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Ungulate fencing and management plan for Lualualei Valley, Oahu, Hawaii Final Project Report

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EXECUTIVE SUMMARY

Lualualei Valley is a caldera remnant of the Wai‘anae Volcano on O‘ahu, Hawai‘i, and is composed of a large, flat valley floor, which includes a number of smaller valleys, that slopes gently into an alluvial fan. The majority of the valley is owned by the Navy who use the valley for communications and munitions storage. Numerous plants and animals listed under the Endangered Species Act (ESA; N=27) inhabit Lualualei. Portions of the valley also have been designated as critical habitat for the O‘ahu ‘elepaio (*Chasiempis ibidis*) and 21 plant species. As such, the Navy has an obligation under federal law to protect these species.

Feral ungulates are affecting the majority of the listed species found in Lualualei, particularly the plants and invertebrates. Feral ungulates have long been recognized as a major threat to the health and integrity of native Hawaiian ecosystems due to their ability to alter entire native habitats which lack natural defenses against them, as well as jeopardize the component species that comprise these areas. The development of an ungulate management plan, and fencing to exclude and prevent ingress of feral ungulates to sensitive areas within Lualualei was recommended in the 2011 Integrate Natural Resource Management Plan (INRMP) for Joint Base Pearl Harbor-Hickam of which Lualualei is a part of. This plan fulfills part of those recommendations by identifying and mapping potential fence unit locations, prioritizing areas to be fenced, providing cost estimates for fence construction and maintenance, identifying of compliance requirements, and providing feral ungulate management recommendations for Lualualei.

Field work was conducted during the fall and winter of 2012/2013 and four fencing units were identified. Once these units were identified, a cost estimate and implementation plan was developed for each site and all sites were numerically prioritized using 15 criteria developed by multiple state and federal agency stakeholders.

The following strategy is being recommended for ungulate management to protect listed species in Lualualei Valley:

1. Construction of four ungulate-proof 50” high panel-fence units in the following order of preference: Halona Valley, Mikilua, Kolekole Pass, and Kauaopu‘u. Costs and sizes of each fence unit can be seen in the table below.
2. Ungulate eradication from within these sites immediately following fence construction using a combination of ground based hunting, aerial shooting, and snaring.
3. Semi-annual ungulate control in four areas containing listed plant species on the valley floor encompassing approximately 5.2 km^2 that will not be fenced.
4. At a minimum, quarterly maintenance and monitoring inspections of all fences.

Site	Fence length (m)	Fence Area (ha)	# Species protected	Construction cost	Annual maintenance cost
Halona	6047	220.5	17	$1,249,235.00	$12,000.00
Mikilua	1048	10.9	14	$87,794.33	$8,000.00
Kolekole pass	3304	58.3	0	$184,608.58	$2,000.00
Kauaopuu	1130	0.7	3	$105,843.27	$2,000.00

Based on the existing knowledge of listed species occurrences in the Valley, these management activities will secure a total of 290 ha (14% of the Navy-owned component of Lualualei Valley) of habitat and protect the vast majority of species present in Lualualei Valley

from ungulates. This plan does not address other threats such as weeds, vertebrate predators, disease or fire.

BACKGROUND

Islands make up 1.3% of the U.S. land area yet are home to 43% of species listed under the Endangered Species Act (ESA) and 53% of extinctions (Reaser et al 2007). Invasive species are the primary threat to island ecosystems and are responsible for approximately two-thirds of all island extinctions in the past 400 years (Reaser et al 2007). Hawai‘i not only is the state with the greatest number of threatened, endangered, and extinct species, but also the state with the highest proportion of endemic flora and fauna (Ziegler 2002). Non-native mammals – primarily rats (*Rattus* spp.), cats (*Felis catus*), mongoose (*Herpestes auropunctatus*), goats (*Capra hircus*), sheep (*Ovis aries*), and pigs (*Sus scrofa*), in addition to invasive weeds, disease and fire, have had devastating impacts on ESA listed and at-risk species and are major factors in population declines and extinctions in Hawai‘i and elsewhere (Ziegler 2002, Reaser et al 2007). The purpose of this plan to discuss the specific impacts of ungulate damage to listed species within Lualualei Valley on the Island of O‘ahu, while still acknowledging that other threats exist in addition to ungulates.

Ungulates were first introduced to the Hawaiian Islands over 1,000 years ago when Polynesians brought domestic pigs to the islands followed by Europeans bringing goats, European pigs, sheep, and cattle in the late 18th century (Tomich 1969). Ungulate populations flourished because of the mild climate, abundant food sources, and a lack of predators. Hawaiian flora and fauna evolved over millions of years in the absence of large mammalian herbivores, and lack defenses to browsing such as stinging hairs, repellent odors, or thorns (Ziegler 2002). As such, they are particularly vulnerable to the effects of non-native ungulates. Non-native ungulates alter native ecosystems through browsing, stripping bark off trees, and altering habitat by trampling, soil erosion, digging (pigs), and inhibiting the regeneration of native species (Cabin et al. 2000). Non-native ungulates increase soil disturbance and encourage the spread of nonnative plants which compounds the impacts on native species that are already declining. Finally, feral ungulates also impact human use of native ecosystems through accelerated erosion, reduced water quality and potential for increased disease transmission through creating mosquito breeding habitat (i.e. pig wallows). Fortunately, control methods have been successfully established to mitigate the threat of non-native ungulates on ecosystems in Hawaii.

Fencing has been proven to effectively exclude ungulates from sensitive habitats once they have been removed from within the fenced area, and indeed ungulates have already been successfully removed from several large tracts of sensitive habitat in Hawai‘i. Most fences 50” high are capable of preventing feral goat and pig entry provided that goats are not driven into the fence at a full sprint (i.e. in densely forested areas). In areas where goats are able to get a running start at a fence, a 52 or 55” high fence can be used to ensure that animals cannot jump over it under any circumstances. Fifty-inch high ungulate fencing has been used throughout the Wai‘anae mountains on O‘ahu to exclude ungulates, particularly by the O‘ahu Army Natural Resources Program (OANRP 2003). Once fences have been erected, a variety of methods, from ground based hunting, to snares to aerial shooting can be used to eradicate them from within a fenced area.

Lualualei Valley is a caldera remnant of the Wai‘anae Volcano on O‘ahu, Hawai‘i comprised of a large, flat valley floor, which includes a number of smaller valleys, gently sloping into an alluvial fan. It is the largest valley in leeward O‘ahu at 631 ha in size and ranging in elevation from sea level to 953 m, the third highest peak on O‘ahu. It is bound by Wai‘anae Valley to the north, Nānākuli Valley to the south, 35 km of the Wai‘anae Range on the west, and the Pacific Ocean on the east. The climate ranges from semi-arid at sea level to mesic forest at

the summit of Pu‘u Kaua. The majority of the valley is owned by the Navy who use the valley for communications and munitions storage. For the purposes of this plan, the remainder of the discussion will focus on Navy-owned property.

Numerous federally protected and ESA listed plants and animals inhabit Lualualei: four listed waterbird species, one listed forest bird species, one state-listed owl species, one federally-listed snail species, 21 listed endangered plants, two candidate plant species, and six plant species of concern. In addition, critical habitat areas have been designated within Lualualei for the O‘ahu ‘elepaio (*Chasiempis ibidis*) and 21 plant species. Feral ungulate damage impacts the majority of these species, in particular, the plants and invertebrates and as such efforts are underway to exclude ungulate from areas with high numbers of sensitive species.

Fencing to prevent ingress of feral ungulates was recommended in the 2011 Integrate Natural Resource Management Plan (DON 2011) for Joint Base Pearl Harbor-Hickam of which Lualualei is a part of. In the INRMP recommended management actions (Item 19, table 9-3), fencing of multiple management units was recommended, with Halona Valley on the Southern boundary of Lualualei being identified specifically as a priority site due to the relatively high numbers of listed species present. These management activities would serve as a net benefit to the listed species with ungulate fencing being one of those activities. Finally, Lualualei was also identified as a priority management unit for feral goat management by the 2001 Wai‘anae Mountains Feral Goat Management Group (OANRP 2003) which is an organization comprised of state and federal agencies as well as private landowners. Running along the Wai‘anae summit border of Lualualei are the Palikea, Pualii, and ‘Ekahanui fence units managed by Army Environmental which are also part of the Feral Goat Management Group.

The purpose of this plan is to identify and map potential fence unit locations, prioritize areas to be fenced, provide cost estimates for fence construction and maintenance, identify of compliance requirements, and provide feral ungulate management recommendations for Lualualei Valley. Feral ungulates have been recognized by the Navy as a major threat to the health and integrity of native Hawaiian ecosystems. Their ability to alter entire native habitats, as well as jeopardize the component species that comprise these areas, makes feral ungulate management for Lualualei Valley a high priority. Ungulate control and fencing activities should be done in conjunction with other threat control measures (such as other predator control, weed control, out-planting and fire control) outlined in the INRMP and the USFWS critical habitat designation to provide an ecosystem based management plan for the valley.

INFORMATION GATHERING

Scoping meetings

A scoping and information meeting was held on 26 September 2012 with PRC, Navy officials and a botanist from the O‘ahu Early Detection Program. This meeting served to review access and safety issues for conducting surveys on Navy property, to discuss the sites themselves, and introduce all parties to the project. A second meeting was held with PRC, the Navy, and the USFWS to discuss recommendations from the USFWS on fence locations and sizes prior to conducting the majority of the field work and to give agency representatives background information on the project. USFWS indicated their preference was not only to protect extant populations of listed species, but to also include unoccupied critical habitat in the fenced areas. Upon completion of field work in April 2013, a third meeting was held with the agencies above as well as a representative from the state of Hawai‘i to complete the prioritization exercise. A final meeting was held with Navy representatives in order evaluate the NEPA requirements for the project and to discuss any final recommendations for inclusion in the plan. The initial proposed fencing units provided by the Navy were based almost exclusively on the location of critical habitat for species found within the valley, and not necessarily in areas that could be fenced (Figure 1).

Site visits

A total of thirteen field days were spent conducting site visits, with two to four biologists and fencers participating in each visit. A helicopter overview flight was done in November 2012 to assess access points and general feasibility of candidate fencing sites in the steep, montane areas. Similarly, two vehicle based site assessment were done on the valley floor of Lualualei to determine ground-based access points, and to visit fencing locations that were immediately adjacent to roads. From those three initial assessment visits, the remaining field visits were planned.

Sites that were along roads on the valley floor were assessed for fencing as there were several that contained listed plants (specifically *Abutilon menziesii, Marsilea vilosa* and *Cyperus trachysanthos*). While fencing these sites would be relatively straightforward, it was determined that periodic ungulate control on the valley floor would be much more cost-effective than fencing since ungulates are in low densities in those areas to begin with and the plants appear to be doing well with current management strategies. As such, none of these sites were selected for fencing implementation plans. If it is decided that a fence is needed for those sites in the future, the cost/unit length estimate for the Kolekole pass fence (which is along an existing road and thus easier to build) would provide a comparable estimate.

From the initial site assessments, particularly the aerial overview, it was apparent that the majority of initially proposed fence units in the scope of work were not feasible due to topographical constraints. In order to overcome this while still protecting most of the listed species found in Lualualei, a smaller number of larger fences (rather than a larger number of smaller sized fences) were planned in ArcGIS and Googleearth™ prior to visiting the sites. These sites were selected based primarily on the feasibility of fence construction, but also on the potential to encompass representative individuals from each listed listed species in Lualualei Valley. Once these sites were mapped, they were each visited on foot at least twice if they were selected for implementation plans, and three times in the case of Halona Valley, which was the most complex fence site chosen. Two additional sites that were mapped and visited, but did not

end up having implementation plans done, were along the summit ridge leading to Pu‘u Kaua and joining into the Army ‘Ekahanui fence, and a small, hanging valley on the summit between Kalena and Kaua. These two sites appeared to be ‘fenceable’ when examining GIS data, but once site visits were conducted, it became apparent that they were not. The four areas that were ultimately selected for fence implementation plans were Kauaopuu, Kolekole pass road, Mikilua and Halona Valley and they represent a wide range of ecosystems and support numerous listed species that warrant protection. By fencing these areas and combining that with periodic ungulate control on the valley floor, the Navy would be providing protection from ungulates for the majority of the listed species within Lualualei.

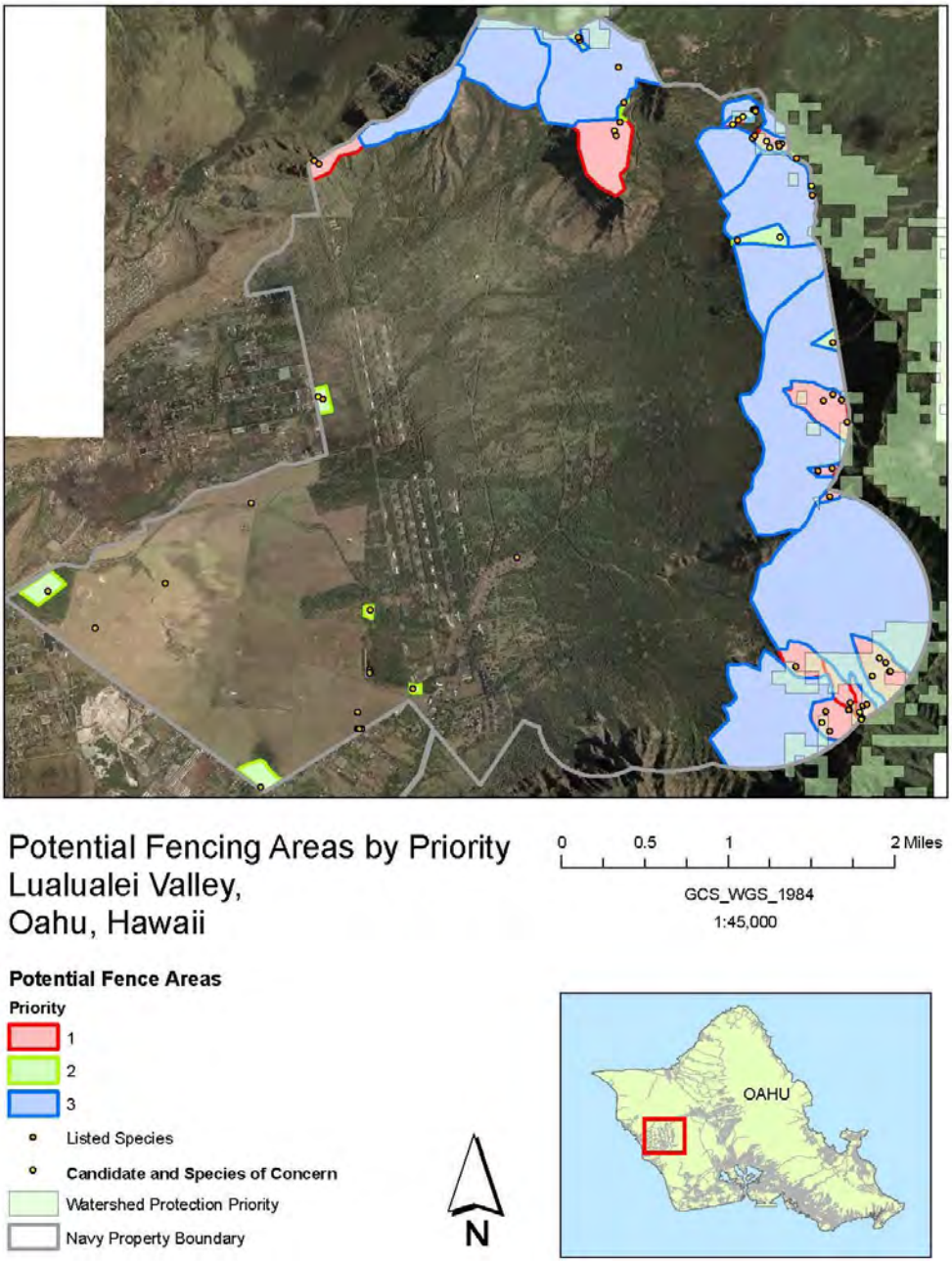


Figure 1: Initial proposed fencing units in Lualualei Valley developed by the Navy

The Kolekole, Mikilua, and Halona fencelines were first flown at low elevation using a Countour Plus™ GPS-enable video camera. This camera recorded video images while simultaneously taking a GPS track. This enabled biologists to review the topography afterwards on a computer and pause the video to determine where specific features or TMK boundaries were on a map. The videos also serve as a useful tool to describe the fence line to others that did not participate in the site visit. After the fly-overs, all proposed fence lines were hiked on foot at least twice while taking GPS tracks of the preferred fence lines. The Kauaopu‘u fence was accessed by vehicle from the valley floor, and due to its relatively small size, it was not feasible to fly the perimeter with the camera because the error associated with the GPS would have caused too much confusion, so only a ground-based GPS track exists for this fence.

