



PAHOLE

NATURAL AREA RESERVE



2016
MANAGEMENT PLAN

Cover photo credit: *Kamehameha butterfly* by Dr. William P. Haines, University of Hawai‘i at Manoa



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SUMMARY OF ACRONYMS

BLNR	Board of Land and Natural Resources
CTAHR	College of Tropical Agriculture and Human Resources
DLNR	Hawai'i Department of Land and Natural Resources
DOCARE	Division of Conservation and Resource Enforcement
DOFAW	Division of Forestry and Wildlife
EA	Environmental Assessment
FR	Forest Reserve
ICA	Incipient Control Area
NAR	Natural Area Reserve
NARS	Natural Area Reserves System
NARSC	Natural Area Reserves System Commission
NEPM	Native Ecosystem Protection and Management
OANRP	O'ahu Army Natural Resource Program
OISC	O'ahu Invasive Species Committee
PEPP	Plant Extinction Prevention Program
SEPP	Snail Extinction Prevention Program
SHPD	State Historic Preservation Division
UH	University of Hawai'i
USDA-FS	U.S. Department of Agriculture Forest Service
USFWS	U.S. Fish and Wildlife Service
WCA	Weed Control Area
WMWP	Wai'anae Mountains Watershed Partnership
YCC	Youth Conservation Corps

PAHOLE NATURAL AREA RESERVE MANAGEMENT PLAN
SIGNATURE PAGE

O‘ahu Branch: This plan was prepared by the Division of Forestry and Wildlife (DOFAW) to provide a management framework for Pahole Natural Area Reserve.

Marigold Zoll - DOFAW O‘ahu Branch Manager

Date

DOFAW Administrator: I have reviewed the Pahole Natural Area Reserve Management Plan and agree it will serve as a guiding document for the management of Pahole Natural Area Reserve.

David G. Smith - DOFAW Administrator

Date

Board of Land and Natural Resources: This plan conforms with the purpose of the Natural Area Reserve System as stated in Hawai‘i Revised Statutes (HRS § 195-1) and associated Hawai‘i Administrative Rules (HAR§ 13-209) and the mandates of the State Forest Reserve System which includes HRS § 183 and HAR § 13-104.

Suzanne D. Case - BLNR Chairperson

Date

Approved by the
Board of Land and
Natural Resources at
its meeting held

Date

EXECUTIVE SUMMARY

Pahole Natural Area Reserve (NAR or Reserve) is situated on the northeastern face of the Wai‘anae Mountain Range in the district of Waialua on the island of O‘ahu. The Reserve was formally established in 1981 by Governor’s Executive Order 3098 from lands withdrawn from the Mokulē‘ia Forest Reserve (FR). The 658 acre (ac) (266 hectare (ha)) Reserve was created to protect lowland native mesic and dry forest and natural communities, including rare and endangered plants and animals. These forests are noted for their species diversity and richness, and are becoming increasingly uncommon.

The overall management goal of the Pahole NAR Management Plan is to protect, maintain, and enhance the Reserve’s unique natural, cultural, and geological resources. This management goal is aligned with the overall vision, mission, goals and management objectives for the Natural Area Reserves System (Division of Forestry and Wildlife, 2008). Management programs have been developed to support this overall goal and include the following:

1. Management of Natural Resources
2. Integration with Other Department of Land and Natural Resources (DLNR) and Division of Forestry and Wildlife (DOFAW) Programs
3. Administration and Infrastructure
4. Monitoring and Data Collection
5. Cultural Resources
6. External Partnerships
7. Outreach and Education

This Management Plan outlines the planned management activities in the Reserve over the next fifteen years.

Section I of the Management Plan provides background information on the physical setting, land use, condition of resources in the NAR and summarizes past and current management. Section II describes the planned management actions including overall goals and objectives and planned short term and long term management actions. Section III summarizes planned management actions and the associated budget proposed to complete those actions. Section III is intended to be regularly updated (approximately every two years) and will primarily be used internally by NARS staff for operational and biennium budget planning. The plan appendices, which will also be regularly updated, consist of more technical information, primarily for the use of staff and partners.

SECTION I - BACKGROUND AND CURRENT CONDITION

INTRODUCTION

The Natural Area Reserves System (NARS) was created in 1971 by the Hawai‘i State Legislature to “preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawai‘i (HRS § 195-1).” The legislature further found that these unique natural assets should be protected and preserved, both for the enjoyment of future generations and to provide baselines against which changes to Hawaii’s environment can be measured. The NARS is administered by the Hawai‘i Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW). NARS Commission members act in an advisory capacity for the Board of Land and Natural Resources, which sets policies for the Department. Hawai‘i Administrative Rules 13-209 relate to the management of the NARS.

The NARS is based on the concept of protecting ecosystems – not merely single species. Because the natural resources of Hawai‘i have been modified over time and are under constant threat from invasive species, human encroachment, feral ungulates, climate change, and other threats, the NARS seeks to protect the best remaining examples of the State’s unique ecosystems. In addition to setting aside these areas as reserves, the NARS program strives to actively manage these reserves in order to preserve the unique characteristics that make these areas an integral part of the natural heritage of Hawai‘i. Reflecting this, the mission of the NARS program is: “The NARS exists to ensure the highest level of stewardship for Hawaii’s natural resources through acquisition, active management, and other strategies (DOFAW 2008).”

The NARS presently consists of 21 reserves on five islands, encompassing more than 123,000 ac (49,776 ha) of the State’s most unique ecosystems. The diverse areas found in the NARS range from marine and coastal environments to alpine desert, and from fresh lava flows to wet forests. These areas often serve as habitat for rare native plants and animals, many of which are on the verge of extinction. The NARS also include important watersheds and are an important part of the scenic landscape and natural beauty of Hawai‘i. The NARS website at <http://dlnr.hawaii.gov/ecosystems/nars/> provides general information on NARS programs and policies as well as information on NARS management across the state.

SITE DESCRIPTION (PHYSICAL AND BIOLOGICAL RESOURCES)

Location

The Reserve is located on the northeastern face of the northern half of the Wai‘anae Mountain Range in the district of Waialua on the island of O‘ahu (Tax Map Key (TMK) 1-6-8-001-002). The elevation ranges from 1,040 feet to approximately 2,590 feet (ft) (317 – 789 meters (m)). The Reserve is bordered by the U.S. Army’s Mākuā Military Reservation on the south, Mokulē‘ia Forest Reserve (FR) on the eastern and western sides and privately owned land to the north (Figure 1). The NAR consists of three drainages: Pahole, Kapuna and Keawapilau and contains open ridge, wet gulch, and mesic to dry forests (Figure 2).

Figure 1. Pahole NAR General Location and Public Access

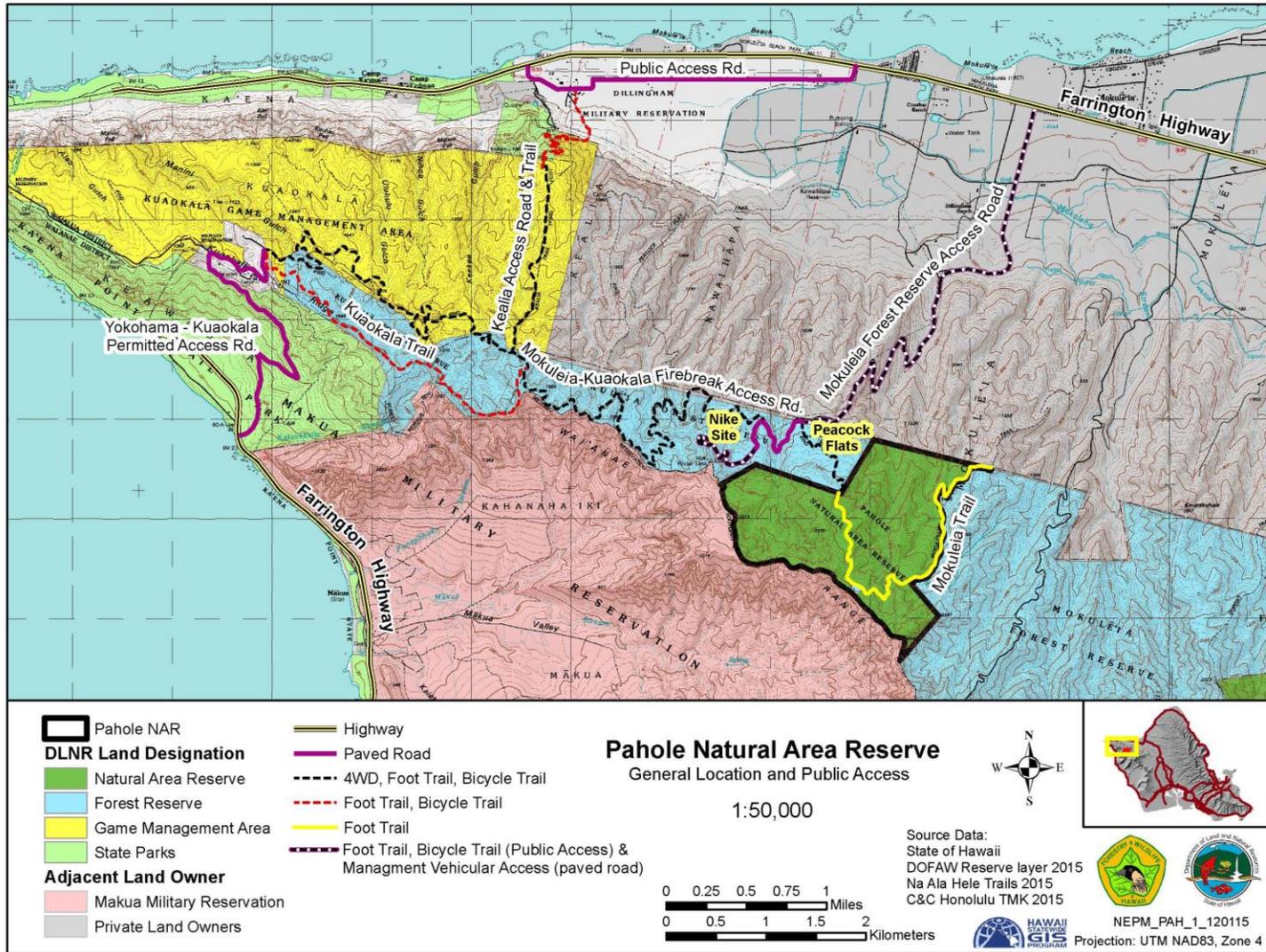
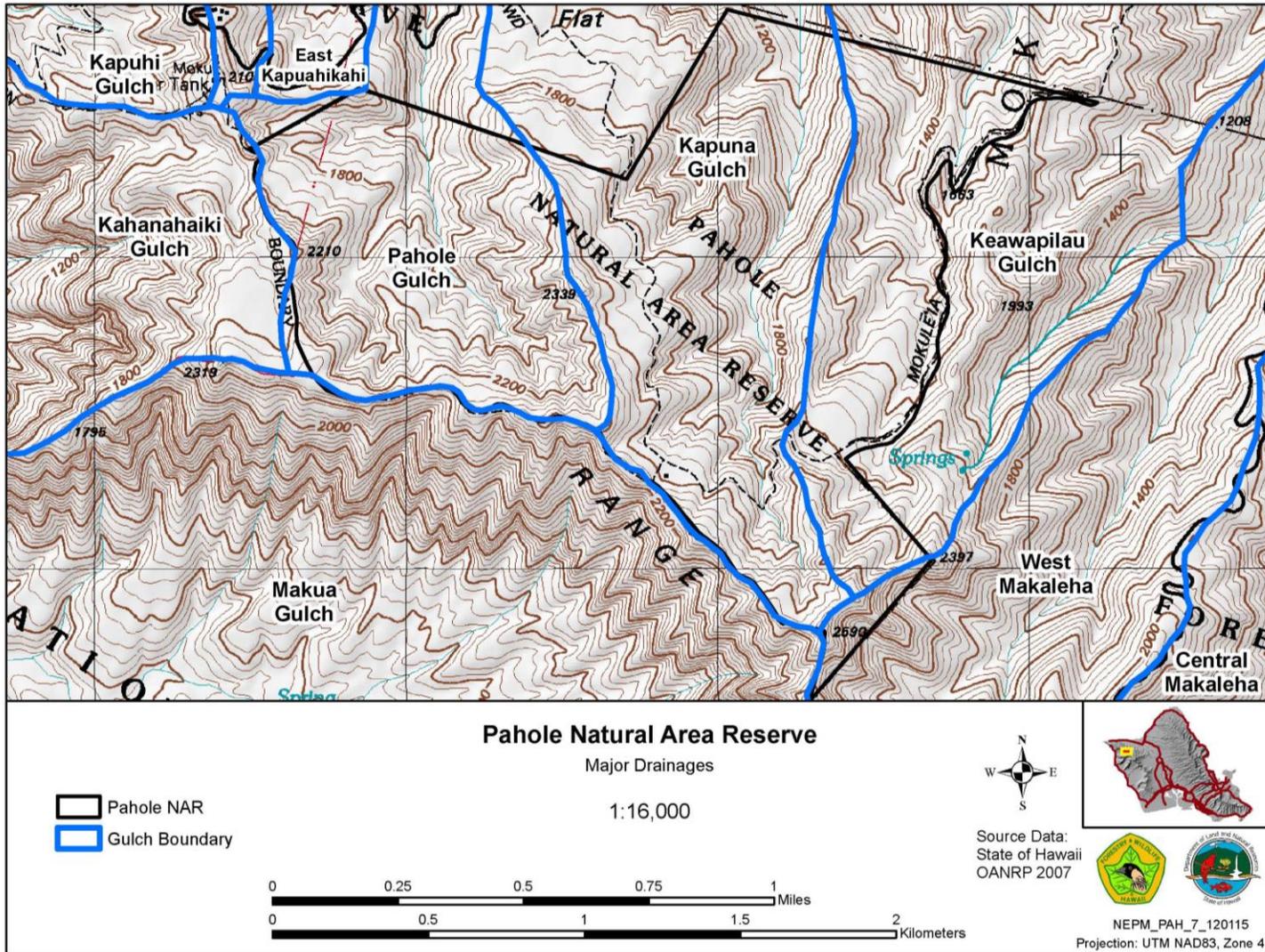


Figure 2. Pahole NAR Major Drainages



Climate

The Reserve's climate is influenced by local topography and the prevailing northeasterly tradewinds, and the climate varies depending on elevation and season. Average annual air temperature is approximately 68 F (20 C) and ranges from 64.5– 73.4 (18– 23 C) (Giambelluca et al 2014). Mean annual rainfall is approximately 50-65 inches (1,270 – 1,651 millimeters) (Giambelluca et al 2013).

Geology

The Wai'anae Mountain Range as described by the U.S. Geological Survey (USGS) revision of stratigraphic nomenclature of Wai'anae Volcano, O'ahu, is made up the three volcanic groups (Palehua, Kamaileunu, and Lualualei) ranging in age from 3.8 to 2.4 million years ago (Ma) (Sinton 1986). The Reserve contains substrates originating from the Palehua and Kamaileniu Members (Figure 3). The Kamaileunu Member is the second oldest of the Wai'anae Volcanics (3.46 -2.95 Ma) and was formed during the transitional or late –shield stage of volcanic activity. The youngest of the Wai'anae Volcanics is the Palehua Member which has an age range of 2.95-2.4 Ma and represents the post-caldera stage of the Wai'anae Volcanics. Exposed substrates from the Palehua member can be found at higher elevations of the Wai'anae Mountain Range and is the predominant substrate on which the NAR is located.

Soils

The Reserve contains soils that belong to the Inceptisol, Ultisol, Mollisol and Histosol soil orders (Foote et al., 1972; Natural Resource Conservation Service Web Soil Survey) (Figure 4). The predominant soil type is the Tropohumults-Dystrandepts association which is broadly classified as an Inceptisol. The Tropohumults-Dystrandepts association is primarily found in the Wai'anae Mountain range from 600 - 4,000 ft (183 – 1,219 m) and covers roughly 8% of the Island of O'ahu (Foote et al., 1972). Generally, this association is described as well-drained, medium to extremely acidic soil underlain by soft, weathered rock, volcanic ash or colluvium. The soil association is typically found on narrow ridgelines and steep slopes of 30-90% and is derived from volcanic basalt which includes several soil series (Table 1).

The Tropohumults soil great group is defined as a well-drained, highly acidic to extremely acidic soil found on higher elevation ridges (Nagata et al., 1980). The surface horizon of the Tropohumults soil consists of reddish-brown silty clay underlain by an ironstone pan or by saprolite. In areas that have been denuded of vegetation, the soil surface can appear as a hard crust with a purplish cast. The Dystrandepts soil great group is part of the Inceptisol soil order and is described as a soil with a surface horizon primarily composed of silty clay, and its color is darker than that of the Tropohumults. Dystrandepts are found in concave portions of steep side slopes and are mainly derived from volcanic ash mixed with colluvium.

The wetter areas near mountain peaks and upper ridgelines of the NAR are occupied by Histosols. The Alakai Mucky Peat soil series is the predominant soil representing the Histosol soil order and is primarily made up of deposited and decomposed organic matter at the tops of mountains and ridges (Nagata 1980). A very small area along the northern fringes of Pahole

NAR are also occupied by the Kemoo silty clay which is a Mollisol and described as a well-drained soil with well-defined surface horizons and moderate to neutral acidity (Table 1).

Table 1. Summary of soils found in Pahole NAR

Soil Series or Association	Soil Order	pH range	Acres	% Occurrence In Pahole NAR
Kemoo silty clay, 35 to 70 percent slopes	Mollisol	6.1-7.3	2.0	0.3%
Alakai mucky peat, 0 to 30 percent slopes	Histosol	3.5-4.4	4.6	0.7%
Tropohumults-Dystrandeps association	Inceptisol	3.6-6.0	649.2	98.6%
Combination of rocky outcrops and steep stony lands	N/A	5.1-7.3	2.8	0.4%

Figure 3. Pahole Geology (Substrate Age)

