Forest Management Plan for the
Waiākea Timber Management Area

Revised June 2015

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State of Hawai‘i

Department of Land and Natural Resources

Division of Forestry and Wildlife

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Hawai'i District certification: This plan was prepared by a team of Division of Forestry and Wildlife (DOFAW) staff to provide a management framework for the Forest Reserves listed. The plan was developed in consultation with other governmental agencies, community, and environmental organizations.

Steven T. Bergfeld - Hawai'i District Branch Manager — Date: 4/21/16

DOFAW Administrator's approval: I have reviewed the enclosed Forest Management Plan and concur with the recommendations herein. I agree that resource management implementation will follow those specified in the Management Plan for the Forest Reserves listed.

David G. Smith - Administrator — Date: 4/15/16

Department of Land and Natural Resources Board approval: This plan meets the criteria established for State Forest Reserve Management Plans as mandated by Chapter 183, Section 16.5, Hawai'i Revised Statues.

Suzanne D. Case - Chairperson — Date: 4/18/16

I. INTRODUCTION

The Division of Forestry and Wildlife proposes to harvest timber from the Waiākea Timber Management Area (WTMA) to meet the goals stated in Section V of this document. After Board of Land and Natural Resources approval of the WTMA plan and the accompanying Environmental Assessment, the following actions will be taken:

1. A Request for Proposals (RFP) will be issued under the authority of Chapter 103D, HRS
2. A Land License will be issued to the selected project(s).

The 2004 survey "Economic Value of Hawaii's Forest Industry in 2001" revealed that over 900 workers were employed in Hawai'i forest industry, with a corresponding payroll of $30.7 million (Yanagida et al. 2004). This is an increase in forestry jobs from the 1991 report in which the forest industry in Hawai'i contributed $29 million and 736 jobs to our economy. This places the average wage rate for forest industry employees at over 50 percent higher than the average for farm labor (Robinson 2007). Additionally, the retail value of Hawaii-grown forest products was $23.9 million, distributed among all the main islands; 75 percent of which were sales of koa (Friday et al 2006). Sustainable commercial forest management can bring economic stability; enhance the environment, while retaining the rural character of the islands. The island of Hawai'i is the best location in the State to stimulate local forest industry as it has high unemployment, thousands of acres of vacant and/or under-utilized high quality forest land, and an existing commercial forest resource base that can support a range of value added forest processing options.

An aggressive yet attainable integrated forest industry initiative of 60,000 acres of forest plantations on the island of Hawai'i could support sustainable long-term direct employment of nearly 500 people. This does not take into account indirect benefits such an industry would have on the local economy. The forest growing and harvesting program would employ over 200 people, with peaks of over 300 in the early establishment years. The processing sector would provide additional long term employment of 235 people. Using a multiplier factor of 2.2 for each direct job, the creation of 1,000 jobs is a realistic possibility. A large number of skilled workers will be required to staff these plants, including engineers, computer operators, marketing personnel and accountants.

Based on current Hamakua Coast logging operations and U.S. West Coast estimates, about 15 to 20 new jobs for harvest operations, transportation, and replanting could be created by implementation of this Forest Management Plan, and perhaps twice that many indirect and manufacturing jobs could be created or retained. As the local wood products industry develops and faster growing plantations become established, additional jobs could be created. Currently there are estimated to be approximately 50 people on Hawaii Island that are full time timber or wood product employees.

Although the economics of forestry has been variable, the State can provide a strategic role by guiding public timber assets into local processing facilities that will optimize jobs for the local community, provide for local energy needs, as well as contribute to carbon sequestration. The Waiākea Timber Management Area, which contains substantial timber resources on the island of Hawai'i, will influence how the forest industry develops and help define the role of public forest assets in overall commercial forestry development throughout the State.

II. DIVISION OF FORESTRY & WILDLIFE

The Division of Forestry and Wildlife (DOFAW) is one of the Divisions of the Department of Land and Natural Resources. DOFAW is the largest land management entity in the State and has direct responsibility for over 900,000 acres of State-owned trust lands. These lands are managed through an integrated system of forest and natural area reserves, wildlife sanctuaries, and wilderness and game management areas. Within this system lie the vast majority of America's tropical rainforests and the world's most unique and threatened biodiversity. Ecosystems managed by DOFAW include subalpine communities, mesic forests, montane and lowland rainforests, tropical dry forests and woodlands, coastal strand forests, and introduced forest plantations. On the Island of Hawai'i, DOFAW currently has the direct management responsibility for over 700,000 acres of which approximately 440,000 acres are within the forest reserve system. Of the over 440,000 acres, under five percent or 18,441 acres could be managed for timber harvesting.

Principal responsibilities for DOFAW statewide include watershed protection, forest product development, nursery seedling production, native and endangered species protection, wildland fire suppression, public trails and access, and game management programs. A variety of landowner assistance programs that focus on conservation, restoration and/or forest products are also available through DOFAW to non-industrial private forest landowners.

III. PURPOSE OF THE FOREST MANAGEMENT PLAN

The Waiākea Timber Management Area (WTMA), as revised, is designed to meet the requirements of Chapter 183, Hawai'i Revised Statues regarding timber harvesting on State lands. DOFAW's vision for the WTMA is to provide a model for developing and utilizing timber management areas throughout the State that will sustainably supporting the growth of the forest industry in Hawai'i.

> **"Environmentally sustainable, economically profitable, accommodating the needs of the people of Hawai'i, fitting within a landscape of forest watersheds and healthy native ecosystems."**

The WTMA has several important public uses in addition to timber resources, including recreation, gathering, hunting, habitat for native biodiversity and watershed protection. Developed with the most currently available data, the WTMA plan will ensure that all of these uses are considered and that Best Management Practices (Appendix A) will be employed to mitigate any potential negative impacts from commercial forestry activities. Plan revisions will be conducted as necessary to reflect environmental and cultural changes as well as technical advancements.

The WTMA plan, approved September 1998, included open dialogue and input from the community and interest groups resulting in a mutually agreeable plan for the management of the WTMA. The plan is intended to guide the growing forest industry of Hawai'i and fit within the broader management context of native forest protection. Input and assistance from special interest groups and local communities were solicited and community field trips were held so interested parties can see the WTMA first hand. The revised Forest Management Plan incorporates new information and data, and management decisions consider the previously provided community input. The plan is the basis for an environmental assessment (EA) developed under Chapter 343, HRS. Both the WTMA plan and EA will be used as the basis for soliciting additional community and public input on the use of WTMA. The State of Hawai'i intends to engage the private sector in the sale of timber and other wood fiber resources in WTMA through traditional timber licenses in order to develop a sustainable local wood products industry, and at the same time, maintain native forest ecosystems, preserve hunting and established recreational uses, and accommodate existing traditional gathering practices.

IV. THE WAIĀKEA TIMBER MANAGEMENT AREA

A. Purpose and history: The original purpose of the WTMA was to establish a forest resource base that could provide a consistent wood and forest products supply for the forest product industry in Hawai‘i. From 1956-1960, the Waiākea Arboretum was used to test adaptability and growth potential of 84 introduced timber species to be planted within the WTMA. Major planting efforts began in 1959 and continued through 1968. Approximately 330 acres of land, formerly leased to the Puna Sugar Company, was also planted in the early 1980's. Some WTMA plantation units were weeded or fertilized in the early years, but the majorities were allowed to grow without any timber stand improvement (TSI) activity. From 2001 to 2011, the majority of acres within the WTMA were under timber land license agreements; however, due to a myriad of start-up problems there has been very little timber harvest or further developed in WTMA. To date, there is approximately 1,000 acres of WTMA under a timber land license, which is set to expire within the next one to five years.

B. Location: The WTMA is located on the slopes of Mauna Loa volcano, approximately five miles southwest of Hilo town along the Stainback Highway and within the South Hilo and Puna Districts. Portions of the Waiākea (WFR), Upper Waiākea (UWFR), and ‘Ōla‘a Forest Reserves (OFR) comprise the approximately 12,500 acre WTMA unit (Figure 1). The WTMA represents less than three percent of the forest reserve acreage managed by DOFAW on the Island of Hawai‘i. Approximately 330 acres of former Puna Sugar lands (TMK 2-4-08-22) are currently included at the east end of WTMA. The land was added to the Waiākea Forest Reserve in September 2009 in Executive Order 4296.

Table1. Government Tax Map Key (TMK) parcels currently comprising public lands of Waiākea Timber Management Area

TMK Number	Owner	Tax Acres (entire TMK)	GIS Acres (entire TMK)	GIS WTMA Acres
318012001	State of Hawai‘i	5292.760	5089.990	2775.939
324008001	State of Hawai‘i	62855.855	61933.945	8325.493
324008006	State of Hawai‘i	150.000	150.930	29.579
324008010	State of Hawai‘i	259.679	261.277	261.277
324008022	State of Hawai‘i	1159.881	1095.597	1095.597
			TOTAL	12487.885

C. Physical site data: Waiākea Timber Management Area currently occupies lands in the ahupua‘a of Waiākea and ‘Ōla‘a (See Figure 1), extending from 400 to 3,200 feet in elevation. Median annual rainfall in the WTMA varies with elevation, exceeding 200 inches annually at 400 feet elevation, and gradually decreasing to 150 inches at 3,200 feet elevation. Mean annual temperature at 1,800 foot elevation is approximately 79 °F (See Figure 2). The WTMA is situated on relatively young, shallow ‘a‘ā and pāhoehoe lava flows ranging from 150 to 9,000 years old. Soils overlay lava substrata and are composed primarily of thin ash layers with high to extreme leaching conditions. Swampy conditions are found in some areas due to impermeable substrata. Slopes within the WTMA are very constant, averaging six percent.

D. Existing vegetation: During initial land clearing operations in WTMA, many large native trees such as ‘ōhi‘a lehua *(Metrosideros polymorpha),* koa *(Acacia koa),* and loulu *(Pritchardia spp.)* were left undisturbed. Today, these plants are intermixed with non-native timber species. Primary understory species include hāpu‘u *(Cibotium spp.)* and scattered native understory shrub species and non-native, invasive plants. The heavy equipment used to clear and level land also created rocky areas where a portion of the soil was removed and re-deposited in some of the many depressions in the area. Approximately 480 acres of native forest that was not bulldozed remain in the WTMA. These areas are classified as native ‘ōhi‘a and ‘ōhi‘a-hāpu‘u wet forest, or koa /‘ōhi‘a wet forest. These vegetation types have scattered to closed canopies (up to 75 feet tall in places) and contain a variety of native and non-native tree and shrub species. The invasive species densities in the low

elevation native forest are similar to those of other native forests in area. Inventory data summarizes the acreage breakdown based on dominant overstory tree species (Appendix B and Figure 3).

The historical plantation establishment in the 1960s and 1970's, cleared the majority of native forest remnants in the WTMA and impacted the native plants that once were found in the WTMA. Rare and uncommon plant species historically and presently found in the WTMA area include:

- *Cyanea platyphylla*. Endangered (Present in Upper Waiakea FR adjacent to the WTMA, last observed in 2012).
- *Cyrtandra giffardii*. Endangered (Present in the WTMA, last observed in 2012).
- *Sicyos alba.* Endangered (Present in Puu Makaala NAR adjacent to WTMA, observed 2011).
- *Cyanea tritomantha*. Candidate for Listing as Endangered (Present in Puu Makaala NAR and Upper Waiakea FR adjacent to the WTMA, last observed in 2012).
- Na`u or Nanu (*Gardenia remyi*). Candidate for Listing as Endangered (Present in the WTMA, Last observed 2010).
- ʻohe (*Joinvillea ascendens ssp. ascendens*). Candidate for Listing as Endangered (present in Puu Makaala NAR adjacent to the WTMA, last observed in 2010).
- *Phyllostegia floribunda*. Candidate for Listing as Endangered (Present in Upper Waiakea FR adjacent to the WTMA, last observed in 2012).
- *Phyllostegia vestita*. Species of Concern (Present in Upper Waiakea FR adjacent to the WTMA, last observed in 2012).
- *Stenogyne scrophularioides*. Species of Concern (Present in Upper Waiakea FR adjacent to the WTMA, last observed in 2012).
- *Trematolobelia grandifolia*. Species of Concern (Present in Upper Waiakea FR adjacent to the WTMA, last observed in 1998).

E. Existing wildlife: The WTMA supports several species of game and non-game wildlife (Appendix C). Feral pigs are the most common and actively managed big game species found in the area. Pig hunting is allowed year-round; however, the use of dogs is restricted between Tree Planting Road and Powerline Road between January and June. Hawaiʻi Wildlife Branch has constructed a series of gates and berms across certain roadways to improve game management and redirect hunter access throughout the WTMA.

Kalij pheasants are the most plentiful game bird inhabiting the WTMA. Other game bird species are present, but are usually restricted to forest edges or along roadways and lava flows. Game bird hunting is open on weekends and holidays from the first Saturday of November through the third Sunday in January. Game bird populations are managed primarily by opening and closing hunting season and by setting bag limits.

Native birds are the primary form of native wildlife found in the WTMA. Common endemic species inhabiting the forest are ʻamakihi (*Hemignathus virens*), ʻapapane, (*Himatione sanguinea*),ʻiʻiwi (*Vestiaria coccinea*), ʻōmaʻo (*Myadestes obscurus*), ʻelepaio, (*Chamsiempis sandwichensis*) and pueo (*Asio flammeus*). These birds are most frequently observed above 3,000 feet elevation, which is the upper extreme of the WTMA. In recent years, no threatened or endangered birds, except the Hawaiian hawk or ʻio (*Buteo solitaries*), have been observed in the WTMA. However, other rare species have been known to occur in native forests adjacent to the WTMA. These include the ʻōʻū (*Psittirostra psittacea*), ʻakiapolaʻau (*Hemignathus munroi*), and Hawaiʻi ʻākepa (*Loxops coccineus*). It is unlikely that any of these rare species permanently inhabit the WTMA, as introduced timber species fail to provide the necessary habitat requirements for these rare birds. Native birds and the Hawaiian hoary bat are protected under Hawaiʻi Administrative Rules, Chapter 123, Indigenous Wildlife, Endangered and Threatened Wildlife and Introduced Wild Birds. The Federal Endangered Species Act of 1973 also applies to officially listed species.

The native bat or ʻōpeʻapeʻa (*Lasiurus cinereus semotus*) is the only endemic land mammal in Hawaiʻi. This rare mouse-like creature is a subspecies of the mainland hoary bat and is officially

listed as endangered. Hawaiian hoary bats roost solitarily in the foliage of trees. They are most active at dusk when they forage on flying insects. Bats have been seen in the WTMA and its environs, but no information on the density and distribution of these animals is available. There are no records of bats breeding in the area.

F. Cultural resources: Historically the lands of the WTMA were used for transit to other areas, collection of vegetation resources, collection of birds, and canoe making. Gathering of vegetation still continues for lei making, and other cultural activities.

G. Access: Vehicular access to the WTMA area is available via paved highways, and the area itself is well-roaded. Stainback Highway provides the primary access and is maintained by the State Department of Public Safety and the County of Hawai‘i. North Kūlani Road runs from Stainback Highway to Highway 11 near Mountain View, which can be used to access the area. Approximately 130 miles of unimproved access roads grid the WTMA tree planting area into 40 acre blocks. These roads provide access for DOFAW and the public for hunting, recreation, non-timber forest product gathering, forest protection and timber management.

H. Timber resources: From 1985 to 1988, Puna Sugar Company and the State entered into a timber harvest agreement for 2000 acres of *Eucalyptus* in WTMA; no other planted hardwoods were harvested within WTMA at this time with the exception of small-scale sales and timber salvage operations. The majority of WTMA has been under a timber land license from 2001 to present to either or both Tradewinds Forest Products, LLC and/or Hawaii Island Hardwoods, LLC. Large scale harvesting operations were never untaken by either of these parties.

Tree fern harvesting occurs with approximately 500 linear feet of logs removed and sold for use in the flower and landscape industry per year. The market for tree ferns is small and the work to remove the logs is arduous. In some areas, tree ferns have subsequently grown back vigorously in some of the planted areas.

I. Non-timber forest products: Non-timber forest products are commonly collected within the WTMA, including:

- Ferns
- Ti leaves
- Maile
- Flowers

Gathering of material from plant species that are not on Federal or State threatened and endangered species lists will be permitted and regulated by DOFAW through standard forest permit procedures. Gathering of plant materials from threatened or endangered species may be allowed if individuals have obtained special collecting permit from DLNR. Permits for gathering plant material can be obtained from the DOFAW-Hilo office at 19 E. Kāwili Street, Hilo, Hawaii 97620. Hours are Monday through Friday except State holidays from 7:45 am to 4:30 pm. These permits are free and are available for non-commercial, home use only. Approximately 750 permits are issued for the Waiākea area on an annual basis.

J. Other public uses: Although established for commercial timber management, the WTMA provides several other important public uses. The plantations and surrounding native forests are used extensively for feral pig hunting. Motorcycle and all-terrain vehicle (ATV) riders use the well-developed road network within the area. Other recreational activities include mountain biking, horseback riding, bird watching, botanical exploration and hiking.

DOFAW's Nā Ala Hele Trails and Access program manages the Upper Waiākea ATV/ Dirt Bike Park which is located within the WTMA between Flume and Tree Planting Roads. It has been in operation

since July 4, 2004, and offers 28 miles of trails that can be ridden in both directions. In order to use the park, permits and waivers must be obtained from the DOFAW office in advance.

The Mauna Kea 200 motorcycle event (MK200), held nearly every year since 1976, utilizes the area for course mileage, and the Rock Island Riders (who implement the MK200) have volunteered time to keep many of the grid roads within WTMA open and identifiable.

There are also established mountain bike trails in the lower portion of WTMA, primarily in the area below Quarry Road in the former sugar plantation lands. There are approximately 11 miles of single track and 15 miles of double track mountain bike trails that traverse through approximately 230 acres of *Eucalyptus saligna* and *E. grandis* plantation timber. In order to use these mountain bike trails, permits and waivers must be obtained from the DOFAW office in advance. Permits have been issued to mountain bike clubs that sponsor riding events.

Equestrian use is common along the Puna boundary of the forest reserve. Bird watching, botanical exploration and hiking occurs less frequently.

K. Education and research: Forests plantations in the WTMA provide excellent opportunities for individuals, organizations and institutions to study both native and introduced forest communities. In the 1960's to the 1970's, the State Department of Health conducted studies on the population dynamics of rodents in Waiākea Forest Reserve. In the 1970's, the U.S. Fish and Wildlife Service conducted native forest bird surveys on the Island of Hawai‘i and several of the survey transects extended through the WTMA. During the Vietnam war, the U.S. Army conducted several research projects in the Waiākea, Upper Waiākea and ‘Ōla‘a Forest Reserve including chemical gases, defoliants and phosphate explosives devices. The USDA Forest Service, Institute of Pacific Island Forestry, has been monitoring forestry research projects in the WTMA since the late 1950's to present day. Some of their research projects include nutrient recycling, watershed quality of various native forest plant communities, wood properties for commercial native tree species and ‘ōhi‘a decline occurrence.

There is a significant potential for field research within the WTMA especially related to introduced timber species in Hawai‘i. Growth plots may be implemented in a joint DOFAW UHH study. In addition, the University of Hawai‘i at Hilo (UHH), the Hawai‘i Community College (Forest TEAM Program) and DOFAW developed a forestry curriculum in their agriculture program. The close proximity of UHH to the WTMA has encouraged forestry students the opportunity for hands-on-training in applied forest management techniques. DOFAW faculty have used the WTMA for giving talks and demonstrating forest measurement techniques to university students in the recent past, and there are plans to conduct many more in the future.

V. MANAGEMENT GOALS FOR THE WTMA

The following nine guiding principles were used to develop this plan and will be used in the disposition of the commercial forest resources within the WTMA:

Guiding Principle # 1

The State should utilize its land and timber within the WTMA to maximize local processing where feasible, create jobs, and encourage development of *integrated processing facilities* that provide suitable outlets for the range of species and grades of wood that currently exist. The availability of plantation forest resources within the WTMA could allow for development of a variety of wood processing plants (e.g., lumber and veneer) and biomass power or biofuels facilities. This will provide *immediate employment opportunities*. It will also encourage other investors and landowners to become involved in plantation forestry at the onset, stimulating additional employment opportunities.

DOFAW should also look at current market and future demand projections, to help decide what will be the most valuable and in demand timber to replant.

Guiding Principle # 2

Effective soil erosion control practices, including harvesting methods and replanting; safe use of herbicides; and visual buffers along major transportation corridors will be required for all commercial forest operations within the WTMA as outlined in the State's *Best Management Practices* (attached as Appendix A).

Guiding Principle # 3

The State will not replant non-native invasive species with a score rating of seven or higher on the Hawaii Weed Risk Assessment within the WTMA. Further, the State will evaluate all non-native species proposed for planting in the WTMA for their potential invasiveness if they have not been evaluated through the Hawaii Weed Risk Assessment. All species currently in the WTMA have the option of being replanted.

Guiding Principle # 4

The need to *involve the public* in project planning and development is important to account for the appropriate use of the resources, especially when it affects local communities. Careful integration of timber management with *hunting, recreational and gathering activities* will aid in developing community support for growing and processing timber resources.

Guiding Principle # 5

A portion of the timber within the WTMA should be reserved to *supply local entrepreneurs and small businesses*, thus increasing community recognition regarding the economic opportunities offered by sustainable forest management. This reservation percentage will be based on the amount of local demand. The *higher value timber* within the WTMA can provide wood needed to take advantage of new forest marketing programs to stimulate the creation *of niche market for locally grown woods.* Portions of the WTMA should also be used for the development of non-timber forest products.

Guiding Principle # 6

The public forest estate in Hawai'i (11th largest in the U.S.) has *a low level of public investment* (e.g. one forester per 150,000 acres of public forest reserve on the Island of Hawai'i). This investment is not expected to increase significantly with the current fiscal situation in Hawai'i. In order to manage the WTMA sustainably, a portion of the timber proceeds should be reinvested back into the forest.

Guiding Principle # 7

Timber management and research activities in the WTMA can provide a valuable educational role in extension and training, contributing practical information to both the government and private sectors while helping create a professional forestry work force. Portions of the forest can be used as an outdoor laboratory for the forestry curriculum for various colleges within the University of Hawai'i system.

Guiding Principle # 8

There will be no timber harvesting, forest clearing, or other commercial timber operations within designated **native forest** sections of the WTMA. Special harvesting permits for the cultural gathering of native species may be granted.

VI. FOREST MANAGEMENT OPPORTUNITIES

Timber inventory data from 1997 indicated that the WTMA contains over 17,000,000 ft^3 of timber on a gross merchantable basis (Table 2). This represents enough wood to build and panel approximately 6,800 houses.

Table2. 1997 Forest inventory data summary for the WTMA [1]

Tree Species	Acreage	Cubic Feet
Queensland Maple *(Flindersia brayleyana)*	1,485	2,607,000
Eucalyptus saligna and *grandis*	3,749	9,669,000
Eucalyptus robusta	227	1,177,000
Eucalyptus deglupta and *pilularis*	54	94,000
Toon or Australian red cedar *(Toona ciliata)*	3,500	2,667,000
Tropical ash *(Fraxinus uhdei)*	2,060	1,052,000
Sugi *(Cryptomeria japonica)*	102	25,000
Nepal alder *(Alnus nepalensis)*	24	119,000
TOTALS	11,704	17,410,000

These estimates have been further refined from field observations. Some acres of toon and tropical ash have been re-categorized as native forest to reflect the poor growth of certain plots and the regeneration of native forest in those areas.

Table3. Current summary of primary timber species within WTMA

Tree species (common name)	**Scientific name**	**Likely Use; Other uses**	**Acreage in WTMA**	**Estimated volume (ft3)**	**Estimated board foot (BF)***
Sydney bluegum and grand eucalyptus	*Eucalyptus saligna & E. grandis*	Biofuel; paper production, saw timber, veneer	3,745	8,176,042	37,132,760
Swamp mahogany	*E. robusta*	Wood products; biofuel	227	1,007,433	4,816,112
Indonesian gum and Blackbutt eucalyptus	*E. deglupta & E. pilularis*	Biofuel; saw timber	54	88,711	401,217
Australian toon	*Toona ciliata*	Wood products; biofuel	3,343	2,588,887	9,504,944
Tropical ash	*Fraxinus uhdei*	Biofuel	1,577	863,971	3,324,086
Queensland maple	*Flindersia brayleyana*	Wood products;	1,536	2,539,213	10,287,031

* Scribner's BF, using modified data from the 1997 timber inventory survey.

[1] *Data represent total stem volume from one foot stump height to a four inch diameter top, and for all tree stems having a minimum diameter of eight inches at breast height.*

A. *Eucalyptus* species: Most commercial species of *Eucalyptus* are well suited to the growing conditions found in the WTMA. Rapid growth rates, high yields, and straight form of these trees make them desirable for a wide variety of processing opportunities including dimensional lumber, veneer and plywood, poles and chips. *Eucalyptus* has not spread readily into adjacent areas of native forest in the WTMA area. Current *Eucalyptus* wood resources within the WTMA range from seedlings, to stands that contain medium or "pole" sized (6-12" diameter) trees, and mature or "saw timber" sized (> 12" diameter) trees. Most *Eucalyptus* stands are in the latter two categories, indicating a great potential to begin harvesting mature stands immediately, allowing pole stands to continue growing, while simultaneously expanding the *Eucalyptus* acreage by planting additional seedling acreage.

B. Queensland maple: While initially planted on a smaller scale than the *Eucalyptus*, Queensland maple *(Flindersia brayleyana)* has proven to be well adapted to the growing conditions in the WTMA. This species produces a high quality, light colored wood that is useful for finish grade dimensional lumber, veneer and plywood. This wood represents an important resource for high quality, value added operations such as furniture or cabinet making. For these reasons, Queensland maple is considered to be a key species for intensified timber management activities within the WTMA. As with the *Eucalyptus*, a full range of stand ages and tree sizes are present, allowing for both immediate harvest opportunities, and new plantings.

C. Other species: Large areas (Figure 3) of the WTMA were originally planted with Tropical ash (*Fraxinus uhdei*) and Australian red cedar *(Toona ciliata)*. While Australian red cedar grows well only on the best quality sites, Tropical ash has proven to be poorly adapted to local site conditions. After more than 35 years of growth, most stands of these species contain only scattered pole sized trees. These areas could play an important role in future timber management by being made available to community groups or small businesses interested in managing parcels for salvage operations. After the trees are removed from the poorly stocked stands, site conversion to other high-value species can be realized. Other areas could be made available to community groups or small businesses interested in managing parcels for production of specialty timber or non-timber forest products.

VII. FOREST MANAGEMENT PRESCRIPTIONS

All field management prescriptions related to commercial timber management will be guided by Best Management Practices (BMP) policies (Appendix A). DOFAW has more than 40 years of management experience in the WTMA and recommends the following general guidelines for commercial timber management:

A. Commercial forest management:

1. Species selection: In general, species selection will depend largely on what species was harvested, growth potential for a given site, specific qualities of a species (e.g., growth rate, disease resistance, wood characteristics, ease of removal, tolerance to volcanic emissions), seedling availability, available or future markets for the specific species, and goals for that unit. Site productivity for tree growth in the WTMA can be broadly linked to lava flow type and age. Older flows are more productive sites than younger, while ʻaʻā sites are more productive then pāhoehoe. In addition, depressions in the landscape and drainage areas seem to provide the highest growth potential, due to higher accumulation of geologically recent ash deposits and perhaps soil scraped from higher ground when the area was leveled in the 1960's and 1970's. Non-native species selection will incorporate evaluation through the Hawaii Weed Risk Assessment to determine the potential invasiveness of the species as indicated by a scoring of seven or higher.

2. Site preparation: Site preparation is achieved by the removal of competing vegetation and exposure of surface soils to aid planting operations. Site preparation is often the most costly

silvicultural operation. Manual clearance using saws and machetes can be implemented where brush and trees are relatively sparse and short in height. Manual clearance is useful for cutting planting lines in existing plantations for supplemental planting and where planting sites are small and scattered.

The primary form of site preparation recommended for the WTMA is mechanical crushing of existing vegetation. This is usually conducted with heavy crawler tractors, which run over shrub and weed species, and scatter tree debris. This method of site preparation has two primary merits. First, soil disturbance is minimized, which helps maintain soil productivity and nutrient cycling potential. Second, desirable stems of both native and non-native tree species can be left standing, contributing to future stand diversity and value. The rocky nature of much of the area also constrains other site preparation mechanical options.

Herbicides are sometimes used for site preparation. Herbicides are used to reduce competition from grass along planting lines before planting and undesired remnant woody vegetation. When herbicides are applied, all Federal and State rules and regulations need to be followed to protect both the worker and the environment. All label instructions will be followed for any herbicides used in the WTMA. Use of fire for site preparation is prohibited.