Resources protected

The proposed fencing units protect populations of at least 20 endangered species, two candidate species and two species of concern (see table 1). Several of these species occur outside of Navy property and do not have extant populations on Navy property, but are found within the fenceline on adjacent state land. In these cases, Navy owned property within Lualualei is considered critical habitat for these species. Listed species that were not included within the proposed fenced units include the three plants described above that occur on the valley floor, and *Schiedea pentandra* and *Melanthera tenuis*. *Schiedea pentandra*- is found on Pu‘u hapapa which is not fenceable, and *M. tenuis*, while listed as being present in Lualualei, does not have a current location description or GPS coordinates, so it is unknown whether it is included within the fence units.

Table 1- Endangered and candidate species protected by fencing in Lualualei listed by fence site

Species	Status	Halona	Kauaopuu	Kolekole	Mikilua
Abutilon sandwicense	Endangered	yes			yes
Achatinella mustelina	Endangered	yes			yes
Alectryon macrococcus macrococcus	Endangered				yes
Bonamia menziesii	Endangered	yes			yes
Chamaesyce kuwaleana	Endangered		yes	yes	
Diellia unisora	Endangered	yes			
Flueggea neowawraea	Endangered	yes			yes
Hedyotis parvula	Endangered	yes			
Lepidium arbuscula	Endangered	yes			
Lipochaeta lobata leptophylla	Endangered				yes
Lobelia niihauensis	Endangered	yes		yes	yes
Melicope pallida	Endangered	yes			
Melicope Saint-Johnii	Endangered	yes			
Neraudia angulata	Endangered	yes			yes
Nototrichium humile	Endangered				yes
Plantago princeps princeps	Endangered	yes			
Platydesma cornuta var. decurrens	Candidate				yes

Pleomele forbesii	Candidate	yes			yes
Schiedea hookeri	Endangered				yes
Silene Perlmanii	Endangered	yes			
Tetramolopium lepidotum lepidotum	Endangered				yes
Viola chamissoniana chamissoniana	Endangered	yes			yes

PRIORITIZATION AND SITE SELECTION

For the prioritization exercise, a presentation about the fence locations was made by PRC to the agency stakeholder group (Navy, USFWS, Hawai‘i Division of Land and Natural Resources, and Army Environmental employees) described above, the species they protect, and technical considerations involved in building them. The group then developed criteria and weightings that could be used to rank and compare candidate sites. Each proposed fence unit was in a separate row and each criterion listed as a separate column. This allowed participants to rank each site separately and then automatically tally the totals using the weights defined in the ranking spreadsheet.

Determination and weighting of criteria

Fiften ranking criteria that highlighted the biological value, the degree of threat, and various feasibility factors of each proposed fence unit were developed for use in ranking and comparing the proposed fencing sites. A complete description of each criterion, their scale, and weighting can be found in Appendix 1, and are outlined in Table 1 below.

Table 2. Ranking criteria, their numerical scale, and the weight of the ranking

Criteria	Scale	Weight
# Listed species	0- total # species	1
Urgency of listed species	0- total # species	1
Other sensitive species	0- total # species	0.5
Species diversity	1-5	1
Severity of impacts	1-5	1
Potential for future management	1-5	1
Accessibility	1-5	1
Technical feasibility	1-5	1
Length/area protected	1-5	1
Cost	1-5	1
Ability to tie into existing fencelines	1-5	1
Feasibility of predator removal	1-5	1
Potential to control other threats	1-5	1
Potential to use predator proof fencing	1-5	1
Maintenance and fire management potential	1-5	1

By including a variety of criteria the exercise allowed for a numerical comparison of the sites that incorporated both biological and technical factors. The scale of factors ranged from 1-5, with one being the worst and five being the best, or the total number of listed species present. Criteria were weighted based on their importance by multiplying the rank by the weight. An overall score for each site was calculated by summing the ranks of all criteria. Some of the criteria contradicted each other (i.e. high cost was ranked lower, but larger areas ranked higher despite costing more), but these contradicting criteria were kept for informational purposes so that if managers determined at a future date that one factor was indeed more important, they could change the weightings, or eliminate a criteria from completed rankings without having to ask participants to complete the exercise again.

Prioritization summary

Seven recipients returned their ranking sheets and the results were tallied and are presented below. Because some participants chose to weight certain factors differently than others, the total scores were not necessarily comparable, and so both the ranks of the sites (first, second, third, etc.) as well as the total scores were examined across the group. Table three illustrates the ranking sheet and table four shows the average score and overall ranking of each site. Table five provides a summary of the sites.

Table 3: Site ranking results from the prioritization exercise

Site	Rank	Average total score	Total score Std. Dev.	Average rank	Rank Std. Dev.
Halona	1	55.1	15.2	1.4	0.5
Mikilua	2	54.6	14.5	1.6	0.5
Kolekole pass	3	42.4	15.1	3.1	0.4
Kauaopuu	4	40.4	12.4	3.7	0.5

Table 4: Comparison of sites in order of ranking

Site	Fence length (m)	Fence Area (ha)	Ratio area/length (ha/km)	Access	# Species protected	Cost
Halona	6047	220.5	36.5	Good	17	$1,249,235.00
Mikilua	1048	10.9	10.4	Fair	14	$87,794.33
Kolekole pass	3304	58.3	17.6	Excellent	0	$184,608.58
Kauaopuu	1130	0.7	0.6	Good	3	$105,843.27

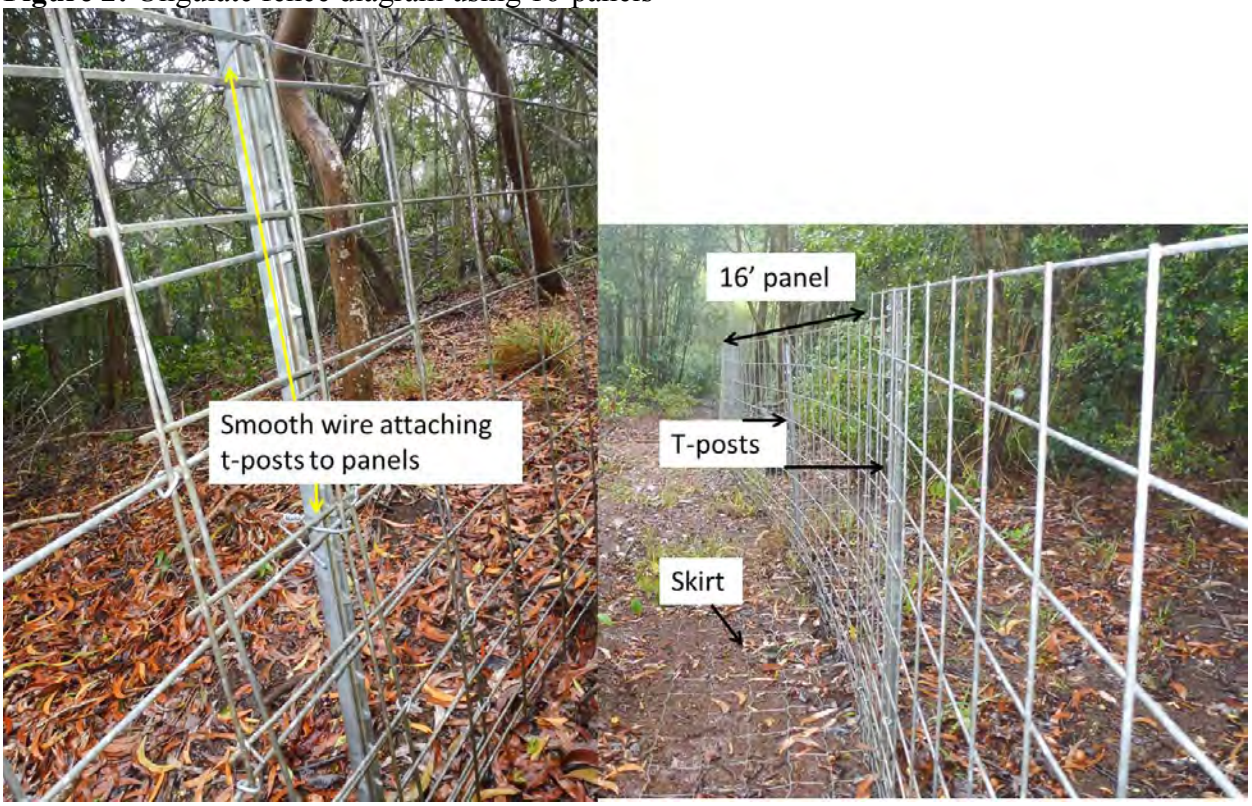
While Halona came out as the highest ranked fencing unit, it was by a small margin to Mikilua in both the total score and average rank. However, given budget constraints and the relatively small size of the Mikilua fence, it may be logical to build the Mikilua unit first while initiating compliance activities for Halona to provide immediate protection to a larger number of listed species since the fence could be built with funding from a single fiscal year and within a relatively short period of time when compared to Halona, and remaining funding could be used to begin the Halona project.

FENCE SPECIFICATIONS AND CONSTRUCTION

All fences described in the implementation plans are intended to exclude feral pigs and goats and the following specifications will be necessary to ensure that animals cannot gain entry into the fenced area after construction. Fences will be 50" high, 16' long combination panels using four gauge class III hot dipped steel. Panel fences are recommended for this project instead of hog-wire because hog wire typically has higher maintenance costs are more susceptible to damage. Sixteen foot span panels have been proven to be ungulate proof against ungulates present in the Waiʻanae mountains and considered to be the industry standard.

Fence specifications

Figure 2: Ungulate fence diagram using 16'panels



Fence panels

Fence panels will be hot dipped galvanized steel 50 inches high by 16 foot long combination panels, quarter inch in diameter (four gauge) with graduated spacing. Panels will be attached to pounded T-posts using nine-gauge smooth wire. At each T-post the panel shall be attached at a minimum of four places; one along the top horizontal, one along the bottom horizontal, and two places evenly spaced in between. Fence panels should be flush along the ground to prevent animals from digging or squeezing underneath. In situations where the ground is uneven, the ground must first be graded to accommodate the fence panel. In event that grading is not enough or not practical, fence panels can be cut to accommodate the shape of the terrain. Successive panels should be attached using hog rings. When attaching two successive panels, a minimum overlap of one column, and ideally two columns of squares must occur to ensure that flex in the fence is minimized. Adjoining panels must also must align and be hog-ringed along the vertical

(not the horizontal) axis. Securing adjoining panels along overlapping vertical axes is the only way to avoid slippage between adjacent panels and is the only acceptable method for connecting panels. A minimum of eight hog rings shall be used to connect adjoining panels; one shall be used at each of the four corners where the two panels overlap, and the other four shall be used at additional areas as needed. Panels may be bent to accommodate slight changes in angle of the fence line, however, when sharp angles are encountered (60 degrees or more) panels should be cut and opposing verticals of the two panels should be interlaced and bent back on themselves.

T-Posts

Posts will be spaced no more than eight feet apart and closer when terrain dictates. At each change in angle of the fence line greater than 30 degrees, three posts shall be used to create the corner. One post shall be driven at the vertex of the angle and two posts shall be driven four feet from either side of the vertex post. Posts shall be driven into the ground so as to withstand 75 pounds vertical pull and any horizontal force that would cause the posts to be uprooted prior to being bent. The T-posts shall be driven by use of a tubular post driver or driving cap in a manner that will prevent damage to the T-post; a Post-mate type driver that attaches around the T-post may also be used. Standing trees or snags should not be used as fence posts. T-posts shall be driven perpendicular to the slope of the terrain so that the height of the fence is not compromised over steep terrain sections.

Skirting

Skirting is not anticipated to be required frequently, but there may be some sections encountered where the soil is loose, where the fence line cuts across potential wash out areas and where the fence is built perpendicular to steep grades in excess of 20 degrees where it is necessary. If skirting is used, hog rings should be used to secure it to the bottom of the panel fence as described above.

Step-overs and stream crossings

The planned fence lines are not anticipated to cross any known stream-beds, however, due to the complexity of the terrain in Halona Valley, any unexpected changes in the fence alignment may require a stream crossing. If a stream is crossed, aprons should be used along the base of the waterways if heavy water flows and/or significant amounts of debris are anticipated to be crossing the area.

Several step-overs will be needed along each fence line. Where the fence follows a trail (such as along summit ridges), the fence should be built in such a way that does not block access to hikers (i.e, situated on one side of the trail or another, but not in the middle).

Site preparation and construction considerations

All of the fence implementation plans will require various amounts of clearing in order to provide an unobstructed corridor and specific site preparation needs are discussed below. The corridor cleared should be no less than four feet and no wider than eight feet to prevent overhanging vegetation from damaging the fence and to prevent feral animals from using vegetation to jump into the enclosures. Any platform (rock, stump etc.) on the outside of the fence more than a foot high should be moved to prevent animals from using it to jump inside an enclosure. In instances were rocks or other features that could provide purchase for animals to jump over the fence are found and cannot be moved, the fence alignment should be adjusted to

avoid these features. Likewise, all T-posts must be pounded perpendicular to the slope to ensure that fence height is not compromised. When panels are placed along uneven terrain, all efforts must be made to first create even terrain by grading the ground to fit the panel. If this is not possible or if large immovable objects cannot be avoided along the path of the fence, such as large boulders, then the fence panel may be cut to fit the shape of the terrain.

All four sites contain features that may potentially need to be avoided and may or may not be currently marked- including archaeological sites, munitions bunkers, unexploded ordinances and occurrences of listed species. The fence alignments described below avoid these features that are currently known, but this may change between the finalization of this report and the construction of the fences. Immediately prior to construction, plant and snail surveys of the precise fence lines will need to be conducted and individual plants/snails flagged in order to be avoided during the construction process.

Assumptions

The costs proposed for each fence are based on several assumptions. If these assumptions change between the time of this report and the time of fence construction, cost estimates should be revised. The assumptions are:

- Cost of global composite carbon steel price of $720 USD/ton and stainless steel 304 price of $2938 USD/ton based on prices obtained in March 2013 when these estimates were produced
- A manpower rate of $25/hr (including fringe). If Davis-Bacon wage rates apply, this rate should be adjusted accordingly.
- Staging areas and sling loads via helicopter will be permitted on Navy property within Lualualei
- Heavy equipment and bulldozing will be allowed on the valley floor in Halona

If these assumptions are not true, or if they change, the cost estimates provided below will likewise change.

MAINTENANCE OF UNGULATE FENCES

A well-built ungulate fence that has been built with precision using proven materials will only be effective in the long term with a regular monitoring and maintenance program. Accidents, vandalism and acts of nature are likely to damage the fence at some point and/or result in an animal breach. A good maintenance and monitoring program will detect the breach immediately upon its occurrence; will have people and resources in place to make emergency repairs; and will have reduced the likelihood of animals entering when a breach occurs.

Many of the projects building ungulate fences aim at achieving complete eradication of all hooved mammalian pests followed by the management and possible reintroduction of threatened indigenous plant and animal species. When these gains have been achieved, the 'biological stakes' will be raised and what can be lost as a result of one hole in the fence will increase substantially. The importance of a well-planned and enforced monitoring and maintenance program in these situations is considerable. In summary the following should be considered:

•An individual within the managing agency should be established as being the primary point of contact for each fence site. This individual will be in charge of scheduling maintenance and monitoring visits (even if they are not the one performing them) and will serve as a point of contact for anyone who needs to report a breach or any other relevant observations on the fence.

• A risk analysis of each fence line should be undertaken regularly (i.e. during each regular monitoring visit) to identify possible areas of weakness. This analysis should identify possible breach sites (such as at the water gates of flood prone streams; adjacent to overhanging trees on steep or wind-prone areas; or next to or in areas of public access).

•To assist in having breaches reported in a timely manner, signs at high-risk areas and/or common public access points should be placed that provides contact information for whom to call in the event that a breach is noticed. Every fence panel should also be tagged with a unique number so that anyone reporting a breach can identify the location easily to Navy personnel (ie. Fence panel #180). These can either be engraved into the fence posts, or added as separate metal tags.

