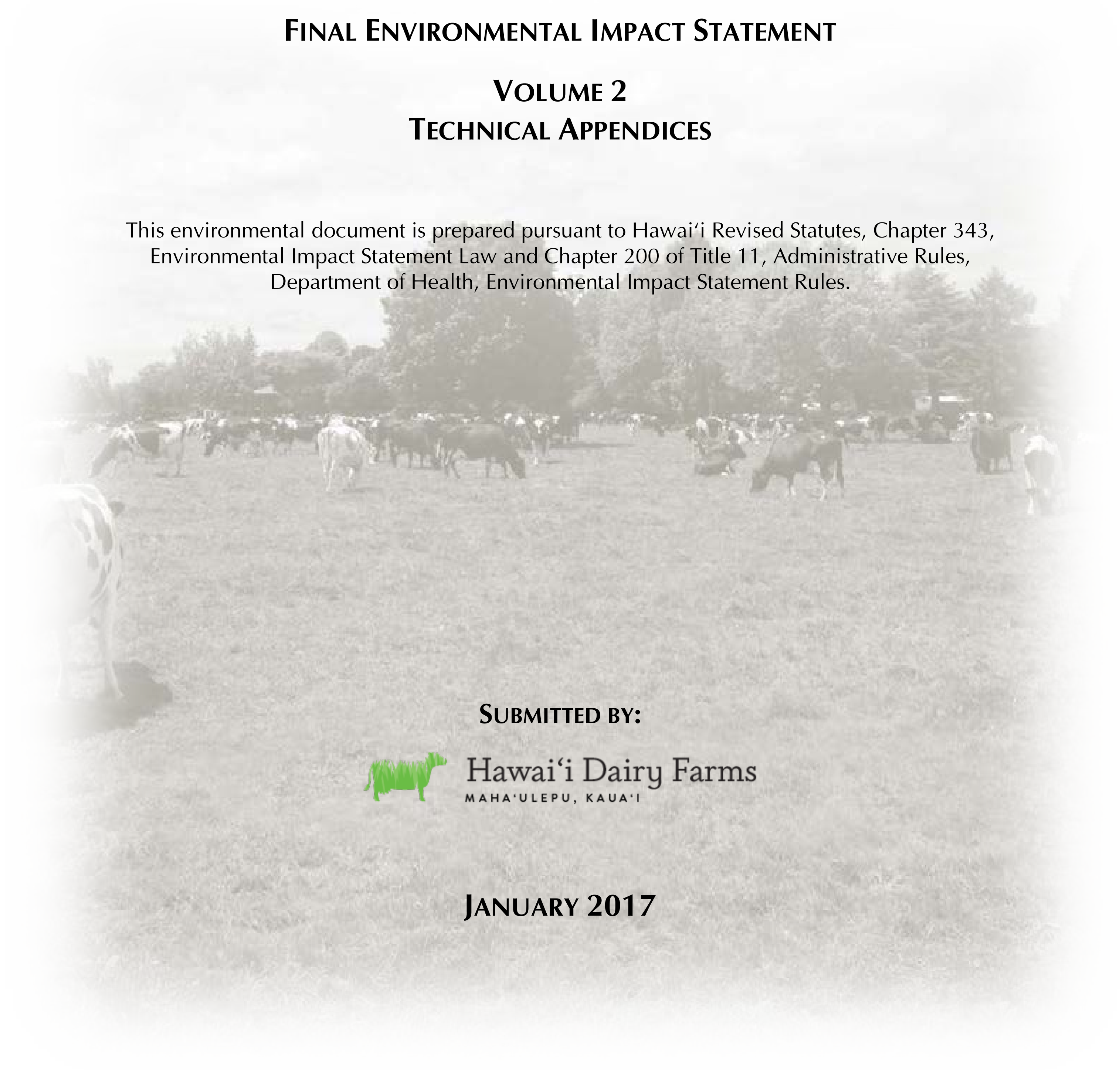
HAWAIʻI DAIRY FARMS

FINAL ENVIRONMENTAL IMPACT STATEMENT

VOLUME 2
TECHNICAL APPENDICES

This environmental document is prepared pursuant to Hawaiʻi Revised Statutes, Chapter 343, Environmental Impact Statement Law and Chapter 200 of Title 11, Administrative Rules, Department of Health, Environmental Impact Statement Rules.



SUBMITTED BY:

Hawaiʻi Dairy Farms
MAHAʻULEPU, KAUAʻI

JANUARY 2017

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PREPARED BY:

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FINAL ENVIRONMENTAL IMPACT STATEMENT
LIST OF VOLUMES

VOLUME

VOLUME 2 - TABLE OF CONTENTS

LIST OF TECHNICAL APPENDICES

APPENDIX

APPENDIX A

FLORA AND FAUNA SURVEYS CONDUCTED FOR THE KAUAI DAIRY FARMS PROJECT MĀHĀ‘ULEPŪ, ISLAND OF KAUA‘I, HAWAI‘I

RANA BIOLOGICAL CONSULTING
AECOS CONSULTANTS

Flora and Fauna Surveys Conducted for the Kauai Dairy Farms Project, Māhāʻulepū, Island of Kauaʻi, Hawaiʻi

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Table of Contents

Introduction and Background

In late 2013, Ulupono Initiative made the investment to fund Hawaii Dairy Farms, the first pasture-based rotational-grazing dairy in the state. Hawaii Dairy Farms LLC (HDF) was formed as a positive step towards the island state's food security, economic diversity and sustainability. Experimental trials were conducted to determine lands capable of growing nutritous forage for dairy cows, and lands meeting the operational requirements for a dairy operation were identified. Kaua'i was determined to best meet the operational requirements, and Māhā'ulepū Valley was found to provide ideal grass growing conditions.

At steady-state production with 699 milking cows, the farm will produce roughly 1.2 million gallons annually at market price. HDF will reduce Hawaii's reliance on imported milk from the mainland United States by increasing current fresh local milk production by approximately 33 percent. The farm will be based on the most successful island dairy models in the world, and will utilize a sustainable, pasture-based rotational-grazing system and 21st century technology. The farm will be very different from conventional feedlot dairy operations.

HDF is committed to establishing a herd of up to 699 mature dairy cows, and demonstrating the pasture-based system as an economically and environmentally sustainable model for Hawai'i. With proven success at a herd size of 699, HDF will contemplate the possibility of expanding the herd in the future. Precision agricultural technology that monitors cows' health, grass productivity, and effluent management will be used to ensure environmental health and safety, as well as best management practices, and help determine the ultimate carrying capacity of the land.

For dairy operations with 700 or more mature dairy cows, additional regulatory review and permitting by the State Department of Health is required. The application process for a National Pollutant Discharge Elimination System (NPDES), Concentrated Animal Feeding Operation (CAFO) permit includes public notification and input. At the discretion of HDF, management may choose to expand operations up to the carrying capacity of the land, which is currently estimated to be up to 2,000 productive milking dairy cows. Permit process compliance would be followed at such time that HDF may decide to pursue an expanded operation.

The project site is located on approximately 557 acres identified as TMK: (4) 2-9-003: 001 por. and 006 por. and (4) 2-9-001: 001 por. Located in Māhā'ulepū Valley (Figure 1).

This report describes the methods used and the results of the botanical, avian and terrestrial mammalian surveys conducted on the project site as part of the environmental disclosure process associated with the proposed project.

The primary purpose of the surveys was to determine if there are any botanical, avian and terrestrial mammalian species currently listed, or proposed for listing under either federal or State of Hawai'i endangered species statutes within or adjacent to the study area. We were also asked to evaluate the potential impacts that the development of the project might pose to any sensitive or protected native botanical, avian or mammalian species, and to propose appropriate minimization measures that could be implemented to reduce or eliminate any such impacts. The federal and State of Hawaiʻi listed species status follows species identified in the following referenced documents, (Hawaii Department of Land and Natural Resources (HDLNR) 1998, U. S. Fish & Wildlife Service (USFWS) 2005a, 2005b, 2014a). Fieldwork was conducted on August 20 and 21, 2014.

Hawaiian and scientific names are italicized in the text. A glossary of technical terms and acronyms used in the document, which may be unfamiliar to the reader, are included at the end of the narrative text.

General Site Description

The project area was historically used for sugar cane production as part of the Kōloa Plantation until the late 1990s when the Kōloa Mill closed. Since the mill closure, the project area has been leased to various tenants for ranching and diversified agricultural operations. A small plot of land in the lower center of the valley is currently used for mixed agriculture, including taro *loʻi*, and will continue to be leased and farmed separate from the dairy and related pastures.

The original sugar cane agricultural infrastructure is largely still in place and continues to be used for on-going agricultural activities. Much of this existing infrastructure will also be used for the dairy, but with significant upgrades and improvements. The existing infrastructure in the project area includes: gravel access roads, field roads, water wells, reservoirs, pipelines, pumps, irrigation ditches, drainage ways and culverts.

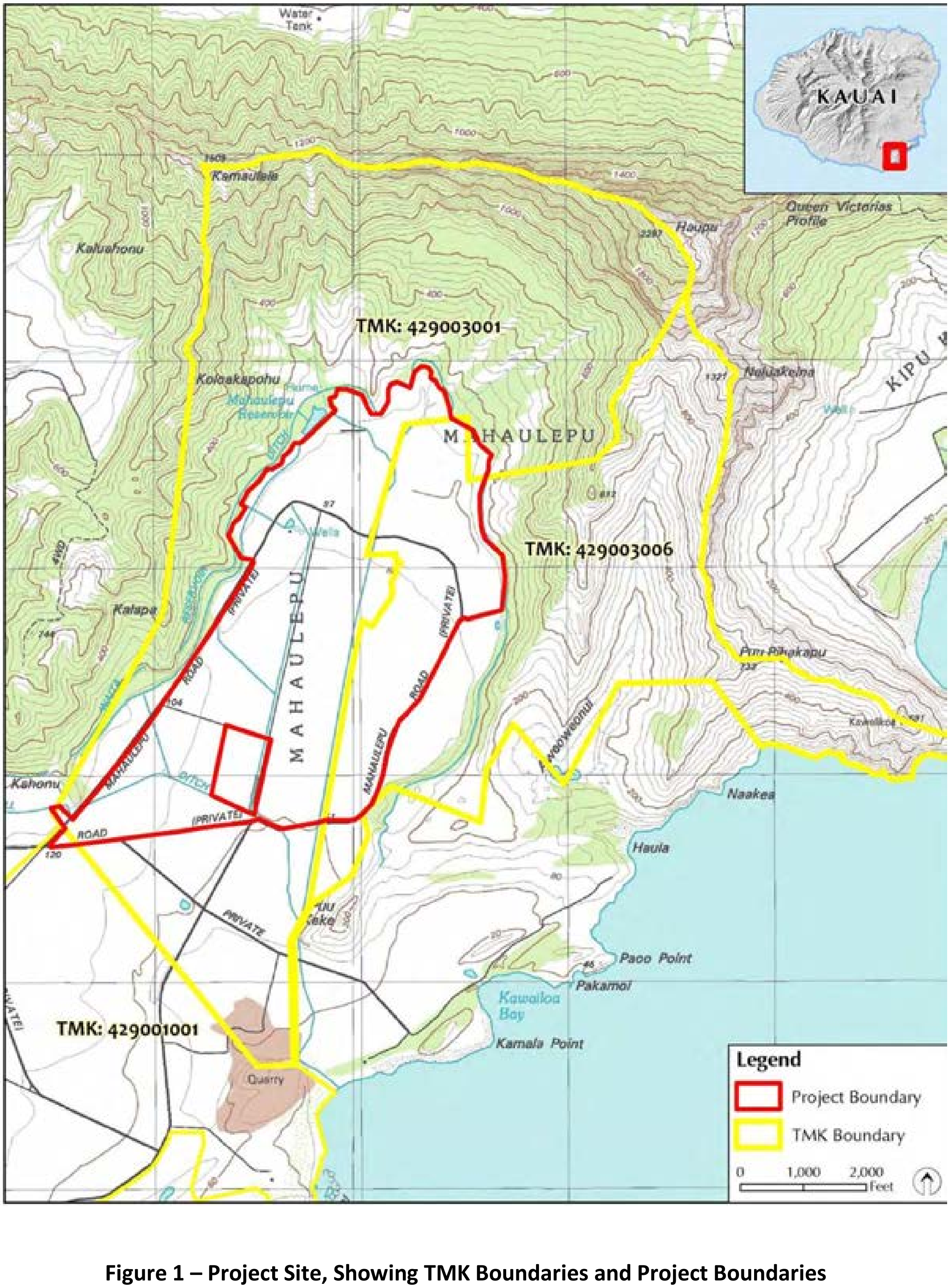

Figure 1 – Project Site, Showing TMK Boundaries and Project Boundaries

As previously mentioned the project site is situated in the Māhāʻulepū Valley on the island of Kaua'i. The valley is on the leeward side of the Hāʻupu mountain ridge, which runs in the east-west direction, and the valley is flanked by ridgelines. Mt. Hāʻupu (Fig. 3) is the highest point on the ridgeline at the back of the valley reaching an elevation of 700 meters above mean sea level (AMSL). From this point, the ground drops away very quickly down to the bottom of the valley to an elevation of approximately 45 meters AMSL. The base of the valley itself gradually slopes from an elevation of approximately 45 meters AMSL down to an elevation of approximately 18 meters AMSL along Māhāʻulepū Road on the *makai* side of the project site near the taro farm.

Vegetation on the site is best categorized as pasture land (Figures 2 and 3).

Figure 2 - Māhāʻulepū Valley looking south from the northern crossroad showing typical pasture land.

Figure 3 - Māhāʻulepū Valley looking north to Hāʻupu peak from the central road showing typical pasture land and valley walls

Methods

Botanical Survey

Plant names mostly follow the *Manual of the Flowering Plants of Hawaiʻi* (Wagner et al., 1990, 1999) for native and naturalized flowering plants, *A Tropical Garden Flora* (Staples and Herbst, 2005) for crop and ornamental plants, and *Hawaiʻi's Ferns and Fern Allies* for ferns (Palmer, 2003). Some plant species names have been updated following more recently published literature as summarized in Imada (2012).

The botanical survey involved a wandering pedestrian transect method that traversed all parts of the property within the designated survey area (Figure 1). A wandering survey is standard methodology for plant surveys of specific parcels of land as it is superior to fixed, linear transects at discovering rare plant species. A hand-held, global navigation satellite system (GNSS) unit (Trimble, 6000 Series GeoXH) was used to record the progress of the botanist and provide real-time feedback on coverage of the survey area. Plant species were identified as they were encountered and field notations used to develop a qualitative sense of abundance as the survey progressed. For a few species not immediately recognized in the field, photographs were taken and/or material collected for identification in the laboratory.

The survey period represents the dry season in Hawaiʻi. Although Kauaʻi was at 87% of normal rainfall for the months of June-August 2014, these values may not reflect conditions along the south coast where the vegetation in the survey area appeared healthy and well-watered during the survey period (rainfall received appeared to be above normal for a dry season).

Avian Survey Methods

The avian phylogenetic nomenclature used in this report follows the *AOU Check-List of North American Birds* (American Ornithologists' Union, 1998), and the 42nd through the 55th supplements to the Check-List (American Ornithologists' Union, 2000; Banks et al., 2002, 2003, 2004, 2005, 2006, 2007, 2008; Chesser et al., 2009, 2010, 2011, 2012, 2013, 2014). Mammalian species scientific names follow (Wilson and Reeder, 2005). Place names follow (Pukui et al., 1976).

A total of 28 avian point count stations were sited approximately 300 meters apart along four linear transects running the length of the project site within Māhāʻulepū Valley. The transects ran roughly in a north-to–south direction. Six-minute point counts were made at each of the count stations. Each station was counted once. Field observations were made with the aid of Leica 8 X 42 binoculars and by listening for vocalizations. Point counts were concentrated during the early morning hours, the peak of daily bird activity. Time not spent at point count stations was used to search the remainder of the project site for species and habitats that were not detected during count sessions.

Mammalian Survey Methods

With the exception of the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*), or *ʻōpeʻapeʻa* as it is known locally, all terrestrial mammals currently found on the Island of Kauaʻi are alien species, and most are ubiquitous. The survey for terrestrial mammalian species was limited to visual and auditory detection, coupled with visual observation of scat, tracks, and other animal sign. A running tally was kept of all terrestrial vertebrate mammalian species detected within the project area during time spent within the project site.

Results

Botanical Survey

Vegetation

The proposed Kauai Dairy farms project site is presently nearly all pastureland. The pastures vary between recently tilled and various states of weedy regrowth. No active grazing was observed. Consequently, while many of the pastures are a mix of open ground and weedy growth, others are densely overgrown with grasses and other herbaceous plants. Trees are few and scattered, mostly along waterways on the property. Along the edges of the survey area, on the east, north, and west, the sloping land is forested. Since nearly all of this forest is out of the survey area, it was visited at numerous points along the margin but not entered for any significant distance (generally only as far as the old circum-valley *ʻauwai*). Thus, the vegetation within the project area is herbaceous and typical of regularly disturbed land (i.e., agricultural).

Flora

"Flora" refers to the species diversity of plants growing in the survey area. A plant checklist (Table 1) was compiled from field observations, with entries arranged alphabetically under plant family names (standard practice). Included in the list are scientific name, common name, and status (for example, whether native or non-native, naturalized or ornamental) for each species observed during the survey.

Qualitative estimates of plant abundance were recorded for each species. Abundance values are coded in the table as explained in the Legend to Table 1. For some species, a two-level system of abundance is used; with a letter-number code indicating a species having a somewhat clustered distribution. For example, a species infrequently encountered but numerous where found would have an abundance rating of "R" indicating a plant encountered only one to three times during the entire survey of the site, but an "R2" to indicate several to many individuals present where encountered. An "R3" would be a plant similarly seldom encountered (i.e., rare), but numerous in one or more of the locations where encountered. A species marked "O3" would be one seen with some regularity, usually occurring in patches of numerous individuals (as opposed to "C" for a species seen with regularity throughout the survey area). For abundances C or A, attached numbers are an indication of a patchy distribution: “C3” would be a species generally common (regularly encountered), but especially numerous in patches.

The note “<1>” indicates a species always observed around the margin of the survey area. For most of these species, the recorded occurrences are close to or actually outside the survey area boundary. Consequently, the abundance values are more indicative of the vegetation immediately off the property. For example, all of the ferns recorded are marked with “<1>”. None of these was seen within the survey area; all occurred along dry stream beds immediately off the property, so close to the boundary that the species is clearly representative of the lands surrounding the pasture lands. Eighteen species (15.6%) of the total species fall into this “category” of being mostly representative of the lands outside of the survey area. This percentage is fairly large and reflects the stark contrast between the forested slopes beyond the project area and the project area pastures.

Table 1 – Flora for Kauaʻi Dairy Farms, August 2014

Species by Family	Common name	Status	Abundance	Notes
FERNS and FERN ALLIES				
BLECHNACEAE				
Blechnum appendiculatum Willd.	---	Nat	R	<1>
POLYPODIACEAE				
Phymatosorus grossus (Langsd. & Fisch.) *Brownlie*	*lauae*	Nat	U	<1>
PSILOTACEAE				
Psilotum nudum (L.) P. Beauv.	*moa*	**Ind**	R	<1>
THELYPTACEAE				
Christells dentata (Forssk.) Brownsey & Jermy	wood fern	Nat	R	<1>
GYMNOSPERMS				
ARAUCARIACEAE				
Araucaria columnaris (G. Forst.) J. D. Hook.	Cook-pine	Nat	R	<1>
FLOWERING PLANTS				
DICOTYLEDONS				
ACANTHACEAE				
Thunbergia fragrans Roxb.	sweet clockvine	Nat	U	
AMARANTHACEAE				
Achyranthes aspera L.	---	Nat	R	<2>
Alternanthera pungens Kunth	khaki weed	Nat	O2	

Amaranthus viridis L.	slender amaranth	Nat	U	
Amaranthus spinosus L.	spiny amaranth	Nat	U	
Gomphrena celosioides Mart.	---	Nat	R	
ANACARDIACEAE				
Schinus terebinthifolius Raddi	Christmas berry	Nat	C1	<1>
ASTERACEAE (COMPOSITAE)				
Ageratum conyzoides L.	*maile hohono*	Nat	R	<2>
Bidens pilosa L.	*ki*	Nat	R	
Conyza bonariensis (L.) Cronq.	hairy horseweed	Nat	R	
Elephantopus mollis Kunth	---	Nat	U1	<1,2>
Emilia fosbergii Nicolson	Flora's paintbrush	Nat	U	
Lactuca serriola L.	prickly lettuce	Nat	R	
Parthenium hysterophorus L.	false ragweed	Nat	AA	
Pluchea carolinensis (Jacq.) G. Don	sourbush	Nat	U	
Sonchus oleraceus L.	sow thistle	Nat	R	
Xanthium strumarium L.	*kīkānia*	Nat	AA	
BRASSICACEAE				
Lepidium virginicum L.	---	Nat	C	
CACTACEAE				
Cereus uruguayanus Ritter ex R. Kliesling	hedge cactus	Nat	R	
CONVOLVULACEAE				
Ipomoea obscura (L.) Ker-Gawl.	---	Nat	U	
Ipomoea triloba L.	little bell	Nat	AA	
CUCURBITACEAE				
Momordica charantia L.	wild bitter melon	Nat	O	
Cucumis dipsaceus Ehrenb. ex Spach	teasil gourd	Nat	U	
EUPHORBIACEAE				
Euphorbia albomarginata Small	rattlesnake weed	Nat	C	
Euphorbia hirta L.	garden spurge	Nat	O2	
Euphorbia hypericifolia L.	graceful spurge	Nat	A	
Euphorbia prostrata Aiton	prostrate spurge	Nat	O	
Euphorbia heterophylla L.	kaliko	Nat	R	
Phyllanthus debilis Klein ex Willd.	*niuri*	Nat	A	
Ricinis communis L.	castor bean	Nat	A1	
FABACEAE				
Acacia farnesiana (L.) Willd.	*klu*	Nat	O	
Caesalpinia sp.	wait-a-bit	Nat?	R	<1,2>
Canavalia cathartica Thours	*maunaloa*	Nat	A	
Chamaecrista nictitans (L.) Moench	partridge pea	Nat	C	
Crotalaria incana L.	fuzzy rattlepod	Nat	AA	
Crotalaria pallida Aiton	smooth rattlepod	Nat	R	
Desmanthus pernambucanus (L.) Thellung	virgate mimosa	Nat	A	
Desmodium incanum DC.	Spanish clover	Nat	C	
Desmodium trifolium (L.) DC.	---	Nat	O	
Indigofera hendecaphyla Jacq.	creeping indigo	Nat	C	

Indigofera suffruticosa Mill.	indigo	Nat	O	
Leucaena leucocephala (Lam.) deWit	*koa haole*	Nat	C	
Macroptilium atropurpureum (DC.) Urb.	---	Nat	O	
Macroptilium lathyroides (L.) Urb.	cow pea	Nat	A	
Mimosa pudica L.	sensitive plant	Nat	AA	
Senna occidentalis (L.) Link	coffee senna	Nat	O	
Senna surattensis (N.L. Burm.) H. Irwin & Barneby	*kolomana*	Nat	R	<1>
LAMIACEAE				
Leonotis nepetifolia (L.) R.Br.	lion's ear	Nat	A	
LYTHRACEAE				
Cuphea carthagenensis (Jacq.) Macbr.	tar weed	Nat	R	
MALVACEAE				
Abutilon grandifolium (Wild.) Sweet	hairy abutilon	Nat	U	
Malvastrum coromandalianum (L.) Garcke	false mallow	Nat	A	
Sida acuta N. L. Burm.	---	Nat	U	
Sida fallax Walp.	*'ilima*	Ind	R	
Sida rhombifolia L.	Cuba jute	Nat	A	
Sida spinosa L.	prickly sida	Nat	AA	
Waltheria indica L.	*'uhaloa*	**Ind**	U	
MYRTACEAE				
Psidium cattleianum Sabine	strawberry guava	Nat	U	
Psidium guajava L.	commom guava	Nat	U	
Rhodomyrtus tomentosa (Aiton) Hassk.	downy myrtle	Nat	R	<1>
Syzygium cumini (L.) Skeels.	Java plum	Nat	A	
NYCTAGINACEAE				
Boerhavia coccinea Mill.	false *alena*	Nat	U	
ONAGRACEAE				
Ludwigia octovalvis (Jacq.) Raven	primrose willow	Nat	C3	
POLGALACEAE				
Polygala paniculata L.	bubblegum plant	Nat	R2	
PORTULACACEAE				
Portulaca pilosa L.	---	Nat	U1	
Portulaca oleracea L.	pigweed	Nat	U	
RUBIACEAE				
Paederia foetida L.	*maile pilau*	Nat	U	<1>
Spermacoce assurgins Ruiz & Pav.	buttonweed	Nat	U	
SAPINDACEAE				
Cardiospermum halicacabum L.	balloon vine	Nat	U	
SOLANACEAE				
Solanum americanum P. Miller	*pōpolo*	Pol	R	
Solanum seaforthianum Andr.	---	Nat	R	<1>
TILIACEAE				
Triumfetta cf. semitriloba Jacq.	Sacramento bur	Nat	A	<2>
VERBENACEAE				
Lantana camara L.	lantana	Nat	U	

Stachytarpheta australis Moldenke	---	Nat	A	
Stachytarpheta cayennensis (Rich.) Vahl	nettle-leaved vervain	Nat	U	

MONOCOTYLEDONS

ALISMATACEAE				
Sagittaria latifolia Willd.	common arrowhead	Nat	R	
CYPERACEAE				
Cyperus cf. *difformis* L.	---	Nat	R	
Cyperus rotundus L.	nut grass	Nat	A	
Cyperus polystachyos Rottb.	---	Ind	U2	
Fimbristylis dichotoma (L.) Vahl.	---	Ind	R	
Fimbristylis miliacea (L.) Vahl.	---	Nat	O3	
Kylinga brevifolia Rottb.	*kili'o'opu*	Nat	R	
LILIACEAE				
Hymenocallis pedalis Herbert	spider lily	Orn	R1	<1>
PANDANACEAE				
Pandanus textorius S. Parkinson ex Z	*hala*	Ind	R	<1>
POACEAE (GRAMINEAE)				
Andropogon virginicus L.	broomsedge	Nat	U2	
Axonopus compressus (Sw.) P. Beauv.	brd-lvd carpetgrass	Nat	R1	
Axonopus fisifolius (Raddi) Kuhlm.	nrw-lvd carpetgrass	Nat	U	
Chloris barbata (L.) Sw.	swollen fingergrass	Nat	O2	
Chloris radiata (L.) Sw.	radiate fingergrass	Nat	R	
Cymbopogon refractus (R. Br.) A. Camus	barbwire grass	Nat	R	<1>
Cynodon dactylon (L.) Pers.	Bermuda grass	Nat	O	
Dichanthium cf. *aristatum* (Poir.) Hubb.	Wilder grass	Nat	R	<1,2>
Digiteria ciliaris (Retz.) Koeler	Henry's crabgrass	Nat	O	
Digitaria violascens Link	violet crabgrass	Nat	U2	
Echinochloa colona (L.) Link	jungle-rice	Nat	C	<1>
Echinochloa crus-galli (L.) P. Beauv.	barnyard grass	Nat	O1	
Eleusine indica (L.) Gaertn.	wiregrass	Nat	A	
Eragrostis pectinacea (Michx.) Nees	Carolina lovegrass	Nat	O	
Eragrostis tenella (L.) P. Beauv. ex Roem. & Schult.	lovegrass	Nat	R	
Melinus repens (Willd.) Zizka	Natal redtop	Nat	R	<1>
Oplismenus hirtellus (L.) P. Beauv.	basketgrass	Nat	U2	<1>
Paspalum conjugatum P.J. Bergius	Hilo grass	Nat	U1	<1>
Paspalum fimbriatum Kunth	fimbriate paspalum	Nat	U	
Paspalum dilatatum Poir.	Dallis grass	Nat	U2	
Paspalum urvillei Steud.	Vasey grass	Nat	U3	
Sporobolis cf. africanus (Poir.) Robyns &Tournay	smutgrass	Nat	A	
Urochloa maxima (Jacq.) Webster	Guinea grass	Nat	AA	
Urochloa mutica (Forssk.) Nguyen	California grass	Nat	AA	
Urochloa distachya (L.) Nguyen	---	Nat	U	

Legend to Table 1

Status = distributional status

End = endemic; native to Hawaiʻi and found naturally nowhere else.

Ind = indigenous; native to Hawaiʻi, but not unique to the Hawaiian Islands.

Nat = naturalized, exotic, plant introduced to the Hawaiian Islands since the arrival of Cook Expedition in 1778, and well-established outside of cultivation.

Orn = exotic, ornamental or cultivated crop; plant not naturalized (not well-established outside of cultivation, at least at this location).

Pol = Polynesian introduction; brought to the Hawaiian Islands before 1778.

Abundance = occurrence ratings for plants on property in August 2014.

R – Rare - seen in only one to three locations and only one or a few plants present.

U - Uncommon – generally rare, but seen in several locations.

O - Occasional - found regularly, but not abundant anywhere.

C - Common - regularly encountered in many areas; some places may be locally abundant.

A – Abundant; present in large numbers in many places in the survey area.

AA – Abundant; a dominant species.

Notes:

<1> Seen only at margins or just off property; associated with forest border.

<2> Plant lacking fruit or flowers and therefore identification may be uncertain.

In all, 115 species[1] of plants were identified from various parts of the survey area. Only 5 of these (or 4.3%) are native Hawaiian species, all of these are considered indigenous (native to Hawaiʻi and other Pacific Islands, as opposed to endemic species that are unique to the Hawaiian Islands). All of the remainder (110 species) are naturalized species, save one regarded as an ornamental. Naturalized species are plants introduced into the Hawaiian Islands that have spread on their own and many now dominate the lowlands of all the Islands.

A somewhat unusual aspect of the flora is the abundance of a number of weedy herbaceous dicots in the fields. Species, such as false ragweed (*Parthenium hysterophorus*), *kikānia* (*Xanthium strumarium*), little bell (*Ipomoea triloba*), fuzzy rattlepod (*Crotalaria incana*), sensitive plant (*Mimosa pudica*), and prickly sida (*Sida spinosa*), are especially abundant covering large areas of relatively recently disturbed pastureland. Guinea grass (*Urochloa maxima*) and California grass (*Urochloa mutica*) are dominate in areas where the pasture has not been disturbed recently by tilling or ungulate browsing, and are abundant mixed with the dicot herbs just mentioned. There are pasture areas where other species of grass predominate.

[1] Includes a vine and a grass, each seen only once, and not identifiable (not included in Table 1).

Avian Survey Results

A total of 1070 individual birds of 31 species, representing 23 separate families, were recorded during station counts (Table 2). Of the 31 species detected during station counts, seven are native species. Four of which, Nēnē (*Branta sandvicensis*), Hawaiian Duck (*Anas wyvilliana*), and the Hawaiian sub-species of the Common Gallinule (*Gallinula galeata sandvicensis*) and Black-necked Stilt (*Himantopus mexicanus knudseni*) are listed as endangered under both federal and State of Hawaiʻi endangered species statutes, the remaining three native species detected during point counts, Black-crowned Night-Heron (*Nycticorax nycticorax hoactli*), Pacific Golden-Plover (*Pluvialis fulva*), and Wandering Tattler (*Tringa incana*) are indigenous species. The heron is an indigenous resident breeding species and the plover and tattler are indigenous migratory shorebird species. An additional endangered endemic species, Hawaiian Coot (*Fulica alai*) was recorded as an incidental observation while transiting from one count station to another. The remaining 27 avian species detected are alien to the Hawaiian Islands (Table 2).

Table 2 – Avian Species Detected Kauaʻi Dairy Farms, August 2014

Common Name	***Scientific Name***	***ST***	***RA***
	ANSERIFORMES		
	ANATIDAE - Ducks, Geese & Swans		
	Anserinae - Geese & Swans		
Hawaiian Goose	*Branta sandvicensis*	ER	0.25
	Anatinae - Ducks		
Hawaiian Duck	*Anas wyvilliana*	ER	0.89
	PHASIANIDAE - Pheasants & Partridges		
	Phasianinae - Pheasants & Allies		
Black Francolin	*Francolinus francolinus*	A	0.46
Red Junglefowl	*Gallus gallus*	A	1.14
Ring-necked Pheasant	*Phasianus colchicus*	A	0.18
	PELECANIFORMES		
	ARDEIDAE - Herons, Bitterns & Allies		
Cattle Egret	*Bubulcus ibis*	A	5.21
Black-crowned Night-Heron	*Nycticorax nycticorax hoactli*	IR	0.11
	GRUIFORMES		
	RALLIDAE - Rails, Gallinules and Coots		
Common Gallinule	*Gallinula galeata sandvicensis*	**ER**	0.18
Hawaiian Coot	*Fulica alai*	**ER**	**I-4**

	CHARADRIIFORMES		
	RECURVIROSTRIDAE - Stilts & Avocets		
Black-necked Stilt	*Himantopus mexicanus knudseni*	ER	0.32
	CHARADRIIDAE - Lapwings & Plovers		
	Charadriinae - Plovers		
Pacific Golden-Plover	*Pluvialis fulva*	IM	0.14
	SCOLOPACIDAE - Sandpipers, Phalaropes & Allies		
	Scolopacinae - Sandpipers & Allies		
Wandering Tattler	*Tringa incana*	IM	0.04
	COLUMBIFORMES		
	COLUMBIDAE - Pigeons & Doves		
Rock Pigeon	*Columba livia*	A	0.04
Spotted Dove	*Streptopelia chinensis*	A	2.18
Zebra Dove	*Geopelia striata*	A	6.82
	STRIGIFORMES		
	TYTONIDAE - Barn Owls		
Barn Owl	*Tyto alba*	A	0.04
	PSITTACIFORMES		
	PSITTACIDAE - Lories Parakeets, Macaws & Parrots		
	Psittacinae - Typical Parrots		
Rose-ringed Parakeet	*Psittacula krameri*	A	1.75
	PASSERIFORMES		
	ALAUDIDAE - Larks		
Sky Lark	*Alauda arvensis*	A	0.04
	CETTIIDAE - Cettia Warblers & Allies		
Japanese Bush-Warbler	*Cettia diphone*	A	0.04
	ZOSTEROPIDAE - White-eyes		
Japanese White-eye	*Zosterops japonicus*	A	3.43
	TIMALIIDAE - Babblers		
Chinese Hwamei	*Garrulax canorus*	A	2.04
	TURDIDAE - Thrushes		
White-rumped Shama	*Copsychus malabaricus*	A	0.25
	MIMIDAE - Mockingbirds & Thrashers		
Northern Mockingbird	*Mimus polyglottos*	A	0.14
	STURNIDAE - Starlings		
Common Myna	*Acridotheres tristis*	A	4.21
	THRAUPIDAE - Tanagers		
Red-crested Cardinal	*Paroaria coronata*	A	0.50
	CARDINALIDAE - Cardinals Saltators & Allies		
Northern Cardinal	*Cardinalis cardinalis*	A	0.61
	ICTERIDAE - Blackbirds		
Western Meadowlark	*Sturnella neglecta*	A	0.18
	FRINGILLIDAE - Fringilline and Carduline Finches &		

	Allies Carduelinae - Carduline Finches and Hawaiian Honeycreepers		
House Finch	*Haemorhous mexicanus*	A	2.96
	ESTRILDIDAE - Estrildid Finches		
Common Waxbill	*Estrilda astrild*	A	0.64
Red Avadavat	*Amandava amandava*	A	2.25
Scaly-breasted Munia	*Lonchura punctulata*	A	0.25
Chestnut Munia	*Lonchura atricapilla*	A	0.93

Legend to Table 2

ST = Status
A = Alien – Introduced to the Hawaiian Islands by humans
ER = Endemic, endangered species, unique to the Hawaiian Islands and listed as an endangered species
IR = Indigenous resident species, native but not unique to the Hawaiian Islands.
IM = Indigenous Migratory species, native migratory species, not unique to the Hawaiian Islands
RA = Relative Abundance, number of birds counted divided by the number of stations (n~28)

Avian diversity and densities were in keeping with the location of the property and the habitats presently on the site. Four species, Zebra Dove (*Geopelia striata*), Cattle Egret (*Bulbucus ibis*), Common Myna (*Acridotheres tritis*) and Japanese White-eye (*Zosterops japonicus*) accounted for 52% of all birds recorded during station counts. The most commonly recorded species was Zebra Dove, which accounted for 18 percent of the total number of individual birds recorded. An average of 38 individual birds was recorded per station count; a number that is relatively high for a lowland site on Kauaʻi.

Mammalian Survey Results

We recorded six terrestrial mammalian species while on the site (Table 3). A small herd of cows (*Bos taurus*) were seen within a paddock on the east side of the property. Flocks of recently shorn sheep were present within the Taro farm, which is located within the project site, but is not part of this project. All of the other species detected are detailed in Table 3.

No mammalian species proposed for listing, or listed as endangered or threatened under either federal or state of Hawaiʻi endangered species statutes, was recorded during the course of this survey (HDLNR 1998; USFWS 2014a).

Common Name	Scientific Name	ST	Detection Type
	RODENTIA - Gnawers		
	MURIDAE - Old World Rats & Mice		
European house mouse	*Mus musculus domesticus*	A	V
	CARNIVORA- Flesh Eaters		
Domestic dog	*Canis f. familiaris*	A	V, Au, Tr, Sc
House cat	*Felis catus*	A	V, Tr, Sc
	ATRIODACTYLA - Even-Toed Ungulates		
	SUICIDAE - Old World Swine		
Pig	*Sus s. scrofa*	A	V, Au, Tr, Sc
	BOVIDAE- Hollow-horned Ruminants		
Domestic cattle	*Bos taurus*	A	V, Au
Domestic sheep	*Ovis aries*	A	V, Au

Table 3 – Terrestrial Mammalian Species Detected Kauaʻi Dairy Farms Site

Legend to Table 3

ST = Status
A = Alien – Introduced to the Hawaiian Islands by humans
V = Visual – Species seen
Au = Audio – Species heard
Tr = Tracks – Species tracks seen
Sc = Scat – Species droppings seen

Aquatic Features

The project area represents bottom-land of upper Māhāʻulepū Valley; the elevation from the upper pastureland to the lower end representing only about a 20-meter drop, nearly half of which occurs before upper Māhāʻulepū Road. The valley is fed by several intermittent streams coming off the south slope of the Hāʻupu Ridge between Kāmaulele and Hāʻupu peaks. These normally dry streams feed onto the valley floor, converging at around the 34-meter elevation. Through the upper pastureland, the streams become man-made ditches, incised to a depth of 2-3 meters. At the time we visited, the branch off Kāmaulele had seeps in the bed starting a short distance up from the convergence. Below the convergence, slow moving water is present in a man-made channel running through the project site. The ditch extends southward off the property, passing under lower Māhāʻulepū Road.

A second ditch parallels to the west the one described above. This second ditch originates in the vicinity of a pond in an area of water wells in the upper west side of the valley. We did not establish the source of the water in this ditch, but the ditch contains water and extends south, passing beside an agricultural operation that includes *kalo loʻi* (taro fields), from which it receives additional flow. This ditch then joins a larger ditch known as Mill Ditch (USGS, 1996) carrying water flowing from west to east across the valley within the project area. Mill Ditch turns southward near the center of the valley, passes under Māhāʻulepū Road, and some 460 meters south, joins the first ditch coming down the valley. The two become Waiopili Ditch, with an outlet at Māhāʻulepū Beach. Mill Ditch is actually receiving water from a pipe located adjacent to the west side of Māhāʻulepū Road. Another small intermittent stream enters the project property nearby. This stream originates in a small valley called Kalapa, and is marked by a boulder bed where it crosses under Māhāʻulepū Road, becoming a dry ditch through the pasture to Mill Ditch.

An old agricultural *ʻauwai*, called Waitā Reservoir Ditch once brought water from Waitā Reservoir into the upper part of the valley, feeding Māhāʻulepū Reservoir (off property to the northwest) and wrapping around the upper valley and ending near Pu'u Keke on the east side close to Waiopili Stream. This *ʻauwai* is abandoned and no longer functional.

A second *ʻauwai* extends from Māhāʻulepū Reservoir to the southwest, paralleling Waitā Reservoir Ditch at a slightly lower elevation (and flowing water in the opposite direction). This *ʻauwai* is also clearly abandoned and non-functional. An interesting feature associated with this supply ditch is a large, six-sided concrete pipe that fed water into the small reservoir on property ("pond"). Inscribed on a concrete support column for this pipe is "THAIN 10-4-73".

Spread across the pastures on the valley floor are numerous straight agricultural ditches that serve the purpose of draining runoff from various pasture areas. These were nearly all dry during our survey, and the network was not fully explored, nor was it determined how these presently all interconnect. Presumably these drain eventually into one of the three water-filled features on the property described above.

Many of the aquatic features just described are shown on the USFWS National Wetlands Inventory (NWI) and assigned codes that describe the habitat type presumed by the Inventory (most information in the NWI was derived from aerial photographs and maps, not field investigations; USFWS, 2014b). All of the water ditches on the property (and the *ʻauwai* around the margin of the valley floor) are coded "R4SBCx", which represents: intermittent (seasonally flooded) flowing water, in an excavated channel. An exception is the ditch (and channel upslope) directing stream flow off Kāmaulele, which is coded R3RBH: an upper perennial stream with a rock bottom. Characterization as an interrupted perennial stream is possible given that the stream arises in two branches over 300 meters above sea level, but unlikely[2].

Three agricultural ponds or reservoir features are coded PUBHh, (permanently flooded, man-made pond with sediment bottom). Māhāʻulepū Reservoir is the largest, but located entirely off property. Two reservoirs are indicated within the project area, but one may no longer exist (could not be located in the field) and the other is the small pond in the well area on the upper northwest side. The latter is described by Tom Nance Water Resource Engineering (TNWRE, 2016) as the sump at "Well 14 Battery" and appears to be disconnected from even the local groundwater.

[2] The state perennial streams inventory (HCPSU, 1990) lists no streams for Māhāʻulepū, but lists a "Kipu Kai Stream" for Kauaʻi in this general area (ID No. 2-3-01, Lihue Quadrangle). The newer, watershed atlas (Parham et al., 2008) lists Mahaulepu as a non-perennial stream, assigning the watershed code: 23011. The watershed delineation report (GDSI, 1994) separates Kipu Kai and Mahaulepu watersheds, although mapping them as a single watershed. Physically, the two valleys are quite distinct (and separated by intervening Aweoweonui Gulch).

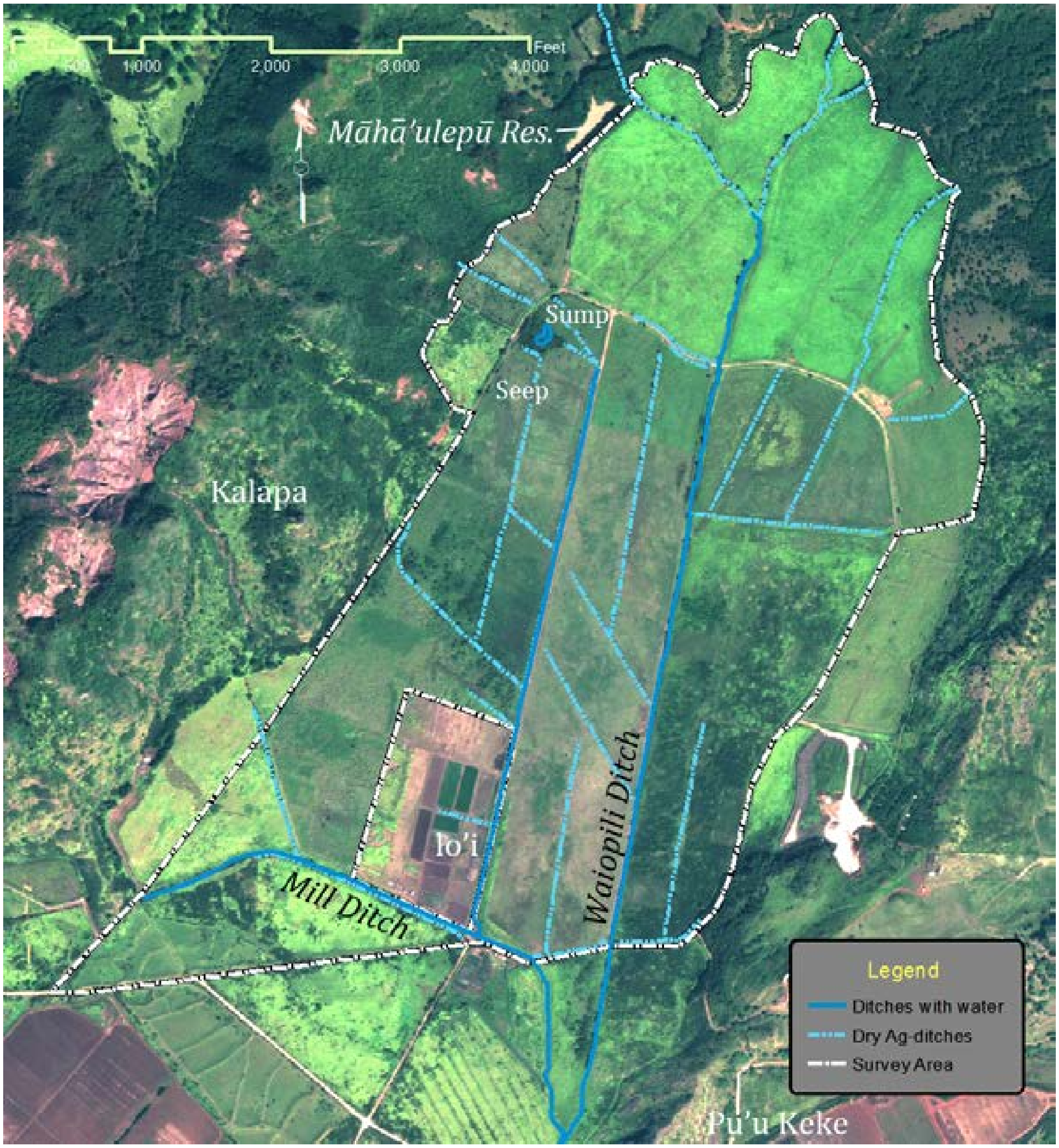

Figure 4 - Map of aquatic features in the project vicinity in Māhāʻulepū Valley.

Discussion

Botanical Resources

The nature of the land and its present and historical uses for intensive agriculture very much limit the natural botanical resources anticipated to occur here. The results of our survey substantiate this prediction. The low percentage (4%) of native plant species is an indication that because of constant disturbances, only species adapted to such conditions can survive, and with but a few exceptions, these adapted species are non-natives in the lowlands of the Hawaiian Islands.

A search of Bernice P. Bishop Museum Herbarium records conducted by Anita Manning, yielded 91 entries for "Mahaulepu". The majority of the natives in the listing were collected along the coast or "Haupu Ridge" or "Puu Pihakapu". The list of rare native species is impressive. Though the locations are roughly associated with Māhāʻulepū Valley, they represent environments vastly different from those of the upper valley floor (project area). Indeed, all of the plants of interest were collected in either coastal dunes, exposed coastal sites, or steep, rocky cliffs at elevations well above the project. All species in the collection with locations likely to be similar to, if not in, the project pasture lands, are non-native species.

Avian Resources

The findings of the avian survey are consistent with the location of the property, and the habitat present on the site and with at least two relatively recently conducted faunal surveys conducted on lands close to the study site (Guinther and David, 2009; David, 2013; David and Guinther, 2013). During the course of this survey we recorded 31 avian species during point counts, with a further species being recorded as an incidental observation while transiting between count stations. Of the 32 species detected on the site five; Nēnē, Hawaiian Duck, Common Gallinule, Black-necked Stilt and Hawaiian Coot are native endemic species or sub-species all of which are currently listed as endangered species under both federal and State of Hawaiʻi endangered species statutes (Table 2). Additionally three other species recorded; Black-crowned Night-Heron, Pacific Golden-Plover, and Wandering Tattler are native indigenous species. The Black-crowned Night-Heron is an indigenous resident water obligate species and the plover and tattler are indigenous migratory shorebird species which nests in the high Arctic during the late spring and summer months, returning to Hawaiʻi and the tropical Pacific to spend the fall and winter months each year. They usually leave Hawaiʻi and return to the Arctic in late April or the very early part of May. The remaining 24 avian species detected are alien to the Hawaiian Islands (Table 2).

Four of the five endangered birds recorded during the course of this survey were concentrated in or close to the taro cultivation site located on the south-central part of the property, though not part of the proposed dairy operations, were waterbirds: Hawaiian Duck, Common Gallinule, Black-necked Stilt and Hawaiian Coot (Figure 5). Nēnē were also recorded close to the taro *loi*, but were also encountered at other locations on the property, and could in future be expected to use resources anywhere on the site with fresh grass. The majority of the Hawaiian Ducks recorded were seen either on the Māhāʻulepū Reservoir located outside of the dairy operations area on the northeast corner of the property (Figure 1), or flying over the greater site or within the taro *loi*.

Although not detected during this survey, the endangered Hawaiian Petrel (*Pterodroma sandwichensis*), and the threatened endemic sub-species of the Newell's Shearwater (*Puffinus auricularis newelli*) have been recorded over-flying the general project area between April and the end of November each year (David, 2013; David and Guinther, 2013; Morgan et al., 2003, 2004; David and Planning Solutions 2008). Additionally, the Save Our Shearwaters Program has recovered both species from the general Koloa area on an annual basis over the past three decades (Morgan et al., 2003, 2004; David and Planning Solutions, 2008; Save our Shearwater Program, 2013).

The petrel is listed as endangered, and the shearwater as threatened under both Federal and State of Hawaiʻi endangered species statutes. The primary cause of mortality in both Hawaiian Petrels and Newell's Shearwaters is thought to be predation by alien mammalian species at the nesting colonies (USFWS 1983, Simons and Hodges 1998, Ainley et al., 2001). Collision with man-made structures is considered to be the second most significant cause of mortality of these seabird species in Hawaiʻi. Nocturnally flying seabirds, especially fledglings on their way to sea in the summer and fall, can become disoriented by exterior lighting. When disoriented, seabirds can collide with manmade structures, and if they are not killed outright, the dazed or injured birds are easy targets of opportunity for feral mammals (Hadley 1961; Telfer 1979; Sincock 1981; Reed et al., 1985; Telfer et al., 1987; Cooper and Day, 1998; Podolsky et al. 1998; Ainley et al., 2001; Hue et al., 2001; Day et al 2003).

Mammalian Resources

The findings of the mammalian survey are consistent with the location of the property and the habitat currently present on the site. We did not record Hawaiian hoary bats overflying the site. Hawaiian hoary bats are widely distributed in the low to mid-elevation areas on the Island of Kauaʻi, and have been documented in and around almost all areas that still have some dense vegetation (Tomich, 1986; USFWS 1998, David, 2014).

Thenonly rodent species detected during this survey were several European house mice. (*Mus musculus domesticus*). It is probable that one or more of other three established alien muridae found on Kauaʻi, roof rat (*Rattus r. rattus*), brown rat (*Rattus norvegicus*), and possibly Polynesian rats (*Rattus exulans hawaiiensis*) use various resources found within the general project area. All of these introduced rodents are deleterious to native ecosystems and the native faunal species dependent on them

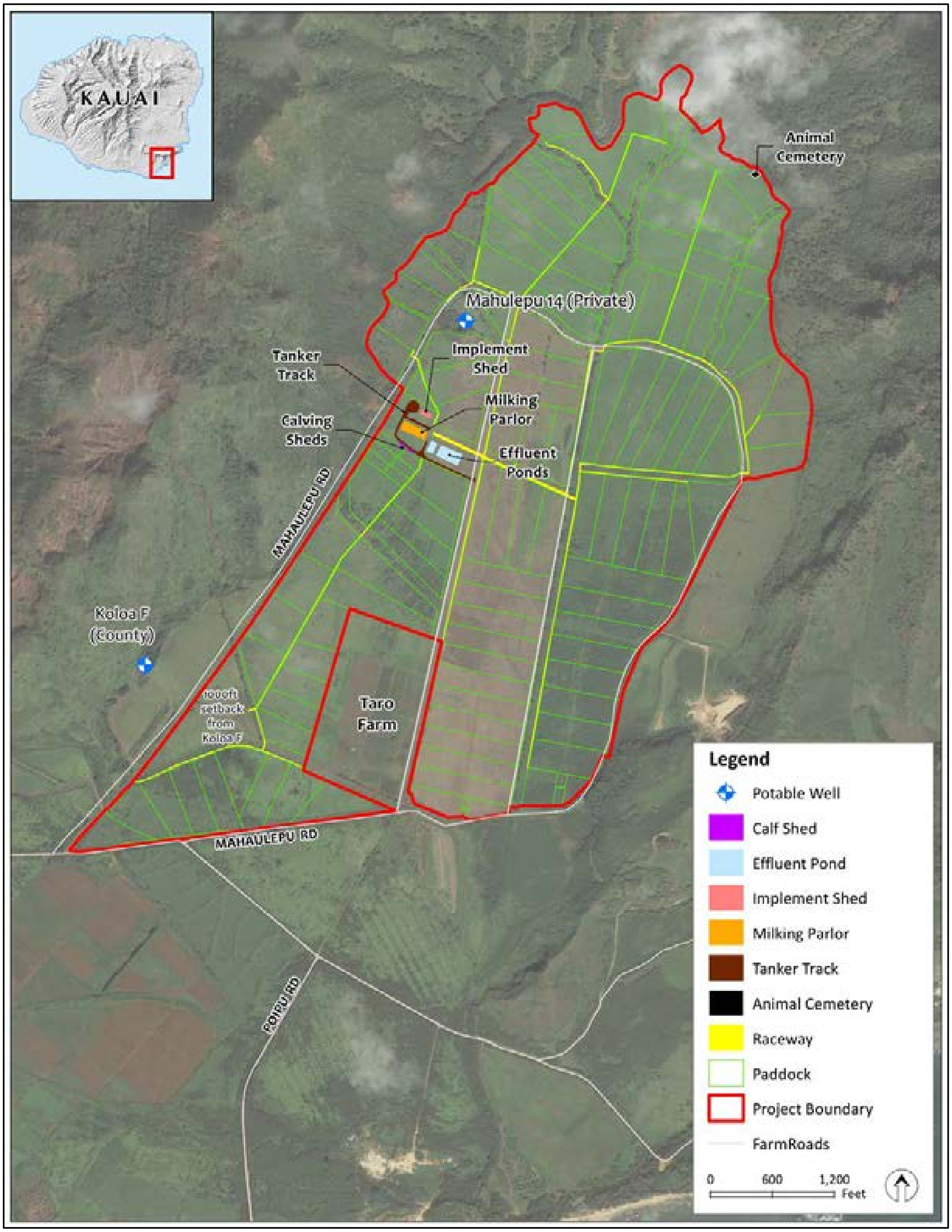

Figure 5 – Farm Map showing existing Taro Farm and proposed Dairy Farm Infrastructure

Potential Impacts to Protected Species

Botanical

No protected botanical species (for example, threatened or endangered species under state and federal statutes; USFWS, 2014; HDLNR, 1998) occur on the project property. Thus the construction and subsequent operation of the proposed dairy is not expected to result in deleterious impacts to any protected botanical species. Although possibly some areas around the valley margin might have once supported a population of ʻohia (*Sesbania tomentosa*)—a species of shrub that is listed as endangered—the highly disturbed nature of the valley floor precludes the possibility of any such population surviving after the start of agriculture here. Today, this plant is much more likely to be found very close to the ocean shore or inland where dunes prevail.

Waterbirds

Four endangered waterbird species, Hawaiian Duck, Common Gallinule, Black-necked Stilt and Hawaiian Coot were recorded on the property. The principal potential impacts that the development and operation of the proposed dairy farms on the site poses to these four species fall can be broken down into those potentially associated with construction activities and those associated with dairy farm operations following build-out.

During construction especially during clearing and grubbing phases of the project, clearing vegetation, opening up and clearing of agricultural irrigation features and the construction and/or upgrading of roadways within the farm has the potential to disturb nesting waterbirds, nests, eggs and young. Controls should be put in place to avoid deleterious interactions between endangered waterbirds and construction equipment, vehicles and construction personnel. Waterbirds disturbed when nesting may abandon their nest, eggs and to a lesser degree chicks. Increased vehicular traffic associated with construction activities also increases the risk of birds being run over or hit by vehicles, within the project site.

Nēnē

Nēnē were seen on the site, and in discussions with DOFAW biologists we were told that they are regularly seen on the subject property. It is probable that some nest on or adjacent to the site as this species nests in the general Kōloa area (David, 2013; David and Guinther 2013), and the habitat present on parts of the site are suitable for Nēnē nesting. Potential impacts to this species are similar to those discussed for waterbirds. With the singular difference that Nēnē could potentially nest anywhere on the site which has adequate shrubby or rank grass under which they can build a nest. Unlike the four waterbirds discussed above Nēnē often nest relatively far from water.

Seabirds

The principal potential impact that construction of the proposed dairy farms poses to protected seabirds is the increased threat that birds will be downed after becoming disoriented by lights associated with the project during the nesting season. The two main ways that outdoor lighting could pose a threat to these nocturnally flying seabirds is if, 1) during construction it is deemed expedient, or necessary to conduct nighttime construction activities, and 2) following build-out, the potential operation of streetlights or security lighting.

Hawaiian hoary bats

It is likely that Hawaiian hoary bats overfly the project area on a seasonal basis. The principal potential impact that the development of the proposed dairy farms poses to bats is during the clearing and grubbing phases of construction as vegetation is removed. The removal of vegetation within the project site may temporarily displace individual bats, which may use the vegetation as a roosting location. As bats use multiple roosts within their home territories, the potential disturbance resulting from the removal of the vegetation is likely to be minimal. During the pupping season, females carrying their pups may be less able to rapidly vacate a roost site as the vegetation is cleared. Additionally, adult female bats sometimes leave their pups in the roost tree while they forage. Very small pups may be unable to flee a tree that is being felled. Potential adverse effects from such disturbance can be avoided or minimized by not clearing woody vegetation taller than 4.6 meters (15-feet), between June 1 and September 15, the period in which bats are potentially at risk from vegetation clearing. With that said, there are almost no suitable roost trees within the proposed project site, thus it is not expected that the project will result in deleterious impacts to this listed mammalian species.

Recommendations

Construction

During the construction phase of the project we recommend the following minimization measures and training be implemented to ensure that construction activities do not result in deleterious impacts to the trust faunal species that may be encountered during construction.

- Develop an endangered species awareness training module
- Endangered Species Identification with photographs and description of habitats and areas on the property where species are most likely to occur and/or nest
- Construction workers should undergo endangered species awareness training prior to starting work on the project
- 15 MPH Speed limit signs posted and enforced on all roads within the project
- No pets allowed on property – especially dogs and cats

- Closed trash receptacles for food and beverage containers, and disposal of same, should be provided

- No feeding of birds

- No feeding or watering of feral cats and dogs

- Specified construction personnel parking areas

- Construction materials and construction equipment parking and maintenance areas surveyed and delineated

- These requirements should be included as special Construction BMP contract provisions

- Immediately prior to construction activities Surveys for nesting waterbirds and Nēnē should be conducted by a qualified biologist, if nesting activity is identified within 100 feet of proposed construction activity, construction activity should be halted until nesting activity has ended, or consultation with the state and federal wildlife regulators should be initiated to determine the best course of action.

- If nighttime construction activity or equipment maintenance is proposed during the construction phases of the project, all associated lights should be shielded, and when large flood/work lights are used, they should be placed on poles that are high enough to allow the lights to be pointed directly at the ground.

- If streetlights or exterior facility lighting is installed in conjunction with the project, it is recommended that the lights be shielded to reduce the potential for interactions of nocturnally flying seabirds with external lights and man-made structures (Reed et al., 1985; Telfer et al., 1987).

Dairy Operations

Following build-out and the start of Dairy operations we recommend that the following recommendations be implemented:

- Develop an Endangered Species Protection Plan, the plan would include all of the topics outlined above. The material would be presented in more detail and with the rationale for why following those BMP's is necessary to ensure that Dairy operations do not result in deleterious impacts to protected wildlife. The Plan would also include these additional topics:

- Endangered Species Identification with photographs and description of their habitats, and likely areas on the property where they are most likely to occur and/or to nest

- Employee endangered species training, provided both in writing and as a PowerPoint presentation for use in training new personnel and annual updates of training
- Predator control program
- Downed seabird, and injured waterbird response protocols

Critical Habitat

There is no federally delineated Critical Habitat for any species present on or adjacent to the project area. Thus the development and operation of the proposed project will not result in impacts to federally designated Critical Habitat. There is no equivalent statute under State law.

Glossary

Alien – Introduced to Hawaiʻi by humans
Commensal – Animals that share human food and lodgings, such as rats, mice cats and dogs.
Crepuscular – Twilight hours
Endangered – Listed and protected under the Endangered Species Act of 1973, as amended (ESA) as an endangered species
Endemic – Native to the Hawaiian Islands and unique to Hawaiʻi
Indigenous – Native to the Hawaiian Islands, but also found elsewhere naturally
Mauka – Upslope, towards the mountains
Muridae – Rodents, including rats, mice and voles, one of the most diverse families of mammals
Naturalized – A plant or animal that has become established in an area that it is not indigenous to
Nocturnal – Night-time, after dark
ʻŌpeʻapeʻa – Endemic endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*)
Pelagic – An animal that spends its life at sea – in this case seabirds that only return to land to nest and rear their young
Phylogenetic – The evolutionary order that organisms are arranged by
Ruderal – Disturbed, rocky, rubbishy areas, such as old agricultural fields and rock piles
Sign – Biological term referring to tracks, scat, rubbing, odor, marks, nests, and other signs created by animals by which their presence may be detected
Threatened – Listed and protected under the ESA as a threatened species.

Acronyms

AMSL – Above mean sea level
CAFO - Concentrated Animal Feeding Operation
HDF - Hawaii Dairy Farms LLC
HDLNR – Hawaiʻi State Department of Land & Natural Resources
DOFAW – Division of Forestry and Wildlife
ESA – Endangered Species Act of 1973, as amended
GNSS – Global Navigation Satellite System (formerly as Global Positioning System), an accurate worldwide navigational and surveying facility based on the reception of signals from an array of orbiting satellites.
MSL – Mean sea level
NDI - USFWS National Wetlands Inventory
NPDES - National Pollutant Discharge Elimination System
TMK – Tax Map Key
USFWS – United State Fish & Wildlife Service
USGS – United States Geological Survey
UTM – Universal Transverse Mercator System, a standardized mapping coordinate system that uses grids to identify the specific location of any feature on the surface of the planet

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APPENDIX B

CATTLE MANURE-RELATED INSECT SPECIES AND BIOLOGICAL CONTROLS FOR HAWAI‘I DAIRY FARMS MĀHĀ‘ULEPŪ, KAUA‘I, HAWAI‘I

STEVEN LEE MONTGOMERY, PH. D.

Cattle Manure-related Insect Species and Biological Controls for Hawai’i Dairy Farms, Māhā’ulepū, Kaua’i, Hawai’i

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Submitted to: Group 70 International

For: Hawai’i Dairy Farms, LLC

January 29, 2016

Table of Contents

Tables

Figures

INTRODUCTION

This report summarizes the findings of an insect survey conducted at and near the proposed site of Hawai'i Dairy Farms (HDF), Māhā'ulepū, Kaua'i, (Figure 2, 4) in September 2014.

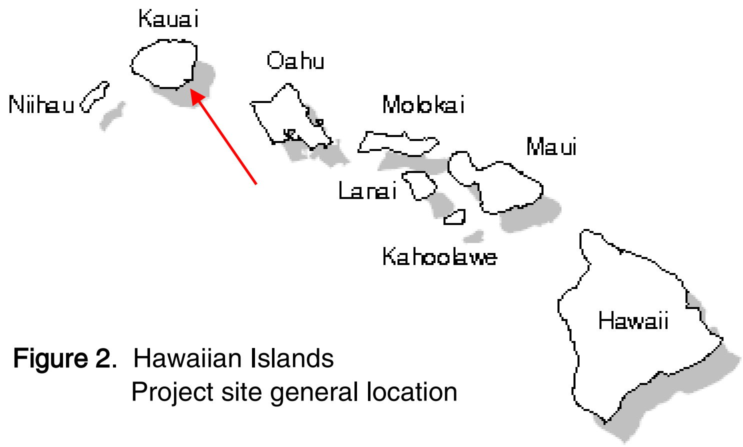


Figure 2. Hawaiian Islands
Project site general location

The primary purpose of the survey was to determine the presence or absence of species associated with the manure of cattle and of the parasites and predators that control them. The survey also was designed to provide information to assist in planning a control program for problem species. The survey also notes species that could be injurious to humans or cattle and was alert to the presence of any Endangered or Threatened species.

Executive Summary

Most insects are obligatorily attached to specific food sources, prey or host plants, being able to use only that source. Those relationships are ancient and intertwined. The amount of food and the levels of predators and parasites determine the abundance or scarcity of species. Those feeding behavior patterns are part of an inter-dependent web in nature, and the basis of integrated pest management (IPM). Knowledge of this web has been used for many decades in Hawai'i to naturally control alien pest species associated with cattle manure by disrupting reproduction with appropriate means at each part of the life cycle. Birds, spiders, or dragonflies eat adult insects. Ants attack eggs or larva. Birds eat the larva or pupa. Dung beetles minimize food for larvae. Micro-wasps parasitize the larva and pupa.

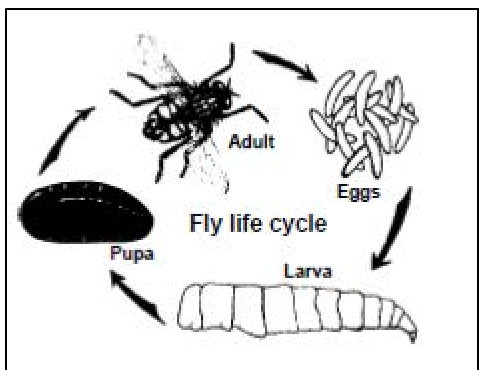


Figure 3. Life cycle of fly (DuPonte & Larish 2003)

Executive Summary continued

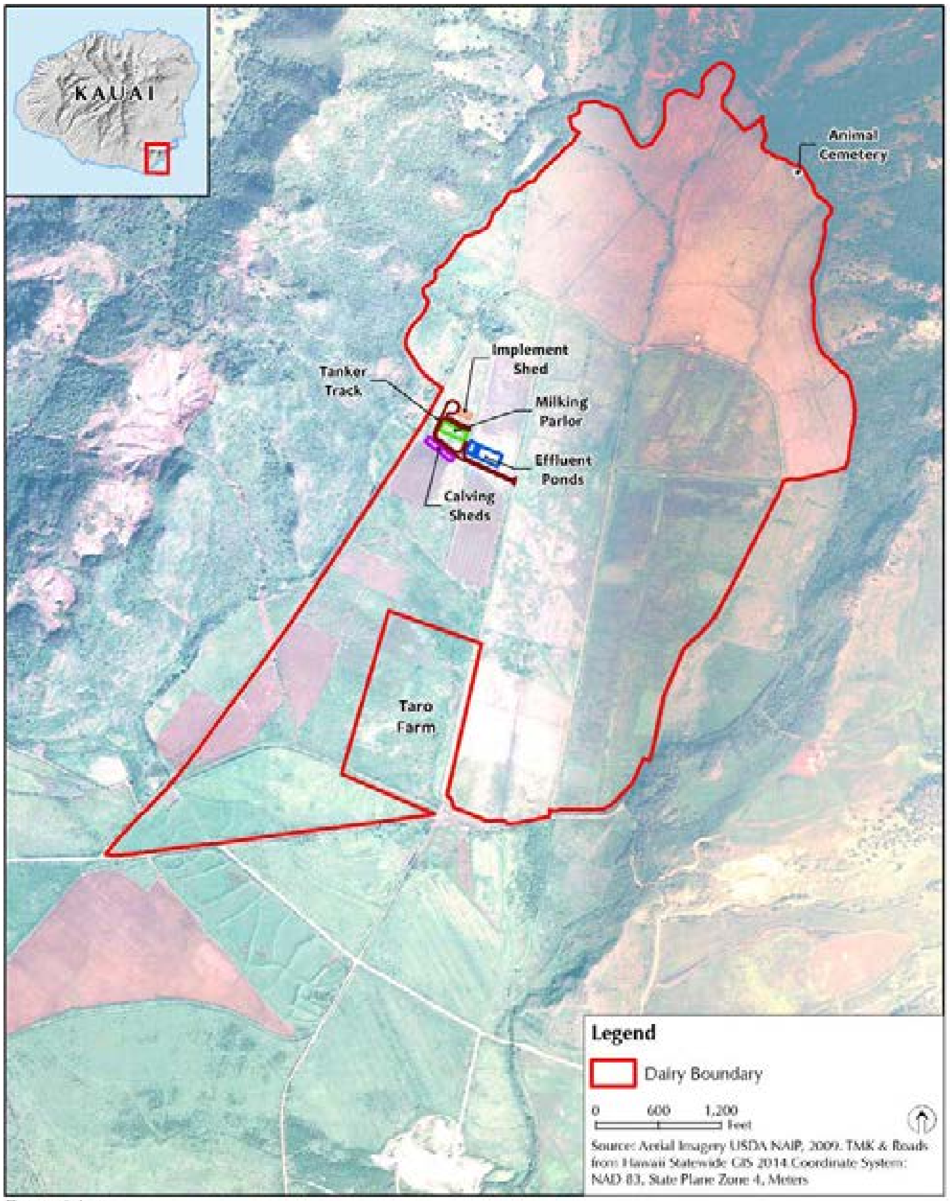
The manure of near-by beef cattle was monitored in the field and in the lab to observe that predator / prey web of control. Known manure-related species such as the “stable fly” were present, but so were some of the known control species such as dung beetles. Birds and other vertebrates disturb the dung, eat pest species and make breeding by pests much less successful. Disturbance also exposes the pests to predation by other predator insects. Spiders and dragonflies, apex predators on flying adult pest species also were present. (See pages 11, 14, 18-19)

This web of control is a proven, successful strategy. We experienced it personally when Feb 22-28, 2011, we assisted Hawai‘i film makers Moana Productions in site location and animal wrangling for a dairy promotion using the pastures and animals of Kohala’s Cloverleaf Dairy. (This was for a continental dairy taking advantage of Hawaii’s mild climate to film in winter for spring showing at home.) We were in the cow paddocks and open fields with the cattle during the day and a crew of 20 ate lunches in an open tent most days in the fields. Flies were not a nuisance or even noted at all on the food or when we were working in the fields. The ongoing, natural web of predator / prey relationships kept pest species under control.

Some of the manure-related insect predatory species long established in the Hawaiian Islands are present elsewhere on Kaua’i, but not now present near the proposed HDF site. Recommendations are made on their introduction to the site. Other species are not known on Kaua’i, thus their introduction from other Hawaiian islands is recommended. Together these predatory species hold fly species in check. None of the predator insects have any history of attacking native Hawaiian insects. (See page 24)

The project site does have species that could be injurious to humans or cattle, but none are exclusively associated with cattle. All are common throughout the island chain, have been present on Kaua’i for many decades, and are seen in virtually every survey we do. Cautions and controls are discussed. (See page 25)

Historically, no native invertebrates of **any** species are known to be attracted to manure of large herbivores. The field survey around the site confirmed native invertebrates were NOT attracted to manure of nearby beef cattle. This survey showed no evidence of lava tubes (caves) that would support the endangered Kaua’i cave wolf spider or cave amphipod. Neither the Blackburn’s sphinx moth nor its host plants were observed. The project location does not provide any habitat for Kaua’i species of native Hawaiian pomace flies listed as endangered (*Drosophila musaphilia & D. sharpi*) and these have no historical sightings within many miles of the HDF site. (See page 20)



Farm Map

Figure 4. Site of proposed Hawai’i Dairy Farm, Kaua’i (Provided by Group 70)

GENERAL SITE DESCRIPTION

The proposed project site at Māhā’ulepū Valley, Kaua’i, comprises 557 acres, excluding the existing kalo lo‘i (taro pond) operation at the makai end (Figure 4). The land is largely in grass with a variety of weedy species[1] (e.g., castor bean, koa haole) along the sides of gravel roads. The grazing area slopes from 150 ft. to 60 ft. along Māhā’ulepū Road at the makai end of the site.

Although most of the ditches running mauka-makai were dry during the September 2014 survey, one small ditch was running with clear water (Figure 5) and a parallel ditch had some slowly moving water and standing water (Figure 6).

Figure 5. Mauka-makai clear running ditch provided habitat for several aquatic species.

Figure 6. Water in a ditch parallel to one side of the kalo fields was muddy and slow moving.

[1] Technical terms are defined in the Glossary, page 36.

INVERTEBRATE SURVEY METHODS

Previous Surveys and Literature Search

Prior to the field survey, a search was made for publications relating to invertebrates associated with this particular site or with nearby sites. A search was made for other projects in the general area that generated an Environmental Assessment or Environmental Impact Statement filed at the web site of the State’s Office of Environmental Quality Control (2014). This review did not show any previous invertebrate surveys in the area. The results of recent avian-mammalian and botanical surveys of the project area by David and Guinther (2014) were helpful in preparing for this study. Searches were made in the University of Hawai’i and Bishop Museum library catalogs and in the University of Hawai’i, Hamilton Library’s Hawai’i-Pacific Journal Index (2014). Searches were made for publicly available articles mounted on the web through Google Scholar.

Most helpful were searches in the Bishop Museum’s Natural Sciences databases (2014) and the University of Hawai’i Insect Museum “holdings” database (2014).

As the record of Hawaii’s economic entomology activity for over 100 years, the journal, *Proceedings of the Hawaiian Entomological Society*, was very useful.

Fieldwork

The field survey was conducted in September 2014, beginning with a general assessment of terrain and habitats. Surveying efforts were conducted at various times of day, a technique that is vital for a thorough survey. See Figure 9 for manure survey location.

Fieldwork schedule

September 15, 2014: 4 hours; Site examination, orientation, general surveying, baiting
September 16, 2014: 7 hours; General surveying, baiting, sample collection

Lab-rearing schedule

September 17-October 13, 2014

Manure collected in the field (Figure 9) was observed in lab to rear any dung associated species. Specimens emerging in the lab are recorded in Table 1 with the field collected specimens.

Survey Methods

Wandering transects were walked across pastures. Spot surveys were made at both a shallow, flowing ditches and at more slowly moving water that included seepage from the kalo ponds of W.T. Haraguchi Farm, Inc. (Killermann 2014).

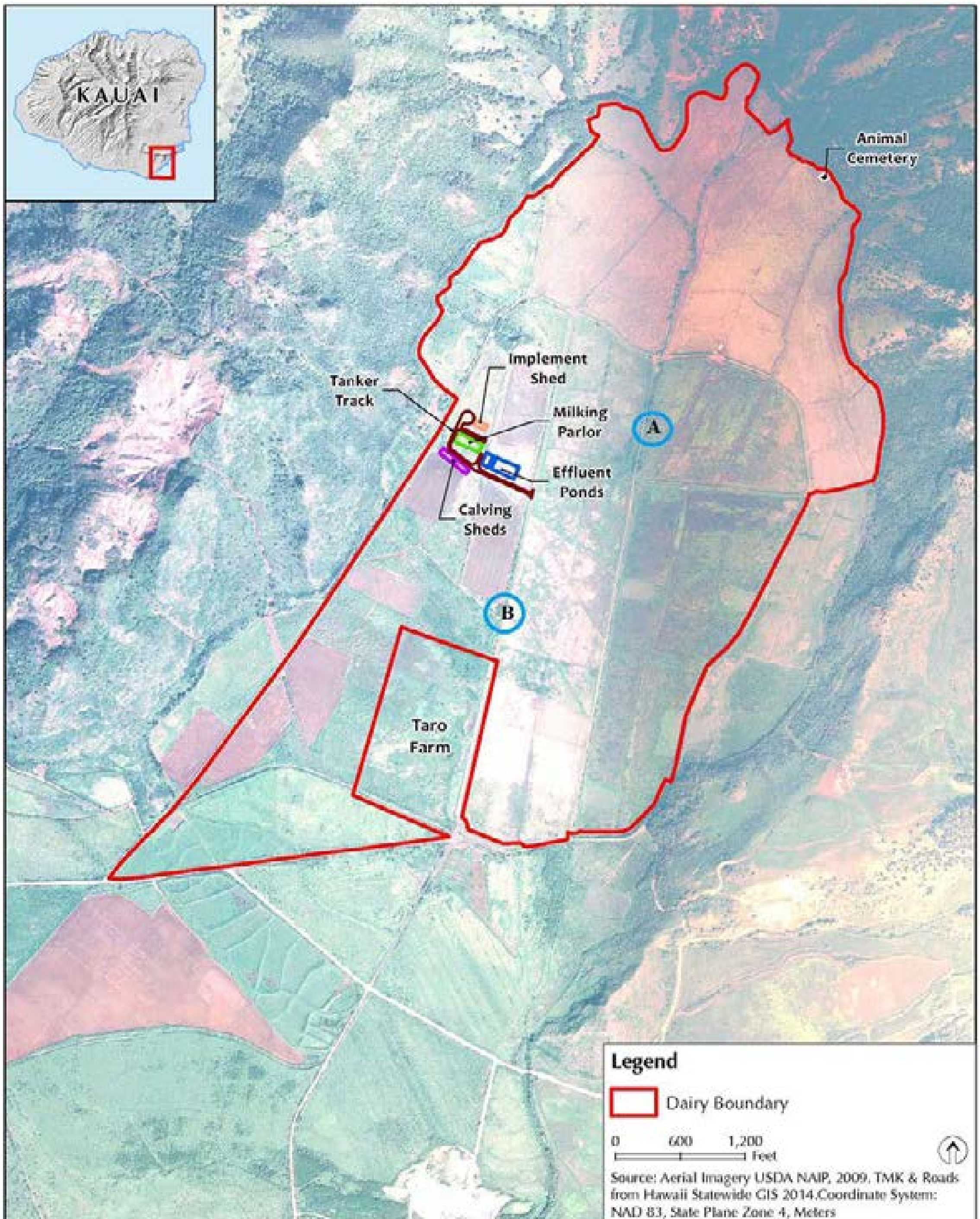


Figure 7. Entry point for ditch with flowing water (**A**) and slow moving water (**B**) (Group 70 2015)

INVERTEBRATE SURVEY METHODS: continued

The major focus of the survey was on the fresh and dry manure generated by beef cattle (Figure 8) at the adjacent pasture for Mahaulepu Cattle Co. (Figure 9).

Figure 8. Beef cattle are present in fields adjacent to the HDF property. Manure from these animals provided examples of the invertebrate species likely to be present at HDF.

The following methods for invertebrate surveying were used as appropriate to the terrain, botanical resources, and target species.

Visual observation / examination of manure

At all times, the survey was alert for evidence of any animal presence or interaction with manure. Visual observations provide valuable evidence and provide a cross check that extends the reach of structured sampling techniques. Visual observation also included examination of manure and decaying matter, turning over rocks, dead wood, and other debris.

Daily observations were made of manure samples returned to the lab. Emergence of various species differs based on time from egg to adult. Samples were monitored for more than 21 days, sufficient for most species to emerge.

INVERTEBRATE SURVEY METHODS: continued

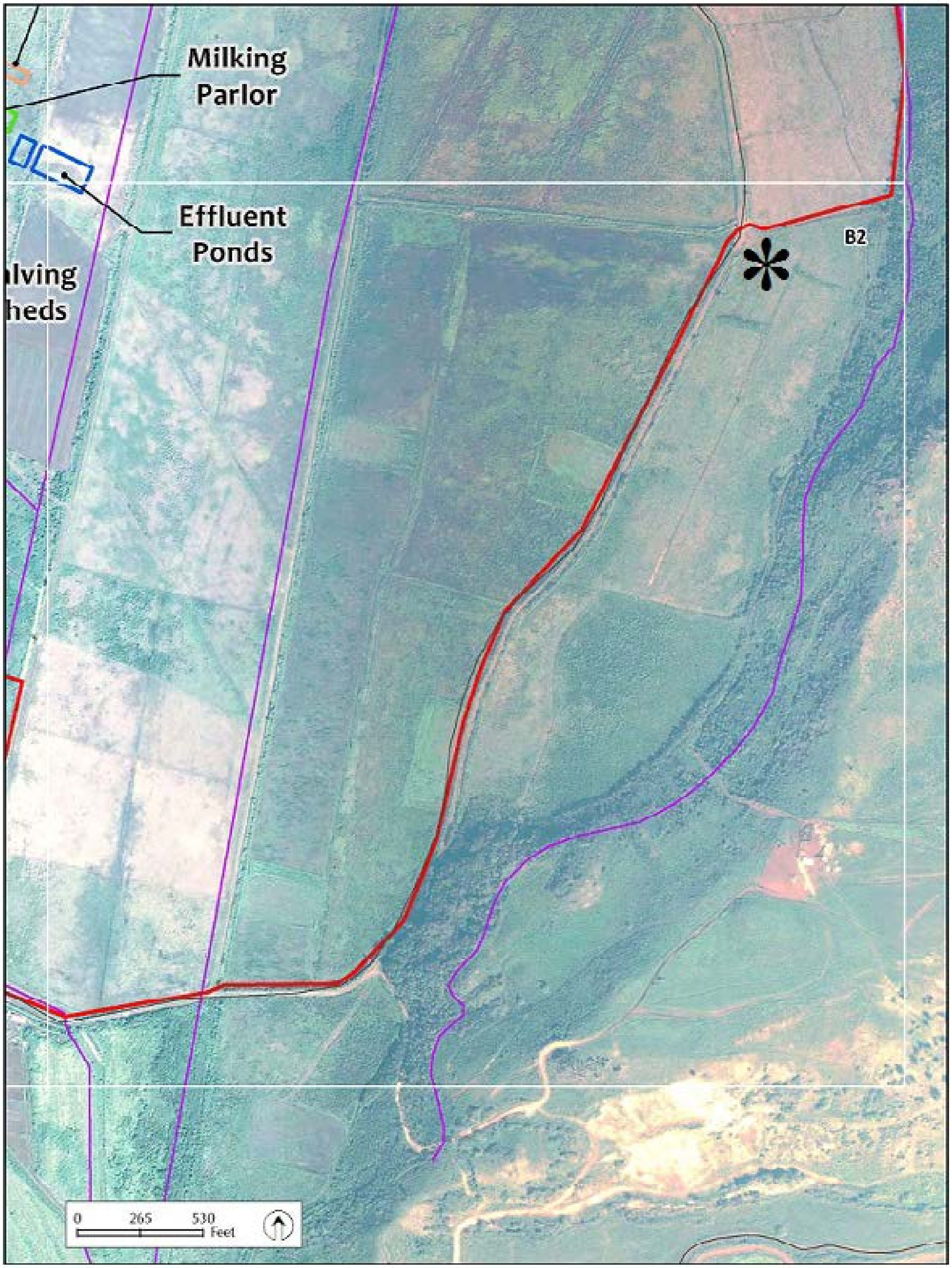


Figure 9. Location of Mahaulepu Cattle Co. animals (*) where manure was collected for rearing of dung associated species in lab. (map Group 70 2015)

INVERTEBRATE SURVEY METHODS: continued

Baited traps

Baited Multi-Lure traps (Figure 10) were deployed near a resting spot favored by Mahaulepu Cattle Co. animals. On September 15, fresh manure was placed in traps suspended above the ground and directly adjacent to the location where the cattle had deposited manure (Figure 11). No flies came to the traps in 8 hours. On September 16, the traps were moved closer to the ground, but again, no flies came to the traps. The flies stayed on the manure on the ground.

Figure 10. Multi-Lure traps entice flying insects to enter by the bait's scent, but prevent exit. The efficacy of the trap is attested to by its 'sole source' status for procurement by U. S. Dept. of Agriculture's Animal & Plant Health Inspection Service (APHIS). (2014)

Figure 11. Traps successful at luring and holding flies were used with fresh manure as bait.

Food scraps were left in the open about 5 yards from the paddock where the Mahaulepu Cattle Co. animals congregated for water and 10 yards from the nearest manure. No flies came to the food scraps, the manure being their preferred ecological niche.

Sweep net

This is the most common method of collecting flying and perching insects. A fine mesh net was swept across plants, manure piles, etc. to collect flying insects. Net contents were transferred into a holding container.

INVERTEBRATE SURVEY METHODS: continued

Survey Limitations / Conditions

The ability to form an advisory opinion is conditioned in the following ways:

Seasons

Weather and availability of food sources play a role in any survey of invertebrates. Arthropod breeding responds to access to food sources for the young and the on-going cattle operation assured a steady source of manure to host the pest / predator population. Nevertheless, monitoring at a different time of the year might produce a longer or slightly different invertebrate list.

Weather

Weather was favorable for surveying during each field day, although relatively warm. Water was present in two ditches, although several were dry.

Limited duration

It is possible that surveying for a longer period of time might enlarge the list of species. To balance that possibility, manure samples were collected and returned to the lab, monitored, and species collected as they emerged. This helped the survey provide a more accurate review of the species present. Nevertheless, it is likely some species present on Kaua'i were not captured, and may later come to manure at HDF. These are noted below in Table 2: Invertebrates known on Kaua'i but not present (page 21).

Selectivity

The survey was focused on finding alien arthropod species present in the area having a relationship to operation of a dairy (Table 1). No attempt was made to document the many non-dairy related alien invertebrate species that might be present in any open field area in Hawai'i (e.g., cabbage butterfly). No attempt was made to document endemic and indigenous Hawaiian invertebrate species, although they were reported when seen. No habitat or host plants of endangered and threatened species were observed.

Diet of Animals

Although the Mahaulepu Cattle Co. animals are fed with pasture grass, as will be the HDF animals, it is anticipated there will be supplemental feeding at the milking site. This diet addition may change the composition of the manure in ways we can not anticipate. This could change the attractiveness of the manure to various invertebrate species already on Kaua'i, but not now found at the site (page 21, Table 2). The management of feed and implementation of integrated pest management techniques should provide controls in anticipation of this option. In addition to the introduction of known predator species already on Kaua'i and in the island chain (See page 29), diet management can be helpful. A prime example is the dog dung fly, which is known to breed in cow manure in small numbers. This can be reduced by omitting corn from feed. Lee and Toyama (1991) showed female flies preferred laying eggs in dairy cow dung containing the residues of digested ground corn.

DISCUSSION

VERTEBRATES NOTED

Because the feces of chickens, cats, and dogs also provide habitat for pest fly species, the survey was alert for the presence of these animals. Although cats and chickens were observed, neither was seen in numbers that added much food for pest flies.

Feral pigs (*Sus scrofa*) were noted on HDF property. Their rooting is currently one of the factors breaking up manure of the Mahaulepu Cattle Co. animals. It is assumed, however, that the feral animals will be removed as a health hazard to the HDF cattle and as destructive to the pastures and water resources.

Several species of birds are present. Many of them feed on seeds and small insects. Numerous manure piles showed signs of being disturbed by birds scratching at, or beaking the pile to find larvae or undigested seeds. (Figure 12) This assists in the breakdown of the piles making them more easily dissolved by sprinklers and more accessible to other colonizing insects that reduce the pile. A disturbed pile also is much less suitable habitat for fly larvae, reducing breeding success.

Figure 12. Undisturbed manure (left) contrasted with manure disrupted by dung beetles and birds searching for seeds or larvae (right).

Cattle egrets (*Bubulcus ibis)* were sighted among the sheep grazing near the kalo field, including a bird riding the back of one member of the flock. The birds were present among the Mahaulepu Cattle Co. animals and in the open fields on HDF lands. In 1959, the original intent in purposefully introducing these birds was, as their name implies, to co-habit with cattle and eat insects associated with the herd. The commonly seen behavior of egrets following large grass mowers mimics their natural behavior of following large animals like cattle to catch insects disturbed by the animals. Their presence is one part of the integrated pest control web.

SURVEY RESULTS: Cattle related species

Table 1: Wildlife present at Māhā'ulepū, Kaua'i, associated with manure or manure pests

Species	Common Name	Status	Frequency	Notes / breeding sites
ARTHROPODA				
ARACHNIDA				
ARANEAE	spiders			
Araneidae				
Argiope appensa (Walckenaer 1841)	orb weaver spiders	Adv	O	multiple webs in Norfolk Is. Pines, road makai property boundary
Tetragnathidae				
Tetragnatha mandibulata Walckenaer, 1841	long jawed spider	Adv	O	on web over ditches
INSECTA				
COLEOPTERA				
Scarabaeidae				
Aphodius lividus (Olivier, 1789)		Adv	A	brown, striped; slender species; 6mm size
Onthophagus gazella (Fabricius, 1787)	brown dung beetle	Pur	C	black, common in/under manure pads; 12mm
DIPTERA				
Calliphoridae				
Lucilia sericata (Meigen, 1826)	greenbottle fly	Adv	C	shiny; 5 to 10 mm
Muscidae				
Haematobia irritans (Linnaeus, 1758)	horn fly	Adv	O	slender, gray; 5mm
Stomoxys calcitrans (Linnaeus, 1758)	stable fly	Adv	A	spots on abdomen; common on manure; 6mm
Sepsidiae				
Sepsis biflexuosa biflexuosa Stobl, 1893		Adv	AA	black, slender flies mass on fresh manure
HYMENOPTERA	wasps, bees, ants			
Formicidae	ants			
Ochetellus glaber (Mayr, 1862)		Adv	C	on fresh manure
Pheidole megacephala (Fabricius, 1793)	bigheaded ant	Adv	AA	on soil near manure
Camponotus variegatus	carpenter ant	Adv	U	under dried manure
Vespidae				
Polistes sp.	common paper wasp	Adv	C	office trailer; empty nest on plains

Table 1: continued

Species	Common Name	Status	Frequency	Notes / breeding sites
LEPIDOPTERA	butterflies & moths			
Lycaenidae				
Lampides boeticus (Linnaeus)	bean butterfly	Adv	C	flock to minerals at moist soil with urine
ODONATA	dragonflies; damselflies			
Coenagrionidae	damselflies			
Ischnura ramburii (Selys-Longchamps)	Rambur's damselfly	Adv	C	in flight at ditches
Libellulidae	skimmers			
Orthemis ferruginea (Fabricius, 1775)	roseate skimmer	Adv	O	in flight near ditches
Pantala flavescens (Fabricius, 1798)	globe skimmer	Ind	C	adult in flight proposed Hawai'i Dairy pastures; naiad in Mahaulepu Cattle Co.'s water tank
VERTEBRATA				
Amphibia				
Bufonidae				
Bufo marinus Schneider, 1799	cane toad or bufo	Pur	A	tadpoles in ditches; adults in HDF pastures
Ranidae				
Rana catesbeiana	bull frog	Pur	U	in ditches
Aves				
Ardeidae				
Bubulcus ibis	Cattle egret	Pur	C	proposed Hawai'i Dairy pastures
Nycticorax nycticorax hoactli	Black-crowned night-heron	Ind	U	proposed Hawai'i Dairy pastures / near stream
Phasianidae				
Francolinus sp.	Francolin	Pur	O	proposed Hawai'i Dairy pastures
Gallus gallus domesticus	Feral chicken	Pur	C	proposed Hawai'i Dairy pastures

FREQUENCY = occurrence ratings:

R	Rare	seen in only one or perhaps two locations.
U	Uncommon-	seen in several locations
O	Occasional	seen with regularity
C	Common	observed numerous times
A	Abundant	found in large numbers
AA	Very abundant	abundant and dominant

STATUS:

End	endemic to Hawaiian Islands
Ind	indigenous to Hawaiian Islands
Adv	adventive
Pur	purposefully introduced
?	unknown

Survey Results: Dairy related species continued

INVERTEBRATES NOTED
ARTHROPODA
ARANEAE (spiders)
Spiders are a part of the natural web of control system against flying insects.

Argiope appensa (Walckenaer 1841)
The HDF property has a very large number of orb weaver spiders. The line of Norfolk Island pine trees at the makai end of the property are especially well placed to host the spiders as breezes deliver flying insects to their webs. They are easily spotted by the distinctive white X where they rest ready to rush out and wrap up the next item snagged by their web. These spiders pose no threat to people or livestock.[2]

Figure 13. Orb weaver in Norfolk Island pine along lower road. The occupant is easily found on the white X at center of web.

Tetragnatha mandibulata Walckenaer, 1841 long jawed spider
This slender spider was seen on webs spun up over the ditches (Figure 5, 6, 7) to snag flying insects emerging from or going to the water. This spider is not a threat to humans or livestock.

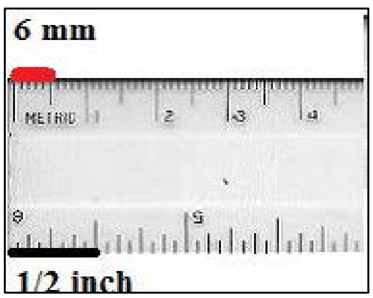
[2] For anyone skeptical of the safety of these spiders: we used them in filming scenes for the TV series LOST where the actor had to have the spider ON them; we use them with children's wildlife classes.

Invertebrates Noted: continued

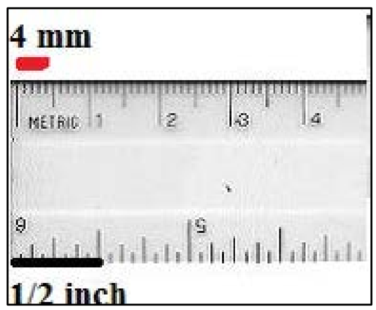
ARTHROPODA
INSECTA
DIPTERA (flies)

Two species of flies were common on the manure piles: *Stomoxys calcitrans* (Linnaeus, 1758) and the smaller and slimmer *Sepsis biflexuosa biflexuosa* Stobl, 1893, 4 mm long. Both are widespread throughout the island chain. *Stomoxys* has the common name "stable fly" due to its association with the manure of horses and cattle, but it also breeds in rotting vegetation, including beach seaweeds. The adult stable fly is 6 millimeters (mm) long, with abdominal spots and prefers to land on animals' legs, causing much annoyance and loss of productivity. The adults feed on the blood of livestock and nearby humans by piercing the skin. Proven control methods include introduction of parasitic micro-wasps and spreading out of manure. (DuPonte and Larish 2003).

The 5 mm horn fly, *Haematobia irritans*, congregates near the horns of cattle on all isles where their biting causes pain and annoyance, interferes with feeding, but it rarely bites man. It has been widespread since 1898 and Kaua'i herds have benefitted from control by imported micro-wasps and beetles that reduce larvae breeding in dung.



actual size *Stomoxys* fly



actual size *Sepsis* fly

Figure 14. Red lines show size of the two most numerous flies on manure: *Stomoxys calcitrans*; and *Sepsis biflexuosa biflexuosa*

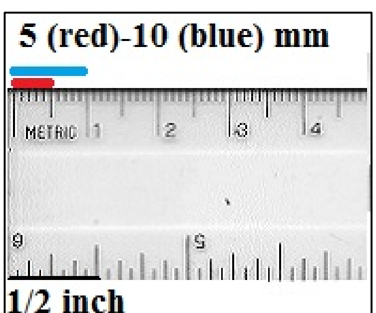


Figure 15. The greenbottle fly is slightly larger and might be confused with the house fly.

The greenbottle fly (*Lucilia sericata (Meigen, 1826)*) was not seen on site, but was reared in small numbers from manure in the lab. It varies in size 5-10 mm in length. This fly feeds by soaking up fluids with a sponge-like mouth and can not bite or sting.

Invertebrates Noted: continued

LEPIDOPTERA (butterflies, moths)
Lycaenidae
Lampides boeticus (Linnaeus) or bean butterfly

Figure 16. The bean butterfly was frequently found on the manure and dirt wet with urine.

At all times of day, these small, attractive bean butterflies were numerous throughout the property. They were observed sitting on manure or wet earth, where it appears they take up minerals in the manure. Their caterpillars are hosted by legumes, on site mostly the alien weed, smooth rattlepod (*Crotalaria pallida* Aiton). In home gardens, however, they are a significant pest of peas and string beans.

Invertebrates Noted: continued

COLEOPTERA (beetles)

Dung beetles destroy manure by both physically tunneling into it, using it as food for their larvae, and by burying it. Breaking up the manure also makes it more accessible to other controlling species. For example, opening up the piles makes it easier for birds to find the larvae of flies. Burying of manure aids soil fertility. Some species of these beetles are already active in the adjoining property. Dung beetles are a key part of the integrated pest management web.

Figure 17. The dung beetles (circle) burrow into the manure leaving distinctive circular holes (arrow).

Scarabaeidae
Aphodius lividus (Olivier, 1789)
Considered a very early, accidental introduction with the first cattle to reach the Hawaiian Islands (Funasaki et al 1988); noted on Kaua'i in 1985 survey (Markin et al. 1998).

Onthophagus gazella (Fabricus, 1787)
Adults and larvae reduce the cattle manure by eating, dispersing, and excavating it. In Hawai'i since 1957; re-released in 1959 and 1973 (Funasaki et al 1988); Noted on Kaua'i in 1985 survey as "most abundant." (Markin et al. 1998)

Invertebrates Noted: continued

HYMENOPTERA (wasps, bees, ants)

Three species of ants were noted in the survey (See Table 1). All are widespread in the island chain. They were observed as present on and under manure where they are predators on eggs and larvae of pest flies. They are part of the integrated pest management web.

- Big-headed ants (*Pheidole megacephala*) are especially fierce predators on other insects, including other ants.
- Carpenter ants (*Camponotus variegatus*), despite the name, do not eat wood, rather the species is attracted to sweet things.
- *Ochetellus glaber* (no common name) is attracted to sweet foods and is recorded as a biter. We have personal experience with *O. glaber* swarming on clean, unused soft paper even in boxes. (e.g., facial tissue) (Figure 18).

Figure 18. *Ochetellus glaber* (inset) ants swarming tissue.

None of the three species sting, but all can bite. Still, despite our close interaction with *O. glaber*, we have only rarely been bitten in 15 years, and that when we were removing them from the area.

See *What's Bugging Me?* [3] and *Pests of Paradise* for suggestions on control measures. See also <u>Medically important species</u> section (page 25)

[3] In 1995, when *What's Bugging Me?* was published, *O. glaber* was only found on O'ahu and Maui; by 2002 when the same author edited the *Hawaiian Terrestrial Arthropod Checklist*, the species had spread to Kaua'i and Hawai'i islands as well.

Invertebrates Noted: continued

ODONATA (dragonflies, damselflies)
Dragon fly adults and young are predators in the integrated pest management web.

Libellulidae: *Orthemis ferruginea*
This handsome dragonfly has both red and pink coloring. It was seen over and near the water in ditches (Figure 5, 6, 7). The adults and young are general predators and so are part of the overall 'natural control' system. Pest flies are among adult dragonfly food items. The young, termed naiads, mature from egg masses laid in fresh water. They control the young of pest species that live in water (such as mosquito larvae).

Figure 19. Dragonflies patrol seeking prey

Figure 20. Pink phase *Orthemis* dragonfly

INVERTEBRATES NOT PRESENT: Native Hawaiian

No federally or state listed endangered or threatened invertebrate species were noted in this survey (DLNR 1997; USFWS 2014). There is no federally designated Critical Habitat for any invertebrate species on or adjacent to the subject property. No anticipated actions related to the proposed project activity in the surveyed locations are expected to threaten entire species or entire invertebrate populations.

MOLLUSCA

Gastropoda (Snails) Pulmonata

Lymnaeidae: *Erinna newcombi* Adams & Adams, 1855 Newcomb's Snail

This threatened Kaua'i native fresh water snail was not found during the survey. The location does not provide appropriate habitat for this species. None of the designated critical habitat for the snail is on the property. (USFWS 2000, 2006b)

ARTHROPODA

ARANEAE (Spiders)

Adelocosa anops Kaua'i cave wolf spider

This survey showed no evidence of lava tubes (caves) that would support the endangered Kaua'i cave wolf spider. An archaeological survey of the area (Dega, et al. 2014) also found no evidence of lava tubes. None of the areas designated as critical habitat for the recovery of this species are in the project area (USFWS 2003a).

INSECTA

Diptera: Drosophilidae *Drosophila*

No native *Drosophila* were observed on the property. The location does not provide appropriate habitat for the native *Drosophila musaphilia* listed as endangered on Kaua'i. (USFWS 2006a). The only critical habitat designated for this species is at Kōke'e, Kaua'i. (USFWS 2008).

Lepidoptera: Sphingidae *Manduca blackburni*

Blackburn's sphinx moth, an endangered species, was not present (USFWS 2003b, 2005). Neither the moth's solanaceous native host plant, 'Aiea (*Nothocestrum* sp.), nor the best alien host, tree tobacco (*Nicotiana glauca*), was observed on the property in this survey or recent botanical surveys (David and Guinther 2014).

Odonata:

No native damselfly species were observed during the survey.

CRUSTACEA

Amphipoda: *Spelaeorchestia koloana* Kaua'i cave amphipod

No suitable habitat for the Kaua'i Cave Amphipod is located on the property (USFWS 2003a) [see above <u>Kaua'i cave wolf spider</u>].

INVERTEBRATES NOT PRESENT: Manure-related

Considerable literature exists on manure-related pest species and their parasites and predators. From these sources, it can be theorized what species of invertebrates might be attracted to fresh manure at HDF sites. Table 2 lists invertebrates species recorded as present on Kaua'i, some for many decades, but not found on site in this survey. The dog dung fly, resident in areas with high pet populations, is notoriously pestiferous due to persistent landings on human legs. Mostly thriving in yards of dog owners not promptly removing dung, farms may be erroneously blamed for high densities of these annoying flies. A few do breed in cow droppings, but this can be reduced with less corn in feed, as Lee and Toyama (1991) showed a positive ovipositional response of *M. sorbens* to residues of digested ground corn in feces of dairy cows.

Table 2. Invertebrates known on Kaua'i but **NOT** present at HDF site

Species	Common Name	Status	on Kaua'i	**not** at HDF
DIPTERA	Flies			
Faniidae				
Fannia canicularis (Linnaeus, 1761)	little house fly	Adv	✓	X
Fannia pusio (Wiedemann, 1830)	chicken dung fly	Adv	✓	X
Muscidae				
Musca domestica Linnaeus, 1758	house fly	Adv	✓	X
Musca sorbens Wiedemann, 1830	dog dung fly	Adv	✓	X
COLEOPTERA	Beetles			
Histeridae				
Pachylister caffer (Erichson, 1834)		Pur	✓	X
Hydrophilidae				
Sphaeridium scarabaeoides (Linnaeus, 1758)		Pur	✓	X
Scarabaeidae				
Copris incertus prociduus Say, 1835	black dung beetle	Pur	✓	X
Oniticellus militaris (Castelnau, 1840)		Pur	✓	X
HYMENOPTERA	parasitoid wasps			
Chalcididae				
Brachymeria podagrica (Fabricus 1787)		Adv	✓	X
Eucoilidae				
Eucoila impatiens (Say, 1836)		Pur	✓	X
Pteromalidae				
Spalangia cameroni Perkins, 1910		Pur	✓	X

STATUS:
Adv adventive Pur purposefully introduced

See Funasaki et al 1988; Markin et al. 1998; Toyama & Ikeda 1976

Invertebrates Not Present: Manure-Related continued

Diptera - flies

These fly species were NOT noted on site in this survey. As these species occur on Kaua‘i, it is possible they could be attracted to cow manure if it were allowed to accumulate in places like the milking areas. The HDF waste management plan minimizes such accumulations of manure. The presence of dung beetles and birds disrupting the manure is an important control mechanism to reduce fly egg laying in the fields.
[See also Recommendations page 28]

Fannia canicularis (Linnaeus, 1761) little house fly

Fannia pusio (Wiedemann, 1830) chicken dung fly
Although several parasitic species have been introduced to the Hawaiian chain to attack this pest, most have not established on Kaua’i. As the common name implies, this fly prefers to breed in large accumulations of chicken dung at night roosting locations. It can breed in cow manure, however, it was not noted at the HDF site during the survey.

Musca domestica Linnaeus, 1758 house fly
Breeds in wide variety of materials, including animal manure of many kinds. Several of the micro wasps introduced to control this fly have not been recorded on Kaua’i.

Musca sorbens Wiedemann, 1830 dog dung fly
As with *F. pusio* and *M. domestica*, species introduced to control this fly have not established on Kaua’i. Found most commonly in dog droppings that are left in the open, the fly can use cow manure for egg laying.

Coleoptera – beetles

Adults and larvae of several beetle species reduce cattle manure by eating and moving it. This disrupts, degrades, and reduces the volume of manure, making less habitat for flies. At no point in their life cycle do dung beetles feed on any living plants, and they are incapable of biting or stinging humans or animals.

In addition to the two species of dung beetles seen during the survey, the manure-feeding species in Table 2 are known to have been present on Kaua’i for many years. These species would naturally move to the new manure resources created by the HDF operation. The beetles also could be imported to the site to start the population. [See Recommendations page 28]

Pachylister caffer (Erichson, 1834)
In Hawai’i since 1957; Noted on Kaua’i in 1985 as “very common” (Markin et al. 1998).

Sphaeridium scarabaeoides (Linnaeus, 1758)
In Hawai’i since 1909 (Funasaki et al 1988); Noted on Kaua’i in 1985 survey as “common” (Markin et al. 1998)

Invertebrates Not Present: Manure-Related continued
Coleoptera – beetles continued

Copris incertus prociduus Say, 1835
In Hawai’i since 1922 (Funasaki et al 1988); noted as present on Kaua’i in 1985 survey, but not a robust population (Markin et al. 1998).

Oniticellus militaris (Castelnau, 1840)
In Hawai’i since 1957 (Funasaki et al 1988); noted as present on Kaua’i in 1985 survey, but not a robust population (Markin et al. 1998).

Hymenoptera - ants, bees, wasps

Several extremely tiny parasitic wasps have been introduced to the Hawaiian Islands as a means of reducing pest fly populations for many decades. The adult wasps lay their eggs in the larvae of flies. These wasps do not sting humans or livestock, their ‘stinger’ is actually an ovipositor – a way to put their eggs into the larvae of a fly. The adult male wasp has no ‘stinger’.

Figure 21. Life size comparison (left to right) of US dime, parasitic wasp, fly pupa (King)

Eucoila impatiens (Say, 1836)
In Hawai’i since 1910 (Funasaki et al 1988); known on all major islands

Brachymeria podagrica (Fabricus 1787)
This species is established on O’ahu and Kaua’i. It was not purposefully introduced, but most likely came into the islands very early aboard a ship carrying livestock or horses and their manure.

Spalangia cameroni Perkins, 1910
Introduced to Hawai’i 1914-1920 (Funasaki et al 1988); Known on all major islands.

Figure 22. *Spalangia cameroni attacking* fly pupa to lay her own egg [left (Jones)]. Adult wasp emerging from housefly pupa [right (EntomoBiotics)].

Both images much larger than life size. See Figure 21 for actual size scale.

Potential Impacts of Control Measures on Endangered or Threatened Native Species Diptera: *Drosophila*

The project location does not provide any habitat for *Drosophila musaphilia*, the only Kaua'i species of native Hawaiian fly listed as Endangered or Threatened (USFWS 2008). Any control measures taken to curb cattle-associated pest fly species at this site will not affect native *Drosophila* many miles away in high elevation koa forests. In citing the reasons for the decline of the native *Drosophila,* U.S. Fish & Wildlife notes as a threat the yellow-jacket wasp (*Vespula pensylvanica*) a large, aggressive wasp [see following sections Medically important species]. (USFWS 2006a) Yellow-jacket wasps are unrelated to the tiny parasitic wasps used for control of pest flies associated with cattle operations. Venomous yellow-jackets are predators, attacking other insects, and are a danger to humans, pets, and livestock. Parasitic wasps target a few specific species, lay eggs in the larvae of these target flies, and pose no threat to humans, pets, or livestock.

None of the control species (beetles or wasps) for manure-related pests are known to target native Hawaiian species (Funasaki et al. 1988). Additionally, the elevation and habitat at the HDF site are not appropriate for native Hawaiian flies.

No native invertebrates of **any** species are attracted to manure of large herbivores. As deer, goats, cattle, pigs, and horses were NOT present in pre-human Hawai'i, native invertebrates did not evolve to use large manure piles as habitat or food.

Potential Impacts of Control Measures on Beneficial Adventive Species

All of the parasitic or predator species listed in Table 2 and 3 have been in the Hawaiian Islands for many decades, in some cases for more than half a century. Each species is focused on a particular target species and is not a general predator. For example, as flies and bees are in very different insect lineages, a predator focused on flies would not select bees as a target. Honey bees have not been affected by any fly predators. Recent honey bee declines in the wild on O'ahu and Hawai'i islands are due to recent accidental introductions of the Varroa mite that directly targets honey bees, and a souring beetle that ferments nectar in the hive. Neither has been reported on Kaua'i, and quarantines must be maintained to ensure they do not arrive. Strict compliance with agricultural / equipment inspections and with shipping rules is important.

Medically Important Species

Honey bees (*Apis mellifera)* were seen at the watering trough for the Mahaulepu Cattle Co. stock (Figure 23) and on HDF overhead sprinklers. It is to be expected that honey bees will visit any water source set up for the HDF herd. Bees are an essential part of the overall agricultural ecosystem. A ‘ramp’ should be built into any open water source to allow bees some chance of escape rather than drowning (red circle). A struggling bee, floating in the tank, lapped up by a drinking cow could sting by reflex. It would be appropriate to use a scoop or sieve to remove bees before stock enter the drinking area.

[See Cautions end of this section, page 27]

Figure 23. Any water source will attract bees, an important part of the agricultural system. An “escape ramp” can reduce drowning.
[photo of non-HDF water trough]

Medically important species: continued

Leaf cutter bees (megachilids), also on site, may be found in hollow twigs, tubing and similar hollow structures. A member of the public could confuse a leaf cutter bee with a honey bee or large fly, so reports of such should be verified.

© **Figure 24**. Black female, golden male Carpenter bees; tunnel

Carpenter bees (*Xylocopa sonorina*) are on the property. The big, black carpenter bee females and golden males are easily seen. Carpenter bees carve out a short tube shaped tunnel in soft wood (fence post, dry branches) (Figure 24). They do not form colonies, but live solitarily.

Neither leaf cutter nor carpenter bees are a danger to people or livestock if undisturbed.

Figure 25. Paper wasp nest at office

Common paper wasps (*Polistes* sp.) were seen, in several places on the property. There are two species known on Kaua'i. This wasp may expand their numbers when structures are erected on the property, creating dry, sheltered sites. These wasps are common throughout the island lowlands and especially like to build their 'paper' nests under the overhangs of buildings. One was noted in the Norfolk Island pine directly outside the HDF office trailer (Figure 25). They are a danger to humans. They sting repeatedly, unlike honey bees. Nests are best destroyed at night when all wasps are on the paper nest. Destroying the nest during daylight hours will result in rebuilding when the wasps return later in the day.

Medically important species: continued

Mud dauber wasps (*Sceliphron caementarium*) were seen on the HDF site. This medium-sized wasp builds a shelter for its young from mud and supplies the nest with food such as small spiders. Occasionally, the wasps will congregate in a sheltered location such as an overhang to rest. They can sting humans, but rarely come in direct contact with people. If encountered, do not interfere with them. The wasps are shy and should not be a risk to the livestock under normal conditions. They are spider predators.

© **Figure 26**. Ground nesting yellow-jacket wasps are currently known only in higher elevations on Kaua'i. None were observed; however employees should be alert for the wasps and obtain help if a nest is discovered.

Yellow-jacket wasps (*Vespula pensylvanica* (Saussure, 1857)) (Figure 26 above) were **NOT** seen on HDF property, although the species is present on mauka Kaua'i. This large, ground nesting, aggressive wasp is a danger to humans, pets, and livestock. HDF staff should be familiar with the appearance of yellow-jacket nest entrances and obtain professional extermination help immediately if one is suspected. Cordon off the area and restrict access until an eradication team with proper protective gear can arrive. Never attempt to deal with this wasp yourself.

The property includes habitat for **centipedes, scorpions, and brown widow spiders**. Although these medically important species were not seen in this quick survey, they are likely to be present in the area. They are general insect predators and will attack a wide variety of species.

GENERAL CAUTIONS: Avoid storing boxes or bags directly on the ground or on cement floors, as this provides 'habitat' for centipedes and others that can sting when disturbed. Be alert when moving stones or piled brush. Wearing gloves, covered shoes, long sleeves, and long pants will greatly reduce the risk of accidental stings or bites.

Medically important species: Cautions   continued

Important to survival of useful insects and vertebrates (e.g., bees, birds) are safe application practices when using any unavoidable herbicide or pesticide. Carefully chosen materials with narrowly targeted applications directed toward the pest species are important. Anyone using herbicides or pesticides should be trained and informed for safety of workers, cattle, and all non-target wildlife. If a honey bee colony location appears to be a danger to workers or cattle, contact a local beekeeper for advice and removal.[4]

Please see *What Bit Me?* (Nishida and Tenorio 1993) and *Pests of Paradise* (Scott and Thomas 2000) for additional information on human / insect interaction.

NOTE: **None** of the parasitic wasps discussed in this report as potential controls of pest flies are listed as threats to humans in either *Pests of Paradise* or *What Bit Me?*

Employees should be alert for all species named above during work on the property. Some individuals can experience anaphylactic reactions to the venom, not just of honey bees, but to any of the arthropods mentioned in this section. Each of these species may pose a serious risk to some individuals, and supervisors should be aware of any special employee allergy. Any allergic employees should have their antidote nearby at all times and ensure others know where it is and how to assist them.

RECOMMENDATIONS

MONITOR NEAR-BY, NON-DAIRY FLY BREEDING LOCATIONS

Be vigilant regarding the number of chickens, cats, and dogs in the vicinity of the HDF operation. While these may have their place in a farm operation, each of these species can provide sufficient manure to breed flies, for example, chickens are among the birds disturbing cattle manure and helping to reduce fly habitat. Dogs discourage wild pigs and rats. Cats reduce rats and mice. Proper disposal of dog and cat feces is important. If the chickens increase and congregate, feces may accumulate to an amount sufficient to become a fly breeding location.

Good housekeeping is an important tool in controlling establishment of most flies. Human food waste from on-site workers’ meals should be disposed of in a covered, lined container and removed from the site often. Any spilled or waste supplement foods for the cattle should not be allowed to become wet and stay exposed. As it rots, it will provide attractive habitat for fly breeding. Dispose of these materials promptly.

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[4] Find a beekeeper via Hawaii Beekeeper’s Association. www.hawaiibeekeepers.org/list.php

Recommendations: continued

An increase in illegal dumping of household trash may prove to be an unintended consequence of the new Kaua'i County Council's approval of a variable rate / volume trash disposal fee (Moriki *2014*). The anonymity provided by locations such as the country roadsides in the near vicinity of HDF may become a convenient place to drop trash. For example, after large parties, bags of trash containing food remains may be dumped, rather than held at home when a family's smaller trash cart is filled. Household trash sitting in the open is a recognized fly breeding habitat (Ikeda et al. 1973). HDF personnel should be alert for bags along the roads around the property and remove them if practical. If left, the trash bags could breed flies that would then migrate to the nearest habitat of interest – the cattle manure.

ENCOURAGE ECOSYSTEM TRANSFER:
As Mahaulepu Cattle Co. stock are present in the adjacent property, the species associated with manure breakdown also are present. If the HDF cattle began their journey around the HDF paddocks in the sections near areas where the Mahaulepu Cattle Co. herd was recently grazing, the predators and parasites would more readily migrate to the manure being deposited by HDF cattle.

INCREASE DUNG BEETLE DIVERSITY:
Among the effective methods of controlling flies that breed in cattle manure is to speed the manure toward composting. Dung beetles are specialists in the very important natural process of breaking up and quickly recycling bovine manure pads. Below are outlined short-term and long-term methods of enhancing existing dung beetle numbers to breakdown larger quantities of manure patties.

A. Immediate increase in numbers
In the new pastures, it would be beneficial to quickly boost the breeding population of dung beetles as the cows arrive and begin defecating. This could be accomplished by transplanting adult beetles from older Kaua'i pasture locations. Dung beetles are attracted to light at night, so by visiting locations where beef cattle are established and setting up a typical entomological night collection light with white sheet (Figure 27), it would be possible to collect many adults.

©**Figure 27**. Typical night collection sheet / light set up.

Recommendations: Increase Dung Beetle Diversity: continued

These could be transported to HDF pastures and placed near fresh manure, which they would quickly colonize and break down as part of their breeding cycle. This would accelerate a dung population increase.

B. Multiple benefits of diverse dung beetle species

Cattle manure contains carbon and valuable soil nutrients, and is a food source for soil microflora, protozoa, and earthworms. For the manure's value to be realized, it must be incorporated into the soil profile. Dung beetles are nature's way of recycling these resources back into the soil to be further broken down and encourage plant growth. If manure stays on the soil surface and dries, 80% of the nitrogen is lost into the atmosphere. (Griffith 1997)

Australia provides an example of the efficiency and results provided by dung beetles. Unburied manure from Australia's imported cattle was a fertile breeding ground for nuisance flies until a comprehensive bio-control project to reduce and recycle bovine manure was initiated by Professor George Bornemissza, Commonwealth Scientific and Industrial Research Organisation (CSIRO). The project replicated the intricately adapted dung processing by beetles known in Africa and Europe. In 1972 the first dung beetles were brought into Australia, and the beetles now break up the pads and bury the rolled away dung balls after laying their eggs in them. This ecologically based work both controlled the fly nuisance and helped to improve soil fertility. Dr. Bornemissza found that 95% fewer horn flies emerged from cow pats attacked by the beetle, *Onthophagus gazella*, than from pats without beetles. (Ūrményházi 2010)

In 1998, entomologists George Markin, U S Forest Service, and Ernie Yoshioka, Hawai'i Department of Agriculture (HDOA), both now retired, wrote a history and evaluation of a century of manure insect biological control work by HDOA and cooperators. These experts wrote that some of these species could be distributed to new islands to more quickly recycle bovine manure pads and reduce fly larva habitat. Dr. Markin writes:

> "In the State of Hawaii, the horn fly control program was one of the longest and most extensive biological control projects for a single insect pest. It resulted in the establishment of a complex of 25 agents, representing 6 families of insects, all using the same ecological resource, cattle dung, in diverse pasture habitats and microclimates. The program appears to have been successful in some parts of the island of Hawai'i, and probably would have also shown similar success on neighboring islands, if vigorous redistribution of the new African beetles had been attempted." (Markin and Yoshioka 1998)

Recommendations: Increase Dung Beetle: Diversity

In an ideal complex of dung beetles, manure burial would be ongoing 24 hours a day. Though it may take several different dung beetle species to accomplish this goal, the behavioral diversity among species makes it a feasible goal. Some are nighttime flyers, some fly during the day, and some prefer older manure to very fresh. If several species are working together, some may bury the brood ball close to the manure pat, some farther away, some shallow and some deep. (Figure 28) (Thomas 2001)

High populations of dung beetles will bury dung pats in one to three days. This destroys the habitat for other insects and internal parasites to complete their life cycle. Charles Griffith has reported that Texas scholar, Dr. Truman Fincher has studied both the Hawai'i Parker Ranch dung beetle populations and worked with many Texas cattle herders who changed to holistic management using cell grazing systems and high stock density. Additionally, his work showed less use of veterinary parasiticide chemicals with long lasting residues helped dung beetle populations soar, and kept pastures cleaner. A report by K. Kruger and C. H. Scholtz in a recent publication of the *Journal of Agriculture Ecosystems and Environment,* on lethal and sublethal effects of ivermectin on dung beetle breeding stated that treated cattle's manure had suppressed development of the dung beetle *E. intermedius* for 28 weeks after injection. (Griffith 1997)

A long-term, ecological method of combating manure fly breeding would be increasing the diversity of dung beetle species now present on Kaua'i. The distribution records (Bishop Museum 2014) show only some of the 14 dung beetle species imported between 1898 and 1982 were located on Kaua'i in a 1985 survey (See Table 3 by Markin and Yoshioka 1998). Bringing some of these additional beneficial species to Kaua'i might be done in cooperation with the Hawai'i Department of Agriculture and other cattle owners to the benefit of all cattle operations.

Table 3. Natural enemies of horn flies and their relative abundance recovered in a 1985 survey on four Hawaiian islands. Parasitic Hymenoptera were not included in this survey.

Species	Year(s) of Introduction	Abundance Hawai'i	Maui	O'ahu	Kaua'i
Scarabaeidae (Dung Beetles)					
Aphodius fimetarius	1909	+++	++	+++	?
A. lividus	Cosmopolitan	+++	++	+++	+
Canthon humectus	1923	++	–	–	–
Copris incertus (=*incertus*)	1922	++	+	++	+
Euoniticellus africanus	1974	++	–	–	–
Oniticellus (=*Liatongus*) *militaris*	1957	+++	++	+++	+
Oniticellus cinctus	1958	–	–	++	–
Onitis alexis	1976	++	–	–	–
O. vanderkelleni	1976	+	–	–	–
Onthophagus binodis	1973	++	–	–	–
O. gazella (=*catta*)	1957, 1973	+	++++	++++	++++
O. incensus	1923	+	–	+++	–
O. nigriventris	1975	++++	+	–	–
O. sagittarius	1958	–	–	+++	–
Histeridae					
Hister (=*Pachylister*) *caffer*	1957	+	+++	+++	+++
H. nomas	1957	+	+	++	–
H. bimaculatus[4]	1909	–	–	–	–
H. coenosus[4]	1952	–	–	–	–
H. (=*Pachylister*) *lutarius*[4]	1958	–	–	–	–
Hydrophilidae					
Sphaeridium scarabaeoides	1909	+++	+++	++	++
Staphylinidae					
Oxytelus sp.	1920	+	+	+++	

– = Not recovered; + = One or two specimens recovered; ++ = Common at a few locations; +++ = Very common at most locations; ++++ = Most abundant species in the complex

[4] Previously recorded as established (Table 1), but not recovered in these surveys.

Table 3. Markin and Yoshioka listed enemies of flies not established on Kaua'i (far right) by 1985. A **dash** indicates their survey did not find that species. (1998, p 47)

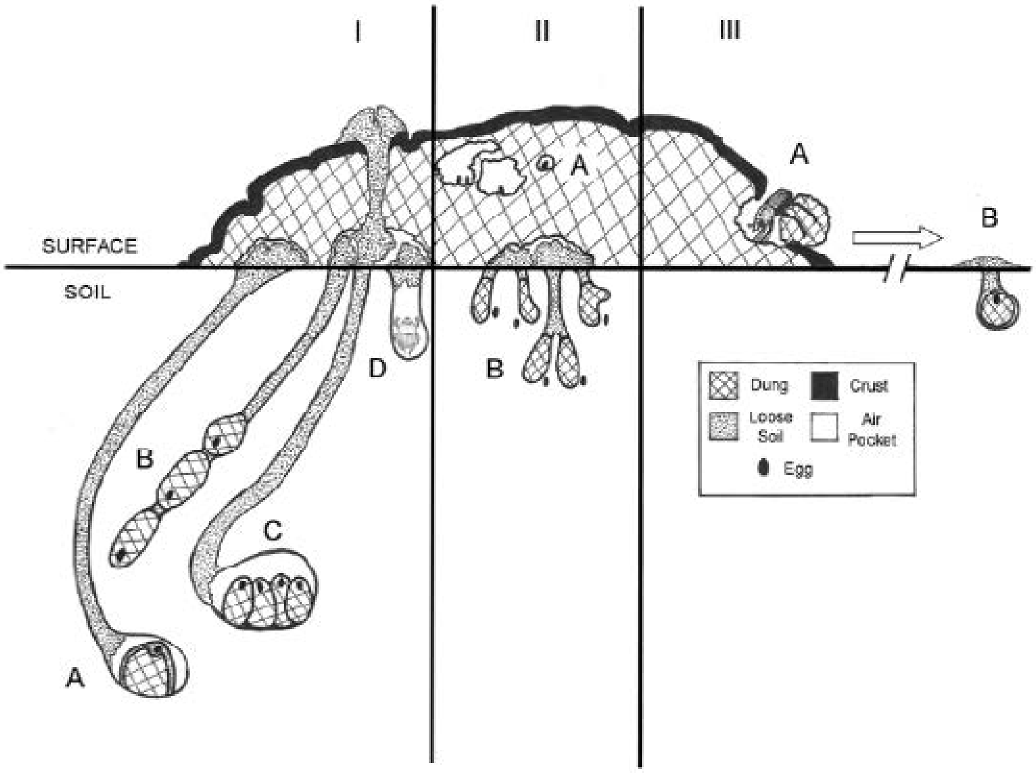

Figure 1. Cross section through dung pat depicting three nesting types:

Tunnelers I-A. *Phanaeus vindex* tunnel with single, soil-coated brood ball in single chamber; B. *Onthophagus* species tunnel with multiple brood masses; C. *Copris minutus* multiple brood balls; D. beetle excavating new tunnel (note subsurface soil is pushed through the dung pat crust)

Dwellers II-A. *Aphodius pseudolividus* eggs are laid singly or in groups inside dung pat; B. *Aphodius erraticus* bury dung under pat with eggs laid beside brood masses.

Rollers III-A. *Canthon pilularius* adult carving out dung into a ball; B. ball rolled a distance away from pat and buried shallowly.

Figure 28: Graphic illustration of the classic break down of dung, shows why establishing species already in the state, but not on Kaua’i is important. Each dung beetle species uses a different strategy in manure break down and cleanup. Multiple species lessen competition by using a different area of the manure and moving it to a different place. (from Bertone et al. n.d.)

ACKNOWLEDGMENTS

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Steven Lee Montgomery conducted all collecting and is responsible for all conclusions. Anita Manning assisted in the field survey and contributed to preparation of this report. Some images used in this report were not taken in the course of this project. These photos, marked by © symbol are not released for other uses. They were made by Anita Manning and/or S. L. Montgomery prior to this contract and were chosen because they best illustrate the subject.

STANDARD NOMENCLATURE

Bird names follow *Hawaii's Birds* (Hawaii Audubon Society 2005).
Invertebrate names follow
Common Names of Insects & Related Organisms (HES 1990)
Hawaiian Terrestrial Arthropod Checklist (HBS2002a; Nishida 2002)
Mammal names follow *Mammals in Hawaii* (Tomich 1986).
Place name spelling follows *Place Names of Hawaii* (Pukui et al. 1976).
Plant names follow
Manual of the Flowering Plants of Hawaii (Wagner et al. 1999)
A Tropical Garden Flora (Staples and Herbst 2005)

ABBREVIATIONS

APHIS U. S. Dept. of Agriculture's Animal & Plant Health Inspection Service

CSIRO Commonwealth Scientific and Industrial Research Organisation [federal government agency for scientific research in Australia]

DLNR Department of Land and Natural Resources, State of Hawai’i

DOFAW Division of Forestry and Wildlife, State of Hawai’i

HDF Hawai’i Dairy Farms

HDOA Hawai’i Department of Agriculture

sp. species

spp. more than one species

USFWS United States Fish and Wildlife Service

GLOSSARY[5]

Adventive: organisms introduced to an area but not purposefully.

Alien: occurring in the locality it occupies ONLY with human assistance, accidental or purposeful; not native. Both Polynesian introductions (e.g., coconut) and post-1778 introductions (e.g., guava, goats, and sheep) are aliens.

Arthropod: insects and related invertebrates (e.g., spiders) having an external skeleton and jointed legs.

Endemic: naturally occurring, without human transport, ONLY in the locality occupied. Hawaii has a high percentage of endemic plants and animals, some in very small microenvironments.

Indigenous: naturally occurring without human assistance in locality it occupies; may occur elsewhere, including outside the Hawaiian Islands. (e.g., Naupaka kahakai (*Scaevola sericea*) is the same plant in Hawai'i and throughout the Pacific).

Insects: arthropods with six legs, and bodies in 3 sections

Invertebrates: animals without backbones (insects, spiders, snails / slugs, shrimp)

Kalo lo'i: taro farm

Larva / larval / larvae (plural): immature stage of offspring of many types of animals.

Makai: toward the ocean

Mauka: toward the mountains

Native: organism that originated in area where it lives without human assistance. May be indigenous or endemic.

Natural control: the predator – prey balance in nature that keeps numbers in check. For example, if there's an increase in flies, spiders, dragonflies, and others have more food, are healthier, and can have more young of their own species. The balance is soon restored. This is as opposed to bio-control which involves humans adding predators to the ecosystem.

Naturalized: an alien organism that, with time, yet without further human assistance, has become established in an area to which it is not native.

Pupa: the stage between larva and adult in insects with complete metamorphosis, a non-feeding and inactive stage often inside a case

Purposefully introduced: an organism brought into an area for a specific purpose, for example, as a biological control agent.

Rare: infrequently found, low numbers.

Species: all individuals and populations of a particular type of organism, maintained by isolating mechanisms that result in their breeding mostly with their kind.

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5 Glossary based on definitions in *Biological Science: An Ecological Approach*, 7th ed., Kendall/Hunt Publishing Co.; on *Manual of Flowering Plants of Hawai'i*, glossary, and other sources.

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APPENDIX C

HAWAIʻI DAIRY FARMS SOILS BASELINE NUTRIENT STATUS: IMPLICATIONS FOR LONG-TERM SUSTAINABILITY, PRODUCTIVITY, AND SOIL HEALTH

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Hawaiʻi Dairy Farms Baseline Nutrient Status: Implications for Long-Term Sustainability, Productivity, and Soil Health

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May 24, 2016

Prepared for Group 70 International

Introduction

Hawai‘i Dairy Farms, located in Maha‘ulepu Valley, Kaua‘i (Figure 1), implements a new approach, in Hawai‘i, to sustainable dairy operations. The land application of manure nutrients used for crop production, and the subsequent monitoring and managing of key nutrient cycles, specifically those of nitrogen, phosphorus and potassium, as well as hydrologic and carbon cycles, are used to guide dairy management in order to ensure sustainable production while maintaining or improving soil and ecosystem health. The application of effluents generated from dairy operations via irrigation systems has been shown to be an effective means of both managing the effluent while simultaneously returning nutrients needed by the productive tropical grasses (Fulkerson et al., 2016). The value of returning nutrients from dairy effluent has been demonstrated and documented in Hawai‘i conditions by Valencia-Gica (2012). Effluents also contain large quantities of nutrient salts such as sodium (Richards, 1954; Cameron et al., 2003) and potassium that, under specific conditions, require specific management.

Knowledge of the area’s hydrologic conditions, specifically soil drainage characteristics, is essential to utilizing beneficial nutrients from dairy effluent while reducing or eliminating detrimental accumulations of sodium and salts (Silva et. al., 1999). Because one of the objectives of dairy management is to provide ample quantities of nutritious forage for the dairy animals, an assessment of nutrient status and content is needed to ensure maximum productivity of the tropical grasses selected for the dairy. Lastly, an initial characterization of nutrient status constitutes a baseline for future monitoring of nutrient cycles. Macronutrients, nitrogen and phosphorus are major components of pasture grass productivity, ecosystem health and sustainability. The purpose of this study was to review existing information regarding soil nutrient status and to suggest management that would be needed to improve soil health so as to ensure forage grass productivity and sustainability.

Previous Work

Previous survey, characterization and analysis of the Hawai‘i Dairy Farm site was carried out and produced the following reports:

- Spectrum Soils Data Analysis
- Field Trials and estimates of kikuyu forage grass production
- Groundwater Assessment and Hydrologic Analysis of the Hawai‘i Dairy Farm site
- Waste Management Plan, for 699 Mature Dairy Cows
- Estimates of nutrient balance and management for 699 to up to 2,000 mature dairy cows

Spectrum Soils Data Analysis

Samples from all proposed paddocks were taken and analyzed. The results from 22 samples of soils from paddocks 101 to 123 (upper central portion of the dairy) are given in Table 1.

Table 1. Average soil pH, soil organic carbon, and key nutrient levels in soils of the proposed site at Hawai‘i Dairy Farms, Maha‘ulepu Valley, Kaua‘i (Spectrum Analysis of 22 samples – North portion of the dairy).

Soil Measurement	Mean	Range
pH - water	6.7	5.6 - 8
Total carbon (estimated from organic matter, %	3.03	1.92 – 4.42
Mehlich extractable phosphorus (plant available), mg kg^{-1}	10.4	4 - 42
Exchangeable potassium, cmol kg^{-1}	0.45	0.13 – 0.97
Exchangeable calcium, cmol kg^{-1}	13.4	3.29 – 39.76
Exchangeable magnesium, cmol kg^{-1}	7.25	3.07 – 11.1
Exchangeable sodium, cmol kg^{-1}	-	-
Soil salinity, dS m^{-1}	-	-

These results report that soil pH was highly variable, ranging from a low of 5.6 to a high of 8. This indicates a great deal of variability that should be considered in developing management options. Soil organic carbon levels were moderately high, yet highly variable throughout the sampled area. Plant extractable phosphorus was generally low, but varied greatly – from 4 to 42 mg P kg^{-1}. Exchangeable potassium was generally low (0.45) but also varied widely from 0.13 – 0.97. Average exchangeable calcium was moderately high but also varied the most among soil nutrients from 3.29 to 39.76 cmol kg^{-1}. Average exchangeable magnesium was also relatively high at 7.25 and also varied widely from 3.07 – 11.1 cmol kg^{-1}. Soil salinity and sodicity were not initially measured but were assessed with a subsequent sampling and analysis given in this report.

Low initial levels of soil nutrients

A summary of the results indicated that levels of soil nutrients were generally low and inadequate to sustain high forage grass productivity. Such low levels of nutrients were only of moderate concern because the application of manures and effluents are known to supply substantial quantities of nutrients that can enrich and regenerate soil fertility (Valencia-Gica et al., 2012). While initial soil carbon values were moderate, it is likely that management for high forage yield through irrigation and organic fertilization with manure will greatly improve soil carbon levels and improve soil health.

Field Trials and estimates of kikuyu forage grass

On site estimates of forage grass productivity were conducted to assess actual forage grass productivity of the Maha‘ulepu.

Table 2. Actual yields of kikuyu (*Pennisetum clandestinum*) forage on site at Maha‘ulepu, Kaua‘i (2014-2015).

Average yield[1], ton dry matter/Acre/year	Range of yield (minimum March, maximum September)
16.3	3.0 – 25.1

[1]Note: It is likely that forage yields would increase considerably with optimal irrigation and application of nutrients. These preliminary results indicate that productivity varies sharply throughout the year requiring some reserve forage.

Hydrologic analysis of the Hawai‘i Dairy Farm site

A hydrologic report from TNWRE (2016) reports an analysis of major hydrologic features of the dairy, comprised of surface water and groundwater. This report concludes that potential losses of nitrogen and phosphorus to surface and groundwater, groundwater flow will not be a significant. “…Relative to the surface water, the groundwater flow in the alluvium is very modest. The formation is poorly permeable and even after HDF is in full operation, its contribution to an increase in nutrient load will not be significant in comparison to surface water.”(TNWRE 2016). Thus the potential loss of nitrogen and phosphorus is primarily dependent on the amount of surface water and runoff, which is minimal due to minimal rainfall (98% of the days have less than 0.8 inches). It is estimated there will be 7 to 8 days a year in which rainfall derived runoff will occur (TNWRE 2016). Best management practices outlined in the Waste Management Plan seem more than adequate to reduce and minimize nutrient loss.

Best management practices identified

Knowledge of the area’s hydrologic conditions, specifically soil drainage characteristics is essential to utilizing the beneficial nutrients from dairy effluent while reducing or eliminating detrimental accumulations of sodium and salts (Silva et. al., 1999). The extensive occurrence of “poorly drained” soils as described further in this report limit leaching of surface water into groundwater as also indicated in the hydrologic report of TNRWE, 2016). Best management practices were identified for controlling surface water in the HDF Waste Management plan (Group70, 2014). The HDF Waste Management Plan (Group70, 2014) calls for a series of BMPs (Best Management Practices) that reduce or eliminate nutrient loading from surface water including set backs, filter strips, buffer plantings and maintaining herbaceous covers. TNRWE, 2016 concludes that the primary challenge will be the operating skills of the HDF personnel, including tracking the actual nutrient balances within the soil, forage, and manure to ensure high forage productivity, avoiding excess fertilizer and anticipating / preparing for weather patterns that might produce runoff. An initial analysis of the nutrient cycling through assessment of the nutrient balances are given below.

Waste Management Plan, for 699 Mature Dairy Cows

A comprehensive waste management plan was prepared and presented in the Waste Management Plan (Group70, 2014). This plan includes assessments and a management plan that includes water resources, flood hazards, soil characterization, dairy management suggestions, irrigation, waste management systems and precautions, as well as monitoring of both soil and water resources.

Implementation of this plan will be essential for ensuring the sustainability of production of forage and the health of the water and soil resources. While quite comprehensive, the report did not include an assessment of the salinity (the addition of nutrient salts) and sodicity (the amount of soil sodium) that might be associated with the high levels of nutrient flux involved as the dairy achieves maximum productivity (Muscolo et al., 2003, El-Swaify, 2000). Other research has shown that effluent in particular contains large amounts of salts (Cameron et al., 2003; Valencia-Gica. 2012). Many of those salts are nutritionally beneficial but some require monitoring such as levels of sodium. The additional sampling, soil characterization, and analysis of the nutrient cycling as represented by the nutrient balance analysis add to nutrient management plan.

Estimates of nutrient balance and management for 699 to up to 2,000 mature dairy cows: *A first approximation of the nutrient balance and estimate of fluxes of nutrients*

An initial estimate of the nutrient balance for the major nutrients nitrogen and phosphorus was reported by Red Barn and Group 70, (2016), Table 3. These calculations provide the basis for estimating nutrient requirements from fertilizers and external sources to ensure grass productivity is sustained at a high level.

Table 3. Estimates of annual nutrient (nitrogen and phosphorus) uptake, manure production, and fertilizer requirements for 470 acres of irrigated dairy pasture (Red Barn and Group 70 report, 2016) revised by including manure contributions from calves.

	Number of cows:	
Average	699	2000
	lbs/acre	
N uptake by pasture	1043	1043
P uptake by pasture	185.8	185.8
N from manure	318.1	920.6
P from manure	66.5	193.6
Nutrients from Supplemental fertilizer		
N	724.8	122.4
P	119.2	-7.9

The nutrients from supplemental fertilizer, shown in Table 3, are not an exact accounting of the total amount of commercial fertilizer to be purchased and applied to the pasture every year. Rather, these values represent the net amount of nutrients required to maintain high forage productivity and soil health from commercial fertilizer, which is beyond nutrients available from manure sources. Fertilization, especially the additional of nitrogen from a commercial fertilizer can be inefficient with respect to forage production and protein content, and fertilization needs can be as much as 25% to 50% greater than the arithmetical difference resulting from a nitrogen balance calculation. The addition of phosphorus from a commercial fertilizer is also quite inefficient, because of the extensive sorption and binding reactions of phosphorus with the soils at the HDF site, sharply reducing the amount that becomes plant available (Jackman et al. 1997).

Grasses with fibrous root systems are typically among the most efficient plants in using applied (whether through manure or commercial fertilizer) nutrients, especially nitrogen. Previous studies have shown that application of effluents generated from dairy operations via irrigation systems is an effective means of both managing the effluent while simultaneously returning nutrients needed by the productive tropical grasses (Fulkerson et al., 2016), and that the value of returning nutrients from dairy effluent has been demonstrated and documented in Hawai‘i conditions by Valencia-Gica (2012). Therefore, commercial fertilization requirements to maintain high forage productivity and soil health can substantially exceed the arithmetic difference between the nutrients applied by manure and effluent and the forage uptake.

Objectives of the further soil characterization and assessment presented in this report:

Based on the above initial information, several gaps were identified that required further data to characterize and assess soil properties to ensure high productivity and sustainability of the dairy. The assessment of salinity and sodicity potential is important because it can affect forage productivity and soil health. This additional sampling of soils of the Hawai‘i Dairy Farm was carried out with the following purposes:

1. Establish a quantitative baseline of nutrients needed to ensure maximum forage productivity.
2. Establish a quantitative baseline for nutrients that are typically supplied in dairy effluent.
3. Evaluate the extent of the “poorly drained” map units of the proposed dairy
4. Establish a quantitative baseline for the salinity and sodicity status of soils. This baseline will provide a reference point to monitor and ensure sustained productivity and soil health of the dairy land.

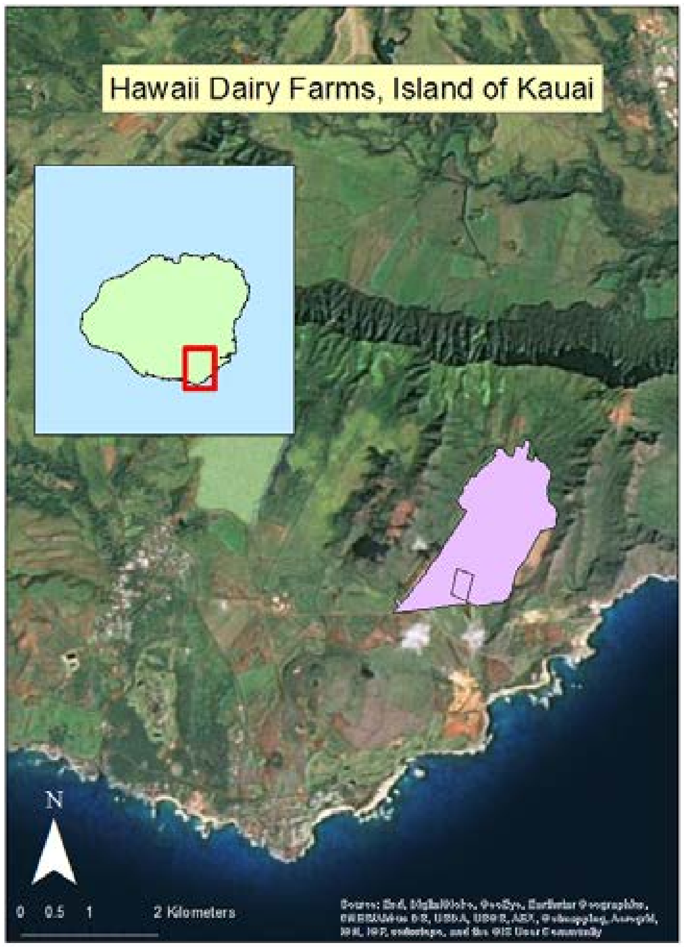

Figure 1. Location of Hawaii Dairy Farms site, Kaua'i, Hawaii

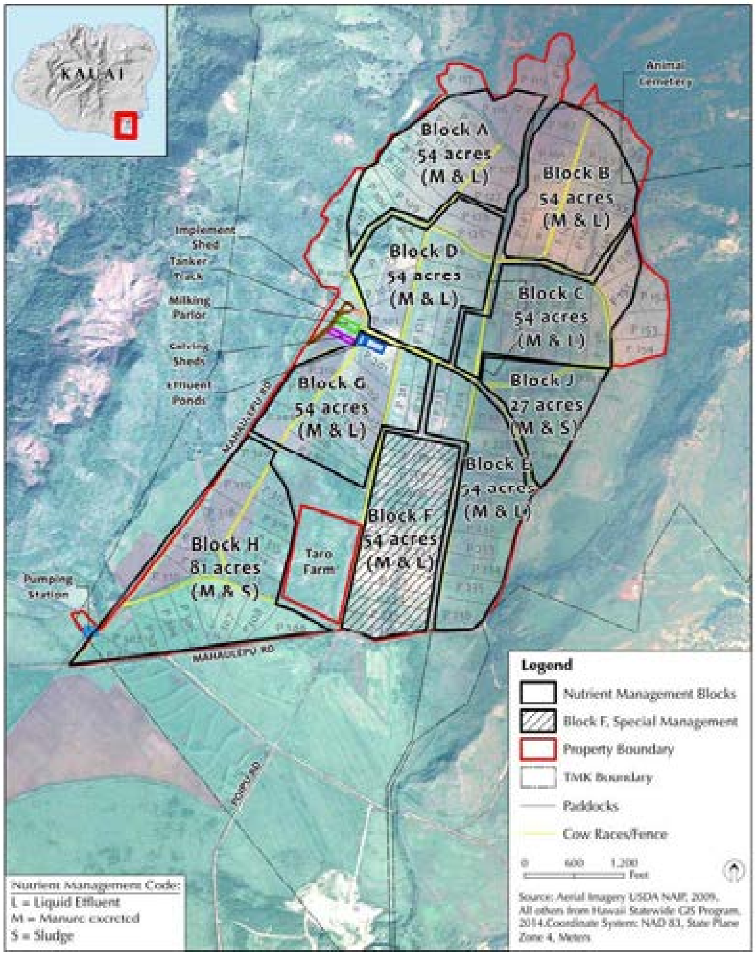

Figure 2. Map of the Dairy showing proposed fields, field management units, and proposed facilities. Note the numbered parcels that comprise fenced grazing units, and "Blocks" that represent proposed management units for 699 mature dairy cows (Waste Management Plan, 2014, prepared by Group70, Honolulu, Hawai'i.)

Sampling, Measuring and Analytical Methods

1. Establishing a quantitative baseline of nutrients needed to ensure maximum forage productivity.

Sampling locations were selected on a gridded map, then entered as points into a geographical information system (ArcGIS) and also uploaded to a handheld global positioning system (GPS) for field location (Fig. 3). Once a sampling site was located with the handheld GPS unit, three subsamples approximately one meter apart were taken for each depth, mixed to prepare a composite sample per depth, then prepared and transported for processing. Processing included drying, crushing, and passing the soil samples through a 2 mm sieve. Processed samples were then delivered to CTAHR's Agricultural Diagnostic Service Center for the analysis.

Soil Analysis

Soils were analyzed for pH, extractable phosphorus, exchangeable potassium, calcium, magnesium, electrical conductivity (EC), and sodium. Finally soil organic carbon and total soil nitrogen were determined. Total nitrogen and total carbon values were analyzed via dry combustion (LECO, 2002) and expressed in weight percent. Phosphorus was analyzed using Olsen's extractable P method (Watanabe and Olsen, 1965), and reported in mg kg^{-1} (equivalent to parts per million or ppm). Cations (potassium, calcium, magnesium and sodium) are reported as centimoles of charge per kilogram (cmol kg^{-1}) in order to account for the amount of charge of the various cations and to permit the calculation of the relative concentration of sodium. Sodium percent of cations (ESP) was calculated as cmol kg^{-1} sodium divided by the cmol kg^{-1} of all cations (potassium, calcium, magnesium and sodium) x 100% in order to compare with literature values in order to evaluate for excessive sodicity. This standard measurement of soil sodicity helps assess the likelihood of soil dispersion, and to compare with recommended values from the NRCS (2012) and other scientific references (McIntyre, 1979; Cameroon et al. 2003). This assessment provides a measure to ensure sustainable productivity and health of the soil resources of the dairy.

Statistical Analysis

The assessment of nutrient adequacy was the statistical comparison and calculations among the soil mapunits. These were carried out using the JMP statistical software (JMP®, 2007). Standard least squares methods were used to test for differences between soil depth and soil mapunit for the nutrient and element contents. Differences were considered significantly different at a probability level of 0.05, although a probability of 0.10 or less was also considered important and worthy of further consideration. Samples from the Ws soil mapunit were not included in the ANOVA since it was only a small portion of the southern portion of the dairy and is basically atypical of the dairy.

Mapping

A geostatistical analysis of the data was also conducted with ArcGIS Geostatistical Analyst Extension using Empirical Bayesian Kriging to map the variability of the fertility characteristics and to interpolate levels of soil measurements to display patterns and trends for the entire dairy. This analysis produces a smooth map of nutrient variation throughout the dairy as illustrated in Figures 3, 4, 5, and 6 illustrating trends and patterns in the soil properties. The analysis also produces a map of prediction error indicating where predictions were less accurate (Figure 7). The map of prediction error helps to identify areas on the dairy which would most benefit from further sampling (Map 10, Sampling Variability). This map of prediction error was almost identical for all response variables, therefore only one (from pH data) is included in this report.

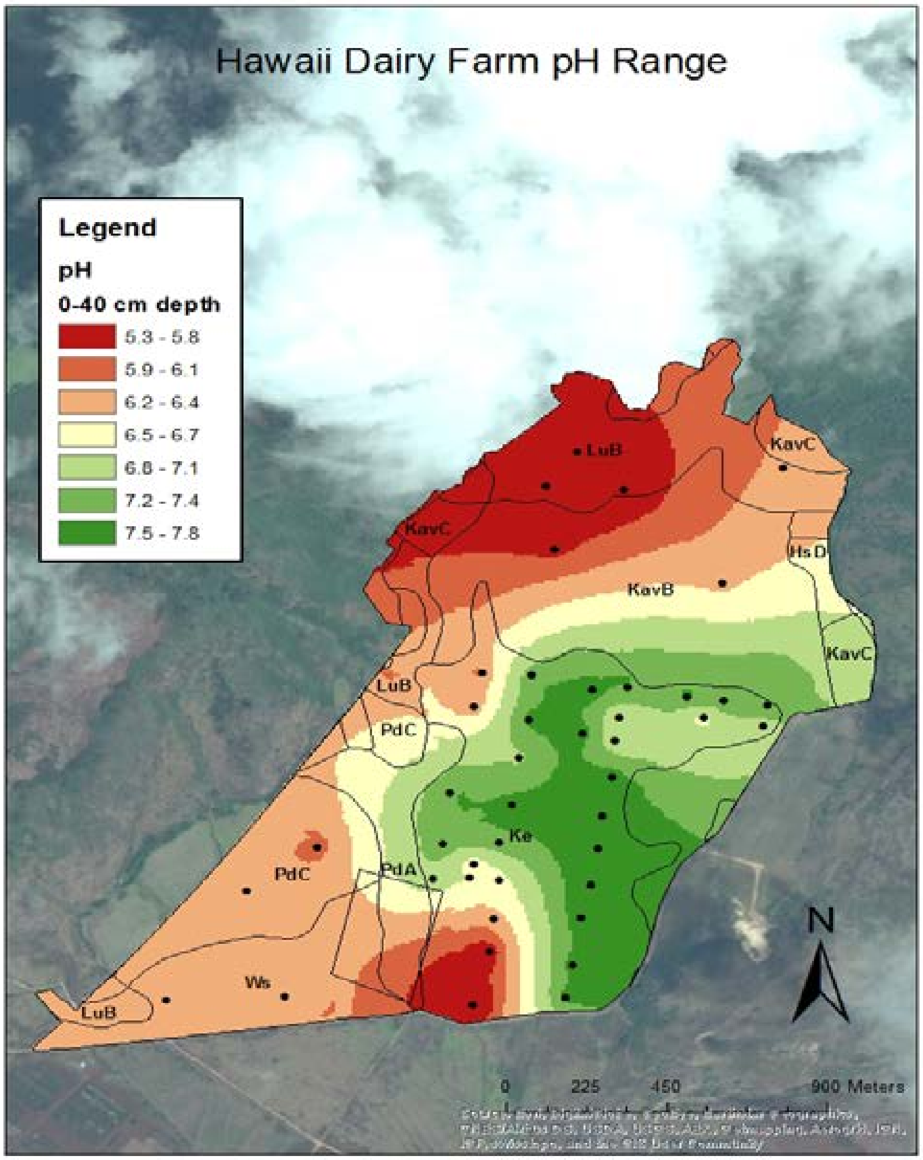

Figure 3. Soil sampling design (43 locations), soil mapunits and initial soil pH map. Note: LuB: Lualualei soil series, well-drained, 2 – 6 % slope; Ws: Waikomo, well-drained, stony clay, PdC: Pakala clay loam, well-drained, 2 – 10% slope; PdA: Pakala clay loam, well-drained, 0 – 2 % slope; Ke: Kalihi clay, poorly-drained; KavB: Ka`ena clay brown variant, poorly-drained, 1 – 6 % slope; KavC: Ka`ena clay brown variant, poorly drained, 6-12% slope; HsD: Hanamaulu silty clay, well-drained, 15-25% slope.

2. Establishing a quantitative baseline for nutrients that are typically supplied in dairy effluent.

The nutrients typically supplied in dairy manure and effluent include nitrogen, potassium and phosphorus, which were measured for input into nutrient balance calculations. A quantitative baseline for these nutrients will enable the monitoring the balance of nutrient removals by grazing animals and the return and recycling of nutrients through re-use of manures and effluents. Deficits in the recycling of nutrients will be made up by judicious application of nutrients through organic amendments and fertilizers.

The pasture – soil nitrogen status is especially difficult to quantify because nitrogen exists in soil, solution, and gaseous phases. In addition the soil and solution forms are microbially mediated between inorganic and organic forms. As a result nutrient nitrogen additions may differ from the simple arithmetic difference between forage and animal outputs and organic and fertilizer inputs. Nonetheless, determining a quantitative baseline of nutrient status is the currently best approach to nutrient monitoring.

The cations (potassium, calcium, magnesium and sodium) are reported as centimoles of charge per kilogram (cmol kg^{-1}) in order to account for the amount of charge of the various cations and to permit the calculation of nutrient balance and the relative concentration of sodium needed to estimate hazards from sodicity.

3. Determining the extent of "poorly drained" soil mapunits

Two soil samples were taken from each of the 43 locations at the Dairy site, at depths of 0-20cm and 20-40cm, for a total of 86 samples (Figure 2). Thirty-three locations chosen for sampling were from Kalihi Clay (soil mapunit Ke) which is characterized as "poorly drained" and comprises the primary soil mapunit of the south-central area of the dairy. Two samples were taken from the Ka'ena Clay Brown Variant (soil mapunit KavB, KavC), which is also "poorly drained". Four additional locations were sampled from Lualualei clay (soil mapunit LuB), and two additional locations from Pakala Clay Loam (soil mapunit PdC) and Waikomo Stony Silty Clay (soil mapunit Ws), all of which were classified as "well-drained", were collected in an effort to gain a broader sense of the site-wide fertility status and to enable a statistical comparison among the various mapunits that comprise the proposed dairy area. In summary the soil mapunits Ke, KavB, and KavC comprised the portion of the dairy that was characterized as "poorly drained." The management of nutrients and irrigation on this portion of the dairy will differ from that of the "well drained" portion of the dairy (all of the other soil mapunits).

4. Establish a quantitative baseline for the salinity and sodicity status of soils.

Assessing soil salinity and sodicity requires measures of soil cations
The soil salinity is measured as electrical conductivity (EC), which is a quantitative estimate of the amount of salt in the soil. The units are deciSiemens per meter, which is

similar to the historical unit of mmhos/cm (El-Swaify, 2000). A level of soil salinity of 2 to 4 dS m^{-1} represents an amount of salts in the soil that can cause reduction in growth of some salt-sensitive plants (Hanson et al., 1999). Kikuyu grass, however, seems relatively salinity tolerant (Muscolo et al., 2003).

Sodicity, or the relative amount of soil sodium, is expressed as the exchangeable sodium percentage (ESP), which is the concentration of sodium relative to the other cations (calcium, magnesium and potassium). Values of soil sodicity that exceed 15% are recognized as levels that could lead to problems of soil dispersion and altered soil physical properties (Richards 1954; McIntyre 1979; El-Swaify, 2000). This standard measurement of soil sodicity helps to assess the likelihood of soil dispersion, and to compare with recommended values from the NRCS (2012) and other scientific references. These two important measures of soil health provide a quantitative measure useful to monitor and ensure sustainable productivity and health of the soil resources of the dairy.

Results

1. Establishing a quantitative baseline of nutrients needed to ensure maximum forage productivity.

As indicated in the introduction, the goal and objective of the Hawai‘i Dairy Farm is to improve both the food security of the county of Kaua‘i and state by producing nutritious food while also ensuring and improving soil health. The scientific management of the nutrient cycles is a way to achieve these two goals. The nutrient management of nitrogen, phosphorus, and potassium recommended in this report is designed to achieve both goals. The overall nutrient management strategy proposed in this report is comprised of two steps: 1) Adjust the levels of the critical nutrients in the dairy soils to meet the needs of the fully productive forage grass while avoiding excessive applications that might enter surface and groundwater, and 2) When the pasture and dairy are fully established and achieving full productivity, ensure the sustainability of achieving high productivity while maintaining or improving soil health. A quantitative baseline for these nutrients will enable the monitoring the balance of nutrient removals by grazing animals and the return and recycling of nutrients through re-use of manures and effluents. Deficits in the recycling of nutrients will be made up by judicious application of nutrients through organic amendments and fertilizers.

Adjustment of nutrient levels on specific soil mapunits
The first step in ensuring productivity of the forage is to ensure sufficient nutrients are provided to the forage grass. To achieve this, the dairy soils were sampled and analyzed to complement and extend the earlier soil analysis (see Table 1 for preliminary results and Table 4 for the data analysis conducted for this report). These analytical results were obtained by Spectrum Analysis (Table 1) and from the Agricultural Diagnostic and Service Center of the University of Hawai‘i (Table 4).

Table 4. Overall means for soil pH, soil nutrients phosphorus, potassium, calcium, magnesium and sodium. Values for soil salinity, and soil carbon and nitrogen are also given for Hawaiʻi Dairy Farms, Mahaʻulepu Valley, Kauai. Analysis by the Agricultural Diagnostic and Service Center, University of Hawaiʻi.

Soil Measurement	Mean	Range
pH - water	6.8	4.7 – 8
Extractable phosphorus, mg kg^{-1}	17.2	7.1 – 49
Exchangeable potassium, cmol kg^{-1}	0.58	0.1 – 6.7
Exchangeable calcium, cmol kg^{-1}	21.3	5.2 – 46.5
Exchangeable magnesium, cmol kg^{-1}	11.1	4.8 – 19.7
Exchangeable sodium, cmol kg^{-1}	1.13	0.24 – 4.44
Soil salinity (electrical conductivity), dS m^{-1}	0.44	0.04 – 1.73
Total Carbon, %	2.49	0.68 – 6.2
Total Nitrogen, %	0.17	0.002 – 0.51

The soil mapunits varied widely for the values of soil pH, potassium, calcium, magnesium, salinity (EC), and sodium (Table 4). These baseline results indicate major differences among the soils of the dairy. These results indicate that in order to achieve maximum forage grass production additional nutrients are needed and they need to be gauged according to soil mapunit. In addition, the large differences among the mapunits, especially in calcium, magnesium, and sodium show that the poorly drained soils will likely need to be monitored separately from those that are not poorly drained. This suggests that regular monitoring of the soil status of paddocks on these soil mapunits are needed as part of the overall monitoring program.

Table 5. Mean soil nutrient contents of phosphorus, potassium, calcium, and magnesium variation with soil mapunit in relation to recommended levels.

	Phosphorus	Potassium	Calcium	Magnesium
Soil mapunit	mg kg^{-1}	—cmol kg^{-1} —	— cmol kg^{-1} —	— cmol kg^{-1} —
KavB	16.0 a†	0.31 b†	7.5 b†	10.1 bc†
Ke	16.3 a	0.34 b	25.3 a	11.3 b
LuB	19.0 a	0.50 b	9.1 b	13.9 a
PdC	15.8 a	1.21 a	8.7 b	7.4 c

†Values followed by the same letter indicate that the values were essentially the same. Otherwise values are ranked by decreasing alphabetical order. Target values are for the following nutrients: phosphorus: 25-35 (mg/kg or ppm), potassium: 0.5-0.76 (200-300 mg/kg or ppm), calcium: 3.75-5.0 (1500-2000 mg/kg or ppm), and magnesium: 2.5-3.5 (300-400 mg/kg or ppm) (Yost and Uchida, 2000).

Soil nutrient levels

Soil phosphorus levels of the dairy were largely inadequate for maximum grass forage productivity (Table 4&5). Portions of the dairy (Figure 4) that are yellow, orange, and red (not green) indicate the regions that were characterized by low levels of the nutrient phosphorus. Soil phosphorus, however, was higher and marginally adequate in the green regions of the dairy. The sharp boundaries of the phosphorus map probably reflect the fact that phosphorus as a nutrient in the soil moves very little and creates localized zones with high levels next to zones with low levels. The soil potassium map shows much smoother boundaries than does the phosphorus map probably reflecting the much greater mobility of potassium in soils. The soil nutrient potassium was higher on the PdC mapunit of the southwest corner of the dairy site. The higher levels of potassium and phosphorus may have been on fields previously fertilized for other crops. Soil calcium levels were extremely variable representing the sharply contrasting soil mapunits found on the dairy. Levels ranged from marginally adequate in the north portion of the dairy to high and very high in the central southern portion of the dairy. These contrasting levels of calcium may reflect the differences in drainage and nutrient dynamics on the differing mapunits. Calcium levels were adequate but were clearly greater on the Ke mapunit. Soil magnesium levels were similar on all mapunits except the PdC mapunit, which may have included soil of an adjacent field that was previously fertilized and managed differently. The substantially higher levels of soil calcium, magnesium, and sodium on the Kalihi mapunit than on other mapunits probably reflects the results of the lower amounts of water movement through the soil profile and a difference in soil mineralogy – a result of the “poorly drained” water status of the soils. This indication of differing nutrient dynamics may imply monitoring with possible adjustment to the nutrient additions to compensate for nutrient deficits predicted to result from nutrient recycling described below.

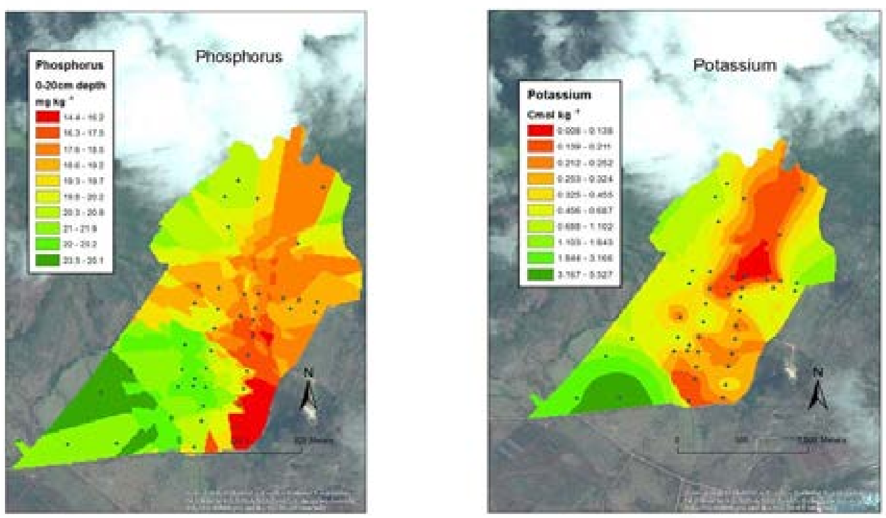

Figure 4. Status of soil phosphorus and potassium, Hawai`i Dairy Farms, Maha`ulepu site, Kaua‘i.

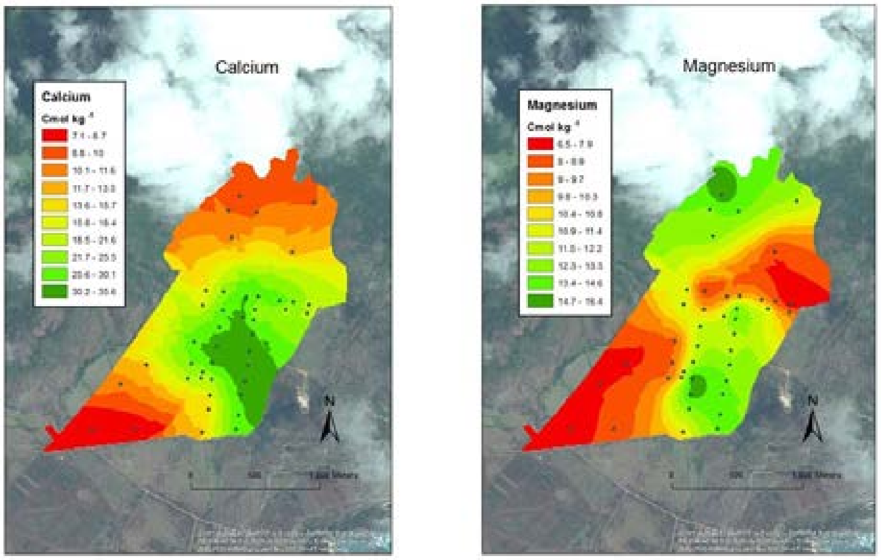

Figure 5. Status of macronutrients calcium and magnesium, Hawai`i Dairy Farms, Maha`ulepu site, Kaua'i.

Initial and maintenance nutrient requirements

As indicated from the initial sampling, soils at the site differ according to the mapunit. A two-step recommendation is proposed. The first step, "restorative nutrient management" is the application of nutrients in the first year to bring the initially low soil nutrient levels to a level to ensure maximum grass establishment and productivity. The second step, "maintenance nutrient management" which is difficult to predict beforehand, is the amount of nutrients to be added for each grazing rotation for each paddock management unit after pasture establishment and grazing frequency and intensity are determined. Applications to paddocks on specific soil mapunits for step 1 were calculated and are given in Table 6. While levels of phosphorus are low on all mapunits, levels of potassium vary and will require adjustment according to mapunit and specific productivity of paddocks on that mapunit. With the initial adjustment of nutrient levels and the close monitoring of nutrients and soil calcium, magnesium, and sodium status on the poorly drained mapunits high productivity and improved soil health is expected.

Table 6. Initial annual levels of nutrient fertilizers that need to be applied to each of the mapunits to achieve potential grass productivity.

	Phosphorus	Potassium		
Soil mapunit	Lbs/A P_2O_5	Lbs/A K_2O	Soil pH†	Lime requirement lbs/A
KavB	490	180	5.9 b	0
Ke	490	180	7.1 a	0
LuB	490	105	5.7 b	0
PdC	490	0	5.9 b	0

†Values followed by the same letter indicate that the values were essentially the same. Otherwise values are ranked by largest (letter a) to smallest.

The second step in managing nutrient cycles is the careful monitoring of the actual nutrient balances once the dairy is in operation – the “maintenance nutrient management”. The discussion of these recommendations follows in a separate section that describes the monitoring and assessment of the respective nutrient cycles and balances of nitrogen, phosphorus, and potassium. This requirement also depends on the actual animal grazing pressure.

2. *Monitoring and balancing nutrients recycled in manure and effluent*

In managing nutrient cycles of the dairy the recycling of animal manures constitutes an important input of nutrients to the pasture, particularly in the forms of nitrogen, phosphorus and potassium, all of which are initially present at inadequate levels in the dairy soil. These recycled nutrients substantially reduce the need for fertilizers to maintain forage grass productivity (Fulkerson et al, 2016). The following nutrient balance estimates illustrate the estimated nutrient additions resulting from the recycling.

Table 7. Estimated nutrient balance for each month of the year resulting from forage consumption and manure return (assuming 699 animals). Adapted from a nutrient balance analysis by Red Barn and Group70, 2016.

	Nutrient removed by the forage			Added by manure, effluent, and slurry			Deficit		
Month	N	P	K	N	P	K	N	P	K
	- - - lb/A - - -								
Jan	88.6	15.8	80.3	27.0	5.7	61.6	61.6	10.1	18.7
Feb	80.0	14.3	72.5	24.4	5.1	61.6	55.6	9.2	10.9
Mar	88.6	15.8	80.3	27.0	5.7	61.6	61.6	10.1	18.7
Apr	85.7	15.3	77.7	26.2	5.5	61.6	59.6	9.8	16.1
May	88.6	15.8	80.3	27.0	5.7	61.6	61.6	10.1	18.7
Jun	85.7	15.3	77.7	26.2	5.5	61.6	59.5	9.8	16.1
Jul	88.6	15.8	80.3	27.0	5.7	61.6	61.6	10.1	18.7
Aug	88.6	15.8	80.3	27.0	5.7	61.6	61.6	10.1	18.7
Sep	85.7	15.3	77.7	26.2	5.5	61.6	59.5	9.8	16.1
Oct	88.6	15.8	80.3	27.0	5.7	61.6	61.6	10.1	18.7
Nov	85.7	15.3	77.7	26.2	5.5	61.6	59.5	9.8	16.1
Dec	88.6	15.8	80.3	27.0	5.7	61.6	61.6	10.1	18.7
Annual	1043.	185.8	945.	318.1	66.5	738.	724.8	119.2	207

Nutrient removals in forage and additions in manures

The results presented in Table 7 indicate that the projected removal of nutrients by the highly productive forage grass is not quite balanced by the addition of nutrients in the manures and effluents. This deficit will need to be made up with the addition of nutrients from other sources such fertilizers. The amounts that are predicted to be necessary are actually quite small since the dairy will be following a rotational grazing system and animals will be grazing intensively on a paddock for a short period of time. The end of a grazing cycle would be an ideal time for the application of the small amounts of nutrients to restore the nutrient balance.

Nutrient balance deficit
Table 7 provides an initial estimate of the nutrient balance deficit. Note that there is a predicted deficit in each of the macronutrients N, P, and K even with the return of manures and effluents. There are two variables that fundamentally determine the nutrient balance estimates of Table 7. The first is the actual forage yield. The estimates in Table 7 for dry matter production are a major determinant of the amount of nutrient removed. The predicted yields for the spring part of the year may well be somewhat less than assumed in Table 7 based on the preliminary yield experiments described in Table 2. The second key variable in determining the actual nutrient balance is the number of animals in the dairy. The number of animals assumed in Table 7 is 699. A nutrient balance calculated with a higher number of animals such as 2000 (data not shown) results in a small excess of phosphorus due to much larger amounts of recycled nutrients.

Nutrient phosphorus should be monitored carefully
Soil phosphorus levels were significantly higher in the 0-20cm depth than the 20-40cm depth (Table 8), a not so unusual occurrence where animal manures, as-excreted, are applied. There were no significant differences among soil mapunits. There were some trends in the distribution of phosphorus over the site as illustrated in Figure 4. Nutrient phosphorus is a noteworthy management variable because it typically accumulates or is static because removal rates seldom dramatically exceed application rates. This result also occurs because as indicated earlier, soils especially of the mapunits of the dairy are known to adsorb and retain large amounts of the nutrient phosphorus.

Table 8. Mean extractable soil phosphorus levels by depth.

Depth (cm)	Mean phosphorus — mg kg^{-1} —
0-20	19.7 a†
20-40	13.9 b

†Treatment means within a column not followed by the same letter are different ($P \leq 0.05$).

3. Location and extent of "poorly drained" soil mapunits

"Poorly drained" soil mapunits tend to reduce leaching of nutrients to groundwater.
The previous mapping of the dairy site soils by the Natural Resources Conservation Service (Foote et al., 1972) provides useful information about the status and characterization of the soils of the Hawai‘i Dairy Farms site. The majority of the soils of

the proposed dairy site were classified as “poorly drained” (Figure 3). A further more detailed map of the paddocks that were on the “poorly drained” versus the “well-drained soil is given in Figure 6. A specific listing of the paddocks that are located on “poorly drained” and “well-drained” soil are also given in Appendix 1. It is important to note that the classification of soils as “poorly drained” indicates that on such soils there is less lateral and downward movement of soil water than in soils classified as “well drained”. The designation of “poorly drained” is not an indication of low or poor infiltration, which refers to the ability of water and effluents to enter the soil surface. Said another way, soil “drainage” refers to the movement of water within or through the soil profile. Additionally, “poorly drained” soils often exhibit anaerobic conditions, which are important in both the presence and movement of nutrients that can affect soil environmental health, most importantly nitrogen and its various soluble forms nitrate, nitrite, and ammonium. Anaerobic conditions typically result in higher rates of nitrogen loss due to denitrification, which is the conversion of potentially environmentally hazardous nitrate and nitrite to gaseous, innocuous forms, reducing or eliminating levels in soils of both the nitrate and very toxic nitrite.

Higher levels of nutrients in “poorly drained” soil mapunits. As a result of the reduced movement of water through the soil profile of “poorly drained” soils, the mobility of other nutrients such as potassium and phosphorus is usually reduced as well. In this way “poorly drained” soils tend to retain more nutrients within the soil profile than do “well-drained” soils. This may well be one of the reasons for the higher soil pH and higher levels of calcium and magnesium noted in the Ke mapunit (Tables 5 and 6). The reduced loss of other nutrients has important impacts on the nutrient balances that need to be calculated and monitored to ensure soil health and quality are sustained. “Well-drained” soils, while allowing movement of water out of the soil profile, still fully support the naturally-occurring, cleansing processes that filter and process water moving through the profile. Other considerations such as depth to the water table and hydrologic conditions are important.

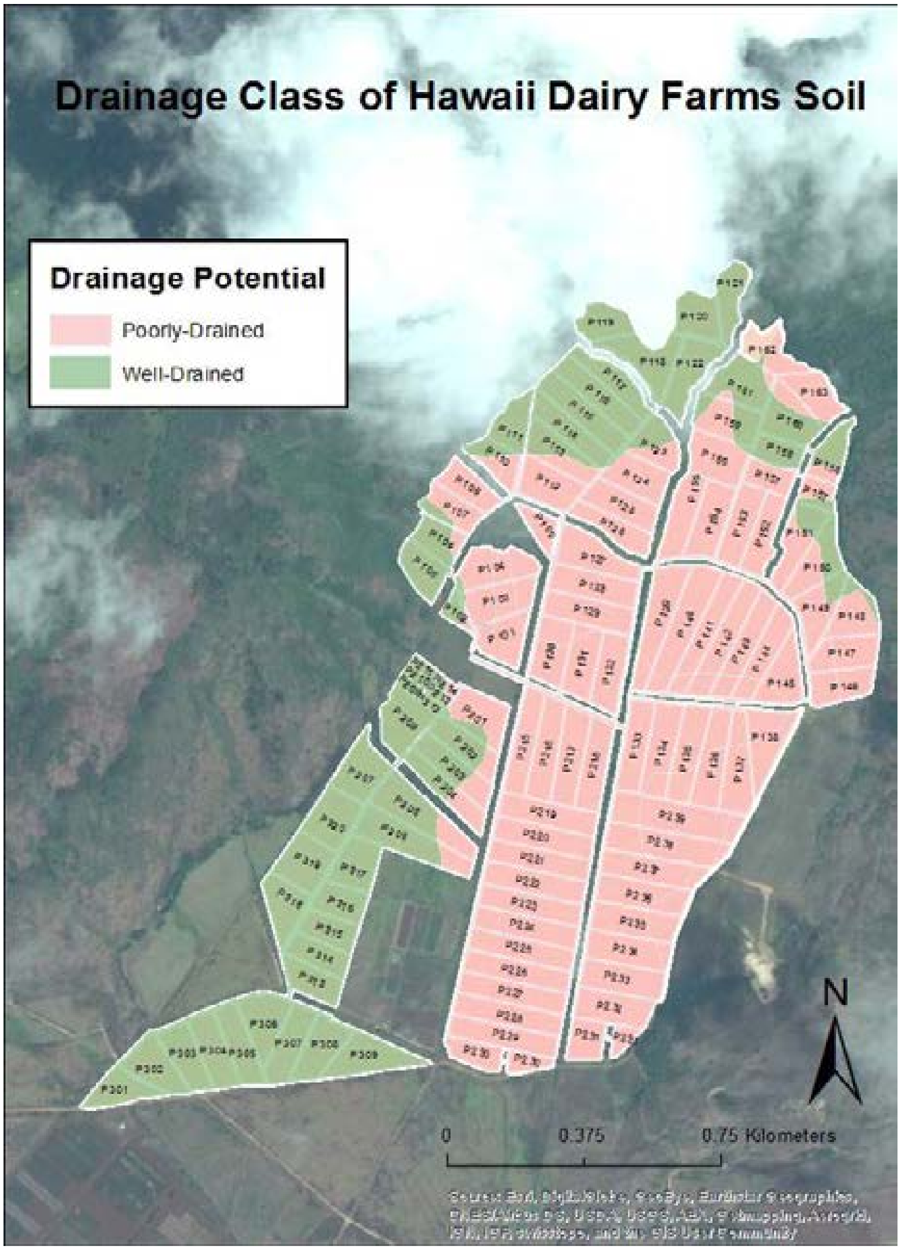

Figure 6. List of HDF paddocks and the soil drainage characteristic of each.

Reduced likelihood of deep leaching of nutrients from surface to groundwater

The hydrology of the proposed dairy site has been thoroughly characterized and documented in the report by Nance (2016). This report indicates that the amounts of soil water that can move from the soil surface into underlying groundwater is minimal when the dairy land is irrigated and manure effluents are applied. While the underlying hydrological conditions tend to separate the surface and underlying aquifers there are important differences reported in the hydrologic study that are discussed above in the section on “poorly drained” soil mapunits. The implications of whether forage is produced on soil mapunits that are “poorly drained” or “well-drained” may affect nutrient and fertilization requirements as well as determination of the nutrient balance of the various paddocks and nutrient management blocks (Figure 2), thus justifying careful monitoring of the nutrient balance once the dairy is in operation.

4. *Establish a quantitative baseline for the salinity and sodicity status*

The pH of the dairy site soils ranged from the high for the Ke mapunit of to 8 to a low of 4.7 in the KavB and PdC soil mapunits (Table 5, Figure 3). The higher soil pH of mapunit Ke probably was a result of the higher levels of soil sodium recorded in that mapunit. Soil salinity was uniformly low and did not differ much among the soil mapunits (Table 4, Table 9, Figure 7).

Table 9. Levels of soil pH, soil salinity (EC), and soil sodium for major mapunits.

Soil mapunit	Soil pH†	Soil salinity (EC), dS m^{-1}	Sodium, cmol kg^{-1}	ESP, %
KavB	5.9 b	0.27 a	0.78 ab	4.2
Ke	7.1 a	0.48 a	1.31 a	3.4
LuB	5.7 b	0.25 a	0.67 b	2.8
PdC	5.9 b	0.19 a	0.38 b	2.1

†Values followed by the same letter indicate that the values were essentially the same. Otherwise values are ranked by largest (letter a) to smallest. Soil salinity in the range of 2 to 4 dS m^{-1} are considered high enough to affect salt-sensitive plants. Exchangeable sodium levels are well below the threshold of 15% sometimes considered indicative of potential soil physical problems (Richards, 1954; El-Swaify, 2000, Cameroon et al, 2003).

Soil sodium levels were much, much higher in Ke than in the LuB and PdC soil mapunits, while levels of sodium in the KavB mapunit were intermediate (Table 9, Figure 8). The key measurement of soil sodicity, the ESP value, remained well below the level of 15%, frequently considered as the threshold between low, acceptable levels and high, unacceptable levels. It is interesting to note that while the Ke mapunit contained almost double the amount of sodium than did the KavB mapunit, the calculated ESP was similar on both soils pointing out the importance of considering all cations in evaluating sodicity.

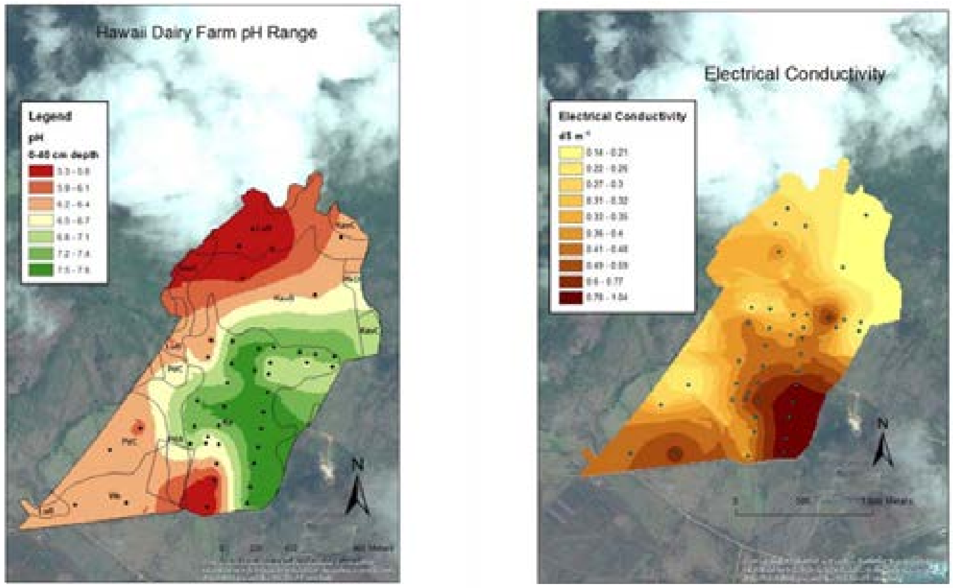

Figure 7. Status of soil pH and salinity (EC), Hawai'i Dairy Farms, Maha'ulepu, Hawai'i.

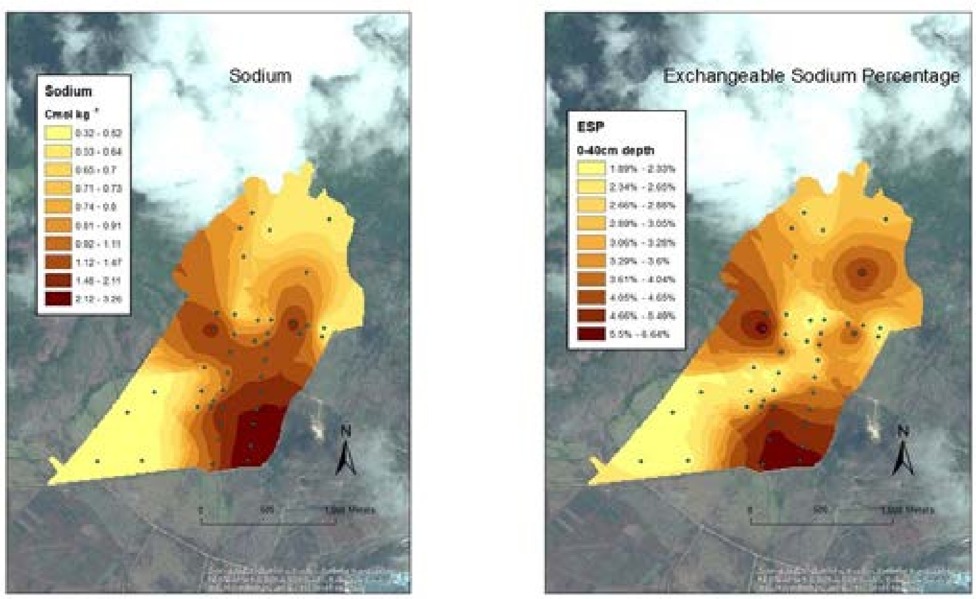

Figure 8 Status of soil sodium and exchangeable sodium percentage (ESP), Hawai`i Dairy Farms, Maha'ulepu, Hawai'i.

Conclusions and Recommendations

1. *Establishing a quantitative baseline of nutrients needed to ensure maximum forage productivity.*

The results of the initial soil sampling together with the analysis presented in this report indicate that current nutrient levels are generally inadequate for phosphorus and potassium in the soils of the proposed dairy site.

The results suggest two steps to restore and ensure adequate levels of nutrients so that the forage grass becomes well-established and achieves and maintains maximum productivity.

Step 1. “Restorative nutrient management”, which is dependent on the initial, baseline quantitative measurement of soil conditions

Step 2. “Monitoring and adaptive nutrient management”, which is dependent on number of grazing animals, grass productivity, and amount of recycled nutrients and which may vary with soil mapunit.

2. *Establishing a quantitative baseline for nutrients that are typically supplied in dairy effluent.*

An initial estimate of the nutrient cycles of nitrogen, phosphorus, and potassium indicate that even if all of the manures and effluents are returned to the pasture there will still be a small nutrient deficit that depends on the numbers of animals managed. At the maximum proposed animal population there might be a slight excess of nutrient phosphorus. Alternative best management practices are available to reduce the amount of phosphorus recycled to the dairy paddocks.

3. *Location and extent of “poorly drained” soil mapunits*

The occurrence of several “poorly drained” soil mapunits, on one hand, confirms the hydrologic study results that concluded little of the surface water would reach the groundwater. In addition, the “poorly drained” property of many of the soils suggests that nitrogen risk may be reduced due to the expected conversion of unhealthy forms of nitrogen such as nitrate and nitrate, and ammonium to gaseous nitrogen through denitrification.

Nonetheless, the impact of the “poorly drained” property on the soil salinity and sodicity should be monitored because those properties vary according to the soil mapunit and will be sensitive to actual nutrient cycles.

4. Establish a quantitative baseline for the salinity and sodicity of the dairy soils.

Initial results of measures of soil salinity and sodicity suggest no threat to soil health at present levels. Due to the differing dynamics of “poorly drained” soils, paddocks of the “poorly drained” mapunits Ke, KavB, and KavC should be monitored carefully.

A general recommendation is that ensuring forage grass productivity and sustainability of the dairy will require at least two steps: 1) Restorative nutrient management to ensure grass establishment and productivity, and 2) Maintenance nutrient management, designed to monitor the actual nutrient balance needs. Factors that are likely to cause major impact on the maintenance nutrient requirements are 1) The actual productivity of forage grass, and 2) The number of animals consuming forage and 3) The efficiency in returning manures and effluents to the growing grass. The amounts of rainfall are also important in determining the actual nutrient cycles.

Monitoring the nutrient cycles is thus a primary management variable for sustainable production and for the improvement and sustaining of health of the dairy site soils.

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Appendix 1. List of HDF paddocks and their most probable drainage class.

Paddock	Drainage	Paddock	Drainage	Paddock	Drainage	Paddock	Drainage
P 101	Poor	P 132	Poor	P 163	Poor	P 231	Poor
P 102	Well	P 133	Poor	P 201	Poor	P 232	Poor
P 103	Poor	P 134	Poor	P 202	Well	P 233	Poor
P 104	Poor	P 135	Poor	P 203	Well	P 234	Poor
P 105	Well	P 136	Poor	P 204	Well	P 235	Poor
P 106	Well	P 137	Poor	P 205	Well	P 236	Poor
P 107	Poor	P 138	Poor	P 206	Well	P 237	Poor
P 108	Poor	P 139	Poor	P 207	Well	P 238	Poor
P 109	Poor	P 140	Poor	P 208	Well	P 239	Poor
P 110	Poor	P 141	Poor	P 209	Well	P 301	Well
P 111	Well	P 142	Poor	P 210	Well	P 302	Well
P 112	Poor	P 143	Poor	P 211	Well	P 303	Well
P 113	Well	P 144	Poor	P 212	Well	P 304	Well
P 114	Well	P 145	Poor	P 213	Well	P 305	Well
P 115	Well	P 146	Poor	P 214	Well	P 306	Well
P 116	Well	P 147	Poor	P 215	Poor	P 307	Well
P 117	Well	P 148	Poor	P 216	Poor	P 308	Well
P 118	Well	P 149	Poor	P 217	Poor	P 309	Well
P 119	Well	P 150	Poor	P 218	Poor	P 313	Well
P 120	Well	P 151	Poor	P 219	Poor	P 314	Well
P 121	Well	P 152	Poor	P 220	Poor	P 315	Well
P 122	Well	P 153	Poor	P 221	Poor	P 316	Well
P 123	Well	P 154	Poor	P 222	Poor	P 317	Well
P 124	Poor	P 155	Poor	P 223	Poor	P 318	Well
P 125	Poor	P 156	Poor	P 224	Poor	P 319	Well
P 126	Poor	P 157	Poor	P 225	Poor	P 320	Well
P 127	Poor	P 158	Well	P 226	Poor		
P 128	Poor	P 159	Poor	P 227	Poor	Total Well:	48
P 129	Poor	P 160	Well	P 228	Poor		
P 130	Poor	P 161	Well	P 229	Poor	Total Poor:	71
P 131	Poor	P 162	Poor	P 230	Poor		

APPENDIX D

NUTRIENT BALANCE ANALYSIS FOR HAWAIʻI DAIRY FARMS

GROUP 70 INTERNATIONAL AND RED BARN CONSULTING

NUTRIENT BALANCE ANALYSIS

for

HAWAIʻI DAIRY FARMS

MĀHĀ ʻULEPŪ, KAUAʻI, HAWAIʻI

TMK: (4) 2-9-003: 001 por and 006 por
(4) 2-9-001: 001 por

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~~May 24~~December 16, 2016

Table of Contents

LIST OF FIGURES

LIST OF TABLES

1.0 Project Overview

In late 2013, Ulupono Initiative made the investment to fund Hawaiʻi Dairy Farms, the first pasture-based, rotational-grazing dairy in the state. Hawaiʻi Dairy Farms, LLC (HDF) was formed as a positive step toward the island state's food security, economic diversity, and sustainability. At steady-state production with 699 mature dairy cows cows, the farm will produce roughly ~~1.2~~ 1.5 million gallons annually. HDF will reduce Hawaiʻi's reliance on imported milk from the mainland United States by increasing current fresh local milk production by approximately 33 percent. The farm will be based on the most successful island dairy models in the world, and will utilize a sustainable, pasture-based rotational-grazing system and 21st century technology. The farm will be very different from conventional feedlot dairy operations.

HDF is committed to establishing a herd of up to 699 mature dairy cows, and demonstrating the pasture-based system as an economically and environmentally sustainable model for Hawaiʻi. With proven success at a herd size of 699, HDF will contemplate the possibility of expanding the herd in the future. Precision agricultural technology that monitors cows' health, grass productivity, and effluent management will be used to ensure environmental health and safety, as well as best management practices, and help determine the ultimate carrying capacity of the land.

For dairy operations with 700 or more mature dairy cows, additional regulatory review and permitting by the State of Hawaiʻi, Department of Health (DOH) is required. The application process for a National Pollutant Discharge Elimination System (NPDES) Concentrated Animal Feeding Operation (CAFO) permit includes public notification and input. At the discretion of HDF, management may choose to expand operations up to the carrying capacity of the land, which is currently estimated to be up to 2,000 productive milking dairy cows. Permit process compliance would be followed at such time HDF may decide to pursue an expanded operation.

The project will be located in the Māhāʻulepū Valley on the island of Kauaʻi, exclusively within the approximate 556.8 acres of land leased by HDF from Mahaulepu Farm LLC. **See Figure 1 – Vicinity Map**.

The project will be fully enclosed by perimeter fencing along the boundary of the leased premises, which will ensure that livestock and grazing activities are contained within the project area. The project area has historically been used for agriculture, including commercial sugar cane production for over one hundred years, and is comprised of lands designated pursuant to the Hawaiʻi State Constitution as Important Agricultural Lands. Accordingly, the project is consistent not only with past agricultural use of the area, but with ongoing constitutionally recognized interest in maintaining and utilizing the area for agricultural purposes that promote agricultural self-sufficiency.

Unlike traditional conventional feed-lot dairies, in which mature dairy cows are confined and fed only feed such as grain, hay and silages, the project will be the first dairy in the State to utilize rotational, pasture-based grazing. The rotational, pasture-based grazing approach is a system that involves regularly rotating cows through farm paddocks, where they will primarily feed on locally grown grass, supplemented with grain and vitamins as needed. This approach optimizes grass growth, cow health and milk production, facilitates even applications of waste products for fertilization, prevents over-grazing and over-application of fertilizers, and maintains erosion and runoff controls.

The initial herd of up to 699 mature dairy cows will be divided into groups and rotated through a series of paddocks over an 18-day period to access fresh grass and deposit manure throughout the area. Cows will move through a system of raceways to and from the milking parlor, where they will be milked twice a day for a total of two hours. The remaining dry cows, heifers and 90-day and older calves will be managed off-property on existing ranches that are owned and operated by other local ranchers.

HDF has prepared this Nutrient Balance Analysis for its Environmental Impact Statement (EIS), to disclose the planned waste management systems to support the initial herd operation as well as full-production (up to the carrying capacity of the land) operation. The analysis has been based upon the State of Hawaiʻi, Department of Health (DOH) "Guidelines for Livestock Management", prepared in collaboration with the University of Hawaiʻi at Manōa, Cooperative Extension Service, College of Tropical Agriculture and Human Resources (CTAHR), West Maui Soil & Water Conservation District, USDA – Natural Resource Conservation Service, U.S. Environmental Protection Agency – Region 9, dated January 19, 2010 (hereon as

"Guidelines")~~"Guidelines for Livestock Waste Management", prepared by the University of Hawai'i Mānoa Cooperative Extension Service, College of Tropical Agriculture and Human Resources (CTAHR) in consultation with the State of Hawai'i Department of Health~~.

