Hawai'i Multi-Resource Forest Management Plan

Applicant: **Kealakekua Heritage Ranch**
Gregory Hendrickson, Real Property Administrator
Hokukano Ranch
P.O. Box 2240
Kealakekua, HI. 96750
Phone: **(808) 323-2299**
Fax: **(808) 323-2371**
Email: greg@ghendricksonlaw.com

Location of Property: South Kona District, Hawai'i Island

Property tax map key number:	3-8-2-012:001
Total Property Acreage:	11,470
Acres of Proposed Multi-Resource Forest Management Plan Area:	9,018

Prepared by: James A Mehrwein
McKenzie River Associates, LLC
1186 Olive Street, Eugene, OR 97401
Phone: (541) 242-0770
Fax: (541) 242-0742
Email: jimm@mrallc.com

John R Henshaw
Consulting Forester
43 Via La Morra
American Canyon, CA 94503
Phone: (707) 320-0606
Cell: (707) 673-7553
Email: johnrhenshaw@yahoo.com

Kona Hills
TMK
8-2-012:012
Included
In this plan.

Date: **August 7, 2013**

Signature Page

In our capacity as consulting foresters, we provided technical services and assistance in the preparation of this amended plan.

Prepared by:

McKenzie River Associates, LLC
1186 Olive Street
Eugene, OR 97401

James A Mehrwein
Consultant

Prepared by:

John R Henshaw
43 Via La Morra
American Canyon, CA 94503

John R Henshaw
Consultant

Applicant Certification: I have reviewed this Multi-Resource Forest Management Plan and hereby certify that I concur with the recommendations contained within. I agree that resource management activities implemented on the lands described shall be done so in a manner consistent with the practices recommended herein.

Prepared for:

Kealakekua Heritage Ranch
P.O. Box 2240
Kealakekua, HI. 96750

Gregory D. Hendrickson
Real Property Administrator

State Forester's Approval: This plan meets the criteria established for Multi-Resource Forest Management Plans by the Hawai'i's Forest Stewardship Advisory Committee for plans required under Forest Legacy Program conservation easements (FLP CE).

Approved by:

Roger Imoto, Administrator
Hawai'i Division of Forestry and Wildlife
Date:

Approved by:

Forest Stewardship Advisory Committee
Date: 5/10/2013

Contents

Executive Summary

Kealakekua Heritage Ranch (KHR) is a privately owned 11,470 acre property in South Kona, Hawai'i. Kealakekua Heritage Ranch encompasses a range of forest types including dense lowland mesic forest to sub-alpine woodlands (Map 1 and Map 2). This plan covers the 9,018 acres of KHR which was placed under a Forest Legacy Program (FLP) conservation easement (CE) in June of 2011. As of the date of the CE and currently, over 75% of the conservation easement area is considered forested by State standards. The vision for this property is to bring the KHR CE area forestland back to a fully stocked, ecologically sound, Hawai'i native dominated forest that provides a sustainable level of goods and services. Objectives and practices have been developed to move the present condition of this property towards the vision of the area over the next ten years.

Principal Revisions to the 2006 Plan

This plan amends the approved 2006 Forest Stewardship plan for KHR, accepted by the State of Hawai'i, consistent with the rules of FLP.[1] This amendment only changes and updates approximately 20 to 30% of the prior approved 2006 plan. The following adjustments were made to create this Multi-Resource Forest Management Plan:

1. To the area the plan covers, in order to be consistent with the final area approved in the CE. The CE was completed five years after the approved Forest Stewardship Management plan. The 2006 plan had a slightly different boundary to the CE area due to the desire of KHR and the State to have some CE area on the south boundary of the lower area of the ranch. The 2006 approved plan identified and mapped management zones and units on the plan area. The boundaries of these management zones and units were adjusted for the new plan in the lower part of the CE area to fit the final CE boundaries. The following maps depict the changes to these zones and units (Map 3 compared with Map 4 and Map 5).

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1 The approved 2006 plan was completed to Hawai'i state standards for the Hawai'i Forest Stewardship Program because it was intended that KHR would use the plan to apply for State financial assistance. KHR did not apply for that assistance and has since decided to forgo any State assistance, therefore the plan title has been changed to Multi-Resource Forest Management Plan under the Forest Legacy program rules.

2. To provide a more complete analysis of the timber resources, including the identification and mapping of all forest (timber) stands and the modeling of a sustainable harvest level for live tree timber (see Appendixes 1, 2 and 3). Please note that the identified harvest level in this plan is much lower than the models potential sustainable harvest level.

3. The 2006 approved plan had no provision for the harvest of live tree timber. This Multi-Resource Forest Management Plan allows up to 250 thousand board feet net (MBF)/year of live tree timber to be harvested using the advice of a professional forester.[2] This harvest level is considered under the CE to be de-minimus to commercial management given the growth of the existing forest inventory and the increase in stocking obtained by the planned regeneration. Figure 1 below was modeled to show the increase in timber inventory that will occur over time. As you can see from the chart, in the first 10 years the volume increases from approximately 7.5 million board feet to15.3 million board feet after subtracting the 250 MBF net of harvesting per year.[3] In addition to the live tree harvest the ranch will harvest dead and down material as contemplated under the first approved plan and as allowed in the conservation easement (see Covenants and Restrictions 3 (a)).

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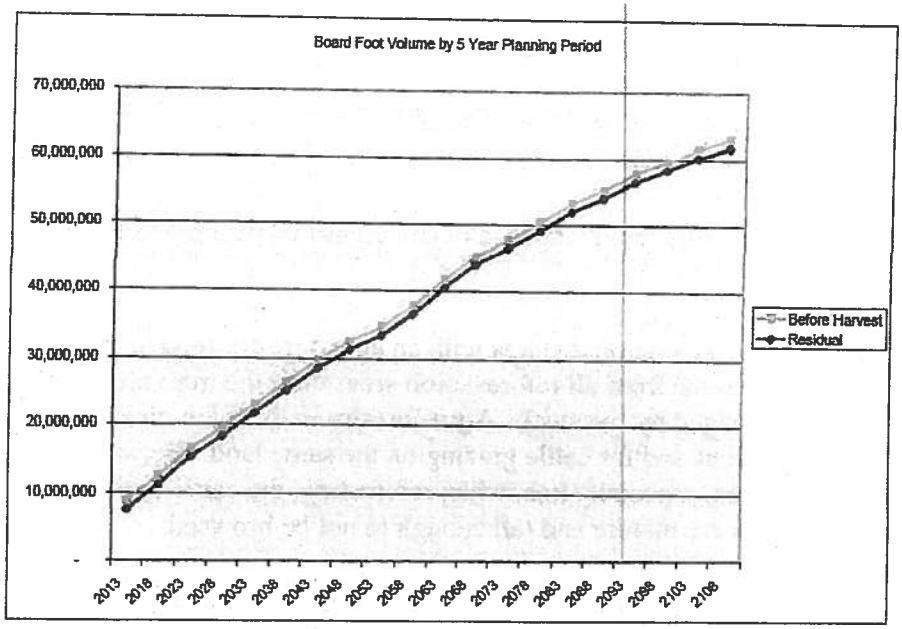
2 Additional harvest amounts are permissible under the CE provided that:(i) Restrictions on percentage of inventory harvested and opening size limitations are observed; and (ii)A more substantial timber inventory (a cruise with a higher statistical level of confidence) and monitoring program are completed. It is not anticipated that this will happen during this plans 10-year horizon.

3 The current forest was modeled to include harvesting at sustainable levels to measure the forests' potential and gauge the impact of a harvest level of 250 MBF/year of net live trees as is prescribed in this plan. The results of this modeling are found in Appendix III and indicate that a sustainable level of harvest is significantly higher than 250 MBF/year net and that the anticipated harvest of this plan is well less than the volume the forest is growing.

Figure 1 – Volume by Planning Period



Major Activities Included in this Plan (Next 10 Years)

This Multi-Resource Forest Management Plan details management action that will be implemented over 9,018 acres of the 11,470 acre Kealakekua Heritage Ranch. Practices described within this plan will address a broad range of issues, including ecosystem conservation, reforestation, timber production, fire management, livestock management, weed and pest management, management of sensitive features, scientific research, education, and recreation. Highlights of those activities are:

1. Management of all existing infrastructure – roads, fences, water facilities, etc. It is anticipated that approximately one mile of new or re-constructed fence for management purposes will be constructed each year under this plan.

2. Reforestation of under-stocked areas (targeting 50 acres per year) and accomplishing the reforestation of 500 acres over the 10 years of the plan.

3. Harvesting live trees only after a professional forester has written a silvicultural prescription and estimated volumes to be tracked. Harvests (not to exceed 250 MBF/year net) will focus on near-dead timber to capture

mortality and on the rehabilitation of stands considered to be in decline by the forester.

4. Harvest of dead and down trees as allowed under the conservation easement.

5. Working with Kohala Center and other partners to develop a KHR Education, Research, and Recreational Opportunities Plan (ERROP) which will guide activities in these areas.

6. Early detection and rapid response to any identified pest problems or fire risks.

7. Management of cattle on the area with an agro-forestry model, ensuring that cattle are removed from all reforestation areas until the trees are large enough to not be damaged by livestock. Agro-forestry in this plan means that we will manage for trees and for cattle grazing on the same land. Because the cattle eat young trees, especially koa, when reforesting, the cattle will be removed until the trees are mature and tall enough to not be browsed.

8. Thinning of young koa stands at approximately 20 years of age.

Implementation of this Multi-Resource Forest Management Plan will provide a net benefit to the people and natural resources of the region through the protection and restoration of ecologically functioning native forests, the reforestation of large tracts with native forest, and the production of a sustainable level of goods and services. In addition, information related to growth and yield of native hardwoods, and soil scarification techniques to promote koa regeneration will be obtained through application of innovative management techniques and regular monitoring by ranch management (monitoring will occur by photos after treatments and at one year intervals). The plan will be in effect from 2013 to 2023. Every ten years, or as needed, this forest management plan will be reviewed and updated based upon the results of implementation.

I. Introduction

The Kealakekua Heritage Ranch (KHR) sits on an 11,470-acre contiguous parcel on the Western Flank of Mauna Loa on the Big Island of Hawai'i. Property zoning of KHR is Agricultural. The area that this plan covers is the conservation easement (CE) area within KHR (TMK 3-8-2-12:011) that is under a CE with the State of Hawai'i and covered by the rules of the U. S. Forest Service, Forest Legacy Management Program (FLP) containing 9,018 acres. This area is over 75% forested by State standards. KHR is located up slope of the Māmalahoa Highway and the rural village of Captain Cook, in the South Kona County Election District Map 1. The boundary between North Kona and South Kona County Districts runs along the KHR north boundary with Hōkukano Ranch and Ka'awaloa Ranch. KHR is bordered to the east by sub-alpine vegetation on recent lava flows owned by Kamehameha Schools and to the south by the Kamehameha Schools' Hōnaunau Forest Reserve.

This plan amends the approved 2006 Forest Stewardship plan for KHR, accepted by the State of Hawai'i, consistent with the rules of FLP. This amendment only changes and updates approximately 20 to 30% of the prior approved 2006 plan.

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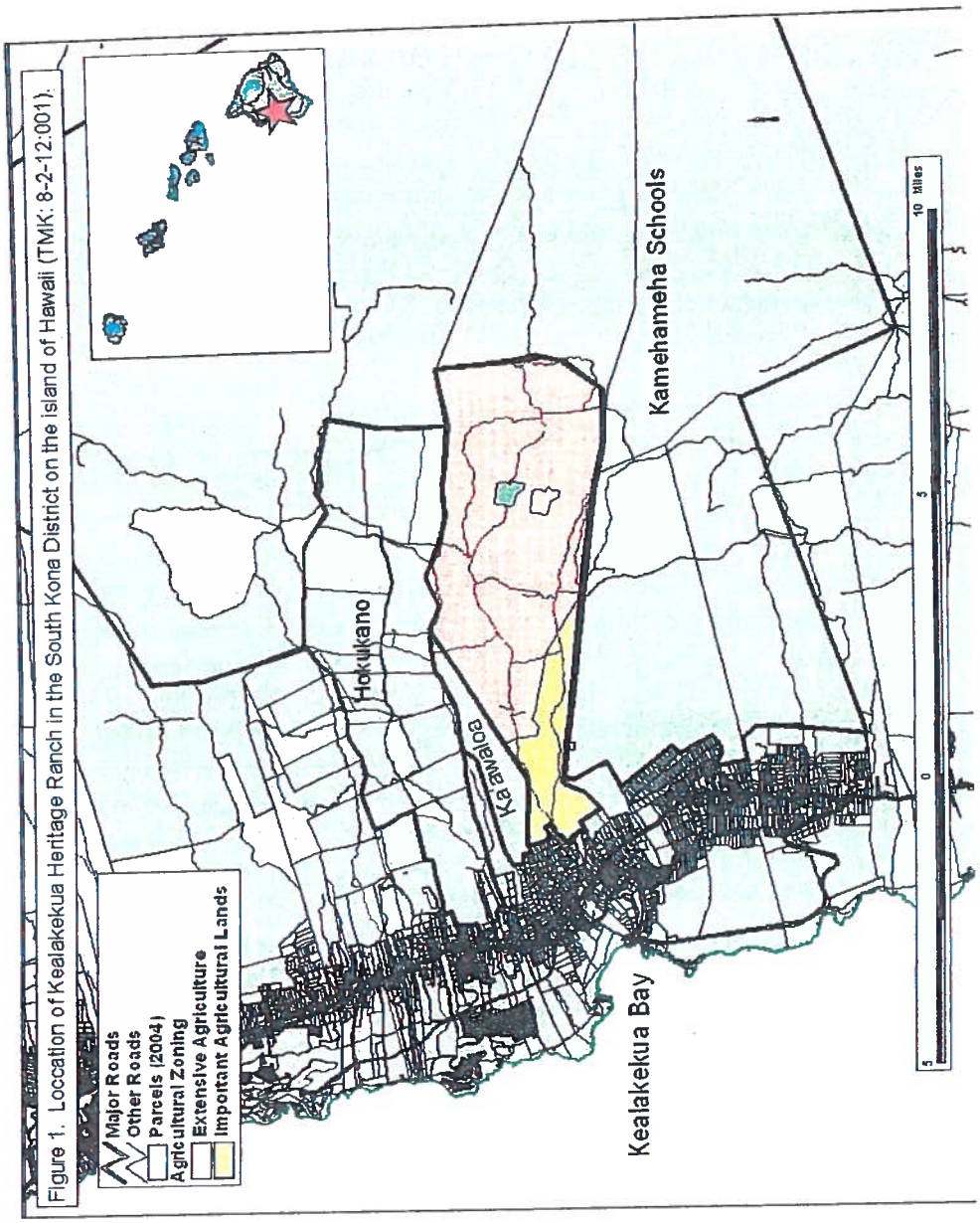
Map 1 below provides an overview of the Kealakekua Heritage Ranch. The green area a little east of the center of the ranch indicates other ownership and is not included in the management plan or the maps' legend. Extensive agriculture refers to all of the aspects of management addressed in this plan.

Map 2 depicts the subject property for this management plan in red and the adjacent parcels owned by the same landowner in other colors, further described by parcel name.

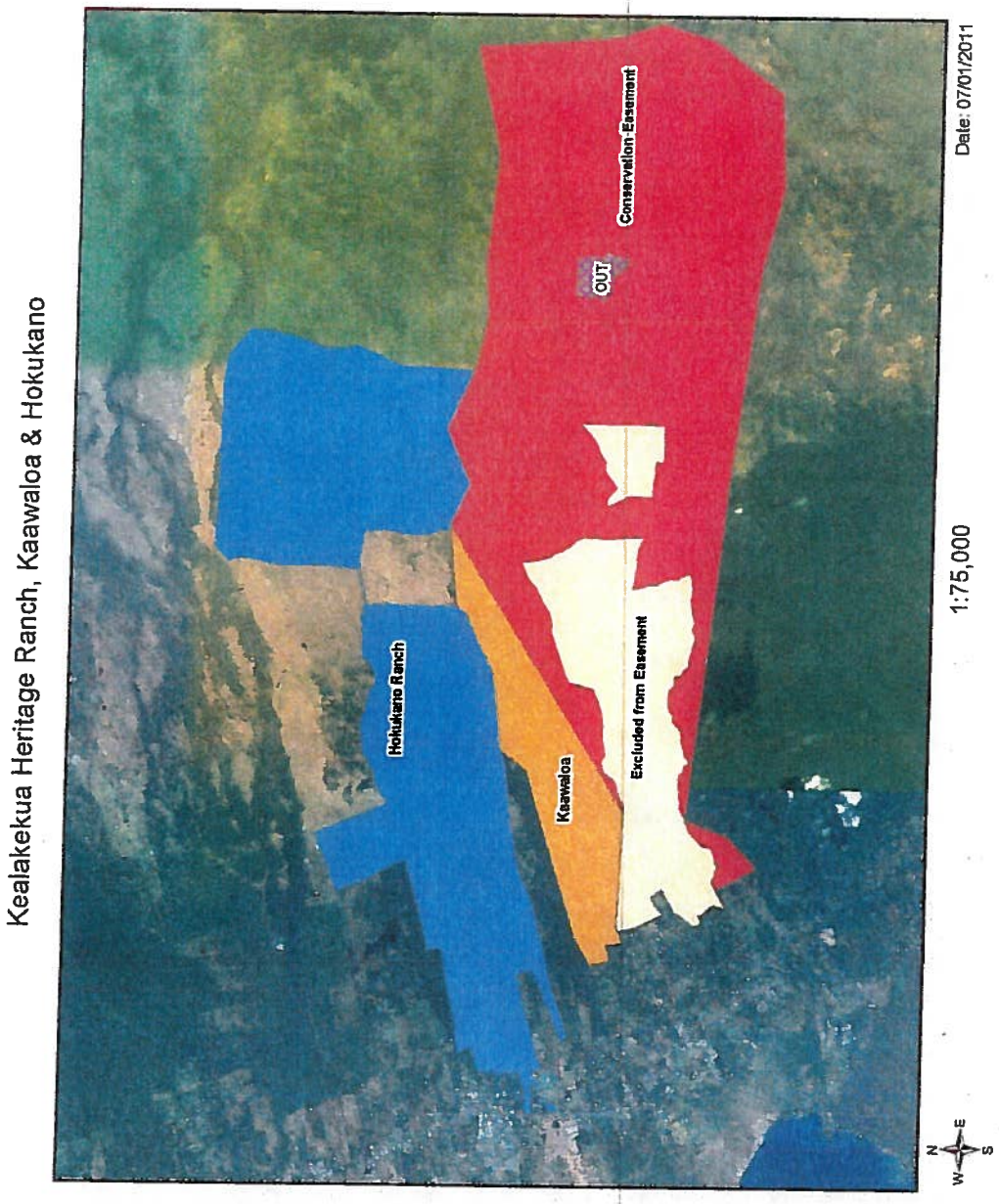
Map 3 shows the management zones from the 2006 approved plan.

Map 4 and Map 5 show the new management zones and management units specific to this management plans' subject area.

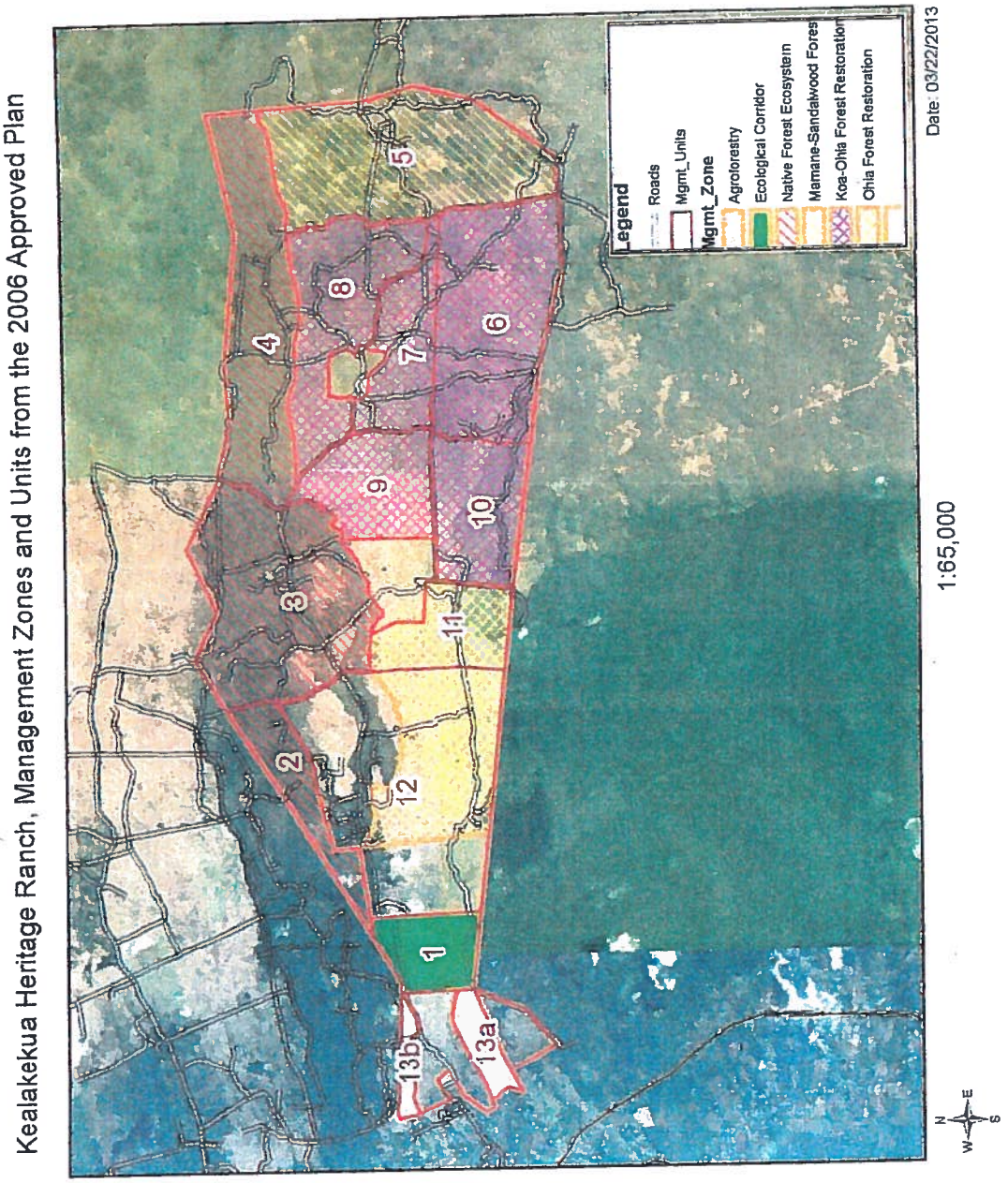
Map 1 - Overview



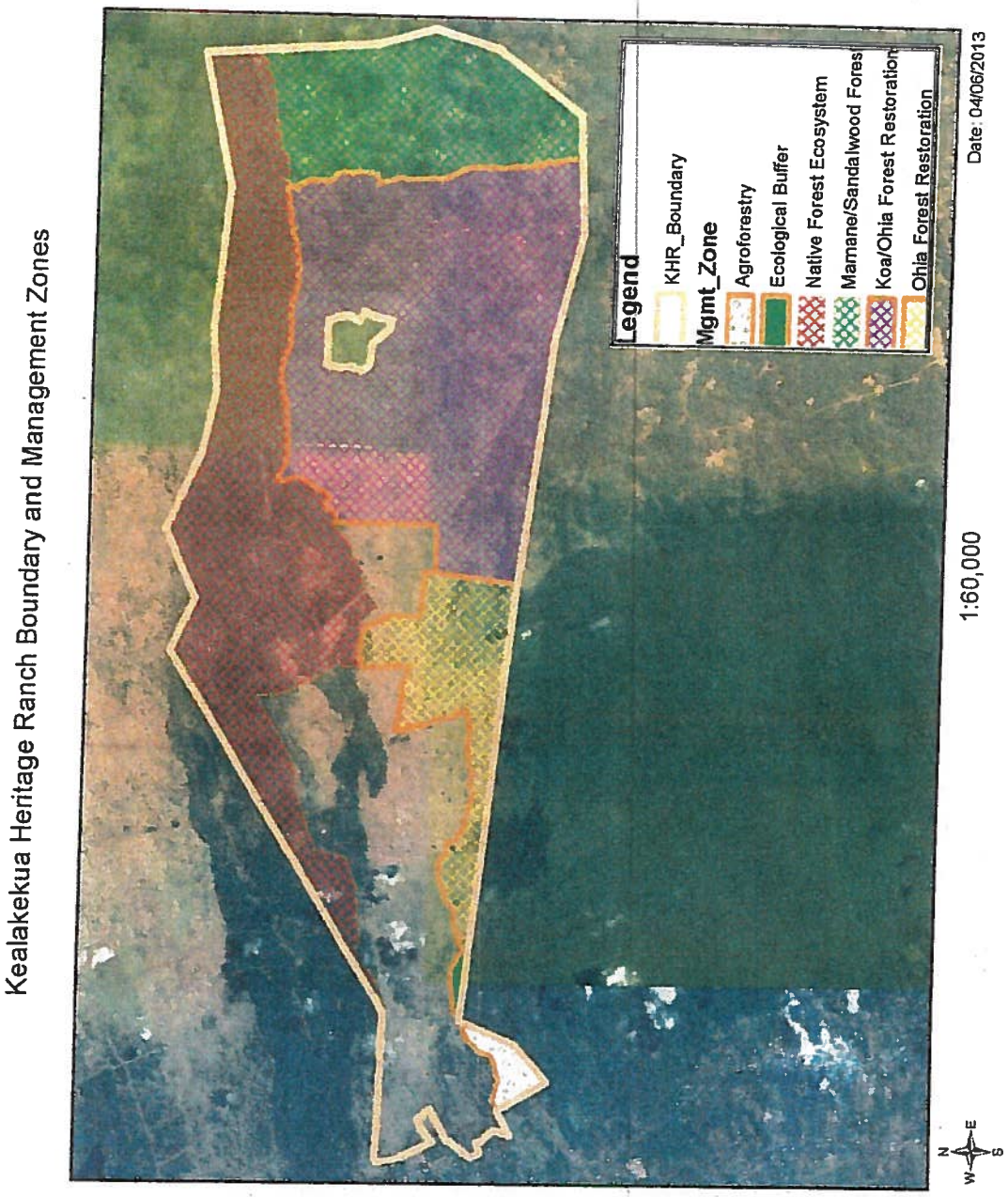
Map 2 – Kealakekua, Kaawaloa & Hokukano Parcels



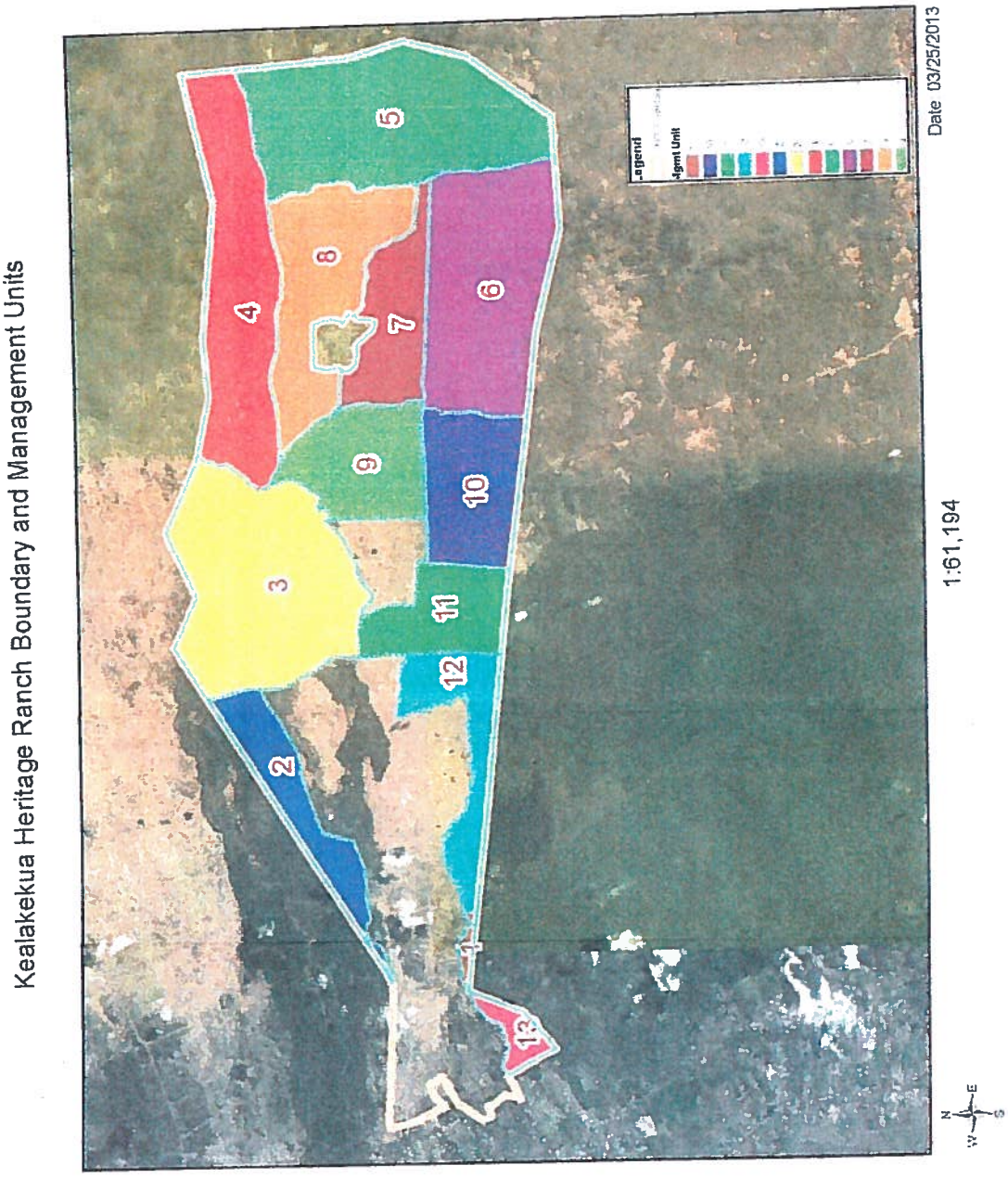
Map 3 – Management Zones from 2006 Approved Plan



Map 4 – Management Zones



Map 5 – Management Units



II. History of Use and Present Condition

The first formal agricultural use of the upper lands of Kealakekua was cattle ranching started in 1875 by Henry N. Greenwell. According to a 1929 livestock survey, the "Aurther [sic] Greenwell Ranch in South Kona had about 12,000 acres, of which about one-half was suitable for grazing, and about 1,500 head of cattle." Later becoming Sherwood Greenwell's Kealakekua Ranch, this property was in the ownership of the Greenwell family and probably continuously in ranching from 1875 until it was sold to Seikin International Co. Ltd. of Tokyo, Japan in 1989. During that time much of the land was cleared in the harvesting of sandalwood and koa. A permanent lumber mill is known to have existed at approximately 3,175 ft. elevation and was in operation from about 1900 to 1926. Logging within the ranch area over this time is believed to have occurred mostly below the Pauahi cattle camp at 4,400 ft. elevation. However the cutting of koa and processing using portable mills continued through the mid 1990's. Logging and conversion of forest to pasture through the seeding of exotic grasses for beef and dairy production also occurred during that period. Historically, four dairy operations were established at different locations on the ranch, and primary production included dairy products as well as the cattle products of hides and tallow. The Portuguese dairy and cattle camps cultivated small acreages in orchards and as large gardens, but most remnants of this early agriculture have vanished. Timber production through selective and opportunistic harvest of koa was continued as its market value warranted, most recently just prior to the 1989 sale to Seikin International. Significant efforts were made by previous owners to curtail surface runoff following intense rainfall events through the construction of diversions and cofferdams. The degree to which these engineering efforts were successful is uncertain.

Seikin International incorporated in Hawai'i as the Kealakekua Development Corporation in 1989, with the intention of converting the ranch to residential properties. The Kealakekua Development Corporation spent over two decades attempting to get the land rezoned and approved for residential and recreational development without success. During this period cattle grazing continued and some minimal logging activities were undertaken that could best be characterized as salvage cuts. In the early 1990's two 20-acre sites were planted with Koa and another 80 acres was scarified with a bulldozer to promote koa regeneration. About eight years ago, Tom Pace and his family, the owners of the adjoining Hōkukano and Ka'awaloa Ranches acquired the property.

Currently the property has many physical attributes that bring value to its inclusion in the Forest Stewardship and Forest Legacy Programs. Previous land use practices have left their marks on the land, however large tracts of high quality diverse native forest and large stands of native 'ōhi'a, koa, and māmane forest remain throughout the property. The property is currently over 75% forested but most areas have a low density of trees compared to their potential. The past land use and remaining timber resources underscore the native timber production value of these lands. In addition, the large tracts of high quality native forest on the property, set against the highly diverse and species

rich nature of the forested leeward slopes of Mauna Loa volcano, establish the importance of this site in sustaining unique native Hawaiian ecosystems and presenting opportunities for discoveries in applied conservation. Kealakekua Heritage Ranch provides the opportunity to build an economically viable model of land stewardship that can be replicated on other, similarly situated lands in the Pacific region. This Multiple Resource Management Plan Project is a major part of this vision.

III. Land and Resource Description

A. Existing Vegetation and Cover Types

Currently there is no complete inventory of all non-native and native plants on KHR. This land was once covered with dense native forest that included ʻŌhiʻa *(Metrosideros polymorpha)*, Koa *(Acacia koa*), Sandalwood *(Santalum paniculatum)* and Naio *(Myoporum sandwicense)* among its overstory. Historically, valuable sandalwood trees were logged and skidded to Kealakekua Bay for transport to markets in both the East and West, until their scarcity made the practice uneconomical. All the past alterations of Hawaiʻi Island west slope forests – clearing to create pastureland, aerial application of exotic grass seeds, cattle grazing, logging of koa and sandalwood - have occurred on this property and result in its current vegetation communities. The following vegetation types are recognized (Gagne and Cuddihy 1990):

1. Lowland Mesic Forest

ʻŌhiʻa Lowland Mesic Forest: This vegetation type occurs over approximately 375 acres of relatively young a'a flow (300 – 750 years old) that receives on the average between 40 and 60 inches of rainfall per year. This classic native lowland mesic forest occurs throughout Management Unit 2 (Native Forest Ecosystem). The vegetation within this unit is structurally diverse with the dominant type being a dense mixed ʻōhiʻa forest with open stands that include koa. This forest is estimated to be almost entirely native-dominated and includes ʻōhiʻa, koa, kōlea, hoawa (*Pittosporum* sp.), pāpala kēpau (*Pisonia* sp.), pāpala (*Charpentiera* sp.), pilo (*Coprosma* spp.), ʻieʻie (*Freycinetia arborea*), *Perrotettia sandwicensis*, hāpuʻu(*Cibotium* sp.), ʻamau (*Sadleria* sp.) maile (*Alyxia oliviformis*) mamake (*Pipturus albidus*), palapalai (*Microlepia strigosa*), and others.

2. Montane Mesic Forest

ʻŌhiʻa Montane Mesic Forest: This vegetation type occurs between 4,000 and 5,000 ft. elevation on the relatively young a'ā flow along the northern boundary of the property and in kipukas and on the older soil types adjacent to the flow. Rainfall averages between 30 and 40 inches annually. This vegetation type includes the entire 1,415-acre Management Unit 3 (Native Forest Ecosystem) and the roughly 375 acres of Management Unit 10 (Koa/ʻŌhiʻa Forest Restoration) that occurs on young lava along the southern boundary of the property. The vegetation within these units is structurally diverse and dominated by a mixture of native tree and shrub species including ʻōhiʻa,

koa, kōlea, kopiko (*Psychotria* spp.), naio (*Myoporum sandwicense*), māmane (*Sophora chrysophylla*), manono (*Hedyotis terminalis*), hoawa, ʻohēlo (*Vaccinium calycinum*), pilo, ʻaʻaliʻi (*Dodonaea viscosa*), maile, mamake, palapalai, and others. At higher elevations on the young flow that runs down the northern boundary ʻōhiʻa dieback is evidenced by the high density of bare poles and low-sprouting ʻōhiʻa. The entire community is species poor and appears to be suffering from a die-back condition of unknown cause.

Koa/ʻŌhiʻa Montane Mesic Forest: This vegetation type occurs on the moderately young soils (750 to 1,500 years) that span the slopes of the property between 5,200 and 5,900 ft. elevation. The three Management Units 6, 7, and 8 occupy approximately 2,524 acres of this vegetation type. These areas represent the upper koa belt where *Acacia koa* dominates an open to closed uneven mixed canopy of koa and ʻōhiʻa, with koa occasionally emerging above the ʻōhiʻa canopy. Species are generally similar to the ʻŌhiʻa Montane Mesic Forest, but the mid-canopy is comprised of native māmane, with sandalwood, naio, aʻaliʻi, pilo, and ʻākala. The koa/ʻōhiʻa montane Mesic Forest may also include aʻaliʻi, laukahi (*Dryopteris wallichiana*), and a surface vegetation of exotic pasture grasses such as *Ehrharta stipoides*.

ʻŌhiʻa Montane Savanna[4]: This vegetation type is characterized by ʻŌhiʻa Savanna with kikuyu (*Pennisetum clandestinum*) as the dominant grass species. This vegetation type is the result of cattle ranching as a principal activity over the past 4 to 5 decades. Relatively older soil types (1,500 to 5,000 years) underlie these units that surround the historic Pauahi Cattle Camp. ʻŌhiʻa Savanna occupies about 85% of the 1,996 combined acres of Management Units 9 – 12. The combined effects of continuous cattle grazing and periodic logging of koa and ʻōhiʻa have resulted in limited recruitment of trees over much of this area, leaving small groups of older trees scattered over kikuyu grassland.

3. Subalpine Forest

ʻŌhiʻa Subalpine Forest: This forest occurs above 5,900 ft. elevation where annual rainfall averages about 25 inches per year and a substantial proportion of the precipitation comes in the form of cloud moisture (fog drip). The 1,385-acre Management Unit 5 (Māmane Forest) occupies the extent of this type. On the older soils of the property ʻōhiʻa takes a lower-stature form and shares dominance with koa, māmane, and sandalwood in this area. Other common species include pukiawe (*Styphelia taimeamea*), and pilo.

Māmane/Koa Forest: This type is represented by the 1,412 acre management unit at the top of the property. It occurs on relatively young lava with poor soil development and average annual rainfall of 25 inches or less. Vegetation is dominated in density and cover

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4 Not described by Gagne and Cuddihy, 1999

by māmane. Subdomimant are ʻōhiʻa, koa, naio, sandalwood, and ʻākala (*Rubus hawaiiensis*), and a mixture of exotic pasture grasses.

B. Existing Forest Health and Function

Although the forest is degraded from decades of ranching, feral ungulates, and high-grading, it is generally healthy and without significant disease problems. However, the relatively new forest pathogen ʻōhiʻa rust, *Puccinia psidii*, that affects members of the Myrtle family and is most prevalent on rose apple *(Syzigium jambos)*, also occurs on ʻōhiʻa nursery stock and in wild stands and appears to be spreading throughout the island. This pathogen, or future strains of the pathogen, may become a concern in the South Kona area in the future. The *Fusarium* fungus is likely present, but does not cause disease because of the higher elevations and cooler temperatures of the ranch.

Another tree disease that is not currently known to occur at Kealakekua Heritage Ranch but could spread there in the future is known as koa wilt. Koa wilt is a vascular pathogen associated with the soil-borne fungus *Fusarium oxysporum.* It affects primarily young *Acacia* koa (less than 15 years) by causing a decrease in tree health and vigor and even death. Also, naio thrips, *Klambothrips myopori*, is a new pest that is killing naio statewide. It is not currently to be present on the ranch, but is likely to occur in the future.

An insect pest known as the *Acacia* psyllid (*Psylla uncatoides*) affects new growth of koa and is a concern when establishing young stands of koa. The psyllid feeds on the sap of young shoots which may cause the death of the leading shoot and trigger early branching. Such effects may impact the growth form of koa trees decreasing merchantable volumes of wood in eventual harvest. In addition, the black twig borer, koa rust, and mistletoe are also known to affect koa.

