# NATURAL RESOURCES MANAGEMENT PLAN
for
## WAIHOU and ʻAIEA CONSERVATION UNITS

**View of the Aiea Conservation Unit. Photo courtesy of Elliott Parsons**

*Prepared for*:
**STATE OF HAWAIʻI**
**DEPARTMENT OF LAND AND NATURAL RESOURCES**
**DIVISION OF FORESTRY AND WILDLIFE**

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# NATURAL RESOURCES MANAGEMENT PLAN

For

# WAIHOU AND ʻAIEA CONSERVATION UNITS

Within the Puʻuwaʻawaʻa Forest Reserve

*Submitted by*:

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## INTRODUCTION

A Resource Management Plan for Puʻuwaʻawaʻa Forest Reserve was approved in concept by the Hawaiʻi Board of Land and Natural Resources on July 15, 2003. That document presents 62 unique objectives that are intended to provide a framework for management of the Forest Reserve over a 10-year period. The plan also establishes eleven conservation units within the forest reserve for the specific purpose of resource protection. Management Objective #9 in the document calls for fencing the units and subsequent removal of all ungulates. All units are managed by the Hawaiʻi Division of Forestry and Wildlife (DOFAW) and are part of the Hawaiʻi Experimental Tropical Forest System administered by DOFAW and the U.S.D.A. Forest Service (USFS).

Management plans for conservation units are intended to supplement the 2003 plan and serve as internal documents to guide DOFAW in the restoration of conservation units. The following plan provides a framework for the restoration and sustainable management of the Waihou and ʻAiea conservation units. Both units are treated together as they are ecologically similar and share a common boundary. The plan presents a brief history of forest conditions, a description of natural resources, and offers specific recommendations for management actions including: infrastructure maintenance, forest restoration, invasive weed control, ungulate control, wildlife habitat improvement, and wildfire prevention.

The Waihou/ʻAiea units contain a number of important geological and biological features that will be protected under this plan:

- An ancient volcanic spatter cone
- A notable site known as Waihou Forest
- Rare native plant communities and their associated wildlife
- Area of great botanical diversity
- Federally designated Critical Habitat for four (4) taxa of endangered species

## PROPERTY DESCRIPTION

### Location and General Description

The Waihou/ʻAiea conservation units are located in the Puʻuwaʻawaʻa Forest Reserve, North Kona District, Island of Hawaiʻi (USGS quadrangles: Kailua and Hūalalai). They fall within the Hawaiian land division or *ahupuaʻa* of Puʻuwaʻawaʻa and are situated directly downslope from the Puʻuwaʻawaʻa Forest Bird Sanctuary (fig. 1). Topography is gradually sloping with a north-facing aspect. The Waihou unit covers 211 acres, extending from 3,400 to 3,900 feet elevation while the ʻAiea unit covers 286 acres, extending from 3,520 to 4,000 feet elevation. Total area of the two units is 497 acres.

The conservation units are situated within a seasonally dry woodland, characterized by low rainfall and frequent droughts. This plant community is an important conservation link, connecting dry lowlands below with the moist mesic uplands. Plant species characteristic of both moisture regimes occur in the community. The woodland also serves as a refuge for many species of rare and endangered plants. Tree canopy cover is generally sparse, but native vegetation has excellent potential for recovery. Primary threats to plant recovery are habitat disturbance by non-native ungulates, invasive non-native plants, pest insects, loss of native pollinators, and wildfire.

**Land Use**

The Territory of Hawai‘i and Hawai‘i state government have leased Pu‘uwa‘awa‘a *ahupua‘a* to private parties for ranching purposes since 1892. Various lessees have grazed livestock on the land under the name of Pu‘uwa‘awa‘a Ranch. Formal ranching operations ceased in August, 2000 when the last general lease expired. However, some of the pastures are still being grazed by cattle under a year-to year revocable permit system.

**Existing Improvements**

Fence construction, to exclude ungulates from the Waihou unit, began in 1994. An unnamed cinder cone, in the central portion of the unit, was fenced to create a one-acre exclosure for out-planting *Delissea undulata.* This rare lobeliod has no common name so the site was named Delissea exclosure.

In 2003, the entire Waihou conservation unit was enclosed within a woven wire fence (48 inch high). A strand of smooth wire was added above the woven wire to discourage ingress by domestic livestock and feral animals. This fence effectively protected 211 acres of native forest from damage by ungulates. An old ranch road bisects the interior of the unit and another exists along the eastern boundary. This latter road was extended downslope to provide additional access to the fence line. Animal drives were conducted, upon completion of the fence, in an effort to remove all domestic and feral ungulates from the unit. Cattle and feral sheep were successfully removed, but a few feral pigs remained inside for several years. In 2011, the Three Mountain Alliance, a Watershed Partnership that includes Pu’uwa’awa’a Forest Reserve, worked with the Division of Forestry and Wildlife to remove the remaining feral pigs from the fenced unit. The unit was declared pig free (and thus ungulate free) in 2012.

In January 2018, another 286 acres of native forest was fenced to protect the Aiea conservation unit. Woven wire (six feet high), was installed along the northern and eastern boundaries. These tied into existing fence lines along the eastern, southern and western boundaries. Additionally, three one-way release doors were installed along the lower (northern) boundary to facilitate feral pig removal. These traps allow pigs to exit the unit, but they cannot return. An old ranch road, extending diagonally through the interior of the unit was cleared to provide additional access. Old paddock fences, gates, water tanks, pipes, and livestock troughs used for ranching operations

were the only structures present in the units. Most of these were removed before the units were fenced.

The Aiea unit contains several features that are culturally significant. An abandoned stone structure with attached cistern is located along the main access road at approximately 4,000 feet elevation. This building was historically used by Puʻu waʻawaʻa Ranch for their dairy operation. The cistern held water, but was also used to store and cool containers of fresh milk until they could be transported to ranch headquarters. The building was said to be constructed during Robert Hinds tenancy on the ranch (Sonny Keakealani, pers. comm., 5/6/2018).