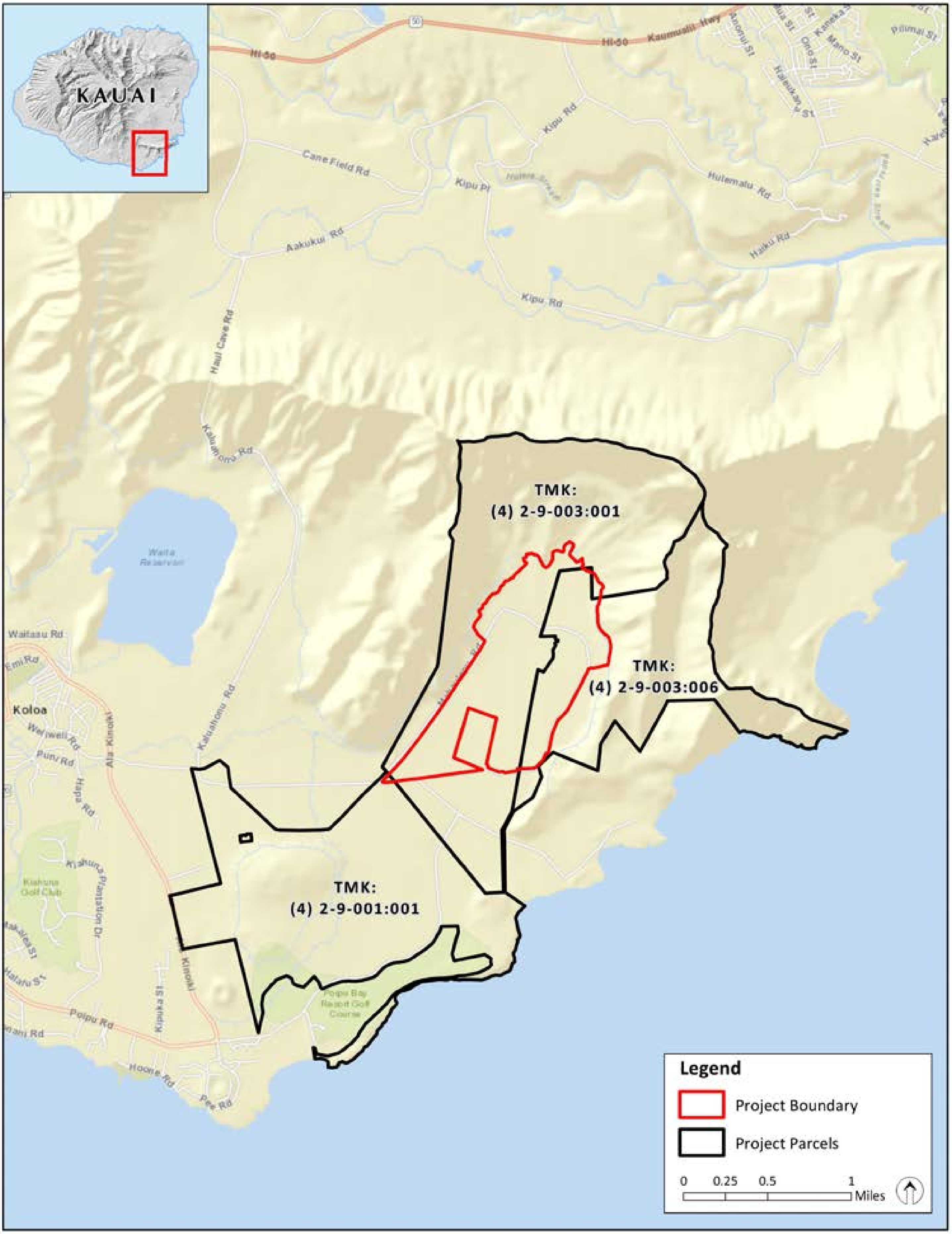


Figure 1 – Vicinity Map

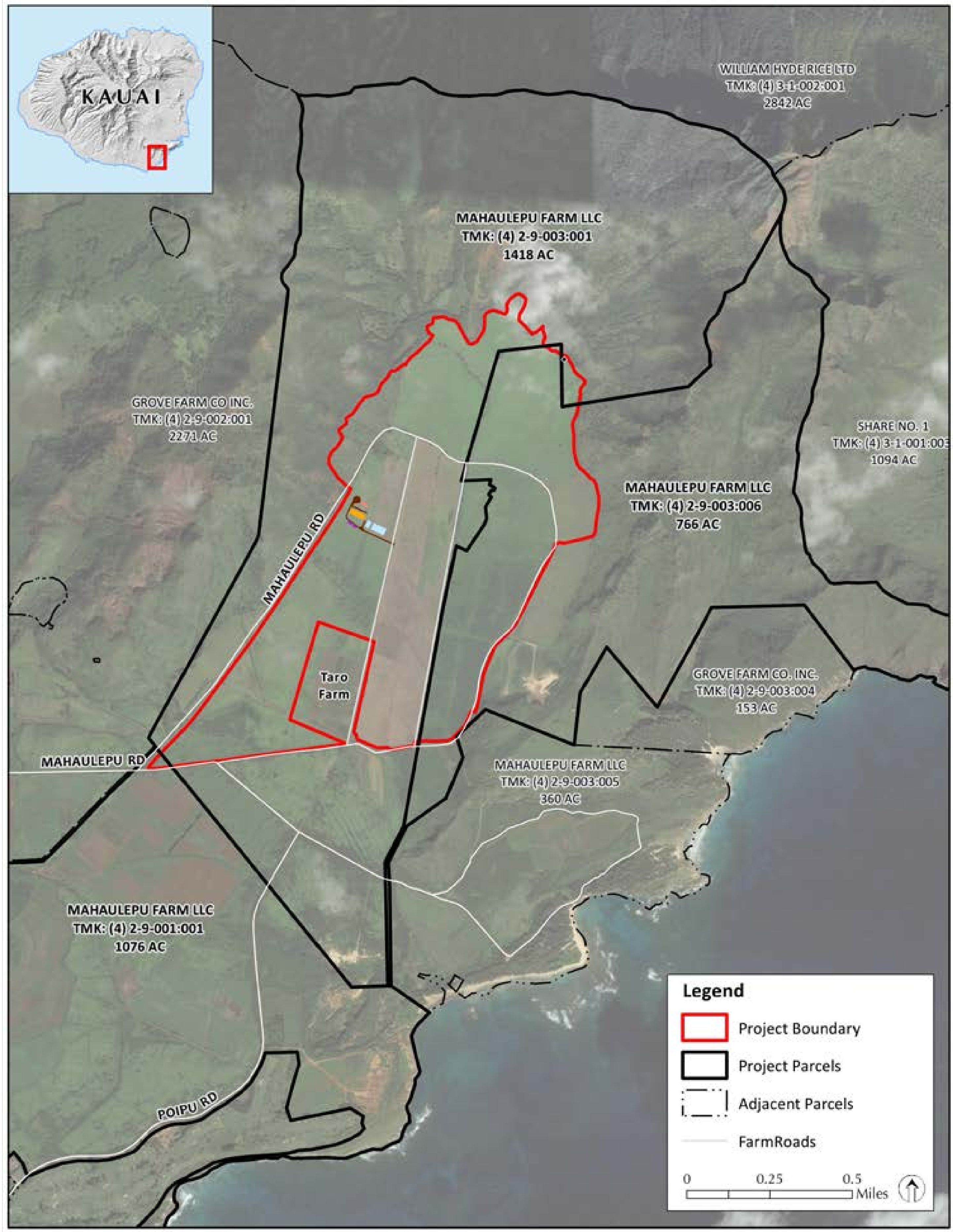


Figure 2 – Project Location Map

2.0 Existing Conditions

The project area has historically been used for sugar cane production as part of the Kōloa Plantation until the late 1990s when the Kōloa Mill closed. Since the mill closed, the project area has been leased to various tenants for ranching and diversified agricultural operations. A small plot of land in the lower center of the valley is currently used for taro loʻi and will continue to be leased (by a third party) and farmed after the dairy and related pastures are in full operation. **See Figure 2 – Project Location Map.**

The original agricultural infrastructure from the sugar plantation is largely still in place and continues to be used for on-going agricultural activities. Much of this existing infrastructure will also be used for the dairy, but with a significant amount of upgrades and improvements. The existing infrastructure in the project area includes: gravel and dirt access roads, field roads, water wells, reservoirs, pipelines, pumps, irrigation ditches, drainage ways and culverts.

2.1 Topography

The project site is situated in the Māhāʻulepū Valley on the island of Kauaʻi. The valley is on the leeward side of the Hāʻupu mountain ridge, which runs in the east-west direction, and the valley is also flanked by ridge lines on both sides. Mt. Hāʻupu is the highest point on the ridge line at the back of the valley with an elevation of 2,297 feet. From this point, the ground drops very quickly down to the bottom of the valley to about an elevation of 150 feet. The base of the valley itself is somewhat gradually sloped from an elevation of 150 feet to an elevation of 60 feet along Māhāʻulepū Road on the makai side of the project site near the taro farm. **See Figure 3 - USGS Map.**

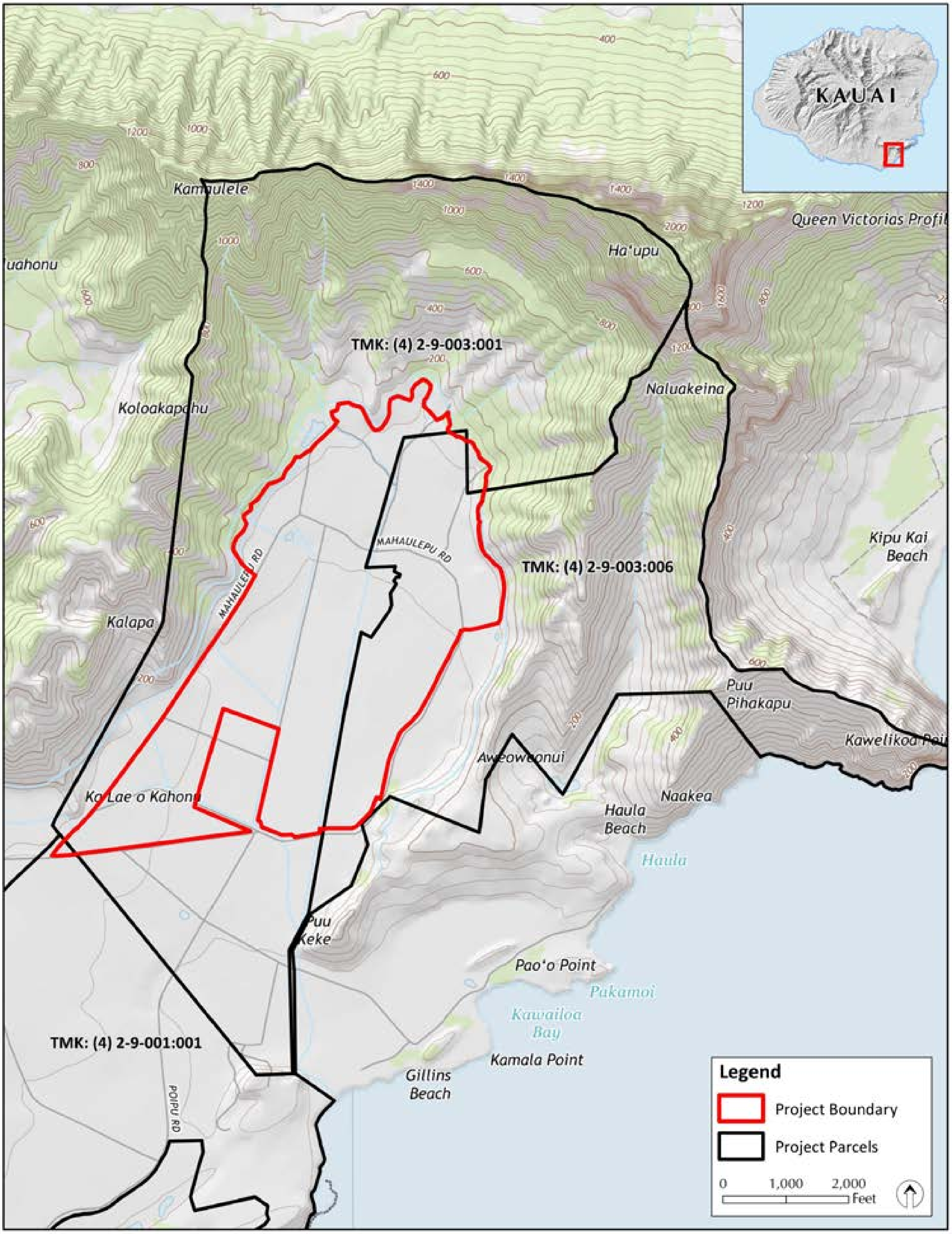


Figure 3 – USGS Map

2.2 Water Resources

The Māhāʻulepū Valley has been in agricultural use for decades and much of the water resources and infrastructure in the valley are man-made and were constructed to provide irrigation water for commercial sugar cane cultivation throughout the valley. Systems of ditches, reservoirs and irrigation pipes and pumps are still in place and are still used to provide water to the existing taro ponds, and to irrigate fields and pasture. Existing groundwater wells, monitoring wells, and drainage ways and water bodies are shown on Figure 4. **See Figure 4 - Water Resources**.

2.2.1 Receiving Water Body State Water Quality

The drainage ways and ditches within Māhāʻulepū Valley and within the project site are not classified for protection by the Department of Health, and therefore fall into Class 2 Inland Waters (HAR §11-54-5.1(a)(1)(C)). These canals and ditches flow in the makai direction, beyond the project site, across Māhāʻulepū Road, and into the adjacent agricultural lands. The unnamed drainage ways from the valley all converge near Puʻu Keke and are discharged into marine waters along the Māhāʻulepū coastline between Kamala Point and Punahoa Point.

This stretch of open coastal waters ~~is~~ are not classified for protection by DOH, and therefore fall into ~~as~~ Class A for water quality standards in HAR §11-54, which states: "the objective of Class A [marine] waters is that their use for recreational purposes and aesthetic enjoyment be protected. Any other use shall be permitted as long as it is compatible with the protection and propagation of fish, shellfish, and wildlife, and with the recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class" (DOH, 2014) (HAR §11-54-6(b)(2)(B)).

2.2.2 Wetlands

Biological resources, including aquatic systems and wetlands, are discussed in the Flora and Fauna, Biological Survey, conducted by Rana Biological Consulting (2016) under separate cover.

2.2.3 Water Wells

The State Department of Land and Natural Resources (DLNR) Commission on Water Resource Management (CWRM) manages and tracks water resources in the State including groundwater wells. The State database identifies two primary well sites in the Māhāʻulepū Valley, in proximity to the proposed project. The Kōloa F Well is a public drinking water source used by the County of Kauaʻi Department of Water Supply (DOW). The Māhāʻulepū Well site includes up to 14 groundwater wells drilled by the sugar cane plantations. The water wells are shown on **Figure 4 - Water Resources**. The Kōloa F well is located over 0.5 miles away from the dairy facility including the milking parlor, and is approximately 580 feet from the westernmost boundary of the farm. Though not required by DOH ~~or~~ within the "Guidelines for Livestock ~~Waste~~ Management (2010)", ~~prepared by the CTAHR,~~ a setback of 1,000 feet will be provided around Kōloa F from any pasture activities, application of effluent, or livestock grazing (the guidelines require a minimum 50′ setback for public water drinking sources from land application of effluent).

Existing monitoring wells, recently installed prior to the commencement of the EIS, are located on the project site. **See Figure 4 - Water Resources**. Groundwater resources are discussed in the "Estimates of the Potential Impact on Groundwater and Surface Water by Hawaii Dairy Farms in Mahaulepu, Kauai" report, conducted by Tom Nance Water Resource Engineering (2016).

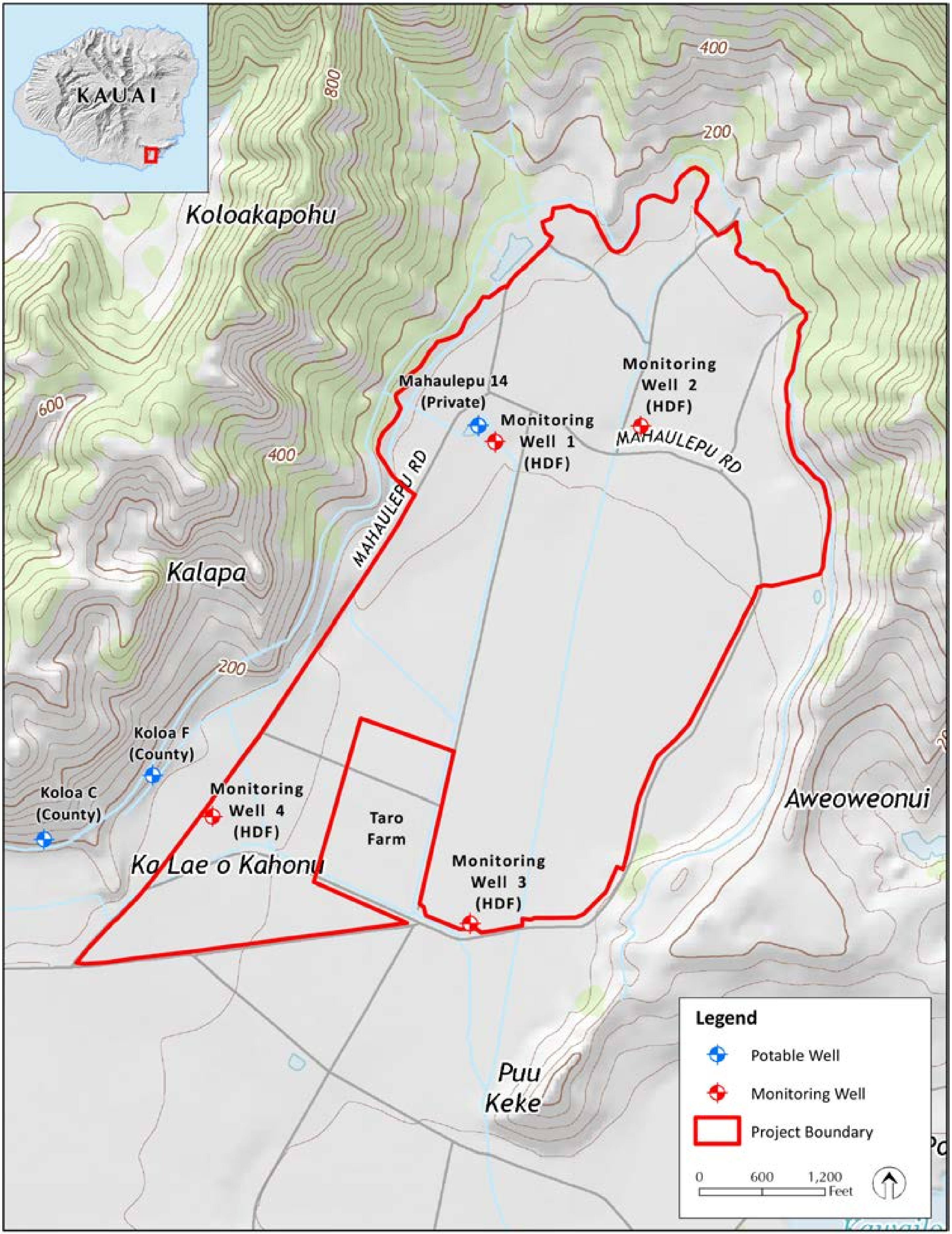


Figure 4 – Water Resources

2.3 Rainfall Data

The data sources used for sizing of the waste management systems at the dairy facility site and for pasture irrigation scheduling are described in this section.

2.3.1 Normal Precipitation

Normal monthly precipitation depths at the dairy facility were obtained from the University of Hawaiʻi Rainfall Atlas of Hawaiʻi (2011). The average monthly precipitation depths will be used for sizing of the waste management systems and irrigation scheduling as required by the Guidelines.

Table 1 – Average Monthly Precipitation Data

Month	Mean Monthly Rainfall (in)
January	4.88
February	4.20
March	5.04
April	3.66
May	3.05
June	2.86
July	3.13
August	3.20
September	3.25
October	4.96
November	6.01
December	5.71
Annual	49.95

2.3.2 NOAA 24-Hour Rainfall

Precipitation depths at the dairy facility, for various durations and recurrence intervals were obtained from NOAA Atlas 14, Volume 4, Version 3. The 25-year 24-hour precipitation data will be used for sizing of waste management systems as required by the Guidelines.

Table 2 – NOAA 24-Hour Rainfall Data

Storm Event (Recurrence Interval)	Storm Duration	
	1-hour	24-hour
1-year	1.18"	3.47"
2-year	1.55"	4.78"
10-year	2.54"	8.18"
25-year	3.17″	**10.4″**
50-year	3.70"	12.2"
100-year	4.25"	14.1"

2.3.3 NOAA Rain Gauge Data

Rain gauge data was obtained from NOAA National Climatic Data Center for the Māhāʻulepū 941.1 rain gauge located on the farm off of Māhāʻulepū Road (GHCND:USC00515710 - MĀHĀʻULEPŪ 941.1 HI US). The rain gauge is located at: Elevation = 24.4 (meters above mean sea level), Latitude = 21.90194, Longitude = -159.42111. The data record analyzed included daily precipitation records from 1/1/1984 to 12/31/2013 for a total of approximately 10,957 days (30 years). The rainfall events were ranked based on days of consecutive rainfall (DAPR) and the corresponding multiday precipitation total (MDPR). The data suggests that having more than a week of consecutive rain is very unusual for Māhāʻulepū Valley with this only having occurred 5 times in the last 30 years.

Table 3 – NOAA Rain Gauge Data

GHCND:USC00515710 - MĀHĀʻULEPŪ 941.1 HI US			
DATE	**MDPR, in**	**DAPR**	**Occurrence**
19960108	1.90	17	1
19920922	2.60	12	1
19930104	3.70	7	3
19960930	0.20	7	
19980105	1.48	7	
19920928	0.02	6	5
19940105	0.03	6	
19960923	0.03	6	
19970106	0.05	6	
20031229	0.20	6	
19861229	0.04	5	21

MDPR – Multiday precipitation total

DAPR – Number of days included in the multiday precipitation total (MDPR)

Occurrence – number of occurrences in 10,957 day record between 1/1/1984 to 12/31/2013

Daily rain gauge data from Māhāʻulepū was utilized to determine the irrigation water balance. The average monthly precipitation data recorded from the Māhāʻulepū Station 941.1 are as follows:

Table 4 – NOAA - Average Monthly Precipitation Data

Month	Mean Monthly Rainfall (in)
January	4.22
February	3.70
March	5.35
April	3.17
May	2.61
June	2.39
July	2.77
August	2.98
September	2.73
October	3.99
November	4.66
December	5.69
Annual	44.26

2.4 Evaporation Data

Pan evaporation data was obtained from State of Hawaiʻi DLNR Pan Evaporation Report R74 dated August 1985 for station Māhāʻulepū 940.00. Evapotranspiration data was obtained from UH Mānoa Department of Geography, 2014 Evapotranspiration Maps (Lat 21.907N, 159.422W). Potential evapotranspiration data (ETo) for a grass reference was used – as the site will have an all grass crop, and then the rate was further adjusted for Kikuyu grass using a crop coefficient of 0.85 to determine an evapotranspiration rate for Kikuyu crop (ETc).

Table 5 - Evaporation Rates

Month	Days	Evapotranspiration		Pan Evaporation
		ETo, Grass Reference in	ETc, Crop in	Māhā'ulepū 940 in
January	31	6.877	5.845	5.14
February	28	6.819	5.796	5.65
March	31	7.850	6.673	6.93
April	30	7.967	6.772	7.43
May	31	8.864	7.534	7.82
June	30	9.053	7.695	8.05
July	31	9.394	7.985	9.10
August	31	9.409	7.998	9.37
September	30	9.092	7.728	8.23
October	31	8.600	7.310	7.33
November	30	7.037	5.981	6.17
December	31	7.101	6.036	5.40
Total	365	98.063	83.354	86.62

2.5 Flood Hazards

The entire project area is located within Federal Emergency Management Agency (FEMA) Zone X based on FEMA Flood Insurance Rate Map (FIRM) panels 1500020316E and 1500020318F. Zone X includes areas determined to be outside the 0.2% annual chance floodplain.

2.6 Soils

According to the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) survey data, the project area consists of a variety of soils. Soil characteristics are summarized in the table below. **See Figure 5 - Soil Map**.

Table 6 – Soil Characteristics Summary

Soil Classification	Soil Classification	Slope Range (%)	Hydrologic Soils Group	Drainage Class	Depth to Water Table (inches)	Capacity to transmit water – Ksat (in/hr)	Typical Soil Profile - Layer 1 (depth from surface)	Typical Soil Profile - Layer 2 (depth from surface)	Typical Soil Profile - Layer 3 (depth from surface)
Hanamaulu Silty Clay	HsD	15 to 20%	B	Well Drained	> 80″	0.14 to 1.98	0 to 11″ Silty Clay	11 to 36″ Silty Clay	36 to 72″ Silty Clay Loam
Hanamaulu Stony Silty Clay	HtE	10 to 35%	B	Well Drained	> 80″	0.20 to 2.00	0 to 11″ Stony Silty Clay	11 to 36″ Silty Clay	36 to 72″ Silty Clay Loam
Ka'ena Clay, Brown Variant	KavB	1 to 6%	D	Poorly Drained	24 to 60″	0.00 to 0.20	0 to 10″ Clay	10 to 37″ Stony Clay	37 to 54″ Stony Clay
Ka'ena Clay, Brown Variant	KavC	6 to 12%	D	Poorly Drained	24 to 60″	0.00 to 0.20	0 to 10″ Clay	10 to 37″ Stony Clay	37 to 54″ Stony Clay
Kalapa Silty Clay	KdF	40 to 70%	B	Well Drained	> 80″	0.00 to 0.20	0 to 10″ Silty Clay	10 to 60″ Clay	
Kalihi Clay	Ke	n/a	D	Poorly Drained	24 to 60″	0.06 to 0.60	0 to 16″ Clay	16 to 70″ Clay	
Kalapa Very Rocky Silty Clay (Very Rocky)	KEHF	40 to 70%	B	Well Drained	> 80″	0.00 to 0.20	0 to 10″ Silty Clay	10 to 60″ Clay	
Kalapa Very Rocky Silty Clay (Rock Outcrop)	KEHF	40 to 70%	D			0.00 to 0.06	0 to 60″ Bedrock		
Lualualei Clay	LuB	2 to 6%	D	Well Drained	> 80″	0.00 to 0.20	0 to 10″ Clay	10 to 60″ Clay	
Pakala Clay Loam	PdA	0 to 2%	B	Well Drained	> 80"	0.60 to 1.98	0 to 16″ Clay Loam	16 to 60″ Silty Clay Loam	
Pakala Clay Loam	PdC	2 to 10%	B	Well Drained	> 80"	0.60 to 1.98	0 to 16″ Clay Loam	16 to 60″ Silty Clay Loam	
Rock Land	rRK	n/a	D	Well Drained	> 80"	0.00 to 0.06	0 to 4″ Silty Clay	4 to 8″ Silty Clay	8 to 20″ Bedrock
Rock Land (Rock Outcrop)	rRK	n/a	D			0.00 to 0.06	0 to 60″ Bedrock		
Waikomo Stony Silty Clay	Ws	n/a	D	Well Drained	> 80"	0.00 to 0.06	0 to 14″ Stony Silty Clay	14 to 20″ Stony Silty Clay Loam	20 to 30″ Bedrock

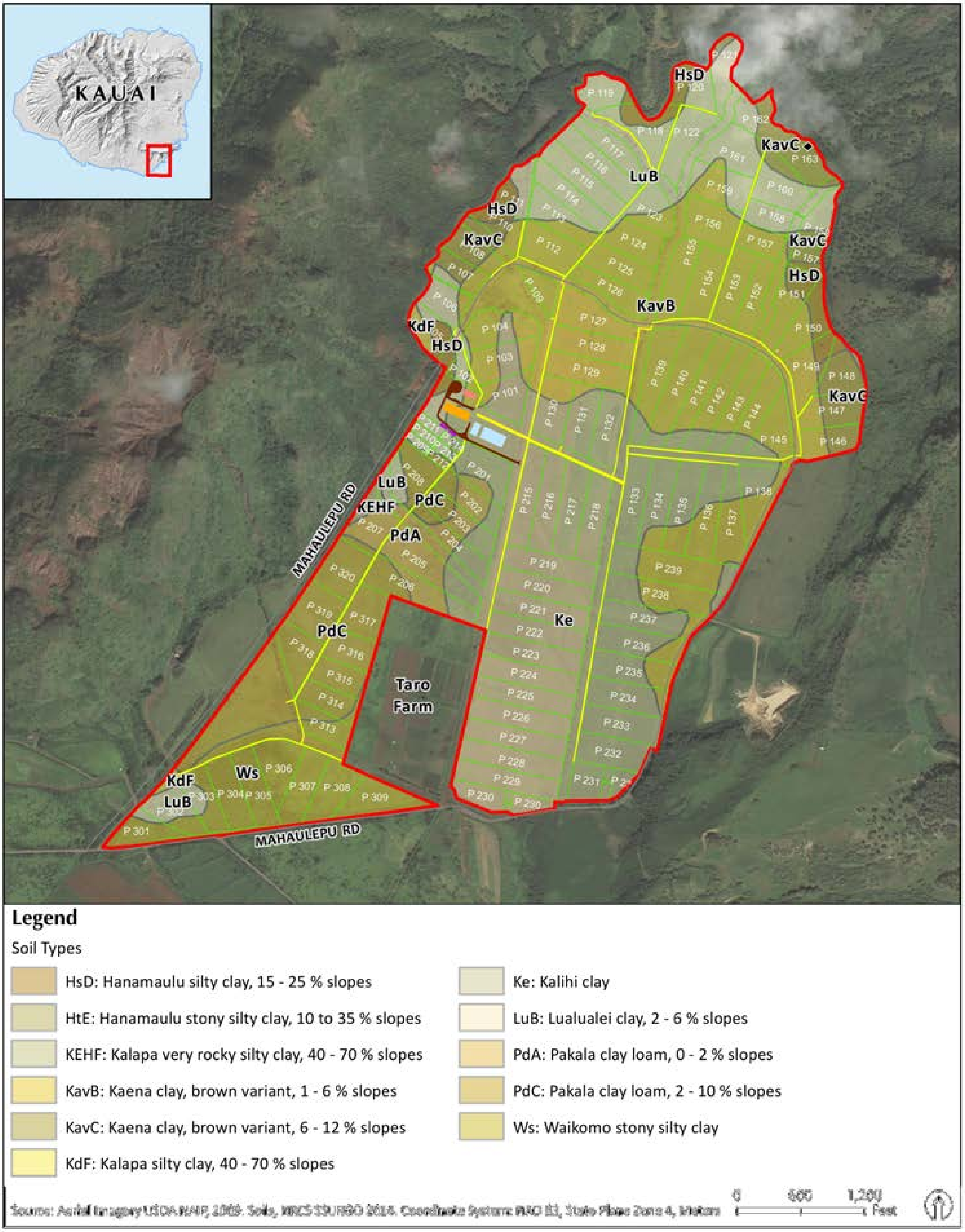


Figure 5 – Soils Map

3.0 Land Use Summary

The total dairy farm area inclusive of pasture and dairy facility, but excluding the existing taro farm, is 556.8 acres. The dairy project site has been divided into two land use areas as described in Table 7 (below): The farm area consists of 547.1 acres for pasture, roads, and setbacks and 9.7 acres for the dairy facility. **See Figure 6 – Paddock Map.**

Table 7 – Land Use Summary

Land Use	Acres
Farm	
Paddocks / Pasture	469.9
Cow Races, Farm Roads, Drainage Ways & Setbacks / Vegetated Buffers	77.2
Subtotal	**547.1**
Headquarters / Dairy Facility	
Milking Parlor, Yards, Sheds, Road, Ponds	9.7
Subtotal	**9.7**
TOTAL	**556.8**

The farm is broken up into a total of 119 paddocks, the majority of which are approximately 3 to 5 acres in size. Paddocks smaller in size near the dairy facility would be used for temporary holding for calves less than 90 days old, prior to moving off of the farm, or for temporary holding for other mature dairy cows. **See Figure 6 - Paddock Map and Table 8 - Paddock Area Summary**. Other land uses within the farm areas include the cow races, walkways, farm roads, drainage ways, animal cemetery, and effluent ponds. The animal cemetery is located on paddock 163 and is included in the total paddock area.

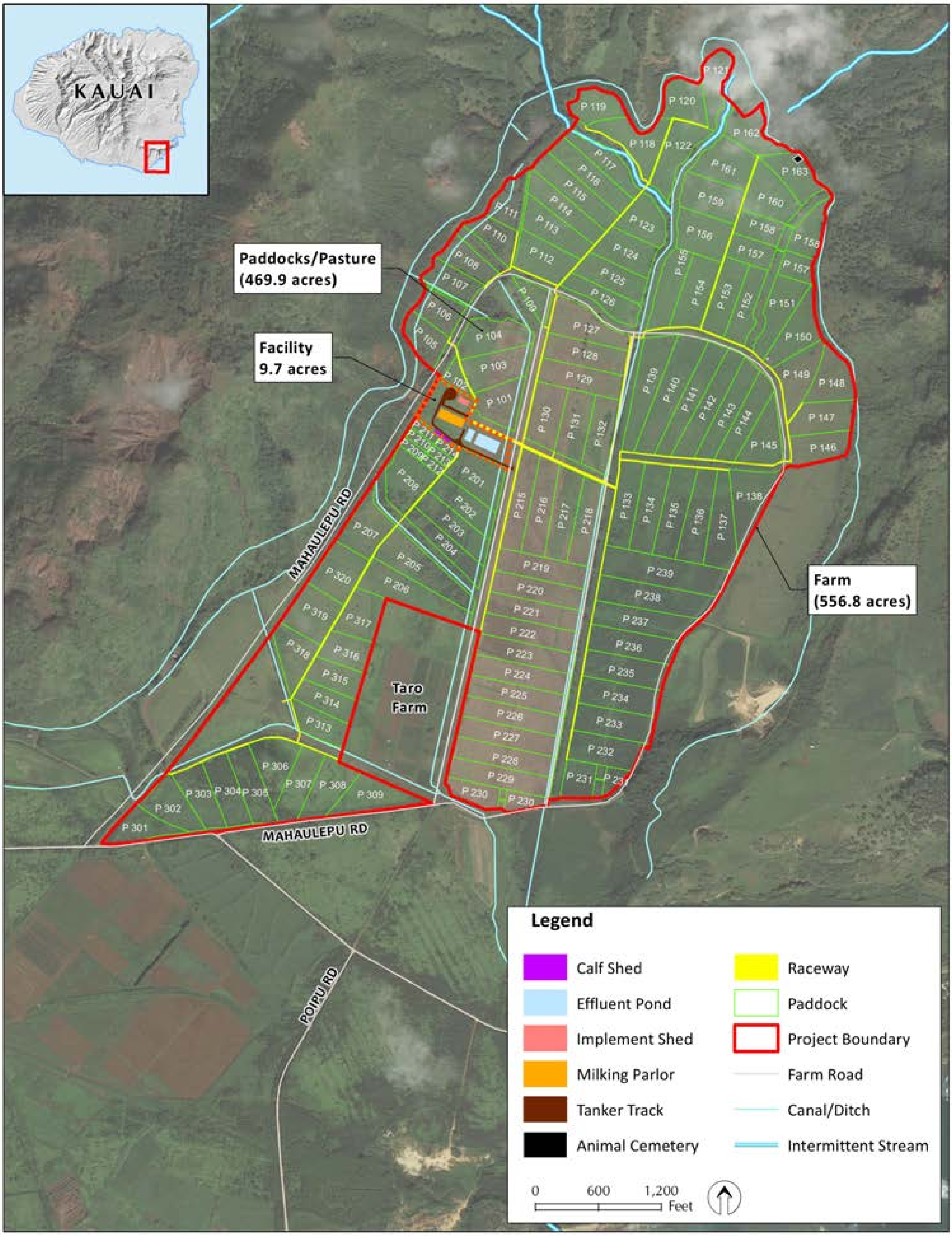


Figure 6 – Paddock Map

Table 8 – Paddock Area Summary

Field	Acres	Field	Acres	Field	Acres	Field	Acres
P 101	3.62	P 133	4.26	P 202	3.60	P 234	4.64
P 102	1.12	P 134	4.73	P 203	3.99	P 235	4.62
P 103	4.47	P 135	4.74	P 204	3.40	P 236	4.67
P 104	4.54	P 136	4.78	P 205	6.01	P 237	5.04
P 105	3.08	P 137	4.81	P 206	6.04	P 238	6.14
P 106	2.94	P 138	5.06	P 207	4.17	P 239	7.63
P 107	3.02	P 139	5.53	P 208	4.41	P 301	3.29
P 108	2.91	P 140	6.57	P 209	0.55	P 302	3.94
P 109	1.69	P 141	4.76	P 210	0.59	P 303	3.65
P 110	2.83	P 142	4.93	P 211	0.63	P 304	3.97
P 111	3.04	P 143	4.32	P 212	0.52	P 305	4.01
P 112	4.19	P 144	3.94	P 213	0.51	P 306	4.16
P 113	4.12	P 145	3.87	P 214	0.48	P 307	4.11
P 114	3.80	P 146	3.43	P 215	4.24	P 308	4.02
P 115	4.51	P 147	3.89	P 216	4.54	P 309	4.55
P 116	4.29	P 148	3.88	P 217	4.64		
P 117	3.29	P 149	4.11	P 218	4.20		
P 118	4.54	P 150	4.17	P 219	4.41		
P 119	3.06	P 151	4.23	P 220	4.32	P 313	3.00
P 120	3.49	P 152	3.44	P 221	4.30	P 314	3.01
P 121	3.17	P 153	4.03	P 222	4.29	P 315	3.01
P 122	4.25	P 154	4.46	P 223	4.35	P 316	3.02
P 123	3.53	P 155	3.94	P 224	4.41	P 317	3.78
P 124	3.90	P 156	4.46	P 225	4.38	P 318	3.64
P 125	3.89	P 157	4.14	P 226	4.42	P 319	4.34
P 126	3.24	P 158	5.24	P 227	4.46	P 320	4.29
P 127	4.59	P 159	4.49	P 228	4.50		
P 128	4.38	P 160	4.56	P 229	4.47		
P 129	4.35	P 161	4.52	P 230	3.69		
P 130	4.10	P 162	3.54	P 231	3.39		
P 131	4.02	P 163	3.43	P 232	4.26		
P 132	3.94	P 201	4.47	P 233	4.55	Total	469.9

4.0 Farm Description

Dairy-related facilities will occupy approximately 9.7 acres along the western boundary of the project area. Buildings will include a milking parlor/barn with a rotary milking platform and milk storage tanks, two calf sheds, and an implemen~~tation~~ shed for tools and equipment. Manure captured during the milking process will be transferred through underground pipes to two nearby effluent ponds, where solids will be settled out and the remaining fluid stored for application to the pasture through the irrigation system. When applied via the irrigation system, non-potable water from the Waita Reservoir will be added to nutrient rich liquid for irrigation use. The effluent ponds will be sealed with a flexible membrane liner, and will be constructed within a secondary containment berm. Paved access roads and a truck turnaround area for milk tanker trucks, feed silos, and a holding yard for cows waiting to enter the milking parlor will also be part of the project.

Agricultural infrastructure from prior sugar cane cultivation within the project area, such as gravel access roads, field roads, reservoirs, pipelines, irrigation ditches, drainage ways and culverts, will be adapted for reuse where possible. Additional field improvements will include a livestock water distribution system, pivot irrigation system, culverts and perimeter and paddock fencing.

The majority of the dairy farm area (i.e. ~83%) is dedicated to pasture. Much of the remaining area is dedicated to access roads, cow races, the dairy facility, and waterway setback / buffers. The dairy facility including the parlor, effluent ponds and secondary containment areas is contained within a 9.7-acre area, which represents about 1.7% of the entire farm. The corresponding building areas are under 0.1% of the total farm area. The dairy farm infrastructure is summarized as follows and shown on **Figure 7 - Farm Map**:

- Paved Access Road and Truck Turnaround
- Cow Walkways/Races and Farm Roads
- Concrete Holding Yards and Gravel Farm Races
- Milking Parlor
- Implement Shed
- Calf Sheds (2)

- Settling Pond and Storage Pond
- Effluent and Sludge Pumps and Distribution System
- Irrigation Water Storage and Distribution System
- Existing Potable Well and Water Line to Milking Parlor
- Potable Water Tank for Milking Parlor and Livestock Consumption
- Livestock Water Distribution System
- Feed Silos
- Milking Parlor - Individual Wastewater System (IWS)
- Animal Cemetery (Located on Paddock 163)
- Paddock fencing and perimeter fencing

4.1 Physical Setbacks for Water Resources

Physical setbacks are incorporated into the farm's design, where no active pasture, effluent application, or grazing activities will occur, intended to protect and improve water resource quality. Paddock and perimeter fencing, based upon NRCS Conservation Practice Standard specifications, are set back 35 feet from water resources and are designed to keep livestock from entering and polluting water resources. Though not required by the "Guidelines for Livestock Waste Management", HDF has also agreed to provide a 1,000 foot setback from the Kōloa F County Well through an agreement with the County of Kaua'i, Department of Water (DOW), where no active pasture, effluent application, or grazing activities will occur within 1,000 feet of the County Kōloa F Well.

Restoration of the banks and edges of waterways with plants suitable for site conditions are also incorporated into the farm's design. These vegetation setback / buffers are intended for erosion and sedimentation control, and removal of pollutants through bio-filtration of runoff. NRCS Conservation Practice Standard specifications will be followed, and plant species will be identified in conjunction with the NRCS District Conservationist.

The setbacks and restorations are part of an approved NRCS Conservation Plan for Hawai'i Dairy Farms, which consists of NRCS-approved Best Management Practices (BMPs) for farming activities. The following summary of physical setbacks and related NRCS Conservation Practice Standards will be used adjacent to water resources:

- County Well KōloaKolo'a F – no active pasture, effluent application, or grazing activity within **1,000 feet** radius.
- Paddock Fencing – **35 feet** from top of bank of the water resource on both sides.
- Re-vegetation of 35-foot Setback – NRCS Conservation Practice Standard 390

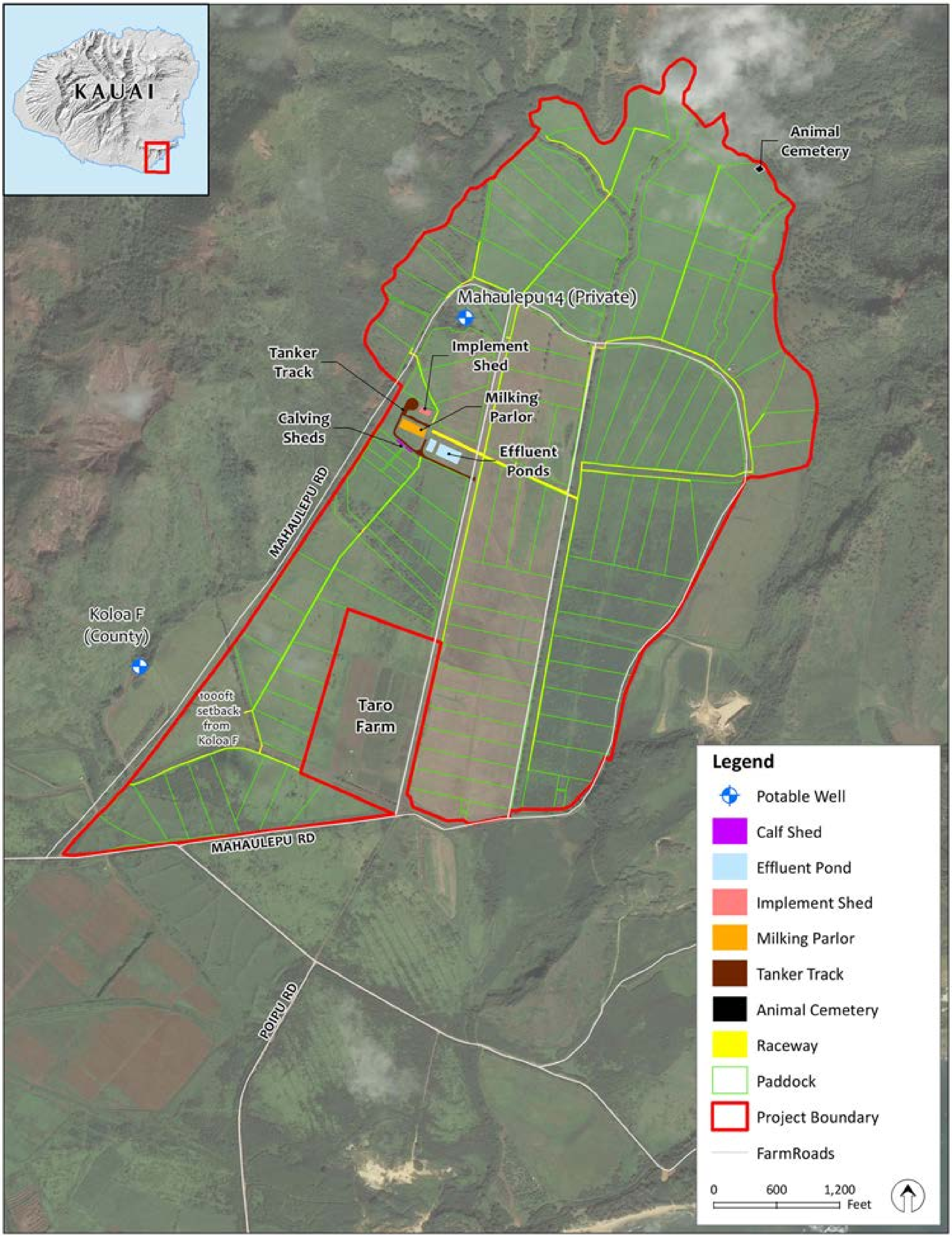


Figure 7 – Farm Map

4.2 Cows Walkways and Races

The dairy farm pasture areas will be divided into 3- to 5-acre paddocks as shown on **Figure 6 - Paddock Map**. A network of walkways and races will ~~connect~~ serve the paddocks ~~together~~ and provide access to and from the dairy facility. The walkways and races are generally aligned with existing farm roads where possible, but additional walkways and races will be constructed through the existing fields.

The walkways and races will be compacted crushed rock access ways that are approximately 16 to 20 feet in width. The cow races will allow twice daily movement of the cows from the paddocks to the Milking Parlor. The cow races are not irrigated and will be frequently maintained to maximize efficient and rapid movement to and from the dairy with minimal injury to livestock. The races will be bordered by 3 wire electrical fencing.

At waterways and drainage ways, animal crossings will be added consisting of a bridge or culvert, and will be designed to appropriate NRCS Conservation Practice Standards and Codes.

4.3 Dairy Facility

4.3.1 Calf Sheds

Calf sheds will be constructed to provide safe housing for calves at the HDF site, which are kept until approximately 90 days of age. There will be two open bay calf sheds, which will be steel structures with metal roofs on concrete slabs. Each shed will be approximately 81 ft. long by 26 ft. wide by 15 ft. tall. A minimum of approximately 21 sq. ft. area is allocated for each calf and 20 calves will be kept in one pen (approximately 26 ft. x 16 ft.) at any given time. Each pen is divided in two areas (feeding area and bedding area). Overall, the calf sheds will provide capacity for up to 200 calves. The feeding area will be washed daily and wastewater will be transferred to the effluent ponds via drain inlets and conveyance piping. Calf bedding will consist of sand. Calves will transition to pasture near the calf sheds after 3-4 weeks. **See Figure 8 - Facility Site Plan.**

4.3.2 Implement Shed

An implement shed will be constructed for storage of equipment, tools, and farm machinery parking. The implement shed will be an open bay steel structure with metal roofs on a concrete slab, similar to the calving sheds. The implement shed will be approximately 65 ft. long by 26 ft. wide by 15 ft. tall for a total area of 1,690 sq. ft. **See Figure 8 - Facility Site Plan.**

4.3.3 Milking Parlor

The Milking Parlor will be the single largest structure on the dairy farm with dimensions of approximately 256 ft. long by 88.5 ft. wide by 33 ft. tall. The Milking Parlor will contain a highly-automated 60-stall rotary, which completes one rotation of 60 cows in approximately 8-10 minutes. It will operate 365 days a year. **See Figure 8 - Facility Site Plan.**

The initial herd of 699 mature dairy cows will be managed in mobs of 105 – 115 cows according to their calving, lactation, and health status. At full production, if expanded, up to 2,000 mature dairy cows will be managed in mobs of 300 – 330 cows according to their calving, lactation and health status. The mobs will be brought into the holding yard and Milking Parlor twice a day for milking. Each time, an individual cow's maximum milking time will be 10 minutes and the maximum time off pasture will be 1 hour. The individual milking time of cows will be the same, regardless of the total number of animals on the farm, with total time in the milking parlor corresponding to the total size of the mob and the ~~amount~~ number of animals that must be milked in the parlor. Each mob will still be brought into the holding yard and milking parlor twice a day for milking.

The Milking Parlor building includes the following components:

- Covered Loading Area
- Milking Area
- Holding Pens
- Mechanical Room and Pump Room
- Office Space
- Veterinary Space and Storage
- Staff Restrooms
- Milk Storage

4.3.4 Milking Parlor Feeding System

In-parlor feeding will be offered to the cows to provide additional nutrients, which will improve animal health and milk production. Cows will be eager to enter into the parlor where they will receive feed, so the overall milking process time is typically improved. A small portion of feed (6.6 lbs.) will be offered to cows during the milking time (8-10 min), which will be stored in two 44-ton – 60-degree cone silos.

4.3.5 Holding Yard

The holding yard is designed to hold a single 330-cow mob at any one time, and will be approximately 150 ft. long by 82 ft. wide for a total area of 12,300 sq. ft. The holding yard area will be heavily used by livestock and will need to be cleaned frequently. Manure/nutrient-laden water will be transferred to the effluent pond through underground pipes. No feed will be offered in the holding yard and each mob will spend less than one hour in the yard before entering into the Milking Parlor. **See Figure 8 - Facility Site Plan.**

4.3.6 Access Road and Tanker Truck Turnaround

A new 20-foot wide paved access road / tanker track will be constructed off of the adjacent farm roads to the dairy facility. The access road will serve as the primary access to the dairy and will be used by milk tanker trucks for transport of milk off-site, as well as for supply trucks making deliveries. A paved truck turnaround will be located at the end of the access road and will lead up to a covered loading area where milk will be pumped directly into the trucks. **See Figure 8 - Facility Site Plan.**

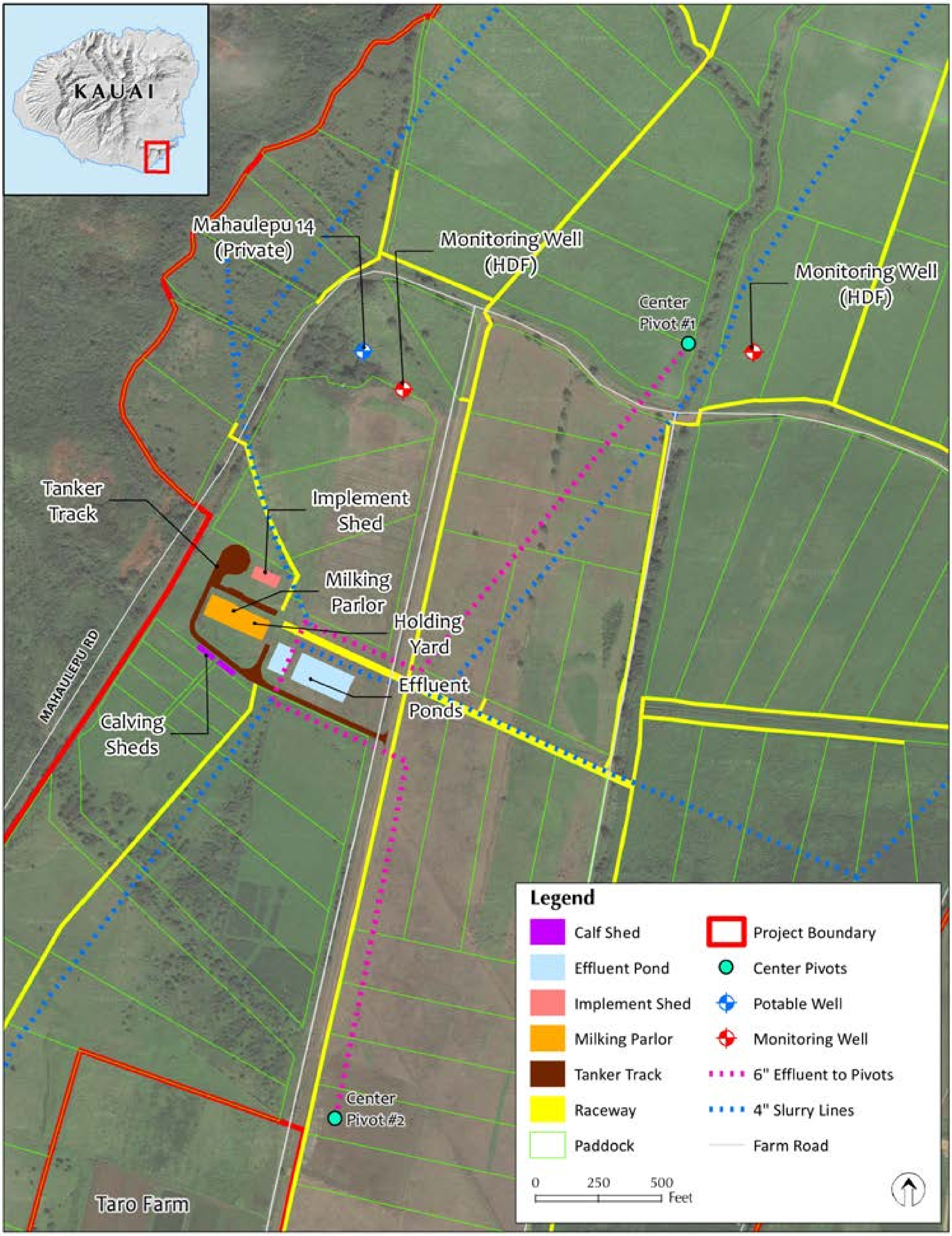


Figure 8 – Site Plan

5.0 Potable Water Systems

Potable water is required for the washing down of the milk parlor and yards, milk cooling, potable consumption within the dairy facility, washing down the calf facility, and for livestock consumption. At the committed herd size of 699 mature dairy ~~milking~~ cows, approximately 12,163 gallons will be used per day. At the contemplated herd size of 2,000 mature dairy ~~milking~~ cows, approximately 34,800 gallons will be used per day. The cows on pasture will also consume approximately 25.0 gallons per day for drinking purposes. Daily consumption of the 699 mature dairy ~~milking~~ cows will be approximately 17,475 gallons. The 2,000- mature dairy ~~milking~~ cow herd will drink 50,000 gallons per day. The total potable water demand per day will be approximately 29,638 gallons per day at the committed herd size, and about 84,800 gallons per day for the contemplated 2,000-cow herd size.

5.1 Water Source and Quality

Potable water for the dairy facility and livestock consumption must be of acceptable quality per DOH requirements. Water will be sourced from the Māhāʻulepū Well located within the project site. The well site once contained up to 14 wells, drilled for the sugar plantation between 1897 and 1928. Of the 14 wells, only 3 were located and are able to be utilized by HDF. One well will be used for potable water, one will be used for aquifer / deep groundwater monitoring, and one will be used as a backup. The water source has been tested and is of an acceptable quality. Further information on the wells in the area and baseline water quality information is documented in "Estimates of the Potential Impact on Groundwater and Surface Water By Hawaii Dairy Farms in Mahaulepu, Kauai" by Tom Nance Water Resource Engineering (2016).

5.2 Livestock Water Distribution System

Availability of drinking water has an impact on animal health and milk production. The livestock water distribution system has been designed to supply a large volume of water to meet the seasonal high daily water demand of 25 gpd per cow. The total livestock drinking water demand is estimated to be 17,475 gpd for the initial herd of 699 cows, and 50,000 gpd for up to 2,000 mature dairy cows. Two large covered and lined water storage tanks will be located at the Milking Parlor providing total storage of nearly 80,000 gallons.

Water from the storage tanks will be distributed into the Milking Parlor and to adjacent buildings for dairy use. Water will also be distributed throughout the paddocks for livestock consumption. Small booster pumps will be used to ensure the required flow will be delivered throughout the farm.

Small diameter water mains, 2 to 3 inches in size, will deliver water to the paddocks. Two concrete troughs, at minimum, will be installed in each paddock to give animals easy access to drinking water at all times. Troughs will be raised and placed on a crushed rock base to provide a firm and stable surface for animal movement around the trough. The trough is high enough for the animal to reach over and in, but will discourage the animal from stepping into the trough. The troughs are also fitted with valves to stop the flow of water into the trough when the trough is full and refill the trough as the water is consumed, ensuring maximum water efficiency.

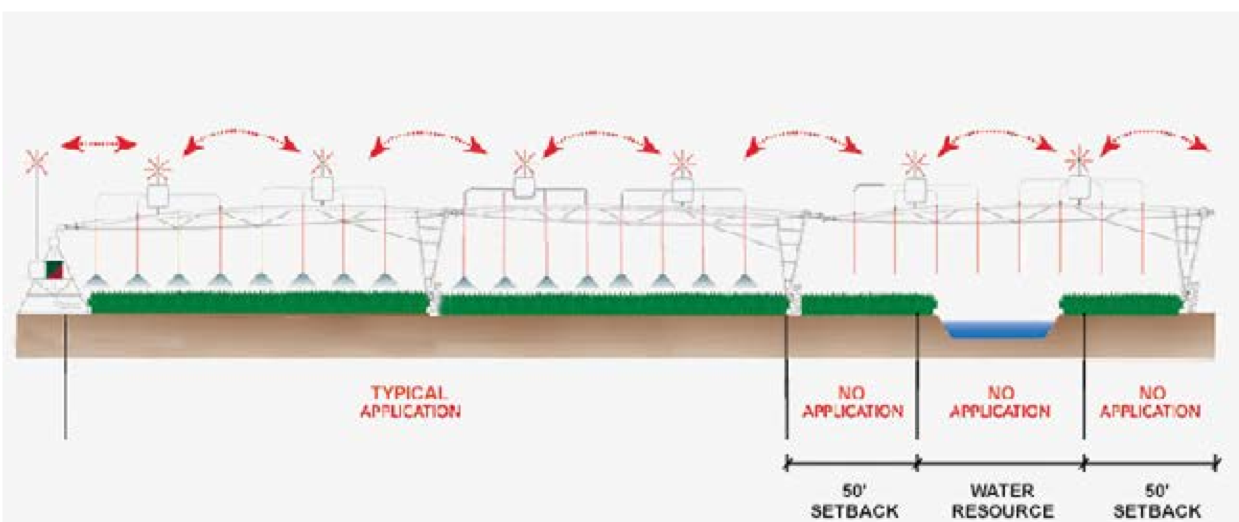
6.0 Irrigation

The total pasture area of the farm is 469.9 acres. The majority of the pasture area will be irrigated with either irrigation water, liquid effluent, or both through either pivot irrigation systems or through gun irrigators with a hard-hose reel, which can be moved throughout the farm as needed. **See Figure 9 - Irrigation Map.**

6.1 Pivot Irrigation System

The pivot irrigation system will consist of two center pivots. A center pivot irrigation system is an overhead irrigation system, which includes irrigation pipes supported on trusses mounted on wheeled towers that rotate around a central water supply point. The farm will have two pivots; irrigation pivot #1 will be a full circle (FC) pivot and irrigation pivot #2 will be a partial circle (PC) pivot. **See Figure 10 - Irrigated Pasture Areas.** The irrigation system including irrigation application rates and emitters is controlled using computer software and GPS receivers to allow very precise application of irrigation on the pasture.

The pivot is capable of spraying at a rate of 1,030 gpm, but the pivots can apply irrigation water at different rates depending on the actual irrigation needs of the farm. A somewhat typical application rotation and rate would include a 48-hour rotation and application of up to 0.39 inches of irrigation onto the paddocks. The various components of the central pivot irrigation control system are shown below:



Pivot crossings at waterways and ditches, ~~provided~~ at the wheel track locations, will allow the pivot to traverse the waterway without impact, and consist of an elevated metal track anchored on both sides of the waterway. Pivot tracks will be replanted with grass as required to minimize erosion and sediment runoff

6.2 Gun Irrigation System

The gun irrigation system will utilize a rotating, hard-hose reel gun system in makai areas of the farm, where the center pivots are unable to reach. The gun irrigators can be moved around the farm to provide maximum reach and even distribution of irrigation water to areas not served by the center pivot irrigation system. **See Figure 10 - Irrigated Pasture Areas.** Gun irrigators will not apply liquid effluent and will utilize irrigation water sourced to the farm, currently from Waita Reservoir. Irrigation water will be filtered and pumped into the gun irrigation system.

A separate rotating, hard-hose reel gun system will be installed for slurry application and is further discussed in **Section 8 – Nutrient Management**. This system will be used to apply solids from the settling pond where needed to provide nutrients to the paddocks much like commercial fertilizer would be applied, and is not relied upon for regular irrigation to meet the daily water demand of the grass crop. The slurry application system will be completely separate from the gun irrigation system in the makai areas of the farm. Because the slurry is used to provide nutrients to the farm, slurry application is discussed later in this report.

6.3 Non-Irrigated Areas (Pasture and Non-Pasture)

Approximately 26.2% of the total pasture area will not be irrigated, primarily in the mauka areas of the farm where the pivots are unable to reach. No gun irrigation system, utilizing irrigation water only, will be used in this area in HDF's current plans, but could be added as needed, for management and operational purposes. **See Figure 11 – Non-Irrigated Areas.**

While non-irrigated areas do not receive regular irrigation to meet crop water demands, some non-irrigated pasture areas will still receive water in the form of precipitation as well as nutrients in the form of fertilizer or slurry required for grass growth. Nutrient application rates in this area, as with other pasture areas, will be properly managed to avoid over-application or application around a significant rain event. Application of slurry is discussed in **Section 8.4, Nutrient Application.**

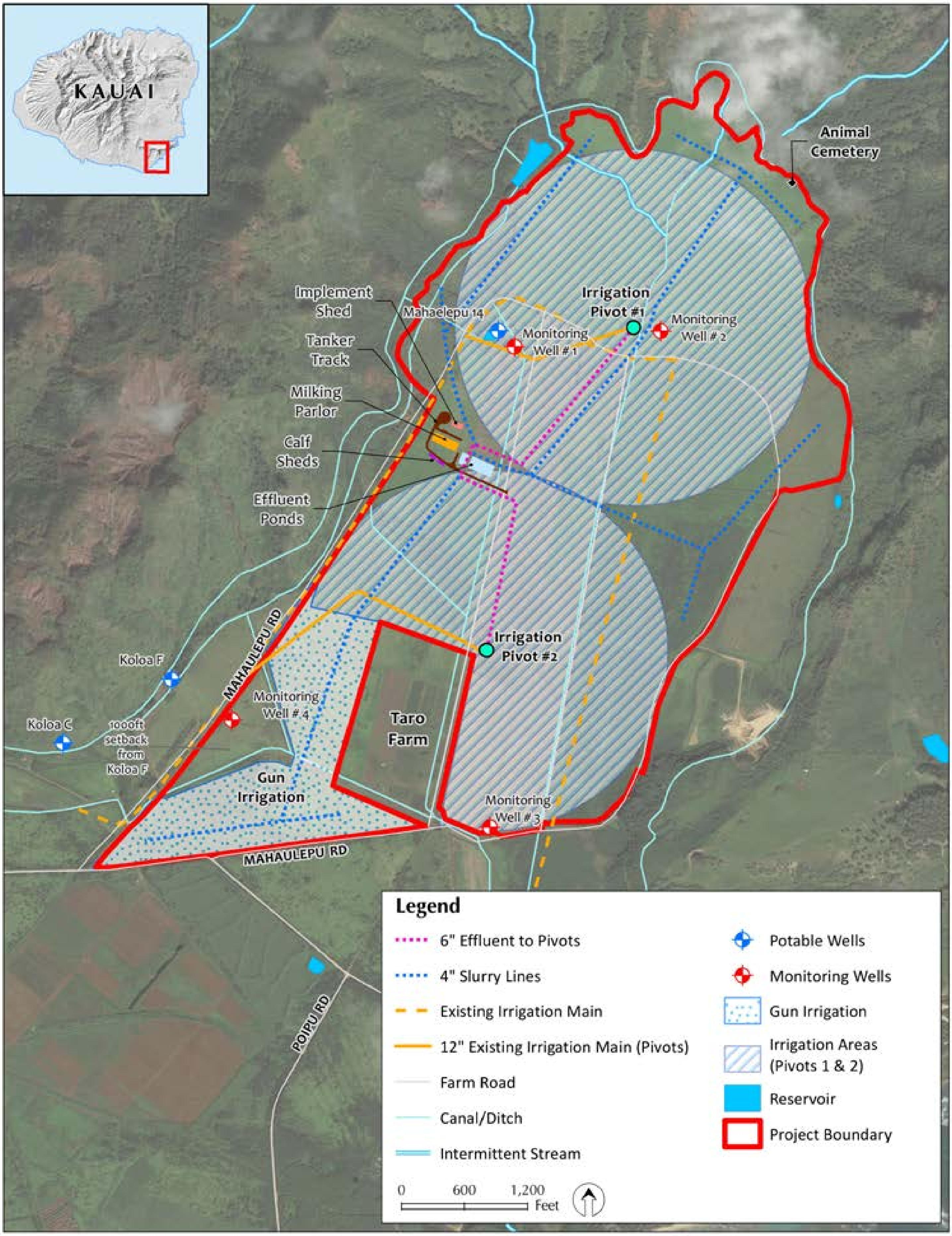


Figure 9 – Irrigation Map

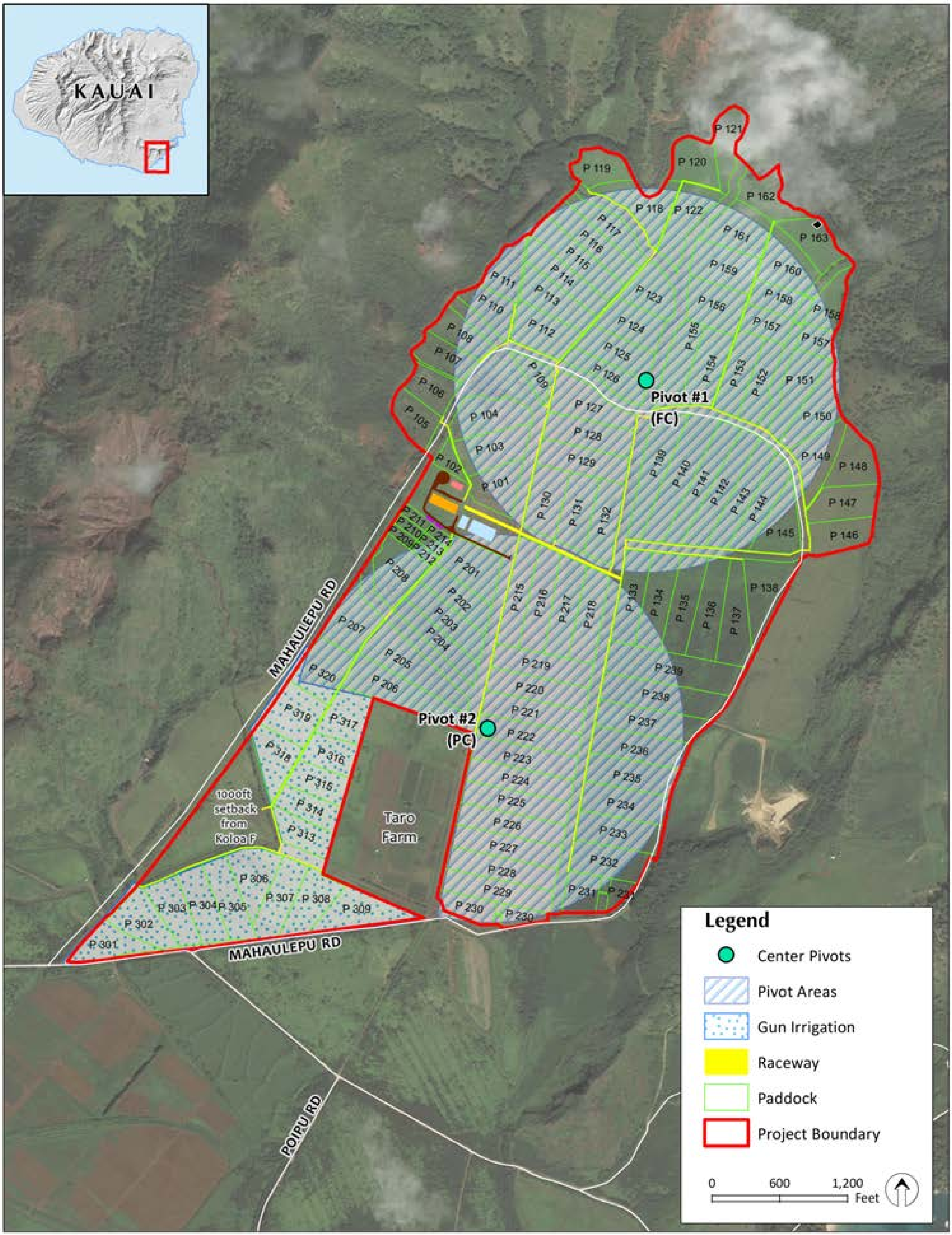


Figure 10 – Irrigated Pasture Areas

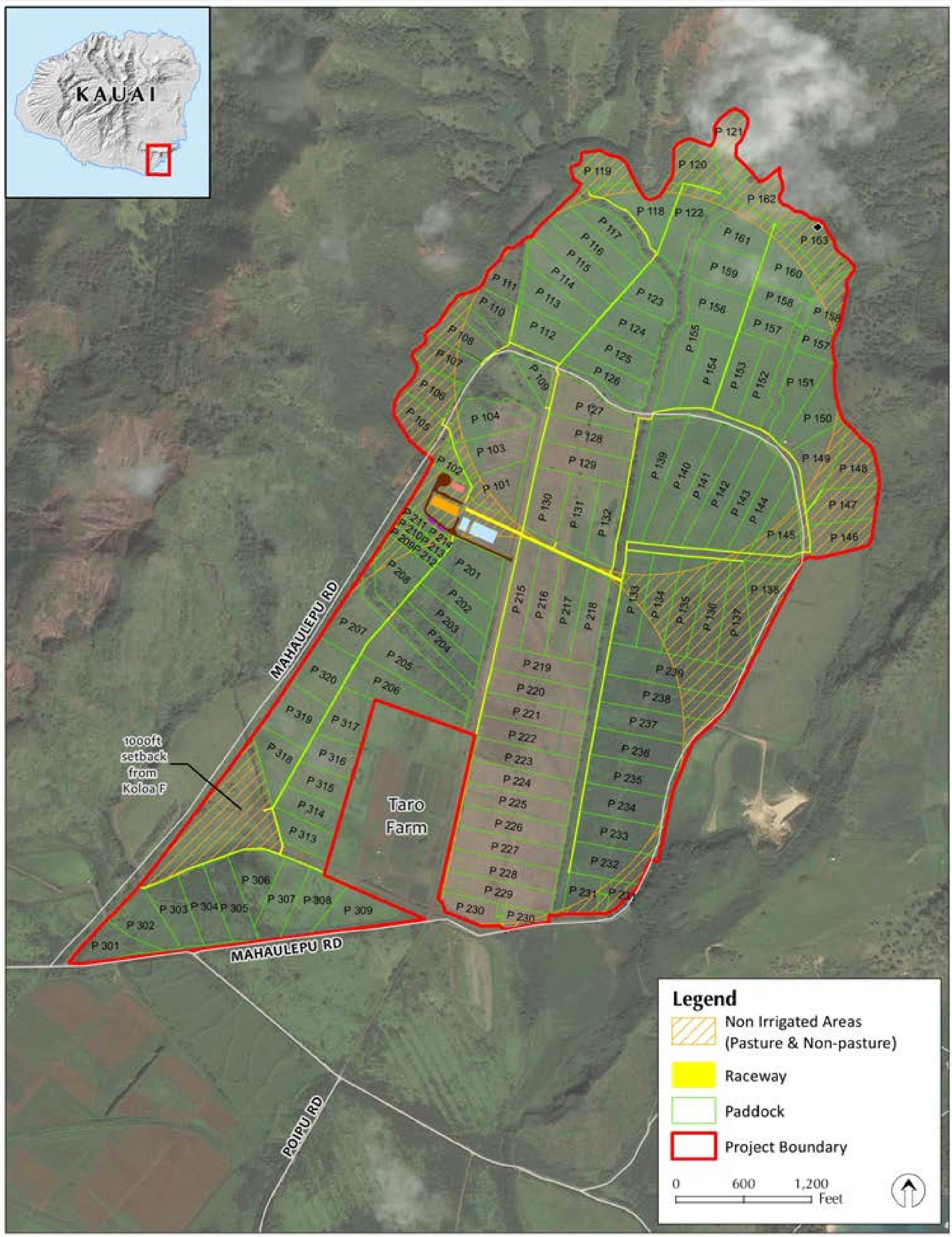


Figure 11 – Non-Irrigated Areas

6.4 ~~Irrigation~~ Effluent Application Setbacks

~~Irrigation s~~Setback distances have been established to limit irrigation activity or ~~irrigation with~~application of liquid effluent within specific areas under the pivot or with the rotating gun slurry system. The pivot irrigation systems are configured with GPS-controlled emitters that will turn off so that liquid effluent is not directly applied to the ditches, cow races and any other agricultural or natural water resources. The following liquid effluent setbacks are incorporated into the design and no ~~irrigation~~ application of effluent will occur within the distance specified for each of the following:

- County Well Kōloa~~Kolo'a~~ F – **1,000 feet** on all sides (through County DOW agreement)
- Irrigation ditch, agricultural water, and natural water resource - **50 feet** from top of bank of the water resource on both sides.
- Cow walkways and races - **6 feet** on both sides
- Existing taro farm - **20 feet** on all sides

The setback distances from water resources are based upon requirements contained within the "Guidelines for Livestock ~~Waste~~ Management", by the DOH~~University of Hawai'i Mānoa – CTAHR~~. While the minimum setback distance for the application of effluent from public drinking water sources is 50 feet per the Guidelines, HDF has agreed to increase this setback to 1,000 feet following consultation with the County of Kaua'i Department of Water (DOW).

Therefore, application of liquid effluent~~ in addition~~ is prohibited within 50 feet of water resources on the farm, while application of as-excreted manure (during normal grazing) is prohibited within 35 feet of water resources on the farm by physical setbacks (fencing) previously described in **Section 4.1 – Physical Setbacks for Water Resources**,

6.5 Irrigation Areas

The irrigated pasture areas are summarized in **Table 9 – Irrigated Pasture Area Summary**, below. The non-irrigated pasture areas are summarized in **Table 10 – Non-Irrigated Pasture Area Summary**, below:

Table 9 – Irrigated Pasture Area Summary

Irrigated Pasture Area	Acres
Irrigation Pivot #1 (Full Circle)	164.7
Irrigation Pivot #2 (Partial Circle)	120.4
Subtotal	285.1
Gun Irrigation Area	61.4
Total Irrigated Pasture Area	**346.5**

Table 10 – Non-Irrigated Pasture Area Summary

Non-Irrigated Pasture Area	Acres
Pasture Area within 50′ Pivot Irrigation Setback	13.8
Remaining Non-Irrigated Pasture Area	109.6
Total Non-Irrigated Pasture Area	**123.4**

Table 11 – Irrigation Area Summary

Area	Acres
Irrigated Pasture Area (Table 8)	346.5
Non-Irrigated Pasture Area (Table 9)	123.4
Total Pasture Area (Table 6)	**469.9**

Irrigation water is expected to be provided via Waita Reservoir and it is not anticipated that the potable wells from the Māhāʻulepū 14 well site would provide irrigation water to the pivots or to the gun irrigation system.

While non-irrigated areas do not receive regular irrigation to meet crop water demands, some will still receive water in the form of precipitation as well as nutrients in the form of fertilizer or slurry application that is required for grass growth, which will be properly managed to avoid over application or application around a significant rain event. Because the slurry is used to provide nutrients to the farm, slurry application is discussed later in this report.

6.6 Irrigation Demand

The irrigation demand will not change depending on the amount of animals on the farm. With a herd size of 699 ~~milking~~ mature dairy cows or 2,000 ~~milking~~ mature dairy cows, the same amount of irrigated pasture will be utilized for each rotating mob of dairy cows.

Under typical conditions, the irrigation systems will be designed and sized for an upper –end application rate of 0.24 inches per acre per day on 285.1 acres of pivot area and 61.4 acres of gun irrigation area, which equates to approximately 2.26 million gallons per day (MGD) of irrigation per day, on average. This demand is used conservatively for infrastructure planning purposes.

The actual amount of applied irrigation and schedule of irrigation days will depend on the number of rain days and amount of precipitation. Therefore, irrigation demand is further examined on a monthly basis for operational purposes, based upon historical rainfall data, the pasture grass crop evapotranspiration (ET) rates, and average monthly precipitation. Effective precipitation is assumed to be up to 0.80 inches of the daily rainfall amount at the Māhāʻulepū Rain Gauge Station 941.1, with the assumption that remaining rainfall greater than 0.80 inches is either lost to deep percolation into the soil or runoff, thereby reducing precipitation available to the crop (Refer to the Estimates of the Potential Impact on Groundwater and Surface Water by Hawaii Dairy Farms in Mahaulepu, Kauai by Tom Nance Water Resource Engineering, 2016).

The calculated monthly irrigation demand is summarized in **Table 12 – Monthly Irrigation Demand**. The demand indicates a clear deficit in precipitation (and need for irrigation) during the spring, summer and fall seasons with only a modest demand for irrigation during the winter season. Actual irrigation volumes to meet the actual crop demand will likely be approximately 10 - 20% higher than the estimated demand shown below, depending on irrigation equipment efficiency (lost to evaporation) and current conditions. The table below are conservative estimates of irrigation demand without taking into account these factors.

Table 12 – Monthly Irrigation Demand

Month	Days	ETo in	ETc in	P in	Pe in	Irrigation Demand Monthly in	Daily in	Monthly gal	Daily Gpd
January	31	6.877	5.845	4.22	2.63	3.22	0.10	30,253,962	975,934
February	28	6.819	5.796	3.70	2.56	3.24	0.12	30,448,727	1,087,455
March	31	7.850	6.673	5.35	3.35	3.32	0.11	31,261,188	1,008,425
April	30	7.967	6.772	3.17	2.76	4.01	0.13	37,748,179	1,258,273
May	31	8.864	7.534	2.61	2.14	5.39	0.17	50,755,562	1,637,276
June	30	9.053	7.695	2.39	2.24	5.46	0.18	51,326,214	1,710,874
July	31	9.394	7.985	2.77	2.49	5.49	0.18	51,701,160	1,667,779
August	31	9.409	7.998	2.98	2.42	5.58	0.18	52,479,749	1,692,895
September	30	9.092	7.728	2.73	2.40	5.33	0.18	50,132,690	1,671,090
October	31	8.600	7.310	3.99	3.00	4.31	0.14	40,552,512	1,308,146
November	30	7.037	5.981	4.66	3.17	2.81	0.09	26,452,752	881,758
December	31	7.101	6.036	5.69	3.27	2.77	0.09	26,023,704	839,474
Total	365	98.063	83.354	44.26	32.43	50.92			

ETo, Grass Reference Monthly evapotranspiration rate (in/mo) for a grass reference obtained from UH Mānoa Dept. of Geography, 2014 Evapotranspiration Maps (Lat 21.907N, 159.422W)

ETc, Crop Monthly crop evapotranspiration rate (in/mo) for Kikuyu grass calculated using a crop coefficient of 0.85

P Average rainfall from the 30-year daily record of Māhāʻulepū Station 941.1 from January 1984 through December 2013.

Pe Effective precipitation assumed to consist of up to 0.80 inches of rain, shown at the Māhāʻulepū Station 941.1. Daily amounts greater than 0.80 inches are assumed to become runoff.

During the wet winter months of November, December and January, the demand for irrigation, and therefore, the frequency of use of the pivot and gun irrigators, is significantly lower than other times of the year. Yet, as there are a number of dry days in those months, irrigation is still required, with an average monthly irrigation demand of between 26.0 MG and 30.3 MG, compared with up to 52.5 MG in the dry summer months.

A weather station is installed on-site, capable of measuring temperature, humidity, rain, wind direction and speed, irradiance and evaporation. Soil moisture meters will also be added to determine the ideal moisture bandwidth for grass growth, and will support irrigation decisions and management.

The proposed irrigation systems for the farm are high-tech in nature and require significant coordination and calibration prior to and during farm operation. Irrigation for the entire farm will be managed precisely based upon the various factors previously discussed, including but not limited to the amount of precipitation, number of rain days, soil moisture and nutrient content, irrigation supply sources, and effluent pond levels and volumes.

Based upon the demand estimates and methodology above, an Irrigation Water Management Plan, which will detail specific farm operating procedures, will be developed to provide the farm operator a plan for proper management and application of irrigation water to allow efficient use of water, minimize energy consumption, and maximize crop yield. Refer to NRCS Practice Code Standards 430 Irrigation Pipeline, 442 Irrigation System, Sprinkler, & 449 Irrigation Water Management.

7.0 Wastewater Management

The dairy farm is a pasture-based, rotational-grazing operation, and the mature dairy cows spend a limited time in the holding yard and milking parlor. Livestock waste and wastewater generated from the milking parlor, holding yards, and calf sheds, including any stormwater and wash down runoff from these areas, will be collected, stored, and reused on the farm as natural fertilizer. Fundamentally, the wastewater system at the dairy facility recycles 100% of all livestock and wash water from the milking process with no direct discharge into State waters from the dairy facility. The objectives of the design are:

i. To capture all of the animal effluent that is produced at the milking parlor holding areas, and calving sheds.
ii. To spread the effluent on the grazing land to meet the nutrient demand of the crop/pasture
iii. To control the effluent application rate and spread effluent only on the desired areas within the project boundaries
iv. To keep effluent completely separate from potable water to prevent contamination of the potable water sources or storage
v. To comply with all regulatory requirements under the state and federal laws

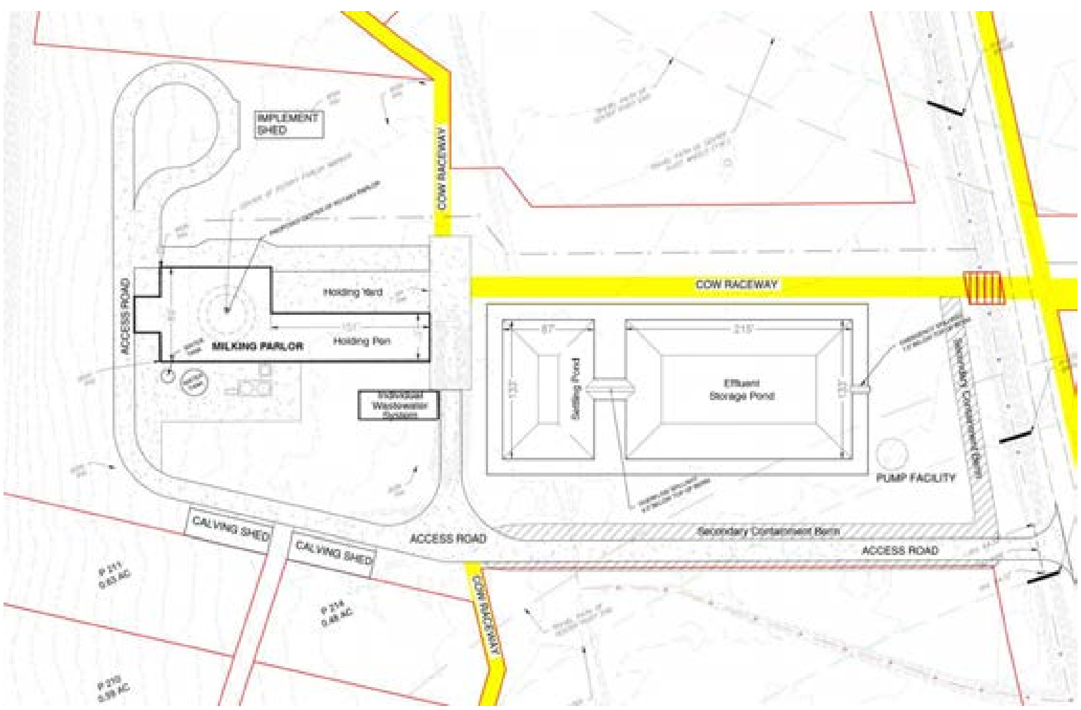


Figure 12 –Dairy Facility Site Plan

The dairy facility including the wastewater ponds and other infrastructure will be sized and constructed for the capacity of 2,000 mature dairy cows, though the initial herd will start at 699 mature dairy cows. Calculations provided herein will show effluent and nutrient operational values of the dairy farm at a proposed herd size of 699 mature dairy cows as well as the contemplated expansion of up to 2,000 mature dairy cows. Refer to NRCS Practice Code Standard 633 Waste Utilization.

7.1 Effluent/Manure Volume

Several criteria serve as the basis of calculating the total amount of manure and effluent that will be collected within the milking parlor, holding yards, and adjacent sheds, and then conveyed to the ponds. The following describes the methodology behind calculating the total manure and effluent volumes, which will need to be accounted for in sizing the waste management ponds in this section, and then managed during reapplication to the pasture areas, as described in **Section 8 – Nutrient Management**.

HDF is a pasture-based, rotational-grazing dairy farm that is being designed for kiwi-cross animals. A mature kiwi-cross cow's weight is about 1,200 lbs. and it produces an average of 90.8 lbs. of manure per day or 10.9 gallons of manure per day, or 0.68 gallons average per waking hour. These values were calculated using the Cornell Net Carbohydrate Protein System (CNCPS) model, further discussed in **Section 8.3 - Nutrient Balance**.

The 699 cows in the initial herd will be maintained in mobs of 105-115 animals and each mob will rotate through a group of 18 paddocks. Under full operation as part of a contemplated herd expansion, up to 2,000 mature dairy cows will be maintained in mobs of 300-330 animals. The cows graze for one day per paddock, so once every 18 days the entire mob will produce the majority of its effluent on that one paddock as it grazes.

Grass-fed dairy cattle produce significantly more liquid manure than cattle fed on concentrate and Kikuyu is also a relatively wet grass (87% water). The total amount of manure produced in the milking platform and holding yards each day is calculated below:

Table 13: Manure Produced in the Milking Parlor and Yard for Mature Dairy Cows

Initial Herd Size of 699	951 gpd	699 x (1 hr x 2 milkings per day) x manure of 0.68 gallon per hour
Contemplated Expansion to 2,000	2,720 gpd	2,000 x (1 hr x 2 milkings per day) x manure of 0.68 gallon per hour

From a waste volume perspective, a dairy operation should also account for the calves that will be on site. For the committed herd size of 699 mature dairy ~~milking~~ cows, there will be approximately 150 calves on the HDF site at any one time, 50 of which will be housed within the calf sheds. Should HDF decide, in the future, to expand operations to the contemplated herd of up to 2,000 mature dairy cows, there will be approximately 500 calves at any one time, 167 of which will be housed within the calf sheds. The remainder will be on the pasture grazing, depending on their age, size and health. Once the calves reach 165 lbs or are 90 days old, they will be transferred to an off-site calf raising facility. A calf produces approximately 2.244 gallons of manure per day. Because manure in the calf sheds is conveyed to the effluent pond system, the total amount of manure produced in the calf sheds (for the 699 herd size and 2,000 herd size) is calculated below:

Table 14: Manure Produced in the Calf Sheds for Calves

Initial Herd Size of 699	112.2 gpd	50 calves in pen x manure of 2.244 gallon per calf per day
Contemplated Expansion to 2,000	374.7 gpd	167 calves in pen x manure of 2.244 gallon per calf per day

The holding yard and milking parlor are washed twice a day after each milking, and the calf sheds are also periodically washed (collecting manure generated by the calves on-site that are housed in the pens – further discussion of calf manure is discussed in **Section 8 – Nutrient Balance**). All of the manure produced in the milking parlor, yards, and calf sheds is washed out and the nutrient-laden water is transferred to the settling pond. The milk storage tanks located within the milking parlor are also washed out after milk is pumped to tanker trucks for delivery. Wash water from the milk tanks is also transferred to the settling pond. Total wash water from all processes at the parlor, yards, calf sheds (including calf manure), and remaining facility is estimated to be at 17.4 gpd per mature dairy cow.

Table 15: Wash Water Produced in the Milking Parlor, Yards, and Calf Sheds

Initial Herd Size of 699	12,162.6	gpd
Contemplated Expansion to 2,000	34,800	gpd

Therefore, the total wastewater volume from the manure at the milking parlor, holding yards, calf sheds, machine wash, yard wash, and milking activity wash is summarized below:

Table 16: Total Wastewater Volume at the Dairy Facility

Initial Herd Size of 699	13,225.8	gpd
Contemplated Expansion to 2,000	37,894.7	gpd

See Figure 13A & B - Water Flow Schematic for a schematic diagram of the water and wastewater flow through the pasture-based, rotational-grazing system. Two diagrams are provided: one for the initial herd size of 699 and one for the contemplated expansion to 2,000.

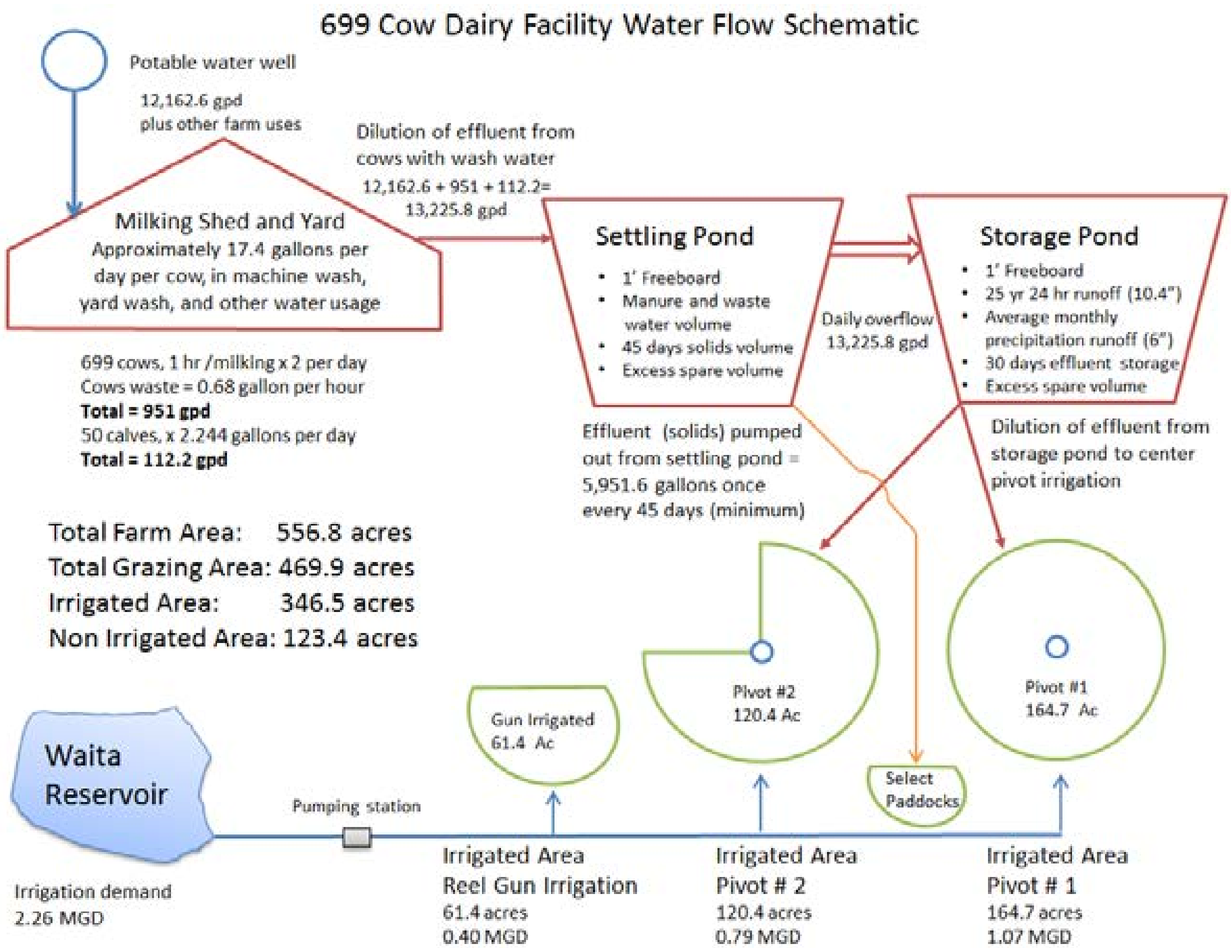


Figure 13A - Water Flow Schematic for 699 Mature Dairy Cows

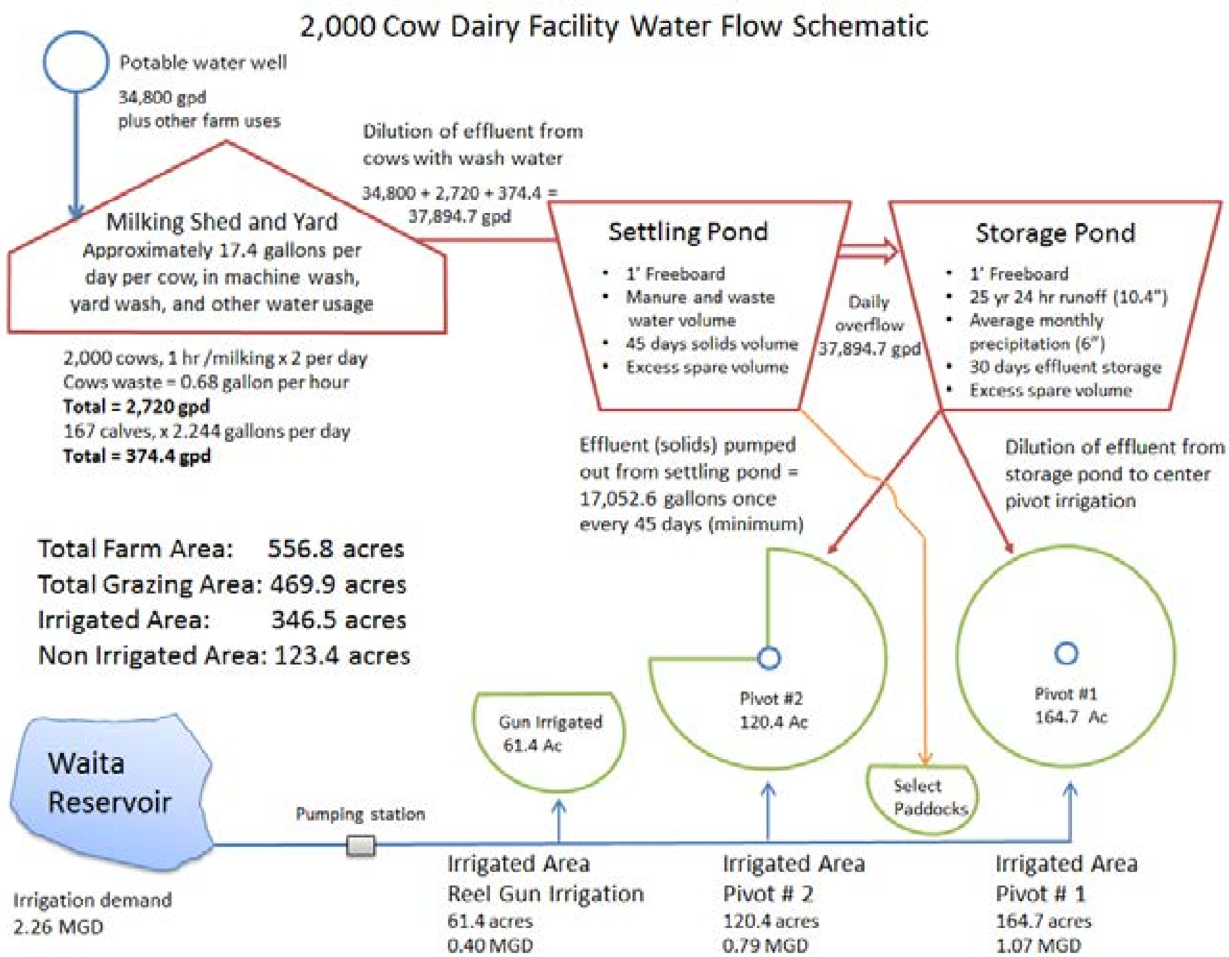


Figure 13B - Water Flow Schematic for 2,000 Mature Dairy Cows

All of the manure and wash down water that is collected from the milking facility, yards, and calf sheds is transferred to the effluent ponds, consisting of a two-stage system including a settling pond and a storage pond, prior to application on the pastures through the irrigation system. The sizing and the operation of the effluent ponds is described below:

7.2 Effluent Ponds

The effluent ponds will be constructed for effluent collection, management and proper utilization of nutrients available from livestock waste. The pond design is based on a two-step system, which includes a settling pond and storage pond. The settling pond allows for the settlement and accumulation of wastewater sludge with the overflow of liquid effluent entering the storage pond. The settling pond and storage pond separate solids from liquids and hold the effluent, respectively, for management purposes. The ponds will be located a minimum distance of 1,000 feet from public drinking water resources and 50 feet from surface water resources as required by the "Guidelines for Livestock ~~Waste~~ Management", by ~~University of Hawaiʻi Mānoa – CTAHR~~the DOH. **See Figure 8 - Facility Site Plan.**

Sizing of the effluent ponds is highly dependent on the amount of effluent and subsequently the nutrients collected, the normal precipitation collected, and the volume of a 25-year, 24-hour storm event. In turn, sizing of the ponds is dependent on how often and at what rate, the collected effluent and precipitation will be reapplied to the field. As previously discussed, in effect, 100% of all manure and effluent captured at the dairy facility will be reapplied to the pasture for its nutrient value.

Nutrient application means and methods are further discussed in **Section 8 – Nutrient Management**. However, the following criteria will be used in sizing both the settling and storage ponds for both the committed 699 herd size scenario, as well as at the contemplated herd size of 2,000 mature dairy cows:

7.2.1 Pond Operation and Sizing Criteria

Wastewater from the dairy facility, yards, and calf sheds is discharged into the settling pond first. Solids settle and accumulate at the bottom of this pond as liquid effluent collects over several days. A stirrer pump is operated two hours per day to break up the solids in the settling pond. Once the settling pond is full with both solids and liquid, any additional liquid effluent (minus settled solids) that enters the settling pond daily, overflows to the adjacent storage pond through screened overflow pipes (13,225.8 gpd for 699 mature dairy cows and 37,894.7 gpd for 2,000 mature dairy cows). The settling pond remains full in normal steady state until the solids are utilized on the pasture.

Accumulated solids in the settling pond will be pumped out as weather and paddock conditions permit (slurry application – discussed in **Section 8.4 Nutrient Application**), but at a minimum of once every 45 days (will be emptied with no more than 45 days' worth of accumulated solids). An appropriate mixing volume of liquid is required for stirring the solids into a slurry suspension, for pumping to the pasture.

The storage pond will be emptied according to a 4-day application schedule (i.e. planned every 4 days). The effluent will be applied only when there has been no significant rain in the last two days and no significant heavy rain is forecasted for the next two days.

While the settling pond typically remains full, the level of the storage pond will rise slightly during each milking wash down, when the daily amount of manure and effluent from the dairy facility will enter the storage pond, and will lower on irrigation days when the pond is emptied.

On irrigation days, liquid effluent from the storage pond is applied onto the pastures after being diluted and injected into the irrigation water stream through the center pivots. The daily amount of effluent added to the storage pond (13,225.8 gpd for 699 mature dairy cows and 37,894.7 gpd for 2,000 mature dairy cows) is only a small fraction of the upward estimate of a potential daily irrigation application of 2.26 MGD. This daily amount is still only a small fraction of irrigation even during the winter months, where the daily irrigation demand is at its lowest at 839,474 gpd (in the month of December). As such, effluent pumped to the center pivots is diluted and applied to the pasture at an application rate significantly less than the nutrient requirement of the grass (See **Section 8.4 Nutrient Application**).

The minimum required effluent volume in both ponds shall also include the additional storage required during periods of heavy, sustained rainfall when irrigation application of effluent or slurry application of solids is not possible. The design effluent period includes allowances for the following volumes:

- Effluent volume for 4-day period between scheduled irrigation of effluent
- Effluent volume for maximum 17 consecutive rain days based on NOAA rain gauge data, See **Table 3 – NOAA Rain Gauge Data**
- Effluent volume for 2 day period prior to forecasted heavy rain
- Effluent volume for 2 day period for minimum of pasture dry time after heavy rain

Based on the above volumes, the minimum effluent volume provided should include 25 days of effluent volume. The design volume required will be set to 30 days of effluent, which will provide an additional capacity buffer.

The ponds have the capacity for the following volumes:

- Volume of manure, wastewater, and other wastes accumulated during the period between effluent irrigation application
- Volume of accumulated solids during the period between the maximum time allowed for slurry application
- Depth of the 25-year, 24-hour storm precipitation
- Depth of highest monthly average precipitation for the 30-day design volume period

The pond volume calculations are based on the following assumptions:

Table 17 – Effluent Pond Sizing Criteria

Design Criteria/Assumption	699 Mature Dairy Cows	2,000 Mature Dairy Cows	Pond
Daily Wastewater Generation	13,225.8 gpd	37,894.7 gpd	
Percentage of Solids	1%	1%	Settling
Volume of Accumulated Solids for 45-day Period Between Application	5,951.6 gal	17,052.6 gal	Settling
Daily Flow to Storage Pond	13,225.8 gpd	37,894.7 gpd	
Minimum Volume of Effluent for 30-day Design Volume Period	396,774 gal	1,136,841 gal	Storage
Depth of 25-Year, 24 Hour Storm	10.4 inches	10.4 inches	Storage
Depth of Normal Precipitation for 30-day Design Volume Period	6 inches	6 inches	Storage

The effluent ponds and concrete holding areas are not covered. All rainfall in these areas is collected and conveyed to the ponds. Approximately 1.76 acres of area at the dairy facility drain to the ponds and are accommodated in the pond sizing and minimum volume requirements including runoff from the calf sheds and concrete gutter, the uncovered holding pens and yards, the uncovered loading areas, and the settling and storage pond areas. Rainfall collected from the roofs of the milking parlor and implement shed is discharged directly to grassed/landscaped areas adjacent to the buildings, and does not enter the effluent system.

Evaporation from the water surface of the ponds is likely to occur, as the ponds are not covered. However, for the purposes of sizing the effluent ponds, evaporation is not taken into account. The volume of evaporation during the 30-day design period adds to the ponds' available holding capacity.

7.2.2 Settling Pond Size

As previously mentioned, the settling pond is sized to include the volume of accumulated solids for a maximum of 45 days, based on the maximum period between solids application.

In addition to the solids volume, a mixing volume will be provided within the settling pond, to allow for the stirring and suspension of solids when slurry application to the pastures is initiated. The minimum mixing volume is dependent on type of equipment, operational needs and operator preferences. For the settling pond, the mixing volume in the pond will be 362,020 gallons for the 699 mature dairy cow herd size, or 350,919 gallons for the contemplated 2,000 herd size. Additional mixing water can be injected, as needed, when applying the slurry.

The top of the settling pond is 87′ x 133′ with a total depth of 12′ from invert to overflow spillway. The settling pond total available volumes are shown in the figure below.

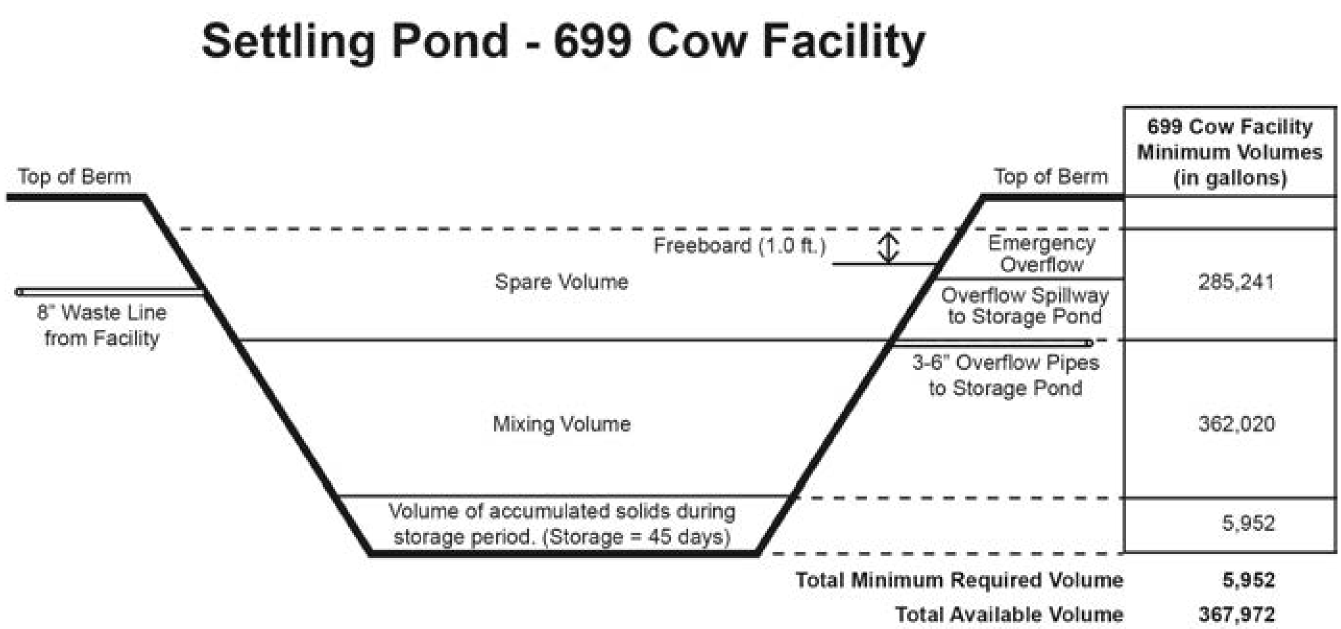


Figure 14A - Settling Pond Typical Section & Volumes for 699-cow Herd Scenario

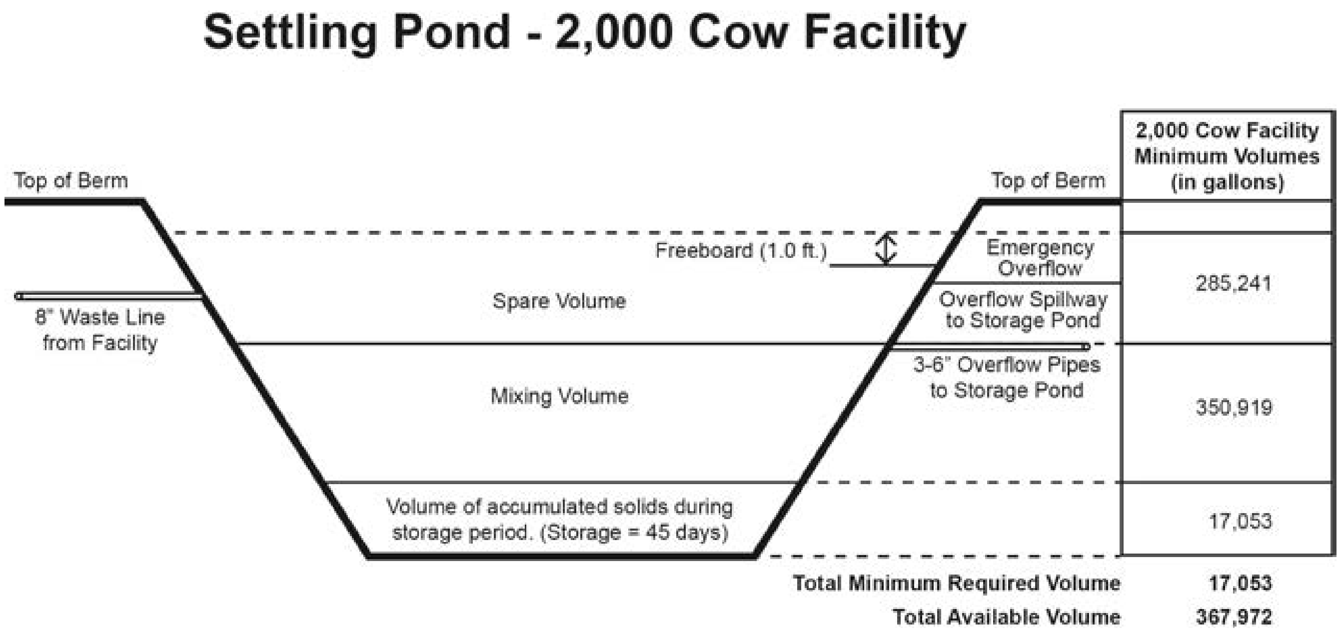


Figure 14B - Settling Pond Typical Section & Volumes for 2,000-cow Herd Scenario

See **Section 8.4 – Effluent Application** for additional information about the slurry application.

7.2.3 Storage Pond Size

When the settling pond fills completely with effluent over a period of several days following slurry application and lowering of the settling pond, liquid effluent then overflows through three 6-inch screened overflow pipes into the storage pond. The clear screens are fitted into the overflow pipes and do not allow solids to enter into the storage pond.

As previously mentioned, the volume of effluent storage within the storage pond is sized to allow for a minimum of 30 days of design volume storage for the contemplated herd size of up to 2,000 milking cows based upon a conservative evaluation of the irrigation schedule and rainfall data.

The top of the storage pond is 215′ x 133′ with a total depth of 16′. The storage pond total available volumes are shown in the figure below.

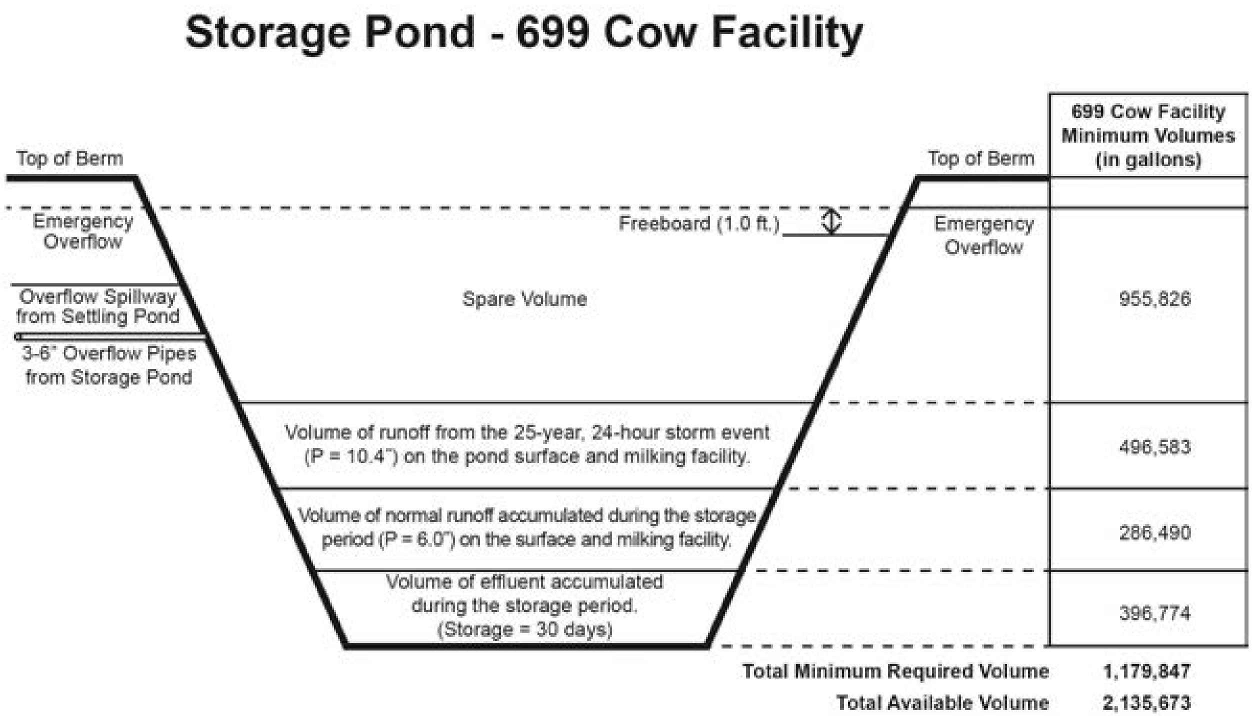


Figure 15A - Storage Pond Typical Section & Volumes for 699-cow Herd Scenario

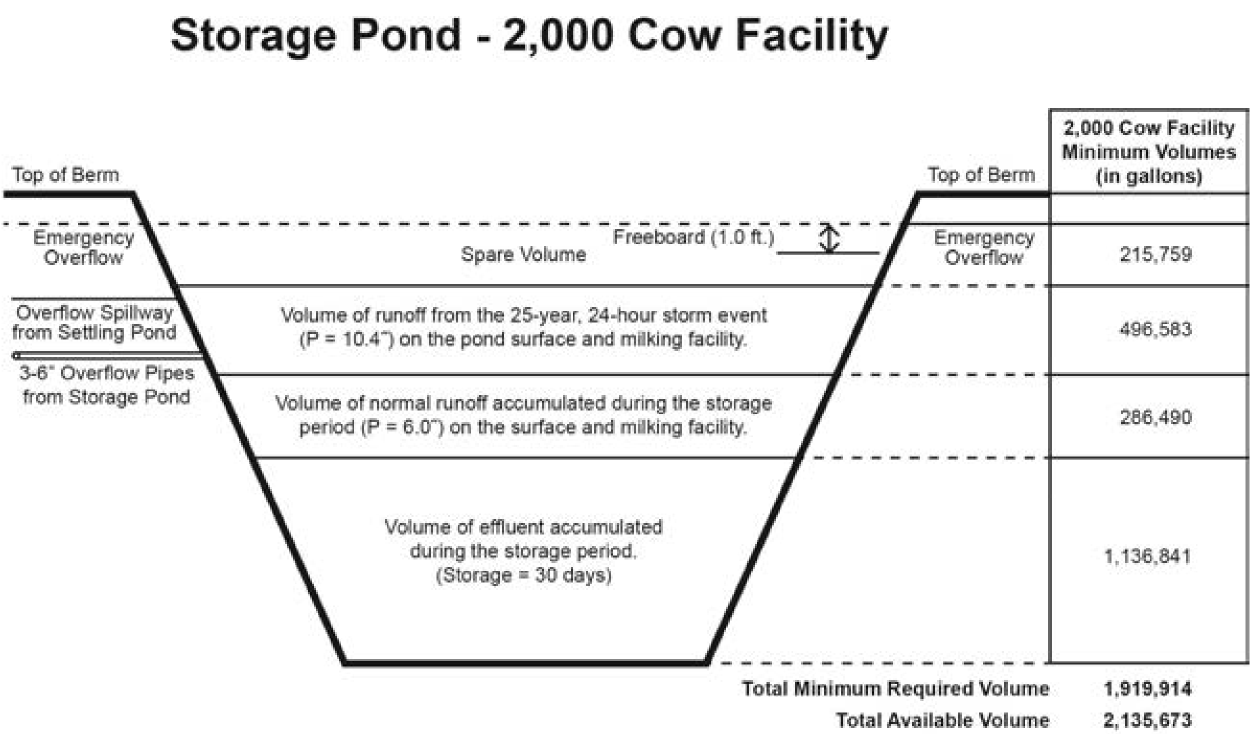


Figure 15B - Storage Pond Typical Section & Volumes for 2,000-cow Herd Scenario

The storage pond design incorporates an emergency spillway to direct overflow in case of a cataclysmic event. In normal operation, the storage pond provides additional spare volume at the top of the pond. In the 699-cow scenario, the spare volume is an additional 45% of the total volume required available, and is nearly double the total volume required. In the 2,000-cow scenario, the spare volume represents an additional buffer of up to 12%. These spare volumes provide even greater buffer above the design capacity which includes storage for the required 25-year, 24 hour storm event, as well as volumes for 30 days of storage and normal precipitation on the adjacent areas which will drain to the ponds.

7.2.4 Effluent Pond Design

Ponds will have a bottom elevation that is a minimum of 2-feet above the seasonal high water table. Excavated side slopes will not be steeper than 2 horizontal to 1 vertical. An inlet pipe with a minimum diameter of 8 inches will be used for milking parlor waste for discharge into the settling pond. The pipe terminates a sufficient distance from the shoreline of the pond to ensure good distribution. A cleanout is also provided for removing obstructions. Three (3) 6-inch diameter pipes will be used for daily overflow from the settling pond into the storage pond.

The minimum elevation of the top of the settled embankment shall be 1 foot above the pond's required volume. The combined side slopes of the settled embankment shall not be less than 5 horizontal to 1 vertical, and neither slope shall be steeper than 2 horizontal to 1 vertical unless provisions are made to provide stability. Embankments and disturbed areas surrounding the pond are treated to control erosion. This includes the inside slopes of the pond as needed to protect the integrity of the liner.

Pond lining will be installed to prevent seepage of wastewater from the waste impoundment structure for water conservation and environmental protection. All inlets, outlets, ramps, and other appurtenances will be installed in a manner that does not damage or impair the proper operation of the liner.

The pond perimeter will be fenced and warning signs posted to prevent people from using the area for activities other than its intended purpose. A marker or water level measuring device will be installed in the pond to indicate the stored volume and/or storage capacity remaining.

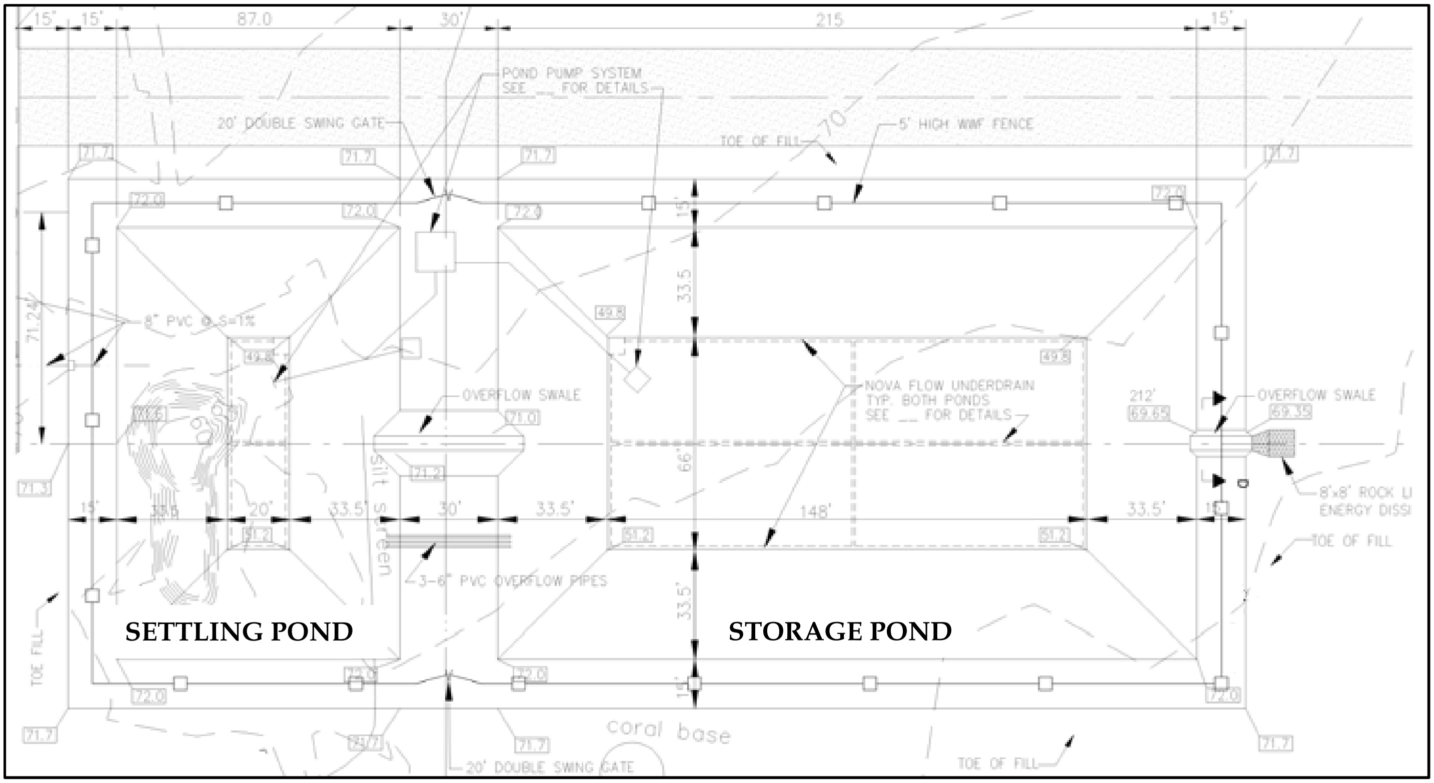


Figure 16 - Effluent Ponds Plan

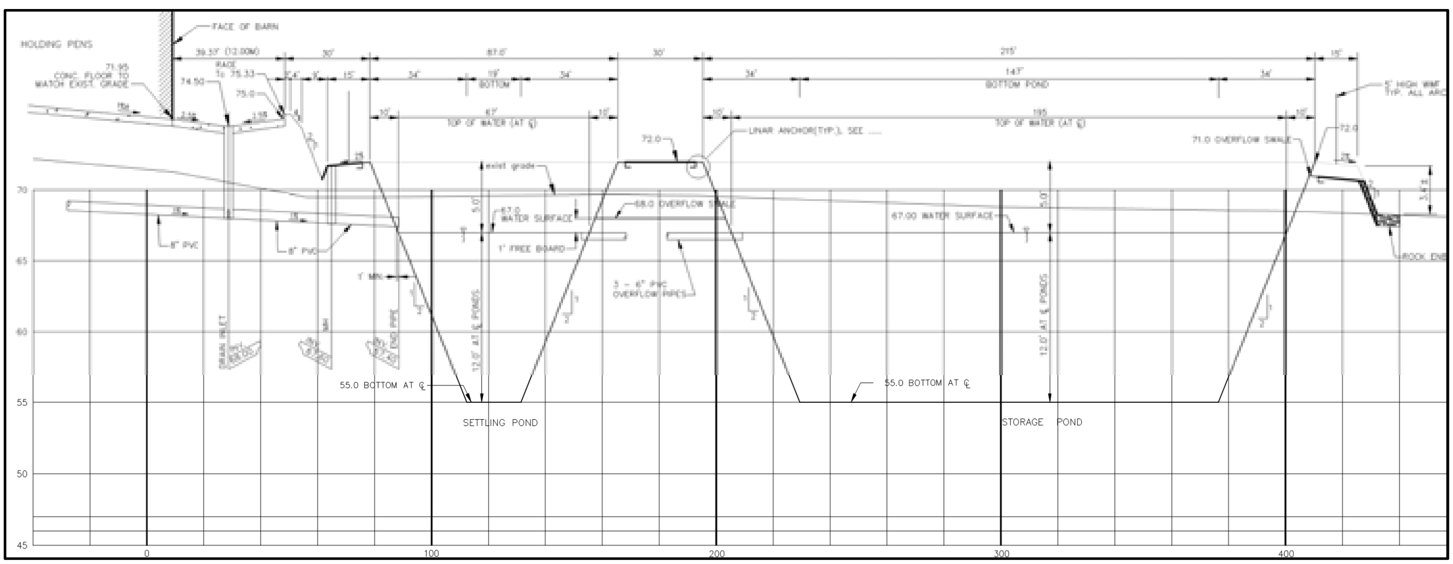


Figure 17 - Effluent Ponds Section

7.2.5 Emergency Spillway and Secondary Berm

The storage pond will have an emergency overflow spillway that will allow discharge from the pond in the event of a cataclysmic emergency such as a rainfall event greater than the 25-year, 24-hour storm or other natural disaster. A secondary berm will also be constructed downhill of the effluent ponds before the existing drainage way and access / farm road, to contain an emergency discharge from the pond from the overflow spillway. Although not required by the ~~guidelines~~ Guidelines, this secondary containment area will provide additional capacity ~~containment~~ that will be roughly equivalent to 30 days of total liquid effluent volume ~~collected over the 30-day storage period~~ for the 2,000 herd size, or 1,136,841 gallons of additional emergency storage.

8.0 Nutrient Management

HDF has committed to establishing the dairy with up to 699 mature dairy cows and associated calves. This size of operation does not require a Concentrated Animal Feeding Operation (CAFO) permit to be issued prior to operation.

Following establishment of the initial herd of 699 mature dairy cows, HDF is contemplating expansion of the herd to up to 2,000 mature dairy cows and associated calves. This size of operation will require a Concentrated Animal Feeding Operation (CAFO) permit to be issued prior to exceeding 699 mature dairy cows. Previous Environmental Protection Agency (EPA) regulations based the definition of CAFO's on the number of "animal units" confined. EPA no longer uses the term "animal unit," but instead refers to the actual number of mature dairy animals at the operation to define a CAFO. Additionally, though the cows are grazing in the paddocks and pasture and are not "confined", the EPA still permits a CAFO based on the number of "animal units".

From a nutrient management perspective, a dairy operation must also account for the calves that will be born on site. For the initial herd, there will be approximately 150 calves on the HDF site at any one time. At full operation as part of a contemplated herd expansion of up to 2,000 mature dairy cows, there will be approximately 500 calves at any one time. Some calves will be housed in the calving sheds, while others will be on the pasture grazing, depending on their age, size and health. Once the calf reaches 165 lbs or is 90 days old, they will be transferred to an off-site heifer raising facility. Nutrient management data and calculations hereon are presented for both the initial herd size and contemplated herd expansion.

8.1 Historical Background

The historical use of the land has been for sugar cane production terminated in the late 1990s, and after that time, for a beef cattle operation. The historical uses of the farm have left the soils depleted of the essential nutrients required for crop growth. A well-managed, pasture-based, rotational-grazing dairy focused on the application of nutrients will be a benefit to the existing soil structure and composition.

8.2 HDF Pasture-Based Dairy Background

The proposed HDF is a pasture-based system where cows are divided and managed in a series of fenced paddocks for rotational grazing. Through internal herd growth and the purchase of additional young stock when needed, the dairy herd is planned to consist of 699 head of mature dairy cows and approximately 150 calves at the initial operation, and may be expanded to up to 2,000 head of mature dairy cows and approximately 500 dairy calves at full operation. Although, at full production, a 2,000 mature dairy cow stocking density is contemplated, the number of cows will ultimately be decided by the land that is supporting the pasture-based system. The 469.9 acre pasture has been and will continue to be planted with a predominantly Kikuyu grass mix that will serve as the base diet for the grazing animals.

The mature dairy cows will be managed in small groups (initially 105 – 115 cow mobs, but up to 300-330 cow mobs at the contemplated herd size) and are milked twice a day (1 hour per milking). Only one mob can be held in the milking facility at any one time. Manure deposited within the dairy facility will be collected and stored into a two stage manure storage system located to the south of the milking parlor. The manure storage is connected to two GPS enabled center pivot irrigation circles as well as a hard hose reel irrigation application system for the areas outside of the center pivots.

The farm is managed under a Conservation Plan developed with Natural Resource Conservation District (NRCS) guidance, and approved by the West Kauaʻi Soil and Water Conservation District. The Conservation Plan specifies a variety of agricultural best management practices (BMPs) to be installed and implemented, as appropriate, prior to farm population and operation of the dairy. Each BMP follows the current specifications for the Pacific Islands conservation practice standards. Each of these BMPs is designed to minimize agricultural impacts to waters of the State of Hawaiʻi.

8.3 Nutrient Balance

Managing the amount, source, placement, and timing of plant nutrients and soil amendments is critical for the nutrient balance of the farm, and is the purpose of the Nutrient Management

Plan (NMP), which is prepared under technical guidance from the NRCS for nutrient management on the farm. A NMP, submitted for 699 mature dairy cows in July 2014 and titled "Waste Management Plan for Hawaii Dairy Farms", has been reviewed by DOH, while an updated NMP for up to 2,000 mature dairy cows will be prepared for review by DOH for the larger herd size, should the herd size increase past 699 mature dairy cows.

This type of planning minimizes the agricultural impacts to surface water and groundwater by properly utilizing manure and commercial fertilizers in balance with plant nutrient requirements. By following the Natural Resource Conservation Service Nutrient Management Standard (590), HDF will optimize nutrient applications through proper timing, placement, utilization, and monitoring of nutrients. NMPs typically include the following components:

- An inventory of nutrient sources on the farm, including manure and crop residues.
- Nutrient analyses of each nutrient source.
- A budget to supply and conserve nutrients for plant production.
- Soil tests to determine the nutrient needs of the crops to be grown.
- Procedures for when and how to apply the manure to maximize crop benefit and minimize the potential environmental impacts of the nutrients.
- Best Management Practices that minimize the potential for nutrient loss from the fields.
- Best Management Practices that minimize agricultural impacts to surface and groundwater resources.
- Procedures to monitor and maintain or improve the physical, chemical, and biological condition of the soil.

One of the most important considerations in nutrient management planning for farms is the understanding that the NMP is an adaptive management tool. Some even describe it as a living, breathing document that is constantly monitored and updated as the conditions of the farm evolve. The results from annual soil testing, manure testing, and forage testing will be used to update and inform the nutrient management process for HDF as the farm becomes established and operations mature.

8.3.1 NMP Basis of Design

The first year of the Nutrient Management Plan will be based off of a combination of available field data and theoretical modelling in order to come up with the proper nutrient application rates and timing. In year one of the plan, a nutrient mass balance will be performed to balance application rates. The variation of nutrient application will be based upon localized weather events and other management factors. Once manure has been excreted, captured and stored, a site specific manure analysis will be taken and analyzed.

8.3.2 Data Acquisition

Through the utilization of on-site grass data gathered by HDF, and the Cornell Net Carbohydrate Protein System (CNCPS) model, an estimate of the grass productivity, farm carrying capacity, milk production and manure excretion has been calculated, respectively.

8.3.3 Manure Excrete Models

The CNCPS model was used to determine and model the metabolizable energy (ME) and metabolizable protein (MP) requirements generated from varying levels of neutral detergent fiber intake (NDFi) and complementary grain given at milking time. After accounting for daily maintenance requirements, grass and grain analytics, and dry matter intake (DMI), the expected milk production and manure excretion can be calculated. This analysis was performed by Robert C. Fry, DVM, a dairy nutritionist with Atlantic Dairy Consulting.

Estimates of manure volume and nutrient quantity, calculated by CNCPS, were compared against the USDA/NRCS Agricultural Waste Management Field Handbook (March 2008), along with the USDA/NRCS Ag Waste Management Software Program. The field handbook utilizes established American Society of Agricultural Engineers (ASAE) values. The calculated and estimated values from the CNCPS Model will be replaced with actual site specific data once HDF is in operation and site specific manure analysis can be conducted.

8.3.4 Manure Model Analysis and Outputs

The CNCPS model was also utilized to calculate manure production per cow per day. CNCPS was also utilized to forecast the nutrient concentration of the as excreted manure collected at the dairy facility, slurry, and stored lagoon effluent that will be applied through irrigation systems. Total collected manure includes parlor wash down water, rain water deposited on the holding area and within the manure storage system, and manure produced during the two hours of milking per day as well as the manure produced in the calf sheds. The CNCPS Model Manure Production = 90.8 lbs per cow per day. ASAE D384.2 MAR2005 publication from the American Society of Agricultural Engineers was utilized to estimate the calf manure production and associated nutrient content. ASAE Calf Manure Production = 19 lbs per calf per day.

Based upon the CNCPS Model, the following nutrient characteristics for the as-excreted manure of both mature dairy cows and calves are shown below:

Table 18A: Nutrient Characteristics of Manure for a Mature Dairy Cow

Animal Nitrogen Excretion	0.546	Lbs-N / Cow / Day
Animal Phosphorus Excretion	0.11	Lbs-P / Cow / Day

Table 18B: Nutrient Characteristics of Manure for a Calf

Animal Nitrogen Excretion	0.140	Lbs-N / Calf / Day
Animal Phosphorus Excretion	0.044	Lbs-P / Calf / Day

Based upon the milking process and parlor design, the estimated waste generation within the various locations and processes on the farm from both the mature dairy cows and calves are shown below:

Table 19A: Estimated Waste Generation of a Mature Dairy Cow

Manure Production	90.8	Lbs/Day
Cow Waking Hours	16	Hours
Cows in Parlor	2	Hours
Manure Production in Parlor	1.361	Gal / Cow / Day
Cows at Pasture	14	Hours
Manure Production in Pasture	9.52	Gal / Cow / Day
Parlor Wash Water	17.40	Gal / Cow / Day

Table 19B: Estimated Waste Generation of a Calf

Manure Production	19	Lbs/Day
Manure Production in Pasture or Manure Production in Calf Shed	2.244	Gal / Cow / Day

ASAE American Society of Agricultural Engineers referenced for calf manure production.

Based upon the size of the effluent ponds and holding areas, additional normal rainfall and captured runoff must be accounted for. The sizes of the ponds are input as shown below:

Table 20: Areas Used to Determine Rainfall and Captured Runoff Input

Storage Pond #1 (Settling Pond)		
Length	132	Feet
Width	85.5	Feet
Top Area	11,286	Square feet
Storage Pond #2 (Storage Pond)		
Length	212	Feet
Width	132	Feet
Top Area	27,984	Square feet
Holding Area	6,795	Square feet

Based upon these parameters, the amounts of monthly effluent generation collected within the effluent ponds serving the dairy facility are calculated below for the 699 mature dairy cow scenario and the 2,000 mature dairy cow scenario. These numbers are critical in validating the size of the effluent ponds, as well as tracking the overall movement, collection, and distribution of nutrients through the farms systems, from grass uptake to as-excreted manure in the facility, to collection in the effluent ponds, and ultimate redistribution and nutrient for grass growth.

Table 21A: Estimated Monthly Effluent Generation Collected in Manure Storage System (Operational) for 699 Mature Dairy Cows and 50 Calves in Pens

Month	Days per Month (days /mo)	Manure Collected in Parlor and Calf Pens (gal/mo)	Wash Water Collected in Parlor (gal/mo)	Average Month Rainfall – P (in.)	Average Month Pan Evapora -tion – Ea (in.)	Average Month Manure Storage – Em (50% of pan) (in.)	Average Monthly Net Rainfall Directly on Manure Storage (P – Em) (in.)	Average Montly Net Rainfall on Pond Area (gal/mo)	Average Monthly Net Rainfall of Holding Area (gal/mo)	Total Effluent (rainfall + wastewater) Collected (gal/mo)
January	31	32,960	377,041	4.88	5.14	2.57	2.31	56,545	20,669	487,215
February	28	29,770	340,553	4.20	5.65	2.83	1.38	33,658	17,789	421,770
March	31	32,960	377,041	5.04	6.93	3.47	1.58	38,553	21,347	469,901
April	30	31,897	364,878	3.66	7.43	3.72	-0.05	-1,346	15,502	410,930
May	31	32,960	377,041	3.05	7.82	3.91	-0.86	-21,051	12,918	401,868
June	30	31,897	364,878	2.86	8.05	4.03	-1.17	-28,517	12,114	380,371
July	31	32,960	377,041	3.13	9.10	4.55	-1.42	-34,759	13,257	388,499
August	31	32,960	377,041	3.20	9.37	4.69	-1.49	-36,350	13,554	387,204
September	30	31,897	364,878	3.25	8.23	4.12	-0.87	-21,174	13,766	389,366
October	31	32,960	377,041	4.96	7.33	3.67	1.30	31,699	21,008	462,708
November	30	31,897	364,878	6.01	6.17	3.09	2.93	71,599	25,456	493,829
December	31	32,960	377,041	5.71	5.40	2.70	3.01	73,680	24,185	507,865
Annual Total	365	388,076	4,439,349	49.95	86.62	43.31	6.64	162,536	211,566	5,201,526

*** Manure estimates provided by Cornell Net Carbohydrate Protein System model for the Mature Dairy Cow and American Society of Agricultural Engineers ASAE D384.2 MAR2005 for Dairy Calves.**
**** Rainfall data provided by University of Hawai‘i Rainfall Atlas of Hawai‘i (2011).**
***** Pan evaporation data provided by State of Hawai‘i DLNR Pan Evaporation Report R74 dated August 1985 for station Māhā‘ulepū 940.00.**

Table 21B: Estimated Monthly Effluent Generation Collected in Manure Storage System (Operational) for 2,000 Mature Dairy Cows and 167 Calves in Pen

Month	Days per Month (days/mo)	Manure Collected in Parlor and Calf Pens (gal/mo)	Wash Water Collected in Parlor (gal/mo)	Average Month Rainfall – P (in.)	Average Month Pan Evapora-tion – Ea (in.)	Average Month Manure Storage – Em (50% of pan) (in.)	Average Monthly Net Rainfall Directly on Manure Storage (P – Em) (in.)	Average Montly Net Rainfall on Pond Area (gal/mo)	Average Monthly Net Rainfall of Holding Area (gal/mo)	Total Effluent (rainfall + wastewater) Collected (gal/mo)
January	31	95,971	1,078,800	4.88	5.14	2.57	2.31	56,545	20,669	1,251,985
February	28	86,683	974,400	4.20	5.65	2.83	1.38	33,658	17,789	1,112,530
March	31	95,971	1,078,800	5.04	6.93	3.47	1.58	38,553	21,347	1,234,671
April	30	92,875	1,044,000	3.66	7.43	3.72	-0.05	-1,346	15,502	1,151,031
May	31	95,971	1,078,800	3.05	7.82	3.91	-0.86	-21,051	12,918	1,166,638
June	30	92,875	1,044,000	2.86	8.05	4.03	-1.17	-28,517	12,114	1,120,472
July	31	95,971	1,078,800	3.13	9.10	4.55	-1.42	-34,759	13,257	1,153,269
August	31	95,971	1,078,800	3.20	9.37	4.69	-1.49	-36,350	13,554	1,151,974
September	30	92,875	1,044,000	3.25	8.23	4.12	-0.87	-21,174	13,766	1,129,467
October	31	95,971	1,078,800	4.96	7.33	3.67	1.30	31,699	21,008	1,227,479
November	30	92,875	1,044,000	6.01	6.17	3.09	2.93	71,599	25,456	1,233,930
December	31	95,971	1,078,800	5.71	5.40	2.70	3.01	73,680	24,185	1,272,636
Annual Total	365	1,129,981	12,702,000	49.95	86.62	43.31	6.64	162,536	211,566	14,206,082

*** Manure estimates provided by Cornell Net Carbohydrate Protein System model for the Mature Dairy Cow and American Society of Agricultural Engineers ASAE D384.2 MAR2005 for Dairy Calves.**
**** Rainfall data provided by University of Hawaiʻi Rainfall Atlas of Hawaiʻi (2011).**
***** Pan evaporation data provided by State of Hawaiʻi DLNR Pan Evaporation Report R74 dated August 1985 for station Māhāʻulepū 940.00.**

8.3.5 Grass Yields

The pasture-based system enables the mature dairy cows to spend 22 hours (16 waking hours) in the paddocks, where a corresponding proportion of their excreted manure will be discharged directly onto the paddocks. The dominant grass is Kikuyu; (*Pennisetum clandestinum*) a high yielding species, that (when properly fertilized) can yield more than 20 tons (U.S.) per acre. This grass is more adapted to warm or hot seasonal conditions under moist or dry environments and is known to produce more than 35 tons of dry matter per acre per year.

The Kikuyu is extremely effective in the tropics and adds significant protection to soils in terms of creating a tight organic thatch. As the cattle excrete on the Kikuyu thatch, it is incorporated into what is effectively an organic net. Due to the high moisture and moderate temperatures, the microbial activity in the thatch is very high and the effluent will be largely broken down by microbial activity within 24 hours.

The Kikuyu thatch will also reduce runoff during heavy rain events by holding water in its dense but also porous structure. Preventing and reducing runoff will keep nutrients within the paddocks and soils on the farm for uptake by the grass, where effluent can be broken down quickly as noted above. Additionally, grass yields are directly related to soil compaction, whether through hoof compaction of soils or disturbance in the soil structure caused by machine cultivation. Once the Kikuyu thatch is established, the soil itself is not disturbed by cultivation; only the thatch will be exposed to grazing pressure.

The grass will need significant additional nutrient application with conventional fertilizers for the initial herd size of 699 mature dairy cows. The grass will also need some, but less, additional nutrient application with commercial fertilizer at the contemplated herd size of up to 2,000 cows. Nutrient mass balance scenarios for both herd sizes are discussed in Section 8.3.9.

The project has an estimated annual yield goal of 20 tons (U.S.) of dry matter production of Kikuyu per acre. Kikuyu yield ranges between 4 tons unfertilized and 20-plus tons of dry matter (DM)/acre/year depending on levels of N fertilization. Kikuyu's response to fertilization is very good and linear, and combined with irrigation, anticipated growth rates in Māhāʻulepū are estimated to be some of the best in the world. The average local temperature is in the ideal 60°F and 104°F range for Kikuyu pastures.

Although the annual goal is for a 20-ton Kikuyu yield for mature pasture grass, actual yield data, based on ~~15~~ 24 months of growth trials on 70 acres of pasture on the farm is available, and is the basis for all nutrient application rates. The actual yield data takes into account variations in field-verified yields due to seasonal variability, and HDF has also incorporated a reduction in yield due to approximately 26% of the farm consisting of non-irrigated pastures. Thus far, ~~The~~ the Kikuyu grass trials, utilizing primarily Kikuyu grass mixed with some guinea grass, and interspersed with diversified forages from November to March (winter months), have annually averaged between 17 tons of Dry Matter (DM) / acre / year to over 20 tons DM / acre / year with appropriate fertilizer and irrigation applications that do not exceed the agronomic need of the crop (based upon our grass and forage expert's recommendations for fertilizer and visual observation for irrigation). The monthly-tested, projected yields exceed 20 tons DM / acre / year in the summer months but lower to between 15 and 18 tons DM / acre / year in the winter months (with diversified forage), to reach annual average yields between 17 and 20 tons DM / acre / year. This was verified by on-site forage testing and laboratory analysis conducted by Farms n' Forages and Cumberland Valley Analytic Services (CVAS) respectively. The range in annual average yield represents different fields with different percentages of Kikuyu grasses tested.

Farms n' Forages also has experience with non-irrigated pastures in Hawaiʻi and has previously measured approximately 30% to 40% greater yields in irrigated pastures than in non-irrigated pastures. Applying a subsequent percentage reduction in yield over the corresponding irrigated versus non-irrigated acreage (74% to 26% respectively), HDF conservatively projects, based upon the field-tested data and taking into account seasonal variability and non-irrigated pasture areas, that 16.3 tons of Dry Matter (DM) / acre / year is a low-end and conservative, but realistic and reasonable, yield value meeting the requirements of NRCS Conservation

Practice Standard 590 – Nutrient Management. Monthly-tested yield results are projecting more than 20 tons DM / acre / year in the summer and between 15 tons and 18 tons DM / acre / year in the winter, and as such, a 16.3 annual yield value is conservatively used. Calculations provided hereon will utilize a grass production of 16.3 tons of DM / acre / year, although after several years of pasture maturation and establishment, average annual yields closer to or exceeding 20 tons of DM / acre / year, even considering seasonal variability and non-irrigated pasture areas, are realistic. The more grass that is grown allows more cows to be sustained on the farm as grass provides the majority of their feed and also uptakes nearly all of their manure / effluent.

Based upon the grass growth trials on 70 acres of pasture on the farm along with grass nutrient content tested and analysed by HDF's team of Farms n' Forages, CVAS, and Atlantic Dairy Consulting, the nutrient uptake rates for Kikuyu in lbs of uptake per ton of Dry Matter (DM) are as follows:

Lbs of Nitrogen (N) uptake per ton DM = 64 lbs. N
Lbs of Phosphorus (P) uptake per ton DM = 11.4 lbs. P
Lbs of Potassium (K) uptake per ton DM = 90 lbs. K

HDF coordinated the collection of Kikuyu grass samples beginning September 2, 2014 and repeated sampling every fourth harvest after an 18-day rest period. The intent was to simulate the harvest of grass by cows grazing a paddock every 18 days. The trials were conducted in different locations on the farm for over a year.

Kikuyu grass samples were collected at 18 days of rest. The procedure for collection included random grab samples to replicate a cow grazing. Samples were collected every 5 steps while walking diagonally across the field. About 30 grabs were collected from each field and mixed to create a composite sample for the field. These samples were collected and dried at the same time as the production data samples and sent to Cumberland Valley Analytical ~~services~~ Services (CVAS) for wet chemistry and in vitro assay of forage quality.

When diversified forages were tested in the winter months, the seeds were planted using a no-till drill to ensure that the Kikuyu thatch was maintained and not destroyed, such that the

Kikuyu could easily and quickly increase production in the spring and also maximize nutrient uptake and minimize potential runoff during the winter months.

8.3.6 Grass Nutrient Content

Cumberland Valley Analytic Services, certified by the National Forage Testing Association, performed wet chemistry analysis for Dry Matter, Crude Protein, Soluble Protein, Acid Detergent Fiber, Neutral Detergent Fiber, Ash, Calcium, Phosphorus, and in vitro NDF analysis as a method of assessing the nutritive value of the grass trial samples. NDF digestibility was reported at 30, 120, and 240 hour time points for the generation of rates and pools used in the CNCPS model.

8.3.7 Soils Analysis

The NRCS soils classifications and descriptions provide a good base layer of information to use for nutrient budgeting. However, additional soil testing is required to determine soil nutrient levels to be used in the nutrient budget analysis. Soil samples have been taken throughout the farm and have been analyzed for pH, phosphorus, nitrogen, potassium, calcium, magnesium, organic matter, salinity, micronutrients and other constituents.

The farm has approximately 469.9 acres in pasture, which is divided up into 119 total paddocks of about 3 to 5 acres in size. In 2014, soil sample grabs were taken at various locations on the farm and within the different paddocks, and then combined into one representative sample per paddock. The samples were tested by Spectrum Analytical, and soil fertility recommendations were then provided based off of baseline of soil chemical composition and content. This baseline data has been used to inform the nutrient balance of the farm by indicating the fertility requirement of the crop. Subsequent sampling will occur during operation to monitor nutrient levels in the soils so the nutrient budgets can be adjusted during operation.

In 2015, Dr. Russell Yost and Nicolas Krueger, of the University of Hawaiʻi-Mānoa – CTAHR, conducted additional soil sampling to provide additional baseline data of soil quality, nutrient, status, and health of the sections of the dairy with comparisons to different soil types. Soil cores were collected at sampling locations using a standard probe with locations identified by GPS. Samples were collected and analyzed, with resulting data plotted, mapped and interpreted. Composite samples were taken at approximately 50 locations with two depths for each sample

(0-20cm and 20-40cm). The composites were comprised of three samples per composite sample. Saturated paste electrical conductivity was determined as well as exchangeable sodium percentage, calcium, magnesium, and potassium. Levels of nitrogen and phosphorus were also assessed to establish the nutrient baseline. Refer to the "Hawaiʻi Dairy Farms Baseline Nutrient Status: Implications for Long-Term Sustainability, Productivity, and Soil Health" report by Russell Yost & Nicholas Krueger, University of Hawaiʻi-Mānoa – CTAHR.

8.3.8 Soils Risk Assessment Classification

Because the basis of design for the farm is pasture-based, rotational-grazing, and no significant amount of annual tillage planned, soil loss tolerance (T) is manageable in accordance with the NRCS Conservation Plan prepared by Hawaiʻi Dairy Farms, and approved by the West Kauaʻi Soil and Water Conservation District in December 2013. Additional risk assessments for nitrogen and phosphorus leaching are indicated below:

Nitrogen Leaching Index per Hawaiʻi NRCS 590 Standard

Annual Rainfall	Soil Hydrologic Group			
	A	B	C	D
>100"	H	H	M	M
50-100"	H	M	M	L
<50"	M	M	L	L

Low – No additional mitigation required
Mod – Timing of nitrogen applications must be applied to coincide with crop growing season
High – Timing of nitrogen applications must coincide with crop growing season and be split applied to prevent leaching

HDF Site Soils Highlighted in Table

The nitrogen leaching index was run on each soil type. Below are the results by soil type:

Soil Type	Soil Hydrologic Group	Annual Rainfall	Nitrogen Leaching Potential
HsD	B	<50"	Moderate
HtE	B	<50"	Moderate
KavB	C	<50"	Low
KavC	C	<50"	Low
KdF	C	<50"	Low
Ke	C	<50"	Low
KEHF	C	<50"	Low
LuB	C	<50"	Low

PdA	B	<50"	Moderate
PdC	B	<50"	Moderate
Ws	C	<50"	Low

The risk for leaching nitrogen is low to moderate in all locations of the farm, and nitrogen applications on areas with a moderate risk will be managed and timed to the crop growing season (Kikuyu growing season is year-round in Hawai'i). Therefore, application of nitrogen could occur year-round in amounts appropriate to the soil type and crop growth.

Phosphorus Index Interpretation per Hawai'i NRCS 590 Standard:

Risk Assessment	Phosphorus Index Value
Low	<30
Mod	30-90
High	>90
Low - phosphorus can be applied at rates greater than crop requirement not to exceed the nitrogen requirement for the succeeding crop if manure or other organic materials are used to supply nutrients **Mod** - phosphorus can be applied not to exceed the crop requirement rate **High** - phosphorus can be applied not to exceed the crop removal rate if the following requirements are met: A soil phosphorus drawdown strategy has been implemented, and a site assessment for nutrients and soil loss has been conducted to determine if mitigation practices are required to protect water quality. Any deviation from these high risk requirements must have the approval of the Chief of the NRCS.	

The phosphorus leaching index was run on each soil type. Below are the results by soil type:

Soil Type	Phosphorus Index Value	Phosphorus Leaching Potential
HsD	10-18	Low
HtE	10-18	Low
KavB	10-18	Low
KavC	10-18	Low
KdF	10-18	Low
Ke	10-18	Low
KEHF	10-18	Low
LuB	10-18	Low

PdA	10-18	Low
PdC	10-18	Low
Ws	10-18	Low

The risk for leaching phosphorus is low in all locations of the farm and phosphorus could be applied at rates greater than the crop requirement not to exceed the nitrogen requirement for the succeeding crop, to maximize crop productivity and improve soil health. However, since the grass crop is not newly planted for each rotation and the growing season is constant and year-round, the phosphorus application is planned to be managed and adjusted to not exceed the crop requirement rate once the pasture has been established.

8.3.9 Nutrient Mass Balance

The annual net nutrient (nitrogen and phosphorus) demand for Kikuyu is summarized in the following tables. The crop nutrient needs will be satisfied by the application of effluent, manure, and supplemental commercial fertilizer. The commercial fertilizer need is expressed as a nutrient deficit of nitrogen and phosphorus based upon the conservative average annual Kikuyu yield of 16.3 tons DM / acre / year~~Kikuyu yields~~. Mass balance calculations are shown by month, even though a uniform yield rate of 16.3 tons DM / acre / year is used. As previously discussed, the 16.3 tons DM / acre / year is a low-end, conservative projection meeting NRCS Conservation Practice Standard 590 – Nutrient Management requirements in planning new dairy operations, with summer months likely to exceed 20 tons DM / acre / year.

The following table may be updated as crop yields change, as the nutrient balance of the farm is a dynamic environmental analysis. As the yield of Kikuyu increases as expected, due to pasture maturation and establishment as well as nutrient management (to reach the yield goal of 20 tons DM per acre per year), the annual net nutrient demand of nitrogen and phosphorus will also increase, meaning either more manure (and more cows, up to 2,000) or more commercial fertilizer may be used to maintain a healthy pasture and soil nutrient balance. The pasture-based, rotational-grazing system must manage these different environmental variables.

It is important to note that even as nutrient demand increases as the crop yield improves and the pasture matures, nutrients (nitrogen and phosphorus) will not be applied at rates that exceed the recommendations of the leaching indexes interpretations shown in the NRCS 590

Standard above, or beyond the agronomic need of the crop, once the pasture has been established.

The nutrient mass balance approach for HDF assumes that 100% of the *manure* nutrients are 100% available at the time of application. This is a very conservative way of calculating nutrients that are available for crop uptake, and ultimately the stocking density and number of animals that can be supported on the pasture. Because of nitrogen dynamics, most nutrient management plans only account for 50% of the nitrogen to be plant available while the other 50% is lost to the environment through volatilization. **This nutrient balance analysis does not take any volatilization into account.** Plant nutrient uptake is also inefficient with respect to phosphorus because of the extensive sorption and binding reactions of phosphorus with the soils at the HDF site, sharply reducing the amount that is plant available. This mass balance uses the full amount of *manure* nutrients applied to the fields, whether it is irrigated, applied as slurry, or is excreted by the cow directly onto the pasture, as available to the crop, in the management of the farm's nutrient cycle and to determine the overall stocking density. If volatilization or soil sorption were taken into account, more *manure* nutrients (and therefore more cows) could be used to maintain a healthy pasture and soil/crop nutrient balance.

While the nutrient deficits shown in the tables below represent the supplemental fertilizer required for the Kikuyu crop, they are not an exact accounting of the total amount of *commercial* nutrients that must be applied to maintain high forage productivity and soil health. Rather, these values only represent the net amount of nutrients that need to be provided to and utilized by the crop through *commercial* fertilization, beyond the nutrient that is available to the crop from *manure* sources. Fertilization, especially the application of commercial nitrogen, can be inefficient with actual requirements ~~with respect to forage production~~ of the forage, and fertilization needs can be as much as 25% to 50% greater than the arithmetical difference resulting from a mass balance calculation - due to volatilization or soil sorption as mentioned above. Refer to the previously mentioned soils report by Russell Yost & Nicholas Krueger, UH-Mānoa – CTAHR. It should be noted and planned that the *commercial* fertilization requirements to maintain high forage productivity and soil health can exceed the simple arithmetic difference between the nutrients applied by manure and the forage uptake.

While these two factors in nutrient availability may seem contrary to each other in nutrient management analyses, where it would appear that *manure* nutrients are 100% available to the crop but more *commercial* nutrients would be needed due to inefficiencies in fertilization, the *manure* nutrient application and availability are first and foremost, the primary factors in measuring the stocking density of the farm, as the manure is the primary source of nutrients for the kikuyu Kikuyu-mix crop. The *commercial* nutrient application is only meant to provide the needed deficit of nutrients to the crop, beyond what is provided by the manure, to maintain high forage productivity and soil health. The inefficiencies of nutrient application from a mass balance perspective and from a commercial fertilization perspective do not have the same impacts on the pasture-based rotational-grazing dairy system. By assuming 100% of *manure* nutrients are available to the crop (though it is anticipated that nutrients are lost to volatilization of nitrogen and soil sorption of phosphorus), HDF is proposing a very conservative mass balance approach that reduces the stocking density of the farm. By understanding that *commercial* fertilizers are inefficient due to these same dynamics, HDF is realistic in its commercial fertilizer expectations and what is needed to provide the remaining nutrients to the crop that it does not get from manure sources.

HDF will utilize a proven, pasture-based, rotational-grazing dairy system with highly productive forage grasses. These grasses, with fibrous root systems, are typically among the most efficient plants in using applied nutrients (whether through manure or commercial fertilizer) and studies have shown that application of effluents generated from dairy operations via irrigation systems is an effective means of both managing the effluent while simultaneously providing nutrients needed by these productive tropical grasses. Still, HDF must be diligent and balance its planned applications of manure, effluent, slurry, and commercial fertilizer to ensure environmental sustainability and protection.

Table 22A: Hawai‘ i Dairy Farms Nutrient Mass Balance for 699 Mature Dairy Cows and 150 calves in Pens and Pasture

Month	N Collected in Pond (lbs-N/mo)	P Collected in Pond (lbs-P/mo)	N Excreted on Pasture (lbs-N/mo)	P Excreted on Pasture (lbs-P/mo)	N Total Deposited on Farm (lbs-N/mo)	P Total Deposited on Farm (lbs-P/mo)	N Total Uptake from Farm (lbs-N/mo)	P Total Uptake from Farm (lbs-P/mo)	N Deficit (lbs-N/mo) (Fertilizer Need)	P Deficit (lbs-P/mo) (Fertilizer Need)
January	1,696	366	11,003	2,290	12,699	2,656	41,633	7,416	28,934	4,760
February	1,532	331	9,939	2,069	11,470	2,399	37,604	6,698	26,134	4,299
March	1,696	366	11,003	2,290	12,699	2,656	41,633	7,416	28,934	4,760
April	1,641	354	10,648	2,216	12,290	2,571	40,290	7,177	28,001	4,606
May	1,696	366	11,003	2,290	12,699	2,656	41,633	7,416	28,934	4,760
June	1,641	354	10,648	2,216	12,290	2,571	40,290	7,177	28,001	4,606
July	1,696	366	11,003	2,290	12,699	2,656	41,633	7,416	28,934	4,760
August	1,696	366	11,003	2,290	12,699	2,656	41,633	7,416	28,934	4,760
September	1,641	354	10,648	2,216	12,290	2,571	40,290	7,177	28,001	4,606
October	1,696	366	11,003	2,290	12,699	2,656	41,633	7,416	28,934	4,760
November	1,641	354	10,648	2,216	12,290	2,571	40,290	7,177	28,001	4,606
December	1,696	366	11,003	2,290	12,699	2,656	41,633	7,416	28,934	4,760
Annual Total	19,968	4,311	129,556	26,966	149,524	31,277	490,200	87,317	340,676	56,040

Table 22B: Hawai' i Dairy Farms Nutrient Mass Balance for 2,000 Mature Dairy Cows and 500 calves in Pens and Pasture

Month	N Collected in Pond (lbs-N/mo)	P Collected in Pond (lbs-P/mo)	N Excreted on Pasture (lbs-N/mo)	P Excreted on Pasture (lbs-P/mo)	N Total Deposited on Farm (lbs-N/mo)	P Total Deposited on Farm (lbs-P/mo)	N Total Uptake from Farm(lbs-N/mo)	P Total Uptake from Farm(lbs-P/mo)	N Deficit (lbs-N/mo) (Fertilizer Need)	P Deficit (lbs-P/mo) (Fertilizer Need)
January	4,956	1,080	31,791	6,650	36,747	7,730	41,633	7,416	4,887	*(314)*
February	4,477	976	28,714	6,006	33,191	6,982	37,604	6,698	4,414	*(283)*
March	4,956	1,080	31,791	6,650	36,747	7,730	41,633	7,416	4,887	*(314)*
April	4,796	1,045	30,765	6,435	35,561	7,480	40,290	7,177	4,729	*(304)*
May	4,956	1,080	31,791	6,650	36,747	7,730	41,633	7,416	4,887	*(314)*
June	4,796	1,045	30,765	6,435	35,561	7,480	40,290	7,177	4,729	*(304)*
July	4,956	1,080	31,791	6,650	36,747	7,730	41,633	7,416	4,887	*(314)*
August	4,956	1,080	31,791	6,650	36,747	7,730	41,633	7,416	4,887	*(314)*
September	4,796	1,045	30,765	6,435	35,561	7,480	40,290	7,177	4,729	*(304)*
October	4,956	1,080	31,791	6,650	36,747	7,730	41,633	7,416	4,887	*(314)*
November	4,796	1,045	30,765	6,435	35,561	7,480	40,290	7,177	4,729	*(304)*
December	4,956	1,080	31,791	6,650	36,747	7,730	41,633	7,416	4,887	*(314)*
Annual Total	58,356	12,720	374,308	78,293	432,664	91,012	490,200	87,317	57,536	****(3,695)*

*** **See next page.**

Phosphorus is applied to the pasture as nutrient in the form of manure and fertilizer. At 699 mature dairy cows, the amount of phosphorus applied in the form of manure only (P Total Deposited on Farm in lbs/month) does not meet the crop demand (P Total Uptake From Farm in lbs/month) at a crop yield of 16.3 tons of DM per acre per year, as shown in the tables above. Additional phosphorus must be applied using commercial fertilizer to maintain high productivity and soil health. At 2,000 mature dairy cows, the amount of phosphorus applied in the form of manure only slightly exceeds the crop demand at a crop yield of 16.3 tons of DM per acre per year, as shown in the tables above. An excess of over 300 lbs of phosphorus per month could be expected.

As previously mentioned, nutrient management and mass balance analyses are dynamic and are influenced by the many different environmental variables that enter into nutrient cycle planning from grass yields, stocking density, manure nutrient content, soil nutrient content, and crop nutrient content.

Soils analyses currently indicate that the farm soils are extremely deficient in phosphorus. In the initial phases of the farm, HDF anticipates that larger amounts of phosphorus beyond the crop need will improve soil conditions, as the binding of phosphorus to the soil ensures that it stays in the soil profile and is available for continued use by the grass during the paddock's 18-day rest period. Ultimately, when the farm is established after a few years, HDF intends to provide only the nutrient the grass crop needs, once the soil conditions improve and the farm nutrient balance and management becomes a "maintenance" operation. Until then, additional phosphorus, beyond the crop demand, is allowable in soils with low phosphorus leaching properties, per the NRCS Risk Analyses.

Based upon the soils health report by Dr. Russell Yost and Nicholas Krueger, University of Hawaiʻi at Mānoa, College of Tropical Agriculture and Human Resources (CTAHR), an initial (one-time or cumulative over the first few years) application of up to 230,000 lbs ~~an application of over 230,000 lbs~~ of phosphorus ~~per year~~ over 469.9 acres of pasture will be beneficial to the current soil nutrient content to maximize productivity for the grass crop during the establishment phase of the pasture. The planned application for phosphorus for the contemplated 2,000 mature dairy cow herd is approximately 91,000 lbs of phosphorus annually, of which around 87,300 lbs will be taken up by the forage. Stated differently, the 91,000 lbs of phosphorus per year exceeds the crop uptake demand at a grass yield of 16.3 tons of DM per acre per year by about 3,700 lbs of phosphorus. The planned amount of 91,000 lbs per year of applied phosphorus in this scenario, however, While 91,000 lbs of phosphorus per year, exceeds the crop uptake demand at a grass yield rate of 16.3 tons of DM per acre per year, representing a 3,700 lbs overage per year, the planned amount of applied phosphorus in this scenario is only a fraction of what could be applied to improve soil conditions as recommended by Dr. Russell Yost when soil nutrient content was measured. At 699 mature dairy cows and 150 calves, there is simply a deficit of nutrient to meet crop demand, regardless of the soil nutrient conditions.

Other management options exist to keep phosphorus in balance. Higher grass yields would demand additional phosphorus. With an increase from the current 16.3 tons of dry matter (DM) per acre per year to a yield of 17.3 tons DM per acre per year, phosphorus demand by the pasture crop will eliminate any phosphorus overage at 2,000 mature dairy cows and 500 calves. Based on grass field trials by consultants to HDF, yields of 20 tons DM per acre per year are anticipated following establishment of the committed herd of 699 milking cows and several years of pasture maturation.

The 3,700 lbs of excess phosphorus per year is estimated at 2,000 cows, and does not take into account that HDF's operations would grow incrementally. With refined nutrient values for manure and grass yields, the number of cows between 699 mature dairy cows and up to 2,000 mature dairy cows can be determined to avoid any projected phosphorus excess by maintaining the herd size at fewer than 2,000 cows to match the agronomic need of the crop and the optimum soil phosphorus content. Should grass yields not increase as planned projected, the carrying capacity of the farm would be reduced to approximately 1,875 mature dairy cows (from rather than 2,000 mature dairy cows). With reduced quantities of manure, phosphorus application levels would be in balance with phosphorus demands of the pasture, and meet the nutrient need of the grass without fertilizer.

It is critical to manage nitrogen applications as well, especially since nitrogen is soluble and typically moves through the environment quickly through rainfall, runoff, and groundwater. As shown by HDF's nutrient mass balance, however, in either the committed 699 mature dairy cow or contemplated, up to 2,000 mature dairy cow scenario, nitrogen will not be applied in quantities exceeding the crop demand. In fact, nitrogen for commercial fertilizer will be required to maintain high pasture productivity and soil health.

8.4 Nutrient Application

As previously mentioned, managing the amount, source, placement, and timing of plant nutrients and soil amendments is critical for the nutrient balance of the farm. Application of these nutrients, whether via the liquid effluent collected in the storage pond, slurry suspended in the settling pond, as-excreted manure on the pasture, or commercial fertilizers used as supplement, must be managed to ensure that nutrient is not over-applied or under-applied to different areas of the farm. Multiple criteria must be taken into account when discussing application of nutrients and are discussed in further detail below. The following tables represent a summary of the nutrient mass balance (from **Section 8.3.9 - Nutrient Mass Balance**) on the farm anticipated for 699 mature dairy cows and for up to 2,000 mature dairy cows. **Refer also to Figure 18A & B – Nutrient Management Map.**

Table 23A: Summary Nutrient Mass Balance for up to 699 Mature Dairy Cows

Nutrient Application	Area (acre)	Nitrogen Applied (lbs N/ year)	Phosphorus Applied (lbs P_2O_5 / year)
Manure As-Excreted	469.9	129,556	26,966
Liquid Effluent	285.1	11,980.8	2,586.7
Slurry Application	42.0	7,987.2	1,724.4
Total		**149,524**	**31,277**
Plant Nutrient Demand		**490,200**	**87,317**
Percentage from Animals		30.5%	35.8%
Required Chemical Fertilizer		340,676	56,040
Percentage Demand from Fertilizer		69.5%	64.2%

Table 23B: Summary Nutrient Mass Balance for up to 2,000 Mature Dairy Cows

Nutrient Application	Area (acre)	Nitrogen Applied (lbs N/ year)	Phosphorus Applied (lbs P_2O_5 / year)
Manure As-Excreted	469.9	374,308	78,293
Liquid Effluent	285.1	35,013.7	7,631.7
Slurry Application	171.0	23,342.5	5,087.8

Total	**432,664**	**91,012**
Plant Nutrient Demand	**490,200**	**87,317**
Percentage from Animals	88.3%	104.2%
Required Chemical Fertilizer	57,536	(3,695)
Percentage Demand from Fertilizer	11.7%	(4.2)%

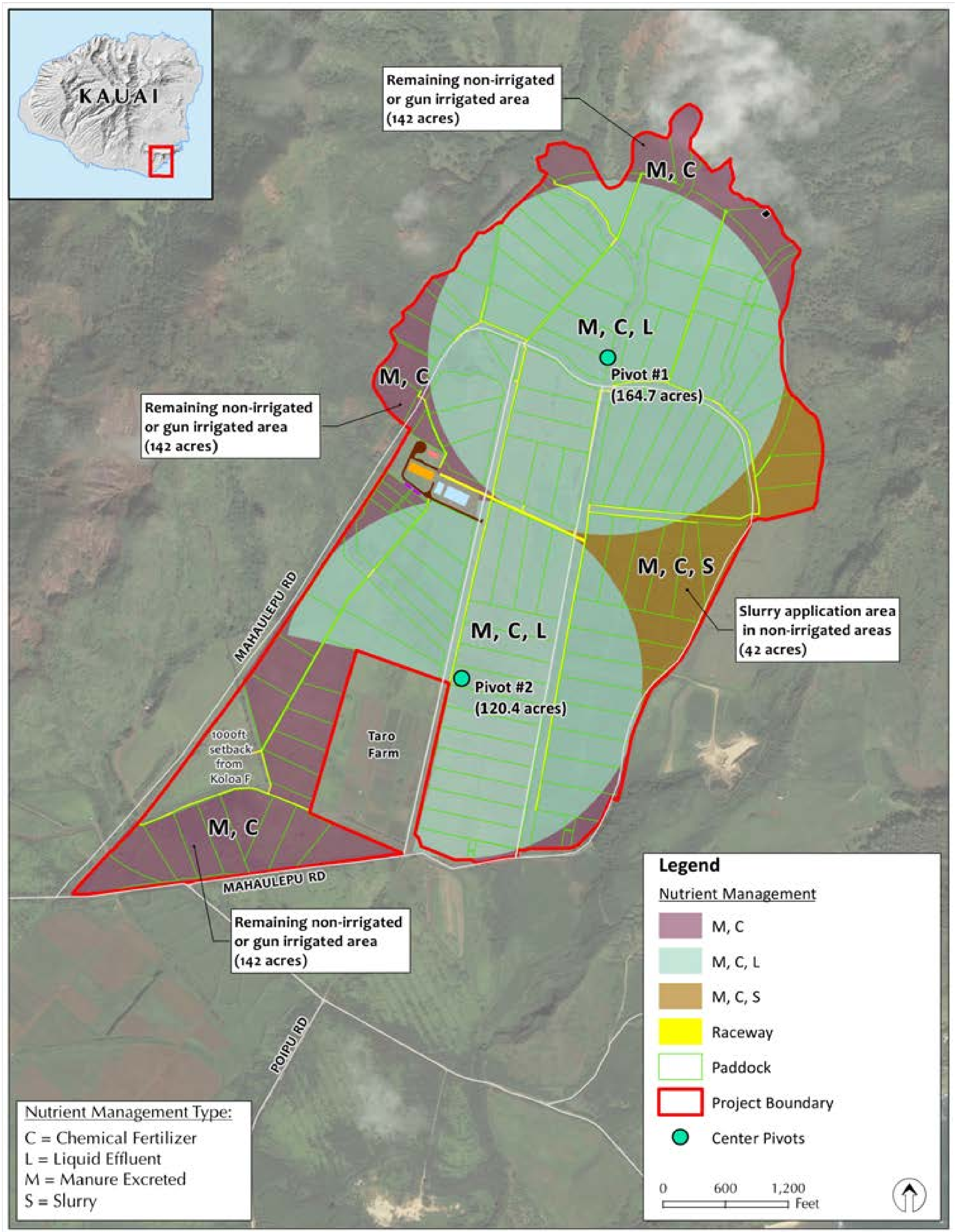


Figure 18A – Nutrient Management Map *(699-cow Herd Size Scenario)*

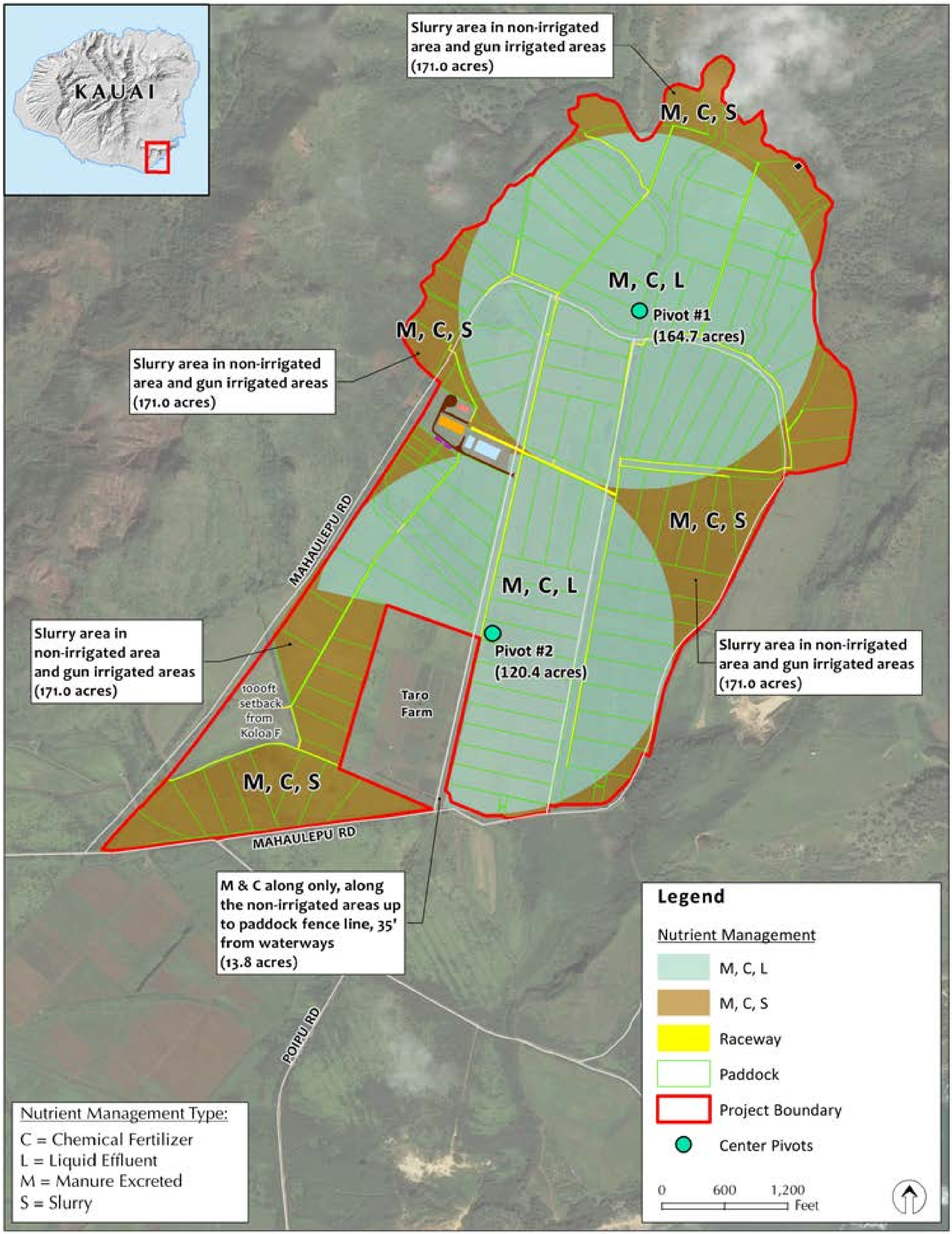


Figure 18B – Nutrient Management Map *(Up To 2,000-cow Herd Size Scenario)*

8.4.1 Typical Liquid Effluent Application

Liquid effluent, containing vital nutrients for the Kikuyu crop that will support and feed the mature dairy cows on pasture, will be applied through either of the two center pivots, providing nutrients over a total application area of 285.1 acres (this area excludes the access roads, cow raceways, gun irrigation areas, and 50-ft. setback from drains/watercourses).

Although it is possible to apply effluent through both center pivot machines at the same time, it is much simpler from a management and control perspective to only apply effluent through one pivot machine at a time – the other pivot will either be applying only irrigation water or not operating. The best time to apply the effluent water is a few days after the cows have finished grazing, allowing for the as-excreted manure on the paddocks from the grazing cows to decompose and provide nutrients to the grass immediately after the paddock is used for grazing. This still allows approximately 15 days for the grass to utilize the nutrients from the pivot irrigation of liquid effluent before the cows next enter that paddock.

As mentioned in **Section 6.1 – Pivot Irrigation System**, the design allows both pivots to do a typical rotation every 48 hours, with a planned application of 0.39 inches of irrigation and effluent. The maximum flow rate from the pump injecting the effluent from the storage pond is 320 gallons per minute (gpm), which is 30% of the total flow capacity of the nozzle package fitted to either center pivot (capable of spraying at 1,030 gpm). During the 48-hour cycle, this means that a maximum of 0.12 inches of liquid effluent could be applied via injection into the irrigation water stream to the center pivot, as part of the full 0.39 inches of irrigation per cycle. However, at any given time, either pivot~~s~~ will not be applying 0.12 inches of liquid effluent per run, as the total volume of liquid effluent in each application would greatly exceed the stored amount of volume of effluent in the storage pond. More irrigation water in lieu of liquid effluent will be applied on a typical basis.

A typical liquid effluent application, which is planned for every 4 days during the spring, summer, and fall months, and whenever able based on rainfall, is shown below:

Table 24A: Typical Liquid Effluent Application

Parameter	Area (acre)	699 Scenario	2,000 Scenario
Application Schedule (Days)		4	4
Daily Effluent Generation		13,225.8 gpd	37,894.7 gpd
Available Liquid Effluent (4 days)		52,903 gal / cycle	151,579 gal / cycle
Pivot #1 Liquid Effluent	164.7	30,562 gal / cycle	87,567 gal / cycle
Pivot #2 Liquid Effluent	120.4	22,341 gal / cycle	64,012 gal / cycle
Minimum Daily Irrigation Demand (Fall, Spring, Summer)		1,258,273 gpd	1,258,273 gpd
Required Irrigation Water Per Cycle		1,205,370 gal	1,106,694
Effluent Percentage of Irrigation		4%	12%

As the pivots apply effluent, the storage pond effluent level is managed and a safe buffer of spare volume is maintained.

Soil moisture and the amount of precipitation will ultimately determine the actual amount of both irrigation water and effluent to be applied in an application, with the deficit below field capacity determining the amount that can be applied. The number of rain days will dictate the schedule of both irrigation water and effluent application, and irrigation will not be applied if the soil is too wet.

8.4.2 Liquid Effluent Application during the Winter Season

Effluent application during the wet winter months will be closely monitored such that the irrigation of effluent does not exceed the capacity of the soil, but also is not building up within the ponds, when irrigation demand of the crop is lowered due to higher amounts of rainfall. The center pivot irrigators can be adjusted to apply as little as 0.04 inches of irrigation per cycle, to minimize over-irrigation of the crop. The pivots can also be adjusted to apply liquid effluent and irrigation water at a 1:1 dilution, in lieu of the smaller percentages of effluent anticipated in a typical liquid effluent application, so that less irrigation water is needed per cycle.

In the winter, because more heavy rain ~~events~~ days ~~are~~ can be anticipated, longer periods between applications will be needed (still less than the 30-day storage period). As the number of available irrigation cycles per month decreases due to the rainy season, it is important to maximize effluent distribution while ensuring that the irrigation demands of the crop are not exceeded. A 1:1 dilution of liquid effluent to irrigation water allows for more effluent application in some instances, when irrigation can be applied, while the adjustment of the center pivot irrigators to provide less overall flow is important for control of the irrigation amounts to not exceed grass crop demands when there is more rain.

Table 24B: Maximized Liquid Effluent Application in Winter Months

Parameter	Area (acre)	699 Scenario	2,000 Scenario
Maximum Flow Rate		320 gpm	320 gpm
Liquid Effluent Injected into Irrigation		0.05 inches	0.12 inches
Pivot #1 Liquid Effluent	164.7	229,247 gal / cycle	536,640 gal / cycle
Pivot #2 Liquid Effluent	120.4	167,527 gal / cycle	392,298 gal / cycle
Total Effluent Application		396,774 gal / cycle	928,938 gal / cycle
Volume of Liquid Effluent (in days)		30	24.5
Minimum Required Irrigation (1:1)		396,774 gal / cycle	928,938 gal / cycle
Total Irrigation Amount per Cycle (2 days)		793,548 gal / cycle	1,857,876 gal / cycle
Total Irrigation Amount per Day		396,774 gal	928,938 gal
Effective Irrigation Percentage		85%	85%
Effective Irrigation Per Day		337,258 gpd	789,597 gpd
Minimum Daily Irrigation Demand (Winter)		839,474 gpd	839,474 gpd

Minimizing the amount of liquid effluent irrigation days means that the amount of liquid effluent application must be maximized to ensure proper management of the pond levels, but must be carefully balanced with the grass crop irrigation demand. The table indicates that running the pivots, at minimum, only twice a month during the wet winter months will ensure that the effluent levels in the ponds do not exceed the 30-day storage period, and that an application twice a month will not exceed the irrigation demand of the crop.

As the historical rain data indicates, having a period of more than ~~5~~7 days (more than one week) of continuous rain (in which irrigation would be prohibited) is very unusual, with only 5 occurrences in the last 30 years. In most cases during the winter months, the application of liquid effluent may occur more than two times that month – utilizing less effluent each time and greater dilution.

Operationally, both ponds also have the capacity to store suspended solids, liquid effluent, slurry mixing volume, normal precipitation for up to 30 days, and rainfall from the 25-year, 24-hour event. Therefore, the total required volume of **both** ponds, when completely full from 30 days' worth of storage and no irrigation of effluent or application of slurry within that 30 day storage period is 2.28 MG or 2,276,645 gallons.

As previously mentioned, both pivots could apply 0.93 MG or 928,938 gallons of liquid effluent at maximum over two days. It would only take 3 application runs to completely empty both effluent ponds for a total application of 2.79 MG or 2,786,814 gallons of effluent, during a winter month. If running at 1:1 dilution, the minimum amount of total liquid effluent and irrigation water, combined, that would be applied over those three runs would be 5.58 MG or 5,573,628 gallons. Such application of liquid effluent and minimal irrigation water is still well below the total irrigation demand of the crop during the winter months, which varies between 26.7 MG and 31.0 MG per month, meaning that additional irrigation water will still be required to meet the irrigation needs of the grass. These monthly irrigation demands far exceed the required monthly volume capacity of the ponds for the 30-day storage period, showing that the ET of the crop ensures that irrigation of liquid effluent is required even during the winter months.

Further, the daily irrigation demands during the winter months range from 0.84 MG to 0.98 MG per day. While it may appear that the irrigation demand would be exceeded by a single run of both pivots with liquid effluent water and minimal irrigation water, there is room to cut back the amount applied. The center pivot irrigators can be adjusted to apply as little as 0.04 inches of liquid effluent per cycle or 0.31 MG of liquid effluent per run. The total irrigation application at 1:1 dilution is 0.62 MG, which is less than the daily irrigation demand low of 0.84 MG.

Finally, the liquid effluent applied by one run of either pivot, even at minimum application, is well above the daily effluent generation of 13,225.8 gallons per day (699 scenario) or 37,894.7 gallons per day (2,000 scenario), ensuring that the storage pond effluent level is cumulatively lowering after each application cycle, and that pond levels can be effectively managed.

As noted above, the center pivot technology used on the farm has been carefully selected to adequately adapt and apply the effluent in different volumes and capacities to manage irrigation and effluent application for the varying conditions between the seasons.

8.4.3 Slurry Application

The first of the effluent ponds is for the settling of solids (i.e. the settling pond). It will typically be filling with or full of liquid effluent, with the solids content having settled to the bottom and the liquid component then flowing from the top of this pond into the second pond for storage (i.e. the storage pond).

Solids (mostly soft organic matter, but also some sand and mud, etc.) will be mixed with liquid effluent or irrigation water into a slurry suspension, and will be applied on designated areas, at a minimum, of every 5 weeks (within 45 days). The slurry will be applied through a slurry gun irrigation system. The slurry gun system is separate from the hard-hose reel gun system used only for irrigation at the makai side of the farm.

The slurry application areas will vary based upon the number of mature dairy cows on the farm, as the total amount of slurry varies as well. In the ~~initial~~ committed herd size of 699 mature dairy cows, less manure is generated and less land area could be used to apply the slurry without exceeding the nutrient demand of the Kikuyu crop. Therefore, slurry can be applied, typically, in approximately 42 acres of non-irrigated areas on the eastern portion of the farm, which are outside of the liquid effluent application area from the center pivot as well as the gun irrigation system using only irrigation water. The extent of this type of application has been reviewed by DOH within the Waste Management Plan submitted for 699 mature dairy cows in July 2014. **See Figure 19A – Slurry Management Map (*Up To 699-cow Herd Size Scenario*).**

If and when the herd expands up to the contemplated herd size of 2,000 mature dairy cows, more manure will be generated and management of the farm's nutrients will need the option to apply slurry to other nutrient deficient areas, which will likely include all non-irrigated areas on the farm, but also expand to include areas under the gun irrigation system. When it is determined that the slurry application has met the nutrient demand of the crop in a specific area, other areas will be utilized as needed to ensure that nutrients are not over-applied. This change in slurry application at the larger contemplated 2,000 mature dairy cow herd size, as compared to the reviewed 699 mature dairy cow Waste Management Plan, will be reviewed as part of a NPDES CAFO Permit application process. **See Figure 19B – Slurry Management Map (*Up To 2,000-cow Herd Size Scenario*)**.

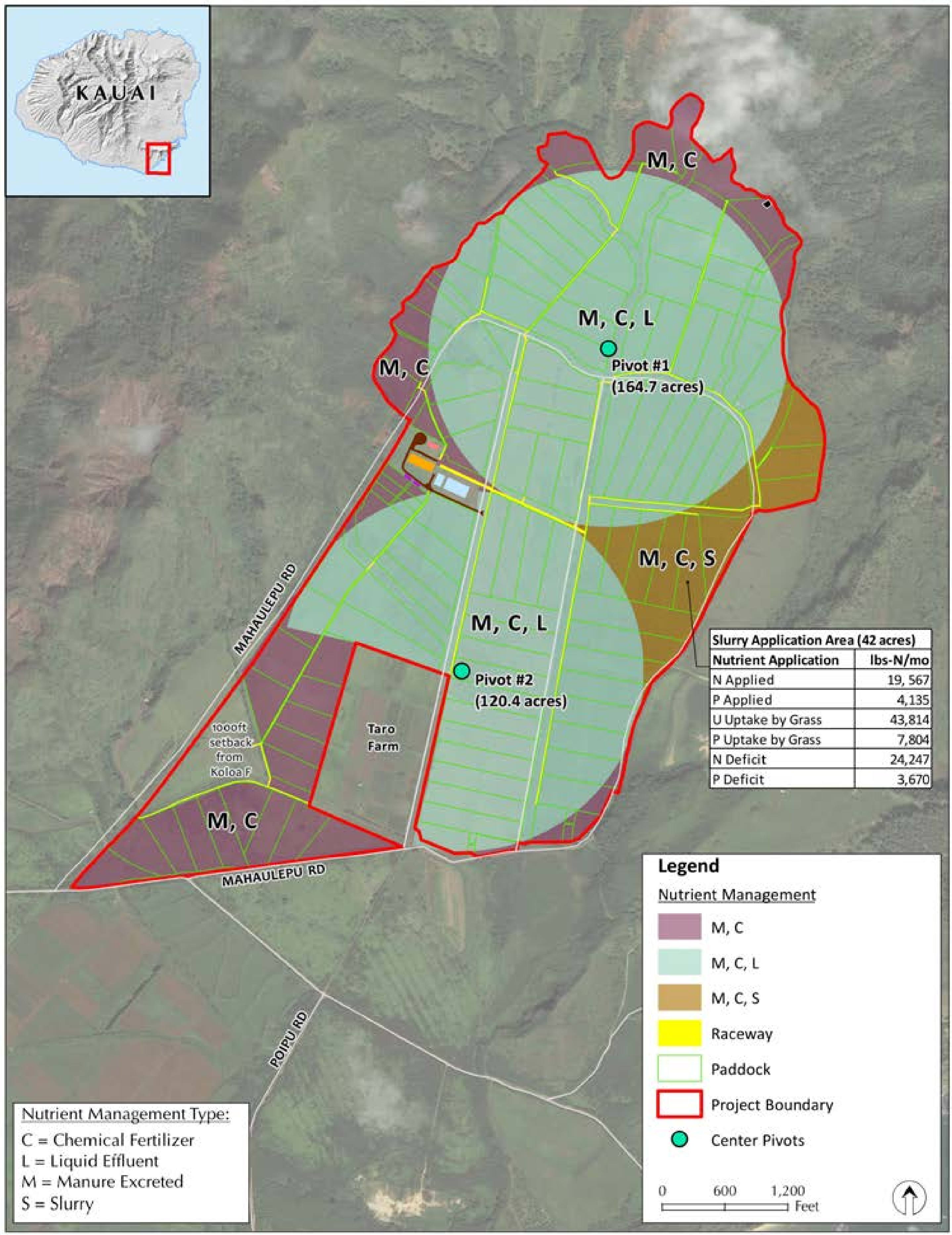


Figure 19A – Slurry Management Map (*Up To 699-cow Herd Size Scenario*)

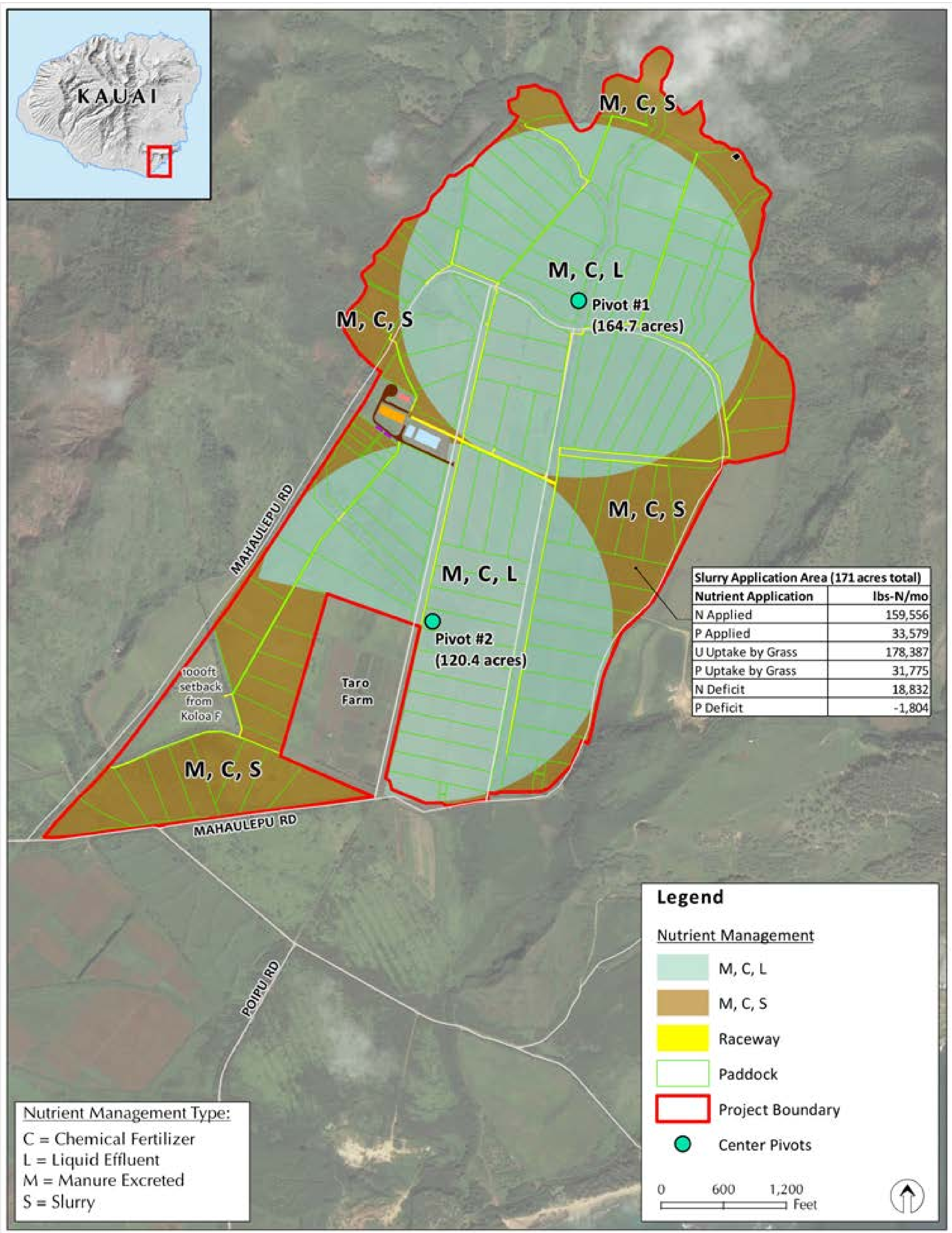


Figure 19B – Slurry Management Map (*Up To 2,000-cow Herd Size Scenario*)

It is not anticipated that the area within the liquid effluent application area from the center pivots will receive slurry, although based upon the nutrient requirement of these areas, slurry could be applied in lieu of using more commercial fertilizer. Typically, however, HDF will not utilize the areas under the pivots for slurry application, so that nutrients are spread out upon areas not already receiving nutrients from liquid effluent. However, as the slurry is meant to offset the need for commercial fertilizer, slurry may be applied in any location on the farm where it is determined such application would not exceed the nutrient demand of the Kikuyu crop, regardless of where or how the nutrient is supplied (as-excreted manure, liquid effluent from the ponds, slurry, or commercial fertilizer). Proper utilization of the slurry nutrients may reduce the need for commercial fertilizer, reduce operating costs, and improve soil health as a natural source of soil nutrient. As previously mentioned, the application of slurry within the larger contemplated 2,000 mature dairy cow scenario will be reviewed as part of the NPDES CAFO Permit application process.