The koa moth (or koa looper) is an endemic insect on the islands of Hawaiʻi, Maui, and Oʻahu. The caterpillars specialize in feeding on koa leaves and seed pods, and are capable of defoliating mature koa trees. Population explosions have been documented historically on Maui and Hawaiʻi islands, where large areas of koa forest have been defoliated. An outbreak was recently detected on Hawaiʻi Island starting in January 2013. At this time, scientists do not know what triggers these occasional population explosions, but it is believed to be a natural phenomenon with several outbreaks have been recorded over the past 100 years. The January 2013 outbreak is the first reported on Hawaiʻi Island since the 1950's. Healthy koa forests generally recover after defoliation by the koa moth, but mortality as high as 35% has been documented in forests under stress. The eventual causes of the moth population's crash, thus ending defoliation events, is not known. They may be brought under control by predators (e.g. birds, spiders, other insects), parasitoids (e.g. wasps), or diseases, or they may simply lose momentum as food resources are depleted. Control of the moths by pesticides is a possibility but is generally cost-prohibitive over the large landscape scale the outbreaks generally cover. A few caterpillars or moths on koa can be commonly seen. During outbreaks, caterpillars can be

seen swarming on vegetation and the ground, or moths may be stirred up by the dozens from dark areas such as hollow logs or dead tree-fern fronds.

The overall threat of wildfire is moderate on the ranch but varies with elevation, weather and vegetation conditions. Areas with high loads of grasses become susceptible to fire during periods of low fuel moisture – typically during mid to late winter. High loads of dry fine fuels (grasses) ignite easily and carry fire quickly over large areas. Fire history on the property is limited, however there was a fire on Kamehameha School's Hōnaunau Forest lands that came onto the property in 2010 and burned about 50 acres. Potential ignition sources on the property are restricted to rare occurrences of lightening and human causes such as vehicles, use of equipment and machinery not equipped with spark arresters, and careless activities such as smoking. Wildfire threat has the potential to increase dramatically as a result of fountain grass invasion from the north through the Hualalai-Mauna Loa saddle. However the spread of this species will be aggressively controlled through the weed control program. Other pests and diseases that have the potential to affect the health of native forests and forestry operations will be monitored by ranch management (monitoring means we will watch the situation and take action if management could reasonably improve the condition) and managed through management practices.

C. Soils

The property has a westerly aspect with slopes that range from 8% at upper elevations to 15% in the lower part of the property below 2,600 ft. Soils are classified as Histosols characterized by a thin layer of organic material over well-drained volcanically young lavas ranging in age from 250 to 5,000 years old. Their condition is generally healthy although there has been some level of compaction and soil loss associated with logging and cattle grazing activities in the past. Soils are described more fully in the discussion for each management unit.

D. Water Resources and Condition

Due to the highly porous nature of the underlying Mauna Loa substrate, there are no perennial streams or permanent water bodies on the property. The forest is part of the watershed of the South Kona region. This watershed area recharges groundwater resources and contributes to regular subsurface water flow toward Kealakekua Bay and other nearby coastal areas. There is a history of flooding in nearby populated areas below the property. It is unclear to what extent the current simplified condition of the vegetation within the more open portions of the property have contributed to these events and to what extent such flooding events are natural occurring. Overall, the current condition of the watershed is generally healthy, with most areas covered by vegetation. The expected increase in understory and overstory vegetation cover that will result from implementation of the management practices described herein are expected to reduce flood potential to areas downslope.

The property has three primary drainages that feed out near the bottom of the property. Labeled in the drainage study as DW 10, DW 11, and DW 21, these three drainages are estimated to have 100-year peak discharges of 1,105; 598; and 2,217 cubic feet per second, respectively (Towill 1993). This plan includes measures to either preserve native forest or restore native forest to the upland areas in those drainage systems. While flood events are a natural phenomenon, KHR aims to minimize the damaging effects of natural floods through the preservation of existing native forest, and the restoration of healthy native forest ecosystems.

KHR has contacted the Three Mountains Watershed Alliance about membership in the watershed partnership and to assess the opportunities for landscape scale watershed restoration.

E. Wetland Resources

There are no permanent wetlands that are known to occur on the property. Due to the geologically young and porous nature of the underlying substrate, wetland soils do not occur on the property. There are no standing bodies of water on the property and wetland vegetation is absent, except for small patches of sedges that are adapted to living in the perpetually wet understory of the lowland mesic forest. These sites are generally small in size (<1 m^2) and are more or less evenly scattered throughout the highest rainfall zones of the property. While these small sites possess plant species that also occur in perpetually wet soil conditions, they do not represent classic wetlands.

F. Timber Resources

Timber resources that exist on the property are mostly native timber species. *Acacia koa,* the principal native species traditionally harvested in Hawai'i, is somewhat abundant on the property. 'Ōhi'a, another commonly used native forestry species, and the less-common sandalwood also occur on the property. The endemic koa is the second most prevalent tree in Hawaiian forests. Naturally occurring trees in the forest often possess a wide symmetrical crown and bole diameters up to 6 ft. or more. Koa has been considered the most valuable species in the islands and in modern times has been utilized for a wide range of timber products ranging from lumber for construction to furniture and fine craft wood. In ancient times large logs of the species were carved by Hawaiians into great war canoes while the bark was utilized as a tanning dye (Rock 1913). One of the most notable characteristics of the species is the presence of two kinds of leaves, true leaves present on seedlings and saplings and phyllodes, or elongated leaf petioles that function as leaves and characterize adult trees. Projected yields of 90–180 cubic meters per hectare (m3/ha) or 6.5–13 thousand board feet per acre (MBF/acre) may be possible in pure stands in 30–50 years; much less in open-grown stands in pastures or in mixed stands in natural forests (Elevitch et. al, 2006).

Three koa plantings exist on the property. The first is the 20-acre Koa Test Planting Area I, located at 4,100 ft. elevation and planted in May of 1991. In this area, grazing was

curtailed, grass cleared, and 3,150 koa and 1,000 toon (Australian cedar) were planted. All plants were fertilized equally during the first year, and then only preferred individuals were selected for fertilization. Some level of pruning was performed in the stand. After two years there was apparently good survival of both species. The second planting was also approximately 20 acres in size and occurred in April of 1992 in a previously cleared portion of the ranch. Part of this area was planted with 4,500 koa and 1,500 toon seedlings and a few blue marble and Queensland maple were also planted. Another 80 acres adjacent to this site was scarified with a bulldozer to successfully promote koa regeneration. Results of that scarification effort were the successful establishment of koa seedlings throughout the scarified area.

The third area was planted in 4 small units for research by Colorado State University in 2010. All plantings are near management unit 10 and are 3 one-acre plots and one three-acre plot. All plots were fenced with 7-strand barbed wire.

ʻŌhiʻa (*Metrosideros polymorpha*) is a slow growing species endemic to Hawaiʻi and is the most prevalent tree in the forest. The largest ʻōhiʻa forests occur on the slopes of Mauna Loa and Mauna Kea on the island of Hawaiʻi. The wood of the ʻōhiʻa is a dark reddish color, durable, hard and equal in strength to the Oak. It has been used by Hawaiians for carving idols, spears, mallets, etc., and later for paving blocks, flooring and interior house finishings. Later, there was a significant export of ʻōhiʻa for use as railroad ties on several U.S. mainland railroads (Rock 1913). Today the main products include flooring, pole wood, fuel wood, and as habitat for honeybee pasturage. High-volume, old-growth stands may yield 70–84 m3/ha or 5000–6000 bf/ac; stands on poor soils such as lava rock may yield much less (Friday and Herbert, 2006). At KHR ʻōhiʻa occurs throughout the property and is in the lowest density within the middle-elevation savannas that have been heavily used in the past for cattle production. On the upper reaches of the young aʻa flow that spans the north boundary of the property, the canopy, dominated almost exclusively by ʻōhiʻa, has experienced dieback leaving mostly dead poles.

Sandalwood (*Santalum* sp.) is a hemi-parasitic tree that is reported to reach heights of 80 ft. and achieve a diameter of 3 ft. (Rock 1913). The value and fragrance of the tree increases with age as only the heartwood bears the fragrance for which the species is valued. In Hawaiʻi sandalwood, or ʻiliahi, is represented by six species that exhibit a wide range of variation in vegetative and floral characteristics. Beginning in 1778, sandalwood started to be exported in exchange for goods and dollars. The trade was robust until the supply essentially ran out around 1820. An attempt to revive the trade was made by substituting naio (*Myoporum sandwicense*), or bastard sandalwood, but this attempt proved unsuccessful. The most abundant sandalwood species that occurs at KHR is *Santalum paniculatum* which occurs at low frequencies in the upper portion of the property. *S. ellipticum* may also occur with less frequency in lower forested portions of the property. The white sandalwood native to India, *Santalum album*, has been planted on

Oahu and Kauai but is not naturalized on the island of Hawai'i (Wagner et. al 1990). DOFAW has some indication that *Santalum album* has been planted on the island; however that has not been confirmed by staff. The growth rate of these species is slow to moderate, 0.3–0.7 meters/year (1–2.3 feet/year). Today the species are mainly planted in home gardens and in mixed species forestry. The heartwood possesses the characteristic odor for which sandalwood is famous and is used for crafts and limited essential oil extraction. Very little is known about timber yields or rotation ages, however it is reported that the species yields heartwood in 30+ years (Merlin et. al, 2006).

1. Timber Inventory

The original timber volume estimate was developed by McKenzie River Associates, LLC, which worked as a sub-contractor to the Hallstrom Group of Honolulu, HI, which was under a State of Hawai'i managed appraisal contract. The stated goal was to develop a timber volume estimate based on field sampled data, not to conduct an extensive forest inventory.

The process followed to develop the timber volume estimate began with the delineation of individual timber stands. This work was accomplished using a combination of publicly available orthophotos, digital topographic maps, and a digital **LIDAR** (**Li**ght **D**etection **A**nd **R**anging) layer. LIDAR is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target (Wikipedia). The LIDAR layer was produced by Aerial Surveying, Inc. of Kona, HI at the request of KHR. All digital information was imported into ArcMap, a geographic information system (GIS) computer program. ArcMap is produced by the Environmental Systems Research Institute, Inc. of Redlands, CA.

Following the delineation of timber stands, representative stands were visited to verify the delineation work and measure trees using variable radius sample plots. Tree data collected on the sample plots were species, diameter at breast height (DBH), total tree height and visible defect. The variable radius sample plot design used had several advantages over a fixed area plot design; plot boundaries do not have to be measured; the number of trees to measure and tally are greatly reduced; there is a better balance between trees of large and small diameter when volume is calculated; and, it is simpler to use and reduces time spent on each plot (Bell-Dilworth, "Log Scaling and Timber Cruising"). Equipment used included a diameter tape, a Criterion RD 1000 digital relaskop and a Laser Tech Impulse laser range finder.

Since the volume estimate was not designed to include a complete timber cruise, only 65 sample plots were measured. Stands were sampled between June 18th and 25th, 2010. They were selected to obtain information for the range of tree data in the most heavily stocked stands. Volume estimates were made for stands where no sample plots were taken. Stands that were very similar to sampled stands relied on the sampled stands volumes per acre for their volume estimate. The remainder of the unsampled stands had

very low stocking levels and average trees per acre by diameter and height were estimated based on field observations. To facilitate this process, all of the timber stands on the subject property were visited and photographed using a Nikon D300 camera linked to a Garmin 60CSx GPS. This created geo-referenced photos which were loaded into the GIS database using ArcPhoto, and ArcMap application. The combination of orthophotos and geo-referenced ground-based photos greatly enabled the process of assigning surrogate sampled stands for unsampled stands.

Forest Planning and Projection System (FPS) software was used to process field collected data from the individual stands. The Forest Biometrics Research Institute (FBRI) is a non-profit research corporation established in 2002 for the advancement of research, education, and services in forest biometrics. Dr. James D. Arney, the founder of FBRI, developed the FPS software.

The field collected sample plot data was compiled in FPS to derive individual log segment diameters and lengths. Gross and net volume by tree and individual log within each tree were calculated. The numbers of trees per acre as well as the averages for the entire timber stand were determined. A hidden defect deduction was applied in addition to the visible defect noted in the field. Thirty percent hidden defect was applied to Koa and fifty percent hidden defect was applied to ʻōʻhia. Trees were merchandised using a nominal 16 foot log length but minimum piece size was 1 foot for Koa and Sandalwood and 4 feet for ʻōʻhia. Although the standard error varied significantly between each stand, the overall standard error for board foot volume per acre for the sampled stands was 7.6%. This means that two out of three times, the likelihood of the average volume per acre is within 7.6% of the mean for the cruise.

Once the compilation process was complete, expansions (using sampled stands to estimate volume for similar unsampled stands) were made. The individual timber stands were compared using the orthophotos, LIDAR, and ground-based photos to determine which stands to expand from and expand into.

FPS is a distant dependent tree growth model that computes a clumpiness factor based on plot to plot variation for each cruised stand. This factor is used to increase the reliability of growth projections by accounting for tree-to-tree competition and the fact that trees generally grow in clumps rather than being evenly spaced throughout the stand. A unique habitat class was computed for each stand and used by the model to predict existing tree growth, new tree ingrowth, and mortality. In addition to the habitat classes assigned to each stand, habitat groups were designated. The habitat groups are used to group stands of like species composition. The lower elevation areas along the northern border of KHR exhibit more of a rainforest type of habitat and stands in that area were placed in a separate habitat group. Stands at higher elevations are much drier and include sandalwood. These stands were placed in another habitat group. Different yield tables were built for each habitat group to accommodate these differences.

The inventory showed that there was about 7.4 million net board feet of timber on the property within the conservation easement. The net volume is approximately 50% of the gross volume after accounting for visible and expected hidden defect.

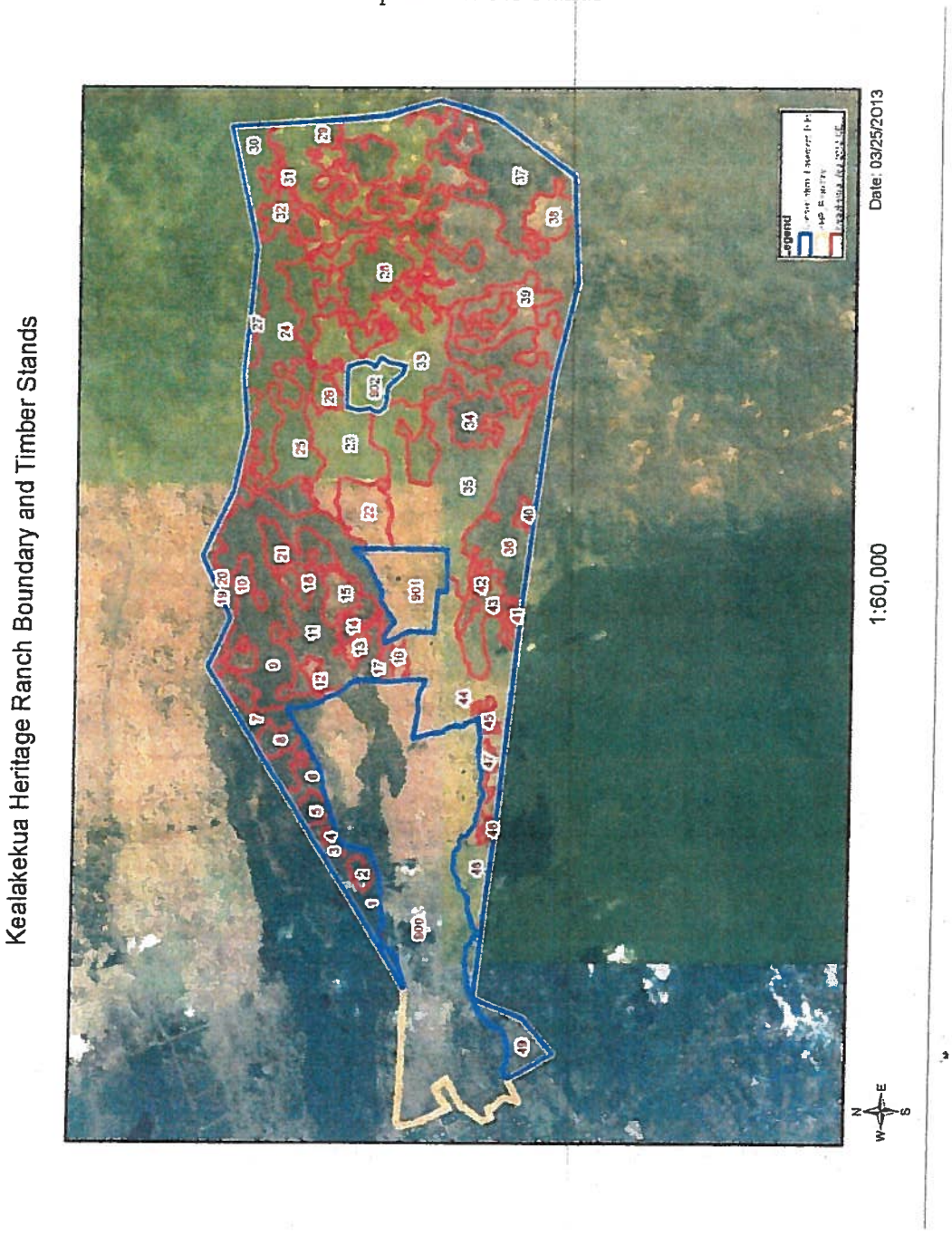
Trace species occur on the subject property. For areas where Sandalwood occurs, one tree per 2 acres was assumed. A small amount of eucalyptus is present but not included in the inventory.

The entire KHR property was mapped as forest (timber) stands. The areas outside the plan area are some of the most degraded forests (highly converted to pastureland). Each stand in the plan area will have a silvicultural prescription, written by a professional forester, to advance the stand as well as the entire plan area towards the larger scale vision for the property.

Representative ground-based photographs are included in Appendix I for the majority of the timber stands. These photographs were taken with a Nikon D300 Digital SLR camera linked to a Garmin 60Scx GPS receiver so that the exact coordinates of the location where the photograph was taken is recorded in the metadata of the photograph. This process enabled a pictorial review of the stands during office computations.

Map 6 shows the individual delineated timber stands. The stand numbers shown relate to the stand numbers listed in the Stand, Species Summary Report above. Stands 900, 901 and 902 are not part of this volume estimate as they are areas excluded from the conservation easement.

Map 6 – Timber Stands



G. Non-Timber Forest Resources

In addition to timber species, other non-timber native species have also been harvested for non-timber uses. Such species include hāpu'u (*Cibotium sp.*) for fiber, the maile vine (*Alyxia stellata*) used in lei making, and māmane (*Pipturus albidus*) used traditionally by Hawaiians as medicinal tea.

H. Significant Historic and Cultural Resources

The Henry N. Greenwell Ranch was established in 1875 as the first formal cattle ranch in South Kona. Two significant historic features, the Pawaina corral and the Pauahi Cattle Camp, exist on the property and will be preserved and protected. An archaeological study was prepared in 1991 for the lower portion of the property below 3,100 ft. elevation by Cultural Surveys Hawai'i. Their study included a detailed cultural inventory survey of lands below 3,000 ft. elevation, but also summarized existing knowledge of historic and prehistoric activities and uses and identified specific historic and cultural features that occur throughout the property. Their report provides recommendations for treatment of those sites. Sites of interest include Japanese agricultural settlements, a sandalwood pit, a constructed trail alignment, and historic complexes at Pawina, Pauahi, and Papaloa. The study recommended that these sites be added to the State Registry of Historic Places. In addition, their study identified kuaiwi linear mound features in the extreme northwest portion of the property that indicate possible inclusion in the Kona Field System. Some of these sites occur outside the area covered by this plan. The agricultural homestead and Kona field system sites occur on lands represented by Management Units 1 (Ecological Corridor) and 13 (Agrarian Forest Reserve) of this plan. No surface disturbing practices are planned for these units.

The region is recognized as an important historic area due to the arrival spot of Captain Cook's third voyage at nearby Kealakekua Bay. Less known are the roles the region played in ancient times as part of the Kona Agricultural Field System and later to support multiple ethnic groups in turn of the century agriculture activities. Noteworthy features from that era include homestead sites from Japanese settlers (Hammatt et al. 1993). But prior to Kona's historical entrance into the global market, a prehistoric field system had been in place. Recognized agricultural practices, which began in the twelfth century, included shifting cultivation, cross-slope terraces, parallel walls called kuaiwi, and variously sized stone mounds placed between the kuaiwi (Allen 2001). For these and other reasons KHR plans to retain all known cultural and historical features in their current state. If a discovery is made of previously unknown and new sites, a trained archaeologist will be brought to assess the site and make recommendations for protection.

I. Existing Wildlife and Threatened and Endangered Species

Intact native forests, of the type previously found on this property, supported a unique community of diverse endemic plants and animals, many of which are either extinct or critically endangered. The vision for KHR is to restore forest cover in the landscape thus creating more suitable habitat for protected (endangered, threatened, candidate and proposed) plant and wildlife species. Once sufficient acres of tree are planted, KHR plans to enter into a Safe Harbor Agreement with the U.S. Fish and Wildlife Service (USFWS). This will allow the take of endangered species incidental to otherwise lawful activities on the land. A consultant will work with the USFWS to complete the baseline surveys and to prepare and submit the required reports.

Prior to the preparation of this plan, several state and federal conservation organizations and agencies were contacted in an effort to locate records of rare plant or wildlife species historically present on the property. Literature sources were also reviewed and information extracted.

The Hawai'i Biodiversity and Mapping Program (HBMP), located at the University of Hawai'i at Mānoa, collects information on the location and condition of Hawai'i's rare plants, animals, and natural communities (ecosystems). Their database records span a period from the 1800's to present. A search of the database provided several records of rare species historically present on the property.

The Hawaiian Forest Bird Survey (HFBS) was the most extensive effort to inventory Hawaiian birds in modern times. This study covered a seven year period from 1976 to 1983 and focused on all native forests above 3,200 feet elevation (Scott et al. 1986). Portions of two HFBS transects extended into the easement area allowing biologists to obtain data on birds that were present in 1978. Transect 59 extended along the northern side of the easement while transect 60 cut through the central portion of the property. Results of these surveys were obtained from the Hawai'i Cooperative Studies Unit at the University of Hawai'i at Hilo.

Rare species accounts relevant to Kealakekua Heritage Ranch lands are presented below:

1. Plants

At least three endangered plant species were historically present in the easement area. 'Oha wai (*Clermontia pyrularia*), *Neraudia ovata* (no common name), and Wawae'iole (*Huperzia manni*) were all recorded during the 1940's and 1950's (HBMP database). The rare *Ranunculus mauiensis* was also present during the same, but this plant is not listed as endangered. None of the above species are known to exist on the property today.

Field surveys to describe the major vegetation types and to search for sensitive native plant communities as well as threatened and endangered plant species were conducted in 1991 by Winona Char (Towill, R.M. Corp., 1993). This survey extended from about 2,200 to 4,120 feet elevation on the property. None of the native species found during the survey are officially listed as threatened or endangered; nor are any proposed or candidates for such status. No additional botanical surveys for T & E species have been conducted on the ranch in recent years.

2. Wildlife

a. Forest Birds

The 1978 Hawai'i Forest Bird Survey recorded 25 species of native and non-native birds along transects 59 and 60. Eight of these species were endemic Hawaiian birds: 'Apapane (*Himatione sanguinea*), Hawai'i 'Amakihi (*Hemignathus virens virens*), Hawai'i 'Elepaio (*Chasiempis sandwichensis sandwichensis*), Hawai'i Creeper (*Oreomystis mana*), 'Alalā (*Corvus hawaiiensis*), I'o (*Buteo solitarious*), 'I'iwi (*Vestiaria coccinea*), and Pueo (*Asio flammeus sandwichensis*).

In 1991, Phil Bruner conducted a wildlife survey (Towill, R.M. Corp., 1993) in the easement area. He recorded the presence of both 'Io and Pueo as well as four other endemic bird species: 'Apapane, Hawai'i 'Amakihi, Hawai'i 'Elepaio, and 'I'iwi. The 1991 survey also detected the indigenous Kōlea or Pacific Golden Plover (*Pluvialis fulva*) and listed three species of endangered birds that could potentially occur on the property, but were not sighted. This latter group included the 'Ākepa (*Loxops coccineus*), 'Akiapōlā 'au (*Hemignathus munroi*), and Hawai'i Creeper. Sixteen exotic or introduced bird species were recorded. The most abundant were Japanese White Eye (*Zosterops japonicas*), Nutmeg Mannikin (*Lonchura punctulata*), Turkey (*Meleagris gallopavo*) and Yellow-Fronted Canary (*Serinus mozambicus*).

'Alalā: KHR is among the last known habitat of the rare and endangered Hawaiian Crow, or 'Alalā. 'Alalā are endemic to the Island of Hawai'i with their historic range extending south from Pu'u Anahulu in North Kona District to Kilauea crater in the Ka'u district. These birds were commonly found in upland forests on Hualalai and Mauna Loa prior to 1980. 'Alalā tend to be omnivorous, but fruit from native trees is an important part of their diet (Giffin et al., 1987).

The HBMP database and HFBS recorded several sightings of endangered 'Alalā at KHR. Birds were present in the easement area during the 1960's and 1970's. In 1980, at least nine 'Alalā were observed near the KHR property boundary, at Honaunau Forest Reserve (Giffin, 1983). Native crows are now considered to be extirpated in the wild, but the

USFWS plans to re-introduce these birds at Kulani in 2014 (Jay Nelson, pers. comm. 4/1/13).

'Ākepa: Hawai'i 'Ākepa are colorful insectivorous birds that glean insects from tree foliage, usually 'ohi'a leaf buds and koa phyllodes. They are most common on Hawai'i Island above 4,800 feet elevation in tall, mesic to wet forests, and are absent from māmane woodlands (Scott et al., 1986). Exhaustive surveys by the U.S. Fish and Wildlife Service in the late 1970's only detected a single 'Ākepa on the Kona slopes of Mauna Loa. This bird was heard by J. Jacobi above Honaunau Forest Reserve (Scott et al., 1986). 'Ākepa have not been found in the KHR area in recent decades.

'Akiapōla'au: These bizarre looking honeycreepers are rare to uncommon inhabitants of mesic to wet koa- 'ohi'a forest and dry māmane-naio woodland on Hawai'i Island. A small population of less than 20 birds is on the verge of extinction in central Kona (Scott et al., 1996). None were found during the HFBS nor are any expected to occur in the KHR area.

Hawai'i Creeper: Creepers exist on all major Hawai'i Island volcanoes except Kohala Mountain. They are most common in mesic and wet forest above 4,900 feet elevation. Surveys in Kona indicated that Hawai'i Creepers primarily inhabited koa- 'ohi'a forests and were restricted to areas above 4,800 feet elevation (Scott et al., 1986). A single Creeper was observed on KHR lands during the 1978 HFBS. This bird was observed along the northern boundary of the easement at approximately 4,300 feet elevation (transect 59, station 104).

'I'iwi: 'I'iwi are widely distributed on Hawai'i Island. In the Kona region, moderate densities occur as low as 960 feet elevation. These birds feed primarily on flower nectar and foliage insects (Scott et al., 1986). The 1991 avifauna survey conducted by Bruner (Towill, R.M. Corp, 1993) recorded the presence of two 'I'iwi on KHR. 'I'iwi are of special concern since they are currently being considered by the USFWS for listing under the Endangered Species Act of 1973.

Palila: The endangered Palila (*Loxiodes bailleui*) is a finch-billed Hawaiian honeycreeper that feeds primarily on the green seed pods of māmane trees. This species is currently found only in the māmane-naio woodlands on Mauna Kea. Historically, Palila occupied māmane-naio forests on the west and southwest slopes of Mauna Loa (Scott, et al., 1986). In the 1890's, Perkins (1903) noted that Palila were "extremely numerous" in Kona māmane forests between 4,000 and 6,000 feet elevation. KHR is within a mile of

Kamehameha Schools' Lupea Project, a proposed re-introduction site for Palila. Palila habitat restoration activities are currently in progress at that location and provide ample opportunity for partnering with the school and government agencies to restore palila habitat in the central Kona region.

b. Birds of Prey

Only two raptors are native to the Islands, the endangered Hawaiian hawk or 'Io and the native Hawaiian Owl, or Pueo.

'Io: Hawaiian hawks are restricted to the Big Island, but are wide-spread and utilize many different habitat types. They generally hunt prey from a perch, feeding on native and non-native song birds, game birds, rats, mice and insects. However, the bulk of their diet is composed of rodents (Klavitter, 2000). Hawaiian hawks are occasionally seen in the KHR area, but there are no records of birds nesting on the ranch.

Pueo: Pueo or short-eared owls are an endemic subspecies commonly found in upland pastures. This species is not listed as endangered, but their numbers have declined in recent decades. Pueo feed extensively on mice and Polynesian rats. Their ground-nesting behavior makes them vulnerable to predation by cats and mongooses (Scott et al. 1986). Pueo are seen less often than hawks, but are sometimes observed in the open pastures at KHR.

c. Waterfowl

Suitable habitat for native waterfowl is generally lacking at KHR. There are no perennial streams or standing bodies of water to attract these birds. No endangered koloa (*Anas wyvilliana*) or nene (*Branta sandvicensis*) have been reported in the easement area.

d. Mammals

Mammals detected during Bruner's 1991 survey (Towill, R.M., Corp., 1993) included those common throughout the west slope of Mauna Loa. All are introduced species. This group consisted of cattle (*Bos taurus*), feral cats (*Felix domesticus)*, feral goats *(Capris hircus),* feral pigs (*Sus scrofa*), feral sheep (*Ovis aries*), Mouflon sheep (*O. musimon*), mongooses (*Herpestes auropunctatus*), mice (*Mus musculus*) and rats (*Rattus rattus*). Feral dogs have been reported in the general area, but have not been observed on the ranch.

'Ope'ape'a: The endangered Hawaiian Hoary Bat or 'Ope'ape'a (*Lasiurus cinereus semotus*) is Hawai'i's only native land mammal. Today, sightings of this small animal are common in the Kona Region. Bruner's 1991 mammal survey at KHR failed to record any

bats despite spending three evenings searching for them (Towill, R.M. Corp., 1993). The HBMP database recorded two bat sightings at KHR, one in 1966 and another in 1978. It is likely that bats frequently commute and forage in the easement area, but no information is available on their distribution, population size, roosting sites, or breeding activity. Koa reforestation is expected to create additional suitable habitat for this small mammal.

3. Special Plant and Wildlife Designations

Land use decisions on private property often have important implications for endangered species. The USFWS encourages land owners to voluntarily engage in management actions that benefit endangered species and their habitats. Accordingly, the Service has designated "Critical Habitat" and "Forest Bird Recovery Area" units on both public and private lands that are of high importance to endangered species.

"Critical Habitat" is a term used in the U. S. Endangered Species Act identifying geographic areas that are essential for the conservation of threatened or endangered plant and animal species and may require special management considerations. Designation of land as critical habitat does not require the landowner to implement recovery actions or to manage the land in a certain way, but it does require the landowner to consult with the USFWS if they undertake projects that entail federal funding or permitting.

Critical Habitat maps published by the USFWS (2012) were reviewed to determine if any Critical Habitat units for threatened and endangered plants or animals were designated for the easement area. This review confirmed that none of these units fall within the property boundaries.

"Forest Bird Recovery Area" is a non-legal designation used by the U.S. Fish and Wildlife Service to delineate habitat areas necessary for the recovery of endangered bird species. Identification of land as recovery area does not create or imply any legal requirement of the property owner to implement recovery actions, nor does it impose any limitation on the types of activities that the landowner may choose to engage in. Recovery areas are those that, from a purely biological standpoint, have the greatest potential to provide habitats important to the recovery of endangered forest birds.

The Revised Recovery Plan for Hawaiian Forest Birds (USFWS, 2006) presents maps showing the location of Forest Bird Recovery Areas in Hawai'i. This plan was reviewed to determine if any designated areas fell within the KHR easement. A visual inspection of the maps indicates that Forest Bird Recovery Areas for four endangered bird species extend into the KHR easement. Recovery areas are indicated for 'Akiapōlā 'au, Hawai'i

'Ākepa, Hawai'i Creeper, and Palila. All designated units are situated above 4,000 feet elevation.

J. Existing Recreational and Aesthetic Values

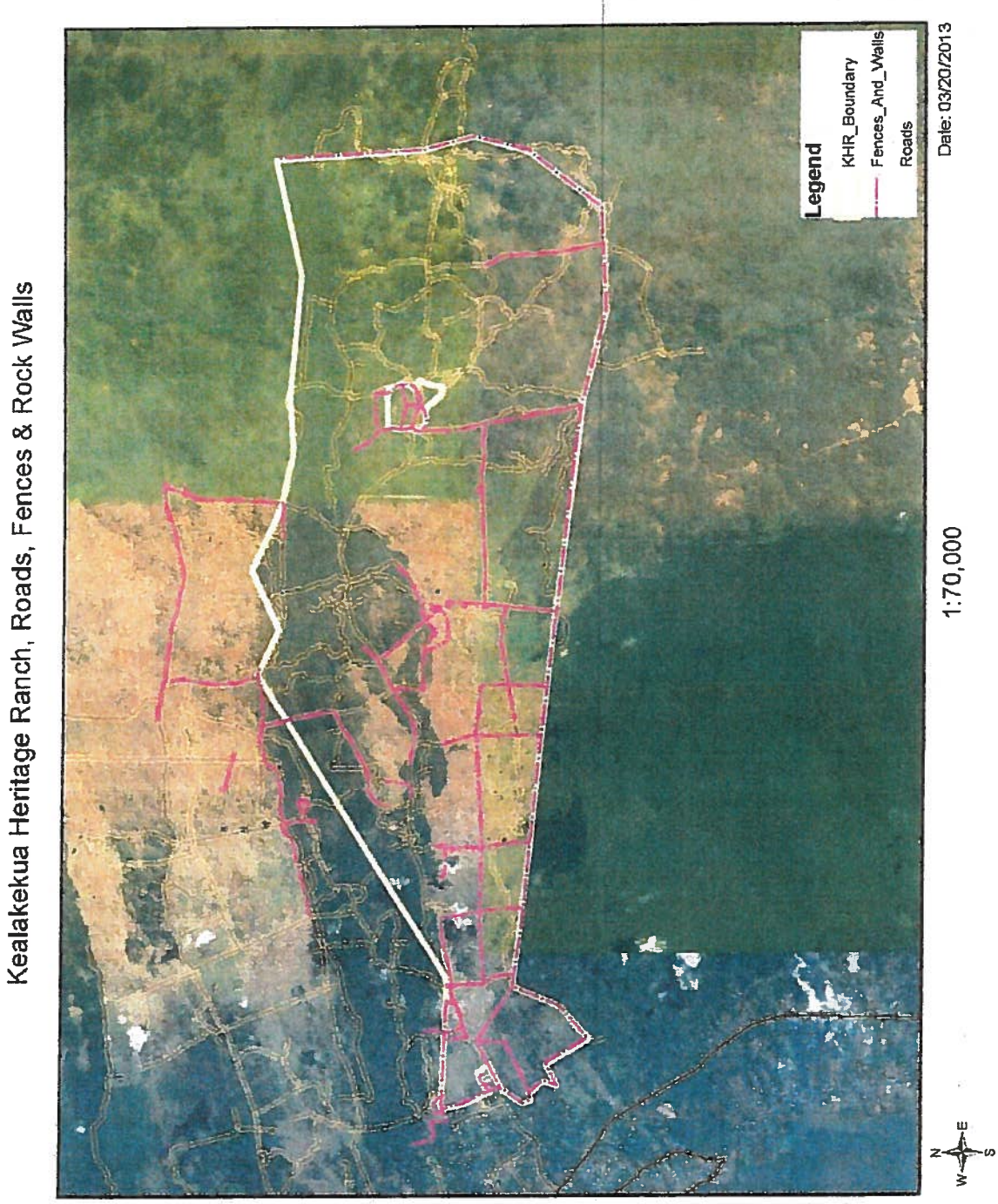
KHR lies as the backdrop to Kealakekua Bay, a popular site for most first time visitors to the island. The coastline downslope of the property is used by locals and visitors alike for a broad range of ocean-based recreational activities from fishing to surfing to kayaking and snorkeling.

Currently the ranch licenses property to Kona Eco Adventures ("KEA"). KEA has built a new Zipline on the Ka'awaloa Ranch adjacent to KHR, which is also owned by the Pace family. Foot and ATV trails located on KHR are part of the KEAs' eco-tours, which are being conducted consistent with the terms of the CE. There is a rural network of ranch roads and trails that could provide an ideal setting for equestrian activities such as horseback riding and the development of foot-trails for hiking and naturalist activities. Portions of the property are occasionally used for hunting by employees or by local residents with permission from KHR. There is a hunting concession that covers Hokukano and KHR. The concession outfitter brings hunters onto the ranches to hunt a variety of game species. In 2012 there were 43 hunters that were guided by Hawaiian Safaris on Hokukano/Kealakekua Ranches.

11. Existing Fence on KHR

The ranch owners have been building fence on KHR for many years for management purposes. The attached map shows the existing fencelines. The ranch has a fence building and repair program in place and has built nearly 9 miles of fence under the first plan for KHR. Currently there is approximately 45 miles of fence on the ranch. Most is 5 or 7 strand barb-wire with some of the newer fence being hog-wire. In addition there is about 2 miles of planned fence along the north boundary that will soon be under construction and is not included on the map at this point.

Map 7 – Roads, Fences & Rock Walls



IV. Vision, Objectives and Practices

The vision for this property is to bring the KHR CE area forestland back to a fully stocked, ecologically sound, Hawai'i native dominated forest that provides a sustainable level of goods and services. Objectives and practices have been developed to move the present condition of this property towards the vision of the area over the next 10 years or so. This plan will remain in effect until revised.

A. Description of objectives

1. Growth and Management of Forests for Timber and other Forest Products

i) Harvest select downed and dead native koa and sandalwood

ii) Harvest standing dead 'ōhi'a poles from Management Units 3, 4, and 6-9

iii) Capture mortality by the harvest of near dead trees

iv) Harvest a sustainable level of live tree timber (not to exceed 250 MBF/year net)

v) Increase the stocking level in understocked stands

vi) Improve the overall vigor and growth rates

vii) Certify forest lands under the American Tree Farm System

viii) Thin overstocked stands.

2. Native Species Restoration/Reforestation and Habitat Improvement

i) Maintain and enhance high quality forest areas through removal of livestock and control of invasive and alien plant species.

ii) Increase native tree cover and restore mixed-composition native forest stands in partially degraded forest areas through planting and encouraging natural recruitment from existing seedbank (scarification).

iii) Gain control of livestock population and utilize herd as a tool for hazardous fuels reduction and scarification in restoring native forest to degraded areas.

iv) KHR management will track the success and effectiveness of management practices toward meeting management objectives and will make adjustment of management practices in order to increase their effectiveness (adaptive forest management).

3. Agroforestry

i) Conduct a ranch-wide forest stand inventory to appropriate standards as needed.

ii) Restore native forest stands in moderately to heavily degraded areas through intensive management practices that include rest from grazing, scarification, seeding, and planting

iii) Establish long-term forest production monitoring by ranch management (monitoring will be by establishing system of permanent plots with remeasurement on a 5-year basis).

iv) Select key stands from inventory as indicator locations

v) Keep all cattle out of reforestation units.

vi) Establish monitoring plots in key stands and revisit and measure every 5 years

vii) Assess soil seed bank composition and density within koa rooting zone (Koa/Ohia Forest Restoration Management Zone)

viii) Build new and replacement fence each year to manage livestock.

ix) Evaluate and document site preparation techniques

x) Rest from grazing

xi) Scarification by excavator

xii) Scarification by bulldozer

xiii) Scarification by mechanical roller

4. *Watershed, Riparian, and/or Wetland Protection and Improvement*

i) Maintain existing watershed quality by maintaining health and condition of native forest areas.

ii) Enhance watershed function through increasing the extent and complexity of native vegetation cover throughout the property by reforesting pastures and protecting and restoring native forest communities.

iii) Establish and maintain large contiguous belts of native forest vegetation to provide ecological connectivity of habitats and vegetation

5. *Ecosystem Management*

i) Monitor status and condition of native ecosystems by ranch management (this monitoring will be done by managements observations).

ii) Monitor population status and recovery of rare plants and animals (same as i above)

iii) Forest pests and invasive species

a. Early detection

b. Inventory and mapping

c. Risk assessment and priority setting

d. Effectively apply rapid response and management strategies

6. *Community and Educational Institution Outreach and Experiential Education*

i) Conduct research to add to existing knowledge base regarding growth and yield of native forestry species, use of cattle as a scarification and grass management tool in forestry and ecosystem restoration practices, nature of seedbank composition in mid-elevation to upper-elevation South Kona environments with logging and cattle land use history, and impacts of domestic cattle and feral sheep on native forest structure and composition and forestry operations.

ii) Provide education and outreach opportunities by implementing management and research practices cooperatively with local schools and community organizations and a range of academic institutions.

