	4.93	6.7	8.04	9.8	11.1	12.5
10-day	5.84	7.99	10.9	13.2	16.3	18.7	21.1

4.8.2 Runoff

The Honouliuli Watershed is defined as the drainage basin of the streams that start at the crest of the Waianae mountain range, roughly between Pohakea Pass to the north and Palikea Ridge on the south. A number of streams converge into Honouliuli Stream before it crosses under the H-I freeway. Honouliuli Stream meanders through the Honouliuli community and through the West Loch Golf Course to outlet into the West Loch of Pearl Harbor. A majority of the reaches of Honouliuli Stream are intermittent and dry for most of the time. While the stream is well-formed, and incised in the area above the H-I freeway, the infrequent streamflow and the deposition of storm sediment in the lower reaches has resulted in inadequate stream capacity in some reaches and frequent out-of-bank flooding events in the Honouliuli community.

Difficulties in delineating the Honouliuli Watershed and estimating runoff include the uncertainties in runoff direction from the gently sloping pasture and farmlands along the Honouliuli/Kaloi watershed boundary, numerous roadside drainage ditches and culverts, and effects of the irrigation water ditches. Delineation of the Honouliuli watershed for the runoff analysis was conducted using the 40-foot contours on the USGS' Digital Raster Graphics. In addition, drainage practices installed to protect the farmland and pastureland can also affect the location of the drainage and watershed boundary. A likely more significant factor affecting the runoff from the watershed is the crossing of the Waiahole Ditch and other ditch and drainage structures in the farming area. The Waiahole Ditch has a capacity to transport 27 million gallons per day (mgd) from Windward O'ahu to the leeward plains. If the same capacity can be used to transport stormwater into or out of the Honouliuli Watershed, nearly 40 cubic feet per second (cfs) could be added or subtracted from streamflow downstream of the ditch. The runoff analysis conducted for this study did not account for the effects of the Waiahole Ditch.

4.9 Data Gaps

Although land use in the project region continues to consist primarily of large scale agricultural practices, lack of quantitative monitoring data throughout the watershed currently precludes any reliable estimates of NPS loading originating from agriculture lands as compared to other sources (such as the steep slopes of the upland headwaters to the lowland urban developmental areas). Spatially identifying the NPS contributing areas in the watershed can provide an effective way to prioritize the implementation of management and control practices.

To ensure that NPS loadings are being properly identified to the source, an assessment of the type and relative contribution of contaminants from the major land use types would assist in addressing problem areas and allocating management measures. There is currently one operating CSG located adjacent to the Honouliuli stream at Farrington Highway that records peak water flow. The drainage area for this gage is

11.09 square (sq) mi and includes the entire upper watershed area. The CSG does not partition out the contributing NPS loads generated from each of the land use types or tributaries above the sampling station. At present, there is no data available to estimate the loads being contributed from runoff generated below the sediment sampling station (before entering into Pearl Harbor). Sufficient quantitative and qualitative water quality data is necessary to determine a sediment budget for the Honouliuli stream and its overarching watershed. A recent initiative by USGS to collect sediment from the Honouliuli stream is beneficial; however, may not be entirely representative of sediment loads for each event since these collections are typically taken hours after peak flow and do not capture the initial flush.

4.10 Identification of Pollutant Causes and Sources

Identifying the causes and sources of NPS pollutants entering the waters of Honouliuli Stream and Pearl Harbor will aid in making informed decisions about terrestrial management measures and conservation practices that will ultimately improve the water quality of these waterways. Primary NPS pollutants in Hawaii's impaired waters have been identified as turbidity, nutrients and bacteria. Furthermore, the most likely sources for these pollutants in Hawaii's watersheds generally include animal wastes, fertilizer, exotic species, stream bank erosion, impacts of feral animals and natural flood events (Tetra Tech 2010).

By definition, NPS pollutants are derived from diffuse sources. Identifying specific locations within the project area where NPS pollutants are derived from would require a complex undertaking of soil and water sampling and statistical analysis. By focusing on land use and its associated activities, the primary pollutant types and their causes are discussed. Known and perceived concerns in these land use types that could potentially lead to water quality impairments were identified by gathering and summarizing existing data such as climate conditions, land use and land cover, current management methods, stakeholder concerns and observations and existing management plans that include the project area. This data was then used to make informed decisions to identify, describe and geographically reference causes and sources of impairments. For example, analysis of seasonal rainfall patterns in the project area indicated an increased occurrence of natural floods and stormwater runoff, and subsequently degraded water quality during the wet season. While there are climatic and environmental variables such as precipitation and wind that affect conservation practices differently, there are limited actions that can be taken to control them. Conservation management variables, such as land use type and site design, can be included in the preliminary planning to address NPS pollutants and can also be effective when controlling NPS problems as they arise. The two major land use types in the project area that are spatially distributed, uniformly utilized, and may contribute large portions of NPS pollution loads are agriculture and forest reserve. Simplified conceptual models were developed to link major causes and impacts of water quality concerns in the project area's varying land use types (see Figure 6 and Figure 7). A conceptual model was developed for the causes and sources of pollutants from the project area and their delivery to stream waters that discharge into Pearl Harbor Bay (see Figure 8).

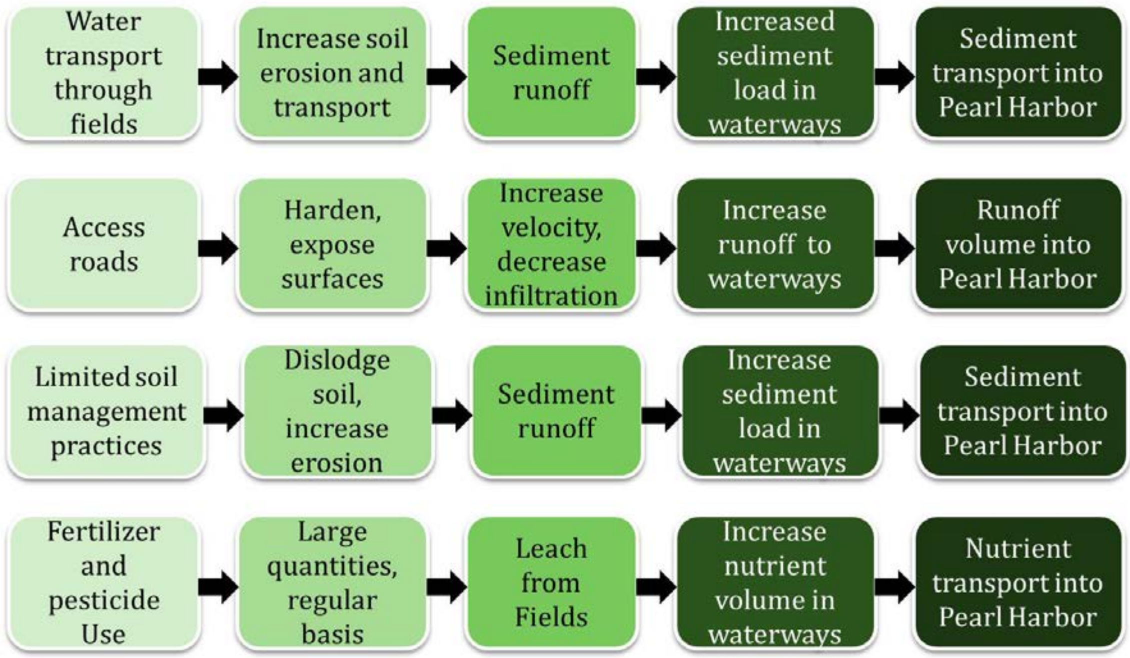


Figure 6: Modeling Resource Concerns for Agricultural Lands

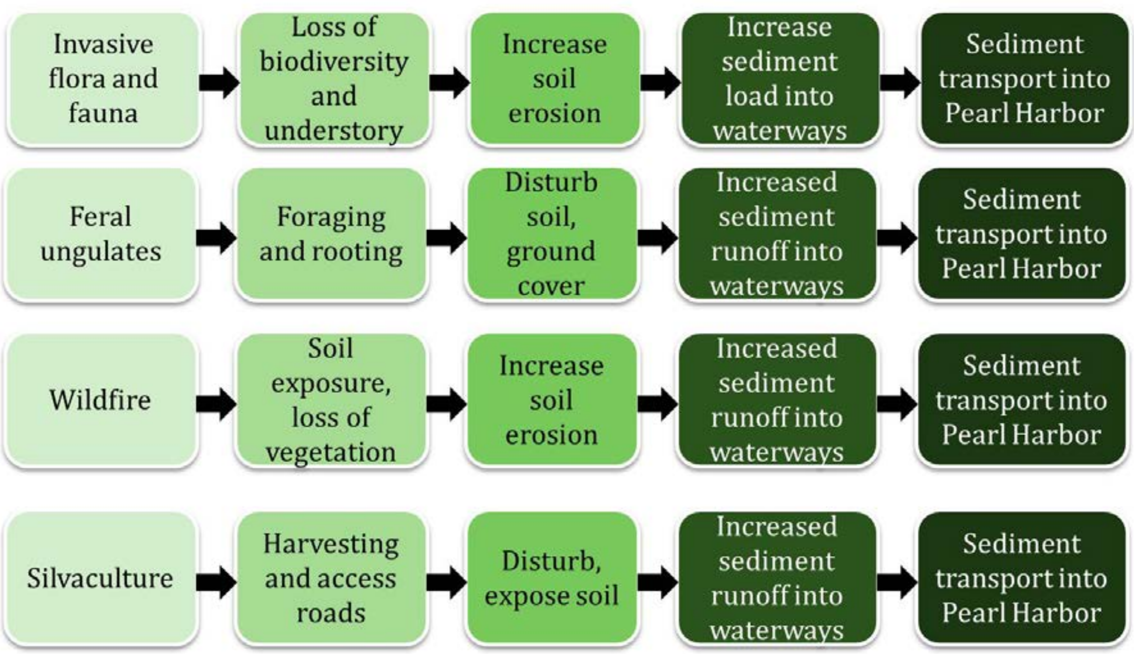


Figure 7: Modeling Resource Concerns for Forest Reserve Lands

4.10.1 Agricultural Land Use

Row Crops

Soil erosion can be characterized as the transport of particles that are detached as a result of rainfall, flowing water or wind. Water flowing across the soil surface, surface runoff, is the most important detachment and transport mechanism (State of Hawaiʻi 1996). Soil erosion and runoff from land used for agricultural purposes (crop cultivation, grazing, etc.) affects water resources directly by delivering sediment, pollutants attached to sediment and pollutants in solution to surface water.

The project area has a long history of crop production. Sugarcane remained a dominant form of land use in the Pearl Harbor watershed since the late 19th century until 1996, and the deleterious effects of the chemical use on water quality are well documented (Oki and Brasher 2003; Tomlinson and Miller in press). The majority of the currently cultivated areas carry a slope of less than 6.5 percent; although some upper elevation agricultural areas include steeper slopes (up to 30 percent). A large area that includes uneven terrain and steep slopes (0-32 percent) in the upper elevations of the project area is currently undergoing a transition from fallow into truck crop production. These landscape changes and related drainage issues could potentially increase erosion and runoff if not managed properly. For example, running an access road straight up and down hill would produce a new waterway that would increase runoff velocity and accelerate sediment delivery.

Excessive soil erosion is often a symptom of poor soil management, whether it is inadequate plant nutrients or improper cropping systems (Havlin 1999). While the objective of any soil and crop management system is sustained profitable production, different management practices can affect sediment and runoff quality/ quantity, crop productivity and soil health. Measures that focus on soil conservation embrace a system that meets the three interlocking goals of sustainability: being economically sound, socially acceptable and environmentally benign. An efficient nutrient management program supplies an adequate quantity of plant nutrients required to sustain maximum crop productivity and profitability while minimizing the environmental impact from nutrient use. Crop management that focuses on OM content is critical because of its influence on many biological, chemical and physical characteristics inherent in productive soil. Soil erosion and OM loss reduces the productive capacity of the soil that in turn leads to the ongoing need to return nutrients to the soil for plant uptake via fertilization. Improper planting systems that utilize large areas of row crops and have limited crop rotation or do not utilize cover crops leave large areas of exposed soil surfaces that can accelerate sheet and rill erosion. Surface runoff, drainage pathways, and infiltration rates are influenced by tillage patterns and by access roads that partition precipitation and that create hardened surfaces, respectively. Conservation tillage systems, which leave more crop-residue on the soil surface, can effectively reduce water and sediment loss (Wang 2008).

Grazing

In 1906, Ralph S. Hosmer, former Superintendent of Forestry, first recommended establishing a forest reserve along the east slope of the Waianae Mountains (Hawaiʻi 1906). Located within the private lands of Honouliuli, many obstacles arose that prevented the culmination of his proposal at that time; instead, the land was leased for grazing purposes by a local ranch company. As a result, the native forest has been greatly reduced in size and in many places has disappeared altogether; moreover, small springs that used to run perennially in many of the gulches have now been dry for many years (Hawai‘i 1923). Tummon (2003) describes the first account of cattle at a ranch in Waianae in the early 19th century:

> *"…in those areas where sugar planters had no interest in either land or water, ranching was generally regarded as the next best use of the land. A pattern of land use emerged that was unchallenged, for the most part, through the 20th century. Sugar planters obtained the choice agricultural lands on each of the main islands and the rights to develop water for fluming or irrigation from windward mountain slopes. The rest went to the ranchers."*

Land currently used for grazing purposes in the project area continues to follow Tummon's description being located in the upper elevations and on steeper slopes. Vegetation in these areas generally consists of alien Koa Haole (*Leucaena leucocephala*) shrubland and grasses (i.e. Star (*Cynodon nlemfuensi*) and Pangola (*Digitaria eriantha Steud*)), and Kiawe (*Prosopis pallid*) forest (HI-GAP 2000). Livestock access control is important because there is great risk for the loss of native and understory vegetation in the Honouliuli Forest Reserve if grazers were to enter into that area. Access control from the intermittent stream banks and riparian ecosystems located in the grazed areas are also important to decrease pollution entering the waterways.

4.10.2 Forest Reserve Land Use

The native forest in Honouliuli was largely devastated by sandalwood extraction and grazing during the 1800s. Native forest remnants are now concentrated on the summit areas where cattle could not access them, but small patches of native vegetation are still found at lower elevations. Between the 1920s and late 1940s, several fast-growing tree species were planted in this area of mono-specific stands in order to reduce erosion and to facilitate groundwater recharge (Restom Gaskill 2004).

The Honouliuli Forest Reserve has been recognized as having significant value for its biological resources and was managed by The Nature Conservancy (TNC) as a refuge for rare and endangered plants and animals, and as an area for research and education, community service and cultural preservation (TNC 2000). An extensive Honouliuli Forest Reserve Master Plan (TNC 2000) was released that encompassed strategies and actions related to the Forest Reserve's goal of resource management and active public participation. Ownership of the Honouliuli Forest Reserve was acquired by the DOFAW in March 2010 and management is currently ongoing as a forest reserve for watershed and habitat protection. While the DOFAW's management goals for the Reserve continue to focus on watershed management and protecting the existing areas of threatened and endangered (T&E) plants, this new management is also supportive of forestry production, such as Eucalyptus species (*robusta eucalypts*) and Paper bark (*Melaleuca quinquener*) (D. Smith, Personal Communication, June 20, 2011).

Hawai‘i offers an ideal climate with limited competition for introduced flora and fauna to succeed in establishment and survival. Flora and fauna that are not native to Hawai‘i can become invasive when they quickly spread and out-compete native species for space, water and light. Invasive species in Hawai‘i's forests have led to a loss of biodiversity and understory plants. The effects of feral pigs on native ecosystems are wide ranging and there is emerging evidence that their presence alone may be linked to increases in runoff and soil loss (Dunkell 2009). Management practices to restore native ecosystems have included decreasing the spread of plants by physical removal and by limiting the spread of seed by cleaning all gear and equipment (clothing, vehicles, etc.) before entering the Forest Reserve area and by protecting critical habitat areas by fencing off areas from animals, people and vehicles.

Although forest fires are of less concern in the project area due to the decline in sugar cane production and the associated controlled burning of biomass after harvest, the potential for uncontrolled fires still exists during the dry season. Hawaii's ecosystem has not adapted to wildfire and as such, its harmful effects have resulted in the elimination of some of the last known species of certain native plants, caused increased soil erosion and damaged the infiltration rates of effected soil (PDC 2011). Management measures should focus on protecting T&E species, installing safeguards such as fire breaks, and having an emergency plan in place.

Economic opportunities from Honouliuli are being considered by the DOFAW and include recreation and conservation incentives and forestry activities. If managed well alongside conservation practices, forestry practices can be sustainable and work cooperatively with existing preservation activities. States with significant forestry activities have recognized and documented the effects of poor forestry management on water quality. Local impacts of timber harvesting and road construction on water quality can be severe, especially in smaller headwater streams (USEPA 1993). Water quality can be degraded severely from forestry operations without adequate controls. Increased contaminants from forestry activities include sediment, nutrients, forest chemicals and organic debris resulting from harvesting. Vegetation removal in the riparian zone by harvest or herbicide can increase stream temperature and reduce stream flow. Increased water temperatures can have adverse effects on aquatic species and habitat by increasing the metabolic rates of most stream organisms (thereby increasing the need for oxygen), while decreasing the dissolved oxygen holding capacity in the waterbody.

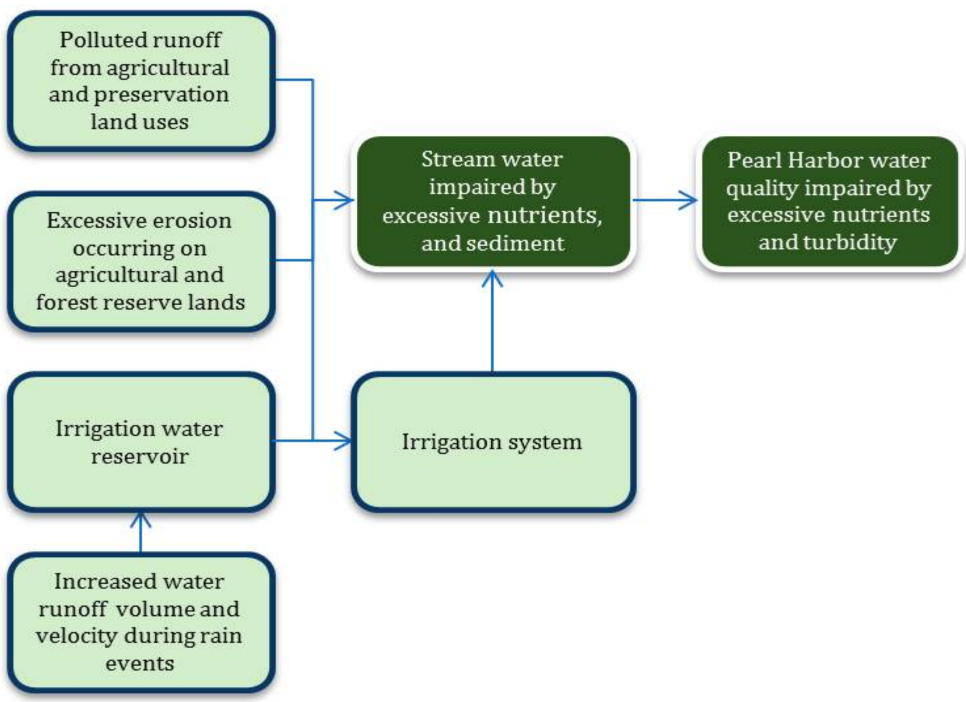


Figure 8: Conceptual Model of Causes of Water Quality Impairments and the Sources of Pollutants.

5 Public Participation and Partnerships

Successful development and implementation of a watershed plan depends primarily on the commitment and involvement of community members. Of primary importance is engaging stakeholders who understand issues and concerns firsthand, who make and implement management decisions, and those that may be affected by any decision making processes. The principal stakeholders for the Honouliuli Project are landowners and land managers, government agencies and organizations. Meetings and discussions were held with the stakeholders, both individually and in group settings (e.g. public meetings and field days). The following is a list of stakeholder meetings and events that took place during the development of this watershed plan:

Table 7. Stakeholder Meetings and Events

Event	Date	Description
Landowner / Land Manager Meeting	November 2010	Explained cost-share process and distributed applications to farms in the project area
Field Day (Kunia Loa Ridge)	February 2011	Featured techniques for beginning farmers: site preparation, soil erosion prevention, plant selection and layout.
Ewa Neighborhood Board	March 2011	Provided general information on Project goals, objectives and desired outcomes.
Field Day (Monsanto)	September 2011	Highlighted BMPs installed on farms in the project area: cover crops, vegetative barriers and diversions (terraces). Included a field tour of practices.
Hanauma Bay	February 2012	Provided overview of watershed planning process and discussed relationship between coral reef health and land-based pollutants.
Watershed Plan Review	September 2012	Convened landowners and land managers

In addition to the above listed public events, field visits and one-on-one discussions were held with the following entities:

- Agriculture Development Corporation (Waiahole Ditch System)
- Circle C Ranch
- City and County of Honolulu (ENV staff and select partners from AECOM, USGS, and DOH)
- Department of Land and Natural Resources (DLNR) -Division of Forestry and Wildlife
- FAT Law Farms
- Hawaii Agriculture Research Center
- Honouliuli Village Residents – downstream of the project area)
- Kunia Loa Ridge
- Larry Jefts Farms
- Monsanto
- Pioneer Hi-Bred
- Second City Property Management (Kunia Village Water System)
- Syngenta
- West O‘ahu Soil and Water Conservation District

5.1 Stakeholder Concerns

The following is a summary of concerns expressed by stakeholders that were generated from survey data, during in-field discussion, and through individual interviews:

- Feral ungulates and invasive species present in forest reserve land
- Change in agricultural land use (from pineapple to seed corn) has led to increased runoff and sedimentation in lower parts of the watershed.
- In-field structures (diversions, sediment basins, etc) were previously managed by Plantation, now fragmented ownership makes uniform management and maintenance very difficult.
- Overgrazing
- Lack of (financial) resources to deal with flooding and sediment deposition in lower watershed
- New farms being created on steep slopes may increase runoff and erosion
- Runoff from fields impacting Waiahole Ditch System
- New or small farmers (on Kunia Loa Ridge) are not familiar with local climate and underestimate erosion potential
- Seems to be less annual precipitation, but larger storm events

6 Pollution Control Strategy

Existing data was gathered and used to identify and/ or determine potential causes and sources of erosion and sediment loading, suspended sediment load reduction opportunities and practices, and follow-up monitoring approaches to evaluate effectiveness of practice implementation. The concentration of suspended sediment that is transported by a stream past a point (i.e. a site of stream gage) is referred to here as sediment "load" or "loading". Field visits, interviews, meetings, and conferences with project area stakeholders and land managers who influenced decision-making in the project area were included in the initial stages of data collection.

6.1 Management Goals and Indicators

The objectives of this plan include management goals that focus on mitigating and controlling the identified pollutant causes and NPS sources within the Honouliuli watershed's project area. This section discusses these management objectives and how they will be implemented and achieved in the project area. Table 8 lists the associated indicators and targets that will be used to quantifiably evaluate and measure the progress toward meeting the report objectives and goals.

Table 9 lists other measurable indicators (environmental, programmatic and social) included for management in the project area. Environmental indicators are a direct measure of the resource concerns and environmental conditions that a watershed plan seeks to address. Programmatic indicators are indirect measures of resource protection or restoration; for example, the number of conservation plans on file or management practices implemented per conservation plan. Social indicators measure changes in social or cultural practices; for example, increased awareness of watershed issues and behavior changes that lead to implemented management practices and subsequent water quality improvements (Tetra Tech 2010).

Table 8: Goals, Management Objectives and Indicators.

Goal	Management Objective	Indicator/ Target
Achieve water quality standards in the Honouliuli stream and Pearl Harbor watershed	Reduce nutrient and sediment loads from nonpoint and point sources	Decrease in total suspended sediments and nutrients in receiving waterbodies
Identify and prioritize management practices for controlling pollutant causes in the project area	Strategically select the most efficient and effective methods and locations for management practice implementation	• Outline/ timeline for implementation of selected management practices • Map of locations for management practice execution
Decrease pollutant loads from entering Pearl Harbor	Implement management practices along pollutant sources in the project area	Continuous monitoring of samples in (above) and out (below) of the device shows a significant reduction in pollutant load
Provide support for stakeholders in the project area to implement conservation management	Stakeholders become encouraged to implement conservation into their management activities	Management plans begin to include short- and long-term definitive plans to implement management practices

Table 9: Environmental, Programmatic and Social Indicators

Goal	Management Objective	Indicators/ Targets
Environmental (baseline condition)	TSS, nutrients, flow rate	Direct water quality measurements
Environmental (measure implementation progress)	TSS, nutrients, flow rate	Direct water quality measurements
Programmatic	Number of participants in conservation plan development	Public records and database
Programmatic	Number of management practices implemented	Tracking database
Social	Number of landowners aware of technical and financial assistance to install management practices	Pre- and post- survey
Social	Number of landowners requesting assistance to implement management practices	Phone and email log

7 Load Reduction

Establishing a link between load reduction and water quality responses will serve to better understand the role of management measure implementation. Conservation practices to be implemented with the intention to reduce and control sediments and/ or nutrients are required to provide estimates of the expected NPS pollutant load reductions. Two methods for measuring load reduction were selected for this report. The Revised Universal Soil Loss Equation Version 2.0, or RUSLE2, was used to analyze load contributions and reductions on the field level; whereas the WinTR-55 Small Watershed Hydrology computer program was used to analyze sediment movement and reductions on a larger scale, such as across the entire project area. Below are descriptions of analysis methods used for the selection of management measures, as well as the programs used for estimating soil loss and sediment delivery from the project area.

7.1 Analysis Tools For Soil Erosion and Sediment Yield

The NRCS has established standards and technical materials that were utilized to identify, select, and evaluate conservation practices, and estimate associated load reductions.

Conservation Practice Physical Effects (CPPE)

The NRCS national office developed the Conservation Practice Physical Effects (CPPE) database to document the physical effects of conservation practices on natural resource problems. In short, the CPPE is a matrix that displays an effects value from +5 to -5 for each of the conservation practices found in the NRCS electronic FOTG. The CPPE matrix displays in subjective detail the physical effects that conservation practices have on natural resource problems, based on experience and availability of technical information (NRCS 2006). CPPE's are generic and provide an indication of the physical conservation effects (CE) expected to occur once an individual practice is implemented (see Table 10).

The CPPE matrix was utilized to select different conservation practices for specific land use management types and resource concerns within the project area. Practices that had a high potential to solve one or more resource problems (a high CE score), without increasing problems on another resource, were selected. (NRCS 2006).

Table 10. Effect of a Single Conservation Practice on Resource Problems

Values in the CPPE National Template	Values in SmarTech CPPE
Substantial Improvement	+5
Moderate to Substantial Improvement	+4
Moderate Improvement	+3
Slight to Substantial Improvement	+3
Slight to Moderate Improvement	+2
Slight Improvement	+1
Not Applicable	0
Neutral	0
Slight Worsening	-1
Slight to Moderate Worsening	-2
Moderate Worsening	-3
Slight to Substantial Worsening	-3
Moderate to Substantial Worsening	-4
Substantial Worsening	-5

Revised Universal Soil Loss Equation (RUSLE)

The Revised Universal Soil Loss Equation Version 2.0 (RUSLE2) is the most recent of a family of models proven to provide robust estimates of the average annual soil erosion by rainfall from a wide range of land use, soil, and climatic conditions (Dabnet et al. 2010). The USDA–NRCS believes that

RUSLE2 is the most practical erosion prediction technology that can be easily applied at the local level. Modeling soil erosion by RUSLE2 has already been applied for long-term water erosion prediction (Renard et al. 1997). The RUSLE2 program is a valuable tool in that it provides an inventory of erosion rates and estimates the rate of sediment delivery from the project area. The objective of this report is to strategically identify and prioritize conservation practices, utilizing RUSLE2, that will control NPS pollution at the field level and minimize their delivery to receiving waterbodies.

The RUSLE2 is a computer program that estimates rill and inter-rill (sheet) erosion by solving a set of mathematical equations (Toy et al. 2002). The RUSLE2 model is based on assigned factor values that represent how climate, soil, topography, and land use affect rill and inter-rill soil erosion caused by raindrop impact and surface runoff. In general, erosion depends on the amount and intensity of rainfall and runoff, protection provided to the soil by land use against the direct forces of raindrop impact and surface runoff, susceptibility of soil to erosion as a function of intrinsic soil properties, soil properties modified by land use, and the topography of the landscape as described by slope length, steepness and shape. The RUSLE2 factors that compute daily soil loss are organized into the following equation:

$$\mathbf{A = r\ k\ l\ s\ c\ p}$$

Daily Factors

r - Rainfall/ runoff	s - Slope steepness
k - Soil erodibility	c - Cover management
l - Slope length	p - Supporting practices

A = Average annual soil loss (ton/ acre/ year)

A (Average annual soil loss) = The computed spatial average soil loss and temporal average soil loss per unit of area, expressed in the units selected for k and for the period selected for r. These are usually selected so that A is expressed in tons per acre per year.

r =The r factor represents rainfall/ runoff erosive factor at a particular location. It is the average annual summation values over a normal year's rain. Storms less than 0.5 inches are not included in the erosivity computations because these storms generally add little to the total r value. When other factors are constant, storm losses from rainfall are directly proportional to the product of the total kinetic energy (E) of the storm, times its maximum 30-minute intensity (I). R factors represent the average storm EI values over a 22-year record. R is an indication of the two most important characteristics of a storm, determining its erosivity through the amount of rainfall and peak intensity sustained over an extended period, at a particular location.

k = The k factor is an empirical measure of soil erodibility as affected by intrinsic soil properties. The k factor represents both susceptibility of soil to erosion and the rate of runoff, as measured under the standard unit plot condition. Erosion measurements based on unit plot conditions are used to experimentally determine values for k. The k factor is influenced by the detachability of the soil, infiltration and runoff, and the transportability of the sediment eroded from the soil.

> **Soil map units and an erodibility index will be used as the basis for identifying highly erodible land. The erodibility index for a soil is determined by dividing the potential average annual rate of erosion for each soil by its predetermined soil loss tolerance (T)*

value. The T value represents the maximum annual rate of soil erosion that could occur without causing a decline in long-term productivity.

l = The l factor is the slope length factor which represents the ratio of soil loss from the field slope length to soil loss from a 72.6 feet (ft) length on the same soil type and gradient. Slope length is the distance from the origin of overland flow along its flow path, to the location of either concentrated flow or deposition. Surface runoff will usually concentrate in less than 400 ft.

s = The s factor represents the effect of slope steepness on erosion. It is the ratio of soil loss from the field gradient to that from a 9% slope under otherwise identical conditions. Soil loss increases more rapidly with slope steepness than it does with slope length.

c = The c factor is the cover management factor, which reflects the effect of cropping and management practices on erosion rates and represents the effects of plants, soil cover, soil biomass, and soil disturbance activities on erosion. It is the factor used most often to compare the relative impacts of management options on conservation plans. The c factor indicates how the conservation plan will affect the average annual soil loss and how that soil loss potential will be distributed in time during construction activities, crop rotations or other management schemes. As soil loss ratios vary during the year and cover conditions continuously change, computing the c factor uses a function of three subfactors: crop canopy, surface or ground cover, and surface roughness.

p = The p factor is the support practice factor. The supporting practice factor represents the effect of applied conservation supporting practices used to control erosion such as vegetation, management systems (terraces, sediment basins, etc.) and mulch additions. Supporting practices typically affect erosion by redirecting runoff around the slope so that it has less erosivity or slows down the runoff to cause deposition, such as concave slopes or barriers similar to vegetative strips. The major factors considered in estimating a p factor value include: 1) *runoff rate* (as a function of location, soil type, and management practice); 2) *erosivity and transport capacity of the runoff* (as affected by slope steepness and hydraulic roughness of the surface); and 3) *sediment size and density*.

All factors used in the RUSLE2 were calculated for areas within the project area using local data and are based on long-term averages. As such, the RUSLE2 cannot be used to estimate or predict soil loss from individual storms or from a particular year of weather conditions. The RUSLE2 program is also limited to smaller field lengths than that typically exist in the project area. The RUSLE2 is a predictive method and was determined to be the most appropriate means of estimating the Honouliuli project area's resource conditions. Estimated results from RUSLE2 gave an indication of relative changes in soil loss and sediment delivery from a particular site with implemented conservation practices. Planners used a deductive approach in determining resource conditions as it related to data standards and current practice inputs. The absolute values of the estimates thus become less important as the emphasis shifts to trends of degradation or improvement (Jones 1995).

WinTR-55

Over the past 50 years, NRCS has developed and improved upon on a rainfall-runoff model that is based on the runoff curve number (CN), drainage area characteristics, and the generation of hydrographs. Hydrographs are curves that plot runoff against time and can show the rise and fall in streamflow over a storm period. The recently-issued WinTR-55 Small Watershed Hydrology computer program (NRCS

2009), was used to calculate storm runoff for the project area. WinTR-55 is a single-event hydrologic model with the capability to handle subareas, channels, and storage structures within the watershed.

The basic inputs into Win TR-55 are rainfall, soil infiltration characteristics (hydrologic soil group), land use data, and slope and channel characteristics. The soil and land use data are used in the determination of CN. The 24-hour storm rainfall derived from NOAA Atlas 14 for the 1-, 2-, 10-, 25-, 100-, and 500-year recurrence interval storms were used as input. WinTR-55 is only able to analyze the 24-hour storm. The curve number is determined in WinTR-55 when a Hydrologic Soil Group (HSG) and a land use/cover is selected for a grouping of acres in the watershed. A built-in table in Win TR-55 permits entry of acres of land, soil, and land use/ cover combinations. Customized input is also accommodated. Land use/cover choices that are built into Win TR-55 reflect conditions that are found throughout the U.S. It is often difficult to match categories to the condition found in the local watershed.

The Honouliuli project area was divided into four subwatershed areas to consolidate similar land uses and to improve the timing of the hydrographs in the model. The peak discharge outputs from the WinTR-55 model were compared to the annual CSG records and to the results from regional flood equations used by the National Flood Frequency Program. Adjustments to CN and time of concentration were made to calibrate the WinTR-55 model for existing conditions. The adjustments were also applied to the improved condition which included the future implementation of conservation practices. The peak discharges for the existing condition were compared to the improved condition to ascertain the effectiveness of conservation practices to reduce storm runoff. The storm runoff hydrographs were used to estimate sediment yield for storms under the existing and improved conditions. See Appendix 4.

7.2 Management Measures and Practices to Achieve Load Reductions

This section describes specific management measures to address priority concerns and approaches to achieving pollutant load reductions in the Honouliuli project area. Figure 9 demonstrates the linkages between the identified causes and sources of pollution, goals and management objectives, load reductions and the subsequent management measures. Management measures are defined by the Coastal Nonpoint Pollution Control Program as, "economically achievable measures to control the addition of pollutants to our coastal waters, which reflect to the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operation methods, or other alternatives" (USEPA 1993). Management measures were categorized by the major land uses (i.e. agriculture and forestry) and their resource concerns. Management measures are implemented by applying one or more management practices appropriate for the pollutant source and its location.

This section also includes specific recommendations from the EPA's guidance documents of the types of practices that can be applied to successfully achieve the management measures. Management practices were identified and prioritized using the NRCS's CPPE matrix (see Appendix 2). The list of practices (see Table 11 and Table 12) for each management measure is not all-inclusive and includes those that scored high CE values as well as those selected to be effective by experts in the field. These practices correspond with NRCS's electronic FOTGs that contain standards and specifications (for these practices) and may be found online at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/fotg (USDA 2011).

