MAUNA KEA WATERSHED MANAGEMENT PLAN

Prepared for the

Mauna Kea Watershed Alliance

by

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15 April 2010

Mauna Kea Watershed Management Plan

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4WD	four-wheel drive vehicle
ac.	acre
ALISH	Agricultural Lands of Importance to the State of Hawai‘i
ASEA	Aquifer Sector Areas
ASYA	Aquifer System Areas
ATV	all-terrain vehicle
BIISC	Big Island Invasive Species Council
BLNR	Board of Land and Natural Resources
BMP	best management practice
CCC	Civilian Conservation Corps
CCP	Comprehensive Conservation Plan (for Hakalau Forest NWR)
cm.	centimeters
CDUA	Conservation District Use Application
CMP	Comprehensive Management Plan (for Mauna Kea)
CREP	Hawai‘i Conservation Reserve Enhancement Program
CRP	NRCS Conservation Reserve Program
CTAHR	UH College of Tropical Agriculture and Human Resources
CWA	Federal Clean Water Act
CWRM	Hawai‘i Commission on Water Resource Management
DAR	DLNR’s Division of Aquatic Resources
DHHL	Department of Hawaiian Homelands
DLNR	Hawai‘i Department of Land and Natural Resources
DOA	Hawai‘i Department of Agriculture
DOCARE	DLNR’s Division of Conservation and Resource Enforcement
DOFAW	DLNR’s Division of Forestry and Wildlife
DOH	Hawai‘i Department of Health
DOT	Hawai‘i Department of Transportation
DWS	Hawai‘i County Department of Water Supply
EPA	U.S. Environmental Protection Agency
EQIP	NRCS Environmental Quality Incentives Program
FLEP	Forest Land Enhancement Program
FSP	Hawai‘i Forest Stewardship Program
ft.	feet

GMA	Game Management Area
GRP	NRCS Grassland Reserve Program
HAR	Hawai‘i Administrative Rules
HCC	Hawai‘i County Code
HCFD	Hawai‘i County Fire Department
HCP	Habitat Conservation Plan
HCPD	Hawai‘i County Police Department
HELCO	Hawai‘i Electric Light Company
HETF	Hawai‘i Experimental Tropical Forest
HFRP	NRCS Healthy Forests Reserve Program
HI-GAP	Hawai‘i Gap Analysis Program
HRS	Hawai‘i Revised Statutes
IAL	important agricultural lands
IFS	instream flow standards (established by CWRM)
INRMP	Integrated Natural Resources Management Plan (for PTA)
KBC	Kanakaleonui Bird Corridor
KS	Kamehameha Schools
LIP	Landowner Incentive Program
LSB	Land Study Bureau Classification
LUC	Hawai‘i Land Use Commission
LUPAG	Land Use Pattern Allocation Guide (for Hawaii County)
MGD	million gallons per day
MKSR	Mauna Kea Science Reserve
MKSS	Mauna Kea Observatories Support Services
MKWA	Mauna Kea Watershed Alliance
MOU	Memorandum of Understanding
NAPP	Hawai‘i Natural Areas Partnership Program
NAR	Natural Area Reserve
NEON	National Ecological Observatory Network (USFS)
NRCS	USDA Natural Resources Conservation Service
NWR	USFWS National Wildlife Refuge
OMKM	University of Hawai‘i Office of Mauna Kea Management
PTA	U.S. Army’s Pōhakuloa Training Area
RAWS	remote automated weather stations
SHPD	DLNR’s State Historic Preservation Division

T&E	threatened and endangered (plants or animals)
TMDL	Total Maximum Daily Load (of pollutants)
TNC	The Nature Conservancy
TSS	total suspended solids
UH	University of Hawai‘i
USDA	U.S. Department of Agriculture
USDOT	U.S. Department of Transportation
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
VIS	Visitor Information Station (on Mauna Kea)
WHIP	NRCS Wildlife Habitat Incentives Program
WRP	NRCS Wetland Reserve Program

Mauna Kea Watershed Management Plan

EXECUTIVE SUMMARY

Mauna Kea, Hawai‘i Island’s tallest mountain, is rich in biological and watershed resources, holds deep cultural significance to Hawaii’s people, and has experienced land modifications that are representative of Hawai‘i’s history and evolving economy. Mauna Kea provides the primary water source for Big Island residents, and its forests are home to rare and increasingly threatened native species and ecosystems. The area is also the food and fiber basket of Hawai‘i Island, making it essential to the island’s water, food, and fiber security. Mauna Kea is also a focal point of Native Hawaiian culture and spirituality. The perpetuation of this area’s richness depends on its users, owners, and managers serving as stewards to protect its unique resources for current and future generations.

As described in Chapter 1, the Mauna Kea Watershed Alliance brings together major landowners on Mauna Kea around a shared interest to protect the ‘āina by working together to manage threats that occur across common land ownership boundaries, pooling limited resources to achieve conservation goals, and promoting collaboration in protecting vital resources across large landscapes.

The vision of the Mauna Kea Watershed Alliance (MKWA) is to protect and enhance watershed ecosystems, biodiversity and resources through responsible management, while promoting economic sustainability and providing recreational, subsistence, educational and research opportunities. This management plan describes Mauna Kea’s watershed resources and associated values, identifies the threats to those resources, and directs the activities of the MKWA toward their protection. This document establishes management goals and objectives, and recommends specific actions to implement these goals and objectives, to the benefit of Mauna Kea’s unique watershed resources. The area addressed by this plan encompasses over 525,000 acres of land.

Chapter 2 of the management plan describes the resources, uses, and current conditions of the MKWA area, including physical characteristics, hydrology and water use, biological resources, and socio-cultural resources. There are 85 perennial streams originating from the slopes of Mauna Kea, and the area captures significant groundwater resources on Hawai‘i Island. The MKWA area is rich in biological resources, unique ecosystems, and rare and endangered plant and animal species. The area provides habitat for almost two dozen threatened and endangered plant species, 14 native birds, Hawaii’s only land mammal – the Hawaiian hoary bat - and various native invertebrates that fill a wide variety of ecological roles. The streams on Mauna Kea harbor native aquatic insects, fishes, crustaceans, and mollusks.

The MKWA area is also rich in cultural history. Lower elevation lands were cleared historically by Native Hawaiians for agriculture and settlement, using advanced systems of irrigation ditches. Access to mauka regions and resources was limited and reserved for significant purposes only. The introduction of cattle and other ungulates to the

Hawaiian Islands in the late 1700s changed the natural landscape, and many areas of Mauna Kea were converted to ranching. A sugar industry began to develop on the Hāmākua coast in the 1800s, and logging became a commercial industry at about the same time. In the mid-1900s, the military established a presence in the MKWA area with the establishment of the Pōhakuloa Training Area. More recently, the summit of Mauna Kea has become an important site for astronomical observations. Mauna Kea was crisscrossed historically by numerous trails linking the east and west sides of Hawai'i Island. Hawai'i's people still access places on Mauna Kea. Public lands on Mauna Kea are commonly used for hunting, hiking, horseback riding, bird watching, botanical exploration, mountain biking, collecting and gathering of fruit, greenery and other plant parts, camping, motorcycle and ATV riding, sunset viewing, and snow play.

Chapter 3 of the management plan explains the threats to Mauna Kea's watershed resources. Today, the primary threats are from alien plants and animals and their effects, and other factors such as wildfire and climate change. Human activities in the MKWA area, most of which are done with good intentions, can also have a negative impact on the watershed. Chapter 4 describes the many existing management authorities and efforts within the Mauna Kea Watershed Alliance area by State and Federal agencies, private landowners, and even the non-profit sector. The chapter also provides information on a number of programs at the Federal and State level that provide financial incentives to landowners for the implementation of conservation practices in order to protect forest, wildlife and watershed resources. These are particularly applicable to the sustainable use of agricultural and forested lands in the MKWA area.

Chapter 5 outlines a management program to protect, conserve and sustainably use the resources of the Mauna Kea watershed. To achieve the MKWA's stated vision, this chapter identifies GOALS related to the protection of water resources, watershed functions, and native species' biodiversity; management of threats to these resources; and economic sustainability. Recognizing that a management program cannot be effectively implemented without sufficient infrastructure and personnel, recommendations addressing the administration of the program are incorporated. Finally, the chapter addresses compatible public use of the watershed.

OBJECTIVES and recommended ACTIONS to implement the ten management GOALS identified by the MKWA members are also described in this chapter. Under each management GOAL, there is one or more related OBJECTIVES. Each objective identifies management ACTIONS to achieve the OBJECTIVE. Some recommended ACTIONS are general, while others are specific because they have been approved by the implementing entity. For specific actions, the implementing entity is noted.

The management program outlined here was developed in a series of planning meetings held by the Mauna Kea Watershed Alliance, drawing from previous information and planning efforts, and with input from land owners and resource managers. It reflects the ideas and watershed management goals of the MKWA. Recommended actions have not been finalized or prioritized at this time. The MKWA

believes it is important to get further input on the plan before the management program is finalized.

The proposed management goals and objectives are delineated below.

Management Goal 1: Protect ground and surface water resources.

Objective 1A: Protect, enhance, and monitor high-yield watershed areas to maintain water quantity and quality.

Objective 1B: Support appropriate water development to meet the needs of future water demand.

Management Goal 2: Protect and enhance native terrestrial and aquatic ecosystems and their biodiversity and species.

Objective 2A: Maintain and/or restore native forest cover.

Objective 2B: Protect and recover rare species.

Objective 2C: Protect and enhance riparian buffers to protect stream corridors.

Management Goal 3: Manage non-native plant and animal species within appropriate areas to reduce the impacts to native ecosystems and species.

Objective 3A: Strategically manage feral ungulate damage in high priority native ecosystems and watersheds while providing for increased hunting opportunities in designated areas.

Objective 3B: Strategically manage other pest species that threaten native ecosystems.

Objective 3C: Strategically control invasive plants to protect high quality native ecosystems and endangered species.

Objective 3D: Control priority invasive aquatic species in windward streams on Mauna Kea.

Management Goal 4: Prevent and minimize wildfires on Mauna Kea.

Objective 4A: Install on-the-ground fuel management measures intended to reduce the number and/or severity of fires.

Objective 4B: Reduce fuel loads in fire-prone areas, ensuring compatibility with other habitat and watershed protection goals.

Objective 4C: Develop water sources for fire-fighting purposes in fire-prone areas.

Objective 4D: Coordinate pre-suppression planning and fire response protocols among landowners.

Objective 4E: Promote effective communication and public safety during extreme fire weather and during fire-response events.

Objective 4F: Manage access to fire-prone areas during extreme fire danger weather.

Objective 4G: Promote post-fire assessment and restoration of burned areas.

Management Goal 5: Promote and encourage economic sustainability in balance with habitat and watershed protection goals.

Objective 5A: Encourage permitted ecotourism, well-managed wilderness experiences, and other forms of managed access, as appropriate and permissible, on public and private lands.

Objective 5B: Manage future development to ensure it will not have a detrimental impact on the ecosystems of Mauna Kea.

Objective 5C: Support sustainable uses of the land in balance with habitat and watershed protection goals.

Management Goal 6: Manage human activities in the watershed to promote recreational and subsistence opportunities that are compatible with habitat and watershed protection goals.

Objective 6A: Create and encourage safe and appropriate patterns of access for hiking and recreation on public lands.

Objective 6B: Continue support of hunting on appropriate lands, where compatible with watershed protection goals and applicable laws.

Objective 6C: Maintain and secure Keanakolu-Mānā Road and Mauna Kea Summit Access Road to facilitate managed access.

Management Goal 7: Protect the cultural landscape and historical resources of Mauna Kea.

Objective 7A: Ensure that archaeological and other cultural sites within the MKWA area are identified and protected.

Objective 7B: Provide opportunities for cultural practices that are compatible with habitat and watershed protection goals.

Objective 7C: Promote awareness of Mauna Kea as an important cultural resource.

Management Goal 8: Enhance community awareness and support of watershed values, resources, and management activities on Mauna Kea.

Objective 8A: Develop and implement education and outreach programs for community members, landowners, and other stakeholders.

Objective 8B: Provide on-the-ground service learning opportunities for school children and community members.

Management Goal 9: Promote and facilitate research opportunities that will enhance the management of Mauna Kea's resources.

Objective 9A: Monitor long-term trends in watershed health and water quality.

Objective 9B: Assess the success of management actions to accomplish habitat and watershed management goals and provide direction for future actions.

Objective 9C: Support research to help guide new and innovative uses of the land that will sustain economic activities while protecting habitat and watershed values.

Management Goal 10: Provide effective administrative coordination, infrastructure, and enforcement.

Objective 10A: Promote and support the enforcement of existing laws and rules to ensure public safety and prevent unregulated and illegal land and resource uses.

Objective 10B: Provide and maintain the appropriate infrastructure and administration to allow for effective watershed management and coordination of activities between Mauna Kea Watershed Alliance members.

Chapter 6 is the bibliography. Appendices make up the last part of the management plan. Appendix A is a copy of the MOU for the Mauna Kea Watershed Alliance.

Mauna Kea Watershed Management Plan

CHAPTER 1: INTRODUCTION

In 1991, public and private landowners on the island of Maui organized Hawai‘i’s first watershed partnership to address shared management concerns about the future of the East Maui forests that supply most of the island’s fresh water. The watershed partnership model launched on Maui quickly spread throughout the State. In 2000, the growing movement received a boost when the Hawai‘i Legislature approved the use of year-to-year state funds for “projects undertaken in accordance with watershed management plans negotiated with private landowners.” Nine watershed partnerships or alliances have been formed on six islands, covering over 1.6 million acres of land in the State. These alliances involve over 45 private landowners and 24 public agencies.

In 2008, the Department of Land and Natural Resources (DLNR) began contemplating a watershed alliance for Mauna Kea on Hawai‘i Island. It drafted a *Mauna Kea Watershed Partnership Scoping Study* to assess the feasibility of forming a Mauna Kea Watershed Alliance, focusing on the area from Hilo to just south of Waipi‘o Valley, which is the boundary of the Kohala Watershed Partnership. Through resource analysis, interviews with owners and managers, and discussions with community stakeholders, the study concluded that there was sufficient confluence of interest, need, and opportunity to merit establishment of an alliance for Mauna Kea. Mauna Kea provides the primary water source for Big Island residents and its forests are home to rare and increasingly threatened native species and ecosystems. The area encompasses numerous aquifer systems defined by the Hawai‘i Commission on Water Resource Management. The area is also the food and fiber basket of the Big Island, making it essential to the island’s water, food, and fiber security. The study identified key threats to these important resources, including invasive species, feral ungulates, wildlife, aquatic pollutants, and human activities.

The study recommended establishing a watershed alliance for Mauna Kea, focusing on large landowners (> 1,000 acres) above the 2,000-ft. elevation. This boundary encompasses over 500,000 acres on Mauna Kea and abuts the Three Mountain Alliance to the south and the Kohala Mountain Watershed Partnership to the north. A Memorandum of Understanding (MOU) has been drafted for the Mauna Kea Watershed Alliance (See Appendix A), and it is being signed by interested landowners.

The MOU for the newly-formed Mauna Kea Watershed Alliance (MKWA) calls on members to:

- Identify important watershed areas that would benefit from coordinated management;
- Develop plans to document resources, identify priority management objectives/ strategies;
- Meet to determine programs and projects;

- Obtain funds for projects to the extent that each member agrees;
- Develop specific agreements and plans for projects involving all or some members;
- Enter into agreements to hire personnel, use equipment, and purchase supplies;
- Employ a consensus-based approach to decision-making; and
- Allow additional members by amendment, by consensus of current members.

Members also agree that the MOU does not obligate resources, lands, or funds nor does it create a legal partnership or modify the existing authority of any governmental agency.

By bringing public and private landowners together around a shared interest, such as watershed protection, this alliance enables landowners to work together to manage threats that occur across common land ownership boundaries, pool limited resources to achieve conservation goals, and promote collaboration in protecting vital resources across large landscapes.

This management plan describes Mauna Kea's watershed resources and associated values, identifies the threats to those resources, and directs the activities of the MKWA toward their protection. This document establishes management goals and objectives, and recommends specific actions to implement these goals and objectives, to the benefit of Mauna Kea's unique watershed resources.

CHAPTER 2: DESCRIPTION AND RESOURCES OF MAUNA KEA WATERSHED

A. Biophysical Resources

1. Area, Location, Climate, Geology, Soil Types

The Mauna Kea Watershed Alliance (MKWA) area encompasses over 525,000 acres (820 square miles) above the 2,000-ft. elevation contour on the slopes of Mauna Kea, Hawai'i Island's tallest mountain (Figure 1). This massive mountain, which reaches a height of 13,796 ft. (4,205 meters) is estimated to be between 600,000 and 1.5 million years old (Moore and Clague 1992; DePaolo and Stolper 1996; Wolfe *et al.* 1997; Sharp and Renne 2005). It is considered an active post-shield volcano (Macdonald *et al.* 1983). Mauna Kea last erupted within the past 5,000 years and is considered dormant, not extinct. Mauna Kea's geology is comprised mostly of lava from the Hāmākua and Laupāhoehoe Series. A layer of Pāhala ash covers portions of the lower slopes (Macdonald *et al.* 1983).

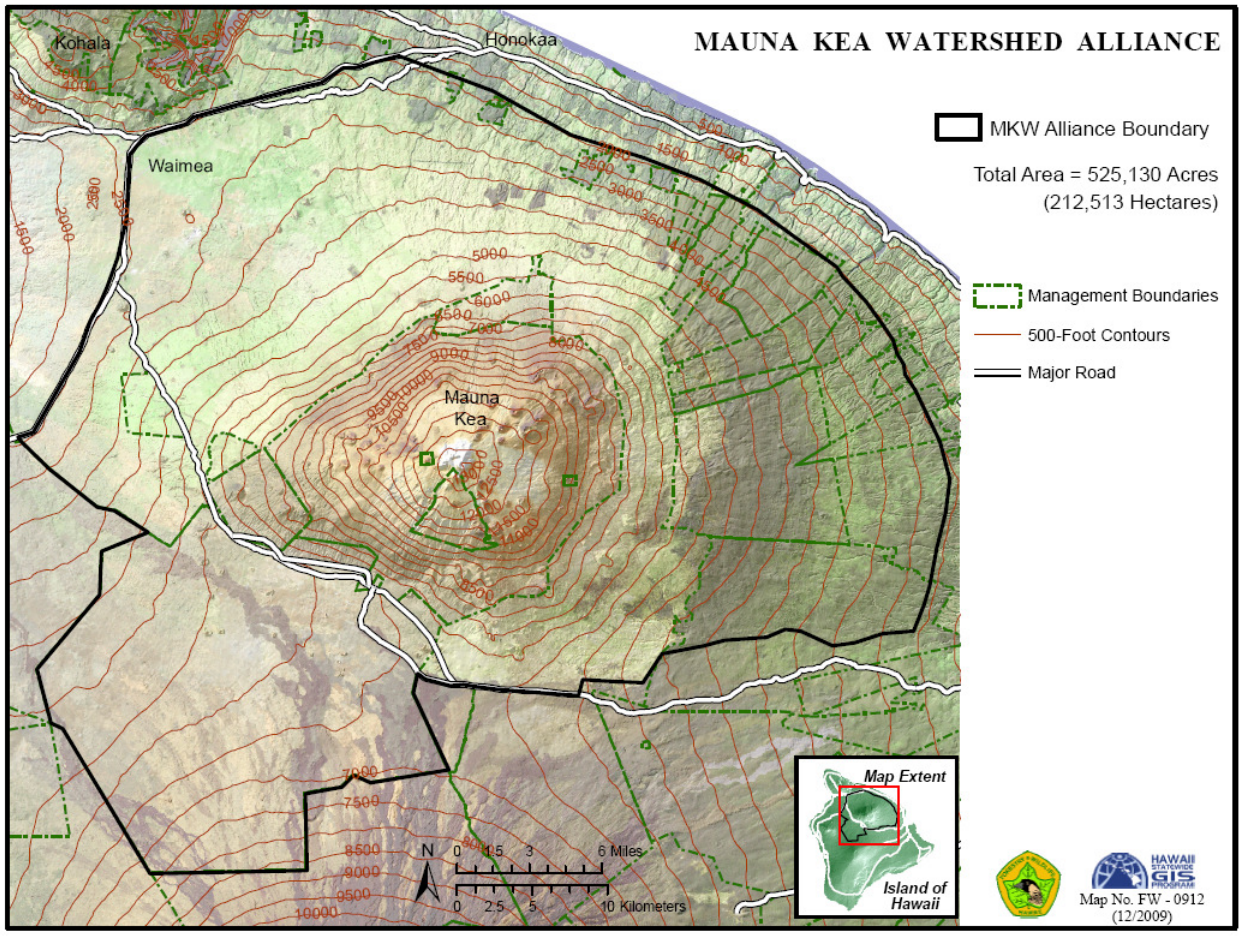


Figure 1: Mauna Kea Watershed Alliance area [new boundary? Revised map?]

With elevations ranging from 2,000 to 13,796 feet about sea level, low temperatures can drop below freezing, with snow and frost occurring primarily during the winter months.

In some years, the snow will persist through the summer. Rainfall varies considerably over the area, determined in part by the orographic effect (Cuddihy 1989; DWS 2006; Giambelluca and Sanderson 1993; daSilva 2006; Juvik and Juvik 1998) (Figure 2). The windward slopes of the mountain intercept the moist air, and water precipitates out as rainfall or fog drip. On the windward side of Mauna Kea, the coastal areas can experience 100-150 inches of rain per year, while the forested band in the 2,000-5,000-ft. elevation range receives up to 300 inches annually. Rainfall on the leeward side, which is in the "rain shadow," ranges from 9 inches at the coast to nearly 50 inches, while annual rainfall in the saddle between Mauna Kea and Mauna Loa is approximately 45 inches, but can be as little as 10 inches. A temperature inversion layer and high evaporation rates in the upper elevations (above 7,000 ft.) create extremely dry conditions most of the year (daSilva 2006). Rainfall at the summit averages 20 inches per year.

Any changes in rainfall patterns or frequency and duration of droughts can have a significant impact on Hawaii's water resources. Oki (2004) noted a downward trend in annual rainfall across much of the state between 1913 and 2002, with an associated reduction in stream base flows. At the same time, there have been more frequent droughts, leading to crop damage, cattle losses, and wildfires, particularly in leeward locations. Most severe drought events in the past 15 years have been associated with the El Nino weather phenomenon.

During the Pleistocene era, an ice cap existed atop Mauna Kea. In fact, studies have shown the existence of deposits from four distinct episodes of glaciation during the past 300,000 years (Macdonald *et al.* 1983; Sherrod *et al.* 2007). Some of the distinctive features on Mauna Kea are a result of the erosional and depositional characteristics of glaciers, including the present gorge of Pōhakuloa Stream and the head of Waikahalulu Gulch formed by glacier meltwater.

Because the amount of rainfall varies from one side of Mauna Kea to the other, the sides have not advanced through the erosional cycle at the same rate. The drier leeward slope has experienced little erosion, with poorly-defined stream channels and intermittent stream flow. In contrast, the windward slope, exposed to regular tradewind showers, has many deep gulches and perennial streams, where the erosive action is slowly extending the gulches headward (MacDonald *et al.* 1983).

There are twenty-eight soil series represented in the MKWA area, with additional non-soil geologies such as lava flows (aʻa and pāhoehoe), rock land, rough broken land, very stony land, and cinder land making up the remaining areas (Figure 3). The twenty-eight soil series can be further delineated by rainfall, soil depth, and slope conditions.

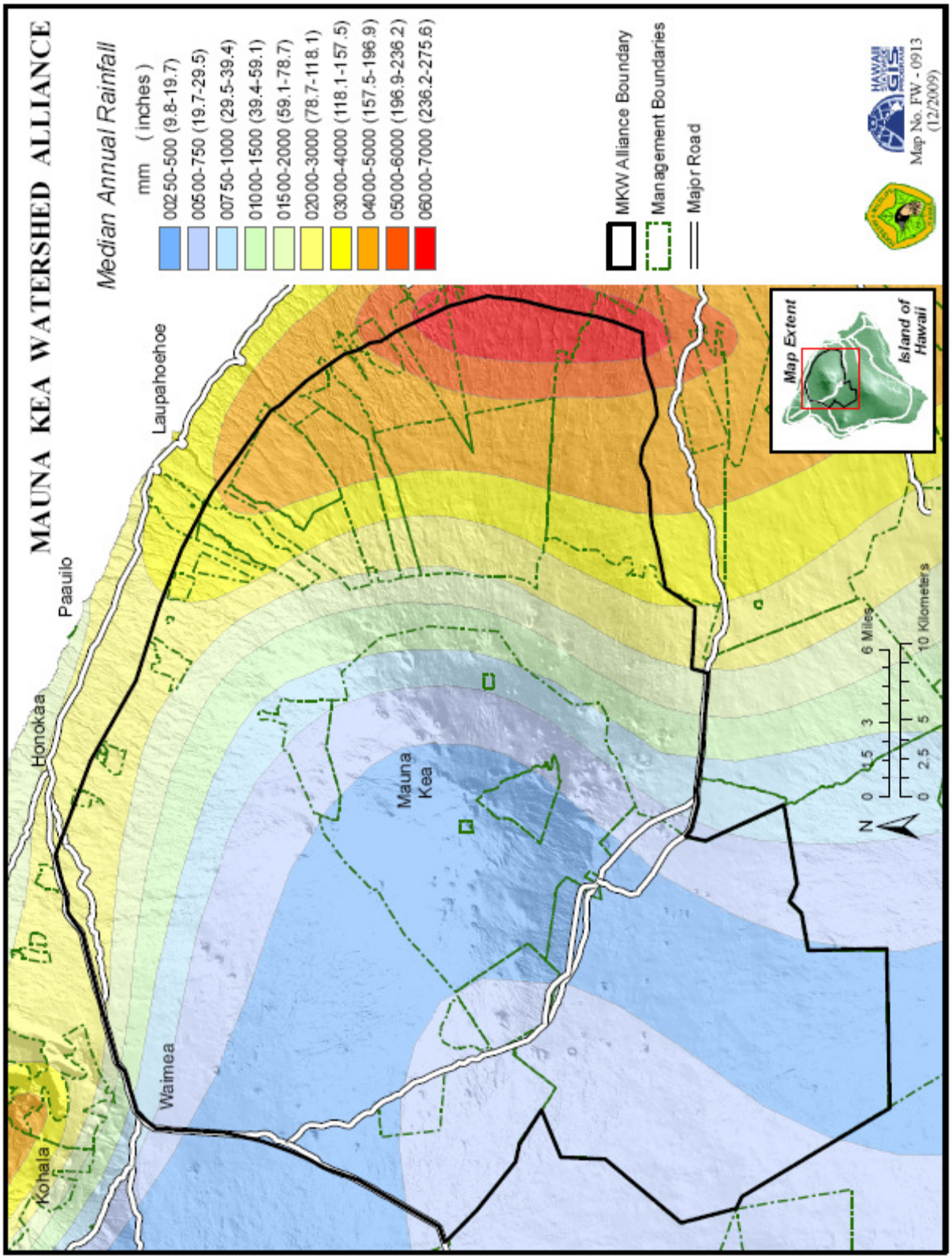


Figure 2: Annual Rainfall [new map?]

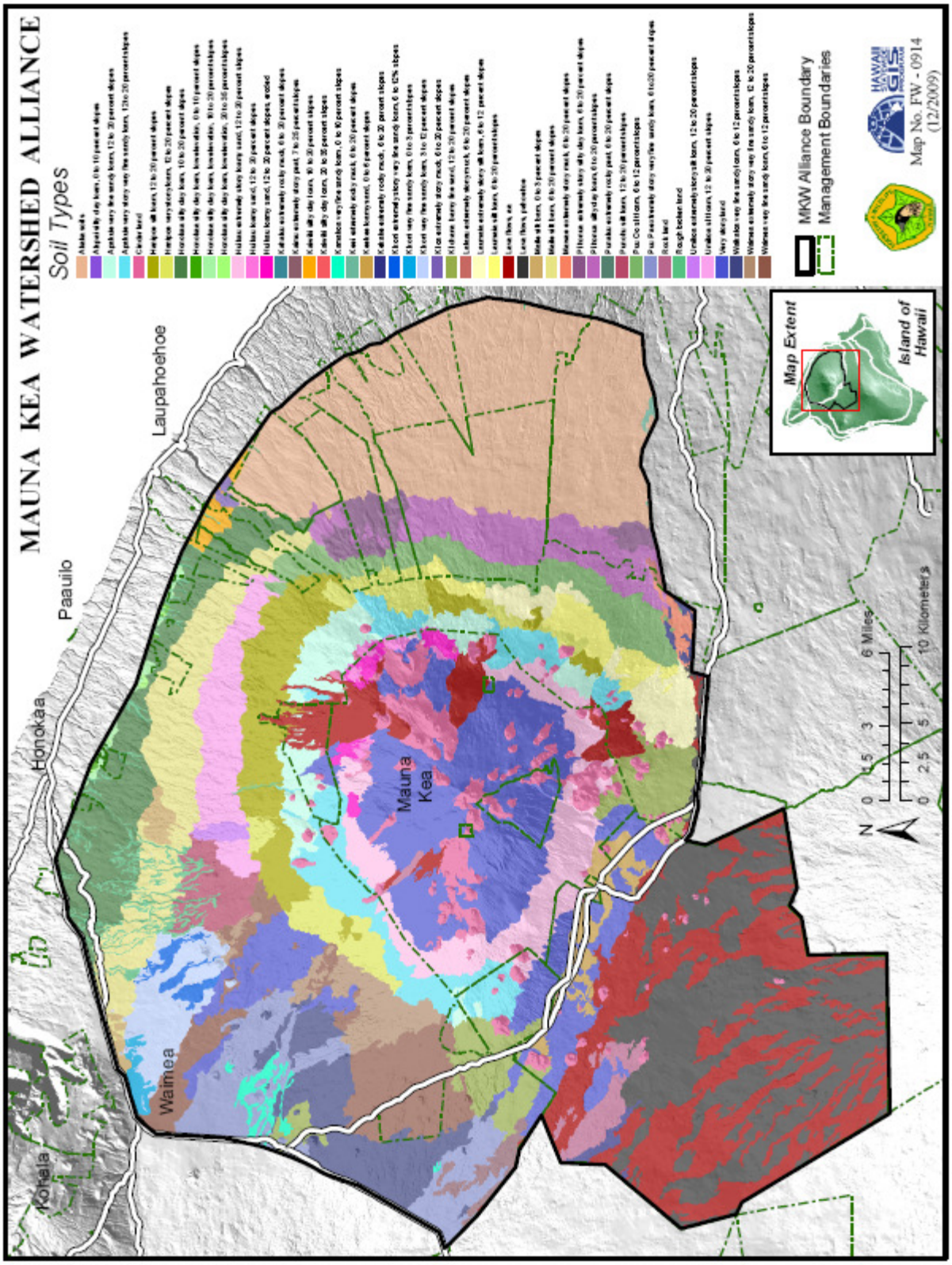


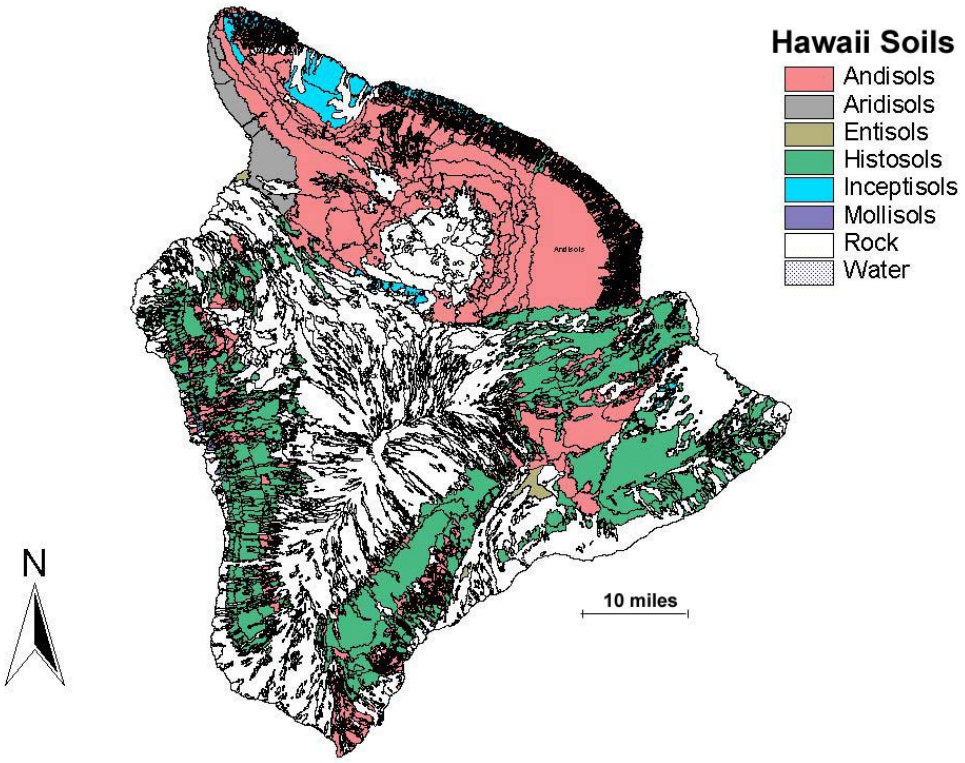
Figure 3: Soil Types on Mauna Kea [new map?]

The following table categorizes each of the twenty-eight soil series into its corresponding soil order (Table 1). While ten of the twelve global soil orders exist in the State of Hawai‘i, four of those are represented in the MKWA area. Of the four, andisols and histosols make up the majority of the area, with finite patches of entisols and inceptisols (Figure 4).

Table 1: Soils Categorized by Soil Order

Soils within MKWA area	Soil Order
Akaka, Alapai, Apakuie, Hanipoe, Honokaa, Huikau, Kaiwiki, Kikoni, Kilohana, Laumaia, Maile, Piihonua, Punohu, Puu Oo, Puu Pa, Umikoa, Waikoloa, Waimea	Andisol
Kahaluu, Kaimu, Keei, Kekake, Kiloa, Lalaau, Mawae, Punaluu	Histosol
Kamakoa	Entisol
Keekee	Inceptisol

Figure 4: Map of Hawai‘i Soils Classified by Soil Order (University of Hawai‘i 2010)



Andisols make up the majority of soil types in the MKWA area. The andisols are soils developing in parent material containing at least fifty percent volcanic ash or volcanic ejecta. They occur near individual volcanoes, such as Mauna Kea, that are created from andesite-rich magma. Andisols are dominated by short-range-order minerals. They include a range of weakly weathered and strongly weathered soils with much volcanic glass (NRCS 2010). Andisols have unique chemical and physical properties that include high water- and nutrient-holding capacity. They are considered fertile soils, with physical properties that favor the growth of most plants (NRCS 1999).

Histosols make up the second highest number of soil types in the MKWA area. These soils are comprised mainly of organic materials. Histosols form in areas with high rainfall or water input, such as wetlands, where drainage is restricted. As a result, decomposition of plant and animal remains is inhibited. This causes organic materials to build up over time, further restricting drainage. These organic soils hold water exceptionally well. Histosols are often referred to as peat or muck. They contain 20-30% organic matter by weight (by definition, 40 cm of organic soil material is in the upper 80 cm), and have low bulk densities (Univ. of Idaho 2010).

Inceptisols and entisols occur in small portions of the MKWA area, and are both very young, undeveloped soil types. They are juvenile soils that have not acquired the distinct features of mature soils. Entisols show little or no structure or soil horizon development, display a marked absence of organization of soil materials, and are virtually unaltered from their parent material, which can be unconsolidated sediment or rock (Univ. of Hawaiʻi 2010). Inceptisols exhibit only moderate degrees of soil weathering or development because of constant surface exposure or location in poorly drained areas.

2. Hydrology and Water Resources

Primary water inputs to Mauna Kea's ground and surface water resources are rainfall, snow, and fog drip. Fog drip is the direct interception of water by vegetation from clouds or fog. This is "likely an important contribution to the hydrologic budget in Hawaiʻi's forested areas frequently enveloped in clouds. This is especially true when there is little or no precipitation occurring" (CWRM 2008: 4-70). There have been few studies, due to the difficulty of monitoring, to quantify the contribution of fog drip to the overall water budget.

2A. Flowing Surface Water Resources

A watershed is the land area that drains surface water to a stream, river, lake or ocean. These drainage areas are normally confined by topographic divides, such as ridgelines. Drainage basins in Hawaiʻi are typically small, primarily because the distance from the headwaters to the stream mouth is short and the adjacent streams are closely spaced. This is noticeably the case on windward Mauna Kea (Figure 5). While drainage basins on the leeward size are generally larger, average annual streamflow is much less, because of the drier weather conditions.

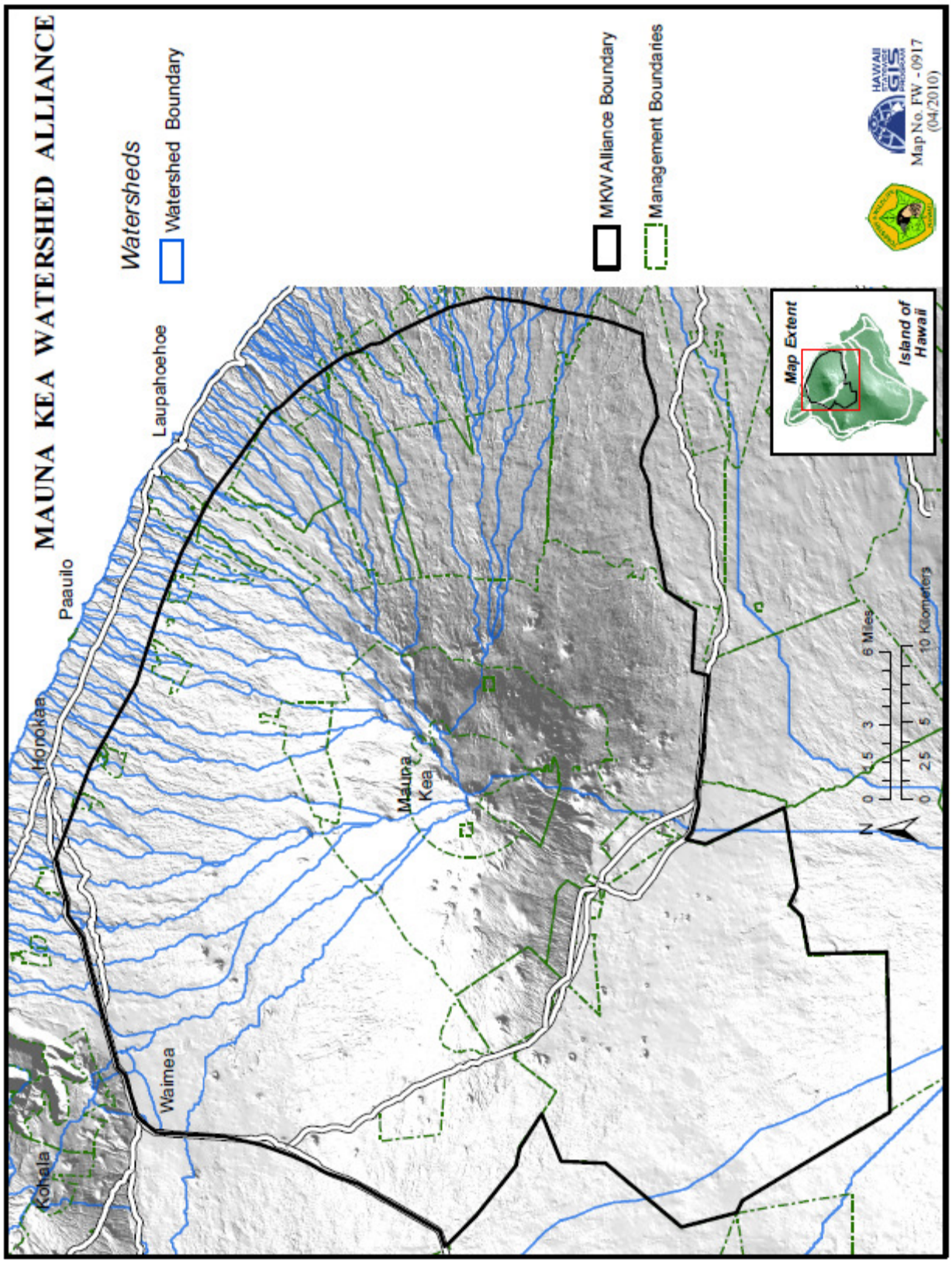


Figure 5: Watersheds on Mauna Kea [new map?]

The wet forests of Mauna Kea – with their layers of plants and diversity of species -- are vital to the capture of rainfall that fills the aquifers and streams. In a healthy natural watershed, 50% of precipitation will infiltrate into groundwater, 40% will return to the atmosphere through evaporation and plant transpiration, and 10% will runoff into streams and other waterbodies. When the groundcover in a watershed is altered, runoff generally increases, at the expense of infiltration and evapotranspiration. Increased runoff can exacerbate streambank erosion, generate increased turbidity and water pollution, and escalate the potential of streams to overtop their banks, leading to flooding of adjacent or downstream properties.

Typically, streams and rivers convey water from Hawai‘i’s mountainous interior to the coasts. Most streams originate in the mid-elevation rainfall belt between 2,000-5,000-ft. elevation. Eighty-five perennial streams are found on this side of Mauna Kea, some continuous and some interrupted (Figure 6). Streams with continuous flows flow to the ocean year round. Those with interrupted flows normally flow year round in the upper reaches and intermittently at the lower elevations. Although portions of the streams may be dry during parts of the year, native species exist in ponds in the upper reaches, and recruitment occurs during periods of continuous flow. In contrast, the leeward side of Mauna Kea has few streams, demarcated by large watersheds. These streams are primarily ephemeral, meaning they are dry gulches that flow only in direct response to infrequent rainfall. Hawai‘i’s streams are flashy, because “rainfall is intense, drainage basins are small, basins and streams are steep, and channel storage is limited” (Oki 2003: 1). This means the streams can rise rapidly in response to periods of intense rainfall, leading to flooding, property damage, and loss of life.

Freshwater streams have many values. They provide irreplaceable habitats for aquatic fauna and flora. Streams link the mountains with the ocean. They are essential to the productivity and quality of Hawai‘i’s nearshore waters. Stream health is both integral to the survival of the unique stream organisms and indicative of the overall quality of our island environment.

While Mauna Kea’s streams originate in the rainbelt, generally protected by the Conservation District land use designation, the majority of them flow through agricultural and urban lands on their way to the ocean. In 1992, the State proposed to reclassify some of these stream corridors from an Agricultural land use designation to Conservation, in order to afford these special streams greater protection (OSP 1992). These special streams were identified using the Hawai‘i Stream Assessment (DLNR 1990) and input from stream experts, based on the presence of outstanding aquatic resources, and habitat for aquatic and riparian fauna and flora. These streams are highlighted in Table 2.

The Nature Conservancy of Hawai‘i, through its Hawaiian High Island Ecoregion planning process (described in Chapter 4) also identified two streams on Mauna Kea, Hanawi and Honoli‘i, as among the highest quality streams on the island because of their rich complement of native fauna and high quality and quantity of water in channels with high structural heterogeneity.

