CONSERVATION DISTRICT USE APPLICATION (CDUA)

All permit applications shall be prepared pursuant to HAR 13-5-31

File No.: OA-3780
Acceptance Date: Aug 31 2016 180-Day Expiration Date: Feb 27 2017
Assigned Planner: Tiger
for DLNR Use

RECEIVED
OFFICE OF CONSERVATION
AND COASTAL LANDS
2016 JUL 28 A 9:35
DEPT. OF LAND & NATURAL RESOURCES
STATE OF HAWAII

PROJECT NAME: Makaha transpiration study

Conservation District Subzone: Resource

Identified Land Use: Data Collection
(Identified Land Uses are found in Hawai'i Administrative Rules (HAR) §13-5-22 through §13-5-25)

Project Address: Makaha Valley

Tax Map Key(s): 8-4-002:001

Ahupua'a: Makaha

District: Waianae

County: Honolulu

Island: Oahu

Proposed Commencement Date: July 2016

Proposed Completion Date: July 2020

Estimated Project Cost: $21,865 (materials)

TYPE OF PERMIT SOUGHT: ☐ **Board Permit** ☒ **Departmental Permit**

☐ Temporary Variance *(ref §13-5-36)*
☐ Site Plan Approval *(ref §13-5-38)*

Note: The two items on the left do not require that a full CDUA be filled out. Please complete the first four pages of this application and refer to the relevant HAR sections for the required documentation.

ATTACHMENTS *(where applicable)*

$ n/a Application Fee *(ref §13-5-32 through 34)*
$ n/a Public Hearing Fee *($250 plus publication costs; ref §13-5-40)*
☒ 20 copies of CDUA for Board and Departmental Permits (*5 hard + 15 hard or digital copies)*
☐ Management Plan *or* Comprehensive Management Plan (*ref §13-5-39 and Chapter 13-5 Exhibit 3)*
☐ Draft / Final Environmental Assessment *or* Draft / Final Environmental Impact Statement
☒ Special Management Area Determination *(ref Hawai'i Revised Statutes (HRS) 205A)*
☐ Shoreline Certification (*ref §13-5-31(a)(8))* if land use is subject to coastal hazards.
☐ Kuleana documentation (*ref §13-5-31(f))* if applying for a non-conforming kuleana use.
☐ Boundary Determination *(ref §13-5-17)* if land use lies within 50 feet of a subzone boundary.

REQUIRED SIGNATURES

Applicant

Name: Thomas Giambelluca
Title; Agency: Professor, Geography Department, University of Hawaii at Manoa
Mailing Address: 445 Saunders Hall, 2424 Maile Way
Honolulu, Hawaii 96822
Contact Person & Title: *see "agent" below
Phone: 808-956-7390
Email: thomas@hawaii.edu
Interest in Property: Researcher working with landowner HBWS

Signature: Thomas Giambelluca **Date:** 7/15/16

Signed by an authorized officer if for a Corporation, Partnership, Agency or Organization

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Landowner (if different than the applicant)

Name: Ernest Lau
Title; Agency: Manager and Chief Engineer, Honolulu Board of Water Supply
Mailing Address: 630 South Beretania Street
Honolulu, Hawaii 96843
Phone: 808-748-5061
Email: elau@hbws.org

Signature: BH for EL **Date:** 7/21/16

For State and public lands, the State of Hawai`i or government entity with management control over the parcel shall sign as landowner.

Agent

Agency: Geography Department, University of Hawaii at Manoa
Contact Person & Title: Aurora Kagawa-Viviani, graduate student
Mailing Address: 445 Saunders Hall, 2424 Maile Way
Honolulu, Hawaii 96822
Phone: 808-956-7390
Email: kagawa@hawaii.edu

Signature: Aurora K. Kagawa-Viviani **Date:** 7/15/2016

For DLNR Managed Lands

State of Hawai`i
Chairperson, Board of Land and Natural Resources
State of Hawai'i
Department of Land and Natural Resources
P.O. Box 621

Honolulu, Hawai'i 96809-0621

Signature: _____ **Date:** _____

PROPOSED USE

Total size/area of proposed use (indicate in acres or sq. ft.): 100 sq ft for setup of research infrastructure, <5000 sq ft for study site

Please provide a detailed description of the proposed land use(s) in its entirety. Information should describe what the proposed use is; the need and purpose for the proposed use; the size of the proposed use (provide dimensions and quantities of materials); and how the work for the proposed use will be done (methodology). If there are multiple components to a project, please answer the above for each component. Also include information regarding secondary improvements including, but not limited to, grading and grubbing, placement of accessory equipment, installation of utilities, roads, driveways, fences, landscaping, etc.

Attach any and all associated plans such as a location map, site plan, floor plan, elevations, and landscaping plans drawn to scale *(ref §13-5-31)*.

PRIOR CONSERVATION DISTRICT USE PERMITS (CDUP) and SITE PLAN APPROVALS:

Based on records provided by landownder Honolulu Board of Water Supply (HBWS), the following CDUPs were issued for activities on TMK 8-4-2:001:

1) OA-1317 for drilling of Makaha Exploratory Well III, approved May 8, 1981

2) OA-1336 and OA-1337 for drilling of Makaha Exploratory Wells IV and V, approved July 10, 1981

3) OA-1968 for development of Makaha Wells III and IV (TMK 8-4-2:001, 013, 014) and OA-2071 for development of Makaha Wells II and IV (TMK 8-4-2:001, 013) approved January 22, 1988.

4) OA-3274 for installation of a fenceline for ungulate control, approved June 20, 2006 by Dawn Hegger (TMK 8-4-2:001 and 014).

5) Site plan approval OA-15-27 for another ungulate exclusion fence within TMK 8-4-2:001 granted by OCCL Dec 20, 2014. Previous authorization for fencing activities granted with CDUP OA-3274.

LOCATION:

The project "Transpiration characteristics of native and non-native plants at a mesic forest site in Makaha Valley" will take place in the upper Makaha Valley, Waianae Range on the island of Oahu, at a single site within TMK 8-4-002:001. The project is being carried out at request of and in partnership with the landowner, Honolulu Board of Water Supply, City and County of Honolulu (See attached Figure 1). The specific site of interest in within the "resource" subzone of the conservation lands.

RESEARCH OBJECTIVES:

The project associated with this permit application is a case study focused on understanding plant water use characteristics of native and non-native trees and forest stands. For this paired-plot study, we are comparing a mixed native stand of lama (Diospyros sandwicensis) and olopua (Nestegis sandwicensis) with a nearby nearly monotypic stand of strawberry guava (Psidium cattleianum) and java plum (Syzigium cumini). We are interested in how these different tree covers, through physiological and structural

differences, influence stand-scale water fluxes. By monitoring these fluxes over several years, we anticipate learning more about if and how species differences scale up to stand-level hydrological differences. Findings from this study will inform ongoing and future watershed and invasive species management activities.

To carry out this research, we will (1) determine transpiration rates for lama, olopua, strawberry guava, and java plum trees; (2) determine leaf-level gas exchange characteristics of these species; (3) quantify the effects of changing environmental conditions (solar radiation, humidity, soil moisture, temperature and canopy wetness) on gas exchange of those plants; and (4) provide an assessment of the general effects of non-native plant cover relative to native plant cover for this mesic site on Oahu. In order to safely access tree canopy leaves for leaf-level gas exchange measurements, we will need to erect light infrastructure consisting of two scaffolds (see "Research Infrastructure" below).

This mesic forest site in Makaha is particularly valuable because previous research comparing hydrological effects of strawberry guava and native cover (ohia, Metrosideros polymorpha) has only been carried out in wetter montane cloud forest (in Hawaii Volcanoes National Park); the effects of invasion/species replacement in drier lowland areas has not been well-studied. This research also builds upon previous research on forest hydrology in Makaha that found strawberry guava generates a much higher stemflow fraction than other invasive species, Christmasberry (Schinus terebinthifolius) and coffee (Coffea arabica). This finding has implications for sediment generation and runoff under strawberry guava. We note these previous studies did not compare invasive species with co-occurring native species and did not consider possible differences in plant water uptake (transpiration) and net effects on overall water balance and recharge. Better understanding of transpiration losses as well as possible native vs non-native invasive plant differences would improve our overall understanding of species' effects on local hydrology.

For more information on the research, see Attachment 1: Makaha transpiration study, Attachment 2: Geography seed grant proposal

FIELD SITES:

Field sites for this study will be collocated with those of the "Canopy Interception Study" initiated by the Honolulu Board of Water Supply in 2014 in Makaha Valley, Oahu. A pair of sites
(500 meters above sea level, ~1640 feet) have been set up for the ongoing rainfall interception study and represent native and invaded forest described above (see Fig. 1).

DURATION:

After setting up research infrastructure, measurement and monitoring will continue for up to 3 years. We hope to install research infrastructure before the end of the 2016 calendar year. At the end of the project, we will remove all materials from the site. We understand the standard conditions are 1 year for installation and because our monitoring project will run longer than this, we would like to be considered for a time extension to accommodate the 3 years of monitoring as well as time for removal of infrastructure at the project's end.

PROPOSED RESEARCH INFRASTRUCTURE:

Accessing the tree canopies for leaf-level gas-exchange measurements requires installation of two 16-20' scaffolds. One of these scaffolds will house sensors for measuring micrometeorology (rainfall, air temperature, relative humidity, wind speed and direction, solar radiation). Solar panels will be mounted on each scaffold, and these will power sensors for measuring tree sapflow on up to 6 individual trees per species. We also plan to monitor soil conditions (moisture, heat flux, and temperature), and leaf wetness. We intend to keep the scaffolds in operation for the duration of the project (3 years) and have committed to removing all materials from the site at the project conclusion. Construction/deconstruction and maintenance of the scaffolds will be the responsibility of the researchers led by principal investigator Thomas Giambelluca.

The proposed 16'-20' scaffolds each have roughly a 35 sq ft footprint (5'x7') and would look something like the diagram attached (see Attachment 3 submitted to HBWS). The scaffolds will be set on four shallow concrete piers/footings to prevent the frame from sinking into soft/wet soil. These will be no more than 1' deep, and each will have a 2'x2' footprint. Installation of these footings for each of the two scaffolds will require initial removal of approximately 16 cubic feet of soil. The displaced soil will be located in a level site or small depression near to each scaffold, so that it remains contained on-site and does not run offsite during heavy rainfall events.

