APPENDIX A

CDUP LETTERS FROM DLNR

LINDA LINGLE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

Office of Conservation and Coastal Lands
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

AUG 10 2007

File No.: LA-3419

Mr. Charlie Karustis
TETRA TECH EC, INCORPORATED
737 Bishop Street, Suite 3020
Honolulu, HI 96813

Dear Mr. Karustis:

This is to inform you that on August 8, 2007, the Chairperson of the Board of Land and Natural Resources approved your client's application for the installation of one (1) metrological tower at site Number 6, and preliminarily approved installation of the remaining six (6) meteorological measurement towers on the Island of Lanai, TMK (2) 4-9-002:01, subject to the following conditions:

1. The applicant shall comply with all applicable statutes, ordinances, rules, and regulations of the Federal, State and County governments, and the applicable parts of Section 13-5-42, Hawaii Administrative Rules;

2. The applicant, its successors and assigns, shall indemnify and hold the State of Hawaii harmless from and against any loss, liability, claim or demand for property damage, personal injury or death arising out of any act or omission of the applicant, its successors, assigns, officers, employees, contractors and agents for any interference, nuisance, harm or hazard relating to or connected with the implementation of corrective measures to minimize or eliminate the interference, nuisance, harm or hazard;

3. The applicant shall comply with all applicable Department of Health administrative rules;

4. Where any interference, nuisance, or harm may be caused, or hazard established by the use the applicant shall be required to take measures to minimize or eliminate the interference, nuisance, harm, or hazard within a time frame and manner prescribed by the Chairperson;

5. Any work done on the land shall be initiated within one year of the approval of such use, and unless otherwise authorized be completed within three years of the approval. The applicant shall notify the Department in writing when construction activity is initiated and when it is completed;

6. The applicant shall obtain the approval of the "Post-Construction Monitoring Protocol for the Meteorological Towers at the Lanai Wind Farm, Lanai, Hawaii", prior to installing any tower;

7. Should an impact with flying wildlife occur, the applicant shall remove the tower(s) until such time as the tower(s) are covered by an Incidental Take License and accompanying (amended) Habitat Conservation Plan;

8. This approval permits the installation of one (1) meteorological tower at site No 6. Subsequent tower construction shall proceed only after review and approval by the Division of Forestry and Wildlife and the Office of Conservation and Coastal Lands, based on positive avian survey results and the successful actions of the applicant to mitigate potential avian impacts;

9. Before proceeding with any work authorized by the Board, the applicant shall submit four (4) copies of the construction and grading plans and specifications to the Chairperson or his authorized representative for approval for consistency with the conditions of the permit and the declarations set forth in the permit application. Three (3) of the copies will be returned to the applicant. Plan approval by the Chairperson does not constitute approval required from other agencies;

10. In issuing this permit, the Department has relied on the information and data that the applicant has provided in connection with this permit application. If, subsequent to the issuance of this permit, such information and data prove to be false, incomplete or inaccurate, this permit may be modified, suspended or revoked, in whole or in part, and/or the Department may, in addition, institute appropriate legal proceedings;

11. Should historic remains such as artifacts, burials or concentration of charcoal be encountered during construction activities, work shall cease immediately in the vicinity of the find, and the find shall be protected from further damage. The contractor shall immediately contact SHPD (692-8015), which will assess the significance of the find and recommend an appropriate mitigation measure, if necessary;

12. The applicant understands and agrees that this permit does not convey any vested rights or exclusive privilege;

13. Prior to construction, the applicant shall have a wildlife biologist survey the area within a 125-yard radius of each proposed tower to re-confirm the absence of notable wildlife (e.g. nesting birds). If sensitive wildlife or nesting activities are noted, the applicant shall coordinate with DOFAW to tailor the methods and timing of installation to minimize the risk of adverse impacts;

14. Best management practices for prevention of introducing exotic species to the site shall be observed;

15. Upon the end of the duration of data collection or the end of the equipment lifecycle or within three years, all equipment shall be removed and the land shall be restored to its original condition;

16. The applicant acknowledges that the approved work shall not hamper, impede or otherwise limit the exercise of traditional, customary or religious practices in the immediate area, to the extent such practices are provided for by the Constitution of the State of Hawaii, and by Hawaii statutory and case law;

17. Other terms and conditions as may be prescribed by the Chairperson; and

18. Failure to comply with any of these conditions shall render this Conservation District Use Permit null and void.

Please have the applicant acknowledge receipt of this permit, with the above noted conditions, in the space provided below. Please sign two copies, retain one, and return the other within thirty (30) days of the date of this letter.

Should you have any questions on any of these matters, please feel free to contact Michael Cain at 587-0048.

Aloha,

Samuel Lemmo, Administrator

Receipt acknowledged

____
Signature

____
Date

cc: Chairman's Office
Caste & Cooke Resorts, LLC
Maui Board Member
Maui Land Agent
County of Maui Planning Department
DOFAW
DOCARE
HPD
USFWS

LINDA LINGLE
GOVERNOR OF HAWAII

STATE OF HAWAI`I
DEPARTMENT OF LAND AND NATURAL RESOURCES
Office of Conservation and Coastal Lands

POST OFFICE BOX 621
HONOLULU, HAWAI`I 96809

ref: OCCL:MC

CDUP LA-3419

SEP 27 2007

Timothy A. Hill, Executive Vice President
Castle & Cooke Lāna`i
PO Box 630310
Lāna`i City, HI 96763

Dear Mr. Hill,

SUBJECT: CONSERVATION DISTRICT USE PERMIT (CDUP) LA-3419
Clarification on Condition 7, Meteorological Towers
Northwest Lāna`i, Lahaina District, Maui
TMK (2) 4-9-02:01

The Office of Conservation and Coastal Lands (OCCL) has reviewed you request to clarify Condition (7) of CDUP LA-3419 for the Lāna`i Meteorological Towers.

Condition (7) reads:

> *Should an impact with flying wildlife occur, the applicant shall remove the tower(s) until such time as the tower(s) are covered by an Incidental Take License and an accompanying (amended) Habitat Conservation Plan.*

Castle & Cooke Lāna`i point out that there is no mechanism to acquire an Incidental Take Permit for wildlife that is not covered by the Endangered Species Act. The applicant concludes that Condition (7) should only apply to state or federally listed threatened or endangered species.

OCCL concurs with this, and will interpret Condition (7) as applying to state or federally listed threatened or endangered species, namely but limited to the `ua`u, Hawaiian petrel (*Pterodroma sandwichensis*); the `a`o, Newell's Shearwater (*Puffinus newelli*); and the `ope`ape`a, Hawaiian hoary bat (*Lasiurus cinereus semotus*).

Should you have any questions please feel free to contact Michael Cain at 587-0048.

Sincerely,

Samuel J. Lemmo, Administrator
Department of Land and Natural Resources

cc: *DLNR – Chair, DOFAW*
Charlie Karustris, Tetra Tech, Inc., 737 Bishop Street, Suite 3020 Honolulu, HI 96813
USFWS

APPENDIX B

STATE HISTORIC PRESERVATION DIVISION LETTER

Cultural Surveys Hawai'i Inc.
Archaeological and Cultural Impact Studies
Hallett H. Hammatt, Ph.D., President

Providing Excellence in Cultural Resource Management

O'ahu P.O. Box 1114
Kailua, HI 96734
Ph.: (808) 262-9972
Fax.: (808) 262-4950

Maui 16 S. Market St., #2N
Wailuku, HI 96793
Ph.: (808) 242-9882
Fax.: (808) 244-1994

Kaua'i P.O. Box 498
Lawai, HI 96765
Ph.: (808) 245-4883

CSH Job Code: KAALA-2

Sunday, April 22, 2007

Melissa Kirkendall, Ph.D
Maui Island Archaeologist
State Historic Preservation Division
Maui Island Office
130 Mahalani Street
Wailuku, Maui 96793

Subject: Archaeological Field Inspection of Eight Meteorological Tower Sites, Ka‘ā, Paoma‘i, and Mahana Ahupua‘a, Lahaina District, Lāna‘i Island, TMK: (2) 4-9-002: 001 por.

Dear Dr. Kirkendall,

An archaeological field inspection of eight potential locations for meteorological monitoring towers (TMK: [2] 4-9-002: 001 por) (Attachment 1 – Exhibit A) was conducted by Tanya L. Lee-Greig, M.A. of Cultural Surveys Hawai‘i, Inc. A brief review of the available historical and archaeological literature was carried out to gain some insight into the types of historic properties that might be located in the vicinity of the tower locations. This information was then considered in the subsequent field inspection of the proposed meteorological tower location and lay-down area in order to assess the area for significant historic properties.

The scope of work for this field inspection was limited to the area of potential effect (APE) for each proposed meteorological tower site to include the location of the tower itself (3’x3’ area), as well as a 150-ft radius surrounding the tower location that would take into account the lay-down radius and guy wire anchors (see Attachment 1 – Exhibit A). Soils in the areas of the proposed tower locations are of the Pauwela-Haiku-Alaeloa Association and the Ustorthents-Lithic Ustorthents-Rock Outcrop Association (Attachment 2) (U.S. Department of Agriculture, Natural Resources Conservation Service 2001). More specifically, the predominant soils in the project area are classified as “rVT2 Very Stony Land Eroded”, and “rRK Rock Land” (Foote et al. 1972: 86). The “rVT2” strongly weathered soils consist of large areas of severely eroded soils on Moloka‘i and Lāna‘i. Approximately 50 to 75 percent of the surface is covered with stones and boulders. With the exception of a few low-lying areas, the soil depth in most cases is fairly shallow at less than 24 inches deep to bedrock. These areas were commonly used for pasture and wildlife habitat (Foote et al. 1972:124). Rock land “rRK” is made up of areas where exposed rock covers 25 to 90 percent of the surface. This land type is nearly level to very steep, and occurs at elevations from nearly sea level to 6,000 feet.

Overall, the vegetation density surrounding the proposed tower locations varies from barren to ankle and waist-high buffelgrass (*Cenchrus ciliaris*), *pili* grass (*Heteropogon contortus*), and various alien grass species interspersed with sparse occurrences of ‘*ilima* (*Sida fallax*)*, a‘ali‘i (Dodonaea viscosa)* and ‘*uhaloa* (*Waltheria indica*) at each lcoation.

Results of Historic Record Review and Predictive Model

A review of the historic documentation indicates that the coastal areas of Ka‘ā, Paoma‘i, and Mahana Ahupua‘a were actively settled by Hawaiians during the pre-contact era (i.e. prior to 1778), and that the upland areas, where soils allowed for dryland agriculture, were also settled, albeit with far less intensity. It is of interest that the place names noted within the project area refer primarily to bays and headlands rather than gulches or other terrestrial landmarks, suggesting that the coastal environs, rather than inland areas, were more intensively used for habitation and subsistence during the traditional or pre-contact time period. Further indication of the importance of coastal resources and intensity of habitation can be found along the northwestern coastline of Lānaʻi where the remains of a fishing village at Polihua, on the Cape of Kāʻena, includes a *koʻa* (shrine) dedicated to the demi-god ʻAiʻai (Emory 1921).

The shallow rocky ravines and stony soils of the transitional barren zone, where the proposed tower locations are sited, did not allow for agricultural cultivation, a condition exacerbated by lack of rainfall. It appears that the initial occupants of these barren transitional slopes did not tend agricultural plots, but rather obtained food from the coastal villages that were located at alluvial agricultural areas, with water supplied from seeps or intermittent streams. Kirch (1985) presumed that agricultural sites for these areas of Lānaʻi would have occurred in the "upland zone of this region", and not in the transitional/ barren zone represented by most of the overall project area.

The upland zone of the northwestern portion of the island, located in the central portion of the proposed project area, was described by Kenneth Emory to include a consolidated group of villages on the plateau immediately east of Kānepuʻu. Set against the ridgeline of Kakaʻalani, west of Kōʻele, and ending at Kānepuʻu, the dryland plateau includes village areas comprised of some 31 visible house sites (Emory 1921:27). Based on traditional subsistence travel patterns between upland areas and coastal settlements, evidence that temporary habitation and activity areas recorded in the transitional zone of the project area points to the existance of trails, although specific trail locations have not been previously noted.

Pre-contact sites previously identified along the northern coast of the proposed project area during a survey by Tomanari-Tuggle and Tuggle (1992) of the Kaiolohia-Kahue Trail, include temporary habitation terraces and enclosures with such features as fire pits (SIHP 50-40-98-1542, -1545 and -1546) and dry-stacked rock cairns interpreted as *ahu* (mound) markers (SIHP 50-40-98-1555, -1556 and -1557). During Emory's 1924 investigations west of those performed by Tomari-Tuggle and Tuggle in 1992, habitation complexes of coastal villages became more diverse, and included a ceremonial *heiau* structure at Kaʻena iki, multiple fishing shrines (*koʻa*) most notably at Kahue Bay, and a unique type of platform burial, more fully described by Hiroa (1957:572).

In 1997, David Tuggle performed an archaeological inventory survey of five locations within the rural districts of Kaʻā and Paomaʻi Ahupuaʻa. Four historic properties that were identified as a part of this study are located in the surrounding area of two of the eight proposed tower locations. SIHPs -1942 through -1944 are located near "Met Tower 1" (Attachment 3) and consists of three separate surface scatters of cultural material including an exposed horizon of charcoal and burned soil; an intact hummock, which displayed a hearth-like area with fire-cracked rock; and an exposed hearth feature respectively. Although the approximate locations of these historic properties are shown within the vicinity of the lay-down area of "Met Tower 1", SIHP -1942 is located approximately 915 ft (278 m) from the boundary of the lay-down area, SIHP -1943 is located approximately 1012 ft (308 m) from the boundary of the lay-down area, and SIHP -1944 is located approximately 292 ft (89 m) from the boundary of the lay-down area. SIHP -1945 is located approximately 488 ft (148 m) from the boundary of the lay-down area near "Met Tower 2" (Attachment 4) and consists of a terrace of faced, upright stones or slab-shaped cobbles constructed against a large boulder outcrop. Due to the apparent unusual method of construction and use of uncommon construction materials, this historic property was interpreted by David Tuggle as a feature associated with ceremonial uses.

Based on the brief review of the literature presented above it is likely that the coastal and inland environs were more intensively utilized by the Lanaʻi Island population with marine resource exploitation being the primary subsistence focus of the former settlement zone and agricultural pursuits for the latter. The barren or intermediate zone, where the proposed tower locations are sited, is extensive in this portion of Lānaʻi. The intermediate zone would have likely been used more for quarry resources and limited dry-land agricultural pursuits just inland of the primary coastal settlement zone and along the outer periphery of the inland settlement zone. The archaeological correlate to these types of activities would likely consist of dispersed pre-contact temporary habitation sites, such as those described by Tuggle (1997), SIHP 50-40-98-1942 through 1944, where lithic reduction activities and cooking were the primary focus, as well as sparse pre-contact remnants of dispersed, low-intensity, dry-land agricultural terraces and temporary habitation features, like those described by Emory (1924).

Results of Archaeological Field Inspection

The field inspection of the proposed meteorological tower locations (Attachment 1 – Exhibit A) and 150-ft lay-down radius took place on April 11th and 12th, 2007 and consisted of a cursory surface assessment of each approximate 1.62-acre area (Attachment 5, Table 1. Descriptive Summary of Proposed Meteorological Tower Locations). Point locations for each proposed tower location were recorded using both a Garmin GPS 76 unit and Garmin eTrex Legend Cx unit (UTM Coordinate System and WGS84 Datum.) Point locations for areas archaeological interest were collected using the Garmin GPS 76 unit.

A total of five archaeological sites, one modern petroglyph, and one probable modern hunting blind were identified during the course of the field inspection. Because there was no formal archaeological documentation of most of the historic properties in the area, and correlation to previous studies go beyond the current scope of work, each area of interest, including apparent modern sites, was assigned a temporary field number (CSH-1 through CSH-7) for record keeping purposes.

"Met Tower 1" (Attachment 6)

CSH-1

CSH-1 is a concentration of historic era cultural materials located approximately 220 ft. (67 m) outside of the lay-down area of "Met Tower 1". Likely associated with historic era ranching, this surface scatter consist of rusted fencing debris and milled wood fragments (Attachment 8)

CSH-2

CSH-2 is a modern petroglyph depicting a man on a skateboard located on the left side of the road to Lapaiki (Attachment 7). While this feature is located within the APE of "Met Tower 1", due to the modern age determination, CSH-2 was evaluated as not historically significant.

CSH-3

CSH-3 consists of a discrete, medium density surface scatter of cultural materials eroding out of a small hummock and intact cultural layer located approximately 150 ft. (45 m) outside of the lay-down area of "Met Tower 1" (Attachment 8). Cultural materials observed eroding out of the hummock include lithic debitage, fire cracked rock, and charcoal.

"Met Tower 2" (Attachment 9)

No historic properties were identified within the APE, as defined for this field inspection, for "Met Tower 2".

"Met Tower 3" (Attachment 9)

CSH-4

CSH-4 is a small terrace constructed of a single alignment of small basalt boulders located approximately 25 ft. (7.5 m) outside of the lay down area of "Met Tower 3".

"Met Tower 4" (Attachment 10)

CSH-5

CSH-5 consists of a medium to high density surface scatter of cultural materials eroding out of a small hummock located approximately 88 ft. (26 m) outside of the lay-down area of "Met Tower 4" (Attachment 11). Cultural materials observed eroding out of the hummock include small fragments of false-brain coral, lithic debitage, fire cracked rock, and charcoal. A small boulder with modern petroglyphs (Attachment 11) was also observed on the southern perimeter of the scatter.

<u>*CSH-6*</u>

CSH-6 is a hearth feature exposed in the side of a remnant hummock located on the western side of the jeep trail, approximately 56 ft. (17 m) outside of the lay-down area of proposed tower location (Attachment 12).

<u>*CSH-7*</u>

CSH-7 is a probable hunting blind located approximately 100 ft (30 m) southwest of the tower footprint. Based on the modern trash remnants, including bottle glass fragments and a "Vienna Sausage" can observed in the vicinity of the hunting blind, as well as the construction style, it is likely that this blind more of a modern construct (Attachment 12). While this feature is located within the APE of "Met Tower 4", due to the modern age determination, CSH-7 was evaluated as not historically significant

"Met Towers 5-8"

No historic properties were identified within the APE, as defined for this field inspection, for "Met Towers 5-8".

Summary and Recommendations

A total of five historic properties and two, likely modern era, sites were identified during the course of an archaeological field inspection of the proposed locations for eight meteorological towers. With the exception of the modern petroglyph (CSH-2) and modern hunting blind (CSH-7), all of the properties lay outside of the area of potential effect (APE). While these properties lay outside of the APE for each proposed tower they are close enough to be exposed to potential secondary impacts related to tower construction (e.g. vehicular traffic, staging areas, and potential landing zones). With these concerns in mind, it is highly recommended that interim protective measures, to include archaeological monitoring of construction and excavation activities for "Met Towers 1, 3, and 4", be established for historic properties identified during the course of this field inspection. With regard to "Met Towers 2, and 5-8" we are fairly confident that the APE and area within 100-ft of the APE has been adequately examined and no impacts to historic properties are anticipated.

If you have any further questions or concerns regarding this field inspection, please feel free to contact me at either our Wailuku location (808) 242-9882 or via e-mail at leegreig@culturalsurveys.com.

Sincerely,
Cultural Surveys Hawai'i, Inc.

Tanya L. Lee-Greig, M.A.
Archaeologist/Maui Office Director for
Hallett H. Hammatt, Ph.D.

Attachments (12)

Emory, Kenneth P.

1921 *Visit to the Island of Lanai, Hawaiian Islands* For the Bernice Pauahi Bishop Museum, Archaeological and Ethnological Survey (Field Journal), Bishop Museum MS, Honolulu, HI0

1924 *Village and House Sites Elsewhere Than at Kaunolu, Lana'i*, Manuscript, Bishop Museum, Department of Anthropology, Honolulu, HI.

Foote, Donald E., Elmer L. Hill, Sakuichi Nakamura, and F. Stephens

1972 *Soil Survey of the Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii.* U.S. Department of Agriculture, U.S. Government Printing Office, Washington, D.C.

Tomonari-Tuggle, M.J., and H. David Tuggle

1992 Archaeological Survey of Two Demonstration Trails of the Hawaii Statewide Trail and Access System: Kaiolohia-Kahue Coastal Trail, Island of Lāna‘i, Hawai‘i, International Archaeological Research Institute, Inc. Honolulu.

Tuggle, David H.

1997 *Northwestern Uplands of the Island of Lanai: Archaeological Inventory Survey of Five Locations* Proposed for U.S. Marine Helicopter Landing Zones, International Archaeological Research Institute, Inc., Honolulu.

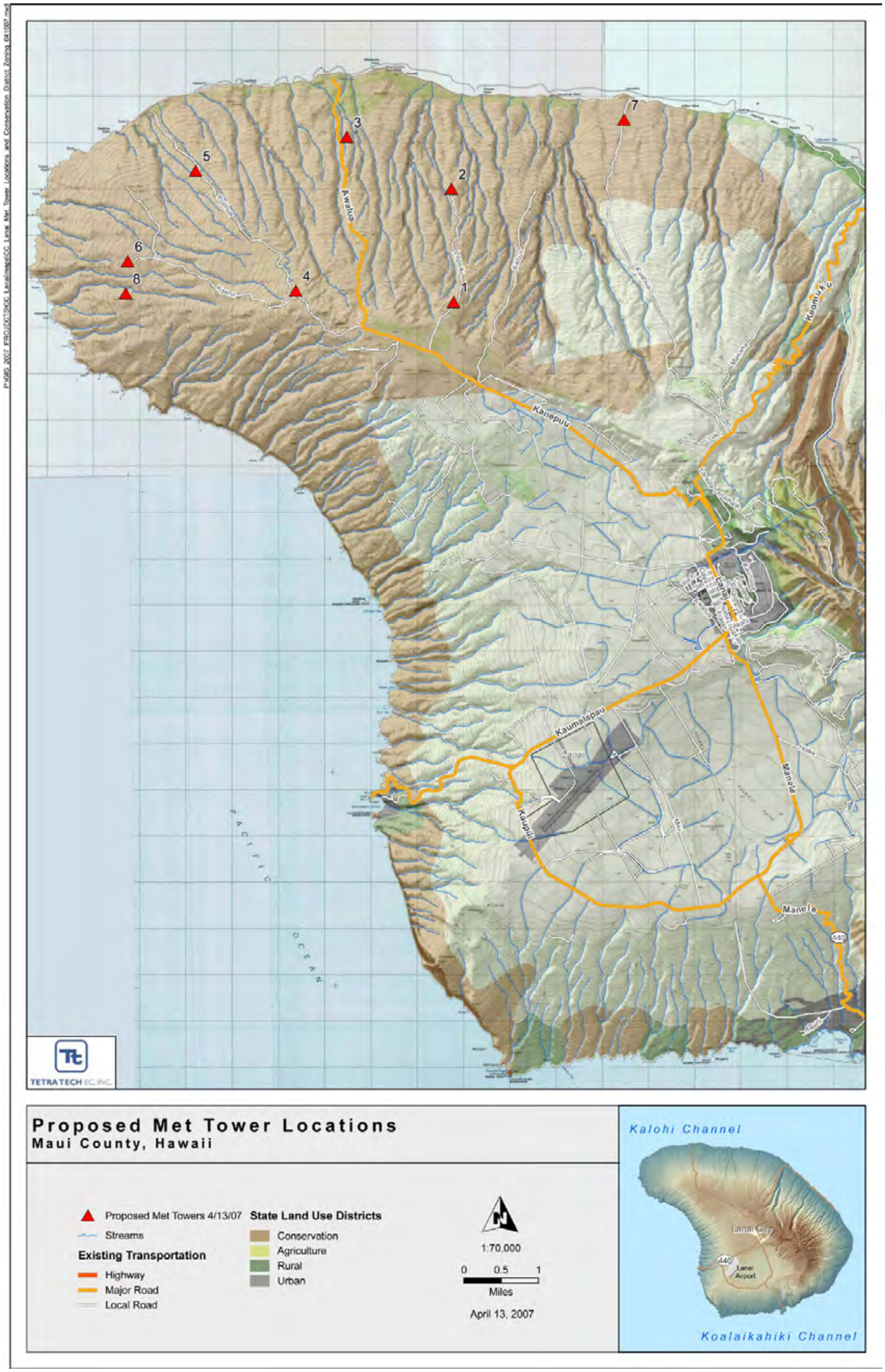
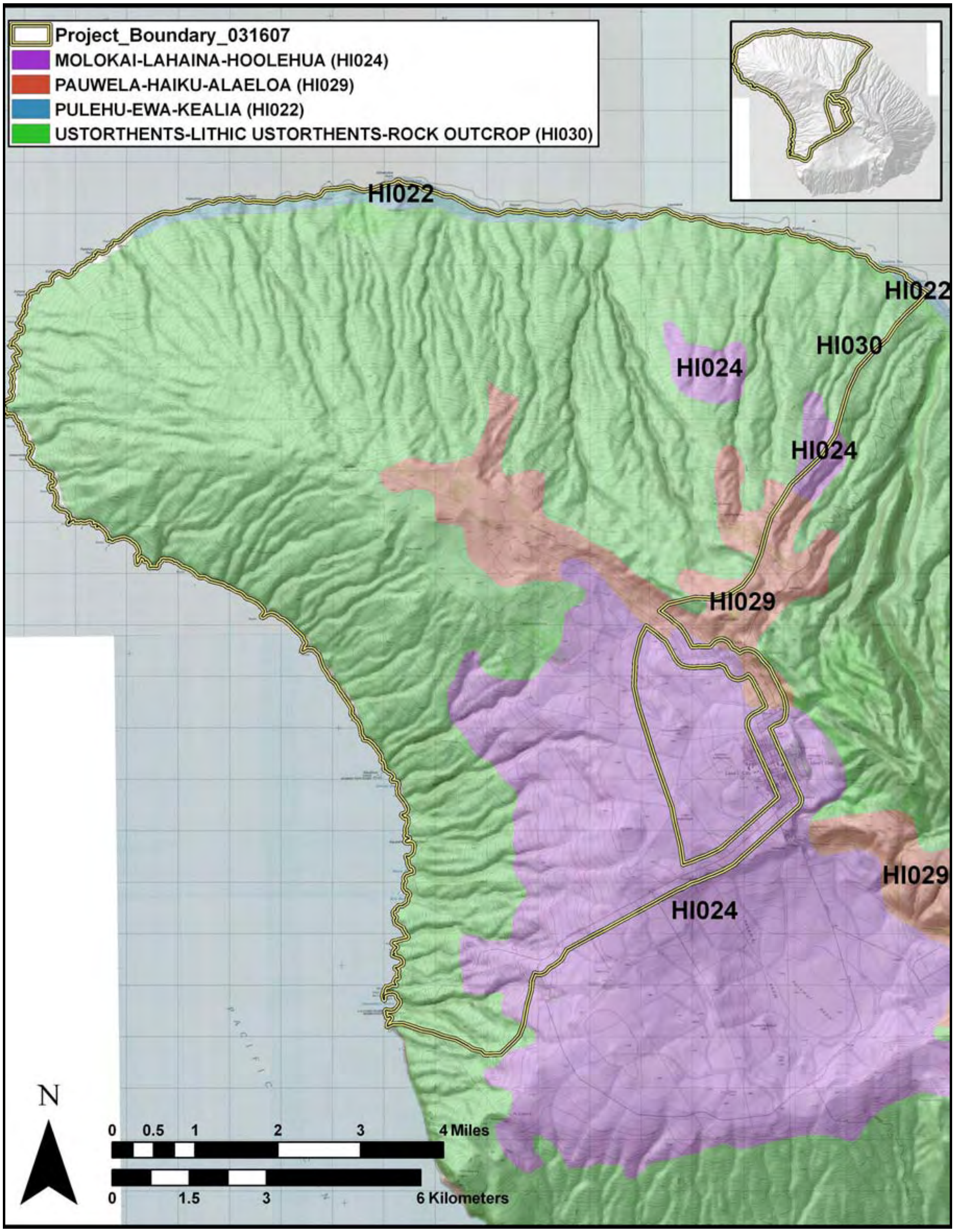
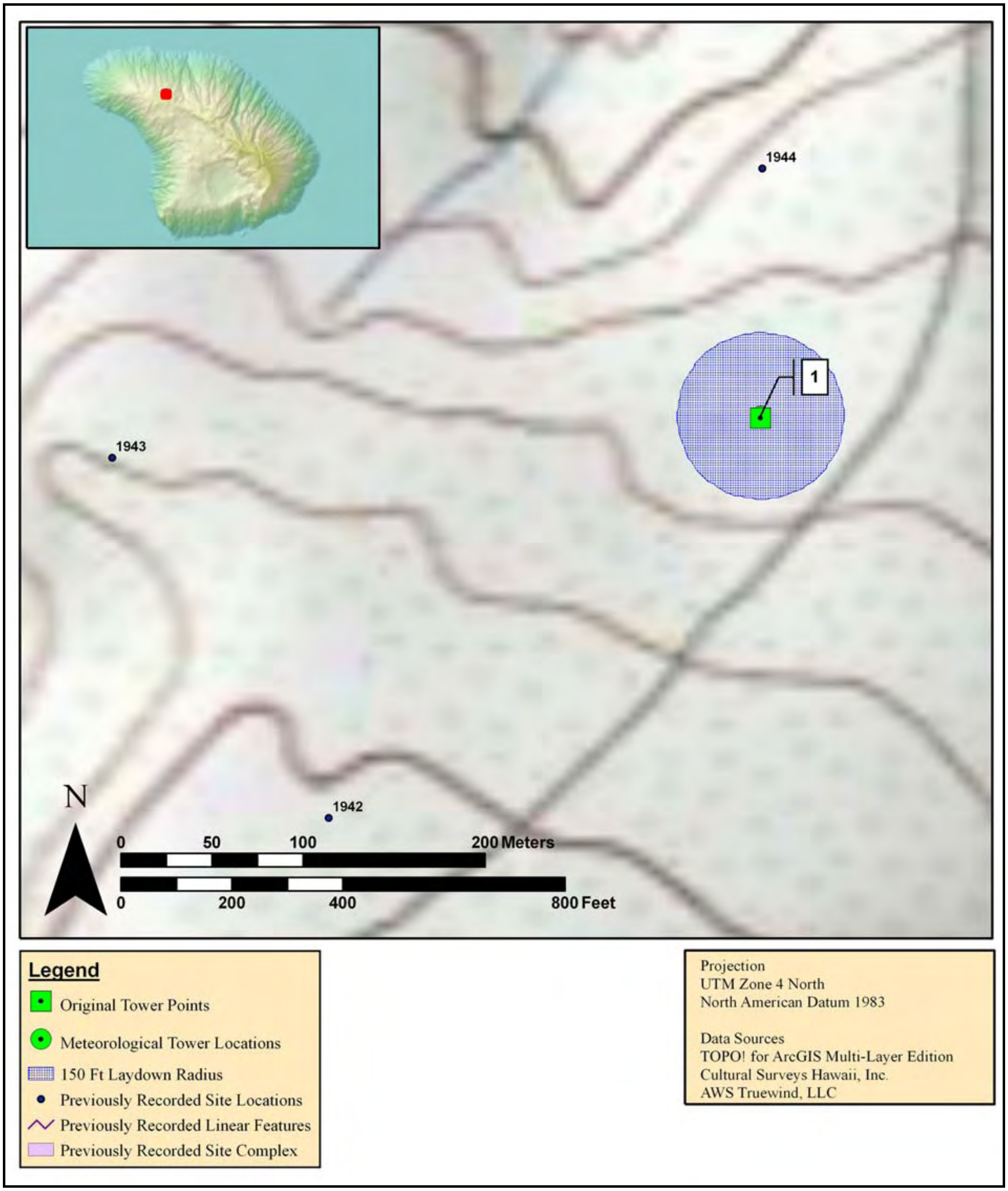


Exhibit A, showing proposed meteorological tower locations (map courtesy of Tetra Tech EC, Inc.)