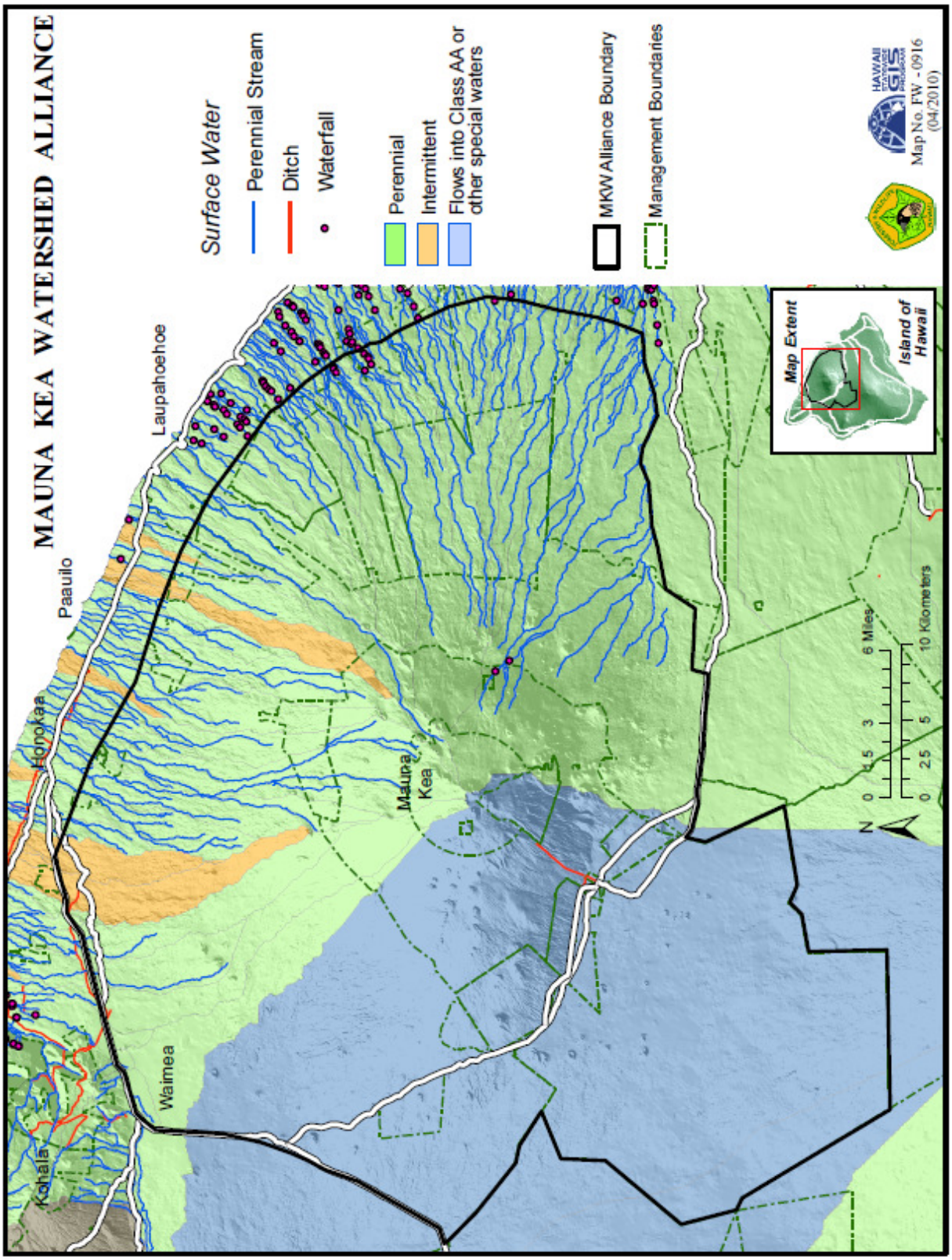


Figure 6: Streams on Mauna Kea [new map?]

The Wailuku River drains the largest area on the windward side of Mauna Kea. The drainage basin is 226 square miles and originates high up the mountain. The Wailuku River is the second longest perennial river in the state of Hawai‘i (total stream length is 196.1 miles) and the largest source of surface water to Hilo Bay. It is important to geologists because it marks the approximate boundary between lava flows of Mauna Kea and Mauna Loa. An average of 275-million gallons of water flows through the Wailuku to Hilo every day. During intense storms, the discharge can be more than 20 times greater. Wailuku’s flowing water provides a renewable source of energy by generating some of the electricity used on the Big Island.

The Hawai‘i Commission on Water Resource Management (CWRM) has its own nomenclature to identify watersheds or drainage basins, each comprising a stream or stream system. These surface water hydrologic units have each been given a unique four digit numeric code. The hydrologic units contained within the Mauna Kea Watershed Alliance area start from 8043 Waiulili to 8138 Wailuku, moving clockwise, with 8157 Pōhakuloa, 8158 Kamakoa, and 8161 Waikoloa on the leeward side. Table 2 lists each stream, its drainage area, numbers of diversions, gages and active gages, and applicable streamflow standards (described below). It also highlights (in blue) streams identified by OSP (1992) as Special Streams; streams on the Department of Health’s (DOH) Section 303(d) list of impaired waters (bold and italicized font), which are described in more detail below and in Table 3; and streams containing native aquatic species (marked with an “X”) as identified in the Department of Land and Natural Resources’ (DLNR) stream survey database. DLNR Division of Aquatic Resources (DAR) has a different numbering system for the streams.

Table 2: Inventory of Streams in the MKWA area (adapted from CWRM 2008)

Native Spp.?	Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
X	***8043***	***Waiulili***	***28.93***	***1***	***4***	***0***	***Chapter 13-169-46, HAR***
	8044	Waikoekoe	1.61				Chapter 13-169-46, HAR
	8045	***Waipunahoe***	***16.51***				***Chapter 13-169-46, HAR***
	8046	***Wai‘ale‘ale***	***0.79***				***Chapter 13-169-46, HAR***
	8047	***Waikoloa***	***16.95***				***Chapter 13-169-46, HAR***
	8048	***Kapulena***	***3.08***				***Chapter 13-169-46, HAR***
	8049	***Kawaikalia***	***1.84***				***Chapter 13-169-46, HAR***
	8050	Malanahae	2.24				Chapter 13-169-46, HAR
	8051	Honokaia	16.09	0	1	0	Chapter 13-169-46, HAR
	8052	Kawela	1.31				Chapter 13-169-46, HAR
	8053	Keaakaukau	0.87				Chapter 13-169-46, HAR
	8054	Kainapahoa	9.08	1	1		Chapter 13-169-46, HAR
	8055	***Nienie***	***4.95***	***2***			***Chapter 13-169-46, HAR***
	8056	Papuaa	4.73		2		Chapter 13-169-46, HAR
	8057	Ouhi	0.45				Chapter 13-169-46, HAR
	8058	Kahaupu	11.27				Chapter 13-169-46, HAR
	8059	Kahawaili‘ili‘i	15.56				Chapter 13-169-46, HAR
	8060	Keahua	1.70				Chapter 13-169-46, HAR
	8061	Kalōpā	30.94				Chapter 13-169-46, HAR
	8062	Waikaalulu	3.06				Chapter 13-169-46, HAR
	8063	Kukuilamalamahii	2.28				Chapter 13-169-46, HAR
	8064	Alilipali	1.60				Chapter 13-169-46, HAR
	8065	Kaumoali	9.39				Chapter 13-169-46, HAR
	8066	Pohakuhaku	2.45				Chapter 13-169-46, HAR

Native Spp.?	Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
	8067	Waipunahina	15.86				Chapter 13-169-46, HAR
	8068	***Waipunalau***	***3.84***				***Chapter 13-169-46, HAR***
	8069	Paʻauilo	1.57	1			Chapter 13-169-46, HAR
	8070	ʻĀʻāmanu	0.64				Chapter 13-169-46, HAR
	8071	Koholālele	14.40				Chapter 13-169-46, HAR
	8072	Kalapahapuu	6.43				Chapter 13-169-46, HAR
	8073	Kūkaʻiau	2.40				Chapter 13-169-46, HAR
	8074	Puʻumaile	9.13				Chapter 13-169-46, HAR
	8075	Kekualele	2.18				Chapter 13-169-46, HAR
	8076	Kaʻala	6.62				Chapter 13-169-46, HAR
	8077	Kealakaha	3.49				Chapter 13-169-46, HAR
	8078	Keehia	1.72		1		Chapter 13-169-46, HAR
	8079	Kupapaulua	2.54				Chapter 13-169-46, HAR
	8080	Kaiwiki	2.24				Chapter 13-169-46, HAR
	8081	Kaʻula	14.35				Chapter 13-169-46, HAR
	8082	Kaohaoha	1.49				Chapter 13-169-46, HAR
	8083	Kaawalii	13.93				Chapter 13-169-46, HAR
	8084	Waipunalei	2.07				Chapter 13-169-46, HAR
	8085	Laupāhoehoe	4.71				Chapter 13-169-46, HAR
X	8086	Kīlau	2.43	1			Chapter 13-169-46, HAR
X	8087	Manowaiʻōpae	1.74	2	1		Amended to include SCAP HA-195 on stream for a permitted diversion (5/31/96)
X	8088	Kuwaikahi	0.72	1			Chapter 13-169-46, HAR
X	8089	Kihalani	0.70	1			Chapter 13-169-46, HAR
X	8090	Kaiwilahilahi	6.69	1			Chapter 13-169-46, HAR
	8091	Haʻakoa	6.26				Chapter 13-169-46, HAR
X	8092	Pāhale	3.92				Chapter 13-169-46, HAR
X	8093	Kapehu Camp	1.74	2			Chapter 13-169-46, HAR
	8094	Paeohe	0.85				Chapter 13-169-46, HAR
X	8095	Maulua	5.30				Chapter 13-169-46, HAR
X	8096	Pōhakupuka	3.63	1	1		Chapter 13-169-46, HAR
	8097	Kulanakiʻi	0.71				Chapter 13-169-46, HAR
	8098	Ahole	0.67				Chapter 13-169-46, HAR
	8099	Poupou	0.62				Chapter 13-169-46, HAR
X	8100	Manoloa	1.32				Chapter 13-169-46, HAR
	8101	Nīnole	1.67	2			Chapter 13-169-46, HAR
	8102	Kaaheiki	0.27	1			Chapter 13-169-46, HAR
	8103	Waikolu	0.63	4			Chapter 13-169-46, HAR
X	8104	Waikaumalo	16.10				Chapter 13-169-46, HAR
	8105	Waiehu	0.61	1			Chapter 13-169-46, HAR
X	***8106***	***Nanue***	***5.53***	***1***			***Chapter 13-169-46, HAR***
X	8107	Opea	2.31				Chapter 13-169-46, HAR
	8108	Peleau	1.12	3			Amended to include SCAP HA-314 on stream for diversion of 8.0 mgd for ag use (8/23/00)
X	8109	Umauma	33.83	1			Chapter 13-169-46, HAR
X	***8110***	***Hakalau***	***10.26***				***Chapter 13-169-46, HAR***
X	***8111***	***Kolekole***	***20.82***	***8***			***Chapter 13-169-46, HAR***
X	***8112***	***Pāheʻeheʻe***	***2.87***				***Chapter 13-169-46, HAR***
X	8113	Honomū	3.12	2			Amended to include SCAP HA-317 on stream for 2" pipe diversion for washing farm equipment (2/28/01)
X	8114	Laimi	0.89	1			Chapter 13-169-46, HAR
	8115	***Kapehu***	***1.60***	***2***	***1***		***Chapter 13-169-46, HAR***

Native Spp.?	Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
X	8116	Makea	2.08	4			Chapter 13-169-46, HAR
X	8117	Alia	1.31	2	1		Amended to include SCAP HA-387 on stream for diversion of 0.058 mgd for ag use (5/24/06)
	8118	Makahanaloa	0.48				Chapter 13-169-46, HAR
	8119	Waimaauou	1.33	1			Chapter 13-169-46, HAR
X	8120	Waiaama	3.53	2			Chapter 13-169-46, HAR
X	8121	Kawainui	8.52	1	1		Chapter 13-169-46, HAR
	8122	Onomea	0.85	5			Amended to include SCAP HA-214 on stream for relocation of pipe diversion to mitigate concerns over an existing diversion dam (3/19/97)
	8123	Alakahi	0.30	1			Chapter 13-169-46, HAR
X	8124	Hanawi	3.96				Chapter 13-169-46, HAR
	8125	***Kalaoa***	***0.51***	***3***			***Chapter 13-169-46, HAR***
	8126	Aleamai	0.32		1		Chapter 13-169-46, HAR
X	***8127***	***Ka'ie'ie***	***2.75***				***Chapter 13-169-46, HAR***
X	8128	Puuokalepa	0.93	2			Chapter 13-169-46, HAR
	8129	Ka'āpoko	0.32				Chapter 13-169-46, HAR
	8130	Pāpa'ikou	0.19				Chapter 13-169-46, HAR
X	***8131***	***Kapue***	***11.86***				***Chapter 13-169-46, HAR***
X	8132	Pāhoehoe	6.96	1			Chapter 13-169-46, HAR
X	8133	Paukaa	0.65				Chapter 13-169-46, HAR
X	***8134***	***Honoli'i***	***16.59***		***2***	***1***	***Chapter 13-169-46, HAR***
X	***8135***	***Maili***	***4.09***	***1***			***Chapter 13-169-46, HAR***
	8136	Wainaku	1.86				Chapter 13-169-46, HAR
X	***8137***	***Pukihae***	***3.23***				***Chapter 13-169-46, HAR***
X	***8138***	***Wailuku***	***225.56***	***11***	***14***	***1***	***Amended to include SCAP HA-219 on Waiau Stream for a diversion dam constructed to generate electricity to a farm operation (10/22/97). Amended to include SCAP HA-047 on Hookelekele Stream for 3 diversion structures constructed as part of a hydroelectric project (10/18/89)***
	8157	Pōhakuloa	348.76	4			Chapter 13-169-46, HAR
	8158	Kamakoa	192.20		2		Chapter 13-169-46, HAR
X	8161	Waikoloa	51.96	11	4	2	Chapter 13-169-46, HAR

Good water quality is essential to maintaining high quality stream resources and other values. The Federal Clean Water Act directed states to determine which waterbodies in their states do not meet state water quality standards for conventional pollutants, such as nutrients and sediments, toxic pollutants and indicator bacteria. The law is implemented by regulations found in 40 CFR Part 130.7(b)(5) and (6) which identify a broad set of data sources and submittal requirements that states must consider prior to developing a Clean Water Act §303(d) List of Impaired Waters for submittal to the U.S. Environmental Protection Agency (EPA).

To develop this §303(d) List of Impaired Waters, Hawaiʻi Department of Health (DOH) used all "existing and readily available data" that meets its water quality monitoring requirements for quality assurance/quality control, and that were obtained in the six year period prior to the determination. Data can be obtained from a variety of sources including governmental agencies, universities, and community groups and individuals responding to a published statewide "Call for Data." In accordance with a complex system of priority ranking and listing/delisting criteria described in the DOH report, "...waterbodies were sorted into one of three priority categories. Priority 1 waters have sufficient data to clearly support a listing/delisting criteria based on wet and/or dry conditions. Priority 2 waters have limited data, which requires DOH to use a weight-of-evidence approach for listing/delisting decision. Priority 3 waters have extremely limited data and require future monitoring before a listing decision can be made" (DOH 2008: II-13). Once EPA approves the §303(d) list of Impaired Waterbodies, the state must develop Total Maximum Daily Loads (TMDLs) for all listed pollutant/waterbody combinations. Streams were identified as of low, medium or high priority for developing TMDLs.

In 1998, there were five streams in the MKWA area that were listed on the §303(d) list of Impaired Waterbodies: Hakalau Stream (nutrients and turbidity), Honoliʻi Stream (nutrients and turbidity), Kaʻieʻie Stream (nutrients), Kolekole Stream (nutrients and turbidity) and Wailuku Stream (nutrients and turbidity).

In 2002, DOH developed the *Final 2002 List of Impaired Waters in Hawaiʻi Prepared Under Clean Water Act §303(d)*, using additional water quality data and visual assessments that were obtained in some streams (DOH 2002). All five streams listed in the 1998 §303(d) list were also listed on the 2002 list; four streams were identified as medium priority for establishing TMDLs (Hakalau, Honoliʻi, Kaʻieʻie and Kolekole), and one stream was identified as low priority (Wailuku). For Wailuku Stream, the parameters were changed from "nutrients and turbidity" to only "nutrients," since the geometric mean of the limited data available was well below the dry season standard, the majority of dry season samples were below the dry season standard, and all of the wet season samples were below the wet season standard. The visual assessment of Wailuku Stream was inconclusive for nutrients, and it was noted that the stream "needs assessment of lower freshwater segment" (DOH 2002: 59). For Kolekole Stream, the data were inconclusive as to whether the turbidity standard was exceeded, and the visual assessment "contradicts" the 1998 listing for nutrients and turbidity, so it was identified for future monitoring and not delisted for turbidity. Water quality data for Honoliʻi exceeded the turbidity standard for the dry season. There were four streams identified as Priority 1 streams: Kolekole (also listed in 1998), Honoliʻi (also listed in 1998), Wailuku (also listed in 1998), and Kapehu (not listed in 1998) (DOH 2002: 19). It is noted that at Kapehu, the 2002 data showed no turbidity (DOH 2002: 59). Numerous streams were identified as in need of future monitoring because of very limited water quality data, including Waiulili, Waipunahoe, Waiʻaleʻale, Waikoloa, Kapulena, Kawaikalia, Malanahe, Nienie, Papuaa, Kahaupu, Kahawailiʻiliʻi, Keāhua, Kalōpā, Waikaalulu, Kukuilamalamaheʻe, Alilipali, Kaumōʻali, Waipunahina, Waipunalei, Hakalau, Kolekole, Kapehu, Kaʻieʻie, Honoliʻi and Wailuku (DOH 2002: 59-60).

In 2004, DOH prepared its *Final 2004 List of Impaired Waters in Hawai‘i Prepared Under Clean Water Act §303(d)* (DOH 2004). For this determination, additional water quality data were gathered in some streams and visual assessments were done for some streams. Six streams were listed on the 2004 §303(d) list of Impaired Waterbodies. These six streams included the five streams listed in 1998 and 2002 (Hakalau, Honoli‘i, Ka‘ie‘ie, Kolekole and Wailuku) plus Kapehu Stream, for which water quality data showed an exceedance of the dry season standard for turbidity (DOH 2004: 25-26, 49). Kolekole Stream was delisted for turbidity based on numeric assessment during wet and dry seasons, but was still listed for nutrients based on visual assessment in 2002. Honoli‘i Stream was delisted for wet season turbidity since sufficient water quality data showed attainment of the wet season turbidity standard. But, due to lack of sufficient data on dry season, Honoli‘i remained listed for nutrients for the dry season on the basis of visual assessment. Wailuku was delisted for turbidity during both seasons and delisted for nutrients during the wet season based on available data. Wailuku is still listed for nutrients during the dry season until more data is gathered (DOH 2004: 49). Of these six streams, four streams were identified as medium priority for establishing TMDLs (Hakalau, Honoli‘i, Ka‘ie‘ie and Kolekole), and two streams were identified as low priority (Kapehu and Wailuku). All of the streams identified in 2002 as in need of future monitoring because of very limited water quality data were listed again in 2004.

In 2008, DOH produced *2006 State of Hawai‘i Water Quality Monitoring and Assessment Report: Integrated Report to the U.S. Environmental Protection Agency and the U.S. Congress Pursuant to Sections §303(D) and §305(B), Clean Water Act (P.L. 97-117)* (DOH 2008), its first report that integrated both reporting requirements of the Clean Water Act (CWA) §305(b) and §303(d). The CWA §305(b) requires states to describe the overall status of water quality statewide and how well this water quality supports a healthy population of shellfish, fish and wildlife, and allows recreational activities in and on the water. The CWA §303(d) requires States to submit a list of Water Quality-Limited Segments, plus a priority ranking of listed waters based on pollution levels and uses of the water. Waterbodies are prioritized as High, Medium or Low for Total Maximum Daily Load (TMDL) development based on the number of parameters listed and severity of exceedances.

In addition, DOH (2008) classified Hawai‘i’s waterbodies into EPA Categories. A waterbody is classified as Category 1 if there are sufficient data to document that all water quality standards and designated uses are being attained. At this time, DOH has determined that not enough data have been collected to assign any waterbody to this category. Category 2 streams show attainment of some of the water quality standards; however, none of the data sets are complete and/or consistent with the state’s listing methodology and water quality standards. Of the streams in the Mauna Kea Watershed Alliance area, Pukihae, Kalaoa, Pāhe‘ehe‘e, Nanue and Hakalau Streams are listed in Category 2.

In Chapter 2 of DOH (2008), it is noted that

> Although limited numerical data exists for Nanue and Hakalau Streams on Hawai‘i Island...these streams are included in Category 2 due to their status as reference sites for biological resources as utilized in the Hawai‘i Stream Bioassessment Protocol [Kido 2002], and as such, are deemed to be meeting the designated use of the native aquatic life support. No data exists for recreational use attainment decisions for streams. All of the state's waterbodies fall into Category 3, in which "data are insufficient to support a decision..." for at least one of the designated uses. (DOH 2008: II-30).

The waterbodies that are currently 303(d) listed for specific water quality parameters, but need more data to determine compliance with other water quality standards or use attainments, are sorted into Categories 3 to 5. Category 5 is a waterbody in which there is one or more designated use non-attainments or water quality impairments. Category 4 is a waterbody in which there is one or more designated use non-attainments or water quality impairments and a TMDL has been approved, the use impairment is caused by a pollutant that is being addressed by the state through another requirement, or the use is impaired but not caused by a pollutant (DOH 2008: II-30).

Table 3 presents the Mauna Kea streams that are included in DOH (2008). The table shows the stream name, the season in which the data were gathered, the data for the presence of enterocci, Total Nitrogen, nitrate+nitrite (NO_3^-+NO_2^-), Total Phosphorus, Turbidity and Total Suspended Solids (TSS). The table also lists the category for the stream as described above, and whether the stream has a low, medium or high priority for developing TMDLs.

The report notes that:

> Waterbodies entered in the table are not necessarily reflective of all waters of the state; rather they indicate areas where sampling has taken place, and areas of higher incidence of human contact. Areas not shown in the table do not have any sampling data available, and are considered to be in category "3," more information needed to make a decision. Future reporting cycles may add waterbodies as necessary. Tools utilized for the assessment in the 2006 reporting cycle included chemical analyses, bacteriological analyses, and Hawai‘i Stream Bioassessment Protocol scores (for native aquatic life – Class 1 Streams) (DOH 2008: 16).

While some data have been collected for streams on Mauna Kea, it is clear that additional information needs to be collected in order to change the status of listed streams in terms of their EPA categories and TMDL priorities, and to determine if listed streams should be delisted or if unlisted streams should be listed.

Typical surface water quality impairments in Hawai‘i are sediments and nutrients. Sediments derive from soil erosion from improperly managed construction sites and

Table 3: Mauna Kea Streams Listed in DOH (2008)

Stream name	Season	Enterococci	Total N	NO3+NO2	Total P	Turb	Other Pollutant	Category	TMDL priority	Comments
Waiulili	Dry	?	?	?	?	?	TSS (?)	3		
Waiulili	Wet	?	?	?	?	Ac	TSS (?)	3		
Waipunahoe		?	?	?	?	?	TSS (?)	3		
Wai‘ale‘ale		?	?	?	?	?	TSS (?)	3		
Waikoloa		?	?	?	?	?	TSS (?)	3		
Kapulena		?	?	?	?	?	TSS (?)	3		
Kawaikalia		?	?	?	?	?	TSS (?)	3		
Nienie		?	?	?	?	?	TSS (?)	3		
Waipunalau		?	?	?	?	?	TSS (?)	3		
Nanue		?	?	?	?	?	TSS (?)	3		
Hakalau		?	V	V	V	V	TSS (?)	2, 3, 5	M	
Kolekole	Dry	?	A	A	A	A	TSS (A)	3		Delisted
Kolekole	Wet	?	A	A	A	A	TSS (A)	3		Delisted
Pāhe‘ehe‘e	Dry	?	Ac	Ac	Ac	A	TSS (Ac)	2, 3		
Pahe‘ehe‘e	Wet	?	Ac	Ac	Ac	Ac	TSS (Ac)	2, 3		
Kapehu	Dry	?	Ac	N	A	N	TSS (A)	3, 5	L	
Kapehu	Wet	?	A	A	A	A	TSS (A)	3		
Kalaoa	Both	?	Ac	Ac	Ac	Ac	TSS (Ac)	2, 3		
Kalaoa	Dry	?	Ac	Ac	Ac	A	TSS (Ac)	2, 3		
Ka‘ie‘ie	Dry	?	A	A	A	?	TSS (A)	3		
Ka‘ie‘ie	Wet	?	V	V	V	?	TSS (?)	3, 5	L	
Kapue	Dry	?	Ac	Ac	Ac	N	TSS (Ac)	3, 5	L	
Kapue	Wet	?	Ac	Ac	Ac	?	TSS (Ac)	3		
Honoli‘i	Dry	?	A	A	A	N	TSS (A)	3, 5	L	
Honoli‘i	Wet	?	A	A	A	A	TSS (A)	3		
Maili	Dry	?	Ac	Ac	Ac	N	TSS (Ac)	3, 5	L	
Maili	Wet	?	Ac	Ac	Ac	Ac	TSS (Ac)	3		
Pukihae	Dry	?	Ac	Ac	Ac	A	TSS (Ac)	2, 3		
Pukihae	Wet	?	Ac	Ac	Ac	Ac	TSS (Ac)	2, 3		
Wailuku	Dry	?	A	N	A	A	TSS (A)	3, 5	L	
Wailuku	Wet	?	A	A	A	A	TSS (A)	3		

Decision codes: ? = unknown; N = not attained; A = attained; Ac = Attained (with combined season data); Nc = Not attained (with combined season data); N1 = Not attained (by 2 times the standard); N1c = not attained (by combined data, 2 times the standard); V = visual listing from 2001 – 2004; L = previous listing from 1998 or earlier.

croplands, degraded forest lands, and eroding streambanks. Erosion can also transport adsorbed contaminants into surface waters. Nitrogen and phosphorus are the two major nutrients most commonly found in Hawaiʻi streams. These come from agricultural and residential areas, normally resulting from excessive or improperly-applied fertilizer or improperly constructed or maintained on-site domestic sewage treatment systems (*e.g.*, cesspools and septic systems). Elevated nutrient levels can also come from animal manure. These pollutants can have a negative effect on instream aquatic resources and downstream nearshore resources. Leptospirosis is also a problem in Hawaiʻi's streams. This disease can be transmitted to humans that come into contact with urine of infected animals, mainly pigs, dogs, and rats, typically by swimming in streams exposed to ungulate impact.

The State is concerned not only about surface water quality but also water quantity. Streamflow is important for both the amphidromous life cycle of the native aquatic species and the productivity and quality of the nearshore marine resources. In addition, streamflow has been essential for both potable and non-potable water supplies since the Polynesians settled Hawaiʻi. According to Oki (2003), "[s]treamflow in Hawaiʻi is highly variable both in space in time" (p.2). Streamflow depends on factors such as rainfall, drainage basin size, land use, surface water diversions, and groundwater discharges. Generally, streamflow tracks rainfall patterns.

The dependence on surface water for water supplies can be challenging. Streamflow is made up of direct runoff of rainfall (overland flow and subsurface storm flow), groundwater discharge (base flow), and flow related to streambank storage. During extremely dry weather, flows may drop below the required rate. During high rainfall periods, water may be turbid. EPA standards for treating surface water for domestic consumption have become more stringent in recent years, increasing the production costs, and making groundwater a more attractive long-term alternative for domestic water supplies. However, surface water still remains a desirable choice for agricultural water, as long as sufficient flows can be maintained for instream uses.

To address these issues, the State is in the process of establishing instream flow standards for the perennial streams, in order to balance maintenance of fish and wildlife habitat, estuarine, wetland and stream ecosystems, and water quality with use of the water (CWRM 2005). Section 13-169-46 of the Hawaiʻi Administrative Rules (HAR), adopted in 1988, establishes interim instream flow standards (IFS) for Hawaiʻi. These were generally defined as the amount of water flowing in each stream on the effective date of the standard. The standards for individual streams have subsequently been amended as a result of petitions to amend the IFS and describe the amount of water that can be withdrawn from the stream. Streams with individual standards are noted in the far right column of Table 2.

<u>2B. Lake Water Resources</u>

Lake Waiau, located in the Mauna Kea Ice Age Natural Area Reserve at 13,020 feet on Mauna Kea, is one of the highest lakes in the United States (Ehlmann *et al.* 2005). The diameter and depth of the lake varies in size depending on rainfall, but the maximum

diameter is 90 meters and depth is 3 meters. It is believed to have formed about 15,000 years ago, following the last glacial retreat (Woodcock 1974). The source of the lake water is thought to be rainfall and snow melt, not groundwater contained in relic ice or permafrost as previously hypothesized (Ehlmann *et al.* 2005). In periods of high water levels, Lake Waiau drains into Pōhakuloa Gulch through a small outlet on the northwest end (Ehlmann *et al.* 2005). Lake Waiau provides a habitat for unique aquatic insects and is of great cultural significance to the Hawai‘i’s people.

2C. Groundwater Resources

Groundwater distribution also reflects rainfall patterns, in that the water-rich windward areas capture and retain significantly more water in the aquifers than the drier leeward side. This can be problematic, particularly when groundwater is not concentrated where population growth is projected. Basal groundwater is generally found up to five miles inland from the coasts. High level water may occur at great depths at significant distances from the coasts; however, these locations are often difficult to access and far away from the end users. According to the Department of Water Supply (DWS 2006), high level dike water exists in the rift zone section of Mauna Kea, and perched water is common in the Laupāhoehoe series.

Groundwater hydrologic units have been established by CWRM to provide a basis for managing groundwater resources. In general, each island is divided into regions, called Aquifer Sector Areas (ASEA), that reflect broad hydrogeological similarities. Aquifer Sector Areas are then divided into smaller sub-regions called Aquifer System Areas (ASYA) “based on hydraulic continuity and related characteristics” (CWRM 2008: 3-12). Using analytical and numerical groundwater modeling, sustainable yields[1] have been estimated for aquifers in Hawai‘i, most recently in 2008 (CWRM 2008).

The primary Aquifer Sector Areas on Mauna Kea are East Mauna Kea, with an estimated yield of 388 million gallons per day (MGD), and West Mauna Kea, with an estimated sustainable yield of 24 MGD (Figure 7). The East Mauna Kea Aquifer Sector is broken into 4 aquifer systems: Honoka‘a (31 MGD), Pa‘auilo (60 MGD), Hakalau (150 MGD), and Onomea (147 MGD). The West Mauna Kea Aquifer comprises the single ASYA of Waimea. A portion of the Mauna Kea Watershed Alliance area also falls within the NW Mauna Loa ASEA (30 MGD) and the Hilo ASYA (347 MGD) of the NE Mauna Loa Aquifer Sector Area.

Mauna Kea captures significant water resources on Hawai‘i Island. Municipal production wells are generally located outside of the Mauna Kea Watershed Alliance area, and most of the MKWA area is not covered by the county’s water distribution system. Current DWS (2006) municipal water use for the entire island is 25.257 MGD. Estimates from privately-owned public water systems and catchment water systems are 8.40 MGD and 4.97 MGD respectively.

[1] Sustainable yield is defined as “the maximum amount of water that may normally be withdrawn from a source without significantly impairing the source” (CWRM 2008: 3-56).

There are 26 production wells in the East Mauna Kea ASEA -- 9 municipal, 5 domestic, 4 irrigation, 7 industrial, and 1 other – all located outside the MKWA area (DWS 2006). There are 62 declared stream diversions (DWS 2006). DWS has ten water systems in the East Mauna Kea ASEA, tapping into a combination of surface and groundwater resources for their supply. Seven spring sources are used in six of the water systems, with an estimated capacity of less than 1 MGD (DWS 2006). Current water usage from the East Mauna Kea ASEA is estimated to be 2.84 MGD excluding agricultural (non-potable) use and 12.40 MGD with agricultural use, or 1% and 3%, respectively, of the sustainable yield.

There are 30 production wells in the West Mauna Kea ASEA: 15 municipal, 11 irrigation, 2 industrial, and 2 other (DWS 2006). There are seven declared stream diversions, four near Mauna Kea State Park on the southwestern side of Mauna Kea

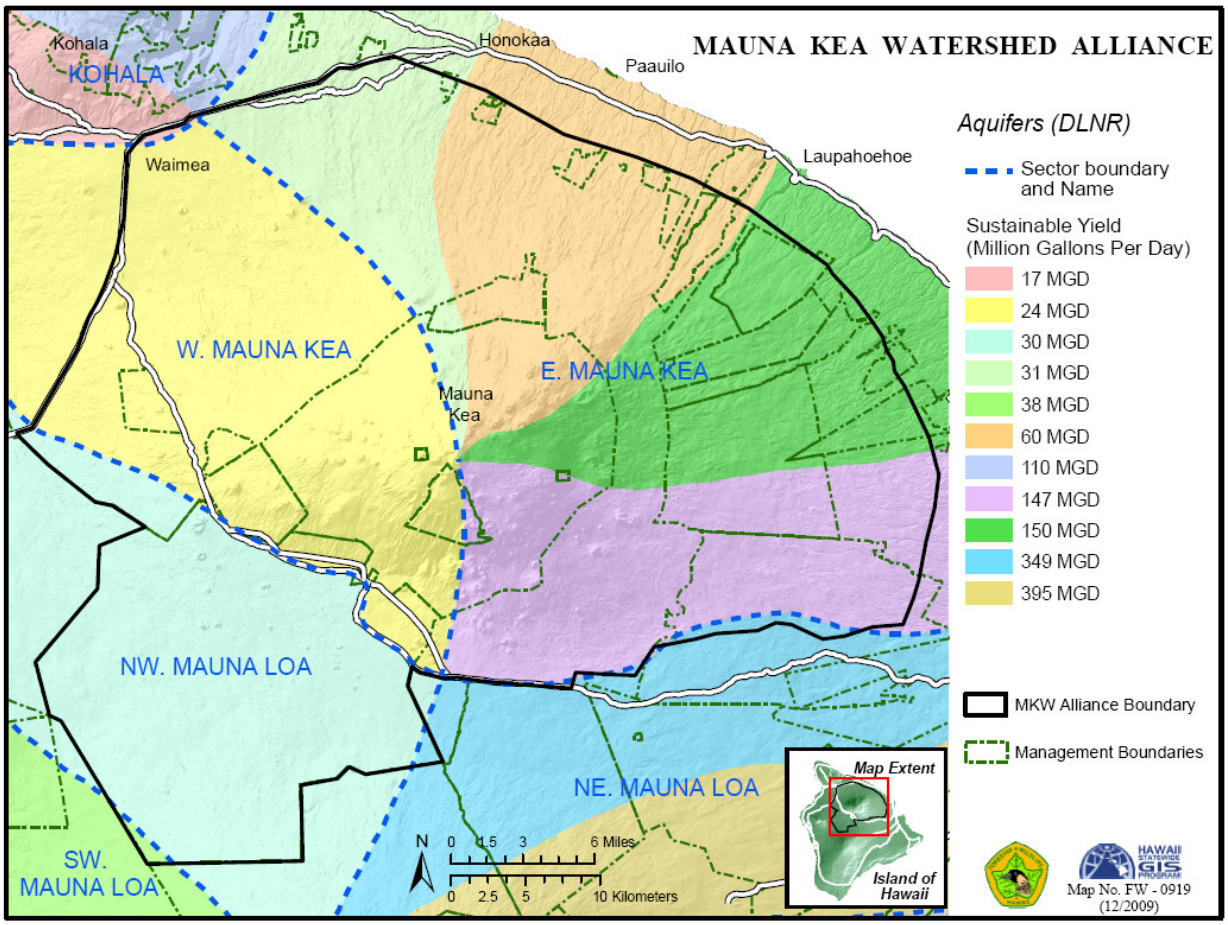


Figure 7: Island of Hawai‘i Ground-Water Hydrologic Units (from CWRM 2008)

near Saddle Road and three on Waikoloa Stream. The diversions at Mauna Kea State Park (managed by DLNR) historically provided potable water to the park. Now, the U.S. Army maintains the sources and transmission lines in exchange for water use for Pōhakuloa Training Area (PTA) (CWRM 2003). The source for the water system includes five springs: Upper Hopukani Spring, Hopukani Spring, Waihu Spring, Liloe Spring and an un-named spring. The estimated source capacity is 0.00125 MGD,

which does not meet existing consumption needs. During periods of high usage, additional water is hauled in by tankers from municipal systems in Hilo or Waimea (DWS 2006).

There are two DWS water systems within the West Mauna Kea ASEA: one providing water to the Waimea area and the other servicing the leeward coast. Private water systems service Waikoloa Village (4.5 MGD) and Waikiʻi Ranch (0.04 MGD). Current usage from the West Mauna Kea ASEA is estimated to be 7.71 MGD without agricultural use and 11.05 MGD with agricultural use, or 32% and 46%, respectively, of sustainable yield.

While PTA and parts of Waikoloa Village fall within the NW Mauna Loa ASEA, the potable water for these areas is obtained from neighboring ASEAs.

The Hilo ASYA of the NE Mauna Loa ASEA includes urban Hilo as well as the Wailuku River. There are 10 declared diversions within the NE Mauna Loa ASEA, including several on the Wailuku River. HELCO's Waiau and Puʻuʻeo hydropower plants each utilize a single stream diversion to power their turbines. This "run of the river" hydroelectric generation returns the water to the river without it being heated or treated with chemicals. The Wailuku River Hydroelectric Power Co. also diverts water from the junction of the Wailuku River and Kaloheahewa stream to produce electricity for sale to HELCO. Wenko Energy Co., another company selling power to HELCO, uses a stream diversion on Ainako stream, a tributary of the Wailuku River, to produce electricity.

There are approximately 24 contaminated groundwater wells and springs outside the MKWA area along the Hāmākua coast, mostly the result of contamination from chemicals used in the sugar industry.

The County of Hawaiʻi's *Water Use and Development Plan* (DWS 2006) serves as a long-range guide for water resource development in the county. It projects water demand for each Aquifer Sector Area, based on full build-out scenarios, given existing zoning and land use changes recommended in the Hawaiʻi County General Plan (2005). It also projects water demand based on historical DWS water consumption data from 1970-2003. Water demand projections for each ASEA within the Mauna Kea Watershed Alliance area are provided in Table 4.

Table 4: Water Demand Projections

Water Demand Projections (by ASEA)	Comments
East Mauna Kea Sector (SY: 388 MGD) Current Zoning: 378.1 MGD total, or 8.2 MGD excluding agriculture General Plan: 405.5 MGD total, or 25.4 MGD excluding agriculture DWS Water Demand Projection through 2025[2]: 15.7 MGD total, or 3.6 MGD excluding agriculture	❖According to DWS (2006), "Full build-out water demands associated with the maximum density of LUPAG and Zoning land uses are both sustainable if agricultural demands are not included." (p. 802-30) ❖Most non-potable water used for agriculture in the East Mauna Kea Sector originates in the Kohala ASEA and is transported through the Upper and Lower Hamakua ditches. DWS recommends that surface water continue to be the primary source of non-potable agricultural water (DWS 2006)
West Mauna Kea Sector (SY: 24 MGD) Current Zoning: 150.6 MGD total, or 13.8 MGD excluding agriculture General Plan: 186.7 MGD total, or 52.1 MGD excluding agriculture DWS Water Demand Projection through 2025: 20.0 MGD total, or 13.9 MGD excluding agriculture	❖ Excluding agricultural demands, the water demands using the full build-out scenario contained in the General Plan are not sustainable. ❖ Excluding agricultural demands, both the existing zoning build-out and 2025 water demand projection requires 60% of the existing sustainable yield.
NW Mauna Loa Sector (SY: 30 MGD) Current Zoning: 18.1 MGD total, or 11.0 MGD excluding agriculture General Plan: 88.7 MGD total, or 81.7 MGD excluding agriculture DWS Water Demand Projection through 2025: 14.7 MGD total, or 14.4 MGD excluding agriculture	❖ According to DWS (2006), "Full build-out water demands based on LUPAG are nearly three times the sustainable yield of sector area." (p. 807-25) ❖ The zoning demand, including agriculture, is 60% of the sustainable yield, while 20-year project demands are nearly 50% of the sustainable yield.
NE Mauna Loa Sector (SY: 740 MGD; 347 MGD for Hilo ASYA only) Current Zoning: 107.4 MGD total, or 26.3 MGD excluding agriculture General Plan: 202.6 MGD total, or 118.6 MGD excluding agriculture DWS Water Demand Projection through 2025: 9.8 MGD total, or 7.6 MGD excluding agriculture	

3. Ecosystems and Species

Hawai'i has long been known for its diversity of ecosystems and the high level of endemism in its plant and animal communities, resulting from its topography, large climatic range, and extreme isolation (Wagner *et al.* 1985). With this endemism comes a vulnerability to outside influences from human activities and introduced plants and animals.

[2] Using medium growth rate figures.

3A. Ecosystems

Hawai‘i’s forests play a critical role as watersheds, providing recharge to groundwater aquifers and supplying surface water to streams. Unfortunately, many of Hawai‘i’s natural forest ecosystems have been destroyed through clearing for pasture use or development, or degraded by feral animal activity and the spread of invasive plant species.

The diversity of Hawai‘i’s ecosystems can be categorized by ecological systems or vegetation zones (Price *et al.* 2007; TNC 2007; Gagné and Cuddihy 1990; Jacobi 1989; Wagner *et al.* 1985; Cuddihy 1989; DLNR 1989; DLNR 2006). These zones are influenced by moisture, elevation and climate, as illustrated in Figure 8.

The Mauna Kea Watershed Alliance area can be divided into the following ecological zones:

Lowland (Wet) Rain Forest: The lowland rain forest typically occurs on the windward side up to an elevation of 2,500 to 3,000-ft. It is dominated by a closed canopy of ohia (*Metrosideros polymorpha*). Koa (*Acacia koa*) is often co-dominant with ‘ōhi‘a. There is a well-developed secondary sub-canopy of lower-statured tree species, such as ‘olapa (*Cheirondendron* spp.), hame (*Antidesma platyphyllum*), tree ferns (*Cibotium* spp.), kōpiko (*Psychotria* spp.), pilo (*Coprosma* spp.), manono (*Gouldia* spp.), and ‘ahakea (*Bobea* spp.). Native shrubs – such as ‘ākia (*Wikstroemia* spp.), naupaka-kuahiwi (*Scaevola* spp.), māmaki (*Pipturus albidus*), and *Cyrtandra* spp. – and lianas and vines – such as ‘ie‘ie (*Freycinetia-arborea*) and nuku‘i‘iwi (*Strongylodon ruber*) are also prevalent in the understory. Undisturbed forests also have a diversity of mosses, sedges, and small ferns as groundcover. “On steep slopes and in more open lowland wet forests, the matted fern uluhe (*Dicranopteris linearis*) and its relatives may form a dense cover beneath the tree layer” (Cuddihy 1989: 30).

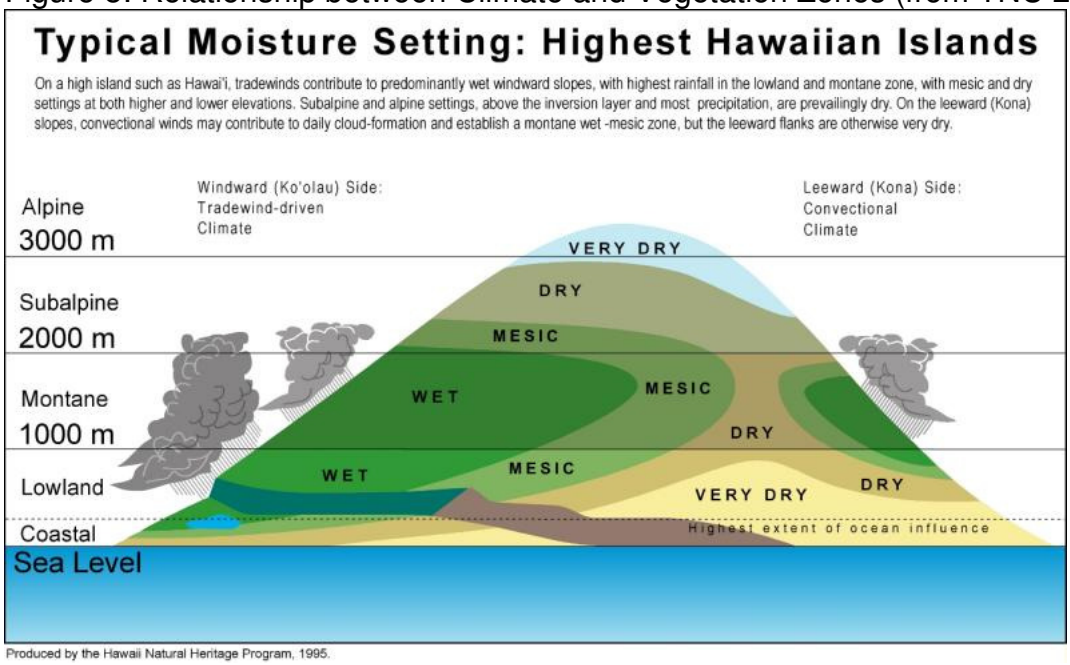
Much of the lowland rain forest was developed for agriculture, beginning with the arrival of early Polynesians. Many remaining forests have been heavily affected by introduced plants and animals. Remaining forests are typically contained in forest reserves, natural area reserves, and national wildlife refuges, providing significant ecological services through the capture of precipitation.