For extra stability and safety, we will guy the scaffold to four heavy duty T-posts (~6') or screw-in ground anchors. The guy wires will extend out from each corner at a distance approximately half the height of the scaffold. We estimate approximately 50 sq ft will be impacted per scaffold. We are locating and positioning scaffolds in a way that ensures as little impact to the site as possible, as this can adversely influence the nearby trees and thus our measurements.

Measurements necessary for the research include sapflow sensing and periodic sampling of plant tissue and soil/soil water. Plant leaves will be sampled for tissue chemical analyses (monthly) and twigs, soil, and soil water will be sampled for water stable isotope analyses, which allow us to trace plant water sources. We will install sapflow sensors in trees to measure water uptake; we intend to install only as many sensors as necessary to obtain quality measurements, thereby minimizing impact to the native trees. The heat ratio methods for sapflow involve insertion of three needle-sized probes (~3/32" diam) into the tree trunk, and we intend to install these carefully since damaging trees negatively impacts sapflow data quality.

Installation of soil moisture, soil heat flux, and soil temperature sensors and passive capillary soil water samplers will require temporary disturbance to the soil as we will need to bury equipment at different depths. Small holes no more than 1 m deep (~3 feet) will be dug for soil measurements. We anticipate no more than 6 cubic feet will be displaced per site as part of the soil water and energy monitoring efforts. As with the scaffold installation, we will contain displaced soil onsite to ensure it does not contribute to sediment runoff or otherwise impact the immediate or neighboring ecosystems.

INSTALLATION AND REMOVAL:

Precise locations for the scaffolds have been proposed to and discussed with HBWS staff familiar with the sites. These are located on level or gently sloping spots where installation will require at most clearing of small brush including mildly invasive thimbleberry. All holes for concrete footings and soil moisture measurements will be dug by hand or auger.

Materials for research infrastructure including concrete, scaffolding panels, solar panels, batteries, dataloggers, and sensors will be dropped by helicopter to existing cleared sites. Following complete installation, trash will be hiked out from the site. During the 3-year research project, replacement sensors and other research equipment be hiked in and out as necessary via a trail and access road managed by HBWS. HBWS access agreements and protocols are already in place.

At project completion, all materials will be removed from the site and all holes will be backfilled to return the site to as close to pre-project conditions as possible. The concrete footings, scaffolding panels, batteries, solar panels, and other equipment will be lifted by helicopter and transported out of the valley for proper disposal and storage/reuse. These are conditions set by landowner and project funder HBWS and agreed upon by the researchers.

GRADING AND GRUBBING:

No grading or major landscaping will be performed. At most, the footing positions/depths will be adjusted to ensure the installed scaffold remains level. Grubbing for installation of the scaffold footings will be limited to the 35 sq ft footprint for each of the two proposed scaffolds. Grubbing for soil monitoring will be limited to 6 cubic feet; as mentioned earlier, soil will remain onsite, deposited upslope of logs, rock, fallen branches, or in nautral depressions to prevent erosion. Impact to vegetation will be minimal and temporary, at most pruning several thimbleberry bushes and possibly one to two maile plants; we intend to avoid disturbing any native trees.

Again, at the close of the project, all project-related infrastructure will be removed from the site and holes backfilled with the soil displaced during installation.

PLACEMENT OF ACCESSORY EQUIPMENT:

We anticipate construction of the scaffolds to last less than one week. During this time, we may store our materials onsite near the scaffolds, covered by a tarp, or hidden to be inconspicuous. After installation, we will hike out tools, trash, and accessory equipment.

During our monitoring period, all loggers will be stored in secured, painted logger boxes either on the scaffold itself or under the scaffold within the 35 sq ft footprint.

INSTALLATION OF UTILITIES:

Solar panels to power all loggers and sensors will be placed on the scaffolds at a level above the tree canopy. These will run to a charge regulator and battery bank that will be secured to the scaffold and painted to be inconspicuous. Datalogger housing will be mounted to (or beneath) the scaffold, and sensors will be run out from there. We may lightly bury sensor cables running from the logger to trees/soil to protect them from sharp objects and chewing animals.

ROADS/DRIVEWAYS/FENCES/LANDSCAPING:

Not applicable

EXISTING CONDITIONS

Please describe the following, and attach maps, site plans, topo maps, colored photos, and biological or archaeological surveys as appropriate:

Existing access to site:

A one-lane blacktop access road approximately 1.5 miles long, extends to upper Makaha Valley from Mauna Olu Estates/Kaneaki Heiau. Access to the specific project site is via landowner HBWS. This project is being carried out in partnership with HBWS, and they have granted right of entry and have provided access protocols. We park at the end of the road at their uppermost well and hike the remaining distance about 0.5 miles to the field site.

Existing buildings/structures:

HBWS owns and maintains structures in TMK 8-4-002:001 including wells along the access road and upland ungulate control fences managed in partnership with Oahu Army Natural Resources (OANRP). The project site is near one of these fences but will not impact it. The parcel is very large and other than the fence, these existing structures do not relate directly to this project site, which is located approximately 0.5 miles east of the last well/end of access road.

Existing utilities (electrical, communication, gas, drainage, water & wastewater):

There are no existing utilites at this specific project field site. Existing utilities (wells) in this TMK are on the valley bottom, the closest of which is 0.5 miles from the field site.

Physiography (geology, topography, & soils):

The project site is in a level to gradually sloped area atop a ridge at 500 m (1640') elevation above sea level. Soils found in the area belong to the Tropohumults-Dystrandepts association (USSCS, 1972) . This association consists of well drained, organic matter-rich soils with strong physical structure. According to a water permeability map (http://gis.ctahr.hawaii.edu/downloads/soilAtlas/WaterPermeability.jpg), permeability is "fast" between 10-100 µm/s.

Hydrology (surface water, groundwater, coastal waters, & wetlands):

"From a water supply perspective, Makaha and Waianae are the most critical watersheds in the Waianae District and many watershed projects are focused here. These watersheds have the most ground water and surface water use, available agricultural lands, important cultural significance, and perennial stream segments in the upper valleys." -excerpt from the Waianae Watershed Management Plan, 2009

Surface water bodies in TMK 8-4-002:001 include Makaha stream, about 0.25 miles downslope from the site of interest. Makaha stream is one of only 6 major streams in the Waianae watershed and baseflow is fed by ground and surface waters from Mt. Kaala at the top of the watershed at 4,025 feet above sea level. While Makaha stream's upper reaches are perennial, its lower reaches are intermittent. According to a 1990 Hawaii Stream Assessment, its median annual flow is 0.323 mgd or 0.5 cubic feet per second (cfs). The stream is gauged and monitored by USGS, and HBWS staff note that even when the USGS gauge reads no flow, the stream continues to flow underground.

Makaha Stream is one of the few Waianae streams that remains unchannelized. It flows to the

southwest and terminates behind a large sand berm at Makaha Beach Park, nearly 4 miles southwest and downstream of our proposed field site. There the stream meets the West Makaha Stream on the north side of the valley, closer to Kepuhi Point than Lahilahi Point. A 2014 flood mitigation study indicates this northern side of the valley is a subject to flooding. The report also notes that prior to 2008, there used to be a natural pond near the shore that served as a detention pond. This area was filled in during a Honolulu City and County effort to restore Makaha Surfing Beach following a 2008 storm and now consists of an area ~50 feet wide that instead channels water from Makaha Stream to the West Makaha Stream outlet, no longer serving as a debris catchment. During flood conditions, this berm is breached and water flows at Makaha Surfing Beach, carrying along with it sediment from upstream.

Groundwater resources in Makaha are a valuable part of the Waianae Range's water resources, with sustainable yield of the aquifer set at 3 million gallons per day (mgd, CWRM 2005). The sustainable yield set for the encompassing Waianae aquifer system is 16 mgd, however, not all aquifers in Waianae Range watersheds are utilized. Makaha alone, pumped at a mean annual rate of 1.8 mgd, provided nearly 40% of the Waianae aquifer system's total yield in 2005 (Waianae Watershed Management Plan, 2009). Most municipal water for the Waianae district comes from the adjacent Pearl Harbor Aquifer, and of the 9.3 mgd demand by both public and private users in the area, Makaha consumes 2.2 mgd (HBWS website). Thus local demand is greater than supply.

Most rainfall feeding Makaha's water resources comes in winter months through passing cold fronts and Kona storms. Understanding how these rainfall events contribute to surface and groundwater resources is a component of this study as we observe how large and small rainfall events interact with vegetation at the stand scale in the upper areas of the catchment. Mean annual precipitation at the field site is estimated at 1800mm/year.

Flora & fauna (indicate if rare or endangered plants and/or animals are present):

The project site encompasses forest stands dominated by strawberry guava (Psidium cattleianum) and java plum (Syzigium cumini) and a restoration area co-dominated by lama (Diospyros sandwicensis), olopua (Nestegis sandwicensis), alahee (Psydrax odorata), kukui (Aleurites moluccana), and ki (Cordyline fruticosa). No federally listed rare or endangered plants are present in the immediate vicinity. The native trees we intend to monitor, although uncommon, are not federally listed, and non-native strawberry guava along with other invasive species are being actively managed in native plant restoration/outplanting activities described below.

Upper Makaha Valley is dominated mostly by non-native species on an areal basis (see Figure 2). It is home, however, to several populations of threatened and endangered plant species, which are being managed through a HBWS-Oahu Army Natural Resources collaboration. OANRP also conducts weed, ungulate, and predator control as well as native plant restoration projects in the upper Makaha Valley. DLNR- Division of Forestry and Wildlife and Waianae Mountains Watershed Partnership also carry out watershed management activities in upper Makaha.

Natural hazards (erosion, flooding, tsunami, seismic, etc.):

Natural hazards for Makaha Valley as a whole include lowland flooding near the coast and flash flooding in upper stream reaches during heavy rains, described to us by HBWS staff and visible by the debris at the high water line, evidence of large streamflow events.

Brushfires are a hazard for the dry Waianae Range in general, where they start in lowland grass-dominated areas and then run quickly uphill. Upper Makaha, however, is relatively moist and the presence of the residential gated community of Mauna Olu Estates and golf course at base of the

upper valley suggests easier fire suppression with HFD support (and road access, fire hydrants, water bodies).