3. Timber stand improvement: Fertilizer application is essential for satisfactory seedling survival and growth. During and after planting, commercial fertilizer applications will be manually applied as needed. Weed control may be required in newly planted stands to reduce seedling mortality and competition. Herbicide use will be limited to manual applications in an area about two to three feet in radius around seedlings. Chemical quantities will be carefully prescribed at levels to control the specified target population, and will not be applied in buffer zones for surface waters. Only approved chemicals will be used in the WTMA in strict accordance with the manufacturer's label.

Young tree stands may require side branch pruning to maximize potential value of crop trees. Pruning will be conducted manually on species that can produce high-value solid wood end products, such as Queensland maple or African mahogany *(Khaya spp.)*.

4. Harvesting: All timber harvesting activities will be conducted according to a timber harvesting plan approved by DOFAW. The timber harvesting plan shall include all of the forest management practices that are specified in the State's Best Management Practices (BMPs) for timber harvesting. All efforts will be taken to harvest trees in such a way that the least amount of ecological damage occurs, including avoiding sensitive and/or threatened and endangered species.

DOFAW will not prescribe a specific management regime for harvesting timber with the WTMA (e.g., regeneration harvest vs. selective harvest of specific trees). Due to the age of the trees, efficiency considerations related to mobilizing equipment and labor, and replanting considerations, DOFAW recognizes that cutting entire stands will be necessary. At the same time, DOFAW acknowledges the public perception and visual impacts related to regeneration harvest of large areas. Therefore, to address these concerns, harvesting restrictions for the WTMA include:

- Regeneration harvest, where previously planted trees and other vegetation are cleared, is limited to 40-acre blocks,
- Adjacent 40-acre blocks may not be harvested simultaneously,
- Harvested blocks must be replanted within six months, and new growth must reach 15 to 20 feet tall, before adjacent blocks may be harvested,
- Up to 600 acres of regeneration harvest may be done annually,
- Thinning and selective tree removal may occur in other units (in addition to the 600 acres), and
- DOFAW may identify specific tree(s) to be left standing for visual buffers, wildlife habitat, or other reasons.

Restricting harvest of entire stands to 600 acres a year provides a secondary benefit of facilitating a sustained supply of timber from the WTMA over time.

Transportation of logs and other wood products, such as chips, will be planned and coordinated with state and local authorities. In the case of Stainback Highway, this would include the County of Hawai‘i (Pana‘ewa Zoo) as well as the State Department of Corrections (Kūlani Prison).

5. Replanting: Replanting of a harvested area will usually be implemented within six months of the harvest to reduce the establishment of invasive or weed species in the area. For areas that may be susceptible to increase soil erosion, an annual crop cover may be established until replanting operations can occur. The replanting of a harvested area will be coordinated with harvesting operations to ensure that they are being implemented seamlessly. All planting specifications, such as density, species selection, site preparation, planting method, seedling protection and minimum survival expectations will be included in a replanting plan for the area.

6. Repair and maintenance of existing road infrastructure: Approximately 130 miles of unimproved access roads grid the WTMA into 245 40-acre blocks. These roads can be utilized for timber harvest purposes, and with this network of roads in place, no new permanent roads need to be constructed. Improvements to the existing road, such as clearing, grading, or reconstruction of water bars, dips, culverts and cross drainages, may be required to accommodate harvesting activities and to repair or restore the existing roads after harvesting activities are complete. Temporary skid trails, used to move logs from the forest to the landing area, and landings, where logs are loaded into trucks for transportation, will be permitted, with locations determined in advance after collaboration with DOFAW. Temporary trails and landings will be allowed to re-vegetate naturally or artificially after harvesting activities are complete. All roads, skid trails, and landing sites utilized within the WTMA must be mapped and approved by DOFAW prior to any harvest activities. Because forest roads have the potential to create more erosion than any other forestry activity, all improvements and maintenance of the existing access roads and all work related to temporary skid trails will conform to the BMPs attached in Appendix A.

B. Native forest management:

Within the WTMA, approximately 779 acres of native forest (defined as areas containing 50 percent or more native forest cover) remain. Commercial timber harvest will not occur in these areas. The primary goal in these areas will be forest protection and management of threatened and endangered plants, and they will remain accessible for traditional gathering of forest resources, research, hunting, and recreation.

Road Q Native Forest Withdrawal: The approximately 779 acres of native forest include the 40-acre blocks located above road Q on the North side of Stainback road, which are high-quality, predominantly native forest with some struggling, poor quality tropical ash (*F. uhdei*). These blocks will be retained for their native forest character and composition and will not be managed for timber production.

Endangered plant information in this plan is derived from The Nature Conservancy of Hawai‘i’s Rare Plant Database and should not be considered comprehensive. If threatened or endangered species are encountered within existing introduced timber plantations, a buffer zone of 50 feet of undisturbed vegetation will be fenced around the plant individual or population in question. Known locations of threatened and endangered plant species will be visited to collect seed or cuttings for propagation efforts as needed. Fencing will be constructed as appropriate for each site and species. Such activity will lead to out-planting in areas actively managed for rare plant species that are within that species historical range. Potential out-planting sites include the blocks of native forest scattered throughout the WTMA. A map and associated database for threatened and endangered species within the WTMA will be maintained by DOFAW.

C. Invasive species management: Although it has not been a major problem to date, non-native timber species may spread into native forest areas adjacent to the WTMA. This encroachment may be exacerbated if a major disturbance such as fire or hurricane occurs and opens the native forest canopy, providing suitable habitat for exotic and pest species to become established. Additionally, recently cleared areas may represent suitable establishment sites for invasive species. DOFAW will monitor any spread that occurs and control if necessary.

Invasive weeds are a serious threat within WTMA and can be spread rapidly by birds, wind and mammals, including humans. Invasive weed species that occur in thick and fast-growing patches in the WTMA include strawberry guava *(Psidium cattelianum)*, palm grass *(Setaria palmifolia)*, *Clidemia hirta var. hirta*, *Melastoma candidum*, and *Tibouchina urvilleana*. Many of these weeds are found only in specific locations (such as lower elevations), and not throughout the WTMA. Additional fast-growing species that could cause weed problems in this area include Australian tree fern *(Angiopteris evecta)*, miconia *(Miconia calvescens)*, yellow Himalayan raspberry (*Rubus ellipticus var. obcordatus)*, and gunpowder tree *(Trema orientalis)*. These latter species are scatted throughout the area, but have the potential to become dominant in a given location. Other problematic invasive species include fire ants, coqui frogs, and soil-born organisms.

Intensive forestry operation could potentially spread invasive species further across the timber management area on machinery, gear, and equipment. Harvest operations will be strongly encouraged to move from upper elevations down to lower elevations to minimize opportunities for spreading common low-elevation weeds, such as *Clidemia hirta*, into upper elevations where these weeds are not yet found. A sanitation protocol for machinery, gear, and equipment will be prescribed to minimize the potential for introduction of new species and prevent the movement of established and incipient invasive species found within the WTMA, covering plants, invertebrates (such as fire ants and coqui frogs), soil-born organisms, etc. Species-specific protocols will be developed as necessary to contain problem species known to occur in portions of WTMA and prevent their spread in WTMA and to adjacent native forest areas.

D. Insects and disease monitoring: *Phytophthora cinnamomi* (root rot disease) will cause limited damage to some tree seedlings planted on pāhoehoe lava flows that have poor water drainage. The tree species affected are Spanish cedar *(Cedrela odorata)*, *Casuarina spp.* and various mahogany species. Whenever this disease problem is known or observed to occurs, other tree species will be selected for planting such as Australian red cedar, Queensland maple, or Eucalypts. The black twig borer *(Xylosandrus compactus)* has been problematic at lower elevations in the WTMA, especially for seedlings of koa, Queensland maple, African mahogany, Spanish cedar, and Australian red cedar. These insects do not kill tree seedlings, but do hinder their growth and development.

Trees within the WTMA will be monitored by DOFAW employees for evidence of insect damage or disease. If problems arise, qualified entomologists or plant pathologists will be consulted to identify the problem and develop a solution to control or minimize the damage.

E. Fire prevention and control: The WTMA is located in a high rainfall zone where wild fire occurs only during extreme drought conditions. Though rare, the potential occurrence of drought does require active fire control planning. In February, 1926, an escaped trash fire burned 125 acres in Waiākea Forest Reserve, and in March, 1926, a land-clearing fire escaped and burned 20 acres of forest. In late March, 1926, a fire started from a fisherman's camp on the coast burned 4,000 acres, 700 of which was in the Pana'ewa Forest Reserve. Smaller fires occurred more recently in 1970 - 1972, and 1998.

Typically, fire risk increases in forested areas with increased human activity. However, intensification of management activities within the WTMA is expected to have negligible impact on fire risk. This area is normally very wet and will not readily burn. Maintenance of the road network within the WTMA for timber management activities will improve access and facilitate rapid containment of fire. During dry periods, DOFAW will post fire prevention signs, distribute

brochures, and employ Public Service Announcements to increase public awareness of fire risk. In extreme conditions, DOFAW will consider public access restrictions and minimize timber management activities to mitigate increased fire risk. Operators in WTMA will be informed for fire dangers and the appropriate prevention measures during timber and/or replanting operations.

F. Watershed management: The WTMA has extensive tree and ground cover making the area a valuable watershed. Spring-fed Waiākea stream is perennial in its upper reaches, and there are flumes that retain water much of the year. There is no known surface water sources used for domestic or agricultural purposes. Tree and ground cover will ensure steady infiltration of rapid runoff of storm flows, prevent soil erosion, improve water quality, prolong periods of stream flow and aid in recharging underground aquifers. A 50 foot buffer adjacent to all streams and wetlands will be established within the WTMA prior to timber management activities to ensure maintenance of water quality and reduce stream sedimentation.

G. Wildlife management: Wildlife in the WTMA offers opportunities for hunting for recreational and subsistence purposes, bird watching and rare species restoration.

1. Public hunting: DOFAW promulgates hunting rules to regulate seasons and bag limits while wildlife enforcement responsibilities lie with the Division of Conservation and Resources Enforcement. Hunting rules are set forth in Chapter 122, Rules Regulating Game Bird Hunting and Chapter 123, Rules Regulating Game Mammal Hunting. The WTMA includes sections of three Hunting Units: B, H, and K. Hunters are required to check in and out at established checking stations and report game harvests on official field forms.

Most timber management blocks within the WTMA are too overgrown with introduced weeds to offer good game animal habitat. Timber harvesting activities will encourage production of young herbaceous vegetation and create edges between vegetation types. Both of these habitat conditions favor the production of wild turkeys, Kalij pheasants, wild pigs and other game species.

2. Native species: The impact of timber harvesting activities on native bird populations is expected to be minimal. Very few native birds nest in non-native timber trees.

Timber felling will not be allowed between June 1 and September 15 due to potential impacts to the Hawaiian hoary bat, or ʻōpeʻapeʻa (*Lasiurus cinereus semotus*). However, this restriction may be lifted upon additional surveys and the development and implementation of additional mitigation actions, if DOFAW Wildlife staff and USFWS concur that the proposed mitigation actions will adequately protect the bat from take during ongoing harvesting activities. Other project activities, including loading and transporting timber, road maintenance, site preparation, and replanting, may still occur within the WTMA during the "no-harvest" period.

In addition to a Timber Harvest Management Plan, surveys for threatened and endangered bats and birds will be made and provided to DOFAW prior to the commencement of harvest activities. If any rare animal roosting trees or active nests are encountered, a no harvest zone (250 feet in radius) will be established around each site and no new harvest will take place until authorized by DOFAW.

H. Public access and other public uses: When harvesting or transporting timber or equipment on the roadways, special attention will be directed towards traffic safety and informing the public prior to the start date of operations.

1. Stainback: Since Stainback Rd. is regularly used by the people living on North Kulani Rd. to access Route 11, signs will be utilized to alert drivers when harvesting operations begin. The size

and location of the signs will be determined by DOFAW. A public notice will also be issued to the local newspaper.

2. ATV Park: The Na Ala Hele Trails and Access Hawaii District Program manager will be informed at least 2 months in advance of any operations occurring in the timber stands surrounding the ATV Park (See Fig. 4). When harvesting operations are occurring in any block containing or adjoining any of the ATV trails, the affected trails will be closed. Signs will be put in place to alert the public prior to the closure of any roads.

3. Bicycle Trails: Advanced noticed will be given to the mountain bike community who ride the trails located below Quarry road (See Fig. 4) before harvesting is to take place in the area. Trails to be cleared and re-established after harvest will be designated by DOFAW prior to harvest. Some slash may be left as desired by the mountain bike community to provide obstacles for the trail riders.

I. Cultural resources: In the event any unanticipated sites or remains such as bone or charcoal deposits, human burials, rock or coral alignments, paved sites or walls are encountered, all activities in the near vicinity shall stop and the State Historic Preservation Division will be contacted immediately.

VIII. SPECIES SPECIFIC CONSIDERATIONS

Each of the introduced commercial timber species or species groups grown and managed within the WTMA has unique management requirements. These are due to differences in physiology, growth potential, utilization value, and products.

A. Queensland maple (*Flindersia brayleyana*)**:** DOFAW considers Queensland maple to be the most valuable introduced timber species in this forest because of its high wood quality, desirable growth characteristics, and site adaptability. This timber species will be managed under the guidelines of selective tree harvesting to create and maintain an uneven age timber stand. Six type classes of Queensland maple currently exist within the WTMA, coded FB00, FB11, FB22, FB33, FB44 and FB55 (Appendix B). Initially, intensive forest management practices will be applied to type class FB33 and FB44. These two type classes are comprised of 290 acres of medium and high-stocked timber, with a merchantable volume of 1,338,000 ft^3 or approximately 50 percent of the total wood volume, on only 20 percent of the area for all Queensland maple stands in the WTMA.

An annual goal of commercial thinning on 100 acres of Queensland in FB33 and FB44 could provide as much as 55,000 ft^3 of wood to the island's markets each year for 15 years. Wood marketing and utilization will both need to be enhanced to accommodate this level of production. If local markets do not absorb such wood production, DOFAW will shift forest management activities to focus on timber stands which are young or composed primarily of smaller diameter trees. Such activities would include re-planting, weeding and pre-commercial thinning. DOFAW will also consider making wood available for export or energy production should there be a demand for small diameter logs.

B. *Eucalyptus* species (*Eucalyptus saligna, E. grandis, E. robusta, E. deglupta, E. pilularis:* The WTMA contains a total merchantable volume of 10,941,000 ft^3 of various *Eucalyptus* species. *E. grandis* and *E. saligna* constitute 88 percent of the total *Eucalyptus* volume in the WTMA, with minor components of other species (Table 2). The following are the recommended harvesting guidelines for the *E. grandis and E. saligna* species.

1. Harvest units will not exceed 40 acres. A modified regeneration harvest will be required *Eucalyptus* because these species require an open, well prepared site to regenerate and grow vigorously.

2. Specific conditions or leave or residual trees within the 40 acre harvesting blocks will be specified in the Timber Land License. These residual trees are for wildlife habitat, regeneration enhancement, and aesthetics.
3. All harvested areas will be replanted with Eucalyptus species, Queensland maple, or other high value hardwood timber species. Trees grown for the specific purpose of biofuel may be considered in appropriate locations when sufficient potential demand exists and economics permit. In no case will biofuel plantings take place in designated native forest areas or where higher-value species with good current or potential markets could be planted instead.

To manage the 4,030 acres of *Eucalyptus* species on a sustained yield basis, up to 500 acres of *Eucalyptus* could to be harvested and replanted annually based on a 14-year rotation cycle. The 14 year cycle is desirable for maximizing wood production over time and maintaining harvest log size near a 12 inch DBH, since larger logs are prone to splitting and checking. This prescription may be changed based on commercial experience and silvicultural research.

DOFAW considers *E. robusta* to be a valuable introduced timber species because of its high wood quality, desirable growth characteristics, site adaptability, and apparent local and regional markets. Ideally, this timber species will be managed under the guidelines of selective tree harvesting to create and maintain an uneven age timber stand. However, selective harvest may not be feasible in all locations due to the mature age and size of much of the *E. robusta*.

Annual wood productions from the harvest of *Eucalyptus* in the WTMA may contribute to supporting local wood manufacturing companies which currently obtain wood from other sources. *Eucalyptus* appears to grow well in all areas of the WTMA except on very shallow pāhoehoe lava flows.

C. Tropical ash (*Fraxinus uhdei*) **and Australian red cedar or toon** (*Toona ciliata*)**:** After more than 35 years of growth, a majority of Australian red cedar and tropical ash trees are still pole sized (e.g., 4 to 10 inches in diameter at breast height). Due to this poor performance, no additional plantings of either species will take place. DOFAW will prioritize conversion of acreage containing Australian red cedar and tropical ash to *Eucalyptus* species and Queensland maple, and other prospective high-value species such as brush box (*Lyphostemon confertus*), Spanish cedar, African mahogany, or koa (*Acacia koa*). Prior to replacement plantings, salvage sales will be conducted to utilize any Australian red cedar or tropical ash wood resources with commercial value.

IX. OPTIONS FOR DISPOSITION OF TIMBER

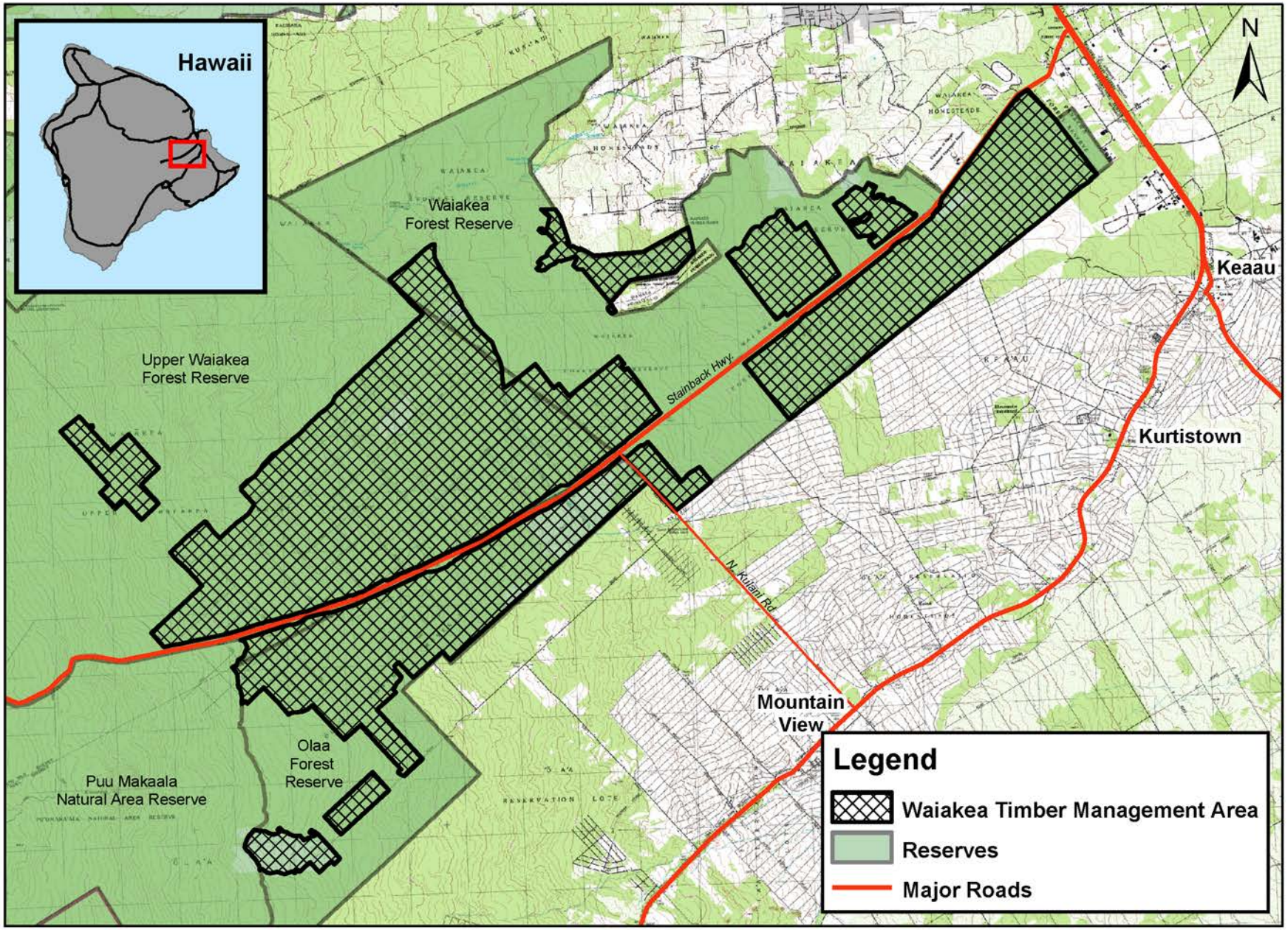
DOFAW has received numerous requests from the private sector for access to the timber within the WTMA. These have primarily come from entrepreneurs interested in wood chips, veneer, plywood, lumber, other higher value forest products, and biofuel. DOFAW has in the past attempted to sell larger quantities of timber through forms of public bidding with a final timber license approved by the Board of Land and Natural Resources. Small-scale sales or timber salvage operations, where commercial value did not exceed $10,000, were handled directly by the Hawai‘i District.

While this process may still be used, more flexible forms of sale of forest products are of interest to optimize the commercial forest and job potential within the WTMA. DOFAW is charged to make the Forest Reserve System as self-sustaining as possible. Increased monitoring and compliance responsibilities associated with timber operations will also demand more concentrated staff time.

For any major commercial harvesting activities to occur within the WTMA, reforestation and other essential forest management activities must be supported. This can be done by reinvesting portions of the value derived from existing forest resources in the WTMA. Reinvesting revenues can improve forest health, as well as stimulate job creation and value-added processing, without impacting existing funding sources. It is recognized that the public is likely to respond more favorably to the use of its

forest resources if proceeds derived from harvesting can be reinvested in local forests to create a sustainable local wood products industry and improve forest health and growth.

Figure 1: Current extent of Waiakea Timber Management Area



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February 2013

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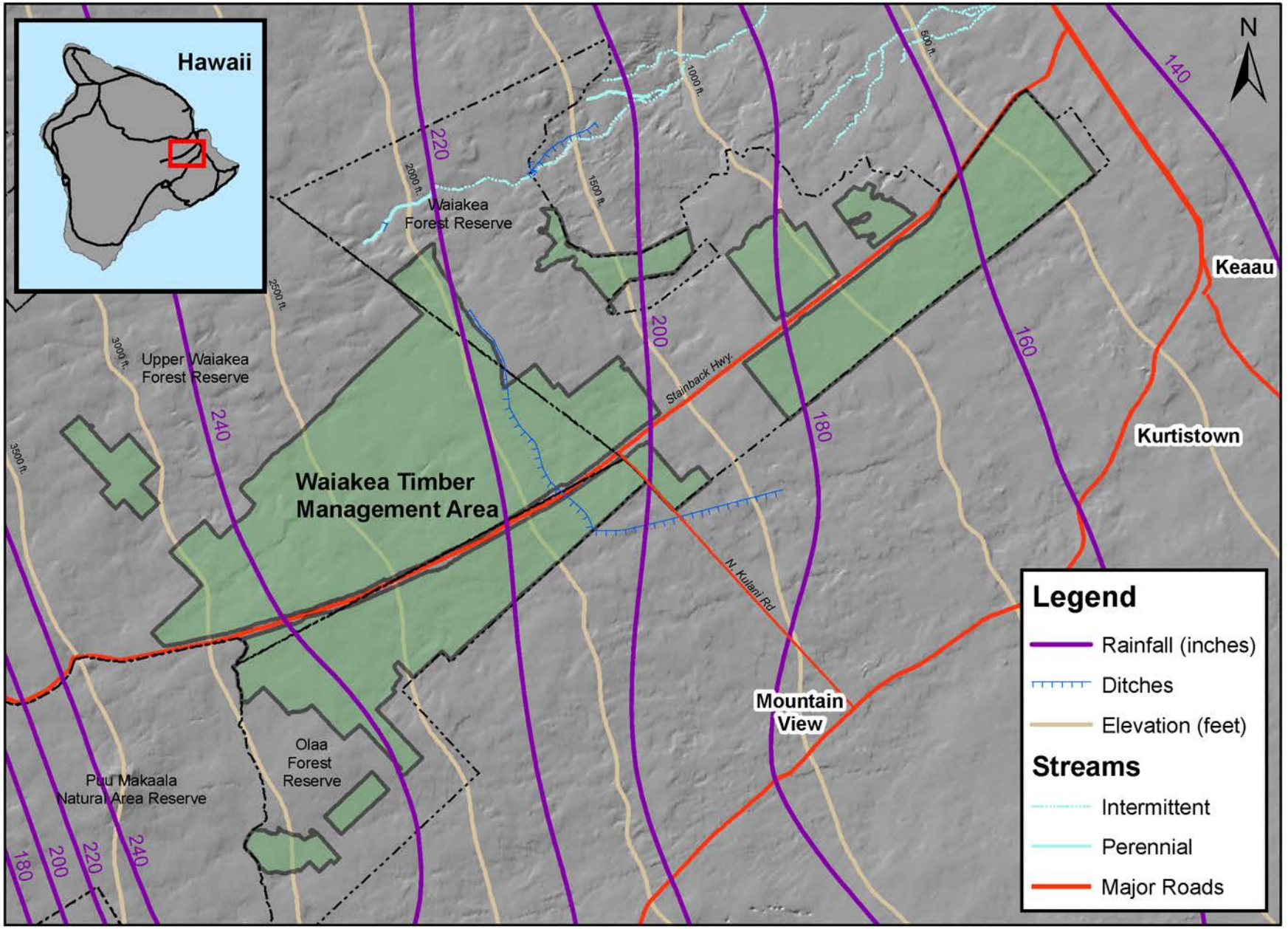
Figure 2: Hydrological features and elevation of Waiakea Timber Management Area (WTMA)



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0 0.5 1 2 3 4 Miles

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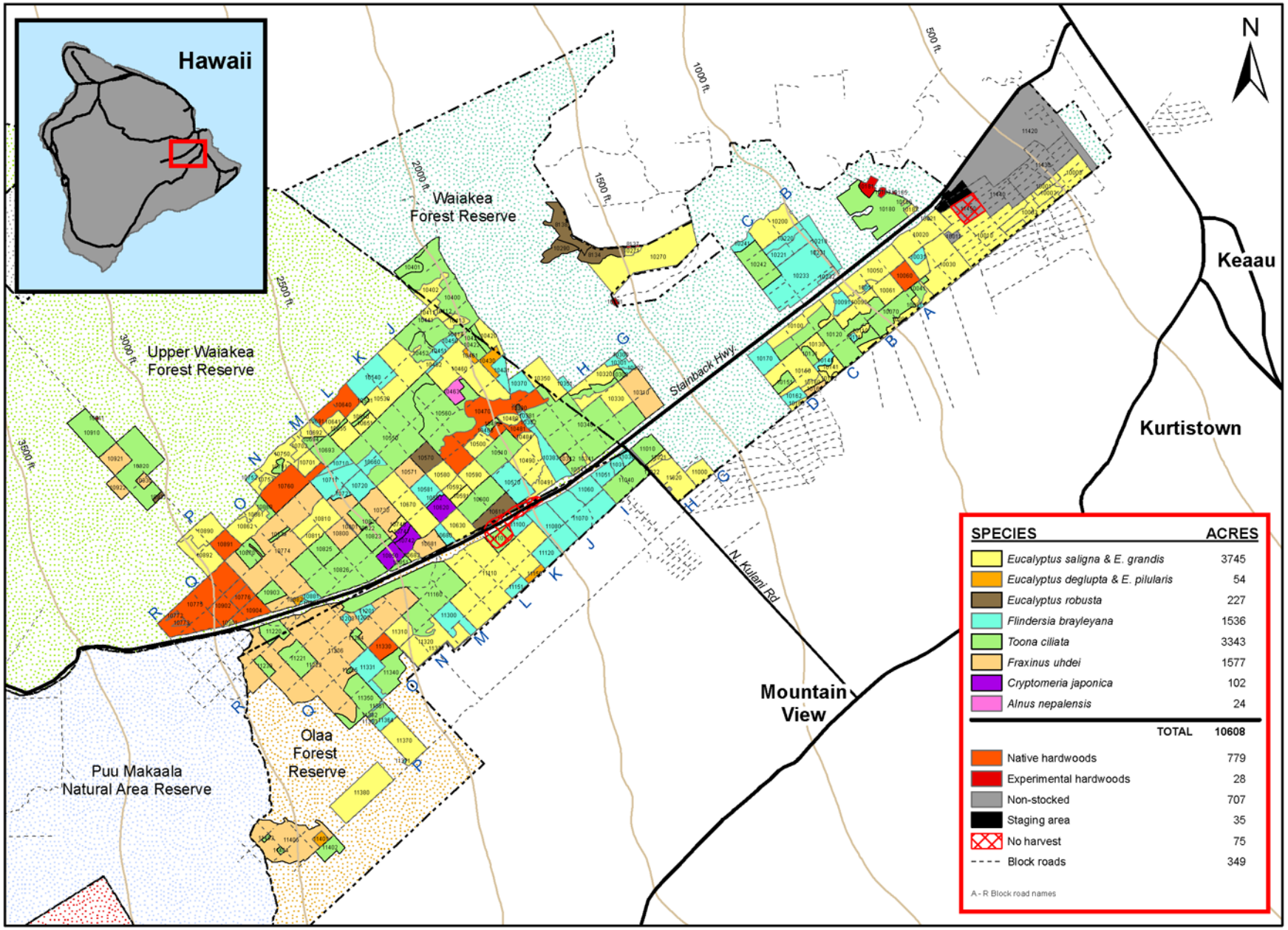
Figure 3: Waiakea Timber Management Map
Primary Tree Species - Based on 1997 Timber Inventory