•Managers should make provisions for fence repair supplies to be stored in the vicinity of high-risk areas to facilitate rapid repairs. This can be done by transporting extra materials up at the time of construction and storing them on-site.

•All fences will need to be physically inspected on a regular basis. How regularly this is done depends on the risks prevalent on the site. Proximity to the public (vandalism and accidental damage); the nature and size of animals adjacent to the fence (damage from large livestock such as cattle and horses); the proximity, extent and size of trees; the regularity and severity of flooding; and the regularity of people entering and leaving the fenced area, plus the value of what exists on the inside of the fence all contribute to the risks faced and should determine the regularity of inspection. Inspection may need to be monthly for some fences vs. quarterly for others. Recommendations specific to each site are made in the implementation plans below.

• A physical fence inspection should be undertaken on foot where possible. Walking along the fence line allows the observer to view and inspect the fence closely and directly. Inspections should be periodically undertaken from both sides of the fence.

• To reduce the likelihood of animals entering the protected area through a fence breach, it is recommended that animals be periodically controlled in areas surrounding the fences on the outside. This will reduce the pressure on the fence as well as providing additional protection for threatened species on the outside of protected areas. Methods for conducting ungulate control are discussed in a separate section of this report.

• When a fence breach occurs it is important that any pests that do enter the pest-free area are detected early. If a breach goes unnoticed for some time and there is no pest detection program in place, it may very quickly become necessary for the entire fenced area to be re-eradicated to attain ungulate free status again. Methods for detecting and removing ungulates are discussed later in this report.

While it may not be possible to implement all of these suggestions at every site, they at the very least provide a foundation of the factors that should be considered when managing ungulate proof fences.

COMPLIANCE REQUIREMENTS

Constructing a fence in any natural area, particularly one with listed species, will require a suite of permits and consultations with multiple state and federal agencies. The use of federal funds and the construction on federal land will trigger a section seven consultation under the Endangered Species Act (ESA), National environmental protection act (NEPA) review, and section 106 consultation under the National Historic Preservation (NHP) Act of 1966. As significant historic properties are in the project's area of potential effect (APE) and the project could adversely affect these properties, a section 106 Memorandum of Agreement (MOA) will be required at a minimum for the Halona unit where known cultural features exist.

In cases where the proposed fence follows an existing fence line with an existing environmental assessment (EA), such as for the portion of the Halona fence unit that ties in with multiple Army Environmental fences, the EA and compliance documentation may cover the installation of the new fence. In areas without a fence and/or has a fence but construction of a new fence significantly alters the surrounding area, a new EA may be required. For fences that fall under a categorical exclusion, NEPA requirements (EA, Section 7 consultation) may be waived. For sites where a categorical exclusion cannot be applied, or where an existing EA does not cover the activity, an EA, ESA Section 7 and NEPA consultation will be required. In addition, the Halona and Kauaopu'u fences will cross multiple land owners and negotiations will need to be made with partners for permission to build.

For Kauaopu'u and Halona, the fencelines will fall onto state lands, and for the Kauaopu'u fence, Hawaiian Homelands also owns part of the parcel being fenced. Cooperative agreements will need to be formed with the Hawai'i Department of Land and Natural Resources and Hawaiian Homelands in order to gain permission to build on their land. All four fences also fall within the conservation district in either the general, limited, or protective subzones with protective being the most restrictive. While activities on federal lands are exempt from obtaining a conservation district use permit (CDUP), portions of the fences that fall on state land, particularly those in the protective subzone, may be required to go through the CDUP application process which will require an EA for the specific activity.

While the permits required will vary depending on the location and its zoning, the species present and existing permits (and are discussed for each fence unit in the implementation plans), the list below covers most permits that may be required for fence construction in Lualualei Valley. Many of these permits can be applied for simultaneously greatly shortening the time required to obtain approval.

Table 5: List of permits, issuing agencies, and when permits are required

Permit/Consultation	Issuing/Approving Agency	Requirements
EA	Navy	Development that impacts natural areas
ESA Section 7 Consultation	USFWS	Actions that effect critical habitat and/or ESA species
NEPA	EPA	See above
Section 106 consultation	SHPO, National Historical Register	If historical sites are present (anything older than 1950)
CDUP	DLNR	Protected and limited subzones

UNGULATE REMOVAL AND MANAGEMENT WITHIN FENCES

Once construction on a fence unit is completed and inspected for quality control it will be necessary to remove all non-native mammals from within the fenced areas. In larger units (>50 ha), establishing ungulate transects within the units will facilitate compiling baseline ungulate activity levels and will also help in determining whether an eradication has been achieved. Standard practice among other ungulate management units in the Wai‘anae Mountains are 500 m belt transects that are 5 m wide with monitoring stations installed every 10 m (OANRP 2003). At each station observers record all ungulate sign (feeding, scat, wallows and trails). These same transects can also be used as access point from which to conduct hunts. These transects should then be used to regularly monitor for ungulate sign throughout the eradication period which will help to evaluate the progress of the eradication, and ultimately, whether it is successful. In addition to assisting in eradication procedures, utilizing the same methods will allow for comparison between other units in the Wai‘anae mountains with existing data.

With the exception of Halona Valley, which will require a multi-faceted approach to eliminate ungulates, virtually all ungulates can likely be removed with ground hunting techniques from the remaining fence units. Halona Valley will require a combination of ground hunting, snaring, aerial hunting, and Judas goats. Each technique is described below.

Ground hunting

Ground hunting should be conducted using teams of two to four hunters wearing blaze orange and carrying two-way VHF FM radios for safety purposes. Firearms commonly used in Hawai‘i for ungulate hunting include a variety of calibers (.308, .270, .223) and actions (bolt, lever, semi-automatic), all of which will provide sufficient power to dispatch the species present (Burt and Jokiel 2011). For goats, this method involves using long-range firearms and picking key vantage points to survey for herds and dispatching as many animals at once before they give chase.

To locate pigs, hunters typically walk through an area utilizing existing game trails (or transects if it is a large area) with several hunting dogs trained on pig scent (hound mixes are the breeds typically used). Any located pigs are chased by the dogs and caught or bailed until hunters arrive and dispatch the animal (bull-terriers are typically used for this component). This technique is particularly effective for pigs that are shy of other removal methods, and in areas with small remnant populations.

Snaring

Cable snares consist of a loop of steel cable fastened to a secured or heavy object and situated to catch an animal it passes it’s head through the narrow opening, ultimately killing the animal through suffocation. Multi-strand aircraft quality steel cable snares should be placed strategically along narrow trails used by ungulates using no more than one snare per acre. Whenever feasible, snares should be placed in steep areas so that animals cannot regain their footing and are asphyxiated quickly and humanely. Nooses should be suspended 75-125 cm above the ground and have an aperature of 25-40 cm in diameter (Burt and Jokiel 2011) and be signed above the snare so that they are visible to people. Snares should be serviced relatively frequently when they are first set up to ensure that animals are dispatched humanely, or they can be coupled with remotely triggered infrared cameras that text photographs via cellular networks to determine the fate of animals in the snare.

Aerial hunting

A Hughes 500 helicopter operating with the doors off with one shooter and one spotter on board will facilitate dispatch of animals in hard to reach places. Typical protocols are for the pilot to search frontally, and the shooter sideways. Having ground based spotters to assist those in the air will likely increase the effectiveness of aerial hunts, and in previous hunts in similar terrain, up to nine ground-based spotters were flown into position (Burt and Jokiel 2011). Aerial hunting can be done by flying transects of an area, or other systematic search patterns. Once animals are located from the air, the shooter dispatches them from the helicopter. Previous aerial hunts in Hawai‘i have used Benelli semi-automatic 12 gauge shotguns with 00 buck shot (Burt and Jokiel 2011).

Judas goats

Judas goats are individuals that are outfitted with a tracking device that help lead hunters to herds of wild goats and facilitate their dispatch (Taylor and Katahira 1988). When captured from wild herds (domestic goats may not seek out wild herds and should not be used), Judas goats have been shown to be an effective tool in locating remaining herds of wild goats as displaced individuals (i.e. the ‘Judas’) will attempt to re-join their herds after separation. Ideally, multiple animals from different herds should be used in order to locate different populations of goats.

To obtain a goat from a wild population, they should be net-gunned from a helicopter. Once the animal has been captured, it is then outfitted with a GPS transmitter. Previous studies utilized radio telemetry, but because this requires triangulation in order to locate the animal, it is imprecise and it can be difficult to re-locate the tagged goat. As such, using GPS tags that give a precise reading will better facilitate locating the animal in future hunts.

Once the goat is tagged and released, hunting (ground or aerial) can commence as soon as the next day after release using the GPS coordinates of the animal as a starting point for hunting (aerial or ground based). If snares have been set in the area, hunting using the Judas goat method should begin soon after its release to prevent it from being snared before it can be used to locate other animals. Ideally, the Judas goat should be left alive until all ungulate sign has disappeared, and dispatched either once all sign as disappeared, or when the battery of the GPS unit is expected to stop (whichever comes first) so that it can continue to lead hunters to any remaining animals for as long as possible.

HALONA VALLEY IMPLEMENTATION PLAN

Land ownership

The area within the proposed fence includes lands owned by the Navy and the state of Hawai‘i. It is on preservation land in the limited and protective subzone of the conservation district.

Biological value

Halona Valley is a diverse valley within Lualualei that goes from approximately 1000’ above sea level to 3000’. There are not only numerous listed species, but several examples of good remnant native mesic forest along the summit ridges composed of 'ōhi'a (*Metrosideros polymorpha*), 'uluhe (*Dicranopteris linearis*) and other native forest communities. While the valley floor is dominated by non-native vegetation, the summits and cliffs are still highly desirable habitat.

Table 6: List of listed species found within the Halona fence area

Species
Abutilon sandwicense
Achatinella mustelina
Bonamia menziesii
Diellia unisora
Flueggea neowawraea
Hedyotis parvula
Lepidium arbuscula
Lobeila niihauensis
Lobelia yuccoides
Melicope pallida
Melicope saint-johnii
Neraudia angulata angulata
Neraudia angulata var dentata
Plantago princeps princeps
Pleomele forbesii
Silene Perlmanii
Viola chamissoniana chamissoniana

Site analysis

GPS measured proposed fence length: 6053 m GPS/map estimated area:
GPS/map estimated area: 220.6 ha

This is a large fence encompassing 220.6 ha and is 6053 m in total length. The path largely follows the Wai‘anae summit from Pohakea pass until the ridge that borders Nanakuli and Lualualei, at which point it turns west to go down the ridge that separates the two valleys. Approximately 400m down the ridge, it makes a 90˚ turn to descend into the floor of Lualualei/Halona valley. The path through the valley floor generally parallels Dent Road above

the line of the bunkers and then connects back on an old carriage trail to join up with Pohakea pass.

Of the total length, 2482 m is on relatively flat terrain and is accessible by vehicle. The remainder is helicopter-only access; 2744 m on moderately steep slopes, primarily along the summit ridges, and 827 m along very steep sections- the descents from Pohakea pass, and the descent from the south summit point. Thus the majority of the fence construction will rely on helicopter access and require camping for construction crews. Two cliff-face ties-ins will be required on the two summit descents. Two fences maintained by the Army Natural Resources program (Palehua and Pualii) are present on the summit ridge for a total of 631m of tie in (factored into length estimate provided above).

The substrate on each section of the fenceline also varies, which in turn impacts the equipment needed and the manpower required to install it. The Pohakea pass through the Waiʻanae summit section is ~75% soil and 25% rock; the descent from south summit point and the valley floor is a mix of large boulders and soil.

Figure 3: Halona fence diagram with listed species locations noted in red

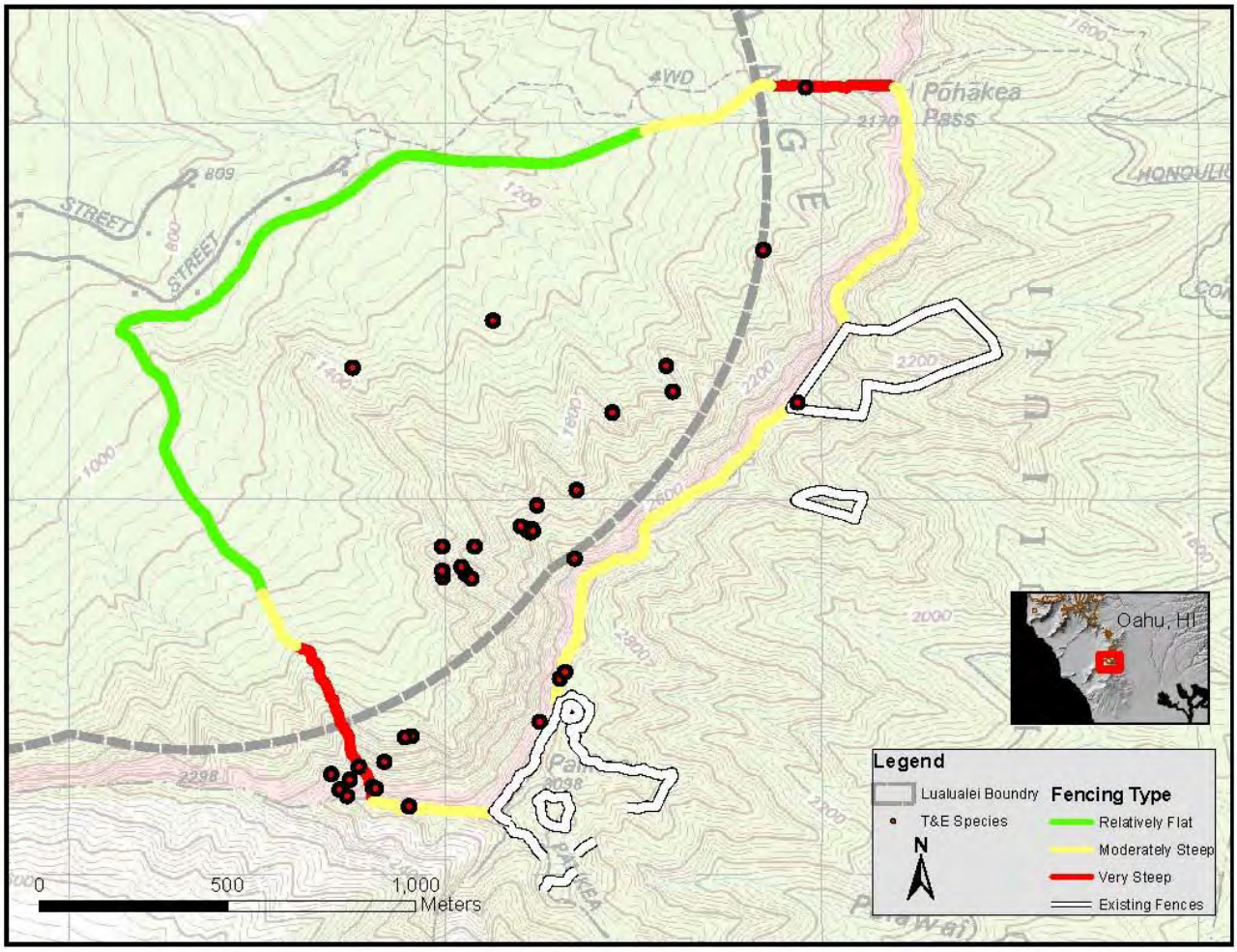
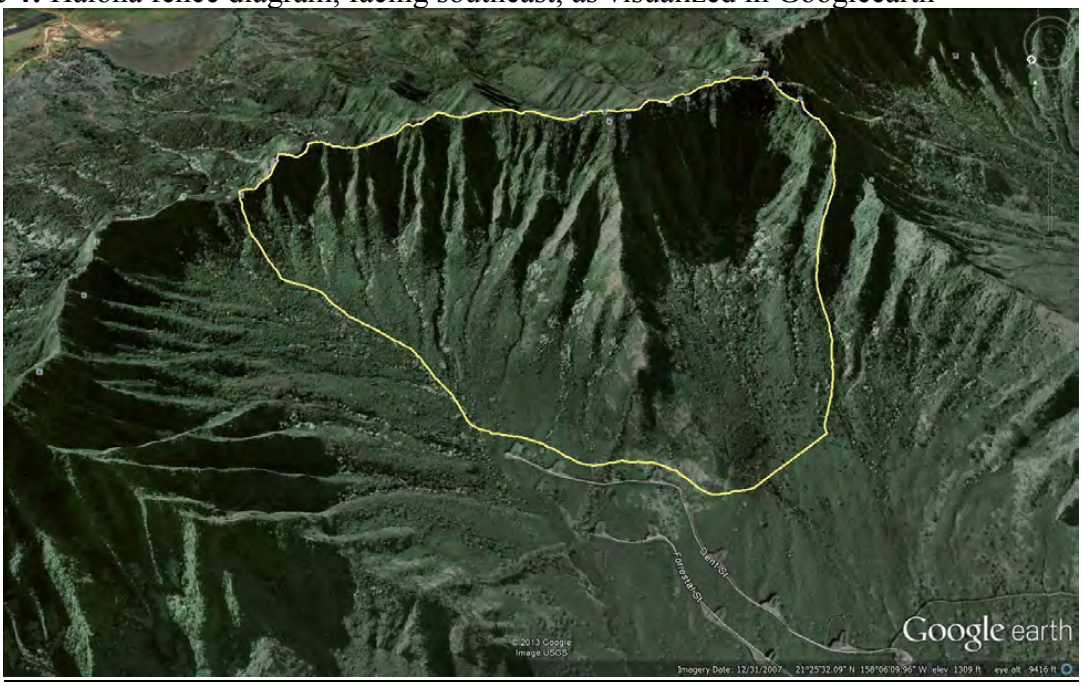