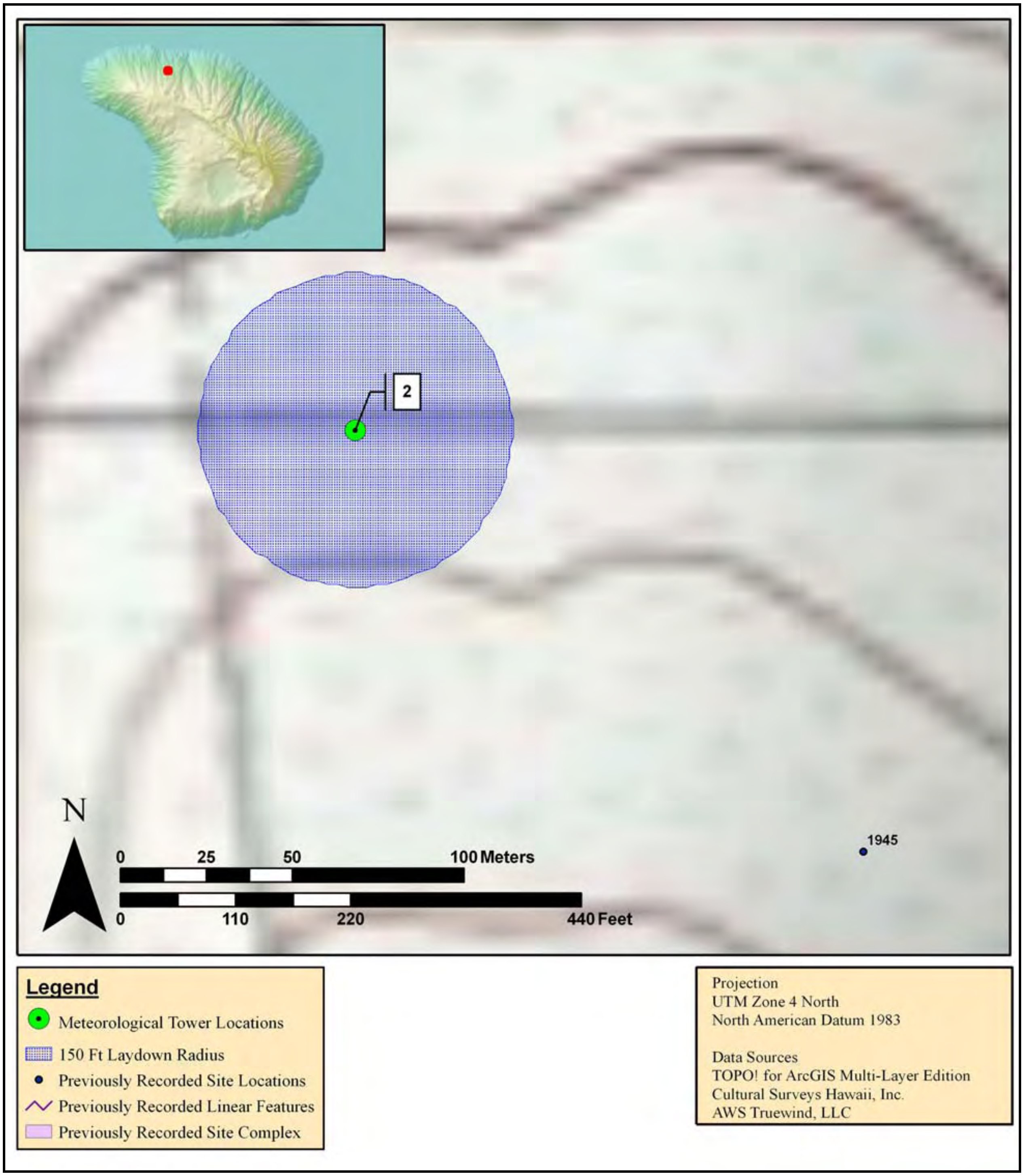


Portions of the Garden of the Gods (1991), Makalau (1991), Lana‘i City (1984), and Ha‘alelepa‘akai 7.5-minute series USGS topographic quadrangles, showing the project area relative to the local soil series (U.S. Department of Agriculture, Natural Resources Conservation Service 2001)



Previously recorded historic properties (Tuggle 1997[†]) in relation to "Met Tower 1" and lay-down area, as well as, historic properties identified during the course of the subject field inspection

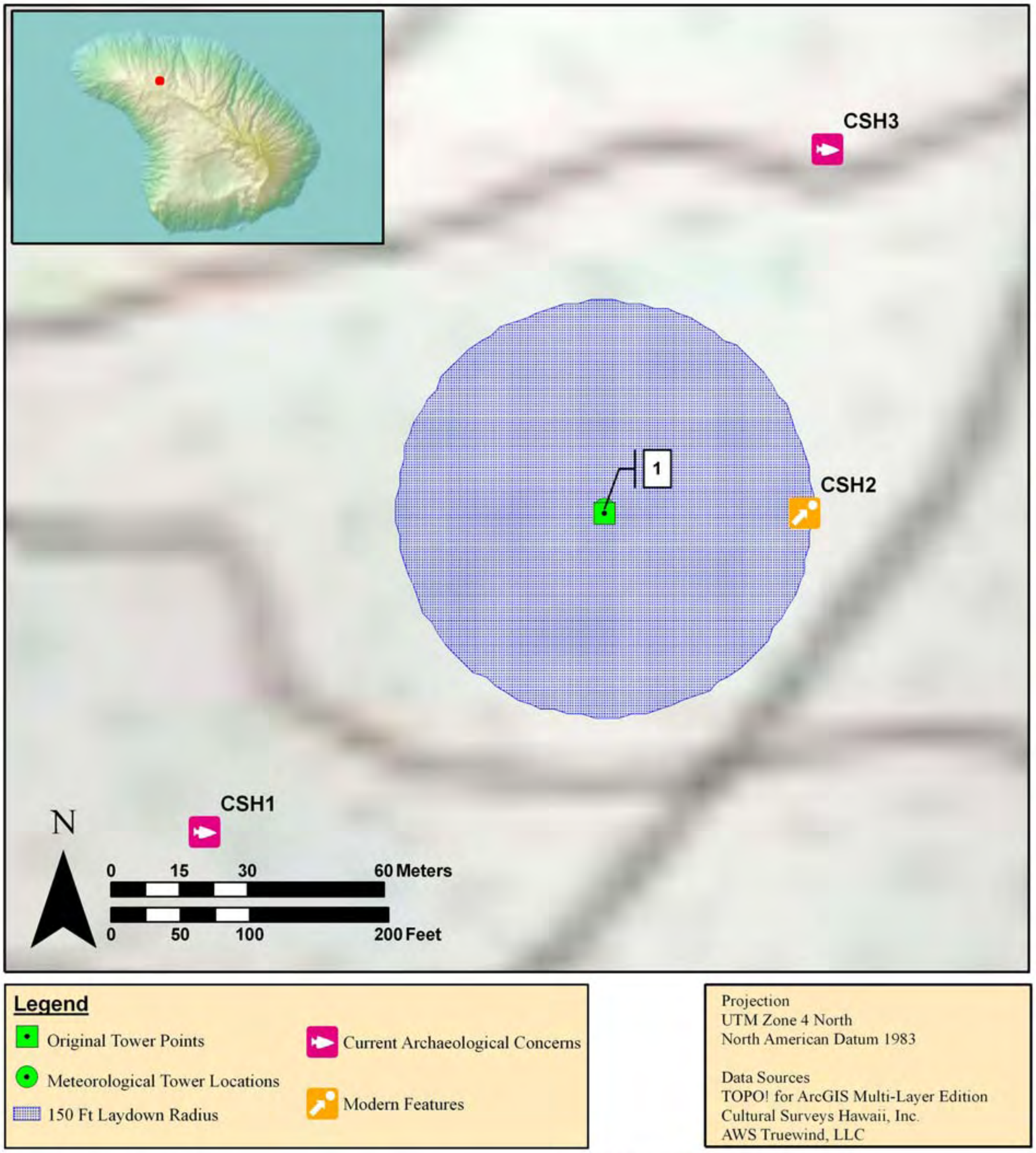
[†] Locations of previously recorded historic properties generated by georefencing the site location map provided in Tuggle 1997 using ArcView 9.1 3rd Polynomial Transformation and known landmarks. The information provided is only as accurate as the site location map provided in the final report.



Previously recorded historic properties (Tuggle 1997[see footnote†]) in relation to "Met Tower 2" and lay-down area

Table 1. Descriptive Summary of Proposed Meteorological Tower Locations

Tower Number	General Observations
Met Tower 1	Overall area consist of barren, clay hardpan. Overall visibility was excellent. Two historic properties (CSH-1 and -2) were identified outside of the APE for this location. One modern petroglyph (CSH-3) was identified within the APE.
Met Tower 2	Vegetation varied from bare to knee high grasses lending to ground visibility ranging from excellent to fair. Aeolian and alluvial deposits appear to be fairly shallow as bedrock outcrops were visible on the surface. Observed materials included modern trash, empty gun shell casings, and fragment of milled wood. Not historic preservation concerns were noted for this area.
Met Tower 3	Overall vegetation consisted of knee high grass, lending to fair ground visibility. Soil deposits appear to be fairly shallow as low-lying bedrock outcrops were exposed on the surface. One historic property (CSH-4) was identified at this location. Due to the proximity of the site to the original location of the proposed tower, the footprint of the tower was moved approximately 100-feet to the southwest.
Met Tower 4	Overall vegetation ranged from bare to shoulder high grasses indicating fairly deep soil in the low-lying areas. Two historic properties (CSH-5 and -6) as well as a modern hunting blind (CSH-7) were noted along the periphery of the lay-down area for this tower location. Due to concerns regarding the proximity of the historic properties to the APE, the footprint of the tower was moved approximately 90 ft southeast of the original location.
Met Tower 5	Overall vegetation consisted of ankle to knee high grasses. No historic preservation concerns were noted for this area.
Met Tower 6	Overall vegetation consisted of ankle high grasses. One apparently recent burn area and evidence of recent hunting activities. No historic preservation concerns were noted for this area.
Met Tower 7	Overall vegetation consisted of ankle high grasses in an area of exposed basalt bedrock outcrops. Outcrops within the APE and approximately 50-ft surrounding the APE were closely investigated. While there are some naturally occurring terraces in the area, no evidence of cultural modifications were evident and no cultural material remains were observed. No historic preservation concerns were noted for this area.
Met Tower 8	Overall vegetation consisted of ankle high grasses and sparsely scattered low-lying shrubs. Due to possible wetland concerns within the APE for this tower, the footprint was moved approximately 50-ft to the south.

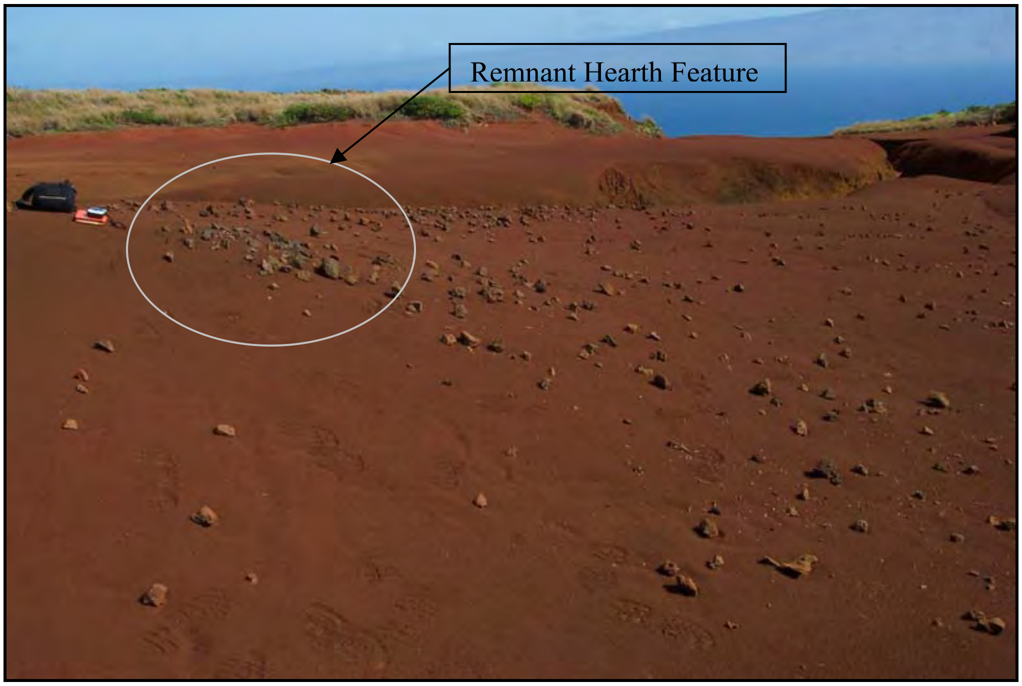


Temporary Site Number	*Formal Type*	*Estimated Time Period*
CSH-1	Fencing Remnants	Historic Ranch Era
CSH-2	Modern Petroglyph	Modern Era
CSH-3	Lithic Scatter and Intact Cultural Layer	Pre-Contact Era

Locations of historic properties identified during the course of the subject archaeological field inspection in relation to propose location of “Met Tower 1” and lay-down area.

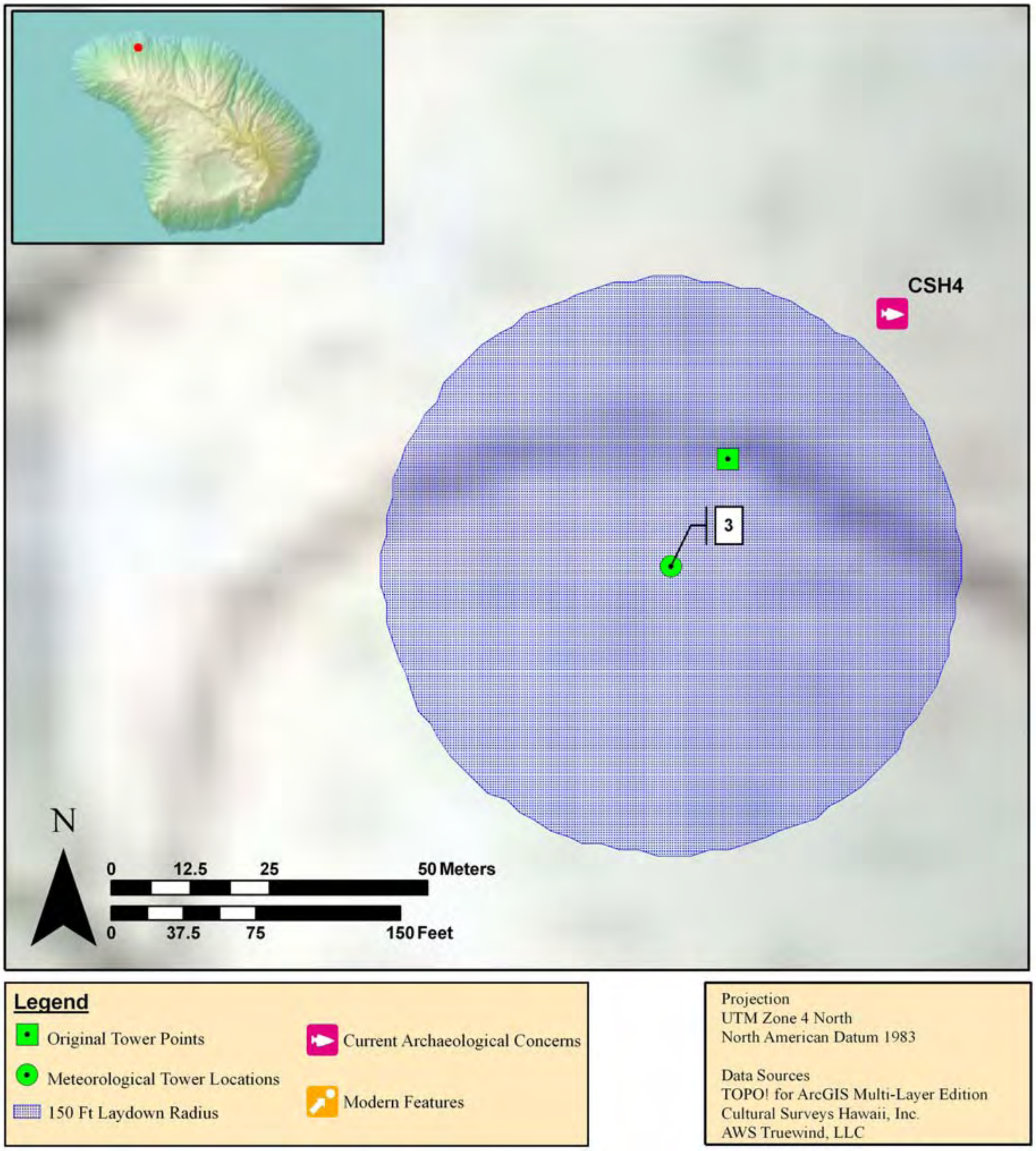
CSH-1, surface scatter of historic era cultural materials

CSH-2, modern petroglyph



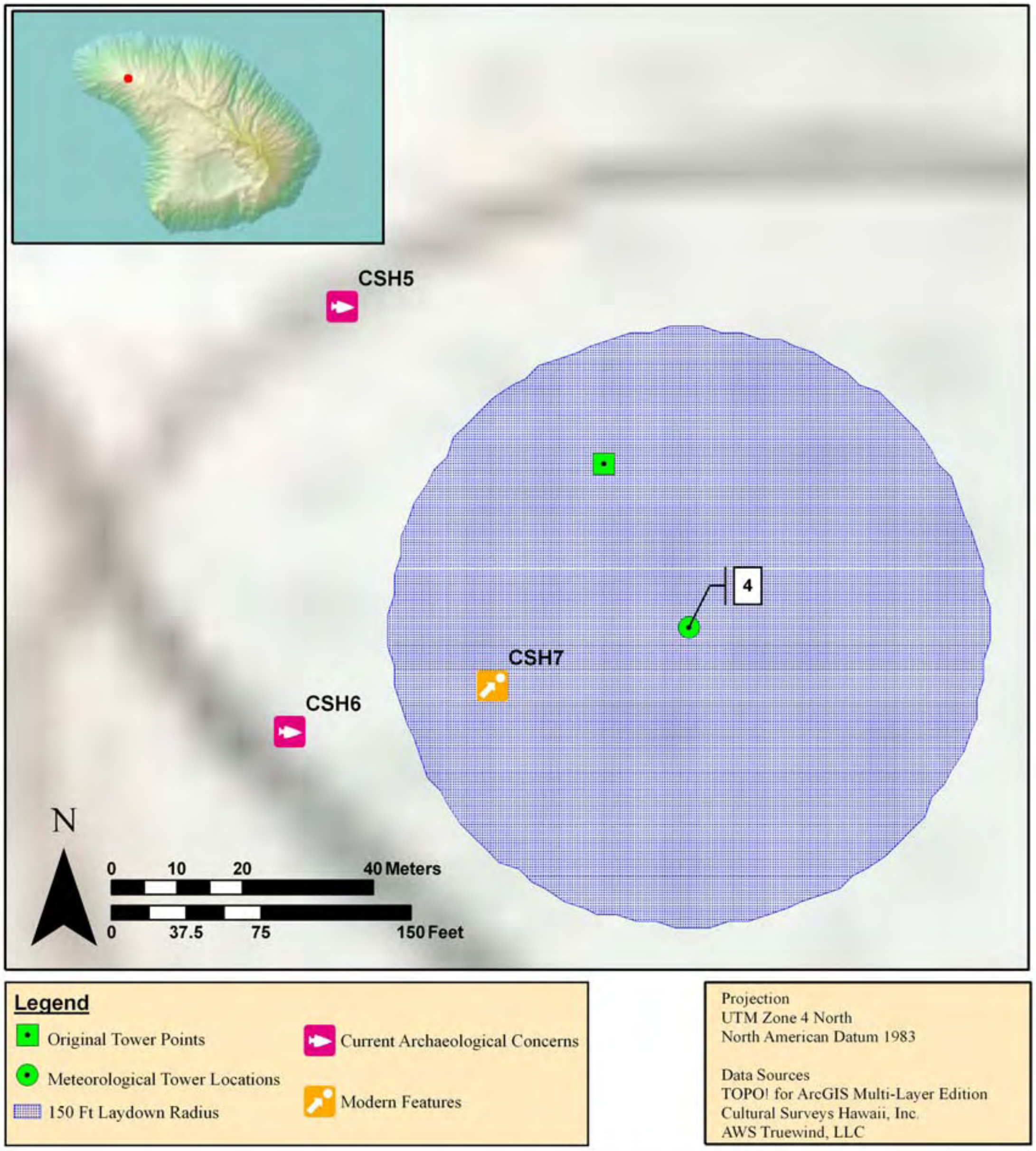
CSH-3, surface scatter of historic era cultural materials

CSH-3, intact cultural layer



Temporary Site Number	*Formal Type*	*Estimated Time Period*
CSH-4	Terrace	Pre-Contact Era

Locations of historic properties identified during the course of the subject archaeological field inspection in relation to the original proposed tower location and relocated location of "Met Tower 3" and lay-down area.



Temporary Site Number	*Formal Type*	*Estimated Time Period*
CSH-5	Lithic Scatter	Pre-Contact Era
CSH-6	Eroding Hearth	Pre-Contact Era
CSH-7	Hunting Blind	Modern Era

Locations of historic properties identified during the course of the subject archaeological field inspection in relation to the original proposed tower location and relocated location of "Met Tower 4" and lay-down area

CSH-5, surface scatter of historic era cultural materials

Modern petroglyphs at CSH-5

CSH-6, exposed remnant fire hearth feature

CSH-7, modern hunting blind

APPENDIX C
CULTURAL RESOURCES LETTER FOR THE MITIGATION AREA

CULTURAL SURVEYS HAWAI`I
ARCHAEOLOGICAL, CULTURAL, AND HISTORICAL DOCUMENTATION SERVICES - SINCE 1982

O`ahu Island
P.O. Box 1114
Kailua, Hawai`i 96734
Ph: (808) 262-9972
Fax: (808) 262-4950

Maui Island
1993 Main Street
Wailuku, Hawai`i 96793
Ph: (808) 242-9882
Fax: (808) 244-1994

Branch Offices:
Hilo, Hawai`i
Kona, Hawai`i
Lāwai, Kaua`i

May 5, 2008

Mr. Jay F. Penniman
Maui District Endangered Species Research Specialist
PCSU/DOF AW
Pacific Cooperative Studies Unit/
Department of Forestry and Wildlife
Department of Land and Natural Resources
Kalanimoku Building
1151 Punchbowl St., Room 325
Honolulu, HI 96813
Phone: (808) 280-4114
Email: jayfp@hawaii.edu

Subject: Archaeological Inspection of the 6-Acre Lānaʻihale ʻUaʻu Restoration Area of the Lānaʻihale Forest and Watershed Project

Aloha Mr. Jay F. Penniman:

The purpose of this letter is to report the results of an archaeological field inspection of two (2) - three (3) acre parcels designated as priority areas for the Lānaʻihale ʻUaʻu Restoration Project. The purpose of Lānaʻihale ʻUaʻu Restoration Project is to restore *uluhe* fern (Dicranopteris linearis and Diplopterygium pinnatum) habitat to promote nesting for the Hawaiian petrel, (Uaʻu). The project area is located at the ridge crest of Lānaʻihale and is transected by the Munro Trail (see attached Figure 1 and Figure 2). The project area is level to gently sloping and along the northeast side borders the upper slope of Honoʻumi Gulch. The project area is fairly heavily vegetated with Strawberry guava (Psidium cattleianum) with some open areas of *uluhe* fern.

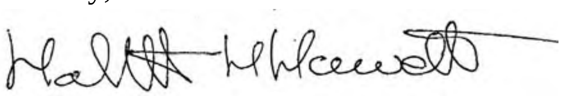
This inspection took place on March 3, 2008 over a period of approximately six hours. The field inspection was conducted by pedestrian sweeps, in which five individuals traversed parallel lines from southwest to northeast spaced at 30-foot distances from each other. The individuals conducting the sweeps were under my direct supervision and were instructed beforehand on the nature and description of potential site areas that could be located in this area of Lānaʻi, such as stone walls, stone mounds, *ahu*, terraces or alignments. If such features were noted during the sweeps, the individuals were asked to notify me so that these potential features could be inspected. The participants in the walk through were Mr. Jay Penniman, Ms. Christine Costales of the Pacific Cooperative Studies Unit (PCSU), Ms. Kauʻi Spitalski, and Ms. Linda Williams, volunteer.

The boundaries of the project area had been previously marked with flagging tape. The sweeps were conducted to thoroughly cover the project area in a slow and deliberate manner. No potential archaeological sites were located within the project area. At the southwest corner of Area 1 directly outside of the designated project area, a concrete stairway was noted descending with several steps down the slope to the southwest. The function of the stairway is uncertain, but its construction indicates a modern age. Since this stairway is located outside the designated project area and no ground disturbance other than vegetation clearance within the project area will take place, no impact to these stairs is anticipated.

As I am confident that the project area was thoroughly covered and the potential for subsurface cultural deposits is low, I would, however, recommend that as this project proceeds, the participants in the fieldwork conducting vegetation clearing and restoration, be made aware of the possibility of encountering historic properties and that Department of Land and Natural Resources/ State Historic Preservation Division - Maui Office be contacted at (808) 243-5169 if potential findings are encountered. I will be happy to provide additional information as requested.

If you have any questions or comments, please feel free to call me at (808) 262-9972 on O‘ahu or toll free at 1-800-599-9962. You may also reach me by e-mail at hhammatt@culturalsurveys.com.

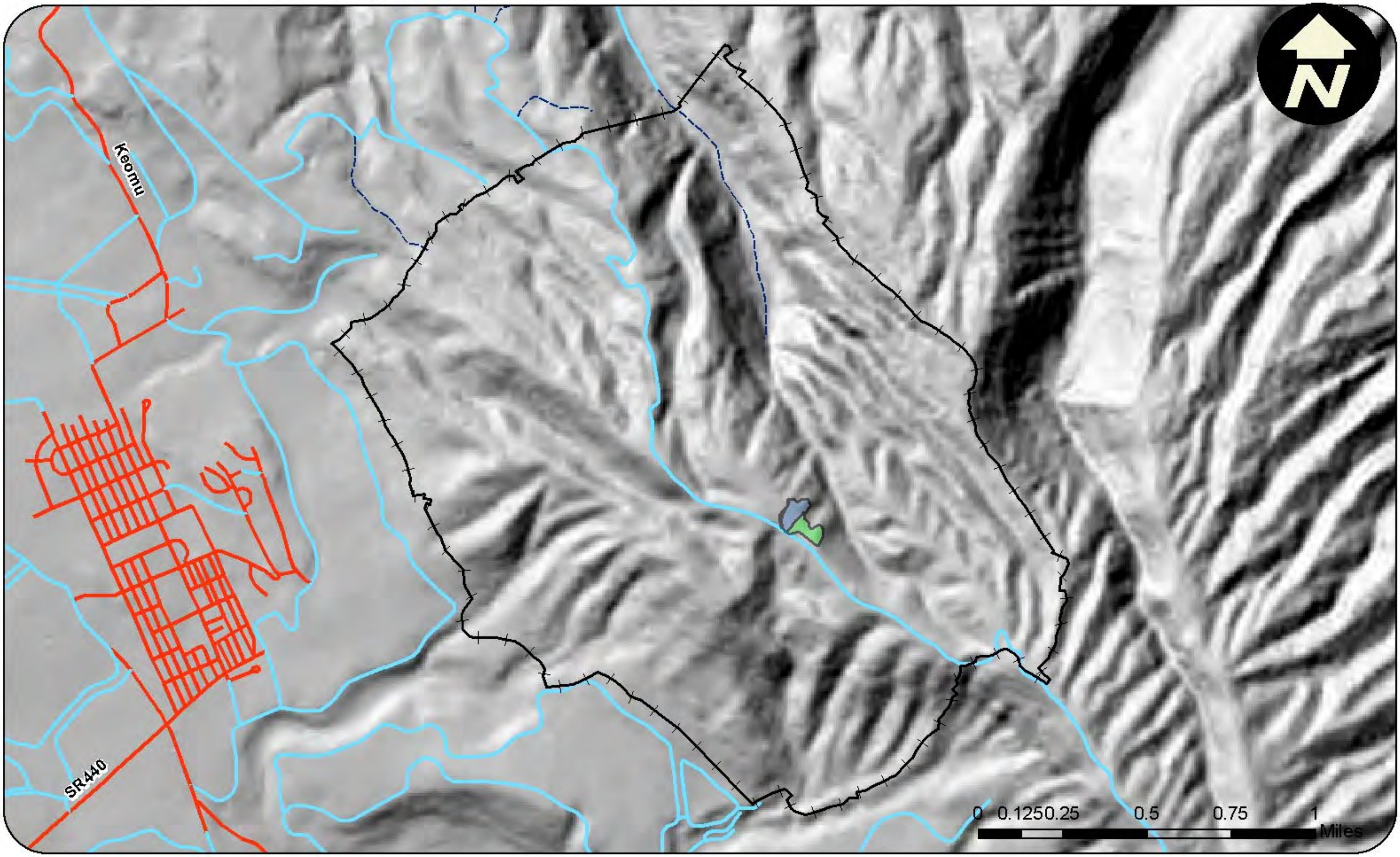
Sincerely,



Hallett H. Hammatt PhD, President

Länä'i Hale 'Ua'u Restoration Area

Created by BVM, Date Printed: 11/15/2007

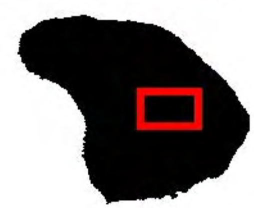


Priority Areas

- Area 1, ~3 acres
- Area 2, ~3 acres
- Castle & Cooke Wtrshd Fence, ~1,795 acres

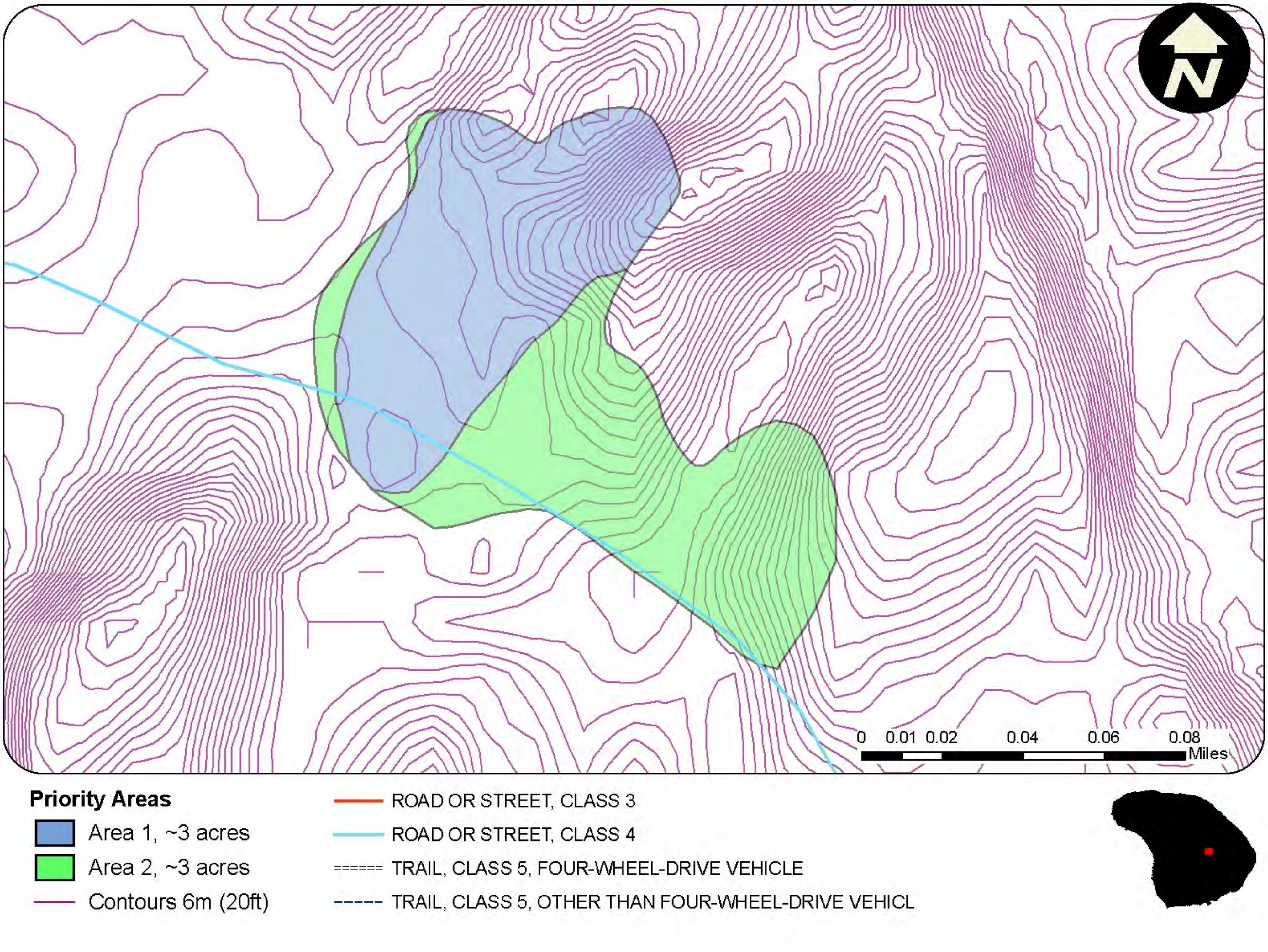
Minor Roads

- ROAD OR STREET, CLASS 3
- ROAD OR STREET, CLASS 4
- TRAIL, CLASS 5, FOUR-WHEEL-DRIVE VEHICLE
- TRAIL, CLASS 5, OTHER THAN FOUR-WHEEL-DRIVE VEHICL



Läna'i Hale 'Ua'u Restoration Area

Created by BVM, Date Printed: 11/15/2007



APPENDIX D
AGENCY CONTACTS AND CORRESPONDENCE

AGENCY CONTACTS AND CONSULTATIONS

The following are agency staff coordinated with in the development of this environmental assessment.

Norma Bustos:	Wildlife Program Specialist, DOFAW, Honolulu, HI
Fern Duvall:	Wildlife Biologist, DOFAW, Honolulu, HI
Roy Kam:	Database Manager, Hawaii Biodiversity Mapping Program, Honolulu, HI
Aaron Nadig:	Biologist, Consultation and Technical Assistance Program USFWS, Honolulu, HI
Marcos Gorresen:	Modeling specialist. Hawaii Forest Bird Interagency Database Project, USGS, Hawaii Volcanoes National Park, HI
Nick Holmes:	Coordinator, Kauai Endangered Seabird Recovery Project, Waimea, HI
Scott Fretz:	Wildlife Program Manager, DOFAW, Honolulu, HI
Melissa Kirkendall:	Maui Island Archaeologist, SHPD, Maui Island Office, Wailuku, Maui
Jeff Newman:	Assistant Field Supervisor for Habitat Conservation, USFWS, Honolulu, HI
Jay Penniman:	Maui District Endangered Species Research Specialist, PCSU/DOF AW, Honolulu, HI
Gina Shultz:	Assistant Field Supervisor - Endangered Species, USFWS, Honolulu, HI
Bill Standley:	Fish and Wildlife Biologist, Pacific Islands Office, USFWS, Honolulu, HI

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122, Box 50088
Honolulu, Hawaii 96850

In Reply Refer To:
2008-TA-0001
2007-TA-0256
2007-TA-0250
2007-B-0039

OCT 2 2 2007

Ms. Jina Sagar
Tetra Tech EC, Incorporated
1750 SW Harbor Way, Suite 400
Portland, Oregon 97201

Subject: Species List for a Proposed Metrological Tower Project, Lanai, Hawaii

Dear Ms. Sagar:

Thank you for your electronic mail dated September 27, 2007, indicating that your organization is compiling information that will be used in the preparation of an environmental assessment for a proposed Metrological Tower project on the island of Lanai. Specifically, you requested a list of federally protected and candidate species that may occur on Lanai.