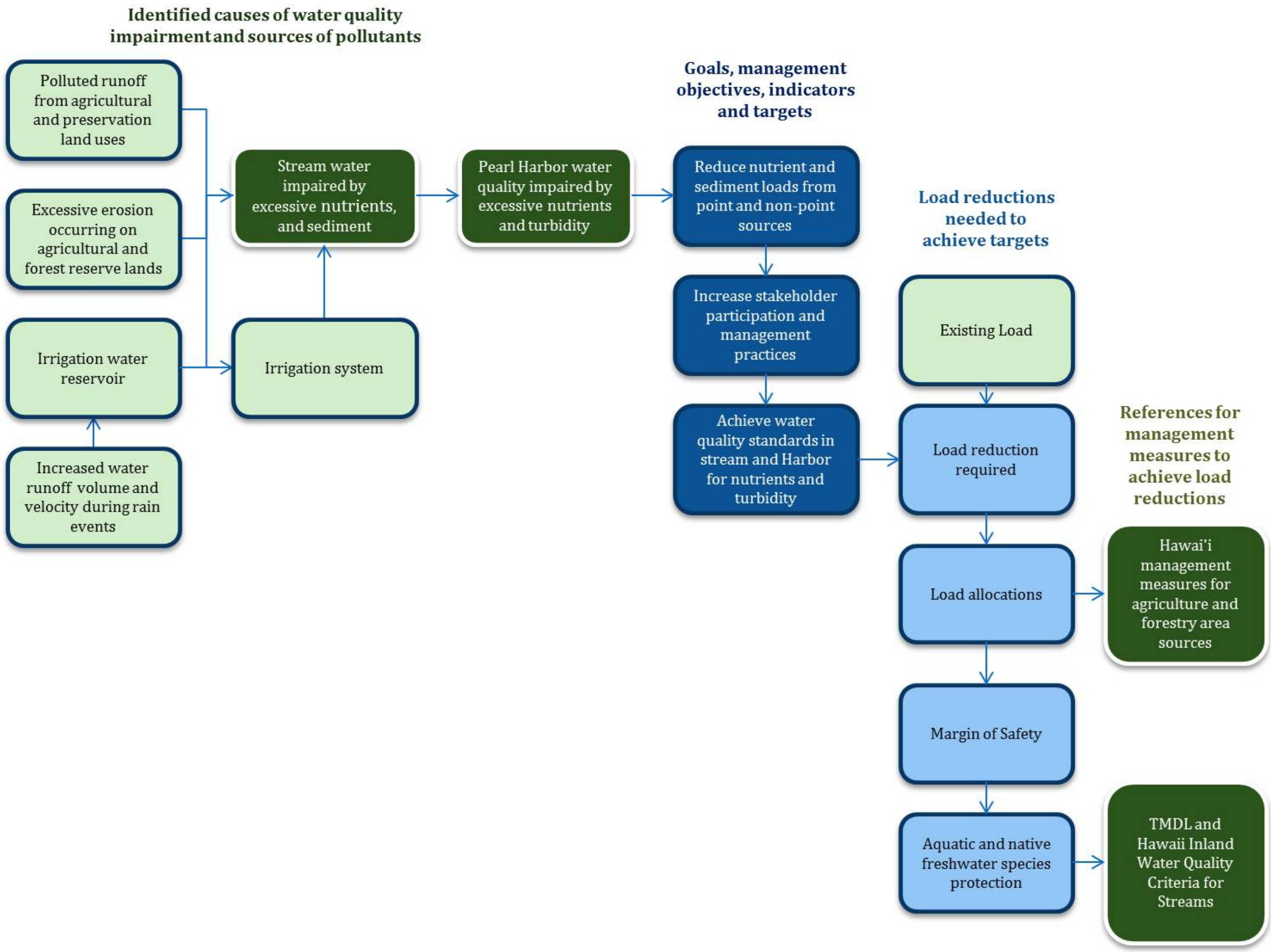


Figure 9. Linkages between Watershed Goals and Management Measures to Achieve Load Reductions.

7.2.1 Agricultural Land Use

Addressing NPS pollutant runoff from agricultural lands in the project area will need to integrate management technologies that continue to support soil productivity, farm profitability and environmental qualities. There are five management measures that apply to and address the management of polluted runoff from agricultural operations in the Honouliuli project area. These five management measures include:

A. Erosion and Sediment Control
B. Nutrient Management
C. Pesticide Management
D. Irrigation Water Management
E. Grazing

Table 11. Recommended Management Measures and Practices for Agricultural Land Use with Associated NRCS FOTG Number.

Erosion and Sediment Control	
Conservation Practice	**NRCS eFOTG**
Access Control	472
Access Road	560
Conservation Cover	327
Conservation Crop Rotation	328
Contour Farming	330
Cover Crop	340
Critical Area Planting	342
Deep Tillage	324
Diversion	362
Field Border	386
Filter Strip	393
Grassed Waterway	412
Mulching	484
Residue and Tillage Management	329
Rock Barrier	555
Row Arrangement	557
Sediment Basin	350
Structure for Water Control	587
Terrace	600
Underground Outlet	620
Vegetative Barrier	601
Water and Sediment Control Basin	338
Nutrient Management	
Nutrient Management	590
Pesticide Management	
Pest Management	595
Irrigation Water Management	
Irrigation System, Micro-Irrigation	441
Irrigation Water Management	449
Grazing	
Access Road	560
Brush Management	314

Fence	382
Field Border	386
Heavy Use Area Protection	561
Planned Grazing Systems	556
Prescribed Grazing	528
Proper Woodland Grazing	530
Range Planting	550
Riparian Forest Buffer	391
Stream Crossing	578
Streambank Protection	580
Tree/Shrub Establishment	612
Watering Facility	614

Erosion and Sediment Control

The primary intent of the erosion and sediment control management measure is to reduce the load of sediment reaching a waterbody and to improve water quality and the use of the water resources. The first, and most desirable, strategy would be to implement practices that prevent erosion and the transport of sediment. Practices should protect the ground surface from exposure to precipitation and other climatic factors. Rainfall impact on exposed surfaces dislodges soil particles and, depending on the rate and amount of runoff associated with the rainfall event, can result in significant soil loss. The second strategy is to route runoff through practices that remove sediment. Other intentions of this measure are to protect the physical and chemical properties of the soil, break up slope length, divert runoff, and to buffer and filter any field runoff before reaching waterways. Site conditions will dictate the appropriate combination of practices for any given situation.

For further information see:
Agronomy Management for Pacific Island Farms USDA NRCS, Seven Example Practices (ftp://ftp-fc.sc.egov.usda.gov/HI/pub/technical/0_FOTG_Notice_PI-24_Section_IV_Seven_Agronomy_Practices/).

Nutrient Management

Nutrient management means implementing and/ or updating a nutrient management plan and applying practices that will control the amount, source, placement, form and timing of the application of plant nutrients and soil amendments. Components of a nutrient management plan include identification of the appropriate timing and application methods to ensure that nutrients are provided at rates necessary to achieve realistic crop yields, reduce nutrient losses and avoid over application during periods of leaching or runoff. Application of nutrient management practices are intended to maintain or improve the physical, chemical and biological condition of soil, while preventing or mitigating off-site nutrient pollution to water quality from leaching, solution runoff and adsorbed runoff losses.

For further information see:
Nutrient Management for Pacific Island Farms USDA NRCS Practice 590 (ftp://ftp-fc.sc.egov.usda.gov/HI/pub/technical/conservation_system/CSG_Nutrient_Management_590.pdf).

Pesticide Management

Integrated pest management is a site-specific combination of pest prevention, pest avoidance, pest monitoring, and pest suppression strategies, also known as integrated pest management (IPM). Practices for pesticide management are intended to prevent or mitigate off-site pesticide risks to water quality due to leaching, solution runoff and adsorbed runoff losses. Efficient management includes calibrating equipment, using appropriate pesticides for relevant situations and using alternative methods to control pests.

For further information see:
IPM Management for Pacific Island Farms USDA NRCS Practice 595 (ftp://ftp-fc.sc.egov.usda.gov/HI/pub/technical/0_FOTG_Notice_PI-28_Section_IV_Integrated_Pest_Management/3_Integrated_Pest_Management_595/3_595_Standard_PI_12.2.10.pdf).

Irrigation Water Management

Irrigation water management measure is intended to be applied to activities on irrigated lands, including agricultural crop, orchard, and pasture lands. Practices associated with this type of management measure are developed to prevent the movement of pollution from the land into the ground or surface water. General principles for irrigation management include the proper scheduling of delivery, efficient application and transport of irrigation water, use of runoff or tailwater, and the management of drainage water. Well-designed and managed irrigation systems remove runoff and leachate efficiently, control deep percolation, and minimize erosion from applied water. The type of irrigation system present will dictate which type of management practices can be employed.

For further information see:
Irrigation Water Management for Pacific Island Farms USDA NRCS Practice 449
(http://efotg.sc.egov.usda.gov/references/public/HI/1_449_stand_pi_jan_2007.pdf).

Grazing

Pasture management practices are intended to be applied in areas where land is being grazed continuously by domestic livestock. The selection of practices to be implemented for this type of management measure should be based on an evaluation of current conditions, problems identified, quality criteria, and management goals. Pasture management practices include grazing management systems, livestock access limitation, and vegetation stabilization. Practices are applied as a part of a conservation management system to improve or maintain plant communities, surface water quality, and soil conditions, as well as to reduce accelerated soil erosion. Sediment delivery is reduced through proper use of vegetation, streambank protection, planned grazing systems and livestock management. Enforcing access restriction and vegetated buffers to the forest reserve areas and streams will provide protection for T&E species and understory vegetation, both of which are beneficial for soil protection and erosion control. Livestock control and access restriction to streambanks and riparian zones will reduce the physical disturbance and direct loading of animal waste and sediment caused by livestock. This type of approach includes fencing, providing stream crossings, and alternative water and shade locations.

For further information see:

Grazing Management for Pacific Island Farms USDA NRCS, Six Example Practices (ftp://ftp-fc.sc.egov.usda.gov/HI/pub/technical/0_FOTG_Notice_PI-33_Six_Practices_3-22-11/).

7.2.2 Forest Reserve Land Use

Addressing NPS pollutant runoff from the Honouliuli Forest Reserve land use in the project area will need to integrate management technologies that continue to support conservation, recreation, and some forestry operation. There are five management measures that apply to and address the management of potential NPS pollution runoff from the Honouliuli Forest Reserve project area. These five management measures include:

A. Pre-harvest Planning
B. Streamside Management Zone
C. Road Management
D. Fire Management
E. Re-vegetation of Disturbed Areas

Table 12. Recommended Management Measures and Practices for Forest Reserve Land Use With Associated NRCS FOTG Number.

Pre-harvest Planning	
Conservation Practice	**NRCS eFOTG**
Access Control	472
Forest Stand Improvements	666
Forest Trail and Landings	655
Recreation Trail and Walkway	568
Sediment Basin	350
Water and Sediment Control Basin	638
Streamside Management Zone	
Riparian Forest Buffer	391
Stream Habitat Improvement and Management	395
Road Management	
Access Road	560
Fire Management	
Firebreak	394
Re-vegetation of Disturbed Areas	
Brush Management	314
Restoration and Management of Rare or Declining Habitats	643
Upland Wildlife Habitat Management	645

Pre-harvest Planning

With the potential for forestry activities occurring in the Honouliuli Forest Reserve, there is an opportunity to implement management practices in advance, before problems arise, to ensure that silviculture activities are conducted without significant NPS delivery to streams and coastal areas. Pre-harvest planning is a synthesis of information collected for the harvest site to make an effective environmental plan. Executing pre-meditated planning can alleviate anticipated erosion and sediment problems and accommodate access for recreational usage and forestry equipment through planning, design and location. Recommended practices take into consideration harvesting methods, site preparation, road construction, and drainage as part of silviculture activities, as well as, other management uses for the Forest Reserve, such as recreation and T&E species protection.

The *Best Management Practices for Maintaining Water Quality in Hawaiʻi* (DOFAW 1996) was adopted by Hawaii's Board of Land and Natural Resources as a guide to promote better stewardship of forest resources in Hawaiʻi. This guide contains specific language about pre-harvest planning stating, "An effective pre-harvest plan will take into consideration all aspects of the timber harvest which may lead to water quality degradation for the implementation of best management practices which will minimize or avoid the adverse effects of the operation" (DOFAW 1996). The guide further outlines recommendations of best practices to promote water quality protection and how to subsequently implement them. To be specific, as expressed in the guide, scale of operation and harvest methods are examples of variables that will influence the extent of practices to be implemented. As such, a large-scale operation (> 5 acres) utilizing a clear-cut harvest method may require an engineered approach to control sediment such as implementing a sediment basin. On the other hand, a smaller scaled operation (<5 acres) utilizing selective cutting methods may achieve adequate NPS pollution control through effective planning that takes into consideration site conditions (i.e. topography, drainage, high erosion hazards) and timing of harvest (i.e. season-specific).

For further information see:
The *Best Management Practices for Maintaining Water Quality in Hawaiʻi* (DOFAW 1996)
(http://www.state.hi.us/dlnr/dofaw/wmp/bmps.htm) and **The *Hawaiʻi Watershed Guidance* (Tetra Tech 2010)**, Pg 90
(http://hawaii.gov/dbedt/czm/initiative/nonpoint/HI%20Watershed%20Guidance%20Final.pdf).

Streamside Management Zone

A streamside management zone is an established and maintained vegetative buffer along surface waters that is properly sized to provide shade, streambank stability and erosion control, while also providing detritus and woody debris needed for instream channel structure and aquatic species habitat. This measure is especially pertinent for lands where silviculture or forestry operations are planned or conducted, and should be maintained along all perennial streams, where forest disturbances occur and surface runoff will carry sediment loads. There are several factors that determine the proper width of the buffer, including size and type of waterbody, adjacent soil erodibility, slope, etc.

For further information see:
The *Best Management Practices for Maintaining Water Quality in Hawaiʻi* (DOFAW 1996)
(http://www.state.hi.us/dlnr/dofaw/wmp/bmps.htm) and **USDA NRCS Technical Guides 391 and 395:**
(http://efotg.sc.egov.usda.gov/references/public/HI/1_391_Standard_PI-25_10.10.pdf and
http://efotg.sc.egov.usda.gov/references/public/HI/395_PI_Standard_11-2011.pdf).

Road Management

The *Best Management Practices for Maintaining Water Quality in Hawaiʻi* states, "Forest roads cause more erosion than any other forestry activity" (DOFAW 1996). Road management is intended to prevent sedimentation and pollution from runoff-transported materials on existing roads. Components of this measure generally apply to active and inactive roads constructed for silviculture activities and include inspection and maintenance to prevent erosion of road surfaces, keep drainage systems operating, and ensure the continued effectiveness of stream crossing structures. The Honouliuli Forest Reserve has roads that continue to be used on occasion by the public for recreational purposes or may need to be closed due to non-use or because they run through protected areas. The TNC management report (2005) noted that the Honouliuli Forest Reserve is accessed primarily via roads that are maintained by other land managers (i.e. Estate of James Campbell, Del Monte, Inc., ranchers, etc.) and that lie within the Forest Reserve. Under TNC's management, portions of the Contour Road (part of the Honouliuli Contour Trail) were cleared for use..

For further information see:
The *Best Management Practices for Maintaining Water Quality in Hawai'i* (DOFAW 1996) (http://www.state.hi.us/dlnr/dofaw/wmp/bmps.htm) and **Access Road USDA NRCS Technical Guide 560 (**http://efotg.sc.egov.usda.gov/references/public/HI/560_PI_Standard_1-2012.pdf).

Fire Management

Fire breaks or lines are strips of bare land or vegetation that slow down the growth and spread of wildfire as well as control prescribed fires. Fire management was essential when sugarcane was the primary crop in adjacent agricultural lands, and it is still needed in the forest reserve in order to protect the native ecosystem communities and natural resources from the devastating effects of wildfire. Fireline construction and maintenance is an essential part of forest and other land management activities. This type of land management practice deals with site preparation burning, prescribed burning and wildfire defense and control. There are a number of fire control management practices that can be implemented during fireline construction to prevent unnecessary erosion; to be specific, periodic inspection and proper maintenance can help to prevent potential erosion on established firelines.

For further information see:
The *Best Management Practices for Maintaining Water Quality in Hawai'i* (DOFAW 1996) (http://www.state.hi.us/dlnr/dofaw/wmp/bmps.htm) and **Firebreak USDA NRCS Technical Guide 394 (**http://efotg.sc.egov.usda.gov/references/public/HI/1_394_pi_stand_jan_2007.pdf).

Re-vegetation of Disturbed Areas

This management measure applies to disturbed areas resulting from harvesting activities, the clearing of invasive species, and from road construction related to silviculture activities. Present management work within the Forest Reserve aims to sustain, protect, and increase T&E species and includes the following activities:

- The management or removal of woody (non-herbaceous or succulent) plants including those that are invasive and noxious,
- Restoring, conserving, and managing unique or diminishing native terrestrial and aquatic ecosystems,
- Providing and managing upland habitats and connectivity within the landscape for wildlife.

For further information see:

Management for Pacific Island Farms USDA NRCS Practice guides (314, 643, 645) (http://efotg.sc.egov.usda.gov/references/public/HI/3_314_PI_Standard_01-2011.pdf, http://efotg.sc.egov.usda.gov/references/public/HI/643_PI_Standard_11-2011.pdf, http://efotg.sc.egov.usda.gov/references/public/HI/645_PI_Standard_11-2011.pdf).

7.3 Erosion Control

7.3.1 RUSLE2

This plan has utilized the RUSLE2 computer model to estimate soil loss and sediment delivery from the project area. The RUSLE2 computer model was utilized as a predictive tool to determine the effectiveness of implementing the recommended management measures and practices. While implementing nutrient management into agricultural land uses should reduce the amount of nutrient runoff, the primary transport of nutrients resides with their attachment to soil particles which are then controlled through the implementation of erosion and sediment control practices (USEPA 1993).

Alternative conservation management systems (CMS) (Baseline, Progressive, and Comprehensive) were developed for each land use type. These different CMS scenarios were analyzed through the RUSLE2 model. Estimates from the RUSLE2 model showed a compared return value with different P factors.

- **Baseline Management System** represents the minimal conservation approach with zero to limited management measure implementation.
- **Progressive Management System** represents an intermediate conservation approach that incorporated a management practice that focused on reducing either soil loss or sediment delivery rates.
- **Comprehensive Management System** represents a conservation approach that incorporated multiple management measures to reduce soil loss and sediment delivery rates.

The RUSLE2 model was run for the major agricultural land uses in the project area (row crops and grazing) and was based on the three conservation management systems, with their selected parameters listed in Table 13 and Table 16 respectively. The RUSLE2 is limited to smaller field lengths than is typically observed within the project area. Utilizing a smaller l factor, and therefore a smaller slope length segment, reduces errors caused by irregular slopes, sediment concentration, and differing soil types. The RUSLE2 model allows for only a few and limited c factors to be analyzed at once and therefore not all recommended CPPE practices are able to be analyzed. Field locations are shown in Figure 10. These example field locations were selected to represent the recommended overland flow slope length (l factor), the various field slopes (s factor), and different erosion potentials found within each type of land use.

The RUSLE2 analysis also evaluated soil loss and sediment delivery from mild and steep slopes. The NRCS Highly Erodible Lands map was used to develop an Erosion Potential map (see Figure 11) for the project area which reflected the different slope conditions compared in the RUSLE2 analysis (HEP, HMEP, and MEP).

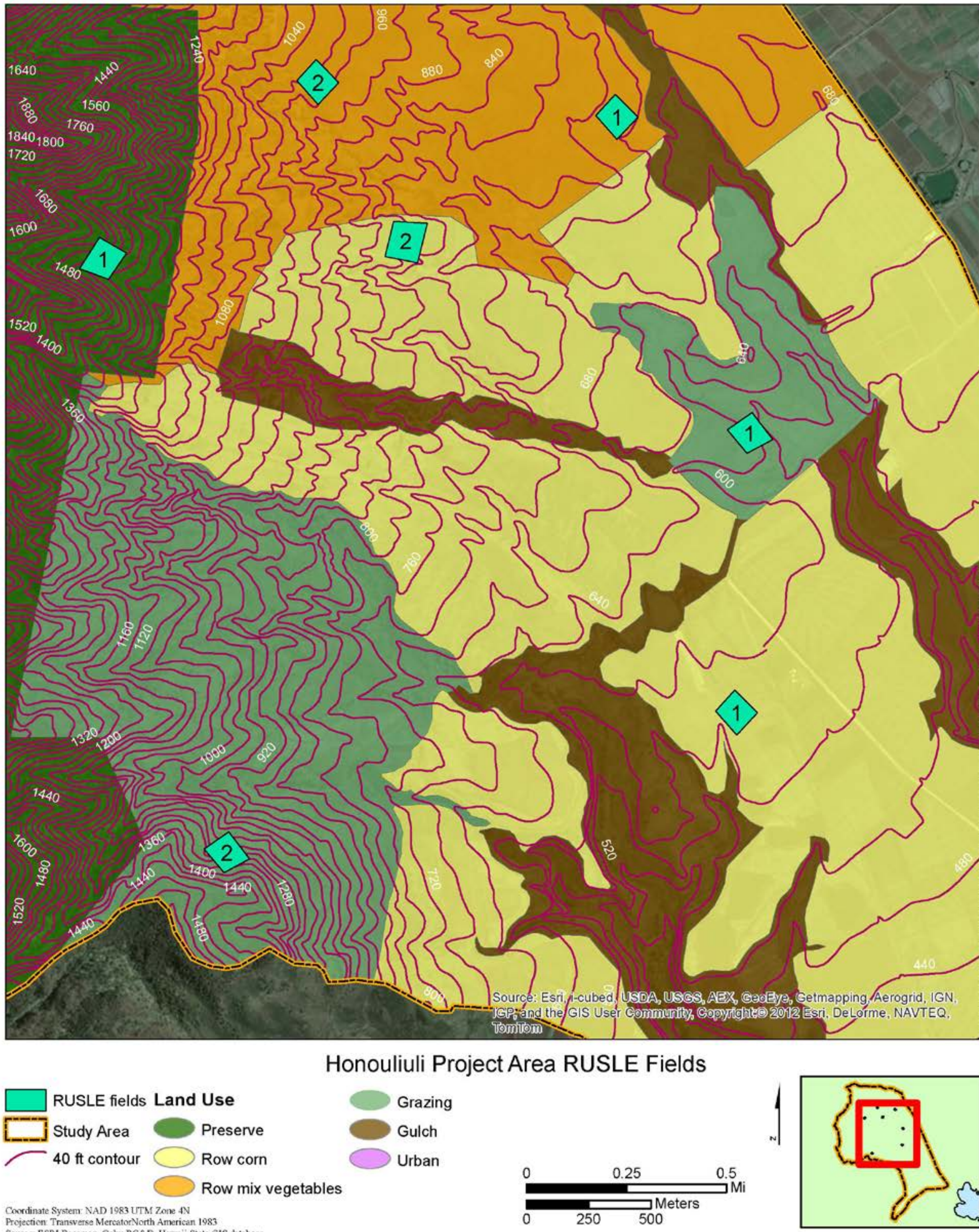


Figure 10. RUSLE Field Locations.

Example field locations were selected to represent various slope lengths (l factor) and steepness (s factor), and different erosion potentials found within each type of land use.

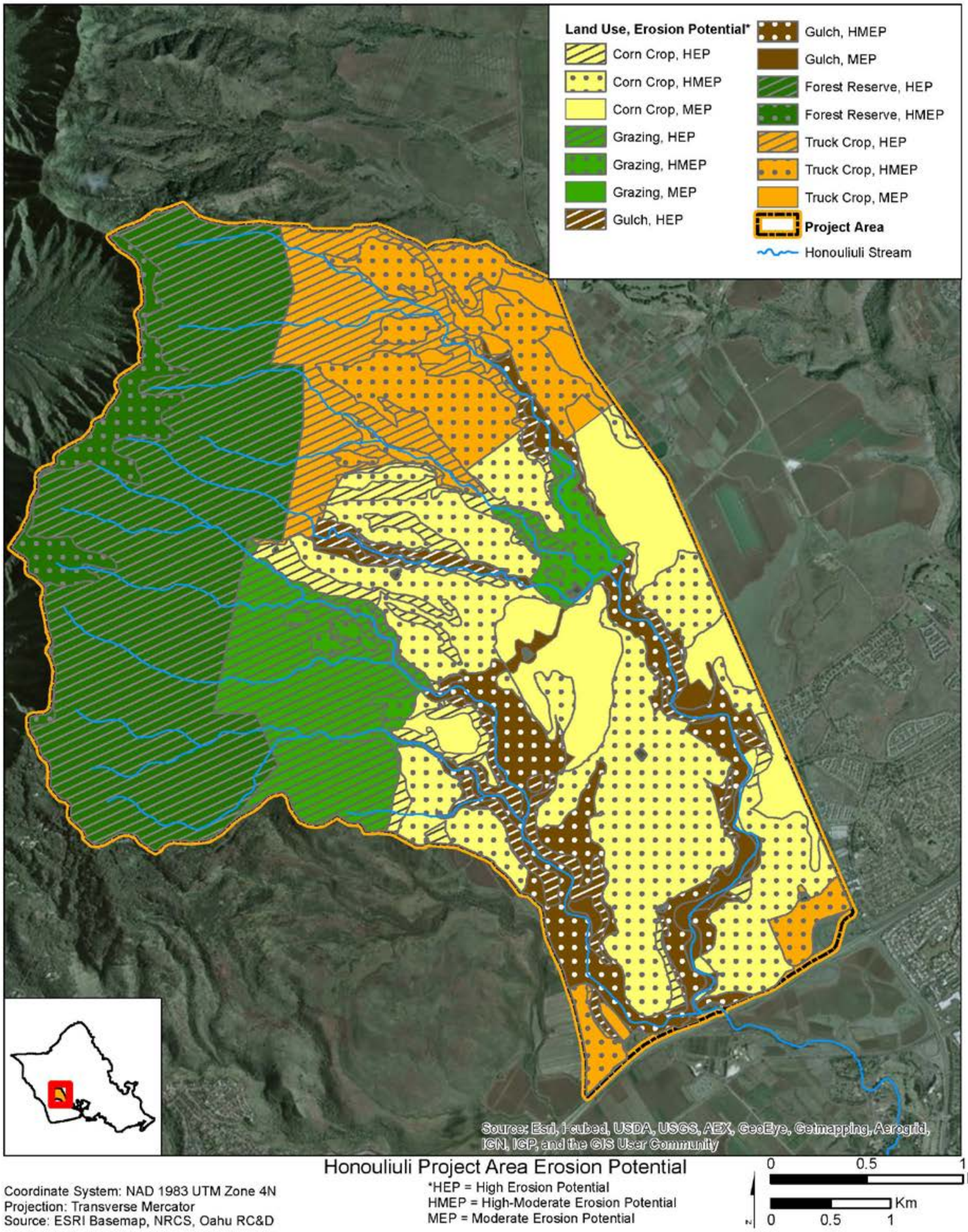


Figure 11. Erosion Potential
Erosion potential within the project area was based on NRCS's highly erodible land categorization, and was used to evaluate pollutant loads in the RUSLE2 model.

Agricultural Land Use

Row Crop - Corn

The baseline management system for seed corn production did not account for any additional measures to prevent erosion or impede the delivery of sediment from the field. The progressive management system A included a single herbaceous vegetated filter strip that was 10% of the slope length, equaling 20 ft in width. This filter strip was included for the purpose of capturing suspended solids and associated contaminants in stormwater and irrigation runoff. Progressive management system B incorporated a cover crop into the management rotation, whereas the previous management rotations left the fields exposed between corn plantings. Cover crops work to prevent erosion by runoff and wind and further assist to capture and recycle or redistribute nutrients in the soil profile.

Results from RUSLE2 showed that field 1 had decreased sediment delivery rates to below the T-value for both progressive management systems A and B. Soil loss rates were reduced to below the T-value when a cover crop was added to the management rotation in progressive system B. The comprehensive management system resulted in the lowest values for both soil loss and delivery rates to below the T-value. Results for field 2, with 10% slope, showed a reduction in sediment delivery rates to below the T-value with the progressive management system A and the comprehensive management system. Results for row crop management systems indicate that the field slope is an important factor to consider when selecting management measures to reduce soil loss and sediment delivery rates. Installing management measures that focus on either soil loss or delivery rates will in turn reduce the other; however reduction rates were magnified when both were implemented in the comprehensive system.

Row Crop - Truck Crop

A majority of the truck crop fields are located in the upper elevations of the watershed where the terrain is typically steeper. These fields, therefore, have greater slope percents, (s factor), and smaller field lengths, (l factor). Inputs for the RUSLE2 model defined practices that reduced sediment being delivered from the fields and then to retain runoff and reduce erosion by reducing the slope length. The inputs for truck crops included 1) vegetative barriers along the slope to break up the slope length and reduce sheet and rill erosion, and 2) cover cropping to limit exposed soil and reduce dislodgement of soil particles.

Results from running the RUSLE2 model indicated that without management measures soil loss and sediment delivery is well above the T-Value. Incorporating progressive system A (vegetative barriers) showed the greatest reduction for sediment delivery, whereas progressive system B (cover crops) reduced soil loss within the field. Soil loss and sediment delivery rates remained above the T-Value for both progressive systems. The greatest reduction in soil loss and delivery rates were shown when incorporating both progressive measures into the comprehensive management system.

Table 13. The RUSLE2 Parameters for Row Crop Management Systems

<table>
<tr><th rowspan="2">RUSLE Factors</th><th colspan="2">Row Crop</th></tr>
<tr><th>Corn</th><th>Truck Crop</th></tr>
<tr><td>r</td><td>• 32-36” of rain per year</td><td>• 32-36” of rain per year</td></tr>
<tr><td>k</td><td>• Field 1: WaA silty clay
• Field 2: KuC Kolekole silty clay loam</td><td>• Field 1: KyB Kunia silty clay
• Field 2: McE2 Mahana silty clay loam</td></tr>
<tr><td>ls</td><td>• Field 1: 200 ft at 4%
• Field 2: 200 ft at 10%</td><td>• Field 1: 100 ft at 8%
• Field 2: 100 ft at 20%</td></tr>
<tr><td>c</td><td>• See Appendix 3</td><td>• See Appendix 3</td></tr>
<tr><td>CMS: p</td><td>• Baseline:
o Contour: Up and down hill
• Progressive:
▪ Contour: Up and down hill
System A:
▪ Filter strip: 1 Bermuda grass filter strip with a width of 10 percent of slope length.
System B:
▪ Cover crop added to management rotation
• Comprehensive:
▪ Contour: Up and down hill
▪ Filter strip: 1 Bermuda grass filter strip with a width of 10 percent of slope length.
▪ Cover crop added to management rotation</td><td>• Baseline:
o Contour: Up and down hill
• Progressive:
▪ Contour: Up and down hill
System A:
▪ Vegetative Barriers (grass hedges): 2 Vegetative Barriers, 1 in middle and 1 at bottom of slope
System B:
▪ Cover crop added to management rotation
• Comprehensive:
▪ Contour: Up and down hill
▪ Vegetative Barriers (grass hedges): 2 Vegetative Barriers, 1 in middle and 1 at bottom of slope
▪ Cover crop added to management rotation</td></tr>
</table>

Table 14. The RUSLE2 Results for Row Crop: Corn Management Systems.

T-Value: 5	Soil Loss[4]	Sediment delivery[5]
	t/ac/yr	
Management Systems		
Field 1; Slope = 4%; Erosion potential = MEP		
Baseline	7.9	7.9
Progressive A	6.1	1.4
Progressive B	2.3	2.3
Comprehensive	1.8	0.43
Field 2; Slope = 10%; Erosion potential = HMEP		
Baseline	24	24
Progressive A	12	3.5
Progressive B	6.8	6.8
Comprehensive	5.2	1.3

Table 15. The RUSLE2 Results for Row Crop: Truck Crop Management Systems.

T-Value: 5	Soil Loss	Sediment delivery
	t/ac/yr	
Management Systems		
Field 1; Slope = 8%; Erosion potential = HMEP		
Baseline	11	11
Progressive A	7.8	2.3
Progressive B	5.6	5.6
Comprehensive	3.7	1.0
Field 2; Slope = 20%; Erosion potential = HEP		
Baseline	32	32
Progressive A	23	6.9
Progressive B	17	17
Comprehensive	4.2	1.1

[4] Soil erosion rates reflect the amount of soil being displaced within the field. The displaced soil particles may be redeposited within the field, and do not necessarily move off-site or enter nearby water bodies.
[5] Sediment delivery rates reflect the amount of displaced soil that moves off-site, potentially entering nearby water bodies.

Table 16. The RUSLE2 Parameters for Grazing Management Systems.

RUSLE Factors	Grazing
Management	• Continuous overgrazing
r	• 32-36” of rain per year
k	• Field 1: KyC Kunia silty clay • Field 2: HLMG Helemano silty clay
ls	• Field 1: 100 ft at 30% • Field 2: 100 ft at 60%
c	• See Appendix 3
CMS: p	▪ **Baseline**: ▪ Contour: Default ▪ **Progressive**: ▪ Contour: Default **System A:** ▪ Hillside ditch: 1 hillside 0.05% grade at bottom of RUSLE slope. **System B:** ▪ Hillside ditches: 1 hillside ditch 0.05% grade in middle of RUSLE slope. ▪ **Comprehensive**: ▪ Contour: Default ▪ Hillside ditches: 2 hillside ditch 0.05% grade 1 in middle of RUSLE slope at bottom of RUSLE slope.

Table 17. The RUSLE2 Results for Grazing Management Systems

	Soil Loss	Sediment delivery
	t/ac/yr	
Management Systems		
Field 1; Slope 30%; T-Value 5; Erosion potential = HMEP		
Baseline	1.3	1.3
Progressive A	1.0	0.64
Progressive B	0.93	0.83
Comprehensive	0.82	0.57
Field 2; Slope 60%; T-Value 4; Erosion potential = HEP		
Baseline	2.4	2.4
Progressive A	1.7	0.84
Progressive B	1.5	1.3
Comprehensive	1.3	0.71

Grazing

Estimates from the RUSLE2 showed soil loss and delivery rates below the T-value; indicating that land used for grazing is likely not a major contributor to sediment running off the project area. Land used for grazing in the Honolulili project site has a high s factor and a low l factor. The RUSLE2 model showed reductions in both soil loss and sediment delivery when diversion measures were implemented. A hillside ditch was selected to safely control the flow of water by diverting runoff from upland sloping areas to a stable outlet.

Forest Reserve Land Use

Modeling soil erosion in forested watersheds remains a difficult and challenging task due to the physical and logistical reality of this remote and, in many areas, extreme environments. In forested areas, sediment and particulate phosphorus and nitrogen can come from unstable stream embankments, shallow storm-induced landslides, and altered and denuded landscapes as influenced by vegetative cover and wildlife disturbance (State of Hawaii 2009). While the Honouliuli Forest Reserve consists largely of undeveloped forest land, it has significant areas of invasive plant coverage and feral ungulate population. However, scientific research is only just beginning to provide quantitative information about the effectiveness of managing invasive species and feral ungulates to achieve water quality improvements (e.g. Browning 2008). Results from a study in Manoa Valley on O‘ahu demonstrated that runoff and sediment export from the upper forested areas are highly variable (Dunkell 2011).

The RUSLE2 was not used in this report to calculate soil loss from the Honoulilui Forest Reserve. In a recent study, Wang (2010) tested the RUSLE with compared field measurements to determine the magnitude of effects from the topographical attributes, road construction, and harvesting operations on sediment delivery to a stream channel. The soil loss equation displayed poor accuracy, yielding predictions hundreds of times larger than the actual masses of collected data. Wang (2010) concluded, “The RUSLE is an overly simplistic model for complex forested terrains where there are highly heterogeneous surface and slope conditions and complex erosion processes that are dominated by discrete sediment sources. Consequently, prediction models that are overly simplistic and assume homogenous environments within forested watersheds will likely predict sediment delivery poorly”.

A recently published study took place within the adjacent Waikele watershed that compared suspended sediment yield from different land use types. Results from the Kīpapa subbasin, that encompasses an area that is entirely covered by forest land use, had a normalized hillslope suspended-sediment yield of 386 tons/yr/mi2 during the study period; this value is within the range of values reported for other forested valleys in wet climates in Hawai‘i, and is much lower than that of the watershed as a whole (1,810 tons/yr/mi2) (Izuka 2012). These results suggest that the Forest Reserve in Honouliuli’s project area may not be a major source of sediment.

7.4 Sediment Delivery and Yield Reduction

7.4.1 RUSLE2

The total average annual sediment yield from the different agricultural land use types in the project area were estimated based on the RUSLE2 results for the different CMS. Sediment yield from the forest reserve, gulches, or urban areas were not evaluated using RUSLE2. The total sediment yield from each of the agricultural CMS, erosion potential, and management system is shown in Table 18.

Table 18. Sediment Yield from Agricultural Land Use in Honouliuli Project Area (tons/year)

Agricultural Land Use	Erosion Potential[1]	Total Acres in Project Area	Management System			
			Baseline[2]	Progressive A[3]	Progressive B[4]	Comprehensive[5]
Row Crop: Corn	MEP	535	4,227	749	1,231	230
	HMEP	1,471	35,304	5,149	10,003	1912
	HEP	243	5,832	851	1,652	316
Row Crop: Truck Crop	MEP	97	534	97	155	46
	HMEP	585	3,218	585	936	275
	HEP	511	9,198	1,789	1,533	511
Grazing	MEP	17	22	11	14	10
	HMEP	186	242	119	156	106
	HEP	590	1,416	496	767	419
Total Sediment Yield (Tons / Yr)			**59,991**	**9,864**	**16,447**	**3,824**
Percent reduction from Baseline			--	83%	73%	94%

1 – MEP = Medium Erosion Potential; HMEP = High-medium Erosion Potential; HEP = High Erosion Potential. Erosion potential is based on soil characteristics and slope.
2 – Baseline Management System represents the minimum conservation approach, with little to no effort to minimize erosion.
3 – Progressive Management System A represents an intermediate conservation approach incorporating field edge activities that focus on reducing sediment delivery, but does not necessarily reduce soil particle displacement within the field.
4 – Progressive Management System B represents an intermediate conservation approach incorporating in-field activities that focus on reducing soil particle displacement.
5 – Comprehensive management system represents a conservation approach that incorporates management measures from System A and System B to reduce both in-field soil loss and sediment delivery.