Our specific sites of interest are on relatively level ground, 10-20% slope, about 10°. In general, erosion is an issue in steep sections of the valley. We chose our sites to be in an area that was as level as possible but which hosted both native and non-native invasive trees to facilitate a comparative study of tree water use. The sites have good drainage and show no signs of rilling or rapid surface erosion.

Historic & cultural resources:

Several archeological and cultural surveys conducted in Makaha document numerous cultural sites in Makaha. According to the 2009 Waianae Watershed Management Plan: "Along the Leeward coast, Makaha is the most abundant source of water. A large population of about 840 people lived near the upper and middle portions of this valley. Large numbers of permanent house sites have been located. Vegetable food came from two main areas. The upper valley stream flats are nearly all covered with small sets of irrigated kalo fields. Areas from the lower valley to the near-shore are full of remains of dry land agriculture fields that once grew uala, gourds, wauke, and other crops."

Each time we access the field site in upper Makaha, we pass Kaneaki Heiau, a visible reminder of the population, agriculture, and political and cultural significance of the valley. Hiking from the end of the road to our fieldsite in the upper valley, we pass many low walls near the stream indicating once intensive irrigated cultivation of kalo (taro, Colocasia esculenta) along with a population to support it. Deeper in the valley, mango trees were planted along the carriage road and coffee, remnants from plantation days, spread into old lo'i. Most evidence of human habitation and activity are on the valley bottom.

The particular site pertinent to this permit application is more than a half mile directly upslope of the streambed. The native vegetation in the area appears relatively intact and more impacted by competing invasive species rather than human activity. HBWS has in the past facilitated weeding of invasive species and restoration activities at the site, part of which is protected by an ungulate exclusion fence. We note that Makaha Valley archaeological site 50-80-07-6690 is in the vicinity of the fenceline and consists of boulders and low alignments. The fenceline was extended below the rocks to protect the rock clusters. We intend to work even further from this archaeological site- tens of meters from this location and in the middle of more densely forested patches to protect the integrity of the archaeological site. Neither we nor landowner HBWS wish to negatively impact any cultural sites in the area.

EVALUATION CRITERIA

The Department or Board will evaluate the merits of a proposed land use based upon the following eight criteria *(ref §13-5-30(c))*

1. The purpose of the Conservation District is to conserve, protect, and preserve the important natural and cultural resources of the State through appropriate management and use to promote their long-term sustainability and the public health, safety, and welfare. *(ref §13-5-1)* How is the proposed land use consistent with the purpose of the conservation district?

   Insights gained from this study will improve understanding of hydrological effects of vegetation change and watershed management. The attached Makaha Transpiration Study proposal (attachment 1) shines a spotlight on the ecological problem of invasive species in Hawaii and focuses inquiry on the hydrological impacts and processes that may result from species differences. While invasive species globally threaten biodiversity and integrity of native forest ecosystems, hydrologists usually neglect species differences, assuming all forests function similarly, at least at the scale of the watershed catchment. However, controlling or eradicating non-native plants is difficult and expensive. This research is motivated by political pressure to justify watershed management activities/expenditures in terms of water resources. Better basic understanding of how different plant species affect water fluxes at the plot scale will contribute to better understanding of if and how native and non-native trees differ in their hydrological value and impact on both water quantity and quality at local and catchment scales.

2. How is the proposed use consistent with the objectives of the subzone of the land on which the land use will occur? *(ref §13-5-11 through §13-5-15)*

   According to HRS §13-5-13, "the objective of this subzone is to ensure, with proper management, the sustainable use of the natural resources of those areas." This research on plant transpiration, being carried out at request of HBWS, directly supports its water resource management efforts in Makaha Valley. The research complements previous studies of the effects of invasive species on rainfall partitioning (Mair and Fares 2010 and Safeeq and Fares 2014). We also will be extending some updated techniques to trace rainfall from the canopy through the soil to better understand where water goes when it rains, which will complement the sapflow (transpiration) monitoring. We hope that this provides a more complete picture of the mechanisms behind differences/similarities observed between the two vegetation covers.

   Watershed managers may worry that we will find no significant difference between the native and invasive-dominated forest stands. However, knowing more about the dynamics of vegetation-water interactions will expand the conversation on HOW to manage vegetation for recharge/sediment control. We also suspect that by studying guava and mesic forest, we may learn how to better support conservation and restoration of native dry and mesic forest in the context of invasion. The research also provides opportunity to explore the implications of climate change- increased temperatures and changing rainfall regimes- for mesic forests, guava invasion, and the hydrological processes these plant covers mediate. We note that that several other guava-native forest hydrology case studies will be carried out in the next few years that will complement this effort.

3. Describe how the proposed land use complies with the provisions and guidelines contained in chapter 205A, HRS, entitled "Coastal Zone Management" *(see 205A objectives on p. 9).*

   RECREATIONAL RESOURCES: "Provide coastal recreation opportunities accessible to the public"
   Not applicable

RE: HISTORIC RESOURCES, SCENIC/OPEN SPACE RESOURCES, COASTAL ECOSYSTEMS, MARINE RESOURCES, BEACH PROTECTION, ECONOMIC USES: "Protect, preserve, and where desirable restore those natural and manmade historic and prehistoric resources in the coastal zone management area that are significant in Hawaiian and American history and culture (historic resources)... Protect, preserve, and where desirable restore or improve the quality of coastal scenic and open space resources (scenic and open space resources)... Protect valuable coastal ecosystems, including reefs, from disruption and minimize advers impacts on all coastal ecosystems (coastal ecosystems)... Promote the protection, use, and development of marine and coastal resrouces to assure their sustainability (marine resources)... Protect beaches for public use and recreation (beach protection)... Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion, subsidence, and pollution (coastal hazards)... Provide public or private facilities and improvement to the State's economy in suitable locations (economic uses)"

Although we are not working in a coastal zone management area, we believe our efforts to understand effects of vegetation on hydrological processes is part of a broader effort to understand, maintain and improve hydrological function in Hawaiian watersheds and maintain/restore ahupuaa concepts of connectivity. Water is a key part of Makaha Valley's history, present, and future, and appropriate management of these for quantity AND quality should be a collective responsibility. While HBWS manages the upper valley primarily for groundwater recharge, maintaining or increasing instream flow, keeping water temperatures cool and sediment load low are valuable for instream biota and coastal ecosystems and resource users downstream. Thus understanding vegetation's impact on all of these from a plot perspective can contribute to insight to watershed and coastal management.

Moving forward in the next 100 years, human-mediated global climate change will certainly affect local climate, ecosystems, and water resources. This has implications for all aspects of our island, including economically valuable resources such as clean drinking water, clean coastal waters, and healthy coastal ecosystems whether for subsistence or tourism. It is imperative that we understand the ecology and hydrology of our systems in their current state if we are to protect these for Hawaii communities in years ahead.

In the context of direct potential project impacts on any of the above, we contend that while scaffold installation will cause some disturbance to the soil in the area, the <50 cu ft of displaced soil (~16 +6 cu ft for each of two stands) will be contained so that it remains onsite and does not contribute to sediment load of Makaha stream or beach. Again, at the end of the project, the soil will be replaced and research materials removed from the site as consistent with our agreement with HBWS. We acknowledge that installation of sensors will cause some damage to the vegetation we are studying, but again, our goal is to minimize this, consistent with our personal values and our desire to gather high quality data. Our goal for the research is to carry out a thoughtfully designed and well-executed study to offset the collateral damage of the research. We hope to generate significant net benefit for the ecosystems and watersheds we study and for the land managers with whom we work.

RE: MANAGING DEVELOPMENT, PUBLIC PARTICIPATION: "Improve the development review process, communication, and public participation in the management of coastal resources and hazards... Stimulate public awareness, education and participation in coastal management"

While we see this project as focused less on coastal resource, hazards, and management, we speak here to the value of communicating our work with the public. Although these sites are on HBWS

lands not generally accessible to public, we do see evidence of unofficial and unauthorized access by hunters and hikers. We intend to include signage of the study that explains the questions being asked and provide researcher contact information for any curious passers-by. The purpose is two-fold: although our initial concerns were to deter vandalism, we believe education and transparency can engage the public in our research in positive ways. HBWS does not actively encourage public outreach about the Makaha research activities, preferring to minimize traffic and protect groundwater wells and T&E species restoration and watershed projects. However, if people do pass through and see our equipment, we would like to encourage them to value the research and data being generated as work that will eventually benefit them, local ecosystems, and water resources.

4. Describe how the proposed land use will not cause substantial adverse impact to existing natural resources within the surrounding area, community or region.

   The entire broadly delineated study area is less than 2 hectares, and the footprint of the two scaffolds will be less than 50 square feet each (35 sq ft scaffold footprint + installation of anchors). The structures will be positioned in relatively clear areas to avoid removal of trees and minimize impact to surrounding vegetation. As mentioned earlier, less than 50 cubic feet of soil will be displaced for installation of the two scaffolds and this will be contained onsite to avoid erosion/sedimentation. Adverse immediate impacts to community or region should be minimal as access to the site is controlled by HBWS and the footprint is small relative to the size of the watershed. The research itself should, in the long term, improve understanding of water resources and watershed management in Makaha with implications for ecosystems across the Hawaiian Islands.

5. Describe how the proposed land use, including buildings, structures and facilities, is compatible with the locality and surrounding areas, appropriate to the physical conditions and capabilities of the specific parcel or parcels.

   The scaffolds will not be taller than the surrounding canopy trees and will be positioned on relatively level and open ground to minimize disturbance to the vegetation and minimize potential for causing erosion. The research itself is appropriate to the physical conditions and capabilities of the specific parcel as it complements previous Makaha research on invasive vegetation-rainfall interactions and takes advantage of the co-occurring native and non-native vegetation of the valley. The field site's location on Oahu more frequent access for maintenance and sampling, leading to better insight into how this vegetation affects water quantity and quality in Hawaiian watersheds.

6. Describe how the existing physical and environmental aspects of the land, such as natural beauty and open space characteristics, will be preserved or improved upon.

   The light structures will be painted dark colors as to be visually unobtrustive, and concrete pouring will be constrained to small blocks necessary for scaffold stabilization. Again, soil that will be removed during installation will be contained onsite. Upon project completion, all materials will be removed from the site and holes will be backfilled to restore the site to pre-project conditions (as much as possible). The research itself is intended to inform and support management and natural resources in Makaha.

7. If applicable, describe how subdivision of land will not be utilized to increase the intensity of land uses in the Conservation District.