A stone corral occurs on the upper boundary of the unit, near the forest bird sanctuary cabin. This structure was called Nishiyama paʻeke by ranch cowboys. It was constructed by Japanese ranch hands during the Hinds tenancy and was used for holding cattle. A larger and more impressive stone corral occurs below the conservation units at 3,055 feet elevation. This enclosure was called Lahanui paʻeke (Sonny Keakealani, pers. comm., 5/6/2018).

A native shrub and tree planting plot occurs near the forest bird sanctuary cabin (Cabin exclosure). This site was fenced by DOFAW staff in 1992 for the purpose of outplanting rare species native to the *ahupuaʻa* (figure 2). The exclosure was also expected to serve as a seed orchard once plantings matured. The fenced unit was subsequently enlarged by volunteers sometime around 2009 or 2010, effectively doubling its original size.

**Land and Resource Description**

*Rainfall*

Isohyet lines mapped by Giambelluca et al., (2013) for the climatological base period (1978-2007) indicate that rainfall in the units varies from 29.3 to 39.5 inches annually at the lower and upper boundaries, respectively. Most of the precipitation falls from January through July. Kona storms can create large annual fluctuation in rainfall. These weather systems develop west of Hawaiʻi , bringing moist southerly winds and rain which can persist for a week or more (Giambelluca and Schroeder, 1998).The entire Puʻuwaʻawaʻa *ahupuaʻa* is subject to fluctuating rainfall and frequent droughts. Kona had a particularly wet year in 2015 due to an El Nino event.

*Geology*

Volcanic activity at Puʻu waʻawaʻa has created a variety of geologic features. These include ʻaʻa, pahoehoe, and trachytic lava flows; deposits of volcanic glass or obsidian; cinder (pumice) cones; spatter or tuff cones; sink holes; lava tubes with associated entrances and skylights; lava trenches and cracks; rift zones; and tree molds. Lava substrates in the conservation units are a mixture of pahoehoe and ʻaʻa flows. They originated on Hūalalai and are primarily Holocene in age. Geologic maps published by Wolfe and Morris (1996) place these lavas in two general age

classes. The oldest flows are 3,000 to 5,000 years old while younger flows are 1,500 to 3,000 years old (fig. 3).

The most prominent landform in the conservation units is a 5,000–11,000 year old volcanic spatter cone that rises about 75 feet above the surrounding landscape. This un-named vent is situated at 3,750 feet elevation in the Waihou unit. Spatter cones form when hot erupting lava contains just enough explosive gas to prevent the formation of a lava flow, but not enough to shatter it into small fragments. The lava is torn by expanding gases into fluid hot clots, ranging in size from 1 cm to 50 cm in size, called spatter or coarse, near-vent fallout. When the spatter falls back on the vent, clots weld themselves together and solidify forming steep-sided walls.

*Soils*

The soil classification system used worldwide classifies soil into orders (major soil types), based on their measurable physical and chemical properties and the primary environmental factors that influenced their formation. Of the 12 soil orders classified, 11 have been reported in Hawai‘i. Andisols and Histosols are the only two soil orders represented in the conservation units. Andisols include weakly weathered soils with much volcanic glass as well as more strongly weathered soils. They formed in volcanic ash or other volcanic ejecta. These soils have unique chemical and physical properties that include high water-holding capacity and the ability to bind large quantities of phosphorus, making this element unavailable to plants. Andisols are fertile soils and often support a dense natural cover in moist climates (Univ. of Idaho, 2010).

Histosols are soils composed primarily of organic material. They are generally called bogs, moors, peats or mucks (USDA, 2013). Most Histosols form in settings such as wetlands where restricted drainage inhibits the decomposition of plant and animal remains, allowing these organic materials to accumulate over time.

Soil series further define characteristics of soils. These assemblages are typically delineated by parent material, rainfall, soil depth, slope conditions, drainage, and permeability. Hawaiian soil series are generally given geographic place names, but written without diacritical marks.

The most recent comprehensive soil survey of Hawai‘i Island was completed in 2013 by the U.S. Department of Agriculture. Current soil maps (NRCS, 2017) show three different soil series in the conservation units (fig.4). Halekula soils cover the greatest area (232 acres) while Puuiki and Kamawai combinations cover the remainder of the units (table 1).

Table 1. Soil series found within the Waihou and ʻAiea Conservation Units (USDA, 2013).

| Soil Order | Soil Series | Soil Description |
|---|---|---|
| | | |
| Andisols (Mineral soils) | Halekula | Very cobbly silt loam consisting of moderately deep, well drained soils that formed in basic volcanic ash over ʻaʻa lava (3,000 to 10,000 years old). Soil depth to bedrock is 20-40 inches (50-102 cm). |
| | Kamawai decomposed plant material | Extremely cobbly muck consisting of shallow, well drained soils that formed in basic volcanic ash over ʻaʻa lava (1,500 to 3,000 year old). Soil depth to bedrock is 10-20 inches (25-50 cm). |
| | Kamawai organic loam | Extremely cobbly highly organic medial sandy loam consisting of soils that formed in basic volcanic ash in ʻaʻa lava (1,500 to 3,000 years old). Soil depth to bedrock is 10 to 20 inches (25-50 centimeters) |
| Histosols (Organic soils) | Puuiki | Very cobbly highly decomposed plant material consisting of very shallow, moderately well-drained soils that formed in organic material mixed with basic volcanic ash over pahoehoe lava (<5,000 years old) These soils have greater than 25 percent organic carbon (by weight) in the less than 2.0 mm soil material. Soil depth to bedrock is 2-10 inches (5-25 cm). |

**Waihou Forest**

The conservation units are situated in an area that was historically known as Waihou forest. This woodland was famous for its exceptional botanical diversity and relatively high numbers of rare plant species. Joseph Rock, a prominent territorial botanist, first explored the flora of Puʻuwaʻawaʻa in 1909. He described the Waihou region as a semi-wet forest situated at 3,500 feet elevation. In 1909, Waihou forest was dominated primarily by ʻohiʻa (*Metrosideros polymorpha)*, koa (*Acacia koa*), mamane (*Sophora chrysophylla*), naio (*Myoporum sandwicense*) and ʻakoko (*Chamaesyce olowaluana*) trees. Rock reported that opuhe (*Urera sandwicensis* ) grew quite tall along with olapa (*Cheirodendron trigynum*), kolea (*Myrsine lanaiensis*), kawaʻu (*Ilex anomala*), and other species. Rock noted that opuhe "is not uncommon in Waihou forest (elevation 3000 feet), where trees 35 feet in height can be found. It is here that the writer met with the biggest trees; some had trunks of one foot in diameter." (Rock, 1913).