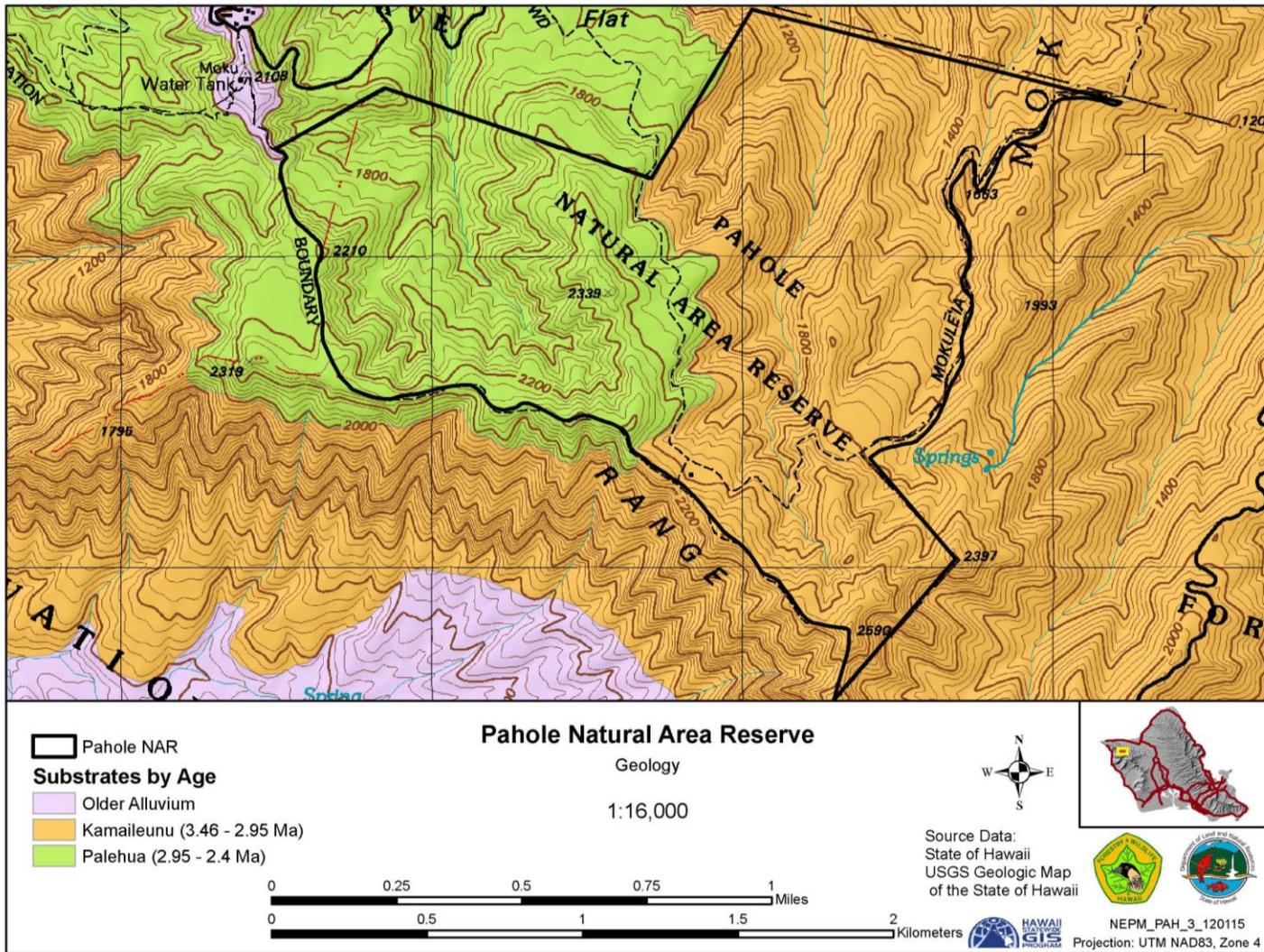
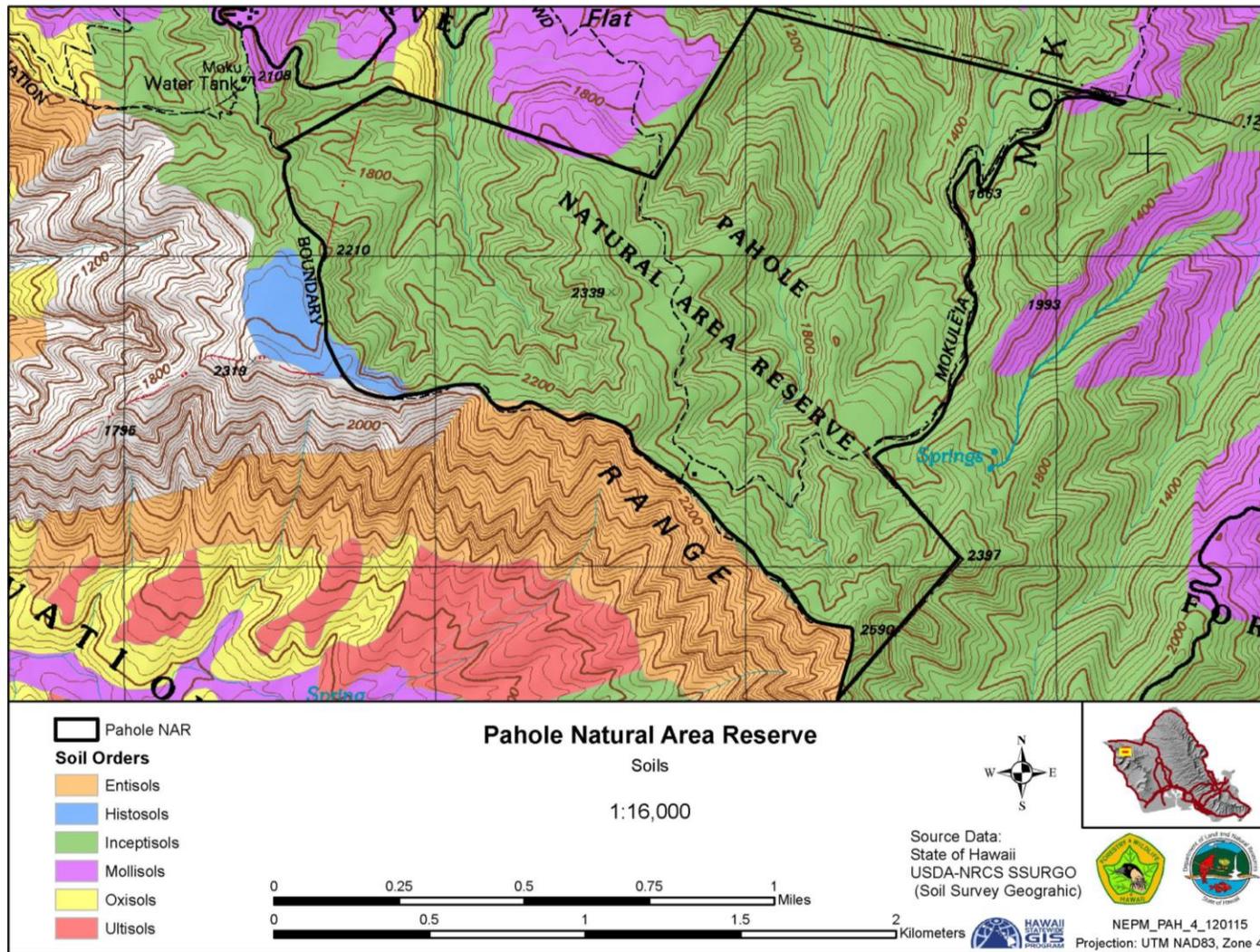


Figure 4. Pahole NAR Soils



Vegetation

The NAR was established in part due to the richness of its native mesic and dry forests. However; nonnative species are replacing the vegetation at the Reserve. In 1988, NARS completed a report of recent plant surveys in the Reserve and noted an increase in nonnative vegetation, estimating that only 23% or 153 ac (62 ha) of the Reserve was still dominated by native species (NARS 1988). Since that report was completed, non-native species have continued to replace the native dry and mesic vegetation in many portions of the NAR (Figure 5).

Vegetation in the NAR was classified in the 1988 NARS report as the following:

- Native Vegetation - Native plants are dominant and there is 60% or more of native tree canopy cover
- Mixed Native/Non-Native - Native and nonnative species are co-dominant
- Nonnative – Mixed native/nonnative associations as well as forests dominated by non-native species. Non-native species dominant in these areas include the following:
 - Java Plum Forest
 - Christmas Berry Forest
 - Eucalyptus Forest
 - Silk Oat Forest
 - Koa Haole Thicket
 - Guava – Strawberry Guava Forest
 - Kukui Forest

Native vegetation canopy species include koa (*Acacia koa*), ‘ōhi‘a (*Metrosideros polymorpha*), olopua (*Nestegis sandwicensis*), lama (*Diospyros* spp.), ‘āla‘a (*Pouteria sandwicensis*), pāpala (*Charpentiera* spp.), pāpala kēpau (*Pisonia* spp.), kōpiko (*Psychotria* spp.), hame (*Andidesma platyphyllum*), ‘ahakea (*Bohea* spp.), and ‘iliahi (*Santalum freycinetianum*). Native understory species include: maile (*Alyxia stellata*), ko‘oko‘olau (*Bidens torta*), pilo (*Coprosma* spp.), and palapalai (*Microlepis strigosa*). Vegetation differs depending on topography (gulch, mid-slope, and ridge) (Table 2, OANRP 2010).

Rare Plants

Numerous rare plants including federally and state listed threatened and endangered (T&E) species are found in the Reserve and are represented by naturally occurring wild populations and outplanted populations (reintroductions and introductions) for recovery purposes. A reintroduction is defined as reintroducing individuals of rare plant taxa back into the wild within its historic range for the purpose of establishing new populations. A rare plant introduction involves introducing a plant taxa outside its historic range based on projected future climate envelope changes (Fortini et al., 2013) also for the purpose of establishing new populations. A summary of these species is included in Appendix A, which was adapted from and includes information from partners such as the O‘ahu Army Natural Resource Program (OANRP) and the Plant Extinction Prevention Program (PEPP). Many of these species are the focus of intensive management efforts by DOFAW and these partners.

Pahole NAR contains federally designated critical habitat for 20 listed plant species (Appendix A). The NAR is included in “Lowland Mesic Unit 1” which includes 3,565 ac (1,443 ha) of State land in the lowland mesic ecosystem in the Wai‘anae Mountains, encompassing a large area including the north slopes of Mt. Ka‘ala, from the Pahole NAR to the Ka‘ala NAR, and south to the Wai‘anae Kai FR (USFWS 2012). U.S. Fish and Wildlife Service (USFWS) has determined this area to be essential for the conservation and recovery of these lowland mesic species.

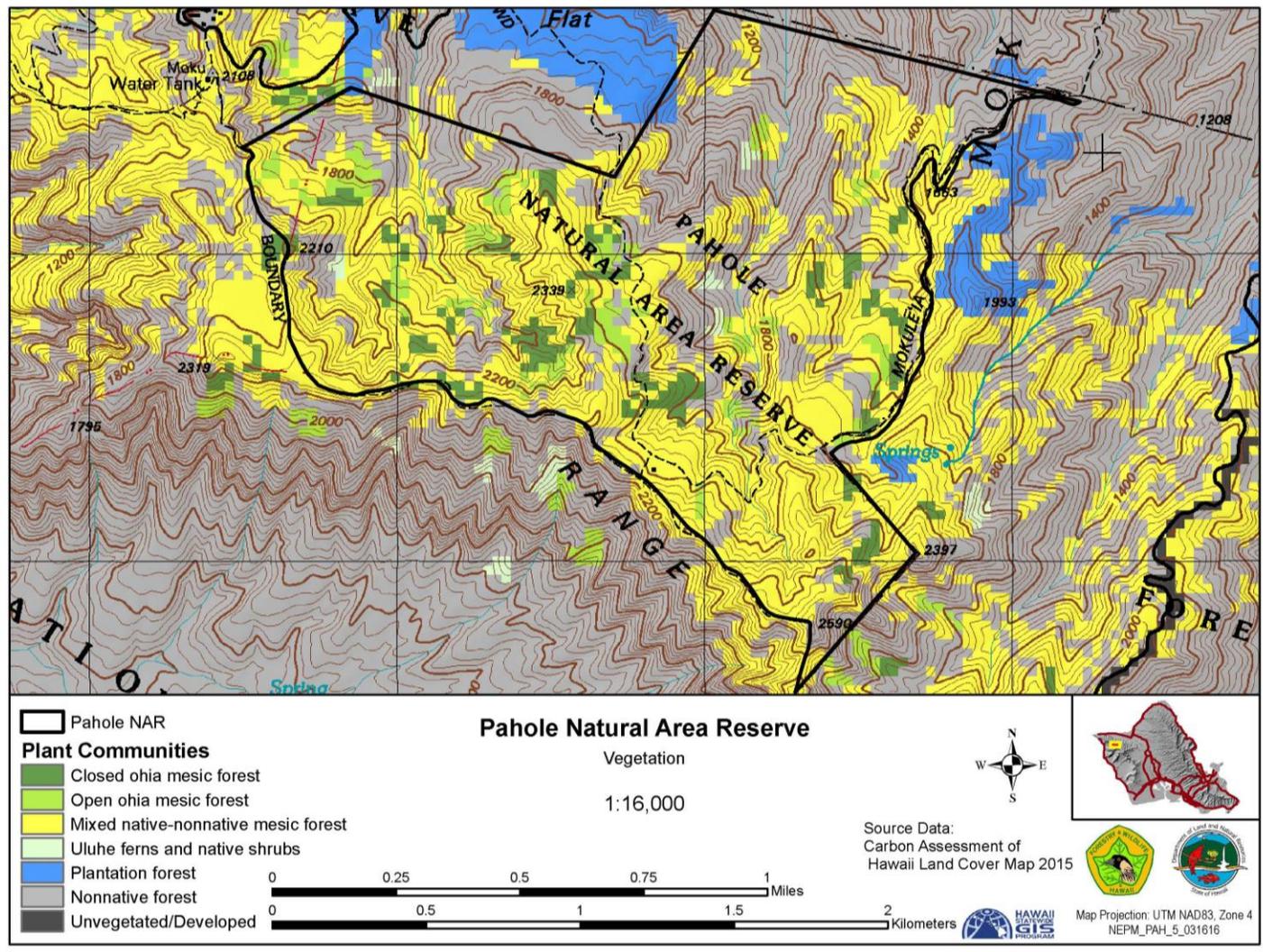
Detailed background on focal species managed by OANRP is available in OANRP Rare Plant Plans (prepared every 5 years) for plants included in the Mākuā Implementation Plan. http://manoa.hawaii.edu/hpicesu/dpw_rpp.htm

USFWS does a five-year status review for all listed T&E species that provides background on threats and management actions. These reviews are much less detailed than the OANRP five – year plans but do provide additional information on past management of species that are not a focus of OANRP.

Table 2. Wai‘anae Native Vegetation Types (adapted from OANRP 2010)

Mesic Ridge/Crest
Canopy includes: The canopy is dominated by <i>Acacia koa</i> and/or <i>Metrosideros polymorpha</i> . Other canopy associates include <i>Psychotria</i> spp., <i>Antidesma platyphyllum</i> , <i>Bobea</i> spp. and <i>Santalum frecinetianum</i> . Understory includes: <i>Microlepidia strigosa</i> , <i>Odontosoria chinensis</i> , <i>Alyxia stellata</i> , and <i>Coprosma</i> spp.
Mesic Slope
Canopy includes: <i>Diospyros sandwicensis</i> , <i>Sapindus oahuensis</i> , <i>Nestigis sandwichensis</i> , <i>Pouteria sandwicensis</i> , <i>Antidesma platyphyllum</i> , and <i>Pisonia</i> spp. Understory includes: <i>A. stellata</i> , <i>Psydrax odorata</i> , and <i>Bidens</i> spp.
Mesic Gulch
Canopy includes: <i>Pisonia</i> spp., <i>Charpentiera tomentosa</i> , <i>Psychotria</i> spp, and <i>D. hillebrandii</i> Understory includes: <i>Diplazium sandwicensis</i> , <i>Microlepidia strigosa</i> and <i>Tectaria gaudichaudii</i> as well as <i>Freycinetia arborea</i> , <i>Urera glabra</i> , <i>Pipturus albidus</i> and <i>Coprosma</i> spp.
<i>NOTE: Vegetation type is described based on theoretical pre-disturbance native vegetation. Alien species are not noted. Vegetation types are subdivided using topography (gulch, mid-slope, ridge) as topography influences vegetation composition and is useful for guiding management.</i>

Figure 5. Pahole NAR Vegetation



Native Wildlife

Native birds currently known from Pahole NAR include ‘apapane (*Himatione sanguinea*), ‘amakihi (*Hemignatuhus virens*), kolea or Pacific golden plover (*Pluvialis fulva*) and the state listed as endangered Pueo or Hawaiian owl (*Asio flammeus sandwichensis*). The endangered O‘ahu ‘elepaio (*Chasiempis sandwichensis ibidis*) has not been detected recently but was present in the NAR in small numbers (18 individuals) in 2001 (VanderWerf *et al.* 2001). The NAR is designated critical habitat for ‘elepaio as part of a larger area in the Northern Wai‘anae Mountains. Appendix C contains a bird species list, which includes native as well as non-native bird species present in the Reserve.

Hawai‘i’s only endemic land mammal, the ‘ōpe‘ape‘a or endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*) is likely to be present, but the Reserve has not been sampled for bat activity.

Hawaiian ecosystems are dependent upon the ecological services completed by a diverse assemblage of native invertebrate species. Invertebrates serve as nutrient cyclers, decomposers, pollinators, and provide food for other native species. Pahole NAR has remnant patches of native mesic forest which support a variety of native invertebrate species. Charismatic native invertebrates such as the Kamehameha butterfly (*Vanessa tameamea*), the Hawaiian sphinx moth (*Hyles calida calida*) the akoko planthopper (*Dictyophordelphax mirabilis*), primitive weevils (*Proterhinus* spp.), picture-wing flies (*Drosophila* spp.), carnivorous caterpillars (*Eupithecia* spp.) and O‘ahu tree snails (*Achatinella mustelina*) are still present, and hint at the diversity that the area once supported. Unfortunately, invasive invertebrate species (such as ants, parasitoids and predatory snails) have become increasingly abundant in this area, and continue to adversely impact the survivorship and distribution of many native species. A species list of native invertebrates known from Pahole will be available through DOFAW’s Native Invertebrate Program. Data on native invertebrates at the Reserve is being compiled and integrated into a statewide invertebrate database.

The endangered native tree snail or kahuli (*Achatinella mustelina*) is present in the NAR. Although *A. mustelina* historically existed in greater densities throughout the NAR, today the vast majority exist in a few concentrated locations with individuals scattered in degraded habitat. Additional snail genera known from Pahole are summarized in Table 3.

Table 3. Native Snails Known From the Pahole NAR Area*

<i>Achatinella mustelina</i>	<i>Lamellidea</i> spp.	<i>Pronesopupa</i> spp.
<i>Auriculella ambusta</i>	<i>Leptachatina</i> sp.	<i>Succinea</i> sp.
<i>Elasmias</i> spp.	<i>Nesopupa</i> spp.	<i>Tornatellaria</i> spp.
<i>Euconulus</i> sp.	<i>Philonesia</i> spp.	<i>Tornatellides</i> spp.

* Species list provided by Dr. Norine W. Yeung, Bishop Museum Malacology Department. Most species have only been identified to the genus level - sp. refers to one species occurring in that genus and spp. refers to multiple species occurring within that genus.

LAND USE

Land Designation and History

The NAR was established in 1981 by Governor's Executive Order 3098 from lands withdrawn from the Mokulē'ia FR. The 658 ac (266 ha) Reserve was created to protect lowland native mesic and dry forest and natural communities, including rare and endangered plants and animals. These forests are noted for their species diversity and richness, and are becoming increasingly uncommon. A small square of land (2 ac (.8 ha)) within the Reserve around what is generally referred to as the "hunter shack" was retained as part of the Mokulē'ia FR to allow for public camping. Camping permits for this site are issued through the O'ahu Branch Forestry Program.

Regional Partnerships

O'ahu Army Natural Resources Program (OANRP) works regularly in the Reserve through a Memorandum of Understanding (MOU) and various permits. The OANRP oversees U.S. Army compliance with federal laws related to endangered species and wildlife to effectively balance the requirements of the Army's training mission with its natural resource responsibilities. The Reserve contains two management units actively managed by the OANRP to stabilize and recover target plant and animal taxa found on military training areas. OANRP management plans and status reports for these areas describe detailed management actions, which are implemented in close coordination with DOFAW staff.

In July 2011, a MOU was signed between the Army and the State of Hawai'i, DLNR. With this basic agreement in hand, the Army and State will continue to develop a more streamlined and comprehensive permit or license agreement to enable the Army to implement conservation actions on DLNR managed lands. Currently, the Army holds six State of Hawai'i permits, including a NAR Special Use Permit, a T&E Species Permit, an Invertebrate Permit, a FR Access Permit, a Conservation District Use Permit, and a Protected Wildlife Permit. The State and Army recently negotiated to extend the term for these permits from one year to three. The Army and the State also have an agreement for OANRP's use of the Nike site greenhouse and associated facilities.

Wai'anae Mountains Watershed Partnership (WMWP) works to cooperatively develop and implement management strategies for the Wai'anae Mountains. DLNR is a member of the partnership and Pahole NAR is included in lands managed by the partnership. WMWP staff members assist DOFAW with watershed related projects mainly focused on weed control in the Reserve.

Plant Extinction Prevention Program (PEPP) protects Hawaii's rarest native plants from extinction by managing wild plants, collecting seeds, and establishing new populations. PEPP focuses on species with fewer than 50 plants remaining in the wild and collaborates with conservation partners who have a shared interest in preserving Hawaii's unique biodiversity. The Reserve is a location where PEPP conducts management activities for a select group of species (see Appendix A) in coordination with DOFAW staff.

Snail Extinction Prevention Program (SEPP) was created to protect Hawaii’s imperiled snail fauna. The SEP Program, along with partner organizations, serves to monitor, provide predator abatement, and habitat protection for snail species currently facing extinction. SEPP currently assists NAR staff with managing the listed snails present in the Reserve and has developed a translocation protocol to improve the survival and aid in the recovery of *Achatinella mustelina*.