Implementation of conservation practices can significantly reduce the sediment yield from the agricultural lands. The categories in the table should serve as indicators of the reductions because, in actuality, each farmer or rancher will select their own unique combination of conservation practices

The table shows realistically attainable reductions of 75% to 85% if Progressive A or Progressive B levels of management systems are utilized. Because of installation costs and demands on land area, it may not be possible to implement Comprehensive management systems on many farms and ranches.

Seed corn production on High-Moderate and High Erosion Potential land can result in large sediment yields if no conservation practices are implemented. The 1,714 acres of HMEP and HEP land that is available to seed corn cultivation can generate over 40,000 tons of sediment discharge in the Baseline condition. Fortunately, all of the areas currently under cultivation for seed corn production have some level of conservation practices implemented, such that actual sediment yields would be expected to lie between the Progressive Management B system and the Comprehensive System.

Truck crop cultivation on High Erosion Potential land can lead to high sediment discharge if conservation practices are not utilized. The developing farms in the Kunia Loa Ridge area are vulnerable in this category.

7.4.2 WinTR-55 Sediment Yield Reduction

Sediment yield reductions were estimated based on the runoff changes from the project area with and without conservation practices installed. WinTR-55 was used to model runoff from storm events, and runoff volume was used to estimate sediment discharge for the project area. Varying vegetation conditions within the model result in changes in runoff quantity, which can then be used to estimate reductions in sediment discharge with the application of conservation practices. For details on WinTR-55, see Appendix 4.

For the purposes of this study and to provide a basis for comparison of suspended sediment yield with possible treatments, we utilized the instantaneous discharge versus suspended sediment concentration curve derived for Kawela Stream on Molokai. In the period 2001 to 2007, the USGS collected suspended sediment records for Kawela Stream on the south shore of Molokai (Stock, 2010). Few water discharge/sediment discharge relationships are available for Hawaii streams. Kawela stream was selected because it was a leeward stream with arid climate for most of its area, however Kawela stream does not have the same agricultural practices found in the project area. The correlative curve for Kawela Stream was applied to the runoff hydrographs generated by WinTR-55 to estimate the suspended sediment discharge for various storm intensities and resource management levels. Due to the lower peak flow rates at Kawela as compared to Honouliuli, extrapolation to higher flow rates result in unrealistically high suspended sediment concentrations. Therefore, the maximum suspended sediment concentration was capped at 50,000 mg/L. The Stock study reported that the maximum suspended sediment concentration recorded by their study was 54,000 mg/L at a relatively low instantaneous flow of 57 cfs.

The WinTR-55 hydrographs for the 2-year to 100-year 24-hour storms at the Honouliuli project area outlet near the H-1 bridge were used in relation to the Kawela Stream sediment discharge curve to estimate suspended sediment discharge from the Honouliuli project area. The WinTR-55 hydrograph can be output as time versus instantaneous discharge table. The average discharge for a time segment was correlated to the Kawela Stream curve to determine the suspended discharge for the time segment. The suspended sediment discharges for all of the time segments were summed to determine the total suspended sediment yield for each storm intensity.

Table 19. Honouliuli Project Area Sediment Yield - Existing Conditions

Storm Recurrence Interval	Peak Discharge	Sediment Yield	per sq mi	per acre
	(cfs)	(tons)	(tons)	(tons)
2-Year	541	2,588	235	0.4
5-Year	1,353	13,082	1,189	1.8
10-Year	2,816	40,012	3,637	5.5
25-Year	4,950	81,258	7,387	11.2
50-Year	7,475	127,538	11,594	17.6
100-Year	9,974	175,379	15,944	24.2

Table 20. Honouliuli Project Area Sediment Yield - Improved Conditions

Storm Recurrence Interval	Peak Discharge	Sediment Yield	per sq mi	per acre
	(cfs)	(tons)	(tons)	(tons)
2-Year	242	730	64	0.1
5-Year	606	4,591	405	0.6
10-Year	1,532	19,774	1,744	2.7
25-Year	3,247	53,859	4,749	7.4
50-Year	5,258	94,588	8,341	13.0
100-Year	7,492	138,000	12,169	19.0

The average annual sediment yield under existing conditions is estimated to be 15,500 tons (determined by multiplying sediment yield for each storm recurrence level by its expected frequency over 100 years). When conservation practices that reduce peak runoff rates and promote infiltration are applied to all of the land uses in the project area, the annual average sediment yield is lowered to 8,700 tons, a reduction of 6,800 tons, or roughly 44 percent.

The average annual sediment load results from the Win TR-55 analysis compare well with the output from the RUSLE2 modeling. RUSLE2 results indicated nearly 60,000 tons/year from a highly-disturbed, but unprotected, agricultural condition on 4,235 acres or, approximately, two-thirds of the project area. With comprehensive conservation treatment the average annual sediment yield from the agricultural lands could be reduced to 3,824 tons.

8 Cost Data Associated with Management Measures

EPA recognizes management practices, or the combination of practices, as a basis for estimating the effectiveness, costs, and economic impacts of achieving the management measure. It is recognized that there are often site-specific, regional and national variability in the selection of appropriate practices, as well as, design constraints and pollution control effectiveness for practices. Each state developed a database containing cost data related to the implementation of NRCS conservation practices and enhancement activities (NRCS 2012b). Total cost data from FOTG Section I for Hawai‘i was compiled for selected management practices in Table 21 and Table 22. This cost data has assisted with conservation planning and for the purpose of NRCS financial assistance programs contracting. Some unit cost estimates were based on conservation planning experience of authors. These costs will serve as the fundamental basis for estimating costs for management measures in the project area.

Table 21. NRCS FOTG Cost Data for Agricultural Management Practices.

Erosion and Sediment Control			
Conservation Practice	**NRCS eFOTG**	**Total Cost Estimate****	**Practice Life (years)**
Access Control	472	$13.56/acre*	1
Access Road	560	$25.00/ft***	10
Conservation Cover	327	$718.01/acre*	5
Conservation Crop Rotation	328	$97.08/acre*	1
Contour Farming	330	$100.00/acre	1
Cover Crop	340	$515.97/acre*	1
Critical Area Planting	342		
Seeding		$856.99/acre*	10
Organic Seeding		$1,504.46/acre*	
Deep Tillage	324	$61.17/acre	3
Diversion	362	$1.17/sq ft*	10
Field Border	386	$4,005.48/acre*	10
Filter Strip	393	$2.50/ft***	-
Grassed Waterway	412	$1.20/sq ft*	10
Residue and Tillage Management	329	$60.00/acre	1
Sediment Basin	350	$0.18/gallon*	20
Terrace	600	$6.78/ft*	10
Vegetative Barrier	601	$5.32/ft*	5
Water and Sediment Control Basin	638	$1,000,000/ea	-
Nutrients			
Nutrient Management	590	$97.31/acre*	1
Pesticides			
Pest Management	595	$77.66/acre*	1
Irrigation Water			
Irrigation System, Microirrigation	441	$2,387.27/acre*	15
Irrigation Water Management	449	$162.53/acre*	1
Grazing			
Access Road	560	$2.46/sq ft*	-
Fence	382	$1.95/ft*	15
Heavy Use Area Protection	561	5,000.00/ac***	-
Prescribed Grazing	528	$117.35/acre*	1
Range Planting	550	$373.92/acre*	10
Riparian Forest Buffer	391		
Native plants, purchased		$7.40/each*	15
Native plants, free		$2.66/each*	
Stream Crossing	578	$5,000.00/ea	-
Watering Facility	614	$2,000.00/ea	-

Cost data sources:
ftp://ftp-fc.sc.egov.usda.gov/HI/pub/technical/4_PI_Schedules_for_eFOTG/;
*ftp://ftp-fc.sc.egov.usda.gov/HI/pub/technical/Economics/Practice%20Payment%20Schedules%20-%20FY12/
**Total cost generally includes the overall materials, equipment, installation, labor, repair and maintenance.
***Cost estimated by plan authors based on experience and observations from stakeholders.

Table 22. NRCS FOTG Cost Data for Forest Reserve Management Practices.

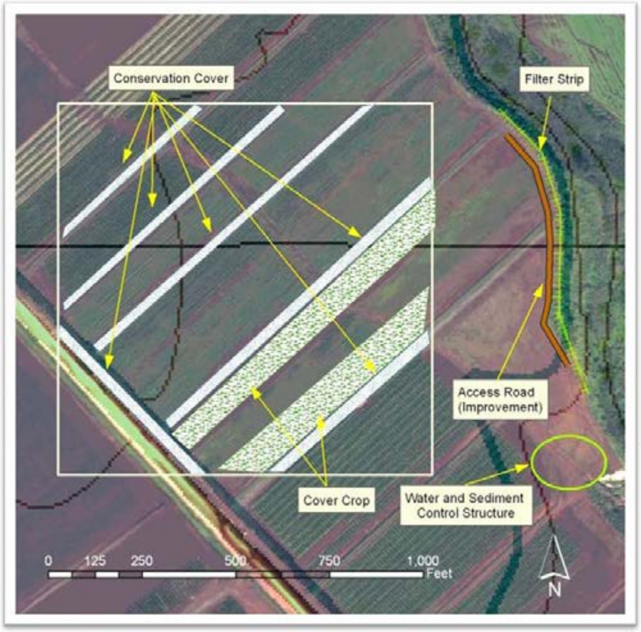
Pre-harvest Planning			
Conservation Practice	**NRCS eFOTG**	**Total Cost Estimate****	**Practice Life (years)**
Access Control	472	$13.56/acre*	1
Fence	382	$1.95/ft*	15
Forest Stand Improvements	666	$378.45/acre*	10
Sediment Basin	350	$0.18/gallon*	20
Water and Sediment Control Basin	638	$0.18/gallon*	20
Streamside Management Zone			
Riparian Forest Buffer	391		
Native plants, purchased		$7.40/each*	15
Native plants, free		$2.66/each*	
Stream Habitat Improvement and Management	395	$0.09/sq ft*	5
Road Management			
Access Road	560	$2.46/sq ft*	10
Fire Management			
Fuelbreak	383	$397.37/acre*	10
Re-vegetation of Disturbed Areas			
Brush Management	314	$42.00/acre*	1
Restoration and Management of Rare or Declining Habitats	643	$436.86/acre*	1
Upland Wildlife Habitat Management	645	$436.86/acre*	1

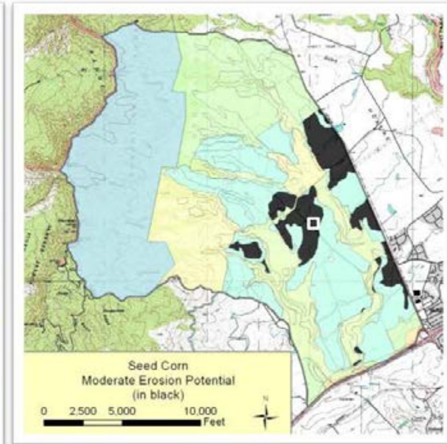
Cost data sources:
ftp://ftp-fc.sc.egov.usda.gov/HI/pub/technical/4_PI_Schedules_for_eFOTG/;
*ftp://ftp-fc.sc.egov.usda.gov/HI/pub/technical/Economics/Practice%20Payment%20Schedules%20-%20FY12/
**Total cost generally includes the overall materials, equipment, installation, labor, repair and maintenance.

A commitment to the operation and maintenance (O&M) of management practices is necessary to ensure continued performance for the design life of the implemented management measure. The primary source for practice life information was derived from NRCS FOTG Section I and the EPA's Guidance Specifying Management Measures of Nonpoint Pollution in Coastal Wetlands (USEPA 1993).

9 Installation Quantification

The quantities of conservation practices required in the project area were estimated based on sampling within 1,000 foot by 1,000 foot (22.96 acres) blocks within each combination of agricultural land use and Erosion Potential category (MEP, HMEP, and HEP) (see Appendix 5). The Gulches and the Forest Reserve were also evaluated for the quantification of conservation practice installation. Many of the block locations were the same sites selected for the RUSLE2 analysis. A sample block is shown in Figure 12. See Appendix 5 for the complete set of sample location maps and conservation practice quantities.





Conservation Practices	Units	Sample Block	MEP Seed Corn
Cover Crop	acre	12	223
Conservation Cover	acre	2	37
Filter Strip	lin. ft.	1,000	18,600
Access Road	lin. ft.	750	14,000
W&S Control Struct.	each	1	47

Conservation Practices for **Seed Corn** Sample Block
Moderate Erosion Potential

Figure 12. Conservation practices identified for a sample 1000 ft x 1000 ft block.
A 1000 ft x 1000 ft (~23 acre) sample block was selected for each land use / erosion potential combination. Each sample block was evaluated to identify conservation practices to reduce erosion and sediment delivery.

Each block was examined for crop type, roadways, existing practices, vegetative cover, water courses, and slope using recent aerial imagery and the USGS Digital Rastor Graphic. Additional conservation practices were considered to, first, prevent erosion in the field such as with cover crops; secondly, filter and settle sediment in the field such as with field borders; thirdly, prevent further erosion along water courses such as with grassed waterways; and, finally, to remove sediment in storm water as with sediment basins. Sediment control practices, approximating the comprehensive management system, were identified over the approximately 23 acre block.

Quantities of the practices were measured either by area or by linear distance. A handful of widely-used conservation practices were applied in this analysis. However, there are many different practices for varied situations that can be considered in addressing the conservation needs discussed above.

The quantities for each 23 acre block were expanded to represent the conservation practice needs for each land use/ Erosion Potential combination. Recognizing that all of the land area would not be converted to agricultural land uses, a factor ranging from 0.5 to 1.0 was used to adjust the land area requiring conservation practices. The quantities of installation for each of the conservation practices needed for the total land use/ erosion potential combination are shown in Table 23. Total costs for implementing these management practices quantities are shown below in Table 24; which were based on costs from Table 21 and Table 22.

Table 23. Quantities Associated with Conservation Management Practice Installation.

		Seed Corn	Seed Corn	Truck Crop	Truck Crop	Grazing	Grazing	Gulches	Forest Reserve	Total Quantity
		MEP	HMEP & HEP	MEP & HMEP	HEP	MEP & HMEP	HEP	All EP	All EP	
Access Road	ft	13,957	20,493	14,826	36,936	3,972	4,489	8,620	11,196	**114,489**
Conservation Cover	ac	37		71	156					**264**
Cover crop	ac	223	373	95	62					**753**
Critical Area Planting	ac					16	36	69	45	**166**
Diversion	ft				31,104					**31,104**
Fence	ft					23,830	89,783		44,783	**158,396**
Filter Strips	ft	18,609	74,522	35,583	15,552	7,943	17,957			**170,165**
Forage Planting	ac					79	90			**169**
Grassed Waterway	ft		37,261	35,583						**72,843**
Heavy Use Area	ac					8	18			**26**
Hillside Ditch	ft				15,552				22,391	**37,943**
Prescibed grazing	ft					119	269			**389**
Residue and tillage Mgt	ac			356	233					**589**
Stream crossing	ea		37		31	16	18			**102**
Terraces	ft		93,152		108,865					**202,017**
Vegetative Barrier	ft			71,165						**71,165**
Watering Facility	ea					2	4			**6**
Water and Sediment Control Structure	ea	47	75	47	47	8	18	34		**276**
Sediment Basin	ea							2		**2**

Table 24. Costs Associated with Conservation Management Practice Installation.

	Seed Corn	Seed Corn	Truck Crop	Truck Crop	Grazing	Grazing	Gulches	Forest Preserve	Total Quant.
	MEP	HMEP & HEP	MEP & HMEP	HEP	MEP & HMEP	HEP	All EP	All EP	
Access Road	$348,913	$512,337	$370,652	$923,410	$99,293	$112,228	$215,489	$279,891	**$2,862,215**
Conservation Cover	$26,722		$51,097	$111,665					**$189,483**
Cover crop	$115,225	$192,266	$48,962	$32,100					**$388,552**
Critical Area Planting					$15,887	$35,913	$68,957	$44,783	**$165,539**
Diversion				$311,043					**$311,043**
Fence					$46,469	$175,076		$87,326	**$308,872**
Filter Strips	$46,522	$186,304	$88,957	$38,880	$19,859	$44,891			**$425,413**
Forage Planting					$29,709	$33,579			**$63,287**
Grassed Waterway		$931,522	$889,565						**$1,821,087**
Heavy Use Area					$39,717	$89,783			**$129,500**
Hillside Ditch				$155,522				$223,913	**$379,435**
Prescribed grazing					$13,941	$31,514			**$45,455**
Residue and tillage Mgt			$21,350	$13,997					**$35,347**
Stream crossing		$186,304	$0	$155,522	$79,435	$89,783			**$511,043**
Terraces		$631,572	$0	$738,106					**$1,369,678**
Vegetative Barrier			$378,599						**$378,599**
Watering Facility					$3,972	$8,978			**$12,950**
Water and Sediment Control Structure	$94,887	$149,043	$94,887	$93,313	$15,887	$35,913	$68,957		**$552,887**
Sediment Basin							$2,000,000		**$2,000,000**
Total	**$632,269**	**$2,789,349**	**$1,944,068**	**$2,573,558**	**$364,169**	**$657,658**	**$2,353,402**	**$635,913**	**$11,950,385**
Acres	**535**	**1,714**	**682**	**511**	**203**	**590**	**793**	**2,060**	
$ per acre	**$1,182**	**$1,627**	**$2,851**	**$5,036**	**$1,794**	**$1,115**	**$2,968**	**$309**	

10 Implementation Strategy

The specific management actions and measures outlined in this Plan will be selected and implemented as relevant with the cooperation of local, state and federal government agencies, by the stakeholders that reside and work within the project area. The framework provided below is intended to assist in this process by outlining several of the basic elements for implementing NPS pollution reduction measures. These elements include a summary of technical and financial assistance and resources, a schedule with interim and measurable milestones, an educational and public outreach component, and a framework for monitoring and evaluating the effectiveness of implemented measures.

10.1 Priority Activites and Management Practices

Recommendations for prioritizing the implementation of conservation practices are provided in a template formatted manner for quick reference on typical combinations of practices to control soil erosion and sediment discharge for the various land use types in the project area. This template format expands upon the list of conservation practices that were selected for use in the RUSLE2 and WinTR-55 models. The models demonstrated that the application of conservation practices reduced erosion and sediment yield at both the typical field and watershed levels. This templates format takes a tailored approach to the various erosion and sediment discharge problems found in the project area. The templates or typical conservation practice combinations are based on land use category and the propensity of the soil at the site to water erosion. Below is a discussion on erosion and sediment problems typically found in each land use category. Conservation practices that mitigate the identified erosion and sediment problems are displayed below with priority practices presented in tables (see Table 25, Table 26, Table 27, and Table 28).

Seed Corn

Seed corn producers in the project area have been actively installing erosion and sediment control practices. The varying production requirements, soil resource condition, and management have resulted in different combinations of practices on the various seed corn farms. The blocks selected for seed corn include one on Moderate erosion potential land and the other on High-Moderate erosion potential land. While use of High erosion potential land is not anticipated for seed corn production, High erosion potential land will be grouped with High-Moderate erosion potential land

Bare areas

Due to their crop management needs to isolate seed corn and research plots from other corn plots and inhibit other plants from their fields, some corn companies use bare ground areas between fields as a buffer for plant material contamination. These bare areas are highly susceptible to rain and wind erosion.

Bare areas used to maintain genetic purity of seed corn are susceptible to erosion.

- Vegetative cover for the bare earth areas will reduce erosion considerably by cutting down the rate of soil detachment by raindrops. For bare areas that are fallow and will be replanted in corn, the Cover Crop (340) conservation practice should be applied. The plant material should be compatible, that is, not compete, with the corn crop. The cover crop will likely be turned under before corn planting and can add valuable organic matter and nutrients to the soil. A suggested plant material is "Tropic Sun" Sunnhemp (*Crotalaria juncea*).


Cover crops like buckwheat (left) and sunn hemp (right) reduce soil erosion and improve soil quality.

- Bare areas between fields that will not be cultivated can be permanently revegetated using the Conservation Cover (327) practice standard. Here again, the plant material should be compatible with seed corn production. Unlike the Cover Crop practice the plant material should be perennial and expected to maintain vigor year around.
- Bare areas that are actively eroding or are in need of immediate revegetation should be treated using the Critical Area Planting (342) conservation practice. Often a reinforcing substrate such as rock or geotextile will be required to stabilize a severe erosion problem

Long cultivation rows

Due to long rows in the fields, sheet and rill runoff concentrates into water streams, along the row, resulting in formation of gullies and an increase in erosion. In order to improve soil moisture and aquifer recharge, rows should be designed to retain and infiltrate precipitation and runoff, as much as possible.

Reducing the length of the row or reducing the slope can cut down on the concentration of runoff that can form gullies.

- On fields with milder slopes, the Row Arrangement (557) conservation practice can be utilized to lay out straight rows with the least amount of slope. This practice is often called "cross slope farming."
- On steeper or more undulating fields, the Contour Farming (330) conservation practice can be utilized to lay out the rows in the field to follow the contours at a specified slope. The curviness of the rows may present a problem for cultivation machinery.
- The capacity to safely hold and discharge runoff with contour farming can be increased using the Terrace (600) conservation practice. Terraces can be used to reduce the lateral slope of the entire field.

- The Vegetative barrier (601) conservation practice can be used to create "mini-terraces" in fields with milder slopes.

Concentration of runoff in the field

Often the capacity of the row to contain runoff is exceeded. Storm runoff will cross from row to row following the field slope and concentrate into gully-forming streams. Methods to safely concentrate the runoff in the field and convey it to an outlet need to be applied. For straight rows, protective water courses that run through the rows and generally along the contour are recommended. These water courses will effectively break up the length of the row and prevent gully forming concentrations in the row.

Runoff from cultivated fields concentrates and forms gullies, carrying large amounts of sediment.

- The Vegetative Barrier (601) conservation practice can be used on milder slopes to create flat terrace-like structures to retain runoff in the field or planted at a low gradient to guide concentrated runoff from the field.
- For larger fields with steeper slopes, Diversions (362) may be necessary to provide the runoff-handling capacity and structural stability. Diversions were common in the pineapple fields in the project area but have been largely removed by the current farming operations.
- As the runoff is concentrated in or between the fields, additional waterway capacity is required. The Grassed Waterway (412) conservation practice can be used to collect and convey water from terraces and diversion to a safe outlet. The grass lining of the waterway can also trap sediment and improve the quality of water leaving the field.

A grassed waterway safely conveys runoff and reduces sediment.

Sediment-laden runoff from the fields

Runoff leaving the field during an intense storm will contain high concentrations of sediment. While the conservation practices discussed earlier serve to reduce erosion in the field, the practices discussed immediately below seek to capture and remove the sediment as near the field as possible and improve the water quality of the storm runoff leaving the farm.

- Runoff from the rows can be dispersed along the field edge. The establishment of a Field Border (386) along that field edge can reduce sediment discharge from the field.
- A secondary "line of defense" to the Field Border would be establishment of a Filter Strip (393) adjacent to the field and before the runoff exits the farm, such as into the gulch. Filter strips are most effective when flow depths are low and the flow is uniformly spread over a wide area.
- Once the sediment-laden flow is in the naturally-formed drainageways, larger structures will be required to remove sediment. A Water and Sediment Control Basin (638) can be installed in minor drainageways to slow velocities and detain runoff to allow sediment to settle. This engineered practice can be constructed at various levels of complexity. A simple structure could incorporate a filter strip in the basin.

Concentrated runoff from the field to an outlet

Runoff leaving the field may be combined with similar discharges from other fields before entering the stream system. The combined runoff will require a drainage system to prevent gully erosion and formation of headcuts.

- Once runoff is collected from rows, terraces, and diversions, the Grassed Waterway (412) conservation practice can be used to convey significant flow volumes to a stream or drainage channel. The grassed lining protects the waterway from erosion while allowing infiltration and sediment filtering and deposition.
- On steeper slopes and in narrow locations, the Grassed Waterway may not be suitable. The Lined Waterway or Outlet (468) conservation practice can help design waterways that are stable under higher water velocities. The conservation practice can also be used to dissipate energy at the outlets, using basins, pools, or blocks, to prevent erosion at the point where the runoff enters the main stream system.

Unpaved farm roads

Farm roads may be a major source of sediment if not engineered correctly. Roads often become the main drainageways for runoff from the fields and erode heavily during storms.

- The Access Roads (560) conservation practice can be used to plan and locate farm roads to be less susceptible to erosion. The conservation practice can also be used to modify existing roads to include drainage elements, such as water bars, to take runoff off of the road and into roadside ditches. The conservation practice can also assist with surfacing or paving of farm roads.
- Some roads are very heavily trafficked or on soils that are not suitable for traffic. These road sections may turn to deep mud when wet and/or dust when dry. The Heavy Use Area Protection (561) can be used to provide surface treatment or subsurface reinforcement to reduce erosion and to improve the utility of the road.
- When roads cross waterways there is a risk of increased bed and bank erosion and washout of the road in intense storms. The Stream Crossing (578) conservation practice can be used to identify and design the most suitable and stable crossings over streams and constructed waterways.

Table 25. Priority Practices for Row Crop: Corn Production

Resource Concern	Moderate Erosion Potential	High-Moderate Erosion Potential	High Erosion Potential
Bare areas between fields	• ***Cover crop*** • Conservation cover • Critical Area Planting	• ***Cover crop*** • Conservation cover • Critical Area Planting	• ***Cover crop*** • Conservation cover • Critical Area Planting
Long, straight rows	• Row Arrangement (Cross slope)	• Contour farming • ***Vegetative barrier*** • ***Terrace***	• Contour farming • ***Vegetative barrier*** • ***Terrace***
Concentration of runoff in the field	• ***Vegetative barrier***	• ***Vegetative barrier*** • Diversion • ***Grassed Waterway***	• ***Vegetative barrier*** • Diversion • ***Grassed Waterway***
Sediment-laden runoff from the field	• Field border • ***Filter Strip*** • ***Water and Sediment Control Basin***	• Field Border • ***Filter Strip*** • ***Water and Sediment Control Basin*** • Sediment Basin	• Field Border • ***Filter Strip*** • ***Water and Sediment Control Basin*** • Sediment Basin
Concentrated runoff from the field to an outlet	• ***Grassed waterway*** • Lined Waterway or Outlet	• ***Grassed Waterway*** • Lined Waterway or Outlet	• ***Grassed Waterway*** • Lined Waterway or Outlet
Unpaved farm roads	• ***Access Road*** • Heavy Use Area Protection • Stream Crossing	• ***Access Road*** • Heavy Use Area Protection • Stream Crossing	• ***Access Road*** • Heavy Use Area Protection • Stream Crossing

Bold-italics face indicates practices of higher relative importance based on practice effectiveness and cost.

Truck Crops

The established truck crop farmers generally farm lands with milder slopes. All of the fields for the established farmers are on High-Moderate erosion potential soils along Kunia Road. Newer farms are developing to the west of the established truck crop farmers. While some of the farms are situated on former pineapple fields on High-Moderate erosion potential land, some farms are located on hillsides and in gulches that have High erosion potential.

Bare areas in the fields

Truck crops are typically grown monoculture in bare soil. The soil is left vulnerable to raindrop erosion and sheet and rill erosion. The soil can be protected by leaving a matrix of plant material from the previous crop in the field.

- The Residue and Tillage Management (329) conservation practice can be applied to retain plant residue in the field and to manage tillage operations to least disturb the soil structure to reduce erosivity of the soil.

- The Mulching (484) conservation practice can be used to protect the soil surface with organic and inorganic materials. Sources of organic mulch include the seed corn residue and commercial composting operations.

- Farmers on steeper slopes may consider the Multi-Story Cropping (379) conservation practice to reduce erosion. The practice calls for a stand of trees planted and managed as a perennial overstory. Beneath the trees, shorter-termed crops can be cultivated. The tree canopy will reduce rainfall erosion and the stand of trees can stabilize soil on the steep hillsides.

Bare areas outside of fields

Bare areas outside of the fields exist throughout the row crop area for roads, buildings, and other facilities; on fallowed fields, and on lands that have been opened but not yet cultivated. Bare areas are being expanded due to a high rate of grubbing and grading occurring in the new farm area. Many of the long-termed bare areas are on steep slopes.

- Vegetative cover for the bare earth areas will reduce erosion considerably by cutting down the rate of soil detachment by raindrops. For bare areas that are fallow and will be replanted, the Cover Crop (340) conservation practice should be applied. The cover crop will likely be turned under before planting of a crop and can add valuable organic matter and nutrients to the soil. A suggested plant material is “Tropic Sun” Sunnhemp (*Crotalaria juncea*).

- Bare areas between fields that will not be cultivated can be permanently revegetated using the Conservation Cover (327) practice standard. Unlike the Cover Crop practice the plant material should be perennial and expected to maintain vigor year around.
- Bare areas that are actively eroding or are in need of immediate revegetation should be treated using the Critical Area Planting (342) conservation practice. Often a reinforcing substrate such as rock or geotextile will be required to stabilize a severe erosion problem

Long cultivation rows

Due to long rows in the fields, sheet and rill runoff concentrates into water streams, along the row, resulting in formation of gullies and an increase in erosion. In order to improve soil moisture and aquifer recharge, rows should be designed with mild gradients to retain and infiltrate precipitation and runoff, as much as possible. Reducing the length of the row or reducing the slope can cut down on the concentration of runoff that can form gullies. Preventing runoff from crossing laterally from row to row can also reduce gully erosion.

- On fields with milder slopes, the Row Arrangement (557) conservation practice can be utilized to lay out straight rows with the least amount of gradient. This practice is often called "cross slope farming."
- On steeper or more undulating fields, the Contour Farming (330) conservation practice can be utilized to lay out the rows in the field to follow the contours at a specified slope. The curviness of the rows may present a problem for cultivation machinery.
- The capacity to safely hold and discharge runoff with contour farming can be increased using the Terrace (600) conservation practice. Terraces can be used to reduce the lateral slope of the field.
- The Vegetative Barrier (601) conservation practice can be used to create "mini-terraces" in fields with milder slopes.
- The Rock Barrier (555) conservation practice can be used on steeper slopes to provide stability on the lower side of terraces.
- A combination of crops, in the same field, can include crops that are more erosion resistant, such as woody or densely spaced trees and shrubs. In the Alley Cropping (311) conservation practice, the more vulnerable crops are grown between rows of the trees and shrubs which provide the structural support for the rows which are installed on the contour.
- The least amount of soil disturbance is recommended on steep slopes. Trees and orchards are compatible with farming on steep slopes due to no periodic tilling required. The Contour Orchard and Perennial Crops (331) conservation practice provides guidance for techniques to minimize soil erosion in the installation and maintenance of orchards and vineyards on steep slopes.

Concentration of runoff in the field

Often the capacity of the row to contain runoff is exceeded. Storm runoff will cross from row to row following the field slope and concentrate into gully-forming streams. Methods to safely concentrate the runoff in the field and convey it to an outlet need to be applied. For straight rows, protective water courses that run through the rows and generally along the contour are recommended. These water courses will effectively break up the length of the row and prevent gully forming concentrations in the row.

- The Vegetative Barrier (601) conservation practice can be used on milder slopes to create flat terrace-like structures to retain runoff in the field or can be planted at a low gradient to guide concentrated runoff from the field.

- For larger fields with steeper slopes, Diversions (362) may be necessary to provide the runoff-handling capacity and structural stability necessary. Diversions were common in the pineapple fields in the project area but have been largely removed by the current farming operations.

- As the runoff is concentrated in or between the fields, additional waterway capacity is required. The Grassed Waterway (412) conservation practice can be used to collect and convey water from terraces and diversion to a safe outlet. The grass lining of the waterway can also trap sediment and improve the quality of water leaving the field.

- Terraces (600) can also be used to limit the concentration of water between groups of rows. Vegetative Barrier (601) and Rock Barrier (555) can be incorporated into the terrace design.

Sediment-laden runoff from the fields

Runoff leaving the field during an intense storm will contain high concentrations of sediment. While the conservation practices discussed earlier serve to reduce erosion in the field, the practices discussed immediately below seek to capture and remove the sediment as near the field as possible and improve the water quality of the storm runoff leaving the farm.

- Runoff from the rows can be dispersed along the field edge. The establishment of a Field Border (386) along that field edge can reduce sediment discharge from the field.

- A secondary “line of defense” to the Field Border would be establishment of a Filter Strip (393) adjacent to the field and before the runoff exits the farm, such as into the gulch. Filterstrips are most effective when flow depths are low and the flow is uniformly spread over a wide area.

- Once the sediment-laden flow is in the naturally-formed drainageways, larger structures will be required to remove sediment. A Water and Sediment Control Basin (638) can be installed in minor drainageways to slow velocities and detain runoff to allow sediment to settle. This engineered practice can be constructed at various levels of complexity. A simple structure could incorporate a filter strip in the basin.

Concentrated runoff from the field to an outlet

Runoff leaving the field may be combined with similar discharges from other fields before entering the stream system. The combined runoff will require a drainage system to prevent gully erosion and formation of headcuts.

- Once runoff is collected from rows, terraces, and diversions, the Grassed Waterway (412) conservation practice can be used to convey significant flow volumes to a stream or drainage channel. The grassed lining protects the waterway from erosion while allowing infiltration and sediment filtering and deposition.

- On steeper slopes and in narrow locations, the Grassed Waterway may not be suitable. The Lined Waterway or Outlet (468) conservation practice can be used to design waterways that are stable under higher water velocities. The conservation practice can also be used to design structures to dissipate energy at the outlets, using basins, pools, or blocks, to prevent erosion at the point where the runoff enters the main stream system.

- On steep slopes, it is difficult to maintain waterway stability without using structural materials, such as reinforced concrete. The Underground Outlet (620) conservation practice can be used to use risers to collect runoff and pipes to convey water to safe outlets. A series of risers can be used in a terrace system connected to a single pipe and outlet.

Unpaved farm roads

Farm roads may be a major source of sediment if not engineered correctly. Roads which are constructed up and down the slope often become the main drainageways for runoff from the fields and erode heavily during storms.

Roads constructed up and down the slope (left), and without proper drainage features, carry large volumes of runoff during storm events. Proper grading, installation of water bars and vegetating road side ditches (right) help manage runoff and reduce sediment.

- The Access Roads (560) conservation practice can be used to plan and locate farm roads to be less susceptible to erosion. The conservation practice can also be used to modify existing roads to include drainage elements, such as water bars, to take runoff off of the road and into roadside ditches. The conservation practice can also assist with surfacing or paving of farm roads.

- Some roads are very heavily trafficked or on soils that are not suitable for traffic. These road sections may turn to deep mud when wet and/or dust when dry. The Heavy Use Area Protection (561) can be used to provide surface treatment or subsurface reinforcement to reduce erosion and to improve the utility of the road.

- When roads cross waterways there is a risk of increased bed and bank erosion and washout of the road during intense storm events. The Stream Crossing (578) conservation practice can be used to identify and design the most suitable and stable crossings over streams and constructed waterways. In steep waterways, the velocity and energy of the runoff needs to be considered in the crossing design. In areas adjacent to forests, blockage by woody debris also needs to be taken into account.

Table 26. Priority Practices for Row Crop: Truck Crop Production

Resource Concern	Moderate Erosion Potential	High-Moderate Erosion Potential	High Erosion Potential
Bare soil in the fields	• ***Cover crop*** • Mulching • Residue Management	• ***Cover crop*** • Mulching • Residue and Tillage Management • Multi-Story Cropping	• ***Cover crop*** • Mulching • Residue and Tillage Management – No Till • Multi-Story Cropping
Bare areas between fields	• Conservation cover • Critical Area Planting	• Conservation cover • Critical Area Planting	• Conservation cover • Critical Area Planting
Long, straight rows	• Row Arrangement (Cross slope)	• Contour farming • Strip Cropping • Alley Cropping • ***Vegetative barrier*** • ***Terrace***	• Contour Orchards and Perennial Crops • Alley Cropping • ***Terrace*** • ***Vegetative barrier*** • Rock Barrier
Concentration of runoff in the field	• ***Vegetative barrier***	• ***Vegetative barrier*** • Diversion • ***Grassed Waterway***	• ***Vegetative barrier*** • Rock Barrier • Diversion • ***Terrace*** • Underground Outlet
Sediment-laden runoff from the field	• Field border • Filter Strip • ***Water and Sediment Control Basin***	• Field Border • ***Filter Strip*** • ***Water and Sediment Control Basin***	• Field Border • ***Filter Strip*** • ***Water and Sediment Control Basin***
Concentrated runoff from the field to an outlet	• ***Grassed waterway*** • Lined Waterway or Outlet	• ***Grassed Waterway*** • Lined Waterway or Outlet	• Lined Waterway or Outlet • ***Hillside Ditch*** • Rock Barrier
Unpaved farm roads	• ***Access Road*** • Heavy Use Area Protection • Stream Crossing	• ***Access Road*** • Heavy Use Area Protection • Stream Crossing	• ***Access Road*** • Heavy Use Area Protection • Stream Crossing

Bold-italics face indicates practices of higher relative importance based on practice effectiveness and cost.