Rock discovered several rare plant species at Waihou, two of which no longer exist in the wild. Hau kuahiwi (*Hibiscadelphus hualalaiensis*) was, "found in 1909 in the forest of Waihou where about a dozen trees are still in existence." (Rock, 1913). Rock also documented the presence of

*Delissea undulata* at Puʻuwaʻawaʻa (3,000-3,500 feet elevation). He noted that plants were numerous, especially in Waihou forest, but they did not attain the height of those seen on Mauna Loa (Rock, 1919).

A "few" ohe mauka (*Tetraplasandra meiandra*) trees were growing at Puʻuwaʻawaʻa in 1909 (Rock, 1913). However, only a single individual was located in 1944. This lone tree was found at Waihou (3,700 feet elevation) by A. L. Mitchel, a Hawaiʻi Volcanoes National Park Naturalist (Mitchel, 1944). *Tetraplasandra* o*ahuensis* is presently considered the accepted name for this species.

ʻAkoko was a major component of Waihou Forest in the early 1900s. This member of the Spurge family (Euphorbiaceae) is the tallest of all the *Chamaesyce* species. It is notable for the milky latex sap that exudes from injured bark, hence the name ʻakoko (blood). *C. olowaluana* only occurs naturally on the island of Hawaiʻi, although the name "akoko" is employed for other species in the island chain (Rock, 1920). Physiologically ʻakoko is unique as it utilizes a photosynthetic pathway (C4) that differs from most tree species. This pathway - typically utilized by light loving tropical grasses $C_4$ plants - has a competitive advantage over plants possessing the more common $C_3$ carbon fixation pathway under conditions of drought, high temperatures, and nitrogen or $CO_2$ limitation (Pearcy and Calkin 1983).

In 1909, Rock found ʻakoko, "on the slopes of Hūalalai between Huehue and Puʻuwaʻawaʻa, Hawaiʻi, at an elevation of 3000 feet, on the rough *aa* lava field and also in the more humid forest of Waihou." Rock described ʻakoko as "a shrub at 2000 feet elevation, while 700 feet higher it is a tree about 25 feet high, with a diameter of 10 inches. The tree yields a large amount of latex, which owing to its predominance in the area of 5000 acres will undoubtedly prove a valuable commercial product." (Rock, (1913).

Rock visited Puʻuwaʻawaʻa again in 1911. His trip report indicated that, ʻakoko was an especially significant component of Waihou Forest." He observed that, "In certain localities the plants are so thick that it is impossible to ride through them. The ground is covered densely with the young seedlings and thousands upon thousands of plants cover that area." (Rock, 1912).

W.A. Anderson, an employee of the Hawaiʻi Agricultural Experiment Station, visited Puʻuwaʻawaʻa in 1912. The purpose of his trip was to document the occurrence of ʻakoko and secure latex samples from the trees. He hoped to determine the adaptability of this species for tapping, cultivation, and rubber production. Anderson reported that, "The trees are growing among other forest growth on several thousand acres of Government land under lease to the Puuwaawaa Ranch." ...."They were found at an elevation of about 3,000 feet, in very thin a-a soil with frequent out-croppings of pahoehoe. The trees large enough for tapping are distributed at irregular intervals among other trees. The ground is covered with seedlings one to six or eight

feet high, mostly of the Euphorbia trees, forming an immense nursery. There is very little undergrowth beside these seedlings. Many of these have been eaten off at the top by cattle, and have started growing again from eyes along the stems." ...."In the portions visited, there are about 50-75 mature trees per acre..." (McGeorge and Anderson, 1912).

A. L. Mitchell conducted botanical surveys at Waihou in 1944 and again in 1945. His reports and field notes provide a detailed description of the forest's botanical composition at that time. Mitchell reported that ʻakoko was still abundant at Puʻuwaʻawaʻa in 1945. His reports list ʻakoko as, "frequent between 2,000 and 3,700 feet elevation." (Mitchell, 1944, 1945a, 1945b).

Today, the ʻakoko community at Puʻuwaʻawaʻa is reduced to a few scattered trees, most of which are of the shrubby variety. A few very large trees were present between 3,800 and 4,200 feet elevation until 2009, but most of those have since died. ʻAkoko is now considered a vulnerable species, likely to become endangered in the near future unless the threats to its survival are removed or reduced (Wagner et al., 1999). The plant is also considered a Species of Concern by the U.S. Fish and Wildlife Service (USFWS). Cattle, sheep, and goats are likely responsible for the decline of this unique species. These animals are regularly observed browsing on ʻakoko seedlings at Puʻuwaʻawaʻa (J. Giffin, pers. obs.).

*Forest Decline*

Mamane was a major component of Waihou Forest until a few decades ago. Billy Paris, a former manager of Puʻuwaʻawaʻa Ranch, stated that the mamane canopy was still intact when he left the ranch in 1959 (B. Paris, pers. comm., 1985). The lead author first visited Waihou in 1980. At that time, the forest looked like it was diseased. Standing skeletons of dead and dying mamane trees marked much of the landscape and the forest understory consisted of non-native grasses. It was apparent that cattle were rapidly converting the forest to open pasture.

Blackmore and Vitousek (2000) documented the decline of forest tree cover at Waihou in 1998. They used aerial photos to measure the long-term loss of forest cover in area that now includes the Waihou and Aiea conservation units. They found that forest cover declined substantially in their study area between 1954 and 1994. By 1994, less than half (62 percent decrease) of the initial forest remained, much of it in a degraded state. While there was no evidence that cattle killed canopy trees, they did prevent any tree reproduction within the area, leading to a gradual loss of forest cover. Additionally, the area covered by grassland increased by 237 percent. No fires or land clearing occurred in the study area between the two dates.