Table 4. Related State and Federal Planning Documents

Plan/Cooperative Effort	Comment
U.S. Army Mākuā and O‘ahu Implementation Plan Status Report (OANRP 2015)	Annual report for participating landowners, USFWS, DOFAW and other partners.
The Rain Follows the Forest - A Plan to Replenish Hawaii’s Source of Water (DLNR, November 2011)	Portions of the Reserve are identified as a priority watershed area on the island of O‘ahu.
U.S. Mākuā and O‘ahu Implementation Plan Status Report (OANRP 2010)	OANRP Ecosystem Restoration Management Unit Plans (includes in Pahole NAR Pahole units)
DOFAW Statewide Assessment and Resource Strategy (SWARS) 2010	Identifies areas of greatest need/opportunity for Hawaii’s forests and develops a long-term management strategy
Strategic Plan for Hawaii’s Natural Area Reserves System (DOFAW 2008)	Identifies a vision, mission, and goals for the NARS program
USFWS Revised Recovery Plan for Hawaiian Forest Birds (2006)	Recovery actions needed for O‘ahu ‘elepaio
Hawai‘i Comprehensive Wildlife Conservation Strategy (2005)	Assesses health of state’s wildlife, plants and habitat, and identifies threats and needed conservation measures
Kapuna Watershed Protection Project Final Environmental Assessment (2003)	Pahole NAR fencing project
Final Mākuā Implementation Plan. Prepared for United States Army Garrison, Hawai‘i, 2003 and Addendum 2005	Guides conservation efforts to stabilize 27 endangered plant taxa and an endangered species of Hawaiian tree snail affected by military training activities at Mākuā Military Reservation. The plan includes management planned for Pahole NAR
USFWS 1999. Recovery Plan for Multi –Island Plants	Recovery actions needed for: <i>Bonamia menziesii</i> , <i>Cenchrus agrimonioides</i> , <i>Flueggea neowawraea</i> , <i>Plantago princeps</i> , <i>Schiedea nuttallii</i>
USFWS 1998. Recovery Plan for O‘ahu Plants	Recovery actions needed for: <i>Chamaesyce herbstii</i> , <i>Cyanea grimesiana subsp. obatae</i> , <i>Cyanea longiflora</i> , <i>Cyanea superba</i> , <i>Cyrtandra dentate</i> , <i>Diellia falcate</i> , <i>Hespermomania arbuscula</i> , <i>Kadua degeneri</i> , <i>Nototrichium humile</i> , <i>Phyllostegia kaalaensis</i> , <i>Schiedea kaalae</i> , <i>Schiedea obovata</i>
USFWS 1997. Recovery Plan for the Maui Plant Cluster	Recovery actions needed for: <i>Alectryon macrococcus</i>
USFWS 1996. Big Island Plant Cluster Recovery Plan	Recovery actions needed for: <i>Colubrina oppositifolia</i>
USFWS 1994. Recovery Plan for <i>Caesalpinia kavaiensis</i> and <i>Kokia drynarioides</i>	Recovery actions needed for: <i>Caesalpinia kavaiensis</i>

Research

The Reserve has been used as a research site for many projects. See Appendix D for a summary of past research projects and topics.

Public Use

The Reserve is accessible to the public via the Mokulē‘ia Trail (Figure 1). The Mokulē‘ia FR access road (available for use by pedestrians and bicycles) runs close to the north side of the Reserve. A four-wheel drive road abuts Mokulē‘ia FR access road near Peacock Flats and traverses the Mokulē‘ia FR upslope to the Mokulē‘ia Trail. The trail continues into Pahole NAR, runs along its eastern boundary, and continues beyond the Reserve’s northeastern boundary. The alignment of the Mokulē‘ia trail on maps is slightly different from the actual alignment of the trail on the ground as the route of the trail has likely shifted slightly over time. The public can also access the Mokulē‘ia Trail trailhead with a four-wheel drive vehicle via Kuoakalā Access Road (requires DOFAW permit for access through the Ka‘ena Point Satellite Tracking Station Road).

Activities such as hiking on designated trails are allowed in the Reserve. Motorized vehicles and mountain bikes are not permitted. Some uses of the Reserve, including hiking or nature study with groups larger than ten, some types of research, scientific collecting, gathering (including Native Hawaiian religious and customary gathering rights) and commercial uses require a Special Use Permit (Hawai‘i Administrative Rules 13-209).

Camping is not allowed in the NAR, however there is permitted public camping available in the adjacent Mokulē‘ia FR at Peacock Flats via online permit (<https://camping.ehawaii.gov/camping/welcome.html>) and at the “hunters shack” via permit through the O‘ahu Branch Forestry Program.

Cultural Resources, Archeological and Historic Sites

The forested landscape and the plants and animals found in the Reserve are an important cultural resource. Many plants found in the Reserve are culturally important, such as trees such as kauila (*Alphitonia ponderosa*) and lama and plants such as maile and palapalai fern. Previous studies and consultation with various Hawaiian groups for projects in the area did not identify any specific sites, legends, traditions or other information relating to the area (DOFAW 2003). The archeological reconnaissance of planned fencing routes was completed and no cultural resources or historic properties were identified along the fence alignment. Portions of the fence that cross trails have step-overs so that the public, including cultural practitioners, can access the area.

SUMMARY OF MAJOR THREATS AND MANAGEMENT ISSUES

Invasive Species – Plants

In a 1988 report 153 ac (62 ha) or 23% of the Reserve was estimated to be dominated by native species (NARS 1988). Invasive non-native plants, or weeds, constitute a severe threat to the

native ecosystems in the NAR. Certain priority weeds are problematic because they can establish and survive in undisturbed native forest; disperse long distances via wind or birds; affect large portions of land; displace native vegetation; grow and reproduce rapidly; convert diverse assemblages of native plants to monocultures of alien species; and encourage fire by increasing fuels. These weeds can displace distinctive native flora, resulting in a loss of species diversity and eventually in more pronounced and permanent changes to ecosystem function such as alteration of nutrient cycling and hydrology. Many invasive weed species completely replace native vegetation resulting in total loss of native habitats thereby negatively affecting native bird, arthropod and snail communities.

Invasive weeds with great potential for spreading and causing habitat modification are identified in this plan as high priority for control or eradication. Weed species were prioritized based on observed invasiveness and other criteria including growth form, dispersal mechanisms, ability to displace native vegetation and ability to alter ecosystem cycles (water, nutrients and succession). High priority invasive weeds currently present in Pahole are summarized in Appendix B.

Additional weed species that are a serious concern to land managers are present in adjoining areas and have not yet been detected in the Reserve. It is a high priority to prevent the establishment of these species in the NAR. Other weed species may be added to the Reserve priority weed list if monitoring shows their range and abundance increasing in native ecosystems targeted for management.

Invasive Animals – Ungulates

Feral pigs are currently the primary ungulate threat to the Reserve. Feral pigs destroy native vegetation and prevent its regeneration by eating, trampling, and digging up plants. Pig disturbance of native ground cover through rooting and wallowing facilitates the invasion and establishment of weeds. In addition, pig wallows and pig-hollowed out hāpu‘u trunks provide mosquito-breeding sites that can promote the spread of avian diseases such as avian malaria and pox – the two most deadly diseases for native forest birds. The continued presence of feral pigs contributes to loss of native plants and loss of ground cover that adversely affects groundwater retention.

Invasive Species - Other Animals

A variety of non-native mammals such as rats (*Rattus* spp.), mice (*Mus musculus*), cats (*Felis silvestris catus*), and mongooses (*Herpestes auropunctatus*) are serious pests to the biodiversity found in the Reserve. Feral cats kill birds, which nest, feed, and roost in trees. Rats and mice prey on birds (particularly females on the nest), eggs, nestlings, native land snails and endemic invertebrates and are also known to eat the seeds, fruits and/or strip the bark of native plants.

Non-native birds may compete with native forest birds for food, nesting sites and other resources and act as reservoirs for avian diseases. Non-native birds also contribute to the spread of weeds by eating the fruits of weedy species and spreading seeds. Jackson’s chameleon (*Chamaeleo jacksonii*) has not been detected in the NAR but they are found nearby and are known predators to native tree snails and native invertebrates.

Non-native invertebrates are present, but largely undocumented, and can consume native plants, interfere with plant reproduction, predate or act as parasites on native species, transmit disease, affect food availability for native birds, and disrupt ecosystem processes. For example, the black twig borer (*Xylosandrus compactus*) is harmful to numerous native tree species. The invasion of the yellowjacket wasp (*Vespula pennsylvanica*), voracious predators of numerous species of native invertebrates, has been identified as another potential threat to native invertebrates in the Reserve. A couple of species of non-native ants have been documented in the Reserve (*Solenopsis papuana* and *Tetramorium simillimum*) and may pose a threat to native species. The predatory snail *Euglandina rosea* is a major threat to native tree snails. Slugs (*Milax gagates*, *Limax maximus*, and *Veronicella* spp.) consume fruit from native plants and prey on seedlings and mature plants. Mosquitoes (*Aedes albopictus* and *Culex quinquefasciatus*) transmit deadly diseases such as avian malaria and avian pox to native birds.

Fire

Wildfires leave the landscape bare and vulnerable to erosion and invasive by non-native weeds. Hawaii's flora evolved with infrequent, naturally-occurring episodes of fire, so most native species are not fire-adapted and are unable to recover well after wildfires. There have not been any recent fires within the NAR; however fires have occurred in adjacent areas (Mākua, Waialua). Invasive, non-native plants, particularly grasses, are often more fire-adapted than native species and will quickly exploit suitable habitat after a fire. The principal human-caused ignition threats are campfires, military training, catalytic converters and other hot surfaces of vehicles or heavy equipment. The principal natural ignition source in this area is lightning.

Disease

Introduced diseases and pathogens can threaten both native animals and plants. The introduction of new diseases and pathogens, in addition to those currently known, is possible. Avian pox and avian malaria are mosquito-transmitted diseases that currently affect native Hawaiian birds. Avian pox is caused by a virus (*Avipoxvirus*) and avian malaria by a single-celled parasite (*Plasmodium relictum*). For some bird species infection with these diseases is almost always fatal.

Other diseases also pose threats to the watershed, humans and wildlife. Cats are host of a potentially fatal disease called toxoplasmosis. In Hawai'i, toxoplasmosis has killed native Hawaiian birds and also poses a threat to marine mammals. In addition to threatening wildlife, toxoplasmosis poses a significant health risk to pregnant women. Feral pigs can serve as reservoirs and vectors of diseases such as brucellosis and pseudorabies which are transmissible to humans, wildlife, pets and livestock. Pigs also spread fatal diseases such as fecal bacteria (*enterococcus*) and *Escherichia coli* (*E. coli*). Another potentially fatal disease, leptospirosis, is also spread by pigs and other small mammals such as rats.

Introduced plant diseases such as 'ōhi'a rust (*Puccinia psidii*), koa wilt (*Fusarium oxysporum f.sp. koae*) and rapid 'ōhi'a death, caused by the vascular wilt fungus, *Ceratocystis fimbriata*, have the potential to impact the major components of the forest throughout the NAR. 'Ōhi'a rust

affects other taxa of the Myrtaceae or myrtle family. In severe infections, growing tips wither and die back. Koa wilt is a serious, often fatal fungal disease of the native koa tree. Trees affected with the disease rapidly lose their canopies and may die within a few months. Rapid 'ōhia death is killing large numbers of mature 'ōhi'a trees on Hawai'i Island. This newly identified disease is thus far only confirmed on Hawai'i Island, but it poses a major threat to native 'ōhi'a dominated forests throughout the state.

Climate Change

Climate change may affect the NAR through altering rainfall patterns and amounts. Changing climate may affect the abundance and seasonality of precipitation, thereby altering forest composition, growth and structure. Rare ecosystems and species may be affected by relatively rapid changes in precipitation, temperature, and humidity that result from a rapid and drastic change in regional or local climate patterns. Detrimental invasive species may change their distribution and abundance due to changes in the climate (e.g. mosquitoes may be more frequently found at higher elevations due to warming temperatures).

Development of Adjacent Areas

Portions of the adjacent private Dillingham Ranch property could potentially be subdivided and developed for residential and/or agricultural uses. This proposed development, and other development in the general area poses potential threats to natural resources in the Reserve and these threats will need to be addressed in future plans, should development of these areas move forward. These potential threats include increased potential for human caused fires, increased invasive plants and animals, and increased recreational pressure.

OVERVIEW OF PAST AND CURRENT MANAGEMENT

The Reserve has never had a management plan, however, DOFAW and partners have been doing management, and past and current management actions are summarized in this section. Both DOFAW and OANRP staff have worked on ongoing management activities described below. In general, OANRP staff provides assistance and/or develops projects that promote the stabilization and recovery of their target plant and animal taxa. OANRP management plans and status reports describe their management actions, which are implemented in close coordination with DOFAW. Overall OANRP management actions goals include the control of threats (ungulate, rodent, arthropod, slug, snail, fire, and weed) to enable formation of a stable, native-dominated matrix of plant communities which support stable population of their focal taxa from the Mākua Implementation Plan.

OANRP management actions occur throughout the entire NAR, and OANRP plans divide the NAR into the Pahole Management Unit (215 ac (87 ha)) and the Upper Kapuna Management Unit (425 ac (172 ha)). OANRP activities and plans for these management units are included in Ecosystem Restoration Management Plans in in the 2010 Mākua and O'ahu Implementation Plan Status Report (OANRP 2010) and are updated every five years.

OANRP activities are coordinated with DOFAW through various mechanisms. The Army currently has a permit to work in the NAR (3 year term). OANRP staff provides a monthly planned action list to DOFAW which provides details on planned actions, staff numbers and locations of activities and reports quarterly on the actions completed. OANRP also prepares annual reports which summarize actions completed and meet annually with DOFAW and other partners via the Implementation Team meetings to discuss significant findings and make decisions regarding new activities. DOFAW participates and is a voting member of the Implementation Team.

Invasive Plant Control

DOFAW staff has worked on numerous invasive plant control projects summarized below. However, lack of a management plan and extremely variable staffing levels and funding has resulted in inconsistency in invasive plant control project implementation and contributed to the continued loss of native forest to invasive plants.

- 1989 – A field crew of 3 including a biologist position is funded. Weeding is identified as its primary responsibility. Weeding was limited to around 100 microsites (less than a tenth of a hectare) – considered manageable at the time - and the following zones: the Mokulē‘ia Trail (from the trail head as far as the eucalyptus plantation), the Hunter’s Shelter, the Mākua Rim Trail (along the head wall of the Pahole drainage continuing above the Kapuna drainage as far the Hunter’s Shelter), the mauka portion of the main ridge separating Pahole from the Kapuna drainage, and portions of the main ravines in Pahole Gulch.
- 1989 - Fifty-three plots are surveyed and flagged on a plateau in sub-gulch 1 in Pahole. Trials are conducted comparing the efficacy of two herbicides using different application methods. All woody non-native species are treated. The plots are monitored once at the end of 1993, however no analysis of the data is done until a botany graduate student at the University of Hawai‘i takes up the project seven years later.
- 1990 – Eradication of Koster’s curse (*Clidemia hirta*) from the Reserve is attempted. This project lasts 2 years before it is abandoned due to the sudden and rapid spread of the target weed despite control efforts.
- 1993 – The NARS field team expands to five full-time and two seasonal workers. One position is dedicated to actions other than weeding.
- 1995 - Larger control areas are designated where strawberry guava is the primary target. These areas are concentrated on broad, gentle slopes with a northerly aspect (tending to have the most continuous native cover) where volunteers on service trips can be more easily used. Work areas that progressively respond to this treatment are expanded.
- 1999 – As a component of the Army’s Mākua Implementation Plan, DOFAW works with OANRP to identify areas where the Army team will work exclusively on achieving their management goals. A limited number of invasive plant control actions are planned to occur at regular intervals for the life of the plan.
- 2000-2007 – No new weeding strategies are developed and at least a portion of the field crew continues to weed in Pahole once or twice a week.
- 2007-2008 – Partnering with OANRP herbicide trials are conducted on silky oak (*Grevillea robusta*).

- 2007-2010 – Control sweeps of toona (*Toona ciliata*) in the Kapuna drainage are pursued as a priority action.
- 2011 – The first weed specialist is hired to develop an integrated weed plan and supervise all weeding activities in the Reserve.
- 2011- 2013 – Focus on conducting herbicide trials to increase efficiency of weed control techniques.
- 2013- current - Development of NEPM zone concept and delineation of management zones.

In 2013, DOFAW began distribution of the approved strawberry guava biocontrol agent *Tectococcus ovatus*, a scale insect, in the NAR. The overall goal of distribution is to reduce and/or prevent the ongoing encroachment of strawberry guava into native dominated forests areas that are a high priority for management and restoration. DOFAW, in collaboration with U.S, Department of Agriculture Forest Service (USDA-FS) is assisting with monitoring strawberry guava growth and reproduction before and after release of the biocontrol agent. These data will be useful for demonstrating the impact of biocontrol and informing future management. Sites in the Reserve are regularly monitored for fruit and seed collection data, native tree and strawberry guava growth rates. Staff has prioritized additional introduction locations throughout the NAR focusing on ridges to aid in biocontrol agent dispersal and dense patches of strawberry guava directly adjacent to native dominated priority restoration and management zones.

Partner Activities

OANRP began extensive weed control in 2004 with actions including:

1) Incipient Taxa Control (Incipient Control Area - ICAs) – Management objective is to eradicate high priority species identified as incipient invasive aliens. OANRP regularly re-visits and controls these taxa as well as collects information on the life cycle of the target species. Target species lists are updated as new incipient taxa are identified by OANRP and NAR staff through regular field work and surveys. OANRP Target Taxa are identified and control locations and management are described in plans (OANRP 2010) and annual status reports (OANRP 2015). Additionally, Appendix B identifies OANRP ICA Target Taxa.

2) Ecosystem Management Weed Control (Weed Control Areas - WCAs) – OANRP has also identified focal areas for weed control at Pahole NAR. Management goals in these areas are focused on removing weeds from the vicinity of rare taxa (wild and reintroduced) and reducing the abundance of alien vegetation cover. Intensive weed control efforts generally occur in a smaller area around rare taxa rather than throughout the entire WCA. WCA's locations and planned management for Pahole NAR (Pahole and Upper Kupuna Management Units) are described in detail in the OANRP Ecosystem Restoration Plan (OANRP 2010) and work completed is described in annual status reports (OANRP 2015).

Invasive Animal Control

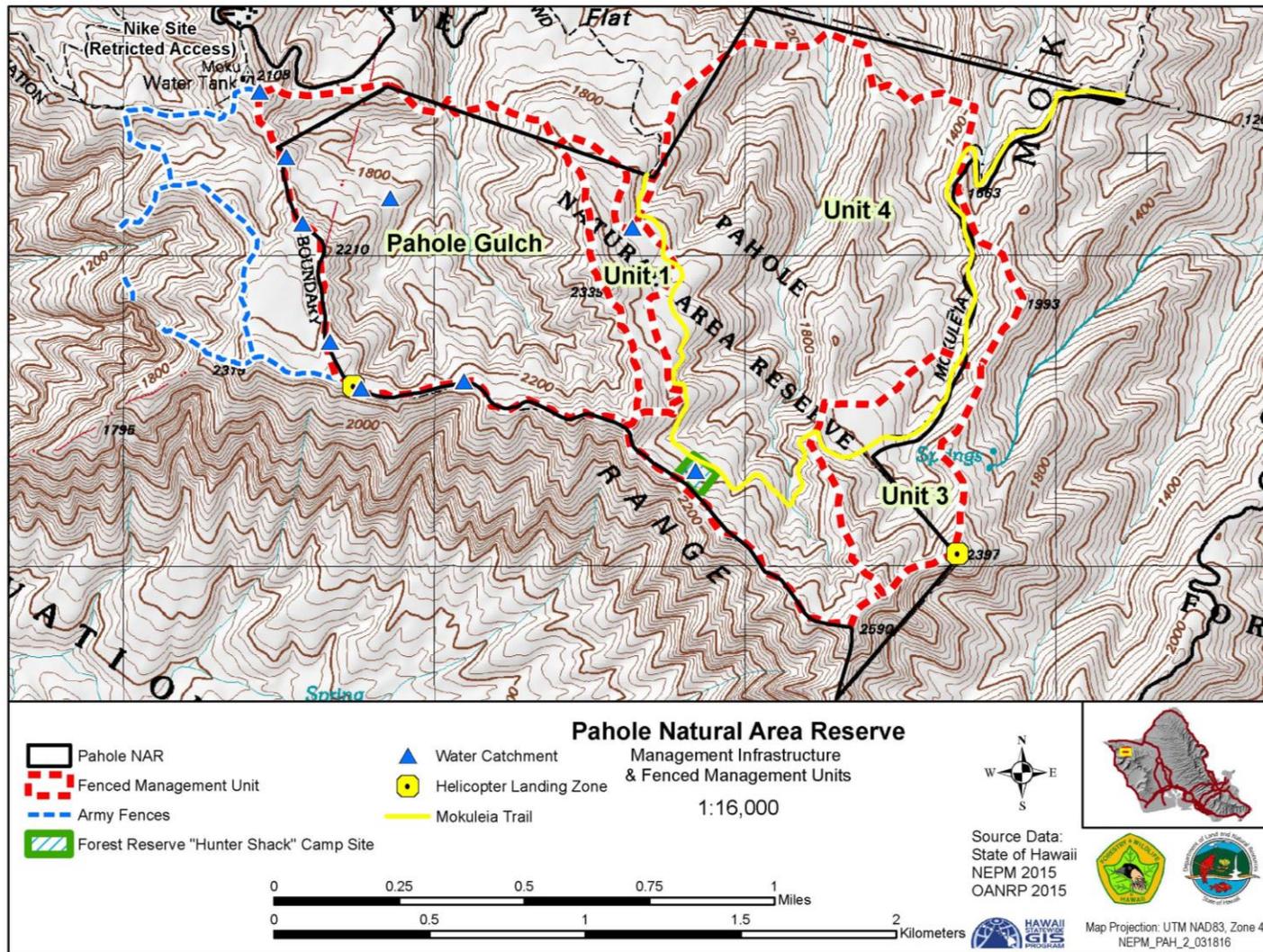
Wildlife control within the NAR primarily includes feral pig management, as pigs cause significant amounts of damage to the Reserve's resources. The Reserve is divided into fenced

management units to more effectively manage pigs, and control efforts have been ongoing since 1996 to remove all pigs from within the Reserve. Control efforts include staff control (hunting, trapping and snaring) as well as public hunts. Pahole Gulch contains one fenced management unit and the upper sections of Kapuna and Keawapilau Gulches are divided into three fenced management units (Units 1, 3 and 4) (Figure 6). Fences follow topographical features rather than land ownership boundaries so small portions of the fence are on U.S. Army land and FR lands and small portions of the Reserve are outside the fence. Fences are inspected on a quarterly basis (work split between DOFAW and OANRP staff) and fences are maintained to prevent ungulate ingress. Some fences required retrofitting with small animal hex fence material to prevent ingress by small pigs, which has occurred in several units bordering unfenced areas. Ungulate ingress requires immediate follow-up control measures to prevent population reestablishment.