We have reviewed the information you provided and pertinent information in our files, including data compiled by the Hawaii Biodiversity and Mapping Program and the Hawaii Geographic Analysis Program. Land cover information for the island of Lanai has multiple classifications (Enclosure 1). Enclosure 2 lists the federally threatened, endangered and candidate species known to occur on the island of Lanai. Enclosure 3 identifies federally designated critical habitat on Lanai.

We hope this information assists you in developing your environmental assessment. If you have questions, please contact Aaron Nadig, Fish and Wildlife Biologist (phone: 808-792-9466; fax: 808-792-9581).

Sincerely,

Christa Russell

for Patrick Leonard
Field Supervisor

Enclosures

Enclosure 1. Land Cover Classifications for the Island of Lanai

Land Cover Classification	Hectares (Acres)
Aalii Shrubland	3602 (8900)
Closed *Pouteria* Forest (Native Trees)	23 (57)
Olopua-Lama Forest (Christmas Berry)	13 (33)
Olopua-Lama Forest (*Lantana*)	41 (101)
Open Ohia Forest (Uluhe)	1296 (3201)
Water	22 (54)
Agriculture	21 (51)
Alien Shrubs and Grasses	1190 (2941)
High Intensity Developed	33 (81)
Low Intensity Developed	307 (757)
Alien Grassland	820 (2026)
Fountain Grass - Buffel Grass Grassland	8713 (21530)
Christmas Berry Shrubland	649 (1603)
Koa Haole Shrubland	5642 (13941)
Alien Forest	1038 (2564)
Kiawe Forest and Shrubland	5772 (14262)
Kiawe-Koa Haole Forest and Shrubland	6605 (16320)
Very Sparse Vegetation to Unvegetated	844 (2085)

Enclosure 2. List of Threatened, Endangered and Candidate Species Reported From the Island of Lanai

Common Name	Scientific Name	Status
Birds		
Hawaiian duck	*Anas wyvilliana*	Endangered
Hawaiian coot	*Fulica alai*	Endangered
Hawaiian stilt	*Himantopus mexicanus knudseni*	Endangered
Ou	*Psittirostra psittacea*	Endangered
Hawaiian petrel	*Pterodroma phaeopygia sandwichensis*	Endangered
Newell's shearwater	*Puffinus auricularis newelli*	Threatened
Mammals		
Hawaiian hoary bat	*Lasiurus cinereus semotus*	Endangered
Hawaiian monk seal	*Monachus schauinslandi*	Endangered
Reptiles		
Pacific green sea turtle	*Chelonia mydas*	Threatened
Hawksbill sea turtle	*Eretmochelys imbricate*	Endangered
Insects		
Orange-black damselfly	*Megalagrion xanthomelas*	Candidate
Lanai tree snail	*Partulina semicarinata*	Candidate
Lanai tree snail	*Partulina variabilis*	Candidate
Plants		
No Common Name	*Abutilon eremitopetalum*	Endangered
Ko oloa ula	*Abutilon menziesii*	Endangered
Hina Hina Ewa	*Achyranthes splendens* var. *rotundata*	Endangered
No Common Name	*Adenophorus periens*	Endangered
Ko oko olau	*Bidens micrantha* ssp. *kalealah*	Endangered
No Common Name	*Bonamia menziesii*	Endangered
Alula	*Brighamia rockii*	Endangered
Uhiuhi	*Caesalpinia kavaiensis*	Endangered
Kamanomano	*Cenchrus agrimonioides* var. *agrimonioides*	Endangered
Awiwi	*Centaurium sebaeoides*	Endangered
Oha Wai	*Clermontia oblongifolia* ssp. *mauiensis*	Endangered
Pauoa	*Ctenitis squamigera*	Endangered
Haha	*Cyanea gibsonii*	Endangered
Haha	*Cyanea grimesiana* ssp. *grimesiana*	Endangered
Haha	*Cyanea lobata*	Endangered
Haha	*Cyanea munroi*	Endangered
No Common Name	*Cyperus fauriei*	Endangered
No Common Name	*Cyperus trachysanthos*	Endangered
Ha iwale	*Cyrtandra munroi*	Endangered
No Common Name	*Diellia erecta*	Endangered

Enclosure 2. List of Threatened, Endangered and Candidate Plants (continued)

Common Name	Scientific Name	Status
No Common Name	*Diplazium molokaiense*	Endangered
No Common Name	*Gahnia lanaiensis*	Endangered
Nanu	*Gardenia brighamii*	Endangered
Pilo	*Hedyotis mannii*	Endangered
Kopa	*Hedyotis schlechtendahliana* var. *remyi*	Endangered
No Common Name	*Hesperomannia arborescens*	Endangered
Ma o Hau Hele	*Hibiscus brackenridgei* ssp. *brackenridgei*	Endangered
Wahine noho kula	*Isodendrion pyrifolium*	Endangered
Kamakahala	*Labordia tinifolia* var. *lanaiensis*	Endangered
Alani	*Melicope munroi*	Endangered
Ma aloa	*Neraudia sericea*	Endangered
No Common Name	*Phyllostegia glabra* var. *lanaiensis*	Endangered
No Common Name	*Phyllostegia haliakalae*	Endangered
Ihi	*Portulaca sclerocarpa*	Endangered
Iliahi	*Santalum freycinetianum* var. *lanaiense*	Endangered
Naupaka	*Scaevola coriacea*	Endangered
Ohai	*Sesbania tomentosa*	Endangered
No Common Name	*Silene lanceolata*	Endangered
Popolo ku mai	*Solanum incompletum*	Endangered
No Common Name	*Spermolepis hawaiiensis*	Endangered
No Common Name	*Tetramolopium lepidotum* ssp. *lepidotum*	Endangered
No Common Name	*Tetramolopium remyi*	Endangered
No Common Name	*Vigna o-wahuensis*	Endangered
No Common Name	*Viola lanaiensis*	Endangered
Hea e	*Zanthoxylum hawaiiense*	Endangered
Awikiwiki	*Canavalia pubescens*	Candidate
Aiea	*Nothocestrum latifolium*	Candidate
Halapepe	*Pleomele fernaldii*	Candidate
Ena ena	*Pseudognaphalium sandwicensium* var. *molokaiense*	Candidate
No Common Name	*Schiedea pubescens*	Candidate

Enclosure 3. Federally Designated Critical Habitat on the Island of Lanai

Common Name	Scientific Name	Hectares (Acres)
Ko oko olau	*Bidens micrantha* ssp. *kalealaha*	161 (397)
Ihi	*Portulaca sclerocarpa*	8 (19)
No Common Name	*Tetramolopium remyi*	151 (373)

APPENDIX E

PHOTOGRAPHS OF METEOROLOGICAL TOWER LOCATIONS

Photograph 5-1. Looking at the proposed MET 1 tower location.

Photograph 5-2. This photograph shows the MET 2 tower location.

Photograph 5-3. Looking north at the proposed MET 3 location.

Photograph 5-4. Proposed MET 4 tower location.

Photograph 5-5. This photograph shows the MET tower 5 location

Photograph 5-6. Proposed MET tower 6 location.

Photograph 5-7. Proposed MET tower 7 location.

APPENDIX F
MET TOWER BOTANICAL SURVEY

Botanical surveys at seven meteorological tower sites on northern Lānaʻi, Hawaiʻi[1]

December 13, 2007 *AECOS* No. 1162

Eric B. Guinther and Shelley A. James, PhD[2]
AECOS, Inc.
45-939 Kamehameha Highway, Suite 104
Kaneʻohe, Hawaiʻi 96744
Phone: (808) 234-7770 Fax: (808) 234-7775 Email: aecos@aecos.com

Summary

The results of two days of surveys at seven meteorological sites (one developed, six proposed) from November 26 through 28, 2007 revealed a mix of introduced and native plant species in essentially grassland to low-growing shrubland communities on the northern part of the Island of Lānaʻi. A list of the species present with an estimate of the relative abundance of species at each site was developed. The surveys extended outward to or slightly beyond a radius of 100 meters from a pre-established center-point for each site in order to provide flexibility in the erection of the meteorological towers. No plant species listed as federally threatened or endangered was observed in any of the survey areas.

Introduction

This report presents the results of botanical surveys at seven specific sites located on the northern part of the Island of Lānaʻi, Maui County, Hawai`i (Figure 1). The sites are to be used for erection of meteorological (met) towers to provide information on wind conditions across the undeveloped part of the Island for the proposed Lānaʻi Wind Energy Project (Project). The purpose of these initial botanical surveys is to assure the planning and engineering teams of the project proponent, Castle & Cooke Resorts, Hawaii, that tower erection can proceed without concern for the presence of federally listed plant species.

[1] Report prepared for TetraTech EC Inc., Honolulu to become part of the public record for the Lanai Wind Energy Facility.
[2] Botany Department, B. P. Bishop Museum.

Figure 1. Northern Lānaʻi showing locations of the seven met tower sites. Project area boundary shown as blue line; orange lines are roads (most paved).

All of the seven sites surveyed are accessible over the network of 4-wheel drive roads that extend from just west of Lanai City to Garden of the Gods (a badland rock formation) and downslope on many of the interfluves (land between gulches or fluves). In all but one case, the sites are located directly adjacent to a 4-wheel drive road. At Site 3, a shallow gulch separates the center of the site from the roadway.

Survey Methods

The primary purpose of this set of surveys is to establish that no federally listed endangered, threatened, or proposed-for-listing plants are growing at or near seven proposed met tower sites. Federal and State of Hawaiʻi listed species status follows species identified in the following documents: DLNR (1998); Federal Register (2005), USFWS (2005, 2006)[3].

Survey boundaries were established to be a minimum of 100 meters (330 feet) out from a center point previously selected as the best position in each specific area for the erection of a tower to hold the meteorological instrumentation. Generally, the boundary was slightly exceeded in any direction where the terrain suggested the met tower could be moved (that is, where the ground remained level or had low slope). Surveys were terminated at steep slopes or at gulch bottoms within the 100 meter radius. Met tower center points provided to the survey team are given in Table 1.

Table 1. UTM and longitude/latitude coordinates for the seven met tower sites surveyed November 26-28, 2007.

Tower Site	Elevation (ft)	NAD83 UTM Zone 4Q X	NAD83 UTM Zone 4Q Y	NAD83 º LAT	NAD83 º LONG
1	1563	710784	2310552	20.883216	-156.973733
2	682	710737	2312995	20.905283	-156.973883
3	370	708471	2314115	20.915650	-156.995533
4	1459	707369	2310790	20.885750	-157.006516
5	492	705205	2313386	20.909433	-157.027000
6	565	703734	2311433	20.891966	-157.041366
7	928	714255	2311957	20.895502	-156.940208

The two botanists started at the center point of a site and moved outward slowly together to develop a species list of the dominant and common species present. Each botanist then separately covered on foot approximately two-thirds of a met tower survey area in wandering transects, using hand-held GPS units to establish that coverage was complete and roughly within bounds. This approach provided an

3 State statutes link the threatened and endangered plant species for the State of Hawaiʻi to the federal list of threatened and endangered species.

efficient use of each botanists' time while insuring some overlap in area actually surveyed by each.

A typical record of the survey track from one of the botanist's GPS unit is shown as Figure 2. Coverage during a wandering transect varied with the terrain and the vegetation type. In areas of low topography with sparse or low-growing grass, this distance might be 20 meters; in areas of greater topography or taller shrub growth, this distance would be reduced to 5 or 10 meters. In badland areas it was possible to inspect the few plants standing out on the barren ground and concentrate on the margins supporting plant growth.

Figure 2. Example of GPS recorded track produced by one of the botanists surveying Site 5 on November 27. Track in yellow represents a November 26 reconnaissance visit. The track of the vehicle along roads was also recorded.

Upon completion of the surveys, the positional information gathered from each site was plotted on a topographic map. This included the central point and a series of waypoints recorded by one GPS unit, and a comparison of the track recorded by the other unit. This approach insured that the resulting smoothed polygon connecting the waypoints incorporated all the area shown by the second GPS unit (which had the capability of recording the actual track as a series of time interval set waypoints). The mapped individual survey areas are presented herein as Figures 3 through 9. Elevation contours on these maps are in meters.

Most plants were easily identified in the field. In a few cases, photographs were taken and specimens collected for closer examination in the laboratory. In one case a mounted voucher specimen of *Mollugo cerviana,* representing a new record for the Island of Lānaʻi was created for deposit in the herbarium of the B. P. Bishop Museum.

With respect to conditions at the time of the survey, rainy weather was experienced throughout the morning of November 27, which slowed the work on that date. However, the wet season on Lānaʻi was well underway and the vegetation was green and flushed with growth. Some annuals were observed only as seedlings, and thus their abundance could not be estimated in any meaningful way. Seedlings of some shrubs, such as ʻilima (*Sida fallax*) and ʻuhaloa (*Waltheria indica*), were very abundant and the abundance estimates for these plants are for adults only.

Results

Lānaʻi has a number of areas where rare native plants are found, and these are scattered widely over the island, although most federally listed species occur in the uplands east of Lānaʻi City and in the dry forest preserve to the north of town. Because of the large population of Axis deer or chital (*Axis axis*) on the island, several areas supporting native plants are fenced to exclude herbivory on the rare native plants.

Some 37 federally listed plants are known from the island, including 7 that are endemic to (known only from) Lānaʻi. The remaining 30 species are also found on other islands in the Hawaiian archipelago (Federal Register, 2002). Critical Habitat has been proposed totaling 4,800 acres (1942 hectares) for some 18 endangered plant species on Lānaʻi. However, presently, a total of 789 acres (320 hectares) has been designated. With one exception, units are all located on the southern half of the Island. The exception is Unit 1 (373 acres or 151 hectares) located between elevations of 590 and 950 feet (180 and 290 meters) upslope of Pōhakuloa Point on the north side of Lānaʻi (Federal Register, 2003). Unit 1 is designated Critical Habitat for *Tetramolopium remyi*, a short-lived perennial in the Family Asteraceae. This species once occupied the designated Unit 1 area but was considered extirpated at the time of the final ruling, with the possibility that there remained a seed bank of *T. remyi* in the area.

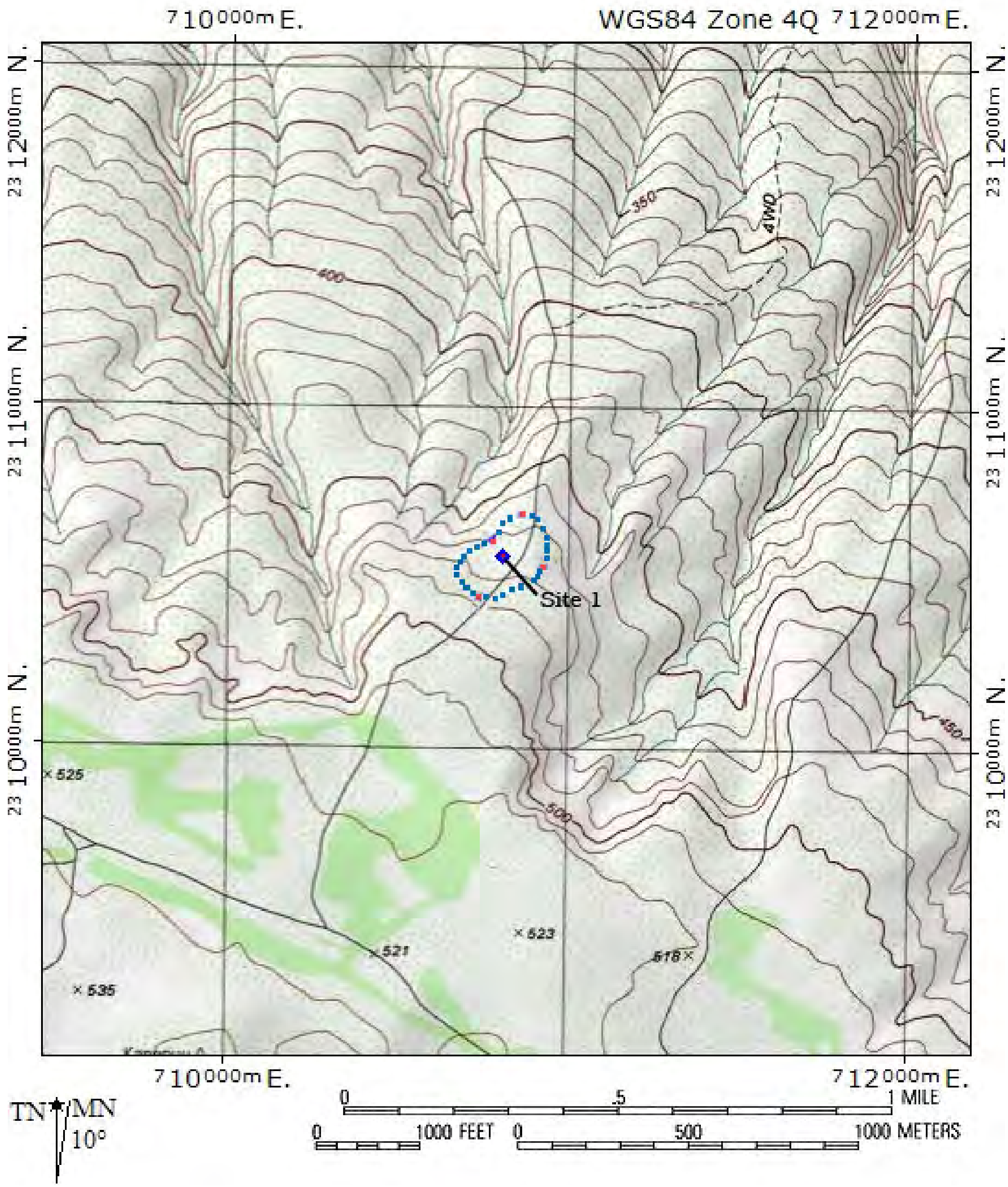


Figure 3. Location and survey area boundary for Site 1, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

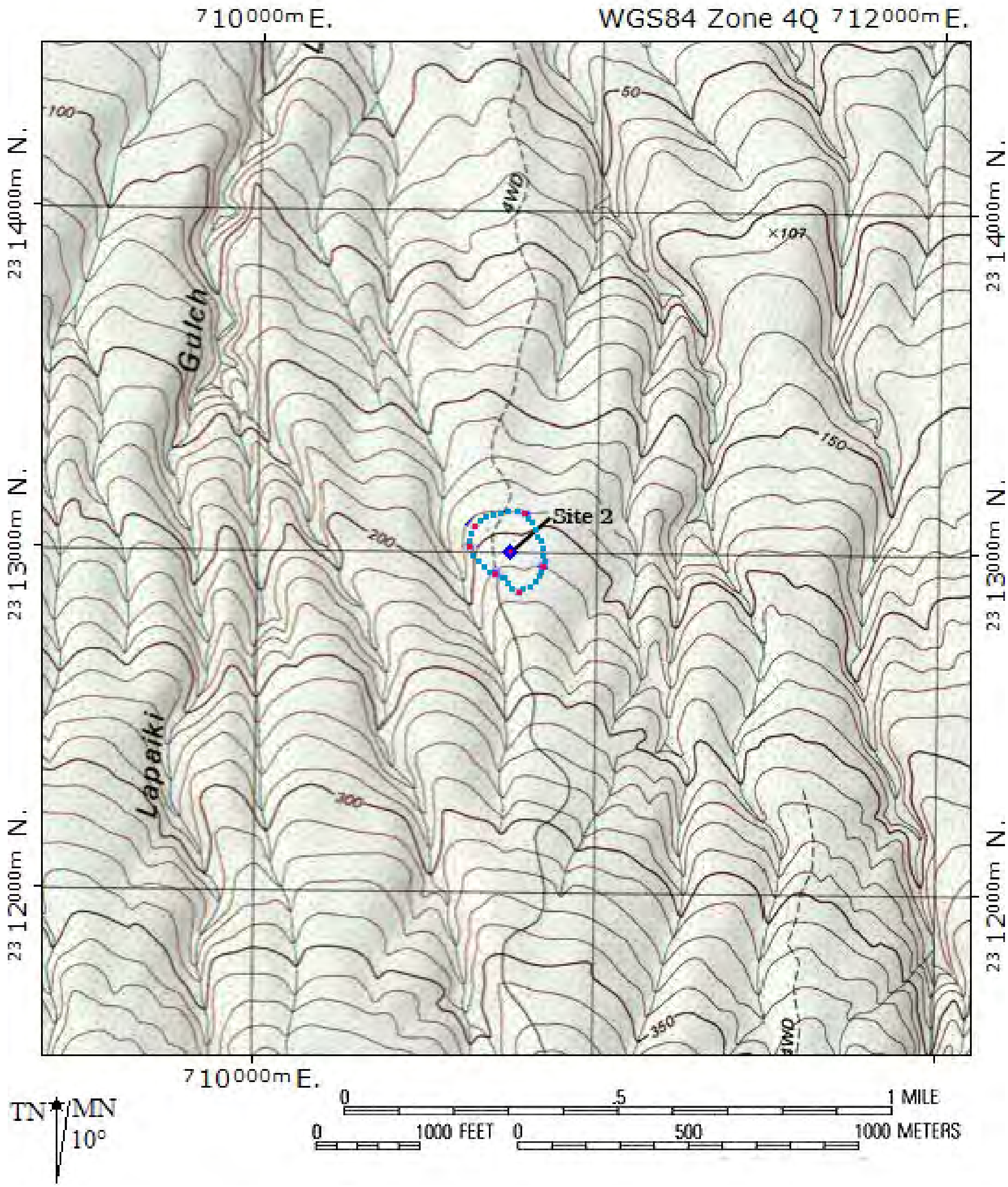


Figure 4. Location and survey area boundary for Site 2, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

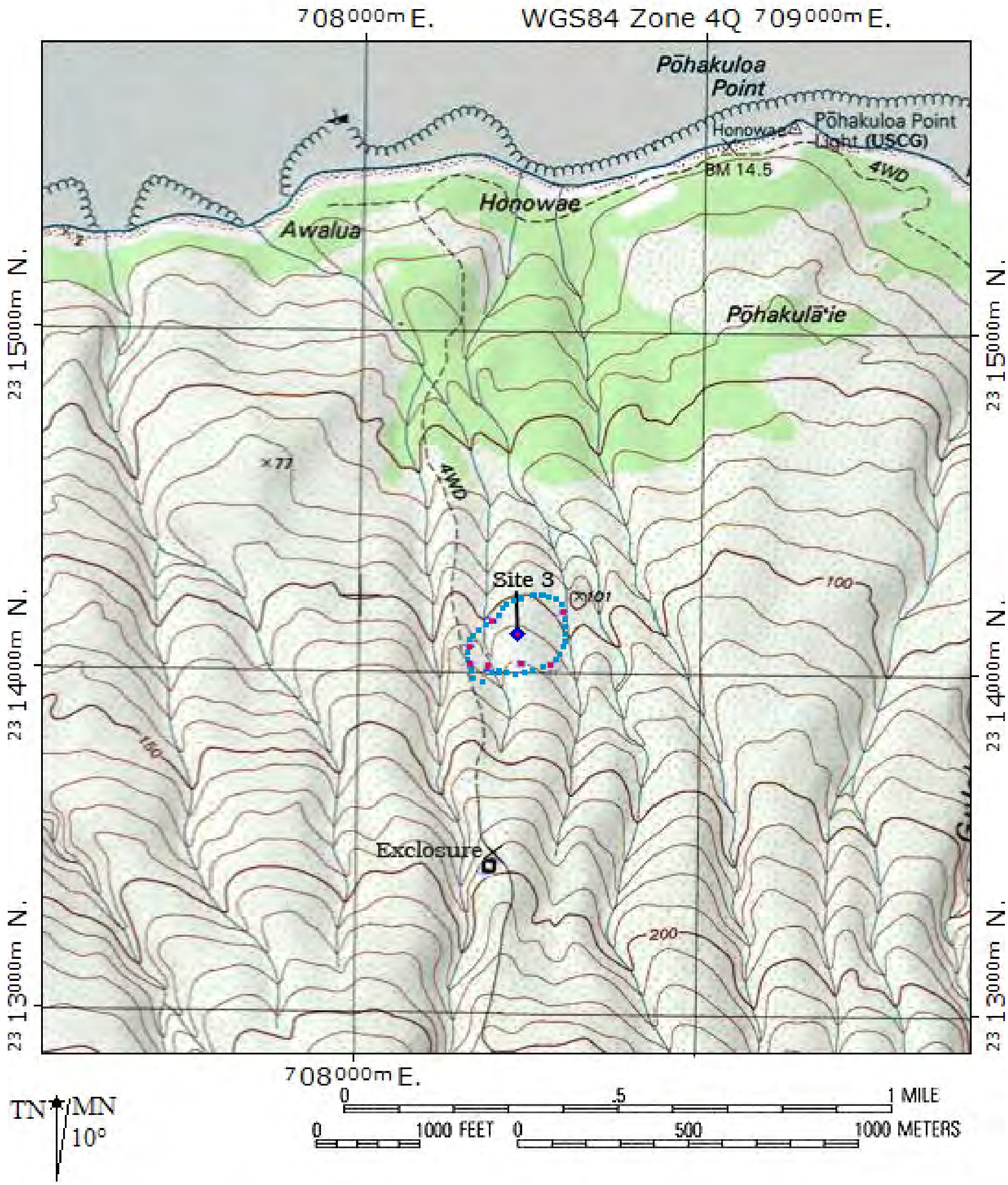


Figure 5. Location and survey area boundary for Site 3, surveyed on November 28, 2007 (GPS recorded waypoints shown in red).

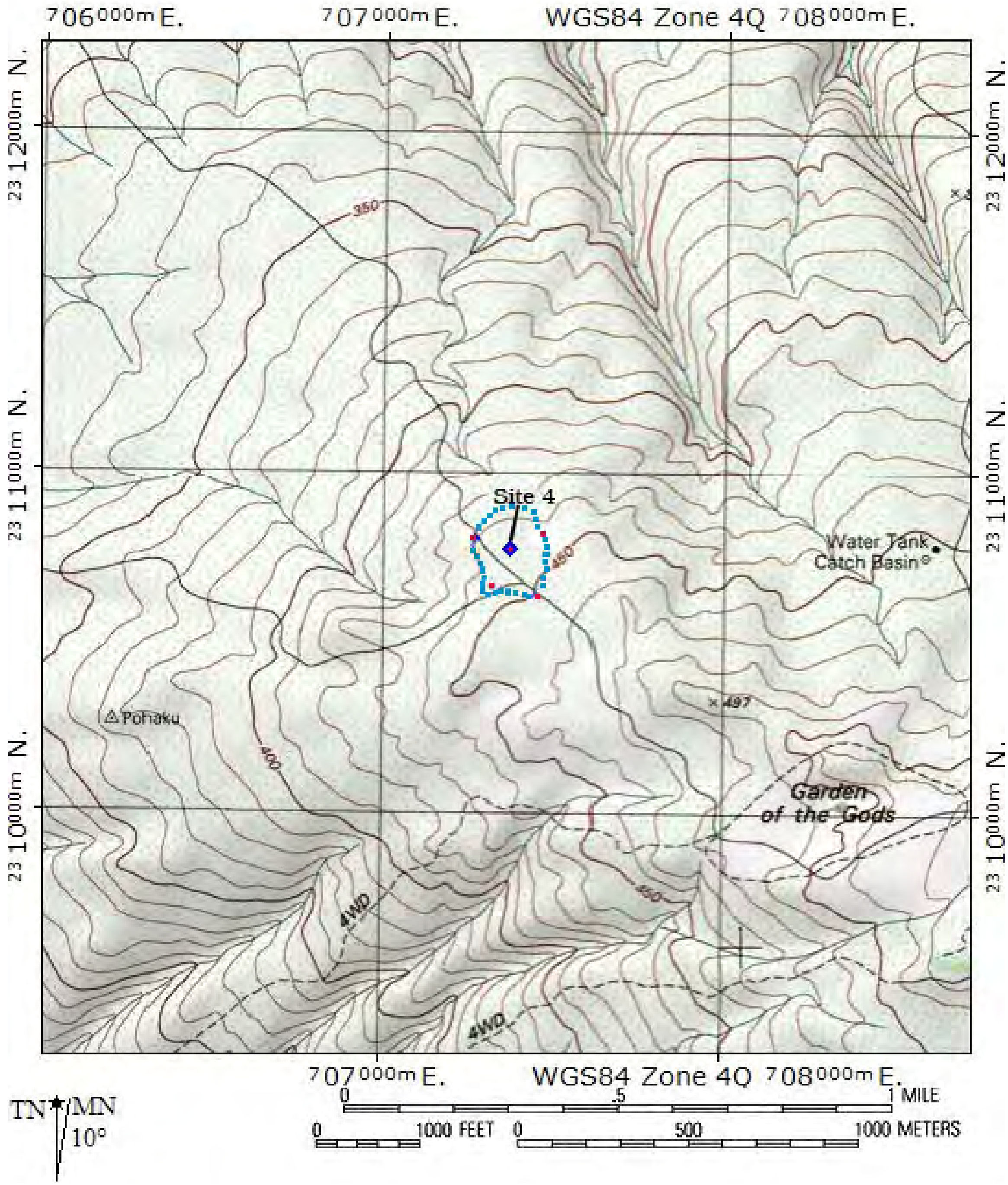


Figure 6. Location and survey area boundary for Site 4, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

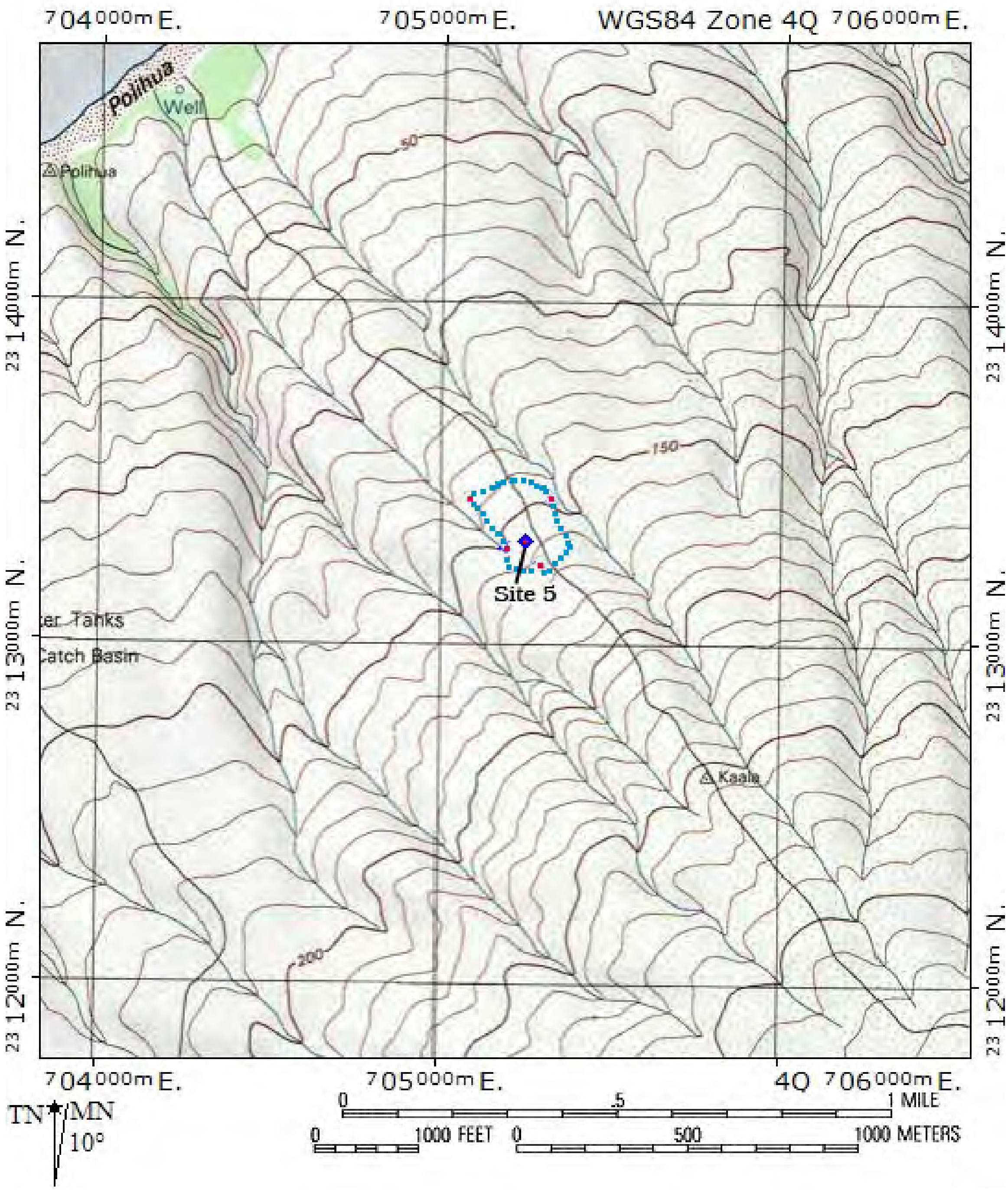


Figure 7. Location and survey area boundary for Site 5, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