   Not applicable-- no subdivision occurring

8. Describe how the proposed land use will not be materially detrimental to the public health, safety and welfare.

The area is restricted access, so immediate impacts on the public should be minimal. No hazardous chemicals will be used, and rechargeable batteries will be kept in containers to avoid potential battery acid spillage onto the soil. Proper signage will inform about the research and discourage tampering of the structures or research equipment. Again, because displaced soil will be contained onsite, there should be little to no erosion affecting downstream water quality. We contend this research will provide net benefits to the public in the long run by informing local watershed management.

CULTURAL IMPACTS

Articles IX and XII of the State Constitution, other state laws, and the courts of the State, require government agencies to promote and preserve cultural beliefs, practices, and resources of Native Hawaiians and other ethnic groups.

Please provide the identity and scope of cultural, historical, and natural resources in which traditional and customary native Hawaiian rights are exercised in the area.

Kaneaki Heiau, located near the base of upper Makaha Valley, is currently stewarded by local caretakers and the surrounding area is cared for by Mohala i ka Wai, a nonprofit working in partnership with landowner HBWS. The research project site is far up the valley past Kaneaki. We believe pig hunters, hikers, and hula practitioners access this part of the valley, likely both with or without authorization from landowner HBWS.

Identify the extent to which those resources, including traditional and customary Native Hawaiian rights, will be affected or impaired by the proposed action.

We do not believe cultural resources will be significantly impaired by the proposed action as our sites are located far from Kaneaki, cultural sites, and more heavily trafficked areas closer to the stream. We also will position our scaffolds to minimize impact to native trees and plants in the area although pouring the shallow concrete scaffold footings may temporarily impact the roots of several trees or nearby individual plants. The site is located away from palapalai (fern) beds and maile of interest to hula practicioners and away from valley bottoms where pig activity, hunting, and archaeological site density are greatest. We believe in the long term that our research may inform and enhance native forest restoration and management in the valley and elsewhere.

What feasible action, if any, could be taken by the Board of Land and Natural Resources in regards to your application to reasonably protect Native Hawai'i rights?

If individuals feel that traditional and customary rights are being adversely impacted, we suggest face-to-face meeting to discuss, hooponopono, and find a solution that can both facilitate research on invasive/native plant species and water and protect the aforementioned rights. We see our proposed research as being aligned with maintaining traditional and customary practices by supporting instream flow, groundwater recharge, and persistence of native forest resources.

OTHER IMPACTS

Does the proposed land use have an effect (positive/negative) on public access to and along the shoreline or along any public trail?

Our proposed research is set away from a trail and should not hinder access. More generally, HBWS limits access to the upper valley as it is managed for water resources and native plant species.

Does the proposed use have an effect (positive/negative) on beach processes?

Because we will contain any displaced soil onsite, we do not foresee our project having significant contribution to sedimentation of Makaha stream or beach. In the long run, we hope to understand how differences in vegetation do/don't contribute to differences in sediment runoff under these covers; this would eventually have positive effects on stream water quality and beach processes.

Will the proposed use cause increased sedimentation?

Because scaffolds will be sited in relatively flat areas and because we plan to contain and replace temporarily displaced soil, we do not foresee increased sedimentation of Makaha stream and/or beach.

Will the proposed use cause any visual impact on any individual or community?

Because of limited access to the upper valley, we do not believe our project infrastructure will have significant visual impact on Makaha valley residents. The scaffold design is 20', which means it will not penetrate the canopy and the solar panels we place on it will be small and we will make these as inconspicuous as possible. We will paint the scaffold dark colors to match the surrounding soil/vegetation and so that it remains visually unobtrusive.

Please describe any sustainable design elements that will be incorporated into the proposed land use (*e.g. the use of efficient ventilation and cooling systems; renewable energy generation; sustainable building materials; permeable paving materials; efficient energy and water systems; efficient waste management systems; etc.).*

This system will work off of solar power, with panels attached to the scaffold. These will power rechargeable batteries that will be contained to prevent spillage of battery acid. Loggers and sensors will be run off of this power supply, and all of the above will be attached to the scaffold to facilitate the smallest footprint possible and lowest cable length necessary. At the close of the project, all materials will be removed from the site and either reused or properly disposed.

If the project involves landscaping, please describe how the landscaping is appropriate to the Conservation District (*e.g. use of indigenous and endemic species; xeriscaping in dry areas; minimizing ground disturbance; maintenance or restoration of the canopy; removal of invasive species; habitat preservation and restoration; etc.)*

Some vegetation may need to be removed for scaffold installation. Preliminary site selection indicates that we will need to remove thimbleberry, a mildly invasive understory plant. We may also need to remove a (native) maile shrub, which we will avoid if possible. We may try to use the scaffold as a trellis for the maile. Again, in the long-term, the research insights should guide ongoing invasive species removal efforts and native plant restoration in Makaha Valley.

Please describe Best Management Practices that will be used during construction and implementation

of the proposed land use.

We will be installing the scaffold manually, hand-digging the footings (or using a small auger), and manually pounding anchors. We will also be pouring footings for the scaffold in smaller blocks to use as little concrete as necessary and to facilitate removal of these at the end of the project. Materials for construction/removal will be flown in/out with as few sling loads as possible, to minimize disturbance to the site vegetation, and other trash will be hiked out of the valley.

We will be painting the scaffold a neutral color to minimize visual impact, and we will include signage to discourage tampering by any potential passers-by. The signs will also describe the research and provide contact information for questions, so any curious passers-by might appreciate the value of the research for watershed management.

Please describe the measures that will be taken to mitigate the proposed land use's environmental and cultural impacts.

MITIGATING ENVIRONMENTAL IMPACTS

As mentioned earlier, although scaffold installation will necessitate disturbance of soil, we will 1) minimize impact to soil/vegetation through small footings and appropriate siting on level, relatively clear spots, 2) contain all displaced soil on-site, 3) remove all materials at the end of the project and backfill holes using the soil displaced earlier. Sapflow sensor installation requires drilling of small holes into the tree trunk. We will practice our sensor installation methods prior to installation on the native trees, and we have in-house an expert to direct our use of this technology. Although it is not our intention to adversely impact this ecosystem, some disturbance is necessary for us to carry out the research. Our aim is to minimize this impact and generate high-quality research datasets contributing to better understanding and management of watersheds.

MITIGATING CULTURAL IMPACTS

Our proposed sites are located far from known archaeological sites and valuable natural resources for hula and other cultural practices. We will be designing signage with information on the study and contact information to provide transparency to let curious passers-by understand the intention of the research. We hope that they may appreciate the research as useful/valuable for the community and watershed, and if conflict arises, we are open to discussion and adjusting our plans as necessary.

SINGLE FAMILY RESIDENTIAL STANDARDS

Single Family Residences must comply with the standards outlined in HAR Chapter 13-5, Exhibit 4. Please provide preliminary architectural renderings (e.g. building foot print, exterior plan view, elevation drawings; floor plan, etc.) drawn to scale.

SIZE OF LOT

	Existing	Proposed	Total
Proposed building footprint			
Paved areas/ impermeable surfaces			
Landscaped areas			
Unimproved areas			

SETBACKS Front: Side: Back:

SHORELINE PROPERTIES

Average Lot Depth (ALD): Average annual coastal erosion rate:

Minimum shoreline setback based on Exhibit 4:

Actual shoreline setback or proposed structure:

MAXIMUM DEVELOPABLE AREA

The Maximum Developable Area includes all floor areas under roof, including first, second, and third stories, decks, pools, saunas, garage or carport, and other above ground structures.

Maximum Developable Area based on Exhibit 4:

Actual Developable Area of proposed residence:

Actual height of the proposed building envelope as defined in Exhibit 4:

COMPATIBILITY

Provide justification for any propose deviation from the established residential standards.

How is the design of the residence compatible with the surrounding area?

If grading is proposed, include a grading plan which provides the amount of cut and fill. Has grading or contouring been kept to a minimum?

CHAPTER 205A – COASTAL ZONE MANAGEMENT

Land uses are required to comply with the provisions and guidelines contained in Chapter 205A, Hawai'i Revised Statutes (HRS), entitled "Coastal Zone Management," as described below:

- **Recreational resources:** Provide coastal recreational opportunities accessible to the public.
- **Historic resources:** Protect, preserve, and, where desirable, restore those natural and manmade historic and prehistoric resources in the coastal zone management area that are significant in Hawaiian and American history and culture.
- **Scenic and open space resources:** Protect, preserve, and, where desirable, restore or improve the quality of coastal scenic and open space resources.
- **Coastal ecosystems:** Protect valuable coastal ecosystems, including reefs, from disruption and minimize adverse impacts on all coastal ecosystems.
- **Economic uses:** Provide public or private facilities and improvements important to the State's economy in suitable locations.
- **Coastal hazards:** Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion, subsidence, and pollution.
- **Managing development:** Improve the development review process, communication, and public participation in the management of coastal resources and hazards.
- **Public participation:** Stimulate public awareness, education, and participation in coastal management.
- **Beach protection:** Protect beaches for public use and recreation.
- **Marine resources:** Promote the protection, use, and development of marine and coastal resources to assure their sustainability.

MANAGEMENT PLAN REQUIREMENTS

Certain land uses require that a Management Plan be approved by the Board of Land and Natural resources. The Management Plan can be processed concurrently with the Conservation District Use Application and must be consistent with HAR Chapter 13-5, Exhibit 3. Please attach the proposed Management Plan as a separate document.

Pursuant to the above, Management Plans must include:

- General description of the proposed use (e.g. forestry, fishpond, astronomy, aquaculture, agriculture)
- Project location (e.g. island maps, location map, site plan (drawn to scale))
- Natural resource assessment, including descriptive information about the natural resources in the project vicinity such as biological, archaeological, cultural, geological, coastal, recreational, and scenic resources, where applicable. The presence of any threatened or endangered species shall be disclosed.
- A description of best management practices used during project construction and implementation (e.g. mitigation measures).
- A description of the best management practices to be used during the lifetime of the project (e.g. mitigation measures)
- A description of the conservation methods as applications to be used in the short term and long term (e.g. mitigation measures)
- Description of existing uses and facilities, if any.
- Description of proposed facilities and uses, including phases, if applicable.
- Project schedule including description of project sequencing from project construction to project completion and on-going maintenance plans, including a description and timing of natural resource monitoring and maintenance plans.
- A description of the annual reporting requirements.
- Any other information or data, as required by the department.