While the total volume of the settling pond will be emptied at least every 45 days, operationally, HDF expects to apply slurry more often than just once every 45 days, helping to manage levels within the settling pond and thereby reducing the overall volume utilized within the storage pond, as more liquid effluent in the settling pond would be used as mixing volume for slurry application in lieu of being injected into the center pivots from the storage pond. Each application of slurry will be managed by area and volume, to ensure nutrients or irrigation water is not excessively applied in any particular area, exceeding Kikuyu crop nutrient demand. Applications will be timed to prevent and eliminate opportunities for nutrients to potentially run off the site.

The slurry application consists of bringing the solids into suspension through adding liquid mixing volume, to the settling pond's capacity, and then stirring the pond. This liquid, along with the suspended solids, is then pumped through a 4-inch underground pipe to a number of hydrants which have a 'gun sprinkler' with a 5/8-inch nozzle attached via a length of flexible hose. The guns (and their 65-foot radius of spray area) will be moved around the paddocks after a period of running so that the solids become evenly spread.

Under normal circumstances there will be two guns running and the pump will be pumping 158 gpm. At this rate it will take approximately a total of 40 hours to nearly empty the settling pond, when full, depending on the amount of mixing volume.

8.4.4 Nutrient Mass Balance by Application

As indicated, nutrients are applied to pasture via four different mechanisms and sources: 1) manure as-excreted on pasture by the mature dairy cows, 2) liquid effluent collected at the dairy facility applied by the center pivot system, 3) suspended solids collected at the dairy facility applied as slurry by a gun sprinkler system, and 4) commercial fertilizer applications.

Each method of applying nutrients ~~must~~ will be managed by area and volume, to ensure nutrients are not excessively applied in any particular area, exceeding Kikuyu crop nutrient demand. Applications will be timed to prevent and eliminate opportunities for nutrients to potentially run off the site. The various tables account for the committed and contemplated herd size with respect to the total number of mature dairy cows and calves on-site, and also takes into account the number of calves in the calf sheds at the committed 699 herd size or contemplated 2,000 herd sizes each.

The following tables show the nutrient mass balance of each application type, with the deficit of nutrient equal to the required amount of nutrient to be applied from commercial fertilizer.

Table 25: Estimated Monthly Nutrient Generation Collected in Manure Storage System (Operational) for 699 Mature Dairy Cows and 50 Calves in Pens

Month	Settled Nutrient Content in Settling Pond	N Collected in Settling Pond (lbs-N/mo)	P Collected in Settling Pond (lbs-N/mo)	Liquid Nutrient Content in Storage Pond	N Collected in Storage Pond (lbs-N/mo)	P Collected in Storage Pond (lbs-N/mo)	N Excreted on Pasture (lbs-N/mo)	P Excreted on Pasture (lbs-P/mo)
January	40%	678	146	60%	1,018	220	11,003	2,290
February	40%	613	132	60%	919	198	9,939	2,069
March	40%	678	146	60%	1,018	220	11,003	2,290
April	40%	656	142	60%	985	213	10,648	2,216
May	40%	678	146	60%	1,018	220	11,003	2,290
June	40%	656	142	60%	985	213	10,648	2,216
July	40%	678	146	60%	1,018	220	11,003	2,290
August	40%	678	146	60%	1,018	220	11,003	2,290
September	40%	656	142	60%	985	213	10,648	2,216
October	40%	678	146	60%	1,018	220	11,003	2,290
November	40%	656	142	60%	985	213	10,648	2,216
December	40%	678	146	60%	1,018	220	11,003	2,290
Annual Total		7,987	1,724		11,981	2,587	129,556	26,966

Table 26A: Estimated Monthly Nutrient on Non-Irrigated Areas for 699 Mature Dairy Cows and 50 Calves in Pen

Month	N Applied on Non-Irrigated Areas (lbs-N/mo)	P Applied on Non-Irrigated Areas (lbs-N/mo)	N Uptake by Grass from Non-Irrigated Areas (lbs-N/mo)	P Uptake by Grass from Non-Irrigated Areas (lbs-N/mo)	N Deficit (lbs-N/mo) (Fertilizer Need)	P Deficit (lbs-P/mo) (Fertilizer Need)
January	3,344	696	12,652	2,254	9,308	1,558
February	3,020	629	11,428	2,036	8,407	1,407
March	3,344	696	12,652	2,254	9,308	1,558
April	3,236	674	12,244	2,181	9,008	1,507
May	3,344	696	12,652	2,254	9,308	1,558
June	3,236	674	12,244	2,181	9,008	1,507
July	3,344	696	12,652	2,254	9,308	1,558
August	3,344	696	12,652	2,254	9,308	1,558
September	3,236	674	12,244	2,181	9,008	1,507
October	3,344	696	12,652	2,254	9,308	1,558
November	3,236	674	12,244	2,181	9,008	1,507
December	3,344	696	12,652	2,254	9,308	1,558
Annual Total	39,371	8,195	148,969	26,535	109,598	18,340

* **142.8 Acres of Gun Irrigated Areas, A Portion of Non-Irrigated Areas, and Pasture Area within 50′ Setback. Areas receive only as-excreted manure in 699 cow scenario.**

** **50 Calves in Pens Accounted For. 100 Calves in Pasture.**

Table 26B: Estimated Monthly Nutrient Application on Center Pivot Areas for 699 Mature Dairy Cows and 50 Calves in Pen

Month	N Applied on Center Pivot Areas (lbs-N/mo)	P Applied on Center Pivot Areas (lbs-N/mo)	N Uptake by Grass from Center Pivot Areas (lbs-N/mo)	P Uptake by Grass from Center Pivot Areas (lbs-N/mo)	N Deficit (lbs-N/mo) (Fertilizer Need)	P Deficit (lbs-P/mo) (Fertilizer Need)
January	7,694	1,609	25,260	4,499	17,566	2,890
February	6,949	1,454	22,815	4,064	15,866	2,611
March	7,694	1,609	25,260	4,499	17,566	2,890
April	7,445	1,557	24,445	4,354	17,000	2,797
May	7,694	1,609	25,260	4,499	17,566	2,890
June	7,445	1,557	24,445	4,354	17,000	2,797
July	7,694	1,609	25,260	4,499	17,566	2,890
August	7,694	1,609	25,260	4,499	17,566	2,890
September	7,445	1,557	24,445	4,354	17,000	2,797
October	7,694	1,609	25,260	4,499	17,566	2,890
November	7,445	1,557	24,445	4,354	17,000	2,797
December	7,694	1,609	25,260	4,499	17,566	2,890
Annual Total	90,585	18,947	297,416	52,977	206,831	34,030

* **285.1 Acres of Area under the Center Pivot. Area receives both as-excreted manure and liquid effluent from the storage pond in 699 cow scenario.**
** **50 Calves in Pens Accounted For. 100 Calves in Pasture.**

Table 26C: Estimated Monthly Nutrient Application on Slurry Areas for 699 Mature Dairy Cows and 50 Calves in Pen

Month	**N Applied on Slurry Areas (lbs-N/mo)**	**P Applied on Slurry Areas (lbs-N/mo)**	**N Uptake by Grass from Slurry Areas (lbs-N/mo)**	**P Uptake by Grass from Slurry Areas (lbs-N/mo)**	**N Deficit (lbs-N/mo)** (Fertilizer Need)	**P Deficit (lbs-P/mo)** (Fertilizer Need)
January	1,662	351	3,721	663	2,059	312
February	1,501	317	3,361	599	1,860	282
March	1,662	351	3,721	663	2,059	312
April	1,608	340	3,601	641	1,993	302
May	1,662	351	3,721	663	2,059	312
June	1,608	340	3,601	641	1,993	302
July	1,662	351	3,721	663	2,059	312
August	1,662	351	3,721	663	2,059	312
September	1,608	340	3,601	641	1,993	302
October	1,662	351	3,721	663	2,059	312
November	1,608	340	3,601	641	1,993	302
December	1,662	351	3,721	663	2,059	312
Annual Total	19,567	4,135	43,814	7,804	24,247	3,670

*** 42 Acres of Area under the Slurry Gun Application. Area receives both as-excreted manure and slurry effluent from the settling pond in 699 cow scenario.**

**** 50 Calves in Pens Accounted For. 100 Calves in Pasture.**

Table 27: Estimated Monthly Nutrient Generation Collected in Manure Storage System (Operational) for 2,000 Mature Dairy Cows and 167 Calves in Pens

Month	Settled Nutrient Content in Settling Pond	N Collected in Settling Pond (lbs-N/mo)	P Collected in Settling Pond (lbs-N/mo)	Liquid Nutrient Content in Storage Pond	N Collected in Storage Pond (lbs-N/mo)	P Collected in Storage Pond (lbs-N/mo)	N Excreted on Pasture (lbs-N/mo)	P Excreted on Pasture (lbs-P/mo)
January	40%	1,983	432	60%	2,974	648	31,791	6,650
February	40%	1,791	390	60%	2,686	585	28,714	6,006
March	40%	1,983	432	60%	2,974	648	31,791	6,650
April	40%	1,919	418	60%	2,878	627	30,765	6,435
May	40%	1,983	432	60%	2,974	648	31,791	6,650
June	40%	1,919	418	60%	2,878	627	30,765	6,435
July	40%	1,983	432	60%	2,974	648	31,791	6,650
August	40%	1,983	432	60%	2,974	648	31,791	6,650
September	40%	1,919	418	60%	2,878	627	30,765	6,435
October	40%	1,983	432	60%	2,974	648	31,791	6,650
November	40%	1,919	418	60%	2,878	627	30,765	6,435
December	40%	1,983	432	60%	2,974	648	31,791	6,650
Annual Total		23,342	5,088		35,014	7,632	374,308	78,293

Table 28A: Estimated Monthly Nutrient on Non-Irrigated Areas for 2,000 Mature Dairy Cows and 167 Calves in Pen

Month	N Applied on Non-Irrigated Areas (lbs-N/mo)	P Applied on Non-Irrigated Areas (lbs-N/mo)	N Uptake by Grass from Non-Irrigated Areas (lbs-N/mo)	P Uptake by Grass from Non-Irrigated Areas (lbs-N/mo)	N Deficit (lbs-N/mo) (Fertilizer Need)	P Deficit (lbs-P/mo) (Fertilizer Need)
January	934	195	1,223	218	289	23
February	843	176	1,104	197	261	20
March	934	195	1,223	218	289	23
April	904	189	1,183	211	280	22
May	934	195	1,223	218	289	23
June	904	189	1,183	211	280	22
July	934	195	1,223	218	289	23
August	934	195	1,223	218	289	23
September	904	189	1,183	211	280	22
October	934	195	1,223	218	289	23
November	904	189	1,183	211	280	22
December	934	195	1,223	218	289	23
Annual Total	10,993	2,299	14,396	2,564	3,404	265

* **13.8 Acres of Pasture Area within 50′ Setback. Area receives only as-excreted manure in 2,000 cow scenario.**
** **167 Calves in Pens Accounted For. 333 Calves in Pasture.**

Table 28B: Estimated Monthly Nutrient Application on Center Pivot Areas for 2,000 Mature Dairy Cows and 167 Calves in Pen

Month	N Applied on Center Pivot Areas (lbs-N/mo)	P Applied on Center Pivot Areas (lbs-N/mo)	N Uptake by Grass from Center Pivot Areas (lbs-N/mo)	P Uptake by Grass from Center Pivot Areas (lbs-N/mo)	N Deficit (lbs-N/mo) (Fertilizer Need)	P Deficit (lbs-P/mo) (Fertilizer Need)
January	22,262	4,683	25,260	4,499	2,998	*(183)*
February	20,107	4,229	22,815	4,064	2,708	*(165)*
March	22,262	4,683	25,260	4,499	2,998	*(183)*
April	21,544	4,532	24,445	4,354	2,901	*(177)*
May	22,262	4,683	25,260	4,499	2,998	*(183)*
June	21,544	4,532	24,445	4,354	2,901	*(177)*
July	22,262	4,683	25,260	4,499	2,998	*(183)*
August	22,262	4,683	25,260	4,499	2,998	*(183)*
September	21,544	4,532	24,445	4,354	2,901	*(177)*
October	22,262	4,683	25,260	4,499	2,998	*(183)*
November	21,544	4,532	24,445	4,354	2,901	*(177)*
December	22,262	4,683	25,260	4,499	2,998	*(183)*
Annual Total	262,115	55,134	297,416	52,977	35,301	****(2,156)*

*** 285.1 Acres of Area under the Center Pivot. Area receives both as-excreted manure and liquid effluent from the storage pond in 2,000 cow scenario.**

**** 167 Calves in Pens Accounted For. 333 Calves in Pasture.**

***** <u>See Note Next Pages</u>**

Table 28C: Estimated Monthly Nutrient Application on Slurry Areas for 2,000 Mature Dairy Cows and 167 Calves in Pen

Month	N Applied on Slurry Areas (lbs-N/mo)	P Applied on Slurry Areas (lbs-N/mo)	N Uptake by Grass from Slurry Areas (lbs-N/mo)	P Uptake by Grass from Slurry Areas (lbs-N/mo)	N Deficit (lbs-N/mo) (Fertilizer Need)	P Deficit (lbs-P/mo) (Fertilizer Need)
January	13,551	2,852	15,151	2,699	1,599	*(153)*
February	12,240	2,576	13,684	2,438	1,445	*(138)*
March	13,551	2,852	15,151	2,699	1,599	*(153)*
April	13,114	2,760	14,662	2,612	1,548	*(148)*
May	13,551	2,852	15,151	2,699	1,599	*(153)*
June	13,114	2,760	14,662	2,612	1,548	*(148)*
July	13,551	2,852	15,151	2,699	1,599	*(153)*
August	13,551	2,852	15,151	2,699	1,599	*(153)*
September	13,114	2,760	14,662	2,612	1,548	*(148)*
October	13,551	2,852	15,151	2,699	1,599	*(153)*
November	13,114	2,760	14,662	2,612	1,548	*(148)*
December	13,551	2,852	15,151	2,699	1,599	*(153)*
Annual Total	159,556	33,579	178,387	31,775	18,832	****(1,804)*

*** 171 Acres of Area under the Slurry Gun Application. Area receives both as-excreted manure and slurry effluent from the settling pond in 2,000 cow scenario.**
**** 167 Calves in Pens Accounted For. 333 Calves in Pasture.**
***** See next page and Section 8.3.9 - Nutrient Mass Balance**

As discussed in **Section 8.3.9 - Nutrient Mass Balance**, phosphorus is applied to the pasture as nutrient in the form of manure and fertilizer. As shown in the tables above, at 699 mature dairy cows, the amount of phosphorus applied in the form of manure only (P Total Deposited on Farm in lbs/month) does not meet the crop demand (P Total Uptake From Farm in lbs/month) at a crop yield of 16.3 tons of DM per acre per year, regardless of the how the nutrient is applied (as-excreted, liquid effluent, or slurry). Additional phosphorus must be applied using commercial fertilizer to maintain high productivity and soil health. At the contemplated herd size of 2,000 mature dairy cows, the amount of phosphorus applied in the form of manure only slightly exceeds the crop demand at a crop yield of 16.3 tons of DM per acre per year, in both the liquid application and slurry application areas. An excess of over 300 lbs of phosphorus per month from these two application types, could be expected.

As previously mentioned, nutrient management and mass balance analyses are dynamic and are influenced by the many different environmental variables that enter into nutrient cycle planning from grass yields, stocking density, manure nutrient content, soil nutrient content, and crop nutrient content. Refer to the discussion in **Section 8.3.9 - Nutrient Mass Balance**, for options to manage phosphorus on the farm, which may include and are not limited to initially planned additions of phosphorus to improve soil health, reduction in the carrying capacity of the farm to approximately 1,875 mature dairy cows from up to 2,000 mature dairy cows, or the expected increase in the grass yields from 16.3 tons of DM per acre per year to 20 tons of DM per acre per year (though an increase to 17.3 tons of DM per acre per year would be sufficient to bring phosphorus applications back into balance with crop demand).

8.4.5 Contingency Applications

It should be noted that the ponds are sized to accommodate 30 days of storage of effluent, normal precipitation, and the 25-year, 24-hour storm event. It will be highly unlikely that the storage pond will be full at any time, which would require a set of highly unlikely events occurring at the same time (large storm events in tandem, extended heavy rain periods, no irrigation days, no application of the settling pond slurry, and spare volume / buffers filled). At 699 mature dairy cows, the spare volume in the storage pond (as the ponds were designed for 2,000 cows) provides an even greater factor of safety. Throughout the 30-day storage period, effluent is planned for application every 4 days and the slurry application is expected at least once every 45 days, ensuring that the pond levels are kept at manageable levels.

Nonetheless, if the storage pond were full and if a cataclysmic storm was forecast, the time to empty the pond is around 100 hours. If warranted due to potential impact from an approaching storm event, the settling pond could also be pumped empty within an additional 40 hours. If the forecasted storm is forecast six days prior, then virtually no effluent would remain in the ponds when the storm arrives.

8.4.6 Nutrient Application Schedule

Manure effluent is typically applied in liquid form with irrigation equipment, and application conditions are documented in the Nutrient Management Plan. All materials will be handled in a manner to minimize the generation of particulate matter, odors and greenhouse gases.

Solid manure effluent will be brought into a liquid suspension and also applied in liquid slurry form with irrigation equipment. Similarly, application conditions are documented in the Nutrient Management Plan. All materials will be handled in a manner to minimize the generation of particulate matter, odors and greenhouse gases.

Manure effluent will be applied at a rate significantly less than the crop (Kikuyu) nutrient requirements and best management practices will be used for maintenance of soil structure. Manure effluent will be applied on recently grazed paddocks and before pasture re-growth starts. Application schedules will vary and nutrients will be adaptively managed to meet the nutrient demand of the crop while considering environmental and biological systems and factors.

8.4.7 Potential Special Management Areas

The Māhāʻulepū soils, particularly in the south-central portion of the farm are perceived as heavy, flood frequently and are difficult to grow crops upon. Much of the water from the northern part of the farm runs through this area. The dominant soils on the lower farm are Kaʻena Clay, Kalapa Silty Clay and Kalihi Clay, which are prone to compaction and the USDA characterizes as “poorly drained”. The poorly drained soils retain nutrients as the soils tend to hold water. While this makes grazing difficult, it also protects other surface water resources as runoff, and therefore nutrients, are contained. However, less than two days after heavy rain and with management of surface water after a significant rain event (diversion to a retention area, etc.), the soils are observed to be dry enough to graze, even without a Kikuyu thatch. Drains may also be installed and used to remove non-nutrient laden water from the surface of these areas to reduce soil dry time and to restore grazing.

Once the farm is in operation, different operational conditions may be used to manage different areas of the farm based on soil types and drainage characteristics. Kikuyu itself doesn't grow as effectively in inundated or overly-wet conditions, so the farm must be managed to make sure the drainage system is effective. Winter weather may dictate if certain areas or paddocks are used, and if nutrients are applied at all in specific areas.

Some paddocks may not receive nutrients if the paddock cannot be utilized at that time. However, all paddocks and pasture will receive nutrients over the year, but their conditions will dictate whether a given paddock will receive nutrients at a particular point in time. Available storage in the ponds should allow for flexibility in situations where additional effluent must be stored when or if it cannot be applied to certain paddocks at a particular point in time. Additionally, as yields increase, more nutrients may be utilized on site.

Proper management of the rotation of mobs will also ensure that certain operationally challenging areas be utilized only when there is limited or no anticipated rain events and not utilized when heavy rain is forecast. Paddocks identified as potentially having drains will be managed so that they are not used during anticipated rain events.

The nursery used for the grass growth trials was intentionally located within an area characterized as "poorly drained" to test grass growth, nutrient application, and drainage. To date, operational and management decisions have allowed the nursery to perform well.

8.5 Soil Sampling Procedures

8.5.1 Soil Testing Frequency

Soils samples and testing will be performed at least annually as required by the Guidelines and NRCS Conservation Practice Standards, and more frequently as needed, during the farm operation, to assist with managing nutrient content of the soils. Soil samples will be collected from each field receiving manure as described in the University of Hawaiʻi CTAHR Cooperative Extension Service publication (SCM-9).

Soil samples will be submitted for analysis to the University of Hawaiʻi ADSC laboratory or another laboratory accepted in state-certified programs, the North American Proficiency Testing Program (Soil Science Society of America), or laboratories whose tests are accepted by the University of Hawaiʻi CTAHR Cooperative Extension Service. All soil analyses will be conducted using methods approved by the University of Hawaiʻi CTAHR.

Soil samples will be analyzed for pH and phosphorus, nitrogen, potassium, calcium, magnesium, organic matter, salinity, micronutrients, and other constituents pertinent to monitoring or amending the annual nutrient budget.

8.6 Manure Sampling

8.6.1 Manure Sampling Frequency

Manure samples will be collected at least quarterly (which exceeds the annual sampling requirements in both the Guidelines and the NRCS Conservation Practice Standards 590 and 633), and more frequently as needed, from both (liquid and solid) effluent ponds, as well as the as-excreted manure, and the result of manure analyses will be used in determining land application rates of manure.

8.6.2 Liquid (Effluent and Slurry) Manure Sampling

Effluent and slurry samples will be taken at the same depth from five sites around the pond. Sub-samples will be mixed in a large, clean plastic container and analyzed while the contents are still swirling.

One pint of material will be collected in an unbreakable container that is no more than three quarters full and sent to the laboratory for analysis.

Samples will be transported in a cooler with ice packs, if necessary. Any stored samples will be refrigerated or frozen before being sent for analysis.

8.6.3 Solid Manure Sampling

Samples from five locations from around the settling pond will be taken at the same depth from which the slurry will be removed for application. Sub-samples will be combined in a clean plastic container and mixed thoroughly.

At least one pint of material will be collected in an unbreakable container, which is no more than three quarters full (a quart-sized freezer bag will be used).

Samples will be transported in a cooler with ice packs. Any stored samples will be refrigerated or frozen before being sent for analysis.

8.7 Forage Sampling

Kikuyu crop samples and testing will be performed at least quarterly (which exceeds the annual sampling requirements in both the Guidelines and the NRCS Conservation Practice Standards 590 and 633), and more frequently as needed, to determine the nutrient content and nutritional value of the crop, both to manage the land application rates of manure and to manage the nutrition of the mature dairy cow.

8.8 Feed Management

A feed management plan will be developed and implemented utilizing the USDA NRCS Feed Management 592 Standard. This standard specifies certain criteria that must be followed and will become an essential component of the NMP. Feed management uses an assortment of tools, including regular analysis of feeds, milk, and manure, to more frequently review nutritional diet formulas and reduce the uncertainties of feed delivery. This process enables maintenance efficiency, improvement in milk production, and/or the improved health of livestock. Stabilizing nitrogen and phosphorus nutrient levels in the manure are also key objectives of HDF, to allow for more precise nutrient management within the farm.

The feed management plan will contain the following information and be developed by a certified animal nutritionist:

- Diets and feed management strategies based upon a benchmark manure sample
- A laboratory analysis completed for the various sources of animal feed (forage or commercial) used to formulate the diet to determine nutrient content for the ration
- Feed analysis conducted by an accepted accredited laboratory
- Adjustments to nutritional levels to improve or sustain livestock productivity
- Diet adjustments to reduce (or not exceed) nitrogen and phosphorus levels in as excreted manure
- Feed management records will be kept on site and reviewed annually along with manure analysis results

8.9 Water Quality Monitoring

HDF will implement a plan for water quality monitoring to assess baseline water quality and monitor water quality during operation, as well as assess the effectiveness of and to adjust HDF's irrigation, nutrient management and conservation practices.

Monitoring Goals:

- Determine baseline water quality
- Monitor water quality during operation of the dairy
- Evaluate and adjust the frequency and timing of nutrient application and irrigation schedule
- Evaluate and adjust conservation practices
- Detect any potential problems early to allow adjustment of practices before the impacts are significant

8.9.1 Sampling Parameters

Parameters for measurement may include the following:

- Temperature
- Flow
- pH
- Dissolved oxygen
- Turbidity
- Total suspended solids

- Bacteria
- Pesticides
- Nitrogen (N), Phosphorus (P), Potassium (K)

A variety of actions could be taken manage water quality and to prevent water quality issues from arising at the site. It is likely that one or more of the following actions would be considered and taken to address typical water quality concerns for this type of agricultural operation:

- Addition/modification to erosion and sediment controls
- Addition/modification to conservation measures
- Adjustment to irrigation application schedules
- Adjustment to effluent and sludge application schedules
- Adjustment to nutrient application
- Adjustment to pasture rotation
- Changes to sampling routines, procedure or scheduling

8.10 Conclusion

This nutrient balance analysis is a very conservative analysis of all nutrients that will be produced on the farm. These conservative assumptions will be replaced with actual field collected data once the farm goes into operation. The Nutrient Management Plan(s) (reviewed by DOH for the committed herd of 699 mature dairy ~~animals~~ cows and to be prepared and reviewed for the contemplated operations for 700 to up to 2,000 mature dairy animals) will be updated on an annual basis to reflect actual conditions of the farm, once the farm is in operation. The update will include an accounting of the acres in pasture, number of animals present, grass yields, and the overall dairy operation.

Fundamentally, HDF will be based on the most successful island dairy models in the world, and will utilize a sustainable, pasture-based, rotational-grazing system utilizing 21st century technology. The farm will be very different from conventional ~~feedlot~~ confinement dairy operations. Manure nutrients produced on the farm will be utilized for forage crop growth, but balanced with crop nutrient need and commercial fertilizer applications to produce maximum forage yield.

One of the most important considerations in nutrient management planning for farms is the understanding that a NMP is an adaptive management tool. Some even describe it as a living, breathing document that is constantly monitored and updated as the conditions of the farm evolve. All nutrient application records, soil sampling records, forage sampling, water resource quality testing, and manure analysis records will be kept on site with the Nutrient Management Plan, for use by the farm operator to make informed nutrient management decisions. The results from annual soil testing, manure testing, forage testing, and water resource quality testing will then be used to update and inform the nutrient management process for HDF as the farm becomes established and operations mature. Record keeping, logs, and updates will be available to the Department of Health for HDF's adaptive nutrient plan.

As the current nutrient balance analysis indicates, with the contemplated 2,000 mature dairy ~~milking~~ cow herd size, mass balance projections for HDF show the pound-per-month quantity of phosphorus will exceed the amount of phosphorus that the pasture crop requires for adequate growth.

Nutrient management and mass balance analyses are dynamic and are influenced by the many different environmental variables that enter into nutrient cycle planning from grass yields, stocking density, manure nutrient content, soil nutrient content, and crop nutrient content. Several management options exist to keep phosphorus and other nutrients in balance, which may include and are not limited to planned additions of phosphorus to improve soil health, reduction in the carrying capacity of the farm to approximately 1,875 mature dairy cows from up to 2,000 mature dairy cows, or the expected increase in the grass yields from 16.3 tons of DM per acre per year to 20 tons of DM per acre per year (though an increase to 17.3 tons of DM per acre per year would be sufficient to bring phosphorus applications back into balance with crop demand and eliminate any phosphorus overage). Higher grass yields would demand additional phosphorus. Based on field trials, yields of 20 tons DM per acre per year are achievable after several years of pasture maturation. Should yields not increase as planned, the carrying capacity of the farm would be reduced. With reduced manure, phosphorus application levels would decrease and balance with the nutrient need of the grass. Nitrogen from commercial fertilizer would be required at both 1,875 and 2,000 milking cows.

HDF is committed to establishing a herd of up to 699 mature dairy cows, and demonstrating the pasture-based system as an economically and environmentally sustainable model for Hawaiʻi. With proven success at a herd size of 699, HDF will contemplate the possibility of expanding the herd in the future. For dairy operations with 700 or more mature dairy cows, additional regulatory review and permitting by the State Department of Health is required. In keeping with the NRCS Nutrient Management practice code and best practices, herd growth would be gradual, and the herd size will be dynamic and based upon the monitoring of nutrients in the manure, uptake by grass, nutrient content of soil, and total acres in pasture.

In accordance with the State of Hawaiʻi, DOH "Guidelines for Livestock Management", prepared in collaboration with the University of Hawaiʻi at Manōa, Cooperative Extension Service, College of Tropical Agriculture and Human Resources, West Maui Soil & Water Conservation District, USDA – Natural Resource Conservation Service, U.S. Environmental Protection Agency – Region 9, dated January 19, 2010~~"Guidelines for Livestock Waste Management", prepared by the University of Hawaiʻi Mānoa – CTAHR, and through consultations with the State of Hawaiʻi Department of Health, NRCS District Conservationist, and the West Kauaʻi Soil and Water Conservation District~~, HDF has prepared this Nutrient Balance Analysis for its Environmental Impact Statement (EIS), stating the intended management methods and techniques which will be used to properly manage its wastewater systems and the nutrient balance of the farm, at ~~a herd size from 699 to up to 2,000 mature dairy animals~~ the committed herd size of 699 mature dairy cows, as well as for the contemplated herd of up to 2,000 mature dairy cows.

APPENDIX E

ESTIMATES OF THE POTENTIAL IMPACT ON GROUNDWATER AND SURFACE WATER BY HAWAII DAIRY FARMS IN MAHAULEPU, KAUAI

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Estimates of the Potential Impact on Groundwater and Surface Water by Hawaii Dairy Farms in Mahaulepu, Kauai

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Table of Contents

List of Figures

Table of Contents
(continued)

List of Figures

List of Tables

INTRODUCTION

This report presents estimates of the potential impact of the proposed Hawaii Dairy Farms (HDF) on groundwater and surface water in Mahaulepu on Kauai. The 557 acre project site will be developed on former sugarcane lands in Mahaulepu Valley. Initially, HDF will have a herd of up to 699 cows. Depending on the success of the initial herd size, expansion of the herd up to the carrying capacity of the site may occur. That carrying capacity is presently thought to be 2000 cows. In the evaluation of impacts in this report, both herd sizes – 699 and 2000 cows – are evaluated.

This report begins with descriptions of groundwater and surface water occurrence within and around the HDF site, including results from the four monitor wells that have been drilled on the site and the results of surface and ground water quality sampling. After these descriptions, estimates of the project's potential impact on water resources are presented. These estimates draw heavily from two reports: (1) "Nutrient Balance Analysis for Hawaii Dairy Farms" by Group 70 and Red Barn Consulting dated March 2016; and (2) "Hawaii Dairy Farms Drainage Memorandum" by Group 70 dated August 2015.

GROUNDWATER OCCURRENCE IN MAHAULEPU

Overview of the Two Groundwater Bodies in Mahaulepu Valley

Groundwater in Mahaulepu Valley occurs in two different geologic formations. The aquifer of highest value and use resides in the unweathered Waimea volcanics which are exposed in the valley walls and buried beneath the thick alluvium which covers the valley floor. All 14 wells of the Grove Farm sugarcane plantation's Well 14 Battery were drilled through the alluvium into the volcanics at depth. The Kauai Department of Water's (DOW's) Koloa Well F (State No. 5425-15) taps into the volcanics of the west valley wall. Two other DOW wells, Koloa C and D (Nos. 5426-04 and -05), tap into the volcanics just outside of the valley (refer to Figure 1). At present, static water levels in all of the wells that tap groundwater in the volcanics stand between 22 and 26 feet above sea level and all of the wells produce water that is of potable quality.

The other groundwater body in Mahaulepu exists in the dark brown to black silty clay and clayey silt that comprise the thick alluvial blanket that covers the valley floor. The permeability of the alluvial mud is highly variable and orders of magnitude less than the permeability of the unweathered Waimea volcanics. Four monitor wells on the HDF site have been drilled into the alluvium (their locations are shown on Figure 1). Water levels in these wells vary from about 80 feet above sea level toward the inland end of the HDF site (wells HDF-1 and HDF-2) to about 50 feet at the makai end of the HDF site (HDF-3). These levels are 30 to more than 50 feet higher than the groundwater levels in the unweathered volcanics.

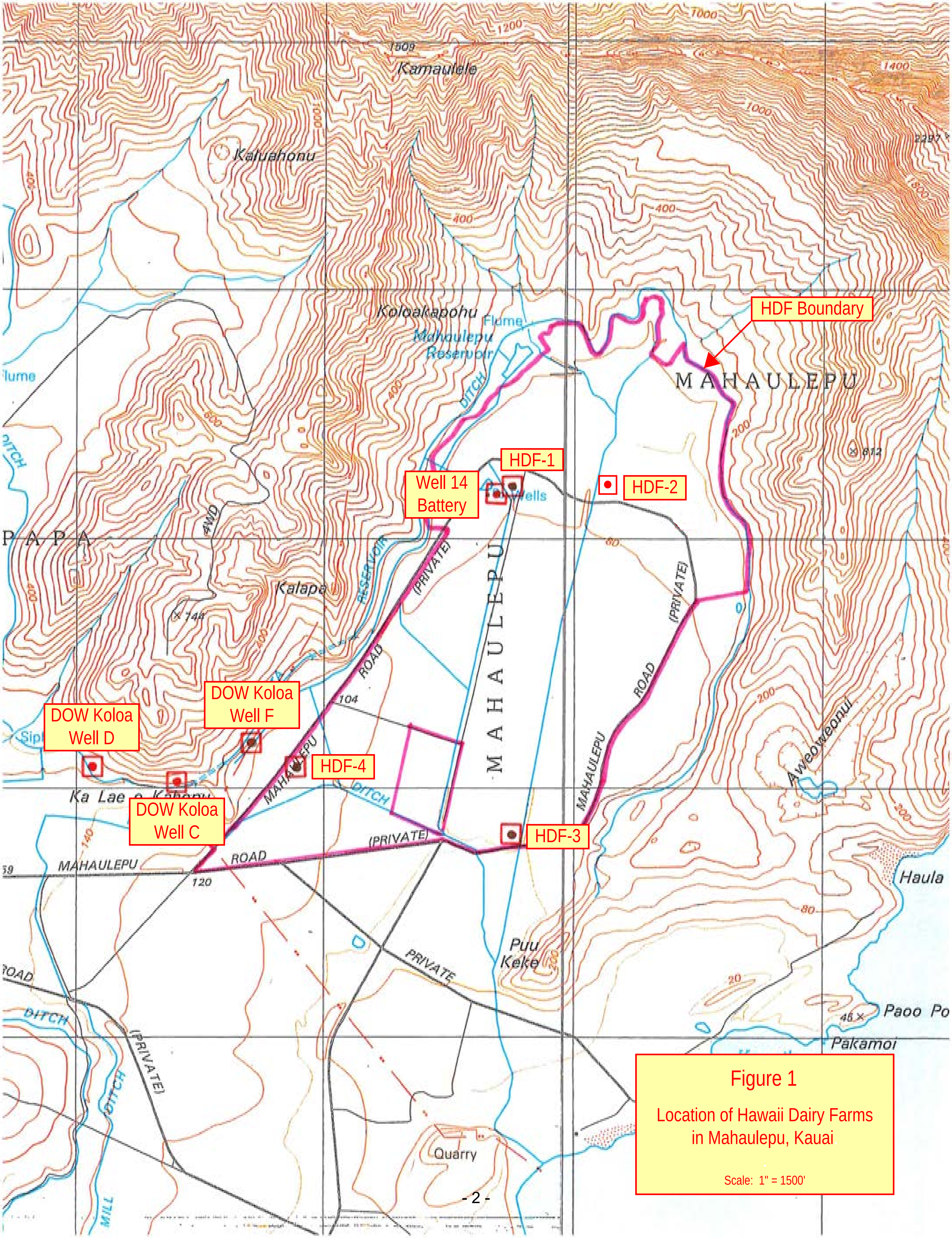


Figure 1

Location of Hawaii Dairy Farms in Mahaulepu, Kauai

Scale: 1" = 1500'

Water Levels and Quality of Groundwater in the Alluvium

Water Levels. Elevations and depths of the four HDF monitor wells are listed in Table 1. Water levels of the four HDF monitor wells were recorded over the May 13 to 20, 2015 period to establish the water levels of groundwater in the alluvium and to depict its mauka-to-makai gradient. Results are shown on Figures 2 through 5. Toward the inland end of the HDF site at the HDF-1 and -2 wells, groundwater levels in the alluvium are about 80 feet above mean sea level (MSL). The level drops rapidly going makai, to 68 feet (MSL) at HDF-4 and to 49 feet at HDF-3. In general, the movement of groundwater in the alluvium is from mauka to makai with ultimate discharge into the marine environment. The gradient is on the order of 35 feet per mile. This is far greater than is typical in Hawaii for groundwater in permeable, unweathered volcanics.

The low permeability and low effective storage of the mud that comprises the alluvial blanket across the valley floor is illustrated by the water level recordings of the HDF-2 and HDF-3 monitor wells over the November 19 to December 28, 2015 period. On November 21st, 5.95 inches of rainfall as measured by the HDF onsite rain gage produced a 2.63-foot rise in HDF-2 (Figure 6) and a 3.91-foot rise in HDF-3 (Figure 7). Over this same period, there was essentially no change in the water level in the Well 14 Battery wells which tap the aquifer in the volcanics at depth below the alluvium.

Water Quality. Table 2 presents the water quality results of two sample sets from the monitor wells taken in May and July 2015, with sampling at two depths in each well. In general, groundwater in the alluvium is fresh (salinities on the order of 0.18 to 0.47 PPT). However, the nitrogen and silica levels are much lower than typical for groundwater in Hawaiian basalt. Typical nitrogen levels in Hawaiian basalt aquifers are 70 to 80 μM. Typical silica levels are 700 μM. For the groundwater in the alluvium sampled from the monitor wells, nitrogen and silica are about half the levels typical in basalt aquifer wells.

Wells Drawing from the Aquifer in the Waimea Volcanics

Available Information on the Well 14 Battery. The Well 14 Battery in Mahaulepu consists of 14 wells which were drilled through the alluvial mud to tap the aquifer in the volcanics at depth (refer to Table 3). The first 10 wells (State Nos. 5425-01 to -10) were drilled in the 1897 to 1901 time period. All of the well depths were between 300 to 303 feet below the existing ground at a reported elevation of 85 feet. All were outfitted with 12-inch solid steel casing to below ground depths between 210 to 242 feet. Lengths of open hole below the solid casing were from 61 to 92 feet, equivalent to between 157 and 218 feet below sea level.

Table 1

Elevations and Depths of the Four HDF Monitor Wells

Monitor Well Name	HDF-1	HDF-2	HDF-3	HDF-4
Approximate Ground Elevation (Feet MSL)	85	92	57	92
Measuring Point Elevation (Feet MSL)	88.16	94.39	60.74	95.47
Well Depth (Feet)	101.6	100.8	51.3	57.7
Elevation at Bottom (Feet MSL)	-13.4	-6.4	9.4	37.8

Notes:
1. Measuring point for all wells is the top of their 4-inch PVC casings.
2. Well depths are measured from the tops of the 4-inch PVC well casings.

Figure 2. Recorded Water Level in the HDF-1 Well

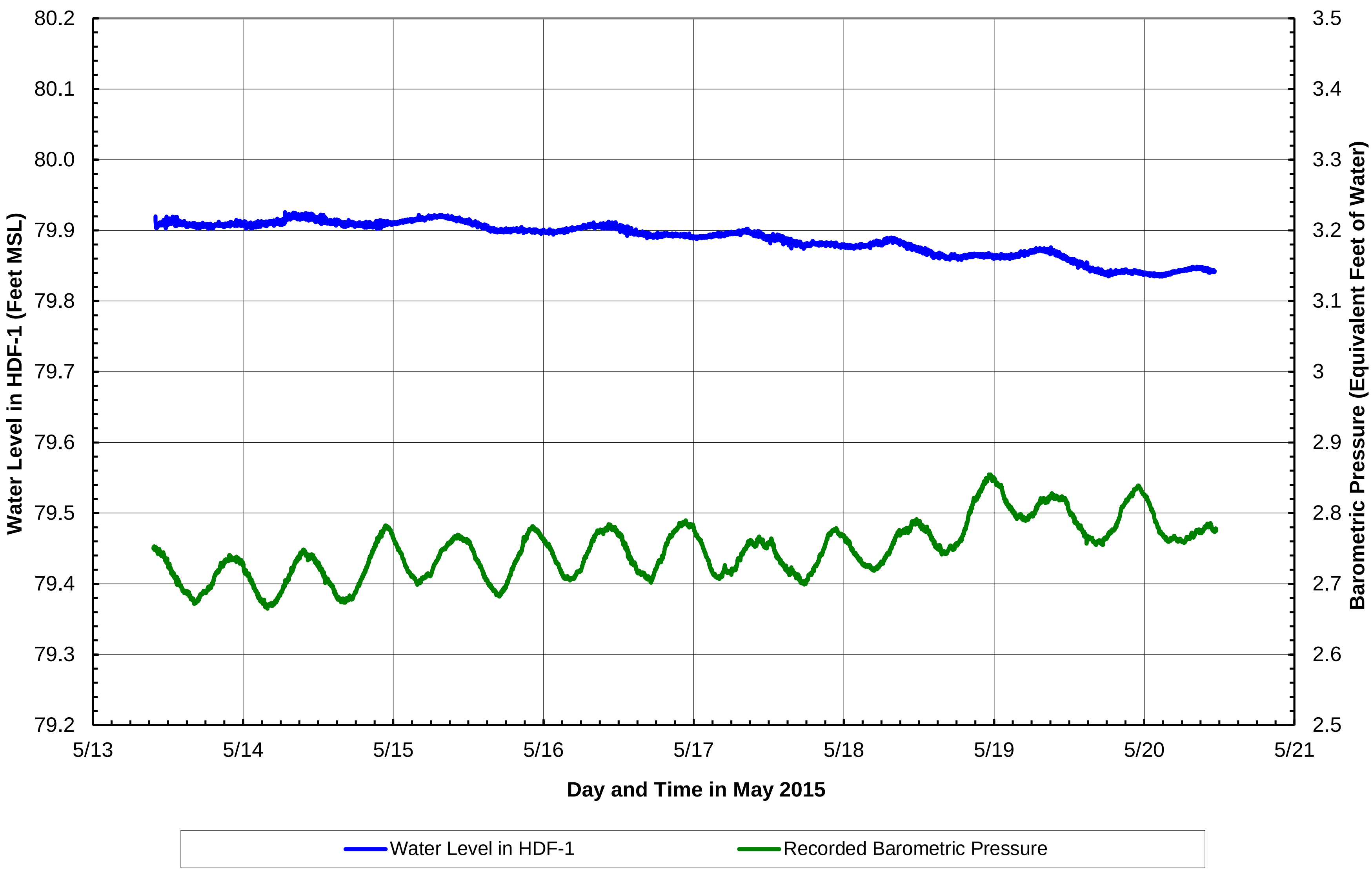


Figure 3. Recorded Water Level in the HDF-2 Well

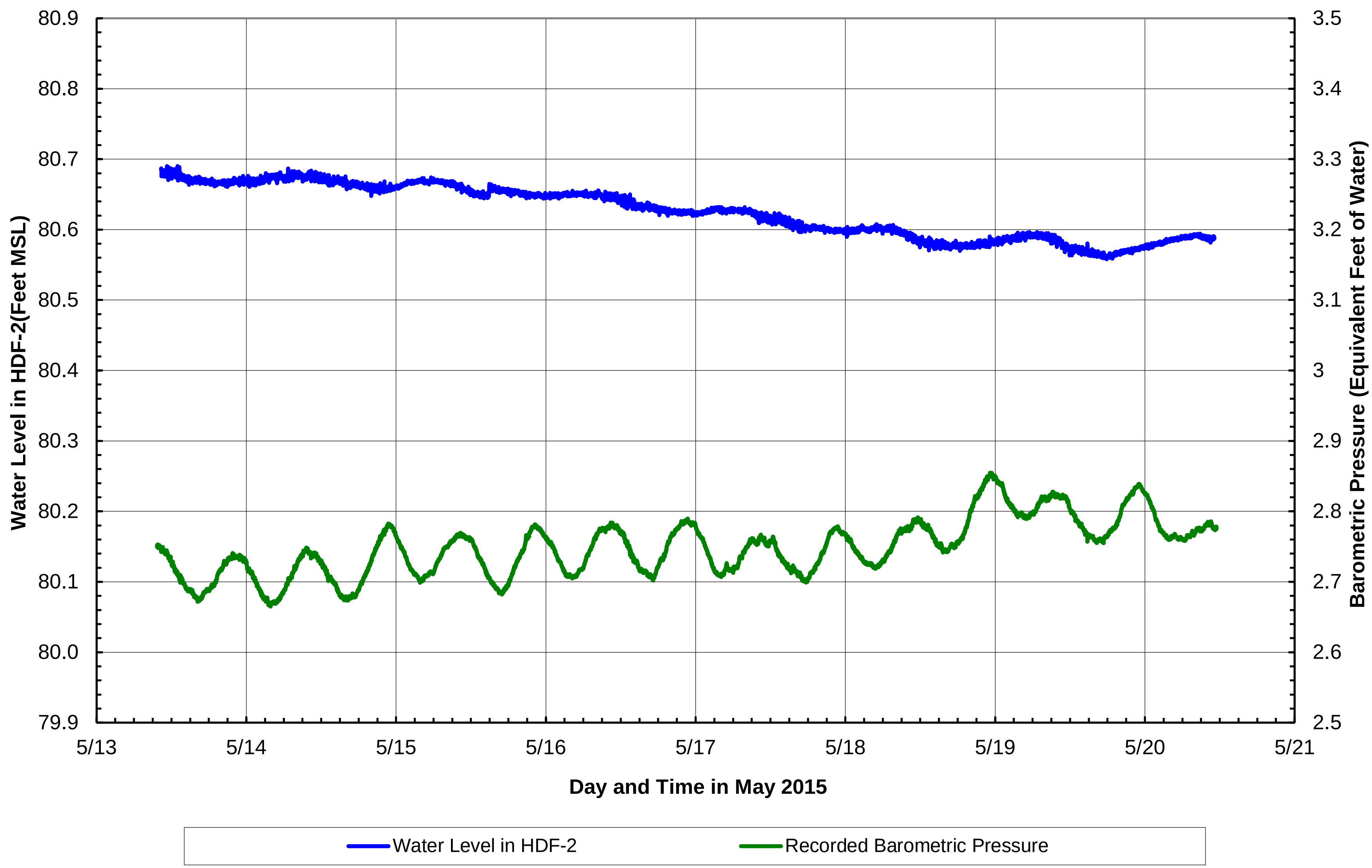


Figure 4. Recorded Water Level in the HDF-3 Well

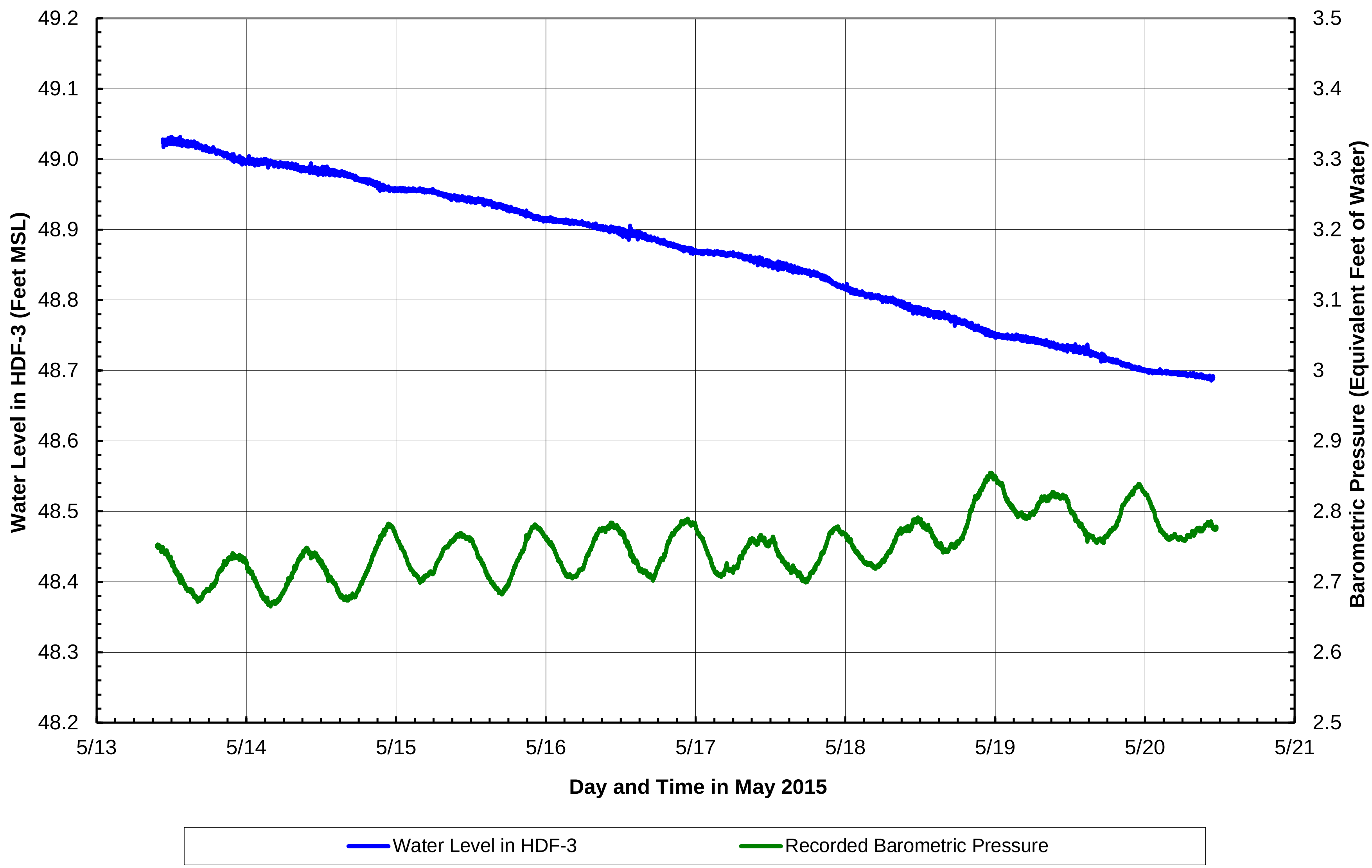


Figure 5. Recorded Water Level in the HDF-4 Well

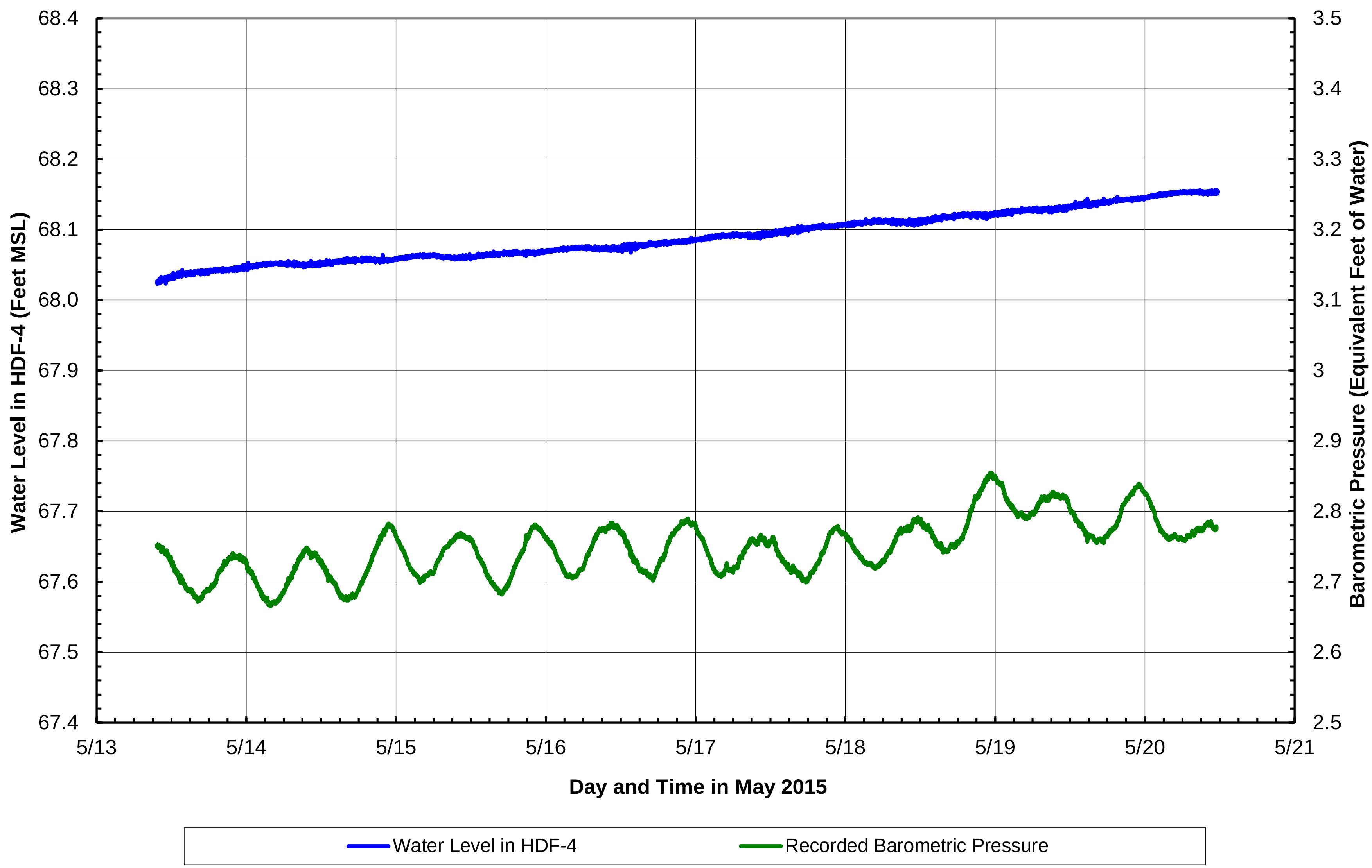


Figure 6. Water Level Response in HDF-2 to Rainfall Over the November 19 to December 28, 2015 Period

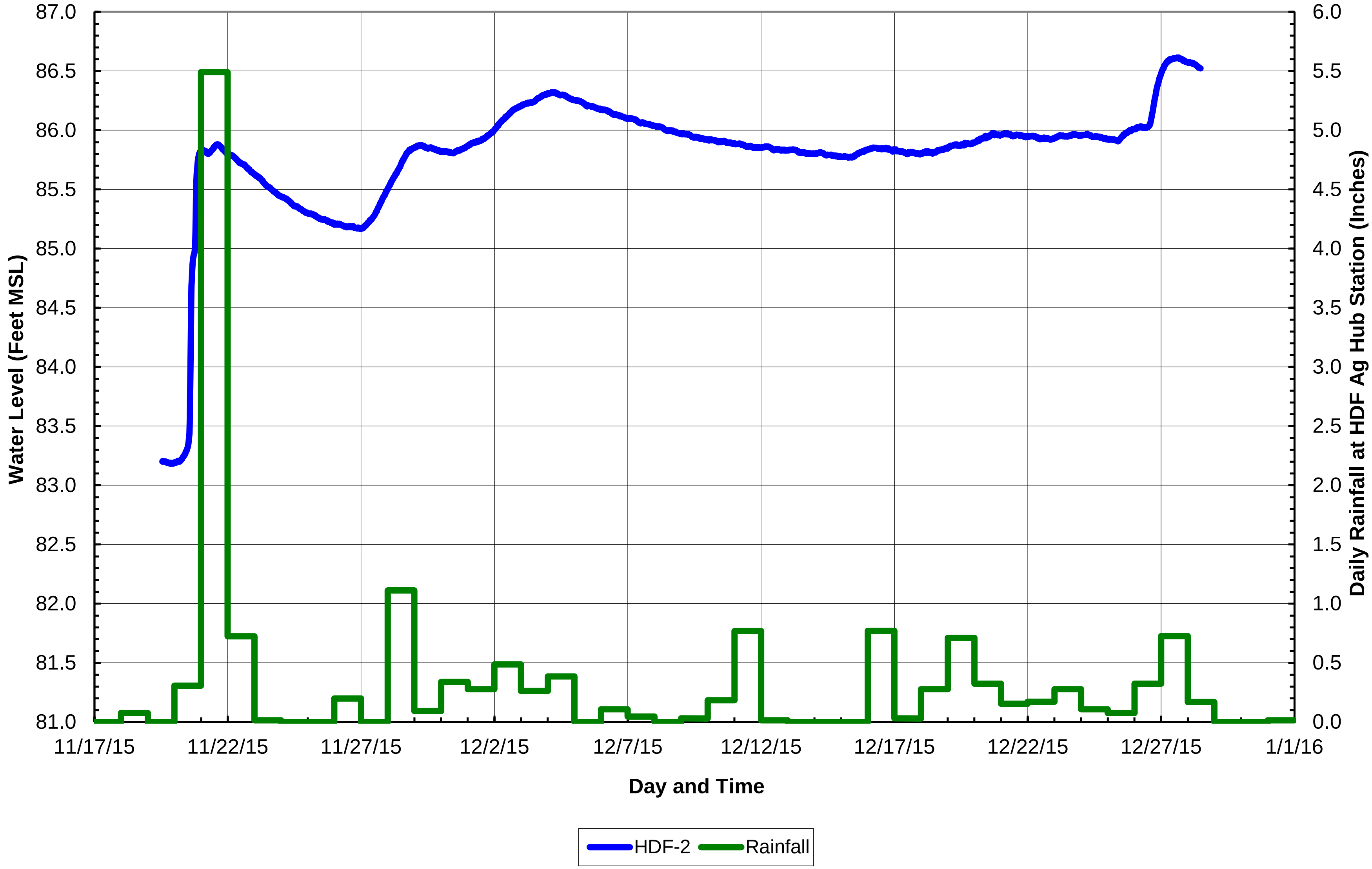


Figure 7. Water Level Response in HDF-3 to Rainfall Over the November 19 to December 28, 2015 Period

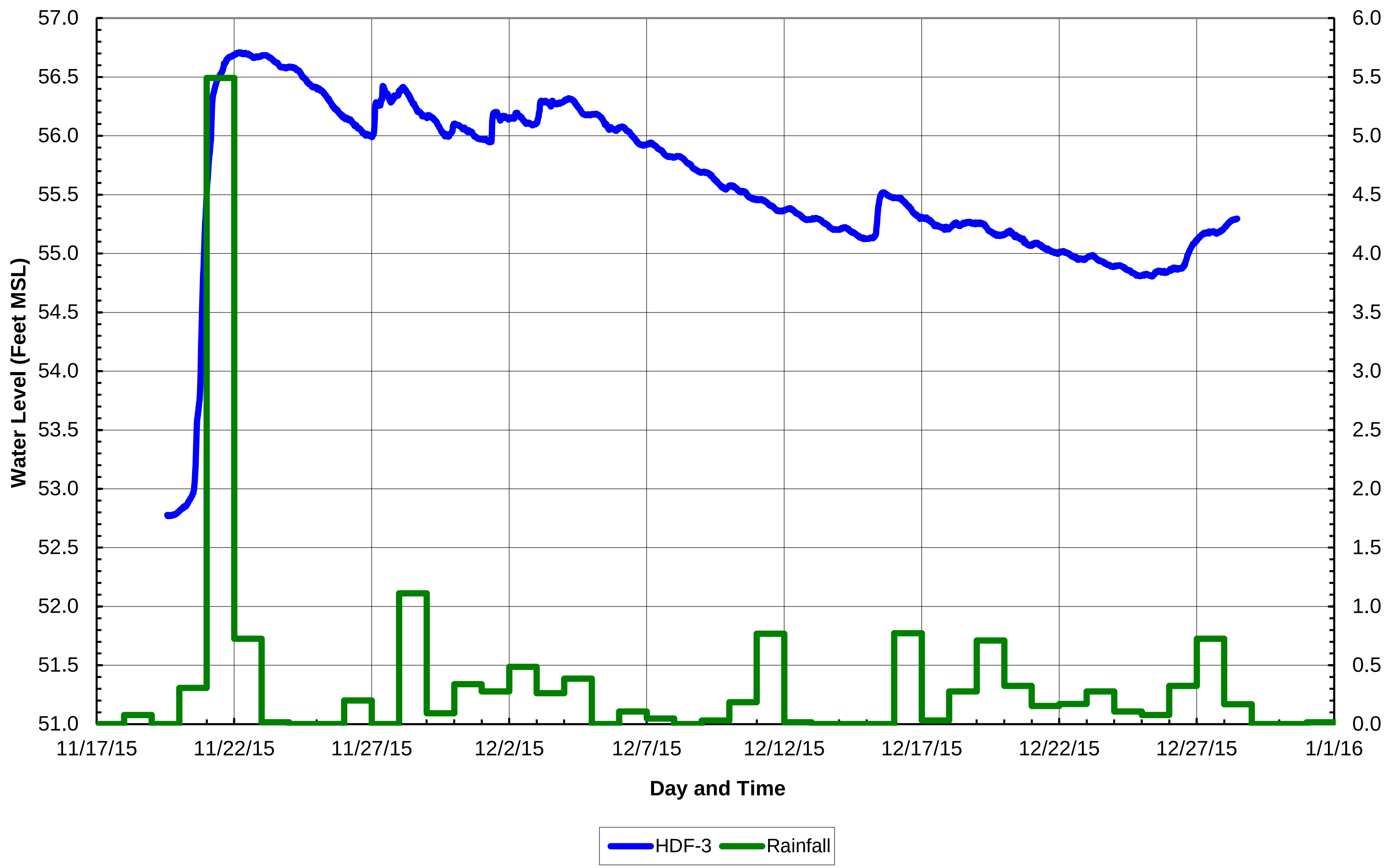


Table 2. Quality of Water Samples Taken from the Monitor Wells on the Hawaii Dairy Farms Site

Monitor Well No.	Sample Date	Depth into Water (Feet)	Forms of Nitrogen $NO_3^-+NO_2^-$ (µM)	NH_4^+ (µM)	TON (µM)	TN (µM)	Forms of Phosphorus PO_4^{3-} (µM)	TOP (µM)	TP (µM)	Silica (µM)	Turbidity (ntu)	Salinity (ppt)	pH (pH Units)
HDF-1	5/8/2015	5	21.23	1.05	5.00	27.28	0.63	0.11	0.74	437	0.99	0.257	6.315
	7/9/2015	5	10.24	1.07	20.42	31.73	0.10	0.25	0.35	360	1.31	0.281	5.938
	5/8/2015	50	28.18	0.93	5.67	34.78	0.73	0.06	0.79	441	1.98	0.241	6.273
	7/9/2015	50	29.29	0.52	12.01	41.82	0.13	0.23	0.36	383	0.95	0.249	6.084
HDF-2	5/8/2015	5	19.50	1.45	12.23	33.18	0.90	0.01	0.91	312	2.32	0.192	6.464
	7/9/2015	5	21.79	0.73	16.26	38.78	0.06	0.24	0.30	294	4.43	0.191	6.130
	5/8/2015	55	13.43	1.00	14.80	29.23	0.63	0.24	0.86	322	1.87	0.184	6.468
	7/9/2015	55	26.05	0.67	9.80	36.52	0.14	0.31	0.45	308	11.2	0.185	6.137
HDF-3	5/8/2015	5	11.90	1.78	15.98	29.65	1.10	0.26	1.36	416	3.02	0.391	7.054
	7/9/2015	5	1.92	0.75	30.02	32.69	0.30	0.42	0.72	379	1.41	0.442	6.805
	5/8/2015	25	14.98	1.30	9.18	25.45	1.23	0.04	1.26	410	1.36	0.474	6.974
	7/9/2015	25	5.31	0.69	21.79	27.79	0.60	0.32	0.92	380	1.01	0.492	6.821
HDF-4	5/8/2015	5	0.63	1.55	19.43	21.60	0.95	0.39	1.34	429	12.7	0.211	6.614
	7/9/2015	5	2.99	0.32	38.01	41.32	0.16	0.48	0.64	432	1.81	0.329	6.378
	5/8/2015	25	13.90	1.68	13.48	29.05	1.03	0.14	1.16	468	18.5	0.357	6.319
	7/9/2015	25	15.8	0.41	12.58	28.79	0.28	0.42	0.70	417	4.49	0.363	6.141

Table 3. Available Information on Wells in and Near to Mahaulepu, Kauai

State Number	Well Name	Year Drilled	Casing Diam (Inches)	Ground Elev. (Feet MSL)	Total Depth (Feet)	Elev. At Bottom of Well (Feet MSL)	Length of Solid Casing (Feet)	Elev. At Bottom of Solid Csg. (Feet MSL)	Length of Slotted Casing (Feet)	Initial Water Level (Feet MSL)	Initial Chlorides (MG/L)	Installed Pump Capacity (GPM)
5425-01	Well 1	1897	12	85	303	-218	242	-157	None			
5425-02	Well 2	1897	12	85	300	-215	242	-157	None			
5425-03	Well 3	1897	12	85	300	-215	220	-135	None			
5425-04	Well 4	1897	12	85	301	-216	224	-139	None			
5425-05	Well 5	1897	12	85	300	-215	210	-125	None			
5425-06	Well 6	1897	12	85	304	-219	212	-127	None			
5425-07	Well 7	1899	12	85	300	-215	215	-130	None			
5425-08	Well 8	1899	12	85	300	-215	215	-130	None			
5425-09	Well 9	1901	12	85	300	-215	215	-130	None			
5425-10	Well 10	1901	12	85	300	-215	215	-130	None			
5425-11	Well 11	1927	12	85	505	-420	245	-160	None	31.1	70	
5425-12	Well 12A	1927	12	85	506	-421	301	-216	None	31.0	65	
5425-13	Well 13	1927	12	85	510	-425	309	-224	None	31.0	72	
5425-14	Well 14	1928	12	85	532	-447	315	-230	None	30.0	75	
5425-15	Koloa F	1998	16	130	377	-247	123	7	175	25.9	84	1200
5426-04	Koloa C	1977	16	157	393	-236	293	-136	None	25.1		1200
5426-05	Koloa D	1981	16	222	420	-198	320	-98	None	24.0	98	1200

Note: Information from the State Commission on Water Resource Management's Groundwater Index

The original 10 wells were linked together by a manifold system about 50 feet below ground. Steam-driven pumps in a pit delivered water from the manifolded wells to the furrow-irrigated sugarcane fields. Difficulty with the stability of the walls of the pump sump led to a major modification of the facility in 1927 to 1928. Four new wells were drilled (Nos. 5425-11 to -14) and the original 10 wells, connecting subsurface manifold, and pump sump were abandoned in place. No plans or drawings could be located that depict the portions of the system that were abandoned. There is a perennial water feature in the near vicinity which is likely to be the location of the abandoned pump sump.

The four new wells that were added to the Well 14 Battery in 1927 to 1928 were drilled deeper than the original 10 wells (to below ground depths of 505 to 532 feet) and also had 12-inch solid casing installed to greater depths (245 to 319 feet). Only three of these four wells can be found today. All three of these wells at one time were outfitted with oil lubricated line shaft turbine pumps, but only one of the three also had a motor when work on this assessment was initiated in 2014. The pumps were still in the other two wells but their motors had been removed. According to recollections of plantation personnel, only the well with the motor was in use for the last 20 or so years of the plantation's existence (it is the westernmost of the three wells and adjacent to what is believed to be the abandoned pump sump for the first 10 wells). Its pump and motor reportedly delivered about 3.0 MGD. The depths of three wells were measured to try to correlate these with historic records. However, the measured depths do not correlate with the historic records (from west to east, the measured depths were 506.1, 494.3, and 500.8 feet).

<u>Information on the Kauai Department of Water (DOW) Wells</u>. DOW has three wells in the near vicinity of the HDF site (refer to Figure 1 and the bottom of Table 2). The closest is Koloa Well F (No. 5425-15). It is located in the west valley wall and is about 580 feet from the HDF's western boundary. The other two wells, known as Koloa Wells C and D, are located at the foot of the valley's west ridge and are 1170 and 2140 feet, respectively, from the nearest point of the HDF site. All three wells are outfitted with 1200 GPM pumps. Depths of these wells are notable, ranging from 247 feet below sea level for Koloa Well F to 198 feet below sea level for Koloa Well D. All three were drilled through weathered volcanics (saprolite) to reach the unweathered, water bearing volcanics.

Possible Hydrologic Connection Between the Groundwater Bodies in the Alluvium and at Depth in the Unweathered Waimea Volcanics

Since groundwater levels in the alluvium are 30 to more than 50 feet higher than the piezometric head of groundwater confined in the underlying and unweathered volcanics at depth below the alluvium, it is reasonable to question whether groundwater in the alluvium discharges into the lower, confined groundwater body in the unweathered volcanics. Several types of information are available to assess this possibility: (1) logs of the last four wells drilled of the Well 14 Battery which fully penetrated the alluvium to the unweathered volcanics at depth; (2) contrasting salinity and temperatures of groundwater in the two groundwater bodies; (3) results of a pump test of one of the Well 14 Battery wells drawing water from the unweathered volcanics at depth with monitoring of the possible response in groundwater in the alluvium; and (4) measured responses of groundwater in the alluvium to operation of the Koloa Well F pump. Each of these is described in the sections following. All indicate that there is complete hydrologic separation of the two groundwater bodies.

Driller's logs of the Well 14 Battery Wells. Driller's logs for the last four wells of the Well 14 Battery are in the 1960 Bulletin 13 of the Hawaii Division of Hydrography (pages 154 to 156) and are reproduced here as Table 4. Sticky red, brown, and purple clay layers are logged from depths of 75 to 300 feet. These layers are essentially impermeable and function as an aquiclude to separate the shallow groundwater in the alluvium from the confined groundwater in the underlying volcanics.

Comparative Salinity and Temperature Profiles. Figure 8 is a conductivity and temperature profile through one of the Well 14 Battery of wells, very likely No. 5425-14 based on the depth of its solid casing. Groundwater in the confined aquifer at depth below the solid casing has an essentially uniform conductivity of 335 µS/cM and temperature of 72.0°F. Conductivity and temperature profiles in the monitor wells are shown on Figures 9 to 12. In contrast to the water in the unweathered volcanics, water in the alluvium is two to six degrees warmer and its conductivity is significantly different, being both fresher (in HDF-2) and significantly more saline (in HDF-1, HDF-3, and HDF-4) than in the groundwater in the volcanics at depth. The source of recharge to groundwater in the alluvium is percolation of rainfall directly on to the alluvium and surface runoff from the upland areas, both of which provide exceptionally fresh water. The source of the much higher salinity water at depth in the HDF-3 and HDF-4 wells is not known. In any event, there are significant salinity and temperature differences of the water in both aquifers which suggest that discharge of water from the alluvium into the volcanics at depth is not occurring.

Pump Test of the Middle Well of the Well 14 Battery. On March 17, 2015, the middle of the three remaining wells of the Well 14 Battery was pumped tested for 10 hours to see if this would produce a response in groundwater in the alluvium. Water level recorders were installed in the pumped well, in the two other Well 14 Battery wells, and in the HDF-1 and HDF-2 monitor wells. All water levels were recorded at 30-second intervals.

Pumping rates and water level response in the pumped well are depicted on Figure 13. Its drawdown at the end of the test was quite substantial (17.1 feet at a pumping rate of 825 GPM) and the drawdown and recovery had a time-dependent component typical of a confined aquifer (Figure 14). Drawdowns in the two adjacent wells of the Well 14 Battery were essentially instantaneous (in the same 30-second recording interval) and were also quite substantial (5.3 and 3.7 feet in the wells to the east and west as shown on Figure 15). These wells are 96 and 67 feet from the pumped well, respectively. They also exhibited similar time-dependent drawdowns and recoveries (Figures 16 and 17).

Table 4. Driller's Log of Wells 5425-11 to -14 in the Well 14 Battery

Well 14K

Driller's log

	Depth (ft.)
Clay	0- 60
Brown and blue lava. Struck water at 64 ft. which rose to 31 ft. below ground. Can bail water down	60- 69
Red clay, caving and sticky	69- 85
Red, blue, and brown clay	85-120
Purple clay, sticky	120-165
Brown sandy clay	165-192
Rotten rock and rubble. Some water at about 198 ft. standing about 26 ft. above sea level, but could bail it down to below sea level	192-248
Porous lava	248-252
Hard blue stone	252-261
Blue and red porous lava. Water at about same level to 330 ft. where it rose to 30 ft. above sea level. Does not bail down	261-342
Hard lava and blue stone	342-345
Porous lava	345-352
Hard lava and blue stone	352-358
Hard blue and red porous lava	358-370
Blue stone and brown lava	370-385
Blue and red porous lava with small streaks of blue stone. At 390 ft. water stands 32 ft. above sea level	385-475
Hard brown lava full of olivines	475-483
Red porous lava and volcanic ash and brown burnt porous clay	483-486
Blue and brown and red lava; blue and brown lava with olivines and very hard	486-506

Well 14L

	Depth (ft.)
Red, blue, and brown clay	0- 54
Hard blue lava	54- 60
Brown and gray rotten lava	60- 63
Hard blue lava	63- 64
Rotten brown lava, some black sand	64- 67
Hard blue lava	67- 76
Reddish brown clay	76- 99
Red, blue, and brown clay	99-114
Purple and brown clay	114-159
Greenish brown clay, sandy	159-184
Brown clay and rotten rock	184-236
Blue and brown lava, hard	236-243
Brown clay and rotten rock	243-252
Blue and brown lava	252-264
Rotten rock	264-292
Red, blue, and brown porous lava, some hard streaks, water	292-319
Red lava, some porous	319-324
Red lava, very hard	324-334
Red, blue, and brown lava, some porous. At 369 ft. water stands 29 ft. above sea level	334-384
Very hard brown lava	384-396
Blue and brown porous lava, some hard streaks	396-434
Red, blue, and brown porous lava	434-449
Blue and brown porous lava	449-479
Hard blue lava full of olivines	479-491
Brown porous lava, some hard streaks. At 501 ft. water stands 32 ft. above sea level	491-502
Hard, brown lava full of olivines. At 506 ft. water stands 31 ft. above sea level	502-506

Well 14M

	Depth (ft.)
Red and blue clay	0- 43
Blue clay	43- 62
Rubble and brown clay. At 72 ft. brown sandy mud thin enough to bail rose to 44 ft.	62- 72
Hard lava, blue and brown	72- 75
Reddish brown clay	75- 97
Brown and purple sandy clay	97-128
Light brown clay, sticky	128-148
Chocolate brown clay, sticky	148-189
Greenish brown clay, very tough and sticky	189-215
Blue clay and rotten rock	215-257
Volcanic ash, cinders, and fine sand, all colors	257-273
Brown clay and lava sand	273-299
Hard red lava. Water stands 25 ft. above sea level	299-311
Hard brown lava	311-326
Hard blue rock. At 328 ft. water stands 27 ft. above sea level	326-330
Hard, red, blue and brown lava, some porous	330-335
Greenish gray sandstone	335-343
Red, blue, and brown lava. At 348 ft. water stands 28 ft. above sea level	343-368
Red lava, porous streaks, some hard streaks	368-373
Brown lava, some porous. At 383 ft. water stands 28 ft. above sea level	373-383
Very hard brown lava	383-395
Brown lava, porous	395-401
Small hard streak	401-402
Red, brown, and greenish sandy lava, porous	402-440
Brown and gray lava, very hard	440-447
Red and brown porous lava	447-459
Red, blue and brown lava; some porous streaks and some very hard streaks full of olivines. At 510 ft. water stands 31 ft. above sea level	459-510

Well 14N

	Depth (ft.)
Red, blue, and brown clay	0- 72
Lava	72- 75
Reddish brown clay	75-124
Purple and brown clay	124-209
Brown clay and rotten rock	209-302
Red lava	302-322
Brown porous lava	322-359
Hard blue lava	359-374
Red, blue, and brown porous lava, hard streaks	374-404
Brown porous lava, some hard streaks	404-434
Hard brown lava, porous streaks	434-454
Red, blue, and brown porous lava	454-462
Blue and brown hard lava full of olivines	462-479
Red and blue hard lava full of olivines	479-489
Red lava full of olivines	489-496
Red and blue hard lava full of olivines	496-502
Red, blue, and brown porous lava full of olivines	502-510
Blue rock and porous lava	510-526

Figure 8. Conductivity and Temperature Profile of the Water Column of the Westernmost Well of the Well 14 Battery Made on November 6, 2014

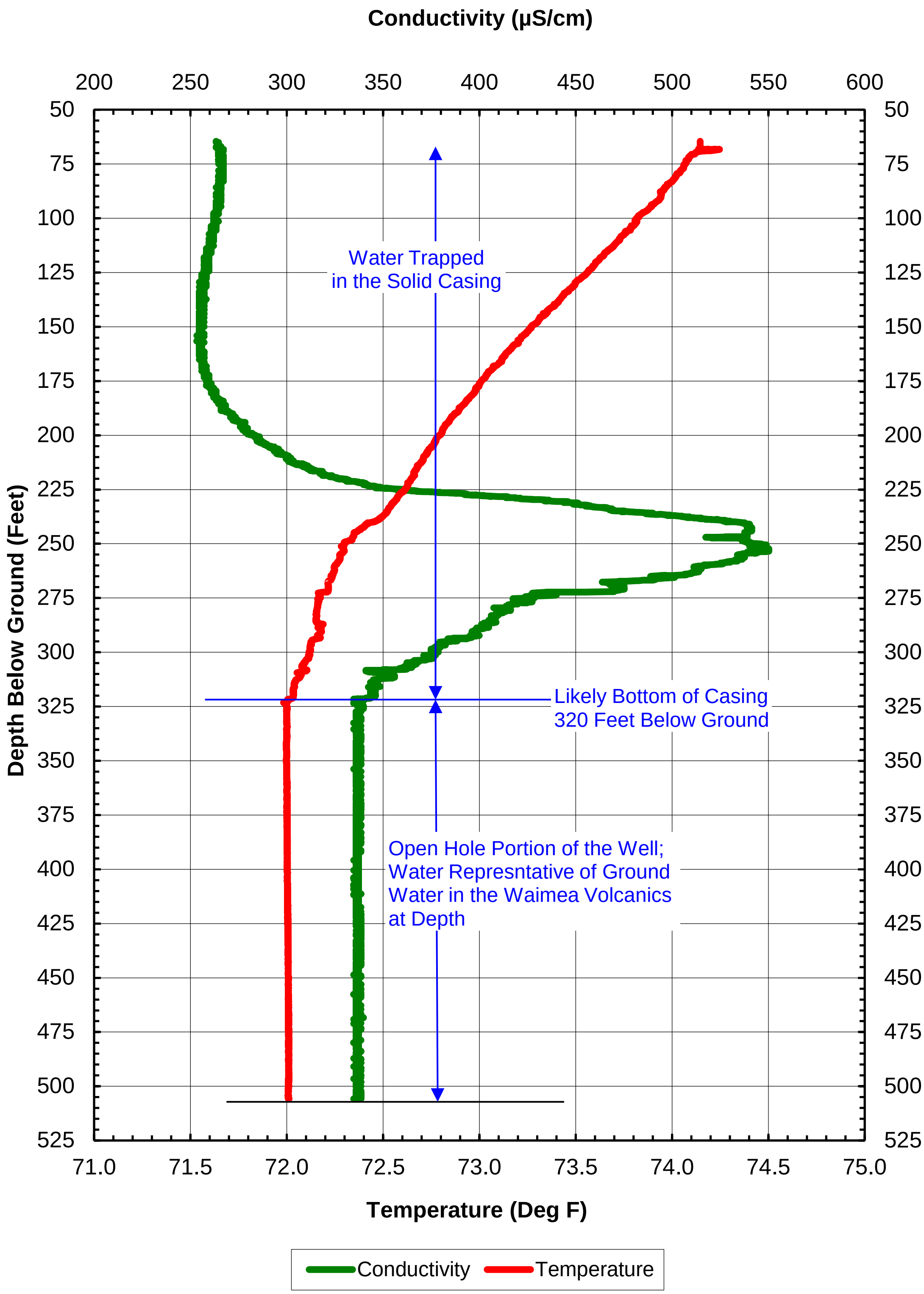


Figure 9. Conductivity and Temperature Profile of the HDF-1 Monitor Well July 9, 2015

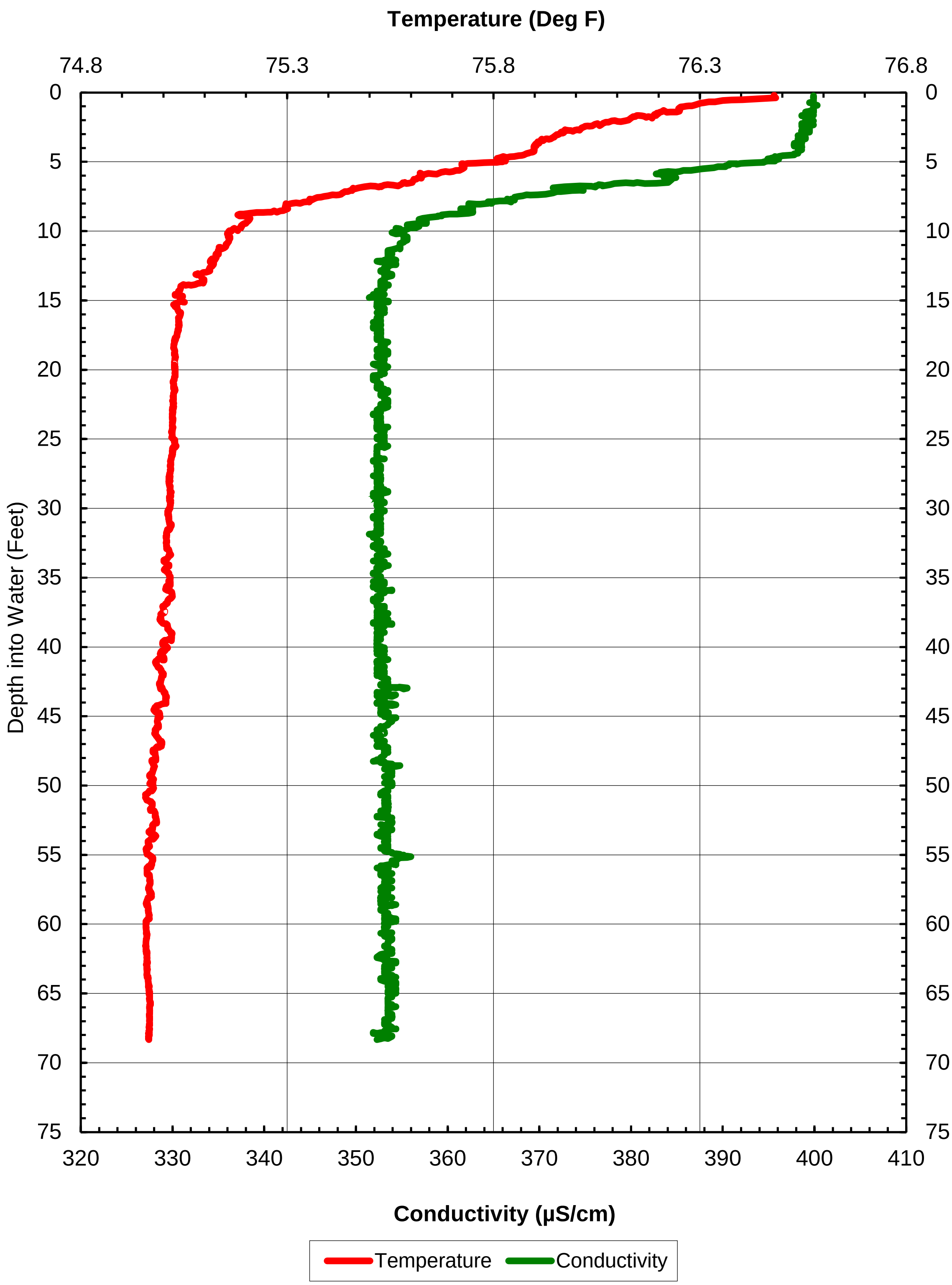


Figure 10. Conductivity and Temperature Profile of the HDF-2 Monitor Well July 9, 2015

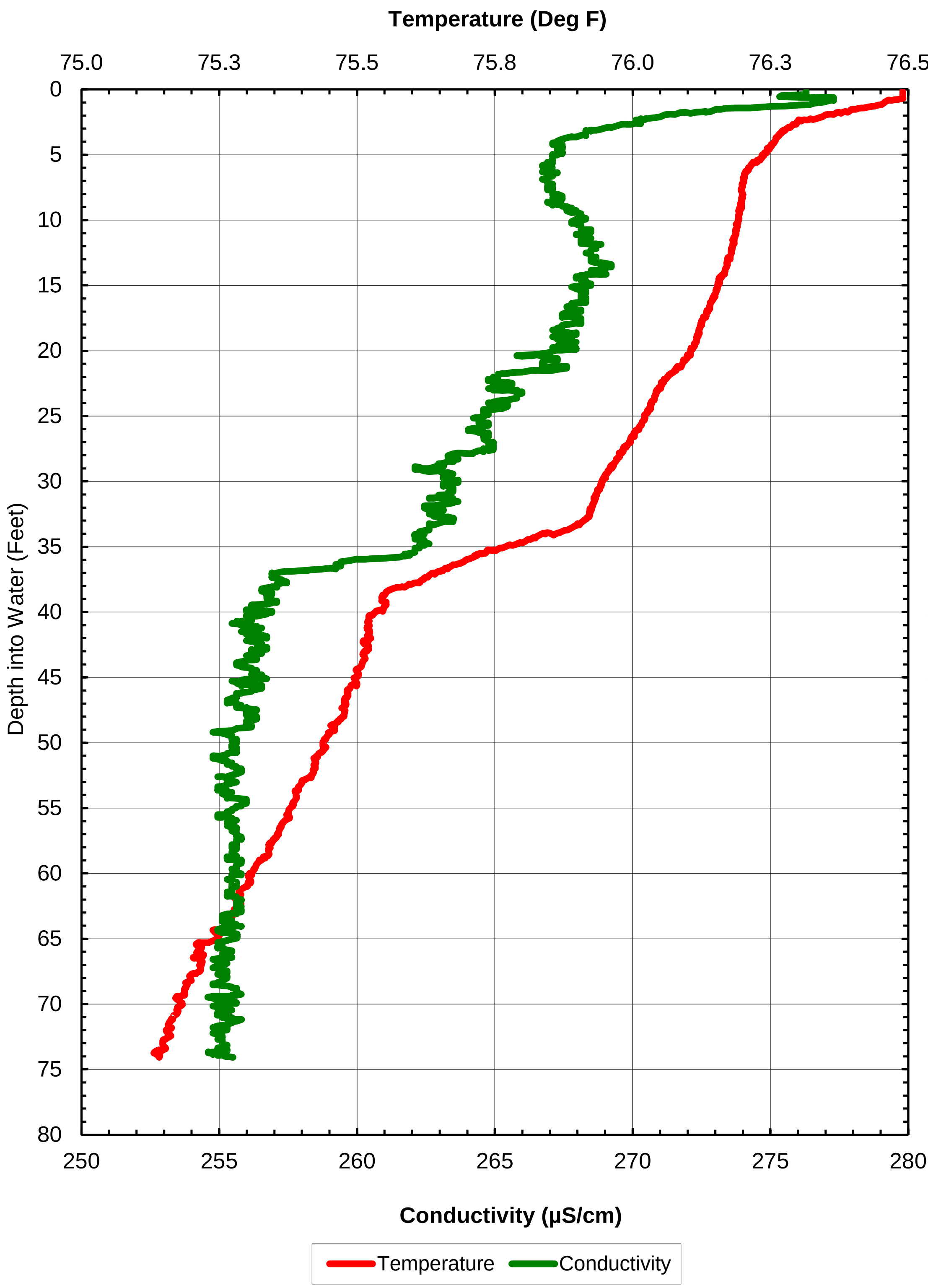


Figure 11. Conductivity and Temperature Profile of the HDF-3 Monitor Well July 9, 2015

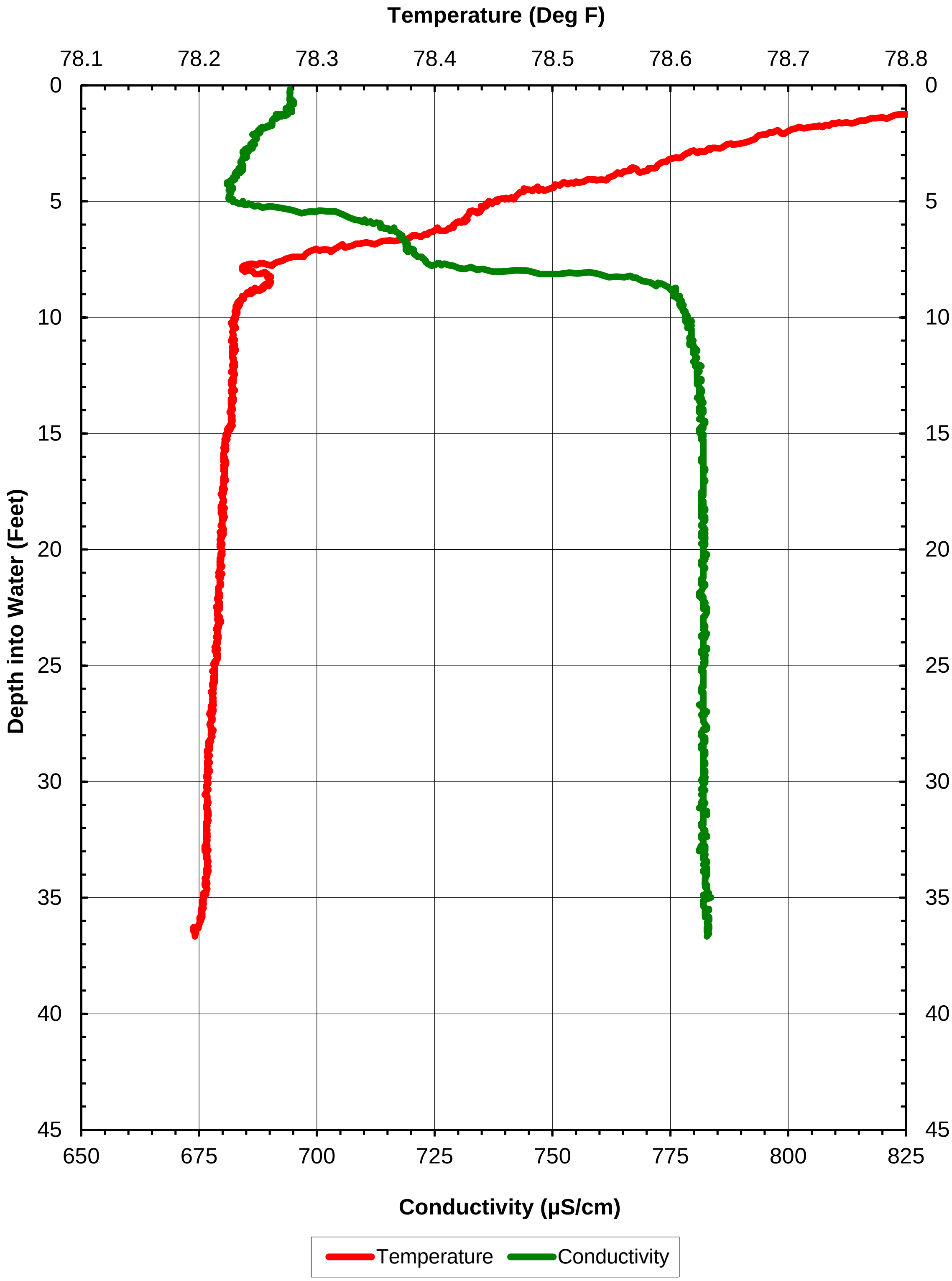


Figure 12. Conductivity and Temperature Profile of the HDF-4 Monitor Well July 9, 2015

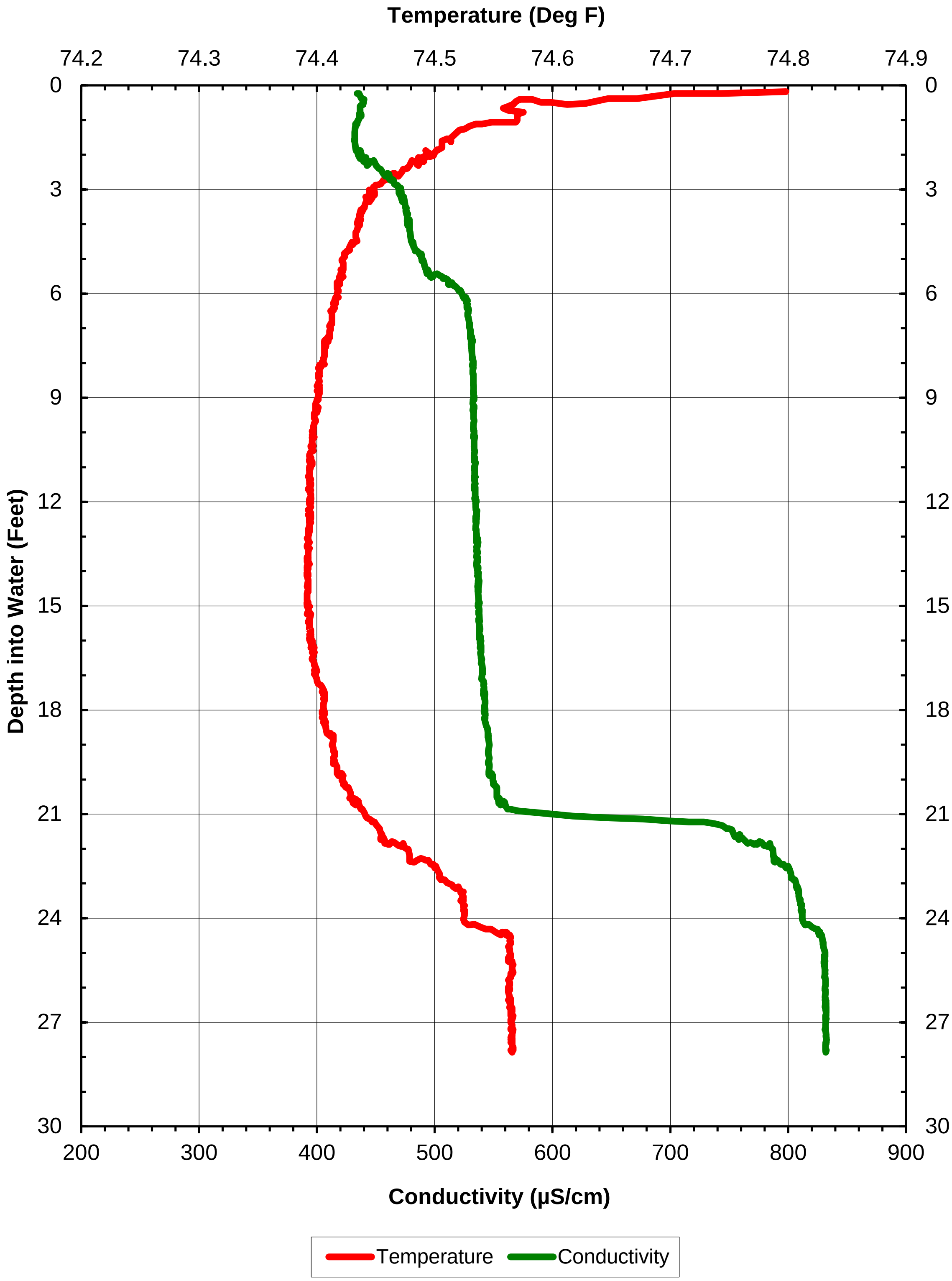


Figure 13. Pumping Rates and Water Level Response in the Pumped Well During the March 17, 2015 Test of the Well 14 Battery

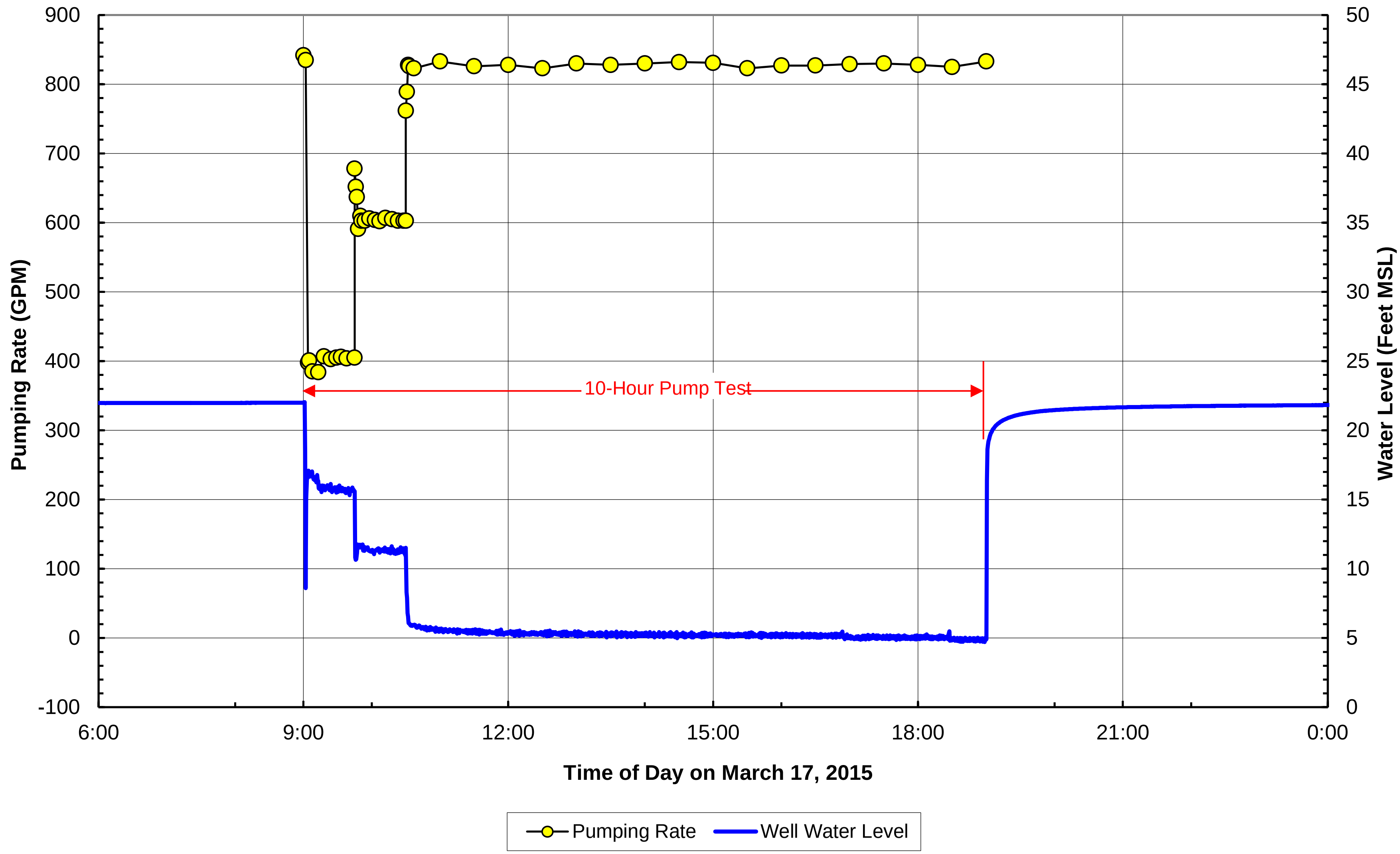


Figure 14. Semilog Plot of Drawdown and Recovery in the Pumped Well During and Following the March 17, 2015 Pump Test

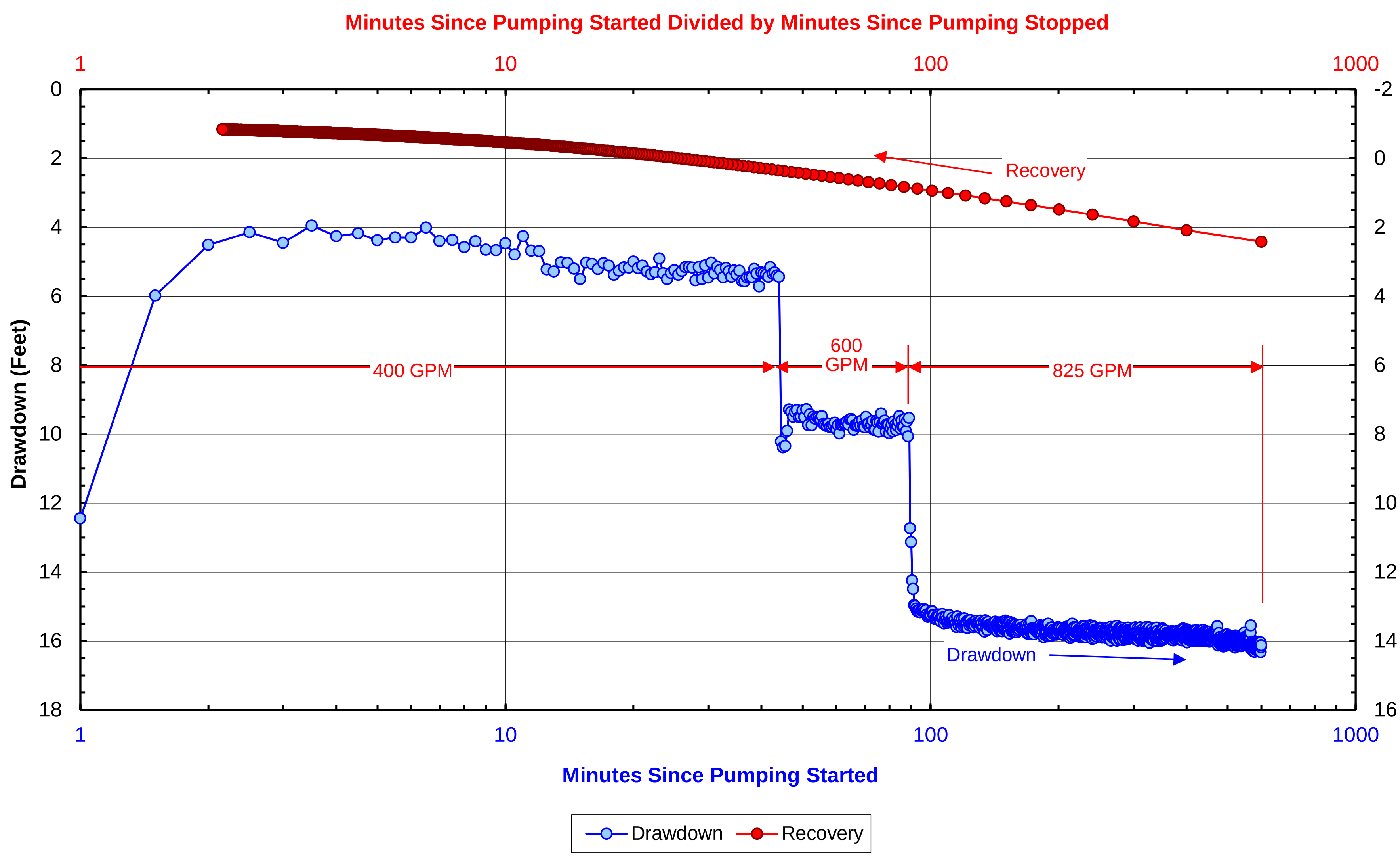


Figure 16. Semilog Plot of Drawdown and Recovery in the Well to the East of the Pumped Well
During the March 17, 2015 Pump Test

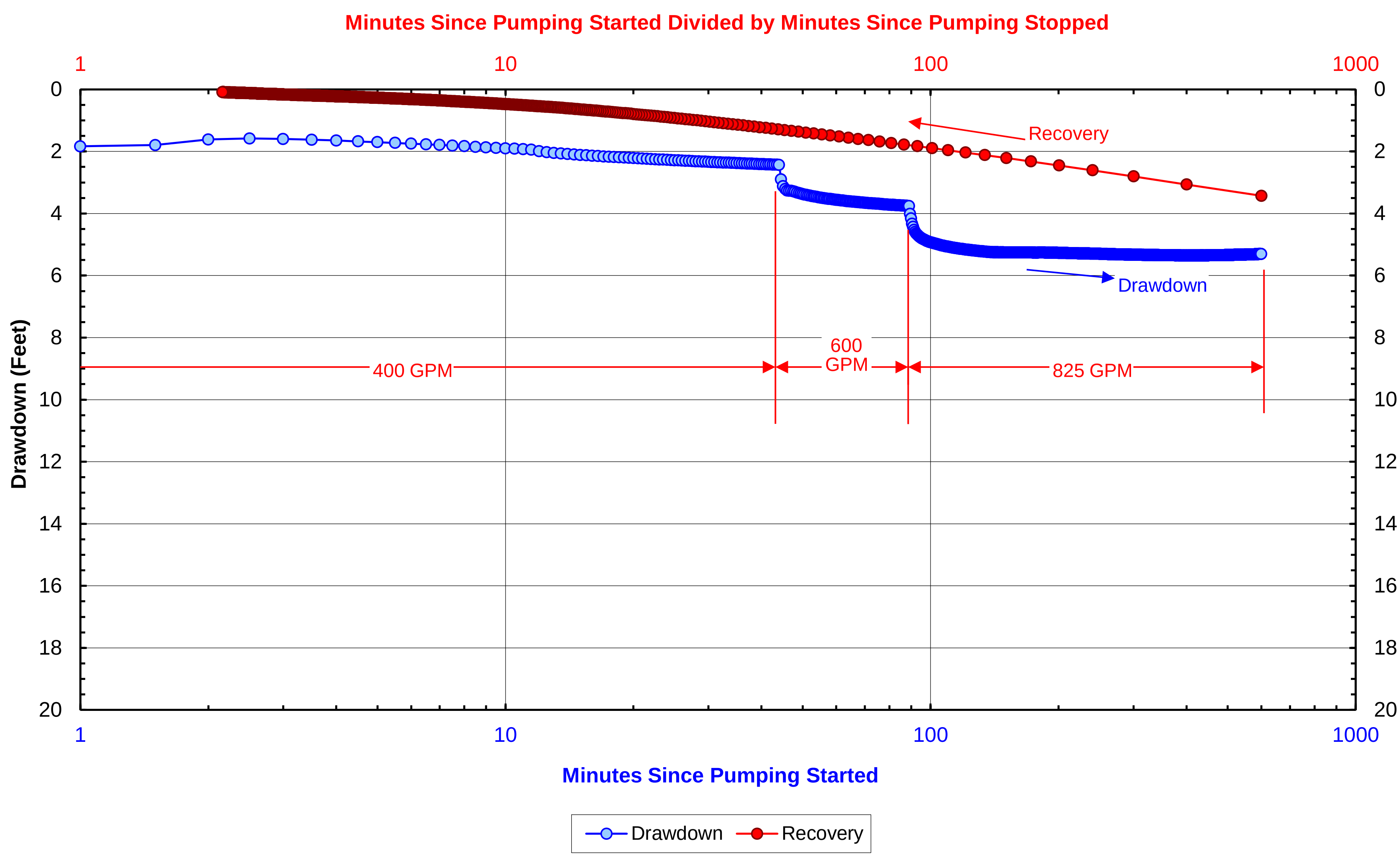


Figure 17. Semilog Plot of Drawdown and Recovery in the Well to the West of the Pumped Well During the March 17, 2015 Pump Test

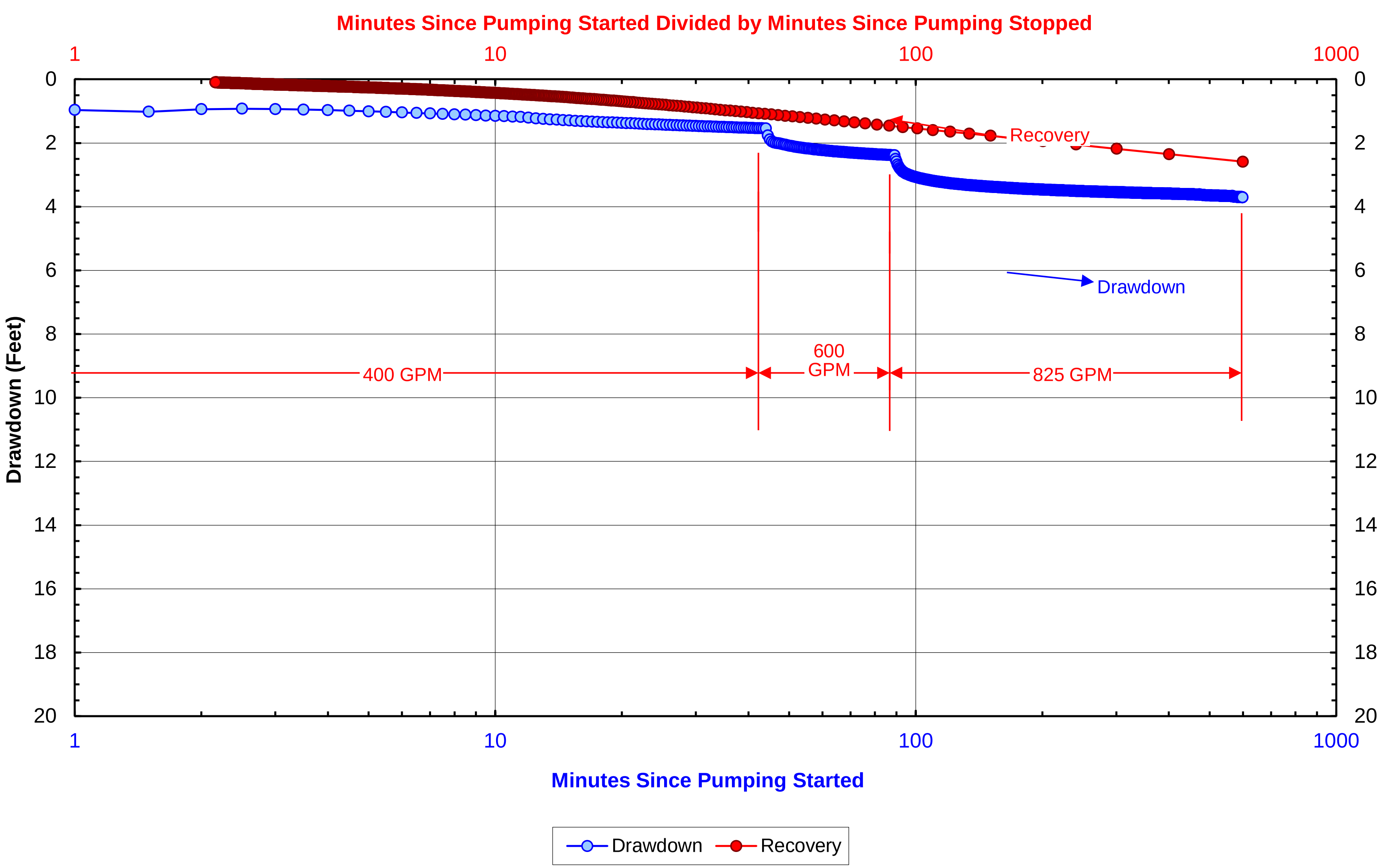
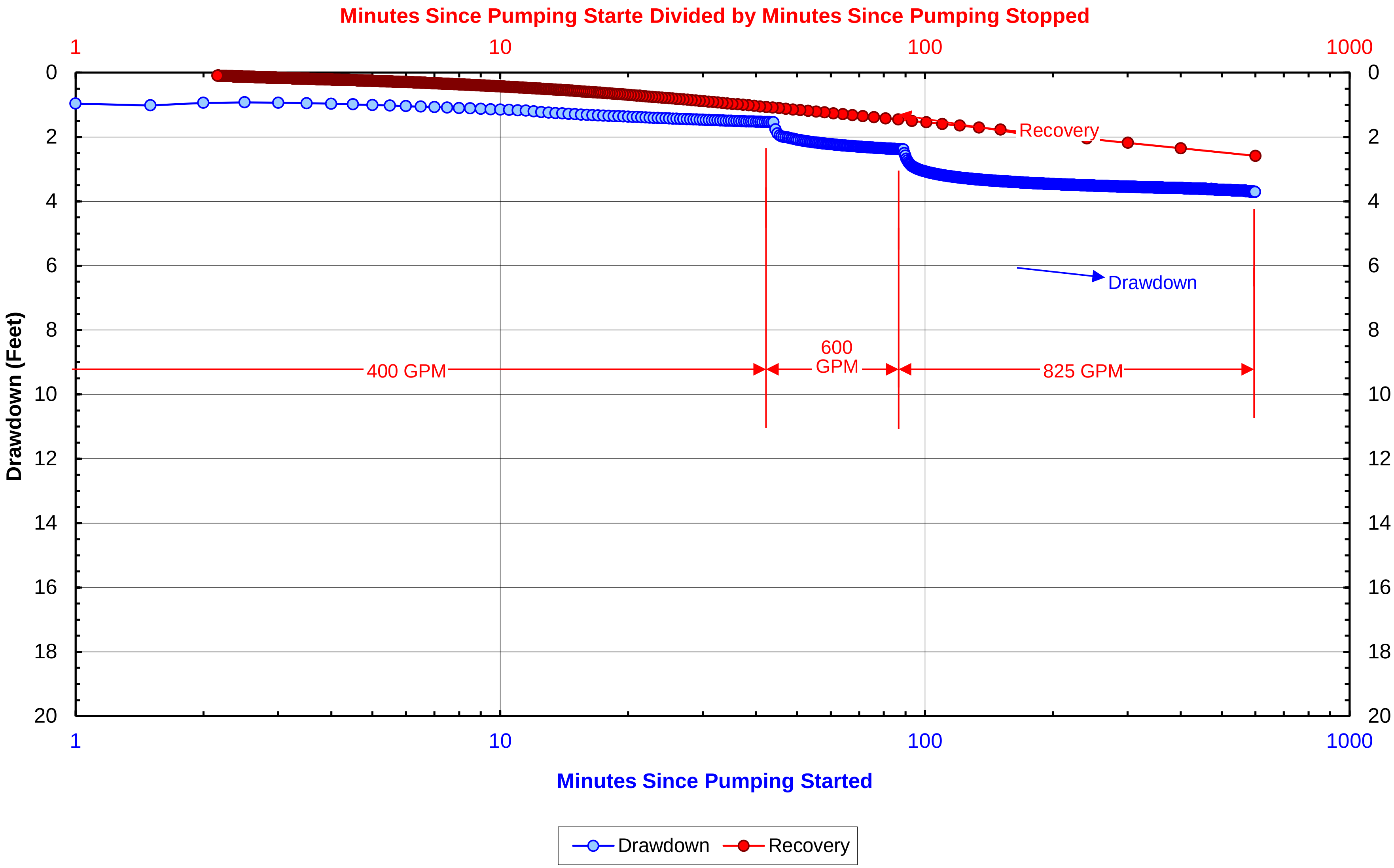


Figure 17. Semilog Plot of Drawdown and Recovery in the Well to the West of the Pumped Well During the March 17, 2015 Pump Test



Water levels recorded in the two monitor wells are shown on Figures 18 and 19. The HDF-1 well is 190 feet to the east of the deep well used for the pump test of the Well 14 Battery. It had an actual build up (rather than drawdown) of 0.05 feet during the pump test, the result of disposal of the pumped water on the ground surface (the clay and silt of the alluvium is compressible, hence the build up). There was otherwise no response to the pumping. The HDF-2 well is 1300 feet to the east of the pumped well of the Well 14 Battery. No response to pumping occurred.

Response of Groundwater in the Alluvium to Pumping of DOW's Koloa Well F. Recorders were installed in all four of the HDF monitor wells and in DOW's Koloa Well F for the 7-day period from May 13 to 20, 2015. The objective was to see if operation of the 1200 GPM pump in Koloa Well F creates an identifiable response in the groundwater in the alluvium. If a response were to occur, it would be most easily identified in the monitor well nearest to Koloa Well F, the HDF-4 well which is 630 feet from Koloa Well F. Figure 20 compares the water level in Koloa Well F with that in HDF-4 at the same vertical scale. Figure 21 shows this comparison with an expanded vertical scale for HDF-4 and over a shorter, 2-day period. If a response were to occur, it would most likely be as a pressure pulse arriving at HDF-4 several minutes following a pump start and/or stop of Koloa Well F. No such response occurred.

SURFACE WATER OCCURRENCE AT MAHAULEPU

Surface Water Courses and Drainage Channels

The main surface water course which crosses the HDF site is not named on the USGS quadrangle map. At its mauka end above the HDF site, it is a relatively steep, naturally occurring water course with several small tributaries. Across the HDF site and for some distance further makai, the stream channel is manmade to facilitate former sugarcane cultivation. Toward the inland end of the HDF site in the vicinity of the HDF-1 and HDF-2 monitor wells, the groundwater level in the alluvium fluctuates with seasonal rainfall-recharge. In wetter periods, the groundwater level rises above the invert elevation of the manmade channels and a modest amount of discharge of groundwater from the alluvium into the drainage channel occurs. Toward the makai end of the HDF site in the vicinity of HDF-3, the groundwater level in the alluvium is substantially below the manmade channel invert, meaning that groundwater discharge from the alluvium into the channels does not occur at the makai end of the HDF site.

There are a number of other drainage channels which cross the HDF site, all of which were constructed to facilitate sugarcane cultivation. These convey surface runoff originating offsite and crossing the HDF site to ultimate discharge at the shoreline. It should also be noted that the Waita Reservoir Ditch circumnavigated the Mahaulepu Valley floor, bringing water into the Mahaulepu Reservoir and also providing direct delivery for furrow irrigation. This ditch apparently fell out of use when the method of irrigation was converted from furrow to drip. From that time forward, water from the Well 14 Battery was apparently the sole source of irrigation for sugarcane in the valley. In the post-plantation

Figure 18. Water Level in the HDF-1 Monitor Well During and Following the Pump Test of the Well 14 Battery on March 17, 2015

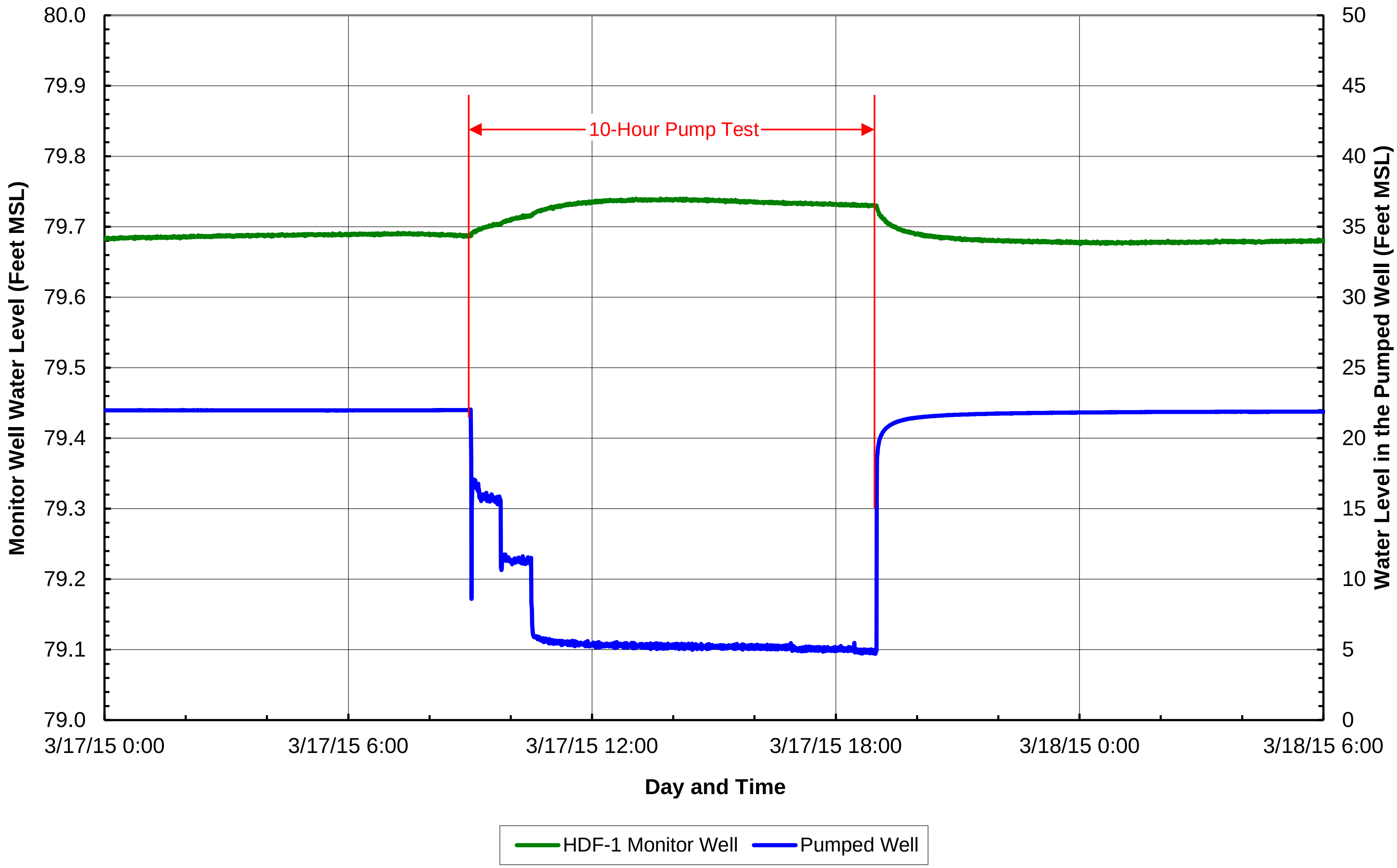


Figure 19. Water Level in the HDF-2 Monitor Well During and Following the Pump Test of the Well 14 Battery on March 17, 2015

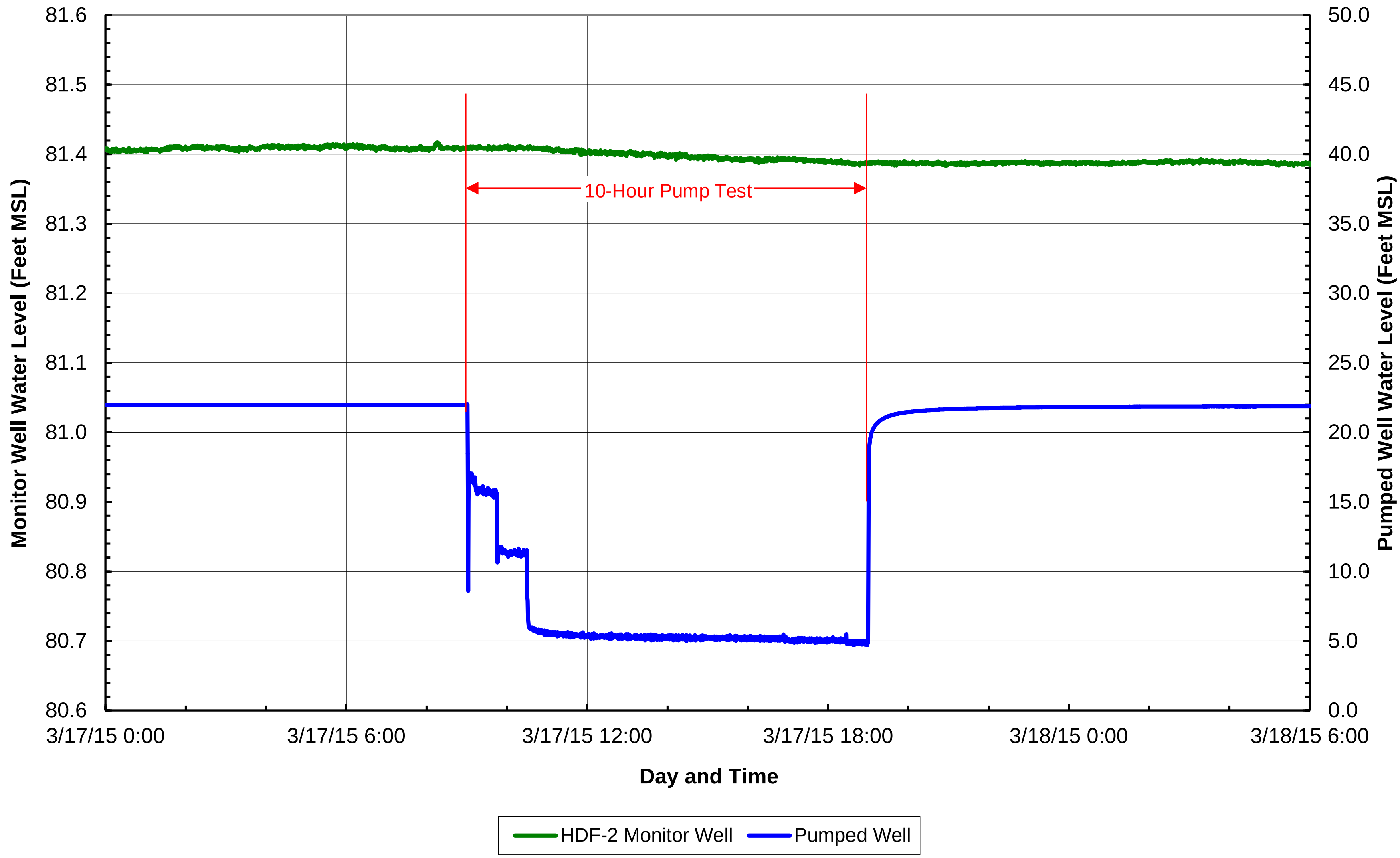


Figure 20. Recorded Water Levels in DOW's Koloa Well F and the HDF-4 Monitor Well

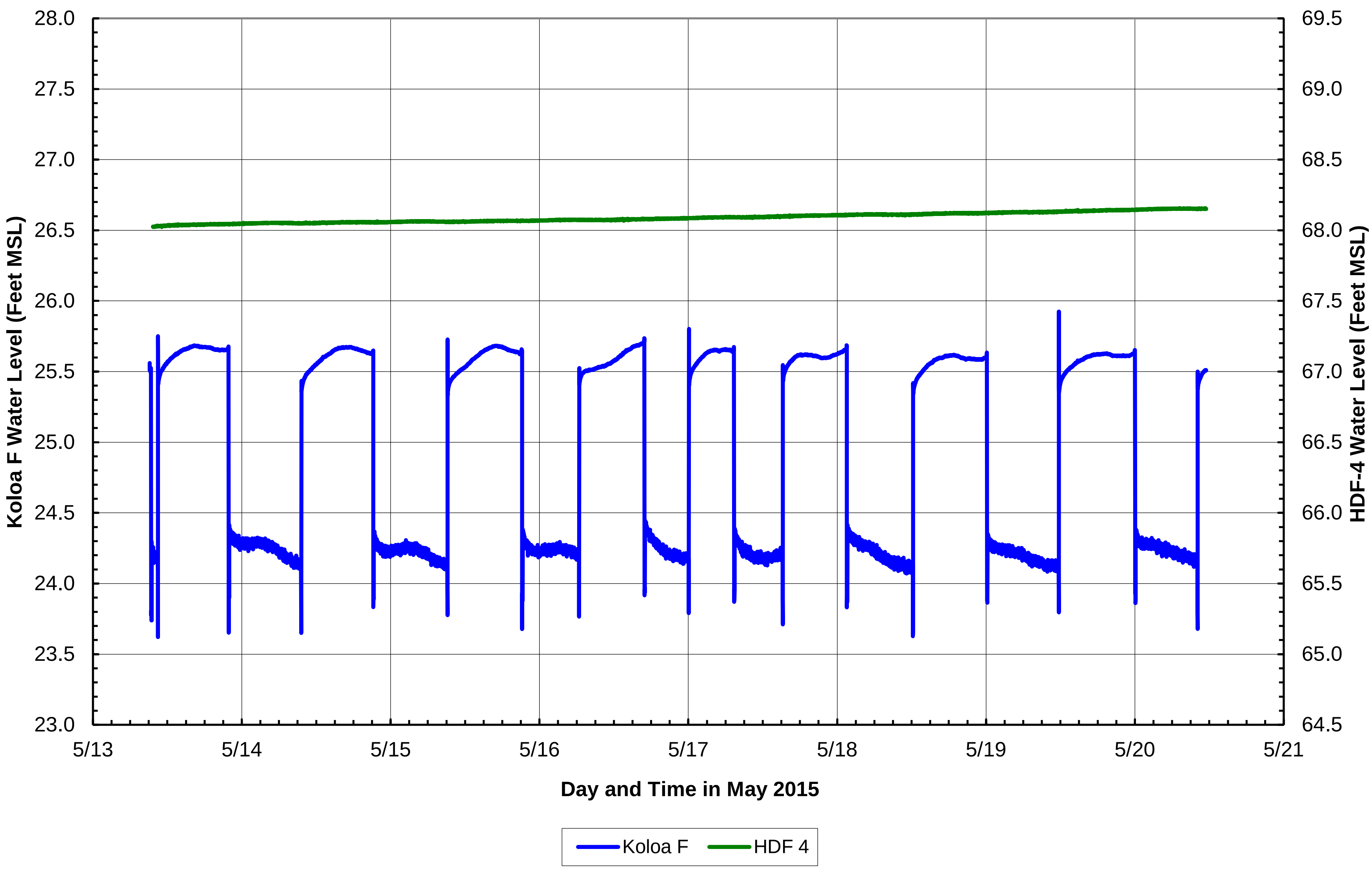
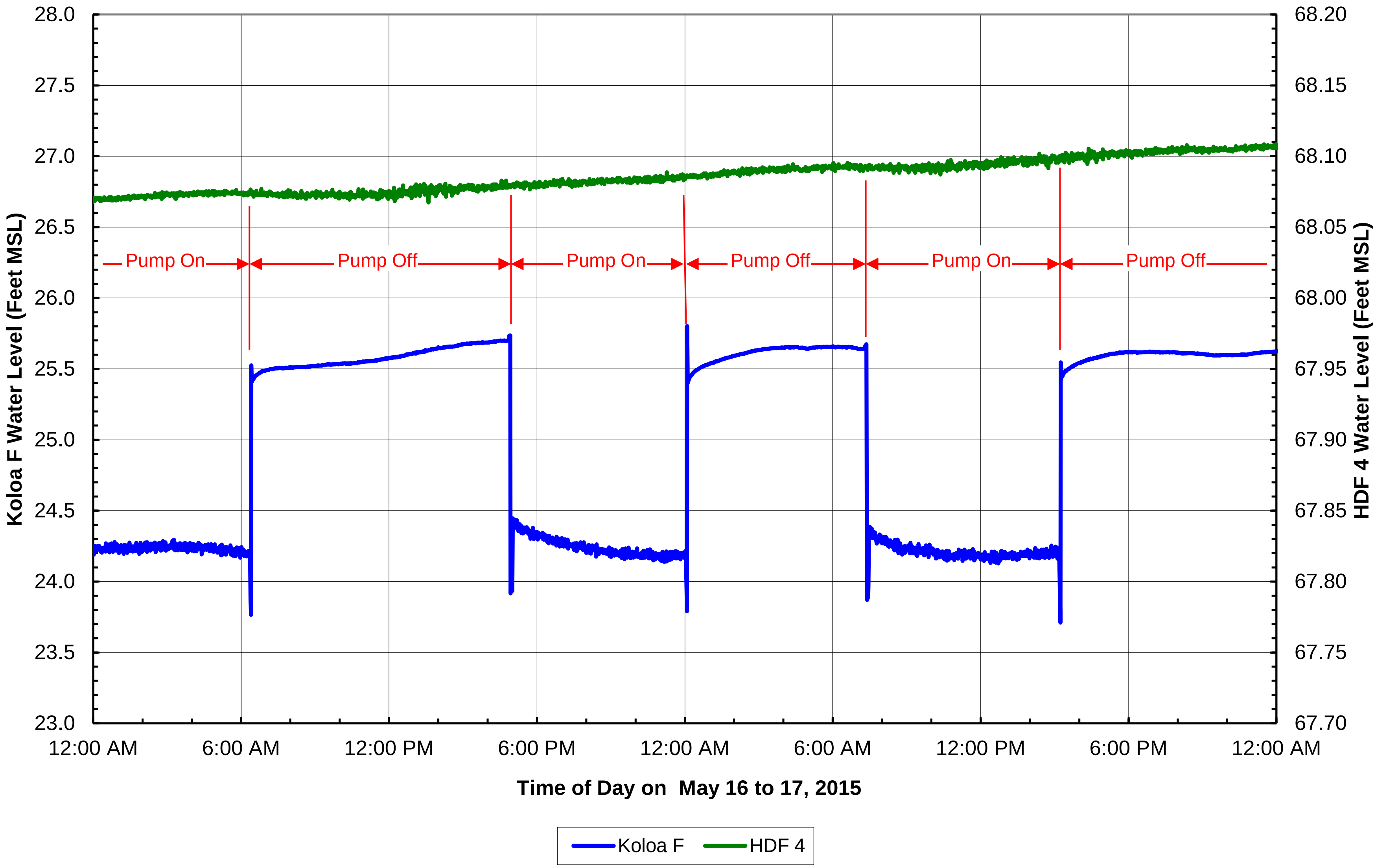


Figure 21. Comparison of the Water Levels in Koloa Well F and HDF-4



period (from about 1999), water from Waita has been delivered to Mahaulepu via a 12-inch pipeline. In addition to irrigation of about 70 acres of Kikuyu grass at the mauka end of the HDF site, the pipeline supplies a taro farm, banana cultivation (near DOW's Koloa Well F), a quarry (on the east side of the valley), and agriculture makai of the HDF site.

Table 5 is a compilation of five surface water sample sets taken at the 12 sample sites above, within, and makai of the HDF site as shown on Figure 22. Sites 1 and 2 are above the HDF project area, sites 3 through 10 are within the HDF site, and sites 11 and 12 are downstream of the HDF site. Depending on location, the samples reflect various components of surface runoff from offsite, Waita Reservoir water brought in for irrigation use, and seepage of shallow groundwater from the alluvium into the drainage courses. Other than all of the samples being of very low salinity, there is significant variability at most sites and from site to site.

Other Perennial Surface Water Features Within or Near to the HDF Site

There are two perennial surface water features in Mahaulepu in addition to the water courses which cross the HDF site. One is the Mahaulepu Reservoir which is just mauka of the HDF site and the other is the presumed pump sump for the original 10 wells of the Well 14 Battery. Each is described below.

<u>Mahaulepu Reservoir</u>. The reservoir was developed to facilitate furrow irrigation of sugarcane at Mahaulepu. It fell out of consistent use after the conversion from furrow to drip. Today, a low water level is maintained in the Reservoir as a watering hole for beef cattle. The water in the reservoir consists of surface water runoff from the upgradient tributary area supplemented, when necessary, by water from Waita Reservoir. The reservoir has an overflow spillway at its east end which discharges directly into the adjacent branch of the unnamed stream.

<u>Perennial Sump at the Well 14 Battery</u>. It appears likely that this perennial water feature is the remnant of the pump sump developed for the battery's first 10 wells and abandoned when the last four wells were drilled and put into operation in 1928. At present, the water depth in the sump is about three (3) feet and the mud bottom is soft. Before the HDF monitor wells were developed, it was assumed that the water level in the sump was a reflection of the groundwater level in the alluvium. Information subsequently developed has shown that this is not the case:

- The water level in the sump is about 70 to 72 feet (MSL). The water level of groundwater in the alluvium in the nearby HDF-1 monitor well is eight to 10 feet higher.
- In December 2014, the sump was pumped for 95 minutes at about 800 GPM (until the pump broke suction). The water level in the sump drew down and did not recover as it would have if it

Table 5. Results of Surface Water Sampling on and Near to the Hawaii Dairy Farms Site

Sample Site	Sample Date	Forms of Nitrogen				Forms of Phosphorus						
		$NO_3^-+NO_2^-$ (µM)	NH_4^+ (µM)	TON (µM)	TN (µM)	PO_4^{3-} (µM)	TOP (µM)	TP (µM)	Silica (µM)	Turbidity (ntu)	Salinity (ppt)	pH (pH Units)
1	10/6/2014	0.05	1.70	7.55	9.30	0.10	0.40	0.50	479	1.2	0.203	6.647
	10/29/2014	0.05	0.33	18.90	19.28	0.05	0.38	0.43	377	1.3	0.222	7.551
	3/4/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	5/8/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	7/9/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	Average	0.05	1.02	13.23	14.29	0.08	0.39	0.47	428	1.3	0.213	7.099
2	10/6/2014	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	10/29/2014	0.00	0.10	11.65	11.75	0.05	0.25	0.30	418	0.8	0.157	7.497
	3/4/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	5/8/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	7/9/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	Average	0.00	0.10	11.65	11.75	0.05	0.25	0.30	418	0.8	0.157	7.497
3	10/6/2014	0.10	1.65	5.30	7.05	0.05	0.45	0.50	315	3.0	0.274	7.057
	10/29/2014	0.03	0.20	13.88	14.10	0.05	0.28	0.33	306	2.5	0.267	7.588
	3/4/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	5/8/2015	0.10	1.05	9.23	10.38	0.50	0.01	0.51	274	0.8	0.267	7.163
	7/9/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	Average	0.08	0.97	9.47	10.51	0.20	0.25	0.45	298	2.1	0.269	7.269
4	10/6/2014	6.00	1.30	0.90	8.20	0.05	0.40	0.45	316	0.9	0.165	6.609
	10/29/2014	12.43	0.50	10.78	23.70	0.18	0.13	0.31	291	1.0	0.181	7.246
	3/4/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	5/8/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	7/9/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	Average	9.22	0.90	5.84	15.95	0.12	0.27	0.38	304	0.9	0.173	6.928
5	10/6/2014	0.60	1.75	15.15	17.50	0.45	0.35	0.80	235	38.5	0.315	7.582
	10/29/2014	0.15	2.75	38.93	41.83	0.63	0.28	0.91	274	35.3	0.299	7.501
	3/4/2015	0.15	1.58	49.48	51.20	1.45	0.50	1.95	205	68.1	0.135	7.795
	5/8/2015	0.10	6.08	34.65	40.83	1.38	0.76	2.14	223	63.4	0.138	7.272
	7/9/2015	0.71	2.50	31.43	34.64	0.26	1.07	1.33	181	61.4	0.178	7.504
	Average	0.34	2.93	33.93	37.20	0.83	0.59	1.43	224	53.3	0.213	7.531
5A	10/6/2014	3.05	2.00	8.40	13.45	0.10	0.70	0.80	249	4.9	0.166	7.676
	10/29/2014	7.00	0.80	15.28	23.08	0.23	0.18	0.41	271	2.8	0.191	7.910
	3/4/2015	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	5/8/2015	2.58	2.55	22.80	27.93	1.15	0.04	1.19	231	19.3	0.119	7.539
	7/9/2015	3.24	1.55	18.95	23.74	0.24	0.62	0.86	238	16.3	0.136	7.601
	Average	3.97	1.73	16.36	22.05	0.43	0.39	0.82	247	10.8	0.153	7.682
7	10/6/2014	0.50	1.40	11.70	13.60	0.35	0.45	0.80	210	28.9	0.113	7.579
	10/29/2014	2.28	0.60	18.40	21.28	0.33	0.35	0.68	194	16.6	0.098	8.167
	3/4/2015	0.10	0.45	22.50	23.05	0.55	0.10	0.65	220	25.7	0.119	8.119
	5/8/2015	0.13	1.70	19.48	21.30	0.93	0.14	1.06	204	29.4	0.113	7.544
	7/9/2015	0.12	0.82	18.61	19.55	0.22	0.64	0.86	209	19.8	0.122	7.837
	Average	0.63	0.99	18.14	19.76	0.48	0.34	0.80	207	24.1	0.113	7.849
8	10/6/2014	1.70	10.15	3.60	15.45	1.45	0.85	2.30	175	68.4	0.121	7.190
	10/29/2014	0.23	51.70	75.35	127.28	4.25	0.05	4.30	219	193.0	0.168	7.378
	3/4/2015	0.50	2.00	42.50	45.00	1.73	0.40	2.13	204	52.7	0.137	7.532
	5/8/2015	1.60	7.38	45.55	54.53	3.00	0.89	3.89	213	114.0	0.133	7.088
	7/9/2015	0.45	5.43	29.47	35.35	0.71	1.42	2.13	144	77.9	0.131	7.431
	Average	0.90	15.33	39.29	55.52	2.23	0.72	2.95	191	101.2	0.138	7.324
9	10/6/2014	1.30	3.95	6.55	11.80	0.95	0.10	1.05	193	48.0	0.124	7.939
	10/29/2014	0.20	0.55	25.48	26.23	0.33	0.43	0.76	193	21.7	0.100	8.049
	3/4/2015	1.33	3.28	35.73	40.33	1.05	0.55	1.60	199	40.0	0.126	7.747
	5/8/2015	0.93	3.65	27.33	31.90	1.85	0.36	2.21	209	71.7	0.123	7.381
	7/9/2015	0.20	1.20	18.83	20.23	0.27	0.72	0.99	184	21.6	0.124	7.366
	Average	0.79	2.53	22.78	26.10	0.89	0.43	1.41	196	45.4	0.119	7.696
10	10/6/2014	3.85	0.40	3.60	7.85	0.15	0.50	0.65	246	19.6	0.167	7.501
	10/29/2014	6.48	0.93	19.05	26.45	0.25	0.25	0.50	272	4.8	0.185	7.888
	3/4/2015	4.20	0.23	22.93	27.35	0.35	0.25	0.60	232	19.5	0.128	7.912
	5/8/2015	2.65	1.98	19.88	24.50	1.05	0.01	1.06	233	19.6	0.118	7.513
	7/9/2015	4.16	1.55	21.43	27.14	0.36	0.75	1.11	240	29.9	0.113	7.505
	Average	4.27	1.02	17.38	22.66	0.43	0.35	0.78	245	18.7	0.142	7.664
11	10/6/2014	4.45	0.90	3.05	8.40	0.25	0.40	0.65	210	35.3	0.114	7.556
	10/29/2014	0.75	0.75	18.58	20.08	0.43	0.63	1.06	200	37.3	0.103	7.921
	3/4/2015	3.53	0.95	24.10	28.58	0.85	0.08	0.93	198	28.7	0.120	7.884
	5/8/2015	1.03	1.98	23.30	26.30	1.18	0.21	1.39	211	30.4	0.115	7.550
	7/9/2015	1.78	1.23	20.73	23.74	0.28	0.76	1.04	206	20.4	0.123	7.508
	Average	2.31	1.16	17.95	21.42	0.60	0.42	1.01	205	30.4	0.115	7.684
12	10/6/2014	4.15	1.05	1.80	7.00	0.20	0.45	0.65	211	43.5	0.113	7.633
	10/29/2014	0.35	0.85	21.28	22.48	0.58	0.23	0.81	197	42.5	0.114	7.985
	3/4/2015	3.53	1.48	23.75	28.75	0.93	0.08	1.00	198	31.6	0.123	7.995
	5/8/2015	1.08	2.18	22.30	25.55	1.23	0.24	1.46	204	38.0	0.120	7.560
	7/9/2015	1.76	1.67	17.45	20.88	0.26	0.54	0.80	202	19.5	0.431	7.503
	Average	2.17	1.45	17.32	20.93	0.64	0.31	0.94	202	35.0	0.180	7.735

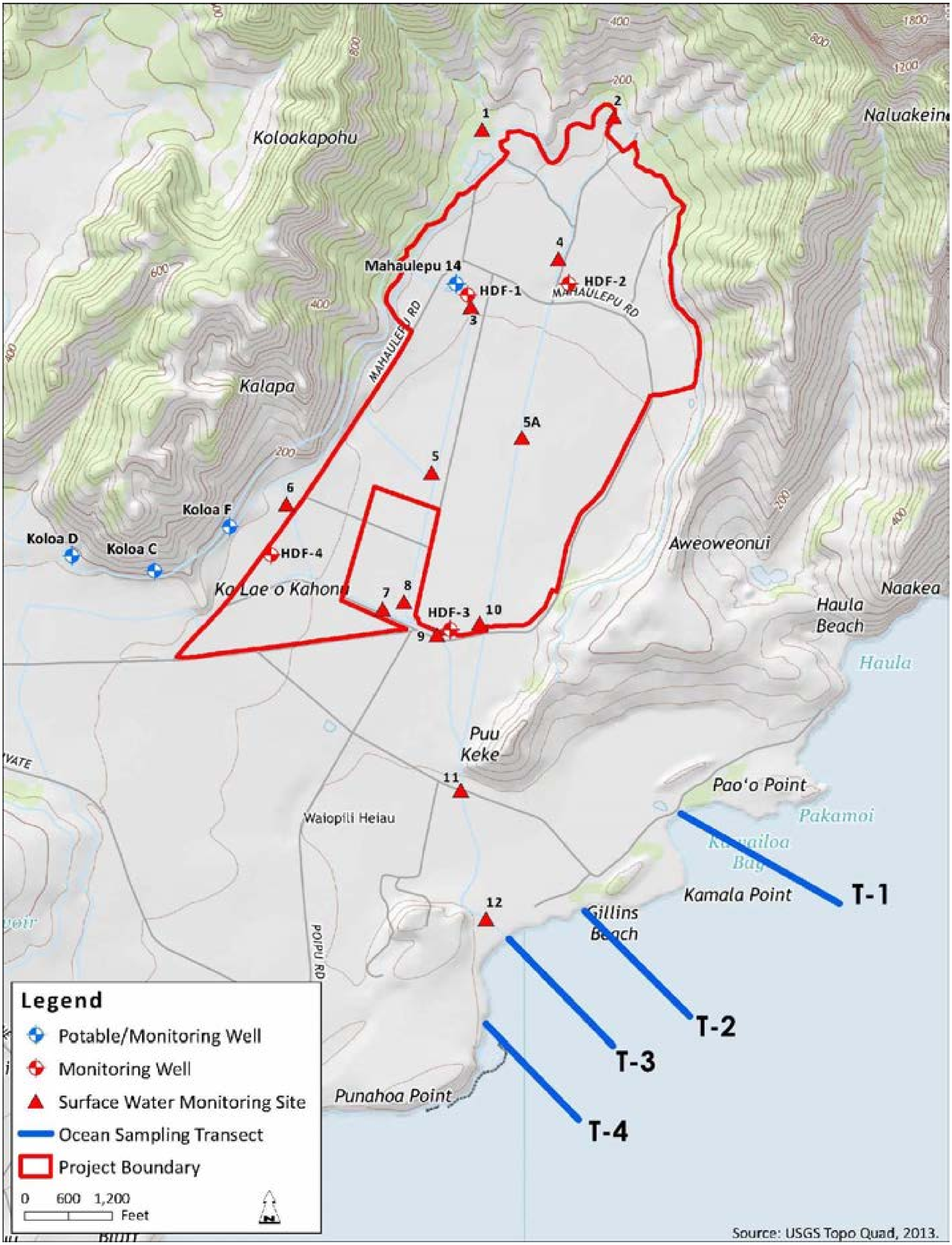


Figure 22

Locations of the 12 Surface Water Sampling Sites (Numbered Red Triangles) were groundwater in the alluvium (Figure 23). In fact, the level in the sump had not recovered as of July 2015, six months after pumping.

- During the pump test of the Well 14 Battery, there was no drawdown in the sump and no response to disposal of the pumped water such as was recorded at HDF-1 (compare Figure 24 of the sump's response to the HDF-1 response on Figure 16).

Based on this information, the perennial sump is hydrologically disconnected from the groundwater in the alluvium and also from the groundwater at depth in the unweathered volcanics. The isolation of the sump from groundwater in the alluvium surrounding it could be due to the remnants of the sump's walls and/or infilling of silt and clay.

ESTIMATES OF POTENTIAL IMPACTS TO GROUNDWATER AND SURFACE WATER

Identification of the Major Potential Impacts to Consider

There are two major impacts to consider for the operation HDF: (1) its use of surface and groundwater; and (2) its potential increase of nutrients (specifically nitrogen and phosphorus) leaving the HDF site and ultimately discharging into the marine environment. Each of these is discussed and quantified in the sections following.

Expected Use of Groundwater and Surface Water by HDF

<u>Use of Groundwater</u>. HDF will require potable quality water to wash down the milking parlor area (about 30,000 GPD) and for consumption by the cows (at 25 GPD per cow, about 17,500 GPD for the initial 699 cows and up to about 50,000 GPD for expansion up to 2000 cows). This supply will be provided by a pump installed in one of the three remaining wells of the Well 14 Battery. Another pump may be installed in a second well to provide redundant capacity. The total draft of about 47,500 GPD for the initial 699 cows and up to 80,000 GPD for expansion to 2000 cows is a small fraction of the three (3) million gallons per day (MGD) that the Well 14 Battery produced when it was formerly used for sugarcane irrigation. The modest use rate by HDF and the 4500-foot distance to the nearest other operating well (DOW's Koloa Well F) mean that no adverse impact to ongoing use of groundwater in the volcanics will occur as a result of this use.

<u>Use of Water from Waita Reservoir to Irrigate the Grass</u>. About 347 acres of HDF's 470 acres of pasture will be irrigated. Two center pivot systems will irrigate 285 acres and 62 acres will be gun irrigated. On Table 6, the estimated monthly and year-round average irrigation rates are compiled (refer to the notes at the bottom of the table for the basis of the calculations). The average irrigation rates are estimated to vary from 0.84 MGD in the wettest month (December) to 1.71 MGD in the driest (June), with a

Figure 23. December 2014 Pump Test of the Perennial Sump at the Well 14 Battery

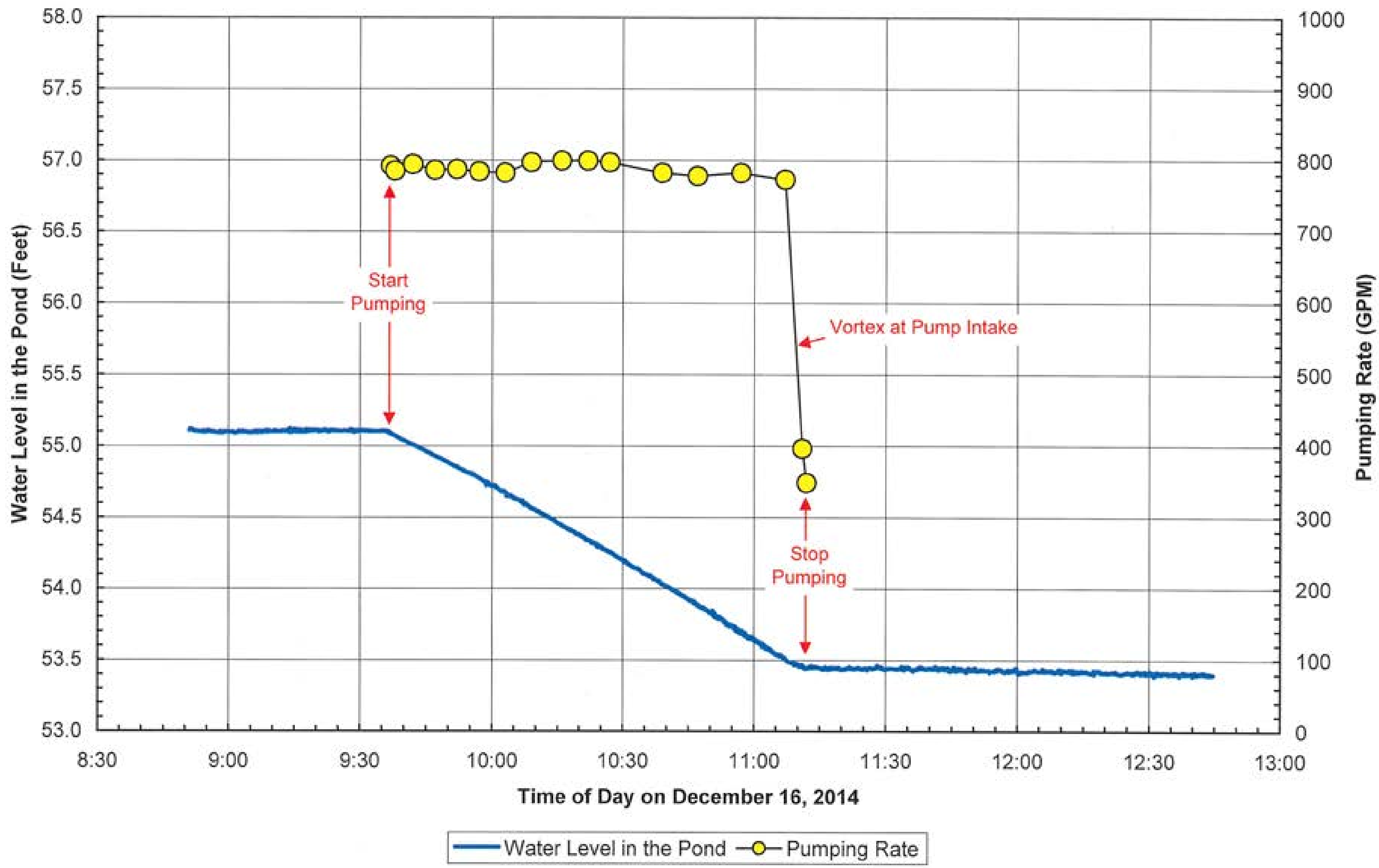


Figure 24. Water Level In the Nearby Sump During and Following the Well 14 Battery Pump Test

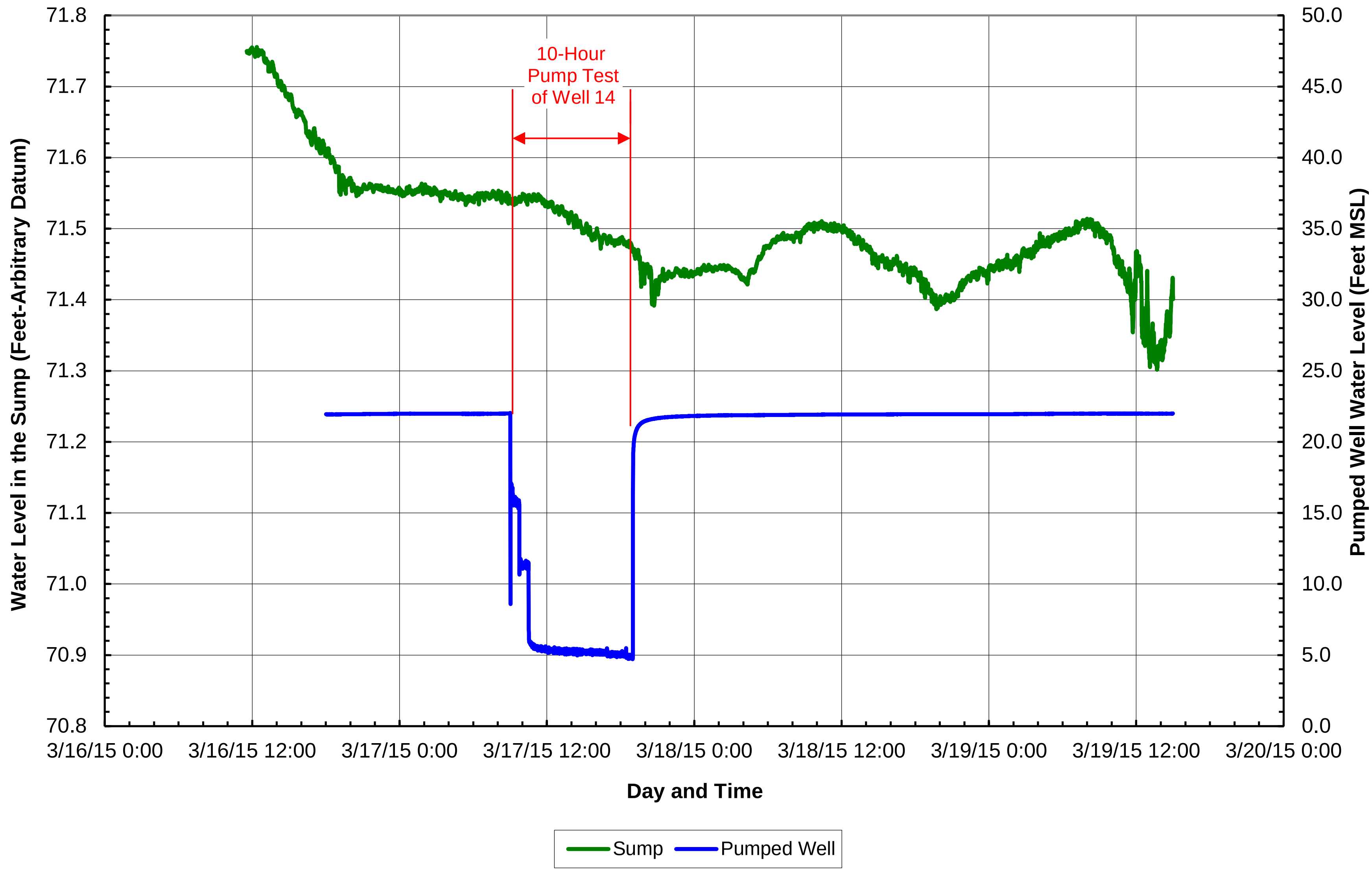


Table 6. Approximation of HDF's Monthly and Annual Average Irrigation Rate

Month	Days in the Month	Potential Evapotranspiration (Inches)	Actual Evapotranspiration (Inches)	Average Rainfall (Inches)	Effective Rainfall (Inches)	Applied Irrigation Monthly (Inches)	Applied Irrigation Equivalent (MGD)
Jan	31	6.88	5.85	4.22	2.63	3.22	0.98
Feb	28	6.82	5.80	3.70	2.56	3.24	1.08
Mar	31	7.85	6.67	5.35	3.35	3.32	1.01
Apr	30	7.97	6.77	3.17	2.76	4.01	1.26
May	31	8.86	7.53	2.61	2.14	5.39	1.64
Jun	30	9.05	7.69	2.39	2.24	5.45	1.71
Jul	31	9.39	7.98	2.77	2.49	5.49	1.67
Aug	31	9.41	8.00	2.98	2.42	5.58	1.69
Sep	30	9.09	7.73	2.73	2.40	5.33	1.67
Oct	31	8.60	7.31	3.99	3.00	4.31	1.31
Nov	30	7.04	5.98	4.66	3.17	2.81	0.88
Dec	31	7.10	6.04	5.69	3.27	2.77	0.84
Annual	365	98.06	83.35	44.26	32.43	50.92	1.31

Notes:
1. Potential evapotranspiration is the "Grass Reference Surface Potential" at 21.907° N, 159.422° W from the Interactive Map of "Evapotranspiration of Hawaii", Geography Department, University of Hawaii at Manoa, 2014.
2. Actual evapotranspiration is 0.85 times potential evapotranspiration, 0.85 being the crop factor for Kikuyu grass.
3. Average rainfall is from the 30-year daily record of Mahaulepu Station 941.1 from January 1984 through December 2013.
4. Effective rainfall is approximated as the daily rainfall amounts up to 0.80 inches at Station 941.1. Daily amounts greater than 0.80 inches are assumed to become runoff.
5. Applied irrigation is actual evapotranspiration less effective rainfall applied to 347 acres of irrigated pasture.

year-round average of 1.31 MGD. This additional use of the Waita Reservoir system is well within its capacity.

Potential Increases of Nitrogen and Phosphorus Leaving the HDF Site

Methodology. The approach to estimate potential increases of nitrogen and phosphorus in surface and groundwater resulting from the development of HDF is to calculate the flow volumes and nutrient loading under "present" (pre-HDF) conditions and to compare those amounts to forecast conditions with the initial farm size of 699 cows and the possible subsequent expansion of up to 2000 cows. The estimates herein rely heavily on information in the "Nutrient Balance Analysis for Hawaii Dairy Farms" (by Group 70 and Red Barn Consulting dated March 2016) and "Hawaii Dairy Farms Drainage Memorandum" (by Group 70 and dated August 2015).

With regard to groundwater, the estimates of potential impacts focus exclusively on the groundwater in the alluvium on which the HDF site sits. As described earlier in this report, the groundwater in the underlying volcanics is hydrologically separate from groundwater in the alluvium and will not be impacted by HDF activities. The surface water estimates include the runoff from the areas outside of the HDF site which flow through the HDF site via the system of natural and manmade waterways which ultimately discharge in one or the other of the two ditches leaving the makai end of the HDF site.

Existing Groundwater Flow and Nitrogen and Phosphorus Loading. Two order of magnitude estimates of the groundwater flow in the alluvium beneath the HDF site have been made to provide an approximation of the flowrate. The area of the alluvium in Mahaulepu Valley is approximately 720 acres. HDF comprises 557 acres of this area and will irrigate 347 acres of its 557-acre site. Rainfall across the alluvium varies from 45 inches per year at the makai end (site of Mahaulepu Station 941.1) to about 55 inches at its mauka end. One order of magnitude estimate assumes 10 percent of the rainfall on the 373 acres of unirrigated area and 10 percent of the applied irrigation on the remaining 347 acres becomes recharge to groundwater in the alluvium. These assumptions amount to a year-round average flowrate of groundwater in the alluvium of about 0.27 MGD.

The other order of magnitude approximation uses the apparent groundwater gradient between the upstream HDF-1 and HDF-2 monitor wells and the downgradient HDF-3 monitor well (a water level drop of 30 feet over a 4800-foot distance), an approximation of the flow's cross sectional area (4500-foot width and 250-foot depth), and an estimate of the formation's average permeability coefficient (almost certainly less than five feet per day; it is highly variable in both horizontal and vertical directions). For these values, the approximated average flowrate is 0.265 MGD, essentially the same as the approximation based on recharge by rainfall and return irrigation. For the computations to follow, it is assumed that the flowrate is 0.27 MGD.

The nitrogen and phosphorus content in this groundwater leaving the makai end of the HDF site is taken as the average concentrations of the four samples taken from the HDF-3 monitor well (refer to Table 2). For the 0.27 MGD average daily flowrate, these concentrations are equivalent to 0.91 and 0.074 pounds of nitrogen and phosphorus per day, respectively, in groundwater in the alluvium leaving the makai end of the HDF site.

Existing Surface Water Flow and Nitrogen and Phosphorus Loading. Approximately 1770 acres of area drain into the two major mauka-to-makai drainageways which leave the makai end of the HDF site. About 720 acres (including all of the 557-acre HDF site) is relatively flat land and the remaining 1050 acres is the steeply sloping surrounding ridges. Average annual rainfall across the flat land is 45 to 55 inches. Average annual rainfall on the steeper ridges is about 60 inches. As a first order approximation, it is assumed that the surface water runoff consists of 15 percent of the rainfall on the flat land and 30 percent of the rainfall on the steeper surrounding ridges. These assumptions translate to average annual runoff rates of 0.40 MGD from the flat land and 1.41 MGD from the steeper ridges. Notably, this estimate of the surface runoff is about seven times greater than the estimated groundwater flowrate in the alluvium.

Nitrogen and phosphorus concentrations in runoff from the flat land are assumed to be the same as the samples from Sample Site 10 at the makai end of the HDF site (Table 5). Concentrations in runoff from the steep surrounding lands are assumed to be the same as Sample Sites 1 and 2 which are inland of the HDF site. For this set of assumptions, the average daily amounts of nitrogen and phosphorus in surface runoff leaving the HDF site are 3.20 and 0.22 pounds, respectively. These amounts are about three times greater than the estimated amount carried in groundwater moving through the alluvium.

Based on the calculations and assumptions described above, the estimated total annual load of nitrogen and phosphorus from groundwater in the alluvium leaving the makai end of the HDF Site under existing conditions is 332 and 27 pounds per year, respectively. The totals for nitrogen and phosphorus in surface water leaving the site are 1170 and 80 pounds per year, respectively.

Potential Nutrient Additions by Hawaii Dairy Farms. From the perspective of potential nutrient additions to surface and groundwater, the operation of HDF can be characterized as a semi-enclosed loop system: nutrients are taken up by the Kikuyu grass; the cows eat the grass as their primary food supply (they will also eat commercial feed while in the milking parlor); nutrients in the grass and commercial feed consumed by the cows are returned to the ground, either as manure excreted on the pastures or as manure collected in the milking parlor and applied to the pastures; and the shortfall of nutrients in the manure to grow the grass is made up by the application of commercial fertilizer.

Quantification of Circulating Nutrient Amounts in the Dairy Operation. Table 7 is a quantification of monthly amounts of nitrogen and phosphorus produced and consumed at HDF, initially with 699 cows and ultimately if the HDF expands up to 2000 cows. The compilations are based on the following:

699 Cows

WASTE AND RUNOFF TO STORAGE PONDS

Animal & Waste Generation Inputs:

Lactating Cow		
Manure Production	90.8	lbs/cow/day
Cow Waking Hours	16	hrs
Cows in Parlor	2	hrs
Manure Production in Parlor	1.361	gal/cow/day
Cows at Pasture	14.00	hrs
Manure Production in Pasture	9.52	gal/cow/day
Parlor Wash Water	17.40	gal/cow/day (from DSL)

Calf		
Manure Production	19	lbs/cow/day
Manure Production	0.3	cf/cow/day
Manure production in Pasture	2.244	gal/cow/day
Manure production in Calf Pens	2.244	gal/cow/day

Rainfall Runoff Generation Inputs:

Storage Pond #1		
Length	212	ft
Width	132	ft
Top Area	27984	sf
Storge Pond #2		
Length	132	ft
Width	85.50	ft
Top Area	11286.00	sf
Holding Area	6795	ft

MASS BALANCE OF NUTRIENTS ON FARM

Animals on Facility Inputs:

Lacting Cow Imputs:		
Herd Size of Lactating Cows	699	ea
Pasture Size	469.9	ac
Animal Nitrogen Excretion	0.546	lbs-N /cow/day
Animal Phosphorus Excretion	0.11	lbs-P /cow/day

Calf Inputs:		
Herd Size, calves on pasture	150	ea
Herd Size, calves in hutches	50	ea
Animal Nitrogen Excretion	0.14	lbs-N /cow/day
Animal Phosphorus Excretion	0.044	lbs-P /cow/day

Grass Production Inputs:		
Kikuya Yield	16.3	Tons DM / ac
Grass Nitrogen Removal	64	lbs-N Removed/ton DM/year
Grass Phosphorus Removal	11.4	lbs-P Removed/ton DM/year
Grass Nitrogen Removal	1043.20	lbs-N/acre/year
Grass Phosphorus Removal	185.82	lbs-P/acre/year

Month	Day per month (days/mo)	Manure Collected in Parlor & Calf Pens (gal/mo)	Wash Water Collected in Parlor (gal/mo)	Ave. Monthly Rainfall -P (in)	Ave. Month Pan Evaporation - Ea (in)	Ave. Month Manure Storage Evaporation - Em (50% of pan) (in)	Ave Monthly Net rainfall directly on Manure Storage (P-Em) (in)	Ave Monthly Net rainfall of pond area (gal/mo)	Ave Monthly Net rainfall of Holding Area (gal/mo)	Total Effluent (rainfall & waste water) Collected (gal/mo)	N collected in pond (lbs-N /mo)	P collected in pond (lbs-P/mo)	N excreted on pasture (lbs-N/mo)	P excreted on pasture (lbs-P/mo)	N Total deposited on Farm (lbs/-Nmo)	P Total deposited on Farm (lbs-P/mo)	N Total removed from Farm (lbs-N/mo)	P Total removed from Farm (lbs-P/mo)	N Deficit (Lbs-N)	P Deficit (Lbs-P)
January	31	32,960	377,041	4.88	5.14	2.57	2.31	56544.873	20669.484	**487,215**	1,696	366	11,003	2,290	12699	2,656	41633	7416	**28934**	**4760**
February	28	29,770	340,553	4.2	5.65	2.825	1.375	33657.6625	17789.31	**421,770**	1,532	331	9,939	2,069	11470	2,399	37604	6698	**26134**	**4299**
March	31	32,960	377,041	5.04	6.93	3.465	1.575	38553.3225	21347.172	**469,901**	1,696	366	11,003	2,290	12699	2,656	41633	7416	**28934**	**4760**
April	30	31,897	364,878	3.66	7.43	3.715	-0.055	-1346.3065	15502.113	**410,930**	1,641	354	10,648	2,216	12290	2,571	40290	7177	**28001**	**4606**
May	31	32,960	377,041	3.05	7.82	3.91	-0.86	-21051.338	12918.4275	**401,868**	1,696	366	11,003	2,290	12699	2,656	41633	7416	**28934**	**4760**
June	30	31,897	364,878	2.86	8.05	4.025	-1.165	-28517.2195	12113.673	**380,371**	1,641	354	10,648	2,216	12290	2,571	40290	7177	**28001**	**4606**
July	31	32,960	377,041	3.13	9.1	4.55	-1.42	-34759.186	13257.2715	**388,499**	1,696	366	11,003	2,290	12699	2,656	41633	7416	**28934**	**4760**
August	31	32,960	377,041	3.2	9.37	4.685	-1.485	-36350.2755	13553.76	**387,204**	1,696	366	11,003	2,290	12699	2,656	41633	7416	**28934**	**4760**
September	30	31,897	364,878	3.25	8.23	4.115	-0.865	-21173.7295	13765.5375	**389,366**	1,641	354	10,648	2,216	12290	2,571	40290	7177	**28001**	**4606**
October	31	32,960	377,041	4.96	7.33	3.665	1.295	31699.3985	21008.328	**462,708**	1,696	366	11,003	2,290	12699	2,656	41633	7416	**28934**	**4760**
November	30	31,897	364,878	6.01	6.17	3.085	2.925	71599.0275	25455.6555	**493,829**	1,641	354	10,648	2,216	12290	2,571	40290	7177	**28001**	**4606**
December	31	32,960	377,041	5.71	5.4	2.7	3.01	73679.683	24184.9905	**507,865**	1,696	366	11,003	2,290	12699	2,656	41633	7416	**28934**	**4760**
Total Annual	**365**	**388075.6159**	**4439349**	**49.95**	**86.62**	**43.31**	**6.64**	**162535.912**	**211565.7225**	**5201526.25**	**19967.96375**	**4311.10625**	**129555.7463**	**26965.74375**	**149523.71**	**31276.85**	**490199.68**	**87316.818**	**340675.97**	**56039.968**

2000 Cows

WASTE AND RUNOFF TO STORAGE PONDS

Animal & Waste Generation Inputs:

Lactating Cow		
Manure Production	90.8	lbs/cow/day
Cow Waking Hours	16	hrs
Cows in Parlor	2	hrs
Manure Production in Parlor	1.361	gal/cow/day
Cows at Pasture	14.00	hrs
Manure Production in Pasture	9.52	gal/cow/day
Parlor Wash Water	17.40	gal/cow/day (from DSL)

Calf		
Manure Production	19	lbs/cow/day
Manure Production	0.3	cf/cow/day
Manure production in Pasture	2.244	gal/cow/day
Manure production in Calf Pens	2.244	gal/cow/day

Rainfall Runoff Generation Inputs:

Storage Pond #1		
Length	212	ft
Width	132	ft
Top Area	27984	sf
Storge Pond #2		
Length	132	ft
Width	85.50	ft
Top Area	11286.00	sf
Holding Area	6795	ft

MASS BALANCE OF NUTRIENTS ON FARM

Animals on Facility Inputs:

Lacting Cow Imputs:		
Herd Size of Lactating Cows	2000	ea
Pasture Size	469.9	ac
Animal Nitrogen Excretion	0.546	lbs-N /cow/day
Animal Phosphorus Excretion	0.11	lbs-P /cow/day

Calf Inputs:		
Herd Size, calves on pasture	500	ea
Herd Size, calves in hutches	167	ea
Animal Nitrogen Excretion	0.14	lbs-N /cow/day
Animal Phosphorus Excretion	0.044	lbs-P /cow/day

Grass Production Inputs:		
Kikuya Yield	16.3	Tons DM / ac
Grass Nitrogen Removal	64	lbs-N Removed/ton DM/year
Grass Phosphorus Removal	11.4	lbs-P Removed/ton DM/year
Grass Nitrogen Removal	1043.20	lbs-N/acre/year
Grass Phosphorus Removal	185.82	lbs-P/acre/year

Month	Day per month (days/mo)	Manure Collected in Parlor & Calf Pens (gal/mo)	Wash Water Collected in Parlor (gal/mo)	Ave. Monthly Rainfall -P (in)	Ave. Month Pan Evaporation - Ea (in)	Ave. Month Manure Storage Evaporation - Em (50% of pan) (in)	Ave Monthly Net rainfall directly on Manure Storage (P-Em) (in)	Ave Monthly Net rainfall of pond area (gal/mo)	Ave Monthly Net rainfall of Holding Area (gal/mo)	Total Effluent (rainfall & waste water) Collected (gal/mo)	N collected in pond (lbs-N /mo)	P collected in pond (lbs-P/mo)	N excreted on pasture (lbs-N/mo)	P excreted on pasture (lbs-P/mo)	N Total deposited on Farm (lbs/-Nmo)	P Total deposited on Farm (lbs-P/mo)	N Total removed from Farm (lbs-N/mo)	P Total removed from Farm (lbs-P/mo)	N Deficit (Lbs-N)	P Deficit (Lbs-P)
January	31	95,971	1,078,800	4.88	5.14	2.57	2.31	56544.873	20669.484	**1,251,985**	4,956	1,080	31,791	6,650	36747	7,730	41633	7416	**4887**	**-314**
February	28	86,683	974,400	4.2	5.65	2.825	1.375	33657.6625	17789.31	**1,112,530**	4,477	976	28,714	6,006	33191	6,982	37604	6698	**4414**	**-283**
March	31	95,971	1,078,800	5.04	6.93	3.465	1.575	38553.3225	21347.172	**1,234,671**	4,956	1,080	31,791	6,650	36747	7,730	41633	7416	**4887**	**-314**
April	30	92,875	1,044,000	3.66	7.43	3.715	-0.055	-1346.3065	15502.113	**1,151,031**	4,796	1,045	30,765	6,435	35561	7,480	40290	7177	**4729**	**-304**
May	31	95,971	1,078,800	3.05	7.82	3.91	-0.86	-21051.338	12918.4275	**1,166,638**	4,956	1,080	31,791	6,650	36747	7,730	41633	7416	**4887**	**-314**
June	30	92,875	1,044,000	2.86	8.05	4.025	-1.165	-28517.2195	12113.673	**1,120,472**	4,796	1,045	30,765	6,435	35561	7,480	40290	7177	**4729**	**-304**
July	31	95,971	1,078,800	3.13	9.1	4.55	-1.42	-34759.186	13257.2715	**1,153,269**	4,956	1,080	31,791	6,650	36747	7,730	41633	7416	**4887**	**-314**
August	31	95,971	1,078,800	3.2	9.37	4.685	-1.485	-36350.2755	13553.76	**1,151,974**	4,956	1,080	31,791	6,650	36747	7,730	41633	7416	**4887**	**-314**
September	30	92,875	1,044,000	3.25	8.23	4.115	-0.865	-21173.7295	13765.5375	**1,129,467**	4,796	1,045	30,765	6,435	35561	7,480	40290	7177	**4729**	**-304**
October	31	95,971	1,078,800	4.96	7.33	3.665	1.295	31699.3985	21008.328	**1,227,479**	4,956	1,080	31,791	6,650	36747	7,730	41633	7416	**4887**	**-314**
November	30	92,875	1,044,000	6.01	6.17	3.085	2.925	71599.0275	25455.6555	**1,233,930**	4,796	1,045	30,765	6,435	35561	7,480	40290	7177	**4729**	**-304**
December	31	95,971	1,078,800	5.71	5.4	2.7	3.01	73679.683	24184.9905	**1,272,636**	4,956	1,080	31,791	6,650	36747	7,730	41633	7416	**4887**	**-314**
Total Annual	**365**	**1129980.776**	**12702000**	**49.95**	**86.62**	**43.31**	**6.64**	**162535.912**	**211565.7225**	**14206082.41**	**58356.2**	**12719.52**	**374307.5**	**78292.5**	**432663.7**	**91012.02**	**490199.68**	**87316.818**	**57535.98**	**-3695.202**

Table 7

Nutrient Balance Calculations for Herd Sizes of 699 and 2000 Cows

- Grass will be grown on 470 acres of the HDF site during the initial herd size of 699 cows and if HDF expands up to 2000 cows;
- Nutrient uptake (specifically nitrogen and phosphorus) by the Kikuyu grass is based on trials at the HDF site conducted to date;
- Manure production rates by the cows are based on available data from cows elsewhere. In the future, the nutrient balance calculations will be updated based on actual manure production at HDF;
- The cows will be awake for 16 hours a day. In two daily 1-hour sessions, the cows will be in the milking parlor or the adjacent holding yard. All manure produced in the milking parlor and holding yard will be collected and redistributed to the pastures, either as diluted liquid effluent in the irrigation water or as slurries applied by pumps to selected pastures;.
- In the 14 hours of the day when cows are awake and in the pastures, all manure produced by the cows will be deposited in the pastures.

Based on the forgoing and as detailed on Table 7, the nutrient amounts in the manure produced by the cows will not be sufficient to grow the grass. The shortfall of the manure-supplied nutrients, detailed in the last two columns of Table 7, define the amounts of nitrogen and phosphorus that will need to be provided by applications of commercial fertilizer. These amounts are summarized on an annual basis on Table 8. It should be noted that, with the present data and assumptions listed in the bullet points above, the calculations show that the phosphorus in the manure produced by 2000 cows exceeds the uptake by the Kikuyu grass (last column on the right at the bottom of Table 7). HDF believes that the current tested grass yield of 16.3 tons of dry matter per acre will increase to about 20 tons of dry matter per acre. With such an increase, an excess of phosphorus in the manure of 2000 cows would not actually occur. If the increase in grass yield does not occur, the ultimate herd size would be less than 2000 cows and the number of cows would be limited by the actual grass yield. Increasing the herd size beyond the initial 699 cows would be gradual and monitoring of nutrients in the manure, actual uptake of nutrients by grass, and the nutrient content in soil would be ongoing.

<u>Potential Losses of Nitrogen and Phosphorus to Surface and Groundwater</u>. In rounded numbers and on an annual basis for both herd sizes, HDF will be circulating 490,000 pounds of nitrogen and 87,000 pounds of phosphorus. These amounts are about 325 and 815 times greater than the estimates of nitrogen and phosphorus currently carried in surface and groundwater moving through the HDF site and ultimately discharging into the marine environment. At issue is how much of the nitrogen and phosphorus deposited on the farm as manure and in applied commercial fertilizer will leave the site and increase the present nutrient load that ultimately discharges into the marine environment. There are several aspects to consider in arriving at an estimate:

- Relative to the amount of surface water moving through the HDF site, the groundwater flow in the alluvium is relatively modest. The formation is poorly permeable and even after HDF is in

Table 8

Annual Nitrogen and Phosphorus Supplements Required
to Ground Kikuyu Grass on 470 Acres of Pasture

	Size of the Herd	
Item	699 Cows	2000 Cows
Uptake by Kikuyu Grass on 470 Acres of Pasture		
• Nitrogen (lbs / year)	490,200	490,200
• Phosphorus (lbs / year)	87,317	87,317
Manure Production in Milking Parlor and Pastures		
• Nitrogen (lbs / year)	149,524	432,664
• Phosphorus (lbs / year)	31,277	91,012
Required Supplements in Commercial Fertilizer to Grow the Grass		
• Nitrogen (lbs / year)	340,676	57,536
• Phosphorus (lbs / year)	56,040	(-) 3,695

full operation, the contribution in the groundwater flow to an increase in nutrient load will be significantly less than in surface water.

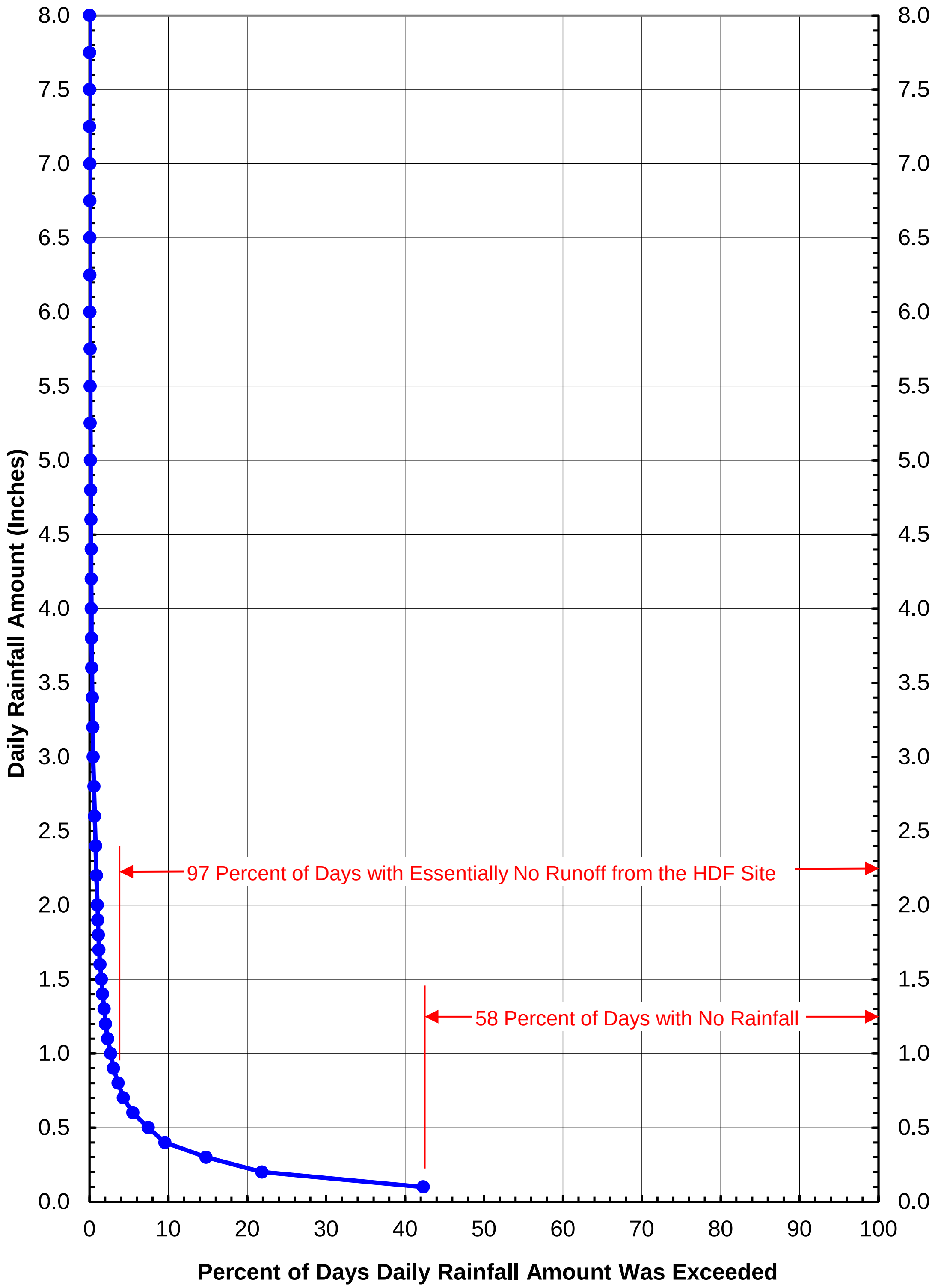
- The Hawaii Dairy Farms Drainage Memorandum (Group 70, August 2015) identifies a number of design and best management practices intended to limit the amount of runoff and to filter the sediment in that runoff. Most significant among these are set backs, filter strips, and buffer plantings on both sides of drainageways. The herbaceous cover area will be 35 feet wide on both sides of the drainageways.
- Perhaps the biggest factor will be the operating skill of the HDF personnel, including tracking the nutrient balance to avoid excessive use of fertilizer and in anticipating weather patterns to avoid irrigating in advance of heavy, runoff-producing rainfall.

Based on the 30-year daily rainfall record of the Mahaulepu 941.1 gage (January 1984 through December 2013), which was located at the makai end of the HDF site, rainfall on the proposed pasture lands is actually quite modest. Fifty eight (58) percent of the days had no rainfall and 97 percent of the days had less than 0.8 inches (Figure 25). Using the NRCS curve number method to compute runoff for the site's B and D class soils and irrigated pasture in good condition, it is anticipated that actual runoff into drainageways from HDF's pastures will only occur on days when the rainfall exceeds 0.8 inches. Using the 30-year record of the Mahaulepu 941.1 gage, such rainfall will occur on about three percent of days or about ten days a year on average. These runoff-producing rainfall events will be the primary mode of conveyance of nitrogen and phosphorus into drainageways and ultimately into the marine environment. The amounts are estimated as follows:

- As a first order approximation, it is assumed that two (2) percent of the nitrogen and one (1) percent of the phosphorus of HDF's annual manure and commercial fertilizer amounts are carried into the drainageways and/or percolate to the shallow groundwater in the alluvium. In round numbers, this would amount to about 10,000 pounds per year of nitrogen and 900 pounds per year of phosphorus. Notably, these amounts would be the same for both the 699- and 2000-cow herd sizes.
- Compared to the present contribution from and through the HDF site, these additions would represent 6.6- and 8.4- fold increases of nitrogen and phosphorus moving to ultimate discharge into the marine environment, respectively
- These increases would primarily occur during and immediately following runoff producing rainfall events rather than occur continuously throughout the year.

Relative to the nutrient loading under existing conditions, the potential increases due to the operation of HDF are obviously substantial. To provide some perspective, a comparison to ongoing nutrient additions to the marine environment by other projects and/or users along the Poipu coastline is instructive. These additions include the production of domestic wastewater and the application of fertilizers

Figure 25. Frequency of Occurrence of Daily Rainfall Amounts at Mahaulepu Station 941.1 (January 1984 thru December 2013 Data)



on the area's two golf courses and other landscaping. Their potential contributions of nitrogen and phosphorus to the marine environment are conservatively estimated as follows:

- The total production and disposal of domestic wastewater in the Koloa-Poipu area is on the order of 1.5 MGD. About 1.36 MGD is in DOH-UIC authorized disposal wells (Table 9) and the balance is an approximation of the contribution from household cesspools and septic tank-leach field systems.
- Nitrogen and phosphorus concentrations in the domestic wastewater are 40 and 10 MG/L, respectively.
- Ultimately, 15 percent of the nitrogen and two (2) percent of the phosphorus enter the marine environment.
- Fertilizer is applied on 400 acres in the Koloa-Poipu area (two golf courses, numerous parks, and other landscaped areas).
- Fertilizer applications of nitrogen and phosphorus average eight (8) and one (1) pound per 1000 square feet per year, respectively.
- Eight (8) and two (2) percent of the applied nitrogen and phosphorus escape to the groundwater below and are ultimately discharged into the marine environment

For this set of assumptions, the ongoing input to the marine environment along the Poipu shoreline is as tallied below. For nitrogen, the ongoing amount is about 3.8 times the estimated potential contribution from HDF. For phosphorus, the ongoing discharge is about 1.4 times as great as the potential discharge from HDF. These discharges are essentially constant throughout the year in comparison to the expected episodic discharges from HDF.

Estimate of Current Input of Nitrogen and Phosphorus
Into the Marine Environment Along the Poipu Shoreline

Contributing Source	Nitrogen (lbs/yr)	Phosphorus (lbs/yr)
Domestic Wastewater	27,360	910
Fertilizing Landscaping	11,150	350
Total	38,510	1260

Attachment 5: List of Injections Wells Poipu-Koloa and Mahaulepu Watersheds

Table: Poipu-Koloa Injection Wells, Volume, UIC #, Location

PERMIT #	# OF WELLS	FACILITY TYPE	FLOW gpd	FACILITY NAME	TMK #
UK-1218	1	WWD	7,000	Koloa Garden Apts SEW	4:2-6-04:033
UK-1236	1	WWD	6,000	Poipu Palms Condo	4:2-8-20:041
UK-1256	3	WWD	27,200	Nihi Kai Villas SEW	4:2-8-19:012
UK-1277	2	WWD	20,000	Whaler's Cove Condo	4:2-6-07:013
UK-1292	4	WWD	240,000	Poipu Kai STP	4:2-8-28:013
UK-1338	3	WWD	10,000	Poipu Shores Condo STP	4:2-8-19:004
UK-1387	4	WWD	0[1]	Old Koloa Town STP	4:2-8-07:003
UK-1476	4	Drainage Well	*	Hyatt Regency Kauai	4:2-9-01:002
UK-1515	1	WWD	50,000***	Hyatt Regency Kauai WWTP	4:2-9-01:002
UK-1556	17	Drainage Well	*	Hyatt Regency Kauai DW	4:2-9-01:002
UK-1609	2	WWD	4,800	Alihi Lani Apts SEW	4:2-8-15:009
UK-1830	2	WWD	3,000	Poipu Makai STP	4:2-8-20:004
UK-1929	3	WWD	16,000	Waikomo Stream Villas	4:2-8-15:07&079
UK-1938	2	WWD	32,000	Makahuena Resort	4:2-8-20:003
UK-2009	1	WWD	3,000	Hale Kahanalu WWTP	4:2-8-18:027
UK-2042	2	Industrial	50,000	Up-to Date Cleaners Kauai	4:2-6-08:03
UK-2095	2	WWD	9,000	Sunset Kahili Condominium	4:2-8-19:03
UK-2103	28**	Drainage	*	Marriott Waiohai Beach Club	4:2-8-17:7,8,12&20
UK-2619	16	WWD	18,000	Hale Ohana I Apts	4:2-8-03:038
UK-2741	5	WWD	16,283	Koloa Elementary School	4:2-8-10:011
UK2620	10	WWD	9,000	Hale Ohana II Apts	4:2-8-0.3:036
UK-1348	6	WWD	92,000	Lawai Beach Resort	4:2-6-05:004
UK-2388	1	WWD	800,000	Poipu WRF	4:2-8-14:027

Source: SDWB UIC Program, July 2015

WWD = Waste Water Disposal

1 Abandoned but not closed

* Variable and Intermittent discharge

** Damage due to hurricane and may not be operating but permit is still open

*** Standby well to accommodate effluent not used for irrigation or water feature at Poipu Kai Golf Course

Source: DOH Clean Water Branch "Mahaulepu Watershed-Waiopili Steam Sanitary Survey, Kauai", July 2015

Table 9

UIC Permitted Disposal Wells in the Koloa-Poipu Area

APPENDIX F

BASELINE CONDITIONS AND AN ASSESSMENT OF THE EFFECT OF THE PROPOSED HAWAII DAIRY FARM ON SURFACE WATER AND MARINE WATER CHEMISTRY MAHAULEPU, KAUAI, HAWAII

MARINE RESEARCH CONSULTANTS, INC.

ADDENDUM:

A PRELIMINARY BASELINE ASSESSMENT OF MARINE BIOTIC COMMUNITY STRUCTURE OFF MAHAULEPU, KAUAI, HAWAII

MARINE RESEARCH CONSULTANTS, INC.

BASELINE CONDITIONS AND AN ASSESSMENT OF THE EFFECT OF THE PROPOSED HAWAII DAIRY FARM ON SURFACE WATER and MARINE WATER CHEMISTRY MAHAULEPU, KAUAI, HAWAII

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I. INTRODUCTION AND PURPOSE

In late 2013, Ulupono Initiative made the investment to fund Hawai'i Dairy Farms, the first pasture-based rotational-grazing dairy in the state. Hawai'i Dairy Farms, LLC (HDF) was formed as a positive step toward the island state's food security, economic diversity, and sustainability. Experimental trials were conducted to determine lands capable of growing nutritious forage for dairy cows, and lands meeting the operational requirements for a dairy operation were identified. Kaua'i was determined to best meet operational requirements, and Māhā'ulepū Valley was found to provide ideal growing conditions.