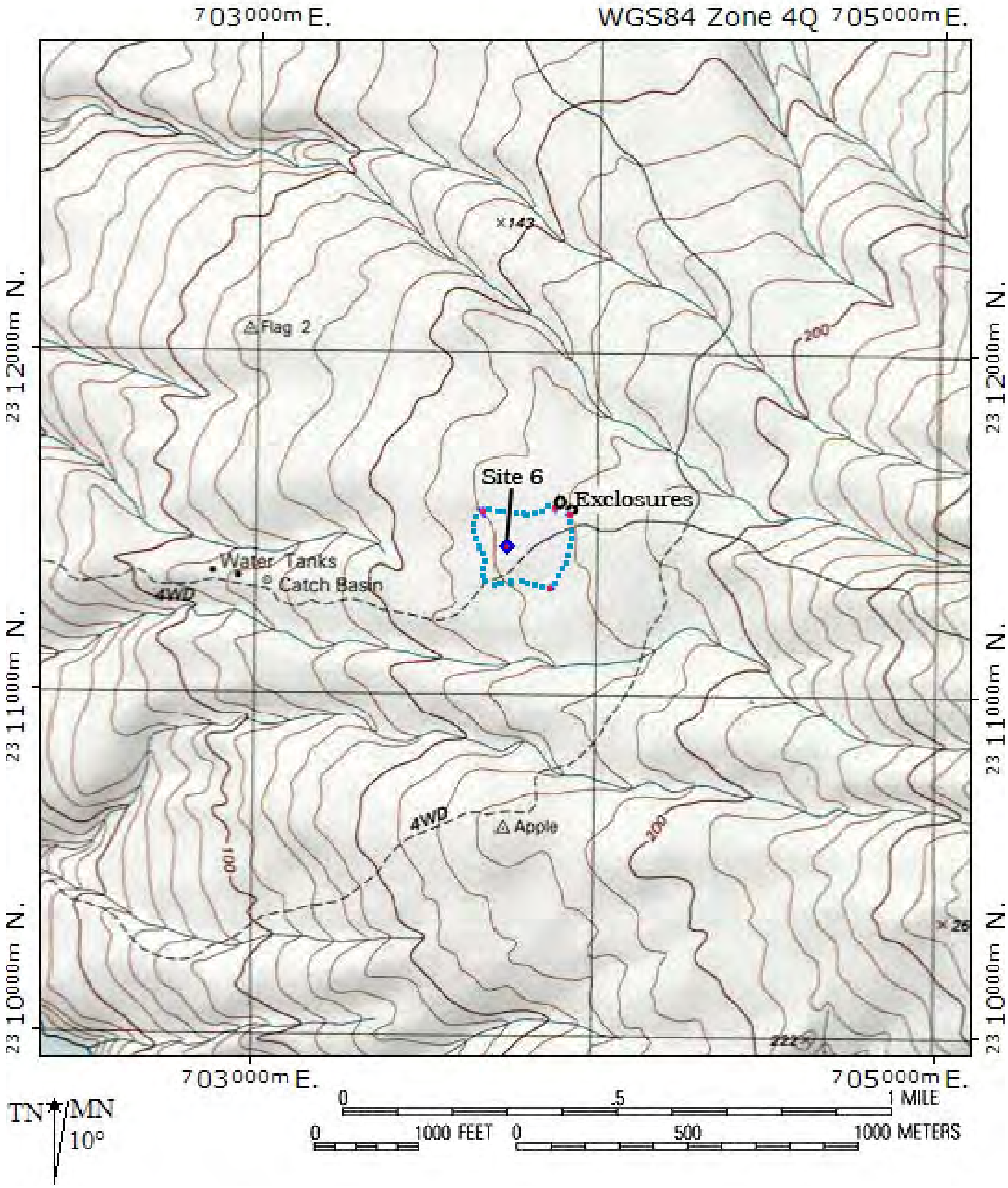


Figure 8. Location and survey area boundary for Site 6, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

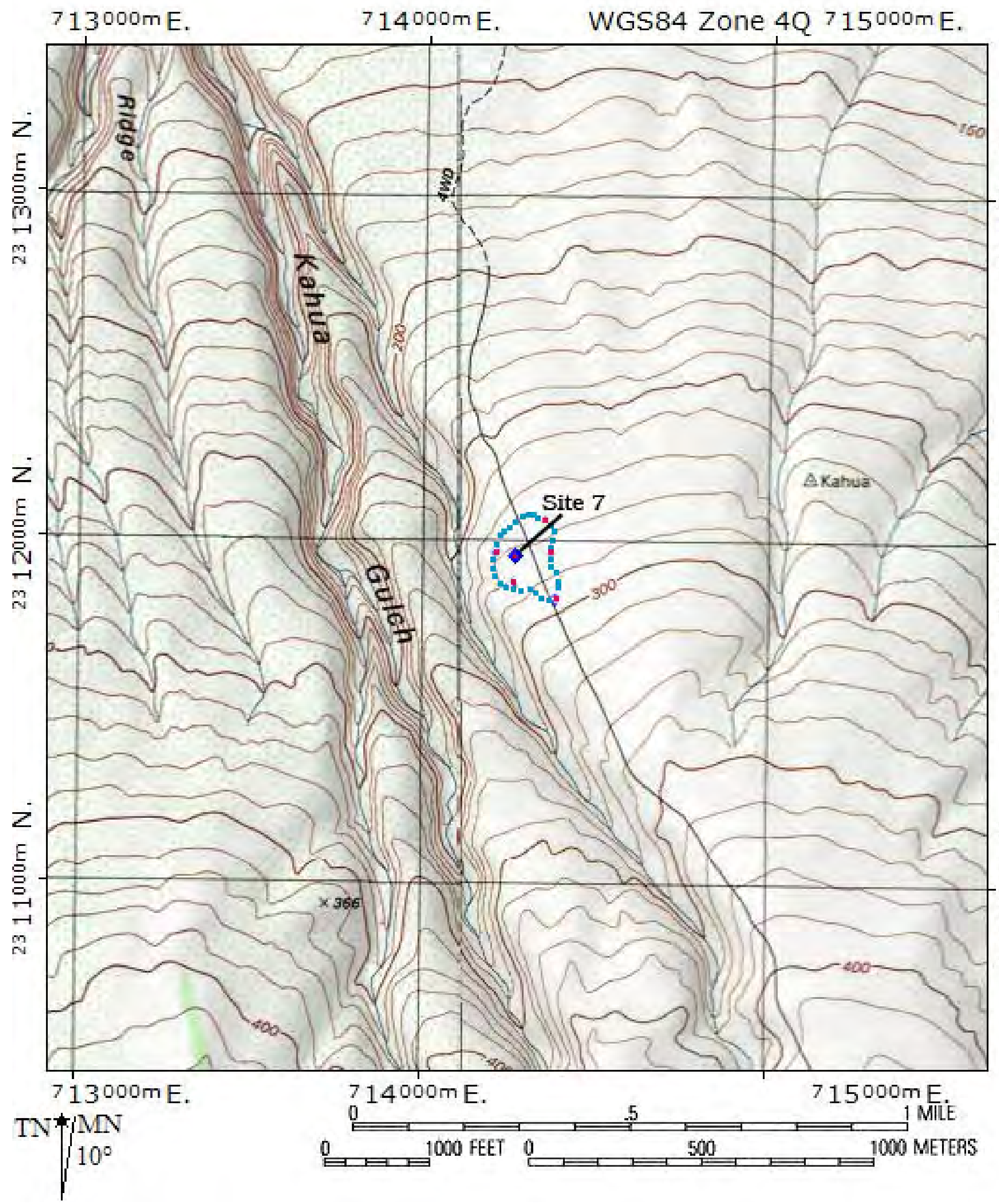


Figure 9. Location and survey area boundary for Site 7, surveyed on November 28, 2007 (GPS recorded waypoints shown in red).

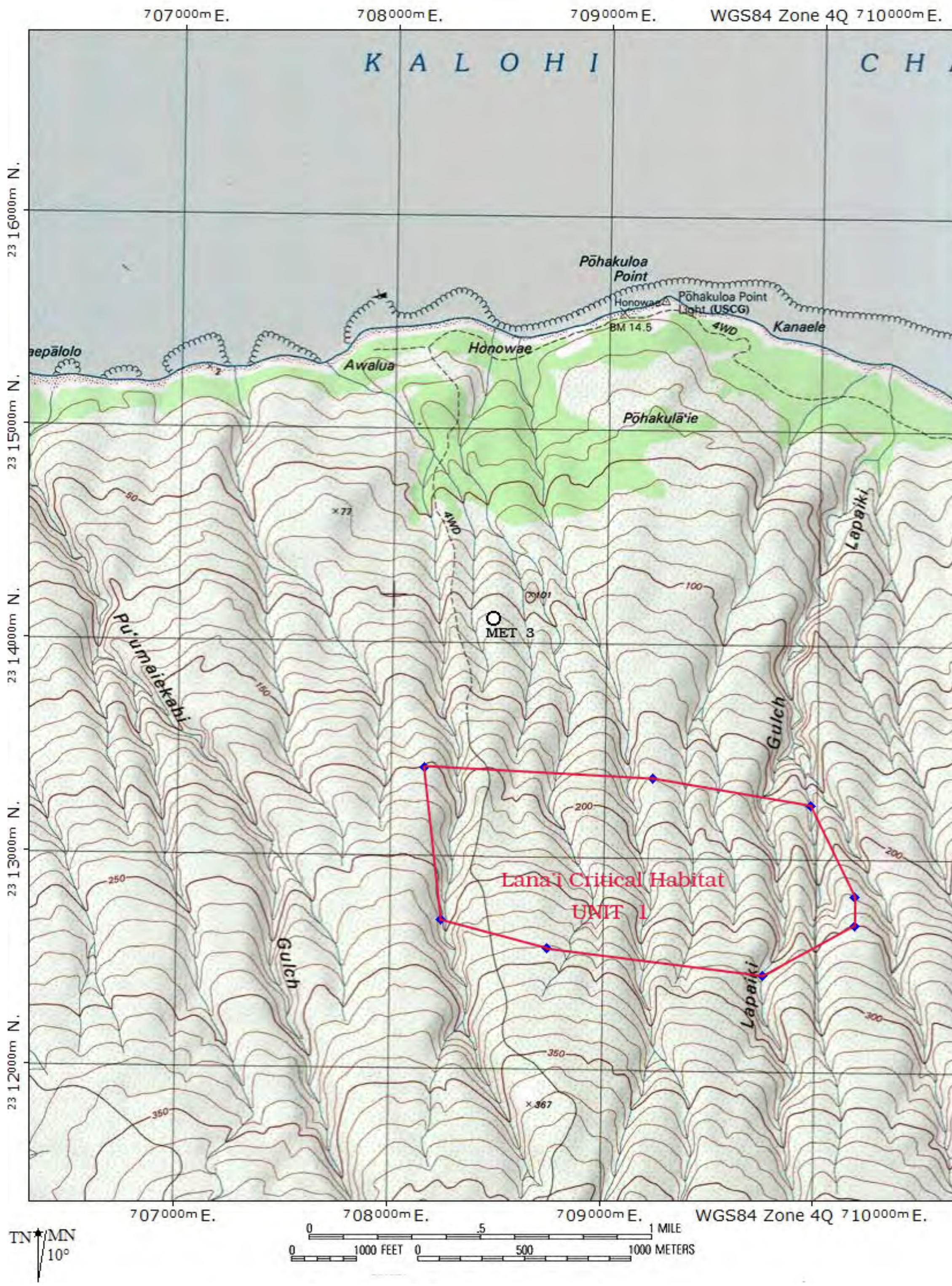


Figure 10. USFWS designated Critical Habitat Unit 1 on Lānaʻi shown in relation to met tower Site 3 (MET 3), the nearest met tower site of the seven proposed.

None of the met tower survey areas is located within a designated Critical Habitat. Met tower Site 3, at 370 feet (113 meters) elevation is located approximately 4000 feet (1200 meters) down slope of Unit 1 (Figure 10). Note that the roadway passing through Unit 1 is specifically exempted from the critical habitat (Federal Register, 2003, §17.96).

General Vegetation Descriptions

A future phase of the botanical efforts to be undertaken on Lānaʻi for the proposed Project will involve mapping of vegetation types within the Project boundary. However, it is valuable to point out here the general vegetation at each of the met tower sites. This vegetation varies from badlands (that is, areas of severe erosion lacking or with extremely sparse plant growth; Figure 11) to grasslands to scrub lands (areas dominated by low or scrubby bushes; Figure 12).

Figure 11. Margin of a badlands area showing invasion by *ʼilima*.

Met tower Site 1 (Figure 3) is in a badlands area. Vegetated land beyond the severely eroded ground covering most of the area is grassland where Angleton grass (*Dichanthium aristatum*) predominates. Very scattered shrub growth consists of ʻaʻaliʻi (*Dodonaea viscosa*), lantana (*Lantana camara*), and ʻuhaloa.

Met tower Site 2 is located further down the interfluve from Site 1 (Figure 4). In this area, the grassland is dominated by Angleton grass and pili grass (*Heteropogon contortus*), with ʻaʻaliʻi common as a low shrub. Another grass, Natal redtop (*Melinus repens*) is prominent. Other plants regularly encountered are ʻilima (*Sida fallax*), ʻuhaloa, lantana, and partridge pea (*Chamaecrista nictitans*). A native shrub, *Lipochaeta heterophylla*, is present in this area, as is an endemic vine, *Ipomoea tuboides*.

Figure 12. Heavily grazed grassland and low-growing shrubs (ʻaàliʻi) at Site 7.

Met tower Site 3 is located well downslope near the coast (at 370 feet or 113 meters) on the road to Awalua (Figure 5). Areas of dense Guinea grass (*Urochloa maxima*) and Christmas berry (*Schinus terebinthefolius*) growth occur along the road further upslope, but the grassland at Site 3 is very open and dominated by a mix of pitted beardgrass (*Bothriochloa pertusa*) and native pili grass. A gulch between the site and the road contains kiawe (*Prosopis pallida*) and indigenous *Abutilon incanum*. A distance of some 0,75 mile (1.2 kilometers) up the road from Site 3 is a small fenced exclosure. This exclosure is located along the northern edge of Critical Habitat Unit 1 (Federal Register, 2003; see Figure 10). The only native plant species seen within the exclosure was a *Bidens* (possibly a hybrid). This plant was, however, more abundant immediately outside the exclosure than inside it. The fence may have been erected to prevent herbivory on germinating of *Tetromolopium remyi* seeds potentially in the soil.

Met tower Site 4 (Figure 6) is located on the central ridge beyond (west of) the Garden of the Gods. A part of the site is badlands. This site is mostly grassland of Angleton grass, but includes significant areas of Guinea grass and shrubland. The shrubland is exclusively low growing ʻaʻaliʻi mixed with Angleton grass in the center of the site, but other areas are a mix of lantana, Guinea grass, and koa haole (*Leucaena leucocephala*). The plants here display greater stature than the grasses and shrubs seen at other sites.

Met tower Site 5 is located off the road to Polihua Beach, at about 490 ft (150 m) in elevation (Figure 7). This area is very open grassland of mostly pili grass and pitted beardgrass. A shallow gulch with kiawe trees lies off to the west. The most common shrubs in this area are klu (*Acacia farnesiana*) and ʻuhaloa.

Met tower Site 6 (Figure 8) already has a met tower erected and is being used to survey interactions between the tower, guy wires, and birds. Although much of the site is fairly open, this site is best described as a koa haole shrubland. Klu is common. The dominant grass is pitted beardgrass, with a few areas dominated by pili grass. Two fenced exclosures are located just outside the survey area, approximately 650 feet (200 meters) from the erected tower. Only one of the exclosures appeared to contain an unusual plant, a single specimen of the endangered *Hibiscus brackenridgei.* The fenced exclosures will not be disturbed by Project activities to ensure no impacts on this specimen.

Met tower Site 7 is located on the interfluves east of Kahua Gulch, furthest east of the proposed met tower sites, and is reached by a 4-wheel drive road off State Route 44 (Figure 9). The grass here appeared either severely cropped or lagging behind the grasses observed at the other sites in reaching maturity (Fig. 11). Both pili and pitted beardgrass are present, and the latter is presumed to be the dominant species over much of the site. However, this site included upslope of the central point, a dense scrub growth of native ʻaʻaliʻi, unusual among all the locations surveyed in the density and monotypic nature of the growth. Another native shrub, *Lipochaeta heterophylla*, and the native vine, *Ipomoea tuboides*, are present in this area, although less abundant than at Site 2.

Flora

A plant checklist (Table 2) was compiled from the observations made on the wandering transects conducted over each of the seven sites. Entries in Table 2 are arranged alphabetically under family names. Included are the scientific name, the common name, and status (whether native or introduced) of each species. The nomenclature of the flowering plants follows that of Wagner, Herbst, and Sohmer

(1999) for both the native and naturalized plants. Names for ferns (only one species was recorded) follow Palmer (2003).

A total of 54 species of flowering plants (and one fern) are listed for all seven met tower sites combined. Of the 55 plant species identified, 13 are regarded as native to the Hawaiian Islands (either indigenous or endemic), or 23.6% of the species. This proportion of natives (nearly one-quarter of the species present) is high compared with most disturbed areas in the Hawaiian Islands. On Oʻahu, lowland and middle elevation sites seldom exceed 12% native species (and are typically under 3%) and the number of natives is typically low. On northern Lānaʻi, the natives at most of the met tower sites remain significant in their abundance.

The native endemics include the fern (*Doryopteris decipiens*), a fairly widespread species in the islands. Less common are the shrub, *Lipochaeta heterophylla,* and the vine, *Ipomoea tuboides.*

Discussion

None of the plants observed at or surrounding (within 100 meters) the seven met tower sites are federally listed, are particularly rare on Lānaʻi, or would require special care to be taken in planning or erecting the met towers. While the native endemics found at a few of the sites are not afforded special protection, minimal anticipated disturbance erecting the met towers should provide ample protection for these somewhat rare representatives of a once more flourishing native community.

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Table 2. Listing of plant species observed at seven meteorological sites on Lānaʻi on November 26-28, 2007.

FAMILY *Species Name*	COMMON NAME	STATUS	TOWER SITE No. 1	2	3	4	5	6	7	Notes
FERNS & FERN ALLIES										
PTERIDACEAE										
Doryopteris decipiens (Hook.) J. Sm.		**end**	--	--	U	--	U	--	--	
FLOWERING PLANTS DICOTYLEDONES										
ANACARDIACEAE										
Schinus terebinthifolius Raddi	Christmas berry	nat	O	--	--	R	--	--	--	
ASTERACEAE										
Acanthospermum australe (Loefl.) Kuntze	Paraguay burr	nat	--	--	--	R	--	--	--	
Ageratum cf. *conyzoides* L.	---	nat	--	--	--	--	--	R	--	(4)
Bidens sp.		nat	--	--	R	--	--	--	--	(4)
Conyza bonariensis (L.) Cronquist	hairy horseweed	nat	R	--	--	--	--	--	--	
Cirsium vulgare (Savi) Ten.	bull thistle	nat	R	--	--	--	--	--	--	(4)
Emilia fosbergii Nicolson	Flora's paintbrush	nat	(1)	(1)	(1)	U	(1)	(1)	(1)	(2)
Heterotheca grandiflora Nutt.	telegraph weed	nat	R	--	--	--	--	--	--	(4)
Hypochoeris radicata L.	hairy cat's ear	nat	--	--	R	--	--	--	--	(4)
Lipochaeta heterophylla A.Gray	---	**end**	--	O1	--	--	--	--	U1	
Pluchea carolinensis (Jacq.) G.Don	sourbush	nat	--	--	--	--	R	--	--	(4)
Sonchus oleraceus L.	sow thistle	nat	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(4)
CONVOLVULACEAE										
Convolvulus arvensis L.	field bindweed	nat	--	--	--	--	R	--	--	(3)
Ipomoea cairica (L.) Sweet	*koali ʻai*	**ind?**	--	--	--	R	--	--	--	(4)
Ipomoea tuboides Degener & Ooststr.	*hunakai*	**end**	--	U	--	--	--	--	R	(4)
CUSCUTACEAE										
Cuscuta cf. *sandwichiana* Choisy	*kaunaʻoa*	**end**	--	--	--	--	--	--	R	
FABACEAE										
Acacia farnesiana (L.) Willd.	*klu*	nat	--	O	O	--	C	C	--	
Chamaecrista nictitans (L.) Moench	partridge pea	nat	O2	(1)	U	O	O	R	U	(1)
Desmodium incanum DC	Spanish clover	nat	--	--	--	R	--	--	--	

Table 2 (continued).

FAMILY *Species Name*	COMMON NAME	STATUS	TOWER SITE No. 1	2	3	4	5	6	7	Notes
FABACEAE (continued)										
Desmodium sandwicense E. Mey.	Spanish clover	nat	--	--	--	R	--	--	--	
Desmodium triflorum (L.) DC	---	nat	--	--	--	R	--	--	--	
Indigofera suffruticosa Mill.	indigo	nat	R	--	--	--	--	--	--	
Leucaena leucocephala (Lam.) de Wit	*koa haole*	nat	U	U	--	O	--	AA	R	
Macroptilium lathyroides (L.) Urb.	cow pea	nat	--	--	(1)	R	(1)	R	--	
Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth	*kiawe*	nat	--	O	O2	--	O2	O	--	
MALVACEAE										
Abutilon incanum (Link) Sweet	hoary abutilon	**ind?**	--	--	U	--	R	U	--	
Malva parviflora L.	cheeseweed	nat	--	--	--	--	--	R1	--	
Malvastrum coromandelianum (L.) Garcke	false mallow	nat	--	--	R	--	--	--	--	
Sida fallax Walp.	*ʻilima*	**ind**	O	C	O	U	C	O	A	
MENISPERMACEAE										
Cocculus orbiculatus (L.) DC.	*huehue*	**ind**	R	--	--	R	--	--	--	
MOLLUGINACEAE										
Mollugo cerviana (L.) Ser.	threadstem carpetweed	nat.	--	--	--	--	--	R	--	(3)
MYOPORACEAE										
Myoporum sandwicense A.Gray	*naio*	**ind**	R	--	--	--	--	--	R	
OXALIDACEAE										
Oxalis corniculata L.	*ʻihiʻai*, yellow wood sorrel	**ind?**	R	--	--	R	--	--	--	
PASSIFLORACEAE										
Passiflora suberosa L.	*huehue haole*	nat	R	--	--	--	--	--	--	(4)
PLANTAGINACEAE										
Plantago lanceolata L.	narrow-leaved plantain	nat	O2	--	--	O	--	--	(1)	
PORTULACACEAE										
Portulaca oleracea L.	pig weed	nat	--	--	--	--	--	R	--	(4)
SAPINDACEAE										
Dodonaea viscosa Jacq.	*ʻaʻaliʻi*	**ind**	AA	A	--	A	--	--	AA	
SOLANACEAE										
Solanum linnaeanum Hepper & P. Jaeger	apple of Sodom	nat	R	--	--	R	--	--	--	

Table 2 (continued).

FAMILY *Species Name*	COMMON NAME	STATUS	1	2	3	4	5	6	7	Notes
STERCULIACEAE										
Waltheria indica L.	*'uhaloa*	**ind?**	A	C	O	U	C	O	C	(2)
VERBENACEAE										
Lantana camara L.	lantana	nat	C	O	O	O	O2	O	O	(2)
Stachytarpheta jamaicensis (L.) Vahl	Jamaican vervain	nat	U2	--	--	U	R	R1	O	
	FLOWERING PLANTS MONOCOTYLEDONES									
POACEAE										
Bothriochloa pertusa (L.) A.Camus	pitted beardgrass	nat	--	A	AA	--	A	AA	(3)	
Cenchrus ciliaris L.	buffelgrass	nat.	--	--	O	--	U3	R1	--	
Cynodon dactylon (L.) Pers.	Bermuda grass	nat	O3	--	--	U2				
Dichanthium aristatum (Poir.) C.E.Hubb.	Angleton grass	nat	AA	AA	--	AA	--	--	U2	
Digitaria insularis (L.) Mez ex Ekman	sourgrass	nat	U3	--	R	R1	--	--	--	
Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	*pili*	**ind?**	--	AA	A	--	AA	O	O2	
Melinis minutiflora P.Beauv.	molasses grass	nat	U1	--	--	R	--	--	--	
Melinis repens (Willd.) Zizka	Natal redtop	nat	R	C	U	U	R1	--	R	
Paspalum dilatatum Poir.	Dallis grass	nat	R2	--	--	R	--	--	--	
Sporobolis cf. *africans*	African dropseed	nat	R	--	--	--	--	--	--	
Setaria gracilis Kunth	yellow foxtail	nat	R	--	--	--	--	--	--	
Urochloa maxima (Jacq.) R. Webster	Guinea grass	nat	R	--	--	O3	R	--	U	
Indet no. 1 "vernal"	---	nat	--	O	U	--	U	--	--	

Status = distributional status

End. = endemic; native to Hawaii and found naturally nowhere else.
Ind. = indigenous; native to Hawaii, but not unique to the Hawaiian Islands.
Ind? = Possibly indigenous or an early Polynesian introduction.
Nat. = naturalized, exotic, plant introduced to the Hawaiian Islands since the arrival of Cook Expedition in 1778, and well-established outside of cultivation.

Abundance = occurrence ratings for plants:

R – Rare - only one or two plants seen.
U - Uncommon - several to a dozen plants observed.

Table 2 (continued).

O - Occasional - More than a dozen plants seen, but encountered infrequently.
C - Common - considered an important part of the vegetation and encountered regularly.
A - Abundant - found in large numbers; may be locally dominant.
AA - Abundant - abundant and dominant; a vegetation defining species for the survey site.
Numbers (1-3) after an abundance rating for a species indicate modifications for localized abundance increases as per the following examples:

R1 – species encountered perhaps once, but several plants seen together.
O2 – a species encountered only occasionally, but seen in clusters of several to many specimens.
U3 – plant uncommon in its distribution, but very numerous where encountered.

Notes:

(1) Present only as numerous seedlings.
(2) Also present as numerous seedlings.
(3) Not previously recorded from the island of Lānaʻi.
(4) Observed, but without flower or fruit and ID therefore tentative.

APPENDIX G
RADAR SURVEY REPORT

RADAR AND AUDIOVISUAL STUDIES OF HAWAIIAN PETRELS NEAR PROPOSED METEOROLOGICAL TOWERS AND WIND TURBINES ON NORTHWESTERN LANA'I ISLAND, MAY–JULY 2007

FINAL REPORT

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October 2007

Printed on recycled paper.

EXECUTIVE SUMMARY

- We used radar and audio-visual methods to collect data on the movements, behavior, and flight altitudes of the endangered Hawaiian Petrel (*Pterodroma sandwichensis*), threatened Newell's (Townsend's) Shearwater (*Puffinus auricularis newelli*), and endangered Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) at nine sites total on Lana'i Island in May–July 2007. We conducted sampling at 3 sites during 15 nights of sampling in late May–early June ("late spring" sampling period) and at 7 sites, including 1 site that was sampled during the previous period, during 35 nights of sampling in late June–early July ("summer" sampling period). The objectives of the study were to: (1) conduct surveys of endangered seabirds and bats in the vicinity of the proposed wind-resource area (WRA); and (2) obtain information to help assess use of the area by these species.
- We recorded 170 radar targets that fit our criteria for petrels and shearwaters during the 15 nights of sampling in late spring 2007. Of these targets, we recorded 37 at the Western site, 73 at the Central site, and 60 at the Eastern site. This pattern of fewer targets in the western portion of the study area also was seen in summer 2007: out of 427 probable petrel targets, we recorded 11 at Lower Ka'ena, 42 at Lower Polihua, 43 at Garden of the Gods (all in the western WRA), 70 at Lower Awalua, 83 at Central, 50 at Upper Lapaiki (all in the central WRA), and 128 at Lower Kuahua (in the eastern WRA). Movement rates also reflected this pattern of fewer petrels in the western portion of the study area.
- In late spring, mean movement rates of landward-flying targets ranged from 0.24–1.96 targets/h in the evening to 0 targets/h during the morning, whereas seaward rates ranged from 1.92–3.48 targets/h in the evening to 0.96–3.68 targets/h in the morning. In summer, mean movement rates of landward-flying targets ranged from 0.0–3.56 targets/h in the evening to 0.0–0.12 targets/h during the morning, whereas seaward rates ranged from 0.48–3.56 targets/h in the evening to 0.60–4.92 targets/h in the morning.
- The overall mean movement rates that we observed on radar at Lana'i tended to be much lower than did rates observed during similar radar studies on Kaua'i and East Maui and were slightly lower than rates on West Maui; however, Lana'i movement rates were similar to rates on Hawai'i.
- We sampled only one location (Central) in both late spring and summer; movement rates at that site were similar between the two periods.
- Seaward movement rates (west or northwest, away from the colony) were higher than landward rates (east or southeast, toward the colony) for all sites, times of day (evening and morning), and sampling periods; however, rates did vary among hours within evening and morning periods. In addition, landward rates in the evening always were equal to or greater than landward rates in the morning, and morning rates usually were 0 targets/h. In contrast, seaward rates did not show a consistent difference between evening and morning. The only sites at which evening rates of seaward-flying targets were higher were the two farthest-inland sites, both of which were located along the east–west spine of the island.
- During audio-visual sampling, we recorded 33 Hawaiian Petrels and 2 unidentified petrels/shearwaters. Petrels were visually observed at all sites except for the Western site. For instance, in late spring, we recorded 5 petrels, with 0 at the Western site, 3 at the Central site, and 2 at the Eastern site. In summer, we recorded 30 petrels, with 1 at Lower Ka'ena, 2 at Lower Polihua, 3 at Garden of the Gods, 6 at Lower Awalua, 6 at Central, 2 at Upper Lapaiki, and 10 at Lower Kuahua.
- The mean (± SE) flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters observed from all sites, times of day, and sampling periods was 47 ± 8 m agl. The mean flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters flying in a landward direction was 34 ± 9 m agl, whereas

the mean seaward flight altitude was higher (71 ± 15 m agl).

- In addition to Hawaiian Petrels, we recorded one Hawaiian Hoary Bat during 485 sampling sessions (i.e., a rate of 0.005 bats/h). Thus, bats were present in the proposed WRA, but they occurred there in very low densities.
- Based on flight-altitude data from Lana'i, we estimate that 64% of the birds flying through this area are flying at altitudes low enough to interact with proposed met towers (i.e., ≤50 m agl) and that 94% of the birds flying through this area are flying at altitudes low enough to interact with proposed wind turbines (i.e., ≤125 m agl).
- To determine risk, we used petrel movement rates, petrel flight altitudes, and dimensions and characteristics of the proposed met towers and proposed wind turbines to generate an estimate of exposure risk. We corrected that estimate by the fatality probability (i.e., the probability of death if a bird does collide with a structure) and a range of estimates for avoidance rates to estimate the annual fatality that could be expected at the proposed met towers and wind turbines.
- Based on data from summer 2007, we estimate annual movement rates of ~983; ~3,660; ~3,365; ~6,046; ~7,629; ~4,278; and ~11,250 Hawaiian Petrels within 1.5 km of the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively.
- We estimated annual fatality rates for the proposed met tower associated with each site by assuming that 0%, 50%, 95%, or 99% of all Hawaiian Petrels flying near a proposed met tower or wind turbine will see and avoid the tower. Based on these scenarios, annual fatality rates for proposed met towers near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites would be 0.1–6.7, 0.3–25.0, 0.2–23.0, 0.4–41.3, 0.5–52.1, 0.3–29.2, and 0.8–76.8 Hawaiian Petrels/tower, respectively. Based on the same set of assumptions about possible avoidance rates, annual fatality rates for proposed wind turbines near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites are estimated to be 0.02–2.2, 0.1–8.2, 0.1–7.5, 0.1–13.5, 0.1–17.0, 0.1–9.5, and 0.2–25.1 Hawaiian Petrels/turbine, respectively. We caution, however, that these assumptions for avoidance rates are not based on empirical data and do not consider effects of potential deterrents (such as white flagging) that might reduce fatality rates.

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ACKNOWLEDGMENTS

The funding for this research came from Castle and Cooke LLC. At KC Environmental, we thank Charlie Fein for project management and Tom Kekona for help with logistics and the audio-visual sampling. At TetraTech EC, Charlie Karustis and Alicia Oller provided thoughtful questions and expertise on wind energy and George Redpath provided logistical assistance. At ABR, Todd Mabee provided field help and report review; Mike Davis, Adam Harris, and Hanna Mounce provided field help; Tom DeLong provided fiscal support; Susan Cooper, John Rose, John Shook, and Delee Spiesschaert helped with logistics; and Pam Odom produced the report.

INTRODUCTION

Castle and Cooke Resorts is interested in developing a windfarm in the western half of Lana'i Island, Hawaii (Fig. 1). As part of the siting and permitting process, Castle and Cooke wanted to obtain initial information on endangered seabirds and bats in the proposed development area. Ornithological radar and night-vision techniques have been shown to be successful in studying these species on Kaua'i (Cooper and Day 1995, 1998; Day and Cooper 1995, Day et al. 2003b), Maui (Cooper and Day 2003), Moloka'i (Day and Cooper 2002), and Hawai'i (Reynolds et al. 1997, Day et al. 2003a), so ABR was hired to survey seabirds and bats in the area with similar techniques. This report summarizes the results of a radar and audio-visual study of seabirds conducted during May–July 2007. The objectives of the study were to: (1) conduct surveys of endangered seabirds and bats in the vicinity of the proposed wind-resource area; and (2) obtain information to help assess use of the area by these species.