Montane (Wet) Rain Forest: The lowland rain forest transitions upslope on the windward side into the montane rain forest. This zone extends above the 5,500-ft. elevation. Like the lowland rain forest, it is also dominated by a closed upper canopy of ‘ōhi‘a or ‘ōhi‘a-koa mix, with an understory of smaller native trees, shrubs, tree-ferns and groundcover. Common species are kāwa‘u or Hawaiian holly (*Ilex anomala*), ‘āweoweo (*Chenopodium oahuense*), ‘ōlapa, pilo, manono, alani (*Pelea* spp.), kōlea (*Myrsine lessertiana*), olomea (*Perrottetia sandwicensis*), *Cibotium* spp., kanawao (*Broussaisia arguta*), ‘ōhelo-kau-la‘au (*Vaccinium calycinum*), kāmakahala (*Labordia* spp.), pūkiawe (*Styphelia tameiameiae*), *Cyrtandra* spp., *Sicyos macrophyllus*, maile (*Alyxia oliviformis*) and various ephiphytes. Undisturbed forests harbor ground cover

species such as ferns, sedges (*Carex alligata*, *Uncinia uncinata*), vines of the mint family (*Stenogyne*, *Phyllostegia*) and numerous *Peperomia* species (‘ala‘ala-wai-nui).

Montane forests shelter many species of native birds and insects. Much of this area is managed by State and Federal agencies to protect this important ecosystem.

Figure 8: Relationship between Climate and Vegetation Zones (from TNC 2007)



Montane Mesic Forest: This zone represents the transition on the windward side between the montane wet forest and the subalpine communities near the temperature inversion layer. This area experiences less rainfall and, therefore, lacks the dense tree fern and understory layers. It is characterized by an open woodland of koa. It has been used historically for ranching, leaving the forest significantly degraded. According to DHHL (2003), the extensive conversion of native forest to pasture has caused microclimatic changes in parts of the watershed area, “resulting in increased wind speed, reduced moisture collection from fog drip, and more pronounced fluctuations in temperature” (p. 6).

Subalpine: The subalpine zone occurs above the tradewind inversion that restricts the upward movement of clouds; this zone encircles the mountain between approximately 6,000 and 10,000-ft. elevation. The vegetation in this zone is adapted to dry conditions and periodic cold temperatures. It is characterized by an open mamāne or mixed mamāne-naio woodland (Loope 1998; Cuddihy 1989; Scowcroft and Conrad 1992). Mamāne (*Sophora chrysophylla*) occurs in almost pure stands on the eastern, northern, and western slopes of Mauna Kea and in a narrow band at the tree line on the southern slope. The mixed mamāne-naio woodland is restricted to the southwestern slope. Native understory species include pūkiawe, ‘ōhelo (*Vaccinium* spp.), ‘āweoweo,

‘ūlei, a‘ali‘i, *Geranium cuneatum*, and *Dubautia arborea*, and native and introduced grasses. The vegetation becomes more sparse and grows more closely to the ground as elevation increases.

The Silversword or ‘āhinahina (*Argyroxiphium sandwicense ssp. sandwicense*) is found in the upper subalpine region on Mauna Kea. The subalpine zone on Mauna Kea is also the critical habitat of the Federally-listed endangered palila bird (*Loxiodes bailleui*).

Alpine: Weather becomes increasingly severe at higher elevations, and vegetation becomes more sparse. The summit area of Mauna Kea receives very little rainfall and experiences large variations in temperature. Only hardy lichens, mosses, and scattered grasses persist. This region atop Mauna Kea does support a community of native invertebrates such as the wēkiu bug (*Nysius wekiuicola*), which subsists on insects blown up by wind to the summit from lower elevations (Loope 1998).

Lowland and Montane Dry: This zone consists of the entire area below the subalpine zone on the leeward side of Mauna Kea. It has a long history of cattle grazing and is characterized by grasslands and remnant dryland forests. This area has been particularly altered by fire, feral animals, grazing, and alien grass invasion.

Bogs: Bogs are a special type of community that occurs in some of the wettest low- and mid-elevation regions of the montane zone. These develop in areas of poorly drained soil (histosoils) or with an impervious substrate. There is an area above the Hilo Forest Reserve near the Wailuku River known as the Waikoloa Ponds that contains a series of natural and manmade ponds that offer excellent habitat for native and migratory waterbirds.

Lava tubes: Subterranean ecosystems harbor unique communities of endemic, cave-adapted invertebrates (Howarth 1987). The Federally-listed endangered fern Asplenium (fragile fern) is also found near lava tube openings. Lava tubes and caves provide moderate fluctuations in temperature and humidity compared to open surface areas, which is vital to these species. Roots of surface plants descending into the caves provide a food source for these native insects and spiders. These unique environments are susceptible to direct damage within the lava tubes and from destruction of native vegetation on the surface of the caves.

Freshwater Ecosystems: As noted earlier, freshwater streams are an important ecological habitat within the MKWA area. Section 3B “Species” describes the unique aquatic species that inhabit this zone. Many members of Hawai‘i’s native stream biota are descendants of marine species (Ford and Kinzie 1982 in Loope 1998). Unfortunately, many of these freshwater ecosystems are not afforded much protection in their lower reaches, as they flow through agricultural and urban areas. Polluted runoff, stream diversions, and introduced species put these ecosystems at risk.

Figure 9 delineates the specific native ecosystems found in the MKWA area. This HI-GAP land cover map depicts specific native cover types, as well as alien-dominated and anthropogenic classes. It provides information on physiognomy (grassland, shrubland, forest), dominant overstory and understory species, and canopy type.

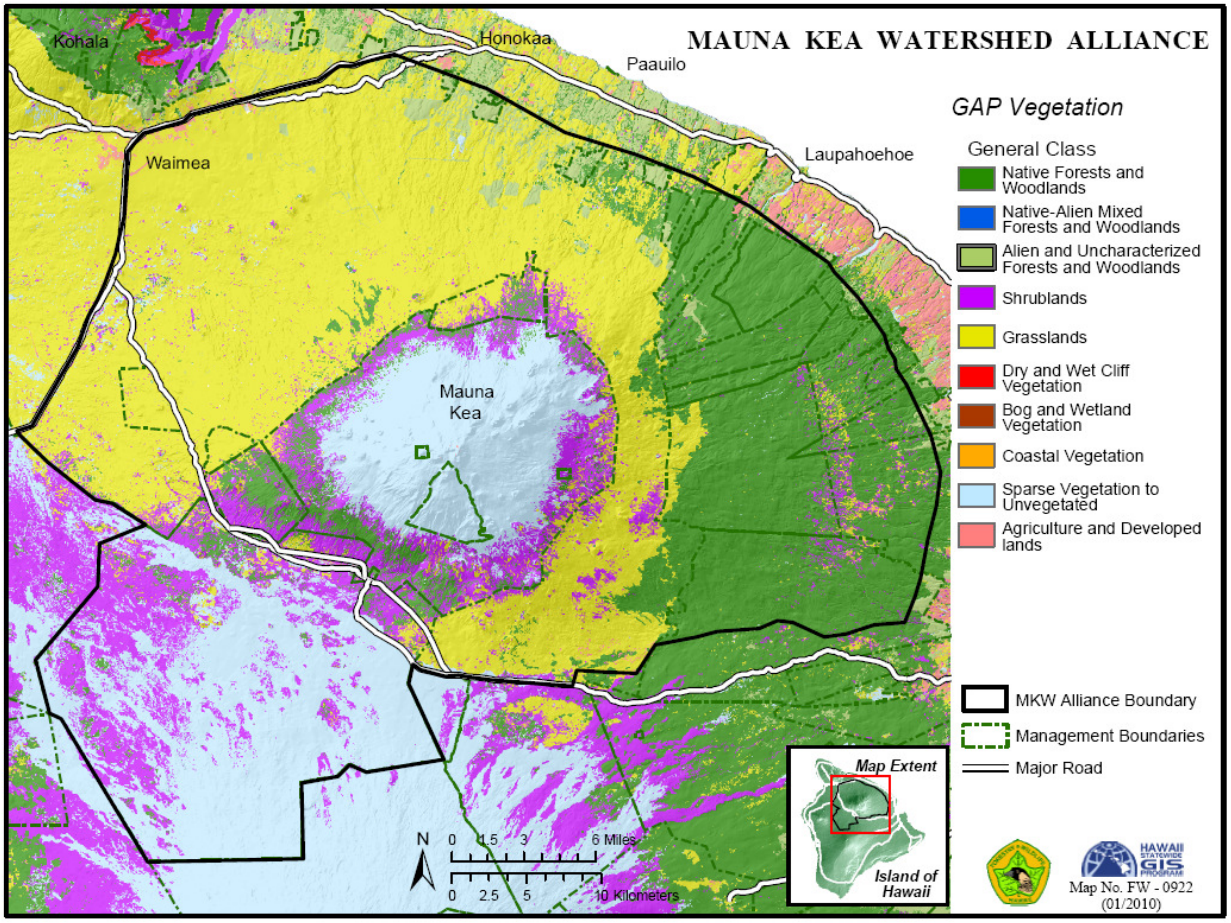


Figure 9: HI-GAP Land Cover (USGS 2006)[create new map similar to one that Namaka has with detailed vegetation types (e.g., closed koa-ohia forest, mamane-naio forest)]

3B. Species

Mauna Kea provides an important habitat for many species of unique plants and animals. The majority of these native birds, mammal, invertebrates, aquatic species, and plants are not well-studied. Some are well-protected, with stable or increasing populations; others are decreasing or nearing extinction, threatened generally by introduced species and landscape changes. Global climate change may also have a long-term effect on many species.

(a) Native Birds: All of Hawai‘i’s endemic bird species evolved from a small number of species that inadvertently migrated to Hawai‘i. Fossil evidence suggests that only a quarter of Hawai‘i’s original bird taxa survive today. Of the 76 species of endemic perching birds and songbirds (passerine species), 31 are known only as fossils, 19 are now extinct, and 18 are listed as endangered species (including some that may have

recently become extinct) (Loope 1998). Only eight species are not classified as endangered.

Non-passerine species include geese, ducks, rails, ibises, and raptors. Of the 39 endemic Hawaiian non-passerine species, the majority are known only as fossils (Loope 1998). Of the eight species known historically, two are extinct and the remaining are listed as endangered.

The following native birds are found in the Mauna Kea Watershed Alliance area (Scott *et al.* 1986; USFWS 2006; Mitchell *et al.* 2005) (Table 5). Scott *et al.* (1986) provides information about each species, its habitat and distribution.

Forest Birds: Of the birds of the Hawaiian honeycreeper family (Fringillidae), apapane, ‘i‘iwi, and ‘amakihi are the most widespread, occurring in the native montane and mesic ‘ōhi‘a-koa forests above 4,100-ft. elevation. The ‘amakihi densities on Mauna Kea are highest in the mamāne-naio forests. The historical range of these honeycreepers was likely broader, but has been limited to higher elevations due to their susceptibility to avian malaria carried by *Culex* mosquitoes at lower elevations. These birds are important ‘ōhi‘a pollinators.

Table 5: Native Birds on Mauna Kea

Hawaiian Name	Scientific Name	Listed T&E	Critical habitat	Recovery plan
‘apapane	*Himatione sanguine* (honeycreeper)			
Hawai‘i ‘amakihi	*Hemignathus virens* (honeycreeper)			
‘i‘iwi	*Vestiaria coccinea* (honeycreeper)			
‘o‘u	*Psittirostra psittacea* (honeycreeper)	1967		2006
‘akiapōlā‘au	*Hemignathus munroi* (honeycreeper)	1967		2006
Hawai‘i creeper	*Oreomystis mana* (honeycreeper)	1975		2006
Hawai‘i ākepa	*Loxops coccineus coccineus* (honeycreeper)	1970		2006
Palila	*Loxoides bailleui* (honeycreeper)	1967	1977	2006
Hawai‘i ‘elepaio	*Chasiempis sandwichensis sandwichensis* *C.s. ridgwayi* *C.s. bryani*			
‘ōma‘o	*Myadestes obscures* (thrush)			
‘io	*Buteo solitarius* (Hawaiian hawk)	1967		1984
Pueo	*Asio flammeus sandwichensis* (Hawaiian short-eared owl)			
Nēnē	*Branta sandvicensis* (Hawaiian goose)	1967		2004
koloa maoli	*Anas wyvilliana* (Hawaiian duck)	1967		2005

Another Hawaiian honeycreeper, the mainly insectivorous ‘Akiapōlā‘au (*Hemignathus munroi*), is Federally-listed as endangered. While its range can

extend from the mesic to wet koa-ʻōhiʻa forest to the dry mamāne-naio woodland, the largest populations in the MKWA are found in the koa-ʻōhiʻa forests on windward Mauna Kea and Mauna Loa from Hakalau Forest National Wildlife Refuge (NWR) to the Waiakea Forest Reserve.

The Hawaiʻi Creeper (*Oreomystis mana*) is another Hawaiian honeycreeper listed as endangered. This bird occurs in four disjunct populations above 5,000-ft. elevation on the windward side of Hawaiʻi Island. It inhabits the mesic and wet forests dominated by ʻōhiʻa and koa.

The ʻoʻu (*Psittirostra psittacea*) is an endangered Hawaiian honeycreeper which may now be extinct (Mitchell *et al.* 2005). This nectivorous bird occurs in mid-elevation mesic to wet ʻōhiʻa forests. The understory plants ʻieʻie (*Freycinetia arborea*) and *Clermontia* spp. are important parts of its diet. While a few birds were sighted on Mauna Kea during the 1976-1981 Hawaiian Forest Bird Surveys, ʻoʻu have not been detected during more recent surveys.

The Hawaiʻi ʻākepa (*Loxops coccineus coccineus*) is an endangered Hawaiian honeycreeper endemic to the island of Hawaiʻi at the subspecies level. It occurs in five disjunct populations all above 4,300-ft. elevation in the ʻōhiʻa and ʻōhiʻa-koa forests on the windward side of the island. The highest density of ʻākepa occurs in the Pua ʻAkala tract of Hakalau Forest NWR.

The palila (*Loxoides bailleui*) is an endangered Hawaiian honeycreeper, whose survival is linked to the subalpine mamāne woodlands on Mauna Kea. Ninety percent of the palila's diet consists of immature mamāne seeds; the remainder comprises mamāne flowers, buds, leaves, and naio berries. The palila is one of the last remaining seed-eating honeycreeper species in the Hawaiian Islands. Palila populations are concentrated on the southern and western slopes of Mauna Kea between 6,500-9,250-ft. elevation. The habitat upon which it depends is threatened by browsing sheep, drought, and risk of wildfire. The palila was Federally-recognized as endangered in 1966 and critical habitat was designated by the U.S. Fish and Wildlife Service (USFWS). Since 1979, the protection of palila critical habitat from ungulates has been legally challenged numerous times (see Chapter 4).

The Hawaiʻi ʻelepaio (*Chasiempis sandwichensis*) is a monarch flycatcher (Monarchiade Family) endemic to the island of Hawaiʻi at the subspecies level. There are three subspecies – *C.s. sandwichensis*, *C.s. ridgewayi*, and *C.s. bryani* – all found on Mauna Kea. The highest densities occur in the ʻōhiʻa and mixed ʻōhiʻa-koa forests above 3,600-ft. There is also an isolated population on the western slope of Mauna Kea.

The ʻōmaʻo (*Myadestes obscures*), one of five species of Hawaiian solitaires, is endemic to Hawaiʻi Island. It occurs on the windward slope of Mauna Kea in the mesic and wet montane ʻōhiʻa and mixed ʻōhiʻa-koa forests. Its life cycle is relatively

well-studied. Its diet consists primarily of fruits of native and introduced understory plant species and invertebrates.

The Hawaiian forest birds found on Mauna Kea are threatened by habitat loss and degradation, susceptibility to introduced avian diseases, predation from introduced animals, competition from introduced birds, reduction in food sources, low reproductive output, and isolated populations.

Non-Passerine Species

Pueo or Hawaiian short-eared owl (*Asio flammeus sandwichensis*) is an endemic subspecies of the short-eared owl. Pueo are active during the day and occupy a variety of habitats, though they are most commonly found in open habitats such as grasslands, shrublands and montane parklands. Their distribution ranges from sea level to 8,000-ft. elevation.

The ʻio or Hawaiian hawk (*Buteo solitarius*) is the only broad-winged hawk known to have colonized Hawaiʻi. The species is Federally-listed as endangered. ʻIo occurs throughout Hawaiʻi Island from sea level to 5,600-ft. elevation. Its diet consists of native and introduced birds and insects, and introduced rodents.

The nēnē or Hawaiian goose (*Branta sandvicensis*) is one of just a few native waterbird species remaining in the Main Hawaiian Islands. All populations of this endangered species have been or are currently being supplemented by captive-bred birds. Once widespread, nēnē suffered drastic decline due to human hunting, predation by introduced mammals, and other human-induced stresses. Current population is estimated at approximately 503 birds on the island of Hawaiʻi. In addition to nēnē at Volcanoes National Park, there are individuals at the Pōhakuloa Training Area and Keʻāmuku Maneuver Area and at Puʻu Oʻo Ranch off Saddle Road. Hakalau Forest NWR also has a breeding population of nēnē. Nene occur from sea level to 7,900-ft. elevation.

Koloa maoli or Hawaiian Duck (*Anas wyvilliana*) is another endangered Hawaiian waterbird. It is generally found in wetland habitats from sea level to 9,900-ft elevation. Populations on Hawaiʻi Island occur in the Kohala Mountains, windward Kohala valleys, and on Mauna Kea.

These species are threatened by predation, habitat loss or degradation, avian diseases, contaminants or toxins, and human interaction.

(b) Native Mammal

The Hawaiian hoary bat (*Lasiurus cinereus semotus*) is the only native terrestrial mammal found in Hawaiʻi. It was Federally-listed as endangered in 1970, and a recovery plan was prepared in 1998 (USFWS 1998a). The hoary bat has not been well-studied. It roosts by day in a variety of tree species and forages by night in a wide range of habitat types. It appears to migrate seasonally and elevationally.

Hoary bat are more common on the drier side of Hawai‘i but are found in wet areas. While the bats occur primarily below 4,000-ft. elevation, they are also commonly seen between 4,000 and 8,000 ft. Bat surveys at Hakalau Forest NWR detected high densities of bats. Bats prefer an edge or open habitat and have been detected in the area of the orchard, old cabin, and roads in the vicinity of Keanakolu (DLNR 2006).

In recent years, there have been several reports of dead Hawaiian hoary bats entangled on the top barbed wire strand on fences at The Nature Conservancy's Kona Hema Preserve (South Kona) and at PTA. These fences have the barbed wire to keep ungulates out of native plant exclosures. A Biological Opinion issued by USFWS in 2008 for PTA requires that the top barbed wire strand be removed from all fences at PTA as a means to address this problem.

(c) Native Invertebrates

Invertebrates fill a wide variety of ecological roles: they pollinate native plants, are important predators and prey in food webs, and return nutrients to the soil. Invertebrates in Hawai‘i, comprising arthropods and snails, have adapted to a wide variety of environments, including lava tubes and cinder fields. Most of these native invertebrates are found nowhere else in the world. Some species are found within limited ranges, and many are extremely host-specific. Most species have been poorly studied, and, in the words of Howarth and Mull (1992), "[m]any native arthropods may become extinct without any documentation that they ever existed" (p. 34).

Table 6 lists invertebrates found on Mauna Kea that are considered of special concern. Some are proposed or candidate species for listing as threatened or endangered under State and/or Federal law. Others are regarded as species of concern. There are undoubtedly many other invertebrate species that also should be identified for special protected status; however, a lack of basic information on their status and natural history hinders quick action.

Table 6: Native Invertebrates of Special Concern

Group	Scientific Name	Common Name	Legal Status
Arthropod	*Nysius wekiucola*	Wēkiu bug	FC[3]
	Agrotis melanoneura	Black-veined agrotis noctuid moth	FSOC[4], HSOC[5]
	Coleotichus blackburniae	Koa bug	FSOC
	Hylaeus difficilis	Difficult yellow-faced bee	HSOC
	Hylaeus flavipes	Yellow-footed yellow-faced bee	FSOC, HSOC
	Hylaeus kona	Yellow-faced bee	FSOC, HSOC
	Hylaeus laetus	Yellow-faced bee	FSOC, HSOC
	Hylaeus ombrias	Yellow-faced bee	FSOC, HSOC
	Hylaeus sphecodoides	Yellow-faced bee	FSOC, HSOC
	Micromus usingeri	Flightless brown lacewing	
	Drosophila spp.	Hawaiian picture-wing flies	FC, SC[6]
	Manduca blackburni	Blackburn's sphinx moth	Endangered
	Megalagrion spp.	Damselfly	SC
Snail	*Succinea konaensis*	Succineid snail	FSOC
	Vitrina tenella	Zonitid snail	FSOC

According to Howarth and Mull (1992), Hawai'i's total insect fauna of about 10,000 endemic species evolved from only 350-400 species that originally colonized the islands. Hawai'i's endemic insects represent only 15% of the known families of insects. Many of Hawai'i's insects made adaptive shifts as they have evolved. For example, many Hawai'i insects have become flightless; others have adapted to cave living; still others have changed their feeding preferences.

The wēkiu bug (*Nysius wekiuicola*) is representative of an unusual insect that inhabits Mauna Kea. It is a small, flightless seed bug that resides in the spaces between the loose cinder on the summit. Rather than eating seeds, it has adapted to feed on insects and other materials blown up from lower elevations on the mountain. It survives in a harsh, desolate environment, frequently covered in snow. Other arthropods inhabit this same environment.

Hawaii's *Drosophila* species were recently listed as species of Federal and State concern. The USFWS prepared a Recovery Outline for twelve Hawaiian Picture-wing

[3] Federal Candidate Species
[4] Federal Species of Concern
[5] Hawaii Species of Concern
[6] State Candidate Species

Flies in August 2006. This document serves as an interim guidance to direct recovery efforts and informs consultation and permitting activities until a comprehensive draft recovery plan has been completed. Two species of the picture-wing flies are found in the mesic to wet montane environments on Mauna Kea: *Drosophila heteroneura* and *Drosophila ochrobasis*.

Hawai‘i’s arthropods are threatened by a number of factors: direct trampling or crushing of species’ habitats; invasive alien insect species that compete with, prey on, or spread disease among native species; insect-loving vertebrates, such as the introduced coqui frog, that consume large numbers; and habitat degradation resulting in the loss of the host species. These threats are described in Chapter 3.

Hawai‘i’s land snails are another important terrestrial invertebrate. Over 98% of known land snail species are endemic to the Hawaiian Islands (Mitchell *et al.* 2005). They occur in all native forests, including dry, mesic and wet. It is believed that 90% of Hawai‘i’s native land snail species are extinct. The remaining ones are dangerously threatened by introduced species, particularly rats. Preliminary field surveys revealed that snails of at least three families persist in subalpine Mauna Kea [Lisa H will provide list], but their population levels and geographic ranges are unknown.

(d) Native Aquatic Species

Hawai‘i’s streams support a unique and diverse native fauna, including native fish, shrimp, mollusks and insects, found nowhere else in the world (See Table 7). As noted earlier, many of these species -- including all five species of fish (four gobies and an eleotrid), shrimp, and snails – descended from marine species. This connection to the ocean remains, in that many of the species have an amphidromous life cycle in which the adults live and breed in fresh water streams, while the newly hatched larvae are washed out to sea where they live in the oceanic plankton for several months before returning to freshwater.

There are five species of native stream fish: four gobies and one eleotrid. Four are endemic and one is indigenous. Native stream shellfish consists of two crustaceans and several mollusks, all of which are endemic. All these species are adapted to life in fast flowing streams. The distribution of the fish species along the stream is believed to be affected by their climbing ability.

Table 7: Hawai‘i’s Native Aquatic Species

Group	Scientific Name	Common Name	Endemic or Indigenous	Distribution
Fish	*Awaous guamensis*	‘o‘opu nakea	I	Lower to middle stream reaches
	Stenogobius hawaiiensis	‘o‘opu naniha	E	Estuary and lower stream reaches; prefers soft bottoms
	Sicyopterus stimpsoni	‘o‘opu nopili	E	Middle stream reaches; fast-flowing water
	Lentipes concolor	‘o‘opu alamo‘o	E	Upper stream reaches

Group	Scientific Name	Common Name	Endemic or Indigenous	Distribution
	Eleotris sandwicensis	‘o‘opu akupa	E	Estuaries and lower stream reaches
Crustacean	*Atyoida bisulcata*	‘ōpae kala‘ole	E	Upper reaches in fast moving water
	Macrobrachium grandimanus	‘ōpae ‘oeha‘a	E	Estuary and lower stream reaches
Mollusks	*Neritina granosa*	Hīhīwai	E	Lower and middle stream reaches
	Neritina vespertina	Hapawai	E	Eastuary and lower stream reaches
	Theodoxus cariosus	Pīpīwai	E	Bracking water species found in estuarine areas
Insects	*Megalagrion blackburni*	Blackburn’s Hawaiian damselfly	E	Along swift, upland streams
	M. calliphya	Beautiful Hawaiian damselfly	E	Upland above 1,000-ft.
	M. xanthomelas	Orangeblack Hawaiian damselfly	E	Lowland species; occasionally breeds along terminal and lower midreaches of perennial streams
	M. hawaiiense	Hawaiian upland damselfly	E	Wide range of elevations, headwaters and midreaches of perennial streams
	M. koelense	Kō‘ele Mountain damselfly	E	Forest canopy; sometimes riparian forests
	Anax strenuous	Pinao, giant Hawaiian dragonfly	E	Streams and wetland areas
	Nesogonia blackburni	Blackburn’s skimmer	E	
	Pantala flavenscens	Globe skimmer	I	
	Anax junius	Green darner	I	

Four fish species belong to the Gobiidae family because their pelvic fins are fused to form a sucking disk: *Awaous guamensis* (‘o‘opu nakea); *Stenogobius hawaiiensis* (‘o‘opu naniha); *Sicyopterus stimpsoni* (‘o‘opu nopili); and *Lentipes concolor* (‘o‘opu Alamo‘o). The sucking disk helps these species cling to rocks in fast-flowing water and allows them to migrate upstream by climbing waterfalls, weirs, and other obstacles. The *Eleotris sandwicensis* (‘o‘opu akupa) is placed in the Eleotridae family because its pelvic fins appear as two distinct fins. None of the native fish species have been Federally-listed, though the ‘o‘opu alamo‘o is considered a potential candidate (Loope 1998).

The primary stream insects associated with Hawai‘i’s streams are damselflies and dragonflies. The native Hawaiian damselflies in the genus *Megalagrion* are endemic. It is believed that all species of *Megalagrion* evolved from a single colonizing species (Polhemus and Asquith 1996; Howarth and Mull 1992). Damselflies formed distinct species on each of the islands or island groups and began to colonize or specialize in different types of habitats. The ancestors of the native Hawaiian dragonflies likely colonized the Hawaiian Islands by flight. As a result, their descendants remain strong fliers and likely move between the islands, so that species are more widespread around the Hawaiian Islands.

DLNR’s Division of Aquatic Resources (DAR) conducts periodic surveys of the biota in Hawai‘i’s streams. Its Freshwater Database contains survey data from the State’s perennial and intermittent streams, compiled from a variety of sources. The database identifies native and exotic species of fish, crustaceans, mollusks, insects, and algae, and notes the elevation at which the data were collected. The data date back to the 1960s. Data for the streams on Mauna Kea were collected in 1966-1969, 1989-1996, and 2003-2004. All of Hawai‘i’s native fish and crustacean species, and two of the mollusks are found on Mauna Kea. *Megalagrion* species are common, as is *Anax strenuus*. Table 2 on page 12 identifies the streams in which native aquatic species have been found.

Hawai‘i’s native aquatic species are threatened by alien aquatic species intentionally or accidentally introduced into streams, water pollution, stream channelization, and reduced stream flow due to diversions.

(e) Native Plants

Hawai‘i’s native-dominated vegetation varies greatly by elevation, moisture regime, and substrate, as described under Ecological Zones above. Native vegetative communities have undergone extreme alteration because of past and present land management practices.

The primary threats to plant species listed in the Big Island Plant Cluster Recovery Plan (USFWS 1996, 1998b) are habitat destruction and modification, and competition from alien species. Specific threats include ranching, alien plant and animal introductions, agricultural development, fire, direct human perturbation such as recreational and military activities, pest invasions, disease, and plant vulnerability due to small population size.

When a species is listed as endangered or threatened under the Endangered Species Act, it is automatically added to the State’s list of protected species (Chapter 195D, Hawai‘i Revised Statutes (HRS)). The Big Island Plant Cluster Recovery Plan (USFWS 1996) and its Addendum (USFWS 1998b) listed the following plants within the MKWA area (Table 8). The current (2010) Hawai‘i Department of Land and Natural Resources list of threatened and endangered plants of Hawai‘i classifies nearly all of these plants as Endangered, with two listed as Threatened (http://www.state.hi.us/dlnr/dofaw/pubs/TEplant.html).

The objectives of the Big Island Plant Cluster Recovery Plan (USFWS 1996, 1998b), as well as the Mauna Kea Silversword Recovery Plan (USFWS 1993), are to protect and conserve these plants and their habitats by controlling threats, increasing wild plant individuals and populations, creating new populations within their historical range, and conducting necessary research. The ultimate goal is recovery sufficient for delisting the species, so that protection by the Endangered Species Act is no longer necessary.

Within the Mauna Kea Watershed Alliance area, a number of formal efforts are taking place to address the protection of native threatened and endangered plants. For example, Hakalau Forest National Wildife Refuge (NWR) has major habitat management programs to conserve endangered forest birds and their habitat. Units within the NWR support nine endangered bird species, one endangered bat species, and more than twenty rare and endangered plant species. Hakalau Forest NWR habitat management programs include the control and removal of feral ungulates and alien species, population monitoring, species outplanting and reforestation, predator control, and biological research. Additionally, within the borders of Pōhakuloa Training Area, 15 plants and 4 animals are on the threatened and endangered species list, and are protected. Some organizations that have collected and germinated seeds of plants covered in the Big Island Plant Cluster Recovery Plan include the Volcano Rare Plant Facility on Hawai‘i Island, Lyon Arboretum on O‘ahu, and National Tropical Botanical Garden on Kaua‘i.

Specific information on individual threatened and endangered plant species can be found in the Big Island Plant Cluster Recovery Plan (USFWS 1996, 1998b) and the Mauna Kea Silversword Recovery Plan (USFWS 1993). These recovery plans summarize available information about each plant, review the threats posed to their continued existence, and list management actions that are needed to control, reduce, or remove these threats.

Table 8: Threatened and Endangered Plants within the MKWA Area

Scientific Name	Common Name	Population within MKWA: Historical (H) Current (C) including outplanted populations	Status: Threatened (T) Endangered (E)	Land Steward of Hawaii Island Populations*
Argyroxiphium sandwicense subsp. *Sanwicense* (Asteraceae). (USFWS 1993)	ʻāhinahina, Mauna Kea Silversword	H, C	T	Multiple
Clermontia lindseyana;	ʻōhā wai	H, C	E	FL, SL, PL
Clermontia peleana subsp. *peleana*	ʻōhā wai	H, C	E	FL, SL
Clermontia pyrularia subsp. *singuliflora*	ʻōhā wai	H	E	FL, SL
Clermontia pyrularia	ʻōhā wai	H, C	E	HNWR
Cyanea platyphylla	hāhā	H, C	E	NAR, FR, PL
Cyanea shipmanii	hāhā	H, C	E	HNWR
Colubrina oppositifolia	kauila	H	E	SL, PL
Cyrtandra giffardii	haʻiwale	H, C	E	FL,SL
Cytrandra tintinnabula	ha'iwale	H, C	E	SL,PL
Mariscus fauriei (may be just outside MKWA area)	No common name	C	E	SL,PL
Melicope zahlbruckneri	Alani	C	E	NP, NAR
Neraudia ovata (may be just outside or along border of MKWA area)	No common name	H, C	E	PTA, SL,PL
Phyllostegia racemosa	kīponapona	H, C	E	NP, HNWR, SL, PL
Phyllostegia warshaueri	No common name	H, C	E	SL, NAR, PL
Plantago hawaiensis (may be just outside or along border of MKWA area)	laukahi kuahiwi	H, C	E	FL, SL
Portulaca selerocarpa	poʻe	H, C	E	PTA
Silene hawaiiensis	No common name	C	T	PTA
Tetramolopium arenarium subsp. *arenarium* var. *arenarium*	No common name	C	E	PTA
Tetramolopium arenarium subsp. *arenarium* var. *confertum*	No common name	H	E	PTA
Tetramolopium arenarium subsp. *Laxum* (possible historic population)	No common name	H	E	PTA
Zanthoxylum hawaiiense	aʻe	H, C	E	PTA

* From 1996 and 1998 Big Island Plant Cluster Recovery Plans: FL-Federal unspecified, PTA- Pōhakuloa Training Area/ Department of Defense, HNWR- Hakalau National Wildlife Refuge, SL- State Land unspecified, NAR- Natural Area Reserve, FR- Forest Reserve, PL- Private Land unspecified

The alpine stone desert is a unique environment found at the summit of Mauna Kea above the 12,800-ft. elevation. According to SRGII (2009), the vegetation community in the alpine stone desert "consists of several species of mosses and lichens, an unknown number of species of algae, and a small number of vascular plants, predominantly the same species found in the alpine shrublands and grasslands" (p. 2.2-12). Over 21 species of lichens and approximately 12 species of mosses have been identified in the alpine stone desert (Smith *et al.* 1982). Around half of the lichen species and most of the moss species found on Mauna Kea are endemic. One species of lichen, *Umbilicaria pacifica,* is found only on Mauna Kea (Smith *et al.* 1982; Char 1999). The most abundant native vascular plant species found in these elevations are two grass species, Hawaiian bentgrass (*Agrostis sandwicensis*) and pili uka (*Trisetum glomeratum*), and two fern species, 'iwa'iwa (*Asplenium adiantum-nigrum*) and Douglas' bladderfern (*Cystopteris douglasii*).

B. Sociocultural Resources

1. Land Ownership

There are 12 major landowners holding properties of more than 1,000 acres within the Mauna Kea Watershed Alliance area. (See Figure 10 and Table 9.) The majority of these landowners are members of the Alliance. Land ownership is divided between public and private landowners, with 78% of the MKWA publicly-owned.

Table 9: Acreage of Parcels over 1,000 Acres Within the MKWA

Major Owner	**Acreage**	**Proportion**
MKWA Members or Membership Under Consideration by Landowner		
Gov't State Dept. of Land and Natural Resources	280,936	54%
Gov't State Dept. of Hawaiian Homelands	68,195	13%
Gov't Federal	56,402	11%
Parker Ranch	80,037	15%
Kukaiau Ranch	9,321	2%
Kamehameha Schools	4,594	1%
Queen Lili'uokalani Trust	1,712	0.3%
Other Landowners		
B.I. Lee	9,336	2%
Hawai'i Forest Preservation LLC	1,579	0.3%
'Ohana Sanctuary	2,775	0.5%
'Ōma'oma'o Corp.	1,982	0.3%
R.B. Acree	1,105	0.2%
Total		99.6%

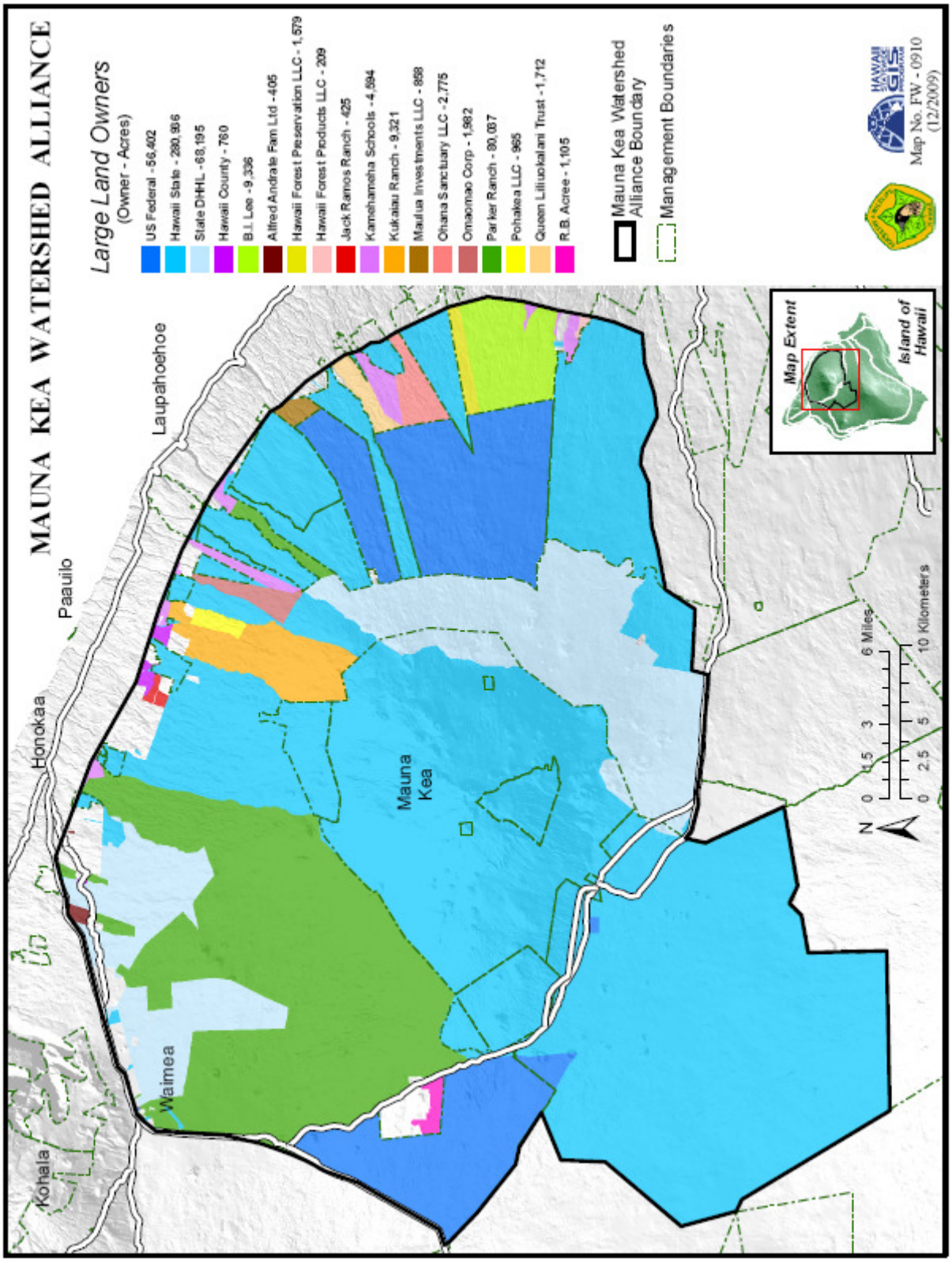


Figure 10: Major Landowners [new map?]

2. Land Use Zones

State Land Use Districts

The Hawai‘i Land Use Law, Chapter 205, Hawai‘i Revised Statutes (HRS), places all lands in the State into four districts: Conservation, Agricultural, Urban and Rural (Figure 11). Lands in the Conservation District are managed by the State. The jurisdiction over Agricultural and Rural District lands is shared by the State Land Use Commission (LUC) and the counties. Responsibility for zoning within the Urban District is delegated to the counties. Changes to the boundaries can be done by ordinance of the County Council for areas of 15 acres or less. Otherwise, the LUC must approve changes by a 2/3 vote (6 of the 9 members must approve). Only the LUC can take land out of the Conservation District.

Conservation District: Lands in the Conservation District are managed by the Department of Land and Natural Resources (DLNR) pursuant to Chapter 183C, HRS, and Chapter 13-5, Hawai‘i Administrative Rules (HAR). Fifty-six percent of the lands within the MKA area fall within the Conservation District. Generally, the lands are managed to conserve, protect, and preserve the important natural resources essential to the preservation of the State’s fragile natural ecosystems and the sustainability of the State’s water supply. A Conservation District Use Application (CDUA) must be submitted to and be approved by the Board of Land and Natural Resources before any use of land in the Conservation District can occur.

The Conservation District on Mauna Kea is subdivided into four subzones: Protective, Limited, Resource, and General (Figure 12). Chapter 13-5, HAR, defines the objectives and types of activities allowed for each subzone. Most of the Conservation District (68%) within the MKWA area falls within the Resource subzone (204,690 ac.), to be managed to ensure sustained use of the natural resources. The other subzones on Mauna Kea are: Limited (60,822 ac. or 20%), where natural conditions suggest constraints on human activities; Protective (29,180 or 10%), encompassing lands and waters necessary to protect watersheds, water sources, and water supplies, as well as natural ecosystems, and significant historic, archeological or geological features; and General (4,997 ac. or 2%), designated open space where specific conservation uses may not be defined but where urban use would be premature.

Agricultural Lands: Forty-four percent of lands within the MKWA area fall within the Agricultural District. Chapter 205, HRS, delegates responsibility for zoning within the agricultural districts to the counties. For agricultural lands, however, Chapter 205, HRS, outlines permitted uses of agricultural lands classified as “A” or “B” by the Land Study Bureau’s land productivity rating system. In Hawai‘i County, Chapter 25, Hawai‘i County Code (HCC), regulates zoning and identifies permitted uses and other regulations. Under this ordinance, the State Agricultural District is further subdivided into subzones (agriculture, family agriculture, intensive agriculture, etc.), which the County also refers to as “districts.”

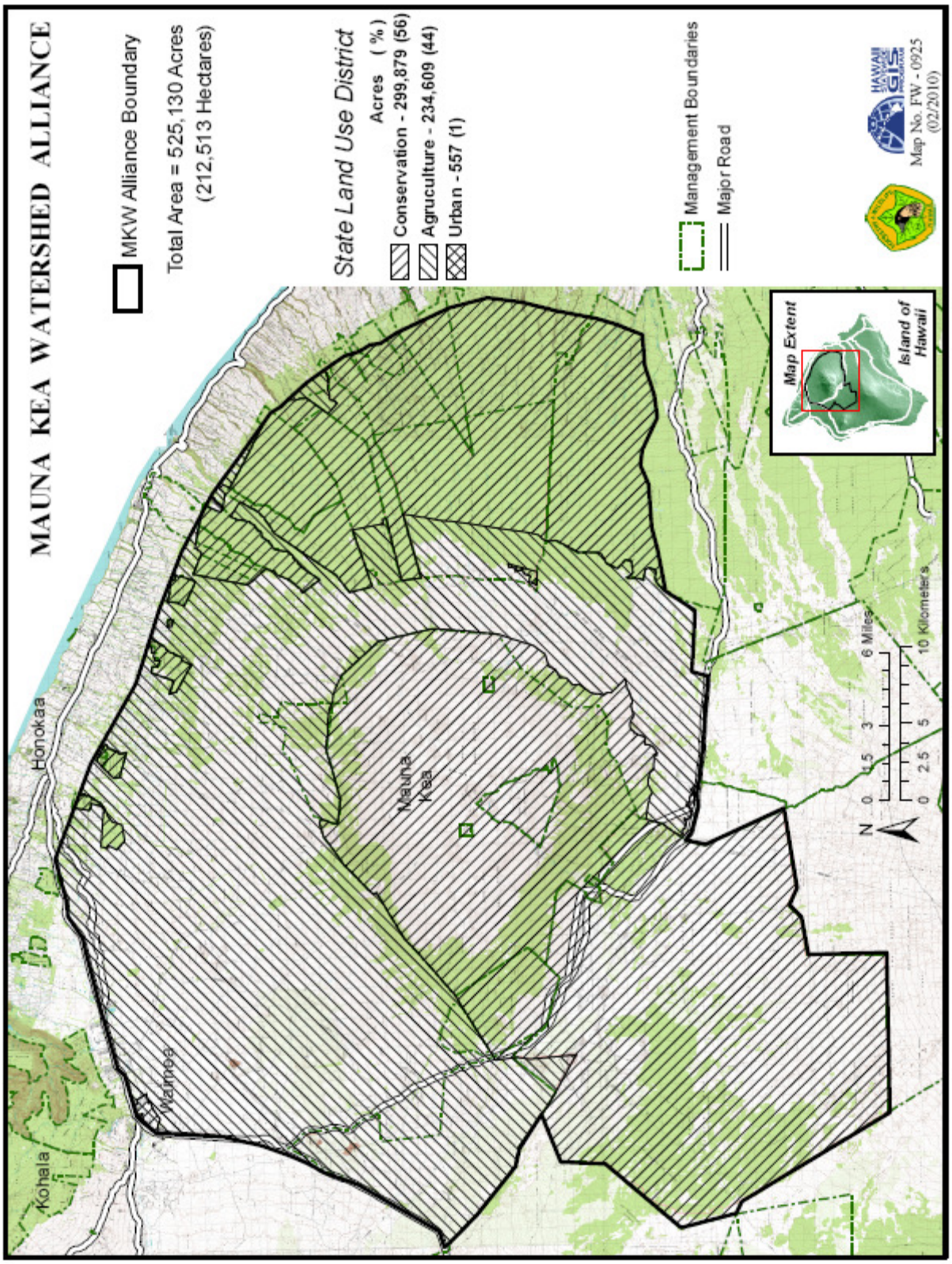


Figure 11: State Land Use Districts [new map?]