At steady-state production with 699 milking cows, the farm will produce roughly 1.2 million gallons annually at market price. HDF will reduce Hawai'i's reliance on imported milk from the mainland United States by increasing current fresh local milk production by approximately 33 percent. The farm will be based on the most successful island dairy models in the world, and will utilize a sustainable, pasture-based rotational-grazing system and 21st century technology. The farm will be very different from conventional feedlot dairy operations.

HDF is committed to establishing a herd of up to 699 mature dairy cows, and demonstrating the pasture-based system as an economically and environmentally sustainable model for Hawai'i. With proven success at a herd size of 699, HDF will contemplate the possibility of expanding the herd in the future. Precision agricultural technology that monitors cows' health, grass productivity, and effluent management will be used to ensure environmental health and safety, as well as best management practices, and help determine the ultimate carrying capacity of the land.

For dairy operations with 700 or more mature dairy cows, additional regulatory review and permitting by the State Department of Health is required. The application process for a National Pollutant Discharge Elimination System (NPDES) Concentrated Animal Feeding Operation (CAFO) permit includes public notification and input. At the discretion of HDF, management may choose to expand operations up to the carrying capacity of the land, which is currently estimated to be up to 2,000 productive milking dairy cows. Permit process compliance would be followed at such time HDF may decide to pursue an expanded operation.

Dairy-related facilities will occupy approximately 10 acres along the western boundary of the project area. Buildings will include a milking barn with a rotary milking platform and milk storage tanks, two calf sheds, and an implementation shed for tools and equipment. Manure captured during the milking process will be transferred through underground pipes to two nearby effluent ponds, where solids will be settled out and the remaining fluid applied to the pasture through the irrigation system. When applied via the irrigation system, non-potable water from the Waita Reservoir will be added to nutrient rich liquid for irrigation use. The effluent ponds will be sealed with a flexible membrane liner, and will be constructed within a secondary containment berm. Paved access roads and a truck turnaround area for milk tanker trucks, grain silos, and a holding yard for cows waiting to enter the milking parlor will also be part of the project.

Agricultural infrastructure from prior sugar cane cultivation within the project area, such as gravel access roads, field roads, reservoirs, pipelines, irrigation ditches, drainage ways and culverts will be adapted for reuse where possible. Additional field improvements will include a livestock water distribution system, pivot irrigation system, culverts and fencing.

Surface waters draining the project site meet Waiopili Ditch, and will eventually reach the ocean. While all construction and operational activities of HDF will utilize best management practices to protect groundwater and surface water resources and the marine environment downslope from the dairy site, it is nevertheless important to identify any potential impacts that may be associated with the planned dairy. Proposed land uses do not include any direct alteration of coastal areas or nearshore waters. However, the dairy operation will result in some changes to the composition and volume of surface water and groundwater that flows beneath the property. Therefore, evaluating the potential for alterations to water quality and marine life from material input from the dairy constitutes an important factor in the planning process.

In the interest of addressing these concerns and assuring maintenance of environmental quality, a program to assess groundwater, surface water, and nearshore marine water quality and potential impact analysis of the nearshore areas off the HDF was conducted in 2014-1015. Baseline data on groundwater, surface water, and nearshore marine water quality was recorded. The rationale of the water quality assessment was to determine the contribution of groundwater to the marine environments down gradient of the HDF site, and to evaluate the effects this input has on water quality at the present time, prior to the commencement of any dairy activities. Combining this information with estimates of changes in groundwater and surface water flow rates and chemical composition that could result from the proposed project provides a basis to evaluate the potential future effects to the marine environment.

Predicted changes in surface water and groundwater composition and flow rates have been supplied by Tom Nance Water Resource Engineering (TNWRE 2016).

Results of the combined evaluation provided an estimate of the degree of change to the marine environment that could occur as a result of Hawaii Dairy Farms project.

II. METHODS

A. Water Quality/Chemistry

Twelve survey sites were established in the surface waters that traverse the HDF property (see Figure 1). Stations 1 and 2 were located outside the mauka boundary of the site, Stations 3-6 were located within the HDF site, while Stations 7-10 were positioned at the makai end of the HDF site. Stations 11 and 12 were located off the HDF property between the boundary and the ocean. Site 12 was located near the juncture of the ditch and the ocean. Samples were collected by monitoring personnel filling pre-rinsed linear polyethylene bottles with undisturbed surface water. Sampling was conducted on six separate occasions (October 14, 2014, October 29, 2014, November 11, 2014, March 4, 2015, May 8, 2015 and July 9, 2015).

In addition, on October 6, 2014 four transects extending from the shoreline to approximately 200 meters (m) offshore were established for marine sampling (Figure 1). Water quality was evaluated on transects that were oriented perpendicular to the shoreline and depth contours. Water samples were collected at five locations on each transect from just seaward of the shoreline to approximately 200 meters (m) offshore (1, 5, 10, 25, 100 and 200 m). Such a sampling scheme was designed to span the greatest range of salinity with respect to potential freshwater efflux at the shoreline. Sampling was more concentrated in the nearshore zone because this area receives the majority of groundwater and surface water discharge, and hence is most important with respect to identifying the current status and potential future impacts.

All water samples were collected by swimmers working from a jet-ski. Owing to the shallow depth of the near-shore shelf, at stations with water depth less than 1 m a single sample was collected within 20 cm of the sea surface by swimmers working from shore. At stations with water depths greater than 1 meter, samples were collected at two depths; a surface sample was collected within approximately 20 (cm) of the sea surface, and a bottom sample was collected within 1 m of the sea floor.

In order to determine the existing chemical constituents of groundwater, samples were collected from several wells on and around the project site in 2015 (see report by Tom Nance Water Resources Engineering for locations of wells and results of well water analyses).

Water quality parameters evaluated included the ten specific criteria designated for open coastal waters in Chapter 11-54, Section 06 (b) of the State of Hawaii Department of Health (DOH) Water Quality Standards. These criteria include: total nitrogen (TN), nitrate + nitrite nitrogen (NO_3^- + NO_2^-, hereafter referred to as NO_3^-), ammonium nitrogen (NH_4^+), total phosphorus (TP), orthophosphate phosphorus (PO_4^{-3}), Chlorophyll a (Chl *a*), turbidity, temperature, pH and salinity. In addition, silica

(Si) was also reported because these parameters are sensitive indicators of biological activity and help determine the degree of groundwater input in the coastal ocean.

Sampling protocols followed the relevant State of Hawaii Department of Health Clean Water Branch Quality Assurance Project Plan. Surface water samples were collected by filling pre-rinsed, 1-liter polyethylene bottles. Deep water samples were collected using a Niskin-type oceanographic sampling bottle. The bottle is lowered to the desired sampling depth with spring-loaded endcaps held open so water can pass freely through the bottle. At the desired sampling depth, a weighted messenger released from the surface triggers closure of the endcaps, isolating a volume of water.

Subsamples for nutrient analyses were immediately placed in 125-milliliter (ml) acid-washed, triple rinsed, polyethylene bottles and stored on ice. Analyses for Si, NH_4^+, PO_4^{3-}, and NO_3^- were performed of filtered subsamples with a Technicon Autoanalyzer using standard methods for seawater analysis (Strickland and Parsons 1968, Grasshoff 1983). TN and TP were analyzed in a similar fashion following digestion. Total organic nitrogen (TON) and total organic phosphorus (TOP) were calculated as the difference between TDN and dissolved inorganic N, and TDP and dissolved inorganic P, respectively.

Water for other analyses was subsampled from 1-liter polyethylene bottles and kept chilled until analysis. Chl *a* was measured by filtering 300 ml of water through glass-fiber filters; pigments on filters were extracted in 90% acetone in the dark at -20° C for 12-24 hours. Fluorescence before and after acidification of the extract was measured with a Turner Designs fluorometer. Salinity was determined using an AGE Model 2100 laboratory salinometer with a readability of 0.0001‰ (ppt). Turbidity was determined using a 90-degree nephelometer, and reported in nephelometric turbidity units (NTU) (precision of 0.01 NTU). Vertical profiles of salinity, temperature and depth were acquired using a RBR-620 CTD calibrated to factory standards.

Surface water samples were also analyzed for the indicator bacteria Enterococcus and *Clostridium perfringens*. Separate water samples were collected in autoclaved polyethylene bottles and returned to the analytical lab within 6 hours of collection. Enterococcus were analyzed according to EPA Method 1600 (Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar [mEI]), while Clostridium were analyzed using membrane filter enumeration following the protocols in Bisson and Cabelli (1979). All indicator bacterial analyses were conducted by Analytical Services, LLC in Honolulu, HI.

All fieldwork for all surveys was conducted by Dr. Steven Dollar. All water chemistry laboratory analyses were conducted by Marine Analytical Specialists located in Honolulu, HI (Labcode: HI 00009). This analytical laboratory possesses acceptable ratings from EPA-compliant proficiency and quality control testing.

III. RESULTS

A. Surface Water Chemistry

1. Distribution of Chemical Constituents

While the main surface water course which crosses the HDF site is called "Waiopili Ditch" this feature is not named on the USGS quadrangle map. At its mauka end above the HDF property, it is a relatively steep, naturally occurring water course with several small tributaries. Across the HDF property and for some distance further makai, the channel is manmade to facilitate former sugarcane cultivation. Along part of the course across the HDF property, the channel functions as a drain for groundwater discharged from the alluvium on a seasonal basis. Most of the channel is overgrown by dense vegetation, making access to flowing water difficult. At no point can the ditch be considered a recreational resource, including the channel near its terminus at the ocean.

Tables 1 and 2 show results of water chemistry analyses for samples collected in surface waters and the adjacent ocean during six increments of sampling in 2014 and 2015. Table 1 shows concentrations of dissolved nutrients in micromolar (µM) units; Table 2 shows concentrations in micrograms per liter (µg/L). Concentrations of twelve water chemistry constituents from the six sampling events are shown in Figures 2-5.

Several patterns of distribution are evident in Tables 1-2 and Figures 2-5. With the exception of Si, concentrations of all dissolved nutrients (NO_3^-, PO_4^{3-}, NH_4^+, TN, TP) are relatively low at mauka sampling stations 1-3 located near the upper boundary of the property (Figures 2 and 3). Concentrations of these constituents increase to higher values at Stations 4-10, located within the boundaries of the HDF site. Values then decrease to relatively constant values at Stations 11-12 makai of the HDF site. Concentrations of all nutrients in the nearshore ocean samples are of similarly low values as concentrations from stations located at the mauka boundary of the HDF property.

As noted above, dissolved Si is the only nutrient that deviates from this pattern. Concentrations of Si are highest at the mauka end of the sampling scheme and lowest at the ocean (Figure 2). As Si is generally higher in groundwater relative to surface water, the observed pattern suggests that the surface water at upper elevations contains of a higher proportion of groundwater. The contribution of low Si surface water makes up a progressively larger component of surface water downgradient of the HDF property. As natural marine waters contain substantially less Si than either surface water or groundwater, mixing of these waters at the shoreline results in the observed lowest concentrations of Si.

The pattern of Si distribution provides an indication of the processes driving the observed patterns of other dissolved nutrients described above (low levels at mauka boundary, higher levels on HDF site, low levels below makai boundary). Composition of surface water at the mauka regions appears to consist primarily of groundwater, as it is relatively low in dissolved plant nutrients (N and P). As water flows through the HDF site, it appears that nutrient concentrations are augmented by input from drainage of surface water that contains some leachate from surrounding lands. Such leachate may contain some subsidies from either prior or ongoing land usages. However, between the time that surface water leaves the HDF site and reaches the ocean, nutrient concentrations return to levels similar to those above the site. As these subsidies are not evident in surface water samples collected below the HDF site, it is likely that the nutrient subsidies are small and rapidly diluted with flow throught the ditch to the ocean. By the time surface water reaches the ocean, nutrient concentrations are similar to those above the HDF site, suggesting that the values at the surface water-ocean boundary are the same as what they would be without the nutrient subsidy from leachate observed on the HDF site.

Plots of salinity at each of the surface water sampling stations shows essentially no change until surface water mixes with ocean water (Figure 4). Plots of turbidity and Chl *a* show similar patterns as the dissolved nutrients. Values are lowest at the mauka end of the sampling regime about the HDF site, show elevated levels at several of the sampling stations within the dairy, and return to baseline low levels below the dairy site and in the nearshore ocean.

2. Indicator Bacteria

Tables 1 and 2 also show counts of Enterococci and Clostridium indicator bacteria measured in surface water during four of the sampling events. For both indicators, there is a general pattern of increasing counts moving closer to the shoreline. During all but one sampling date, the highest single count of enterococcus occurred at either Station 11 or 12 (during the May 8, 2015 survey, the peak value was at Station 5A). Of the two sampling sets that included Clostridium, the May 8, 2015 set showed a clear progression of increasing values, while the July 9, 2015 set revealed no consistent pattern. While the bacteria are generally intended to serve as indicators of human fecal contamination, it is clear from the elevated counts in surface waters that there are other sources contributing to the colony counts. These sources may include feral animals (e.g., pigs) or domesticated animals (sheep) that are being raised near the HDF site. As no dairy cattle were present on the site during any of the sampling events, it is clear that the observed counts of indicator bacteria are not a result of dairy operations.

However, an overall consistent pattern for both indicator bacteria is that counts in nearshore ocean water were consistently lower than in surface waters. During the March 4, 2015, enterococcus counts were 780 at Station 12, and below detection for both samples collected near the juncture of the ditch and ocean. While not reaching levels of non-detection during the other two events where ocean samples were analyzed, counts were substantially lower in the ocean than in the ditches. As these samples are collected within several tens of meters of each other, it is apparent that both physical mixing processes and the lethal effects of high saline water on bacteria result in substantial reduction in the nearshore ocean.

B. Marine Water Chemistry

1. Distribution of Chemical Constituents

Tables 3 and 4 show results of ocean water chemistry analyses for samples collected on October 6, 2014. Table 1 shows concentrations of dissolved nutrients in micromolar (µM) units; Table 2 shows concentrations in micrograms per liter (µg/L).

Concentrations of eight dissolved nutrient constituents in surface and deep samples are plotted as functions of distance from the shoreline in Figure 6. Values of salinity, turbidity, Chl *a* and pH as functions of distance from shore are shown in Figure 7.

Several patterns of distribution are evident in Tables 3-4 and Figures 6-7. It can be seen that on Transects 1, 2 and 4 that dissolved nutrients do not display any distinctly elevated concentrations throughout the length of the sampling transects. Low concentrations at the shoreline with progressively lower values with distance from shore indicates that there is little groundwater or surface water emanating at the shoreline near Transects 1, 2 and 4. Examination of the trends of salinity in Tables 3 and 4 and Figure 7 indicate that only at Transect 4 is there an indication of slightly lower salinity at the shoreline (31.6‰). While there is a corresponding increase in Si, there is no such corresponding increase in NO_3^-, suggesting that the lower salinity is a result of dilution from surface water rather than inputs from groundwater.

Examination of the patterns of nutrient concentrations and salinity as functions of distance from the shoreline at Transect 3 provides an entirely different picture than for the other transects. Samples collected within 5 m of the shoreline exhibit substantially higher values of all dissolved nutrients. These elevated values are the result of input of surface water from Waiopili Ditch. While the values close to the shoreline are elevated, beyond 10 m of the shoreline they return to values similar to the other transects. Hence, while there is a distinct signature from input of surface water, such input is rapidly mixed to background levels within 10 meters of the shoreline.

Salinity, turbidity and Chl *a* on Transect 3 exhibit the same patterns as dissolved nutrients. Within 10 m of the shoreline all of these constituents display elevated values that rapidly return to background levels.

It is important to note that the southeast coastline of Kauai, where the sample sites are located are subjected to direct effects of tradewinds, as well as south, north and east swells. As a result, vigorous physical mixing processes are the typical condition in the nearshore ocean. As safety considerations dictate, ocean sampling can only be conducted during relatively calm seas, as were the conditions during the October 6, 2014 sampling event. In addition, sampling was conducted at low tide, when mixing between groundwater/surface water and ocean water is minimized. Hence, the results of the present study represent a case with minimal mixing of water masses in the nearshore ocean. Under these conditions, the effects of input of groundwater/surface water will be most apparent. It is likely that during typical tradewind conditions, and with larger surf, the zone of mixing would be far smaller than is evident in the data presented in this report.

2. Conservative Mixing Analysis

A hydrographic mixing model is used to interpret the extent of material input from land. In the simplest form, the model plots the concentration of a dissolved nutrient constituents as functions of salinity. The concept of using such mixing models that scale nutrient concentrations to salinity is utilized by the State of Hawaii Department of Health for establishing a unique set of water quality standards for the West Coast of the Island of Hawaii [Hawaii Administrative Rules, §11-54-06 (d)]. While the HDOH has not yet extended this method of analysis to monitoring in other areas of the State, it is useful to employ the techniques as a way of better understanding the sources of material input to marine waters.

Figure 8 plots the concentrations of Si, NO_3^-, PO_4^{3-}, and NH_4^+ as functions of salinity for the samples collected at each ocean transect site. Each graph also shows two conservative mixing lines constructed by connecting the endmember concentrations of open ocean water and groundwater from two monitoring wells that penetrate the alluvium underlying the HDF site, and the mean values of nutrient concentration from Station 12 in Waiopili Ditch (see Figure 1).

Comparison of the curves produced by the distribution of data with conservative mixing lines provides an indication of the origin and fate of the material in question. If the constituent in question displays purely conservative behavior (i.e., no input or removal from any process other than physical mixing), data points should fall on, or near, the conservative mixing line. If however, external material is added to the system through processes such as leaching of fertilizer nutrients to groundwater, data points will fall above the mixing line. If material is being removed from the system by processes such as biological uptake, data points will fall below the mixing line.

Dissolved Si represents a check on the method as this material is usually present in high concentrations in groundwater, low concentration in open coastal waters, and is not a major component of fertilizer or sewage effluent. In addition, Si is not utilized rapidly within the nearshore environment by biological processes. It can be seen in Figure 8 that all data points for all four transect sites fall in a linear array on the conservative mixing line created with end-point concentrations from the water from Waiopili Ditch; none of the data points line near the groundwater mixing line. However, as the concentrations from the samples collected off Transect 3 are so much higher than off the other transects, it is likely that small amounts of groundwater discharge would be masked by surface water input. This plot indicates that at the time of sampling, most of the freshwater entering the ocean emanated from Waiopili Ditch.

The plots of NO_3^- versus salinity show a different distribution thanSi. Data points from Transects 1 and 2 fall near the groundwater mixing line. Such a result is not unexpected as these transects are the farthest from the point of discharge of Waiopili Ditch. The two low salinity points from Transect 3 lie between the mixing lines, suggesting that there is a contribution of both surface water from Waiopili Ditch and groundwater. While this result appears somewhat contradictory to the interpretation of the Si data, it may be explained in that the mean concentration of NO_3^- at Station 12 was less than the concentration on the day of ocean sampling. Data points from Transect 4 lie below the Waiopili Ditch mixing line, suggesting that there is input to the ocean of surface water slightly lower in NO_3^- than found in Waiopili Ditch.

While PO_4^{3-} is also generally found in groundwater in higher concentrations than open coastal water, it occurs in far lower concentrations compared to NO_3^-, owing in part to a high absorptive affinity of phosphorus in soils or rock. It can be seen in Figure 8 that the concentrations of PO_4^{3-} are higher in surface water than in Well water. When plotted as functions of salinity, concentrations of PO_4^{3-} do not prescribe linear patterns similar to Si and NO_3^-. Values of PO_4^{3-} in samples collected near the shoreline of Transect 3 lie far below both mixing lines. As all values of PO_4^{3-} are below 0.2 µM, there is essentially no influence from inputs from land.

Plots of concentrations of NH_4^+ versus salinity show similar relationship as PO_4^{-3}. Plots of concentrations of NH_4^+ versus salinity indicate that the range of values is small, even with the substantial input of surface water at the shoreline.

3. Compliance with DOH Criteria

DOH Water Quality Standards include specific criteria for three situations; criteria that are not to be exceeded during either 10% or 2% of the time, and criteria that are not to be exceeded by the geometric mean of samples. Comparing sample concentrations to these criteria provide an indication of whether water quality is near the stated specific criteria.

Noted in Tables 1 and 2 are samples that exceed DOH 10% water quality standards for open coastal waters under "dry" conditions. The criteria for dry conditions are applied to the Mahaulepu area under the probable assumption that this region receives less than 3 million gallons of groundwater input per mile per day.

Comparison of water chemistry results with DOH criteria reveals that during the October 2014 sampling, the only constituent on transects 1-3 that exhibited consistent exceedance of the “not to exceed more than 10% of the time” criteria was turbidity and Chl *a*. Samples collected with 10 m of the shoreline on transects 2 and 3 had turbidity values that exceeded DOH standards. As these samples were collected in the surf zone at the shoreline, such elevated turbidity is expected as a result of resuspension of naturally occurring marine sands. Similarly, Chl *a* at stations near the shoreline was elevated, likely as a result of resuspension of plant material.

At transect 4, however, all nutrient values in the samples collected within 5 m of the shoreline exceeded the DOH standard. As discussed above, these elevated values are the result of mixing of surface water with ocean water in the nearshore zone. Within 10 meters of the shoreline, water quality is within DOH standards.

IV. DISCUSSION and CONCLUSIONS

The purpose of this assessment is to assemble the information to make valid evaluations of the potential for impact to the marine environments from the proposed Hawaii Dairy Farms operation. The information collected in this study provides the basis to understand the processes that are operating in the nearshore ocean, so as to be able to address any concerns that might be raised in the planning process for HDF.

It is important to note that planning for HDF project will utilize best management practices for nutrient generation and runoff stabilization in order to minimize or even reduce sediment discharge to the channel and groundwater that will eventually reach the ocean.

The proposed HDF does not include plans for any direct alteration of the shoreline or offshore areas. Therefore, potential impacts to the marine environment can only be considered from activities on land that may result in delivery of materials (primarily fresh water and nutrients) to the ocean through either infiltration to groundwater with subsequent discharge to the ocean, and surface runoff. To evaluate the possible magnitude of these processes, a report has been prepared by Tom Nance Water Resource Engineering entitled "*Estimates of the Potential Impact on Groundwater and Surface Water by Hawaii Dairy Farms in Mahaulepu, Kauai*" (TNWRE 2016). The findings of the report are summarized below.

The TNWRE report considers all sources of groundwater and surface water that flow through the project site to the ocean. Based on existing data, the estimated total load of nitrogen from groundwater and surface water leaving the makai end of the HDF site under existing conditions is 1502 pounds per year. Of the total nitrogen, 332 pounds is from groundwater moving through the alluvium and 1170 pounds is from surface water flow. The total load of phosphorus leaving the site is 107 pounds per year, with 27 pounds in groundwater from the alluvium and 80 pounds in surface water. Surface runoff estimates from the HDF site are approximately three times greater than the estimated amounts carried in groundwater moving through the alluvium. Relative to nutrient loading in most areas in Hawaii, these amounts are very low.

From the perspective of potential nutrient additions to surface and groundwater, the operation of HDF can be characterized as a semi-enclosed loop system: nutrients are taken up by pasture kikuya grass; the cows eat the grass as their primary food supply (they will be fed supplemental grain in the milking parlor); nutrients in the grass consumed by the cows are returned to the ground, either as manure excreted on the pastures or as manure collected in the milking parlor and applied to the pastures. Estimated amounts of nutrient in the manure produced by the cows will not be sufficient to promote growth of pasture grass to maintain the system in steady state. The shortfall of nutrients in the manure to grow the grass will be made up by the application of commercial fertilizer.

In rounded numbers and on an annual basis, HDF will be circulating 490,000 pounds of nitrogen and 87,000 pounds of phosphorus. These amounts are 325 and 815 times greater than the estimates of nitrogen and phosphorus currently carried in surface and groundwater moving through the HDF site that ultimately discharge into the marine environment. At issue is how much of the nitrogen and phosphorus anticipated from manure and from applied commercial fertilizer may leave the site and increase the present nutrient load that ultimately discharges into the nearshore marine environment. There are several aspects to consider in arriving at such an estimate:

• Relative to surface water moving through the site, the groundwater flow in the alluvium is very modest. The formation is poorly permeable and even after HDF is in full operation, its contribution to any increase in groundwater nutrient loads will be significantly less than in surface water.

• A number of design and best management practices are proposed to limit the amount of runoff and to filter the sediment in that runoff. Most significant among these are setbacks, filter strips, and buffer plantings on both sides of drainageways. The herbaceous cover area will be 35 feet wide on both sides of the drainageways.

• Perhaps the biggest factor in controlling nutrient discharge from the site will be the operating practices of HDF personnel to track the nutrient balances in order to avoid excessive use of fertilizer and in anticipating weather patterns to avoid irrigating in advance of heavy, runoff-producing rainfall. It is anticipated that actual runoff into drainageways from HDF's pastures will occur on less than three (3) percent of days, which is the equivalent of an average of about ten (10) days per year. These runoff-producing rainfall events will be the primary mode of conveyance of nitrogen and phosphorus into drainageways and ultimately into the marine environment.

• As a first order approximation, it is assumed that two (2) percent of the nitrogen and one (1) percent of the phosphorus of the annual production by HDF are carried into the drainageways and/or percolate to the shallow groundwater in the alluvium.

These percentages would amount to 9,800 pounds per year (lb. /yr.) of nitrogen and 870 lb. /yr. of phosphorus. Notably, these amounts would be the same for dairy herd sizes of both 699 and 2,000 cows.

• Compared to the present contribution of nutrients presently passing through the HDF site, these amounts are 330 and 840 times greater than current nitrogen and phosphorus, respectively. These increases would primarily occur during and immediately following runoff producing rainfall events, and would not be a continuous input throughout the year.

Relative to the annual nutrient loading under existing conditions, the potential increases resulting from the operation of HDF are substantial. To provide some perspective, it is instructive to compare the ongoing nutrient additions to the marine environment along the Poipu coastline. These additions include the production of domestic wastewater and the application of fertilizers on the two golf courses and other landscaping in the Poipu area. The potential contributions of nitrogen and phosphorus to the marine environment from these sources can be conservatively estimated as follows:

The total production and disposal of domestic wastewater in the Koloa-Poipu area is on the order of 1.5 MGD. About 1.36 MGD is in DOH-UIC authorized disposal wells. The balance is an approximation of the contribution from household cesspools and septic tank leach field systems. Nitrogen and phosphorus concentrations in the domestic wastewater are estimated at 40 and 10 MG/L, respectively. Ultimately, 15 percent of the nitrogen and two (2) percent of the phosphorus enter the marine environment.

Fertilizer is applied on 400 acres in the Koloa-Poipu area (two golf courses, numerous parks, and other landscaped areas). Fertilizer applications average eight (8) and one (1) pound per 1000 square feet per year. Eight (8) and two (2) percent of the applied nitrogen and phosphorus escape to the groundwater below and are ultimately discharged into the marine environment. These percentages are estimated based on field validation measured from other golf courses in the State of Hawaii in similar coastal settings as the Poipu Courses (Dollar and Atkinson, 1992).

For this set of assumptions, the ongoing input to the marine environment along the Poipu shoreline is about 38,510 lb./yr. for nitrogen and 1,260 lb./yr. for phosphorus. This amount of nitrogen is about 3.8 times (380%) higher than the potential contribution from HDF (10,000 lbs./yr.). For phosphorus, the ongoing discharge from the Poipu area is about 1.4 (140%) times as great as the potential discharge from HDF (900 lb./yr.). In addition, these discharges from Poipu are essentially constant throughout the year in comparison to the episodic discharges from HDF that will only occur as a result of rainfall associated with storm conditions.

For evaluation of the potential effects of the HDF operation, it is important to consider the composition of the receiving waters. The part of Waiopili Ditch that bisects the

HDF site is narrow, highly overgrown by vegetation, and is a man-made feature created for sugar cane irrigation. It does not represent a recreational resource and does not likely provide value as a unique biotic habitat, functioning mainly as a drainageway. The area of the ditch near the junction with the ocean consists of a deep muddy basin that connects to the ocean through a shallow channel that flows through beach sand. The nearshore marine environment consists of a shallow intertidal reef flat that terminates in a reef crest that slopes sharply on the seaward side to sand and rubble flats. The intertidal reef flat where surface water mixes with ocean water is consistently subjected to substantial wave action and current flow to the west. Owing to shallow depth and almost continuous rough water conditions, the reef flat where mixing occurs can be considered dangerous for humans to use, and does not represent an area of safe or unique recreational use. Measurements made of water chemistry in the marine environment on a rare day of with low wind and wave action indicated that mixing of surface water in the ocean occurs rapidly within a short distance of the shoreline. During periods of more typical tradewind weather with larger waves breaking on the reef crest, the zone of mixing would be even more restricted within the nearshore area. While these measurements were made during a period of dry weather, it is likely that the zone of mixing in the ocean would not be significantly different during higher surface water flow, as wind and surf conditions would likely also increase during storm condition.

Combining these results with the estimates of changes to surface drainage (there are no changes to groundwater discharge) during HDF operations, it can be concluded that the project will not cause substantial effects to marine water quality beyond the immediate area of merging of surface and ocean water near the shoreline. Analyses of surface water quality indicates that while there are presently increases to nutrient concentrations at sampling sites within the HDF property, these increases drop back to levels that occur mauka of the property at stations near the shoreline. Nutrient subsidies to surface drainage should only occur during occasional episodic rainfall events estimated to occur no more than ten days per year. Any increases to surface water nutrient and sediment concentrations resulting from HDF operations should be limited to occur only during these episodes of heavy rainfall. Extreme physical factors in the marine receiving environment should result in mixing of surface water to background marine conditions within a small area near the point of discharge from the ditch.

Measurements of indicator bacteria in the surface water flow reveal elevated numbers under the present conditions that include no dairy cattle. As a result, it can be concluded that these bacterial counts are the result of existing "natural conditions." Like other constituents of water chemistry, indicator bacteria counts decrease rapidly in the marine environment within a small area close to the point of discharge. The rapid decrease in bacterial counts following discharge of surface water to the ocean is likely the result of both physical mixing (i.e., dilution), and toxicity from saline waters. There is no reason to expect that these factors will not continue to keep bacterial counts low in the marine environment.

It is also important to consider that, on an annual basis, ongoing processes in the Poipu area of golf course fertilization and domestic sewage disposal continually discharge up to 3.8 times nitrogen and 1.4 times phosphorus to the marine environment relative to the episodic discharges projected from the HDF operation. This discharge occurs along the entire length of the Poipu coastline, rather than as the limited point source discharge at the mouth of Waiopili Ditch draining Mahaulepu Valley. As noted above, the point of discharge of Waiopili Ditch is not a safe area for marine activities, and does not represent a recreational site. Hence, the potential for impacts to the marine environment from the HDF operation in the confined area of the ditch discharge is small or non-existent in comparison to the potential for impacts associated with ongoing functioning of the Poipu community.

V. SUMMARY

1. Evaluation of water chemistry and indicator bacteria were carried out during six surveys from October 2014 to July 2015 in the section of Waiopili Ditch extending from the mauka boundary of the proposed Hawaii Dairy Farms (HDF) in Mahaulepu, Kauai, across agricultural lands Makai, and to the ocean. In addition, marine water chemistry was evaluated during a field survey which consisted of sampling along four ocean transects downgradient of the HDF site that extended from the shoreline to a distance offshore deemed to be beyond the influence of land. All surveys included analysis of water chemistry constituents listed in State of Hawaii Department of Health water quality standards.

2. With the exception of Silica (Si), surface water samples revealed relatively consistent patterns for all nutrient constituents (NO_3^-, PO_4^{3-}, NH_4^+, TN, and TP). Concentrations of these nutrients were lowest at the stations outside the upper mauka HDF site, increased at stations located within the HDF site, and returned to low levels between the makai end of the site and the ocean. The concentrations of Si displayed a different pattern, with the highest values at mauka sampling stations that steadily decreased closer to the ocean. As Si is typically higher in groundwater than in surface water, the observed pattern for Si indicates that the groundwater contribution to surface water is highest at the mauka end of the property, and decreases through the HDF site and downgradient towards the ocean.

3. As no dairy cows were on site before or during the sampling, the elevated nutrients sampled in the central region are the result of input from existing sources on the property that likely include feral animals, farm animals or crop fertilization in Mahaulepu Valley. The elevated concentrations may also be a result of lower flow in the central sector of the channel resulting in longer residence time. However, the observation that elevated nutrients return to near background levels at stations makai of the HDF site suggest that the inputs are small and localized.

4. Analysis of water chemistry constituents sampled in the marine environment indicates two major patterns. Small elevations of inorganic nutrients (Si, NO_3^-, PO_4^{3-}, TN, and TP) along with corresponding decreases in salinity along the Mahaulepu shoreline indicate only a small input of groundwater to the ocean. While detectable in the nearshore area, groundwater nutrient input is mixed to background oceanic values within meters of the shoreline.

5. At the marine sampling station at the juncture of Waiopili Ditch and the ocean, steep gradients of nutrients, salinity, Chl *a* and turbidity were observed. These gradients were the result of a narrow zone of mixing of surface water and ocean water in the intertidal region of the reef flat. Typical oceanographic conditions with tradewind- generated seas and long-period swells breaking on the reef platform result in rapid mixing and dilution of surface water constituents within a narrow zone that only extends several meters from the shoreline. As a result, input from surface water is highly restricted in terms of spatial distribution and effects to the marine environment.

6. Counts of indicator bacteria (*Enterococcus*, *Clostridium*) in surface water samples and nearshore marine samples indicate no repetitive pattern: counts were high and variable within surface water sites and between times of sampling. As no dairy cow activities existed during the sampling, the high levels of indicator bacteria are the result of naturally occurring sources (feral animals), as well as other existing land uses including crop fertilization.

7. Counts of indicator bacteria decreased substantially in samples collected in the nearshore ocean in the zone where surface water from Waiopili Ditch mixed with marine waters. The rapid decrease is likely a result of both physical mixing of water masses and toxicity to bacteria from saline water. In any event, the elevated levels of indicator bacteria found in surface water samples do not extend beyond the shoreline.

8. Evaluations of changes to groundwater and surface water flux and composition resulting from the project performed by Tom Nance Water Resource Engineering.
In rounded numbers and on an annual basis, HDF will be cycling 490,000 pounds of nitrogen and 87,000 pounds of phosphorus annually through the system in terms of nutrient uptake in grass, excretion by dairy cows, and application on pastures as nutrient sources for pasture grass. These amounts are 330 and 840 times greater than the estimates of nitrogen and phosphorus currently carried in surface and groundwater moving through the HDF site that ultimately discharges into the marine environment. Hence, during dairy operations, cycling of nutrients through the essentially closed system will be far greater than occurs at present.

9. However, as a first order approximation, it is calculated that only two (2) percent of the nitrogen and one (1) percent of the phosphorus of the annual production by HDF

will be lost from the internal cycle, and actually be conveyed beyond the dairy boundaries into the drainageways. The mechanisms for the significant reduction in nutrient transport to the ocean include implementation of design and best management practices that will limit the amount of runoff, and tracking nutrient balances in order to avoid excessive use of fertilizer. It is anticipated that actual runoff into drainageways from HDF's pastures will on an average of about ten days per year. These episodic runoff-producing rainfall events will be the primary mode of conveyance of nitrogen and phosphorus into drainageways and ultimately into the marine environment. Compared to the present contribution of nutrients presently passing through the HDF site, these additions would represent about seven and nine-fold increases of nitrogen and phosphorus, respectively.

10. A comparison to ongoing nutrient additions to the marine environment along the Poipu coastline from the production of domestic wastewater and the application of fertilizers on the two golf courses and other landscaping in the Poipu area indicates that these sources contribute about 3.8 times (380%) more nitrogen and 1.4 (140%) times more phosphorus than the potential discharge from HDF. The Poipu discharges are essentially constant throughout the year, and occur across the entire coastline, including areas of high recreational use. On the other hand, the HDF discharges are episodic, occurring only several times per year, and are restricted to a single small area of discharge at a site not suitable for recreational use.

11. As a result of these findings, it can be concluded that as long as BMP's and other operational practices perform as anticipated in minimizing excess nutrients from leaving the HDF site, all indications are that there is little evidence that operation of the Hawaii Dairy Farm will result in any substantial changes to the marine environment.

12. The water chemistry and indicator bacterial studies conducted for this report can serve as an initial baseline for any monitoring programs that may be required for the Hawaii Dairy Farms.

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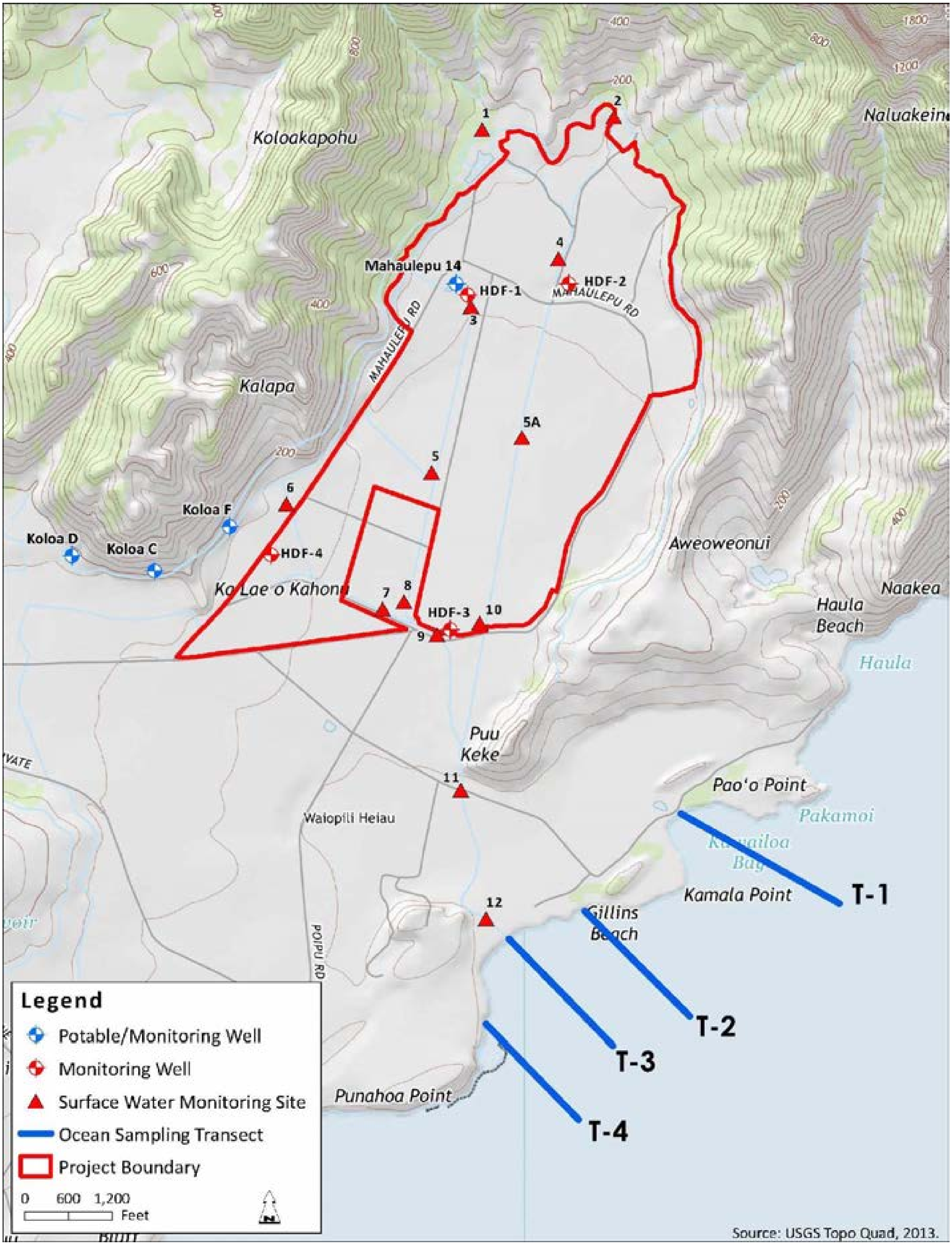

FIGURE 1. Map of Mahaulepu area of Kauai, Hawaii showing boundaries of Hawaii Dairy Farm property. Also shown are locations of sampling stations 1-12 in Waiopili Stream as well as four ocean sampling transects (T-1 through T-4). Tansect T-1 serves as a control that is removed from the influence of discharge from Waiopili Stream. Transect T-4 originates at the mouth of Waiopili Stream.

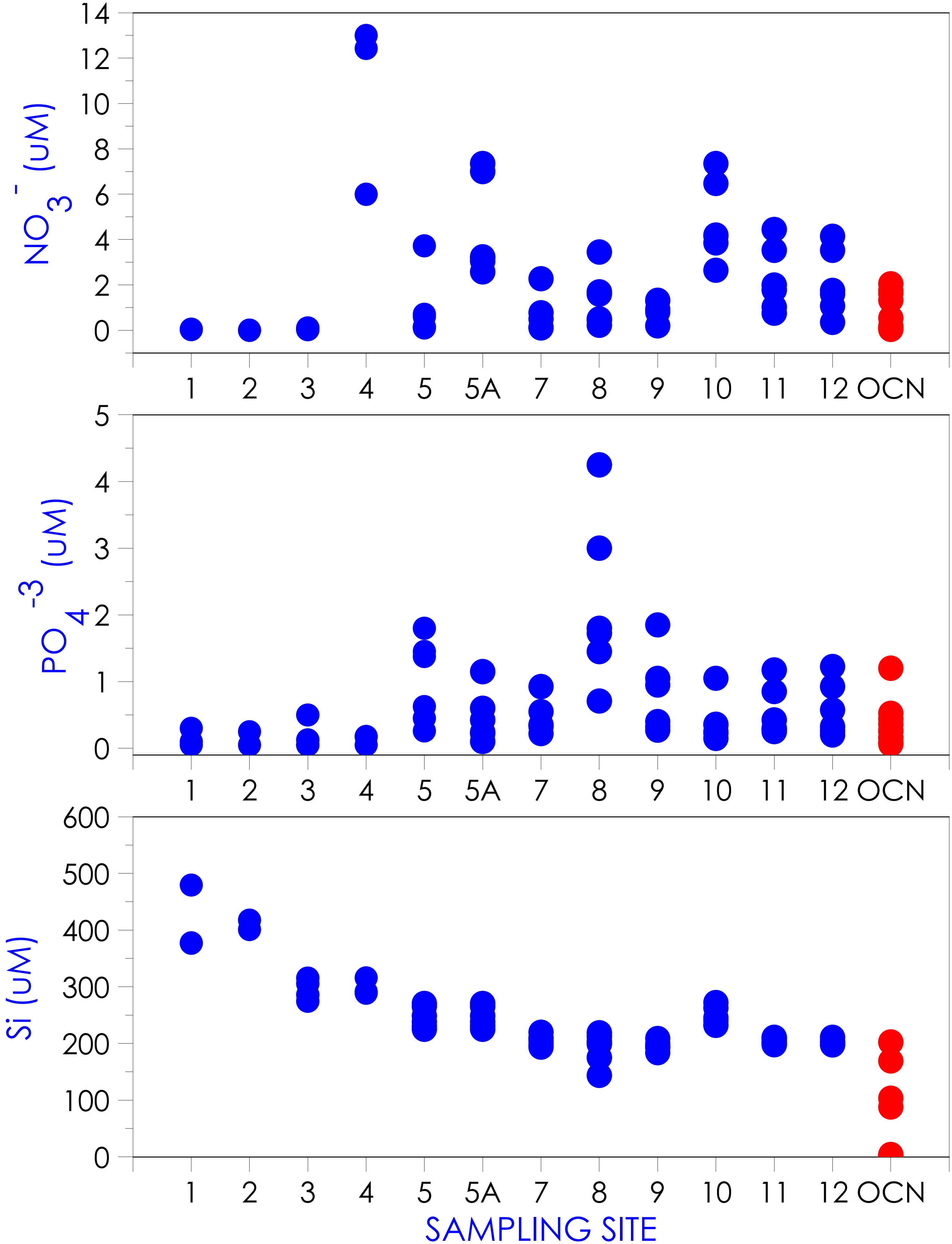

FIGURE 2. Plots of nitrate nitrogen, phosphate phosphorus and silica collected on six occasions from surface water sampling sites from the most mauka area of the Hawaii Dairy Farm through agricultural lands to the ocean. Samples labeled "OCN" are collected at the juncture of Waiopili Ditch and the the ocean. For locations of surface water sampling sites, and dates of sampling, see Figure 1 and Table 1.

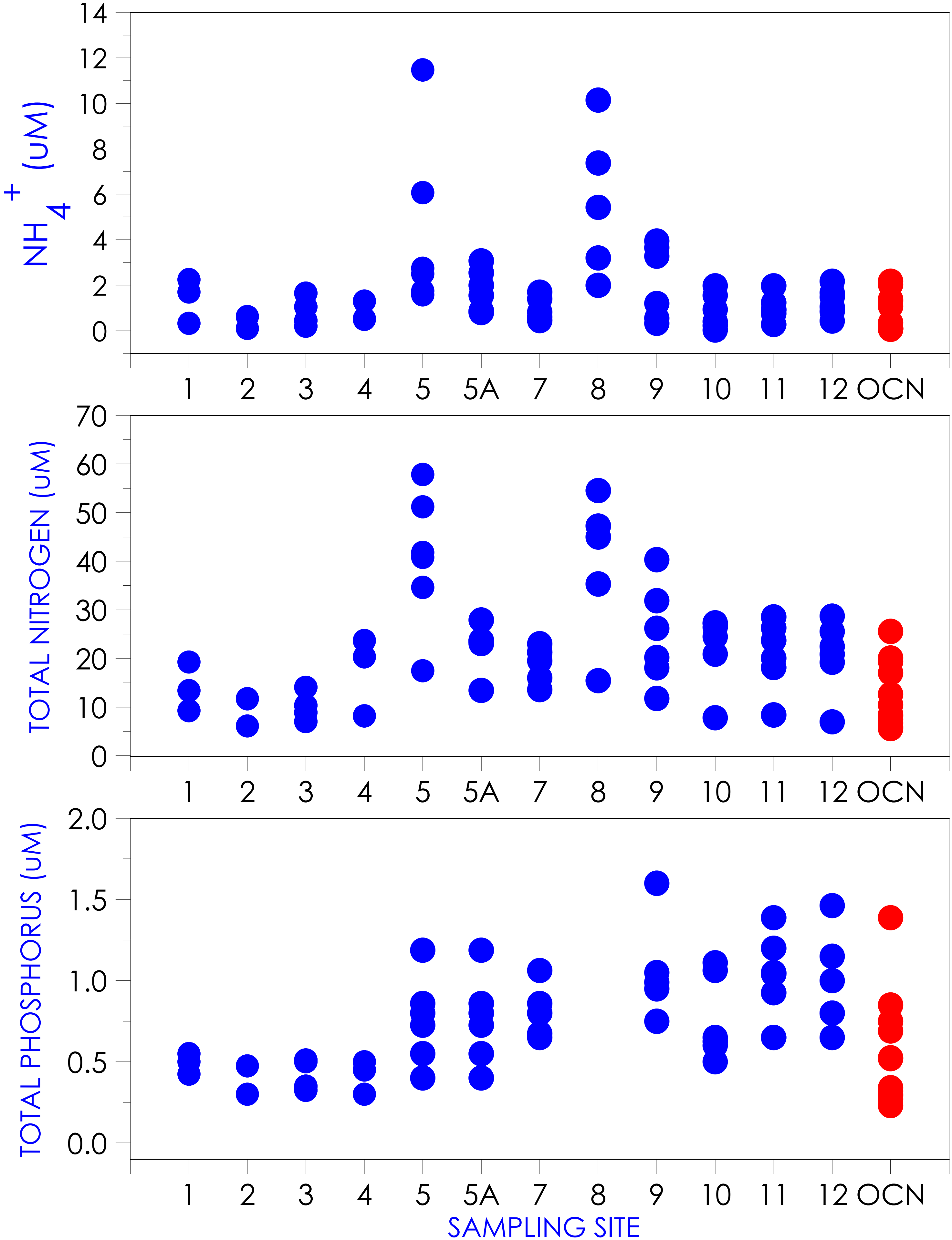

FIGURE 3. Plots of ammonium nitrogen, total nitrogen and total phosphorus collected on six occasions from surface water sampling sites from the most mauka area of the Hawaii Dairy Farm through agricultural lands to the ocean. Samples labeled "OCN" are collected at the juncture of Waiopili Ditch and the ocean. For locations of surface water sampling sites, and dates of sampling, see Figure 1 and Table 1.

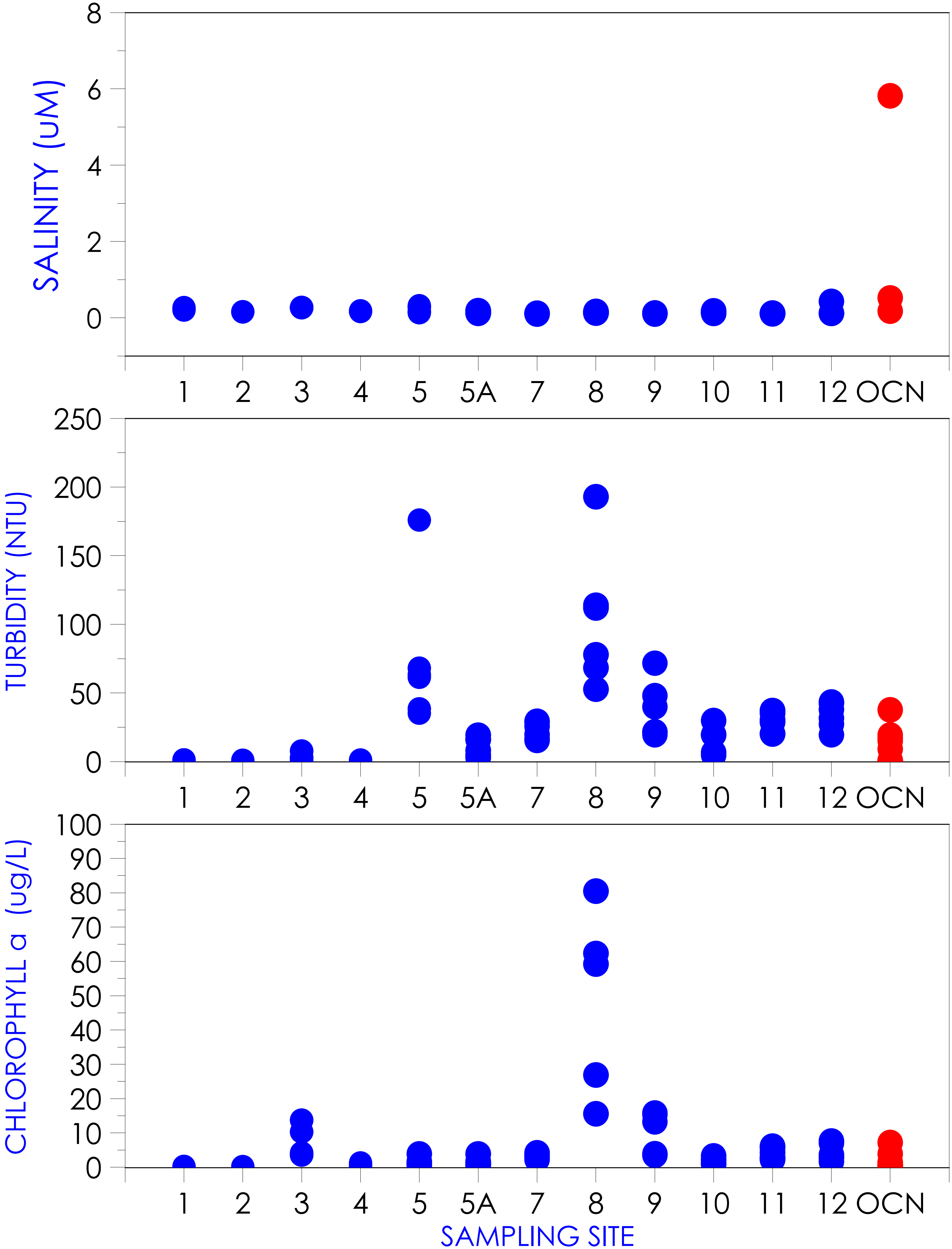

FIGURE 4. Plots of salinity, turbidity, and Chorophyll a collected on six occasions from surface water sampling sites from the most mauka area of the Hawaii Dairy Farm through agricultural lands to the ocean. Samples labeled "OCN" are collected at the juncture of Waiopili Ditch and the ocean. For locations of surface water sampling sites, and dates of sampling, see Figure 1 and Table 1.

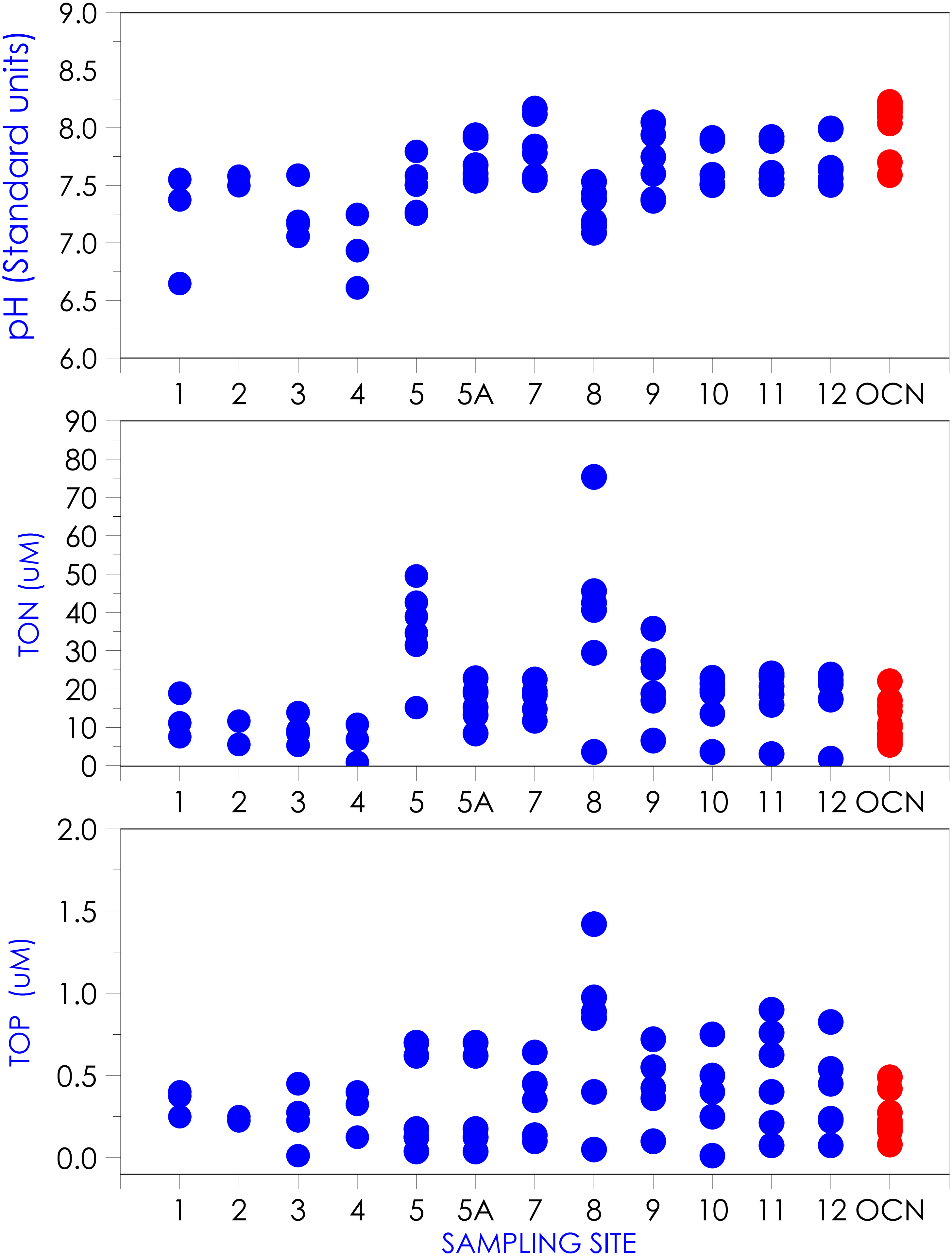

FIGURE 5. Plots of pH, Total organic nitrogen and Total organic phosphorus collected on six occasions from surface water sampling sites from the most mauka area of the Hawaii Dairy Farm through agricultural lands to the ocean. Samples labeled "OCN" are collected at the juncture of Waiopili Ditch and the the ocean. For locations of surface water sampling sites, and dates of sampling, see Figure 1 and Table 1.

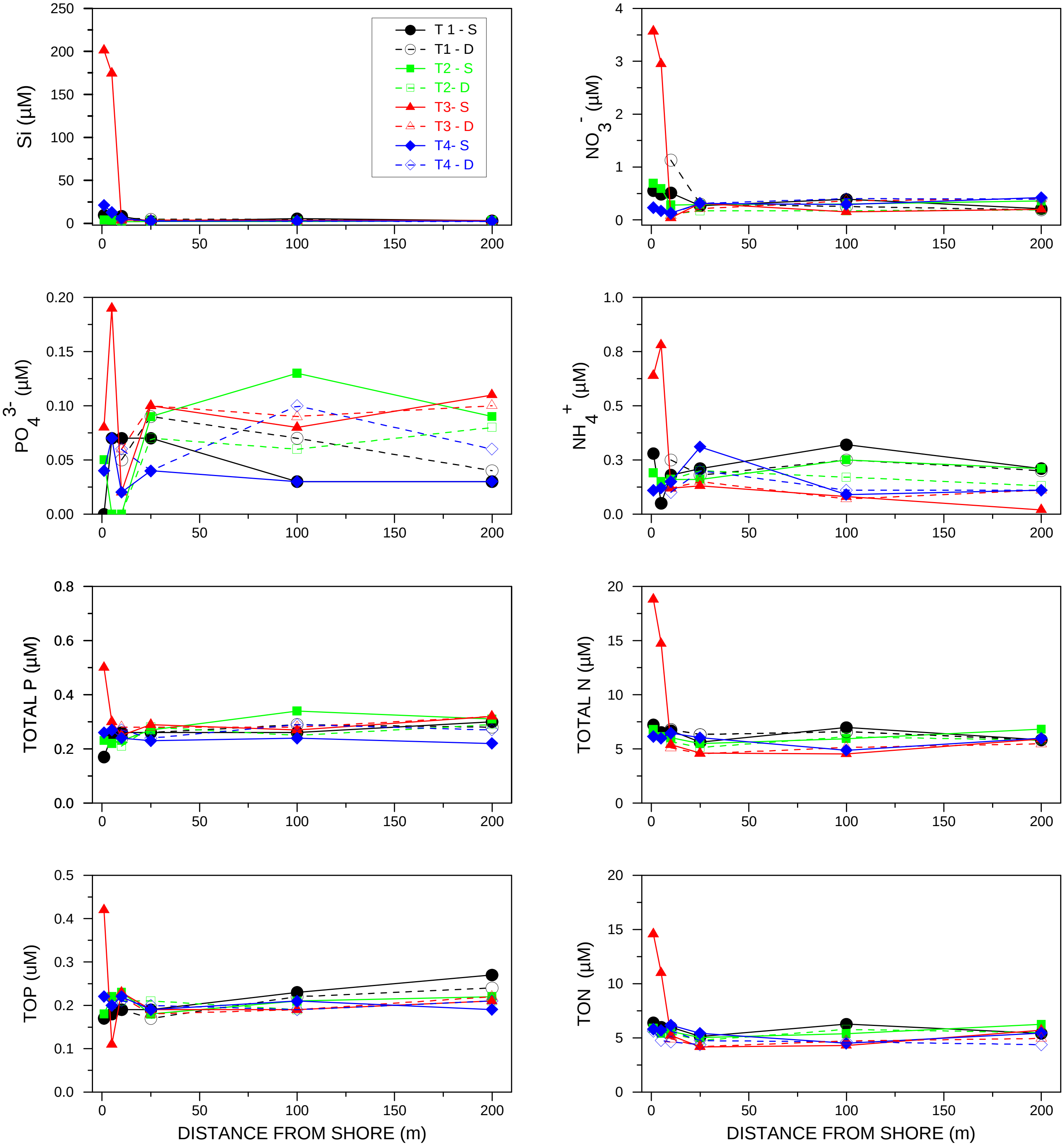

FIGURE 6. Plots of dissolved nutrients in surface (S) and deep (D) samples collected along four transects downgradient of Mahaulepu Valley, Kauai collected on October 6, 2014 as functions of distance from the shoreline. Transect 3 originated at the shoreline where Waiopili Ditch meets the ocean. For locations of transects, see Figure 1.

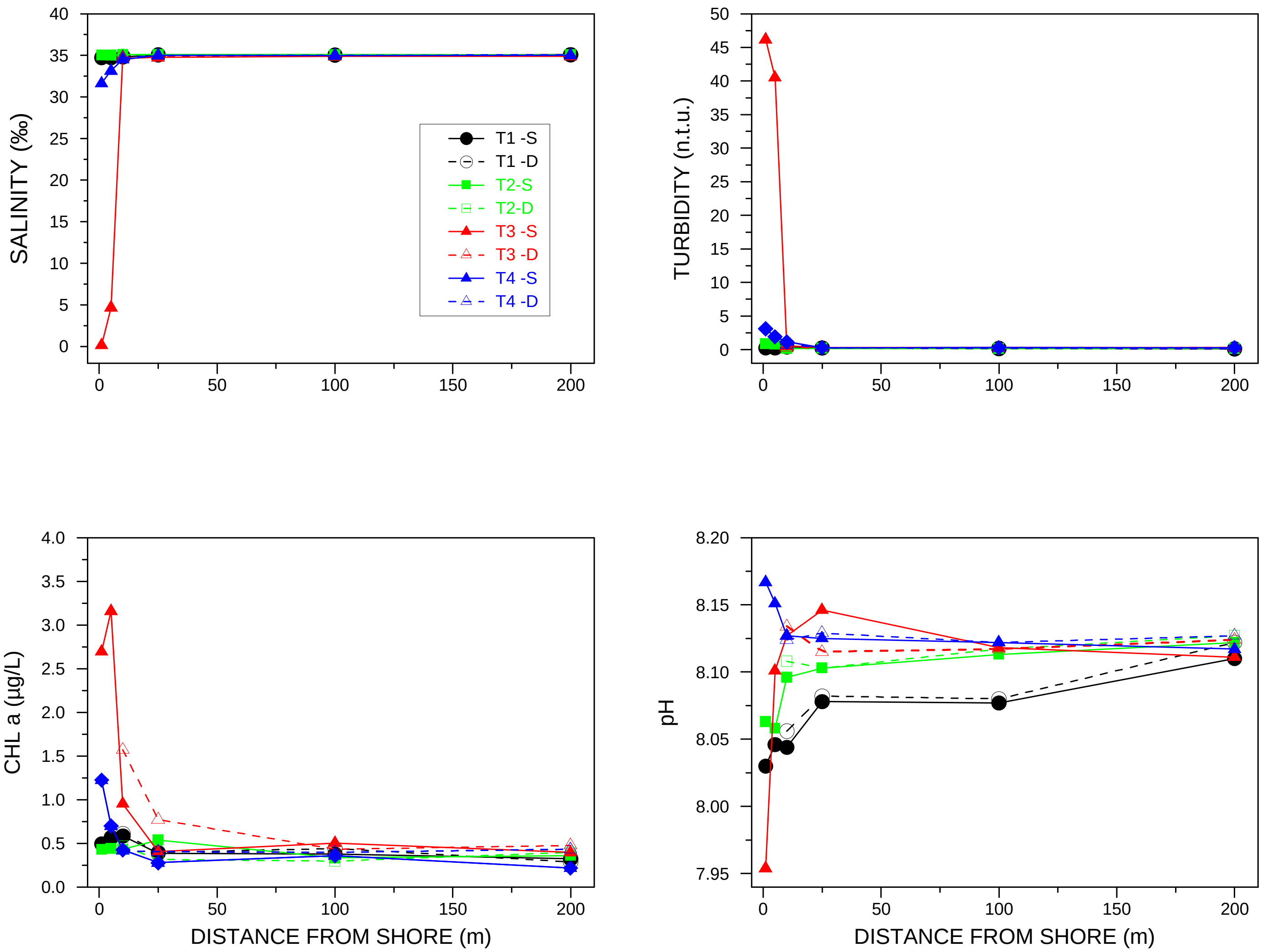

FIGURE 7. Plots of physical properties of seawater in surface (S) and deep (D) samples collected along four transects downgradient of Mahaulepu Valley, Kauai collected on October 6, 2014 as functions of distance from the shoreline. Transect 3 originated at the shoreline where Waiopili Ditch meets the ocean. For locations of transects, see Figure 1.

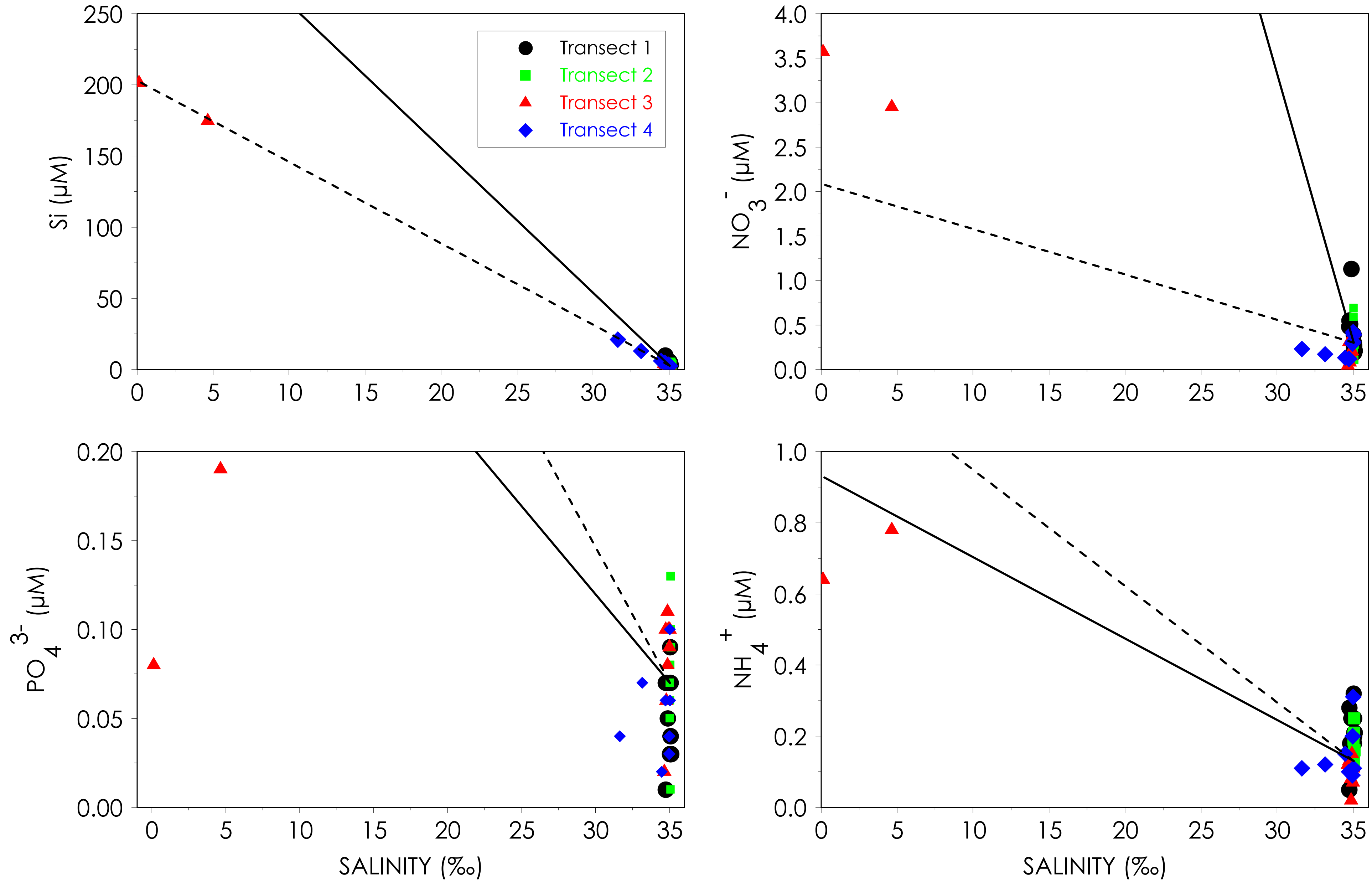

FIGURE 8. Mixing diagram showing concentration of dissolved nutrients from ocean samples collected downgradient of Mahaulepu Valley, Kauai. Data points show concentrations as functions of salinity along four transects collected on October 6, 2014. Straight lines in each plot are conservative mixing lines constructed by connecting the endpoint concentrations in open ocean water with water from groundwater monitoring wells located on the Hawaii Dairy Farm site (solid line) and from surface water from Waiopili Ditch sampling station 12 (dashed line). For locations of sampling transects, see Figure 1.

TABLE 1. Results of surface water chemistry sampling in the vicinity of the site of the Hawaii Dairy Farm (HDF) collected on six occasions in 2014-15. Surface water samples were collected at 12 locations from mauka of the HDF site and along Waiopili Ditch to the coastal area (Sampling sites 1-12). "BEACH" indicates ditch flow across the beach prior to reaching the ocean. "OCEAN" indicates samples collected makai of the coastal shoreline. Nutrient concentrations are shown in micromolar units (µM). "bdl" indicates below detection level. For locations of sampling sites, see Figure 1.

14-Oct-14												
SAMPLING SITE	PO_4^{3-} (µM)	$NO_3^-+NO_2^-$ (µM)	NH_4^+ (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURB (NTU)	SALT (ppt)	pH (rel)	Chl-a (µg/l)
1	0.10	0.05	1.70	479.45	0.40	7.55	0.50	9.30	1.24	0.203	6.647	0.054
3	0.05	0.10	1.65	315.35	0.45	5.30	0.50	7.05	3.02	0.274	7.057	13.744
4	0.05	6.00	1.30	316.00	0.40	0.90	0.45	8.20	0.91	0.165	6.609	0.413
5	0.45	0.60	1.75	234.95	0.35	15.15	0.80	17.50	38.5	0.315	7.582	3.932
5A	0.10	3.05	2.00	248.80	0.70	8.40	0.80	13.45	4.86	0.166	7.676	0.987
7	0.35	0.50	1.40	209.90	0.45	11.70	0.80	13.60	28.9	0.113	7.579	3.241
8	1.45	1.70	10.15	175.25	0.85	3.60	2.30	15.45	68.4	0.121	7.190	114.90
9	0.95	1.30	3.95	192.90	0.10	6.55	1.05	11.80	48.0	0.124	7.939	13.25
10	0.15	3.85	0.40	245.55	0.50	3.60	0.65	7.85	19.6	0.167	7.501	3.321
11	0.25	4.45	0.90	209.65	0.40	3.05	0.65	8.40	35.3	0.114	7.556	4.246
12	0.20	4.15	1.05	211.05	0.45	1.80	0.65	7.00	43.5	0.113	7.633	3.142

29-Oct-14												
SAMPLING SITE	PO4 (µM)	NO3 (µM)	NH4 (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)
1	0.05	0.05	0.33	377.48	0.38	18.90	0.43	19.28	1.32	0.222	7.551	0.117
2	0.05	bdl	0.10	417.73	0.25	11.65	0.30	11.75	0.78	0.157	7.497	0.224
3	0.05	0.03	0.20	305.55	0.28	13.88	0.33	14.10	2.51	0.267	7.588	10.314
4	0.18	12.43	0.50	291.48	0.13	10.78	0.30	23.70	0.98	0.181	7.246	1.293
5	0.63	0.15	2.75	274.25	0.28	38.93	0.90	41.83	35.3	0.299	7.501	10.970
5A	0.23	7.00	0.80	270.75	0.18	15.28	0.40	23.08	2.78	0.191	7.910	0.458
7	0.33	2.28	0.60	193.68	0.35	18.40	0.68	21.28	16.6	0.098	8.167	2.917
8	4.25	0.23	51.70	219.00	0.05	75.35	4.30	127.28	193.0	0.168	7.378	59.25
9	0.33	0.20	0.55	193.43	0.43	25.48	0.75	26.23	21.7	0.100	8.049	3.98
10	0.25	6.48	0.93	272.48	0.25	19.05	0.50	26.45	4.8	0.185	7.888	0.826
11	0.43	0.75	0.75	200.08	0.63	18.58	1.05	20.08	37.3	0.103	7.921	2.953
12	0.58	0.35	0.85	197.43	0.23	21.28	0.80	22.48	42.5	0.114	7.985	2.738

11-Nov-14												
SAMPLING SITE	PO4 (µM)	NO3 (µM)	NH4 (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)
1	0.30	0.03	2.25	377.13	0.25	11.15	0.55	13.43	0.86	0.264	7.374	0.233
2	0.25	bdl	0.63	401.05	0.23	5.53	0.48	6.15	0.98	0.161	7.580	0.144
3	0.13	0.03	0.45	286.18	0.23	8.43	0.35	8.90	7.68	0.260	7.187	3.573
4	0.18	13.00	0.53	288.85	0.33	6.83	0.50	20.35	1.20	0.175	6.933	0.583
5	1.80	3.73	11.48	286.48	0.83	42.65	2.63	57.85	176.0	0.269	7.249	7.433
5A	0.60	7.35	3.08	265.45	0.13	13.20	0.73	23.63	8.15	0.173	7.559	1.239
7	0.35	0.78	0.48	197.95	0.45	14.78	0.80	16.03	15.4	0.105	7.779	2.235
8	1.80	3.45	3.20	199.28	0.98	40.63	2.78	47.28	112.0	0.159	7.145	80.52
9	0.40	0.80	0.33	195.13	0.55	16.98	0.95	18.10	19.6	0.111	7.599	3.46
10	0.23	7.35	0.03	262.85	0.40	13.53	0.63	20.90	6.7	0.175	7.592	1.014
11	0.30	2.00	0.28	202.08	0.90	15.88	1.20	18.15	20.1	0.121	7.609	2.630
12	0.33	1.60	0.43	201.68	0.83	17.20	1.15	19.23	27.3	0.122	7.652	3.716

4-Mar-15													
SAMPLING SITE	PO4 (µM)	NO3 (µM)	NH4 (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)	Entero (#/100 ml)
5	1.45	0.15	1.58	204.58	0.50	49.48	1.95	51.20	68.1	0.135	7.795	27.155	270
8	1.73	0.50	2.00	203.73	0.40	42.50	2.13	45.00	52.7	0.137	7.532	15.620	60
7	0.55	0.10	0.45	219.83	0.10	22.50	0.65	23.05	25.7	0.119	8.119	4.120	590
9	1.05	1.33	3.28	199.40	0.55	35.73	1.60	40.33	40.0	0.126	7.747	15.359	600
10	0.35	4.20	0.23	232.18	0.25	22.93	0.60	27.35	19.5	0.128	7.912	2.145	740
5A	0.43	3.20	0.88	225.33	0.13	19.48	0.55	23.55	16.0	0.124	7.936	1.688	100
11	0.85	3.53	0.95	197.83	0.08	24.10	0.93	28.58	28.7	0.120	7.884	6.158	<1
12	0.93	3.53	1.48	198.25	0.08	23.75	1.00	28.75	31.6	0.123	7.995	7.083	780
OCEAN	0.53	2.05	1.08	103.35	0.23	17.00	0.75	20.13	9.21	16.330	8.168	3.896	<1
OCEAN	0.25	0.18	0.35	2.40	0.28	9.95	0.53	10.48	0.34	34.678	8.093	0.494	<1

TABLE 1. CONTINUED.

8-May-15														
SAMPLING SITE	PO4 (µM)	NO3 (µM)	NH4 (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)	Entero (#/100 ml)	C. perf (#/100 ml)
3	0.50	0.10	1.05	274.48	0.01	9.23	0.51	10.38	0.77	0.267	7.163	4.210	150	<1
5	1.38	0.10	6.08	223.05	0.76	34.65	2.14	40.83	63.40	0.138	7.272	29.85	330	43
7	0.93	0.13	1.70	204.45	0.14	19.48	1.06	21.30	29.40	0.113	7.544	4.219	138	4
8	3.00	1.60	7.38	212.50	0.89	45.55	3.89	54.53	114.00	0.133	7.088	62.34	120	63
9	1.85	0.93	3.65	208.80	0.36	27.33	2.21	31.90	71.70	0.123	7.381	15.84	295	4
10	1.05	2.65	1.98	232.60	0.01	19.88	1.06	24.50	19.60	0.118	7.513	1.391	191	83
5A	1.15	2.58	2.55	231.18	0.04	22.80	1.19	27.93	19.30	0.119	7.539	3.905	1800	49
11	1.18	1.03	1.98	210.75	0.21	23.30	1.39	26.30	30.40	0.115	7.550	5.655	560	100
12	1.23	1.08	2.18	204.00	0.24	22.30	1.46	25.55	38.00	0.120	7.560	7.684	1630	300
BEACH	1.20	1.33	2.18	202.93	0.19	22.08	1.39	25.58	37.70	0.176	7.701	7.217	1320	195
OCEAN	0.44	0.54	1.38	87.99	0.08	10.75	0.52	12.67	15.20	19.441	8.224	1.002	945	100
OCEAN	0.06	0.10	0.08	4.20	0.17	6.55	0.23	6.73	0.89	34.227	8.182	0.745	24	<1
OCEAN	0.16	0.07	0.06	3.25	0.16	5.46	0.32	5.59	0.60	34.288	8.189	0.619	34	12
OCEAN	0.16	0.12	0.10	3.10	0.18	5.78	0.34	6.00	0.60	34.332	8.189	0.521	20	16

9-Jul-15														
SAMPLING SITE	PO4 (µM)	NO3 (µM)	NH4 (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)	Entero (#/100 ml)	C. perf (#/100 ml)
5	0.26	0.71	2.50	180.90	1.07	31.43	1.33	34.64	61.4	0.178	7.504	17.819	<1	80
8	0.71	0.45	5.43	143.79	1.42	29.47	2.13	35.35	77.9	0.131	7.431	26.908	115	249
7	0.22	0.12	0.82	208.86	0.64	18.61	0.86	19.55	19.8	0.122	7.837	3.434	576	130
9	0.27	0.20	1.20	183.67	0.72	18.83	0.99	20.23	21.6	0.124	7.366	3.703	520	40
10	0.36	4.16	1.55	240.42	0.75	21.43	1.11	27.14	29.9	0.113	7.505	2.244	574	165
5a	0.24	3.24	1.55	238.43	0.62	18.95	0.86	23.74	16.3	0.136	7.601	1.032	1056	275
11	0.28	1.78	1.23	206.46	0.76	20.73	1.04	23.74	20.4	0.123	7.508	2.222	1020	175
12	0.26	1.76	1.67	202.07	0.54	17.45	0.80	20.88	19.5	0.431	7.503	1.616	1905	235
BEACH	0.36	1.76	2.03	202.06	0.49	15.63	0.85	19.42	19.4	0.523	7.589	1.459	1000	160
OCEAN	0.27	1.62	1.30	169.31	0.42	14.13	0.69	17.05	17.2	5.821	8.039	1.427	500	200
OCEAN	0.08	0.04	0.08	3.33	0.21	8.02	0.29	8.14	0.98	35.005	8.135	0.449	16	<1
OCEAN	0.08	0.09	0.10	2.62	0.22	8.28	0.30	8.47	0.65	35.054	8.158	0.341	<1	<1
OCEAN	0.08	0.07	0.11	2.56	0.19	7.32	0.27	7.50	0.54	35.106	8.167	0.422	4	<1

TABLE 2. Results of surface water chemistry sampling in the vicinity of the site of the Hawaii Dairy Farm (HDF) collected on six occasions in 2014-15. Surface water samples were collected at 12 locations from mauka of the HDF site and along Waiopili Ditch to the coastal area (Sampling sites 1-12). "BEACH" indicates ditch flow across the beach prior to reaching the ocean. "OCEAN" indicates samples collected makai of the coastal shoreline. Nutrient concentrations are shown in units of micrograms per liter (µg/L). "bdl" indicates below detection level. For locations of sampling sites, see Figure 1.

14-Oct-14												
SAMPLING SITE	PO_4^{3-} (µg/L)	$NO_3^-+NO_2^-$ (µg/L)	NH_4^+ (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (NTU)	SALT (ppt)	pH (rel)	Chl-a (µg/l)
1	3.10	0.70	23.80	13425	12.40	105.70	15.50	130.20	1.24	0.203	6.647	0.054
3	1.55	1.40	23.10	8830	13.95	74.20	15.50	98.70	3.02	0.274	7.057	13.744
4	1.55	84.00	18.20	8848	12.40	12.60	13.95	114.80	0.91	0.165	6.609	0.413
5	13.95	8.40	24.50	6579	10.85	212.10	24.80	245.00	38.5	0.315	7.582	3.932
5A	3.10	42.70	28.00	6966	21.70	117.60	24.80	188.30	4.86	0.166	7.676	0.987
7	10.85	7.00	19.60	5877	13.95	163.80	24.80	190.40	28.9	0.113	7.579	3.241
8	44.95	23.80	142.10	4907	26.35	50.40	71.30	216.30	68.4	0.121	7.190	114.90
9	29.45	18.20	55.30	5401	3.10	91.70	32.55	165.20	48.0	0.124	7.939	13.25
10	4.65	53.90	5.60	6875	15.50	50.40	20.15	109.90	19.6	0.167	7.501	3.321
11	7.75	62.30	12.60	5870	12.40	42.70	20.15	117.60	35.3	0.114	7.556	4.246
12	6.20	58.10	14.70	5909	13.95	25.20	20.15	98.00	43.5	0.113	7.633	3.142

29-Oct-14												
SAMPLING SITE	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)
1	1.55	0.70	4.55	10569	11.63	264.60	13.18	269.85	1.32	0.222	7.551	0.117
2	1.55	bdl	1.40	11696	7.75	163.10	9.30	164.50	0.78	0.157	7.497	0.224
3	1.55	0.35	2.80	8555	8.53	194.25	10.08	197.40	2.51	0.267	7.588	10.314
4	5.43	173.95	7.00	8161	3.88	150.85	9.30	331.80	0.98	0.181	7.246	1.293
5	19.38	2.10	38.50	7679	8.53	544.95	27.90	585.55	35.3	0.299	7.501	10.970
5A	6.98	98.00	11.20	7581	5.43	213.85	12.40	323.05	2.78	0.191	7.910	0.458
7	10.08	31.85	8.40	5423	10.85	257.60	20.93	297.85	16.6	0.098	8.167	2.917
8	131.75	3.15	723.80	6132	1.55	1054.90	133.30	1781.85	193.0	0.168	7.378	59.25
9	10.08	2.80	7.70	5416	13.18	356.65	23.25	367.15	21.7	0.100	8.049	3.98
10	7.75	90.65	12.95	7629	7.75	266.70	15.50	370.30	4.8	0.185	7.888	0.826
11	13.18	10.50	10.50	5602	19.38	260.05	32.55	281.05	37.3	0.103	7.921	2.953
12	17.83	4.90	11.90	5528	6.97	297.85	24.80	314.65	42.5	0.114	7.985	2.738

11-Nov-14												
SAMPLING SITE	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)
1	9.30	0.35	31.50	10560	7.75	156.10	17.05	187.95	0.86	0.264	7.374	0.233
2	7.75	bdl	8.75	11229	6.98	77.35	14.73	86.10	0.98	0.161	7.580	0.144
3	3.88	0.35	6.30	8013	6.98	117.95	10.85	124.60	7.68	0.260	7.187	3.573
4	5.43	182.00	7.35	8088	10.08	95.55	15.50	284.90	1.20	0.175	6.933	0.583
5	55.80	52.15	160.65	8021	25.58	597.10	81.38	809.90	176.0	0.269	7.249	7.433
5A	18.60	102.90	43.05	7433	3.88	184.80	22.48	330.75	8.15	0.173	7.559	1.239
7	10.85	10.85	6.65	5543	13.95	206.85	24.80	224.35	15.4	0.105	7.779	2.235
8	55.80	48.30	44.80	5580	30.23	568.75	86.03	661.85	112.0	0.159	7.145	80.52
9	12.40	11.20	4.55	5464	17.05	237.65	29.45	253.40	19.6	0.111	7.599	3.46
10	6.98	102.90	0.35	7360	12.40	189.35	19.38	292.60	6.7	0.175	7.592	1.014
11	9.30	28.00	3.85	5658	27.90	222.25	37.20	254.10	20.1	0.121	7.609	2.630
12	10.08	22.40	5.95	5647	25.58	240.80	35.65	269.15	27.3	0.122	7.652	3.716

4-Mar-15													
SAMPLING SITE	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)	Ent (#/100 ml)
5	44.95	2.10	22.05	5728	15.50	692.65	60.45	716.80	68.1	0.135	7.795	27.155	270
8	53.48	7.00	28.00	5704	12.40	595.00	65.88	630.00	52.7	0.137	7.532	15.620	60
7	17.05	1.40	6.30	6155	3.10	315.00	20.15	322.70	25.7	0.119	8.119	4.120	590
9	32.55	18.55	45.85	5583	17.05	500.15	49.60	564.55	40.0	0.126	7.747	15.359	600
10	10.85	58.80	3.15	6501	7.75	320.95	18.60	382.90	19.5	0.128	7.912	2.145	740
5A	13.18	44.80	12.25	6309	3.88	272.65	17.05	329.70	16.0	0.124	7.936	1.688	100
11	26.35	49.35	13.30	5539	2.33	337.40	28.68	400.05	28.7	0.120	7.884	6.158	<1
12	28.68	49.35	20.65	5551	2.33	332.50	31.00	402.50	31.6	0.123	7.995	7.083	780
OCEAN	0.53	2.05	1.08	103	0.23	17.00	0.75	20.13	9.21	16.330	8.168	3.896	<1
OCEAN	0.25	0.18	0.35	2.40	0.28	9.95	0.53	10.48	0.34	34.678	8.093	0.494	<1

TABLE 2. CONTINUED.

8-May-15														
SAMPLING SITE	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)	Ent (#/100 ml)	C. perf (#/100 ml)
3	15.50	1.40	14.70	7685	0.39	129.15	15.89	145.25	0.77	0.267	7.163	4.210	150	<1
5	42.63	1.40	85.05	6245	23.64	485.10	66.26	571.55	63.40	0.138	7.272	29.85	330	43
7	28.68	1.75	23.80	5725	4.26	272.65	32.94	298.20	29.40	0.113	7.544	4.219	138	4
8	93.00	22.40	103.25	5950	27.51	637.70	120.51	763.35	114.00	0.133	7.088	62.34	120	63
9	57.35	12.95	51.10	5846	11.24	382.55	68.59	446.60	71.70	0.123	7.381	15.84	295	4
10	32.55	37.10	27.65	6513	0.39	278.25	32.94	343.00	19.60	0.118	7.513	1.391	191	83
5A	35.65	36.05	35.70	6473	1.16	319.20	36.81	390.95	19.30	0.119	7.539	3.905	1800	49
11	36.43	14.35	27.65	5901	6.59	326.20	43.01	368.20	30.40	0.115	7.550	5.655	560	100
12	37.98	15.05	30.45	5712	7.36	312.20	45.34	357.70	38.00	0.120	7.560	7.684	1630	300
BEACH	37.20	18.55	30.45	5682	5.81	309.05	43.01	358.05	37.70	0.176	7.701	7.217	1320	195
OCEAN	13.64	7.56	19.32	2464	2.48	150.50	16.12	177.38	15.20	19.441	8.224	1.002	945	100
OCEAN	1.86	1.40	1.12	118	5.27	91.70	7.13	94.22	0.89	34.227	8.182	0.745	24	0
OCEAN	4.96	0.98	0.84	91	4.96	76.44	9.92	78.26	0.60	34.288	8.189	0.619	34	12
OCEAN	4.96	1.68	1.40	87	5.58	80.92	10.54	84.00	0.60	34.332	8.189	0.521	20	16

9-Jul-15														
SAMPLING SITE	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (ntu)	SALT (ppt)	pH (rel)	Chl-a (µg/l)	Ent (#/100 ml)	C. perf (#/100 ml)
5	8.06	9.94	35.00	5065	33.17	440.02	41.23	484.96	61.4	0.178	7.504	17.819	<1	80
8	22.01	6.30	76.02	4026	44.02	412.58	66.03	494.90	77.9	0.131	7.431	26.908	115	249
7	6.82	1.68	11.48	5848	19.84	260.54	26.66	273.70	19.8	0.122	7.837	3.434	576	130
9	8.37	2.80	16.80	5143	22.32	263.62	30.69	283.22	21.6	0.124	7.366	3.703	520	40
10	11.16	58.24	21.70	6732	23.25	300.02	34.41	379.96	29.9	0.113	7.505	2.244	574	165
5a	7.44	45.36	21.70	6676	19.22	265.30	26.66	332.36	16.3	0.136	7.601	1.032	1056	275
11	8.68	24.92	17.22	5781	23.56	290.22	32.24	332.36	20.4	0.123	7.508	2.222	1020	175
12	8.06	24.64	23.38	5658	16.74	244.30	24.80	292.32	19.5	0.431	7.503	1.616	1905	235
BEACH	11.16	24.64	28.42	5658	15.19	218.82	26.35	271.88	19.4	0.523	7.589	1.459	1000	160
OCEAN	8.37	22.68	18.20	4741	13.02	197.82	21.39	238.70	17.2	5.821	8.039	1.427	500	200
OCEAN	2.48	0.56	1.12	93.2	6.51	112.28	8.99	113.96	0.98	35.005	8.135	0.449	16	<1
OCEAN	2.48	1.26	1.40	73.4	6.82	115.92	9.30	118.58	0.65	35.054	8.158	0.341	<1	<1
OCEAN	2.48	0.98	1.54	71.7	5.89	102.48	8.37	105.00	0.54	35.106	8.167	0.422	4	<1

TABLE 3. Results of water chemistry sampling of nearshore marine waters off the Mahaulepu watershed on October 6, 2014. Samples were collected along four transects downgradient of Mahaulepu Valley, and extended from the highest wash of waves on the beach to the open coastal ocean approximately 200 meters from shore. Two samples were collected at each of six locations on each ocean transect. One sample was collected just below the ocean surface, and one just above the ocean floor (on each transect site 1 on was located at the beach-water interface and only a single sample was collected). The sample collected at the shoreline of Transect 3 was from the point that Waiopili Ditch stream meets the ocean. Nutrient concentrations are shown in micromolar units (µM). Also shown are State of Hawaii Dept. of Health Water Quality Standards for Open Coastal waters under dry conditions. Shaded values are greater than "not to exceed more than 10% of the time" criteria. Abbreviations are as follows: DFS=distance from shore; BDL = below detection limit. "S" indicates surface sample; "D" indicates deep bottom sample. For locations of survey transects and sample sites, see Figure 1.

TRANSECT	SAMPLE SITE	DEPTH (m)	DFS (m)	PO_4^{3-} (µM)	$NO_3^-+NO_2^-$ (µM)	NH_4^+ (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURBIDITY (ntu)	SALINITY (ppt)	pH (rel)	Chl-a (µg/l)	TEMP. (deg. C)	DISS. O2 (% sat.)
1	1-S	0.1	1	bdl	0.55	0.28	9.72	0.17	6.39	0.17	7.22	0.24	34.752	8.030	0.49	27.70	99.36
	2-S	0.1	5	0.07	0.48	0.05	9.63	0.18	5.99	0.25	6.52	0.25	34.751	8.046	0.57	26.80	101.67
	3-S	0.1	10	0.07	0.51	0.18	8.26	0.19	5.99	0.26	6.68	0.40	34.807	8.044	0.58	27.66	99.98
	3-D	1.0		0.05	1.13	0.25	6.16	0.19	5.40	0.24	6.78	0.40	34.891	8.056	0.61	27.74	98.58
	4-S	0.1	25	0.07	0.27	0.21	2.55	0.19	5.14	0.26	5.62	0.24	35.070	8.078	0.39	27.82	99.61
	4-D	1.6		0.09	0.30	0.18	4.88	0.17	5.84	0.26	6.32	0.26	35.042	8.082	0.39	27.83	100.08
	5-S	0.1	100	0.03	0.39	0.32	5.47	0.23	6.27	0.26	6.98	0.18	35.034	8.077	0.38	27.83	100.26
	5-D	2.5		0.07	0.25	0.25	4.81	0.22	6.09	0.29	6.59	0.16	35.062	8.080	0.44	27.84	100.63
	6-S	0.1	200	0.03	0.21	0.21	3.16	0.27	5.41	0.30	5.83	0.12	35.103	8.110	0.32	28.00	99.57
	6-D	6.0		0.04	0.19	0.20	2.55	0.24	5.44	0.28	5.83	0.11	35.072	8.122	0.29	28.05	99.45
2	1-S	0.1	1	0.05	0.69	0.19	3.98	0.18	5.90	0.23	6.78	0.86	35.028	8.063	0.43	27.85	102.55
	2-S	0.1	5	bdl	0.59	0.15	3.64	0.22	5.39	0.22	6.13	0.80	35.036	8.058	0.44	27.85	102.81
	3-S	0.1	10	bdl	0.28	0.16	1.84	0.23	5.59	0.23	6.03	0.18	35.093	8.096	0.43	27.84	100.12
	3-D	1.5		bdl	0.11	0.16	2.53	0.21	5.41	0.21	5.68	0.34	35.078	8.108	0.47	27.86	101.57
	4-S	0.1	25	0.09	0.29	0.16	2.18	0.18	5.03	0.27	5.48	0.18	35.105	8.103	0.54	27.84	98.80
	4-D	1.8		0.07	0.17	0.20	4.13	0.21	4.76	0.28	5.13	0.20	35.029	8.103	0.31	27.87	98.47
	5-S	0.1	100	0.13	0.30	0.25	2.33	0.21	5.38	0.34	5.93	0.15	35.090	8.113	0.33	27.83	99.60
	5-D	5.2		0.06	0.17	0.17	2.99	0.19	5.77	0.25	6.11	0.13	35.043	8.117	0.30	27.91	100.65
	6-S	0.1	200	0.09	0.36	0.21	2.87	0.22	6.24	0.31	6.81	0.17	35.074	8.122	0.36	27.93	99.10
	6-D	8.3		0.08	0.19	0.13	3.21	0.21	5.49	0.29	5.81	0.14	35.051	8.127	0.39	27.92	99.29
3	1-S	0.1	1	0.08	3.57	0.64	201.25	0.42	14.59	0.50	18.80	46.20	0.141	7.954	2.69	27.42	100.12
	2-S	0.1	5	0.19	2.95	0.78	174.60	0.11	10.99	0.30	14.72	40.50	4.660	8.101	3.16	27.12	101.15
	3-S	0.1	10	0.02	0.04	0.12	3.83	0.23	5.23	0.25	5.39	0.55	34.665	8.127	0.95	27.97	99.24
	3-D	1.8		0.06	0.08	0.12	3.35	0.22	4.91	0.28	5.11	0.33	34.783	8.134	1.57	28.07	98.87
	4-S	0.1	25	0.10	0.31	0.13	3.93	0.19	4.16	0.29	4.60	0.31	34.755	8.146	0.40	28.06	99.10
	4-D	3.9		0.10	0.21	0.15	3.16	0.18	4.19	0.28	4.55	0.28	34.934	8.115	0.77	28.02	95.12
	5-S	0.1	100	0.08	0.15	0.08	3.43	0.19	4.30	0.27	4.53	0.30	34.881	8.118	0.50	27.99	99.97
	5-D	6.5		0.09	0.36	0.07	3.07	0.19	4.70	0.28	5.13	0.21	35.000	8.117	0.43	28.06	97.73
	6-S	0.1	200	0.11	0.20	0.02	3.38	0.21	5.70	0.32	5.92	0.29	34.876	8.111	0.39	28.02	99.68
	6-D	10.6		0.10	0.40	0.11	2.72	0.22	4.95	0.32	5.46	0.29	35.021	8.124	0.48	28.11	98.78
4	1-S	0.1	1	0.04	0.23	0.11	20.98	0.22	5.82	0.26	6.16	3.10	31.641	8.167	1.22	27.80	101.05
	2-S	0.1	5	0.07	0.17	0.12	12.94	0.20	5.69	0.27	5.98	1.91	33.161	8.151	0.70	27.81	101.59
	3-S	0.1	10	0.02	0.13	0.15	5.96	0.22	6.18	0.24	6.46	1.15	34.480	8.127	0.42	27.96	102.95
	3-D	1.6		0.06	0.12	0.10	4.68	0.21	5.62	0.27	5.84	0.80	34.735	8.124	0.41	27.97	106.16
	4-S	0.1	25	0.04	0.31	0.31	2.61	0.19	5.41	0.23	6.03	0.27	35.011	8.125	0.28	27.96	102.59
	4-D	2.5		0.04	0.31	0.20	3.28	0.20	4.75	0.24	5.26	0.26	34.979	8.129	0.40	27.95	102.68
	5-S	0.1	100	0.03	0.29	0.09	2.95	0.21	4.49	0.24	4.87	0.30	34.967	8.122	0.36	27.93	99.15
	5-D	4.8		0.10	0.40	0.11	2.65	0.19	4.63	0.29	5.14	0.22	35.023	8.122	0.39	27.94	100.73
	6-S	0.1	200	0.03	0.42	0.11	2.52	0.19	5.45	0.22	5.98	0.27	35.006	8.117	0.22	27.95	99.90
	6-D	7.7		0.06	0.39	0.11	2.35	0.21	4.36	0.27	4.86	0.16	35.046	8.127	0.43	27.98	100.80
DOH WQS OPEN COASTAL WATERS (DRY)																	
Geometric Mean					0.25	0.14				0.52	7.86	0.20			0.15		
NTE 10%					0.71	0.36				0.97	12.86	0.50			0.50		

TABLE 4. Results of water chemistry sampling of nearshore marine waters off the Mahaulepu watershed on October 6, 2014. Samples were collected along four transects downgradient of Mahaulepu Valley, and extended from the highest wash of waves on the beach to the open coastal ocean approximately 200 meters from shore. Two samples were collected at each of six locations on each ocean transect. One sample was collected just below the ocean surface, and one just above the ocean floor (on each transect site 1 on was located at the beach-water interface and only a single sample was collected). The sample collected at the shoreline of Transect 3 was from the point that Waiopili Ditch stream meets the ocean. Nutrient concentrations are shown in micrograms per liters (µg/L). Also shown are State of Hawaii Dept. of Health Water Quality Standards for Open Coastal waters under dry conditions. Shaded values are greater than "not to exceed more than 10% of the time" criteria. Abbreviations are as follows: DFS=distance from shore; BDL = below detection limit. "S" indicates surface sample; "D" indicates deep bottom sample. For locations of survey transects and sample sites, see Figure 1.

TRANSECT	SAMPLE SITE	DEPTH (m)	DFS (m)	PO_4^{3-} (µg/L)	$NO_3^-+NO_2^-$ (µg/L)	NH_4^+ (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURBIDITY (ntu)	SALINITY (ppt)	pH (rel)	Chl-a (µg/l)	TEMP. (deg. C)	DISS. O2 (% sat.)
1	1-S	0.1	1	bdl	7.70	3.92	272.16	5.27	89.46	5.27	101.08	0.24	34.752	8.030	0.49	27.70	99.36
	2-S	0.1	5	2.17	6.72	0.70	269.64	5.58	83.86	7.75	91.28	0.25	34.751	8.046	0.57	26.80	101.67
	3-S	0.1	10	2.17	7.14	2.52	231.28	5.89	83.86	8.06	93.52	0.40	34.807	8.044	0.58	27.66	99.98
	3-D	1.0		1.55	15.82	3.50	172.48	5.89	75.60	7.44	94.92	0.40	34.891	8.056	0.61	27.74	98.58
	4-S	0.1	25	2.17	3.78	2.94	71.40	5.89	71.96	8.06	78.68	0.24	35.070	8.078	0.39	27.82	99.61
	4-D	1.6		2.79	4.20	2.52	136.64	5.27	81.76	8.06	88.48	0.26	35.042	8.082	0.39	27.83	100.08
	5-S	0.1	100	0.93	5.46	4.48	153.16	7.13	87.78	8.06	97.72	0.18	35.034	8.077	0.38	27.83	100.26
	5-D	2.5		2.17	3.50	3.50	134.68	6.82	85.26	8.99	92.26	0.16	35.062	8.080	0.44	27.84	100.63
	6-S	0.1	200	0.93	2.94	2.94	88.48	8.37	75.74	9.30	81.62	0.12	35.103	8.110	0.32	28.00	99.57
	6-D	6.0		1.24	2.66	2.80	71.40	7.44	76.16	8.68	81.62	0.11	35.072	8.122	0.29	28.05	99.45
2	1-S	0.1	1	1.55	9.66	2.66	111.44	5.58	82.60	7.13	94.92	0.86	35.028	8.063	0.43	27.85	102.55
	2-S	0.1	5	bdl	8.26	2.10	101.92	6.82	75.46	6.82	85.82	0.80	35.036	8.058	0.44	27.85	102.81
	3-S	0.1	10	bdl	3.92	2.24	51.52	7.13	78.26	7.13	84.42	0.18	35.093	8.096	0.43	27.84	100.12
	3-D	1.5		bdl	1.54	2.24	70.84	6.51	75.74	6.51	79.52	0.34	35.078	8.108	0.47	27.86	101.57
	4-S	0.1	25	2.79	4.06	2.24	61.04	5.58	70.42	8.37	76.72	0.18	35.105	8.103	0.54	27.84	98.80
	4-D	1.8		2.17	2.38	2.80	115.64	6.51	66.64	8.68	71.82	0.20	35.029	8.103	0.31	27.87	98.47
	5-S	0.1	100	4.03	4.20	3.50	65.24	6.51	75.32	10.54	83.02	0.15	35.090	8.113	0.33	27.83	99.60
	5-D	5.2		1.86	2.38	2.38	83.72	5.89	80.78	7.75	85.54	0.13	35.043	8.117	0.30	27.91	100.65
	6-S	0.1	200	2.79	5.04	2.94	80.36	6.82	87.36	9.61	95.34	0.17	35.074	8.122	0.36	27.93	99.10
	6-D	8.3		2.48	2.66	1.82	89.88	6.51	76.86	8.99	81.34	0.14	35.051	8.127	0.39	27.92	99.29
3	1-S	0.1	1	2.48	49.98	8.96	5635.00	13.02	204.26	15.50	263.20	46.20	0.141	7.954	2.69	27.42	100.12
	2-S	0.1	5	5.89	41.30	10.92	4888.80	3.41	153.86	9.30	206.08	40.50	4.660	8.101	3.16	27.12	101.15
	3-S	0.1	10	0.62	0.56	1.68	107.24	7.13	73.22	7.75	75.46	0.55	34.665	8.127	0.95	27.97	99.24
	3-D	1.8		1.86	1.12	1.68	93.80	6.82	68.74	8.68	71.54	0.33	34.783	8.134	1.57	28.07	98.87
	4-S	0.1	25	3.10	4.34	1.82	110.04	5.89	58.24	8.99	64.40	0.31	34.755	8.146	0.40	28.06	99.10
	4-D	3.9		3.10	2.94	2.10	88.48	5.58	58.66	8.68	63.70	0.28	34.934	8.115	0.77	28.02	95.12
	5-S	0.1	100	2.48	2.10	1.12	96.04	5.89	60.20	8.37	63.42	0.30	34.881	8.118	0.50	27.99	99.97
	5-D	6.5		2.79	5.04	0.98	85.96	5.89	65.80	8.68	71.82	0.21	35.000	8.117	0.43	28.06	97.73
	6-S	0.1	200	3.41	2.80	0.28	94.64	6.51	79.80	9.92	82.88	0.29	34.876	8.111	0.39	28.02	99.68
	6-D	10.6		3.10	5.60	1.54	76.16	6.82	69.30	9.92	76.44	0.29	35.021	8.124	0.48	28.11	98.78
4	1-S	0.1	1	1.24	3.22	1.54	587.44	6.82	81.48	8.06	86.24	3.10	31.641	8.167	1.22	27.80	101.05
	2-S	0.1	5	2.17	2.38	1.68	362.32	6.20	79.66	8.37	83.72	1.91	33.161	8.151	0.70	27.81	101.59
	3-S	0.1	10	0.62	1.82	2.10	166.88	6.82	86.52	7.44	90.44	1.15	34.480	8.127	0.42	27.96	102.95
	3-D	1.6		1.86	1.68	1.40	131.04	6.51	78.68	8.37	81.76	0.80	34.735	8.124	0.41	27.97	106.16
	4-S	0.1	25	1.24	4.34	4.34	73.08	5.89	75.74	7.13	84.42	0.27	35.011	8.125	0.28	27.96	102.59
	4-D	2.5		1.24	4.34	2.80	91.84	6.20	66.50	7.44	73.64	0.26	34.979	8.129	0.40	27.95	102.68
	5-S	0.1	100	0.93	4.06	1.26	82.60	6.51	62.86	7.44	68.18	0.30	34.967	8.122	0.36	27.93	99.15
	5-D	4.8		3.10	5.60	1.54	74.20	5.89	64.82	8.99	71.96	0.22	35.023	8.122	0.39	27.94	100.73
	6-S	0.1	200	0.93	5.88	1.54	70.56	5.89	76.30	6.82	83.72	0.27	35.006	8.117	0.22	27.95	99.90
	6-D	7.7		1.86	5.46	1.54	65.80	6.51	61.04	8.37	68.04	0.16	35.046	8.127	0.43	27.98	100.80
DOH WQS OPEN COASTAL WATERS (DRY)																	
Geometric Mean					3.50	2.00				16.00	110.00	0.20			0.15		
NTE 10%					10.00	5.00				30.00	180.00	0.50			0.50		

A BASELINE ASSESSMENT OF
MARINE BIOTIC COMMUNITY STRUCTURE OFF
MAHAULEPU, KAUAI, HAWAII

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INTRODUCTION

Waiopili Ditch is a man-made drainage channel that flows through the Hawaii Dairy Farm property at Mahaulepu Kauai, and terminates at the ocean. Near the shoreline the ditch consists of a deep muddy basin that connects to the ocean through a shallow channel that flows through beach sand, and subsequently discharges to the ocean. As a result, materials draining from the Dairy may be entrained in ditch flow and reach the marine environment.

In order to evaluate the potential for impacts to the marine environment from the proposed Hawaii Dairy Farm, a baseline survey was conducted of offshore area in November 2016. The purpose of the survey was to collect a quantitative data set that could be used to evaluate the composition of the benthic marine habitats in order to determine if resources exist that might be susceptible to effects of discharge of materials to the ocean emanating from the Dairy operation.

METHODS

Benthic (bottom) composition of the area off Mahaulepu was evaluated by constructing a series of photomosaic composite photographs at representative sites along approximately 1,000 meters of shoreline area off of Waiopili Ditch (Figure1). This region consists of an indentation in the coastal topography forming a semi-embayment which provided natural boundaries to the survey area. Fifteen sites were selected for study that represented the range of physical/biotic habitat features of the area. At each of the sites approximately 300-500 overlapping digital photographs were collected that covered a combined area of approximately 25 meters square (m^2). Geographic coordinates of each of these sites was accurately recorded with a portable differential GPS. Subsequently to fieldwork, photographs were processed using commercially available software "AgiSoft" to produce a seamless image of the entire area. Benthic composition of each image was subsequently evaluated by overlying a grid divided into 200 equally sized units. Composition of each unit was evaluated by trained investigators to the nearest 5%. The resulting data set provides the quantitative calibration/validation data for constructing a benthic habitat map of the area using commercially available hyper-spectral image.

In addition, at each of the 15 calibration/validation sites, field surveys included a quantitative assessment of reef fish. Abundance of fish was estimated using a stationary point count method, where all fish within view were recorded in terms of number of individuals of each species for a period of ten minutes.

The calibration/validation data were also used in conjunction with remote sensing data to produce a map of biotic composition (reef coral bottom cover) of the marine environment of the Mahaulepu reef. Construction of the maps followed standard procedures for processing coral reef remote sensing imagery (e.g., Andréfouët et al. 2003, Bainbridge and Reicheldt 1988, Green et al. 2000, Mumby et al. 1998). All remote sensing analyses were conducted by Dr. E. Hochberg.

A cloud-free, sea surface clutter-free WorldView-2 remote sensing scene of the wider Mahaulepu area using the DigitalGlobe web-based ImageFinder tool. The scene (Product Catalog ID 10400100057E7D00) was taken on December 9, 2014. A standard imagery bundle of panchromatic and eight-band multispectral data was purchased through a certified reseller (Spatial Solutions, Inc.). The panchromatic image had 0.5 m resolution, while the multispectral image had 2 m resolution. Imagery was delivered as georeferenced and gridded on the Universal Transverse Mercator zone 4Q projection, based on the WGS84 ellipsoid.

Using image analysis software "ENVI", each of the 15 field mosaic sites was located on the image and used to define a region of interest (ROI) of 20–30 image pixels. Additional ROIs were defined through visual interpretation to identify areas of purely sandy seafloor. The ROIs were used to segment the survey area into polygons of similar pixel composition using the program "eCognition." Each segment was then classified by percent cover values for each bottom-type, producing final maps showing relative values of coral cover at each point in over the survey area. All remote sensing analyses were conducted by E. Hochberg.

RESULTS

The overall structure of the shoreline and nearshore marine environment off Mahaulepu consists of a submerged basaltic shelf, formed from ancient lava flows, that extends the length of the survey area. Seaward of the basaltic shelf, the central area of semi-embayment consists of expansive sand flats. On each side of the semi-embayment is bounded by extrusions of pillow lava that form distinct shallow dikes that focus breaking waves.

Following is a description of the distinct biotopes that occur in the marine environment off Mahaulepu (a biotope is an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals). Each of these areas is identified in Figure 1, along with a representative mosaic image shown in Figures 2-8. Figure 9 shows the remote sensing map depicting coral cover throughout the survey area. As reef building corals are of major interest, most of the following discussion focuses on the structure of reef coral communities. As with all reef communities in Hawaii, biotic composition, particularly in terms of coral assemblages are primarily determined by physical forces (primarily wave energy) that impact the area (Dollar 1982, Dollar and Tribble 1993, Fletcher et al. 2008, Grigg and Maragos 1974, Grigg 1983, Grigg 1988). As the Mahaulepu area is an open coastal area directly exposed to long-period south and west swells as well as tradewind generated seas, the response to these forces is clearly reflected in coral community structure (Figure 9).

At the terminus of Waiopili Ditch, the shoreline consists of a shallow intertidal reef flat composed of a lava bench that terminates in a reef crest that slopes sharply on the seaward side to the basalt shelf. As the intertidal reef flat where water from Waiopili Ditch mixes with ocean water is consistently subjected to substantial wave action and current flow to the west (Area 1 in Figure 1), physical forces of water movement are maximal, resulting in an environment too harsh for substantial reef development. As a result, only very scattered small corals occur in this area, primarily of the species *Pocillopora meandrina*. At the base of the intertidal drop-off, bottom composition consists of a flat pavement populated with scattered heads of the *Pocillopora meandrina* (Area 2 in Figure 1, Figure 2). *Pocillopora meandrina* is considered a "pioneering species" in that it is adapted to settle and grow in areas too harsh for most other corals. The other dominant bottom cover in the area is patches of the red alga *Asparagopsis taxiformis*, seen as dark patches in Figure 2.

Offshore of the reef bench, bottom composition consists of wide plains of white sand depicted as Zone 3 in Figure 1. The sand plains were characterized by large ripples formed by wave action. Near the northwestern end of the study area a finger of pillow lava extends seaward from the shoreline (Zone 4 in Figure 1, Figure 3). The pillow lava is essentially devoid of reef corals and macroalgae owing to the shallow depth which results in exposure to the atmosphere during low tides. East of the pillow lave extrusion, bottom composition grades to a rough basaltic bench colonized primarily by hemispherical colonies of *Pocillopora meandrina* (Zone 5 in Figure 1, Figure 4). No other corals are apparently able to settle and grow in the basaltic bench area.

The western coastline of the survey area consists of a headland with a shoreline formed by a vertical basalt cliff that extends underwater. The submerged rock surface in this area is composed of a much more rugose lava texture than on the eastern side of the embayment (Zone 6 in Figure 1, Figure 5). As this area is more sheltered from wave effects, and has higher substratum complexity in the form of undercuts, ridges and knolls, coral community structure is more developed both in terms of number of coral species, and bottom cover. In addition to *P. meandrina*, other coral species observed were *Porites lobata*, *Montipora patula* and *M. capitata*. These species are the most common corals in Hawaii and are found on virtually all reefs throughout the State. Total coral cover in the area ranged from about 10-20% of bottom cover.

At the southwestern point of the headland, another shallow pillow lava extrusion extends at an angle into the offshore area (Zone 7 in Figure 1, Figure 6). Directly inshore of the lava dike, bottom composition consists of a field of uniformly sized rubble fragments interspersed with patches of sand (Zone 8 in Figure 1, Figure 7). Few corals occur on the rubble bed.

The shallow depth of the lava dike absorbs wave impacts, resulting in a relatively sheltered wedge-shaped area that extends to the shoreline cliff (Zone 9 in Figure 1, Figure 8). The protection from wave energy in the area between the shoreline and the lava dike results in a unique biotope of the survey area, characterized by bottom cover consisting largely of an solid veneer of limestone created by the deposition of growing corals, primarily of the species *Porites lobata* and *P. compressa*. The high bottom cover and low species diversity of corals in this area is typical of the structure of Hawaiian reefs in wave-sheltered calm water habitats such as Kaneohe Bay on Oahu. Of note is that in the inner areas of the protected wedge, several colonies of *Porites lobata* were observed with diameters up to 5 meters (~16 feet) (Zone 10 in Figure 1, Figure 11). The size of these colonies indicates that if they have grown at a continuous rate, they would be on the order of 200 years old. Regardless of the exact age, the size of these corals indicates that environmental conditions in this specific area have been within the tolerances of this species of coral for an extended period.

DISCUSSION and CONCLUSIONS

In order to assess potential effects of the marine environment from the proposed Hawaii Dairy Farm, a quantitative survey of the nearshore marine habitats off Mahaulepu Kauai was conducted in November 2016. Methods employed in the study used state-of-the art assessment techniques that produced benthic habitat maps that document areas where coral reef resources occur.

The man-made drainage feature called Waiopili Ditch flows through the Dairy property and discharges at the shoreline after flowing across a sand beach and onto a shallow intertidal reef flat. Owing to the shallow depth and direct exposure to long period swells, physical conditions are too extreme for development of coral communities. As a result, the only benthic communities that could be potentially affected by ditch flow are not in the direct discharge path, but rather in areas where exposure would be only to ditch water that is greatly diluted with ocean water.

Survey results of the offshore marine environment reveal that the physical structure of the semi-embayment consists of a lava bench that rims the shoreline. Offshore of the lava bench, the central area of the semi-embayment consists of expansive sand plains. On each end of the semi-embayment, submerged extrusions of pillow lavas form shallow dikes. The dike at the southwestern edge of the study area is oriented so that it forms a barrier to wave forces, creating an area of sheltered habitat that is suitable for coral growth. The only area of such suitability is located approximately 600 meters (0.3 mile, 2,000 feet) from the discharge of Waiopili Ditch.

Coral community structure throughout the exposed nearshore zone that consists of hard bottom is generally restricted to communities consisting primarily of a single species of coral, *Pocillopora meandrina*. The predominance of this coral serves as an indicator that physical conditions of the area are too harsh for the settlement and growth of other coral species. Thus, the majority of the semi-embayment off Mahaulepu does not represent an area of overall suitability for development of coral reefs.

The exception to this biotic structure occurs along the western shoreline of the study area. As this region consists of bottom composition that is more rugose that other areas, and is somewhat protected from direct impact from southern swells, coral communities are more developed. Of the several species observed, all were considered the most common components of most Hawaiian reefs, and do not represent a unique or rare resource.

The oblique orientation of the lava extrusion to the shoreline at the southwestern end of the survey area creates a distinctive habitat owing to the shelter afforded from the destructive force of breaking waves. Inshore of the lava dike, a small area is colonized by large coral colonies that appear to have grown uninterrupted for as long as centuries. As such, these corals have withstood wave forces associated with the two hurricanes that directly impacted Kauai in 1982 and 1992, as well as any other variations in physical and chemical conditions that have occurred over that time.

With respect to potential impacts from discharge from Waiopili Ditch, several important points must be considered. First, there is essentially no biotic community structure in the areas where ditch flow meets the ocean, so impacts to biota cannot occur. In addition, the physical structure and oceanic conditions of this area can be considered dangerous for human uses, indicating that the area does not represent a safe or unique recreational resource.

The discharge from Waiopili Ditch consists of fresh water of very low salinity. Under atypical calm conditions, upon entering the ocean such flow would form a stratified surface layer overlying saline ocean water. With persistent calm conditions, the stratified surface layer would persist, and not be exposed to bottom-dwelling organisms including corals; hence there would be no opportunity for the materials entrained in the surface plume to impact coral communities.

A scenario of consistent calm sea conditions off Mahaulepu does not represent the typical circumstances. Typical conditions during tradewinds and long-period swell result in rapid mixing of the water column. Hence, materials discharging from Waiopili Ditch are rapidly mixed through the water column to background levels within a short distance from the point of discharge. Marine water sampling conducted by Marine Research Consultants that originated at the juncture of Waiopili Ditch and the ocean and extended offshore revealed steep gradients of decreasing nutrients, Chl *a* and turbidity and increasing salinity. These gradients were the result of a narrow zone of mixing between ditch water and ocean water in the intertidal region of the reef flat. Typical oceanographic conditions result in rapid mixing and dilution of ditch water constituents within a narrow zone that only extends several meters from the shoreline. As a result, input from ditch water is highly restricted in terms of effects to the marine environment.

The effect of elevated nutrients on corals is often cited as a major concern regarding the impact of land based discharge to the ocean to reef community structure. Thus, it is important to consider the potential effects of nutrient subsidies on reef corals based on existing scientific literature, particularly in the context of the marine environments in Hawaii.

Kinsey (1991) observed that it is incorrect to jump from the observation that coral reefs can do well under low nutrient conditions to the conclusion that coral reefs require such low nutrient environments. Smith and Buddemeier (1992) agree with this, noting some reefs look healthy and are apparently doing well in a milieu of naturally high nutrient levels. Atkinson and Falter (2003) state that "nutrient loading and its subsequent impact is one of the more important issues concerning conservation and protection of coral reefs. It is widely believed that any nutrient input to coral reefs is deleterious. This conclusion, that nutrients are deleterious to a reef ecosystem, is simply incorrect."

To illustrate, water in tanks growing corals at the Waikiki Aquarium comes from saline groundwater wells, and has a dissolved inorganic nitrogen (DIN) concentration of ~7 µM (98 µg/L) (Atkinson et al. 1995). Growth rates of corals in tanks at the Waikiki Aquarium have been measured to be near the upper rates reported from any natural reefs, demonstrating corals can and do flourish in relatively high-nutrient water. The highest value of DIN recorded in the ocean at the juncture of Waiopili Ditch and the ocean during marine monitoring during average flow conditions was about 4.2 µM (59 µg/L). At a distance of 200 meters away from the ditch, values of DIN were 0.5 µM (7 µg/L) (Marine Research Consultants 2016). As the only area of extensive coral community development is about 500 meters from the discharge, it is likely that DIN concentrations would be even further diluted by ocean water. Hence, the concentrations of DIN at the shoreline juncture of Waiopili Ditch and the ocean is about one half that that occurs continuously in water at the Waikiki Aquarium, where corals flourish. At the distance where corals occur west of the discharge of Waiopili Ditch, it is apparent that nutrient concentrations are orders of magnitude less than that might be contained in water reaching the reef areas is an order of magnitude less than found at the Aquarium where corals grow at maximum rates with no detrimental effects.

The most ambitious field experiment to investigate the effects of nutrient enrichment on a number of coral reef processes was the ENCORE (Elevated Nutrient on Coral Reef Experiment) project on the Great Barrier Reef (Koop et al. 2001). Experimental loading of nutrients to the reefs was increased from 10 µM ammonium and 2 µM phosphate to 20 µM ammonium and 4 µM phosphate in the second year of the study because of the lack of any effects at the original level of nutrient enrichment. Even at the increased levels "impacts were generally sub-lethal and subtle, and the treated reefs at the end of the experiment were visually similar to control reefs." Hence, the highest measured value of elevated nutrients found at the junction of Waiopili Ditch and the ocean was about one-quarter the concentration (4 μM) that produced no serious detrimental effects to corals in the ENCORE experiment. The average value of nutrients over the Mahaulepu reef is far below any values in the existing scientific literature that could be interpreted to be detrimental to coral growth. In addition to nutrients, none of the other chemical or physical parameters measured over the Mahaulepu reef were near any thresholds of impact to coral reef organisms.

Szmant (2002) also feels that support for the claim that nutrient over-enrichment is considered a major cause of degraded reefs by promoting shifts from high coral cover to high cover and biomass of fleshy algae are equivocal at best. While the ENCORE experiment showed that nutrient enrichment is not the sole or major cause of shifts in coral coral/algal abundance, Szmant indicates that other factors, particularly reduction in grazing or stress associated with changes in water properties (i.e., thermal stress) are required to contribute to an imbalance that can lead to shifts in community structure.

Another empirical example of the inaccuracy of assuming that elevated nutrients always result in negative effects to corals can be seen by looking at shallow sewage treatment facility discharges on reefs in Hawaii. Continual monitoring of benthic communities surrounding treated sewage in several reef areas reveal that such continuous discharges of water of far higher nutrient content than the rare episodic discharge of storm flow from Waiopili Ditch have little or no effect on coral survival (Marine Research Consultants 2016). Figure 12 shows underwater views of two discharging diffuser outfalls on Oahu, Hawaii. In both photos, corals are seen to be colonizing the diffuser structures, with no apparent negative impacts. Also evident in Figure 12 is that there are no benthic algal blooms or plankton blooms in the area of active nutrient discharge. These locations are similar to Mahaulepu, in that they are located on coastal locations with good mixing characteristics. Residence time of water in the area is likely so short that plankton communities would not have any chance to develop before being flushed from the reef zone and diluted in the open ocean. Benthic algal blooms require a constant or at least regular input of nutrient subsidies to persist. As such, the episodic nature of storm events that might deliver nutrient subsidies to the reef area are not of a frequency to support benthic algal blooms. Benthic algal blooms on Maui that occurred during the 1990's have not returned for the last decade, indicating that nutrient input is not the sole causal factor (Dollar and Andrews 1997). In addition, the documented algal blooms on Maui occurred in wave-protected nearshore habitats, and would not have been able to persist in the harsh environment off Mahaulepu.

Field investigation of water chemistry over the entire Mahaulepu reef indicated the presence of very limited dissolved nutrients from groundwater discharge along the entire shoreline composing the study area. The only area of distinctly elevated nutrients was at the juncture of the ditch and ocean, and the high values dissipated immediately beyond the shoreline reef bench. When mixing processes are considered that are required to transport the discharge to the zones of the reef where corals occur, nutrient concentrations will be reduced even further.

While a well-established coral community was identified along the shoreline to the southwest of the point of discharge of Waiopili Ditch, it is not likely that this area would be affected by any input from the Dairy that may be incorporated into ditch flow. The isolated area of high coral coverage is approximately 600 meters (0.3 miles) from the point of discharge. Over this distance, mixing processes would dilute any materials in the discharge to background levels. Based on the results of this field survey, as well as consideration of the responses of other marine habitats throughout Hawaii, there is no indication of any conditions associated with the Mahaulepu discharge that could lead to deleterious effects to coral reef communities.

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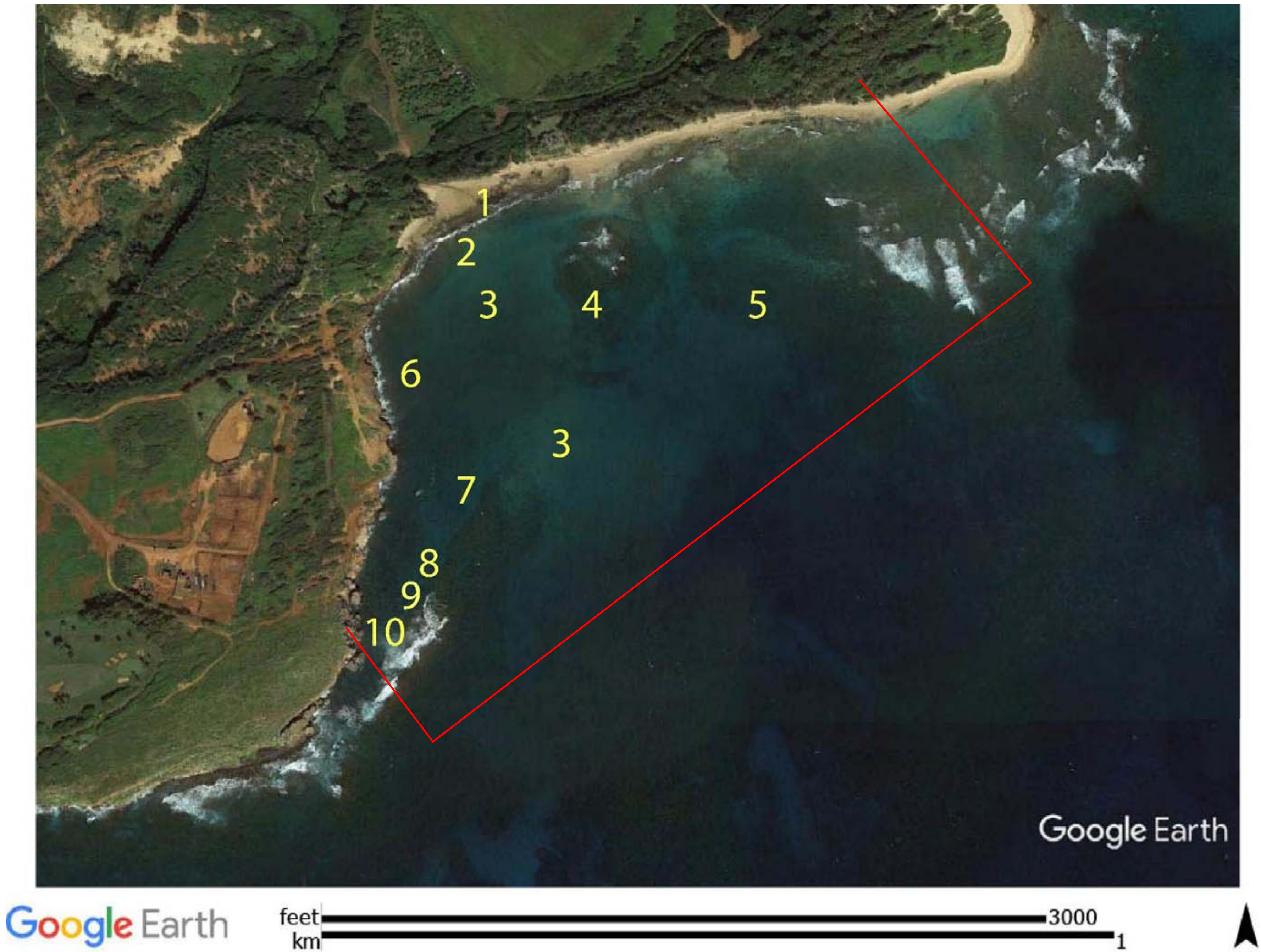

FIGURE 1. Aerial photograph of coastline and offshore marine environment at Mahaulepu, Kauai. Numbers indicate various benthic habitat types. Numeral "1" indicates location of discharge of Waiopili Ditch to ocean.

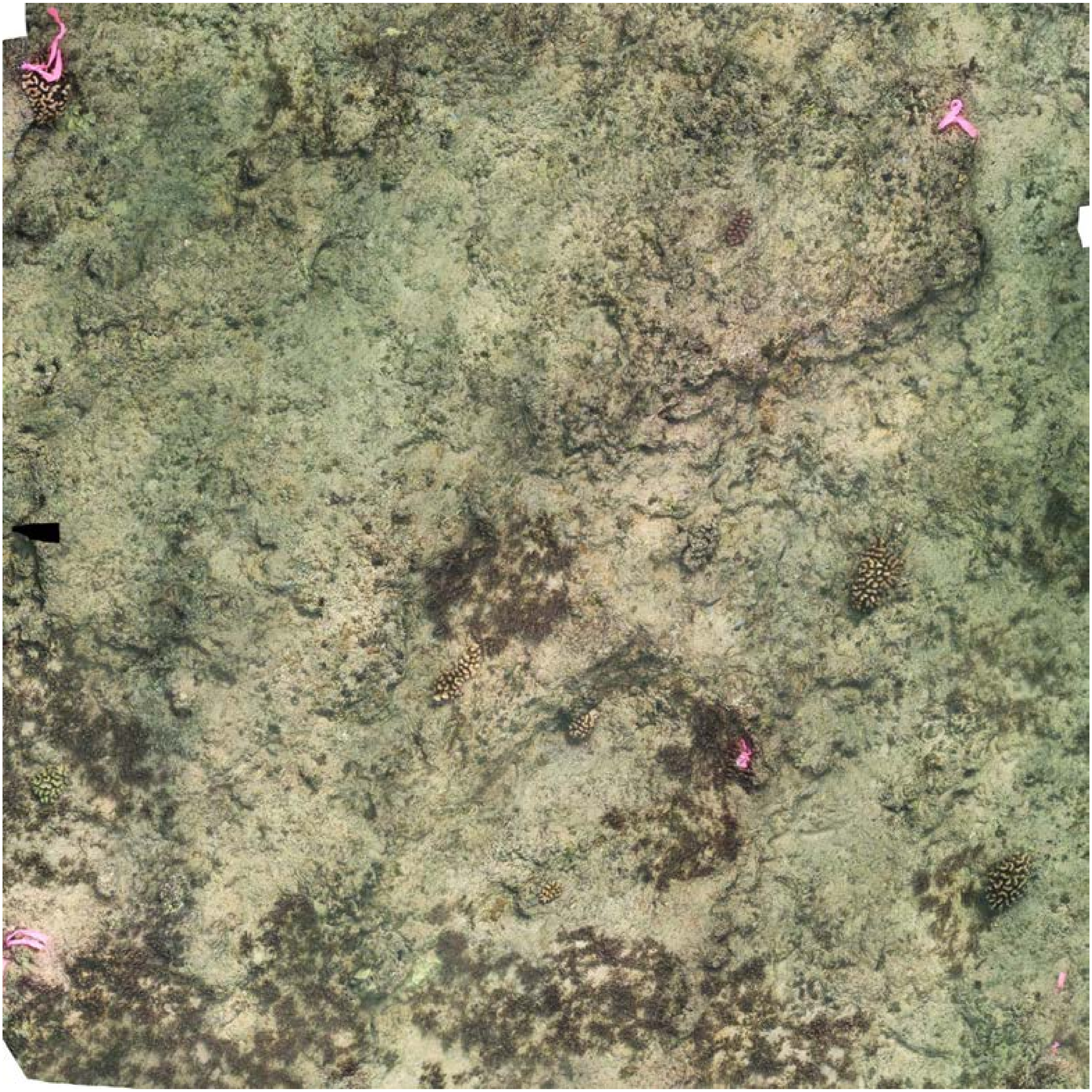

FIGURE 2. Photomosaic image of benthic habitat off Mahaulepu Beach in area marked as ZONE 2 in Figure 1. Bottom composition consists of eroded basaltic bench. Water depth is approximately 8 feet.

FIGURE 3. Photomosaic image of benthic habitat off Mahaulepu Beach in area marked as ZONE 4 in Figure 1. Bottom composition consists of a bed of basaltic pillow lava. Wate depth is approximately 10 feet.

FIGURE 4. Photomosaic image of benthic habitat off Mahaulepu Beach in area marked as ZONE 5 in Figure 1. Dominant coral is *Pocillopora meandrina* growing on a basaltic bench. Water depth is approximately 15 feet.

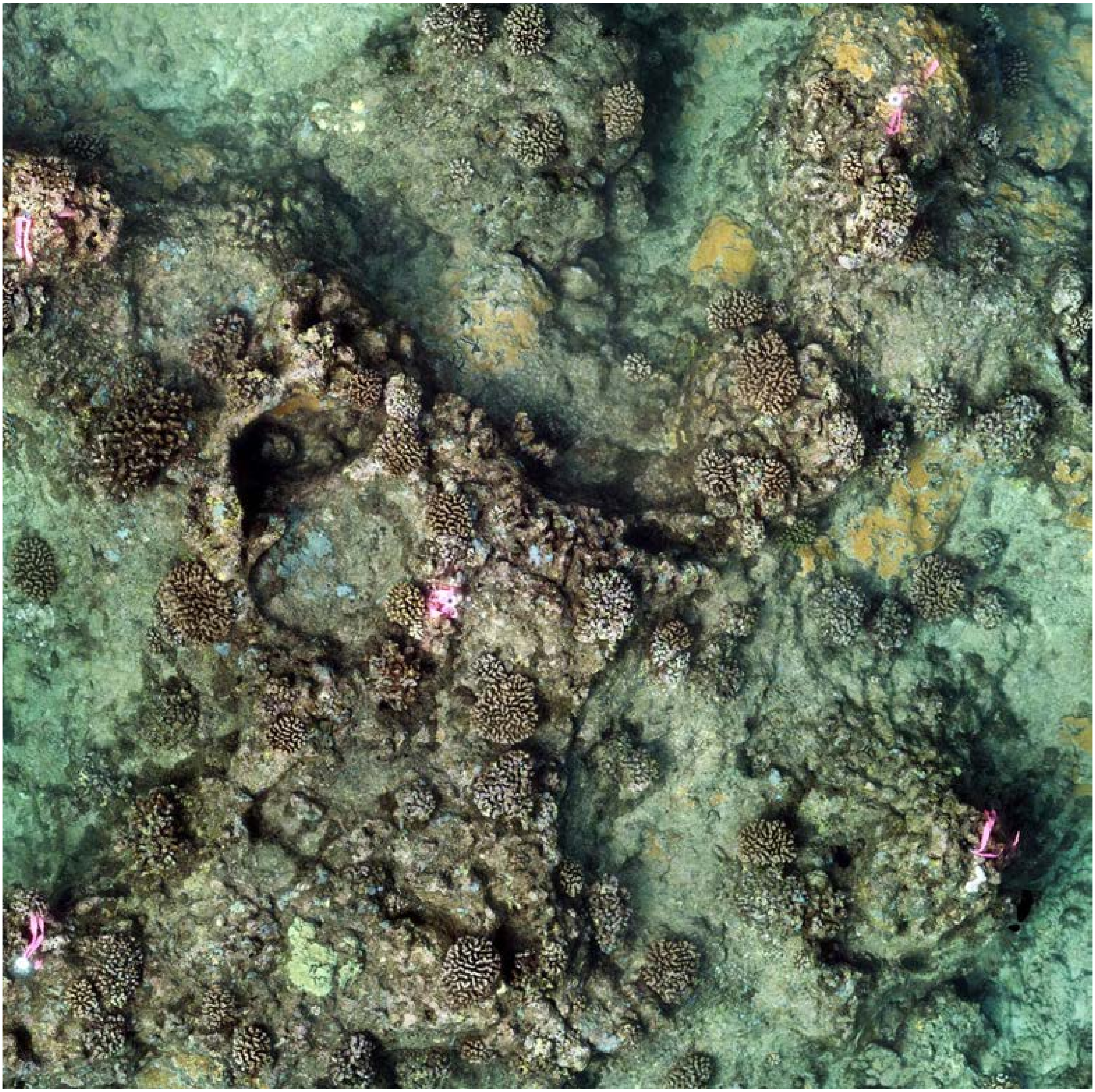

FIGURE 5. Photomosaic image of benthic habitat off Mahaulepu Beach in area marked as ZONE 6 in Figure 1. Bottom composition consists of eroded basaltic structure. Dominant corals are *Pocillopora meandrina* and *Montipora patula* (rust-colored encrusting growth form). Water depth is approximately 12 feet.

FIGURE 6. Photomosaic image of benthic habitat off Mahaulepu Beach in area marked as ZONE 7 in Figure 1. Bottom composition consists of basaltic boulders. Dominant coral is *Pocillopora meandrina*. Water depth is approximately 8 feet.

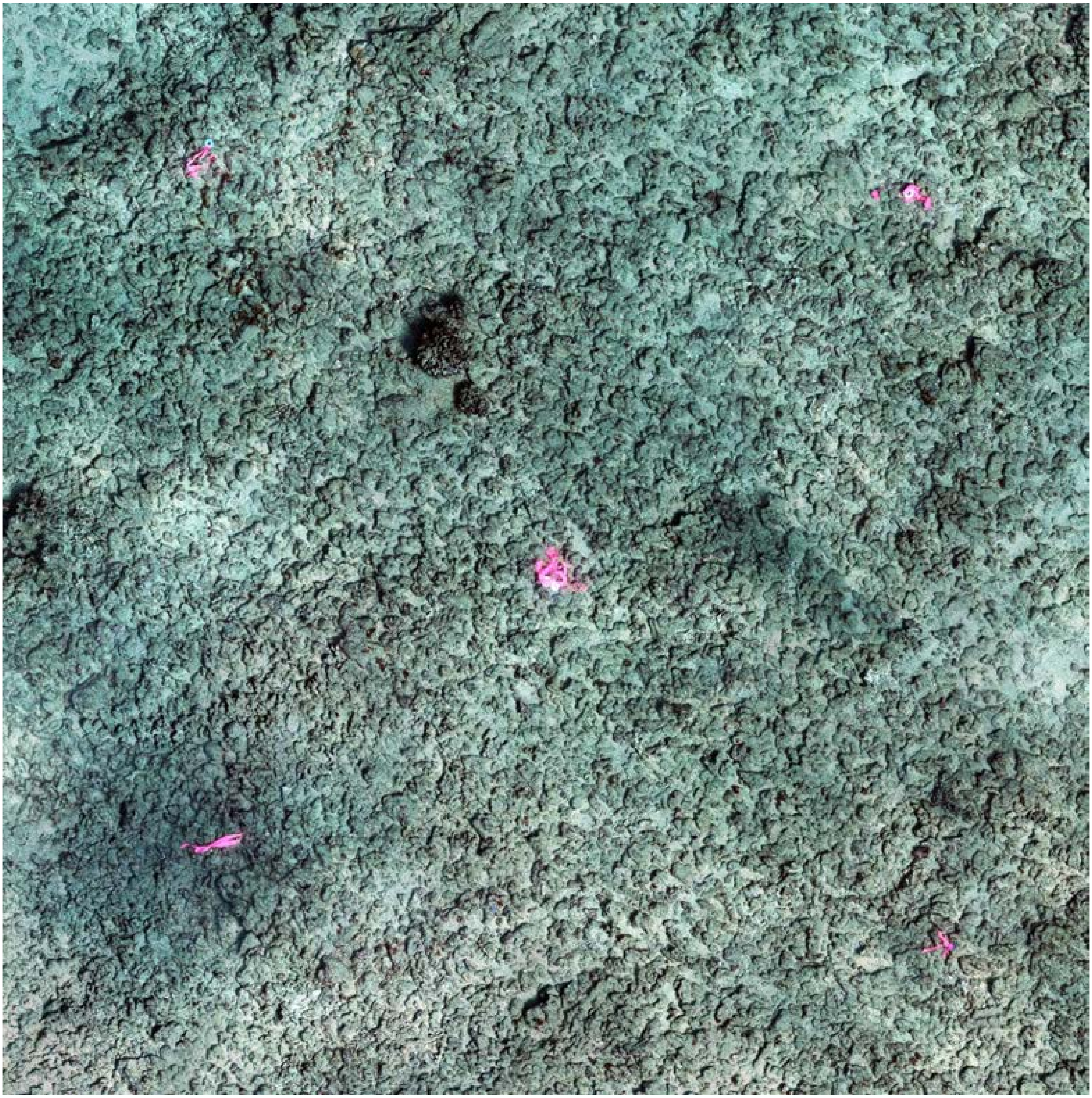

FIGURE 7. Photomosaic image of benthic habitat off Mahaulepu Beach in area marked as ZONE 8 in Figure 1. Bottom composition consists of a bed of rubble at base of basaltic boulders dike. Water depth is approximately 18 feet.

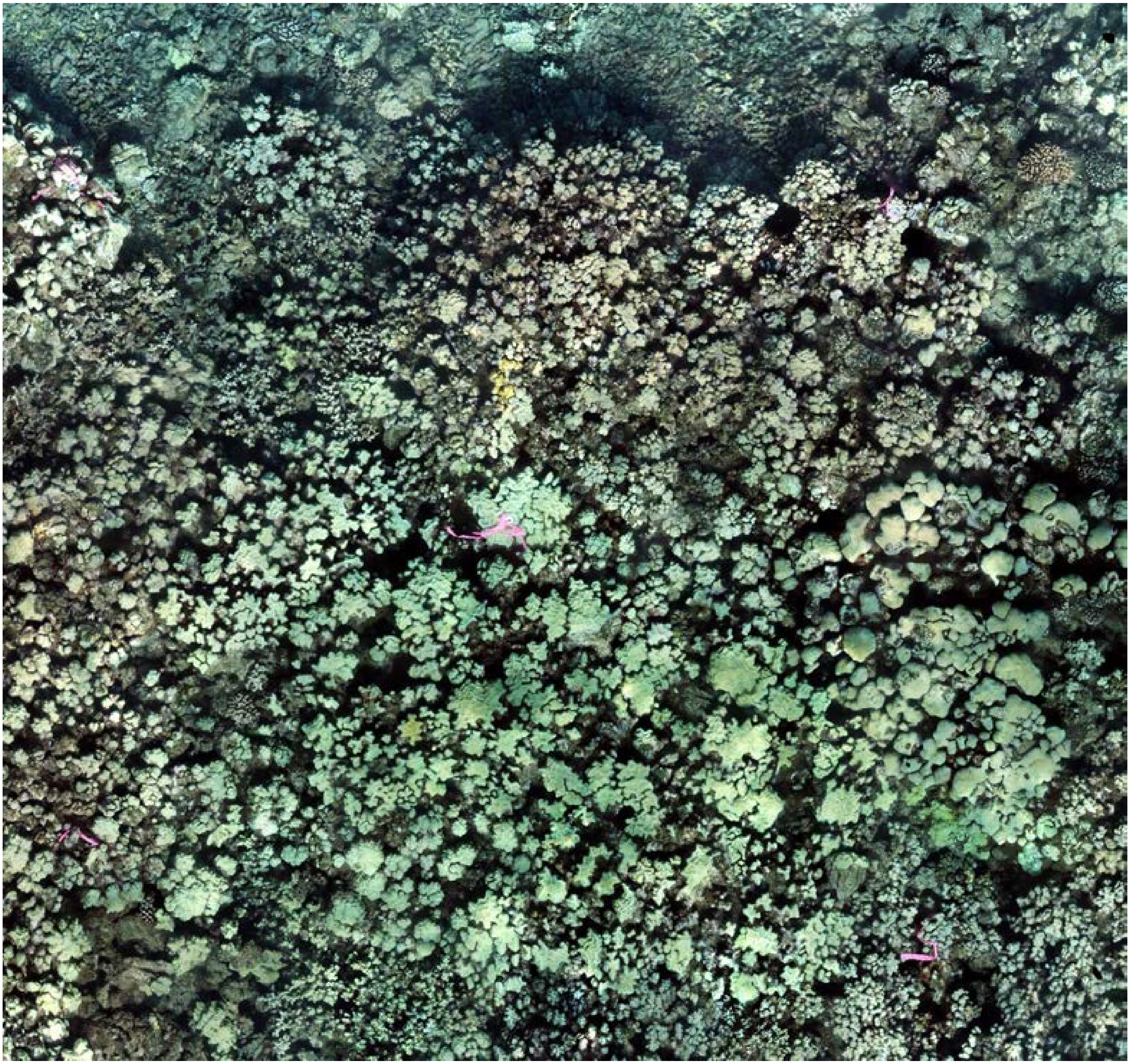

FIGURE 8. Photomosaic image of benthic habitat off Mahaulepu Beach in area marked as ZONE 9 in Figure 1. Bottom composition consists of a solid limestone veneer formed by growing aggregations of *Porites* spp. Water depth is approximately 18 feet.

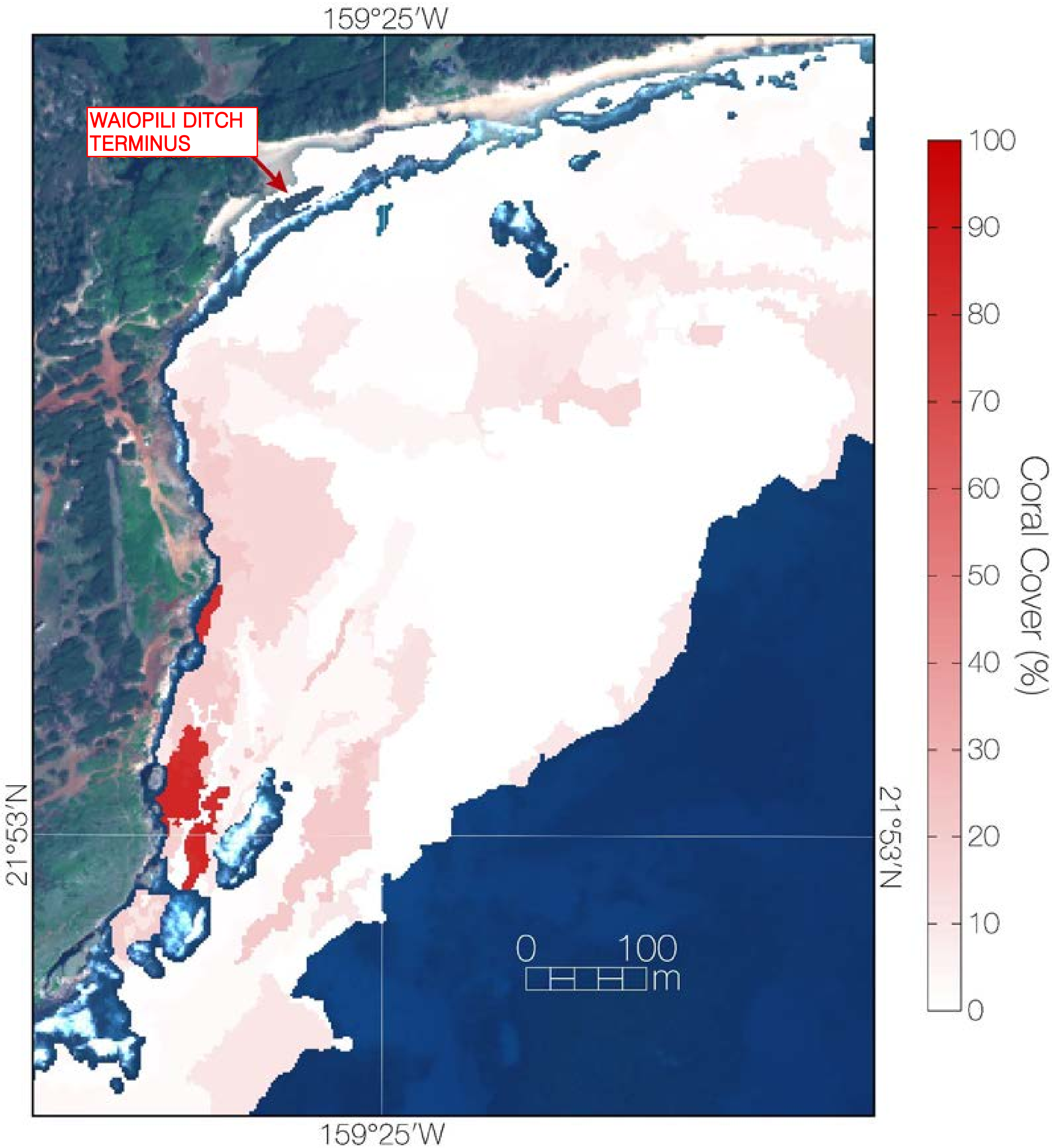

FIGURE 9. Benthic coral habitat map created from satellite remote sensing imagery and groundtruth calibration/validation data. It can be seen that coral cover is very low in the area adjacent to the point of discharge of Waipoli Ditch. The only area of high coral cover is an area approximately 600 meters to the southwest of the Ditch discharge where a lava dike (shown in blue) serves as a barrier to wave forces.

FIGURE 10. Satellite photograph of Mahaulepu coastal area during period of typical wave climate. Swells can be seen traversing the nearshore reef area and breaking on the shoreline directly in front of the point of discharge of Waiopili Ditch.

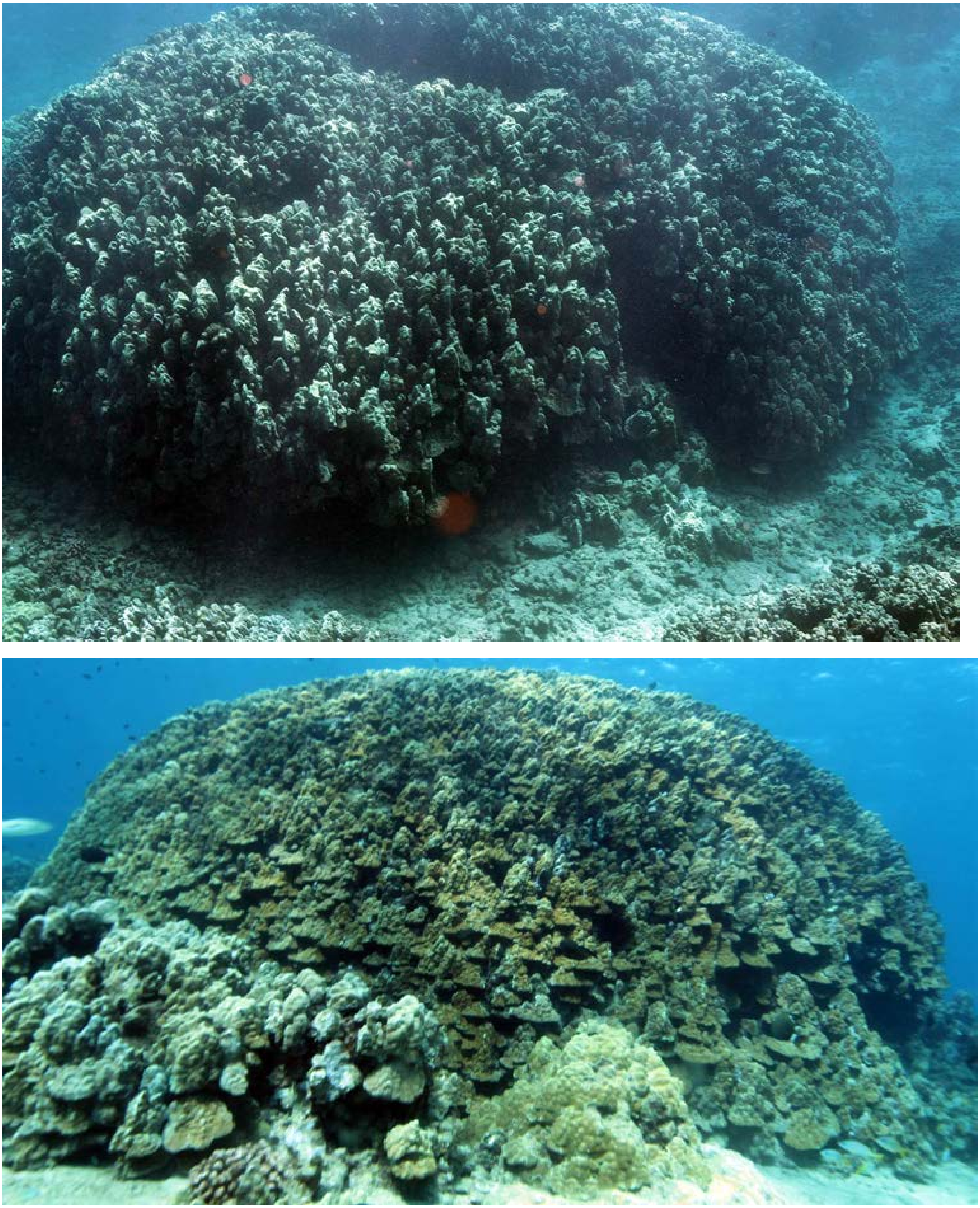

FIGURE 11. Photographs of two large colonies of *Porites lobata* in ZONE 10 in Figure 1. Water depth is approximately 20 feet.

FIGURE 12. Underwater photos of East Honolulu Wastewater Treatment Plant ocean outfall off Sandy Beach, Oahu (top), and Hilo Wastewater Treatment Plant ocean outfall in Puhi Bay, Island of Hawaii (bottom). Treated sewage effluent, with high concentrations of dissolved nutrients, can be seen discharging from diffusers. Both diffuser structures are colonized by healthy reef corals of a variety of species. No benthic algal blooms or high levels of plankton that would be apparent by green water are visible. Both outfalls have been in operation for decades with no impacts to surrounding biota.

APPENDIX G

STATE HISTORIC PRESERVATION DIVISION DETERMINATION LETTER

ARCHAEOLOGICAL INVENTORY SURVEY REPORT, MĀHĀ‘ULEPŪ AHUPUA‘A, KŌLOA DISTRICT, KAUA‘I ISLAND, HAWAI‘I

SCIENTIFIC CONSULTANT SERVICES, INC.

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
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COMMISSION ON WATER RESOURCE MANAGEMENT

KEKOA KALUHIWA
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AQUATIC RESOURCES
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BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

STATE HISTORIC PRESERVATION DIVISION
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December 19, 2016

Amy Hennessy
Hawaii Dairy Farms, LLC
737 Bishop Street, Suite 2360
Honolulu, HI 96813
amy@ulupono.com

Log No. 2016.02684
Doc. No. 1612KM09
Archaeology

Dear Ms. Hennessy:

SUBJECT: **Chapter 6E- Historic Preservation Review –**
Archaeological Inventory Survey Report for Hawaii Dairy Farm
Māhāʻulepū Ahupuaʻa, Kōloa District, Island of Kauaʻi
TMK: (4) 2-9-001:001 por.; 2-9-003:001 por., and 006 por.

Thank you for the opportunity to review the revised draft report titled *Archaeological Inventory Survey Report, Māhāʻulepū Ahupuaʻa, Kōloa District, Kauaʻi Island, Hawaiʻi, TMK: (4) 2-9-001:001 por., (4) 2-9-003:001 por., and (4) 2-9-003:006 por.* (Putzi et al. December 2016). The State Historic Preservation Division (SHPD) received the original submittal on September 25, 2014 and revisions were requested on multiple occasions (December 3, 2014; Log No. 2014.04405, Doc. No. 1410MN02; April 13, 2015 Log No. 2015.01404, Doc. No. 1504MN05; July 15, 2016; Log No. 2016.01324, Doc. No. 1607MN04). Additional revisions were requested on December 11, 2016 (email correspondence; Susan Lebo [SHPD] to Mike Dega [Scientific Consultant Services]). SHPD received final revisions via email on December 13, 2016 (Kepa Lyman [Scientific Consultant Services] to Susan Lebo [SHPD]).

The archaeological inventory survey (AIS) of the 580-acre subject property was conducted at the request of the leasee, Hawaii Dairy Farms, LLC (HDF). The landowner is Grove Farms, LLC. The project area includes the floor of Māhāʻulepū Valley, a relatively level plain framed by Mt. Haʻūpu Ridge and Mountain to the north, and two ridges on the east and west, forming a large, natural amphitheater. The east and west ridges also serve as *ahupuaʻa* (traditional land division) boundaries, with Kipu Kai to the east, and Paʻa on the west. Based on the geological formation of the ridgeline framing the project area, SHPD initially recommended that the project area be defined as the entire area from the ridgeline down. After subsequent discussions, Scientific Consultant Services (SCS) and the landowner agreed to expand the project area approximately 100 meters upslope in all directions. The commercial dairy will require the modification of existing dirt roads, grading ground surfaces for the construction of buildings, the excavation of effluent ponds, and the excavation of pipelines for the watering of cattle. The initial scope of work for the project referenced a herd size of 499 head of cattle, but the current report states that future operations could include up to 2000 head of cattle. The revised report contains references to recent infrastructure improvements.

The AIS newly identified 16 historic properties within the project area, and relocated Site 50-30-10-3094, a large boulder with at least 20 anthropomorphic characters represented, as well as two pecked "cups" or basins. Two other petroglyph rocks (Features B and C) were also identified. Feature C is approximately 70 meters from the other features comprising Site 3094. Sites 50-30-10-2251 through 2262 are associated with plantation-era infrastructure and include irrigation ditches, two bridges, a reservoir, a retaining wall, and sluice gates. Site 2250 is located on the slopes below Mt. Haʻupu and is included in the expanded project area. Site 2250 is an enclosure interpreted as an agricultural heiau due to its size, construction (uprights, paved foundation), location, and lack of cultural materials normally indicative of a kau hale or community hale and for its proximity to LCAs associated with agricultural encampments. Seventeen backhoe trenches were excavated within various portions of the property (partly determined in consultation with SHPD) and included testing within known LCA encampments, and near Site 2250 and Site 3094. A single artifact, a chopper tool, was recovered within Site 2250.

Pursuant to Hawaii Administrative Rules (HAR) §13-284-6, the plantation-era sites (Sites 2251-2262) are assessed significant under Criterion d; and Sites 2250 (a ceremonial enclosure) and Sites 3094 (petroglyph boulders) are assessed significant under Criteria d and e. The report recommends no further work for Sites 2251-2262 but an architectural inventory survey is recommended for these sites prior to future work outside the current project area. Sites 2250 (enclosure) and 3094 (petroglyphs) are recommended for preservation; however, both sites are outside of the present project area and not within land owned by HDF or Grove Farms, LLC. Additionally, the current proposed project will not affect Sites 2250 and 3094. No further mitigation is recommended for Sites 2250 and 3094 for this project but future proposed projects outside the current project area shall require consultation with SHPD. SHPD concurs with the significance assessments, and mitigation recommendations.

The revised report is well written and adequately addresses the issues and concerns identified in our previous correspondence. The report meets the requirements of HAR §13-276-5. **It is accepted**. Please send two hardcopies of the document, clearly marked FINAL, along with a text-searchable PDF version to the Kapolei SHPD office, attention SHPD Library.

Please contact Kimi Matsushima at (808) 692-8027 or at Kimi.R.Matsushima@hawaii.gov for questions regarding archaeological resources or this letter.

Aloha,

Susan A. Lebo

Susan A. Lebo, PhD
Archaeology Branch Chief

cc: Robert Spear, PhD, SCS (bob@scshawaii.com)
Mike Dega, PhD, SCS (mike@scshawaii.com)
Jeff Overton, G70 (jeff@g70.design)

SCS Project Number 1597 AIS-12

ARCHAEOLOGICAL INVENTORY SURVEY REPORT

MĀHĀ'ULEPŪ AHUPUA'A, KŌLOA DISTRICT, KAUA'I ISLAND, HAWAI'I

TMK: (4) 2-9-001:001 por., (4) 2-9-003:001 por., and (4) 2-9-003:006 por.

Prepared by:
Jeff Putzi, B.A.,
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and
Michael Dega, Ph.D.

December 2016

FINAL

Prepared for:
Hawaii Dairy Farms, LLC.
P.O. Box 1690
Kōloa, Kaua'i, Hawai'i 96765

SCIENTIFIC CONSULTANT SERVICES Inc.

HAWAII

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ABSTRACT

Scientific Consultant Services, Inc. (SCS), conducted an Archaeological Inventory Survey (AIS) on behalf of Hawaii Dairy Farms, LLC (HDF) in connection with a proposed dairy farm (project) that HDF seeks to develop on 557 acres within Māhā'ulepū Valley, Māhā'ulepū Ahupua'a, Kōloa District, Island of Kaua'i [TMK: (4) 2-9-001:001 por., (4) 2-9-003-001 por., and 2-9-003:006 por.]. The property comprising the project area is owned by Mahaulepu Farm LLC and leased to HDF for the purpose of developing the proposed dairy farm.

A 100% pedestrian survey was conducted over the entire project area. In addition, through consultation with the State Historic Preservation Division (SHPD), a 100-meter wide zone bordering the northern flanks of the project area was also surveyed. This extended survey area is also owned by Mahaulepu Farm LLC but is not included within the premises leased to HDF. Because the extended survey area is outside HDF's leased premises, HDF was required to obtain permission from Mahaulepu Farm LLC to enter and survey this area. No project impacts are anticipated in this area; thus, the extended survey area is not part of the defined project area although historic properties identified within the extended survey are described in this report.

During the course of the pedestrian survey of both the project area and extended survey area, a total of sixteen historic properties were identified—six of these sites were located within the project area and the remaining ten sites were located in the extended survey area. All six sites found in the project area are associated with sugar cane cultivation. Of the ten sites located outside the project area, two are associated with the pre-Contact and/or early post-Contact periods, one of which was previously identified (Site 50-30-10-3094); the remainder of the sites are affiliated with sugar cane cultivation.

In addition to pedestrian survey, a total of seventeen long trenches were mechanically excavated in various portions of the project area, particularly in a portion of the project area which contained a complex of Land Commission Awards. No cultural deposits, features, artifacts or burials were identified in any of the trenches. Finally, multiple test units were manually conducted in the pre-Contact and/or post-Contact enclosure (Site 50-30-10-2250) located in the extended survey area, which aided in functional interpretations.

Sites 50-30-10-2250 through -2264 have been assessed as significant under Criterion d (information important in prehistory or history). No further work is recommended for any of the sites in the project area, although adaptive re-use is possible with several sites. Sites -3094 and -2250, both occurring outside the proposed project area, have been assessed as significant under Criterion d and e. Because the project will not have impacts outside the project area, and because the sites within the extended survey area are located on lands that HDF has no control over, no further work is recommended for any of these sites at this time. Accordingly, these sites will remain in their existing condition, under the control of landowner Mahaulepu Farm LLC. However, SHPD will be contacted regarding appropriate mitigation (e.g., data recovery, preservation, or no further work) if a future project should be proposed with the potential to impact any of these sites.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Hawai'i Dairy Farms LLC (HDF) has leased certain agricultural lands from Mahaulepu Farm LLC (landowner and lessor), located in Māhā'ulepū Valley, Māhā'ulepū Ahupua'a, Kōloa District, Island of Kaua'i (TMK: (4) 2-9-001:001 por., (4) 2-9-003:001 por., and (4) 2-9-003:006 por.), to establish and operate a dairy farm on the leased property (project) (Figures 1 and 2). It is proposed that the 557-acre leased property will undergo some changes in connection with the development of the project, including: modifying existing dirt roads, grading ground surfaces for the construction of buildings, the excavation of effluent ponds, and the excavation of pipelines for the watering of cattle (Figure 3). Previously the entire project area was utilized for sugar cane cultivation.

At the request of HDF, Scientific Consultant Services, Inc. (SCS) performed an Archaeological Inventory Survey (AIS) of the project area, comprised of the leased premises, along with an extended survey area of approximately 100 meters upslope (Figure 1 and Figure 2). The land within the extended survey area is owned by Mahaulepu Farm LLC, and is not under the control of HDF; accordingly, HDF and SCS had to obtain the permission of the Mahaulepu Farm, LLC to enter those areas. The 557-acre project area, together with the extended survey area, compromise the total surveyed area in this report.

Pursuant to Hawai'i Revised Statutes (HRS) Chapter 6E and Hawai'i Administrative Rules (HAR) Chapters §13-284 and §13-276, the AIS was performed to:

- Identify and document historic properties that may be present in the project area, and given the level of prior disruption of this area, to also identify historic properties in the extended survey area that may provide context and assist in the interpretation of any historic properties in the project area;
- Gather information to evaluate the significance of any newly identified historic properties;
- Determine what effects, if any, the proposed project would have on any identified significant historic properties; and
- Propose mitigation commitments to address possible adverse effects the project would have on the identified significant historic properties.

SCS conducted a 100% pedestrian survey of the project area and extended survey area. The survey located and further documented one previously identified historic property, a carved petroglyph boulder (State Site 50-30-10-3094) and documented 15 historic properties newly identified during this survey. Six sites occur in the project area, and the remaining ten sites were documented in the extended survey area outside of the project area.

Fourteen of the sixteen sites are affiliated with sugar cane cultivation- *i.e.*, bridges, ditches, retaining wall remnants, and culverts dating from the late 19th- 20th century. All six of the sites within the project area, and eight of the sites in the extended survey area, fall within this site classification. The remaining two sites in the extended survey area- an enclosure and three petroglyph features- are associated with the pre- and/or early post-Contact periods.

In addition to pedestrian survey, a total of seventeen long trenches were mechanically excavated in various portions of the project area, particularly in a portion of the project area which contained a complex of Land Commission Awards (LCAs). No cultural deposits, features, artifacts, or burials were identified in any of the trenches. Finally, multiple test units were manually placed in the pre- and/or early post-Contact enclosure (Site 50-30-10-2250) in the extended survey area, which aided in refining functional interpretations of that site.

HAWAII DAIRY FARMS PROJECT DESCRIPTION[1]

> Hawai'i Dairy Farms, LLC (HDF) was formed as a positive step toward the island state's food security, economic diversity, and sustainability. Experimental trials were conducted to determine lands capable of growing nutritious forage for dairy cows, and lands meeting the operational requirements for a dairy operation were identified. Kaua'i was determined to best meet the operational requirements, and Māhā'ulepū Valley was found to provide ideal growing conditions.
>
> At steady-state production with 699 milking cows, the farm will produce roughly 1.2 million gallons annually at market price. HDF will reduce Hawai'i's reliance on imported milk from the mainland United States by increasing current fresh local milk production by approximately 33 percent. The farm will be based on the most successful island dairy models in the world, and will utilize a sustainable, pasture-based rotational-grazing system and 21st century technology. The farm will be very different from conventional feedlot dairy operations.
>
> HDF is committed to establishing a herd of up to 699 mature dairy cows, and demonstrating the pasture-based system as an economically and environmentally sustainable model for Hawai'i. With proven success at a herd size of 699, HDF will contemplate the possibility of expanding the herd in the future. Precision agricultural technology that monitors cows' health, grass productivity, and effluent management will be used to ensure environmental health and safety, as well as best management practices, and help determine the ultimate carrying capacity of the land.
>
> For dairy operations with 700 or more mature dairy cows, additional regulatory review and permitting by the State Department of Health is required. The application process for a National Pollutant Discharge

[1] Text for this section provided by Group 70 International, Inc.

> Elimination System (NPDES) Concentrated Animal Feeding Operation (CAFO) permit includes public notification and input. At the discretion of HDF, management may choose to expand operations up to the carrying capacity of the land, which is currently estimated to be up to 2,000 productive milking dairy cows. Permit process compliance would be followed at such time HDF may decide to pursue an expanded operation.

PROJECT AREA AND EXTENDED SURVEY AREA

The area of potential effect (APE) of the proposed dairy farm, and thus, the project area, for purposes of the AIS, is comprised of the 557 acres HDF leases from Mahaulepu Farm, LLC, a subsidiary of Grove Farm Company, Inc. (Grove Farm). When the dairy is operational, the leased property will be fully enclosed by a fencing system that will ensure that all impacts of the project are maintained within the leased area.

At the request of the State Historic Preservation Division (SHPD), HDF and SCS agreed to include in the AIS an additional area outside the project area, comprised of approximately 100 meters (m) along the northern portion of the valley floor and slightly above, referred to herein as the extended survey area (see Figures 1 and 2). The project is not anticipated to have any impacts in this extended survey area. As the project area was previously used for intensive sugar cane cultivation and is heavily disturbed, it was thought that looking outside the project area could provide additional information that is not readily apparent from its current condition, as well as provide context and information helpful to interpreting sites found within the project area. The project area, together with the extended survey area, is referred to herein as the surveyed area.

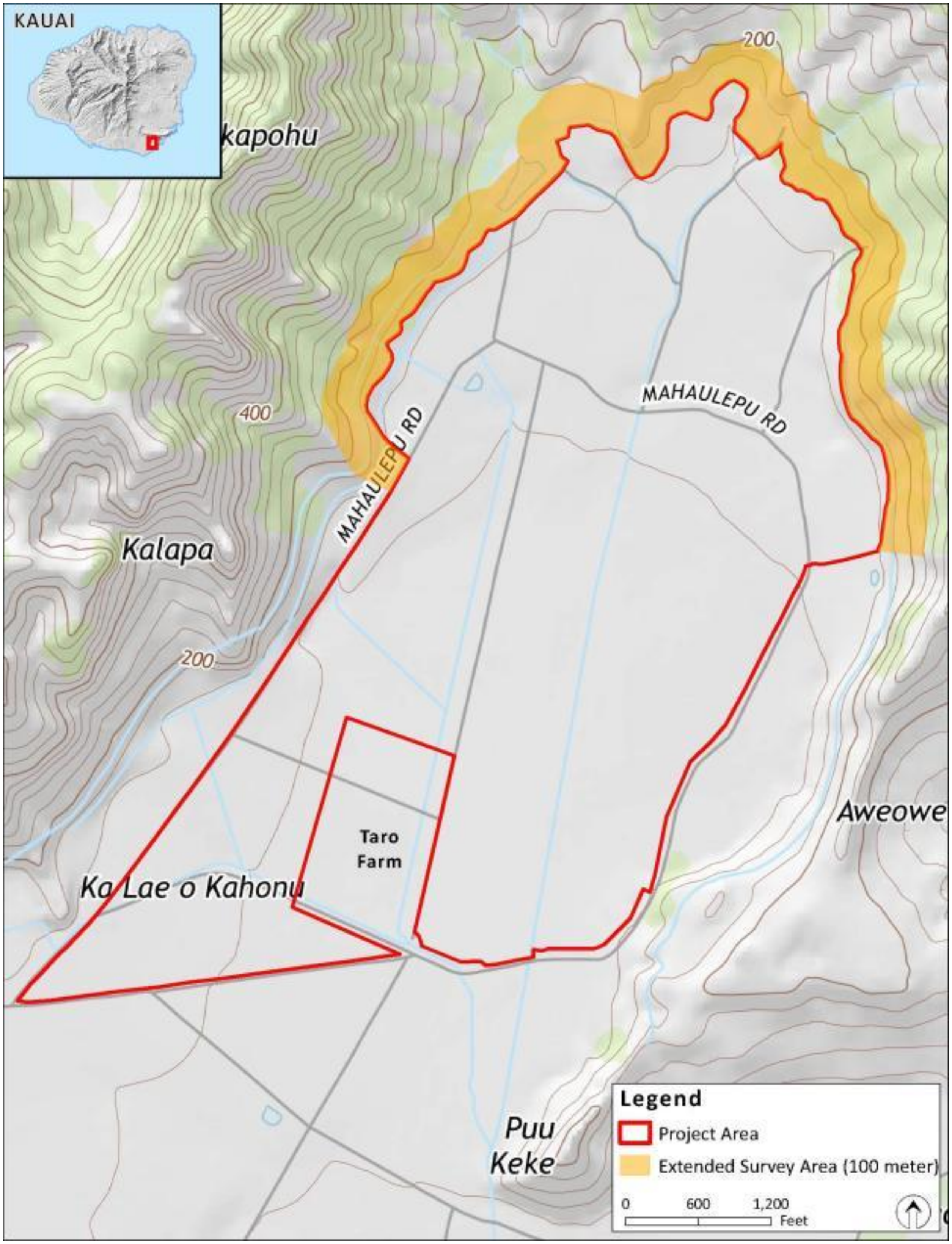

Figure 1. USGS Koloa Quadrangle of the total surveyed area, comprised of the project area and the extended survey area (USGS 7.5 Minute series 2013).

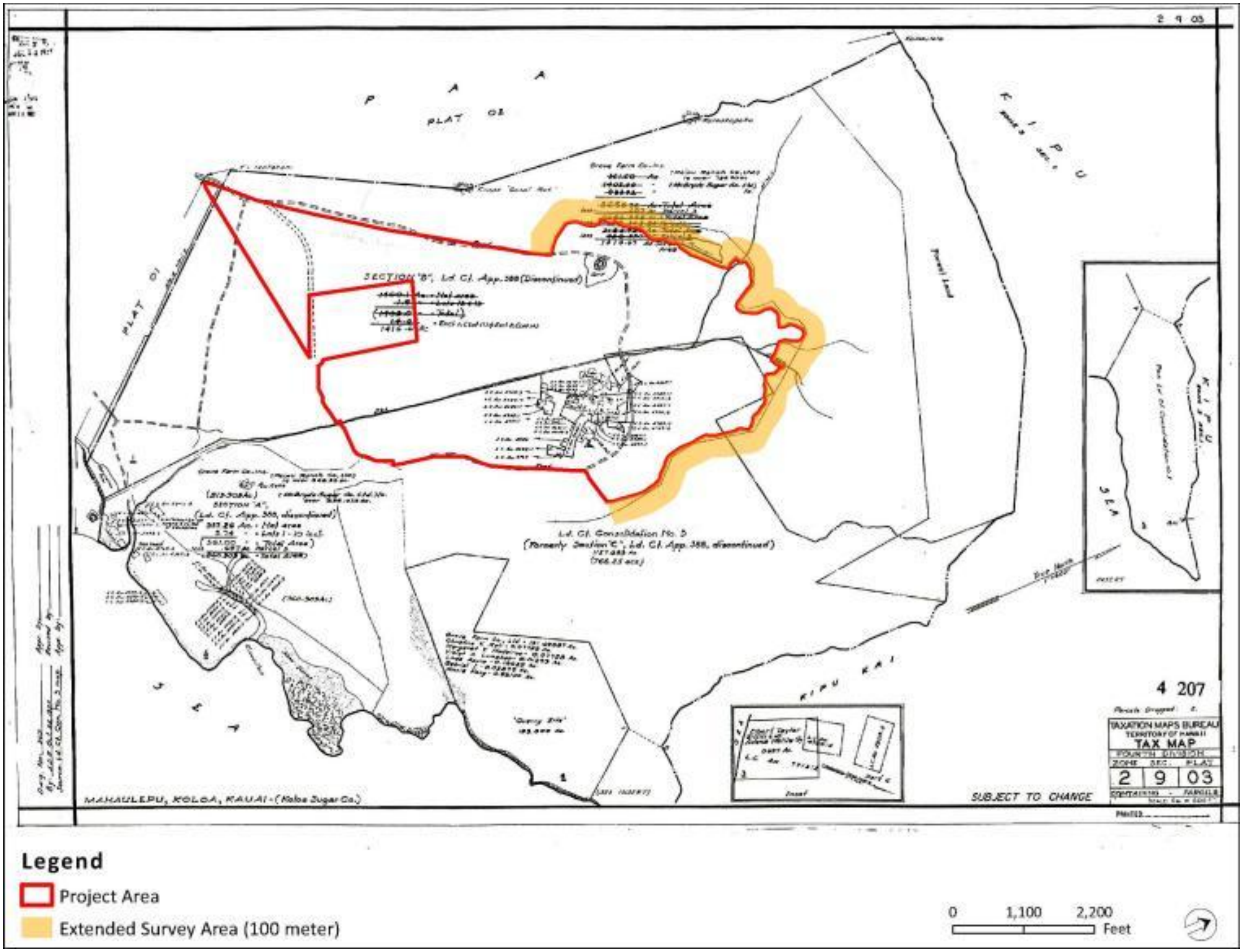

Figure 2. Tax Map Key of the surveyed area, comprised of the project area and the extended survey area.

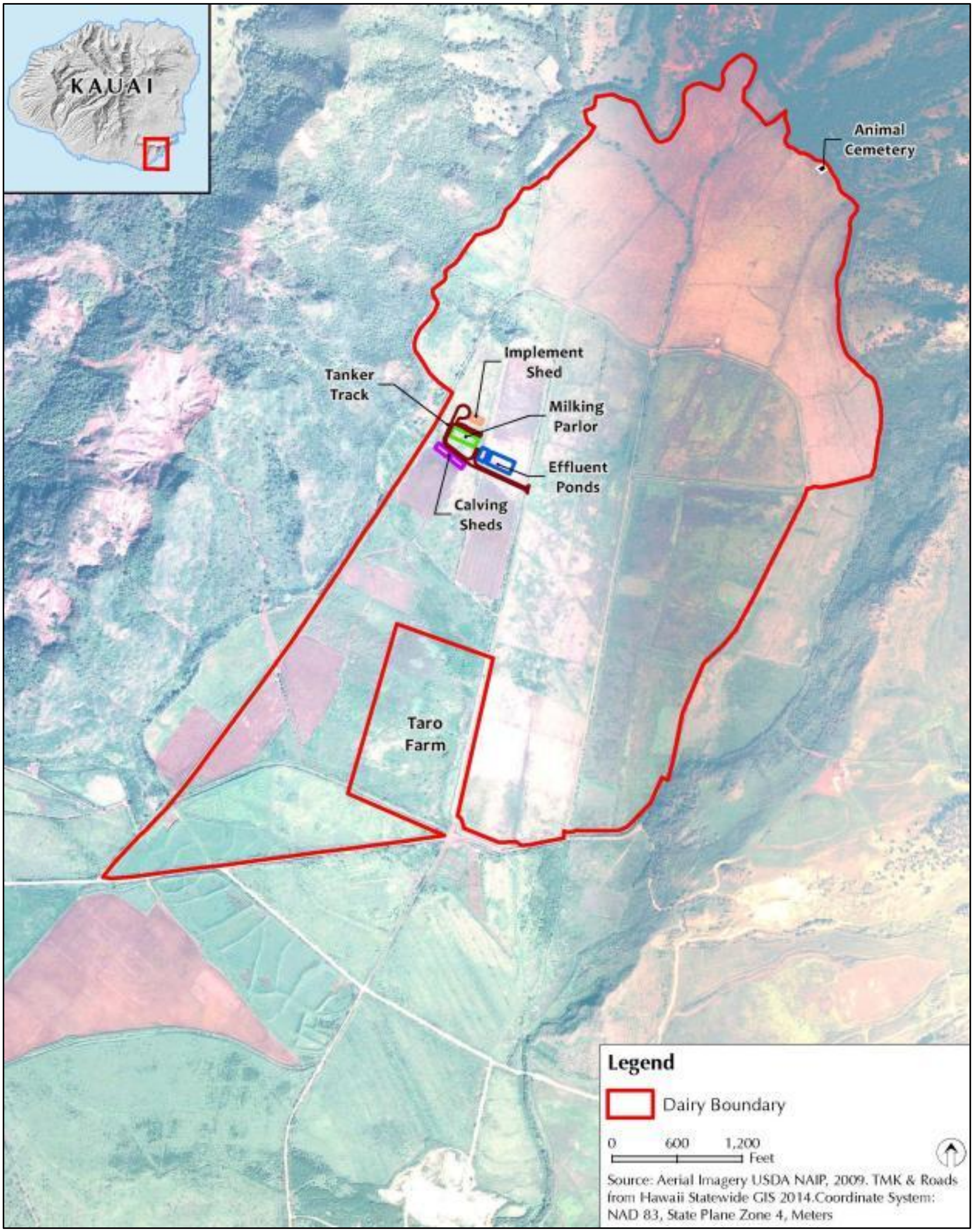

Figure 3. Proposed dairy facilities within the project area.

Overview of Surveyed Area Location and Environment

The surveyed area is situated entirely within Māhā'ulepū Valley, on the southeastern side of the island of Kaua'i. The surveyed area does not extend up any of the adjacent slopes or ridgelines on the east or west, and does not extend south beyond Māhā'ulepū Road. The 100 m extended survey area covers additional land along the northern portion of the valley floor, and also reaches slightly up the northern flank of the valley. Informal survey by the SCS crew extended to the top of the eastern and northeastern ridgelines in attempts to locate any trails (see below). Māhā'ulepū Valley is separated by a ridge from Aweoweonui Valley, within Kipu Kai Ahupua'a, to the east. The ridge is of interest because the northern end is composed of basalt, the middle is limestone, and the southern end is composed of the Haula Sand Dunes, near the coastline. The ahupua'a boundary with Kipu Kai crosses this ridge, and the beach front boundary of Māhā'ulepū Ahupua'a extends from Kawelikoa Point in the north to Makahuena Point in the south. Kalapa ridge separates Māhā'ulepū Valley from Paa Valley, an ahupua'a on the west (Figure 4). The north end of Māhā'ulepū Valley is formed by Ha'upu Ridge and is dominated by Mount Ha'upu (Figure 5 and Figure 6). There are named peaks on all three ridges. South of the surveyed area lies Kapunakea Pond, a relict water feature. Māhā'ulepū is literally translated as "and falling together" (Pukui *et al.* 1974:138), a likely allusion to the ridges bordering the expansive valley.

The surveyed area occurs at an elevation of c. 80 feet amsl to 200 feet amsl and is partially bounded by Māhā'ulepū Road. The road enters the valley along the base of a slope on the western side, extends north, and then runs to the east several hundred meters from the north end of the valley. Traversing the valley, the road then turns south along the eastern ridge slope base, continues the length of the ridge, then turns west, eventually rejoining the entrance. The eastern and western sections of the road form part of the survey area boundaries.

Two parallel dirt roads extend north to south along the center of the valley floor. Both roads have an irrigation ditch parallel to their lengths. Māhā'ulepū Ditch is present on the eastern flank and consists of a modified stream course, the source of which is a series of braided streams at the north end of the valley. These streams enter the valley on the eastern and western sides of the ditch and are referred to as "east stream" and "west stream" in documentation and field notes. The western ditch was constructed in the 20th century and its origin is the Māhā'ulepū Reservoir, at the northwest end of the valley. The reservoir is filled by a series of wells in the immediate vicinity. The ditch appears to have originally been a natural stream course that was modified during the Plantation era. This course is referred to here as the Main Ditch. The primary road up the valley is alongside the Main Ditch. This ditch currently feeds the active taro farm at the southern end of the valley. The taro farm borders the southern edge of the project area, but is not within the surveyed area. Smaller ditches run both parallel and perpendicular to the two larger ditches. The Main Ditch and Māhā'ulepū Ditch join south of the project area to form what is referred to as Waiopili Stream. Waiopili Stream eventually joins a natural spring and the remnants of Kapunakea Pond, then runs by Waiopili Heiau, one of the most significant cultural sites on Kaua'i, and on to the ocean. Land Commission Awards (LCAs) along Māhā'ulepū Ditch in the center of the valley are noted as being in Kawailoa Ili, but it is unclear if this stream also went by the same name (see below).

The climate of the surveyed area is not extreme, with rainfall accumulating at an average rate of 53 inches *per annum*, with average temperatures ranging from 72-86 degrees in the summer and 64-80 degrees in the winter (NPS 2008:7).

LANDFORM, SOILS, AND VEGETATION

The mountain range that flanks the surveyed area to the north and northeast are composed of the most ancient volcanic series in the high islands, the Waimea Canyon Basalts (NPS 2008:11). These formed during the shield-building stage of the Kaua'i volcano, as eruptions gradually built up its sides and widened its base. Most of the range is part of the ancient Napali member of the Waimea series, dating from 4.35 to 5.1 million years ago. The caldera of Mount Ha'upu is a separate geological feature from the rest of the range and remains undated (Blay and Siemens 2004).

Māhā'ulepū lands below Ha'upu ridge are part of the Kōloa series that cloaks most of the eastern half of Kaua'i. The series formed as the Kaua'i volcano ceased major eruption and began to erode, with occasional small eruptions at lava domes, cinder cones, and spatter cones. These produced a layer of lava that, though not large in mass, nevertheless covered a large area. Kōloa volcanics within the study area at Māhā'ulepū include both underlying lava and visible vents, ranging from 0.5 to 2.0 million years in age (Blay and Siemens 2004).

Portions of the valley's slopes have been identified as Rockland (rRK; Foote *et al*. 1972: Sheet 32). This is composed of areas where exposed rock covers 25 to 90 percent of the surface. Rock outcrops and very shallow soils are the main characteristics. The rock outcrops are mainly basalt and andesite. This land type topography is characterized as nearly level to very steep. Elevations range from near sea level to more than 6,000 feet, with annual rainfall amounts between 15 to 60 inches. The vegetation at lower elevations consists mainly of *kiawe*, *klu*, *piligrass*, Japanese tea and *koa haole*.

Soils on the slopes of the valley are also associated with the KEHF series or Kalapa very rocky silty clay (Foote *et al*. 1972: Sheet 32). This is a well-drained soil that occurs at the base of slopes and is associated with moderately sloping to very steep topography. Elevations range from 200 to 1,200 feet amsl, with annual rainfall amounts between 60 to 100 inches. Associated vegetation consists of guava, *lantana*, sensitive plant, *pilipiliula*, *ohia*, Japanese tea, and ferns.

Soils within the valley have been classified as LPE or Lualualei Series, composed of extremely stoney clay (Foote *et al*. 1972: Sheet 32). This series consists of well-drained soils on the coastal plains, alluvial fans, and on talus slopes. They are nearly level and gently sloping. Elevations range from 10 to 125 feet amsl, with annual rainfall amounts to 50 inches per year. There is a prolonged dry spell during the summer. These soils are associated with sugarcane, truck crops, pasture, wildlife habitat, urban development, and military installations on Kaua'i. Associated vegetation consists of *kiawe*, *koa haole*, bristly foxtail, *uhaloa*, and fingergrass. This soil type, extremely stony clay, was identified in several trenches during the AIS, with most stratigraphic trenches excavated on the valley floor being composed of a shallow O-horizon overlaying brown/yellow clays. In other words, there are exceptions to the general soil survey.

Twelve different soils within Māhā'ulepū Valley are identified on a USGS/USDA Soil Map kindly provided to the field crew by HDF (NRCS 2006; Figure 7). The soils map depicts the various soil regimes across the valley floor; these soil differences are most likely a product of water, whether through transport, ground water, or run-off deposition. During pedestrian survey of areas with sparse or no ground vegetation, the transition of soils was visibly recognizable.

The project area has been utilized for commercial sugar cane cultivation and/or livestock pasturage since the middle of the 19th century and is fairly clear of vegetation. Most of the project area lies fallow with the soils exposed. Some of the areas are covered with grasses up to 0.3 m tall, and smaller areas at the northeast and northwest ends of the valley are 100% covered by grasses up to 2.0 m tall. Within the surveyed area are few scattered *koa haole* and java plum trees. These occur outside the main valley footprint/project area, which has been extensively cleared for well over a hundred years. The slopes of the valley outside the project area are forested.

Figure 4. Project area overview. View to the southwest towards Kalapa ridge.

Figure 5. Project area overview. View to northwest. Note Mount Ha'upu at right.

Figure 6. Project area overview. View to north from center of Māhā'ulepū Valley.

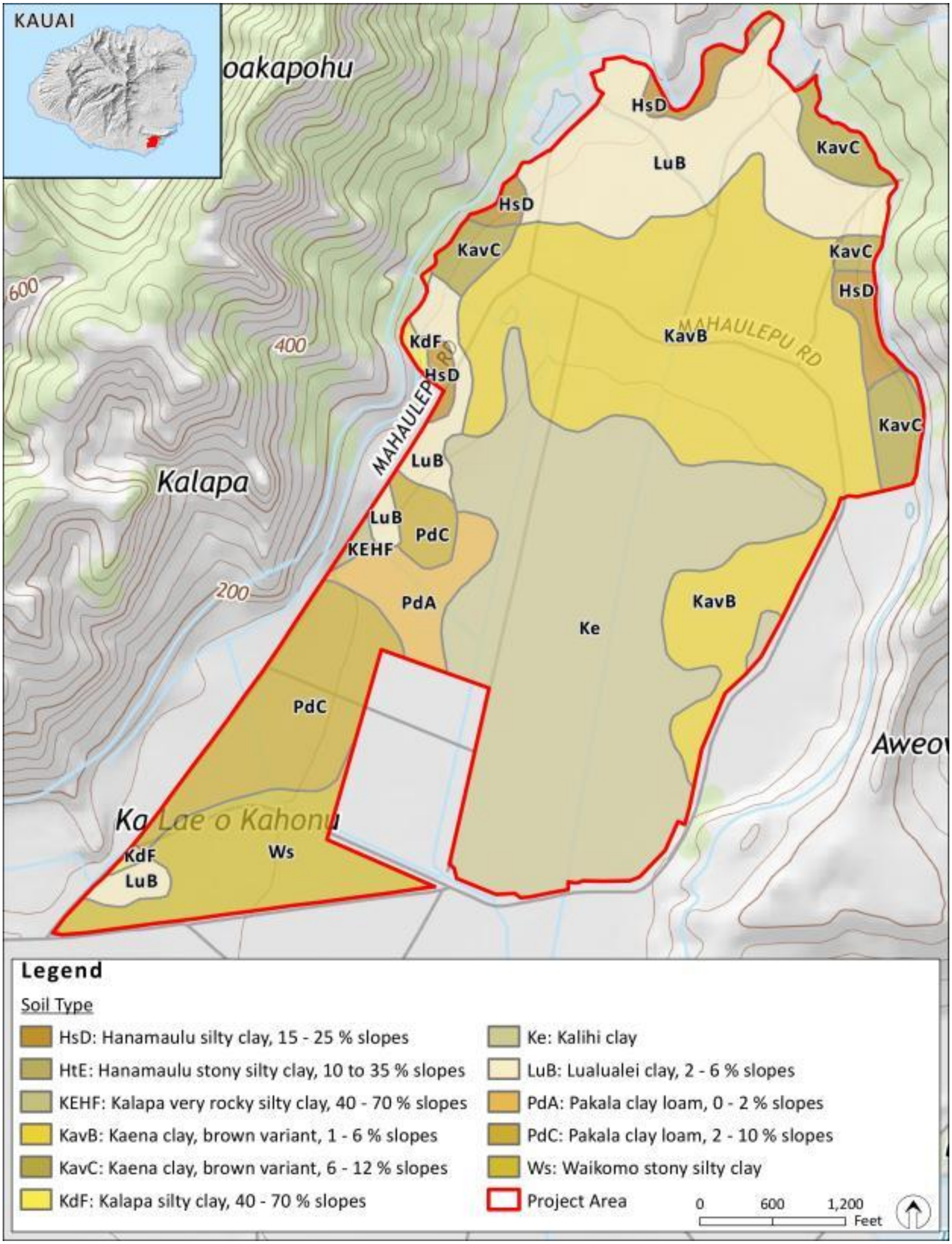

Figure 7. Soils of Māhā'ulepū Valley (USDA; Soils NRCS 2006).

TRADITIONAL AND HISTORIC SETTING

Early settlement and agricultural development is thought to have first occurred on the windward sides of the Hawaiian Islands, including Kaua'i, sometime in the A.D. 900-1000 range during what is known as the Colonization Period (Kirch 2011:22). Most likely arriving from east Polynesia, these early inhabitants brought with them a variety of tools, fishing gear, and household goods. Dogs, pigs and chickens were brought by these Polynesian voyagers for food. The Polynesian rat also arrived with the voyagers, but whether these were intentionally transported as a food source is unclear. Considering that every food crop cultivated by the Polynesians arrived with them, it is evident that these people had considerable knowledge not only regarding how to plant and harvest these crops, but also how to transport crop seeds, cuttings, and roots.

Prior to European Contact in 1778, Hawaiians cultivated taro in both irrigated and dry fields. Other dryland agriculture crops included '*uala* (sweet potato), *uhi* (yams), *maia* (bananas), *ipu* (gourds), and *ko* (sugar cane). Grasses were utilized for thatching the roofs of structures and covering floors, which were then covered by *hala* (pandanus) mats. *Hala* was also used in the making of matting and sails. Important arboreal crops included *niu* (coconut) and *ulu* (breadfruit). Other trees were utilized for the construction of canoes, house frames, tools, and weapons. *Kapa* cloth from *wauke* (paper mulberry) was also tended. There were a variety of medicinal plants utilized and plants, such as *olona*, grown to provide fibers for making cordage (Handy and Handy 1972).