BACKGROUND

Two nocturnal seabird species occur on Lana'i Island: the endangered Hawaiian Petrel (*Pterodroma sandwichensis*), which nests there, and the threatened Newell's (Townsend's) Shearwater (*Puffinus auricularis newelli*), which appears to occur there in very small numbers but whose breeding status is unknown. The Hawaiian Petrel ('Ua'u) and the Newell's Shearwater ('A'o) are tropical Pacific seabirds that nest only on the Hawaiian Islands (American Ornithologists' Union 1998). Both species are Hawaiian endemics whose populations have declined significantly in historical times: they formerly nested widely over all of the Main Hawaiian Islands but now are restricted in most cases to scattered colonies in more inaccessible locations (Ainley et al. 1997b, Simons and Hodges 1998). The main exception is Kaua'i Island, which has no introduced Indian Mongooses (*Herpestes auropunctatus);* there, colonies are still widespread and populations are substantial in size, although Newell's Shearwaters have declined there substantially since the early 1990s (Day et al. 2003b). Because of their low overall population numbers and restricted breeding distributions, both of these species are protected under the Endangered Species Act.

The Hawaiian Petrel nests on most of the Main Islands but is known to nest primarily on Maui (Richardson and Woodside 1954, Banko 1980a; Simons 1984, 1985; Simons and Hodges 1998, Cooper and Day 2003), Kaua'i (Telfer et al. 1987, Gon 1988, Day and Cooper 1995; Ainley et al. 1997a, 1997b; Day et al. 2003b), and, to a lesser extent, Hawai'i (Banko 1980a, Conant 1980, Hu et al. 2001, Day et al. 2003a) and Lana'i (Shallenberger 1974; Hirai 1978a, 1978b; Conant 1980). Recent information from Moloka'i (Day and Cooper 2002) also suggests breeding. Probably several thousand Hawaiian Petrels occur on Kaua'i and Maui (Harrison et al. 1984, Harrison 1990, Day and Cooper 1995, Spear et al. 1995, Ainley et al. 1997a, Simons and Hodges 1998, Day et al. 2003b; Day and Cooper, unpubl. data), and the colony on Lana'i is now considered to be "large" (J. Penniman, State of Hawaii Department of Land and Natural Resources, Division of Fish and Wildlife [DOFAW], in litt. 15 June 2007), possibly being even larger than the colony on Maui.

The Newell's Shearwater breeds on several of the Main Islands, with the largest numbers clearly occurring on Kaua'i (Telfer et al. 1987, Day and Cooper 1995, Ainley et al. 1997b, Day et al. 2003b). These birds also nest on Hawai'i (Reynolds and Richotte 1997, Reynolds et al. 1997, Day et al. 2003a), almost certainly nest on Moloka'i (Pratt 1988, Day and Cooper 2002), probably nest on Maui (Cooper and Day 2003), and may still nest on O'ahu (Sincock and Swedberg 1969, Banko 1980b, Conant 1980, Pyle 1983; but see Ainley et al. 1997b). Although there have been a few recent records of Newell's Shearwaters on Lana'i, there is no evidence of nesting at this time (J. Penniman, DOFAW, pers. comm.). Several tens of thousands of Newell's Shearwaters are estimated to nest on Kaua'i (Harrison et al. 1984, Harrison 1990, Day and Cooper 1995, Spear et al. 1995, Ainley et al. 1997b, Simons and Hodges 1998, Day et al. 2003b; Day and Cooper, unpubl. data), which is the world center of abundance of this species. Finally, although Banko (1980a) listed no historical or recent records of this species on Lana'i, a downed Newell's Shearwater was found in Lana'i City on

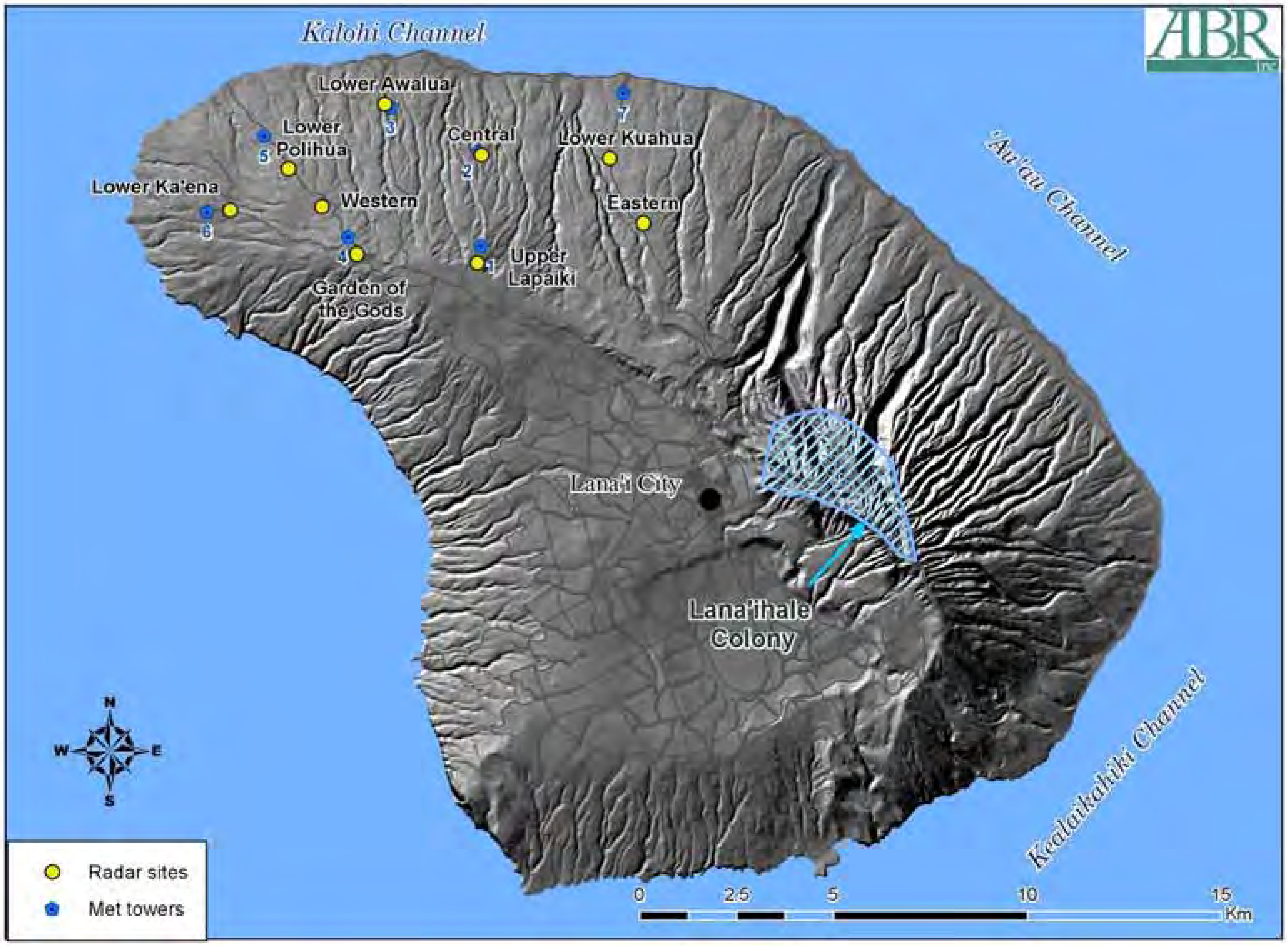

Figure 1. Location of radar-sampling sites and proposed met towers on Lana'i Island, Hawai'i, late spring and summer 2007. Information on the location of the nesting colony of Hawaiian Petrels is from J. Penniman (State of Hawaii DLNR, DOFAW, pers. comm..).

10 October 1983 (Pyle 1984a); the date of the record suggests that the bird was a juvenile. Because this city is located several kilometers inland, it is doubtful that the lights attracted this bird from the ocean; hence, it probably was produced on the island.

HISTORY OF HAWAIIAN PETRELS ON LANA'I

Hawaiian Petrels have been known on Lana'i for many years. Although Munro (1960) had stated that introduced pigs (*Sus scrofus*) and cats (*Felis catus*) had exterminated this species on Lana'i, a nesting population of Hawaiian Petrels still survives there. This island is the only Main Island other than Kauai that is mongoose-free, which may explain the long-term persistence of the species on Lana'i. Shallenberger (1974) reported a Hawaiian Petrel at ~820 m elevation above Kaiholena Gulch on Lana'ihale (the highest point on the island) on 26 October 1973; the bird was attracted to lights set up for insect collecting on a foggy night, suggesting from that fact and the date of the record that it may have been a juvenile.

A colony of ~100 Hawaiian Petrels was found at Kunoa Gulch, along the Munro Trail, on 23 June 1976; this colony was located at ~850 m elevation in the mountain forest (Hirai 1978a, 1978b) and was located just on the other side of the ridge from the Kaiholena Gulch mentioned above. Hirai (1978b) saw Hawaiian Petrels at this site again on 29 May 1977 and suggested that scattered Hawaiian Petrels heard calling at scattered locations along the Munro Trail in June 1976 might represent either adults flying to the one known nesting colony or scattered nesting attempts. Birds also were recorded on Lana'ihale in the summers of 1978 (Pyle 1978) and 1980 (Ralph and Pyle 1980), suggesting breeding.

One Hawaiian Petrel was found downed in the lights of Lana'i City on 5 November 1980 (Pyle and Ralph 1981), with the light-attraction and the date of the record suggesting that the bird was a juvenile; the authors indicated that this species is now "seen and heard by the hundreds each spring" in the mountains of Lana'i. A Hawaiian Petrel fledgling also was picked up at Lana'i City on 8 November 1986 (Pyle 1987); the author indicated that fledglings had been found at this location in previous years, perhaps referring to the 1980 record.

Hawaiian Petrels again were seen and heard in "good numbers" in the mountains of Lana'i in the summer of 1981, and an injured Hawaiian Petrel was found in the Palawai Basin on 19 May 1981 (Pyle and Ralph 1981). Observers also heard five pairs vocalizing and saw six single Hawaiian Petrels before dark at a probable nesting location at Lana'ihale on 24 June 1982 (Pyle 1982).

Hawaiian Petrels also were seen and heard near a small weather station at ~2,000 ft (~610 m) on Lana'ihale on 12 June 1983 (Pyle 1983). At least 50 Hawaiian Petrels were seen or heard near this station again on 26 May 1984; this count was considered low because observation conditions were so poor (Pyle 1984b).

Recent research on Lana'i has indicated that the population of Hawaiian Petrels there is large—probably being even larger than that on Maui (J. Penniman, DOFAW, *in litt*.). The belief is that the Lana'ihale colony was able to survive until protection of the nesting habitat, especially 'uluhe ferns (*Dicranopteris linearis*), from ungulates allowed regrowth of the habitat to a point where the colony could expand. That restoration of habitat appears to have allowed the colony to grow dramatically in the past 20 yr.

HAWAIIAN HOARY BATS

The Hawaiian Hoary Bat (*Lasiurus cinereus semotus*), or 'Ope'ape'a, is the only terrestrial mammal native to Hawaii. It is classified as endangered at both the federal and state levels, primarily because so little is known about its status and population trends. It is a nocturnal species that does not roost communally during the daytime; instead, it roosts solitarily within the forest. This bat occupies a wide variety of habitats, from sea level to >13,000 ft (Baldwin 1950, Fujioka and Gon 1988, Fullard 1989, David 2002). It also occurs on all of the Main Islands, including Lana'i (Baldwin 1950, van Riper and van Riper 1982, Tomich 1986, Fullard 1989, Kepler and Scott 1990, Hawaii Heritage Program 1991, David 2002).

Recent data from Appalachian ridge tops in the eastern US (Erickson 2004, Kerns 2004) have indicated that substantial kills of bats, including Hoary Bats, sometimes occur at windpower projects. Most of the bat fatalities documented at windfarms to date have been of migratory species during seasonal periods of dispersal and migration in late summer and fall. Several hypotheses have been posited, but none have been tested, to explain the cause(s) of these fatalities (Arnett 2005, Kunz et al. 2007). Because of this recent mortality of migratory Hoary Bats at windfarms on the US mainland, there was interest in collecting preliminary visual data on Hawaiian Hoary Bats during this study, even though the Hawaiian subspecies is non-migratory.

STUDY AREA

The proposed windfarm is located in the western half of Lana'i (Fig. 1). This proposed windfarm would include seven 50-m-high meteorological (met) towers (Fig. 1). Each tower would be anchored by six guy wires in each of four directions. All guy wires would be marked with an alternating array of spiral vibration dampers and strips of reflective tape at ~5-m intervals. Each of the ~270 proposed Vestas V90 wind turbines would have a generating capacity of ~1.5 MW, for a total installed capacity of ~400 MW. The currently proposed monopole towers would be ~80 m in height, and each turbine would have three rotor blades. The length of each rotor blade and hub would be ~45 m, thus, the total maximal height of a proposed turbine would be ~125 m at the top of the rotor-swept area.

The Island of Lana'i was formed by a single volcano. The highest point of the island, Lana'ihale, is 3,370 ft (1,027 m) above sea level (asl) and receives ~30–35 in (~75–90 cm) of annual precipitation (Carlquist 1980). There is a large colony of Hawaiian Petrels on the ridge encompassing Lana'ihale (Fig. 1), and native vegetation such as 'ohia trees (*Metrosideros polymorpha*) and 'uluhe ferns dominate the valleys and slopes of Lana'ihale. These two plant species also form the preferred nesting habitat for Newell's Shearwaters (Sincock and Swedberg 1969, Ainley et al. 1997b). In addition to the vegetation, the steepness of the slopes surrounding Lana'ihale suggests suitable nesting habitat in the area for both petrels and shearwaters (Hirai 1978b), as it does on Kaua'i (T. Telfer, DOFAW [retired] pers. comm.) and Maui (Brandt et al. 1995).

In contrast to the top of Lana'ihale, the Wind Resource Area (WRA) in the western half of Lana'i is lower and drier and does not contain any known petrel colonies. Elevations in the WRA range from sea level to ~1,600 ft (~500 m) asl, and the area receives only ~10–20 in (~25–50 cm) of annual precipitation (Carlquist 1980). For many years, the area was used as a cattle ranch and pineapple plantation. The proposed WRA is situated in a highly-eroded area of sloping scrubland, barren areas, and grasslands. The dominant "shrubs" in the area include the non-native kiawe (*Prosopis pallida*), verbena (*Lantana camara*), bull thistle (*Circium vulgare*), and 'ilima (*Sida fallax*; Redpath 2007). The open grasslands include alien invasive species such as buffel grass (*Cenchrus ciliaris*) and native grass species such as pili grass (*Heteropogon contortus*). At the lowest elevations along the coast, kiawe is prevalent and grows to ~5 m in height.

METHODS

DATA COLLECTION

We collected data on the movements, behavior, and flight altitudes of Hawaiian Petrels at nine sites total on Lana'i Island in 2007 (Fig. 1): at 3 sites during 15 nights of sampling in late May–early June ("late spring" sampling period) and at 7 sites, including 1 site that was sampled during the late-spring period, during 35 nights of sampling in late June–early July ("summer" sampling period; Tables 1 and 2). We sampled with ornithological radar and visual equipment for 3 h in the evening and ~2 h in the morning; these two periods correspond to the evening and morning peaks of movement of these birds (Day and Cooper 1995). During sampling, we collected radar and audio-visual data concurrently so that we could use the radar to help the visual observer locate birds for identification and data collection. In return, the visual observer provided information to the radar operator on the identity and flight altitude of individual targets (whenever possible). For the purpose of recording data, a calendar day began at 0700 and ended at 0659 the following morning; that way, an evening and the following morning were classified as occurring on the same day.

Table 1. Radar and audio-visual sampling effort on Lana'i Island, Hawai'i, late spring 2007.

		Sampling type	
Date	Study site	Radar	Audio-visual
26 May	Western	1900–2200; 0400–0630	1900–2200; 0400–0630
27 May	Eastern	1900–2200; 0400–0630	1900–2200; 0400–0630
28 May	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
29 May	Western	1900–2200; 0400–0600	1900–2200; 0400–0600
30 May	Eastern	1900–2200; 0400–0600	1900–2200; 0400–0600
31 May	Central	1900–2200[1]; 0400–0600	1900–2200; 0400–0600
1 June	Western	1900–2200; 0400–0600	1900–2200; 0400–0600
2 June	Eastern	1900–2200; 0400–0600	1900–2200; 0400–0600
3 June	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
4 June	Western	1900–2200[2]; 0400–0600	1900–2200; 0400–0600
5 June	Eastern	1900–2200; 0400–0600	1900–2200; 0400–0600
6 June	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
7 June	Western	1900–2200; 0400–0600	1900–2200; 0400–0600
8 June	Eastern	1900–2200; 0400–0600	1900–2200; 0400–0600
9 June	Central	1900–2200; 0400–0600	1900–2200; 0400–0600

[1] One radar session cancelled because of equipment problems.
[2] Parts of two radar sessions cancelled because of rain.

The ornithological radars used in this study were Furuno Model 1510 X-band radars transmitting at 9.410 GHz through a slotted wave guide with a peak power output of 12 kW; a similar radar unit is described in Cooper et al. (1991). Each radar's antenna face was tilted upward by ~10–15°, and we operated the radars at a range setting of 1.5 km and a pulse-length of 0.07 μsec.

Radar operators had to deal with two issues at each site: ground clutter and shadow zones. Whenever energy is reflected from the ground, surrounding vegetation, and other objects that surround the radar unit, a ground-clutter echo appears on the radar's display screen. Because ground clutter can obscure targets of interest (e.g., birds and bats), we attempted to minimize it by picking optimal sampling locations. Ground clutter was minor at all nine sites and, in our opinion, did not cause us to miss any targets. Shadow zones are areas of the screen where birds were likely to be flying at an altitude that would put them behind a hill, row of vegetation, etc., where they could not be detected. Shadow zones at all sampling sites were minimal; however, because of the unusually low flight altitudes of petrels in this area (see below), it is likely that some birds flew within these zones, especially those toward the edge of the radar screen, and thus were not detected by radar.

We sampled for six 25-min counts during the period 1900–2200 and for four 25-min counts during the period 0400–0600 (Tables 1 and 2). Each 25-min sampling period was separated by a 5-min break for collecting weather data and for switching observers. We attempted to collect data only for petrel-like targets, following methods developed by Day and Cooper (1995). Thus, to help eliminate species other than those of interest (e.g., slowly-flying birds, insects), we recorded data only for those targets flying ≥30 mi/h (≥50 km/h; corrected in real-time for wind speed and direction, per methods described below) and removed otherwise-countable targets (based on target velocity and flight characteristics) identified by visual observers as those of other bird species.

We also conducted audio-visual sampling for birds and bats concurrently with the radar sampling, to help identify targets observed on radar and to obtain flight-altitude information. During

Table 2. Radar and audio-visual sampling effort on Lana'i Island, Hawai'i, summer 2007.

		Sampling type	
Date	Study site	Radar	Audio-visual
21 June	Lower Kuahua	1900–2200; 0400–0630	1900–2200; 0400–0600
22 June	Lower Ka'ena	1900–2200; 0400–0630	1900–2200; 0400–0600
	Upper Lapaiki	1900–2200; 0400–0600	1900–2200; 0400–0600
23 June	Lower Awalua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Garden of the Gods	1900–2200; 0400–0600	1900–2200; 0400–0600
24 June	Lower Polihua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
25 June	Lower Kuahua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Lower Ka'ena	1900–2200; 0400–0600	1900–2200; 0400–0600
26 June	Upper Lapaiki	1900–2200; 0400–0600	1900–2200; 0400–0600
	Garden of the Gods	1900–2200; 0400–0600	1900–2200[1]; 0400–0600[1]
27 June	Lower Awalua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
28 June	Lower Polihua	1900–2200; 0400–0630	1900–2200; 0400–0600
	Lower Kuahua	1900–2200; 0400–0630	1900–2200; 0400–0600
29 June	Lower Ka'ena	1900–2200; 0400–0600	1900–2200; 0400–0600
	Upper Lapaiki	1900–2200; 0400–0600	1900–2200; 0400–0600
30 June	Garden of the Gods	1900–2200; 0400–0600	1900–2200; 0400–0600
	Lower Awalua	1900–2200; 0400–0600	1900–2200; 0400–0600
1 July	Central	1900–2200; 0330–0600	1900–2200; 0400–0600
	Lower Polihua	1900–2200; 0400–0600	1900–2200; 0400–0600
2 July	Lower Kuahua	1900–2200; 0330–0600	1900–2200; 0400–0600
	Lower Ka'ena	1900–2200; 0400–0600	1900–2200; 0400–0600
3 July	Garden of the Gods	1900–2200[1]; 0400–0600	1900–2200; 0400–0600
	Upper Lapaiki	1900–2200[1]; 0400–0600[1]	1900–2200[1]; 0400–0600[1]
4 July	Central	1900–2200; 0330–0600	1900–2200; 0400–0600
	Lower Awalua	1900–2200; 0400–0630	1900–2200; 0400–0600
5 July	Lower Kuahua	1900–2200; 0330–0630	1900–2200; 0400–0600
	Lower Polihua	1900–2200; 0400–0600	1900–2200; 0400–0600
6 July	Upper Lapaiki	1900–2200; 0400–0600	1900–2200; 0400–0600
	Lower Ka'ena	1900–2200; 0400–0600	1900–2200; 0400–0600
7 July	Lower Awalua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Garden of the Gods	1900–2200; 0400–0600	1900–2200; 0400–0600
8 July	Lower Polihua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Central	1900–2200; 0330–0600	1900–2200; 0400–0600

[1] One or more sessions cancelled because of rain or other factors.

this sampling, we used 10× binoculars during crepuscular periods and used PVS-7 night-vision goggles during nocturnal periods to look for targets that were detected on the radar. The magnification of these Generation 3 goggles was 1×, and their performance was enhanced with the use of a 3-million-Cp floodlight that was fitted with an IR filter to avoid blinding and/or attracting these nocturnal birds. During our audio-visual sampling, we also used a Pettersson D-100 heterodyne bat detector to conduct acoustic surveys for bats. During acoustic sampling, we set the bat detector to detect calls in the peak range for Hawaiian Hoary Bats (25–30 KHz) and recorded the number of calls heard during each 25-min session. The bat detector was placed ~0.5 m above ground level and was oriented vertically, so that it sampled the airspace directly overhead.

During the summer study period, we also conducted acoustic surveys to investigate the possibility that some petrels could be nesting away from the main colony and within the WRA. On 15 nights between 22 June and 8 July, one observer (T. Kekona, KC Environmental, Makawao, HI) listened at specific locations along all roads within the proposed WRA for vocalizations typically heard in petrel breeding areas. Survey points were established every ~0.5 mi (~0.8 km) along each of eight roads, resulting in 50 total sampling points. Acoustic surveys were conducted between 1930 and 2300, during which time the observer listened for 10 min at each of as many points as possible along one or more road transects. Each point was visited 2–3 times during the study, with the sampling order of points along each road changed between visits. A hand-held digital audio recorder with a customized hand-held microphone and adjustable pre-amp (built by Bill Evans, Old Bird, Inc., Ithaca, NY) was used to record potential petrel vocalizations. The microphone was designed to eliminate wind noise (<3 KHz), and the pre-amp both allowed the sensitivity of the microphone to be modified to maximize the detection of petrel calls and boosted the signal sent to the audio recorder.

Before each 25-min sampling session, we also collected a series of environmental and weather data, including wind speed (to the nearest 1 mi/h [1.6 km/h]) and wind direction (to the nearest 1°). If the wind speed was >10 mi/h (>16 km/h) and the ground speed of the target was near the 30-mi/h cutoff speed and in such a direction that the target was encountering either a headwind or tailwind, we factored in wind speed to help determine whether those marginal targets made the 30-mi/h cutoff for a petrel target. Following Mabee et al. (2006), airspeeds (i.e., groundspeed corrected for wind speed and relative direction) of surveillance-radar targets were computed with the formula:

$$V_a = \sqrt{V_g^{\,2} + V_w^{\,2} - 2V_g V_w \cos\theta},$$

where V_a = airspeed, V_g = target groundspeed (as determined from the radar flight track), V_w = wind velocity, and θ is the angular difference between the observed flight direction and the direction of the wind vector.

In addition to wind speed and wind direction, we recorded the following standardized weather and environmental data:

- percent cloud cover (to the nearest 5%);
- cloud ceiling height, in meters above ground level (agl; in several height categories);
- visibility (maximal distance we could see, in categories);
- light condition (daylight, crepuscular, or nocturnal, and with or without precipitation)
- precipitation type; and
- moon phase/position (lunar phase and whether the moon was above or below the horizon in the night sky).
- For each appropriate radar target, we recorded a large suite of data:
- species (if known);
- number of organisms (if known);
- time;
- direction of flight (to the nearest 1°);
- transect crossed (the four cardinal points—000°, 090°, 180°, or 270°; also used in reconstructing flight paths);

- tangential range (the minimal distance to the target when it passed closest to the lab; used in reconstructing actual flight paths, if necessary);
- flight behavior (straight, erratic, circling);
- velocity (to the nearest 5 mi/h [8 km/h]); and
- flight altitude (if known).

We also plotted the flight path of each bird target on a transparent overlay of the radar screen for later digitizing into a GIS.

For each bird (or bat) seen during night-vision sampling, we recorded:

- time;
- species (to the lowest practical taxonomic unit [e.g., Hawaiian Petrel, unidentified petrel/shearwater]);
- number of organisms in the target;
- flight direction (the eight ordinal points); and
- flight altitude (meters agl).

For any birds detected during auditory sampling, we recorded species, number of call bouts, direction of call, and approximate distance.

DATA ANALYSIS

We entered all radar and audio-visual data into Microsoft Excel databases. Data files were checked visually for errors after each night's sampling, then were checked electronically for irregularities at the end of the field season, prior to data analyses. All data summaries and analyses were conducted with SPSS 14.0 statistical software (SPSS 2005). For quality assurance, we cross-checked results of the SPSS analyses with hand-tabulations of small subsets of data whenever possible.

We tabulated counts of numbers of targets recorded during each sampling session, then converted those counts to estimates of movement rates of birds (radar targets/h), based on the number of minutes sampled; some sampling time was lost to rain or other factors, so we had to standardize estimates by actual sampling effort. To calculate movement rates, we divided the number of targets recorded during a sampling session by the number of minutes actually sampled during that session, then multiplied that number (expressed as targets/min) by 60 min/h to estimate the movement rate (targets/h) for that session. We then used all of the estimated movement rates across sampling sessions at a site to calculate the mean ± 1 standard error (SE) nightly movement rate by site, by time period (evening, morning), and by flight direction (landward, seaward). Note that data from 0530 to 0600 were excluded from all analyses for the late spring study because of severe contamination of the radar data from non-petrel species such as Common Mynas (*Acridotheres tristis*). Further, only known petrel/shearwater targets or unknown targets with appropriate speeds (i.e., with appropriate target size, flight characteristics, and groundspeeds ≥30 mi/h) were included in data analyses of movement rates, flight directions, and flight behavior; all other species were excluded from those analyses.

We calculated the mean flight direction for all targets seen on radar. We also classified general flight directions of each radar target as inland, seaward, or "other" and summarized those directional categories by site, date, and time of day. To categorize the general flight direction of each target, we defined a landward flight as a radar target flying toward the Lana'ihale petrel colony and within 75° of either side of the approximate outer boundaries of that colony (Table 3). Targets flying in the opposite directions were considered seaward targets (again, with a 75° buffer). For each site, the few remaining flight vectors that were somewhat perpendicular to the direction to the colony were classified as landward or seaward based on their direction relative to the coastline.

We summarized the audio-visual data in terms of species, number, and flight direction. We also tabulated data on minimal flight altitudes of petrels recorded during the visual sampling and used those data for the vertical component in our fatality models (see below).

EXPOSURE AND FATALITY INDICES

To describe potential risk to Hawaiian Petrels within the area potentially occupied by the proposed met towers or wind turbines, we developed Exposure Indices (estimated number of times that a petrel would pass within the airspace

Table 3. Information on met tower covered, time period sampled, and criteria for landward and seaward categories of petrel flight directions at each site, Lana'i Island, Hawai'i, during late spring (LS) and summer (S) 2007.

Site	Met tower(s) covered	Sampling period[1]	Flight direction: Landward	Flight direction: Seaward
Lower Ka'ena	6, 8	S	015–194°	195–014°
Lower Polihua	5	S	045–224°	225–044°
Western	4	LS	045–224°	225–044°
Garden of the Gods	4	S	020–199°	200–019°
Lower Awalua	3	S	050–229°	230–049°
Central	2	LS; S	050–229°	230–049°
Upper Lapaiki	1	S	030–209°	210–029°
Lower Kuahua	7	S	070–249°	250–069°
Eastern	none	LS	055–234°	235–054°

[1] MY–JN = late spring (LS); JN–JL = summer (S).

occupied by the proposed met towers and their guy wires or pass by the proposed wind turbines each night). The Exposure Index for proposed met towers is equal to the number of target/km expected to be flying at or below met-tower height (i.e., ≤50 m agl) each night; this index is calculated by multiplying movement rates from surveillance radar by the percentage of seabirds with flight altitudes ≤50 m agl (maximal height of the proposed met towers). The Exposure Index for proposed wind turbines is more complex and comprises (1) the number of target/km flying at or below turbine height (i.e., ≤125 m agl) each night (calculated by multiplying movement rates from surveillance radar by the percentage of petrels with flight altitudes ≤125 agl [maximal height of the rotor-swept area]); and (2) the turbine area that petrels would encounter when approaching turbines from the side (parallel to the plane of rotation) or from the front (perpendicular to the plane of rotation).

We consider these estimates to be indices because they are based on several simplifying assumptions. The assumptions for this specific project include: (1) a worst-case scenario that the entire met-tower area encompassed by the outermost guy wires is solid, so there is no way that a petrel could fly through it without hitting a wire or pole; (2) a similar worst-case scenario for wind turbines, with the entire disk created by the rotor-swept area assumed to be a solid; (3) that there are minimal (i.e., side profile) and maximal (i.e., front profile, including the entire rotor-swept area) areas occupied by the proposed wind turbines relative to the flight directions of petrels; and (4) a worst-case scenario in which the rotor blades turn constantly (i.e., we used the entire rotor-swept area, not just the area of the blades themselves, to help calculate total turbine area). Note that our Exposure Indices estimate how many times petrels would be exposed to proposed met towers or turbines, not the number of birds that would actually collide with met towers or turbines: some unknown proportion of petrels would detect and avoid these structures, and, in the case of wind turbines, some could pass through the blades without collision. In addition, the Exposure Index calculates the number of exposure incidents, not the number of individuals—i.e., the index takes into account the fact that a single individual could be exposed to towers or turbines multiple times while crossing the WRA.

The Exposure Index is used to estimate daily numbers of birds flying within the airspace occupied by turbines or the proposed met towers and their guy wires. To calculate a Fatality Index, we expand those estimates for a 270-d year that birds are present on this island (late March through late December; J. Penniman, DOFAW, pers. comm.) and, hence, will be exposed to the proposed met towers and wind turbines. The fatality model then combines these estimates of interaction rates with the fatality probability to estimate fatality rates under a worst-case scenario of no collision avoidance (Fig. 2). Finally, it presents possible levels of fatality based on possible levels of collision avoidance by these birds.

RESULTS

RADAR-BASED OBSERVATIONS

MOVEMENT RATES

We recorded 170 targets that fit our criteria for petrels and shearwaters during the 15 nights of sampling in late spring 2007. Of those targets, we recorded 37 at the Western site, 73 at the Central site, and 60 at the Eastern site (Table 4). This pattern of fewer targets in the western portion of the study area also was seen in summer 2007: out of 427 probable petrel targets, we recorded 11 at Lower Ka'ena, 42 at Lower Polihua, 43 at Garden of the Gods (all in the western WRA), 70 at Lower Awalua, 83 at Central, 50 at Upper Lapaiki (all in the central WRA), and 128 at Lower Kuahua (in the eastern WRA; Table 5). Movement rates also reflected this pattern of fewer petrel targets in the western portion of the study area and more in the eastern portion of it, in both the evening and the morning (Figs. 3 and 4).

In late spring, mean movement rates of landward-flying targets ranged from 0.24–1.96 targets/h in the evening to 0 targets/h during the morning, whereas seaward rates ranged from 1.92–3.48 targets/h in the evening to 0.96–3.68 targets/h in the morning (Table 6). In summer, mean movement rates of landward-flying targets ranged from 0.0–3.56 targets/h in the evening to 0.0–0.12 targets/h during the morning, whereas seaward rates ranged from 0.48–3.56 targets/h in the evening to 0.60–4.92 targets/h in the morning. We sampled only one location (Central) in both late spring and summer; movement rates at that site were fairly similar between the two periods.