Figure 4: Halona fence diagram, facing southeast, as visualized in Googleearth



Budget

	Cost/Unit	#	Extended
Materials			
50"x16'x 4 gauge class III hot dipped combination panels	$47.00	14000	$658,000.00
133 x 6' galvanized T-posts class III- with spades	$9.00	1800	$16,200.00
133 x 6' galvanized T-posts class III- without spades	$8.00	1000	$8,000.00
304 stainless steel 12-5 gauge smooth softwire	$6.50	200	$1,300.00
Eye bolts			$600.00
Labor	$25.00	8000	$200,000.00
Rentals			
Helicopter slingloads	$1,200.00	50	$60,000.00
Bulldozer rental (cost/week plus $1000 delivery/pickup)	$1,000.00	3	$4,000.00
Fuel for bulldozer	$30.00	120	$3,600.00
Bulldozer operator	$350.00	15	$5,250.00
Trucking loads	$500.00	8	$4,000.00
Subtotal			$960,950.00
Overhead (incl all small equipment, foreman taxes etc)			$288,285.00
Total			**$1,249,235.00**

Maintenance considerations

If constructed this would be one of the larger ungulate fences on O‘ahu, and given the steep terrain and remote location, will present maintenance challenges. In addition to the maintenance recommendations presented earlier, communication should be established between the Navy and Army Environmental who manage the two fences that this fence will tie into (Pualii and Palikea). Those fences are inspected quarterly, and it would be valuable to combine and share monitoring responsibilities of all three fences, at least along the summit ridges. Walking the summit ridge section of this fence takes one full day which means that any maintenance issues encountered during the inspection would have to be dealt with on another visit. The valley floor fence unit can be hiked in a half day, and it would be possible to combine minor maintenance with an inspection on a single day. At a minimum, this fence will require two full days for inspection every quarter, and likely one to two days for any maintenance needs encountered.

For budgeting purposes, 16 days per year with two people per day would cost approximately $8,000 annually based on labor and overhead rates provided in the cost estimate. If helicopter access costs are included for access to the summit section of the fence and cannot be cost-shared with another agency, then an additional $4,000 should be budgeted for helicopter time.

Ungulate removal considerations

Conducting a complete ungulate removal from Halona Valley will be challenging. It is a large area that likely has numerous ungulates, both goats and pigs. Goats were observed on very steep terrain that may not be accessible from the ground to hunters, and heavy pig activity was observed on the summit ridges and in the lowland riparian areas. A combination of snares, aerial shoots, ground hunts and other more sophisticated methods would need to be used for this site, and due to the size, would likely take an extended period of time.

In order to monitor the success of the eradication within Halona, 500 m belt transects should be installed, ideally during construction, to monitor for goat and pig sign. These same transects can also be used as access point from which to conduct hunts. Transects should be 500 m long and 5m wide. Monitoring stations should be installed every 10 m at which observers record all ungulate sign (feeding, scat and trails). These transects could then be used to regularly monitor for ungulate sign throughout the eradication period which will help to evaluate the progress of the eradication, and ultimately, whether it is successful.

Compliance considerations

At least 50% of this fence will be on state land and is in both the limited and protective subzones of the conservation district on the state-owned portion. As a result, a conservation district use permit (CDUP) may be required to construct the fence on state land, and prior to applying for a CDUP, an EA is normally required. To determine whether a CDUP will be needed, an official memo should be sent to the administrator of the office of conservation and coastal lands. If the administrator waives the permit requirement, then an EA will likely not be needed.

During fence line surveys, numerous archaeological features (both marked and unmarked) were encountered on the valley floor. These features will require a section 106 consultation under the NHPA act of 1966.

KAUAOPU‘U IMPLEMENTATION PLAN

Land ownership

The area within the proposed fence includes lands owned by the Navy, the state of Hawai‘i and Hawaiian Homelands. It is on preservation land in the general subzone of the conservation district.

Biological value

Kauaopu‘u is a small, low elevation dryland site approximately 1000’ above sea level. The species diversity is relatively high for a dryland site and it contains a stand of *Dodonaea viscosa* that is uncommon at low elevations. It is primarily rocky with little vegetation cover and surrounded by sheer, rocky cliffs on all sides. These cliffs have provided natural protection for the species listed below, and as such, it is the single largest extant population for *Chamaesyce kuwaleana* and thus an important site for that species.

Table 7: List of listed species found within Kauaopu‘u fenced area

Species
Chamaesyce kuwaleana
Tetramolopium filiforme
Spermolepis hawaiiensis

Site analysis

GPS measured proposed fence length: 1130 m
GPS/map estimated area: 0.7 ha

This is a relatively small fence meant to protect the peak section of Kauaopuu. The fence will be a combination of panel fencing and natural cliff faces and is roughly follows an elevation contour below the peak. The vast majority of the 1130 m length will be on gentle to moderate slopes and on bare rock. While the fence itself does not change much in elevation as it is following an elevation contour, moving around in the area is very difficult as it is very steep and as such, it is expected that it will be somewhat challenging to build.

Figure 5: Kauaopu‘u fence diagram with listed species locations noted in red

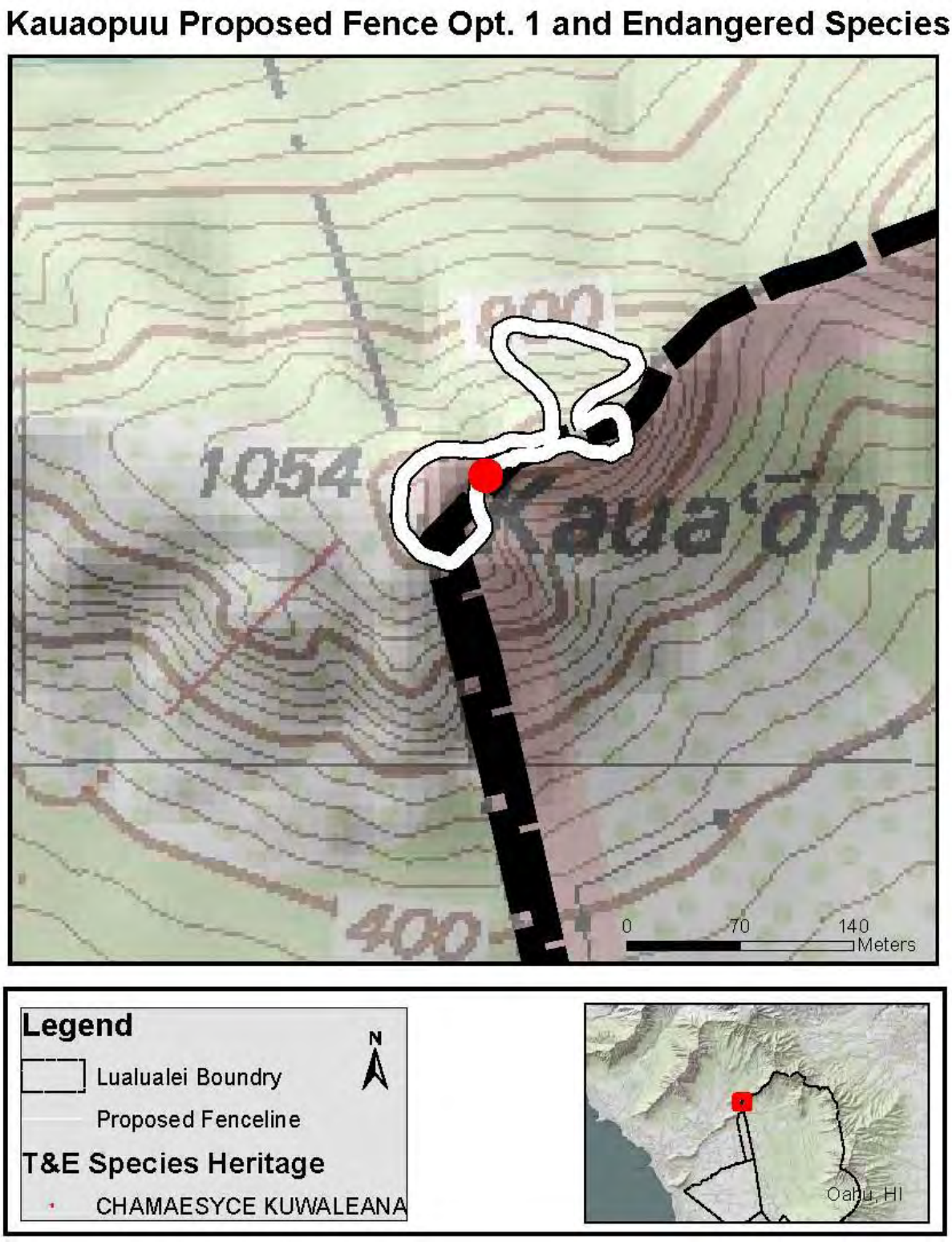
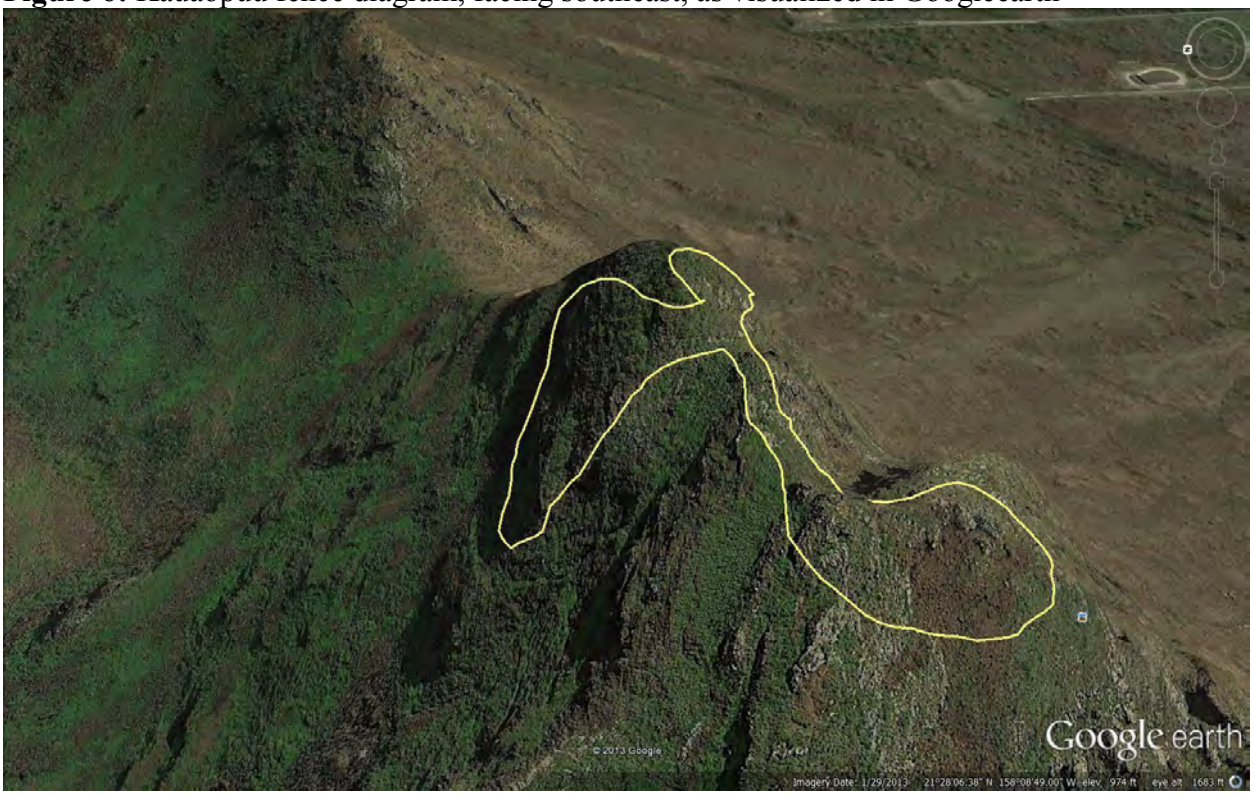


Figure 6: Kauaopuu fence diagram, facing southeast, as visualized in Googleearth



Budget

	Cost/Unit	#	Extended
Materials			
50"x16'x 4 gauge class III hot dipped combination panels	$47.00	250	$11,750.00
133 x 6' galvanized T-posts class III- with spades	$9.00	200	$1,800.00
133 x 6' galvanized T-posts class III- without spades	$8.00	320	$2,560.00
304 stainless steel 12-5 gauge smooth softwire	$6.50	25	$162.50
eye bolts 5/16 x 6" hot dipped galvanized class III	$2.27	20	$45.40
Labor	$25.00	2200	$55,000.00
Rentals			
Helicopter slingloads	$1,200.00	7	$8,400.00
Trucking loads	$500.00	3	$1,500.00
Rock drill	$200.00	1	$200.00
Subtotal			$81,417.90
Overhead (incl all small equipment, foreman taxes etc)			$24,425.37
Total			**$105,843.27**

Maintenance considerations
Maintenance for this fence will be relatively straightforward due to it's small size. The greatest threat will be from rock fall and fire. In addition to quarterly monitoring inspections, it would be beneficial to inspect the fence after heavy rains to check for rock fall. It can be hiked easily in a half day, and it is likely that any maintenance that is needed could be done in a single day.

For budgeting purposes, four days per year with two people per day would cost approximately $2,000 annually based on labor and overhead rates provided in the cost estimate.

Ungulate removal considerations
It is highly likely that all ungulates will have left the area during fence construction due to the small area of the fence and the lack of vegetative cover. Any remaining ungulates on the rocky outcrop could be easily removed with a small number of ground-based hunts in a short period of time.

Compliance considerations
At least 50% of this fence will be on state land and is in the protective subzone of the conservation district on the state-owned portion. As a result, a conservation district use permit (CDUP) may be required to construct the fence on state land, and prior to applying for a CDUP, an EA is normally required. To determine whether a CDUP will be needed, an official memo should be sent to the administrator of the office of conservation and coastal lands. If the administrator waives the permit requirement, then an EA will likely not be needed.

No archaeological features were encountered during fence line surveys, however, the purpose of the surveys was to delineate a fence line and not search for archaeological features. The Navy should refer to their cultural resources specialists and previous archaeological surveys to confirm this, and if no records of historical features are known, then a full section 106 consultation may not be needed.

KOLEKOLE PASS IMPLEMENTATION PLAN

Land ownership:

The area within the proposed fence is owned entirely by the Navy. It is on preservation land in the limited subzone of the conservation district.

Biological value

This site is primarily composed of an arid rocky outcrop dominated by prickly pear cactus (*Opuntia triacantha*), and a mesic semi-forested area along a flowing stream along the western slope that is dominated by invasive grasses, Guava (*Psidium guajava)* and Christmas berry (*Schinus terebinthifolius*). There are few native species at this site, with the exception of some *Dodonaea viscosa* clusters on the north east side of the outcrop. The impacts of ungulates at this site appears to be high. The majority of the habitat is highly degraded non-native forest and shrub land with extensive ungulate damage. Multiple feral pigs were observed during the fence line survey along the stream bed. The listed species observed were almost exclusively growing on near vertical cliff faces that would be inaccessible to ungulates.