Grazing land

There are two major land areas used for grazing totaling nearly 800 acres in the project area. The area to the east is leased for ranching purposes and consists mostly of High-Moderate erosion potential land in gulches with a small amount of upland that is likely deemed not suitable for seed corn production. The larger grazing area to the west is located in the foothills of the Waianae Mountains and is dissected by small gulches. This parcel is almost entirely High erosion potential.

Bare soil in the pastures

The major resource concern is erosion due to bare areas from overgrazing. In some areas even steep gulch slopes are bare.

- The Prescribed Grazing (528) conservation practice can be applied to match the grazing demand of livestock with the vegetative yield of the grazing land. Maintenance adequate ground cover is a major water quality goal of prescribed grazing. Active management of livestock and the forage resource includes monitoring forage quantity and quality, movement of livestock between paddocks, and determining the animal-unit carrying capacity of the grazing land.

Some areas in the grazing land will continue to be bare because continued use, such as trails to fixed water troughs and feeding locations.

- The Heavy Use Area Protection (561) conservation practice can be used to identify and install surface treatment or covering to protect the soil from erosion.

- The Brush Management (314) conservation practice can be used to improve forage accessibility, opening up more of the grazing land for better forage and uniform use. This practice can remove woody noxious and invasive plants can be removed from pastures.

- In many pasture areas, the remaining vegetative community may be a poor mix for erosion protection. In overgrazed pastures, the remaining vegetation usually consists of noxious and unpalatable plants, which may give an impression that forage still exists for the livestock. The Range Planting (550) conservation standard can be used to improve plant communities on grazing land. Better adapted forage and erosion resistant plants can be planted. Plant recommendations can be made by the NRCS Grazing Land Specialist.

- The Forage and Biomass Planting (512) conservation practice can be used to improve the forage quality and erosion resistance of pastures by establishment of plants to provide better ground cover and greater root mass. This practice follows a more focused approach to change pasture plant communities than Range Planting.

- The Fence (382) conservation practice can be used to design and install fences to manage livestock. Fences can be used to create paddocks and temporary paddocks, and exclude animals from locations.

Concentration of runoff in the pastures

Water flowing through the pastures will follow the steepest slope and combine with other flows causing gully erosion,

- Redirection and control of small water courses along milder slopes can be done using the Rock Barrier (555) conservation practice. The rock barrier will not be eaten by livestock.
- For larger flow amounts across the pasture the Diversion (362) conservation practice can be used to reduce the slope of the waterway and intercept water before it flows through critical pasture areas.
- To safely convey water from the top of a gulch to the bottom, the Hillside Ditch (423) conservation practice can be used.
- The Water and Sediment Control Structure (638) can be used across minor water courses to slow flows and trap sediment.
- The Fence (382) conservation practice should always be considered to keep livestock away from conservation improvements that can be damaged by feeding or trampling.

Sediment-laden runoff from pastures

Runoff leaving the pastures during an intense storm will contain high concentrations of sediment. While the conservation practices discussed earlier serve to reduce erosion in the field, the practices discussed below seek to capture and remove the sediment as close as possible to the pasture and improve the water quality of the storm runoff leaving the ranch.

- Runoff from the pastures can be directed to a Filter Strip (393) at the edge of the pasture before it enters the gulch or stream. Filter strips are most effective when flow depths are low and the flow is uniformly spread over a wide area.
- Once the sediment-laden flow is in the naturally-formed drainageways, larger structures will be required to remove sediment. A Water and Sediment Control Basin (638) can be installed in minor drainageways to slow velocities and detain runoff to allow sediment to settle. This engineered practice can be constructed at various levels of complexity. A simple structure could incorporate a filter strip in the basin.
- The Fence (382) conservation practice should always be considered to keep livestock away from conservation improvements that can be damaged by feeding or trampling.

Livestock in the stream

Cattle watering, feeding, and resting in the stream bottom can increase bank erosion and increase nutrient and pathogen loading. In one case, corn waste is delivered to the gulch bottom for feeding.

- The Watering Facility (614) conservation practice can be used to move cattle from the stream area to areas that are less sensitive. Temporary or permanent watering troughs can be located to serve several paddocks in locations that are upslope from the stream.
- The Range Planting (550) conservation practice can be used to plant trees to provide an attractive resting area for cattle.
- The Fence (382) conservation practice can be used to exclude cattle from streams and other sensitive areas.

Unpaved ranch roads

Unpaved ranch roads often become major water conveyances resulting in erosion and requiring regrading.

- The Access Roads (560) conservation practice can be used to plan and locate ranch roads to be less susceptible to erosion. The conservation practice can also be used to modify existing roads to include drainage elements, such as water bars, to take runoff off of the road and into roadside ditches. The conservation practice can also assist with surfacing or paving of ranch roads.
- When roads cross waterways there is a risk of increased bed and bank erosion and washout of the road in intense storms. The Stream Crossing (578) conservation practice can be used to identify and design the most suitable and stable crossings over streams and constructed waterways.

Table 27. Priority Practices for Grazing Lands

Resource Concern	Moderate Erosion Potential	High-Moderate Erosion Potential	High Erosion Potential
Bare soil in the pastures	• ***Prescribed Grazing*** • Critical Area Planting • Range Planting • Forage and Biomass Planting • Brush management • Fence	• ***Prescribed Grazing*** • Critical Area Planting • Range Planting • Forage and Biomass Planting • Brush management • Fence	• ***Prescribed Grazing*** • Critical Area Planting • Range Planting • Forage and Biomass Planting • Brush management • Fence
Concentration of runoff in the pasture	• ***Rock barrierDiversion*** • ***Water and Sediment Control Basin*** • ***Hillside Ditch*** • Fence	• ***Rock Barrier*** • Diversion • ***Water and Sediment Control Basin*** • ***Hillside Ditch*** • Fence	• ***Rock Barrier*** • Diversion • ***Water and Sediment Control Basin*** • ***Hillside Ditch*** • Fence
Sediment-laden runoff from the pasture	• Filter Strip • ***Water and Sediment Control Basin*** • Fence	• Filter Strip • ***Water and Sediment Control Basin*** • Fence	• Filter Strip • ***Water and Sediment Control Basin*** • Fence
Livestock in the stream	• Watering Facility • Range Planting • Fence	• Watering Facility • Range Planting • Fence	• Watering Facility • Range Planting • Fence
Unpaved ranch roads	• ***Access Road*** • Heavy Use Area Protection	• ***Access Road*** • Heavy Use Area Protection	• ***Access Road*** • Heavy Use Area Protection

Bold-italics face indicates practices of higher relative importance based on practice effectiveness and cost.

Gulches

The utilization of the gulches is variable in the project area. Most of the gulches in the lower reaches are left in their natural form with good vegetation cover with minimal disturbance. Gulches in the middle reaches are used for pasture. In the highest reaches, before entering the forest reserve, some of the gulches are incorporated into the small farms, many with the intention of farming across the gulches. The template for conservation practices is the same for all gulch land regardless of erosion potential,

Bare soil

The major resource concern within the gulches is erosion. Gulch erosion is mainly due to bare areas, many of which are in the grazing areas and those areas being prepared for new farms. Gulch bottoms have been cleared and graded and channel formations lost. Disturbance of channel bottoms and their naturally formed armoring of rocks and boulders will increase erosion.

Among the new farms, there are bare areas along the steep sides of the gulches due to clearing and grubbing. Conservation practices and management recommendations for bare gulch areas used for farming and row crops are found above in truck crops.

Overgrazing by cattle is a major cause for erosion. Conservation practices and management recommendations for bare gulch areas used for grazing are found above in grazing Land.

- Bare areas in the gulches, either along its sides or nearer to the channel should be vegetated to protect against erosion. The Critical Area Planting (342) conservation practice can be used to establish permanent vegetation on sites subject to high erosion.
- Limited protection of stream bottoms can be provided using the Vegetative Barrier (601) conservation practice. Permanent lines of vetiver grass have been used in other locations of stream flow to provide grade control and to trap sediments.
- Redefining the stream channel and providing erosion protection can be accomplished using the Open Channel (582) conservation practice. Such work will likely be extensive and will require surveying and engineering analysis.

Sediment-laden runoff

Runoff in the gulches during an intense storm will contain high concentrations of sediment. While the conservation practices discussed earlier serve to reduce erosion in the field and pastures, the practices discussed immediately below seek to capture and remove the sediment in the gulches and improve the water quality of the storm runoff leaving the project area.

- Runoff from small flows into gulches can be directed to a Filter Strip (393) at the edge of the field or pasture before it enters the gulch or stream. Filter strips are most effective when flow depths are low and the flow is uniformly spread over a wide area.

- Once the sediment-laden flow is in the naturally-formed drainageways, larger structures will be required to remove sediment. A Water and Sediment Control Basin (638) can be installed in minor drainageways to slow velocities and detain runoff to allow sediment to settle. This engineered practice can be constructed at various levels of complexity. A simple structure could incorporate a filter strip in the basin.

- The Sediment Basin (350) conservation practice can be used to design and install large structures in the gulches that are capable of extracting significant amounts of sediment from stormflows before leaving the project area. These structures will include an embankment, storage pool and a spillway. Such structures likely will require public funding and support for implementation.

A sediment basin is designed to retain runoff, capturing significant amounts of sediment.

Outlets from surrounding land

A major factor in the erosion process for gulches is the flow down the steep gulch walls. The high velocity and energy of the entering flow is dissipated by scour on the hillside and at the impact points.

- The Lined Waterway or Outlet (468) conservation practice can be used to design and install erosion-resistant materials on the waterway or where impacts can cause erosion.
- To safely convey water from the top of a gulch to the bottom, the Hillside Ditch (423) conservation practice can be used.

Road crossings

There are numerous roads and crossings across the gulches that can erode and increase sediment discharge. Some gulch crossings near the Forest Reserve boundary appear to be inadequately sized and may fail in a major storm event.

- The Access Roads (560) conservation practice can be used to plan and locate crossing roads to be less susceptible to erosion. The conservation practice can also be used to modify existing roads to include drainage elements, such as water bars, to take runoff off of the road and into roadside ditches.
- When roads cross waterways there is a risk of increased bed and bank erosion and washout of the road in intense storms. The Stream Crossing (578) conservation practice can be used to identify and design the most suitable and stable crossings over streams and constructed waterways.

Table 28. Priority Practices for Gulch Lands

Resource Concern	Moderate Erosion Potential	High-Moderate Erosion Potential	High Erosion Potential
Bare soil	• Critical Area Planting • ***Vegetative Barrier*** • ***Open Channel***	• Critical Area Planting • ***Vegetative Barrier*** • ***Open Channel***	• Critical Area Planting • ***Vegetative Barrier*** • ***Open Channel***
Sediment-laden runoff	• ***Filter Strip*** • ***Water and Sediment Control Basin*** • Sediment Basin	• ***Filter Strip*** • ***Water and Sediment Control Basin*** • Sediment Basin	• ***Filter Strip*** • ***Water and Sediment Control Basin*** • Sediment Basin
Outlets from surrounding land	• Lined Waterway or Outlet • ***Hillside Ditch***	• Lined Waterway or Outlet • ***Hillside Ditch***	• Lined Waterway or Outlet • ***Hillside Ditch***
Road crossings	• ***Access Road*** • Stream Crossing	• ***Access Road*** • Stream Crossing	• ***Access Road*** • Stream Crossing

Bold-italics face indicates practices of higher relative importance based on practice effectiveness and cost.

Forest Reserve

Most of the forest reserve is located within the Honouliuli forest reserve. Nearly all of the land is in the High erosion potential category due to steepness. Very little human activity contributes to soil erosion in the forest reserve. There is no forestry harvesting, presently, and hiking pressure is light.

Invasive Plant Species

There is concern that the current forest community dominated by alien trees, planted in the early 20th century, does not adequately protect the soil resource. Focusing change in the plant community to emphasize more understory that will provide soil protection and precipitation storage. These changes to vegetation will require considerable input from stakeholders.

- Bare areas that are actively eroding or are in need of immediate revegetation should be treated using the Critical Area Planting (342) conservation practice. Often a reinforcing substrate such as rock or geotextile will be required to stabilize a severe erosion problem

Some undesirable trees and bushes can be removed using the Brush Management (314) conservation practice to open canopy or expose growing areas for more desirable plants.

Feral Pigs

A major problem for many stakeholders is feral pigs that disturb soil when rooting and create favorable conditions for invasive species. Feral pigs also damage the remaining areas of native plants.


Feral pigs disturb soil and create favorable conditions for invasive species. Photo on right shows effects of feral pigs: the fence prevents pigs from damaging vegetation on the right side

- Fencing and game management have been successful in other areas to control feral pig activity. The Fence (382) conservation practice can be used to design exclusion fencing for the forest reserve areas needing protection..

Access Road and Hiking trails

Unpaved roads and trails often become major water conveyances resulting in erosion and requiring grading and repair.

- The runoff from waterways and ditches can be directed to a Filter Strip (393) before it enters the gulch or stream. Filter strips are most effective when flow depths are low and the flow is uniformly spread over a wide are
- In steep areas where runoff can intersect roads and trails, the Hillside Ditch (423) conservation practice can be used.to convey water away in a safe manner.
- The Rock Barrier (555) conservation practice can also be used to direct water away from trils and roads in steep areas.
- The Access Road (560) conservation practice can be used to plan and locate roads to be less susceptible to erosion. The conservation practice can also be used to modify existing roads to include drainage elements, such as water bars, to take runoff off of the road and into roadside ditches. The conservation practice can also assist with surfacing or paving of heavily used roads.

Table 29. Priority Practices for Forest Reserve Land

	Moderate Erosion Potential	High-Moderate Erosion Potential	High Erosion Potential
Invasive plant species	• ***Critical Area Planting*** • Brush Management	• ***Critical Area Planting*** • Brush Management	• ***Critical Area Planting*** • Brush Management
Feral pigs	• Fence	• Fence	• Fence
Access roads and hiking trails	• ***Filter Strip*** • ***Hillside Ditch*** • Rock Barrier • ***Access Road***	• ***Filter Strip*** • ***Hillside Ditch*** • Rock Barrier • ***Access Road***	• ***Filter Strip*** • ***Hillside Ditch*** • Rock Barrier • ***Access Road***

Bold-italics face indicates practices of higher relative importance based on practice effectiveness and cost.

10.2 Schedule and Milestones

An expedited schedule for implementing NPS management measures is summarized in Table 30. This schedule includes five years of activities that begins in years previous (2010) to this project area's plan formation and that extends beyond its publication (2015). This schedule is intended to prioritize a time-line for gathering resources and funding, installing measures, monitoring their effectiveness, and developing additional plans as needed. Temporary and measurable milestones are included to determine whether NPS water quality criteria and management measures or other controls are being implemented effectively.

Table 30. Implementation Schedule for the Honouliuli Project Area

Watershed-Based Plan Implementation Actions	Year / Quarter																			
	2011		2012				2013				2014				2015				2015	
Information, Education, and Public Participation	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd
Stakeholder meetings																				
Erosion awareness field days																				
Awareness surveys																				X
Publication distribution																				
Public presentation																				
How-To Pamphlet																				
Evaluation and Monitoring																				
Water quality data assessments																				
Water quality monitoring																				X
Sediment delivery monitoring																X				
Gulch erosion/ streamside assessment																				
The RUSLE2 model																				X
Planning and Funding Initiatives																				
Conservation and development plans																		X		
Stakeholder application for Honouliuli watershed project																				
Watershed-based plan review																				
Pursuit of implementation funding																				
Update Forest Reserve management plan																		X		
Management Implementation																				
Baseline management practices																				
Progressive management practices								X												
Comprehensive management practices																	X			

The shaded areas represent the duration of each activity; the X represents the major milestones for implementation of the watershed based plan.

10.3 Information, Education, and Public Participation Component

An outreach strategy for continued participation from stakeholders in the project area and aimed at garnering support from the local community will involve an information, education, and public participation component. Given that the majority of stakeholders in the project area are agricultural operations and farms, it is important to develop information and educational tools that are focused towards this group's interests and needs. Experience has shown that farmers learn best from other farmers. One way for farmers to convey knowledge to other farmers and stakeholders is through field visits. A series of field visits and meetings took place during the initial phase of plan development (2010) in order for farmers and stakeholders to gain a better perspective of the key erosion and sediment issues. An additional series of bi-annual field visits and meetings will occur over the course of the implementation period to highlight sediment reduction, nutrient management or similar conservation farming methods related to NPS pollution. Furthermore, these field visits and meetings will provide an opportunity for farmers and stakeholders to share information and updates about the effectiveness of the Honouliuli project area's management plan.

Figure 13. Field visits for the public and stakeholders in the project area. On left, photo shows 2-3 feet deep gullies in newly graded field that were created from the December 2010 storms; photo on right shows Susan Kubo (NRCS engineer) explaining sediment basin details. Photos provided by Oahu RC&D.

Measureable milestones include a social indicator that will monitor the increased awareness by stakeholders and the public of pollutant problems in the watershed and progress being made by the public towards implementing conservation measures to address them. Stakeholder awareness surveys will be distributed during field days that will evaluate participant's awareness of NPS pollution, the type and numbers of practices that have been implemented, and the number of landowners that are aware of the technical and financial assistance available to support management practice implementation.

Information on erosion control and watershed protection will also be included in publications that are focused towards farmers and agricultural professionals. Examples include the quarterly magazine titled "Ag Hawai‘i", published by the Hawai‘i Farm Bureau Federation, "Hanai‘Ai", the electronic newsletter published by University of Hawai‘i College of Tropical Agriculture and Human Resources (UH-CTAHR) on a quarterly basis, the Farm Service Agency's electronic newsletter, electronic news bulletins published by the ORCD, and other similar publications. In order to garner support and understanding from the broader Honouliuli community, at least one press release on project area's watershed related activities will be developed each year. Informational materials on NPS pollution and management measures recommended in this plan will be distributed at public venues and events within the watershed, or where residents of the watershed are expected to be present. Following the distribution of published materials at these events, a public meeting will be held to share information about NPS pollution, impacts from erosion from the project area, and the Honouliuli watershed management plan. In discussion, is development of an informative 1-page pamphlet that could be distributed to farmers new to the project area and would act as a "How To" guide for including conservation measures into a farm's management plan.

10.4 Evaluation and Monitoring

An evaluation and monitoring program was developed to determine the effectiveness of management measures within the project area over time. This program is intended to measure progress towards meeting water quality criteria and to assess the overall success of water quality improvement efforts in Honouliuli's project area. An effective monitoring and evaluation program will also facilitate adaptations of the watershed plan over time. Environmental indicators (see Table 9) will be identified through direct water quality measurements as well as by visual streamside assessments. Some of the costs and efforts towards implementing an effective evaluation and monitoring plan may be minimized by incorporating existing efforts and volunteer opportunities, as well as, community support.

Utilizing data from the active USGS stream gages will help to continue establishing a baseline condition for TSS and stream flow for Honouliuli stream. A bi-annual assessment of compiling this publicly available data will indicate long term trends and effects from storm events. The NRCS Hawai‘i Stream Visual Assessment Protocol (HSVAP) is a valuable tool for landowners and/ or volunteers to qualitatively evaluate stream conditions. The HSVAP provides the initial steps of stream quality evaluation, focused primarily on physical conditions. It can be used to determine the current stream condition as a snapshot or be used to observe changes over time. It can also be used to identify the need for more thorough assessment methods that focus on a particular aspect of the aquatic system (e.g. water quality or aquatic species habitat) (USDA 2001).

The RUSLE2 model is a valuable tool for tracking progress towards erosion control and sediment delivery reductions in the project area. Utilizing this model after a few years will assist in evaluating any progress with implementing management systems and for tracking changes in management rotations and practice types. The RUSLE2 results can serve as a milestone for indicating success towards NPS load reductions.

10.5 Planning and Funding Initiatives

Management that focuses on the water quality incentives is going to require involvement by stakeholders to identify and define their problems and solutions, as well as present their overall investment and financial requirements for implementation. Incentive programs can assist with funding for implementing management measures, in most cases, only after proper documentation and thorough planning has been completed. Stakeholders in the project area were required to develop individualized Conservation Plans when applying for aid through the Honouliuli Watershed Project. This Conservation Plan was provided to stakeholders at no cost and is a service provided by the USDA-NRCS in cooperation with the local SWCD. Stakeholders (i.e. landowners and land managers) work with the NRCS and/ or SWCD to monitor progress, adjust, and update Conservation Plans as needed. Updating Conservation Plans and the Forest Reserve Management Plan is a goal and measureable milestone to track stakeholder participation and implementation progress.

Implementing conservation management measures recommended in this plan requires a long-term programmatic, as well as financial, commitment. Information about several Federal, State, local, and private programs and initiatives that provide technical support and financial assistance in planning and implementing conservation measures are compiled in **Error! Reference source not found.**. Principal sources of financial assistance include:

- Conservation Grants and Marine and Anadromous Fish Habitat Restoration Grants (Fish America Foundation)
- DOH Polluted Runoff Control Program grants under Section 319(h) of the CWA
- DOH State Water Pollution Control Revolving Fund programs
- Department of Land and Natural Resources (DLNR) Watershed Partnerships Program funding
- Hawaiʻi Coral Reef Initiative, including Local Action Strategy
- Hawaiʻi Ocean Resources Management Plan funding (State of Hawaiʻi Department of Business, Economic Development, and Tourism, Office of Planning CZM Program)
- National Fish and Wildlife Federation grant programs
- National Fish Habitat Action Plan Program, Hawaiʻi Fish Habitat Partnership
- USDA-NRCS farm bill programs

Stakeholders investing and profiting from agricultural production would benefit from cost-sharing programs and other incentives to implement conservation practices onto their land and into their current management. Funding strategies should include accessing several different funding sources. Identifying funding opportunities in an efficient manner can be a challenge. The Catalog of Federal Funding Sources for Watershed Protection web site is a searchable database of financial assistance sources (grants, loans, cost-sharing) available to fund a variety of watershed protection projects (USEPA 2012). The NRCS offers voluntary programs to eligible landowners and agricultural producers that provide financial and technical assistance to help manage natural resources in a sustainable manner. Specifically, NRCS offers programs that provide support for natural resource concerns or opportunities to help save energy and improve soil, water, plant, air, animal and related resources on agricultural lands and non-industrial private forest land. National USDA NRCS conservation programs and their descriptions may be found on their main website (http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs). The majority of the Pacific Island area's NRCS conservation programs are outlined on the Pacific Islands Area NRCS Conservation Programs website (http://www.pia.nrcs.usda.gov/programs/).

Regionally focused programs from the EPA provide financial assistance grants to qualified applicants to support a variety of environmental programs and activities. EPA Region 9 works within the context of the EPA's national grants program to provide funding opportunities specific to EPA's Pacific Southwest Region (http://www.epa.gov/region09/funding/index.html).

Support for projects in the Honouliuli Forest Reserve will receive the most benefit from utilizing The Nature Conservancy's prepared Honouliuli Forest Rreserve Master Plan and developing an updated forest resources management plan. Having an established management plan allows the landowner to participate in several different available programs. The NRCS has put together a guide, *Managing Your Woodlands: A template for your plans for the future* (2011) that includes useful information for landowners including a detailed description of what is necessary to include in each part of the plan template. Other opportunities for the Forest Reserve exist in the form of state run incentive programs, more specific details regarding these programs may be found by contacting the state forester for further information (NASF 2012).

10.6 Management Implementation

The process of implementing conservation measures into agricultural and forest reserve management plans is ongoing. The baseline, progressive, and comprehensive systems utilized in this plan are scenarios that considered the amount of implemented measures and their installed practices. There are many factors that will affect the likelihood, timeline, and number of measures implemented into a management plan. Conservation needs, willingness, site specific challenges, available funding, incentives, and overall success of the management plan will determine the pace of this time lined approach. This timeline was set forth with the hope and expectation of a linear and stacked approach of including and adding measures into management plans.

Table 31. Financial and Technical Assistance Programs and Initiatives

Financial Assistance Programs		
Program/Initiatives	**Agency**	**Intent/Purpose**
Agricultural Management Assistance (AMA)	USDA NRCS	Provides financial and technical assistance to agricultural producers to voluntarily address issues such as water management, water quality, and erosion control by incorporating conservation into their farming operations.
Agricultural Water Enhancement Program (AWEP)	USDA NRCS	Voluntary conservation initiative that provides financial and technical assistance to agricultural producers to implement agricultural water enhancement activities on agricultural land to conserve surface and ground water and improve water quality.
American Recovery and Reinvestment Act of 2009	USEPA	Provides significant funding for states to finance high priority infrastructure projects needed to ensure clean water and safe drinking water.
Clean Water State Revolving Fund (CWSRF)	USEPA	Provides funds annually toward water quality protection projects for wastewater treatment, nonpoint source pollution control, and watershed and estuary management.
Conservation Reserve Program	USDA NRCS	The Conservation Reserve Program is a voluntary program for agricultural landowners. The Conservation Reserve Program can assist with annual rental payments and cost-sharing to establish long-term, resource conserving covers on eligible farmland.
Conservation Stewardship Program	USDA NRCS	Voluntary program that provides financial and technical assistance to promote the conservation and improvement of soil, water, air, energy, plant and animal life, and other conservation purposes.
Cooperative Conservation Partnership Initiative	USDA NRCS	Voluntary conservation initiative that enables the use of certain conservation programs along with resources of eligible partners to provide financial and technical assistance to owners and operators of agricultural and nonindustrial private forest lands.
Emergency Watershed Protection program	USDA NRCS	This program was established to undertake emergency measures. These include the purchase of flood plain easements, for runoff retardation and soil erosion prevention, to safeguard lives and property from floods, drought, and the products of erosion whenever fire, flood or any other natural occurrence is causing or has caused a sudden impairment of the watershed.
Environmental Quality Incentives Program (EQIP)	USDA NRCS	EQUIP helps fund projects that install conservation measures on agricultural lands to address animal waste, sedimentation, noxious weeds, insufficient water supply for crops or livestock, excess surface runoff, pesticide or nutrient contamination of ground or surface waters, or at-risk species habitat.
Farm and Ranch Land Protection Program (FRPP)	USDA NRCS	Provides matching funds to help purchase development rights to keep productive farm and ranchland in agricultural uses.

Program/Initiatives	Agency	Intent/Purpose
Farm Service Agency (FSA)	FSA	FSA makes direct and guaranteed farm ownership and operating loans to family-size farmers and ranchers who cannot obtain commercial credit from a bank, Farm Credit System institution, or other lender. FSA loans can be used to purchase land, livestock, equipment, feed, seed, and supplies. Our loans can also be used to construct buildings or make farm improvements.
Grassland Reserve Program (GRP)	USDA NRCS	Voluntary conservation program that emphasizes support for working grazing operations, enhancement of plant and animal biodiversity, and protection of grassland under threat of conversion to other uses.
Healthy Forests Reserve Program (HFRP)	USDA NRCS	Assists landowners, on a voluntary basis, in restoring, enhancing and protecting forestland resources on private lands through easements, 30-year contracts and 10-year cost-share agreements.
Legacy Resource Management Program	DoD	Provides financial assistance to the Department of Defense (DoD) efforts to preserve our natural and cultural heritage.
National Association of State Foresters	NASF	NASF seeks to discuss, develop, sponsor and promote programs and activities which will advance the practice of sustainable forestry, the conservation and protection of forest lands and associated resources and the establishment and protection of forests in the urban environment.
Targeted Watersheds Grant Program	USEPA	Encourages successful community-based approaches to protect and restore the nation's watersheds. Their web site includes tools, databases, and information about sources of funding to practitioners and funders that serve to protect watersheds.
Water Pollution Control Program Grants (Section 106)	USEPA	Provides federal assistance to states (including territories, the District of Columbia, and Indian Tribes) and interstate agencies to establish and implement ongoing water pollution control programs.
Wildlife Habitat Incentive Program	USDA NRCS	This is a cost-share program (operated through the USDA NRCS) to assist landowners and lessees up to 75% of the cost of the conservation practices.
Wetland Reserve Program	USDA NRCS	This is a cost share program to help landowners and lessees restore, enhance or create wetlands on agricultural lands.

Technical Assistance Programs		
Program	**Agency**	**Intent / Purpose**
College of Tropical Agriculture and Human Resources Cooperative Extension Service	UH-CTAHR	The College of Tropical Agriculture and Human Resources Cooperative Extension Service is a partnership between federal, state, and local governments and has responsibility for providing science-based information and educational programs in agriculture, natural resources, and human resources.
Conservation Technical Assistance Program	USDA NRCS	This program provides land users with proven conservation technology and the delivery system needed to achieve the benefits of a healthy and productive landscape.
State Technical Committees	USDA NRCS	This committee serves in an advisory capacity to the NRCS and other agencies of the USDA on the implementation of the natural resources conservation provisions of Farm Bill legislation. Committees are intended to include members from a wide variety of natural resource and agricultural interests.
Conservation of Private Grazing Land	USDA NRCS	Provides accelerated technical assistance to owners and managers of grazing land. The purpose is to provide a coordinated technical program to conserve and enhance grazing land resources and provide related benefits to all citizens of the United States. Currently, funds have not been appropriated for this program.
Current Research Information System	USDA NIFA	This information system provides documentation and reporting for ongoing agricultural, food science, human nutrition, and forestry research, education and extension activities for the USDA; with a focus on the National Institute of Food and Agriculture (NIFA) grant programs.
Hawaiʻi Heritage Program	TNC	Compiled computerized database for most of the known occurrences of rare, threatened, and endangered ecosystems and species in Hawaii.
Hawaii's Pollution Prevention Information	HAPPI	The HAPPI Home Series is a set of 16 informational worksheets developed to address water-pollution issues in and around your home.
Managing Your Woods: A Template for Your Plans for the Future	ATFS, NRCS, USFS	The goal of this joint management plan template is to allow landowners to use one management plan to participate in the American Tree Farm System (ATFS), the Forest Stewardship Program, and the NRCS incentive programs.
Natural Area Reserves System	DLNR	Established to preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawaiʻi.
Technical Service Providers (TSPs)	USDA NRCS	These are individuals or businesses that have technical expertise in conservation planning and design for a variety of conservation activities. TSPs are hired by farmers, ranchers, private businesses, nonprofit organizations, or public agencies to provide these services on behalf of the NRCS. Each certified TSP is listed on the NRCS TSP online registry, TechReg. The TSP registration and approval process involves required training and verification of essential education, knowledge, skills and abilities.

11 Track Progress and Make Adjustments

As implementation of the watershed plan progresses, record-keeping and reviewing the plan on a regular basis are necessary to make adjustments for any changes in schedule and for watershed plan adaptations to improve implementation results. The list below is taken from the Hawai‘i Watershed Guidance manual (Tetra Tech 2010) and provides information for effective tracking and review of progress:

- **The process used to implement your program.** This includes the administrative and technical procedures used to secure agreements with landowners, develop specifications, hire staff, and engage contractors.
- **Progress on your work plan.** Checklist of items in the annual work plan
- **Implementation results.** Report where and when practices have been installed and have become operational, who installed them, and any lessons learned.
- **Monitoring data.** Two types of progress analyses should be considered: (1) routine summary analysis: conducted at least quarterly, that tracks progress of monitoring activities, assesses the quality of data relative to measurement quality objectives (whether the data are of adequate quality to answer the monitoring question), and provides early feedback on trends, changes, and problems in the watershed; and (2) intensive analysis: conducted at least yearly, to determine status, changes, trends, or other issues that measure the response to implementation of the watershed plan.
- **Feedback from landowners and other stakeholders.** Seek out and review information on the stakeholders’ experience with the implementation process and with operation and maintenance of the practices through meetings, interviews, or other method.

The Watershed Plan is a living document that needs to be constantly updated, modified, and refined. Continual monitoring and evaluation of conditions in the project area and throughout the watershed will assist to identify causes and sources of pollutants and help to determine management methods to address them. If milestones and/ or water quality criteria are not being met, modifications to the plan may become necessary to provide better funding potential, more time, or to account for out-of-the-ordinary weather conditions. Implementation of the plan is a dynamic process and so adaptations to the process can and should be expected.

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Appendix 1. Sample Conservation Plan.

Conservation Plan
Schedule of Operations

Sample Farm

OBJECTIVE(S)

Sample Farm leases approximately 100 acres of former sugar plantation lands for diversified truck crop production. This conservation plan addresses and attempts to mitigate soil compaction, soil erosion, sedimentation, runoff, and air movement concerns. The date for each conservation practice indicates the planned installation start date. Reoccuring practicies (i.e. those activities that occur on an annual basis) are indicated with an R.

Conservation Cover (327)

Establish perennial vegetative cover on land temporarily removed from agricultural production.

Field	Planned Amount	Month	Year	Applied Amount	Date
2	0.1 ac	3	2011	0.1 ac	Mar-11
Total:	0.1 ac			0.1 ac	

Critical Area Planting (342)

Permanent vegetation will be established on areas vulnerable to erosion due to the interception of runoff from adjacent lands.

Field	Planned Amount	Month	Year	Applied Amount	Date
Hqtrs	2 ac	3	2012		
Total:	2 ac				

Cover Crop

Fast growing grasses, legumes or small grains will be grown for seasonal protection, soil improvement and nutrient management.

Field	Planned Amount	Month	Year	Applied Amount	Date
3	10 ac	7	2011R	10 ac	Jul-11
4	20 ac	7	2011R	20 ac	Jul-11
Total:	30 ac			30 ac	

Grassed Waterway (412)

Construct grassed waterway according to NRCS standards and specifications to prevent erosion by providing for the safe disposal of excess surface water.

Field	Planned Amount	Month	Year	Applied Amount	Date
1	0.4 ac	6	2013		
2	0.6 ac	6	2012		
2	0.4 ac	6	2012		
4	0.2 ac	6	2011		
4	0.1 ac	6	2011	0.1 ac	Jun-11
Total:	1.7 ac				

Sediment Basin (350)

Construct a basin to collect and store debris or sediment.

Field	Planned Amount	Month	Year	Applied Amount	Date
2	1 no	6	2012	1 no	Oct-11
4	1 no	6	2011	1 no	Oct-11
4	1 no	6	2013		
Total:	3 no				

Vegetative Barrier (601)

Permanent strips of stiff, dense vegetation along the general contour of slopes or across concentrated flow areas.

Field	Planned Amount	Month	Year	Applied Amount	Date
1	715 ft	4	2013		
2	940 ft	4	2012		
4	1805 ft	4	2011		
Total:	3460 ft				

Windbreak/Shelterbelt Establishment (380)

Plant single or multiple rows of trees or shrubs.

Field	Planned Amount	Month	Year	Applied Amount	Date
1	1700 ft	4	2014		
4	2335 ft	4	2012		
Total:	4035 ft				

I certify that I have been involved in the planning process and agree to the practices listed in this plan. I intend to apply the practices as described within and follow all federal, state, and local regulation in its implementation.

This plan was developed based on current NRCS practice standards and current applicable federal, state, or local regulations and policies. Any changes in these standards, regulations, and/or policies may require plan revision.