CERTIFICATION

I hereby certify that I have read this completed application and that, to the best of my knowledge, the information in this application and all attachments and exhibits is complete and correct. I understand that the failure to provide any requested information or misstatements submitted in support of the application shall be grounds for either refusing to accept this application, for denying the permit, or for suspending or revoking a permit issued on the basis of such misrepresentations, or for seeking of such further relief as may seem proper to the Land Board.

I hereby authorize representatives of the Department of Land and Natural Resources to conduct site inspections on my property. Unless arranged otherwise, these site inspections shall take place between the hours of 8:00 a.m. and 4:30 p.m.

Signature of authorized agent(s) or if no agent, signature of applicant

AUTHORIZATION OF AGENT

I hereby authorize_____Aurora Kagawa-Viviani_____to act as my representative and to bind me in all matters concerning this application.

7/15/16

Signature of applicant(s)

Transpiration characteristics of native and non-native plants at a mesic forest site in Makaha Valley, O'ahu, Hawai'i

Thomas Giambelluca
30 January 2015

Introduction

O'ahu's water resources are dependent on groundwater recharge and streamflow generation driven by rainfall and fog interception. Water evaporates readily from wet vegetation (interception evaporation, E_i) and from exposed moist soil (soil evaporation, E_s). Plants extract soil water and release it to the atmosphere through transpiration (E_t). The sum of these evaporative processes, evapotranspiration (ET), represents a loss of water with respect to water resources. Because of the role of plant structure and physiology in the interception evaporation and transpiration processes, plant species invasion is believed to affect ET and, therefore, groundwater recharge and streamflow generation. Many of Hawai'i's forested watersheds are heavily invaded with non-native invasive plants that have displaced native species. Some evidence has been obtained from field research showing that invasive trees, such as strawberry guava, can increase ET in invaded watersheds (Giambelluca et al., 2012). However, research conducted so far has been quite limited and it is not possible to give reliable estimates of the hydrological effects of non-native plants in all areas of the islands. The effects of strawberry guava, for example, have been studied only for one pair of sites in a relative wet montane cloud forest area of Hawai'i Island. The effects of invasion by strawberry guava and other non-native plants in drier lowland areas are not well studied.

Plant structural characteristics and photosynthetic behavior affect transpiration in various ways. Height, leaf area, and root characteristics of different plant species influence their overall water use. Plants try to maximize uptake of CO2 while minimizing potentially damaging effects of excessive water loss through transpiration. Plants regulate CO2 uptake and transpiration by varying stomatal conductance. Different plant species follow different strategies to manage gas exchange and reduce drought risk (Chaves et al., 2002). Because non-native plants evolved in different climatic and ecological settings, their gas exchange regulation behavior may be quite different from native plants in the areas they invade. Highly invasive plants tend to be fast-growing, suggesting a regulation strategy that emphasizes CO2 uptake, meaning they do not close their stomata as readily as native plants. As a result, they grow fast, but also use water at a higher rate than native plants.

In comparing transpiration of native and non-native plant species, it is important to examine the effects of variations in environmental conditions, including light level, humidity, soil moisture, and canopy wetness, on the process. Non-native plants may have advantages over native plants because of an ability to maintain photosynthesis under conditions in which native plants close stomata. For example, some species

might maintain high stomatal conductance under low light, low soil moisture, or wet canopy conditions. These traits could potentially give non-native plants advantages by allowing them to outperform native plants during marginal conditions. It would also cause them to use more water.

It is known that the native tree ʻōhiʻa (*Metrosideros polymorpha*) grows slowly and uses water sparingly. In comparison with ʻōhiʻa, most non-native trees probably support higher transpiration rates. The transpiration characteristics of other native plant species, especially those in mesic and dry environments are not well known.

Objectives

The goal of the proposed project is to improve understanding of the transpiration characteristics of native and non-native plants in mesic forests in Hawai'i. The specific objectives are to (1) determine the rates of transpiration in selected native and non-native species occurring in mesic forests; (2) determine the gas exchange characteristics of those native and non-native plants; (3) quantify the effects of varying environmental conditions, such as light level, humidity, soil moisture, and canopy wetness, on gas exchange in those plants; and (4) provide an assessment of the general effects of non-native plants on water resources in mesic environments on Oʻahu.

Methods

Field Sites

Field sites for this study will be collocated with those of the "Canopy Interception Study" (Honolulu Board of Water Supply, 2014) in Makaha Valley, Oʻahu. Two sites have been set up for the interception study, representing native and invaded forest.

The CI study native and invaded forest test plots were selected based on several factors: elevation, aspect, gross rainfall, and vegetation type. An effort was made to select test plots having similar characteristics except for vegetation type, to minimize any influences on gross rainfall, throughfall, stemflow or canopy interception other than vegetation type. The following study test plot description is quoted from the Canopy Interception Study proposal (Honolulu Board of Water Supply, 2014):

> "***Elevation:*** About 80 percent of the Makaha watershed lies below the elevation considered to be the lower boundary of "cloud forest", where fog drip becomes a primary component of precipitation (approximately 750 meters, or 2,460 feet MSL). Therefore, test plot locations were selected below this elevation to represent the majority of the watershed area.

"***Aspect:*** In physical geography, aspect refers to the horizontal direction to which a mountain slope faces. The aspect of a slope can significantly influence its local climate (microclimate). To minimize this influence, test plot locations having little to almost zero slope were selected.

"***Gross rainfall:*** Test plot locations were selected close to one another (approximately 200 feet apart), within the same range of historical rainfall. Also, for practical purposes, the historical rainfall amount is on the higher end for the watershed. Given the higher anticipated gross rainfall, differences in throughfall, stemflow and canopy interception may be more readily detected.

"***Vegetation type:*** The native forest test plot was selected with an array of native trees and plants expected for a relatively intact forest at this elevation in the Waianae Mountain range. In contrast, the invaded forest test plot was selected with a classic monotypic character; in this case, the test plot contained almost exclusively *Psidium cattleianum* (strawberry guava). Strawberry guava is considered to be one of the most destructive invasive species in Hawaii by the U.S. Department of Agriculture, the State Department of Land and Natural Resources, the Hawaii Invasive Species Council, and the watershed conservation community in general."

Field Observations

Sap flow will be measured in selected trees at each field site using the heat dissipation method (Granier, 1987). Sap flow velocity will be measured in plant stems and scaled up to give estimates of whole plant and stand-level transpiration.

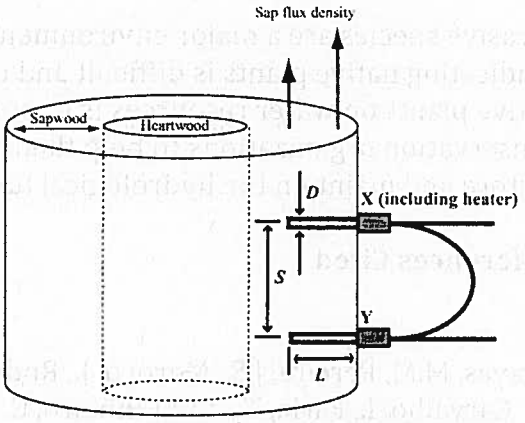


Figure xx. Diagram showing the measurement of sap flow using the heat dissipation method.

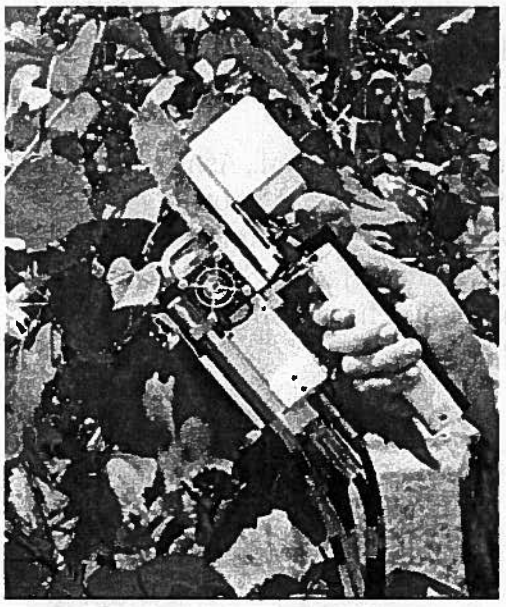


Figure 2. Li-Cor LI-6400 portable photosynthesis system (Li-Cor, Inc., Lincoln, NE).

Leaf-level processes and characteristics will be measured at each field site using a portable photosynthesis system (LI-6400, LiCor, Inc., Lincoln, NE). The Geography Department, UH Mānoa has an LI-6400 which will be made available for use in this study. Measurements will be taken on different species at different times of day and under different environmental conditions.

Environmental conditions will be measured at one location representative of both field sites. Measurements will include net

radiation, air temperature, relative humidity, wind speed, rainfall, soil temperature, and soil heat flux. In addition, at each of the two study sites, soil moisture will be measured at three depths and leaf wetness will be measured at two heights above the ground.

Analysis

The data will be analyzed to obtain estimates of the relative rates of transpiration of the different native and non-native plant species tested, and their responses to variations in environmental conditions. These results will be combined with the results of the canopy interception study to produce estimates of evapotranspiration for native- and non-native-dominated forest stands. Based on these estimates, preliminary projections of the impacts of non-native plants on water resources in mesic forests on O'ahu will be made.

Significance of this work for water resources management and planning

Invasive species are a major environmental problem in Hawai'i. Controlling or eradicating native plants is difficult and expense. Knowledge of the impacts of non-native plants on water resources is important information for water managers and conservation organizations to help them plan for the best use of their resources to restore and maintain the hydrological function of Hawai'i's watersheds.

References Cited

Chaves, M.M, Pereira, J.S., Maroco, J., Rodrigues, M.L., Ricardo, C.P.P., Osório, M.L., Carvalho, I., Faria, T., and Pinheiro, C. 2002. How plants cope with water stress in the field? Photosynthesis and growth. *Ann. Bot.* 89, 907-916, doi:10.1093/aob/mcf105

Giambelluca, T.W., DeLay, J.K., Takahashi, M., Mudd, R.G., Huang, M., Asner, G.P., Martin, R.E., Nullet, M.A. 2012. Effects of an invasive tree on evapotranspiration in tropical montane cloud forest in Hawai'i. 3rd International Conference on Forest and Water in a Changing Environment. Fukuoka, Japan, September 2012.