7. Forest Recreation Enhancement

i) Enhance forest recreational opportunities through the construction of hiking and horseback riding trails, campgrounds, interpretive trails, Ziplines, ATV routes, and by providing opportunities for community members and student groups to engage in forest stewardship practices.

8. Fire Management

i) Maintain access for firebreaks, detection and suppression of wildfire.

ii) Maintain water system for fire suppression purposes.

iii) Keep firefighting equipment in working order, bulldozers, water wagons, etc.

iv) Construct helicopter water dip tank/pond on property.

v) Train ranch personnel in wildland firefighting methods as available.

9. Wildlife Management

i) Native species restoration/reforestation and habitat improvement

ii) Restore and enhance habitat to benefit native plant and animal populations that are currently or were formerly present on the property.

iii) Increase the extent and elevational gradient of forest cover (koa, māmane, sandalwood, and other native species) to benefit endangered wildlife.

iv) The ranch will seek a safe harbor agreement with USF&WL within the first five years of this plan.

v) If any siting of threatened or endangered species occur on the property or if any survey reveals a listed species in an operating area, then silvicultural prescriptions will be created for the area of the occurrence to adjust any timber harvesting so as to not impact the species.

B. Description of Management Practices

1. Infrastructure Installation and Maintenance

i) Water – All existing water resources, including pumps, storage tanks, water lines, wells, and related features will be maintained in working condition so that they effectively serve the needs of livestock management, nursery and special uses, and support wildfire suppression when needed.

ii) Roads – Maintain and improve road system to serve purposes of fire protection access and support all management operations (Map 7).

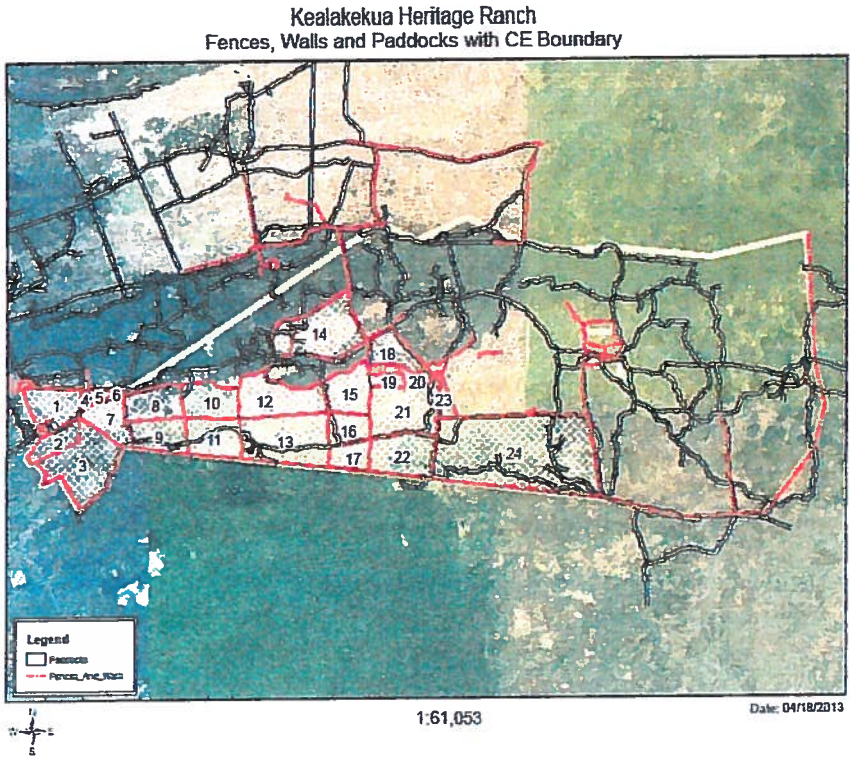
iii) Fences – Prior to the implementation of the 2006 Forest Management plan, most of the existing fence infrastructure was in need of replacement. KHR has a fence building program that has installed approximately 20 miles of livestock fence in the last 6 years. An additional 10 miles is planned to be built over the plan period. KHR shall maintain existing fences to support livestock removal and control operations and to support forestry and native forest restoration operations. KHR will construct and maintain new fences in designated areas for dual purposes of gaining control of livestock and excluding them from forestry and native forest restoration operations.

iv) Fencing will be used to gain control of the wild cattle herd and create an infrastructure where cattle can be effectively managed. Four strand barbed-wire, high-tension smooth wire or electric tape will be used where the primary object is the control of domestic cattle.

v) A grazing and herd management plan will be developed to describe how the existing herd will be brought into control, define how the herd will be managed, set targets for calf production, and schedule how pasture rotations will occur to meet site preparation, soil scarification, and grass management objectives. This plan will be completed in the first two years of the plan implementation. Hog wire has been used in some of the new fence on the ranch and may be used in other areas as needed.

vi) Refer to Map 8 "Kealakekua Heritage Ranch – Fences, Walls, and Paddocks with CE Boundary" This map shows all the fenced in paddocks where KHR grazes cattle. There is no cattle grazing planned outside of any existing or future fenced paddocks. In the portion of Paddock #24 that is unit 10 in the plan all cattle will be removed in the first year as this will be the focus area for reforestation efforts and experiment trials of different methods. There are some wild cattle outside the fenced paddock areas and the ranch will work on having them removed as they find them. An analysis of the lower paddocks where grazing will continue shows that the majority of these paddocks are outside the CE area.

Map 8 – Fences, Rock Walls & Paddocks



2. *Site Preparation*

i) Site preparation will:

a. Address the practices to assess the condition of the soil seed bank

b. Encourage natural seedling recruitment

c. Prepare sites for planting. Techniques will vary depending upon the location, vegetation condition, soil seed bank condition, and management objective for that area.

ii) Seed bank suitability will be estimated using simple random sampling within the 5,932 acres that comprise Management Units 5 through 12. However unit 10 will be a focus area for reforestation efforts over the 2013-2023 plan periods. It is entirely fenced and cattle will be removed before reforestation efforts start. There are about 580 acres in unit 10. The ranch plans to apply for a Natural Resources Conservation Service grant to assist in the trials of different scarification methods (NRCS-CIG). Where an adequate soil seed-bank exists, the site will be experimentally treated to evaluate 3 or more techniques to promote recruitment of koa and other native trees. Where the soil seed bank is depleted of koa and other native tree seed, site prep will occur immediately prior to planting. Site prep for planting areas may include use of hand tools or small hand-held machinery to pre-dig holes. Organic mulch from the

surrounding area will be added to each pre-dug hole for nutrients and moisture retention.

iii) Trials to compare techniques of promoting natural regeneration from existing soil seed banks will apply the following treatments:

a. Mechanical scarification using an excavator equipped with a narrow scoop bucket to scrape small grass-free patches using the tines of the bucket

b. Use of a bulldozer equipped with a blade to scrape grass cover away from soil surface in large patches and rows

c. Mechanical scarification using a roller. Other methods may be tried as well.

iv) Scarification trials will occur within management unit 10 during this plan period as fencing is in and the area is large with poor stocking. Other areas may be expanded into if time and funding are available.

3. Seedling Acquisition

The owners of Kealakekua Heritage Ranch have a nursery facility with almost an acre under roof in a shade house. Formerly used for the commercial production of maile, this facility is currently devoted to growing seedlings for reforestation on the ranch. Seed sources from three ranches or neighboring properties are now being used and will continue to be used for planting projects. KHR's intention is to produce nursery stock in dibble tubes for ease of planting. Propagules of less common and hard-to-grow native plants will be obtained from the Amy B.H. Greenwell Ethnobotanical Garden in Captain Cook or other local native plant nursery. For nursery stock that is not grown from locally-collected seed, special care will be taken to ensure that parent source material is as much from local origin as possible.

There are three tree species currently being grown from local seed for the purposes of reestablishment on the ranch: Koa, ʻŌhiʻa and Sandalwood. Other native species that occur as codominants on the ranch will also be propagated and planted within management units dedicated to providing rare species habitat and performing ecological functions. These species will include native ferns such as Hāpuʻu, ʻAmaʻu (*Sadleria* sp.), vines such as ʻIeʻie, ʻĀnunu (*Sicyos* sp.), and *Gouania vitifolia*, and understory shrubs and trees belonging to genera such as *Alyxia, Cyrtandra, Cyanea, Clermontia, Melicope, Myrsine, Perotettia, Pipturus, Touchardia, Urera* and others. Currently there are no plans to grow non-native forest trees. This decision may change with future conditions, but no invasive species will knowingly be planted on this ranch at any time. The Hawaiʻi Pacific Weed Risk Assessment tool will be utilized to quantify the invasiveness of any non-native species. It is our express desire to grow native forests, as over time these will offer the most stable environment and highest return on investment.

4. Planting

In all reforestation areas, KHR nursery stock of native forest trees, shrubs, and ferns will supply the majority of planting needs. Stocks from other nearby sources such as the Amy Greenwell Ethonbotanical Garden, the Waimea Tree Nursery, and other suppliers will be used to augment what is produced at the KHR facility.

Planting will be accomplished with one of several techniques used to reforest open pastures, establish high-value native hardwood and mixed-species stands, and maintain special management areas. Planting will occur under at least two different scenarios:

i) Interplanting and underplanting as part of native forest reestablishment

ii) Augmenting reforestation efforts where soil seed bank is insufficient to provide for natural recruitment using soil scarification techniques.

Planting efforts will be focused where tree cover is reduced in the Māmane/Sandalwood Forest and Koa/'Ōhi'a Forest Restoration management zones (Units 5-10). Unit 10, which is fenced, will be targeted for reforestation during this plan period. Planting in Management Unit 10 will reestablish stands of koa, 'ōhi'a, māmane, sandalwood, and other native species in areas with depleted soil seed banks, where soil scarification was insufficient to achieve the desired stocking density, and to add under-represented native species where needed. Planting in management Units 2-4 will be low-volume plantings of rare or unique native species.

Planting in Management Units 1 and 13, if any, will be done to add native species cover and hold sites where weeds have been removed. Management Unit 1 (Ecological Buffer) will be rehabilitated to achieve greater than 60% cover of native species across the unit. This new forest will effectively buffer the Hōnaunau Forest Reserve.

5. Sustainable Harvest of Live Trees

In order to assure that the allowed conservation easement volume of 250 MBF net per year in live trees is sustainable, the timber inventory information was used to derive a production model of potential outputs per year (Appendix III).

The Forest Planning and Projection System (FPS) computer program was used to grow each timber stand for 100 years to predict future harvests, residual volumes and determine a sustainable level of harvest. The Forest Biometrics Research Institute is the source of the FPS model. Dr. James D Arney is the author of the program. KHR consulting forester, Jim Mehrwein, is a member of the Institute and listed as a recommended consultant for FPS. He ran the models for this analysis.

To accomplish KHR's predicted future harvest levels, yield tables by habitat group were grown for 100 years using the Hawai'i species library. As stands were selected for harvest in the FPS model, the harvest scheduler populated the harvested stands with data from the yield tables. This data was then used to produce second and subsequent rotation volumes.

Harvest Schedule modeling assumed trees would only reach 70% of their potential height growth. Additionally, the model was set to limit survivability to a 20% of the trees regenerated. This approach allows for less than complete success in controlling competing vegetation and pests such as feral pigs and cattle.

The harvest scheduler was directed to pick stands to optimize sustainability while maximizing the average annual harvest over the 100 year planning horizon. During the first rotation the harvest scheduler optimizes the forest at the expense of the silviculture for any individual stand.

For the second and subsequent rotations, the harvest scheduler optimizes each stand at the expense of the forest. The reasoning is that an unmanaged forest is the current condition (and makes up the first rotation) and the quicker it can become managed the greater the success of maximizing the sustainable harvest volume will be. Once the stand becomes managed (second and subsequent rotations), the harvest scheduler works to maximize each individual stand at the expense of the forest. This way the silviculture for each individual stand becomes the priority.

The output from the model shows that an annual harvest level of 250 MBF net per year would be easily achieved without concern of harvesting at or above a level that is sustainable. Appendix III shows the results of the harvest schedule process.

The average percentage of the annual live tree harvest over the 10-year life of this plan will be based on the current inventory, and range from: 60-70% Koa, 28-38% ʻŌhiʻa, and 1-3% Sandalwood and other species. The objective of the KHR is to manage for a healthy forest, so if forest health issues arise then these averages may be adjusted after consultation with the State. Also because of the majority of the reforestation being in koa, the percentages will change over time and be adjusted in future plans.

In order to verify the inventory estimates over time, a system of permanent plots will be established for the timber production areas of the Ranch. The design of this system will follow the system developed by the Forest Biometrics Research Institute at Oregon State University (Arney and Milner, 2006). The design will be completed in the first year of the plan and all plots will be established by the end of year four of the plan. The information from the plot data as they are measured over time will be used to calibrate the inventory data and track on-going inventory.

In addition to the permanent growth plots installed in existing forest stands, a Nelder wheel plot will be established in a newly planted stand. The design of the Nelder plot will produce valuable information regarding the effect of tree density on tree growth, form, and survival (Parrott, Brinks and Lhotka 2011).

The growth and yield model used for timber yields was adjusted to reduce outputs by the following:

i) Harvest Schedule modeling assumed trees would only reach 70% of their potential height growth. Additionally, the model was set to limit survivability to a 20% of the trees regenerated. This approach allows for less than complete success in controlling competing vegetation and pests such as feral pigs and cattle.

ii) The plan for all reforestation included in the model was to have reforestation areas fenced with no cattle allowed in the area until trees are large enough to not be effected by browsing.

iii) Now that a system of permanent plots will be added to the management plan the information obtained from measuring those plots over time will be used to adjust the model for future runs of the model. It is anticipated that the model will be re-run for each 10-year period when the plan is updated.

Volume of live harvest will be tracked by KHR and reported to the State quarterly. Each harvested tree will have a volume estimate completed before harvest using the same system that was used by the inventory system. KHR plans on selling some stumpage volume so this would fit a stumpage sale. However, in some cases both log and lumber sales will occur.

6. *Basic Silvicultural Prescriptions*

KHR is dedicated to professional management of the timber resource. Before harvest of any trees on the ranch occurs a professional forester will write a silvicultural prescription for the harvesting operation. Volumes will be estimated in advance to track volume removed. The operation will be supervised by a staff person trained by the professional forester or by the professional forester himself/herself. In the first 2-4 years it is envisioned that three general prescriptions will be created.

i) Capture Live Tree Mortality - Under this idea a prescription will be developed to identify and remove trees that have a high probability that they will die within the next 10 years and the wood value would be lost to rot. In each case the forester will mark these trees for removal and after harvesting the tree, an area around the tree will be scarified to help stimulate tree reproduction.

ii) Decadent ʻŌhiʻa Stand Replacement - Under this general prescription stands of the ʻōhiʻa dominated forest that is in decline will be identified by the forester for treatment. In general, the older ʻōhiʻa will be removed and all ʻōhiʻa regeneration will be protected. At least two healthy mature ō'hia trees will be left per acre for seed production. The ranch intends to establish a few trial sites where ōhi'a of varying ages will be left to assess the dieback on the mature trees after harvesting. All Koa in the stand will be retained unless it fits into number (i) above. The area will be scarified and fencing will be installed around the stand to protect the reforestation effort. If scarification does not produce enough regeneration then planting of Koa will occur in follow-up treatments.

iii) Reforestation Units - This effort is planned to focus in Unit 10 as the fencing is already in place. The unit is approximately 580 acres in size so there is room for many methods to be tried. The general situation is very low stocking and a great need for reforestation. This is where prescriptions will try different methods of scarification and planting. Trials will be small at first, 5-10 acres in size. Methods will be designed and then recorded using video. Monitoring by ranch management will follow at 4 months, 8 months and one year (monitoring will be by video) These sites will be used for professional and public tours to show what works and what does not. If scarification fails to produce adequate reforestation then planting will be applied after the first year. The goal is to reforest all of unit 10 over the plan period. It is expected that 75% can be completed with just scarification. The remaining will need to be planted. After the best methods are selected the production of reforestation will increase with the goal of full stocking in all of unit 10 by the end of the planning period for this plan.

iv) Group Selection – Under all-age management, group selection will occur in old stands that need replacement. Group size will be limited to less than 5 acre openings and cattle will be removed from stand area.

v) Thinning – Thinning will be used in dense stands that could grow more rapidly with less tree competition. In this general prescription the best trees will be retained as crop trees and spacing will be a function of stand age. The end result will be a well-spaced, fully stocked stand with the best trees with room to grow.

7. Sandalwood Harvest

This plan recognizes the importance of sandalwood trees in the area. One of the goals of the plan is to increase the amount of sandalwood on KHR. This will be done primarily through protecting natural regeneration from browsing and planting sandalwood trees. In general the harvest of live tree sandalwood will be at a minimum during this planning period. Live sandalwood trees may be harvested under general silvicultural prescriptions above, however, they only will be harvested if, in the opinion of the professional forester, 80% of the crown is dead and/or they exhibit extensive mechanical damage. In each case, if a live tree sandalwood is harvested, the stump will be pulled out of the ground to stimulate the remaining roots to sprout and regenerate new sandalwood trees (as observed on neighboring property).

8. Fire Management

The KHR property is susceptible to wildfires. In order to protect the forest resources on the property KHR maintains equipment and a workforce to provide early detection and response to wildfire. As stated before, water facilities are maintained. In addition, one permanent helicopter dip tank will be installed in a strategic location to support helicopter bucket operations in the event of a wildfire. The ranch has two water trucks with pumps and three bulldozers to use for fire suppression. The road system serves as access for fire suppression as well as a firebreak system.

9. Non-commercial Thinning and Stand Management

Approximately 1,250 acres of scarified and naturally-regenerating timber production stands occurring within the 4,520-acre combined area of Management Units 6-12 will be thinned at approximately 20 years of age using appropriate tools to leave trees that possess the best form, are the most disease and pest resistant, and occur in the appropriate spacing. Initial planting and scarification will encourage tree densities of over 400 trees/acre to thin naturally over the first 20 years and on the 20th year will be actively thinned to achieve a stem density of approximately 80 trees/Ac mostly comprised of koa, but also including ʻōhiʻa, sandalwood, and other native species. Existing planted stands will also be thinned when they reach the age of 20.

Experimental scarification sites that do not result in the successful natural recruitment of native species to a density of approximately 400 stems per acre will be planted with a native species propagated at the nursery facility. A sample of each area planted or scarified can be further evaluated for the benefits of thinning or providing post-establishment management inputs.

10. Weed and Pest Management

Across the entire property, weeds, insect pests, and tree pathogens and diseases will be managed using an integrated long-term approach that considers the site variables, life cycle, and ecology of the species and applies management practices that minimize the potential for pest infestations.

The initial pest inventory will be conducted across the entire management plan area within the first five years. During this inventory, distribution maps of weeds, insect pest infestations, and forest pathogens will be created. Specific measures to monitor weeds by ranch management and other pests will emerge during the initial inventory and development of the management plan (monitoring will be by management observation). Use of pesticides will comply with all applicable government regulations.

The management goal within Management Units 2, 3, 4 is to maintain these areas free of aggressive invasive plant and insect species and free of wild or escaped domestic cattle. These 2,938 acres are currently free of known aggressive invasive species. Potential invaders into units 2 and 3 are Miconia, Silver Oak, Tropical Ash, Bocconia, Clidemia, Tibouchina, Banana poka, and others. Potential invaders into unit 4 include fountain grass and Tropical ash may occur in management Unit 12.

Management Units 1, and 13 are presently in a non-native condition and efforts will be made to restore this unit to a >40% native condition, but not during this 10 year management period. The primary function of these units are to serve as a weed and pest buffer in which new potentially invasive species are detected and removed before becoming established on the property. Management Units 5-12 will be monitored by ranch management for invasive species in the course of conducting other forest management activities. Management Unit 12 will be monitored by ranch management for Tropical Ash invasion and other pests (monitoring will be an annual survey of the area by a professional).

A Forest Monitoring Plan will be developed after completion of the total Forest Inventory (after CE triggers the inventory by exceeding the 250 MBF per year net harvest) will include the specific requirement to observe, record and quantify impacts to forest regeneration efforts caused by the feral ungulates (goats, sheep and pigs common to the Island). When unacceptable levels of damage to the forest regeneration efforts are observed, the Kealakekua Heritage Ranch will design a stand-specific animal management plan to minimize or eliminate those impacts. These stand-specific animal management plans, developed in response to observed grazing or foraging impacts, may include fencing, hunting, trapping, baiting and animal aversion measures, or some combination of these techniques, as deemed appropriate.

Kealakekua will share these plans and the results of implementation of control practices with the State as they develop. The relative effectiveness of the implemented practices may offer practical guidance to other forest managers in the state.

The initial area of concern is to reduce the feral sheep population on KHR. Currently the sheep are not doing significant damage to the young CSU koa planting but as more acres are reforested the population will need to be reduced. Intense hunting will be the first trial method.

11. Special Management Area Maintenance

Special management areas will be established for purposes related to performing education and outreach programs, conducting research, protecting sensitive cultural and biological features, and providing corridors of connectivity between native forest habitats. Special Management Areas will include sites that 1) support rare and endangered species habitat; 2) support seed sources that are otherwise scarce, 3) surround archaeological and cultural features, 4) have a higher than average potential for erosion or flooding, 5) or are used for research. Such management will include monitoring, site maintenance, weed and pest control, planting and re-vegetating, and related activities (currently the CSU site is the only area in this classification and the University is monitoring the trees).

12. Education and Research

The ranch property offers a diverse and important location where meaningful research can be conducted to inform future decisions pertaining to management and stewardship of native forest resources. KHR will allow cooperating research and educational institutions to conduct both short and long term research projects in native hardwood tree production, native forest management and ecosystem restoration. Opportunities for service learning, such as tree planting, weed removal, and seed collection will be made available through the cooperating educational non-profit, The Kohala Center, as these programs are implemented. In addition, KHR will allow, in accordance with the ERROP, undergraduate and graduate forestry and environmental studies opportunities to participate in ecological and natural resource monitoring (monitoring will be included in their study plans).

Potential lines of research include the establishment of long-term, fixed plot forest stand monitoring to study growth and yield for the principal commercial native trees koa and ʻōhiʻa, soil seed bank inventory and monitoring, weed and pest inventory and monitoring, and other ecosystem and site variables (monitoring standards will be in their study plans). KHR is developing a framework with The Kohala Center to engage professional researchers, interns, and educational organizations in furthering our understanding of forest management practices.

Colorado State University (CSU) entered into a long-term research project on KHR to determine effects of growing young stands and their impact on bird habitat. In 2010, 4 units were established on KHR for the study. All units were fenced and planted with Koa. Three units were one acre in size and one unit was three acres in size. This plan has mapped those units and plans to protect them for research purposes.

Additionally, gaps exist in the knowledge of the ecology of sandalwood and the processes for growing this valuable resource on a sustainable basis. Upper reaches of the Kealakekua Heritage Ranch have mature individual sandalwood trees, and the ranch is having success in germinating seeds from these trees. The opportunity exists at this location to undertake meaningful research on sandalwood ecology and production because mature sandalwood occurs naturally on site and because sandalwood seedlings have been successfully produced in the nursery.

Domestic cattle grazing is generally assumed to be incompatible with koa forest regeneration. However, we believe that the two are compatible when managed properly. KHR intends to evaluate the level of grazing needed to trigger release of existing koa seed bank and the amount

of pasture rest that is needed to allow for stand establishment. KHR will also evaluate the time needed for pasture rest before cattle can be rotated back into new stands without causing injury to young trees. These evaluations will be conducted in cooperation with participating educational institutions, past projects, and local experts.

Recreational opportunities for camping, hiking, and horseback riding will be developed in the KHR Education, Research, and Recreational Opportunities Plan (ERROP). The ERROP will detail matters related to use of facilities, access to trail systems, and participation in stewardship activities.

13. Trail and Campsite Construction

Interpretive trail systems at the Kealakekua Heritage Ranch serve as educational and recreational features connecting residents and other users with the land. Trails will link features such as an equestrian center with historical sites, native ecosystems, and forest restoration demonstration sites. Additionally, the proposed Mauna Loa Trail circumnavigating Mauna Loa above 5,000 ft. elevation traverses approximately 2 miles along KHR's upper boundary. This trail, as well as other hiking and equestrian trails will be maintained annually. Trail campsites will be established as defined in the KHR ERROP for use by residents, guests, and visiting researchers. An existing campsite adjacent to the Mauna Loa Trail will be available for use by trekkers with advance arrangements. Hiking access, camping, and related educational and recreational activities will be detailed in the KHR ERROP.

14. Monitoring and Planning

Following the completion of the full forest inventory, a Forest Resource Monitoring Plan will be developed. This full forest inventory is required by the conservation easement at any time that KHR desires to harvest more than the 250 MBF per year net of live trees established in the conservation easement. The monitoring plan will identify the goals and objectives of the monitoring program, describe methodologies, and schedule monitoring activities over the first 10 years. Monitoring will be designed to assess the effectiveness of each of the various management programs in achieving management objectives. Success in achieving each management objective will be determined by tailoring the monitoring programs to apply sampling techniques to answer specific questions under each objective.

15. Wildlife Management Objectives and Practices

Koa (*Acacia koa*) and māmane (*Sophora chrysophylla*) are key habitat elements for most endemic Hawaiian wildlife. These endemic species in the pea family (*Fabaceae*) are considered important host plants for endemic birds and invertebrates. Hawaiian birds use koa and māmane for nesting, feeding, roosting, and other requirements of their life cycle. ʻAlalā, ʻAkiapolaʻau, Creeper, and ʻĀkepa exhibit a strong preference for koa, foraging on wood boring beetles (*Cerambycidae*) and other invertebrates that live under the bark and on the leaves of trees. Palila depend on māmane seed pods and flowers for their continued survival. The success of many native wildlife species at KHR is dependent upon the presence of koa and māmane as forest dominants. Reforestation of the easement area with koa is expected to provide improved foraging, roosting, and breeding habitat for native birds, mammals, and arthropods. Rare native birds can be expected to respond positively to forest recovery and will likely extend their ranges into the easement area if KHR reforestation activities are successful.

16. Biodiversity

The landowner has no plans to specifically manage the ranch for biodiversity; therefore there is no prescription in the plan for biodiversity. That said, with the ranch managed under this plan the level of biodiversity on the ranch is expected to increase due to increase in forest cover by fully stocked forests with native species. As has been seen on Hakalau National Wildlife area, when you bring back an overstory of native trees the biodiversity increases (Conversation with Jack Jeffery). There have been biological surveys on the ranch (See Wildlife section) but few rare and endangered plants have been identified on the area. There are no plans for the ranch to fund additional biological survey but the ranch is open to additional surveys being done on the ranch by others in a partnership with the ranch.

The plan calls for "Special Management Areas" to be developed as needed to protect special places and research. To date the only ones identified are the experimental koa plantings by CSU which will be managed by the ranch under the experimental design for the study. If we find other special areas that have cultural or biological importance we will identify them and protect them. Also the plan calls for an Ecological Buffer (Management Unit 1) which by the nature of the management practices in that unit will most likely increase biodiversity.

V. Implementation of Management Practices

For ease of reference, management practices are described in the following section first by Management Zone, then by Management Unit. Management Zones define large areas that will be managed for a primary function, such as to maintain high-quality native forest, restore a native lowland ecological corridor, or reforest upland koa/sandalwood/māmane forest. Each management Zone is further partitioned into Management Units defined by vegetation, access, soil type, or other features (Map 5).

The descriptions below contain a variety of practices that will assist in advancing the management goals of the ranch. Many of these practices, however, will not be implemented within the first 10-year plan period. During the first ten year period, the primary management activities will be 1) improved livestock control through round-up and fence construction, 2) reforestation, and 3) timber management. A year-by-year outline of anticipated activities is included in the practice implementation schedule below.

A. Management Zones

Implementation of management practices will occur sequentially after approval of this plan by the State of Hawai'i. In this section, management goals and specific actions are described by management zone. Management Zones, Units and Stands have all been mapped and are in a comprehensive GIS System that will be used for detailed prescriptions for treatment. The system will allow the identification and mapping of all treatment on the ground as they are implemented. Field hand-held GPS instruments will be used to locate and adjust treatment areas.

1. Agroforestry Reserve [Management Unit 13]

The Agroforestry Reserve will provide a setting where compatible agricultural and forestry practices work together to achieve multiple objectives. Management goals within this zone include Restoration, Reforestation, Watershed and Recreation. Future management practices will address maintenance of infrastructure, protection of historic and cultural sites, site preparation for planting, planting, weed and pest management, research, monitoring, and education. This area in the 2006 plan was mapped as 13a and 13b. Both these areas were dropped from the CE area in the final agreement for the FLP CE, therefore unit 13 has become in this plan the area on the south boundary of the lower KHR area and labeled unit 13 on the maps now.

2. Ecological Buffer [Management Unit 1]

The Ecological Corridor Management zone was designed in the 2006 plan to create a native lowland mesic forest corridor that will connect the Forest Reserve of Hōnaunau to the south with the forests of Kaawaloa and Onouli to the north. Most of this unit (#1) was dropped from the CE by the state and KHR during the final preparation of the CE. The new Management Unit #1 is placed along the south boundary of the lower KHR to form a buffer to the Kamehameha School's Hōnaunau Forest Reserve.

Management goals of the Ecological Buffer Zone (Unit #1) included in the restoration, reforestation, watershed, recreation, and education. Future management practices will address maintenance of infrastructure, site preparation for planting, planting, weed and pest management, protection and management of cultural and historical sites, research, and outreach. This area is to be planted and maintained with native species to provide ecosystem and watershed services, buffer against the invasion of weeds and pests, and provide habitat for native birds, plants, and invertebrate species, and will be used for research and education. Timber harvest is not planned for this unit.

3. Native Forest Ecosystem [Management Units 2-4]

The Native Forest Ecosystem Management zone is the large contiguous band of forest that runs mauka-makai along the northern boundary of the property. The management zone encompasses the most structurally diverse native forest on the property, forest that has been less impacted by previous land uses and is virtually free of major alien plant and pest infestations. The high quality of this long belt of native forest underscores its importance in providing ecological connectivity along an elevational gradient. This zone encompasses primarily the successionally young a'ā lava flow that runs along the north boundary, but also includes kipukas and portions of older substrates that support patches of successionally older forest.

Ultimately, primary management goals for this zone include timber production, restoration, and watershed management practices that will address maintenance of infrastructure, removal of 'ōhi'a die back trees, site preparation and scarification, planting, weed and pest management, protection and management of cultural and historical sites, management of other sensitive features, research, and education.

4. Māmane-Sandalwood Forest [Management Unit 5]

The Māmane-Sandalwood Forest Management zone captures the high elevation lands of KHR. These lands are forested with a decadent overstory of ʻōhiʻa, koa, māmane, naio, and ʻiliahi and have an uneven aged cohort of māmane coming in to replace the old trees. The area has historically been used for cattle grazing and koa timber harvest but still retains substantial slash and downed and standing dead trees.

Primary management goals for this zone include salvage of near-dead and dead trees, reforestation, restoration, and watershed. Future management practices will address maintenance of infrastructure, site preparation for planting, seed collection, planting, weed and pest management, salvage harvest of dead koa and ʻiliahi, protection and management of cultural and historical sites, management of other sensitive features, research, and education.

5. Koa/ʻŌhiʻa Reforestation [Management Units 6-10]

The Koa-ʻŌhiʻa Reforestation Management zone captures a broad section of the upper portion of KHR from Pauahi Camp at 4,600 ft. to the boundary with the Māmane-Sandalwood Forest Management zone at 5,600 ft. elevation. These lands are forested with a decadent overstory of ʻōhiʻa and koa, have scattered ʻiliahi, kōlea, and other species, and have primarily a grass understory. The area has historically been used for cattle grazing and koa timber harvest but still retains substantial slash and downed and standing dead trees. The condition of the soil seedbank of koa within this Management Zone is unknown but of great interest. There are no major forest pests known to occur within this zone.

Primary management goals for this zone include salvage production, timber production, reforestation, watershed, education, and recreation. Future management in this Zone will entail conducting a soil seedbank assessment, gaining control of the cattle, using them for grass reduction followed by a 6 to 8 year period of rest, and periodically rotating a small well-managed herd through previously planted areas for the purposes of wildfire fuels control. Unit 10 is fenced and all cattle will be removed in the first year of this plan. This area will be a focus area during this plan period for reforestation trials and research. Future management practices will address maintenance of infrastructure, site preparation for planting, soil scarification, seed collection, planting, weed and pest management, salvage harvest of dead koa and ōhi'a, protection and management of cultural and historical sites, management of other sensitive features, research, and education. Research related to scarification methods, and koa and sandalwood growth and yield will be conducted and criteria will be developed and tested to determine at what growth stage koa and other native trees can sustain a pulse of grazing to retard the grass understory and the build-up of potentially hazardous wildfire fuels

6. ʻŌhiʻa Forest Restoration [Management Units 11 and 12)

The ʻŌhiʻa Reforestation Management zone captures the central portion of KHR from the lower edge of the Pauahi Camp at 4,500 ft. down to the historic Pawaina Cattle Camp at 3,600 ft. elevation. These lands are generally open canopied by a decadent overstory of ʻōhiʻa and have primarily a grass understory. The area has historically been used for cattle grazing. The main pest to monitor in this zone is Tropical Ash spreading from the old forestry planting along the Hōnaunau forest boundary south from Pawaina.

Primary management goals for this zone include reforestation, watershed, education, and recreation. Most of unit 12 was removed for the CE, however, unit 11 and the part of unit 12 in the CE will be managed in this zone. Future management in this Zone will entail gaining control of the cattle, using them for soil scarification where sufficient soil seed bank exists, and planting in areas where soil seed banks are depleted. Future management practices will address maintenance of infrastructure, site preparation for planting, soil scarification, planting, weed and pest management, protection and management of cultural and historical sites, management of other sensitive features, research, and education. Additional fencing will be done in this area to allow exclusion of cattle.

VI. KHR Areas Not Included in Management Plan

Approximately 2,470 acres of KHR occurs outside of the management areas addressed by this plan and not in the conservation easement area. One such parcel is the 100-acre Papaloa inholding located within Management Zone E at approximately 5,000 ft. elevation. The parcel is owned by the Greenwell Estate.

The other two areas are an old historical ranching area (Pauahi Cattle Camp) and the agricultural area on the lower end of the ranch which was held out of the FLP CE.

VII. Practice Implementation Schedule

Management practices will be implemented incrementally over the 10 years of this plan. KHR has sufficient resources to implement the actions identified in this plan and will do so using KHR staff and working in cooperation with other partners. Costs of the management actions described within this plan will be covered by KHR and any Federal or State partners that enter into agreements with KHR to assist in meeting the plans goals.

Kealakekua Heritage Ranch is currently working with or developing working relationships with several partners in resource management, research, and education.

These include, but are not limited to:

The Kohala Center, and through the Kohala Center and directly:

- Yale School of Forestry and Environmental Studies
- University of California at Santa Barbara, Biological Sciences
- Cornell University College of Agriculture and Life Sciences
- Colorado State University
- University of Hawai'i – Mānoa
- University of Hawai'i – Hilo
- Hawai'i Community College – Tropical Forest Ecosystems and Agroforestry Management Program
- Stanford University
- Amy B.H. Greenwell Ethnobotanical Garden
- Hawai'i Natural Resources Services, LLC
- American Tree Farm System (ATFS)
- Konawaena High School
- Natural Resources Conservation Service

In order to schedule the implementation of the practices in this plan over the ten-year period the following table was developed to give the reader an estimate of timing on applying practices on KHR FLP CE area. This table does not attempt to show the day to day operations of the ranch such as cattle management, maintenance of all infrastructure, and other standard operation of the property. It does try to identify the practices that need to happen to move the property towards its goal of a sustainable forest operation. Also the details are more specific towards the earlier

years of the plan. For the purpose of Table 1, Management Zones have been given the following numbers:

- 1 = Native Forest Ecosystem
- 2 = Māmane/Sandalwood Forest
- 3 = Koa ʻŌhiʻa Forest Restoration
- 4 = ʻŌhiʻa Forest Restoration
- 5 = Ecological Buffer
- 6 = Agroforestry

Table 1 – Schedule of Management Practices by year (after approval in 2013)

Plan Year	Objective	Zone	Unit	Stand	Management Practice
2013	Restoration	3	10	35/36	Reforestation trials
	Timber	All	All	All	Harvest of dead & down timber
	Agroforestry	6	13	27	Build one mile of boundary fence
	Timber	*	*	*	Harvest of live timber
2014	Restoration	1	3	10/20	ʻŌhiʻa Stand treatment & ʻŌhiʻa sale
	Timber	All	All	All	Harvest of dead & down timber
	Outreach	*All*	*All*	*All*	*Start work on ERROP with Kohala C*
	Agroforestry	1	4	30	Build one mile of boundary fence
	Pests	All	All	All	Reduce feral sheep on upper ranch
	Timber	All	All	All	Apply for Forest Certification w/ATFS
	Timber	*	*	*	Harvest of live timber
	Agroforestry	*	*	*	Start grazing and herd management plan
2015	Outreach/Rec	All	All	All	Finish ERROP report with Kohala C
	Timber	All	All	All	Harvest of dead & down timber
	Agroforestry	1	3	10/20	Build fence around ʻŌhiʻa Harvest area
	Reforestation	3	10	35	Scarification of 50 acres
	Fire Mgmt	*	*	*	Construct helicopter dip tank
	Wildlife	All	All	All	Start Safe Harbor agreement
	Timber	*	*	*	Harvest of live timber
	Agroforestry	*	*	*	Finish grazing and herd management plan
2016	Timber	All	All	All	Harvest of dead & down timber
	Agroforestry	6	13	35	Const/Reconst 1-mile of mgt fence
	Reforestation	3	10	35	Scarification of 50 acres, Inter-plant 15 ac.
	Timber	*	*	*	Harvest of live timber
2017	Timber	All	All	All	Harvest of dead & down timber
	Reforestation	3	10	35	Scarification of 50 acres, Inter-plant 15 ac.
	Agroforestry	*	*	*	Const/Reconst 1-mile of mgt fence
	Timber	*	*	*	Harvest of live timber
2018	Timber	All	All	All	Harvest of dead & down timber
	Reforestation	3	10	36	Scarification of 50 acres, Inter-plant 15 ac.
	Agroforestry	*	*	*	Const/Reconst 1-mile of mgt fence
	Timber	*	*	*	Harvest of live timber
	Wildlife	*	*	*	Finish Safe Harbor Agreement (USFWLS)
2019	Timber	All	All	All	Harvest of dead & down timber
	Reforestation	3	10	36	Scarification of 50 acres, Inter-plant 15 ac.

Plan Year	Objective	Zone	Unit	Stand	Management Practice
	Agroforestry	*	*	*	Const/Reconst 1-mile of mgt fence
	Timber	*	*	*	Harvest of live timber
2020	Timber	All	All	All	Harvest of dead & down timber
	Reforestation	3	10	36	Scarification of 50 acres, Inter-plant 15 ac.
	Agroforestry	*	*	*	Const/Reconst 1-mile of mgt fence
	Timber	*	*	*	Harvest of live timber
2021	Timber	All	All	All	Harvest of dead & down timber
	Reforestation	3	10	40	Scarification of 50 acres, Inter-plant 15 ac.
	Agroforestry	*	*	*	Const/Reconst 1-mile of mgt fence
	Timber	*	*	*	Harvest of live timber
2022	Timber	All	All	All	Harvest of dead, near-dead & down timber
	Reforestation	3	10	42	Scarification of 50 acres, Inter-plant 15 ac.
	Agroforestry	*	*	*	Const/Reconst 1-mile of mgt fence
	Timber	*	*	*	Harvest of live timber
2023	Timber	All	All	All	Harvest of dead, near-dead & down timber
	Reforestation	3	10	35	Scarification of 50 acres, Inter-plant 15 ac.
	Agroforestry	*	*	*	Const/Reconst 1-mile of mgt fence
	Timber	*	*	*	Harvest of live timber

Table Notes: Annual road and fence maintenance will be done. Live tree volume harvest will be tracked by a professional forester and will not exceed 250 net MBF in any year.
* Location to be determined

VIII. List of Persons Consulted

The following professionals were consulted in the course of preparing the approved 2006 Forest Stewardship plan that this plan was modified from.