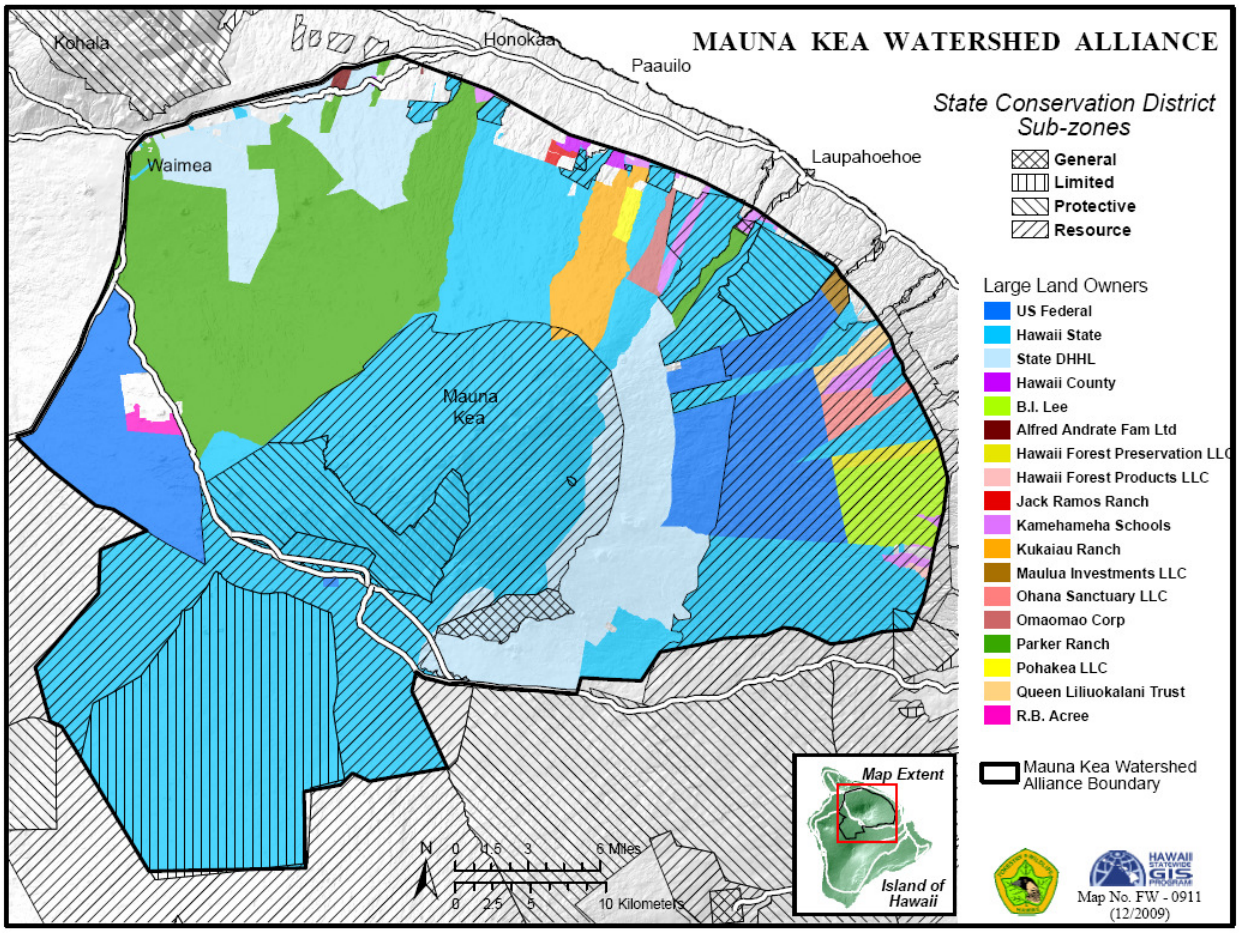


Figure 12: Conservation District Subzones

Article XI, Section 3, of the Hawai‘i State Constitution mandates the State to conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency and assure the availability of agriculturally-suitable lands. Chapter 205, HRS, also requires that State and county agricultural policies, tax policies, land use plans, ordinances and rules promote the long-term viability of agricultural use of important agricultural lands. The County General Plan (Hawai‘i County 2005) establishes policies to prohibit rezoning of important agricultural lands to parcels too small to support economically-viable farming units in order to discourage speculative residential development on agricultural lands.

Important Agricultural Lands (IAL) are those with better potential for sustained high agricultural yield because of soil type, climate, topography, or other factors. They were determined in the Hawai‘i County General Plan (Hawai‘i County 2005) by including the following lands identified in a number of studies (ALISH classification system, LSB soil survey report, NRCS study of suitability). Figure 13 present the Land Use Pattern Allocation Guide (LUPAG) map from the Hawai‘i County General Plan (2005). Important Agricultural Lands are identified by the light green.

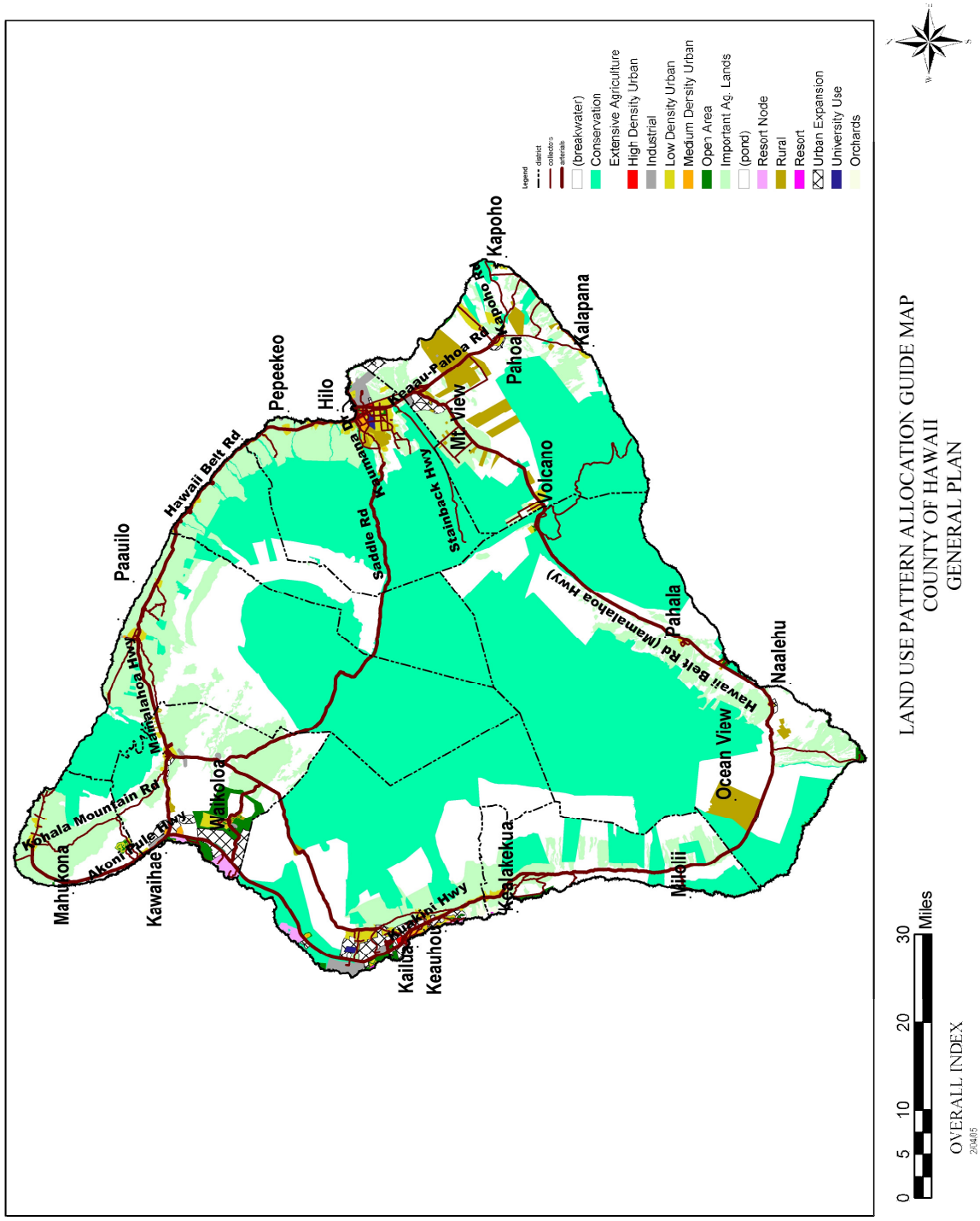


Figure 13: Hawai‘i Land Use Pattern Allocation Guide (LUPAG) map
(Hawai‘i County 2005)

Urban Lands: Less than one percent of the Mauna Kea Watershed Alliance area is designated Urban. The urban district is entirely under county jurisdiction, and uses are controlled only by county zoning. The Zoning Code, Chapter 25, HCC, lists the permitted uses within each zone, and also the required setbacks, height limits, parking areas for commercial developments, and other controls.

Generally, all development within the County must conform to the policies outlined in its General Plan (2005) and specific community development plans. The County general plan provides a coordinated set of guidelines for decision-making regarding future growth and development, and protection of natural and cultural resources. The general plan also guides revisions and updates to the county code. The plan is given the effect of law through adoption by the County Council. Generally, the general plan has policies related to protecting the county's natural resources and minimizing adverse effects resulting from the inappropriate location, use, or design of sites and structures; protecting wetlands and riparian areas; and designing drainage systems to minimize polluted runoff, retain streambank vegetation, and maintain habitat and aesthetic values.

The County general plan is implemented through the specific community development plans; budgeting and capital improvement programs guided by the goals, objectives and policies of the general plan and community development plans; county laws amended to be consistent with the intent of the general plan components; and approval or disapproval of developments seeking zoning and other development approvals based on how they support the visions expressed in the general plan. A community development plan for the South Kohala district was completed in 2008 and adopted by the County Council (Hawaiʻi County 2008). The community development plan for the Hāmākua district is currently in process.

Hawaiʻi County's 2005 General Plan also includes Land Use Pattern Allocation Guide (LUPAG) maps by district that show conservation, agricultural, rural, resort and urban areas, urban expansion areas, and open areas (Figure 13). These serve to guide the location, type, and intensity of different land uses.

3. Historic and Current Land Management

Hawaiʻi's traditional system of land and water tenure and management centered on the ahupuaʻa, a wedge of land that extended from the mountains to the ocean and often followed natural watershed divisions. Land and water resources were under the control of the aliʻi (chief), providing an efficient means of constructing land and water infrastructure. This infrastructure consisted of a highly advanced system of irrigation ditches that would carry water from mountain streams into loʻi (irrigated terraces). Native Hawaiians drew their water supplies from fresh water springs, lakes, streams, and shallow wells (Handy and Handy 1972), and cleared lower elevation lands for agriculture and settlement (Kirch 1982; McEldowney 1983; Loope 1989). Access to mauka regions and resources was limited and reserved only for significant purposes.

Goats (*Capra hircus*) and European pigs (*Sus scrofa*) were introduced by Captain James Cook in 1778. While sheep (*Ovis aries*) were also introduced to the islands in 1793, it was the introduction of cattle (*Bos taurus*) to the Hawaiian Islands that same year that changed the natural landscape forever. Kamehameha I declared a kapu on cattle shortly after their introduction, and they were allowed to roam free and unharmed, damaging the natural environment and becoming a public nuisance. During the 1800s, there were enormous herds of wild cattle ranging across the slopes of Mauna Kea. The Keanakolu area served as a major focal point.

By 1825, foreign bullock hunters had established camps on the slopes of Mauna Kea to hunt the herds of wild bullocks. By the 1850s, the bullock and sheep hunting activities were giving way to formal ranching operations (Maly and Maly 2006; DHHL 2003; Tomonari-Tuggle 1996), which have remained a dominant land use within the MKWA area. By the late 1800s, Parker Ranch, Kūkaʻiau Ranch, Puʻu ʻAkala Ranch, and Puʻu ʻŌʻō Ranch all operated on the slopes of Mauna Kea. In the mid-1850s, an informal sheep station was established near Humuʻula by German immigrants. The 50,000-acre area was acquired by Parker Ranch in 1914, and sheep operations continued in Humuʻula until 1963 (Maly and Maly 2006).

Early land managers recognized the negative impact feral sheep were having on native ecosystems. The Civilian Conservation Corps (CCC), established by the Federal government in the 1930s, constructed fences to control an estimated 40,000 feral sheep that were affecting native forests, primarily mamāne. From 1936 to 1950, a campaign was carried out to decrease the population of feral sheep on Mauna Kea. By 1950, the population had been reduced to 200 individuals. However, according to L.W. Bryan (1950), the intention was never to completely eliminate the entire population, because sheep hunting was considered an excellent sport and important form of recreation. Within a decade, the population had grown again, to 3,500. Mouflon sheep (*Ovis musimon*) were introduced into the Mauna Kea Forest Reserve in 1962.

The sugar industry began to develop on the Hāmākua coast in the 1800s. The Reciprocity Treaty of 1875 provided that no duty would be imposed on Hawaiian sugar imported into the United States, establishing sugar as the economic engine along the Hāmākua's coast. Water for the sugar plantations came primarily from Kohala Mountain, through the Upper and Lower Hāmākua Ditches. Because of more favorable rainfall, the Hāmākua plantations did not depend as much on the water for irrigation; instead, it was used primarily at the mills and for fluming (Wilcox 1996). The sugar industry dominated, with over 35,000 acres under cultivation, until the closure of the final sugar company in 1994. Since the demise of the sugar industry, much of this land has been replaced by plantation forestry (eucalyptus) and various food crops, providing a more diversified agricultural base.

Koa harvest became a commercial industry in the 1800s, and the demand for firewood increased between 1820 and 1870 to supply the whaling industry and, later, the sugar plantations. By the mid-1850s, sawmills were established near Hilo, and lumber was harvested from the forests.

According to Maly and Maly (2006), "[t]he impacts of logging and grazing were noticed to be taking their toll on the land by the middle to late 1850s, and Government Leases incorporated conditions meant to conserve the forest resources" (p. 117). In 1876, King Kalākaua signed into law an "Act for the Protection and Preservation of Woods and Forests" to set aside forest lands best suited for the protection of water resources. In 1905, the Hilo Forest Reserve was established. R. Hosmer, Superintendent of Forests at the time, believed the land above the proposed Hilo Forest Reserve could be used for purposes other than forest (*i.e.*, grazing), without detriment to the forest (Maly and Maly 2006). In 1909, the summit of Mauna Kea was removed from the ranching leases and the boundaries of the Mauna Kea Forest Reserve were approved (Maly and Maly 2006). The primary purpose of the forest reserves was to set aside the forest areas receiving the heaviest precipitation and containing the headwaters of the streams in order to protect water resources needed by the sugar plantations and ranches, and prevent excessive runoff and soil erosion.

In 1972, Mauna Kea was designated a National Natural Landmark, in recognition of its exceptional geological features. The State never formally followed up by registering the site on the National Registry. However, it did establish the Mauna Kea Ice Age and Laupāhoehoe Natural Area Reserves in 1981 and 1983, respectively, adding additional protection to these areas that had been in the forest reserve system. In 1985, the Federal government established the Hakalau Forest NWR to protect forest birds, and, a decade later, the State designated palila mitigation areas to protect that endangered bird species.

The Civilian Conservation Corps (CCC) also built Keanakolu-Mānā Road during the 1930s, following the general alignment of Laumaiʻa Road, which had evolved from the earlier Laumaiʻa trail. This road is used today to access public lands for hunting and other recreational opportunities.

Current land uses in the MKWA area are varied. Cattle grazing remains a dominant use of the land, despite reduced production volumes since the mid-1980s. Parker Ranch grazes private and leased lands on leeward and north Mauna Kea. Kūkaʻiau Ranch runs cattle on its lands. K.K. Ranch, S.C. Ranch, Ernest DeLuz, and Boteilho Hawaii Enterprises lease State lands on the north slope of Mauna Kea, while Alfred Nobriga leases State lands on the southeast slope off of Saddle Road. The Department of Hawaiian Homelands (DHHL) has let many of its large grazing leases at Humuʻula expire and plans to support sustainable koa forestry, forest conservation, rural homesteading, with some grazing over the next century. Diversified agriculture is another growing land use in the Waimea and Hāmākua areas, with agro-forestry, edible crops, and flowers dominating.

Timber harvest of native and introduced species on both private and public lands, while controversial, will likely increase in upcoming years. Most of the harvest of native species is salvage of dead and fallen trees, used by craftspeople. DLNR has issued some timber licenses for harvest of introduced species within the forest reserve. The

eucalyptus trees planted on former sugar lands are ready for harvest as soon as a buyer is found.

The Saddle Road was constructed in 1943 by the U.S. Army to access the emerging PTA. Ownership of the road was assumed by the Territory of Hawaiʻi in 1947. Significant portions of Saddle Road have recently been improved and partially realigned. The planning for the final portions is currently underway. When completed, the new Saddle Road will be safer and reduce the drive time between Kona and Hilo. While this has many positive benefits, it will also enable greater numbers of people to access the resources of Mauna Kea.

Pōhakuloa Training Area (PTA) evolved into an installation between 1942 and 1955. In 1956, the Pōhakuloa area began to be withdrawn from the leases of Parker Ranch by Executive Order for military purposes. PTA is located in the saddle between Mauna Kea and Mauna Loa. It now consists of 132,950 acres, much of which is under conservation management. PTA is the largest training area within Hawaiʻi. Administration facilities and quarters for approximately 2,000 troops are located on 600 acres at the base of Mauna Kea.

Momentum to build a road to the summit of Mauna Kea began in the early 1960s, when interest was expressed in using the summit for lunar research. Governor Burns authorized State monies to build a rough, four-wheel drive road from Hale Pōhaku to Puʻu Poliʻahu, which was dedicated in 1964. This road is now paved to Hale Pōhaku and again near the summit, leaving the middle section unpaved to discourage traffic.

In 1968, lands were taken out of the Mauna Kea Forest Reserve and leased to the University of Hawaiʻi for a scientific complex atop Mauna Kea. This area now comprises approximately 12,000 acres of State leased land, managed by the University of Hawaiʻi's Office of Mauna Kea Management. The majority of this land, 10,800 acres, is protected in a Natural/Cultural Preservation Area.

4. Population and Local Communities

Currently, there are few residents who live full-time within the MKWA area boundaries. However, there are major communities that surround Mauna Kea, whose residents benefit from its natural, cultural, and scenic resources.

The Mauna Kea Watershed Alliance area falls within four Hawaiʻi County Districts: South Hilo, North Hilo, Hāmākua, and South Kohala (Figure 14). Using 2000 population statistics, these districts combined have 46% of the island's population (Table 10).

Table 10: Populations of Relevant Hawai‘i County Districts (Hawai‘i County 2008b)

District	Population	Notes
South Hilo	47,386	6.2% increase from 1990
North Hilo	1,720	11.6% increase from 1990, though overall decline over past 50 years
Hāmākua	6,108	10.2% increase since 1990
South Kohala	13,131	43.7% increase from 1990 and 98.4% increase from 1980
TOTAL	68,345	

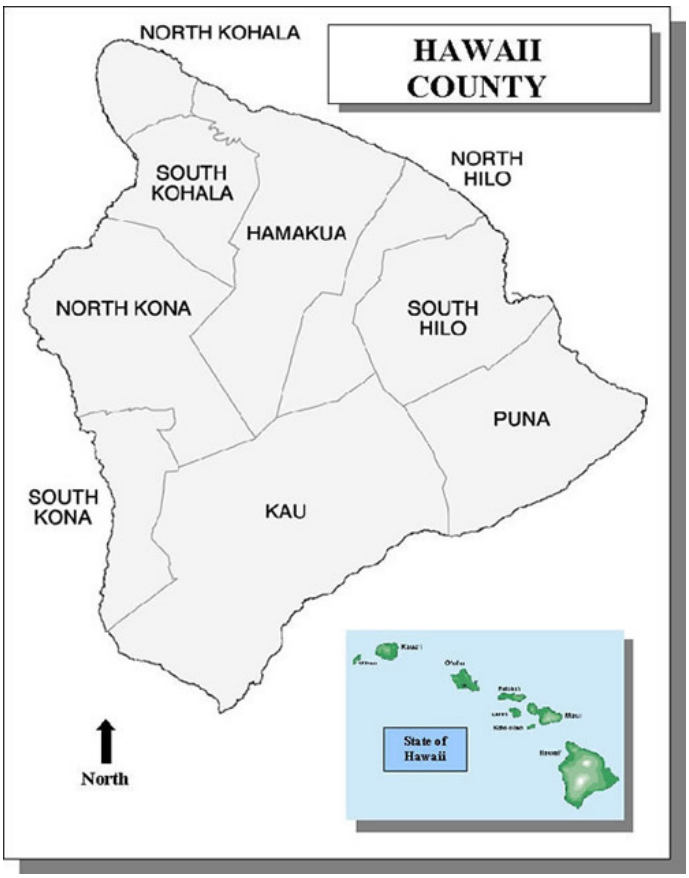


Figure 14: Hawai‘i County Districts

South Hilo consists of the city of Hilo and the towns of Paukaa, Pāpa‘ikou, Pepe‘ekeo, Honomū, and Hakalau. Hilo is the seat of County government and functions as the island’s industrial, commercial, and population core. Approximately 33% of all Hawai‘i Island residents live in Hilo. Historically, sugar was the biggest industry in South Hilo. Now, South Hilo is known for its fruit and plant nursery production, food processing, livestock production, and garment manufacturing. The populations in Hilo and in the older plantation-based communities on the coast north of Hilo have seen little or no growth.

The North Hilo district comprises the former plantation towns of Laupāhoehoe, ‘O‘ōkala, Nīnole, and Pāpa‘aloa. Like Hāmākua to the north, North Hilo is agriculturally-oriented. Former sugar cane lands in the lower elevations are now being cultivated with a diverse range of crops, as well as planted in eucalyptus trees. Cattle grazing and logging of native and planted trees are other land use activities. The population in North Hilo has been declining overall for more than 50 years, despite an increase between 1990 and 2000.

The Hāmākua District includes the towns of Kukuihaele, Honoka‘a, Pā‘auhau, Pa‘auilo and Kūka‘iau. Hāmākua’s population has increased over the past 30 years, even with the closing of sugar operations in 1994. This can be attributed to continuing settlement of the rural homestead areas and former sugar plantation workers commuting to jobs at the resorts in South Kohala. There are numerous cattle ranches and various crops planted in the district. Eucalyptus trees have also been planted on some 15,000 acres of former sugar cane lands as a commercial crop.

The South Kohala District includes the towns of Waimea, Kawaihae, and Waikoloa Village. The population in this district has increased dramatically over the past 30 years. Although tourism is currently the leading economic industry in the district, the area is also well-known for its cattle ranching (Parker Ranch) and vegetable production. Cattle ranching uses most of the land area within this district.

5. Historical and Cultural Resources

Mauna Kea is rich in historical and cultural resources. Various written accounts, including PCSI (2009), SRGII *et al.* (2009), Maly and Maly (2005 and 2006), DHHL (2003), Maly (1997) and Tomonari-Tuggle (1996), document this rich cultural history.

Mauna Kea may be interpreted literally as “white mountain” because its summit is often covered in snow during the winter. It may also be translated as “Wakea’s Mountain.” Wākea, also written and pronounced as Ākea and Kea, was the god-father of the island of Hawai‘i. The island child was born of Papa or Haumea, the goddess who gave birth to islands.

Mauna Kea, especially its summit region, holds deep significance to Native Hawaiian culture and religion. There are many ancient myths and traditional gods and goddesses associated with the mountain. While the upper elevations were too cold for habitation and agriculture, they were used for resource procurement and for religious and healing purposes. These upper elevations were called the “wao akua” (region of the gods) and visited infrequently and generally in association with ceremonial observances and burials.

The Mauna Kea adze quarry, located just below the summit, may have been the largest source of high quality stone for adze making in all of Polynesia (SRGII *et al.* 2009). It was placed on the National Register of Historic Places in 1962 as a National Historic

Landmark. It is protected within the Mauna Kea Ice Age Natural Area Reserve, established in 1981.

Historically, Mauna Kea was crisscrossed by major trails linking the east and west sides of the island. While these trails began as footpaths, many evolved over the years to accommodate horses, wagons, and, more recently, vehicles. There are two major named trails in the summit region of Mauna Kea: the Mauna Kea-Humuʻula Trail on the south side (now closely followed by the Mauna Kea summit access road) which was declared a public trail under the Highways Act of 1892; and the Mauna Kea-ʻUmikoa Trail on the north side. The Laumaiʻa trail, routed above the ʻōhiʻa-koa forest line, connected the Kohala-Waimea-Waipiʻo region to the Hilo area, through Mānā and Kulaʻimano. This route (now Keanakolu) was formally laid out and constructed in 1854 under government contract, with modifications in 1877 and in the 1890s, as part of the Humu`ula sheep station operation (Maly and Maly 2006). The present day Keanakolu-Mānā Road, considered a public road under the Highways Act of 1892, is a result of work done by the Civilian Conservation Corps (CCC) in the 1930s.

Other historic trails on Mauna Kea include the Kalaʻiʻeha-Puʻu ʻŌʻō-Keanakolu trail (Puʻu ʻŌʻō trail), Laupāhoehoe-Waipunalei-Keanakolu-Mauna Kea summit trail, Kahinahina-Kaʻaliʻali trail (connecting Laumaiʻa with Kanakaleonui mauka of Hakalau forest area), Makahalau-Kemole to Waiau trail, Waikiʻi-Puʻu Laʻau to Waiau trail, and Maulua trail (originally a horse trail built by the CCC).

Many historic sites on Mauna Kea have likely been destroyed by agriculture, urban growth, and natural changes in landforms. Others may be difficult to discern within the heavily-forested regions of the mountain. According to McCoy *et al.* (2009) and McCoy and Nees (2009), there are hundreds of archaeological sites within the Science Reserve and Mauna Kea Ice Age NAR, including traditional cultural properties, shrines, and burials and possible burials; stone tool quarry/ workshop complexes; adze quarry ritual center; isolated adze manufacturing “workshops”; isolated artifacts; stone markers/memorials; temporary shelters; and historic campsites, at elevations favorable to the preservation of these features.

The Hawaiian Constitution protects the rights of Native Hawaiians to exercise traditional and customary practices for subsistence, cultural, and religious purposes, as established in Article XII, Section 7. Defined as “those beliefs, customs, and practices of a living community of people that have been passed down through generations, usually orally or through practice” (Parker and King 1998: 1; PHRI 1999:1), the right to practice these traditions is held uniquely by Native Hawaiians and not shared by the general public. These traditional and customary practices include exercising religious and spiritual observances, performing prayer and ritual observances, accessing Lake Waiau for religious, spiritual and cultural practice, using the summit as repository for human burial remains, scattering of ashes of individuals with lineal connection to Mauna Kea, using historic trails, and traditional gathering (for food, medicine, lei making, and cordage).

Hunting was not a traditional cultural practice (Maly and Maly 2005). Hunting for subsistence and sport began on Mauna Kea in the late 19th century, following the introduction of non-native ungulates such as cattle, goats, and sheep. According to Maly and Maly (2005), a legal dispute in 1861 led to the decision that no hunting could take place on Mauna Kea, except for individuals with leasehold interests on the mountain or who were granted special permission. It was not until after World War II that public hunting on Mauna Kea lands was permitted. This policy was developed in part because of the negative impact goats and sheep were having on the forests and in part because of a growing interest in the right to hunt for subsistence. Hunting can now be viewed as a contemporary cultural practice that has evolved from non-Hawaiian traditions (PCSI 2009). The majority of State lands on Mauna Kea are open for public hunting.

There are a number of historical sites and properties on Mauna Kea. A stone cabin built in 1936 by Territorial Forester L.W. Bryan is located at Hale Pōhaku. Two cabins on Hakalau NWR are being considered for the National Historic Register: a cabin in the Pua Akala parcel built in 1883 and the Nauhi cabin built in the Honohina parcel in the 1920s. Keanakolu cabin, currently managed by the DLNR's Division of Forestry and Wildlife (DOFAW), was built in 1934. On DHHL lands there are the transient paniolo living quarters of Kahinahina Forest cabin, Hopuwai cabin, and Kanakaleonui cabin. A monument to David Douglas was erected in 1934 at the top of the Laupāhoehoe section of the Hilo Forest Reserve to commemorate the naturalist's death in a bull pit in 1834.

Development activities that have an impact on cultural or historical resources normally must go through an environmental review process, which requires an assessment of impacts to these cultural and historical resources. If the State environmental review process is triggered, then DLNR's State Historic Preservation Division (SHPD) gets involved. The SHPD maintains an inventory of known historic sites and promotes surveys to identify and document new sites. This agency also is involved in placing significant sites on the Hawaii Register of Historic Places and coordinates the nomination of sites to the National Register. SHPD also administers the Burial Sites Program. For projects triggering the national environmental review process, Section 106 of the National Historic Preservation Act mandates that federal agencies take into account the effects of their actions on properties listed or eligible for listing on the National Register of Historic Places. Federal agencies are responsible for initiating Section 106 review, most of which takes place between the agency and State officials.

After the acceptance of the 2000 Master Plan for the summit of Mauna Kea by the Board of Regents, the University created a volunteer council called Kahu Kū Mauna. This council, comprising Native Hawaiians, advises the Mauna Kea Management Board, the Office of Mauna Kea Management, and the University of Hawai'i at Hilo Chancellor on Hawaiian cultural matters affecting the UH Management Areas.

6. Recreational/Educational Opportunities

DLNR's Division of Forestry and Wildlife (DOFAW) regulates activities in the ____ acres of forest reserves on Mauna Kea under Chapter 13-104, Hawaiʻi Administrative Rules (HAR). These rules prohibit taking of any plant or animal life, except by permit; disturbing of any natural or historic feature; introduction of plants and animals; dumping and littering; and fires. The rules also disallow driving motorized vehicles in any area or trail not designated for that purpose, and prohibit unlicensed vehicles. Camping is allowed in designated areas or sites with a permit from DLNR. Hunting is allowed only as provided for in Chapters 122 (Game bird hunting) and 123 (Game mammal hunting), HAR.

DLNR-DOFAW also regulates activities within restricted watersheds, including the Hilo Restricted Watershed, under Chapter 13-105, HAR. The rules provide for scientific research; hunting, as permitted by hunting rules; hiking and other recreational pursuits; and collecting of fruits, greenery and other plant parts for personal use with a permit for DLNR. These activities are regulated by Chapter 13-104, HAR, rules regulating activities within forest reserves.

Chapter 13-209, HAR, regulates activities within Natural Area Reserves (NARs), of which there are two on Mauna Kea (Laupāhoehoe and Mauna Kea Ice Age). The rules and prohibitions are similar to those within forest reserves, with a few exceptions. Camping is prohibited in the NARs, and any hiking groups larger than ten individuals are required to have a special use permit from DLNR.

Bird and mammal hunting is permitted by persons with valid Hawaiʻi hunting licenses under Chapter 183D, HRS, in designated public hunting areas following guidelines set forth in Chapter 122, HAR, Exhibits 1 and 2, and Chapter 123, HAR, Exhibits 11 and 12. Approximately 165,000 acres of public hunting areas are located on Mauna Kea, within designated Units B, C, and I (forest reserve), D (restricted watershed), A, E, and G (game management areas), F (PTA cooperative game management area), and K (Laupāhoehoe and Ice Age NARs) (Figure 15). Hunting for wild pigs, wild sheep and wild goats in units B, G and K (Laupāhoehoe NAR only) is permitted year-round on a daily basis, while hunting in units C, D, E (Pōhakuloa GMA) and I is limited to weekends and State holidays. Wild sheep and goats may be hunted year-round in Unit A (including the Ice Age NAR), with no bag limits. Mammal hunting in Unit F is regulated by the PTA Commander, so that it does not conflict with the military training schedule. Bird hunting is permitted on public lands during designated hunting seasons. A spring wild turkey season is provided in Units A, F, and G. Bag limits for mammals and birds are specified within the regulations by hunting unit and game to be taken.

While Chapter 183D, HRS, provides for the establishment of Game Management Areas, there have been no rules governing activities in these areas. Hunting on private land requires a valid Hawaiʻi hunting license under Chapter 183D, HRS, and permission of the landowner. Individuals leading commercial hunting tours must have a hunting guide license from DLNR-DOFAW. Commercial hunting tours are prohibited in the UH

[Figure 15: Hunting Areas on Mauna Kea]

Management Areas. The Department of Hawaiian Homelands prohibits hunting on its lands on Mauna Kea.

Public lands on Mauna Kea are commonly used for hunting, hiking, horseback riding, bird watching, botanical exploration, mountain biking, collecting and gathering of fruit, greenery and other plant parts, camping, motorcycle and ATV riding, sunset viewing, and snow play. The cabins at Keanakolu are open for camping and for gathering fruit in the orchards by permit from DLNR. Mauna Kea State Park, located adjacent to Saddle Road at the 6,500-ft. elevation, also provides cabin lodging and picnic opportunities. There have been problems with off-road vehicles leaving the designated roads approved for their use and doing damage to natural features. DLNR has been working with riding clubs to help educate users and change behaviors. If this does not work, DLNR may have to resort to limiting off-road vehicles to certain areas of Mauna Kea.

The Maulua Unit of the Hakalau Forest National Wildlife Refuge (NWR) is open to public use year-round. Access to the remaining portions of the NWR is limited to permitted ecotours, yearly public information "open houses," and research activities permitted by the Refuge. DLNR's newly-developed Kaulanamanu Rainforest Trail and Interpretive Site, or Kīpuka 21, off Saddle Road, provides visitors an opportunity to experience the unique ecosystem of a kīpuka and watch native birds in an easily-accessible environment.

Keanakolu-Mānā Road remains a major access route to public and private lands on Mauna Kea, encircling the mountain from Waimea to Saddle Road. Keanakolu-Mānā Road is considered a public road under the Highways Act of 1892 and a "road in limbo" in that all State and county agencies deny responsibility for it. According to anecdotal information, weekend vehicular traffic on Keanakolu-Mānā Rd. can average 60+ trucks. As a result of legal action (Nobriga v. County of Hawaiʻi) in 2002, the County agreed to maintain, for safety purposes, a 16.6-mile portion of the road that leads to the Maulua Unit entrance to the Hakalau Forest NWR from the Mauna Kea summit access road. Additional spot maintenance work has been done periodically since 2002.

There are numerous trails crisscrossing Mauna Kea. The major trails are part of the State's Na Ala Hele Trail and Access Program. The Na Ala Hele Program, established in 1988 in response to public concern about the loss of public access to certain trails, is administered by DLNR-DOFAW under Chapter 198D, HRS. These trails are described in Table 11.

There are a number of social trails used by the public today at the summit of Mauna Kea. Social trails are trails that are informally created when people chose the easiest route to their desired destination (SRGII *et al.* 2009). The trail to Puʻu Wēkiu, the summit of Mauna Kea and sacred to Hawaiians, is located in the UH Management Area. This social trail, which experiences heavy user traffic, is poorly placed and vulnerable to erosion. Another social trail has become established that continues around the crater rim, further disturbing the cinder soil (SRGII *et al.* 2009). Other intensively-used social trails lead to Puʻu Kalepeamoa and an unnamed puʻu adjacent and north of Puʻu

Kalepeamoa, that begin in the UH Management Area across the road from the Visitor Information Station at Hale Pōhaku and extend into the State's forest reserve.

Numerous residents and tourists access the summit of Mauna Kea for recreational opportunities every year. The Public Access Plan for the UH Management Areas on Mauna Kea estimates that an average of less than 100 vehicles visit the summit per day (SRGII *et al.* 2009). Vehicles driven by independent travelers (visitors and residents) represented 30% of total vehicle traffic on the summit in 2008. Commercial visitors, observatory personnel, and individuals with permits to film or photograph account for the remaining 70% of visitors to the summit region. Commercial tours transport passengers to Mauna Kea for sightseeing, sunset watching, and stargazing. Commercial activities are managed by the Office of Mauna Kea Management and are currently limited to eighteen 14-passenger vans on the mountain at one time. The Visitor Information Station (VIS) at Hale Pōhaku provides information and activities free of charge to both daytime visitors and night-time stargazers.

Vehicle counts on the summit increase dramatically in the winter when there is snow and the road is open. The count rises to between 450-600 vehicles per snow day as people come to Mauna Kea to play in the snow (SRGII *et al.* 2009). This represents an estimated 1,500 to 2,200 visitors per day. Special duty police officers hired by the Office of Mauna Kea Management have helped with crowd management and traffic on these peak snow days.

Table 11: Na Ala Hele Trails on Mauna Kea

Trail Name	Distance (RT)	Description	Type of Use
Puʻu Laʻau Road	8.4 miles	Just off Saddle Rd, this trail goes to the old Puʻu Laʻau Ranger cabin, passing through native dryland forest that is now designated palila critical habitat.	pedestrian, bicycle, equestrian, 4WD
Mauna Kea Access Road (also called R1)	32 miles encircling Mauna Kea between the 7,000 and 9,000-ft. elevation	This road is within the Mauna Kea Forest Reserve and passes through native sub-alpine woodland and over barren lava flows. The route traverses designated palila critical habitat. The road can be accessed from either the Kilohana Hunter Check Station or the Hale Pōhaku Visitor Center.	pedestrian, bicycle, equestrian, 4WD
Kaluakauka Trail	0.4 mile	Accessible from the Keanakolu-Mānā Road. The trail traverses the forest reserve to the David Douglas monument.	pedestrian
Kaumana Trail	3 mile	This trail, off Saddle Rd., is a remnant portion of the old Hilo-Puʻu ʻŌʻō Horse Trail. The trail follows the 1855 lava flow, passing through ohia forest and kīpuka of native wet forest.	pedestrian
Humuʻula Trail (different than trail to Mauna Kea summit)	10.5 mile	This trail ascends 3,250-ft. in 5.5 miles from ʻOʻōkala through the forest reserve to reach the old CCC camp and ranger station at Keanakolu.	pedestrian

7. Infrastructure and Facilities

There are limited facilities and infrastructure on Mauna Kea. The most significant facilities are associated with the observatories, the military training area, and Waimea town.

The summit of Mauna Kea houses the largest ground-based astronomical observing site in the world, with 13 observatories of varying sizes located within the UH Science Reserve. The observatory support facilities at Hale Pōhaku, at the 9,200-ft. elevation, provide dormitories and dining facilities for scientists. There is also a visitor information station (VIS) at Hale Pōhaku that houses an interpretive center and rest stop for visitors on their way to the summit.

Pōhakuloa Training Area (PTA), located in the saddle between Mauna Kea and Mauna Loa, is the largest military training area in Hawaiʻi. It encompasses 132,950 acres, of which 51,000 acres is used as an impact area for artillery and other live fire exercises. Facilities located on 600 acres adjacent to Saddle Road (the cantonment area) contain logistic and administrative facilities, in addition to quarters for approximately 2,000 troops. The base camp includes 154 buildings, including three fully equipped with dining facilities, two motor pools, 2.1 million gallons of water storage, a rations warehouse, a bulk fuel facility, a chapel, a theater, a recreational club including game courts, and a medical facility (DOT and USDOT 2009). Bradshaw Army Airfield has a runway of 3,700-ft. that can accommodate small aircraft. A project to lengthen the runway is currently under review by the Army.

Portions of Waimea town fall within the MKWA area, including the commercial center of Waimea. There are residential neighborhoods in Waimea and mauka of Mamalahoa Highway between Waimea and Honokaʻa included in the watershed management area. These areas receive County water and electrical service, as do the residents in ʻUmikoa Village on Kukaiau Ranch. Waikiʻi Ranch is a gated residential community accessible by Saddle Road and surrounded on three sides by PTA's Keamuku parcel. Its water comes from a deep private well.

Other structures within the MKWA area include cabins at Keanakolu, Kanakaleonui, Hopuwai, and Mauna Kea State Park; historic cabins and administrative facilities at Hakalau Forest NWR, the old sheep station off the Mauna Kea summit access road on DHHL property, and the Puʻu ʻŌʻō ranch house. Alfred Nobriga and the George Robertson Family own small parcels to the north of the NWR Upper Maulua Unit, accessible by Keanakolu-Mānā Road. Nobriga's 40-acre parcel includes a ranch house which is occupied 80% of the time. There are two 40-acre parcels owned by the Robertson family.

Major roads include Saddle Road, the Mauna Kea summit access road, and Keanakolu-Mānā Road. Saddle Road, or Highway 200, traverses the saddle area between Mauna Kea and Mauna Loa and connects the east and west sides of Hawaiʻi Island. Average traffic on Saddle Rd. during 2008 was 1,400 vehicles (SRGII *et al.* 2009). This road is in the process of being re-aligned and improved for increased safety and capacity, and

decreased cross-island travel times (DOT and USDOT 2009). As road conditions improve, traffic volumes on Saddle Road will likely increase significantly. The Mauna Kea summit access road, named John A. Burns Way, leads from Saddle Road to the summit of Mauna Kea. The road is paved for about six miles to Hale Pōhaku, unpaved for the next 4.6 miles, and paved again above the 11,820-ft. elevation.

There is a system of four-wheel drive roads (4WD) and trails throughout the MKWA area. Keanakolu-Mānā Road is a primary access road linking Waimea to Saddle Road around the windward side of Mauna Kea. Mauna Kea access road (R1) encircles Mauna Kea from Hale Pōhaku (9,200-ft. elevation) around the north side of the mountain in the Mauna Kea Forest Reserve between the 7,500 and 9,000-ft. elevation and descends along the northwest side of the Kaohe GMA to Saddle Road (Kilohana) at the 5,700-ft. elevation. This 4WD road is 35.5 miles in distance. Other 4WD roads traverse both public and private lands.

There is significant infrastructure on Mauna Kea associated with ranching activities. This includes fences, roads, and non-potable water systems.

Potable water resources within MKWA area are limited. There is no County municipal water distribution system along the southern part of Mauna Kea. This means that all the astronomical facilities at Hale Pōhaku and the summit use water hauled in by tanker trucks. PTA currently receives a portion of its water from springs on Mauna Kea, which is purified by a water filtration system. During periods of high usage, this water is supplemented by water hauled to PTA by truck. A project to establish an exploratory water well is under review by the U.S. Army.

CHAPTER 3: THREATS TO THE MAUNA KEA WATERSHED

There are a number of threats to the environment and resources of the Mauna Kea Watershed Alliance area, most the result of human introductions, whether intentional or accidental, and activities. Primary threats are from alien plants and animals and their effects, human activities, and other factors such as wildfire and climate change.

A. Invasive Plants/Weeds

Invasive species are introduced (alien) species that significantly disrupt the community structure or proper function of an ecosystem. The effects of alien invasive species on native habitats are a well-documented management problem in Hawai'i's natural areas (Smith 1985; HEAR 2010; Cuddihy and Stone 1990). The Hawaiian archipelago has had more than 8,000 plant species or cultivars introduced over the past 200 years (Loope 1998). Of these, 861 (11%) are now naturalized with reproducing populations (Wagner *et al.* 1990). In 1985, Smith listed 86 invasive plant species that pose a threat to native Hawaiian ecosystems. This number is likely much higher, as new species continue to be introduced at an alarming rate.

Biological attributes of habitat-modifying plant species are propagules dispersed by animals (fur, feathers, feces) or wind, high fecundity, and rapid growth rate. Weed species are most prevalent at the interface between pasture and forest, edges of the forest reserve, along trails, and in disturbed areas.

The most problematic invasive plants within the Mauna Kea Watershed Alliance area are listed in Table 12. The table provides scientific and common names, indicates prevalent locations, and whether it is considered a noxious weed under State law.