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October 2013

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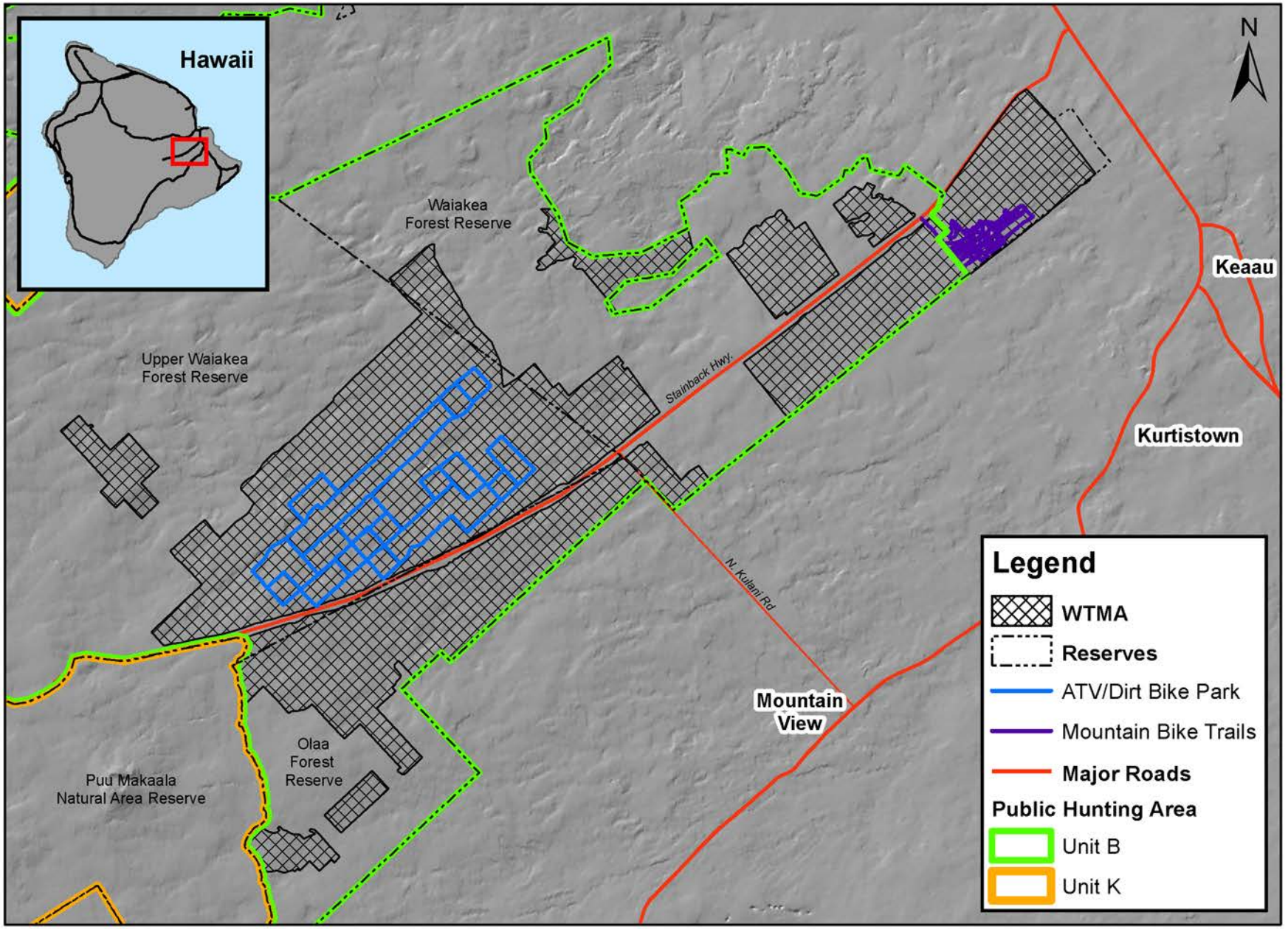
Figure 4: Waiakea Timber Management Area Recreation and Access.



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February 2013

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HAWAII STATEWIDE GIS PROGRAM

BEST MANAGEMENT PRACTICES

FOR

MAINTAINING WATER QUALITY

IN HAWAII

State of Hawaii
Department of Land and Natural Resources
Division of Forestry and Wildlife
February 1996

FOREWORD

Best Management Practices (BMPs) are effective, practical, structural or nonstructural methods which prevent or reduce the movement of sediment, nutrients, pesticides and other pollutants from the land to surface or ground water, or which otherwise protect water quality from potential adverse effects of silvicultural activities. These practices are developed to achieve a balance between water quality protection and the production of wood crops within natural and economic limitations.

A thorough understanding of BMPs and the flexibility in their application are of vital importance in selecting BMPS which offer site specific control of potential nonpoint source pollution. With each situation encountered at various sites, there may be more than one correct BMP for reducing or controlling potential nonpoint source pollution. Care must also be taken to select BMPs that are practical and economical while maintaining both water quality and the productivity of forest land.

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500 (and as amended by Sec. 319, 1986), require the management of nonpoint sources of water pollution from sources including forest-related activities. BMPs have been developed to guide forest landowners, other land managers and timber harvesters toward voluntary compliance with this act. Maintenance of water quality to provide "fishable" and "swimmable" waters is central to this law's objectives. The Environmental Protection Agency (EPA) recognizes the use of BMPs as an acceptable method of reducing nonpoint source pollution.

Nonpoint source is diffuse pollution that comes from almost everywhere; it even occurs naturally to a certain extent. The amount of pollutants from any particular spot is small and insignificant, but when combined from over the landscape, can create water quality problems. **Although it is unrealistic to expect that all nonpoint source pollution can be eliminated, BMPs can be used to minimize the impact of forestry practices on water quality. These practices must be reasonable, achievable and cost effective.** The adoption and use of BMPs will provide the mechanism for attaining the following water quality goals:

* to maintain the integrity of stream courses;

* to reduce the volume of surface runoff originating from an area of forest management disturbance and running directly into surface water;

* to minimize the movement of pollutants i.e. pesticides, nutrients, petroleum products, etc. and sediment to surface and ground water;

* to stabilize exposed mineral soil areas through natural or artificial revegetation means.

The intent of this guide is to promote better stewardship of the forest resources. This guide delineates environmentally responsible land management methods which, when applied properly, minimizes adverse impacts on the forest ecosystem and maximizes landowner objectives. Unusual situations may arise or pollution control measures other than those recommended here may be found. In these cases, common sense is most often the best guide.

Information presented in this guide is not to be used as the basis for setting water quality standards or as the basis of required use of watershed protection practices. Compliance with any watershed protection practices would be on a voluntary basis backed up with a public water quality education and awareness program. Changing of water quality standards or the required use of protection practices should not be attempted without careful study of the beneficial effects gained from modifying existing silvicultural practices now in use.

INTRODUCTION

The Division of Forestry and Wildlife (DOFAW) is mandated by HRS, Chapter 183 to "...devise ways and means of protecting, extending, increasing, and utilizing the forests and forest reserves, more particularly for protecting and developing the springs, streams, and sources of water supply to increase and make that water supply available for use..."

The number one resource that is generated by the forest is water. Since the establishment of the Department of Agriculture and Forestry in 1900, the concern for the protection of forest lands for the purpose of water has been a high priority. Fencing to keep out wild cattle and other feral animals and reforestation efforts to re-establish watersheds have been the key to the continuance of the production of high quality water.

In 1961, Hawaii created, by law, the nation's first statewide zoning districts, and today approximately 95% of the Hawaii's four million acres are zoned for agricultural or conservation uses. The Conservation district, which is under the jurisdiction of the Department of Land and Natural Resources (DLNR), encompasses almost one-half of the State, of which one million acres is state-owned. The majority of Conservation lands are covered by forests, but also contain grasslands, coastlines, cliffs, offshore islets, and wetlands. Vegetative communities include lowland and montane rainforests and unique examples of tropical biodiversity, much of it endangered.

The Division of Forestry and Wildlife recognizes the need for responsible stewardship of the natural resources, which include soil and water. **The success of BMPs to protect water quality within Hawaii depends on mutual cooperation and trust among landowners, industry, environmentalists, wood producers, regulatory agencies, governmental officials, and the general public.** All have an interest in good land management as it relates to water quality.

THE FOREST/WATER RELATIONSHIP

The forest and water resources are mutually dependent upon one another. Forests depend on water, namely rain, surface water, and groundwater for their growth and reproduction. Major long-term changes in the water supply can cause permanent changes in the content, quality and vitality of forest lands.

On the other hand, surface and groundwater quantity and quality are largely influenced by the surface on which rain falls and through which it percolates. The tremendous filtering capacity of forest lands provide effective and high quality groundwater recharge.

Hawaii's streams and aquifers all benefit from the presence of forests. In addition to these water quality benefits, forests provide needed wood and fiber products, wildlife habitat, aquatic resources and habitat, recreation values and aesthetic benefits. It is in managing forests for these benefits that damage to the water resource can result. Following is a brief discussion of the most commonly used forest management practices and the impacts they can have on the quality of the water resource.

Timber Harvesting

The removal of trees from a site has little impact on water quality, as long as the trees do not provide vital shade to streams and as long as the slope of the land is not excessive. The natural warmth of many streams can be exaggerated by removing shading vegetation from their banks. Increased water temperature promotes lower dissolved oxygen levels, placing stress on fish and other aquatic organisms.

Removing timber per se does not directly cause significant water quality changes, since ground cover is not excessively disturbed during proper logging operations. On steep slopes, however, careless timber removal can increase the likelihood of runoff and soil loss. This may lead to water quality degradation as well as a loss of site productivity. Steep areas should therefore be logged carefully using proper harvesting techniques for the sake of both water quality protection and site protection.

Road Construction and Drainage Techniques

All facets and phases of a sound forest management program rely heavily on accessibility to the forest. Consequently, temporary and permanent access roads are necessary components of all management programs. They are also one of the most costly investments made in a forests.

Temporary access roads are constructed to facilitate harvesting operations, site preparation and planting and often abandoned after the new stand is established. When abandoned, these temporary roads are normally allowed to revegetate naturally or are planted with trees.

Pollutants from Silvicultural Activities

The major types of water pollutants that can be generated from forest management disturbances to the forest ecosystem include sediment, nutrients, pesticides, and debris.

1) Sediment

Sediment is the most common pollutant resulting from silvicultural activities. Sediment principally results from erosion of soil, but may also include organic matter. Excessive sediment upsets balanced ecology within streams by smothering bottom dwelling organisms in the water, interfering with photosynthesis by reducing light penetration, serving as carriers of nutrients and pesticides, inhibiting fish reproduction and altering stream flow.

2) Nutrients

Nutrients, primarily phosphorous and nitrogen fertilizers, are sometimes applied to the forest to stimulate tree growth. Soluble nutrients may reach surface or ground water through runoff, seepage, and percolation. Insoluble forms may be absorbed on soil particles and reach water by direct wash-off of debris and recently applied fertilizer. Excessive nutrients lead to an imbalance in natural life cycles of water bodies.

3) Pesticides

Pesticides, if applied during silvicultural activities, may be soluble or insoluble. Pesticides in surface or ground water may result in toxicity problems, affecting water quality and food sources for aquatic life.

4) Debris

Tree limbs, tree tops, and other waste materials are the principal organic pollutants from silviculture. They reach streams through direct pushing or felling into water drainages, and washout during storms. Organic materials may place an oxygen demand on the receiving water body during the decomposition process. In addition, associated problems may include odor, color, taste and nutrients. Inorganic material such as oil cans and pop bottles are also considered nonpoint source debris.

BEST MANAGEMENT PRACTICES

1.0 Forest Roads

Standards and Use

Forest roads are managed to provide adequate access to lands for timber management, fire suppression, wildlife habitat improvement and a variety of dispersed and developed recreational activities. Generally, these are low volume roads that must carry heavy loads for short periods of time. The potential for adverse impacts from forest roads exists in areas where steep slopes, erodible soils, or where forest roads are located near water. **Forest roads cause more erosion than any other forestry activity.** Most of this erosion can be prevented by locating, constructing, and maintaining roads to minimize soil movement and pollution of streams. The need for higher standard roads can be alleviated through better road-use management. Design roads to the minimum standard necessary to accommodate anticipated use and equipment.

Planning, Design, and Location

A well planned access system is a sound method of reducing erosion and sedimentation in areas requiring frequent or temporary access. Proper location and construction of roads will provide for safety, longer operating periods, lower maintenance and operating costs, and minimal impacts to water quality. The value of the resource served and site characteristics will influence the choice of road construction standards and maintenance activities. The following practices are recommended:

(1) Use a design to minimize damage to soil and water quality.

(2) Roads should be designed no wider than necessary to accommodate the immediate anticipated use.

(3) Design cut and fill slopes to minimize mass soil movement.

(4) Provide culverts, dips, water bars, and cross drainages to minimize road bed erosion.

(5) Design bridge and culvert installations using stream flow data, with a margin of safety proportional to the importance of the road and the protected resources.

(6) Provide drainage where surface and groundwater cause slope instability.

(7) Avoid diverting water from natural drainage ways. Dips, water bars, and cross drainage culverts should be placed above stream crossings so that water can be filtered through vegetative buffers before entering streams.

(8) Locate roads to fit the topography and minimize alterations to the natural features.

(9) Avoid marshes and wetlands.

(10) Minimize the number of stream crossings.

(11) Cross streams at right angles to the stream channel.

(12) A road may not be located in a Streamside Management Zone (SMZ) except where access is needed to a water crossing, or where there is no feasible alternative. A road in any SMZ must be designed and located to minimize adverse effects on fish habitat and water quality.

Construction

Once the road's location and design is staked out, road construction begins. Timber is out, logs and vegetation are removed and piled along the lower side of the right-of-way.

Most forest roads are built by excavating a road surface. Road design and layout on-the-ground show machine operators the proper cut slopes and indicate cut slope steepness. The bulldozer starts at the top of the cut slope, excavating and sidecasting material until the desired road grade and width is obtained. Material from cuts is often pushed in front of the blade to areas where fill is needed. Road fill is used to cover culverts and build up flat areas. Since fill must support traffic, it needs to be spread and compacted in layers to develop strength. The following practices are recommended:

(1) Construct roads when moisture and soil conditions are not likely to result in excessive erosion or soil movement.

(2) The boundaries of all SMZs shall be defined on the ground prior to the beginning of any earth-moving activity.

(3) Construct a road sufficient to carry the anticipated traffic load with reasonable safety and with minimum environmental impact.

(4) When using existing roads, reconstruct only to the extent necessary to provide adequate drainage and safety.

(5) Avoid construction during wet periods, when possible, to minimize unnecessary soil disturbance and compaction.

(6) Road grades should be kept at less than 10%, except where terrain requires short, steep grades.

(7) Minimize the number of stream crossings. Stream crossing construction should minimize disturbance of the area in which the crossing is being constructed.

(8) As slope increases, additional diversion ditches should be constructed to reduce the damages caused by soil erosion; ditches, adequate culverts, cross drains, etc., should be installed concurrent with construction.

(9) To control erosion, cut and fill slopes should conform to a design appropriate for the particular soil type and topography.

(10) Stumps, logs, and slash should be disposed of outside of the road prism; in no cases should they be covered with fill material and incorporated into road beds.

(11) Stabilize the side banks of a road during construction to aid in the control of erosion and road deterioration; this may require mesh or other stabilizing material in addition to planting and/or seeding and other structural measures.

(12) Water bars should be located to take advantage of existing wing ditches and cross drainage. Water bars should be constructed at an angle of 30 to 45 degrees to the road. Water bars should be periodically inspected and damage or breeches should be promptly corrected. Install water bars at recommended intervals to provide the drainage. Water bar spacing recommendations are as follows:

Grade of Road	Distance Between Water bars
2%	250 ft.
5%	135 ft.
10%	80 ft.
15%	60 ft.
20%	45 ft.
25%	40 ft.
30%	35 ft.
40%	30 ft.

Water bars may need to be spaced closer together depending on soil type and rainfall.

(13) Bridges and overflow culverts should be constructed to minimize changes in natural stream beds during high water.

(14) Culverts on perennial streams should be installed low enough to allow passage of aquatic life during low water.

Maintenance

Maintenance of active and inactive roads shall be sufficient to maintain a stable surface, keep the drainage system operating, and protect the quality of streams. The following are recommended:

(1) Maintenance should include cleaning dips and crossdrains, repairing ditches, marking culverts inlets to aid in location, and clearing debris from culverts.

(2) Keep culverts, flumes, and ditches functional before and during the rainy season to diminish danger of clogging and the possibility of washouts. This can be done by clearing away any sediment or vegetation that could cause a problem. Provide for practical and scheduled preventative maintenance programs for high risk sites that will address the problems associated with high intensity rainfall events.

(3) Conduct road surface maintenance as necessary to minimize erosion of the surface and subgrade.

(4) During operations, keep the road surface crowned or outsloped, and keep the downhill side of the road free from berms except those intentionally constructed for protection of fill.

(5) Avoid using roads during wet periods if such use would likely damage the road drainage features.

(6) Water bars should be inspected after major rain storms and damage or breeches should be promptly corrected.

Harvesting - Temporary Access Roads and Landings

(1) The location of temporary access roads (logging roads) should be planned before operations begin.

(2) Road construction should be kept to a minimum.

(3) Landings should be located to minimize the adverse impact of skidding on the natural drainage pattern.

(4) Logging roads and landings should be located on firm ground.

(5) Landings should be kept as small an area as possible.

(6) When operations are completed, provisions should be made to divert water run-off from the landings and roads.

2.0 Pre-Harvest Planning

Pre-harvest planning is the collection of information about the area to be harvested and the synthesis of that information into an effective environmental plan. This plan will consider the silvicultural prescription for the species and site, the best estimate of the time and method of harvest and any post-harvest site preparation and reforestation activities.

At this stage, it is assumed that all federal, state, and local government regulations regarding harvesting have been met.

An effective pre-harvest plan will take into consideration all aspects of the timber harvest which may lead to water quality degradation and plan for the implementation of BMPs which will minimize or avoid the adverse effects of the operation. The objective of pre-harvest planning from the perspective of non-point source pollution is to determine which BMPs are necessary to protect water quality and how those BMPs will be implemented. The following is recommended:

(1) A pre-harvest plan should include the following information:

A. Physical and administrative description

1. Property boundaries & administrative boundaries (zoning, etc.)
2. Topography
3. Location of streams and drainages
4. Location of SMZs and buffer strips
5. Forest types
6. Soil types
7. Areas of ecological and/or archaeological concerns

B. Management Activities

1. Design and construction techniques for all new roads, skid trails, and landings or modification of existing roads, skid trails and landings.
2. Felling and bucking techniques
3. Yarding systems and layout
4. Planned stream crossings
5. Disposal of waste materials (machine lubricants)
6. Post-harvest site preparation
7. Reforestation activities

(2) The use of topographic maps, road maps, aerial photos, forest type maps, and soil surveys in combination with field reconnaissance is essential to determine site conditions and plan operations.

(3) Field reconnaissance with a trained forester or one who is knowledgeable about the specific area is highly recommended.

(4) Preliminary planning should consider the maintenance of existing drainage patterns and the location of environmentally sensitive areas such as streams, wet areas, and high erosion hazard areas.

(5) The design of roads, skid trails, and landings shall be integrated to minimize their impact.

(6) The grade of logging roads and skid trails should be less than 10% when possible, with 3-5% being the norm. Long, straight, unbroken grades are to be avoided. Adequate surface drainage shall be provided.

(7) Time the harvesting activity for the season or moisture conditions when the least impact occurs.

(8) A final pre-harvest site review shall be conducted by management so that road alignments and other considerations can be visually checked prior to road construction. The reconnaissance plan shall be modified as necessary to make desirable adjustments based on the final site review.

2.1 Timber Harvesting

Standards and use

Timber harvesting is an integral part of most forest management programs. Harvesting operations cause a temporary disturbance in the forest as well as diminish water quality. However, it can be conducted in a manner where the impact to water quality is minimized and the re-establishment of vegetative cover is realized. Guidelines to help reduce the potential for nonpoint source pollution from harvesting trees are as follows:

Felling and Bucking

(1) Careful felling can minimize the impact of subsequent phases of the logging operation.

(2) Trees should not be felled into streams, except where no safe alternative exists. In the latter case, such trees should be removed promptly.

Skidding

(1) Skidding should be done so as to avoid disrupting natural drainage and to prevent excessive soil displacement.

(2) Stream channels or road ditches should not be used as skid trails.

(3) Skid trails on steep slopes should have occasional water bars.

(4) Servicing of equipment involving fuel, lubricants, or coolants should be performed in places where these materials cannot enter streams. Spent oil should be collected for proper disposal, never poured on the ground.

(5) Upon completion of logging, erosion-prone areas should be mulched or seeded.

Mechanical Site Preparation

(1) Avoid excessive soil compaction.

(2) Minimize erosion and the movement of sediment into waters.

(3) Prevent accumulation of debris in ponds, streams, or rivers.

(4) Windrows, disking, bedding, and planting with "furrow" type mechanical planters should follow contours.

(5) Avoid complete disking of steep slopes with extremely erodible soil.

(6) Plant trees on contour.

Disposal of Debris and Litter

(1) Logging debris in streams should be removed immediately.

(2) Debris from landings should not be pushed into drains, streams or Streamside Management Zones (SMZs)

(3) All trash associated with the logging operation should be promptly removed (not buried) and hauled to a legal disposal site.

3.0 Silvicultural Chemical Management

Description and Purpose

Pesticides are used on forest lands to facilitate meeting forest management objectives. The purpose of a pesticide application is to rid an area of undesirable vegetation or control insects or diseases to promote the establishment, survival, growth or maintenance of a desired species or condition.

Planning Considerations

Planning is an essential first step in reducing pest problems. A plan is needed by which the application of pesticides is utilized in an efficient manner that produces no adverse impacts on the environment. The maintenance of water quality is an important consideration in all aspects of pesticide operation planning.

Pesticide Selection

When the decision is made to use pesticides, choose products suitable for use on the target species and registered for the intended uses. Use only pesticides registered by the Environmental Protection Agency. Prior to using any pesticide, carefully read and follow all label directions.

When selecting pesticide options, more than effectiveness and cost should be evaluated. Consideration should be given to site factors, application conditions and techniques and products that can influence impacts to water quality.

Three main characteristics can greatly affect a pesticide potential to contaminate surface or ground water. They are solubility, absorption and breakdown rate.

1) Solubility

Solubility is the ability of a pesticide to dissolve in water. The greater the solubility, the greater the chance that the chemical will leach to ground water.

2) Absorption

Absorption is the inherent ability of a pesticide to bind with soil. Some pesticides stick very tightly to soil while others are easily dislodged. A greater absorption means a pesticide will remain longer in the soil and thus be less likely to leach down into the ground water before it has degraded. Absorption increases as soil organic matter increases.

3) Breakdown Rate

Breakdown rate or half-life is the time a pesticide takes to degrade or breakdown into other chemical forms. Pesticides that do not break down quickly can be hazardous if they move to ground water or surface water.

In a given situation, pesticides with the highest water solubilities, greatest persistence, lowest affinities for absorption to organic matter and other soil components, and highest application rates have the greatest potential for movement in surface water or to ground water. An alternative means of minimizing the potential movement of a pesticide is to select a non-broadcast application

technique for the same pesticide that reduces the amount of the chemical applied directly to the soil.

Procedures for Chemical Use

Proper pesticide management practices make efficient use of chemical while preventing contamination of surface water or ground water. Residues of pesticides used in forestry can affect water quality at several phases of the chemical use cycle. These phases are: 1) transportation, 2) storage, 3) mixing and loading, 4) application, and 5) cleanup and disposal. To minimize potential impacts on water quality, use of the following practices is encouraged.

A) Transportation

(1) Inspect all containers prior to loading and ensure all caps, plugs and bungs are tightened.

(2) Handle containers carefully when loading them onto vehicles.

(3) Secure containers properly to prevent shifting during transport.

(4) Check containers periodically enroute.

(5) Limit access to containers during transport to prevent tampering.

(6) Educate and inform the driver of the proper transportation precautions.

(7) Never transport pesticides unless arrangements have been made to receive and store them properly.

B) Storage

(1) Chemicals should be managed and stored in accordance with all applicable federal, state, or local regulations. These would include:

(a) The EPA container registration label, as printed on the label;

(b) Label instruction for use as provided by the manufacturer;

(c) Requirements or the use, application, and registration of pesticides;

(d) Requirements relating to the licensing of applicators.

(2) All containers should be labeled in accordance with applicable federal, state and local regulations.

(3) Apply pesticides under favorable weather conditions. Never apply a pesticide when there is a likelihood of significant drift.

(4) Always use pesticides in accordance with label instruction, and adhere to all Federal and State policies and regulations governing pesticide use.

E) Cleanup and Disposal

(1) Before disposal, containers should be rinsed as described in equipment cleanup.

(2) Cleanup should be in a location where chemicals will not enter any stream, pond, or where stream pollution might occur.

(3) Rinse empty pesticide containers and mixing apparatus as many times as needed. This flushing should be applied in spray form to the treated area, NOT into the ground near streams.

(4) Dispose of pesticide wastes and containers according to federal and state laws. Some pesticide wastes are specifically identified as hazardous wastes by law and must be handled and disposed of in accordance with hazardous waste regulations. For more information about proper management of waste pesticides, contact the Department of Health, Environmental Health Administration.

Other chemicals

Improper storage and handling of oil products and fuel can be a water quality hazard. Improper disposal of oil or fuel can contaminate ground water and seep into streams. The following are recommended:

(1) Locate facilities away from streams and be prepared to clean up spills.

(2) Know and comply with regulations governing the storage, handling, application (including licensing of applicators), and disposal of hazardous substances.

(3) Do not transport, handle, store, load, apply or dispose of any hazardous substance or fertilizer in such a manner as to pollute water supplies or cause damage or injury to land, including humans, desirable plants and animals.

(4) Do not store, mix, or rinse hazardous substances or fertilizers within the streamside management zone or where they might enter streams or waterways.

(5) Develop a contingency plan for hazardous substance spills, including cleanup procedures.

(6) Report all spills to the Department of Health, Environmental Health Administration.

4.0 Streamside Management Zone (SMZ)

The Special Management Zone (SMZ) is a specific area associated with a stream, lake, wetland or other waterbody that is designated and maintained during silviculture operations. The purpose of the SMZ is to protect water quality by reducing or eliminating forestry related ouputs, i.e. sediment, nutrients, logging debris, chemicals, and water temperature fluctuations that can adversely affect aquatic communities. SMZs provide shade, streambank stability and erosion control, as well as detritus and woody debris which benefit the aquatic ecosystem in general. In addition, the SMZ is designed to maintain certain forest attributes that will provide specific wildlife habitat values. Snags, den and cavity trees as well as mast producing trees, left in the SMZ, are necessary to meet habitat requirements for certain wildlife.

The SMZ has specific criteria, that defines operational restrictions and special management objectives. In addition, the SMZ has a specific width which is based on the size and type of waterbody involved.

A Streamside Management Zone (SMZ) is an area covered with vegetation or ground cover on both sides of perennial, intermittent streams and other bodies of open water, where extra precaution is used in carrying out forest management practices. The SMZ also provides shade and functions as a buffer when fertilizers, pesticides, etc. are applied to adjacent lands. For practical purposes, an SMZ must be wide enough to protect water quality and stream characteristics. Precaution is needed in carrying out forest management practices in order to protect bank edges and water quality. Determining the necessary width involves in part a judgement factor based on reliable local experience.