CERTIFICATION OF PARTICIPANTS

______________________ __________
SAMPLE FARMER DATE

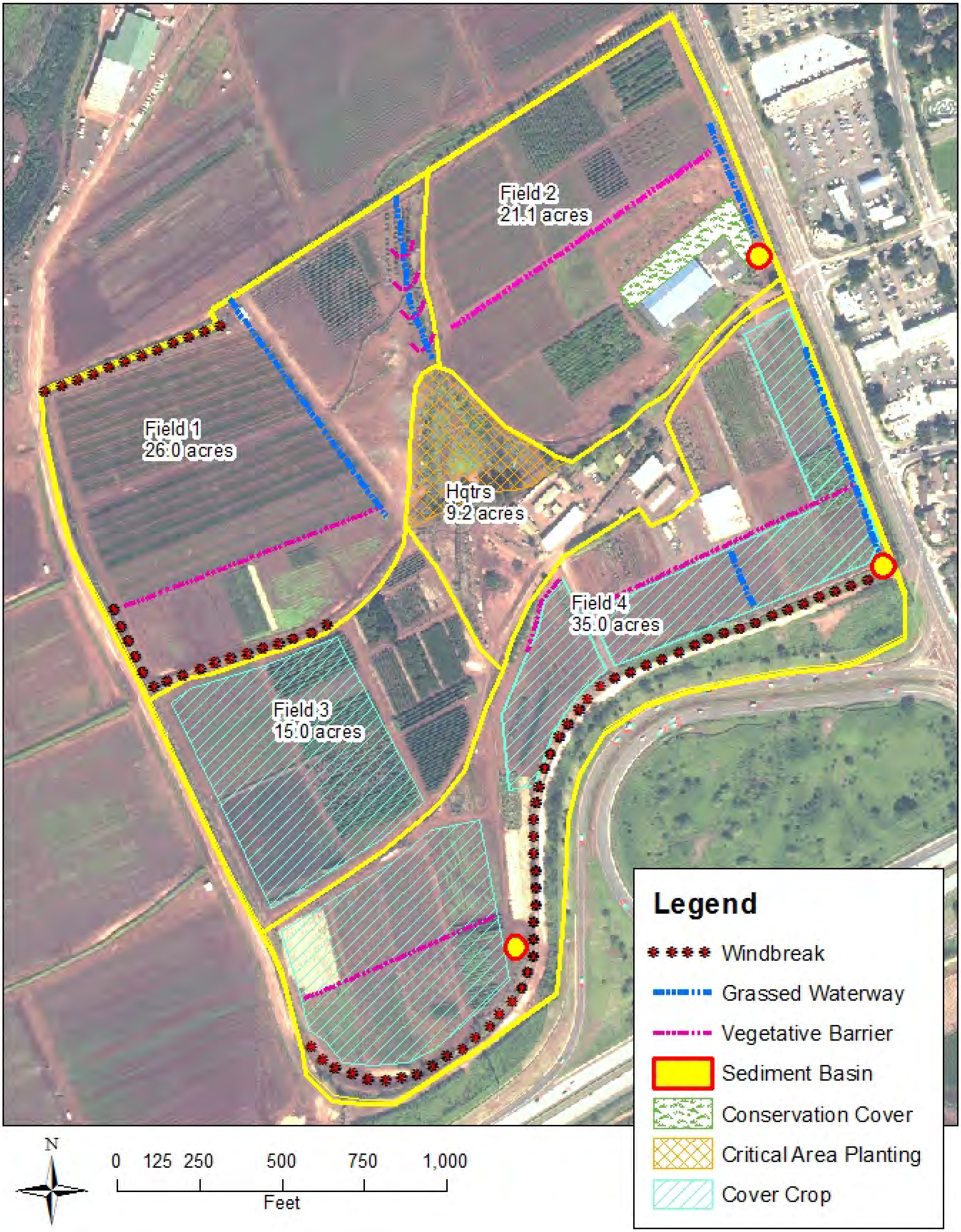
CONSERVATION PLANNER

______________________ __________
NAME DATE

CONSERVATION DISTRICT

______________________ __________
SWCD CHAIR DATE

CONSERVATION PLAN MAP
(SAMPLE)



Appendix 2: Conservation Practice Physical Effects (CPPE) Database Values for Land Use Types in the Honouliuli Project Area.

Land Use Type: Agricultural

Resource Concern	472 Access Control	560 Access Road	309 Agrichemical Handling Facility	311 Alley Cropping	591 Amendments for the Treatment of Agricultural Waste	316 Animal Mortality Facility	575 Animal Trails and Walkways	370 Atmospheric Resource Quality Management	314 Brush Management	322 Channel Bank Vegetation	326 Clearing and Snagging	317 Composting Facility	327 Conservation Cover	328 Conservation Crop Rotation	330 Contour Farming	331 Contour Orchard and Other Fruit Area	340 Cover Crop	342 Critical Area Planting	589C Cross Wind Trap Strips	402 Dam	324 Deep Tillage
Soil Erosion																					
Sheet and Rill	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Ephemeral Gully	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Classic Gully	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Soil Condition																					
Organic Matter Depletion	2	0	5	4	0	0	0	4	0	0	0	2	2	4	0	0	2	0	0	0	2
Compaction	2	0	5	4	0	0	0	4	0	0	0	2	2	4	0	0	2	0	0	0	2
Water Quantity																					
Excessive Runoff, Flooding, or Ponding	3	0	0	4	0	0	0	0	3	3	2	0	3	3	2	2	3	4	4	0	2
Inadequate Outlets	3	0	0	4	0	0	0	0	3	3	2	0	3	3	2	2	3	4	4	0	2
Reduced Capacity of Conveyances by Sediment Deposition	3	0	0	4	0	0	0	0	3	3	2	0	3	3	2	2	3	4	4	0	2
Reduced Storage of Water Bodies by Sediment Accumulation	3	0	0	4	0	0	0	0	3	3	2	0	3	3	2	2	3	4	4	0	2
Water Quality																					
Excessive Nutrients and Organics in Surface Water	2	1	0	2	0	0	1	1	3	3	0	0	3	3	3	3	2	4	1	3	2
Excessive Suspended Sediment and Turbidity in Surface Water	2	1	0	2	0	0	1	1	3	3	0	0	3	3	3	3	2	4	1	3	2

Land Use Type: Agricultural, page 2/4.

356 Dike	362 Diversion	382 Fence	386 Field Border	393 Filter Strip	394 Firebreak	399 Fishpond Management	384 Forest Slash Treatment	666 Forest Stand Improvement	655 Forest Trails and Landings	383 Fuel Break	410 Grade Stabilization Structure	412 Grassed Waterway	548 Grazing Land Mechanical Treatment	561 Heavy Use Area Protection	422 Hedgerow Planting	603 Herbaceous Wind Barriers	423 Hillside Ditch	464 Irrigation Land Leveling	552 Irrigation or Regulating Reservoir	436 Irrigation Storage Reservoir	441 Irrigation System, Microirrigation	442 Irrigation System, Sprinkler	443 Irrigation System, Surface and Subsurface	430DD Irrigation Water Conveyance, Pipeline, High-Pressure, Underground, Plastic	430EE Irrigation Water Conveyance, Pipeline, Low-Pressure, Underground, Plastic	430FF Irrigation Water Conveyance, Pipeline, Steel	449 Irrigation Water Management	460 Land Clearing	466 Land Smoothing	468 Lined Waterway or Outlet	484 Mulching	379 Multi-Story Cropping	590 Nutrient Management	582 Open Channel	512 Pasture and Hay Planting
3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4	0	0	0	0
3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4	0	0	0	0
3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4	0	0	0	0
0	0	0	2	2	0	0	0	2	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	4
0	0	0	2	2	0	0	0	2	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	4
-1	2	0	2	5	-1	0	1	1	0	-1	1	2	1	2	0	1	-1	1	0	0	3	3	1	0	0	0	3	-1	0	2	3	4	0	-2	2
-1	2	0	2	5	-1	0	1	1	0	-1	1	2	1	2	0	1	-1	1	0	0	3	3	1	0	0	0	3	-1	0	2	3	4	0	-2	2
-1	2	0	2	5	-1	0	1	1	0	-1	1	2	1	2	0	1	-1	1	0	0	3	3	1	0	0	0	3	-1	0	2	3	4	0	-2	2
-1	2	0	2	5	-1	0	1	1	0	-1	1	2	1	2	0	1	-1	1	0	0	3	3	1	0	0	0	3	-1	0	2	3	4	0	-2	2
0	2	0	3	5	-1	0	1	0	0	-1	2	2	2	2	0	1	2	1	0	2	0	0	0	1	1	1	3	-1	1	2	2	4	0	0	2
0	2	0	3	5	-1	0	1	0	0	-1	2	2	2	2	0	1	2	1	0	2	0	0	0	1	1	1	3	-1	1	2	2	4	0	0	2

Land Use Type: Agricultural, page 3/4.

595	516	378	521D	521A	462	528	533	550	562	566	568	345	329	346	344	643	391	390	555	558	557	798	350	646	381	632	574	578	395	580	585
Pest Management	Pipeline	Pond	Pond Sealing or Lining, Compacted Clay Treatment	Pond Sealing or Lining, Flexible Membrane	Precision Land Forming	Prescribed Grazing	Pumping Plant	Range Planting	Recreation Area Improvement	Recreation Land Grading and Shaping	Recreation Trail and Walkway	Residue and Tillage Management, Mulch Till	Residue and Tillage Management, No-Till/Strip Till/Direct Seed	Residue and Tillage Management, Ridge Till	Residue Management, Seasonal	Restoration and Management of Declining Habitats	Riparian Forest Buffer	Riparian Herbaceous Cover	Rock Barrier	Roof Runoff Structure	Row Arrangement	Seasonal High Tunnel System for Crops	Sediment Basin	Shallow Water Development and Management	Silvopasture Establishment	Solid/Liquid Waste Separation Facility	Spring Development	Stream Crossing	Stream Habitat Improvement and Management	Streambank and Shoreline Protection	Stripcropping
0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	2	0	2	0	0	0	0	0	0	0	0	3	3	0	0	1	0	0	0	1	0	2	0	0	0	0
0	0	0	1	1	1	2	0	2	0	0	0	0	0	0	0	0	3	3	0	0	1	0	0	0	1	0	2	0	0	0	0
1	0	0	0	0	0	1	0	2	2	0	2	2	3	2	2	0	5	5	1	1	1	0	4	3	1	0	0	1	0	3	2
1	0	0	0	0	0	1	0	2	2	0	2	2	3	2	2	0	5	5	1	1	1	0	4	3	1	0	0	1	0	3	2
1	0	0	0	0	0	1	0	2	2	0	2	2	3	2	2	0	5	5	1	1	1	0	4	3	1	0	0	1	0	3	2
1	0	0	0	0	0	1	0	2	2	0	2	2	3	2	2	0	5	5	1	1	1	0	4	3	1	0	0	1	0	3	2
3	0	3	0	0	1	3	0	3	4	2	2	1	3	2	1	2	4	4	2	1	2	1	4	2	3	0	1	2	3	3	3
3	0	3	0	0	1	3	0	3	4	2	2	1	3	2	1	2	4	4	2	1	2	1	4	2	3	0	1	2	3	3	3

Land Use Type: Agricultural, page 4/4.

587	607	608	600	612	660	490	620	645	601	630	367	313	634	629	359	633	638	636	614	658	659	657	644	380	650
Structure for Water Control	Surface Drainage, Field Ditch	Surface Drainage, Main or Lateral	Terrace	Tree/Shrub Establishment	Tree/Shrub Pruning	Tree/Shrub Site Preparation	Underground Outlet	Upland Wildlife Habitat Management	Vegetative Barrier	Vertical Drain	Waste Facility Cover	Waste Storage Facility	Waste Transfer	Waste Treatment	Waste Treatment Lagoon	Waste Utilization	Water and Sediment Control Basin	Water Harvesting Catchment	Watering Facility	Wetland Creation	Wetland Enhancement	Wetland Restoration	Wetland Wildlife Habitat Management	Windbreak/Shelterbelt Establishment	Windbreak/Shelterbelt Renovation
1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
0	1	0	0	2	1	0	0	0	-2	0	0	2	0	0	3	0	0	0	0	1	1	1	0	2	2
0	1	0	0	2	1	0	0	0	-2	0	0	2	0	0	3	0	0	0	0	1	1	1	0	2	2
2	-2	-2	2	4	0	0	2	1	5	1	0	0	0	0	0	0	4	0	1	3	3	3	0	1	1
2	-2	-2	2	4	0	0	2	1	5	1	0	0	0	0	0	0	4	0	1	3	3	3	0	1	1
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1	-2	-2	3	4	0	-1	0	2	2	1	0	0	0	0	0	0	4	0	2	2	2	2	3	2	1
1	-2	-2	3	4	0	-1	0	2	2	1	0	0	0	0	0	0	4	0	2	2	2	2	3	2	1

Land Use Type: Grazing

Resource Concern	Access Control 472	Access Road 560	Agrichemical Handling Facility 309	Alley Cropping 311	Amendments for the Treatment of Agricultural Waste 591	Animal Mortality Facility 316	Animal Trails and Walkways 575	Atmospheric Resource Quality Management 370	Brush Management 314	Channel Bank Vegetation 322	Clearing and Snagging 326	Composting Facility 317	Conservation Cover 327	Conservation Crop Rotation 328	Contour Farming 330	Contour Orchard and Other Fruit Area 331	Cover Crop 340	Critical Area Planting 342	Cross Wind Trap Strips 589C
Soil Erosion																			
Sheet and Rill	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Classic Gully	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Streambank	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Irrigation Induced	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Mass Movement	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Soil Condition																			
Organic Matter Depletion	2	0	5	4	0	0	0	4	0	0	0	2	2	4	0	0	2	0	0
Rangeland Site Stability	2	0	5	4	0	0	0	4	0	0	0	2	2	4	0	0	2	0	0
Compaction	2	0	5	4	0	0	0	4	0	0	0	2	2	4	0	0	2	0	0
Water Quantity																			
Rangeland Hydrologic Cycle	3	0	0	4	0	0	0	0	3	3	2	0	3	3	2	2	3	4	4
Excessive Runoff, Flooding, or Ponding	3	0	0	4	0	0	0	0	3	3	2	0	3	3	2	2	3	4	4
Water Quality																			
Excessive Nutrients and Organics in Surface Water	2	1	0	2	0	0	1	1	3	3	0	0	3	3	3	3	2	4	1
Excessive Suspended Sediment and Turbidity in Surface Water	2	1	0	2	0	0	1	1	3	3	0	0	3	3	3	3	2	4	1
Animal Wildlife																			
T&E Species: Declining Species, Species of Concern	2	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0

Land Use Type: Grazing, page 2/4.

402	324	356	362	382	386	393	394	399	384	666	655	383	410	412	548	561	422	603	423	464	552	436	441	442	443	430DD	430EE	430FF	449	460	466	468	484
Dam	Deep Tillage	Dike	Diversion	Fence	Field Border	Filter Strip	Firebreak	Fishpond Management	Forest Slash Treatment	Forest Stand Improvement	Forest Trails and Landings	Fuel Break	Grade Stabilization Structure	Grassed Waterway	Grazing Land Mechanical Treatment	Heavy Use Area Protection	Hedgerow Planting	Herbaceous Wind Barriers	Hillside Ditch	Irrigation Land Leveling	Irrigation or Regulating Reservoir	Irrigation Storage Reservoir	Irrigation System, Microirrigation	Irrigation System, Sprinkler	Irrigation System, Surface and Subsurface	Irrigation Water Conveyance, Pipeline, High-Pressure, Underground, Plastic	Irrigation Water Conveyance, Pipeline, Low-Pressure, Underground, Plastic	Irrigation Water Conveyance, Pipeline, Steel	Irrigation Water Management	Land Clearing	Land Smoothing	Lined Waterway or Outlet	Mulching
0	0	3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4
0	0	3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4
0	0	3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4
0	0	3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4
0	0	3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4
0	2	0	0	0	2	2	0	0	0	2	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	2	2	0	0	0	2	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	2	2	0	0	0	2	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	-1	2	0	2	5	-1	0	1	1	0	-1	1	2	1	2	0	1	-1	1	0	0	3	3	1	0	0	0	3	-1	0	2	3
0	2	-1	2	0	2	5	-1	0	1	1	0	-1	1	2	1	2	0	1	-1	1	0	0	3	3	1	0	0	0	3	-1	0	2	3
3	2	0	2	0	3	5	-1	0	1	0	0	-1	2	2	2	2	0	1	2	1	0	2	0	0	0	1	1	1	3	-1	1	2	2
3	2	0	2	0	3	5	-1	0	1	0	0	-1	2	2	2	2	0	1	2	1	0	2	0	0	0	1	1	1	3	-1	1	2	2
1	0	1	0	0	0	0	0	2	0	3	-1	0	1	1	1	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0

Land Use Type: Grazing, page 3/4.

379 Multi-Story Cropping	590 Nutrient Management	582 Open Channel	512 Pasture and Hay Planting	595 Pest Management	516 Pipeline	378 Pond	521D Pond Sealing or Lining, Compacted Clay Treatment	521A Pond Sealing or Lining, Flexible Membrane	462 Precision Land Forming	528 Prescribed Grazing	533 Pumping Plant	550 Range Planting	562 Recreation Area Improvement	566 Recreation Land Grading and Shaping	568 Recreation Trail and Walkway	345 Residue and Tillage Management, Mulch Till	329 Residue and Tillage Management, No-Till/Strip Till/Direct Seed	346 Residue and Tillage Management, Ridge Till	344 Residue Management, Seasonal	643 Restoration and Management of Declining Habitats	391 Riparian Forest Buffer	390 Riparian Herbaceous Cover	555 Rock Barrier	558 Roof Runoff Structure	557 Row Arrangement	798 Seasonal High Tunnel System for Crops	350 Sediment Basin	646 Shallow Water Development and Management	381 Silvopasture Establishment	632 Solid/Liquid Waste Separation Facility
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	2	0	4	0	0	0	1	1	1	2	0	2	0	0	0	0	0	0	0	0	3	3	0	0	1	0	0	0	1	0
4	2	0	4	0	0	0	1	1	1	2	0	2	0	0	0	0	0	0	0	0	3	3	0	0	1	0	0	0	1	0
4	2	0	4	0	0	0	1	1	1	2	0	2	0	0	0	0	0	0	0	0	3	3	0	0	1	0	0	0	1	0
4	0	-2	2	1	0	0	0	0	0	1	0	2	2	0	2	2	3	2	2	0	5	5	1	1	1	0	4	3	1	0
4	0	-2	2	1	0	0	0	0	0	1	0	2	2	0	2	2	3	2	2	0	5	5	1	1	1	0	4	3	1	0
4	0	0	2	3	0	3	0	0	1	3	0	3	4	2	2	1	3	2	1	2	4	4	2	1	2	1	4	2	3	0
4	0	0	2	3	0	3	0	0	1	3	0	3	4	2	2	1	3	2	1	2	4	4	2	1	2	1	4	2	3	0
0	0	0	0	0	0	4	1	1	0	0	0	0	2	0	0	0	0	0	0	5	3	3	0	0	0	0	1	2	0	0

Land Use Type: Grazing, page 4/4.

574 Spring Development	578 Stream Crossing	395 Stream Habitat Improvement and Management	580 Streambank and Shoreline Protection	585 Stripcropping	587 Structure for Water Control	607 Surface Drainage, Field Ditch	608 Surface Drainage, Main or Lateral	600 Terrace	612 Tree/Shrub Establishment	660 Tree/Shrub Pruning	490 Tree/Shrub Site Preparation	620 Underground Outlet	645 Upland Wildlife Habitat Management	601 Vegetative Barrier	630 Vertical Drain	367 Waste Facility Cover	313 Waste Storage Facility	634 Waste Transfer	629 Waste Treatment	359 Waste Treatment Lagoon	633 Waste Utilization	638 Water and Sediment Control Basin	636 Water Harvesting Catchment	614 Watering Facility	658 Wetland Creation	659 Wetland Enhancement	657 Wetland Restoration	644 Wetland Wildlife Habitat Management	380 Windbreak/Shelterbelt Establishment	650 Windbreak/Shelterbelt Renovation
0	0	0	0	0	1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1	0	0	2	1	0	0	0	-2	0	0	2	0	0	3	0	0	0	0	1	1	1	0	2	2
2	0	0	0	0	0	1	0	0	2	1	0	0	0	-2	0	0	2	0	0	3	0	0	0	0	1	1	1	0	2	2
2	0	0	0	0	0	1	0	0	2	1	0	0	0	-2	0	0	2	0	0	3	0	0	0	0	1	1	1	0	2	2
0	1	0	3	2	2	-2	-2	2	4	0	0	2	1	5	1	0	0	0	0	0	0	4	0	1	3	3	3	0	1	1
0	1	0	3	2	2	-2	-2	2	4	0	0	2	1	5	1	0	0	0	0	0	0	4	0	1	3	3	3	0	1	1
1	2	3	3	3	1	-2	-2	3	4	0	-1	0	2	2	1	0	0	0	0	0	0	4	0	2	2	2	2	3	2	1
1	2	3	3	3	1	-2	-2	3	4	0	-1	0	2	2	1	0	0	0	0	0	0	4	0	2	2	2	2	3	2	1
5	0	3	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	2	0	2	5	5	5	5	0	0

Land Use Type: Forest Reserve

Resource Concern	472 Access Control	560 Access Road	309 Agrichemical Handling Facility	311 Alley Cropping	591 Amendments for the Treatment of Agricultural Waste	316 Animal Mortality Facility	575 Animal Trails and Walkways	370 Atmospheric Resource Quality Management	314 Brush Management	322 Channel Bank Vegetation	326 Clearing and Snagging	317 Composting Facility	327 Conservation Cover	328 Conservation Crop Rotation	330 Contour Farming	331 Contour Orchard and Other Fruit Area	340 Cover Crop	342 Critical Area Planting	589C Cross Wind Trap Strips	402 Dam	324 Deep Tillage
Soil Erosion																					
Ephemeral Gully	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Streambank	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Mass Movement	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Road, Road Slides and Construction Sites	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Water Quantity																					
Excessive Runoff, Flooding, or Ponding	3	0	0	4	0	0	0	0	3	3	2	0	3	3	2	2	3	4	4	0	2
Water Quality																					
Excessive Suspended Sediment and Turbidity in Surface Wate	2	1	0	2	0	0	1	1	3	3	0	0	3	3	3	3	2	4	1	3	2
Plant Condition																					
Plants Not Adapted or Suited	3	4	0	0	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0
Threatened and Endangered Plant Species	3	4	0	0	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0
4. T&E Plant Species: Declining Species, Species of Concern	5	0	0	0	0	0	1	0	3	3	0	0	3	0	0	0	0	1	0	0	0
5. Noxious and Invasive Plants	4	-3	0	4	0	0	-1	0	4	4	0	1	4	3	0	0	3	4	4	0	-1
7. Wildfire Hazard	3	4	0	0	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0
Animal Wildlife																					
4. Habitat Fragmentation	5	-1	0	3	0	0	-1	0	3	4	-2	0	2	1	0	0	2	2	2	-4	0
6. Threatened and Endangered Fish and Wildlife Species	5	0	0	0	0	0	0	0	3	3	0	0	3	0	0	0	0	0	0	0	0
7. T&E Species: Declining Species, Species of Concern	5	0	0	0	0	0	0	0	3	3	-1	0	3	0	1	1	0	0	0	0	0

Land Use Type: Forest Reserve, page 2/4.

356	362	382	386	393	394	399	384	666	655	383	410	412	548	561	422	603	423	464	552	436	441	442	443	430DD	430EE	430FF	449	460	466	468	484
Dike	Diversion	Fence	Field Border	Filter Strip	Firebreak	Fishpond Management	Forest Slash Treatment	Forest Stand Improvement	Forest Trails and Landings	Fuel Break	Grade Stabilization Structure	Grassed Waterway	Grazing Land Mechanical Treatment	Heavy Use Area Protection	Hedgerow Planting	Herbaceous Wind Barriers	Hillside Ditch	Irrigation Land Leveling	Irrigation or Regulating Reservoir	Irrigation Storage Reservoir	Irrigation System, Microirrigation	Irrigation System, Sprinkler	Irrigation System, Surface and Subsurface	Irrigation Water Conveyance, Pipeline, High-Pressure, Underground, Plastic	Irrigation Water Conveyance, Pipeline, Low-Pressure, Underground, Plastic	Irrigation Water Conveyance, Pipeline, Steel	Irrigation Water Management	Land Clearing	Land Smoothing	Lined Waterway or Outlet	Mulching
3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4
3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4
3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4
3	2	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	-2	0	2	4
-1	2	0	2	5	-1	0	1	1	0	-1	1	2	1	2	0	1	-1	1	0	0	3	3	1	0	0	0	3	-1	0	2	3
0	2	0	3	5	-1	0	1	0	0	-1	2	2	2	2	0	1	2	1	0	2	0	0	0	1	1	1	3	-1	1	2	2
0	0	0	0	0	5	0	4	5	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
0	0	0	0	0	5	0	4	5	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
0	0	0	1	1	3	1	0	3	-3	3	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	3	3	4	-2	4	4	4	4	-2	0	4	-1	4	4	3	0	1	0	0	1	1	1	0	0	0	1	-3	3	0	3
0	0	0	0	0	5	0	4	5	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
-1	0	-2	2	1	0	0	0	3	-1	0	0	1	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	-3	-1	0	0
0	0	0	3	0	0	0	0	3	-3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-3	-1	-1	0
0	0	0	3	0	0	0	0	3	-3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-3	-1	-1	0

Land Use Type: Forest Reserve, page 3/4.

379 Multi-Story Cropping	590 Nutrient Management	582 Open Channel	512 Pasture and Hay Planting	595 Pest Management	516 Pipeline	378 Pond	521D Pond Sealing or Lining, Compacted Clay Treatment	521A Pond Sealing or Lining, Flexible Membrane	462 Precision Land Forming	528 Prescribed Grazing	533 Pumping Plant	550 Range Planting	562 Recreation Area Improvement	566 Recreation Land Grading and Shaping	568 Recreation Trail and Walkway	345 Residue and Tillage Management, Mulch Till	329 Residue and Tillage Management, No-Till/Strip Till/Direct Seed	346 Residue and Tillage Management, Ridge Till	344 Residue Management, Seasonal	643 Restoration and Management of Declining Habitats	391 Riparian Forest Buffer	390 Riparian Herbaceous Cover	555 Rock Barrier	558 Roof Runoff Structure	557 Row Arrangement	798 Seasonal High Tunnel System for Crops	350 Sediment Basin	646 Shallow Water Development and Management	381 Silvopasture Establishment
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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4	0	0	2	3	0	3	0	0	1	3	0	3	4	2	2	1	3	2	1	2	4	4	2	1	2	1	4	2	3
2	0	0	0	3	0	0	0	0	0	3	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2	0	0	0	3	0	0	0	0	0	3	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3
0	0	0	0	5	0	0	0	0	0	1	0	3	-1	-1	-1	0	0	0	0	5	5	3	0	0	0	0	0	1	0
4	0	0	4	5	0	0	0	0	0	4	0	4	4	4	-1	0	0	0	0	4	4	4	0	0	0	0	0	1	4
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3	3	-2	0	3	0	2	1	1	0	4	0	4	-1	-1	-1	0	0	0	0	5	5	5	0	0	0	0	0	2	0
0	0	1	3	5	0	5	1	1	0	3	0	3	-3	-3	-3	1	1	1	1	5	5	5	0	0	0	0	0	3	0
0	0	1	3	5	0	5	1	1	0	3	0	3	-3	-3	-3	1	1	1	1	5	5	5	0	0	0	0	0	3	0

Land Use Type: Forest Reserve, page 4/4.

632 Solid/Liquid Waste Separation Facility	574 Spring Development	578 Stream Crossing	395 Stream Habitat Improvement and Management	580 Streambank and Shoreline Protection	585 Stripcropping	587 Structure for Water Control	607 Surface Drainage, Field Ditch	608 Surface Drainage, Main or Lateral	600 Terrace	612 Tree/Shrub Establishment	660 Tree/Shrub Pruning	490 Tree/Shrub Site Preparation	620 Underground Outlet	645 Upland Wildlife Habitat Management	601 Vegetative Barrier	630 Vertical Drain	367 Waste Facility Cover	313 Waste Storage Facility	634 Waste Transfer	629 Waste Treatment	359 Waste Treatment Lagoon	633 Waste Utilization	638 Water and Sediment Control Basin	636 Water Harvesting Catchment	614 Watering Facility	658 Wetland Creation	659 Wetland Enhancement	657 Wetland Restoration	644 Wetland Wildlife Habitat Management	380 Windbreak/Shelterbelt Establishment	650 Windbreak/Shelterbelt Renovation
0	0	0	0	0	0	1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
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0	0	1	0	3	2	2	-2	-2	2	4	0	0	2	1	5	1	0	0	0	0	0	0	4	0	1	3	3	3	0	1	1
0	1	2	3	3	3	1	-2	-2	3	4	0	-1	0	2	2	1	0	0	0	0	0	0	4	0	2	2	2	2	3	2	1
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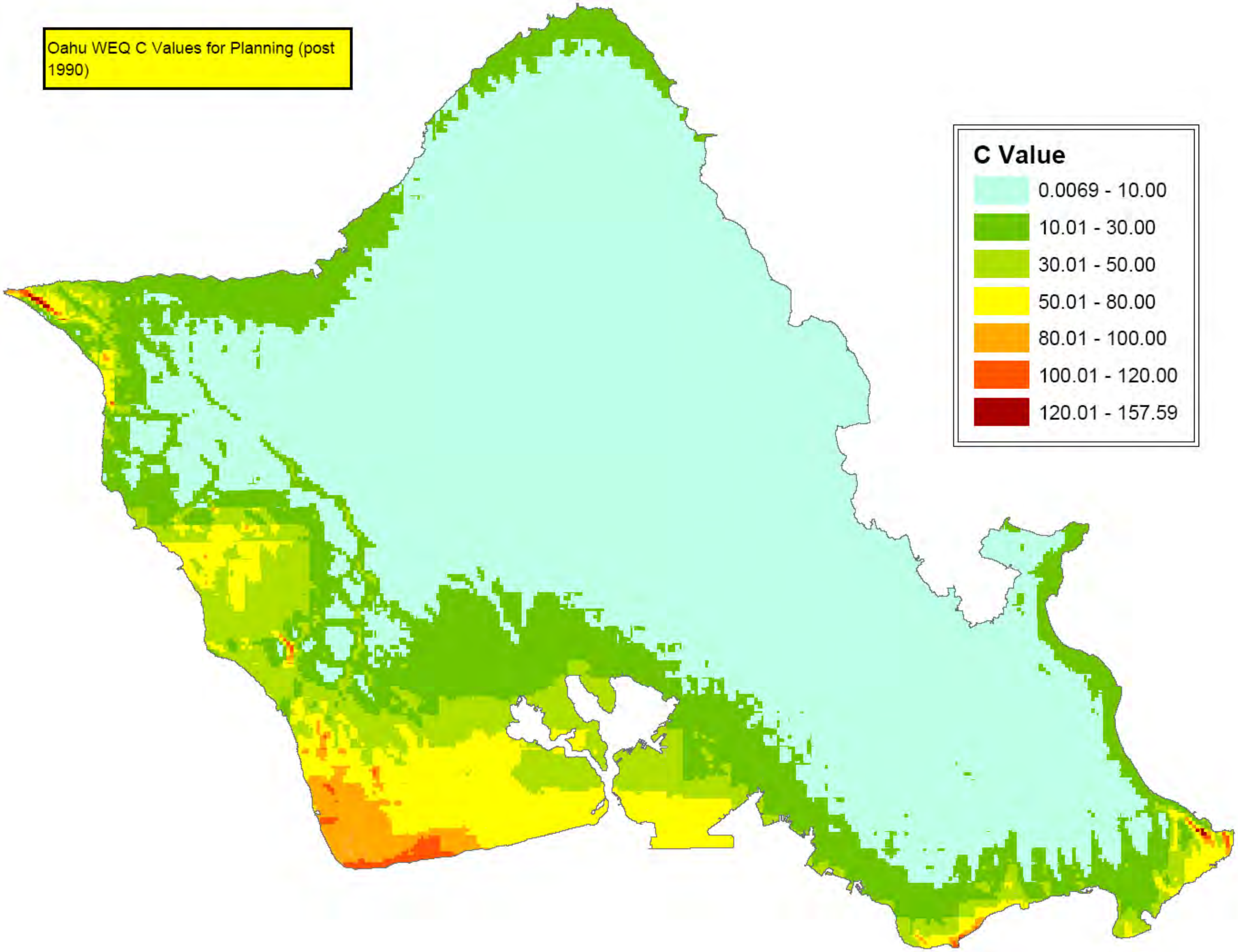
0	0	0	0	0	0	0	0	0	0	0	2	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	3	0	3	3	0	1	0	0	0	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	3	5	5	5	1	1
0	0	0	4	4	0	0	0	0	0	4	0	4	0	4	0	0	0	0	-1	0	0	0	0	0	0	4	4	4	4	4	4
0	0	0	0	0	0	0	0	0	0	0	2	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	3	0	4	2	1	1	0	0	0	4	0	0	0	5	1	0	0	0	0	0	0	0	0	2	2	5	5	5	5	3	3
0	3	0	3	3	1	1	0	0	0	5	0	0	0	5	1	0	0	0	0	0	1	0	0	1	0	5	5	5	5	3	3
0	3	1	3	3	1	1	0	0	0	5	0	0	0	5	1	0	0	0	0	0	0	0	0	1	0	5	5	5	5	3	3

Appendix 3: Cover-Management Factor, C-Factor, Map of O‘ahu.



Appendix 4: Hydrology, Hydraulics and Sediment Yield in the Honouliuli Project Area

A hydrologic model was used to compare the effects of conservation practices in the project area on runoff volumes for various levels of storm rainfall. The change in runoff quantity was then used to estimate reductions in sediment discharge with the application of conservation practices.

Rainfall

Honouliuli is located in the southwestern portion of the island of Oahu and is considered to be in the hot and dry region, characteristic of the leeward side of the island. Much of the moisture in the usually prevailing tradewinds is extracted as orographic rainfall by the Koolau Mountains before reaching Honouliuli. Central and leeward Oahu typically receive most of their annual rainfall during the winter season when Kona storms and cold fronts disrupt the tradewinds and bring moisture from other directions (Juvik, Sonia and James Juvik, Atlas of Hawaii, Third Edition, 1998).

The number of rainfall gauges in the Honouliuli area and the intensity of gauging effort have declined following the closure of the sugar and pineapple industries and the advent of new precipitation quantification technologies such as radar. The USGS-operated network included only the Poamoho Rain Gage in central Oahu in their 2005 listing of their raingage network. Other agency or private gauges exist in and near the project area, but records are not correlated regionally. Fortunately, earlier, more extensive records have been incorporated into average rainfall and storm rainfall tools that are used to project rainfall for this study. Unfortunately, the uncertainties of global climate change reduce the confidence in the projections based on historical data.

The average annual rainfall ranges from 47 inches at the Waianae mountain peaks to 24 inches near the H-1 freeway (Geography Department, UH, Rainfall Atlas of Hawaii, website: http://rainfall.geography.hawaii.edu/). Representative storm rainfall for the project was determined using the NOAA Atlas 14 Point Precipitation Estimate Tool (NOAA, Hydrometeorological Design Studies Center, Precipitation Frequency Data Server, website: http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_hi.html). Storm rainfall amounts are shown on Table 1 for the centroid of the project Area.

Table 1 - Storm Rainfall in Honouliuli Project Area (inches)

Storm Duration	Recurrence Interval						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
1-hour	1.24	1.63	2.13	2.52	3.04	3.44	3.85
6-hour	2.47	3.27	4.37	5.19	6.26	7.07	7.86
24-hour	3.6	4.93	6.7	8.04	9.8	11.1	12.5
10-day	5.84	7.99	10.9	13.2	16.3	18.7	21.1

Runoff

The Honouliuli Watershed is defined as the drainage basin of the streams that start at the crest of the Waianae mountain range, roughly between Pohakea Pass to the north and Palikea Ridge on the south. A number of streams converge into Honouliuli Stream before it crosses under the H-I freeway. Honouliuli Stream meanders through the Honouliuli community and through the West Loch Golf Course to outlet into the West Loch of Pearl Harbor. Most reaches of Honouliuli Stream are intermittent and dry for most of the time. While the stream is well-formed, and incised in the area above the H-I freeway, the infrequent streamflow and the deposition of storm sediment in the lower reaches has resulted in inadequate stream capacity in some reaches and frequent out-of-bank flooding events in the Honouliuli community.

Difficulties in delineating the Honouliuli Watershed in the project area and estimating runoff include the uncertainties in runoff direction from the gently sloping pasture and farmlands along the Honouliuli/Kaloi watershed boundary, numerous roadside drainage ditches and culverts, and effects of the irrigation water ditches. Delineation of the Honouliuli watershed for the runoff analysis was conducted using the USGS 40-foot contours on the DRG. In addition, drainage practices installed to protect the farmland and pastureland also affect the location of the drainage and watershed boundary. A likely more significant factor affecting the runoff from the watershed is the crossing of the Waiahole Ditch and other ditch and drainage structures in the farming area. The Waiahole Ditch has a capacity to transport 27 million gallons per day (mgd) from Windward Oahu to the leeward plains. If the same capacity can be used to transport stormwater into or out of the Honouliuli Watershed, nearly 40 cubic feet per second (cfs) could be added or subtracted from streamflow downstream of the ditch. The runoff analysis conducted for this study did not account for the effects of the Waiahole Ditch.

A crest-type stream gage (USGS 162125000) is located on Honouliuli Stream at its crossing of Farrington Highway, below the H-1 freeway and west of Waipahu. A crest stage gage is a non-continuous device that records the highest level of the stream stage at the gage location. The gage is read only after a storm discharge. Channel geometry and hydraulic relationships are used to estimate the peak discharge correlated to the flood crest elevation. This gage was installed in 1956. USGS has calculated the drainage area to be 11.09 square miles or 7097.6 acres. The highest discharge at the gage was estimated to be 3,500 cfs on January 6, 1982.

Two new continuous recording gages with water quality sampling capacity were installed by USGS, in partnership with the C&C of Honolulu's Department of Environmental Services, in 2012. City funding for these gages is guaranteed for four years.

A new gage, USGS 16212480, was activated on August 30, 2012 on the southern tributary of Honouliuli Stream at a location just upstream of its crossing of the Waiahole Ditch. The gage is located 629 feet above sea level with a drainage area of 1.86 square miles. Most of the land use above the gage is grazing and forest reserve. Real time monitoring in 15 minute time increments is available on the USGS National Water Information System (NWIS) website.