Hawaiian aquaculture was extensive, and included the construction and maintenance of coastal and riverine fish ponds. Fishing ranged from shoreline to pelagic, with different strategies for each. In order to maintain and benefit from all of these resource zones, Hawaiian polities were organized into *ahupua*'*a,* which gave residents access to a wide array of resources extending from mountain top forests to deep sea fishing zones. An *ahupua'a* was an ancient land division that ran from the ocean to the mountains and allowed those living there to proffer from all the different environmental zones of the land. *Ahupua*'*a* boundaries could expand, contract, appear, and disappear, depending upon political events. Given the size of Māhā'ulepū Valley, Māhā'ulepū Ahupua'a was highly valued.

PRE-CONTACT ERA

Initial Polynesian settlement of Kaua'i occurred in the resource-rich regions surrounding Wailua River on the east coast; the equally verdant Waimea River region on the southern coast; and the Hanalei region on the north coast (Joesting 1984). As with all the Hawaiian Islands, each district and region was eventually settled. These settlements developed into polities which allied, warred, and co-existed with one another until Kaua'i came under unified rule of a single king. This process occurred in different stages on different islands. Because of the relative distance of Kaua'i from O'ahu, Moloka'i, Maui, Lana'i, and Hawai'i Island, the polities of Kaua'i and her neighbor Ni'ihau became their own entity, while the other islands struggled first for internal control and later, for the conquest and rule of several, and ultimately all, the islands.

The primary residence of the high king was in the Wailua River region of Kaua'i, with miles of cultivated lands, mountain resources, religious sites, and shoreline to pelagic fishing. Broad stretches of beach allowed for canoe landings but there was no deep water anchorage, despite the presence of the Wailua River.

Initial settlement is presumed near the coastline in the A.D. 1000-1200 range, with expansion inland during the A.D. 1400-1600s, as was typical across the islands (see Kirch 1985). Agricultural field systems were created at these inland areas, closer to fresh water resources and soil more amenable to *kalo* and sweet potato production. Permanent habitation locales were present from the coast to this more inland area, with ceremonial sites, walls, and other associated structures being built. Within the mountainous areas, such as at the back of Māhā'ulepū Valley, temporary habitation loci such as rock shelters/caves or small enclosures (C-shapes) were utilized by those gathering upland resources. The middle zone, between the coastlines and mountains, such as Māhā'ulepū, was ideal for agriculture and homesteads, as witnessed by the numerous LCA's occurring in a small section of the valley later. However, historic land use obliterated much of the archaeological signatures for these settlements.

In early 1778 Captain James Cook and the two ships under his command, H.M.S. *Resolution* and H.M.S. *Discovery* arrived off of Kaua'i. Finding that they could not make land fall at Wailua, Cook continued westward until reaching Waimea. This would be the beginning of contact between Europeans and Hawaiians (Salmond 2003).

EUROPEAN CONTACT AND THE KAMEHAMEHA DYNASTY

The third voyage commanded by Captain Cook was undertaken primarily to discover the fabled Northwest Passage, which supposedly linked the Pacific, Arctic, and Atlantic Oceans. As he had during previous journeys, Cook visited Tahiti and it was from there that he set out for the northern Pacific coast of North America.

The voyage put him within sight of the island of O'ahu, but adverse winds prevented his arrival. Continuing on to Kaua'i, he sighted Wailua, but could not make landfall. The ships continued southwest and then westward, past Mount Ha'upu and Māhā'ulepū Valley. Both were sketched and drawn by expedition artist John Webber, the first European artwork to depict a Hawaiian Island.

Cook found a manageable anchorage at the mouth of Waimea River. Several trips ashore by him and a select group of his officers, marines, and crew led to generally good relations with the Hawaiians. It is unclear what Cook and the others learned about the politics of Kaua'i and her eastern neighbor. It is probable that at this time (1778) Kaeokulani was ruler of Kaua'i. He was of high rank, a chief born on Maui, and the half-brother of the paramount king of Maui, Kahekili.

After a short time on Kaua'i in the early months of 1778, Cook departed to continue the search for the Northwest Passage. A year passed after which Cook returned to the Hawaiian Islands. This time, Maui was sited and briefly visited, but the island of Hawai'i became the focus of the remainder of the voyage of Cook and ultimately of his demise, at Kealakekua Bay (Salmond 2003).

After the death of Cook, the journey continued, now under the command of Captain Clerke. The ship passed O'ahu, and returned to Waimea, Kaua'i. After their departure a short time later, it would not be until 1786 that Europeans returned to the Hawaiian Islands, with Waimea (Kaua'i) receiving her share of British and American vessels focusing on the lucrative fur trade in the Pacific Northwest. These visits coincided with, and perhaps accelerated, the growing conflict for control of the eastern islands.

Beginning in approximately 1790, battles on and around Maui, Moloka'i, and Hawai'i Island between several rulers occurred with increasing ferocity. Safely in control of Kaua'i, Kaeokulani became a participant, bringing fleets of warriors to assist his half-brother on Maui. Many European and American ship captains had contact with all the rivals, and a fairly coherent chronology of events is known. What certainly is known is that Kaeokulani was killed during a battle in Honolulu in 1794 while fighting his nephew Kalanikupule, who had taken rule of Maui and O'ahu upon the death of his father Kahekili in Waikiki, several years earlier in 1791 (Ridley 2010).

The son of Kaeokulani was Kaumuali'i. Born around 1780, the young king went through a period where a Regent (an older relative) made the decisions, but Kaumuali'i eventually came to rule on his own. The remainder of his days was spent trying to keep Kamehameha, who had consolidated the rule of the other islands, from bringing Kaua'i in as well.

Kamehameha had difficulty solidifying his rule. Rebellions, plague, and appeasing subordinates all kept him from mounting more than two serious efforts at physical conquest of Kaua'i. The first effort to fail occurred in 1796 when Kamehameha sailed with an invasion fleet for Kaua'i. Hit by a heavy storm, the fleet turned back to O'ahu (Kamakau 1961). The second effort failed in 1804 when Kamehameha mustered his forces on O'ahu, but the army fell victim to *oku'u*, a smallpox epidemic. Kamehameha himself almost died, and far too many of his troops, counselors, and their families did succumb (Kamakau 1961). In 1810 Kamehameha used diplomacy, suggesting that he rule the eastern islands in name and deed, while Kaumuali'i acknowledge his suzerainty but continue to rule Kaua'i and Ni'ihau. It was agreed that the arrangement would end with the death of Kaumuali'i and that rule would then pass to the heirs of Kamehameha. It was an arrangement that Kamehameha and Kaumuali'i would honor, but that the heirs of Kamehameha would not (Joesting 1984).

This arrangement lasted between 1810 and 1822. It endured the death of Kamehameha the Great in 1819. During these 12 years, Kaumuali'i solidified rule of his kingdom and engaged in efforts to gain foreign weapons and support from the Russian Fur Company (Mills 2002). Also during this time, the trade in sandalwood flourished. Harvested in the Hawaiian Islands, traded for goods to European and American captains, and sold in the Chinese trade ports of Macao and Canton, sandalwood became the first Hawaiian cash crop (Ridley 2010). The Hawaiians called it *laau ala* (sweet wood) or *iliahi* (fiery surface) for its reddish blooms. They used this wood for scenting bark cloth, making dyes, and for medicinal purposes (Ridley 2010).

At first, the sandalwood revenue went solely to the paramount chiefs, Kamehameha and Kaumuali'i. However, with the death of Kamehameha, nearly all of his chiefs called upon the young heir, Liholiho, and the Regents, among whom was Ka'ahumanu, the favorite wife of Kamehameha but not mother of his heirs, to allow the chiefs to harvest sandalwood for their own profit. This practice would affect and disrupt the rule of Hawai'i and the welfare of the common people for decades.

The upland forests were scoured, crops were neglected, commoners suffered malnutrition and disease, chiefs went into debt to foreigners, and Liholiho was hard pressed to find new resources for his chiefs to exploit. Kaua'i appeared to be the answer. While continuing to honor the arrangement made by his father, Liholiho arrived on Kaua'i in 1822, visited with Kaumuali'i, and then kidnapped him, returning to O'ahu with his captive. In order to secure the rule of Kaua'i, Kaumuali'i was forced to marry not an heir of Kamehameha, but his wife, Ka'ahumanu. To ensure her hold, she also wed her new husband's son, Keali'iahonui. This second marriage was later dissolved. However, ties between dynasties stayed strong as Keali'ihonui married a granddaughter of Kamehameha, named Kekauōnohi (Mills 2002).

Ka'ahumanu had been instrumental in the overthrow of the *kapu* system of Hawaiian governance and social behavior, as well as one of the earliest and most prominent proponents of conversion to Christianity. That she utilized polyandry to achieve control of Kaua'i is just one example of her abilities to utilize both traditional and introduced ways of life to achieve her goals (Joesting 1984).

While still titular ruler, Kaumuali'i did not exercise any power. Governors were appointed by the Regents, the first of these being the brother of Ka'ahumanu, named Kahekili Ke'eaumoku. Beginning with this Governor, land acquisitions beneficial not just to the Kamehameha line but to their powerful subordinates started.

The practice of allowing individual chiefs to harvest sandalwood was carried over to Kaua'i. How many Kaua'i chiefs retained their lands during this time is not certain. What is certain is that the mountains of Kaua'i, including Ha'upu, yielded the valuable resource. And practically the only place that it could be shipped from was the secure anchorage at Waimea River. Waimea also served as a provisioning port of call to the growing number of whaling ships that began to appear in the Pacific.

The independent rule of Kaua'i came to an end in 1824 with the death of Kaumuali'i. This same year, the heir of Kamehameha, Liholiho Kamehameha II also died. The kingdom of Hawai'i would now be ruled by a queen.

THE REGENCY OF KA'AHUMANU

Ka'ahumanu was one of Kamehameha's primary wives, his favorite in fact, but not of sufficient rank to be mother of his heirs. It appears she never bore the king, or anyone else, any children. From her actions following his death in 1819, it is apparent that Ka'ahumanu considered herself Kamehameha's heir. The mother of the heirs, Keopuolani, died in 1823. Her first son was Liholiho, born in 1796, made king in 1819, and died visiting London in 1824. Her second son was Kauikeaouli (Kamehameha III), born in 1813. Her daughter, Nahienaena was born in 1815 (Day 1984). With the death of Liholiho and his mother, Ka'ahumanu became Regent of the kingdom until Kauikeaouli (Kamehameha III) would come of age. Her rule of Hawai'i in general, and Kaua'i specifically, was adroit, intelligent, and shrewd.

George Kaumuali'i and a number of Kaua'i chiefs forcefully resisted the rule of the Kamehameha line, and their revolt was crushed. As with many Byzantine events in Hawaiian history, some Kaua'i chiefs stood with the old, while others stood with the new. In this case, as with any other, people chose who they thought would benefit them most. Those who rebelled had their lands and lives taken, while those who did not, benefitted.

The first long term governor during the regency was Kaikioewa, a high chief born at Waimea, Kaua'i. He was a first cousin and brother-in-law of Kamehameha, a guardian of Kauikeaouli, and a principal leader in crushing the 1824 rebellion (Mills 2002). He reigned as governor from 1825 until his death in 1839. During his tenure, we know of at least one *konohiki*, or land manager, for Māhā'ulepū. Documents show that in 1826, Hukiku was *konohiki*. He was in attendance that year during a visit by the governor. Kaikioewa was accompanied by missionary Samuel Whitney of Waimea, who left an account of this event. It is unknown if Hukiku was Kaua'i born, or one of the conquerors invested with this stewardship. He may be the chief Kukiku, who Kaikioewa named commander of Paulaula o Hipo, also known as "The Russian Fort" (Mills 2002).

One of the duties Hukiko performed may have been overseeing the efforts to harvest sandalwood from the ridge and transport it to foreign ships at Waimea or Kōloa. Eventually, as did so many other *ali'i*, the governor would go into debt to foreign captains and merchants. When the sandalwood ran out, it is not clear how Kaikioewa paid his bills (Joesting 1984).

Ka'ahumanu ruled as Regent until her death in 1831. A daughter of Kamehameha, Kīnau, took over as Regent until 1834, at which time Kauikeaouli Kamehameha III took the throne. He had lived on Kaua'i as a boy under the protection of Kaikioewa but had spent the majority of his youth on O'ahu. Ruling until his own early death in 1854, his reign was admirable for its civil rights, efficiency, and the initiation of the Great Māhele. In Māhā'ulepū, there were many Land Commission Awards (LCA), discussed below, but the majority of the acreage was retained by the royalty. During his reign, there was an increase in the number of immigrants from Europe, the United States, and China. Missionaries, merchants, laborers, and farmers of multiple nationalities added to the diversity and complexity of the Kingdom.

LAND COMMISSION AWARDS

In 1840, the "Constitution and Laws Regulating Property" was established for the legal protection of the property and land held by the people. In 1848, the Great Māhele divided the land between the crown, chiefs, and government, excepting the rights (*kuleana*) of native tenants (*hoa'aina*) who lived and worked small parcels. These tenants could claim title to their traditional properties by initiating a land commission award (LCA). If occupation could be established through the testimony of two witnesses, the petitioners were awarded the claimed LCA and issued a Royal Patent, after which they could take possession of the property (Chinen 1961:16).

In effect, the Māhele transformed Hawaiian society from a "Marxian feudal/Asiatic" into an early-capitalism mode of production (Hindess and Hirst 1975). Though viewed by contemporary elites as a "peaceful and beneficent revolution" (Hawaiian Annual 1891:105), the Māhele was more of a political compromise that translated traditional social hierarchies into economic reality. Out of the 1.5 million acres of land allotted to the crown and chiefs, and the one million acres allotted to the government, the *hoa'aina* received just 30,000 acres through 13,514 *kuleana* grants (Kuykendall 1947:293).

However, Kuykendall (1947:294) states that "it must be remembered that nearly all the kuleanas were lands very valuable for native agriculture… while extensive areas of crown, government, and chiefs' lands were useless mountain wastes or lava strewn deserts." These more useless tracts, not well adapted to native agriculture and beyond the financial capability of the chiefs or commoners to develop, were highly desirable by foreign investment for ranching and sugar cultivation (Barerre 1975:29).

Boundaries were defined in a variety of ways. Land divisions descend in size from *ahupua'a* to *kuleana* to *'ili*, thence *apana,* and finally *mala,* which are individual garden plots, fields, and/or *lo'i* (Pukui 1983). Other boundaries were defined by names of neighboring occupants or by use of the land. Testimonies were given regarding which chief had granted the occupant use of the land. This is compelling, because occupants claimed title based on grants from Kaumuali'i, last independent king of Kaua'i, to Kaikioewa, governor from 1824 to 1839 for the Kamehameha Dynasty, to his *konohiki* for Māhā'ulepū, Hukiki. They invoked the names of Ka'ahumanu, the Regent for nearly a decade, to Kīnau, Regent and half-sister to King Kauikeaouli Kamehameha III until he took the throne. Some claims were contested, others were not, and some were won on appeal. When one studies the LCAs of Māhā'ulepū, it can be seen that claims of land, in a variety of places, for a variety of uses, were made by individuals throughout the *ahupua'a*.

The entirety of the Māhā'ulepū *ahupua'a* was awarded to a member of the royal family, Victoria Kamāmalu under Land Commission Award #7713 (R.P. 4481) and consisted of approximately 2,657 acres (Registered Survey Map #1898, M.D. Monsarrat, 1896; Figure 8). Kamāmalu was the *Kuhina Nui* (Regent) and crown princess, brothers of both Kamehameha III and IV (State Archives). Although her award included the entire *ahupua'a,* the inclusive *kuleana* of the native tenants were preserved by their own Māhele claims.

For example, LCA 5080 was awarded to Kiko, LCA 4767 to Napaliala, and LCA 4769 to Nahuma, were all claimants who had tenure from Kaumuali'i. It is presumed that their neighbors had similar histories (Ching 1974). That these residents all received their awards is notable because their claims were based on the right of use granted by the former ruler, and not by permission of the Kamehameha Dynasty as represented by the crown princess V. Kamāmalu. A 1896 Registered Survey map by M.D. Monsarrat (#1898) of the valley, depicts a "house" and "cattle pen" in the northern part of the valley and the LCA just below, in what today is the mid-section of the valley (Figure 9). Registered Survey Map #1900 (M.D. Monsarrat, 1897) (Figure 10) shows a detail view of the LCAs.

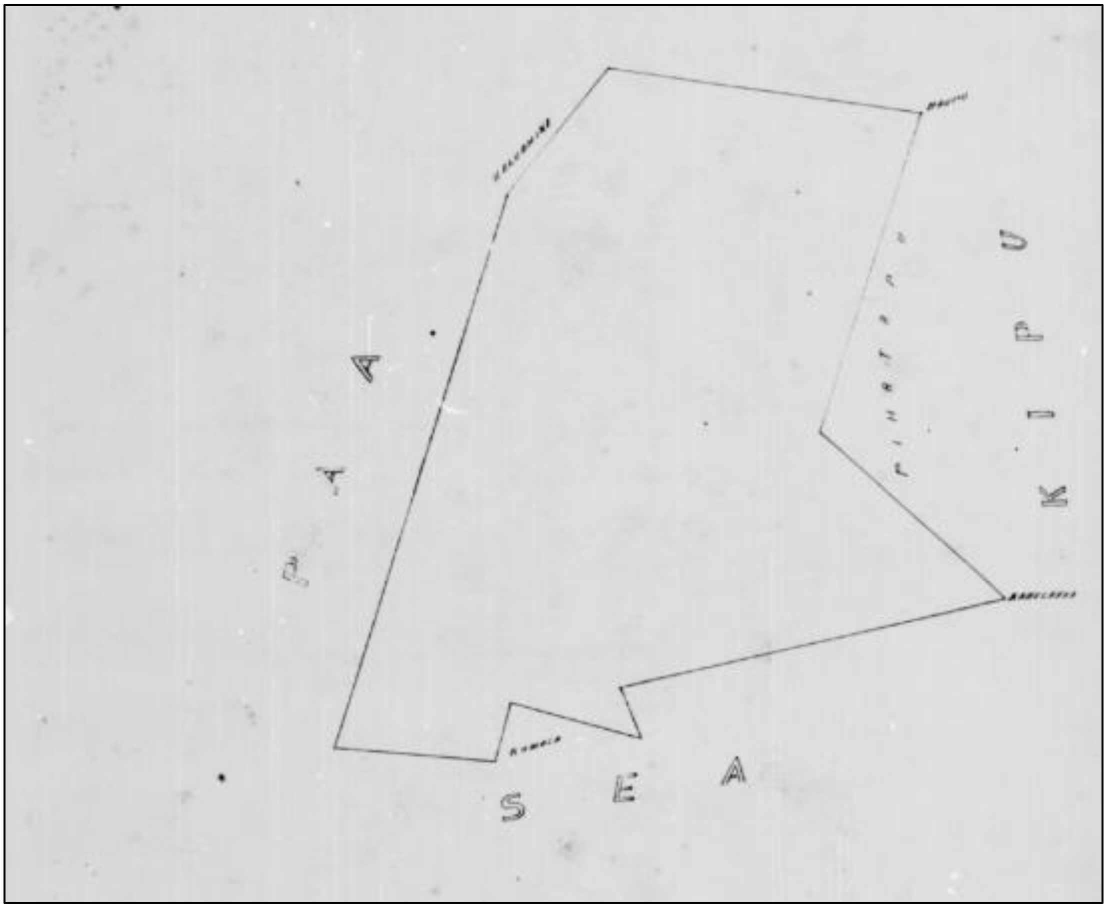

Figure 8. Survey drawing of LCA 7713 awarded to Victoria Kamāmalu (Kipuka Database, http://kipukadatabase.com/Docs/LCA/7713-02.pdf; Accessed 12/12/16).

Many of LCAs for Māhā'ulepū are tightly clustered within the 'ili of Kawailoa (Figure 11). It is interesting to note the estimated population of this portion of Māhā'ulepū Valley at this time. In 1848, 46 male names appear in genealogical records (M. Ching, LDS Records). If one were to reasonably add one wife and at least one child per household, the population would have been 138 persons. In 1855, a total of 36 male names occur in the Māhā'ulepū records. Using the same figures, the total would have been 108 persons. This represents a fairly sizeable population for this upper valley at that time, all likely associated with the LCAs.

The following provides a representative sample of names and LCAs that are both present on the LCA map within the project area and are described in previous literature (Ching 1974). Claimants used owners of adjacent lands as boundary references and/or supporters of their claims. Many claimants were related in some way. The claimants of LCAs within the project area often also had additional claims downstream of Māhā'ulepū Ditch on the coast or elsewhere. Thus, only some of the claims discussed (*kula* [plains, open country] lands, etc.) may actually be in the project area. An example is LCA 5080, where a salt pan is discussed. Such claims related to salt pans would have occurred far outside the current project area near the coastline. In addition, some of the claims also include information about other LCAs claimed by the same person. Ching (1974) summarizes the following four LCAs:

> **LCA 4767** Napaliala received his lands in the days of Kaumuali'i, who died in 1824. This was waste land when Napaliala took it over, occupied it, and developed it. He died in the late 1840s and his wife then possessed the land.
>
> **LCA 4769** Nahuma was another native who occupied lands prior to 1824. One piece was waste land when he took it over, built on it, and fenced it with stone. In addition he received on the death of relatives other lands occupied previous to 1824: two (2) *lo'i* in the 'Ili of Kauki'i, which had belonged to his wife through her parents; 7 dry taro patches in Kioea received through his father-in-law, *kula* land at Waipa which his brother had taken possession of, planted orange trees and cultivated; and two salt ponds. Nahuma appears to have been an affluent native.
>
> **LCA 4910** Kahee claimed property in the *'Ili* of Kapakalehu; this property in the late 1840s had one orange tree. The *konohiki* contested the title of this property, claiming that Governess Kekaonohi had given it, and two more, to him and that he had cared for them, harvesting the fruit. Kahee never collected the oranges but contended that the governess had no right to give the trees to the *konohiki* as they had belonged to Kahee's parents, who had planted them and he was the rightful heir. That was the foundation of his claim.
>
> **LCA 5080** Kiko took over waste land, built his own fences and dug his own salt pond in the 'Ili of Kawailoa (Note: the salt pond would be outside the project area, near the coastline). The date of occupancy is not given but it probably was later than Kaumuali'i, for Kiko's *lo'i* came from Kīna'u's time. Kīna'u was a daughter of Kamehameha, mother of the kings Kamehameha IV and V, and was Regent between the death of Ka'ahumanu and the ascendancy of Kamehameha III, her half-brother.

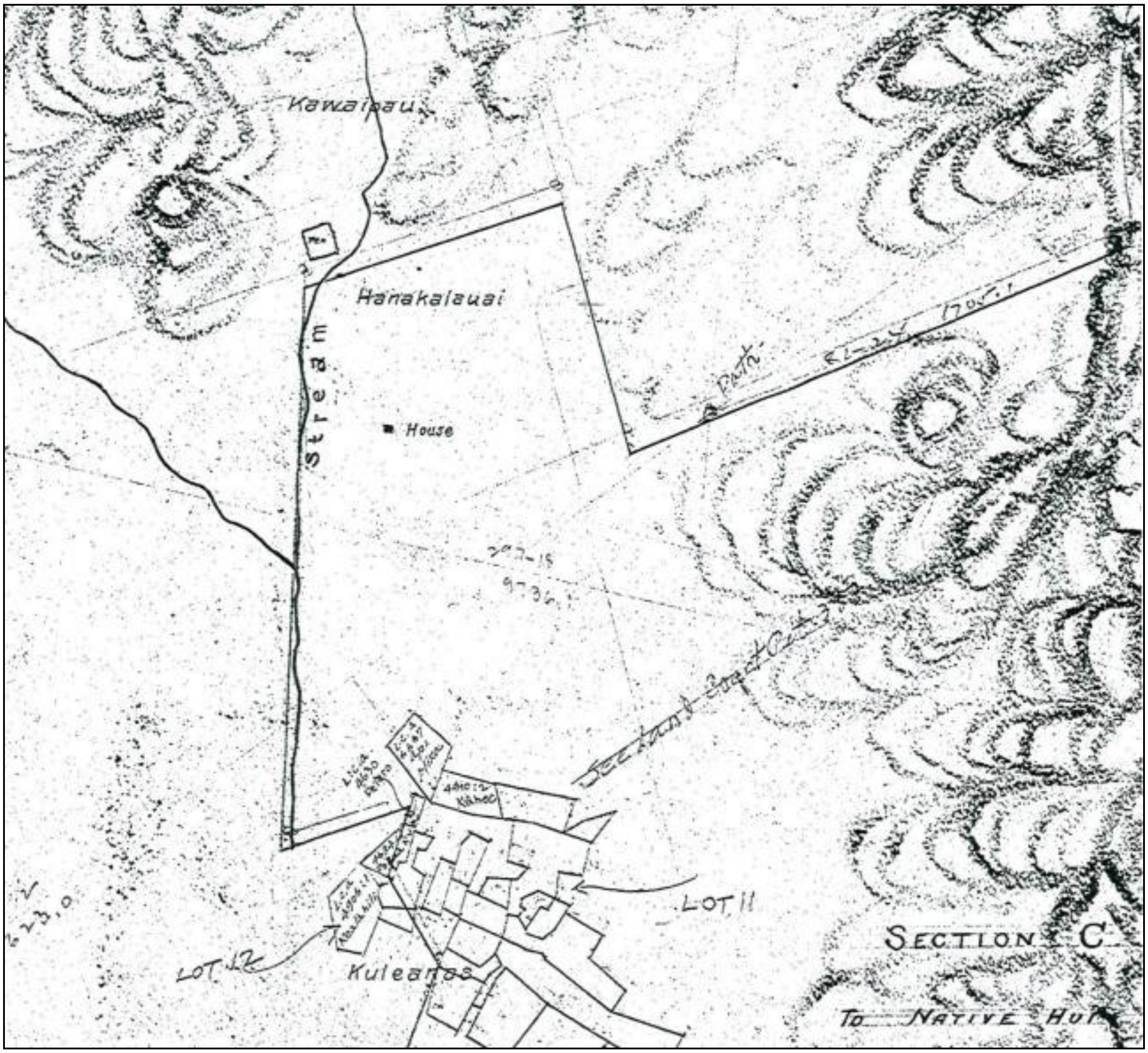

Figure 9. Registered Survey Map #1898 (1896) showing location of "House", "Cattle Pen", and LCAs in mid-valley. Note: "Path" in map center (M.D. Monsarrat #1898; 1896) .

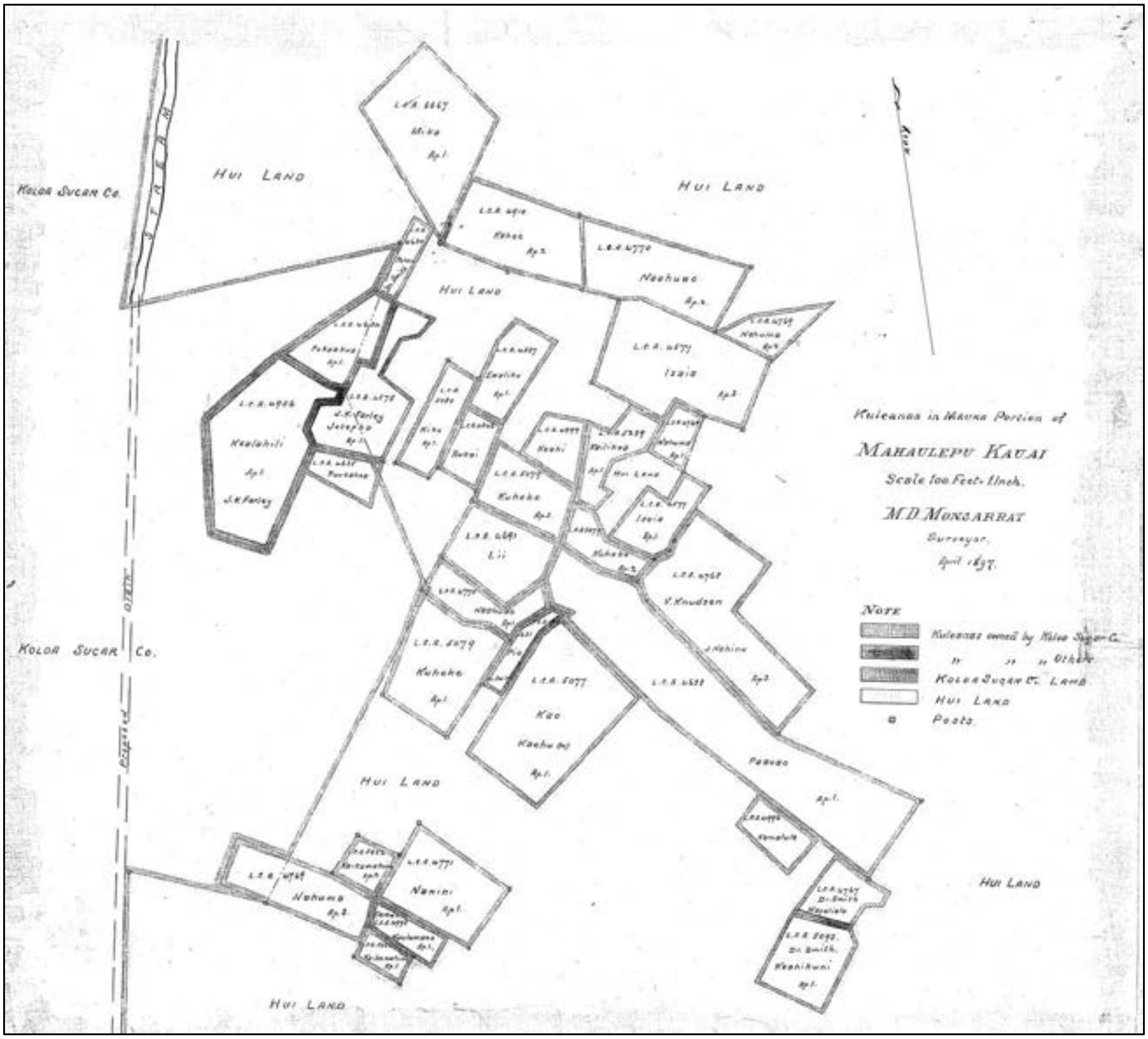

Figure 10. Registered Survey Map #1900 (1897) of LCAs in Māhā'ulepū Valley (M.D. Monsarrat #1900; 1897).

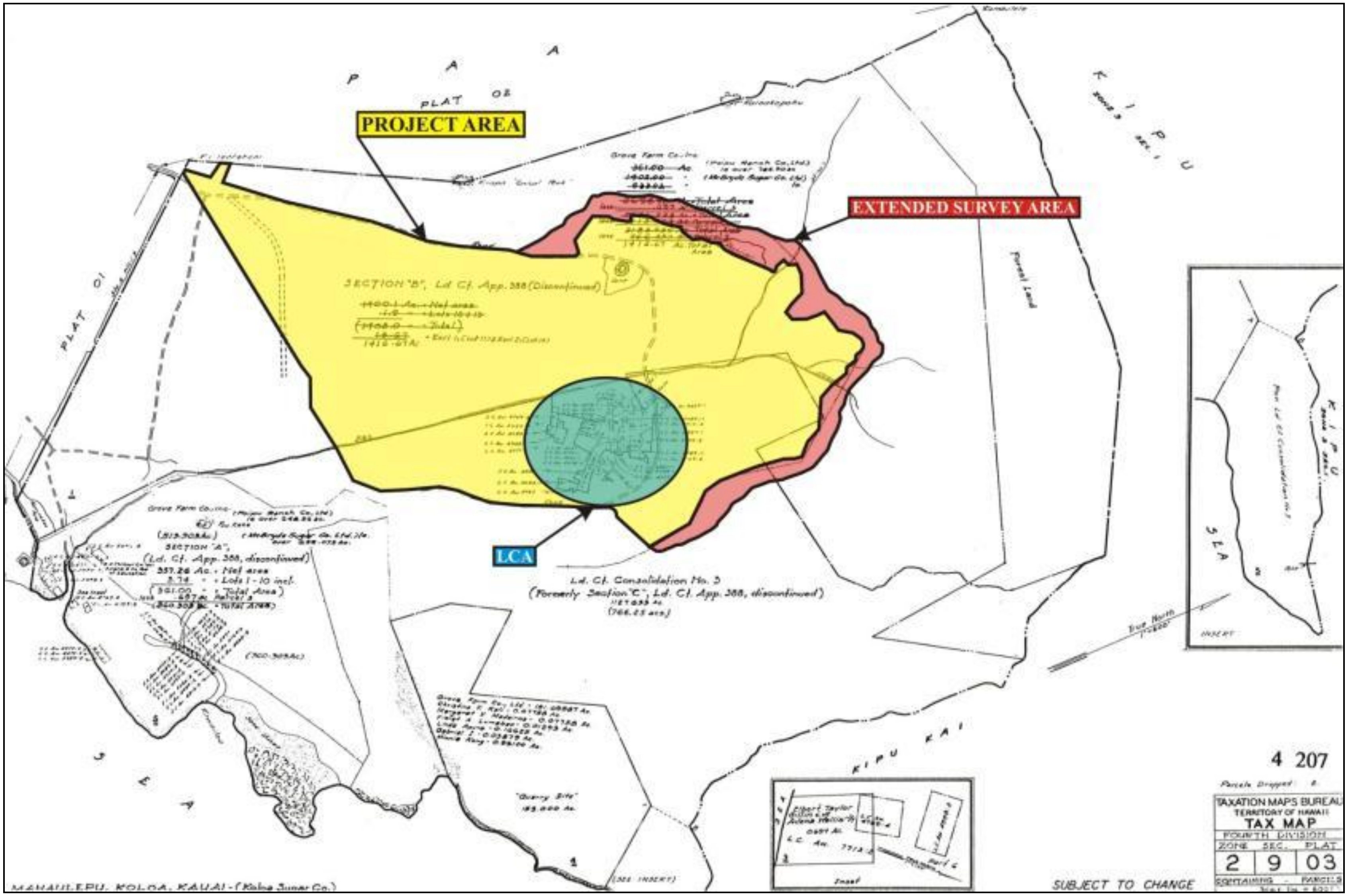

Figure 11. Modern TMK map of Māhā'ulepū Valley depicting LCAs shown in Figure 10. Note the Section "B" from LCA 7713 included in the Land Court Application #388 (see text below and Figure 13).

Ching (1974) argues the recovery of waste land mentioned in LCA records was the clearing of previously untouched lands for cultivation. However, Putzi (2014) argues that these were previously cultivated areas left unattended due to a declining native population, but were brought back into production because of the incentive of individual ownership. It may be that land ownership, as well as the threat of feral cattle and pigs, led to the construction of fences of either stone or wooden posts to delineate property boundaries. Other claimants shown on the LCA map were identified in the Mahele Database (http://ulukau.org/cgi-bin/vicki?l=haw):

> **LCA 4770** Naahuao. The land came to Naahuao through his father, who was granted the land by Hukiku, the *konohiki* of Māhā'ulepū during the reign of Governor Kaikioewa. He gives his testimony as follows:
>
> > Greetings to the Land Commissioners: Be it known to you, the ones who quiet land titles, that I, Naahuao, a man living at Māhā'ulepū, island of Kaua'i have a claim for land, and the kula. The genuine land is 56 fathoms long by 26 fathoms wide. The mala of noni is 26 fathoms long by 13 fathoms wide. The salt land is 6 fathoms long by 4 fathoms wide. Another salt land is 10 fathoms long by 7 fathoms wide. A house lot is 28 fathoms on the long sides and 25 fathoms on the wide side. My message is ended. A respectful farewell to you, Naahuao.
>
> **LCA 6667** Mika received lands from Ahukai (owner of LCA 4543) on the LCA map, but no further information has been gained. Mika received lands from Kaikioewa in the days of Kinau. His testimony reads:
>
> > The Land Commissioners, greetings: I, Mika, a Hawaiian subject living in Māhā'ulepū, hereby state my claim for 4 lo'i, 5 sweet potato enclosures, 4 mala of noni, and 3 orange trees. However, these claims are not situated together, but are in various cultivated places of Māhā'ulepū, also 1 mala of uhi/yam/ a kula planting of wauke and one other lo'i. 1 loko/ either fish pond or taro pond/ and 13 lo'i are bounded 80 fathoms on the east, 80 fathoms on the south, 20 fathoms on the west and 10 fathoms on the north. That is my claim which was received from Ahukai. There is also a kula named Hoopouliloa. Respectfully, Mika

The testimony of Mika says much about how Hawaiians utilized the Māhā'ulepū landscape and environs. Parcels were utilized for the cultivation of several food crops, for raising fish, and for growing *wauke* for the production of *kapa* cloth. Except for the orange trees, this is a classic example of traditional Hawaiian life. The mention of sweet potato enclosures is interesting because '*uala* were traditionally raised in long rows of intermittent mounds. It may be that these fields were fenced in to protect them from pigs or cattle, or that land ownership required definitive boundaries.

It is worthy to note that all the LCAs in the Māhā'ulepū project area are confined to a central area, on the east side of Māhā'ulepū Stream, with the remainder of the valley claimed as government lands. These LCAs form a tight cluster. Of additional interest is that during the height of the sandalwood trade the adjacent Ha'upu Ridge was claimed by Kaikioewa. It would appear that after his death in 1839 these mountain claims would revert to government control.

The Governor of Kaua'i in 1842 was Kekauonohi, the granddaughter of Kamehameha who had wed Keli'iahonui after having been a wife to her uncle Liholiho Kamehameha II. During her governorship, Kekauonohi partook in land exchanges, consolidating her grants in Māhā'ulepū and Kōloa. These consolidated lands would become the basis for the next cash crop – sugar, which, unlike sandalwood, could be rejuvenated and continued. From the 1830s until the 1980s, sugar would be the economic focus of Māhā'ulepū. Remnants of industrial-level sugar cane cultivation in the area represent the greatest number of historic properties documented during the current AIS.

SUGAR AND THE HISTORIC ERA OF KŌLOA AND MĀHĀ'ULEPŪ

The sugar cane history of Māhā'ulepū is intricately tied with the history of Kōloa. Sugar cane began to be grown and milled commercially in Māhā'ulepū Valley and around Kōloa in the 1820s, one of the first places in Hawai'i where sugar was commercially grown (Donohugh 2001). Some of the earliest efforts were undertaken by Chinese immigrants (post 1820s-30s) who had a small mill in Māhā'ulepū, as well as in Kōloa and other parts of the island. The mills were small, producing raw sugar and molasses for local consumption. By 1835, however, many of these farmers were out of business and were later employed by new plantation owners.

In 1835, a sugar cane plantation owned by Ladd and Company was located to the west of the surveyed area. This was the first attempt at producing sugar cane at an industrial scale. The land was leased for a fifty year period from Kaua'i Governor Kaikioewa and King Kamehameha. Importantly, the lease was the first of its kind in Hawai'i and represented the first formal recognition that someone other than a chief could control land use. Koloa Plantation, formally established in 1841, is universally known to be the first commercial sugar plantation in the islands. Ladd and Company was the first owner of the plantation but financial difficulties caused them to sell in 1845. Robert Wood and his brother-in-law bought the plantation and kept the plantation going until 1899 when the Koloa Agricultural Company, the McBryde family, bought the plantation. The Koloa Plantation merged with Grove Farm in 1948 and continued operations through 1996 (Donohugh 2001).

The sugar industry grew sporadically between 1845 and 1875. At this latter date, the Hawaiian government signed a reciprocity treaty with the United States was negotiated. This allowed unrefined Hawaiian sugar to be admitted into the United States duty free and the cultivation of sugar was to become profitable (Alexander 1985:74).

Koloa Plantation commenced growing sugar cane in Māhā'ulepū Valley in 1878, having focused more on lands to the west near Kōloa. A total of 875 acres of the flat valley floor was made available. The land was level, sheltered, and had a good underground water supply. However, there was an initial problem with the ground water as some of the valley was saturated and other areas were dry. Accordingly, Koloa Plantation undertook efforts to build infrastructure that would drain waters from the saturated areas, and divert that water to irrigate drier fields (Alexander 1985). Sugar cane requires much water so in 1897, the Koloa Plantation also excavated several wells to irrigate the cane in Māhā'ulepū Valley (Donohugh 2001).

By 1897, the main source of irrigation water for the valley came from the ground water. At the northwest end of the valley, six wells were drilled and the water was pumped approximately a quarter mile to the north into the recently constructed Māhā'ulepū Reservoir (Figure 12). The area of the wells was known as "Māhā'ulepū 14", probably because that was the number of wells eventually drilled and/or in service. The primary source of irrigation water for Māhā'ulepū appears to have been the six wells drilled in 1897. Four more were drilled later and all were located near the western side of the valley. These wells pumped water to Māhā'ulepū Reservoir, where it was stored and released, when needed, to various parts of the valley via the irrigation ditch (Alexander 1985:97)

Irrigation ditches at both the north and south ends of the Māhā'ulepū Reservoir served to transport water to the crops and to receive water from existing streams descending from Ha'upu Ridge. A pumping station was built and manned with full-time resident staff who lived with their families in a camp here. The larger north to south irrigation ditch that extends the length of the valley was excavated but does not appear on the 1935 Koloa Plantation map (Figure 14). Intensification of irrigation efforts, which added to the waters provided by Māhā'ulepū Ditch, began after this date (Alexander 1985:98).

The thick clay soils of the Valley were difficult to till using plows pulled by teams of oxen. However, with the introduction of steam powered tractors, more land began to be put into production. Development thus began to escalate at the start of the 20th Century. The number of laborers increased from 430 in December, 1900 to 769 in July, 1901. In February 1904 it was reported that 600 out of 730 men were working on permanent improvements. Infrastructure modifications in Māhā'ulepū Valley also intensified at the start of the 20th Century, with the excavation of canals, reservoirs, and wells. A narrow gauge railway was also constructed in the valley. The railway extended from Koloa Mill to "Māhā'ulepū 14", the series of wells on the valley floor at the northwestern end of the valley itself. The railway tracks were movable, but SCS found no evidence of them in the valley during the current AIS. Other portable narrow gauge rail systems were utilized to facilitate the harvest (Alexander 1985:99).

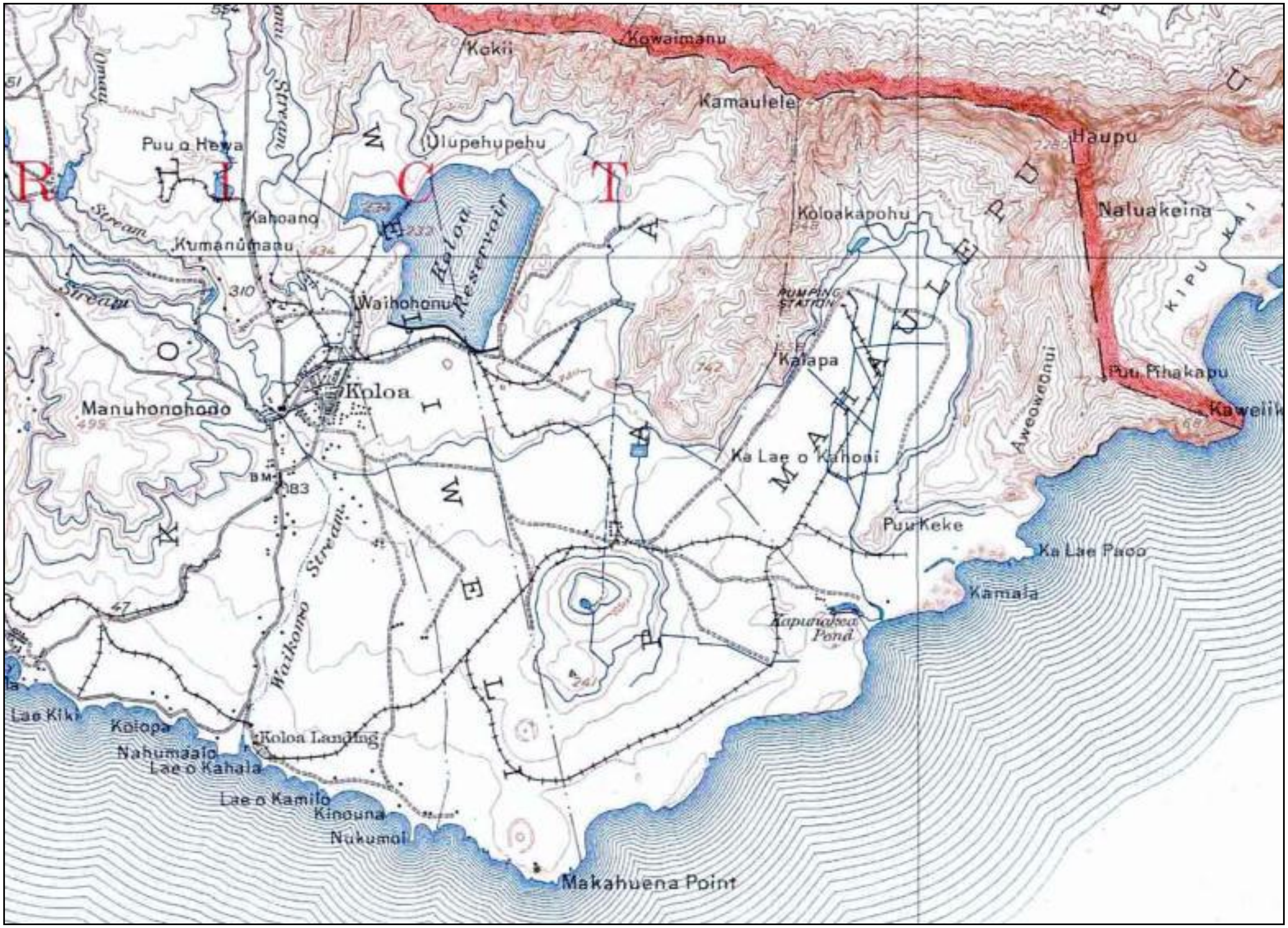

Figure 12. Koloa Plantation infrastructure (1912 USGS Territory of Hawai'i Quadrangle portion).

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In 1904, $16,420.81 was spent on additions to the plantation railroad system, including "a three-mile addition to the Puuhi railroad and a short cut road to Maha'ulepu" *(Ibid.*). Considering a laborer in the fields made about $17 per month, this was quite an expenditure at the time (Alexander 1985:122).

In 1917, the Koloa Sugar Company attempted to expand their portion of land owned within the valley by completing a Land Court Application. The application was divided into geographical sections designated A through C. Section B is contained within the project area. This area originally consisted of LCA 7713 to V. Kamāmalu and also contained the LCA cluster located mid-valley. Heirs of the LCA awards are addressed by name within the application ("The Garden Island," Tuesday July 29, 1919; p6). According to a modern TMK plat map (see Figure 11) and the Land Court Application map (Figure 13), the application was later cancelled.

Koloa Plantation contracted with groups of approximately a dozen men to manage parcels of fifty to one hundred acres. The Plantation "…furnish[ed] land, seed-cane, water, fertilizer, and tools, and perform[ed] such portions of the work as require[d] expensive machinery, such as plowing, furrowing and hauling the cane to the mill" (*Ibid*. 97-98). The contractors, however, otherwise took care of their parcels from planting to harvest, selling the cane to the Plantation at a set price. This method kept the land under one owner, but provided the contractors incentive to raise a bountiful crop (*Ibid*. 123).

Early 20th century maps document the extent of the fields throughout the Kōloa and the Māhā'ulepū Valley areas. The fact that Māhā'ulepū Valley was used for extensive sugar cane cultivation is also evidenced by the infrastructure developed within the valley over time. Thus, the available information demonstrates that HDF's project area consists of lands that were previously used for sugar cultivation.

Grove Farm continued to produce sugar cane in the greater Kōloa area, including Māhā'ulepū, until 1974, when it leased its Kōloa lands and mill to McBryde Sugar Company. Sugar production continued under McBryde until September 1996 when the mill officially closed (Donohugh 2001).

The Wilcox Family sold Grove Farm to S. Case in 2000. From the early cultivation times until then, the lands extending from Māhā'ulepū Valley to the sea were extensively modified for the cultivation of sugar. Fields were plowed, streambeds cleared, irrigation ditches excavated, reservoirs created, roads built, and wells drilled.

During the days of the Kingdom, Republic, Territory, and into Statehood, sugar cultivation and Māhā'ulepū would be synonymous. More recently, since sugar cane cultivation operations ceased, Māhā'ulepū Valley has been the location of cattle ranching (2002) and taro cultivation (2007), the latter being done through lease to W.T. Hara (Donohugh 2001).

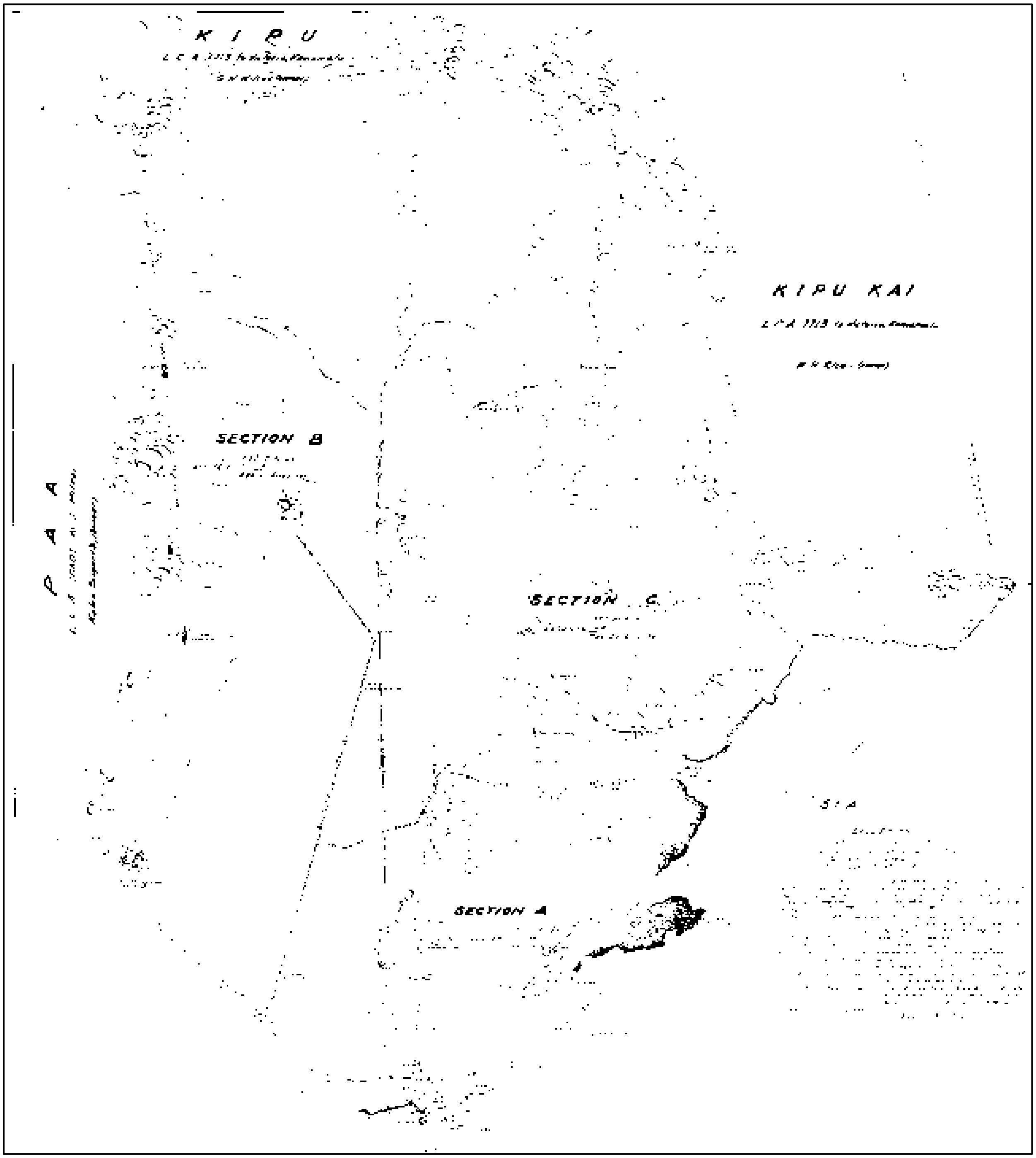

Figure 13. Map of Land Court Application 388 (F. Harvey, Land Court App. 388, 1917).

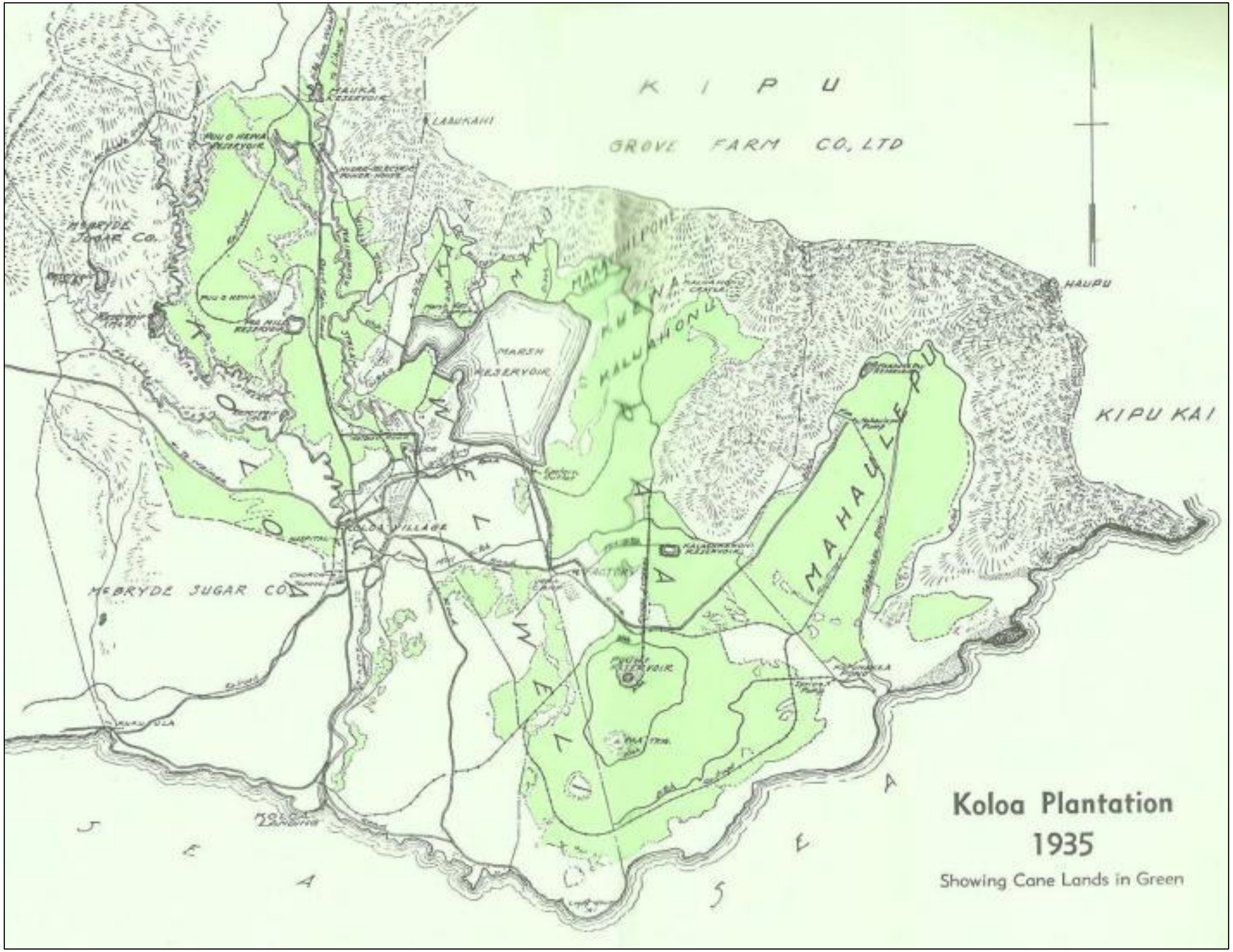

Figure 14. Distribution of Koloa Plantation lands (from Alexander 1935).

PREVIOUS ARCHAEOLOGY

There have been numerous archaeological studies along the coast of Māhā'ulepū, but archaeological studies within Māhā'ulepū Valley and nearby inland environs have been limited. Figure 15 shows sites within the entirety of the ahupua'a while Figure 16 shows the location of relevant studies both within the current project area. The reader is also referred to a National Park Service (NPS; 2008) regional study for a praxis of the projects conducted within the ahupua'a. Four projects were conducted adjacent to the project area: Thrum (1907), Kikuchi (1963), Ching *et al*. (1974), and NPS (2008).

The earliest study was by F.K. Farley in 1898. During this study, petroglyphs were discovered beneath sand dunes at Keoneloa Beach, to the southeast of the current project area near the Hyatt hotel. According to Farley, local residents knew of the petroglyphs and reported that they had been exposed previously.

The antiquarian T.G. Thrum documented two *heiau* on Kaua'i named Weliweli and Waiopili (SIHP #50-30-10-00087; Thrum 1907). The former was not accurately plotted on any map, while the latter was located along the stream of the same name that descends from Māhā'ulepū Valley. Waiopili Heiau was formerly located just south of the current project area near the present-day quarry.

Within the valley itself, but outside of the project area, Thrum identified the possible location of a large *heiau* named Hanakalauea. This heiau was reported to have been dismantled in the 1860s by a gentleman named Fredenberg and the stones then used to build cattle pens (Thrum 1907). Thrum also reports a fourth *heiau*, named Keolewa (SIHP #50-30-11-90), on the crest of Mount Ha'upu (Thrum 1907; see also Bennett 1931, Site 90). It is not certain if Thrum or Bennett actually visited the site, but both noted that it was a small *heiau* dedicated to a goddess named Laka (Thrum 1907; Bennett 1931). A cursory field inspection of the summit by SCS archaeologists in December 2015 did not note any definitive structural remnants of this *heiau*.

During an archaeological survey conducted in 1928-1929, Bennett (1931) located or re-located the *heiau* at Weliweli and Waiopili. The Keoneloa Beach petroglyphs were not exposed during this visit but Bennett collected information about them from local residents.

According to Bennett (1931:46), at Waiopili Heiau, "a tower of stone stands in one corner. It is solid enough to climb upon and an excellent view is afforded from the top. It is a unique feature for Kaua'i *heiau*, and if modern, defies conjecture as to the reason of its construction." According to Ching (1974), "Waiopili Heiau is a rectangular walled enclosure, which lies on a smooth pahoehoe lava bed. The limestone cliff which forms a natural boundary between Māhā'ulepū and Pa'a lies almost directly to the south of this temple.” Chang (1974) further states that Kapunekea Pond is nearby and that the walls were large, 2.5 m wide and 2.0 m high, constructed of pahoehoe slabs. The *heiau* was still mostly visible in 1974. By 2006, only a very small portion of the southern wall of the *heiau* was visible, near a spring pump house. The *heiau* has been mostly destroyed by quarrying activities, as well as by the quarry road which runs along the southern boundary of the former structure.

In 1963, Kikuchi conducted an archaeological investigation of coastal Kōloa and Māhā'ulepū. In addition to identifying new sites near the coast, he re-located several sites described by Farley, Thrum, and Bennett: Site 96 (Kane'aukai Heiau); Site 97 (dune burials); Site 98 (Keoneloa Beach Petroglyph Field); Site 99 (Weliweli Heiau); Site 100 (Keoneloa Beach Walls); Site 101 (Makaweki Point petroglyphs); and Site 102 (a structure).

Kikuchi also documented the only previously identified site within the surveyed area, SIHP #50-30-10-3094. This site is composed of a large boulder sitting in a pasture at the northern end of the valley. Kikuchi (1963) notes this boulder was two miles inland. Some twenty anthropomorphic figures, two pecked cups (4 inches deep), and a long groove are etched on the surface (Ching *et al*. 1974). Interpretation of the groove is uncertain. This site was fully recorded and mapped during the current project. In addition to the one boulder previously identified by Kikuchi (1963), two additional petroglyph rocks associated with this site were also documented during the current AIS (see Results section below). This brings the total identified features at Site -3094 to three.

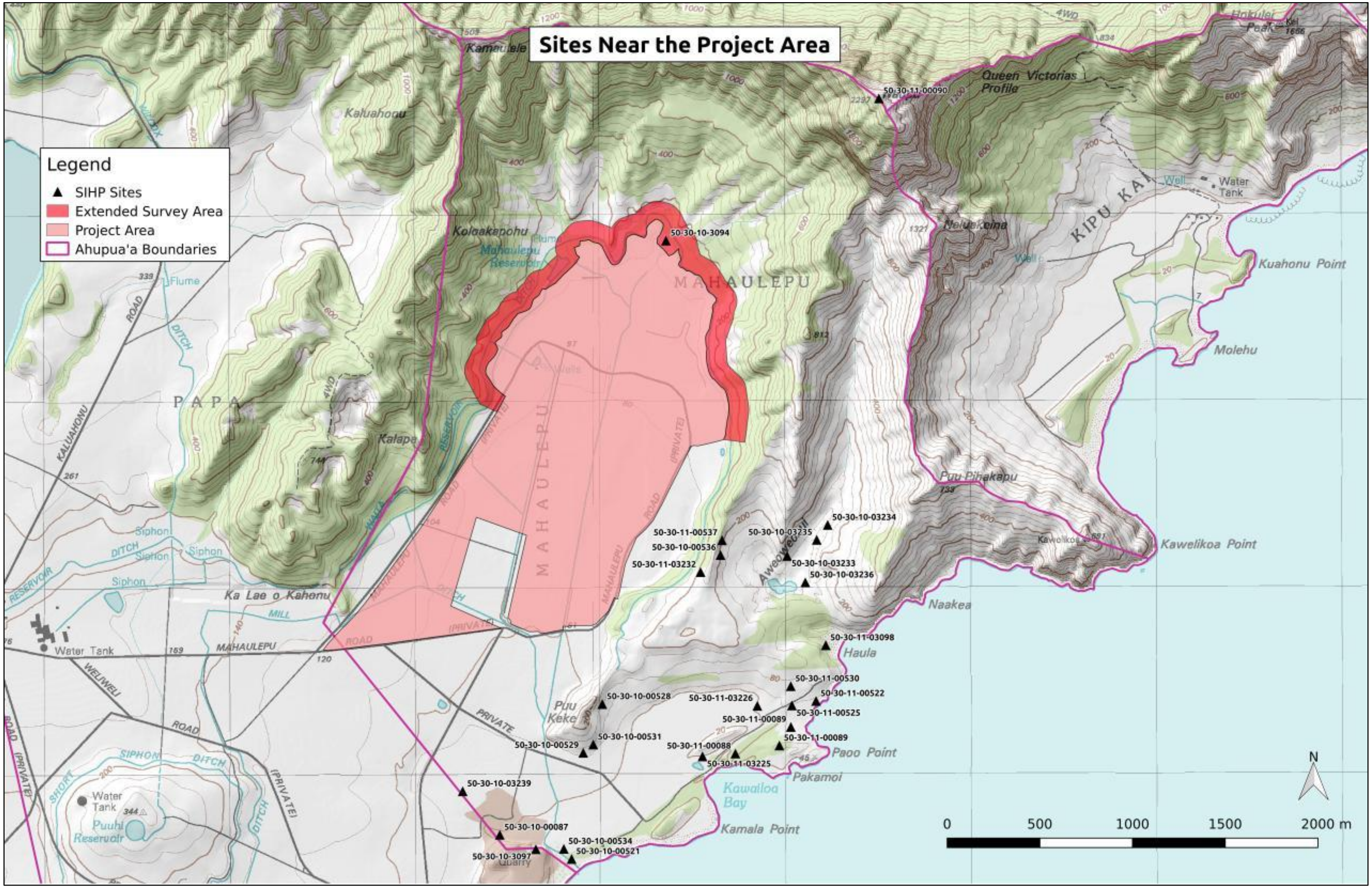

Figure 15. Previously identified sites near the project area (portion USGS Kauai composite DRG (n.d.) / 10m DEM; site spatial and attribute information by SHPD).

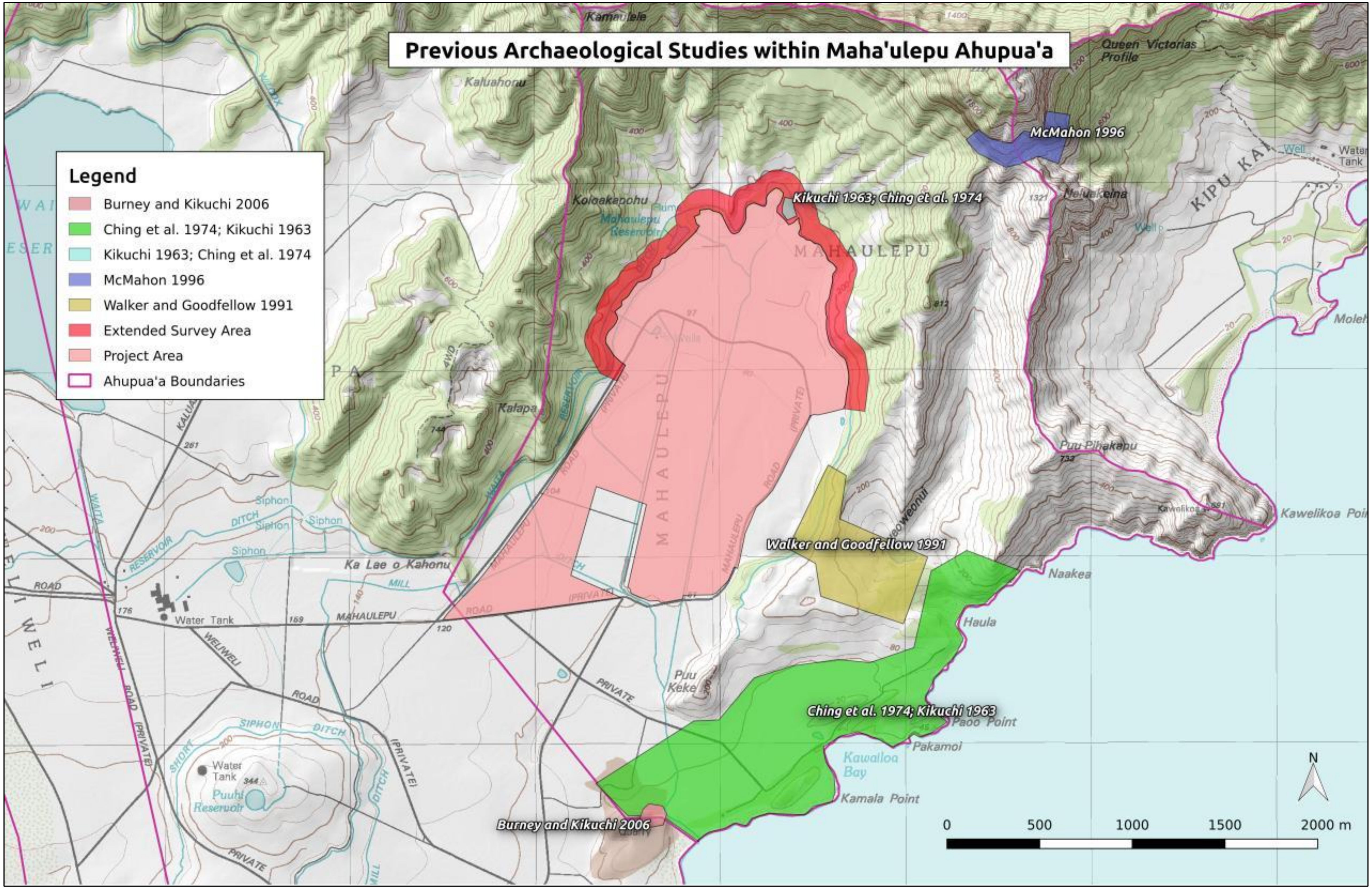

Figure 16. Previous archaeological studies near the project area (portion USGS Kauai composite DRG (n.d.) / 10m DEM). Note that extents of previous studies are approximate.

During surface survey of 1,100 acres along the coastal lands of Weliweli, Paa, and Māhā'ulepū Ahupua'a, Ching *et al.* (1974) wrote of Weliweli Heiau: "no actual alignments or other features were noted at the reported location of this temple. This site has either been completely destroyed or is located elsewhere" (Ching *et. al*. 1974:81). During the Ching study, the archaeologists found and sketched the petroglyphs at Keoneloa (Site 84), found sand dune burials (Sites 50-30-11-3096, -3097 and -3024) and re-located Waiopili Heiau (Site 87). They also located Waiopili Pond and Kapunakea Spring, but these were not given site designations (Rosendahl et al. 1994).

In 1991, Walker and Goodfellow conducted an archaeological inventory survey in a portion of Māhā'ulepū as an additional parcel of the Grove Farm Kawailoa Property survey. The survey was located to the southeast of the current project area. During the work five new sites were identified (SIHPs 50-30-11-536 through 540). Two midden scatters, historic period walls, and a ditch/flume were documented.

McMahon (1996) conducted an archaeological field inspection of an area approximately 25,000 square feet in size on the southeast flank of Ha'upu Ridge for the proposed installation of a radio tower. The project area for that study was located at 1,500 ft. asl. No sites were identified, nor were any trails observed along the ridgeline; the area was, as McMahon notes (1996), only accessible by helicopter.

Following this study by McMahon (1996), a letter was submitted by the Office of Hawaiian Affairs (OHA) in March 1998 to the Federal Communications Commission opposing the construction of a radio tower on Mount Ha'upu. The letter stated that the mountain is of special significance to Native Hawaiians as a *wahi kapu* (sacred place): "Ha'upu is our kin, descendent of Papa [Earth mother] and Wakea [Sky father], and older sibling of the Hawaiian people. This is the main reason why we, as Hawaiians, hold Ha'upu sacred in our hearts". According to the OHA (1998) document, Ha'upu was named after a demi-god/warrior who took a large boulder from Kaua'i and threw it across the Ka'ie'ie Waho Channel, where it killed an enemy chief on O'ahu. The small *heiau* atop Mount Ha'upu is dedicated to the goddess of hula (Laka). Both the *heiau* and the wooded areas at Ha'upu Summitt are known as *keolewa*, a word common in Hawaiian oral traditions. In addition, Ku and Hina, the first Hawaiian god and goddess, live on Ha'upu Ridge. Mount Ha'upu was also an important navigational landmark for traditional Native Hawaiian fishermen, and Hawaiians today still view the mountain with reverence (OHA 1998).

Beginning in the 1990s, Burney and Kikuchi began excavating the Makauwahi Cave and Sinkhole (SIHP # 50-30-10-3097). They stated that within the cave there was "in a single stratigraphic sequence and encapsulated view of the full span of human occupation, including the millennia preceding human arrival, earliest human evidence, subsequent population increased and cultural change, European contact, and modern transformation" (Burney and Kikuchi 2006). Amongst the many discoveries from this study are bones of a Polynesian rat, which dated to 1039-1241 A.D. Because the rats were in the canoes with Polynesian voyagers, this is some of the earliest evidence for human occupation of this area. Excavations also exposed intact cultural layers, as well as culturally sterile deposits. Artifacts such as files, picks, scrapers, adzes, fish hooks, octopus lures, game stones, sling stones, and hammer stones were recovered. The preservative qualities of the deposits in the sinkhole were excellent. Fiber cordage, wooden fragments from canoes, paddles, and tool handles were also recovered. These materials came from three excavations. There is much potential for more information to be gained from this site (Burney and Kikuchi 2006).

The most recent comprehensive effort at documenting the biology, botany, geology, ecology, and archaeology of the region is that compiled by the National Park Service (NPS; 2008). "The Māhā'ulepū, Island of Kaua'i Reconnaissance Survey" published in 2008 consists of an effort by the NPS to re-identify multiple natural and cultural features in the Māhā'ulepū Valley and environs. The goal was to argue for the importance of conducting a more thorough natural and cultural study of the area along the southeast coast of Kaua'i from Kōloa to Poipū, and northward along Māhā'ulepū, Kipu Kai, Niumalu, and Nawilili Harbor. Included in the study is Mount Ha'upu and the ridgelines extending from it (NPS 2008). The study presents a summary of the natural and cultural features for the area and effectively argues for additional research.

SETTLEMENT PATTERN AND SITE EXPECTATIONS

Prior to European contact, the rulers of the Hawaiian islands divided the landscape into political entities known as *ahupua'a*. These landholdings varied in size but shared a few common traits. Their boundaries extended from the mountains to the sea shore, with fishing rights extending to pelagic waters. Where possible, the boundaries incorporated natural features such as ridgelines and streams. Each *ahupua'a* was ruled by single *ali'i*, or noble, and the holdings were managed by *konohiki*, persons of slightly lesser status. The pre-Contact population was composed of farmers, fishermen, craftsmen, priests, rulers, and soldiers. Given the size and natural diversity of Māhā'ulepū Ahupua'a, there was probably a large population scattered throughout.

A PREDICTIVE MODEL OF TRADITIONAL SITE DISTRIBUTION.

Dega and Powell (2003) developed a landscape model of variation in physiographic and environmental *zones* in eastern Kaua'i as a way of predicting the general location of traditional sites and features, including buried sites. This model is being applied across Kaua'i. [Note, Hammatt *et al*. (2009) have used a slightly different variation of this zone model idea in numerous reports (*e.g*. Masterson *et al*. 1994)]. This section describes the *zone model*, as defined by Dega and Powell, and modifies it slightly to more explicitly include the potential impact of historic activities on traditional sites (*e.g*. road cuts, utility excavations, irrigation ditches and pipelines, sugar cane cultivation), but also the preservation and protection of surface and/or buried traditional sites. These historic impacts are discussed in relatively broad terms here. Specific archaeological and historic data directly relevant to the project area are presented in the following section.

Particularly for traditional Hawaiians in pre-Contact times, resources and opportunities to exploit them were distributed unevenly across the landscape, and the archaeological record should reflect this. The model divides landforms into five general zones, and Dega and Powell (2003) integrate broad patterns in the known distribution of archaeological finds within these zones. This allows for more specific – and scientifically testable – predictions than simply the probability of finding sites in a given location. The model predicts, for example, not only that the coast and near-coast were more intensely inhabited than the foothills and plateaus, but also that the types of sites created in these zones would be different. The zone model is therefore based on empirical data documenting variation in the physical as well as the cultural landscape of Kaua'i. As stated, historic impacts on traditional sites should be considered, and some fairly general observations can be used to predict at least some of these. Here, only general references and broad trends in the archaeological record of Kaua'i are relevant.

SITE TYPE PREDICTIONS AND FREQUENCY BY ZONE

The model divides the landscape into five broad zones: Coast (I), Back Beach (II), Marsh (III), Hills/Plateau (IV), and Mountains and Steep Slopes (V). According to the model, the first three zones (coast to marsh) have been more or less continually utilized, in some way, from very early times into the present. Especially in the pre/early post Contact periods, Zone II has been most important for habitation for two main reasons: (1) it straddles two highly productive and accessible eco-zones (*i.e*., marine-coastal and pond-estuary), meaning that its inhabitants could easily exploit both areas; and (2) in geomorphological terms, Zone II is a relatively stable landform not prone to flooding from either the sea (as with Zone I) or the uplands (as with Zone III). Note that the model does not take into account population pressure or chiefly edicts that might cause people to settle in marginal areas or cause people to pursue less than optimal adaptive strategies. Māhā'ulepū Ahupua'a contains all five zones, with the survey area primarily occurring in Zone IV to the base of Zone V.

Zone I (Coast)

Zone I consists of beach sands and adjacent coastal dunes, which include frontal accretion deposits, backslopes, the crest, and the slip face. Zone I includes the area from the high-tide water mark of the ocean to the lower portion of the slip face near the interdune area, or, where the backside of the dune becomes flat and expansive. Zone I sediments are primarily composed of beach sands. These sands are subject to variable sorting when energy depositional events such as storm surges or tsunamis lead to the deposition of coarser sand grains while low energy events can lead to well-sorted, often fine-grained, sedimentary deposition. This is a dynamic zone in terms of landscaped morphology as it constantly evolves through wind and tides, particularly if vegetation or modern impediments do not curtail dune migration.

Archaeological work in Zone I commonly yields habitation sites and features, but there are rarely the remains of permanent settlements. The potential difficulties of living permanently in Zone I include dangerous flooding, high winds, and shifting sand. Landscape features can be quickly buried and/or exposed in Zone I, where more temporary sites, such as fishing camps were located. Archaeological evidence of activity area, such as tool and gear workshops and maintenance sites, are also common in Zone I, but these tend to be relatively ephemeral because they are usually the result of short duration visits. Traditional Native Hawaiian burials are another important site type in Zone I sediments. Burials in this zone would have been located at or above the typical high tide mark, *i.e.* near the transition to Zone II, rather than towards the seashore itself. With the recent increase in beach erosion, burials have been found in more frequency in these tidal zones.

Historic impacts in Zone I include the construction of sea walls, jetties, and retaining walls. Sea walls and retaining walls, in particular, have the effect of stabilizing and sometimes burying Zone I sediments, potentially locking in subsurface deposits. Much of the Māhā'ulepū coast has been modified in this manner, especially at Poipu and Kōloa.

Zone II (Back Beach)

Zone II occurs inland from Zone I, and represents a more stable land surface. This zone comprises the coastal plain or back beach environment. Like Zone I, Zone II primarily consists of calcareous sand beaches derived from the decomposition of coral and seashells. These deposits and associated coralline basements occur far inland in some areas, reflecting the Holocene high sea stand occurring between c. 5,500 years go and lasting until about 2,000 years ago (Fletcher and Jones 1996). Zone II represents an area that almost never floods, except in the rarest of conditions (*e.g.*, a 100 year event). Along the Māhā'ulepū coast there are windblown modern dunes, and a fossil-rich lithified dune system in Zone II (NPS 2008).

Archaeological work in Zone II commonly yields permanent habitation sites and burials from traditional Native Hawaiian occupation. In fact, all manner of sites, and features associated with settled, near-coastal communities were located in Zone II, and large population centers were common.

Because Zone II landforms are stable, accessible, near-coastal settings, usually over relatively level terrain, historic impacts have been severe. These impacts include road building, residential and commercial construction, excavation for utility trenches, and mining of the sand for construction purposes.

Zone III (Marsh)

Zone III consists of wet marshland, or slightly depressed pond areas, inland of Zones I and II. Zone III is amenable to soil catchment (*i.e*. sedimentary deposition), and is located at or very near sea level, yet retains more terrigenous characteristics. This marshland does contain some sandy sediment, but alluvial silty clays and clays from the uplands dominate soil matrices. Zone III would have been an unique eco-zone for hunting marsh birds for food and feathers, and the collecting of their eggs.

In the pre/early post Contact periods, Zone III provided a near-coastal alternative for agricultural production normally only afforded at locations farther inland. Archaeological work in Zone III commonly yields evidence of traditional walls, ditches and terraces of the *lo*'*i* (irrigated) field systems. Fishponds were sometimes located in this zone. Residents on either side of Zone III could utilize this area for agriculture, aquaculture, and wildlife harvest.

South of the project area, Māhā'ulepū Ditch, formerly a natural stream, joins with a natural spring and the remnants of Kapunakea Pond, and regains a more natural appearance. It continues to the coast, re-named Waiopili Stream (NPS 2008). It flows near Waiopili Heiau, and a unique site in Hawaiian archaeology, Makauwahi Cave. Makauwahi Cave is a limestone sinkhole with interior caves containing a complex stratigraphy with the different layers containing evidence of traditional Hawaiian occupation and the natural deposits accumulated prior to the arrival of the first voyagers.

Zone IV (Hills and Plateau)

Zone IV is characterized by hills, valleys, and grassy plateaus that lead into more mountainous terrain. Subsurface deposits are dominated by silty clays and clays derived from the decomposition of underlying basalt, as well as the deposition of alluvial and colluvial clays, particularly in valley areas. In many places, the soils are also rich in iron and other nutrients amenable to the cultivation of traditional food crops and, historically for the industrial production of Kaua'i's most lucrative commercial crop, sugar cane. Archaeological evidence has documented a number of site types in Zone IV:

1. Trails connecting lowland and upland sites and resource areas, varying in construction and size;
2. Agricultural plots, with terraces and retaining walls, for garden and/or medicinal plants, and terraces for dry land agriculture such as 'uala (sweet potato) could be present within this zone;
3. Arboriculture would have flourished in this zone. Thus, evidence of the cultivation and maintenance of ulu (breadfruit) and other tree resources could be found here.
4. Permanent and temporary habitation sites; and
5. Heiau.

The project area for this AIS is located in Māhā'ulepū Valley, on relatively level ground previously utilized for sugar cane cultivation. The intensive transformation of the landscape through clearing, plowing, and harvesting has resulted in the removal and/or destruction of archaeological sites and related features.

Zone V (Mountains and Steep Slopes)

Zone V consists of the steep slopes of mountains and those of major drainages such as gullies and ravines. Lands classified as Zone V are typically rugged, remote areas of the terrain where human occupation and utilization are temporary and/or episodic. Soils and sediments in Zone V derive from the decomposition of the underlying bedrock. Because of the prevalence of steeps slopes in this zone, soils and sediments are relatively thin and subject to downslope movement. Cultural features such as retaining walls, terraces and trails are usually found in association with rock outcrops and caves. Erosion is the greatest threat to whatever cultural deposits might be found on these slopes. During informal survey of this zone by the SCS crew, several sets of agricultural terraces were located on the eastern slopes of the valley, far outside the project area and extended survey area, the terrace sets were in poor condition due to natural erosion and located adjacent to several small drainages.

Traditionally, Hawaiians did construct *heiau* at elevations, but in some instances a natural place could be considered sacred without an actual structure (*i.e*., Ha'upu Ridge). Stone was quarried traditionally for tools of high grade basalt and the forests were harvested for building materials. Increasingly through the first four decades of the 19th Century, sandalwood was collected until near extinction, which increased the risk of erosion in the mountains. Later in the 19th Century and into the 20th Century, irrigation infrastructure for the sugar cane industry was carved into the mountains and slopes as well.

SITE DISTRIBUTION AND CHRONOLOGY

Site distribution across these five zones is often determined by historic land use, when landowners and others utilized the same lands as were previously cultivated and occupied during pre-Contact times. Sometimes these earlier signatures are erased, depending upon the intensity of historic land alterations; sometimes, however, they are not, as evidenced by the many inland, pre-Contact sites occurring across southern Kaua'i. Pre-Contact sites are identified in coastal or near coastal areas, locations removed from intensive sugar cane production, but also in large valleys and uplands that were not disturbed through time. *Heiau*, as seen via this report, and fishponds, among other pre-Contact site classes, are also preserved inland. This pattern occurs beyond the south shore as well, where pre-Contact sites are preserved inland, such as in Waimea Canyon and Makaweli, for example. Typically, however, the earliest dates for initial settlement of an area, for this part of Kaua'i, occur at the coastline.

Dates from the coastline fall in the A.D. 1000-1200 range for this part of Kaua'i, with expansion inland proposed to have been during the A.D. 1400-1600s, as was a pattern across the islands (see Kirch 1985). Agricultural field systems were created within inland areas, closer to fresh water resources and soil more amenable to *kalo* and sweet potato production. Permanent habitation locales were present from the coast to more inland areas, with ceremonial sites, walls, and other associated structures being built near the coast and far upland. Within the mountainous areas, such as at the back of Māhā'ulepū Valley, temporary habitation loci would have been utilized by those gathering upland resources. The middle zone, such as Māhā'ulepū Valley, was ideal for agriculture and homesteads, as witnessed by the numerous LCA's occurring in a small section of the valley. However, it appears that historic land use would have erased many of the archaeological signatures for such settlements/land use. This is evidenced by the presence of a ceremonial site (SIHP 50-30-10-3094; see below) in the extended survey area. What is more apparent now in the archaeological record of Māhā'ulepū is infrastructure associated with that intensive sugar cane production from the plantation period.

METHODOLOGY

Several phases of fieldwork were undertaken as part of this AIS. Prior to fieldwork, a review of the archival record and previous archaeological work in the surveyed area and environs was completed. This archival work was integral in determining the types and nature of sites that could be encountered, as well as to aid in determining trenching locations. A search of Kaua'i Historical Society photograph collections by M. Ching did not yield any photos significant for the surveyed area or this study.

FIELD METHODS

Fieldwork was conducted between July 7 through 25, 2014 and August 20 through 26, 2014 by Jeff Putzi, B.A., James Powell, B.A., Milton Ching, B.A., and Michael Dega, Ph.D (Principal Investigator). Fieldwork consisted of a systematic 100% pedestrian survey of the entire project area and extended survey area, representative mechanical trenching on the valley floor, and manual excavation units. For purposes of the pedestrian survey, the crew was spaced a variable 5 to 10m apart, depending upon ground visibility. Visibility was very good across the valley floor and good around the perimeter of the floor. When sites were identified, they were mapped to scale using tape and compass (except for the longer ditches), digitally photographed, and GPS recorded. The longer ditches were recorded using GPS (both terminal ends) and appear on most maps/aerial photographs for the area. Sites were recorded in detail to reflect their overall integrity, size, and location in the surveyed area.

As noted above, given the historic land use in the project area and associated likelihood of the destruction of historic properties through that land use, SHPD requested that the scope of the AIS be extended beyond the project area to include the extended surveyed area at the back of the valley to the north, east, and west flanks. Because the extended survey area is outside of the footprint of historic sugar cultivation, surveying this area could provide information and context no longer available in the project area. The land in the extended survey area is owned by Mahaulepu Farm LLC but not within the property leased to HDF for the project. Thus, HDF and SCS needed to obtain permission from the landowner to enter and survey the extended survey area, which ultimately increased the surveyed area by some 1,300 square meters beyond the original survey area.

In addition, a total of seventeen stratigraphic trenches were mechanically excavated by backhoe across portions of the valley floor. Trenches were mostly focused on the cluster of LCAs in the central/eastern portion of the project area and, through the area of the proposed effluent ponds, where excavation for the project is proposed. All trenches were examined, profiled, and photographed. Manual testing of nine units was completed at

SIHP #50-30-10-2250, an enclosure located within the extended survey area. This additional testing was also approved by SHPD to further understand the function of the site. The number of units was increased to a total of nine units as no cultural materials were identified in the first several test units. All sediment from the units was screened through 1/4" and 1/8" wire mesh screens, to recover any smaller cultural material fractions. All units were plotted on a site planview map, profiled, and back-filled. No units were left open at the end of each day.

In addition, an SCS crew field visit was completed on June 19, 2015 to the location where the word "Path" was marked on Registered Survey Map #1898 (M.D. Monsarrat, 1896). The additional survey was recommended to assess the presence/absence of a "path" or trail in the area. As discussed further below, this field visit confirmed that there is no evidence of a path/trail present in the noted map location or in the vicinity. The "path" survey point marked the location of a ditch on the eastern flank of the valley.

LABORATORY METHODS

As only one artifact was recovered during surface survey, trenching, and testing, laboratory methods were primarily limited to drafting field site plan view maps, stratigraphic trench profiles, profiles of the test units, cataloguing all photographs and maps acquired during the AIS, and reporting. The single artifact, from a test unit outside Site -2250, the enclosure in the extended survey area, was analyzed and catalogued. This artifact was returned to the site during a February 3, 2015 field visit with the SHPD and others. All field notes, maps, and photographs pertaining to the AIS are currently being curated at the SCS main laboratory in Honolulu.

CONSULTATION

Preliminary consultation, as described further below, was undertaken in connection with the current AIS by the archaeological field crew. A more formal consultation, via a Cultural Impact Assessment, has also been undertaken to provide much more in-depth information through personal interviews of those related to the project area. For the AIS, the following individuals and groups were consulted:

State Historic Preservation Division-Kaua'I (SHPD)

SHPD was consulted prior to the commencement of fieldwork, during fieldwork, and post-fieldwork. Following one of two field visits to the project area, SHPD recommended that survey be conducted not only of the immediate project area in the valley, but also up to the ridgeline. The presence of Keolewa Heiau, on Ha'upu Ridge, and a former *heiau*, Hanakalauea Heiau, within the valley, suggest the possibility that pre-Contact/historic era trails may have at one time connected the project area to the upper ridgeline. However, as discussed below, SCS did not observe any evidence of trails.

The presence of the enclosure, interpreted to be an agricultural *heiau* in the extended survey area (Site -2250, see below) and small terracing, the latter occurring well beyond the extended survey area, also suggested that additional pre-Contact sites could possibly be present further upslope from the project area proper. However, the fact that additional sites may be located upslope does not mean the proposed project will have any impacts on such properties. As discussed above, given the scope of the project and the manner in which it will be managed and contained, impacts outside of the leased property are not anticipated; thus, the project area for purposes of this AIS is the area leased by HDF. Nonetheless, in an abundance of caution, and to maximize the possibility of finding information relevant to the project area, HDF agreed to include the extended 100 m survey area within this study.

Kaua'i Historical Society

Research was undertaken by M. Ching and J. Powell for historical photographs and maps of the Māhā'ulepū area, as well as text references (i.e., Bennett 1931) to further understand the sites they had documented during fieldwork.

Individuals

SCS (M. Ching) conducted interviews with several local residents who lived and worked for decades in the Kōloa-Māhā'ulepū area. M. Ching talked primarily with 84-year-old Nelson Abreu and his nephew Russell Abreu. Discussions centered on land use through time and their knowledge of any historic or cultural properties in the Māhā'ulepū area. Their insights regarding Plantation Era land use in the area, as well as the families who lived there, were invaluable.

SCS also interviewed James Case, now 95 years of age, who was born on Grove Farm and grew up in the Kōloa area. His thoughts on trails in the area and in general, life from the 1920s onwards, are presented below in short form. Mr. Case offered a tremendous historical recollection of these times, from Kōloa through Māhā'ulepū and beyond to Nawiliwili and Līhu‘e, among other locations.

SCS is currently conducting a Cultural Impact Assessment (CIA) for the project, with many of the individuals noted herein getting additional time to discuss their knowledge of the area with SCS. This CIA will be completed in the near future.

February 3, 2015 Field Visit

On February 3, 2015, SCS, SHPD (Kaua'i Lead Archaeologist Mary Jane Naone), land representatives, and community members met at the project area to conduct a field trip of the sites documented during this study and to obtain any insight these individuals may have on said sites. The secondary purpose was to get more overall feedback on the AIS, should they have any questions or comments. The following individuals from the community were present on the fieldtrip: Terrie Hayes and Billy Kaohelaulii, Mary Jane Naone (SHPD), Teddy Blake, , Kalani Kumai, Bridget Hammerquist, Rupert Rowe, and Jim Garmatz (manager for HDF). SCS was represented by J. Powell and M. Dega. During the visit, the group first stopped at the petroglyph rocks and second, at the *heiau* (Site -2250) in the extended survey area. In both locations, Kalani Kumai (aka Branch Harmony) conducted ceremonies to consecrate the sites. He also spiritually “closed” the *heiau*. The one artifact recovered during the AIS project, a lithic chopping tool (see below), was placed back in its original location, as witnessed by the group. Overall, the group visit was well received and the ceremonies accomplished goals set by many for being there. Both the petroglyph rocks and *heiau* were discussed in terms of the AIS, with these interpretations noted below.

Office of Hawaiian Affairs (OHA)

A copy of the initial draft Archaeological Inventory Survey report was submitted to OHA on May 16, 2015 for comments. SCS received no written comments from OHA on that draft. SCS will submit this revised report to OHA concurrent with submittal to the SHPD.

ARCHAEOLOGICAL INVENTORY SURVEY RESULTS

A total of sixteen (16) sites were identified during the AIS (Figure 17 and Figure 18). These sites were all identified through pedestrian survey of the project area and extended survey area. Fifteen (15) of the sites were newly identified during the current survey and one (1) site, State Site 50-30-10-3094, was previously identified and re-located. Of the sixteen identified sites, six (6) sites occur in the project area and ten (10) sites occur in the extended survey area (Table 1). Only one of these newly identified sites is believed to be associated with the pre-/post-Contact and/or early historic periods, the Site -2250 enclosure. The remaining sites consist of historic-era bridges, ditches, culverts, retaining walls, and a flume system dating from the 20th century and affiliated with sugar cane cultivation. That a majority of the documented sites are related to the historic-era is not surprising, given the extensive landscape modifications that occurred during intensive sugar cane cultivation on the valley floor. Even historic era cultural materials associated with the many LCAs in the project area were non-existent, as explored through survey and subsurface testing.

In addition to survey, a total of seventeen (17) trenches were mechanically excavated in various portions of the project area, with no cultural findings. Trenching was concentrated in areas where excavation will be required for the proposed project and second, in the area where many LCAs are clustered in the valley. In addition to this trenching, multiple manual test units were placed in Site -2250 to refine functional interpretations.

Note that Sites -2251, -2252, -2253, and -2259 all appear to conform to the same ditch (Figure 15), with the Site -2258 reservoir also being present near the ditch line. The ditch, as constructed following the creation of the reservoir, may have followed the course of historic or pre-Contact *'auwai,* but no evidence of such water ways along or perpendicular to the ditch were found during the survey. Sluice gates emptying into the valley were found, but there were no associated ditches, suggesting the gates may have been placed there to deal with overflow or flooding, and not necessarily for the irrigation of a specific field. The flume with trestle bridge over the irrigation ditch appears to have been constructed after the ditch/reservoir system was built. The flume and trestle appears to have been constructed to continue the flow of water from streambeds off the ridgeline, into the natural water courses in the valley itself.

The following presents the sites in numerical order, as site numbers were presented to and provided by the SHPD. Please note Table 1 summarizes those sites occurring inside the project area (N=6) and those occurring outside the project area (N=10).

Table 1. Site Location and Descriptive Data.

SIHP No. 50-30-10-	Site Type	Function	# Features	Age	Site Location
2250	Enclosure	Ceremonial	1	Pre-Contact	Outside Project Area
2251	Ditch, Gate	Irrigation	2	Historic	Outside Project Area
2252	Ditch, Gate	Irrigation	3	Historic	Outside Project Area
2253	Ditch	Irrigation	1	Historic	Outside Project Area
2254	Retaining Wall	Soil Retention	1	Historic	Inside Project Area
2255	Culvert Bridges	Irrigation	4	Historic	Inside Project Area
2256	Bridge	Transport	1	Historic	Inside Project Area
2257	Retaining Wall	Soil Retention	1	Historic	Inside Project Area
2258	Reservoir	Water Storage	1	Historic	Outside Project Area
2259	Ditch	Irrigation	1	Historic	Outside Project Area
2260	Bridge	Transport	1	Historic	Outside Project Area
2261	Bridge	Transport	1	Historic	Outside Project Area
2262	Flume, Gates	Irrigation	3	Historic	Outside Project Area
2263	Bridge	Transport	1	Historic	Inside Project Area
2264	Pipe/Foundation	Irrigation	1	Historic	Inside Project Area
3094	Petroglyphs	Ceremonial	3	Pre-Contact	Outside Project Area

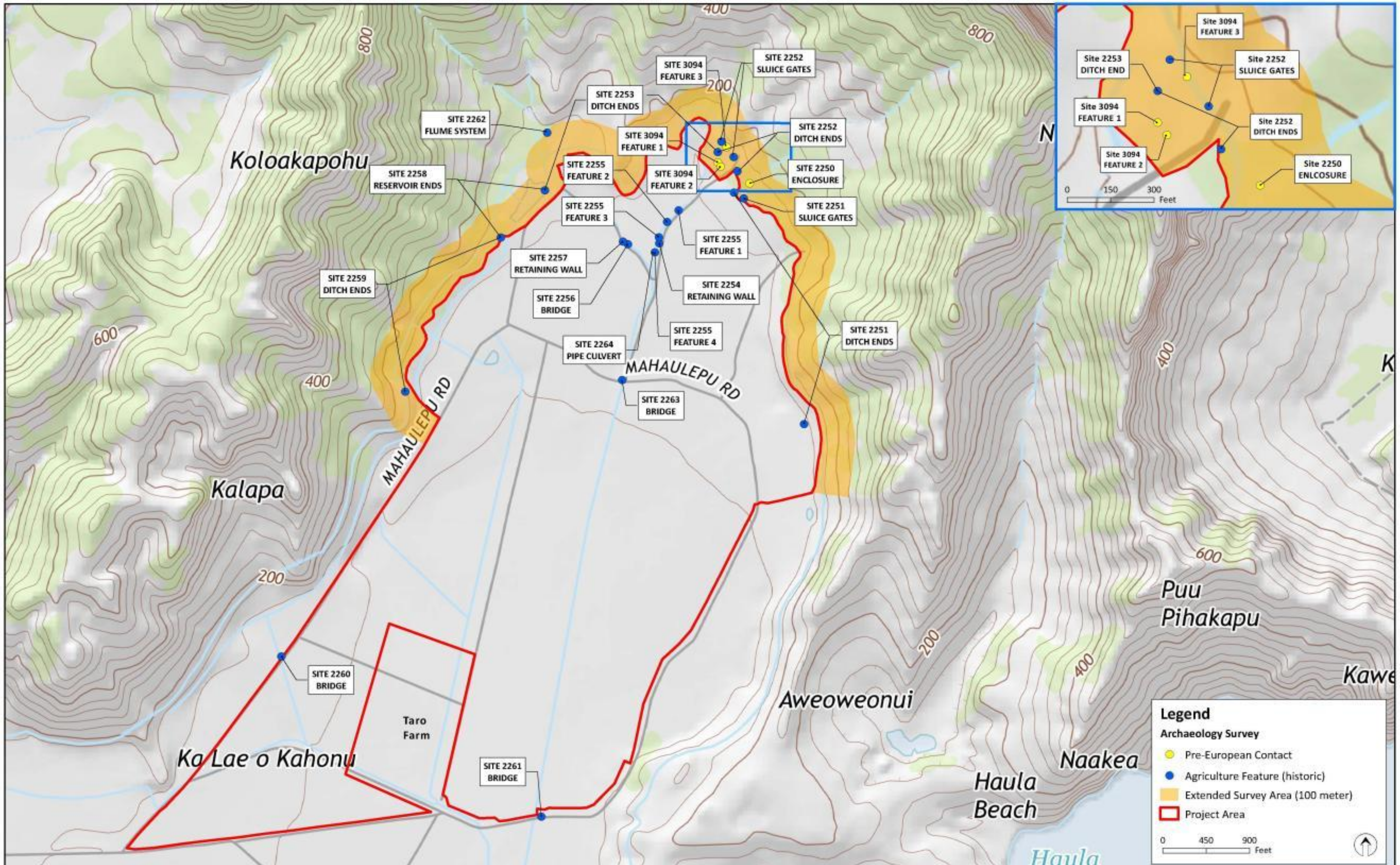

Figure 17. USGS map showing location of identified historic properties in the surveyed area (USGS 7.5 Minute series 2013).

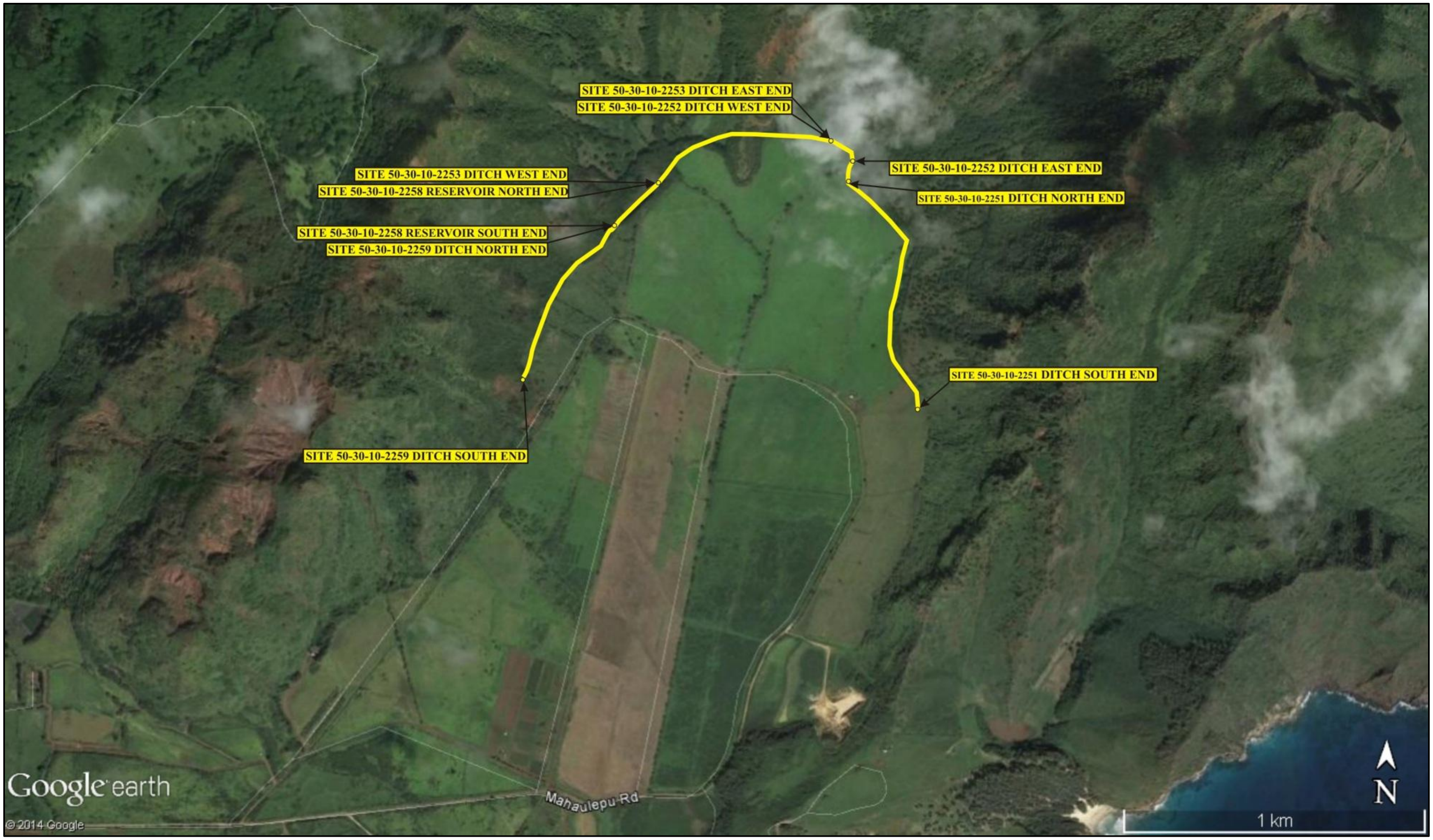

Figure 18. Aerial photograph showing location of ditch, Site -2251, -2252, -2253, and -2259.

STATE SITE NO. 50-30-10-2250 (TS-1)

Site -2250 consists of a rock enclosure occurring at the back of the valley within the extended survey area (Figure 19). The site lies c. 30 m off the valley floor. The enclosure is rectangular and measures 20 meters north-south by 9 meters east-west (180 m sq.; Figure 20 through Figure 23). The corners of the enclosure all occur at cardinal directions. The northeast wall is constructed of an alignment of small basalt boulders, at least 0.5 m in diameter, all of them fairly uniform in size. Two taller, but not wider, boulders are upright in this alignment. There is an opening at the west side of the northern end, which appears to form a formal entrance/exit for the enclosure.

The southeast wall of the site is constructed of basalt cobbles and boulders piled two to three courses wide and two courses high (0.30 m above surface, average). The cobbles and boulders range in size from 0.2 m in diameter to 1.0 m in diameter. Some portions of this wall appear to have collapsed but on the whole, the enclosure wall is in good condition. At the south end of the site are two upright boulders approximately 0.60 m in diameter and up to 1.4 m high. These are adjacent to a very large boulder that forms the south corner of the enclosure.

One large boulder at the southern corner is pyramidal in shape. It measures 4.0 m by 3.0 m by 1.4 m tall. Test Unit 4 was placed against this boulder (see below) as it would have acted as a “catchment” for any eroding cultural materials from the slightly uphill, northern end of the site. Extending westward are several other large boulders. Overall, a few small boulders are piled but the majority of the enclosure wall along the southern flank is formed by these roughly aligned boulders.

The long western wall is constructed in much the same manner as the long east wall. However, the former extends northwest before turning northeast to the presumed entry/exit to the enclosure. An upright boulder is present south of the corner, with two more upright boulders occurring to the north of the corner.

The area within the enclosure is mostly level but with a slight southward descent. The ground to the north is slightly higher in elevation. The site area is lightly forested with java plum, eucalyptus, and *haole koa*, but there is a dense grove of *hau* 25.0 meters to the southeast of the enclosure. There are no interior features within the site.

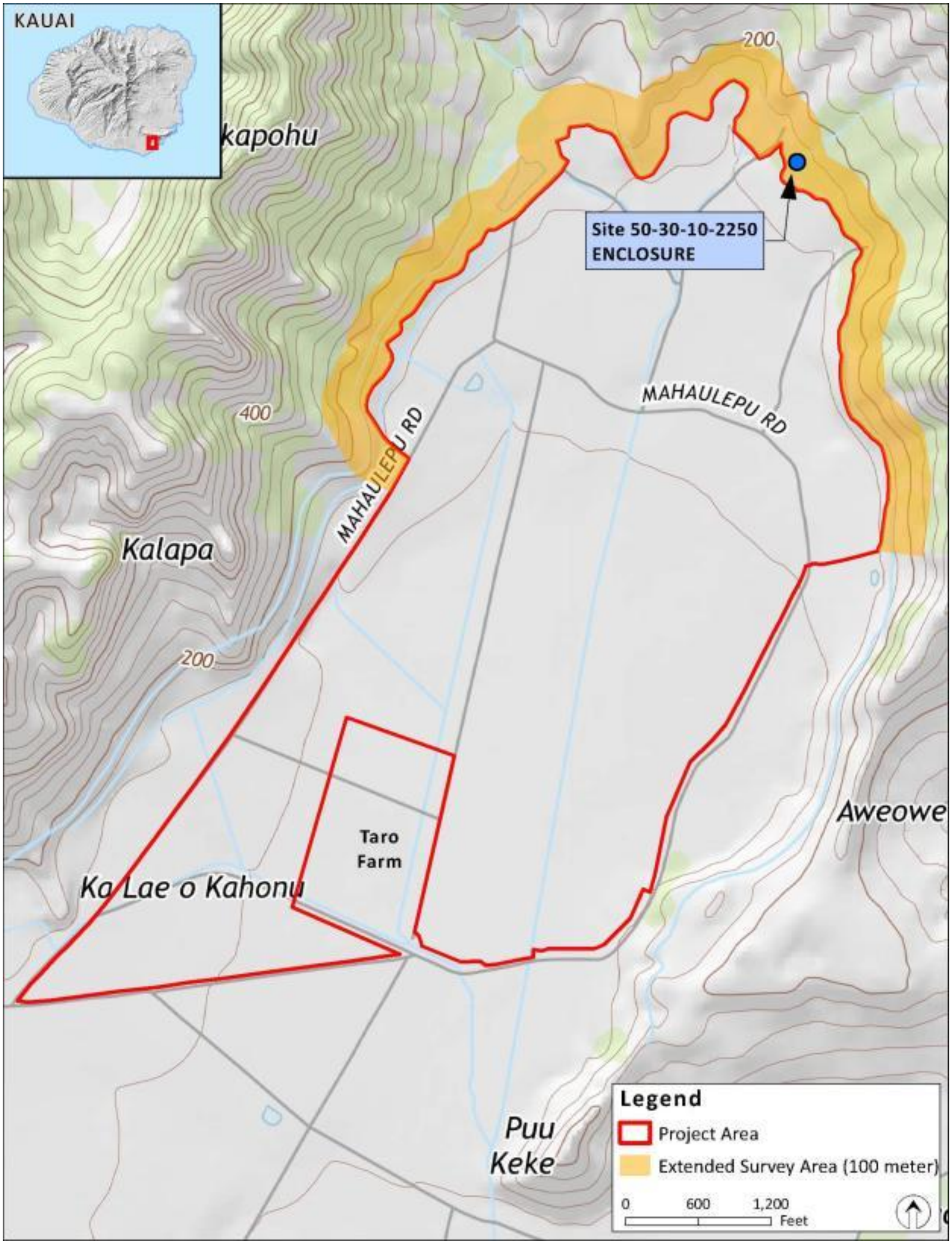

Figure 19. Portion of USGS 7.5-minute series topographical map (2013) showing location of Site - 2250 (outside project area).

Plan View of Site 50-30-10-2250

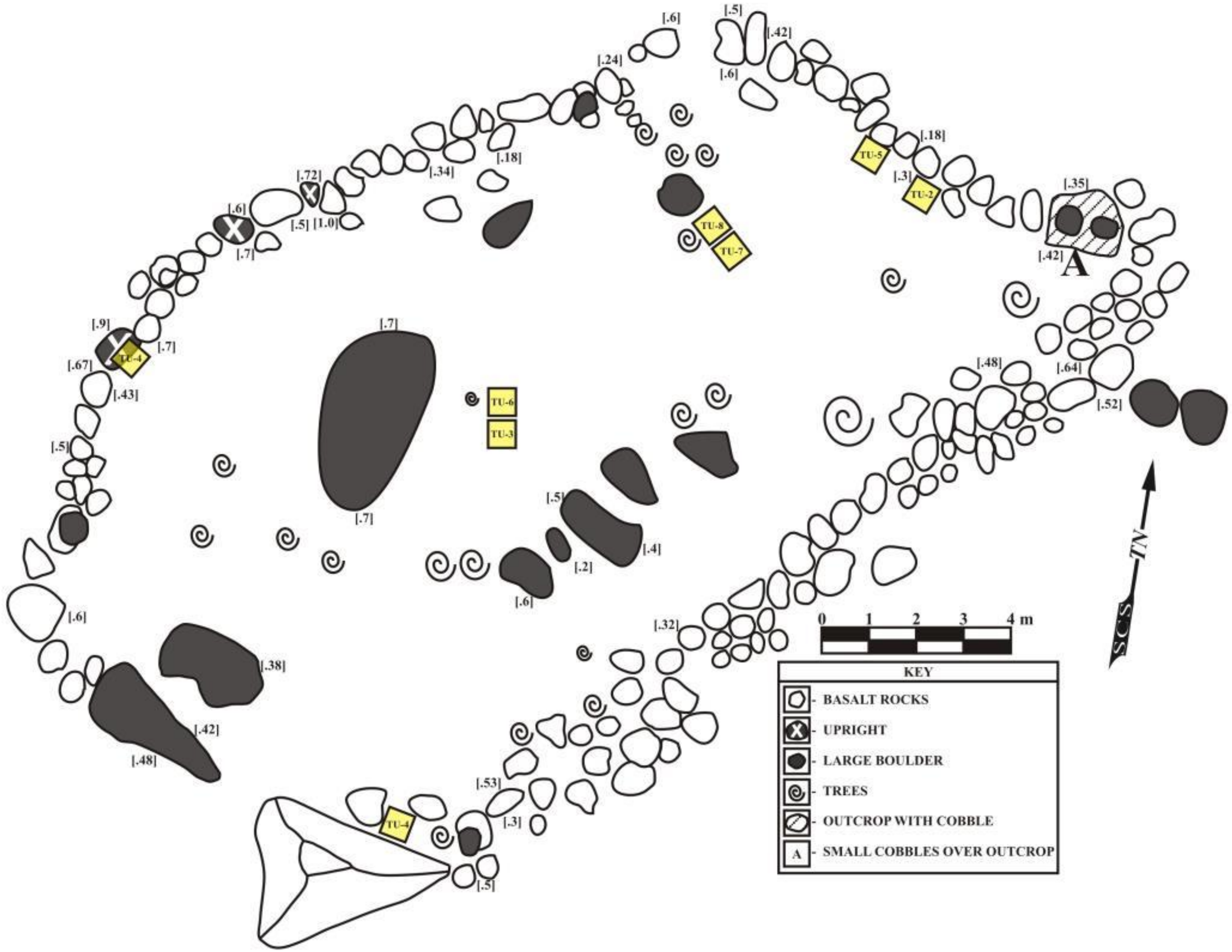

Figure 20. Plan view of Site -2250.

Figure 21. Site -2250. View to south.

Figure 22. Site -2250. View to west.

Figure 23. Site -2250. Note uprights in construction. View to west.

No cultural materials of any era were identified within the enclosure, its walls, or outside the enclosure. Given the size and shape of the site, its proximity to Māhā'ulepū Stream, its placement at the head of the valley, and the southern commanding view over the valley itself, the site was initially interpreted as either a large *hale* or an agricultural *heiau*. The site did not appear to be a traditional residence as these were most often multi-structural affairs spread over the landscape. None were found nearby. The site was also defined with each wall built in a different, distinct manner, with many upright boulders being incorporated into wall construction. Testing was conducted to confirm or modify initial interpretations of the site.

Testing

A total of eight test units (TU) were shovel excavated within the Site -2250 enclosure, with a ninth unit excavated 20 m to the northwest. Testing was completed in two phases, with 4 units being completed at the start of the survey and 5 units toward the end of the study. SCS consulted with the SHPD on all the excavation work, discussing the lack of cultural data recovered from the first few units, and agreeing to add several more units to Site -2250 in an effort to obtain more information about the feature, as its function was still in question.

Shovel Test Units 1 and 2 were excavated during the initial field work in July, 2014 with the remainder excavated during the additional efforts in August, 2014. The large number of test units was necessary given initial site interpretations (significant site) and second, the lack of findings in the first few test units. Testing aided in refining the site function determination.

TU-1 measured 0.5 m by 0.5 m and was excavated to a depth of 0.38 m below ground surface (Figure 24). The unit was placed along the interior of the west wall, south of the corner where the wall turns from the northwest to the northeast. This corner is defined by two upright boulders north of the corner and one upright boulder south of the corner. The unit was placed along the base of the upright boulder south of the corner. Two strata were present in TU-1: Layer I (0-0.30 mbs) was composed of dark brown (10YR3/4) silty clay. Layer II (0.30-0.38 mbs) consisted of a layer of gravel and cobbles, with silty clay between them. Excavation ceased after exposing the surface of a deposit of small sub-angular basalt cobbles and gravels. The goal was to keep it intact to assess the presence/absence of other possible pavements at the same depth in the enclosure. Layer II represented a paving and/or a foundation for the upright and the west wall. No cultural materials were observed in the unit.

TU-2 measured 0.5 m by 0.5 m and was excavated to a depth of 0.3 m below the ground surface (Figure 25). This unit was placed midway along the length of the interior, north wall. The north wall is an alignment of small boulders with one cobble extending south into the interior of the enclosure. TU-2 was placed with the boulders of the wall to the north and the cobble to the east. Excavation extended to a depth below the boulders to determine the presence of any cultural materials, particularly charcoal to date site construction. One stratum was present in TU-2: Layer I (0-0.3 mbs) was composed of dark brown (10YR3/4) silty clay. Roots and rootlets were common from surface to the base of excavation. No cultural materials were observed.

TU-3 measured 0.7 m by 0.7 m and was excavated to a depth of 0.2 m below the ground surface. This unit was placed at the approximate center of the enclosure. One stratum was present in TU-3: Layer I (0-0.2 mbs) was composed of dark brown (10YR 3/4) silty clay. No evidence of paving or cultural materials were identified in the unit.

TU-4 measured 1.0 m by1.0 m and was excavated to a depth of 0.34 m below the ground surface. This unit was placed along the interior base of the large, pyramidal-shaped rock that forms the south corner of the enclosure (Figure 26). It was theorized that placement of the unit here would expose a possible “backstop” or location where midden/artifacts could have been culturally or naturally deposited. Large *in situ* boulders rendered the unit smaller so that by the base of excavation there was little soil to excavate. One stratum was present in TU-4: Layer I (0-0.32 mbs) was composed of dark brown (10YR 3/4) silty clay. Roots and rootlets were common from surface to the base of excavation. Clastics were not common but increased in frequency with depth. They represent natural deposits and were not representative of a paving or cultural formation. No cultural materials were observed in the unit.

TU-5 measured 0.7 m by 0.7 m and was excavated to a depth of 0.59 m below the ground surface (Figure 27 and Figure 28). This unit was placed along the interior of the north wall, approximately 0.7 m to the west of TU-2. Three strata were present in the unit. Layer I (0-0.07 m) consisted of dark reddish brown (2.5YR 3/3) silty clay. Layer II (0.07-0.29 m) was composed of reddish grey (5YR 5/2) silty clay with many cobbles and gravels. This layer was interpreted as a possible paving and/or a foundation for the north wall. Continuing below the cobbles and gravels was natural sediment, Layer III (0.29-0.59 m) composed of reddish brown (5YR 5/4) silty clay. Unlike the nearby TU-2, no roots were present. No cultural materials were observed in the unit.

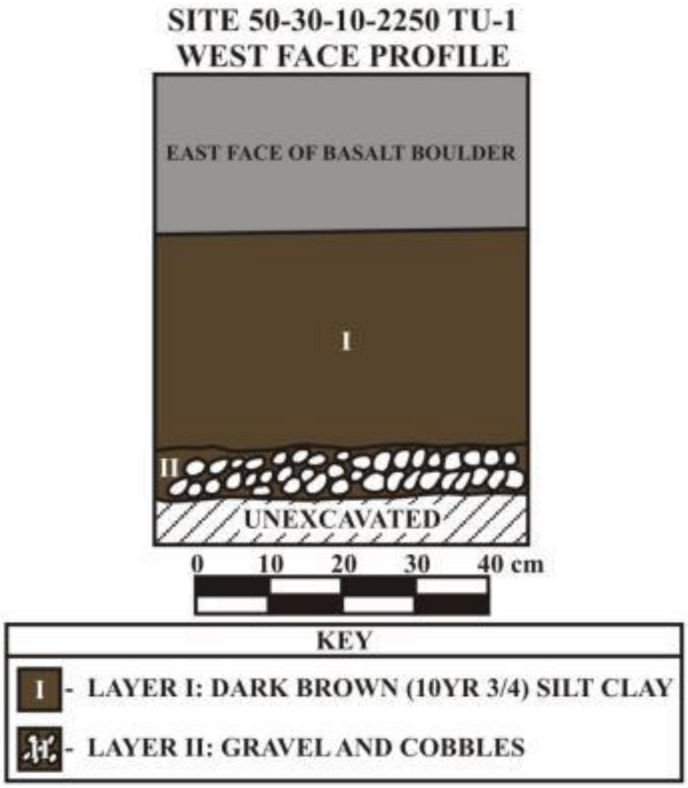

Figure 24. Site -2250, TU-1 profile. West face.

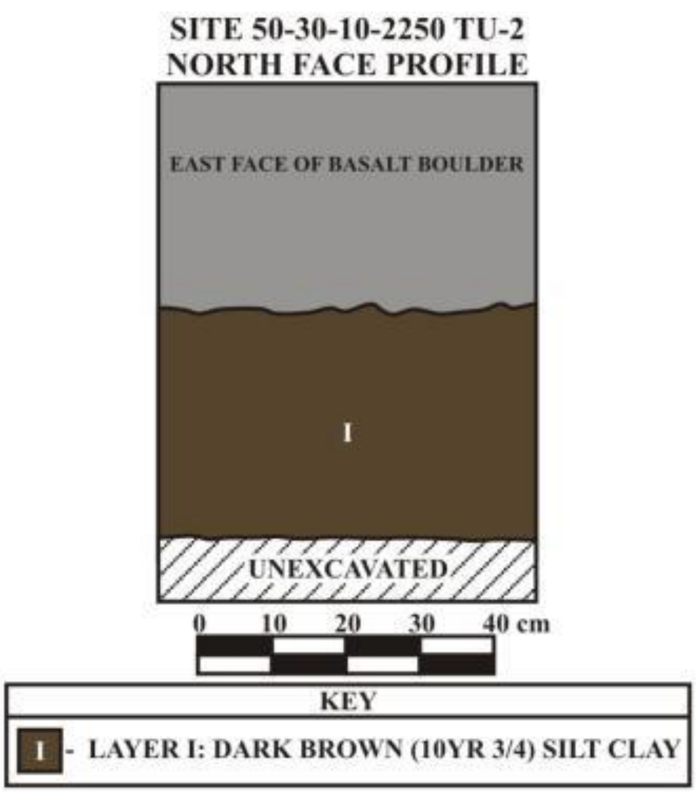

Figure 25. Site -2250, TU-2 profile. North face.

TU-6 measured 0.7 m by 0.7 m and was excavated to a depth of 0.2 m below the ground surface. This unit was placed adjacent to TU-3 at the center of the enclosure. The surface of the boulder found in TU-3 was entirely exposed. The rock's diameter measured 0.7 m and was interpreted as an isolated, natural stone. One stratum was present in TU-6: Layer I (0-0.2 mbs) was composed of dark brown (10YR 3/4) silty clay. No evidence of paving cobbles and no cultural materials were observed in the unit.

TU-7 measured 0.5 m by 0.6 m and was excavated to a depth of 0.2 m below the ground surface. This unit was placed within the interior of the enclosure approximately 5.0 m south of the passageway at the northern corner. TU-7 was placed 6.0 m north of TU-3 and 3.0 m south of TU-5. One stratum was present in TU-7: Layer I (0-0.2 mbs) was composed of dark brown (10YR 3/4) silty clay. Roots and rootlets were common from surface to the base of excavation. No evidence of paving cobbles and no cultural materials were observed.

TU-8 measured 0.4 m by 0.4 m and was excavated to a depth of 0.3 m below the ground surface. This unit was placed to the north of TU-7. Excavation exposed the surface of a deposit of small, sub-angular basalt cobbles and gravels. These were originally thought to represent a paving such as was exposed in TU-2 and TU-5. However, TU-8 is not adjacent to any wall and the stones appear to represent a natural deposition. One stratum was present in TU-8: Layer I (0-0.3 mbs) was a dark brown (10YR 3/4) silty clay. No roots were present here, as compared to the nearby TU-7. No cultural materials were observed in the unit.

TU-9 measured 0.70 m by 0.70 m and was excavated to a depth of 0.20 m below the ground surface and ceased on bedrock. This unit was placed 20 m to the northwest of the enclosure and contained only one layer, dark brown (10YR 3/4) silty clay (see TU-7 for a representative profile, they are identical to TU-9). The unit was excavated amidst a scattering of large and small boulders to assess if they were natural or an extension of the -2250 enclosure. At 0.17 m below ground surface, a small cobble-sized basalt chopper was recovered (Figure 29). The basalt tool has a fractured end, which may have been a deliberately formed edge. There are no signs of pecking or flaking, and no signs of wear, but it may have been a tool formed specifically for one task and then discarded. No other cultural materials were observed in the unit. The scattered boulder area was determined not to be an extension of the enclosure itself, even though one artifact was present. The rocks were misaligned and did not connect to the enclosure. These rocks were also not a separate site; only the presence of the isolated artifact shows cultural use of the area.

Figure 26. TU-4 location. View to south.

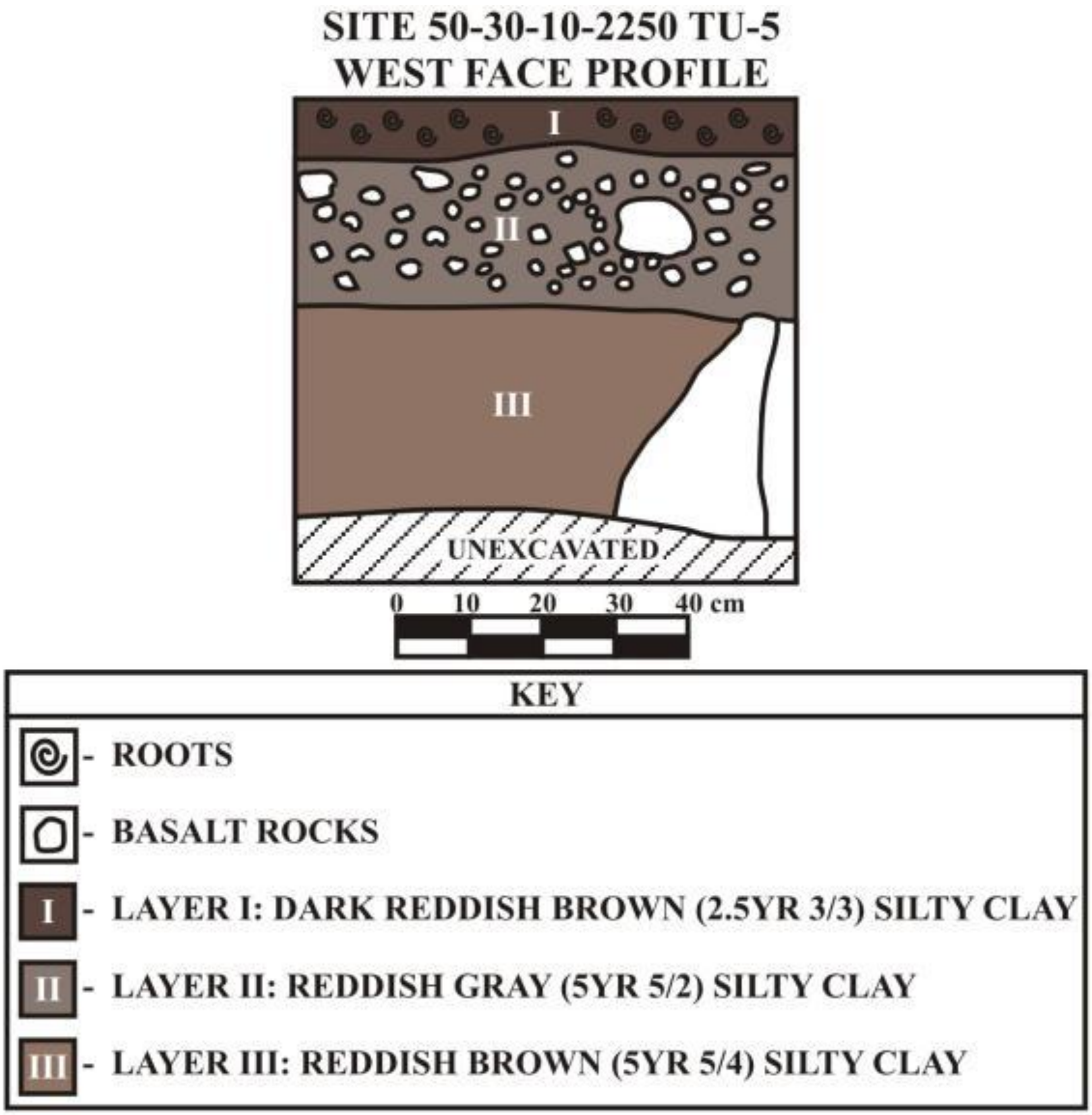

Figure 27. Site -2250, TU-5 profile. West face.

Figure 28. TU-5 at base of excavation. View to west.

Figure 29. Chopper tool from TU-9. Note: this artifact was taken back to the site in February, 2015 and placed in the same location where it was discovered.

Results of Testing

A total of eight test units were excavated within the Site -2250 enclosure, with a ninth unit excavated 20 m to the northwest. No cultural materials were observed in any of the test units within the enclosure; the only discovery was a single chopping tool found in TU-9, outside the site. TU-1, placed against the interior of the west wall and at the base of an upright basalt boulder, and TU-5, placed against the interior of the north wall, both exposed a deposit of sub-angular basalt cobbles and gravels that is interpreted as a paving, a foundation for their respective walls, or a combination of both. TU-8, placed approximately 5.0 m south of the entrance at the north corner of the enclosure exposed a similar deposit. TU-2 was placed along the interior of the north wall, but did not expose this cobble and gravel deposit. TU-4, TU-7, and TU-9 did not expose the cobble and gravel deposit. TU-3 and TU-6 together exposed the flat surface of a boulder, but it was determined to be a natural occurrence. Excavation of TU-4 was halted due to tightly packed naturally-deposited boulders.

TU-9, excavated 20 m from the enclosure proper, along what initially appears to be a connected alignment, yielded the only associated artifact, a small, smooth, oblong basalt cobble that could have been utilized as a chopper. The artifact is composed of fine-grained basalt and measures 16 cm long by 15 cm wide. It is fractured on one end and rounded on the other end, with smooth flanks. The artifact was found in TU-9, directly below a large boulder. The extended alignment was later interpreted to be a natural feature; the alignment was not proven to link with the enclosure in any way after the area was cleared. The artifact is considered to be an isolated find and was repatriated to its place of origin during a community fieldtrip in February, 2015. There is no definitive relationship between the single stone tool and the Site -2250 main structure. Instead, it appears to be an isolated find- no artifacts were found in the enclosure on the surface or in any of the 8 test units.

The site is interpreted as an agricultural *heiau*. The enclosure is large (180 m sq.), with single-course, well-constructed walls that are in excellent condition. In planview, the enclosure is rectilinear and the four corners are at the cardinal directions. There is a formal passageway at the north corner of the structure. One very large boulder forms the corner of the east and south walls, and several large boulders form the south wall, which faces into Māhā'ulepū Valley. There are no surface features within the enclosure but there are several large boulders. The ground within the enclosure is flat with a slightly descending slope to the south. Trees are scattered throughout the site area, including a grove of *hau* trees to the southwest. The interior of *heiau* were often paved, but the extent of the paving varied. The absence of cultural materials in all of the test units suggests that this structure was not associated with the everyday tasks attributed to a *kau hale* or habitation complex. The uprights appear to distinguish this site even more.

STATE SITE NO. 50-30-10-2251 (TS-2)

Site -2251 is composed of two plantation-era features, both in fair condition. This site occurs in the extended survey area. Feature 1 is a sugar cane irrigation ditch approximately 2.0 m wide and ranging from 0.5 m to 1.5 m deep (Figure 30). The feature is approximately 800 meters long and extends along, and just above, the base of the northern survey area slope. The feature alternates between being covered by high grasses and also passing through and along the edge of the tree line. The ditch passes south and west of -2250 (enclosure) and terminates at the streambed which forms the eastern side of -2252 (ditch, sluice gates).

Feature 2 consists of a plantation-era sluice gate directly affiliated with Feature 1 (Figure 31). This feature occurs in the extended survey area and is located 25 m southeast of the -2250 enclosure and is built on the southern side of the main ditch. The gate is composed of an upright, concrete slab measuring 1.5 m long by 0.06 m thick. The exterior face is 0.75 m high but the interior is 0.20 m high, the latter portion obscured by the main ditch filling with eroded and water-born soils and detritus. The concrete slab has an interior slot on its top that contains an iron door for the gate. Basalt cobbles are aligned along the interior of the ditch on either side of the concrete. Approximately 1.0 m east of the gate, on both sides of the ditch, are two retaining components built of metal posts and sheet metal. These components worked in conjunction with the main gate. Neither the ditch nor the sluice gate have been maintained for some time.

Figure 30. Site -2251, Feature 1 ditch and Feature 2 sluice gate. View to southeast.

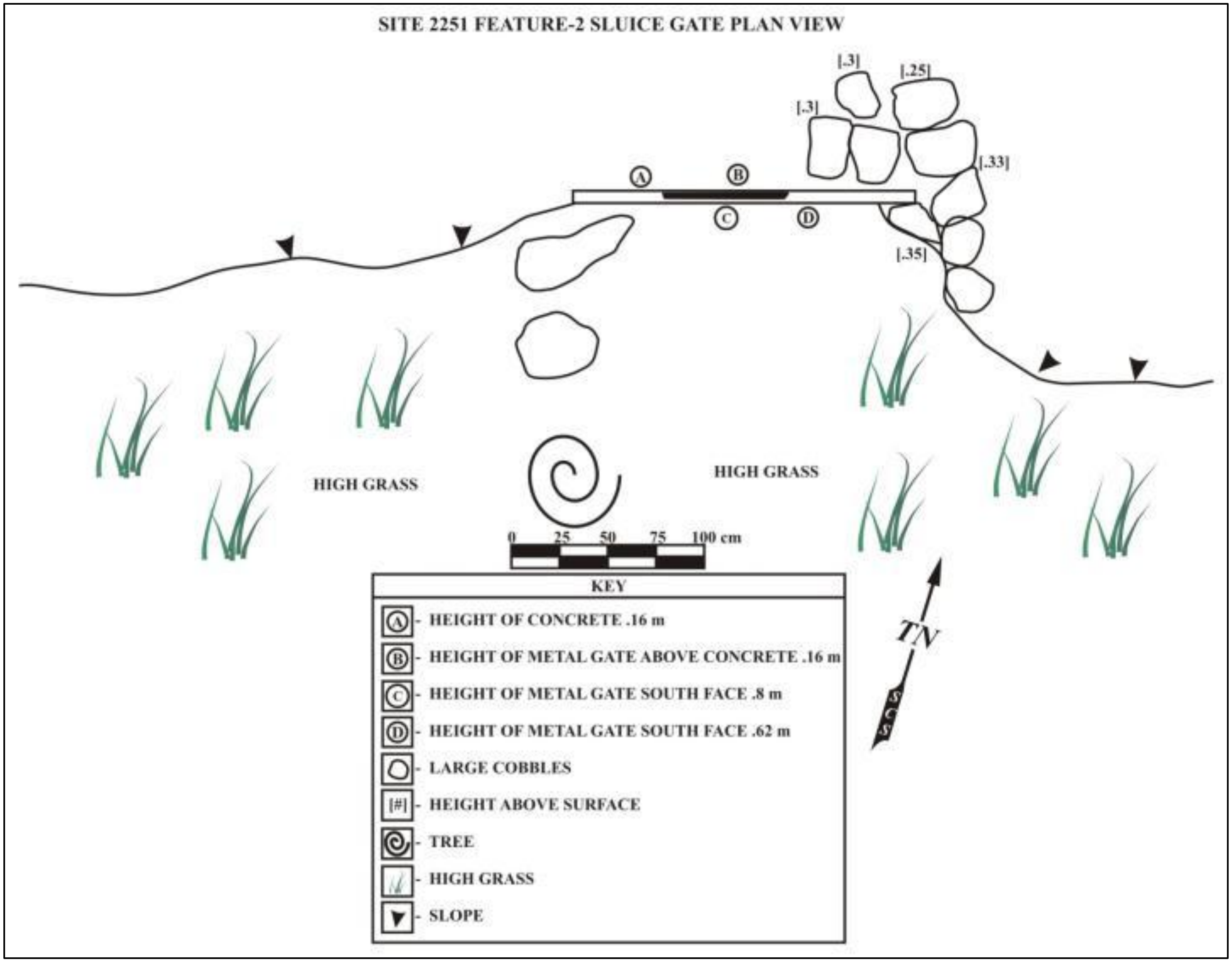

Figure 31. Plan view of Site -2251, Feature 2 sluice gate.

STATE SITE NO. 50-30-10-2252 (TS-3)

Site -2252 is composed of three historic irrigation features, all directly related to sugar cane production (see Figure 17). The site occurs in the extended survey area. Feature 1 consists of an irrigation ditch measuring approximately 2.0 m wide and is a variable 1.0 m to 1.5 m deep (Figure 33). This ditch connects to, and is perpendicular with, two southward descending streambeds, which are approximately 100 m apart. Within the valley, these two streams join and form the Main East Ditch. Feature 1 is the same ditch as Site -2251, Feature 1 to the east and Site -2253, to the west. These features received different site numbers as they are non-contiguous in places. The ditch is identifiable but partially collapsed and filled with soil and detritus.

Feature 2 consists of a Plantation era sluice gate, similar to that described above at Site -2251, and having been identified in the southern face of Feature 1 and 30 m east of the western stream (Figure 32). This feature occurs outside the project area. The feature is 70 m west of Feature 3. This feature is in good condition.

Feature 3 consists of another sluice gate outside the project area, which occurs in the south face of Feature 1, 10 m west of the east stream (Figure 34). The feature is 70 m east of Feature 2. This feature is in poor condition: the metal door is missing and the concrete is weathered.


Figure 32. Site -2252, Feature 2 sluice gate. View to northwest.

Figure 33. Site -2252, Feature 1 ditch and Feature 2 sluice gate. View to south.

Figure 34. Site -2252. View to southwest.

STATE SITE NO. 50-30-10-2253 (TS-4)

The site consists of a single feature: a sugar cane Plantation era irrigation ditch that extends west and southwest from the western stream at Site -2252 (Figure 35; see Figure 18 for overview). This site is outside the project area in the extended survey area (see Figure 17). The ditch terminates at Site -2258, Māhā'ulepū Reservoir. The ditch is entirely earthen and measures 2.0 m wide by up to 1.5 m deep. Site -2253 measures approximately 2,007 feet long and is in poor condition, having been neglected and filled with eroding soils and rocks.

STATE SITE NO. 50-30-10-2254 (TS-5)

The site is a single-feature site consisting of a retaining wall that was constructed of dry stacked, sub-angular basalt cobbles and boulders (Figure 36). The site is within the project area (see Figure 17). Site -2254 was built into the east bank of the east stream descending from above Site -2252. Given that the features comprising Site -2255 (Plantation era culvert bridges) occur to both the north and south of -2254, this retaining wall appears to be associated with them in the Plantation era. The retaining wall measures 7.3 m long by 1.8 m high and the visible ground surface width is up to 1.0 meter. The wall is 6 to 8 courses high, two courses wide, and was built of cobbles on an earthen bench, the latter being a remnant of the original stream bank and bed. This bench or terrace extends 4.0 m north and 4.0 m south from the ends of the wall (Figure 37). The bench extends 1.0 m out from the base of the wall. Both upstream and downstream from Site -2254, the sides of the stream have been intentionally excavated so as to make them nearly vertical. Such modifications did not occur at the Site -2254 locale as the wall has kept the slope vertical through time. No artifacts were present within the wall. Also, there was no concrete or coral-based mortar used in the construction of the wall. The short wall segment is in fair condition.

Figure 35. Site -2253 ditch. View to east.

Figure 36. Site -2254 retaining wall. View to east.

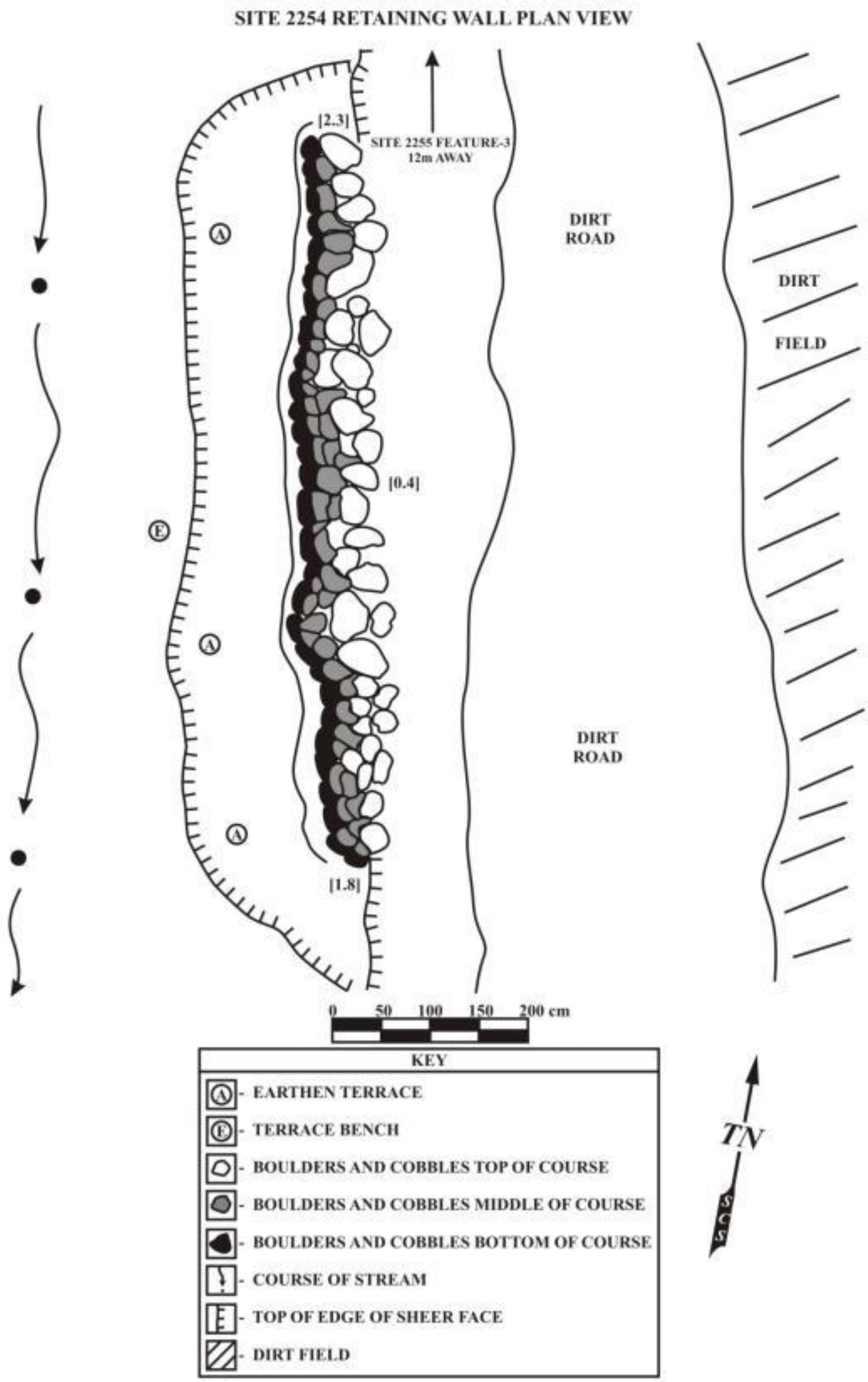

Figure 37. Plan view of Site -2254 retaining wall.

STATE SITE NO. 50-30-10-2255 (TS-6)

Site -2255 is composed of four (4) culvert bridges crossing over the east stream that descends from above Site -2252 (see Figure 17). These culverts were designated as Features 1, 2, 3, and 4, with Feature 1 being the most northern of the group. Features 1 and 2 are present to the north of Site -2254 (retaining wall) and Features 3 and 4 are south of the wall. Site -2255 occurs in the project area. Jim Garmatz, Hawaii Dairy Farms Manager, stated that these culverts were completely rebuilt in 2014 (personal communication, Dec. 2016).

Each culvert was constructed in the same way. A corrugated metal pipe, measuring 1.3 m in diameter, was placed directly at the base of the ditch. Packed earth extends from each bank to the pipe, to a height of 0.50 m, with the remainder composed of small boulder-sized, quarried basalt.

Feature 1 measures 6.5 m north-south by 6.0 m and is 2.0 m high from the road surface to the base of the ditch (Figures 36 through 40). The bridge's long axis is 340 degrees T. From the southwest corner of Feature 1 to the southeast corner of Feature 2, the distance is 52 m.

Feature 2 measures 5.8 m east-west by 4.5 m north-south and is 2.4 m high from road surface to the base of the ditch (see Figure 39). The bridge long axis is 90 degrees T.

Feature 3 measures 6.1 m east-west by 5.8 m north-south and it is 2.4 m high from road surface to the base of the ditch (see Figure 42). The bridge long axis is 90 degrees T. Feature 3 is located 44 m from Feature 4.

Feature 4 measures 6.0 m east-west by 5.6 m north-south and it is 2.9 m high from road surface to the base of the ditch (see Figure 42). The bridge's long axis is 90 degrees T. Feature 4 is approximately 25 m north of the junction of the two streams that pass to either side of Site -2252 (ditch, sluice gates).

Figure 38. Site -2254 retaining wall and Site -2255, Feature 1 (culvert). View to north.

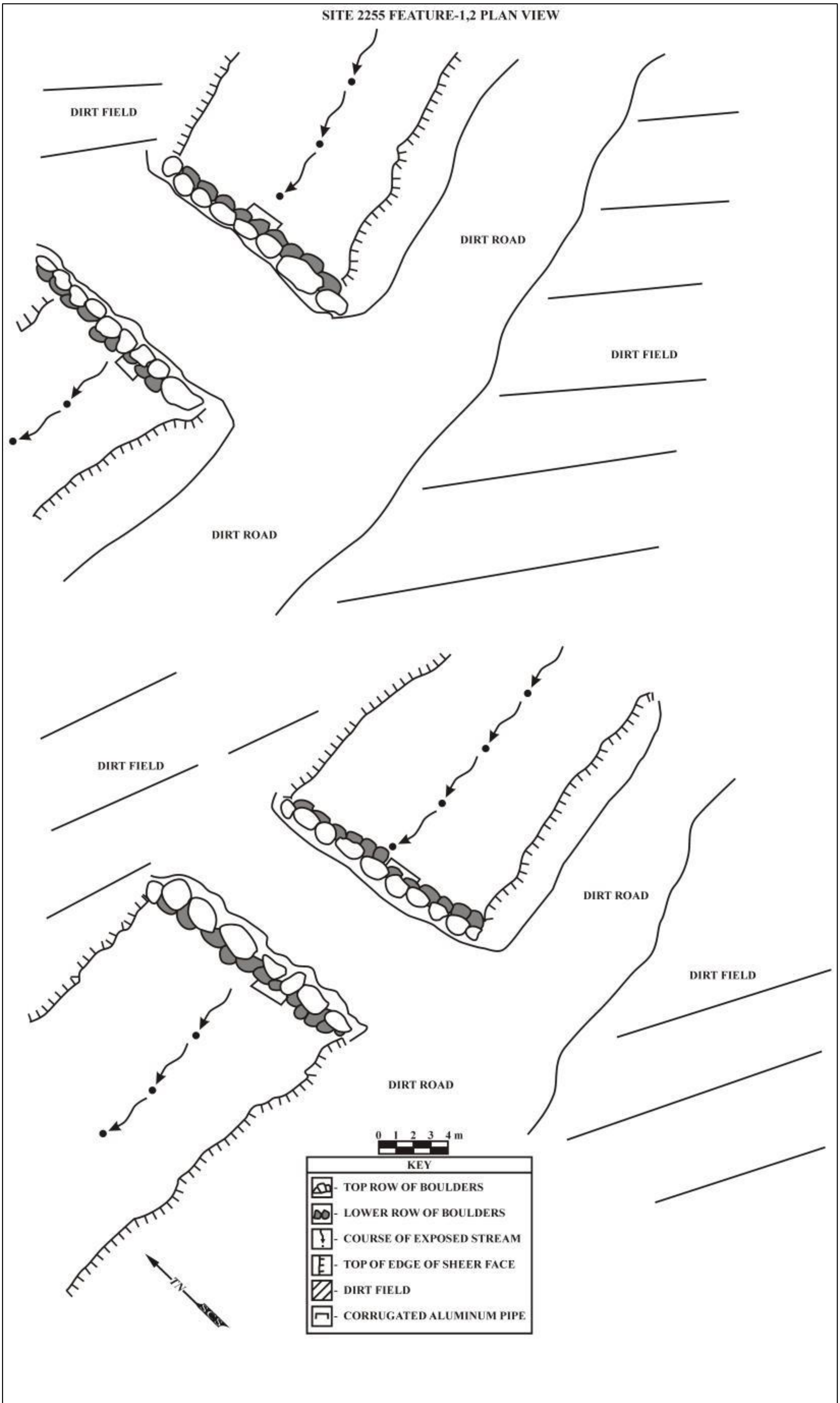

Figure 39. Plan view of Site -2255, Features 1 (top) and 2 (bottom).

Figure 40. Site -2255, Feature 3 culvert. View to north. Representative example of all four culvert features rebuilt in 2014.

Figure 41. Site -2255 Feature 3 culvert. View to south. Representative example of all four culvert features rebuilt in 2014.

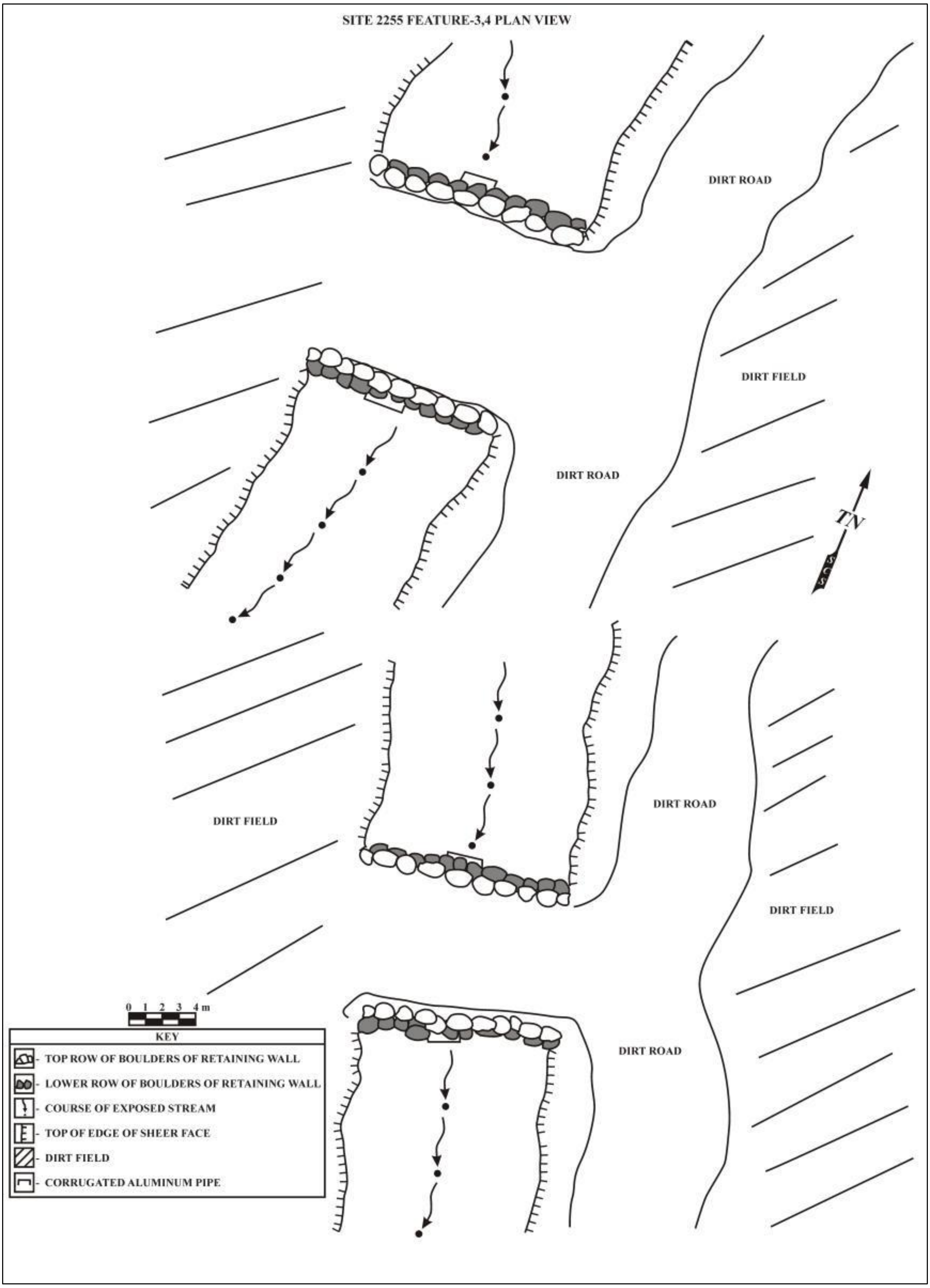

Figure 42. Plan view of Site -2255, Features 3 (top) and 4 (bottom).

STATE SITE NO. 50-30-10-2256 (TS-7)

Site -2256 is composed of a board-formed concrete-decked bridge crossing over the west stream that descends from above Site -2252 (Figure 43; Figure 44). The bridge is located within the project area (see Figure 17). The bridge itself was manufactured of poured and formed concrete, with a 0.2 m raised curb along each edge. The bridge measures 5.3 m north-south by 5.0 m east-west. The height from the top of the curb to the base of the stream is 3.6 m. The long axis of the bridge is 20 degrees T (Figure 45).

Both stream banks have retaining walls supporting the bridge (Figure 46). These are constructed of boulder-sized, quarried basalt and are mortared or cemented together. The wall faces are 3.6 m apart. The base of the west end, of the northern wall is weathered. A surprisingly large tree root is protruding out of the south wall's face. There are no trees remaining on the surface in this area, but there are several dead or cut trees rooted in the stream bed and banks in the immediate vicinity.

The stream bed of the western stream, north and south from the bridge, is deeper and not as modified as the eastern stream. Also, the western stream bed is nearly covered by both water worn basalt and sub-angular basalt. The eastern branch had perhaps 10% of these materials. The eastern branch may have had these materials removed during plantation maintenance. The mix of materials in the west branch suggests that not only was this a flowing stream, but that the other materials may have been pushed into the stream when fields were being cleared. The junction of the two streams is 110 m and 150 degrees from Site -2256.

STATE SITE NO. 50-30-10-2257 (TS-8)

Site -2257, is located within the project area (see Figure 17) and is a retaining wall similar to Site -2254 but not as well preserved (Figure 47). The feature is constructed of dry stacked, sub-angular basalt cobbles and boulders, is 7.5 meters northwest to southeast, as is built into the south bank of the Main East ditch's western stream. The width of the surface is approximately 1.0 m. However, the terminus of the southeastern end has partially collapsed and stacked cobbles and boulders are visible in the collapsed bank, suggesting that the internal width is greater than that of the surface. The retaining wall is 4.0 m tall and composed of up to 6 courses of cobbles and small boulders, extending from ground surface to stream bottom. As with Site -2254, there is a bench or terrace present upon which the wall was built. This short segment also appears to shore up the ditch in this area. It is interpreted to be built during the historic period and is in very poor condition.

Figure 43. View to southeast of Site -2256 bridge.

Figure 44. View to south of bridge deck, Site -2256.

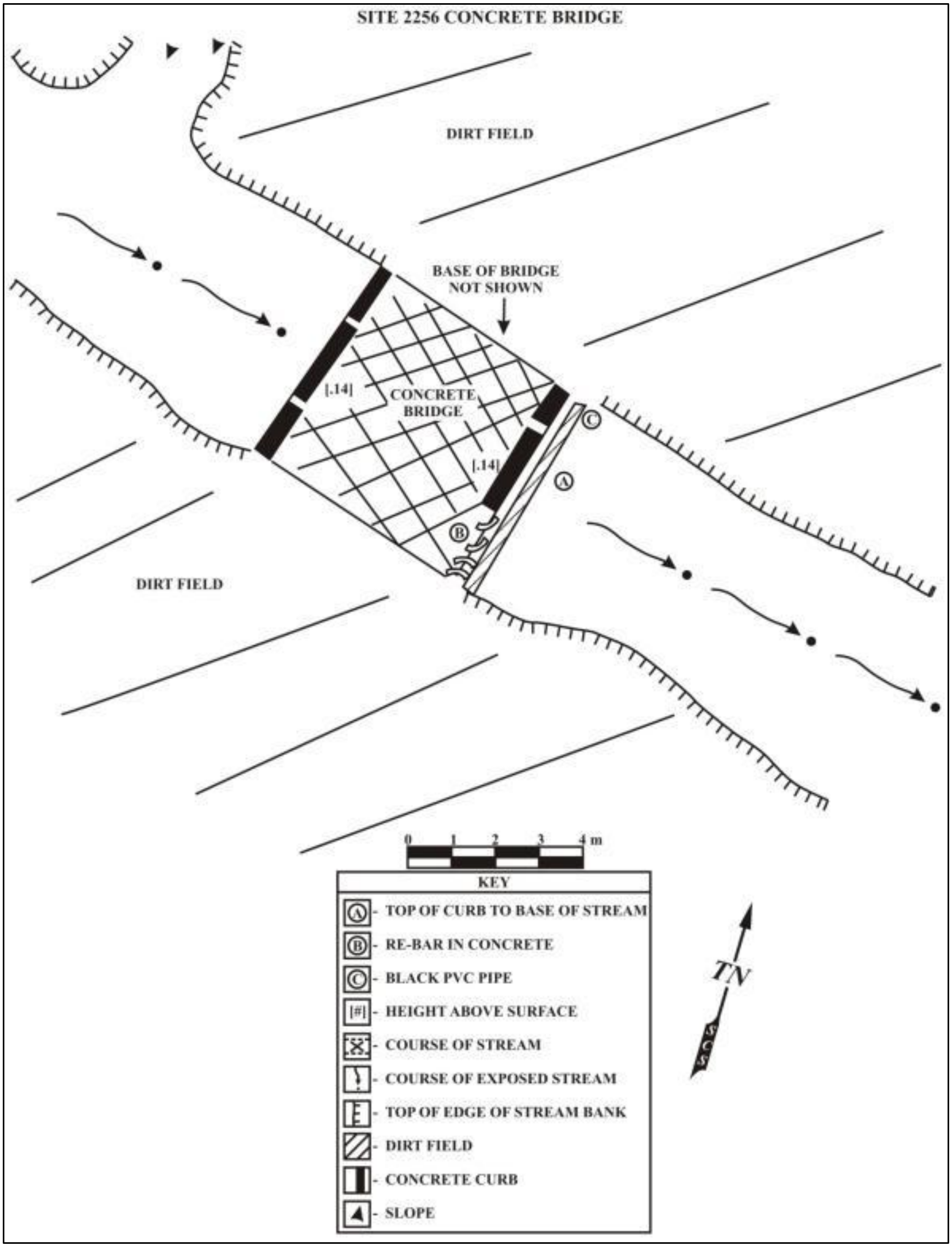

Figure 45. Plan view of Site -2256 bridge concrete deck and floor.

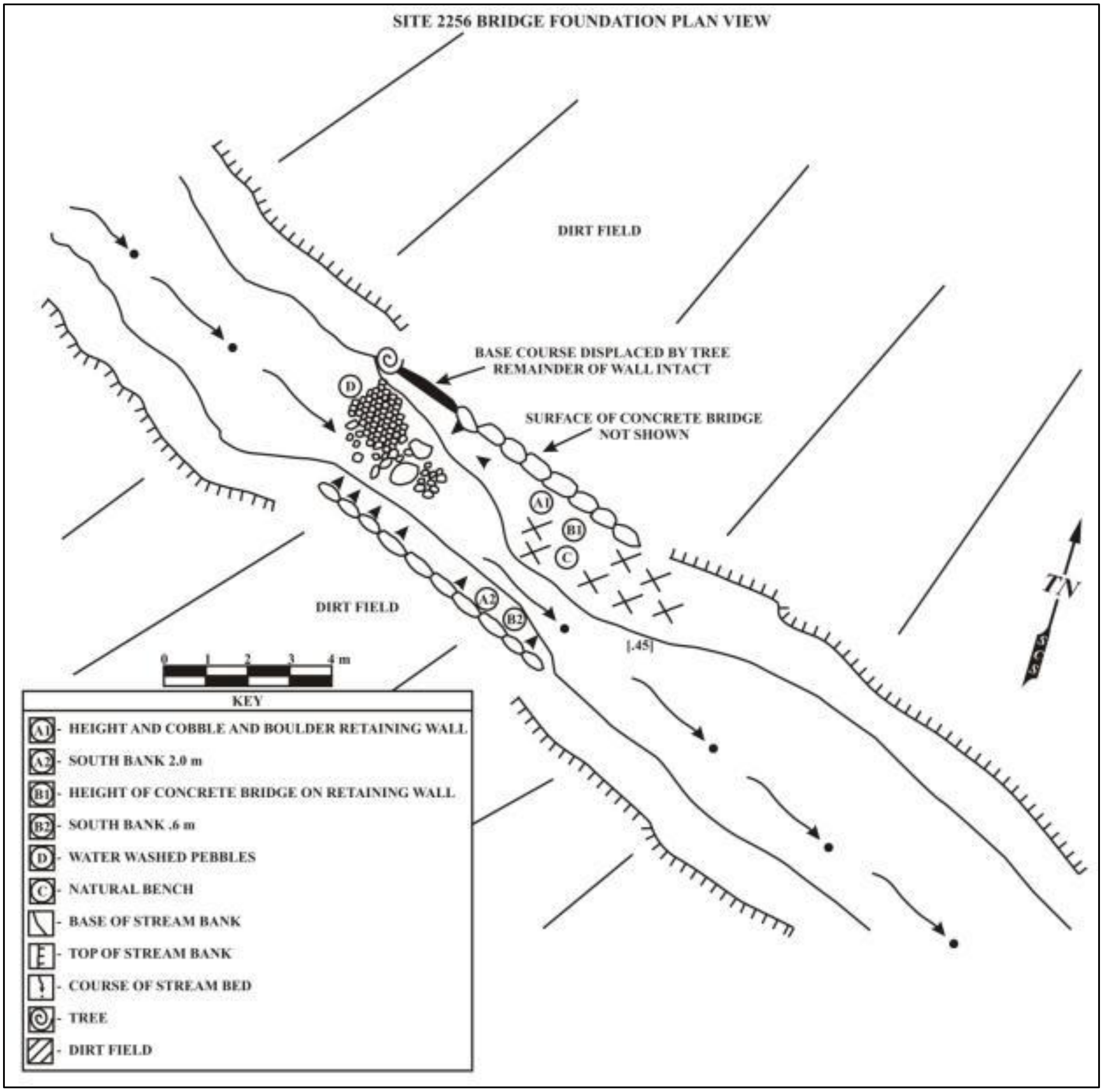

Figure 46. Plan view of Site -2256 bridge retaining walls.

Figure 47. Site -2257 retaining wall remnant. View to southwest.

STATE SITE NO. 50-30-10-2258 (TS-9)

Site -2258 is the Māhā'ulepū Reservoir (Figure 48 and Figure 49). It is located outside of the project area and was built in the 20th century by the Koloa Plantation (see Figure 17). It is unknown if there was a spring at this location. The reservoir is large, measuring about 200 m in diameter. During the time of the field survey in July 2014 the water level appeared low. The south and east sides of the reservoir are bordered by high, long, and wide dikes or levees. The ground level ascends to the north and west and so additions were not required on these sides. A metal catwalk extends from the southern dike into the reservoir. This is part of the irrigation pipe and pump system that releases water into the Main western ditch that feeds the taro fields at the south end of the valley. The base and flanks of the reservoir are all earthen, compacted soil with no physical architecture supporting the flanks. The reservoir is a man-made construction and likely took some time, given its breadth and depth (about 4+ meters). It is not known if the reservoir is at its original size or was expanded through time. The reservoir functioned in concert with the many ditches and irrigation works occurring throughout the valley and documented herein.

STATE SITE NO. 50-30-10-2259 (TS-10)

Site -2259 consists of a Plantation-era irrigation ditch that extends southward from Site -2258 along the base of a slope at the western side of Māhā'ulepū Valley. Site -2259 occurs outside the project area (see Figure 17). The earthen ditch is c. 2 m wide and extends near the northern borders of the survey area (Figure 50). The ditch is similar in design, measurement, and function to Site -2251. The ditch measures 2.0 m wide and the depth varies up to 2.5 m deep. The length of the ditch is approximately 1,020 m (3,323 ft.) and extends south from the reservoir.

STATE SITE NO. 50-30-10-2260 (TS-11)

Site -2260 is located outside the project area (see Figure 17). It is an historic board-formed concrete-deck bridge that crosses over a natural stream that enters Māhā'ulepū Valley from the western ridge (Figure 51). The stream originates between named peaks, Kalaeakohani to the south and Kolopa to the north. Like the streams entering the valley from the north, this watercourse has been modified upon its entrance into the valley. The bridge surface is comprised of two concrete slabs measuring 7.5 m north-south by 3.0 m east-west and are 0.2 m thick. The long axis is oriented at 210 degrees and the slabs have a 0.1 m gap between them. The west side of the bridge is not modified. The east side of the bridge has a concrete curb that extends 6.8 m in length and is 0.31 m wide. The interior height of the bridge is 0.56 m, while the exterior height is 0.89 m. An iron railing is affixed to the top of the curb. This railing appears to be from the narrow gauge railroad that once extended along the southwestern flank of Māhā'ulepū Valley. Within the stream bed, there are remnants of dry stacked basalt cobble retaining walls on the north and south banks of the west side of the bridge. The walls are composed of cobbles and small boulders extending up to 12 courses high. Inscribed on the exterior face of the curb is the date “1951”, with a flourish on the upper bar of the “5” (Figures 49 through 51).

STATE SITE NO. 50-30-10-2261 (TS-12)

Site -2261 is located outside of the project area and consists of a bridge crossing over the Main East ditch at the southern end of the survey area (see Figure 17). It is located along Māhā'ulepū Road. This bridge is unique to the project area in that it shows two distinct phases of construction (Figure 55). The bridge measures 10 meters east-west by 8.5 m north-south, with each style of construction composing approximately half of the bridge.

The northern half of the bridge is a masonry arch bridge, and is constructed of quarried basalt boulders which are mortared into place to form retaining walls on the east and west stream banks, as well as the north and south flanks (Figure 56). The northern side is clearly visible from the fields and road to the north but the southern side must be viewed from within the stream bed. Both of these sides show an artisan's flair in that there is an arch to the bridge that is not seen on any other feature within the valley. On the north edge of the bridge surface there is a concrete curb with a basalt cobble alignment upon it. Inscribed in the surface of the concrete is “July 30, 1908”. There is 0.35 m of gravel and dirt forming the road above the concrete. From road surface to the base of the stream bed measures 2.4 meters.

The southern half of the bridge is of the board-formed concrete-decked type and is constructed entirely of concrete. Concrete retaining walls line both banks of the watercourse. These descend 1.9 m to an extended 0.5 m foundation on the stream bed. On the southern side of the concrete bridge is a concrete curb which is 0.9 m high and extends to the surface of the concrete retaining walls. An iron rail is affixed to its surface, which is similar to that at Site -2260. Clearly, the narrow gauge railroad along the southern portion of the western half of the valley was dismantled. Salvaged materials also were utilized for other plantation projects. On the southern face of the concrete curb there is the inscription “1951”, again with a flair on the upper bar of the 5 (Figure 57). “1951” appears to be the year in which many modifications occurred on the plantation. No other bridge found during the AIS shows such obvious evidence of additional phases of construction.

Figure 48. Site -2258 reservoir. View to southwest.

Figure 49. Site -2258 reservoir. View to north.

Figure 50. Site -2259 ditch. View to west.

Figure 51. Site -2260 bridge showing parapet, railing, and bridge deck. View to northwest.

Figure 52. Site -2260 bridge view of stone parapet and '1951' inscription. View to east.

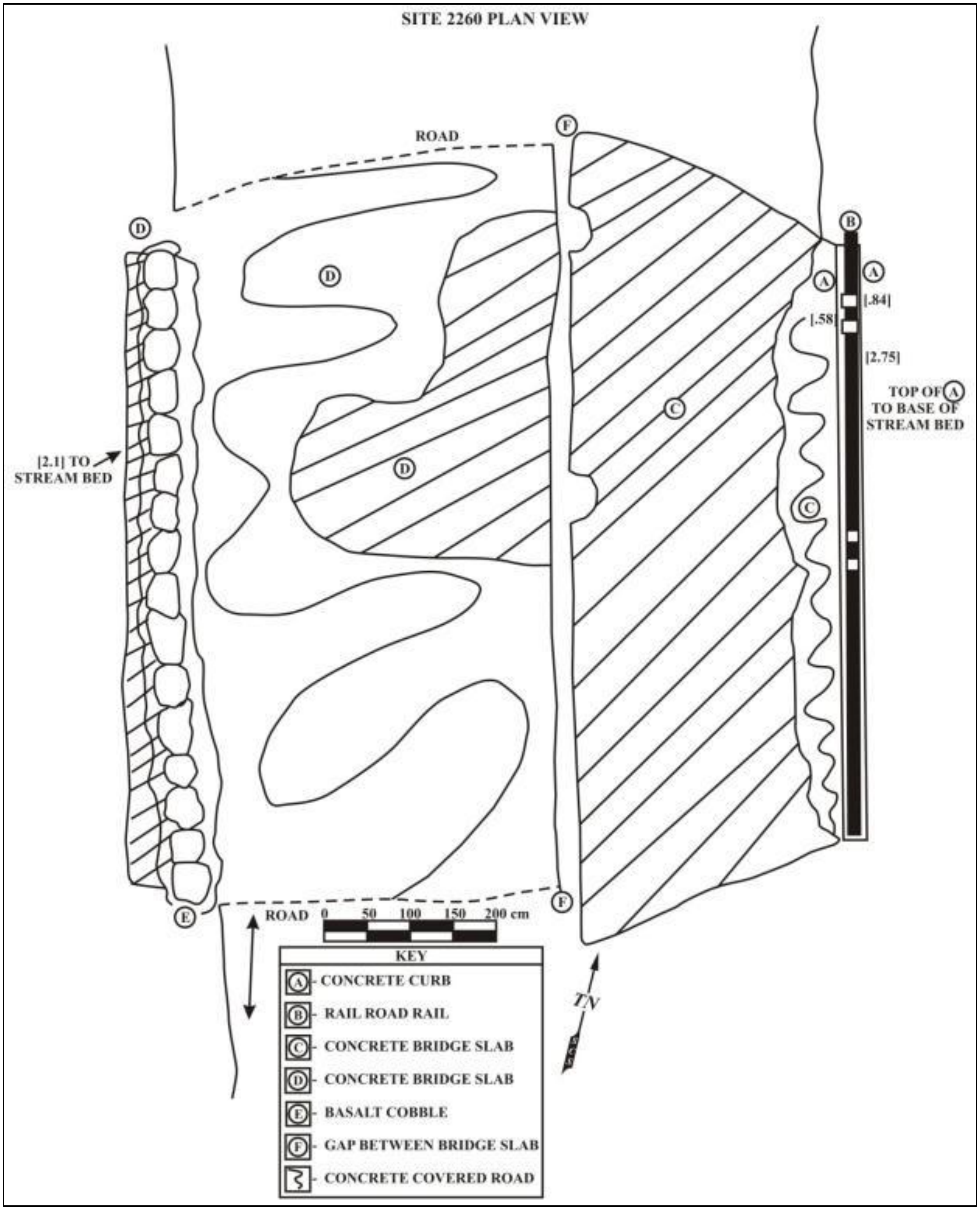

Figure 53. Plan view of Site -2260 bridge.

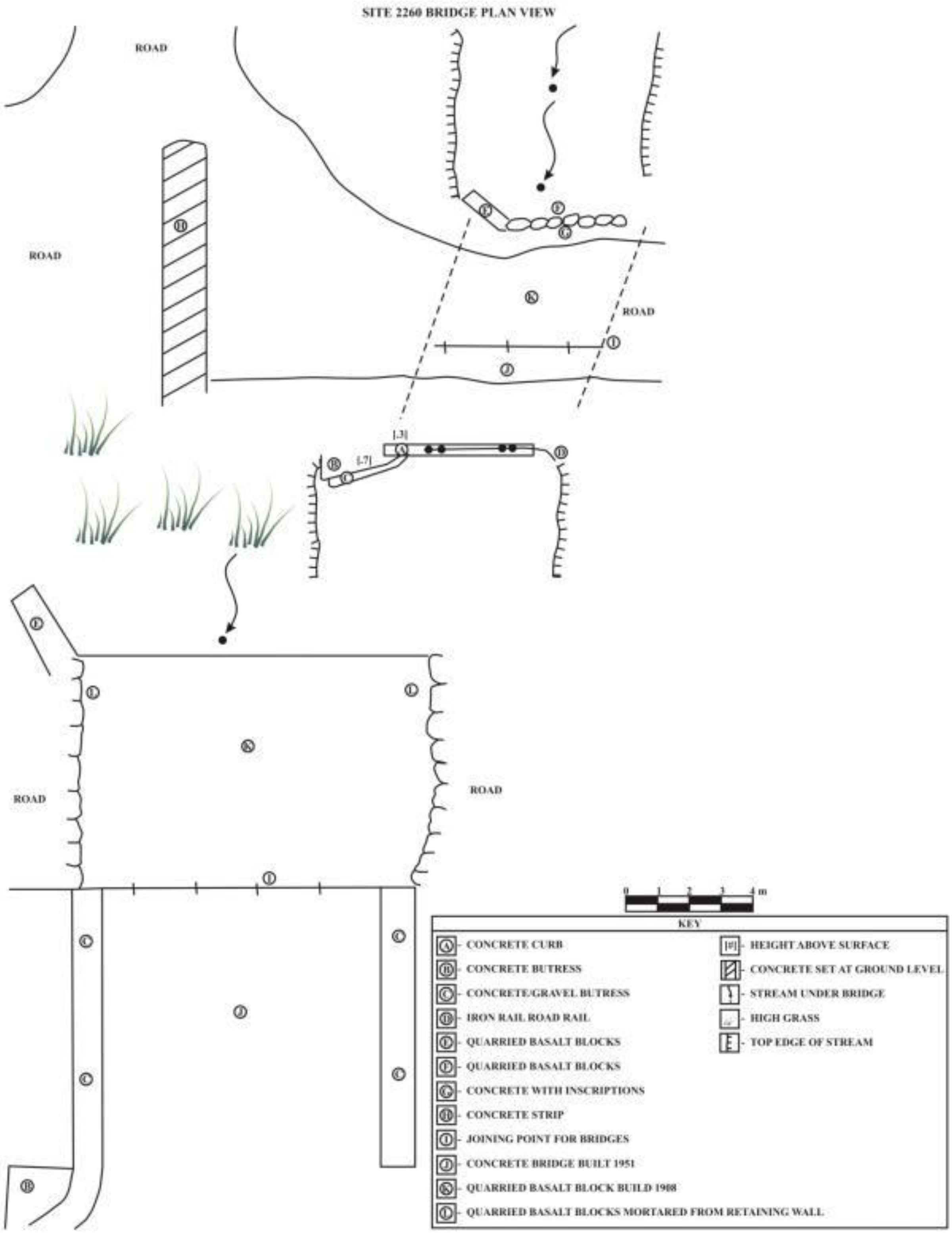

Figure 54. Plan view of Site -2260 bridge.

Figure 55. Site -2261 bridge, showing 1908 section and 1951 section. View to northeast.

Figure 56. Site -2261, ‘1908’ section, view of north parapet. View to north.

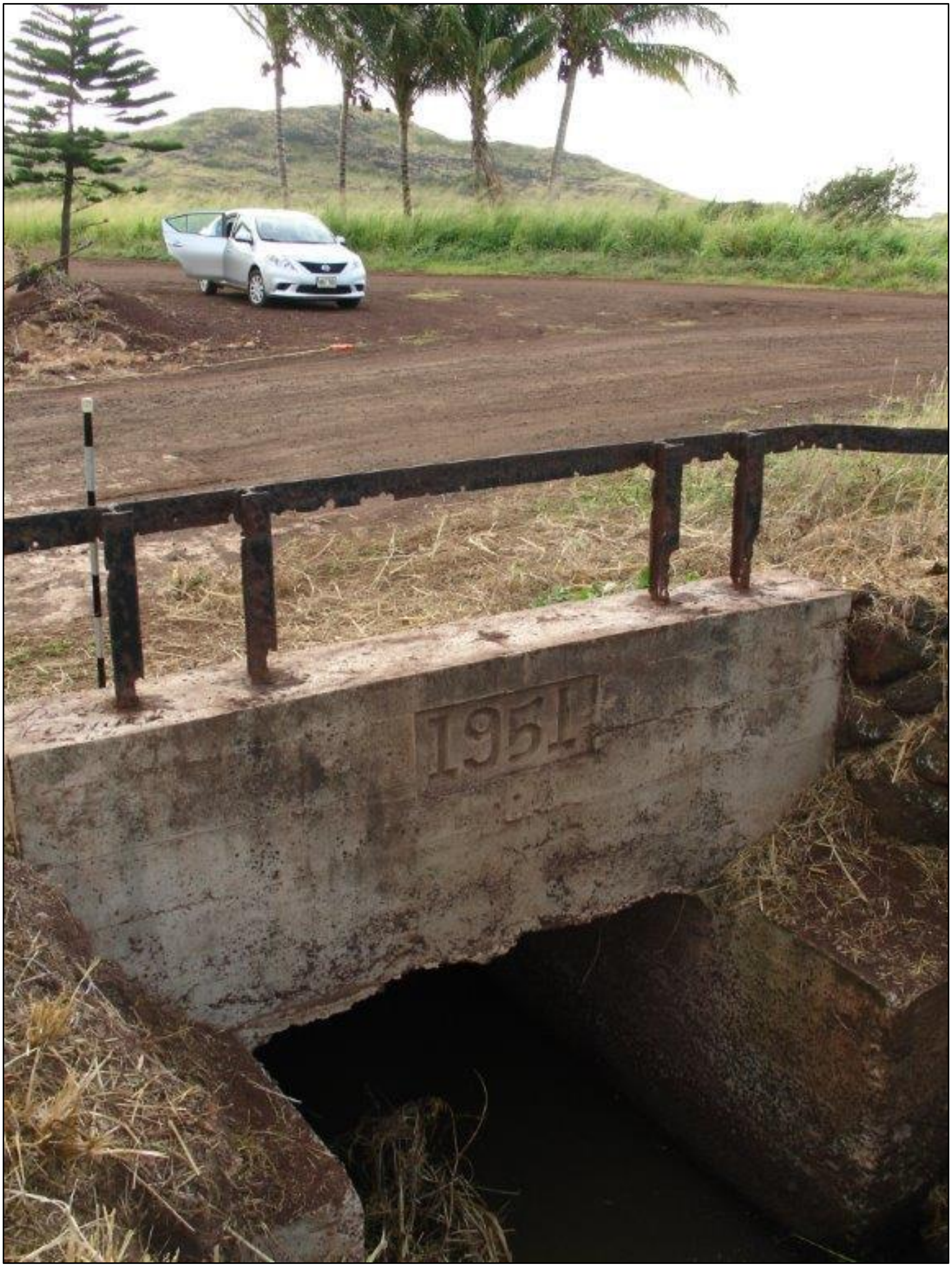

Figure 57. Site -2261 bridge, view of '1951' inscription and parapet. View to northeast.

STATE SITE NO. 50-30-10-2263 (TS-14)

Site -2263 consists of a bridge crossing over the Main East Ditch, located inside the project area on the east-west extent of Māhā'ulepū Road (see Figure 17). The bridge is adjacent to, and northwest of the many LCA awards at the center of the valley. It is a culvert bridge which appears to have been built in stages (Figure 58). The base within the streambed consists of 3 to 4 courses of boulder-sized, quarried basalt which are mortared on either side of a concrete culvert, the latter which measures 1.0 m in diameter. The culvert appears to be younger in origin than the walls to either side. The mortared blocks extend halfway up the side of the concrete culvert. On them are dry stacked, sub-angular, vesicular basalt boulders which extend from 0.5 m to 1.5 m above the stream bed. On top of this are boulders of a similar type which are mortared together and extend from 1.5 m to 2.0 m above the stream bed (Figure 59). Additionally, along the western side of the large culvert are two smaller concrete culverts, one above the other. This culvert bridge appears to have been constructed and provided with additions over time.

STATE SITE NO. 50-30-10-2264 (TS-15)

Site -2264 is located inside the project area. It is the remnant of an irrigation pipe that appears to have crossed over the Main East Ditch, immediately south of the location where the east and west streams that pass Site -2255 join together (see Figure 17). There is a partially collapsed concrete foundation on the east side of the ditch, with a corrugated metal pipe 0.6 m in diameter extending 0.9 m from it (Figure 60). The intact remnant of the concrete foundation measures 2.2 m north-south by 1.0 m east-west and is 0.6 m high. On the far bank, concrete rubble is present. Upstream from this point, the stream beds are dry, but downstream there is an increasing water flow. It is unclear at present if the source of the flow is from the pipe or from a spring within the stream bed.

Figure 58. Site -2263 bridge. View to south.

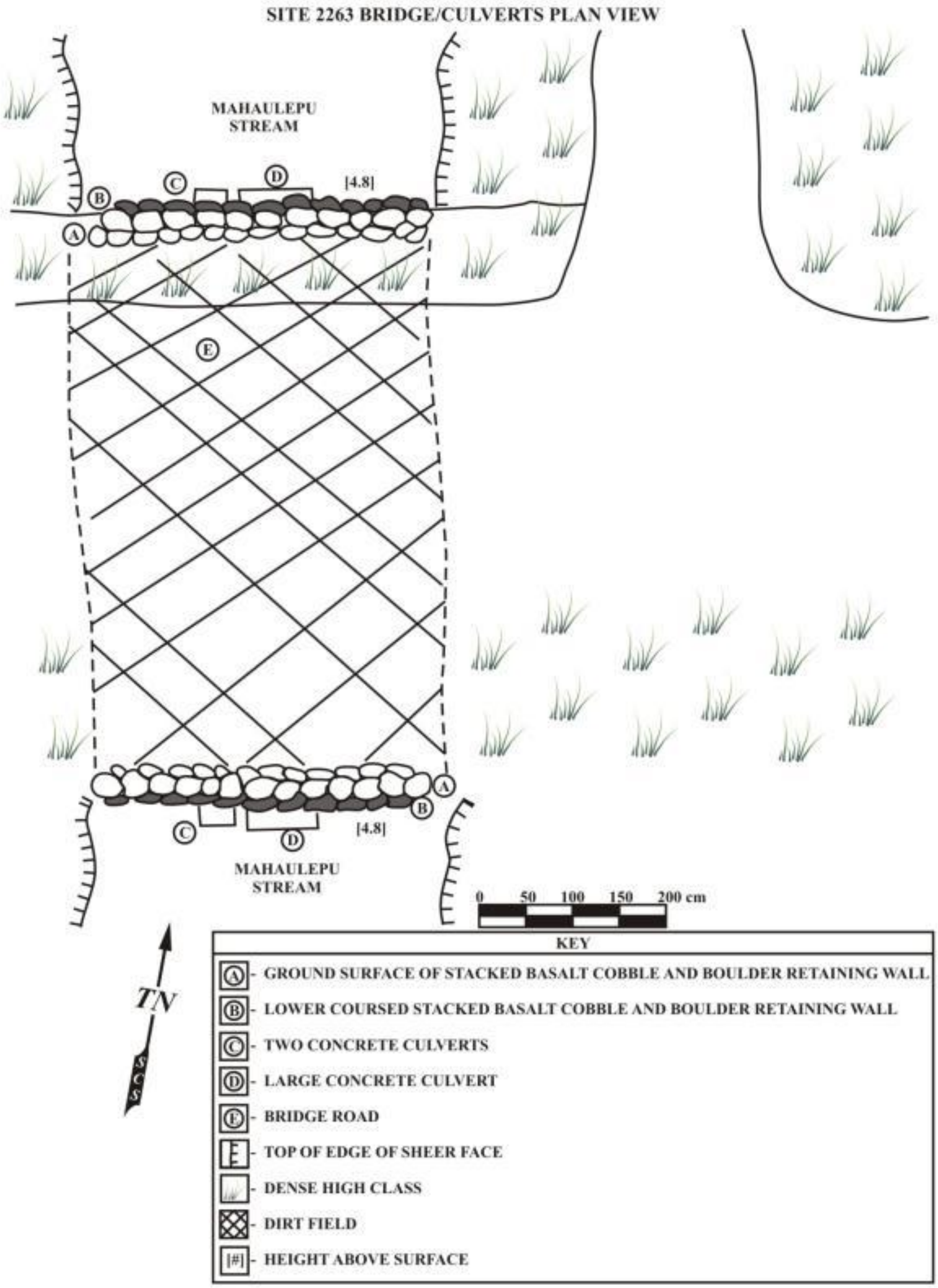

Figure 59. Plan view of Site -2263, retaining walls and culverts.

Figure 60. Site -2264 culvert and pipe. View to northeast.

STATE SITE NO. 50-30-10-2262 (TS-16)

Site -2262, occurring outside the project area (see Figure 17), is composed of three features and was identified in the northwestern portion of Māhā'ulepū Valley (Figure 61). This site was identified during August 2014 sweeps of the extended survey area. Feature 1 consists of a remnant section of an irrigation flume system constructed of concrete foundations, a trestle of wooden beams, a concrete bridge, a concrete wall that extends east and west from the southern end of the bridge, and an open-topped metal culvert (Figure 62 through Figure 68). The overall length of the entire structure is 14.0 m and the overall width is 2.3 meters. The culvert measures 14.0 m long by 1.0 m wide and is 0.5 m deep. The supporting concrete bridge is 14.0 m long by 1.5 m wide and is 0.2 m thick. The southern concrete foundation measures 2.0 m long by 0.45 m wide and is 0.85 m tall. The long axis is oriented east-west. The southern foundation contains a trestle of wooden beams on top that support the base of the concrete bridge. The northern concrete foundation measures 2.3 m long by 0.45 m wide and is 2.5 m tall. The north foundation directly supports the base of the concrete bridge. The base of the concrete bridge is 3.2 m above the base of the irrigation ditch (Site -2253) that the flume crosses over. The ends of the flume are within a stream course which descends from the north into the valley. This stream course eventually braids with the two courses to the east and forms Māhā'ulepū Ditch. Each branch of the concrete wall extending east and west from the south end of the concrete bridge measures 2.0 m long by 0.45 m high and is 0.15 m thick. Feature 2 extends from the eastern flank of the east wall.

Feature 2 is a concrete sluice gate. The overall length is 3.0 m, with the central opening measuring 1.0 m wide. The concrete side walls measure 1.0 m long by 0.45 m tall and are 0.15 m thick. Where the walls face each other, the concrete is grooved vertically, but there is no remnant of a metal or wooden gate. The opening faces east. On top of the south wall "J Torre" is inscribed into the concrete. On top of the north wall is the inscription "1924".

Feature 3 consists of a pair of sluice gates located to the south of, but not contiguous with Feature 2. They are placed at the end of a short ditch extending away from the stream course. The walls of this ditch are paved with concrete. At the gates, there is a central concrete pillar separating the openings, as well as concrete walls extending away from the opening. Basalt cobbles support the exterior of the concrete walls. A narrow gauge railroad rail is incorporated into the top of, but not on top of, both walls and the column. Each gate opening measures 0.6 m wide by 0.9 m tall, from the base of the ditch to the top of column. The column measures 0.2 m on each side and is 0.9 m tall. Each concrete wall measures 0.7 m long by 0.2 m wide by 0.9 m tall. The ends of the concrete walls facing the column and the corresponding faces of the column are grooved vertically but there is no remnant of a metal or wooden gate. Inscribed into the concrete surface of the north wing wall is “Koloa Plantation, April 12/24 By D.S.K.”.

Site -2262 crosses over Site -2253, to the northeast of Site -2258, Māhā'ulepū Reservoir. Site -2253 is an irrigation ditch which terminates at the reservoir on its south end and connects to Site -2252 on its north end. The north and south ends of Site -2262 are within a streambed that descends from the north. Site -2262 was built after the excavation of Site -2253. Site -2262 has multiple functions: to carry stream water over the irrigation ditch and continue its flow into the valley as a source for Māhā'ulepū Ditch. With three mountain born water sources braided together at the north end of the valley floor, the original Māhā'ulepū Stream, later modified to become Māhā'ulepū Ditch, would have been a substantial water course even prior to the sugar cane industry.

The sluice gates of Features 2 and 3 face eastward. Flow from the stream would have emptied into Site -2253, the irrigation ditch and presumably carried it to Site -2258, Māhā'ulepū Reservoir. The date of the inscriptions at both gates gives the year “1924”. This shows that excavation of the ditch that incorporates Sites -2251, -2252, -2253, and -2259 predates the construction of -2262. The concrete bridge of Feature 1 is collapsed upon the northern concrete foundation. The wooden trestle is standing but the beams are rotting.

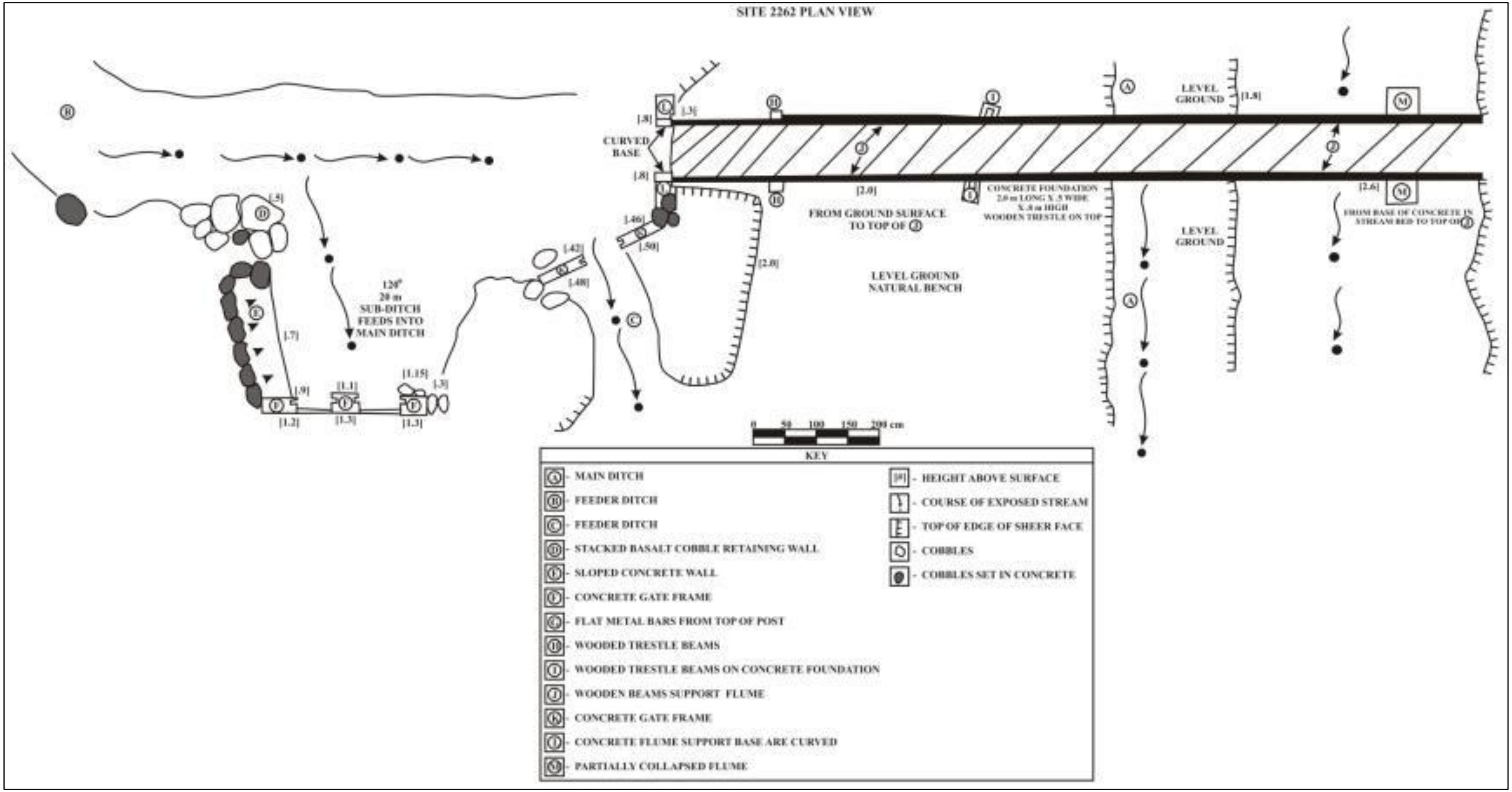

Figure 61. Plan view of Site -2262.