Table 2 – Persons Consulted for 2006 Forest Stewardship Plan

Dr.	J.B.	Friday	UH-Mānoa, CTAHR Cooperative Extension Forester
Dr.	Pamela	Scheffler	Hawai'i Community College, Department of Math and Natural Sciences
Dr.	Mark	Throne	UH-Mānoa, CTAHR Cooperative Extension Range Management Specialist
Mr.	Kamakane	Dancil	Kamehameha Schools
Mr.	Nicholas	Koch	Forest Solutions, Inc.
Mr.	William	Rice	Forest Solutions, Inc.
Mr.	Michael	Robinson	Hawai'i Department of Hawaiian Home Lands
Ms.	Tanya	Rubenstein	Ola'a-Kilauea Partnership
Ms.	Gail	Byrne	H.W. Inc.

The following additional professionals were consulted in the course of preparing this revision.

Table 3 – Persons Consulted for this Revision

Mr.	Jim	Mehrwein	Forester, McKenzie River Associates, LLC
Mr.	John	Henshaw	Forester
Mr.	Jon	Giffin	Wildlife Biologist

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X. Appendixes

Appendix I - Stand Photos

The following timber stand maps are based on infra-red orthophotos which more clearly show the distinction between timber types than true-color orthophotos. The accompanying ground-based photographs were taken within the individual stands indicated and geo-referenced through the use of a geographical positioning system (GPS) device coupled to a Nikon D300 camera. The GPS data was record in the metadata of the photographs.

Map 9 – Stands 1 & 2

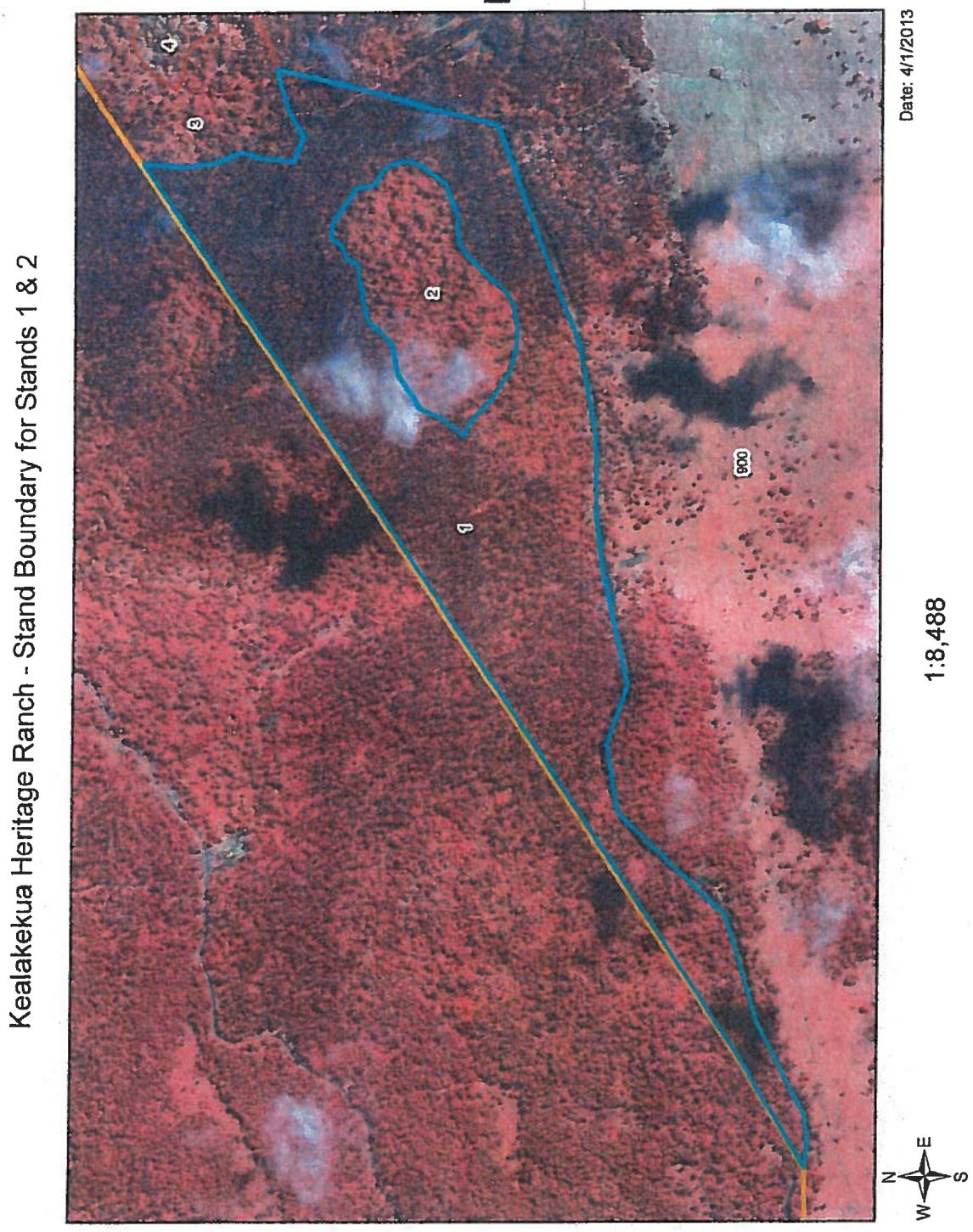


Photo 1 – Stand 1

Photo 2 – Stand 2

Map 10 – Stands 3 & 4

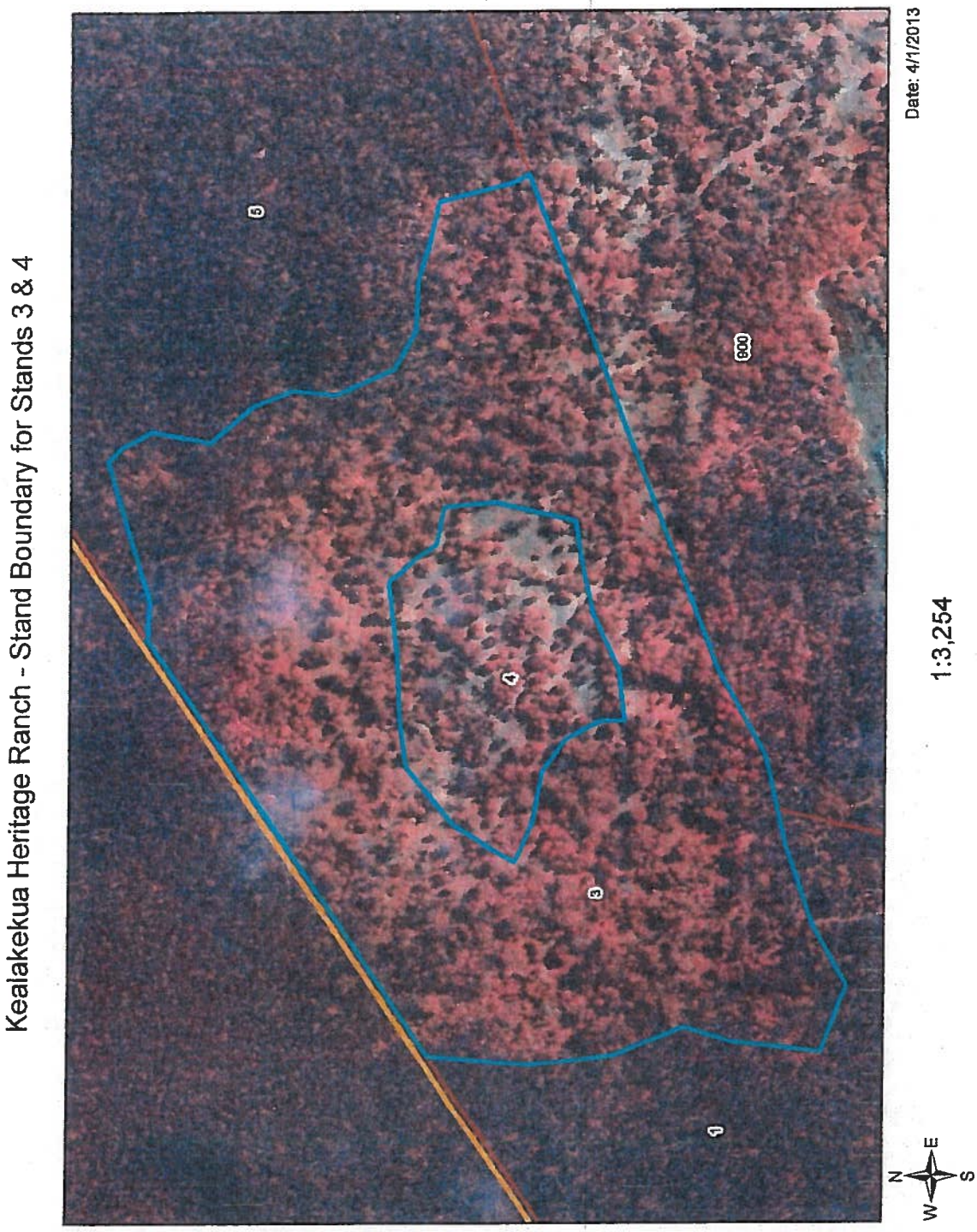


Photo 3 – Stand 3

Photo 4 - Stand 4

Map 11 – Stands 5 & 6

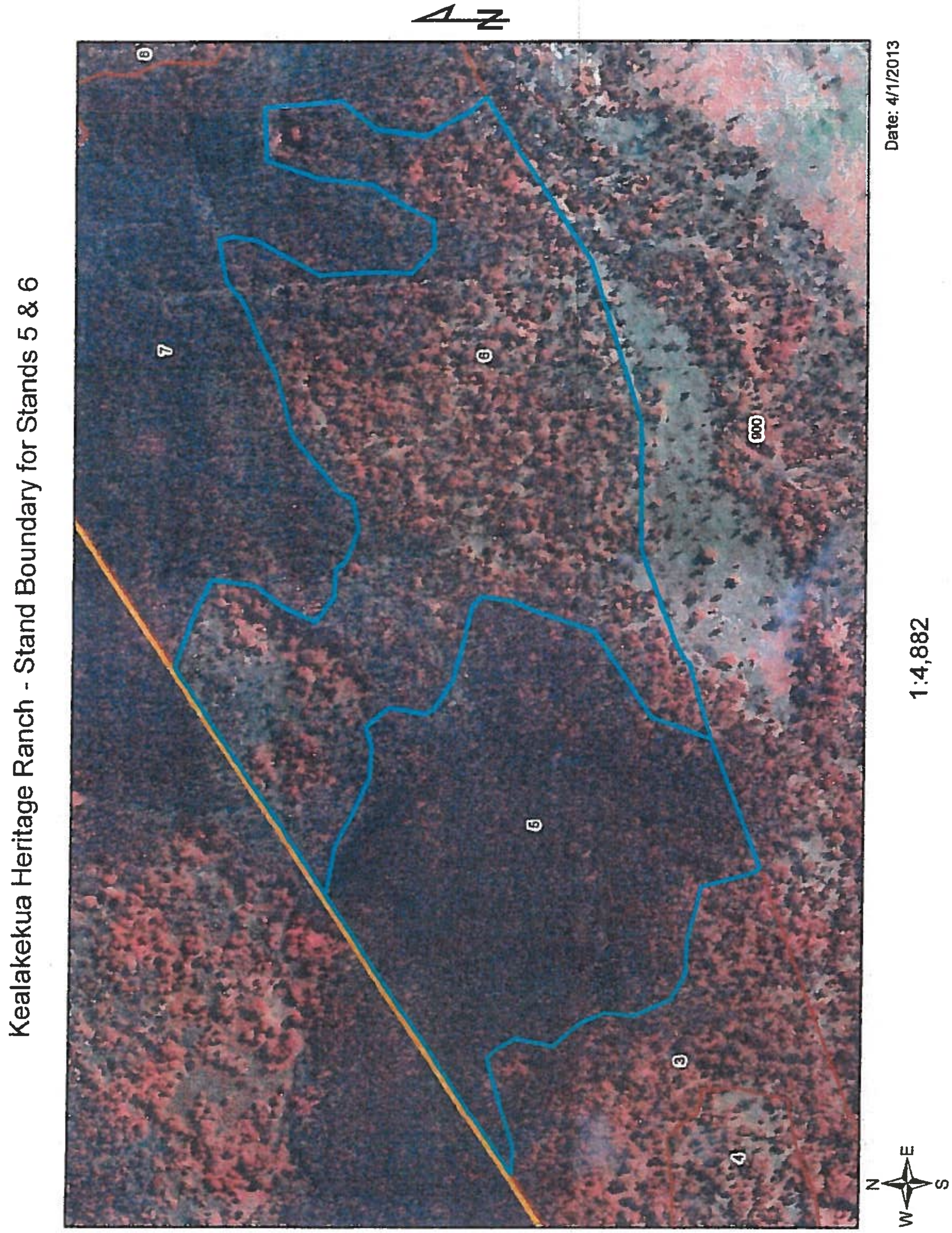


Photo 5 - Stand 5

Photo 6 - Stand 6

Map 12 – Stands 7 & 8

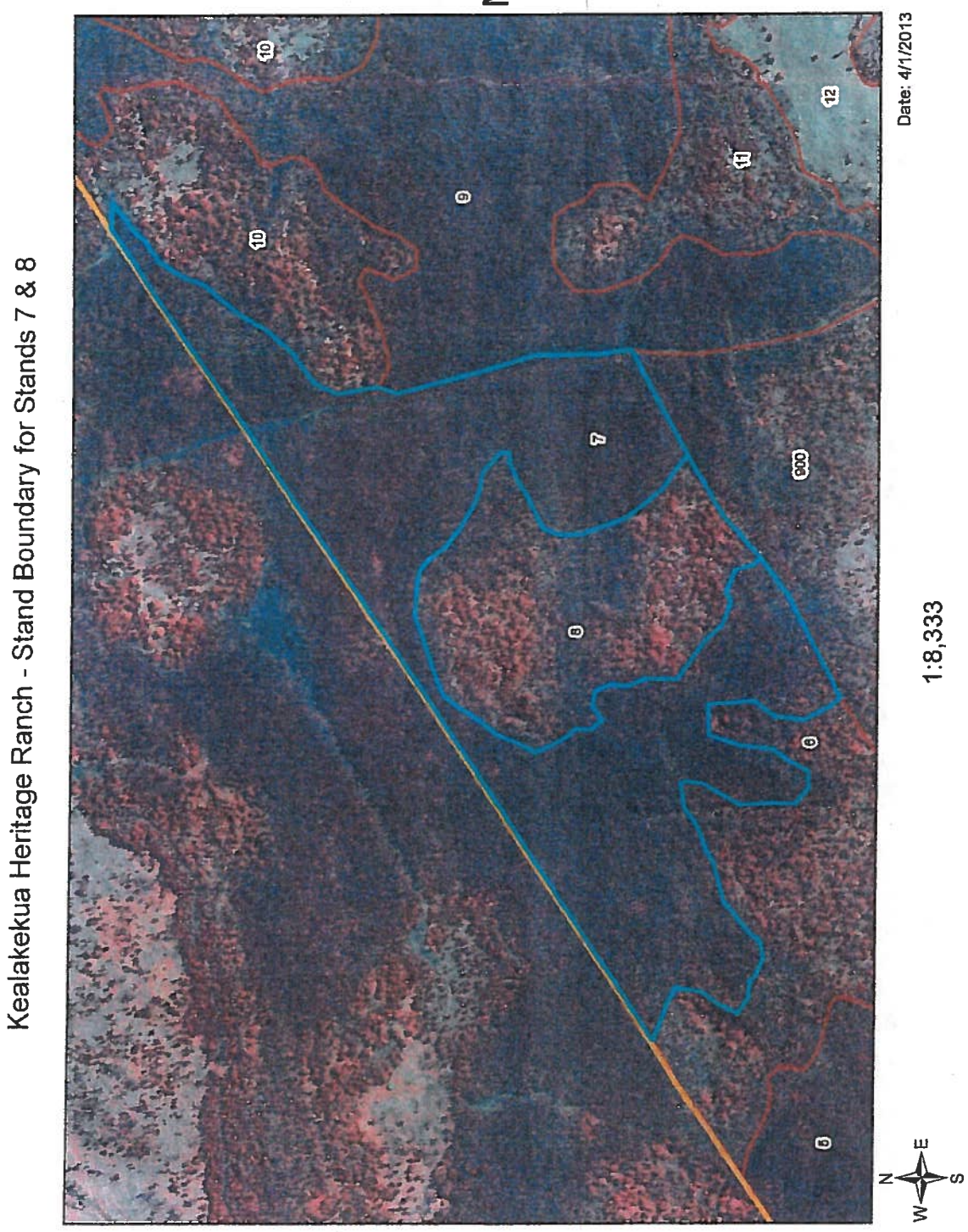


Photo 7 - Stand 7

Photo 8 - Stand 8

Map 13 - Stand 9

42

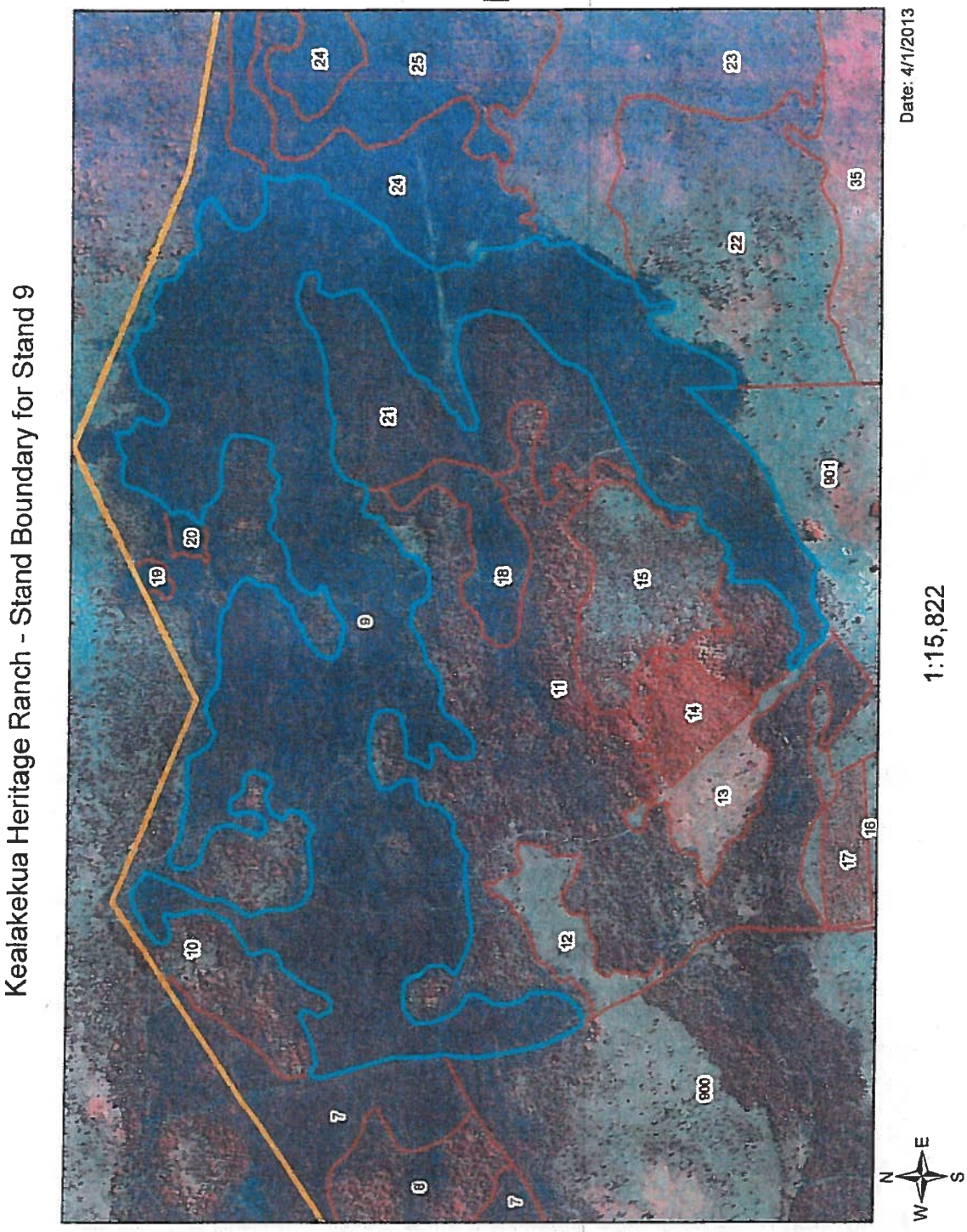
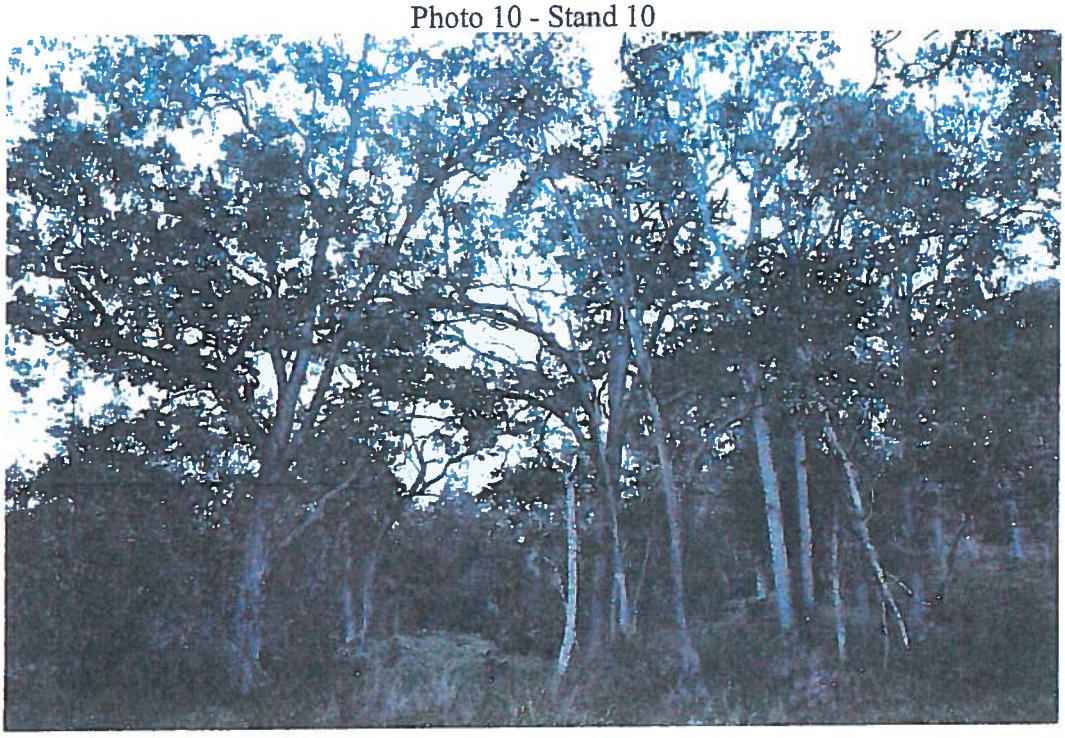


Photo 9 - Stand 9

Photo 10 - Stand 10



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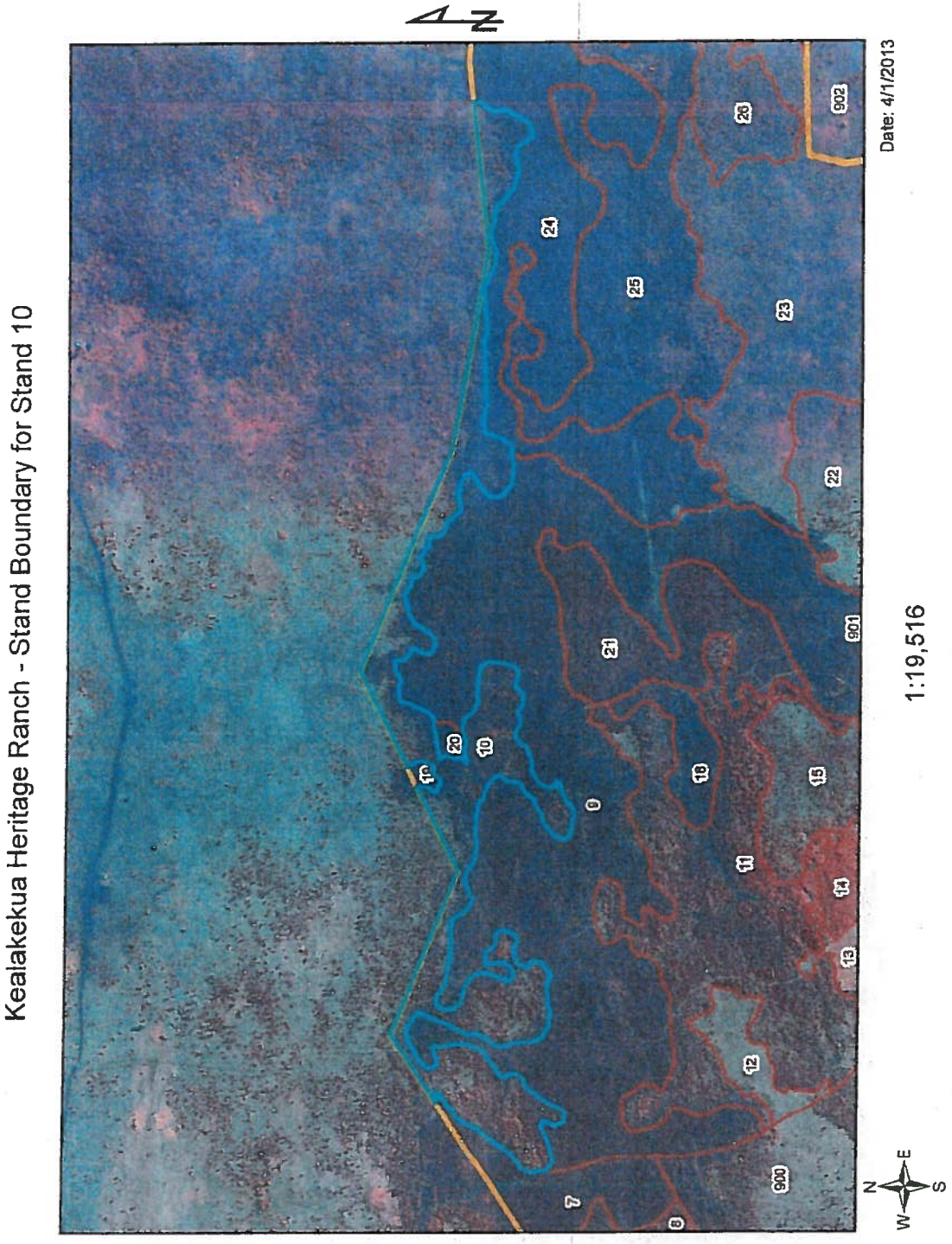

Map 15 - Stands 11 & 12

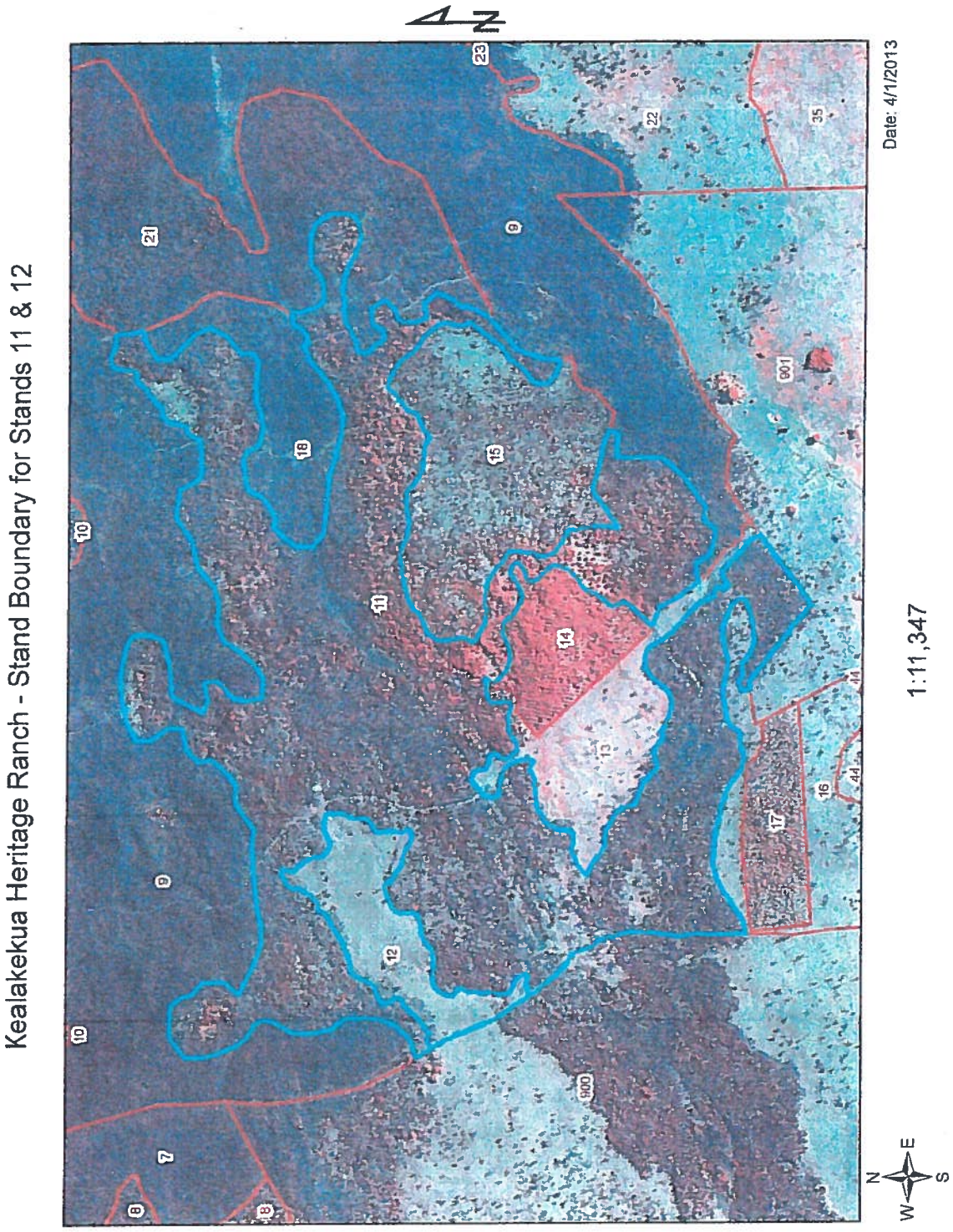

Photo 11 - Stand 11

Photo 12 - Stand 12

Map 16 - Stands 13 & 14

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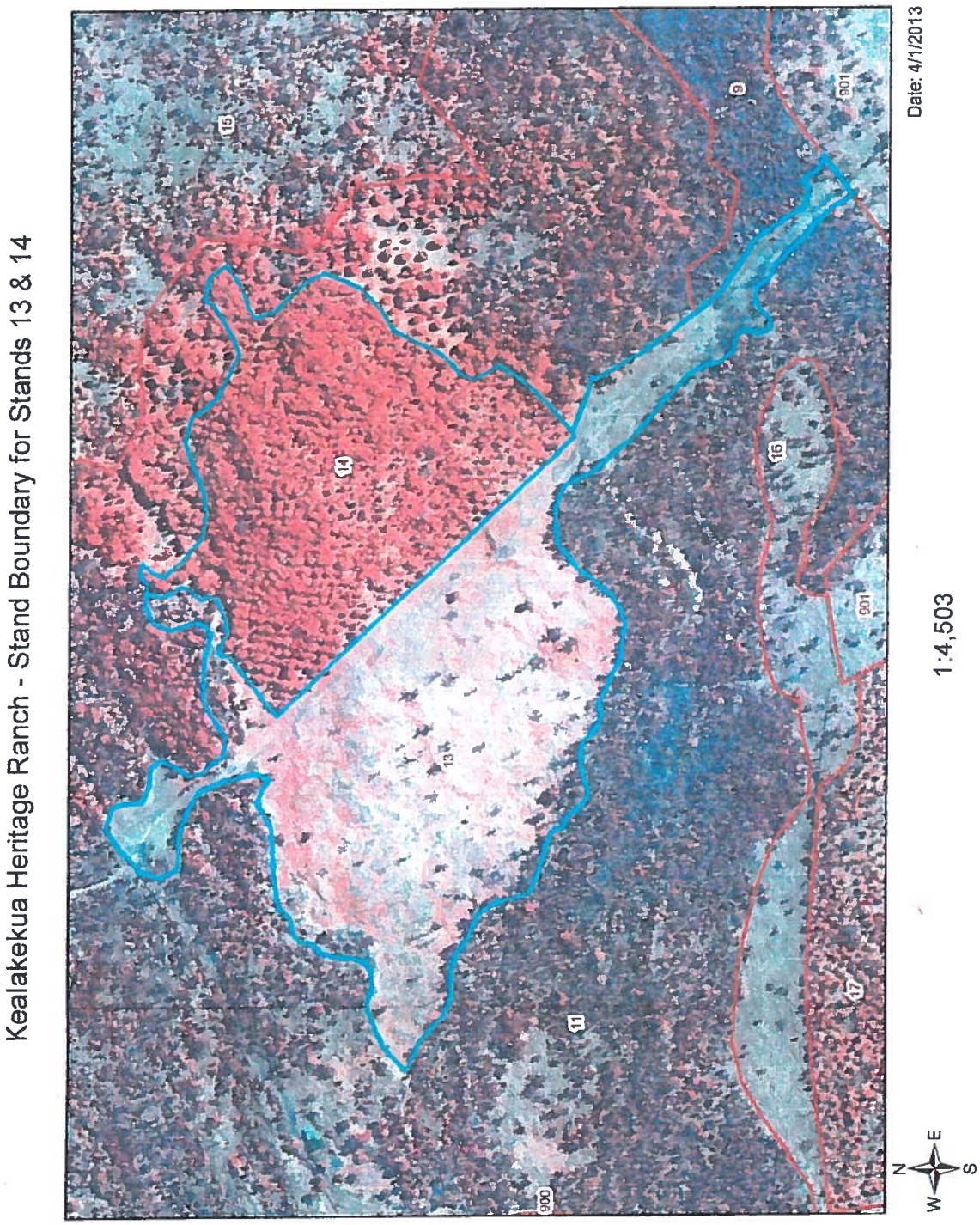
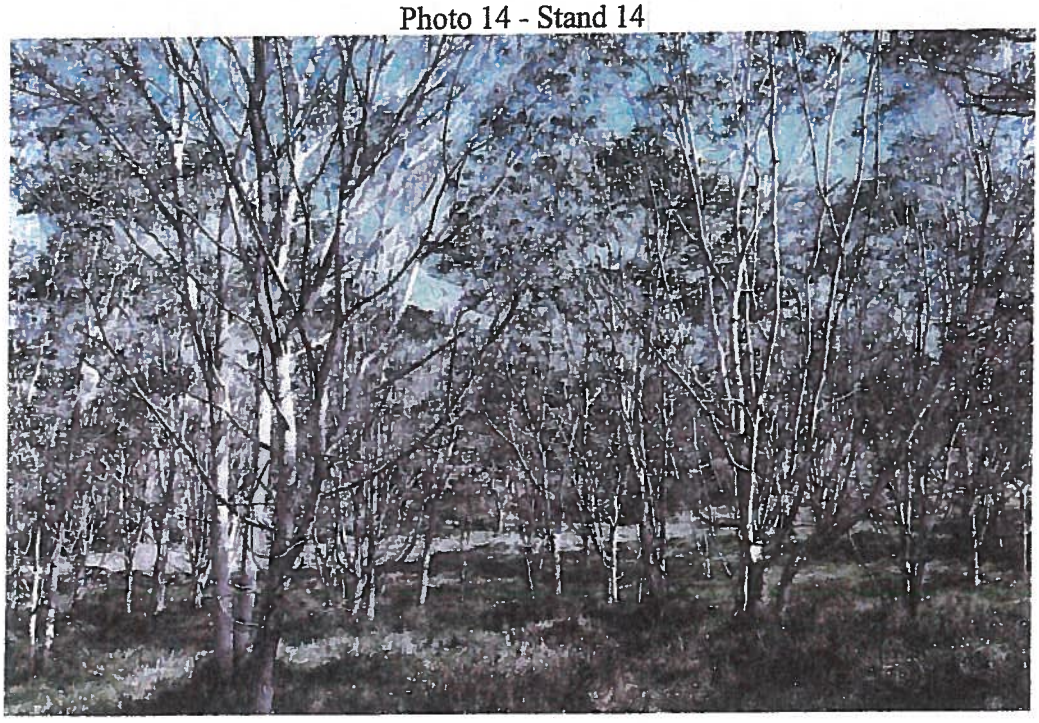


Photo 13 - Stand 13

Photo 14 - Stand 14



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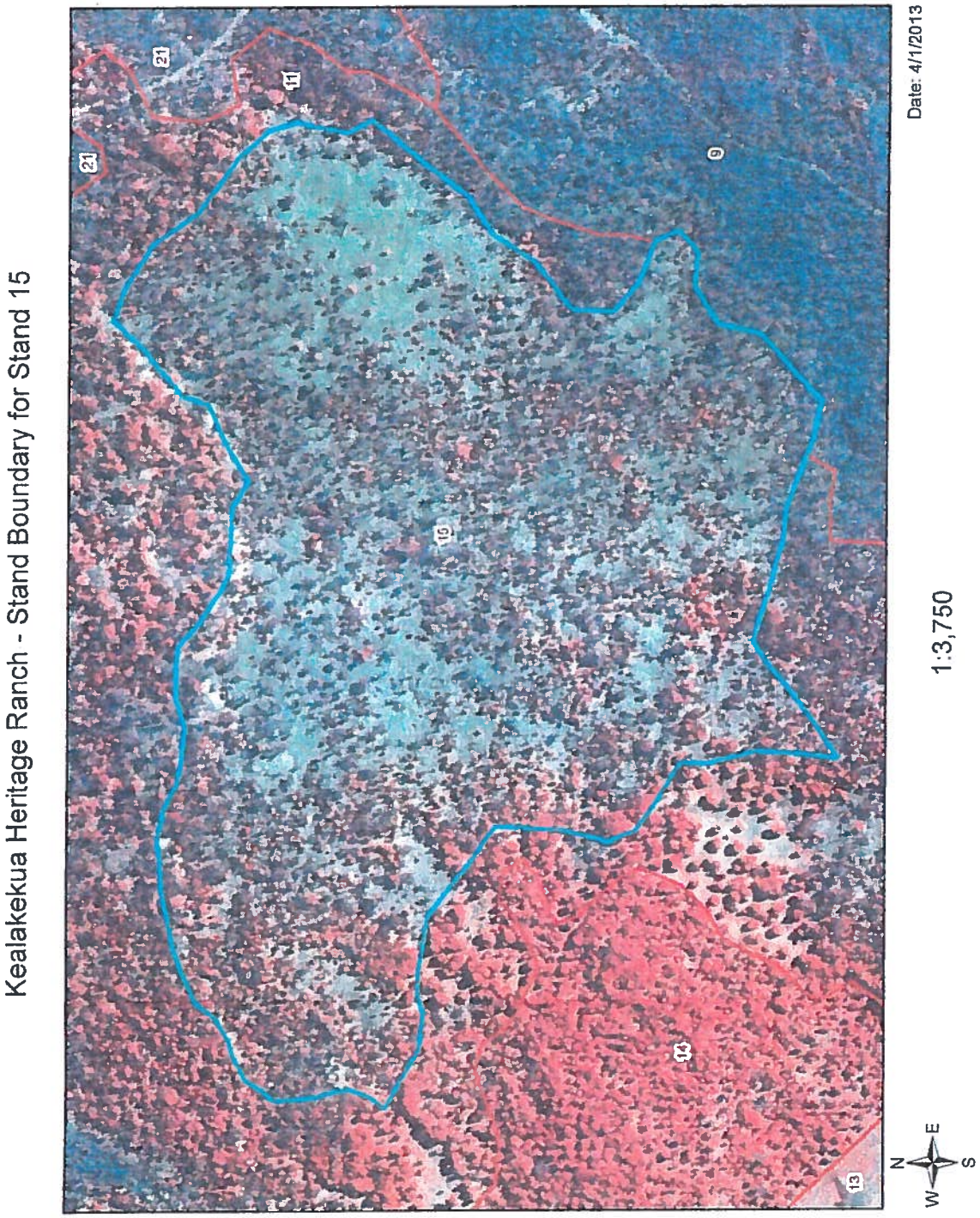