Table 5. Summary of Pahole Fencing and Ungulate Control

Fenced Unit	Size (acres)	Date Completed	Year Ungulates Removed
Pahole Gulch	222	12/1996	1999; 2006 ingress pigs removed by 2008
Unit 1	30	12/2006	2007
Unit 3	62	2/2008	2008 no pigs in unit when fence completed; 2013 ingress pigs removed 2013
Unit 4	339	7/2008	2013

Figure 6. Management Infrastructure and Fenced Management Units



Rare Species Restoration

Rare Plants

Pahole NAR has been a focal site for intensive rare plant management, particularly by the OANRP. The OANRP prepares Rare Plant Plans (every 5 years) for plants included in the Mākua Implementation Plan (http://manoa.hawaii.edu/hpicesu/dpw_rpp.htm). Plants managed by the OANRP are listed in Appendix A. Five-year rare plant plans prepared by OANRP include information on the following:

- Species Description and photos
- Historic Collections Table
- Species Occurrence Maps
- Habitat Characteristics and Associated Species
- Population Structure and Population Estimates
- Monitoring Plan
- Reproductive Biology Table
- Genetic Storage
- Reintroduction Plan
- Stabilization Goals Update
- 5 Year Action Plan

DOFAW and PEPP also manage rare plants in the Reserve, particularly species that are not a focus of management by OANRP (Appendix A). Management includes removal of invasive species, collection of propagation materials for ex-situ conservation and propagation, and reintroduction. Pahole Rare Plant Facility, located at the Nike site in the Mokulē‘ia FR, is part of a state-wide network of facilities developed to assist with the propagation and living storage of PEPP species (those species with fewer than 50 individuals remaining in the wild). This facility assists in *ex situ* aspects of the recovery of declining plant species as part of a larger strategy to reintroduce species back into suitable protected and managed habitat. Priorities for this facility are generally primarily in support of PEPP mid-elevation species from the island of O‘ahu, including PEPP species known from the Reserve (Appendix A). Secondary goals for these facilities include propagation of reintroduction material from non-PEPP rare species, propagation of common native species for restoration efforts, and education, provided time and resources are available and the operation is self-supporting and does not detract from primary priorities related to PEPP species.

Rare Animals

The endangered *Achatinella mustelina* has been a focus of management. The population of *A. mustelina* at the Reserve is “managed for stability” together with populations managed by OANRP on adjacent Army lands as part of the Mākua Implementation Plan. The Army’s 2015 status report contains a detailed description of threats to the species as well as past and planned management activities (OANRP 2015).

Although *A. mustelina* occurs throughout the entire Wai‘anae Mountain range, the population at the NAR and the surrounding areas are considered a genetically distinct population on a unique evolutionary trajectory from the rest of the species and are treated as distinct species for management purposes. Because of the limited number of populations and individuals known, this population is considered imperiled and at an increased risk of extinction by SEPP. In 2015, the *A. mustelina* population in the northern Wai‘anae Mountains was estimated at 336 total individuals (OANRP 2015). The population extended across the following three gulches: Kahanahaiki, Pahole, and Kapuna on both state and U.S. Army lands.

The Reserve has a long history of rare snail monitoring and management and is the location of the first of many iterations of a predator-proof fence design. In 1998, DLNR built an enclosure to protect *A. mustelina* from predation by the invasive snail *Euglandina rosea*. The walls of the enclosure are composed of corrugated metal and the predator barrier consists of a trough of salt. The Pahole enclosure population has been regularly monitored by the University of Hawaii’s Hawai‘i Tree Snail Conservation Laboratory since 1998. DOFAW and OANRP have cooperated with other snail management actions in Pahole and adjacent Army lands including snail monitoring and control of black rats and *E. rosea*) both within the enclosure and outside.

Decline in native tree cover within the Pahole snail enclosure starting in 2000 caused the soil to dry out and created poor environmental conditions leading to the decline of snails in that population. Additionally, *E. rosea* was found in the enclosure in 2014. OANRP, SEPP and DOFAW have been working to improve the enclosure habitat through removal of predators, planting of native species and are planning on building a new enclosure to better protect snails from predators.

Research and Monitoring

Numerous studies have been conducted in the Reserve due to its accessibility, as well as proximity to the University of Hawai‘i for student research projects (see Appendix D for summary of research projects). In an attempt to better understand and incorporate research findings into management strategies, researchers are now required to submit track and point location geospatial data with final reports.

Invertebrates

Obtaining basic measures of invertebrate diversity would ideally be a component of any natural area management program however the labor intensive nature of such projects is cost prohibitive. As an alternative, DOFAW has encouraged researchers from across Hawai‘i and the mainland, to initiate multi-year research projects in the area. These projects, while often narrow in scope, provide valuable information about distribution, systematics and the conservation status of specific invertebrate taxa. Approximately 300 arthropod species or morphospecies have been identified from Pahole and neighboring Kahanahaiki by University of Hawai‘i researcher Paul Krushelnycky, as part of a study which examined the effect of rat control on arthropod populations and diversity. A one-time invertebrate Bioblitz was conducted the NAR in 2010, and provided a snapshot of invertebrate species present at the time. Volunteer participants identified over 100 species during the three day event. As part of a larger USFWS funded project, these

data are being compiled and integrated into an invertebrate database where they will be more accessible to managers to review. Long-term, dedicated invertebrate survey and monitoring in the NAR would help us to understand the changes that are occurring in Pahole as a result of invasive species and habitat alteration, and potentially how to mitigate impact to invertebrate species.

Vegetation Monitoring and Surveys

DOFAW and OANRP staff regularly monitor certain high-traffic areas such as trails, roads, fence and helicopter landing zones for incipient alien taxa to prevent the establishment of new invasive alien plant or animal species. At Pahole NAR, these areas include the Mokulē‘ia Trail Access Road and the Mokulē‘ia Trail.

The OANRP monitored vegetation along transects in the Upper Kapuna Management Unit in 2011. This Management Unit will be monitored next in 2016 and then on a five-year interval. Vegetation monitoring data will provide OANRP and NARS with trend analysis on the percent cover for alien vegetation in the understory and canopy, invasion and spatial distribution of priority weed species, and species richness.

OANRP summarized 2011 monitoring results including percent cover for native and non-native canopy and understory, data for the proportion of plots with >50% native canopy, and frequencies for native and non-native understory and canopy species. In 2011, 29% of the plots had 50% or more native canopy cover. These plots will be tracked closely because they represent the more intact sections of the management unit. This analysis will be used to monitor the success of weed control efforts in targeted areas. If future monitoring indicates a negative trend in native cover, weed control strategy will need to be adjusted. Frequency data was recorded for all species observed during vegetation monitoring, including species actively targeted for weed control. Future monitoring will help determine if management efforts have significantly reduced the distribution of these species or if weed control strategy needs to be re-assessed.

DOFAW is conducting aerial surveys for rapid ‘ōhi‘a death on O‘ahu as well as other islands, and Pahole NAR was surveyed in May 2016. This newly identified disease has thus far only confirmed on Hawai‘i Island, but it poses a major threat to native ‘ōhi‘a dominated forests throughout the state and ‘ohi‘ā forests, including Pahole NAR will continue to be regularly monitored for this threat.

Education and Outreach

The O‘ahu NARS Outreach and Education Program *Ola ka ‘Āina I ke Kaiāulu*¹ is designed to promote outreach and education in the form of service learning to reach various NARS management goals including Goal #7 of the 2008 Strategic Plan for Hawaii’s Natural Area Reserves System which is to foster understanding of and sense of responsibility for the State’s unique native resources. Objective 7.1 of this strategic plan is to strengthen natural resource

¹ The literal translation of *Ola ka ‘Āina I ke Kaiāulu* is the land lives or thrives through community.

education in grades K-12 and in institutions of higher learning to enhance understanding of key native resource management concepts and encourage inquiry, problem solving and service. Pahole NAR has been a focus on education and outreach efforts due to its relative accessibility and ongoing management needs. This ongoing program has several different components: Adult service learning, Youth service learning, and *Pakapakakuāua*² Adopt-A-Forest <http://dlnr.hawaii.gov/volunteer/adopt-an-area/adopt-a-forest/>.

- Adult Service Learning – Community groups and various individuals and organizations (e.g. environmental organizations, church groups, military) volunteer their time to assist with ongoing management such as invasive weed control and restoration outplanting.
- Youth Service Learning – This program is similar to Adult Service Learning except the focus is working with youth groups. Typically youth groups are larger and require more transportation assistance and staff supervision. Groups have included various Kupu programs, High School Hikers Ecology camp, YMCA Camp Erdman and school groups. YMCA Camp Erdman groups have been particularly actively participating in summer programs 2012-2015, regularly camping at Peacock Flats Campground and working on weed control projects with students from ages 12 -15.
- *Pakapakakuāua* Adopt-A-Forest – This program started in 2011 and combines service with more intensive educational projects with a focus on high school students in upper level environmental studies classes (Mililani, Waipahu and Mid-Pacific Institute). Over 300 students have participated since the program began (approximately 20-30 students per trip). The program includes a cultural component (chanting *oli*), plant identification, native species monitoring, forest sampling, insect and rodent tracking, endangered snail management, weeding, and forest restoration. Students do day trips or camp 1-2 nights at Peacock Flats and are in the field to collect data on native flora and fauna and implement resource management activities. DOFAW staff has also provided classroom presentations to participating groups prior to field work. This program has also assisted various schools with native plant propagation at on-site school nurseries, primarily koa for outplanting.

In addition to these programs, O‘ahu NARS also regularly requests interns from the State of Hawai‘i Youth Conservation Corp (YCC) Program, which enables young adults to gain entry-level experience as they work with natural resource professionals to conduct natural resources management. Internships often lead to future jobs or advanced degrees in natural resource management.

Administration and Infrastructure

The O‘ahu Branch Administrative offices are located at the Makiki DOFAW office, which also has a Nursery which produces common native plants for restoration of the Reserve. Other

² According to Kamakau (page 80) in *The Works of the People of Old*, *Pakapakakuāua* is a large kauila tree famous in olden times which grew in the vicinity of Pahole NAR. *Pakapakakuāua* translates to numerous showers with *pakapaka* also the word for raindrops. The area where we work is a mesic forest which is threatened by climate change, drought and invasive species. This name invokes the hope that forest restoration through volunteer work will bring more showers and native trees such as kauila back.

offices, storage, and supplies including a NEPM short term (1-5 years) seed storage facility are located at the DOFAW Waimano Baseyard.

The Nike site (former U.S. Army site) is outside the Reserve on FR lands. The buildings of this facility are currently used for storage of NEPM equipment/materials, and as a bunkhouse for volunteers and staff. Adjacent facilities include outdoor mid-elevation nurseries (used by OANRP and PEPP), which also have closed areas used for storage of equipment and supplies as well as seed storage.

Infrastructure within the Reserve is minimal. NEPM staff maintains the Mokulē‘ia Trail (Na Ala Hele Program Trail) through the Reserve, due to the sensitivity of native resources in close proximity to the trail. Volunteers from the Hawai‘i Trail and Mountain Club have been regularly providing assistance with trail maintenance through a Special Use Permit.

There are currently seven small water catchment sites to collect water used in management activities (invasive plant control, native plant restoration).

Two helicopter landing zones (LZ) are maintained as a helicopter landing zone for emergencies and natural resources management purposes (Figure 6).

SECTION II - PLANNED MANAGEMENT ACTIONS

OVERVIEW

This section describes the planned management actions. Each section includes background, objectives, a summary of planned short term and long term management actions, and a more detailed narrative description for each of the planned actions. The overall focus and priority for the management plan is management of natural resources. Management actions are described under applicable goals as described in the NARS Strategic Plan (DOFAW 2008):

- Management of Natural Resources
- Integration with Other DLNR and DOFAW Programs
- Administration and Infrastructure
- Monitoring and Data Collection
- Cultural Resources
- External Partnerships
- Outreach and Education
- Enforcement

MANAGEMENT OF NATURAL RESOURCES

The NARS Strategic Plan states the overall goal of natural resources management is to manage NARS for high quality, natural resource integrity, and functioning ecosystems. Management of native ecosystems involves understanding what threatens these areas, and actively working to protect them from these threats. This plan will also help better define future DOFAW management actions and priorities. There is a great deal of partner interest and activity in this Reserve and we need a coordinated strategy to avoid duplication of partner actions and instead build on joint accomplishments and maximize limited financial and staff resources.

Strategic plan objectives for management of natural resources described in this section include:

- Employing appropriate strategies to minimize and control existing and future invasive plant and animal species; and
- Managing native, rare, and T&E plant and animal species and their habitats at sustainable community and population levels (DOFAW 2008).

This section describes the general approach for natural resources management for Pahole NAR including:

- Invasive Plant Control
- Invasive Animal Control
- Habitat Restoration
- Rare Species Restoration

The dry and mesic forests at Pahole NAR are highly altered, due to historic impacts of humans (e.g. grazing/ranching, water production, military training and logging) and impacts of invasive

species, negatively affecting the functioning of native ecosystems and the survival of rare and endangered plants and animals. Although the threats are difficult to manage, this forest type is extremely rare in the Hawaiian Islands, and Pahole NAR is the best remaining example of this forest type on O‘ahu. Thus, intensive management is needed to maintain the areas dominated by native forest containing unique native species and restore the quality and functioning of these remaining native ecosystems.

The planned strategy for natural resources management primarily focuses on implementing intensive management and restoration in Native Ecosystem Protection and Management (NEPM) Zones, which are the best remaining native ecosystems in the Reserve (Figure 7). Many portions of the Reserve are heavily degraded by weed invasion and widespread control of weeds and restoration of those areas is not feasible with current methods, limited staffing and budget. NEPM Zones are prioritized for management based on native species dominance, the presence of T&E species, partnership capabilities and management accessibility. NEPM Zone Class priority ranking from 1 to 4 helps to define the management goals and aids in overall prioritization of management efforts. NEPM Zone Class 1 and 2 areas are the highest priority for management as these are generally the most intact remaining native habitat.

In order to increase the effectiveness of management efforts, NAR staff will focus management efforts in the most native dominated areas within the NEPM Zones and as resources become available will expand the areas to link managed and restored forest. NEPM zone boundaries will be re-assessed every five years to determine the overall success of management, and determine whether NEPM zones can be expanded.

While this section of the plan describes the general approach to management, Appendix E contains detailed NEPM Zone site descriptions and associated maps and outlines the intensive management actions specifically planned for these sites. Appendix E is for internal DOFAW use only as NEPM Zone descriptions and maps contain information on locations of sensitive and T&E species.

Invasive Plant Control

Background: Invasive non-native plants or weeds are a major threat to the Reserve, and species with high potential for spreading and modifying habitat are a high priority for control. The overall approach includes: 1) preventing the establishment of habitat modifying species through early detection and rapid response; 2) eradicating high priority invasive plants from the NAR; 3) control of invasive plants in designated native forest sites (NEPM Zones) to reduce invasive plant density and allow native forest and rare species restoration and recovery; and 4) reducing the size of core populations of invasive plants to inhibit their spread into new areas. This approach is modeled after the National Park Service management of invasive plants within Special Ecological Areas (Loh et al 2014) as a way to more effectively manage priority native ecosystems with limited resources. This plan will use the definition of weed management goals as outlined below:

Prevention – Prevention of a weed problem is the most cost-effective action possible. During surveillance, the establishment of new species into an area is prevented through early detection and rapid response. Ensuring best sanitation practices are followed and public outreach are valuable tools to aid in the prevention of new introductions.

Maintenance Control – This balanced approach maintains weeds at the lowest densities possible while optimizing cost and size of managed area.

Contain/Suppress – Containment inhibits the spread of weeds from core infestations into new areas. Suppression is the reduction in size of the core population.

Eradication – Aims to remove all individuals from a specific area, such as watershed or island-wide. Regular monitoring is required to ensure no new individuals return to the area. *For the purpose of this plan 'Eradication' is defined as removing individuals from the NAR.*

A combination of control techniques including manual, mechanical and chemical are used to remove weeds. The technique used is based on the characteristics of the target species, the sensitivity of the area in which the species is found, and the effectiveness of the control technique. The use of herbicides will be conducted in strict accordance with state and federal law and according to the herbicide label requirements. Staff strive to use the least amount of herbicide possible to reduce potential risk to sensitive environments and because it is more cost-effective.

Objective: Protect and restore native forest by preventing the establishment of new invasive plants and removing established invasive plants from targeted areas within the NAR.

Actions:

1. Prevent the establishment of habitat modifying weeds in the NAR.
2. Control target weeds within the highest priority intact native areas of the NAR.
3. Contain and suppress target weeds to prevent further establishment and spread.

4. Monitor weeds to detect changes in long term distribution and abundance in the NAR.
5. Support research including improved weed control and monitoring techniques for the NAR.

Narrative Description of Actions:

1. Prevent the establishment of habitat modifying weeds – Weed control goals include early detection and preventing the establishment of incipient, habitat modifying weeds that are not currently present in the NAR or are still localized (Appendix B). Pahole incipient species or **eradication** targets are typically found along disturbed areas such as roads, trails and fences as these serve as corridors for weed establishment and spread. Prevention is a critical component of the weed management program, and it is important to avoid and/or reduce the inadvertent introduction and spread of weeds by the public, researchers, managers and students working in and visiting the area. NARS staff and volunteers will follow protocols for cleaning of boots, equipment and vehicles prior to entry into the NAR. NARS staff will work closely with OANRP on weed prevention and eradication. OANRP has already identified Incipient Control Areas (ICAs) and OANRP incipient target species at Pahole NAR (OANRP 2010). NARS will continue to coordinate and work with OANRP on identification and control of incipient targets. The public will be encouraged to clean boots using boot brushes placed at trailheads and informational signs will recommend cleaning boots and equipment prior to entering the Reserve.

2. Control target weeds within the highest priority intact native areas – Priority areas for weed management (NEPM Zones) are identified and described in detail in Appendix E. *Summary of Management Actions by NEPM Zone*. NEPM Zones contain the most intact native ecosystems in the Reserve and are prioritized for weed control based on native species dominance, the presence of T&E species, partnership capabilities and management accessibility. Many portions of the Reserve are heavily degraded by weed invasion and widespread control of weeds in those areas is not feasible with current methods, limited staffing and budget. NAR staff will focus weed control efforts in the most native dominated areas within the NEPM Zones and as resources become available will expand the areas to link managed and restored forest plots. NEPM zone boundaries will be assessed every five years to determine the overall success of management, and determine whether NEPM zones can be expanded. Invasive plant control in NEPM Zones will be done in conjunction with habitat restoration with the goal of replacing invasive plants with common native plants. Areas managed by the OANRP as Weed Control Areas (WCAs) for the benefit of T&E species generally overlap with NEPM Zones, and NARS will prioritize weed control within those areas in order to complement joint management efforts. Although target weeds are generally identical, intensive OANRP weed control efforts are primarily directed towards smaller, localized areas within the WCAs to stabilize rare taxa whereas the NARS will be focused on larger-scale ecosystem stabilization.

For priority target weeds (Appendix B) already present in the NAR, the goal is **maintenance control** of all known occurrences within targeted control areas (NEPM Zones). Areas will be regularly swept by staff to search for and control target weed species. Removal of invasive plants from NEPM Zones will require a heavy investment of workload in the early phases (e.g., during initial knockdown of high populations and densities) of priority target weed control but

workloads are expected to drop significantly after initial control efforts are completed. Staff will continue to regularly sweep and control weeds within set intervals during the maintenance phase to ensure that the weed infestation is reduced to low, manageable levels. Weed control within NEPM Zones will be approached in stages to ensure there is adequate effort to regularly maintain managed sections. Continual follow-up is required in all managed areas and will be needed indefinitely.