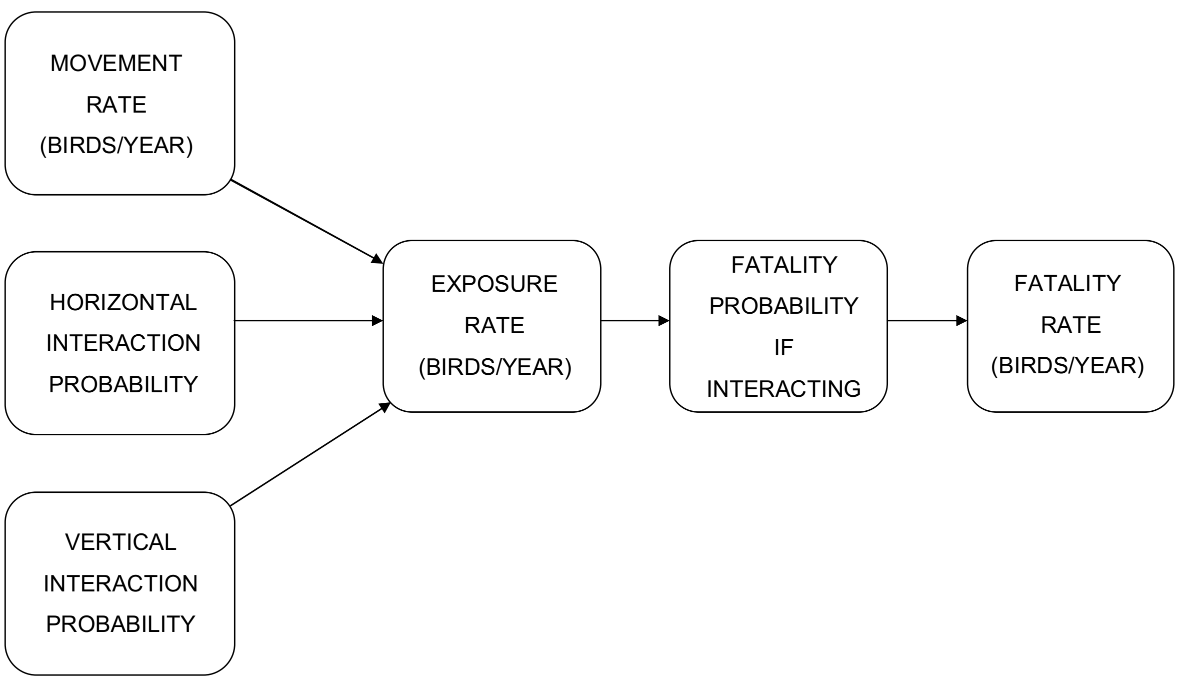

Figure 2. Major variables used in estimating possible fatality of Hawaiian Petrels at proposed met towers and wind turbines on Lana'i Island, Hawai'i. See Tables 13 and 14 for details on calculations.

Table 4. Number of probable Hawaiian Petrel targets observed on surveillance radar at Lana’i Island, Hawai’i, in late spring 2007, by study site, date, time of day, and flight direction. *n* = number of sampling sessions.

		Evening (1900–2200)		Morning (0400–0530)	
Site	Date	Landward (*n*)	Seaward (*n*)	Landward (*n*)	Seaward (*n*)
Western	26 May	1 (6)	4 (6)	0 (3)	3 (3)
	29 May	0 (6)	0 (6)	0 (3)	1 (3)
	1 June	0 (6)	3 (6)	0 (3)	1 (3)
	4 June	0 (6)	1 (6)	0 (3)	3 (3)
	7 June	2 (6)	16 (6)	0 (3)	2 (3)
	Total	3 (30)	24 (30)	0 (15)	10 (15)
Central	28 May	0 (6)	4 (6)	0 (3)	1 (3)
	31 May	1 (5)	4 (5)	0 (3)	2 (3)
	3 June	0 (6)	4 (6)	0 (3)	4 (3)
	6 June	5 (6)	13 (6)	0 (3)	10 (3)
	9 June	2 (6)	17 (6)	0 (3)	6 (3)
	Total	8 (29)	42 (29)	0 (15)	23 (15)
Eastern	27 May	4 (6)	2 (6)	0 (3)	1 (3)
	30 May	11 (6)	7 (6)	0 (3)	1 (3)
	2 June	1 (6)	5 (6)	0 (3)	1 (3)
	5 June	2 (6)	4 (6)	0 (3)	0 (3)
	8 June	6 (6)	14 (6)	0 (3)	3 (3)
	Total	24 (30)	32 (30)	0 (15)	6 (15)

At all sites, times of the day, and sampling periods, mean seaward movement rates always were higher than landward rates were (Table 6). The one exception was at Lower Kuahua, where evening movement rates in summer were identical between landward and seaward targets. In addition, landward rates in the evening always were equal to or greater than landward rates in the morning, and morning rates usually were 0 targets/h. In contrast, seaward rates did not show a consistent difference between evening and morning. It appears, however, that the only sites at which evening rates of seaward-flying targets were higher (Garden of the Gods and Upper Lapaiki) were the two farthest-inland sites, both of which were located along the east–west spine of the island (Fig. 1).

FLIGHT DIRECTION

The flight-direction data also reflected the pattern of higher seaward counts than landward counts. In spring 2007, most probable petrel targets were flying toward the west or northwest (i.e., away from the Lana’ihale colony) in both the evening (Fig. 5) and the morning (Fig. 6). At the Western site, however, an appreciable number also were heading toward the southwest in the evening.

The flight-direction pattern seen in summer 2007 was similar to that seen in late spring 2007: most probable petrel targets were heading toward the west or northwest, away from the colony, in both the evening and the morning (Figs. 7 and 8). In addition, targets were seen heading toward the colony only in the evening. However, the only site at which a substantial number of evening targets was heading southeasterly, toward the colony, was at Lower Kuahua, which was that site located closest to the colony (Fig. 7). In addition, a substantial number of targets at the Upper Lapaiki site were heading in a southerly direction.

We were able to collect flight-path data on a subset of 11 targets that were seen concurrently by the radar and verified as a petrel by audio-visual

Table 5. Number of probable Hawaiian Petrels observed on surveillance radar at Lana'i Island, Hawai'i, in summer 2007, by study site, date, time of day, and flight direction. *n* = number of sampling sessions.

		Time of day			
		Evening (1900–2200)		Morning (0400–0600)	
Site	Date	Landward (*n*)	Seaward (*n*)	Landward (*n*)	Seaward (*n*)
Lower Ka'ena	22 June	0 (6)	1 (6)	0 (4)	3 (4)
	25 June	0 (6)	0 (6)	0 (4)	0 (4)
	29 June	0 (6)	2 (6)	0 (4)	1 (4)
	2 July	0 (6)	1 (6)	0 (4)	1 (4)
	6 July	0 (6)	2 (6)	0 (4)	0 (4)
	Total	0 (30)	6 (30)	0 (20)	5 (20)
Lower Polihua	24 June	1 (6)	0 (6)	0 (4)	4 (4)
	28 June	0 (6)	1 (6)	0 (4)	0 (4)
	1 July	1 (6)	1 (6)	0 (4)	3 (4)
	5 July	2 (6)	6 (6)	0 (4)	1 (4)
	8 July	2 (6)	12 (6)	0 (4)	8 (4)
	Total	6 (30)	20 (30)	0 (20)	16 (20)
Garden of Gods	23 June	0 (6)	9 (6)	0 (4)	4 (4)
	26 June	0 (6)	9 (6)	0 (4)	3 (4)
	30 June	1 (6)	3 (6)	0 (4)	2 (4)
	3 July	0 (5)	8 (5)	0 (4)	0 (4)
	7 July	0 (6)	4 (6)	0 (4)	0 (4)
	Total	1 (29)	33 (29)	0 (20)	9 (20)
Lower Awalua	23 June	1 (6)	5 (6)	0 (4)	5 (4)
	27 June	0 (6)	6 (6)	1 (4)	2 (4)
	30 June	3 (6)	10 (6)	0 (4)	4 (4)
	4 July	1 (6)	9 (6)	0 (4)	5 (4)
	7 July	1 (6)	6 (6)	0 (4)	11 (4)
	Total	6 (30)	36 (30)	1 (20)	27 (20)
Central	24 June	4 (6)	10 (6)	0 (4)	9 (4)
	27 June	0 (6)	4 (6)	0 (4)	3 (4)
	1 July	2 (6)	5 (6)	0 (4)	7 (4)
	4 July	2 (6)	8 (6)	0 (4)	10 (4)
	8 July	1 (6)	8 (6)	0 (4)	11 (4)
	Total	9 (30)	35 (30)	0 (20)	40 (20)
Upper Lapaiki	22 June	2 (6)	5 (6)	0 (4)	4 (4)
	26 June	2 (6)	1 (6)	0 (4)	3 (4)
	29 June	4 (6)	5 (6)	0 (4)	2 (4)
	3 July	1 (5)	3 (5)	0 (2)	0 (2)
	6 July	5 (6)	11 (6)	0 (4)	2 (4)
	Total	14 (29)	25 (29)	0 (18)	11 (18)
Lower Kuahua	21 June	11 (6)	5 (6)	1 (4)	6 (4)
	25 June	2 (6)	8 (6)	0 (4)	7 (4)
	28 June	0 (6)	2 (6)	0 (4)	0 (4)
	2 July	13 (6)	12 (6)	0 (4)	17 (4)
	5 July	17 (6)	16 (6)	0 (4)	11 (4)
	Total	43 (30)	43 (30)	1 (20)	41 (20)

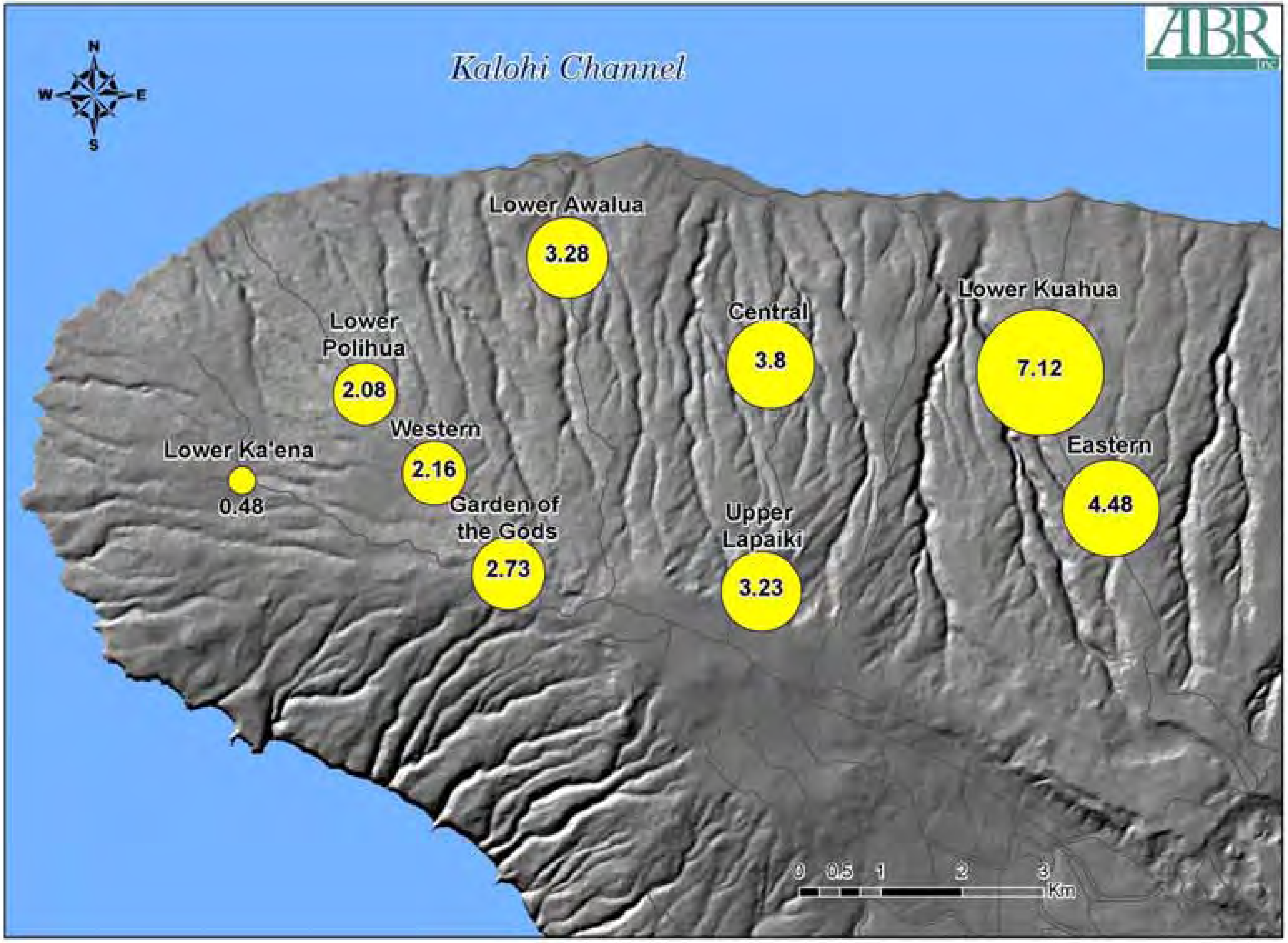

Figure 3. Geographic variation in mean movement rates (targets/h) of all probable Hawaiian Petrel targets observed during evening radar sampling at each site on Lana'i Island, Hawai'i, late spring and summer 2007. Sizes of circles are proportional to mean movement rate; numbers in/near circles are actual mean rates.

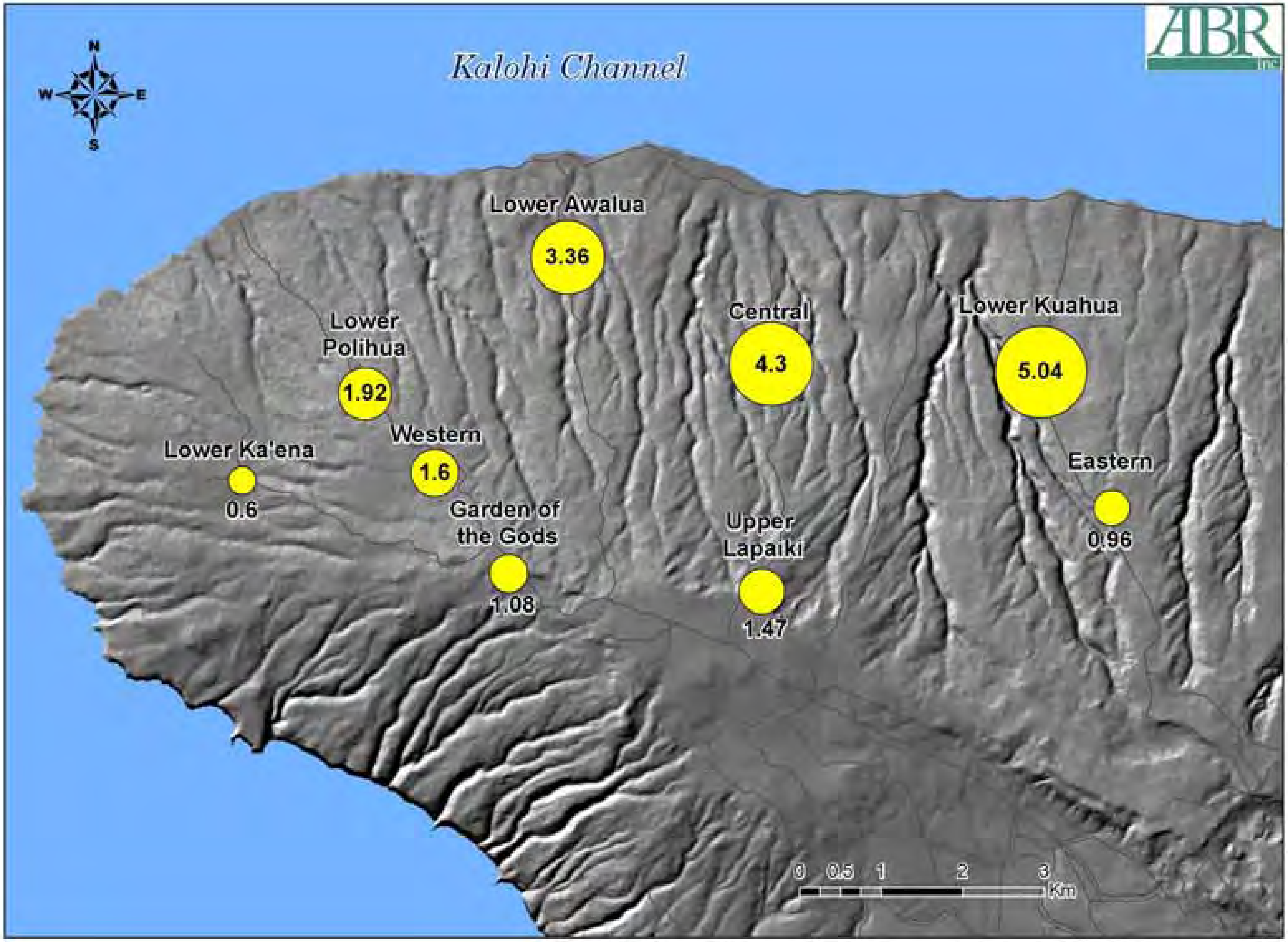

Figure 4. Geographic variation in mean movement rates (targets/h) of all probable Hawaiian Petrel targets observed during morning radar sampling at each site on Lana'i Island, Hawai'i, late spring and summer 2007. Sizes of circles are proportional to mean movement rate; numbers in/near circles are actual mean rates.

Table 6. Mean movement rates and mean counts of probable Hawaiian Petrel targets observed on surveillance radar at Lana'i Island, Hawai'i, late spring and summer 2007, by study site, time of day, and flight direction.

Sampling		Movement rate (targets/h)		Number of targets[1]	
period/site	Time of day	Landward	Seaward	Landward	Seaward
LATE SPRING					
Western	Evening	0.24	1.92	0.72	5.76
	Morning	0.00	1.60	0.00	4.80
Central	Evening	0.66	3.48	1.98	10.44
	Morning	0.00	3.68	0.00	11.04
Eastern	Evening	1.92	2.56	5.76	7.68
	Morning	0.00	0.96	0.00	2.88
SUMMER					
Lower Ka'ena	Evening	0.00	0.48	0.00	1.44
	Morning	0.00	0.60	0.00	1.80
Lower Polihua	Evening	0.48	1.60	1.44	4.80
	Morning	0.00	1.92	0.00	5.76
Garden of Gods	Evening	0.08	2.65	0.24	7.95
	Morning	0.00	1.08	0.00	3.24
Lower Awalua	Evening	0.48	2.80	1.44	8.40
	Morning	0.12	3.24	0.36	9.72
Central	Evening	0.72	2.72	2.16	8.16
	Morning	0.00	4.83	0.00	14.49
Upper Lapaiki	Evening	1.16	2.07	3.48	6.21
	Morning	0.00	1.47	0.00	4.41
Lower Kuahua	Evening	3.56	3.56	10.68	10.68
	Morning	0.12	4.92	0.36	14.76

[1]Number = movement rate * 3 to calculate the number of targets moving during the evening and morning peaks of activity.

observers (Fig. 9). That subset of visual and radar data also had a high proportion of petrels flying toward the colony, with some birds also flying away from the colony.

TIMING OF MOVEMENTS

The timing of landward movement of probable petrel targets was typical of that observed for petrels and shearwaters, with a peak in evening numbers during ~1930–2030 and very little movement in the morning during 0400–0600 (Fig. 10).The timing of the movement of seaward-flying targets however, was very different from the typical pattern, with targets moving at all hours of the night. In addition, movement rates during the final two hours of the evening and throughout the entire morning were high. In fact, seaward rates in the morning were high during even the first morning sampling session (0400–0430), which usually has little movement on other islands (Day and Cooper, unpubl. data).

BEHAVIOR

Most targets observed on radar were flying in a straight-line (directional) pattern, rather than with an erratic or circling behavior. For all sites, times, and sampling periods combined, 88.4% of flights were straight-line directional flights, 11.5% were erratic, and 0.2% were circling.

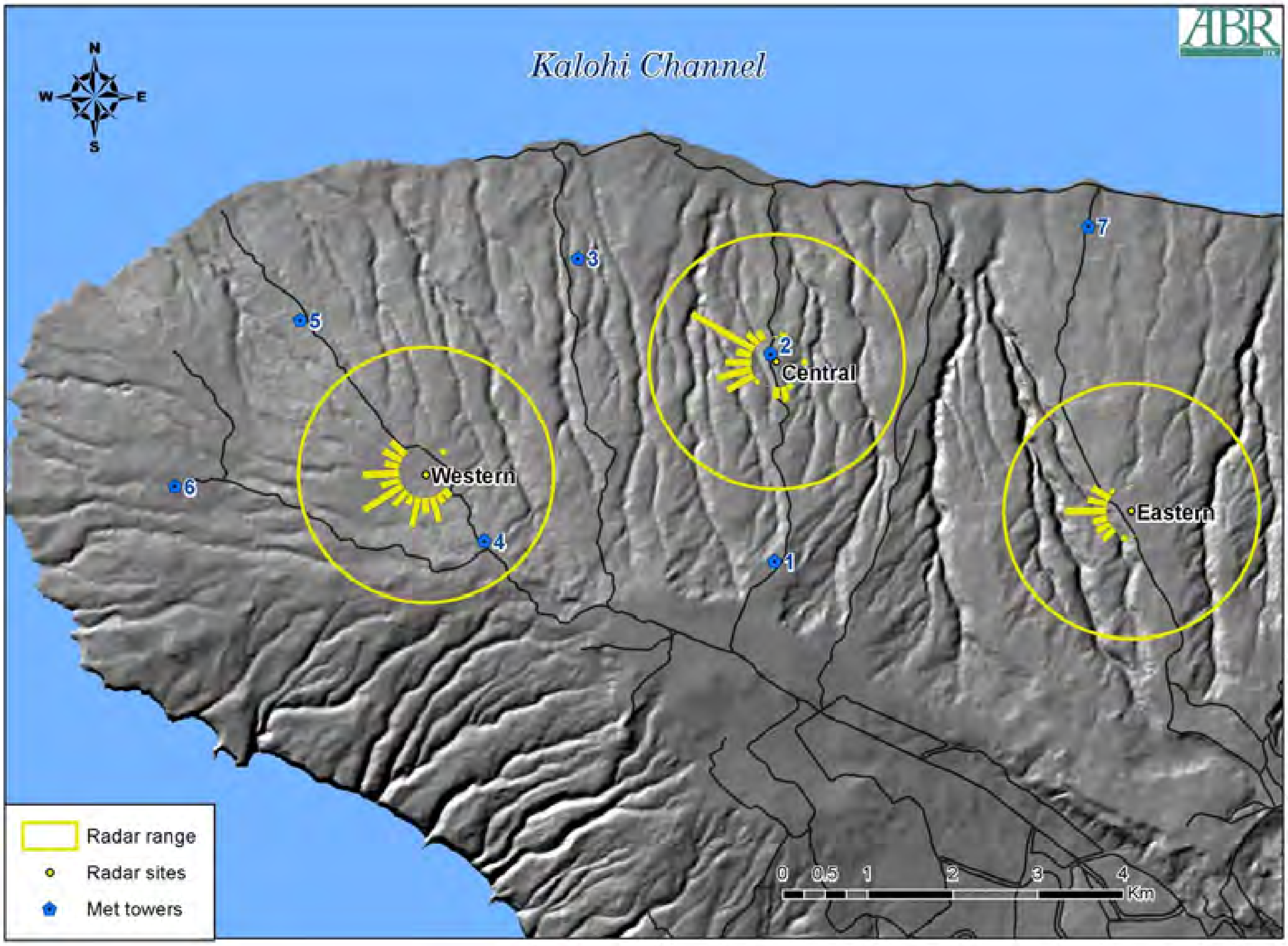

Figure 5. Flight directions of probable Hawaiian Petrel targets observed at each site during evening radar sampling on Lana'i Island, Hawai'i, late spring 2007. Length of spoke is proportional to the number of birds traveling in that direction.

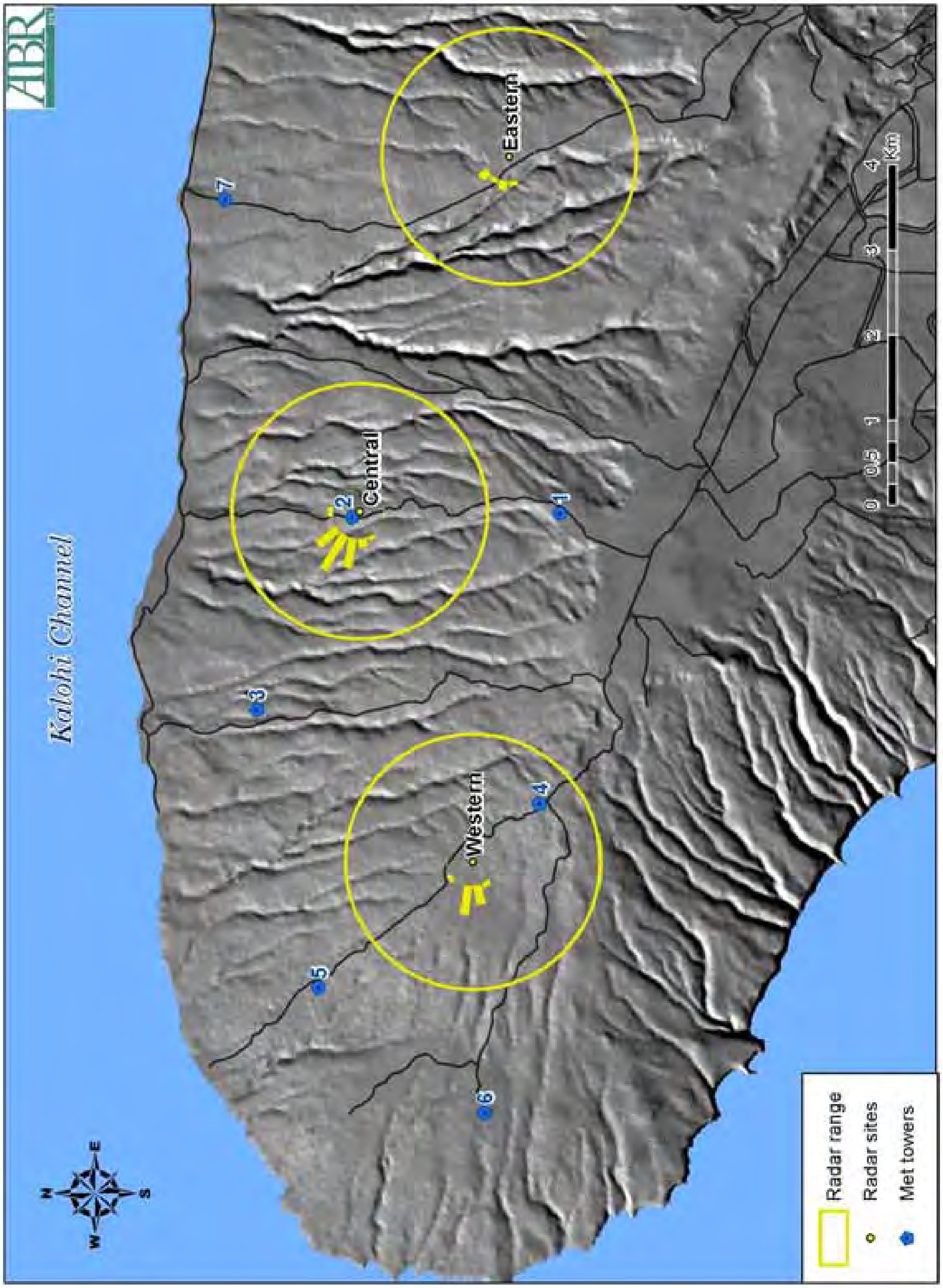

Figure 6. Flight directions of probable Hawaiian Petrel targets observed at each site during morning radar sampling on Lana'i Island, Hawai'i, late spring 2007. Length of spoke is proportional to the number of birds traveling in that direction.

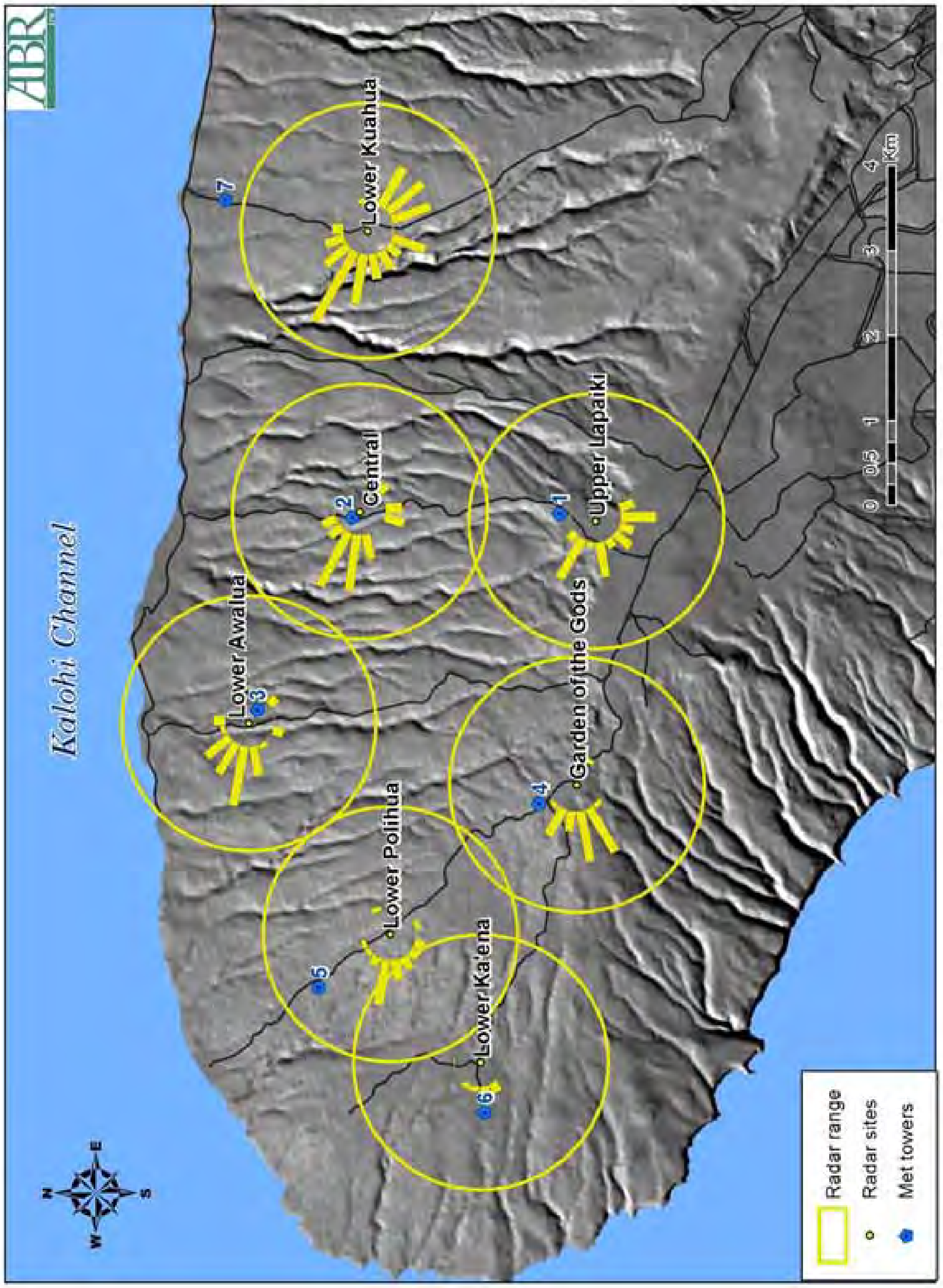

Figure 7. Flight directions of probable Hawaiian Petrel targets observed at each site during evening radar sampling on Lana’i Island, Hawai’i, summer 2007. Length of spoke is proportional to the number of birds traveling in that direction.

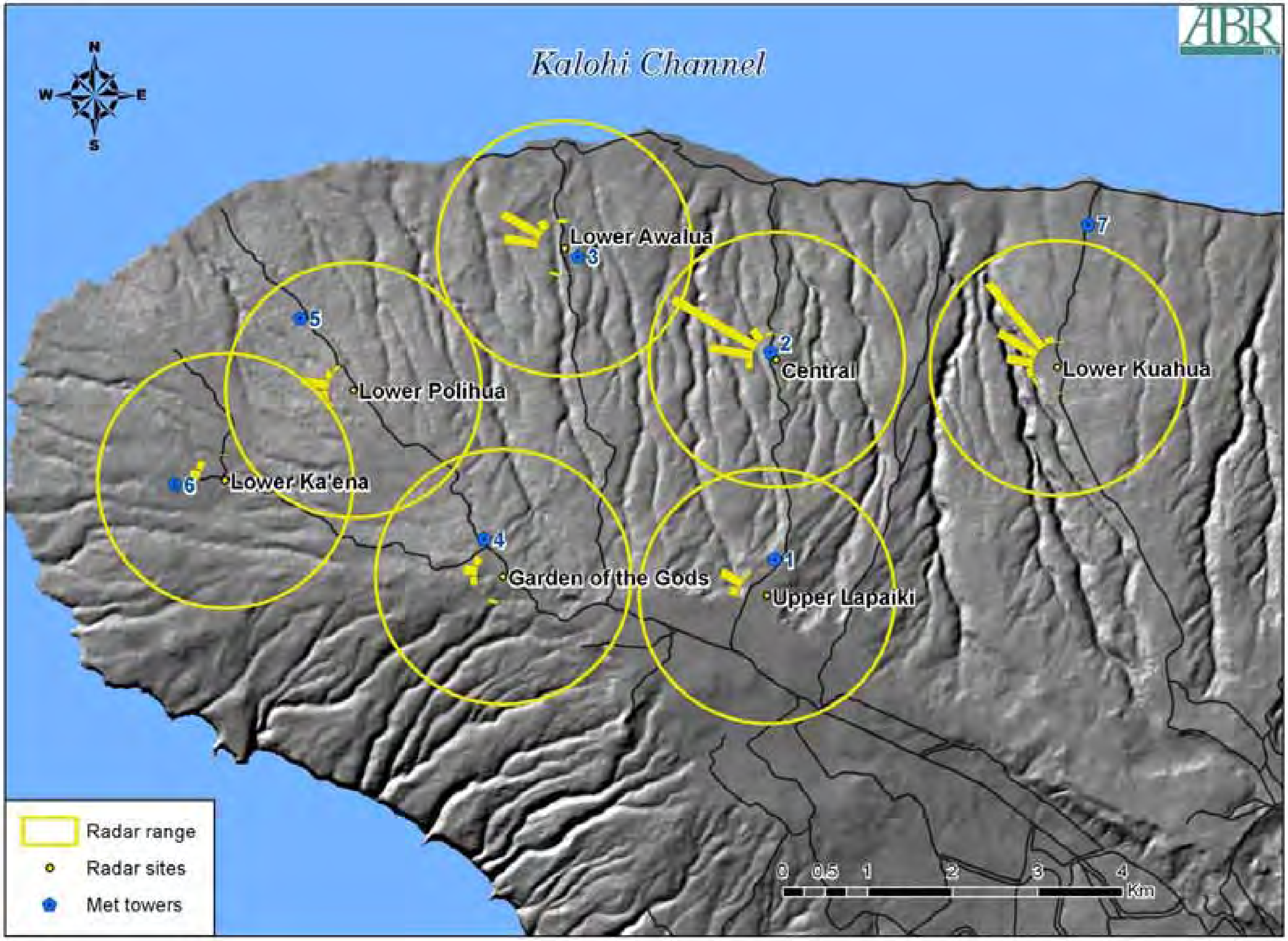

Figure 8. Flight directions of probable Hawaiian Petrel targets observed at each site during morning radar sampling on Lana'i Island, Hawai'i, summer 2007. Length of spoke is proportional to the number of birds traveling in that direction.