Table 8: List of listed species found within Kolekole fenced area

Species
Chamaesyce kuwaleana
Tetramolopium filiforme
Spermolepis hawaiiensis

Site analysis

GPS measured proposed fence length: 2432 m
GPS/map estimated area: 58.3 ha

This fence will mostly follow Kolekole road as it winds up the peak towards Kolekole pass and ~ 67% of the fence will run directly parallel to the road and require minimal clearing or drilling. Along this section, panels will intermittently be tied into vertical cliff faces to utilize natural ungulate boundaries, as such the length of fence required will be 1640 m, which is considerably shorter than the distance the road covers. In areas that don't require full panel fencing, but still need some level of protection against ungulates (~100 m), concertina wire can be used. At the top, there will be 792 m of fencing required that will follow the south side of a moderately vegetated flowing stream to connect the top and bottom section. This will be an ungulate panel fence.

Access for this fence will be by vehicle with one to two helicopter sling loads of material required along the stream section. Camping would not be required and heavy machinery (if needed) could be brought in easily. The substrate for the majority of the fence is soil, slope is gentle to moderate, and clearing would only be needed along the western flank that borders the stream (792 m).

Figure 7: Kolekole fence diagram with listed species locations noted in red

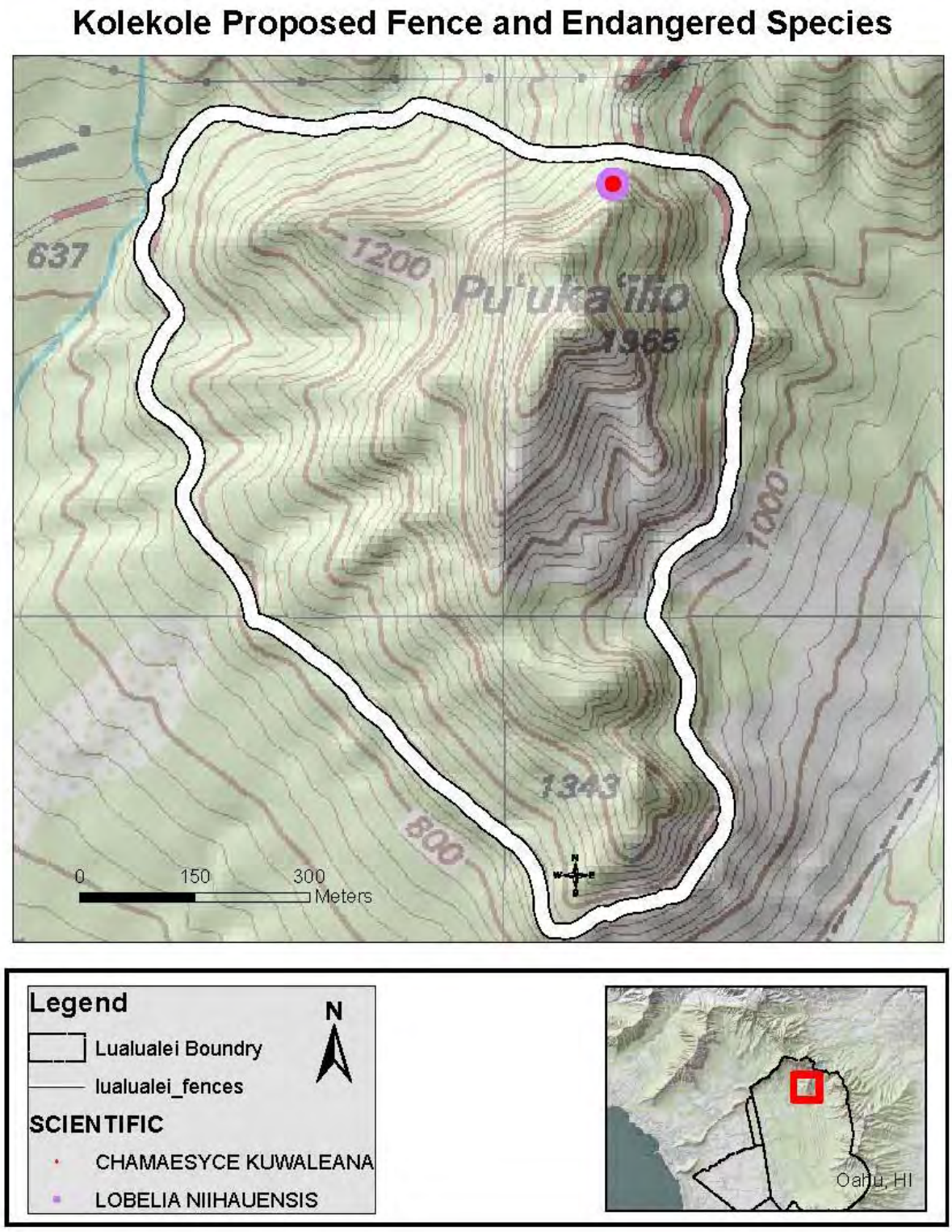


Figure 8: Kolekole fence diagram, facing east, as visualized in Googleearth

Budget

	Cost/Unit	#	Extended
Materials			
50"x16'x 4 gauge class III hot dipped combination panels	$47.00	540	$25,380.00
133 x 6' galvanized T-posts class III- with spades	$9.00	850	$7,650.00
133 x 6' galvanized T-posts class III- without spades	$8.00	275	$2,200.00
304 stainless steel 12-5 gauge smooth softwire	$6.50	80	$520.00
eye bolts 5/16 x 6" hot dipped galvanized class III	$2.27	80	$181.60
Concertina wire	$2.50	330	$825.00
Labor	$25.00	3900	$97,500.00
Rentals			
Helicopter slingloads	$1,200.00	5	$6,000.00
Trucking loads	$500.00	3	$1,500.00
Chainsaw, weedwhacker	$250.00	1	$250.00
Subtotal			$142,006.60
Overhead (incl all small equipment, foreman taxes etc)			$42,601.98
Total			**$184,608.58**

Maintenance considerations

Maintenance on this fence will be relatively straightforward and will primarily be related to rock fall. For the majority of the fence that follows the road, Military Police who patrol the area daily could be trained to spot maintenance needs, such as rocks accumulating at the base of the fence, and pass on information to maintenance staff if problems are encountered. This would enhance the quarterly inspections that should be done along the stream bed portion of the fence.

For budgeting purposes, four days per year with two people per day would cost approximately $2,000 annually based on labor and overhead rates provided in the cost estimate above.

Ungulate removal considerations

Any remaining goats on the rocky outcrop could be easily removed with a small number (1-2) aerial hunts, and pigs on the north slope by the stream could likely be removed relatively easily with ground-based hunting methods in a short period of time.

Compliance considerations

This fence will be entirely on Navy property which will exempt it from the CDUP process. It also follows an existing road for the majority of the area, and in the area where it parallels the streambed, no listed species are in the area that will need to be cleared. Thus, it is conceivable that it would qualify for a categorical exclusion. No archaeological features were encountered during the fence line survey, however, previous survey records should be consulted to determine if a section 106 consultation is needed.

MIKILUA IMPLEMENTATION PLAN

Land ownership:

The land inside the proposed fence is owned entirely by the Navy, although the boundaries along the northern portion of the ridge are very close to state land and care should be taken to have the fence remain on Navy land. It is on preservation land in the limited subzone of the conservation district.

Biological Value

The purpose of this fence is to protect 13 endangered plant species, one endangered snail species (*Achatinella mustelina)* and one critically rare, but not listed snail species (*Amastra cyclindrica*) from ungulate browsing and trampling. Mikilua is a unique hanging valley on the Lualualei side of the summit from 2000-2700' above sea level that faces north and likely has a specific micro-climate pattern of cooler temperatures and higher moisture than the surrounding area which presumably contributes to the high level of biodiversity for such a small area.

Table 9: List of listed species found within Mikilua fenced area

Species
Abutilon sandwicense
Achatinella mustelina
Alectryon macrococcus macrococcus
Bonamia menziesii
Flueggea neowawraea
Lipochaeta lobata leptophylla
Lobelia niihauensis
Lobelia yuccoides
Neraudaia angulata var dentata
Nototrichium humile
Platydesma cornuta var decurrens
Pleomele forbesii
Schiedea hookeri
Tetramolopium lepidotum lepidotum
Viola chamissoniana chamissoniana

Site analysis

Proposed fence length: 1048 m
Estimated area: 10.9 ha

The proposed fence is a U-shape that follows the Wai'anae range summit for the eastern portion of the 'U' and a side ridge for the western side of the 'U'. The north end is open and abuts a vertical cliff edges that will be used to tie the fence into and act as a natural ungulate barrier. The entire fence line is along moderate to very steep terrain. The Eastern summit (620 m in length) has a narrow, hard rock substrate, but is relatively clear of vegetation and will not require substantial clearing. The Western ridge (428 m) has a soil substrate, and while wide, is significantly steeper and covered by heavy vegetation (Christmas berry).

Access to this site is by helicopter only and would require overnight camping in order to complete the construction. Heavy machinery will not be possible to use at this site. This fence will utilize sheer cliff faces on the northern boundary as a natural fence; thus some species points are including in the fenced area even if they do not appear to be enclosed by the fence itself.

Figure 9: Mikilua fenceline along with occurrences of listed species in the area.

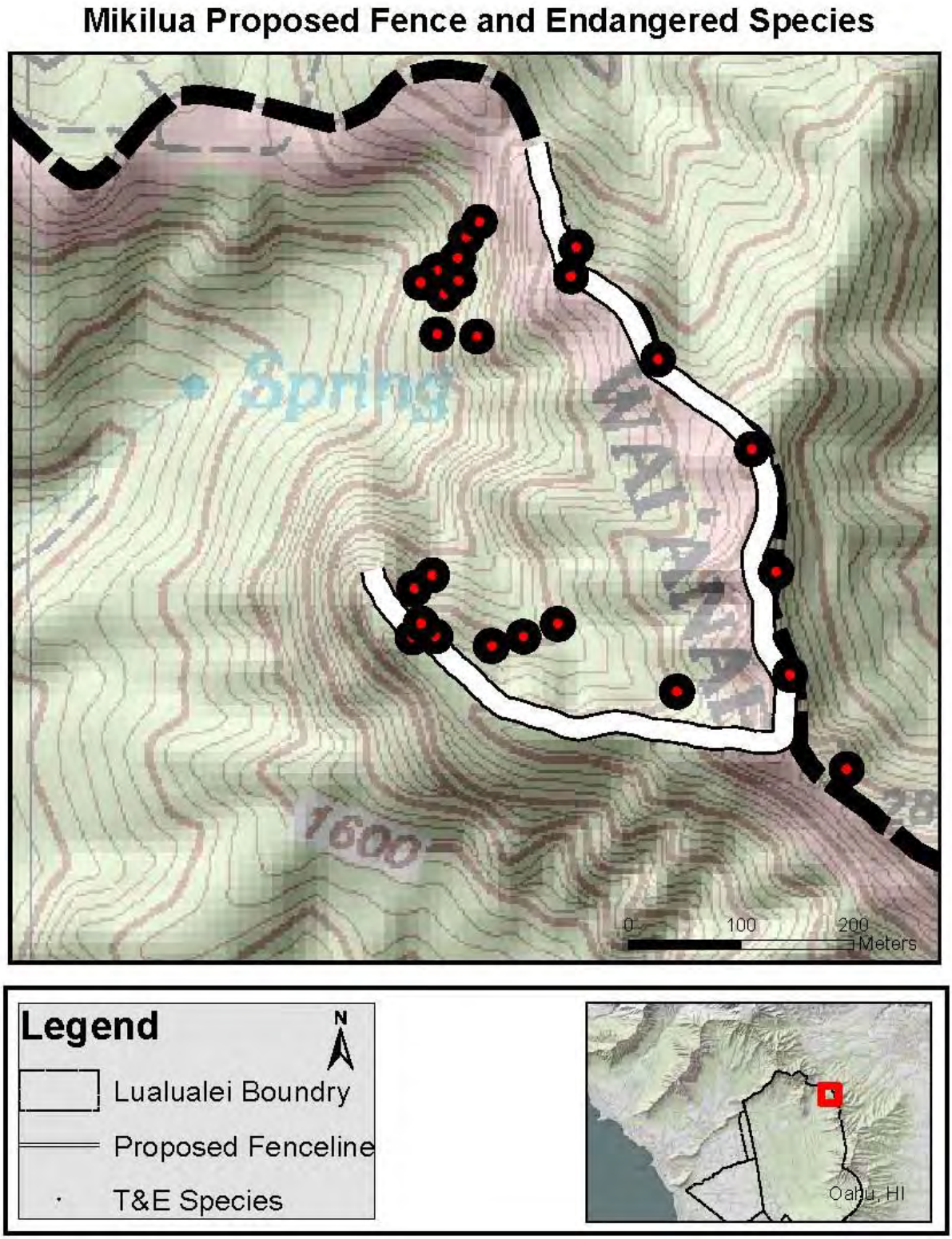
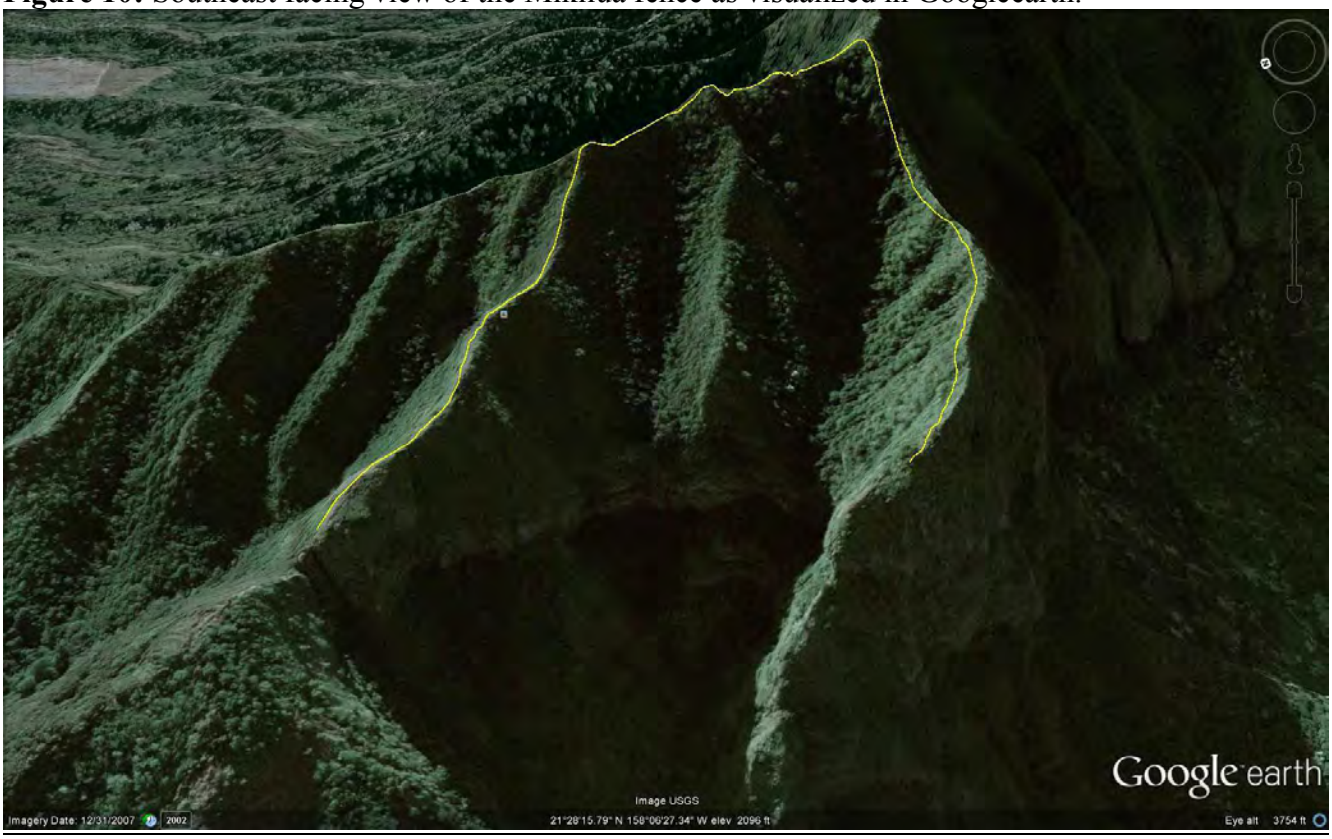


Figure 10: Southeast facing view of the Mikilua fence as visualized in Googleearth.