Another new gage will be installed adjacent to the Board of Water Supply pumping station just north of the H-1 freeway bridge. This gage location will include all of the Honouliuli Project

Area, including the cropland. This gage is expected to replace the Honouliuli Stream crest gage near Farrington Hwy. Description of this gage was not available at the time this report was written. Real time data from the gage should be available on the USGS NWIS website in the future.

WinTR-55 Hydrologic Model

The absence of stream gauging in the Honouliuli project area calls for other methods to be used to estimate storm runoff quantities. The NRCS has developed a rainfall-runoff relationship that factors precipitation, initial infiltration and storage, and potential infiltration and storage (NRCS, Chapter 10 Estimation of Direct Runoff from Storm Rainfall, National Engineering Handbook, 2004). The varying characteristics of initial and potential infiltration and storage for a particular condition of soil, cover, and imperviousness are captured in the Runoff Curve Number, often abbreviated as CN. A CN of 100 means complete imperviousness and all rainfall will run off. A CN of 50 reflects an area with good infiltration potential and considerable storage, likely in the form of plant canopy and ground cover. An area with a CN of 50 may absorb two to three inches of rainfall before runoff starts. The CN factor was used in the estimations of storm runoff for the Honouliuli project area.

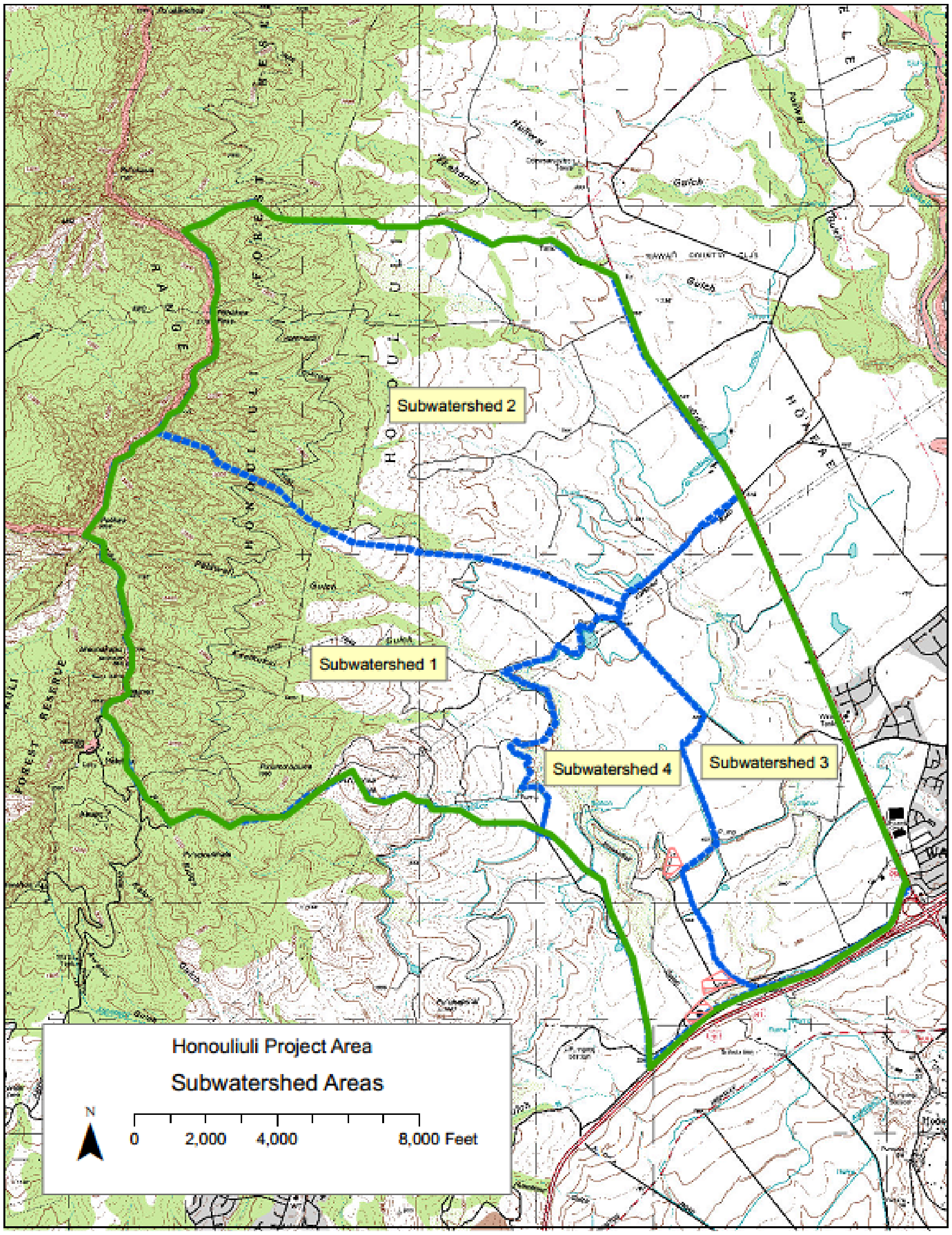
Over the past 50 years, NRCS has developed and improved upon a rainfall-runoff model that is based on the runoff curve number (CN), drainage area characteristics, and the generation of hydrographs. Hydrographs are curves that plot runoff against time and can show the rise and fall in streamflow over a storm period. The recently-issued WinTR-55 Small Watershed Hydrology computer program was used to calculate storm runoff for this study (NRCS, WinTR-55, 2009). WinTR-55 is a single-event hydrologic model with the capability to handle subareas, channels, and storage structures within the watershed.

The WinTR-55 model is based originally on empirical relationships measured in the U.S. Midwest. Often, the application of WinTR-55 to conditions that are significantly different will produce results that do not match the known runoff conditions. Calibration to established discharges for various storm frequencies is necessary. Adjustment of the CN and time of concentration can be made to calibrate the WinTR-55 model.

Subwatersheds

The Honouliuli project area watershed is the drainage area that collects at the bridge under the H-1 freeway west of the Kunia interchange. The Honouliuli project area has been measured to be 7,256 acres. The measured acreage for this study is larger than the area calculated by USGS for their stream gage at Farrington Highway. The issues described above can account for the discrepancy.

Four subwatershed areas, in a quadrant pattern, were delineated within the Honouliuli project area. Establishing the subwatersheds improved modeling control and output quality by separating land use/cover types and allowing different hydrographs for each of the subwatersheds. The four subwatersheds were numbered 1 through 4, starting from the upper westernmost watershed and working clockwise. Subwatershed 1 flows into Subwatershed 4 and Subwatershed 2 flows into Subwatershed 3. The two major tributaries to Honouliuli Stream distinguish Subwatersheds 1 and 4 from Subwatersheds 2 and 3. The Waiahole Ditch is the demarcation between the two upper and two lower subwatersheds.



Subwatershed Area	Acres	Major Landuse/Cover
1	2,358	Forest, Pasture,
2	2,700	Forest, Pasture,
3	1,314	Farmland
4	884	Farmland

The basic inputs into WinTR-55 are rainfall, basin area, soil infiltration characteristics (hydrologic soil group), land use data, and slope and channel characteristics. The soil and land use data are used in the determination of runoff curve number (CN).

Rainfall

The 24-hour storm rainfall derived from NOAA Atlas 14 for the 1-, 2-, 10-, 25-, 100-, and 500-year recurrence interval storms were used as input. The 24-hour rainfall rates are shown in Table 1. WinTR-55 is only able to analyze the 24-hour storm.

Determination of CN

The curve number is determined in WinTR-55 when a Hydrologic Soil Group (HSG) and a land use/cover are selected for a grouping of acres in the watershed. A built-in table in WinTR-55 permits entry of acres for standard soil and land use/cover combinations. Customized input is also accommodated.

The HSG is a four level index describing the infiltration capacity of the soil. Infiltration rates for soils were established during the mapping of the soils by NRCS. The HSG levels are A, B, C, and D. Soils in HSG A have high infiltration rates, will lessen runoff, and will contribute to lower CN values. Soils in HSG D have little infiltration capacity and will contribute to high CN values. The HSG designations for soil series are provided in the state soils database available at the NRCS' SoilDataMart website.

Land use/cover choices that are built into WinTR-55 reflect conditions that are found throughout the U.S. It is often difficult to match a land use/cover category to the condition found in the local watershed.

Time of Concentration

The last major parameter to be entered into WinTR-55 is the time of concentration (Tc). Tc is a measure of time for all of the rainfall in a drainage area to contribute to runoff. Generally it is measured as the travel time along the longest flow path in the drainage area. Knowledge of open channel flow characteristics is helpful. WinTR-55 offers calculation aids which provide choices for flow depth, surface roughness, and slope to estimate Tc. Slope values were estimated from the USGS topographic map. Surface roughness was based on Manning's roughness coefficients.

TR-55 results and calibration

The initial peak discharge results from the WinTR-55 analysis, using unadjusted input values, were judged to be extremely high. The peak discharge for the various storm frequencies is shown as WinTR-55 in Table 2.

Two other estimates of storm runoff for various recurrence intervals were used to calibrate the WinTR-55 model.

The first used the 55 years of peak annual discharge records from the Honouliuli Stream gage at the Farrington Highway bridge (USGS 16212500). A log-Pearson frequency analysis was conducted on the 55-year record. A concern in the analysis was the low discharge rates, which could have been caused by obstructions and unaccounted storage upstream. None could be found during this study. The results of the analysis are shown as USGS Gaging Station in Table 2 and Figure 1.

The second source of flood estimates derived from the regression equations that are used by the National Flood Frequency Program to determine flood runoff from ungaged streams for floodplain regulatory purposes. Three sets of equations are used on Oahu. The equation set for leeward and central Oahu were used. The inputs to the equation are drainage area and 24-hour precipitation. The results of the analysis are shown as NFFP Regression Equations in Table 2 and Figure 1.

The absence of any recorded flow events approaching even one-half of the NFFP 100-year peak discharge, made the results of the stream gage frequency analysis less realistic than the output from the NFFP regression equations. The WinTR-55 model was then calibrated to the NFFP regression equation results.

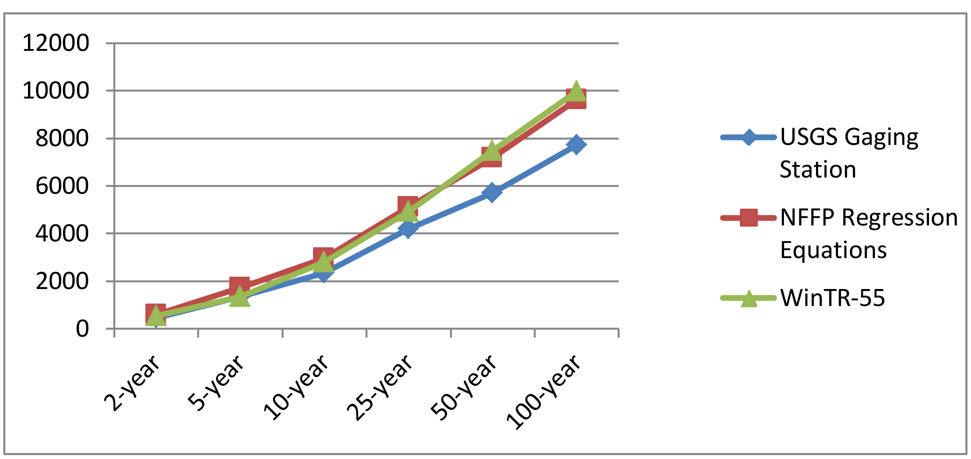
Adjustments to the CN and Tc values were made to reduce the peak discharges of the existing condition WinTR-55 model to be close to the values resulting from the NFFP model.

Adjustment of the input parameters is not unprecedented in Hawaii. It is difficult to use the WinTR-55 model in Hawaii without such adjustments. Varied conditions from the empirical basis exist in higher slopes, higher rainfall, and soil characteristics. A 35% reduction in CN was selected as the base model. A 30% reduction in CN was used for the 2-year value. The results of the analysis are shown as WinTR-55 in Table 2 and Figure 1.

Table 2 - Comparison of Peak Discharge by Analysis Method (cubic feet per second)

	2-year	5-year	10-year	25-year	50-year	100-year
USGS Gaging Station	456	1361	2335	4200	5717	7721
NFFP Regression Equations	614	1731	2958	5102	7175	9617
WinTR-55	541	1353	2816	4940	7475	9974

Figure 1 – Peak Discharge for Storms by Analysis Method (cubic feet per second)



Rainfall/Runoff/Sediment Discharge Relationship

Rainfall and storm runoff are the primary agents in soil movement in the Honouliuli Watershed. While wind erosion and vehicular tracking of soils can also account for soil movement, those processes are not as significant as water-caused soil erosion and movement. Soil erosion occurs when raindrops impact exposed soil surfaces and detach smaller particles. Water flowing on the surface of the soil breaks off more small particles through flow turbulence and entrains the soil particles in the flow. Suspended sediment is soil particles, typically clay and silt, that are fully entrained in the flow and are distributed evenly in the flowing water column. Bedload sediment is the sediment that is in constant or frequent contact with the stream bottom as it is moved downstream. Bedload is concentrated near the bottom of the water column. Water quality impacts are caused by elevated suspended sediment concentrations in runoff. Suspended sediment is generally reported as a concentration in milligrams of sediment per liter of water (mg/l). Suspended sediment yield can also be reported as a mass in tons per day or tons per year.

The amount of soil erosion and sediment transported by rainfall and runoff is a nonlinear function of the intensity of the rainfall and magnitude of the storm runoff. Many rain events do not generate runoff, as light or well-distributed rainfall is able to infiltrate into the ground or be stored in depressions or on vegetation before it can concentrate into streams. The amount of sediment eroded and transported is an exponential function of the magnitude of stormwater runoff. The velocity and depth of streamflow are the primary factors in the energy available to transport sediment and to scour and erode available sediment sources.

Sediment discharge is very episodic. It is generally accepted that the greatest sediment discharge occurs during infrequent but intense storms. It is not unusual for most of the sediment discharged from an area over a multi-year period to result from a single storm event. This relationship between storm frequency and sediment discharge is reflected in the Hawaii Water Quality Standards which allow for higher sediment concentrations during infrequent events.

The Waikele Watershed suspended sediment study conducted by USGS correlated streamflow rates at four stream gages in the central Oahu watershed to suspended sediment concentrations during the 2008, 2009, and 2010 Water Years (WY) (USGS, Sources of Suspended Sediment in the Waikele Watershed, Oahu, Hawaii, SIR 2012-5085, 2012). (The USGS Water Year extends from October in the previous year to September to keep whole the fall and winter seasonal storm grouping.) The study reported that a single storm on December 11, 2008, resulted in the highest suspended sediment yield for three of the four gages used in the study. The fourth gage was destroyed by the flood. The December 11, 2008 storm "constituted 81 percent to 99 percent of the WY2009 load, and 46 to 92 percent of the total suspended-sediment load measured during the study period [at the 3 gages]."

<u>Sediment Concentration-Stormwater Discharge relationship</u>
Measurements on several Hawaiian streams have been made in recent years that advance our understanding of the relationship between instantaneous stormwater discharge rates and sediment concentrations. In the period 2001 to 2007, the USGS collected suspended sediment records for Hanalei River on the north shore of Kauai and Kawela Stream on the south shore of Molokai

(Stock, Jonathan and Gordon Tribble, 2010, Erosion and Sediment Loads from Two Hawaiian Watersheds, 2nd Joint Federal Interagency Conference). The Hanalei Watershed (18.7 mi^2) is typically very wet supporting continuous flow in the Hanalei River. The Kawela Watershed (5.3 mi^2) is on the dry, leeward side of Molokai, although the upper reaches of the watershed are in the heavily forested mountains. Streamflow in Kawela Stream occurs less than 40 percent of the time. An earlier USGS study of Moanalua Valley on Oahu used instantaneous monitoring of suspended sediment and stream flow for a strom on April 19, 1974, to develop a suspended sediment concentration (mg/L) versus instantaneous discharge (CFS) curve (Shade, P.J., 1984, Hydrology and Sediment Transport, Moanalua Valley, Oahu, Hawaii, USGS WRIR:84-4156).

USGS has reported instantaneous suspended sediment concentrations and flow rates at Gage 16212500 on Honouliuli Stream by Farrington Hwy, for eight data points between February 2010 and May 2011. The data points were graphed on a log-log plot and curve fitted to the eight points. The greatest flow rate of the eight points is 80 cfs. Confidence in extrapolating the curve to higher flow rates is low, however, due to the intermittent nature of Honouliuli Stream. Many of the eight data points may be representative of the "first flush" following a dry period when sediment availability is increased resulting in high suspended sediment readings. Steady streamflow following the "first flush" will usually exhibit lower suspended sediment concentrations.

The four instantaneous discharge versus suspended sediment concentration curves were plotted together to observe any emerging patterns and to determine if an instantaneous discharge versus suspended sediment concentration relationship could be applied to the Honouliuli Watershed.

A distinct separation of perennial streams from intermittent streams was obvious. The continually high volume Hanalei Stream exhibited the lowest suspended sediment concentration, followed by the low volume, but continuous, Moanalua Stream. Kawela Stream, which is reported to flow approximately 40 percent of the time had higher suspended sediment concentrations than Moanalua by an order of magnitude and Hanalei by nearly two orders of magnitude. The curve for Honouliuli, based on very limited data, was over an order of magnitude greater in suspended sediment concentration than Kawela.

It is important to note that sediment concentration by itself does not indicate the amount of sediment discharged. The USGS report calculated that the annual sediment yield in the Hanalei basin (1,360 tons/yr/mi^2) actually exceeded the Kawela basin yield (1,020 tons/yr/mi^2) (Stock 2010).

For the purposes of this study and to provide a basis for comparison of suspended sediment yield with possible treatments, we utilized the instantaneous discharge versus suspended sediment concentration curve derived for Kawela Stream. The correlative curve was applied to the runoff hydrographs generated by WinTR-55 to estimate the suspended sediment discharge for various storm intensities and resource management levels. Due to the lower peak flow rates at Kawela as compared to Honouliuli, extrapolation to higher flow rates result in unrealistically high suspended sediment concentrations. Therefore, the maximum suspended sediment concentration was capped at 50,000 mg/L. The Stock study reported that the maximum suspended sediment concentration recorded by their study was 54,000 mg/L at a relatively low instantaneous flow of 57 cfs.

The WinTR-55 hydrographs for the 2-year to 100-year 24-hour storms at the Honouliuli Project Area outlet near the H-1 bridge were used in relation to the Kawela Stream sediment discharge curve to estimate suspended sediment discharge from the Honouliuli Project Area. The WinTR-55 hydrograph can be output as time versus instantaneous discharge table. The average discharge for a time segment was correlated to the Kawela Stream curve to determine the suspended discharge for the time segment. The suspended sediment discharges for all of the time segments were summed to determine the total suspended sediment yield for each storm intensity. The peak discharge and storm sediment yield for the existing condition are shown in Table 3.

Table 3 - Honouliuli Project Area Sediment Yield - Existing Conditions

Storm Recurrence Interval	Peak Discharge	Sediment Yield	per sq mi	per acre
	(cfs)	(tons)	(tons)	(tons)
2-Year	541	2,588	235	0.4
5-Year	1,353	13,082	1,189	1.8
10-Year	2,816	40,012	3,637	5.5
25-Year	4,950	81,258	7,387	11.2
50-Year	7,475	127,538	11,594	17.6
100-Year	9,974	175,379	15,944	24.2

Improved treatment of the Honouliuli project area to reduce erosion and runoff was modeled in WinTR-55. The resulting reduced runoff and sediment yield are shown on Table 4.

Table 4 - Honouliuli Project Area Sediment Yield - Improved Conditions

Storm Recurrence Interval	Peak Discharge	Sediment Yield	per sq mi	per acre
	(cfs)	(tons)	(tons)	(tons)
2-Year	242	730	64	0.1
5-Year	606	4,591	405	0.6
10-Year	1,532	19,774	1,744	2.7
25-Year	3,247	53,859	4,749	7.4
50-Year	5,258	94,588	8,341	13.0
100-Year	7,492	138,000	12,169	19.0

The estimated sediment yield for annual storms in a 100-year series was summed and divided by 100 to derive the average annual load. Tables 5 and 6 display the computation for the existing condition and improved conditions. On the basis of average annual sediment load, improving the conditions in the lower and middle project areas can reduce annual erosion and sediment delivery to the outlet by 44 percent, from 15,466 tons to 8,687 tons.

Table 5 – Average Annual Sediment Load Computation – Existing Condition

Existing Condition				
Recurrence Interval	# Years	Storm Sediment Yield	Summed Storm Sediment Yield	Average Annual Sediment Load
		(tons)	(tons)	(tons)
0	13		0	
2-year	50	2,588	129,400	
5-year	20	13,082	261,640	
10-year	10	40,012	400,120	
25-year	4	81,258	325,032	
50-year	2	127,538	255,076	
100-year	1	175,378	175,378	
	100		1,546,646	15,466

Table 6 – Average Annual Sediment Load Computation – Improved Condition

Improved Condition				
Recurrence Interval	# Years	Storm Sediment Yield	Summed Storm Sediment Yield	Average Annual Sediment Load
		(tons)	(tons)	(tons)
0	13		0	
2-year	50	730	36,500	
5-year	20	4,591	91,820	
10-year	10	19,774	197,740	
25-year	4	53,859	215,436	
50-year	2	94,588	189,176	
100-year	1	138,000	138,000	
	100		868,672	8,687

Appendix 5: Estimation of Conservation Practices

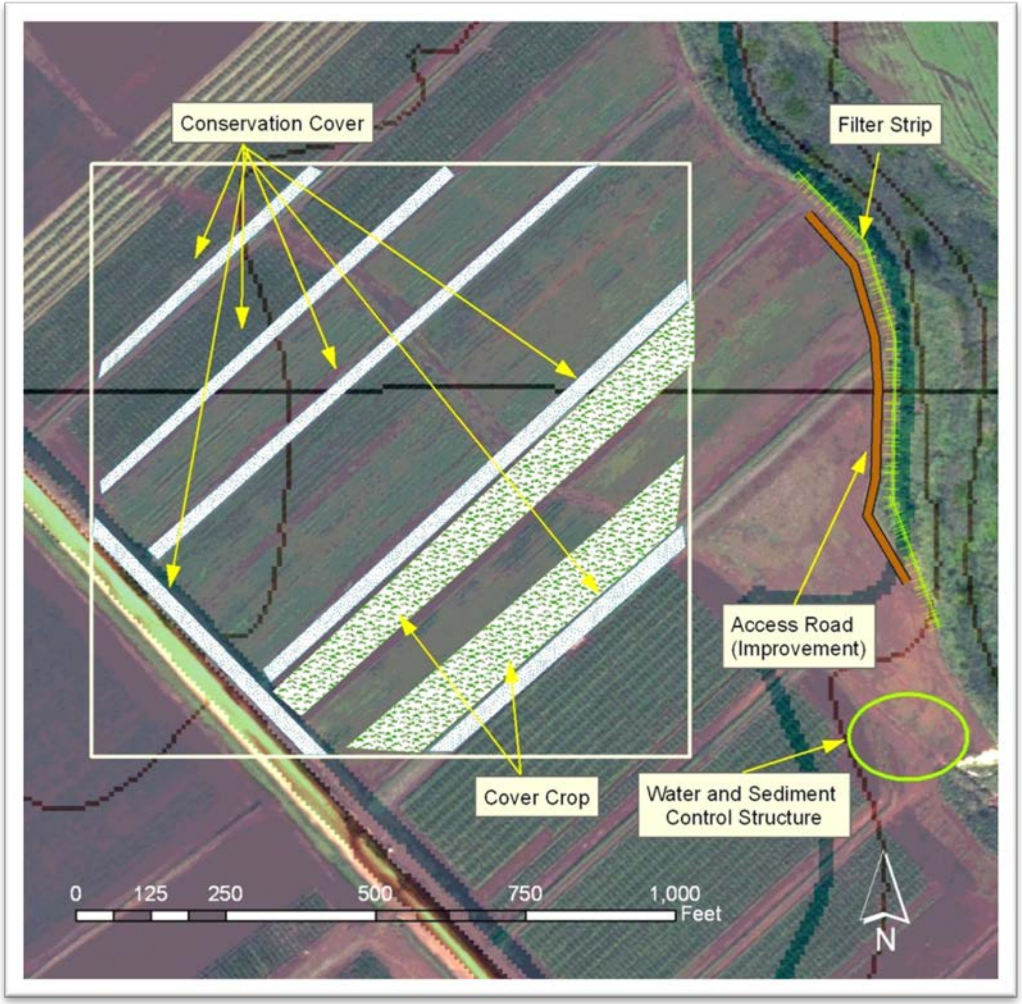
The quantities of conservation practices required in the entire project area were determined based on sampling within 1,000 foot by 1,000 foot (~ 23 acres) blocks. Nine sample blocks were selected to represent the different combinations of agricultural land use and erosion potential category (MEP, HMEP, and HEP).

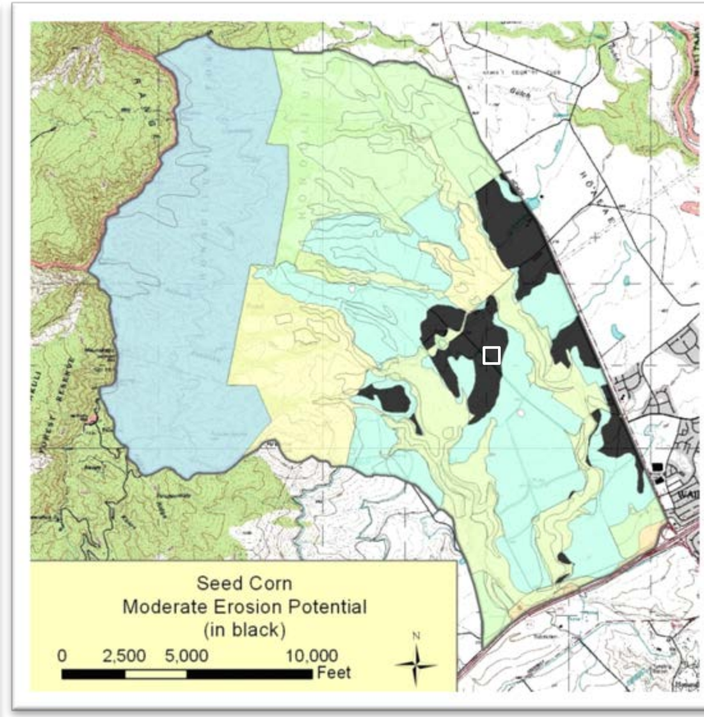
Types and quantities of conservation practices required within each block were estimated and then applied to similar land use / erosion potential combinations within the project area.

Below is an example assessment process and calculation for truck crops on high erosion potential land:

> The sample evaluation block for truck crops with high erosion potential was located at the transition from steep Waianae mountains to the milder central Oʻahu plain. Slopes in this area range from 14 to 20 % with steeper slopes on gulch walls. Due to small parcel sizes in this area, farmers will likely be tempted to cultivate as much of their land as possible.
>
> Conservation practices to minimize soil erosion were identified within the sample block, and quantities (e.g. acres, linear feet) were measured or using GIS. Quantities determined for the sample block were then extrapolated onto the entire 511 acres within the project area categorized as truck crops with high erosion potential. Adjustments were made to account for land that would not be actively farmed, such as reservoirs, major roads, and buildings. In the case of truck crop / high erosion potential, a factor of 30% was used.
>
> The remaining acreage was divided by 23 (sample block size), to determine a multiplication factor. Quantities of the conservation practices for the sample block were then multiplied by this multiplication factor to determine conservation practice quantities for all acres within the project area exhibiting the truck crop / high erosion potential combination. A similar process was used for each of the other land use / erosion potential combinations.

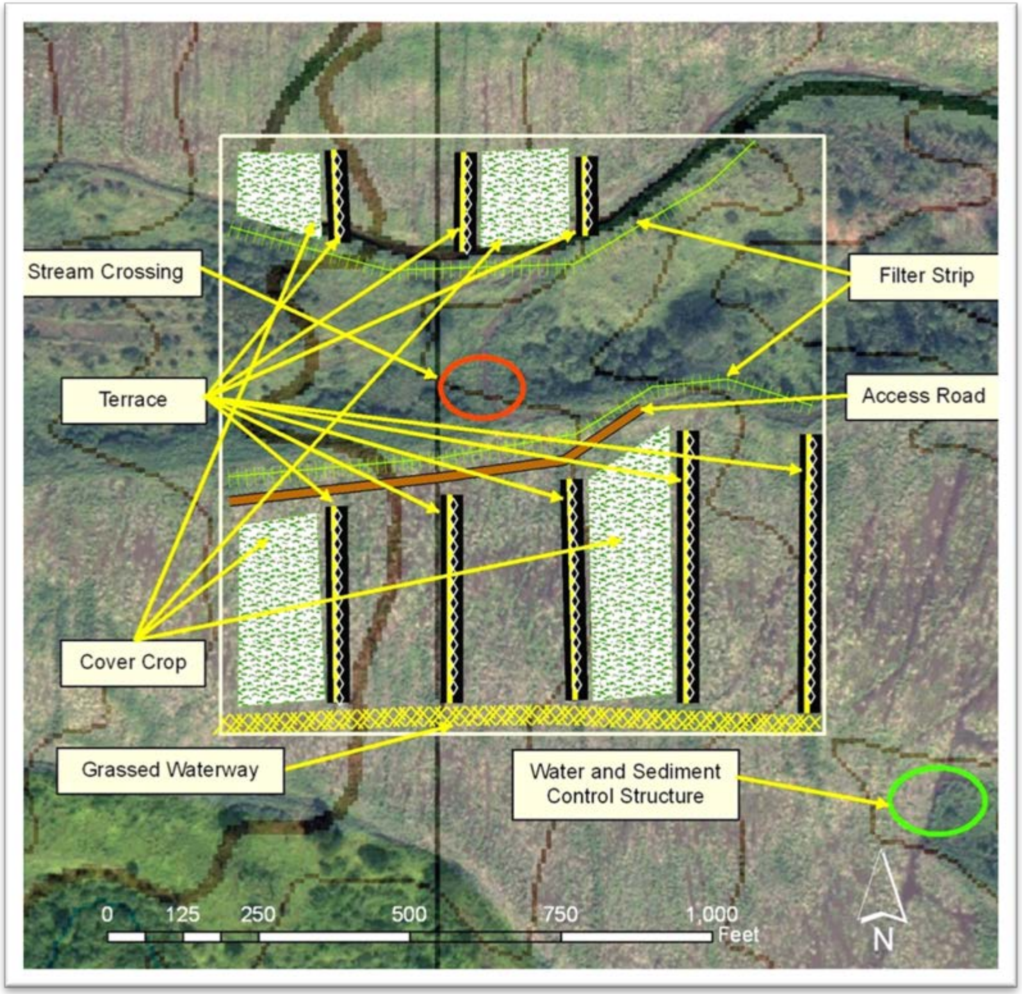
The following pages depict conservation practices for each of the nine sample blocks, and list conservation practice quantities based on total acres within the project area with the same land use / erosion potential combination. The location map identifies the sample block location within the specified land use / erosion potential combination.

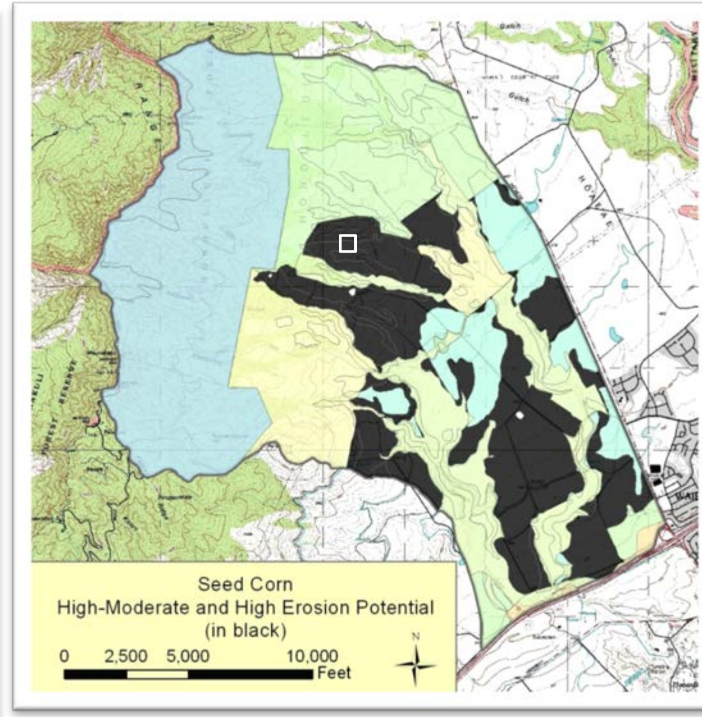




Conservation Practices	Units	Sample Block	MEP Seed Corn
Cover Crop	acre	12	223
Conservation Cover	acre	2	37
Filter Strip	lin. ft.	1,000	18,600
Access Road	lin. ft.	750	14,000
W&S Control Struct.	each	1	47

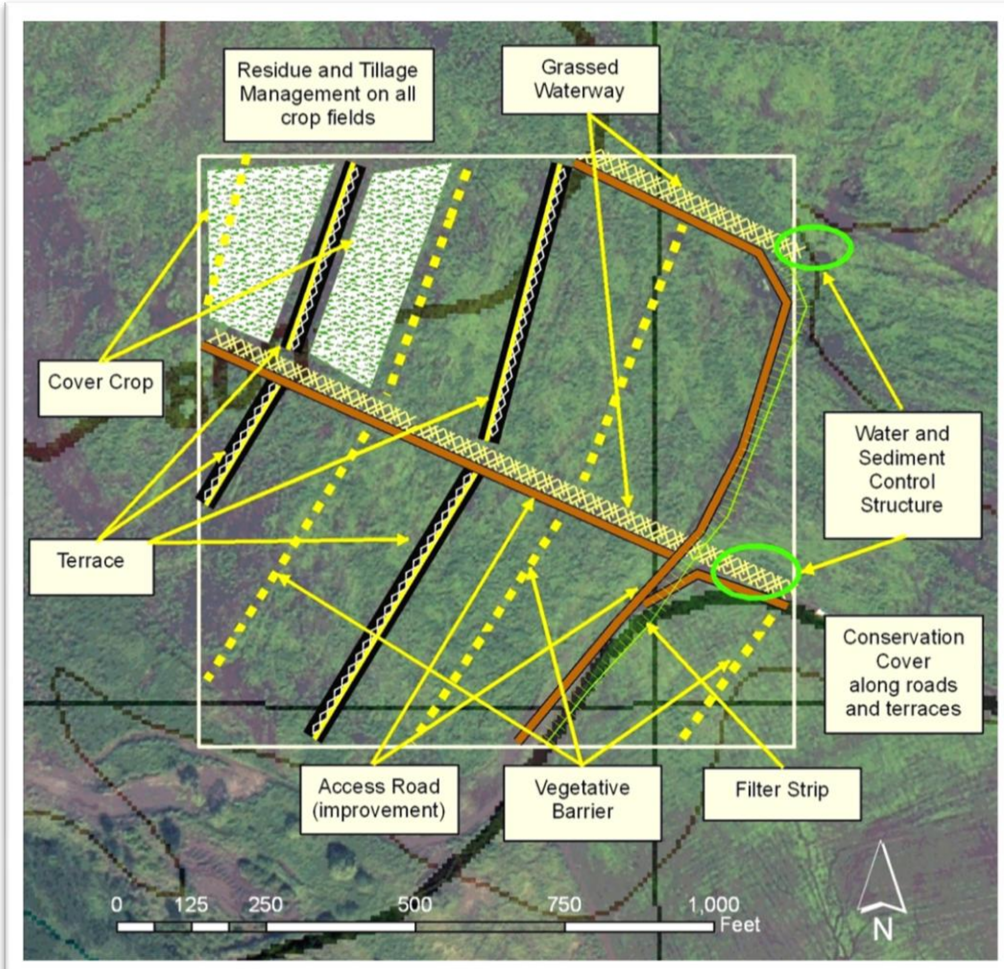
Conservation Practices for **Seed Corn** Sample Block
Moderate Erosion Potential