**Existing Forest Cover**

Koa, ʻohiʻa, and mamane are the primary tree species growing in the conservation units today. Native canopy crown cover varies greatly, ranging from very scattered (<5% cover) near the lower boundary of the units to open koa-ʻohiʻa-mamane trees (>25-60% cover) near the upper boundary (Jacobi 1989). Understory vegetation consists primarily of non-native pasture grasses,

especially Kikuyu (*Pennisetum clandestinum*) and fountain grass (P*ennisetum setaceum*).
In 1991, a survey of existing plant species was conducted in the Waihou unit by J. Giffin, DOFAW biologist. At least 23 species of native trees and shrubs were present in the unit at that time (table 2).

Table 2. Plant species growing in the Waihou Conservation Unit in 1991. Data collected by Jon Giffin, DOFAW biologist.

| **Scientific name** | **Common name** | **Protective Status and number observed** |
|---|---|---|
| *Acacia koa* | koa | none |
| *Alyxia oliviformis* | maile | none |
| *Chamaesyce olowaluana* | ʻakoko | rare (1) |
| *Charpentiera obovata* | papala | none |
| *Claoxylon sandwicense* | poʻola | none |
| *Coprosma menziesii* | pilo | none |
| *Lipochaeta subcordata* | nehe | none |
| *Melicope hawaiensis* | manena | rare (7) |
| *Melicope volcanica* | alani | none (1) |
| *Metrosideros polymorpha* | ʻohiʻa | none |
| *Myoporum sandwicense* | naio | none |
| *Myrsine lanaiensis* | kolea | none |
| *Myrisne lessertiana* | kolea lau nui | none |
| *Nestegis sandwicensis* | olopua | none |
| *Nothocestrum breviflorum* | ʻaiea | endangered (>3) |
| *Nototrichium sandwicense* | kului | none (1) |
| *Pisonia brunoniana* | papala kepau | none |
| *Pittosporum hosmeri* | hoawa | none |
| *Psychotria hawaiiensis* | kopiko | none |
| *Santalum paniculatum* | ʻiliahi | none |
| *Sophora chrysophylla* | mamane | none |
| *Streblus pendulinus* | aʻiaʻi | none |
| *Zanthoxylum dipetalum var. tomentosum* | aʻe | endangered (2) |

No plant surveys were conducted in the Aiea unit in 1991 because its boundaries were not established. However, field notes recorded by the lead author list the presence of the following species: koa, ʻohiʻa, mamane, poʻola (*Claoxylon sandwicense*), kopiko (*Psychotria hawaiiensis*), papala kepau (*Pisonia brunoniana* ), ʻaiea (*Nothocestrum breviflorum*), aʻe (*Zanthoxylum dipetalum* var. *tomentosum*), manena (*Melicope hawaiensis*), and ʻakoko. None of the species were abundant except for koa, ʻohiʻa, and mamane.

Thousands of native plants have been outplanted in the Waihou unit since it was fenced in 2003. In 2005 a research project was conducted in the Waihou unit. Researchers from the USFS and DOFAW compared three large scale treatments: broadcast seeding, herbicide, and broadcast seeding combined with herbicide. After two years their study results suggested that broadcast seeding and the favorable microclimate created by eliminating invasive grasses through herbicide application increased native seed germination and survival and promoted higher species diversity (Brooks et al. 2009). From 2012 to 2017, more than 11,738 native tree and shrub seedlings, consisting of 32 species, were outplanted in the unit. The primary species planted were koa (8,776 or 75%), aʻaliʻi (943 or 8%), and mamane (868 or 7%). Other species accounted for 10 percent of the total. No outplanting has taken place in the ʻAiea unit to date, but 11 endangered ʻaiea trees and one large papala (*Charpentiera obovata*) have been enclosed with heavy wire panels to protect them from ungulate damage.

**Rare Plants**

In 2003, DOFAW staff conducted a detailed inventory of rare plants in the Waihou unit. The only endangered species recorded were ʻaiea (9), and aʻe (2). Other rare plants included ʻakoko (3) and manena (8). The latter two species are considered, by experts, to be imperiled, but have no formal designation. All four species require protection to ensure their continued survival. A total of 29 ʻaiea were present in the Aiea unit in 2018 (E. Parsons, pers. comm., 1/30/2018). Species formerly present, but now extirpated in the wild include *Delissea undulata* and hau kuahiwi.

The last known wild hau kuahiwi grew at Waihou in a stand of scattered mamane (3,350 feet elevation). This individual was fenced prior to 1980 to protect it from ungulates, but the plant died in 1992. Progeny of the plant have been planted extensively in exclosures at Puʻuwaʻawaʻa (J. Giffin, pers. obs.).

Wild *Delissea undulata* were last sighted at Puʻuwaʻawaʻa in 1922, but the species persisted elsewhere on Hūalalai until 1971. It was thought to be extinct after that date (Wagner et al., 1999). *D. undulata* was rediscovered at Puʻuwaʻawaʻa in 1992. A single individual was growing on the wall of a lava tube skylight where it was protected from herbivores. The plant was discovered along the eastern edge of Waihou forest in the Henahena paddock (3,520 feet elevation). It occurred in a mesic forest dominated by ʻohiʻa, koa, naio, and sandalwood (*Santalum paniculatum*) trees. Numerous seeds were collected from this rare lobelia before it died in 1993 (J. Giffin, pers. obs.).

The first *Delissea undulata* seedlings to be propagated after the species rediscovery were outplanted in the one-acre Delissea exclosure in 1994. All seedlings were placed in the vent of the spatter cone. This site was chosen because it was fenced and the interior walls and floor of the vent provided wind protection and deep soils thought to be necessary for the species survival. No *Delissea* plants were present on the cone when it was fenced.