Photo 15 - Stand 15

Photo 16 - Stand 16

Map 18 – Stands 16 & 17

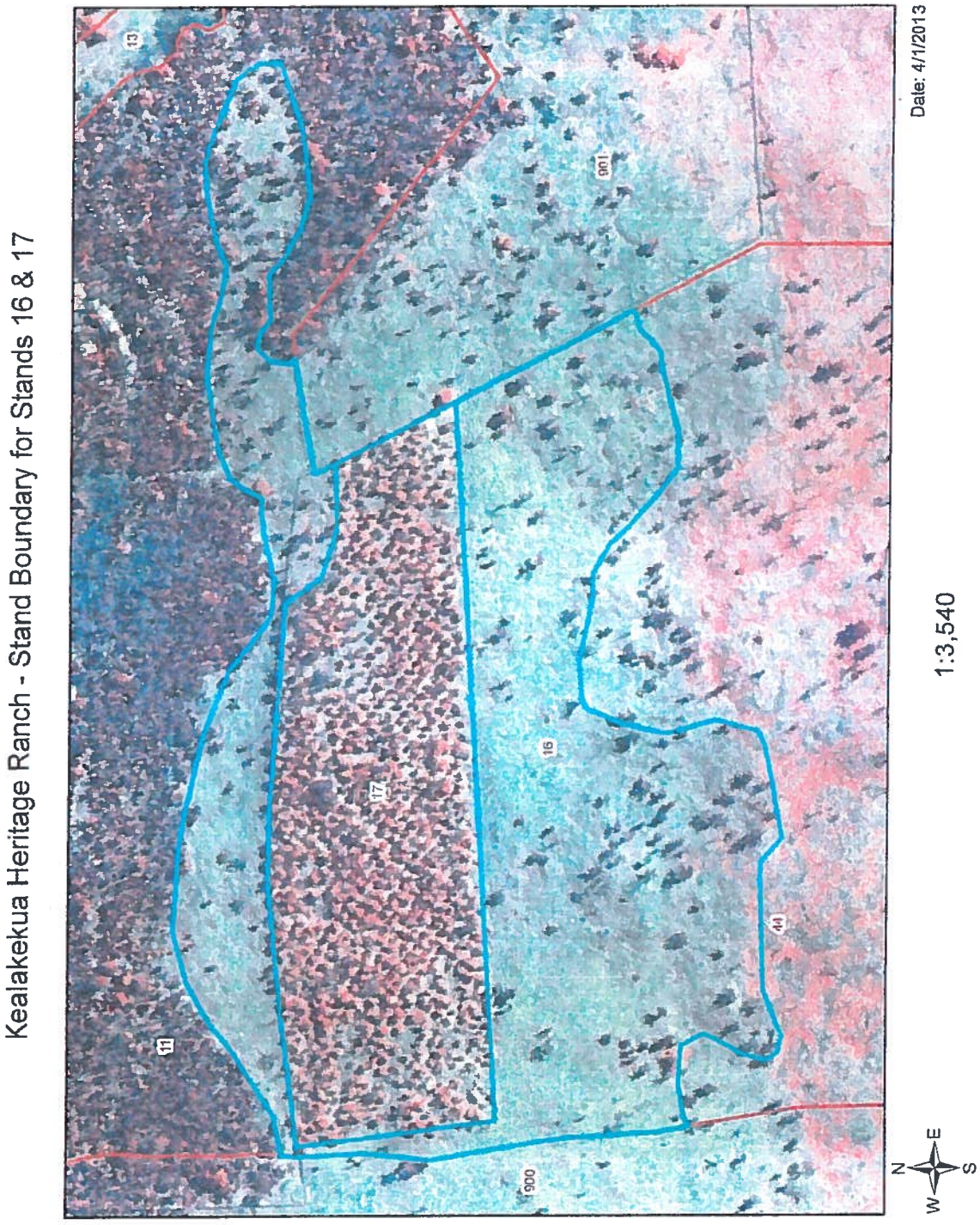
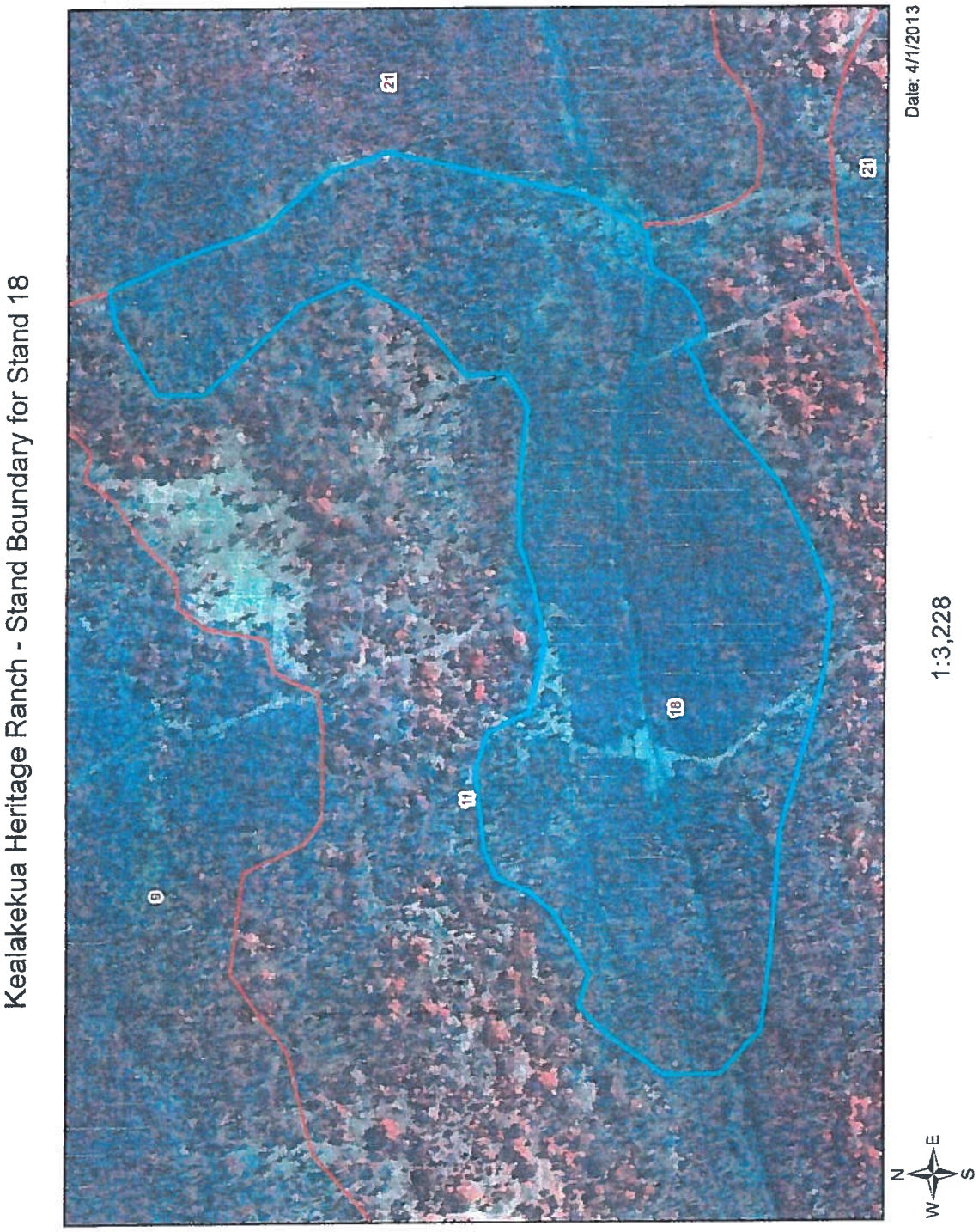


Photo 17 - Stand 17

Photo 18 - Stand 18

Map 19 – Stand 18



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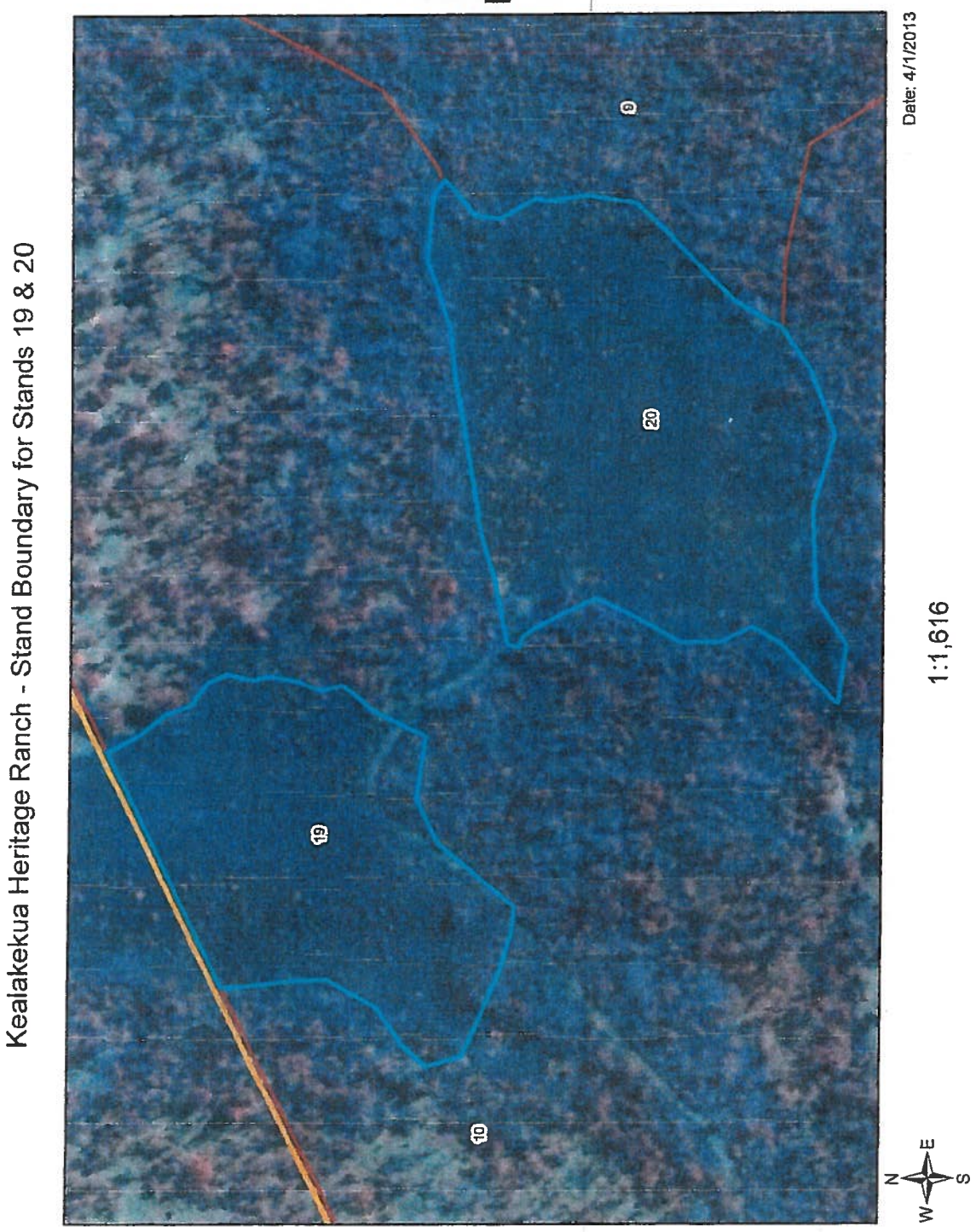

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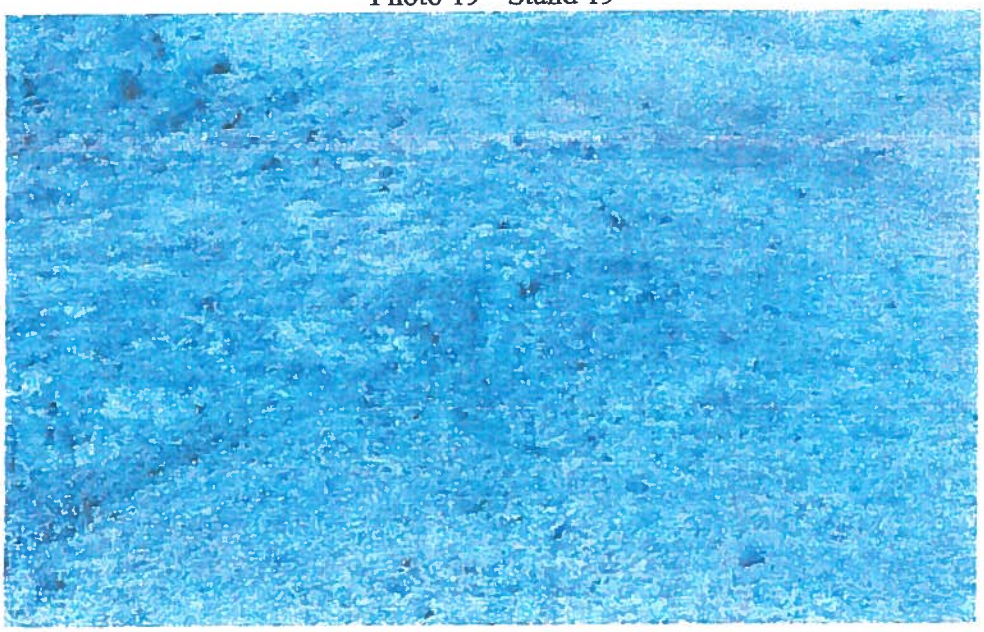


Photo 20 - Stand 20

Map 21 – Stand 21

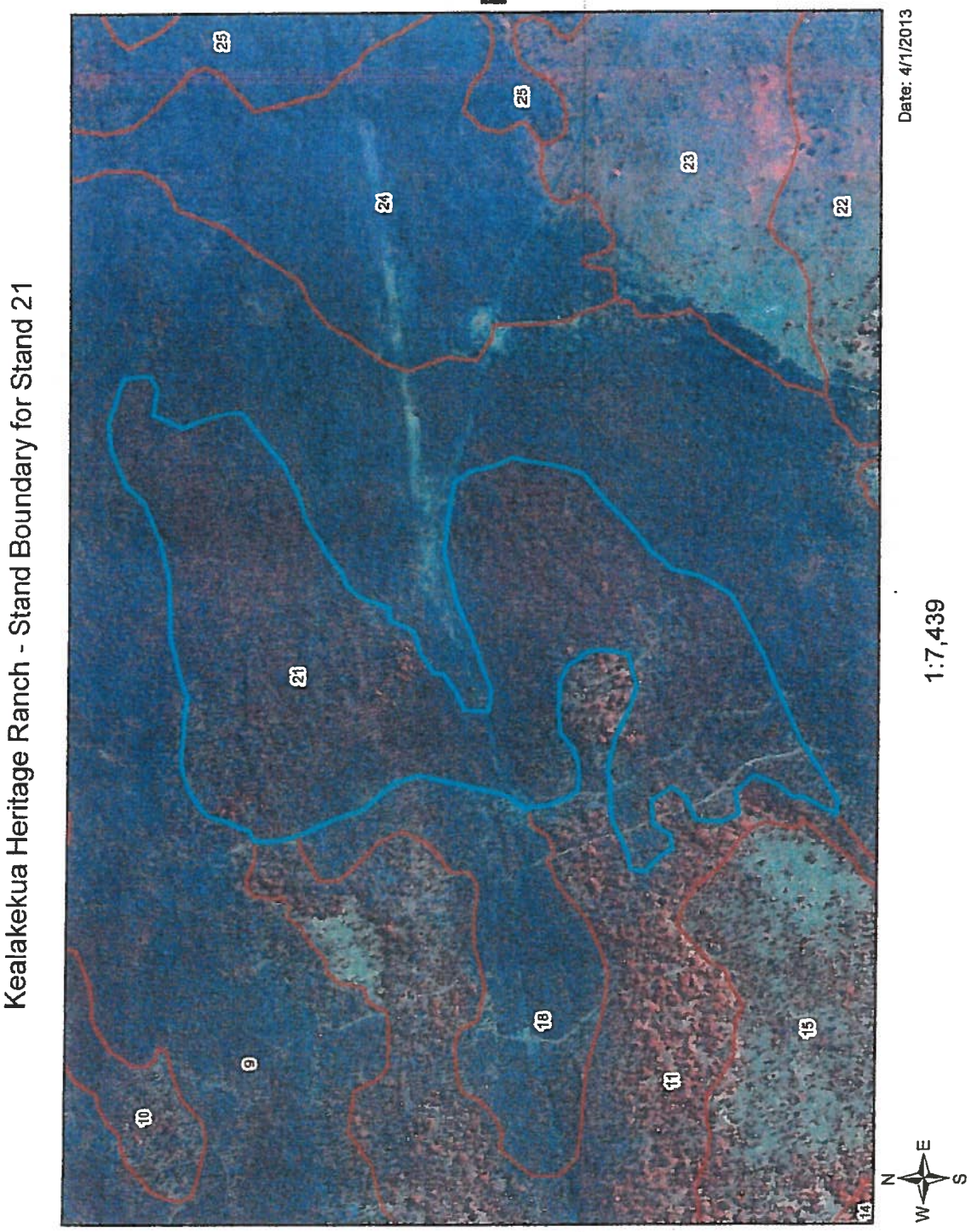


Photo 21 - Stand 21

Map 22 – Stands 22 & 23

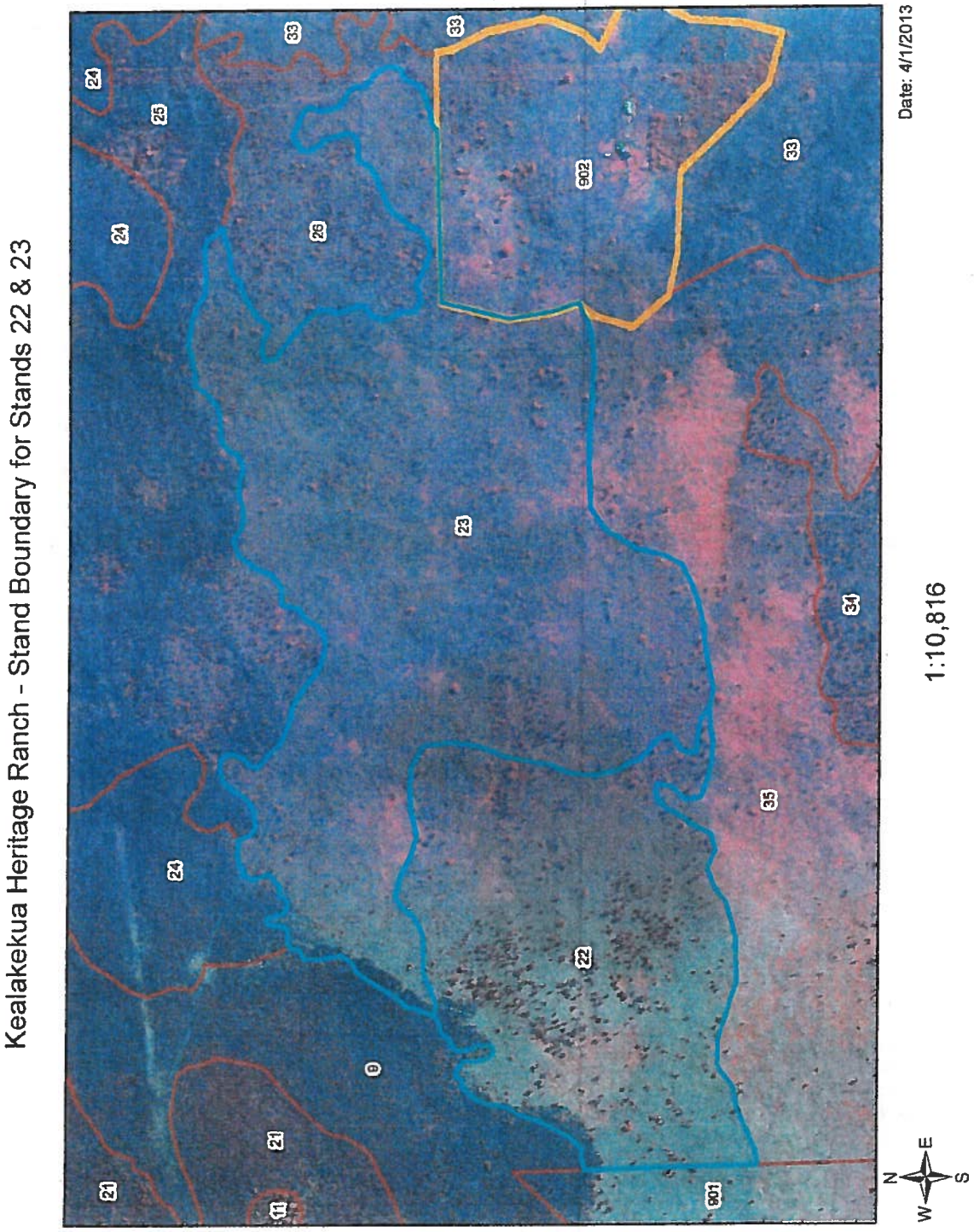
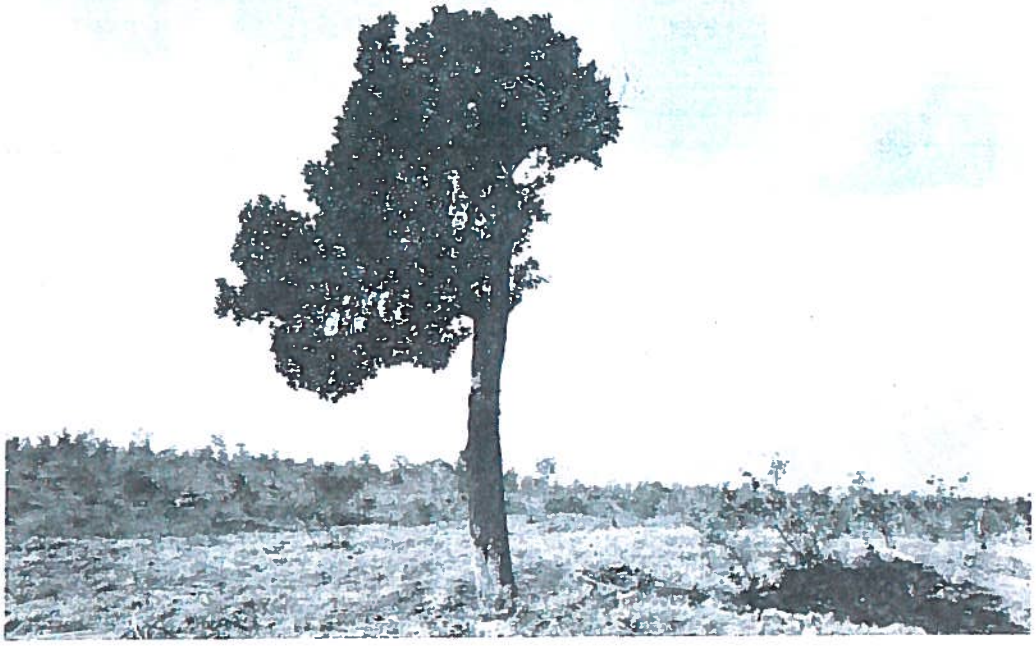


Photo 22 - Stand 22

Photo 23 - Stand 23



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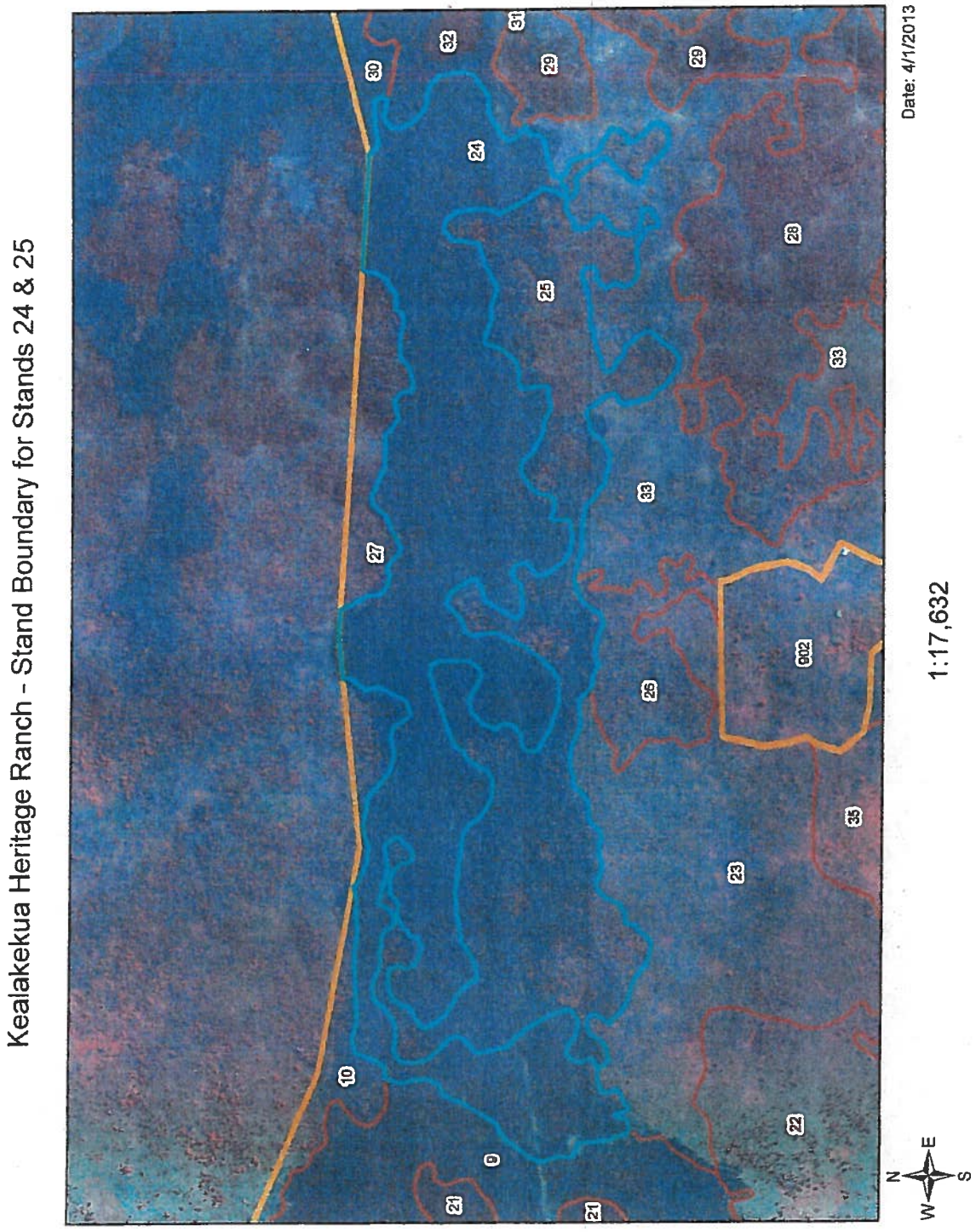


Photo 24 - Stand 24

Photo 25 - Stand 25

Map 24 – Stand 26

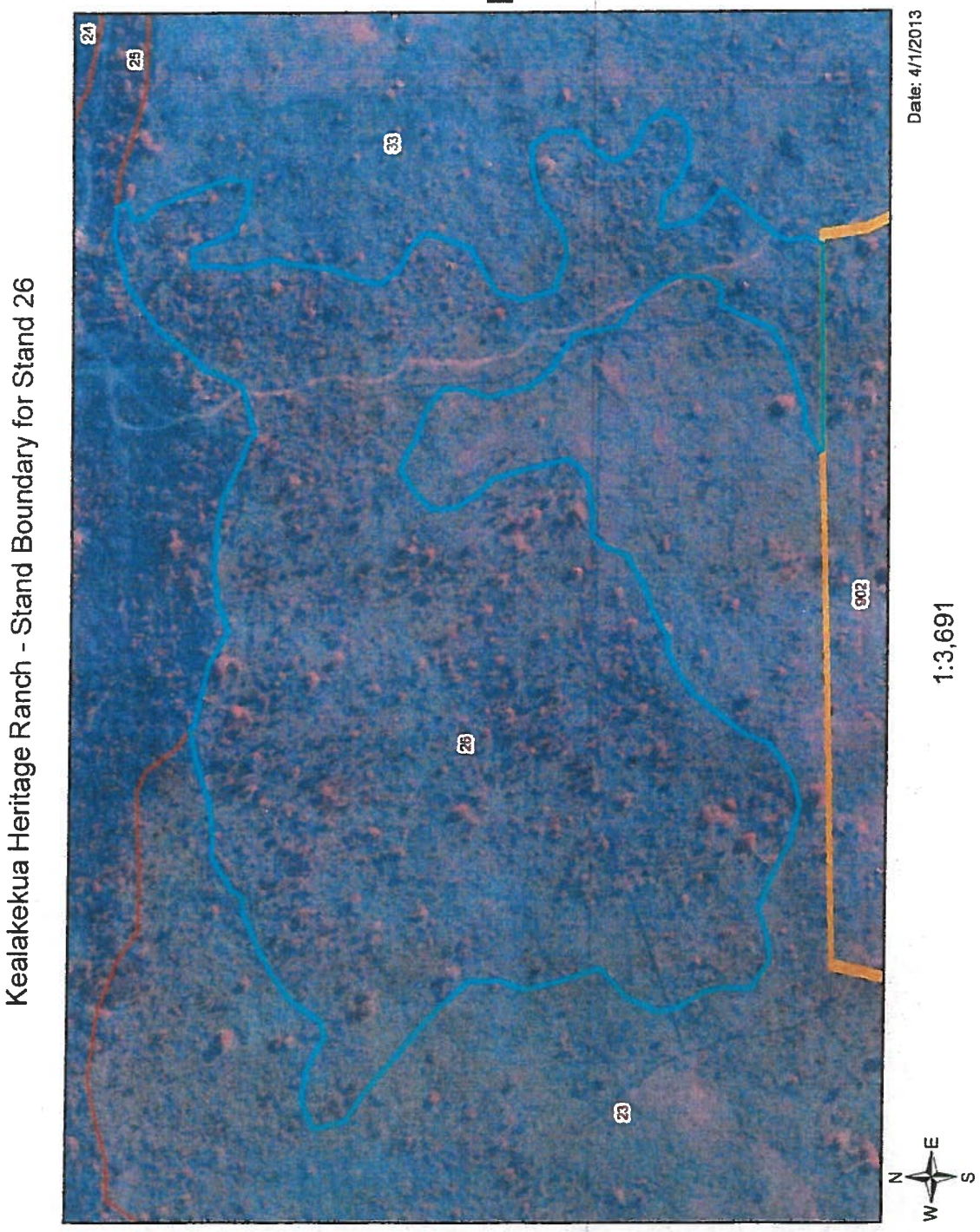
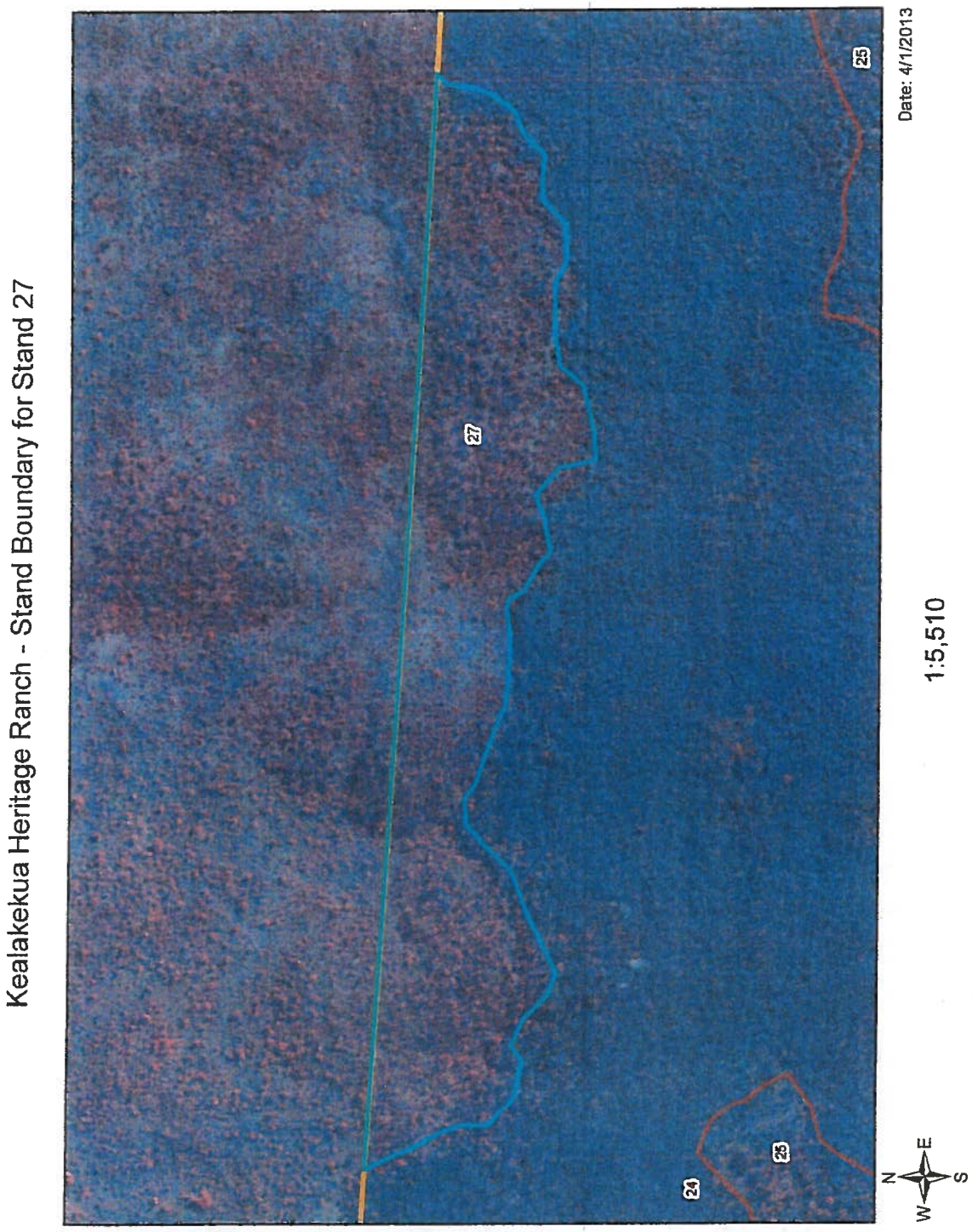


Photo 26 - Stand 26

Photo 27 - Stand 27

Map 25 – Stand 27



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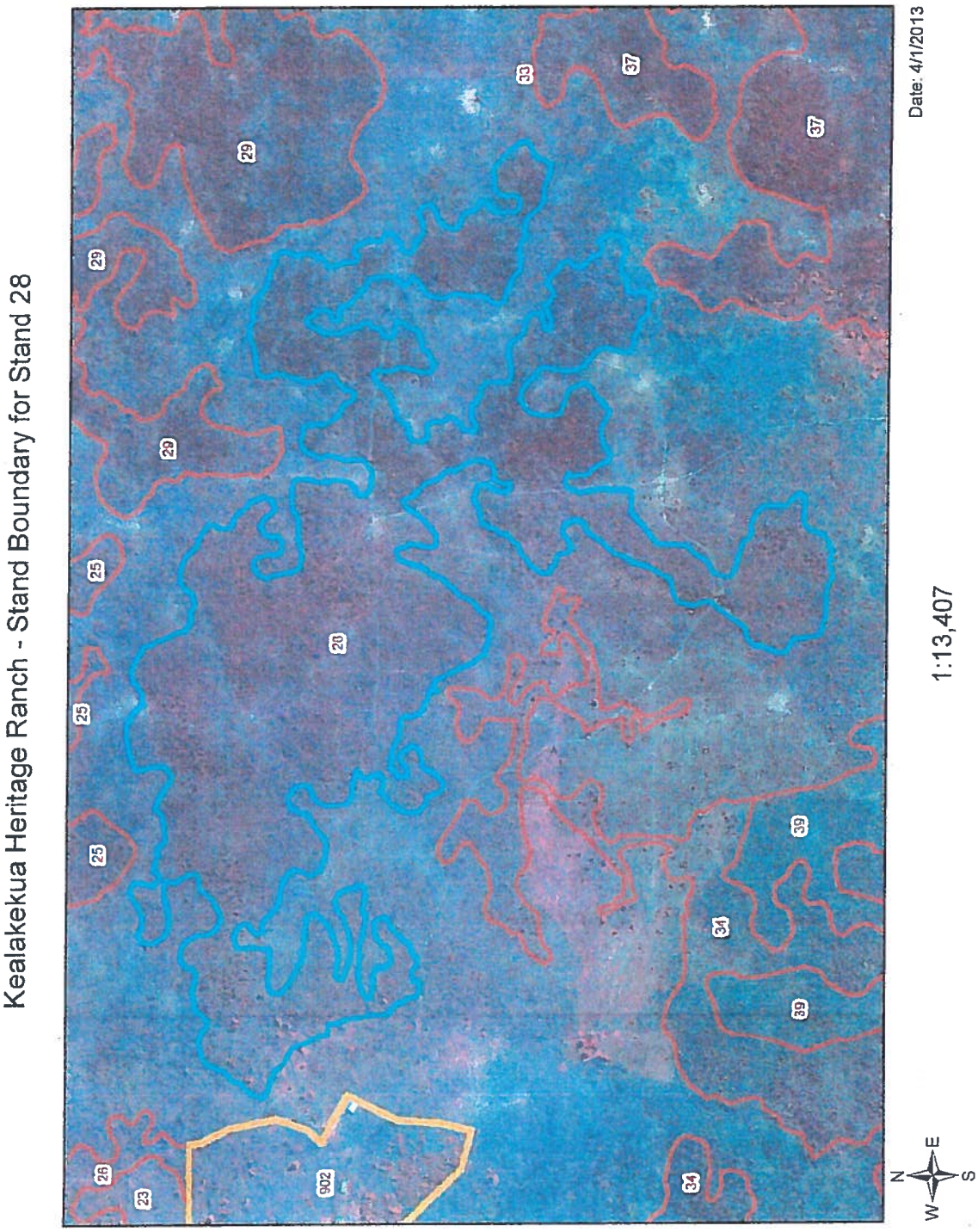