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Budget

	Cost/Unit	#	Extended
Materials			
50"x16'x 4 gauge class III hot dipped combination panels	$47.00	235	$11,045.00
133 x 6' galvanized T-posts class III- with spades	$9.00	240	$2,160.00
133 x 6' galvanized T-posts class III- without spades	$8.00	240	$1,920.00
304 stainless steel 12-5 gauge smooth softwire	$6.50	35	$227.50
9 gauge class III galvanized soft smooth wire/ 50lb roll	$90.80	2	$181.60
Labor	$25.00	1600	$40,000.00
Rentals			
Helicopter slingloads	$1,200.00	10	$12,000.00
Subtotal			$67,534.10
Overhead (includes small equipment, foreman, taxes etc)			$20,260.23
Total			**$87,794.33**

Maintenance considerations

Due to the inaccessible nature of this site, materials should be stored on-site and relatively close to the summit for easy access. It is also along a summit trail that likely has regular hikers, and thus could be vulnerable to vandalism if step-overs are not incorporated into the design at natural trail crossing points.

For budgeting purposes, eight days per year with two people per day would cost approximately $4,000 annually based on labor and overhead rates provided in the cost estimate above. If helicopter access costs are included and cannot be cost-shared with another agency, then an additional $4,000 should be budgeted for helicopter time.

Ungulate removal considerations

Given the small area, and limited evidence of active ungulate damage, ungulate removal should be relatively straightforward at this site. Several ground based hunts could be conducted in a short period of time to remove any remaining pigs and goats from the area.

Compliance considerations

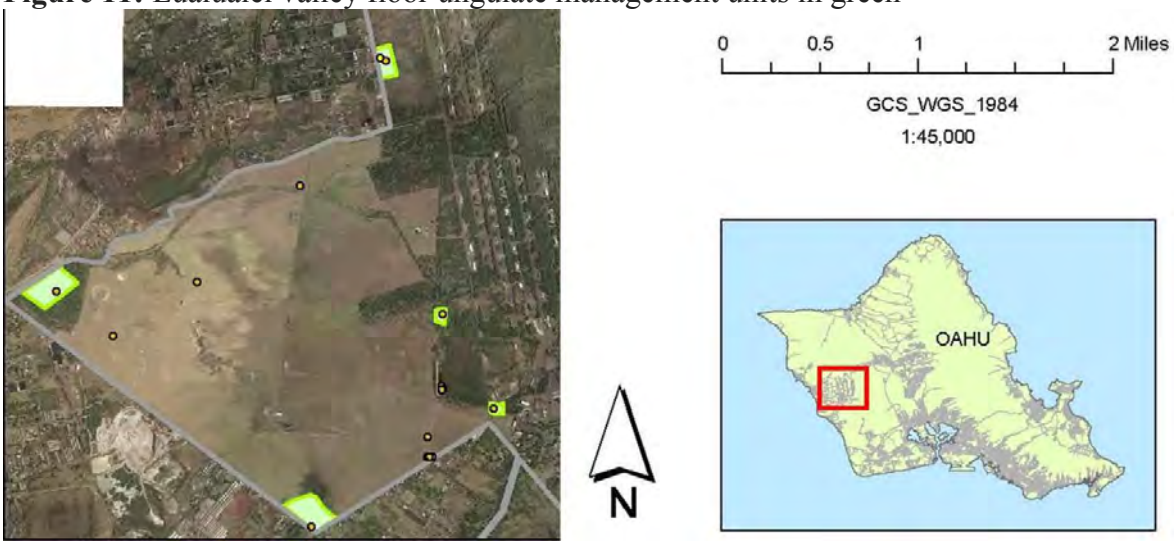
There are no known cultural features in the proposed fenced area which would trigger a section 106 consultation, but previous archaeological reports should be consulted to confirm this. This fence falls within the limited subzone of the conservation district, but since it is entirely owned by the Navy, it should be exempt from the CDUP process.

VALLEY-WIDE UNGULATE MANAGEMENT

The 11 sites that were along roads on the valley floor were assessed for fencing as there were several that contained listed plants (specifically *Abutilon menziesii, Marsilea vilosa* and *Cyperus trachysanthos*). While fencing these sites would be relatively straightforward, it was determined that periodic ungulate control on the valley floor would be much more cost-effective than fencing since ungulates are in low densities in those areas to begin with and the plants appear to be doing well with the current management strategies.

Approximately half (five) of the sites are in the mowed antennae field with very little sign of ungulates. Two sites in the South and West corners of the antenna field where contain small Haole Koa (*Leucaena leucocephala*) and Kiawa (*Prosopis pallida*) forests that could presumably harbor pigs. Semi-annual ground- based hunts of these two vegetated areas would likely provide sufficient protection for these seven sites found throughout the antenna fields. The remaining sites could be protected with two small hunts- one in the North by Wayne's dairy which is relatively open scrubland, and another in an approximately 5 km^2 area North of the Base Police headquarters in Haole Koa/Kiawe forest. It is unlikely that goats are present at these sites, so hunting techniques suitable for pigs would likely be sufficient (figure 11).

Figure 11: Lualualei valley floor ungulate management units in green

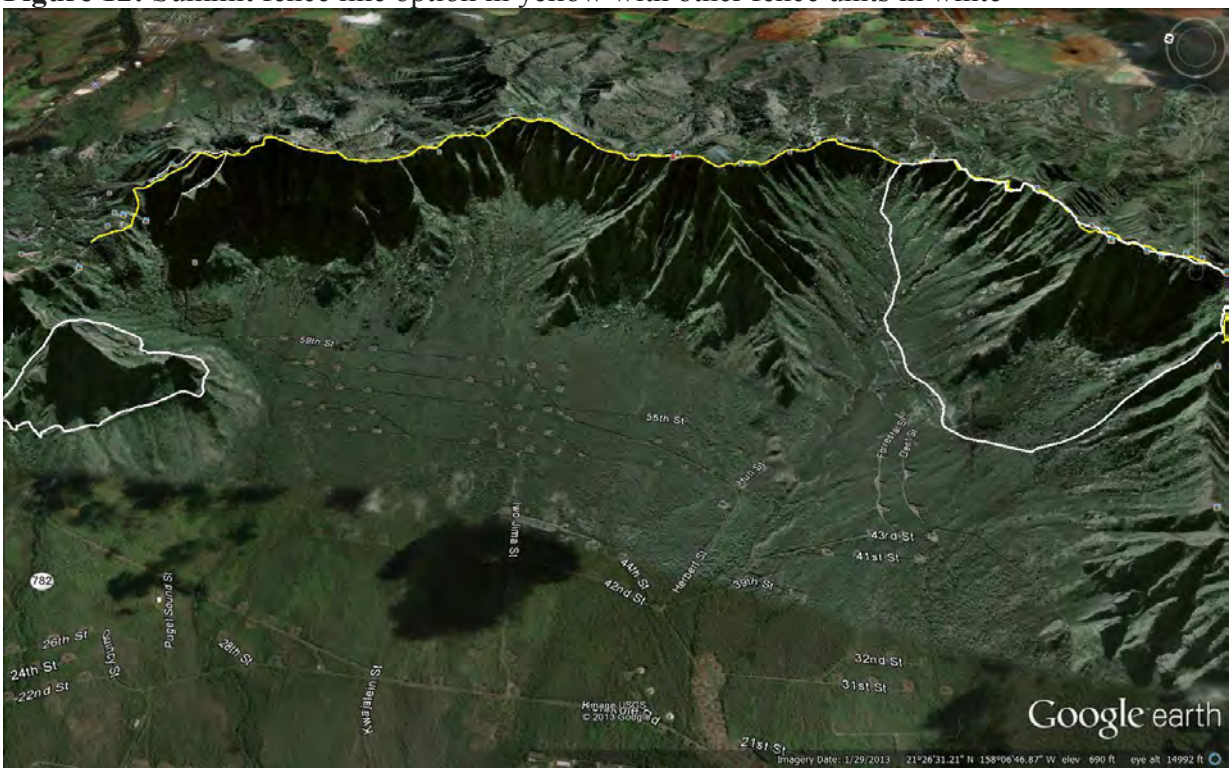


A final option that was discussed, but not pursued was the idea of a 'summit fence' along the majority of the Wai'anae summit behind Lualualei Valley that would prevent ungulate ingress from the east over the summit and presumably present some level of protection for listed species in areas that were 'unfenceable' along the summit ridges. This option would be coupled with active ungulate control throughout Lualualei Valley to reduce the resident animal population to as near zero as possible.

The fence discussed would extend from Kolekole pass road and connected up to the Halona unit of the fence and would be approximately 5.2 km and would like be comparable in price to the Halona fence cost estimate. However, given the size, high cost, and open nature of this fence, several key variables would need to be estimated before it is explored as a viable alternative (or in addition to) the existing proposed fences. Mainly, levels of ungulate ingress and resident ungulate reproduction rates would need to be examined to determine if ungulates are coming into Lualualei from the East by transiting the summit, or if they are in higher densities on the Valley floor. If the main source of feral animals is from the East, then this style of fencing

would likely present a considerable level of protection to Lualualei Valley on a landscape scale when coupled with large-scale ungulate control/removal. However, if ungulate ingress is primarily from the Valley floor (which does contain several agricultural/farming operations both on and off Navy property), then this option would likely not be a cost-effective management strategy as it would not prevent immigration of ungulates from the West into sensitive areas. Based on previous studies conducted from 1930-1971 in Hawai‘i Volcanoes National Park on Hawai‘i Island, efforts to remove pigs from an ungulate management unit were not successful, largely due to the inability to carry out sustained reduction efforts and prevent reentry of pigs into ungulate-control areas without a complete enclosure fence (Katahira et al. 1993). Thus, in the absence of data to determine rates and direction of feral ungulate immigration into Lualualei Valley, this option was not investigated further in this report, but is instead presented as a possible future direction that could be explored once sufficient data on ungulate movement patterns exists.

Figure 12: Summit fence line option in yellow with other fence units in white



CONCLUSIONS

Based on data collected during this project and knowledge of current best management practices for fencing and ungulate removal, the following strategy is being recommended for ungulate management to protect listed species in Lualualei Valley:

1. Construction of four ungulate-proof 50" high panel-fence units in the following order of preference: Halona Valley, Mikilua, Kolekole Pass, and Kauaopu`u. Costs and sizes of each fence unit can be seen in the table below.
2. Ungulate eradication from within these sites immediately following fence construction using a combination of ground based hunting, aerial shooting, and snaring.
3. Semi-annual ungulate control in four areas containing listed plant species on the valley floor encompassing approximately 5.2 km^2.
4. At a minimum, quarterly maintenance and monitoring inspections of all fences.

Site	Fence length (m)	Fence Area (ha)	# Species protected	Construction cost	Annual maintenance cost
Halona	6047	220.5	17	$1,249,235.00	$12,000.00
Mikilua	1048	10.9	14	$87,794.33	$8,000.00
Kolekole pass	3304	58.3	0	$184,608.58	$2,000.00
Kauaopuu	1130	0.7	3	$105,843.27	$2,000.00

Based on the existing knowledge of listed species occurrences in the Valley, these management activities will secure a total of 290 ha (14% of the Navy-owned component of Lualualei Valley) of habitat and protect the vast majority of species present in Lualualei Valley from ungulates. This plan does not address other threats such as weeds, vertebrate predators, disease or fire.

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APPENDIX 1: SITE PRIORITIZATION CRITERIA

INSTRUCTIONS

There are three components to this exercise: prioritization criteria that will be used to rank each site, a description of the sites (i.e. fence units), and a separate excel spreadsheet where you enter in your rankings for criteria each site. To complete this exercise, please read the descriptions of prioritization criteria below and the site descriptions first. Once you have done that, open the excel spreadsheet and enter in the value for each of the 15 criteria listed below for each site.

If you feel that certain criteria should be weighted higher, you can change the weighting of them. Right now everything is weighted at 1 with the exception of "other at-risk species" which is weighted at 0.5. Since the Navy is proposing these fences to protect critical habitat, we are treating listed species with higher priority (weighting of 1.0) than other ones that may be rare, but aren't listed (weighting of 0.5). The criteria below are what each proposed fence unit will be judged upon to determine the order in which units are constructed. They are divided into two sets of criteria- biological considerations which are related to the species being protected and the degree of threat they are under, and site considerations which are related to the feasibility of fence construction.

BIOLOGICAL CONSIDERATIONS

1. Number of listed species Scale: 0-total # species Weighting: 1.0

Protection and recovery of species listed under the U.S. Endangered Species Act is the primary goal of the Lualualei ungulate management plan. The number of listed species present at a site is therefore an important factor in considering which sites are of highest priority. One point is awarded for each listed species present within a proposed fence unit.

2. Urgency of listed species Scale: 0-total # species Weighting: 1.0

Species under greater threat of extinction and/or where their only occurrence within Lualualei is in a single fence unit should be considered higher priority than species for which extinction risk is less urgent or where multiple occurrences within Lualualei and/or a larger area occur. For example, almost the entire species population of *Chamaesyce kuwalena* (Akoko) occurs in Lualualei Valley.

3. Other At-risk or sensitive species Scale: 0-total # species Weighting: 0.5

Not all species in need of protection are listed under the U.S. Endangered Species Act. These species also deserve some consideration, though they may be lower priority from the perspective of the Navy. Examples of such species include candidates for listing, species of concern, species that have been overlooked by regulatory agencies (such as Amastrid snails), and populations or varieties that are unusual or ecologically important in some way. One point is awarded for each sensitive species present at a site, but this criterion is weighted by a factor of 0.5 since these species are less of a management concern than ESA listed ones.

4. Species diversity Scale: 1-5 Weighting 1.0

Sites that support a variety of native plants, invertebrates, and vertebrates should be ranked higher than sites that support only a few native species since a more intact native ecosystem will further facilitate recovery of ESA listed species after the removal of invasive ungulates. For example, sites dominated by alien species and that support few or no native

plants or animals should be scored 1, sites that have some native plants but are lacking native animals (and vice versa) might scored 2 or 3, and sites with more intact native ecosystems composed of numerous native plants and animals should be scored 5.

5. Need/Severity of impacts Scale: 1-5 Weighting 1.0

The effects of invasive mammals are more serious at some sites than at others. Just because alien species are present at a site does not mean a fence is needed to exclude them since limited access as a result of cliff faces, or existing fence units may provide some level of protection. Sites where listed species or sensitive habitats are currently experiencing serious impact from ungulates should be ranked higher. Sites where impacts are less severe or where there is only potential for impact (such as in unoccupied critical habitat) should be ranked lower. Sites where impacts are unknown might receive a moderate score.

6. Potential for future management programs Scale: 1-5 Weighting 1.0

Some sites may lend themselves more to developing management programs than others. Site that are relatively accessible, have overlap with other natural resources programs (i.e. share fence line with Army environmental, such as with Halona, or are close to other managed sites, such as Mikilua) should be ranked higher. The relative benefit of time spent doing management to the whole area as well as the potential for future outplanting should also be considered and ranked higher.

SITE CONSIDERATIONS

7. Accessibility Scale 1-5 Weighting 1.0

Greater accessibility will obviously make it easier and cheaper to construct a fence and may influence the effectiveness of the fence since accessible fences are easier to maintain. Accessibility includes ability to deliver fence materials and equipment to the site preferably by vehicle, ease of construction by fencing crews, and the ability to follow prescribed fencing specifications. Road access makes it easier and cheaper to deliver materials, fencing crews could reach the site faster and move around the site more quickly, and might allow use of heavy equipment to prepare the site in addition to providing a means for fencing crews to stay off-site and avoid camping. Narrow ridges or steep slopes would preclude vehicle access and might make it difficult to create the desired vegetation clearance around the fence and should be ranked lower. Helicopter access may be an option for delivery of materials, but would be more costly and could present additional logistical difficulties, such as precluding the use of heavy equipment.

8. Technical feasibility Scale 1-5 Weighting 1.0

Certain fence units will provide more challenging conditions than others. For example, on several fence units sheer cliff faces will be used as an ungulate barrier since they are too steep to fence and appear to be too steep for ungulates to traverse. However, these are less desirable than complete enclosures that have fences on all sides, so the greater the number of locations within a fenceline that have cliff faces being utilized, the higher the chance for pest incursions and the lower the rank. Presence of unexploded ordnance also may make some sites technically challenging, and sites where there is known to UXO that could inhibit ground disturbance for fence construction and use of equipment should be ranked lower. Finally, sites that must allow

human/vehicle access and/or to traverse should be ranked lower as they will require specialized components (gates, cattle guards etc).