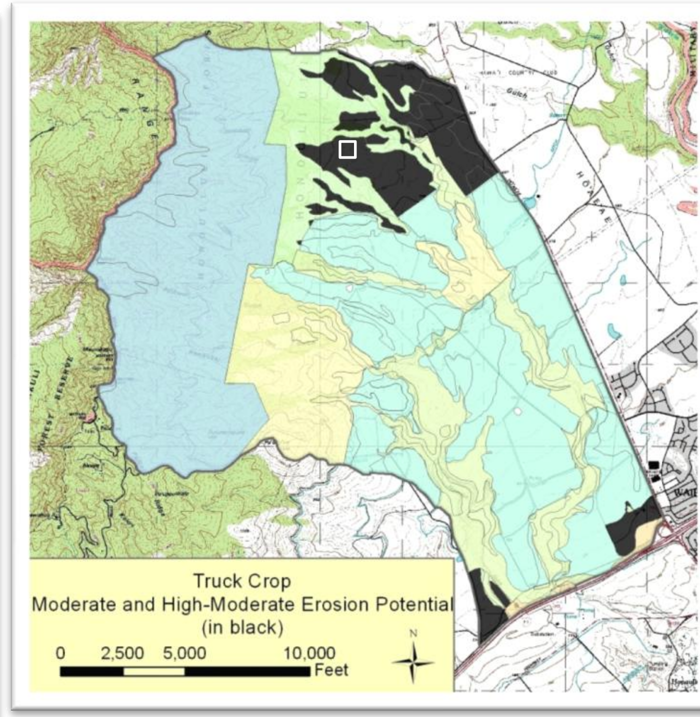




Conservation Practices	Units	Sample Block	HMEP and HEP Seed Corn
Cover crop	acre	10	373
Filter Strips	lin. ft.	2,000	74,500
Terraces	lin. ft.	2,500	93,200
Grassed Waterway	lin. ft.	1,000	37,300
Stream crossing	each	1	37
Access Road	lin. ft.	550	20,500
W&S Control Struct.	each	2	75

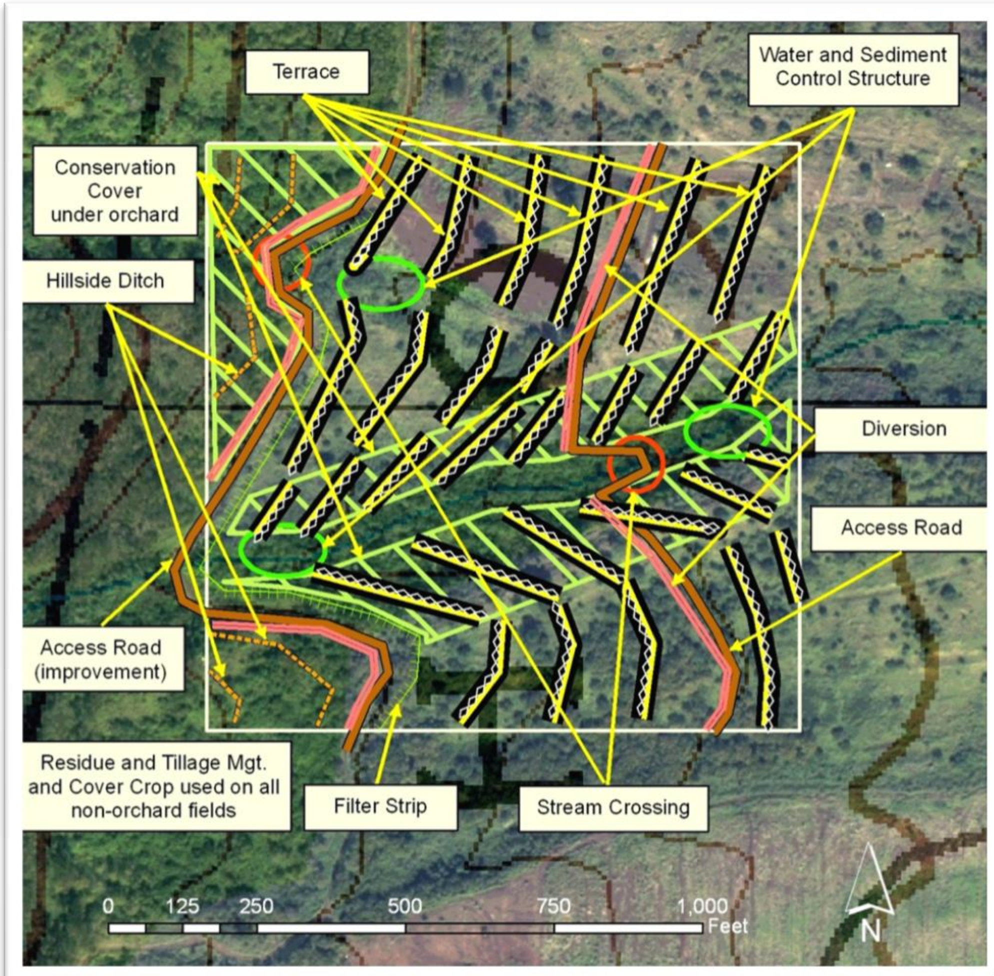
Conservation Practices for **Seed Corn** Sample Block
High-Moderate and High Erosion Potential

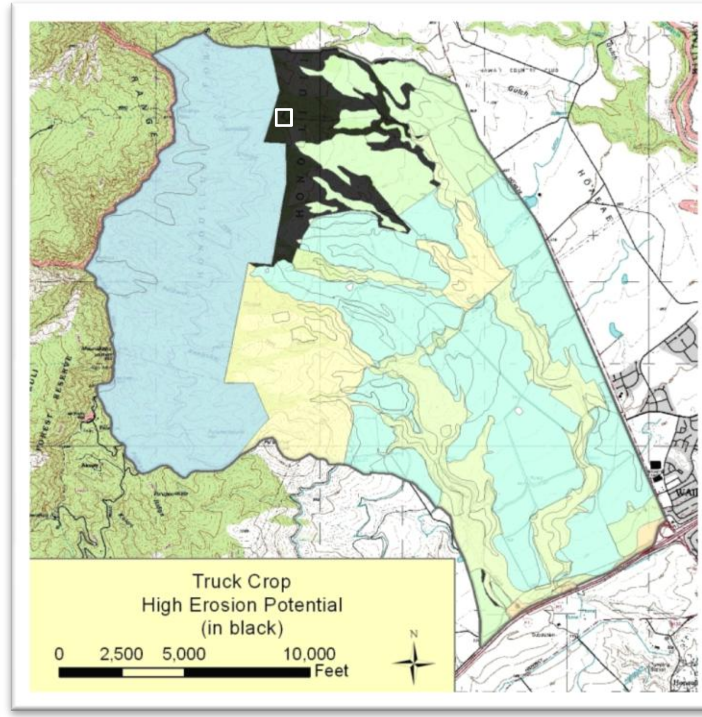




Conservation Practices for **Truck Crop** Sample Block
Moderate and High-Moderate Erosion Potential

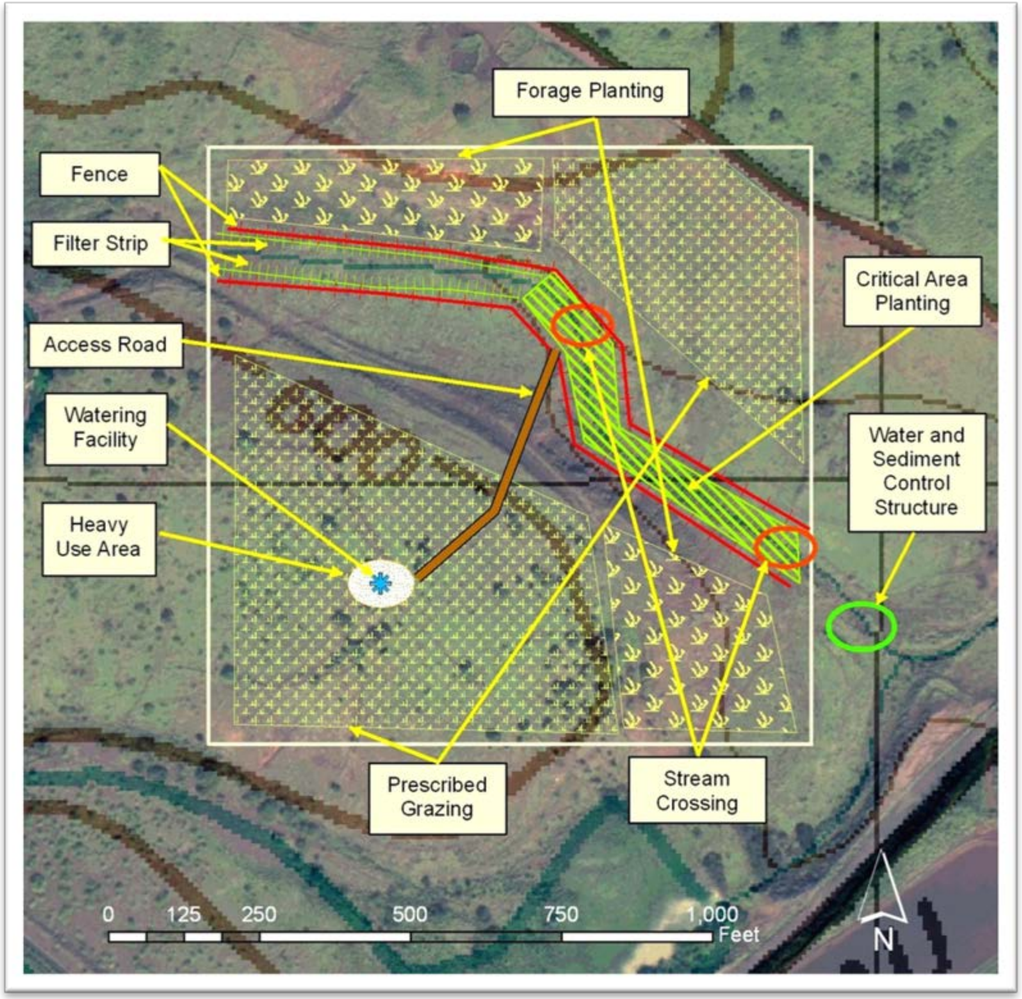
Conservation Practices	Units	Sample Block	MEP and HMEP Truck Crop
Residue and tillage Mgt	acre	15	356
Cover crop	acre	4	95
Conservation Cover	acre	3	71
Filter Strips	lin.ft.	1,500	35,600
Vegetative Barrier	lin.ft.	3,000	71,200
Grassed Waterway	lin.ft.	1,500	35,600
Access Road	lin.ft.	625	14,800
W&S Control Struct.	each	2	47

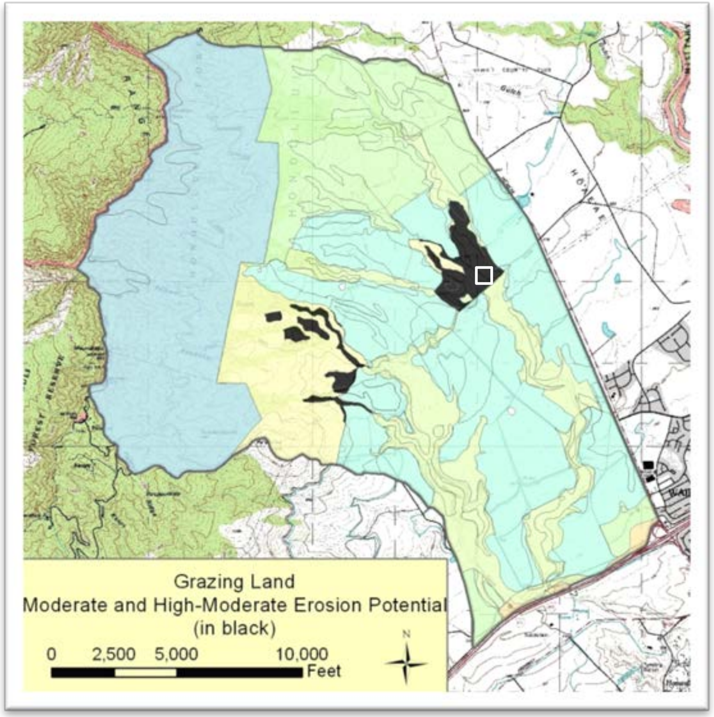




Conservation Practices for **Truck Crop** Sample Block
High Erosion Potential

Conservation Practices	Units	Sample Block	HEP Truck Crop
Residue and tillage Mgt	acre	15	233
Cover crop	acre	4	62
Conservation Cover	acre	10	156
Filter Strips	lin.ft.	1,000	15,500
Diversion	lin.ft.	2,000	31,100
Terraces	lin.ft.	7,000	108,900
Hillside Ditch	lin.ft.	1,000	15,600
Access Road	lin.ft.	2,375	36,900
Stream Crossing	each	2	31
W&S Control Struct.	each	3	47

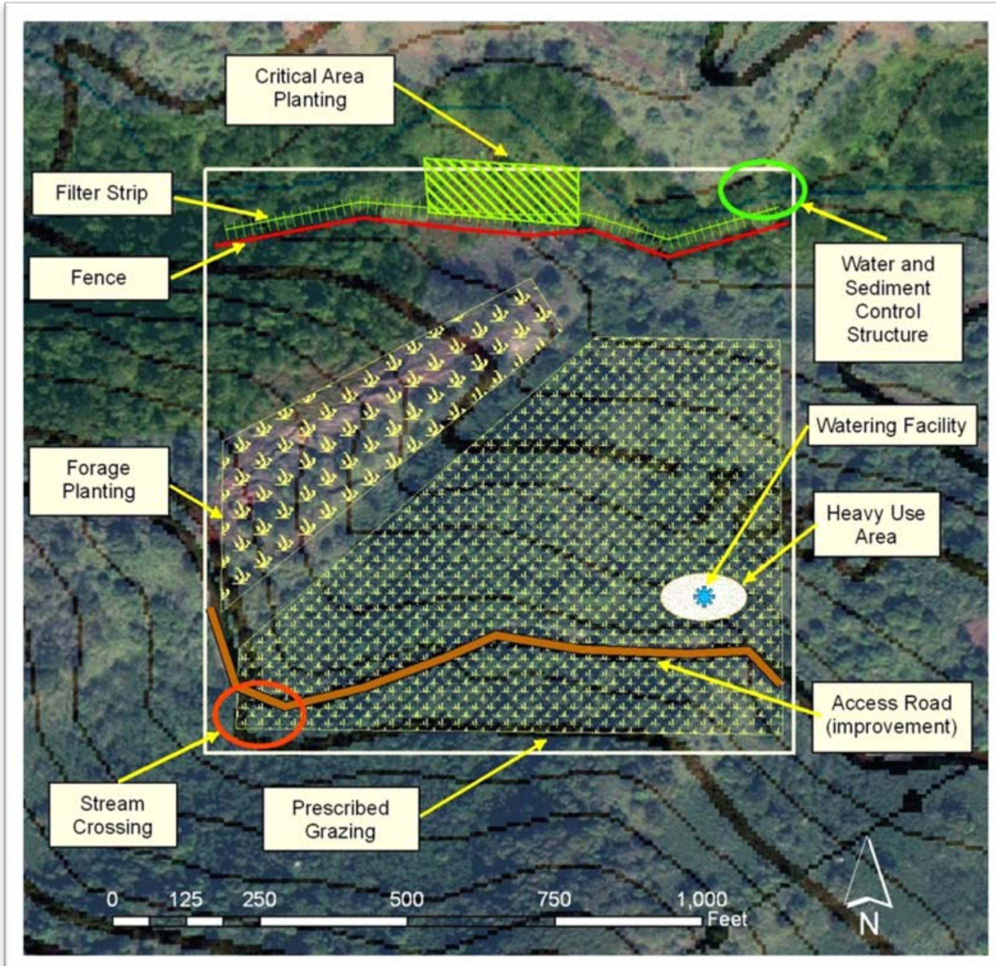


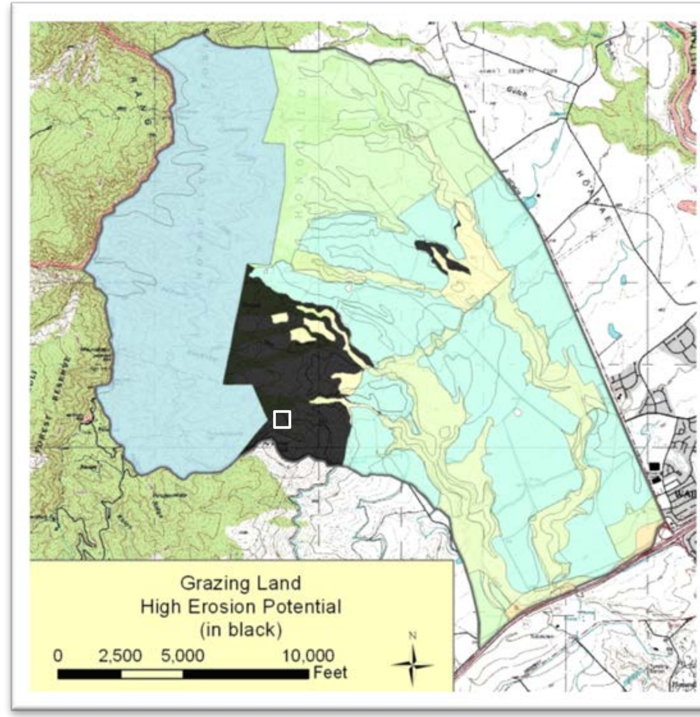


Conservation Practices	Units	Sample Block	MEP and HMEP Grazing Land
Prescibed grazing	acre	15	119
Critical Area Planting	acre	2	16
Forage Planting	acre	10	79
Fence 1/	lin. ft.	3,000	23,800
Filter Strip	lin. ft.	1,000	7,900
Stream Crossing	each	2	16
Heavy Use Area	acre	1	8
Watering Facility	each	1	2
Access Road	lin. ft.	500	4,000
W&S Control Structure	each	1	8

1/ Fence around perimeter and paddocks.

Conservation Practices for **Grazing Land** Sample Block Moderate and High-Moderate Erosion Potential

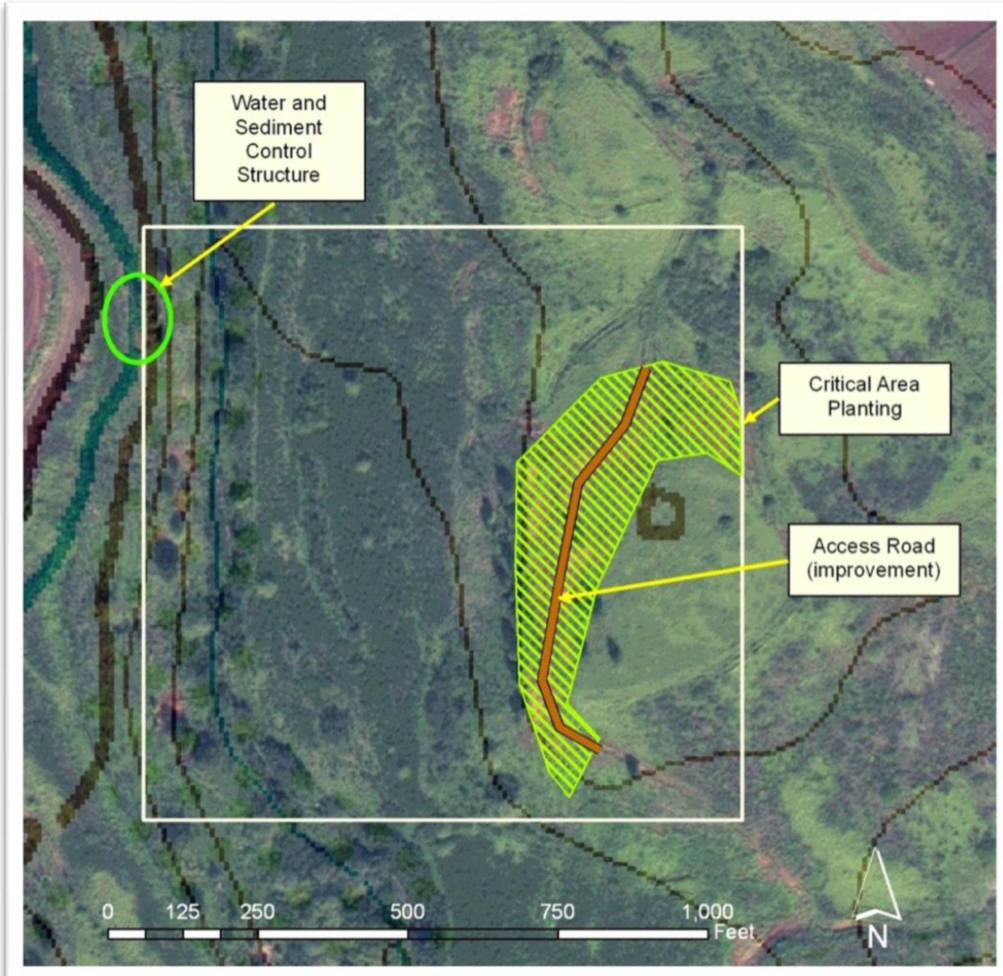


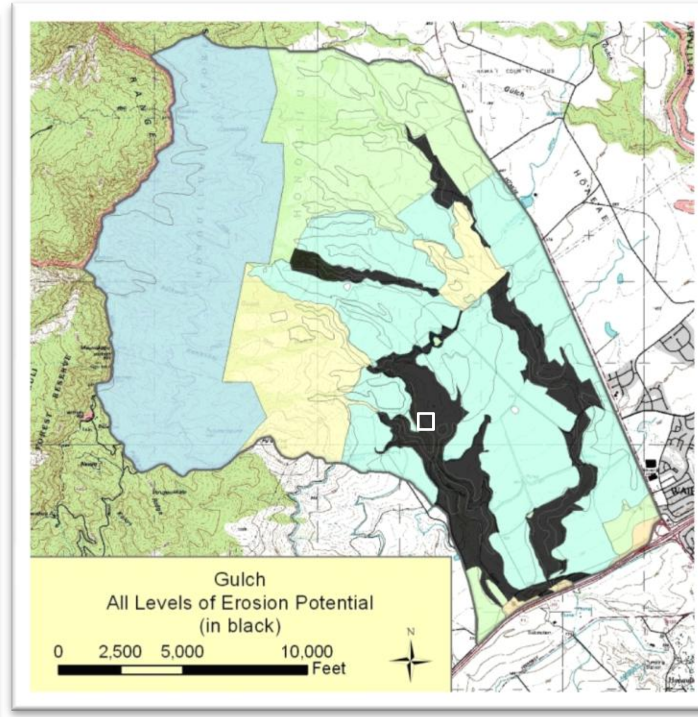


Conservation Practices	Units	Sample Block	HEP Grazing Land
Prescibed grazing	acre	15	269
Critical Area Planting	acre	2	36
Forage Planting	acre	5	90
Fence 1/	lin. ft.	5,000	89,800
Filter Strips	lin. ft.	1,000	18,000
Stream Crossing	each	1	18
Heavy Use Area	acre	1	18
Watering Facility	each	1	4
Access Road	lin. ft.	250	4,500
W&S Control Struct.	each	1	18

1/ Fence around perimeter and paddocks

Conservation Practices for **Grazing Land** Sample Block
High Erosion Potential

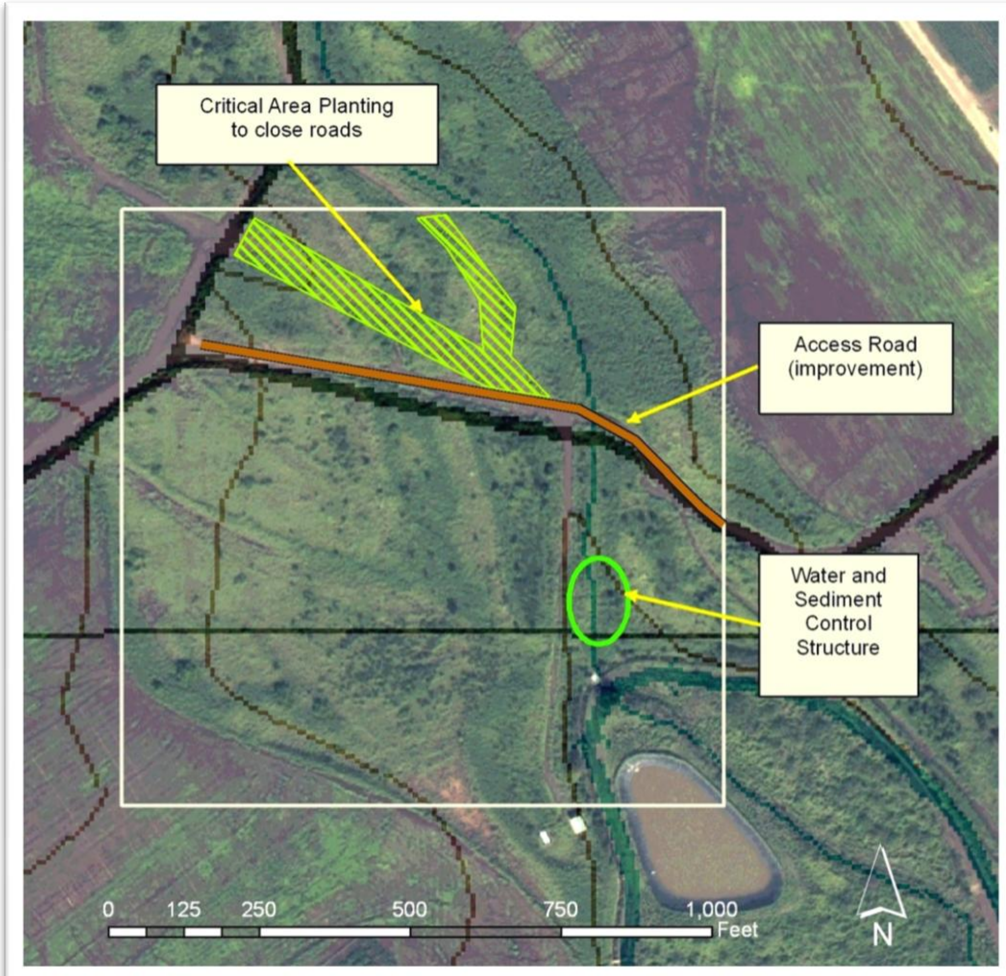


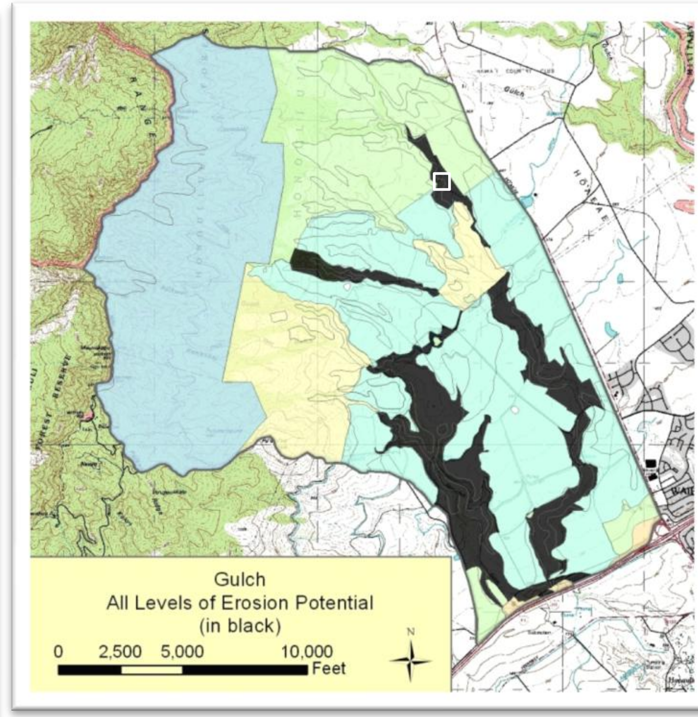


Conservation Practices	Units	Sample Block	All EP Gulch
Critical Area Planting	acre	2	69
W&S Control Structure	each	1	34
Access Road	lin. Ft	250	8,600
Sediment Basin 1/	each	0	2

1/ Locate major Sediment Basins near lower ends of the two gulch systems in the project area.

Conservation Practices for **Gulch 1** Sample Block
All Erosion Potential

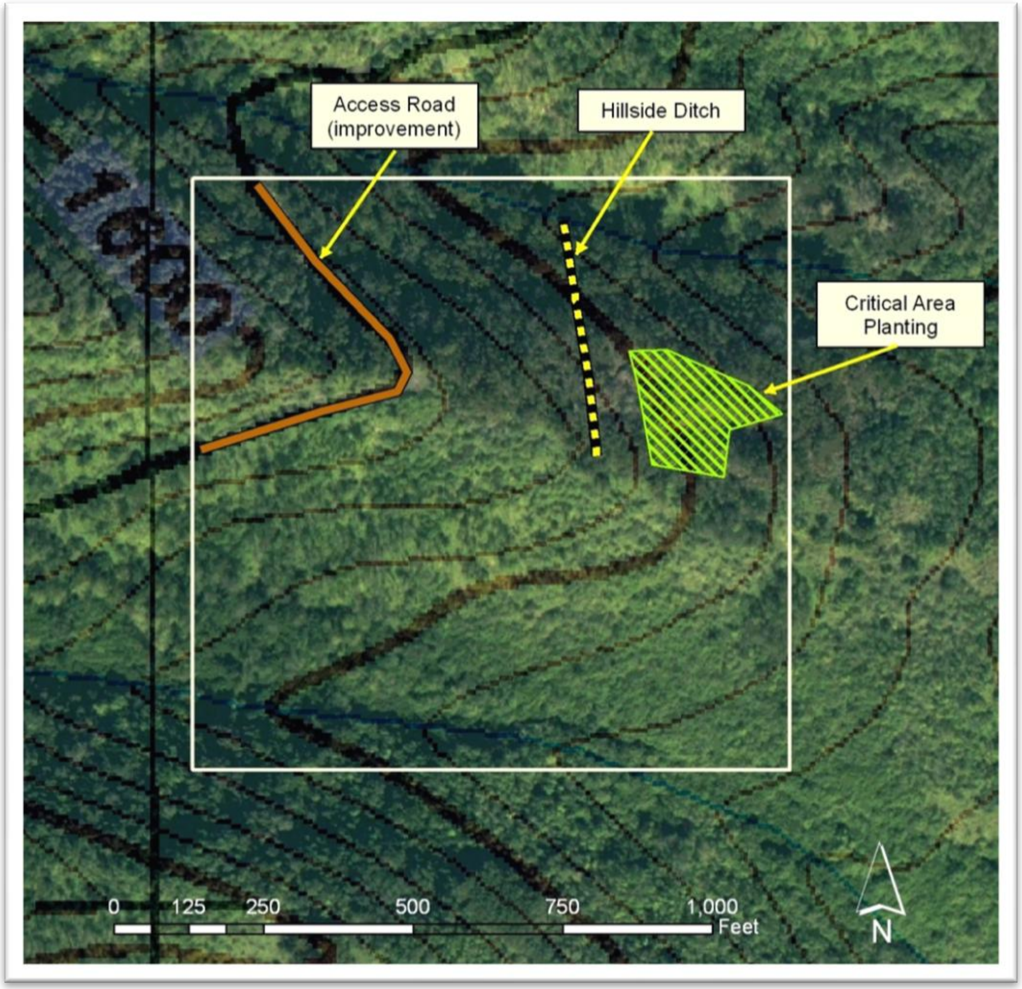


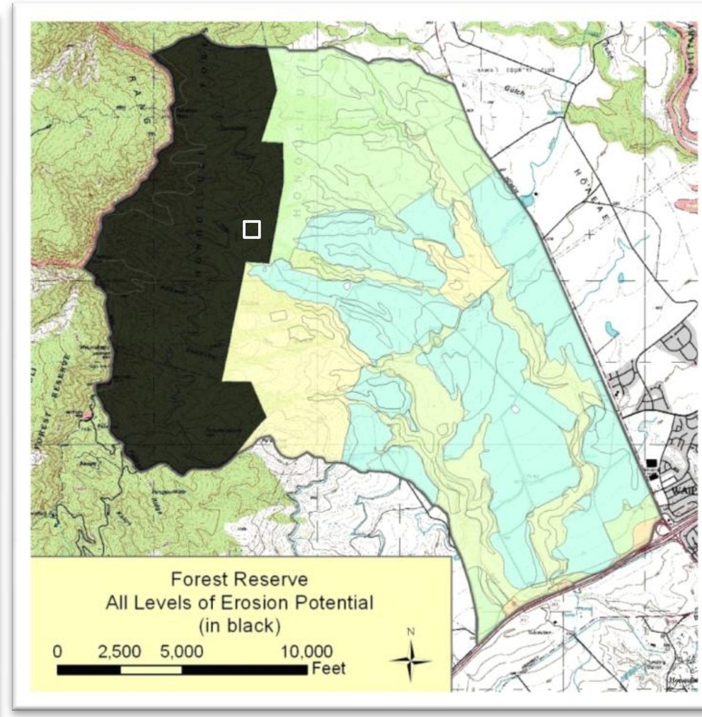


Conservation Practices	Units	Sample Block	All EP Gulch
Critical Area Planting	acre	2	69
W&S Control Structure	each	1	34
Access Road	lin. Ft	250	8,600
Sediment Basin 1/	each	0	2

1/ Locate major Sediment Basins near lower ends of the two gulch systems.

Conservation Practices for **Gulch 2** Sample Block All Erosion Potential





Conservation Practices	Units	Sample Block	Forest Reserve
Critical Area Planting	acre	1	45
Hillside Ditch	lin. ft.	500	22,400
Fence 1/	lin. ft.	1000	44,800
Access Road	lin. ft.	250	11,200

1/ Pig exclusion fence around sensitive ecological systems.

Conservation Practices for **Forest Reserve** Sample Block
All Erosion Potential Categories

APPENDIX 6. ADDENDUM TO THE WATERSHED BASED MANAGEMENT PLAN FOR HONOULIULI WATERHSED: A GUIDE FOR EROSION AND SEDIMENT CONTROL ON AGRICULTURAL AND FOREST RESERVE LANDS

August 2025

Appendix 6: Estimating Pollutant Load Reductions Resulting from Control and Removal of Invasive Plant and Animal Species and Establishment of Native Species

Introduction

This addendum has been developed by the Hawaii Department of Health (HDOH) to address additional considerations and updates relevant to watershed management efforts. This addendum supplements the Watershed Based Management Plan for Honouliuli Watershed: A Guide for Erosion and Sediment Control on Agriculture and Forest Reserve Lands to include activities and additional guidance related to the removal of invasive plants and animals, as well as the reintroduction of native species. In addition to including these activities in the menu of best management practices (BMPs) that are eligible for 319 funding, this addendum provides an approach for calculating the pollutant reductions associated with these restoration activities. These pollutant reductions can be used by project managers and sub-grantees to develop individual project plans and by HDOH to calculate annual pollutant reductions for the broader NPS program.

Pollutant Loading from Invasive Species

Invasive plants and animals are an increasingly challenging source of pollution in many of Hawaii's watersheds. Invasive plants, such as miconia, have shallow root systems, which are unable to stabilize the soil and are susceptible to erosion and landslides during rainfall events. Invasive animals, such as feral hogs, are destructive grazers, uprooting plant material and exposing additional areas to erosion.

As a result, sediment is the primary pollutant of concern from invasive species, although other pollutants may also be transported during rainfall events (e.g., nutrients and bacteria). Sediment has been identified by HDOH as a pollutant of concern across the state and is a focus of water quality improvement efforts. This watershed-based plan already includes a discussion of pollutants of concern and the load reductions needed to return the impaired waters to attainment. This addendum supplements that discussion; invasive species are one of multiple pollutant sources to be addressed.

Pollution Control Practices

Across Hawaii, many organizations (including federal, state and local government, as well as watershed groups) are working to mitigate these problems. In many cases, this involves removing the invasive species and replacing them with native species. Native plant species[1] are better adapted to the soils and climate and provide improved soil retention, among other benefits. Excluding invasive animals, such as using fencing to block access to an area, allows vegetation to recover and thrive.

[1] See, for example, https://dlnr.hawaii.gov/forestry/plants/ for a discussion of native plant species.

Table 1 below includes BMPs that can address pollutant loading caused by invasive species.[2] As shown by the large number of potential BMPs, vegetative plantings are a common element of many BMPs; ensuring that native species are used (and in the necessary quantities for establishment) will help to restore native plant communities. Managing invasive animal species is typically limited to exclusion or removal.

Table 1 - Selection of BMPs to Address Invasive Species

Management Practice	Description
Bioretention Cell (Rain Garden)	Depression consisting of native plant species and soil mixtures that receives stormwater flow and infiltrates to treat pollutants.
Channel Maintenance and Restoration	Practices used to control sediment and plant pollution into waterways during earthwork such as stream bank stabilization or habitat enhancement. Examples include floating booms and silt curtains extended across river or stream banks downstream of work.
Constructed Wetlands	Creation of an artificial wetland ecosystem to improve the quality of stormwater runoff or other water flows. A constructed wetland provides biological treatment in areas where wetland function can be created or enhanced. Constructed wetlands also can be used to treat runoff from agricultural land uses and stormwater runoff and other contaminated flows from urban areas and other land uses. The practice involves establishment of inlet and outlet control structures for an impoundment designed to accumulate settleable solids, decayed plant matter, and microbial biomass and support propagation of hydrophytic vegetation.
Critical Area Planting	Establishment of permanent vegetation in areas with heavy erosion problems. Particularly useful for areas that need stabilization before/after flood events.
Grassed Waterway	A shaped or graded channel that is established with suitable vegetation to convey surface water at a non-erosive velocity using a broad and shallow cross section to a stable outlet. Used to convey runoff from terraces, diversions, or similar; to prevent gully formation; and to protect or improve water quality.
Herbaceous Weed Treatment/Invasive Species Removal	The removal or control of herbaceous weeds, including invasive, noxious, and prohibited plants.
Sediment Basin	Captures and retains stormwater runoff until sediments settle out; water is released through engineered outlet.
Feral Ungulate Fencing	A structural conservation practice that prevents movement of ungulates across a given boundary. Within areas impacted by feral ungulate presence, fences prevent their movement into the forested lands. Ungulate fencing prevents direct contact of fecal matter with

[2] The table shows only a selection of BMPs. Other BMPs may also accomplish the goals of invasive removal and re-establishment of native species. Watershed planners should consult with HDOH when developing project plans to ensure BMP eligibility.