SMZs should be used where: 1) water quality is impaired and adjacent land use contributes to that degradation, 2) good water quality exists and protection against potential future impairment is desired, 3) streambank erosion is a concern, 4) wildlife habitat enhancement is desired, and/or 5) silviculture practices are to be implemented, and 6) the lower edge of cropland, grassland, or forest land is adjacent to permanent or intermittent streams, or border streams, rivers, ponds or intermittent or permanently flooded, open-water wetlands.

SMZ benefits include the following:

(1) Shade - Trees within the SMZs provide shade to maintain cool water temperatures which aid in the spawing of fish. Without trees and overhanging shrubs, stream temperatures would increase during the summer. Some fish species and aquatic organisms would then be unable to live in the streams. In the summer, water from shaded streams eventually flows into larger bodies of water and helps maintain its fish and aquatic life by keeping these waters cool all the way downstream.

(2) Food - Leaves and insects drop into streams from overhanging trees and shrubs. In fact, 90% of the food in the forested streams comes from bordering vegetation.

(3) Protection of Streambanks - Many streambanks are stabilized by streambank trees. They anchor banks and prevent erosion during periods of high water. Removing trees and shrubs and substituting shallow rooted grasses can lead to streambank collapse and stream sediment. Bank overhang is created by stream flows undercutting the stream bank and tree roots. Fish can rest, hide from predators, and feed in these protected areas.

(4) Flooding - Healthy SMZs stabilize floodplains. During times of high water, SMZs reduce the velocity of floodwaters. Their dense vegetation and deep humus slow down racing waters. Forest floodplains suffer less damage when SMZs are protected during harvesting activities.

(5) Recreation - The recreational activities that we enjoy in and around streams are many. This includes swimming, fishing, camping, hunting, and backpacking to name a few.

(6) Timber Production - For those who grow and harvest trees, the fact is that trees often grow best in SMZs. Trees respond to those deep, fertile, and moist soils. Logging activities should not be eliminated within SMZs but modified to insure that stream channels and banks are protected from disturbance. SMZs are not timber harvest "keep out" zones, but there are locations where timber harvesting activities must be modified to protect the many benefits mentioned above.

Recommendations

SMZs should be maintained along all perennial streams or where forest disturbances occur and surface runoff will carry sediment loads. SMZs should be maintained around streams, ponds, perennial flowing natural springs, and all springs and reservoirs serving as domestic water supplies. The following best management practices are recommended:

(1) The width of SMZs should be determined depending on the following conditions: slope of land adjacent to stream, soil erodibility, precipitation, knowledge of particular area, sensitivity of stream, etc. These factors can be obtained from soil maps, on-the-ground evaluation and measurements, weather data, etc.

(2) SMZs should be designed on a case-by-case basis. Most important is that SMZs be consistent with stream characteristics and wide enough to protect water quality.

Soil Type	Percent Slope	SMZ Width (each side)
Slightly erodible	0-5	35'
Slightly erodible	5-20	35-50'
Slightly erodible	20+	50-160'
Erodible	0-5	35-50'
Erodible	5-20	80' minimum
Erodible	20+	160' minimum

Table 1. Recommended Widths for Streamside Management Zone

[NOTE: Please contact your local Natural Resources Conservation Service office to determine the erodibility factor of the soil before determining the proper width of the SMZ.]

(3) On relatively flat terrain (0-5%) on slightly erodible soils, the width of an SMZ should be at least 35 feet wide on each side of a stream.

(4) On relative flat terrain (0-5%) on erodible soils, the SMZ width should range between 35 to 50 feet on each side of a stream.

(5) On slightly erodible soils with slopes ranging between 5 and 20 percent, the SMZ width should range between 35 to 50 feet wide on each side of a stream.

(6) On erodible soils with slopes ranging between 5 and 20 percent, the SMZ width should range between 50 to 160 feet on each side of a stream.

(7) On slightly erodible soils with slopes exceeding 20 percent, the SMZ width should be at least 80 feet on each side of a stream.

(8) On erodible soils with slopes exceeding 20 percent, the SMZ width should be a minimum of 160 feet on each side of a stream.

(9) Partial harvesting is acceptable. A minimum of 50% of the original crown cover or 50 square feet of basal area per acre, evenly distributed, should be retained in the SMZ. This may be adjusted to meet on-site conditions.

(10) Clearcutting is always prohibited within the SMZ.

(11) Designate SMZs to provide stream shading, soil stabilization, sediment and water filtering effects, and wildlife habitat.

(12) Strive to protect the forest floor and understory vegetation from unnecessary damage. Do not remove (harvest) trees from banks, beds or slopes if it will destablilize the soil. Trees on the south and west banks provide the most critical shading of water.

(13) Access roads should cross perennial or intermittent streams at or near a right angle.

(14) Drainage structures such as ditches, cross drain culverts, water bars, rolling dips, and broad-based dips should be used on all roads prior to their entrance into an SMZ to intercept and properly discharge runoff waters.

(15) SMZs may be desirable on intermittent streams for large drainage areas where wildlife is a major landowner concern or for other reasons.

5.0 Fencing

(1) Fencing out livestock, pigs, and other animals in certain areas will help to prevent water quality degradation of streams, protect threatened and endangered plants, reduce soil compaction and maintain soil productivity. Fencing is applicable where desired forest reproduction, soil hydrologic values, existing vegetation, aesthetic values, and recreation are prevented or damaged by these animals.

(2) Pastures should be fenced separately from woodlands. Consider maintenance as well as ease of construction when planning a fence location. By taking advantage of natural barriers such as cliffs, the cost of animal exclusion can be reduced. Also consider use of fences to protect vegetation that provides wildlife food and cover.

(3) Fences should be permanent stock fences built in accordance with good construction principles and workmanship.

6.0 Wildfire Damage Control and Reclamation/Prescribed Burn

The prevention, control, and extinguishment of all wildfires on grass, brush, and watershed lands and the implementation of a prescribed fire program is a desirable goal. Where wildfires do occur, the first and foremost concern is to control the fire and limit the damage. Fire suppression activities can add to the problem of water quality protection.

The loss of vegetative cover, destruction of soil-holding feature of root masses, the exposure of bare mineral soil, is a combination that makes the area burned a highly erodible one. The effects of suppression efforts and equipment operations necessary to control and stop the fire can magnify the erosion problem.

The following are best management practices for wildfire control and reclamation:

(1) The first and foremost concern in wildfire control is to prevent harm or damage to people and property. Fireline best management practices should incorporate minimum impact strategies, which meet land and resource management objectives;

(2) Areas with bare mineral soils should be revegetated and areas where vegetative cover has been killed or severely degraded should be regenerated with plant species appropriate for the soil conditions;

(3) First priority for revegetation/reforestation should be given to banks of surface water bodies so that the SMZ is reestablished;

(4) Firelines should be stabilized and, if necessary, revegetated. Erodible areas altered by suppression equipment activities should be repaired and revegetated as necessary;

(5) Access road surfaces should be repaired and stabilized as necessary.

(6) Whenever possible, avoid using fire suppression chemicals over watercourses and prevent their runoff into watercourses. Do not clean application equipment in watercourses or locations that drain into watercourses.

(7) Provide advance planning and training for firefighters that considers water quality impacts when fighting wildfires. This can include increasing awareness so direct application of fire suppression chemicals to waterbodies is avoided and firelines are appropriately placed.

(8) Include rehabilitative practices as part of suppression and post-suppression tactics and strategies to mitigate non-point source pollution.

6.1 Fireline Construction and Maintenance

Fireline construction and maintenance is an essential part of forest and other land management activities. It deals with site preparation burning, prescribed burning, and wildfire defense and control. A number of control practices can be implemented during fireline construction to prevent unnecessary erosion. Periodic inspection and proper maintenance can prevent potential erosion on established firelanes. The following are best management practices for fireline construction and maintenance:

(1) Firelines should be constructed on the perimeter of the burn area and along the boundary of the Streamside Management Zone. The purpose of protecting the Streamside Management Zone from fire is to safeguard the filtering effects of the litter and organic matter;

(2) Firelines should follow the guidelines established for logging trails and skid trails with respect to waterbars and wing ditches, and should be only as wide and as deep needed to permit safe prescribed burns or fire suppression needs;

(3) Firelines which would cross a drainage should be turned parallel to the stream or have a wing ditch or other structure allowing runoff in the line to be dispersed rather than channeled directly into the stream.

(4) All firelines should be assessed after the fire is controlled for appropriate stabilization, and if necessary, proper rehabilitation should be done while equipment and people are in place.

6.2 Prescribed Burn

(1) Intense prescribed fire for site preparation shall be conducted only if it achieves desired results with minimum impacts to water quality.

(2) Burning on steep slopes or highly erodible soils should be conducted when they are absolutely necessary and should follow carefully planned prescriptions.

(3) Carefully plan burning to adhere to time of year, weather, topography, and fuel conditions that will help achieve the desired results and minimize impacts on water quality. With proper planning, prescribed fires should not cause excessive sedimentation due to the combined effect of removal of canopy species and the loss of soil-binding ability of the subcanopy and herbaceous vegetation roots, in streamside vegetation, small ephemeral drainages, or on very steep slopes.

(4) Site preparation burning creates the potential for soil movement. Burning in the SMZ reduces the filtering capacity of the litter. All efforts should be made to plan burns to minimize impacts on the SMZ.

(5) All bladed firelines, for prescribed fire and wildfire activities, should be built so as to minimize erosion. If necessary, the firelines should be stabilized with water bars and/or other appropriate techniques to control excessive sedimentation or erosion of the fireline. Include any erosion control practices in the construction of firelines.

7.0 Reforestation

Reforestation refers to those operations undertaken to establish a new forest. Site preparation, for the purpose of forest regeneration, is a basic silvicultural tool where for competing vegetation and

reduction of logging debris are necessary. Common site preparation techniques include, manual, mechanical, fire, and herbicides.

Regeneration includes hand and machine planting and direct seeding. Since hand planting and direct seeding pose no water quality problems, BMPs are not necessary. Some mineral soil exposure does occur with machine planting and BMPs are offered.

1) Sites should receive the minimum preparation necessary to successfully control competing vegetation and establish a desirable timber stand. In general, the more intensive the treatment, the more concern for water quality.

2) When working on slopes, mechanical operations such as ripping, shearing, etc., should follow contours.

3) Hand planting, direct seeding or natural regeneration should be used on protected areas adjacent to streams or on slopes too steep to machine plant.

APPENDICES

1. Definition of Terms
2. Road Construction Applications
3. Streamside Management Zone
4. Available Assistance
5. Suggested Readings

definition of terms

DEFINITION of TERMS:

Best Management Practices -- effective, practical, structural or nonstructural methods which prevent or reduce the movement of sediment, nutrients, pesticides and other pollutants from the land to surface or ground water, or which otherwise protect water quality from potential adverse effects of silvicultural activities. These practices are developed to achieve a balance between water quality protection and the production of wood crops within natural and economic limitations.

Bucking -- to saw felled trees into predetermined lengths.

Clearcutting -- the removal of all standing trees within a designated area.

Cross drain -- a cross ditch used to move water from one side of the road to the other side to prevent accumulation of runoff without the need of a culvert or bridge.

Culvert -- a conduit through which surface water can flow under roads.

Diversion ditch - a ditch built across the top of a slope to divert surface water from that slope.

Felling -- the process of severing trees from stumps.

Firebreaks -- naturally occurring or man-made barriers preventing the spread of fire.

Fireline construction -- the construction of a barrier used to prevent the spread of fire.

Intermittent streams -- streams that provide water flow continuously during some seasons of the year but little or no flow during the remainder of the year.

Landing -- an area in the field where logs are collected.

Non-point source -- a source of water pollution which are induced by natural processes, including precipitation, seepage, percolation, and runoff; and not traceable to any discrete or identifiable source.

Perennial streams -- streams which provides water flow at all times except during extreme drought.

Pesticides -- any herbicide, insecticide, or rodenticide, but does not include non-toxic repellents or other chemicals.

Pre-commercial thinning - the removal of selected trees within an established forest destined for commercial use.

Prescribed burning -- the controlled application of fire as a management tool in forest management.

Reforestation -- the successful reestablishment of tree species following harvest.

Silvicultural practices -- all forest management practices, including the establishment, composition, constitution, and growth of forests.

Site preparation -- the removal of unwanted vegetation and other material prior to reforestation.

Skid trails -- routes over which logs are moved to a landing or road.

Streamside Management Zone -- an area on each side of the banks and above the head of intermittent streams, perennial streams, and other drains or bodies of water where extra precaution in carrying out best management practices is needed to protect bank edges and water quality.

Waterbar -- a cross drainage diversion ditch and/or hump in a trail or road for the purpose of diverting surface water runoff into roadside vegetation, duff, ditch, or dispersion area to minimize the volume and velocity which can cause soil movement and erosion.

Wetlands -- geographic areas that are inundated or saturated by surface or groundwater at a frequency or duration sufficient to support (and under normal circumstances do support) a prevalence of vegetation typically adapted for life in saturated soil conditions.

Wing ditch -- a water turnout or diversion ditch constructed to move and disperse water away from the road and side ditches into adjacent undisturbed areas so that the volume and velocity of water is reduce on slopes.

Yarding -- the method of log transport from the harvest area to the storage area.

BROAD BASED DIPS

Definition:

A dip and reverse slope in a truck road surface with an outslope in the dip for natural cross drainage.

Purpose:

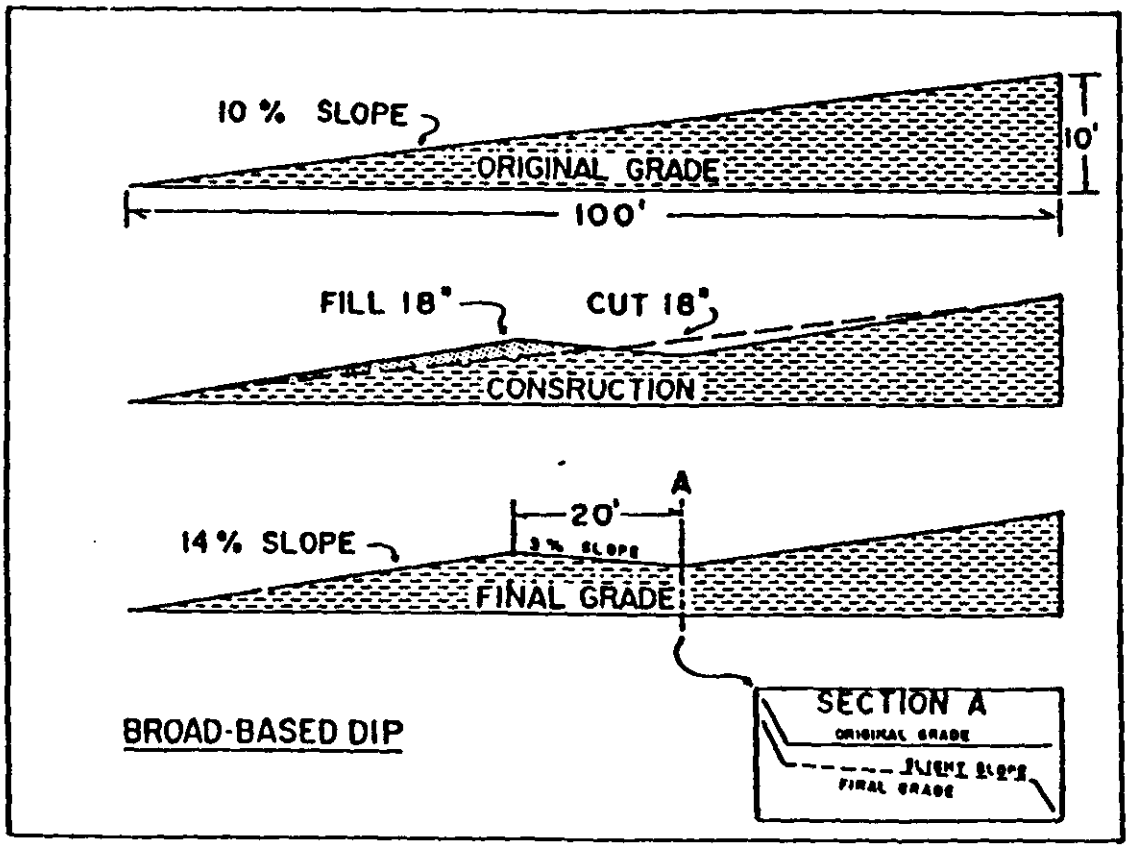
To provide cross drainage on insloped truck roads to prevent build-up of excessive surface runoff and subsequent erosion.

Conditions Where Practice Applies:

Use on truck roads and heavily used skid trails having a gradient of 10% or less. May be substituted for other cross drainage structures where no intermittent or permanent streams are present.

Guidelines:

* Proper construction requires an experienced bulldozer operator.
* Installed after the basic roadbed has been constructed and before major hauling use.



- On grades steeper than 8%, surface dips with stone (approx. 3" diameter) or gravel.
- Use dips on approaches to steep declines in heavily used skid trails.
- Discharge area should be protected with stone, grass sod, heavy litter cover or slash and logs to reduce the velocity and filter the water.

SPACING FOR BROAD BASED DIPS

Road Grade (percent)	Spacing Between Dips (feet)
2	300
4	200
6	165
8	150
10	140
12	130

WATER BARS

Definition:

An earthen or reinforced berm constructed across a truck road or skid trail.

Purpose:

To intercept and divert water from side ditches and truck road or skid trail surfaces, therefore minimizing erosion by decreasing the slope length of surface water flow.

Conditions Where Practice Applies:

Utilized on any sloping truck road or skid trail where surface water runoff may cause erosion.

Guidelines:

* Start placement of water bars at the farthest skid trail and work back to the log landing and then to the truck road.
* Install water bars with a skidder blade, dozer blade, or by hand.
* Install water bars at the top of any sloping road or trail and at proper spacing along steep sections.

* Water bars may be shallow or deep depending on the need.

* Soil should be left along the lower side of the water bar.

* Should be constructed at a 30° - 35° angle downslope from a line perpendicular to the direction of the truck road or skid trail.

* Should drain at a 3% outslope onto undisturbed litter or vegetation.

* The uphill end of the water bar should extend beyond the side ditch line of the road or trail to fully intercept any water flow.

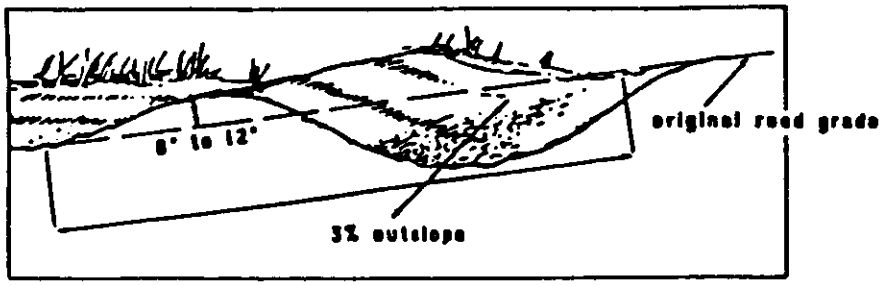
* The downhill end of the water bar should be fully open and extended far enough beyond the edge of the road or trail to disperse runoff water onto undisturbed forest floor.

* Place rocks, slash, or logs to disperse water coming from a water bar.

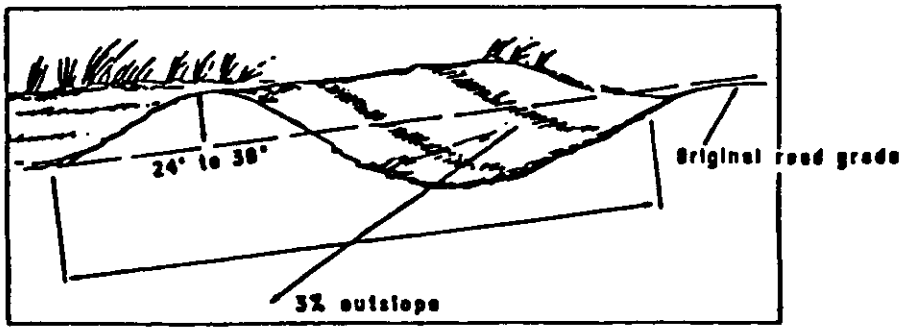
* If the road or trail is to be kept open after the harvesting operation, the following guidelines should be used in order to preserve effective water bars.

  - Reinforce the water bars
  - Keep travel to a minimum
  - Use only in dry weather
  - Make frequent inspections
  - Maintain as needed

SHALLOW WATER BAR



DEEP WATER BAR



SPACING FOR WATER BARS

Road/Trail Grade (percent)	Spacing Between Water Bars (feet)
2	250
5	135
10	80
15	60
20	45
30	35

CROSS DRAINAGE CULVERTS

Definition:

Corrugated pipe, well casing, dredge pipe, or other suitable material placed under a truck haul road or major skid road to transmit ditch runoff and seeps from a drainage area of less than 10 acres.

Purpose:

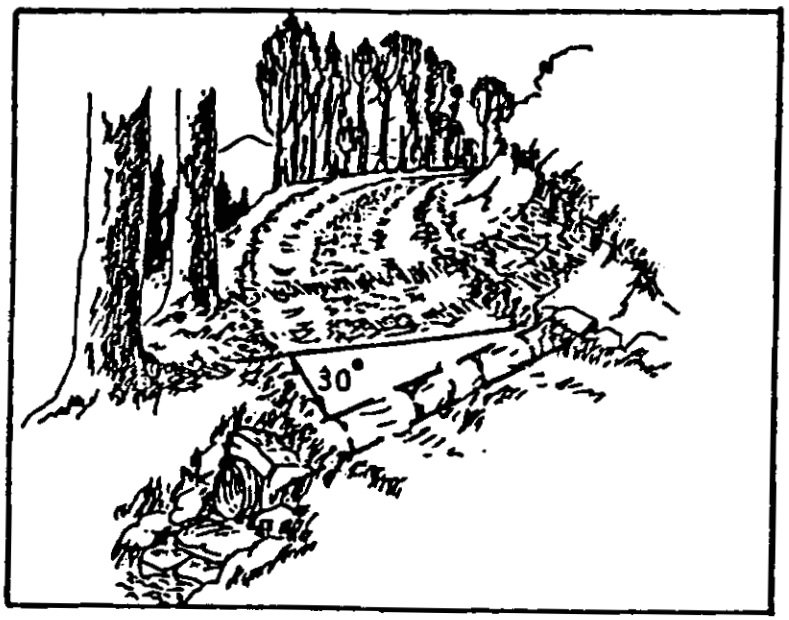
To collect and transmit water flows from side ditches and seeps, under truck haul roads and major skid trails safely without eroding a drainage system or road surface.

Conditions Where Practice Applies:

For any size operation where cross drainage of storm water is required temporarily or permanently.

Guidelines:

* This is the most expensive method of road cross drainage and should be used where heavy road use is anticipated during and after the harvesting operation.



* When sizing culverts for temporary roads, allow for periods of high flow, such as spring runoff or cloudbursts.

* The minimum size culvert to be installed is 12 inch diameter and 20 feet in length.

- When constructing roads on sidehill locations, ditch uphill side of the roadway to intercept surface runoff.

- Allow inlet end of culvert to extend into side ditch so that it intercepts water flowing in the ditch. Construct a berm across the side ditch to assist in diverting water into the culvert.

- Allow outlet end of culvert to extend beyond any fill and empty onto an apron of rock, gravel or logs.

- Space culverts according to road grade:

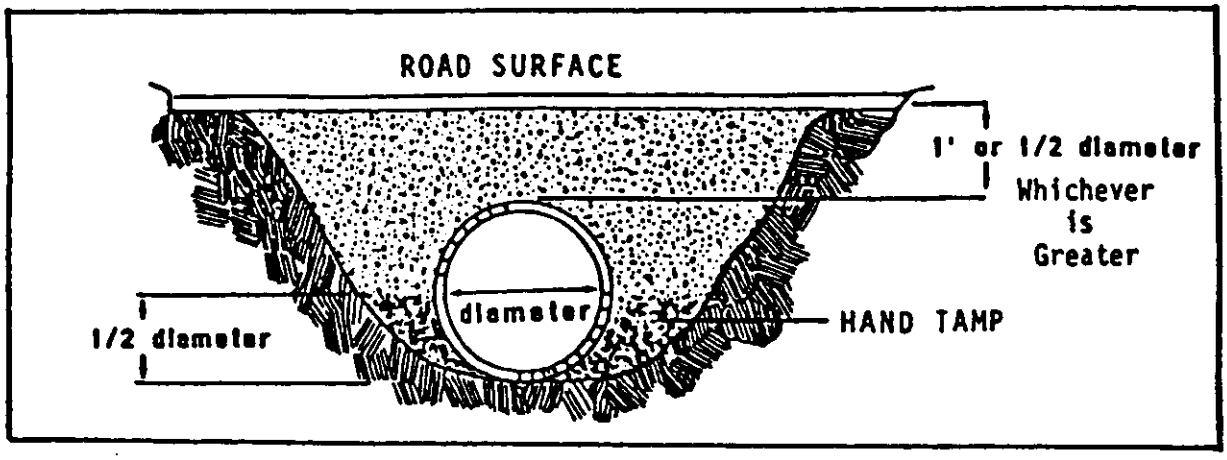
On gentle slopes (1-2%)	300 feet
On moderate slopes (3-10%)	150 feet
On steep slopes (10%+)	100 feet or less

- Culverts should be installed at a 30-35 degree angle downgrade.

- Culverts should be sloped at least 5 inches for every 10 feet of length to permit self-cleaning.

- When harvesting operation has been completed, the road should be stabilized by installing water bars and removing all pipe culverts from truck roads which will not be maintained.

- Culverts, when not maintained, are very likely to become blocked with rocks, ice or other debris. Runoff water can become rerouted over and around the culvert and may wash out sections of road into brooks, streams, ponds or wetlands. It is important to clean culverts regularly. Check after every storm.



- Culvert size selection should be based on the size of the drainage area of a forested watershed and should be able to handle the largest flows.

- Estimating drainage area by taking measurements on a USGS topographic map, using contour lines to define the drainage limits. The Soil Conservation Service can assist you with determination of drainage area.

OPEN TOP CULVERTS

Definition:

A wooden culvert placed across truck haul roads to convey surface runoff and side ditch flows across to downslope side.

Purpose:

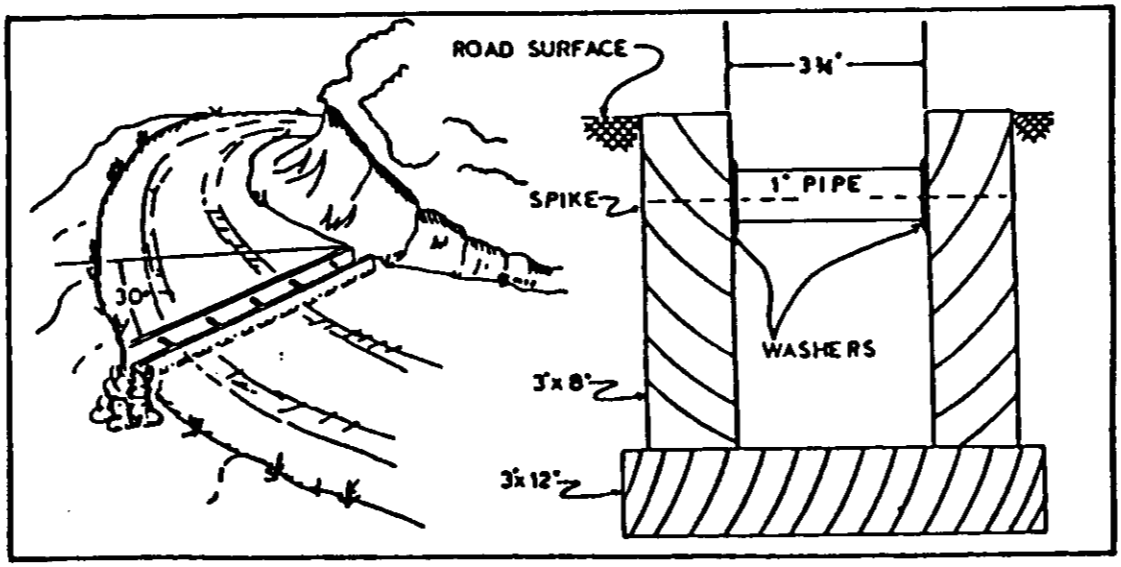
To collect and direct road surface storm runoff and upslope side ditch flows across road without eroding drainage system or road surfaces.