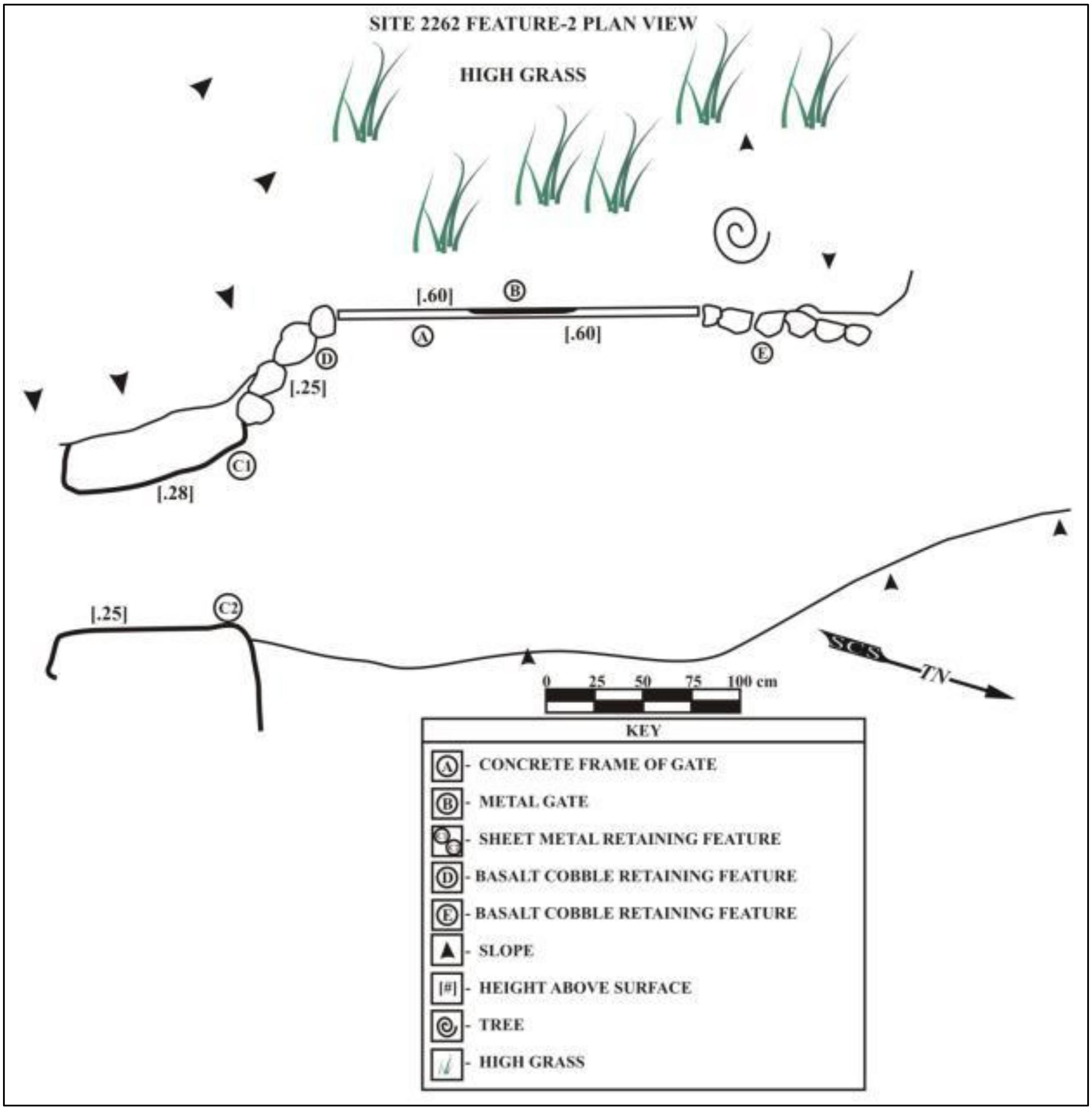

Figure 62. Plan view of Site -2262, Feature 2 retaining features.

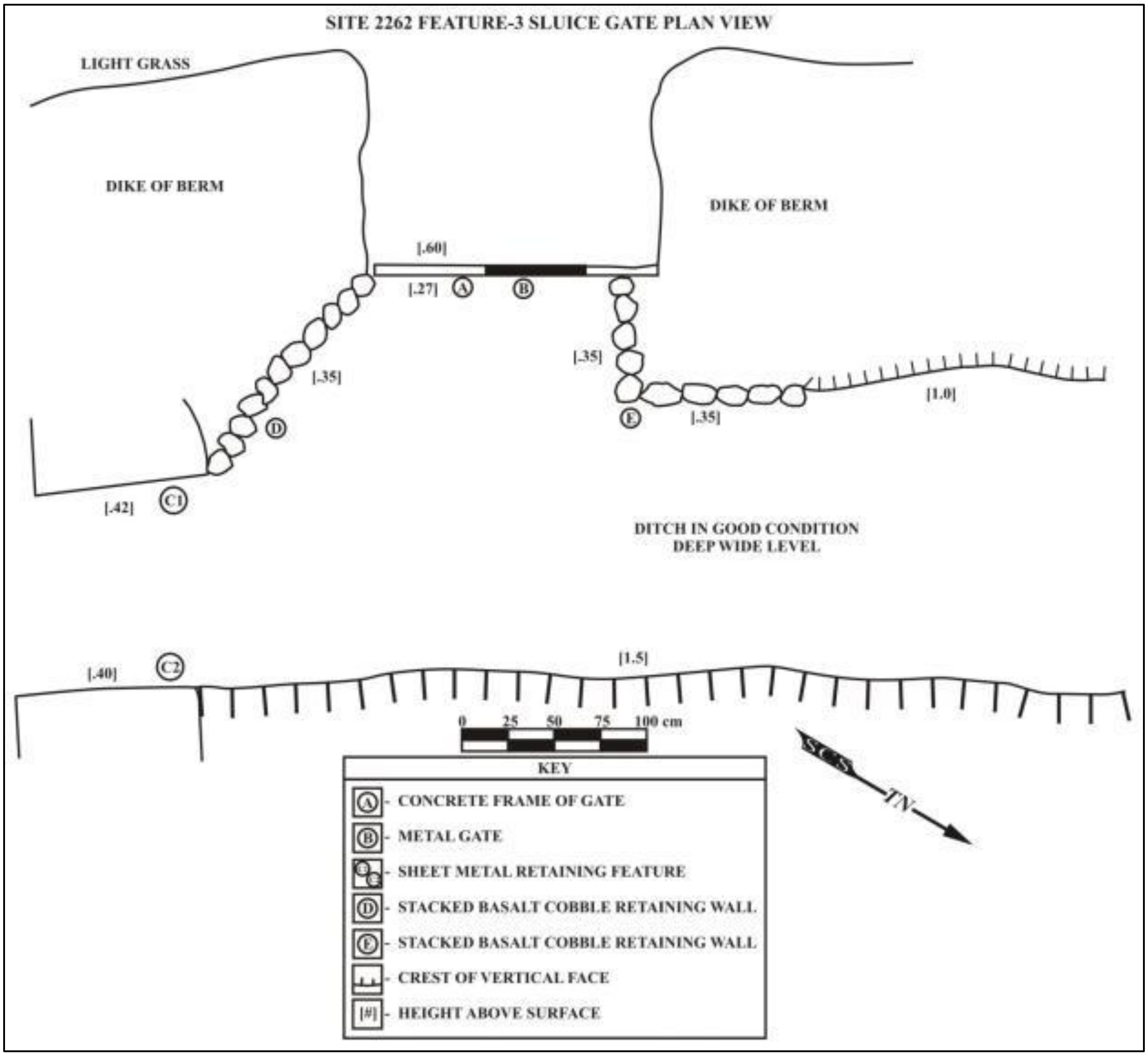

Figure 63. Plan view of Site -2262, Feature 3 retaining walls.

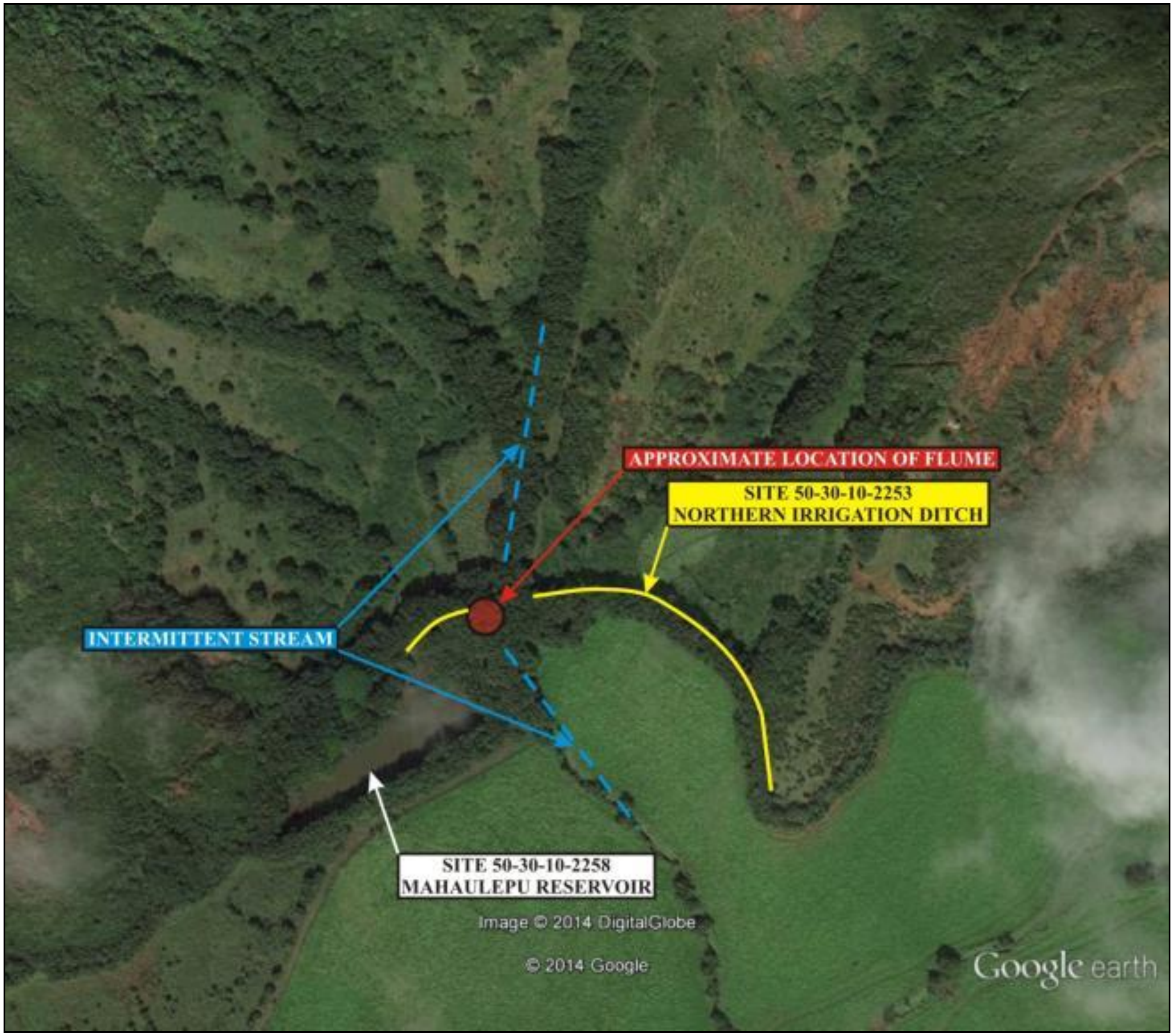

Figure 64. Google Earth aerial imagery of Site -2262 in relation to Sites -2253 and -2258.

Figure 65. Site -2262 structural supports of the flume. View to east.

Figure 66. Site -2262 north bank foundation. View to north.

Figure 67. Site -2262 flume system. View to northeast.


Figure 68. Site -2262 double gate with cement and rock wall to prevent erosion. View to north.

STATE SITE NO. 50-30-10-3094

Site -3094 consists of a previously identified petroglyph rock (designated as Feature 1), along with two other petroglyph rocks (designated as Feature 2 and Feature 3) that were identified during the current survey. All three features occur outside the project area in the extended survey area. Feature 1 consists of a large boulder with petroglyphs that was previously identified. Feature 2 is either exposed bedrock or a buried boulder with two petroglyphs visible located 20 m southeast from, and in the same clearing as Feature 1. Feature 3, which was identified by SHPD during a field visit in 2014, is located approximately 70 m to the northeast of Feature 1, and is at the base of the wooded slope in the extended survey area.

The area surrounding Feature 1 is currently covered by tall grasses (Figure 69). Excavation of test trenches during this AIS showed that the ground east, north, and west of Feature 1 had been plowed for the cultivation of sugar cane. To the south, however, the test trench exposed intact natural stratigraphy. The area south from Feature 1 extends to one branch of the southward flowing Māhā'ulepū Stream. The absence of disturbed soils in this area, and the absence of any signs of impact by machinery on the boulder suggest that care had been taken not to disturb the boulder.

Feature 1 measures 4.0 m long by 3.8 m wide, with the long axis north to south. The boulder is 1.1 m high at its northern end, 1.3 m at its center, and ranges from 0.6 to 0.8 m high at the southern end. The eastern, northern and southern faces are vertical, while the southern end slopes steeply in the ground surface. The ground to the south is at a slightly higher elevation than the boulder, and the ground slopes away from the boulder in the other directions. The high center of the boulder is an east to west extending ridge across the top of the boulder. From this crest, the top surface of the boulder is smooth and descends gradually northward. On the east and northwest sides of the surface, the surface slopes slightly before turning into vertical faces. The remaining sides of the boulder are all vertical to the top surface. South from the crest, the slope is shorter, steeper, and the surface is rough and pockmarked from natural causes.

At the crest of the ridge is a pecked cup or basin measuring 0.1 m in diameter and 0.1 m deep. From this cup is a pecked groove approximately 0.03 m wide and approximately 0.01 m deep that descends northward in a gradual curve across the surface of the boulder, ending at the northwest side. Parallel to this groove is a natural bifurcated fissure that descends with one branch ending at the northwest end of the boulder next to the groove and the other branch ending at the northeast end (Figure 70).

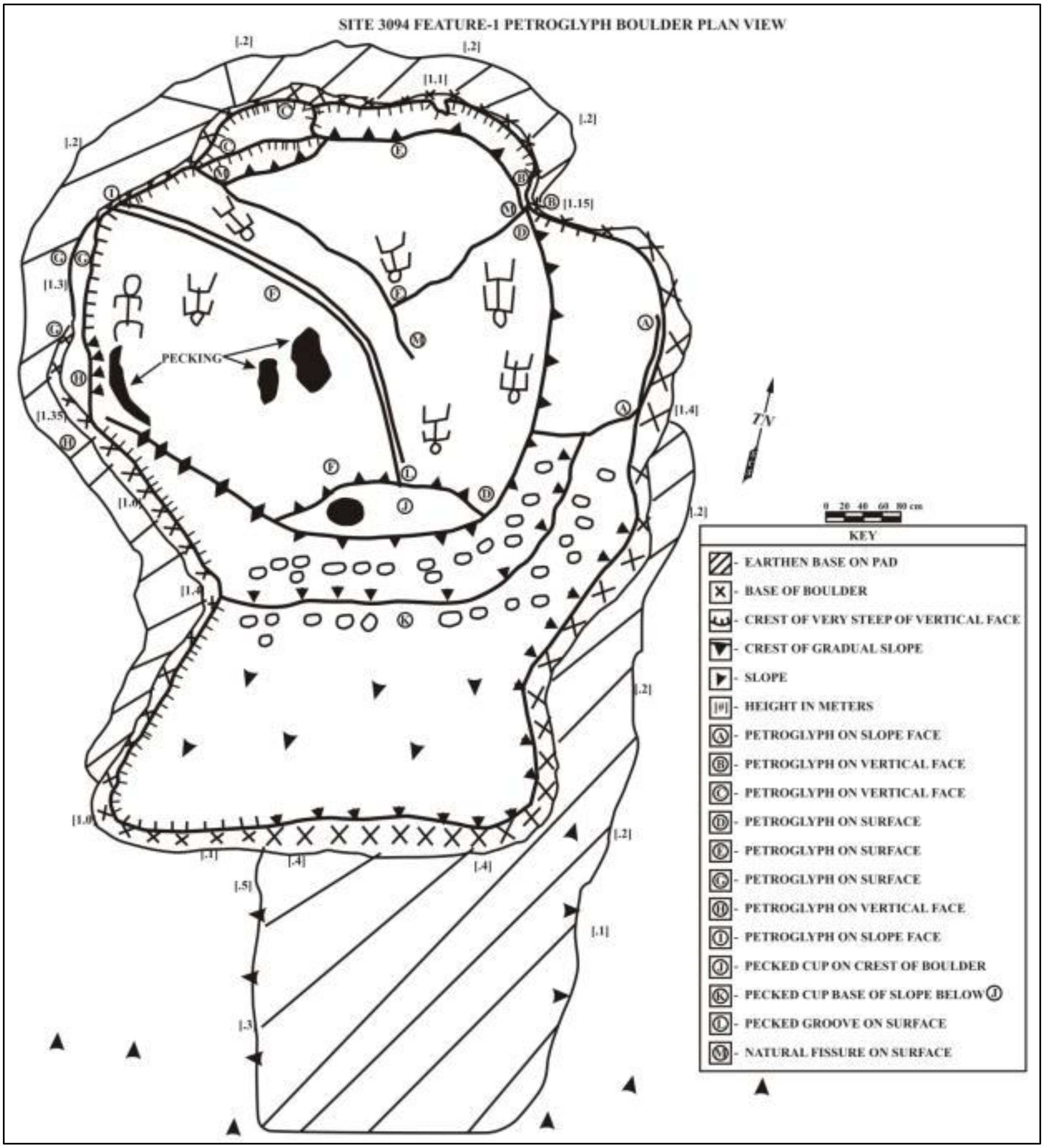

Figure 69. Plan view of Site -3094, Feature 1 overview.

Petroglyphs representing human figures are pecked into four vertical faces, two sloped faces, and the top surface of the north end of the boulder. On the top surface, there are figures on either side of the groove and all sides of the fissure, and one is placed between the groove and the fissure. These were documented and illustrated as separate panels but the panels are regarded as being part of the whole entity of the boulder (Figure 71 through Figure 81).

The vertical and sloped panels each have between one and three figures, while the top surface has a total of seven figures. Some panels have pecked areas and/or lines as well. What these pecked areas represent is not currently understood. The petroglyphs are stick figured and limbed, with round heads. There are figures with extensions at the ends of limbs and at least one has male genitalia represented. The figures vary in size but do not exceed 0.3 m in length or width.

There are no figures on the slope south from the crest but there is a second pecked basin or cup, this one at the base of the slope. It has the same dimensions as the one at the crest, but there are no associated figures, grooves, or fissures.

The meaning of these petroglyphs and their placements on the boulder is open to interpretation. One interpretation is that, despite being oriented in the opposite direction, the crest represents Ha'upu Ridge, and Mount Ha'upu, and the groove represents Māhā'ulepū Stream as it descends and curves to the coast (Ching *et al*. 1974). The basins may represent head waters to streams. The petroglyphs may represent population centers, chieftains or the divine. The fissure, being natural, may represent either another stream course, or perhaps a ridgeline. Another interpretation is that these are all representing someplace on Kaua'i where a stream actually does flow north. It may be that all of this represents some facet of navigation, ceremony, cosmology, or documentation of events which we do not as of yet understand.

During the current AIS, a second feature with petroglyphs was identified (N457372, E2423831). Feature 2 was identified by the backhoe driver as he was clearing grasses in the area to conduct trenching around the Feature 1 boulder. Feature 2 is located 20 m (at 140 degrees) from Feature 1. This second "boulder" is only slightly exposed at ground surface and may actually be a natural basalt outcrop. Feature 2 measures 1.5 m in diameter and rises only 0.2 m above the current ground surface. The exposed rock measures 1.72 m (north flank) by 1.98 m (east side). The figures on Feature 2 are different, and not as clearly defined, as those on Feature 1. There is a stick-figured human standing legs apart and wide-armed, holding what appears to be a spear upright in his right hand. Perpendicular to this is a three-leafed image on a staff, possibly a *kahili* image. Neither of these are as clearly defined as the petroglyphs on the larger

Feature 1 boulder, which is not surprising considering it occurs on the surface of the fields. Other scratches on the surface of Feature 2 are indistinct (Figure 71).

Because Feature 2 is at ground surface level, and because there are fewer, less distinct images, it appears that the markings on Feature 2 were etched for a different purpose than those on Feature 1. If the figure is a *kahili*, then this could indicate the area being decreed *kapu.* A *kapu* could be seasonal, periodical, or eternal. This may explain why the main boulder was left intact and *in situ* throughout the Kingdom and the modern era. The figure that appears to be holding a staff or spear is not as distinct as those figures on Feature 1. None of the Feature 1 figures appear to be holding anything.

Feature 3 is located 70 m to the north/northeast of Features 1 and 2, in the extended survey area. This boulder measures 2.5 m by 2.1 m by 1.7 m tall, with its long axis northeast to southwest (Figure 72). Feature 3 contains etchings of several human figures with stick torsos and limbs. These are located on the *mauka* face of a large, slab-like boulder. The figures of Feature 3 are slightly larger than those of Feature 1. The meaning and purpose of Feature 3 is open for interpretation, but likely represents individuals of the area.

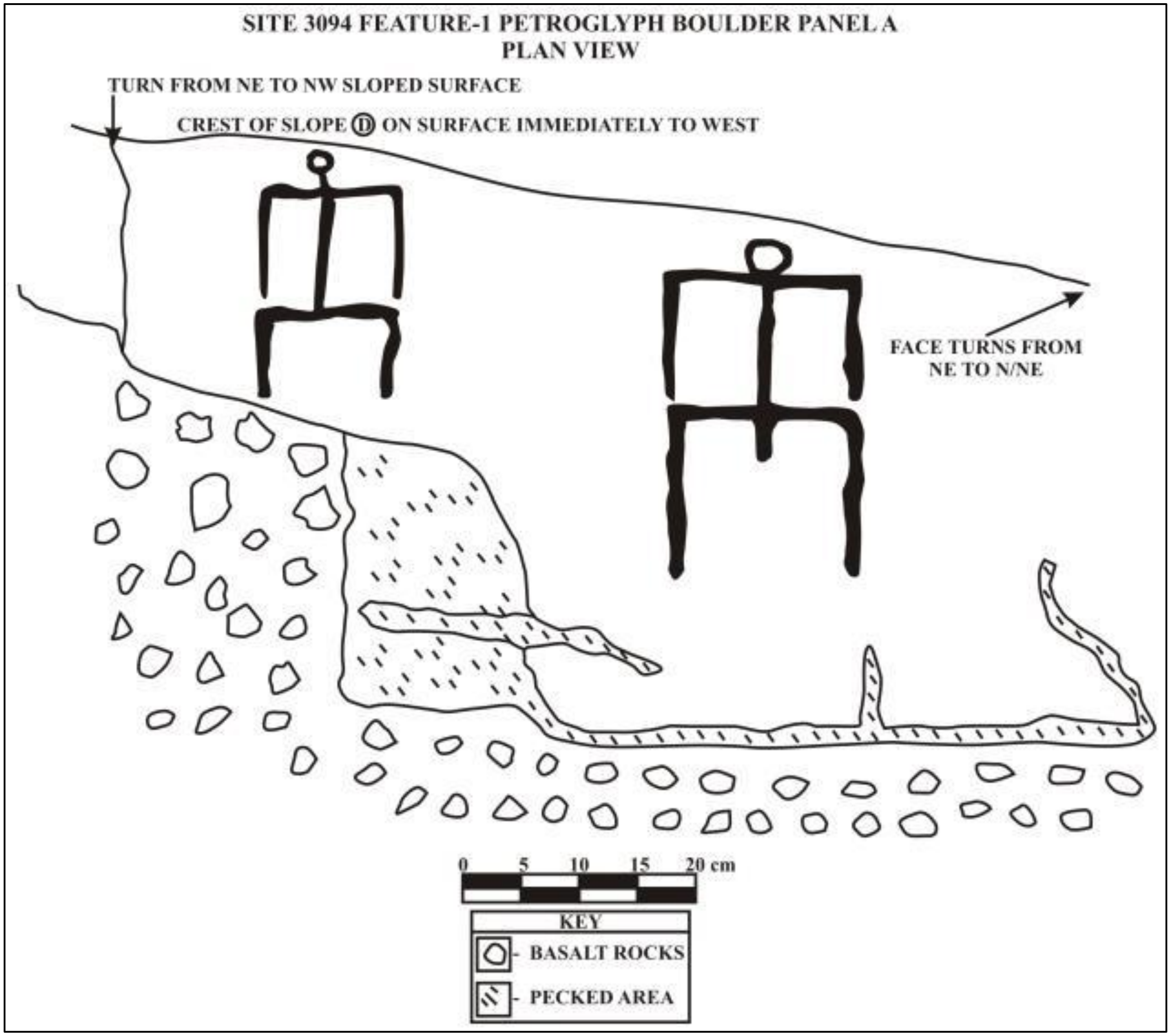

Figure 70. Plan view of Site -3094, Feature 1 Panel A.

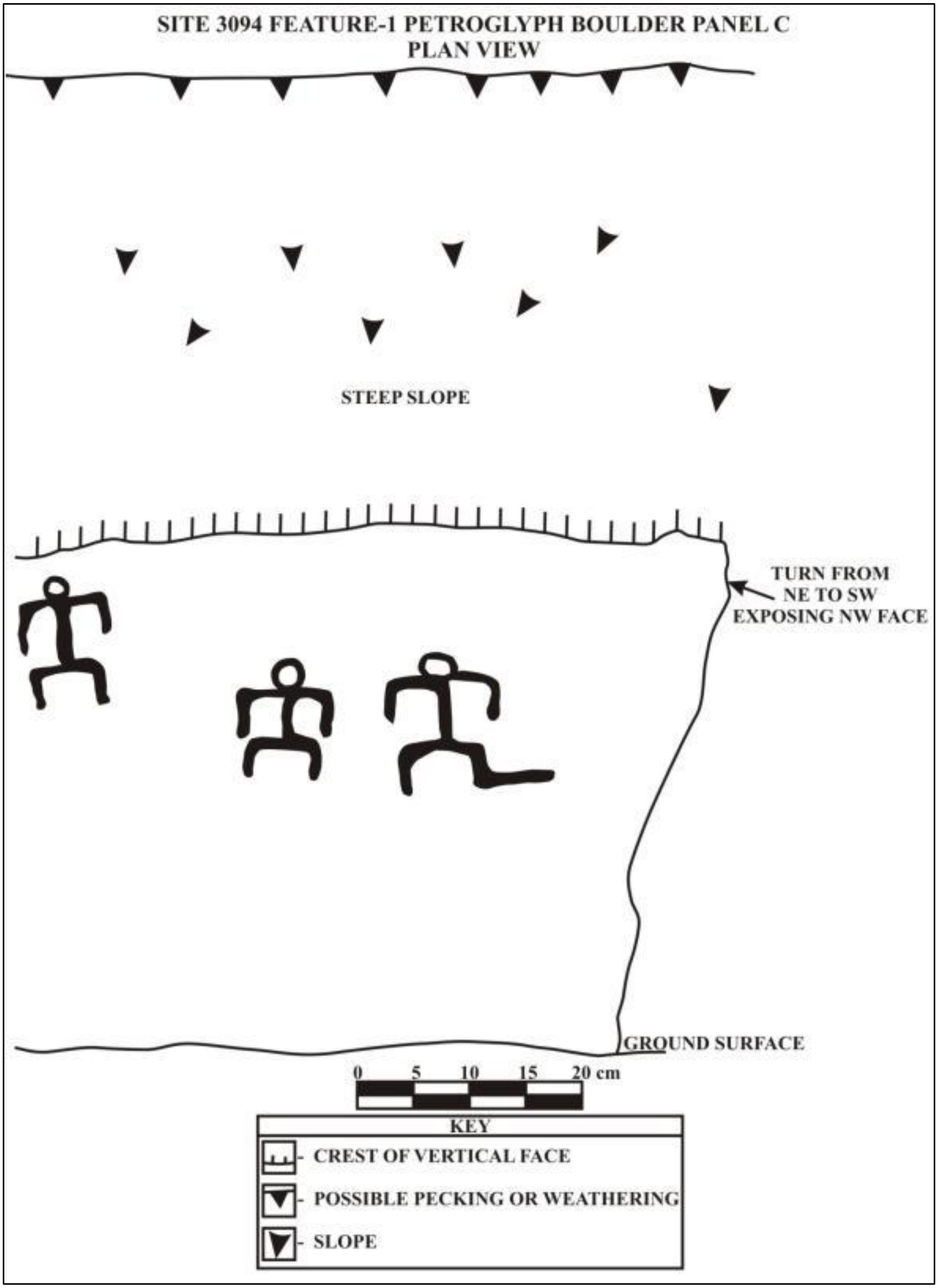

Figure 71. Plan view of Site -3094, Feature 1 Panel C.

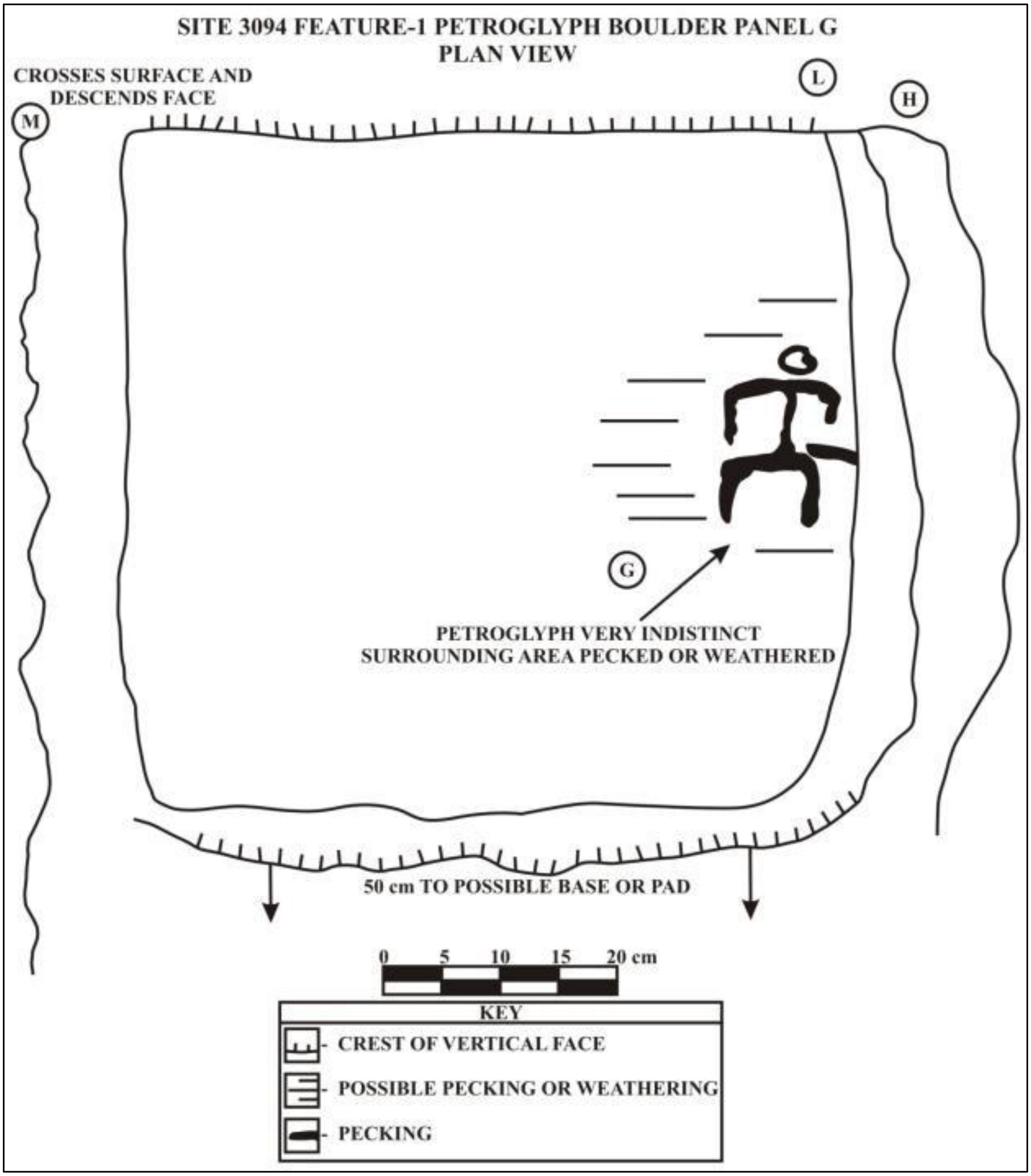

Figure 72. Plan view of Site -3094, Feature 1 Panel G.

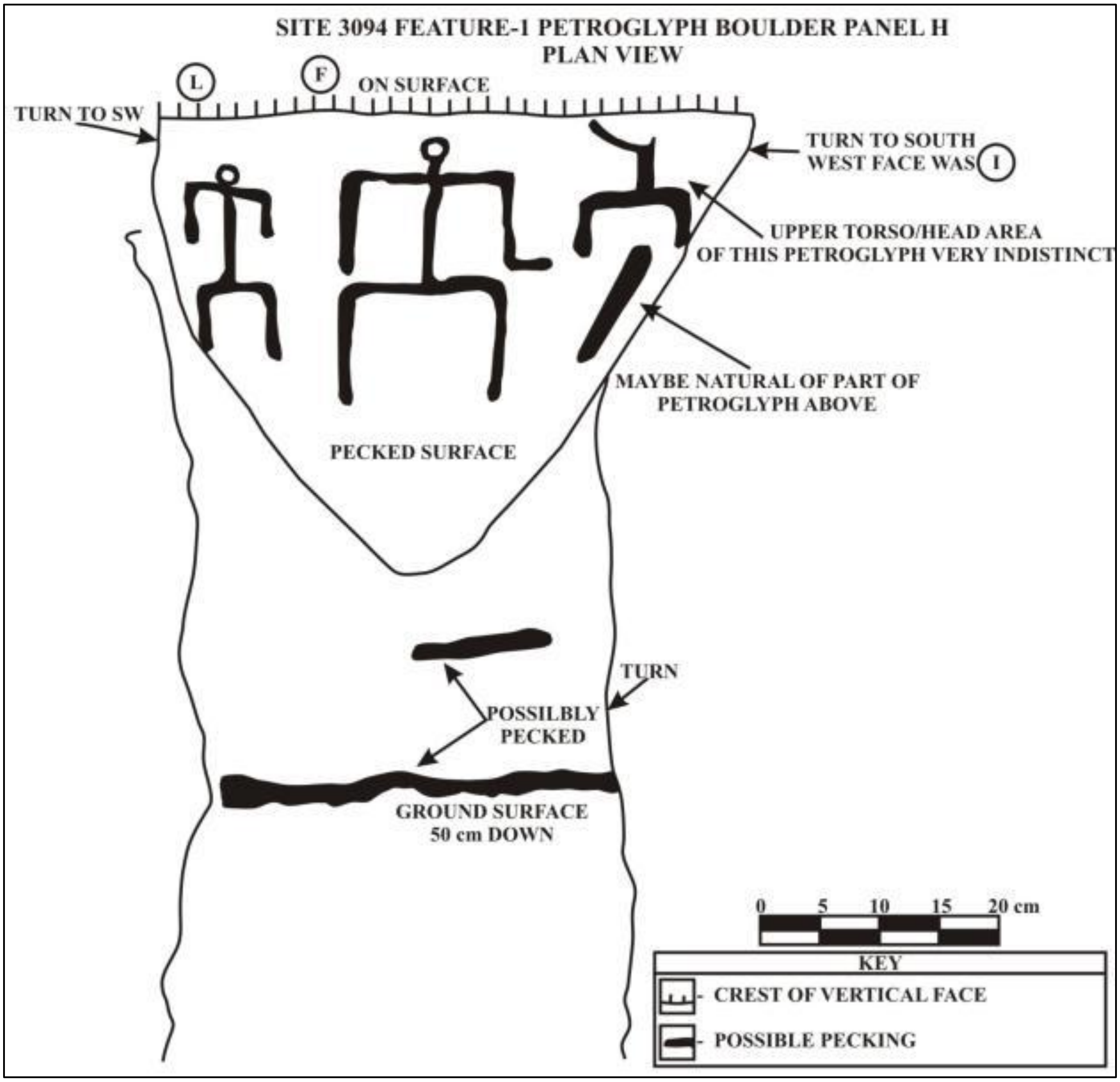

Figure 73. Plan view of Site -3094, Feature 1 Panel H.

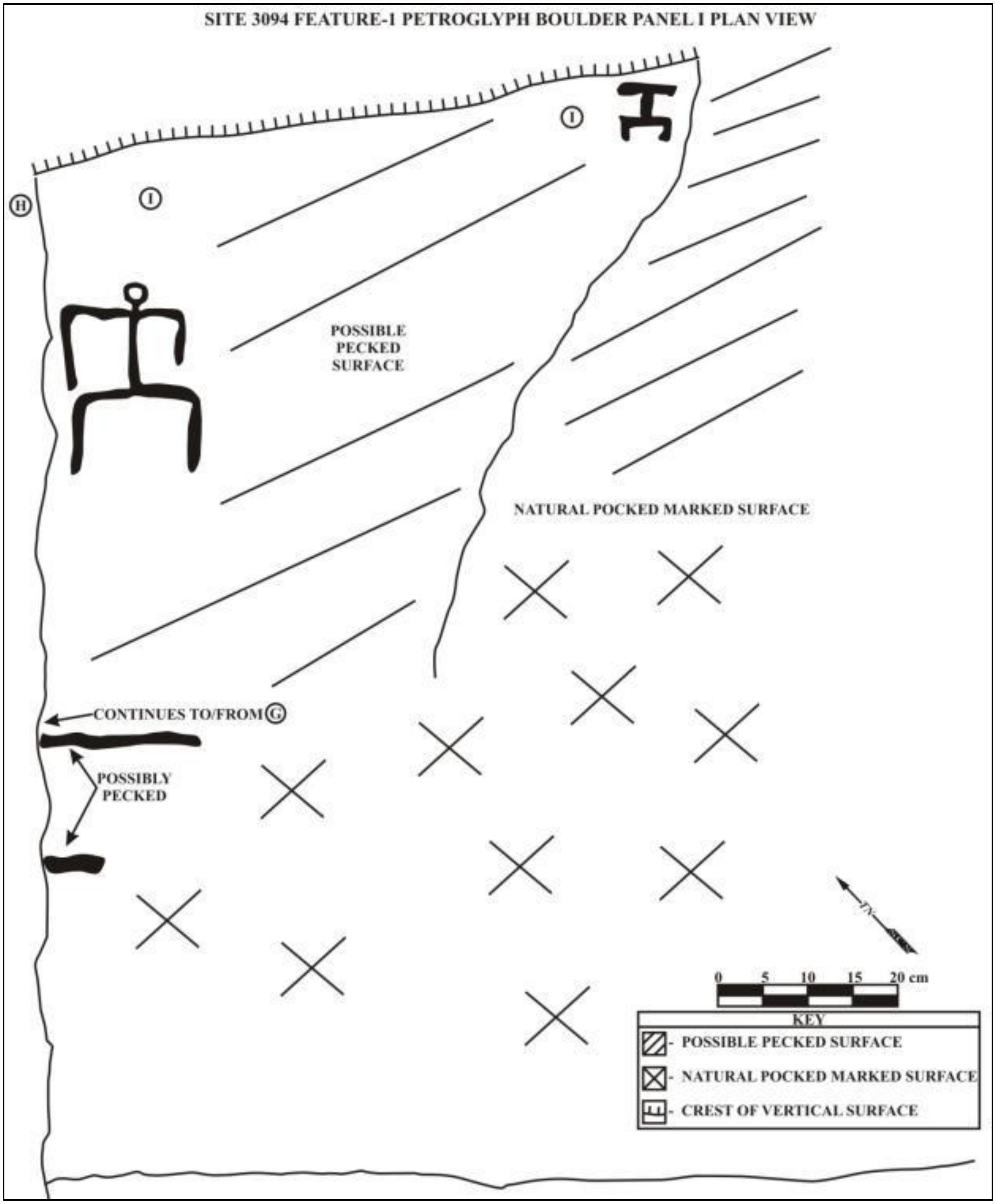

Figure 74. Plan view of Site -3904, Feature 1 Panel I.

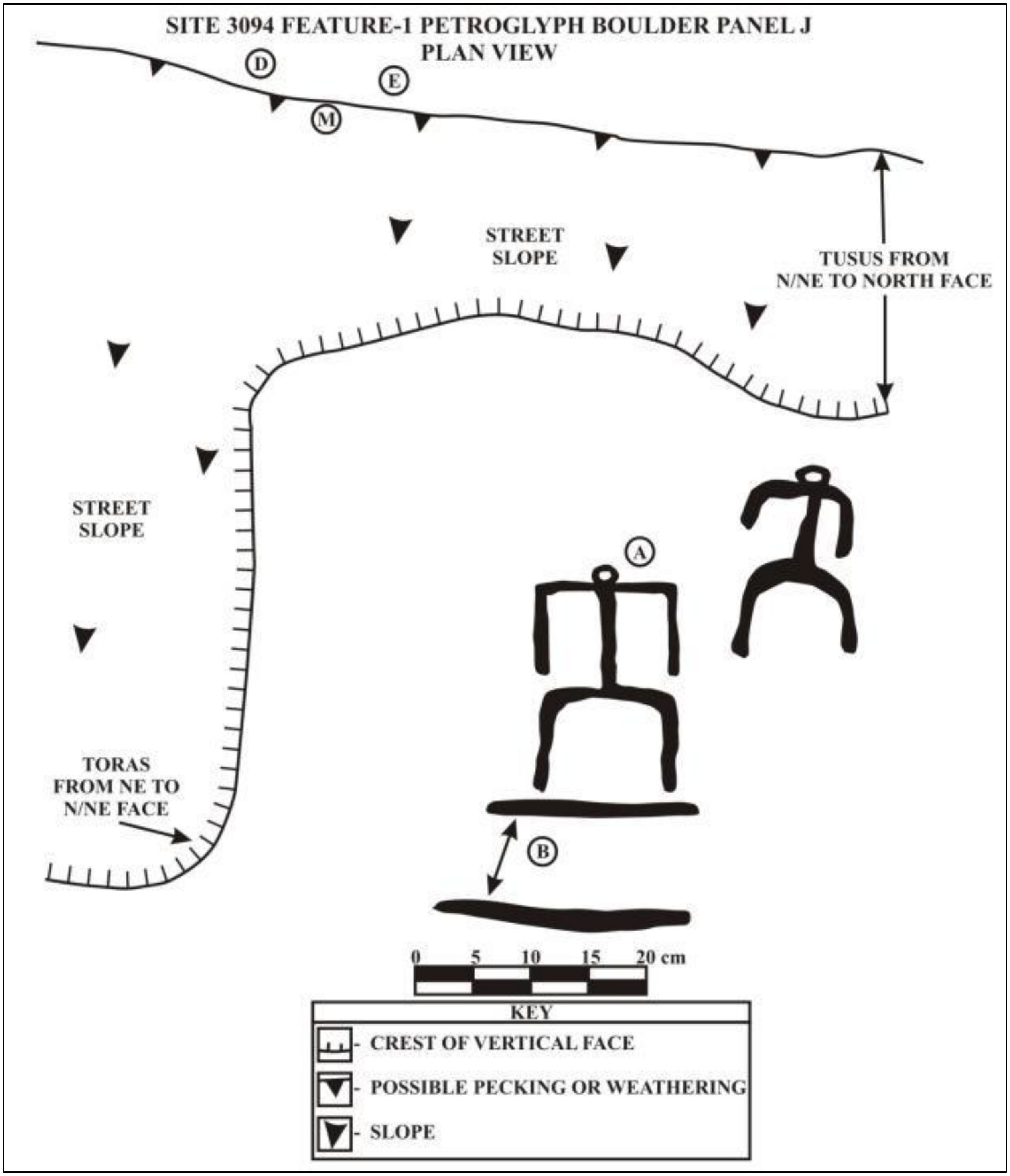

Figure 75. Plan view of Site -3094, Feature 1 Panel J.

Figure 76. Site -3094, Feature 1, petroglyph boulder in field. View to east.

Figure 77. Site -3094, Feature 1, surface of petroglyph boulder. Note groove down center and anthropomorphic figures on either side of groove. View to south.

Figure 78. Site -3094, Feature 1, Petroglyphs, north side of boulder. View to south.

Figure 79. Site -3094, Feature 1, petroglyphs and pecked cup at east end of boulder. View to west.

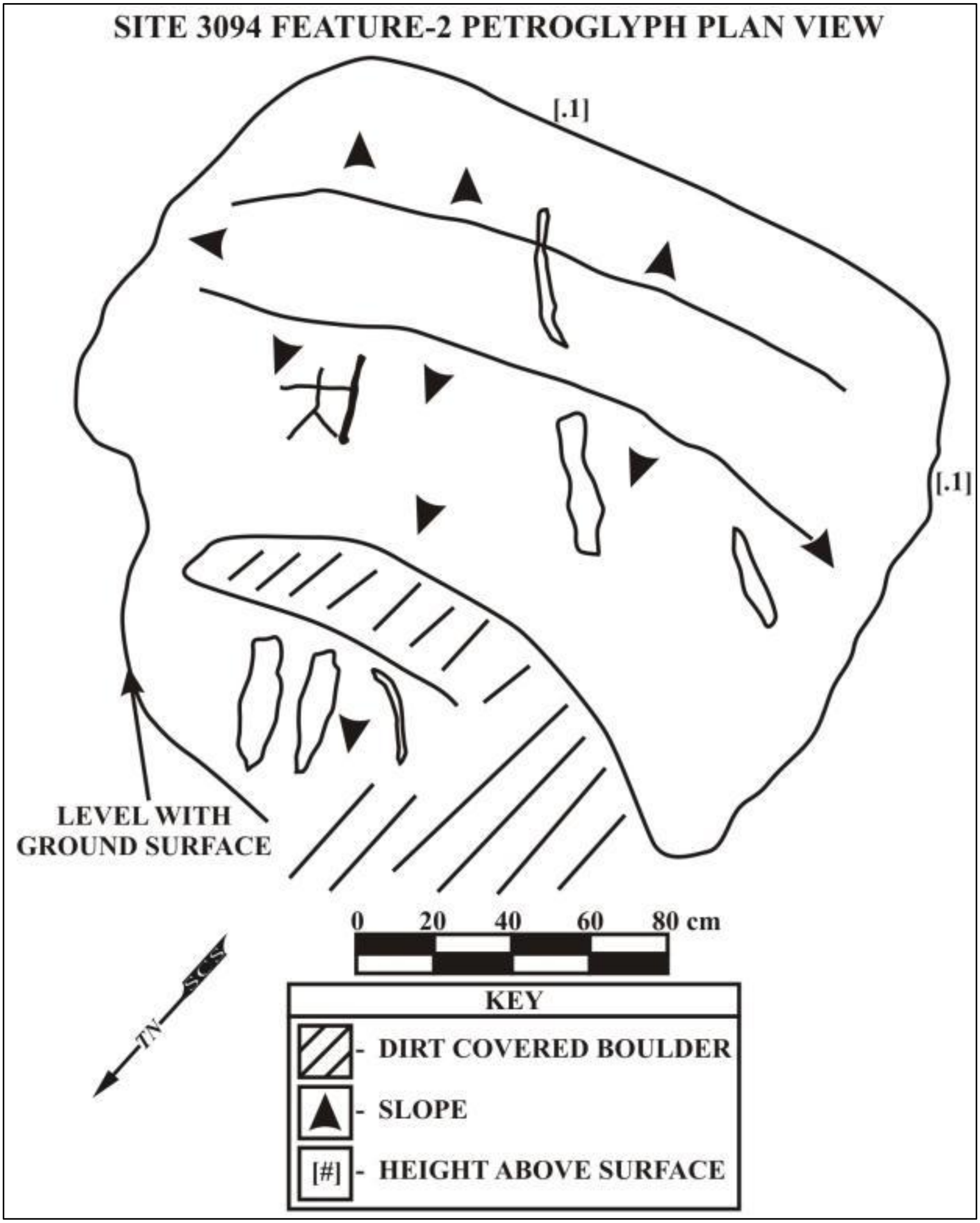

Figure 80. Plan view of Site -3094, Feature 2 petroglyph panel.

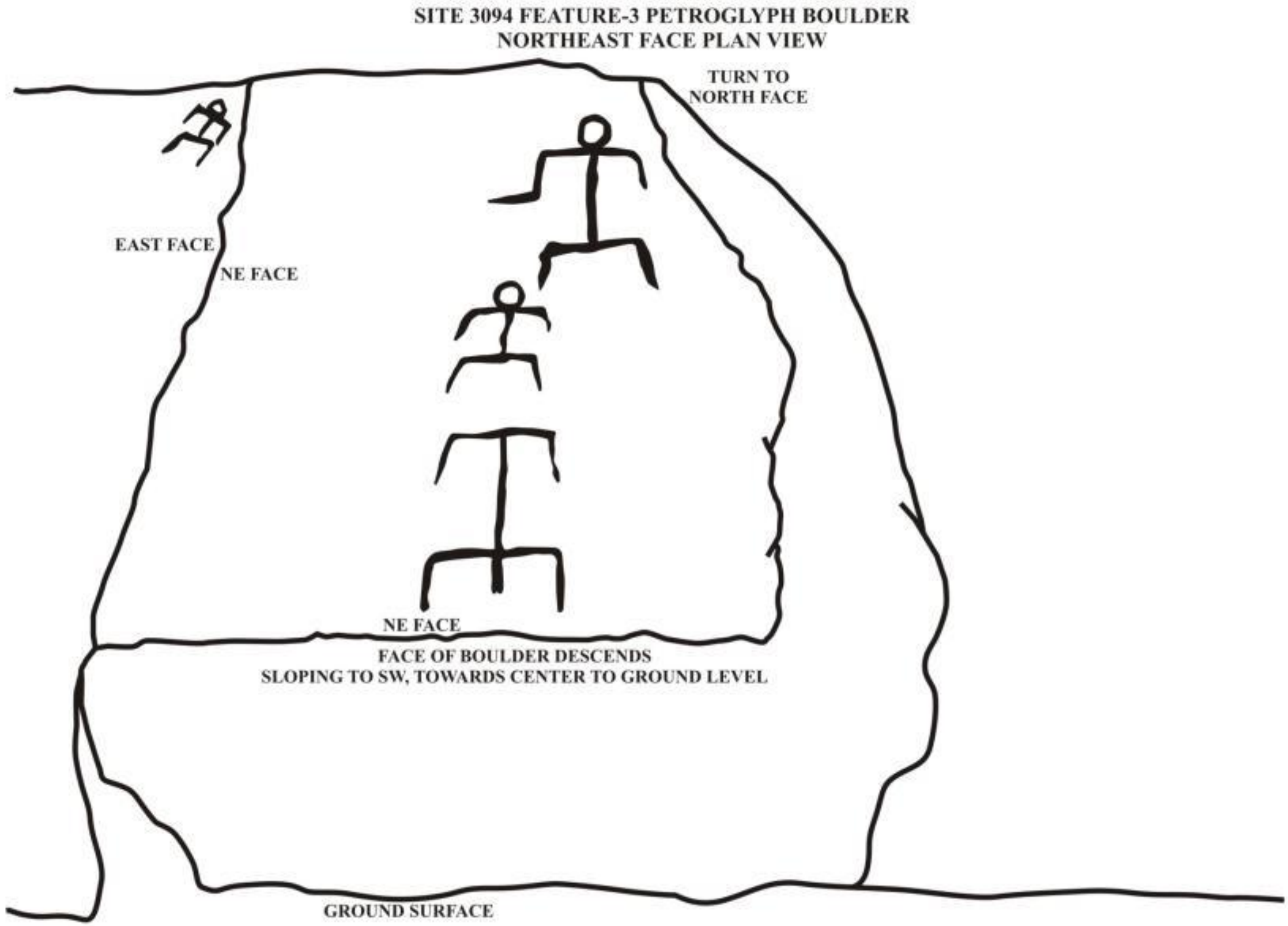

Figure 81. Plan view of Site -3094, Feature 3 petroglyph panel.

STRATIGRAPHIC TRENCH EXCAVATIONS

Stratigraphic trench excavations were conducted mechanically with a backhoe in areas within and around historically interesting areas, one known site (Site -3094), and proposed effluent ponds along the western flank of the project area (Figure 82). Several of the trenches were concentrated near the cluster of LCAs located on the east side of the Main East Ditch. These LCAs were awarded during the Great Māhele and were occupied and/or utilized until approximately the 1880s, when individual ownerships passed over to group and corporate development for the Koloa Sugar Cane Plantation.

A total of nine (9) trenches were mechanically excavated within the former LCA cluster area. The trenches, designated Stratigraphic Trenches (ST), were numbered sequentially and excavated in rows of three. The southernmost row, ST-1 to ST-3 was excavated east to west. The middle row, ST-4 to ST 6, was excavated west to east. The northernmost row, ST-7 to ST-9, was excavated east to west. To area to the east from this point is currently marshland and an excavator could not safely be brought in to excavate. The previously noted soils map identified the soils exposed by ST-1 through ST-9 as KavB or Kaena Clay, Brown Variant.

The next area of excavation occurred around Feature 1 of Site -3094, the previously-identified petroglyph boulder. Four (4) trenches were mechanically excavated here. The soils map identified the soils exposed by ST-10 through ST-13 as HsD or Hanamaulu Silty Clay.

A single trench was excavated east of the -2254 retaining wall in an attempt to find remnants of a historic household that is shown on older maps of the area. The soils map identified these soils as KavB or Kaena Clay, Brown Variant.

Trenches were planned for a small knoll at the northwest turn of Māhā'ulepū Road. On older maps of the area, this location is designated as “Camp”, but no further explanation is provided. However, a trench with water lines is present alongside the road and prevented access to this area. Alternatively, two trenches were excavated to the southeast of the knoll, in the fields south of existing pump station structures. These structures service a series of wells known as Māhā'ulepū 14, drilled during the 20th century to service irrigation for the plantation. The soils map identified the soils as KavB or Kaena Clay, Brown Variant.

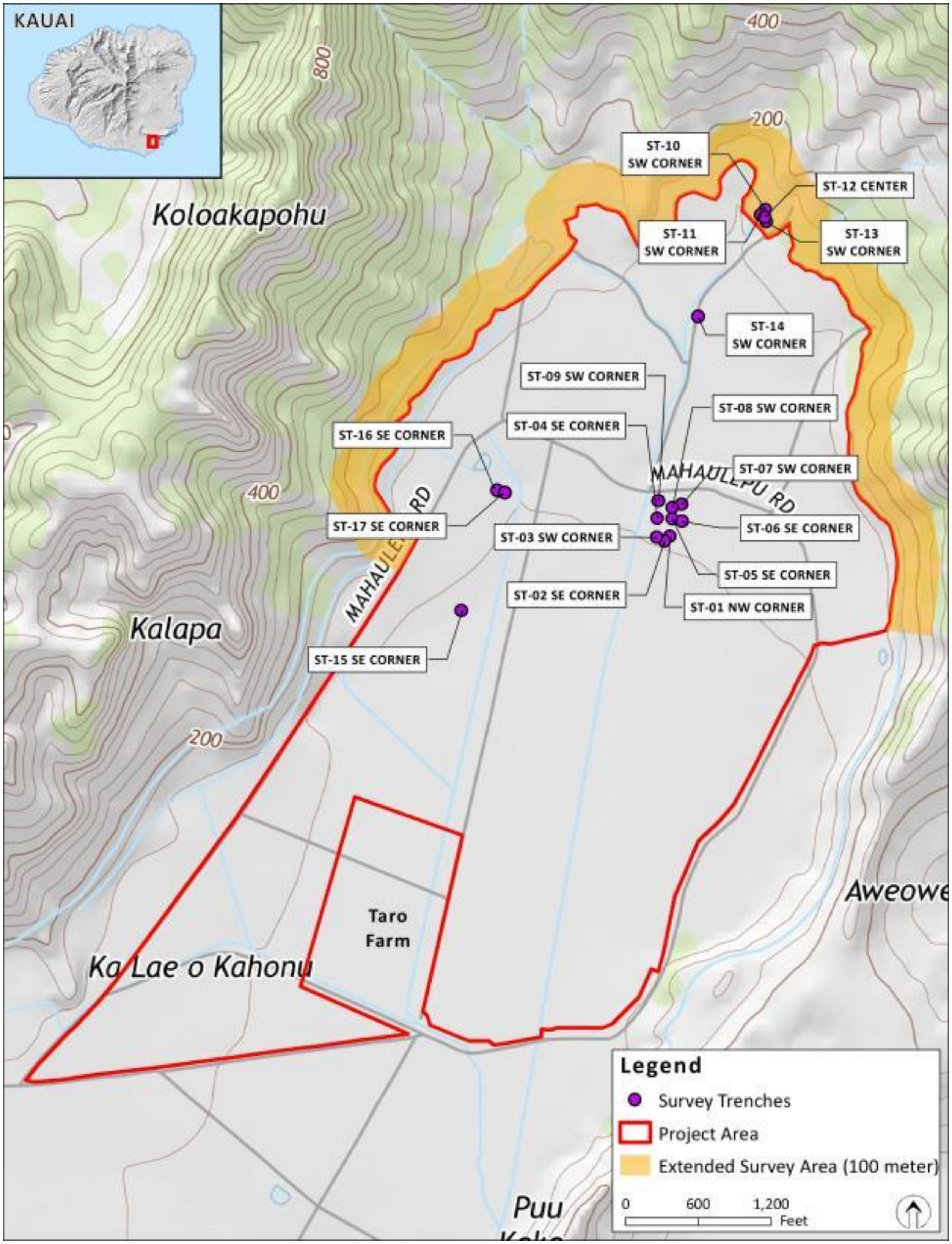

Figure 82. USGS Map depicting stratigraphic trench locations (USGS 7.5 Minute series 2013).

A final trench was excavated within the area of the Effluent Ponds and other infrastructure proposed to be constructed for the project. The soils in this area are identified as KavB or Kaena Clay, Brown Variant.

SPECIFIC TRENCHING METHODS

All trenches were excavated with use of a small, tracked, excavator. Each trench was 10.0 m long (9.14 m being the average open space, the remaining 0.86 consisting of the ramp into the trenches) and the width of the bucket, 0.75m wide. Depth of the trenches varied, depending on the water table. If the table was encountered, excavation was halted. If the water table was not encountered, excavation extended to 2.0 m below the ground surface for the first 2.0 m of the trench, and then was reduced to 1.5 m for the remainder. In each trench, the uppermost 0.2 to 0.8 m below ground surface was composed of grey brown loam with fine grass roots. This was identified as a disturbed plow zone. The trenches excavated in rows in the LCA area were 20 m apart and the rows were approximately 40 m apart. Each trench was documented with soil descriptions, profiles, written descriptions, and photographs.

At each trench location, an area approximately 15 m wide and long was cleared by the excavator down to the ground surface. This was done to allow complete views of the interior of the trench, to expose areas around it in the event of additional excavations, and to facilitate greater ease and access when back filling was undertaken.

A total of seventeen (17) stratigraphic trenches were mechanically excavated. The greatest concentration of these was within the area identified as containing numerous LCA properties. The second largest concentration was around Site -3094. No cultural deposits or features were exposed during any of these excavations. Appendix A provides stratigraphic profiles and representative photographs of the trenches.

PROJECT AREA

Stratigraphic Trench 1 (ST-1)

ST-1 measured 9.14 m long, 0.6 m wide, and was oriented at 120/300 degrees. The trench was excavated to a maximum depth of 1.52 m at the north end and 1.8 m at the south end. Three stratigraphic layers were identified. Layer I (0.0-0.16 mbs) is composed of dark brown (10YR 3/5) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 1% gravel. Lower boundary was abrupt and wavy. Layer II (0.16-0.56 mbs) is a dark grayish brown (10YR 4/2) clay, structureless, plastic, less than 1% roots and gravel. Layer III (0.56-1.5/1.8 mbs) consisted of dark grayish brown (10YR 4/2) clay that was structureless, plastic, with no roots and no gravel. The water table was exposed at the base of the excavation. This trench was located in the center of the project area, east of Māhā'ulepū Ditch, and south of Māhā'ulepū Road.

Stratigraphic Trench 2 (ST-2)

ST-2 measured 9.14 m long and 0.6 m wide and was oriented at 180/360 degrees. The trench was excavated to a maximum depth of 1.52 m at the north end and 1.8 m at the south end. Three stratigraphic layers were identified. Layer I (0.0-0.16 mbs) is a dark brown (10YR 3/5) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 1% gravel. Lower boundary was abrupt and wavy. Layer II (0.16-0.56 mbs) is a dark grayish brown (10YR 4/2) clay that is structureless, plastic, less than 1% roots and gravel. The lower boundary was clear and wavy. Layer III (0.56-1.5/1.8 mbs) consisted of dark grayish brown (10YR 4/2) clay that was structureless, plastic, with no roots and no gravel. The water table was exposed at the base of this excavation. This trench was located in the center of the project area, east of Māhā'ulepū Ditch and south of Māhā'ulepū Road.

Stratigraphic Trench 3 (ST-3)

ST-3 measured 9.14 m long and 0.6 m wide and was oriented at 180/360 degrees. The trench was excavated to a maximum depth of 1.52 m at the north end and 1.8 m at the south end. Three stratigraphic layers were identified. Layer I (0.0-0.16 mbs) is composed of a dark brown (10YR 3/5) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 1% gravel. Lower boundary was abrupt and wavy. The lower boundary was clear and wavy. Layer II (0.16-0.56 mbs) was a dark grayish brown (10YR 4/2) clay that was structureless, plastic, less than 1% roots and gravel. The lower boundary was clear and wavy. Layer III (0.56-1.5/1.8 mbs) consisted of dark grayish brown (10YR 4/2) clay that was structureless, plastic, with no roots and no gravel. The water table was exposed at the base of this excavation. The trench was located in the center of the project area, east of Māhā'ulepū Ditch and south of Māhā'ulepū Road.

Stratigraphic Trench 4 (ST-4)

ST-4 measured 9.14 m long and 0.6 m wide and was oriented at 20/160 degrees. The trench was excavated to a maximum depth of 1.52 m at the north end and 1.8 m at the south end. Three stratigraphic layers were identified. Layer I (0.0-0.16 mbs) is composed of a dark brown (10YR 3/5) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 1% gravel. The lower boundary was abrupt and wavy. Layer II (0.16-0.56 mbs) is a dark grayish brown (10YR 4/2) clay that was structureless, plastic, less than 1% roots and gravel. The lower boundary was clear and wavy. Layer III (0.56-1.5/1.8 mbs) consisted of dark grayish brown (10YR 4/2) clay that was structureless, plastic, and with no roots and no gravel. The water table was exposed at the base of this excavation. This trench was located in the center of the project area, east of Māhā'ulepū Ditch and south of Māhā'ulepū Road.

Stratigraphic Trench 5 (ST-5)

ST-5 measured 9.14 m long and 0.6 m wide and was oriented at 90/270 degrees. The trench was excavated to a maximum depth of 1.52 m and exposed two stratigraphic layers. Layer I (0.0-0.3m) was a dark brown (10YR3/5) silty clay that was structureless, slightly plastic, and includes roots, rootlets, and less than 1% gravel. The lower boundary was abrupt and wavy. Layer II (0.3-1.52m) was a dark brown (10YR 3/3) clay with no roots and no gravel. The water table was exposed at the base of this excavation. This trench was located in the center of the project area, east of Māhā'ulepū Ditch and south of Māhā'ulepū Road.

Stratigraphic Trench 6 (ST-6)

ST-6 measured 9.14 m long and 0.6 m wide and was oriented at 180/360 degrees. The trench was excavated to a maximum depth of 1.52 m and exposed five stratigraphic layers. Layer I (0.0-0.3m) was composed of dark brown (10YR3/5) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 1% gravel. The lower boundary was abrupt and wavy. Layer II (0.3-0.6 m) is a dark brown (10YR 4/2) clay that was structureless, plastic and had no roots or gravel. The lower boundary was clear and wavy. Layer III (0.6-1.0 m) is a brown (10YR4/3) clay that was structureless, plastic, and had no roots or gravel. The lower boundary was clear and wavy. Layer IV (1.0-1.2 m) is a dark grayish brown (10YR 4/2) clay that was structureless, plastic, and had no roots and no gravel. The lower boundary was clear and smooth. Layer V (1.2-1.5 m) is a brown (10YR 4/3) clay that was structureless, plastic, and had no roots and no gravel. The water table was reached at 0.9 m below the ground surface. This trench was located in the center of the project area east of Māhā'ulepū Ditch and south of Māhā'ulepū Road.

Stratigraphic Trench 7 (ST-7)

ST-7 measured 9.14 m long and 0.6 m wide and was oriented at 90/270 degrees. The trench was excavated to a maximum depth of 1.52 m and exposed four stratigraphic layers. Layer I (0.0-0.2 m) is a dark brown (10YR3/5) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 1% gravel. The lower boundary was abrupt and wavy. Layer II (0.2-0.5 m) is a yellow brown (10YR 5/4) clay that was structureless, plastic, and had no roots and no gravel. The lower boundary was abrupt and wavy. Layer III (0.5-0.73 m) is a black clay that was structureless, plastic, and had no roots and no gravel. The lower boundary was abrupt and wavy. Layer IV (0.73-1.52 m) is a brown (10YR4/3) clay that was structureless, plastic, and had no roots or gravel. The water table was exposed at the base of the excavation. This trench was located in the center of the project area east of Māhā'ulepū Ditch and south of Māhā'ulepū Road.

Stratigraphic Trench 8 (ST-8)

ST-8 measured 9.14 m long and 0.6 m wide and was oriented at 180/360 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed three stratigraphic layers. Layer I (0.0-0.2 m) is a dark brown (10YR4/3) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 1% gravel. The lower boundary was abrupt and wavy. Layer II is a yellowish brown (10YR5/6) clay that was structureless, plastic, and had no roots or gravel. The lower boundary was clear and smooth. Layer III was a bluish gray (Gley 2 5/1) clay exposed, with the water table, at the base of the excavation. This color clay was not exposed in any other excavation and simply represents water saturated soils. This trench was located in the center of the project area east of Māhā'ulepū Ditch and south of Māhā'ulepū Road.

Stratigraphic Trench 9 (ST-9)

ST-9 measured 9.14 m long and 0.6 m wide and was oriented at 90/270 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed two stratigraphic layers. Layer I (0.0-0.2 m) is composed of dark brown (10YR4.3) silt that was structureless, slightly plastic, and includes roots, rootlets, and less than 1% gravel. The lower boundary was abrupt and wavy. Layer II (0.2-1.5 m) is a yellowish dark brown (10YR4/4) clay that was structureless, plastic and had no roots or gravel. The water table was exposed at the base of the excavation. This trench was located in the center of the project area east of Māhā'ulepū Ditch and south of Māhā'ulepū Road.

Stratigraphic trench 14 (ST-14)

ST-14 measured 9.14 m long and 0.6 m wide and was oriented at 20/200 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed two stratigraphic layers. Layer I (0.0-0.4 m) was composed of dark brown (10YR4/3) silty clay that was structureless, slightly plastic, and included no roots and less than 1% gravel.. The lower boundary is abrupt and wavy. Layer II (0.4-1.8 m) is a dark yellowish brown (10YR3/6) clay that was structureless, plastic and contained no roots or gravel. The water table was not exposed in this excavation. This trench was located to the east of the fork in the Māhā'ulepū Ditch.

Stratigraphic Trench 15 (ST-15)

ST-15 measured 9.14 m long and 0.6 m wide and was oriented at 180/360 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed three stratigraphic layers. Layer I (0.0-0.1 m) was composed of dark brown (10YR4/3) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 10% gravel. The lower boundary is abrupt and wavy. Layer II (0.1-0.46 m) is a dark grayish brown (10YR4/6) clay that was structureless, plastic, and had no roots and less than 1% gravel. The lower boundary is clear and wavy. Layer III (0.46-1.52 m) is a dark grayish brown (10YR4/2) clay that was structureless, plastic, and had no roots or gravel. Layer III was moist but the water table was not exposed in this excavation. This trench was located immediately south of the pumping station of the “Māhā'ulepū 14” wells at the northwest end of the property where Māhā'ulepū Road turns to the east.

Stratigraphic Trench 16 (ST-16)

ST-16 measured 9.14 m long and 0.6 m wide and was oriented at 0/360 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed three stratigraphic layers. Layer I (0.0-0.16 m) was composed of dark brown (10YR4/3) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 10% gravel. The lower boundary is clear and wavy. Layer II (0.16-0.82 m) is a dark grayish brown (10YR4/2) clay that was structureless, plastic, and had no roots and less than 1% gravel. The lower boundary is clear and wavy. Layer III (0.82-1.52 m) is a dark grayish brown (10YR4/2) clay that was structureless, plastic, and had no roots or gravel. The water table was not exposed in this excavation. This trench was located in the proposed Effluent Pond area along the western side of the project area.

Stratigraphic Trench 17 (ST-17)

ST-17 measured 9.14 m long and 0.6 m wide and was oriented at 0/360 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed four stratigraphic layers. Layer I (0.0-0.05 m) was composed of dark brown (10YR4/3) silty clay that was structureless, slightly plastic, and included roots, rootlets, and less than 10% gravel. The lower boundary is clear and wavy. Layer II (0.05-0.4 m) is a mottled gray (10YR5/2) and dark brown (10YR4/3) clay that was structureless, slightly plastic, and included roots, rootlets, and less than 10% gravel. The lower boundary is clear and wavy. Layer III (0.4-0.88 m) is a dark yellowish brown (10YR4/6) clay that was structureless, plastic, and had no roots or gravel. The lower boundary was clear and wavy. Layer IV (0.88-1.52 m) is a dark gray (10YR4/2) clay. The sediment was structureless, plastic, and included no roots or gravel. The water table was not exposed in this excavation. This trench was located in the proposed Effluent Pond area along the western side of the project area.

EXTENDED SURVEY AREA

Stratigraphic Trench 10 (ST-10)

ST-10 measured 9.14 m long and 0.6 m wide and was oriented at 100/280 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed two stratigraphic layers. Layer I (0.0-0.4 m) is composed of a dark brown (10YR4/3) silt that was structureless, slightly plastic, and included grass roots and no gravel. The lower boundary was abrupt and smooth. Layer II (0.4-1.8 m) is a yellowish brown (10YR5/8) silt that was fine, slightly plastic, and had no roots or gravel included. The water table was not exposed in this excavation. This trench was located to the north of Feature 1, Site -3094.

Stratigraphic Trench 11 (ST-11)

ST-11 measured 9.14 m long and 0.6 m wide and was oriented at 180/360 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed two stratigraphic layers. Layer I (0.0-0.4 m) was composed of dark brown (10YR4/3) silt that was structureless, slightly plastic, and included grass roots and no gravel. The lower boundary was abrupt and smooth. Layer II (0.4-1.8 m) is a yellowish brown (10YR5/8) silt that was fine, slightly plastic, and had no roots or gravel included. The water table was not exposed in this excavation. This trench was located to the west of Feature 1, Site -3094.

Stratigraphic Trench 12 (ST-12)

ST-12 measured 9.14 m long and 0.6 m wide and was oriented at 100/280 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed two stratigraphic layers. Layer I (0.0-0.4 m) was composed of dark brown (10YR4/3) silt that was structureless, slightly plastic, and included grass roots and no gravel. The lower boundary was abrupt and smooth. Layer II (0.4-1.8 m) is a yellowish brown (10YR5/8) silt that was fine, slightly plastic, and had no roots or gravel included. The water table was not exposed in this excavation. This trench was located to the south of Feature 1, Site -3094.

Stratigraphic Trench 13 (ST-13)

ST-13 measured 9.14 m long and 0.6 m wide and was oriented at 40/220 degrees. The trench was excavated to a maximum depth of 1.8 m and exposed two stratigraphic layers. Layer I (0.0-0.4 m) was composed of dark brown (10YR4/3) silt that was structureless, slightly plastic, and included grass roots and no gravel. The lower boundary was abrupt and smooth. Layer II (0.4-1.8 m) is a yellowish brown (10YR5/8) silt that was fine, slightly plastic, and had no roots or gravel included. The water table was not exposed in this excavation. This trench was located to the east of Feature 1, Site -3094.

DISCUSSION AND CONCLUSIONS

IDENTIFIED SITES

A total of sixteen (16) sites were identified within the project area and extended survey area. As shown in Table 1 above, six sites occur within the project area (Sites -2254, -2255, -2256, -2257, -2263, and -2264) and ten sites occur outside the project area (Sites -2250, -2251, -2252, -2253, -2258, -2259, -2260, -2261, -2262, and -3094).

Fifteen (15) of the sites were newly identified during the current survey; and one site, a boulder with petroglyphs designated State Site 50-30-10-3094, was re-located in the extended survey area. During pedestrian survey of the extended survey area, a buried boulder or exposed bedrock outcrop with petroglyphs was identified 20 m to the southeast of the primary boulder (Site -3094, Feature 2). During survey of the extended survey area, approximately 70 m northeast of the primary boulder, a third feature (Site -3094, Feature 3), a large boulder with vertical faces and petroglyphs of human figures was found by the SHPD. These two new features are added to Site -3094 to form the petroglyph complex. All three features occur outside the project area.

PRE-CONTACT/EARLY HISTORIC PERIOD SITES

Sites 50-30-10-2250 (enclosure) and -3094 (petroglyphs), both located outside the project area, are believed to be associated with pre-Contact and/or early historic occupation. Site 50-30-10-2250 has been identified as an agricultural *heiau*. Multiple test units were placed at this site. No cultural materials were found within the enclosure. However, excavations at several locations along the north and west walls did expose what appear to be foundations for the walls built of sub-angular gravel and cobble sized basalt. Excavations within the interior of the enclosure exposed no such deposit, so it is thought that rather than a paving, the deposit represents a construction or engineering component of the *heiau*. Given the location of Site -2250, at the base of Ha'upu ridge, where rain water runoff would have flowed, it would be necessary for walls to have a foundation base course component. One artifact, a lithic chopping tool, was recovered from 20 meters to the east of the enclosure but interpreted as an isolated find with no connection to Site -2250.

Site -2250 is interpreted as an agricultural *heiau* due to its size, construction (uprights, paved foundation), location, and lack of cultural materials normally indicative of a *kau hale* or community *hale*. An agricultural *heiau*, also referred to as *mapele* or Hale O Lono (the god of fertility) is directly associated with ceremonies to ensure the fertility of the crops (Handy 1972:386). These *heiau* are often utilized for prayer and meditation, which could explain the lack of cultural materials recovered during excavations of the site.

Examples of other agricultural *heiau* include Kaneaki Heiau in Makaha (O'ahu) and Pahua Heiau in Hawaii Kai (O'ahu). The differences between these agricultural *heiau* and the one documented herein are quite vast in terms of monumental construction. While the size of each may be similar, the actual construction was vastly different. Many *heiau* often consist of massive amounts of rocks, multiple courses of rocks piled many meters high, and which stand out in complexity and breadth (Thrum 1907). However, there are many exceptions as *heiau*, in the broader sense, can encompass smaller structures such as small agricultural *heiau* and *ahu*. The current Site -2250 enclosure fits more into this latter category as it is only monumental in size, not construction, is rather compact, and its outline is clearly defined. The north, east and west walls are two to three courses wide and two to three courses high. Located at the north corner entrance and the bend in the western wall both are upright, small boulders. In terms of energy expenditure, what is viewed today would not have taken much labor to create. However, the structure is solidly constructed and is at present in good condition. The walls are too low for this to have served as an animal pen.

A cluster of LCA settlements were located several hundred meters to the south of the *heiau*. It is possible that Site -2250 is associated with some activity from those households. However, Site -2250 is placed at the base of the slope off the ridge, amidst a scattering of boulders that may have been too numerous to move, or that moving them was unnecessary as they were located within a woodland valued for its resources. The structure being built in this location, where it was unnecessary and impractical to dismantle, as well as a healthy respect by residents for something built by their ancestors, may have led to the preservation of this site. That the archaeological record of the site did not allow for dating, due to the lack of cultural materials, charcoal, coral, or midden, will undoubtedly ensure some conversation on the chronology of the site.

Site -3094 consists of a previously identified petroglyph rock, with two additional petroglyph rocks (designated as Feature 2 and Feature 3) identified during the current survey. Feature 1 is a large petroglyph boulder. Feature 2 is either exposed bedrock or a buried boulder with two petroglyphs visible located 20 m southeast from, and in the same clearing as Feature 1. Feature 3 is located approximately 70 m to the northeast of Feature 1, and is at the base of the wooded slope, with several pecked figures. The petroglyphs are interpreted to be pre-Contact features. Feature 1 is perhaps the most interesting, having a large number of petroglyphs around the rock faces, as well as mortars and carved lines on the top of the rock. During a community site visit in February 2105, a gentleman (K. Pike) noted that the curved lines on the top of the rock, leading from a circular mortar, could indeed be a map of a water spring in the area, with the curved lines representing a drainage. He stated that it could also be that offerings were placed in the mortar, and would “flow” down the curves and back into the lands. Both were viable interpretations and could be equally appropriate.

HISTORIC PERIOD SITES

The remaining sites documented during this AIS within and outside the project area formed an interesting network of features, all associated in some manner with the intensive cultivation of sugar cane in the valley. For example, the two retaining walls, Sites -2254 and -2257, supported the stream banks so water could continue to flow unimpeded, and are located within two different stream bed branches upstream of where the two braid together forming the main course of Māhā'ulepū Stream. Both are walls constructed of dry stacked sub-angular basalt cobbles and boulders built into the face of the stream bank and upon earthen terraces at the base of slope into their respective stream beds. Site -2254 appears to be primarily intact. Site -2257 has partially collapsed at its western end but the remainder appears solid. These walls have weathered the course of time well. Of note is that the stream bed containing Site -2254 has been modified in recent years by the construction of Site -2255, four culvert bridges for the conveyance of agricultural equipment. This stream bed was nearly empty of gravels, cobbles, or boulders.

The stream bed containing Site -2257 (retaining wall) had an associated historic-era feature, Site -2256, a concrete bridge with retaining walls of boulder sized quarried basalt blocks mortared together with concrete. These retaining walls appear to be contemporaneous with the bridge but appear to post-date Site -2257. Additionally, the stream containing Sites -2256 and -2257 has an abundance of water worn gravels and cobbles, and sub-angular basalt cobbles and boulders strewn along the bed, from where the stream enters the valley to its junction with the other branch of the stream. The mixture of water worn and sub-angular basalt suggests that this stream bed was not so thoroughly modified during plantation operations. It is possible that the function of both of these retaining walls may be related to mid-19th century LCA activities in the valley.

The remaining sites consist of features also constructed during various phases of the development of sugar cane cultivation within Māhā'ulepū Valley. State Site 50-30-10-2261 is a good example of this. The northern component of the bridge is constructed of boulder sized quarried basalt blocks, with the date “1908” inscribed into the concrete surface. The southern component is constructed of concrete, with an inscription of “1951” on the southern face of the curb. Furthermore, this southern curb has a metal rail constructed of a narrow gauge rail road rail. A similar rail is affixed to Site -2260, a bridge that also has the date “1951” inscribed into face of its concrete curb. As stated above, Site -2257 has two components, retaining walls of boulder sized quarried basalt blocks mortared together, and a concrete bridge mounted atop them.

All of these are examples of development of the plantation infrastructure over time. Mortared basalt walls post-date traditional dry stacked construction utilizing sub-angular basalt cobbles and boulders. These walls built of quarried basalt in turn pre-date infrastructure built of concrete, but could, as in the case of Sites -2257, and more dramatically, Site -2261, be incorporated into more recent efforts to update the infrastructure of the plantation. Similarly, the utilization of rail road rails into these updates is telling. The steam driven sugar cane railroads were utilized during the late 19th and early 20th centuries, post-dating the use of draft animals.

The rail road lines were designed to be transported and laid into fields where needed during harvest. The use of the rail coincided with the use of steam-powered tractors, which also took over from draft animals. The age of steam came to an end in the third decade of the 20th century, and was replaced by gas, diesel and oil powered vehicles. The use of trucks required the improvement of the infrastructure, in the form of more bridges and roads. As the 20th century proceeded, so too did the improvement in size and power of these vehicles, once again requiring the improvement of the infrastructure. While rail roads were no longer necessary, the rails could still be used in new ways.

The date “1951” inscribed on two bridges is another indicator of change. The plantation flourished with the world economy, doing well in the early 20th century up until The Great Depression. Followed by the tumult of World War II, it would have been a leaner decade for landowner Koloa Plantation than hoped for. This may have led to the sale of the plantation from Koloa Plantation to Grove Farm in 1948. Improvement of the infrastructure by the new owners is marked by the inscription of the date “1951” on some of these improvements.

The development of fuels for engines beyond steam power also allowed for improvements to irrigation. Not having to rely on gravity, rainfall, wind power or steam engines, wells could be drilled and the water pumped from well stations into places such as Site -2258, the Māhā'ulepū Reservoir. From the Reservoir, ditches, probably existing from earlier phases, were improved to carry increased flow along the valley edges and directed into desired areas.

That the valley was intensively transformed for the industrial-level of sugar cane cultivation is well documented. The many bridges, culverts, ditches, and sluice gates all speak to the incredible management, especially of water to the thirsty sugar cane, needed to produce such a crop. While the landscape contains such infrastructure, it was also destructive to the earlier archaeological record. Such massive landscape changes often results in the destruction of earlier sites, such as *kuleana* walls, mounds, enclosures, and other residential structures. The importance of the Plantation era to the economics and lifestyle of the 19th and 20th centuries in Māhā'ulepū and the greater Kōloa region is vastly important to understanding the entire chronology and land use of the area.

The primary 20th century modification to the valley was the drilling of wells to feed the Māhā'ulepū Reservoir. Ditches documented during the AIS led to and from the northern and southern ends of the reservoir, with pipelines extending to the ditch that paralleled the Māhā'ulepū stream course. Clearly, the reservoir was taking water out of the valley to other fields of the Kōloa area plantation. There is no evidence that these modifications were built on the backs of earlier historic or traditional era irrigation systems. It must be kept in mind that the intensity of sugar cane cultivation operations erased a great deal of evidence of previous occupation.

Sugar cane cultivation required plowing operations that could reach depths of up to 1 meter below ground surface. Nearly one hundred years of these operations have scoured the Māhā'ulepū Valley floor. No cultural materials of any era were found during pedestrian survey of the valley floor. Areas identified on historic maps as having been wells and pumping stations, as well as LCA settlements had no materials or artifacts which could be attributed to the former occupants.

However, it has been borne out by the current research, in some areas, the deeper past is preserved, both within the fields and on their outer reaches. Site -3094 and Site -2250 remain intact and are thought to represent pre-/early Contact period ceremonial pursuits. That Feature 1 of Site -3094 petroglyph boulder was preserved, when all around it sugar cane was cultivated, speaks to its importance. Intensive transformation occurred in the valley, which is why Feature 2 of Site -3094 was such an interesting find: it occurred beneath the grasses in the only location which mechanical stratigraphic test trenching showed not to have been impacted by sugar cane cultivation.

TRAILS

SHPD and the community emphasized the need to consider potential trails in the area, particularly those that would lead to the top of the ridgeline to the east. Given reports of Keolewa Heiau possibly located atop Mount Ha'upu, and the former Hanakalauea Heiau within the valley (outside the current project area), this could suggest that pre-/post Contact/Historic era trails may have once connected the project area to the upper ridgeline. The ridgeline has also been considered as culturally significant by some. Despite ethnographic accounts of Keolewa Heiau, there are no direct observations of such a religious structure; and it may be that the crest of the mountain was regarded as holy but no structure was ever constructed and sanctified through ceremony to make it so. A limited field inspection by SCS to the summit in December 2015 did not discover any definitive structural elements typically associated with *heiau* construction.

An archaeological survey was conducted of the extended survey area, and a brief reconnaissance survey was also conducted along the base of the valley's slopes and up toward the ridgeline to the north and east to ascertain the presence/absence of trails to the ridgeline. SCS archaeologists hiked to just below the summit of the northern and eastern ridgelines, which proved to be inaccessible from this location. Although a modern trail can be observed in Google Earth imagery (2014) from the summit proceeding down the southern ridge, it is likely that the trail continues south along the eastern ridge of Māhā'ulepū Valley towards Pu'u Keke and does not connect to the project area.

An SCS crew field visit was completed on June 19, 2015 to the location where the word "Path" was marked on Registered Survey Map #1898 (see Figure 9). Given that the possible path shown in the survey map was marked slightly on the *mauka* side of a land division which still exists today, the map was georeferenced to existing TMK and physical landscape features and the path location was exported to a GPS for relocation in the field.

Upon arriving at the precise georeferenced location, it was apparent that the possible path was situated directly on the uphill side of a former historic period agricultural ditch. Both flume and lock components which functioned to control the flow of water into the field were visible in the vicinity of the possible path. On the uphill side of the ditch is a fence and on the uphill side of the fence, and following it, is a flattened area which served the maintenance of the fence. The flume, fence, and maintenance path continue northwest towards the former reservoir and southeast towards Pu'u Keke. *Mauka* (east) of the agricultural infrastructure the land becomes rapidly and increasingly steep and is crisscrossed with informal game trails and erosional gullies. No evidence was found that a path or any other cultural feature was located above the area where the agricultural infrastructure flanks the field.

Finally, SCS had the pleasure of sitting down and listening to Mr. James Case, born and raised in Kōloa and now 95 years of age. Mr. Case presented a fascinating background of the Kōloa area, from his birth in 1920 through the plantation days and into the present. Of particular interest was his knowledge of trails in the area. Mr. Case, who was born on Grove Farm and grew up in Kōloa across the street from Wilcox Dairy, and had walked all over Kōloa and beyond as a child/teenager, and later, as a professional surveyor (prior to getting into law). He explored all the reaches of Māhā'ulepū Valley and even swam in the reservoir as a young boy.

Per trails in the Māhā'ulepū area, Mr. Case emphatically stated that he was unaware of any formal trails in or out of the valley. He reasoned that a) during the early days, it was easier to move by canoe on the ocean than by foot through the mountains; and b) all folks ascending the mountains would have used the Kōloa Gap, and not attempted to climb the ridges of Māhā'ulepū and beyond. He knew of many trails from Kipukai to Nawiliwili but none in Māhā'ulepū . He noted that, to his knowledge, there was no trail on top of the ridges around Māhā'ulepū as the east-west transition for all was indeed the Kōloa Gap.

Of additional interest, Mr. Case talked with SCS about land use through time and was not surprised that mainly historic sites were documented. He reasoned that sugar cultivation utilized a ratoon system for sugar cane cultivation, with deep excavation (to 4-5 feet below surface) and raising of furrows and mounds c. 6 feet apart across the surface. He noted that every 6 years the land was plowed for new crops, inferring that after so many decades of doing this intrusive work, it was unlikely any traces of former activities would be present.

Overall, there was no empirical evidence on the ground for any trails connecting the project area or the extended survey area to the eastern or northern ridgelines, especially the former, which would be a direct route to Mount Ha'upu. Only sporadic pig trails were present. These animal trails lead to dead ends below steep cliffs and slopes. However, there are easier ways to gain the heights of the ridge, and traditional occupants may not have found it necessary to access the steep eastern and northern valley walls to gain access to the ridgelines above.

Older maps also do not show access routes up to the ridgeline (see Figure 9). It is worth noting that when a prior survey was conducted of the ridgeline itself, no trails were evident and archaeologists had to be dropped by helicopter and cleared their way through the survey area (McMahon 1996). The only sign of any possible trail was found in Registered Survey Map #1898 which noted the presence of a "Path." This may simply have referred to a survey point on the ditch and not an actual trail.

Another line of evidence was that older generations may recall trails in the area. An interview with Mr. James Case, born and raised in the area, indicated that he had no knowledge of any trails or paths in the Māhā'ulepū area. Similarly, none of the other parties that were consulted in connection with this AIS provided any information about any trails (nor has any such information been discovered through the interviews conducted for the Cultural Impact Assessment).

In total, the findings of the AIS were as somewhat predicted, given the intensive land use during the 19th and 20th centuries in the project area. It was also interesting to note that the *heiau* was identified, and occurred in an un-cleared areas above the project area flat lands. Plantation-era features dominate the current landscape, as expected, given the industrial nature of the cultivation and process. It is within this vein that the project is proposed to move forward, also potentially utilizing the soils and infrastructure (ditches, etc.) created during this large-scale land alteration period.

ASSESSMENT OF PROJECT EFFECT ON HISTORIC SITES

In total, none of the 16 sites will be adversely affected by the proposed project, but safeguards will be in place. Those sites related to historic era sugar cane activities may be adaptively re-used. These are presented in Table 2, as well as avoidance measures to minimize negative impacts to the sites.

SIGNIFICANCE ASSESSMENTS AND RECOMMENDATIONS

All sixteen (16) sites previously or newly identified during the current AIS have been evaluated and identified as exhibiting one or more attributes of integrity and have been assessed for site significance according to HAR §13-284-6, Criteria a through e. The five criteria are listed below:

Criterion a: Site is associated with events that have made a significant contribution to the broad patterns of our history;

Criterion b: Site is associated with the lives of persons significant to our past;

Criterion c: Site is an excellent site type; embodies distinctive characteristics of a type, period, or method of construction, or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components may lack individual construction;

Criterion d: Site has yielded or has the potential to yield information important in prehistory or history;

Criterion e: Site has cultural significance; probable religious structures or burials present.

Table 2 summarizes descriptive information on the 16 sites, including location, their significance, proposed mitigation, and recommendations. Fourteen sites were assessed as significant only under Criterion d (information potential). These sites have been adequately documented and no further work is recommended.

Two sites (Sites -2250 and -3904) were assessed as significant under Criterion d (information potential) and e (cultural value) but occur outside the project area. Neither site will be adversely affected by the current proposed project.

SHPD recommends, in the advent of future work outside of the project area, that an architectural inventory survey be conducted for those sites related to the sugar industry in Māhā'ulepū Valley (Sites -2251, -2252, -2253, -2258, -2259, -2260, -2261 and -2262).

The enclosure (Site -2250) and the petroglyph complex (Site -3094) occur outside the project area, in an area the SHPD required for survey (see Methodology section). While permission was granted to survey this area, the current landowner wherein the two sites occur is not party to the current document. Therefore, this document does not apply any recommendations for these two sites. For future development outside the HDF site, SHPD has indicated that it may recommend preservation of the two sites.

Table 2. Site Descriptive Data, Significance, Recommendations, and Possible Adaptive Re-uses.

SIHP 50-30-10-	Site Type	Function	# Features	Age	Significance & Recommendations	Adaptive Re-use	Location
2250	Enclosure	Ceremonial	1	Pre/early post Contact	d, e; Preservation	None; Consultation to occur prior to any future proposed impacts to the area.	Out of Project Area
2251	Ditch, Gate	Irrigation	2	Historic	d; NFW*	None at this time.	Out of Project Area
2252	Ditch, Gates	Irrigation	3	Historic	d; NFW*	None at this time.	Out of Project Area
2253	Ditch	Irrigation	1	Historic	d; NFW*	None at this time.	Out of Project Area
2254	Retaining Wall	Soil Retention	1	Historic	d; NFW	Cows will be excluded from feature by fencing as it lies near waterway.	Inside Project Area
2255	Culvert Bridges	Irrigation	4	Historic	d; NFW	Will be used to cross existing waterway.	Inside Project Area
2256	Bridge	Transport	1	Historic	d; NFW	Will be used to cross existing waterway.	Inside Project Area
2257	Retaining Wall	Soil Retention	1	Historic	d; NFW	Cows will be excluded from feature by fencing as it lies near waterway.	Inside Project Area
2258	Reservoir	Water Storage	1	Historic	d; NFW*	None at this time.	Out of Project Area
2259	Ditch	Irrigation	1	Historic	d; NFW*		Out of Project Area
2260	Bridge	Transport	1	Historic	d; NFW*	None at this time.	Out of Project Area

SIHP 50-30-10-	Site Type	Function	# Features	Age	Significance & Recommendations	Adaptive Re-use	Location
2261	Bridge	Transport	1	Historic	d; NFW*	None at this time.	Out of Project Area
2263	Bridge	Transport	1	Historic	d; NFW*	Will be used to cross existing waterway.	Inside Project Area.
2264	Pipe/Foundation	Irrigation	1	Historic	d; NFW	Possible Re-use.	Inside Project Area.
2262	Flume, Gates	Irrigation	3	Historic	d; NFW*	Out of Project Area	Out of Project Area
3094	Petroglyphs	Ceremonial	3	Pre/early post-Contact	d, e; Preservation	Out of Project Area	Out of Project Area

***SHPD recommends an architectural survey be completed for this site prior to initiation of any future proposed project that may impact this historic property.**

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APPENDIX A: STRATIGRAPHIC PROFILES AND REPRESENTATIVE TRENCH PHOTOGRAPHS

ST-1 TRENCH

Figure 83. ST-1 view to east.

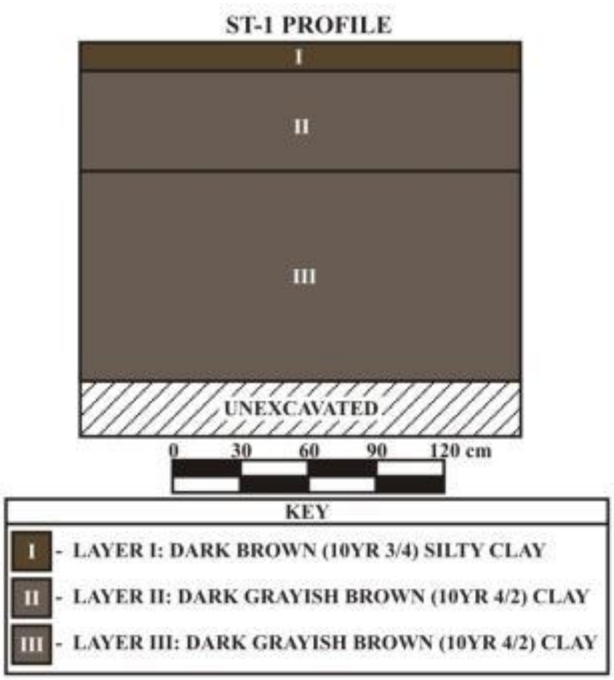

Figure 84. ST-1 profile, north wall.

ST-2 TRENCH

Figure 85. ST-2 view to west.

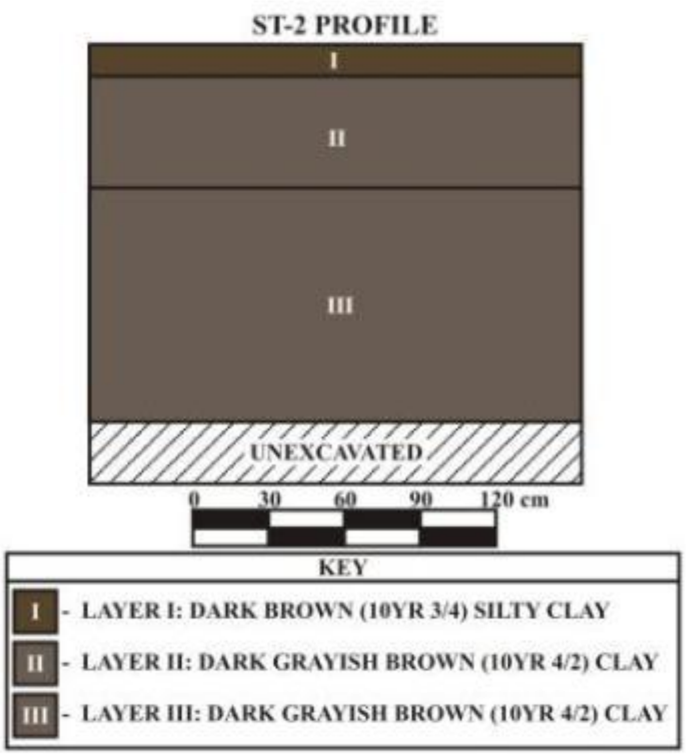

Figure 86. ST-2 profile, north wall.

ST-3 TRENCH

Figure 87. ST-3 view to west.

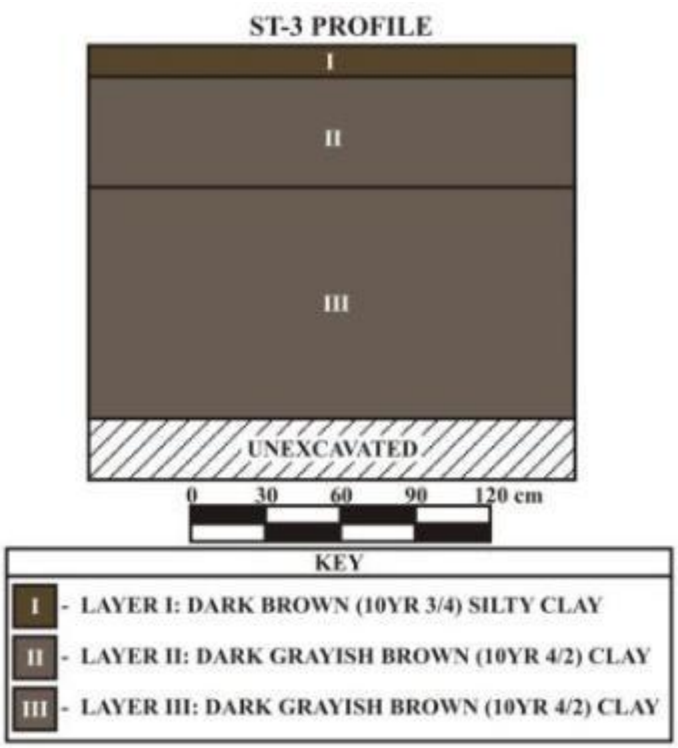

Figure 88. ST-3 profile, south wall.

ST-4 TRENCH

Figure 89. ST-4 view to east.

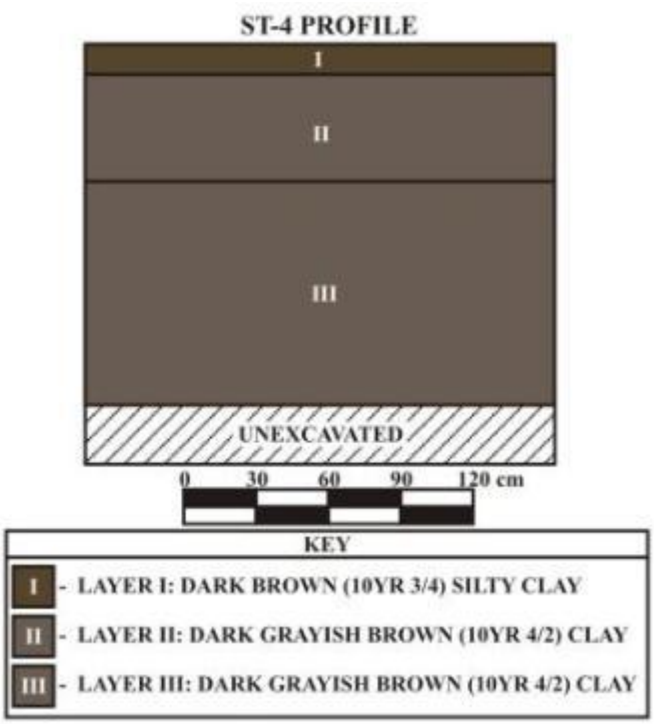

Figure 90. ST-4 profile, north wall.

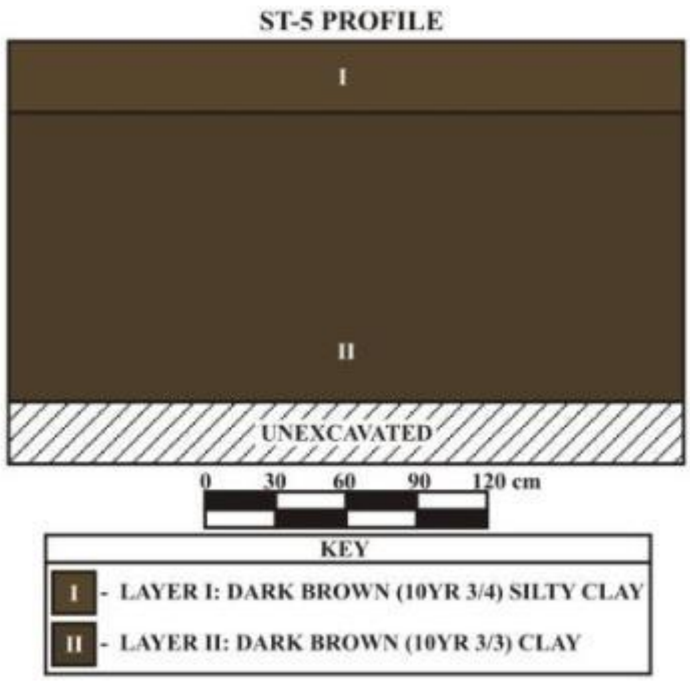

Figure 91. ST-5 profile, north wall.

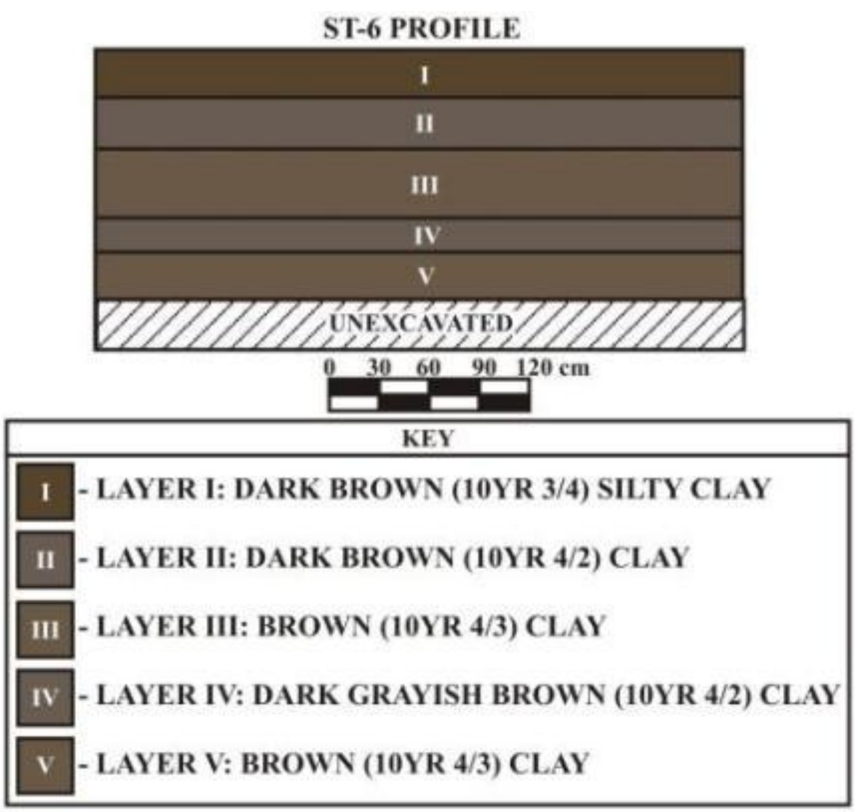

Figure 92. ST-6 profile, south wall.

ST-7 TRENCH WEST WALL

Figure 93. ST-7 west wall, view to north.

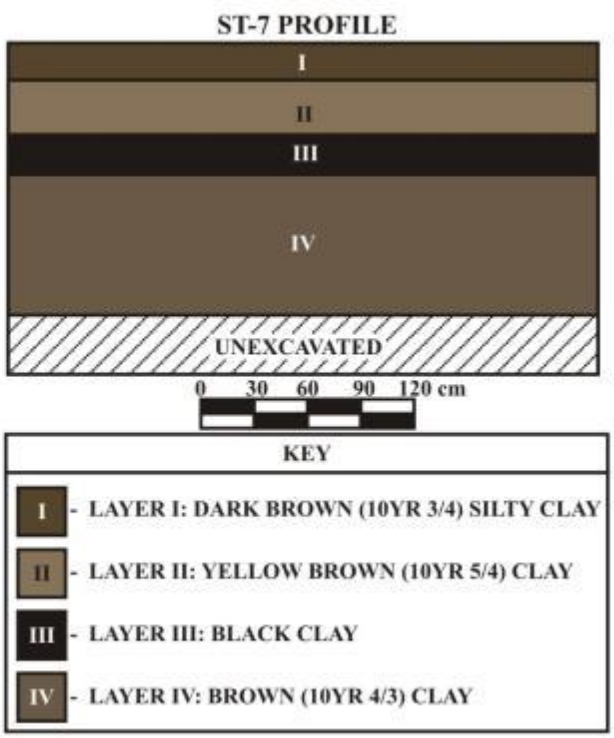

Figure 94. ST-7 profile, north wall.

ST-8 TRENCH

Figure 95. ST-8 trench north wall, view to north.

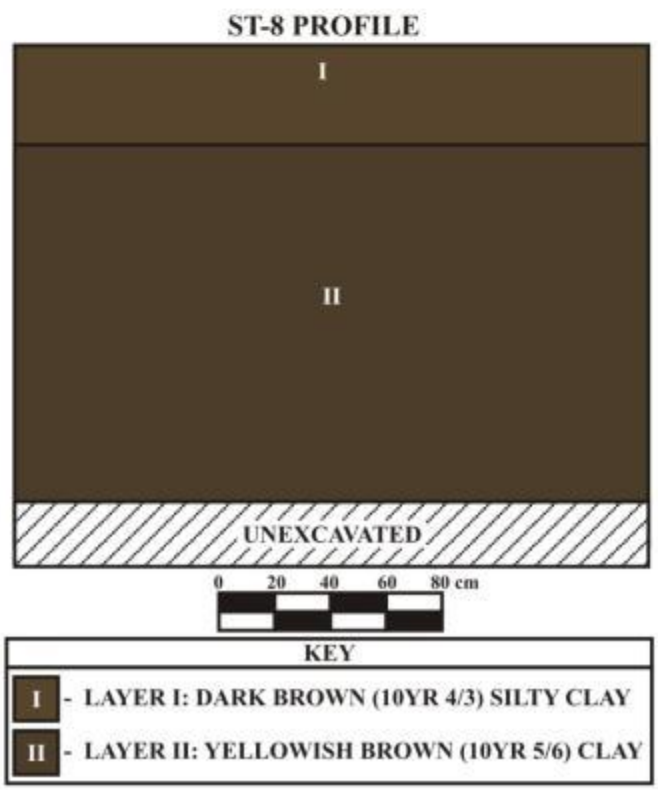

Figure 96. ST-8 profile, view to north.

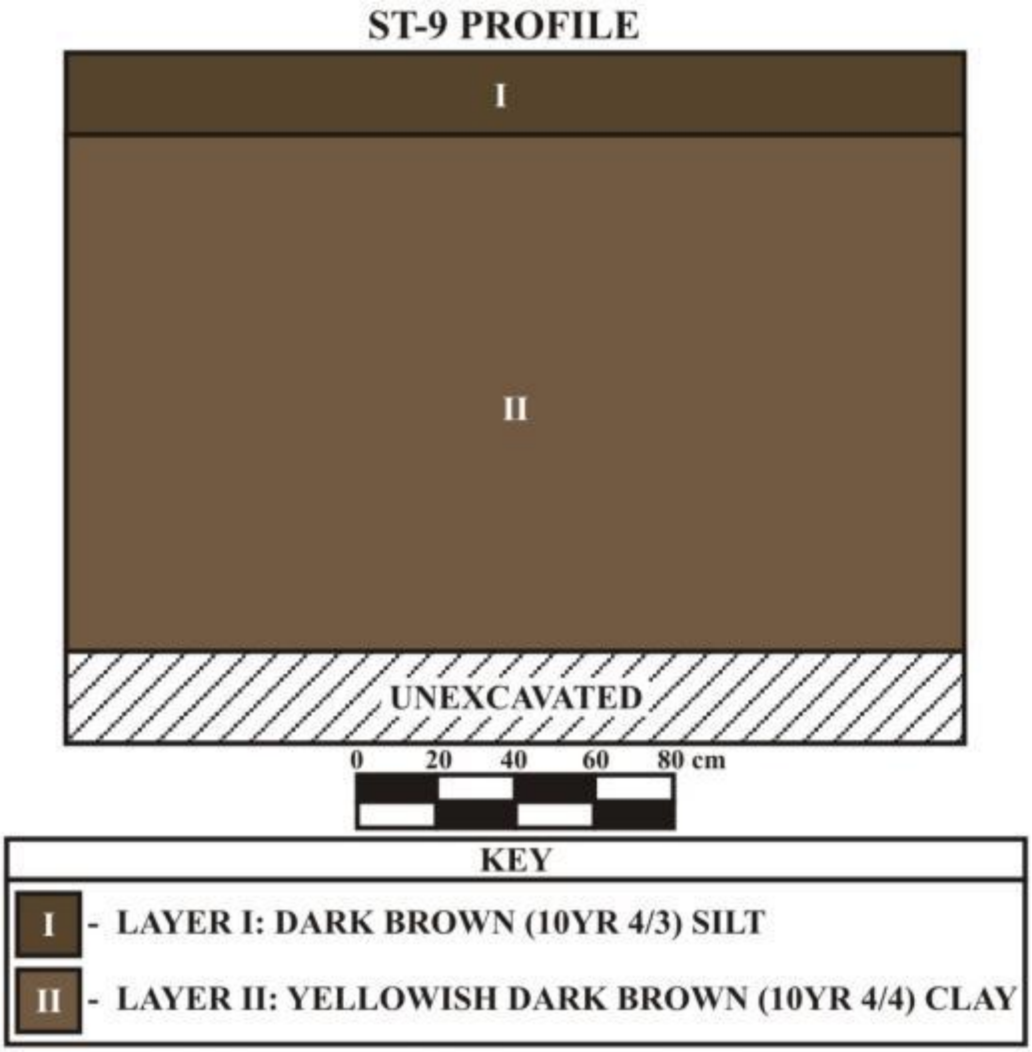

Figure 97. ST-9 profile, north face.

ST-10 TRENCH

Figure 98. ST-10 view to east.

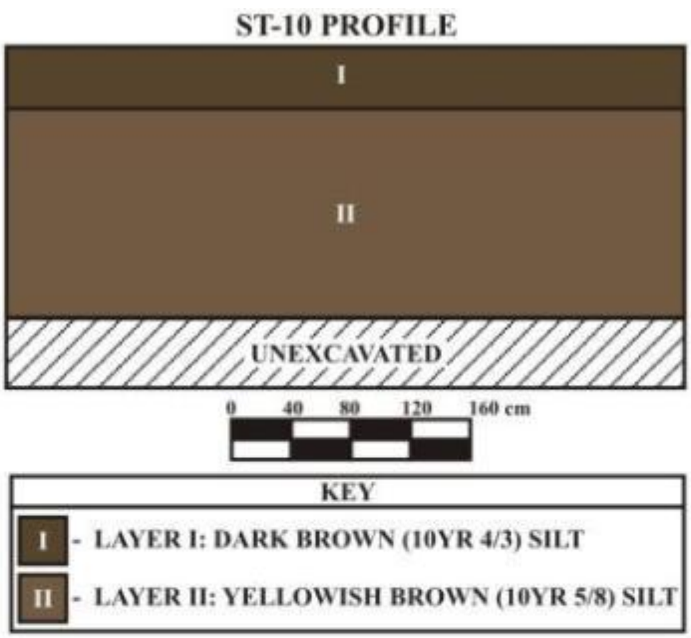

Figure 99. ST-10 profile, south wall.

ST-11 TRENCH WITH SITE -3094

Figure 100. ST-11 view to north.

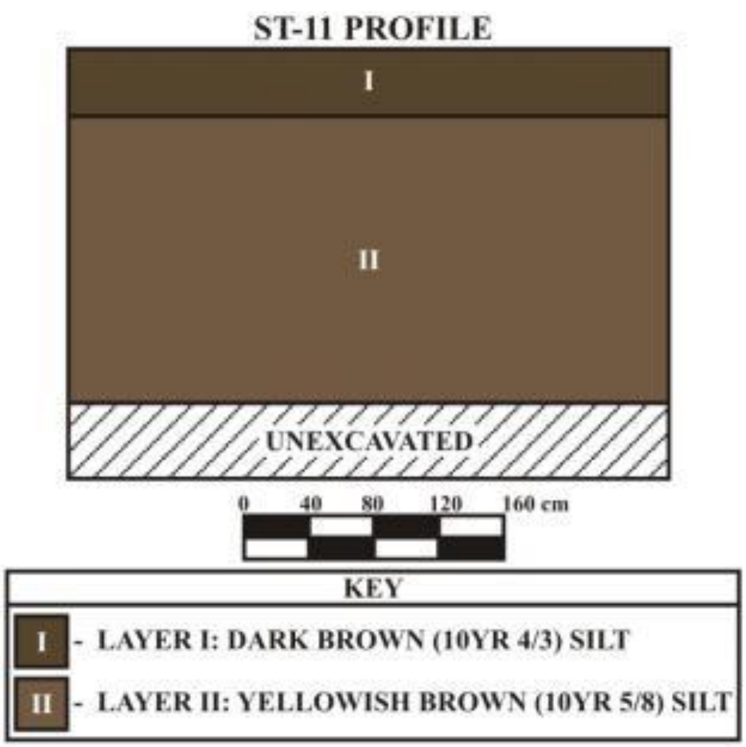

Figure 101. ST-11 profile, north wall.

ST-12 AND ST-13 TRENCHES

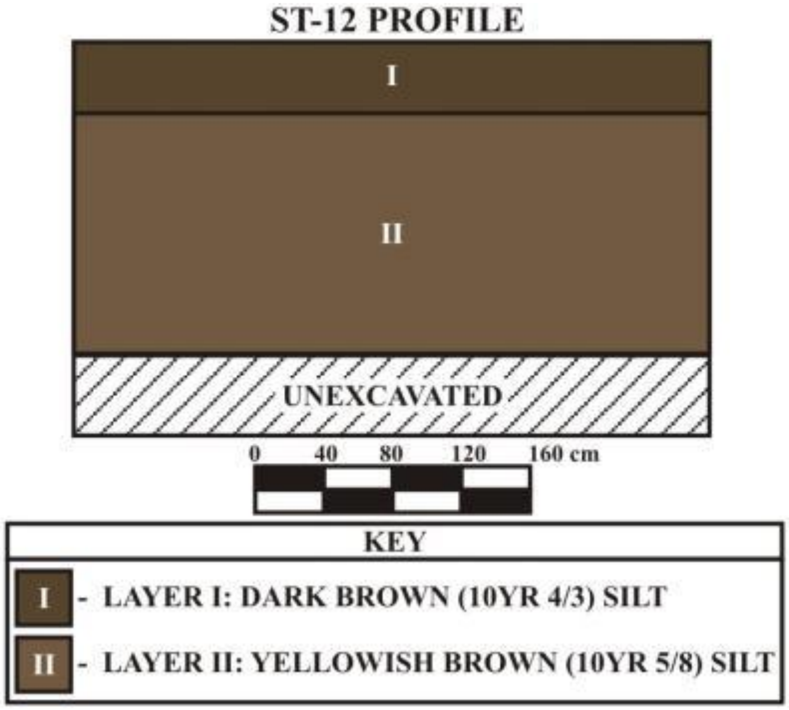

Figure 102. ST-12 profile, north wall.

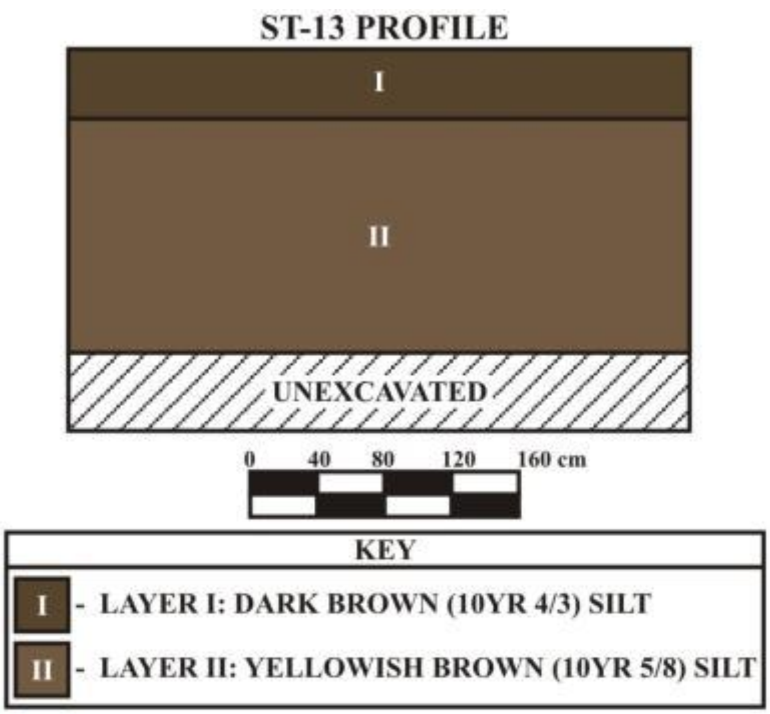

Figure 103. ST-13, south wall.

ST-14 TRENCH

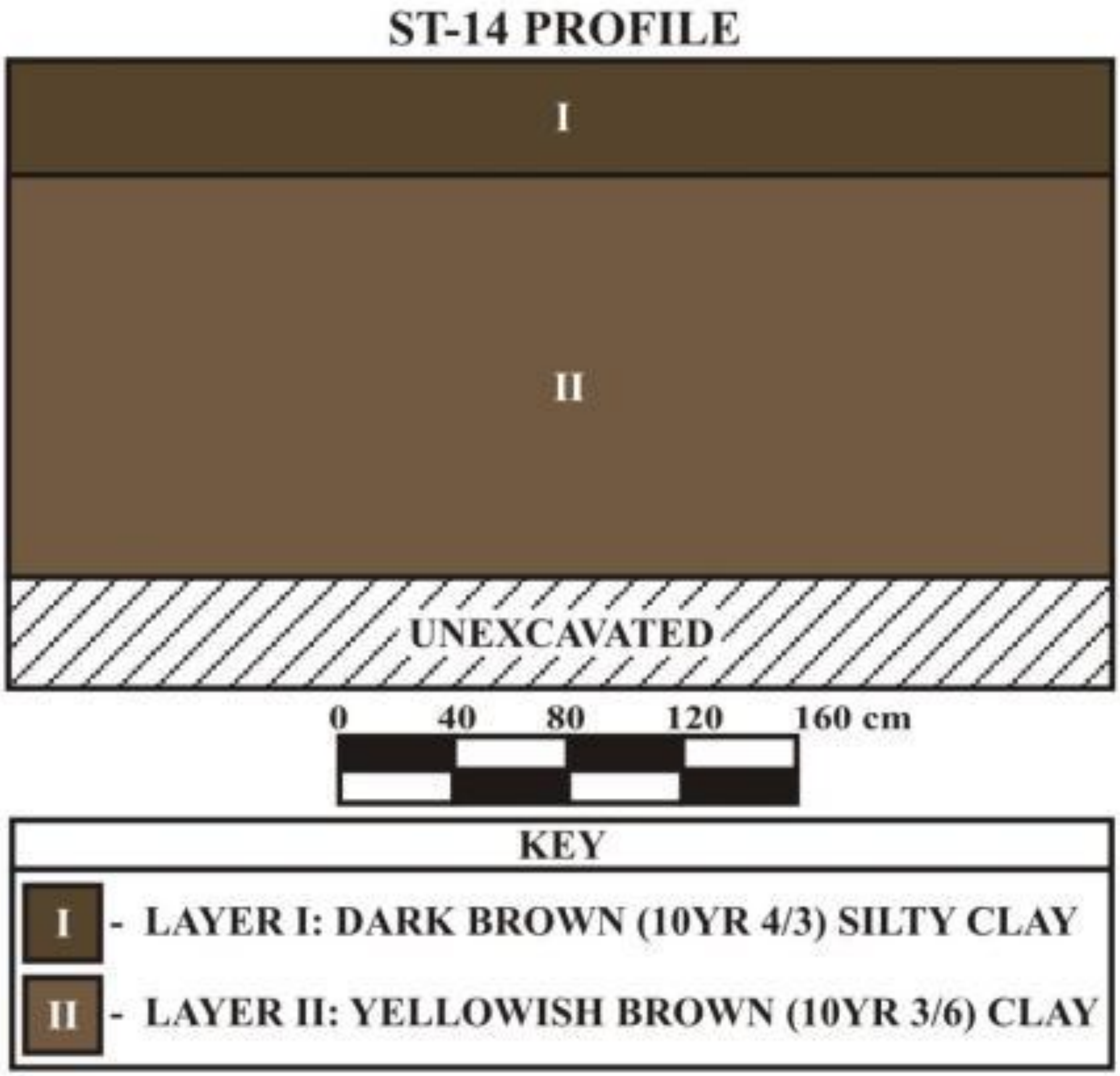

Figure 104. ST-14 profile, south wall.

ST-15 TRENCH

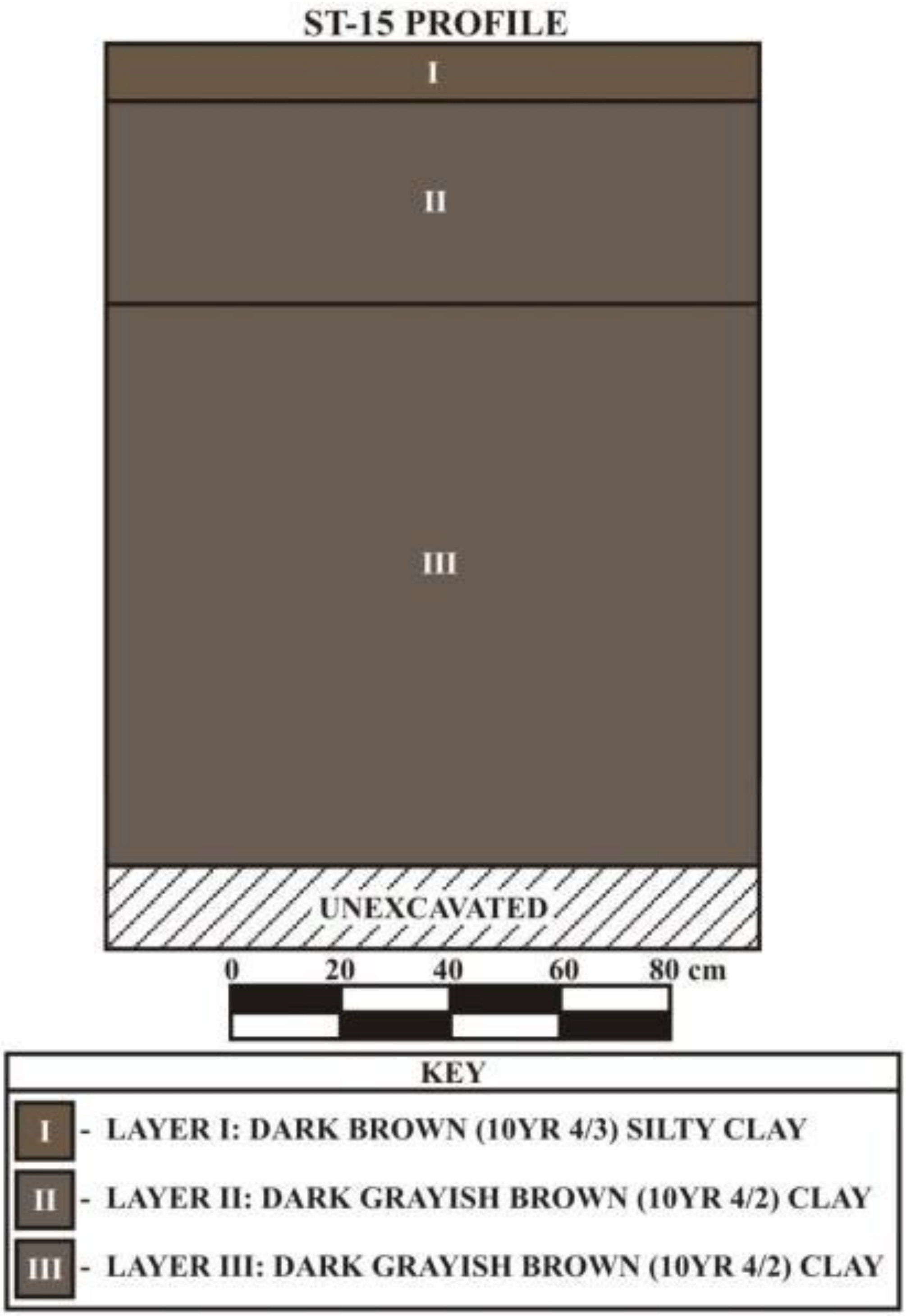

Figure 105. ST-15 profile, west wall.

ST-16 TRENCH

Figure 106. ST-16 view to north.

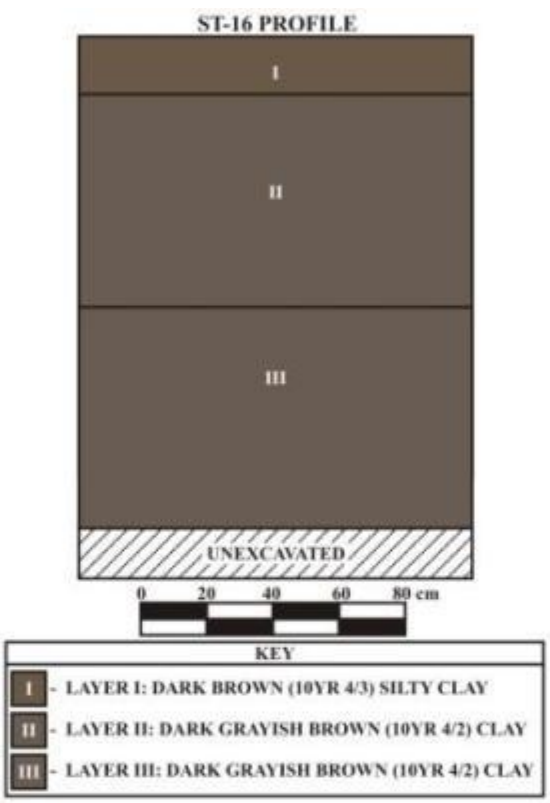

Figure 107. ST-16 profile, east wall.

ST-17 TRENCH

Figure 108. ST-17 west wall detail, view to west.

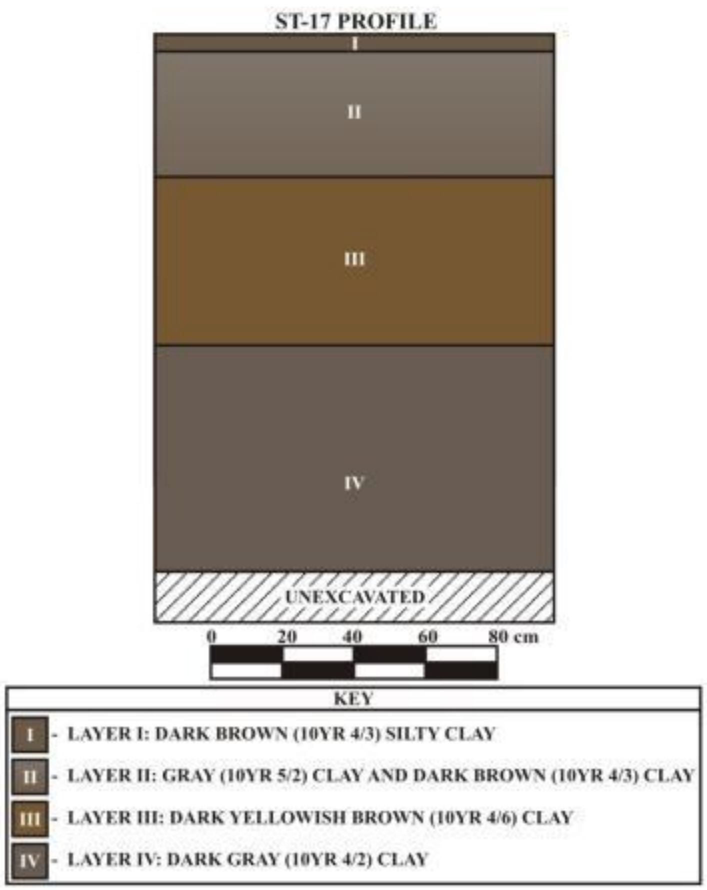

Figure 109. ST-17 profile, west wall.

APPENDIX H

CULTURAL IMPACT ASSESSMENT, MĀHĀʻULEPŪ AHUPUAʻA, KŌLOA DISTRICT, KAUAʻI ISLAND, HAWAIʻI

SCIENTIFIC CONSULTANT SERVICES, INC.

SCS Project No. 1683-3 CIA

CULTURAL IMPACT ASSESSMENT
MĀHĀ'ULEPŪ AHUPUA'A, KŌLOA DISTRICT, KAUA'I ISLAND, HAWAI'I

TMK: (4) 2-9-001:001 por., (4) 2-9-003:001 por., and (4) 2-9-003:006 por.

Prepared by:

Michael F. Dega., Ph.D.

May 2016

Prepared for:

Hawaiʻi Dairy Farms LLC
P.O. Box 1690
Kōloa, Kaua'i, Hawai'i 96765

SCIENTIFIC CONSULTANT SERVICES Inc.

1347 Kapiolani Blvd., Suite 408 Honolulu Hawai`i 96814

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

At the request of Hawaii Dairy Farms LLC, Scientific Consultant Services, Inc. prepared a Cultural Impact Assessment (CIA) of a 557 acre in advance of proposed improvements for a proposed dairy farm property located within Māhā'ulepū Valley, Māhā'ulepū Ahupua'a, Kōloa District, Island of Kaua'i. The property is owned by Mahaulepu Farms LLC and comprises TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por. (Figures 1 and 2).

The Constitution of the State of Hawai'i clearly states the duty of the State and its agencies is to preserve, protect, and prevent interference with the traditional and customary rights of Native Hawaiians. Article XII, Section 7 (2000) requires the State to "protect all rights, customarily and traditionally exercised for subsistence, cultural and religious purposes and possessed by *ahupua'a* tenants who are descendants of Native Hawaiians who inhabited the Hawaiian Islands prior to 1778." In spite of the establishment of the foreign concept of private ownership and western-style government, Kamehameha III (Kauikeaouli) preserved the peoples traditional right to subsistence. As a result in 1850, the Hawaiian Government confirmed the traditional access rights to Native Hawaiian *ahupua'a* tenants to gather specific natural resources for customary uses from undeveloped private property and waterways under the Hawaiian Revised Statutes (HRS) 7-1. In 1992, the State of Hawai'i Supreme Court, reaffirmed HRS 7-1 and expanded it to include, "native Hawaiian rights…may extend beyond the *ahupua'a* in which a Native Hawaiian resides where such rights have been customarily and traditionally exercised in this manner" (Pele Defense Fund v. Paty, 73 Haw.578, 1992).

Act 50, enacted by the Legislature of the State of Hawai'i (2000) with House Bill (HB) 2895, relating to Environmental Impact Statements, proposes that:

> …there is a need to clarify that the preparation of environmental assessments or environmental impact statements should identify and address effects on Hawaii's culture, and traditional and customary rights… [H.B. NO. 2895].

Articles IX and XII of the State constitution, other state laws, and the courts of the State impose on government agencies a duty to promote and protect cultural beliefs and practices, and resources of Native Hawaiians as well as other ethnic groups. Act 50 also requires state agencies and other developers to assess the effects of proposed land use or shoreline developments on the "cultural practices of the community and State" as part of the HRS Chapter 343 (2001) environmental review process.

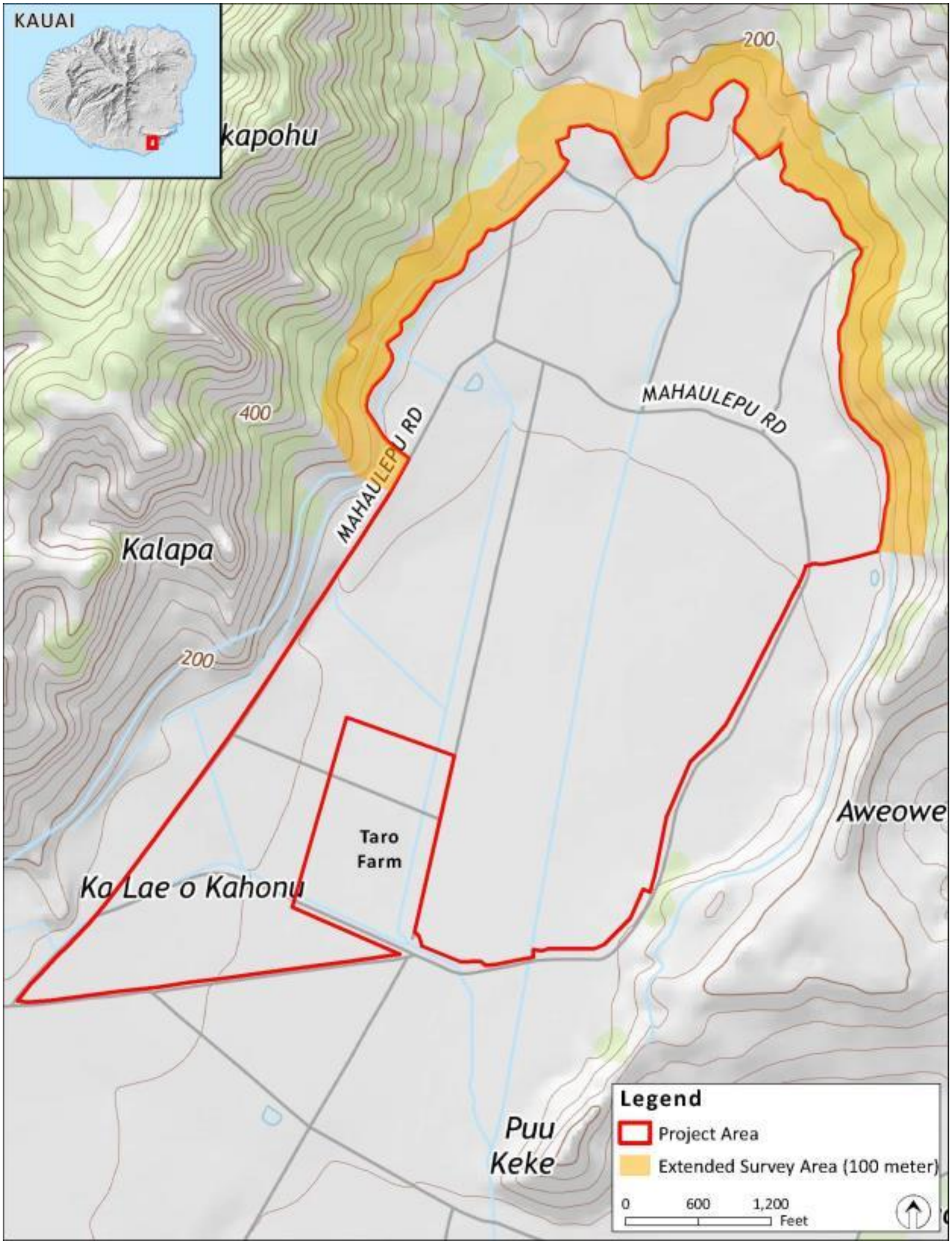

Figure 1: USGS Quadrangle (Lihue 1996; 1:24,000) Map Showing Project Area Location.

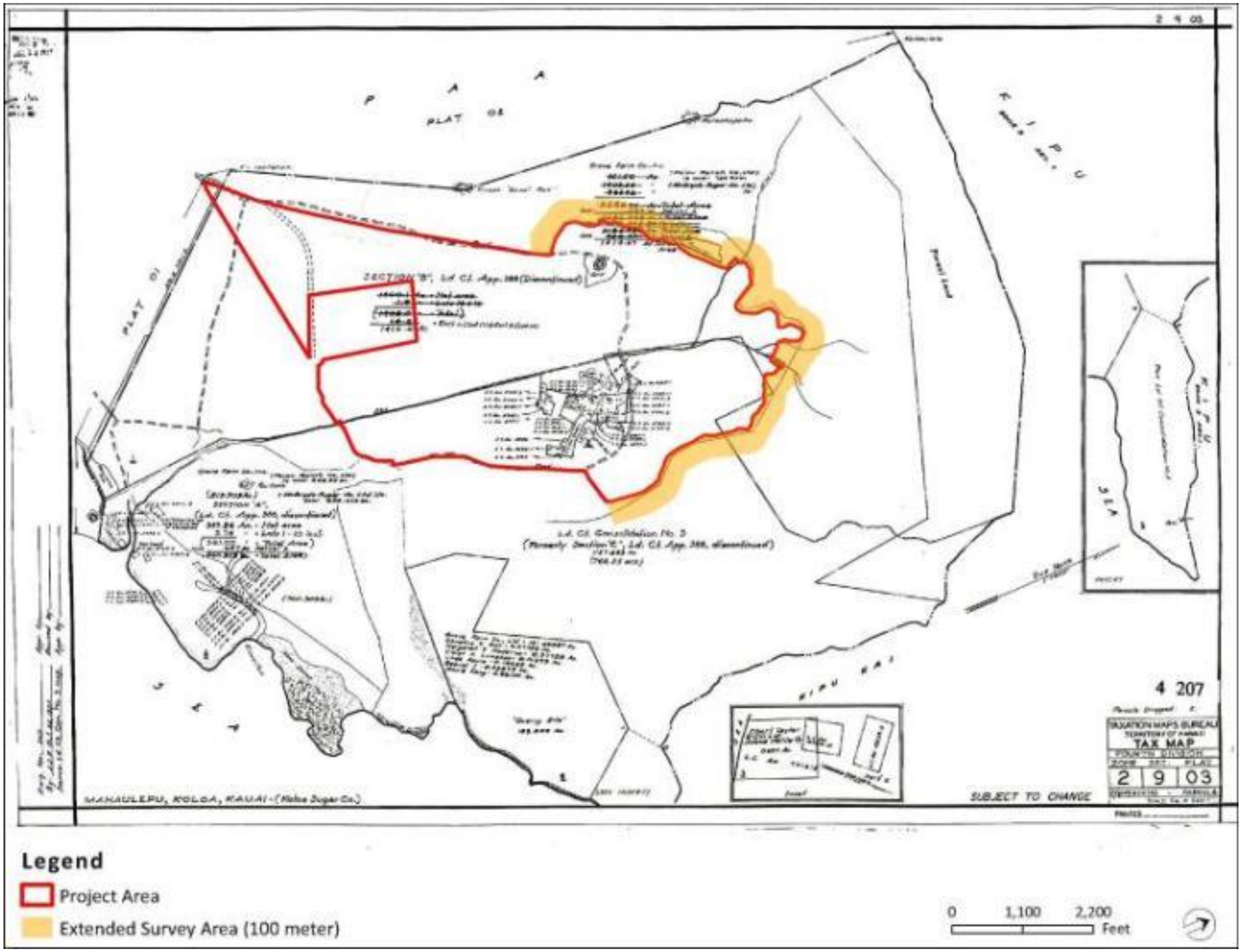

Figure 2: Tax Map Key [TMK: (4) 2-9-003] Map Showing Project Area Location.

It also redefined the definition of “significant effect” to include “...the sum of effects on the quality of the environment, including actions that irrevocably commit a natural resource, curtail the range of beneficial uses of the environment, are contrary to the State's environmental policies . . . or adversely affect the economic welfare, social welfare or cultural practices of the community and State” (H.B. 2895, Act 50, 2000). Cultural resources can include a broad range of often overlapping categories, including places, behaviors, values, beliefs, objects, records, stories, etc. (H.B. 2895, Act 50, 2000).

Thus, Act 50 requires that an assessment of cultural practices and the possible impacts of a proposed action be included in Environmental Assessments and Environmental Impact Statements, and to be taken into consideration during the planning process. As defined by the Hawaii State Office of Environmental Quality Control (OEQC), the concept of geographical expansion is recognized by using, as an example, “the broad geographical area, e.g. district or *ahupua'a*” (OEQC 2012:12). It was decided that the process should identify 'anthropological' cultural practices, rather than 'social' cultural practices. For example, *limu* (edible seaweed) gathering would be considered an anthropological cultural practice, while a modern-day marathon would be considered a social cultural practice.

Therefore, the purpose of a CIA is to identify the possibility of ongoing cultural activities and resources within a project area, or its vicinity, and then assessing the potential for impacts on these cultural resources. The CIA is not intended to be a document of in-depth archival-historical land research, or a record of oral family histories, unless these records contain information about specific cultural resources that might be impacted by a proposed project.

According to the Guidelines for Assessing Cultural Impacts established by the Hawaii State Office of Environmental Quality Control (OEQC 2012:12):

> The types of cultural practices and beliefs subject to assessment may include subsistence, commercial, residential, agricultural, access-related, recreational, and religions and spiritual customs. The types of cultural resources subject to assessment may include traditional cultural properties or other types of historic sites, both manmade and natural, which support such cultural beliefs.

The meaning of “traditional” was explained in *National Register Bulletin*:

> "Traditional” in this context refers to those beliefs, customs, and practices of a living community of people that have been passed down through the generations, usually orally or through practice. The traditional cultural significance of a historic property then is significance derived from the role the property plays in a community's historically rooted beliefs, customs, and practices. . . . [Parker and King 1990:1]

METHODOLOGY

This CIA was prepared as much as possible in accordance with the suggested methodology and content protocol in the Guidelines for Assessing Cultural Impacts (OEQC 2012:11-13). In outlining the "Cultural Impact Assessment Methodology," the OEQC (2012:11) states that:

> …information may be obtained through scoping, community meetings, ethnographic interviews and oral histories…

This report contains archival and documentary research, as well as communication with organizations having knowledge of the project area, its cultural resources, and its practices and beliefs. An example of the letters of inquiry is presented in Appendix A. Copies of the posted newspaper notice and the affidavit are presented in Appendix B. An example of the follow-up letter of inquiry is presented in Appendix C. The signed information release form is presented in Appendix D. This CIA was prepared in accordance with the suggested methodology and content protocol provided in the Guidelines for Assessing Cultural Impacts (OEQC 2012:13), whenever possible. The assessment concerning cultural impacts may include, but not be limited to:

A. Discussion of the methods applied and results of consultation with individuals and organizations identified by the preparer as being familiar with cultural practices and features associated with the project area, including any constraints or limitations which might have affected the quality of the information obtained.

B. Description of methods adopted by the preparer to identify, locate, and select the persons interviewed, including a discussion of the level of effort undertaken.

C. Ethnographic and oral history interview procedures, including the circumstances under which the interviews were conducted, and any constraints or limitations which might have affected the quality of the information obtained.

D. Biographical information concerning the individuals and organizations consulted their particular expertise and their historical and genealogical relationship to the project area, as well as information concerning the persons submitting information or interviewed their particular knowledge and cultural expertise, if any, and their historical and genealogical relationship to the project area.

E. Discussion concerning historical and cultural source materials consulted, the institutions and repositories searched and the level of effort undertaken. This discussion should include, if appropriate, the particular perspective of the authors, any opposing views, and any other relevant constraints, limitations or biases.

F. Discussion concerning the cultural resources, practices and beliefs identified, and, for resources and practices, their location within the broad geographical area in which the proposed action is located, as well as their direct or indirect significance or connection to the project site.

G. Discussion concerning the nature of the cultural practices and beliefs, and the significance of the cultural resources within the project area affected directly or indirectly by the proposed project.

H. Explanation of confidential information that has been withheld from public disclosure in the assessment.

I. Discussion concerning any conflicting information in regard to identified cultural resources, practices and beliefs.

J. Analysis of the potential effect of any proposed physical alteration on cultural resources, practices or beliefs; the potential of the proposed action to isolate cultural resources, practices or beliefs from their setting; and the potential of the proposed action to introduce elements which may alter the setting in which cultural practices take place.

K. A bibliography of references, and attached records of interviews which were allowed to be disclosed.

If ongoing cultural activities and/or resources are identified within the project area, assessments of the potential effects on the cultural resources in the project area and recommendations for mitigation of these effects can be proposed.

ARCHIVAL RESEARCH

Archival research focused on a historical documentary study involving both published and unpublished sources. These sources included legendary accounts of native and early foreign writers; early historical journals and narratives; historic maps; land records, such as Land Commission Awards, Royal Patent Grants, and Boundary Commission records; historic accounts; and previous archaeological reports.

INTERVIEW METHODOLOGY

Interviews are conducted in accordance with Federal and State laws and guidelines when knowledgeable individuals are able to identify cultural practices in, or in close proximity to, the project area. If they have knowledge of traditional stories, practices and beliefs associated with a project area or if they know of historical properties within the project area, they are sought out for additional consultation and interviews. Individuals who have particular knowledge of traditions passed down from preceding generations and a personal familiarity with the project area are invited to share their relevant information concerning particular cultural resources. Often people are recommended for their expertise, and indeed, organizations, such as Hawaiian Civic Clubs, the Island Branch of Office of Hawaiian Affairs (OHA), historical societies, Island Trail clubs, and Planning Commissions are depended upon for their recommendations of suitable informants. These groups are invited to contribute their input and suggest further avenues of inquiry, as well as specific individuals to interview. It should be stressed again that this process does not include formal or in-depth ethnographic interviews or oral histories as described in the OEQC's *Guidelines for Assessing Cultural Impacts* (2012). The assessments are intended to identify potential impacts to ongoing cultural practices, or resources, within a project area or in its close vicinity.

If knowledgeable individuals are identified, personal interviews are sometimes taped and then transcribed. These draft transcripts are returned to each of the participants for their review and comments. After corrections are made, each individual signs a release form, making the interview available for this study. When telephone interviews occur, a summary of the information is usually sent for correction and approval, or dictated by the informant and then incorporated into the document. If no cultural resource information is forthcoming and no knowledgeable informants are suggested for further inquiry, interviews are not conducted.

HAWAII DAIRY FARMS PROJECT DESCRIPTION[1]

> Hawai'i Dairy Farms, LLC (HDF) was formed as a positive step toward the island state's food security, economic diversity, and sustainability. Experimental trials were conducted to determine lands capable of growing nutritious forage for dairy cows, and lands meeting the operational requirements for a dairy operation were identified. Kaua'i was determined to best meet the operational requirements, and Māhā'ulepū Valley was found to provide ideal growing conditions.
>
> At steady-state production with 699 milking cows, the farm will produce roughly 1.2 million gallons annually at market price. HDF will reduce

[1] Text for this section provided by Group 70 International.

Hawai'i's reliance on imported milk from the mainland United States by increasing current fresh local milk production by approximately 33 percent. The farm will be based on the most successful island dairy models in the world, and will utilize a sustainable, pasture-based rotational-grazing system and 21st century technology. The farm will be very different from conventional feedlot dairy operations.

HDF is committed to establishing a herd of up to 699 mature dairy cows, and demonstrating the pasture-based system as an economically and environmentally sustainable model for Hawai'i. With proven success at a herd size of 699, HDF will contemplate the possibility of expanding the herd in the future. Precision agricultural technology that monitors cows' health, grass productivity, and effluent management will be used to ensure environmental health and safety, as well as best management practices, and help determine the ultimate carrying capacity of the land.

For dairy operations with 700 or more mature dairy cows, additional regulatory review and permitting by the State Department of Health is required. The application process for a National Pollutant Discharge Elimination System (NPDES) Concentrated Animal Feeding Operation (CAFO) permit includes public notification and input. At the discretion of HDF, management may choose to expand operations up to the carrying capacity of the land, which is currently estimated to be up to 2,000 productive milking dairy cows. Permit process compliance would be followed at such time HDF may decide to pursue an expanded operation.

LANDFORM, SOILS, AND VEGETATION

The mountain range that flanks the surveyed area to the north and northeast are composed of the most ancient volcanic series in the high islands, the Waimea Canyon Basalts (NPS 2008:11). These formed during the shield-building stage of the Kaua'i volcano, as eruptions gradually built up its sides and widened its base. Most of the range is part of the ancient Napali member of the Waimea series, dating from 4.35 to 5.1 million years ago. The caldera of Mount Ha'upu is a separate geological feature from the rest of the range and remains undated (Blay and Siemens 2004).

Māhā'ulepū lands below Ha'upu ridge are part of the Kōloa series that cloaks most of the eastern half of Kaua'i. The series formed as the Kaua'i volcano ceased major eruption and began to erode, with occasional small eruptions at lava domes, cinder cones, and spatter cones. These produced a layer of lava that, though not large in mass, nevertheless covered a large area. Kōloa volcanics within the study area at Māhā'ulepū include both underlying lava and visible vents, ranging from 0.5 to 2.0 million years in age (Blay and Siemens 2004).

Portions of the valley's slopes have been identified as Rockland (rRK; Foote *et al*. 1972: Sheet 32). This is composed of areas where exposed rock covers 25 to 90 percent of the surface.

Rock outcrops and very shallow soils are the main characteristics. The rock outcrops are mainly basalt and andesite. Elevations range from near sea level to more than 6,000 feet, with annual rainfall amounts between 15 to 60 inches. The vegetation at lower elevations consists mainly of *kiawe*, *klu*, *piligrass*, Japanese tea and *koa haole*.

Soils on the slopes of the valley are also associated with the KEHF series or Kalapa very rocky silty clay (Foote *et al*. 1972: Sheet 32). This is a well-drained soil that occurs at the base of slopes and is associated with moderately sloping to very steep topography. Elevations range from 200 to 1,200 feet above sea level, with annual rainfall amounts between 60 to 100 inches. Associated vegetation consists of guava, *lantana*, sensitive plant, *pilipiliula*, *ohia*, Japanese tea, and ferns.

Soils within the valley have been classified as LPE or Lualualei Series, composed of extremely stoney clay (Foote *et al*. 1972: Sheet 32). This series consists of well-drained soils on the coastal plains, alluvial fans, and on talus slopes. They are nearly level and gently sloping. Elevations range from 10 to 125 feet above sea level, with annual rainfall amounts to 50 inches per year. There is a prolonged dry spell during the summer. These soils are associated with sugarcane, truck crops, pasture, wildlife habitat, urban development, and military installations on Kaua'i. Associated vegetation consists of *kiawe*, *koa haole*, bristly foxtail, *uhaloa*, and fingergrass. This soil type, extremely stony clay, was identified in several trenches during the AIS, with most stratigraphic trenches excavated on the valley floor being composed of a shallow O-horizon overlaying brown/yellow clays. In other words, there are exceptions to the general soil survey.

Twelve different soils within Māhā'ulepū Valley are identified on a USGS/USDA Soil Map kindly provided to the field crew by HDF (NRCS 2014). The soils map depicts the various soil regimes across the valley floor; these soil differences are most likely a product of water, whether through transport, ground water, or run-off deposition. During pedestrian survey of areas with sparse or no ground vegetation, the transition of soils was visibly recognizable.

The project area has been utilized for commercial sugar cane cultivation and/or livestock pasturage since the middle of the 19th century and is fairly clear of vegetation. Most of the project area lies fallow with the soils exposed. Some of the areas are covered with grasses up to 0.3 m tall, and smaller areas at the northeast and northwest ends of the valley are 100% covered by grasses up to 2.0 m tall. Within the surveyed area are few scattered *koa haole* and java plum trees. These occur outside the main valley footprint/project area, which has been extensively cleared for well over a hundred years. The slopes of the valley outside the project area are forested.

TRADITIONAL AND HISTORIC SETTING

Early settlement and agricultural development is thought to have first occurred on the windward sides of the Hawaiian Islands, including Kaua'i, sometime in the A.D. 900-1000 range during what is known as the Colonization Period (Kirch 2011:22). Most likely arriving from east Polynesia, these early inhabitants brought with them a variety of tools, fishing gear, and household goods. Dogs, pigs and chickens were brought by these Polynesian voyagers for food. The Polynesian rat also arrived with the voyagers, but whether these were intentionally transported as a food source is unclear. Considering that every food crop cultivated by the Polynesians arrived with them, it is evident that these people had considerable knowledge not only regarding how to plant and harvest these crops, but also how to transport the crops' seeds, cuttings, and roots.

Prior to European Contact in 1778, Hawaiians cultivated taro in both irrigated and dry fields. Other dryland agriculture crops included '*uala* (sweet potato), *uhi* (yams), *maia* (bananas), *ipu* (gourds), and *ko* (sugar cane). Grasses were utilized for thatching the roofs of structures and covering floors, which were then covered by *hala* (pandanus) mats. *Hala* was also used in the making of matting and sails. Important arboreal crops included *niu* (coconut) and *ulu* (breadfruit). Other trees were utilized for the construction of canoes, house frames, tools, and weapons. *Kapa* cloth from *wauke* (paper mulberry) was also tended. There were a variety of medicinal plants utilized and plants, such as *olona*, grown to provide fibers for making cordage (Handy and Handy 1972).

Hawaiian aquaculture was extensive, and included the construction and maintenance of coastal and riverine fish ponds. Fishing ranged from shoreline to pelagic, with different strategies for each. In order to maintain and benefit from all of these resource zones, Hawaiian polities were organized into *ahupua'a,* which gave residents access to a wide array of resources extending from mountain top forests to deep sea fishing zones. An *ahupua'a* was an ancient land division that ran from the ocean to the mountains and allowed those living there to proffer from all the different environmental zones of the land. *Ahupua'a* boundaries could expand, contract, appear, and disappear, depending upon political events. Given the size of Māhā'ulepū Valley, Māhā'ulepū Ahupua'a was highly valued.

PRE-CONTACT ERA

Initial Polynesian settlement of Kaua'i occurred in the resource-rich regions surrounding Wailua River on the east coast; the equally verdant Waimea River region on the southern coast; and the Hanalei region on the north coast (Joesting 1984). As with all the Hawaiian Islands, each district and region was eventually settled. These settlements developed into polities which allied, warred, and co-existed with one another until Kaua'i came under unified rule of a single king. This process occurred in different stages on different islands. Because of the relative distance of Kaua'i from O'ahu, Moloka'i, Maui, Lana'i, and Hawai'i Island, the polities of Kaua'i and her neighbor Ni'ihau became their own entity, while the other islands struggled first for internal control and later, for the conquest and rule of several, and ultimately all, the islands.

The primary residence of the high king was in the Wailua River region of Kaua'i, with miles of cultivated lands, mountain resources, religious sites, and shoreline to pelagic fishing. Broad stretches of beach allowed for canoe landings but there was no deep water anchorage, despite the presence of the Wailua River.

Initial settlement is presumed near the coastline in the A.D. 1000-1200 range, with expansion inland during the A.D. 1400-1600s, as was typical across the islands (see Kirch 1985). Agricultural field systems were created at these inland areas, closer to fresh water resources and soil more amenable to *kalo* and sweet potato production. Permanent habitation locales were present from the coast to this more inland area, with ceremonial sites, walls, and other associated structures being built. Within the mountainous areas, such as at the back of Māhā'ulepū Valley, temporary habitation loci such as rock shelters/caves or small enclosures (C-shapes) were utilized by those gathering upland resources. The middle zone, between the coastlines and mountains, such as Māhā'ulepū, was ideal for agriculture and homesteads, as witnessed by the numerous LCA's occurring in a small section of the valley later. However, historic land use obliterated much of the archaeological signatures for these settlements.

In early 1778 Captain James Cook and the two ships under his command, H.M.S. *Resolution* and H.M.S. *Discovery* arrived off of Kaua'i. Finding that they could not make land fall at Wailua, Cook continued westward until reaching Waimea. This would be the beginning of contact between Europeans and Hawaiians (Salmond 2003).

WAHI PANA (LEGENDARY PLACES)

Māhā'ulepū literally translates as "and falling together" (Pukui et al. 1974:138), a likely reference to the ridges flanking the sizable valley. Handy and Handy (1972:427) describe Māhā'ulepū as a

> Broad, rich valley with a broad bottom, not planted with sugar cane but no doubt it was once had some *lo'i.* The area is in the lee of the …Wai'ale'ale mountain. Some inferior taro was grown in mounds (*pu'epu'e*) in semibrackish spring water in the lower valley.

According to Wichman (1998:47-48), the name "Māhā'ulepū" refers to a great battle that occurred in Māhā'ulepū in the 1300s. Kalaunuiohua, an *ali'i* from the island of Hawai'i, was attempting to conquer all of the Hawaiian Islands. He had already succeeded in gaining control over the islands of Maui, Moloka'i, and O'ahu and was carrying the ruling *ali'i* from those islands with him as prisoners when he set sail for Kaua'i. Kūkona, the ruling *ali'i* of Kaua'i at that time, was aware of the coming invasion and placed his warriors in the mountain ridges above and his canoes in Hanapēpē Bay where they could not be seen. Wichman (1998:47-48) describes the battle as follows:

> [Kūkona] allowed Kalaunuiohua to land unopposed and soon the Hawai'i canoes were drawn up on the beach, the royal prisoners safely housed, and all the invading warriors formed into their fighting order. Then Kūkona, dressed in full royal regalia of helmet and cloak and with his *Kāhili* towering above him, appeared on the ridge above. Kalaunuiohua hurried to meet his enemy, but when he arrived, no chief was there. Then, a shout was heard, and Kalaunuiohua saw Kūkona on the neighboring ridge. From ridge to ridge, Kūkona drew his invaders farther and farther from the beach, until they reached the plains of Wahiawa. Here Kūkona ordered his army to attack, and the invading army, stretched thinly over so many miles, was easily defeated.
>
> Meanwhile, Kūkona's canoe fleet sped from Hanapēpē and caught the invading canoes before they even had time to launch them again. In the fierce battle between canoes, blood flowed freely. Only one enemy canoe managed to escape to bring the dreadful news back to their home island. By nightfall, Kalaunuiohua's was gone and he was a prisoner. The other royal prisoner's had been found, and Kūkona found himself in the position of being able to take command of all the islands. While he decided what to do, he took his captured chiefs on an extended tour of the island.

Subsequently, significant landmarks in the area were named after events from this battle. The ridge beneath which the invading canoes met their demise became known as “Kawelikoa” (terror of the warriors), the cape where the invading army beached their canoes and came ashore is now known as “Nā'ākea” (starboard hulls of the double canoe), and the bay is known today as “Papamō'i (platform of the king) in reference to the ruling *ali'i* who encountered each other there.

Māhā'ulepū Ahupua'a sits in the shadow of Mount Hā'upu (to recollect), a 2,297 foot peak within the Wai'ale'ale Mountain Range. Mount Hā'upu is associated with numerous legends and chants. According to Pukui et al. (1974:187) Mount Hā'upu was possibly named after a demigod. According to legend, there is a legendary stone at located at Ka'ena Point, O'ahu, that was thrown by an *ali'i* from Kaua'i named Hā'upu (Westervelt in Sterling and Summers1978:93-94). Hā'upu was a great warrior capable of great feats of strength. However, when he was angered he often acted rashly. One night while he was sleeping on the side of a mountain facing O'ahu, he was awakened by shouting. As he looked towards O'ahu he could see numerous lights out on the water. As he had just awakened from a deep sleep, Hā'upu was not thinking clearing and thought a great fleet of enemy warriors was coming to attack Kaua'i. So, in an effort to defeat the enemy, Hā'upu tore loose a huge boulder and hurled it at the lights and voices killing, many members of a fishing party from O'ahu. The rock thrown by Hā'upu became embedded in the ocean, but as it was so large, the upper portion rose far out of the water. Later, when the demo-god Māui attempted to unite the islands of O'ahu and Kaua'i together, "sea goddesses snagged his hook on this rock."

Oral traditions reflect the beauty and the prominent role of Mount Hā'upu. The following Hawaiian proverbs, collected, translated, and interpreted by Mary Kawena Pukui (1983) refer to Mount Hā'upu:

> Hā'upu mauna Kilohana i ka la'i.
>
> Hā'upu, a mountain outstanding in the calm.
>
> Said of a person of outstanding achievement. Also used in praise of Hā'upu, Kaua'i (Pukui 1983:59).
>
> Ka'i ka pua'a i luna o Hā'upu e au ana.
>
> When the pigs move around the summit of Hā'upu, it is going to rain.
>
> When puffy "pig" clouds encircle the top of Hā'upu, above Kīpū, on Kaua'i, it is a sign of rain (Pukui 1983:151).
>
> Ka'ohu wānana ua o Hā'upu.
>
> The mist of Hā'upu that foretells rain.
>
> When clouds circle the peak of Hā'upu. Kaua'i, it is sure to rain.

EUROPEAN CONTACT AND THE KAMEHAMEHA DYNASTY

The third voyage commanded by Captain Cook was undertaken primarily to discover the fabled Northwest Passage, which supposedly linked the Pacific, Arctic, and Atlantic Oceans. As he had during previous journeys, Cook visited Tahiti and it was from there that he set out for the northern Pacific coast of North America.

The voyage put him within sight of the island of O'ahu, but adverse winds prevented his arrival. Continuing on to Kaua'i, he sighted Wailua, but could not make landfall. The ships continued southwest and then westward, past Mount Ha'upu and Māhā'ulepū Valley. Both were sketched and drawn by expedition artist John Webber, the first European artwork to depict a Hawaiian Island.

Cook found a manageable anchorage at the mouth of Waimea River. Several trips ashore by him and a select group of his officers, marines, and crew led to generally good relations with the Hawaiians. It is unclear what Cook and the others learned about the politics of Kaua'i and her eastern neighbor. It is probable that at this time (1778) Kaeokulani was ruler of Kaua'i. He was of high rank, a chief born on Maui, and the half-brother of the paramount king of Maui, Kahekili.

After a short time on Kaua'i in the early months of 1778, Cook departed to continue the search for the Northwest Passage. A year passed after which Cook returned to the Hawaiian Islands. This time, Maui was sited and briefly visited, but the island of Hawai'i became the focus of the remainder of the voyage of Cook and ultimately of his demise, at Kealakekua Bay (Salmond 2003).

After the death of Cook, the journey continued, now under the command of Captain Clerke. The ship passed O'ahu, and returned to Waimea, Kaua'i. After their departure a short time later, it would not be until 1786 that Europeans returned to the Hawaiian Islands, with Waimea (Kaua'i) receiving her share of British and American vessels focusing on the lucrative fur trade in the Pacific Northwest. These visits coincided with, and perhaps accelerated, the growing conflict for control of the eastern islands.

Beginning in approximately 1790, battles on and around Maui, Moloka'i, and Hawai'i Island between several rulers occurred with increasing ferocity. Safely in control of Kaua'i, Kaeokulani became a participant, bringing fleets of warriors to assist his half-brother on Maui. Many European and American ship captains had contact with all the rivals, and a fairly coherent chronology of events is known. What certainly is known is that Kaeokulani was killed during a battle in Honolulu in 1794 while fighting his nephew Kalanikupule, who had taken rule of Maui and O'ahu upon the death of his father Kahekili in Waikiki, several years earlier in 1791 (Ridley 2010).

The son of Kaeokulani was Kaumuali'i. Born around 1780, the young king went through a period where a Regent (an older relative) made the decisions, but Kaumuali'i eventually came to rule on his own. The remainder of his days was spent trying to keep Kamehameha, who had consolidated the rule of the other islands, from bringing Kaua'i in as well.

Kamehameha had difficulty solidifying his rule. Rebellions, plague, and appeasing subordinates all kept him from mounting more than two serious efforts at physical conquest of Kaua'i. The first effort to fail occurred in 1796 when Kamehameha sailed with an invasion fleet for Kaua'i. Hit by a heavy storm, the fleet turned back to O'ahu (Kamakau 1961). The second effort failed in 1804 when Kamehameha mustered his forces on O'ahu, but the army fell victim to *oku'u*, a smallpox epidemic. Kamehameha himself almost died, and far too many of his troops, counselors, and their families did succumb (Kamakau 1961). In 1810 Kamehameha used diplomacy, suggesting that he rule the eastern islands in name and deed, while Kaumuali'i acknowledge his suzerainty but continue to rule Kaua'i and Ni'ihau. It was agreed that the arrangement would end with the death of Kaumuali'i and that rule would then pass to the heirs of Kamehameha. It was an arrangement that Kamehameha and Kaumuali'i would honor, but that the heirs of Kamehameha would not (Joesting 1984).

This arrangement lasted between 1810 and 1822. It endured the death of Kamehameha the Great in 1819. During these 12 years, Kaumuali'i solidified rule of his kingdom and engaged in efforts to gain foreign weapons and support from the Russian Fur Company (Mills 2002). Also during this time, the trade in sandalwood flourished. Harvested in the Hawaiian Islands, traded for goods to European and American captains, and sold in the Chinese trade ports of Macao and Canton, sandalwood became the first Hawaiian cash crop (Ridley 2010). The Hawaiians called it *laau ala* (sweet wood) or *iliahi* (fiery surface) for its reddish blooms. They used this wood for scenting bark cloth, making dyes, and for medicinal purposes (Ridley 2010).

At first, the sandalwood revenue went solely to the paramount chiefs, Kamehameha and Kaumuali'i. However, with the death of Kamehameha, nearly all of his chiefs called upon the young heir, Liholiho, and the Regents, among whom was Ka'ahumanu, the favorite wife of Kamehameha but not mother of his heirs, to allow the chiefs to harvest sandalwood for their own profit. This practice would affect and disrupt the rule of Hawai'i and the welfare of the common people for decades.

The upland forests were scoured, crops were neglected, commoners suffered malnutrition and disease, chiefs went into debt to foreigners, and Liholiho was hard pressed to find new resources for his chiefs to exploit. Kaua'i appeared to be the answer. While continuing to honor the arrangement made by his father, Liholiho arrived on Kaua'i in 1822, visited with Kaumuali'i, and then kidnapped him, returning to O'ahu with his captive. In order to secure the rule of Kaua'i, Kaumuali'i was forced to marry not an heir of Kamehameha, but his wife, Ka'ahumanu. To ensure her hold, she also wed her new husband's son, Keali'iahonui. This second marriage was later dissolved. However, ties between dynasties stayed strong as Keali'ihonui married a granddaughter of Kamehameha, named Kekauōnohi (Mills 2002).

Ka'ahumanu had been instrumental in the overthrow of the *kapu* system of Hawaiian governance and social behavior, as well as one of the earliest and most prominent proponents of conversion to Christianity. That she utilized polyandry to achieve control of Kaua'i is just one example of her abilities to utilize both traditional and introduced ways of life to achieve her goals (Joesting 1984).

While still titular ruler, Kaumuali'i did not exercise any power. Governors were appointed by the Regents, the first of these being the brother of Ka'ahumanu, named Kahekili Ke'eaumoku. Beginning with this Governor, land acquisitions beneficial not just to the Kamehameha line but to their powerful subordinates started.

The practice of allowing individual chiefs to harvest sandalwood was carried over to Kaua'i. How many Kaua'i chiefs retained their lands during this time is not certain. What was certain is that the mountains of Kaua'i, including Ha'upu, yielded the valuable resource. And practically the only place that it could be shipped was from the only secure anchorage at Waimea River. Waimea also served as a provisioning port of call to the growing number of whaling ships that began to appear in the Pacific.

The independent rule of Kaua'i came to an end in 1824 with the death of Kaumuali'i. This same year, the heir of Kamehameha, Liholiho Kamehameha II also died. The kingdom of Hawai'i would now be ruled by a queen.

THE REGENCY OF KABBAHUMANU

Ka'ahumanu was one of Kamehameha's primary wives, his favorite in fact, but not of sufficient rank to be mother of his heirs. It appears she never bore the king, or anyone else, any children. From her actions following his death in 1819, it is apparent that Ka'ahumanu considered herself Kamehameha's heir. The mother of the heirs, Keopuolani, died in 1823. Her first son was Liholiho, born in 1796, made king in 1819, and died visiting London in 1824. Her second son was Kauikeaouli Kamehameha III, born in 1813. Her daughter, Nahienaena was born in 1815 (Day 1984). With the death of Liholiho and his mother, Ka'ahumanu became Regent of the kingdom until Kauikeaouli would come of age. Her rule of Hawai'i in general, and Kaua'i specifically, was adroit, intelligent, and shrewd.

George Kaumuali'i and a number of Kaua'i chiefs forcefully resisted the rule of the Kamehameha line, and their revolt was crushed. As with many Byzantine events in Hawaiian history, some Kaua'i chiefs stood with the old, while others stood with the new. In this case, as with any other, people chose who they thought would benefit them most. Those who rebelled had their lands and lives taken, while those who did not, benefitted.

The first long term governor during the regency was Kaikioewa, a high chief born at Waimea, Kaua'i. He was a first cousin and brother-in-law of Kamehameha, a guardian of Kamehameha III, and a principal leader in crushing the 1824 rebellion (Mills 2002). He reigned as governor from 1825 until his death in 1839. During his tenure, we know of at least one *konohiki*, or land manager, for Māhā'ulepū. Documents show that in 1826, Hukiku was *konohiki*. He was in attendance that year during a visit by the governor. Kaikioewa was accompanied by missionary Samuel Whitney of Waimea, who left an account of this event. It is unknown if Hukiku was Kaua'i born, or one of the conquerors invested with this stewardship. He may be the chief Kukiku, who Kaikioewa named commander of Paulaula o Hipo, also known as “The Russian Fort” (Mills 2002).

During his term as governor, Kaikioewa claimed Ha'upu Ridge, to the east/northeast of Māhā'ulepū, as his personal sandalwood reserve. One of the duties Hukiko performed may have been overseeing the efforts to harvest sandalwood from the ridge and transport it to foreign ships at Waimea or Kōloa. Eventually, as did so many other *ali'i*, the governor would go into debt to foreign captains and merchants. When the sandalwood ran out, it is not clear how Kaikioewa paid his bills (Joesting 1984).

Ka'ahumanu ruled as Regent until her death in 1831. A daughter of Kamehameha, Kīna'u, took over as Regent until 1834, at which time Kauikeaouli Kamehameha III took the throne. He had lived on Kaua'i as a boy under the protection of Kaikioewa but had spent the majority of his youth on O'ahu. Ruling until his own early death in 1854, his reign was admirable for its civil rights, efficiency, and the creation of the Great Māhele, by which land awards to commoners and granting ownership to the disenfranchised was achieved. In Māhā'ulepū, there were many Land Commission Awards (LCA), discussed below, but the majority of the acreage was retained by the government. During his reign, there was an increase in the number of immigrants from Europe, the United States, and China. Missionaries, merchants, laborers, and farmers of multiple nationalities added to the diversity and complexity of the Kingdom.

LAND COMMISSION AWARDS

The Great Māhele was yet another drastic change in the lives of Hawaiians. Commoners, also known as *maka'ainana*, had for centuries been allowed use, but denied ownership of the lands they worked. This changed in the late 1840s when private ownership of lands was made into law. Certainly *ali'i*, or nobles, had the better of the deal, but commoners were allowed to claim, through right of labor and longevity of occupancy, Land Commission Awards (LCA). King Kauikeaouli Kamehameha III was a sovereign brought up in the old ways who saw that some things must change, and orchestrated this new policy. A legal process was established, in which land claimants testified, and had others support their testimony, before a Commission appointed by the king. Traditional land use was communal and land use was often dendritic, following the course of streams and occupation zones from the coast to the mountains. Claimants were often related and the lands they claimed were as varied in their usage as they were in their location. For a traditional *ahupua'a* to work, those *mauka* (towards the mountains) had to work with those *makai* (towards the ocean). The private ownership offered through the Māhele, however, created new risks for landowners. A commoner who did not own the land could not go into debt; but, one who did could achieve profit or debt.

Land claim testimonials are complex documents. Boundaries are defined in a variety of ways. Land divisions descend in size from *ahupua'a* to *kuleana* to '*ili*, thence *apana,* and finally *mala,* which are individual garden plots, fields, and/or *lo*'*i* (Pukui 1957). Other boundaries are defined by names of neighboring occupants or by use of the land. Testimonies were given regarding which chief had granted the occupant use of the land. This is compelling, because occupants claimed title based on grants from Kaumuali'i, last independent king of Kaua'i, to Kaikioewa, governor from 1824 to 1839 for the Kamehameha Dynasty, to his *konohiki* for Māhā'ulepū, Hukiki. They invoked the names of Ka'ahumanu, the Regent for nearly a decade, to Kīna'u, Regent and half-sister to King Kauikeaouli Kamehameha III until he took the throne. Some claims were contested, others were not, and some were won on appeal. When one studies the LCAs of Māhā'ulepū, it can be seen that claims of land, in a variety of places, for a variety of uses, were made by individuals throughout the *ahupua*'*a*. With modern ownership, a traditional lifestyle could be maintained, but once individual plots began to be sold, and relationships were sundered, life for the commoners and nobles alike began to change drastically.

On Kaua'i, and in Māhā'ulepū Valley specifically, a number of land claims were made by residents who had been allowed use of the land during the reign of the previous king. In the valley, LCA 5080 to Kiko, LCA 4767 to Napaliala, and LCA 4769 to Nahuma, for example, were all claimants who had tenure from Kaumuali'i. It is presumed that their neighbors had similar histories (Ching 1974). That these residents all received their awards is notable because their claims were based on the right of use granted by the former ruler, and not by permission of the Kamehameha Dynasty. An 1896 map of the valley, depicts a “house” and “cattle pen” in the northern part of the valley and the LCA's just below, in what today is the mid-section of the valley (Figure 3). The 1896 map also shows the word “Path”, far above the LCA area. This “path” was fully investigated during the AIS (2016) and shown not to exist (see below). An 1897 survey map by Monsarrat (Figure 4) shows a better view of the LCAs.

Many of LCAs for Māhā'ulepū are tightly clustered within the 'ili of Kawailoa (Figure 5). There is a cluster east of Māhā'ulepū Ditch near the center of the valley. The remainder of the valley was deemed government land. Thus, no LCAs occur elsewhere in the project area or the extended survey area. It is interesting to note the estimated population of this portion of Māhā'ulepū Valley at this time. In 1848, 46 male names appear in genealogical records (M. Ching, LDS Records). If one were to reasonably add one wife and at least one child per household, the population would have been 138 persons. In 1855, a total of 36 male names occur in the Māhā'ulepū records. Using the same figures, the total would have been 108 persons. This represents a fairly sizeable population for this upper valley at that time, all likely associated with the LCAs.

The following provides a representative sample of names and LCAs that are both present on the LCA map within the project area and are described in previous literature (Ching 1974). Claimants used owners of adjacent lands as boundary references and/or supporters of their claims. Many claimants were related in some way. The claimants of LCAs within the project area often also had additional claims downstream of Māhā'ulepū Ditch on the coast or elsewhere. Thus, only some of the claims discussed (*kula* lands, etc.) may actually be in the project area. A good example is LCA 5080, where a salt pan is discussed. Such claims related to salt pans would have occurred far outside the current project area near the coastline. In addition, some of the claims also include information about other LCAs claimed by the same person. While somewhat confusing, the summary of records are presented in full here in order to get a clearer picture of the LCAs in and around the surveyed area:

> **LCA 4767** Napaliala received his lands in the days of Kaumuali'i, who died in 1824. This was waste land when Napaliala took it over, occupied it, and developed it. He died in the late 1840s and his wife then possessed the land.
>
> **LCA 4769** Nahuma was another native who occupied lands prior to 1824. One piece was waste land when he took it over, built on it, and fenced it with stone. In addition he received on the death of relatives other lands occupied previous to 1824: two (2) *lo'i* in the 'Ili of Kauki'i, which had belonged to his wife through her parents; 7 dry taro patches in Kioea received through his father-in-law, *kula* land at Waipa which his brother had taken possession of, planted orange trees and cultivated; and two salt ponds. Nahuma appears to have been an affluent native.
>
> **LCA 4910** Kahee claimed property in the '*Ili* of Kapakalehu; this property in the late 1840s had one orange tree. The *konohiki* contested the title of this property, claiming that Governess Kekaonohi had given it, and two more, to him and that he had cared for them, harvesting the fruit. Kahee never collected the oranges but contended that the governess had no right to give the trees to the *konohiki* as they had belonged to Kahee's parents, who had planted them and he was the rightful heir. That was the foundation of his claim.
>
> **LCA 5080** Kiko took over waste land, built his own fences and dug his own salt pond in the 'Ili of Kawailoa (Note: the salt pond would be outside the project area, near the coastline). The date of occupancy is not given but it probably was later than Kaumuali'i, for Kiko's *lo'i* came from Kīna'u's time. Kīna'u was a daughter of Kamehameha, mother of the kings Kamehameha IV and V, and was Regent between the death of Ka'ahumanu and the ascendancy of Kamehameha III, her half-brother.

Ching (1974) argues the recovery of waste land mentioned in LCA records was the clearing of previously untouched lands for cultivation. However, Putzi (2014) argues that these were previously cultivated areas left unattended due to a declining native population, but were brought back into production because of the incentive of individual ownership. It may be that ownership, as well as the threat of feral cattle and pigs, led to the construction of fences of either stone or wooden posts to delineate property boundaries. Other claimants shown on the LCA map were identified in the Mahele Database:

> **LCA 4770** Naahuao. The land came to Naahuao through his father, who was granted the land by Hukiku, the *konohiki* of Māhā'ulepū during the reign of Governor Kaikioewa. He gives his testimony as follows:
>
>> Greetings to the Land Commissioners: Be it known to you, the ones who quiet land titles, that I, Naahuao, a man living at Māhā'ulepū, island of Kaua'i have a claim for land, and the kula. The genuine land is 56 fathoms long by 26 fathoms wide. The mala of noni is 26 fathoms long by 13 fathoms wide. The salt land is 6 fathoms long by 4 fathoms wide. Another salt land is 10 fathoms long by 7 fathoms wide. A house lot is 28 fathoms on the long sides and 25 fathoms on the wide side. My message is ended. A respectful farewell to you, Naahuao.
>
> **LCA 6667** Mika received lands from Ahukai (owner of LCA 4543) on the LCA map, but no further information has been gained. Mika received lands from Kaikioewa in the days of Kinau. His testimony reads:
>
>> The Land Commissioners, greetings: I, Mika, a Hawaiian subject living in Māhā'ulepū, hereby state my claim for 4 lo'i, 5 sweet potato enclosures, 4 mala of noni, and 3 orange trees. However, these claims are not situated together, but are in various cultivated places of Māhā'ulepū, also 1 mala of uhi/yam/ a kula planting of wauke and one other lo'i. 1 loko/ either fish pond or taro pond/ and 13 lo'i are bounded 80 fathoms on the east, 80 fathoms on the south, 20 fathoms on the west and 10 fathoms on the north. That is my claim which was received from Ahukai. There is also a kula named Hoopouliloa. Respectfully, Mika

The testimony of Mika says much about how Hawaiians utilized the Māhā'ulepū landscape and environs. Parcels were utilized for the cultivation of several food crops, for raising fish, and the growth of *wauke* for the production of *kapa* cloth. Except for the orange trees, this is a classic example of traditional Hawaiian life. The mention of sweet potato enclosures is interesting because '*uala* were traditionally raised in long rows of intermittent mounds. It may be that these fields were fenced in to protect them from pigs or cattle, or that land ownership required definitive boundaries.

It is worthy to note that all the LCAs in the Māhā'ulepū project area are confined to a central area, on the east side of Māhā'ulepū Stream, with the remainder of the valley claimed as government lands. These LCAs form a tight cluster. Of additional interest is that during the height of the sandalwood trade the adjacent Ha'upu Ridge was claimed by Kaikioewa. It would appear that after his death in 1839 these mountain claims would revert to government control.

The Governor of Kaua'i in 1842 was Kekauonohi, the granddaughter of Kamehameha who had wed Keli'iahonui after having been a wife to her uncle Liholiho Kamehameha II. During her governorship, Kekauonohi partook in land exchanges, consolidating her grants in Māhā'ulepū and Kōloa. These consolidated lands would become the basis for the next cash crop – sugar, which, unlike sandalwood, could be rejuvenated and continued. From the 1830s until the 1980s, sugar would be the economic focus of Māhā'ulepū. Remnants of industrial-level sugar cane cultivation in the area represent the greatest number of historic properties documented during the current AIS.

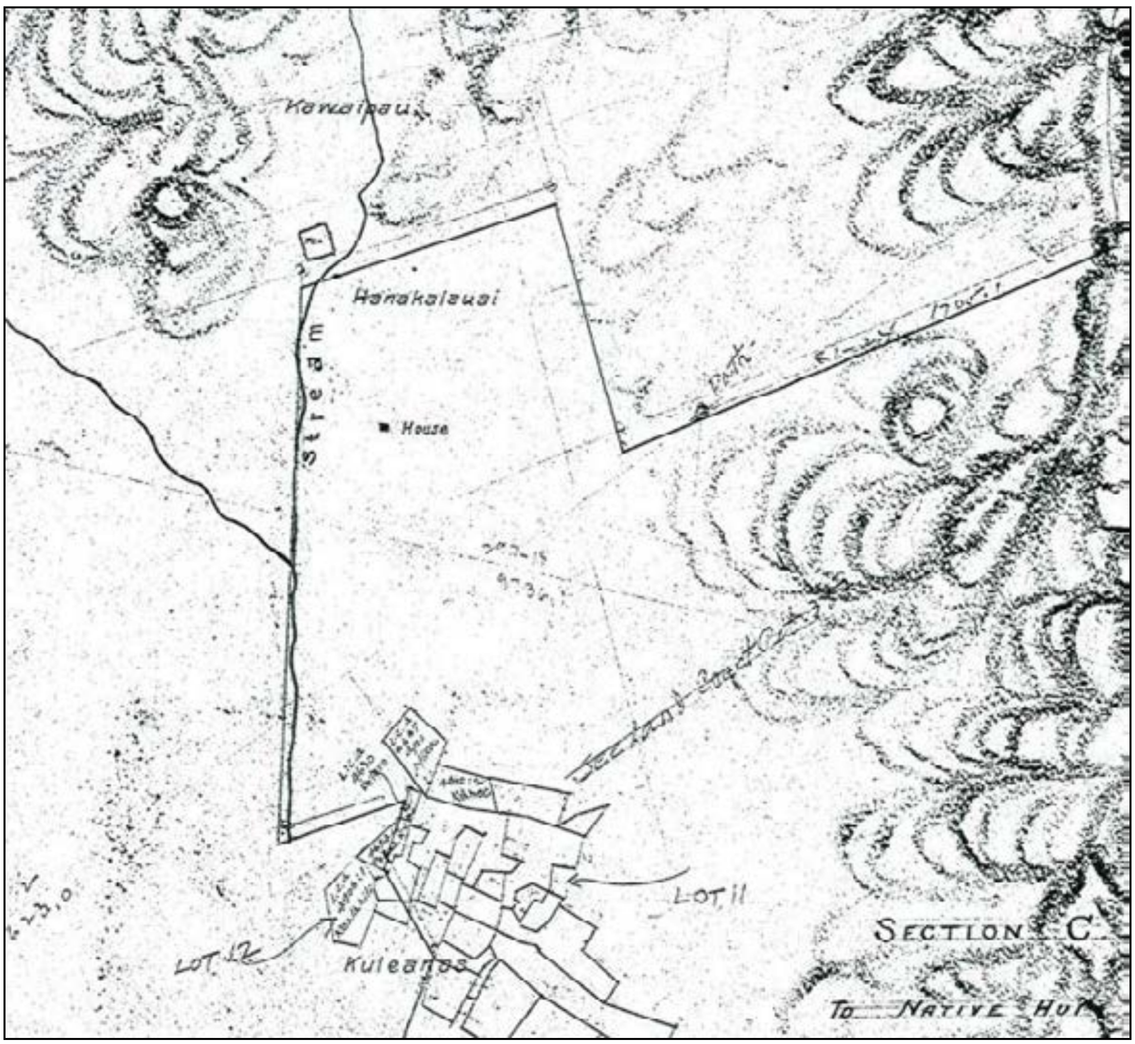

Figure 3: Registered Survey Map #1898 showing location of "House", "Cattle Pen", and LCAs in mid-valley. Note: "Path" in map center.

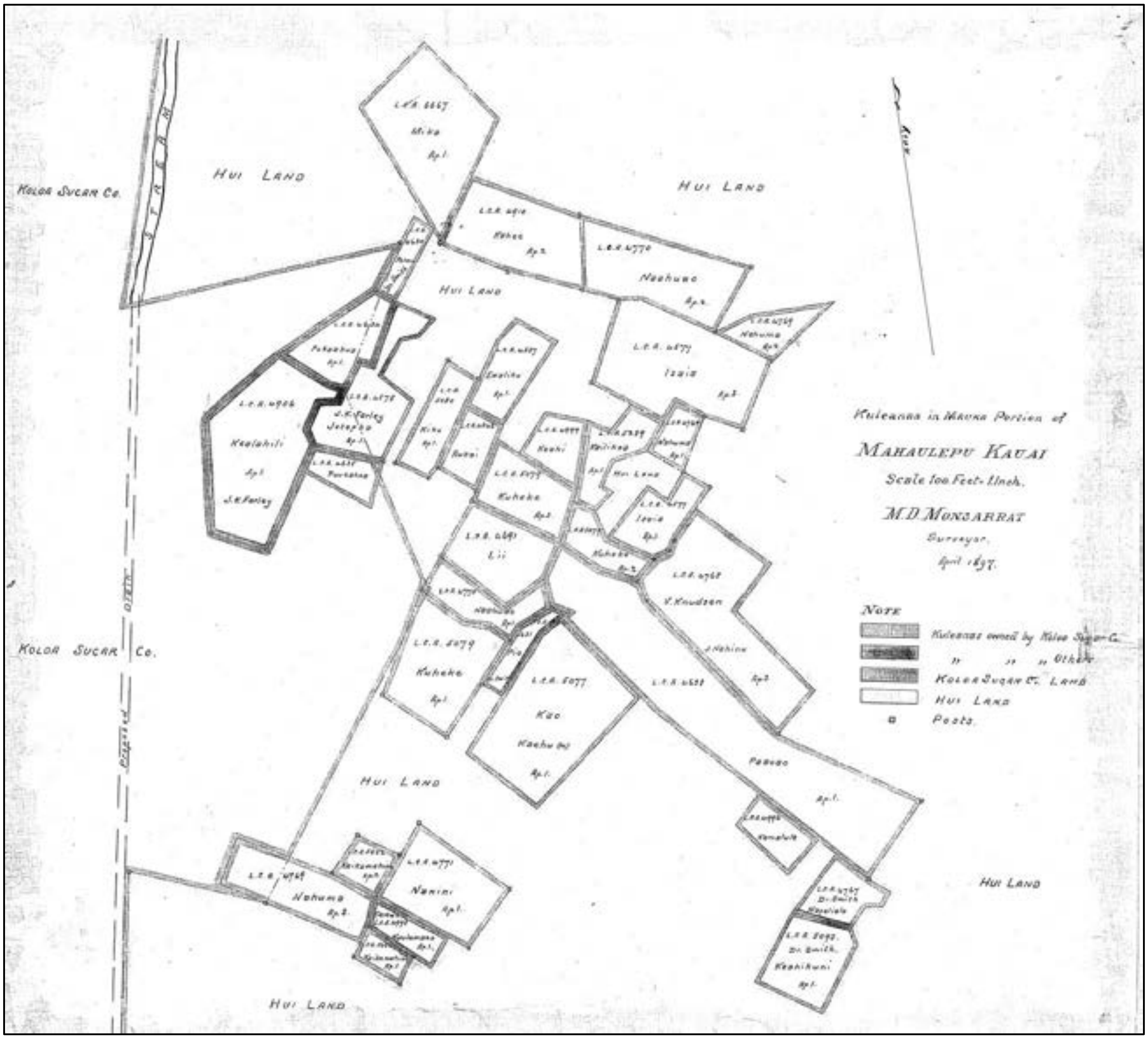

Figure 4: Registered Survey Map #1900 (1897) of LCAs in Māhā'ulepū Valley.

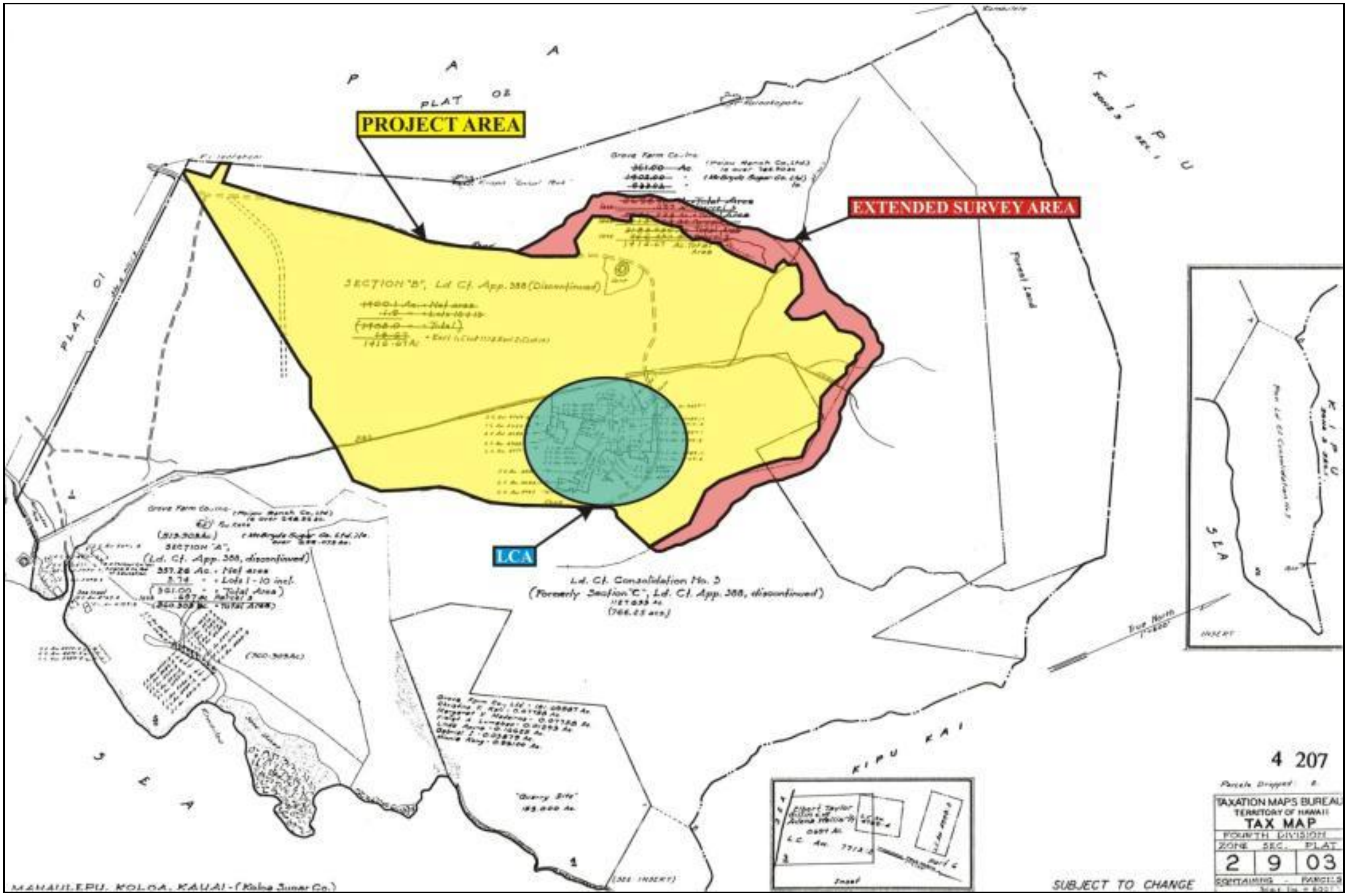

Figure 5: Modern TMK map of Māhā'ulepū Valley depicting LCAs.

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SUGAR AND THE HISTORIC ERA OF KŌLOA AND MĀHĀ'ULEPŪ

The sugar cane history of Māhā'ulepū is intricately tied with the history of Kōloa. Sugar cane began to be grown and milled commercially in Māhā'ulepū Valley and around Kōloa in the 1820s, one of the first places in Hawai'i where sugar was commercially grown (Donohugh 2001). Some of the earliest efforts were undertaken by Chinese immigrants (post 1820s-30s) who had a small mill in Māhā'ulepū, as well as in Kōloa and other parts of the island. The mills were small, producing raw sugar and molasses for local consumption. By 1835, however, many of these farmers were out of business and were later employed by new plantation owners.

In 1835, a sugar cane plantation owned by Ladd and Company was located to the west of the surveyed area. This was the first attempt at producing sugar cane at an industrial scale. The land was leased for a fifty year period from Kaua'i Governor Kaikioewa and King Kamehameha III. Importantly, the lease was the first of its kind in Hawai'i and represented the first formal recognition that someone other than a chief could control land use. Kōloa Plantation, formally established in 1841, is universally known to be the first commercial sugar plantation in the islands. Ladd and Company was the first owner of the plantation but financial difficulties caused them to sell in 1845. Robert Wood and his brother-in-law bought the plantation and kept the plantation going until 1899 when the Koloa Agricultural Company, the McBryde family, bought the plantation. The Koloa Plantation merged with Grove Farm in 1948 and continued operations through 1996.