Management Practice	Description
	waterways, allows for restoration of vegetation, and reduces bacteria and nitrogen loadings and sediment input into waterways.
Feral Ungulate Removal	Hunting or trapping wild goats, pigs, and other non-native hoofed mammals to reduce erosion caused by trampling and vegetation removal, as well as nutrient and bacterial impacts from defecation in and around water bodies.

Through this addendum, these BMPs are now eligible for funding under Section 319 to address water quality concerns caused by invasive species (if the BMPs were not already identified in the original plan). Implementation of these BMPs will lead to a reduction in pollutant loading in the watershed. The original watershed-based plan may include information on specific locations or land use types that may be most appropriate for invasive species BMPs. Additional information can be found in other resources, such as the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's *Field Office Technical Guide* for Hawaii.[3]

Calculating Pollutant Reductions

Accounting for the total pollutant reductions is an important step in tracking water quality improvements. HDOH and watershed stakeholders develop watershed-based plans under the state's nonpoint source pollution (NPS) program; these plans include a projected level of pollutant reduction for the proposed project.

There are various models that can be used to calculate the pollutant reductions associated with BMP implementation. HDOH researched the advantages and disadvantages of each model, including the ease of use for watershed project managers and evaluating the model's appropriateness for use in Hawaii. After reviewing several models, HDOH selected the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model.

Description of the InVEST Model

InVEST is a suite of models focused on ecosystems and how they connect to downstream economics. This addendum is focused on the sediment delivery ratio model in the InVEST suite. The InVEST sediment delivery ratio model was chosen by HDOH because it is easy to use and its ability to estimate sediment loading both with current condition and with BMPs implemented. Additionally, the InVEST model can be modified to accommodate the unique geologic conditions in Hawaii.

The InVEST sediment delivery ratio model is focused on sediment loading and erosion. The model outputs a set of maps showing the sediment erosion, including the amount of sediment soil loss per pixel, and the amount of erosion that is prevented by the presence of vegetation per pixel. The effect of BMPs on sediment erosion can be measured by comparing model outputs ran under the current conditions against model outputs ran with BMPs implemented. To calculate the annual soil loss per pixel, the InVEST model uses the Revised Universal Soil Loss Equation (RUSLE; Renard et al., 1997). Along with the factors that are in the RUSLE equation (rainfall

[3] https://efotg.sc.egov.usda.gov/#/state/HI/documents

erosivity, soil erodibility, slope length gradient, cover management, and support practice), this addendum recommends including an additional terrain factor to accommodate for the geology of Hawaii. The inclusion of the terrain factor prevents the model from overestimating the soil loss in places with geologically new basaltic bedrock which has minimal soil cover (Falinski, 2016). The required data inputs for this model are integrated into the RUSLE equation. To determine the effects of BMPs on sediment load reduction and erosion, the model should be run with altered data inputs.

The required data inputs include GIS data, a table, and five additional values. These five inputs are described in detail in the Step-by-Step Procedure below. To measure the reduction in sediment load and erosion with BMP implementation, these inputs can be changed to integrate the increase in vegetation that would come along with BMP implementation. The Step-by-Step Procedure section of this addendum describes each of these required inputs in further detail along with recommended values and sources for GIS data inputs.

Step-by-Step Procedure

The step-by-step procedure begins with collecting and creating the proper data inputs for the current conditions in the watershed and running the InVEST model with those data inputs. After the first model run, the next step is to use multiple lines of evidence, including model outputs and other information, to determine the most appropriate areas in the watershed to implement BMPs. Next, the model should be run again with inputs that incorporate the impacts that BMPs would have on the land cover or support practices. The reduction in pollutant loading is the difference between the two model output runs. The steps to compile each data input and descriptions of each required data input are shown in Table 2. All GIS inputs must be the same coordinate reference system. The coordinate reference system must be projected and in linear units of meters.

Table 2 - Required Data Inputs for the Invest Model

GIS Data Inputs		
Input Name and Description	**Data Type**	**Suggested Sources**
Digital Elevation Model: A digital elevation map (DEM) showing elevation in meters. The map should be clipped beyond the watershed boundary.	Raster	The 3D Elevation Program (3DEP) from USGS.[4] The best available resolution for the state is 1/3 arc-second.
		The Hawaii Statewide GIS Program's Digital Terrain Model.[5] Data is only available for portions of the state and as a JPEG or PNG, so it must be converted to a raster format. The resolution is 1 meter, and the elevation values are in meters.
Erosivity: A map of rainfall erosivity in units of MJ • mm/(h • ha • year). The map should illustrate both intensity and duration of rainfall.	Raster	For the island of Hawaii, NOAA's digitized version of the rainfall erosivity map from the Agriculture Handbook No. 703.[6] The units are US customary units, so the units must be converted by multiplying each value by 17.02 (Renard, et al., 1997).
		For the island of Oahu, NOAA's digitized version of the rainfall erosivity map from the Agriculture Handbook No. 703.[7] The units are US customary units, so the units must be converted by multiplying each value by 17.02 (Renard, et al., 1997).
		The rainfall erosivity map on page 57 of the Agriculture Handbook No. 703. This map must be digitized into raster data by a GIS specialist and units must be converted to SI by multiplying each value by 17.02 (Renard, et al., 1997).
		A rainfall erosivity raster can be made using precipitation from the Hawaii Climate Data Portal.[8] Rainfall erosivity can be calculated using the Roose equation (Renard and Freimund, 1994): $R = 0.5 \times P \times 17.02$, where R is the rainfall erosivity value in the proper SI units and P is the annual rainfall in mm/year.
Soil Erodibility: A map showing the soil erodibility in the watershed. Soil erodibility, also called K factor, is the likelihood of soil particles to	Raster	Soil data, including K factors, is available from the Soil Survey Geographic Database (SSURGO).[9] This database provides raster data of soil type in an area of interest, and a table showing the K factor of each

[4] https://apps.nationalmap.gov/downloader/
[5] https://geoportal.hawaii.gov/datasets/HiStateGIS::hawaii-dtm-elevation/about
[6] https://www.fisheries.noaa.gov/inport/item/48225
[7] https://www.fisheries.noaa.gov/inport/item/48230
[8] https://www.hawaii.edu/climate-data-portal/data-portal/
[9] https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo

erode and be transported downstream by precipitation or runoff. The soil erodibility raster must be in units of t · h · ha / (ha · MJ · mm).		soil type. Raster data of K factors in a projected coordinate system will have to be generated by combining the soil raster data and the K factor table.
Land Use/Land Cover: A map showing the land use and land cover within the watershed. The C-CAP raster described below must also be combined with geology data. Each pixel should be categorized by its land use/land cover and geologic origin from the geology dataset. Every combination of land use/land cover and geologic origin should be assigned a unique LULC code.	Raster	NOAA has C-CAP high resolution land cover raster data available for the entire state of Hawaii from 2021.[10] NOAA's land cover data has a resolution of 1-meter and includes up to 25 classifications including forests and urban development.
		Geology data for the state of Hawaii is available for download from USGS.[11] This data is available as shapefiles, so it must be converted to raster data.
Watersheds: A map of the boundary of the watershed.	Vector (polygon/ multipolygon)	The USGS Watershed Boundary Dataset has vector watershed delineation data available at different hydrologic unit levels for the entire state of Hawaii.[12]
		The Hawaii Statewide GIS Program has vector watershed delineation data available that was created by the Division of Aquatic Resources (DAR).[13]
		The InVEST suite includes the DelineateIt tool, used for generating watersheds based on user inputs. This tool outputs a GeoPackage containing a vector with the model's estimated watershed delineations. More information on this tool can be found in the DelineateIt section of the InVEST suite.[14]
		Watershed delineations can be generated using a USGS StreamStats's tool.[15] Delineations can be downloaded as vectors.
Other Required Data Inputs		
Input Name and Description	**Data type**	**Suggested Input Value**

[10] https://coast.noaa.gov/digitalcoast/data/
[11] https://pubs.usgs.gov/of/2007/1089/
[12] https://www.usgs.gov/national-hydrography/watershed-boundary-dataset
[13] https://geoportal.hawaii.gov/datasets/HiStateGIS::watersheds-dar-version/about
[14] https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/delineateit.html
[15] https://www.usgs.gov/streamstats

Threshold Flow Accumulation: The minimum number of pixels that flow into another pixel for it to be classified as a stream.	Number of pixels	This value should be determined by the user via trial and error. Users should test different values until the streams on the output maps resemble the streams in the watershed.
Borselli k Parameter: A calibration parameter in the sediment delivery ratio equation.	Number	This value is based on watershed location. Table 3 shows the Borselli k Parameter by location.
Maximum SDR Value: The maximum sediment delivery ratio a pixel is allowed to have.	Number between 0 and 1	For all watersheds in the state of Hawaii, the value should be 0.5 (Falinski, 2016).
Borselli IC_0 Parameter: A calibration parameter in the sediment delivery ratio equation.	Number	For all watersheds in the state of Hawaii, the value should be 0.1 (Falinski, 2016).
Maximum L Value: The maximum allowed slope value in the slope length-gradient factor.	Number	For all watershed in the state of Hawaii, the value should be 122 (Falinski, 2016).
Biophysical Table: A table mapping each LULC code to its cover-management factor (C) and support practice factor (P). One column should be named "lucode" and contain the LULC code from the land cover and land use raster. The other two columns should be named "usle_c" and "usle_p" and contain the associated C factor and P factor, respectively. The C factor indicates how much erosion is likely to occur at this land use/land cover type. The smaller the C factor value, the less erosion is expected to come from that type. To account for the terrain factor in the model run, the C factor in the biophysical table should be modified. The C factor for each LULC code should be the original C factor from Table 4 multiped by the terrain factor from Table 5 that is associated with the geologic origin under that LULC code. The P factor indicates whether erosion reduction practices are implemented in that area. A value of 1 means there are no erosion reduction practices implemented in that land cover/land use type and a smaller value indicates best management practices are implemented in that land cover/land use type.	.CSV file	Table 4 shows the C factors for land use/land covers in Hawaii, and Table 5 shows the terrain factor by geologic origin.

Workspace: The folder where outputs will be written.	Folder name	--

Table 3 - Borselli k Parameter by Watershed Location (Falinski, 2016)

Watershed Location	Borselli k Parameter
Windward part of the island of Hawaii	4
Leeward part of the island of Hawaii	2.5
Oahu	2.5
Maui	2
Lanai	2
Molokai	1.25
Kahoolawe	2.4
Kauai	1.6
Niihau	1.5

Table 4 - C Factor Values for Land Use/Land Cover (Falinski, 2016)

Land Use/Land Cover	**C Factor**	**Land Use/Land Cover**	**C Factor**
Evergreen	0.014[16]	Developed, Medium Intensity	0.01
Scrub Shrub	0.014[17]	Impervious Surface	0.001
Bare Land	0.7	Palustrine Scrub Shrub Wetland	0.003
Pasture/Hay	0.05	Palustrine Emergent Wetland	0.003
Grassland	0.05	Unconsolidated Shore	0.003
Open Water	0	Estuarine Forested Wetland	0.003
Cultivated Land	0.24[18]	Estuarine Scrub Shrub Wetland	0.003
Developed, Low Intensity	0.03	Estuarine Emergent Wetland	0.003
Palustrine Forested Wetland	0.003	Background	0
Open Space Developed	0.05	Palustrine Aquatic Bed	0

Table 5 - Terrain Factor by Geologic Origin (Falinski, 2016)

Hawaii		**Oahu, Kauai and Niihau**	
Geologic origin	**Terrain factor**	**Geologic origin**	**Terrain factor**
Hamakua Volcanics	1	Honolulu Volcanics	1
Hawi Volcanics	1	Kolekole Volcanics	1
Hilina Basalt	0.001	Koolau Basalt	1
Hualalai Volcanics	0.001	Waianae Volcanics	1
Kahuku Basalt	0.001	Kiekie Volcanics	1
Kau Basalt	0.001	Koloa Volcanics	1
Laupahoehoe Volcanics	0.1	Paniau Basalt	0.1
Ninole Basalt	1	Waimea Canyon	0.1
Pololu Volcanics	1	--	--
Puna Basalt	0.001	--	--

[16] Evergreen forest: 0.035 for Hamakua and Kohala volcanoes
[17] Scrub/shrub: 0.05 for leeward volcanic units
[18] Cultivated land: 0.4 for pineapple (Lanai) or 0.51 for sugarcane crop (central Maui)

Maui, Molokai, Lanai and Kahoolawe		**All Islands**	
Geologic Origin	**Terrain factor**	**Geologic origin**	**Terrain factor**
East Molokai Volcanics	1	Open water	1
Hana Volcanics	0.001	Fill	1
Honolua Volcanics	1	Alluvium	1
Honomanu Basalt	1	Landslide Deposits	1
Kalaupapa Volcanics	1	Slope Deposits	0.001
Kanapou Volcanics	1	Tephra Deposits	0.1
Kaupo Mud Flow	1	Beach Deposits	0.1
Kula Volcanics	0.01	Lagoon Deposits	1
Lahaina Volcanics	1	Older Dune Deposits	1
Lanai Basalt	1	Younger Dune Deposits	0.1
Wailuku Volcanics	1	Talus and Colluvium	0.1
West Molokai Volcanics	1	Marine Conglomerate and Breccia	0.1
--	--	Caldera Wall Rocks	0.001

The most relevant output is the "sed_export.tif', showing the sediment exported from every pixel. Because of the geology of Hawaii, data on the pixel level from this raster may be inaccurate. The model tends to predict higher sediment export from areas with steeper slopes. In Hawaii, high slopes occur in high elevation areas where the sediment supply may be naturally limited by the unique geology of Hawaii. Therefore, the model overestimates the amount of sediment export in the mountains because it assumes unlimited sediment supply in steep areas with thin or little soil. For this reason, the sediment export raster data should not be used as the sole or main method for determining where BMPs should be implemented within the watershed.

The sediment export raster can be combined with land use/land cover data to determine which land use classes are disproportionately contributing to sediment loading. The amount of sediment mass exported per acre for each land use can be calculated by adding up the value of every pixel in the sediment export raster in each land use and dividing that sum by the number of acres that the land use covers.

It is crucial that multiple lines of evidence are considered when determining where BMPs should be implemented. The normalized difference vegetation index (NDVI)[19] is a satellite-based measurement that could be useful in identifying areas with minimal vegetation which may be susceptible to increased erosion. The NDVI quantifies vegetative health and density. NDVI values closer to positive 1 indicate the presence of abundant and healthy vegetation, and a value closer to 0 indicates there is less vegetation (NASA, 2025). Looking at NDVI data in a raster format would allow a user to visualize areas within the watershed that have little vegetation or unhealthy vegetation, indicating that the area could benefit from BMP implementation. If the

[19] One potential source of NDVI data is NOAA's Suomi National Polar-orbiting Partnership (Suomi NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Vegetation Indices (VNP13A2) Version 2 data product which can be queried using the 'modisfast' R package.

resolution of the NDVI data is a lower resolution, it may be difficult to pinpoint areas where BMP implementation would be the most valuable. Therefore, further evidence should be used when selecting areas for BMP implementation. A high resolution and recent satellite image can supplement older land use/land cover data and lower resolution NDVI raster data. A satellite image can be used to more accurately identify areas with minimal vegetative cover which could benefit most from BMP implementation. Further useful evidence can be collected on-site in the watershed. If possible, a person can walk along streams in the watershed and identify locations in the watershed where BMP implementation would be the most advantageous, such as locations with invasive plant species, minimal vegetation and/or the presence of feral ungulates. Each of the options listed above is important evidence that should be considered when the user is deciding on locations for BMP implementation.

After determining where BMPs will be implemented, the next step is to re-run the model with inputs that account for the BMPs that would be implemented to determine how they would affect sediment loading. The model inputs for the revised run should remain almost entirely the same. A different directory should be entered into the Workspace field or the results from the last model run will be overwritten. Additionally, either the support practice factors in the biophysical table or the land use/cover raster should be edited:

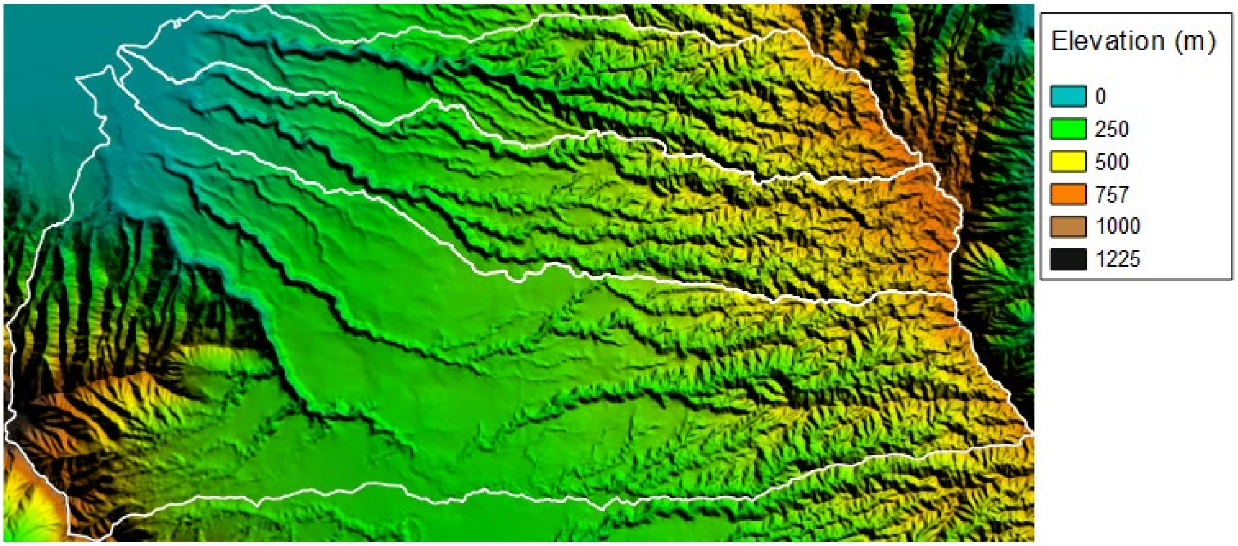
- The P factors in the biophysical table should be decreased for each land use/land cover type where an erosion reduction practice will be implemented.
- Alternatively, the land cover/land use raster should be edited to show how the land use/land cover would change with erosion reduction practices implemented. For example, bare land could be changed to a type of forest cover if a best management practice would be to plant native species on non-vegetated land.

To determine the effect that the implementation of best management practices would have on sediment exports, the outputs from both model runs can be compared. The sum across every pixel in "sed_export.tif" outputs illustrate how much sediment load reduction would occur with BMP implementation on the watershed level.

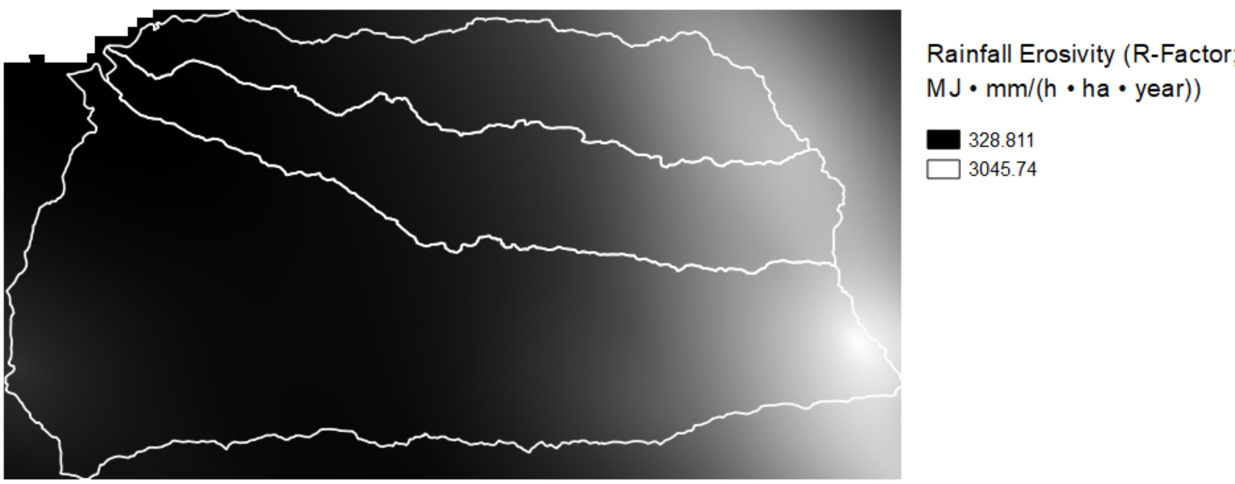
Example Use of the Procedure

To illustrate the Step-by-Step Procedure, this section looks at an example watershed: Kaiaka Bay. The Kaiaka Bay watershed is on the coast of the island of Oahu. The Kaiaka Bay and several streams that drain into the bay are listed as impaired. Both invasive plant species and feral ungulates are thought to cause high levels of erosion in this watershed, making the Kaiaka Bay watershed a good example watershed for the procedure (AECOM et al., 2018). The GIS data inputs for the InVEST model must all be in the same projected coordinate reference system, so every GIS data input is in the NAD83 coordinate reference system. The data inputs used for running the model with current conditions are below:

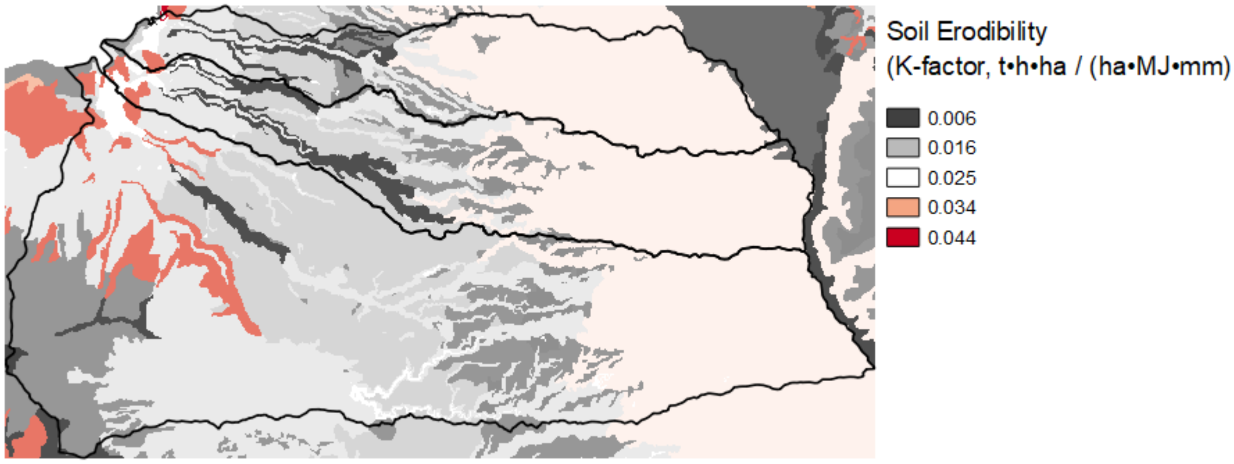
- Elevation Map: A DEM raster showing elevation in meters in the Kaiaka Bay and the surrounding area. This raster is a valid input for the InVEST model because the elevation is in meters and it extends beyond the Kaiaka Bay watershed boundary.



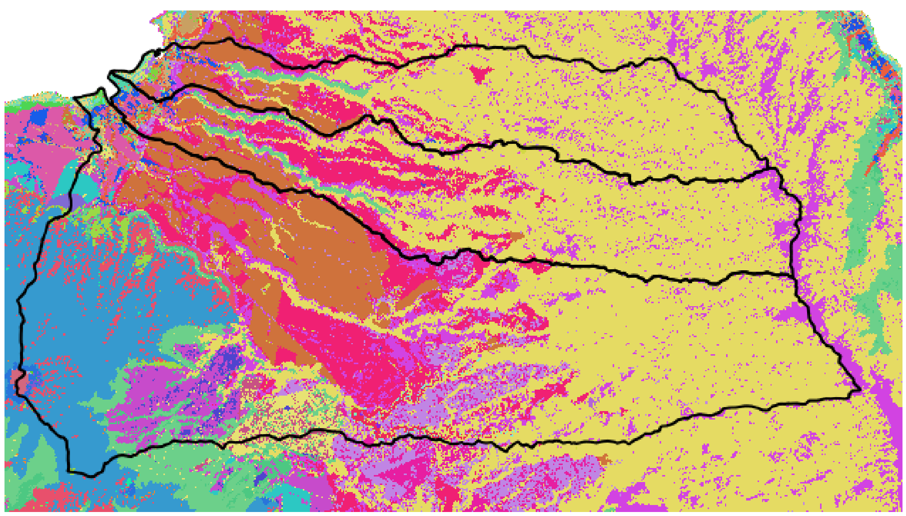
- Rainfall Erosivity: A rainfall erosivity map in raster format showing the rainfall erosivity throughout the Kaiaka Bay watershed in MJ • mm/(h • ha • year), the units required by the model.



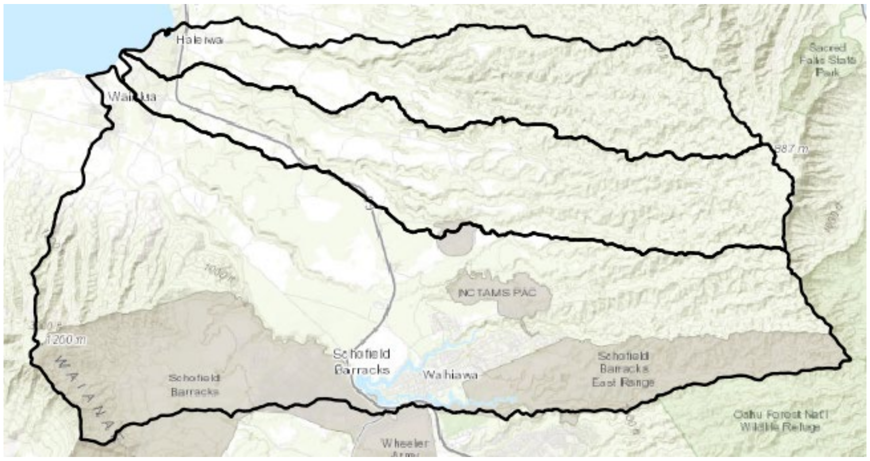
- Soil Erodibility: A map showing soil erodibility, or K factors, within the Kaiaka Bay watershed in raster format. The values in the raster format are in the proper units for the model, t • h • ha / (ha • MJ • mm).



- Land Use & Land Cover and Geologic Formation: A raster categorizing the land in Kaiaka Bay watershed by their land use/land cover and their geologic formation. This raster has over 1000 land cover/geologic formation categories, but not all categories have pixels that belong to them. Each land cover/geologic formation category has a unique LULC code so that this raster can be connected to the biophysical table.



- Watershed boundary: A vector outlining the Kaiaka Bay watershed.



- Threshold Flow Accumulation: 200. Value was derived through trial and error, and was identified when the delineated stream network approximately matched the "real" stream network for the watershed.

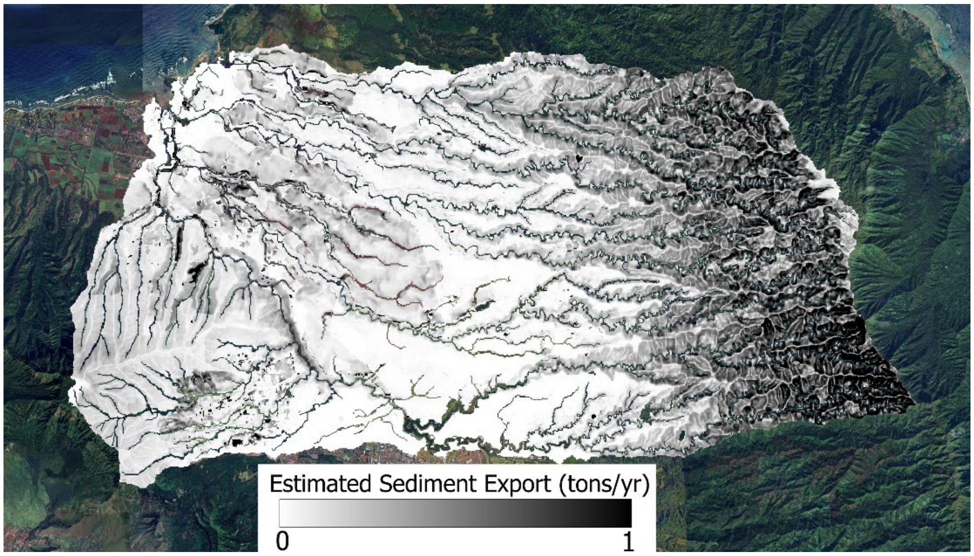
- Borselli k Parameter: The Borselli k parameter for this model run is 2.5, the value for all watersheds on Oahu.

- Maximum SDR Value: The maximum SDR value for this model run is 0.5, the value for all watersheds on the state of Hawaii.

- Maximum L Value: The maximum L value for this model run is 122, the value for all watersheds on the state of Hawaii.

- Biophysical Table: The biophysical table for this model run contains a column with each LULC code from the land use and land cover raster. Each LULC code is mapped to a modified C factor that is the original C factor from Table 4 multiplied by the terrain factor from Table 5 or the geologic origin associated with the LULC code. For example, a small piece of land in the Kaiaka Bay watershed is scrub shrub land (C factor = 0.014) with beach deposits as its geologic formation (terrain factor = 0.1), so the modified C factor in the biophysical table is 0.0014. The P factor for every LULC code is 1 because no support practices have been implemented in this watershed.

Once the inputs have been gathered, the baseline scenario is run. The model outputs suggest that a disproportionate amount of sediment export is occurring in the mountainous area of the Kaiaka Bay watershed. The sediment export raster is shown below:



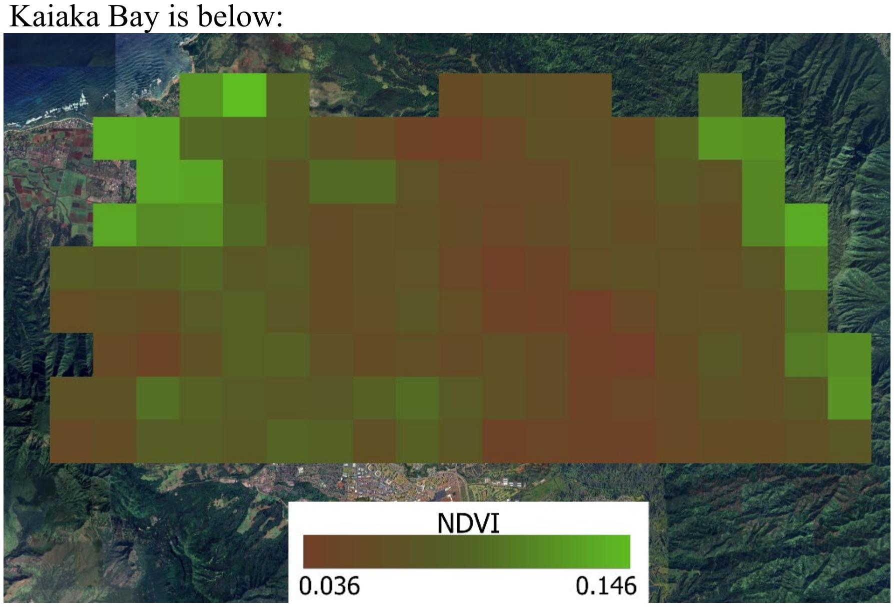
This raster indicates that the model expects the highest amount of sediment export to occur at the higher elevations of the watershed, but as discussed in the Step-by-Step Procedure section, the InVEST model tends to overestimate sediment export in high elevation areas. For this reason, multiple lines of evidence are considered when deciding on the locations for BMP implementation in this example. To determine the land class/land uses that contribute the most to sediment export relative to their area in the watershed, the pounds of sediment exported per acre is important evidence to evaluate as well. This value is calculated by adding the sediment export for every pixel in each land use/land cover and then dividing this sum by the acres each land use covers in the watershed. For example, bare land covers 405 acres of land in the Kaiaka Bay watershed and the model estimates that 1790.5 pounds of sediment are exported from bare land each year, so the pounds of sediment load per acre per year for bare land is 1790.5 divided by 405 which is 4.42. The sediment load per acre for each land use is shown in Table 6.

Table 6 - Pounds of Sediment Load Per Acre Per Year by Land Use

Class	Edge of Stream Sediment Load (lbs/acre/year)
Developed, High Intensity	0.00
Developed, Med Intensity	0.00
Developed, Low Intensity	0.00
Developed, Open Space	0.11
Cultivated Crops	1.08
Pasture/Hay	0.26
Grassland/Herbaceous	0.44
Evergreen Forest	1.37
Scrub/Shrub	0.90
Palustrine Emergent Wetland	0.01
Palustrine Forested Wetland	0.01
Palustrine Scrub/Shrub Wetland	0.01
Estuarine Forested Wetland	0.03

Class	Edge of Stream Sediment Load (lbs/acre/year)
Estuarine Scrub/Shrub Wetland	0.23
Unconsolidated Shore	0.00
Bare Land	4.42
Open Water	0

This table indicates that bare land areas contribute the most sediment per acre in the Kaiaka Bay watershed, so bare land within the watershed may be a beneficial target for BMP implementation. Planting native plant species could minimize the sediment load coming from areas that are currently bare land by transforming it into vegetative cover (or evergreen forest in terms of land cover classes). Currently, bare land covers 405 acres of the watershed and the sediment export from this land is 1790.5 pounds. To calculate the amount of sediment load from this land after BMP implementation, assuming all the bare land becomes evergreen forest, the acres of bare land should be multiplied by the sediment load per acre for evergreen forest. This returns a value of 554.85 pounds of sediment load per year from this land, a 1235.65 pound decrease. These calculations should be considered when selecting locations for BMP implementation, but additional evidence should be evaluated as well. As discussed in the Step-by-Step Procedure section, NDVI data can be useful evidence as well. The NDVI data in raster format for the Kaiaka Bay is below:



The pixels with a lower NDVI index, which are shown in darker brown, are less vegetated areas. This image indicates that the middle section of the Kaiaka Bay watershed is less vegetated, so BMP implementation could be especially valuable in this area. However, the resolution of this raster data is low, so it is difficult to use it to precisely choose locations for BMP implementation. Therefore, other evidence such as high-resolution satellite images and drone footage can be used to pinpoint areas with minimal or invasive vegetation. As an additional line of evidence, people familiar with the Kaiaka Bay watershed can be interviewed to collect information on areas with minimal vegetation, invasive plants and/or feral ungulates. Furthermore, a person can walk along streams in the Kaiaka Bay watershed and document the most eroded areas. The information gathered from the InVEST model run, the NDVI index raster, satellite images, drone footage, interviews and documentation from someone on site should all be carefully considered when determining where BMPs should be implemented.

Useful Resources and Materials

To supplement the information included in this addendum, more information on the InVEST model and using this model in the state of Hawaii is linked below:

- More information on the InVEST sediment ratio delivery model including background information, required data inputs, and guidance on interpreting outputs is here: SDR: Sediment Delivery Ratio — InVEST® documentation
- More information on the InVEST DelineateIt tool discussed in the Step-by-Step Procedure to create watershed boundaries: DelineateIt — InVEST® documentation
- Further details on the Kaiaka Bay watershed: Kaiaka Bay Watersheds Characterization
- For more information on running the InVEST model for watersheds in Hawaii, including the rationale for many of the non-GIS inputs see Predicting Sediment Export into Tropical Coastal Ecosystems to Support Ridge to Reef Management [dissertation], available for download here: (PDF) PREDICTING SEDIMENT EXPORT INTO TROPICAL COASTAL ECOSYSTEMS TO SUPPORT RIDGE TO REEF MANAGEMENT

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United States Geological Survey (USGS). 2025. 1/3rd arc-second Digital Elevation Models (DEMs) - USGS National Map 3DEP Downloadable Data Collection. https://data.usgs.gov/datacatalog/data/USGS:3a81321b-c153-416f-98b7-cc8e5f0e17c3