Conditions Where Practice Applies:

This is a temporary drainage structure for on-going harvesting operations. Property built and maintained, it can be used for cross drainage on roads of smaller operations as a substitute for a pipe culvert. This practice should not be used for handling intermittent or live streams or skid trail cross drainage.

Guidelines:

* Can be constructed of cull logs or from sawn lumber. If made of durable wood or treated material, these culverts will give many years of service.



- To be installed flush with the road surface and skewed at an angle not less than 30 degrees downgrade.
- Allow the inlet end to extend into the cut slope or side ditch so that it intercepts water.
- Allow outlet end to extend beyond any fill and empty onto an apron of rock, gravel or logs.
- Open top culverts must be cleaned regularly to remove sediments, gravel, and logging debris to allow normal function of structure at all times.

SPACING FOR OPEN TOP CULVERTS

Road Grade (percent)	Spacing Between Culverts (feet)
2	300
4	200
6	165
8	150
10	140
12	130

road construction applications

OUTSLOPING

Definition:

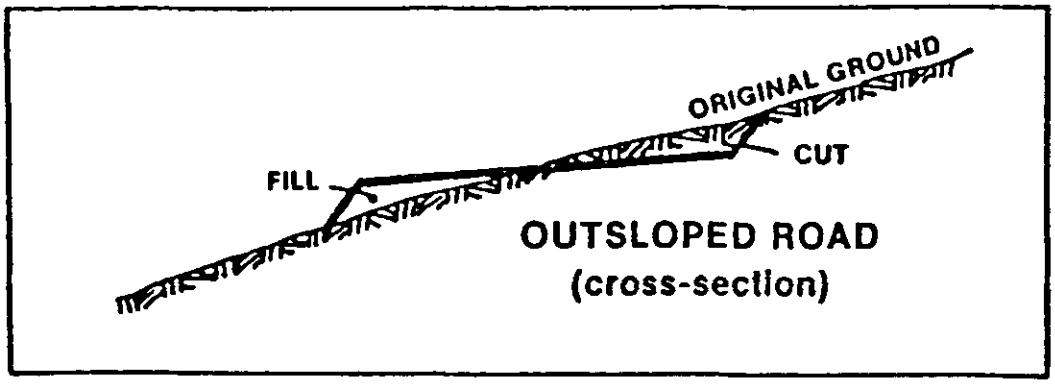
A section of road is sloped slightly (1-3%) from the cut bank to the outside edge of the road bed.

Purpose:

Effective way of limiting erosion because water is removed from the road surface quickly and diverted on to the forest floor.

Condition Where Practice Applies:

Used when the area is entirely rock, or when water can be diverted on to undisturbed forest floor.



INSLOPING

Definition:

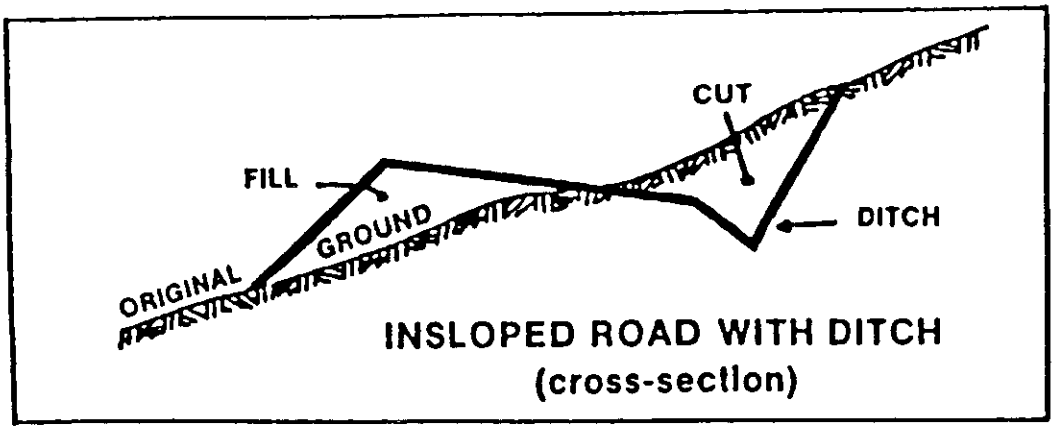
A section of road is sloped slightly (1-3%) toward the cut bank.

Purpose:

Effective way of limiting erosion because water is removed from the road surface quickly and diverted directly to the inside ditch which will carry the water into a culvert.

Condition Where Practice Applies:

Used when the soils are easily saturated or highly erodible. This will limit the amount of ditch water which will flow on to unstable fills.



INSLOPED ROAD WITH DITCH
(cross-section)

CROWNING

Definition:

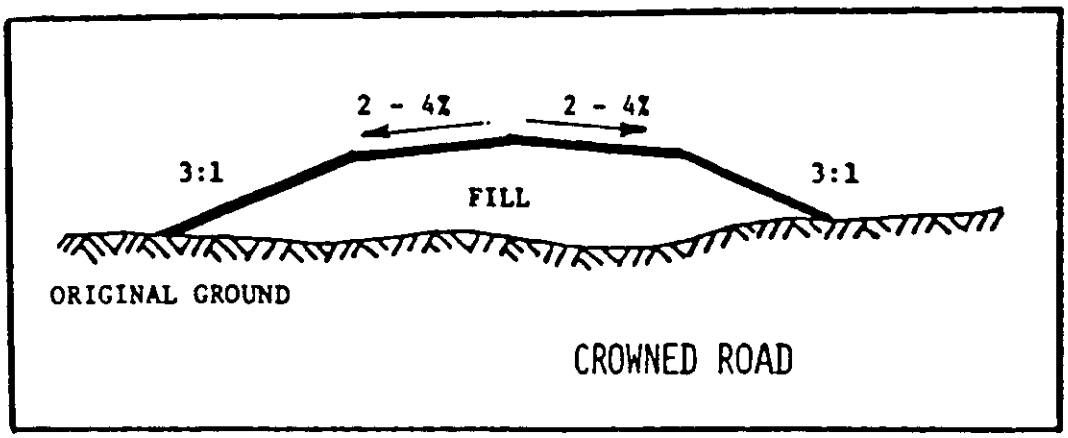
A section of road is sloped slightly (2-4%) from the center line of the road to the outside edges of the roadbed.

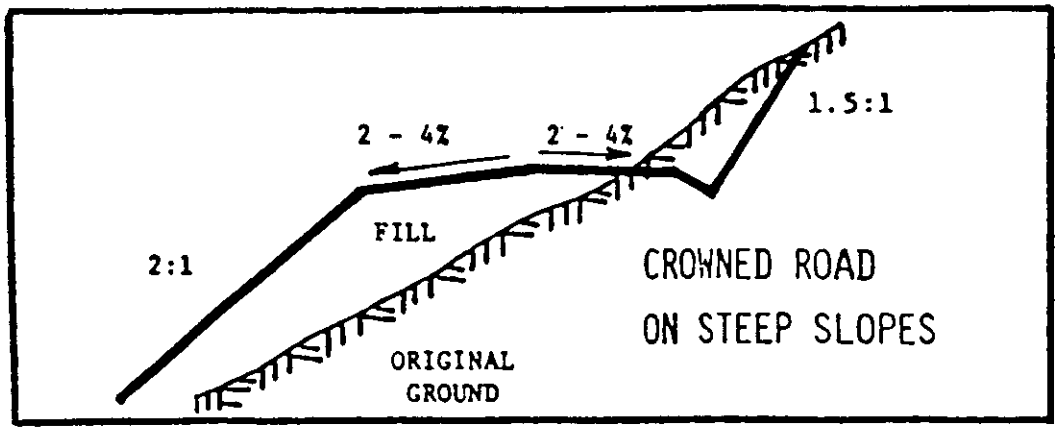
Purpose:

Effective way of limiting erosion because water is removed from the road surface quickly and diverted directly onto the forest floor or into a ditch which will carry the water into a culvert.

Conditions Where Practice Applies:

Used when soils are easily saturated or highly erodible when adjacent areas are relatively level with roadbed or on steep side hills.





streamside management zone

STREAMSIDE MANAGEMENT ZONE

Streamside Management Zones (SMZs) should be maintained along all perennial streams or where forest disturbances occur and surface runoff will carry sediment loads. SMZs should be maintained around streams, ponds, perennial flowing natural springs, and all springs and reservoirs serving as domestic water supplies.

The width of SMZs should be varied, depending on the following conditions: slope of land adjacent to stream, soil erodibility, precipitation, knowledge of particular area, sensitivity of stream, etc. These factors can be obtained from soil maps, on-the-ground evaluation and measurements, weather data, etc.

SMZs should be designed on a case-by-case basis. Most important is that SMZs be consistent with stream characteristics and wide enough to protect water quality.

The following is offered as a guideline:

Soil Type	Percent Slope	SMZ Width (each side)
Slightly erodible	0-5	35'
Slightly erodible	5-20	35-50'
Slightly erodible	20+	50-160'
Erodible	0-5	35-50'
Erodible	5-20	80' minimum
Erodible	20+	160' minimum

[NOTE: Please contact your local Natural Resources Conservation Service office to determine the erodibility factor of the soil before determining the proper width of the SMZ.]

available assistance

Available Assistance

Department of Land & Natural Resources
Division of Forestry and Wildlife
1151 Punchbowl Street, Room 325
Honolulu, HI 96813
Telephone: (808) 587-0166 Facsimile: (808) 587-0160

Hawaii Branch

P.O. Box 4849
Hilo, HI 96720-0849
Telephone: (808) 974-4221
Facsimile: (808) 974-4226

Maui Branch

54 High Street
Wailuku, Hi 96793
Telephone: (808) 984-8100
Facsimile: (808) 984-8111

Oahu Branch

2135 Makiki Heights Drive
Honolulu, HI 96822
Telephone: (808) 973-9778
Facsimile: (808) 973-9781

Kauai Branch

3060 Eiwa Street, Rm. 306
Lihue, HI 96766-1875
Telephone: (808) 274-3433
Facsimile: (808) 274-3438

Natural Resources Conservation Service
Prince Kuhio Federal Bldg., Rm 4-118
Honolulu, HI 96850
Telephone: (808) 541-2600

Hawaii District Offices

Hilo Office
154 Waianuenue Avenue
Hilo, HI 96720
Telephone: (808) 961-5502

Kealakekua Office
P.O. Box 636
Kealakekua, HI 96750
Telephone: (808) 322-2484

Kamuela Office
P.O. Box 1089
Kamuela, HI 96743
Telephone: (808) 885-6602

Pahala Office
P.O. Box 807
Pahala, HI 96777
Telephone: (808) 928-6185

Natural Resources Conservation Service, cont'd.

Maui District Offices

Wailuku Office
70 S. High Street
Wailuku, HI 96793
Telephone: (808) 2444-3729

Molokai Office
P.O. Box 376
Kaunakakai, HI 96748
Telephone: (808) 567-6530

Kauai District Office

Lihue Office
4334 Rice Street, Rm. 104
Lihue, HI 96766
Telephone: (808) 245-6513

Consulting Foresters

Contact the Division of Forestry and Wildlife at (808) 587-0166 for the latest list.

NOTES

Suggested Readings

1. "Logging Roads and Skid Trails, A Guide for Soil Protection and Timber Access," Indiana Department of Natural Resources - Division of Forestry, 21 pp.

2. Dellberg, Robert A., "Road Building for Small Private Roads," Mendocino County Resource Conservation District, Ukiah, CA., July 1992, 73 pp.

3. Walbridge, T.A. Jr., "The Direct Location of Forest Roads," Virginia Polytechnic and State University, Blacksburg, VA., 1990, 70 pp.

4. Walbridge, T.A. Jr., "The Paper Location of Forest Roads," Virginia Polytechnic and State University, Blacksburg, VA., 1990, 75 pp.

5. Walbridge, T.A. Jr., "Field Tables for the Direct Location of Forest Roads," Virginia Polytechnic and State University, Blacksburg, VA., 1991, 15 pp.

6. Wenger, Karl F., "Forestry Handbook, Second Edition," Society of American Foresters, 1984, 1,335 pp.

7. "Erosion and Sediment Control Guide for Hawaii," Soil Conservation Service, 1981, 178 pp.

A TIMBER INVENTORY OF THE

WAIAKEA TIMBER MANAGEMENT AREA

Michael Constantinides

Ronald J. Cannarella

Honolulu, Hawaii
May, 1999

Supported by:

The USDA Forest Service Economic Recovery Program
The Hawaii Forestry and Communities Initiative
The Division of Forestry and Wildlife

Executive summary:

In 1997, the first comprehensive inventory of timber resources in the Waiakea Timber Management Area (WTMA) was conducted. Primary survey objectives included producing accurate forest type maps, estimating wood volume, and providing training for field crew members in timber inventory methodology.

Mapping efforts revealed that the WTMA was comprised of 228 timber stands, 28 forest types, and occupies 12,043 acres. Sampling was conducted on a systematic grid of fixed radius plots over the entire landscape. The grid was intensified in high volume *Flindersia brayleyana* stands to provide stronger estimates for this species of special commercial interest.

The sum of merchantable volume in all forest types exceeded 16,300,000 cubic feet, or approximately 81,500,000 board feet assuming a conversion factor of five board feet per cubic foot. The survey intensity and resulting volume and value analyses of this study were designed to provide guidelines for long-term forest management, and were not intended to be the sole basis for conducting timber sales.

Various eucalyptus species and Queensland maple appear to be well suited to the growing conditions found in the WTMA. Mean annual increment (MAI) values for these species ranged between 150-500 ft^3 $acre^{-1}$ $year^{-1}$. *Toona ciliata* and *Fraxinus uhdei* are not well adapted to site conditions within the WTMA, with mean annual increments typically less than 25 ft^3 $acre^{-1}$ $year^{-1}$.

Introduction:

From June to October, 1997, the Hawaii Forestry and Communities Initiative (HFCI) timber survey crew conducted an inventory of timber resources located within the Waiakea Timber Management Area (WTMA). The primary objectives of the inventory were to provide:

1. Accurate forest type maps.
2. Volume estimates of commercial timber resources.
3. Training for the HFCI survey crew in timber inventory methodology.

The WTMA is located along Stainback Highway, on the northeast slopes of Mauna Loa. Elevations within the tract range from approximately 380-3200 feet. Rainfall exceeds 200 inches per annum at lower elevations, and gradually declines with increasing elevation. A majority of the WTMA is situated on relatively recent lava flows (less than 1,500 years old), and surface soils are typically rocky with only a few inches of mineral soil. Surface soils can be broadly categorized as aa lava, pahoehoe lava, or mineral. The latter occurred in areas of older and more weathered lava flows, areas of ash accumulation from a past eruption of Puu Makaala, or depressions with accumulation of mineral sized soil particles.

Originally comprised of wet ohia (*Metrosideros polymorpha*) - hapuu (*Cibotium* spp.) forests, most areas within the WTMA were cleared by bulldozer in the mid-1960's and converted to plantations of commercial non-native hardwood species. Most hardwoods were planted using a 10 x 10 foot spacing with the exception of some low-elevation eucalyptus stands that were planted at 8 x 8 foot spacing. Primary planting efforts occurred from 1960-1980, after which harvesting of some *E. saligna* occurred. The latter areas were re-planted with *E. grandis*.

Survey methodology:

Planting maps, harvest maps, satellite imagery and aerial photographs were used to develop initial stand boundaries for the WTMA. During field inventory work, the survey crew verified and updated these boundaries, while concurrently assigning forest types to each stand based on primary commercial species present, age, and stand composition.

Sampling was based on a systematic grid with one point every five acres. Using a random start, sample plots were established at every ninth grid point over the entire landscape. Within *Flindersia brayleyana* stands, sample plots were established at every grid point. Once the initial survey was completed, all timber stands were post-stratified by type, and all plot data were aggregated by forest type for subsequent volume analyses. Additional grid points were randomly selected and sampled to increase the plot sample size in forest types that had inadequate plot representation in the standard grid system.

Circular sample plots were 0.20 acres in size, with a fixed radius of 52.66 feet. All trees larger than 5" diameter at breast height (DBH) were measured as "main plot" trees. Each plot tree was numbered and measured for DBH. Total height was recorded for every fifth tree of each species encountered on the plot. Regeneration data were recorded by tallying all tree stems in a DBH range of 2-5" within a nested 0.10 acre (26.33 feet in radius) "sub-plot."

Three primary overstory, understory, and groundcover species at or near each plot point were recorded in order of decreasing abundance. These data did not represent actual stem counts. All tree species encountered were included in volume analyses, though some may currently be considered non-merchantable (Appendix A). Other descriptive data collected included slope, aspect, surface soil type, and weather conditions.

Survey data were analyzed using Forestry Projection System software version 5.3a (Forest Biometrics, 1998). Gross wood volume calculations represented volume from tree base to tree tip. Merchantable wood volume calculations were based on 16 foot log sections, a minimum top diameter of four inches, a stump height of one foot, and a minimum DBH of eight inches. No defect deductions were applied to volume analyses in this study. Volume calculations were based on data from all cruised stands within each forest type. These data were subsequently used to predict volume in non-cruised stands of the same type.

Three local taper profiles were available for volume analyses of species encountered during this survey, necessitating the use of taper profiles from alternate species and regions (Appendix B).

Survey results:

The post stratified WTMA survey map contained 228 timber stands totaling 12,043 acres (Figure 1). Total merchantable wood volume within the WTMA exceeded 16,300,000 cubic feet (Table 1) in 1997. All mapped stands were stratified into 28 unique forest types based on dominant overstory tree species, age and stand structure, allowing type-level volume summaries (Table 2). Additional detail for type-level volume data are presented in Appendix C. Approximately 51% of total merchantable volume occurred on only 20% of the total acreage in the WTMA (forest type codes of "33" or higher). These stands contained a high proportion of total volume due to relatively high tree stocking and large tree size. The remaining 49% of total merchantable volume occurred on 80% of the total acreage in the WTMA (forest type codes of "22" or lower). The latter forest types included stands that had poor survival or growth, were poorly stocked, were recently planted, or were cut over. If the entire inventory of trees within the WTMA were harvested at once and cut into sixteen foot logs, total merchantable wood in log diameter classes of 4-8", 8-12", and 12+" would equal 7,163,586, 5,473,901, 3,681,865 cubic feet, respectively (44%, 34%, and 23% of total merchantable volume, respectively).

Table 1. Total merchantable wood volume summary for WTMA timber resources. Values in parentheses represent nearest whole percentages of area and volume totals.

Species	Total Acres	Total merchantable volume (ft^3)
Eucalyptus robusta	227 (2)	1,007,433 (6)
E. saligna & E. grandis	3,749 (31)	8,180,306 (50)
E. deglupta & E. pilularis	54 (0)	88,711 (1)
Flindersia brayleyana	1,485 (12)	2,557,756 (16)
Toona ciliata	3,500 (29)	2,682,282 (16)
Fraxinus uhdei	2,060 (17)	1,128,586 (7)
Cryptomeria japonica	102 (1)	30,798 (0)
Alnus nepalensis	24 (0)	110,855 (1)
Metrosideros polymorpha	205 (2)	167,113 (1)
Acacia koa	272 (2)	327,086 (2)
Experimental Hardwoods	28 (0)	38,427 (0)
Out or Non-stocked	17 (0)	0 (0)
Block Roads	320 (3)	0 (0)
Total	12,043	16,319,353

Differentiation between *Eucalyptus saligna* and *E. grandis* proved to be very difficult during the field survey – particularly for trees younger than 15 years of age. Many *E. saligna* stands were harvested and re-planted to *E. grandis* in the mid-1980's. Numerous trees that were sampled and identified as *E. saligna* in these stands were undoubtedly *E. grandis*. Taper profiles for these two species are very similar, and we expect volume differences to be minor.

Figure 1. Timber stands represented by primary overstory species in the WTMA.

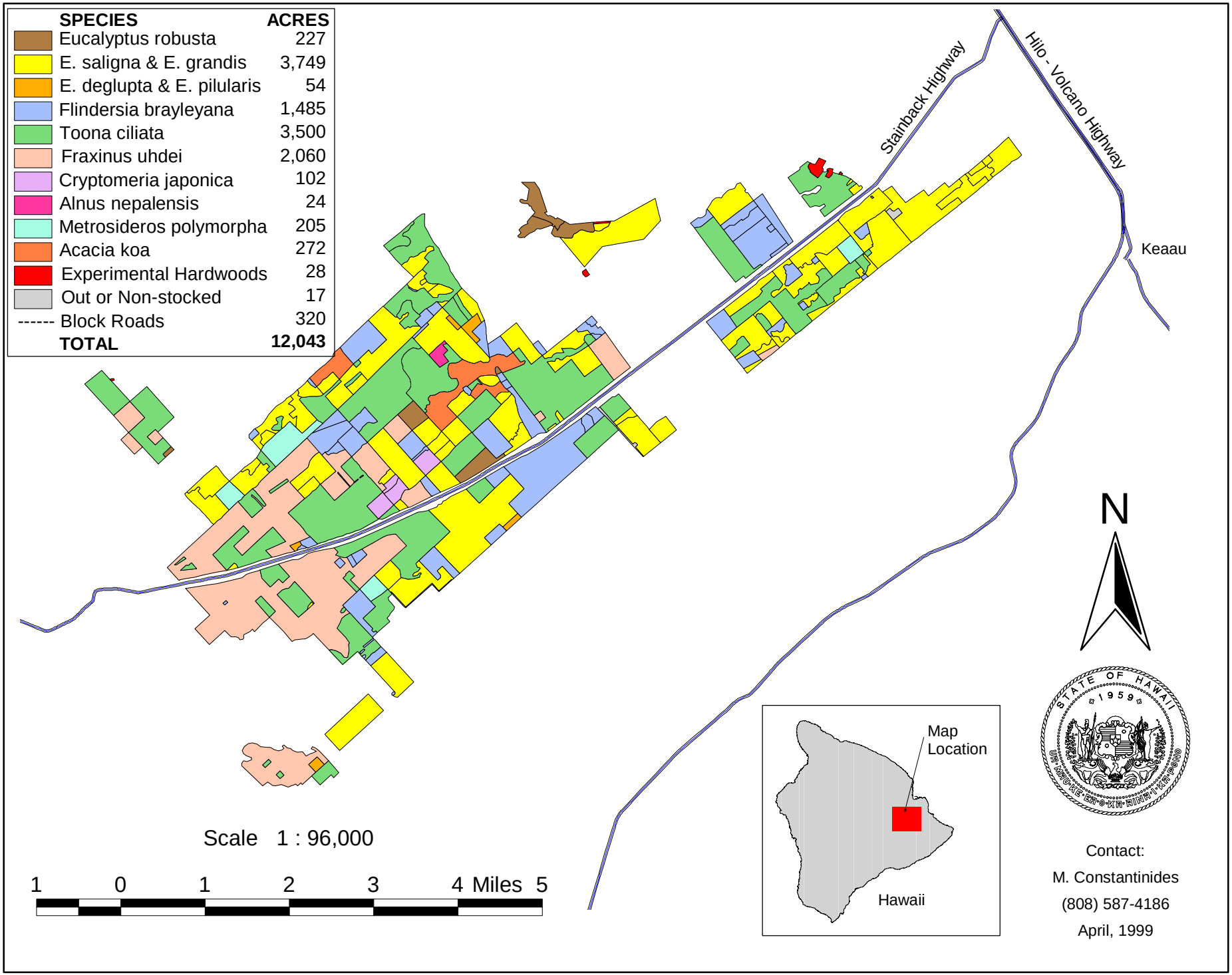


Table 2. Descriptive statistics for timber types in the WTMA. Age data represent original planting date, while stocking and DBH data represent all tree species with a minimum DBH of 2 inches. Maximum DBH data represent planted, non-native trees only.

Species & Type	Description	Net Acres	Age in Years	Stocking Trees ac^{-1}	DBH Range	Mean DBH	--Mean ft^3 ac^{-1}-- Gross	Merch	Total merchantable volume (ft^3) by log minimum diameter class 4-8"	8-12"	> 12"	Row Sub-Totals
Flindersia brayleyana												
FB00	Recent plantings / sapling stands	242	1-15	256	2-17	6	742	481	91,682	14,418	10,306	**116,407**
FB11	Low volume pole and saw timber	715	28-35	161	2-23	8	1,095	901	282,010	236,022	125,904	**643,936**
FB22	Low to moderate volume pole and saw timber	114	28-31	221	2-30	10	2,782	2,442	95,683	96,576	85,164	**277,424**
FB33	Moderate volume pole and saw timber	171	32	208	2-27	11	3,808	3,447	170,624	238,173	181,978	**590,775**
FB44	High volume pole and saw timber	120	32	255	2-28	12	5,649	5,214	203,486	265,708	158,616	**627,810**
FB55	Similar to FB33 with 20% volume as Toona ciliata	123	29	153	2-29	11	2,716	2,460	86,411	112,601	102,392	**301,404**
Sub-Total FB:		**1,485**							**929,896**	**963,499**	**664,361**	**2,557,756**
Eucalyptus saligna and grandis												
ES00	Recent plantings / sapling stands	113	5-8	314	2-10	5	478	206	13,613	3,145	5,898	**22,655**
ES11	Cut over, or low volume pole and saw timber	730	12-30	192	2-28	7	1,141	913	307,493	197,181	161,797	**666,470**
ES22	Low to moderate volume pole and saw timber	1447	11-31	280	2-26	7	2,119	1,653	1,313,800	853,728	224,350	**2,391,877**
ES33	Moderate volume pole and saw timber	1057	29	279	2-31	8	3,498	3,105	1,289,546	1,270,558	729,895	**3,289,999**
ES44	High volume pole and saw timber	185	14	241	2-19	11	6,243	5,699	443,557	473,387	136,282	**1,053,226**
ES55	Moderate volume saw timber	218	28	117	2-29	12	3,710	3,476	153,420	238,481	364,177	**756,078**
Sub-Total ES:		**3,749**							**3,521,429**	**3,036,479**	**1,622,397**	**8,180,306**
Eucalyptus robusta												
ER22	Low to moderate volume pole and saw timber	44	30	50	8-31	18	2,663	2,564	15,781	27,897	68,374	**112,051**
ER33	Moderate volume pole and saw timber	87	31-53	163	2-42	11	3,536	3,305	45,406	63,642	179,507	**288,556**
ER55	Moderate volume saw timber	57	53	208	2-40	12	4,814	4,475	49,946	59,546	146,017	**255,509**
ER66	High volume saw timber	39	59	219	2-37	16	9,541	9,078	65,106	81,882	204,329	**351,317**
Sub-Total ER:		**227**							**176,240**	**232,967**	**598,226**	**1,007,433**
Eucalyptus deglupta and pilularis												
ED11	Cut over, or low volume pole and saw timber	20	29	88	2-9	6	354	184	1,507	755	1,489	**3,752**
ED22	Low to moderate volume pole and saw timber	34	29	156	2-17	10	2,825	2,499	23,020	29,717	32,221	**84,959**
Sub-Total ED:		**54**							**24,527**	**30,473**	**33,711**	**88,711**
Toona ciliata												
TC11	Low volume pole and saw timber	3,178	30-35	263	2-24	6	873	595	1,088,854	487,061	314,593	**1,890,508**
TC22	Low to moderate volume pole and saw timber	69	30	199	2-15	9	1,986	1,698	73,634	43,879	0	**117,513**
TC33	Moderate volume pole and saw timber	253	30-35	239	2-20	9	3,023	2,667	309,814	255,219	109,229	**674,262**
Sub-Total TC:		**3,500**							**1,472,301**	**786,159**	**423,822**	**2,682,282**

Table 2. Continued.

Species & Type	Description	Net Acres	Age in Years	Stocking Trees ac^{-1}	DBH Range	Mean DBH	--Mean ft^3 ac^{-1}-- Gross	Merch	Total merchantable volume (ft^3) by log minimum diameter class 4-8"	8-12"	> 12"	Row Sub-Totals
Other species												
FU11	Low volume tropical ash pole and saw timber	2,060	34	348	2-18	5	902	548	855,304	250,770	22,512	**1,128,586**
AN33	Moderate volume Nepal alder pole and saw timber	24	30	154	2-27	14	4,956	4,677	30,245	41,110	39,500	**110,855**
CJ00	Recent Sugi plantings / sapling stands	102	7-10	395	2-14	5	618	303	17,333	4,039	9,426	**30,798**
AK11	Low volume koa pole and saw timber	272	NA	Native species			1,296	1,204	63,272	70,620	193,194	**327,086**
MP22	Low volume ohia pole and saw timber	205	NA	Native species			978	817	58,435	45,139	63,538	**167,113**
XH33	Moderate volume experimental hardwoods	28	38	Experimental species			1,512	1,387	14,603	12,646	11,178	**38,427**
Sub-Total other species:		**2,689**							**1,039,192**	**424,324**	**339,348**	**1,802,864**

Total forested acreage: **11,704**

Merchantable volume summary:
Cubic foot totals by log diameter and timber type class.