The sugar industry grew sporadically between 1845 and 1875. At this latter date, the Hawaiian government scored a coup of its own when a reciprocity treaty with the United States was negotiated. This allowed all unrefined Hawaiian sugar to be admitted into the United States duty free. The cultivation of sugar was going to become profitable (Alexander 1985:74).

Koloa Plantation commenced growing sugar cane in Māhā'ulepū Valley in 1878, having focused more on lands to the west near Kōloa. A total of 875 acres of the flat valley floor was made available. The land was level, sheltered, and had a good underground water supply. However, there was an initial problem with the ground water as some of the valley was saturated and other areas were dry. Accordingly, Koloa Plantation undertook efforts to build infrastructure that would drain waters from the saturated areas, and divert that water to irrigate drier fields (Alexander 1985). Sugar cane requires much water so in 1897, the Koloa Plantation also excavated several wells to irrigate the cane in Māhā'ulepū Valley (see Donohugh 2001).

By 1897, the main source of irrigation water for the valley came from the ground water. At the northwest end of the valley, six wells were drilled and the water was pumped approximately a quarter mile to the north into the recently constructed Māhā'ulepū Reservoir (Figure 6). The area of the wells was known as “Māhā'ulepū 14”, probably because that was the number of wells eventually drilled and/or in service. The primary source of irrigation water for Māhā'ulepū appears to have been the six wells drilled in 1897. Four more were drilled later and all were located near the western side of the valley. These wells pumped water to Māhā'ulepū Reservoir, where it was stored and released, when needed, to various parts of the valley via the irrigation ditch.

Irrigation ditches at both the north and south ends of the Māhā'ulepū Reservoir served to transport water to the crops and to receive water from existing streams descending from Ha'upu Ridge (Alexander 1985:97-98). A pumping station was built and manned with full-time resident staff who lived with their families in a camp here. The larger north to south, excavated irrigation ditch that extends the length of the valley was excavated but does not appear on the 1935 Koloa Plantation map (Figure 7). Intensification of irrigation efforts, which added to the waters provided by Māhā'ulepū Ditch, began after this date.

The thick clay soils of the Valley were difficult to till using plows pulled by teams of oxen. However, with the introduction of steam powered tractors, more land began to be put into production. Development thus began to escalate at the start of the 20th Century. The number of laborers increased from 430 in December, 1900 to 769 in July, 1901. In February, 1904 it was reported that 600 out of 730 men were "working on permanent improvements." (*Ibid*.) Infrastructure modifications in Māhā'ulepū Valley also intensified at the start of the 20th Century, with the excavation of canals, reservoirs, and wells. A narrow gauge railway was also constructed in the valley. The railway extended from Koloa Mill to "Māhā'ulepū 14",the series of wells on the valley floor at the northwestern end of the valley itself. The railway tracks were movable, but SCS found no evidence of them in the valley during the current AIS. Other portable narrow gauge rail systems were utilized to facilitate the harvest.

In 1904, $16,420.81 was spent on additions to the plantation railroad system, including "a three-mile addition to the Puuhi railroad and a short cut road to Maha'ulepu" *(Ibid*.). Considering a laborer in the fields made about $17 per month, this was quite an expenditure at the time (Alexander 1985:122).

While the Plantation owned all the land, they contracted with groups of approximately a dozen men to manage parcels of fifty to one hundred acres. Koloa Plantation "…furnish[ed] land, seed-cane, water, fertilizer, and tools, and perform[ed] such portions of the work as require[d] expensive machinery, such as plowing, furrowing and hauling the cane to the mill" (*Ibid*. 97-98). The contractors, however, otherwise took care of their parcels from planting to harvest, selling the cane to the Plantation at a set price. This method kept the land under one owner, but provided the contractors incentive to raise a bountiful crop (*Ibid*. 123).

Early 20th century maps document the extent of the fields throughout the Kōloa and the Māhā'ulepū Valley areas. The fact that Māhā'ulepū Valley was used for extensive sugar cane cultivation is also evidenced by the infrastructure developed within the valley over time. Thus, the available information demonstrates that HDF's project area consists of lands that were previously used for sugar cultivation.

Grove Farm continued to produce sugar cane in the greater Kōloa area, including Māhā'ulepū, until 1974, when it leased its Kōloa lands and mill to McBryde Sugar Company (Donohugh 2001). Sugar production continued under McBryde until September, 1996 when the mill officially closed.

The Wilcox Family sold Grove Farm to S. Case in 2000. From the early cultivation times until then, the lands extending from Māhā'ulepū Valley to the sea were extensively modified for the cultivation of sugar. Fields were plowed, streambeds cleared, irrigation ditches excavated, reservoirs created, roads built, and wells drilled.

During the remainder of the Kingdom, then the Republic, through the Territorial Period, and into Statehood, sugar cultivation and Māhā'ulepū would be synonymous. More recently, since sugar cane cultivation operations ceased, Māhā'ulepū Valley has been the location of cattle ranching (2002) and taro cultivation (2007), the latter being done through lease to W.T. Hara.

PREVIOUS ARCHAEOLOGY

There have been numerous archaeological studies along the coast of Māhā'ulepū, but archaeological studies within Māhā'ulepū Valley and nearby inland environs have been limited. Figure 8 shows the location of relevant studies both within the current project area and close to the project area. The reader is also referred to a National Park Service (NPS; 2008) regional study for a praxis of the projects conducted along the coastline. A sampling of other studies that are further removed from the Māhā'ulepū project area are also briefly described below to provide additional context on a regional scale. Studies performed in areas closer to the ocean include those conducted by Farley (1898), Thrum (1907), Bennett (1931), Kikuchi (1963, 1980,1981, 1988-d), Ching et al. (1974), Neller (1981, Rosendahl (1988, 1989), Hammatt (1979, 1989a, b, 1990 a, b) Pietrusewsky (1990), Walker and Rosendahl (1991) and Firor and Rosendahl (1994). Four projects were conducted directly with the current project area: Thrum (1907), Kikuchi (1963), Ching *et al*. (1979), and NPS (2008). The studies described below are listed in chronological order, not by geographic location, and provide both a regional and local context to previous archaeological work in the Māhā'ulepū area.

The earliest study was by F.K. Farley in 1898. During this study, petroglyphs were discovered beneath sand dunes at Keoneloa Beach, to the southeast of the current project area near the Hyatt hotel. According to Farley, local residents knew of the petroglyphs and reported that they had been exposed previously.

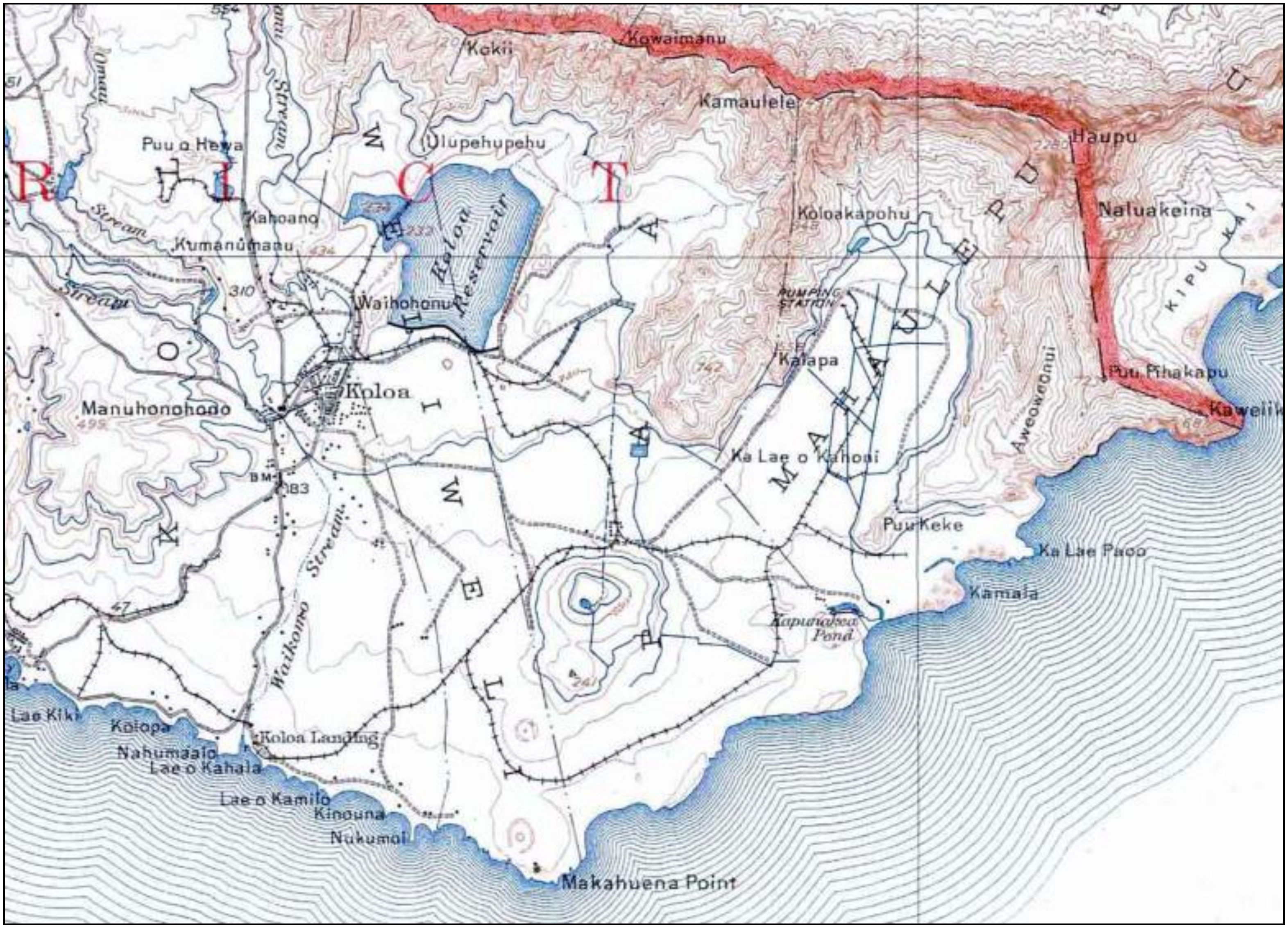

Figure 6: Koloa Plantation infrastructure (1912 USGS Territory of Hawai'i Quadrangle portion).

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The antiquarian T.G. Thrum documented two *heiau* on Kaua'i named Weliweli and Waiopili (Thrum 1907). The former was not accurately plotted on any map, while the latter was located along the stream of the same name that descends from Māhā'ulepū Valley. Waiopili Heiau was formerly just south of the current project area, near the present-day quarry.

Within the valley itself, but outside of the project area, Thrum identified the possible location of a large *heiau* named Hanakalauea. This *heiau* was reported to have been dismantled in the 1860s by a gentleman named Fredenberg and the stones then used to build cattle pens (Thrum 1907). Thrum also reports a fourth *heiau*, named Keolewa, on the crest of Mount Ha'upu (Thrum 1907; see also Bennett 1931, Site 90). It is not certain if Thrum or Bennett actually visited the site, but both noted that it was a small *heiau* dedicated to a goddess named Laka (Thrum 1907; Bennett 1931). A cursory field inspection of the summit by SCS archaeologists in December 2015 did not note any definitive structural remnants of this heiau.

During an archaeological survey conducted in 1928-1929, Bennett (1931) located or re-located the *heiau* at Weliweli and Waiopili. The Keoneloa Beach petroglyphs were not exposed during this visit but he collected information about them from local residents. Bennett also recorded human burials within the sand dunes at Makahuene Point.

According to Bennett (1931:46), at Waiopili Heiau, "a tower of stone stands in one corner. It is solid enough to climb upon and an excellent view is afforded from the top. It is a unique feature for Kauai *heiau*, and if modern, defies conjecture as to the reason of its construction." According to Ching (1974), "Waiopili Heiau is a rectangular walled enclosure, which lies on a smooth pahoehoe lava bed. The limestone cliff which forms a natural boundary between Māhā'ulepū and Pa'a lies almost directly to the south of this temple." Chang (1974) further states that Kapunekea Pond is nearby and that the walls were large, 2.5 m wide and 2.0 m high, constructed of pahoehoe slabs. The *heiau* was still mostly visible in 1974. By 2006, only a very small portion of the southern wall of the *heiau* was visible, near a spring pump house. The *heiau* has been mostly destroyed by quarrying activities, as well as by the quarry road which runs along the southern boundary of the former structure.

Kikuchi (1963) conducted an archaeological investigation of coastal Kōloa. In addition to identifying new sites near the coast, he re-located several sites described by Farley, Thrum, and Bennett: Site 96 (Kane'aukai Heiau); Site 97 (dune burials); Site 98 (Keoneloa Beach Petroglyph Field); Site 99 (Weliweli Heiau); Site 100 (Keoneloa Beach Walls); Site 101 (Makaweki Point petroglyphs); and Site 102 (a structure).

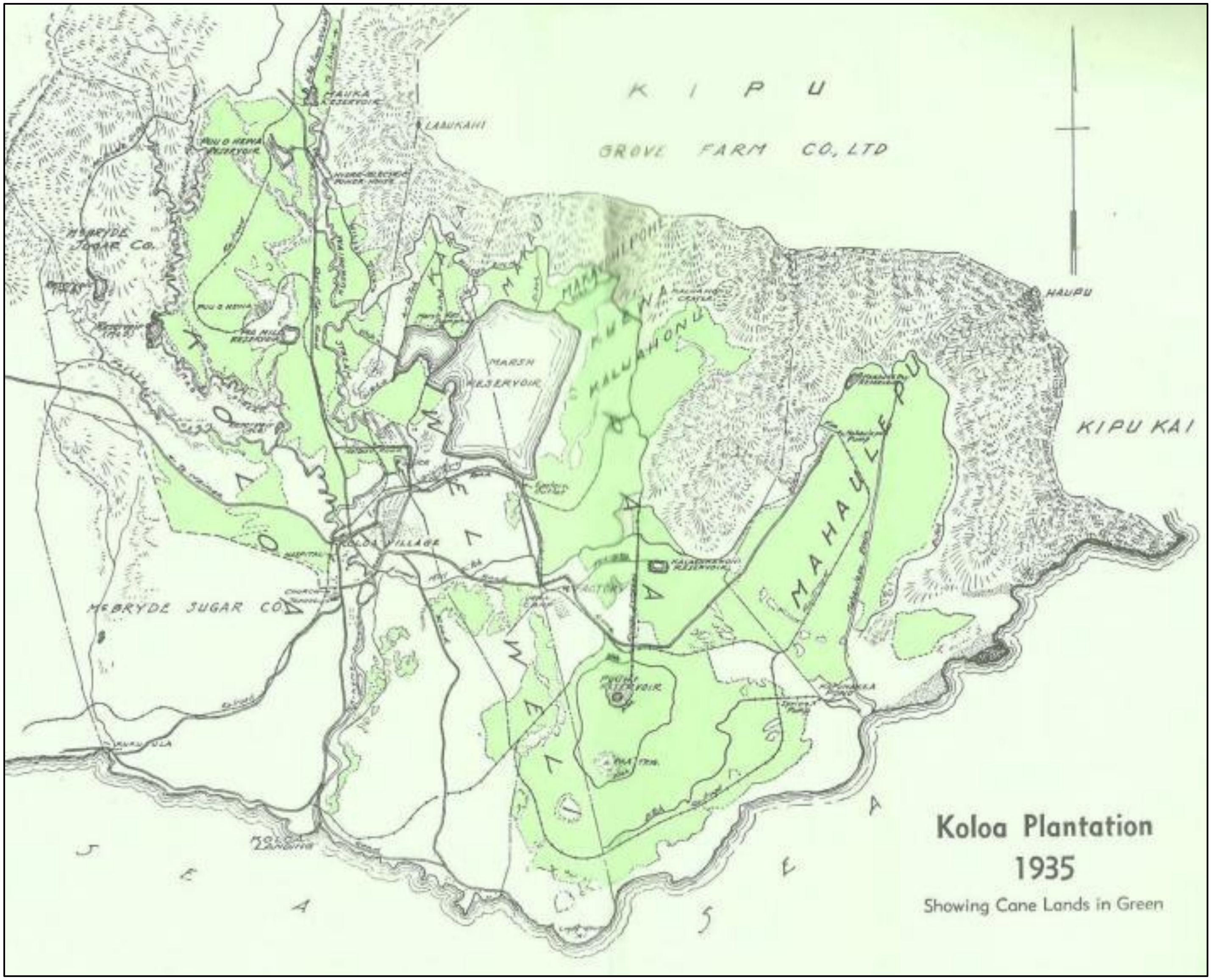

Figure 7: Distribution of Koloa Plantation lands (1935).

Kikuchi also documented the only previously identified site within the surveyed area, Site -3094. This site is composed of a large boulder sitting in a pasture at the northern end of the valley. Kikuchi (1963) notes this boulder as occurring some 2 miles inland. Some twenty anthropomorphic figures, two pecked cups (4 inches deep), and a long groove are etched on the surface (Ching *et al*. 1974; McMahon 2007; see also Cox and Stasack 1970). The groove may represent a stream, but interpretation is uncertain. As discussed below, this site was fully recorded and mapped during the current project. In addition to the one boulder previously identified by Kikuchi (1963), two additional petroglyph rocks associated with this site were also documented during the current AIS (see Results section below). Thus, Site -3094 now consists of three features.

During surface survey of 1,100 acres along the coastal lands of Weliweli, Paa, and Māhā'ulepū Ahupua'a, Ching *et al.* (1974) wrote of Weliweli Heiau: “no actual alignments or other features were noted at the reported location of this temple. This site has either been completely destroyed or is located elsewhere” (Ching *et. al*. 1974:81). During the Ching study, the archaeologists found and sketched the petroglyphs at Keoneloa (Site 84), found sand dune burials (Sites 3096, 3097 and 3024) and re-located Waiopili Heiau (Site 87). They also located Waiopili Pond and Kapunakea Spring, but these were not given site designations (Firor and Rosendahl 1994).

Kikuchi (1984) continued archaeological investigations along the coastline of Keoneloa Beach. Kikuchi documented numerous sites and at least one, but possibly two, cultural layers that extended along the length of Keoneloa Bay (Kikuchi 1998a). This was the beginning of an era of extensive archaeological excavations and monitored construction excavations in this area. Work by Neller (1981), Rosendahl (1988, 1989), Hammatt (1979, 1989a, b, 1990 a, b) Pietrusewsky (1990), Walker and Rosendahl (1991) and Firor and Rosendahl (1994) followed.

McMahon (1996) conducted an archaeological field inspection of a circa 25,000 sq. ft. area on the southeast flank of Ha'upu ridge for the proposed installation of a radio tower. The project area for that study was located at 1,500 ft. asl. No sites were identified, nor were any trails observed along the ridgeline; the area was, as McMahon notes (1996), only accessible by helicopter.

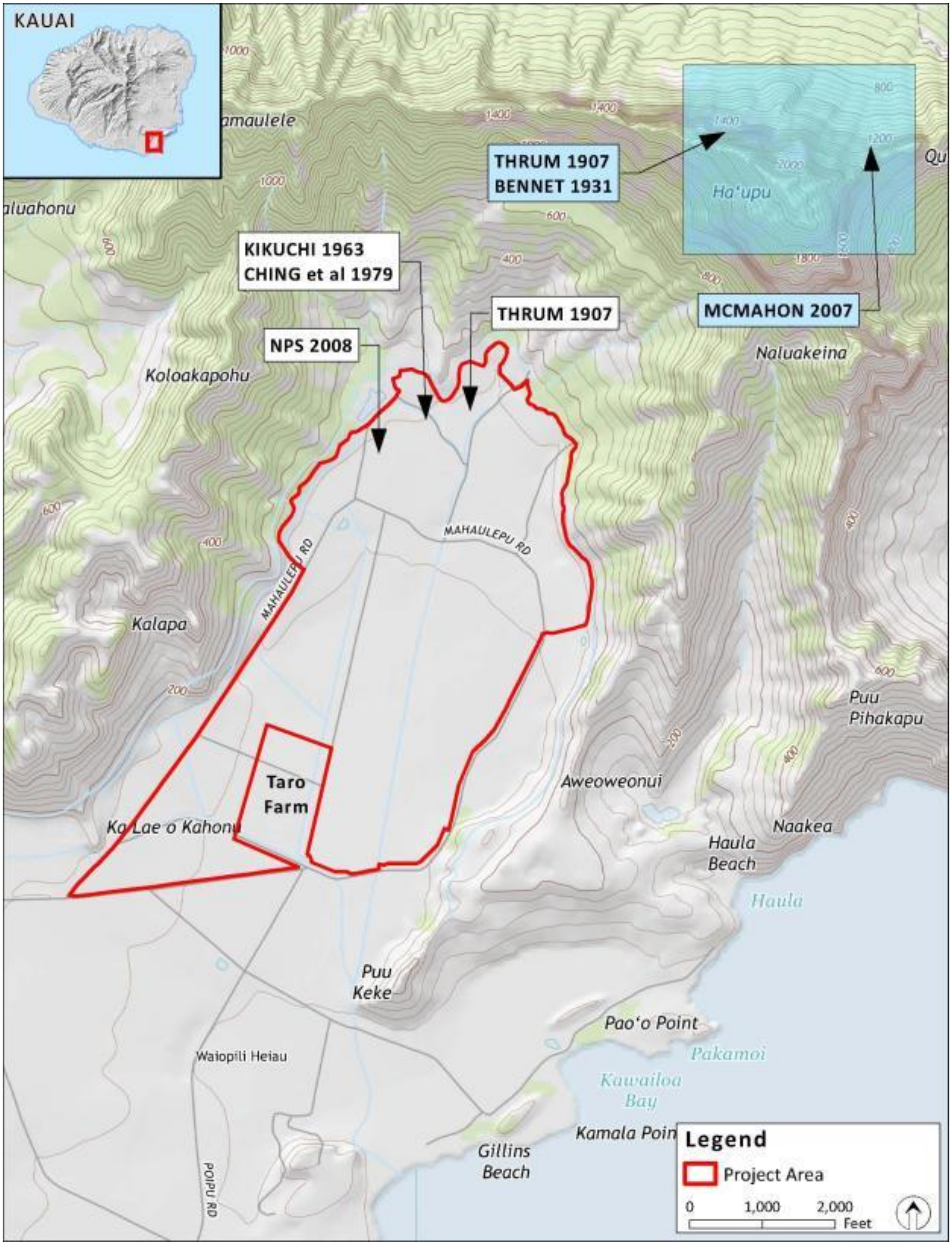

Figure 8: Previous archaeological studies in the Māhā'ulepū area.

Following this study by McMahon (1996), a letter was submitted by the Office of Hawaiian Affairs (OHA) in March 1998 to the Federal Communications Commission opposing the construction of a radio tower on Mount Ha'upu. The letter stated that the mountain is of special significance to Native Hawaiians as a *wahi kapu* (sacred place): "Ha'upu is our kin, descendent of Papa [Earth mother] and Wakea [Sky father], and older sibling of the Hawaiian people. This is the main reason why we, as Hawaiians, hold Ha'upu sacred in our hearts". According to the OHA (1998) document, Ha'upu was named after a demi-god/warrior who took a large boulder from Kaua'i and threw it across the Ka'ie'ie Waho Channel, where it killed an enemy chief on O'ahu. The small *heiau* atop Mount Hā'upu is dedicated to the goddess of hula (Laka). Both the *heiau* and the wooded areas at Hā'upu Summitt are known as *keolewa*, a word common in Hawaiian oral traditions. In addition, Ku and Hina, the first Hawaiian god and goddess, live on Ha'upu Ridge. Mount Ha'upu was also an important navigational landmark for traditional Native Hawaiian fishermen, and Hawaiians today still view the mountain with reverence (OHA 1998).

Beginning in the 1990s, Burney and Kikuchi began excavating the Makauwahi Cave and Sinkhole. They stated that within the cave "in a single stratigraphic sequence and encapsulated view of the full span of human occupation, including the millennia preceding human arrival, earliest human evidence, subsequent population increased and cultural change, European contact, and modern transformation" (Burney and Kikuchi 2006). Amongst the many discoveries from this study are bones of a Polynesian rat, which dated to 1039-1241 A.D. Because the rats were in the canoes with Polynesian voyagers, this is some of the earliest evidence for human occupation of this area. Excavations also exposed intact cultural layers, as well as culturally sterile deposits. Artifacts such as files, picks, scrapers, adzes, fish hooks, octopus lures, game stones, sling stones, and hammer stones were recovered. The preservative qualities of the deposits in the sinkhole were excellent. Fiber cordage, wooden fragments from canoes, paddles, and tool handles were also recovered. These materials came from three excavations. There is much potential for more information to be gained from this site (Burney and Kikuchi 2006).

Archaeological surveys and field work were conducted farther to the southwest along Waikomo Ditch by Cultural Surveys, Hawaii, Inc. (Hammatt*, et. al*. 2004). The terrain this ditch flows through is different from the terrain that the stream which flows out of Māhā'ulepū Valley travels through. Features originating during the pre-Contact era include agricultural terraces, habitation terraces and platforms, and irrigation *auwai* along both crests and bases of long, low ridges were observed (Hammatt*, et. al*. 2004). This complex of sites is designated the Kōloa Field System.

The most recent comprehensive effort at documenting the biology, botany, geology, ecology, and archaeology of the region is that compiled by the National Park Service (NPS; 2008). “The Māhā'ulepū, Island of Kaua'i Reconnaissance Survey” published in 2008 consists of an effort by the NPS to re-identify multiple natural and cultural features in the Māhā'ulepū Valley and environs. The goal was to argue for the importance of conducting a more thorough natural and cultural study of the area along the southeast coast of Kaua'i from Kōloa to Poipū, and northward along Māhā'ulepū, Kīpū Kai, Niumalu, Nawilili Harbor and then to Līhu'e. Included in the study is Mount Ha'upu and the ridgelines extending from it (NPS 2008). The study presents a summary of the natural and cultural features for the area and effectively argues for additional research.

CONSULTATION

Consultation was conducted via telephone, e-mail, personal interviews, and the U.S. Postal Service. Consultation was sought from Dr. Kamana'opono M. Crabbe, Chief Executive Officer, Office of Hawaiian Affairs; Vincent H. Rodrigues, Cultural Historian, State Historic Preservation Division; Missy Kamai, Na Kuleana o Kanaka Oiwi; Teddy Blake, Kōloa Community Association; Randy Wichman, President Kaua'i Historical Society; Jane Kamahaokalani Gray, Director of the Kaua'i Museum; Office of Hawaiian Affairs, Kaua'i Branch; Sherri “Puni” Patrick, kupuna; Rupert Rowe, community member, and proficient fisherman; Beryl Blaich, Executive Director of Malama Maha'ulepu; Bridget Hammerquist, Friends of Maha'ulepu; Kalanikumai (aka Branch Harmony), traditional cultural practitioner and member of Malama Maha'ulepu; Terrie Hayes, community member; Llewelyn “Billy” Kaohelauli'i, community member; Ali'i Nui Aleka Aipolani, Polynesian Kingdom of Atooi; Gordon Higa, community member; David Chang, long-time resident, founder of Ohana o Maha'ulepu, and founder of Malama Maha'ulepu; Napua Wong Romo, Vice-President Malama Maha'ulepu; Kunane Aipoalani; Leinaala Pavao Jardin, Kumu Hula; Aletha "Puna" Kaohi; Scott Sagum, Vice President of the Royal Order and President of the Ho'ola Lahui Hawaii Board of Directors; David Burney, steward of Makauwahi Cave; Lida Burney, steward of Makauwahi Cave; Catherine Lo, community member; Karl Lo, community member, Reverend Doctor Alan Akana, community member, and Reverend of Kōloa Union Church; Kauilani Kahalekai, community member and cultural practitioner; William Ho'ohuli, community member; and Jim Case, longtime resident.

In addition, a Cultural Impact Assessment Notice was published on October 24, 25, and 28, 2012, in *The Honolulu Star-Advertiser* and in *The Maui News*, which published on the same dates on Maui, and the January 2015 issue of the OHA newspaper, *Ka Wai Ola* (see Appendix B). These notices requested information of cultural resources or activities in the area of the proposed project, stated the Tax Map Key (TMK) number, and where to respond with pertinent information. Based on the responses, an assessment of the potential effects on cultural resources in the project area and recommendations for mitigation of these effects can be proposed.

CULTURAL IMPACT ASSESSMENT INTERVIEWS AND CONCERNS

Analysis of the potential effect of the project on cultural resources, practices or beliefs, the potential to isolate cultural resources, maintain practices or beliefs in their original setting, and the potential of the project to introduce elements that may alter the setting in which cultural practices take place is a requirement of the OEQC (2012:13). As stated earlier, this includes the cultural resources of the different groups comprising the multiethnic community of Hawai'i.

Initially, Mr. Kawika McKeague, Group 70 Cultural Liaison, planned to sit in on the interviews. However, due to health reasons, Mr. McKeague was unable to attend either session. Due to a family emergency, Missy Kamai was unable to attend either interview session. David Chang planned on attending the April 17, 2015 interview session, but called Friday morning to say he was not feeling well. Scott Sagan, also, planned on attending, but health issues prevented kept him away, as well.

Consultation was conducted in person on April 16 by SCS Senior Archaeologists Ms. Dagher and Jim Powell, B.A. These semi-private interviews were hosted by Mr. and Mrs. Hammerquist and with the permission of those in attendance; the interviews were conducted on the Hammerqust's *lanai*. Those interviewed on April 16, 2015 included:

- Rupert Rowe
- Kalanikumai
- Reverend Doctor Alan Akana
- Llewelyn “Billy” Kaohelauli'i
- Terrie Hayes
- Kauilani Kahalekai
- Bridget Hammerquist

RUPERT ROWE

Rupert Rowe explained that this area has three springs set up to feed taro patches so that water is filtered on its journey to the ocean. Big land owners, in Hawai'i, are able to colonize the islands because there is no treaty between the Kingdom and the United States. As wards of the State, which is based on a liquid measurement, Native Hawaiians really do not have the resources to fight the corporations that occupy Hawai'i. When asked by one of the interviewers if he knew the names of the springs, Mr. Rowe answered that he could not reveal their names because a lot of the secrets about the culture are being invaded by people who try to do what they want to do. There is no place in the world where the culture is second best to the citizens of America. By becoming wards of the United States, Native Hawaiians are totally dysfunctional under the puppet government of the State of Hawai'i because as the host culture, they can never protect their assets of the past, the future, and the present. Archaeologists and consultants conducting research try to document the mystical part of Hawaiian culture, but it can't be understood by outsiders “it's like talking bubbles under water.”

As a *kanaka maoli*, Mr. Rowe can only speak of the culture and its unique situation as it applies to this [Māhā'ulepū] valley. Native Hawaiians are the only people in Hawai'i who do not have a say in what happens. Everyone else is just interested in making money, but what they are really doing is stealing the treasury of the Kingdom of Hawai'i. You cannot buy land in Hawai'i and come out with a valid deed. In order to own the land out right, you have to have clear title to the land, which is a treaty between two states. When the time came for Hawai'i to become a part of the United State, the native people didn't want to become American because they saw it as a country without a culture (i.e*.,* as a country without a race). They saw the moral values of the Americans as based on the face of the dollar that says “In God we trust.” The people wondered what does god have to do with a piece of paper? Native people understand that energy is within a person and when you talk of a spiritual bond between native cultures and the land, it is understood that all people have a great bond between the land and their souls (i.e., they intuitively understand the uniqueness of what is there).

When asked by one of the interviewers if he was from the Maha'ulepu area, Mr. Rowe responded that his '*ohana* where from Māhā'ulepū and Kōloa. Mr. Rowe added that, as had said earlier, the outside people want to know the genealogies of the people from a particular area, but culturally, the ranking *ali'i* did not disclose their identity to their enemies. Kalanikumai interjected that Rupert's family, in Kōloa and, Māhā'ulepū goes back many, many, many generation before western contact and that Rupert's family name appears on the roles and on the records. Mr. Rowe believes that letting his cultural and familial secrets out to the westerner world is a violation of his human and civil rights.

Concerns

Mr. Rowe is concerned that the proposed dairy will disturb the bond between the soul and land. He strongly believes that it's important for native people to have a voice in what happens to the land. Mr. Rowe's opinion is that the native person really loses out when the western mentality of taking “what is yours to be theirs.”

KALANIKUMAI

Kalanikumai Ka Mak'ul'uli 'O Na Ali'i Hanohano: Representing the 7th generation of aboriginal descendants of Kōloa District since Western contact, Kalanikumai stated that his Mo'okuauhau [genealogy] goes back many generations before western contact. Kalanikumai knows of two of the springs in the area. One spring is currently owned by the County and there used to be a habitation site built there located above the road. Title to this Spring site is clouded as the County contacted and obtained a signature from one member of the Kekauoha family [Vice-Principal at Hanalei School 1940's post-war], while seven other brothers and sisters held equal claim unsettled. (source: Samuel Kekauoha/ family Elder & Genealogist).

Another spring is located in Hidden Valley (also known as 'Aweoweonui). Kalanikumai's great-great-great grandfather (Nakapa'ahu, [1798-1895] son of Nahinu, a grand-nephew of Kaumuali'i, and first-cousin to the Kamehameha regime, who was principal Ali'i Nui of Kōloa prior to the overthrow, and later the superintendent (Ilāmuku) of Kōloa under the Kingdom, built and occupied a Kauhale by the Spring through the auspices of Hannah Moore, who had adopted Nakapa'ahu's daughter and encouraged Nakapa'ahu to live on the property and work the land. Nakapa'ahu developed the Hidden Valley spring, on land given to him by Mika who had acquired the land through a trade. Mika was tax collector for the Kingdom, and first Lay Teacher at the Catholic “San Rafael” Parish School operated by the Belgian “Sacred Heart” Order. Mika's mother, Hannah Moore, negotiated the transfer of land from Mika to Nakapa'ahu, as documented in the records. Mika married Nakapa'ahu's daughter Rose. Trained by her husband, Rose became the second Lay Teacher at San Rafael's. Rose, in turn, trained her elder sister Halieta's daughter [Rebecca] as the third, and final Lay Teacher at that school. The two families were closely intertwined.

Nakapa'ahu built up the spring, established a home there, with cultivated lo'i, garden, and raised his daughter there for the last twenty-six years of his life. He fostered a relationship with a haole named William Brown, who organized the kalo farmers in the Māhā'ulepū Valley, who were at odds with Koloa Sugar over the kalo lands. There was a case where Mr. Brown got Koloa Sugar to pay a settlement to him (Nakapa'ahu), which he distributed among the tenant kale farmers, for violations and intrusions that Koloa Sugar had been doing on the kalo lands. Two years after Nakapa'ahu died, in 1897, Knudsen Estate and Koloa Sugar tried to claim the land. Mr. Brown helped Nakapa'ahu's daughter, got legal counsel, organized a defense against Knudsen Estate and Koloa Sugar. Knudsen Estate and Koloa Sugar tried to exclude Brown from representing Nakapa'ahu's daughter, as he was no relation to her. So, William Brown married Nakapa'ahu's daughter, in order to be able to speak for her. In 1899, the Kauai District Court ruled that the land belonged to Nakapa'ahu's heirs fee simple, under the right of Adverse

Possession. In 1991, Kalanikumai discovered documentation indicating Grove Farm had acquired quiet title to the land in1976. Kalanikumai states he has direct Kuleana claim to land at 'Aweoweonui and that Mika had registered LCAs in Māhā'ulepū to which Kalanikumai has kuleana rights. Court documentation demonstrates that some 300 acres of Māhā'ulepū Valley land was in tenant Kalo cultivation as late as 1899.

Kalanikumai collects 'aweoweo (*Chenopodium oahuense*), herbals, botanicals, and vegetation; has documentation to show that he has repeatedly used trails in Māhā'ulepū since returning to Kauai in 1989. He frequents Hau'ula, the 'Aweoweonui Burial Dunes, "Hidden Valley", the "Petroglyph field"; Unu Heiau; Plateau; Bamboo groves and Waterfall above the Plateau; and the Pa'a- Māhā'ulepū Alahele, as well as the coastal & beach shoreline. As Kalanikumai believes there are post-Contact burials in Māhā'ulepū near the LCAs, he would like further archaeological work conducted in this area. According to Kalanikumai, it was a common practice to bury infants, less than 1 year old, in lo'i with the kalo, so as to be absorbed by Haloa and nourishing successive generations. He has first-hand experience with this practice. When his infant sister died, his family buried her in the lo'i with the kalo that was his sustenance until seven years of age.

During the post-Contact Period, family burials were customarily interred within the LCA awarded plots containing habitations near the house site. Subsequent surface clearing activities removing signs of habitation for agricultural repurposing obscures, but fails to remove the presence of burials.

Kalanikumai mentioned that there was a habitation and ceremonial site on the plateau, above Māhā'ulepū Valley, used from the pre-Contact Period into the post-Contact Period. Kalanikumai also said that there were salt pans located down in the conservation zone outside of project area that are hydrologically linked to the valley's drainage as well as from Ditch 1, Ditch 2, and Waiopili Ditch. Restoration of this culturally significant unique practice, exclusive to Hawai'i, limited to few environmentally suited locations, would be irrevocably precluded by the inevitable seepage of soil contaminants resulting from the Dairy installation. According to Kalanikumai, the heiau (State Site 50-30-10-2250) was of the Unu type or classification of the heiau (i.e., a low circular structure, with northern and southern doorways). The heiau was an agricultural heiau associated with the god Lono, but was also associated with other ceremonies, including the ceremony of the First Fruits and Makahiki. Kalanikumai stated that he is planning on conducting a First Fruits Ceremony at State Site 50-30-10-2250 in the near future. The unu'unu is not separate from the petroglyph heiau or the petroglyph boulders in the back of the valley, which are associated with the god Kāne and Lono; "…they are all part of one… different practices were conducted at the different areas there."

Kalanikumai also stated that he recently conducted two ceremonies in Māhā'ulepū Ahupua'a [February and March 2015] during New Moon at State Site 50-30-10-2250. Māhā'ulepū is also associated with the goddess Laka. There is a burial cave on the plateau and two sacred bamboo groves are located above the plateau, between 800 and 900 feet above the valley floor, that are associated with the legendary demi-god (Kupua) Palila of the House of Moana. The legend of Pele's sister Hi'iaka-I-Ka-Poli-'O Pele recounts how Hi'iaka addressed prayers of supplication toward the Heiau of Laka, positioned in the meadow sheltered in the lee of Hā'upu's prominent knoll. There is a Lele (a jumping off space or portal) known as Ke O Lewa, located in the atmosphere, suspended in the heights, above Mount Hā'upu.

Kalanikumai stated that pre-Contact Period burials are located all along the mountain and coastal cliffs, in crevices and in caverns. During the post-Contact Period, people would inter their dead near their homes. Kalanikumai believes that the historic burials on the valley floor, in the LCAs, were not impacted by the commercial production of sugar, as only the ground surface was graded and scraped. So, Kalanikumai believes there may still be still be Historic burials there. Prior to WWII there was a village at Māhā'ulepū. After the WWII, the people were displaced from the valley.

Kalanikumai confirmed that the plateau, located approximately 450 to 600 feet above the valley floor, was designated as a pu'u honua (see Kauelani Kahalekai testimony below). He has collected herbs, flowers, plants, spring-water, calcite minerals and other native resources in Maha'ulepu Ahupua'a for over 25 years, following in the footsteps of his Kupuna Kaluhimoku Nakapa'ahu, a Kahuna La'au Lapa'au (son of the Ali'i Nui), whose practice in this area has been documented.

Concerns

Kalanikumai is concerned with access to the valley, highlands and natural resources; that seepage and discharge from the dairy will contaminate the Kalo Lo'i, the salt pans, the Makauwahi Cave Complex, Wetlands and near-by Waiopili Heiau. He believes there may still be still be Historic burials in the LCAs and would like to see additional archaeological work in this area. Kalanikumai would like to see Māhā'ulepū Ahupua'a preserved in vegetative and biodiverse crops.

Kalanikumai believes that vegetative crop cultivation is the best and highest use of this environmentally sensitive and fragile area. Kalo and Pa'akai cultivation and production are cultural priority crops. Historic uses have demonstrated success with 'Uala (Sweet Potato), Oranges, 'Ulu, and other dioecious crops. Introduction of associated airborne, water, and soil contamination on a scale of magnitude such as is inevitable with this project will produce a devastating effect, not only upon the environment and shoreline, but accordingly, upon the economy; businesses; tax base; tourism; residents; health and welfare of the community. Ignoring facts, dissembling or prevarication thereof, misrepresentation or promotion of inaccuracies, distorting information revealed thru Community scrutiny in examination of the impact and details of this intended operation is morally reprehensible. The continuation of presenting slanted distortions of fact that fly in the face of reason only prolong the inevitable,and display corporate consumptive greed over public welfare, besmirching the character of those who would continue to deny the devastating effect this would have upon our Island.

Kalanikumai Ka Maka'uli'uli 'O Na Ali'i Hanohano
Waiuka Poele'ele, Awawa Lawa'i, i Kona Kaua'i. 18 Aukake [August] 2015.

REVEREND DOCTOR ALAN AKANA

Reverend Doctor Akana has family roots on Hawai'i and Kaua'i Islands, now lives on Kaua'i, and is the pastor of Kōloa Union Church. Reverend Akana hikes, runs, and swims in Māhā'ulepū. He has visited the Makauwahi Cave Reserve on several occasions and is aware of its rich cultural importance. Although he knows of no other specific cultural sites, he feels the importance of the area. Reverend Doctor Akana said that Māhā'ulepū feels like a special place to him, he sees Māhā'ulepū as a "cultural *kipuka*" (i.e., an old growth area surrounded by more recent lava flow), and as a place for Hawaiian people to gather. Reverend Akana understands the importance of being connected to an area and believes it is important to have a "sense of place." He also stressed the importance of having undeveloped areas as nature reserves for people to be able to retreat, away from modern development. Reverend Akana also stressed the importance of people who are connected to the land to have a say in what happens to land and how it is used. He believes it is important that "sacred places" are preserved for the people, regardless of who owns the land. He comes from farming and agricultural family and is not opposed to agriculture or dairy. Per se, Reverend Doctor Akana understands the importance of "sustainable agriculture," but is not convinced that it applies to the proposed dairy at Māhā'ulepū.

Concerns

Mr. Akana is concerned that the people culturally connected to the land have a say in how it is used. He believes that it is important that some areas remain pristine, undeveloped, and available to the public, in order for people to have a place to go to feel connected to the land, to a place, to each other, and to their history. Mr. Akana is not convinced that the plan for the planned dairy at Māhā'ulepū is good for the Hawaiian people, nearby residents, the water table or shoreline.

LLEWELYN "BILLY" KAOHELAULI'I

Mr. Kaohelauli'i is the Moku for the Kona District, one of the six and the largest of the Moku Districts on the Island of Kaua'i. Within the Kona Moku, there are 11 Ahupua'a, one of which is Māhā'ulepū. As the Moku for this District, it is his duty to work with the Ahupua'a representative of Māhā'ulepū (among others) and do whatever he can to communicate with the Department of Land and Natural Resources. In his position as the appointed Hawaiian representative, he is committed to protecting and preserving the water and other environmental resources of the areas of his District.

Mr. Kaohelauli'i was born in Waimea Hospital (Kaua'i) in 1950. He has lived all his life in Kōloa, and is the fourth generation fisherman in a family who's initial roots were at Māhā'ulepū. The most important things to him are fishing and farming, which he sees as providing sustainability for the people of the ahupua'a. He has spent his life helping the people of the Kona District, teaching youth how to fish and gather *opihi* and *limu*. His ancestral background and life's activities were a likely influence in his selection by more than 200 Kupuna as the Moku for the Kona District.

Mr. Kaohelauli'i has fished every bay from Po'ipū all the way to Līhu'e, the whole coast, and all the way down to the west side of the island. He has fished/gathered for limu, *opihi, wana, loli, uhu, manini, kala, menui, weke, moi, aholehole*. Mr. Kaohelauli'i stated that fishponds and fishing grounds are located along the coastline of Māhā'ulepū and that one of the fishing areas is located near "kitchen rock." Mr. Kaohelauli'i's parents used to go back by the *heiau* in Māhā'ulepū (State Site 50-30-10-2250) to collect plants including, maile, mokihana, and the seeds of black eyed susans for lei making.

The main thing they used to gather was the water from Hidden Valley ('Aweoweonui) - from the fresh water spring, which is located "high up" in the valley. Hidden Valley is located on the other side of Māhā'ulepū Ridge. In Hidden Valley ('Aweoweonui) there is a spring and a grove of Java plum where the cows, horses, and pigs gather. (Kalanikumai interjects that this is where Nakapa'ahu's residence was – on a 9 acre parcel in 'Aweoweonui/Hidden Valley). All the local people went there to collect the fruits and water, which was known for being clean and pure. Mr. Kaohelauli'i's grandfather used to own 100 acres of land in the Valley. The land was given to Mr. Kaohelauli'i by Eke Opunui, the *ali'i* of Po'ipū.

The area can still be accessed by trails which are currently used by hunters. When Mr. Kaohelauli'i used to hunt, he would climb up the mountain, from Māhā'ulepū side, down the ridge, to a road going across and to another trail that goes to Black Mountain. Trails go across to Kīpū Kai, and back by Makawehi Cave. When Mr. Kaohelauli'i was a boy, even when his father was alive, they used to go to an area of Makawehi Cave to gather Hawaiian herbs, including *pilo*, for medicinal use. Back in the day, the area was very spooky. No one wanted to go there at night because it was a known Hawaiian burial area and people were said to see spirits walking. When Mr. Kaohelauli'i was young, he used to walk trail from Po'ipū to Māhā'ulepū, as this area was the family gathering area. Mr. Kaohelauli'i has lived on fish all his life and still engages in subsistence fishing today. He is a strong believer in sustainability so that the resources will be available for future generations.

Concerns

Mr. Kaohelauli'i expressed concerns about the negative impacts the dairy will have on contaminating the streams, ponds, wells, and the ocean, all fish, the reef and fishing. It will adversely impact Kauai's resources, such as the reef, the fish, the drinking water, and fishing. As a strong proponent of sustainability, Mr. Kaohelauli'i favors a balanced ecosystem and wants fish and lands for farming to be available for future generations.

Mr. Kaohelauli'i was recently denied access to the heiau at Māhā'ulepū for cultural practices by Grove Farm, because of the lease with Hawaii Dairy Farms. This is a violation of the State Constitution and the Hawaii Revised Statutes, which provide access for ongoing traditional uses and cultural practitioners.

Mr. Kaohelauli'i is also concerned that there are Hawaiian families still in the area with unresolved LCA (Land Commission Awards) Claims in the very area where the Dairy is planned to be. Mr. Kaohelauli'i is worried that although many of the families still live in the area, they were not contacted for their cultural input or to find out about their sustenance fishing, hunting, and gathering practices in this area. He believes a more in-depth study of the ongoing use of this Valley and its waters and coastline should be conducted.

TERRIE HAYES

Ms. Hayes visited the islands for 30 years before coming to live here over 13 years ago. Ms. Hayes, a teacher and educator by trade, has now been living with Mr. Kaohelauli'i on the Kaohelauli'i family property in Kōloa for twelve years. Ms. Hayes stated that Mr. Kaoheluli'i also fishes in Pā'ā Ahupua'a, which is where the fishponds are. Ms. Hayes is familiar with native plants and understands farming. Ms. Hayes explained the *Aha Moku* system of resource management, which utilizes traditional native knowledge of agriculture and fishing as a method of preserving natural resources. Ms. Hayes stated that the *Aha Moku* system of management, which was enacted by the legislature as SB 288 in 2012, empowers the *kanaka maoli* and gives them a voice.

Concerns

Ms. Hayes' greatest concerns are the potential impacts the dairy will have on the environment, specifically to the drinking water, groundwater, ocean, and reef. She is also very concerned about the *kanaka maoli* being kept from their customary access – access is imperative to maintain their traditions. Ms. Hayes stated that tests have shown that the soils in Māhā'ulepū are clay based and while suitable for some agriculture like Taro, they are poorly draining which will increase the risk of Waste runoff. Historically, the sugar plantation put in a large network of ditches to carry the excess water that collects on the soil surface, to the ocean. Ms. Hayes explained that the dairy representatives told them that they have restored the ditch network and intend to use it, admitting that they still drain to the ocean. The ditch system running through the dairy property increases the risk of contamination of all waters in Māhā'ulepū.

In addition, the roads to Māhā'ulepū are now gated and locked making accessibility very difficult to impossible. Ms. Hayes believes it is also extremely important to preserve the cultural resources for future generations.

The proposed HDF Plan claims that there will be zero discharge of waste, stating no waste will leave their farm. They seem only to have considered runoff in that statement; because there is no way that they can prevent groundwater contamination in the areas where the soil is well draining. According to their Plan, they need to pump and empty the effluent ponds when there is a hurricane. They also say that this process takes approximately 96 hours to empty the ponds. Thus far this hurricane season would have forced the emptying of effluent ponds six times in the past three months. This is an impending disaster that the sacred Māhā'ulepū Valley could not endure. Dairy representatives told us that each mature Dairy cow will produce approximately 143lbs. of wet manure and 8-10 gallons of urine per day. Even their starting herd of 699 pregnant cows will add more than 100,000 lbs of waste per day. As Poipu and Kōloa drinking water wells are also contained within the valley, contamination would be unavoidable. Ms. Hayes feels strongly that the proposed dairy would be terrible for the people of Kaua'i and in the future.

BRIDGET HAMMERQUIST

Mrs. Hammerquist is *kama'aina*, born in Hilo, Hawai'i prior to Statehood. She grew up on Sugar Plantations on the Big Island, as her father, Frank Sweeney, worked for Sugar Companies from the time she was born. She believes in agriculture and has many fond memories of her time on the Sugar Plantation, remembering issues about water in years that were dry and the effect on Sugar content when the cane was harvested. She and her brothers had a favorite pastime of sitting out on the porch when fields near the house were being burned, enjoying the ash that fell on their clothing. She knows that sugar companies didn't do everything right but she learned a genuine concern for the environment. As a young person, attending Paauhau School, she raised a garden, an option to P.E. that Paauhau students were offered. She enjoyed selling the vegetables in the village and really believes in the importance of locally produced food.

When she was in high school, her father was transferred to Olokele Sugar Company, at Kaumakani Kaua'i. On weekends, it was a favorite pastime of her family to picnic, swim, and hike the trails in Māhā'ulepū. At the time, Grove Farm issued a car pass which she recalls was necessary for their entrance. For her, the treasures of Māhā'ulepū are the memories of the cultural treasures as well, including the petroglyph boulders, that she visited with her family when she was growing up. Now, Mrs. Hammerquist is raising her three grandchildren and resides full time in Kōloa on Kaua'i. Not only did she take her own children to Māhā'ulepū when they were growing up, often staying with her parents who lived in Weli Weli track, but she continues to share the joys of Māhā'ulepū Valley with her grandchildren. They have hiked, snorkeled, ridden horses, and all have enjoyed multiple visits to the Makauwehi Cave.

Mrs. Hammerquist became concerned about the impact of the proposed Dairy when she read the Dairy's plan and learned about the amount of waste that would be produced and the amount water that would be consumed, 2.93 million gallons daily (MGD) from the Waita Reservoir for irrigation. In addition, the dairy intends to draw potable water for the cows to drink and for washing their udders, all from the Māhā'ulepū Wells. She is also very worried about the amount of biting flies (already on Kaua'i at some farms) that will breed and multiply in the large waste deposits from the proposed dairy herd. From her background as a nurse, she fears the spread of Zoonotic diseases by the flies. She also feels the flies will be very damaging to the South Shore visitor population. She explained that the Dairy representatives have stated their goal is for a 2,000 cow dairy, starting with 699 pregnant cows. On page 42 of their plan, the dairy states that each cow will produce at least 143 pounds of wet manure per day not including 8-10 gallons of hormone and ammonia laden urine daily. Mrs. Hammerquist says, when you do the math, there will be more than 100,000 lbs. of waste per day of waste from the start up herd, and more than 300,000 lbs. per day once the herd is expanded to 2,000 cows. When she attended Hawaii Preparatory Academy on the Big Island, she regularly rode with Mr. Samulsen on Parker Ranch pastures. She recalls that cow manure remains on the ground for a long time. As a result, she is very concerned about the massive accumulation of waste over time, even when it falls on grass, increasing the risk of further contamination of the ditches, Waiopili Stream, groundwater, and nearby coastal waters.

On review of their plan, Mrs. Hammerquist read that there is to be an 81 acre manure and sludge pad that the Dairy plans to locate approximately 750 to 1,000 feet from three existing County wells that currently supply drinking water for all of Pō'ipu and much of Kōloa. She became more concerned after reading the soils study and learning that the soils of the valley are primarily poorly draining, with one of the exceptions in the 81 acre proposed manure and sludge pad (their block H). The Dairy's plan calls for pumping the effluent pond contents onto the 81 acre pad every 5 weeks, the area closest to the County Wells. The sludge pumped from the effluent ponds to Block H, will be an addition to any manure deposited by the cows that graze on that same area. Thus, she is concerned that the sludge will percolate down into the water table and the well capture zone, contaminating the drinking water. She has read numerous reports of communities in the Mainland United States (New Mexico, New York, Washington, Wisconsin, Iowa, and others) that have lost wells due to nitrate infiltration. She reported that in Des Moines, Iowa, a city of 504,000, they are projecting a cost of $100 million to purchase, install, and operate a plant to extract the unsafe nitrates from their potable water.

Concerns

Mrs. Hammerquist has expressed deep concerns about manure and sludge seepage from the dairy contaminating drinking water, making it very difficult for residents of Pō'ipu and Kōloa to continue who have to rely on the County Wells as their sole source of drinking water. She is also concerned that the runoff from the dairy will flow into the ocean and contaminate the coastal area and marine resources, which will negatively affect the people who use those resources for subsistence. Mrs. Hammerquist is also concerned about access, as the gates into the valley area are now gated and locked. With access now denied, she fears that this rich cultural experience, enjoyed by many and the site of a routine, third grade field trip for Kōloa School (among others), is now lost. She views the valley as a local environmental and cultural treasure that is important for the people of Kaua'i now and for the future generations to experience.

The April 17, 2015 interviews were held at Kōloa Neighborhood Center Annex, former judge's chambers, ands conducted, in person, by Ms. Dagher. Initially, the April 17, 2015 interviews were slated to be private, individual, interviews. However, as all in attendance were in agreement, the private interview organically morphed into a group conversation. Those interviewed on April 17, 2015 included:

- Teddy Blake
- Napua Wong Romo
- Catherine Lo
- Karl Lo

TEDDY BLAKE

Mr. Blake was raised from birth to third grade in Ho'ai, Kualu, Kōloa, his house was right next to Kūhiō Park. When he was in third grade, his family moved to the present family residence on Waikomo Road, in Kōloa. Long time Kōloa residents refer to the entire area from Waitā Reservoir all the way down to Māhā'ulepū as one area. So, when facing the Kōloa Mill, everything before you was Māhā'ulepū. Mr. Blake spent a lot of time growing up in Māhā'ulepū, as did Napua Wong Romo and David Chang. Growing up, weekdays, after the chores were finished; weekends; vacations; and holidays were spent exploring the Māhā'ulepū area.

Waita Reservoir, the largest man-made reservoir in the State of Hawai'i, was built in 1906 by Grove Farm. The water from Waita Reservoir was a source of irrigation water for the entire south side of the island. Following the construction of the reservoir, the production of sugar cane increased dramatically. When Mr. Blake was growing up, Māhā'ulepū, in its entirety, was in sugar cane, while approximately ¾ of the *ahupua'a* of Weliweli and Pā'ā were under the commercial production of sugar cane. Waita Reservoir was a source of recreation and his friends played there throughout their childhood. At the reservoir, they fished for blue gills and encountered native plants, including *mokihana* (*Rutaceae Melicope anisata*), *maile oli* (*Alyxia* sp.), and introduced plants such as tapioca root, coffee, cacao. Coffee and cacao were planted by the plantation as possible cash crops. A mud slide at Watagi Falls was another area of recreation frequented by Mr. Blake and his childhood friends.

Mr. Blakes's childhood treks to Māhā'ulepū were for camping, swimming, and fishing at Kawailoa Bay, now referred to as Māhā'ulepū. The Vasconcellos family raised cattle in the area. Although the Vasconcellos sons were older than Mr. Blake, he knew who they were: “Blondie” Vasconcellos and his brother David worked for Grove Farm, where Blondie ran the quarry and David was a mechanic at the shop.

Although he was not interested in cultural sites when he was growing up, Mr. Blake had seen petroglyphs in Māhā'ulepū and an agricultural *heiau* at Ka Lae o Kahonu, a promontory on the west side of Māhā'ulepū. The next point of importance was a small *heiau* called Keolewa (Keonelewa), which was dedicated to the goddess Laka, located on top of Mount Ha'upu. The floor of Keolewa is covered in ocean sand. The agricultural *heiau*, Waiopili, is also close by.

Two to three hundred years before Kamehameha I attempted to conquer Kaua'i, the battle of Kaweliweli'iwi occurred. The king of Kaua'i, at that time was Kukona, his son was Manokalanipo. Kalaunuiohua, a chief from the west side of Hawai'i Island, had set his eyes on Maui, and when he felt the time was appropriate, he brought his forces together and conquered the king, who was Kamaluaohua. From Maui, he went to Moloka'i and conquered the king there.

With the two conquered kings with him, Kalaunuiohua traveled to O'ahu and conquered the *ali'i* (chief) of the west side of the island, before heading for Kaua'i. However, Kukona had heard that Kalaunuiohua was coming and was prepared for him. All of the Kaua'i chiefs united under Kukona and decimated Kalaunuiohua when he and his fleets came ashore along the Kōloa coast, at Kīpū. Mr. Blake believes that most of the human skeletal remains in the beach sands of Māhā'ulepū are from this battle.

Mr. Blake states that in his lifetime, there were no communities at Māhā'ulepū. No one lived there because it was all in sugar. Mr. Blake is the *limu* (algea) gatherer of his family. His favorite is *limu kohu* (*Asparagopsis taxiformis*), which is hard to find as it does not grow prolifically along the coast as other *limu* do. *Limu kohu* is high in iron and is good for the blood, so and he often was sent out by his father to Māhā'ulepū to collect it for his mother and sister to give them another boost of iron. Na'akea is the first bay you come to when coming around Kawelikoa Point. Although it was a long walk from his house and not easy to get to, Mr. Blake would often collect the *limu kohu* from Na'akea Bay (also known by its popular name, Second Ha'ula), because he knew that if it couldn't be found at the regular spots, it could always be found there, as it could be at Ha'ula. Ha'ula is a type of *limu*, but Mr. Blake has never eaten it, doesn't know how it can be used, nor does he remember hearing his parents or grandparents talk about it. Fishermen caught *'ulua* and other fish by shoreline cast fishing on the points.

Continuing along the coastline to the south, you come to Kawailoa Bay, which is sandy and where people liked to camp. Mr. Blake would come to spend the weekends there fishing, swimming, and camping and end up spending the whole summer. From Kawailoa Bay, the sandy beach extended all the way to Waiopili Stream. This is presently called Māhā'ulepū Beach, as Kawailoa is also called Māhā'ulepū Beach today. The proper name is Kāmala and it extends a point to the north a short distance past Waiopili Stream. Just west of Waiopili Stream is the seaside border of Māhā'ulepū Ahupua'a and Pā'ā Ahupua'a.

Waiopili Stream started from the Kapunakea Spring, located near Waiopili Heiau. The spring was named for the white coral walls of the spring. Mr. Blake believes that there are no archaeological sites on the Māhā'ulepū Valley floor, he believes they were destroyed by the commercial production of sugar cane. He is not sure when sugar cane came to Māhā'ulepū, but the commercial production of sugar cane started on Kaua'i in 1835. The valley floor was deep-plowed twice every two years, which would have destroyed any archaeological sites that were there.

Mr. Blake says the clayey soils of Māhā'ulepū make it one of the best places to grow taro. As the sub-soils were comprised of clay, very little water was lost because the water could not permeate through the soil. Mr. Blake said that he had been told that the entire Māhā'ulepū

Valley, approximately 400 acres, had been in taro at one time. Mr. Blake goes on to say that none of the pesticides used by the plantation have impacted the ground water Māhā'ulepū, because the soil is impermeable.

Concerns

Mr. Blake doesn't believe the proposed Māhā'ulepū dairy will have a negative impact on the environment or on traditional cultural practices, previously or currently, conducted in Māhā'ulepū Ahupua'a.

CATHERINE AND KARL LO

Mrs. Lo first was not born here. The first time she came to hear about Māhā'ulepū was when Charles Tanimoto wrote the book "Return to Māhā'ulepū, which was published in 1982. At that time she and her husband, Karl, went to the library to borrow the book. Mrs. Lo is writing a book about New Mill Camp and one of the things she noticed was that the people she is interviewing keep going back to their childhood days when they were fishing and picnicking. There was a Māhā'ulepū Camp, where Mr. Tanimoto was born and lived with his family, that dates back to the turn of the 19th century. The plantation had wells in Māhā'ulepū and Mr. Tanimoto's father was one of the mechanics that maintained the power plant that pumped out water to irrigate the cane fields. When Mr. Tanimoto was 75 he returned to Māhā'ulepū see where he grew up. He remembered the fishing; he looked for the wells, etc.

There was a small camp located in the shadow of Mount Hā'upu, near Koloa Mill, called New Mill Camp, where workers and their families lived. Many of former residents of New Mill Camp remember hiking to and overnight fishing at Black Mountain and picnicking, fishing, and camping at Māhā'ulepū's Kawailoa Beach. They also remember going to Gillin's Beach during the 1950s and 1960s, when Māhā'ulepū was pristine.

Mrs. Lo recalls that after the hurricane of 1992, she and Karl went to Māhā'ulepū see the petroglyphs which had been exposed for the first time in years. By the time they got to the site, a day or two after they learned about it, sand had covered the petroglyphs.

Concerns

Catherine and Karl Lo submitted a letter, via e-mail dated April 17, 2015, which expresses their concerns about the dairy (Appendix E).

JAMES (JIM) H. CASE

In 1918, Mr. Case's father graduated from the University of Hawai'i and joined the Hawaii National Guard. Soon after graduation, the Hawaii National Guard was mobilized, and Mr. Case's father was immediately assigned to the North Shore of O'ahu to guard Hawai'i from attacks by Germans and Austrians. That same year, Mr. Case's mother graduated from the University of California, Los Angeles. Mr. Case's mother's roommate was from Honolulu. So, following graduation, Mr. Case's mother went to Honolulu to visit her roommate. She liked it there, got a job, and met Mr. Case, Sr. Along the way, his parents married and Mr. Case was born on April 10, 1920, on Grove Farm. The house Mr. Case grew up in was located right in the middle of Grove Farm Plantation, about 200 yards away from G.N. Wilcox's house and office.

In 1920, following the end of World War I, Mr. Case, Sr., was hired by Grove Farm. According to Mr. Case, Grove Farm was started on the site of a huge kukui grove, and that is how Grove Farm came to be named. George N. Wilcox [owner of Grove Farm] acquired all of the land on the west side of a stream, which was located within a deep gulch, which emptied into Nāwiliwili Bay. Lihue Plantation is located on the east side of the stream. Mr. Wilcox gradually acquired all of the land on the west side of this stream up to the Kōloa Gap, with the exception of the Kīpū Ahupua'a, which was acquired by the Rice family a long time ago. The main valuable lands were located on the east side of Ha'upu Ridge. This area consisted of nice flat land that was good for the cultivation of all types of crops. This area includes Hulē'ia River, which flows along the bottom of the ridge, a large fishpond that is still there, but not Kīpū Kai (the seaward portion of Kīpū Ahupua'a).

Jim Case was born in 1920 at Grove Farm. The family home was 200 yards away from George N. (G.N.) Wilcox's house and office. As a boy, Mr. Case would go down on his bicycle to the (12 to 15 acre) Grove Farm dairy every morning, at 6 am, with a pale, to get milk. Jim Case went to elementary school at the Līhu'e Grammar School until the age of 13. His classmates included Elizabeth Knudsen, whose family owned a huge swath of land in the Kōloa/Po'ipti area. The Knudsen family home was at a place called Waiohai, on the beach at Po'ipū. Mr. Case visited there frequently throughout his youth, where he played polo with them. Outside of the plantation, the Knudsen family was one of the largest land owners in the area and very knowledgeable about the area. Mr. Case learned about the Kōloa area through his childhood friend, Elizabeth Knudsen.

Another one of Mr. Case's classmates was John Troop Moir, III, the son of the Koloa Plantation manager. As a boy, Mr. Case spent a lot of time at the Moir's house. He and John Troop Moir, III, went swimming at the beach, swam and fished at the [Waitā] reservoir, and drove around the fields.

Mr. Case got to know the Kōloa area even better through G.N. Wilcox's nieces, Ethel and Mabel Wilcox. They owned a beach home overlooking Brennecke's Beach, one of the best body surfing spots at the time. Every summer Ethel and Mabel loaned this house to Mr. Case's family. Mr. Case spent his childhood summers in this portion of Po'ipū, where he and his family often drove the family car on a dirt road along the length of Māhā'ulepū Beach, stopping to swim and picnic along the way. Mr. Case stated that he and his family saw [human] bones, which were extruded out of the ground, in the sand dunes at the main beach. Some say there was a huge battle there. Mr. Case believes that Native Hawaiians lived near the beach and buried their dead close to where they lived and that it is not likely that the Native Hawaiians buried their dead in their taro patches.

Mr. Case stated that during his youth he saw no evidence of any habitation or of Hawaiian trails during his youthful driving excursions along the dirt roads within the sugar plantation. Although, he did observe Hawaiian trails on the sand dunes. He never climbed Mount Ha'upu Ridge, as "it was a long way up." He has hiked all over the Nāwiliwili side of Ha'upu Ridge from Kīpū Kai to Nāwiliwili Bay along ancient Hawaiian Trails. Of note, in this area is a ledge overlooking the entrance into Nāwiliwili Bay. The konohiki would climb to this ledge to sight schools of fish. When the konohiki sighted a school of fish he would blow his conch shell to notify the fishermen. This was still occurring during Mr. Case's childhood. As a boy, Mr. Case knew a konohiki there whose daughter was a few years ahead of Mr. Case in school and whose son played tennis with Mr. Case.

According to Mr. Case, no one he knew would go from Kōloa to Līhu'e over the mountain because Kōloa Gap was right there. Mr. Case believes the Hawaiians did go through Kōloa Gap because the only alternative route was by boat and the ocean was rough. Mr. Case said it was possible to travel by boat from Kōloa to Nāwiliwili Bay in order to access Kīpū Kai. Based on Mr. Case's knowledge of Hawaiian history, there would have been trails from the beach and lowlands up the mountain that the Hawaiians used to access areas for gathering flowers and plants for food and medicinal purposes. However, he never heard of any trails in the dairy area. Mr. Case stated that there are other ways to access the mountain without going through the dairy.

Mr. Case's knowledge comes from growing up on Grove Farm, spending a lot of time visiting with his classmates in Kōloa and spending summers in Po'ipū. Most of Mr. Case's information, in terms of what went on the old days," was learned from Elizabeth Knudsen's father, Erik, whose family had lived on Kaua'i for many years. Mr. Case and his friends did not spend much time in Māhā'ulepū because the area was covered in sugar cane fields, although they did go through the sugar cane fields to access Waitā Reservoir.

In 1948, G.N. Wilcox acquired Koloa Plantation and incorporated it into the Grove Farm Plantation. Prior to 1948, Grove Farm and Koloa Plantation were entirely separate operations. In 1948, Mr. Case was in law school and his father was the chief financial officer, for Grove Farm, where he was responsible for all of the plantation operations, with the exception of the agricultural operations. Mr. Case. Sr. negotiated this acquisition from the owners of the Koloa Plantation from AMFAC. As Mr. Case was studying corporate law, his father sent him copies of all the paperwork associated with this acquisition, which allowed him to go through the acquisition process as a law student.

Concerns

Mr. Case doesn't believe the proposed Māhā'ulepū dairy will have a negative impact on the environment or on traditional cultural practices, previously or currently, conducted in Māhā'ulepū Ahupua'a.

SUMMARY

The "level of effort undertaken" to identify potential effect by a project to cultural resources, places or beliefs (OEQC 2012) has not been officially defined and is left up to the investigator. A good faith effort can mean contacting agencies by letter, interviewing people who may be affected by the project or who know its history, researching sensitive areas and previous land use, holding meetings in which the public is invited to testify, notifying the community through the media, and other appropriate strategies based on the type of project being proposed and its impact potential. Sending inquiring letters to organizations concerning development of a piece of property that has already been totally impacted by previous activity and is located in an already developed industrial area may be a "good faith effort." However, when many factors need to be considered, such as in coastal or mountain development, a good faith effort might mean an entirely different level of research activity.

In the case of the current undertaking, letters of inquiry were sent to individuals and organizations that may have knowledge or information pertaining to the collection of cultural resources and/or practices currently, or previously, conducted in close proximity to the proposed dairy to be located on an 557-acre property within Māhā'ulepū Valley, Māhā'ulepū Ahupua'a, Kōloa District, Island of Kaua'i. The property is owned by Mahaulepu Farms, LLC and comprised of TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.

Historical and cultural source materials were extensively used and can be found listed in the References Cited portion of this report. Such scholars as Samuel Kamakau, Martha Beckwith, Jon J. Chinen, Lilikalā Kame'eleihiwa, R. S. Kuykendall, Marion Kelly, E. S. C. Handy and E.G. Handy, and Mary Kawena Puku'i and Samuel H. Elbert continue to contribute to our knowledge and understanding of Hawai'i, past and present. The works of these and other authors were consulted and incorporated in this report where appropriate. Land use document research was supplied by the Waihona 'Aina Database (2014).

CULTURAL ASSESSMENT

Analysis of the potential effect of the project on cultural resources, practices or beliefs, its potential to isolate cultural resources, practices or beliefs from their setting, and the potential of the project to introduce elements which may alter the setting in which cultural practices take place is a suggested guideline of the OEQC (2012). As indicated by the responses received from the community, the broad area constituting Māhā'ulepū Ahupua'a, has been, and is currently, used for traditional cultural purposes. However, the project area itself is not being utilized for these activities. The areas used to gather plants and marine resources; the plateau; the coastal petroglyphs; the trails; State Site 50-30-10-2250 (the agricultural *heiau*); and State Site 50-30-10-3094, Feature 3 (a petroglyph boulder), are all located outside of the project area.

Of the eleven individuals interviewed, two individuals believed that the dairy would not have an impact on traditional cultural practices or to the environment. The remaining individuals expressed a variety of concerns about impacts the proposed dairy may have which are indirectly and directly related to traditional cultural practices. The indirect negative impacts would affect:

- The environment (i.e., seepage, discharge, and runoff would impact the groundwater, drinking water, and the watershed, the reef, the ocean and marine resources, and the smells will pollute the air);
- Activities the interviewees enjoyed as children would not be experienced by future generations (i.e., camping, hiking, swimming); and to
- Archaeological/cultural features and sites located along the coast (i.e., the salt pans, the “kitchen” or “kitchen rock”, Makawehi Cave, and Waiopili Heiau, and the coastal petroglyphs).

Many the interviewees go to Māhā'ulepū Ahupua'a to conduct traditional cultural activities. These individuals expressed concerns regarding restricted access to Māhā'ulepū Ahupua'a and to the adjacent coastal area, restricted access to the trails within the *ahupua'a*, which are utilized to gather natural resources for cultural purposes, and restrictions on conducting traditional ceremonies within the *ahupua'a*. Concerns were also expressed in regards to impacts to the natural resources gathered and collected from the area resulting from the proposed dairy polluting the air, land, and the water. The traditional cultural activities include collecting specific terrestrial and marine resources and conducting ceremonies.

- Native plants gathered from Māhā'ulepū Ahupua'a, for traditional use include; 'aweoweo, maile, mokihana, 'ohi'a 'ai, pilo, hinahina, limu kohu, mokihana, maile oli, and various native fruits and limu. Non-native plants collected from Māhā'ulepū Ahupua'a for traditional use include the seeds of black eyes susans, cat's claw, and Java plum. These plants are used as medicines, in lei making, in ceremonies, traditional dance, and as food resources

- At least one traditional ceremony was recently conducted in Māhā'ulepū Ahupua'a;
- Native fish, used as food resources, caught from the waters of Māhā'ulepū Ahupua'a include 'ulua, opihi, wana, loli, uhu, manini, kala, menui, weke, moi, aholehole.
- The spiritual connection between the people and the land;

CONCLUSION

While some members of the community expressed concern about impacts from the dairy, others did not. Given the ability of the Environmental Impact Statement to address these impacts, it seems reasonable to conclude that, pursuant to Act 50, the exercise of native Hawaiian rights, or any ethnic group, related to numerous traditional cultural practices including, gathering, access, cultivation, the use of traditional plants, and the use of trails, will not be adversely impacted by the proposed dairy.

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APPENDIX A: EXAMPLE LETTER OF INQUIRY

In compliance with the State of Hawai'i Revised Statute (HRS) Chapter 343 Environmental Impact Statements Law, and in accordance with the State of Hawai`i Department of Health's Office of Environmental Quality Control (OEQC) Guidelines for Assessing Cultural Impacts as adopted by the Environmental Council, State of Hawai`i on November 19, 1997, Scientific Consultant Services, Inc. (SCS) is in the process of preparing a Cultural Impact Assessment (CIA) in advance of proposed improvements for a proposed dairy farm property located within Māhā'ulepū Valley, Māhā`ulepū Ahupua`a, Kōloa District, Island of Kaua`i. The property is owned by Māhā`ulepū Farms, LLC. [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.] (Figures 1 and 2)

Scientific Consultant Services has conducted an Archaeological Inventory Survey of the proposed project area (Putzi *et al.* 2014, in prep.) in order to determine the presence of archaeological cultural materials. During the survey, one previously identified historic property, a carved petroglyph boulder (State Site 50-30-10-3094), was re-identified and 15 historic properties were newly identified and documented (Putzi *et al.* 2014, in prep.).

According to the *Guidelines for Assessing Cultural Impacts* (Office of Environmental Quality Control, Nov. 1997):

> The types of cultural practices and beliefs subject to assessment may include subsistence, commercial, residential, agricultural, access-related, recreational, and religious and spiritual customs…The types of cultural resources subject to assessment may include traditional cultural properties or other types of historic sites, both man made and natural which support such cultural beliefs…

We are seeking any information that you or other individuals have which might contribute to the knowledge of traditional cultural activities that were, or are currently, conducted in the vicinity of the proposed project area. We are also asking for any information pertaining to traditional cultural activities or traditional rights which may be impacted by the construction of the proposed dairy improvements. The results of the cultural impact assessment are dependent on the response and contributions made by individuals and organizations such as yours.

Enclosed are maps showing the proposed project area. Please contact me at the Scientific Consultant Services, Honolulu, office at (808) 597-1182 or via e-mail (cathy@scshawaii.com) with any information or recommendations concerning this Cultural Impact Assessment.

Sincerely yours,

Cathleen Dagher
Senior Archaeologist
Enclosures (2)

APPENDIX B: NEWSPAPER NOTICE AND AFFIDAVIT

1683

AFFIDAVIT OF PUBLICATION

IN THE MATTER OF
SCS Proj 1683 CIA Notice

STATE OF HAWAII } SS.
City and County of Honolulu }

Doc. Date: DEC 2 9 2014 **# Pages:** 1

Notary Name: Patricia K. Reese First Judicial **Circuit**

Doc. Description: Affidavit of Publication

PATRICIA K. REESE NOTARY PUBLIC Comm. No. 86-467 STATE OF HAWAII

Patricia K. Reese DEC 2 9 2014
Notary Signature Date

Lisa Kaukani being duly sworn, deposes and says that she is a clerk, duly authorized to execute this affidavit of Oahu Publications, Inc. publisher of The Honolulu Star-Advertiser and MidWeek, that said newspapers are newspapers of general circulation in the State of Hawaii, and that the attached notice is true notice as was published in the aforementioned newspapers as follows:

Honolulu Star-Advertiser 3 times on:
12/24, 12/25, 12/28/2014

Midweek Wed. 0 times on:

______ times on:

Information requested by Scientific Consultant Services, Inc. (SCS) on cultural resources; and traditional, or on-going, cultural activities on or near a proposed dairy farm on a 578 acre property within Maha'ulepu Valley, Maha'ulepu Ahupua'a, Koloa District, Island of Kaua'i [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. Please respond within 30 days to Cathleen Dagher at (808) 597-1182.
(SA702090 12/24, 12/25, 12/28/14)

And that affiant is not a party to or in any way interested in the above entitled matter.

Lisa Kaukani
Lisa Kaukani

Subscribed to and sworn before me this 29th day of December A.D. 20 14

Patricia K. Reese
Patricia K. Reese, Notary Public of the First Judicial Circuit, State of Hawaii

My commission expires: Oct 07, 2018

PATRICIA K. REESE NOTARY PUBLIC Comm. No. 86-467 STATE OF HAWAII

Ad # 0000702099

SP.NO.: __________ L.N.

1683

AFFIDAVIT OF PUBLICATION

IN THE MATTER OF
SCS Proj 1683 CIA Notice

STATE OF HAWAII } SS.
City and County of Honolulu

Doc. Date: DEC 2 9 2014 **# Pages:** 1
Notary Name: Patricia K. Reese First Judicial **Circuit**
Doc. Description: Affidavit of Publication

Patricia K. Reese DEC 2 9 2014
Notary Signature Date

PATRICIA K. REESE NOTARY PUBLIC Comm. No. 86-467 STATE OF HAWAII

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Honolulu Star-Advertiser 0 times on:

Midweek Wed. 0 times on:

THE GARDEN ISLAND 3 times on: 12-24, 12-25, 12-28-14

And that affiant is not a party to or in any way interested in the above entitled matter.

Lisa Kaukani
Lisa Kaukani

Subscribed to and sworn before me this 29th day of December A.D. 20 14

Patricia K. Reese
Patricia K. Reese, Notary Public of the First Judicial Circuit, State of Hawaii

My commission expires: Oct 07, 2018

Ad # 0000700891 SP.NO.: ______ L.N.

Information requested by Scientific Consultant Services, Inc. (SCS) on cultural resources; and traditional, or on-going, cultural activities on or near a proposed dairy farm on a 578 acre property within Maha'ulepu Valley, Maha'ulepu Ahupua'a, Koloa District, Island of Kaua'i [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. Please respond within 30 days to Cathleen Dagher at (808) 597-1182.
(TGI700891 12/24, 12/25, 12/28/14)

PATRICIA K. REESE NOTARY PUBLIC Comm. No. 86-467 STATE OF HAWAII

APPENDIX C: EXAMPLE FOLLOW-UP LETTER

Dear:

This is our follow-up letter to our December 23, 20142 letter which was in compliance with the statutory requirements of the State of Hawai'i Revised Statute (HRS) Chapter 343 Environmental Impact Statements Law, and in accordance with the State of Hawai`i Department of Health's Office of Environmental Quality Control (OEQC) Guidelines for Assessing Cultural Impacts as adopted by the Environmental Council, State of Hawai`i, on November 19, 1997.

Scientific Consultant Services, Inc. (SCS) is in the process of preparing a Cultural Impact Assessment (CIA) in advance of improvements to a dairy farm located within Māhā'ulepū Valley, Māhā`ulepū Ahupua`a, Kōloa District, Island of Kaua`i [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. The 580-acre property is owned by Māhā`ulepū Farms, LLC.

In 2014, SCS (Putzi *et al.* 2014, in review) conducted an Archaeological Inventory Survey of the proposed project area in order to determine the presence, or absence, of historic properties. During the survey, one previously identified historic property, a carved petroglyph boulder (State Site 50-30-10-3094), was re-identified and 15 historic properties were newly identified and documented.

According to the *Guidelines for Assessing Cultural Impacts* (Office of Environmental Quality Control, Nov. 1997):

> The types of cultural practices and beliefs subject to assessment may include subsistence, commercial, residential, agricultural, access-related, recreational, and religious and spiritual customs…The types of cultural resources subject to assessment may include traditional cultural properties or other types of historic sites, both man made and natural which support such cultural beliefs…

We are seeking any information that you or other individuals have which might contribute to the knowledge of traditional cultural activities that were, or are currently, conducted in the vicinity of the proposed project area. We are also asking for any information pertaining to traditional cultural activities or traditional rights which may be impacted by the construction of the proposed dairy improvements. The results of the cultural impact assessment are dependent on the response and contributions made by individuals, such as you.

Please contact me at the Scientific Consultant Services, Honolulu, office at (808) 597-1182 or via e-mail (cathy@scshawaii.com) with any information or recommendations concerning this Cultural Impact Assessment.

Sincerely yours,
Cc:

APPENDIX D: SIGNED INFORMATION RELEASE FORM

INFORMATION RELEASE FORM

I, the undersigned, personally participated in an interview with Cathleen Dagher from Scientific Consultant Services, Inc., on April 17, of the year 2015. The interview was conducted by telephone, by e-mail, or in person.

I understand that the information I have provided to Scientific Consultant Services, Inc., shall be submitted as part of a Cultural Impact Assessment report on the proposed dairy farm property located within Māhā'ulepū Valley, Māhā`ulepū Ahupua`a, Kōloa District, Island of Kaua`i. The property is owned by Mahaulepu Farms, LLC. [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. This information will be subject to publication which will be submitted to the public for general review.

I have read the summary of the interview and the information is true and accurate to the best of my knowledge. By signing this release form, I am providing my approval for the release of the information to Scientific Consultant Services, Inc., for the purpose outlined above (*i.e.*, making the contents of this interview available for publication to the general public).

Print Name: CATHERINE LO

Signature: Catherine Lo

Release Dated: August 11, 2015

INFORMATION RELEASE FORM

I, the undersigned, personally participated in an interview with, Cathleen Dagher from Scientific Consultant Services, Inc., on April 16, of the year 2015. The interview was conducted by telephone, by e-mail, or in person.

I understand that the information I have provided to Scientific Consultant Services, Inc., shall be submitted as part of a Cultural Impact Assessment report on the proposed dairy farm property located within Māhā'ulepū Valley, Māhā'ulepū Ahupua'a, Kōloa District, Island of Kaua'i. The property is owned by Mahaulepu Farms, LLC. [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. This information will be subject to publication which will be submitted to the public for general review.

I have read the summary of the interview and the information is true and accurate to the best of my knowledge. By signing this release form, I am providing my approval for the release of the information to Scientific Consultant Services, Inc., for the purpose outlined above (*i.e.*, making the contents of this interview available for publication to the general public).

Print Name: TERRIE L. HAYES

Signature: Terrie Hayes

Release Dated: SEPT. 5, 2015

INFORMATION RELEASE FORM

I, the undersigned, personally participated in an interview with, Cathleen Dagher from Scientific Consultant Services, Inc., on April 16, of the year 2015. The interview was conducted by telephone, by e-mail, or in person.

I understand that the information I have provided to Scientific Consultant Services, Inc., shall be submitted as part of a Cultural Impact Assessment report on the proposed dairy farm property located within Māhā'ulepū Valley, Māhā`ulepū Ahupua`a, Kōloa District, Island of Kaua`i. The property is owned by Mahaulepu Farms, LLC. [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. This information will be subject to publication which will be submitted to the public for general review.

I have read the summary of the interview and the information is true and accurate to the best of my knowledge. By signing this release form, I am providing my approval for the release of the information to Scientific Consultant Services, Inc., for the purpose outlined above (*i.e.*, making the contents of this interview available for publication to the general public).

Print Name: Bridget Hammerquist

Signature: Bridget Hammerquist

Release Dated: 9-6-2015

INFORMATION RELEASE FORM

I, the undersigned, personally participated in an interview with, Cathleen Dagher from Scientific Consultant Services, Inc., on April 16, of the year 2015. The interview was conducted by telephone, by e-mail, or in person.

I understand that the information I have provided to Scientific Consultant Services, Inc., shall be submitted as part of a Cultural Impact Assessment report on the proposed dairy farm property located within Māhā'ulepū Valley, Māhā'ulepū Ahupua'a, Kōloa District, Island of Kaua'i. The property is owned by Mahaulepu Farms, LLC. [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. This information will be subject to publication which will be submitted to the public for general review.

I have read the summary of the interview and the information is true and accurate to the best of my knowledge. By signing this release form, I am providing my approval for the release of the information to Scientific Consultant Services, Inc., for the purpose outlined above (*i.e.*, making the contents of this interview available for publication to the general public). AS corrected by me 8/17/15 K'O-

Print Name: Kalanikumai KaMakaʻiulīʻi ʻO Nā Aliʻi Hawaiʻi

Signature: [signature]

Release Dated: 8/19/2015

INFORMATION RELEASE FORM

I, the undersigned, personally participated in an interview with, Cathleen Dagher from Scientific Consultant Services, Inc., on April 16, of the year 2015. The interview was conducted by telephone, by e-mail, or in person.

I understand that the information I have provided to Scientific Consultant Services, Inc., shall be submitted as part of a Cultural Impact Assessment report on the proposed dairy farm property located within Māhā'ulepū Valley, Māhā'ulepū Ahupua'a, Kōloa District, Island of Kaua'i. The property is owned by Mahaulepu Farms, LLC. [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. This information will be subject to publication which will be submitted to the public for general review.

I have read the summary of the interview and the information is true and accurate to the best of my knowledge. By signing this release form, I am providing my approval for the release of the information to Scientific Consultant Services, Inc., for the purpose outlined above (*i.e.*, making the contents of this interview available for publication to the general public).

Print Name: RUPERT ROWE

Signature: Rupert Rowe

Release Dated: 12/1/15

INFORMATION RELEASE FORM

I, the undersigned, personally participated in an interview with, Cathleen Dagher from Scientific Consultant Services, Inc., on April 17, of the year 2015. The interview was conducted by telephone, by e-mail, or in person.

I understand that the information I have provided to Scientific Consultant Services, Inc., shall be submitted as part of a Cultural Impact Assessment report on the proposed dairy farm property located within Māhā`ulepū Valley, Māhā`ulepū Ahupua`a, Kōloa District, Island of Kaua`i. The property is owned by Mahaulepu Farms, LLC. [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. This information will be subject to publication which will be submitted to the public for general review.

I have read the summary of the interview and the information is true and accurate to the best of my knowledge. By signing this release form, I am providing my approval for the release of the information to Scientific Consultant Services, Inc., for the purpose outlined above (*i.e.*, making the contents of this interview available for publication to the general public).

Print Name: Ted Kauoakinehelelani Blake

Signature: [signature]

Release Dated: 9 September 2015

INFORMATION RELEASE FORM

I, the undersigned, personally participated in an interview with, Cathleen Dagher from Scientific Consultant Services, Inc., on April 16, of the year 2015. The interview was conducted by telephone, by e-mail, or in person.

I understand that the information I have provided to Scientific Consultant Services, Inc., shall be submitted as part of a Cultural Impact Assessment report on the proposed dairy farm property located within Māhā'ulepū Valley, Māhā`ulepū Ahupua`a, Kōloa District, Island of Kaua`i. The property is owned by Mahaulepu Farms, LLC. [TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.]. This information will be subject to publication which will be submitted to the public for general review.

I have read the summary of the interview and the information is true and accurate to the best of my knowledge. By signing this release form, I am providing my approval for the release of the information to Scientific Consultant Services, Inc., for the purpose outlined above (*i.e.*, making the contents of this interview available for publication to the general public).

Print Name: LLEWELYN H. KAOHELAULI'I

Signature: Llewelyn H. Kaohelauli'i

Release Dated: SEPT. 5, 2015

INFORMATION RELEASE FORM

I, the undersigned, personally participated in an interview with, Cathleen Dagher from Scientific Consultant Services, Inc., on November 5, of the year 2015. The interview was conducted by telephone, by e-mail, or in person.

I understand that the information I have provided to Scientific Consultant Services, Inc., shall be submitted as part of a Cultural Impact Assessment report on the proposed dairy farm property located within Maha'ulepu Valley, Maha'ulepu Ahupua'a, Koloa District, Island of Kaua'i. The property is owned by Mahaulepu Farms, LLC. and iscomprised of TMK: (4) 2-9-003-001 por. & 006 por. and (4) 2-9-001:001 por.This information will be subject to publication which will be submitted to the public for general review.

I have read the summary of the interview and the information is true and accurate to the best of my knowledge. By signing this release form, I am providing my approval for the release of the information to Scientific Consultant Services, Inc., for the purpose outlined above *(i.e.,* making the contents of this interview available for publication to the general public).

Print Name: James Hebard Case

Signature: __

Release Dated: March 31, 2016

APPENDIX E: CATHERINE AND KARL LO'S CONCERNS

Print | Close Window

Subject: April 17, 2015: CIA Interviews
From: Karl & Catherine Lo <cpl123@hawaiiantel.net>
Date: Fri, Apr 17, 2015 5:41 pm
To: Cathleen Dagher <cathy@scshawaii.com>
Cc: Beryl Blaich <blaich@aloha.net>, tony_napua <tony_napua@msn.com>, Ted Kawahinehelelani Blake <tkblake@mac.com>

Aloha, Cathy:

It was a pleasure meeting you today and listening to Teddy Blake and Napua Romo share their personal knowledge on Maha`ulepu.
We regret that David Chang is ill and couldn't be at the meeting.

We await to see your notes on today's sharing.

As to Hawai`i Dairy Farms at Maha`ulepu, here are our thoughts:

The dairy should be situated elsewhere away from homes, beaches and resorts.

Our concerns are based on experience, not fear. We remember Waimea Dairy, which in more recent years was owned by Meadow Gold Dairies. From the Westside, Meadow Gold moved to the North Shore and operated a dairy in Moloa`a until 2000. Unpleasant odors during visits to the Westside and North Shore always assaulted our olfactory organs as we approached and passed the dairies.

Remembrance of the dairies always bring back memories of noxious odors. Cow manure is cow manure! They all have very unpleasant, harmful and poisonous fumes that pollute the environment and the air we breathe and compromise human comfort and well-being. Also, cow manure is breeding ground of bacteria and viruses that can cause disease making public health a concern.

With the diary located so close to the ocean, it's hard to convince the community that dairy waste will not create in some way runoff that will pollute Kawailoa Bay. Also, swimming and picnicking at Kawailoa Beach, fishing at Black Mountain, walking along the shore and enjoying a leisurely day at Maha`ulepu may become the joys of yesteryears with the dairy taking over the valley.

Equally important to us as supporter of Malama Maha`ulepu is our concern that a dairy at this pristine valley will destroy the natural, cultural and historical heritage for which Maha`ulepu is appreciated and loved by residents and visitors alike.

Malama Maha`ulepu's mission is to take care of Maha`ulepu, educate the public about it and preserve it for future generations. The question is: Is Hawai`i Dairy Farms putting an end to this mission?

We hope that our paths will cross again. Until then ...

Mahalo nui loa,
K & C

Karl & Catherine Lo
P. O. Box 887
Koloa, HI 96756
(808) 742-7238
cpl123@hawaiiantel.net
Website:
http://www.htcelebration.org/poemswithoutborders

APPENDIX I

HAWAII DAIRY FARMS AIR EMISSIONS AND ODOR EVALUATION TECHNICAL REPORT

ARCADIS

ADDENDUM: HAWAII DAIRY FARMS REVISED ODOR EVALUATION TECHNICAL REPORT

ARCADIS

Hawaii Dairy Farms

Air Emissions and Odor Evaluation Technical Report

Group 70 International, Inc.

Kauai Dairy
Maha‘ulepu, Hawaii

May 4, 2016

Prepared for:
Group 70 International, Inc.

Prepared by:
Arcadis U.S., Inc.
1003 Bishop Street Suite 2000
Honolulu, Hawaii, 96813
Tel 808.522.0321
Fax 808.522.0366

Our Ref.: HI011182.0000

Table of Contents

Figures

1 Introduction

Hawai‘i Dairy Farms LLC (HDF) intends to develop a dairy with up to 2,000 cows in the Maha‘ulepu Valley on the island of Kaua‘i. The project will utilize a pastoral-based rotational grazing system. To demonstrate the sustainability of the dairy, HDF is committed to establishing a herd of 699 cows. HDF will contemplate the possibility of expanding the herd up to 2,000 cows. Both herd sizes are analyzed in this report. This air emissions and odor evaluation report presents the analysis used to determine the potential impacts of odors from both herd sizes and fugitive dust concentrations for the larger contemplated herd size of the proposed dairy facility at off-site receptors. In addition, to evaluate the potential impact of particulate matter (PM) and greenhouse gas (GHG) emissions, the report evaluates the annual emissions from the project for these constituents of concern.

2 Project Site

The project area has historically been used for sugar cane production as part of the Koloa Plantation until the late 1990s when the Koloa Mill closed. Since the mill closed, the project area and its surrounding has been leased to various tenants for ranching and diversified agricultural operations. A small plot of land in the lower center of the valley is currently used for taro lo‘i and will continue to be leased and farmed after the dairy and related pastures are in full operation. Recreational land use such as golf courses and hotels are located approximately 0.9 miles to the south and residential properties are located more than 1.5 miles to the southwest and west. Figure 1 presents a project location map showing the project site and surrounding land use.

The total dairy farm area inclusive of pasture and dairy facility, but excluding the existing taro farm, is 556.8 acres. For the purposes of this evaluation, the dairy project site was divided into two land use areas: Field 1, 547.1 acres of pasture; and Field 2, 9.7 acres containing the dairy facility. Field 1 is broken up into paddocks of approximately 4 to 5 acres in size.

3 Air Dispersion Modeling Methodology

3.1 Model Selection

Computer-based air dispersion models can be used to determine the concentration and frequency of odors and fugitive dust at specific locations around a source using local weather data. The AERMOD modeling system (AERMOD (version 15181) and its pre-processing programs, AERMAP and AERMET) were used for the analysis. AERMOD is a steady-state Gaussian plume model that requires four general types of input data: emission source information, receptor locations, meteorology, and model specific control options.

3.2 Receptors[1]

Fenceline (boundary) receptors and one Cartesian grid of receptors extending out to 4.5 km from the site were used for the modeling analysis. Fenceline receptor spacing was 25 meters while the Cartesian receptor grid spacing is 100 meters between receptors. All receptors were placed at ground level in the model based on standard modeling protocol.

3.3 Terrain

The project site is situated in the Maha‘ulepu Valley on the island of Kaua’i. The valley is on the leeward side of the Ha‘upu mountain ridge, which runs in the east-west direction, and the valley is also flanked by ridge lines on both sides. Mt. Ha‘upu is the highest point on the ridge line at the back of the valley with an elevation of 2,297 feet. From this point, the ground drops very quickly down to the bottom of the valley to about an elevation of 150 feet. The base of the valley itself is somewhat gradually sloped from an elevation of 150 feet to an elevation of 60 feet along Maha‘ulepu Road on the makai side of the project site near the taro farm.

Terrain elevations were obtained from National Elevation Dataset (NED) digitized terrain data from the United States Geological Survey (USGS), and processed using AERMAP.

3.4 Meteorological Data

One year (2014) of AERMET-ready meteorological data for the project site was obtained from Lakes Environmental. The meteorological data were derived from the NCAR MM5 (5th-generation Mesoscale Model) prognostic meteorological model. The data were used to develop the necessary surface and upper air files for the project's location and modeling domain. These files were used as inputs into the AERMET pre-processing software. The final AERMOD-ready meteorological data file was processed using estimated surface characteristics in the project vicinity with AERMET. The surface characteristics were estimated from available aerial photos for the project location. A wind rose plot of meteorological data is presented in Figure 2. This figure shows that the predominant wind direction is towards the southwest.

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[1] Receptors are defined as locations at which odor or particulate concentrations are estimated and do not necessarily denote where a person is located.

3.5 Model Control Options

The analysis included the use of selected model control options that allow the model to be made more site and project specific. These model options include land use classification, incorporation of building wake information, averaging time, and regulatory control options. The modeling used the AERMOD regulatory default option. This option includes elevated terrain algorithms, the effects of stack-tip downwash, missing data routines, and calm wind processing. In addition, rural boundary layer effects were incorporated into the model.

3.6 Emission Sources

3.6.1 Odors

Odor emissions are generated during incomplete anaerobic decomposition of organic matter in manure. Potential sources at the facility would include the effluent ponds, the irrigation system which utilizes effluent, manure from pasture fields, and the dairy buildings. These sources are described in detail in the sections below.

Odor refers to the combined effect of a mixture of gases on the sense of smell. For livestock sources, it may contain hundreds of trace compounds including ammonia (NH_3) and hydrogen sulfide (H_2S). Instead of measuring the individual components of an odor, as is done in standard air concentration modeling, odor concentration is reported in odor units per cubic meter (OU/m^3), and odor emissions are reported in units of OU/s (for point sources) and $OU/s/m^2$ (for area sources). An odor concentration of 1 OU/m^3 is defined as the threshold where the odor of a sample has a 50 percent probability of being perceived by a trained odor specialist.

3.6.1.1 Effluent Ponds

The effluent pond design includes two ponds: a settling pond and storage pond. The settling pond allows for the settlement and accumulation of solids with the overflow of liquid effluent entering the storage pond. The effluent ponds are open to the atmosphere. The top of the settling pond is 87 feet by 133 feet with a total depth of 17 feet with side slopes not steeper than 2 horizontal to 1 vertical. Effluent from the settling pond overflows through overflow pipes and into the storage pond. The top of the storage pond is 215 feet by 133 feet with a total depth of 17 feet. However, it is not likely the effluents would reach the top of the ponds as it is designed for a 25-year flood level. Based on a normal 30-day period of rain and effluent storage, the settling pond would be 12 feet deep and the storage pond would be 10.75 deep. The corresponding widths and lengths are 67 feet by 113 feet and 190 feet by 108 feet for the settling pond and storage pond, respectively. The effluent ponds were modeled at ground level.

Each pond was modeled in AERMOD as an area source with dimensions of the anticipated 30-day period of rain and effluent storage effluent surface. Odor emission rates were taken from Feitz 2002 (Dairy Australia, December 2008) which measured 30 ponds over 12 months in Australia. These results were selected over other data presented in Dairy Australia (2008) as it was measured using a wind tunnel apparatus as opposed to isolation flux hoods. According to Dairy Australia, most research shows that isolation flux hoods under-predict odor emissions relative to wind tunnels.

3.6.1.2 Irrigation

Odors from the irrigation process will be based on the odors volatilizing from effluent water mixed with irrigation water. This water will be applied through two center pivots and released approximately one meter from the ground surface. Irrigation droplets are typically large (200 µm or larger) in order to prevent droplets from evaporating before hitting the ground (Hardy et al., 2006). These larger sized aerosols also limit the physical dispersion of the water droplets used in the center pivot. Therefore, the evaluation of the irrigation droplets as particulates is not considered. Irrigation pivot #1 will be a full circle pivot and irrigation pivot #2 will be a ¾-circle pivot.[2] Before application, the effluent water will be diluted by a factor of 12. Only one pivot will be applying effluent at any given time. The pivots can complete a full rotation every 40 hours.

The odor emissions associated with the effluent ponds were reduced by a factor of 12 to account for dilution of the effluent for irrigation. The diluted effluent will be quickly absorbed into the ground and the odor will be short-lived. Therefore, the area covered in an hour (1/40 of a complete rotation) was modeled as an area emission source. As a worst case scenario, the section closest to the southern boundary was used in this evaluation.

3.6.1.3 Pasture

The cows will be maintained in six mobs of animals. At the committed herd size of 699 cows, mobs will contain up to 115 animals and for the contemplated herd size of up to 2,000 cows, mobs will contain up to 334 animals. The cows graze for one day per paddock and will produce the majority of the manure in that one paddock as they graze. Each mob will graze in a separate paddocks of 27 to 81 acres, and

[2] The ¼ circle not reached by irrigation pivot #2 will receive water through a hard-hose gun irrigation system.

adjacent to paddocks with other mobs. Paddock blocks that would be occupied on a given day were selected based on a typical scenario and were modeled as an area source.

Odor emission rates were based on a study by Topper et al. (2008) which evaluated odors from manure of dairy heifers. Various diets were evaluated in the Topper et al. (2008) study. The odor emissions used for this odor evaluation was for high concentrate (HC) and 20% corn silage. Although this diet does not necessarily coincide with the project (pasture fed cows were not evaluated in Topper et al., 2008), the HC; 20% silage resulted in the highest percentage of urine in the manure which is consistent with the anticipated manure. The samples used in the Topper et al study were 200 grams in weight placed in a 3.8-liter glass jar. The odor emission rate used in this report was adjusted from the sample size used in Topper et al. (2008) (Appendix A).

3.6.1.4 Slurry

Solids collected from the settling pond will be applied on designated areas through a “gun type” application system to areas outside the liquid effluent application. The slurry consists of three components; 1) liquid effluent, 2) settled solids from the liquid effluent, and 3) irrigation/collected rain water. The settled solids will be mixed with liquid (effluent or irrigation and/or collected rain water) to create a solids suspension slurry, which can then be pumped to the hydrants. The ratio of liquid to solids will be 20:1 (mixing volume to solids volume). Since the liquid will consist of either effluent or irrigation/collected rain water, it is conservatively assumed that all the liquid will be effluent. The slurry will be pumped through underground pipes to hydrants which have a “gun sprinkler” with a 65 foot radius. The planned location of the application (the “sludge delivery area”) is anticipated to be on the east portion of the site between the area that is covered by the irrigation two center pivots for the committed herd size of 699 cows and anywhere within the site. As a worst case scenario for the contemplated herd size of up to 2,000 cows, the section closest to the southern boundary not occupied by cows (since sludge is not applied to occupied areas) was used in this evaluation.

The odor emissions associated with the slurry were based on undiluted effluent and pasture manure, described in Sections 3.6.1.2 and 3.6.1.3 in a ratio of 20:1 effluent to manure. An area covering a circle with a 65-foot radius, consistent with the gun sprinkler reach was modeled with a ground level release height.

3.6.1.5 Dairy Facility

The dairy facility is contained within an approximately 10-acre area in Field 2. The corresponding building areas are under 0.1% of the total farm area. The dairy buildings include the milking parlor, an implement shed, and calf sheds. The milking parlor contains an automated 60-stall rotary which is approximately 256 feet by 88.5 feet by 33 feet tall. Two open bay calf sheds will be constructed to provide safe housing to newly born calves. Each shed will be approximately 81 feet by 26 feet by 15 feet tall. The feeding area will be washed daily and the wastewater transferred to the effluent ponds.

Dairy facility odor emissions were modeled as area sources with dimensions of the building footprint. Emission rates consistent with free stall dairy buildings from Jacobson et al. (2001) were used.

Table 1 summarizes the emission fluxes used in the evaluation and the area of the emission source. The emission flux estimates are detailed in Appendix A.

Table 1. Hawaii Dairy Farms Odor Modeling Parameters

Location	Source	Emission Flux(OU / s / m^2)	Area (ft^2)
Effluent Ponds	Settling Pond	8.1	7,571
	Storage Pond	8.1	20,520
Irrigation	Effluent	0.675	222,828
Pasture	699 Herd	0.13	1,217,078
	2,000 Herd	0.37	1,217,078
Nutrient Application	Slurry	8.0	13,273
Dairy Facility	Bay Calf Shed #1	1.84	2,106
	Bay Calf Shed #2	1.84	2,106
	Milking Parlor	1.84	22,656

Notes:
All sources were modeled as area sources with a ground level release (i.e., release height = 0) with the exception of irrigation which was modeled with a release height of 1 meter (the height of the effluent water from the center pivots).

3.6.2 Fugitive Dust

Fugitive dust emissions, measured as particulate matter (PM), are generated from the movement of cows along the walkways and races that connect the paddocks together and provide access to and from the dairy facility.[3] The cow races allow twice daily movement of the cows from the paddocks to the Milking Parlor and are not irrigated. Figure 4 shows the cow walkways and races. Emission rates, in mass of PM per time, were estimated using USEPA AP-42 emission factors. These emission factors were developed from literature sources from a number of dairy farm sources including scrape freestall barns, drylots, liquid manure land application activities, and solids storage. The only source with measureable PM emissions was from drylots. Drylots are confined areas where animals are walking over dirt and dried manure throughout the day. In the project scenario, cow movement along the walkways and races would occur for brief periods of time during the day. Therefore, use of the PM emission factor from AP-42 will overestimate PM emissions associated with cow movement along the cow walkways and races. Calculated emission rates were then used in the AERMOD model to estimate downwind concentrations in micrograms per cubic meter (µg/m^3). Emissions were evenly distributed throughout the cow walkways and races and assumed to occur between the hours of 6 am and 9 pm. Figures 3 and 4 shows the locations of the modeled odor emission sources and particulate matter sources, respectively.

3.7 Thresholds

3.7.1 Odor

The development of a target odor criteria is complicated by the difficulties in odor sampling and measurement combined with a lack of suitable data on odor levels associated with annoyance and complaint. Mahin (2003) presented regulatory off-site limits based on levels predicted by dispersion modeling in the U.S. range from 1 OU/m^3 to 50 OU/m^3 for a variety of averaging times.

Table 2. Regulatory Odor Thresholds

Location	Off-site standard or guideline	Averaging times
Allegheny County Wastewater Treatment Plant (WWTP)	4 OU/m^3 (design goal)	2-minute
San Francisco Bay Area Air Quality District	5 OU/m^3	Applied after at least 10 complaints within 90-days

[3] As discussed in Section 3.6.1.2, irrigation droplets are typically large (200 µm or larger) and are therefore not included in PM_{10} (particulate matter 10 µm or less) and $PM_{2.5}$ (particulate matter 2.5 µm or less) analyses.

State of Colorado	7 OU/m^3 (Scentometer)	
State of Connecticut	7 OU/m^3	
State of Massachusetts	5 OU/m^3*	
State of New Jersey	5 OU/m^3 **	5-minutes or less
State of North Dakota	2 OU/m^3 (Scentometer)	
State of Oregon	1 to 2 OU/m^3	15-minute
City of Oakland, CA	50 OU/m^3	3-minute
City of San Diego WWTP	5 OU/m^3	5-minute
City of Seattle WWTP	5 OU/m^3	5-minute

* draft policy and guidance for composting facilities

** for biosolids/sludge handling and treatment facilities

Many of these values are for wastewater treatment plant or composting facilities, but none of the regulatory standards are specific to dairy farms. However, an Australian study by Wang and Feitz (2004) suggested 6.5 OU/m^3, 1-hour averaging and 99.5th percentile at receptor as appropriate criteria for the assessment of dairy farm odors. Based on the source of the odor, this odor threshold was selected for this analysis. These criteria represent the extent of the 6.5 OU/m^3 level that could be expected to be reached only 0.5% of the time (1 – 99.5%), or once per 200 hours, or 44 hours per year. In other words, 99.5% of the time the odor threshold of 6.5 OU/m^3 is less than the extent shown, and only 0.5% of the time is it at or beyond the extent shown.

3.7.2 Fugitive Dust

Fugitive dust was modeled as PM_{10} (respirable dust particles of less than 10 microns) and $PM_{2.5}$ (fine dust particles less than 2.5 microns). Modeled PM_{10} and $PM_{2.5}$ concentrations were added to background concentrations and compared to State and Federal ambient air concentration standards. The standards are presented in Table 3.

Table 3. Air Quality Standards Attainment Status for Hawaii

Parameter		State Standard	Federal Standard
Particulate Matter (PM_{10})	24-Hour	150 µg/m^3	150 µg/m^3
	Annual Arithmetic Mean	50 µg/m^3	--
Particulate Matter – Fine ($PM_{2.5}$)	24-Hour	--	35 µg/m^3
	Annual Arithmetic Mean	--	12 µg/m^3

3.8 Results

3.8.1 Odor

Odor isopleths were created using the results of AERMOD modeling. The odor modeling analysis and isopleths indicate that the 99.5th percentile of 6.5 OU/m^3 odor threshold extend beyond the dairy farm boundary, however it does not reach recreational nor residential areas. Figures 5 and 7 illustrate the extent of the odors for both herd sizes, respectively. Figures 6 and 8 show close-up views of the same odor extents. It should be noted that the parameters used in this analysis were intentionally very conservative and the impacts shown depend on an unlikely confluence of worst-case meteorological data, irrigation location, and grazing location; thus, actual offsite odor impacts are likely to be much lower and/or less frequent than shown.

3.8.2 Fugitive Dust

Fugitive dust concentrations from the contemplated herd size were estimated using the results of AERMOD modeling. The fugitive dust concentration from the dairy farm was added to the background concentration and compared to the state ambient air quality standards. All of these concentrations were less than the applicable state and federal standards. Because of the relatively low impact even at the contemplated herd size, fugitive dust modeling was not conducted for the committed herd size.

Table 4. Fugitive Dust Analysis – Contemplated Herd Size

Pollutant	Average Time	Concentration (μg/m^3)	Background	Total Impact	Standards
PM_{10}	24 hr	2.01	39 μg/m^3	41.01 μg/m^3	150 μg/m^3
PM_{10}	annual	0.33	15 μg/m^3	14.83 μg/m^3	50 μg/m^3
$PM_{2.5}$	24 hr	0.23	12 μg/m^3	12.23 μg/m^3	35 μg/m^3
$PM_{2.5}$	annual	0.04	3.9 μg/m^3	3.94 μg/m^3	15 μg/m^3

3.8.3 Overall

Based on the air dispersion modeling conducted for both committed and contemplated herd sizes development, neither the odor nor fugitive dust emissions from the dairy farm would exceed applicable thresholds. In addition, aerosols from irrigation water would not extend across the facility boundary.

4 Annual Emissions from Potential Constituents of Concern

In addition to modeling concentrations of odors and particulate matter (PM), total annual emissions (in tons per year) were estimated for PM and greenhouse gases (GHGs). Total annual emissions are typically estimated for potential Hawaii Department of Health (DOH) Clean Air Branch (CAB) permitting applicability. The minimum annual emission threshold for regulated pollutants emitted from regulated sources are given in Hawaii Administrative Rules (HAR) Chapter 11-60.1. For GHGs, the threshold is 3,500 tons per year, and for PM is 2 tons per year. However, for the dairy project, the sources of GHGs and PM (enteric fermentation by cattle, manure application, and fugitive dust from cattle raceways) are not considered regulated sources by CAB standards. Therefore, total annual emissions are estimated only for comparison purposes.

4.1 Emission Sources

4.1.1 Particulate Matter

Fugitive dust emissions, measured as PM, are generated from the movement of cows along the walkways and races that connect the paddocks together and provide access to and from the dairy facility.

4.1.2 Greenhouse Gases

Dairy cows can result in methane (CH_4) emissions from enteric fermentation and both CH_4 and nitrous oxide (N_2O) emissions from manure application. Manure application includes direct deposition from cows and application of slurry and irrigation water containing manure.

4.2 Emission Factors

4.2.1 Particulate Matter

Emission rates, in mass of PM per time, were estimated using USEPA AP-42 emission factors from the Emissions from Animal Feeding Operations Report. A PM emission rate of 2.3 pounds per year per “animal unit” (where 1 cow equals 0.7 animal units [AU]), was obtained for dairy cattle from drylots. Specific parameters are presented in the attached Table A-3.

4.2.2 Greenhouse Gases

GHG emission rates were calculated using IPCC’s Guidelines for National Greenhouse Gas Inventories (IPCC 2006). Specific parameters were selected for Oceanic dairy cattle in warm climates to most accurately represent conditions at the Hawaii Dairy Farms. CH_4 and N_2O emissions were converted to carbon dioxide equivalents (CO_2e) using the IPCC's AR4 global warming potential (GWP) that relates the GHG to CO_2. Specific parameters are presented in the attached Tables A-4 to A5.

4.3 Results

For the committed and contemplated herd sizes, GHG emissions were estimated to be 2,693 and 7,705 CO_2e metric tons per year, respectively. The total annual PM for the committed and contemplated herd sizes is 0.6 and 3.3 tons per year. Detailed calculations are provided in Appendix A.

5 References

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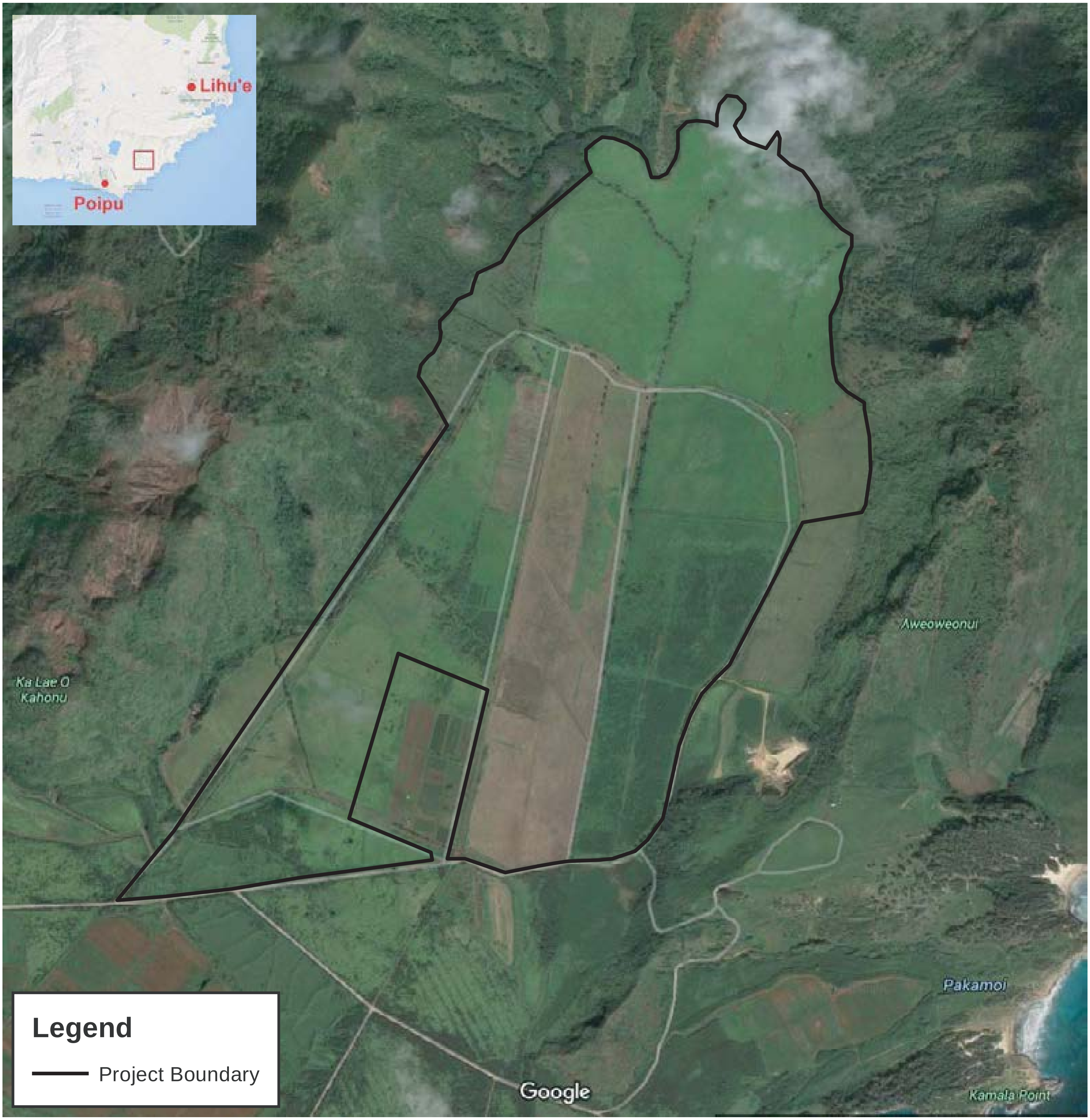
Figures



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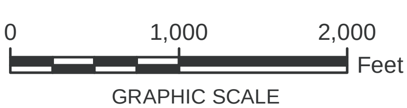

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Project Location Map

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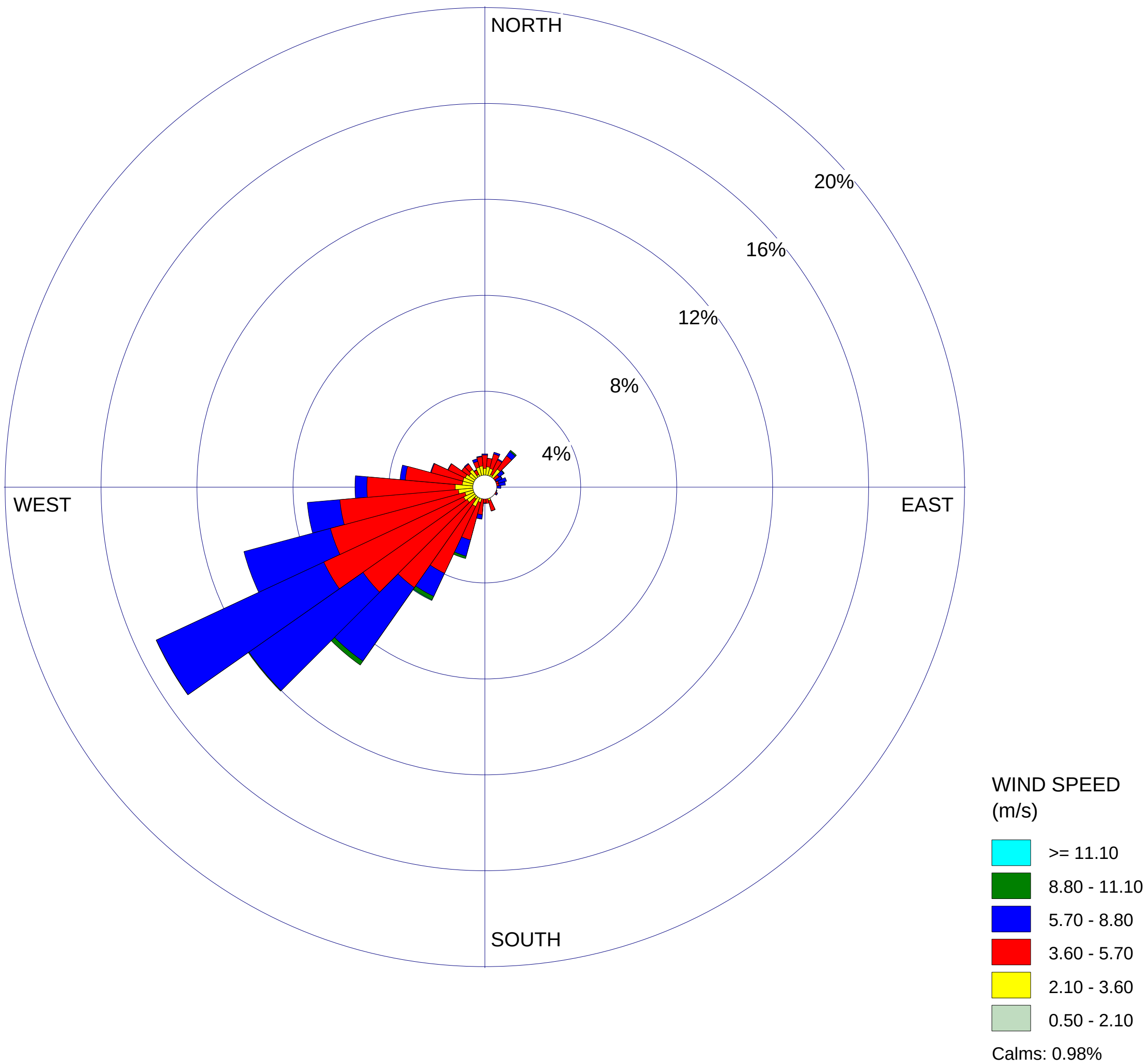
FIGURE 1

WIND ROSE PLOT:

MM5 2014 Met data

DISPLAY:

Wind Speed
Flow Vector (blowing to)



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
	Start Date: 1/1/2014 - 00:00 **End Date: 12/31/2014 - 23:00**	MODELER:	
	CALM WINDS: **0.98%**	TOTAL COUNT: **8760 hrs.**	
	AVG. WIND SPEED: **4.64 m/s**	DATE: **5/23/2015**	PROJECT NO.:

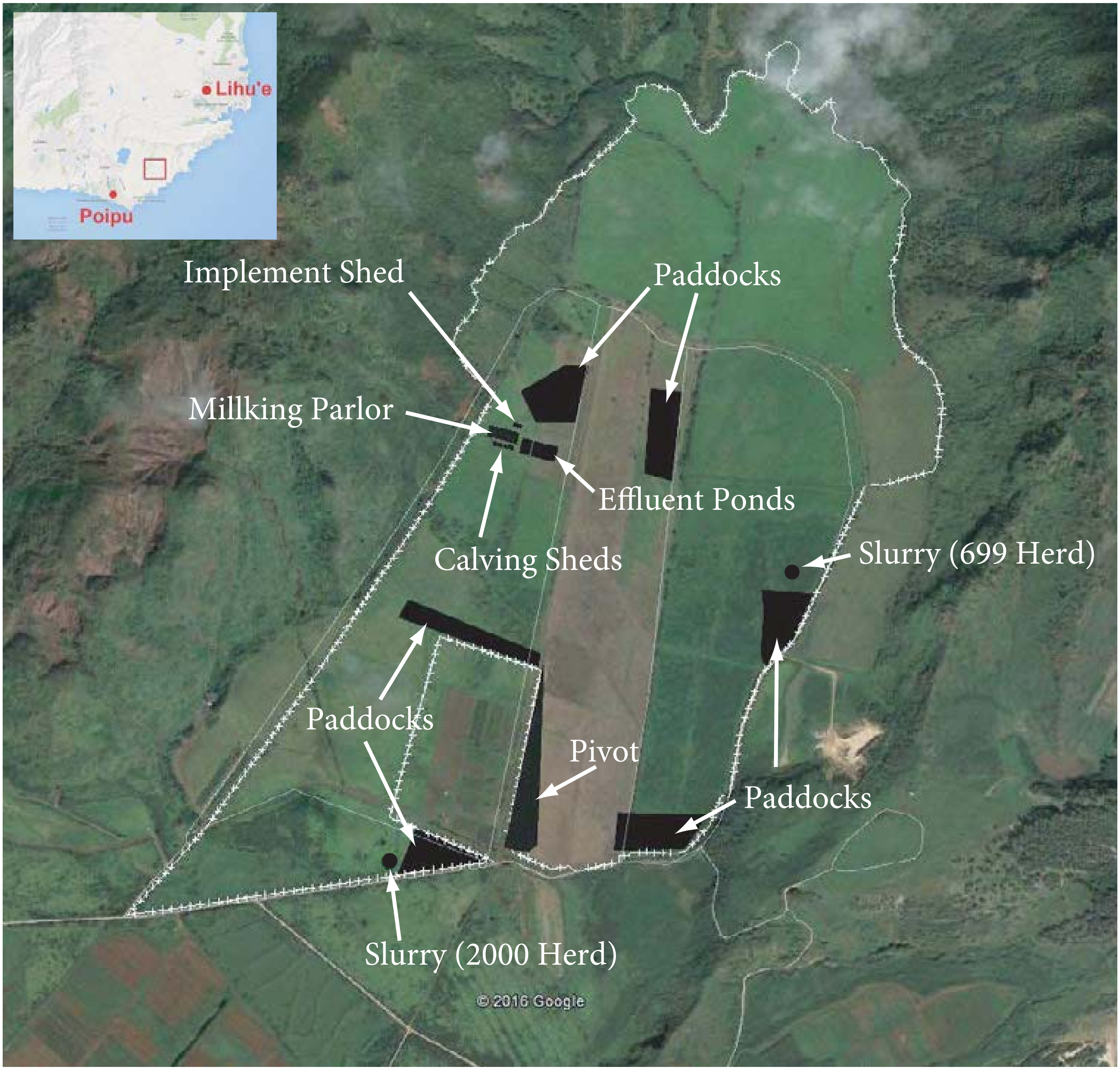
WRPLOT View - Lakes Environmental Software

Group 70 International, Inc.

AERMOD Wind Input

ARCADIS Design & Consultancy for natural and built assets

FIGURE
2



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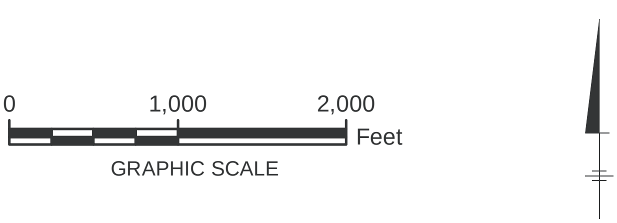

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Modeled Odor Sources

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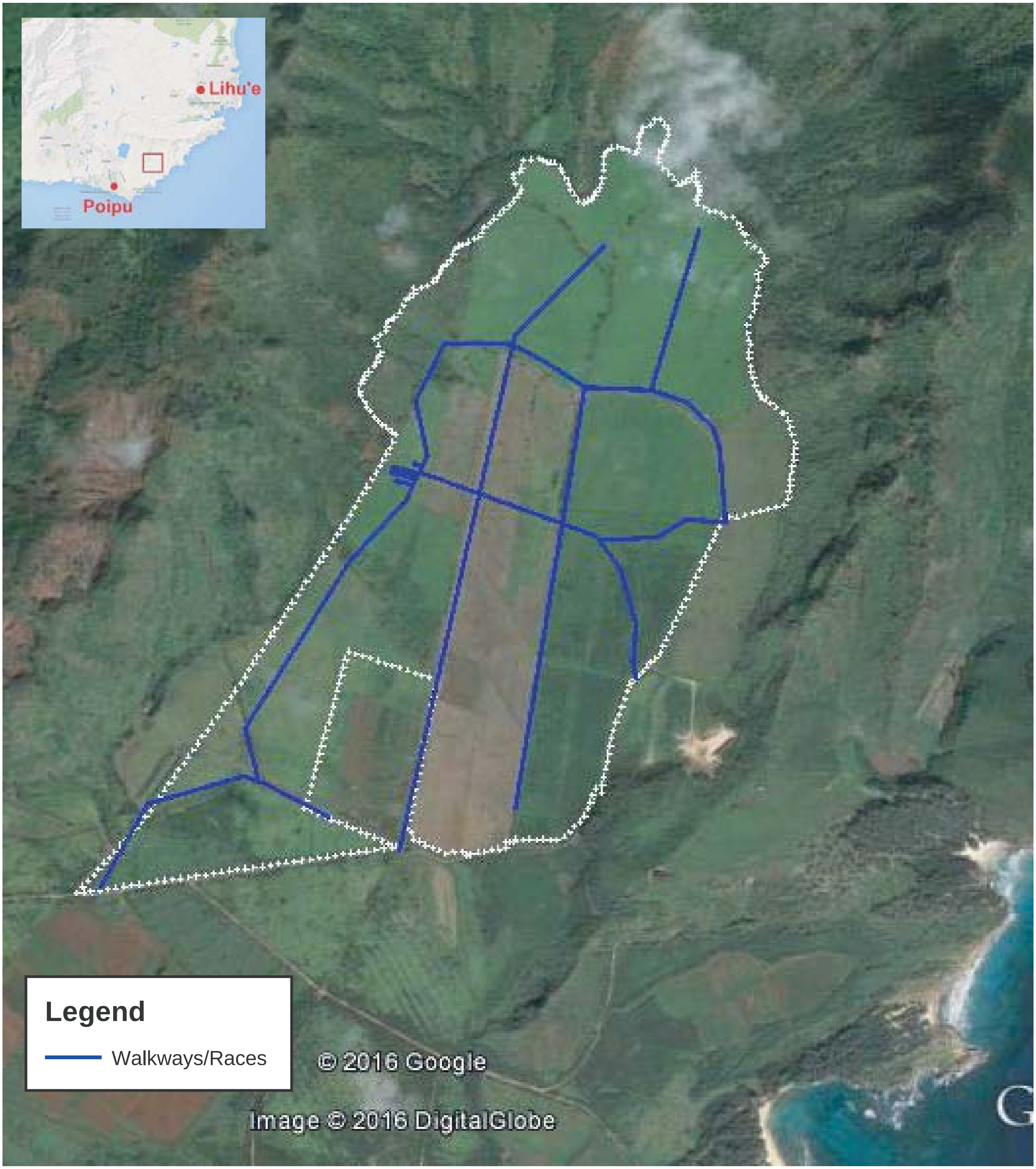
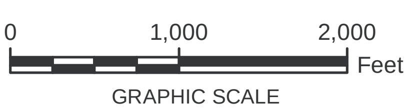
FIGURE 3





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Modeled Particulate Matter Sources

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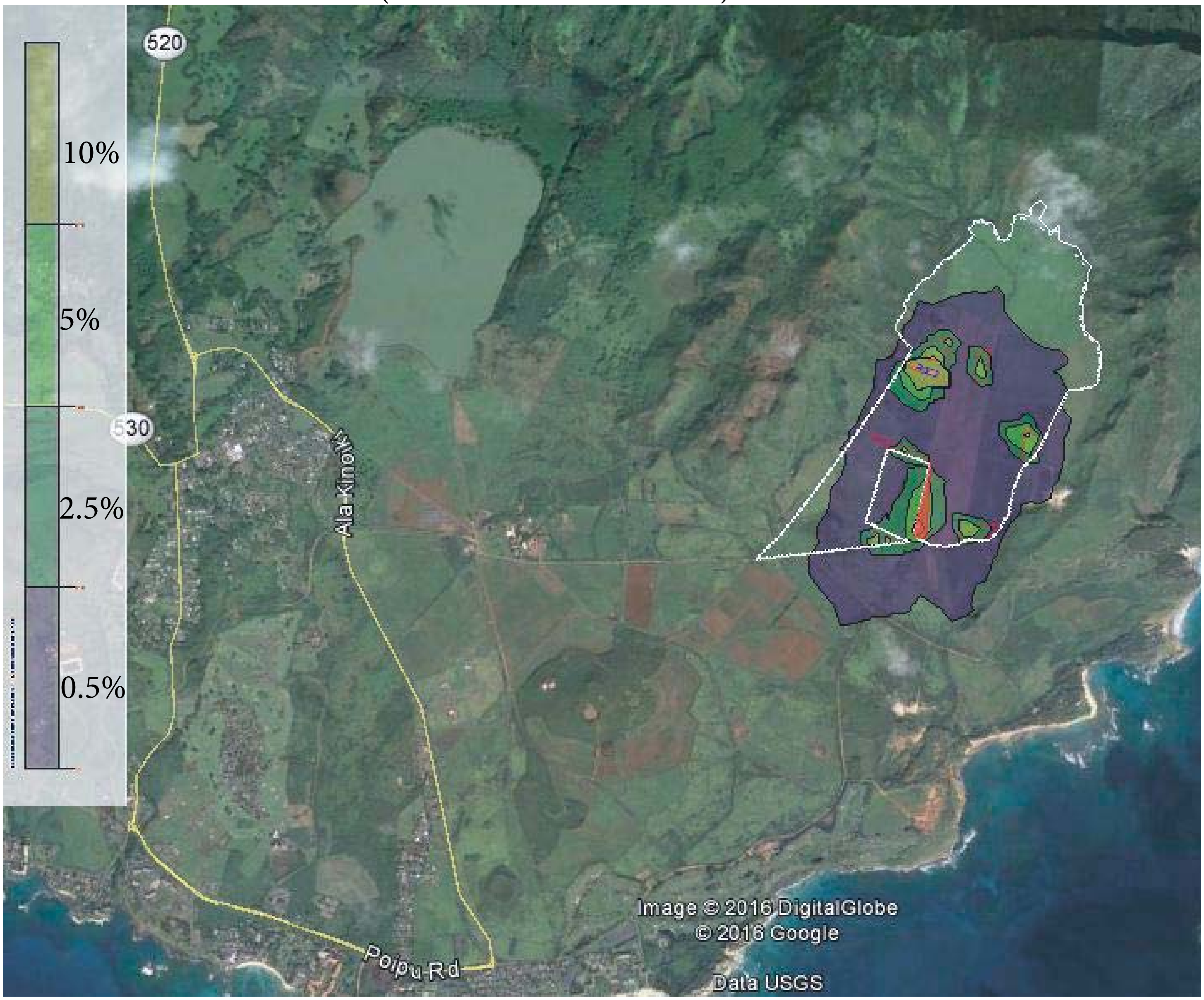
FIGURE 4

Exceedances of 6.5 OU/m3 (0.5% = 99.5th Percentile)



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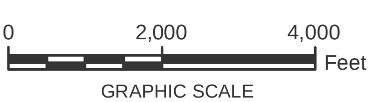

Group 70 International, Inc.	
Extent of 6.5 OU/m3 at 99.5th Percentile - Committed Herd Size (699 Cows)	
ARCADIS Design & Consultancy for natural and built assets	FIGURE 5

Exceedances of 6.5 OU/m3 (0.5% = 99.5th Percentile)

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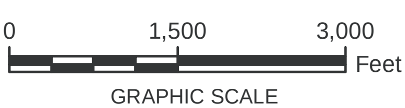

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Extent of 6.5 OU/m3 at 99.5th Percentile - Committed Herd Size (699 cows) - Close Up

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FIGURE 6

Exceedances of 6.5 OU/m3 (0.5% = 99.5th Percentile)

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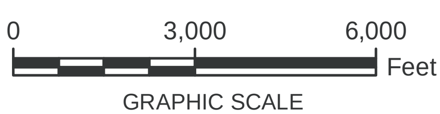
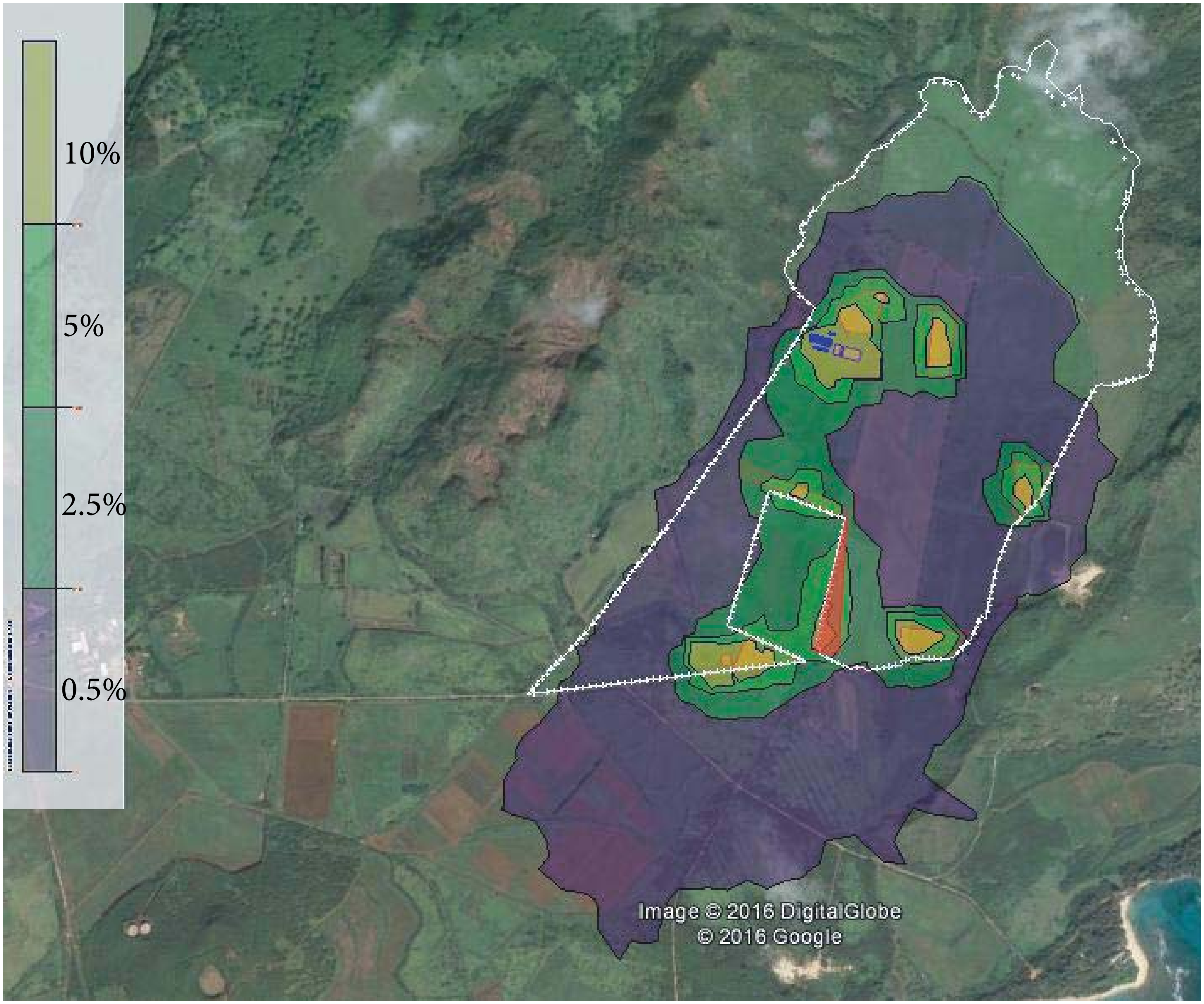


Group 70 International, Inc.	
Extent of 6.5 OU/m3 at 99.5th Percentile - Contemplated Herd Size (2,000 cows)	
ARCADIS Design & Consultancy for natural and built assets	FIGURE 7

Exceedances of 6.5 OU/m3 (0.5% = 99.5th Percentile)



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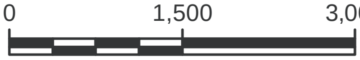

Group 70 International, Inc.
Extent of 6.5 OU/m3 at 99.5th Percentile - Contemplated Herd Size (2,000 cows) - Close Up
ARCADIS Design & Consultancy for natural and built assets — FIGURE **8**

Appendix A

TABLE A-1
Emission Fluxes Used in Odor Evaluation
Hawaii Dairy Farms

Source	**Odor Emission Flux ($OU/m^2/s$)**	**Source**
Settling Pond	8.1	Feitz 2002
Storage Pond	8.1	Feitz 2002
Pivot irrigation	0.675	Storage pond effluent diluted by a factor of 12
Drip irrigation	0	Subsurface unlikely to result in significant odors
Pasture - Phase 1	0.13	Derived from Topper et al (see Table 2)
Pasture - Phase 2	0.37	Derived from Topper et al (see Table 2)
Slurry	8.0	1:20 ratio of solids (manure) to effluent (storage pond)
Bay Calf Sheds	1.84	Jacobson *et al* 2001
Milking Parlor	1.84	Jacobson *et al* 2001

TABLE A-2
Pasture Manure Emission Flux Estimates
Hawaii Dairy Farms

Parameters	**Phase 1**	**Phase 2**	**Topper Study**
# Cows	699	2000	
Daily rate (lbs/day)	143	143	
Weight (lbs)	8.8	8.8	0.44
Mass (g)	3,995	3,995	200
Volume (gal)	1.05	1.05	0.05
Volume (m^3)	0.004	0.004	0.0002
Area of Emission (m^2)[1]	2,257	6,458	0.01
Field area (m^2)	113,073	113,073	
Odor ($OU/m^2/s$)[2]			6.55
Adjusted Odor	**0.13**	**0.37**	

Notes:
[1] Assumes manure in the Topper *et al* 2008 study has a 2 cm height.
[2] From Topper *et al* 2008 for a heifer fed a high concentrate diet and 20% silage.

TABLE A-3
Annual PM Emissions
Hawaii Dairy Farms

Parameters	699 Cow Herd	2,000 Cow Herd	Unit
Emission Factor	2.3		lb/yr/AU
Dairy Cattle AU	0.7		
# Cattle	699	2000	
PM Emissions	1,125	6,571	lb/yr
	0.6	3.3	tons/yr

Notes:
Emission factor and animal unit (AU) from USEPA AP-42.
AU = Animal unit

Table A-4
Phase 1 GHG Emissions
Hawaii Dairy Farms

GHG	Annual Emissions		CO_2 equivalent Emissions	
	kg/yr	MT/yr	GWP	CO_2e MT/yr
Methane (CH_4)	84579	85	25	2114
Nitrous oxide (N_2O)	1940	2	298	578
TOTAL				2693

Notes
GWP from IPCC 2007 AR4

Facility Information	
550	kg/ cattle
699	Cattle

Value	Unit	Parameter	Source	Table	Table Name
90	kg CH4/head/yr	Oceania, Dairy Cattle	IPCC 2006	Table 10.11	Tier 1 Enteric Fermentation Emisison Factors for Cattle
31	kg CH4/head/yr	Oceania, Dairy Cattle, Warm Climate	IPCC 2006	Table 10.14	Manure Management Methane Emission Factors by Temperature for Cattle, Swine, and Buffalo
0.44	kg N/1000kg/day	Oceania, Dairy Cattle	IPCC 2006	Table 10.19	Default values for nitrogen excretion rate
0.02	kg N2O-N/kg N	Cattle	IPCC 2006	Table 11.1	Defaut Emisison factors to Estimate Direct N2O from Managed Soils

	Emission Factor	Number of Dairy Cattle	Emissions
Emission Source	kg CH_4/head/yr		Gg CH_4/yr
Enteric Fermentation	90	699	0.06291
Manure Management	31	699	0.021669

84579 kg CH_4/yr

EQUATION 10.19

ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY

$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right)$$

Where:

Emissions = methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of head of livestock species / category T in the country

T = species/category of livestock

EQUATION 10.22

CH_4 EMISSIONS FROM MANURE MANAGEMENT

$$CH_{4Manure} = \sum_{(T)} \frac{\left(EF_{(T)} \bullet N_{(T)}\right)}{10^6}$$

Where:

$CH_{4Manure}$ = CH_4 emissions from manure management, for a defined population, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of head of livestock species/category T in the country

T = species/category of livestock

Variable	Description	Value	Unit
NT	Number of Dairy Cattle	699	
Nrate	N excretion per cattle	0.44	kg N/1000kg/day
TAM		550	
NexT	N excretion per cattle	88.33	
MS	Fraction excreted in pasture	1	
FPRP	Manure deposited	61742.7	kg N/yr
EF3PRP	Emission Factor	0.02	kg N2O-N / (kg N)
N2O-NPRP	N2O-N emissions	1234.85	kg N2O-N / (kg N input)
	Annual Emissions	1940.48	kg N2O/yr

EQUATION 11.1

DIRECT N_2O EMISSIONS FROM MANAGED SOILS (TIER 1)

$$N_2O_{Direct}\text{–}N = N_2O\text{–}N_{N\,inputs} + N_2O\text{–}N_{OS} + N_2O\text{–}N_{PRP}$$

Where:

$$N_2O\text{–}N_{N\,inputs} = \left[\begin{matrix}\left[(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \bullet EF_1\right] + \\ \left[(F_{SN} + F_{ON} + F_{CR} + F_{SOM})_{FR} \bullet EF_{1FR}\right]\end{matrix}\right]$$

$$N_2O\text{–}N_{OS} = \left[\begin{matrix}(F_{OS,CG,Temp} \bullet EF_{2CG,Temp}) + (F_{OS,CG,Trop} \bullet EF_{2CG,Trop}) + \\ (F_{OS,F,Temp,NR} \bullet EF_{2F,Temp,NR}) + (F_{OS,F,Temp,NP} \bullet EF_{2F,Temp,NP}) + \\ (F_{OS,F,Trop} \bullet EF_{2F,Trop})\end{matrix}\right]$$

$$N_2O\text{–}N_{PRP} = \left[(F_{PRP,CPP} \bullet EF_{3PRP,CPP}) + (F_{PRP,SO} \bullet EF_{3PRP,SO})\right]$$

Where:

N_2O_{Direct}–N = annual direct N_2O–N emissions produced from managed soils, kg N_2O–N yr^{-1}

N_2O–$N_{N\,inputs}$ = annual direct N_2O–N emissions from N inputs to managed soils, kg N_2O–N yr^{-1}

N_2O–N_{OS} = annual direct N_2O–N emissions from managed organic soils, kg N_2O–N yr^{-1}

N_2O–N_{PRP} = annual direct N_2O–N emissions from urine and dung inputs to grazed soils, kg N_2O–N yr^{-1}

F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}

F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (Note: If including sewage sludge, cross-check with Waste Sector to ensure there is no double counting of N_2O emissions from the N in sewage sludge), kg N yr^{-1}

F_{CR} = annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N yr^{-1}

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr^{-1}

F_{OS} = annual area of managed/drained organic soils, ha (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

F_{PRP}= annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1} (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

EF_1 = emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)$^{-1}$(Table 11.1)

EF_{1FR} is the emission factor for N_2O emissions from N inputs to flooded rice, kg N_2O–N (kg N input)$^{-1}$ (Table 11.1) [5]

EF_2 = emission factor for N_2O emissions from drained/managed organic soils, kg N_2O–N ha^{-1} yr^{-1}; (Table 11.1) (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

EF_{3PRP} = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O–N (kg N input)$^{-1}$; (Table 11.1) (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

EQUATION 11.5
N IN URINE AND DUNG DEPOSITED BY GRAZING ANIMALS ON PASTURE, RANGE AND PADDOCK (TIER 1)

$$F_{PRP} = \sum_{T} \left[\left(N_{(T)} \bullet Nex_{(T)} \right) \bullet MS_{(T,PRP)} \right]$$

Where:

F_{PRP} = annual amount of urine and dung N deposited on pasture, range, paddock and by grazing animals, kg N yr^{-1}

$N_{(T)}$ = number of head of livestock species/category T in the country (see Chapter 10, Section 10.2)

$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N $animal^{-1}$ yr^{-1} (see Chapter 10, Section 10.5)

$MS_{(T,PRP)}$ = fraction of total annual N excretion for each livestock species/category T that is deposited on pasture, range and paddock[12] (see Chapter 10, Section 10.5)

EQUATION 10.30
ANNUAL N EXCRETION RATES

$$Nex_{(T)} = N_{rate(T)} \bullet \frac{TAM}{1000} \bullet 365$$

Where:

$Nex_{(T)}$ = annual N excretion for livestock category T, kg N $animal^{-1}$ yr^{-1}

$N_{rate(T)}$ = default N excretion rate, kg N $(1000 \text{ kg animal mass})^{-1}$ day^{-1} (see Table 10.19)

$TAM_{(T)}$ = typical animal mass for livestock category T, kg $animal^{-1}$

$$N_2O = N_2O\text{–}N \bullet 44/28$$

Table A-5
Phase 2 GHG Emissions
Hawaii Dairy Farms

GHG	Annual Emissions		CO_2 equivalent Emissions	
	kg/yr	MT/yr	GWP	CO_2e MT/yr
Methane (CH_4)	242000	242	25	6050
Nitrous oxide (N_2O)	5552	6	298	1655
TOTAL				7705

Notes
GWP from IPCC 2007 AR4

Facility Information	
550	kg/ cattle
2000	Cattle

Value	Unit	Parameter	Source	Table	Table Name
90	kg CH4/head/yr	Oceania, Dairy Cattle	IPCC 2006	Table 10.11	Tier 1 Enteric Fermentation Emisison Factors for Cattle
31	kg CH4/head/yr	Oceania, Dairy Cattle, Warm Climate	IPCC 2006	Table 10.14	Manure Management Methane Emission Factors by Temperature for Cattle, Swine, and Buffalo
0.44	kg N/1000kg/day	Oceania, Dairy Cattle	IPCC 2006	Table 10.19	Default values for nitrogen excretion rate
0.02	kg N2O-N/kg N	Cattle	IPCC 2006	Table 11.1	Defaut Emisison factors to Estimate Direct N2O from Managed Soils

	Emission Factor	Number of Dairy Cattle	Emissions
Emission Source	kg CH_4/head/yr		Gg CH_4/yr
Enteric Fermentation	90	2000	0.18
Manure Management	31	2000	0.062

242000 kg CH_4/yr

EQUATION 10.19
ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY

$$Emissions = EF_{(T)} \bullet \left(\frac{N_{(T)}}{10^6} \right)$$

Where:

Emissions = methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of head of livestock species / category T in the country

T = species/category of livestock

EQUATION 10.22
CH_4 EMISSIONS FROM MANURE MANAGEMENT

$$CH_{4_{Manure}} = \sum_{(T)} \frac{\left(EF_{(T)} \bullet N_{(T)}\right)}{10^6}$$

Where:

$CH_{4Manure}$ = CH_4 emissions from manure management, for a defined population, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ = the number of head of livestock species/category *T* in the country

T = species/category of livestock

Variable	Description	Value	Unit
NT	Number of Dairy Cattle	2000	
Nrate	N excretion per cattle	0.44	kg N/1000kg/day
TAM		550	
NexT	N excretion per cattle	88.33	
MS	Fraction excreted in pasture	1	
FPRP	Manure deposited	176660	kg N/yr
EF3PRP	Emission Factor	0.02	kg N_2O-N / (kg N)
N_2O-NPRP	N_2O-N emissions	3533.2	kg N_2O-N / (kg N input)
	Annual Emissions	5552.17	kg N_2O/yr

EQUATION 11.1
DIRECT N_2O EMISSIONS FROM MANAGED SOILS (TIER 1)

$$N_2O_{Direct}\text{–}N = N_2O\text{–}N_{N\,inputs} + N_2O\text{–}N_{OS} + N_2O\text{–}N_{PRP}$$

Where:

$$N_2O\text{–}N_{N\,inputs} = \left[\begin{array}{l}\left[\left(F_{SN} + F_{ON} + F_{CR} + F_{SOM}\right) \bullet EF_1\right] + \\ \left[\left(F_{SN} + F_{ON} + F_{CR} + F_{SOM}\right)_{FR} \bullet EF_{1FR}\right]\end{array}\right]$$

$$N_2O\text{–}N_{OS} = \left[\begin{array}{l}\left(F_{OS,CG,Temp} \bullet EF_{2CG,Temp}\right) + \left(F_{OS,CG,Trop} \bullet EF_{2CG,Trop}\right) + \\ \left(F_{OS,F,Temp,NR} \bullet EF_{2F,Temp,NR}\right) + \left(F_{OS,F,Temp,NP} \bullet EF_{2F,Temp,NP}\right) + \\ \left(F_{OS,F,Trop} \bullet EF_{2F,Trop}\right)\end{array}\right]$$

$$N_2O\text{–}N_{PRP} = \left[\left(F_{PRP,CPP} \bullet EF_{3PRP,CPP}\right) + \left(F_{PRP,SO} \bullet EF_{3PRP,SO}\right)\right]$$

Where:

N_2O_{Direct}–N = annual direct N_2O–N emissions produced from managed soils, kg N_2O–N yr^{-1}

N_2O–$N_{N\,inputs}$ = annual direct N_2O–N emissions from N inputs to managed soils, kg N_2O–N yr^{-1}

N_2O–N_{OS} = annual direct N_2O–N emissions from managed organic soils, kg N_2O–N yr^{-1}

N_2O–N_{PRP} = annual direct N_2O–N emissions from urine and dung inputs to grazed soils, kg N_2O–N yr^{-1}

F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}

F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils (Note: If including sewage sludge, cross-check with Waste Sector to ensure there is no double counting of N_2O emissions from the N in sewage sludge), kg N yr^{-1}

F_{CR} = annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N yr^{-1}

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr^{-1}

F_{OS} = annual area of managed/drained organic soils, ha (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

F_{PRP}= annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1} (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

EF_1 = emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)$^{-1}$(Table 11.1)

EF_{1FR} is the emission factor for N_2O emissions from N inputs to flooded rice, kg N_2O–N (kg N input)$^{-1}$ (Table 11.1) [5]

EF_2 = emission factor for N_2O emissions from drained/managed organic soils, kg N_2O–N ha^{-1} yr^{-1}; (Table 11.1) (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

EF_{3PRP} = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O–N (kg N input)$^{-1}$; (Table 11.1) (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

EQUATION 11.5
N IN URINE AND DUNG DEPOSITED BY GRAZING ANIMALS ON PASTURE, RANGE AND PADDOCK (TIER 1)

$$F_{PRP} = \sum_{T} \left[\left(N_{(T)} \bullet Nex_{(T)} \right) \bullet MS_{(T,PRP)} \right]$$

Where:

F_{PRP} = annual amount of urine and dung N deposited on pasture, range, paddock and by grazing animals, kg N yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country (see Chapter 10, Section 10.2)

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* in the country, kg N $animal^{-1}$ yr^{-1} (see Chapter 10, Section 10.5)

$MS_{(T,PRP)}$ = fraction of total annual N excretion for each livestock species/category *T* that is deposited on pasture, range and paddock[12] (see Chapter 10, Section 10.5)

EQUATION 10.30
ANNUAL N EXCRETION RATES

$$Nex_{(T)} = N_{rate(T)} \bullet \frac{TAM}{1000} \bullet 365$$

Where:

$Nex_{(T)}$ = annual N excretion for livestock category *T*, kg N $animal^{-1}$ yr^{-1}

$N_{rate(T)}$ = default N excretion rate, kg N $(1000 \text{ kg animal mass})^{-1}$ day^{-1} (see Table 10.19)

$TAM_{(T)}$ = typical animal mass for livestock category *T*, kg $animal^{-1}$

$$N_2O = N_2O\text{–}N \bullet 44/28$$

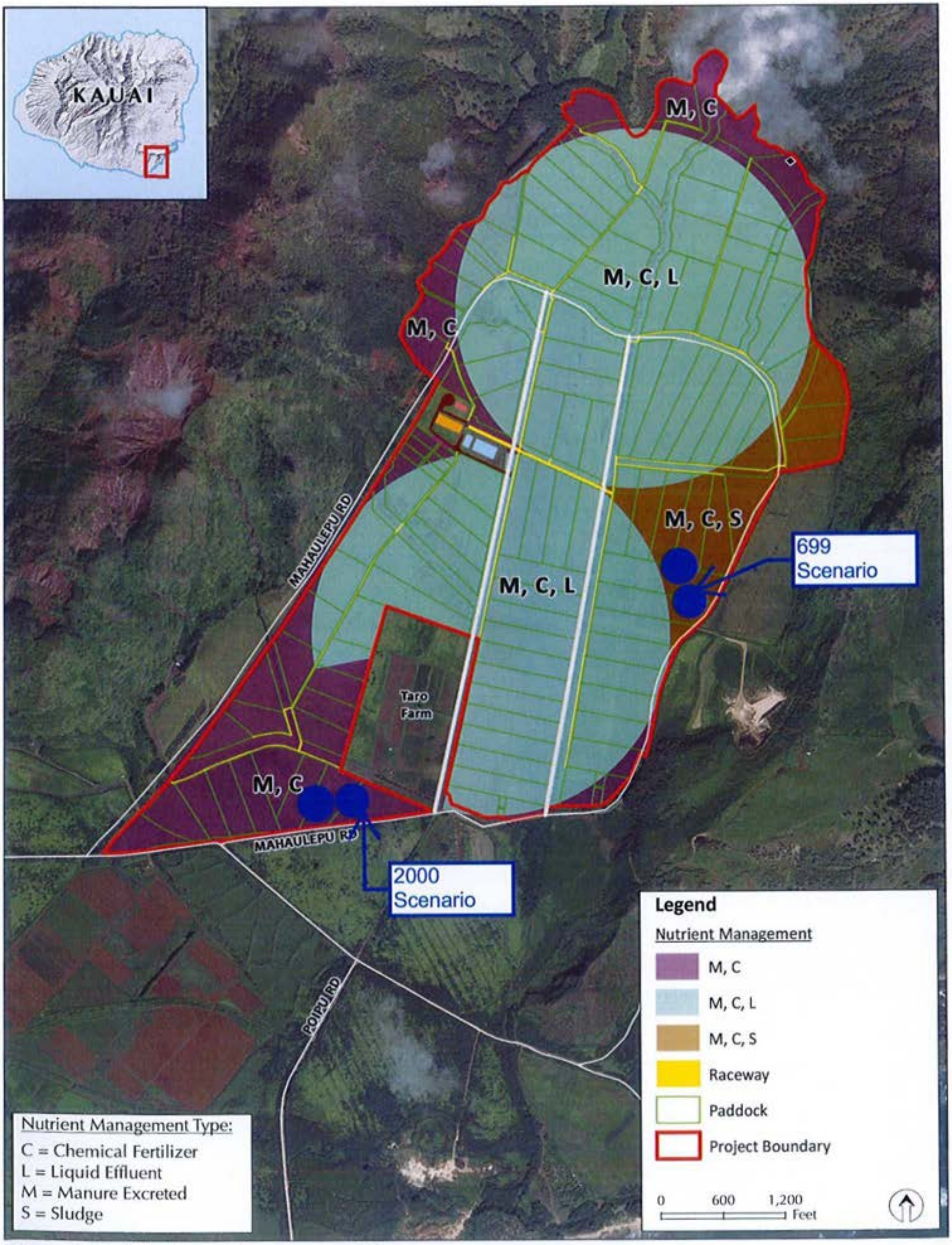

Figure 18 - Nutrient Management Map

MEMO

To:

Hawaii Dairy Farms

Copies:

1

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California 94104
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From:

Bryan Chen, Arcadis

Date:

December 16, 2016

Arcadis Project No.:

HI011182.0000

Subject:

Response to Comments in Exponent Report

Introduction

The Hawai'i Dairy Farm (HDF) submitted a Draft Environmental Impact Statement (DEIS) that included an odor impact analysis that evaluated potential odor impacts from the proposed project. In response to the odor impact analysis, Exponent, Inc. ("Exponent"), retained by Goodsill Anderson Quinn & Stifel LLP on behalf of Kawailoa Development LLP ("Kawailoa") prepared a separate odor analysis (Exponent 2016) and provided comments regarding the odor analysis in the DEIS. This document responds to the main comments made in the Exponent document. Revisions based on these comments are included in the Revised Odor Evaluation Technical Report (December 2016) as presented in Attachment 1.

Odor Thresholds

Exponent Comment

"The odor threshold of 6.5 OU/m^3 averaged over one hour used in the DEIS to evaluate impacts was not considered appropriate for a sensitive population such as hotel guests at a resort area. The DEIS odor threshold being used has not been adopted by any governmental authority or agency. Odors are perceived over much shorter time periods than one hour." (page 2)

Response

The odor threshold of 6.5 OU/m^3 averaged over one hour and 99.5th percentile was selected based on the specificity to dairy farms. In his comparison of odor regulations and guidance from four continents and New Zealand, OU/m^3 limits from Mahin (2001) show off-site standard or guidelines in the U.S. to be between 2 and 50 OU/m^3 with the majority of the values between 5 and 7 OU/m^3. Low OU/m^3 values are often difficult to observe. For instance, California's South Coast Air Quality Management District's states that at 5 D/T (OU/m^3) people become consciously aware of the presence of an odor and that at 5 to 10 D/T odors are strong enough to evoke registered complaints (SCAQMD 1993). While odors may be perceived over time periods less than one hour, the selected threshold was designed for a one hour average. If a shorter time period was desired, a higher value (perhaps closer to 10 OU/m^3) would have been selected. Further, the modeling considers the emission sources at their most impactful locations even though some of the sources are temporary (i.e., irrigation and slurry application). Given the conservative nature of the air dispersion modeling, the threshold used in the DEIS was determined to be appropriate.

Odor Emission Rates

Exponent Comment

"The odor emissions for some sources that were used in the DEIS were considered significantly underestimated. For example, HDF failed to include the odor emissions from fields that had received effluent irrigation or slurry in the hours before the one being modeled and grossly underestimated the odor strengths from several sources." (page 2)

Exponent proposed using odor emission rates from Pain et al. 1988 for irrigation and a separate rate for slurry application and use of the OFFSET model (Jacobson et al. 2001) for emission rates the manure. Exponent concurred with the Arcadis (May 2016) modeling conducted for the DEIS related to emissions from the buildings and effluent ponds.

Response

Irrigation

The longer duration and higher concentrations of odors observed in the Pain et al. 1988 study is likely a result of 1) higher concentration of solids in the effluent; 2) higher application rates; 3) lower absorption rate of the grassland compared to the Kikuyu crop at the project site; and 4) higher silage diet.

For the project site, it is anticipated that the Kikuyu thatch would absorb the liquid and accompanying malodorants from the diluted effluent within a short timeframe, modeled as a one-hour timeframe in this analysis. The effluent to be used at the project will have virtually no dry matter, while the "separate slurry" used in the Pain study reported a value of 5.4%. As it is likely that the solids encompass the majority of the odors, using the separate slurry emission rate is not an appropriate substitute for the effluent. The use of the emission rate for the effluent pond as used in the DEIS is therefore a better option. Although this approach does not account for potential turbulent aeration, it assumes the entire surface of the ground covered within the hour is covered with irrigation water and that the odors from the effluent ponds have not decreased over time due to breakdown of odor related compounds. However, adjustments to the dilution will be made to account for the variable dilutions possible throughout the year as presented in the Attachment 1.

Slurry

Similar to the differences noted above regarding the applicability of the Pain et al.1988 study results of irrigation liquid for this analysis, the slurry in the Pain et al. 1988 study has a higher concentration of solids in the effluent and lower absorption rate of the grassland. The Pain et al. 1998 study used a slurry with 9.2% dry matter while the slurry from HDF is anticipated to be closer to 5% dry matter, thus the value used for the separate slurry would be more appropriate. Additionally, the slurry used at HDF will typically be diluted by 50% or more. The use of revised odor emission rates based on the Pain et al. 1998 study are presented in Attachment 1.

Manure

The results of the Topper data were used in the initial odor model for the DEIS to account for the unique diet of the cows at the project. The use of an open lot value from the OFFSET model does not account for the diet and subsequent feces/urine ratio. Nor does this approach account for the fact that an open lot is a compacted dirt (or concrete) area as opposed to the Kikuyu thatch that where manure is incorporated into what is effectively an organic net. However, the emission rates based on the Jacobson et al. 2001 study for the open lot value used in the OFFSET model can be modified to account for the issues above and are presented in Attachment 1.

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ATTACHMENT 1

Hawaii Dairy Farms Revised Odor Evaluation Technical Report

Group 70 International, Inc.

Kauai Dairy
Maha‘ulepu, Hawaii

December 16, 2016

Prepared for:
Group 70 International, Inc.

Prepared by:
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Figures

1 Introduction

Hawaiʻi Dairy Farms LLC (HDF) intends to develop a dairy with up to 2,000 cows in the Mahaʻulepu Valley on the island of Kauaʻi. The project will utilize a pastoral-based rotational grazing system. To demonstrate the sustainability of the dairy, HDF is committed to establishing a herd of 699 cows. HDF will contemplate the possibility of expanding the herd up to 2,000 cows. Both herd sizes are analyzed in this report. This odor evaluation report presents an updated analysis used to determine the potential impacts of odors from both herd sizes for the larger contemplated herd size of the proposed dairy facility at off-site receptors. This report updates the odor section contained in the Air Emissions and Odor Evaluation Technical Report dated May 2016.

2 Project Site

The project area has historically been used for sugar cane production as part of the Koloa Plantation until the late 1990s when the Koloa Mill closed. Since the mill closed, the project area and its surrounding has been leased to various tenants for ranching and diversified agricultural operations. A small plot of land in the lower center of the valley is currently used for taro loʻi and will continue to be leased and farmed after the dairy and related pastures are in full operation. Recreational land use such as golf courses and hotels are located approximately 0.9 miles to the south and residential properties are located more than 1.5 miles to the southwest and west. Figure 1 presents a project location map showing the project site and surrounding land use.

The total dairy farm area inclusive of pasture and dairy facility, but excluding the existing taro farm, was initially calculated as 556.8 acres. For the purposes of this evaluation, the dairy project site was divided into two land use areas: Field 1, 547.1 acres of pasture; and Field 2, 9.7 acres containing the dairy facility. Field 1 is broken up into paddocks of approximately 3 to 5 acres in size.

3 Air Dispersion Modeling Methodology

3.1 Model Selection

Computer-based air dispersion models can be used to determine the concentration and frequency of odors and fugitive dust at specific locations around a source using local weather data. The AERMOD modeling system (AERMOD (version 15181) and its pre-processing programs, AERMAP and AERMET) were used for the analysis. AERMOD is a steady-state Gaussian plume model that requires four general types of input data: emission source information, receptor locations, meteorology, and model specific control options.

3.2 Receptors[1]

Fenceline (boundary) receptors and one Cartesian grid of receptors extending out to 4.5 km from the site were used for the modeling analysis. Fenceline receptor spacing was 25 meters while the Cartesian receptor grid spacing is 100 meters between receptors. All receptors were placed at ground level in the model based on standard modeling protocol.

3.3 Terrain

The project site is situated in the Maha‘ulepu Valley on the island of Kaua’i. The valley is on the leeward side of the Ha‘upu mountain ridge, which runs in the east-west direction, and the valley is also flanked by ridge lines on both sides. Mt. Ha‘upu is the highest point on the ridge line at the back of the valley with an elevation of 2,297 feet. From this point, the ground drops very quickly down to the bottom of the valley to about an elevation of 150 feet. The base of the valley itself is somewhat gradually sloped from an elevation of 150 feet to an elevation of 60 feet along Maha‘ulepu Road on the makai side of the project site near the taro farm.

Terrain elevations were obtained from National Elevation Dataset (NED) digitized terrain data from the United States Geological Survey (USGS), and processed using AERMAP.

3.4 Meteorological Data

One year (2014) of AERMET-ready meteorological data for the project site was obtained from Lakes Environmental. The meteorological data were derived from the NCAR MM5 (5th-generation Mesoscale Model) prognostic meteorological model. The data were used to develop the necessary surface and upper air files for the project's location and modeling domain. These files were used as inputs into the AERMET pre-processing software. The final AERMOD-ready meteorological data file was processed using estimated surface characteristics in the project vicinity with AERMET. The surface characteristics were estimated from available aerial photos for the project location. A wind rose plot of meteorological data is presented in Figure 2. This figure shows that the predominant wind direction is towards the southwest.

3.5 Model Control Options

The analysis included the use of selected model control options that allow the model to be made more site and project specific. These model options include land use classification, incorporation of building wake information, averaging time, and regulatory control options. The modeling used the AERMOD regulatory default option. This option includes elevated terrain algorithms, the effects of stack-tip

[1] Receptors are defined as locations at which odor are estimated and do not necessarily denote where a person is located.

downwash, missing data routines, and calm wind processing. In addition, rural boundary layer effects were incorporated into the model.

3.6 Odor Emission Sources

Odor emissions are generated during incomplete anaerobic decomposition of organic matter in manure. Potential sources at the facility would include the effluent ponds, the irrigation system which utilizes effluent, manure from pasture fields, and the dairy buildings. These sources are described in detail in the sections below.

Odor refers to the combined effect of a mixture of gases on the sense of smell. For livestock sources, it may contain hundreds of trace compounds including ammonia (NH_3) and hydrogen sulfide (H_2S). Instead of measuring the individual components of an odor, as is done in standard air concentration modeling, odor concentration is reported in odor units per cubic meter (OU/m^3), and odor emissions are reported in units of odor units per second, OU/s (for point sources) and odor units per second per square meter, $OU/s/m^2$ (for area sources). An odor concentration of 1 OU/m^3 is defined as the threshold where the odor of a sample has a 50 percent probability of being perceived by a trained odor specialist.

3.6.1 Effluent Ponds

The effluent pond design includes two ponds: a settling pond and storage pond. The settling pond allows for the settlement and accumulation of solids with the overflow of liquid effluent entering the storage pond. The effluent ponds are open to the atmosphere. The top of the settling pond is 87 feet by 133 feet with a total depth of 17 feet with side slopes not steeper than 2 horizontal to 1 vertical. Effluent from the settling pond overflows through overflow pipes and into the storage pond. The top of the storage pond is 215 feet by 133 feet with a total depth of 17 feet. However, it is not likely the effluents would reach the top of the ponds as it is designed for a 25-year flood level. Based on a normal 30-day period of rain and effluent storage, the settling pond would be 12 feet deep and the storage pond would be approximately 10.75 deep. The corresponding widths and lengths are 67 feet by 113 feet and 190 feet by 108 feet for the settling pond and storage pond, respectively. The effluent ponds were modeled at ground level.

Each pond was modeled in AERMOD as an area source with dimensions of the anticipated 30-day period of rain and effluent storage effluent surface. Odor emission rates were taken from Feitz 2002 (Dairy Australia, December 2008) which measured 30 ponds over 12 months in Australia. These results were selected over other data presented in Dairy Australia (2008) as it was measured using a wind tunnel apparatus as opposed to isolation flux hoods. According to Dairy Australia, most research shows that isolation flux hoods under-predict odor emissions relative to wind tunnels.

3.6.2 Irrigation

Odors from the irrigation process will be based on the odors volatilizing from effluent water mixed with irrigation water. This water will be applied through two center pivots and released approximately one meter from the ground surface. Irrigation pivot #1 will be a full circle pivot and irrigation pivot #2 will be a ¾-circle pivot.[2] Before application, the effluent water will be diluted with irrigation water. The effluent concentration will be 4% for the committed herd size and 12% for the contemplated herd size. In typical years, these concentrations will remain relatively consistent throughout the year. However, during years where the winter season is unusually wet, less water will be added to the effluent prior to application and thus the effluent will be in a higher concentration in the irrigation water. For these winter seasons, the effluent concentration could be up to 50% for both the committed and contemplated herd size. Typically, only one pivot will be applying effluent at any given time. The pivots can complete a full rotation every 40 hours.

The odor emissions associated with the effluent ponds were reduced by a factor proportional to dilution of the effluent for irrigation. The diluted effluent will be quickly absorbed into the ground and the odor will be short-lived. Therefore, the area covered in an hour (1/40 of a complete rotation) was modeled as an area emission source. As a conservative scenario, the section closest to the southern boundary was used in this evaluation.

3.6.3 Pasture

The cows will be maintained in six mobs of animals. At the committed herd size of 699 cows, mobs will contain up to 115 animals and for the contemplated herd size of up to 2,000 cows, mobs will contain up to 334 animals. The cows graze for one day per paddock and will produce the majority of the manure in that one paddock as they graze. Each mob will graze in separate paddocks of 27 to 81 acres, and adjacent to paddocks with other mobs. Paddock blocks that would be occupied on a given day were selected based on a typical scenario and were modeled as an area source.

Odor emission rates were based on the Jacobson et al. 2001 study for the open lot value used in the OFFSET model which evaluates odor from feedlot setbacks. However, the use of the open lot value in Jacobson et al. 2001 does not account for the diet and subsequent feces/urine ratio that would be found in cows for this project. Nor does this approach account for the fact that an open lot is a compacted dirt (or concrete) area as opposed to the Kikuyu thatch that where manure is incorporated into what is effectively an organic net. Therefore, the odor emissions in Jacobson et al 2001 was adjusted by the ratio of the estimated odor for a high concentrate (HC) and 20% corn silage diet and low concentrate (LC) and 80% corn silage (typical dairy cows) observed in the Topper et al. (2008) study. Although the HC diet does not necessarily coincide with the project (pasture fed cows were not evaluated in Topper et al., 2008), the HC; 20% silage resulted in the highest percentage of urine in the manure which is consistent with the composition of the anticipated manure. In addition, the impact of the Kikuyu thatch and loose

[2] The ¼ circle not reached by irrigation pivot #2 will receive water through a hard-hose gun irrigation system.

soil is accounted for by using a control efficiency value consistent with an 8" straw or natural crust in the OFFSET model.

3.6.4 Slurry

Solids collected from the settling pond will be applied on designated areas through a "gun type" application system to areas outside the liquid effluent application. The slurry consists of three components; 1) liquid effluent, 2) settled solids from the liquid effluent, and 3) irrigation/collected rain water. The solids will be mixed with irrigation and/or collected rain water at a 1:1 ratio to create the slurry, which can then be pumped to the hydrants resulting in a dry matter percentage of approximately 4%. The slurry will be pumped through underground pipes to hydrants which have a "gun sprinkler". The slurry guns will have an application rate of approximately 158 gallons per minute over a 160 foot spray length at a rate of 0.60 minutes per foot. Approximately 16,000 square feet will be covered with slurry in an hour and application will occur for up to 8 hours a day and will cover approximately 128,000 square feet (2.94 acres) in one day.

The slurry application will not occur in paddocks when occupied by cows. The planned location of the application is anticipated to be on the east portion of the site between the area that is covered by the irrigation two center pivots for the committed herd size of 699 cows. For the contemplated herd size of up to 2,000 cows, slurry will be applied to non-irrigated paddocks and those irrigated without the addition of effluent. Application of the slurry will be periodic (at least every 45 days) and will not occur under the following conditions: 1) Slurry application will not coincide with effluent application via the center pivot; and 2) Slurry will not be applied during days with average wind speeds less than 4 m/s or greater than 8.9 m/s.[3]

The odor emissions associated with the slurry were based on the Pain et al. 1988 study for separated slurry (consistent with the dry matter content). The Pain et al. 1988 study indicated that odors may remain past the first hour after application and vary by time with measurements at application, two hours after application, five hours after application, seven hours after application, and 24 hours after application. The emissions for each hour was extrapolated from these measurements and reduced by a factor of two to account for the dilution of the slurry before application. In addition, an adjustment for the diet, similar to the manure odors, was made. As a conservative estimate, the areas closest to the southern boundary and adjacent to occupied paddocks were used in this evaluation.

3.6.5 Dairy Facility

The dairy facility is contained within an approximately 10-acre area in Field 2. The corresponding building areas are under 0.1% of the total farm area. The dairy buildings include the milking parlor, an implement

[3] Based on the 2014 meteorological data used, the limits of the daily wind speeds will reduce the number of days of potential application to 243 days in a year.

shed, and calf sheds. The milking parlor contains an automated 60-stall rotary which is approximately 256 feet by 88.5 feet by 33 feet tall. Two open bay calf sheds will be constructed to provide safe housing to newly born calves. Each shed will be approximately 81 feet by 26 feet by 15 feet tall. The feeding area will be washed daily and the wastewater transferred to the effluent ponds. Dairy facility odor emissions were modeled as area sources with dimensions of the building footprint. Emission rates consistent with free stall dairy buildings from Jacobson et al. (2001) were used.

Table 1 summarizes the emission fluxes used in the evaluation and the area of the emission source. The emission flux estimates are detailed in Appendix A. As a conservative estimate, the evaluation considers the emission sources at their most impactful locations even though some of the sources are temporary (i.e., irrigation and slurry application).

Table 1. Hawaii Dairy Farms Odor Modeling Parameters

Location	Source	Emission Flux (OU / s / m^2)	Area (ft^2)
Effluent Ponds	Settling Pond	8.1	7,571
	Storage Pond	8.1	20,520
Irrigation	Effluent* – wet years, winter	4.05	222,828
	Effluent* Committed	0.32	222,828
	Effluent* Contemplated	0.97	222,828
Pasture	Committed Herd	0.16	1,217,078
	Contemplated Herd	0.45	1,217,078
Slurry Application	Application + 1 hour	6.31	16,000
	Application + 2 hour	7.21	16,000
	Application + 3 hour	7.10	16,000
	Application + 4 hour	7.00	16,000
	Application + 5 hour	6.89	16,000
	Application + 6 hour	5.83	16,000
	Application + 7 hour	4.77	16,000
	Application + 8 hour	4.77	16,000
Dairy Facility	Bay Calf Shed #1	1.84	2,106
	Bay Calf Shed #2	1.84	2,106
	Milking Parlor	1.84	22,656

Notes:
* For typical precipitation conditions, the dilution is anticipated to be 4% for the 699 herd scenario and 12% for the 2,000 herd scenario. During these periods, effluent will only be diluted at approximately 50% at maximum.

3.7 Thresholds

The development of a target odor criteria is complicated by the difficulties in odor sampling and measurement combined with a lack of suitable data on odor levels associated with annoyance and complaint. Mahin (2003) presented regulatory off-site limits based on levels predicted by dispersion modeling in the U.S. range from 1 OU/m^3 to 50 OU/m^3 for a variety of averaging times.

Table 2. Regulatory Odor Thresholds

Location	Off-site standard or guideline	Averaging times
Allegheny County Wastewater Treatment Plant (WWTP)	4 OU/m^3 (design goal)	2-minute
San Francisco Bay Area Air Quality District	5 OU/m^3	Applied after at least 10 complaints within 90-days
State of Colorado	7 OU/m^3 (Scentometer)	
State of Connecticut	7 OU/m^3	
State of Massachusetts	5 OU/m^3*	
State of New Jersey	5 OU/m^3 **	5-minutes or less
State of North Dakota	2 OU/m^3 (Scentometer)	
State of Oregon	1 to 2 OU/m^3	15-minute
City of Oakland, CA	50 OU/m^3	3-minute
City of San Diego WWTP	5 OU/m^3	5-minute
City of Seattle WWTP	5 OU/m^3	5-minute

Notes
* draft policy and guidance for composting facilities
** for biosolids/sludge handling and treatment facilities

Many of these values are for wastewater treatment plant or composting facilities, but none of the regulatory standards are specific to dairy farms. However, an Australian study by Wang and Feitz (2004) suggested 6.5 OU/m^3, 1-hour averaging and 99.5th percentile at receptor as appropriate criteria for the assessment of dairy farm odors. Based on the source of the odor, this odor threshold was selected for this analysis. These criteria represent the extent of the 6.5 OU/m^3 level that has the potential to be reached 0.5% of the time (100% – 99.5%). Using hourly meteorological data, 0.5% would be equivalent to a result exceeding 6.5 OU/m^3 once per 200 hours evaluated. If the emission source could be operated anytime throughout the year, this would equate to 44 hours per year. However, for emission sources such as the slurry application, where application (and therefore odor emissions) would be limited to 243 days of the year (based on daily wind speeds), this would equate to 29 hours per year. In other words, there is a 99.5% chance that the odor threshold of 6.5 OU/m^3 is less than the extent shown, and only 0.5% chance it will be at or beyond the extent shown.

3.8 Results

Odor isopleths were created using the results of AERMOD modeling. The odor modeling analysis and isopleths indicate that the 99.5th percentile of 6.5 OU/m^3 odor threshold extend beyond the dairy farm boundary, however it does not reach recreational nor residential areas. As discussed above, slurry application and effluent application would not occur on the same day. Therefore, separate figures showing the extent of the potential odor impacts were prepared for the slurry application and effluent application in Figures 4 and 5 for the committed herd size and Figures 6 and 7 for the contemplated herd size, respectively. It should be noted that the parameters used in this analysis were intentionally very conservative and the impacts shown depend on an unlikely confluence of most impactful emission source locations; thus, actual offsite odor impacts are likely to be much lower and/or less frequent than shown.

4 References

Dairy Australia. 2008. Effluent and Manure Management Database for the Australian Dairy Industry. December.

Jacobson, L.D., Schmidt, S. Wood. 2001. OFFSET: Odor from feedlots setback estimation tool. University of Minnesota Publication F0-07680-C.

Mahin, T. 2003. Measurement and regulation of odors in the USA. Odor Measurement Review, Japan Ministry of the Environment. Pp. 62-68.

Pain, B.F., Rees, Y.J., Lockyer, D.R., 1998. Odour and Ammonia Emission Following the Application of Pig or Cattle Slurry to Land. Volatile Emissions From Livestock Farming and Sewage Operations. Edited by V.C. Nielsen, J.H. Voorburg, and P.L. L'Hermite. pp. 2-11.

Topper, Patrick A., Robin Brandt, A. Adviento-Borbe, G.J. Lascano, A.J. Heinrichs, E.F. Wheeler. 2008. Odor Evaluation and Gas Emission from Manure of Dairy Heifers Fed High/Low – Forage Quality and High/Low-Concentrate Diets. ASABE Meeting Presentation. June 29-July 2.

Wang, X. and A.J. Feitz 2004. Odor impact criteria for Australian dairy farms, Enviro 04, Sydney NSW, 29-31 March 2004.

Figures

Google earth

miles 1
km 2

Group 70 International, Inc. (Kauai Dairy)

Site Location Map

ARCADIS Design & Consultancy for natural and built assets

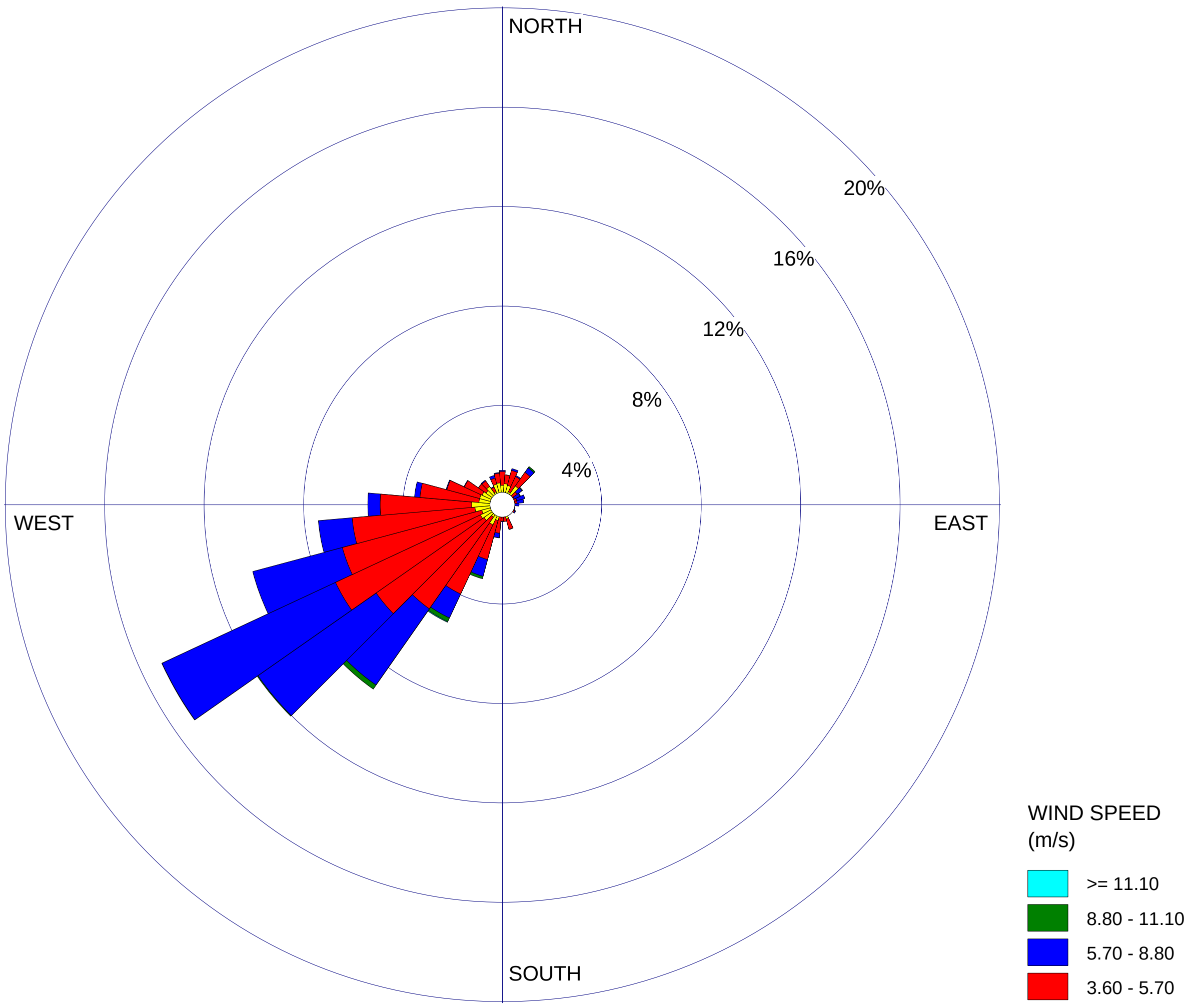
FIGURE 1

WIND ROSE PLOT:

MM5 2014 Met data

DISPLAY:

Wind Speed
Flow Vector (blowing to)



COMMENTS:

DATA PERIOD:

Start Date: 1/1/2014 - 00:00
End Date: 12/31/2014 - 23:00

COMPANY NAME:

MODELER:

CALM WINDS:

0.98%

TOTAL COUNT:

8760 hrs.

AVG. WIND SPEED:

4.64 m/s

DATE:

5/23/2015

PROJECT NO.:

WRPLOT View - Lakes Environmental Software

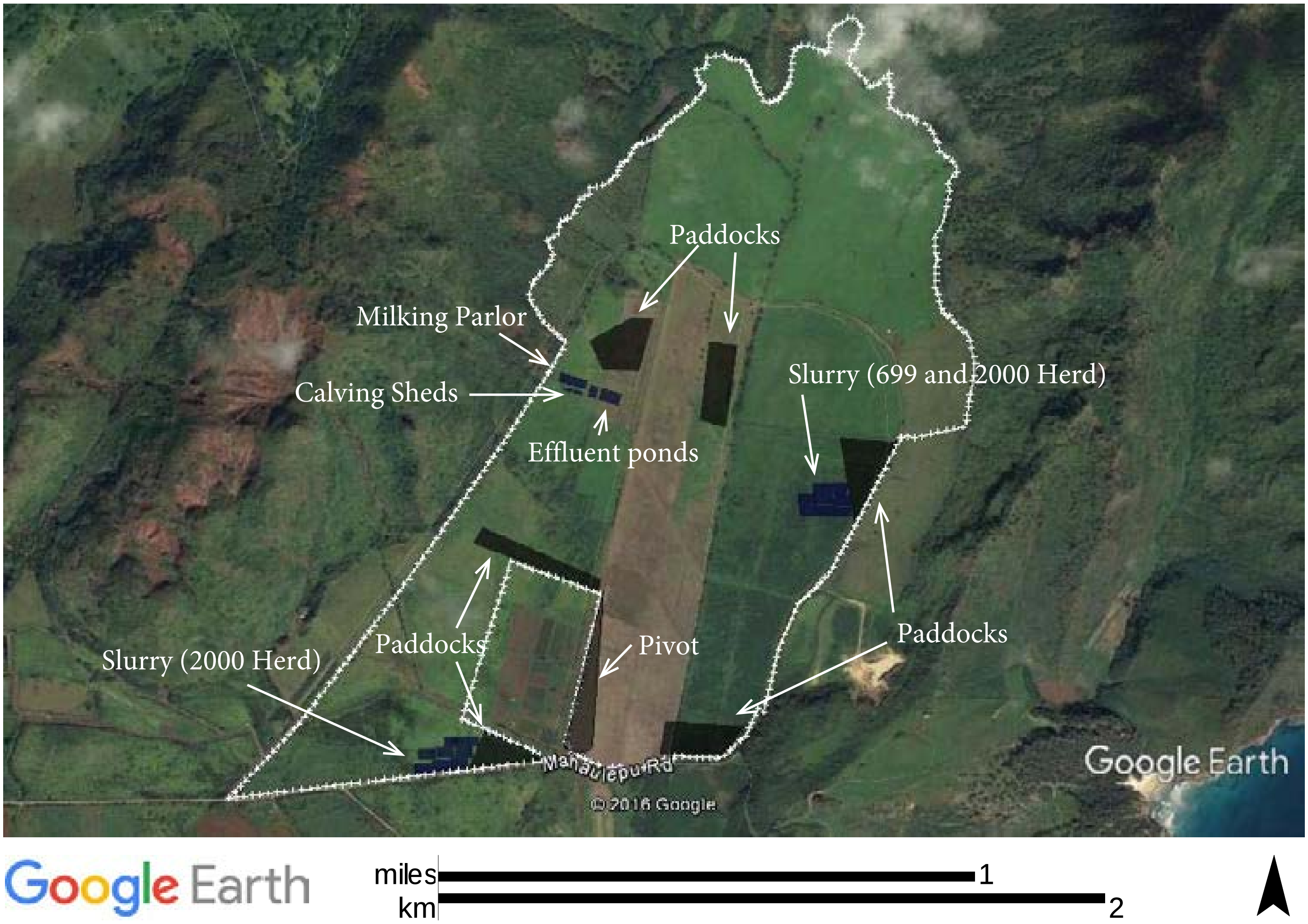
Group 70 International, Inc. (Kauai Dairy)

AERMOD Wind Input

ARCADIS Design & Consultancy for natural and built assets

FIGURE

2



Group 70 International, Inc. (Kauai Dairy)

Modeled Odor Sources

ARCADIS Design & Consultancy for natural and built assets

FIGURE 3

Group 70 International, Inc. (Kauai Dairy)

Extent of 6.5 OU/m3 at 99.5th Percentile for Slurry Application– Committed Herd Size

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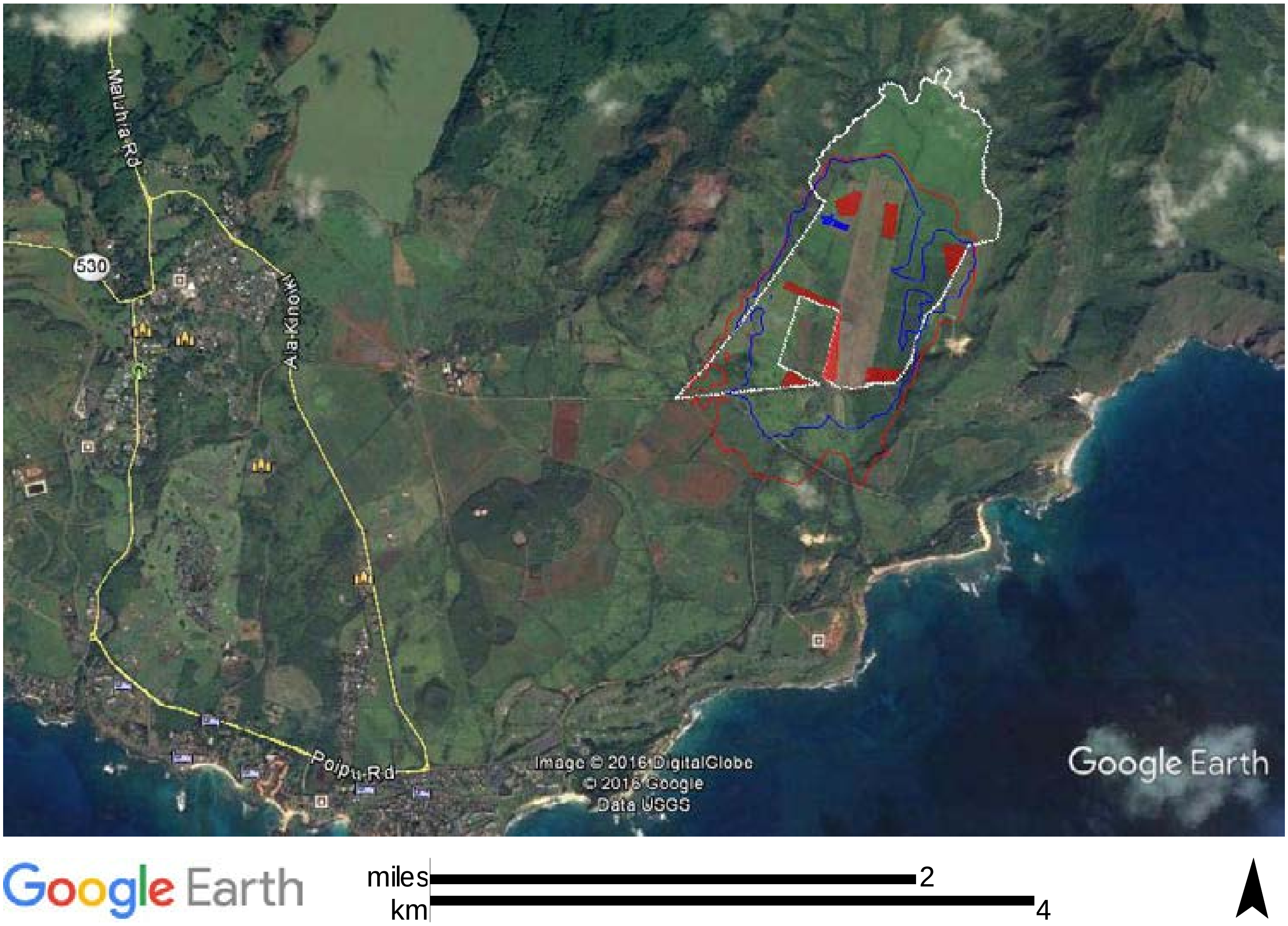
FIGURE 4



Typical Application

Wet Period Application

Group 70 International, Inc. (Kauai Dairy)

Extent of 6.5 OU/m3 at 99.5th Percentile for Effluent Application– Committed Herd Size

ARCADIS Design & Consultancy for natural and built assets

FIGURE 5

Group 70 International, Inc. (Kauai Dairy)

Extent of 6.5 OU/m3 at 99.5th Percentile for Slurry Application– Contemplated Herd Size

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FIGURE 6

Typical Application

Wet Period Application

Group 70 International, Inc. (Kauai Dairy)

Extent of 6.5 OU/m3 at 99.5th Percentile for Effluent Application– Contemplated Herd Size

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FIGURE 7

Appendix A

TABLE A-1
Emission Fluxes Used in Odor Evaluation
Hawaii Dairy Farms

Source	Odor Emission Flux (OU/m2/s)	Source
Settling Pond	8.1	Feitz 2002
Storage Pond	8.1	Feitz 2002
Pivot irrigation - winter (wet)	4.05	Storage pond effluent diluted by a factor of 2
Pivot irrigation - Committed	0.32	Storage pond effluent diluted by a factor of 25
Pivot irrigation - Contemplated	0.97	Storage pond effluent diluted by a factor of 8.3
Gun irrigation	0	No effluent water applied to the area
Pasture - Committed	0.16	Derived from Jacobson *et al* 2001
Pasture - Contemplated	0.45	Derived from Jacobson *et al* 2001
Sludge - 1st hour	6.31	Derived from Pain 1998
Sludge - 2nd hour	7.21	Derived from Pain 1998
Sludge - 3rd hour	7.10	Derived from Pain 1998
Sludge - 4th hour	7.00	Derived from Pain 1998
Sludge - 5th hour	6.89	Derived from Pain 1998
Sludge - 6th hour	5.83	Derived from Pain 1998
Sludge - 7th hour	4.77	Derived from Pain 1998
Sludge - 8th hour	4.77	Derived from Pain 1998
Bay Calf Sheds	1.84	Jacobson *et al* 2001
Milking Parlor	1.84	Jacobson *et al* 2001

TABLE A-2
Emission Fluxes From Sludge Application
Hawaii Dairy Farms

Measurement Hour[1]	Emission Flux[1]		Applied Dilution[2]	Diet Adjustment[3]	Adjusted Emission Flux
	$OU/m^2/hr\ 10^{-4}$	$OU/m^2/s$			$OU/m^2/s$
0	5.1	14.17	0.5	0.76	5.41
2	6.8	18.89	0.5	0.76	7.21
5	6.5	18.06	0.5	0.76	6.89
7	4.5	12.50	0.5	0.76	4.77

Hour After Application	Emission Flux ($OU/s/m^2$)
1	6.31
2	7.21
3	7.10
4	7.00
5	6.89
6	5.83
7	4.77
8	4.77

Notes
1 Values taken from Pain 1988, Figure 2.
2 Slurry will be diluted prior to application at a 1:1 ratio, at minimum.
3 Adjustment to account the difference in diet for the project cows and typical dairy cows based on the Topper et al 2008 study.