Granier, A. 1987. Evaluation of transpiration in a Douglas fir stand by means of sap flow measurements. *Tree Physiol.* 3, 309–320.

Attachment 2: Geog seed grant: Makaha water isotope sampling (TMK 8-4-2:001)

UHM Geography Department Student Seed Grant RFP (Feb 15, 2016)
Project Title: Invasion ecohydrology in the upper Mākaha watershed
Grad Student Investigator: Aurora Kagawa-Viviani
Advisor: Thomas Giambelluca
Budget Requested: $3,528 Awarded $1,500, March 2016

A. Rationale: Decreasing rainfall and warming temperatures associated with anthropogenic climate change are expected to affect Hawaii's ecosystems (Chu and Chen 2005, Giambelluca et al. 2008, 2013, Frazier et al. 2011), yet exactly how these climatic stressors will influence vegetation remains an active area of research (Crausbay et al. 2014). In addition to climate change, Hawaii's ecosystems face threats in the form of invasive species, a major research and management priority for the conservation-minded watershed management community. The 2011 release and 2013 funding of the Hawaii DLNR watershed plan, however, has increased pressure on watershed managers to demonstrate their invasive species and outplanting activities improve hydrologic function. As a result, the popular narrative and handful of studies suggesting invasive plant species may decrease recharge has come under close scrutiny. Increased evaporative losses associated with invasive species have been observed, but mechanisms are not always clear; issues of scale come to play as species' leaf-level physiological differences may not scale up to stand-level differences, and stand-level differences may change in time with phenology or stand age. There is room to improve mechanistic understanding of observed differences in water and energy balance of Hawaii's forests, and doing this would improve understanding of the hydrological impacts of not only plant species invasion, but also climate change.

To begin to untangle the complexity of interactions in the "critical zone" from canopy to aquifer, researchers of water-limited systems suggest focusing on "hot moments" and "hot spots" (McClain et al. 2003, Wang et al. 2015). Close observation of rainfall pulses and dynamics can yield important hydrological and biogeochemical insights difficult to observe at longer temporal intervals. Considering heterogeneity of hydrological processes under different vegetation covers can also be illuminating. In a comparison of three non-native stands, Safeeq and Fares (2014) found that differences in tree architecture resulted in a significantly larger stemflow fraction for invasive tree *Psidium cattleianum* than for other invasive trees with lower funneling ratios. This and other rainfall partitioning studies highlight the importance of considering the interaction of precipitation regimes with plant species and site characteristics in studying surface water balance.

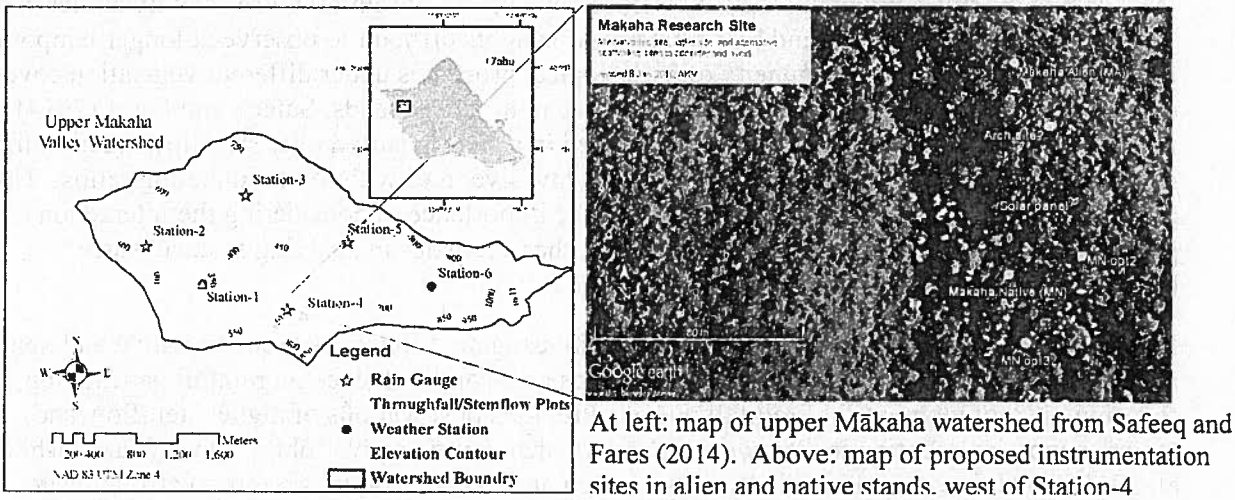
B. Objectives: The objective of this study is to investigate differences between native and non-native forest ecohydrology by considering species and stand influence on rainfall partitioning, focusing on "hot moments" of rainfall pulses. Previous observations of higher stemflow and lower canopy interception in *Psidium cattleianum* than paired native 'ōhi'a stands (Takahashi et al. 2011, cloud forest) and invaded stands (Safeeq and Fares 2014, mesic forest) also indicate stand level comparisons must consider species and site differences in the context of different rainfall events. I have an opportunity to build upon this previous research at paired site study in Mākaha valley on O'ahu, and have broken down my question into a series of smaller questions:

- **How does vegetation differ between native and invaded stands?** I will characterize species traits as well as stand-level variables that might influence rainfall partitioning.
- **How does rainfall partitioning during events differ between the two stands?** By monitoring multiple rainfall events during the course of at least one full year, and monitoring rainfall (RF), throughfall (TF), and stemflow (SF), we can compare the

effects of event magnitude (depth) and intensity on partitioning in native and non-native stands and incorporate species and stand structure metrics to aid interpretation of results.

- **How do differences in vegetation result in soil moisture differences?** If RF partitioning differs between vegetation covers, is post-event soil moisture greater under canopy with greater TF and SF? For a stand with greater SF fraction, is soil moisture more spatially heterogeneous?
- **How do evaporative fluxes differ in the two stands?** What effect does vegetation structure and physiology have on the partitioning of soil evaporation and transpiration? Can we detect this using stable isotopes of soil and stem water complemented with measurements of sap flow?
- **Can we quantify evaporative losses of TF using stable water isotopes?** Quantifying wet canopy evaporation normally requires sophisticated eddy flux equipment. What might isotopic differences between RF, TF, and SF tell us about evaporation (evaporative enrichment of remaining liquid water) during rain events?
- **How does infiltration differ between native and invaded vegetation?** What are root density profiles and soil characteristics under the two vegetation types? Can we track the fate of stemflow using stable isotopes of soil water and soil moisture measurements?

C. Methods: To compare plant-water dynamics of canopies dominated by native trees and invasive trees, I will monitor water balance at under two forest plots in the upper Mākaha Valley, O'ahu, Remnant native stands include lama (*Diospyros sandwicensis*) and alahe'e (*Psydrax odorata*) trees, while monotypic strawberry guava (*Psidium cattleianum*, ssp. unknown) dominates a nearby invaded stand.



At left: map of upper Mākaha watershed from Safeeq and Fares (2014). Above: map of proposed instrumentation sites in alien and native stands, west of Station-4

These paired sites were designated for an ongoing study of net precipitation (TF and SF) being carried out by the Honolulu Board of Water Supply with ecophysiological measurements to be made by researcher Yoshiyuki Miyazawa. I propose to complement the measured rates and volumes of RF, TF, SF, soil moisture and sapflow by collecting and analyzing samples of these waters for stable isotope ratios (δD and $\delta^{18}O$) with an explicit focus on event-scale dynamics. Samples for soil water and stem waters should be collected both before and after the rainfall event, to trace source waters for transpiration. Field environmental sensors will continuously track micrometeorology, including rainfall, temperature, humidity, wind, solar radiation as well

as soil temperature and moisture to provide information on covariates important for interpretation of water isotope data. Yoshi Miyazawa will be monitoring xylem sap flux density and leaf level physiology of the dominant trees throughout the study. Collectively, we will have an exciting and dense dataset that will help us track the fate of rainfall under the two vegetated conditions.

Event sampling for water isotopes		Samples	Minimum
RF: 2 reps		2	2
TF: 2 reps x 2 sites		4	4
SF: 2 reps x 2/3 species x 2 sites		10	(composite) 4
Before and after event	Before/after	Samples	Minimum
Soil water (from soil samples): 2 reps x 2 sites	4	8	8
Pore water: 2 reps x 3 depths x 2 sites	12	24	0
Stem water: 2 reps x 2/3 species x 2 sites	10	20	12
**stem and soil samples require water extraction*			
Minimum samples needed per event			38

D. Expected benefits: The siting of this project on O'ahu will allow me to sample soil and vegetation waters for stable isotopes at much higher frequency and longer period than previous plant water isotope studies in Hawaii, and would allow me to track water sources immediately prior to and after pulse rain events. Pulse dynamics work has largely focused on semi-arid ecosystems of the American southwest, and this research would be the some of the first work to test hypotheses generated there in seasonally dry Hawaiian forest.

E. Budget Justification:

Requested research supplies for soil waters

Soil sampling equipment would facilitate grab samples of soil for extraction of "tightly bound" water that is hypothesized to support plant transpiration (Goldsmith et al. 2012, McDonnell 2014). Soil sampling would be conducted before and after rainfall events or at regular 2-week intervals at multiple depths. Suction lysimeters facilitate continuous collection of "mobile" soil pore waters and are installed in field and are periodically checked. Two samplers are requested for three depths at each site to ensure replication in the native and nonnative plot and/or sufficiently large soil water samples. Finally, supplies requested for the construction of passive capillary samplers would allow me to test another method for continous collection of "mobile" waters in the unsaturated soil layers. The design recommended to me was for snowmelt collection (Frisbee et al. 2010a, 2010b) and I need to verify that this cheaper soil water collection method 1) effectively wicks soil moisture and 2) provides water isotope samples comparable to the standard suction lysimeter methods.

While I have a stock of sample vials and access to tools necessary for collecting stem water, rainfall, and other meteoric waters, I lack tools to properly sample soil and soil water. These supplies would enable me to begin collecting samples immediately and when the need arises for rain events in the months ahead.

Requested sample analysis for 3 rainfall events

Funding for stable isotope analysis of water samples would enable preliminary analysis of a few rain events I anticipate monitoring in early-mid 2016. Having preliminary data would also make my outside research funding applications more competitive; I will need more funding than I have requested here to complete sample analysis for this dissertation chapter. The preliminary data would allow me to verify the effectiveness of my planned sampling scheme or give me time to

adjust my sampling strategy if necessary. I have been and will continue to explore cost-effective ways to process water samples through contacts both at UHM and at other universities with stable isotope labs.