Photo 28 - Stand 28

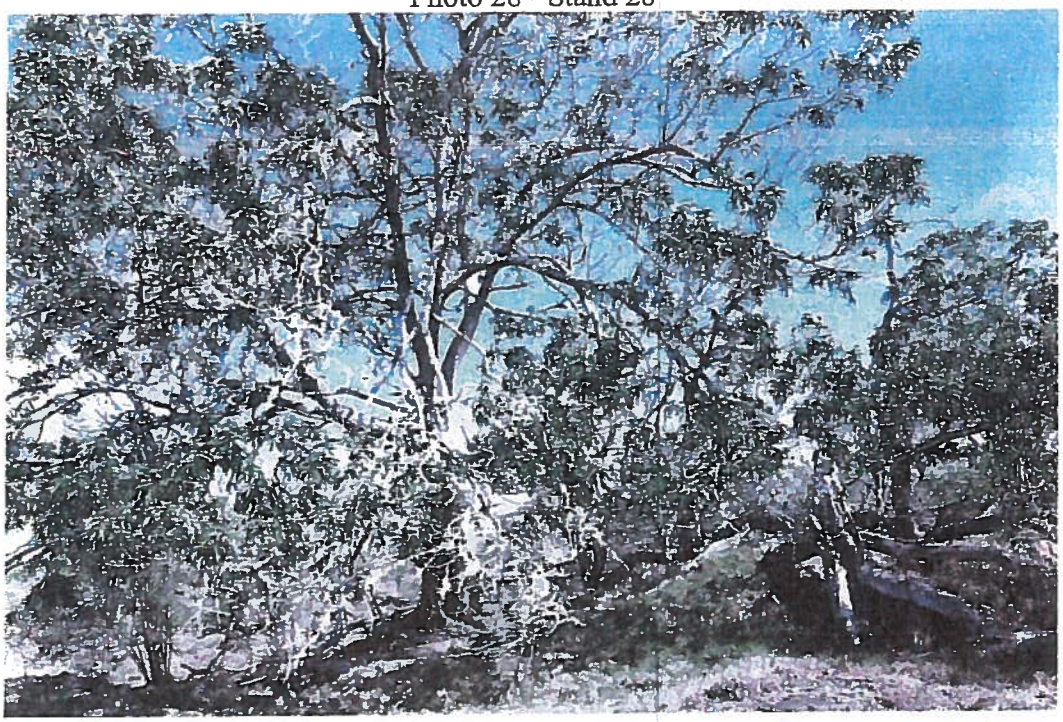

Photo 29 - Stand 29

Map 27 – Stand 29

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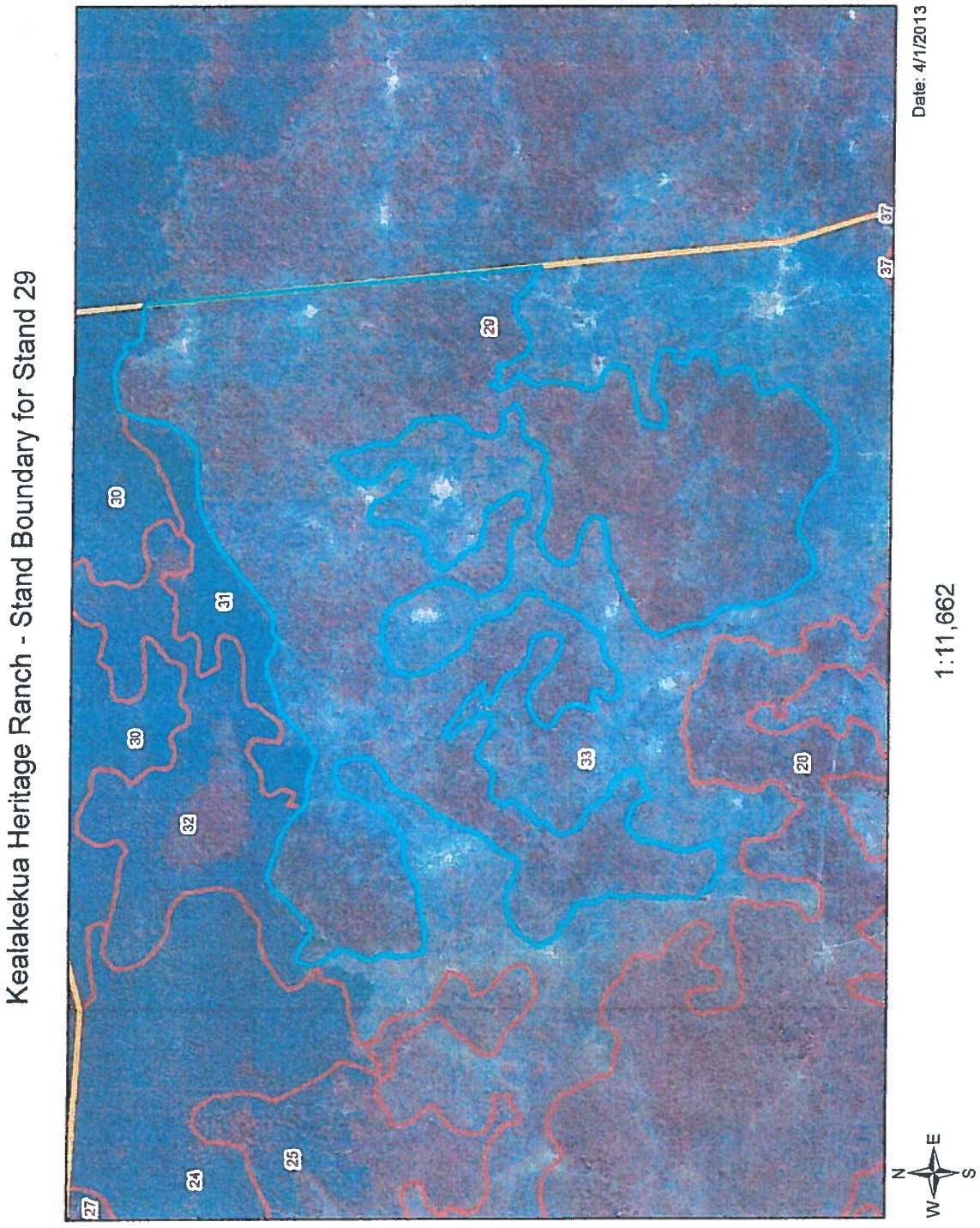

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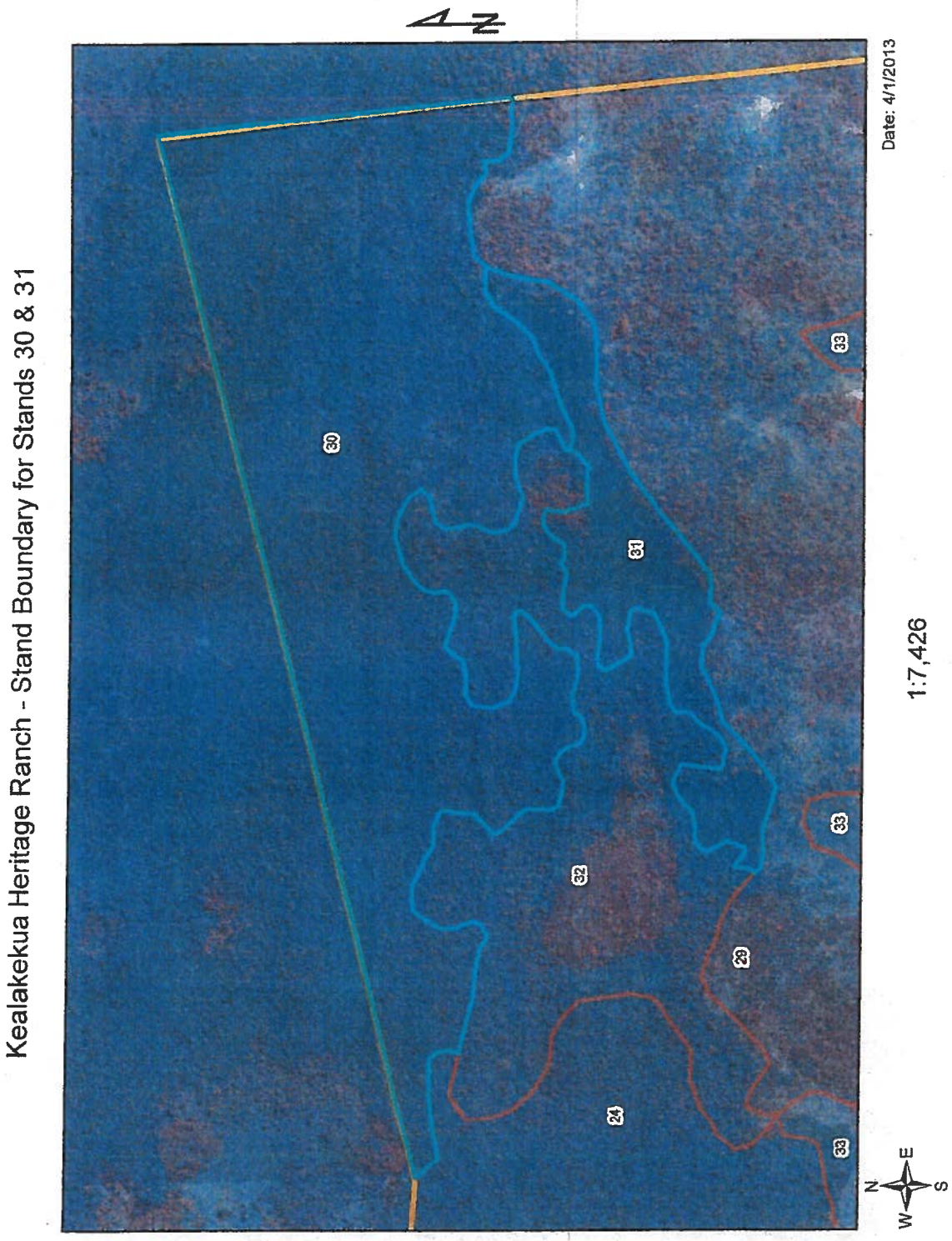

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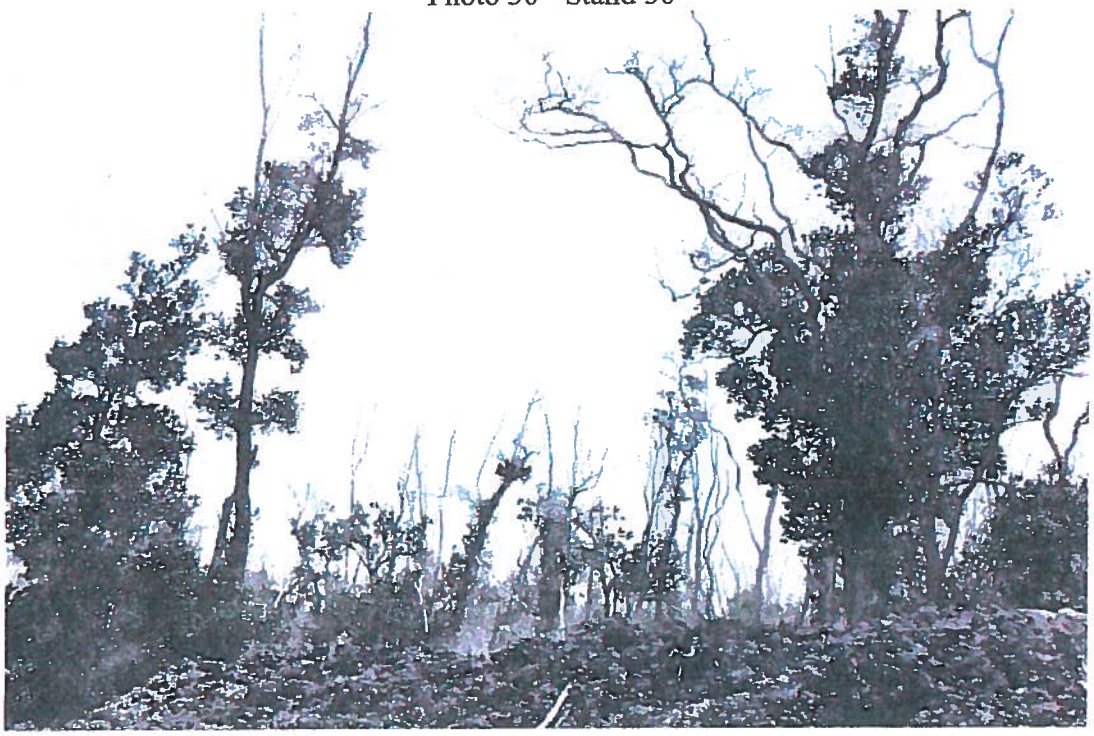
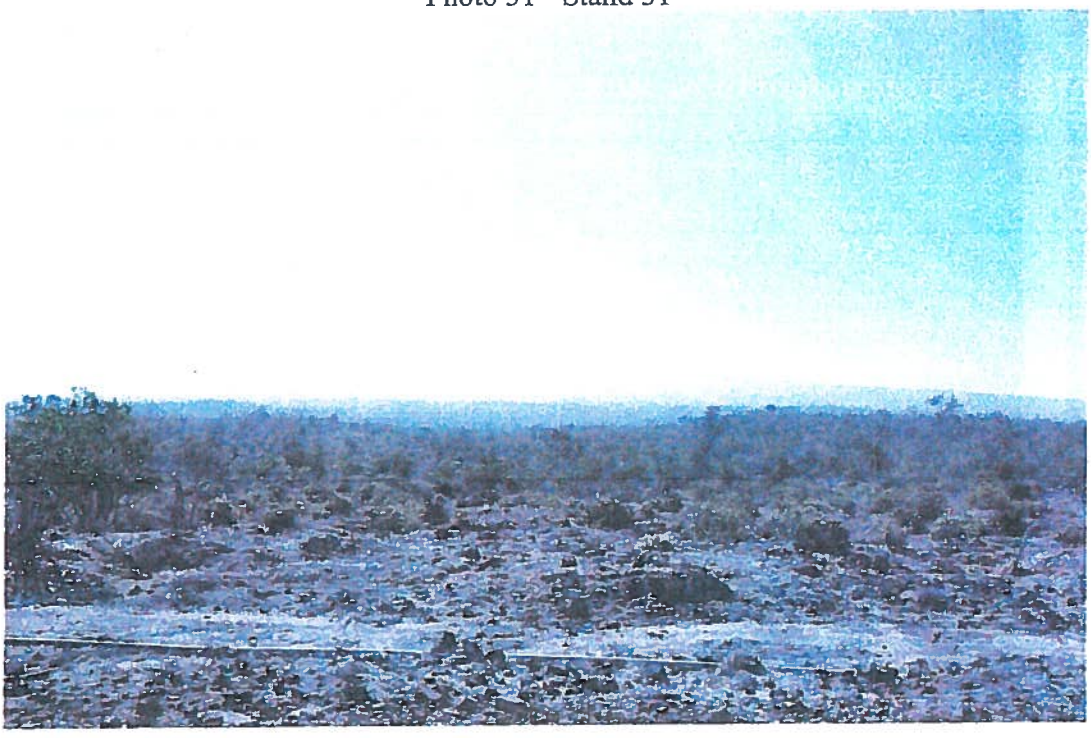


Photo 31 - Stand 31



Map 29 – Stand 32

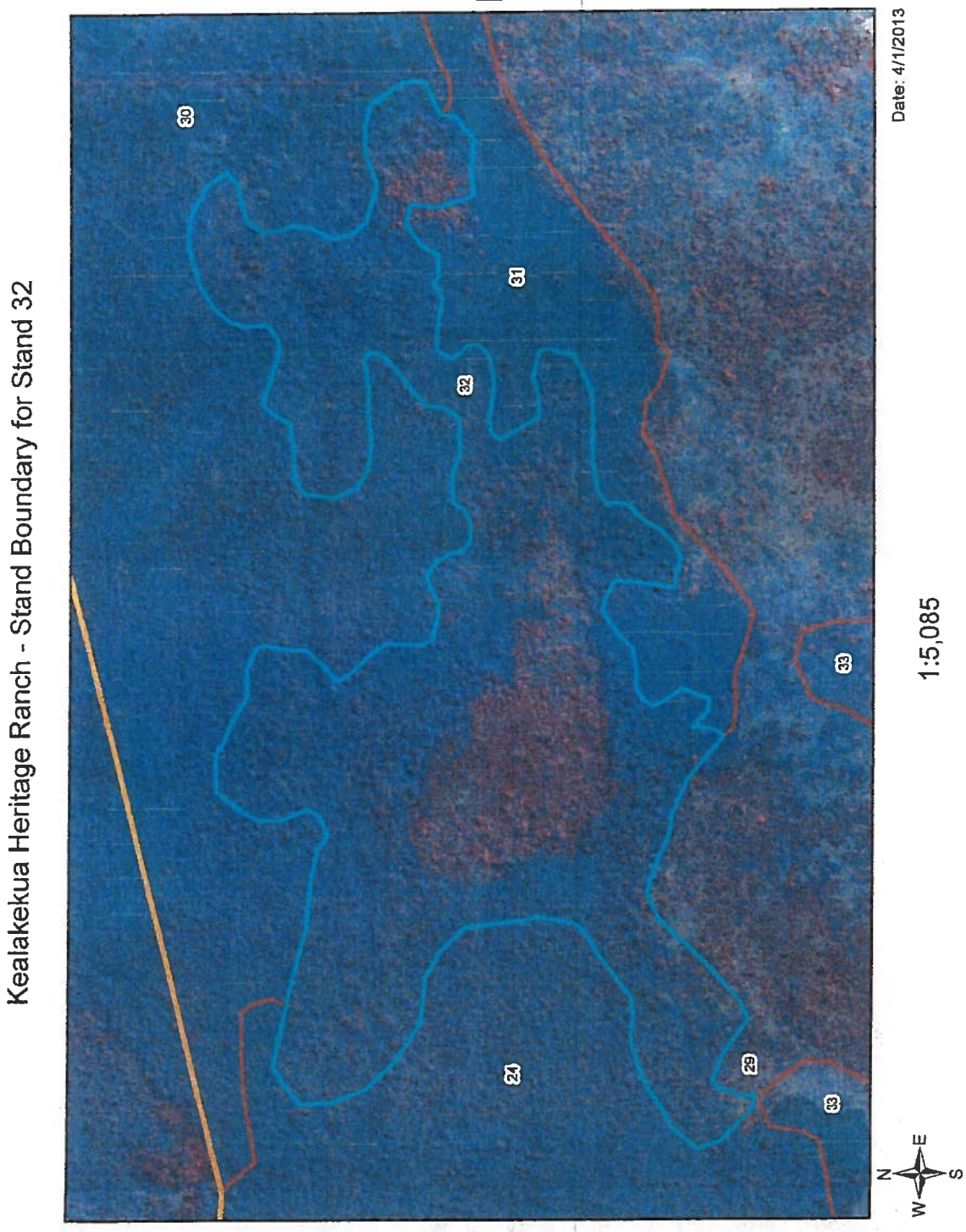
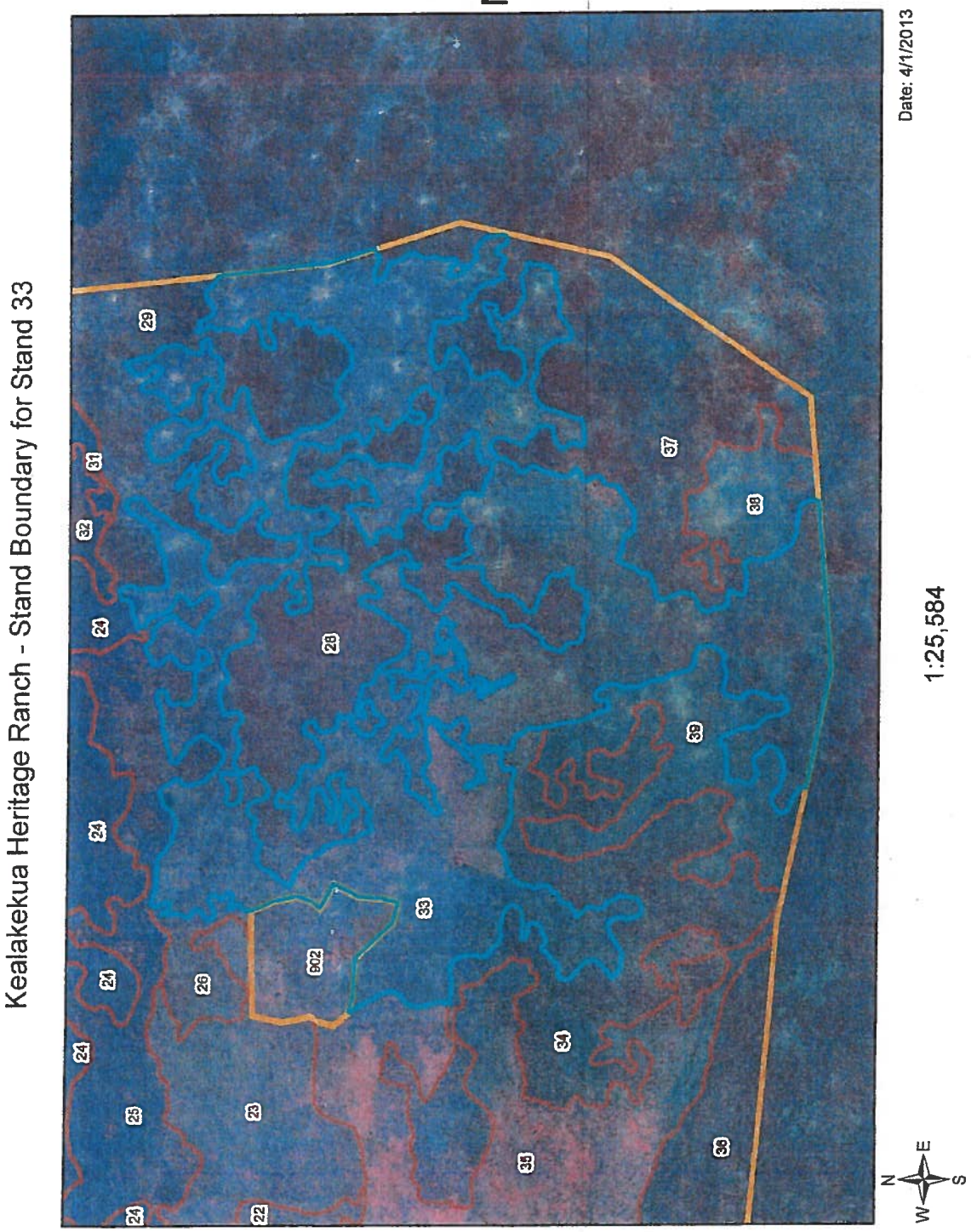


Photo 32 - Stand 32

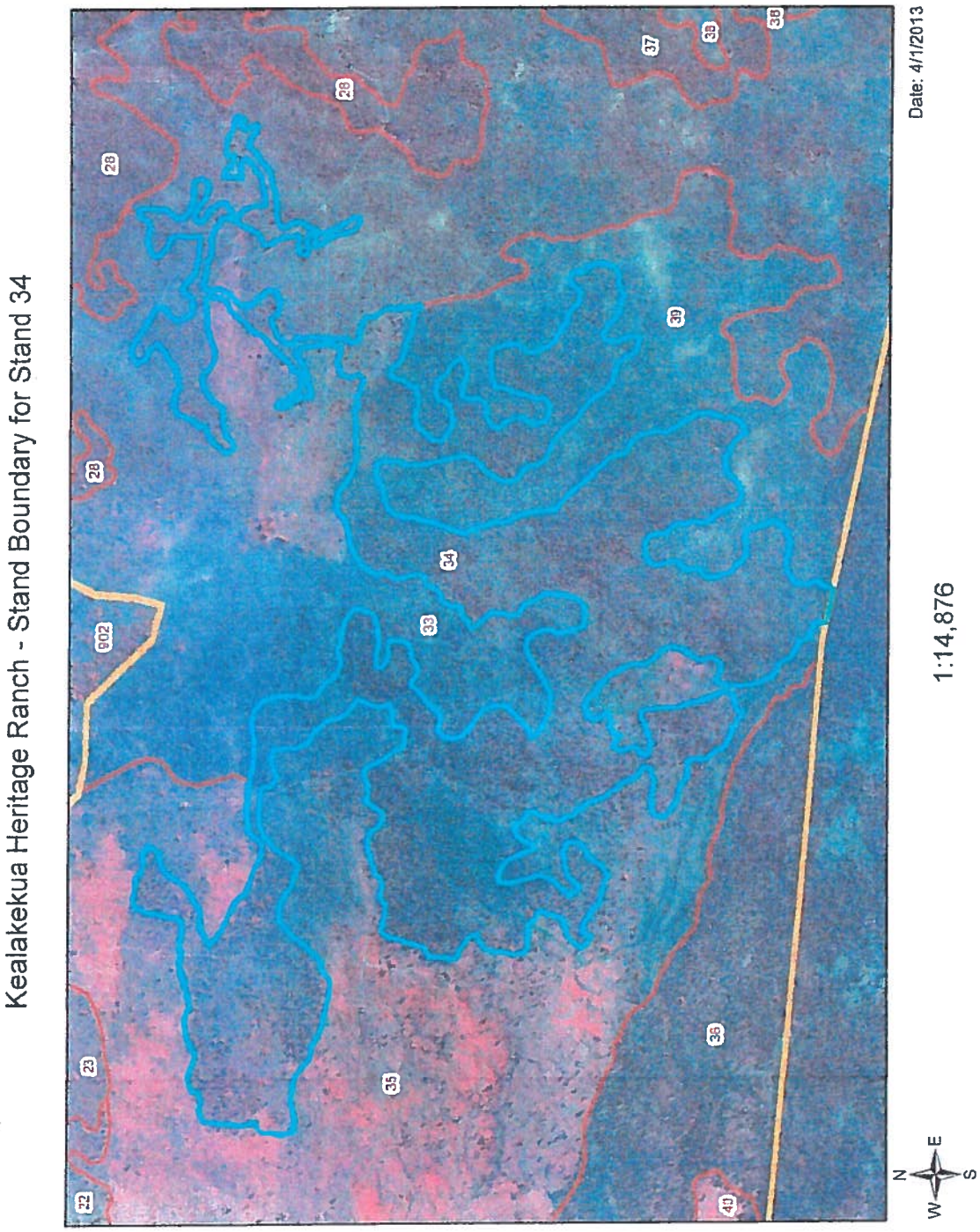
Photo 33 - Stand 33

Map 30 – Stand 33

42



Map 31 – Stand 34



4

Photo 34 - Stand 34

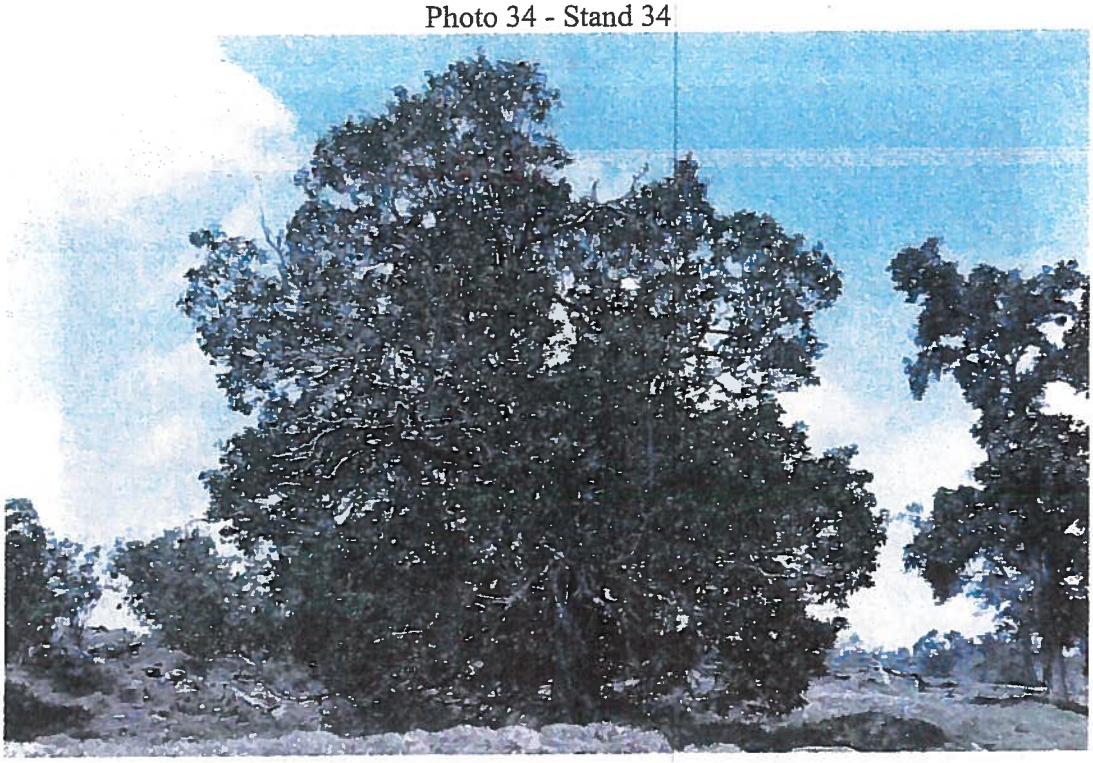
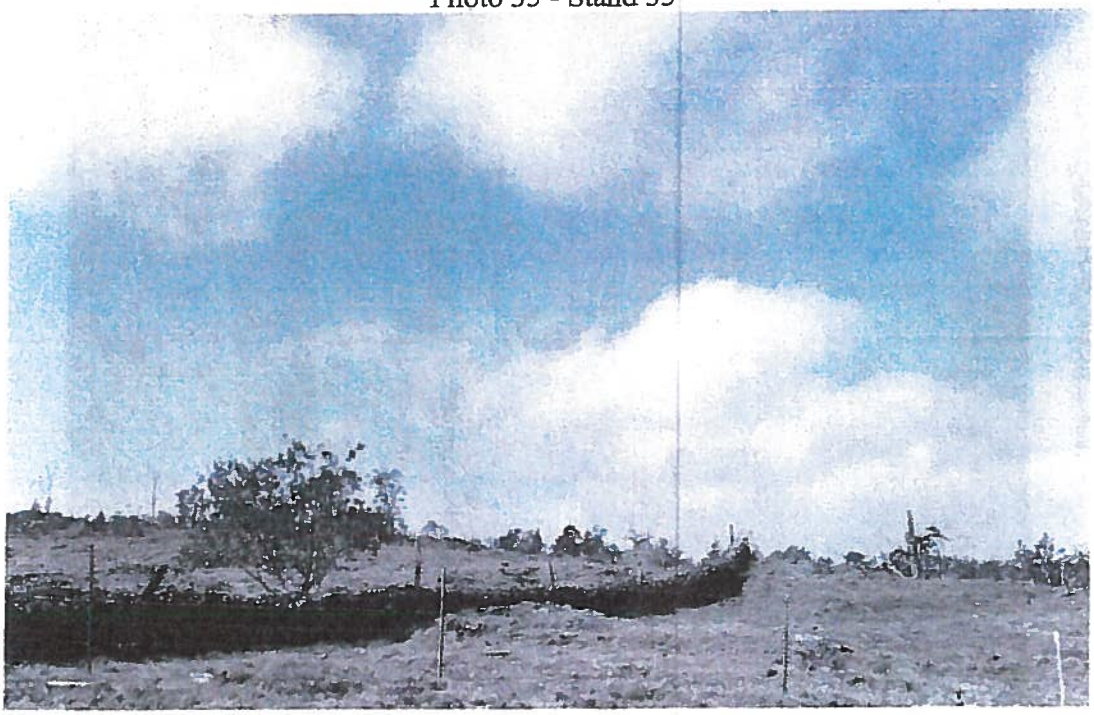
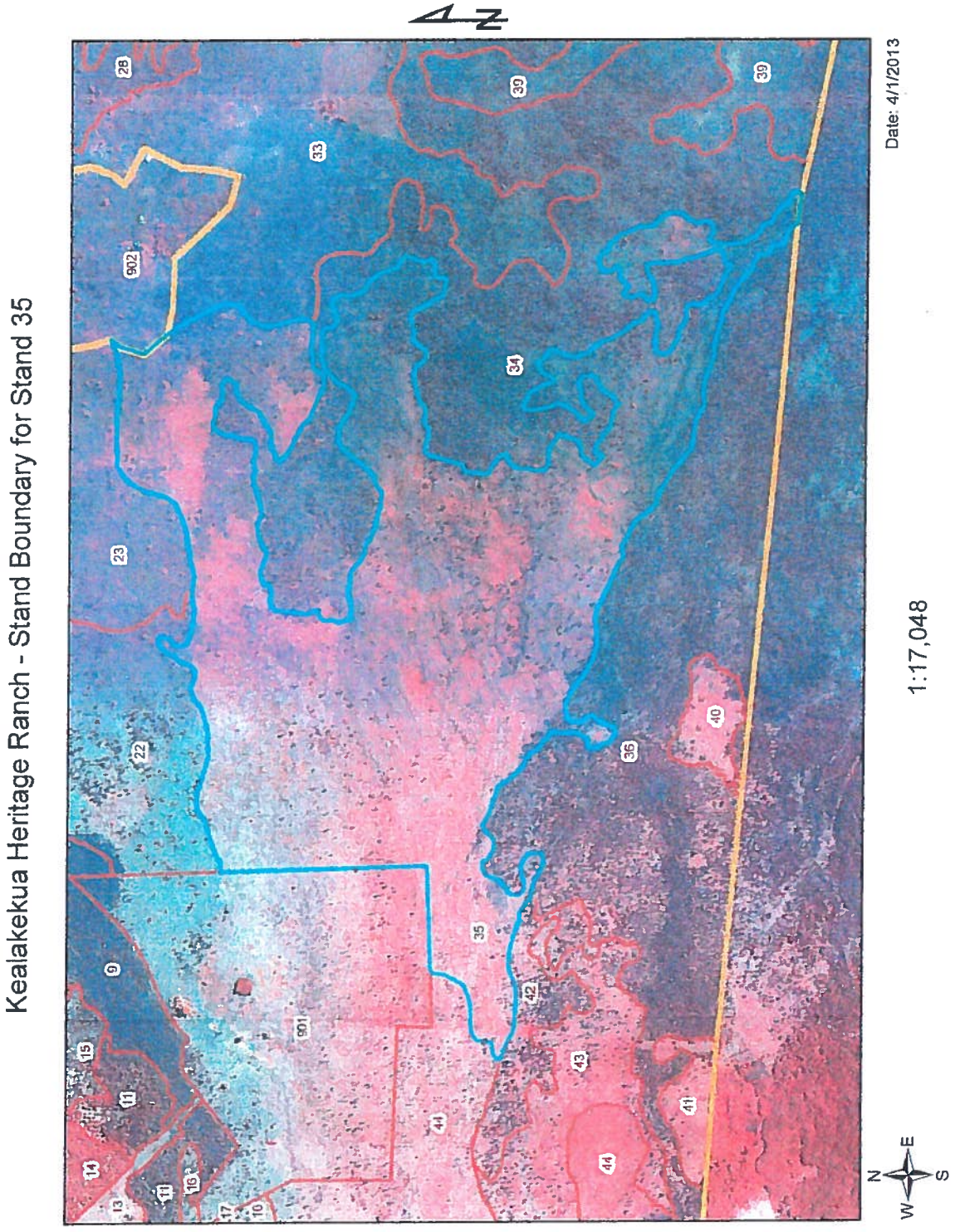


Photo 35 - Stand 35

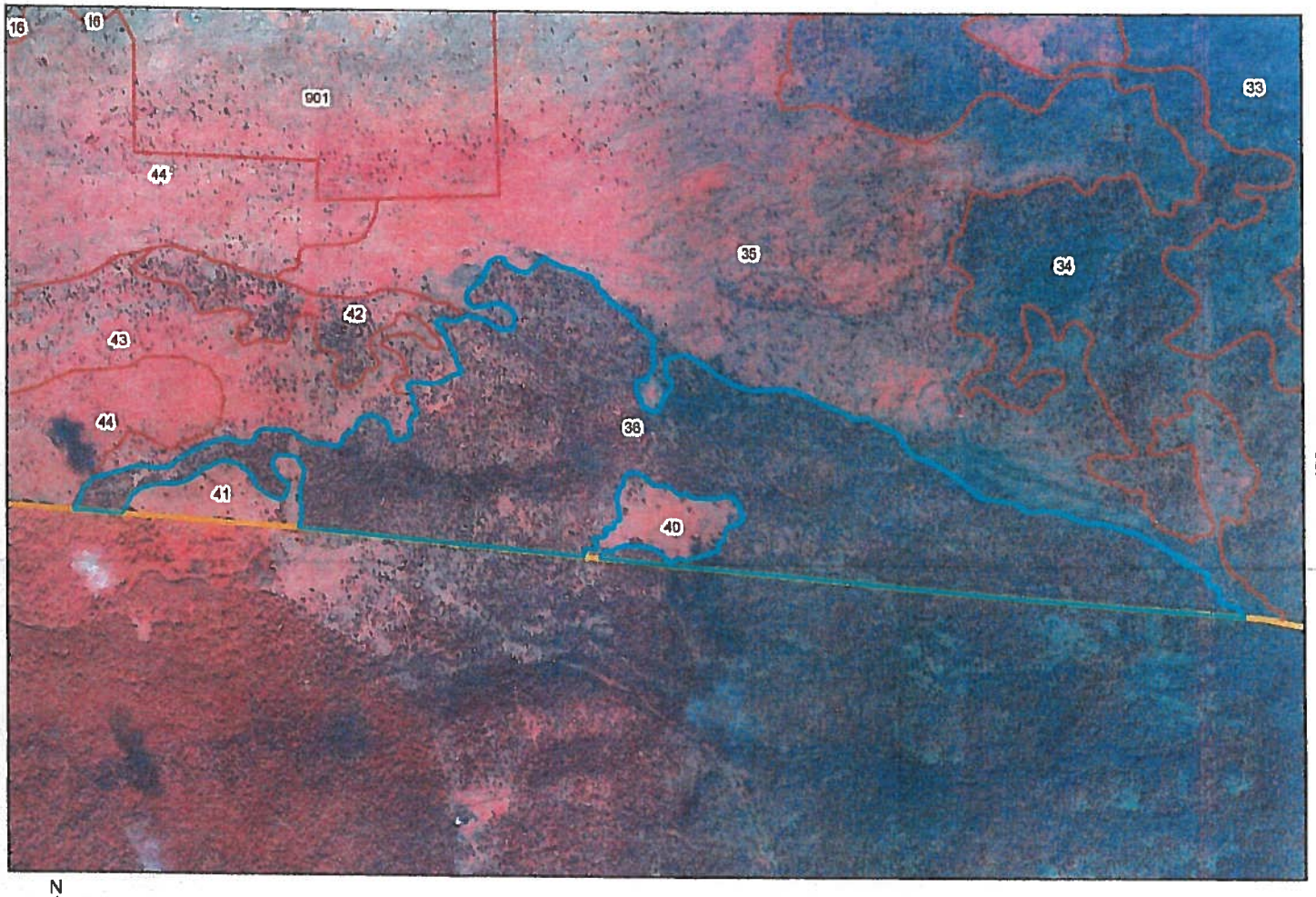


Map 32 – Stand 35



Map 33 – Stand 36

Kealakekua Heritage Ranch - Stand Boundary for Stand 36



Date: 4/1/2013

1:16,193

[101]