Type Class	Acres	----Log minimum diameter---- 4-8"	8-12"	> 12"	Total
00	456	122,629	21,602	25,630	169,860
11	6,975	2,598,440	1,242,408	819,490	4,660,338
22	1,912	1,580,353	1,096,936	473,647	3,150,937
33	1,620	1,860,237	1,881,348	1,251,287	4,992,872
44	305	647,043	739,095	294,897	1,681,036
55	397	289,777	410,628	612,586	1,312,992
66	39	65,106	81,882	204,329	351,317
Total	11,704	7,163,586	5,473,901	3,681,865	16,319,352

Volume results expressed in units of mean cubic feet per acre were derived from statistical sampling, and are therefore estimates. Standard error (SE) analysis provides one tool for assessing the strength of the field survey data. Because sampling intensity was proportional to area, volume analyses for larger forest types were based on a larger number of sample plots. In forest types with codes of "33" or more, standard error values rarely exceeded 10 percent of the mean, except in smaller types (Table 3). In forest types with codes of "22" or less, standard error values commonly exceeded 10 percent of the mean due to factors such as a small number of sample plots, or relatively heterogeneous stand conditions. Confidence intervals offer a second approach for analyzing cruise precision (Table 3). The reported confidence intervals represent ranges of gross volume per acre that are 80% likely to contain the true mean volume per acre for each forest type.

While stands were assigned to forest types based on the dominant overstory species, type level volume data also included components of secondary species. Most forest types had three or fewer principal species components (Table 4). *Toona ciliata* was a common secondary overstory species in both *Flindersia brayleyana* and *Eucalyptus saligna* stands, while ohia was evenly distributed throughout the entire WTMA (Figure 2). Though sparse in distribution, the remaining *Acacia koa* were concentrated near the north end of Flume Road.

Relatively undisturbed blocks of *Metrosideros polymorpha* and *Acacia koa* forest exist in approximately 4% of the total area of the WTMA (Figure 1). Within the remaining non-native timber plantations, large ohia and koa trees were left standing during initial land clearing operations, some of which remain to this day. As a result of this practice, ohia and to a lesser extent koa, were observed as secondary overstory species at 17% and 3% of all sampled points, respectively.

Other tree species observed and measured in minor quantities during the survey included olapa (*Cheirodendron* spp.), loulu palms (*Pritchardia* spp.), iron wood (*Casuarina equisetifolia*), blackwood acacia (*Acacia melanoxylon*), silk oak (*Grevillia robusta*), gunpowder tree (*Trema orientalis*), paperbark (*Melaleuca quinquenervia*) and African tulip tree (*Spathodea campanulata*). Detailed volume and distribution analyses were not conducted for these species due to their scattered occurrence.

Relative abundance data for understory species revealed that *Cibotium* spp. and *Psidium* spp. dominate the forest understory throughout the WTMA. Combined, these two species account for 86% of primary understory species (Figure 3), and 70% of secondary understory species (data not shown) observed at all sample plots. *Psidium cattleianum* is the most common and aggressive species of guava present in the WTMA. *Psidium* spp. appears to be encroaching from lower elevation, and from the South. In a vast majority of cases, where *Psidium* spp. was the primary understory species, *Cibotium* spp. was the secondary understory species, and vice versa. Excluding *Cibotium* spp., native tree and shrub species were recorded as primary and secondary understory species on 3%, and 16 % of sample plots, respectively.

Psidium spp. occurred as the primary groundcover species almost exclusively in well-stocked and mature stands of timber, revealing a relatively strong shade tolerance for this shrub

Table 3. Cruise precision analyses for the WTMA timber inventory. Volume data are presented in gross cubic feet.

Type	Acres	Sample Plots	Mean	SE	% SE	----80 % CI---- Low	High
			-----ft^3 ac^{-1}-----			-----ft^3 ac^{-1}-----	
FB00	242	7	742	294	40	319	1,164
FB11	715	13	1,095	154	14	886	1,304
FB22	114	20	2,782	194	7	2,525	3,040
FB33	171	26	3,808	284	7	3,434	4,182
FB44	120	24	5,649	326	6	5,219	6,080
FB55	123	26	2,716	178	7	2,482	2,951
ES00	113	2	478	19	4	420	535
ES11	730	17	1,141	128	11	970	1,313
ES22	1,447	41	2,119	105	5	1,982	2,255
ES33	1,057	26	3,498	281	8	3,128	3,868
ES44	185	4	6,243	681	11	5,129	7,358
ES55	218	6	3,710	383	10	3,145	4,275
ER22	44	1	2,663	NA	NA	NA	NA
ER33	87	8	3,536	687	19	2,564	4,507
ER55	57	7	4,814	352	7	4,307	5,321
ER66	39	6	9,541	508	5	8,791	10,290
ED11	20	3	354	89	25	185	522
ED22	34	3	2,825	1,370	48	241	5,410
TC11	3,178	71	873	50	6	808	938
TC22	69	1	1,986	NA	NA	NA	NA
TC33	253	6	3,023	447	15	2,363	3,683
FU11	2,060	47	902	37	4	853	950
AN33	24	3	4,956	287	6	4,415	5,497
CJ00	102	3	618	238	39	169	1,067
AK11	272	6	1,296	259	20	914	1,678
MP22	205	4	978	252	26	564	1,391
XH33	28	1	1,512	NA	NA	NA	NA
XX00	17	0	NA	NA	NA	NA	NA
Roads	320	0	NA	NA	NA	NA	NA
Total	**12,042**	**382**					

SE = standard error; % SE = standard error / mean volume per acre * 100
80 % CI = 80 percent confidence interval

FB = Flindersia brayleyana; ES = Eucalyptus saligna & E. grandis; ER = E. robusta
ED = E. deglupta; TC = Toona ciliata; FU = Fraxinus uhdei; AN = Alnus nepalensis
CJ = Cryptomeria japonica; AK = Acacia koa; MP = Metrosideros polymporpha
XH = experimental hardwoods; XX = open or cleared area; NA = not applicable

Table 4. Component merchantable volume for timber types in the WTMA.

		--mean ft^3 ac^{-1}--			----------Component merchantable volume per acre by species* (ft^3 ac^{-1})----------													
Type	**Acres**	**Gross**	**Merch**	**% Merch**	**FB**	**TC**	**MP**	**ES**	**ER**	**ED**	**AK**	**FU**	**TO**	**EM**	**CJ**	**AN**	**MQ**	**OTH**
FB00	242	742	481	65		359	56				17	12					26	11
FB11	715	1,095	901	82	592	83	100				63	59						4
FB22	114	2,782	2,442	88	1,922	100	225		7		10	178						
FB33	171	3,808	3,447	91	3,056	21	235				8	124						2
FB44	120	5,649	5,214	92	5,058	63	94											
FB55	123	2,716	2,460	91	1,756	427	229				46						2	
ES00	113	478	206	43		34	118	54										
ES11	730	1,141	913	80		35	81	729			68							
ES22	1,447	2,119	1,653	78		24	18	1,538	22	2	1	11	38					
ES33	1,057	3,498	3,105	89		146	20	2,810				40	80					7
ES44	185	6,243	5,699	91				5,629					71					
ES55	218	3,710	3,476	94		36	92	3,349										
ER22	44	2,663	2,564	96		1,155			1,410									
ER33	87	3,536	3,305	93			666	1,537	1,015			53					28	5
ER55	57	4,814	4,475	93			118	862	3,041			31		74			349	
ER66	39	9,541	9,078	95				369	8,709									
ED11	20	354	184	52			124			53								7
ED22	34	2,825	2,499	88			469			1,885	144							
TC11	3,178	873	595	68		300	228	5	1		45	10						7
TC22	69	1,986	1,698	86		1,698												
TC33	253	3,023	2,667	88		2,105	10				552							
FU11	2,060	902	548	61		29	28					487						3
AN33	24	4,956	4,677	94			61				193					4,424		
CJ00	102	618	303	49			150					132			24			
AK11	272	1,296	1,204	93		28	725				452							
MP22	205	978	817	84			811											5
XH33	28	1,512	1,387	92			263											1,124
XX00	17	NA	NA	NA														
Roads	320	NA	NA	NA														

*FB = Flindersia brayleyana; ES = Eucalyptus saligna & E. grandis; ER = E. robusta; ED = E. deglupta; TC = Toona ciliata
FU = Fraxinus uhdei; AN = Alnus nepalensis; CJ = Cryptomeria japonica; AK = Acacia koa; MP = Metrosideros polymporpha
TO = Trema orientalis; EM = E. microcorys; MQ = Melaleuca quinquenervia
XH = experimental hardwoods; XX = open or cleared area; NA = not applicable

Figure 2. Secondary overstory species at sample plot locations in the WTMA.

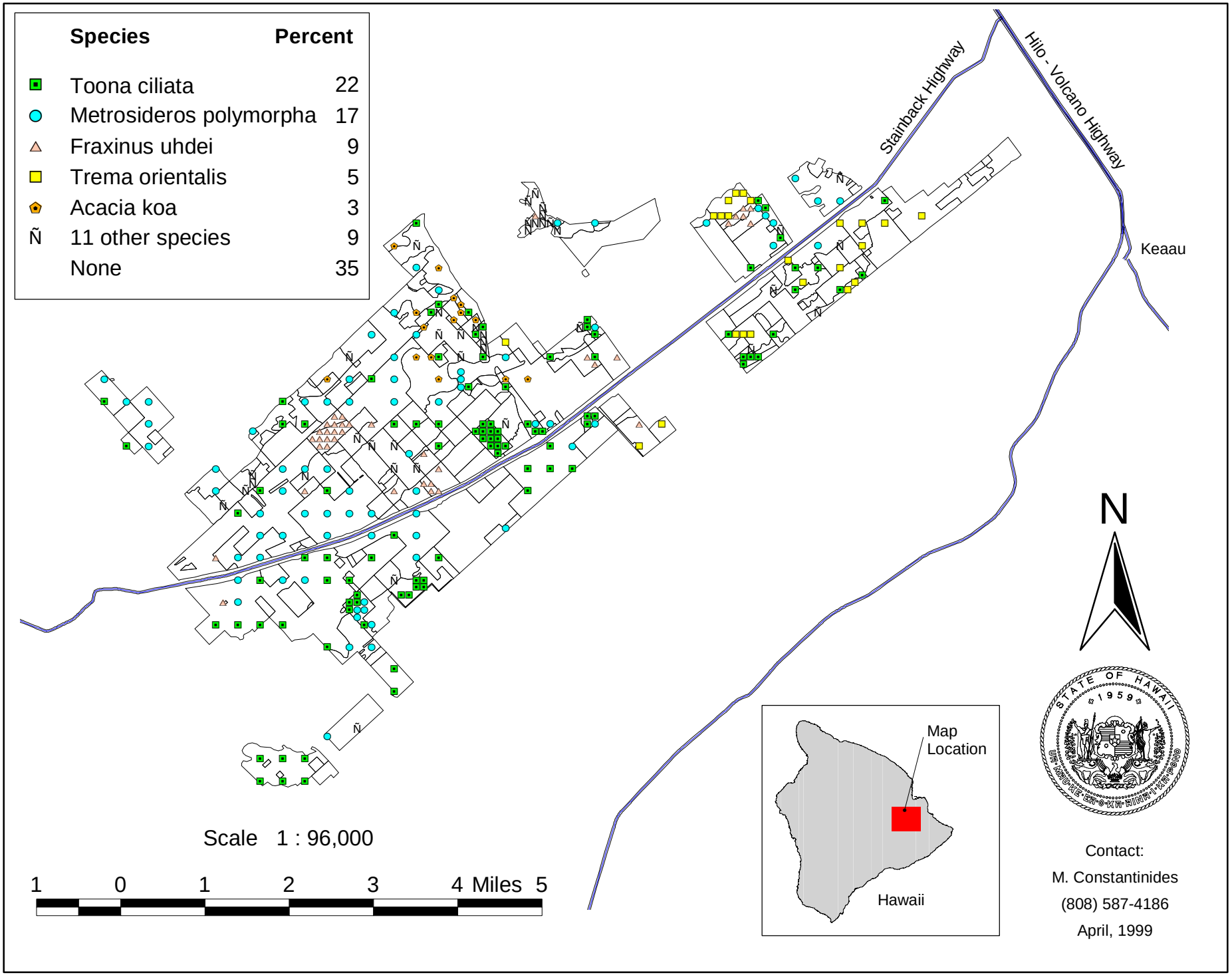
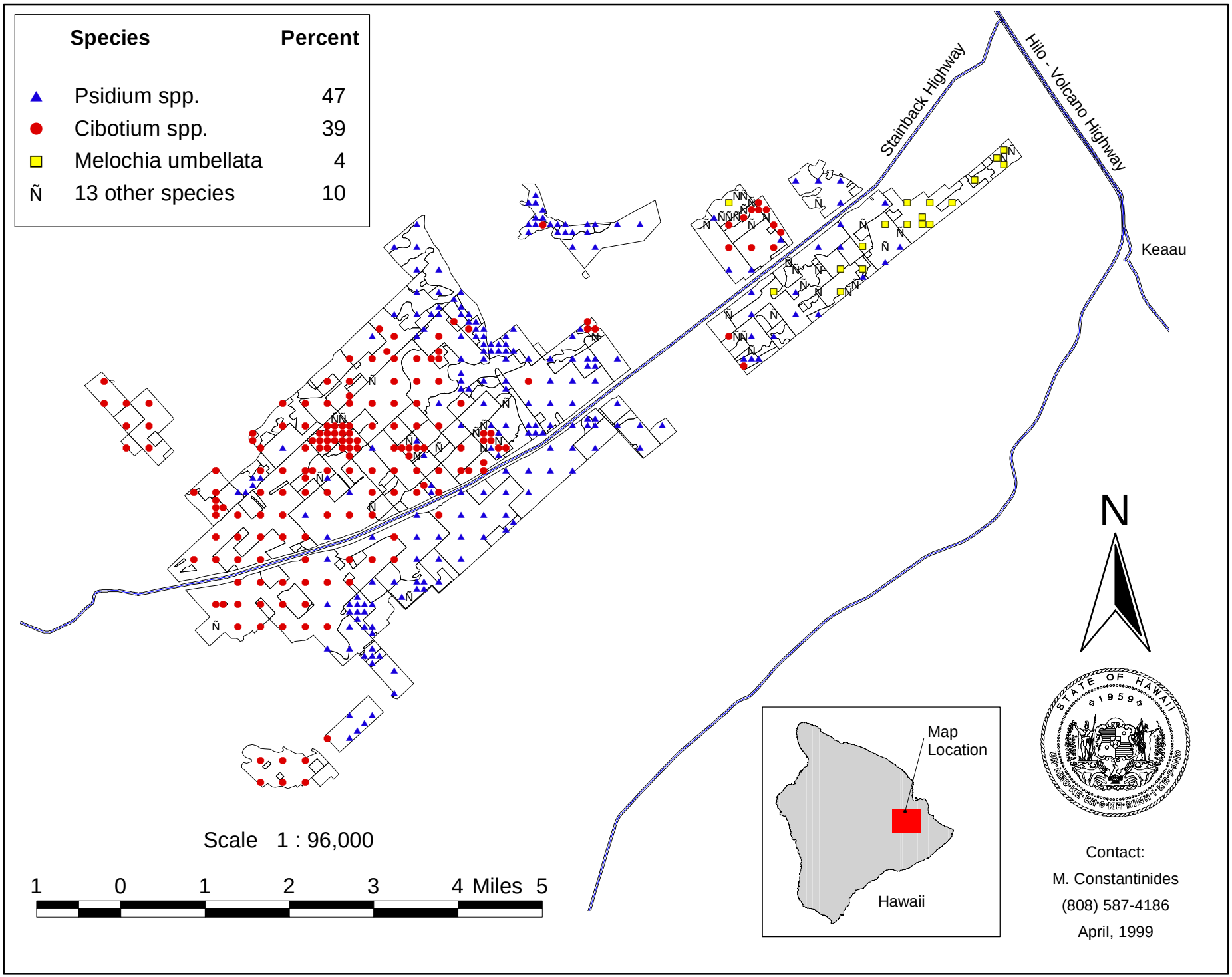


Figure 3. Primary understory species at sample plot locations in the WTMA.



species (Figure 4). In most other areas, *Dicranopteris linearis* dominated the groundcover layer, with the exception of an apparent outbreak of *Setaria palmifolia* in the north-central zone of the WTMA. Excluding *Dicranopteris linearis.*, native tree and shrub species were recorded as primary and secondary understory species on 3%, and 11 % of sample plots, respectively.

The low-elevation zone of the WTMA provided an exception to the understory and groundcover trends discussed above. The lower sites appeared to be a zone of concentration for *Trema orientalis* in the overstory (Figure 2), *Melochia umbellata* in the understory (Figure 3), and *Melastoma* spp. and *Nephrolepis multiflora* in the groundcover layer (Figure 4).

Discussion and planning implications:

The commercial timber plantings within the WTMA exhibited a wide range of growth potential both within, and among species. Site adaptation, surface soil conditions, and site preparation appeared to be the primary factors that influenced stand growth potential. Current within-species productivity differences can not be attributed to varying stand management or maintenance, since little has been implemented historically in the WTMA. However, intensive stand management in future rotations may significantly increase the productivity and yield of timber stands in the WTMA.

In order to compare productivity of different species, representative stands within the most important commercial forest types were selected for mean annual increment (MAI) analyses (Table 5). Among the original and secondary hardwood species planted, the eucalypts were best adapted to site conditions within the WTMA. *E. saligna* and *E. grandis* stands commonly had MAI values ranging from 250 –500 ft^3 ac^{-1} yr^{-1}. Surface soils appeared to be the primary factor influencing within-species differences in MAI. For example, though they had similar ages, stand 10010 was located on relatively deep mineral soil, stand 10200 had mixed aa-mineral soils and included a depression (zone of mineral soil accumulation), and stand 11110 had relatively shallow and rocky surface soils. Stands 10892 and 11380 were older, and were probably in a condition where mortality and residual growth did not differ greatly. Again, we attribute the differences between MAI in the latter two stands to surface soils conditions – 11380 had relatively deep mineral surface soils, while 10892 had primarily aa.

Relatively low MAI values for *E. robusta* may be misleading since most of these stands are the oldest within the WTMA, and had stagnated. Based on visual observations, young *E. robusta* trees often had similar size and vigor as adjacent *E. grandis*. Two stands of *E. microcorys* and *E. pilularis* appeared to be vigorous as well. *E. deglupta* had a relatively moderate MAI value in stand 10430 (Table 5), but scattered individuals at other locations within the WTMA appeared to be fast growing and vigorous.

Queensland maple (*Flindersia brayleyana*) is the most promising non-eucalyptus hardwood from the original WTMA plantings. With the exception of shallow pahoehoe sites, this

Figure 4. Primary groundcover species at sample plot locations in the WTMA.

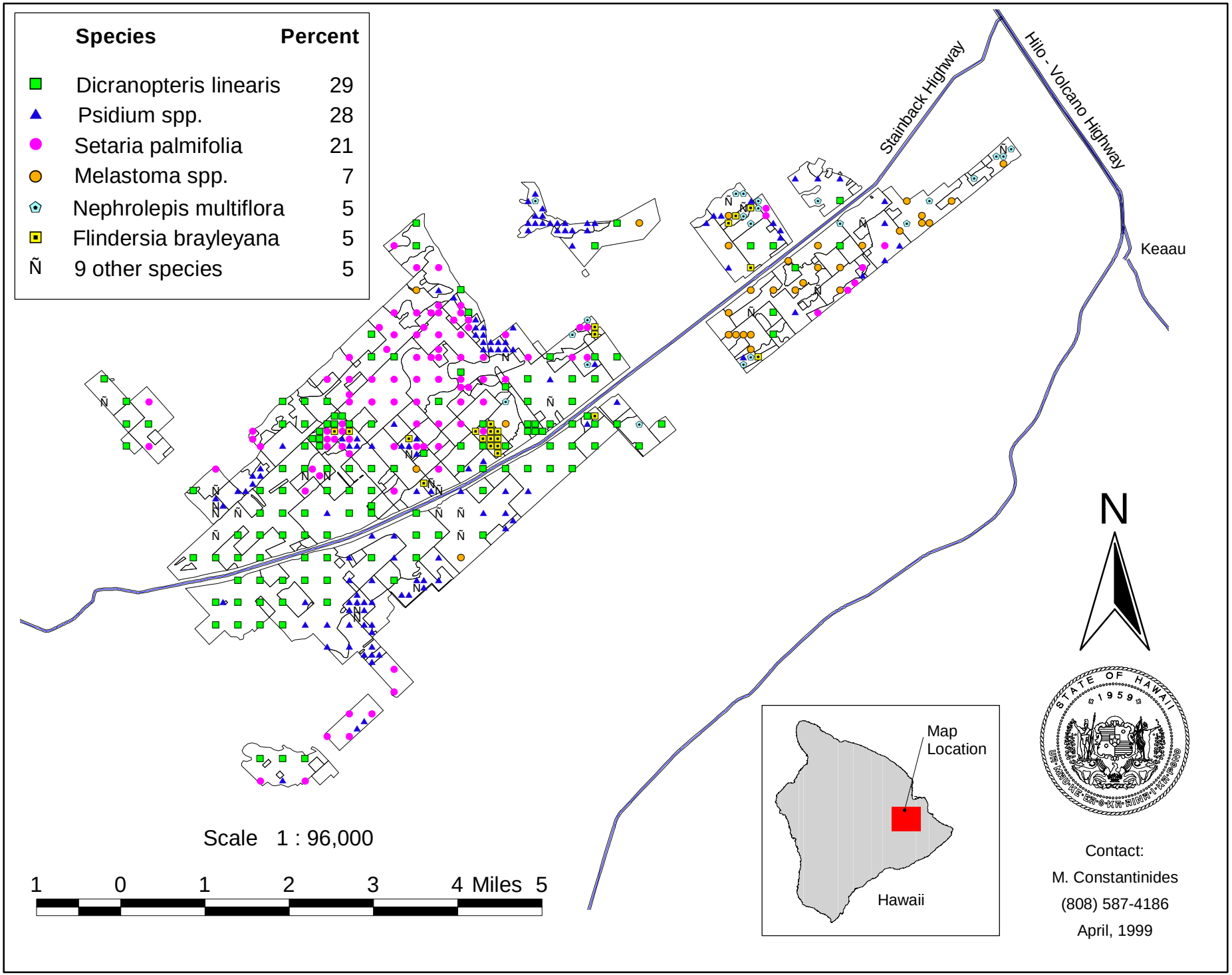


Table 5. Mean annual increment (MAI) analyses for selected stands in the WTMA based on 1997 data. All figures in each species section represent trees of that species only that have a miniumum DBH of two inches.

Species & Type	Stand ID	Net Acres	Plots	Age (Yr)	Trees Per Acre	Maximum DBH	Median DBH	Basal Area (ft^2)	Gross volume ($ft^3\ ac^{-1}$)	MAI ($ft^3\ ac^{-1}\ yr^{-1}$)
Flindersia brayleyana										
FB11	10710	22	4	32	144	17	7	54	1,145	36
FB11	11050	308	7	30	42	18	11	27	563	19
FB22	10680	16	4	31	80	27	12	84	2,194	71
FB33	10711	64	12	32	143	23	11	105	2,935	92
FB33	11331	58	10	32	102	27	14	121	3,662	114
FB44	10581	37	8	31	230	28	10	166	5,085	164
Eucalyptus saligna and E. grandis										
ES22	11110	381	9	10	206	17	7	71	2,665	267
ES33	10200	84	7	11	147	20	10	89	4,574	416
ES33	10892	61	5	27	119	23	10	82	2,896	107
ES44	10010	185	6	14	266	19	10	166	7,090	506
ES55	11380	118	6	29	122	28	11	103	4,552	157
Eucalyptus robusta										
ER33	10610	53	3	31	283	26	4	89	2,068	67
ER55	8138	57	7	53	134	40	6	119	3,245	61
ER66	8134	39	6	59	217	37	11	283	9,163	155
Eucalyptus deglupta										
ED22	10430	23	3	29	125	17	9	66	2,845	98
Toona ciliata										
TC11	10340	390	7	35	137	20	7	45	775	22
TC22	10070	69	1	30	180	15	8	87	1,966	66
TC33	10560	186	4	30	213	20	7	83	2,203	73
Fraxinus uhdei										
FU11	11200	915	19	34	167	17	6	42	690	20
Alnus nepalensis										
AN33	10463	24	3	30	152	27	13	164	4,643	155

species always exhibited vigorous growth once established. However, maple may be more difficult to establish than the eucalypts. Almost without exception, type codes FB33, FB44, and FB55 were comprised of stands where surface soils at sample plots were recorded as aa. This indicates that maple was either intentionally planted on aa sites, or that a unique scarification method was applied to surface soils prior to planting. Many FB11 stands are represented by low stocking and MAI values (e.g. stand 11050, Table 5), suggesting problems with seedling establishment or early weed competition. One area was planted across a surface soil change (Stands 10710 and 10711) from shallow pahoehoe to aa, and the latter stand had MAI that was nearly triple that of the former. Maple is probably the most shade tolerant hardwood planted within the WTMA, and natural regeneration was often prolific under dense canopies. Thinning and uneven-age management of this species merit future research.

The single stand of *Alnus nepalensis* within the WTMA had an MAI value similar to that for the best maple stands. However, this stand appeared to be located on a site having surface soils of above average productivity. Any future attempt to plant *Alnus nepalensis* as a commercial species in the WTM A should be preceded by additional site suitability tests.

Toona ciliata and *Fraxinus uhdei* plantings essentially failed on a large scale. *T. ciliata* showed moderate growth potential only on the best sites (e.g. stand 10560, Table 5). These species otherwise exhibited poor growth, and are not suited to site conditions within the WTMA. *Cryptomeria japonica* trees were too young to evaluate at this time, but field observations indicated that survival and growth rates for 7-10 year old stands of this species have been reasonable. These stands will likely require 35 or more years to reach merchantable size.

Tree DBH ranges and mean DBH values were relatively similar among forest types of the same species (Table 2), suggesting that type differences were directly proportional to stocking differences. What are not apparent in these data are differences in DBH distribution. For example, Queensland maple types FB33 and FB44 had similar DBH ranges and mean DBH values, most trees within FB33 had DBH near the mean value of 11 inches, while FB44 had a relatively even distribution of tree DBH ranging in size from 8-28 inches. FB44 therefore had higher volume per acre due to higher stocking and larger volume contribution per tree from larger diameter classes.

Qualitative data collection for the relative abundance of primary and secondary species in the above ground forest strata indicated that the WTMA is dominated by non-native timbers, underlain by invasive non-native weed species. If current commercial timber resources are harvested, control of these weed species will probably require significant resources during planting and establishment of future timber plantations. Overstory ohia and koa trees that remain within non-native timber plantations are generally senescent, contain considerable defect, and have poor form. Excluding *Cibotium* spp. and *Dicranopteris linearis*, the presence of native tree and shrub species in understory and groundcover layers was negligible.

Total wood volume estimates within the WTMA exceeded 16,300,000 merchantable cubic feet, or approximately 81,500,000 merchantable board feet. Forest types coded "22" or lower could be considered to represent pre- or non-commercial timber acreage as of 1997 due to their low volume or heterogeneous composition. Well-stocked stands in these forest types could have significant commercial value in future years, while others will have salvage potential at best unless they are replaced. Forest types coded "33" or higher contained a majority of timber resources with current commercial value, where total merchantable volume exceeded 8,300,000 cubic feet, or approximately 41,500,000 merchantable board feet.

The WTMA represents a readily accessible timber resource due to its close proximity to Hilo and an extremely well laid out road network. Though several block roads have become overgrown with weeds, they could be easily cleared, and would be operable 365 days per year. Within the tract, slopes typically range between 5-10%, which would not limit operation of mechanized equipment. One exception would small areas having relatively deep mineral surface soils that may become inaccessible when saturated. The close proximity of virtually all stands to Stainback Highway would facilitate harvesting and transportation of logs, replanting, and stand management efforts.

Analysis of survey precision indicated that reported timber volumes were robust – particularly in forest types representing the greatest current commercial value (type codes "33" or higher). The volume data in this report are not intended to be the sole basis for negotiation of timber sale contracts, but rather a guideline to long term timber management planning within the WTMA. Additional inventory data, or careful scaling of timber removed from harvest sites are highly recommended for all harvest contracts.

Acknowledgements:

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Appendix A. Botanical species tallied during the WTMA survey.