In 2002, a single ohe mauka tree was rediscovered at Pu‘uwa‘awa‘a (Halepiula 1 paddock, 3,900 feet elevation). Hundreds of seeds were collected from the tree before it died, but only three seedlings were successfully germinated. These were planted at the Cabin rare plant exclosure in 2003. Only two of these trees are still alive today (J. Giffin, pers. obs.)

**Existing Wildlife Species**

The conservation unit provides habitat for a number of rare animals. Endangered bats, birds, and insects have all been recorded in the two conservation units. Species include the hoary bat (*Lasiurus cinereus semotus*), ‘io or Hawaiian hawk (*Buteo solitarius*), and Blackburn’s sphinx moth (*Manduca blackburni*).

The ‘ope‘ape‘a or Hawaiian hoary bat is Hawaii 's only native land mammal. This cryptic foliage-roosting creature was originally considered to be a distinct species, but is now classified as a subspecies of the U. S. mainland hoary bat. Hawaiian bats are officially listed as an endangered species by the USFWS. They occur from sea level to the highest volcanic peaks on Hawai‘i Island. Sightings of native bats are common in the Kona region. Local bats appear to concentrate in the coastal lowlands during the breeding season (May through October) and migrate to interior highlands during the winter non-breeding season. There is a significant association between bat occupancy and prevalence of mature forest cover (Gorresen et al., 2013). Hoary bat are sometimes seen flying in the units at dusk and probably forage and roost there also. Little is known about the population size or distribution of this nocturnal animal.

Hawaiian hawks attain relatively high population densities at Pu‘uwa‘awa‘a . USFWS biologists detected at least 29 individuals at Pu‘uwa‘awa‘a between March 1998 and April 1999. Two active nests were present in the Waihou unit at that time. Hawks at Pu‘uwa‘awa‘a appear to favor the forest-grassland interface that occurs near the upper boundary of the Waihou and ‘Aiea conservation units. This location is also a favored nesting area.

Blackburn’s sphinx moth was thought to be extinct on the Big Island until December, 1998, when it was rediscovered in the dry forest at Pu‘uwa‘awa‘a (1,800 ft. elevation) by two professional photographers (Susan Middleton and David Liittschwager). This species was officially listed as endangered on February 1, 2000. Moth caterpillars feed primarily on leaves of the endangered ‘aiea tree and the introduced tree tobacco (*Nicotiana glauca* ). Adult sphinx moths and their caterpillars have been observed a few hundred feet upslope from the conservation units and probably occur inside the unit.

*Plagithmysus montgomeryi*, a rare long-horned beetle, has been collected in the conservation units. This species is restricted to ‘akoko and cannot survive without its imperiled host. Yellow-faced bees (*Hylaeus* spp.) are common in the conservation units. They are especially attracted to ‘akoko despite the tree’s rarity and peculiar flowers, which are minute and effectively petal-less (Magnacca, 2007). ‘Akoko, when flowering, attracts a great diversity of native bees in search of

nectar.

Other species of long-horned beetles are also present in the units, two of which are classified as "Species of Concern" (SOC) by the USFWS. These insects are so highly specialized that they can only exist on their respective host plants. *Plagithmysus simplicicollis* is restricted to the endangered ʻaiea tree while the closely related *Plagithmysus elegans* only inhabits the rare papala tree (*Charpentiera obovata*). Both beetle species are on the verge of extinction because their host trees are also rare or endangered. The koa bug (*Coleotichus blackburniae*) is listed as a SOC even though its host (*Acacia koa*) is generally common. A rare comb-clawed beetle (*Labetis hawaiiensis*) has also been collected in the Waihou unit (J. Giffin, pers. obs.).

Fossilized shells of a large tree snail (*Partulina confusa*) and other species of native land snails have been recovered from slopes of the volcanic spatter cone inside *Delissea* exclosure. All of these mollusk species are now considered extinct.

**Critical Habitat Designation**

"Critical habitat" is a term used in the U.S. Endangered Species Act to identify geographic areas that are essential for the conservation of threatened or endangered species. This designation is used by the USFWS for both public and private lands considered essential for the conservation of threatened or endangered plant or animal species. Designation of land as critical habitat does not require the landowner to implement recovery actions or to manage the land in any certain way. However, the Service does require landowners to consult with the USFWS if undertaking projects that entail federal funding or permitting.

The USFWS has designated Critical Habitat for a number of endangered plant and animal species that inhabit Puʻuwaʻawaʻa . Boundaries of four (4) Critical Habitat areas overlap the conservation units. These include:

- Blackburn's sphinx moth (*Manduca blackburni*)
- Hau kuahiwi (*Hibiscadelphus hualalaiensis*)
- ʻAiea (*Nothocestrum breviflorum*)
- Aʻe (*Zanthoxylum dipetalum*)

## RESOURCE MANAGEMENT OBJECTIVES AND PRACTICES

The protection of natural resources, including rare species, is a prime management goal for the conservation units. Management objectives and practices proposed in this plan are expected to have positive environmental impacts by restoring native forests, controlling weeds, improving habitat for threatened and endangered species, and contributing to Hawaii's overall biodiversity. The actions needed to achieve these goals are as follows:

***Objective 1*: *Control Ungulates***

Fencing plays a critical role in native forest protection. The exclusion of ungulates by fencing allows native vegetation to recover from past damage.

*Management practices*:

- Remove all domestic cattle and feral ungulates from the conservation units using organized drives, hunting, traps, and snares.
- Check perimeter fences monthly for damage or signs of ungulate ingress.
- Monitor the unit for evidence of use by feral ungulates or domestic livestock.

***Objective 2*: *Prevent the introduction and spread of habitat modifying weeds.***

Non-native plant species were introduced into the islands beginning with the first Polynesians and they continue to spread today. Invasive non-native plants pose a particular threat to native ecosystems. These plants may aggressively out-compete natives, degrade natural habitats, and impact sensitive species. Non-native species often have few ecological controls and thrive under disturbed conditions created and maintained by man and his introduced animals. In most cases, it will not be possible or even desirable to eliminate invasive plant species altogether. Therefore, the following recommendations focus on targeting those species with the greatest potential for habitat disturbance. The most severe potential disturbance regime is the introduction of the grass-fire cycle where native fire intolerant woody vegetation gets replaced by fire adapted invasive grasses. With the cessation of cattle in many parts of Puʻuwaʻawaʻa, the less fire prone grass *Pennisetum clandestinum* (kikuyu grass) is being replaced by the more fire prone grass *Pennisetum setaceum* (fountain grass) (Blackmore and Vitousek (2000).