Complete eradication of target species within NEPM zones is not expected. Continued search and retreatment efforts will be needed to offset re-establishment from seed dispersal from outside areas and expression of the soil seed bank. No studies have focused on the threshold abundance needed for an invasive species to disrupt ecological processes at the landscape level, thus staff will develop weed control interval guidelines to maximize the length of time between sweeps and minimize time and staff effort needed for ongoing maintenance.

Maintenance control will also be conducted along fence lines and management trails as needed. Targets include species easily dispersed via hikers such as *Triumfetta semitriloba*, *Acharanthes aspera* and *Desmodium* spp.

3. Contain and suppress certain weed species to prevent further establishment and spread – Contain and suppress targets include species that are established within a portion of the NAR and are not realistic to eradicate. These species pose a high enough threat to uninfested portions of the Reserve thus control efforts to prevent further establishment and spread are warranted. Examples of contain/suppress targets include *Schefflera actinophylla*, *Montanoa hibiscifolia* and *Megathyrsus maximus*.

Due to widespread and heavy infestations of certain weeds and limited resources, NARS staff and partners intend to continue to test the efficacy of approved biocontrol agents within the Reserve. The continued distribution of the approved strawberry guava biocontrol *Tectococcus ovatus* is a high priority. Strategic introductions will occur within heavily infested areas adjacent to NEPM zones and along rim tops and ridges to aid in dispersal of the agent since it has limited mobility and is typically wind dispersed. Since the *T. ovatus* only slows the growth and reduces fruit production the goal of introductions is to limit further encroachment of strawberry guava into NEPM zones.

4. Monitor weeds to detect changes in long term distribution and abundance – NARS staff will monitor management efficacy in NEPM Zones with photopoints and data records (e.g. staff effort, area/numbers of individuals controlled, amount of herbicide used) to determine if weed control measures and re-visitation intervals are effective. Ideally, the level of effort needed for control should decrease over time until leveling off to a lower level of effort for maintenance control. If control efforts increase or stay high at any given site, staff will either increase interval visitation to the site and/or re-assess the feasibility of control. For eradication species staff will monitor maturity of plants found. Control time interval time will be decreased if staff observes seeding plants to prevent establishment of a larger seed bank. The OANRP has an ongoing vegetation monitoring program for portions of the Reserve, and this data provides a valuable

baseline for weed distribution and abundance and will help assess the effectiveness of management efforts.

5. Support research including improved weed control and monitoring techniques – Research into new monitoring, mapping and weed control methods will be integrated into the weed management program over the course of this plan as appropriate. NARS staff will participate, where appropriate, in experimental weed control management methods to improve the efficiency and scope of invasive plant management. Staff will continue working with USDA-FS on monitoring long term efficacy of *T. ovatus* for control of strawberry guava and continue collaborating with University of Hawai‘i College of Tropical Agriculture and Human Resources (CTAHR) staff to improve herbicide control techniques. NARS Staff initiated and actively coordinates an O‘ahu Weed Working Group to improve collaboration between agencies and organizations working on invasive plant control. The goals of this group are to increase management efficiency, prioritize species in need of improved control methods, improve monitoring techniques and develop consistent mapping and data recording protocols for O‘ahu species.

Invasive Animal Control

Background: Eliminating threats from invasive animals is a high priority management objective. The boundary of the Reserve has been fenced and feral ungulates removed. Ungulate control requires ongoing effort to maintain the integrity of the fencing and animal free status due to continual threat of ingress of feral pigs from adjacent areas. Other invasive animals such as mammalian predators (e.g., cats, rats, mongooses, mice), and invasive snails and slugs are also actively controlled in localized areas to reduce threats to endangered species.

Objective: Enhance the maintenance and recovery of native forest and T&E species by controlling invasive animal species.

Actions:

1. Feral Ungulate Management – Protect native forest and watershed from feral ungulates.
 - Fencing – Maintain integrity of existing fenced units through regular inspection, maintenance and replacement of fencing.
 - Ungulate control – Monitor fenced units for ungulate ingress, and remove animals, if necessary.
2. Invasive Animal Management – Reduce threats to endangered species through control of mammalian predators, invasive snails and slugs and other invasive animals.

Narrative Description of Actions:

Removal of ungulates from fenced units is a critical first step in native forest conservation because it allows for the recovery of native vegetation by minimizing ground disturbance and reducing the spread of weeds by ungulates. Removal of ungulates also benefits native plants including T&E species by reducing the threat of direct predation, trampling and/or uprooting.

1. Feral Ungulate Management – Currently, the only ungulates that threaten the NAR are feral pigs. Ungulate management is an ongoing management program in the NAR. As the entire NAR is already fenced, inspection and maintenance of existing fences and monitoring for ungulate presence is necessary to prevent reinvasion of ungulate-free areas.

- Fencing – Maintain integrity of existing fenced units (Pahole Gulch, Unit 1, Unit 3 and Unit 4) through quarterly inspection and maintenance of external fences by DOFAW staff with assistance from OANRP. OANRP is responsible for repair and maintenance of the Mauka rim fencing and is planning to replace the oldest section of fence along the Mākua rim in approximately 10-20 years.
- Ungulate control – Ungulate control is ongoing due to occasional ingress of animals into ungulate-free areas. DOFAW staff will monitor fenced units for ungulate ingress during regular fence inspections, along ungulate monitoring transects and using game cameras. Ungulate levels within all fenced units will continue to consist of maintaining a zero tolerance for presence, and any animals detected will be controlled using approved methods.

2. Invasive Animal Management – Current and planned management focuses on reducing localized threats such as rats, slugs and snails (*E. rosea*) to T&E species, particularly endangered plants and snails (*A. mustelina*). NARS staff will continue work with partners (OANRP, SEPP, and PEPP) to control and monitor invasive animal threats in high priority areas. Current methods used include repeater traps, snap traps and tracking tunnels for removal and monitoring of rodents; sluggo for removal of slugs around T&E plants; and predator proof fencing to prevent ingress of invasive animals into endangered snail habitat.

NARS staff will also continue to work with partners and researchers to monitor the Reserve for the presence of new invasive animals that may be harmful to native resources, and develop and use the most effective methods available for removal of invasive animals that pose a threat to native resources.

Habitat Restoration

Background: The overall NARS management goal includes maintaining the integrity of high quality functioning native ecosystems. However; over the past few decades the conversion of the native forest to non-native forest has been very detrimental to the quality, integrity and functioning of native ecosystems within the Reserve. DOFAW has identified and prioritized native forest areas (NEPM Zones) and will focus management, including habitat restoration, within these sites. Restoration efforts focus on maintaining native dominated communities and expanding and connecting these communities by controlling target invasive weeds in conjunction with planting common and rare native species in order to create a stable native ecosystem.

Objective: Restore forest in the Reserve to maintain, connect and create larger, more stable, native-dominated plant communities.

Actions:

1. Control invasive plants within NEPM Zones.

2. Restore NEPM zones through planting of common native species.
3. Monitor restoration efforts.

Narrative Description of Actions:

1. Control invasive plants within NEPM Zones – Weed control is the first, critical step in habitat restoration in the Reserve (see Invasive Plant Control section above and Summary of Management Actions for NEPM Zones – Appendix E for a detailed description of priorities and planned actions). Weed control will first focus on clearing native dominated areas of invasive plants. These areas will be gradually expanded to connect and create larger more intact stands of native forest.

2. Restore NEPM Zones through planting of common native species – Plantings of common native species complement and typically follow intensive weed control efforts. Planting will be used in conjunction with other strategies such as natural regeneration, transplanting and seed sowing. Native species that will be used for habitat restoration are summarized in Table 6. Refer to NEPM Zone Summary section for a description of specific habitat restoration goals and strategies as well as detailed actions. General actions include the following:

- Standardize common native plant collection for propagation protocols including but not limited to tagging plants, founder amounts, collection intervals, seed banking, taking cuttings, etc.
- Seed collection – Staff will search for and collect propagation material as available. Seed from common, widespread species within or close to the NAR are prioritized as seed sources and seeds will be taken from as many founders as practicable. Seed collection requires a lot of time monitoring seed development along with collecting and processing the seeds. Staff will utilize volunteers to assist in seed processing and will continue the partnership with Leeward Community College students to aid in processing large collections. Seeds of appropriate species may not all be available from within the Reserve. Seed collection with partners across a larger landscape will enable collection from a greater variety of individual plants as well as species, increasing genetic variation and species diversity.
- Propagation – Propagation material is transferred to the appropriate nursery facility for propagation or cleaned, processed and stored in the NEPM short term (1-5 years) seed storage facility for later use in restoration seed sows, propagation, or fire reforestation. Propagation will primarily be done at the DOFAW Makiki nursery and/or through a contract nursery. An effort to propagate a mix of fast and slow growing common native species is used. Nurseries used must comply with the nursery sanitation guidelines.
- Planting and Seed Sowing – The basic habitat restoration strategy is to provide a boost to the ecological succession of native species after an intensive (clear cut) weed control effort. The ‘head start’ provided by propagated plants aids in faster native establishment which then reduces the effort needed for follow-up invasive plant control. Refer to outplanting sanitation protocol for procedures on outplanting sanitation.
- Transplanting – Transplanting is the most efficient way to provide an extra boost for native establishment after intensive weed management although drawbacks include possible reduced genetic fitness and low survival. Thus far only a few species have

successfully transplanted including palapalai due to its rhizomal characteristics along with pāpala kēpau seedlings due to production of an abundance of seedlings at one time.

- Natural Regeneration – Certain areas can be restored effectively through natural regeneration once invasive plants are removed, particularly areas with abundant native seed and certain fast growing native species. Weed control methods that most effectively promote natural regeneration will be used, when feasible.

Table 6: Summary of Common Native Plants for Habitat Restoration in Pahole NAR

Species	Common name	Description	Method(s)
<i>Acacia koa</i>	Koa	Fast growing large tree, nitrogen fixing	Natural regeneration, seed storage, outplant, seed sow
<i>Bidens torta</i>	Ko'oko'olau	Fast growing, clumping, annual shrub, drought tolerant and requires full sun	Seed sow
<i>Carex</i> spp. (<i>wahuensis</i> var. <i>wahuensis</i> ; <i>meyenni</i>)	Carex	Long lived, grass like clumping sedge	Seed storage, seed sow, outplant
<i>Diospyros</i> spp. (<i>hillebrandii</i> ; <i>sandwicensis</i>)	Lama	Long lived, slow growing small to medium tree, prefers partial sun to shade	Outplant
<i>Dianella sandwicensis</i>	Uki uki	Long lived (>5 yrs.) grass like, non-woody, spreading shrub	Seed storage, seed sow, outplant,
<i>Dodonaea viscosa</i>	A'ali'i	Long lived, fast growing, woody shrub to small tree, partial to open sun, tolerates high winds	Seed storage, seed sow, outplant
<i>Metrosideros polymorpha</i>	‘Ōhi‘a	Slow growing, highly variable growth (prostate shrub to large tree)	Seed storage, outplant
<i>Microlepia strigosa</i> var. <i>strigosa</i>	Palapalai	Long lived tall fern, non-woody spreading	Transplanting, outplant
<i>Pipturus albidus</i>	Mamaki	Long lived fast growing shrub, prefers partial sun	Natural regeneration, Seed storage, seed sow
<i>Pittosporum</i> spp. (<i>glabrum</i> ; <i>flocculosum</i>)	Hō'awa	Long-lived large shrub to small tree wind and drought tolerant	Outplant
<i>Pisonia</i> spp. (<i>sandwicensis</i> ; <i>brunoniana</i> ; <i>umbellifera</i>)	Pāpala Kēpau	Medium to large, long-lived tree, native snail host plant	outplant, transplant seedlings
<i>Sapindus oahuensis</i>	Lonomea	Long lived medium to large tree, drought and wind tolerant	Seed storage, outplant
<i>Scaevola gaudichaudiana</i>	Mountain Naupaka	Long lived, large shrub to small tree, difficult to outplant	Natural regeneration, outplant

3. Monitor restoration efforts – A subset of outplanted plants will be tagged and monitored annually to determine survival rate, growth and plant health. Protocols for monitoring (e.g. percentage of plants monitored) will need to be determined. Staff will also maintain data records summarizing the date, numbers and species of plants outplanted in specific locations. Photo points will be placed within certain habitat restoration areas to show change over time. In addition, the OANRP has an ongoing vegetation monitoring program for portions of the Reserve,

and this data provides a valuable baseline for weed and native plant distribution and abundance and will help assess the effectiveness of habitat restoration efforts.

Due to limited staff, volunteers will be heavily relied on to perform habitat restoration work including intensive weed management, restoration of areas cleared of weeds with common native plantings and seed collection and sowing. These restoration efforts are used to promote education and outreach activities while simultaneously accomplishing the habitat restoration goals. Refer to the Outreach and Education section for details on these activities.

Rare Species Restoration

Background: Landscape-scale habitat protection and management through management actions such as invasive plant and animal control and habitat restoration are critical to the long-term integrity and recovery of native ecosystems including rare species. However, these actions are not enough to recover certain rare and endangered plants and animals. These species may have wild populations that are so small that the species cannot survive and recover without additional species-specific management.

Objective: Protect and manage rare, and T&E plant and animal species in the Reserve and their habitats at sustainable community and population levels.

Actions:

1. Snail Restoration – Protect existing populations of *A. mustelina* from threats and restore this species in fenced, protected habitat to contribute to population stabilization and recovery.
2. Rare Plant Restoration – Protect existing wild populations of T&E plant species from threats and restore these species in appropriate habitat to contribute to their population stabilization and recovery (see Appendix A for a list of rare plants).
3. Arthropod Restoration - Protect existing wild populations of rare and endangered arthropod species from threats and restore these species in appropriate habitat to contribute to their population stabilization and recovery.
4. Vertebrate Wildlife Restoration - Protect existing wild populations of rare and endangered vertebrate wildlife species from threats and restore these species in appropriate habitat to contribute to their population stabilization and recovery.

Narrative Description of Actions:

1. Snail restoration - *A. mustelina* recovery at Pahole will be done cooperatively with other organizations including SEPP, OANRP, and USFWS. SEPP does not currently have a specific numerical target of snails at the Reserve but has an overall goal of a steadily increasing population to maintain genetically viable populations. Planned conservation actions will focus on management of the fenced, protected population and are aligned with OANRP goals and plans for this species across the NAR as well as other sites where the species occurs (OANRP 2015).

- Pahole NAR snail enclosure – While an effective barrier, 17 years of continual salt exposure has begun to undermine the metal walls. In addition, this enclosure was never intended to keep out other predators like rats and Jackson’s chameleons, as the extent to which these predators negatively impact snail populations was discovered years after its construction. Therefore, DOFAW plans to rebuild the enclosure, updating it with new predator barriers and expanding it to encompass more native habitat. The NEPM Zone Summary contains a detailed description of management actions planned for this area.
 - Maintain and upgrade enclosure to better protect against threats such as rats, Jackson’s chameleons and *E. rosea*.
 - Continue ongoing management actions in enclosure and adjacent sites including rat control and monitoring, protecting against invasive snail ingress with regular restocking of salt tray barrier (until new enclosure is completed as the new design will not use salt) and *E. rosea* monitoring.
 - Habitat restoration – Improve snail habitat through removal of invasive plants, and restoration of native snail host plants.
 - Installation of a sprinkler system in the enclosure to enhance habitat restoration and improve snail habitat by increasing microclimate humidity level.
 - Monitor snail populations within the enclosure.
- Translocate remnant populations of snails in the NAR into the improved Pahole enclosure and the Army’s Kahanahaiki protective enclosure. Snails will have increased survival potential within enclosures. Additionally, combining small fragmented populations that were once likely connected across short geographic distances will increase genetic diversity and decrease inbreeding. DOFAW has prepared a detailed *A. mustelina* translocation plan which summarizes past and planned management work at the Reserve and adjacent sites (DOFAW 2015).
- Determine future translocations between protected snail enclosure to allow optimal gene flow between the populations and spread the individuals across secure sites (e.g. Pahole enclosure and Kahanahaiki enclosure on Army land).
- Continue to work with partners to develop other tools for snail management (e.g. captive propagation and reintroduction to increase populations, enclosure design and potentially building a new snail enclosure in appropriate site).

Table 7. Summary of Snail Management Activities Planned at Pahole (DOFAW 2015)

Site	Management Action	Lead Organization	Purpose
Pahole Enclosure	Restock salt tray	SEPP	Prevent <i>E. rosea</i> ingress
	Secure surrounding vegetation via trimming and tree rings	NARS/SEPP	Prevent rat ingress
	Restore native vegetation inside enclosure	SEPP/NARS	Improve habitat
	Restore adjacent surrounding habitat/canopy (5-10 meter canopy buffer)	NARS	Improve and stabilize habitat, increase microclimate moisture levels
	Check & bait traps inside enclosure, monitor presence of rat activity	SEPP	Prevent rat predation
	Timed monitoring counts	SEPP	Monitor population trends
	<i>E. rosea</i> searches	SEPP	Prevent/monitor <i>E. rosea</i> predation
Below Pahole Enclosure	Maintain trapping grid	OANRP	Prevent rat predation
	Timed quadrant monitoring counts	NARS	Monitor population trends
	Tracking tunnels (below enclosure & control site)	NARS	Monitor rat presence/activity
	Weed control	NARS/OANRP	Habitat maintenance in native dominated zone

2. Rare plant restoration - NEPM staff will work cooperatively with other organizations and agencies including the OANRP, PEPP, Pahole Rare Plant Facility, DOFAW botanical staff and USFWS. Additional details on responsible entity, goals and focal species for management are summarized in Appendix A.

- Re-introduce certain species of rare and endangered plants in appropriate protected habitat through outplanting. Over the past decade, numerous species of rare plants have been propagated and planted at Pahole to contribute to their overall recovery in the wild. Reintroduction is defined as reintroducing individuals back into the wild within its historic range for the purpose of establishing new populations. Reintroduction can include establishing new populations for species that still occur within the Reserve as well as for species historically known from the Reserve that have been extirpated.
- Conduct novel introductions of certain species of rare and endangered plants based on predicted climate change trajectories. Introduction involves introducing plant taxa outside its historic or current range and may be needed to recover certain rare taxa in protected habitat due in the Reserve due to climate change and/or other threats.
- Rare plant management actions by NEPM staff, OANRP, PEPP and other agencies and organizations working on rare plant recovery in the Reserve will be coordinated through and require prior approval by the O‘ahu NAR Manager.

- Actions for rare species designated under the management of O‘ahu DOFAW will be aligned with goals outlined in the USFWS Recovery Plan for the species.
- Ensure rare plant management actions are aligned with objectives in other plans (e.g. OANRP Rare Plant Plans (prepared every 5 years) for plants included in the Mākuā Implementation Plan. http://manoa.hawaii.edu/hpicesu/dpw_rpp.htm) and PEPP species management plans <http://www.pepphi.org/> including any propagated plants supplied to the NEPM program by OANRP or PEPP sourced from populations in Pahole NAR.
- Conduct surveys to locate wild individuals, collect propagation and genetic storage materials and reintroduce through outplanting.
- Follow rare plant collection and reintroduction guidelines recommended by the Hawai‘i Rare Plant Restoration Group <http://hrprg2.webnode.com/> and Standard Operating Procedures for Outplanting (DOFAW O‘ahu Branch).
- Integrate rare plant reintroductions with larger habitat restoration and invasive plant control projects to ensure rare plants are reintroduced in sufficiently mature restoration areas. Successfully implementing these projects around outplanted rare species is difficult and may put plants at risk. NEPM Zones ranked as Class 1 are prioritized for outplantings of rare species as these are generally the most intact habitat with consideration given to other areas with NAR manager prior approval.
- Tag and map the locations of all outplanted plants and monitor survival and growth for a minimum of one year after outplanting and every 2-3 years thereafter to assess success and provide information for future outplanting.
- Maintain introductions by conducting annual maintenance control of invasive plants around outplanted populations to ensure habitat remains appropriate.
- Provide additional management of wild and/or reintroduced populations if needed (e.g. insects, slugs, plant disease and/or mammalian predators).
- Continue to acquire and compile geospatial data for rare plants in Pahole NAR including status of population as wild, reintroduction, or introduction.