F. Additional sources of project funding/leverage: If awarded, I will leverage this funding support with my current Ford Foundation pre-doctoral fellowship stipend which allows me to focus full-time on research but includes no funds for research or supplies. With my remaining year of funding, I plan to focus on intensive fieldwork and apply for dissertation completion funding in fall 2016 (for 2017-2018 academic year). I recently utilized the departmental Abraham Pi'ianai'a Scholarship to purchase a computer to facilitate my data analysis for other dissertation chapters, health insurance, and cover some workshop/conference attendance costs.

The funding requested would also be leveraged against a Honolulu Board of Water Supply grant to T. Giambelluca for personnel and environmental measurements to be carried out in Mākaha over the next three years. This Honolulu Board of Water Supply grant has not yet been signed and ***does not*** include support for stable isotope sampling or the requested equipment. The grant also is restricted to equipment and time for transpiration and micromet measurements. My proposed water isotope sampling is outside the scope of the grant but greatly benefits from the concurrent measurements that will be made at Mākaha in the next few years.

G. References:

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Scaffolding for Makaha research site

Purpose: access canopy and sun leaves for leaf physiological measurements; attach climate station sensors and solar panels for powering all equipment.

Will the scaffold tower be permanent?

Scaffolding will remain in place for the 3-year duration of the project and removed at project completion.

Who will be responsible for constructing/deconstructing and maintenance of the tower?

Construction/deconstruction and maintenance of the scaffolding will be the responsibility of the researchers led by principal investigator Thomas Giambelluca

Who will access the tower, how many times per month?

Yoshiyuki Miyazawa, Aurora Kagawa-Viviani, and Mike Nullet will access the canopy via the scaffolding once per month.

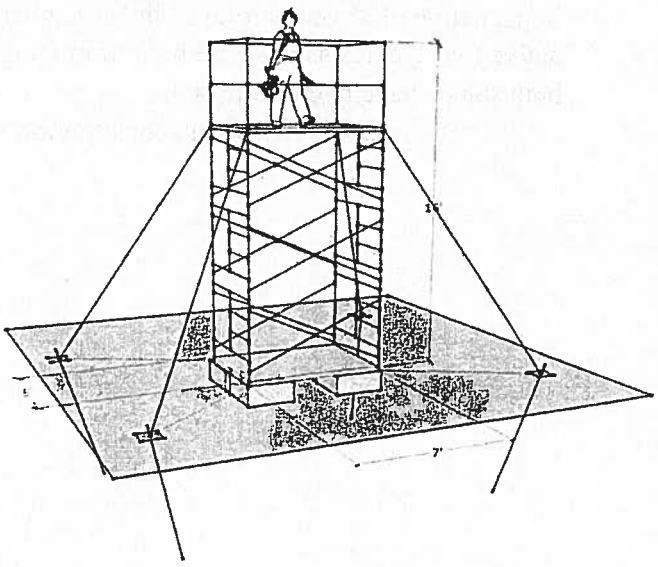
What security measures will be in place to prevent tampering to the tower/equipment?

The solar panel and other valuable equipment will be locked to deter tampering. The scaffolding should be located away from the trail and appropriate signage will be put up to inform potential visitors of the purpose of the equipment. As recommended, the platform will not exceed the height of the canopy, but it will be tall enough so that researchers can take measurements of sun-lit leaves located 15-25' above the forest floor (15'-20' at native site and 20-25' in invaded).

Will there be signage?

Yes, there will be signage indicating the purpose of the tower and research, email/phone for inquiries, and a request to leave the equipment undisturbed.

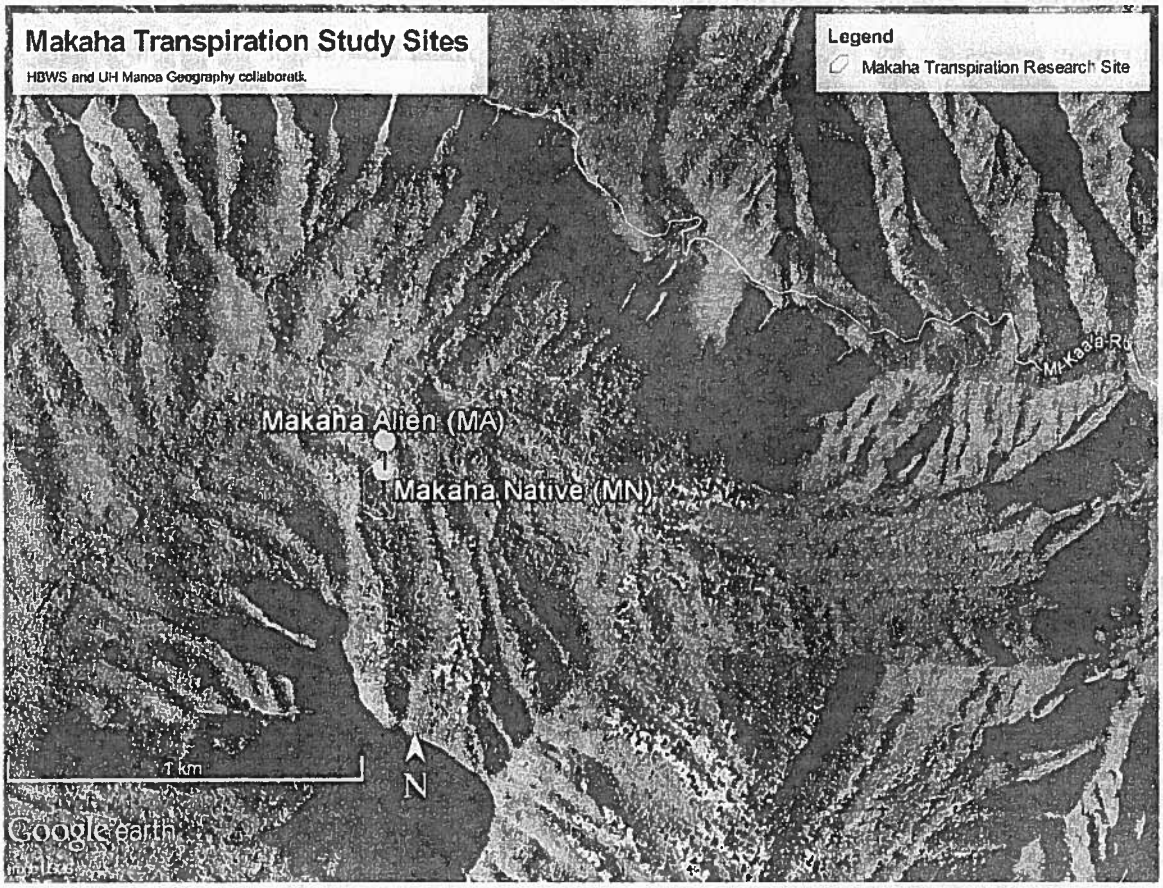
Setup: The proposed 16' or 20' scaffolding (5'x7' footprint) might look something like the figure at right. Four heavy-duty T-posts will anchor the scaffold at a distance half the height of the scaffold.



Shallow but wide concrete piers below scaffolding will be required to prevent the frame from sinking into soft/wet soil; these will be ~1' deep, 2'x2'.

Siting: We propose two sets of scaffolding located in both the non-native site, away from the trail, and the native site near the fenceline on the lower slope. In this case, solar panels will be mounted atop of each scaffolding to power sap flow sensors and micromet sensors.

Attachment 3: Scaffolding description for HBWS (TMK 8-4-2:001)



In the map above, the MA and MN sites indicate potential locations of scaffolding. Several sites in the native plot were surveyed in November 2015 with the intention of accessing as many native tree species as possible but minimizing impact to the area. Locations for scaffolds within both stands have been proposed ' (Alien site) and (Native site) in consultation with HBWS staff familiar with the sites.

Attachment 4:
SMA determination
(TMK 8-4-2:001)

DEPARTMENT OF PLANNING AND PERMITTING
CITY AND COUNTY OF HONOLULU
650 SOUTH KING STREET, 7TH FLOOR • HONOLULU, HAWAII 96813
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MUFI HANNEMANN
MAYOR

HENRY ENG, FAICP
DIRECTOR

DAVID K. TANOUE
DEPUTY DIRECTOR

2005/ELOG-1025(eym)

Mr. Clifford S. Jamile, Manager and Chief Engineer
Board of Water Supply
630 South Beretania Street
Honolulu, Hawaii 96813

Dear Mr. Jamile:

Special Management Area Review
Makaha Fence
Tax Map Key : 8-4-002:001 & 14
Type of Project: Installation of new fenceline enclosures for the purpose of protecting endangered species.

The proposed project on the above-referenced tax map key has been reviewed. We find that it:

[X] Is not within the Special Management Area.

[ ] Is within the Special Management Area, but is not defined as "development" and is therefore, exempt (Section 25-1.3[2][ ], Chapter 25, Revised Ordinances of Honolulu).

Should you have any questions, please contact Eileen Mark at 527-5374.