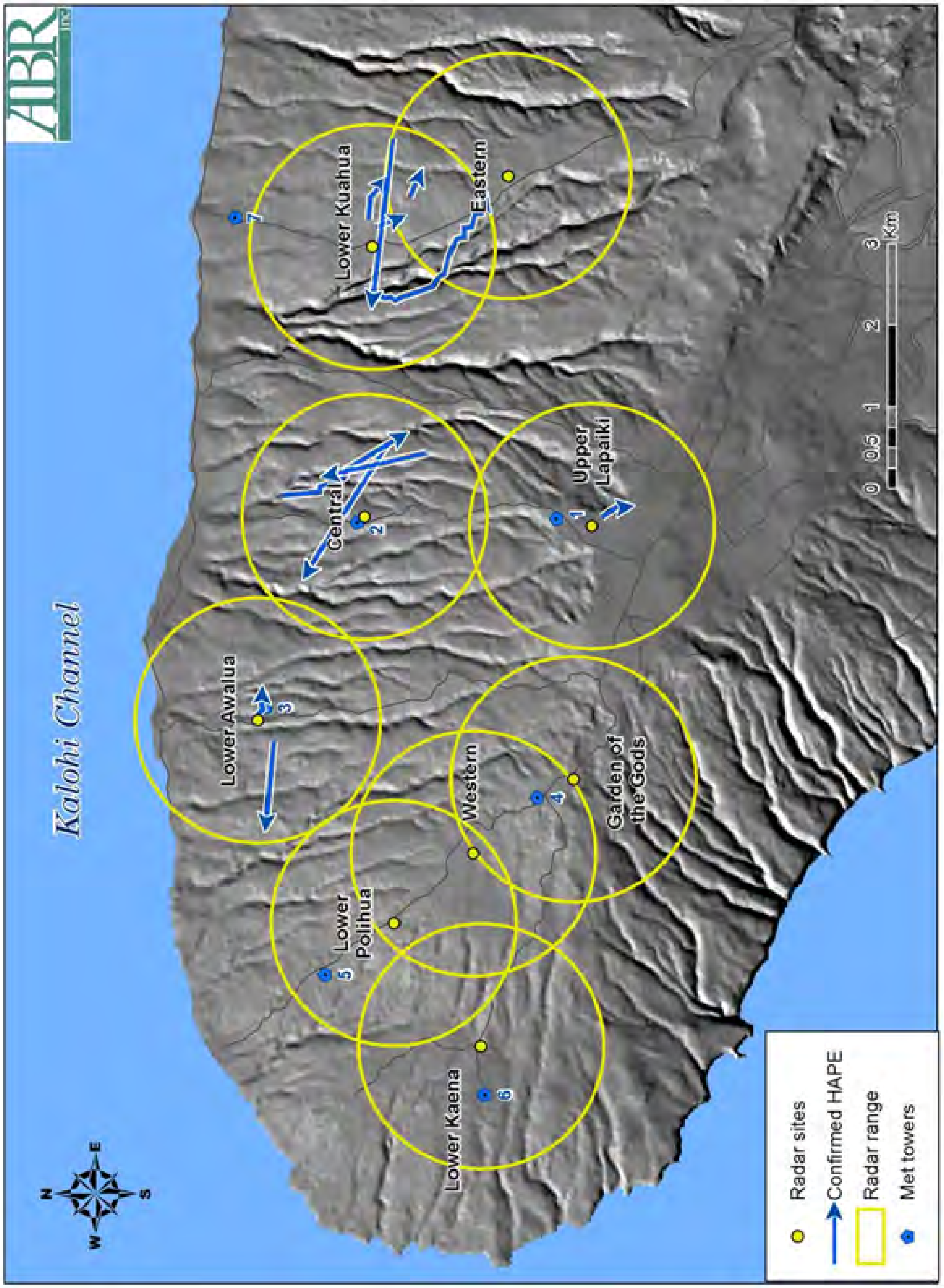

Figure 9. Flight paths (blue arrows) of 11 Hawaiian Petrels that were concurrently observed by radar and visual observers, Lana'i Island, Hawai'i, late spring and summer 2007.

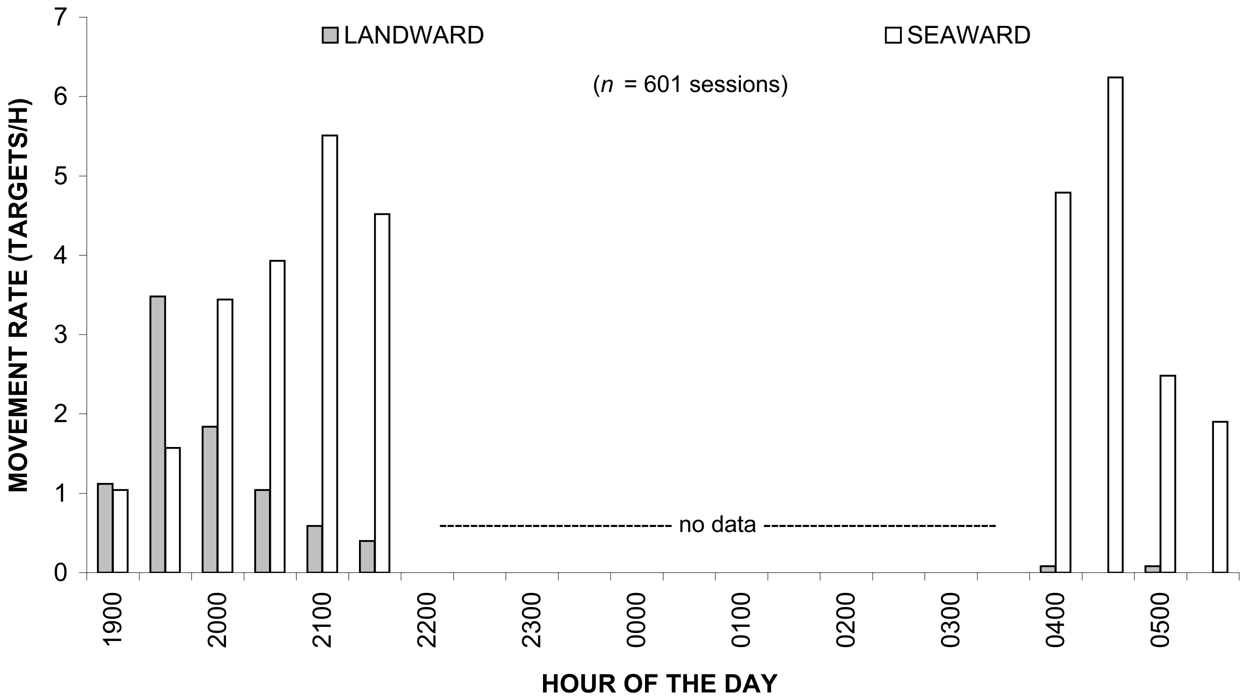

Figure 10. Hourly seaward and landward passage rates of probable Hawaiian Petrel targets observed on radar on Lana'i Island, Hawai'i, during late spring and summer 2007. Note that the number on the X-axis refers to the time that the sampling session began, not the midpoint of the session. The asterisk denotes times that were not sampled.

AUDIO-VISUAL OBSERVATIONS

NUMBERS AND SPECIES-COMPOSITION

We recorded 33 Hawaiian Petrels and 2 unidentified petrels/shearwaters during late spring and summer. Of the 5 birds recorded in late spring, we observed 0 at the Western site, 3 at the Central site, and 2 at the Eastern site (Table 7). In summer, we recorded 30 petrels, with 1 at Lower Ka'ena, 2 at Lower Polihua, 3 at Garden of the Gods, 6 at Lower Awalua, 6 at Central, 2 at Upper Lapaiki, and 10 at Lower Kuahua (Table 8).

In addition to Hawaiian Petrels, we also recorded other species of interest during our late spring and summer surveys. For instance, we saw one Hawaiian Hoary Bat at Garden of the Gods on the evening of 3 July (Tables 9 and 10). No other bats were recorded visually during the study; further, no bats were heard during the opportunistic acoustic monitoring that we did with the bat detector. Other species recorded during the audio-visual sampling included White-tailed Tropicbird (Koa'e Kea; *Phaethon rubricauda*), Greater Frigatebird ('Iwa; *Fregata minor*), Hawaiian Stilt (Ae'o; *Himatopus mexicanus knudseni*), Pacific Golden-Plover (Kolea; *Pluvialis fulva*), Short-eared Owl (Pueo; *Asio flammeus*), and Common Myna.

FLIGHT DIRECTION

We were able to assign flight directions to all Hawaiian Petrels and unidentified petrels/ shearwaters that we recorded visually during late spring and summer. Flight directions of these birds for all data combined showed a pattern of landward flights toward the colony, plus a few seaward flights, in the evening but only seaward flights away from the colony in the morning (Fig. 11). This landward–seaward pattern was similar to that seen on radar during both sampling periods (Figs. 5–8).

FLIGHT ALTITUDE

Visual observations also provided information on flight altitudes of Hawaiian Petrels and

Table 7. Number of Hawaiian Petrels and unidentified petrels/shearwater observed during visual sampling on Lana'i Island, Hawai'i, in late spring 2007, by study site, date, time of day, and flight direction. *n* = number of sampling sessions.

		Evening (1900–2200)		Morning (0400–0530)	
Site	Date	Landward (*n*)	Seaward (*n*)	Landward (*n*)	Seaward (*n*)
Western	26 May	0 (6)	0 (6)	0 (3)	0 (3)
	29 May	0 (6)	0 (6)	0 (3)	0 (3)
	1 June	0 (6)	0 (6)	0 (3)	0 (3)
	4 June	0 (6)	0 (6)	0 (3)	0 (3)
	7 June	0 (6)	0 (6)	0 (3)	0 (3)
	Total	0 (30)	0 (30)	0 (15)	0 (15)
Central	28 May	0 (6)	0 (6)	0 (3)	0 (3)
	31 May	1 (6)	0 (6)	0 (3)	0 (3)
	3 June	0 (6)	0 (6)	0 (3)	0 (3)
	6 June	1 (6)	0 (6)	0 (3)	1 (3)
	9 June	0 (6)	0 (6)	0 (3)	0 (3)
	Total	2 (30)	0 (30)	0 (15)	1 (15)
Eastern	27 May	0 (6)	0 (6)	0 (3)	0 (3)
	30 May	1 (6)	0 (6)	0 (3)	0 (3)
	2 June	0 (6)	0 (6)	0 (3)	0 (3)
	5 June	0 (6)	0 (6)	0 (3)	0 (3)
	8 June	0 (6)	1 (6)	0 (3)	0 (3)
	Total	1 (30)	1 (30)	0 (15)	0 (15)
Total	–	3 (90)	1 (90)	0 (45)	1 (45)

unidentified petrels/shearwaters. Of the 5 petrels seen during the May–June sampling period and the 30 petrels observed during the June–July sampling period, 25 (71.4%) were flying at or below met-tower height (i.e., ≤50 m agl). Flight altitudes varied by flight direction, however: 20 (87.0%) of the 23 landward-flying petrels were flying ≤50 m agl, whereas only 5 (41.7%) of the 12 seaward-bound petrels were flying ≤50 m agl. Further, 33 (94.3%) of the 35 Hawaiian Petrels and unidentified petrels/shearwaters were flying at or below proposed turbine height (i.e., ≤125 m agl). At this high a cutoff altitude, however, flight altitudes did not differ by flight direction: 22 (95.7%) of the 23 landward-bound petrels and 11 (91.7%) of the 12 seaward-bound petrels were flying ≤125 m agl.

The mean (± SE) flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters observed at all sites, times of day, and sampling periods combined was 47 ± 8 m agl (range = 5–200 m agl; *n* = 35 birds). Following the directional pattern seen above, however, the mean flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters flying in a landward direction was 34 ± 9 m agl (range = 5–200 m agl; *n* = 23 birds), whereas the mean altitude of seaward-flying birds was more than 100% higher, at 71 ± 15 m agl (range = 10–175 m agl; *n* = 12 birds).

We recorded only one Hawaiian Hoary Bat during 485 audio-visual sampling sessions (i.e., a rate of 0.005 bats/h). The one bat that we recorded was seen flying towards the northwest over Garden of the Gods at an altitude of ~15 m agl. This bat appeared to be associated with a swarm of insects that had become collected near the ground in the lee of the ridge crest.

Table 8. Number of Hawaiian Petrels and unknown petrel/shearwaters observed during visual sampling on Lana'i Island, Hawai'i, in summer 2007, by study site, date, time of day, and flight direction. *n* = number of sampling sessions.

		Time of day			
		Evening (1900–2200)		Morning (0400–0600)	
Site	Date	Landward (*n*)	Seaward (*n*)	Landward (*n*)	Seaward (*n*)
Lower Ka'ena	22 June	0 (6)	0 (6)	0 (4)	0 (4)
	25 June	0 (6)	0 (6)	0 (4)	0 (4)
	29 June	0 (6)	0 (6)	0 (4)	0 (4)
	2 July	1 (6)	0 (6)	0 (4)	0 (4)
	6 July	0 (6)	0 (6)	0 (4)	0 (4)
	Total	1 (30)	0 (30)	0 (20)	0 (20)
Lower Polihua	24 June	0 (6)	0 (6)	0 (4)	0 (4)
	28 June	0 (6)	0 (6)	0 (4)	1 (4)
	1 July	0 (6)	1 (6)	0 (4)	0 (4)
	5 July	0 (6)	0 (6)	0 (4)	0 (4)
	8 July	0 (6)	0 (6)	0 (4)	0 (4)
	Total	0 (30)	1 (30)	0 (20)	1 (20)
Garden of Gods	23 June	1 (6)	0 (6)	0 (4)	0 (4)
	26 June	0 (6)	0 (6)	0 (4)	0 (4)
	30 June	1 (6)	0 (6)	0 (4)	0 (4)
	3 July	0 (6)	0 (6)	0 (4)	0 (4)
	7 July	0 (6)	0 (6)	1 (4)	0 (4)
	Total	2 (30)	0 (30)	1 (20)	0 (20)
Lower Awalua	23 June	0 (6)	0 (6)	0 (4)	0 (4)
	27 June	0 (6)	0 (6)	0 (4)	0 (4)
	30 June	1 (6)	0 (6)	1 (4)	0 (4)
	4 July	0 (6)	0 (6)	0 (4)	1 (4)
	7 July	2 (6)	0 (6)	0 (4)	1 (4)
	Total	3 (30)	0 (30)	1 (20)	2 (20)
Central	24 June	0 (6)	0 (6)	0 (4)	0 (4)
	27 June	0 (6)	1 (6)	0 (4)	0 (4)
	1 July	1 (6)	0 (6)	0 (4)	0 (4)
	4 July	3 (6)	0 (6)	1 (4)	0 (4)
	8 July	0 (6)	0 (6)	0 (4)	0 (4)
	Total	4 (30)	1 (30)	1 (20)	0 (20)
Upper Lapaiki	22 June	0 (6)	0 (6)	0 (4)	0 (4)
	26 June	0 (6)	0 (6)	0 (4)	0 (4)
	29 June	1 (6)	0 (6)	0 (4)	0 (4)
	3 July	0 (5)	0 (5)	0 (0)	0 (0)
	6 July	0 (6)	0 (6)	0 (4)	1 (4)
	Total	1 (29)	0 (29)	0 (16)	1 (16)
Lower Kuahua	21 June	1 (6)	0 (6)	0 (4)	0 (4)
	25 June	1 (6)	0 (6)	0 (4)	0 (4)
	28 June	0 (6)	0 (6)	0 (4)	0 (4)
	2 July	4 (6)	0 (6)	0 (4)	1 (4)
	5 July	1 (6)	1 (6)	0 (4)	1 (4)
	Total	7 (30)	1 (30)	0 (20)	2 (20)
Total	–	18 (209)	3 (209)	3 (136)	6 (136)

Table 9. Number of Hawaiian Hoary Bats observed during visual sampling on Lana'i Island, Hawai'i, in late spring 2007, by study site, date, and time of day. *n* = number of sampling sessions.

		Time of day	
Site	Date	Evening (1900–2200)	Morning (0400–0600)
Western	26 May	0 (6)	0 (3)
	29 May	0 (6)	0 (3)
	1 June	0 (6)	0 (3)
	4 June	0 (6)	0 (3)
	7 June	0 (6)	0 (3)
	Total	0 (30)	0 (15)
Central	28 May	0 (6)	0 (3)
	31 May	0 (6)	0 (3)
	3 June	0 (6)	0 (3)
	6 June	0 (6)	0 (3)
	9 June	0 (6)	0 (3)
	Total	0 (30)	0 (15)
Eastern	27 May	0 (6)	0 (3)
	30 May	0 (6)	0 (3)
	2 June	0 (6)	0 (3)
	5 June	0 (6)	0 (3)
	8 June	0 (6)	0 (3)
	Total	0 (30)	0 (15)
Total	–	0 (90)	0 (45)

AUDITORY SURVEYS ALONG THE ROAD SYSTEM

During the summer study period, we also conducted auditory surveys along the entire road system within the WRA to investigate the possibility that some petrels were nesting away from the main colony and within the proposed project development area. This concern was raised because of the low flight altitudes of landward-flying Hawaiian Petrels seen during audio-visual surveys (see above); such low altitudes usually are seen near nesting colonies (Cooper and Day, pers. obs.). No petrels were seen or petrel-like calls were heard on any of the 15 nights of sampling that were conducted during summer 2007 (Table 11), suggesting that no petrels were nesting within the WRA.

EXPOSURE INDICES AND FATALITY MODELING

The risk-assessment technique that we have developed involves the use of both radar data and visual data in estimating the fatality of petrels and shearwaters near structures in the Hawaiian Islands (Fig. 2). This modeling technique uses the radar data on movement rates to estimate numbers of birds flying over the area of interest (sampling sites), then expands those estimates for a 270-d year that birds are present on this island (late March through late December; J. Penniman, DOFAW, pers. comm.) and, hence, will be exposed to the proposed met towers and wind turbines. The model then uses information on the physical characteristics of the towers/turbines themselves to estimate horizontal interaction rates, uses visual flight-altitude data to estimate vertical interaction rates, and combines these estimates of interaction rates with the fatality probability to estimate

Table 10. Number of Hawaiian Hoary Bats observed during visual sampling on Lana'i Island, Hawai'i, in summer 2007, by study site, date, and time of day. *n* = number of sampling sessions.

Site	Date	Time of day	
		Evening (1900–2200)	Morning (0400–0600)
Lower Ka'ena	22 June	0 (6)	0 (4)
	25 June	0 (6)	0 (4)
	29 June	0 (6)	0 (4)
	2 July	0 (6)	0 (4)
	6 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Lower Polihua	24 June	0 (6)	0 (4)
	28 June	0 (6)	0 (4)
	1 July	0 (6)	0 (4)
	5 July	0 (6)	0 (4)
	8 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Garden of Gods	23 June	0 (6)	0 (4)
	26 June	0 (6)	0 (4)
	30 June	0 (6)	0 (4)
	3 July	1 (6)	0 (4)
	7 July	0 (6)	0 (4)
	Total	1 (30)	0 (20)
Lower Awalua	23 June	0 (6)	0 (4)
	27 June	0 (6)	0 (4)
	30 June	0 (6)	0 (4)
	4 July	0 (6)	0 (4)
	7 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Central	24 June	0 (6)	0 (4)
	27 June	0 (6)	0 (4)
	1 July	0 (6)	0 (4)
	4 July	0 (6)	0 (4)
	8 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Upper Lapaiki	22 June	0 (6)	0 (4)
	26 June	0 (6)	0 (4)
	29 June	0 (6)	0 (4)
	3 July	0 (5)	0 (0)
	6 July	0 (6)	0 (4)
	Total	0 (29)	0 (16)
Lower Kuahua	21 June	0 (6)	0 (4)
	25 June	0 (6)	0 (4)
	28 June	0 (6)	0 (4)
	2 July	0 (6)	0 (4)
	5 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Total	–	1 (209)	0 (136)

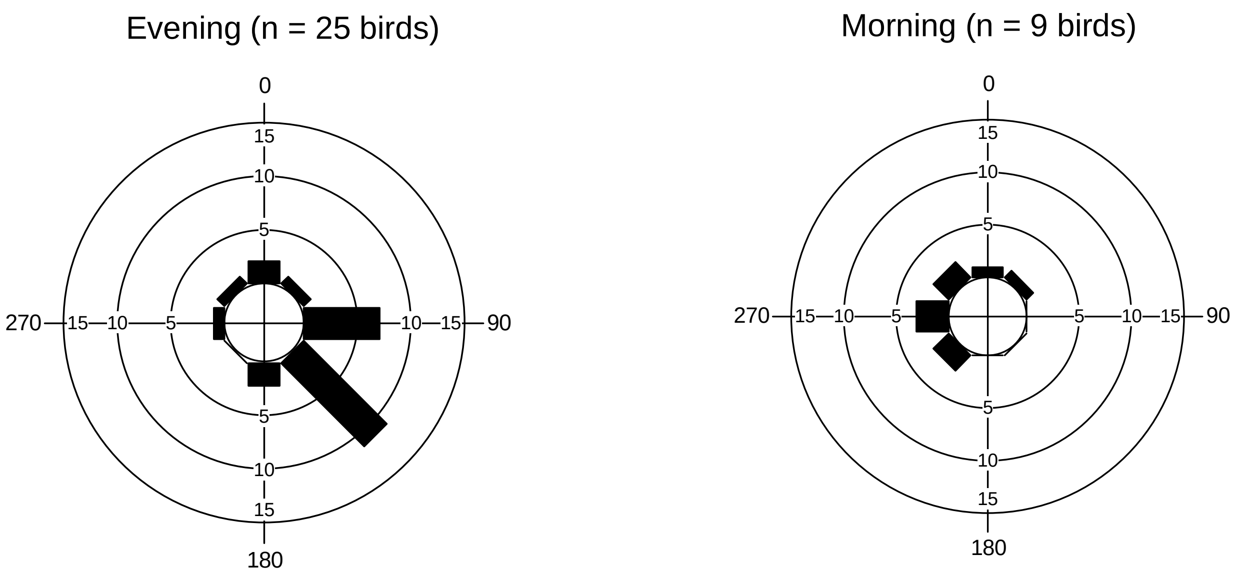

Figure 11. Flight direction of Hawaiian Petrels and unidentified shearwaters/petrels observed during visual sampling on Lana'i Island, Hawai'i, late spring and summer 2007, by time of day. Length of spoke is proportional to the number of birds traveling in that direction.

Table 11. Sampling effort and number of Hawaiian Petrels detected on acoustic surveys during late spring 2007.

Road system	No. sampling points	No. point visits	No. petrel calls
Ka'ena	7	21	0
Polihua	7 [1]	20	0
Road #7	4	8	0
Kanepu'u	6	16	0
Awalua	6	15	0
Lapaiki	8	22	0
Kahua	6	18	0
Kuahua	7	20	0

[1]One of the seven sampling points was dropped after the first visit.

fatality rates under a worst-case scenario of no collision avoidance. Finally, it presents possible levels of fatality based on possible levels of collision avoidance by these birds.

We analyzed the data separately for each of the seven radar sampling sites that we sampled in summer (late June–early July) 2007 (Fig. 1) and constructed fatality estimates for any proposed met towers or wind turbines that will be associated with each site. We tabulated all data from Lana'i on minimal flight altitudes of petrels recorded during the visual sampling and used those data for the vertical-interaction component of our fatality model. Of the 4 petrels seen during the May–June sampling period and the 31 petrels seen during the June–July sampling period, 20 (87.0%) of the 23 landward-flying petrels and 5 (41.7%) of the 12 seaward-flying petrels were flying ≤50 m agl. Further, 22 (95.7%) of the 23 landward-flying petrels and 11 (91.7%) of the 12 seaward-flying petrels were flying ≤125 m agl. We used the midpoints of the landward and seaward percentages (i.e., 64.4% and 93.7% for proposed met towers and wind turbines, respectively) in our fatality models because we assumed that there would be approximately equal numbers of landward and seaward targets passing over a location on any given night.

MOVEMENT RATE

The movement rate is an estimate of the average number of birds passing in the vicinity of the proposed towers/turbines in a day, as indicated by what is seen on the radar screen. It is generated from the radar data by: (1) multiplying the average evening landward and morning seaward movement rates by 3 h to estimate the number of targets moving over the radar site in those first and last 3 h of the night; (2) multiplying the sum of those evening landward counts and morning seaward counts by the quantity (1 + the proportion [12.6%] of targets that move during the rest of the night [= 1.126]) to account for movement during the middle of the night (Tables 6 and 12), following Day and Cooper (1995, unpubl. data); (3) adding the evening seaward counts and morning landward counts to the previous number of targets to get the total number of probable Hawaiian Petrel targets passing within 1.5 km of each site in a night; and (4) multiplying that total number of targets/night by the mean number of petrels/target to generate an estimate of the number of petrels passing in the vicinity of the proposed tower/turbine during an average night (Table 12).

Because we did not have all-night radar data available for Lanai, we used data from all-night sampling sessions on Kaua'i (Day and Cooper 1995) to determine that ~87% of the entire night's movement occurs during the evening and morning landward and seaward peaks, respectively (Day and Cooper, unpubl. data). We believe that all of the radar targets seen during this study were those of Hawaiian Petrels; certainly, all of the targets identified to species were petrels, and all birds definitely identified to species visually were petrels. The estimate of mean flock size for Hawaiian Petrel targets (1.05 ± SE 0.01 birds/target) is calculated from all visual data on this species on Kaua'i, Lana'i, Maui, and Hawai'i combined between 1992 and 2007 (*n* = 810 observations; Day and Cooper, unpubl. data). We then multiplied this estimate of nightly movement by 270 d (April–December) to generate an estimate of movement over each site during an entire breeding season.

Although we had to base this model of annual fatality on movement rates from the one study period, mean nightly movement rates are known to differ seasonally. For example, because movement rates tend to decrease from summer to fall (Day and Cooper 1995), the use of movement rates from only the summer will tend to overestimate annual interaction and fatality rates, whereas the use of movement rates from only the fall will tend to underestimate annual interaction and fatality rates. At this point, we are unclear exactly what movement rates in spring (April) will be, but State of Hawaii DOFAW personnel believe that that might be the season when the most birds are present at the Lana'ihale colony (J. Penniman, DOFAW, pers. comm.).

Because the resulting estimate of the number of birds/yr is not an integer, we then round it upward to the next whole number to generate an estimate of the average number of birds passing within 1.5 km of the radar site during a year. This rounding technique results in slightly-inflated fatality estimates, but we are being conservative about the fatality of an endangered species.

Table 12. Estimates of mean numbers of probable Hawaiian Petrel targets/night flying over radar-sampling sites on Lana'i Island, Hawai'i, in late spring and summer 2007, by season, radar-sampling site, time of day, and flight direction.

	Time of day				
	Evening (1900–2200)		Morning (0400–0600)		
Sampling period/study site	Mean landward movement (targets)	Mean seaward movement (targets)	Mean landward movement (targets)	Mean seaward movement (targets)	Mean nightly movement (targets)[1]
LATE SPRING					
Western	0.72	5.76	0.00	4.80	11.97552
Central	1.98	10.44	0.00	11.04	25.10052
Eastern	5.76	7.68	0.00	2.88	17.40864
Mean	2.82	7.96	0.00	6.24	18.16156
SUMMER					
Lower Ka'ena	0.00	1.44	0.00	1.80	3.46680
Lower Polihua	1.44	4.80	0.00	5.76	12.90720
Garden of Gods	0.24	7.95	0.00	3.24	11.86848
Lower Awalua	1.44	8.40	0.36	9.72	21.32616
Central	2.16	8.16	0.00	14.49	26.90790
Upper Lapaiki	3.24	6.207	0.00	4.41	15.08776
Lower Kuahua	10.68	10.68	0.36	14.76	39.68206
Mean	2.78	6.81	0.10	7.74	18.74948

[1] This value = ((mean landward evening movement + mean seaward morning movement) × 1.126) + mean seaward evening movement + mean landward morning movement.

INTERACTION PROBABILITIES

We have separated the interaction probability into horizontal and vertical components to make its estimation more tractable. The horizontal interaction probability is the probability that a bird seen on radar will pass through or over the airspace occupied by a proposed met tower or proposed turbine located somewhere on the radar screen. This probability is calculated from information on the two-dimensional area (side view) of the proposed tower/turbine and the two-dimensional area sampled by the radar screen to determine the interaction probability. The proposed met-tower system has a central tower with four sets of guy wires attached at five heights; hence, the tower/guy-wire system appears from the side to be an isosceles triangle 50 m high with a base of 67 m and a mean width of 33.5 m (Table 13). The proposed wind turbines have 80-m monopole towers and 45-m-long blades. Two calculations of area were made for turbines because of the huge differences in area of the structure that depended on the orientation when approaching it: a minimal area occupied by each proposed turbine if a bird approaches it from the side (i.e., side profile) and a maximal area occupied by each turbine if a bird approaches it from the front (i.e., front profile, including the rotor-swept area; Table 14). The ensuing ratio of cross-sectional area of the proposed tower/turbine to the cross-sectional area sampled by the radar indicates the probability of interacting with (i.e., flying over or through the airspace occupied by) the proposed tower or turbine. Because the dimensions of the proposed towers/turbines will not differ among sampling periods, estimates of horizontal interaction probabilities will be identical during all sampling periods.

The vertical interaction probability is the probability that a bird seen on radar will be flying at an altitude low enough that it might pass through the airspace occupied by a proposed tower/turbine located somewhere on the radar screen. This probability is calculated from visual data on flight altitudes and from information on the proposed towers' and turbines' heights. Because we do not have sufficient data to determine whether flight altitudes differ seasonally, we assume here that they do not vary; hence, estimates of vertical interaction probabilities will be identical during all seasons.

EXPOSURE RATE

The exposure rate is calculated as the product of the preceding three variables (annual movement rate, horizontal interaction probability, vertical interaction probability). As such, it is an estimate of the number of birds flying in the vicinity of the proposed tower/turbine (i.e., crossing the radar screen) that could fly in a horizontal location and that could fly at a low enough altitude that they could interact with the tower/turbine. Because movement rates vary among sampling periods, estimates of annual exposure rates also will vary seasonally, as described above; however, in this case, we are estimating annual rates based only based on summer (June–July) data.

FATALITY PROBABILITY

Not all birds possibly interacting with the proposed tower/turbine might be killed by it (e.g., some birds might just brush towers or guy wires with their wingtips and fly away uninjured), necessitating the estimation of the fatality probability. Factors that affect tower fatality probability include whether the tower is a solid monopole or a lattice-type tower, whether the tower is free-standing or guyed, and, if it is a lattice-type tower, the size of the lattice interstices (large free-standing lattice towers will have frameworks with openings several meters wide for birds to pass through safely, whereas towers with small lattices and multiple guy wires effectively are solid objects). Factors that affect wind-turbine fatality probability include the speed and orientation of the bird relative to the rotational speed and orientation (side view or front view) of the turbine blades.

The estimate of fatality probability is derived as the product of (1) the probability of colliding with the proposed tower or its guy wires/the proposed turbine if the bird enters the airspace occupied by either of these structures and (2) the probability of dying if it hits either the tower frame/guy wires or the turbine. The former probability is needed because the above estimates of horizontal interaction probability are calculated as if the proposed tower and its guy wires/turbine are one solid structure, as described above. In the

Table 13. Estimated met tower exposure indices and fatality indices of Hawaiian Petrels (HAPE) at each site on Lana'i Island, Hawai'i, based on radar data collected in late June–early July 2007 and flight-altitude data from Lana'i Island during May–July 2007. Values of particular importance are in boxes.