*Management practices*:

- Control fountain grass by mowing, weed-whacking old foliage, or pulling plants and then treating new growth with herbicide.
- Control Kikuyu grass around newly outplanted seedlings.
- Kill all silk oak trees within the conservation units and in a buffer zone one-half mile wide around the units.
- Locate and control other high priority weed infestations with herbicide applications or by manual removal.
- Prevent new habitat-modifying weeds from establishing/spreading.
- Utilize domestic livestock to reduce fire fuel biomass around the perimeter of the conservations units.
- Monitor efficacy of invasive weed control activities using photo plots or sampling techniques.
- Monitor ʻohiʻa trees for evidence of rapid ʻohiʻa death (ROD) caused by *Ceratocystis* fungi.

***Objective 3*: *Restore Forest Vegetation***

Limited habitat protection has already been achieved through conservation unit designation and removal of domestic livestock. Regeneration of forest "infrastructure species" such as koa, mamane, and ʻohiʻa, is occurring naturally from the soil seed bank and root sprouts. Native vegetation is still threatened, however, by ingress of feral animals, invasive weeds, rodents, slugs, ants, and other non-native organisms. The presence of koa is especially important for forest recovery. Research at other locations on the Island of Hawaiʻi has shown that developing stands of koa physically modify pasture lands and create conditions more favorable to growth and survival of native understory species (Baker et al., 2009). Soils at Puʻuwaʻawaʻa may be nitrogen limited due to their long history of grass production for livestock. By re-establishing nitrogen fixing trees such as koa and mamane, these limitations may be lessened. An established canopy of koa and mamane will also help shade out non-native pasture grasses and provide an environment more beneficial to shade tolerant native ferns and shrubs.

Lava flow age and soil type at Puʻu waʻawaʻa has an important effect on botanical diversity. The richest floral composition at Puʻuwaʻawaʻa occurs on 3,000-5,000 year old ʻaʻa and pahoehoe lava flows. Younger flows (1,500-3,000 years) support native forest dominated by koa, ʻohiʻa, and mamane, but lack the botanical complexity of older soils. Lava flows in both age classes occur in the conservation units (fig. 3). Outplanting of rare species should be concentrated on the older flows to increase their potential for long-term survival. Common structural tree species, such as mamane, koa, ʻohiʻa, and especially ʻakoko should be planted on younger flows. Seedlings should initially be concentrated within existing stands of forest that offer more shade and damper microhabitats. Over time, these stands should be enlarged and coalesced to recreate closed canopy forest conditions.

*Management practices*:

- Increase native plant abundance and species diversity by outplanting seedlings.
- Plant "infrastructure species" like koa, ʻohiʻa, and mamane to speed forest recovery.
- Plant rare species on the oldest substrates to increase survival.
- Plant common tree species on the youngest substrates.
- Plant ʻakoko in all substrates including ʻaʻa lava fields.

***Objective 4*: *Protect native invertebrates and restore their habitat***

Many native invertebrates at Puʻuwaʻawaʻa are obligate specialists on rare host plants. Since some of these plants are in turn threatened or endangered, their importance in terms of Hawaiian invertebrate conservation is considerable.

Several native arthropod species are currently facing local extirpation or extinction at Puʻuwaʻawaʻa due to the loss of their host plants. Long-horned beetles (*Plagithmysus* spp.) are probably the most impacted as they are highly specialized feeders and many of their host trees are

rare or endangered. Yellow-faced bees show a marked preference for ʻakoko flowers and their populations may be affected by the loss of these trees.

*Management practices*:

- Propagate and outplant host plant species that support rare insect associations. These species include ʻakoko, papala, and ʻaiea. The protection and restoration of ʻakoko is a critical conservation action to ensure the continued survival of several rare arthropod species, most of which have extremely limited distributions.
- Place seedlings in close proximity or interspersed among existing wild individuals that support target arthropods. This will facilitate natural colonization of the new plants.
- Protect or fence new plant colonies as needed to prevent damage by rodents or ungulates.
- Avoid application of pesticides on host plants unless absolutely necessary.
- Control slugs by baiting plants with metaldehyde snail bait. Bug-geta (Ortho brand) snail and slug bait pellets are recommended for this pest (S. Montgomery, pers. comm.).
- Monitor for the presence or absence of rare host-dependent insects on new plant communities to determine the effectiveness of management actions.

***Objective 5*: *Minimize the threat of wildfires***

The Hawaiʻi County Fire Department (HCFD) is the first responder for wildfires in the Puʻuwaʻawaʻa Forest Reserve. The Hawaiʻi Division of Forestry and Wildlife (DOFAW) will also respond to any wildfires in the reserve.

*Management Practices*:

- Establish /implement fire prevention and response protocols for staff and visitors.
- Identify/purchase needed fire suppression equipment
- Remove tall vegetation from roads by applying herbicide, mowing/ clearing, or grazing with domestic livestock.
- Establish fuel-free parking areas for vehicles.
- Control fire fuels around the perimeter of conservation units by grazing domestic livestock in paddocks adjacent to the protected areas.

***Objective 6*: *Monitor natural resources***

Resource monitoring and recording changes over time provides critically important data for managing biological resources. This information will allow the determination of trends, as well as noting the results of management actions. Monitoring provides a consistent, definitive way of knowing what is going on with the resource. For example, transects designed to monitor vegetation recovery in the units will document changes in the plant community, including the distribution and abundance of invasive plant species, and will help gauge the ability of disturbed habitat to recover in the absence of ungulate activity.