9. Fence area/length protected Scale 1-5 Weighting 1.0

Circular fence lines provide the maximum protected area per unit of length and are preferable to those that 'zig-zag' and have a lower area/length ratio. Additionally, fences that utilize cliff faces, while more technically challenging, provide a greater area/length ratio and should be ranked higher. In short, the larger the area protected with a shorter fence line provides maximum cost-savings and maintenance efficiency in the future.

10. Cost per unit area Scale 1-5 Weighting 1.0

Tied to length/area calculations are the costs as shorter fence lines will be less expensive. It is anticipated that the Navy will have approximately $400,000 every other fiscal year to spend on fencing, and those fences that fall under this value should be ranked higher since they can be completed within a fiscal year. Fences that are from $400,000 to $800,000 could be timed to have the construction period overlap two fiscal years and should be ranked intermediate, and those over $800,000 should be ranked lowest.

11. Ability to tie into existing or proposed fence lines Scale 1-5 Weighting 1.0

Fences that tie into existing fence lines reduce costs for both construction and maintenance since multiple groups will (in theory) share surveillance responsibility and should be ranked highest. Fences that tie into proposed future fencelines should also be ranked higher for the same reasons as above.

12. Feasibility of ungulate removal Scale 1-5 Weighting 1.0

Ungulate removal will be necessary once fences have been completed to ensure the fences provide an effective barrier ungulate damage to listed species. Smaller fences (area; not length) may be ungulate free by the time construction is completed and should be ranked higher as they will be easier to remove ungulates from. Larger areas, and those that have steep terrain should be ranked lower as ungulate removal will take longer, cost more and be more technically challenging.

13. Potential to control other threats Scale 1-5 Weighting 1.0

While this plan specifically focuses on ungulates, other predators have potential to harm listed species found within the proposed fence units. Specifically, rats and non-native slugs which are known plant and snail predators. Areas that are smaller in size, and also known to contain native snails which are highly susceptible to predation by rats and slugs, should be ranked higher. Larger sites where landscape level control may not be possible should be ranked lower.

14. Potential for future predator proof fences Scale 1-5 Weighting 1.0

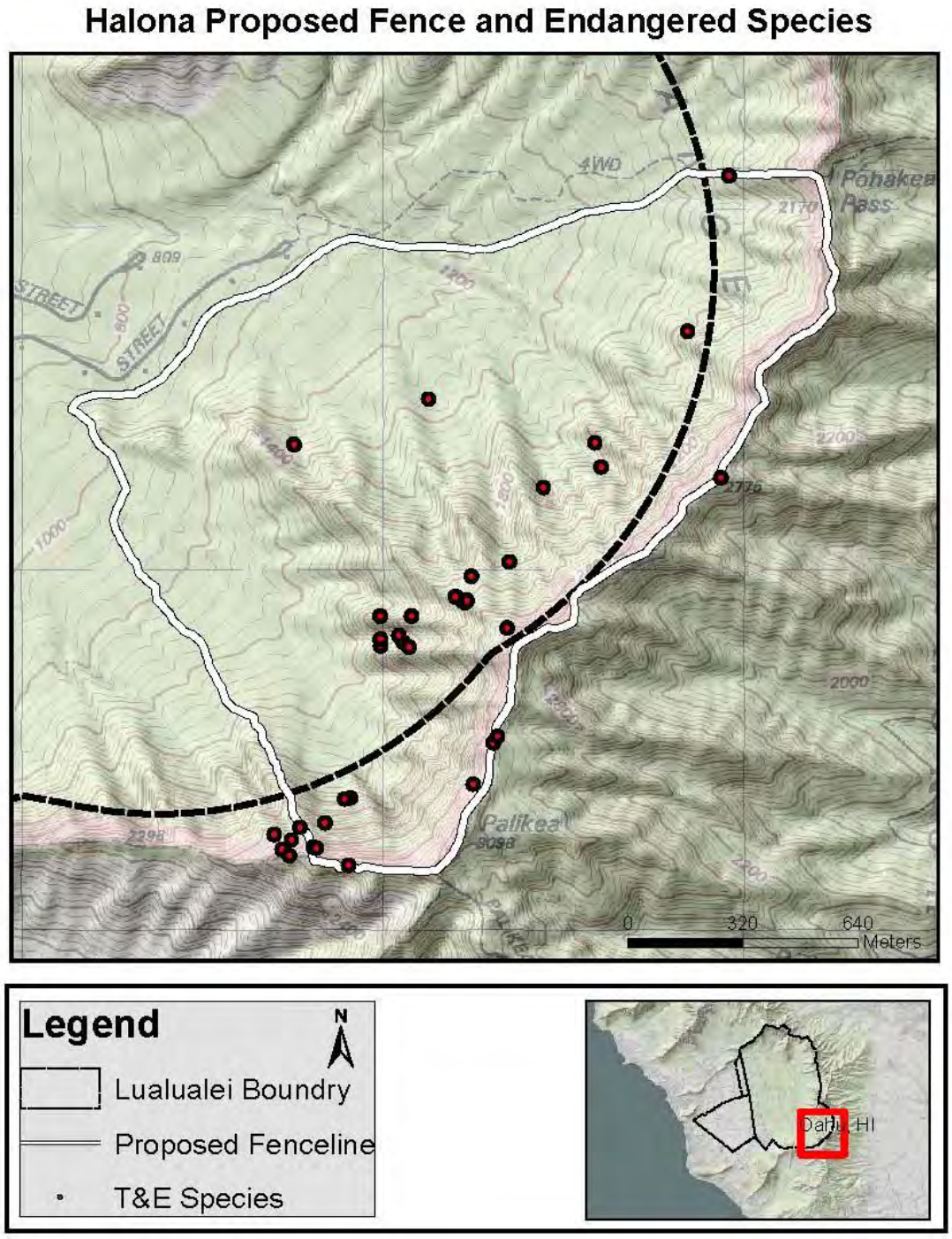
As described in the previous criteria description, rats, slugs and other predators are threats for many listed species. Site which could possibly have predator proof fences built should be ranked higher than those where it would be impossible and/or impractical.

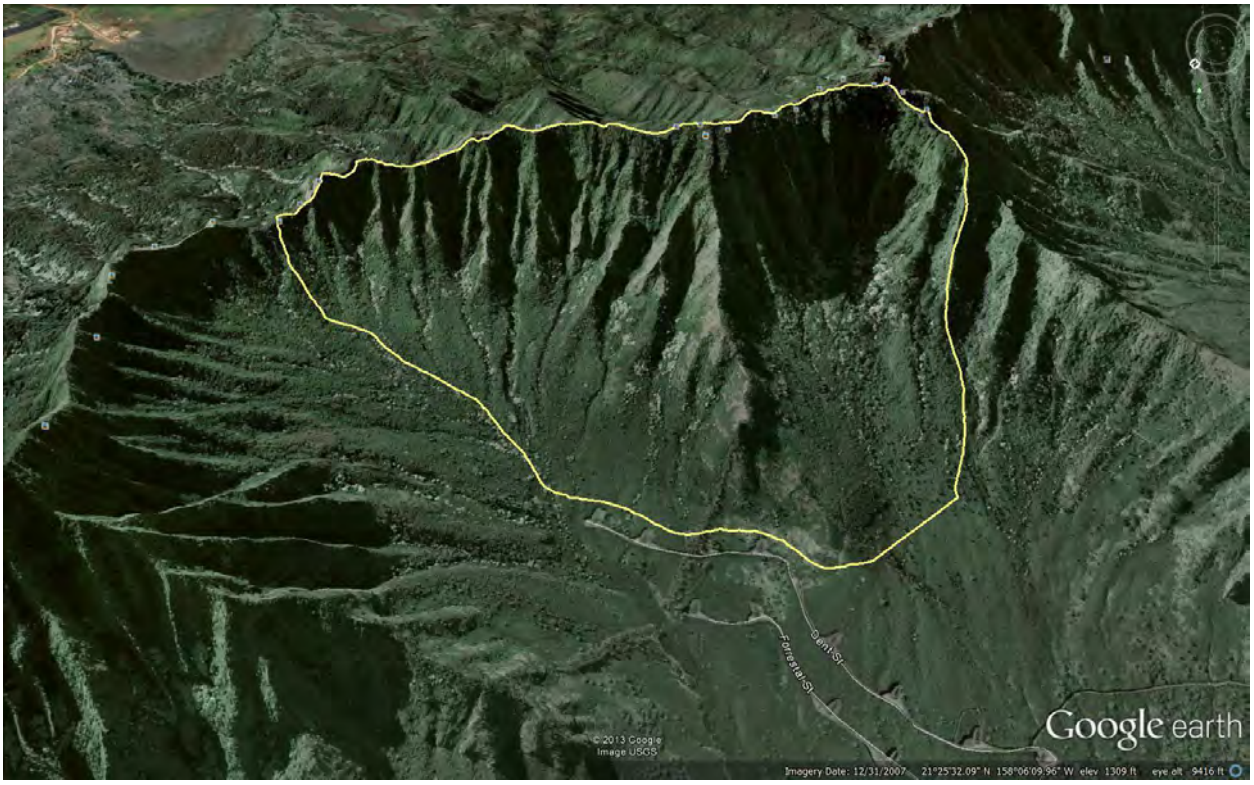
15. Maintenance and fire management potential Scale 1-5 Weighting 1.0

Fences that are easier to maintain will last longer and provide a more lasting benefit to listed species. Sites that are more accessible, smaller and visited more frequently for other purposes (thus increasing probability that a problem will be detected early) should be ranked higher. Sites that potentially share fence lines or management responsibility with other agencies should also be ranked higher. Fences that may end up with higher fuel loads due to decreased browsing (such as in drier habitats or those with high ungulate impacts) should be ranked lower.

APPENDIX 2: SITE DESCRIPTIONS USED FOR RANKING

Halona Unit:





 # Listed species:

17- 16 plants and 1 invertebrate

Species
Abutilon sandwicense
Achatinella mustelina
Bonamia menziesii
Diellia unisora
Flueggea neowawraea
Hedyotis parvula
Lepidium arbuscula
Lobeila niihauensis
Lobelia yuccoides
Melicope pallida
Melicope saint-johnii
Neraudia angulata angulata
Neraudia angulata var dentata
Plantago princeps princeps
Pleomele forbesii
Silene Perlmanii
Viola chamissoniana chamissoniana

Other rare species:

Two plant species of concern/candidates for listing are found in the area.

Species diversity:
High. There are not only numerous listed species, but several examples of good remnant native mesic forest along the summit ridges composed of Ohia, Uluhe and other native forest communities. While the valley floor is dominated by non-native vegetation, the summits and cliffs are still highly desirable habitat.

Severity of impacts:
High. Goats were observed on very steep terrain and are likely present throughout the fence area. Heavy pig activity was observed on the summit ridges, including multiple instances of rooting and browsing in native vegetation.

Accessibility and technical feasibility:
Challenging. Of the 6053m in total length, 939m is on relatively flat terrain and accessible by vehicle. The remainder is mostly helicopter access and is 4281m on moderate slopes, primarily along the summit ridges and 827 along very steep sections- the descents from Pohakea pass, and the descent from the south summit point. Thus the majority of the fence construction will rely on helicopter access and likely require camping for construction crews. Two cliff-face ties ins will be required on the two summit descents. While a predator proof fence could be constructed at this site, it would likely be prohibitively expensive and be very technically challenging on the summit descent sections.

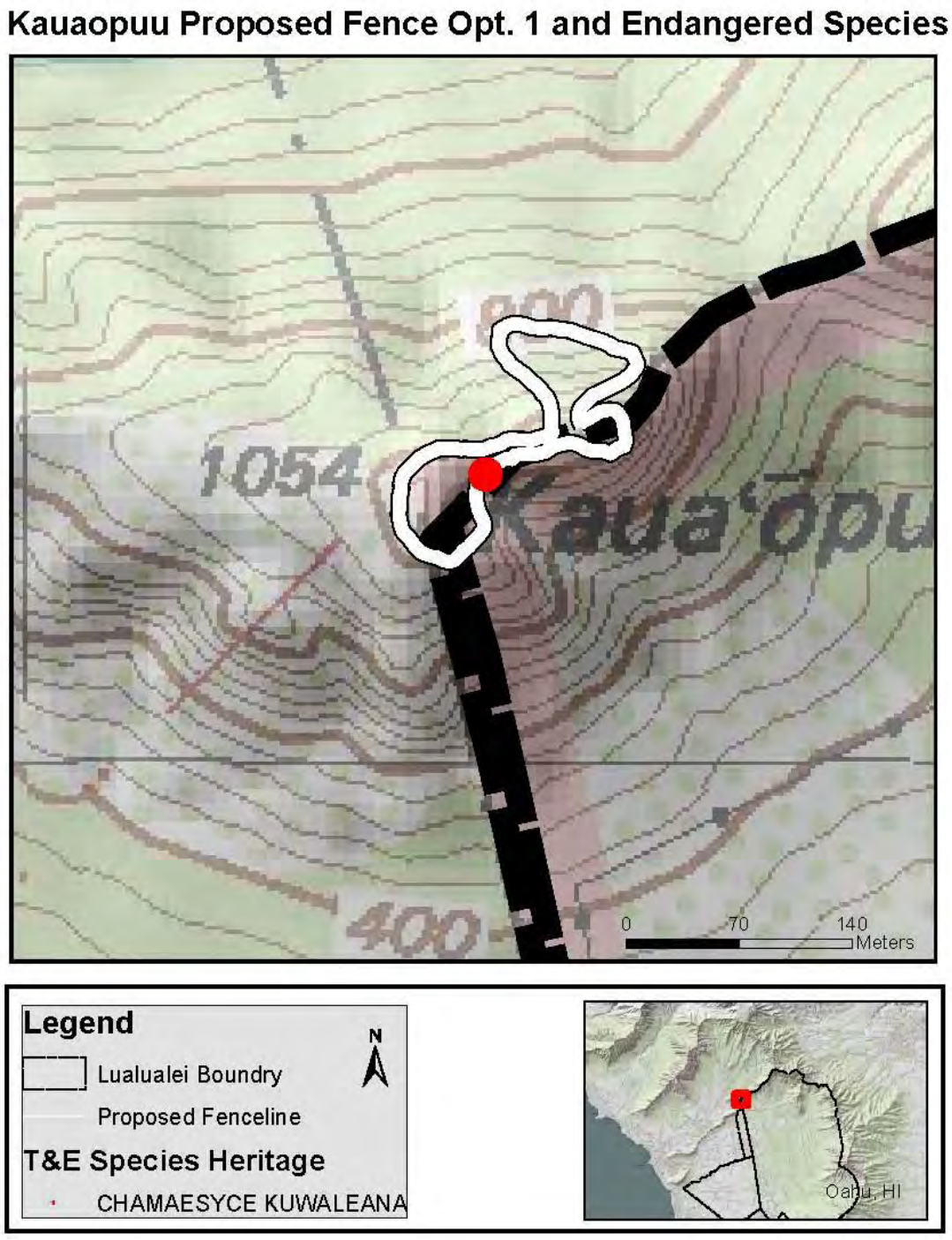
Area/Length:
220.6ha/ 6053m = 36.5 ha/km of fence

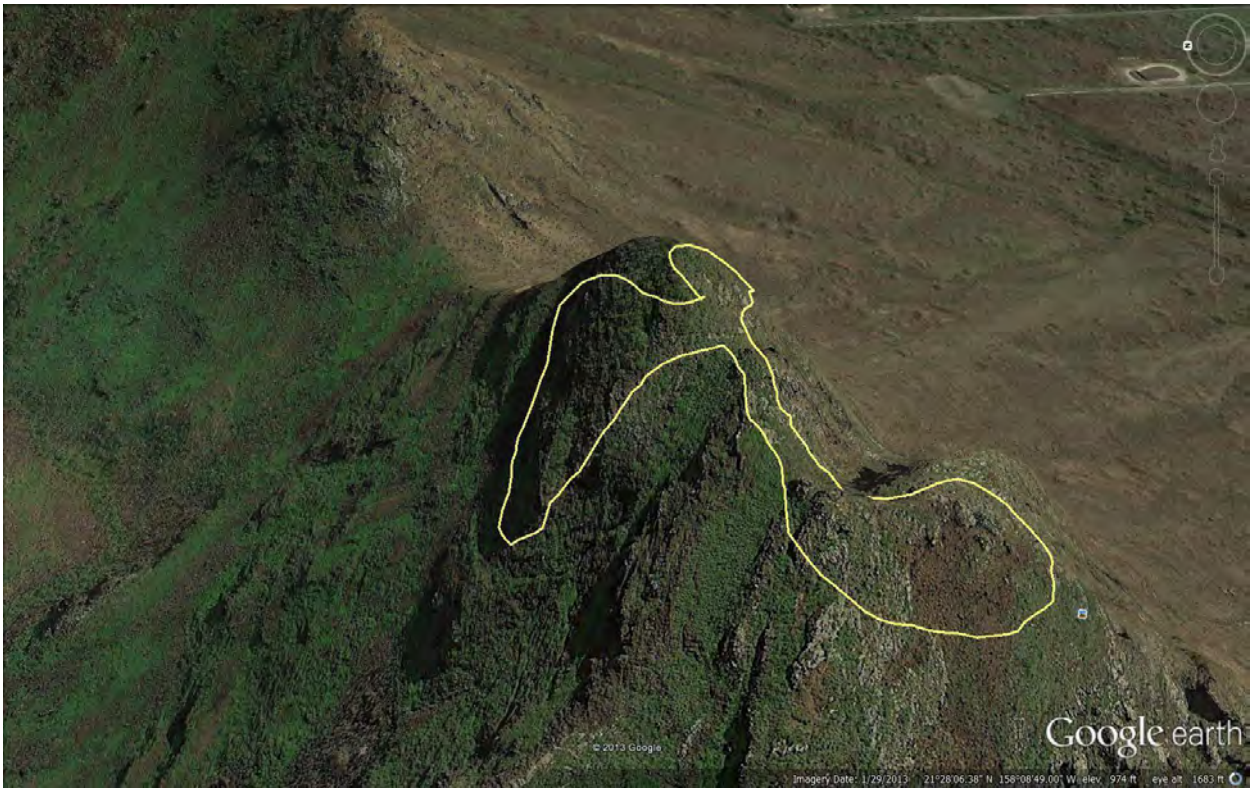
Cost:
$1,249,235.00

Additional fence tie-ins:
Multiple. Two fences maintained by the Army Natural Resources program (Palehua and Pualii) are present on the summit ridge for a total of 631m of tie in, and several fences in the planning phases along the same ridge line. Future fences extending down the eastern slopes could use this fence as summit tie-in. Potential exists for management sharing activities with Army Environmental.