TREE SPECIES

Latin genus and species	Common name
Acacia koa	Koa
Acacia melanoxylon	Blackwood
Alnus nepalensis	Nepal alder
Casuarina equisetifolia	Ironwood
Cheirodendron trigynum	Olapa
Cryptomeria japonica	Sugi
Eucalyptus deglupta	Mindanao gum
Eucalyptus grandis	Rose gum
Eucalyptus microcorys	Tallow-wood
Eucalyptus pilularis	Black butt
Eucalyptus robusta	Swamp mahogany
Eucalyptus saligna	Sydney blue gum
Flindersia brayleyana	Queensland maple
Fraxinus uhdei	Tropical ash
Grevillia robusta	Silk oak
Melaleuca quinquenervia	Paper bark
Metrosideros polymorpha	Ohia
Pritchardia spp.	Loulu
Spathodea campanulata	African tulip tree
Toona ciliata	Australian red cedar
Trema orientalis	Gunpowder tree

UNDERSTORY AND GROUNDCOVER SPECIES

Latin genus and species	Common name
Cheirodendron trigynum	Olapa
Cibotium spp.	Tree ferns
Dicranopteris linearis	Uluhe fern
Melastoma spp.	Melastoma family
Melochia umbellata	Melochia
Nephrolepis multiflora	Sword fern
Psidium spp.	Guavas
Setaria palmifolia	Palm grass
Zanthoxylum dipetalum	Kawau

Appendix B. Species assignments by taper profile class for volume analyses.

Species analyzed using *Flindersia brayleyana* taper profile:

1. *Acacia koa*
2. *Acacia melanoxylon*
3. *Alnus nepalensis*
4. *Casuarina equisetifolia*
5. *Cheirodendron trigynum*
6. *Flindersia brayleyana*
7. *Fraxinus Uhdei*
8. *Grevillia robusta*
9. *Metrosideros polymorpha*
10. *Pritchardia* spp.
11. *Toona ciliata*
12. *Trema orientalis*
13. *Spathodea campanulata*
14. *Zanthoxylum dipetalum*

Species analyzed using *Eucalyptus saligna* taper profile:

1. *Eucalyptus microcorys* (bark thickness coefficients 1.5 times those of *E. saligna*)
2. *E. robusta* (bark thickness coefficients 2.0 times those of *E. saligna*)
3. *E. saligna*
4. *Melaleuca quinquenervia* (bark thickness coefficients 2.0 times those of *E. saligna*)

Species analyzed using *Eucalyptus grandis* taper profile:

1. *Eucalyptus deglupta*
2. *E. grandis*

Species analyzed using a West-coast *Thuja plicata* (Western red cedar) taper profile:

1. *Cryptomeria japonica*

Appendix C. Stand tables by forest type.

Guidelines for interpreting stand table data:

1. Stand tables summarize sample plot analyses by presenting one inch DBH classes. Statistics provided for each DBH class include trees per acre, basal area per acre (ft^2), average tree height (feet), and cubic foot volume per acre. Gross cubic volume represents the tree bole from tree base to tree tip. Merchantable wood volume calculations were based on 16 foot log sections, a minimum top diameter of four inches, a stump height of one foot, and a minimum DBH of eight inches.

2. For each forest type, statistics are first presented by tree species. The last row of each species section gives a species summary (species codes typically use the first initial from both genus and species names). The species summary shows average DBH, total trees per acre, total basal area per acre, and total volume per acre.

3. After all species for a particular forest type have been listed, two final rows provide type level summary statistics. The first row represents all trees with a DBH of two inches or larger. The second row represents only trees with a minimum DBH of eight inches. Type level summaries show average DBH, total trees per acre, total basal area per acre, and total volume per acre. Type level volume totals may differ slightly from those reported in Tables 2-4 due to rounding errors.

Forest type FB00: Recent *Flindersia brayleyana* plantings / sapling stands.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Eucalyptus saligna			
	4	29	2.9	0	2	0
ES summary:	4		2.9	0	3	0
			Melaleuca quinquenervia			
	17	90	0.7	1	26	25
MQ summary:	17		0.7	1	27	26
			Flindersia brayleyana			
	2	22	6.4	0	1	0
	4	46	2.9	0	3	0
	6	61	1.6	0	6	0
FB summary:	3		10.9	1	12	0
			Toona ciliata			
	2	19	51.4	1	9	0
	4	29	60	5	58	0
	6	39	17.2	3	49	0
	7	37	8.6	2	32	0
	8	40	12.3	4	65	55
	9	44	5	2	36	31
	10	54	7.4	4	78	71
	11	52	7.9	5	99	90
	12	44	3.6	3	46	42
	13	51	1.4	1	24	22
	14	53	0.7	1	14	13
	16	55	0.7	1	19	18
TC summary:	6		176.3	34	534	346

Appendix C (continued).

Forest type FB00 (continued):

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Fraxinus uhdei			
	11	17	0.7	0	4	3
	15	27	0.7	1	9	8
FU summary:	13		1.4	1	14	12
			Metrosideros polymorpha			
	2	18	20	0	3	0
	4	34	17.1	1	18	0
	6	43	4.3	1	13	0
	7	44	0.7	0	3	0
	11	58	0.7	0	9	8
	26	59	0.7	3	50	48
MP summary:	5		43.6	6	99	56
			Acacia koa			
	2	24	11.4	0	2	0
	9	73	0.7	0	8	7
	10	76	0.7	0	10	9
AK summary:	4		12.9	1	21	17
			Acacia melanoxylon			
	13	49	0.7	1	12	11
AM summary:	13		0.7	1	12	11
			Trema orientalis			
	4	21	5.7	0	4	0
	6	33	1.6	0	3	0
TO summary:	4		7.3	1	8	0
			-- Type Level Summary --			
All trees:	5.7		256	46	730	468
Merch trees:	10.8		44	29		

Forest type FB11: Low volume *Flindersia brayleyana* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Fraxinus uhdei			
	2	14	4.6	0	0	0
	4	25	6.2	1	5	0
	6	34	3.1	1	7	0
	7	36	1.5	0	5	0
	8	45	0.8	0	4	3
	9	40	2.3	1	15	13
	10	47	0.4	0	3	3
	11	50	1.2	1	13	12
	12	52	0.8	1	11	10
	14	59	0.8	1	17	16
FU summary:	7		21.5	5	86	60

Appendix C (continued).

Forest type FB11 (continued):

	DBH (in)	Average Height (ft)	Number of Trees	Basal Area	--Volume (ft^3)-- Gross	Merch
			Flindersia brayleyana			
	2	28	7.7	0	1	0
	4	41	13.8	1	16	0
	6	50	2.7	1	9	0
	7	56	5.4	1	29	0
	8	53	4.6	2	31	26
	9	68	2.3	1	24	21
	10	58	3.1	2	35	31
	11	58	4.2	3	57	53
	12	59	5.4	4	89	82
	13	58	2.7	2	51	47
	14	65	1.5	2	37	35
	15	66	2.7	3	75	71
	16	67	0.8	1	24	23
	17	82	2.3	4	99	95
	18	67	0.8	1	31	29
	20	82	0.4	1	22	21
	22	82	0.4	1	27	26
	23	70	0.4	1	25	24
FB summary:	10		61.2	31	690	592
			Toona ciliata			
	2	13	13.8	0	2	0
	4	26	9.2	1	8	0
	6	50	2.7	1	9	0
	7	35	2.7	1	10	0
	8	38	1.5	1	8	7
	9	50	0.8	0	5	5
	10	58	0.4	0	4	3
	11	57	0.4	0	5	4
	12	74	0.8	1	15	14
	14	66	0.4	0	9	8
	15	77	0.4	0	13	12
	16	72	0.4	1	12	11
	17	75	0.4	1	16	15
TC summary:	6		33.8	6	120	83
			Metrosideros polymorpha			
	2	8	23.1	1	4	0
	4	22	12.3	1	10	0
	6	34	1.9	0	4	0
	7	40	0.8	0	3	0
	8	50	0.4	0	2	2
	9	48	0.4	0	3	2
	12	63	0.4	0	6	6
	17	67	0.4	1	13	13
	18	65	1.2	2	45	43
	19	70	0.4	1	17	17
	20	71	0.4	1	20	19
MP summary:	6		41.5	7	132	104
			Spathodea campanulata			
	9	68	0.4	0	4	3
SC summary:	9		0.4	0	4	4

Appendix C (continued).

Forest type FB11 (continued):

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Acacia koa			
	8	81	0.4	0	3	3
	9	83	0.4	0	4	4
	10	84	0.4	0	6	5
	11	86	0.8	1	14	13
	13	88	0.8	1	21	20
	16	91	0.4	1	16	15
AK summary:	12		3.1	2	67	63
			-- Type Level Summary --			
All trees:	7.7		161	52	1099	905
Merch trees:	12.5		50	43		

Forest type FB22: Low to moderate volume *Flindersia brayleyana* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Acacia koa			
	11	69	0.3	0	3	3
	13	78	0.3	0	6	6
AK summary:	12		0.5	0	11	10
			Flindersia brayleyana			
	2	15	9	0	1	0
	4	37	7	1	7	0
	6	60	5.3	1	21	0
	7	56	6	2	32	0
	8	61	4	1	30	26
	9	65	7.2	3	73	65
	10	79	8.4	5	124	113
	11	66	6.5	4	98	91
	12	76	7.8	6	160	150
	13	69	4.8	4	107	100
	14	85	5.9	6	182	173
	15	91	3	4	112	107
	16	84	4.3	6	169	161
	17	89	3.1	5	146	140
	18	82	2.9	5	141	135
	19	84	2.8	5	151	145
	20	82	1.3	3	74	71
	21	98	1.8	4	134	129
	22	75	0.8	2	49	47
	23	80	1.3	4	94	90
	24	89	0.3	1	22	21
	25	80	0.3	1	22	21
	26	90	0.3	1	26	25
	27	90	0.6	2	71	68
	30	92	0.3	1	35	34
FB summary:	12		94.5	78	2093	1924

Appendix C (continued).

Forest type FB22 (continued):

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Toona ciliata			
	2	18	5	0	0	0
	4	32	4	0	4	0
	6	42	3.8	1	11	0
	7	52	1.8	0	8	0
	8	60	1.3	0	9	0
	9	59	2	1	18	16
	10	47	0.3	0	2	2
	11	59	0.8	1	10	9
	12	39	0.8	1	8	7
	13	85	1	1	27	26
	14	81	0.8	1	21	20
	15	80	0.3	0	7	7
	17	77	0.3	0	10	9
TC summary:	7		21.8	7	143	100
			Fraxinus uhdei			
	2	9	12	0	1	0
	4	20	12	1	9	0
	6	31	7.7	2	18	0
	7	43	11.9	3	50	0
	8	51	7.5	3	48	41
	9	50	5.5	2	45	39
	10	49	3.5	2	34	30
	11	63	2	1	29	27
	12	76	1.8	1	35	33
	13	68	0.3	0	5	5
FU summary:	7		64.1	16	279	178
			Metrosideros polymorpha			
	2	12	26	1	3	0
	4	28	6	1	5	0
	6	40	0.8	0	2	0
	8	57	0.7	0	4	4
	9	53	0.9	0	7	6
	10	56	1	1	10	9
	11	51	0.9	1	11	10
	12	65	0.3	0	4	4
	13	63	0.3	0	5	4
	14	66	0.8	1	18	17
	15	86	0.8	1	26	25
	16	69	0.5	1	16	15
	18	72	0.3	0	10	10
	22	77	0.3	1	16	15
	25	78	0.5	2	43	41
	30	85	0.5	2	65	63
MP summary:	7		40.3	11	254	230
			Eucalyptus robusta			
	16	75	0.3	0	7	7
ER summary:	16		0.3	0	7	7
			-- Type Level Summary --			
All trees:	9.6		221	112	2787	2449
Merch trees:	13.4		102	99		

Appendix C (continued).

Forest type FB33: Moderate volume *Flindersia brayleyana* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Flindersia brayleyana			
	2	17	5.4	0	0	0
	4	41	6.9	1	8	0
	6	52	4.7	1	17	0
	7	66	7.9	2	48	0
	8	70	5.7	2	48	41
	9	74	10.3	5	117	105
	10	79	7.9	4	117	108
	11	86	8.5	6	166	155
	12	75	8.3	7	170	159
	13	82	10.7	10	276	261
	14	86	9.4	10	295	281
	15	81	8.2	10	276	263
	16	94	7.5	10	328	315
	17	90	7.5	12	355	341
	18	93	4.1	7	222	213
	19	105	3.1	6	208	201
	20	90	4.2	9	275	265
	21	90	1.4	3	99	96
	22	94	0.8	2	62	60
	23	87	0.6	2	47	45
	24	88	0.2	1	17	16
	25	96	0.6	2	60	58
	26	97	0.4	1	43	42
	27	98	0.2	1	23	22
FB summary:	13		124.4	130	3289	3056
			Toona ciliata			
	2	7	1.5	0	0	0
	4	22	3.1	0	2	0
	6	51	0.8	0	2	0
	7	41	1	0	3	0
	8	59	1.3	0	9	8
	9	46	0.4	0	2	2
	11	72	0.4	0	6	5
	12	76	0.2	0	3	3
TC summary:	6		8.7	2	33	21
			Fraxinus uhdei			
	2	14	5.4	0	0	0
	4	26	22.3	2	20	0
	6	41	10.3	2	30	0
	7	43	8.3	2	35	0
	8	41	5.4	2	29	24
	9	49	3.3	1	26	23
	10	59	2	1	22	20
	11	58	1	1	14	13
	12	62	0.2	0	3	3
	13	80	0.2	0	4	4
	14	68	0.4	0	9	9
	17	77	0.6	1	23	22
FU summary:	6		59.3	12	221	121

Appendix C (continued).

Forest type FB33: (continued).

	DBH (in)	Average Height (ft)	Values per acre — Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Metrosideros polymorpha			
	2	5	6.9	0	0	0
	4	13	1.5	0	0	0
	6	72	0.8	0	4	0
	7	33	0.2	0	0	0
	8	50	1.2	0	7	0
	9	62	1	0	9	8
	10	50	0.6	0	5	5
	11	56	0.2	0	2	2
	12	61	0.2	0	3	3
	14	45	0.2	0	3	2
	15	79	0.6	1	19	18
	16	31	0.4	1	6	5
	18	82	0.2	0	9	8
	19	84	0.2	0	10	10
	20	65	0.4	1	18	17
	21	89	0.4	1	27	26
	22	91	0.2	1	15	14
	24	95	0.2	1	18	17
	26	70	0.2	1	15	14
	28	48	0.2	1	13	12
	30	78	0.2	1	23	22
	31	105	0.2	1	31	30
MP summary:	11		16	10	246	222
			Acacia koa			
	15	95	0.2	0	7	7
AK summary:	15		0.2	0	8	8
			Pritchardia spp.			
	9	29	0.2	0	1	0
	11	37	0.2	0	1	1
PR summary:	10		0.4	0	3	2
			-- Type Level Summary --			
All trees:	11		208	139	3800	3429
Merch trees:	13.9		120	127		

Forest type FB44: High volume *Flindersia brayleyana* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre — Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Acacia koa			
	8	65	1	0	7	0
AK summary:	8		1	0	8	0

Appendix C (continued).

Forest type FB44: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Flindersia brayleyana			
	2	12	23.3	1	3	0
	4	35	21.7	2	23	0
	6	57	8.6	2	33	0
	7	51	13.3	4	65	0
	8	75	12.3	4	112	97
	9	77	12.7	6	150	135
	10	83	15.2	8	236	216
	11	86	15	10	291	271
	12	87	16.3	13	379	357
	13	85	15.5	14	413	391
	14	87	16.5	18	517	493
	15	91	17.2	21	646	617
	16	87	14.8	21	605	580
	17	89	8.5	13	398	382
	18	90	9.6	17	511	492
	19	84	5.6	11	306	294
	20	98	3.9	8	271	261
	21	94	1.9	5	141	136
	22	98	1.4	4	117	114
	23	102	0.4	1	39	38
	24	103	1	3	107	104
	25	104	0.2	1	23	22
	27	92	0.2	1	24	23
	28	106	0.2	1	29	28
FB summary:	12		235.1	187	5452	5060
			Toona ciliata			
	4	23	1.7	0	1	0
	6	44	1.5	0	4	0
	7	59	2.3	1	13	0
	8	70	0.8	0	7	6
	9	70	2.3	1	25	22
	10	54	1.3	1	13	12
	11	73	0.2	0	3	3
	12	59	0.2	0	3	3
	13	80	0.4	0	10	9
	16	60	0.2	0	6	5
TC summary:	8		10.9	4	88	63
			Metrosideros polymorpha			
	2	5	5.8	0	0	0
	4	6	0.8	0	1	0
	16	80	0.2	0	7	7
	17	54	0.2	0	5	5
	18	57	0.2	0	7	7
	20	63	0.2	0	9	9
	25	85	0.2	1	19	18
	28	51	0.2	1	14	13
	35	77	0.2	1	33	31
MP summary:	10		8.1	4	100	94
			-- Type Level Summary --			
All trees:	11.9		255	196	5648	5217
Merch trees:	14		175	187		

Appendix C (continued).

Forest type FB55: Similar to FB33 *Flindersia brayleyana* with 20% volume as Toona ciliata.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Melaleuca quinquenervia			
	9	65	0.3	0	2	2
MQ summary:	9		0.3	0	2	2
			Flindersia brayleyana			
	2	21	1.5	0	0	0
	4	43	4.6	0	5	0
	6	60	0.4	0	1	0
	7	62	1.5	0	9	0
	8	64	1.9	1	15	13
	9	61	2.5	1	24	21
	10	57	1.5	1	17	15
	11	71	4.1	3	67	62
	12	67	4	3	72	68
	13	76	4	4	97	92
	14	83	5.8	6	173	165
	15	84	5.9	7	205	196
	16	82	5	7	194	185
	17	85	3.5	5	157	151
	18	81	3.1	5	148	142
	19	86	3.4	7	191	184
	20	78	1.8	4	103	99
	21	85	1.3	3	90	87
	22	100	0.6	2	49	47
	23	84	1	3	76	73
	24	80	1.1	3	88	85
	26	87	0.2	1	19	19
	27	88	0.2	1	23	22
	29	89	0.2	1	24	23
FB summary:	15		59.2	69	1860	1756
			Toona ciliata			
	2	6	5.4	0	1	0
	4	20	18.5	2	14	0
	6	36	8.7	2	23	0
	7	42	9.5	3	40	0
	8	47	8.2	3	49	41
	9	52	6.2	3	51	45
	10	63	6.8	4	82	74
	11	56	3.2	2	42	38
	12	71	3.4	3	65	61
	13	70	1.2	1	25	24
	14	72	0.8	1	20	19
	15	76	1	1	31	29
	16	84	0.4	1	15	14
	17	79	0.8	1	32	30
	19	83	0.2	0	11	11
	20	80	0.4	1	22	21
	21	85	0.2	0	12	12
TC summary:	8		74.7	27	543	427

Appendix C (continued).

Forest type FB55: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Metrosideros polymorpha			
	2	5	6.2	0	0	0
	4	13	5.4	0	3	0
	7	17	0.2	0	0	0
	9	75	0.8	0	8	7
	22	69	0.4	1	23	22
	25	42	0.2	1	9	8
	28	55	0.3	1	23	22
	30	67	0.3	2	32	30
	31	68	0.2	1	21	20
	35	72	0.2	1	28	27
	36	73	0.6	4	91	87
MP summary:	12		14.7	12	244	228
			Acacia koa			
	7	72	0.6	0	3	0
	8	70	1.2	0	9	0
	9	68	0.2	0	1	1
	10	60	0.4	0	4	4
	11	75	1	1	16	15
	12	57	0.8	1	12	11
	14	61	0.4	0	9	8
	15	60	0.2	0	5	4
AK summary:	10		4.6	3	63	46
			-- Type Level Summary --			
All trees:	11.5		153	110	2712	2459
Merch trees:	14.4		89	102		

Forest type ES00: Recent *Eucalyptus saligna* plantings / sapling stands.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Eucalyptus saligna			
	2	12	70	2	10	0
	4	29	30	3	28	0
	6	41	7.5	1	22	0
	7	45	7.5	2	33	0
	8	49	10	3	63	53
ES summary:	4		125	11	158	54
			Toona ciliata			
	2	8	20	0	3	0
	4	17	20	2	15	0
	6	25	17.5	4	37	0
	7	30	12.5	3	41	0
	8	27	5	2	21	18
	10	33	2.5	1	17	15
TC summary:	5		77.5	12	138	34

Appendix C (continued).

Forest type ES00: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Metrosideros polymorpha			
	2	16	30	1	4	0
	4	23	10	1	8	0
	6	28	5	1	11	0
	12	35	2.5	2	26	23
	19	42	2.5	5	73	68
MP summary:	6		50	9	125	92
			Casuarina equisetifolia			
	8	43	2.5	1	12	0
CE summary:	8		2.5	1	13	0
			Trema orientalis			
	2	8	50	1	9	0
	4	17	10	1	7	0
TO summary:	2		60	2	17	0
			-- Type Level Summary --			
All trees:	4.6		315	36	450	180
Merch trees:	10.6		22	14		

Forest type ES11: Cut over, or low volume *Eucalyptus saligna* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Eucalyptus saligna			
	2	8	41.2	1	6	0
	4	30	21.2	2	20	0
	6	50	11.2	2	39	0
	7	60	9.4	3	53	0
	8	76	7.1	2	65	56
	9	74	6.8	3	77	69
	10	80	2.9	2	44	41
	11	87	5	3	99	93
	12	89	2.4	2	56	53
	13	94	2.6	2	79	75
	14	100	2.1	2	74	71
	15	108	1.2	1	52	50
	18	109	0.3	1	18	18
	19	111	0.3	1	21	20
	22	117	0.3	1	29	28
	23	119	0.6	2	65	63
	28	102	0.6	3	81	79
ES summary:	7		115	32	889	724
			Eucalyptus robusta			
	7	61	0.3	0	1	0
	7	60	0.9	0	4	0
	8	66	0.3	0	1	0
ER summary:	7		1.5	0	7	0

Appendix C (continued).

Forest type ES11: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Toona ciliata			
	2	18	1.2	0	0	0
	4	31	3.5	0	3	0
	6	38	1.8	0	4	0
	7	50	1.2	0	5	0
	8	44	0.6	0	3	2
	10	53	0.3	0	3	2
	11	57	1.2	1	15	14
	12	59	0.6	0	9	8
	14	63	0.3	0	6	6
TC summary:	7		10.6	3	52	35
			Fraxinus uhdei			
	2	6	23.5	1	0	0
	4	20	7.1	1	5	0
	6	42	0.9	0	2	0
FU summary:	3		31.5	1	8	0
			Metrosideros polymorpha			
	2	10	14.1	0	2	0
	4	24	2.4	0	2	0
	6	33	0.9	0	2	0
	7	34	0.6	0	2	0
	9	42	0.3	0	2	1
	11	46	0.6	0	6	5
	12	52	0.3	0	4	3
	13	49	0.3	0	4	4
	15	51	0.3	0	6	6
	18	54	0.3	1	9	9
	19	47	0.3	1	9	8
	20	58	0.6	1	25	23
	21	56	0.3	1	13	12
MP summary:	7		21.2	5	91	77
			Acacia koa			
	7	40	0.3	0	1	0
	8	48	0.9	0	5	4
	9	50	1.5	1	11	10
	10	49	0.9	0	8	7
	11	56	0.6	0	8	7
	14	74	0.3	0	8	8
	16	84	0.3	0	11	10
	19	98	0.3	1	18	18
	27	45	0.3	1	17	16
AK summary:	12		5.3	4	91	83
			Trema orientalis			
	2	8	2.4	0	0	0
	4	30	4.7	0	4	0
TO:	3		7.1	0	5	0
			-- Type Level Summary --			
All trees:	6.7		192	47	1143	919
Merch trees:	12.2		43	35		

Appendix C (continued).

Forest type ES22: Low to moderate volume *Eucalyptus saligna* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Eucalyptus grandis			
	6	78	0.1	0	0	0
	8	99	0.1	0	1	1
	10	115	0.2	0	6	5
	11	108	0.2	0	7	6
	12	111	0.1	0	4	4
	13	114	0.4	0	15	15
	14	107	0.4	0	16	16
	16	122	0.4	1	24	24
EG summary:	13		2	2	78	74
			Eucalyptus saligna			
	2	13	41.5	1	6	0
	4	41	41.2	4	50	0
	6	68	18.6	4	84	0
	7	75	16.1	4	111	0
	8	91	14.3	5	156	136
	9	84	11.1	5	144	130
	10	90	11	6	187	173
	11	92	9.5	6	199	186
	12	93	6.4	5	161	152
	13	105	4.8	4	159	152
	14	108	5.3	6	207	198
	15	95	2.6	3	102	98
	16	112	1.2	2	63	61
	17	67	0.6	1	22	21
	18	116	0.1	0	8	8
	19	102	0.5	1	32	31
	20	120	0.4	1	33	32
	21	121	0.1	0	11	11
	22	123	0.1	0	12	12
	24	125	0.1	0	15	15
	26	120	0.1	0	17	16
ES summary:	8		185.9	59	1790	1440
			Deglupta Eucalyptus			
	6	42	0.4	0	1	0
	7	45	0.5	0	2	0
	10	62	0.1	0	1	1
ED summary:	7		1	0	6	2
			Eucalyptus robusta			
	2	8	2	0	0	0
	4	29	4.9	0	3	0
	6	55	1.5	0	4	0
	7	60	1.8	0	8	0
	8	71	1.1	0	7	6
	9	69	0.7	0	6	5
	10	78	0.2	0	2	2
	11	75	0.4	0	5	4
	12	87	0.1	0	2	2
ER summary:	6		12.7	2	41	21

Appendix C (continued).

Forest type ES22: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Fraxinus uhdei			
	2	5	1.5	0	0	0
	4	10	0.5	0	0	0
	6	21	0.2	0	0	0
	7	27	0.4	0	1	0
	9	39	0.2	0	1	1
	11	41	0.1	0	1	1
	12	59	0.4	0	5	5
	14	63	0.1	0	2	2
FU summary:	7		3.4	1	13	11
			Acacia koa			
	4	19	0.5	0	0	0
	7	38	0.1	0	0	0
	8	60	0.1	0	0	0
AK summary:	5		0.7	0	2	1
			Toona ciliata			
	2	22	7.1	0	1	0
	4	35	12.7	1	13	0
	5	59	0.1	0	0	0
	6	48	3.3	1	11	0
	7	44	1.6	0	7	0
	8	57	0.9	0	6	5
	9	75	0.2	0	2	2
	10	48	0.2	0	2	2
	12	53	0.1	0	1	1
	16	72	0.4	1	13	12
TC summary:	5		26.7	4	61	24
			Metrosideros polymorpha			
	2	5	12.9	0	0	0
	4	9	2.9	0	1	0
	6	41	0.2	0	0	0
	7	26	0.1	0	0	0
	11	49	0.1	0	1	1
	12	44	0.4	0	4	4
	20	57	0.1	0	5	4
	26	52	0.1	0	7	7
MP summary:	4		17	2	22	18
			Trema orientalis			
	2	52	12.7	0	4	0
	4	59	8.8	1	14	0
	6	66	3	1	13	0
	7	62	1.9	1	11	0
	8	69	1.6	1	13	11
	9	60	0.8	0	7	7
	10	85	0.8	0	12	11
	11	69	0.1	0	1	1
	12	69	0.4	0	6	6
TO summary:	5		30.1	4	87	38

Appendix C (continued).

Forest type ES22: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	--Volume (ft^3)-- Gross	Merch
			Spathodea campanulata			
	4	41	1	0	1	0
SC summary:	4		1	0	1	0
			-- Type Level Summary --			
All trees:	6.9		280	74	2100	1629
Merch trees:	11.1		80	54		

Forest type ES33: Moderate volume *Eucalyptus saligna* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	--Volume (ft^3)-- Gross	Merch
			Eucalyptus saligna			
	2	11	10.8	0	1	0
	4	38	25.4	2	29	0
	6	61	9.6	2	39	0
	7	71	11.5	3	76	0
	8	84	6.8	2	69	60
	9	87	11.8	5	158	143
	10	104	11.3	6	219	203
	11	109	7.4	5	182	172
	12	110	9.3	7	274	261
	13	121	7.3	7	275	263
	14	115	8.1	9	335	323
	15	122	5.9	7	296	286
	16	112	5.5	8	286	277
	17	126	3.2	5	210	204
	18	105	2.4	4	151	146
	19	120	0.6	1	49	48
	20	129	1.3	3	124	121
	21	97	1	2	74	72
	22	135	1	3	110	108
	23	135	0.2	1	24	23
	24	136	0.2	1	26	25
	25	138	0.2	1	28	28
	31	145	0.2	1	45	44
ES summary:	11		141	85	3093	2814
			Fraxinus uhdei			
	2	5	17.7	0	0	0
	4	12	7.7	1	4	0
	6	40	0.4	0	1	0
	7	17	1.3	0	3	0
	8	66	1	0	7	0
	9	53	0.6	0	5	4
	10	64	0.6	0	7	6
	11	45	0.6	0	6	5
	14	86	0.2	0	5	5
	15	92	0.2	0	7	7
	16	96	0.2	0	8	7
FU summary:	5		30.4	3	57	37

Appendix C (continued).