Variable/parameter	Radar-sampling site (met-tower number)						
	Lower Ka'ena (6)	Lower Polihua (5)	Garden of Gods (4)	Lower Awalua (3)	Central (2)	Upper Lapaiki (1)	Lower Kuahua (7)
MOVEMENT RATE (MVR)							
A) Movement rate (petrel targets/night)	3.46680	12.90720	11.86848	21.32616	26.90790	15.08776	39.68206
B) Mean number of HAPE/target	1.05	1.05	1.05	1.05	1.05	1.05	1.05
C) Daily movement rate (HAPE/day =B*C)	3.64	13.55	12.46	22.39	28.25	15.84	41.67
D) Fatality domain (days/year)	270	270	270	270	270	270	270
E) Annual movement rate (HAPE/year; =C*D, rounded to next whole number)	983	3,660	3,365	6,046	7,629	4,278	11,250
HORIZONTAL INTERACTION PROBABILITY (IPH)							
F) Maximal cross-sectional area of tower and guys (side view = ((33.5m * 50 m)/2)*2 = 1675 m²	1,675.0	1,675.0	1,675.0	1,675.0	1,675.0	1,675.0	1,675.0
G) Cross-sectional sampling area of radar at or below 50 m tower height (= 3000 m * 50 m = 15,000 m²)	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000
H) Horizontal interaction probability (= F/G, rounded to 8 decimal places)	0.01116667	0.01116667	0.01116667	0.01116667	0.01116667	0.01116667	0.01116667
VERTICAL INTERACTION PROBABILITY (IPV)							
I) Vertical interaction probability (proportion petrels flying ≤ tower height; rounded to 8 decimal places)	0.64350000	0.64350000	0.64350000	0.64350000	0.64350000	0.64350000	0.64350000
EXPOSURE RATE (ER; = MVR * IPH * IPV)							
J) Daily exposure rate (HAPE/day = C*H*I, rounded to 8 decimal places)	0.02615714	0.09738531	0.08954813	0.16090668	0.20302111	0.11383771	0.29940263
K) Annual exposure rate (HAPE/year = E*H*I, rounded to 8 decimal places)	7.06359225	26.29984500	24.18004875	43.44504450	54.82008675	30.74063850	80.83968750

Table 13. Continued.

Variable/parameter	Radar-sampling site (met-tower number)						
	Lower Ka'ena (6)	Lower Polihua (5)	Garden of Gods (4)	Lower Awalua (3)	Central (2)	Upper Lapaiki (1)	Lower Kuahua (7)
FATALITY PROBABILITY (MP)							
L) Probability of striking tower or guys if in airspace	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M) Probability of fatality if striking tower or guys	0.95	0.95	0.95	0.95	0.95	0.95	0.95
N) Probability of fatality if an interaction (= L*M, rounded to 5 decimal places)	0.95000	0.95000	0.95000	0.95000	0.95000	0.95000	0.95000
ANNUAL FATALITY RATE (= IR * MP)							
O) Annual fatality rate with 0% exhibiting collision avoidance (HAPE/tower/year = K*N, rounded to 5 decimal places)	6.71041	24.98485	22.97105	41.27279	52.07908	29.20361	76.79770
P) Annual fatality rate with 50% exhibiting collision avoidance (HAPE/tower/year = K*N*0.5)	3.35521	12.49243	11.48553	20.63640	26.03954	14.60181	38.39885
Q) Annual fatality rate with 95% exhibiting collision avoidance (HAPE/tower/year = K*N*0.05)	0.33552	1.24924	1.14855	2.06364	2.60395	1.46018	3.83989
R) Annual fatality rate with 99% exhibiting collision avoidance (HAPE/tower/year = K*N*0.01)	0.06710	0.24985	0.22971	0.41273	0.52079	0.29204	0.76798

Table 14. Estimated turbine exposure indices and fatality indices of Hawaiian Petrels (HAPE) at each site on Lana'i Island, Hawai'i, based on radar data collected in late June–early July 2007 and flight-altitude data from Lana'i Island during May–July 2007. Values of particular importance are in boxes.

Variable/parameter	Radar-sampling site (met-tower number)						
	Lower Ka'ena (6)	Lower Polihua (5)	Garden of Gods (4)	Lower Awalua (3)	Central (2)	Upper Lapaiki (1)	Lower Kuahua (7)
MOVEMENT RATE (MVR)							
A) Movement rate (petrel targets/night)	3.46680	12.90720	11.86848	21.32616	26.90790	15.08776	39.68206
B) Mean number of HAPE/target	1.05	1.05	1.05	1.05	1.05	1.05	1.05
C) Daily movement rate (HAPE/day =B*C)	3.64	13.55	12.46	22.39	28.25	15.84	41.67
D) Fatality domain (days/year)	270	270	270	270	270	270	270
E) Annual movement rate (HAPE/year; =C*D, rounded to next whole number)	983	3,660	3,365	6,046	7,629	4,278	11,250
HORIZONTAL INTERACTION PROBABILITY (IPH)							
F) Turbine height (m)	125	125	125	125	125	125	125
G) Blade radius (m)	45	45	45	45	45	45	45
H) Height below blade (m)	35	35	35	35	35	35	35
I) Front to back width (m)	6	6	6	6	6	6	6
J) Min side profile area (m^2) = (A x D)	750	750	750	750	750	750	750
K) Max front profile area (m^2) = (C x D) + (p x B^2)	6,572	6,572	6,572	6,572	6,572	6,572	6,572
L) Cross-sectional sampling area of radar at or below 50 m tower height (= 3000 m * 50 m = 150,000 m^2)	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000
M) Minimal horizontal interaction probability (= J/L)	0.00500000	0.00500000	0.00500000	0.00500000	0.00500000	0.00500000	0.00500000
N) Maximal horizontal interaction probability (= K/L)	0.04381160	0.04381160	0.04381160	0.04381160	0.04381160	0.04381160	0.04381160
VERTICAL INTERACTION PROBABILITY (IPV)							
O) Vertical interaction probability (proportion petrels flying ≤ turbine height)	0.93700000	0.93700000	0.93700000	0.93700000	0.93700000	0.93700000	0.93700000
EXPOSURE RATE (ER; = MVR * IPH * IPV)							
P) Daily minimal exposure rate (HAPE/day = C*M*O)	0.01705406	0.06349374	0.05838402	0.10490871	0.13236669	0.07422046	0.19520597
Q) Daily maximal exposure rate (HAPE/day = C*N*O)	0.14943310	0.55635250	0.51157947	0.91924371	1.15983927	0.65034345	1.71045721
R) Annual minimal exposure rate (HAPE/year = E*M*O)	4.60535500	17.14710000	15.76502500	28.32551000	35.74186500	20.04243000	52.70625000
S) Annual maximal exposure rate (HAPE/year = E*N*O)	40.35359422	150.2483772	138.1381938	248.1971827	313.1816585	175.61818524	461.8290285

Table 14. Continued.

Variable/parameter	Radar-sampling site (met-tower number)						
	Lower Ka'ena (6)	Lower Polihua (5)	Garden of Gods (4)	Lower Awalua (3)	Central (2)	Upper Lapaiki (1)	Lpwer Kuahua (7)
FATALITY PROBABILITY (MP)							
T) Probability of striking turbine if in airspace on a side approach	1.00	1.00	1.00	1.00	1.00	1.00	1.00
U) Probability of striking turbine if in airspace on frontal approach	0.14	0.14	0.14	0.14	0.14	0.14	0.14
V) Probability of fatality if striking turbine	0.95	0.95	0.95	0.95	0.95	0.95	0.95
W) Probability of fatality if an interaction on side approach (= T*V)	0.95000	0.95000	0.95000	0.95000	0.95000	0.95000	0.95000
X) Probability of fatality if an interaction on frontal approach (= U*V)	0.13585	0.13585	0.13585	0.13585	0.13585	0.13585	0.13585
ANNUAL FATALITY RATE (= IR * MP)							
Minimal annual fatality rate with 0% exhibiting collision avoidance (HAPE/turbine/year = R*W)	1.75003	6.51590	5.99071	10.76369	13.58191	7.61612	20.02838
Maximal annual fatality rate with 0% exhibiting collision avoidance (HAPE/turbine/year = S*X)	2.19281	8.16450	7.50643	13.48703	17.01829	9.54309	25.09579
Minimal annual fatality rate with 50% exhibiting collision avoidance (HAPE/turbine/year = R*W*0.5)	0.87502	3.25795	2.99536	5.38185	6.79096	3.80806	10.01419
Meximal annual fatality rate with 50% exhibiting collision avoidance (HAPE/turbine/year = S*X*0.5)	1.09641	4.08225	3.75322	6.74352	8.50915	4.77155	12.54790
Minimal annual fatality rate with 95% exhibiting collision avoidance (HAPE/turbine/year = R*W*0.05)	0.08750	0.32580	0.29954	0.53818	0.67910	0.38081	1.00142
Maximal annual fatality rate with 95% exhibiting collision avoidance (HAPE/turbine/year = S*X*0.05)	0.10964	0.40823	0.37532	0.67435	0.85091	0.47715	1.25479
Minimal annual fatality rate with 99% exhibiting collision avoidance (HAPE/turbine/year = R*W*0.01)	0.01750	0.06516	0.05991	0.10764	0.13582	0.07616	0.20028
Maximal annual fatality rate with 99% exhibiting collision avoidance (HAPE/turbine/year = S*X*0.01)	0.02193	0.08165	0.07506	0.13487	0.17018	0.09543	0.25096

proposed met-tower design, the tower frame is a solid monopole, and the four sets of guy wires at five heights each occupy a substantial proportion of the total cone of airspace enclosed by the tower and guy wires, making it a low probability that a bird could fly though the space occupied by this tower without hitting some part of it. Hence, we estimated the probability of hitting the tower or guy wires if the bird enters the airspace at 100%. We consider this probability to be a worst-case scenario for this tower and guy-wire layout, both because of this assumption of hitting some part of the structure and because we assume that there is no behavioral avoidance of the structure by these birds (but see below).

Similarly, a bird approaching a turbine from the side has essentially a 100% probability of getting hit by a blade; in contrast, a bird approaching from the back or front has only a 14.9% probability of hitting a blade. This calculation for the "frontal" bird approach was based on the length of a petrel (43 cm; Simons and Hodges 1998); the average groundspeed of petrels on Lana'i (mean velocity = 48.5 ± 0.4 mi/h; *n* = 597 probable petrel targets); and the time that it would take a 43-cm-long petrel to travel completely through a 2-m-wide turbine blade spinning at its maximal rotor speed (19 revolutions/min); also see Tucker (1996). Thus, these calculations indicated that 14.9% of the disk of the rotor-swept area would be occupied by a blade sometime during the length of time (i.e., 0.0017 min) that it would take a petrel to fly completely past a rotor blade (i.e., to fly 2.43 m). Again, this probability is a worst-case scenario that assumes no avoidance behavior.

Finally, a bird hitting either the proposed met-tower frame or guy wire or the proposed wind turbine will have a high probability of actually dying unless it just brushes the structure with a wingtip; therefore, we used an estimate of 95% for that parameter. Hence, the overall fatality probability of a bird entering the airspace occupied by a proposed met tower is high and is estimated at 95% (i.e., 1.00 [= probability of colliding with the structure] × 0.95 [= probability of dying if colliding]). The overall fatality probability of a bird entering the airspace occupied by a proposed turbine is estimated at 95% (i.e., 1.00 × 0.95) for a side approach and 14.3% (i.e., 0.149 × 0.95) for a frontal approach. Because these probability estimates do not differ among sampling periods, this estimate of fatality probability will be identical among sampling periods.

FATALITY RATE

The annual fatality rate is calculated as the product of the exposure rate (i.e., the number of birds that might fly in the airspace occupied by the proposed met tower/guy wires or the proposed wind turbine) and the fatality probability (i.e., the probability of collision with a portion of the structure and dying while in the airspace). It is generated as an estimate of the number of birds killed/year as a result of the tower/turbine, based on a 270-d breeding season. Because movement rates vary seasonally (i.e., among sampling periods), fatality rates also will. Again, however, we present annual estimates here based on only on summer data.

The major variables involved in this fatality estimation are presented in Figure 2. The individual steps and estimates involved in these calculations are shown in Table 13 for proposed met towers and Table 14 for proposed wind turbines. Based on data from summer 2007, we estimate annual movement rates of ~983, ~3,660, ~3,365, ~6,046, ~7,629, ~4,278 and ~11,250 Hawaiian Petrels within 1.5 km of the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively (Tables 13 and 14). Thus, there is a gradation of increasing bird numbers from west to east in the proposed windfarm (also see Figs. 3 and 4). Based on flight-altitude data from Lana'i., we estimate that, on average, 64% of the birds flying through the WRA are flying at altitudes low enough to interact with the proposed met towers (i.e., ≤50 m agl) and that 94% fly at altitudes low enough to interact with the proposed turbines (i.e., ≤125 m agl). Based on these altitudes, the estimated annual movement rates, and the horizontal interaction probability, annual fatality rates at proposed met towers are estimated to be 6.7, 25.0, 23.0, 41.3, 52.1, 29.2, and 76.8 Hawaiian Petrels/tower near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and

Lower Kuahua radar sites, respectively, assuming that no collision-avoidance behavior occurs (Table 13). Based on these altitudes, the estimated annual movement rates, and the horizontal interaction probabilities, annual fatality rates at proposed wind turbines are estimated to be 1.8–2.2, 6.5–8.2, 6.0–7.5, 10.8–13.5, 13.6–17.0, 7.6–9.5, and 20.0–25.1 Hawaiian Petrels/turbine near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively, assuming that no collision-avoidance behavior occurs (Table 14). Fatality rates for proposed wind turbines are presented as ranges because of differential risks associated with side and frontal views of the turbines, as described above.

EFFECTS OF COLLISION AVOIDANCE ON ESTIMATES

We emphasize here that these fatality estimates assume a worst-case scenario in which there is no collision-avoidance behavior by Hawaiian Petrels. Because these birds mostly move during periods of daylight or twilight (Day and Cooper 1995, unpubl. data), however, it is likely that many will be able to see and avoid met towers/guy wires and wind turbines. Similarly, avoidance rates for nocturnally-moving Hawaiian Petrels should be high during periods when the moon is fairly full and visible. Consequently, we have recalculated estimated annual fatality rates for each site and flight-altitude scenario by assuming that 0%, 50%, 95%, or 99% of all Hawaiian Petrels flying near a met tower will see and avoid it. Based on these assumptions about possible collision-avoidance rates, annual fatality rates for proposed met towers are estimated to be 0.1–6.7, 0.3–25.0, 0.2–23.0, 0.4–41.3, 0.5–52.1, 0.3–29.2, and 0.8–76.8 Hawaiian Petrels/tower near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively (Table 13). Based on the same set of assumptions about possible avoidance rates, annual fatality rates for proposed wind turbines are estimated to be 0.02–2.2, 0.1–8.2, 0.1–7.5, 0.1–13.5, 0.1–17.0, 0.1–9.5, and 0.2–25.1 Hawaiian Petrels/turbine near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively (Table 14). We caution again, however, that these assumptions for avoidance rates are not based on empirical data.

DISCUSSION

PETRELS AND SHEARWATERS

SPECIES COMPOSITION

Our visual data suggest that all of the radar targets that we observed with the radar on Lana'i in 2007 were Hawaiian Petrels. Of the 33 tubenoses seen during visual sampling and identified to species, all were identified as Hawaiian Petrels, so we assume that the 2 unidentified petrels/shearwaters also were petrels. Thus, there was no indication from the visual data that Newell's Shearwaters also flew over the area. In addition, other researchers on Lana'i consider Newell's Shearwaters to be extremely rare and are not even convinced that the species nests there (J. Penniman, DOFAW, pers. comm.).

We have suggested previously that Hawaiian Petrels on other islands (Kaua'i, Maui, and Hawai'i) fly into nesting areas earlier in the evening than Newell's Shearwaters do (Cooper and Day 2003; Day et al. 2003a, 2003b). Consequently, we have suggested that radar targets observed after ~30 min past sunset (i.e., at about the point of complete darkness) are predominantly Newell's Shearwaters. Clearly, this is not the case on Lana'i, where there are many Hawaiian Petrels flying into colonies well after the point of complete darkness. On the other hand, our studies from the other islands emphasized coastal sampling, whereas the Lana'i work (this study) and recent research on Maui (Day et al. 2005a, Day and A. Gall, unpubl. data) have occurred inland; in the three latter studies, Hawaiian Petrels were recorded flying primarily after dark, apparently reflecting the time it takes for these birds to fly from the coast to the colonies.

MOVEMENT RATES

Our sampling dates occurred during the incubation period (i.e., the May–June observations) and late-incubation/early chick-rearing period (i.e., the June–July observations) of Hawaiian Petrels (Simons and Hodges 1998; J.

Penniman, DOFAW, pers. comm.). During the summer period, breeding adults, nonbreeding adults, and subadults are visiting the colonies (Simons 1985, Simons and Hodges 1998). The average incubation shift is 16.5 d for Hawaiian Petrels (Simons 1985), so a breeding adult visits the nesting colony every 16–17 d, on average. Further, it is doubtful that all nonbreeding adults and subadults visit the colonies every night. Hence, the mean radar movement rates that we have presented here represent far less than the actual number of birds visiting the colony.

Overall mean movement rates (landward + seaward) on radar recorded on Lana'i tended to be much lower than were rates recorded during radar studies on Kaua'i and East Maui and were slightly lower than rates on West Maui; however, movement rates recorded on Lana'i were similar to rates recorded on Hawai'i (Table 15). Our data from Lana'i also indicate that there are fewer petrels flying over the western portion of the Lana'i WRA than over the central and eastern parts of it. This finding makes sense, given that it is the portion of the WRA that is farthest from the Lana'ihale colony. In fact, mean movement rates in the western portion of the WRA were lower than rates recorded at nearly all other locations that have ever been studied in the Hawaiian Islands (Cooper and Day 2003; Day et al. 2003a, 2003b, Day and Cooper, unpubl. data). Mean overall (i.e., landward + seaward) movement rates near the recently-installed Met Tower 6 in the western end of the study area were ~0.5 targets/h, which is even lower than mean movement rates at the recently-built Kaheawa Wind Park on Maui (1.0–1.2 targets/h; Day and Cooper 1999, Cooper and Day 2004a).

The typical movement pattern for Hawaiian Petrels and Newell's Shearwaters on the way to and from nesting colonies is a pattern of substantial landward movement toward the colonies for ~2 h after sunset, followed by low levels of landward and seaward movement during the middle of the night, followed by a substantial seaward departure from the colonies for 1–2 h prior to sunrise (Day and Cooper 1995, Cooper and Day 2003, Day et al. 2003a). This pattern also fits fairly well with what is known about the timing of vocalizations near the colonies and the timing of nest exchanges (Simons and Hodges 1998). Surprisingly, it appears that the movement pattern on Lana'i may be different from what has been seen on other islands. On Lana'i, the pattern that we observed was that seaward rates always were higher than landward rates, even in the evening; however, seaward rates were as high or higher in the morning than in the evening at most sites, similar to what we have seen on other islands. Seaward rates were as high or higher in the evening than in the morning at only two of seven sites, and those shared similar geographical (farthest inland) and geomorphological (along the east–west ridge) characteristics.

Until more data are collected, we hesitate to speculate extensively on the reasons for the early

Table 15. Mean movement rates (targets/h) of probable Hawaiian Petrel targets observed during radar studies on Lana'i, Kaua'i, East Maui, West Maui, and Hawai'i islands during 2001–2007.

Island	Year	Movement rate (targets/h)[1] Mean	Range	No. sites sampled	Source
Lana'i	2007	2.9	0.5–7.1	9	this study
Kaua'i[2]	2001	118	8–569	13	Day et al. (2003b)
East Maui	2001	53	3.6–134	8	Cooper and Day (2003)
West Maui[2]	2001	8.7	0.4–21	6	Cooper and Day (2003)
Hawai'i[2]	2001–2002	2.5	0–25.8	18	Day et al. (2003a)

[1]All rates are total movement rates (i.e., landward + seaward).
[2]Definitely or probably includes Newell's Shearwaters.

seaward movements over the Lana'i study area, but these movements could be related to differences in landward and seaward flight paths into and out of the Lana'ihale colony. For instance, if most birds flew into the colony from the closest shorelines (as seems to be the case on the other islands; Cooper and Day, unpubl. data) but dispersed seaward in a variety of directions (clearly seen on Lana'i), one would expect a pattern of higher seaward movements like those we saw during both late spring and summer 2007. On the other hand, perhaps landward-flying targets flew inland at rates similar to seaward ones throughout the study area but flew at altitudes lower than seaward-flying ones did, making them less likely to be detected by radar; however, that alternative explanation does not explain the extensive seaward movements that we observed in the evening. Radar observations of birds around the perimeter of the island near the colony and, to some extent, around the rest of the island, could be used to answer these questions and to determine better the movement patterns between the inland colony and marine foraging areas. Such a study also could be used to help determine approximate colony size and to determine the proportion of landward and seaward movements that were from/toward the proposed WRA.

FLIGHT ALTITUDES

The mean flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters recorded at all sites and during all times of day and sampling periods was 47 m agl. Further, the mean landward flight altitude of these birds was much lower (34 m agl) than was the mean seaward flight altitude (71 m agl). Thus, mean flight altitudes (especially landward ones) tend to be much lower than the average seen elsewhere in Hawaii: the mean flight of Hawaiian Petrels on Kaua'i, Maui, and Hawai'i combined is 200 m agl (range = 2–1,000 m agl; n = 696 birds; Day and Cooper, unpubl. data). It is possible that the lower flight altitudes on Lana'i could be related to the moderate, gently-sloping terrain between the coast and the low-elevation colony on Lana'ihale and/or to the low-elevation location of the colony itself: these birds nest at much higher elevations on all other islands, so birds there probably have to fly higher because they have a greater climb to the colonies. Another factor that may cause these lower flight altitudes for birds flying inland is the fact that those birds crossing the WRA are flying primarily into a headwind or a quartering headwind, so perhaps they are flying low because they are trying to get down into the boundary layer to reduce the effects of the headwind.

HAWAIIAN BATS

We recorded only one Hawaiian Hoary Bat during 485 sampling sessions. Thus, our data indicate that bats were present in the proposed WRA but occurred there in very low densities during the study period. Hoary Bats are known to occur on all of the Main Hawaiian Islands, including Lana'i (Baldwin 1950, van Riper and van Riper 1982, Tomich 1986, Fullard 1989, Kepler and Scott 1990, Hawaii Heritage Program 1991, David 2002), so our record is not unexpected. More extensive visual and/or acoustic work could be done to provide better information on the distribution and abundance of bats in the WRA, but our data from this study so far suggest that bat numbers will be low.

EXPOSURE INDICES AND FATALITY MODELING

We estimate that ~8–81 Hawaiian Petrels/yr (i.e., exposure rate) will fly within the space occupied by each proposed met tower in the study area and that 5–462 Hawaiian Petrels/yr will fly within the space occupied by each proposed wind turbine in the study area, based on movement-rate data collected during the late June–early July period. We used these estimated exposure rates as a starting point for developing a complete avian risk assessment; however, we emphasize that it currently is unknown whether bird use and fatality at windfarms are strongly correlated. For example, Cooper and Day (1998) found no relationship between movement rates and fatality rates of Hawaiian Petrels and Newell's Shearwaters at powerlines on Kaua'i. Other factors (e.g., weather) could be more highly correlated with fatality rates than is bird abundance. To determine which factors are most relevant, studies such as those that collect concurrent data on movement rates, weather, and fatality rates would be needed to begin to determine whether movement rates and/or weather conditions can be used to predict the likelihood of petrel fatalities at these proposed met towers and the proposed windfarm.

In addition to these questions about the unknown relationships among fatality, weather, and abundance, there also are no hard data available on the proportion of petrels and shearwaters that do not collide with towers or turbines because of collision-avoidance behavior (i.e., birds that alter their flight paths and/or flight altitudes to avoid colliding with these structures); however, see Winkelman (1995), Desholm and Kahlert (2005), and Desholm et al. (2006) for studies of avoidance of wind turbines by waterbirds in Europe. Clearly, the detection of met towers/turbines could alter movement rates, flight paths, and/or flight altitudes of these birds, which, in turn, would reduce the likelihood of collision. In addition, there could be differences among species in their ability to avoid obstacles. For example, Cooper and Day (1998) believed that Hawaiian Petrels have flight characteristics that make them more maneuverable at avoiding powerlines than do Newell's Shearwaters, suggesting that this greater maneuverability also might increase their ability at avoiding towers or turbines.

There is evidence that many species of birds do detect and avoid wind turbines in low-light conditions (Dirksen et al. 1998, Winkelman 1995, Desholm and Kahlert 2005, Desholm et al. 2006), but no petrel-specific data on avoidance of met towers or wind turbines is available. For example, seaducks in Europe have been found to detect and avoid wind turbines >95% of the time (Desholm 2006). Further, natural anti-collision behavior (especially alteration of flight paths) is seen in migrating Common and King eiders (*Somateria mollissima* and *S. fischeri*) approaching human-made structures in the Beaufort Sea off of Alaska (Day et al. 2005b) and in diving ducks approaching offshore windfarms in Europe (Dirksen et al. 1998). Collision-avoidance rates around wind turbines are high for Common Eiders in the daytime (Desholm and Kahlert 2005), gulls (*Larus* spp.) in the daytime (>99%; Painter et al. 1999, cited in Chamberlain et al. 2006), Golden Eagles (*Aquila chrysaetos*) in the daytime (>99%; Madders 2004, cited in Chamberlain et al. 2006), American Kestrels (*Falco sparverius*) in the daytime (87%, Whitfield and Band [in prep.], cited in Chamberlain et al. 2005), and passerines during both the day and night (>99%; Winkelman 1992, cited in Chamberlain et al. 2006). Further, Erickson et al. (2002) suggested that the proportion of nocturnal migrants that detect and avoid turbines must be very high because fatality rates of nocturnal migrants appear "insignificant" relative to nocturnal passage rates of migrating birds. Although Hawaiian Petrels have flight characteristics very different from those of these other species, they are adept at flying through forests near their nests during low-light conditions; hence, it is reasonable to assume that they too have enough visual acuity and maneuverability to help avoid met towers and wind turbines if they see them. Thus, while we agree with others (Chamberlain et al. 2006, Fox et al. 2006) that species-specific and site-specific data are needed in models to estimate fatality rates accurately, we speculate that a high proportion of petrels would detect and avoid large structures under average conditions of weather and visibility. Until petrel-specific data on the relationship between exposure and fatality rates are available, however, we provide a range of assumptions for this variable in our fatality models.

To err on the conservative side, we used a wide range of assumptions about the proportion of petrels and shearwaters that would detect and avoid the proposed met towers (i.e., 0%, 50%, 95%, and 99%) and estimated an annual take of ~7–77 Hawaiian Petrels/tower if 0% of them detect and avoid the met towers; 4–39 if 50% of them detect and avoid the met towers; 1–4 if 95% of them detect and avoid the met towers; and ≤1 if 99% of them detect and avoid the met towers. Obviously, there is a wide range in fatality estimates within each location, but one will be able to refine these estimates only with further research on avoidance behavior at met towers and on the proportion of petrels and shearwaters able to fly close to the met towers without being killed or injured.

Although the actual avoidance rate of wind turbines by petrels is unknown at this time, recent data from the Kaheawa Wind Plant on Maui Island suggests that it is high. After ~1 yr of operation, the recorded (but uncorrected for sampling bias) petrel mortality rate at that 20-turbine windfarm has been 1 Hawaiian Petrel (B. Standley, USFWS, pers.

comm.). Cooper and Day (2004b) modeled seabird fatality for the KWP based on movement rates from radar studies there (Day and Cooper 1999, Cooper and Day 2004a) and estimated that the combined annual fatality of Hawaiian Petrels and Newell's Shearwaters at that site would be ~3–18 birds/yr with a 50% avoidance rate, ~1–2 birds/yr with a 95% avoidance rate, and <1 bird/yr with a 99% avoidance rate. Thus, this data set from 1 yr of operation suggests that the true avoidance rate of petrels around wind turbines is ~95%.

There are several factors that could affect our estimates of exposure and fatality, some in a positive direction and some in a negative direction. One factor that would have increased these estimates was the inclusion of targets that were not petrels or shearwaters. Our visual observations (especially during crepuscular periods, when we could use binoculars) helped to minimize the inclusion of non-target species, but it is possible that some of our radar targets after dark were of other fast-flying species that were active at that time (e.g., Pacific Golden-Plover, Greater Frigatebird).

A second factor that could increase our exposure and fatality estimates was that we collected data during the late incubation period, which is that time when some of the highest counts of the entire breeding season are expected, and then extrapolated those rates across the entire 270-d breeding season. For example, radar counts of petrels and shearwaters on Kaua'i in 1993 were significantly (~3 times) higher in summer (incubation period) than in fall (fledging period; Day and Cooper 1995). The increase in movement rates during incubation and early chick-rearing occurs because of regular visits of breeding birds after hatching and because non-breeders visit the colonies at that time, whereas the fall declines occur because attendance at colonies by non-breeders and failed breeders declines as chick-rearing progresses (Serventy et al. 1971, Warham 1990, Ainley et al. 1997b, Simons and Hodges 1998). We plan to collect data during late fall 2007 to help increase our understanding of this seasonal variation in movement rates on Lana'i Island.

A third factor that would increase our exposure and fatality estimates is that petrels may enter and leave the colony by different routes, as suggested above. Our radar data suggest that petrels are flying inland over the WRA in lower numbers than are petrels flying seaward. Because the risk-assessment modeling assumed that the number flying inland over the WRA balanced the number flying seaward, we took the midpoint between the percentage of inland-flying and seaward-flying petrels that were flying low enough to hit a proposed met tower (87.0% and 41.7%, respectively) or turbine (95.7% and 91.7%, respectively) in the modeling exercise. If, however, more birds were flying seaward than inland because most birds flew inland farther east (out of the WRA), the true vertical interaction probability would be closer to the lower value than to the midpoint. Because we suspect that petrels may be flying into and out of the colony by different routes (see above), our modeling probably overestimates the true fatality rate.

A factor that would decrease our exposure and fatality estimates is if inland-flying targets were missed because they flew low to the ground, within radar shadows. The sites generally were excellent from a radar-sampling perspective, but we know that we missed some targets on radar because of the unusually low flight altitudes of petrels on Lana'i: the mean flight altitude was only 47 ± 8 m agl, or much lower than a mean flight altitude of 200 m agl for all of the other Main Hawaiian Islands combined (Day and Cooper, unpubl. data). For example, ~63% of the 35 birds observed visually in the present study were not detected on radar, suggesting that many were flying too low for the radar to detect them. In contrast, only 9 of the 121 radar targets that passed within 250 m of the visual observer were observed by the visual observer, even though the radar operator alerted the visual observer to the approach of these targets. Thus, the radar and visual techniques are sampling only partially-overlapping subsets of birds, making it problematic to calculate a valid correction factor for the percentage of low-flying targets that the radar might have missed.

A second factor that would decrease our exposure and fatality estimates is if some of the peak morning-movement period occurred before sampling began at 0400. Although our evening and morning sampling periods correspond to the evening and morning peaks of movement for these birds at other islands (Day and Cooper 1995), we noticed on Lana'i that some birds were flying seaward, even in the half-hour before observations began at 0400, suggesting that the peak morning movement out of the colony already had begun before our sampling started. To account in the fatality model for this unexpected-early morning exodus, we expanded our peak morning movement rates to 3 h (i.e., 0300–0600), rather than just to the 2-h sampling window (i.e., 0400–0600) when sampling occurred. Clearly, some all-night radar sampling on Lana'i would help us refine our understanding of the movement patterns of petrels during the middle of the night.

A factor that could affect our exposure and fatality estimates in either direction is interannual variation in counts. For example, counts on Kaua'i were four times lower in fall 1992 than in fall 1993, with the lower counts in 1992 being attributed to the effects of Hurricane Iniki, one of the strongest hurricanes ever to hit the Hawaiian Islands (Day and Cooper 1995). In addition, oceanographic factors (e.g., El Niño–Southern Oscillation events) also vary among years and are known to affect the distribution, abundance, and reproduction of seabirds (e.g., Ainley et al. 1994, Oedekoven et al. 2001).

A final factor affecting exposure indices involves marking of the proposed met towers and guy wires with white flagging to make them more visible to flying Hawaiian Petrels. This flagging has been found to be effective in reducing collisions of Hawaiian Petrels with ungulate fences near breeding colonies on Hawai'i Island, both because Hawaiian Petrels see flagged structures more easily and because they see them at greater distances, allowing more time for collision avoidance to occur (Swift 2004). Anecdotal information from the petrel colony on Lana'i also suggests that white flagging on ungulate fences there are effective in reducing collisions of petrels with the fence (J. Penniman, DOFAW, pers. comm.). We see no reasons why Hawaiian Petrels' ability to see white-flagged met towers should differ from their ability to see white-flagged fences, so we encourage marking of the towers and guy wires to increase their visibility to these birds and, thus, to increase the birds' anti-collision behavior.

CONCLUSIONS

Although the number of Hawaiian Petrels that might be killed by collision with the proposed met towers and turbines on Lana'i is unknown, we have used our risk-assessment model to approximate their potential fatality rates. The model is affected by all of the input variables; however, the collision-avoidance rate variable has both a very large effect on modeled estimates and also is one of the most poorly understood variables at this time. It will take nocturnal behavioral sampling to understand how these birds will behave around met towers and wind turbines in this proposed windfarm. There is a body of evidence that indicates that a high percentage of birds see and avoid structures (see above), and the limited data from the Maui windfarm suggest that avoidance rates will be high. We suspect that Hawaiian Petrels also have good nocturnal eyesight, given the fact that they must be able to see well to get to and from their burrows. Consequently, we suspect that there will be natural anti-collision behavior as they approach these structures, although the true rate of avoidance is unknown at this time. The fact that many petrels move while there is still light in the sky also will enhance their anti-collision behavior. Finally, we believe that marking the met towers and guy wires to make them more visible to petrels also will increase anti-collision behavior and decrease risk. Hence, we believe that the proportion of petrels that see and avoid the proposed met towers and turbines will be high and will be enhanced by marking but emphasize that, until studies to measure avoidance behavior at marked structures are conducted, that proportion will remain unknown.

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