Table 12: Invasive Plant Species in the MKWA area

Noxious Weed?	Scientific Name	Common Name	Windward	Leeward	Subalpine
	Delairea odorata	Cape Ivy, German ivy	X	X	
X	*Pennisetum setaceum*	Fountain grass	X	X	
X	*Passiflora tarminiana*	Banana Poka	X		
X	*Ulex europaeus*	Gorse			
	Psidium cattleianum	Waiawi, strawberry guava	X		
X	*Rubus argutus*	Blackberry	X		
	Holus lanatus	Velvet grass			X
	Anthoxanthum odoratum	Sweet vernalgrass			X
X	*Verbascum thapsus*	Common mullein			X

Noxious Weed?	Scientific Name	Common Name	Windward	Leeward	Subalpine
X	*Senecio madagascariensis*	Fireweed	X	X	X
X	*Clidemia hirta*	Koster's curse	X		
	Fraxinus uhdei	Tropical white ash	X		
X	*Tibouchina herbacea*	Glory bush	X		
	Ilex aquifolium	English or European holly	X		
	Photinia davidiana	Photinia	X		
	Sphaeropteris cooperi	Australian tree fern	X		
	Angiopteris evecta	Mule's foot fern	X		
	Hedychium gardnerianum	Kahili ginger	X		
X	*Rubus ellipticus*	Yellow Himalayan raspberry	X		
X	*Miconia calvescens*	Miconia	X		
	Tibouchina urvilleana	Glory bush, princess flower	X		
	Andropogon virginicus	Broomsedge			
	Melastoma candidum	Melastome	X		
	Setaria palmifolia	Palm grass	X		
	Ficus rubiginosa	Fig	X		
	Melastoma candidum	Malabar malastome	X		

Once established, successful invaders may out-compete native plants for nutrients or water, and quickly modify a native ecosystem by changing the vegetation. Often, establishment of invasive plants can convert a forested area from a relatively diverse ecosystem to a monotypic stand of alien species, often accelerating erosional processes. Invasive plants interfere with ecological processes and functions, such as reducing the ecosystem's ability to capture fog and store rainfall and fog water for steady release into streams.

Changing plant composition also fuels an increase in wildfires, carried primarily by introduced grass species. Smith (1985) identifies 8 species of alien weeds that are considered "fire enhancers" – species that increase the areal extent or intensity of fires. These species are both fire prone and fire adapted, meaning they increase the potential for fire and rapidly colonize an area that has been burned. Fountain grass (*Pennisetum setaceum*), for example, is a significant threat to the dry forest ecosystems on the leeward side of Mauna Kea that receive less than 50 inches of annual rainfall (Jacobi and Warshauer 1992). Grasses also form thick mats, inhibiting native plant regeneration.

Cape ivy (*Delairea odorata*), also known as German ivy or *Senecio mikanioidis* (Starr *et al.* 2003), is also established on the leeward slopes of Mauna Kea (Ka‘ohe GMA). It has the potential to occupy a larger range (Scowcroft and Conrad 1992). *D. odorata* is an aggressive smothering vine, climbing native trees and growing as a groundcover.

Gorse (*Ulex europaeus*) is classified as a noxious weed under Chapter 68, HAR. The shrub grows thickly to heights of 6 to 10 feet and produces sharp, three inch thorns covered with a thick, waxy substance. In high densities, this impenetrable shrub renders the land nearly useless. The plant is highly flammable. Efforts to control gorse started as early as the 1890s (Maly and Maly 2006). Its greatest density covers between 10,000-13,000 acres in the central portion of DHHL‘s Humu‘ula lands, with patches in surrounding areas and spreading down the Wailuku River corridor. The gorse infestation worsened in the mid-1980s, when sheep eradication efforts increased. The gorse seeds remain viable in the soil for up to 70 years; therefore, any eradication strategy must be long-term in its approach.

The wet koa-‘ōhi‘a forests are extremely susceptible to invasion of habitat-modifying species. These alien plants change the forest composition and likely affect invertebrate habitat. Strawberry guava or waiawi (*Psidium cattleianum*) is a serious threat to native forest ecosystems below 4900-ft. elevation (Smith 1985). Clidemia or “Koster’s curse” (*Clidemia hirta*) forms dense monotypic stands in mesic to wet environments up to 4,900-ft. elevation. While banana poka (*Passiflora tarminiana*) is found in many vegetation types, it is concentrated in the wet forest in eastern Mauna Kea (LaRosa 1992), with high densities in the Laupāhoehoe/ Keanakolu area. Malabar malastome (*Melastoma candidum*) has invaded the wet forest on windward Mauna Kea below 2,950-ft. Other invasive species that dominate the wet forest on the windward side include blackberry (*Rubus argutus*), *Ficus rubiginosa*, tropical white ash (*Fraxinus uhdei*), Australian tree fern (*Sphaeropteris cooperi*), and miconia (*Miconia calvescens*).

A number of invasive plants are currently found in the subalpine and alpine plant communities near the summit of Mauna Kea. These include non-native grasses and invasive herbs such as common mullein (*Verbascum thapsus*) and fireweed (*Senecio madagascariensis*).

B. Feral Ungulates

The natural resources of Mauna Kea have been negatively affected by over 200 years of ungulate impact, including feral and domestic cattle, sheep, goats, and pigs. Feral ungulates contribute to the loss of forest cover and changing forest composition that adversely affects stream quality, native species’ habitat, groundwater retention, and native plant and invertebrate species.

Cattle (*Bos taurus*)

As described earlier, domestic cattle were given as a gift to King Kamehameha I by Captain Vancouver in 1793. When the king issued a kapu on the killing of these cattle,

they proliferated across the landscape and inflicted heavy damage to the native ecosystems. Currently, most cattle grazing takes place on private (or leased) managed lands. However, wild cattle persist in limited forested areas and on former ranch lands, both private and public, where inadequate fencing has allowed cattle to wander in search of palatable foods. Feral cattle are concentrated on and around DHHL lands and in the Hilo Forest Reserve. It is estimated that there are approximately 4,000 head in the forest reserve and 2,000 head on DHHL lands. "Cattle reduce native plant diversity and simplify structure, composition and function vegetation" (Stone 1985: 260). They destroy native forests and threaten rare plants, and the birds and invertebrates that depend on them.

Sheep (*Ovis aries*, *Ovis musimon*, hybrid)

Sheep (*Ovis aries*) were also introduced to the islands in 1793. By 1825, feral sheep were established in the subalpine woodland of Mauna Kea. By the early 1930s, the sheep population had reached about 40,000 animals (Bryan 1937), causing significant damage to the native vegetation and competing with commercial flocks. In response, the Territorial government built a fence around the Mauna Kea Forest Reserve and began reducing sheep populations. In 1937, the sheep population was reduced to about 5,000 individuals, then to 200 by 1950.

Sustained yield management for public hunting began in 1955. Mouflon sheep (*Ovis musimon*) were released into the Mauna Kea Forest Reserve in 1962. With hunting, the populations were maintained at 1,000 to 4,000 animals until 1980. However, these sheep were continuing to have a negative impact on the mamāne (*Sophora chrysophylla*) forest, the habitat of the native palila bird. When critical habitat was designated in 1977, it included almost all the State-owned mamāne and naio-mamāne woodlands on Mauna Kea (USFWS 2006). The protection of this palila habitat from ungulates has been legally challenged six times since 1979. The palila have prevailed each time, and the State has been ordered to completely remove all feral sheep, mouflon sheep and *Ovis aries-Ovis musimon* hybrids. While the numbers have been significantly reduced, sheep still remain. With the reduction in sheep, the mamāne has started to recover; however, without grazing control, grasses have also spread and accumulated rapidly, increasing the fire hazard (Scowcroft and Conrad 1992; DLNR 1997).

Feral sheep on Mauna Kea threaten native vegetation and regeneration, by grazing vegetation right down to the ground. This directly affects the habitat of the endangered palila bird. Feral sheep may also be directly affecting nesting resources for ʻuaʻu (*Pterodroma sandwichensis* (Hawaiian petrel)) and ʻakeʻake (*Oceanodroma castro* (band-rumped storm petrel)) (Mitchell *et al.* 2005).

Goats (*Capra hircus*)

The negative effects of goats on vegetation are known worldwide (Loope 1998). Goats browse on woody plants, herbs, and grasses, in both dry and wet ecosystems. They destroy native plants, introduce invasive plant species, and hasten soil erosion by

denuding all vegetative ground cover. Goat populations on Mauna Kea have been reduced as part of the legal actions to eradicate sheep in palila critical habitat.

Pigs (*Sus scrofa*)
While pigs were brought to the islands by early Polynesian settlers, the environmental damage caused by pigs appears to result from the more recent release of a non-Polynesian genotype (Diong 1982). Stone (1985) asserts that pigs today are the major modifiers of Hawaiian rainforests. Pigs are also found in dry ecosystems. They are omnivores that consume both plant and animal materials, and native plants and groundcover have been particularly affected. Pigs carry seeds of invasive plants, particularly banana poka and strawberry guava, on their coats and in their digestive tracts. They aggressively till the forest floor, exacerbating erosion potential and weed introduction. They also serve as carriers and vectors of parasites and diseases (Cory 2000).

C. Other Non-native Pest Species
Other animals also have the potential to become serious pests in the MKWA area (Table 13). Rats have a significant effect on native vegetation and bird species. Black rats (*Rattus rattus*) and Polynesian rats (*Rattus exulans*) are the dominant species throughout most of Hawai‘i’s forests. They consume the seeds, fruits, and flowers of numerous native plant species, including many rare ones (Atkinson 1977; Stone 1985). Rats also prey on native bird eggs and nestlings. Like ungulates, rats can affect water quality by serving as vectors for water-borne diseases such as Leptospirosis and Cryptosporidiosis.

Other non-native animals that can pose problems in the watershed include mongoose, feral cats, dogs, mice, and birds. Feral cats are a significant problem in the core palila habitat. Non-native forest birds have been observed in all vegetation types. Species present include the Common Mynah (*Acridotheres tristis*), House Finch (*Carpodacus mexicanus*), House Sparrow (*Passer domesticus*), Hwamei (*Garrulax canorus*), Japanese White-eye (*Zosterops japonicus*), Nutmeg Mannikin (*Lonchura punctulata*), Red-billed Leiothrix (*Leiothrix lutea*), and Northern Cardinal (*Cardinalis cardinalis*). These species compete with native forest birds for food and other resources, help spread avian diseases, and are vectors for the spread of alien plants such as Clidemia, kahili ginger and strawberry guava.

Coqui frogs (*Eleutherdactylus coqui*) were accidentally introduced to Hawai‘i from Puerto Rico in the late 1980s by the horticultural trade. They are very adaptable to different ecological zones and elevations. Coqui have been found from sea level to about 4,000-ft. It is estimated that they infest over 60,000 acres on the Big Island. The frogs have no natural predators in Hawai‘i and eat large quantities of insects. While their impacts on Hawai‘i’s native ecosystems have not been well-studied, they have the potential to disrupt the balance of vulnerable ecosystems by consuming native and introduced insects that provide pollination services, and competing with endemic birds and other native animals that rely on insects for food. Currently, the coqui are

concentrated around Hilo and the Puna district. However, they have been gradually moving up the Hāmākua coast and are now as far as Honokaʻa and Waimea. The male of this small, nocturnal frog emits a loud (as high as 100 dB), incessant mating call.

Invasive insects are one of the greatest threats to the native invertebrate fauna. Currently, there may be 2,500 species that are successfully established in Hawaiʻi (Howarth and Mull 1992). Ant species are some of the most problematic. Ants with large aggressive colonies such as the big-headed ant (*Pheidole megacephala*), Argentine ant (*Linepithema humile*), and long-legged ant (*Anoplolepis longipes*) have been implicated in the extinction of native species. An aggressive yellowjacket wasp (*Vespula pensylvanica*) is also considered a highly threatening invasive species. Other threats include non-native parasitoids that impact native caterpillars, and introduced bees that compete with native pollinators (Oboyski *et al*. 2004; Daly and Magnacca 2003).

Avian diseases (malaria and pox virus) carried by the mosquito (*Culex quinquefasciatus*) have been found in lowland areas and may occur seasonally at higher elevations on windward Mauna Kea. Disease carrying mosquitoes restrict the range of native forest birds to upper elevation areas (Loope 1998). These mosquitoes are known to breed in wet forests disturbed by ungulates.

Leptospirosis and Cryptosporidiosis are potentially fatal illnesses caused by water-borne micro-organisms spread by pigs, dogs, mongooses, rats, and even frogs. A few people become ill each year from wading in ponds or drinking water from affected springs and streams. Leptospirosis is from a bacterium, transmitted from animals to humans where people contact the bacteria through water or mud that has been contaminated by animal urine or droppings. About 500 cases, including 7 deaths, have been reported in Hawaiʻi in the past decade. According to DOH statistics, the windward side of the Island of Hawaiʻi historically reports the largest number of cases.

Table 13: Other High Priority Non-native Species for Control Activities (adapted from SRGII 2009)

Type	Common Name (Scientific Name)	Control Locations
Mammals: Predators	Cats (*Felis catus*) Mongoose (*Herpestes auropunctatus*) Rats (*Rattus rattus, R. exulans, R. norvegicus*) Mice (*Mus musculus*)	-Any areas found to be used by native bird species -Control rats and mice at summit to protect summit arthropods
Mammals: Seed eaters	Rats (*Rattus rattus, R. exulans, R. norvegicus*) Mice (*Mus musculus*)	-Silversword exclosures -Restoration areas -Areas with rare or protected native species or high native plant diversity

Type	Common Name (Scientific Name)	Control Locations
Invertebrates Hymenoptera	Yellowjackets (*Vespula pensylvanica*) European Paper Wasp (*Polistes dominula*) Argentine ant (*Linepithema humile*) Cardiocondyla ant (*Cardiocondyla venustula*) Big headed ant (*Pheidol megacephala*) Guinea ant (*Tetramorium bicarinatum*) Pharaoh ant (*Monomorium pharaonis*)	-Control if found in any location
Amphibian	Coqui frog (*Eleutherdactylus coqui*)	-Control if found in any location
Pathogens	*Plasmodium relictum* (avian malaria) *Poxvirus avium* (avian pox virus) *Cryptosporidium* *Leptospira* spp.	-Any areas found to be used by native bird species -Upstream of high use freshwater swimming areas

More than fifty species of alien aquatic species are established in Hawai‘i’s streams. Some were introduced intentionally as food fish, ornamentals, or for mosquito and weed control. Others were dumped into streams with no thought about the consequences. Exotic fishes, mollusks, crustaceans, invertebrates, and amphibians can compete with the native stream fauna for food and habitat, introduce parasites, and feed on native species. Invasive aquatic species can also cause economic impacts to agricultural users of water, resulting in crop damage, infrastructure damage, or contamination. While DLNR aquatic surveys of Mauna Kea’s streams reveal the presence of a majority of Hawai‘i’s native aquatic species, they also indicate the existence of exotic species, particularly guppies, crayfish, Tahitian prawns, green swordtails, toads and frogs, and midges.

D. Aquatic Pollutants

Very little information exists about specific aquatic pollutants originating in the Mauna Kea Watershed Alliance area. Anecdotal information suggests that the water quality is generally good. However, the Department of Health’s most recent list of impaired waters in Hawai‘i includes a number of streams that originate on the slopes of Mauna Kea. These streams exceed State water quality standards for turbidity and/or nutrients. (See Table 3 in Chapter 2.)

E. Wildfire

Because Hawai‘i’s plants evolved without frequent, naturally-occurring episodes of fire, most native species are not as well-adapted to fire as introduced species. “While some of the species in [the drier upper elevation] zone are fire tolerant (*e.g.*, mamāne, naio, ‘ōhelo, native bunchgrass), none require fire to regenerate, and they all can be killed by intense fire” (Smith and Tunison 1992). There are some native species, such as koa, that will be killed by fire, but their seeds are stimulated to germinate following a fire.

Healthy forest cover reduces the risk of wildfire by reducing surface temperature fluctuations, increasing relative humidity, and reducing wind speeds. The changing composition of vegetation on Mauna Kea has contributed to an increased fire hazard. Many introduced species of plants, particularly grasses, are often more fire-adapted than native species and will not only carry fire well but also quickly exploit suitable habitats after a fire. Fountain grass (*Pennisetum setaceum*), a highly fire-adapted species, is now found throughout much of the dry, southwestern side of Mauna Kea, including areas that formerly consisted of lava. Introduced pasture grasses, including kikuyu (*Pennisetum clandestinum*), sweet vernal grass (*Anoxanthum odoratum*), and narrow-leaved carpet grass (*Axonopus affinis*), are the dominant understory in the mid-elevations traditionally used to graze cattle. These grasses can provide a heavy load of fine fuel when left unmanaged. The introduced gorse (*Ulex europaeus*) is also an aggressive and highly flammable shrub that is well-established in grazing lands on the eastern side of Mauna Kea. Fire-adapted aliens are established in lower, leeward slopes and some subalpine areas.

As grazing animals are removed from the mountain, the tall, ungrazed non-native grasslands that remain greatly increase the risk of fire. This is a concern year-round on the leeward side of Mauna Kea and during dry weather conditions on the windward side. A fire started in the grasslands can quickly move into forested areas, where it can destroy whole forest ecosystems.

Causes of wildfire on Mauna Kea include vehicles (accidents, catalytic converters), human activities, lightning, and military activities. Rough and irregular terrain, along with steep slopes, make fire-fighting difficult. High altitude can reduce the efficiency of helicopters performing water drops. Geographically-induced air currents also add to the difficulty of air operations. Given the conditions that make fire suppression difficult on Mauna Kea, the implementation of adequate pre-suppression measures is all the more important for minimizing fire losses.

Most of the large landowners on Mauna Kea have installed at least some on-the-ground measures, including fuel breaks, access roads, and water sources, to reduce the potential for fire starts, slow the spread of fire, protect rare species and native habitats from fire, and provide access for fire-fighting purposes. DLNR, DHHL, Hakalau Forest NWR, and PTA all have fire management plans (DLNR 1997; USFWS 2002; U.S. Army 2003; DHHL 2007), which identify infrastructure, equipment and personnel resources, outline fire response procedures, and provide guidelines for appropriate fire suppression activities. A new wildland fire management plan is under development for Pōhakuloa Training Area, with an anticipated completion date toward the end of 2010, and a fire management plan is under development for the palila critical habitat area.

Fires cause the removal of vegetation cover and exposure of bare soil. This combination makes burned areas susceptible to high levels of erosion, which can impact stream and nearshore water quality. Fire also destroys native plants and habitats, and allows habitat-modifying weed species to take hold.

F. Climate Change
Global and local climate change have the potential to affect the weather and hydrology of Mauna Kea by altering temperature and rainfall patterns, and elevating cloud banks. Changing climate would affect the abundance and seasonality of precipitation, thereby affecting native plant species and agricultural water users over a broad geographic area. Watershed functions would be compromised from the drying of the air, vegetation and soil, resulting from an elevation of the cloud bank.

Some ecosystems and species may be negatively affected by relatively rapid changes in precipitation, temperature, and humidity that result from a rapid and drastic change in regional or local climate patterns. For example, increases in temperatures may enable the avian-disease carrying mosquitoes to move further up the mountain, where native forest birds are now safe from these mosquitoes because of their intolerance to cooler temperatures. At the same time, other ecosystems and species at higher elevations may benefit from these changes.

The exact changes to the precipitation and temperature regime, and subsequently the plant life, are unknown due in part to the complexity of the climatic system and the data necessary to generate precise model outputs. Ongoing monitoring of weather and climate will help Hawai‘i develop model inputs and anticipate the nature of local climatic changes and their possible effects.

G. Human Activities
Hawai‘i’s natural environment reflects a diverse patchwork of historic and ongoing changes in land use, beginning with natural processes, and accelerating with human modifications of the environment; first the Hawaiian construction of fishponds and other subsistence agriculture systems and, in the most recent two centuries, a series of changes as Hawai‘i industrialized and entered a global economy.

The introduction of ungulates to Hawai‘i led to the vast conversion of forested areas to pasture, which continued unchecked until the mid-1850s. By the early 20th century, Hawai‘i’s government began setting aside large areas as forest reserves to protect the forested watersheds upon which the large agricultural interests depended. With the passage of Hawai‘i’s land use law in the 1960s, further natural areas were protected by inclusion in the Conservation District. To counter urban sprawl and conversion of prime agricultural lands to residential use, the State’s land use law, Chapter 205, HRS, also designated Agricultural and Urban districts.

Today, most development is confined to the lower elevations, where the biggest impact is on streams and riparian corridors. The State’s environmental review process (Chapter 343, HRS) and pollution laws, and County ordinances for zoning, subdivisions, soil erosion and sediment control, and floodplain management help regulate new development and ensure management measures are put in place to reduce the effects

of development on natural resources. Development at the summit of Mauna Kea remains controversial.

Continued conversion of agricultural lands for residential use led to the passage of Act 233 in 2008, once again emphasizing the need to protect important agricultural lands for agricultural activities. Existing ranches within the Mauna Kea Watershed Alliance area all abut conservation areas and often contain degraded forest and riparian areas. Animal grazing adjacent to forest reserves can help reduce the fuel loads and resulting fire risk. However, this grazing can facilitate the spread of invasive weeds and ungulates into the forest reserves and precludes any restoration efforts on degraded pasturelands.

Native stream communities are dependent on stream flows to the sea to support the life cycles of the native aquatic species. Many of the streams in the Mauna Kea Watershed Alliance area are already diverted on a relatively-small scale for agricultural, domestic, and industrial purposes. However, these and other streams remain vulnerable, as the demand for fresh water outstrips the current yield. The State Water Code (Chapter 174C, HRS) provides mechanisms for protecting stream flow, and instream flow standards are being developed for individual streams within the MKWA area.

Logging was a historical use of Hawai‘i’s forests, with native koa (*Acacia koa*), ‘ōhi‘a (*Metrosideros* spp.), sandalwood (*Santalum* spp.), hāpu‘u tree ferns (*Cibotium* spp.) and others harvested (often unsustainably) for timber, firewood, and crafts. Timber harvest on public lands is now regulated through a licensing process, with an emphasis on harvest of non-native species and salvage of dead and dying native species. Currently, there are about 24,000 acres of former sugar cane land on the Hāmākua coast planted in eucalyptus. Harvest of these trees will begin as soon as a buyer is found. While some people opposed the planting of eucalyptus in the late 1990s, a 1981 DLNR-DOFAW study identified approximately 80,000 acres of former sugar cane land as ideal for the establishment of a forest plantation. An additional 100,000 acres of pasture and brush lands were identified for longer-rotation forest plantations.

Forestry activities can threaten the natural environment if not properly managed. Species selection for plantation forestry is important to prevent unintentional spread of a habitat-modifying species into forest reserves and other protected lands. Managing trees during their growing phase to mitigate wildfire risks is also important. It is during the harvest phase that the most environmental damage can occur. Improper harvest can cause erosion and impaired water quality, and damage riparian buffers. All commercial forestry activities conducted on public (State) leased lands or on private lands participating in a State Forest Stewardship or Tree Farm program must implement relevant best management practices (BMPs) contained in DLNR’s *Best Management Practices for Maintaining Water Quality in Hawaii* (June 1998). This requirement needs to be extended to private lands in managed forestry. Harvest activities, particularly in managed native forests, can also adversely affect native birds and invertebrates that have moved into these habitat areas.

While military training activities can adversely affect native vegetation, increase wildfires, and introduce alien species, the U.S. Army has instituted a natural resources management program at PTA to mitigate these impacts. The U.S. Army is among the best-funded and most active stewards of native ecosystems in Hawaiʻi.

As the major roads on Mauna Kea, including Saddle Road, the Mauna Kea summit access road, and Keanakolu-Mānā Road, are improved, more people will be able to gain access to natural areas that were previously difficult to access. This will likely exacerbate ongoing problems caused by: off-road vehicles leaving the designated roadways and damaging natural features; unplanned “social” trails that scar the landscape and provide undesired access to fragile natural and cultural features; the spread of invasive plant and animal species; overharvesting of plants for home and cultural uses; and unintentional fire starts. There are also human health and safety issues associated with more people accessing a larger but still remote region.

Chapter 4: Existing Management within the Mauna Kea Watershed Alliance Area

A. STATE

There are 349,131 acres of land on Mauna Kea held in stewardship by the State government. Of this, 123,555 acres are managed directly by the Hawai‘i Department of Land and Natural Resources (DLNR). DLNR’s DOFAW manages lands in forest reserves, natural area reserves, palila mitigation areas, and game management areas. DLNR’s Land Division manages 37,578 acres of State land set aside for agricultural leases. The Department of Hawaiian Homelands (DHHL) manages 68,195 acres. The University of Hawai‘i’s Office of Mauna Kea Management manages approximately 12,000 acres in association with the observatories at the summit, and the U.S. Army leases 22,988 acres of State land for its Pōhakuloa Training Area.

1. DOFAW Management

Figure 16 shows areas under DOFAW management. With the exception of the palila mitigation areas, these lands all fall within the Conservation District. An important goal of DLNR-DOFAW’s watershed management program is to prevent cattle from entering forest reserves (including the restricted watershed), game management areas, public hunting areas, and natural areas reserves. Section 183-19, HRS, guides this activity. By law, ranchers are required to keep cattle out of these areas, and DLNR may remove, shoot, or destroy the cattle without compensation to the owner, after a 30-day public notice.

(a) Forest Reserves

The Hilo, Manowaialee and Hāmākua Forest Reserves are located on the north and northeast slopes of Mauna Kea. Primary vehicular access to these areas is by Highway 19. DLNR-DOFAW regulates activities in the forest reserves under Chapter 13-104, HAR. These rules prohibit taking of any plant or animal life, except by permit; disturbing of any natural or historic feature; introduction of plants and animals; dumping and littering; and fires. They provide for hunting, as permitted under Chapters 122 and 123, HAR, gathering, cultural and recreational activities, education, research, endangered species management, and protection of native ecosystems.

The Hilo Forest Reserve units within the MKWA area include the Hilo Restricted Watershed, and Kaiwiki, Kamaee, Opea, Pīhā, Laupāhoehoe and Humu‘ula sections. The Hilo Restricted Watershed and Kaiwiki, Kamaee and Opea sections are representative of the ‘ōhi‘a and ‘ōhi‘a-uluhe lowland wet forest communities. These sections also contain stands of swamp mahogany (*Eucalyptus robusta*), with a mixture of native and non-native understory species. The Piha and Laupāhoehoe sections are representative of the koa-‘ōhi‘a montane wet forest above 3,000-ft. elevation and the koa-‘ōhi‘a lowland wet forest below 3,000-ft., with differences in understory species composition between the two ecosystem types. Tropical ash (*Fraxinus uhdei*) is the dominant introduced timber species in these sections, found between 4,800-5,400-ft. elevation. The Humu‘ula section is characterized by degraded koa-‘ōhi‘a lowland wet forest, with stands of silk oak (*Grevillea robusta*) and Sydney bluegum (*Eucalyptus*

saligna). The majority of these units fall within the Resource subzone of the Conservation District.

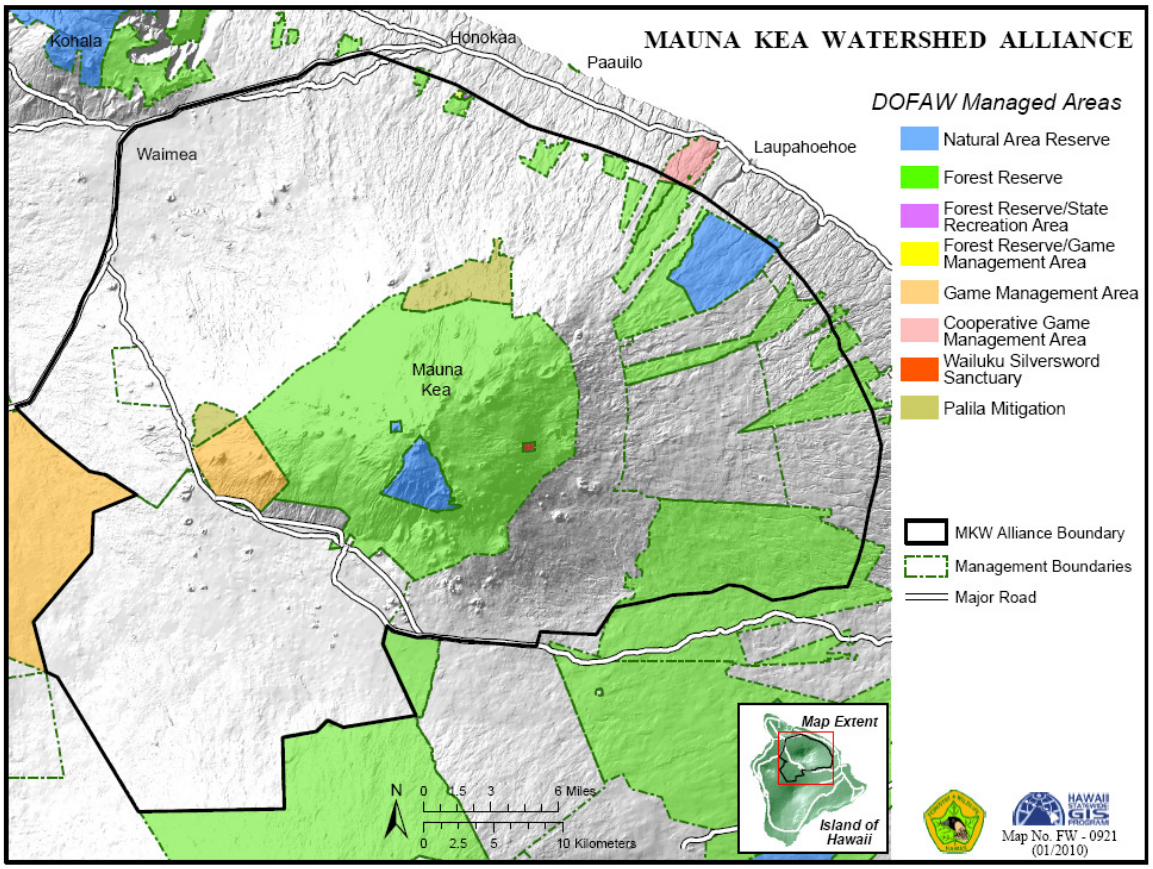


Figure 16: DOFAW Managed Areas

DOFAW has proposed to stimulate natural koa (*Acacia koa*) regeneration and koa forest growth in approx 600 acres of heavily-degraded forest areas (now primarily kikuyu grass and ‘akala berry) in the mauka portion (4,900-5,900 ft. elevation) of the Laupāhoehoe and Humu‘ula sections of the Hilo Forest Reserve through a combination of methods (soil scarification, feral cattle control, supplemental koa outplantings, fence repair, control of invasive weeds, etc.) (DLNR 2006). These degraded areas are adjacent to State and private lands traditionally used for long-term cattle grazing operations, where poorly maintained fences allowed cattle to cross into forested lands. Salvage of down, dead or dying koa is also proposed for the Humu‘ula Forest unit (approximately 2,005 acres) through a bid process, with eligible trees clearly identified.

The Pīhā section of the Hilo Forest Reserve divides the Hakalau Forest National Wildlife Refuge into two sections. Pīhā is not currently managed for conservation. Habitat degradation by ungulates and invasive plant species in Pīhā threatens efforts at Hakalau Forest as well (Mitchell *et al.* 2005).

The Manowaialee Forest Reserve is composed of the lands of Manowaialee. This forest reserve comprises a mix of degraded koa-ohia lowland wet forest and planted forest dominated by mixed *Eucalyptus* species between 2,600-2,800-ft. elevation, and swamp mahogany and Sydney bluegum between 3,500-4,100-ft. There are also mixed conifers including redwood (*Sequoia sempervirens*), Monterey cypress (*Cupressus macrocarpa*), and sugi in this section.

The Hāmākua Forest Reserve sections within the Mauna Kea Watershed Alliance area include Hōʻea-Kaao, Paʻauilo, Kalōpā, Āhualoa, and Nienie. These sections are primarily degraded koa-ʻōhiʻa lowland wet forest with stands of introduced timber species, including silk oak, ironwood (*Casuarina equisetifolia*), swamp mahogany, Sydney bluegum, tallowood (*Eucalyptus microcorys*), Australian red cedar, Red River gum (*Eucalyptus rostrata*), Queensland maple (*Flindersia brayleyana*), turpentine tree (*Syncarpia glomulifera*), and brushbox (*Lophostemon confertus*).

DLNR is contemplating the harvest of introduced tree species within the forest reserves in order to replace them with preferred species. DLNR issues licenses for the harvest of timber. Only two such timber licenses have been issued on Hawaiʻi Island in the past thirty years.

(b) Hilo Restricted Watershed

The _____-acre Hilo Restricted Watershed (Hunting Unit D) was established in 1980 within the Hilo Forest Reserve to protect a watershed where public water supplies are vulnerable to contamination by public access. Under Chapter 13-105, HAR, people are prohibited from entering the Hilo Restricted Watershed, except by permit from DLNR for official duties, research and scientific pursuits, recreational and educational purposes, and collection of plants for personal use. Public hunting in Unit D is permitted under Chapters 122 and 123, HAR; persons with a valid Hawaiʻi hunting license may hunt on weekends and holidays year-round for game mammals and on weekends and holidays during the open hunting season for game birds.

Feral cattle are a problem within the Hilo Restricted Watershed. DOFAW opened a special hunting season from November 2005-November 2006 to allow the public to hunt feral cattle. These hunts were characterized by low public participation due to long travel times and difficulty in removing cattle from the forest reserve.

(c) Natural Area Reserves (NAR)

There are two NARs within the Mauna Kea Watershed Alliance area, one designated to protect geological features and the other to protect high quality native forest ecosystems. Chapter 13-209, HAR, permits hiking and nature study, and hunting pursuant to the hunting rules.

The Mauna Kea Ice Age NAR (3,886 acres) was established in 1981 to protect geological features. This area, ranging from 10,000-13,441-ft. in elevation, also encompasses an invertebrate-dominated aeolian desert and the State's only alpine lake, Lake Waiau. The NAR comprises two parcels: a square 143.5-acre parcel around

Pu‘u Pōhaku, where fossil ice left behind by glaciations has been found; and a 3,750-acre triangular-shaped parcel that includes the Mauna Kea Adze Quarry, Lake Waiau, and geomorphic features created by glaciers, such as moraines and glacial till.

Current management includes wēkiu bug surveys and research, and ongoing ungulate control. An archaeological survey and cultural assessment have been completed. DLNR has a 9.9-acre monitoring exclosure in this NAR to demonstrate the recovery of sub-alpine and alpine ecosystems when feral sheep are excluded. There is currently no management plan for this NAR. Beginning in 2008, DLNR is partnering with the University of Hawai‘i’s Office of Mauna Kea Management to use its Mauna Kea rangers to help provide resource protection within the NAR.

The Laupāhoehoe Natural Area Reserve was established by Executive Order in 1983. This area of approximately 7,894 acres, formerly part of the Hilo Forest Reserve, is managed by DLNR to protect valuable native forest ecosystems spanning elevation ranges from 1,700 to 4,700-feet. The NAR protects montane wet communities and lowland wet communities, including forest birds, ‘io, koloa-maoli, terrestrial invertebrates, and rare plants. A management plan was drafted in 1989 (DLNR 1989) but needs to be updated. Laupāhoehoe NAR is designated public hunting area Unit K, which allows persons with valid Hawai‘i hunting licenses to hunt daily and year-round for game mammals and on weekends and holidays during the open hunting season for game birds. In 2007, a federal Experimental Forest overlay was designated, and now the State and U.S. Forest Service co-manage the area.

DLNR has been collecting baseline vegetation data in the Laupāhoehoe NAR since 1988. It installed five additional mauka-to-makai transects in 2008-2009. DLNR staff maintain numerous plant exclosures, conduct weed control, maintain access roads and trails, and install emergency corral exclosures around remote rare plants in the NAR. In upcoming years, DLNR plans to build an additional 9.9-acre remote exclosure and several fenced units to protect remaining high quality forest above the 3000-ft. contour.

Recently, the Natural Area Reserve Commission identified the mamāne-naio forest as a missing ecosystem in the NAR system. Potential sites within the Forest Reserve system on Mauna Kea are being considered for inclusion in the NAR system.

(d) Palila Mitigation Areas

Critical habitat for the endangered palila bird (*Loxioides bailleui*) was designated in 1977. The critical habitat includes the historical range of the mamāne forest that encircled Mauna Kea. The palila population is currently concentrated on western Mauna Kea, where the forest is most extensive. This core population represents over 90% of the remaining individuals and is located within the Mauna Kea Forest Reserve. This makes the species vulnerable to extinction in the event of fire, drought, storm, disease, and predation.

In December 1999, the USFWS approved a realignment of Saddle Road (Highway 200) through palila habitat on the condition that the loss of this habitat be mitigated. A key

component of mitigation was to temporarily suspend cattle grazing in pastures adjacent to the palila range to allow habitat recovery. Mitigation funding also provided for the re-introduction of palila near Puʻu Mali on Mauna Kea's northern slope, where trans-location of wild palila from the western slope began in 2005. Specifically, the USFWS's Biological Opinion requires provision of approximately 5,143 acres of land on the north slope and approximately 1,400 acres of land immediately adjacent to the current palila population on the west slope of Mauna Kea for palila habitat restoration (USFWS 1998). The establishment of these Palila Mitigation Areas was accomplished by overlaying an easement to the Hawaiʻi Department of Transportation (DOT) Highways Division on lands currently under State pasture leases to K.K. Ranch, S.C. Ranch, and Boteilho Hawaiʻi Enterprises on the north slope at Puʻu Mali and on unencumbered lands near Kaʻohe. The removal of these Palila Mitigation Areas from pasture leases has been extremely controversial.

The Palila Mitigation Areas, as well as core palila habitat in the Mauna Kea Forest Reserve, are under management by DLNR-DOFAW. A Mauna Kea Dry Forest Restoration Plan was drafted by DLNR in 2006. The focus of the plan is restoration of subalpine forest areas on the western and northern slopes of Mauna Kea for improved palila habitat by fencing and removing ungulates and outplanting native seedlings. Current management activities include: outplanting 29,000 seedlings and scarifying 200 acres at Puʻu Mali; removal of mouflon sheep from Puʻu Mali; developing a volunteer program to assist with outplanting efforts; identifying current distribution of fountain grass on Mauna Kea; trapping feral cats in the core palila habitat; and removing pigs from the Kaohe mitigation area. The U.S. Army is in the process of developing a fire management plan for the palila mitigation areas.

Currently, there is no formal agreement to sustain restoration at Puʻu Mali and Kaʻohe beyond 2012, when the lease expires. A mechanism is needed for the long-term protection of these sites.

(e) Plant Exclosures

DLNR-DOFAW manages numerous plant exclosures on Mauna Kea to protect and restore rare plant species, including the Mauna Kea Silversword. Exclosures, which protect plants from ungulate impacts, can surround individual rare plants and communities of plants, and allow for native regeneration and outplanting.

(f) Game Management Areas

Under Chapter 183D, HRS, DLNR is authorized to establish game management areas (GMAs). GMAs can be designated by executive order, rule, cooperative agreement, or action of the Board of Land and Natural Resources. According to Section 183D-4, HRS, the purpose of GMAs is to manage, sustain, and enhance habitat and populations of game mammals and/or game birds, and provide public hunting and other compatible uses. In the Mauna Kea Watershed Alliance area, there are GMAs at Kaʻohe and in association with the Mauna Kea Forest Reserve. Cooperative GMAs are established at Pōhakuloa in partnership with the U.S. Army. While there are currently no specific rules for GMAs, public hunting regulations apply.

(g) DOFAW Draft Management Guidelines

DLNR has developed a set of guidelines for balancing desired levels of human use on all DOFAW-managed lands. These guidelines emphasize three program areas with conflicting resource demands or user groups, recognize and prioritize the importance and sustainability of native ecosystems, and are intended to provide administrative policy direction and prioritize resource management activities. Maps show native vegetation classified according to its relative intactness and habitat quality, and recommended levels of human use within these vegetation classifications for outdoor recreation, forest products, and game management.

The vegetation classes of DOFAW-managed lands within the Mauna Kea Watershed Alliance area are primarily V-2: Predominantly Native Areas and V-3: Considerably Disturbed Areas, with relatively small patches of Badly Degraded Areas (V-4). V-2 units consist of areas in which native plants predominate in communities that are relatively intact and are minimally disturbed. V-3 units consist of areas that had a considerable amount of disturbance, where vegetation does not reflect a naturally-evolved species composition, but rather a mixture of small remnant patches dominated by native plants, patches of largely invasive weedy alien plants, and areas of mixed native and non-native plants.

The majority of DOFAW-managed lands within the MKWA area are classified as R-2: Medium Use Areas, with respect to recreation management (Figure 17). These are areas where outdoor recreation is limited or controlled, or where it may be integrated with other uses. Facilities are not highly developed and include trails, rustic shelters, or unimproved campsites. Mauna Kea's Natural Area Reserves (Laupāhoehoe and Ice Age), Hilo Restricted Watershed, the Pīhā section of the Hilo Forest Reserve, and the Pa‘auilo section of the Hāmākua Forest Reserve are classified as R-3: Light Use Areas, where recreation should be limited to certain areas or occasional use due to impacts on resources or programs.

According to the draft management guidelines, game birds are managed in the Mauna Kea Forest Reserve and GMA and Ka‘ohe GMA for game production (A-1) (Figure 18). This means that game is the primary objective in these areas. Hunting seasons and bag limits for game birds provide maximal sustained public hunting opportunities and benefits. The remaining DOFAW-managed lands on the mountain are to be managed for mixed game and other uses, where game management for game birds is an objective integrated with other uses (A-2). The draft guidelines recommend management of game bird populations to acceptable levels using public hunting.

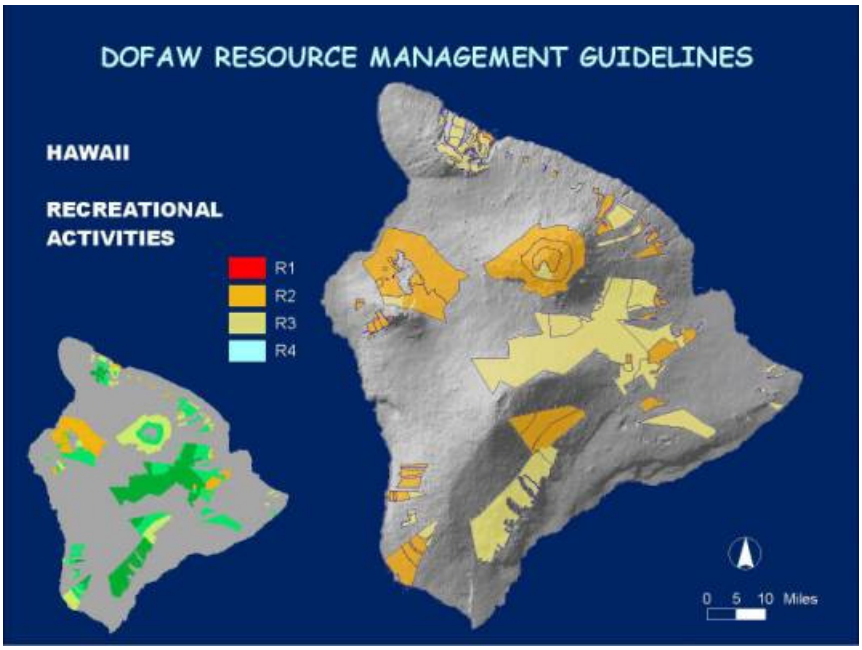


Figure 17: DOFAW Draft Management Guidelines for Recreational Activities

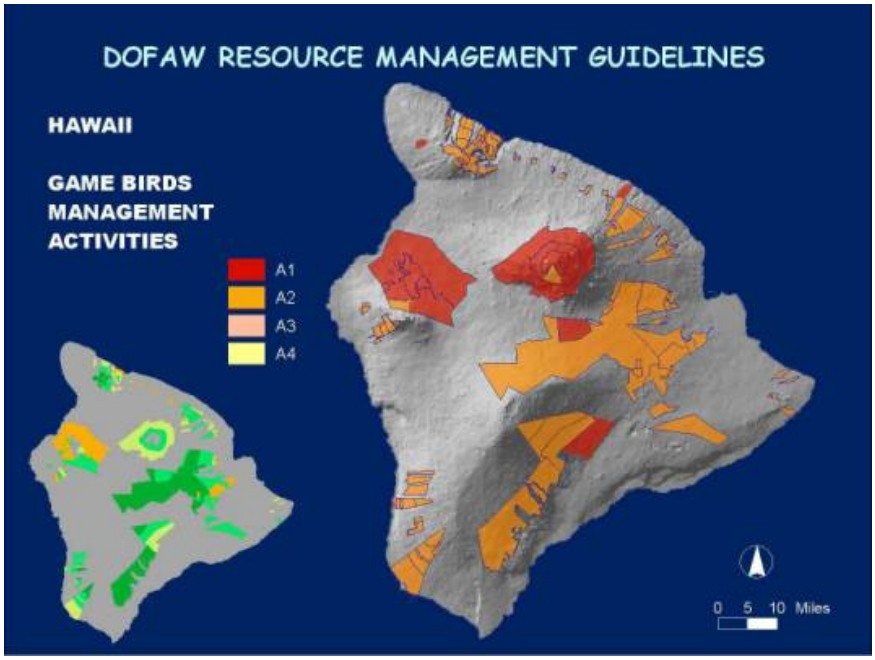


Figure 18: DOFAW Draft Management Guidelines for Game Bird Management Activities

Feral pigs are managed for a variety of objectives, depending on location (Figure 19). In the Laupāhoehoe NAR and Hilo Restricted Watershed, resource protection is the primary objective noted in the draft guidelines, with an emphasis on native plant

communities and watersheds (A-3). Seasons and bag limits are designed for public hunting to reduce impacts to native resources. In one section of the Laupāhoehoe NAR, animal removal is to be done only by DLNR staff or agency designees because of environmental sensitivity, remoteness, or public safety (A-4). The remaining sections of the Hilo Forest Reserve and Hōʻea Kaao section of the Hāmākua Forest Reserve are managed for mixed game and other uses, where game management is an objective integrated with other uses (A-2). Feral pig populations are managed to acceptable levels using public hunting. The remaining sections of the Hāmākua Forest Reserve are managed for game production (A-1).