*Management practices*:

- Prioritize and document the efficacy of management actions.
- Monitor growth and survival out-planted species.
- Monitor efficacy of invasive weed control activities.
- Determine human use thresholds that would trigger management/remedial actions.

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**Figure 1. Location of the Waihou/Aiea Conservation Units.**

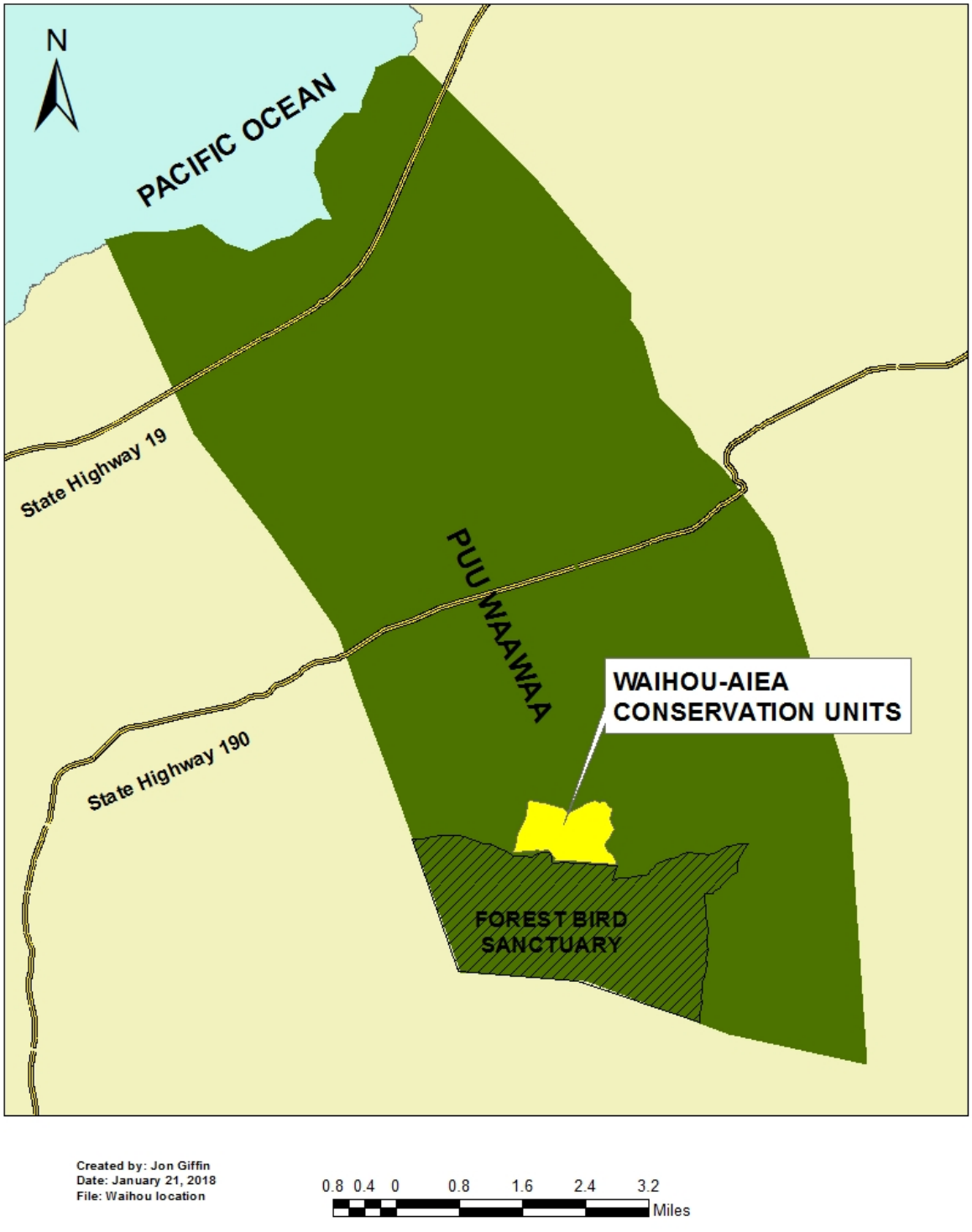

**Figure 2. Topographical features in the Waihou/Aiea Conservation Units**

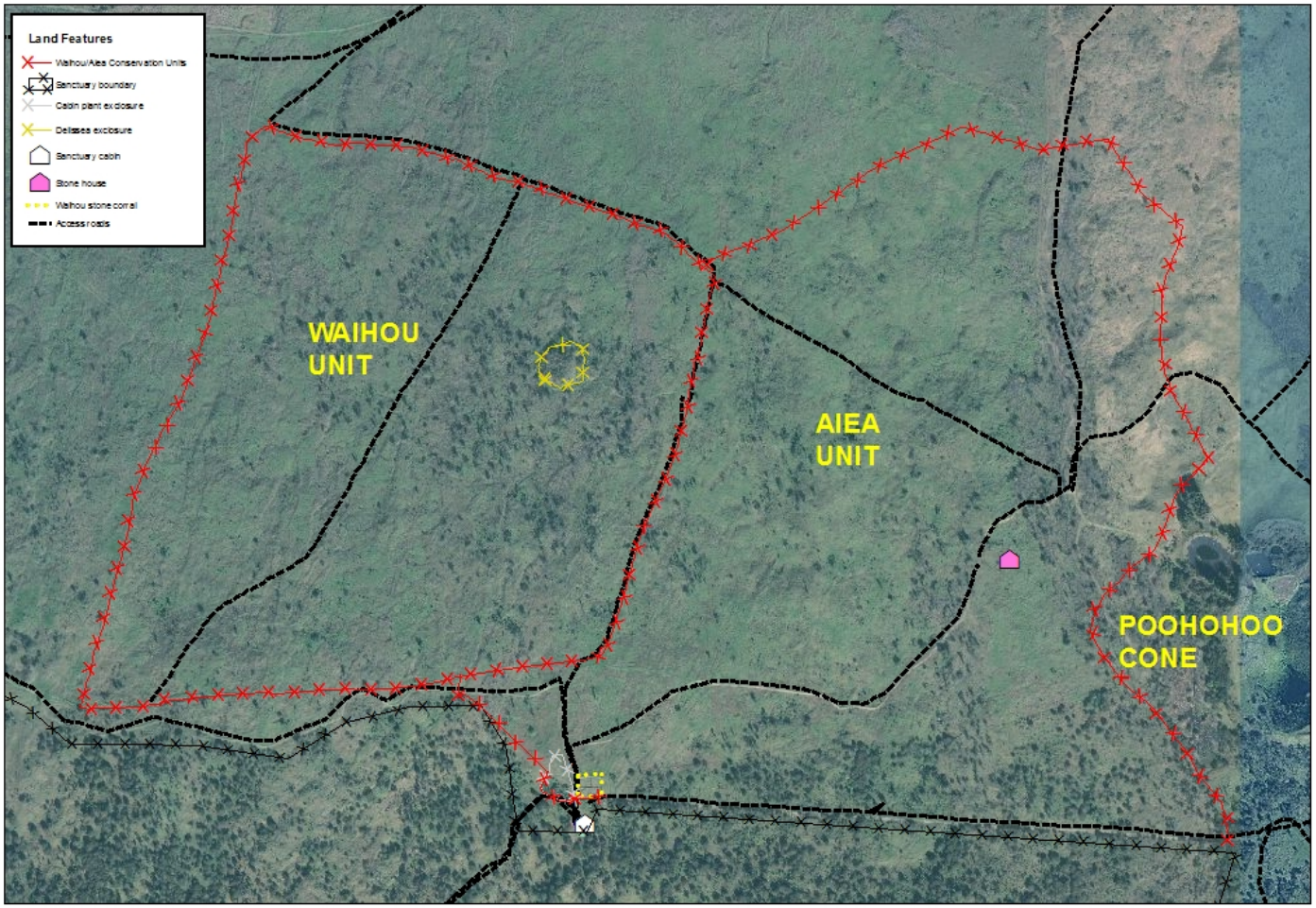

**Figure 3. Distribution of Lava Flow Age Classes in the Waihou/Aiea Conservation Units.**

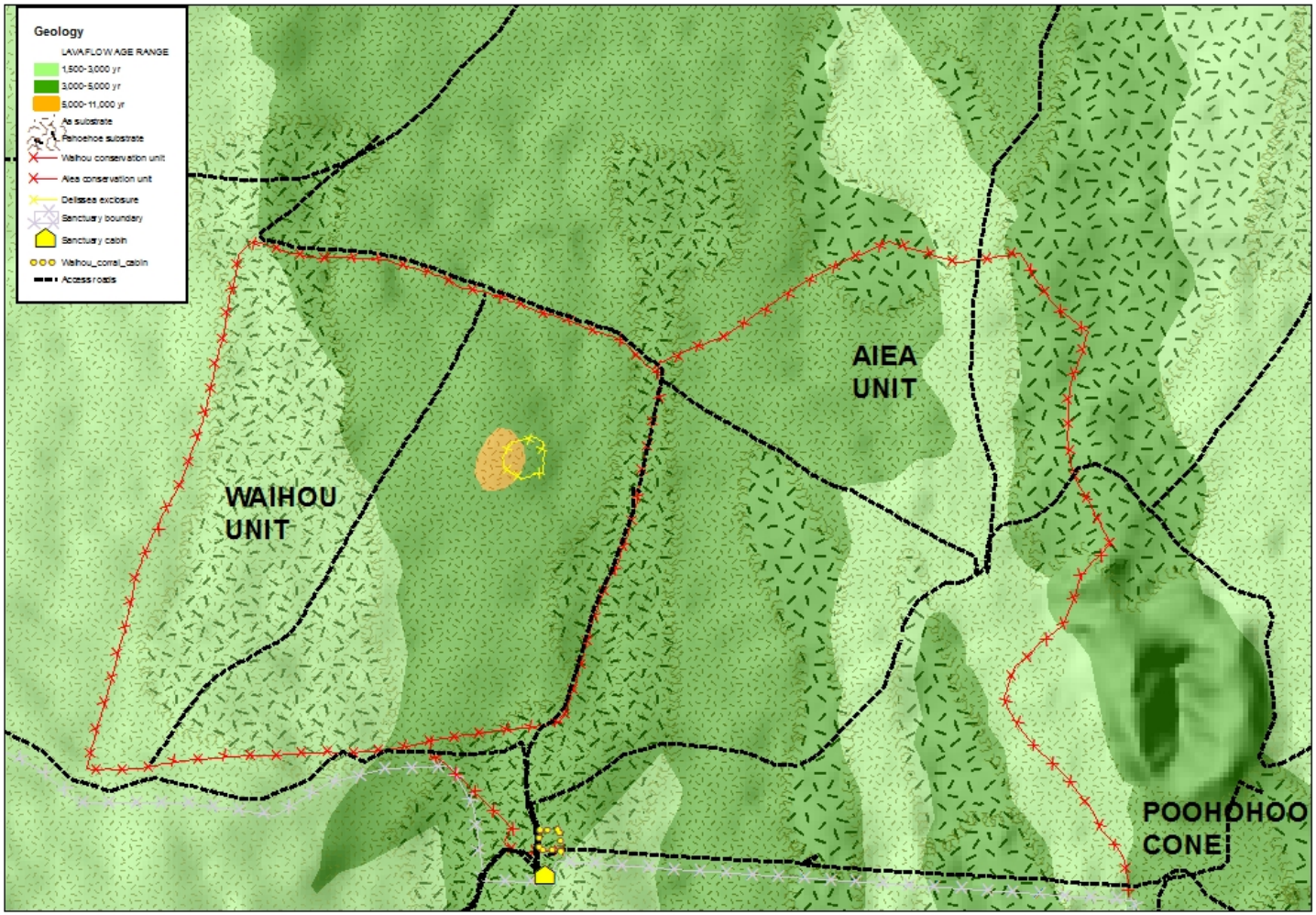

**Figure 4. Distribution of Soils Series in the Waihou/Aiea Conservation Units.**