Ungulate removal:
Challenging. This is a large area that likely has quite a few ungulates, both goats and pigs. Goats were observed on very steep terrain that may not be accessible from the ground to hunters, and heavy pig activity was observed on the summit ridges. A combination of aerial shoots, ground hunts and other more sophisticated methods would need to be used for this site, and due to the size, would likely take an extended period of time.

Kauaopuu Unit:





 # Listed species:
Three- all plants.

Species
Chamaesyce kuwalena
Tetramolopium filiforme
Spermolepis hawaiiensis

 # Critically endangered species:
One is endemic to Lualualei and Waianae Kai valleys with the vast majority of the population found within the proposed fence.

Other rare species:
None.

Species diversity:
Relatively high for a dryland site; contains a stand of *Dodonaea viscosa* that is uncommon at low elevation sites such as this.

Severity of impacts:
High. While there was little ungulate sign noted on either site visit, it is clear that the listed species are restricted to the steep slopes, likely as a result of browsing. A fire four months prior to the first site visit had destroyed much of the vegetation likely making it undesirable for ungulates to visit. However, by the second site visit three months later, significant regeneration of the vegetation was occurring which would likely be more attractive to ungulates. So this is rated high as it is easily accessible to ungulates and the listed species distribution likely reflects

this. At the time of the first post-fire site visit, NAVFAC-HI staff reported seeing a feral pig at the summit of this site.

Accessibility:
Relatively accessible. While materials will need to be flown in via helicopter, crews can hike it and out relatively easily on a daily basis which would eliminate the need to camp and provide greater flexibility during the construction period.

Technical feasibility:
Challenging. Numerous cliff faces and high rockfall will make this a challenging fence to construct since there will be numerous tie ins with the hillside. In addition, the land ownership is complex (State, Federal and Hawaiian Homelands) and it is unclear whether all parties that own parts of the summit (which will be critical to building an effective fence) will be open to the idea of construction on the site.

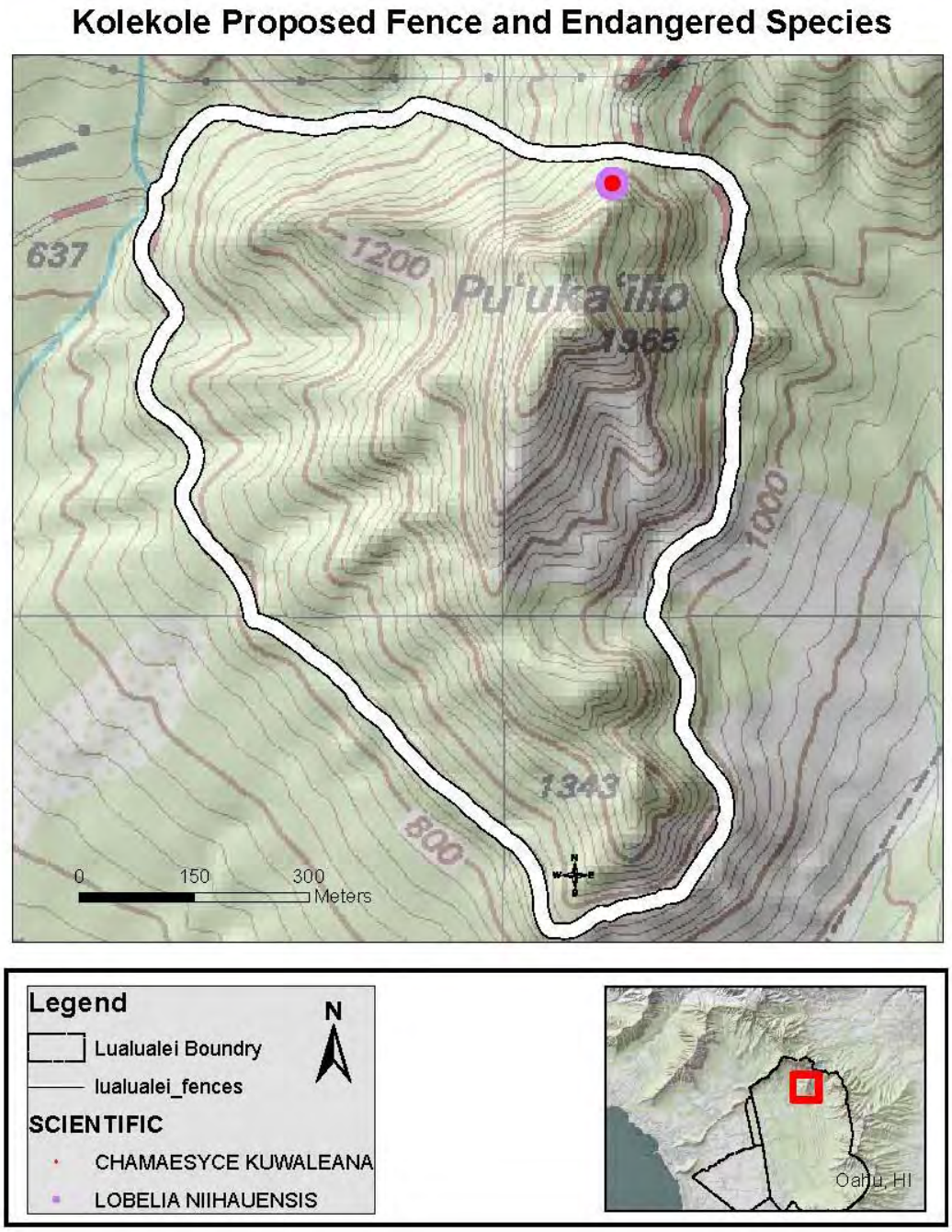
Area/Length:
0.7 ha/ 1130m

Cost:
$105,843.27

Additional tie-ins:
Numerous existing cliff faces will be used to create natural barriers and reduce the need for fence materials to be used for ungulate exclusion. It is estimated that there are ~100 m of cliff face tie ins available at this site.

Ungulate removal potential:
Straightforward. Any remaining ungulates on the rocky outcrop could be easily removed with a small number (1-2) of ground-based hunts in a short period of time. No evidence of ungulates was seen on either site visit.

Kolekole pass Unit:



This fence will mostly follow Kolekole road starting at the base of a rocky outcrop that the road winds around to gain elevation before connecting through the pass. The fence would encircle ~75% of this rocky outcrop by following the inside (upslope) edge of the road, and then cut up a slope on the north side to connect itself.

 # Listed species:
Three. While none have been recently reported, scoping visits for this project discovered *Chamaesyce Kuwaleana, Tetramolopium filiforme* and are included in other fence units.

Species
Chamaesyce kuwalena
Tetramolopium filiforme
Spermolepis hawaiiensis

 # Critically endangered species: 0

Other rare species: 0

Species diversity:
Low. There are few native species at this site, with the exception of some *Dodonaea viscosa* clusters on the NE side of the outcrop. The arid rocky outcrop is dominated by prickly pear cactus, and the mesic semi-forested area along the north slope has a flowing stream dominated by invasive grasses, Guava and Christmasberry.

Severity of impacts
High. The majority of the habitat is highly degraded non-native forest and shrub land with extensive ungulate damage. Multiple feral pigs were observed during the fence line survey. The

listed species observed were almost exclusively growing on near vertical cliff faces that would be inaccessible to ungulates.

Accessibility:
Very accessible- all materials could be delivered by trucks and would not require any helicopter slings loads or personnel camping on-site.

Technical feasibility:
Straightforward. Despite running mostly parallel to an existing road, there is poor drainage along the inside of the road since drainage ditches were not put in place during road construction. As a result, water appears to actively flow along the inside (upslope side) of the road which will provide future maintenance issues, although not preclude construction at the site.

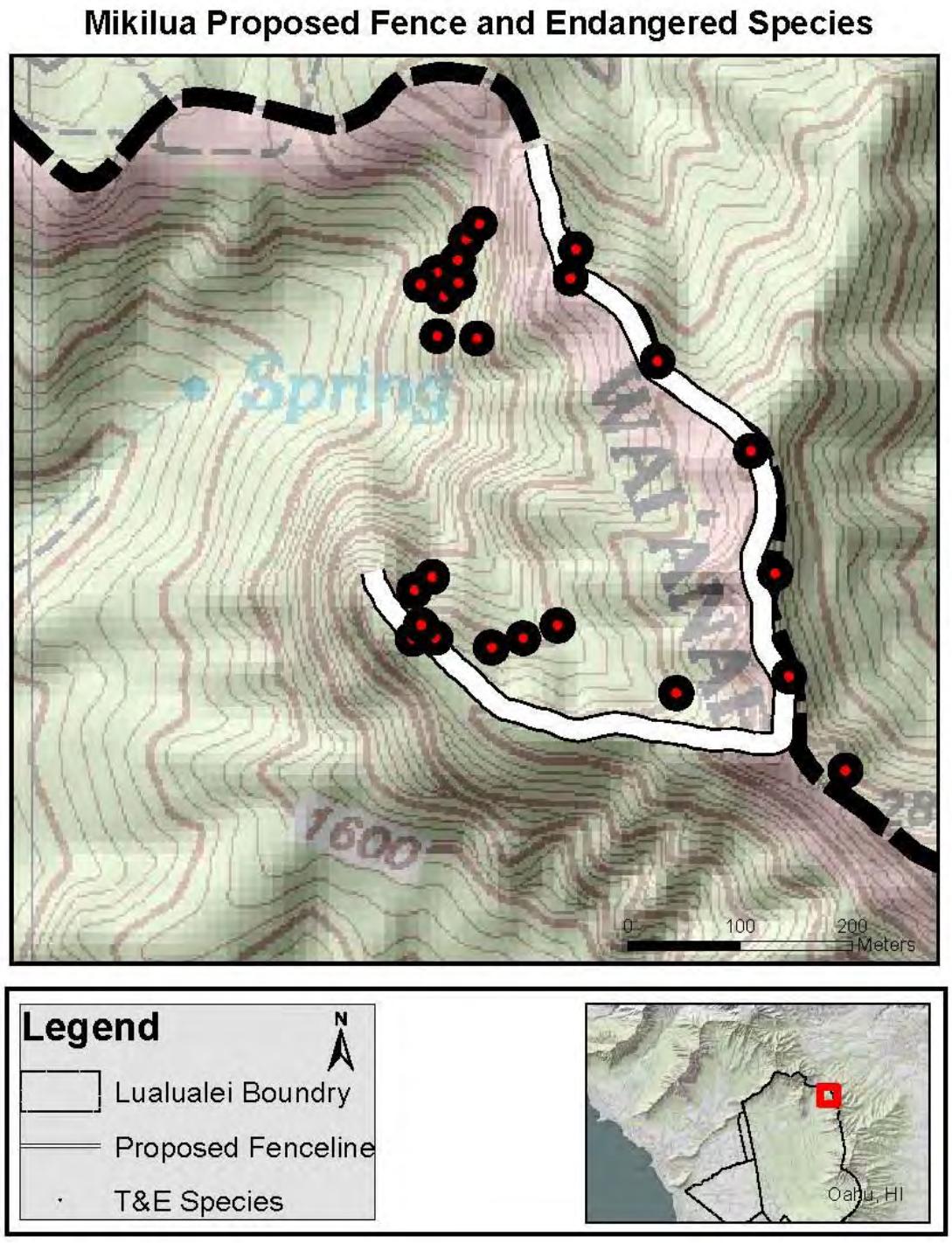
Area/Length:
58.3 ha/ 2432m; 1738m along roadbed with a gentle slope, 694 along streambed with a gentle to moderate slope

Cost:
$105,843.27

Additional fence tie-ins:
872 m of cliff face can be used as tie-in which will provide substantial cost-savings.

Ungulate removal:
Straightforward. Any remaining goats on the rocky outcrop could be easily removed with a small number (1-2) aerial hunts, and pigs on the north slope by the stream could likely be removed relatively easily with ground-based hunting methods in a short period of time.

Mikilua Unit:



 # Listed species:

14 species; 13 plants and one invertebrate

Species
Abutilon sandwicense
*Achatinella mustelina (*invertebrate- snail)
Alectryon macrococcus macrococcus
Bonamia menziesii
Flueggea neowawraea (thought to be dead)
Lipochaeta lobata leptophylla
Lobelia niihauensis
Lobelia yuccoides
Neraudaia angulata var dentata
Nototrichium humile
Platydesma cornuta var decurrens
Pleomele forbesii
Schiedea hookeri
Tetramolopium lepidotum lepidotum
Viola chamissoniana chamissoniana

 # Critically endangered species:

Other rare species:

Amastra cyclindrica, is a rare snail that while not ESA listed, is only known from Mikilua and could be a future candidate for listing.

Species diversity:
High. There are numerous native species in this area in addition to the listed species described above, and it is a relatively nice example of mesic habitat.

Severity of impacts:
Ungulate impacts appeared to be minimal at this site due to it's inaccessibility. However, due to the high number of listed species, particularly those with a limited distribution and low, prostrate stature, even periodic ungulate browsing could have an extremely detrimental impact. In addition, one of the species of concern, the Amastrid snail, lives under rocks and leaves on the ground and would be susceptible to trampling.

Accessibility:
Challenging. This site would be helicopter only access with relatively narrow summit ridges available for staging materials. It would require camping.

Technical feasibility:
Moderate. This fence buts up against cliff edges and is 'open' on the north end which will make securing the ends somewhat difficult. However, while the majority of it is moderately steep, it is a small fence, and one of the ridges is relatively vegetation free and would require minimal clearing (if any). A predator proof fence could be constructed at this site, and would likely provide considerable benefit to native snails relative to increase the cost.

Area/Length:
10.9ha/1048m = 10.4ha/km

Cost:
$87,794.33

Additional fence tie-ins:
No additional fences are directly tied into, but the fence does utilize sheer cliff faces on its northern boundary which negates the need for a complete circular enclosure and thus reduces the amount of fencing material required. Army Environmental manages several sites immediately adjacent to the fence and could likely assist in monitoring the fenceline for breaches.

Ungulate removal:
Straightforward. There was not much active sign of ungulates during the two sight visits, likely because of the steep slopes, and lack of access from the northern boundary due to a steep cliff. Any ungulates remaining after construction could likely be removed relatively easily with ground-based hunting methods.