Photo 36 - Stand 36

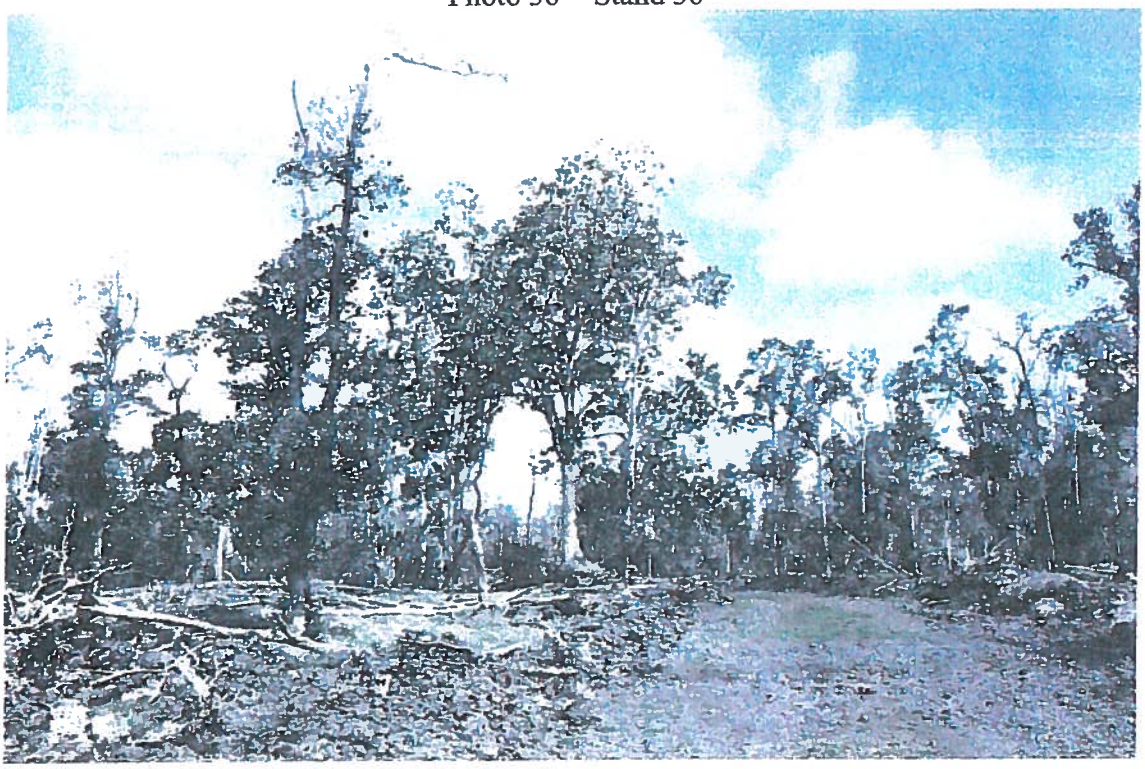
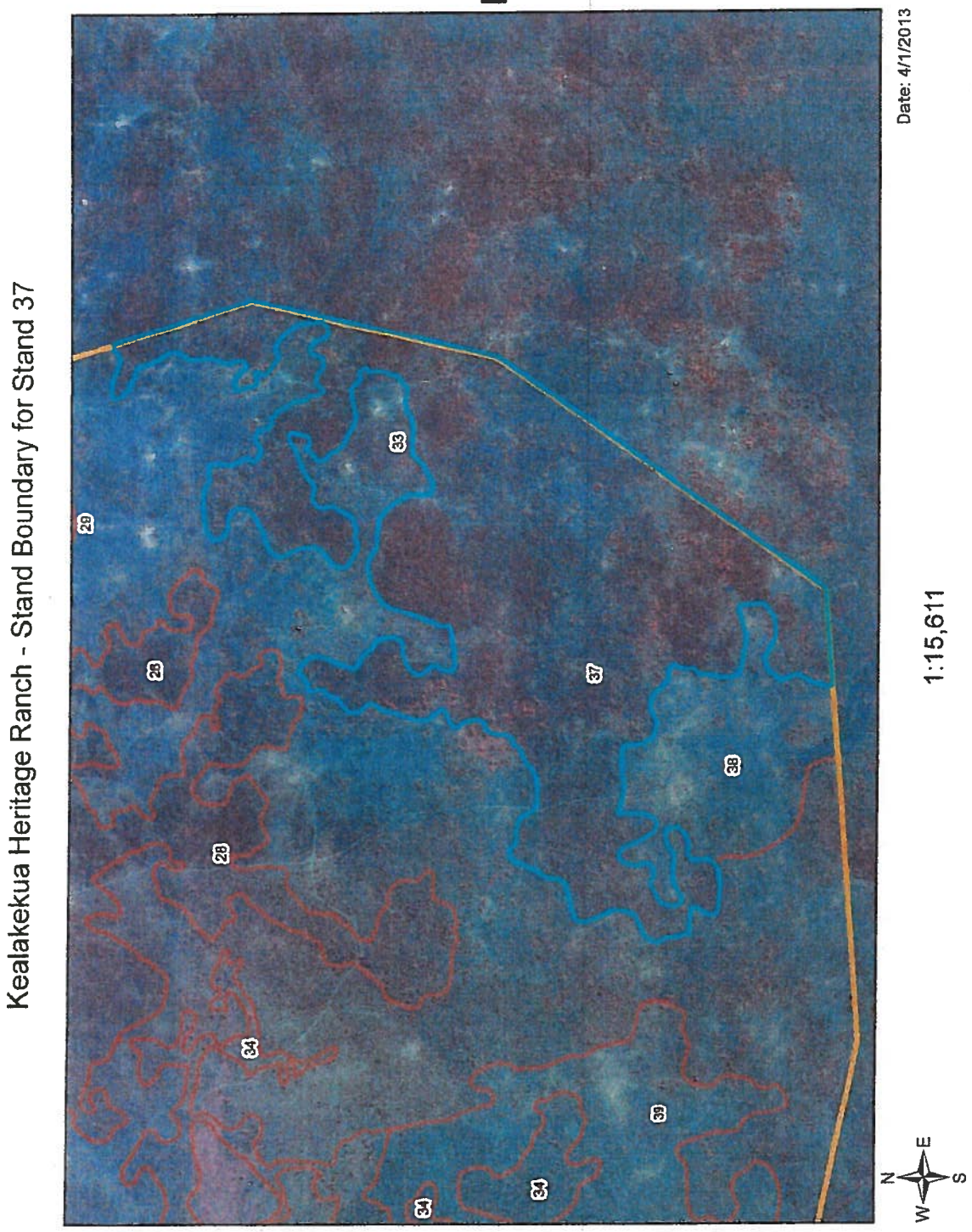


Photo 37 - Stand 37

Map 34 – Stand 37

42



Map 35 – Stand 38

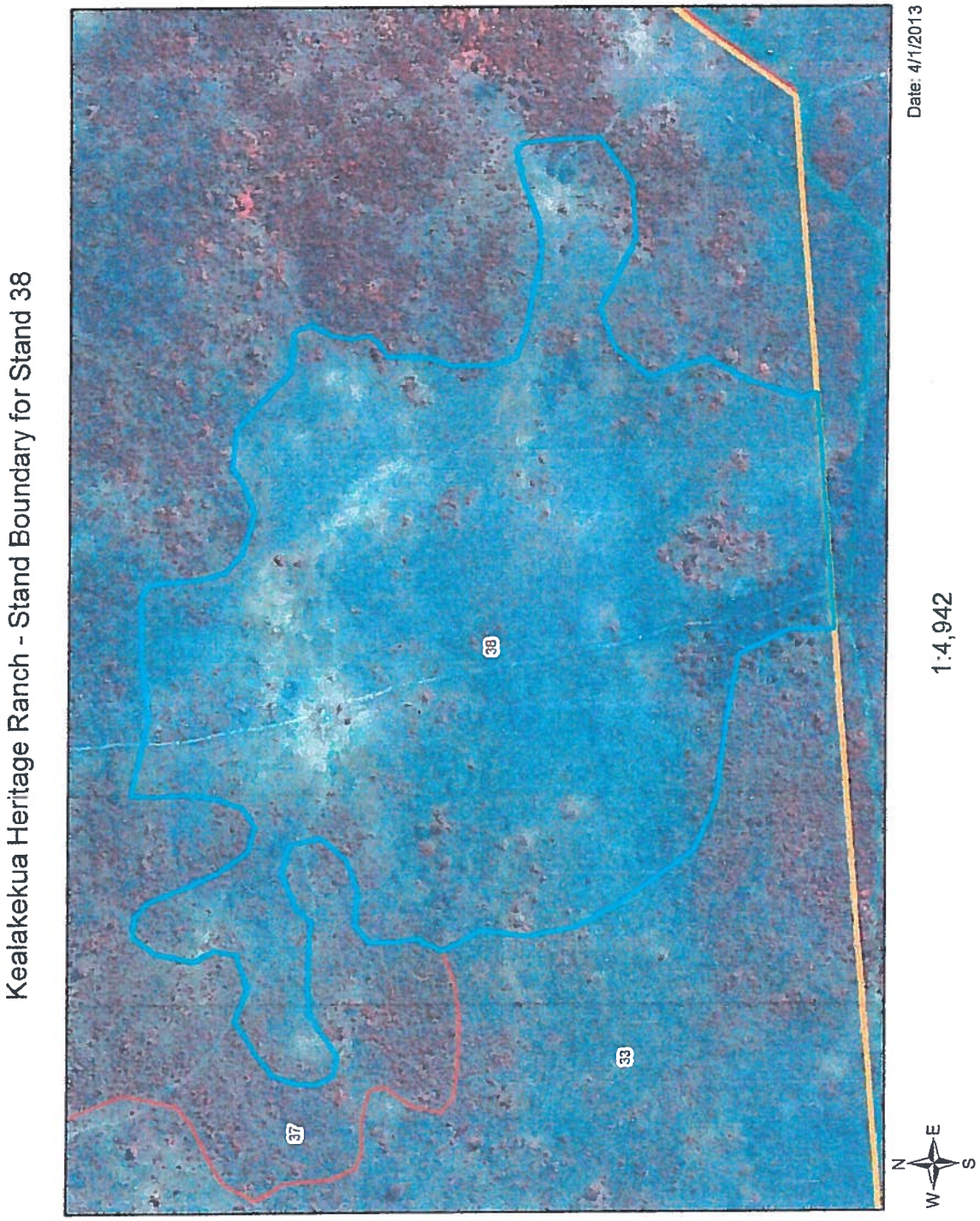
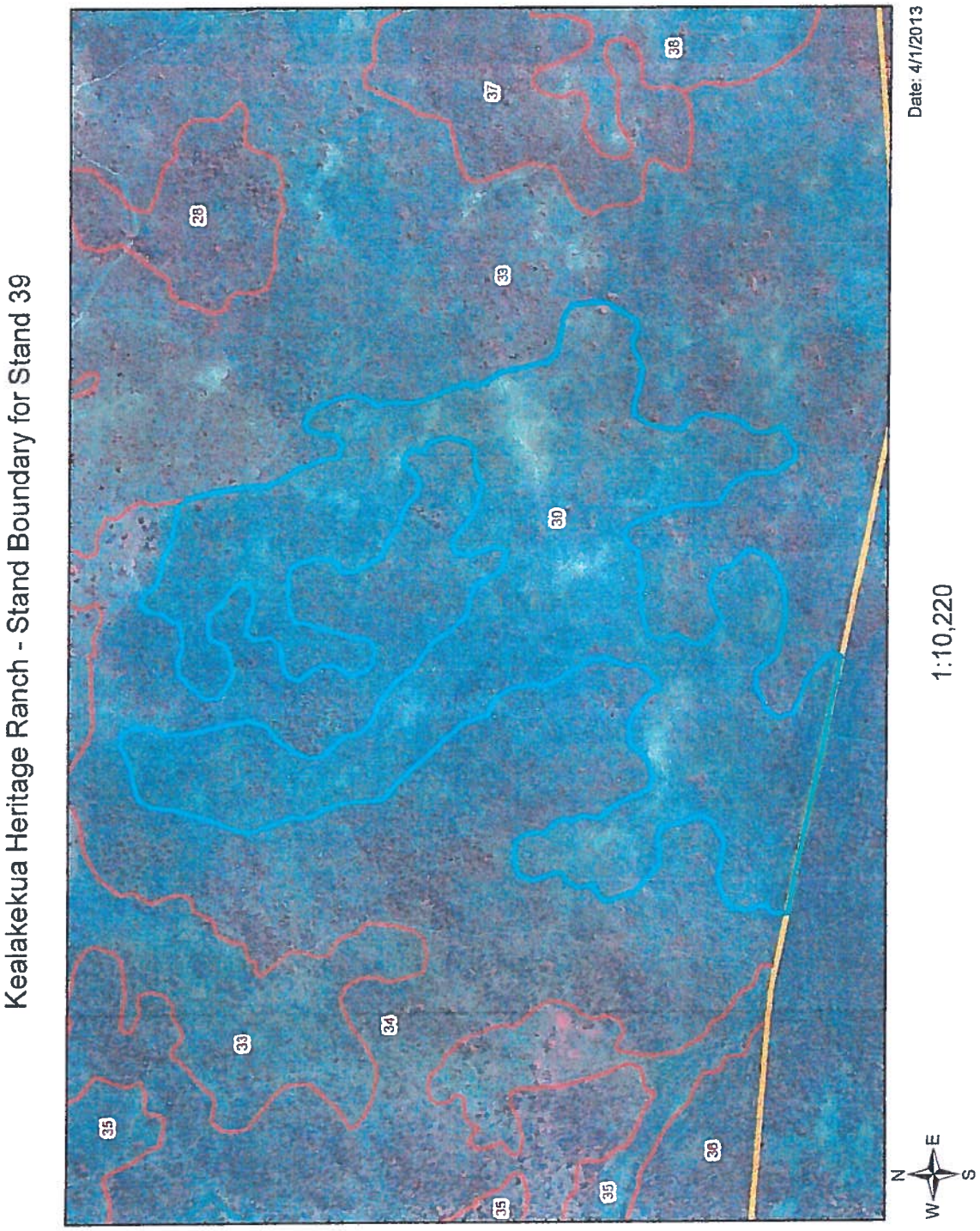


Photo 38 - Stand 38

Photo 39 - Stand 39

Map 36 – Stand 39



Map 37 – Stand 40

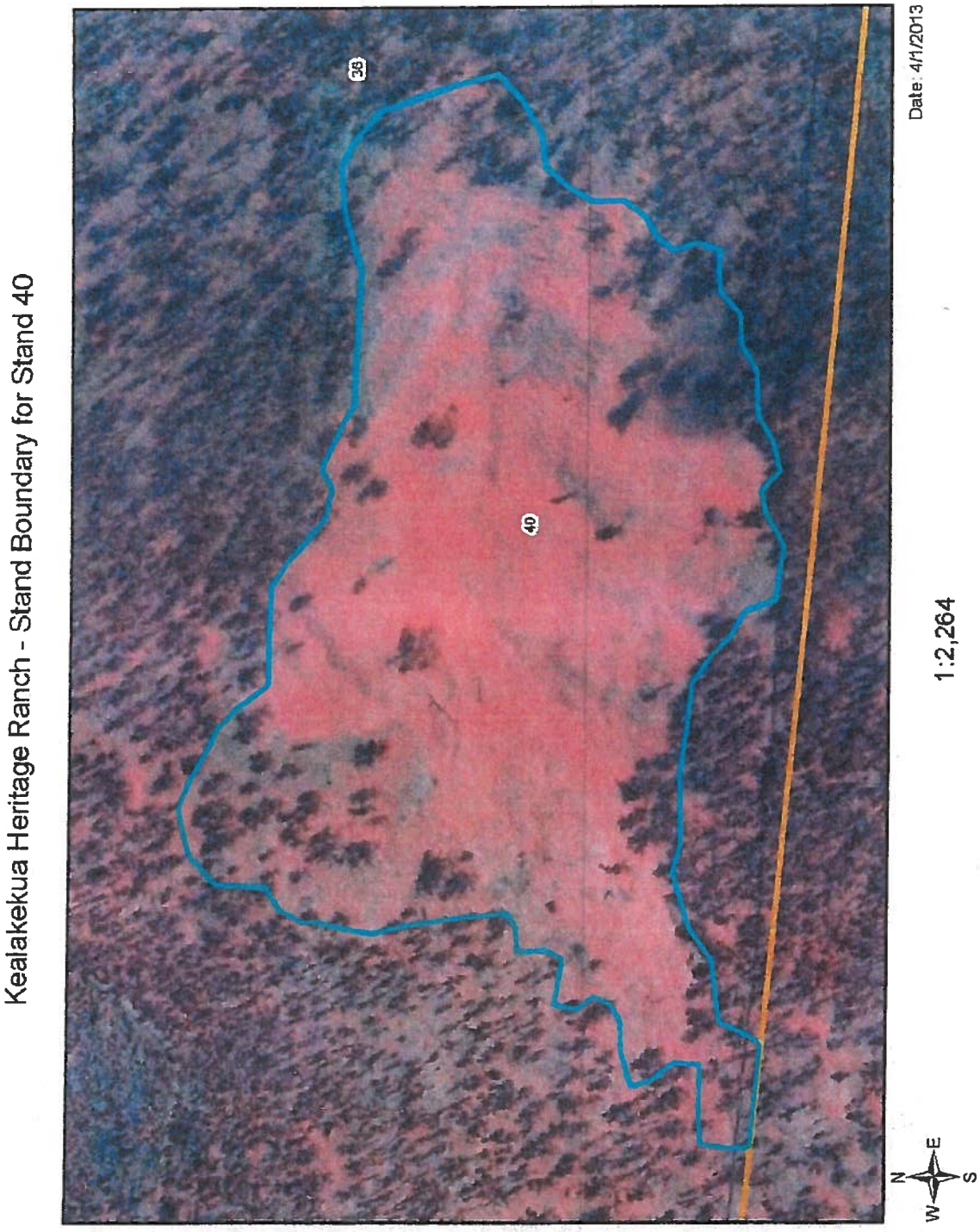
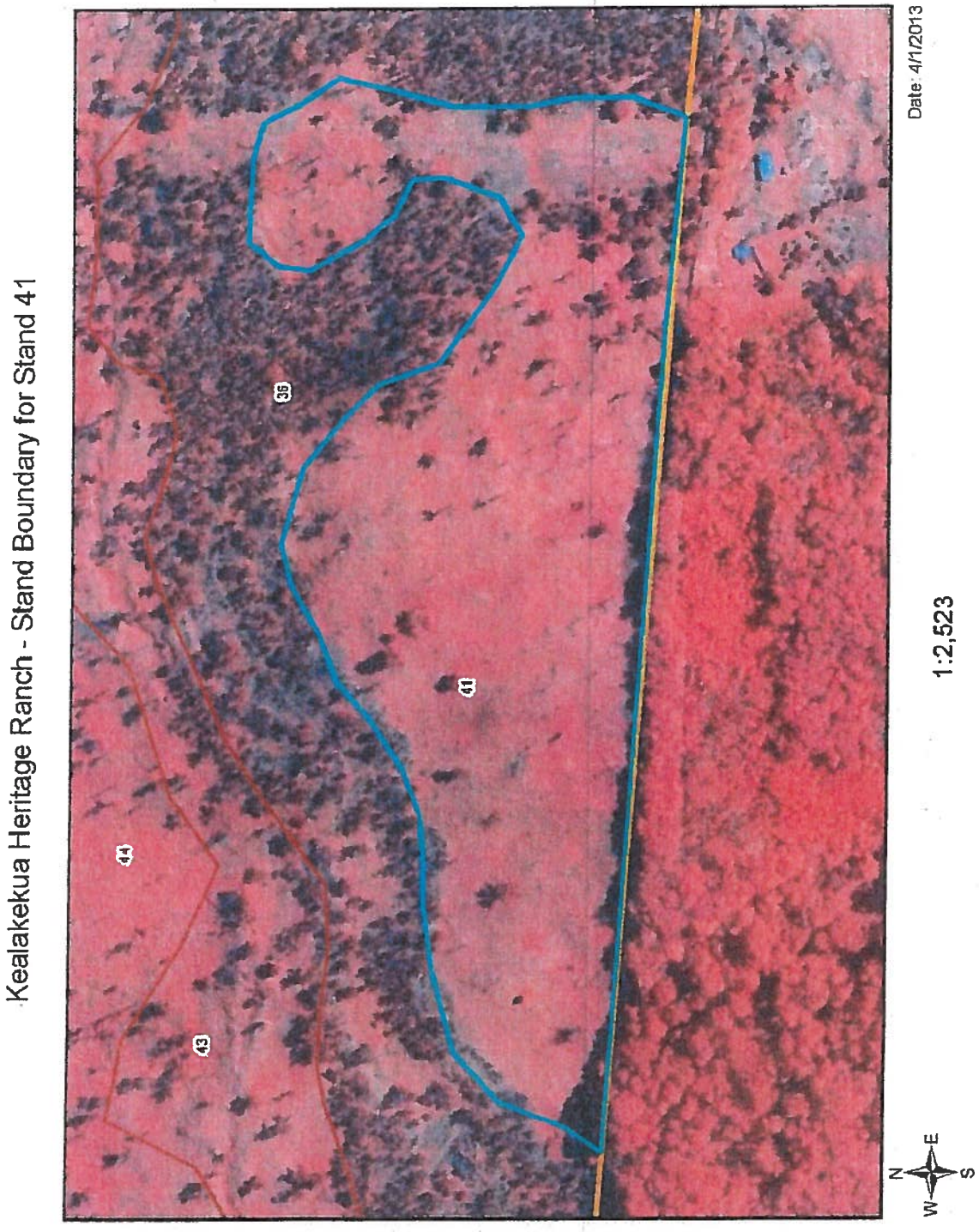


Photo 40 - Stand 40

Photo 41 - Stand 41

Map 38 – Stand 41



Map 39 – Stand 42

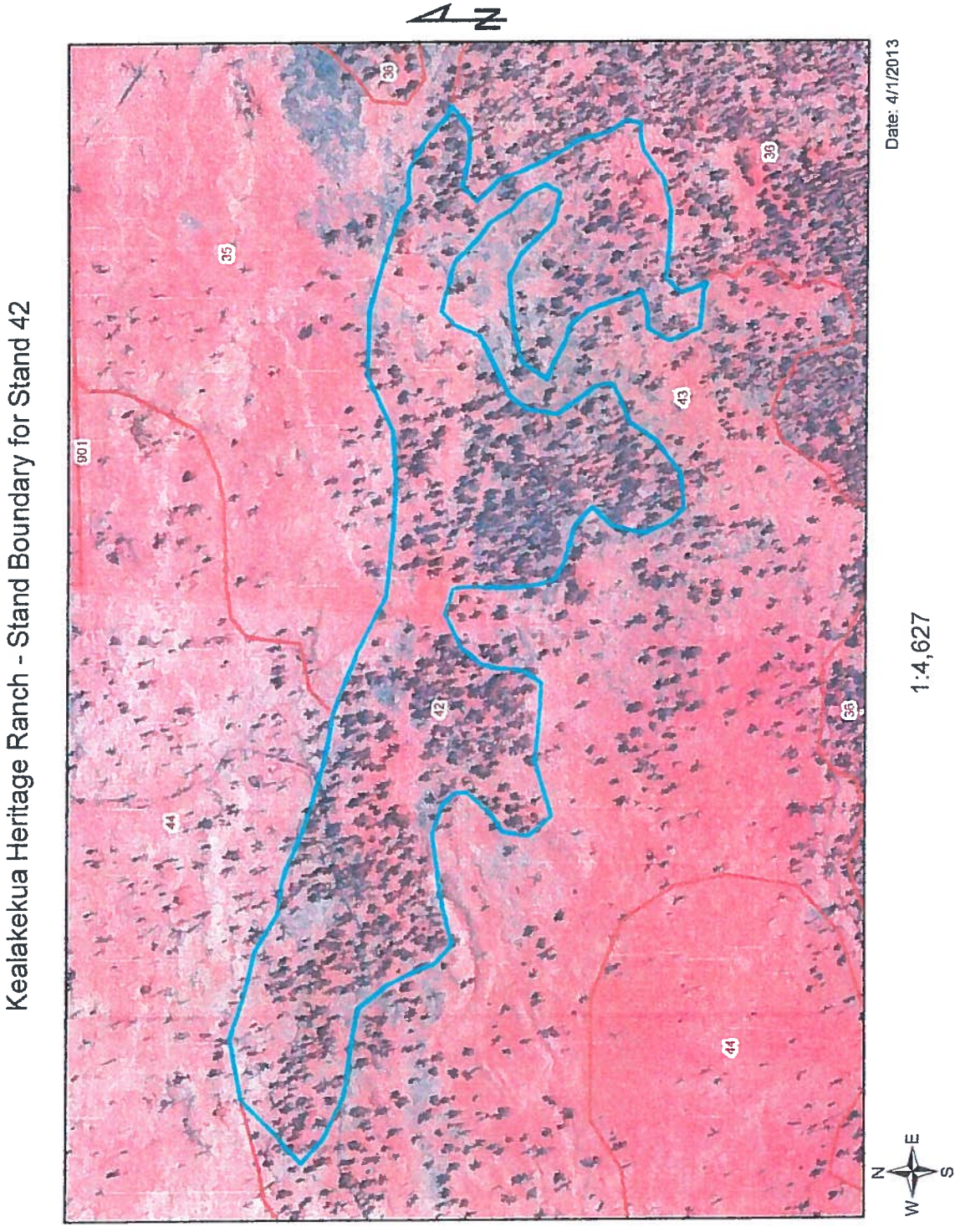
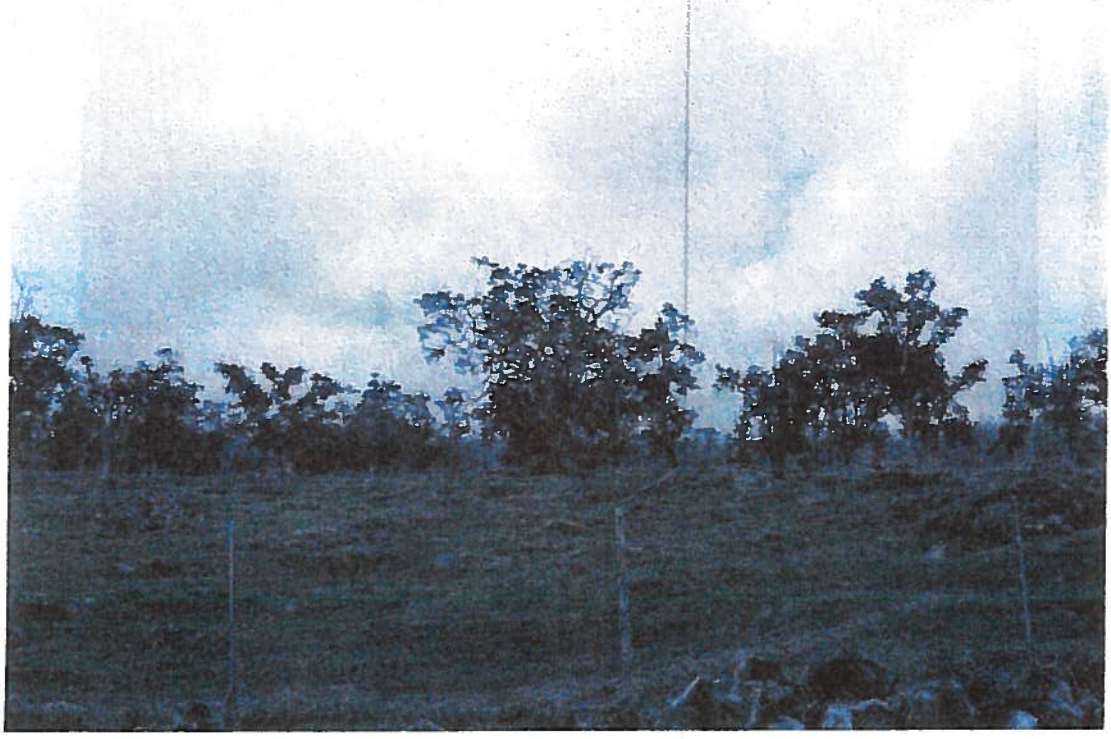
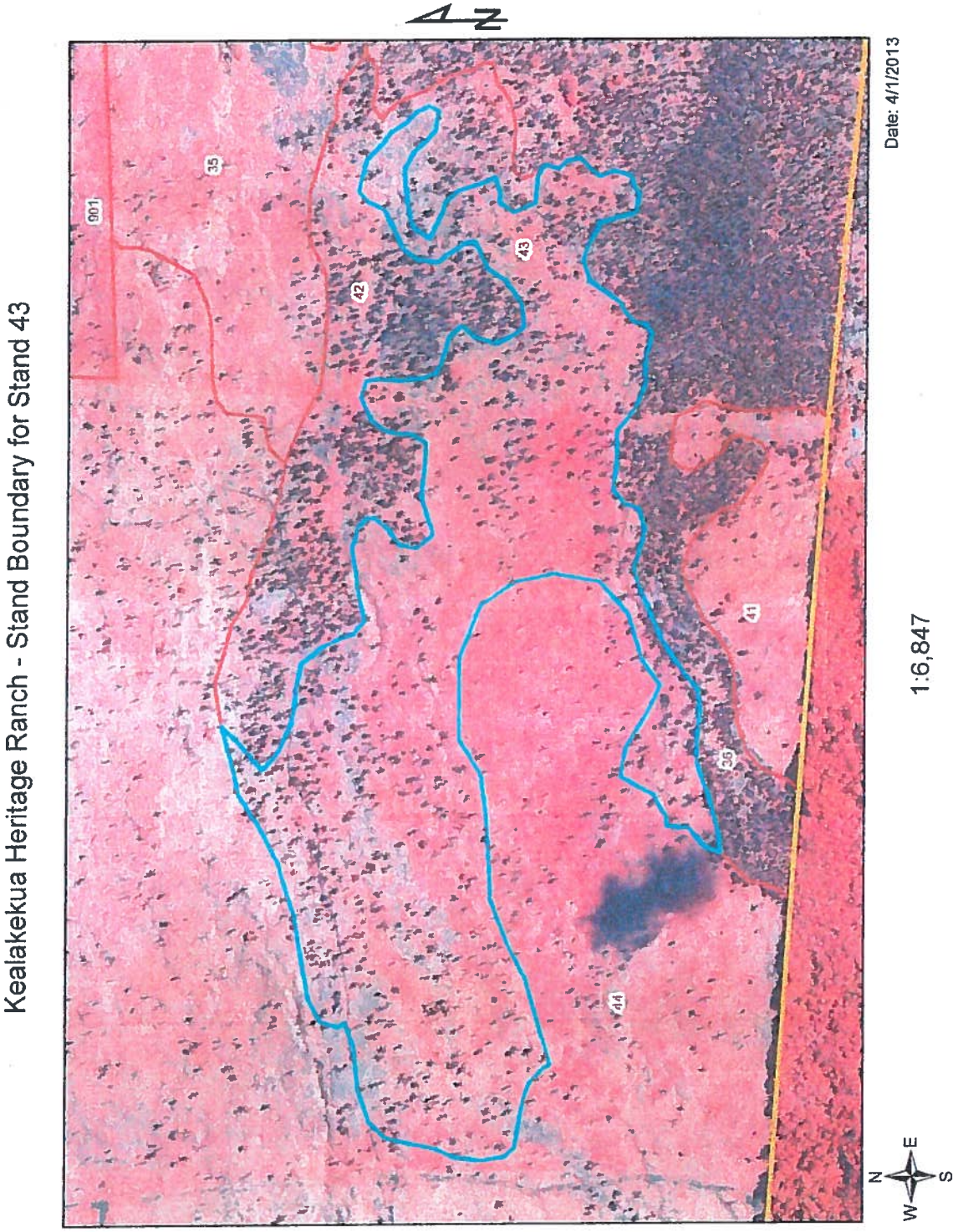


Photo 42 - Stand 42

Photo 43 - Stand 43



Map 40 – Stand 43



Map 41 – Stand 44

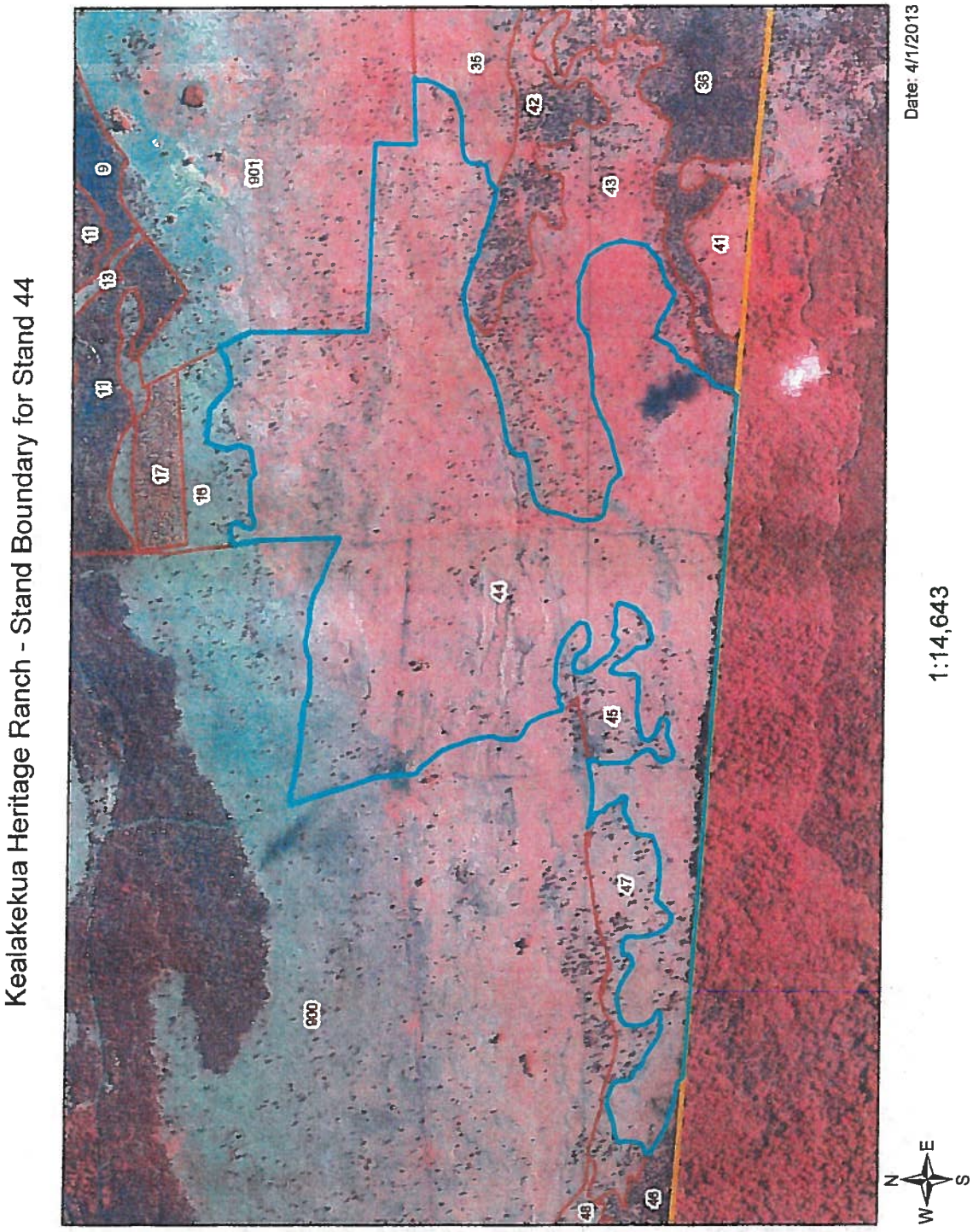
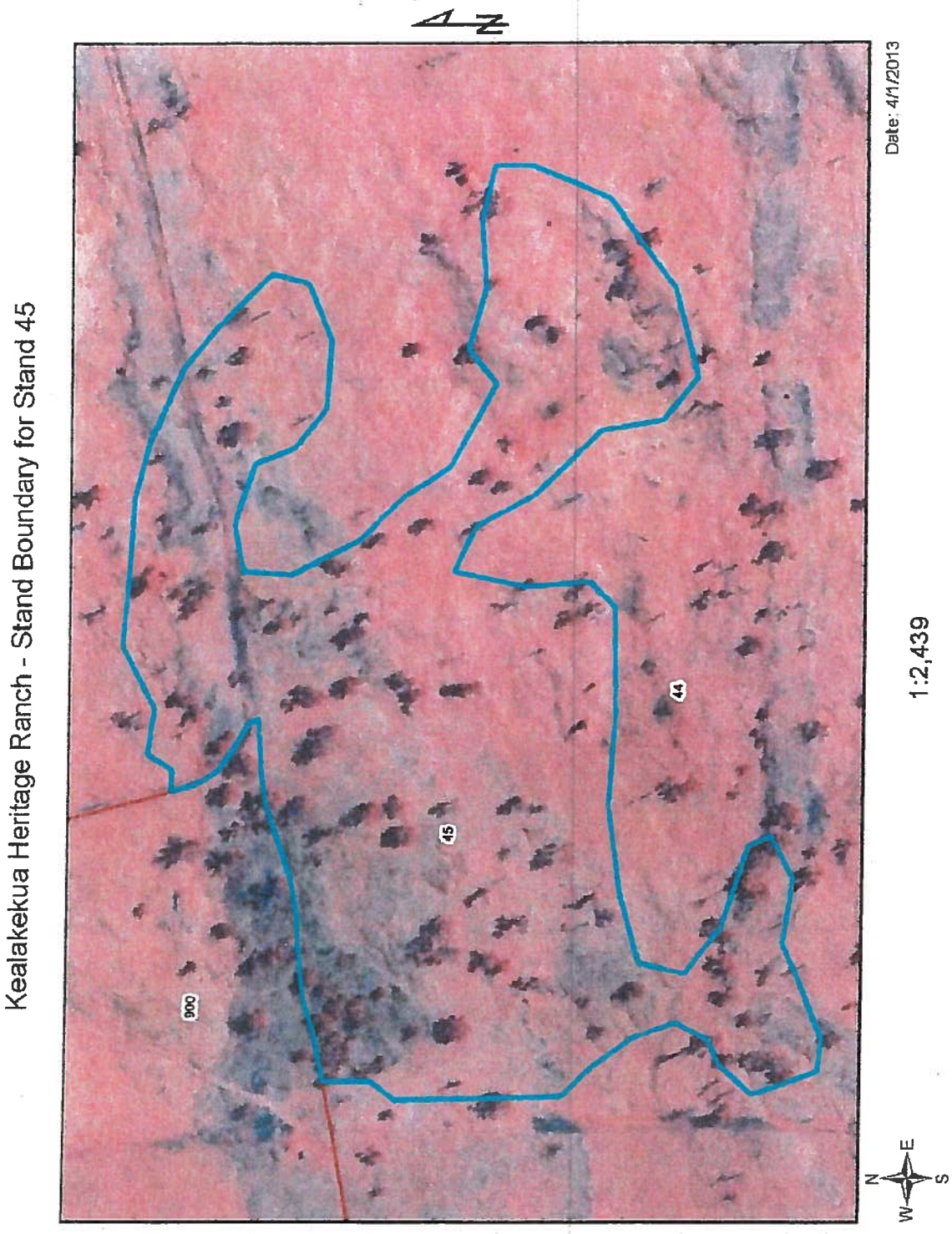