3. Arthropod Restoration – Kapuna Gulch in Pahole NAR has been identified as a potential field site for the establishment of a population of the orange-black damselfly, *Megalagrion xanthomelas*. This native damselfly was conferred federal protection in September 2015 and will be formally listed in September 2016. The species is currently known from only one population on the island of O‘ahu, and both State and Federal land managers are interested in increasing the number of populations of the species. Kapuna Gulch/Stream has no surface water connection to lower stream reaches, lacks key predators known to predate damselfly naiads (such as Poeciliid fish, cane toads or bullfrogs), and as a consequence, still supports other native damselfly species. DLNR-DOFAW, in partnership with the University of Hawai‘i at Manoa, USFWS, and OANRP, conducted an orange-black damselfly translocation in September 2015. A total of 74, 10th instar naiads were released at the Kupuna Gulch site. Subsequent monitoring events have not detected adults or naiads of the species, but monitoring and additional translocation efforts will likely continue at the site in 2016.

Various other arthropod species may require future management and restoration in appropriate habitat at Pahole NAR to contribute to their population stabilization and recovery. Specific plans for restoration of these species have not yet been developed but may be developed in the future.

4. Vertebrate Wildlife Restoration – Various native wildlife species such as birds (e.g. ‘elepaio) and bats may require future management and restoration in appropriate habitat at Pahole NAR to contribute to their population stabilization and recovery. Specific plans for restoration of these species have not yet been developed but may be developed in the future.

Research and Monitoring

Background: The Reserve offers unique opportunities for research and staff review all research permits before they are approved. NEPM staff will continue to collaborate with partners, interested researchers, and students, so their research can better address critical management needs. Ongoing monitoring programs are used to monitor the status and trends of natural resources throughout the NAR and these will be continued and expanded, as resources allow.

Objective: Encourage monitoring, surveys and research to address critical natural resource management needs in the Reserve and assess the long-term status of natural resources.

Actions:

1. Continue ongoing monitoring programs for ungulates, weeds, *A. mustelina* and rare plants to measure the success of management and detect changes in abundance and distribution.
2. Develop and/or identify appropriate monitoring protocols and implement monitoring for key community indicators that are not currently being monitored.
3. Encourage research including applied research with direct relevance to land management and threats such as climate change.

Narrative Description of Actions:

1. Continue ongoing monitoring programs for ungulates, weeds, *A. mustelina* and rare plants to measure the success of management and detect changes in abundance and distribution - NAR staff and partners are planning on continuing these ongoing monitoring programs, which are described in greater detail in other relevant sections of the plan (invasive plant control, invasive animal control, rare species restoration, habitat restoration, vegetation monitoring). Vegetation such as ‘ōhi‘a will continue to be monitored to detect threats such as rapid ‘ōhi‘a death.

NAR staff will continue to refine and modify existing programs (monitoring protocols, data management and analysis) in order to make the program more effective and ensure monitoring is providing information relevant to informing management. There is currently limited staff availability for intensive monitoring and data analysis; therefore, increases in efficiency and greater collaboration with partners will help increase program effectiveness.

2. Develop and/or identify appropriate monitoring protocols and implement monitoring for key community indicators that are not currently being monitored (e.g., birds, invertebrates etc.) -

Additional information on the basic natural history and abundance of the endemic and often endangered plants and animals in the Reserve is needed to understand how species may respond to a changing environment (e.g. as a result of climate change) and how management and conservation measures can be used to enhance recovery and adaptation. The uncertainty of potential changes in future climate creates challenges for restoration and management because past conditions may not be accurate predictors of the conditions under which plant and animal communities will survive, evolve, and adapt at particular locations. Climate change may result in changes in community structure and shifts in biomes that alter suitable habitat for species. Effective management will depend on accurate predictions of potential changes, effective monitoring to document patterns of change, and adaptive management to respond to changing circumstances. Baselines research/survey needs include:

- Identify critical gaps in natural resource inventories for the NAR and initiate additional surveys and monitoring (e.g. bird surveys, invertebrate surveys).
- Weather, climate and hydrologic research and monitoring, in cooperation with partners.

3. Encourage research including applied research with direct relevance to land management - Pahole NAR offers unique opportunities for research, and NAR staff review all research permits before they are approved. NARS staff will work with interested researchers in the academic community as well as scientists so their research can better address critical management needs. Additional research is needed on the following topics:

- Effective management of invasive plants and animals, and recovery of endangered native plants and animals. The Reserve also provides an ideal site in which to test hypotheses about how invasive species impact ecosystems and determine the most effective methods of controlling or eliminating invasive species.
- Effective ecosystem restoration is of great relevance to the Reserve as well as other areas in Hawai'i.
- Climate change models, and predictions, that relate to the region and site specific and species specific modeling that will help determine current and future management in relation to climate change. These models may be used to assist the recovery of endangered species for which the NAR may provide future suitable habitat in the face of climate change.

INTEGRATION WITH OTHER DLNR AND DOFAW PROGRAMS

Fire Management

Background: Fire management is incorporated as part of this management plan because of the threat it poses to the Reserve native forests and neighboring forests across the Wai'anae Mountains.

Objective: Employ appropriate fire management strategies including pre-suppression, suppression, and post-suppression rehabilitation to reduce wildfire occurrence and minimize wildfire impacts.

Actions:

1. Implement fire prevention measures, including fire breaks, educational outreach to neighbors and signage along roads.
2. Suppress fires safely and aggressively using appropriate means.
3. Continue NAR staff training and certifications for effective and safe fire response.

Narrative Description of Actions:

1. Implement fire prevention measures, including maintaining fire breaks, educational outreach to neighbors and signage along roads - Most fires are caused by humans, so fire prevention measures will include increased educational efforts for those accessing the property, road or area closures in the event of extreme fire danger and suppression of non-native grasses in fire prone areas. Weed control and planting of common native species will be used to restore certain disturbed areas to prevent fire and/or following damage from fire.

2. Suppress fires safely and aggressively using appropriate means - In the event of fire, DOFAW is identified as the primary responder to fires in the Reserve. The most effective control of a fire will be through measures that result in the least amount of impact or disturbance to natural and archeological resources. The method of suppression will be determined by the on-site situation, with special regard to the potential expansion of fire damage to the resources within the Reserve. Minimum impact methods of suppression will be applied whenever such methods are sufficient.

3. Continue NAR staff training and certifications for effective and safe fire response – Training of existing and new staff is a critical component of effective response to fire. NEPM staff will maintain current fire response certifications by attending regular required staff trainings.

Enforcement

Background: The DLNR’s Division of Conservation and Resource Enforcement (DOCARE) is responsible for enforcement of state laws at the Reserve, including laws regulating protection of resources (e.g. illegal harvesting, vandalism etc.). Improved collaboration between the NAR program and DOCARE will improve the effective enforcement of laws that protect the Reserve.

Objective: Ensure effective enforcement of laws that protect Pahole NAR.

Actions:

1. Explore opportunities to collaborate with DOCARE to improve voluntary compliance with laws and strategies to improve the effectiveness of enforcement.

Narrative Description of Actions:

1. Explore opportunities to collaborate with DOCARE to improve voluntary compliance with laws and strategies to improve the effectiveness of enforcement – Illegal activities at the Reserve include mountain biking, commercial tours, illegal harvest, illegal camping and vandalism. For example, a Reserve fence was vandalized in 2007. Certain illegal activities may be able to be effectively prevented and/or minimized with staff presence, appropriate signage and public education. Reserve staff will continue to work closely with DOCARE on preventing illegal activities from occurring and improving the effectiveness of enforcement.

ADMINISTRATION AND INFRASTRUCTURE

Background: Sufficient staff and appropriate support (facilities, essential infrastructure, equipment, infrastructure, training, etc.) is needed to protect and effectively manage the NAR and support management actions. Current NEPM staff on O‘ahu includes four state civil service employees and five University of Hawai‘i Pacific Cooperative Studies Unit staff. Staff are responsible for managing Pahole NAR, three other NAR’s on O‘ahu, and various other high priority NEPM managed sites and species on other DOFAW lands. Existing facilities and infrastructure include offices, baseyards and nurseries, management and public access trails, water storage and helicopter landing zones.

Objectives: Maintain and develop sufficient staff and appropriate support (facilities and infrastructure) to protect and effectively manage the Reserve.

Actions:

1. Develop and maintain needed facilities and infrastructure.
2. Ensure sufficient staff and appropriate training and support.

Narrative Description of Actions:

1. Develop and maintain needed facilities and infrastructure – DOFAW needs to develop and maintain facilities, field infrastructure and equipment to ensure the implementation of the strategic and operational plans.

- Acquire sufficient office and baseyard space to support staffing levels within the program and in the field. Current space is at capacity and additional space will be required to meet management needs. The current Waimano Baseyard space is shared with the Ko‘olau Mountains Watershed Partnership (KMWP). While there are many benefits to being co-located, an option for additional space for O‘ahu NEPM would be for KMWP to move to a different facility.
- Maintain and improve NEPM Program facilities at the Nike site (former U.S. Army site). The Nike site is outside the Reserve on FR lands and is managed by the O‘ahu Branch Forestry Program. Some buildings of this facility are currently allocated for use by the NEPM Program for equipment/materials storage, and as a bunkhouse for volunteers and staff. The facility needs regular maintenance (painting, upkeep) as well as Capital Improvement Projects such as replacement of the bulkhead, roof repairs, and asbestos abatement. Portions of the facility are rented to the OANRP, State Civil Defense and for-profit entities. Adjacent facilities include outdoor mid-elevation nurseries (OANRP and PEPP), which also have indoor areas used for storage of equipment and supplies as well as seed storage.
- Maintain and improve NEPM Program facilities at Makiki Baseyard. This facility provides office space for the NEPM Manager as well as a nursery used for propagation of common native plants for habitat restoration.
- Maintain and improve NEPM Program facilities at the Reserve. Field infrastructure and facilities at the Reserve will be limited, small-scale and in many cases temporary to ensure minimal impacts on the environment and natural and cultural resources. These sites include water catchment and helicopter landing zones.

- Maintain public trails. NEPM staff will continue to maintain and improve the Mokulēʻia Trail (Na Ala Hele Program Trail) in collaboration with the Na Ala Hele Program and the volunteer community group, Hawaiian Trail and Mountain Club.
2. Ensure sufficient staff and appropriate resources, training and support are available for staff.
- Ensure that sufficient staffing resources are available directly within the NARS program or through partners that share mutual interests.
 - Assess program needs in the areas of professional experience, skills, and abilities needed to implement the strategic and operational plans.
 - Hire, train, and retain qualified and committed full-time staff.
 - Ensure that formal relationships exist with independent contractors and others that expand the capacity of the NARS program staff to further NARS goals.
 - Build and maintain an organization with the skills, motivation and commitment needed to implement the strategic and operational plans through training and development.
 - Provide opportunities for continuous learning to increase capacities of NARS program staff to achieve high priority goals and objectives.
 - Acquire or upgrade various systems, hardware, software, and office tools to improve collaboration, work flow, and productivity.

CULTURAL RESOURCES

Background: The forest landscape and the native plants and animals found in the Reserve are an important cultural resource. Previous studies and consultation with various Hawaiian groups for projects in the area did not identify any specific sites, legends, traditions or other information relating to the area (DOFAW 2003). NARS strategic plan goals include developing the capacity to effectively address and accommodate constitutionally and statutorily protected cultural values and traditional and customary practices in the NARS (DOFAW 2008). While the NAR does not appear to be currently heavily used for traditional and customary practices, cultural connections with plants and animals in the NAR can be enhanced through the continued incorporation of cultural values and practices in planned outreach and education programs.

Objective: Enhance cultural connections with natural resources of the Reserve while effectively addressing and accommodating constitutionally and statutorily protected cultural values and traditional and customary practices.

Actions:

1. Encourage cultural connections with the forest and native species through ongoing and planned outreach and education programs.
2. Engage with the ‘Aha Moku representative for O‘ahu and the Traditional and Cultural representative on the Natural Area Reserves System Commission (NARSC) to promote better collaboration with the Hawaiian community.
3. Ensure cultural gathering is appropriately monitored and permitted.

Narrative Description of Actions:

1. Encourage cultural connections with the forest and native species through ongoing and planned outreach and education programs - The Reserve's forests and species are an important Hawaiian cultural resource that will continue to be incorporated into educational and outreach programs. Hawaiian dry and mesic forests such as Pahole NAR are particularly rare and declining ecosystems, and the proximity of the Reserve to urban areas and its accessibility provides a unique opportunity to foster the connection between natural and cultural resources.

Planned and existing outreach and education programs include identification of species including their Hawaiian names and cultural uses; potential partnerships with Hawaiian immersion schools and translation of curriculum into Hawaiian; and working with Hawaiian practitioners/ students to develop *oli* specific for entering the Reserve (see Outreach and Education section below).

2. Engage with the 'Aha Moku representative for O'ahu to promote better collaboration with the Hawaiian community - Act 288, Hawai'i Legislative Session Laws 2012, formally recognized the 'Aha Moku System and established the 'Aha Moku Advisory Committee (AMAC) within the Department of Land and Natural Resources. Through the combined efforts of kupuna and Native Hawaiian resource practitioners of the 43 moku in the State of Hawai'i, the 'Aha Kiole Advisory Committee restored the 'Aha Moku System of land and ocean resource management. Dating back to the 9th Century and handed down through oral history and generational knowledge, the 'Aha Moku System was proven to sustain the natural ecosystem and environment of Hawai'i. It is a site-specific and resource based methodology that balances land and ocean resources needed to sustain healthy thriving communities. The 'Aha Moku System uses a foundation based on Native Hawaiian generational knowledge that ensures a community consultation process focused on the health and welfare of natural and cultural resources in Hawai'i. Leialoha "Rocky" Kakuhihewa, Po'o, Moku o Kakuhihewa is the Aha Moku representative for O'ahu and Leimana DaMate is the Executive Director of the Advisory Committee.

The NARSC has a Traditional and Cultural Representative (currently Hi'ilei Kawelo), who assists the Natural Area Reserves System with issues and management of cultural resources.

O'ahu NEPM will reach out to the 'Aha Moku group as well as the NARSC Cultural representative to better communicate and collaborate with the Hawaiian community on management of the NAR.

3. Ensure cultural gathering is appropriately monitored and permitted – There have not been any permits applied for and/or issued for cultural gathering in the Reserve to date although staff has observed evidence of collection of palapalai fern. Cultural practitioners should be encouraged to communicate with managers and apply for permits for gathering of cultural resources to avoid negative impacts to the NAR or overharvesting of certain resources. Practitioners could also be provided with additional information about appropriate sites for gathering to avoid negative impacts to sensitive natural resources (e.g. T&E species). Permits will help staff better monitor cultural uses of certain resources. Other entities such as the Office of Hawaiian Affairs and the

NARSC can assist in developing appropriate guidelines for reviewing/approving NARS Special Use Permit applications involving traditional and customary practices.

EXTERNAL PARTNERSHIPS

Background: Collaboration is critical to expanding the resources available to fulfill NARS mission and goals. Working with partners can increase the effectiveness and efficiency of management with limited resources. In addition, many of the threats to Hawaii's natural resources, such as feral ungulates, invasive weeds, fire, invasive insects, and introduced plant and animal diseases, occur across land ownership boundaries.

Objective: Collaborate with external partners to support NARS mission and goals.

Actions:

1. Communicate regularly on active restoration projects and management objectives with O'ahu Army Natural Resources Program (OANRP) in order to promote collaborative and efficient management efforts.
2. Continue partnerships with adjacent landowners through the Wai'anae Mountains Watershed Partnership (WMWP) to address threats and management needs on a regional basis.
3. Continue working with other groups collaboratively to address joint management needs (e.g. invasive species management, rare plant management, education, monitoring and research, cultural values).

Narrative Description of Actions:

1. Communicate regularly on active restoration projects and management objectives with OANRP in order to promote collaborative and efficient management efforts - OANRP works regularly in the Reserve to stabilize and recover target plant and animal taxa impacted by military training. OANRP management plans and status reports for these species describe detailed management actions, which will continue to be implemented in close coordination with DOFAW staff. On a more frequent basis, OANRP submits action requests monthly and action reports quarterly. DOFAW staff regularly accompanies OANRP staff on management actions that may affect the NAR and participates in training opportunities organized by OANRP.

2. Continue partnerships with adjacent landowners through the WMWP to address threats and management needs on a regional basis - Continued collaboration with the OANRP and other adjacent landowners will enhance the effectiveness of response to regional threats like feral ungulates, weeds and fire. Examples of ongoing and future collaboration include linking restoration sites on Army and NAR land (NEPM Zones), cooperation with T&E recovery actions (snails, rare plants) and watershed scale management activities such as control of ecosystem modifying weeds in the NAR.

3. Continue working with other groups collaboratively to address joint management needs (e.g. invasive species management, rare plant management, education, monitoring and research,

cultural values) - Continued collaboration with other groups in addition to the WMWP and OANRP will also assist Reserve management in various areas. NAR staff will continue to work closely with the following groups:

- OISC to jointly address incipient invasive species of plants and animals.
- OANRP and PEPP on rare plant recovery (OANRP and PEPP).
- SEPP to monitor, provide predator abatement, and habitat protection for snail species currently facing extinction.
- Community groups and volunteers to restore native habitat and species.
- O‘ahu Native Ecosystem Working Group (Priority ONE) serves as an advising committee to facilitate weed control and restoration technology development and research.
- University of Hawai‘i Pacific Cooperative Studies Unit (UH-PCSU) to implement research and trial management actions in the NAR.

OUTREACH AND EDUCATION

Background: DOFAW’s mission includes facilitating partnerships, community involvement and education. The O‘ahu NARS Outreach and Education Program *Ola ka ‘Āina I ke Kaiāulu* is designed to promote outreach and education to achieve various NARS management goals. Several service learning programs are ongoing and are planned to be continued. These include adult and youth service learning programs (*Nā Makua* and *Nā Haumana*) and *Nā Kahu o Pakapakakuāua/Adopt a Forest*. DOFAW outreach staff uses a variety of methods to connect with communities including: youth programs, field trips, websites, social media, press releases, public outreach events, educator workshops, and classroom visits. Due to the accessible location of Pahole NAR, many educational activities are feasible on site. Educational goals will be integrated with other aspects of natural and cultural resource management and research and will be accomplished through a strong reliance on partnerships with schools and other community groups and organizations.

Objectives: Build public understanding and support for the NAR and the state’s unique native resources.

Actions:

1. Maintain and expand Adult and Youth Service Learning Programs.
2. Maintain and expand *Pakapakakuāua/Adopt a Forest* Program.
3. Maintain and expand youth internships.
4. Provide the public with information about the Reserve and ongoing management.

Narrative Description of Actions:

1. Maintain and expand Adult and Youth Service Learning Programs. Volunteer service trips are currently used to promote public understanding and support for conservation. Volunteer groups have regularly assisted with weed control; trail maintenance and restoration projects planting native species. NAR staff will continue these types of programs because they provide educational opportunities for interested groups and individuals to learn more about the Reserve

and Reserve management programs. In addition, volunteers contribute useful assistance in labor-intensive activities.

2. Maintain and expand *Pakapakakuāua* Adopt a Forest Program. This program supports Objective 7.1 of the NARS strategic plan is to strengthen natural resource education in grades K-12 and in institutions of higher learning to enhance understanding of key native resource management concepts and encourage inquiry, problem solving and community service. Additionally, a goal of this program is to complement NARS management objectives, particularly for invasive species control and habitat restoration. While high school level students in upper level environmental studies classes will be the primary target, the program can easily be adapted to fit the needs of lower grades and other types of classes.

Sites used will generally be accessible areas along the Mokulē‘ia Trail in the Kapuna drainage. The areas chosen are made up of a mixture of native mixed-mesic forest with some strawberry guava which seems to be the easiest and best invasive species target for student or youth focused service-learning groups. Planned future projects include:

- Increase program awareness and participation.
 - Improve visibility of program through creation of a logo and improvements in the website.
 - Increase school participation by sending informational materials to various schools to generate additional participating schools and potentially working with other partners such as KUPU E²U program.
 - Enable Hawaiian immersion schools to participate in the program through ‘ōlelo Hawai‘i by adapting the program guide and instructions.
 - Assist schools with supplies (e.g. tents, field equipment) and transportation.
- Develop new projects with students.
 - Create an internet application to assist hikers on the Mokulē‘ia trail with identification of plants and other general points of interest.
 - Monitor height and circumference of trees in program plots.
 - Work with Hawaiian practitioners/ students to develop *oli* specific for entering the Reserve.
 - Update the Pahole dichotomous plant key (for plant identification) by developing a digital version with improved photos and drawings.
 - Display student data on the web site for other students and staff so data can be used for science projects, science fair and/or to look at changes in monitored resources over time (e.g. increases or decreases in invasive species).
 - Have students write essays or create videos about their experiences to post on a web site to share with other students.
 - Continue collaboration with Mililani High School Youth Envisioning Sustainable Futures project, in which the students make posters, videos about research or surveys on topics related to sustainable futures.
 - Assist interested teachers with developing native gardens at their schools to help familiarize the students with native plants from Pahole NAR.
- Habitat and native species restoration projects.