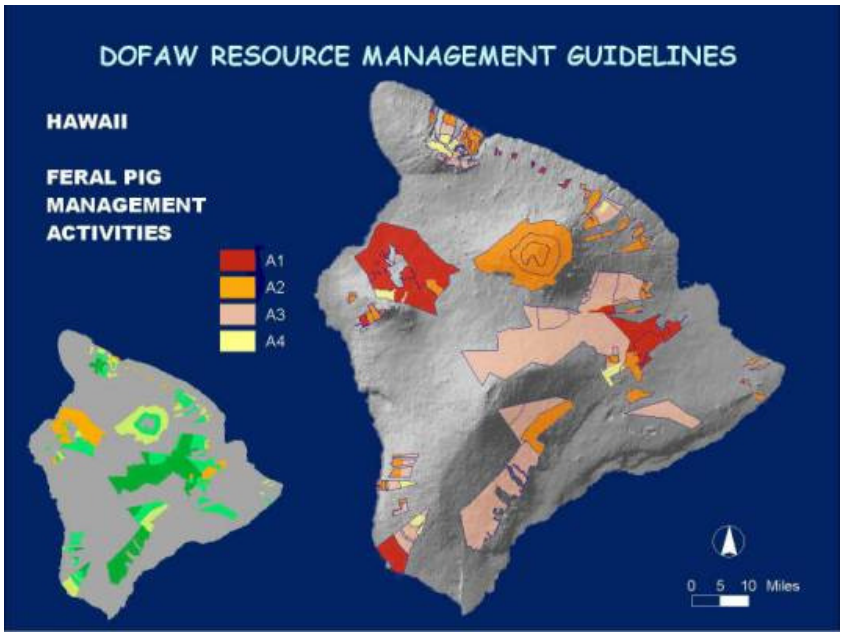


Figure 19: DOFAW Draft Management Guidelines
for Feral Pig Management Activities

Wild sheep and goats in the upper elevations of Mauna Kea (Forest Reserve and GMA, Ice Age NAR, and Kaʻohe GMA) are managed by supervised game control, meaning that in these areas animals are to be removed by DLNR staff or agency designees because of environmental sensitivity, remoteness, or public safety (A-4) (Figure 20). In the Laupāhoehoe NAR and Hilo Restricted Watershed, resource protection is the primary objective, with an emphasis on native plant communities and watersheds (A-3). Seasons and bag limits are designed for public hunting to reduce impacts to native resources. The remaining sections of the Hilo Forest Reserve and Hōʻea Kaao section of the Hāmākua Forest Reserve are managed for mixed game and other uses, where game management is an objective integrated with other uses (A-2). According to the draft management guidelines, the remaining sections of the Hāmākua Forest Reserve are to be managed for game production (A-1).

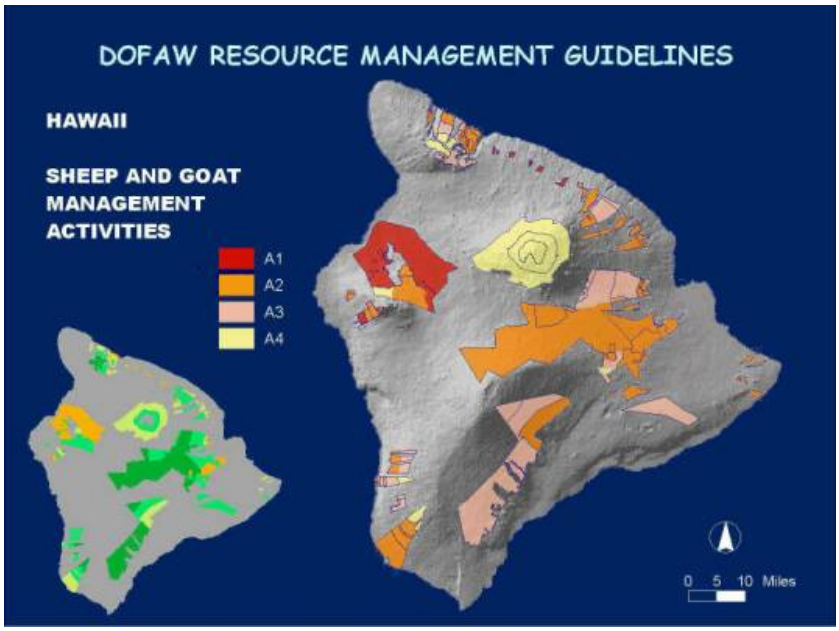


Figure 20: DOFAW Draft Management Guidelines
for Sheep and Goat Management Activities

Within the majority of DOFAW-managed lands in the Mauna Kea Watershed Alliance area, forest products may be harvested for personal use (F-3) (Figure 21). The exception is within the Natural Area Reserves, where harvesting is restricted (F-4). Some smaller areas of the forest reserves are classified for small (F-2) and large scale (F-1) harvesting or salvage. In these areas, permits and/or licenses are required, with appropriate restrictions.

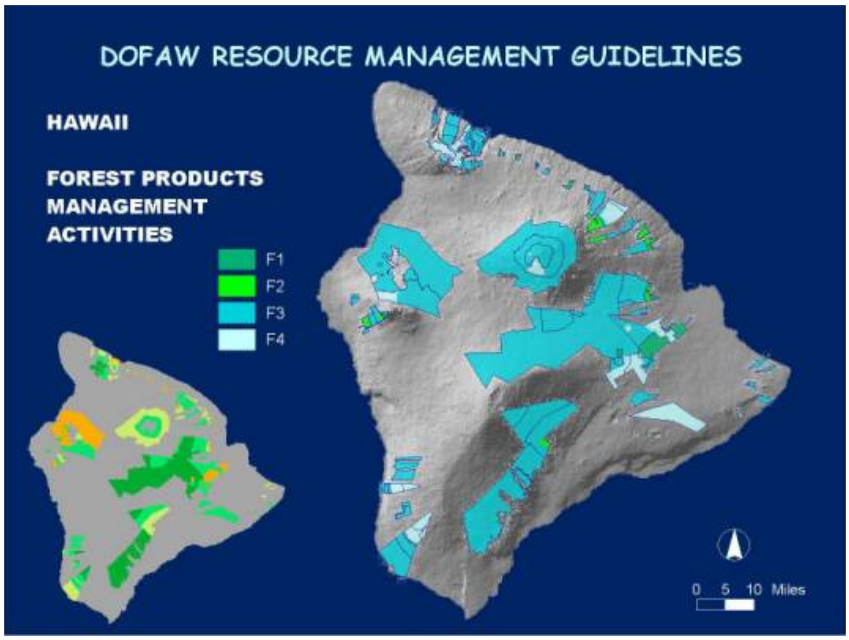


Figure 21: DOFAW Draft Management Guidelines
for Forest Products Management Activities

2. Land Division Management

Pursuant to Chapter 171, HRS, DLNR, through its Land Division, is responsible for disposition of public lands that are not set aside for use by other government agencies. Unless otherwise authorized, DLNR must dispose of lands as leases determined by public auction.

Public lands are classified as intensive agricultural use, special livestock use, pasture use, commercial timber use, quarry use, mining use, recreational use, watershed use, residential use, commercial and industrial use, hotel, apartment and motel use, resort use, and unclassified uses. Agricultural or forestry-related lands are further divided into classes based on productivity or potential economic yield. Before any parcel of land is auctioned off, DLNR must classify the land according to its uses, determine the specific use or uses for which the disposition is intended, parcel the land into a size sufficient for an economic operation, determine the requirements for the construction of buildings or other improvements which are necessary to encourage the highest use of the land, and determine the upset price or lease rental. For intensive agricultural and pasture uses, the State will also note existing improvements, extent of uncontrolled erosion, nature of forage, and extent of noxious weed infestation.

Each Land District office maintains a register in which all people interested in acquiring public lands register. The State is always looking for the highest and best use of its lands. The register is a way for people to express interest not only in acquiring public lands but also to identify other potential uses of those lands.

The Board of Land and Natural Resources may withdraw any portion of land from a lease with reasonable notice and without compensation for public uses or purposes (Section 171-37, HRS). The rent is reduced in proportion to the value of the land withdrawn.

There are seven agricultural leases for pasture, totaling 29,845 acres, within the MKWA area on the north slope of Mauna Kea: Parker Ranch has 1,839 acres under GL S-4471 and RP S-7331; Ernest and Marian DeLuz have 5,012 acres under General Leases S-4472 and S-4473; K.K. Ranch, under General Lease S-4475, has 7,282 acres, of which approximately 2,124 were removed for palila mitigation; S.C. Ranch, under General Lease S-4477, has 7,780 acres, of which 791 acres were withdrawn for palila mitigation; and Boteilho Hawaii Enterprises, under General Lease S-4478, has 7,932 acres, of which 2,228 were removed for palila mitigation. In exchange for the withdrawal of lands for palila mitigation, rents were reduced proportionally, leases on the remaining lands were extended 20 years, and, pursuant to Act 236 HSL620, lessees were allowed to use 10% of the remaining leased land for alternative agricultural use.

Alfred Nobriga has a pasture lease of 5,994 acres on the southeast side of Mauna Kea, adjacent to the Wailuku River corridor and the Hilo Restricted Watershed. This area contains some important mesic and wet koa-ʻōhiʻa forest remmants and provides a link between wet and dry forest communities. While Nobriga has fenced his cattle out of the

Wailuku River corridor, gorse spreading downstream in the corridor has begun to infest his leased lands.

DLNR's Land Division also manages 1,739 acres of unencumbered land formally leased by Parker Ranch near Kaʻohe. Fourteen hundred acres of this parcel are currently under management by DOFAW for palila habitat.

Beginning in 2010, the authority to manage certain public lands that are designated important agricultural lands pursuant to Section 205-44.5, HRS, will be transferred to the Hawaiʻi Department of Agriculture (DOA). It is uncertain at this time if any of these parcels will be transferred to DOA for management.

3. Department of Hawaiian Home Lands (DHHL) Management

The Department of Hawaiian Home Lands (DHHL) manages 68,195 acres in the Mauna Kea Watershed Alliance area. Approximately 56,200 acres are on the east slope of Mauna Kea (Humuʻula/ Piʻihonua), while the remainder are located on the northwest slope between Waimea and Honokaʻa. The lands on the northwest slope are managed for grazing, homesteading, and farm lots. Keanakolu-Mānā Road connects DHHL's parcels on Mauna Kea and traverses the length of the Humuʻula/ Piʻihonua parcel. The headwaters of Wailuku River are also found on DHHL lands.

The Humuʻula/Piʻihonua lands range from approximately 4,500-9,000-ft. elevation. They are characterized by their isolation, high elevation, cool temperatures, and lack of infrastructure. The vegetation is dominated by an understory of introduced grass species over much of the land, with degraded koa-ʻōhiʻa forest in portions of Piʻihonua, scattered koa and mamāne in the northern portion, and remnant mamāne in the upper elevations. Gorse covers between 10,000-13,000 acres in the central portion of Humuʻula, rendering the land virtually useless. Patches or individual plants can be found across another 10,000 acres, and populations are established along stream courses and gullies.

Much of the land was leased historically. Parker Ranch held the longest ranching lease to the property, from 1901 to 2002, initially for sheep ranching and later focused on cattle operations. The lease extended around Mauna Kea to the Puʻuhuluhulu vicinity. Piʻihonua Mauka was most recently leased as Puʻu ʻŌʻō Ranch until the early 1990s and there are still feral cows (2,000 or more) in this area. DHHL is in the process of developing a feral cattle removal plan, aimed at removing all feral cattle over the next five years. Since 2002, when existing cattle leases expired, most of these lands have been inactive. Efforts to restore the land's productivity via gorse control, native bird corridors, and koa forest restoration have begun in priority areas.

In 2001, DHHL proposed to salvage koa (*Acacia koa*) from 125 acres of pasture lands in Waipunalei adjacent to Keanakolu Road in Humuʻula and reforest with koa (DHHL 2001). The land was historically used for cattle grazing, and the forest is degraded. As proposed in the plan, trees were salvaged in cutting blocks of 5 to 15 acres. Leave trees remained based on their health, diameter and height. The area was fenced to

control ungulates and the soil scarified to stimulate koa regeneration from the existing seedbank. The project was completed in 2004, and DHHL is evaluating the progress of the area's post-harvest condition.

In 2004, DHHL proposed to salvage koa on a total of 930 acres of former pasture land in Pīhā Mauka adjacent to Keanakolu-Mānā Road and north of the Kanakaleonui corridor (DHHL 2004). Salvage sales would be divided into three units. Fifty percent of the koa overstory would be harvested from 600 forested acres on the parcel. Dead and unhealthy trees would be harvested, and healthy trees left to provide bird habitat, foraging opportunities for native species, and koa seed production. DHHL proposed to reforest the land through scarification and hand planting if necessary. The first Pīhā salvage sale of 103 acres has been completed; the second one of approximately 270 acres is in process. The third Pīhā unit remains to be harvested. According to DHHL (2004), "sustainable forest practices can bring economic diversity and employment to our beneficiaries, enhance the environment, while retaining the rural character of the islands" (p. 2).

DHHL has partnered with USFWS and others to initiate a number of restoration projects on the Humuʻula/ Piʻihonua lands. The 514-acre Kanakaleonui Bird Corridor (KBC) restoration project represents a collaborative multi-organizational effort to re-establish and maintain wildlife habitat for native bird populations. This ungulate-free makai to mauka corridor will create a flyway connecting the lower elevation koa and ʻōhiʻa forest in Hakalau Forest NWR with the upper elevation mamane forest in the Mauna Kea Forest Reserve. A management plan for this project was developed in April 2009 (DHHL 2009). Other project goals include creating a volunteer program to assist with project implementation and providing recreational opportunities.

Phase 1 of the Humuʻula Koa Buffer was implemented on 190 acres of gorse-infested pasture on DHHL land immediately mauka of Hakalau Forest NWR. Koa was planted in high density on DHHL land to try shading out gorse along the *mauka* boundary of the Hakalau Forest NWR. The NWR provided site preparation, DHHL sprayed gorse with herbicide and planted approximately 40,000 koa trees, and USFWS's Partners for Fish and Wildlife program funded fencing to keep cattle out of the area where koa was planted.

Phase 2 of the Humuʻula Koa Buffer comprises 460 acres immediately north of the Phase 1 area and adjacent to Hakalau Forest NWR. This area consists of pasture land with patches of gorse (not high density). The project has been funded but not yet implemented. The Refuge will provide site preparation and scarification for koa, DHHL will conduct herbicide spraying of gorse patches, and Partners for Fish and Wildlife will provide fencing.

Hakalau Forest NWR and DHHL also share 10 miles of fuel break along the western boundary of the Refuge. USFWS has a 20-year Memorandum of Understanding (MOU) with DHHL for access and fuel break maintenance.

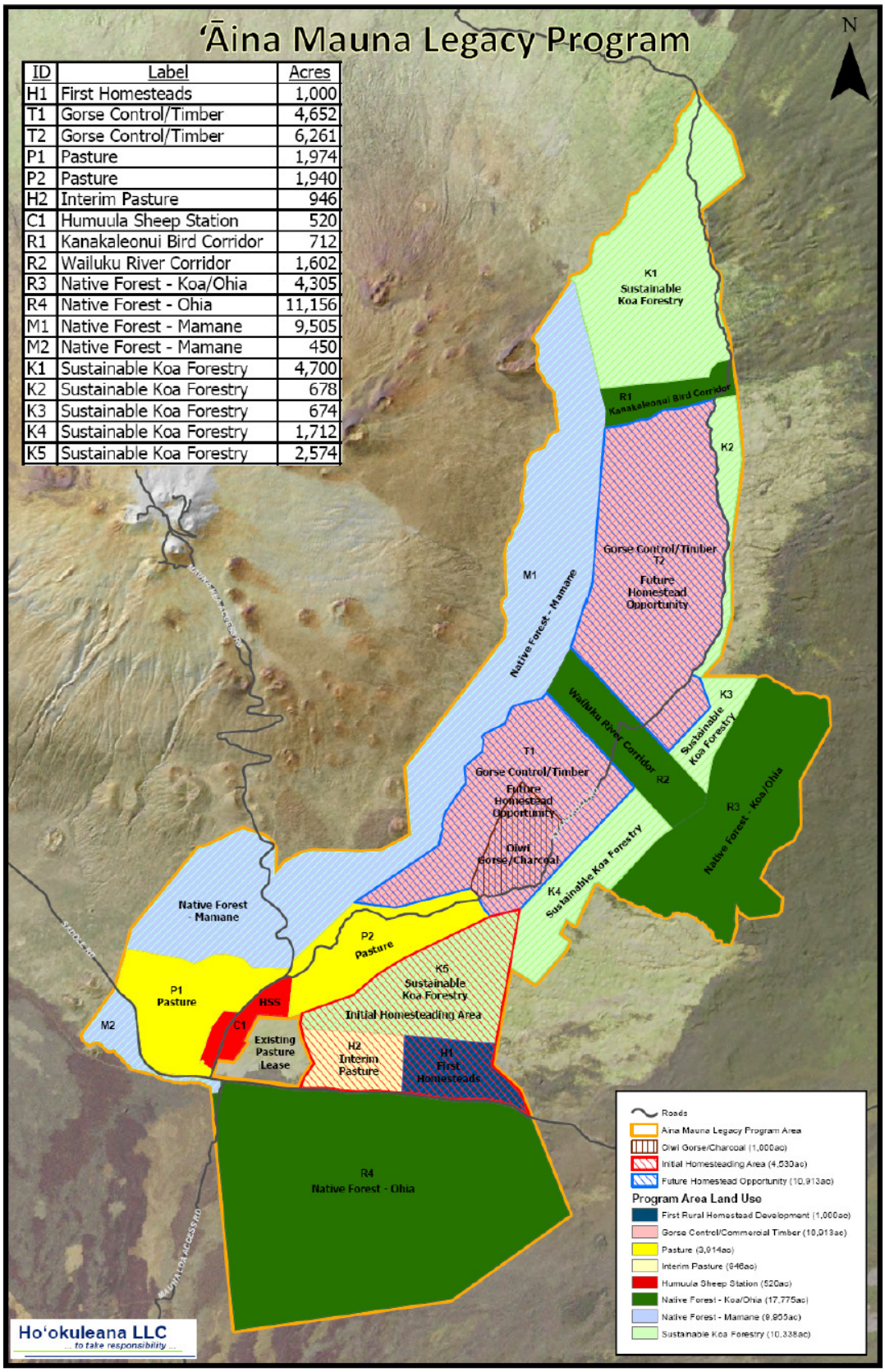
In December 2009, the Hawaiian Homes Commission approved the ʻĀina Mauna Legacy Program to serve as a guide as DHHL moves forward in managing the lands of Humuʻula/ Piʻihonua (DHHL 2009b). The primary goal of the program is to develop an economically self-sustaining improvement and preservation program for the natural and cultural resources of Humuʻula/ Piʻihonua. This long-term program proposes a range of uses that will provide homesteading, sustainable restoration of native forests, sustainable forestry, and ecotourism opportunities (Figure 22).

One program component involves using commercial timber for gorse control and ecosystem restoration. This project would use initial plantings of sugi and/or eucalyptus on a commercial scale on 10,913 acres in the core gorse infestation area to shade out gorse and generate income, with successional plantings and harvests until the gorse seed bank is no longer viable. These lands would be leased competitively for commercial timber production. The time estimated for gorse control is approximately 100 years due to the estimated 70-year viability of gorse seeds, allowing numerous timber growth/harvest cycles. Once it has been determined that gorse seed germination is no longer a threat, the area would be restored to koa forest.

Another program component entails establishing an initial minimally-developed rural homestead development for DHHL beneficiaries on 1,000 acres in the southern portion of the property along Saddle Road. Preliminary design concepts call for a subdivision of 100-200 homestead sites of about 5-acres each for self-sustaining homesteading, including land for a home site, subsistence farming, and other agricultural uses.

The ʻĀina Mauna Legacy Program also recommends the establishment of commercially-sustainable koa forest management areas, initially on about 10,000 acres. On these lands, DHHL would continue to implement a koa salvage and reforestation program. These areas could be expanded to include an additional 10,000 acres once gorse has been eradicated from the Humu`ula parcel. Management of DHHL lands as koa forests combines high quality hardwood returns from the sale of koa wood, ecotourism opportunities as the forest is restored, and cultural uses such as gathering and canoe logs. According to DHHL (2009b), managing all potential koa lands at Humuʻula/ Piʻihonua Mauka would create a harvest potential of 310 acres per year and income of $4,450 per harvested acre. Total benefits to the trust from Humuʻula koa could be $1,379,500 in annual revenues, 15 to 20 onsite jobs from logging and tree maintenance, and enough wood for at least 150 woodworkers.

While most of the cattle leases expired in 2002, cattle can serve as beneficial tools in controlling fire fuels, particularly in areas frequented by people. A program component calls for limited pasture use on 4,860 acres, consistent with the DHHL Fire Management Plan (DHHL 2007), as a cost-effective way to reduce fuel loads along Saddle Road, Mauna Kea summit access road, and Keanakolu-Mānā Road. Management efforts will balance between grazing for wildfire protection and not exacerbating the gorse problem. One existing pasture lease currently exists near the Humuʻula Sheep Station.



ID	Label	Acres
H1	First Homesteads	1,000
T1	Gorse Control/Timber	4,652
T2	Gorse Control/Timber	6,261
P1	Pasture	1,974
P2	Pasture	1,940
H2	Interim Pasture	946
C1	Humuula Sheep Station	520
R1	Kanakaleonui Bird Corridor	712
R2	Wailuku River Corridor	1,602
R3	Native Forest - Koa/Ohia	4,305
R4	Native Forest - Ohia	11,156
M1	Native Forest - Mamane	9,505
M2	Native Forest - Mamane	450
K1	Sustainable Koa Forestry	4,700
K2	Sustainable Koa Forestry	678
K3	Sustainable Koa Forestry	674
K4	Sustainable Koa Forestry	1,712
K5	Sustainable Koa Forestry	2,574

Figure 22: DHHL's 'Āina Mauna Legacy Program

The ‘Āina Mauna Legacy Program further recommends setting aside areas of native forests that are not commercially harvested but instead protected and restored to a natural condition. According to DHHL (2009b), these areas will provide ecosystem services, including the production of food and water, control of climate and disease, and maintenance of habitat and species diversity; and opportunities for cultural and recreational uses. Native forest areas would include 10,000 acres of mamāne forest, 11,156 acres of ‘ōhi‘a forest, 4,305 acres of koa-‘ōhi‘a forest, 1,602 acres of riparian corridor along the Wailuku River, and 712 acres in the Kanakaleonui Bird Corridor.

The final component of the ‘Āina Mauna Legacy Program comprises education and ecotourism related activities. It proposes to use the Humu‘ula sheep station as a gateway to Mauna Kea and the ‘Āina Mauna lands, according to recommendations in the Humu‘ula Sheep Station Adaptive Reuse Plan (DHHL 2004b). The Reuse Plan proposes a mix of land uses, including a historic/community center (5.5-6.0 acres), open campground (2.0-2.5 acres), and commercial area (7.0-8.0 acres) with retail, recreational, lodging, and restaurant facilities. From the Sheep Station, people could undertake ecotourism-related activities, such as biking, hiking, bird watching, camping, horseback riding, and skiing. A remote lodge could be developed at the existing Pu‘u ‘Ō‘ō Ranch facilities, with horseback riding, hiking, and ecotours offered. The former cowboy huts could also provide rustic overnight accommodations. Request for Proposals will be issues to solicit prospective operators for ecotourism activities.

Other activities planned by DHHL include developing infrastructure for volunteer groups working in the Kanakaleonui bird corridor and fencing the Wailuku River corridor as an additional bird flyway.

4. University of Hawai‘i, Office of Mauna Kea Management

The University of Hawai‘i (UH) manages approximately 12,000 acres of State lands on Mauna Kea associated with the observatories at the summit of the mountain (Figure 23). These UH Management Areas comprise the Mauna Kea Science Reserve, public summit access road, and mid-level facilities at Hale Pōhaku. The Mauna Kea Science Reserve was established in 1968 through a 65-year lease and comprises lands generally above 11,500-ft. elevation. This area is divided into a 525-ac. Astronomy Precinct, where development is to be consolidated to maintain a close grouping of astronomy facilities and support infrastructure, and a 10,763-ac. Natural/ Cultural Preservation Area to protect natural and cultural resources. The observatory support facilities at Hale Pōhaku, at the 9,200-ft. elevation, sit on 19.3 acres. The University also manages the summit access road plus a 400-yard strip on either side of the road, except for areas within the Mauna Kea Ice Age NAR.

Management of the Mauna Kea Science Reserve (MKSR) is spelled out in the lease (General Lease S-4191), State administrative rules, and conditions imposed by the conservation district use permit. A series of plans have been developed for Mauna Kea, including the 1977 *DLNR Mauna Kea Plan*, which served as a policy framework for the management of Mauna Kea; the 1985 *University of Hawai‘i Mauna Kea Management Plan*; and the 1995 *Revised Management Plan for the UH Management Areas on*

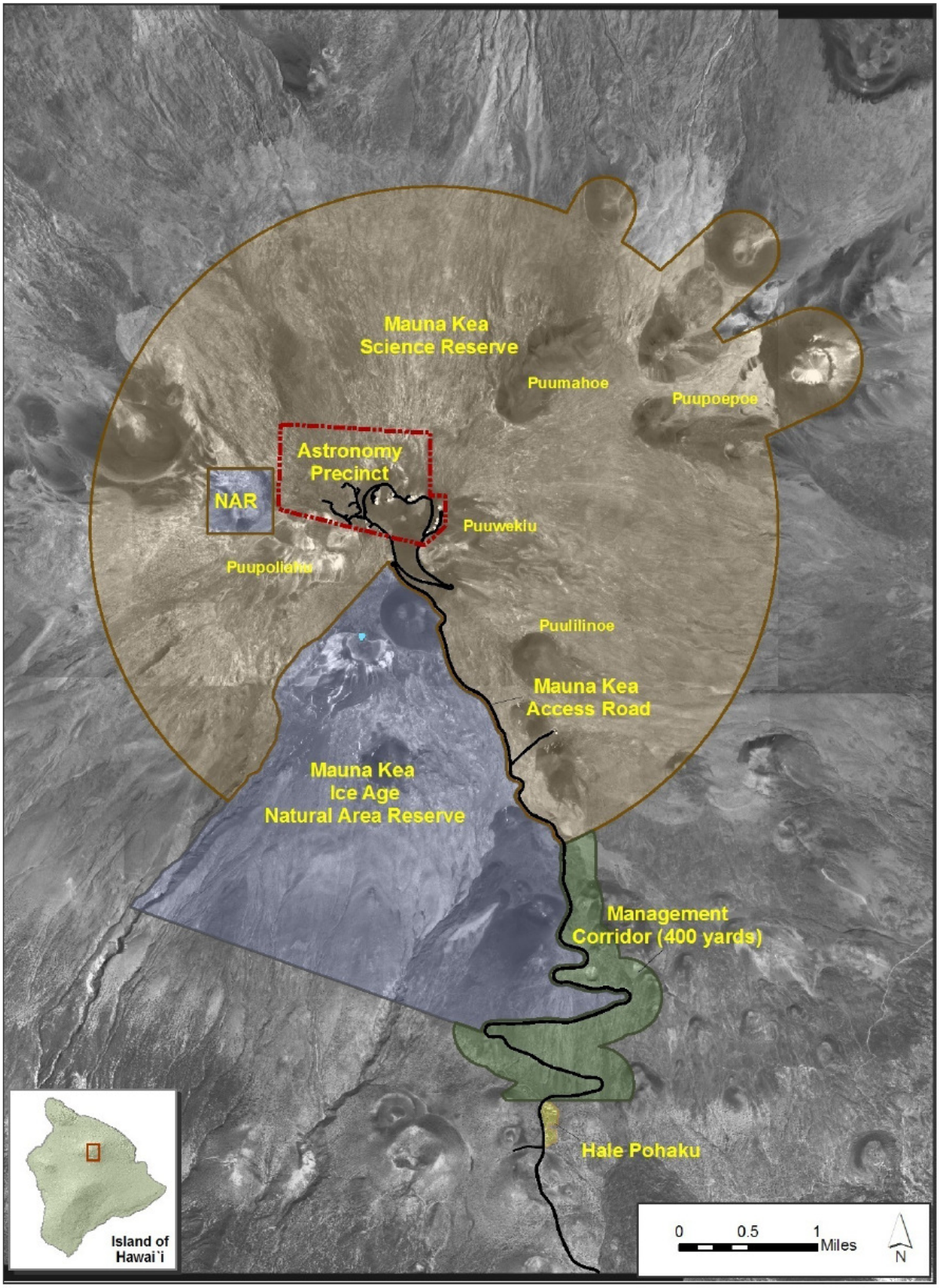


Figure 23: University of Hawai‘i Management Areas (from SRGII 2009)

Mauna Kea. The 2000 *Mauna Kea Science Reserve Master Plan* (Group 70 2000), adopted by the UH Board of Regents, establishes management guidelines for the next 20 years. The 2009 *Comprehensive Management Plan* (CMP) provides a guide for managing existing and future activities to ensure Mauna Kea's unique cultural and natural resources are protected in perpetuity. It was approved with conditions by the Board of Land and Natural Resources in April 2009, subject to the completion and approval of several sub-plans. Sub-plans for cultural resources management, natural resources management, and public access were developed in 2009 and were approved by the BLNR on March 25, 2010 (PCSI 2009; SRGII 2009; SRGII *et al.* 2009). The series of plans that have been developed since 1977 reflect public and government concerns over the use of Mauna Kea, including respect for Hawaiian cultural beliefs, protection of environmentally-sensitive habitat, and recreational use of the mountain, in addition to astronomical research.

Pursuant to the 2000 Master Plan, an Office of Mauna Kea Management (OMKM) based at UH Hilo oversees efforts to protect, preserve and enhance the natural, cultural and recreational resources of Mauna Kea; undertakes day-to-day management of cultural and natural resources within the UH Management Areas; ensures compliance with the 2000 Master Plan and 2009 Comprehensive Management Plan; manages with the Mauna Kea Observatories Support Services the ranger program; and issues tourism-related commercial permits.

The Mauna Kea Observatories Support Services (MKSS) is funded by and operates under direction from the observatories. It oversees the general maintenance and logistical services to all Mauna Kea observatories and the facilities at Hale Pōhaku; conducts summit access road maintenance; and supports ranger services.

The Mauna Kea rangers are an onsite cohort of individuals whose responsibilities include management of public health and safety, and public access. These rangers provide information; direct visitors to established hiking trails; monitor commercial tours; patrol the summit to observe and document activities; manage visitors on peak days; and maintain sites and trails.

Under a 2008 agreement, OMKM works cooperatively with DLNR's Natural Area Reserve program on cross-boundary management issues. Under this agreement, the OMKM provides visitor assistance in the NAR using Mauna Kea rangers, engages in joint research and educational efforts with NAR staff, and reports violations occurring in the NAR.

Act 132, signed into law by the Governor in June of 2009, gives UH the authority to develop, implement, and enforce rules and regulations for public and commercial activities within the UH Management Areas. UH assumed responsibility for commercial tour permitting in 2007. UH will begin the rule-making process in the near future.

Given the cultural significance of Mauna Kea to the Hawaiian people, there are significant cultural resources within the UH Management Areas. The 2009 Cultural

Resources Management Plan (PCSI 2009) describes potential threats to the historic and cultural resources and how these impacts can be mitigated. It recommends specific long-term management strategies, program, and plans, and presents a plan to implement these management actions.

There are also significant geological, plant and animal resources within the UH Management Areas. These are described in the 2009 Natural Resources Management Plan (SRGII 2009), which focuses on the protection and preservation of these resources. The plan provides detailed information on the status of and threats to the natural resources and recommends management actions to conserve these resources.

The purpose of the 2009 Public Access Plan (SRGII *et al.* 2009) is to provide guidance in addressing public access in the UH Management Areas. The objective of the plan is to provide a set of principles and policies to guide UH in the development of administrative rules related to the management of public access. It also discusses current and future public and commercial activities in the UH Management Areas, public access-related issues, and makes recommendations regarding those issues.

B. FEDERAL

The Federal government owns 56,402 acres of land in the Mauna Kea Watershed Alliance area, including Hakalau Forest National Wildlife Refuge (33,000 acres), the PTA cantonment area, and the recently-purchase Keʻāmuku Maneuver Area of PTA (23,022 acres) (Figure 24). In addition, the U.S. Army leases 22,988 acres of State land in the saddle area between Mauna Kea and Mauna Loa for military training activities at PTA. The U.S. Army also has 84,815 acres of land set aside by Executive Order; these lands would revert to State ownership if they were not used for military purposes. Finally, the U.S. Forest Service co-manages 12,343 acres of State land in the Laupāhoehoe Natural Area Reserve and Forest Reserve, as part of the Hawaiʻi Experimental Tropical Forest.

1. U.S. Fish and Wildlife Service Management

(a) Hakalau Forest National Wildlife Refuge

Hakalau Forest National Wildlife Refuge (NWR), located on the windward slopes of Mauna Kea (see Figure 25), was established in 1985 under the authority of the Endangered Species Act to protect endangered forest birds and their rain forest habitat. The Refuge comprises nearly 33,000 acres extending from 2,500 to 6,600-ft. elevation and characterized primarily by some of the best stands of wet and mesic koa (*Acacia koa*) and ʻōhiʻa (*Metrosideros polymorpha*) forest remaining in Hawaiʻi. The NWR is bisected by numerous streams, many of which become perennial at lower elevations, and constitutes an important watershed area. While most of the Refuge is closed canopy forest, about 5,000 acres were converted to open woodland and pasture dominated by introduced grasses by over 100 years of cattle grazing, logging, and burning.

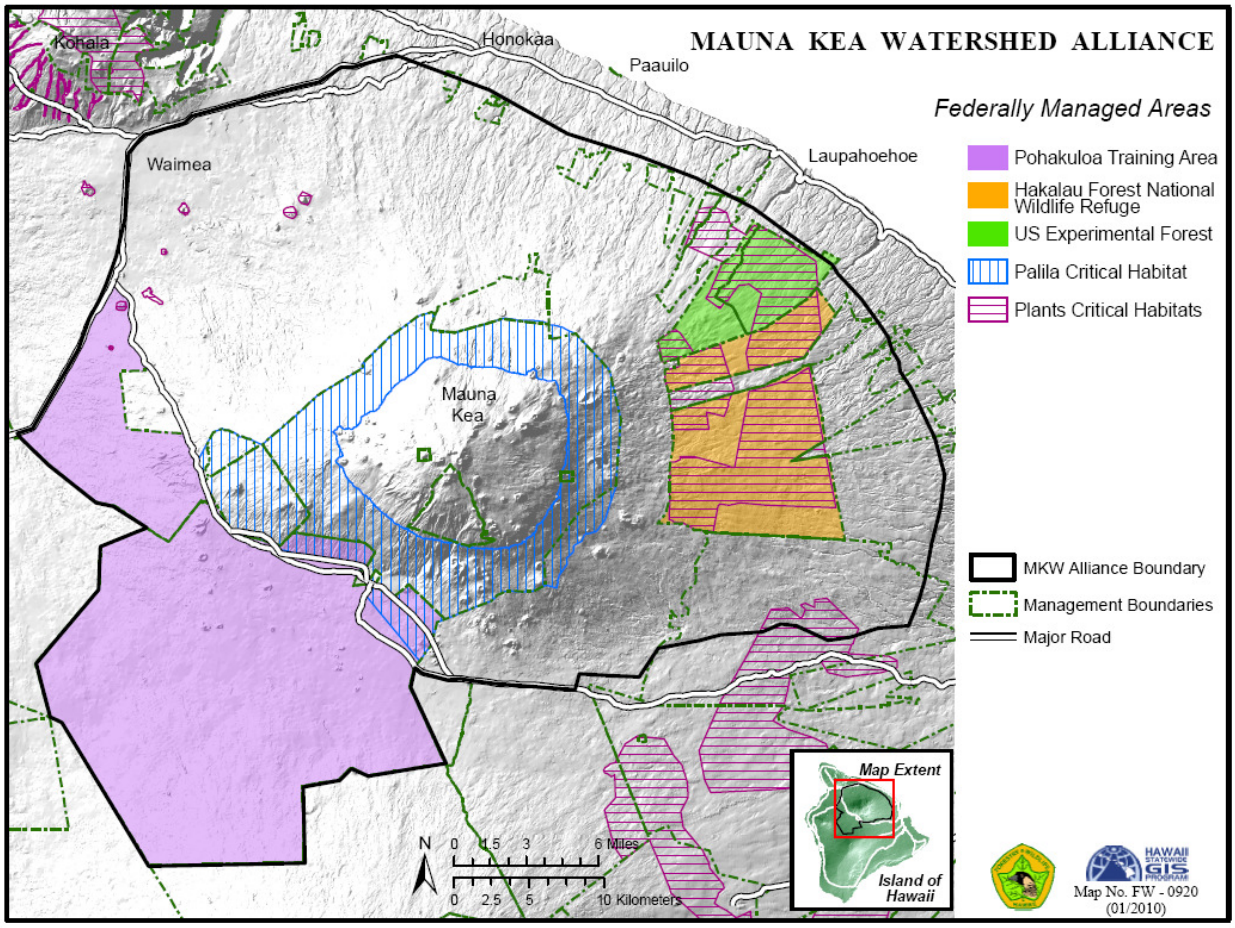


Figure 24: Federally-Managed Lands

Forested portion of Hakalau contain some of the highest densities of native forest birds in the State (Scott *et al.* 1986). Endangered forest birds found at Hakalau include ‘Akiapola‘au (*Hemignathus monroi*), Hawai‘i creeper (*Oreomystis mana*), Hawai‘i ‘Ākepa (*Loxops coccineus coccineus*), ‘O‘u (*Psittirostra psittacea*), and ‘Io or Hawaiian Hawk (*Buteo Solitarius*). Several small flocks of Nēnē or Hawaiian goose (*Branta sandvicensis*) were re-introduced to the area in 1995. The endangered Koloa Maoli or Hawaiian Duck (*Anas wyvilliana*) is also found on small ponds throughout the abandoned pastures (DHHL 2003). The endangered Hawaiian hoary bat, Hawaii’s only land mammal, roosts and feeds within the Refuge. Hakalau Forest NWR is also home to 29 rare and endangered plant species (Stone *et al.* 1987), as well as native invertebrates, including land snails.

A management plan for Hakalau NWR was developed in 1989. The goals of the Refuge are to protect and restore endangered plant and animal species and their habitats, control weeds and ungulates, and provide wildlife-dependent cultural, educational, and recreational opportunities. A Comprehensive Conservation Plan (CCP) for Hakalau is currently under development.

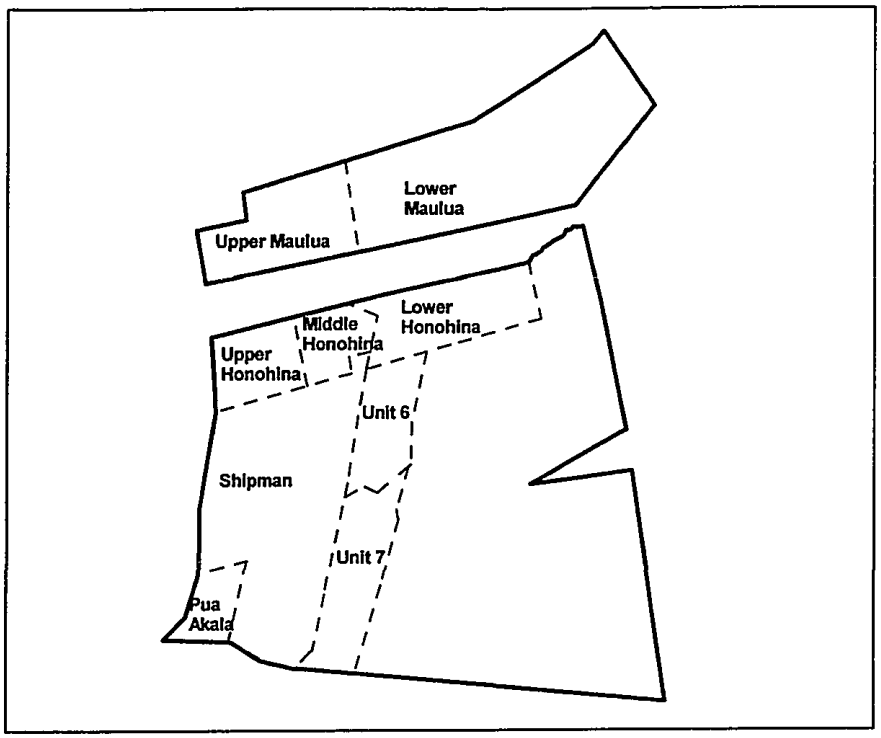


Figure 25: Hakalau Forest National Wildlife Refuge - Units

Current management efforts include habitat restoration via koa reforestation in the dry koa-mamāne and open pasture zones (greater than 400,000 trees to date), fencing and ungulate control, alien plant control, and propagation and outplanting of understory and endangered plant species in the mesic koa-ʻōhiʻa zone; annual forest bird surveys; and vegetation monitoring. The highest priority weed species on the Refuge in 1989 was gorse (*Ulex europus*), but today the focus is largely on Florida blackberry (*Rubus argutus*) and banana poka (*Passiflora tarminiana*). In accordance with a feral ungulate management plan approved in 1996 (USFWS 1996b), feral pigs and cows have been removed from approximately half of the Refuge following fencing, allowing forest recovery in areas previously grazed. Fencing and ungulate control for the remaining half of the Refuge is a priority action.

USFWS developed a wildland fire management plan for the Hakalau Forest NWR in 2002 (USFWS 2002). It has partnered with neighboring DHHL to create fuel breaks to prevent the spread of fires in the upper elevation areas to reduce risk of wildfire due to heavy growth of pasture grasses, gorse infestation, and potential for ignition. The Refuge has a 20-year MOU with DHHL for access/ fuel break maintenance on 10 miles of shared fuel break along the western boundary of the Refuge. USFWS also partners with other neighboring land owners and conservation agencies to encourage management for the benefit of native species and habitats.

The 2,000-acre Upper Maulua Unit is open to the public for birding, photography and hiking on weekends and holidays with prior permission. Access to the remaining 31,000 acres requires a Special Use Permit. The Friends of Hakalau Forest NWR was started in 2006 to support the work of the Refuge, by providing a volunteer corps to help with restoration efforts.

There are 2 buildings at Hakalau Forest NWR being considered for the National Historic Register: a cabin in the Pua Akala parcel built around 1883 and the Nauhi cabin built in the Honohina parcel in the 1920s.

(b) Recovery Plans and Critical Habitats

Recovery plans delineate actions required to recover and protect federally-listed plant and animal species. Recovery plans have been prepared for a number of plant and animal species found on Mauna Kea, including the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) (USFWS 1998a); Hawaiian forest birds, including ‘o‘u, palila, ‘akiapola‘au, Hawai‘i creeper, and Hawai‘i ‘ākepa (USFWS 2006); Hawaiian duck or koloa (*Anas wyvilliana*) (USFWS 2005); ‘Io or Hawaiian hawk (USFWS 1984); Nēnē or Hawaiian goose (*Branta sandvicensis*) (USFWS 2004); Big Island plant clusters (multiple native species) (USFWS 1996, 1998b, 1999, 2003b); Mauna Kea silversword (*Argyroxiphium sandwicense* ssp. *sandwicense*) (USFWS 1993); and the Hawaiian fern *Asplenium fragile var. insulare* (USFWS 1998c).