Forest type ES33: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Toona ciliata			
	2	14	13.1	0	2	0
	4	30	8.5	1	8	0
	6	49	2.9	1	10	0
	7	49	1.7	0	8	0
	8	52	2.8	1	18	15
	9	63	1.2	1	11	10
	10	90	1.3	1	22	20
	11	100	0.4	0	8	8
	12	67	0.6	0	10	9
	13	76	1	1	23	21
	14	105	1	1	36	34
	15	92	0.4	0	14	13
	18	103	0.2	0	11	11
TC summary:	6		34.9	8	186	146
			Metrosideros polymorpha			
	2	11	22.3	0	3	0
	4	25	6.2	1	5	0
	6	30	0.2	0	0	0
	8	41	0.2	0	1	0
	10	45	0.2	0	1	1
	21	60	0.2	0	9	8
	22	47	0.2	1	9	8
MP summary:	4		29.4	3	31	20
			Trema orientalis			
	2	6	13.8	0	4	0
	4	20	9.2	1	7	0
	6	35	2.8	1	7	0
	7	46	1.8	0	8	0
	8	56	2.5	1	17	14
	9	47	0.2	0	1	1
	10	67	1.2	1	15	13
	11	82	0.8	1	15	14
	12	60	0.2	0	3	2
	13	77	0.2	0	4	4
	15	83	0.2	0	6	6
	17	82	0.2	0	8	8
	18	92	0.3	0	14	13
TO summary:	6		33.4	6	114	80
			Spathodea campanulata			
	2	28	0.8	0	0	0
	6	56	0.6	0	2	0
	8	67	0.4	0	3	2
	9	68	0.2	0	2	1
	11	70	0.2	0	3	2
SC summary:	6		2.1	0	11	7

Appendix C (continued).

Forest type ES33: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Casuarina equisetifolia			
	2	11	6.2	0	0	0
	4	38	1.5	0	1	0
CE summary:	3		7.7	0	3	0
			-- Type Level Summary --			
All trees:	8.3		279	105	3494	3106
Merch trees:	12.7		102	90		

Forest type ES44: High volume *Eucalyptus saligna* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Eucalyptus saligna			
	4	56	25	2	39	0
	6	75	13.5	3	71	0
	7	95	14.8	4	131	0
	8	109	18.3	7	245	216
	9	105	21.5	10	352	321
	10	123	20.3	11	469	437
	11	117	19	13	495	467
	12	122	27	21	872	831
	13	136	16.5	15	691	664
	14	133	17.3	18	798	769
	15	140	17.3	21	993	961
	16	141	5.5	8	364	354
	18	155	5.5	10	503	491
	19	148	1.3	2	116	113
ES summary:	11		222.5	145	6146	5629
			Trema orientalis			
	2	31	10	0	2	0
	6	60	2.5	1	10	0
	7	65	1.3	0	6	0
	10	77	3.8	2	55	51
	11	79	1.3	1	21	19
TO summary:	6		18.8	4	97	71
			-- Type Level Summary --			
All trees:	10.6		241	149	6243	5699
Merch trees:	12.1		174	139		

Appendix C (continued).

Forest type ES55: Moderate volume *Eucalyptus saligna* saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Eucalyptus saligna			
	2	14	10	0	1	0
	4	46	6.7	1	9	0
	6	75	6.7	1	33	0
	7	85	4.2	1	32	0
	8	95	5	2	56	49
	9	103	5	2	77	70
	10	109	0.8	0	16	15
	11	115	5	3	129	121
	12	113	10	8	301	287
	13	134	2.5	2	103	99
	14	129	1.7	2	77	74
	15	145	6.7	8	392	380
	16	149	2.5	3	171	167
	17	110	3.3	5	193	187
	18	145	3.3	6	279	272
	19	150	3.3	7	320	312
	20	147	0.8	2	86	84
	22	151	1.7	4	213	208
	26	179	3.3	12	688	676
	28	168	0.8	4	186	182
	29	135	0.8	4	161	157
ES summary:	13		84.2	78	3533	3349
			Toona ciliata			
	4	46	6.7	1	8	0
	6	57	2.5	0	9	0
	7	63	2.5	1	14	0
	8	65	0.8	0	6	0
	12	76	0.8	1	16	15
	13	80	0.8	1	21	19
TC summary:	7		14.2	3	77	36
			Metrosideros polymorpha			
	2	12	16.7	0	2	0
	14	48	0.8	1	15	13
	18	60	0.8	1	29	27
	24	60	0.8	3	53	50
MP summary:	7		19.2	5	100	92
			-- Type Level Summary --			
All trees:	11.6		117	87	3710	3476
Merch trees:	15.6		60	81		

Appendix C (continued).

Forest type ER22: Low to moderate volume *Eucalyptus robusta* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Eucalyptus robusta			
	14	105	5	5	153	146
	23	119	5	14	449	436
	31	126	5	26	827	807
ER summary:	24		15	46	1431	1390
			Toona ciliata			
	8	65	5	2	41	35
	9	67	5	2	53	47
	11	72	5	3	87	80
	14	75	5	6	145	137
	19	79	5	10	255	244
	20	81	5	11	304	292
	21	82	5	12	313	300
TC summary:	15		35	46	1200	1140
			-- Type Level Summary --			
All trees:	18.3		50	92	2631	2531
Merch trees:	18.3		49	92		

Forest type ER33: Moderate volume *Eucalyptus robusta* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Eucalyptus robusta			
	2	35	52.5	1	11	0
	4	53	17.5	2	21	0
	6	81	3.8	1	15	0
	7	71	7.5	2	39	0
	8	69	2.5	1	17	13
	9	71	5.6	2	49	43
	10	109	2.5	1	40	37
	11	45	5	3	44	40
	12	105	1.3	1	28	26
	13	90	2.5	2	57	54
	14	77	3.1	3	72	68
	15	92	2.5	3	78	74
	16	94	2.5	3	90	86
	17	96	1.3	2	51	49
	18	98	0.6	1	29	28
	20	144	0.6	1	51	50
	21	102	2.5	6	164	158
	22	104	0.6	2	45	43
	24	106	0.6	2	54	52
	26	108	0.6	2	64	62
	36	117	0.6	4	126	122
ER summary:	9		116.3	47	1155	1015

Appendix C (continued).

Forest type ER33: (continued).

	DBH (in)	Average Height (ft)	Number of Trees	Basal Area	--Volume (ft^3)-- Gross	Merch
			Eucalyptus saligna			
	4	26	2.5	0	2	0
	8	69	0.6	0	5	4
	9	84	0.6	0	8	7
	10	85	0.6	0	10	9
	12	98	0.6	0	16	15
	13	93	0.6	1	18	17
	15	113	0.6	1	29	28
	17	141	2.5	4	183	178
	18	125	0.6	1	45	44
	20	153	0.6	1	67	66
	22	136	0.6	2	72	70
	23	138	2.5	7	320	313
	24	140	0.6	2	88	86
	25	114	0.6	2	78	76
	26	153	1.3	5	222	217
	28	148	0.6	3	123	121
	42	164	0.6	6	286	280
ES summary:	20		16.9	36	1578	1537
			Melaleuca quinquenervia			
	24	57	0.6	2	29	28
MQ summary:	24		0.6	2	30	28
			Fraxinus uhdei			
	2	24	7.5	0	1	0
	4	35	10	1	10	0
	6	42	1.3	0	3	0
	8	48	0.6	0	3	3
	9	62	0.6	0	6	5
	11	54	0.6	0	7	7
	14	47	0.6	1	11	10
	19	64	0.6	1	26	25
FU summary:	6		21.9	4	73	52
			Metrosideros polymorpha			
	7	10	0.6	0	1	0
	15	41	0.6	1	11	10
	18	49	0.6	1	19	17
	20	60	0.6	1	28	26
	21	100	0.6	2	49	47
	22	44	1.3	3	50	47
	25	77	0.6	2	53	51
	28	95	0.6	3	80	77
	54	125	0.6	10	334	325
MP summary:	26		6.3	23	628	604
			Spathodea campanulata			
	7	47	0.6	0	2	0
	9	65	0.6	0	6	5
SC summary:	8		1.3	0	9	5
			-- Type Level Summary --			
All trees:	11.2		163	112	3472	3241
Merch trees:	18		59	105		

Appendix C (continued).

Forest type ER55: Moderate volume *Eucalyptus robusta* saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Eucalyptus saligna			
	6	91	0.7	0	4	0
	9	85	2.1	1	27	25
	10	130	0.7	0	17	15
	12	107	1.4	1	40	38
	15	111	0.7	1	32	31
	17	93	0.7	1	35	34
	20	134	0.7	2	68	66
	23	120	0.7	2	80	78
	26	121	1.4	5	204	198
	32	125	0.7	4	154	150
	39	128	0.7	6	227	222
ES summary:	20		10.7	23	893	862
			Eucalyptus robusta			
	2	11	28.6	1	3	0
	4	34	28.6	2	24	0
	6	61	10	2	32	0
	7	52	5.7	2	22	0
	8	76	5	2	36	30
	9	95	6.4	3	74	65
	10	79	2.1	1	26	23
	11	88	6.4	4	104	96
	12	77	5	4	85	79
	13	90	1.4	1	33	31
	14	126	5.7	6	208	199
	15	92	1.4	2	44	42
	16	75	2.9	4	83	79
	17	100	1.4	2	61	59
	18	97	4.3	8	199	192
	20	120	2.1	5	148	144
	21	107	1.4	3	98	94
	22	108	2.1	6	162	157
	23	110	0.7	2	59	57
	24	111	0.7	2	65	63
	25	115	2.9	10	291	283
	26	113	1.4	5	153	149
	27	100	1.4	6	146	142
	29	116	2.1	10	288	281
	30	116	0.7	4	103	100
	32	118	0.7	4	117	114
	33	110	1.4	8	231	225
	34	140	0.7	5	154	151
	40	120	0.7	6	180	176
ER summary:	13		134.3	119	3246	3041
			Fraxinus uhdei			
	13	36	0.7	1	9	8
	14	39	0.7	1	11	10
	15	42	0.7	1	12	11
FU summary:	14		2.1	2	34	31

Appendix C (continued).

Forest type ER55: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Alnus nepalensis			
	7	50	1.4	0	6	0
AN summary:	7		1.4	0	7	0
			Eucalyptus microcorys			
	2	30	2.9	0	0	0
	4	54	2.9	0	3	0
	6	66	0.7	0	2	0
	7	65	0.7	0	3	0
	8	74	0.7	0	5	4
	9	76	0.7	0	7	6
	10	90	1.4	1	21	20
	21	84	0.7	2	43	41
EM summary:	8		10.7	4	90	74
			Melaleuca quinquenervia			
	2	52	2.9	0	0	0
	6	64	0.7	0	2	0
	8	75	2.1	1	15	0
	9	67	2.9	1	25	21
	11	69	0.7	0	9	9
	12	55	0.7	1	9	8
	14	71	1.4	2	31	29
	15	65	1.4	2	33	31
	16	90	1.4	2	51	49
	17	67	2.1	3	65	62
	18	73	0.7	1	26	25
	20	74	0.7	2	30	29
	21	74	0.7	2	36	34
	25	80	0.7	2	50	48
MQ summary:	14		19.3	19	388	349
			Metrosideros polymorpha			
	2	18	2.9	0	0	0
	4	29	17.1	1	16	0
	6	37	1.4	0	3	0
	7	43	2.9	1	12	0
	8	45	2.9	1	16	14
	9	46	0.7	0	5	4
	13	55	0.7	1	12	11
	20	52	0.7	2	27	26
	24	83	0.7	2	60	58
MP summary:	7		30	9	157	115
			-- Type Level Summary --			
All trees:	12.4		208	176	4814	4472
Merch trees:	17.7		96	165		

Appendix C (continued).

Forest type ER66: High volume *Eucalyptus robusta* saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Eucalyptus saligna			
	12	125	0.8	1	27	26
	20	153	0.8	2	90	88
	33	173	0.8	5	259	254
ES summary:	23		2.5	7	377	369
			Eucalyptus robusta			
	2	22	3.3	0	0	0
	4	42	26.7	2	26	0
	6	65	14.2	3	48	0
	7	68	15.8	4	79	0
	8	71	8.3	3	58	47
	9	88	16.7	7	180	157
	10	68	11.7	6	124	111
	11	88	13.3	9	217	200
	12	91	11.7	9	232	217
	13	95	7.5	7	182	172
	14	101	9.2	10	272	259
	15	107	7.5	9	268	257
	16	136	3.3	5	169	163
	17	125	10	16	528	510
	18	116	6.7	12	365	353
	19	119	3.3	7	207	201
	20	130	6.7	15	500	486
	21	125	4.2	10	329	320
	22	128	3.3	9	294	286
	23	138	5.8	17	603	588
	24	117	2.5	8	240	233
	25	125	5	17	550	535
	26	134	5	18	633	618
	27	140	0.8	3	117	115
	28	142	2.5	11	384	375
	29	135	1.7	8	259	253
	30	148	3.3	16	606	593
	31	149	0.8	4	161	157
	32	151	1.7	9	346	338
	34	154	0.8	5	197	193
	36	150	1.7	12	426	418
	37	184	1.7	12	546	536
ER summary:	15		216.7	283	9163	8709
			-- Type Level Summary --			
All trees:	15.6		219	291	9541	9078
Merch trees:	18		159	281		

Appendix C (continued).

Forest type ED11: Cut over, or low volume Eucalyptus deglupta pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Eucalyptus deglupta			
	2	11	20	0	3	0
	4	30	33.3	3	34	0
	6	45	13.3	3	51	0
	7	51	11.7	3	69	0
	8	54	1.7	1	14	13
	9	58	3.3	2	40	37
ED summary:	5		83.3	11	214	51
			Metrosideros polymorpha			
	18	66	1.7	3	66	63
	20	52	1.7	4	65	61
MP summary:	19		3.3	7	132	124
			Pritchardia spp.			
	9	29	1.7	1	8	6
PR summary:	9		1.7	1	8	7
			-- Type Level Summary --			
All trees:	6.2		88	19	354	182
Merch trees:	13.2		9	9		

Forest type ED22: Low to moderate volume Eucalyptus deglupta pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Eucalyptus deglupta			
	2	15	13.3	0	2	0
	4	34	33.3	3	37	0
	6	52	16.7	3	73	0
	7	82	6.7	2	60	0
	8	70	5	2	51	46
	9	62	15	7	176	161
	10	71	13.3	7	217	203
	11	113	3.3	2	101	96
	12	97	3.3	3	104	100
	13	104	5	5	194	187
	14	110	5	5	236	228
	15	115	3.3	4	189	183
	16	122	8.3	12	564	549
	17	126	1.7	3	130	127
ED summary:	9		133.3	57	2141	1885
			Acacia koa			
	6	46	3.3	1	10	0
	7	77	5	1	35	0
	8	63	1.7	1	13	11
	10	75	1.7	1	23	21
	13	92	1.7	2	47	45
	17	75	1.7	3	66	63
AK summary:	10		15	8	198	142

Appendix C (continued).

Forest type ED22: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Metrosideros polymorpha			
	4	5	6.7	1	0	0
	42	105	1.7	16	485	469
MP summary:	19		8.3	17	485	469
			-- Type Level Summary --			
All trees:	9.8		156	82	2825	2497
Merch trees:	13.5		71	71		

Forest type TC11: Low volume *Toona ciliata* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3): Gross	Merch
			Toona ciliata			
	2	8	25.4	1	4	0
	4	23	33.8	3	28	0
	6	34	15.5	3	39	0
	7	42	15.3	4	64	0
	8	46	9.5	3	57	48
	9	45	8.1	4	60	52
	10	46	4.3	2	40	36
	11	59	3.7	2	51	47
	12	55	2.2	2	33	30
	13	57	1.1	1	19	18
	14	57	0.7	1	15	14
	15	65	0.3	0	7	7
	16	66	0.2	0	6	6
	17	67	0.4	1	12	12
	18	60	0.1	0	5	4
	19	66	0.2	0	9	9
	20	57	0.1	0	3	2
	23	69	0.1	0	4	4
	24	70	0.1	0	5	4
TC summary:	7		121	28	470	301
			Eucalyptus saligna			
	2	14	0.3	0	0	0
	6	49	0.1	0	0	0
	7	51	0.1	0	0	0
	8	58	0.1	0	0	0
	10	65	0.1	0	0	0
	12	70	0.1	0	1	1
	14	74	0.1	0	1	1
ES summary:	8		0.8	0	6	4
			Eucalyptus robusta			
	4	27	0.3	0	0	0
	10	58	0.1	0	0	0
ER summary:	6		0.4	0	1	1

Appendix C (continued).

Forest type TC11: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	--Volume (ft^3)-- Gross	Merch
			Melaleuca quinquenervia			
	9	70	0.1	0	0	0
MQ summary:	9		0.1	0	1	0
			Fraxinus uhdei			
	2	24	1.1	0	0	0
	4	34	1.4	0	1	0
	6	38	0.2	0	0	0
	7	46	0.1	0	0	0
	8	46	0.1	0	0	0
	9	48	0.1	0	0	0
	10	49	0.1	0	1	0
	13	54	0.1	0	1	1
	16	53	0.1	0	2	2
	22	65	0.1	0	4	3
FU summary:	6		3.4	1	13	10
			Metrosideros polymorpha			
	2	7	76.7	2	16	0
	4	21	36.6	3	29	0
	6	37	5.2	1	13	0
	7	43	2.3	1	10	0
	8	51	1.8	1	11	10
	9	53	3.5	2	29	25
	10	56	0.9	1	10	9
	11	46	0.8	1	8	8
	12	53	0.7	1	10	9
	13	57	1	1	18	16
	14	74	0.8	1	21	20
	15	56	0.4	0	8	8
	16	67	0.4	1	13	12
	17	63	0.4	1	12	11
	18	75	0.3	0	12	12
	19	63	0.2	0	8	8
	20	73	0.2	0	11	10
	21	70	0.1	0	4	3
	22	75	0.2	1	13	13
	24	43	0.2	1	9	9
	25	66	0.1	0	5	4
	26	55	0.1	0	4	4
	28	25	0.1	0	3	2
	29	75	0.1	1	15	15
	33	57	0.1	0	7	7
MP summary:	5		132.9	19	311	225
			Casuarina equisetifolia			
	9	48	0.1	0	0	0
	12	58	0.1	0	1	1
	13	60	0.1	0	2	2
	14	63	0.1	0	1	1
CE summary:	12		0.4	0	6	6

Appendix C (continued).

Forest type TC11: (continued).

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Acacia koa			
	4	18	0.8	0	0	0
	6	67	0.4	0	1	0
	7	41	0.2	0	0	0
	8	52	0.4	0	2	1
	9	45	0.4	0	2	2
	10	60	0.4	0	4	3
	11	53	0.1	0	0	0
	12	55	0.1	0	1	1
	13	75	0.3	0	6	6
	14	61	0.2	0	4	4
	15	63	0.4	0	9	8
	17	65	0.1	0	2	2
	18	15	0.3	0	4	3
	19	70	0.1	0	3	3
AK summary:	11		3.9	2	46	39
			Spathodea campanulata			
	6	45	0.1	0	0	0
SC summary:	6		0.1	0	0	0
			Pritchardia spp.			
	6	24	0.1	0	0	0
	7	56	0.1	0	0	0
	8	29	0.2	0	0	0
	10	42	0.1	0	0	0
PR summary:	8		0.4	0	2	1
			Cheirodendron trigynum			
	4	20	0.3	0	0	0
	6	34	0.1	0	0	0
CH summary:	5		0.4	0	1	0
			-- Type Level Summary --			
All trees:	5.9		263	50	856	587
Merch trees:	11.3		47	33		

Appendix C (continued).

Forest type TC22: Low to moderate volume *Toona ciliata* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Toona ciliata			
	2	16	20	0	3	0
	6	43	5	1	15	0
	7	50	20	5	97	0
	8	51	30	10	193	165
	9	58	30	13	274	243
	10	61	25	14	294	266
	11	66	15	10	228	211
	12	73	15	12	299	279
	13	73	5	5	116	109
	14	76	10	11	279	264
	15	79	5	6	165	157
TC summary:	9		180	87	1966	1698
			Metrosideros polymorpha			
	4	31	20	2	19	0
MP summary:	4		20	2	20	0
			-- Type Level Summary --			
All trees:	9		199	89	1986	1698
Merch trees:	10.5		134	80		

Appendix C (continued).

Forest type TC33: Moderate volume *Toona ciliata* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Toona ciliata			
	2	7	40	1	9	0
	4	23	40	3	33	0
	6	42	14.2	3	43	0
	7	47	14.2	4	65	0
	8	66	16.7	6	134	116
	9	68	18.3	8	194	173
	10	75	12.5	7	177	162
	11	96	11.7	8	251	234
	12	98	10	8	260	246
	13	79	8.3	8	208	197
	14	63	5	5	117	110
	15	91	3.3	4	126	120
	16	85	6.7	9	266	255
	17	97	2.5	4	127	122
	18	97	2.5	4	142	137
	19	102	0.8	2	55	53
	20	70	3.3	7	171	163
TC summary:	9		210	91	2388	2094
			Metrosideros polymorpha			
	2	5	3.3	0	0	0
	11	59	0.8	1	11	10
MP summary:	5		4.2	1	11	10
			Acacia koa			
	7	90	3.3	1	27	0
	8	37	1.7	1	8	6
	9	77	1.7	1	19	17
	10	72	4.2	2	56	51
	11	74	2.5	2	42	39
	12	56	1.7	1	26	24
	13	77	0.8	1	20	19
	14	86	5.8	6	182	173
	15	80	0.8	1	27	26
	16	81	0.8	1	32	30
	18	84	0.8	1	41	39
	21	87	0.8	2	57	55
AK summary:	12		25	20	542	485
			-- Type Level Summary --			
All trees:	9.3		239	112	2941	2589
Merch trees:	12.1		124	100		

Appendix C (continued).

Forest type FU11: Low volume *Fraxinus uhdei* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Fraxinus uhdei			
	2	7	32.8	1	7	0
	4	20	39.6	3	31	0
	6	34	25.5	5	66	0
	7	40	20.4	5	82	0
	8	46	16.6	6	99	84
	9	46	13	6	98	86
	10	47	7.8	4	73	66
	11	52	6.2	4	76	69
	12	58	3	2	48	44
	13	60	2.1	2	40	37
	14	63	1.4	1	32	30
	15	60	1.1	1	27	26
	16	67	0.5	1	17	16
	17	68	0.2	0	7	7
	18	70	0.2	0	8	8
FU summary:	7		170.3	43	718	479
			Toona ciliata			
	2	7	13.6	0	3	0
	4	19	9.8	1	7	0
	6	34	4.6	1	11	0
	7	43	2.5	1	10	0
	8	36	1.7	1	8	7
	9	48	0.6	0	4	4
	10	34	0.3	0	2	2
	11	54	0.2	0	2	2
	12	54	0.3	0	4	4
	13	59	0.1	0	2	1
	15	64	0.1	0	2	2
	16	66	0.1	0	3	3
TC summary:	5		34	5	65	28
			Metrosideros polymorpha			
	2	33	98.7	2	25	0
	4	36	38.7	3	43	0
	6	39	3.5	1	10	0
	7	40	1.1	0	4	0
	8	39	0.2	0	1	0
	9	32	0.1	0	0	0
	10	50	0.2	0	2	1
	11	12	0.2	0	1	0
	13	40	0.1	0	1	1
	14	37	0.1	0	1	1
	15	55	0.1	0	2	2
	16	60	0.3	0	9	8
	18	41	0.1	0	2	2
	19	35	0.1	0	2	2
	20	61	0.1	0	4	4
MP summary:	3		143.8	9	114	28

Appendix C (continued).

Forest type FU11: (continued).

	Average DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Acacia melanoxylon			
	8	49	0.1	0	0	0
	9	48	0.1	0	0	0
	10	51	0.1	0	1	0
AM summary:	9		0.3	0	3	2
			Pritchardia spp.			
	8	21	0.1	0	0	0
	9	25	0.2	0	1	0
PR summary:	9		0.3	0	1	1
			-- Type Level Summary --			
All trees:	5.4		348	56	901	539
Merch trees:	10.1		57	32		

Forest type AN33: Moderate volume *Nepal alder* pole and saw timber.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Metrosideros polymorpha			
	17	72	1.7	3	64	61
MP summary:	17		1.7	3	64	61
			Acacia koa			
	30	80	1.7	8	200	192
AK summary:	30		1.7	8	201	193
			Alnus nepalensis			
	6	52	1.7	0	6	0
	7	39	8.3	2	33	0
	8	55	10	4	69	59
	9	54	11.7	5	103	91
	10	60	11.7	6	139	126
	11	145	11.7	8	371	349
	12	75	15	12	314	295
	13	95	18.3	17	545	518
	14	47	13.3	15	253	234
	15	65	10	12	278	262
	16	83	8.3	12	341	326
	17	97	5	8	250	241
	18	97	8.3	15	472	455
	19	100	5	10	322	311
	20	111	1.7	4	132	128
	21	64	3.3	8	170	162
	22	85	3.3	9	245	236
	24	113	3.3	11	385	374
	27	119	1.7	7	254	247
AN summary:	14		151.7	163	4691	4424
			-- Type Level Summary --			
All trees:	14.4		154	175	4956	4677
Merch trees:	14.8		144	172		

Appendix C (continued).

Forest type CJ00: Recent *Cryptomeria japonica* plantings / sapling stands.

	DBH (in)	Average Height (ft)	Values per acre: Number of Trees	Basal Area	Volume (ft^3) Gross	Volume (ft^3) Merch
			Toona ciliata			
	7	28	1.7	1	6	0
TC summary:	7		1.7	1	6	0
			Fraxinus uhdei			
	6	31	8.3	2	20	0
	7	29	3.3	1	10	0
	8	43	6.7	2	37	31
	9	19	10	4	41	33
	10	25	3.3	2	19	16
	11	24	3.3	2	23	20
	13	23	1.7	2	16	13
	14	23	1.7	2	18	15
FU summary:	9		38.3	17	188	132
			Metrosideros polymorpha			
	14	47	1.7	2	31	29
	23	76	1.7	5	125	120
MP summary:	19		3.3	7	157	150
			Cryptomeria japonica			
	2	24	206.7	5	38	0
	4	31	113.3	10	105	0
	6	36	18.3	4	57	0
	7	37	10	3	42	0
	9	37	1.7	1	11	10
	10	43	1.7	1	15	14
CJ summary:	3		351.7	22	271	24
			-- Type Level Summary --			
All trees:	4.6		395	46	621	305
Merch trees:	11.2		33	23		

APPENDIX C. SUMMARY OF GAME AND NON-GAME WILDLIFE SPECIES PRESENT IN THE WTMA

Game Species	**Mammal**	Feral Pig (Sus scrofa)
	Birds	Kalij Pheasant (Lophura leucomelana)
		Wild Turkey (Meleagris gallopavo)
		Spotted Dove (Streptopelia chinensis)
		Zebra Dove (Geopella striata)
		Japanese Quail (Coturnix japonica)
Non-Game Species	**Introduced Mammals**	Feral Dog (Canis familiaris)
		Feral Cat (Felis catus)
		Mongoose (Herpestes auropunctatus)
		Rat (Rattus spp.)
	Native mammal	Bat (Lasiurus cinereus semotus)
	Native Birds	Akepa (Loxops coccineus)
		Akiapolaau (Hemignathus munroi)
		Amakihi (Hemignathus virens)
		Apapane (Himatione sanguinea)
		Elepaio (Chasiempis sandwichensis)
		Iiwi (Vestiaria coccinea)
		I'o (Buteo solitarius)
		Omao (Myadestes obscurus)
		O'u (Psittirostra psittacea)
		Pueo (Asio flammeus)
	Introduced Birds	Barn Owl (Tyto alba)
		Common Mynah (Acridotheres tristis)
		House Finch (Carpodacus mexicanus)
		House Sparrow (Passer domesticus)
		Japanese White Eye (Zosterops japonicus)
		Melodious Laughing Thrush (Garrulax canorus)
		Northern Cardinal (Cardinalis cardinalis)
		Red-Billed Leiothrix (Leiothrix lutea)