- Increase numbers of common native plants available through the Makiki Nursery to use for student restoration outplanting projects.
- Develop improved procedures for maintaining and using appropriate plants from school based nursery programs, including plant sanitation.
- Manage native non-endangered *Philonesia* snails near the Mokulē‘ia trail.
- Ensure there are sufficient resources such as vehicles and DOFAW staff trained and available to assist with outreach and education programs.
- Improve overall program by soliciting feedback from students and teachers.

3. Maintain and expand youth internships – The NEPM program is planning on continuing participation in the State of Hawai‘i Youth Conservation Corp (YCC) Program, which enables young adults to gain entry-level experience as they work with natural resource professionals to conduct natural resources management. Internships often lead to future jobs or advanced degrees in natural resource management.

4. Provide the public with information about the Reserve and ongoing management –NEPM staff will work with DOFAW Outreach staff and partners such as OANRP and the WMWP to share information on Reserve resources and management through the web, social networking, video, and traditional media. NEPM staff will also provide presentations and outreach to researchers and managers, schools and community groups to communicate research findings and management goals. Limited educational signage will be used on roads and trails on site will be used to increase public knowledge about the NAR.

SECTION III - MANAGEMENT ACTION SUMMARY AND ESTIMATED BUDGET

Action	Description	Periodic estimated costs		Annual estimated costs	Estimated Total Cost (15 years)
		Amount	Time scale		
MANAGEMENT OF NATURAL RESOURCES					
<i>Invasive Plant Control</i>					
1. Prevent the establishment of habitat modifying weeds in the NAR.	DOFAW staff, supplies/materials	0	0	2,000	30,000
2. Control target weeds within the highest priority intact native areas of the NAR.	DOFAW staff, supplies/materials	0	0	35,000	525,000
3. Contain and suppress target weeds to prevent further establishment and spread.	DOFAW staff, supplies/materials	0	0	5,000	75,000
4. Monitor weeds to detect changes in long term distribution and abundance in the NAR.	DOFAW staff, supplies/materials	0	0	3,000	45,000
5. Support research including improved weed control and monitoring techniques for the NAR.	DOFAW staff, supplies/materials	0	0	5,000	75,000
<i>Invasive Animal Control</i>					
1. Feral Ungulate Management <ul style="list-style-type: none"> • Fencing • Ungulate Control 	DOFAW staff, supplies/materials	0	0	5,500	82,500
2. Invasive Animal Management	DOFAW staff, supplies/materials	0	0	1,000	15,000
<i>Habitat Restoration</i>					
1. Control invasive plants within NEPM Zones.	Covered in #2 Invasive Plant Control	0	0	0	0
2. Restore NEPM zones through planting of common native species.	DOFAW staff, supplies/materials	0	0	20,000	300,000
3. Monitor restoration efforts.	DOFAW staff	0	0	800	12,000
<i>Rare Species Restoration</i>					

Action	Description	Periodic estimated costs		Annual estimated costs	Estimated Total Cost (15 years)
		Amount	Time scale		
1. Snail Restoration	DOFAW staff, SEPP	0	0	10,000	150,000
2. Rare Plant Restoration	DOFAW staff, supplies/materials	0	0	7,000	105,000
3. Arthropod Restoration	DOFAW staff, HIP	0	0	10,000	150,000
4. Vertebrate Wildlife Restoration	None	0	0	0	0
Research and Monitoring					
1. Continue ongoing monitoring programs for ungulates, weeds, <i>A. mustelina</i> and rare plants	Covered by other sections	0	0	0	0
2. Develop and/or identify appropriate monitoring protocols and implement monitoring for key community indicators that are not currently being monitored.	TBD	0	0	0	0
3. Encourage research including applied research with direct relevance to land management and threats	DOFAW staff	0	0	10,000	150,000
INTEGRATION WITH OTHER DLNR AND DOFAW PROGRAMS					
Fire Management					
1. Implement fire prevention measures, including fire breaks, educational outreach to neighbors and signage along roads.	DOFAW staff and contractor	0	0	10,000	150,000
2. Suppress fires safely and aggressively using appropriate means.	Falls under DOFAW fire budget	0	0	0	0
3. Continue NAR staff training and certifications for effective and safe fire response.	DOFAW staff	0	0	2,000	30,000
Enforcement					
1. Explore opportunities to collaborate with DOCARE to improve voluntary compliance with laws and strategies to improve the effectiveness of enforcement.	DOFAW staff	0	0	200	3,000

Action	Description	Periodic estimated costs		Annual estimated costs	Estimated Total Cost (15 years)
		Amount	Time scale		
ADMINISTRATION AND INFRASTRUCTURE					
1. Develop and maintain needed facilities and infrastructure.	DOFAW staff, contracts	0	0	3,000	45,000
2. Ensure sufficient staff and appropriate training and support.	DOFAW staff and contracts	0	0	1,500	22,500
CULTURAL RESOURCES					
1. Encourage cultural connections with the forest and native species through ongoing and planned outreach and education programs.	TBD	0	0	0	0
2. Engage with the Aha Moku representative of O'ahu to promote better collaboration with the Hawaiian community.	TBD	0	0	0	0
3. Ensure cultural gathering is appropriately monitored and permitted.	TBD	0	0	0	0
EXTERNAL PARTNERSHIPS					
1. Communicate regularly on active restoration projects and management objectives OANRP in order to promote collaborative and efficient management efforts.	DOFAW staff	0	0	1,000	15,000
2. Continue partnerships with adjacent landowners through the WMWP to address threats and management needs on a regional basis.	None	0	0	0	0
3. Continue working with other groups collaboratively to address joint management needs (e.g. invasive species management, rare plant management, education, monitoring and research, cultural values).	DOFAW staff	0	0	2,000	30,000
OUTREACH AND EDUCATION					

Action	Description	Periodic estimated costs		Annual estimated costs	Estimated Total Cost (15 years)
		Amount	Time scale		
1. Maintain and expand Adult and Youth Service Learning Programs.	DOFAW staff, supplies/materials	0	0	3,000	45,000
2. Maintain and expand Pakapakakuāua/Adopt a Forest Program.	DOFAW staff, supplies/materials	0	0	10,000	150,000
3. Maintain and expand youth internships.	DOFAW staff, supplies/materials	0	0	5,000	75,000
TOTAL COST				152,000	2,280,000

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Appendix A. Rare Plants

Species	Species Code	Common Name	Status*	Management Designation **	Pahole Critical Habitat	Wild/ Reintroduction/ Introduction***
<i>Alectryon macrococcus</i> var. <i>macrococcus</i>	AleMacMac	mahoe	LE	OANRP (MFS)	X	Wild (extant)
<i>Alphitonia ponderosa</i>	AlpPon	kauila	SOC	PEPP		Wild (extant)
<i>Asplenium dielfalcatum</i>	AspDie	no common name	LE	O'ahu DOFAW	X	Wild (extant)
<i>Bonamia menziesii</i>	BonMen	No common name	LE	O'ahu DOFAW	X	Wild (historical)
<i>Cenchrus agrimonioides</i> var. <i>agrimonioides</i>	CenAgrAgr	kāmanomano	LE	OANRP (MFS)	X	Wild (extant) & reintroduction
<i>Chrysodracon forbesii</i>	ChrFor	hala pepe	LE	O'ahu DOFAW		Wild (extant)& reintroduction
<i>Clermontia persicifolia</i>	ClePer	‘ōhā wai	No status	O'ahu DOFAW		Wild (extant) & reintroduction
<i>Colubrina oppositifolia</i>	ColOpp	kauila	LE	PEPP-POP	X	Wild (historical) & reintroduction
<i>Cryptocarya oahuensis</i>	CryOah	hōlio	LE	PEPP		Introduction
<i>Ctenitis squamigera</i>	CteSqu	pauoa	LE	PEPP		Not present in Reserve
<i>Cyanea grimesiana</i> subsp. <i>obatae</i>	CyaGriOba	hāhā	LE	OANRP (MFS)/ PEPP	X	Wild & reintroduction
<i>Cyanea longiflora</i>	CyaLon	hāhā	LE	OANRP (MFS)	X	Wild & reintroduction
<i>Cyanea superba</i> subsp. <i>superba</i>	CyaSupSup	hāhā	LE	OANRP (MFS)/ PEPP	X	Wild (historical) & reintroduction
<i>Cyanea membranacea</i>	CyaMem	hāhā	No status	O'ahu DOFAW		Wild (historical) & reintroduction
<i>Cyrtandra dentata</i>	CyrDen	ha'iwale	LE	OANRP (MFS)	X	Wild (extant)
<i>Delissea waianaeensis</i>	DelWai	No common name	LE	OANRP (MFS)	X	Wild (extant) & reintroduction
<i>Dissochondrus biflorus</i>	DisBif	false bristlegrass	SOC	PEPP		Wild (extant)
<i>Embelia pacifica</i>	EmbPac	kilioe	No status	O'ahu DOFAW		Wild (historical)
<i>Erythrina sandwicensis</i>	ErySan	wiliwili	SOC	O'ahu DOFAW		Wild (extant)
<i>Euphorbia herbstii</i>	EupHer	‘akoko	LE	OANRP (MFS)/ PEPP		Wild (extant) & reintroduction
<i>Exocarpos gaudichaudii</i>	ExoGau	hulumoa	SOC	O'ahu DOFAW		Wild (historical)
<i>Flueggea neowawraea</i>	FluNeo	mēhamehame	LE	OANRP (MFS)/ PEPP	X	Wild (extant) & reintroduction

Species	Species Code	Common Name	Status*	Management Designation **	Pahole Critical Habitat	Wild/ Reintroduction/ Introduction***
<i>Gardenia brighamii</i>	GarBri	nānū, nā'ū	LE	PEPP		Introduction
<i>Gouania vitifolia</i>	GouVit	No common name	LE	PEPP		Not present in Reserve
<i>Gynochodes trimera</i>	GynTri	noni kuahiwi	SOC	O'ahu DOFAW		Wild
<i>Hespermomania arbuscula</i>	HesArb	No common name	LE	OANRP (MFS)	X	Reintroduction
<i>Isodendron laurifolium</i>	IsoLau	aupaka	LT			Introduction
<i>Kadua degeneri</i>	KadDeg	No common name	LE	OANRP (MFS)	X	Wild (extant)
<i>Labordia kaalae</i>	LabKaa	kamakahala	SOC	O'ahu DOFAW		Wild (extant)
<i>Lobelia yuccoides</i>	LobYuc	pānaunau	SOC	O'ahu DOFAW		Wild (historical)
<i>Melicope sandwicensis</i>	MelSan	No common name	SOC	O'ahu DOFAW		Wild (extant)
<i>Mezoneuron kawaiense</i>	MezKav	uhiuhi	LE	PEPP		Reintroduction
<i>Neraudia angulata</i>	NerAng	No common name	LE	OANRP (GSC)/ PEPP		Wild (historical)
<i>Neraudia melastomifolia</i>	NerMel	ma'aloa	No status	O'ahu DOFAW		Wild (extant)
<i>Nothocestrum longifolium</i>	NotLon	'aiea	SOC	PEPP-ROI		Wild (extant)
<i>Nototrichium humile</i>	NotHum	kulu'ī	LE	OANRP (GSC)	X	Wild (extant) & reintroduction
<i>Ochrosia compta</i>	OchCom	hōlei	SOC	O'ahu DOFAW		Wild (extant)
<i>Phyllostegia kaalaensis</i>	PhyKaa	No common name	LE	OANRP (MFS)	X	Reintroduction
<i>Plantago princeps</i> var. <i>princeps</i>	PlaPriPri	laukahi kuahiwi	LE	OANRP (GSC)	X	Wild (extant)
<i>Platydesma cornuta</i> var. <i>decurrens</i>	PlaCorDec	pilo kea	LE	O'ahu DOFAW		Wild (extant) & reintroduction
<i>Polyscias kawaiensis</i>	PolKav	'ohe'ohe	No status	O'ahu DOFAW		Wild (historical)
<i>Polyscias sandwicensis</i>	PolSan	'ohe makai	SOC	O'ahu DOFAW		Reintroduction
<i>Pritchardia kaalae</i>	PriKaa	loulu	LE	O'ahu DOFAW		Reintroduction
<i>Pteralyxia macrocarpa</i>	PteMac	kaulu	LE	O'ahu DOFAW	X	Wild (extant)
<i>Schiedea kaalae</i>	SchKaa	No common name	LE	OANRP (MFS)/ PEPP	X	Reintroduction
<i>Schiedea nuttallii</i>	SchNut	No common name	LE	OANRP (MFS)/ PEPP	X	Wild (extant) & reintroduction
<i>Schiedea obovata</i>	SchObo	No common name	LE	OANRP (MFS)/ PEPP	X	Wild (extant) & reintroduction

Species	Species Code	Common Name	Status*	Management Designation **	Pahole Critical Habitat	Wild/ Reintroduction/ Introduction***
<i>Urera kaalae</i>	UreKaa	opuhe	LE	PEPP		Not present in Reserve
<i>Zanthoxylum kauaense</i>	ZanKau	a'e	SOC	O'ahu DOFAW		Wild (extant)

* Federal Status: Listed Endangered (LE); Listed Threatened (LT); Candidate (C) = Taxa for which substantial information on biological vulnerability and threat(s) support proposal to LE. Species of Concern (SOC) = Taxa for which available information meets the criteria for concern and the possibility to recommend C.

** Management Designation describes lead entities for particular plant taxa. These include focal species for management by Oahu DOFAW, PEPP and OANRP: MFS = Manage for Stability; GSC= Genetic Storage Collection
 POP-PEPP species are potentially PEPP (usually <100 or one site only); ROI-PEPP are Rare On Island (usually <20 individuals on Oahu)
 OANRP/PEPP species are PEPP species that are co-managed by OANRP and PEPP.

*** Wild is a naturally occurring wild population either extant (currently occurs in Reserve) or historic (known from historic records but wild population are no longer known from Reserve).
 Reintroduction is defined as reintroducing individuals back into the wild within its historic range for the purpose of establishing new populations
 Introduction involves introducing plant taxa outside its historic range
 Species not present in Reserve are plant taxa that are being considered for potential Introduction to the Reserve

Appendix B - Non-Native Plant Species List Pahole NAR

Species Name	Species Code	Abundance	Fenceline Hazard (Y/N)	Incipient (Y/N)	Target Control (Y/N)	Notes
<i>Abutilon grandifolium</i>	Abugra	Rare				
<i>Acacia mearnsii</i>	Acamea	Rare			Yes	Locally common outside of NAR, zero tolerance within NEPM zones.
<i>Achyranthes aspera</i>	Achasp	Locally Abundant	Yes		Yes	Maintenance control along fence lines and management trails.
<i>Adiantum hispidulum</i>	Adihis	Locally Common				
<i>Adiantum raddianum</i>	Adirad	Locally Common				
<i>Ageratina adenophora</i>	Ageade	Locally Abundant			Yes	Target around T&E.
<i>Ageratina riparia</i>	Agerip	Locally Common			Yes	Target around T&E.
<i>Ageratum conyzoides</i>	Agecon	Locally Abundant			Yes	Target around T&E.
<i>Albizia chinensis</i>	Albchi	Rare		Yes		One OANRP ICA along Nike access road at Peacock flats gate.
<i>Anagallis arvensis</i>	Anaarv	Locally Abundant				
<i>Andropogon virginicus</i>	Andvir	Locally Common			Yes	Target around T&E.
<i>Angiopteris evecta</i>	Angeve	Locally Abundant			Yes	OANRP conducts sweeps within Keawapilau gulch. Zero tolerance within NEPM zones.
<i>Araucaria columnaris</i>	Aracol	Rare			Yes	Control is difficult on large trees.
<i>Areca sp.</i>	Aresp.	Rare				
<i>Asystasia gangetica</i>	Asygan	Rare				
<i>Axonopus fissifolius</i>	Axofis	Locally Abundant				
<i>Begonia hirtella</i>	Beghir	Locally Common			Yes	
<i>Bidens pilosa</i>	Bidpil	Rare				
<i>Blechnum appendiculatum</i>	Bleapp	Widely Abundant			Yes	Control difficult. More herbicide trials needed. Target as feasible within NEPM zones. Avoid outplanting T&E species near or within.
<i>Buddleia asiatica</i>	Budasi	Widely Common			Yes	
<i>Casuarina glauca</i>	Casgla	Rare			Yes	Control difficult.

Species Name	Species Code	Abundance	Fenceline Hazard (Y/N)	Incipient (Y/N)	Target Control (Y/N)	Notes
<i>Cenchrus ciliaris</i>	Cencil	Rare				
<i>Cerastium fontanum</i>	Cerfon	Rare				
<i>Chrysopogon aciculatus</i>	Chraci	Rare				
<i>Cirsium vulgare</i>	Cirvul	Rare			Yes	Observed in Peacock flats campground. Control if seen in NAR.
<i>Citrus sp.</i>	Citsp.	Rare				
<i>Clidemia hirta</i>	Clihir	Widely Abundant			Yes	Control around T&E and as feasible within NEPM zones.
<i>Commelina diffusa</i>	Comdif	Widely Common			Yes	
<i>Conyza canadiensis</i>	Concan	Sparse Everywhere				
<i>Crassocephalum crepidioides</i>	Cracre	Rare				
<i>Cryptostegia grandiflora</i>	Crygra	Rare		Yes		One OANRP ICA along Nike access road near Dillingham Ranch.
<i>Cuphea carthagenesis</i>	Cupcar	Rare				
<i>Cyclosorus dentata</i>	Cycden	Widely Common			Yes	Control around T&E.
<i>Cyclosorus parasiticus</i>	Cycpar	Widely Common			Yes	Control around T&E.
<i>Cyrtomium falcatum</i>	Cyrfal	Locally Common				
<i>Deparia petersonii</i>	Deppet	Locally Common				
<i>Desmodium incanum</i>	Desinc	Locally Common			Yes	Control around T&E.
<i>Desmodium intortum</i>	Desint	Rare	Yes	Yes		Prevalent along access road. Prevent establishment within NAR. Control along high traffic corridors.
<i>Desmodium tortuosum</i>	Desint	Locally Common				
<i>Digitaria ciliaris</i>	Digcil	Rare				
<i>Digitaria insularis</i>	Digins	Rare				
<i>Drymaria cordata</i>	Drycor	Locally Abundant				
<i>Ehrharta stipoides</i>	Ehrsti	Rare	Yes	Yes		Four ICAs. Easily spread via footwear. Olopua flats ICA is difficult to control due to thick vegetation.
<i>Eleusine indica</i>	Eleind	Rare				

Species Name	Species Code	Abundance	Fenceline Hazard (Y/N)	Incipient (Y/N)	Target Control (Y/N)	Notes
<i>Emilia fosbergii</i>	Emifos	Locally Common			Yes	Control around T&E.
<i>Eragrostis sp.</i>	Erasp.	Rare				
<i>Erechtites valerianifolia</i>	Ereval	Locally Common			Yes	Control around T&E.
<i>Erigeron karvinskianus</i>	Erikar	Rare			Yes	Zero tolerance within NEPM zones.
<i>Eucalyptus robusta</i>	Eucrob	Locally Abundant				Control difficult.
<i>Eucalyptus saligna</i>	Eucsal	Locally Abundant				Control difficult.
<i>Eucalyptus spp.</i>	Eucsp	Locally Abundant				Control difficult.
<i>Ficus microcarpa</i>	Ficmic	Rare			Yes	Control difficult. Continue herbicide trials and control within NEPM zones as feasible.
<i>Ficus rubiginosa</i>	Ficrub	Rare			Yes	Control difficult. Continue herbicide trials and control within NEPM zones as feasible.
<i>Flindersia brayleyana</i>	Flibra	Rare				
<i>Fraxinus uhdei</i>	Frauhd	Locally Abundant			Yes	
<i>Gnaphalium purpureum</i>	Gnapur	Locally Common				
<i>Grevillea robusta</i>	Grerob	Locally Abundant			Yes	
<i>Hypochoeris glabra</i>	Hypgla	Rare				
<i>Hypochoeris radicata</i>	Hyprad	Sparse Everywhere				
<i>Hyptis pectinata</i>	Hyppec	Locally Common				
<i>Indigofera suffruticosa</i>	Indsuf	Rare				
<i>Kalanchoe pinnata</i>	Kalpin	Locally Common	Yes		Yes	
<i>Kyllinga brevifolia</i>	Kylbre	Locally Common				
<i>Lantana camara</i>	Lancam	Widely Common			Yes	
<i>Leonotis nepetifolia</i>	Leonep	Locally Common				
<i>Leucaena leucocephala</i>	Leuleu	Locally Common			Yes	
<i>Lonicera japonica</i>	Lonjap	Rare				
<i>Lophostemon confertus</i>	Lopcon	Locally Common				