USFWS prepared a Recovery Outline for 12 Hawaiian Picture-wing Flies in August 2006. This document serves as an interim guidance to direct recovery efforts and inform consultation and permitting activities until a comprehensive draft recovery plan has been completed. Two species of the picture-wing flies are found in the mesic to wet montane environments on Mauna Kea: *Drosophila heteroneura* and *Drosophila ochrobasis*.

When a species is proposed for listing as endangered or threatened under the Endangered Species Act, the USFWS considers whether there are areas of habitat essential to the species’ conservation. Those areas are proposed for designation as critical habitat. Designated areas may include habitat areas actually occupied by a species, as well as areas within the species’ historical range. Federal agencies are required to consult with USFWS on actions they carry out, fund or authorize to ensure that these actions will not destroy or adversely affect critical habitat. USFWS has designated critical habitat for the palila bird (*Loxioides bailleui*), as well as endangered plant species. (See Figure 24.)

(c) Partners for Fish and Wildlife

USFWS’s Partners for Fish and Wildlife Program was established to offer technical and financial assistance to landowners who wish to restore wildlife habitat (native ecosystems) on their property. Projects can include construction of fences to exclude feral ungulates; control of alien plants, mammalian predators, and feral ungulates; out-planting of native plants; and restoration of native ecosystem elements, such as hydrology and micro-habitat conditions. The assistance provided by USFWS can range

from informal advice on the design and location of potential restoration projects to cost-share funding of project implementation under a formal cooperative agreement with the landowner. USFWS has partnered with DHHL on a number of projects.

B. U.S. Army Management

Pōhakuloa Training Area (PTA), the largest military training area in Hawai‘i, is located in the saddle between Mauna Kea and Mauna Loa. It extends up the slope of Mauna Kea to the 6,800-ft. elevation. PTA encompasses 132,950 acres, of which 23,022 acres are Federally-owned (Ke‘āmuku Maneuver Area + cantonment area) and 22,988 acres are leased from the State. Another 84,815 acres have been set aside for military use by Executive Order. Governor’s Executive Order 1719 (26 January 1956) set aside 758.26 acres for the use by the U.S. Government at PTA, and Presidential Executive Order 11167 (15 August 1964) acquired 84,057 acres from the State at no cost. These lands would revert to State ownership if they were not used for military purposes. The Keamuku parcel was recently purchased by the Army for use as a maneuver area to support training for the Stryker Brigade Combat Teams and Legacy Forces.

PTA lands are within the general, limited and resource subzones of the conservation district. The vegetation of PTA is a mosaic of plant communities related to the type and age of the substrate. Shaw (1997) describes rare plant species found at PTA. These plants are found primarily on the western (Training Areas 22 and 23) and eastern (Training Area 21) sides of PTA. Wildfire, feral animals, and competition from alien plant species are the greatest threats to these plants. One Federally-listed endangered bird species (nēnē) is documented for PTA. The Hawaiian Hawk (‘io) is incidentally but infrequently observed in the skies above PTA but does not use the habitat of PTA. The Hawaiian petrel (‘ua‘u) is being investigated at PTA, but, after four years of study, there is no evidence of a petrel colony on PTA lands. Hawai‘i’s only native land mammal, the Hawaiian hoary bat is also found at PTA. An area in the northern portion of PTA is designated critical habitat for the endangered palila, although no palila have been observed on PTA lands for at least twenty years. Over 343 archaeological and culturally-significant sites are known to be located within PTA (SRGII 2009).

USFWS’s (2003) Biological Opinion addressed impacts from training activities conducted by the Army at PTA to 15 Federally-listed threatened and endangered plant species, the Hawaiian hoary bat (*Lasiurus cinereus semotus*), and palila (*Loxioides bailleui*) critical habitat. It identifies conservation measures the U.S. Army must take to minimize or compensate for project effects on these species. It also requires an Implementation Plan for PTA. This Implementation Plan is currently under development.

An Integrated Natural Resources Management Plan (INRMP) was developed by the U.S. Army to guide implementation of the natural resources program on PTA from 2002-2006 (U.S. Army 2001). The goal of the program is to protect and manage viable populations of rare species, representative native communities and native landscapes and processes on Army-controlled land while accommodating military and other lands uses. The plan describes ecosystem management actions related to endangered

species, biodiversity and ecosystem integrity, pest management, conservation and outreach, and wildfire management. The INRMP is in the process of being revised.

Another Biological Opinion was issued in 2008 (USFWS 2008), to address impacts of new construction, training, and conservation actions not covered under the 2003 Biological Opinion that could affect the endangered *Asplenium fragile* var. *insulare* (fragile fern), the threatened *Silene hawaiienses* (Hawaiian catchfly), and the endangered *Solanum incompletum* (pōpolo, pōpolo ku mai). The 2008 Biological Opinion also addresses the endangered nēnē or Hawaiian goose (*Branta sandvicensis*), which has been observed utilizing areas of PTA and Keʻāmuku. Finally, the 2008 Biological Opinion deals with the contribution of a barbed wire fence to a hoary bat death, requiring USFWS to reconsider conservation measures to protect plant communities.

Since acquiring Keʻāmuku, the Army has fenced Puʻu Papapa and Puʻu Nahono o Hae, two areas with many listed plant species, pursuant to the 2008 Biological Opinion. To comply with the intent of the 2003 Biological Opinion as refined by the 2008 opinion, the Army will fence all of Training Area 21, to protect *A. fragile* var. *insulare* and *S. hawaiiensis*. The Army will also permanently fence all known individuals of *S. incompletum*. In addition, the Army will remove barbed wire from all fences to protect the Hawaiian hoary bat from entanglement.

The 2008 Biological Opinion assesses the effects of all ongoing and proposed training activities on nēnē in the PTA and Keʻāmuku Maneuver Area and recommends conservation measures, including nēnē monitoring, personnel education, training restrictions, development of an alternative site for nēnē flocking, nest monitoring and protection, and nēnē brood translocation if necessary.

The U.S. Army is managing natural resources and endangered species through the use of exclosures and intensive management areas. Crews are fencing to control feral animals in order to protect endangered plants. As fence units are completed, animal drives are conducted to drive the feral ungulates out of each unit. There are 65 miles of fence enclosing 45,000 acres, completed and planned. Fence completion is expected by early 2013. The U.S. Army is also aggressively controlling invasive weeds, conducing nēnē recovery, and conducting bird surveys in the palila habitat areas on the north side of Saddle Road.

Kīpuka Kalawamauna was designated an Endangered Plants Habitat by the U.S. Army after *Haplostachys haplostachya* and *Stenogyne angustifolia* were discovered in 1977 and subsequently listed as endangered. Other rare plants that have been identified in the area include *Chamaesyce olowaluana*, *Asplenium fragile* var. *insulare*, *Eragrostis deflexa*, *Kadua coriacea*, *Silene hawaiiensis*, *Silene lanceolata*, *Zanthoxylum hawaiiense*, and *Tetramolopium arenarium* var. *arenarium*. This protected area consists of 7,869 acres in the northwestern portion of PTA.

Fire is a major concern at PTA. The U.S. Army has standing operating procedures for wildfire (U.S. Army 2003) and a fire department. The Army is in the process of updating its wildland fire management plan for PTA and is preparing a fire management plan for the adjacent palila mitigation areas that are not on PTA lands. There are 35 miles of fuel breaks at PTA, mostly along the western side, with more under development. The Army is also conducting research on changing the grassland-fire cycle.

3. U.S. Forest Service (USFS)

In 1992, the Hawai‘i Tropical Forest Recovery Act authorized the establishment of a Hawai‘i Experimental Tropical Forest (HETF) to “serve as a center for long-term research and a focal point for developing and transferring knowledge and expertise for the management of tropical forests” (USFS 2009: 3). The HETF is divided into two units on Hawai‘i Island: the Laupāhoehoe Wet Forest Unit, which falls within the Mauna Kea Watershed Alliance area, and the Pu‘u Wa‘awa‘a Dry Forest Unit. The USFS and the State of Hawai‘i partner in the management of the experimental forest under a 35-year Cooperative Agreement establishing the Hawai‘i Experimental Tropical Forest, which was executed in 2007. The Laupāhoehoe Forest Unit incorporates 4,449 acres designated as Forest Reserve and 7,894 acres designated as a Natural Area Reserve for a total of 12,343 acres.

The Laupāhoehoe Unit spans four ecological zones between 2,300-ft. and 6,200-ft. elevation. It includes part of the largest remaining native forest in Hawai‘i, dominated by ohia and koa in the overstory. It also contains commercial timber species, degraded pasture, and invasive plant and animal species. The headwaters of seven streams originate in the Laupāhoehoe Unit.

The mission of the HETF is to provide landscapes, facilities, and data/information for those wishing to conduct research and education activities contributing to a better understanding of the biological diversity and functioning of tropical forest and stream ecosystems and their management. The HETF represents a significant contribution in the global effort that is necessary to understand and protect some of the most threatened and endangered ecosystems in the world. This can best be accomplished by facilitating tropical natural areas/species research, fostering an environment for interaction and exchange of information among scientists and to those outside the scientific community, and providing education and demonstration opportunities for those interested in tropical forest studies and management.

While there are currently no facilities located at the Laupāhoehoe Unit, future plans include building dormitories, dry labs, and offices onsite for research and education purposes. The Laupāhoehoe Unit has been selected as the Core Wildland Site for the Pacific National Ecological Observatory Network (NEON) domain. The HIPPNET program, funded by the National Science Foundation, has established one of its permanent research plots at Laupāhoehoe. Finally, the HETF has been selected as a site for the USFS’ Experimental Forest and Range Synthesis Network, one of 18 sites nationwide.

Researchers must apply for a permit to undertake their research and educational activities. Major research themes that the HETF is especially suited to support include: structure and function of tropical wet forest and dry forest watersheds and their component parts; structure and function of freshwater and nearshore marine ecosystems in tropical landscapes; threats to Hawaiʻi tropical forests; methods/tools for restoration of tropical forest ecosystems; impact of global climate change on tropical ecosystems; native Hawaiian/ traditional resource management techniques; and specialty wildland management topics.

C. PRIVATE

Private landowners manage 115,303 acres of land in the Mauna Kea Watershed Alliance Area. The largest of these landowners include: Parker Ranch (80,037 acres), B.I. Lee (9,336 acres), Kūkaʻiau Ranch (9,321 acres), and Kamehameha Schools (4,594 acres).

1. Parker Ranch

Parker Ranch, founded in 1847, manages over 80,000 acres of land on the north and northwestern sides of Mauna Kea. In 1992, following the death of Richard Smart, the ranch's last owner and 6th generation Parker descendant, Parker Ranch was left in trust to support healthcare, education, and charitable giving through named beneficiaries in the Waimea community.

The majority of Parker's land in the MKWA area is on the northwestern slope of Mauna Kea, extending from Mamalahoa Highway to the Mauna Kea Forest Reserve. This land is used primarily for cattle grazing. Ten herds of cattle, comprising 6,000 animals, graze the land. Cattle rotate through paddocks on a 45 to 90-day rotation. Each section and herd has its own grazing plan. Water for these paddocks comes from Waikoloa Stream on Kohala Mountain, supplemented with some County water. The primary vegetation consists of kikuyu, buffel, and fountain grasses, with ʻaʻaliʻi up to 3,000-ft. elevation and māmane in the the gulches at higher elevations.

Parker Ranch also owns 1,500 acres in Waipunalei. While the ranch is no longer grazing cattle on this land, a few wild cattle remain. Parker Ranch is in its 5th year of salvage koa harvest on this land, allowing up to 10% of the koa canopy to be harvested, followed by land scarification to promote koa regeneration.

Parker Ranch owns 6,500 acres above Pāʻauhau, between Māmalahoa Highway and Mānā Road, of which 4,500 acres are planted in eucalyptus. The unplanted areas consist of gulches. Parker Ranch is grazing cattle in the understory in order to reduce the fire hazard.

In addition, Parker Ranch leases 1,839 acres of State land in the MKWA area for grazing under GL S-4471 (1,738 ac.) and RP S-7331 (101 ac.).

2. Kūkaʻiau Ranch
Kūkaʻiau Ranch was established in 1883, first as a horse and oxen supplier for the Hāmākua sugar plantations and later as a supplier of beef and dairy products. The 9,321-ac. ranch is located on the northeastern slope of Mauna Kea and ranges from 2,200-ft. to 8,400-ft. in elevation. Keanakolu-Mānā Road bisects the ranch. ʻUmikoa Village, once the vibrant center of ranch life, contains many historical buildings. ʻUmikoa Trail travels the length of the ranch, with other cultural sites located along the way.

Historically, the ranch included a feedlot, meat processing facility, dairy, and orchards. Now, Kūkaʻiau Ranch runs 1,200 head of cattle and conducts salvage logging of dead and dying koa and ʻōhiʻa. According to The Nature Conservancy (2009), "over the past century,… unsustainable tree harvesting, numerous fires and continuous grazing have caused erosion problems, loss of stream flow and destruction of native plant seedlings." The forested portion of the ranch now contains approximately 2,500 acres of koa and ʻōhiʻa forest.

In December 2009, Kūkaʻiau Ranch entered into a perpetual conservation easement with The Nature Conservancy on 4,469 acres above Keanakolu-Mānā Road (Bureau of Conveyances 2009). The purpose of the easement is "to conserve the productive capacity of the Property for sustainable human use and ecological and watershed function, and to otherwise maintain natural values associated with the Property's current open-space condition" (Bureau of Conveyances 2009: 4). This mauka land is adjacent to the Mauna Kea Forest Reserve and the Puʻu Mali palila mitigation area. The land under easement contains mamāne and koa as dominant tree species, as well as a variety of other native plants and several native birds. Under the conservation easement, about one-quarter of the land will be managed for conservation. The remaining lands under the conservation easement will be managed for sustainable agricultural and forestry activities. A management plan is currently under development.

Specifically, the land under conservation easement will be divided into four different zones (Figure 26). Zone 1, comprising at least 900 acres bordering the Mauna Kea Forest Reserve, will preserve and protect relatively natural habitat and any cultural, archeological and historical features. It will help extend the conservation corridor established by the State to protect native birds and other threatened, endangered, and at-risk species. Efforts will be made to control erosion in the headwaters of the streams, and a reforestation program will be implemented. Zone 2 is intended to protect relatively natural habitat and enable the area to remain in agricultural use, as co-equal purposes. If there is a conflict, the purpose of protecting natural habitat will take priority. Kūkaʻiau Ranch will develop experimental plots of various edible plant species and windbreak trees, to determine which species and varieties grow best at different elevations. With these data, sustainable orchard and timber crops can be planted.

Zone 3, located mid-elevation within the conservation easement, will be designated for diversified agriculture first and conservation second. Kūkaʻiau Ranch intends this zone to be an agroforestry and silvopasture area. Riparian buffers along all gulches and

streams will help stabilize streambanks and reduce the severe erosion. Zone 4, located along Keanakolu-Mānā Road, will be designated for diversified agriculture, focusing on agroforestry with riparian buffers along waterways.

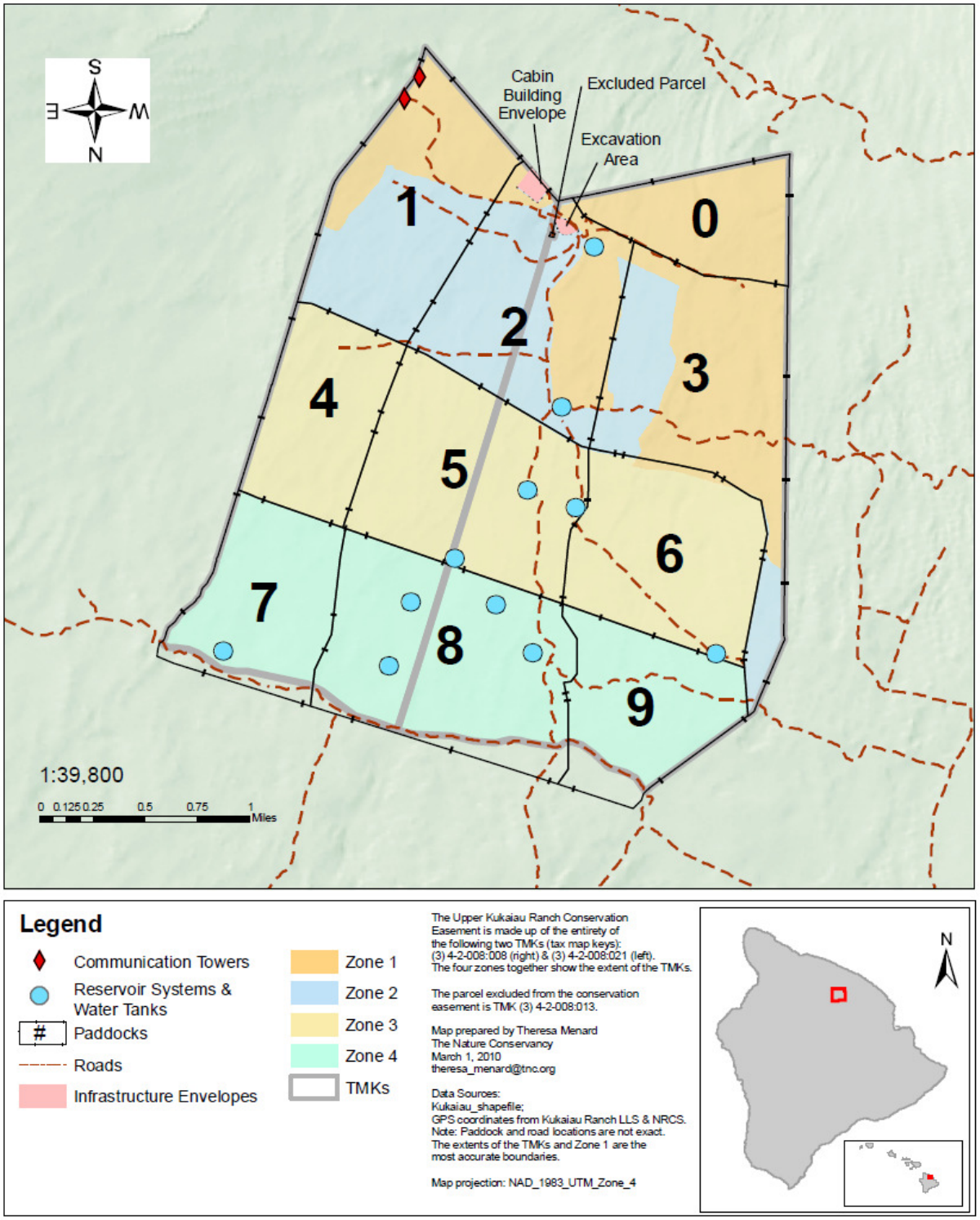


Figure 26: Upper Kūka'iau Ranch Conservation Easement Zones

The eventual goal of Kūkaʻiau Ranch is to protect and restore the important watershed areas in the upper elevation and along riparian corridors, while managing erosion and invasive species and supporting sustainable and diversified agriculture and forestry. The ranch will produce grass-fed beef, fruit and nut trees, grapes, vegetables, timber, and biomass for energy production. Additional water sources will be developed and roads improved. Agro- and eco- tourism opportunities will also be explored.

3. Kamehameha Schools

Kamehameha Schools (KS) is a charitable, landed trust that seeks to create educational opportunities in perpetuity to improve the capability and well-being of people of Hawaiian ancestry. It is the policy of KS to manage its lands and resources to optimize the balance of educational, cultural, economic, environmental, and community returns and steward resources in an ethical, prudent, ecologically and culturally appropriate manner to assure such resources are available in perpetuity. KS lands in the MKWA area include the mauka forested portions of Kaiwiki in Hāmākua, Umauma in North Hilo, and Pāhoehoe, Kīkala, ʻAlae, and Kalalau in South Hilo.

D. NON-PROFIT

1. The Nature Conservancy of Hawaiʻi (TNC)

The Nature Conservancy partners with land owners and land managers in Hawaiʻi to protect important natural areas. These include Conservancy-owned and managed preserves that provide vital habitats for native plant and animal species, collaborative efforts with others (*e.g.*, watershed alliances) to protect larger ecosystems, and conservation easements with private landowners to protect important ecosystems from degradation.

In 1998, TNC completed a Hawaiian High Islands Ecoregion Plan (TNC 1998). In a subsequent related planning process, TNC developed a set of conservation targets (10 ecological systems, perennial stream community, rare bird concentrations, and forest and waterbird concentrations), identified ecosystem integrity (by factoring size, condition, and landscape context), and established conservation goals. From this, TNC identified a portfolio of sixteen conservation areas which represent the primary arena for TNC's Hawaiian High Islands ecoregional efforts.

The portfolio of conservation areas selected comprises the largest and most viable set of areas for establishing effective conservation (legal protection + abatement of critical threats, and maintenance of ecological processes supporting native biodiversity). It reflects the highest priority areas for the work of The Nature Conservancy, focused on maintaining high-viability native ecological systems and species within them.

The alpine and montane wet forest ecosystems on Mauna Kea have been identified as a priority conservation area, as have the native ecosystems within the saddle area

between Mauna Kea and Mauna Loa (Figure 27). In addition, two streams on Mauna Kea, Hanawi and Honoli‘i, were selected as among the highest quality streams on the island because of their rich complement of native macrofauna and high volume, high quality water in a channel with high structural complexity.

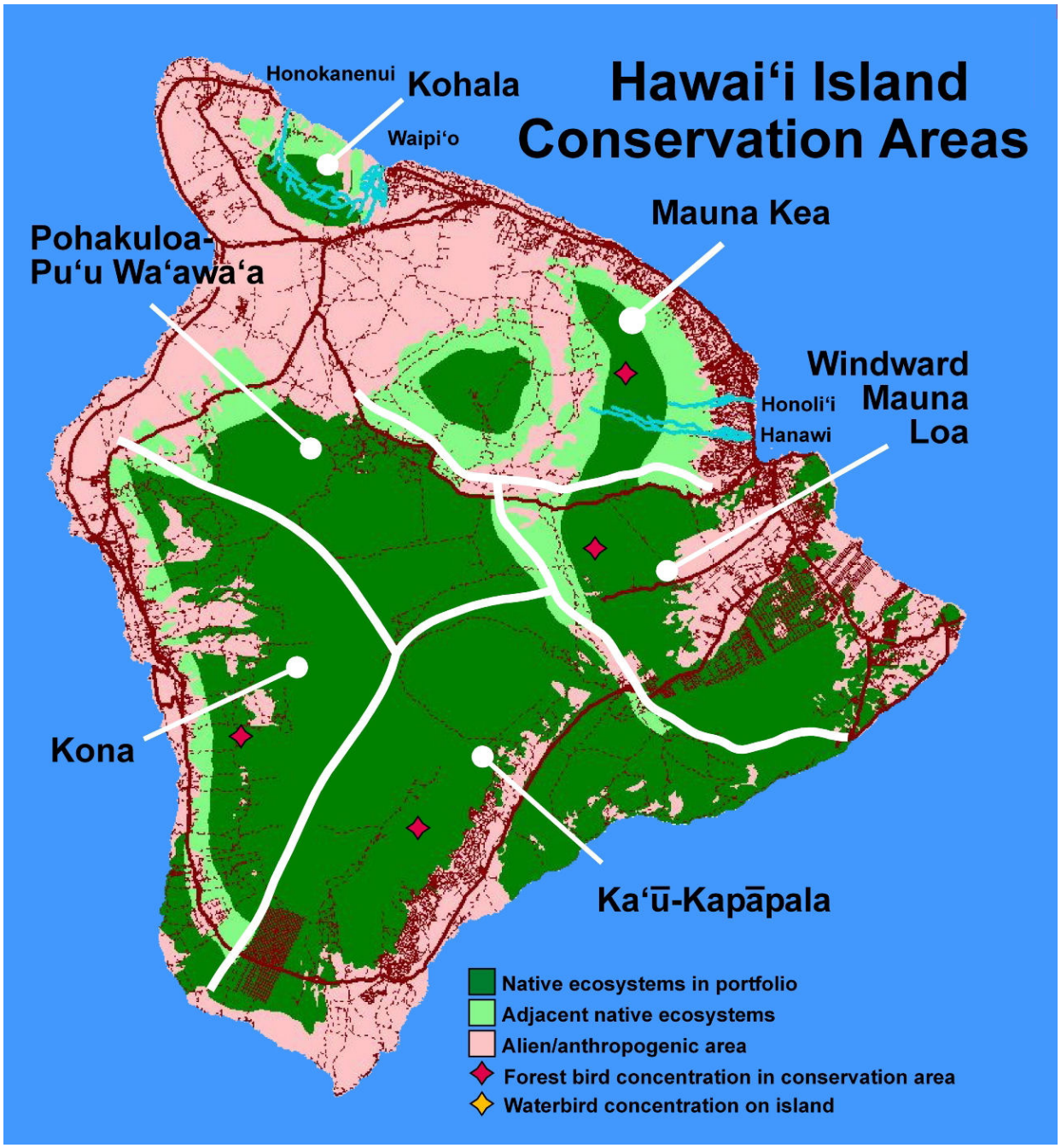


Figure 27: The Nature Conservancy’s Priority Conservation Areas

E. LANDOWNER INCENTIVE PROGRAMS

There are a number of programs at the Federal and State level that provide financial incentives to landowners for the implementation of conservation practices in order to protect forest, wildlife and watershed resources. These are particularly applicable to the sustainable use of agricultural and forested lands in the MKWA area. Table 14 provides a list of incentives programs for land management. More information about these and other programs can be found on the websites for NRCS (www.pia.nrcs.usda.gov/programs/), DLNR (www.state.hi.us/dlnr/dofaw/lap/index.html), and USFWS (www.fws.gov/pacific/ecoservices/habcon/index.html).

Table 14: Federal and State of Hawai'i Incentive Programs for Land Management

Program Name	Administering Agency	Purpose	Eligibility Criteria	Incentive
Partners for Fish and Wildlife	USFWS	Restore natural habitats and provide long-term benefits to threatened and endangered species	Privately-owned land, DHHL	Up to 50% cost share
Wildlife Habitat Incentives Program (WHIP)	NRCS	Develop or improve high quality habitat that supports fish and wildlife populations of national or State significance	Private or leased agricultural land or non-industrial private forest land	Up to 75% cost share for 5-10 yr. contract Up to 90% cost share for 15+ yr. contract
Environmental Quality Incentives Program (EQIP)	NRCS	Promote agricultural production and environmental quality through implementation of conservation practices related to reduction of polluted runoff and erosion, conservation of water, promotion of at-risk species habitat conservation	Private or leased land: cropland, rangeland, pasture, forest	Up to 75% cost share
Wetland Reserve Program (WRP)	NRCS	Provide technical and financial assistance to private landowners to restore, protect, and enhance wetlands in exchange for retiring eligible land from agriculture	Privately-owned land	100% if permanent easement 75% if 30-yr. easement 75% cost share for restoration

Program Name	Administering Agency	Purpose	Eligibility Criteria	Incentive
Grassland Reserve Program (GRP)	NRCS	Protect, restore, and enhance grasslands, land that contains forbs, or shrublands for which grazing is the predominant use through rental contracts and easements	Privately-owned land	Easement payments for 10-30 yr. agreements
Landowner Incentive Program (LIP)	USFWS and DLNR-DOFAW	Technical and financial assistance to improve habitat or implement conservation actions for the benefit of T&E plant and animal species	Privately-owned land, DHHL	
Conservation Reserve Program (CRP) Conservation Reserve Enhancement Program (CREP)	NRCS and DLNR	Improve water quality in stream systems, increase groundwater recharge, restore forest and native species' habitats, control spread of invasive species, and enhance nearshore coastal and coral reef health by removing cropland and marginal pastureland from agricultural production and converting land to native grasses, trees and other vegetation	Land owners and lessees	Annual rental payments for enrolling land in contracts and installing conservation practices 50% cost share for conservation practices
Healthy Forests Reserve Program (HFRP)	NRCS	Restore and enhance forest ecosystems to promote the recovery of threatened and endangered species, improve biodiversity, and enhance carbon sequestration	Privately-owned land	50% cost share with 10-yr. agreement 75% cost share with 30-yr. easement 100% cost share with 99-yr. easement

Program Name	Administering Agency	Purpose	Eligibility Criteria	Incentive
Forest Stewardship Program (FSP)	Hawai‘i DLNR-DOFAW	Assist non-industrial private forest landowners to more-actively manage their forest and related resources, and to increase the economic and environmental benefits of these lands	Owners of non-industrial private forest land	50% cost share Up to $75,000/yr. Averages >$10,000/yr.
Forest Land Enhancement Program (FLEP)	Hawai‘i DLNR-DOFAW	Assist private forest landowners to implement their sustainable forestry management objectives	Private forest landowners	75% cost share <$10,000/yr.
Forest Legacy Program	Hawai‘i DLNR-DOFAW	Precludes conversion of forestland to non-forest uses	Private landowner that is a willing seller, currently 75% forested and threatened by dev’t or fragmentation, must fall within designated “Forest Legacy Areas”	75% cost share Carries potential tax benefits
Safe Harbor Agreements	Hawai‘i DLNR-DOFAW USFWS	Proactive natural resources management to benefit endangered and threatened species	Private and public lands	Provides regulatory assurances that future property-use restrictions will not be imposed
Habitat Conservation Plan (HCP)	Hawai‘i DLNR USFWS	Enables private landowners to use land inhabited by endangered species with development and implementation of a habitat conservation plan to protect, maintain, restore, or enhance ecosystems, natural communities, and habitat types	Privately-owned lands	Allows for some incidental take of protected species

Program Name	Administering Agency	Purpose	Eligibility Criteria	Incentive
Natural Areas Partnership Program (NAPP)	Hawai‘i DLNR-DOFAW	Protect, restore, and enhance significant native resources or geological features	Private landowner who is a willing seller with intact native Hawaiian ecosystems, essential habitat for endangered species, and areas within the protective subzone of the Conservation District	Up to 67% cost share Possible reduced land taxes
Tree Farm Designation	Hawai‘i DLNR-DOFAW	Sustained production of forest products in quantity sufficient to establish a business	Private or leased (minimum 20 yrs.) land	Tax incentives at county level
Native Forest Dedication (Hawaii County)	Hawai‘i County	Preservation, restoration, and conservation of native forest	Private or leased (minimum 20 yrs.) land, minimum 3 ac.	Low tax assessments; same as for pasture

CHAPTER 5: MANAGEMENT PROGRAM

The Mauna Kea Watershed Alliance (MKWA) members recognize the importance of working collectively to address watershed management issues of common interest and concern on Mauna Kea. MKWA members agreed to the following vision statement to guide coordinated management activities within the MKWA area.

> The vision of the Mauna Kea Watershed Alliance is to protect and enhance watershed ecosystems, biodiversity and resources through responsible management, while promoting economic sustainability and providing recreational, subsistence, educational and research opportunities.

To achieve this VISION, this chapter identifies GOALS related to the protection of water resources, watershed functions, and native species' biodiversity; management of threats to these resources; and economic sustainability. Recognizing that a management program cannot be effectively implemented without sufficient infrastructure and personnel, recommendations addressing the administration of the program are incorporated. Finally, the chapter addresses compatible public use of the watershed.

Outlined in this chapter are OBJECTIVES and recommended ACTIONS to implement the ten management GOALS identified by the MKWA members. Under each management GOAL, there is one or more related OBJECTIVES. Each objective identifies management ACTIONS to achieve the OBJECTIVE. Some recommended ACTIONS are general, while others are specific because they have been approved by the implementing entity. For specific actions, the implementing entity is noted.

This plan adopts an adaptive management approach to ensure that knowledge is continually being updated and built upon. While goals and objectives are long-range and not subject to significant change, specific actions may need to be further refined through the management process, as new information is obtained and circumstances evolve. This iterative process allows managers to consider prior results, both positive and negative, and make adjustments to management actions.

The management program outlined here was developed in a series of planning meetings held by the Mauna Kea Watershed Alliance, drawing from previous information and planning efforts, and with input from land owners and resource managers.

Costs for implementing recommended actions can vary considerably depending on when an action is implemented, who does the work (volunteer vs. employee vs. contractor), and other factors. It was the opinion of the MKWA that costs need not be identified in this plan, knowing that when specific projects are budgeted for implementation, cost details will be provided.

Management Goal 1: Protect ground and surface water resources.

Resource experts for over a century have recognized the importance of Hawai'i's forested watersheds in promoting infiltration and groundwater recharge; it was for these reasons that forest reserves began to be set aside in the early 20th century. The forested watershed on the windward slope of Mauna Kea receives about 300 inches of precipitation annually. This area also intercepts significant amounts of fog drip and contains the headwaters of most of Mauna Kea's perennial streams. This mid-elevation rainfall belt comprises the significant portion of the watershed in which groundwater infiltration occurs. A structurally-complex forest promotes infiltration and groundwater recharge and minimizes erosion. For these reasons, it is important to protect forest areas that are important for maintaining high yield watersheds.

Historically, the large agricultural operators kept detailed records of water and weather data. These records included information on rainfall, temperature, evaporation, soil moisture content, stream flow and more. As Hawai'i's economic base has shifted away from agriculture, less of this information has been collected on a regular basis. This deficiency of new data renders it difficult to make informed decisions about watershed health, water allocation, and sustainable yields.

Objective 1A: Protect, enhance, and monitor high-yield watershed areas to maintain water quantity and quality.

Recommended Actions
Manage threats as recommended below to protect and enhance Mauna Kea's forested watershed.
Coordinate the network of remote automated weather stations (RAWS) around the mountain to database information from dispersed sources.
Develop programs to monitor long-term impacts to water quality and watershed health. -Develop a monitoring program to measure sedimentation, stream flow, turbidity and nutrients on a sub-watershed level, in collaboration with Federal and State agencies.

Objective 1B: Support appropriate water development to meet the needs of future water demand.

The total estimated groundwater yield for Mauna Kea is approximately 412 MGD. The majority of this estimated yield (388 MGD) is located in the East Mauna Kea aquifer sector area, which relies primarily on the forested watershed for recharge. The groundwater aquifer on leeward Mauna Kea reflects the generally drier conditions. Unfortunately, while the primary groundwater resources are located on the windward

side, the population growth and supporting residential development are occurring on the leeward side, taxing the limited groundwater resources there.

Currently, potable water on Hawai‘i Island comes from a mix of ground and surface water sources. As treatment requirements for surface water become more stringent, the Department of Water Supply is shifting more to groundwater sources for domestic consumption. Irrigation water frequently comes from surface water sources, including the Upper and Lower Hāmākua Ditches, which bring water from Kohala Mountain to support agriculture in Hāmākua. Surface water is sensitive to climatic variability and must be carefully allocated to maintain sufficient streamflow while providing water for potable and non-potable uses.

Recommended Actions
Support increased use of groundwater for domestic water supplies. [DB concerns re: advocacy]
Support continued use of ditch systems for agricultural irrigation water, as long as they are being used in a reasonable manner with no wastage.
Develop additional catchment and water storage throughout the Mauna Kea watershed management area for use in agriculture, fire control, and conservation activities.
Support establishment of a deep potable water well for PTA, if technologically and economically feasible.
Develop instream flow standards, as necessary, for individual streams on Mauna Kea.

Management Goal 2: Protect and enhance native terrestrial and aquatic ecosystems and their biodiversity and species.

Mauna Kea is rich in ecological communities that support a diversity of native plant and animal species. These ecosystems are complex in structure and composition. Because Hawai‘i’s ecosystems evolved in the absence of the introduced stressors they face today, they are particularly susceptible to habitat degradation and species loss. While the wet ecological zones on windward Mauna Kea still contain intact and remnant plant communities, they face pressure from invasive plants and animals and land use activities, resulting in simplification and loss of native diversity, and loss of understory structure. On the leeward side, a majority of the dry forests have been destroyed. The remnants face threats of fire, invasive species, pressure from development, and ecosystem fragmentation. As the alpine habitat becomes more accessible, it, too, faces habitat degradation. Both protection of remaining high quality ecosystems and restoration of degraded environments are important to sustaining habitat for the variety of endemic and indigenous fauna and flora, as well as enhancing watershed capacity.

Objective 2A: Maintain and/or restore native forest cover.

Recommended Actions	**Implementing Entity**
Conduct and/or update native community/vegetation surveys for region.	
Develop a biodiversity plan to ensure that all of the extant plants and birds known to be native to the watershed will in the future have adequate habitat for their continued survival in the watershed.	
Protect remaining native forest areas important to endangered species recovery through a combination of conservation easement, cooperative agreement, safe harbor agreement, changes in land use designation, leases or purchase from willing sellers.	
Replace or repair the Mauna Kea Forest Reserve boundary fence to protect the remaining māmane-naio forest on Mauna Kea from impacts by feral ungulates.	
Develop specific management plans for key game management areas to minimize negative impacts on adjacent protected areas.	
Protect remaining native forest areas through a combination of fencing, and weed, pest and ungulate control.	
- Fence remaining units of Hakalau Forest NWR and remove ungulates.	USFWS
- Construct three 1,000-acre units in the Laupāhoehoe NAR to protect remaining high quality forest above the 3,000-ft. contour.	DLNR
Restore the māmane forest at Pu‘u Mali and Ka‘ohe to a condition that supports permanent use by palila.	
- Inspect and maintain fences around palila mitigation areas to stop ingress of feral sheep and domestic cattle.	DLNR
- Remove feral ungulates.	DLNR
- Continue outplanting of native plant species.	DLNR
- Scarify areas to stimulate germination of native seedlings.	DLNR

Recommended Actions	Implementing Entity
To improve the capacity of the ground to absorb rainfall and for the benefit of native species and habitats, re-establish native forest cover in mauka areas using a variety of methods, including but not limited to fencing, removal of ungulates, weed control, soil scarification, and outplanting of native species. - Fence and begin reforestation on Kūkaʻiau Ranch on 1,000 acres in Zone 1 above Mānā Road, per 2009 Conservation Easement with TNC. - Continue reforestation efforts at Hakalau Forest NWR, collaborating with neighboring land owners on existing and new projects, as appropriate. - Continue reforestation efforts in the Laupāhoehoe and Humuʻula sections of the Hilo Forest Reserve. - Protect and restore native forest areas on DHHL lands, including 10,000 acres of māmane forest, 11,156 acres of ʻōhiʻa forest, 4,305 acres of koa-ʻōhiʻa forest, 1,602 acres of riparian corridor along the Wailuku River, and 512 acres in the Kanakaleonui Bird Corridor, as described in the ʻĀina Mauna Legacy Program (DHHL 2009).	Kūkaʻiau Ranch USFWS DLNR DHHL
Create exclosures ("kīpuka") to protect communities of plants from ungulate impact and allow for native regeneration and outplanting.	
Establish water sources to help with reforestation efforts. - Develop a water catchment system at Puʻu Mali and Kaʻohe Mitigation Areas that can be used as a water source for outplanting, invasive plant control, and fire suppression.	DLNR
Develop and implement comprehensive management plans and Environmental Assessments for the Laupāhoehoe and Mauna Kea Ice Age Natural Area Reserves.	
Expand the Natural Area Reserve System to include a site representative of the māmane-naio forest type.	
Develop and implement management plans for the Hilo, Manowaialee, and Hāmākua forest reserves.	DLNR
Develop and implement a Comprehensive Conservation Plan for Hakalau Forest NWR.	USFWS
Revise and implement the US Army's Integrated Natural Resources Management Plan for PTA, and complete and implement the Implementation Plan for PTA.	U.S. Army
Finalize and implement the Natural Resources Management Plan for the UH Management Areas.	OMKM
Work to mitigate climate change by promoting carbon sequestration as a strategy for enhancing native forest restoration.	

Objective 2B: Protect and recover rare species.

Habitat degradation and loss threatens native plant and animal communities by directly destroying their physical habitat, or by degrading it to the extent that it can no longer support sustainable populations. Habitat alteration is caused by development, conversion of native plant communities to agricultural fields or grasslands for livestock grazing at lower elevations; and the spread of habitat-modifying species. Pest species can also have a direct effect on rare species.

Recommended Actions for Native Birds	**Implementing Entity**
Conduct and/or update forest bird surveys for region. Conduct avian surveys more frequently for critically endangered species.	
Enhance native forest bird populations through management action including native species reforestation, weed and feral animal control, and predator control, as provided under Objectives 2A, 3A, 3B, and 3C.	
Protect and enhance nēnē populations on Mauna Kea. -Re-establish a viable nēnē population at Hakalau Forest NWR. -Protect nēnē populations at PTA and Keʻāmuku Maneuver Area from military training activities. -Protect nēnē population at Puʻu ʻŌʻō Saddle House.	 USFWS U.S. Army DLNR
Restore mauka-makai corridors to bridge between the lower mixed koa-ʻōhiʻa forest and higher elevation māmane forests to provide seasonal food sources for native forest birds. - Implement management actions in Kanakaleonui Bird Corridor Management Plan (DHHL 2009). - Protect and restore the native forest along the Wailuku River corridor on DHHL land.	 DHHL DHHL
Fence potential palila habitat areas on PTA lands that coincide with current conservation management areas and remove ungulates.	U.S. Army
Reduce or eliminate the detrimental effects of vespula wasps (yellow jackets), Coqui frogs, and other high priority non-native pest species that consume large volumes of insects to protect food sources for native insectivorous birds.	
Implement recommended actions in the Forest Bird Recovery Plan (USFWS 2006) and recovery plans for Hawaiian hawk, Hawaiian duck, and nēnē (USFWS 1984; USFWS 2005; USFWS 2004).	
Continue captive propagation programs for target species.	
Develop methods of evaluating, selecting, and preparing sites for release and/or translocation of endangered birds to ensure long-term persistence of re-introduced populations.	
Develop specific management plans for key game management areas to minimize negative impacts on adjacent protected areas.	

Recommended Actions for Native Mammal
Develop standardized survey and monitoring protocols for determining abundance and distribution, roosting habitat associations, basic life history, biology and food habits of the Hawaiian hoary bat.
Enhance Hawaiian hoary bat populations through management action including native species reforestation, weed and feral animal control, and predator control, as provided under Objectives 2A, 3A, 3B, and 3C.
Explore and implement strategies to reduce bat mortality.

Recommended Actions for Native Invertebrates
Conduct surveys of insect fauna and conduct research on their basic life history and biology.
Reduce or eliminate the detrimental effects of non-native species that prey on and compete for habitat and food sources with native invertebrates.
Enhance native invertebrate populations through management action including native species reforestation, weed and feral animal control, and predator control, as provided under Objectives 2A, 3A, 3B, and 3C.
Prohibit development of any undeveloped nunatak (previously unglaciated summit of pu‘u) to prevent loss of wēkiu bug habitat.
Expand existing wild *Drosophila* host plant populations.
Restore habitat for native insect populations along riparian corridors.

Recommended Actions for Native Plants	Implementing Entity
Continue to conduct rare plant surveys to document location and health of rare plant populations.	
Enhance native plant populations through management action including native species reforestation, and weed and feral animal control, as provided for under Objectives 2A, 3A, 3B, and 3C.	
Identify and protect remnant populations of rare and endangered plants. Continue to create exclosures to protect rare plants from ungulate impact and allow for native regeneration and outplanting. - Fence and protect rare and endangered plants at PTA and the Ke‘āmuku Maneuver Area as required by USFWS’s 2003 and 2008 biological opinions.	U.S. Army
Propagate endangered and native plants and outplant seedlings to restore native habitat, where appropriate.	
Collect seeds of native rare species and store for future use in restoration efforts.	

Recommended Actions for Native Aquatic Species
Conduct comprehensive surveys of all streams and identify the streams with healthiest native stream biota for priority protection.
Continue DLNR-DAR stream surveys.
Fence and restore priority stream corridors on windward Mauna Kea as appropriate and as agreed to by landowner and/or lessee to improve water quality and aquatic species habitat.
Minimize harmful ecologic and economic impacts of invasive aquatic species.

Objective 2C: Protect and enhance riparian buffers to protect stream corridors.

Recommended Actions	Implementing Entity
Identify and protect existing riparian buffers.	
Fence and restore priority stream corridors on windward Mauna Kea with appropriate species and as agreed to by landowner and/or lessee to improve water quality, stabilize streambanks, and control erosion. - Fence the Wailuku River corridor on DHHL land. - Seek Conservation Reserve Enhancement Program (CREP) funding to establish riparian buffers in Zones 3 and 4 of the Conservation Easement on Kūkaʻiau Ranch.	DHHL Kūkaʻiau Ranch
Control weed species in riparian corridors to minimize their potential to spread downstream.	
Identify "hot spots" for waterborne pathogens through monitoring and mapping, and initiate program to reduce upstream vectors.	