Sincerely yours,

For HENRY ENG, AICP
Director of Planning
and Permitting

HE:em
cc: DLNR-Office of Conservation & Coastal Lands

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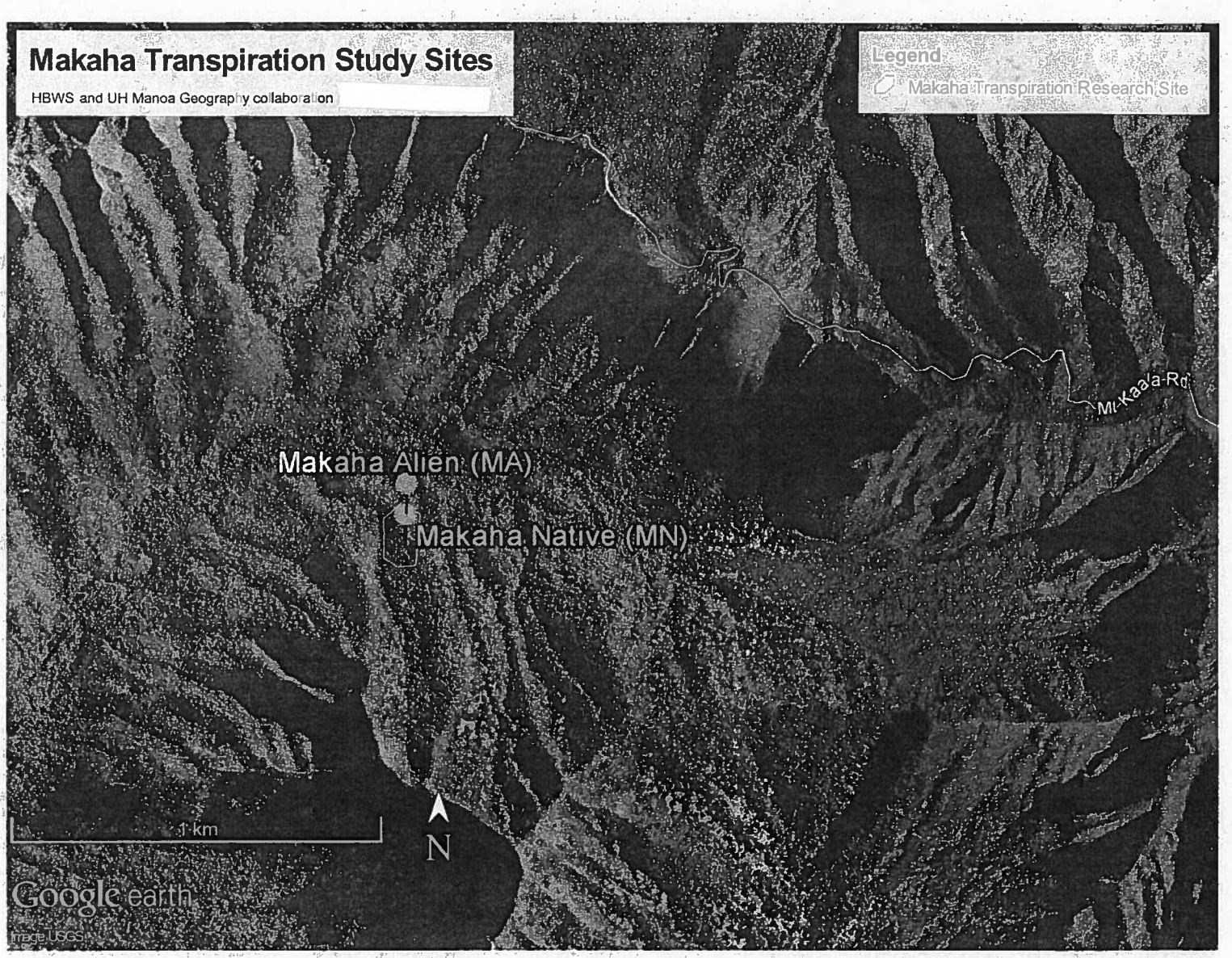
ATTACHMENT 3. SPECIAL MANAGEMENT AREA REVIEW LETTER

Figure 1: Field sites (TMK 8-4-2:001)



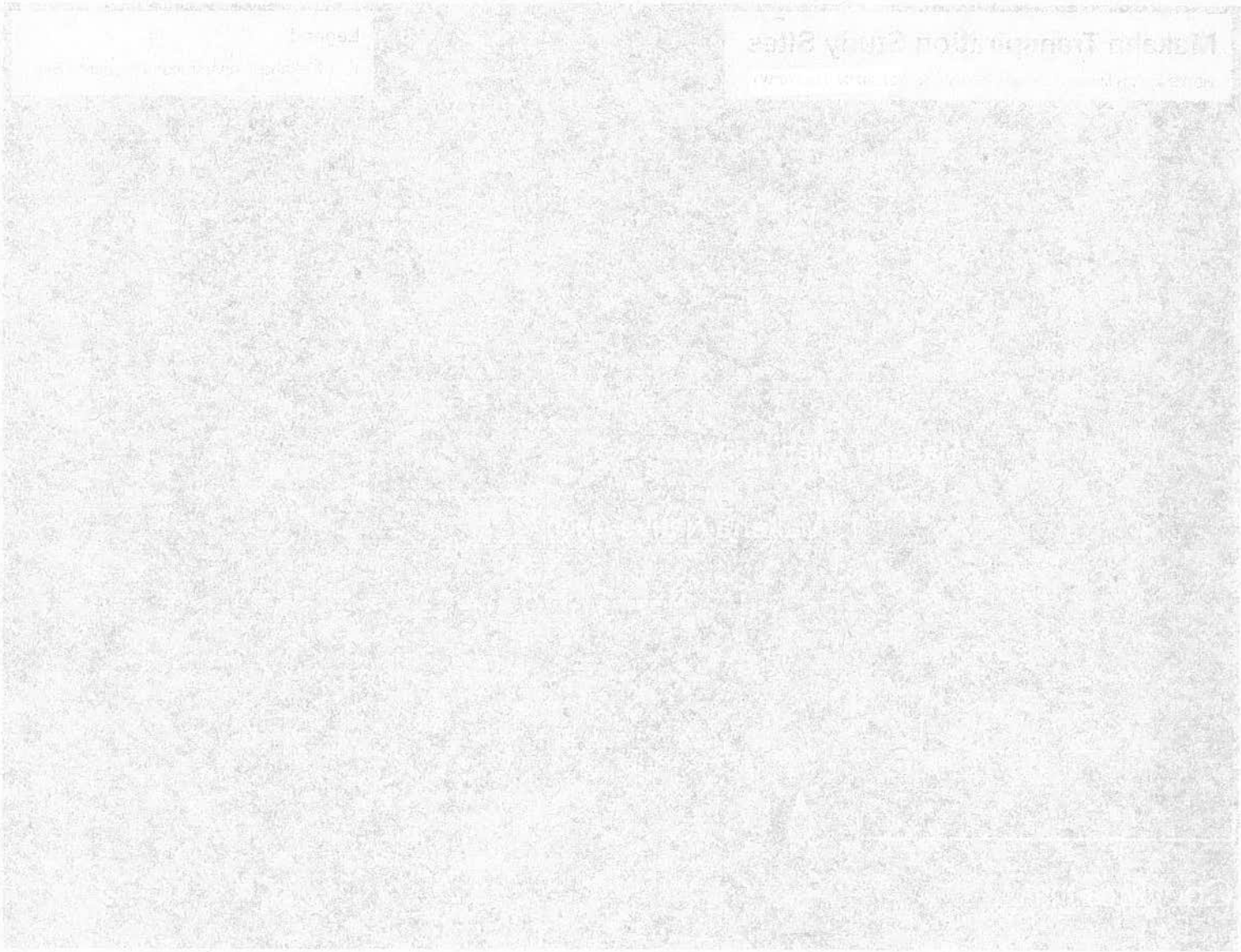


Figure 2: Native/non-native cover in Makaha (TMK 8-4-2:001)

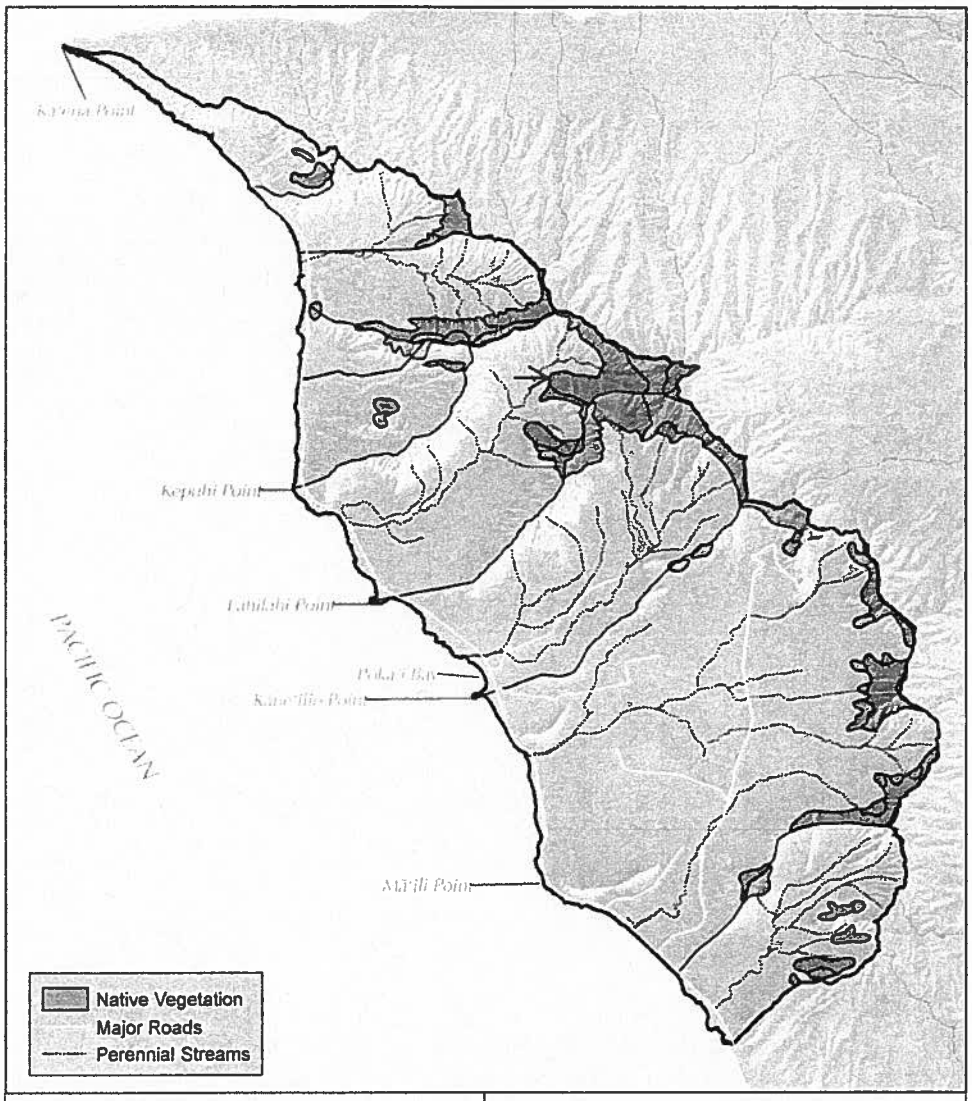


FIGURE 2-7
WAI'ANAE NATIVE VEGETATION
Wai'anae Watershed Management Plan