Species Name	Species Code	Abundance	Fenceline Hazard (Y/N)	Incipient (Y/N)	Target Control (Y/N)	Notes
<i>Malvastrum coromandelianum</i>	Malcor	Rare				
<i>Mangifera indica</i>	Manind	Rare				
<i>Megathyrsus maximus</i>	Megmax	Locally Common			Yes	Contain/suppress target - Found along the entire access road. A population is also spread along rocky talus walls on the west end of the Kapuna drainage making control especially difficult. Control along fence and individuals throughout the reserve are targeted. Staff will monitor spread and as resources become available shall work on an effective containment strategy.
<i>Melaleuca quinquenervia</i>	Melqui	Locally Abundant			Yes	Control difficult.
<i>Melia azedarach</i>	Melaze	Locally Common			Yes	
<i>Melinis minutiflora</i>	Melmin	Locally Abundant			Yes	Control around T&E.
<i>Montanoa hibiscifolia</i>	Monhib	Locally Common			Yes	Contain/suppress target - An established population occurs along the Nike road access to Kapuna gulch and is creeping up to the lower portions of the Reserve. Seeds are wind dispersed thus individual plants and isolated populations are frequently found in the Reserve. There is zero tolerance within management areas (WCAs and NEPM zones) and control is also done outside of management units as feasible.
<i>Nasturtium microphyllum</i>	Nasmic	Rare				
<i>Nasturtium sarmentosum</i>	Nassar	Rare				
<i>Neonotonia wightii</i>	Neowig	Rare	Yes	Yes		Two ICAs. Established along access road. Goal is to prevent establishment within NAR.
<i>Nephrolepis falcata</i>	Nepmul	Locally Common				Apparently hybridizes with the native <i>Nephrolepis exaltata</i> . Control is avoided until further research is conducted.
<i>Oplismenus hirtellus</i>	Oplhir	Widely Abundant			Yes	Target as feasible within NEPM zones to aid in native regeneration.
<i>Oxalis corniculata</i>	Oxacor	Rare				

Species Name	Species Code	Abundance	Fenceline Hazard (Y/N)	Incipient (Y/N)	Target Control (Y/N)	Notes
<i>Oxalis corymbosa</i>	Oxacor	Rare				
<i>Paspalum conjugatum</i>	Pascon	Widely Abundant			Yes	
<i>Paspalum scrobiculatum</i>	Passer	Rare				
<i>Passiflora edulis</i>	Pasedu	Locally Common			Yes	
<i>Passiflora suberosa</i>	Passub	Locally Common			Yes	Zero tolerance within NEPM zones.
<i>Persea americana</i>	Perame	Rare				
<i>Phlebodium aureum</i>	Phlaur	Widely Common				
<i>Phoenix sp.</i>	Phosp.	Locally Common			Yes	Control difficult.
<i>Physalis peruviana</i>	Phyper	Rare				
<i>Pityrogramma calomelanos</i>	Pitcal	Rare				
<i>Plantago lanceolata</i>	Plalan	Locally Common				
<i>Plas stipulare</i>	Plasti	Rare		Yes		One ICA adjacent to Peacock flats campground.
<i>Pluchea symphytifolia</i>	Plusym	Rare			Yes	
<i>Polyscias guilfoyle</i>	Polgui	Rare				
<i>Prunus persica</i>	Pruper	Locally Abundant				
<i>Psidium cattleianum</i>	Psicat	Widely Abundant			Yes	Continue <i>T. ovatus</i> introductions. Control as feasible within NEPM zones.
<i>Psidium guajava</i>	Psigua	Widely Common		Yes	Yes	
<i>Pterolepis glomerata</i>	Pteglo	Rare	Yes	Yes		Two ICAs. Most likely introduced via footwear.
<i>Rhodomyrtus tomentosa</i>	Rhotom	Rare	Yes	Yes		One OANRP ICA along fenceline (bird dispersed). One plant controlled, no plants observed since.
<i>Rhynchelytrum repens</i>	Rhyrep	Sparse Everywhere				
<i>Ricinus communis</i>	Riccom	Rare			Yes	
<i>Rubus argutus</i>	Rubarg	Rare	Yes	Yes		Two ICAs controlled by OANRP.
<i>Rubus rosifolius</i>	Rubros	Widely Common			Yes	Control around T&E.
<i>Sacciolepis indica</i>	Sacind	Locally Common				
<i>Salvia coccinea</i>	Salcoc	Rare				
<i>Schefflera</i>	Schact	Locally Common			Yes	Contain/suppress target - A population begins below the

Species Name	Species Code	Abundance	Fenceline Hazard (Y/N)	Incipient (Y/N)	Target Control (Y/N)	Notes
<i>actinophylla</i>						NAR boundary in Keawapilau gulch. Plants observed are relatively small, although delineation of the population has not been recorded. Fruit is bird dispersed thus plants are occasionally found within the reserve and controlled. Zero tolerance within NEPM zones.
<i>Schinus terebinthifolius</i>	Schter	Widely Abundant			Yes	
<i>Sechium edule</i>	Secedu	Rare				
<i>Setaria gracilis</i>	Setgra	Locally Common				
<i>Setaria palmifolia</i>	Setpal	Rare		Yes		One ICA most likely via footwear. No established populations are known within the NAR.
<i>Sida rhombifolia</i>	Sidrho	Rare				
<i>Solanum americanum</i>	Solame	Rare				
<i>Solanum capsicoides</i>	Solcap	Rare				
<i>Sonchus oleraceus</i>	Sonole	Rare				
<i>Spathodea campanulata</i>	Spacam	Locally Common			Yes	
<i>Spathoglottis plicata</i>	Spapli	Sparse Everywhere				
<i>Sphaeropteris cooperi</i>	Sphcoo	Rare		Yes	Yes	OANRP ICA. Zero tolerance within NEPM zones, control as seen (no herbicide required).
<i>Sporobolus africanus</i>	Spoafr	Locally Common				
<i>Stachytarpheta cayennensis</i>	Stacay	Locally Common			Yes	Control around T&E.
<i>Syzygium cumini</i>	Syzcum	Locally Common			Yes	
<i>Syzygium malaccensis</i>	Syzmal	Rare			Yes	
<i>Tecomaria capensis</i>	Teccap	Rare		Yes		One OANRP ICA located at the top of ridge dividing gulch 2 and 3.
<i>Tibouchina herbecea</i>	Tibher	Rare		Yes		One seedling discovered at snail enclosure in 2014. No plants observed since.
<i>Toona ciliata</i>	Toocil	Locally Abundant			Yes	
<i>Triumfetta semitriloba</i>	Trisem	Sparse Everywhere	Yes		Yes	Control along high traffic corridors. Control as feasible within NEPM zones.

Species Name	Species Code	Abundance	Fenceline Hazard (Y/N)	Incipient (Y/N)	Target Control (Y/N)	Notes
<i>Verbena litoralis</i>	Verlit	Rare				
<i>Vernonia cinerea</i>	Vercin	Rare				
<i>Wedelia trilobata</i>	Wedtri	Rare			Yes	
<i>Youngia japonica</i>	Youjap	Rare				
<i>Zingiber zerumbet</i>	Zinzer	Locally Abundant			Yes	One OANRP ICA within Pahole gulch 5.

Appendix C. Bird Species List (Pahole NAR and Vicinity)

Taxon	Common Name	Status	Recent Detections*
<i>Acridotheres tristis</i>	common myna	non-native	
<i>Anas wyvilliana</i> x <i>A. platyrhynchos</i>	koloa maoli or Hawaiian duck x mallard hybrid	endemic/non-native hybrid	
<i>Asio flammeus sandwichensis</i>	Pueo or Hawaiian short-eared owl	endemic (state listed endangered)	
<i>Cardinalis cardinalis</i>	northern cardinal	non-native	X
<i>Carpodacus mexicanus</i>	house finch	non-native	X
<i>Cettia diphone</i>	Japanese bush warbler	non-native	X
<i>Chasiempis sandwichensis ibidis</i>	O‘ahu ‘elepaio	endemic (federally listed endangered, Pahole Critical Habitat, last detected in Reserve in 2001)	
<i>Columba livia</i>	rock pigeon	non-native	
<i>Copsychus malabaricus</i>	White-rumped shama	non-native	X
<i>Estrilda astrild</i>	common waxbill	non-native	X
<i>Francolinus erckelli</i>	Erckel's Francolin	non-native	X
<i>Garrulax canows</i>	hwamei, melodious laughing thrush	non-native	
<i>Geopelia striata</i>	zebra dove	non-native	X
<i>Hemignathus flavus</i>	O‘ahu ‘amakihi	endemic	X
<i>Himatione sanguinea</i>	‘apapane	endemic	X
<i>Leiothrix lutea</i>	red-billed leiothrix	non-native	X
<i>Lophura leucomelanos</i>	kalij pheasant	non-native	X
<i>Paroaria coronata</i>	red-crested cardinal	non-native	X
<i>Phaethon lepturus dorotheae</i>	koa‘e‘kea or white tailed tropicbird	indigenous	
<i>Pluvialis fulva</i>	kōlea, Pacific golden plover	indigenous	
<i>Pycnonotus cafer</i>	red-vented bulbul	non-native	X
<i>Pycnonotus jocosus</i>	red-whiskered bulbul	non-native	X
<i>Streptopelia chinensis</i>	spotted dove	non-native	X
<i>Tiaris olivacea</i>	yellow-faced grassquit	non-native	X
<i>Tyto alba</i>	barn owl	non-native	
<i>Zosterops japonicus</i>	Japanese white-eye	non-native	X

* Birds Detected during Point Count Surveys and/or Captured in Pahole NAR 2014-2016. Data provided by Erica Dittmar, Hawai‘i Vertebrate Introduction and Novel Ecosystems (Vine) Project funded by Strategic Environmental Research and Development Program through the Department of Defense

Appendix D. Summary of Research Conducted in Pahole NAR

Researcher/Affiliation	NAR Permit Year(s)	Project
Jeffrey Foster, University of New Hampshire	2015	Seed dispersal networks and novel ecosystem functioning - project investigates the roles of non-native rodents and birds as dispersers of native and non-native seeds and their effects on native plant communities.
Patrick O'Grady, UC-Berkley	2013-2015	Surveys for, and collection of, native arthropods as part of comparative phylogenetic study of Hawaiian arthropods
Rosemary Gillespie, UC-Berkley	2013-2015	1) Conduct studies on groups of arthropods that differ in their ecological roles: 1) determine how members of the group have changed over time in diversity, abundance, and interactions with others in the community and 2) using molecular genetic approaches, assess evolutionary changes, including adaptation and speciation, over the same time period. 2) Evolution of color and diversity in Hawaiian spiders, particularly in the genera Theridion, Tetragnatha and Ariamnes.
Durrell Kapan, UH-Manoa	2014-2015	Status update on Hawaiian Drosophila taxa as part of a collaborative effort led by Karl Magnacca to assess range changes relative to historic records and 2) utilize genomic tools to study the conservation biology, ecology and evolution of two key 'genome enabled' Hawaiian Drosophila groups as models for understanding how to utilize the increased information available from modern genomic methods in Hawaiian conservation, evolution and ecological studies.
Karl Magnacca	2015	Sierola spp. Research, Drosophila spp.
Nicole A. Hynson, UH-Manoa	2015	Conduct surveys to determine whether plant fungal symbionts communities, specifically arbuscular mycorrhizal fungi, are affected by plant invasions
Brendon Holland, UH Manoa	2015	Effects of the introduction of Jackson's chameleon <i>T. jacksonii. xantholophus</i> on rare and endemic invertebrate species. Objectives of this study are to: 1) characterize arthropod diversity and abundance in native mesic forest habitats on O`ahu; 2) determine prey availability and prey preference for environmentally damaging invasive Jackson's chameleons; and 3) predict possible range expansions for the species based on prey availability and preference.
Jason Graham, UH	2014	Invertebrate baseline survey (Hyleus and other bees)
Andersonn Prestes, UH Manoa	2014	Conduct collecting of Hawaiian noctuid moths on the main trails to research the relationships and evolutionary histories of native Hawaiian noctuids, and develop an understanding of the geographical range and ecology of the species.

Researcher/Affiliation	NAR Permit Year(s)	Project
Norine Yeung, UH-CCRT	2012-2014	Native and non-native land snail biodiversity
Mike Hadfield, UH	1993 -2014	Life history of Achatinellid snails (<i>Achatinella</i> spp.)
Paul Krushelnycky, UH-Manoa	2012 - 2013	Assess effects of rat removal on arthropod species in the Wai'anae mountains, O'ahu Arthropod sampling
Karen Muscat, Univ. of Melbourne	2013	Collect <i>Dianella</i> for morphological and molecular assessment
Richard Pender, UH-Manoa	2008-2010	Study of restoration plantings of the endangered <i>Delissea waianaeensis</i> and <i>Cyanea superba</i> subsp. <i>superba</i> to understand pollination/floral biology to identify insect and vertebrate flower. Objectives: 1. To understand what pollinates restoration plantings of <i>D. waianaeensis</i> 2. To identify the breeding system and develop a greater understanding of the floral biology of <i>D. waianaeensis</i> and <i>C. superba</i> subsp. <i>superba</i> .
Naomi Arcand, UH Manoa	2006	Examine the distribution, population structure, and restoration importance of <i>Cibotium chamissoi</i> in forest communities on the island of O'ahu.
Roger Sorell, Lyon Arboretum	2001	Survey for <i>Myrsine punctata</i>
Jessica Garb, UH	1999	Study and collect crab spiders (Araneae:Thomisidae) as part of a study on the phylogenetic relationships among Hawaiian crab spiders.
Mandy Heddle, UH-CCRT	1998, 1996	Survey endemic genus of moths, <i>Scotorythra</i>
Manfred Asche and Hannelore Hoch, Museum of Natural History, Berlin	1998	Observe and collect native Hawaiian leaf and planthoppers (Insecta: Homoptera) and to study their biology and ecology.
Eric VanderWerf, UH	1998; 1996	1) Ecology, evolution and dynamics of disease in Elepaio 2) Search for and study Elepaio
Steven Montgomery	1998, 1996	1) Hawaiian coastal and dry shrubland/forest arthropods to evaluation species for the USFWS T&E species program. 2) Study <i>Vanessa tameamea</i>
Curtis Ewing, UH-CCRT	1998	Distribution, host plant associations, and systematics of native souring beetles, or nitidulids (Coleoptera: Cucujoidea)
Chrissen Gemmill, Smithsonian	1997	Collect leaf material of <i>Pittosporum</i> species for DNA analyses and voucher specimens
Greta Binford, University of Arizona	1996, 1994	Collection of Tetragnathid spiders
Vaughn Sherwood, UH	1996	Search for and study Elepaio
Ken Wood, National Tropical	1996	Population monitoring and collect propagative material of

Researcher/Affiliation	NAR Permit Year(s)	Project
Botanical Garden		Alsinidendron obovatum, A. trinerva and Hedyotis degneri var. degneri and study other rare species to determine their population status.
Steve Evans, UH	1995	Alien Canopy Removal: A Possible Restoration Technique in a Partially Degraded Lowland Mesic Forest of Pahole NAR, O'ahu (MS Thesis, UH Botany 1996).
Dan Polhemus, Bishop Museum	1994	Observe and collect damselflies in the genus Megalagrion
Rosemary Gillespie, UH	1993	Collect specimens of Tetragnatha quasimodo
Patricia Welton	NA	Community Organization and Population Structures Of a Lowland Mesic Forest In Pahole Natural Area Reserve, O'ahu (M.S. Thesis, UH Botany, 1993)
William Perreira, UH Maurice and Katy Tauber, Cornell	1992	Collect endemic green lacewings (Chrysopidae: Anomalachrysa spp.)
Andrew Taylor, UH	1991	Sampled insects
Kenneth M. Nagata, UH	NA	Phytogeography of Pahole Gulch (MA Thesis, 1980 Geography)

Appendix E. Summary of Management Actions by NEPM Zone

OVERVIEW

Most intensive management actions will be focused in high priority areas (NEPM Zones) that contain the highest percentages of native forest cover. The NEPM Zone Management Summary provides additional detail on unique habitats and species found at specific sites, past management actions and the rationale behind planned management of these areas.

This section also summarizes the following:

- General restoration goals and target ecosystem type for site.
- Specific invasive plant and animal threats targeted for management and management approach within these sites.
- The presence of rare and T&E plant species is noted and a list of potential species that are biologically suited for each zone for either reintroduction or as a novel introduction based on predicted climate change trajectories is also provided. The availability of propagules will determine which species is initially planted, after which the species assemblage for that zone will be developed using the known natural associates of the initial reintroduced/introduced there.
- Description and location of partner projects in the same area (e.g. OANRP weed control effort, plantings of T&E species, etc.).
- Areas designated for volunteers and educational purposes.
- Summary of weed control methods

NEPM zones were prioritized based on native dominance and relative intact size feasible for effective management. Also taken into account were T&E presence, ecosystem type represented, accessibility, partner management activity overlap and value for volunteer and/or educational purposes. Zones were delineated utilizing GPS when feasible and staff will continue to modify NEPM zone maps and descriptions as more information and vegetation survey data is collected and as restoration work is conducted. NEPM zones are aligned with Reserve fences, which follow topographical features rather than land ownership boundaries so small portions of the NEPM zones are outside the Reserve boundaries.

Each zone is assigned a class rank. Each associated ranking helps to define the management goals and aids in overall prioritization of management efforts. Class 1 and 2 zones receive the first available resources, while class 3 and 4 zones receive additional resources as available and/or as needed (T&E management etc.). Work will progress into class 3 and 4 zones beginning from an adjacent class 1 or 2 zones when feasible. An exception to this rule would be when large volunteer groups are used to contribute to management efforts. Below depicts each class ranking.

Class 1: Native dominated (100% native overstory). No tolerance for alien overstory, understory is native dominated (>50%). Maintenance level weeding required conducted by staff or well qualified volunteers. Appropriate for restoration and outplanting of T&E and rare species.

Class 2: Native dominated (>50%) overstory with some alien overstory, usually due to T&E presence. Understory is mixed native/non-native. Aggressive maintenance weeding required by staff or well qualified volunteers.

Class 3: Alien dominated with native fragments and/or components. Large restoration efforts required. Zone is critical to the overall goal of establishing larger, more stable NEPM zones. Accessibility is ideal, thus volunteers are frequently utilized.

Class 4: Alien dominated with native fragments and/or components. Large restoration efforts required and zone is a critical component to establishing a larger, more stable NEPM zone. Accessibility is more challenging and thus less favorable for volunteer groups – work conducted primarily by staff and hearty volunteers.

Figure E1. Summary Table of NEPM Zones in order of Management Priority

NEPM Zone	Zone Description	Prioritization
PAH-01	Sapindus/mixed forest	Class 1
PAH-03	<i>A. mustelina</i> Snail Enclosure Site	Class 1
KAP-04	Lower Lama Belt Connecting Transect & Honeybee	Class 1
PAH-02	Delwai and Cyasupsup	Class 2
PAH-04	Herbstii 2/3 Ridge	Class 2
PAH-05	Wild Cyrden, Cyalon & Schnut site	Class 2
PAH-07	Lama forest gulch 5	Class 2
PAH-10	Placordec Reintro site	Class 2
PAH-11	Mākua rim lookout	Class 2
KAP-01	Olopuā Flats	Class 2
KAP-02	Sapindus Restoration Site	Class 2
KAP-05	OANRP Outplanting Upper KK Ridge	Class 2
KAP-06	Lama Patch below Huntershelter	Class 2
PAH-08	Pisonia flats	Class 3
PAH-09	Pahole/Kahanahaiki rim	Class 3
KAP-03	Diverse Mixed patch Lower KK	Class 3
KAP-07	Unit I	Class 3
KAP-08	Honeybee/Transect Ridge Restoration	Class 3
PAH-06	Melsan site	Class 4
PAH-12	2/3 Ridge Restoration	Class 4
PAH-13	Fluneo Gulch Restoration	Class 4
KAP-09	KK Ridge Restoration	Class 4

NEPM zone boundaries and management priorities are flexible and will be regularly revised, as needed. Staff will assess the status of these areas every five years to determine if boundaries of NEPM

zones should be revised due to changing conditions and/or progress achieving management goals. Additionally, priorities for management of these areas may also be adjusted depending on availability of staff resources and management progress.

NOTE: T&E and invasive plant species names in NEPM zone tables use a six letter code. Full species names and associated codes are listed in Appendix A (T&E plants) and Appendix B (invasive plants).

NEPM ZONE SUMMARY DESCRIPTIONS AND MAPS

Detailed descriptions and maps of NEPM Zones in Appendix E. are available for internal DOFAW use only as they contain information and locations for sensitive and T&E Species. The full Appendix E may be available upon request to the O‘ahu NEPM Manager