Photo 44 - Stand 44

Photo 45 - Stand 45

Map 42 – Stand 45



Map 43 – Stand 46

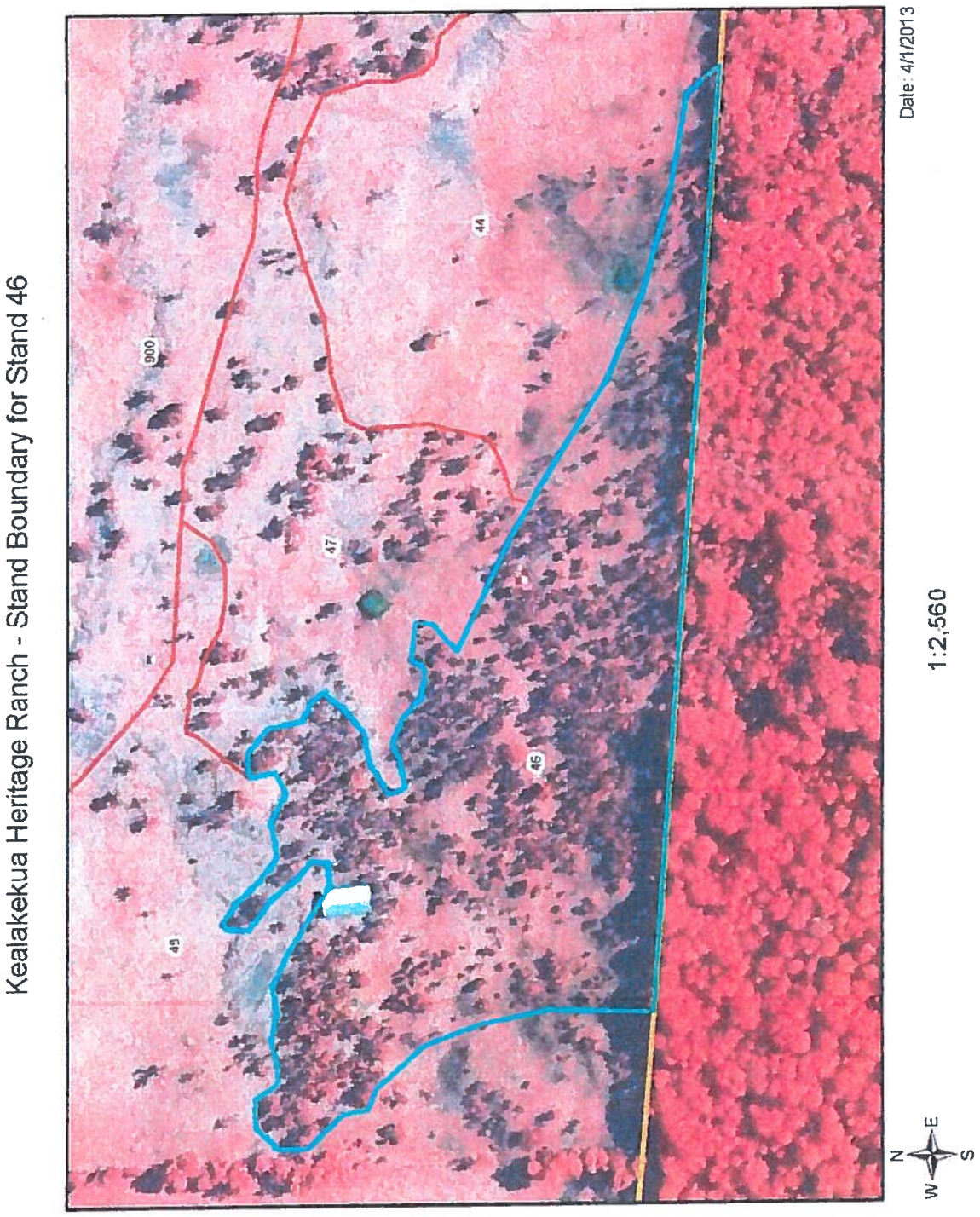


Photo 46 - Stand 46

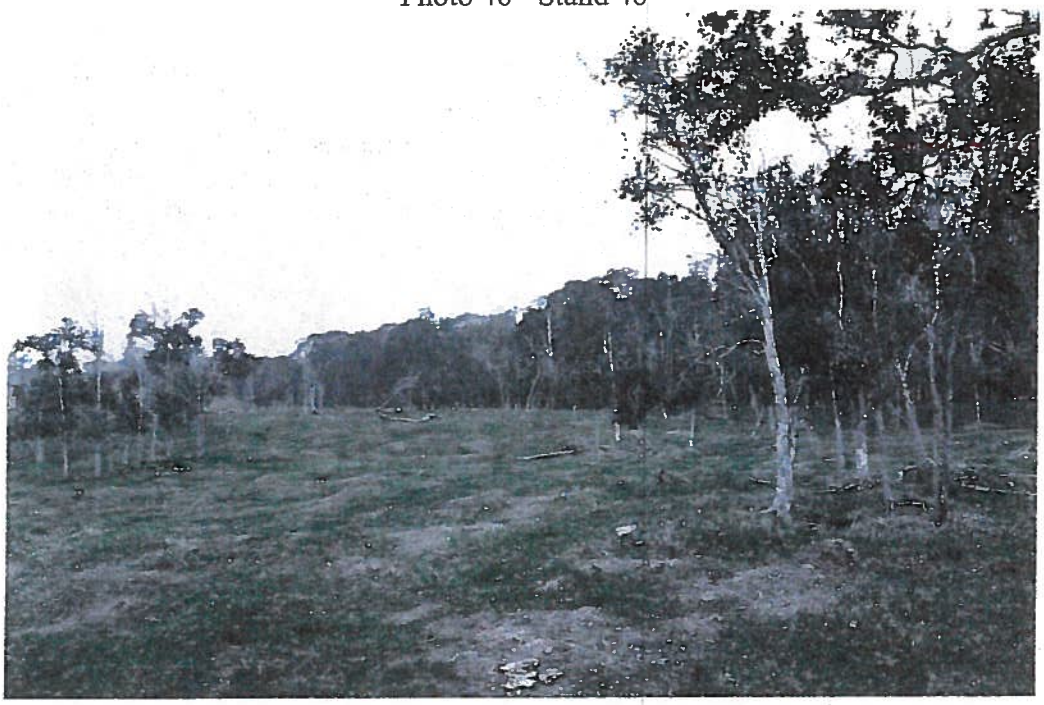
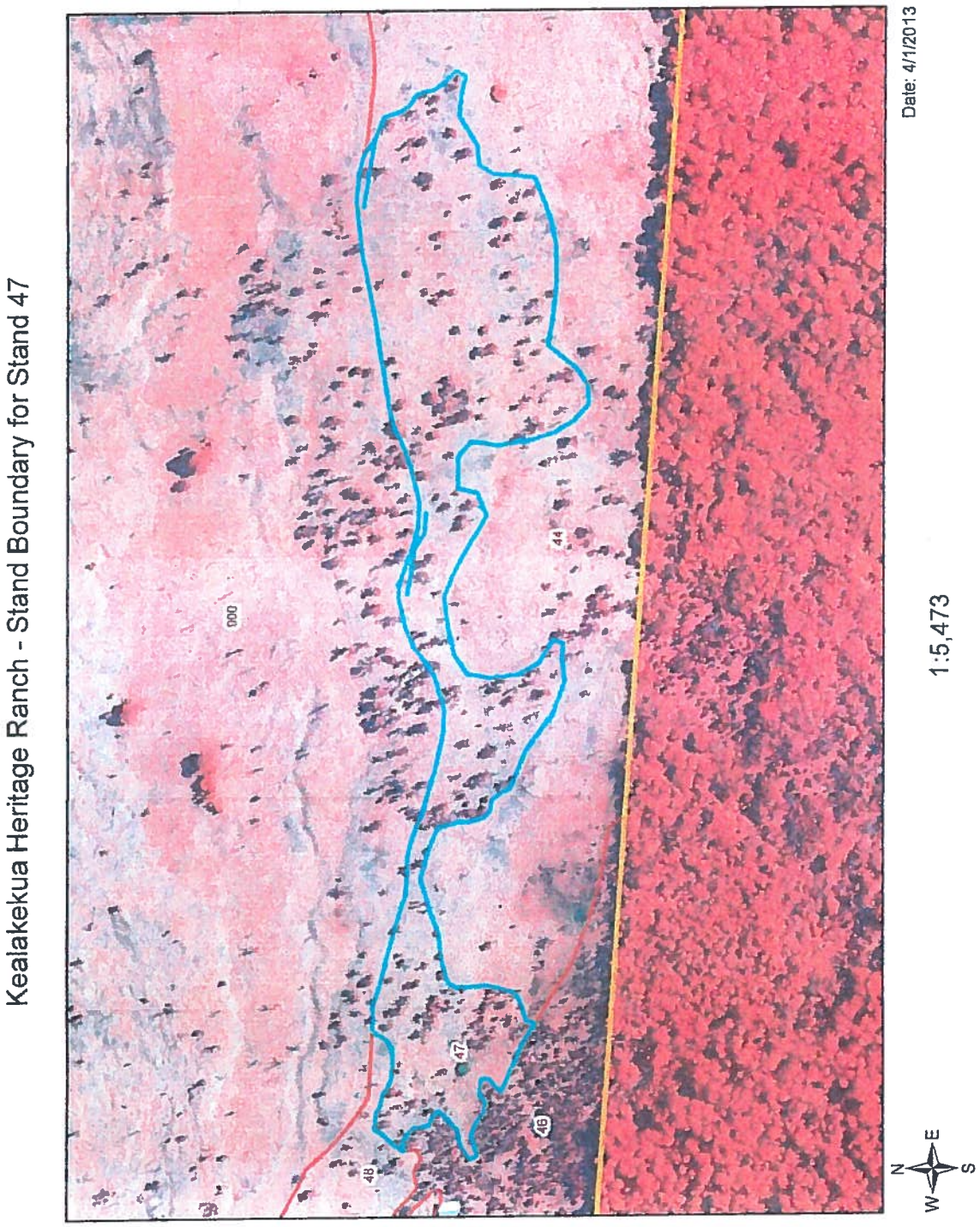


Photo 47 - Stand 47

Map 44 – Stand 47



Map 45 – Stand 48

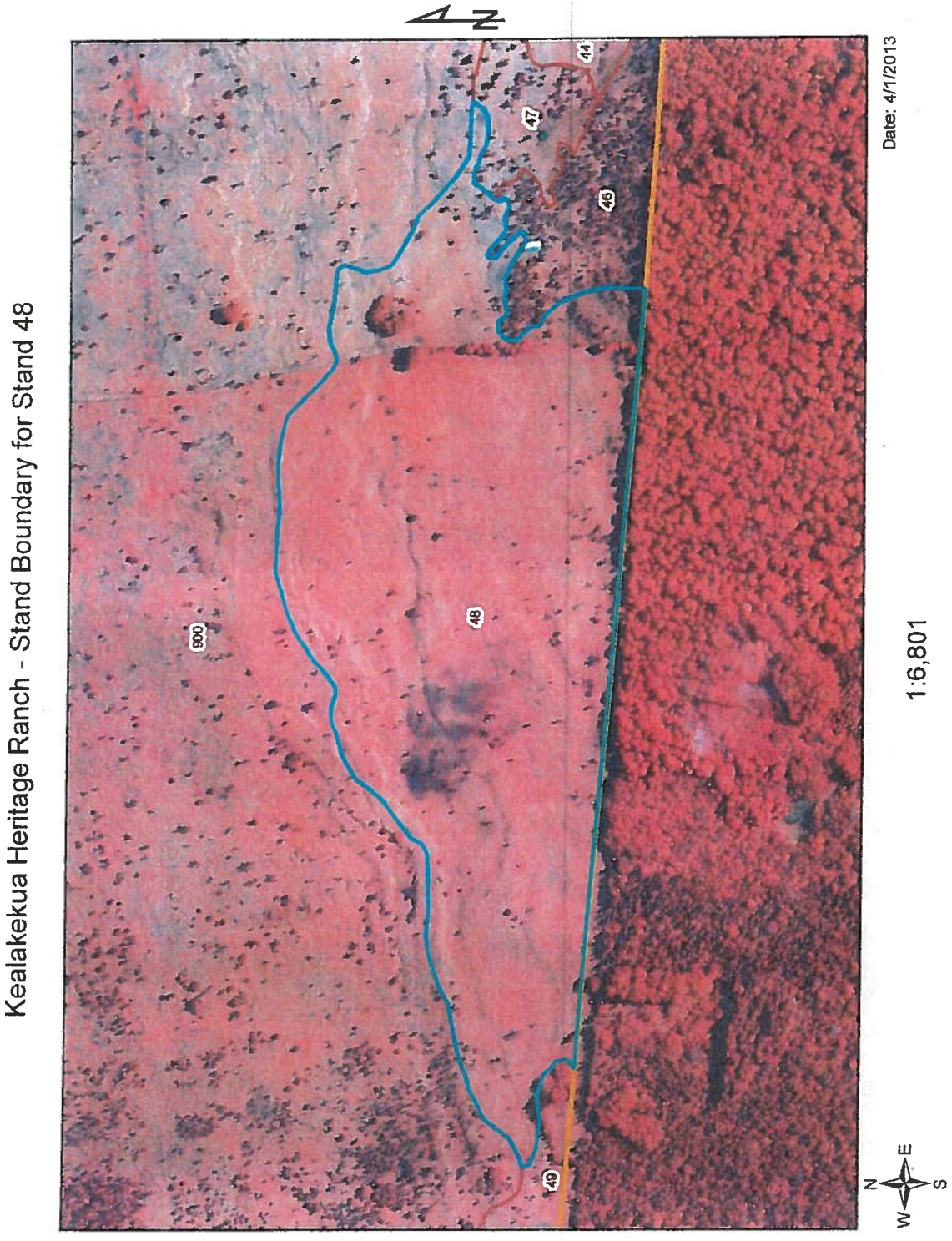


Photo 48 - Stand 48

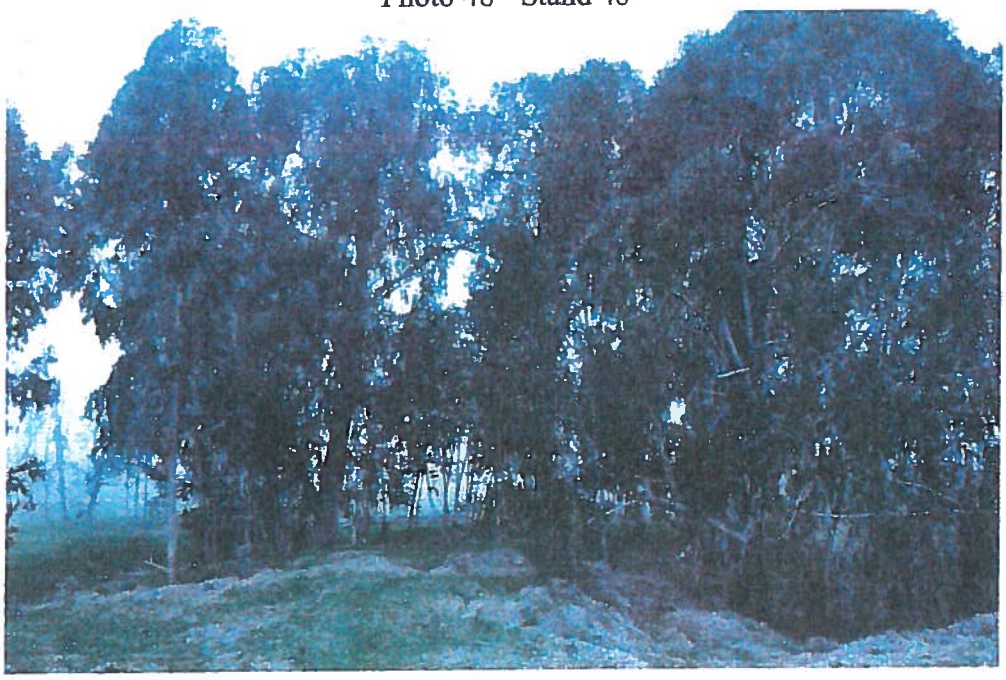
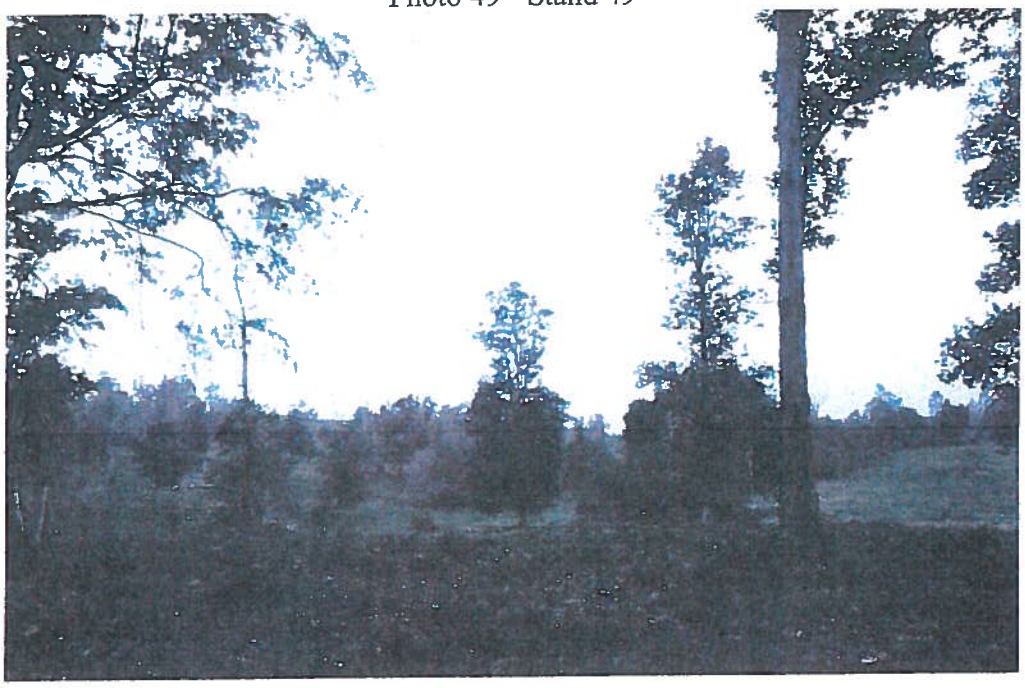
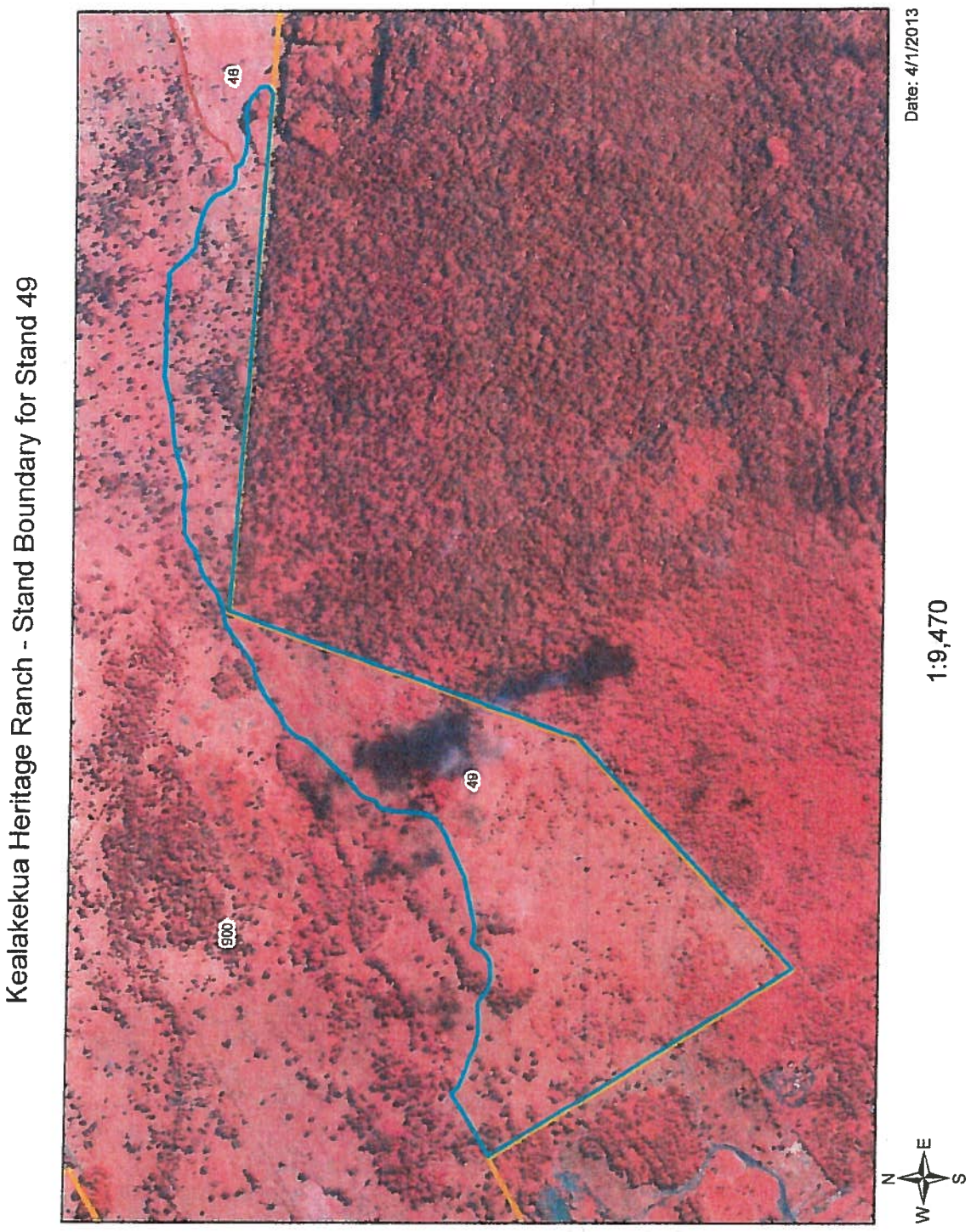


Photo 49 - Stand 49



Map 46 – Stand 49



Appendix II- Stand Volumes

following nine pages are a summary report showing per acre and total values by individual timber stand. The abbreviations that appear in the summary report are described in Table 4 – Abbreviations and Definitions below.

Table 4 – Abbreviations and Definitions

Abbreviation	Description
Sp	Species
Veg_Lbl	Vegetation Label (species, size, density)
Area	Acres in the stand
AK	Koa *(Acacia koa)*
MP	ʻŌhiʻa *(Metrosideros polymorpha)*
TC	Australian Cedar
HX	Sandalwood
CVTS	Cubic volume total stem
GrsBF	Gross Board Feet (per acre)
GrossMBF	Gross Board Feet (x1000)
NetBF	Net Board Feet (per acre)
NetMBF	Net Board Feet (x1000)

Stand, Species - Summary Report

Kealakekua Heritage Ranch

Net of Buffers Acreage

Stand	Veg_Lbl	Area			Per Acre				Total Stand	
			Sp	Dbh	Stems	CVTS	GrsBF	NetBF	GrossMbf	NetMbf
1	MP31	114.7								
			AK	9.4	67	675	2,602	1,693	298,445	194,246
			MP	18.1	48	2,211	11,188	4,884	1,283,295	560,252
				13.7	**115**	**2,886**	**13,790**	**6,578**	**1,581,741**	**754,498**
2	AK21	26.8								
			AK	7.7	218	1,271	3,384	2,285	90,832	61,328
			MP	16.6	16	613	2,753	1,376	73,875	36,938
				8.6	**235**	**1,884**	**6,137**	**3,661**	**164,707**	**98,265**
3	AK21	35.4								
			AK	7.7	218	1,271	3,384	2,285	119,728	80,838
			MP	16.6	16	613	2,753	1,376	97,377	48,688
				8.6	**235**	**1,884**	**6,137**	**3,661**	**217,105**	**129,526**
4	AK21	6.4								
			AK	7.5	191	922	2,638	1,847	17,008	11,906
			TC	2.9	338	176	0	0	0	0
				5.0	**529**	**1,098**	**2,638**	**1,847**	**17,008**	**11,906**
5	AK31	35.8								
			AK	17.2	19	675	2,916	1,700	104,312	60,803
			MP	10.9	24	266	884	442	31,634	15,817
				14.0	**43**	**941**	**3,800**	**2,142**	**135,947**	**76,620**
6	MP21	47.8								
			AK	8.1	118	732	2,841	1,594	135,808	76,196
			MP	9.5	116	1,195	5,138	2,501	245,623	119,565
				8.8	**235**	**1,927**	**7,979**	**4,095**	**381,431**	**195,762**
7	AK31	112.6								
			AK	17.2	19	675	2,916	1,700	328,336	191,384
			MP	10.9	24	266	884	442	99,573	49,787
				14.0	**43**	**941**	**3,800**	**2,142**	**427,909**	**241,171**

Stand, Species - Summary Report

Kealakekua Heritage Ranch

Net of Buffers Acreage

Stand	Veg_Lbl	Area	Sp	Dbh	Per Acre Stems	CVTS	GrsBF	NetBF	Total Stand GrossMbf	NetMbf
8	AK31	39.9								
			AK	14.6	44	997	4,024	2,596	160,497	103,537
			MP	20.2	5	252	1,192	596	47,538	23,769
				15.2	**49**	**1,249**	**5,215**	**3,192**	**208,034**	**127,306**
9	MP21	581.8								
			AK	9.5	73	669	2,444	1,373	1,421,920	798,690
			MP	12.8	45	806	3,292	1,417	1,915,452	824,218
				10.9	**119**	**1,475**	**5,736**	**2,789**	**3,337,373**	**1,622,908**
10	AK32	238.1								
			AK	11.8	220	3,161	12,747	8,151	3,036,047	1,940,723
				11.8	**220**	**3,161**	**12,747**	**8,151**	**3,036,047**	**1,940,723**
11	MP31	327.7								
			AK	9.9	67	656	2,349	1,305	769,677	427,622
			MP	14.2	35	751	3,043	1,306	997,134	428,052
				11.6	**102**	**1,407**	**5,392**	**2,611**	**1,766,811**	**855,675**
14	AK21	30.8								
			AK	7.5	191	922	2,638	1,847	81,210	56,847
			TC	2.9	338	176	0	0	0	0
				5.0	**529**	**1,098**	**2,638**	**1,847**	**81,210**	**56,847**
15	MP40	70.3								
			AK	16.1	2	57	230	161	16,170	11,319
			MP	17.8	3	107	450	225	31,638	15,819
				17.2	**5**	**164**	**680**	**386**	**47,808**	**27,138**
16	MP40	34.1								
			AK	16.1	0	11	46	32	1,567	1,097
			MP	17.8	1	21	90	45	3,066	1,533
				17.2	**1**	**33**	**136**	**77**	**4,633**	**2,630**

Stand, Species - Summary Report

Kealakekua Heritage Ranch

Net of Buffers Acreage

Stand	Veg_Lbl	Area	Sp	Dbh	Per Acre				Total Stand	
					Stems	CVTS	GrsBF	NetBF	GrossMbf	NetMbf
17	AK21	17.7								
			AK	6.5	128	336	362	231	6,423	4,095
				6.5	**128**	**336**	**362**	**231**	**6,423**	**4,095**
18	MP21	31.2								
			AK	9.5	73	669	2,444	1,375	76,251	42,830
			MP	12.8	45	806	3,292	1,417	102,717	44,199
				10.9	**119**	**1,475**	**5,736**	**2,789**	**178,968**	**87,029**
21	MP31	93.5								
			AK	13.3	10	200	766	537	71,702	50,191
			MP	14.9	37	851	3,114	1,419	291,281	132,740
				14.5	**48**	**1,051**	**3,880**	**1,956**	**362,983**	**182,931**
22	AK50	145.3								
			AK	22.7	3	169	760	400	110,407	58,109
			MP	25.3	2	186	1,020	510	148,178	74,089
				23.8	**5**	**355**	**1,780**	**910**	**258,585**	**132,198**
23	MP30	282.2								
			MP	14.0	0	6	21	10	5,927	2,681
				14.0	**0**	**6**	**21**	**10**	**5,927**	**2,681**
25	MP30	335.1								
			AK	11.0	5	59	224	124	74,902	41,609
			MP	13.9	4	70	260	113	87,153	37,755
				12.3	**8**	**130**	**484**	**237**	**162,055**	**79,364**
26	MP30	54.9								
			AK	11.0	3	32	121	67	6,666	3,703
			MP	13.9	2	41	151	66	8,284	3,599
				12.3	**5**	**73**	**272**	**133**	**14,950**	**7,302**

Stand, Species - Summary Report

Kealakekua Heritage Ranch

Net of Buffers Acreage

Stand	Veg_Lbl	Area			Per Acre				Total Stand	
			Sp	Dbh	Stems	CVTS	GrsBF	NetBF	GrossMbf	NetMbf
27	MP30	46.0								
			AK	11.0	5	59	224	124	10,273	5,707
			MP	13.9	4	70	260	113	11,953	5,178
				12.3	8	130	484	237	22,225	10,884
28	AK60	390.9								
			AK	28.4	1	51	230	49	89,913	19,155
			HX	16.0	0	1	4	3	1,368	1,231
			MP	26.6	1	43	172	80	67,239	31,352
				27.1	1	95	406	132	158,521	51,739
29	AK60	342.9								
			AK	28.4	1	51	230	49	78,876	16,804
			HX	16.0	0	1	4	3	1,200	1,080
			MP	26.6	1	43	172	80	58,986	27,504
				27.1	1	95	406	132	139,062	45,388
32	AK60	72.4								
			AK	28.4	1	51	230	49	16,658	3,549
			HX	16.0	0	1	4	3	253	228
			MP	26.6	1	43	172	80	12,457	5,809
				27.1	1	95	406	132	29,369	9,586
33	AK60	1,511.1								
			AK	28.8	1	57	246	93	371,741	140,536
			HX	16.0	0	1	4	4	6,347	5,712
			MP	24.9	1	43	174	81	262,939	122,705
				26.6	1	101	424	178	641,026	268,953
34	AK60	480.3								
			AK	28.7	1	56	238	82	114,116	39,148
			MP	25.2	1	43	174	81	83,374	38,901
				27.0	1	99	411	163	197,490	78,050

Stand, Species - Summary Report

Kealakekua Heritage Ranch

Net of Buffers Acreage

Stand	Veg_Lbl	Area	Sp	Dbh	Per Acre				Total Stand	
					Stems	CVTS	GrsBF	NetBF	GrossMbf	NetMbf
35	MP30	727.1								
			MP	14.0	0	6	21	10	15,269	6,907
				14.0	**0**	**6**	**21**	**10**	**15,269**	**6,907**
36	AK60	366.4								
			AK	28.7	1	56	238	81	87,045	29,853
			HX	16.0	0	1	4	4	1,486	1,338
			MP	25.2	1	43	174	81	63,602	29,676
				26.7	**1**	**100**	**415**	**166**	**152,133**	**60,866**
37	AK60	446.5								
			AK	28.7	1	56	238	81	106,070	36,378
			HX	16.0	0	1	4	4	1,811	1,630
			MP	25.2	1	43	174	81	77,503	36,162
				26.7	**1**	**100**	**415**	**166**	**185,383**	**74,169**
38	AK60	93.1								
			AK	28.4	1	51	230	49	21,410	4,561
			HX	16.0	0	1	4	3	326	293
			MP	26.6	1	43	172	80	16,011	7,465
				27.1	**1**	**95**	**406**	**132**	**37,746**	**12,320**
39	AK60	213.4								
			AK	28.7	1	56	238	81	50,689	17,384
			HX	16.0	0	1	4	4	865	779
			MP	25.2	1	43	174	81	37,037	17,281
				26.7	**1**	**100**	**415**	**166**	**88,591**	**35,444**
40	AK60	20.1								
			AK	28.4	1	51	230	49	4,620	984
			HX	16.0	0	1	4	3	70	63
			MP	26.6	1	43	172	80	3,455	1,611
				27.1	**1**	**95**	**406**	**132**	**8,145**	**2,658**

Stand, Species - Summary Report

Kealakekua Heritage Ranch

Net of Buffers Acreage

Stand	Veg_Lbl	Area	Sp	Dbh	Per Acre				Total Stand	
					Stems	CVTS	GrsBF	NetBF	GrossMbf	NetMbf
41	MP40	22.9								
			AK	16.1	0	11	46	32	1,054	738
			MP	17.8	1	21	90	45	2,063	1,031
				17.2	1	33	136	77	3,117	1,770
42	MP40	43.5								
			AK	27.0	1	38	165	116	7,181	5,026
			HX	16.0	0	1	4	3	152	137
			MP	17.6	8	306	1,310	570	57,010	24,806
				18.3	9	345	1,479	689	64,343	29,969
43	AK50	107.4								
			AK	22.2	2	87	410	221	44,030	23,733
			HX	16.0	0	1	4	3	376	338
			MP	21.0	1	59	280	140	30,070	15,035
				21.6	3	147	694	364	74,476	39,107
44	MP40	498.0								
			AK	16.1	0	11	46	32	22,908	16,036
			MP	17.8	1	21	90	45	44,821	22,410
				17.2	1	33	136	77	67,729	38,446
45	MP40	20.4								
			HX	16.0	0	1	4	3	71	64
			MP	18.1	4	142	645	315	13,157	6,425
				18.0	4	143	649	318	13,228	6,490
46	MP40	16.5								
			MP	16.6	3	99	435	210	7,160	3,456
				16.6	3	99	435	210	7,160	3,456
47	MP40	35.9								
			MP	17.5	3	123	551	268	19,753	9,608
				17.5	3	123	551	268	19,753	9,608

Stand, Species - Summary Report

Kealakekua Heritage Ranch

Net of Buffers Acreage

Stand	Veg_Lbl	Area	Sp	Dbh	Per Acre				Total Stand	
					Stems	CVTS	GrsBF	NetBF	GrossMbf	NetMbf
Sum:		8,117							14,321,419	7,422,383

Appendix III- Yield Modeling

The Forest Projection and Planning System (FPS) *provides a full range of tools for managing a working forest using a forest stand-based relational database actively linked to a forest-wide GIS mapping system. These tools include cruise compilation, valuation, growth projections and long-term planning under optional silvicultural influences from planting, ingrowth, site preparation, thinning, pruning, fertilization and genetics. The forest planning routines provide options for spatially-constrained harvest scheduling due to wildlife nests, watershed buffers and green-up delays from previously assigned neighboring harvest units.*

The Forest Biometrics Research Institute (FBRI) *provides the only fully certified library of regional species quantitative parameters for site capacity, taper and volume determination, growth and mortality rates, and biomass and carbon sequestration rates and capacities. The Hawai'i species libraries were developed in 1999 and updated in 2010. The volume and growth parameters in the FPS Regional Species Libraries are FBRI-certified as the best available databases and research analyses in each region.*

Key features of FPS are listed below by major function:

Forest Inventory:

Stand-based inventory database with active GIS linkages
Sorted-list systematic stand cruise selection tools
Within-stand cruise designs for fixed and variable-radius sampling
Cruise designs for sub-sampled attributes such as height, crown, defect, etc.
Un-biased methods for sampling stand edges
Capacity to compute degree of clumpiness within stands from standard measurements
Automated GIS tools for adjusting road and riparian buffer acre reductions
Built-in year-end tools for harvest depletion updates and reporting
Ability to re-merchandize to any log dimension by species and/or stand
Built-in tools to extrapolate sampled stands to un-sampled stands within a stratum
Tree volume, biomass and valuation localized within and across species ranges
Built-in tools for 3-dimensional tree output by stand of species, size and spatial pattern
Built-in reports by log, tree, stand and forest for volume, value, biomass and carbon

Forest Growth:

1. Individual-tree, distant-dependent growth & yield model for all stand structures
2. Ability to grow individual stands or whole forests from one to hundreds of years
3. Incorporated growth and mortality dynamics for natural, planted, and/or thinned stands
4. Growth dynamics sensitive to stand structure and clumpiness for even or all-aged stands
5. Growth dynamics localized across active ranges of individual tree species
6. Automated tools for classifying habitat as affected by topography, climate and soils
7. Built-in tools for measuring and classifying local site productivity
8. Periodic evaluation and verification of all volume, growth and mortality parameters
9. Only growth model calibrated for natural ingrowth of both tree and non-tree species
10. Only growth model designed and calibrated for genetic variation within species

Forest Planning:

- *Individual stand harvest scheduling for up to thirty-five periods of any length (years)*
- *Ability to evaluate multiple treatment regimes per stand in a single pass over all stands*
- *Built-in capability to optimize the forest goals while seeking the best options per stand*
- *Number of stands and number of regimes are only limited by the size of the database*
- *Alternative goals may be volume, value, biomass or discounted economics over all years*
- *Silvicultural activities may be constrained spatially by proximity to wildlife nest sites*
- *Silvicultural activities may be constrained spatially by neighbor green-up regulations*
- *Only forest-wide model to solve spatial and non-spatial constraints in one pass*
- *Ability to display and interact directly with a GIS database for visual applications*
- *Built-in tools to pre-assign harvests, silvicultural treatments and landscape set-asides*
- *Ability to evaluate selection, seed-tree, shelterwood and/or clearcut regimes in one pass*

Group selection will be the silvicultural system for harvesting. The size of the irregularly shaped openings will vary but likely be between 2 to 5 acres. The intention is to provide sufficient sunlight in the scarified opening for good koa regeneration while minimizing damage to residual trees adjacent to the openings. Regeneration is expected to be dense therefore thinning will be scheduled before there is a loss of vigor (probably between ages 5 and 10). The timing of harvests and/or scarification efforts will be scheduled to take advantage of the rainy season to maximize survival of regeneration.

The first two page report below shows the annual harvests for each 5 year planning period. The mean annual harvest over the 100 year planning period averages 607 MBF. The second two page report shows the residual inventory for each 5 year period. The volume on the property increases significantly under this scenario and shows the potential of the property if managed for timber production.

The potential to increase the overall health and the levels of stocking across the property is significant. Additionally, the opportunity to move the species composition toward what was historically present exists by supplementing natural regeneration with plantings. The modeling conducted in the development of this plan shows that it will take a long time to achieve these desired results, but that significant progress can be made by implementing this management plan.

Harvest Removal Board Foot Summary by Period

Kealakekua Heritage Ranch

Periodic harvest covering 12,402 acres (with re-entries)

Mid Year	# Std /Yr	Averages / Year Age Yrs	Size Ac	Qdbh	Basal /Ac	Trees /Ac	BdFt /Ac	Acres /Year	Totals per year x 1,000s Srt#1 NetMbf	Srt#2 NetMbf	Srt#3 NetMbf	Total NetMbf
2013	0	4	238	11.4	186	262	9,389	48	283	63	101	447
2018	0	9	582	7.1	105	379	4,871	116	257	224	86	567
2023	0	14	328	6.2	118	563	6,577	66	218	129	84	431
2028	0	19	115	8.2	159	432	11,724	23	89	94	86	269
2033	1	20	338	1.9	13	658	585	405	30	51	156	237
2038	1	28	41	5.6	83	482	5,790	41	119	93	25	237
2043	1	28	158	3.1	25	483	1,501	158	58	75	105	238
2048	1	38	37	6.6	108	454	8,031	29	88	77	72	237
2053	1	41	54	6.5	67	289	5,490	44	97	80	62	239
2058	1	44	123	4.1	36	394	2,403	99	83	80	74	237
2063	1	45	291	3.6	23	325	1,443	175	97	41	114	252
2068	0	48	254	7.3	31	105	2,364	101	119	39	82	240
2073	0	56	432	3.6	22	315	1,436	173	145	23	80	248
2078	0	65	238	10.2	125	218	9,236	48	440	0	0	440
2083	0	65	582	10.2	125	218	9,236	116	1,075	0	0	1,075
2088	0	65	328	10.2	125	218	9,236	66	605	0	0	605
2093	0	60	421	2.6	30	806	2,282	168	374	4	6	384
2098	1	65	338	10.2	125	218	9,546	405	3,869	0	0	3,869
2103	1	65	41	10.2	125	218	9,236	41	378	0	0	378
2108	1	65	158	10.2	125	218	9,486	158	1,502	0	0	1,502

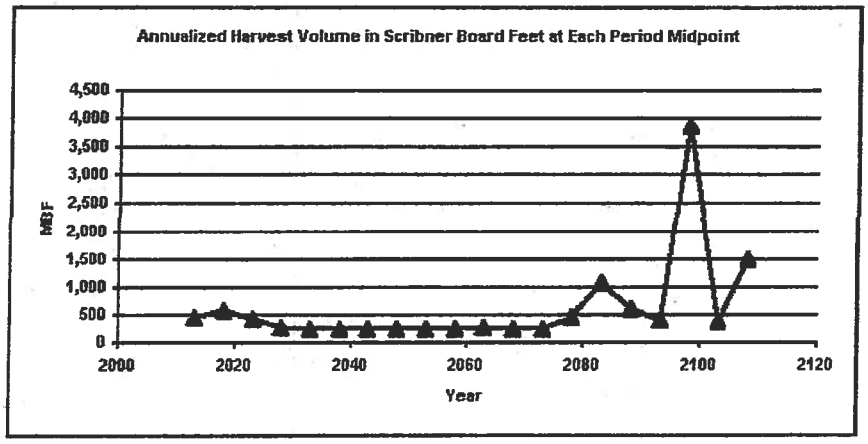
Forest Biometrics

Harvest Removal Board Foot Summary by Period

Kealakekua Heritage Ranch

Periodic harvest covering 24,804 acres (with re-entries)

Mid Year	# Std /Yr	Averages / Year Age Yrs	Size Ac	Qdbh	Basal /Ac	Trees /Ac	BdFt /Ac	Acres /Year	Totals per year x 1,000s Srt#1 NetMbf	Srt#2 NetMbf	Srt#3 NetMbf	Total NetMbf
								Mean Annual Harvest:	496	54	57	607
								Total Harvests:	49,636	5,372	5,655	60,663



Forest Biometrics Research Institute

Residual Volume Board Foot Summary by Period

Kealakekua Heritage Ranch

Mid Year	# Std /Yr	Averages Age Yrs	Size Ac	Qdbh	Basal /Ac	Trees /Ac	BdFt /Ac	Acres /Year	Totals per year x 1,000s Srt#1 NetMbf	Srt#2 NetMbf	Srt#3 NetMbf	Total NetMbf
2013	40	2	203	2.8	20	449	811	8,117	2,722	2,328	1,532	6,582
2018	40	7	203	3.7	17	219	781	8,117	2,576	1,975	1,788	6,340
2023	40	11	203	2.0	15	722	749	8,117	1,924	1,909	2,245	6,079
2028	40	15	203	3.5	16	234	731	8,117	1,876	1,875	2,185	5,936
2033	40	15	203	2.6	16	428	699	8,117	1,954	2,045	1,674	5,674
2038	40	18	203	2.0	20	883	647	8,117	1,489	1,767	1,999	5,255
2043	40	20	203	3.3	23	373	580	8,117	1,387	1,522	1,797	4,705
2048	40	24	203	2.9	28	615	569	8,117	1,760	1,191	1,670	4,621
2053	40	28	203	4.1	33	363	730	8,117	3,582	835	1,512	5,928
2058	40	29	203	3.9	39	465	946	8,117	5,963	489	1,223	7,675
2063	40	29	203	5.0	45	337	1,095	8,117	7,794	357	735	8,886
2068	40	31	203	5.1	51	357	1,822	8,117	14,264	142	383	14,789
2073	40	30	203	6.0	57	297	2,564	8,117	20,771	19	20	20,811
2078	40	32	203	5.2	62	416	2,895	8,117	23,459	21	20	23,500
2083	40	33	203	5.9	62	320	2,885	8,117	23,373	25	21	23,419
2088	40	35	203	6.2	65	316	2,817	8,117	22,819	28	22	22,869
2093	40	34	203	6.8	71	284	3,574	8,117	29,010	0	0	29,010
2098	40	22	203	5.6	49	290	1,778	8,117	14,429	0	0	14,429
2103	40	26	203	4.7	55	457	2,295	8,117	18,627	0	0	18,627
2108	40	24	203	5.7	52	291	1,963	8,117	15,931	0	0	15,931

Residual Volume Board Foot Summary by Period

Kealakekua Heritage Ranch

Mid Year	# Std /Yr	Averages Age Yrs	Size Ac	Qdbh	Basal /Ac	Trees /Ac	BdFt /Ac	Acres /Year	Totals per year x 1,000s Srt#1 NetMbf	Srt#2 NetMbf	Srt#3 NetMbf	Total NetMbf