Management Goal 3: Manage non-native plant and animal species within appropriate areas to reduce the impacts to native ecosystems and species.

Developing an effective management program to restrict the spread and effect of invasive species in native ecosystems requires an integrated approach, combining prevention and interdiction, early detection and rapid response, and ongoing control and eradication. Prevention requires a rigorous education and outreach program to inform land users and the public about the damaging effects of non-native species and soliciting their help in detecting and controlling these species before they become well-established.

Once established, the approach for managing non-native species depends on their distribution, mode of dispersal, tenacity, sensitivity of environment, and other factors. A suite of techniques and tools are available to land managers in combating non-native

species; the method or combination of methods selected will depend on individual circumstances. Adaptive management allows for testing and improvement of methods. Management of non-native species lends itself to cooperation among neighboring land owners.

Objective 3A: Strategically manage feral ungulate damage in high priority native ecosystems and watersheds while providing for increased hunting opportunities in designated areas.

Lacking any large native herbivorous mammals, Hawaiian plants evolved without defenses against browsing or trampling. Unmanaged feral ungulates have contributed to the destruction of forest environments since their introduction in the 1800s. There are a number of techniques available to manage and remove non-native animals. These techniques vary widely in their cost, effectiveness, and length of time taken to complete. Most feral ungulate management alternatives entail the use of fencing. Fences are unmatched in utility when it comes to managing wild animals across large natural landscapes. Ungulate control techniques can be controversial among hunters.

Recovery of habitats disturbed by ungulates can take considerable time and require ongoing protection, aggressive and continual alien plant management, and reintroduction of missing native plant species.

Recommended Actions	Implementing Entity
Map current and potential range of feral ungulates, and identify control methods in place.	
Remove feral cattle from the MKWA area using available techniques.	
- Develop and implement a feral cattle removal plan for DHHL lands.	DHHL
- Fence additional feral cattle and pig management units at Hakalau NWR and remove animals in accordance with the feral ungulate management plan.	USFWS
- Repair and/or maintain fences to prevent cattle from entering forest reserves and restricted watershed; remove feral cattle from these areas.	DLNR
As required by court order, remove mouflon sheep from palila critical habitat on Mauna Kea.	
Replace or repair boundary fence around Mauna Kea Forest Reserve to prevent ingress/ egress of feral ungulates.	
Strategically remove feral ungulates from native plant exclosures at PTA, as required in USFWS's 2003 biological opinion, in a manner that reduces ungulate impacts but does not increase fine fuel loads and fire risk.	

Recommended Actions	Implementing Entity
Remove pigs in appropriate areas where they are contributing to loss of watershed vegetation cover, watershed soil erosion, habitat for avian disease-carrying mosquitoes, and human health risks associated with animal-borne diseases. -Remove feral pigs from the Ka‘ohe palila mitigation area.	DLNR
Seek collaborations with organized hunting groups and community volunteer hunters to utilize their skills for feral ungulate control, as appropriate.	

<u>Objective 3B</u>: Strategically manage other pest species that threaten native ecosystems.

Small mammals such as rats, mice, mongoose, and feral cats prey on native birds. Rats modify vegetative cover through selective seed predation. Alien insects compete with native insects for habitat and food sources. Predatory invertebrates such as ants and other social hymenoptera have greatly disrupted invertebrate communities at all elevations. Diseases and pathogens can quickly weaken or kill populations of native species, resulting in a significant change to the natural communities and ecosystems of which they are a part.

Recommended Actions
Identify, map, and prioritize pest species in the MKWA area that are affecting native species and which require attention and control efforts.
Develop a rapid response program to eradicate incipient invasive species.
Reduce the threat of avian disease by preventing introduction of new diseases, preventing movement of diseases between islands, and controlling the mosquito vector. Eliminate or treat larval habitats for *Culex* mosquitoes in native forest bird recovery and adjacent areas by eliminating habitat modification by feral animals that creates favorable conditions for mosquito breeding and larval development. Also, experiment with novel, albeit short-term, mosquito reduction strategies such as BTI (*Bacillus thuringensis israeliensis* toxin), Dunk, or other environmentally-compatible pesticides that are safe for non-target organisms.
Reduce or eliminate the detrimental effects of vespula wasps (yellow jackets) and other social hymenoptera, Coqui frogs, and other non-native species that prey on native invertebrate species, degrade their habitats, and compete for food sources.

Recommended Actions
Reduce or eliminate the detrimental effects of alien mammalian predators (rats, mice, feral cats, and mongooses) on native forest birds, plants, and invertebrates. - Control alien mammalian predators in core forest bird habitat at Puʻu Mali, Kanakaleonui Bird Corridor, Laupāhoehoe and Pīhā sections of Hilo Forest Reserve, Hakalau Forest NWR, DHHL lands adjacent to Hakalau, Puʻu ʻŌʻō Saddle House, Kaʻohe, and Mauna Kea Forest Reserve. - Depress rodent populations near rare tree snail and plant populations, particularly during sensitive life cycle stages for species known or suspected of being adversely affected by rodents.
Develop an Invasive Species Monitoring Plan for the Mauna Kea Watershed Alliance area.
Identify "hot spots" for waterborne pathogens through monitoring and mapping, and initiate program to reduce upstream vectors.

<u>Objective 3C</u>: Strategically control invasive plants to protect high quality native ecosystems and endangered species.

Much research has been conducted on techniques to control invasive weed species. In fact, The Nature Conservancy's *Weed Control Methods Handbook* (Tu *et al.* 2001) provides a thorough overview. Research continues as new species are continually introduced into the Hawaiian environment. It is often easier to focus initially on outlying populations to reduce the establishment of these species into new geographic areas, isolating areas of major infestation for significant long-term treatment techniques. There are about 200 invasive plant species in Hawaiʻi that are considered extremely aggressive, habitat-modifying weeds.

Available methods and techniques to control invasive plant species include: mechanical, grazing, prescribed fire, chemical, and biological. Mechanical control methods include manual pulling, digging, snipping, cutting, girdling, grinding, and others. Some methods follow treatment immediately with a spot application of herbicide. Mechanical control can be labor-intensive and expensive. However, volunteers can be effectively utilized for well-defined projects. To avoid replacing one weed species with another on a large-scale, weeds should be removed and replaced slowly, in gaps, filling the gaps created by removal with species of choice. This method requires follow-up maintenance.

Domestic cattle and sheep have been used effectively to reduce wildfire grass fuels in pastures and other grasslands on the island. Cattle have been used effectively to reduce fine fuels along roadsides. Sheep have been used to reduce grass fuels in a perimeter fuelbreak for Waikiʻi Ranch. Grazing animals should be used only on pastures and other grasslands, not in the forest.

Prescribed fire can be used to remove or reduce stands of alien species or to reduce roadside stands of wildfire fuels. This method has been used on Mauna Kea to control

gorse, but follow-up herbicide application is required. Burn planning must be done cooperatively, following established procedures and using best management practices.

Chemical control methods are often an important tool in invasive plant management, especially where mechanical control methods are not feasible, where biological control techniques are not available, and when cost and time constraints dictate. When used responsibly and with caution, herbicides can be an effective tool to quickly kill a plant, keeping it from entering its next reproductive cycle; in many instances, the dead plant tissues form a mulch ground cover.

Biological control is another tool used effectively by managers worldwide to control alien plant species. Biological control uses predators and disease organisms of invasive pests from their native ranges to damage targeted weeds. Biological control often provides the only cost-effective method for reducing the negative impacts of priority invasive species that are already well-established. Biological controls have been identified and used with some success on banana poka (*Passiflora tarminiana), Clidemia hirta*, gorse, and ginger.

Recommended Actions	**Implementing Entity**
Regularly assess distribution of problem weed species and maintain current distribution maps.	
Develop a weed management plan for the Mauna Kea Watershed Alliance area that identifies priority weed species in the watershed to focus control efforts and to pursue funding for collaborative weed control projects.	
Prioritize areas for management for each problem species.	
Eliminate gorse from the MKWA area, using a variety of methods, as appropriate, including prescribed burns, herbicide, and high density tree planting to reduce the viability of the shade-intolerant plant.	
- Continue implementation of Phase 1 and Phase 2 of Humu‘ula Koa Buffer areas, a joint project of DHHL, Hakalau Forest NWR, and USFWS Partners for Fish and Wildlife program.	DHHL
- Fence corridor and eradicate gorse from the Wailuku River on DHHL land.	DHHL
- Use commercial timber production as a way to shade out gorse in the core infestation area until the gorse seed bank is no longer viable and native forest restoration can begin.	DHHL
Eliminate ingress of fountain grass into palila habitat areas.	
-Develop plan for controlling fountain grass ingress.	DLNR
-Conduct aerial spot spraying as initial control strategy.	DLNR
Control other high priority weed species, as identified by BIISC and watershed alliance members.	

Recommended Actions	Implementing Entity
Reduce or eliminate detrimental effects of alien plants known to pose significant threat to forest bird recovery areas within forest ecosystems, through mechanical, chemical, or biological means, as appropriate.	
Work with neighboring land managers to control invasive plants that occur near property borders.	
Use control buffers around the borders of established invasive species populations to contain weeds and keep them from spreading.	
For timber species that are problem weed species, use timber harvest to control or eliminate species and prepare the land for more appropriate reforestation.	
Work with the UH College of Tropical Agriculture and Human Resources (CTAHR) and weed specialists to conduct research on effective techniques for controlling invasive weeds.	

Objective 3D: Control priority invasive aquatic species in windward streams on Mauna Kea.

Alien aquatic species impact agriculture, disrupt native stream community structure, and permanently change the make-up of the stream. The current ecological condition of Mauna Kea's streams needs to be assessed and documented, building on DLNR-DAR stream surveys, for future management and monitoring.

The State of Hawai'i Aquatic Invasive Species Management Plan (Shluker 2003) provides a tool to help enhance coordination of current management efforts, identify remaining problem areas and gaps, and recommend additional actions which are needed to effectively address invasive aquatic species.

Recommended Actions
Continue DLNR-DAR stream surveys of perennial streams on Mauna Kea to further assess conditions of streams and presence of invasive species. Evaluate alternative stream bioassessment and monitoring approaches and develop one for long-term use within the MKWA area, if desirable.
Develop distribution map of invasive aquatic species.
Work with DLNR-DAR to develop a system for streamlined reporting, and rapid response, of newly-detected invaders.
Increase knowledge on the biology and ecology of invasive aquatic species, as well as methods for their control.
Continue and increase education efforts, especially those focusing on unauthorized release of organisms into streams.

Management Goal 4: Prevent and minimize wildfires on Mauna Kea.

The vegetated areas on Mauna Kea below 9,500-ft. elevation are of greatest concern with respect to fire. Based on anecdotal accounts and recorded fire history, the leeward, southwest section of Mauna Kea, between Puʻu Lāʻau and Hale Pōhaku, faces the greatest threat of wildfire (DLNR 1997). This area, consisting of fine fuels and steep slopes, and experiencing dry weather, has a year-round fire season which peaks during the summer months. The tall, ungrazed grasslands on the windward side of Mauna Kea can also provide a fire risk. The fire season on the windward side is generally associated with extended drought conditions.

DLNR, DHHL, Hakalau Forest NWR, and PTA all have fire management plans (DLNR 1997; USFWS 2002; U.S. Army 2003; DHHL 2007), which identify infrastructure, equipment and personnel resources, outline fire response procedures, and provide guidelines for appropriate fire suppression activities. A new wildland fire management plan is under development for Pōhakuloa Training Area, with an anticipated completion date toward the end of 2010, and a fire management plan is under development for the palila critical habitat area.

There are mutual aid agreements in effect between and among the County Fire Department, DLNR-DOFAW, National Park Service, and U.S. Army Support Command for wildland fire suppression. These provide the basis for requesting and coordinating assistance. Landowners also cooperate in fire-fighting efforts by providing equipment, and access to water and roads.

Objective 4A: Install on-the-ground fuel management measures intended to reduce the number and/or severity of fires.

Fuel management involves modifying the size, arrangement and kinds of vegetative fuels in fire-prone areas in order to maintain a fuel condition that makes vegetation harder to ignite and fire easier to control. Fuel modification can take several forms: changing the vegetation type, reducing fuel volume, and changing the distribution and loading of fuels within a vegetation type. The construction of fuel breaks or fire breaks is one component of fuel management. Fuel breaks are defined as “a strategically located block or strip on which a cover of vegetation has been manipulated to reduce fuel volume or flammability as an aid to fire control” (U.S. Army 2000: 4-7). The appropriate width of a fuel break is site-specific and dependent on fuel type, terrain features, and expected fire weather conditions, especially wind direction and speed. Fire breaks tend to be narrower strips cleared or grazed to stubble height, which are potential fire control lines. Roads are often maintained as fire breaks.

Most of the large landowners on Mauna Kea have installed at least some on-the-ground measures to reduce the potential for fire starts, slow the spread of fire, protect rare species and native habitats from fire, and provide access for fire-fighting purposes. DLNR-DOFAW maintains a system of access roads and firebreaks within the Mauna Kea Forest Reserve, Kaʻohe GMA, and Mauna Kea Ice Age NAR, described in DLNR

(1997). PTA maintains a system of firebreaks, fuel breaks, and fire management corridors throughout the training area, with an emphasis on the fire-prone western boundary and areas of potential fire starts (*e.g.*, Saddle Road). DHHL has 16 miles of fuel breaks within Humuʻula, including one that surrounds the core area of gorse infestation, and has widened roads to serve as firebreaks. The USFWS constructed a 14.7-mile fuel break on the boundary between Hakalau Forest NWR and DHHL in 2007.

Recommended Actions
Maintain and improve access roads around Mauna Kea to meet fire access and firebreak standards, and to minimize erosion potential, as described in the landowner fire management plans. These include the high priority roads on State land: R-1 (Mauna Kea Access Road), R-10 (Skyline Road), R-12 (Skyline to Puʻu o Kauha), R-13 (R-1 to Puʻu o Kauha to Saddle Road), R-14 and R-15.
Maintain and improve lateral roads, often connecting to ranch roads, to provide firebreaks and alternative access routes in the event of a fire. Construct or re-open strategically-placed roads to act as access routes for ingress/egress during a fire.
Maintain and improve existing firebreaks, as necessary, by widening to firebreak standards, installing water bars, and providing turn-out areas and parking.
Build and maintain additional firebreaks in fire-prone areas, as described in landowner fire management plans, to help compartmentalize any fire starts and provide access for suppression.
Using the range of available tools to reduce hazard fuels, maintain and improve existing fuel breaks on Mauna Kea, including but not limited to the fuel break on the boundary between DHHL and Hakalau Forest NWR, the fuel break surrounding the main gorse infestation area, and the fuel breaks described in the U.S. Army's fire management plan for PTA.
Create additional fuel breaks in priority areas to protect adjacent rare plants, native ecosystems, and critical habitats, particularly where fuel types, terrain features, ignition sources and weather conditions increase wildfire risk.
Restructure fuels along Mānā-Keanakolu Road to minimize the potential for roadside fire starts.

Objective 4B: Reduce fuel loads in fire-prone areas, ensuring compatibility with other habitat and watershed protection goals.

There are a number of tools available to reduce hazard fuels in fire-prone areas: natural wildland fire barriers; biological treatments (livestock grazing, biocontrol release); manual and mechanical treatments (mowing, brush crushing, plowing, disking, pruning, limbing, thinning, chipping, multi-cutting); chemical treatments (herbiciding, retardants); and prescribed burns. Some techniques may be appropriate in certain areas and others not. Appropriate methods should be determined by the landowner based on various criteria, including cost, effectiveness, and compatibility with other habitat and watershed protection goals.

Recommended Actions
Continue prescribed burning of gorse, in combination with timely herbicide applications, to reduce biomass and stimulate gorse seed germination to deplete the gorse seed bank in gorse patches outside the main infestation area.
Use cattle or other grazers to reduce fine fuel loads in approved areas and under strict management guidelines to avoid conversion from one undesirable fuel to another and to protect native plants in adjacent areas.
Use manual, mechanical and/or chemical treatments, as appropriate, to remove hazard fuels in sensitive areas, and along roadways and other ignition corridors.
Implement innovative measures to eradicate gorse from the main gorse infestation area and Wailuku River basin.

Objective 4C: Develop water sources for fire-fighting purposes in fire-prone areas.

Availability of water is critical to the suppression of fire. Water sources are very limited on most parts of Mauna Kea. The Army has eight dip tanks at PTA, with 3 additional tanks going in at the Keāmuku parcel. USFWS maintains some water storage at Hakalau Forest NWR. DHHL has two large reservoirs in Humuʻula, one adjacent to Hale Pōhaku Road and another near Hopowai, both of which need to be relined. Parker Ranch has a water system with pipelines and storage tanks to the north and west sides of Mauna Kea, below the Mauna Kea Forest Reserve. Kūkaʻiau Ranch has a reservoir at Puʻu Kihe on the north side of Mauna Kea, adjacent to the Mauna Kea Forest Reserve at the 7,500-ft. elevation, another reservoir at Hale Piula at the 5,700-ft. level, and a water storage structure along the western boundary at 4,800-ft. elevation. Volumes of water within these water storage facilities are weather-dependent, with less water available during times of dry weather. Use of these resources from private ranch lands can be an imposition on land owners, who are relying on the water catchment for ranch activities.

Recommended Actions
Develop, enhance, and maintain water sources strategically distributed around Mauna Kea for fire-fighting purposes, including access by fire trucks and for helicopter water drop operations.
Reline reservoirs on DHHL's Humuʻula property.

Objective 4D: Coordinate pre-suppression planning and fire response protocols among landowners.

The existing fire management plans and mutual aid agreements outline fire response protocols. Effective pre-suppression planning enables fire-fighters and land managers to more easily and effectively control a fire. Knowing the location of water resources, access points, and roads/ trails, and the types of equipment available from land users for fire suppression enables a quick and effective initial attack. Knowing the location of

significant natural, cultural and economic resources that require special protection is also important.

Recommended Actions
Develop a coordinated response plan to guide response in the MKWA area in the event of a fire.
Use mapping technologies to identify significant natural, cultural and economic resources within the MKWA area, as well as fire suppression resources and equipment. Make these technologies available to landowners and fire-fighters.

Objective 4E: Promote effective communication and public safety during extreme fire weather and during fire-response events.

Fire danger warnings are an effective way to communicate to the public about periods of high fire danger based on current conditions. However, these warnings only work if there is a total commitment to monitor and update posted information. Otherwise, posting inaccurate information damages the credibility of the prevention effort. Accurate warnings rely on an analysis of fire history, fuels, fire behavior models, and localized weather data. While there are some remote automated weather stations (RAWS) in the MKWA area, primarily located within PTA, they are not sufficiently distributed across elevational and climatological ranges to provide accurate fire weather data throughout the region.

Recommended Actions
Install signage, as appropriate and permissible, along major roadways warning of the fire hazard. Consider including fire danger rating information as part of signage.
Develop a wildfire awareness program to educate users of Mānā-Keanakolu Road about fire risks and hazards.
Install milepost signs along Mānā-Keanakolu Road to help citizens accurately report location of fire
Strategically site RAWS around the mountain to facilitate monitoring of fire weather conditions. Proposed sites include Ahumoa, Kaluamakani, Kanakaleonui-Kahinahina, Humuʻula Sheep Station, and Puʻu ʻŌʻō Saddle House to provide data across the range of ecosystems and elevations.
Effectively communicate to the public road closures and reason for road closures during extreme fire conditions or fire-response event.

Objective 4F: Manage access to fire-prone areas during extreme fire danger weather.

Most fires in Hawaiʻi are started by people, whether accidentally or intentionally. Roadways become a vector for fire, as they provide access into or adjacent to fire-prone areas. There are few major public roadways within the MKWA area: namely

Māmalahoa Highway and Saddle Road. These roads are generally paved and their borders fenced, helping to restrict vehicular access off-road. Access points into the 4WD road networks of PTA, Mauna Kea Forest Reserve, and Hakalau Forest NWR can be locked in the event of extreme weather conditions, and the Mauna Kea summit access road can be barricaded. Mānā-Keanakolu Road is a major 4WD roadway around Mauna Kea, for which access cannot currently be managed.

Recommended Actions
Restrict access to fire-prone areas during extreme fire danger weather.
Install a system of gates on Mānā-Keanakolu Road to manage access during times of extreme fire danger.

Objective 4G: Promote post-fire assessment and restoration of burned areas.

Not only does fire itself damage the natural environment, but the process of fighting the fire also affects the natural and cultural resources. Fire removes vegetation and increases the potential for erosion and introduction of opportunistic weed species. Construction of fire breaks during a fire can create channels for future erosion and can damage cultural sites. Therefore, it is critical that post-fire assessments be performed and restoration activities be undertaken.

Recommended Actions
Conduct post-fire analysis survey of burned area to determine effects of fire on native and alien flora and fauna and cultural resources.
Undertake post-fire review to document effectiveness of pre-suppression and suppression efforts.
Assess damage to fuel breaks, access roads, and water sources so that repairs can occur quickly.
Undertake post-fire restoration, rehabilitation or revegetation of areas severely impacted by wildfires.

Management Goal 5: Promote and encourage economic sustainability in balance with habitat and watershed protection goals.

It is important for the watershed alliance members to acknowledge that most private land owners and lessees on Mauna Kea need to generate income from their lands in order to be economically sustainable. With means to generate income or realize tax benefits, land owners and lessees will have the resources to fund conservation activities on their land. This is particularly true if income-generating activities themselves support conservation goals. Recognizing the importance of private landowners in supporting conservation goals, there are a number of State and federal incentive programs for land management on private lands. These are described in Chapter 4.

Objective 5A: Encourage permitted ecotourism, well-managed wilderness experiences, and other forms of managed access, as appropriate and permissible, on public and private lands.

Recommended Actions	Implementing Entity
Use the Humuʻula Sheep Station as a gateway for ecotourism activities on Mauna Kea, according to the recommendations in the *Humuʻula Sheep Station Adaptive Reuse Plan* (DHHL 2004).	DHHL
Explore the feasibility of using the former Puʻu ʻŌʻō Ranch complex at Piʻihonua as a remote lodge for well-managed wilderness experiences.	DHHL
Develop ecotourism and agrotourism opportunities as part of Kūkaʻiau Ranch's comprehensive plan for sustainable land use.	Kūkaʻiau Ranch
Develop rules to regulate public and commercial activities with the UH Management Areas on Mauna Kea.	OMKM

Objective 5B: Manage future development to ensure it will not have a detrimental impact on the ecosystems of Mauna Kea.

Recommended Actions
Use the existing environmental and cultural review and permitting processes to ensure that the cultural and natural resources of Mauna Kea are not negatively impacted by future development activities.
Reuse previously developed sites in preference to developing new sites, and, to the extent possible, restrict new activities to previously disturbed areas.
Encourage land use activities that promote preservation of native forest areas.
Encourage contractors to use best management practices to reduce overall impact of new construction projects and maintenance activities on the natural environment.
Encourage use of best management practices in road building and maintenance work to ensure that roads on Mauna Kea do not convey water in a manner that causes erosion.
Prepare guidelines for consulting with Native Hawaiian organizations and interested members of the Hawaiian community for development activities in the Mauna Kea summit region.

Objective 5C: Support sustainable uses of the land in balance with habitat and watershed protection goals.

Recommended Actions	Implementing Entity
Recognize the importance of agricultural lands on Mauna Kea.	
Consider diversified agriculture as a way for private landowners to generate income so that they can support conservation efforts on other parts of their land. - Conduct research on appropriate food and timber crops for sustainable production. - Promote commercially-sustainable koa timber production on former pasture lands. - Promote cattle grazing in appropriate areas as a way to reduce fine fuel loads and protect adjacent forested areas from fire.	
Develop and implement a sustainable diversified agriculture plan for Kūkaʻiau Ranch.	Kūkaʻiau Ranch
Support salvage logging of dead and dying koa as part of forest restoration efforts in the Humuʻula section of the Hilo Forest Reserve and on portions of DHHL lands as approved by the Hawaiian Homes Commission.	
Working with NRCS, promote agroforestry and silvopasture establishment as a way to reforest pasture land in a way that generates income for the landowner while trees are growing. This new program combines establishment of trees for wood products and forage groundcover for grazing. Animals are excluded from site until trees are of sufficient height to withstand grazing pressure.	
Use commercial harvest of introduced timber species on forest reserve lands as part of forest restoration efforts.	
Encourage all commercial forestry activities on private land to implement relevant BMPs contained in DLNR's *Best Management Practices for Maintaining Water Quality in Hawaiʻi* (June 1998). All commercial forestry activities conducted on public (State) leased lands must implement these BMPs.	
Provide rural homesteading opportunities for beneficiaries on DHHL lands, as provided for in the ʻĀina Mauna Legacy Program (DHHL 2009).	DHHL
Use pasture leases on DHHL lands adjacent to Saddle Road, Mauna Kea summit access road, and Mānā-Keanakolu Road as a way to reduce fuel loads, as recommended in the ʻĀina Mauna Legacy Program (DHHL 2009).	DHHL
Coordinate with DLNR's Land Division and/or the Department of Agriculture, if relevant, to ensure agricultural leases for grazing do not negatively affect critical habitat areas.	
Encourage private land owners and lessees to take advantage of existing State and Federal incentive programs for land management activities on these lands.	

Management Goal 6: Manage human activities in the watershed to promote recreational and subsistence opportunities that are compatible with habitat and watershed protection goals.

It is the intent of this plan to support and encourage forms of public use in areas where it is compatible with conservation of water and related watershed values.

Universal public access to the top of Mauna Kea is relatively new. From a Hawaiian perspective, the summit is considered *wao akua* (region of the gods) and visited infrequently and generally in association with ceremonials observances and burials. With the building of the Mauna Kea summit access road in 1964 and the current improvements to Saddle Road, more and more people are able to access natural areas, including the summit, that were previously difficult to access.

Objective 6A: Create and encourage safe and appropriate patterns of access for hiking and recreation on public lands.

There are a number of trails that are currently accessible to the public on Mauna Kea. Hikers can unwittingly cause environmental damage that affects sensitive ecosystems and degrades watershed functional processes, particular if they go "off-trail." However, carefully-sited hiking trails and controlled access can provide visitors and residents with an experience of a lifetime, in which they gain a greater appreciation for the natural environment.

Recommended Actions	Implementing Entity
Manage access to the Mauna Kea summit.	
- Because of the health and safety issues surrounding hiking on the summit, consider having hikers register so that safety information and information about the summit's natural and cultural resources can be distributed.	OMKM
- Limit public access to the summit region when road, weather conditions, and crowds create conditions that are hazardous to public health and safety.	OMKM
- Regulate commercial activities and enforce permit conditions to ensure that commercial activities operate safely and appropriately in the UH Management Areas.	OMKM
- Develop a specific communication plan to inform visitors on peak snow days regarding road safety, parking, health advisories, trash and basic summit etiquette.	OMKM
- Explore methods to divert summit bound visitors by offering educational and scenic opportunities at lower elevations nearer to Hale Pōhaku.	OMKM

Recommended Actions	Implementing Entity
Develop additional opportunities for recreational activities that have minimal impact on the natural environment.	
- Use the Humuʻula Sheep Station as a gateway for ecotourism activities on Mauna Kea, according to the recommendations in the *Humuʻula Sheep Station Adaptive Reuse Plan* (DHHL 2004).	DHHL
- Explore the feasibility of using the former Puʻu ʻŌʻō Ranch complex at Piʻihonua as a remote lodge for well-managed wilderness experiences.	DHHL
- Develop ecotourism and agrotourism opportunities as part of Kūkaʻiau Ranch's comprehensive plan for sustainable land use.	Kūkaʻiau Ranch
Promote and support public awareness and environmental education about Mauna Kea's natural and cultural resources through increased visitor access on trails with interpretive and educational displays.	
- Develop a visitor services plan to assess the compatibility of public use and associated infrastructure at Hakalau Forest NWR, including roads, trails and a visitor center.	USFWS
- Design and implement signage to guide the use of established trails, promote public safety and enhance interpretation and protection of historic, cultural, and natural resources in the UH Management Areas.	OMKM
- Prepare and implement an interpretive strategy for the summit region in a collaborative effort with DLNR, ʻImiloa Astronomy Center, Kahu Kū Mauna and others.	OMKM
- Improve interpretive and visitor support facilities at the VIS to accommodate current and future needs, including expansion of parking facilities.	OMKM
- Encourage the VIS to install boot scrapers and educational displays that explain how to prevent the introduction of invasive species.	OMKM
Build capacity of existing education/outreach programs and expand curriculum and outreach efforts to include the MKWA area.	
Improve and coordinate management and signage on all trails being used by the public.	
- Review the content and location of all hazard warning signage and directional (trail) signage used throughout the UH Management Areas and implement comprehensive sign improvements. Coordinate this effort with the NAR and the Forest Reserve to accomplish summit-wide coverage.	OMKM
- Install signs designed to certain specifications so that they do not distract from the landscape.	

Recommended Actions	Implementing Entity
Prevent or deter the operation off all motorized and unmotorized land vehicles except on roads or trails specifically designated for this purpose.	
Time high use recreational events to not interfere with breeding periods of endangered species.	
Restrict vehicles to designated parking areas such as those that are formalized and paved or those that are unpaved but marked for this purpose. Discourage off-road parking.	
Enhance protection of especially-sensitive resources by re-routing non-conforming trails, as necessary.	
Install and maintain unobtrusive trash receptacles where users congregate in the Mauna Kea summit region.	

Objective 6B: Continue support of hunting on appropriate lands, where compatible with watershed protection goals and applicable laws.

Recommended Actions	Implementing Entity
Develop/ update game management plans, as necessary, for public and private lands.	
Develop rules to manage activities in Game Management Areas.	
Develop new accesses for public hunting on public lands. Consult with hunters who frequently use the MKWA area and land managers to determine suitable and appropriate locations for establishment of additional new public hunting access points.	
Manage the Mauna Kea Forest Reserve and Kaʻohe GMA for game bird production.	DLNR
Fence game bird watering stations to keep out feral ungulates.	

Objective 6C: Maintain and secure Keanakolu-Mānā Road and Mauna Kea Summit Access Road to facilitate managed access.

Both Keanakolu-Mānā Road and Mauna Kea summit access road are considered public roadways. Regular maintenance of these roads is necessary for public safety. Because these roads access remote areas, there is also a need to be able to control their use in the case of severe weather or fire.

Recommended Actions for Keanakolu-Mānā Road
Coordinate with neighboring land owners, Hawaiʻi County, and Federal Highway Administration for the maintenance and improvement of Keanakolu Road.
Develop strategies to prevent lateral trespass along public access routes.
Work with County and State agencies to develop a strategy to control access in times of extreme weather or fire danger (*e.g.*, system of gates, etc.).

Recommended Actions for Keanakolu-Mānā Road
Work with County and State agencies to deter the operation off all motorized and unmotorized land vehicles, except on roads or trails specifically designated for this purpose.

Recommended Actions for Mauna Kea Summit Access Road	Implementing Entity
Improve signage and road markings to encourage all travelers to stop at the VIS to adjust to high altitude conditions and receive information prior to proceeding to the summit.	OMKM
Maintain and improve current access control methods and procedures during severe weather and icy road conditions to protect public health and safety and summit resources.	OMKM
Work with County and State agencies to deter the operation off all motorized and unmotorized land vehicles, except on roads or trails specifically designated for this purpose.	
Study the feasibility of a self-funding shuttle service to help minimize the number of vehicles in the summit region and to reduce the use of two-wheel drive vehicles on the Summit Access Road.	OMKM

Management Goal 7: Protect the cultural landscape and historical resources of Mauna Kea.

Responsible stewardship of cultural and historical resources requires efforts to survey and document these resources, as well as appropriate measures to enhance their protection. Remaining known cultural and historical resources are located primarily at higher elevations. A number of cultural assessments have been prepared that described the cultural resources and history of Mauna Kea (Maly and Maly 2005; Maly and Maly 2006; DHHL 2003; Maly 1997; Tomonari-Tuggle 1996). A cultural resources management plan has been developed for the summit region of Mauna Kea (PCSI 2009).

Objective 7A: Ensure that archaeological and other cultural sites within the MKWA area are identified and protected.

Recommended Actions	Implementing Entity
Survey and document culturally-significant areas on Mauna Kea, in collaboration with landowners and cultural resource specialists. Develop a plan, in consultation with all landowners and agencies to account for how this information will be shared and protected.	

Recommended Actions	Implementing Entity
Develop and implement a set of standardized procedures for monitoring the condition of historic properties in selected areas of the Mauna Kea Science Reserve and the Mauna Kea Ice Age Natural Area Reserve that have been adversely affected by human activity in the recent past and will likely continue to be affected in the future because of their easy accessibility.	OMKM
Direct visitors to historic properties suitable for visitation if self-guided tours become part of the educational and interpretive program; or inform them of guided tours if tours are incorporated into an educational and interpretive program.	
Prepare Burial Treatment Plans in consultation with the Hawai‘i Island Burial Council and other interested Native Hawaiians for known or suspected burial sites located in areas that are not being developed or actively used.	
Collect and disseminate information, as appropriate, on wahi pana, traditions, historical accounts, and kama‘āina recollections of Mauna Kea.	

Objective 7B: Provide opportunities for cultural practices that are compatible with habitat and watershed protection goals.

Recommended Actions
Provide access to public lands to Native Hawaiians exercising their rights for traditional and customary practices. Seek to ensure the long-term availability and sustainability of resources for gathering, working with cultural practitioners.
Develop guidelines for Native Hawaiian cultural practitioners accessing the summit of Mauna Kea through a process that is inclusive of cultural practitioners and of the Hawaiian community in general.
Continue to provide access on public lands to Native Hawaiians visiting burial sites and ancient shrines for cultural reasons.
Adopt a policy similar to the one developed at Hawai‘i Volcanoes National Park to remove modern rock piles that are deemed to reflect a misguided practice.

Objective 7C: Promote awareness of Mauna Kea as an important cultural resource.

Recommended Actions	Implementing Entity
Collect and disseminate information, as appropriate, on wahi pana, traditions, historical accounts, and kama‘āina recollections of Mauna Kea.	
Seek guidance from Kahu Kū Mauna in the development of an interpretive program to promote Hawaiian cultural education and pono behavior on the summit of Mauna Kea.	OMKM

Recommended Actions	Implementing Entity
Develop curriculum for Mauna Kea rangers, VIS staff, and other interested employees regarding Native Hawaiian cultural practices and beliefs that they should be aware of when working on the summit of Mauna Kea.	OMKM
Work with Kahu Kū Mauna to develop an ongoing, inclusive process by which Native Hawaiians can help develop guidelines and protocols that are needed for the summit of Mauna Kea.	OMKM

Management Goal 8: Enhance community awareness and support of watershed values, resources, and management activities on Mauna Kea.

Educating the public about Mauna Kea, its resources and values, threats to these resources and values, and management activities is vital to the Mauna Kea Watershed Alliance's primary goal of protection and enhancement of watershed ecosystems, biodiversity, and resources. Conservation education and watershed awareness will help reduce unwanted human impacts on the landscape. Greater awareness about the MKWA area should also translate into greater support for management efforts, in the form of a greater community voice for conservation measures and increased volunteerism.

Enhancing public access into the MKWA area, in conjunction with the development of interpretive materials such as trail guides, will serve to both improve the visitor experience and augment environmental and cultural awareness. People who have had a memorable experience in a natural environment often become keen advocates for that environment.

Successful education efforts often target schools and children, with the belief that teaching younger generations not only plants the future seeds of effective conservation but also extends this knowledge to their parents.

Public education and outreach are also helpful in recruiting a cadre of volunteers to assist in certain management activities, especially in labor intensive efforts such as ecosystem restoration. Volunteers tend to be extremely enthusiastic, but often require an organized volunteer program to help keep motivation levels high.

Objective 8A: Develop and implement education and outreach programs for community members, landowners, and other stakeholders.

Recommended Actions	Implementing Entity
Develop and organize ongoing outreach programs in coordination with local community and educational organizations. - Develop educational programs to help manage the negative effects of human activities on the watershed and inspire people about the unique resources of the watershed. - Develop public service announcements highlighting resource values, describing threats to those resources, and identifying management actions community members can take. - Develop a wildfire awareness program to educate users of Keanakolu-Mānā Rd. - Create webcasts and podcasts with information on Mauna Kea's natural resources. Educate elected officials and other decision-makers about the resources, values, and management issues of Mauna Kea in order to ensure broad base of support for proposed activities.	
Develop education and outreach materials. - Develop interpretive signage along trails or self-guided brochures, identifying natural and cultural features, and providing general information about the unique environments of Mauna Kea. Develop or secure quality teaching materials that could be used in local schools to educate children about the resources and values of Mauna Kea for use in conjunction with field trips to sites in the watershed.	
Provide signage and educational material regarding spread of invasive species on equipment and clothing and what steps can be taken to prevent introduction and spread of invasive plant species in the watershed. Provide easily accessible information at DLNR, Hakalau Forest NWR, 'Imiloa Astronomy Center, and VIS at Hale Pōhaku.	
Use Mauna Kea rangers to help provide visitor assistance and education in the Mauna Kea Ice Age NAR	OMKM
Explore the possibility of mandatory orientation video for anyone who accesses the UH Management Areas.	OMKM

Objective 8B: Provide on-the-ground service learning opportunities for school children and community members.

Recommended Actions	Implementing Entity
Promote the creation of and support "Friends" groups, collaborations, environmental outreach programs, and other groups to provide support for refuges, reserves, and natural areas to cultivate understanding and conservation of Hawai'i's natural and cultural resources.	
- Support and enhance the efforts of the volunteer program Friends of Hakalau Forest NWR to assist with tree planting and propagation, weed control, and facilities maintenance and construction.	USFWS
- Continue the development of the Mauna Kea Forest Reserve volunteer and outreach program.	DLNR
- Develop a volunteer program to assist with forest restoration efforts in the palila mitigation area.	DLNR
- Establish a volunteer program to assist with restoration efforts on DHHL lands in Humu'ula.	DHHL

Management Goal 9: Promote and facilitate research opportunities that will enhance the management of Mauna Kea's resources.

While many studies, surveys, assessments and reports have been prepared about the resources of Mauna Kea, there is still much that is unknown. There is a need for more comprehensive information about the majority of the native species, their biology, distribution, habitat range, vulnerability to threats, and need for and methods of protection and/or recovery. Research is needed on restoration methods and invasive species control methods. Long-term monitoring programs need to be established to detect changes in forest cover and composition, stream quality and habitat, vigor of native species, and changes in weather and climate. Monitoring is also needed to detect introduction and spread of invasive plant and animal species. All this information will help guide future management decisions.

Objective 9A: Monitor long-term trends in watershed health and water quality.

Recommended Actions for Research
Encourage and facilitate management-oriented research by U.S. Geological Survey (USGS), the University of Hawai‘i, the U.S. Forest Service, and other agencies and institutions.
Prepare guidelines for which kinds of research projects require permits at which locations on Mauna Kea (*e.g.*, summit, NAR, Experimental Forest, forest reserve, etc.).
Study the effects of climate change on the resources of Mauna Kea.
Monitor human use on Mauna Kea to determine location of damage to natural resources caused by human use; and quantify human use levels.
Research koa forest restoration methods.

Recommended Actions for Invasive Species
Conduct research on additional control methods for priority invasive weed species.
Map current and potential range of feral ungulates, and identify control methods in place and their effectiveness.
Map current distribution of individual pest species.
Regularly assess distribution of problem weed species and maintain current distribution maps.
Continue DLNR-DAR stream surveys of perennial streams on Mauna Kea to further assess conditions of streams and presence of invasive species. Evaluate alternative stream bioassessment and monitoring approaches and develop one for long-term use within the watershed management area, if desirable.
Develop distribution map of invasive aquatic species.

Recommended Actions for Biodiversity Monitoring
Conduct and/or update forest bird surveys for region. Conduct avian surveys more frequently for critically endangered species.
Develop standardized survey and monitoring protocols for determining abundance and distribution, roosting habitat associations, basic life history, biology and food habits of the Hawaiian hoary bat.
Conduct surveys of insect fauna and conduct research on their basic life history and biology. - Conduct research on the interface between snow play and the wēkiu bug.
Continue to conduct rare plant surveys to document location and health of rare plant populations.
Continue DLNR-DAR stream surveys.
Conduct long-term monitoring to determine the status and trends in selected resources, to allow for informed management decisions.
Work with local experts to establish low-impact but large scale monitoring techniques, using remote sensing whenever feasible.

Recommended Actions for Water Quality Monitoring
Develop a monitoring program to measure sedimentation, stream flow, turbidity and nutrients on a sub-watershed level, in collaboration with Federal and State agencies.
Develop a monitoring program for waterborne pathogens, identify vectors for pathogens, and initiate program to reduce vectors in surface and ground water.
Conduct a monitoring program in conjunction with feral ungulate control efforts to document short and long-term changes in water quality resulting from ungulate removal.

Objective 9B: Assess the success of management actions to accomplish habitat and watershed management goals and provide direction for future actions.

Recommended Actions
Assess the success of reforestation efforts in restoring native plant communities and habitats for native bird, mammal, and invertebrate species.
Monitor the patterns of distribution of incipient and well-established weed species and effectiveness of management actions.
Conduct a monitoring program in conjunction with feral ungulate control efforts to document short and long-term changes in the forest cover and quality resulting from ungulate removal.
Assess the success of riparian buffers in protecting or enhancing stream quality and habitat.
Using adaptive management methods, set up monitoring programs and benchmarks to enable managers to judge when more stringent access control methods are needed for the Mauna Kea summit region.
Correlate public use and impact data with other cultural and environmental resource monitoring activities in the Mauna Kea summit region to inform adaptive management initiatives.
Improve data collection on heavy snow play days to monitor areas of significant activity and develop indicators of impact to be used in future management actions.

Objective 9C: Support research to help guide new and innovative uses of the land that will sustain economic activities while protecting habitat and watershed values.

Recommended Actions
Work with State and Federal agencies to develop and implement incentive programs for landowners seeking to employ innovative and economically-sustainable uses of the land in balance with natural resources protection goals.
Work with UH College of Tropical Agriculture and Human Resources and USDA Natural Resources Conservation Service to conduct research on appropriate food and timber crops for sustainable production.

Management Goal 10: Provide effective administrative coordination, infrastructure, and enforcement.

Objective 10A: Promote and support the enforcement of existing laws and rules to ensure public safety and prevent unregulated and illegal land and resource uses.

Recommended Actions
Increase personnel and financial resources for DLNR's Division of Conservation and Resource Enforcement (DOCARE) to enable a greater and more visible presence of DOCARE personnel on Mauna Kea.
Use Mauna Kea rangers to report violations occurring in the Mauna Kea Ice Age NAR and study the feasibility of developing limited citation authority for Mauna Kea rangers.
Develop formal collaborative enforcement relationships between the Hawai'i County Police Department, DOCARE, and OMKM through cooperative agreements or other means to strengthen the partnerships needed for effective response in the Mauna Kea summit region.

Objective 10B: Provide and maintain the appropriate infrastructure and administration to allow for effective watershed management and coordination of activities between Mauna Kea Watershed Alliance members.

Implementation of the management plan is a long-term commitment that requires sufficient personnel and financial resources to not only manage the natural resources but develop and maintain the physical infrastructure. The alliance members will join together to seek funds and potential new members for the projects recommended in this plan. Cooperation and effective communication among alliance members and other land users and managers will be critical to the success of this management effort.

Recommended Actions
Hire a watershed coordinator to: coordinate the implementation of the plan; raise needed funding from a variety of sources; assist MKWA members in implementation projects; and hire staff and obtain equipment, transportation and communication systems as needed.
Complete the process for an Environmental Assessment for the Mauna Kea Watershed Management Plan.
Coordinate use of manpower, equipment, and communication systems throughout the MKWA area.
Maintain communication among alliance members to facilitate information sharing. Develop clear and effective processes for intra-alliance communication.

Recommended Actions
Update and clarify procedures and communications between OMKM, PTA, and Hawai‘i County Fire Department (HCFD) emergency medical response teams to ensure prompt and ongoing emergency response support in the UH Management Areas.
Seek participation of other landowners in or adjacent to the MKWA area and of other entities that are stakeholders in the watershed.
Identify future infrastructure needs to facilitate management activities.
Revise and update the watershed management plan as management needs change, management techniques evolve, and new data become available.

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APPENDICES

A. Memorandum of Understanding (MOU) for the Mauna Kea Watershed Alliance