TABLE A-3
Emission Fluxes From Pasture (Manure)
Hawaii Dairy Farms

Scenario	Reported Emission Flux[1]	Herd Size Density (square feet / head)		Herd Size Adjustment[2]	Diet Adjustment[3]	Ground Cover Adjustment [4]	Adjusted Emission Flux
	$OU/m^2/s$	Reported	Project				$OU/m^2/s$
Committed Herd Size	4.3	275	1741	0.16	0.76	0.70	0.16
Contemplated Herd Size	4.3	275	609	0.45	0.76	0.70	0.45

Notes

1 Values taken from Jacobson et al 2001 for open lot source.

2 Adjustment for the size of herd. Jacobson et al 2001 reported a herd size density of 275 square feet per head.

3 Adjustment to account the difference in diet for the project cows and typical dairy cows based on the Topper et al 2008 study.

4 An odor reduction of 70% accounts for the loose soil and grass present within the paddocks which is consistent with straw cover (8 inches) in the Jacobson et al 2001 study.

APPENDIX J

HAWAIʻI DAIRY FARMS MĀHĀʻULEPŪ: DEMOGRAPHIC AND ECONOMIC ASSESSMENT

PLASH ECON PACIFIC (PEP) INC.

MEMORANDUM: HAWAIʻI DAIRY FARMS: ECONOMIC IMPACTS RELATED TO ODOR-DETECTION LIMITS, DECEMBER, 2016

Hawai'i Dairy Farms:
Socioeconomic Conditions, Economic Impacts, and Fiscal Impacts

HAWAI'I DAIRY FARMS:
SOCIOECONOMIC CONDITIONS, ECONOMIC IMPACTS, AND FISCAL IMPACTS

PREPARED FOR:

Hawai'i Dairy Farms

PREPARED BY:

Plasch Econ Pacific LLC

under subcontract to

Group 70 International

May 2016

CONTENTS

FIGURES

TABLES FOR PART II

TABLES FOR PART III

EXECUTIVE SUMMARY

1. PROPOSED DAIRY

In 2013, Ulupono Initiative funded Hawaiʻi Dairy Farms ("**HDF**" or the "**Dairy**"). The Dairy was formed to increase Hawaiʻi's supply of milk and thereby reduce dependence on imported milk, bolster food security for the islands with a sustainable supply of milk, and help diversify the economy.

The Dairy will be located in Māhāʻulepū Valley in Kōloa, Kauaʻi because the site meets the operational requirements for a dairy, and the Valley was found to provide ideal growing conditions for grass feed and dairy cows. Based on the most successful island dairy models in the world, the Dairy will be the first in Hawaiʻi to use rotational pasture-grazing. The two existing dairies in Hawaiʻi and most dairies on the mainland use feedlots. Also, the Dairy will use the most advanced dairy-farming techniques, including: (1) precision monitoring of the health of the cows; (2) technology to determine the productivity of the land and, ultimately, its carrying capacity; (3) effluent management to ensure environmental health and safety; and (4) other best management practices.

HDF is committed to establishing a herd of up to 699 mature dairy cows, and demonstrating that rotational pasture-grazing is an economically and environmentally sustainable model for Hawaiʻi. With proven success, HDF may expand the herd up to the carrying capacity of the land, which is currently estimated to be up to 2,000 productive milking dairy cows. For dairy operations with 700 or more milking cows, additional regulatory review and permitting by the State Department of Health will be required. The process for the additional approvals, including public notification and input, will be followed if and when HDF decides to pursue an expanded operation.

2. SOCIO-ECONOMIC CONDITIONS

The Dairy site is located in the Kōloa-Poʻipū region. This region has socio-economic conditions similar to those of the entire island except for the following:

— Demographic

- Slower population growth.
- During the previous decade, a slight decline in the male population and a significant increase in the female population (evidently, many males left due to more attractive opportunities elsewhere).
- A slightly older population, with fewer school-age children and more retirees.

- More whites and fewer Asians and Native Hawaiians/Other Polynesians.
- More residents born in another state.
- Smaller households.
- More homes for seasonal, recreational or occasional use.

— Income and Eduction

- Higher per-capita incomes.
- Less poverty.

— Property Values

- Higher average values for both single family homes and condominiums.

It should also be noted that the economy of the region and the entire island depend heavily on tourism, with about 36% of the visitor units located in the Poʻipū area.

3. AGRICULTURAL BENEFITS

a. Increased Food Self Sufficiency

Milk

The Dairy will increase Hawaiʻi's milk self sufficiency and reduce fluid milk imports. At full steady-state operations achieved after the pasture matures, the Dairy will produce about 1.5 million gallons of milk per year for a 699-cow dairy. Should HDF decide, in the future, to expand the herd up to 2,000 milking cows, milk production could reach 4.4 million gallons. This compares to about 4 million gallons produced in Hawaiʻi in 2015. Production was down from a peak of about 18.3 million gallons in 1988 when Hawaiʻi dairies supplied nearly all of the milk consumed in the state.

Livestock

In addition, the Dairy will increase the supply of livestock, including female calves for other dairies, male calves for beef ranching, and culled cows and heifers for beef or dairy operations.

b. Open Space

The Dairy's irrigated pasture will provide about 470 acres of well-maintained grassland divided into 119 fenced paddocks. The herd will be split into 6 groups, each of which will be rotated among the paddocks. Thus, at any given time, about 5% of the pasture land will be occupied by cows (6 of 119 paddocks), and about 95% will be unoccupied green open space. In addition, about 77 acres will be used for cow raceways, internal roads, and setbacks along drainage ditches.

4. EMPLOYMENT BENEFITS

a. Construction and Related Employment

Development of the Dairy and related processing facilities will employ an average of about 12 construction workers during the 2-year construction period for the dairy. Indirect employment related to Dairy development is expected to average about 16 jobs on Kaua‘i and 8 jobs on O'ahu. Thus, total direct-plus-indirect employment associated with Dairy development will average about 36 jobs, of which about 28 jobs will be on Kaua‘i. The actual job counts will fluctuate over time, depending on the pace of construction.

b. Operating Employment

At full operations, the 699-cow dairy will provide about 11 jobs on Kaua‘i, including about 5 farm jobs and about 6 indirect jobs. About 3 indirect jobs will be on O‘ahu.

Corresponding employment figures for the 2,000-cow dairy are about double.

5. FISCAL BENEFITS

a. County

Development of the Dairy is expected to have a negligible impact on County finances inasmuch most taxes on construction activity is collected by the State, and HDF will provide needed infrastructure (interior roads, water distribution, drainage, etc.). Also, most construction workers are expected to be from Kaua‘i, so they already pay taxes and will not require additional services from the County.

At full operations, the Dairy is expected to generate net income to the County of about $51,000 for the 699-cow Dairy. Should HDF decide, in the future, to expand to a 2,000-cow Dairy, net income to the County would be about the same. Most of the taxes will come from property taxes on improvements.

Dairy workers and their families will pay a variety of taxes to the County, while also requiring County services. For these workers and families, the resulting net revenues are expected to be near zero but positive since the County budget is structured to break even, and most Dairy workers will earn wages higher than the County average.

b. State

Unlike the County, the State will derive significant revenues from development activity: a cumulative total of about $650,000 for both the 699-cow dairy and the 2,000-cow dairy. However, the revenues will be offset by the $1 million tax credit for improvements on land designated by the State Land Use Commission as Important Agricultural Lands. Most construction workers are expected to be from Hawai‘i, so they already pay taxes and will not require additional services from the State.

When the Dairy is operational, net income to the State is expected to exceed $60,000 per year for the 699-cow Dairy, and exceed $170,000 per year should HDF decide, in the future, to expand to a 2,000-cow Dairy.

6. NUISANCE ISSUES AND IMPACTS

Given the important economic, residential, and recreational role of the Kōloa-Po‘ipū region, the Dairy must be compatible with, and not cause adverse impacts on regional resorts, commercial areas, homes, recreational activities, etc.

The Dairy will feature modern facilities and practices, and will comply with all applicable Federal and State environmental standards. Considerable distances will separate the Dairy from the resorts, commercial areas, homes and recreational areas. The nearest resort units are about 1.5 miles from a Dairy paddock and about 2.4 miles from the Dairy milking parlor. For the Kōloa town center, the distances from the closest paddock and dairy facilities are about 2.2 and 2.8 miles, respectively. For homes, the distances are about 1 and 2 miles away, respectively. And for recreational activities, the distances are about 0.6 mile and 1.3 miles, respectively.

The environmental studies indicate that no noticeable noise, dust, odors, flies, runoff, or other nuisance impacts will extend to resort, commercial, residential or recreational areas. Noticeable nuisance impacts occurring outside the Dairy property will be limited to the abutting farm and ranch lands which are owned by Māhā‘ulepū Farm, lessor of the Dairy property. These abutting lands are designated Important Agricultural Lands, so they will remain in agriculture for the foreseeable future.

In view of these findings, the Dairy will not adversely affect:

— Guests of resorts in the Kōloa-Po‘ipū region.

— Recreational activities in the region.

— The regional economy (number of visitors, visitor expenditures, retail sales, employment, incomes, etc.)

— Residents when at home in the region.

— Property sales in the region (single-family homes, condominiums, second homes, time-share units, etc.).

— Values of properties in the region.

— County or State taxes derived from residents, resorts, or commercial activities in the region.

From a broader perspective, the Dairy will help maintain the existing rural character and ambience of the Kōloa-Po‘ipū region.

Hawai‘i Dairy Farms:
Socio-economic Conditions, Economic Impacts, and Fiscal Impacts

Part I: Introduction and Proposed Dairy

1. Introduction

a. Content and Purpose

In 2013, Ulupono Initiative funded Hawai‘i Dairy Farms (“**HDF**” or **“Dairy**”). The Dairy will be located in Kōloa, Kaua‘i.

This report addresses the socio-economic conditions on Kaua‘i and the Kōloa-Po‘ipū region, plus the economic and fiscal impacts of the Dairy. The purpose is to provide the community and State and County officials with relevant information about planned development and operations.

<u>Socio-economic conditions</u> includes information about the population, housing, incomes, education, economic activities, employment, labor force, and property values on Kaua‘i and in Kōloa-Po‘ipū.

<u>Economic impacts</u> cover sales and expenditures, profits, employment, and payroll related to (1) construction and related activities, and (2) full operations of the Dairy. Also covered is the impact of the Dairy on property values.

<u>Fiscal impacts</u> address the impact of the Dairy on County and State revenues and expenditures. The material covers the increase in County and State tax revenues, the increase in government support expenditures, and the resulting net revenues to the County and State.

b. Methodology

<u>Socio-economic Conditions</u>

Demographic data for this report was gathered from the U.S. Census Bureau. Data is presented for Kaua'i County and the Kōloa-Po'ipū Census Subdivision. Population counts are provided for 2000 and 2010 from the decennial census. Demographic, social, household and economic characteristics of the population were obtained from the 2000 decennial census and the American Community Survey (“**ACS**”) for 2009-2013. The ACS is an ongoing survey that provides up-to-date information about the nation’s population. The ACS includes questions that were not included in the 2010 decennial census (but, historically, were included in the 2000 census). The ACS releases data every year in the form of estimates. The most up-to-date available data from the ACS are five-year estimates from 2009-2013. In addition to providing population counts for 2000 and 2010, this report provides an analysis of population characteristics for 2000 and an estimate for the period covering 2009-2013.

Additional information on socio-economic conditions and projections for the County and Kōloa-Po'ipū was obtained from the County of Kauaʻi, State Department of Labor and Industrial Relations (**"DLIR")**, the Hawaii Tourism Authority, and the State Department of Business, Economic Development and Tourism.

Residential sales price data was obtained from Locations Hawaiʻi, while assessed property value information for individual properties located nearest to the proposed Dairy were gathered from RealQuest Professional, a private data service that compiles local real property tax data.

Economic and Fiscal Impacts

Multipliers

The proposed development and operations are translated into economic and fiscal impacts based on a number of multipliers (for example, indirect sales as a percentage of direct sales, construction jobs per $1 million in expenditures, indirect jobs per direct jobs, and tax rates). These multipliers reflect the professional judgment of the consultant, and were derived based on information from the following sources: U.S. Census data; the *State of Hawai'i Data Book; The Hawaiʻi State Input-Output Study: 2007 Benchmark Report* (I-O Model)*;* employment and labor rates from DLIR; County and State tax rates; and revenue and expenditure data from the County and the State.

2015 Dollars

For the economic and fiscal impacts (Part III), dollar amounts are expressed in terms of 2015 purchasing power and market conditions. Values, prices, costs and dollar amounts for prior years are adjusted for inflation to 2015 dollars based on the Honolulu Consumer Price Index (CPI) for Urban Consumers. Dollar amounts after 2015 are not increased to account for inflation, appreciation in property values, changes in labor rates, changes in building costs, or other changes in market conditions.

Accuracy of Estimates

Much of the analysis contained in this report is quantitative in nature, where numbers are used to help communicate anticipated impacts. However, these numbers should not be interpreted as precise predictions. Rather, they represent the best estimates of what is expected to occur based on available information about planned development and operations, market conditions, and tax rates. As a general rule, economic and fiscal impact estimates in this report are accurate within about 25%.

c. Organization of the Report

The report is divided into three Parts:

— Part I: Introduction and Proposed Dairy

— Part II: Socio-Economic Conditions

— Part III: Economic and Fiscal Impacts

All Figures in this report are embedded in the text, while all tables are at the end of the report. Socio-economic conditions for Kaua‘i and Kōloa-Po‘ipū are presented in Tables II-1 to II-9. Economic and fiscal impacts are presented in Tables III-1 to III-5: In these tables, the quantities appearing in **bold** highlight the most significant impacts.

d. Economic Consultant

The analysis was conducted by Plasch Econ Pacific LLC, a Hawai'i-based economic-consulting firm specializing in economic development, land and housing economics, feasibility studies, valuations, market analysis, public policy analysis, and the economic and fiscal impacts of projects.

2. DAIRY ACREAGE AND LOCATION

The Dairy will occupy about 557 acres in Māhā‘ulepū Valley in Kōloa, Kaua‘i (see Figure I-1). The Tax Map Keys (TMKs) for the property are: (4) 2-9-003:001 (portion), (4) 2-9-003:006 (portion), and (4) 2-9-001:001 (portion). The land is being leased from Māhā‘ulepū Farm, LLC.

This site was chosen for the Dairy for the following reasons:

— Kaua‘i Island was determined to best meet the operational requirements for the Dairy.

— Māhā‘ulepū Valley has ideal conditions for the Dairy, including favorable soils, high solar radiation, and other agronomic conditions for growing nutritious forage; a sufficient supply of water for cows and for irrigating pastures; minimally sloped terrain with few stones, allowing safe navigation by cows; sufficient contiguous land to support an economically viable pasture-based dairy; long-term availability of the land; and good access.

— The site is sufficiently removed from resorts, residential communities, and recreational areas so as to avoid potential nuisance impacts (noise, dust, odors, flies, runoff, etc.).

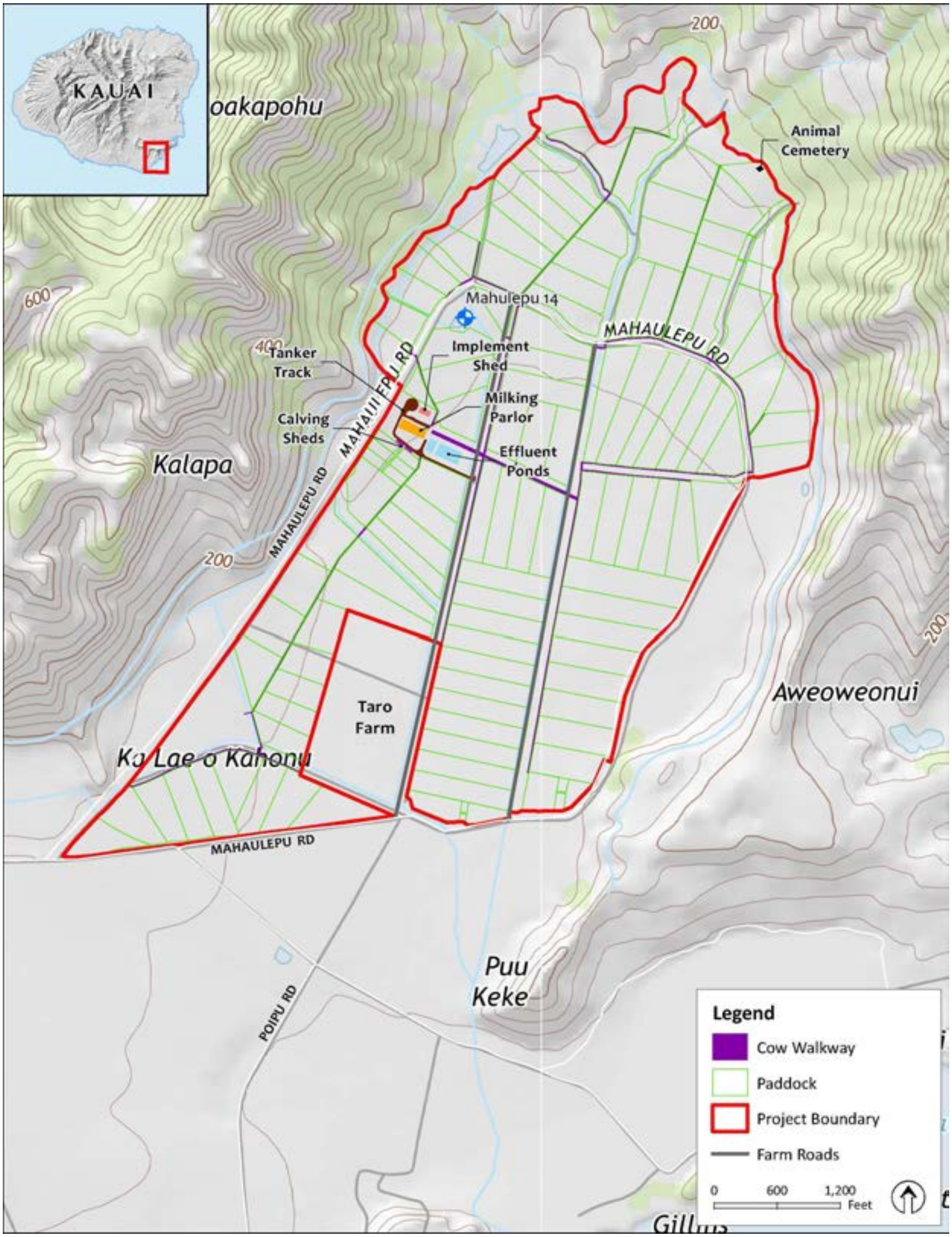

Figure I-1. Hawai'i Dairy Farms Map

Māhāʻulepū Valley has been used for commercial agriculture for over 140 years, notably for cultivating sugarcane as part of the Kōloa Plantation, then by McBryde Sugar Co. which ceased operations in 1996. Ranching began in the valley in 1986, and taro cultivation was introduced on an adjacent parcel in 2007.

In response to a petition by Māhāʻulepū Farm, the State Land Use Commission designated in 2011 about 1,533 acres in Māhāʻulepū as Important Agricultural Lands (“**IAL**”). This designation, which includes the Dairy site, ensures that the land will remain in agriculture for the foreseeable future.

3. PLANS FOR THE DAIRY

a. Contributions

Until 1984, a number of local dairies throughout Hawaiʻi produced all of the milk consumed in Hawaiʻi. But by 2008, most of them had closed due to the high cost of imported feed and competition from low-cost mainland milk imports. Currently, the two remaining dairies, both of which are located on the Big Island, supply only about 10% of the fresh milk consumed in Hawaiʻi, while imports supply about 90%.

The proposed Dairy will reverse this decline. It will increase the supply of local milk and thereby reduce imports, bolster food security for the islands with a sustainable supply of milk, and help diversify the economy.

b. Land Use

The 557-acre Dairy site will include: (1) about 10 acres for farm structures and related facilities; (2) about 470 acres for pastures; and (3) about 77 acres for cow raceways, internal roads, and setbacks along drainage ditches.

c. Rotational Pasture Grazing

The Dairy will be the first in Hawaiʻi to employ rotational pasture-grazing. A herd of up to 699 milking cows will be divided into six mobs, each of which will be rotated systematically through about 119 fenced paddocks to feed on locally grown pasture grass, supplemented with other feeds and vitamins as needed. Kikuyu grass was selected as the most productive and nutritious grass for rotational grazing. About every 12 to 18 hours, each mob of cows will be moved from one paddock to another in order to prevent overgrazing of the pastures within paddocks, and to allow the pastures to recover between grazings. This approach optimizes grass growth, cow health, and milk production; facilitates even deposits of manure for fertilization; and reduces erosion and runoff. The Dairy will use the most advanced dairy-farming techniques, including: (1) precision monitoring of the health of the cows and the productivity of the grass; (2) technology to determine the productivity of the land and, ultimately, its carrying capacity; (3) effluent management to ensure environmental health and safety; and (4) other best management practices.

In contrast to the Dairy's rotational pasture-grazing approach, traditional dairies enclose their milking cows in feed lots where the cows feed on grains, hay and/or silage. In Hawai'i, however, this approach requires farmers to import expensive feed for their animals. The alternative to importing feed is to produce it locally. This has been attempted many times over the past 40 or more years. Problems have included grain-eating birds; humidity that is too high to dry forage crops for hay; occasional high winds or heavy rains which damage feed crops; the high cost of harvesting, processing, and transporting grass to produce silage; etc. The rotational pasture-grazing approach eliminates many of these problems.

d. Cow Breed

The Dairy will use Kiwi-cross cows, which are a cross breed of Friesian-Holstein and Jersey milking cows. They are small in stature, bred to produce milk from grass, and their milk has a high butterfat and protein content, which allows for a wide variety of added-value dairy products such as yogurt and cheese.

e. Milking

The cows will be moved via a system of raceways (aka walkways) to the milking parlor where they will be milked twice a day. The milking will take place on a highly automated 60-stall rotary, which completes one rotation every 9 minutes or so. With this system, the maximum milking time is 10 minutes, and the maximum time off-pasture per milking is 1 hour.

f. Calves

Newborn calves will stay in single crates for up to 10 days, after which they will be transferred to pens that will hold 20 calves each. At age 3 to 4 weeks, calves will transition to pasture. At about 90 days of age, the calves will be transferred to another ranch (see next subsection).

g. Related Ranch Operations

Dry cows, heifers, and calves older than 90 days will be managed off-property on existing ranches that are owned and operated by other local ranchers.

h. Products

The Dairy will produce raw milk that will be sold in bulk to a dairy processor who will process and package the milk and related products for sale to consumers.

Additional revenues will be derived from the sale of female calves to other dairies, male calves for beef ranching, and culled cows and heifers for beef or dairy operations.

i. Reuse of Nutrients

Manure captured during the milking process will be transferred via underground pipes to two nearby effluent ponds (about 7,600 sq. ft. and about 20,500 sq. ft.), where solids will settle out and the remaining fluid stored for application to the pasture via the irrigation system. When applied to the pasture, this nutrient-rich fluid will be mixed with non-potable irrigation water.

The effluent ponds will be constructed within a secondary containment berm, and the ponds be lined with a flexible membrane of synthetic material.

j. Improvements

In converting former sugarcane fields to pastures, the existing infrastructure will be reused where possible. This will include gravel access roads, field roads, reservoirs, pipelines, irrigation ditches, drainage-ways and culverts. Field improvements will include a livestock water-distribution system, two pivot irrigation systems, cow raceways, perimeter and paddock fencing, and additional culverts.

Dairy buildings and related facilities will occupy approximately 10 acres along the western boundary of the farm. The milking parlor (about 22,700 sq. ft.) will be the largest structure on the property, and will include the rotary milking system, a covered milk loading area, holding pens, supplemental feeding facilities, a mechanical room, a pump room, office space, veterinary space and storage, staff restrooms, and containers for milk storage and cooling.

Two calf sheds (each about 2,100 sq. ft.) will provide safe housing for newly born calves. The sheds will have feeding and bedding areas, and one shed will have a milk kitchen and 30 single calf crates.

An implementation shed (about 1,700 sq. ft.) will provide space for storing equipment, tools and farm machinery. This shed will also include a workshop.

Additional improvements will include paved access roads, a paved turnaround area for milk tanker trucks, parking for employees, feed silos, milk storage tanks, a paved holding pen (about 12,300 sq. ft.) for mobs waiting to enter the milking parlor, effluent ponds for manure, a potable water system for both humans and cows, electrical power, communications, a septic system for waste disposal, and photovoltaic panels on roofs for solar power generation.

An existing on-site well will supply potable water, and Waitā Reservoir will supply non-potable irrigation water.

Equipment will include the milking system, tractors, trucks, other farm equipment, mobile tankers, refrigeration, heating, freight containers, office furniture and equipment, etc.

k. Future Plans

HDF is committed to demonstrating that the rotational pasture-grazing approach is an economically and environmentally sustainable model for Hawaiʻi. In the future, HDF may expand the herd to the maximum carrying capacity of the land—estimated by HDF to be up to 2,000 productive cows. Additional regulatory review and permitting would be required by the State Department of Health ("**DOH**") for 700 or more milking cows. The process for the additional approvals, including public notification and input, will be followed if and when HDF decides to pursue an expanded operation.

Eventually, a milk processing plant might be built in an existing industrial area on Kauaʻi or Oʻahu if warranted. The plant would produce finished milk packaged for consumers, and possibly some milk-related products (e.g., yogurt and cheeses).

PART II: SOCIO-ECONOMIC CONDITIONS

1. SOCIO-ECONOMIC CONDITIONS, KAUAI

Tables II-1 to II-9 summarize socio-economic conditions for Kauaʻi County, as well as Kōloa-Poʻipū which is discussed in the next section. Kauaʻi County includes two populated islands: Kaua'i and the small nearby island of Ni'ihau). The data reflect almost entirely the population and economy of the island of Kaua'i because the privately owned island of Ni'ihau contains only 0.3% of the County's population and supports an even smaller percentage of the County's economic activity.

a. Population

In 2010, Kaua'i County had a population of about 67,100 residents, up 14.8% since the 2000 U.S. census (see Table II-1). Residents include those who live full-time or permanently on Kauaʻi, and exclude visitors and part-time residents (i.e., those who reside most of the time in a primary home located elsewhere).

The total County population amounted to only 4.9% of the State population—the smallest of the four counties. Only 170 of the residents, primarily Native Hawaiians, lived on Ni'ihau.

Most Kaua'i residents live in towns around the perimeter of the island, primarily along the east and south shores, with smaller populations living in towns on the north shore. There are no towns on the northwest side of the island or in the mountainous interior.

b. Population Characteristics and Distribution

Kaua'i's population is racially diverse (see Table II-1). For the period spanning 2009 and 2013, Asians comprised 35.7% of the County's population, while people of two or more races made up 19.8% and Native Hawaiian and Other Pacific Islanders represented 9.9%. Kaua'i County has a slightly higher proportion of white residents compared to the State as a whole; 33.4% of County residents were white compared to 25.0% in the State as a whole. . Approximately 55.9% of Kaua'i County residents were born in Hawaiʻi

The median age of Kaua'i residents was 41.6 years old between 2009 and 2013. Consistent with national demographic trends, Kaua'i County's population is aging. In 2000, the median age was 38.4 years old.

c. Households

The average household size in Kaua'i County was 2.99 people per household between 2009 and 2013, a slight increase from 2.87 people per household in 2000 (see Table II-1).

Approximately 62.6% of Kaua'i households are homeowners—a percentage that has not changed significantly over the past decade.

d. Housing

Between 2009 and 2013, Kaua'i County had an estimated 29,972 housing units, up 18.3% from 2000 (see Table II-1). This figure includes resort/residential units that are used as second homes, or are available for visitors, or are vacant. Approximately 25.3% of housing units in the County were vacant, including 14.4% that were for seasonal, recreational, or occasional use. Kaua'i County has a higher proportion of vacant resort/ residential units compared to the State as a whole. Between 2009 and 2013, just 13.8% of housing units in Hawai'i were vacant, including 6.1% that were for seasonal, recreational, or occasional use.

e. Income and Education

Table II-2 provides information on income levels and education for the residents of Kaua'i. The median household income between 2009-2013 is estimated at $62,052—an increase of 37.8% since 2000. An estimated 11.2% of the County population was living below poverty level; 90.1% had a high school degree or higher; and 92.1% spoke English well or very well.

f. Primary Economic Activities

The principal economic driving forces for the economy of Kaua'i County are tourism, agriculture, and technology and defense. Table II-3 summarizes key economic characteristics for Kaua'i County.

Tourism

Kaua'i hosted over 1.11 million visitors in 2014, and visitor expenditures totaled approximately $1.47 billion, making tourism the dominant industry in the County. Visitors to Kaua'i in 2014 represented 13.6% of the State’s visitor arrivals by air, and 10% of Statewide visitor spending.

Figure II-1 presents the annual number of visitor arrivals to Kaua'i County since 2000. As shown, visitor arrivals have been on the rebound since 2009, when the County had less than 1 million visitor arrivals annually. Since that time, visitor arrivals increased steadily.

There were 8,582 visitor units on the island of Kaua'i in 2015, including 1,387 condominium hotel units, 2,667 hotel units, and 2,632 timeshare units (see Table II-4).

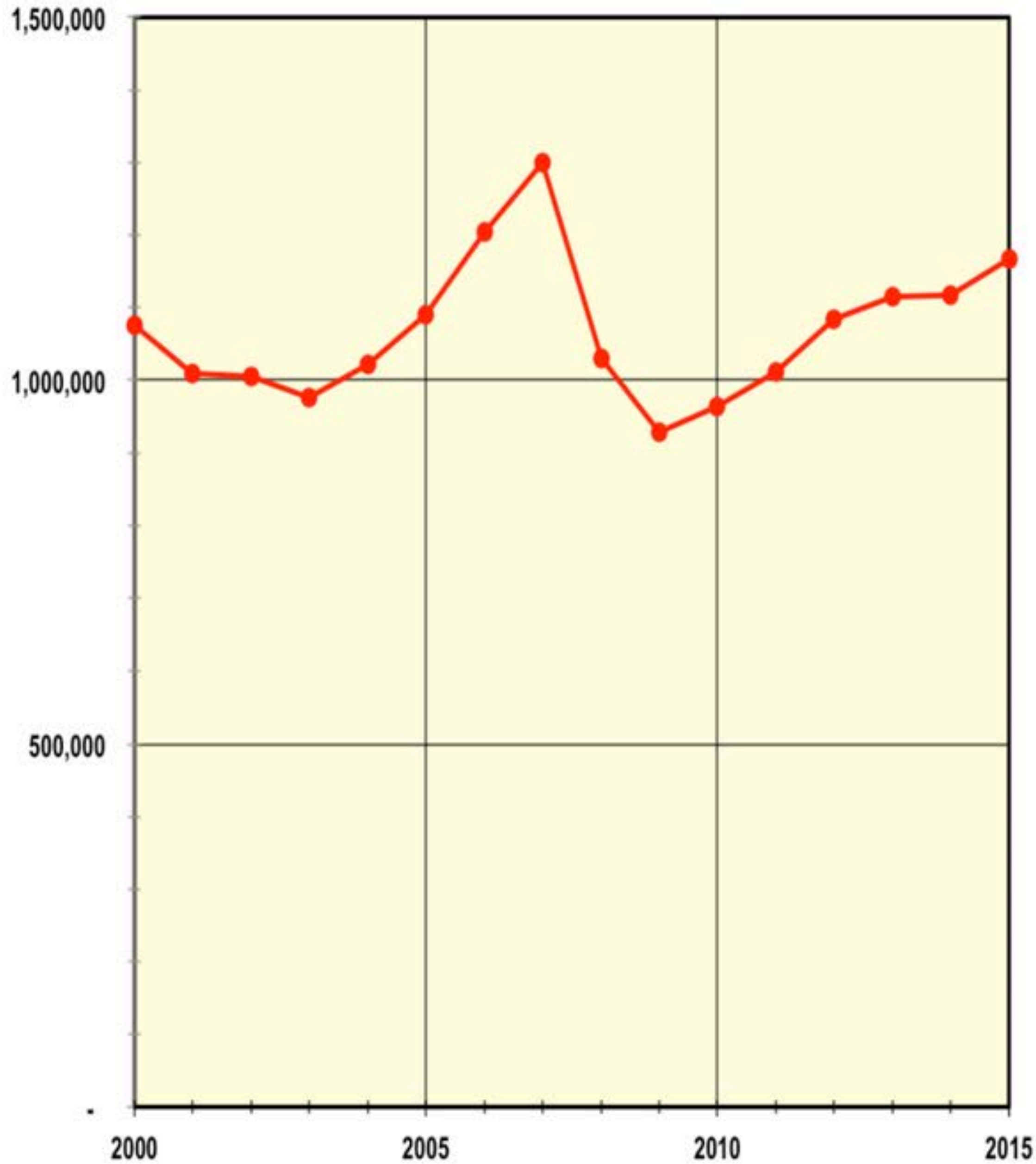

Figure II-1. Visitor Arrivals, Kaua‘i: 2000 to 2015

Defense and Technology

Located in the southwest corner of Kaua'i, the Pacific Missile Range Facility (PMRF) is the world's largest instrumented multi-environment range to support surface, subsurface, air and space operations. PMRF also provides fleet training for the U.S. Navy and the navies of allied nations and plays a significant role in the testing and evaluation of future systems, including the AEGIS ballistic missile defense system and upcoming THAAD (Terminal High Altitude Air Defense) system. Operations vary from small, single-unit exercises to large, multiple-unit battle-group scenarios. Also, the research and testing operations conducted at PMRF have spawned branch operations on Kaua'i of a number of high-technology companies.

PMRF is a major contributor to the economy of Kaua'i County, particularly on the west side of the island. PMRF is one of Kaua'i's largest employers with nearly 1,000 active duty Navy, government, civil service and contract civilians, and Hawai'i Air National Guard members. PMRF's prime contractor is ITT Services, with approximately 500 employees, providing base support as well as high-tech range safety and scheduling operations. Numerous other contractors, both on and off Kaua'i, are associated with PMRF.

Agriculture

For more than a century, sugarcane was the economic mainstay on Kaua'i. In 1980, about 53,600 acres were used for growing sugarcane (see Table II-5). However, the industry suffered major contractions starting in the 1980s, and the last sugar plantation on Kaua'i (Gay & Robinson, Inc.) closed in 2010.

Some of the former sugarcane fields are now used for diversified crops (crops other than the plantation crops of sugarcane and pineapple)—principally coffee (about 3,800 acres) and seed corn (about 13,300 acres). The seed companies reduced their use of land on Kaua‘i in 2015 by over 3,000 acres. Furthermore, they cultivate only about 25% of the land they use and fallow about 75%. Since 1980, the amount of land used for other diversified crops and intensive livestock operations (dairy, hog, and poultry) declined by nearly 500 acres and over 250 acres, respectively. Also, about 1,700 acres of farmland are now used for commercial forests, and about 13,000 additional acres are used for grazing cattle. Cattle grazing is a comparatively low-value use of farmland.

Finally, some of the former farmlands are now used for residential communities and other urban development.

Despite the contraction in the sugar industry, revenues from crops grown on Kaua'i increased from $42.4 million in 2000 to $74.6 million in 2008, the latest year data is available for the County. The increase in revenues can be attributed largely to seed operations. Revenues from livestock and aquaculture sales, however, declined from $6.0 million in 2000 to $3.3 million in 2008.

g. Labor Force and Employment

In 2014, Kaua'i County's civilian labor force numbered 34,600 workers, up 14.4% since 2000 (see Table II-3). Employed civilians totaled 42,950 workers. The unemployment rate in 2014 was 4.9%. Unemployment in the County fluctuated over the 14 years, peaking at 9.8% in 2009 when the national economy was in a recession. Since that time, the County's unemployment rate has gradually decreased each year as the economy recovered and the tourism industry strengthened.

There were 29,400 jobs in Kaua'i County in 2014, an increase of 10.7% from 2000. The leisure and hospitality industry represents the largest proportion of jobs in the County, accounting for 9,300 jobs or 31.6% of countywide jobs. Other industries comprising a large portion of jobs in the County include: Trade, transportation & utilities (5,800 jobs, 19.7%), government (4,600 jobs, 15.6%), professional and business services (2,800 jobs, 9.5%), and educational & health services (2,700 jobs, 9.2%).

Table II-6 also includes job counts for Kauaʻi, but for 2011. This table also includes counts for Kōloa-Poʻipū which is discussed in the next section.

h. Home Prices

Table II-7 presents home sales prices for 2013 to 2015. The median sales price for single-family homes on Kauai in 2015 was $615,000, 15.4% higher than the median price in 2014. Condominium sales prices have also trended upwards in 2015. The median sales price for condominiums on Kauai was $365,000, a 5.5% increase over the 2014 median price.

i. Projected Growth

As part of the Kauaʻi General Plan Update, consultants for the County of Kauaʻi Planning Department prepared socio-economic forecasts for the County. Table II-9 summarizes past growth for the 10-year period from 2000 to 2010, and future projected growth for the 20-year period from 2010 to 2030. Continuation of growth at about the same average rate would result in a percentage change for the future 20-year period that is about double that of the past 10-year period.

As shown, Kauaʻi's resident population is projected to grow from about 67,100 residents in 2010 to about 83,300 residents 2020. This reflects a slight deceleration of growth: from about 14.8% over the past 10 year period to about 24.2% for the future 20-year period. Consistent with this projection, slower growth is projected in the number of households on Kauaʻi as well as the number of housing units.

Kauaʻi's average visitor census is expected to grow to from about 19,500 visitors in 2010 to about 25,700 visitors in 2030. This reflects an acceleration of growth: from about 8.4% over the past 10-year period to about 31.7% for the future 20-year period. Correspondingly, faster growth is projected for the *de facto* population (residents plus visitors less absent residents), wage and salary jobs (largely tied to tourism growth), and the number of visitors arriving by air. In spite of faster growth in the number of visitors on Kauaʻi, slower growth is projected in the number of visitor units on the island: that number is projected to increase 20.2% from 9,345 units in 2010 to 11,230 units in 2030. For the previous 10-year period, the increase was 30.5%.

2. SOCIO-ECONOMIC SETTING, KŌLOA-POʻIPŪ

The proposed Hawai'i Dairy Farm is located within the Kōloa-Po'ipū District (defined as the Kōloa-Po'ipū Census Subdivision as shown in Figure II-2). This district includes the coastal communities of Po'ipū and Kukui'ula.

a. Population and Distribution

In 2010, the Kōloa-Po'ipū District had a resident population of approximately 5,700, or 8.4% of the County population. The population in Kōloa-Po'ipū grew at a slower rate than the County as a whole, increasing by 5.2% from 5,400 residents in 2000. During the previous decade, the male population declined by 1.4% while the female population increased 20.9% (See Table II-1). Evidently, many males left due to more attractive opportunities elsewhere.

Similar to Kaua'i County as a whole, the resident population of the Kōloa-Poʻipū region is racially diverse. Between 2009 and 2013, white residents comprised a slightly higher proportion of the Kōloa-Po'ipū population compared to the County as a whole; 42.1% of residents were white compared to 33.4% of residents in the County (Table II-1). A slightly lower proportion of the Kōloa-Po'ipū population was born in the State of Hawaiʻi; an estimated 51.6% of the region's population was native born to the State compared to 55.9% for the County as a whole.

The resident profile of the Kōloa-Po'ipū region is slightly older than that of Kaua'i County. The median age in Kōloa-Po'ipū was 44.8 years old between 2009 and 2013, compared to 41.6 years old in the County. The Kōloa-Po'ipū region is characterized by a higher proportion of retirement age residents (65 years and older) and a lower proportion of school age children.

b. Households

The average household size in the Kōloa-Poʻipū region was 2.68 people per household between 2009 and 2013—a decrease from 2.71 people per household in 2000 (Table II-1). On average, households in Kōloa-Po'ipū are smaller than households in the County as a whole (2.99 people per household between 2009 and 2013). The smaller household size combined with the higher median age in Kōloa-Po'ipū is indicative of a higher proportion of older residents and households without children.

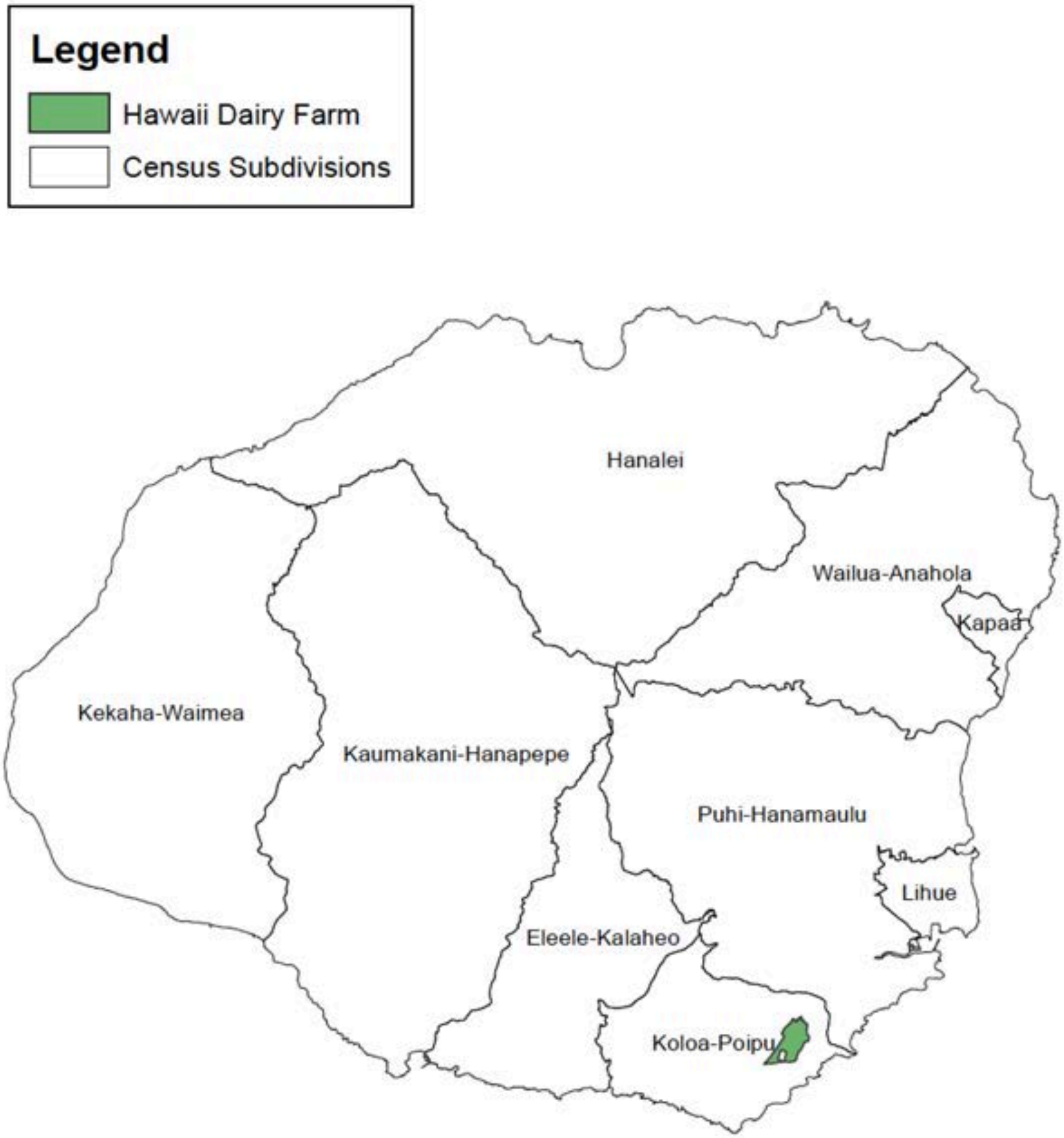

Figure II-2. Kōloa-Poʻipū Census Subdivision

c. Housing

Between 2009 and 2013, the Kōloa-Po‘ipū region had an estimated 3,704 housing units—an increase of approximately 3.1% since 2000 (Table II-1). Consistent with the population growth parameters, the region experienced a slower housing unit growth rate than the County, where the number of housing units increased by 18.3% during the same time period. Kōloa-Po'ipū has a higher proportion of vacant housing units than Kaua'i County as a whole due to the number of second homes. Approximately 36.8% of housing units were vacant for seasonal, recreational, or occasional use between 2009 and 2013 in Kōloa-Po'ipū, compared to 14.4% Kaua'i County.

d. Income and Education

The median household income in Kōloa-Po'ipū between 2009 and 2013 was estimated at $62,083, similar to the County as a whole (Table II-2). However, Kōloa-Po'ipū has a higher per-capita income and a lower proportion of residents living in poverty. An estimated 7.5% of residents were living in poverty in the region, compared to 11.2% for the County. A slightly higher proportion of residents in Kōloa-Po'ipū completed some secondary education compared to the County as a whole. An estimated 66.7% of Kōloa-Po'ipū residents attended some college or received a higher education degree, compared to 61.1% of County residents.

e. Primary Economic Activities

As with Kaua'i County, the primary economic activities in the Kōloa-Po'ipū District are tourism and, to a much lesser extent, agriculture. Defense is not a primary economic activity in the Kōloa-Po'ipū District since it has no military installations.

<u>Tourism</u>

The largest share of visitor units on Kaua'i is located in the Po'ipū/Kukui'ula area. Of the 8,582 visitor units on Kaua‘i, 3,058 (36%) units were located in Po'ipū/Kukui'ula (Table II-4). Hotels in the area include the Grand Hyatt Kaua'i Resort & Spa, Koa Kea Hotel & Resort, and the Sheraton Kaua'i Resort. The Grand Hyatt Kaua'i Resort & Spa is the closest hotel to the proposed Dairy—about 2.4 miles from the Dairy facilities. This resort provides 602 visitor units, and is the largest employer on Kaua'i—in 2014, it employed 941 workers.

Major timeshare properties in Po'ipū/Kukui'ula include the Lawai Beach Resort, Marriott Waiohai Beach Club, Nihi Kai Villas, and The Point at Po'ipū. There are also 11 condominium hotel properties in Po'ipū/Kukui'ula providing 608 units.

Agriculture

Hawai'i's sugar industry began in Kōloa in 1835, and sugarcane cultivation continued in the district until 1996 when the last plantation (McBryde Sugar Co.) finally ceased operations.

Of the 12,000+ acres that were planted in sugarcane, some of it has been or will be urbanized (e.g., the Kukui'ula development); about 3,100 acres are planted in coffee (most of which is in the adjacent region of 'Ele'ele-Kalāheo); about 1,200 acres were in seed corn until 2015; about 1,200 acres are in commercial forest; and some is in other diversified crops (vegetables, tropical fruits, taro, flowers). Most of the remainder is used for low-value cattle grazing or is fallow. Figure II-3 shows agricultural activities in Kōloa and Po'ipū in 2015.

f. Labor Force and Employment

As noted above, tourism is the primary industry in the Kōloa-Po'ipū region. This is reflected in the employment distribution. In 2011—the most recent year jobs data is available at the Census Subdivision level—there were 3,752 jobs in Kōloa-Po'ipū (see Table II-6). This accounted for 13.2% of the 28,300 County-wide jobs in 2011. The leisure and hospitality industry accounted for the vast majority of jobs in Kōloa-Po'ipū at 69.8%. In comparison, leisure and hospitality jobs represented 29.3% of total countywide jobs during the same year. Trade, transportation & utilities jobs represented another 12.2% of jobs in Kōloa-Po'ipū.

g. Home Prices

Sales prices for homes in Kōloa-Po'ipū are significantly higher than County-wide prices. In 2015, the median sales price for single-family homes in Kōloa-Po'ipū was $1,070,000, compared to $615,000 County-wide. The median sales price for condominium units was $425,000 in Kōloa-Po'ipū compared to $365,000 County-wide.

Home prices for Kōloa-Po'ipū can be monitored over time to verify that the Dairy will not adversely impact prices—see Part III, Section 7.

h. Assessed Property Values

Figure II-4 shows distances of various properties and designated areas in Kōloa and Po'ipū that are closest to the Dairy. An analysis of the County's 2016 assessed property values for those properties and areas is summarized in Figure II-5 and in Table II-8. Assessed property values (land and improvements) are the County's estimates of market values.

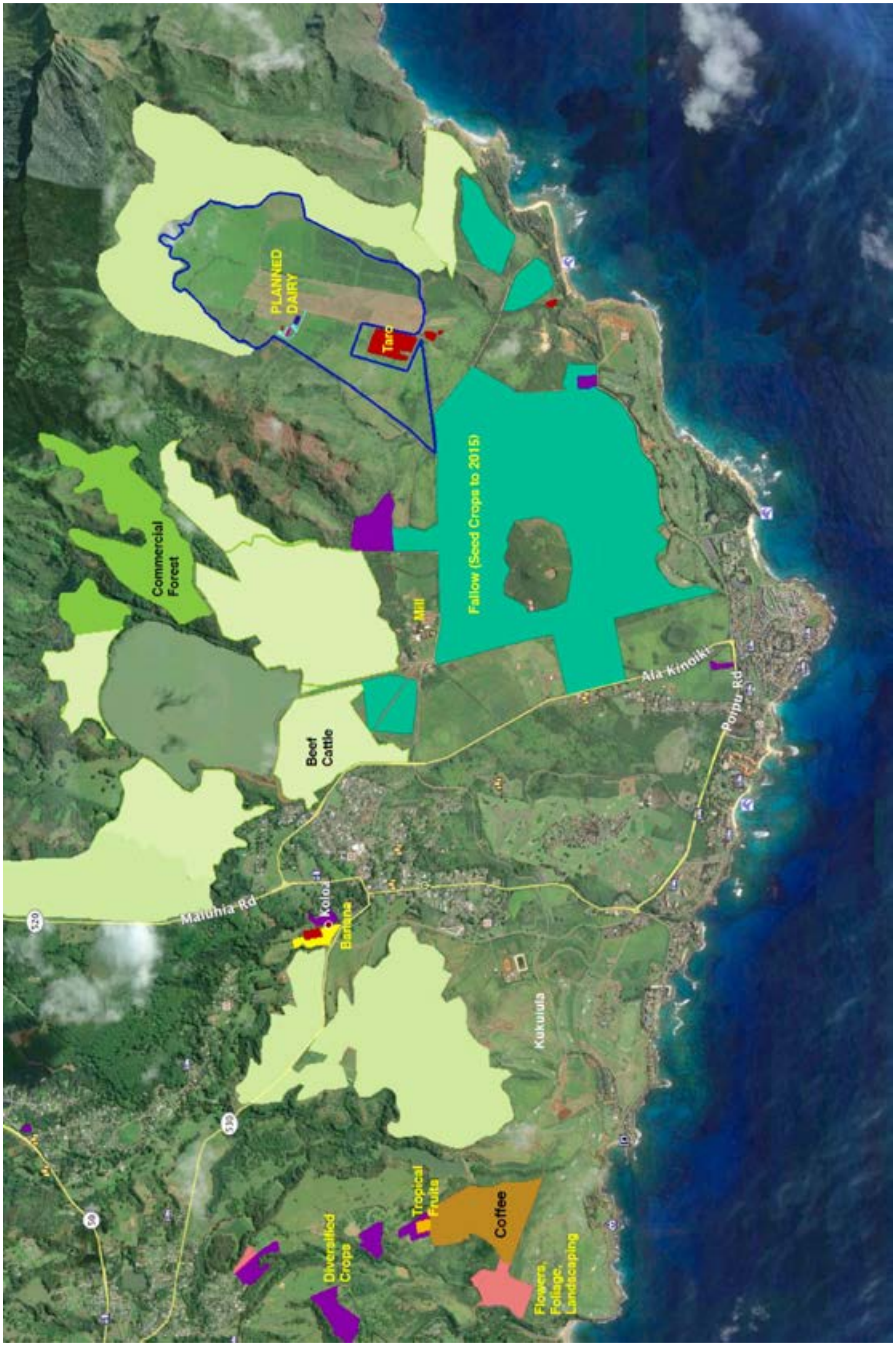

Figure II-3. Agricultural Activities in Kōloa-Poʻipū: 2015

For specified properties and designated areas, Figure II-5 includes: the distance to the nearest pasture, the distance to the Dairy facilities, and the assessed values for vacant and developed properties. For designated areas with multiple properties, median values are shown. Table II-8 lists assessed values by: designated area, TMK, type of property, lot acreage, the year a home on the property was built, square footage, number of bedrooms, and number of bathrooms. For designated areas with multiple properties, median values are shown for vacant and developed properties.

Seven residential and agricultural areas and four resort properties were identified as being the closest to the proposed Dairy. In 2016 the Grand Hyatt Kauai had an assessed value of $212.8 million while the neighboring Poipu Bay Golf Course was valued at $16.3 million.

As shown in Figure II-3, many of the homes in the region are also close to existing beef-cattle operations. The values shown in Figure II-5 and Table II-8 apply also to properties near grazing operations. In addition, Figure II-6 and Table II-8 show values of select properties on the west side of Kōloa nearest grazing operations.

The properties listed in Table II-8 can be monitored over time to verify that the Dairy will not adversely impact property values—see Part III, Section 7. Ideally, just land values should be tracked since property values can change significantly with changes in the improvements on a parcel. However, for each property, Kaua‘i County combines land and improvement values into a single value—other counties separate the two.

i. Projected Growth

The socio-economic projections prepared for the County also include projections by District Planning Areas. The one that includes Kōloa and Po‘ipū is the Kōloa-Po‘ipū-Kalāheo District. In Figure II-2, this District includes the areas labeled (1) Kōloa-Po‘ipū and (2) the adjoining ‘Ele‘ele-Kalāheo.

In addition to the projections for the County, Table II-9 also summarizes the projections for the combined areas of Kōloa-Po‘ipū and ‘Ele‘ele-Kalāheo. For the most part, this Planning District is projected to grow at about the same rate or faster than that of the entire County. However, slightly slower growth is projected for the average visitor census, wage and salary jobs, and the number of visitor units.

Figure II-4. Hawai‘i Dairy Farm and Nearby Properties

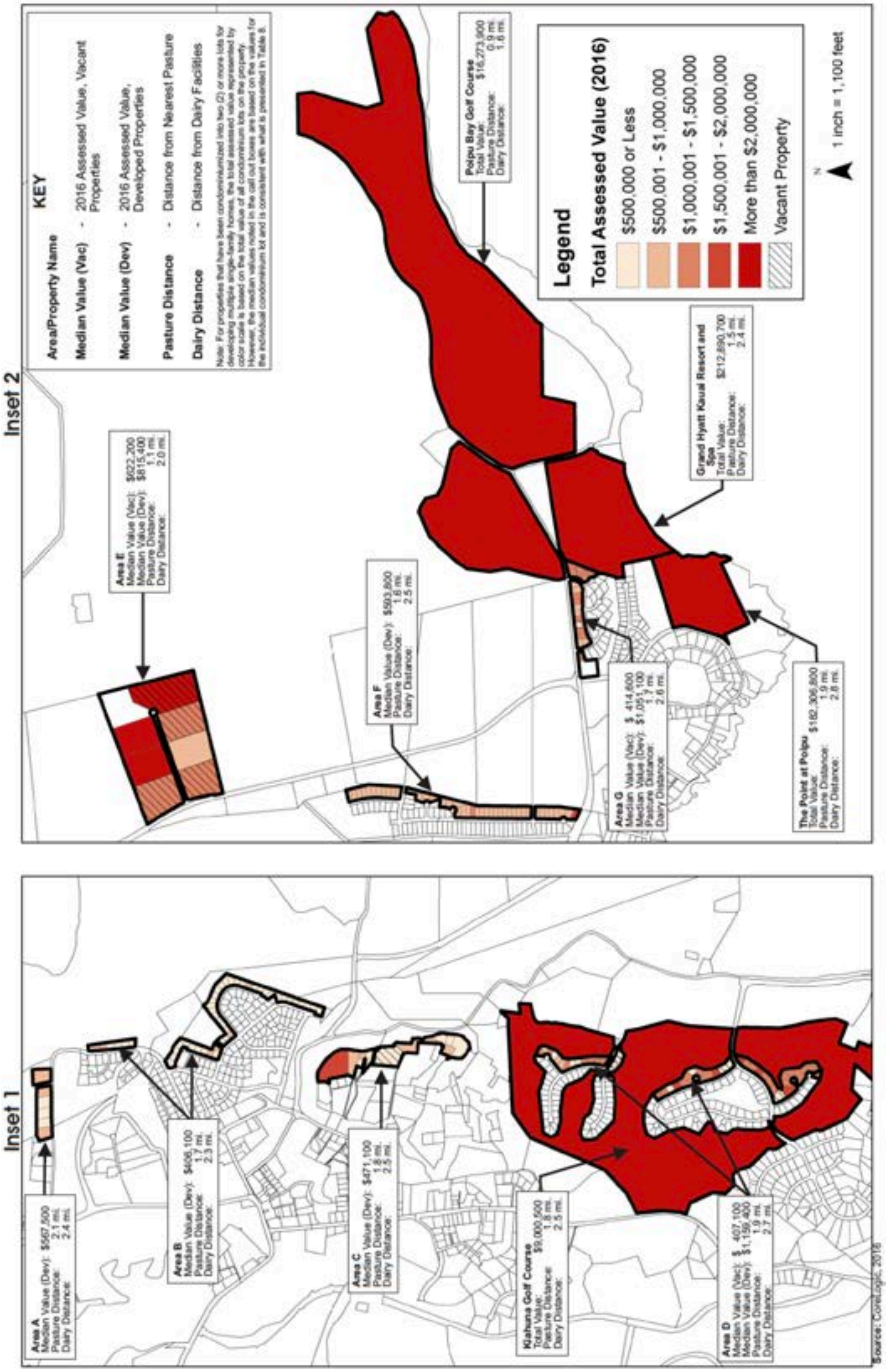

Figure II-5. Assessed Values of Nearby Properties: 2016
(Assessed values from Table II-8)

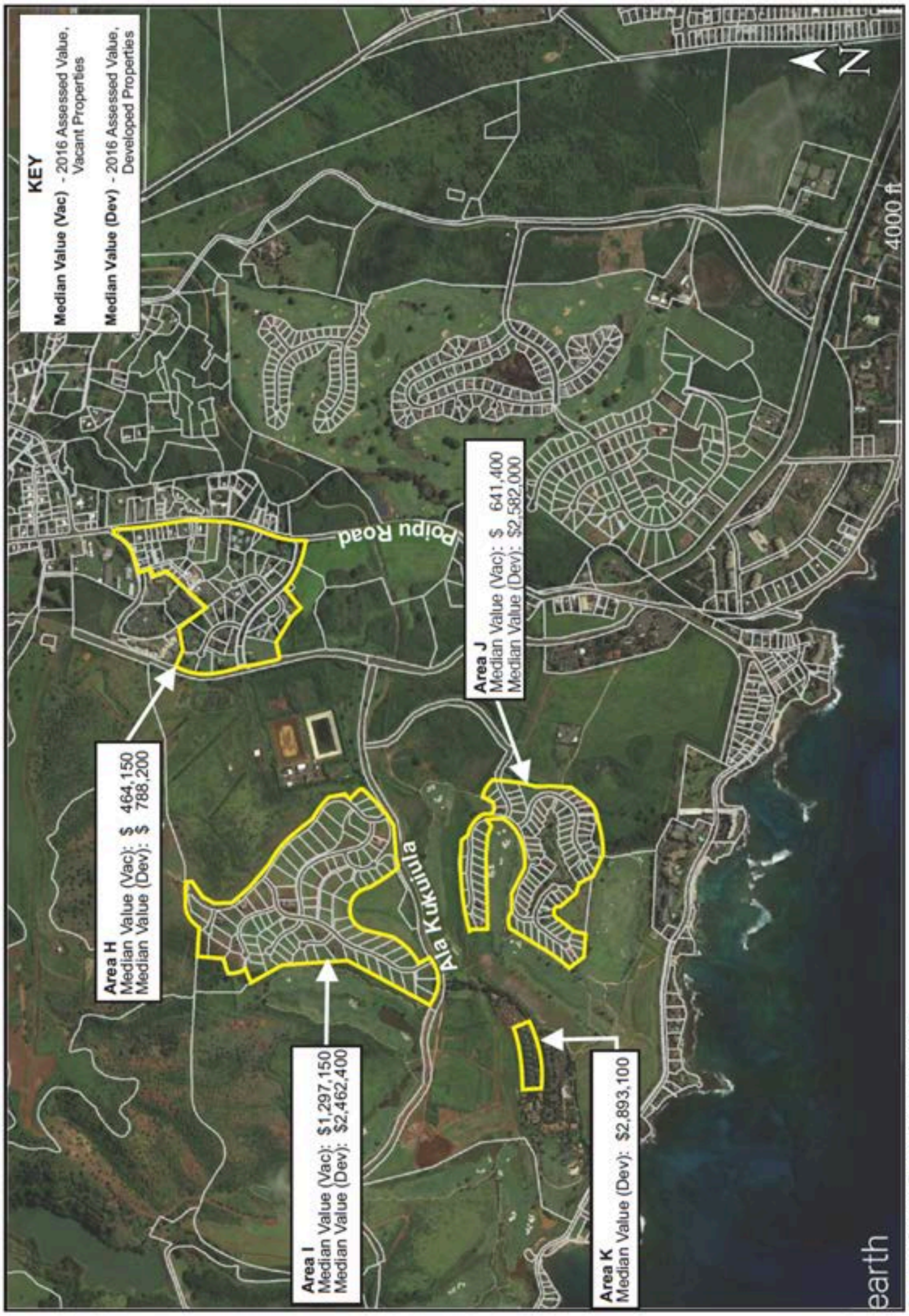

Figure II-6. Assessed Values of Other Properties: 2016
(Assessed values from Table II-8)

PART III: ECONOMIC AND FISCAL IMPACTS

1. PLANS FOR THE DAIRY

Plans for the Dairy are summarized in Part I, Section 3 as well as in Table III-1. This table provides information on the Initial Dairy (up to 699 mature milking cows), a Potential Increase in the size of the Dairy (an additional 1,301 milking cow) sometime in the future, and the Potential Dairy (up to 2,000 mature milking cows).

As indicated, both the Initial Dairy and the Potential Dairy will cover about 557 acres, including (1) about 10 acres for farm structures and related facilities; (2) about 470 acres for pastures; and (3) about 77 acres for cow raceways, internal roads, and setbacks along drainage ditches.

The cows will be grouped into 6 mobs, and the pasture will be divided into about 119 fenced paddocks ranging in size from 3 to 5 acres.

This table also list the farm improvements for (1) the pasture, (2) farm structures and related improvements, and (2) major dairy equipment.

2. ECONOMIC IMPACTS OF DEVELOPMENT ACTIVITIES

The development of the Dairy will involve installing perimeter and paddock fencing, building cow raceways and internal roads, installing an irrigation system, installing a potable water system, preparing sites for buildings, constructing buildings, installing an effluent system, installing equipment, etc. Table III-2 summarizes the direct and indirect economic impacts of these development activities. The material in the table gives the development period, construction expenditures, indirect sales generated by the construction activity, profits, employment and payroll, and the number of residents and houses supported by the development activities.

a. Development Period

As indicated in Section 2.a of Table III-2, the assumed development period is about 2 years. However, development could require more or less time, depending on future market conditions and property sales.

b. Construction Expenditures

Over the 2-year development period, total construction expenditures for the Dairy are estimated at about $7.5 million, plus or minus $1.5 million (see Section 2.b of Table III-2). This translates into average construction expenditures of about $3.75 million per year. In practice, construction expenditures will vary from year to year.

c. Equipment Expenditures

Total equipment expenditures for the Dairy are estimated at about $2 million, plus or minus $0.5 million, or about $1 million per year over the development period (see Section 2.c of Table III-2).

d. Indirect Sales Generated by Construction Activity

In addition to construction expenditures, development activities will generate indirect sales associated with supplying goods and services to construction companies and to the families of their construction workers. In turn, the companies supplying goods and services, and the families of their employees, will purchase goods and services from other companies, and so on. These indirect sales will include sales by companies supplying building materials (fencing, cement, steel, lumber, roofing materials, plumbing equipment, electrical equipment, hardware supplies, lighting, flooring, etc.); rental of construction equipment; equipment repair; warehousing services; shipping and trucking services; etc. Indirect sales also include sales by grocery stores, drug stores, restaurants, service stations, beauty salons, medical providers, accountants, attorneys, insurance agents, etc.

Based on State economic multipliers, these indirect sales are expected to average about $4.4 million per year, of which about $2.9 million will be on Kaua‘i and about $1.5 million on O`ahu (see Section 2.d of Table III-2.).

e. Summary of Expenditures and Sales

Section 2.e of Table III-2 summarizes anticipated expenditures and sales. As indicated, construction expenditures, equipment expenditures, indirect sales related to construction, are expected to average about $9.1 million per year. About $5.7 million per year will be subject to the State 4% excise tax on final sales, while about $3.4 million per year will be subject to the 0.5% excise tax on intermediate sales.

f. Profits

Profits on direct and indirect sales generated by construction of the Dairy are estimated at about $1 million per year (see Section 2.f of Table III-2). This includes estimated profits of: construction companies, subcontractors, the companies supplying goods and services in support of construction activity and to the families of workers, etc.

g. Employment

During the 2-year development period, construction employment is expected to average about 12 jobs (see Section 2.g of Table III-2). These jobs will include supervisors, equipment operators (grading, roads, etc.), cement workers to lay foundations, metal workers, carpenters, plumbers, electricians, roofers, glass and window installers, painters, equipment installers, etc. Other jobs related to construction will include architects, civil engineers, draftsmen, government inspectors, etc. These jobs will range over a variety of skill levels, including entry-level, semiskilled, skilled, management, and professional positions.

As with indirect sales, development activities will generate indirect jobs associated with supplying goods and services to construction companies and to the families of construction workers. In turn, the companies supplying goods and services, and the families of their employees, will purchase goods and services from other companies, and so on. Indirect jobs will include those at companies supplying building materials (fencing, cement, steel, lumber, roofing materials, plumbing equipment, electrical equipment, hardware supplies, lighting, flooring, etc.); rental of construction equipment; equipment repair; warehousing services; shipping and trucking services; etc. Other indirect jobs will include those involved with supplying goods and services to employees and their families: grocery workers, store clerks, restaurant workers, service-station workers, beauty technicians, barbers, bankers, pharmacists, veterinarians, computer technicians, medical workers, accountants attorneys, etc. The jobs will range over a variety of skill levels, including entry-level, semi-skilled, skilled, and management positions.

Based on State employment multipliers, indirect employment related to Dairy development is expected to average about 16 jobs on Kaua‘i and 8 on O`ahu.

Thus, total direct-plus-indirect employment associated with Dairy development activities will average about 36 jobs, of which about 28 jobs will be on Kaua‘i.

h. Payroll

Development activities are expected to generate a total annual payroll of about $1.7 million per year for the Dairy, of which about $640,000 million will be for construction workers, about $690,000 for indirect employment on Kaua‘i, and about $390,000 for indirect employment on O`ahu (see Section 2.h of Table III-2). These estimates are based on the average number of direct and indirect jobs multiplied by average wages as reported to the DLIR.

Wages will range from less than $30,000 annually to over $100,000, and are expected to average about $53,500 per year for construction jobs, about $42,900 for indirect jobs on Kaua‘i, and about $48,500 for indirect jobs on O'ahu.

i. Sources and Training of Construction Workers

As noted above, construction employment is expected to average about 12 jobs during the 2-year development period. This is about 0.8% of the County’s 1,540 construction jobs in 2014 (DLIR). In view of this small percentage, it is expected that the construction jobs for the Dairy will be filled by workers already living on Kaua‘i. As other construction projects are completed on the island, Kaua‘i construction workers will be hired to work on the various components of the Dairy infrastructure and buildings, and then move on to other projects. Thus, the Dairy will help keep a small number of Kaua‘i’s existing construction workers employed.

Special programs to train additional construction workers on Kaua‘i appear to be unwarranted since a sufficient number of workers are already available.

j. Supported Population and Housing

During the 2-year development period, direct and indirect jobs provided by Dairy construction will support about 79 residents housed in about 26 homes (see Sections 2.i and 2.j of Table III-2). Most of the residents supported by the direct-plus-indirect jobs are expected to live on Kaua‘i: about 63 of them housed in about 21 homes.

3. ECONOMIC IMPACTS AT FULL OPERATIONS

Table III-3 summarizes the estimated economic impacts of the Dairy at full steady-state operations achieved after about 5 to 10 years. Included are estimated milk production direct and indirect sales, profits, direct and indirect employment, payroll, and population and housing supported by Dairy operations.

a. Milking Cows

The economic impacts are estimated for two scenarios: the Initial Dairy of 699 milking cows, and a Potential Dairy of 2,000 milking cows (see Section 3.a of Table III-3).

b. Production

Raw Milk

The Dairy will increase Hawai‘i’s milk self-sufficiency and reduce fluid milk imports. At full operations with 699 cows, the Dairy will produce about 1.5 million gallons of raw milk per year, and will produce about 4.4 million gallons with 2,000 cows (see Table III-3, Section 3.a). This compares to about 4 million gallons produced in Hawai‘i in 2015. Production was down from a peak of about 18.3 million gallons in 1988 when Hawai‘i dairies supplied nearly all of the milk consumed in the state.

Livestock

In addition, the Dairy will increase the supply of livestock, including female calves for other dairies, male calves for beef ranching, and culled cows and heifers for beef or dairy operations.

c. Sales

At full operations of the 699-cow Dairy, annual direct-plus-indirect milk sales are estimated at about $10.1 million, of which about $8.1 million will be on Kaua‘i and about $2 million on O`ahu (see Table III-3, Section 3.c).

Should HDF decide, in the future, to expand the herd up to 2,000 cow, annual sales are estimated as follows: about $23.3 million in direct and indirect sales on Kaua‘i, and about $5.7 million in indirect sales on O`ahu, for a total of about $29 million.

d. Profits

At full operations, profits on direct and indirect sales are estimated at about $1 million per year for the 699-cow Dairy, and $2.9 million per year for the 2,000-cow Dairy (see Table III-3, Section 3.d). This includes estimated profits of: the Dairy, its subcontractors, companies supplying goods and services to the Dairy and to the families of Dairy workers, etc.

e. Employment

At full operations, the 699-cow Dairy will provide about 11 jobs on Kaua‘i, including about 5 farm jobs and about 6 indirect jobs (see Table III-3, Section 3.e). About 3 indirect jobs will be on O‘ahu. Thus, the Dairy will generate about 14 direct-plus-indirect jobs. Corresponding employment figures for the 2,000-cow Dairy are about double.

Dairy employment will include a farm manager, a marketing/community relations person, supervisors, and skilled and semi-skilled workers.

The employment figures are relatively low because the Dairy will be a modern facility with labor-savings devices which are needed to achieve profitable operations.

f. Payroll

Section 3.f of Table III-3 addresses payroll at full operations of the Dairy, although estimates are not shown in order to avoid disclosure.

For the Dairy jobs, annual salaries and wages will be competitive, and are expected to range from less than $40,000 to $115,000 or more. Because of the skill requirements for a modern dairy, the average wage for the Dairy is expected to exceed County-wide and State-wide averages. For the indirect jobs, wages will range from less than $30,000 annually to over $100,000.

g. Sources and Training of Farm Workers

As noted above, farm employment is expected to be relatively small: about 5 jobs for the 699-cow Dairy at full operations, and about 10 jobs for a 2000-cow operation. It is expected that most workers will be recruited from Kaua‘i. New workers will be trained by the Dairy.

h. Supported Population and Housing

At full operations, the 699-cow Dairy will provide about 31 direct-plus-indirect jobs for Hawaiʻi residents who will live in about 11 homes (see Sections 3.g and 3.h of Table III-3). It is expected, that most of the workers will be Kauaʻi residents (about 25 residents in 9 homes). Corresponding figures for a 2,000-cow Dairy are about twice those of the 699-cow operation.

4. IMPACTS ON COUNTY REVENUES AND EXPENDITURES

The impact of the Dairy on County revenues and expenditures is shown in Table III-4. This table summarizes: (1) changes in the County's tax and expenditure base, which is used to calculate revenues and expenditures; (2) revenues and expenditures related to Dairy development activities; and (3) revenues and expenditures related to full operations of the Dairy.

a. Development Activities

As shown in Table III-4, Section 4.b, development of the Dairy will result in a negligible impact on County finances. Unlike the State, County taxes on development activity are insignificant. Furthermore, the developer (not the County) will provide the required infrastructure: water, interior roads, waste disposal, drainage, etc. Also, construction companies provide their own security, sanitation, transportation, etc. Thus, few on-site services will be required from the County. And for the most part, construction workers already pay various County taxes, and already receive various County services.

b. Operations at Full Development

At full operations, the Dairy is expected to generate a net income to the County of about $51,000 for both the 699-cow Dairy and the 2,000-cow Dairy (see Table III-4, Section 4.c.). Most of the taxes will derive from property taxes on improvements. County property taxes on land—which are low when dedicated to agriculture—are already being paid, and are not expected to change significantly.

The Dairy will pay a variety of minor taxes and fees to the County (e.g., fuel and vehicle taxes), while requiring few County services.

Dairy workers and their families will pay a variety of taxes to the County, and will require County services. For these workers and families, the resulting net revenues are expected to be near zero but positive since the County budget is structured to break even and, on a per-capita basis, most Dairy workers will pay higher than average taxes since they will earn higher than average wages.

5. IMPACTS ON STATE REVENUES AND EXPENDITURES

The impact of the Dairy on State revenues and expenditures is shown in Table III-5. This table summarizes: (1) changes in the State's tax and expenditure base which is used to calculate revenues and expenditures; (2) revenues and expenditures related to development activities; and (3) revenues and expenditures related to full operations of the Dairy.

a. Development Activities

Unlike the County, the State will derive significant revenues from development activity: a cumulative total of about $650,000 for both the 699-cow Dairy and the 2,000-cow Dairy (see Table III-5, Section 5.b). However, the revenues will be offset by the $1 million tax credit for improvements on land designated by the State Land Use Commission as Important Agricultural Lands.

Other than the IAL tax credit, State expenditures to support the development of the Dairy are expected to be negligible. As mentioned previously, HDF will provide the infrastructure for the Dairy. Also, construction activities require few on-site services from the State. And for the most part, construction workers already pay various State taxes, and already receive various State services.

b. Operations at Full Development

At full operations, the Dairy is expected to generate net income to the State that will exceed $60,000 per year for the 699-cow Dairy. Should HDF decide, in the future, to expand to a 2,000 cow Dairy, net income to the State would exceed $170,000 per year (see Table III-5, Section 5.c). Most of the revenues will derive from excise taxes on sales.

Similar to that for the County, the Dairy will pay a variety of minor taxes and fees to the State, while requiring few State services.

Also, Dairy workers and their families will pay a variety of taxes to the State, and will require State services. For these workers and families, the resulting net revenues are expected to be near zero but positive, since the State budget is structured to break even and, on a per-capita basis, most Dairy workers will pay higher than average taxes since they will earn higher than average wages.

6. OTHER BENEFITS

a. Open Space

The Dairy's irrigated pastures will provide about 470 acres of well-maintained grassland divided into 119 fenced paddocks. The herd will be split into 6 groups, each of which will be rotated among the paddocks. Thus, at any given time, about 5% of the pasture land will be occupied by cows (6 of 119 paddocks), and about 95% will be unoccupied green open space. In addition, about 77 acres will be used for cow raceways, internal roads, and setbacks along drainage ditches.

b. Potential Educational Tours

Although not currently planned, potential exists to add educational tours of the Dairy for school children, residents and visitors. This would provide an interesting learning experience about raw milk production, and possibly offer an additional activity for visitors to Kauaʻi. However, some additional building improvements would be required to accommodate tour groups.

7. NUISANCE ISSUES AND IMPACTS

Given the important economic, residential, and recreational role of the Kōloa-Poʻipū region, the Dairy must be compatible with, and not cause adverse impacts on regional resorts, commercial areas, homes, recreational activities, etc. If nuisance impacts were to occur—which is not expected—it could result in reduced tourism, sales, employment, salaries and wages, property values, personal wealth, State and County tax revenues, enjoyment of homes and recreational activities, etc. As mentioned previously, 36% of the island's visitor units are in Po'ipū and Kukui'ula, including the Grand Hyatt Kaua'i Resort & Spa which is the largest employer in the County. Nuisance impacts on the economy, including property values, are addressed below.

a. Impacts of Concentrated Animal Feeding Operations on Property Values

A number of mainland studies have addressed the impact of large concentrated animal feeding operations ("**CAFOs**") on property values of nearby homes (see listing in References). These operations, which are often called feedlots, confine a large number of animals—hogs, chickens, sheep, or cows—in a small area. Correspondingly, a large volume of manure is generated in a small area, leading to waste-management challenges.

Most CAFOs generate significant odors and other nuisance impacts (flies, dust, noise, runoff, etc.) that can extend beyond the CAFO property boundaries, thereby affecting nearby and downwind properties. Usually, but not always, property values of homes near CAFOs are lower than those of similar homes that are not affected by nuisance impacts of CAFOs. Relevant findings of the various studies, some of which are contradictory, include the following:

— Distance

- Significantly lower home values can be limited to less than 1 mile from a CAFO, but some studies have found that lower values can extend beyond 3 miles.
- Adverse impacts on home values diminish rapidly with distance from a CAFO.

— Size and Concentration
  - In general, larger CAFOs have a more negative effect on home values.
  - However, one study found the opposite to be true, with the possible explanation being that larger CAFOs tend to be newer, so have better manure-management facilities and use better practices.

— Animal Species
  - Most studies found that hog operations have a significant adverse impact on the value of nearby homes.
  - The findings on dairy operations are mixed. Some studies found that dairies lower home values significantly, especially those within 1 mile of a facility. But other studies have found that dairy operations, or a combination dairy/beef-cattle operation, can increase home values by adding a rural-lifestyle amenity.

— Management Practices
  - CAFOs with conservation plans have less of an impact on home values than CAFOs without them.

— Home Values
  - One study found that the less-expensive homes are less impacted by CAFOs than the expensive ones. Another study found the opposite.

— Employment Effect
  - In some cases, homes near a CAFO may increase in value due to the increased demand for homes by CAFO employees.

The above findings about the impacts of CAFOs on home values do <u>not</u> apply to the proposed Dairy for the following reasons:

— The HDF pasture system differs from a conventional dairy where cows are confined to barns. Instead of storing manure in lagoons and feeding silage (fermented vegetation) as forage, the Dairy will use rotational pasture-grazing where the animals are dispersed over a large expanse of grassland.

— Home values will not be affected because no noticeable odors, noise, flies, dust, runoff, or other nuisance impacts from the operation will extend to residential areas (see Subsections 7.c and 7.d). Instead, any noticeable nuisance impacts occurring beyond the Dairy property will be limited to the abutting farm and ranch lands which are owned by Māhāʻulepū Farm, lessor of the Dairy property.

b. Nuisance Impacts of Past and Current Agricultural Activities in Kōloa-Poipu

Unlike urban Honolulu and Waikiki, most of Kauaʻi and its resort areas—including Kōloa and Poʻipū—have a rural ambience. Most homes and visitor units on the island are within one mile of some agricultural activity. This rural character contributes to the charm and appeal of the island. Some agricultural activities generated or currently generate significant nuisance impacts.

Sugar

Poʻipū and Kōloa grew and thrived near sugar operations, which continued until 1996. Sugarcane fields bordered Kōloa to the east, north, and west, and bordered parts of Poʻipū. The Grand Hyatt Kauaʻi opened in 1992 while sugarcane was still being grown just mauka of the hotel property.

Sugarcane caused a number of nuisance impacts, including but not limited to: smoke when cane was burned prior to harvest, dust and soil runoff after fields were plowed, noise when fields were harvested, and field mice.

The large canehual trucks created considerable noise, dust and cane litter. And the Kōloa Mill emitted odors, smoke, and noise. The distance from this mill to the the nearest homes in Kōloa is about 0.8 mile (versus about 2.3 miles for the Dairy facilities). For the nearest visitor units (the Grand Hyatt Kauaʻi), the distance is about 1.6 miles (versus about 2.5 miles for the Dairy facilities).

The nuisance impacts of past sugar operations far exceed the impacts anticipated for the Dairy. Also, these impacts from sugar operations extended to the Kōloa and Poʻipū communities, which will not be the case for the Dairy (see Subsection 7.c).

Seed Crops

From 1996 to 2015, seed crops had a major presence in Kōloa-Poʻipū, with over 1,000 acres used by Dupont Pioneer in 2015 (see Figure II-3). This included land adjacent to the Poʻipū Bay Resort Golf Course, which is the golf course for the Grand Hyatt Kauaʻi. Pioneer recently returned its lease land to Māhāʻulepū Farm.

The seed companies generally farm plots of 1 to 5 acres surrounded by a buffer zone to protect planted areas from pollen drift. Cover crops are often planted to build soil fertility and reduce windblown dust.

Nevertheless, one of more significant nuisance impacts of seed crops is windblown dust. Dust from the Dairy's pastureland will not be a problem since the fields will be kept in grass, won't be plowed, and soil will not be left exposed even for short periods.

Beef Cattle

With the demise of sugar and seed crops in Kōloa and Poʻipū, the cattle grazing for the beef market is now the dominant use of agricultural land in the region (see Figure II-3). Grazing lands to the east, north and west of Kōloa total over 2,900 acres, which is reduced from over 3,300 acres before Māhāʻulepū Valley was leased for the Dairy. In the near term, grazing is likely to expand onto most of the lands used recently for seed crops.

Grazing cattle for the beef market is known as cow-and-calf operations. When the calves reach about 500 pounds, most are shipped to the mainland for finishing. Over 700 cow-and-calf units graze on the land in the region, down from over 800 units before Māhāʻulepū Valley was leased for the Dairy.

Grazing of cattle for the beef market usually uses rotational pasture grazing similar to that planned for the Dairy, with the cattle rotated every 18 to 30 days, depending on the ranch and pasture. But because the pastures for beef cattle are not irrigated nor fertilized, the carrying capacity of the land is less than that for the propsed Dairy; the paddocks are larger; and the animal densities are less.

Grazing cattle near communities is common throughout Hawaiʻi, including but not limited to the following:

— Kauaʻi: Hanalei, Hanapēpē, Kalāheo, Kapaʻa, Kukui'ula, Wailuā
— Oʻahu: Ko ʻOlina, Makakilo, Lāʻie, Waimānalo, Waipiʻo
— Molokaʻi: Kaunakakai, Maunaloa
— Maui: Hāna, Kīhei, Kula, Makawao, Mākena, Wailuā
— Big Island: Hawi, Honokaʻa, Laupāhoehoe, Mountain View, Nāʻālehu, South Hilo, Waimea, Wood Valley

A number of these communities feature expensive homes, and some are resort or resort-residential communities (Kukui'ula and Wailuā on Kauaʻi; Ko ʻOlina on Oʻahu; and Kīhei, Mākena, and Wailuā on Maui).

In Kōloa and Poʻipū, grazing occurs less than 200 feet from some homes, less than 1 mile from some visitor units, less than one-third of mile to the east and west of the main commercial area of Kōloa, and less than 200 feet from a golf course.

Many of the homes in the region that are near cattle operations are in the northeast and eastern sections of Kōloa (Areas A, B and C in Figure II-5). As indicated in Table II-8, most of the homes are old (built before 1980), and most are of modest size (less than 1,200 sq. ft.). For these areas, the 2016 median assessed values are as follows:

— Area A: $567,500
— Area B: $406,100
— Area C: $471,100

Homes in West Kōloa are also near cattle grazing (Area H of Figure II-6). This neighborhood has a mix of older and smaller homes, and newer and larger homes (see Table II-8). The 2016 median assessed values are $464,150 for a residential lot and $788,200 for a single-family home.

At the western end of Poʻipū is Kukui'ula—a luxury residential community that abuts grazing land (Areas I, J and K in Figure II-6). Much of the grazing land is owned by the development company or an affiliated company. Most of the homes are new (built after 2012), and most are large (over 2,100 sq. ft.). For 2016, median assessed values of residential lots and homes are as follows:

— Area I: $1,297,150 for a lot and $2,462,400 for a home

— Area J: $641,400 for a lot and $2,582,000 for a home

— Area K: $2,893,100 for a home

Clearly, beef cattle operations are compatible with nearby homes, commercial areas, resorts, and recreational activities. Although stocking densities are lower for beef cattle on unirrigated pastures than they are for the proposed Dairy on irrigated pastures, the operations are similar: cattle are rotated among pastures as limited by the carrying capacity of the land for feed, reabsorption of nutrients, erosion control, etc.

Feral Chickens

Although few (if any) commercial poultry farms remain on Kauaʻi, former farms have left an impact in terms of feral chickens which are now ubiquitous on the island. While colorful and adding to the rural ambience, they create two nuisance problems: (1) the roosters start crowing about 2 hours before daybreak, and continue to crow occasionally during the day and into the night; and (2) chicken dung provides a breeding ground for flies.

The Dairy will not create animal noises that can be heard in resort, commercial, residential or recreational areas, and the flies will be controlled (see Subsection 7.c).

Application of Reclaimed Wastewater and Nutrients

Reclaimed wastewater is used for irrigating farmlands and golf courses throughout Hawaiʻi, including golf courses in Poʻipū. In 2013, the Limticao Consulting Group reported that the Poʻipū Bay Resort Golf Course, which is the golf course for the Grand Hyatt Kauaʻi, uses a mix of 20% to 40% R-2 rated wastewater. However, a mix of up to 60% wastewater is used on the first three holes, resulting in a slight odor during spraying. For the Dairy, the mix will be less than 8%.

The Kiahuna Golf Course uses a mix of 40% to 60% R-1 rated wastewater, which is cleaner than R-2 rated water. The fairways of the course are lined with single-family homes which, for homes on the east side of the project, have a median assessed value exceeding about $1.16 million (see Figure II-X and Area D Table II-8).

The nutrients in the sludge from wastewater treatments plants may also be reclaimed. From 2003 to 2014, Aqua Engineers applied sludge to about 45 acres of forage grass in Māhāʻulepū. The land bordered Poʻipū Road about 1 mile northeast of the Grand Hyatt Resort, and within about 500 feet of the 12th green of its golf course. Aqua Engineers reports that there were no complaints about odors or other nuisance impacts, and no adverse health or environmental impacts. Nevertheless, the operation was forced to close due to community concerns that it was contributing to high levels of *enterococci* bacteria in Waiopili Ditch which passes about a half-mile to the east of the former sludge-disposal site. In a 2016 report, the DOH found high levels of *enterococci* bacteria in the Ditch after the sludge operation ceased, and determined that the bacteria came from a number of upstream and in-stream sources (see Subsection 7.c below).

These examples indicate that properly managed reclaimed wastewater and nutrients can be compatible with high-end resorts, homes, and recreational areas.

c. Nuisance Impacts

This section summarizes the anticipated economic impacts of nuisance issues due to the Dairy. The information is based on the various environmental studies conducted in preparation of an Environmental Impact Statement.

Overview

The Dairy will feature rotational pasture-grazing along with modern facilities and practices, and will comply with all applicable Federal and State environmental standards. In addition, conditions at the Dairy will be monitored continually to ensure that adverse impacts will not occur, or will be mitigated to minimize adverse impacts.

Considerable distances will separate the Dairy from the resorts, commercial areas, homes and recreational areas. The nearest resort units are about 1.5 miles from a Dairy paddock and about 2.4 miles from the Dairy milking parlor (see Figure II-4). For the Kōloa town center, the distances from the closest paddock and dairy facilities are about 2.2 and 2.8 miles, respectively. For homes, the distances are about 1 and 2 miles away, respectively. And for recreational activities, the distances are about 0.6 mile and 1.3 miles, respectively.

Winds in the region are generally from the east-northeast (normal tradewinds) and range from 5 to 15 miles per hour. The tradewinds blow across the Dairy property and toward Poʻipū, but not toward Kōloa.

Given the plans for the Dairy and its location, environmental studies indicate that no noticeable noise, dust, odors, flies, runoff, or other nuisance impacts will extend to resort, commercial, residential or recreational areas. Noticeable nuisance impacts occurring outside the Dairy property will be limited to the abutting farm and ranch lands which are owned by Māhāʻulepū Farm, the lessor of the Dairy property.

Noise

Most of the noise from milking and related operations will be contained within the milking parlor and other buildings, while noise from tractors and other field equipment will occur mostly during the daylight hours. Some farmers and ranch hands on abutting lands may hear noises from Dairy operations. But the resorts, stores, homes and recreational areas are too distant from the Dairy for visitors and residents to be adversely affected by the noise.

Dust

Dust will be generated as cows move along soft limestone raceways that connect the paddocks and lead to and from the milking parlor. As case with noise, resorts, stores, homes and recreational areas are too distant for visitors and residents to be adversely affected by dust from Dairy operations.

The Dairy will generate far less dust than was the case when sugarcane was grown in the Kōloa-Poʻipū region, and much less dust than typical field farming. Both of these agricultural activities generate considerable dust during plowing, followed by weeks or months of occasional dust when soils are left exposed. The Dairy pasture will not be plowed, and the soils will not be left exposed.

Odors

Potential sources of odor from the Dairy include (1) manure deposited by cows in the milking parlor and holding pens; (2) the two effluent ponds; (3) the irrigation system (which uses effluent); and (4) the manure deposited directly onto the pasture. The manure from the milking parlor and holding pen will be collected frequently and washed into a settling pond that will be aerated to reduce odors. The resulting effluent will be pumped into a storage pond and then used to irrigate the pasture diluted with water from the Waitā Reservoir. To further reduce odors from the Dairy effluent ponds and other facilities, ironwood trees will be planted along the east-southeast boundary of the property.

The majority of manure (about 90%) will be deposited directly onto the pasture where—with the help of cattle egrets and dung beetles—it will break down quickly and provide nutrients to the pasture.

Figures III-1 and III-2 show odor-detection limits for the 699-cow Dairy and the 2,000-cow Dairy, respectively. For people who are sensitive to odors, the limits indicate where 50 percent of them would detect an odor from the Dairy at an average rate of once every 200 hours. The figures are based on an unlikely confluence of worst-case weather conditions and other factors. Thus, in practice, the odor limits are likely to extend a shorter distance.

For the 699-cow Dairy, the odor detection limit extends about 1,670 feet (about one-third mile) outside the Dairy boundary, and about 2,780-feet (about half mile) for the 2,000-cow Dairy. All of the affected area occurs on land owned by Māhāʻulepū Farm.

As above, resorts, stores, homes and recreational areas are too distant for visitors and residents to be adversely affected by odors from Dairy operations.

Flies

Fly populations at the Dairy will be controlled through Integrated Pest Management whereby fly reproduction will be disrupted at key points in the life cycle. Cattle egrets break up the cow patties while searching for prey, and dung beetles bury cow patties in 1 to 3 days. This interrupts the egg-to-fly lifecycle, which ranges from 7 to 20 days depending upon the species of fly. Kaua‘i has 14 dung beetle species, some of which fly at night and some during the day, and some that prefer older manure over fresh.

Supplemental pest control may be used to prevent short-term spikes in fly populations. These could include: sticky tapes or ribbons in the milking parlor and covered areas, outdoor traps, non-toxic repellants, etc. Insecticides are non-discriminatory and kill beneficial as well as pest insects. Such control would only be used when needed by those qualified to apply chemicals, and in accordance with authorized procedures and regulatory labeling requirements.

The Dairy will not encourage or maintain any populations of dogs, cats or chickens at the Dairy because their dung would facilitate breeding of several species of flies that are not currently established on the property. While feral chickens are common throughout Kaua‘i, the Dairy will diligently clean up any spilled feed or other potential attractants to keep chickens away from the Dairy facilities.

In order to avoid rotting garbage that might provide attractive habitat for fly breeding, food waste of on-site workers will be disposed of in covered, lined containers and removed from the site often. Spilled or waste supplement foods for the cows will not be allowed to become wet and stay exposed. And Dairy workers will remove trash found on roads abutting or near the property so that flies do not breed in garbage, and migrate to the Dairy.

In Kōloa and Poi‘pū, flies depend upon local food and breeding sources, such as dog, cat, and chicken dung; rotting fruits and vegetables; exposed garbage; and damp and decaying organic matter. Given the controls that are planned for the Dairy, it is not expected to add to existing fly problems in Kōloa and Po‘ipū.

Runoff

Several intermittent streams drain the southern slopes of Hā‘upu Ridge and converge into man-made ditches that run through the Dairy property into the concrete-lined Waiopili Ditch. This ditch parallels lower Māhā‘ulepū Road and is fed by another ditch from the west. Waipoli Ditch continues southward, terminating at a deep and muddy basin where the ditch water joins the ocean via a channel cut through the beach sand. Mixing of the ditch water with ocean water occurs rapidly just a short distance from the shoreline.

Waiopili Ditch receives runoff from a 2,700-acre sub-watershed, including the runoff from lands mauka and makai of the Dairy. The Dairy property accounts for about 20% of the subwatershed.

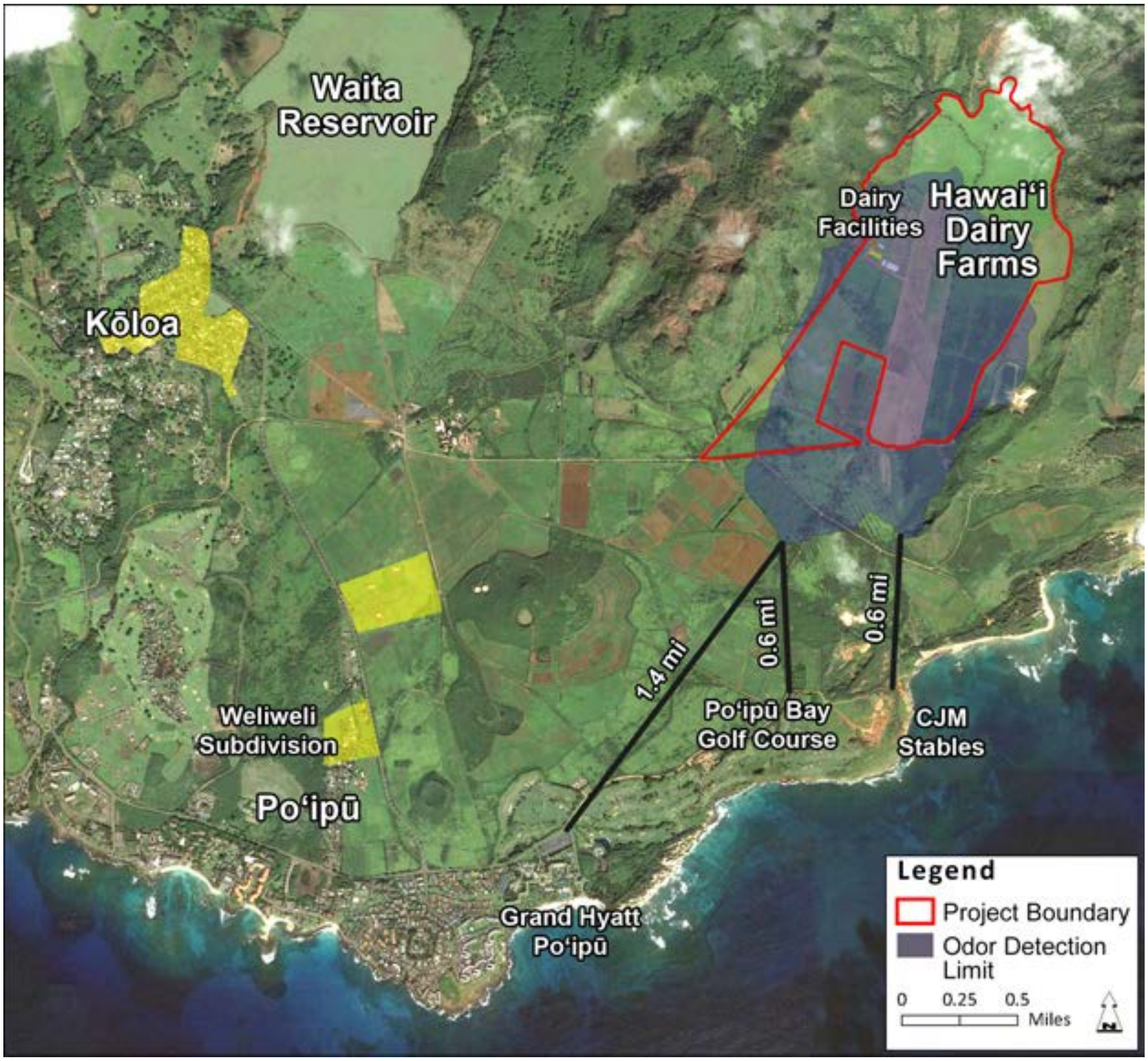

Figure III-1. Odor Detection Limit for 699-cow Dairy

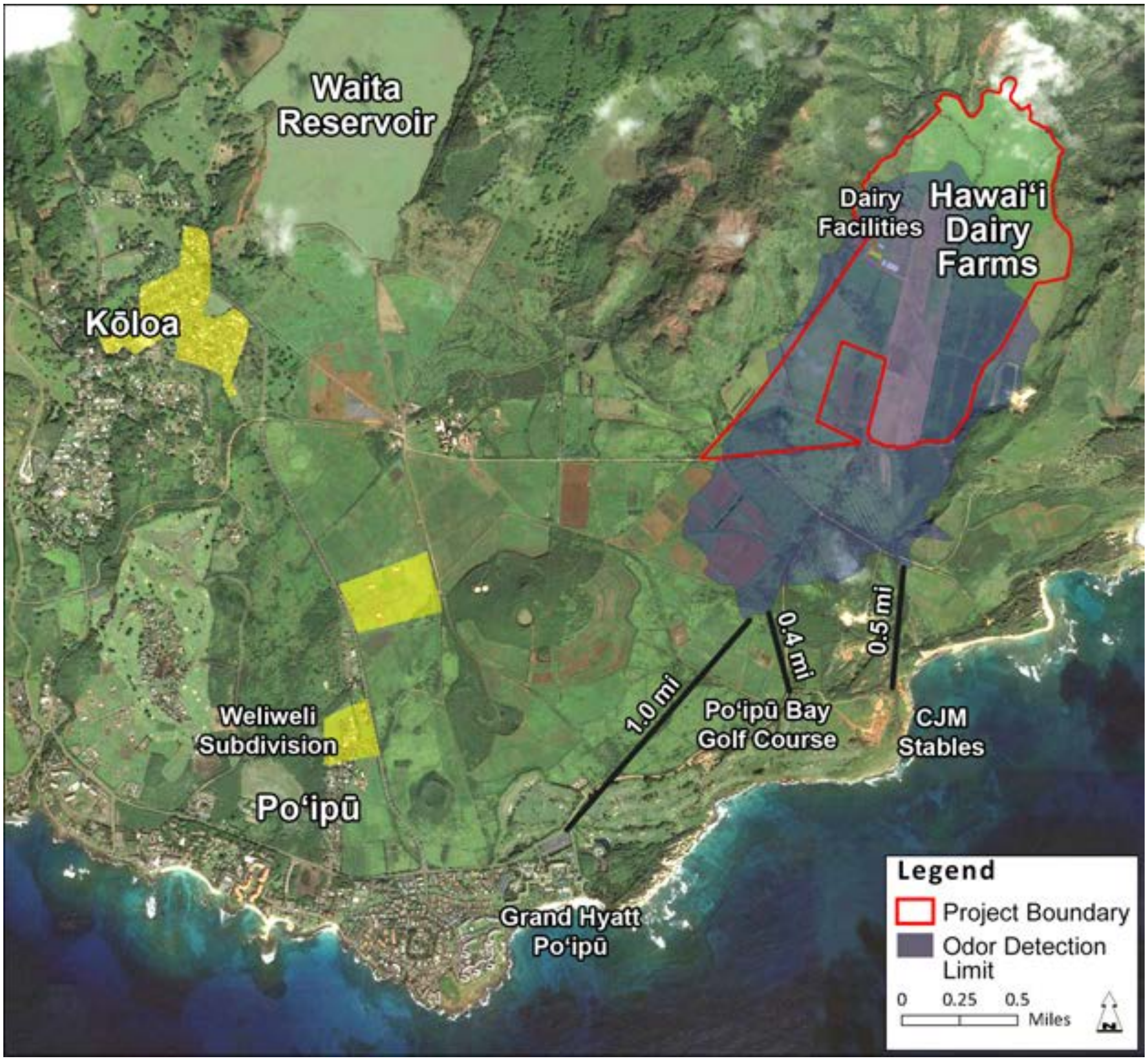

Figure III-2. Odor Detection Limit for 2,000-cow Dairy

Environmental sampling by DOH has identified high levels of *enterococci* bacteria in Waiopili Ditch, particularly near its ocean terminus. According to a 2016 report by DOH, the bacteria appear to originate upstream from feral animals (pigs and some cats and dogs), avian wildlife, domesticated sheep, beef cattle on the slopes of Hāʻupu Ridge, decaying organic matter, vegetation, soils and insects. Two conditions block ultraviolet light that would otherwise reduce bacteria levels: the dense canopy along the makai end of Waiopili Ditch, and the turbidity of the water. Also, the particles that cause turbidity help transport bacteria downstream.

The Dairy is expected to contribute little runoff of soil particles, nutrients, organic debris, pathogens, etc. Cow excretions in the pasture and the effluent applied to pasture will be absorbed quickly by a thick thatch of pasture grass—essentially an organic net. Due to the high moisture and moderate temperatures in the thatch, the microbial activity is very high, and most of the effluent will be broken down by microbial activity within one day, after which the pasture grass will absorb the released nutrients.

Additional measures to prevent or minimize runoff from the Dairy will include:

— Fenced 35-foot-wide vegetation buffers on both sides of drainage ditches to keep cows away from the ditches and to filter water draining into the ditches.

— No application of effluent within 50 feet of drainage ditches.

— No application of effluent to the pasture before or during rainstorms that could result in runoff, or when the soil is completely saturated.

— Ongoing monitoring of surface and coastal waters to gauge whether nutrients and pathogens are reaching levels of concern.

Compared to the current situation, the Dairy will result in a reduction in the runoff from the property of soil particles, nutrients, organic debris, pathogens, etc. In turn, this will result in improved water quality for the affected drainage ditches. However, during rainstorms, nutrient runoff could increase for the 2,000-cow Dairy, but this will not degrade nearshore waters significantly since the nutrients will be diluted with rainwater, then will quickly be dispersed by wave action and ocean currents. Also, the health risk of cattle-fecal contaminate is low, about 0.7% to 4% of that of human-fecal contaminate. In any case, substantial runoff will continue to occur for the 80% of the subwatershed not occupied by the Dairy.

The drainage ditches are not recreational resources used by the public, even near the terminus of Waiopili Ditch at the ocean. Thus, any change in water quality—either positive or negative—will affect neither residents nor visitors.

d. Economic Impacts from Nuisances

As summarized above, no noticeable noise, dust, odors, flies, runoff, or other nuisance impacts from the Dairy will extend to resort, commercial, residential or recreational areas. Noticeable nuisance impacts occurring outside the Dairy property will be limited to the abutting farm and ranch lands which are owned by Māhāʻulepū Farm, the lessor of the Dairy property. These abutting lands are designated IAL, so they will remain in agriculture for the foreseeable future.

Consequently, the Dairy will not adversely affect:

- Guests of resorts in the Kōloa-Poʻipū region.
- Recreational activities in the region.
- The regional economy (number of visitors, visitor expenditures, retail sales, employment, incomes, etc.)
- Residents when at home in the region.
- Property sales in the region (single-family homes, condominiums, second homes, time-share units, etc.).
- Values of properties in the region.
- County or State taxes derived from residents, resorts, or commercial activities in the region.

From a broader perspective, the Dairy will help maintain the existing rural character and ambience of the Kōloa-Poʻipū region.

8. SUMMARY OF SIGNIFICANT BENEFITS AND IMPACTS

The primary economic benefits of the Dairy will include:

- For Hawaiʻi, increased milk self-sufficiency by about 1.5 million gallons per year for the 669-cow Dairy, and about 4.4 million gallons should HDF decide, in the future, to expand to a 2,000-cows Dairy.
- At full operations and depending on the eventual size of the Dairy, about 14 to 28 additional jobs, including about 5 to 10 well-paying farm jobs.
- Preservation of about 547 acres of well-maintained green open space.

No adverse economic impacts due to nuisance issues are anticipated.

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TABLES FOR PART II

Table II-1. Demographic Characteristics, Kauai and Koloa-Poipu: 2000 and 2009-2013 Estimates

Item	Kauai			Koloa-Poipu		
	2000	2009-2013	Change	2000	2009-2013	Change
Defacto Population	75,200	83,513	11.1%	n/a	n/a	n/a
(2010 count, residents & visitors)						
Population (residents)	58,463	67,872	16.1%	5,404	5,922	9.6%
Male	29,252	33,995	16.2%	2,734	2,695	-1.4%
Female	29,211	33,877	16.0%	2,670	3,227	20.9%
Distribution						
Pre-school Age, 4 and Under	50.0%	50.1%		50.6%	45.5%	
School Age, 5 to 17	50.0%	49.9%		49.4%	54.5%	
Population by Age						
Pre-school Age, 4 and Under	3,605	4,398	22.0%	313	385	23.0%
School Age, 5 to 19	13,147	12,198	-7.2%	1,101	889	-19.3%
Working Age, 20 to 64	33,642	40,676	20.9%	3,112	3,558	14.3%
Retirement Age, 65 and Over	8,069	10,600	31.4%	878	1,090	24.1%
Distribution						
Pre-school Age, 4 and Under	6.2%	6.5%		5.8%	6.5%	
School Age, 5 to 17	22.5%	18.0%		20.4%	15.0%	
Working Age, 18 to 64	57.5%	59.9%		57.6%	60.1%	
Retirement Age, 65 and Over	13.8%	15.6%		16.2%	18.4%	
Median Age	38.4	41.6	8.3%	40.6	44.8	10.3%
Ethnicity						
White alone	17,255	22,688	31.5%	2,005	2,492	24.3%
Black or African American alone	177	329	85.9%	12	18	50.0%
American Indian and Alaska Native alone	212	141	-33.5%	22	18	-18.2%
Asian alone	21,042	24,217	15.1%	1,799	1,777	-1.2%
Native Hawaiian and Other Pacific Islander alone	5,334	6,693	25.5%	306	218	-28.8%
Some Other Race alone	505	385	-23.8%	59	25	-57.6%
Two or More Races	13,938	13,419	-3.7%	1,201	1,374	14.4%
Distribution						
White alone	29.5%	33.4%		37.1%	42.1%	
Black or African American alone	0.3%	0.5%		0.2%	0.3%	
American Indian and Alaska Native alone	0.4%	0.2%		0.4%	0.3%	
Asian alone	36.0%	35.7%		33.3%	30.0%	
Native Hawaiian and Other Pacific Islander alone	9.1%	9.9%		5.7%	3.7%	
Some Other Race alone	0.9%	0.6%		1.1%	0.4%	
Two or More Races	23.8%	19.8%		22.2%	23.2%	
Population by Place of Birth						
Native Born, Hawaii	36,237	37,942	4.7%	2,946	3,054	3.7%
Native Born, Other State or Overseas	14,652	19,653	34.1%	1,762	2,107	19.6%
Foreign Born	7,574	10,277	35.7%	696	761	9.3%
Distribution						
Native Born, Hawaii	62.0%	55.9%		54.5%	51.6%	
Native Born, Other State or Overseas	25.1%	29.0%		32.6%	35.6%	
Foreign Born	13.0%	15.1%		12.9%	12.9%	
Households	20,183	22,390	10.9%	1,973	2,173	10.1%
Average Size	2.87	2.99	4.2%	2.71	2.68	-1.1%

Table II-1. Demographic Characteristics, Kauai and Koloa-Poipu: 2000 and 2009-2013 Estimates

(continued)

Item	Kauai			Koloa-Poipu		
	2000	2009-2013	Change	2000	2009-2013	Change
People by Type of Home						
Living in homes, not Group Quarters	57,831	66,940	15.8%	5,349	5,825	8.9%
Living in Group Quarters	632	932	47.5%	55	97	76.4%
Tenure						
Homeowners	12,384	14,010	13.1%	1,138	1,323	16.3%
Renters	7,799	8,380	7.4%	835	850	1.8%
Distribution						
Homeowners	61.4%	62.6%		57.7%	60.9%	
Renters	38.6%	37.4%		42.3%	39.1%	
Household Type						
Family Household	14,572	15,609	7.1%	1,424	1,449	1.8%
Non-Family Household	5,611	6,781	20.9%	549	724	31.9%
Distribution						
Family Household	72.2%	69.7%		72.2%	66.7%	
Non-Family Household	27.8%	30.3%		27.8%	33.3%	
Housing Units	25,331	29,972	18.3%	3,591	3,704	3.1%
Occupied	20,183	22,390	10.9%	1,973	2,173	10.1%
Vacant	5,148	7,582	47.3%	1,618	1,531	-5.4%
For seasonal, recreational, or occasional use	3,850	4,318	12.2%	1,525	1,362	-10.7%
Distribution						
Occupied	79.7%	74.7%		54.9%	58.7%	
Vacant	20.3%	25.3%		45.1%	41.3%	
For seasonal, recreational, or occasional use	15.2%	14.4%		42.5%	36.8%	

Sources

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Table II-2. Income and Education, Kauai and Koloa-Poipu: 2000 and 2009-2013 Estimates

Item	Kauai			Koloa-Poipu		
	2000	2009-2013	Change	2000	2009-2013	Change
Income						
Median Household Income	$45,020	$62,052	37.8%	$48,053	$62,083	29.2%
Per Capita Income	$20,301	$26,658	31.3%	$22,782	$32,022	40.6%
People in Households with Poverty-Level Incomes	6,085	7,602	24.9%	593	444	-25.1%
Percent of Population	10.5%	11.2%		11.0%	7.5%	
Travel Time To Work						
Average Minutes	21.5	21.4		18.8	19.5	
Educational Attainment, 25 Years and Older						
Less than 9th Grade	3,440	2,507	-27.1%	328	225	-31.4%
Grades 9 to 12, No Diploma	3,064	2,225	-27.4%	259	220	-15.1%
High School Graduate, No College	11,546	13,801	19.5%	1,018	982	-3.5%
Some College, No Degree	9,714	11,314	16.5%	928	1,129	21.7%
Associate Degree	3,557	5,809	63.3%	408	541	32.6%
College, Bachelor's Degree	5,168	8,309	60.8%	512	808	57.8%
Graduate or Professional Degree	2,383	3,659	53.5%	252	376	49.2%
Total Population, Age 25 and Older	38,872	47,624	22.5%	3,705	4,281	15.5%
Distrbution						
Less than 9th Grade	8.8%	5.3%		8.9%	5.3%	
Grades 9 to 12, No Diploma	7.9%	4.7%		7.0%	5.1%	
High School Graduate, No College	29.7%	29.0%		27.5%	22.9%	
Some College, No Degree	25.0%	23.8%		25.0%	26.4%	
Associate Degree	9.2%	12.2%		11.0%	12.6%	
College, Bachelor's Degree	13.3%	17.4%		13.8%	18.9%	
Graduate or Professional Degree	6.1%	7.7%		6.8%	8.8%	
School Enrollment						
Nursery School/Preschool	873	961	10.1%	62	66	6.5%
Elementary and High School	12,272	10,828	-11.8%	1,051	816	-22.4%
College	1,736	2,947	69.8%	160	213	33.1%
Total School Enrollment	14,881	14,736	-1.0%	1,273	1,095	-14.0%
English Language Skills, Age 5 and Over						
English Only	44,111	50,194	13.8%	4,179	4,530	8.4%
Language Other Than English	10,711	13,280	24.0%	909	1,007	10.8%
Speak English Very Well	5,924	8,258	39.4%	460	573	24.6%
Speak English Less than Very Well	4,787	5,022	4.9%	449	434	-3.3%
Total Population, Age 5 and Over	54,822	63,474	15.8%	5,088	5,537	8.8%
Distribution						
English Only	80.5%	79.1%		82.1%	81.8%	
Language Other Than English	19.5%	20.9%		17.9%	18.2%	
Speak English Well or Very Well	10.8%	13.0%		9.0%	10.3%	
Speak English Poorly	8.7%	7.9%		8.8%	7.8%	

Sources

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Table II-3. Economic Characteristics, Kauai 2000, 2014 and 2030

Item	2000	2014	Change Since 2000	Projections for 2030	Change Since 2014
Tourism					
Annual Visitors	1,074,821	1,113,605	3.6%	1,330,000	19.4%
Visitor Spending ($million)	$1,200	$1,466	22.2%	$1,358	-7.4%
Lodging Units	7,159	8,492	18.6%	9,690	14.1%
Labor					
Civilian Labor Force	30,250	34,600	14.4%	n/a	n/a
Employed	28,750	32,950	14.6%	n/a	n/a
Unemployment Rate	4.8%	4.9%	2.1%	n/a	n/a
Jobs, Wage and Salary Only	26,550	29,400	10.7%	34,010	15.7%
Nat. Resources & Mining & Construction	1,100	1,200	9.1%	1,850	54.2%
Manufacturing	400	400	0.0%	300	-25.0%
Trade, Transportation & Utilities	5,600	5,800	3.6%	6,180	6.6%
Information	400	200	-50.0%	290	45.0%
Financial Activities	1,200	1,400	16.7%	1,180	-15.7%
Professional & Business Services	2,200	2,800	27.3%	3,690	31.8%
Education & Health Services	2,100	2,700	28.6%	3,660	35.6%
Leisure and Hospitality	7,800	9,300	19.2%	9,180	-1.3%
Other Services	700	1,000	42.9%	1,260	26.0%
Government	4,100	4,600	12.2%	5,610	22.0%
Agriculture	950	n/a	n/a	810	n/a

n/a = not available

Sources

Hawaii Tourism Authority. "2013 Annual Visitor Research Report."

Department of Labor and Industrial Relations. Job Count by Industry. 2014.

Department of Labor and Industrial Relations. Historic Labor Force Estimates. 2014.

Department of Business, Economic Development & Tourism. "Population and Economic Projections for the State of Hawaii to 2040". 2012.

Table II-4. Visitor Plant Inventory, Kauai: 2015

Item	Kauai		Poipu-Kukuiula	
	Properties	Units	Properties	Units
Apartment Hotel	-	-	-	-
Bed & Breakfast	12	56	2	24
Condominium Hotel	22	1,387	11	608
Hostel	-	-	-	-
Hotel	15	2,667	4	1,124
Vacation Rentals*	265	1,800	110	677
Other	4	40	-	-
Timeshare	21	2,632	3	625
Total	339	8,582	130	3,058
Island Share				36%

Source
Hawaii Tourism Authority. "2015 Visitor Plant Inventory."

Table II-5. Agricultural Acreages, Kauai: 1980 and 2015

Item	1980	2015	Change
Crops			
Plantation Crops			
Pineapple	20	-	(20)
Sugarcane	53,596	-	(53,596)
Total Plantation Crops	53,616	-	(53,616)
Large-acreage Diversified Crops			
Coffee	-	3,788	3,788
Macadamia Nuts	-	-	-
Seed Crops	-	13,299	13,299
Total Other Large-acreage Export Crops	-	17,087	17,087
Other Diversified Crops			
Aquaculture	95	183	88
Bananas	505	26	(479)
Flowers, Foliage and Landscape Crops	30	165	135
Forage and Grain	245	-	(245)
Guava (for 2015, included with Other Div. Crops)	343		(343)
Papaya (for 2015, included with Other Div. Crops)	750		(750)
Taro/Wetland Crops	322	443	121
Tropical Fruits (for 1980 included with Other Div. Crops)	-	463	463
Vegetable/Melon (for 2015, included with Other Div. Crops)	80	-	(80)
Other Crops	582	1,199	617
Total Diversified Crops	2,952	2,479	(473)
Total Crops	56,568	19,566	(37,002)
Intensive Livestock			
Dairy	208	-	(208)
Hog	28	-	(28)
Poultry	19	-	(19)
Total Intensive Livestock	255	-	(255)
Commercial Forests	-	1,743	1,743
Grazing/Pasture	28,898	41,934	13,036
Total Agriculture and Forestry	85,721	63,243	(22,478)

Source

Jeffery Melrose, et. al. "Statewide Agricultural Land Use Baseline 2015."

Hawaii Department of Agriculture. "Agricultural Land Use Maps (ALUM)." 1978-80.

Table II-6. Jobs by Industry, Kauai and Koloa-Poipu: 2011

Item	Kauai Jobs		Koloa-Poipu Jobs	
Natural Resources, Mining & Construction	1,300	4.6%	129	3.4%
Manufacturing	300	1.1%	20	0.5%
Trade, Transportation & Utilities	5,600	19.8%	458	12.2%
Information	200	0.7%	36	1.0%
Financial Activities	1,200	4.2%	50	1.3%
Professional & Business Services	2,900	10.2%	91	2.4%
Education & Health Services	2,500	8.8%	130	3.5%
Leisure and Hospitality	8,300	29.3%	2,618	69.8%
Other Services	1,000	3.5%	182	4.9%
Government	4,400	15.5%	32	0.9%
Agriculture	600	2.1%	6	0.2%
TOTAL	28,300	100.0%	3,752	100.0%

Sources

Department of Labor and Industrial Relations. Job Count by Industry. 2014.

U.S. Census Bureau, OnTheMap Application, http://lehdmap.ces.census.gov

Table II-7. Home Sale Prices, Kauai and Koloa-Poipu: 2013 to 2015

Item	Kauai			Koloa-Poipu				
	Sales	Median Price	Average Price	Sales	Median Price	Δ	Average Price	Δ
Single Family Residences								
2013	447	$ 529,000	$ 693,703	56	$ 775,000	47%	$ 1,082,054	56%
2014	467	$ 533,000	$ 865,421	49	$ 1,200,000	125%	$ 1,795,816	108%
2015	487	$ 615,000	$ 1,105,434	45	$ 1,070,000	74%	$ 1,801,767	63%
Condominiums								
2013	351	$ 310,000	$ 424,505	86	$ 467,500	51%	$ 686,305	62%
2014	327	$ 346,000	$ 393,861	68	$ 435,000	26%	$ 545,016	38%
2015	362	$ 365,500	$ 415,295	85	$ 425,000	16%	$ 469,687	13%

Source

Locations Hawaii. 2016.

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
Area A								
428002014	SFR	N	0.75	1926	5	3	2,426	$855,500
428002015	SFR	N	0.5	1926	3	1	1,018	$455,000
428002016	SFR	N	0.62	1926	4	1	1,732	$496,300
428002017	SFR	N	0.59	1926	3	2	1,942	$475,100
428002018	SFR	N	0.6	1922	4	3	2,177	$689,900
428002019	SFR	N	1	1920	4	3	2,586	$638,800
Median			0.61					$567,550
Vacant			-					-
Developed			*0.61*	1926	4.0	2.5	2,060	*$567,550*
Area B								
428002006	SFR	N	0.19	1939	4	1	1,152	$333,700
428002007	SFR	N	0.18	1979	3	1	720	$342,600
428002008	SFR	N	0.17	1926	3	1	924	$386,500
428002009	SFR	N	0.22	1964	3	1	1,712	$490,600
428002010	SFR	N	0.16	1993	3	4	1,988	$551,700
428002011	SFR	N	0.31	1926	5	3	2,145	$508,600
428003040	SFR	N	0.23	2003	2	2	1,244	$462,100
428025024	SFR	N	0.23	1971	3	1	1,040	$431,000
428025025	SFR	N	0.24	1970	4	2	1,421	$444,300
428025038	SFR	N	0.21	1975	3	1	1,364	$409,400
428025039	SFR	N	0.21	1975	4	2	1,268	$456,000
428025040	SFR	N	0.22	1975	3	1	960	$433,200
428025041	SFR	N	0.21	1975	3	1	1,408	$378,600
428025042	SFR	N	0.21	1975	4	1	1,945	$478,400
428025043	SFR	N	0.21	1975	3	1	960	$394,400
428025044	SFR	N	0.22	1975	3	1	2,176	$512,100
428025045	SFR	N	0.22	1974	3	1	904	$402,400
428026002	SFR	N	0.17	1982	4	2	1,826	$520,400
428026003	SFR	N	0.17	1982	3	1	880	$376,000
428026004	SFR	N	0.18	1982	3	1	912	$384,100
428026005	SFR	N	0.19	1982	7	3	2,610	$622,300
428026006	SFR	N	0.17	1978	3	1	880	$368,200
428026007	SFR	N	0.17	1978	4	1	1,292	$401,700
428026008	SFR	N	0.17	1978	3	1	880	$373,500
428026009	SFR	N	0.17	1978	3	1	912	$373,900
428026010	SFR	N	0.19	1978	3	1	960	$377,200
428026011	SFR	N	0.24	1978	5	2	1,300	$446,000
428026012	SFR	N	0.19	1978	5	1	1,432	$411,900
428026013	SFR	N	0.2	1978	3	1	880	$389,900
428026014	SFR	N	0.2	1978	3	1	960	$406,100
428026015	SFR	N	0.22	1977	3	1	912	$384,800
428026016	SFR	N	0.25	1977	3	1	880	$391,600
428026017	SFR	N	0.23	1977	3	1	1,372	$421,800
428026018	SFR	N	0.18	1979	3	1	1,034	$392,700
428026019	SFR	N	0.17	1977	3	1	1,404	$421,400
428026020	SFR	N	0.17	1977	3	2	2,041	$545,700
428026021	SFR	N	0.17	1977	3	1	880	$368,700
428026022	SFR	N	0.18	1977	3	1	1,692	$452,700
428026023	SFR	N	0.19	1978	5	1	1,320	$413,100

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
428026024	SFR	N	0.24	1979	3	2	1,392	$477,200
428026051	SFR	N	0.2	1979	3	1	960	$382,200
428026052	SFR	N	0.18	1979	3	1	880	$375,800
428026053	SFR	N	0.17	1980	3	1	960	$373,300
428026054	SFR	N	0.17	1979	3	1	880	$386,300
428026055	SFR	N	0.17	1979	3	1	1,326	$406,700
428026056	SFR	N	0.17	1980	5	1	1,680	$433,400
428026057	SFR	N	0.18	1979	3	1	960	$379,300
Median			0.19					$406,100
Vacant			-					-
Developed			*0.19*	1978	3.0	1.0	1,152	*$406,100*
Area C								
428011003	SFR	N	2.74	1922	15	6	12,146	$1,781,900
428011021	SFR	N	0.94	1993	2	1	1,078	$652,800
4280110260001	SFR	N	0.8	1940	3	1	699	$280,100
4280110260002	SFR	N	0.12	1940	3	1	782	$295,400
428011027	SFR	N	0.28	1957	6	2	1,610	$403,000
428011030	Residential Lot	Y	1.98					$498,000
428011031	SFR	N	0.29	1947	3	1	758	$355,200
428011034	SFR	N	0.18	1969	3	1	720	$335,600
428012002	SFR	N	1.26	1974	3	2	1,064	$485,200
428012003	SFR	N	0.34	1972	4	3	1,667	$456,800
428012005	SFR	N	0.43	1977	5	2	3,154	$690,200
428012006	SFR	N	0.47	1993	3	2	1,790	$575,000
428012027	SFR	N	0.88	2010	6	5	2,747	$828,300
428012030	SFR	N	0.42	1965	3	1	749	$425,400
Median			0.45					$471,000
Vacant			*1.98*					*$498,000*
Developed			*0.43*	1969	3.0	2.0	1,078	*$471,000*
Area D								
428029001	SFR	N	0.25	2006	4	4	2,728	$1,525,100
428029002	SFR	N	0.26	1988	4	3	2,872	$1,224,500
428029003	SFR	N	0.27	2010	2	2	2,198	$1,395,600
428029004	SFR	N	0.25	1998	4	3	3,299	$1,586,400
428029005	SFR	N	0.26	1988	3	4	2,316	$1,163,200
428029006	SFR	N	0.24	1987	3	2	2,576	$1,108,500
428029007	SFR	N	0.32	1995	4	4	3,195	$1,377,500
428029008	Residential Lot	Y	0.48					$459,900
428029009	SFR	N	0.47	1998	3	2	3,999	$1,650,700
428029010	SFR	N	0.33	2001	3	3	3,120	$1,397,600
428029011	SFR	N	0.25	1985	2	3	1,784	$1,055,200
428029012	SFR	N	0.27	2007	3	3	2,957	$1,339,200
428029013	SFR	N	0.48	1990	4	3	3,516	$1,403,600
428029014	SFR	N	0.28	1989	3	2	2,536	$1,209,700
428029015	SFR	N	0.24	2011	4	2	2,432	$1,159,400
428029016	SFR	N	0.22	1985	3	3	2,300	$1,112,200
428029017	SFR	N	0.19	1987	3	2	2,101	$1,046,300
428029049	SFR	N	0.23	2004	3	2	2,584	$1,201,100
428029050	SFR	N	0.26	1989	2	2	1,997	$1,059,300

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
428029051	SFR	N	0.23	2010	3	3		$400,300
428029052	SFR	N	0.27	2006	4	3	3,061	$1,665,200
428029053	SFR	N	0.32	1987	3	3	2,456	$1,248,200
428029054	SFR	N	0.36	1989	3	3	2,725	$1,386,200
428029055	SFR	N	0.22	2015	3	3	-	$395,900
428029056	SFR	N	0.25	1991	4	3	2,781	$1,189,600
428029057	SFR	N	0.5	1990	3	3	3,028	$1,381,800
428029058	SFR	N	0.63	1984	4	5	4,250	$1,852,400
428029060	Residential Lot	Y	0.3					$428,700
428030015	Residential Lot	Y	0.18					$380,200
428030016	Residential Lot	Y	0.23					$399,600
428030017	Residential Lot	Y	0.18					$380,000
428030071	SFR	N	0.18	2014	2	3	1,660	$1,045,300
428030072	SFR	N	0.18	2014	2	2	1,802	$999,400
428030073	SFR	N	0.18	2013	3	3	1,991	$1,042,200
428030074	SFR	N	0.22	2015	3	3		$395,000
428030075	SFR	N	0.23	2015	3	3	2,071	$774,500
428030076	SFR	N	0.26	2015	3	3	2,071	$796,000
428030077	SFR	N	0.25	2015	3	3	1,938	$1,095,600
428030078	SFR	N	0.2	2015	3	3		$384,900
428030079	SFR	N	0.19	2015	3	3		$380,800
428030080	SFR	N	0.18	2014	3	3	2,223	$1,331,400
428030081	SFR	N	0.19	2015	3	3	2,359	$1,122,400
428030082	SFR	N	0.19	2015	3	3	2,118	$1,113,200
428030083	SFR	N	0.28	2014	3	3	2,071	$1,136,200
428030084	Residential Lot	Y	0.26					$414,600
Median			0.25					$1,113,200
Vacant			*0.25*					*$407,100*
Developed			*0.25*	2006	3.0	3.0	2,432	*$1,159,400*
Area E								
4280220020001	Agricultural Land	Y	2.96					$671,000
4280220020002	Agricultural Land	Y	2.42					$610,300
4280220310001	SFR	N	2.47	2012	3	3	2,928	$2,315,600
4280220310002	Agricultural Land	Y	2.53					$622,600
4280220320001	Agricultural Land	Y	2.53					$621,800
4280220320002	SFR	N	2.58	2011	3	3	2,185	$1,491,500
4280220330001	Agricultural Land	Y	2.73					$644,300
4280220330002	Agricultural Land	Y	2.65					$650,500
4280220330003	SFR	N	2.82	2015	3	3		$655,100
4280220330004	Agricultural Land	Y	2.52					$621,600
4280220330005	Agricultural Land	Y	2.65					$635,600
4280220340001	Agricultural Land	Y	2.44					$611,600
4280220340002	SFR	N	2.6	2015	4	4		$629,600
428022035	Agricultural Land	N	5.05					$815,400
4280220360001	Agricultural Land	Y	2.498					$618,500
4280220360002	Agricultural Land	Y	2.474					$615,800
Median		Y	2.58					$635,600
Vacant			*2.53*					*$622,200*
Developed			*2.60*	2014	3.0	3.0	2,557	*$815,400*

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
Area F								
428023001	SFR	N	0.27	1969	4	2	1,348	$614,000
428023004	SFR	N	0.25	1970	3	2	1,134	$576,000
428023005	SFR	N	0.27	1970	3	2	1,215	$637,800
428023006	SFR	N	0.24	1970	3	2	1,301	$574,000
428023007	SFR	N	0.23	1970	3	2	2,226	$661,800
428023008	SFR	N	0.26	1970	3	2	1,325	$593,800
428023009	SFR	N	0.24	2012	5	4	3,624	$1,017,500
428023010	SFR	N	0.22	1970	3	2	980	$572,900
428023011	SFR	N	0.22	1970	3	2	1,200	$724,400
428023012	SFR	N	0.22	1970	3	2	980	$537,000
428023013	SFR	N	0.22	1984	3	2	1,144	$565,400
428023014	SFR	N	0.22	1969	3	1	1,616	$553,400
428023015	SFR	N	0.22	1970	3	2	1,728	$606,900
428023016	SFR	N	0.22	1970	4	1	1,386	$586,500
428023017	SFR	N	0.23	1969	3	2	1,368	$656,800
428023018	SFR	N	0.23	1970	3	2	1,301	$558,500
428023019	SFR	N	0.23	1969	3	2	1,522	$611,900
428023020	SFR	N	0.23	1971	3	2	1,970	$663,500
428023021	SFR	N	0.24	1971	2	3	1,928	$659,600
428023022	SFR	N	0.24	1975	6	3	2,092	$647,800
428023023	SFR	N	0.22	1975	3	1	1,352	$571,300
428023024	SFR	N	0.22	1975	3	1	992	$561,100
428023025	SFR	N	0.22	1975	3	1	992	$543,700
428023026	SFR	N	0.23	1975	3	1	992	$554,900
428023027	SFR	N	0.25	1975	3	1	992	$562,700
428023028	SFR	N	0.27	1975	3	1	1,792	$650,400
4280230290001	SFR	N	0.14	1975	2	2	1,129	$696,600
4280230290002	SFR	N	0.14	2007	2	2	1,695	$808,800
428024001	SFR	N	0.22	1971	2	2	1,286	$570,200
428024002	SFR	N	0.22	1970	3	2	1,760	$604,300
428024003	SFR	N	0.24	1970	3	1	1,192	$572,800
428024004	SFR	N	0.24	1969	5	3	2,403	$701,300
428024005	SFR	N	0.26	1970	3	2	1,080	$574,100
428024006	SFR	N	0.25	1970	3	2	1,344	$646,400
428024007	SFR	N	0.24	1969	4	2	2,306	$727,000
428024008	SFR	N	0.23	1969	2	2	1,128	$597,400
428024009	SFR	N	0.22	1990	3	2	1,208	$581,100
428024010	SFR	N	0.23	1970	3	1	912	$519,200
428024011	SFR	N	0.25	1969	4	2	2,312	$707,300
428024012	SFR	N	0.2	1970	3	1	960	$502,800
428024021	SFR	N	0.26	1971	3	2	1,518	$550,900
428024022	SFR	N	0.24	1969	4	4	2,667	$900,500
428024023	SFR	N	0.27	1971	3	2	994	$580,900
Median			0.23					$593,800
Vacant			-					-
Developed			*0.23*	1970	3.0	2.0	1,325	*$593,800*

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
Area G								
428028052	SFR	N	0.23	1988	4	3	2,732	$1,018,900
428028059	SFR	N	0.21	1983	3	3	2,117	$893,600
428028060	SFR	N	0.2	1986	2	2	2,298	$949,100
428028061	SFR	N	0.27	1994	5	4	3,796	$1,223,800
428028062	SFR	N	0.24	2005	3	5	3,079	$1,299,600
428028063	Residential Lot	Y	0.23					$414,600
428028064	SFR	N	0.22	1988	3	3	2,582	$1,036,700
428028065	SFR	N	0.22	1988	3	3	2,336	$970,100
428028066	SFR	N	0.23	1988	3	2	1,850	$902,400
428028067	SFR	N	0.24	2004	3	3	2,910	$1,414,200
428028068	SFR	N	0.25	1986	4	3	2,502	$1,051,100
428028069	SFR	N	0.26	1988	3	2	1,846	$924,300
428028070	SFR	N	0.24	1988	3	3	2,112	$920,200
428028087	SFR	N	0.25	2006	4	5	3,551	$1,433,800
428028088	SFR	N	0.32	2007	3	4	3,415	$1,231,300
428028089	SFR	N	0.32	1986	5	4	3,104	$1,343,900
428028090	SFR	N	0.27	1993	4	5	2,918	$1,186,700
428028091	SFR	N	0.25	1999	5	3	2,950	$1,316,900
Median			0.24					$1,043,900
Vacant			*0.23*					*$414,600*
Developed			*0.24*	1988	3.0	3.0	2,732	*$1,051,100*
Grand Hyatt Kauai								
429001002	Hotel	N	37.74	N/A	N/A	N/A	N/A	*$212,890,700*
Kiahuna Golf Course								
428014007	Golf Course	N	102.02	N/A	N/A	N/A	N/A	$6,553,600
428014036	Golf Course	N	38.11	N/A	N/A	N/A	N/A	$2,446,900
Total			*140.13*					*$9,000,500*
Poipu Bay Golf Course								
429001007	Golf Course	N	44.905	N/A	N/A	N/A	N/A	*$2,932,300*
429001009	Golf Course	N	148.14	N/A	N/A	N/A	N/A	*$13,341,600*
Total			*193.05*					*$16,273,900*
The Point at Poipu								
428021001	Apartment	N	20.45	N/A	N/A	N/A	N/A	$182,306,800
Area H								
426004014	SFR	N	0.6	1997	2	1	836	$508,000
426004032	Residentail Lot	Y	1.47					$959,600
426004033	Residential Lot	Y	0.17					
426004035	SFR	N	0.33	1960	3	2	1,849	$428,500
426004060	SFR	N	0.6	2006	3	2	1,686	$788,200
426008001	SFR	N	0.21	1939	3	1	994	$471,000
426008002	SFR	N	0.26	1931	3	2	1,300	$485,600
426008005	SFR	N	0.27	1950	5	2	1,814	$448,400
426008008	SFR	N	0.17	1964	3	2	1,639	$442,300
4260080090001	SFR	N	0.14	1949	3	1	960	$337,600
4260080090002	SFR	N	0.19	1969	4	2	1,168	$413,900
4260080110001	SFR	N	0.12	1928	3	2	968	$350,500
4260080110002	SFR	N	0.11	2002	2	1	924	$392,600
426008012	SFR	N	0.5	1934	6	3	2,419	$586,500

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
426008013	SFR	N	0.21	1971	4	2	1,652	$455,400
426008014	SFR	N	0.22	1953	3	1	1,008	$403,600
426008015	SFR	N	0.38	1946	6	3	2,001	$463,100
426008016	SFR	N	0.16	1950	3	1	1,066	$387,400
426008017	SFR	N	0.22	1974	3	2	1,080	$437,000
426008018	SFR	N	0.45	1953	4	1	1,541	$466,500
426008019	SFR	N	0.15	1958	3	1	858	$385,500
426008020	SFR	N	1.51	1966	2	1	1,094	$520,700
426008021	SFR	N	0.22	1918	4	3	1,746	$482,500
426008022	SFR	N	0.45	1904	7	3	1,978	$539,700
426008023	Residential Lot	Y	0.23					$200,000
426008024	Residential Lot	Y	0.23					$200,200
4260080250001	SFR	N	0.12	1928	2	2	689	$334,100
4260080250002	SFR	N	0.11	2002	3	2	1,196	$427,900
4260080260001	SFR	N	0.13	2003	2	2	1,104	$405,900
4260080260002	SFR	N	0.12	2003	3	2	1,144	$427,800
426008027	SFR	N	0.25	2005	2	2	1,476	$489,900
4260080280001	SFR	N	0.13	2007	2	2	1,196	$465,200
4260080280002	Residential Lot	Y	0.11					$174,900
426014001	SFR	N	1.99	2004	5	2	3,770	$1,753,900
426014002	SFR	N	0.5	1999	3	2	1,520	$1,021,900
426014003	SFR	N	0.55	2002	3	2	1,920	$1,130,300
426014004	SFR	N	0.53	2001	3	2	1,848	$1,168,900
426014005	SFR	N	0.51	2000	3	3	2,036	$1,212,300
426014006	Residential Lot	Y	0.66					$538,200
426014007	SFR	N	1.05	2003	2	3	2,235	$1,478,700
426014008	Residential Lot	Y	0.52					$471,100
426014009	SFR	N	0.5	2006	3	3	2,120	$1,224,400
426014010	SFR	N	0.53	2005	3	3	2,269	$1,327,900
426014011	SFR	N	0.6	2003	3	3	2,987	$1,433,800
426014012	SFR	N	0.5	2003	2	2	2,211	$1,171,100
426014013	SFR	N	0.51	2000	4	2	1,945	$1,329,400
426014014	Residential Lot	Y	0.48					$448,100
426014015	SFR	N	0.5	2015	3	3	2,518	$1,149,900
426014016	SFR	N	0.6	2002	4	2	2,110	$1,270,800
426014017	Residential Lot	Y	0.52					$468,700
426014018	Residential Lot	Y	0.7					$556,900
426014019	SFR	N	1.65	2000	4	2	2,310	$1,502,400
426014020	SFR	N	0.98	2003	2	2	2,346	$1,324,100
426014021	Residential Lot	Y	0.8					$603,300
426014022	SFR	N	1.24	2000	3	3	2,456	$1,342,900
426014023	SFR	N	0.56	2001	3	3	2,357	$1,492,800
426014024	SFR	N	0.6	2000	3	2	2,057	$1,260,200
426014025	SFR	N	0.58	2002	3	3	2,802	$1,601,000
426014026	SFR	N	0.69	2001	3	3	3,155	$1,688,700
426014027	SFR	N	0.52	2001	4	2	2,904	$1,428,000
426014028	SFR	N	0.5	2001	3	2	2,201	$1,225,700
426014029	SFR	N	0.53	2001	3	3	2,614	$1,225,200
426014030	SFR	N	0.58	2000	6	4	4,019	$1,611,100

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
426014031	Residential Lot	Y	0.5					$459,600
426014032	SFR	N	0.5	2003	3	2	2,131	$1,217,900
Median			0.50					$529,450
Vacant SFR			*0.51*					*$464,150*
Developed SFR			*0.50*	2000	3.0	2.0	1,849	*$788,200*
Area I								
426017001	Residential Lot	Y	0.79					$1,707,800
426017002	Residential Lot	Y	0.93					$1,682,000
426017003	Residential Lot	Y	0.76					$1,785,800
426017006	SFR	N	0.84	2010	2	4	4,547	$4,898,800
426017007	Residential Lot	Y	0.68					$1,750,100
426017008	SFR	N	0.55	2013	4	4	4,204	$5,286,400
426017009	Residential Lot	Y	0.67					$1,745,300
426017010	Residential Lot	Y	0.78					$1,599,900
426017011	SFR	N	0.63	2013	5	5	4,193	$4,377,500
426017012	Residential Lot	Y	0.69					$1,016,000
426017013	Residential Lot	Y	1.02					$1,106,500
426017014	Residential Lot	Y	0.76					$1,033,500
426017016	Residential Lot	Y	0.84					$995,800
426017017	Residential Lot	Y	0.83					$989,200
426017018	Residential Lot	Y	0.95					$1,068,300
426017019	Residential Lot	Y	0.97					$1,084,600
426017020	Residential Lot	Y	1.01					$1,108,000
426017021	Residential Lot	Y	0.86					$1,682,300
426017022	SFR	N	0.48	2015	5	5		$1,273,700
426017023	Residential Lot	Y	0.5					$1,295,100
426017024	SFR	N	0.53	2014	5	5	4,130	$3,344,100
426017025	Residential Lot	Y	0.53					$1,325,900
426017026	Residential Lot	Y	0.5					$1,299,200
426017027	SFR	N	0.58	2015	4	4		$1,381,400
426017028	Residential Lot	Y	0.52					$1,253,500
426017029	Residential Lot	Y	0.54					$1,203,400
426017030	Residential Lot	Y	0.52					$1,185,100
426017031	Residential Lot	Y	0.55					$1,215,000
426017032	Residential Lot	Y	0.54					$1,276,100
426017033	Residential Lot	Y	0.61					$1,410,000
426017034	Residential Lot	Y	0.64					$1,444,300
426017035	Residential Lot	Y	0.63					$1,440,000
426018022	SFR	N	0.48	2014	4	5	3,544	$3,721,600
426018023	Residential Lot	Y	0.49					$1,286,900
426018024	Residential Lot	Y	0.62					$1,423,600
426018025	Residential Lot	Y	0.66					$1,466,000
426018027	Residential Lot	Y	0.56					$1,355,000
426018028	Residential Lot	Y	0.71					$1,524,400
426018029	Residential Lot	Y	0.48					$1,268,800
426018030	SFR	N	0.6	2015	4	4		$1,402,400
426018032	Residential Lot	Y	0.44					$1,104,000
426018033	Residential Lot	Y	0.97					$1,629,700
426018034	Residential Lot	Y	1.17					$1,825,200
426018036	Residential Lot	Y	0.54					$1,199,500

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
426018037	Residential Lot	Y	0.51					$1,177,300
426018038	Residential Lot	Y	0.86					$1,520,500
426018039	Residential Lot	Y	0.87					$1,528,300
426018040	Residential Lot	Y	0.39					$1,059,800
426018041	Residential Lot	Y	0.37					$1,040,100
426018042	Residential Lot	Y	0.3					$972,800
426018043	Residential Lot	Y	0.33					$1,001,500
426018044	Residential Lot	Y	0.42					$1,091,300
426018045	SFR	N	0.67	2014	4	4		$1,333,200
426018046	SFR	N	0.39	2013	4	4	3,177	$2,462,400
426018047	SFR	N	0.43	2015	4	4		$1,095,400
426018048	SFR	N	0.44	2013	3	3	2,663	$3,135,600
426018049	SFR	N	0.33	2015	3	3		$999,000
426018050	Residential Lot	Y	0.75					$1,409,400
426018051	Residential Lot	Y	1.49					$2,135,200
426018053	Residential Lot	Y	0.41					$1,430,900
426018054	Residential Lot	Y	0.41					$1,442,300
426018055	Residential Lot	Y	0.43					$1,461,900
Median			0.59					$1,368,200
Vacant			*0.63*					*$1,297,150*
Developed			*0.53*	2014	4.0	4.0	4,130	*$2,462,400*
Area J								
426016001	Residential Lot	Y	0.29					$663,900
426016002	SFR	N	0.21	2013	3	3	1,631	$2,233,100
426016003	Residential Lot	Y	0.21					$609,600
426016004	Residential Lot	Y	0.29					$662,900
426016005	SFR	N	0.35	2015	3	3		$703,200
426016006	Residential Lot	Y	0.21					$604,600
426016007	Residential Lot	Y	0.21					$743,000
426016008	SFR	N	0.22	2013	4	4	2,893	$3,028,700
426016009	SFR	N	0.28	2013	3	4	2,905	$2,552,900
426016010	SFR	N	0.26	2011	3	4	3,025	$2,629,800
426016011	SFR	N	0.24	2011	2	2	1,560	$2,325,300
426016012	SFR	N	0.22	2011	2	2	1,402	$2,261,700
426016013	Residential Lot	Y	0.25					$633,800
426016014	Residential Lot	Y	0.23					$619,700
426016015	SFR	N	0.24	2009	3	3	2,550	$2,734,000
426016016	SFR	N	0.27	2010	3	3		$943,200
426016017	Residential Lot	Y	0.23					$618,300
426016018	SFR	N	0.24	2014	3	3	2,412	$2,287,000
426016019	SFR	N	0.41	2010	3	3	2,475	$3,540,300
426016020	Residential Lot	Y	0.31					$675,100
426016021	Residential Lot	Y	0.21					$606,400
426016022	Residential Lot	Y	0.22					$616,000
426016023	Residential Lot	Y	0.22					$610,800
426016024	Residential Lot	Y	0.24					$626,100
426016025	Residential Lot	Y	0.23					$621,500
426016026	Residential Lot	Y	0.22					$616,300
426016027	SFR	N	0.28	2011	3	3	1,621	$2,705,500
426016028	Residential Lot	Y	0.25					$632,000

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
426016029	SFR	N	0.33	2015	4	4		$685,000
426016030	Residential Lot	Y	0.25					$631,300
426016031	Residential Lot	Y	0.24					$624,200
426016032	Residential Lot	Y	0.23					$619,000
426016033	Residential Lot	Y	0.25					$632,200
426016034	SFR	N	0.27	2012	3	3	1,621	$2,711,500
426016035	Residential Lot	Y	0.23					$622,200
426016036	Residential Lot	Y	0.22					$612,900
426016037	Residential Lot	Y	0.3					$668,000
426016038	SFR	N	0.3	2011	3	3	2,816	$2,838,100
426016039	SFR	N	0.29	2011	3	3	2,492	$2,582,000
426016040	SFR	N	0.33	2011	3	3	2,348	$2,575,700
426016041	Residential Lot	Y	0.23					$617,900
426016042	Residential Lot	Y	0.21					$609,300
426016043	SFR	N	0.22	2011	2	3	1,704	$2,652,900
426016044	Residential Lot	Y	0.23					$617,700
426016045	Residential Lot	Y	0.26					$640,600
426016046	Residential Lot	Y	0.26					$642,200
426016047	SFR	N	0.53	2015	4	4	2,117	$1,192,200
426016049	SFR	N	0.23	2010	2	2	2,059	$2,825,600
426016050	SFR	N	0.28	2009	4	4	2,375	$2,798,800
426016051	SFR	N	0.31	2010	4	4	2,513	$2,901,600
426016052	SFR	N	0.35	2010	4	4	2,840	$3,574,700
426016053	SFR	N	0.23	2014	2	2	1,803	$2,540,600
426016054	Residential Lot	Y	0.22					$613,800
426016055	Residential Lot	Y	0.29					$663,400
426016056	Residential Lot	Y	0.48					$1,144,400
426016058	Residential Lot	Y	0.29					$660,400
426016059	SFR	N	0.23	2012	4	4	2,897	$3,012,500
426016060	Residential Lot	Y	0.34					$695,400
426016061	Residential Lot	Y	0.29					$662,800
426016062	Residential Lot	Y	0.28					$656,000
426016063	Residential Lot	Y	0.3					$666,200
426016064	Residential Lot	Y	0.35					$698,300
426016065	Residential Lot	Y	0.31					$672,100
426016066	SFR	N	0.26	2014	4	4	2,648	$2,390,600
426016067	Residential Lot	Y	0.34					$693,100
426016068	Residential Lot	Y	0.34					$696,300
426016069	SFR	N	0.31	2015	4	4		$671,400
426016070	Residential Lot	Y	0.28					$651,900
426016071	SFR	N	0.26	2015	4	3		$638,300
426016072	Residential Lot	Y	0.26					$638,100
426016073	Residential Lot	Y	0.27					$649,400
426016074	Residential Lot	Y	0.29					$657,600
426016075	Residential Lot	Y	0.27					$648,800
426016076	Residential Lot	Y	0.26					$638,400
426016077	SFR	N	0.26	2012	3	3	3,253	$2,710,800
426016078	Residential Lot	Y	0.28					$653,200
426016079	SFR	N	0.66	2011	4	4	3,239	$3,224,100
426016081	Residential Lot	Y	0.29					$662,300

Table II-8. Assessed Values of Select Properties, Koloa and Poipu: 2016

(Assessed values of specified properties and areas are shown in Figures II-5 and II-6)

Area and TMK	Type of Property	Vacant	Acres	Year Built	Bedrooms	Bathrooms (Full)	Building Sq. Ft.	Assessed Value (2016)
426016082	Residential Lot	Y	0.29					$660,500
426016083	Residential Lot	Y	0.31					$672,000
426016084	Residential Lot	Y	0.3					$602,700
426016085	SFR	N	0.24	2011	2	2	1,698	$2,160,000
426016086	Residential Lot	Y	0.23					$623,100
426016087	Residential Lot	Y	0.24					$906,100
426016088	Residential Lot	Y	0.32					$682,700
Median			0.26					$666,200
Vacant			*0.26*					*$641,400*
Developed			*0.27*	2011	3.0	3.0	2,444	*$2,582,000*
Area K								
426019001	SFR	N	0.28	2011	3	3	2,048	$2,933,200
426019002	SFR	N	0.26	2011	3	3	2,048	$2,893,100
426019003	SFR	N	0.26	2011	3	3	2,048	$2,893,100
426019004	SFR	N	0.26	2011	3	3	2,048	$2,893,100
426019005	SFR	N	0.27	2013	3	3	2,048	$2,920,300
426019006	SFR	N	0.28	2013	3	3	2,048	$2,932,800
426019007	SFR	N	0.29	2013	3	3	2,048	$2,956,900
426019008	SFR	N	0.31	2013	3	3	2,048	$2,826,200
426019009	SFR	N	0.31	2013	3	3	2,048	$2,684,200
426019010	SFR	N	0.31	2012	3	3	2,048	$3,004,100
426019011	SFR	N	0.31	2012	3	3	2,058	$2,502,200
426019012	SFR	N	0.31	2012	3	3	2,104	$2,550,400
426019013	SFR	N	0.31	2012	2	2	2,060	$1,303,100
426019014	SFR	N	0.3	2015	3	3	2,104	$2,956,500
426019015	SFR	N	0.28	2012	2	2	1,696	$2,553,000
426019016	SFR	N	0.22	2013	3	3	1,854	$2,757,200
Median			0.29					$2,893,100
Vacant			-					-
Developed			*0.29*	2012	3.0	3.0	2,048	*$2,893,100*
Kukuiula (Areas I, J, K)								
Vacant			0.34					$720,650
Developed			0.30	2013	3.0	3.0	2,104	$2,705,500

Sources:
CoreLogic. 2016.
County of Kauai. 2016.

Table II-9. Economic and Population Growth, Kauai and Koloa-Poipu & Eleele-Kalaheo: 2000, 2010 and 2030

Item	2000	2010	Change 2000-2010	2030 Projection	Change 2010-2030
Resident Population					
Kauai	58,463	67,091	14.8%	83,328	24.2%
Koloa-Poipu & Eleele-Kalaheo	10,545	11,696	10.9%	15,737	34.6%
Share	18%	17%		19%	
Average Visitor Census					
Kauai	18,041	19,548	8.4%	25,738	31.7%
Koloa-Poipu & Eleele-Kalaheo	5962	7137	19.7%	9311	30.5%
Share	33%	37%		36%	
Defacto Population					
Kauai	75,200	82,101	9.2%	102,500	24.8%
Koloa-Poipu & Eleele-Kalaheo	16012	17248	7.7%	22800	32.2%
Share	21%	21%		22%	
Households					
Kauai	20,370	23,240	14.1%	28,788	23.9%
Koloa-Poipu & Eleele-Kalaheo	3,862	4,250	10.0%	5,699	34.1%
Share	19%	18%		20%	
Housing Units					
Kauai	25,331	29,793	17.6%	37,519	25.9%
Koloa-Poipu & Eleele-Kalaheo	5,780	5,764	-0.3%	7,766	34.7%
Share	23%	19%		21%	
Wage and Salary Jobs					
Kauai	26,550	28,150	6.0%	34,000	20.8%
Koloa-Poipu & Eleele-Kalaheo		5,027		5,892	17.2%
Share		18%		17%	
Visitor Arrivals, by Air					
Kauai	1,075,000	1,033,000	-3.9%	1,278,000	23.7%
Koloa-Poipu & Eleele-Kalaheo	355,000	377,000	6.2%	475,000	26.0%
Share	33%	36%		37%	
Visitor Units					
Kauai	7,159	9,345	30.5%	11,230	20.2%
Koloa-Poipu & Eleele-Kalaheo	2,366	3,412	44.2%	4,050	18.7%
Share	33%	37%		36%	

Source

SMS. "Kauai General Plan Update: Socioeconomic Analysis and Forecasts." February 2014.

TABLES FOR PART III

Table III-1. Plans for the Dairy

(Values in 2015 dollars)

Item	Source or Multiplier	Initial Dairy	Potential Increase	Potential Dairy	Units
1.a. LAND USE					
Farm Structures and Related Facilities	HDF/Group 70	10	-	10	acres
Pastures	"	470	-	470	"
Cow Raceways, Roads & Setbacks	"	77	-	77	"
Total Area		557	-	557	acres
1.b. HERD					
Milking Cows	HDF/Group 70	699	1,301	2,000	cows
Mobs	"	6	-	6	mobs
Cows per mob (average)	"	117	216	333	cows
1.c. PADDOCKS					
Number	HDF/Group 70	118		118	
Size	"	3.5 to 4.5		3.5 to 4.5	acres
1.d. IMPROVEMENTS					
Pasture					
Fencing (perimeter, paddocks and holding yard)	HDF/Group 70				
Cow raceways and roads	"				
Irrigation system	"				
Potable water system and troughs	"				
Farm Structures and Related Improvements					
Milking parlor and storage tanks	"				
Calving sheds	"				
In-shed feeding and silos	"				
Implement shed & workshop	"				
Effluent system	"				
Dairy Equipment					
Tractors, trucks other farm equipment	"				
Milking system	"				
Mobile tankers, refrigeration, heating	"				
Freight containers	"				

Table III-2. Economic Impacts of Development Activities

(Values in 2015 dollars)

Item	Source or Multiplier	Initial Dairy	Potential Increase	Potential Dairy	Units
2.a. CONSTRUCTION PERIOD	PEP	2	1		years
2.b. CONSTRUCTION EXPENDITURES					
Total Construction Expenditures	HDF	$ 7,500,000	$ -	$ 7,500,000	
		$±1,500,000		$±1,500,000	
Annual Construction Expenditures (average)		$ 3,750,000	$ -		per year
2.c. EQUIPMENT EXPENDITURES					
Total Expenditures on Equipment	HDF	$ 2,000,000	$ -	$ 2,000,000	
		$ ±500,000		$ ±500,000	
Annual Equipment Expenditures (average)		$ 1,000,000	$ -		per year
2.d. INDIRECT SALES GENERATED BY CONSTRUCTION	PEP/I-O Model				
Kauai	117% of const. exp. 65% on Kauai	$ 2,851,875	$ -		per year
Oahu	117% of const. exp. 35% on Oahu	$ 1,535,625	$ -		"
Total Indirect Sales		$ 4,387,500	$ -		per year
2.e. SUMMARY OF EXPENDITURES & SALES					
Final Sales (taxed at 4%)					
Construction Expenditures	Section 2.b	$ 3,750,000	$ -		per year
Equipment Expenditures	Section 2.c	$ 1,000,000	$ -		"
Consumption Expenditures	PEP/I-O Model 55% of payroll, Section 2.h	$ 944,548	$ -		"
Total Sales at 4%		$ 5,694,548	$ -		per year
Intermediate Sales (taxed at 0.5%)					
Indirect Sales Related to Construction	Section 2.d	$ 4,387,500	$ -		"
Less Consumption	above	$ (944,548)	$ -		"
Total Sales at 0.5%		$ 3,442,952	$ -		per year
Total Sales (direct and indirect)		$ 9,137,500	$ -		per year
2.f. PROFITS	PEP				
Profits on Total Sales (direct and indirect)	10.0% of sales	$ 913,750	$ -		per year
Risk Premium for Construction	2.0% of construction	$ 75,000	$ -		"
Total Profit from Construction & Related Activity		$ 988,750	$ -		per year
2.g. EMPLOYMENT (on-site & off-site)	PEP/I-O Model				
Kauai					
Construction Jobs	3.31 x sales/$1 mil	12	-		jobs
Indirect Employment Generated by Construction	1.99 x direct jobs 65% on Kauai	16	-		"
Total Kauai Employment		28	-		jobs
Oahu, Indirect Employment Generated by Construction	1.99 x direct jobs 35%	8	-		"
Total Employment		36	-		jobs
2.h. PAYROLL	PEP/DLIR				
Kauai					
Construction Payroll	$ 53,510 average per job	$ 642,120	$ -		per year
Payroll for Indirect Employment	$ 42,928 "	$ 686,848	$ -		"
Total Kauai Payroll		$ 1,328,968	$ -		per year
Oahu, Payroll for Indirect Employment	$ 48,549 average per job	$ 388,392	$ -		"
Total Payroll		$ 1,717,360	$ -		per year

Table III-2. Economic Impacts of Development Activities
(Values in 2015 dollars)
(continued)

Item	Source or Multiplier	Initial Dairy	Potential Increase	Potential Dairy	Units
2.i. POPULATION SUPPORTED BY DEVELOPMENT ACTIVITIES	PEP/Census				
Kauai Residents					
Supported by Construction Jobs	2.28 per job	27	-		residents
Supported by Indirect Jobs	2.28 "	36	-		"
Total Kauai Residents		63	-		residents
Oahu Residents Supported by Indirect Jobs	2.04 per job	16	-		"
Total Residents Supported		79	-		residents
2.j. HOUSING FOR SUPPORTED POPULATION	PEP/Census				
Kauai Homes					
Supported by Construction Jobs	0.33 per resident	9	-		homes
Supported by Indirect Jobs	0.33 "	12	-		"
Total Homes		21	-		homes
Oahu Homes Supported by Indirect Jobs	0.32 per resident	5	-		"
Total Homes Supported		26	-		homes

Table III-3. Economic Impacts at Full Operations

(Values in 2015 dollars)

Item	Source or Multiplier	Initial Dairy	Potential Increase	Potential Dairy	Units
3.a. MILKING COWS	HDF	699	1,301	2,000	cows
3.b. PRODUCTION	PEP/HDF				
Milk	6.0 gallons per day	1,530,810	2,849,190	4,380,000	gallons/yr
Livestock (calves, and culled cows and heifers)			not estimated		
3.c. SALES					
Kauai					
Dairy	PEP/HDF		not shown to avoid disclosure		
Indirect Sales	PEP/I-O Model		not shown to avoid disclosure		
Total Kauai Sales		$ 8,132,887	$ 15,137,177	$ 23,270,064	per year
Oahu Indirect Sales	PEP/I-O Model	$ 1,988,828	$ 3,701,668	$ 5,690,496	per year
Total Sales		$ 10,121,715	$ 18,838,845	$ 28,960,560	per year
Final Consumption Sales (taxed at 4%)	PEP		not shown to avoid disclosure		"
Intermediate Sales (taxed at 0.5%)	"		not shown to avoid disclosure		"
3.d. PROFITS (on direct and indirect sales)	10% of sales	$ 1,012,172	$ 1,883,885	$ 2,896,056	per year
3.e. EMPLOYMENT					
Kauai					
Dairy	HDF	5	5	10	jobs
Indirect Jobs	PEP/I-O Model				
	1.86 x dairy jobs	6	6	12	"
	65% on Kauai				
Total Kauai Employment		11	11	22	
Oahu Indirect Employment	PEP/DBEDT I-O Model				
	1.86 x dairy jobs	3	3	6	jobs
	35% on Oahu				
Total Employment		14	14	28	jobs
3.f. PAYROLL					
Kauai Payroll					
Dairy	PEP/HDF		not shown to avoid disclosure		per year
Indirect Jobs	PEP/DLIR		not shown to avoid disclosure		"
Oahu Payroll	"		not shown to avoid disclosure		"
Total Payroll			not shown to avoid disclosure		per year
Dairy Payroll in Excess of Average Wages					
In Excess of the County Average Wage	PEP/DLIR		not shown to avoid disclosure		per year
In Excess of the State Average Wage	"		not shown to avoid disclosure		"
3.g. POPULATION SUPPORTED BY OPERATIONS	PEP/Census				
Kauai Residents					
Supported by Dairy Jobs	2.28 per job	11	11	22	residents
Supported by Indirect Jobs	2.28 "	14	14	28	"
Total Kauai Residents		25	25	50	residents
Oahu Residents Supported by Indirect Jobs	2.04 per job	6	6	12	"
Total Residents Supported		31	31	62	residents
3.h. HOUSING FOR SUPPORTED POPULATION	PEP/Census				
Kauai Homes					
Supported by Dairy Jobs	0.33 per resident	4	4	8	homes
Supported by Indirect Jobs	0.33 "	5	5	10	"
Total Homes		9	9	18	homes
Oahu Homes Supported by Indirect Jobs	0.32 per resident	2	2	4	"
Total Homes Supported		11	11	22	homes

Table III-4. Impacts on County Revenues and Expenditures
(Values in 2015 dollars)

Item	Source or Multiplier	Initial Dairy	Potential Increase	Potential Dairy	Units
4.a. CHANGE IN TAX & EXPENDITURE BASE					
Development Activities		-	-	-	
Operations	PEP/County				
Assessed Land, Dairy (dedicated to agriculture)	$ 210 per acre	$ 116,970	$ -	$ 116,970	
Less Existing Land Value		$ (116,970)	$ -	$ (116,970)	
Building Improvements, Dairy	Section 2.b	$ 7,500,000	$ -	$ 7,500,000	
Total Change in Assessed Value		$ 7,500,000	$ -	$ 7,500,000	
4.b. DEVELOPMENT ACTIVITIES					
Additional County Revenues		$ -	$ -	$ -	
Additional Expenditures					
Infrastructure (provided by developer)		$ -	$ -	$ -	
Services		$ -	$ -	$ -	
Net Revenues		$ -	$ -	$ -	
4.c. OPERATIONS					
Additional County Revenues					
Property Taxes on Dairy	County				
	$ 6.75 per $1,000	$ 50,625	$ -	$ 50,625	per year
Supported Residents and Businesses			see text		
Additional Expenditures					
Debt Services	PEP/HDF	$ -	$ -	$ -	
Services					
Dairy	PEP/HDF	$ -	$ -	$ -	
Supported Residents and Businesses			see text		
Net Revenues		$ 50,625	$ -	$ 50,625	per year

Table III-5. Impacts on State Revenues and Expenditures

(Values in 2015 dollars)

Item	Source or Multiplier	Initial Dairy	Potential Increase	Potential Dairy	Units
5.a.CHANGE IN TAX & EXPENDITURE BASE					
Development Activities					
Duration	Table III-2, Section 2.a	2	1		years
Final Sales (taxed at 4%)					
Annual Average	Table III-2, Section 2.e	$ 5,694,548	$ -		per year
Cumulative		$ 11,389,096	$ -	$ 11,389,096	
Intermediate Sales (taxed at 0.5%)					
Annual Average	Table III-2, Section 2.e	$ 3,442,952	$ -		per year
Cumulative		$ 6,885,904	$ -	$ 6,885,904	
Profits (on direct and indirect sales)					
Annual Average	Table III-2, Section 2.f	$ 988,750	$ -		per year
Cumulative		$ 1,977,500	$ -	$ 1,977,500	
Payroll					
Annual Average	Table III-2, Section 2.g	$ 1,717,360	$ -		per year
Cumulative		$ 3,434,720	$ -	$ 3,434,720	
Operations					
Sales					
Consumption Expenditures (taxed at 4%)		not shown to avoid disclosure			per year
Indirect Sales (taxed at 0.5%)		not shown to avoid disclosure			"
Total	Table III-3, Section 3.c	$10,121,715	$ 18,838,845	$28,960,560	per year
Profits (on direct and indirect sales)	Table III-3, Section 3.f	$ 1,012,172	$ 1,883,885	$ 2,896,056	"
Payroll in Excess of Average	Table III-3, Section 3.f	not shown to avoid disclosure			
5.b. DEVELOPMENT ACTIVITIES					
Additional State Revenues, Cumulative					
Excise Tax	State				
Final Sales	4.0% of sales	$ 455,564	$ -	$ 455,564	
Intermediate Sales	0.5% "	$ 34,430	$ -	$ 34,430	
Total Excise Tax		$ 489,994	$ -	$ 489,994	
Corporate Income Taxes	PEP/State				
	1.0% of profits	$ 19,775	$ -	$ 19,775	
Personal Income Taxes	PEP/State				
	4.1% of income	$ 140,824	$ -	$ 140,824	
Total State Tax Revenues		$ 650,593	$ -	$ 650,593	
Additional Expenditures	State				
Tax Credits, Important Ag Lands	HDF	$ (1,000,000)	$ -	$ (1,000,000)	
Infrastructure (provided by developer)	PEP/HDF	$ -	$ -	$ -	
Services	PEP/HDF	$ -	$ -	$ -	
Net Revenues, Cumulative		$ (349,407)	$ -	$ (349,407)	

Table III-5. Impacts on State Revenues and Expenditures

(Values in 2015 dollars)

(continued)

Item	Source or Multiplier	Initial Dairy	Potential Increase	Potential Dairy	Units
5.c. OPERATIONS					
Additional State Revenues, Annual					
Excise Tax Generated by:					
Consumption Expenditures		not estimated to avoid disclosure			per year
Indirect Sales	0.5% of sales	$ 50,609	$ 94,194	$ 144,803	"
Corporate Income Tax	PEP/State 1.0% of profit	$ 10,122	$ 18,839	$ 28,961	"
Personal Inc Tax on Payroll in Excess of Average	PEP	not estimated to avoid disclosure			"
Total Revenues		$ 60,731	$ 113,033	$ 173,764	per year
Additional Expenditures, Annual					
Debt Services	PEP/HDF	$ -	$ -	$ -	
Services					
Dairy	PEP/HDF	$ -	$ -	$ -	
Supported Residents and Businesses			see text		
Net Revenues, Annual		$ 60,731	$ 113,033	$ 173,764	per year

Plasch Econ Pacific LLC
Bruce Steven Plasch, Ph.D., President

ECONOMIC CONSULTING: Economic Development • Land Economics • Feasibility & Valuations • Benefits & Impacts

MEMORANDUM

To: Hawai‘i Dairy Farms

From: Bruce S. Plasch, Ph.D.
Plasch Econ Pacific LLC

Date: December 23, 2016

Subject: Hawai‘i Dairy Farms: Economic Impacts Related to Revised Odor-Detection Limits

INTRODUCTION

Arcadis updated their analysis of odor-detection limits of the planned Hawai‘i Dairy Farms (the “Dairy) at Māhā‘ulepū. Their original findings were presented in the report “Hawaii Dairy Farms, Air Emissions and Odor Evaluation Technical Report,” April 2016, and their revised findings were summarized in “Hawaii Dairy Farms Revised Odor Evaluation Technical Report,” December 2016.

This memorandum addresses the resulting changes, if any, in the economic impacts resulting from the revised odor-detection limits. The economic impacts for the original odor-detection limits were presented in my May 2016 report, “Hawai‘i Dairy Farms: Socioeconomic Conditions, Economic Impacts, and Fiscal Impacts.”

REVISED ODOR-DETECTION LIMITS

The revised odor detection limits found by Arcadis are shown in Figures 1 and 2 for the 699-cow Dairy and the 2,000-cow Dairy, respectively. In each figure, limits are shown assuming two weather conditions: (1) typical conditions and (2) wet conditions (i.e, a period of high rainfall), during which the effluent in the irrigation water will be at a higher concentration.

Arcadis intentionally assumed (1) very conservative parameters and (2) an unlikely confluence of worst-case weather conditions and other factors. In practice, actual offsite odor impacts are likely to be much less than shown in Figures 1 and 2.

ECONOMIC IMPACTS: NO CHANGE

Based on the revised odor-detection limits calculated by Arcadis, the findings in my May 2016 economic impact report remain unchanged. The Dairy will have no adverse economic impacts related to nuisance impacts.

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This assessment is based on the finding by Arcadis that no noticeable odors will extend to resort, commercial, residential or recreational areas—see Figures 1 and 2. Noticeable odors occurring outside the Dairy property will be limited to the abutting farm and ranch lands which are owned by Māhā‘ulepū Farm, lessor of the Dairy property.

In view of the lack of odor impacts on resort, commercial, residential or recreational areas, odors from the Dairy will not adversely affect:

- Guests of resorts in the Kōloa-Po‘ipū region.
- Recreational activities in the region.
- The regional economy (number of visitors, visitor expenditures, retail sales, employment, incomes, etc.)
- Residents when they are at home.
- Property sales in the region (single-family homes, condominiums, second homes, time-share units, etc.).
- Values of properties in the region.
- County or State taxes derived from residents, resorts, or commercial activities in the region.

References

Arcadis. “Hawaii Dairy Farms, Air Emissions and Odor Evaluation Technical Report.” April 22, 2016.

Arcadis. “Hawaii Dairy Farms Revised Odor Evaluation Technical Report.” December 16, 2016.

Plasch Econ Pacific LLC. “Hawai‘i Dairy Farms: Socioeconomic Conditions, Economic Impacts, and Fiscal Impacts.” May 2016.

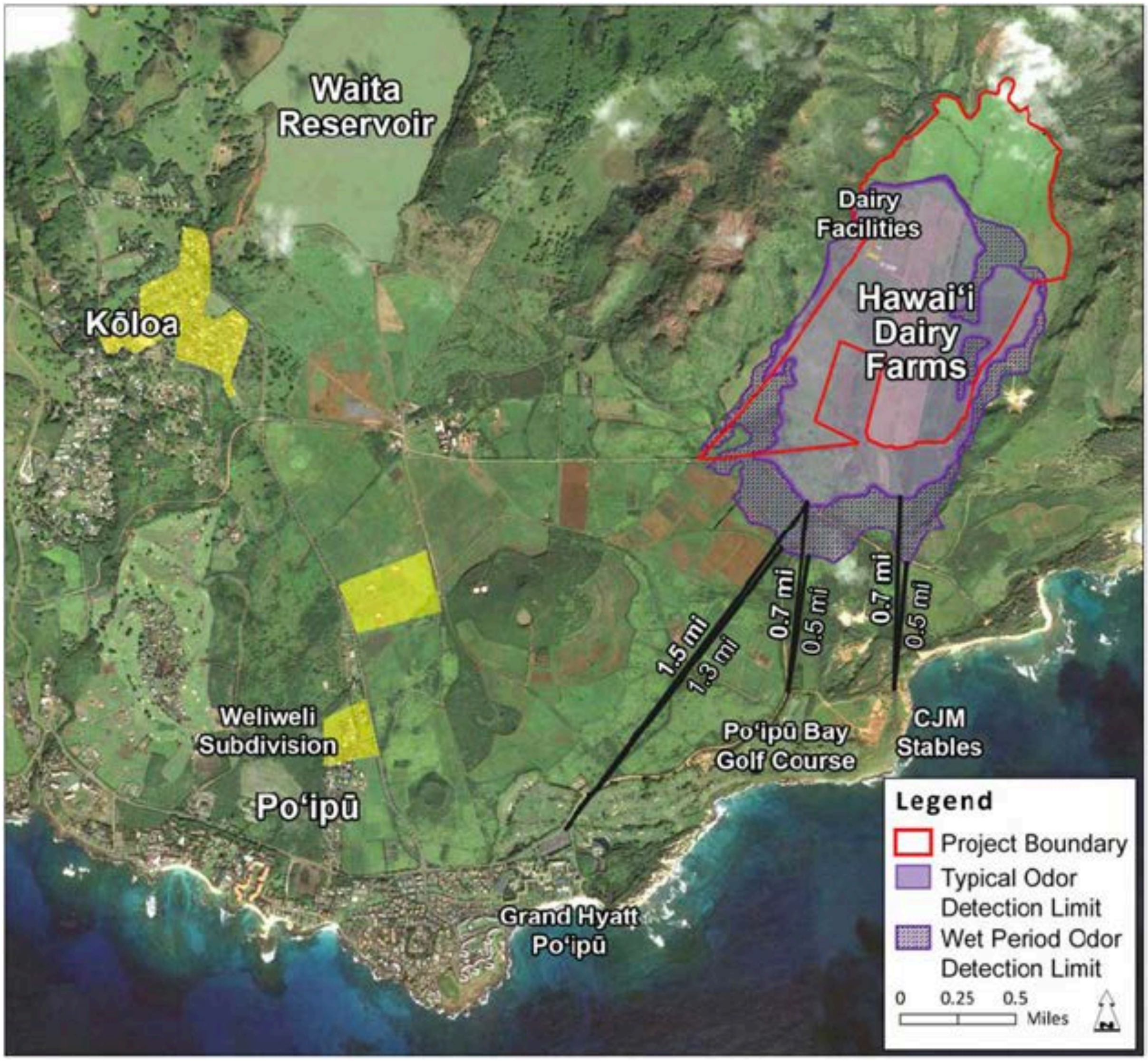

Figure 1. Odor Detection Limits for 699 Mature Cows, Effluent Irrigation Application

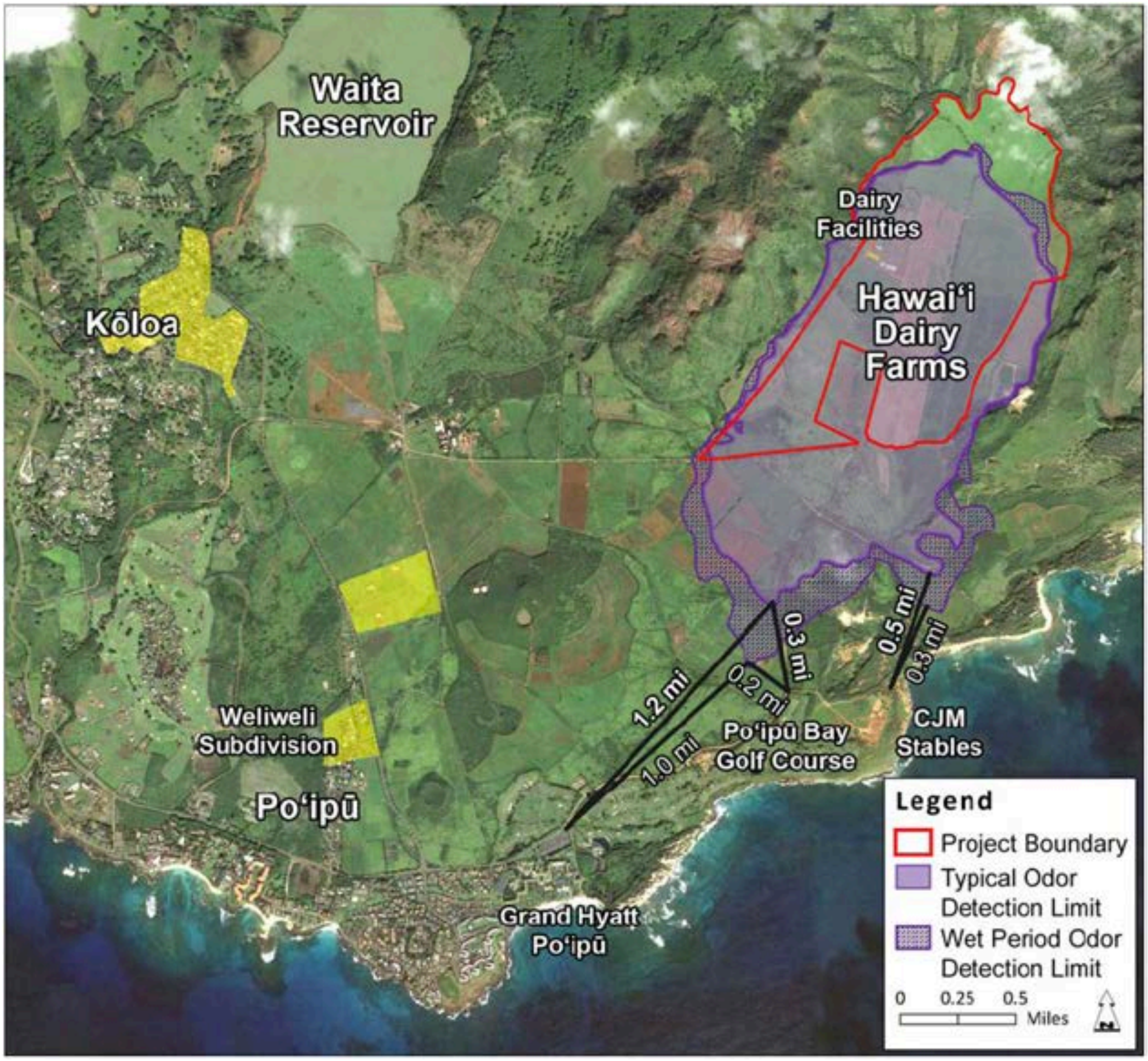

Figure 2. Odor Detection Limits for 2,000 Mature Cows, Effluent Irrigation Application

APPENDIX K

HYDROLOGIC ASSESSMENT FOR THE PASTURE AREAS FOR HAWAIʻI DAIRY FARMS, MĀHĀʻULEPŪ, KAUAʻI, HAWAIʻI

GROUP 70 INTERNATIONAL

HYDROLOGIC ASSESSMENT FOR THE PASTURE AREAS

For

HAWAIʻI DAIRY FARMS

MĀHĀ ʻULEPŪ, KAUAʻI, HAWAIʻI

TMK: (4) 2-9-003: 001 por and 006 por
(4) 2-9-001: 001 por

Prepared for:
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December 1, 2016
~~May 9, 2016~~

TABLE OF CONTENTS

LIST OF FIGURES & TABLES

APPENDICES

1 INTRODUCTION

This assessment presents an overall hydrologic analysis for the existing and proposed conditions for the Hawai‘i Dairy Farms project, as well as the storm drainage design criteria which will be utilized for the design of facility and farm specific drainage infrastructure as part of the project’s Conservation Plan and farm construction plans.

1.1 Proposed Project

In late 2013, Ulupono Initiative made the investment to fund Hawai‘i Dairy Farms, the first pasture-based rotational-grazing dairy in the state. Hawai‘i Dairy Farms, LLC (HDF) was formed as a positive step toward the island state’s food security, economic diversity, and sustainability. At steady-state production with 699 milking cows, the farm will produce roughly 1.2 million gallons annually. HDF will reduce Hawai‘i’s reliance on imported milk from the mainland United States by increasing current fresh local milk production by approximately 33 percent. The farm will be based on the most successful island dairy models in the world, and will utilize a sustainable, pasture-based rotational-grazing system and 21st century technology. The farm will be very different from conventional feedlot dairy operations.

HDF is committed to establishing a herd of up to 699 mature dairy cows, and demonstrating the pasture-based system as an economically and environmentally sustainable model for Hawai‘i. With proven success at a herd size of 699, HDF will contemplate the possibility of expanding the herd in the future. Precision agricultural technology that monitors cows’ health, grass productivity, and effluent management will be used to ensure environmental health and safety, as well as best management practices, and help determine the ultimate carrying capacity of the land.

For dairy operations with 700 or more mature dairy cows, additional regulatory review and permitting by the State of Hawai‘i, Department of Health (DOH) is required. The application process for a National Pollutant Discharge Elimination System (NPDES) Concentrated Animal Feeding Operation (CAFO) permit includes public notification and input. At the discretion of HDF, management may choose to expand operations up to the carrying capacity of the land, which is currently estimated to be up to 2,000 productive milking dairy cows. Permit process compliance would be followed at such time HDF may decide to pursue an expanded operation.

The project will be located in the Māhāʻulepū Valley on the island of Kauaʻi, exclusively within the approximate 556.8 acres of land leased by HDF from Mahaulepu Farm LLC. **See Figure 1 – Vicinity Map**.

Regardless of the amount of animals on the farm, the majority of infrastructure must be constructed prior to commencement of any dairy operations. The farm improvements discussed herein will be used to support the dairy, whether for the initial herd of 699 mature dairy cows, to up to 2,000 mature dairy cows.

1.2 Project Location and Land Use

The project site is situated in the Māhāʻulepū Valley on the island of Kauaʻi. The valley is on the leeward side of the Hāʻupu mountain ridge, which runs in the east-west direction, and the valley is also flanked by ridge lines on both sides. The project area has historically been used for sugar cane production as part of the Kōloa Plantation until the late 1990s when the Kōloa Mill closed. Since the mill closed, the project area has been leased to various tenants for ranching and diversified agricultural operations. A small plot of land in the lower center of the valley is currently used for taro loʻi and will continue to be leased and farmed after the dairy and related pastures are in full operation. **See Figure 2 – Location Map**

The original agricultural infrastructure from the sugar plantation is largely still in place and continues to be used for on-going agricultural activities. Much of this existing infrastructure will also be used for the dairy, but with a significant amount of upgrades and improvements. The existing infrastructure in the project area includes: gravel and dirt access roads, field roads, water wells, reservoirs, pipelines, pumps, irrigation ditches, drainage ways and culverts.

The project area is comprised of lands designated pursuant to the Hawaiʻi State Constitution as Important Agricultural Lands. Accordingly, the project is consistent not only with past agricultural use of the area, but with ongoing constitutionally recognized interest in maintaining and utilizing the area for agricultural purposes that promote agricultural self-sufficiency.

Unlike conventional feed lot dairies, in which mature dairy cows are confined and fed only hay and silages, the project will be the first dairy in the State to utilize rotational, pasture-based grazing. The rotational, pasture-based grazing approach is a system that involves regularly rotating cows through farm paddocks, where they will primarily feed on locally grown grass, supplemented with grain and vitamins as needed. This approach optimizes grass growth, cow health and milk production, facilitates even applications of waste products for fertilization, prevents over-grazing and over-application of fertilizers, and maintains erosion and runoff controls.

The initial herd of up to 699 mature dairy cows will be divided into groups and rotated through a series of paddocks over an 18-day period to access fresh grass and deposit manure throughout the area. Cows will move through a system of raceways to and from the milking parlor, where they will be milked twice a day for a total of two hours. The remaining dry cows, heifers and 90-day and older calves will be managed off-property on existing ranches that are owned and operated by other local ranchers. The project will be fully enclosed by perimeter fencing along the boundary of the leased premises, which will ensure that livestock and grazing activities are contained within the project area.

2 DESIGN CRITERIA

The project will utilize various design criteria due to the available design standards for agricultural operations within the United States, the State of Hawaiʻi, and the County of Kauai. Drainage design criteria and considerations will be used from the following sources:

2.1 References:

1. Storm Water Runoff System Manual, Department of Public Works, County of Kauai, dated July 2001.
2. Standards and Specifications, Field Office Technical Guide (FOTG), Pacific Islands, United States Department of Agriculture (USDA), National Resource Conservation Service (NRCS), dated Various.
3. Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55), USDA, NRCS, Conservation Engineering Division, June 1986
4. All subsequent revisions and amendments for the above referenced standards.

2.2 Design Recurrence Interval (Tm):

Different recurrence intervals will be utilized for analyzing project site and tributary storm drainage flows, and for sizing of the drainage infrastructure on the farm, depending on the type of infrastructure improvements that are constructed and by the governing code and references listed above.

The drainage facility itself is located within 9.7 acres within the farm. Local drainage improvements such as catch basins, storm drain piping, downspouts, and other conveyance systems will be designed to meet the 2-year, 1-hour storm event per County requirements.

Farm-wide improvements will be designed to applicable NRCS Standards and Specifications. If improvements are not covered under applicable NRCS Standards and Specifications, improvements affecting drainage areas less than 100 acres in size will be designed to the 2-year, 1-hour event, and areas greater than 100 acres will be designed to the 100-year, 1-hour event.

Drainage improvements and best management practices will be installed at the guidance, direction, and approval of the NRCS, in accordance with standard practice for agricultural operations, as applicable. These improvements and best management practices will be shown on Hawaiʻi Dairy Farm's Conservation Plan.

Such improvements are typically required to address stormwater management on farm and agricultural lands, and the County typically defers approval of the stormwater and runoff management improvements and best management practices to the local soils and water conservation district, so long as the improvements are constructed to NRCS standards and specifications. The following NRCS practice codes will be used for the site, and the appropriate design recurrence interval is noted.

Standards and Specifications, Field Office Technical Guide (FOTG), Pacific Islands

- <u>For stream/ditch crossings for animals/persons/equipment:</u>
  Tm = 2-year, 24-hour peak discharge
  (Per NRCS Conservation Practice Standard Code 578)

- <u>For stream/ditch crossings for access roads:</u>
  Tm = 10-year, 24-hour peak discharge for frequent use for a farm headquarters
  (Per NRCS Conservation Practice Standard Code 578)

- <u>For vegetated/grassed waterways:</u>
  Tm = 10-year, 24-hour peak discharge
  (Per NRCS Conservation Practice Standard Code 412)

2.3 Runoff Quantity (Q_peak):

Similarly, different methods of calculating peak flows will be utilized for analyzing the project site's generated runoff as well as tributary storm drainage flows for sizing of the drainage infrastructure on the farm, depending on the type of improvements required and by the governing standard.

The drainage facility itself is located within 9.7 acres within the farm. Local drainage flows will be analyzed using the Rational Method, per the County of Kauai standard.

Farm-wide infrastructure improvements, affecting tributary areas greater than 100 acres, will be analyzed using TR-55 or TR-20 programs.

Storm Water Runoff System Manual, Department of Public Works, County of Kauai

- <u>For drainage areas less than 100 acres</u>
  Rational Method, Q = CIA
  Where Q = flow (cfs), C = Runoff Coefficient, I = Intensity (in/hr), and A = Area (acres)

- <u>For drainage areas greater than 100 acres and less than 2,000 acres</u>
  Utilize TR-55 or TR-20 Program

The NRCS Standards and Specifications defer to County requirements to determine peak flows.

Standards and Specifications, Field Office Technical Guide (FOTG), Pacific Islands

- <u>Stormwater Runoff Control, per NRCS Conservation Practice Standard Code 570.</u>
  Prepare a plan, design, and construct controls to comply with applicable federal, state, and local laws and regulations.

2.4 Runoff Coefficient (C) – For Use with the Rational Method:

Storm Water Runoff System Manual, Department of Public Works, County of Kauai

Table 1
TYPICAL RUNOFF COEFFICIENTS FOR BUILT-UP AREAS

LAND USE OR SURFACE CHARACTERISTICS	AVERAGE* PERCENT IMPERVIOUS	STORM FREQUENCY "C" 2	100
Business:			
General Commercial	90	0.82	0.84
Neighborhood Commercial	70	0.60	0.80
Residential:			
R-1	10	0.20	0.40
R-2	20	0.38	0.55
R-4	50	0.43	0.70
R-6	50	0.45	0.75
R-10	50	0.50	0.80
R-20	50	0.55	0.80
5 Acre Lot	8	0.15	0.30
Industrial:			
Limited Industrial	80	0.71	0.82
General Industrial	90	0.80	0.90
Parks, Cemeteries:	7	0.10	0.45
Playgrounds:	13	0.15	0.50
Schools:	50	0.45	0.70
Streets:			
Paved	100	0.87	0.93
Unpaved	95	0.80	0.90
Driveways and Walks:	96	0.87	0.93
Roofs:	90	0.80	0.90
Lawns, Sandy Soil:	0	0.00	0.20
Lawns, Clayey Soil:	0	0.05	0.50

NOTE: (These Rational formula coefficients may not be valid for large basins. These coefficients are also average values and may require adjustments depending on the surface characteristics, soil type, slope, infiltration, evaporation, depression storage, etc. The Engineer shall use sound engineering judgement in selecting the proper coefficient(s).) For composite drainage areas compute "weighted" Rational formula coefficient(s).

*** Average impervious areas do not correlate directly to allowable impervious area.**

2.5 Runoff Curve Number (CN) – For use with TR-55 Program:

TR-55, USDA, NRCS, Conservation Engineering Division

- <u>Land uses based on soils, plant cover, amount of impervious areas, condition, etc.:</u>
  For drainage areas with more than one type of land use, a weighted value of the CN shall be computed.

2.6 Time of Concentration (Tc):

Similarly, different methods of the Time of Concentration (Tc) will be utilized for analyzing the project site's generated runoff as well as tributary storm drainage flows, as required by the governing standard.

Local drainage flows at the facility will be analyzed using the Rational Method as flow paths will be less than 300 feet in length.

Farm-wide improvements will be analyzed using TR-55 or TR-20 programs and will use a summation of distinct, consecutive flow areas.

Storm Water Runoff System Manual, Department of Public Works, County of Kauai

- For flow paths less than 300 feet:
  Use Plate 1

TR-55, USDA, NRCS, Conservation Engineering Division

- For distinct consecutive flow areas:
  The summation of Tc shall be used. Beyond 100 feet, the flow is considered shallow concentrated flow.

2.7 Rainfall Intensity (I):

Similarly, different methods of determining the rainfall intensity will be utilized for analyzing the project site's generated runoff as well as tributary storm drainage flows, as required by the governing standard.

Plate 2 and 3 of the County Code will be used to determine the appropriate rainfall intensity at the dairy facility, to be utilized with the Rational Method.

TR-55 or TR-20 programs, using NOAA 24-hour rainfall for select 24-hour events, will be used to determine rainfall intensity around the farm.

Storm Water Runoff System Manual, Department of Public Works, County of Kauai

- For 2-year, 1 hour event:
  Use Plate 2 and 3 to determine intensity and correction factor

TR-55, USDA, NRCS, Conservation Engineering Division

- Based upon NOAA 24-Hour Rainfall for Select 24-hour Events
  Type I Rainfall Distribution

2.8 NRCS Conservation Practice Standards and Best Management Practices Criteria:

Additional NRCS Conservation Practice Standards, used for specific infrastructure improvements to manage stormwater runoff, may be installed around the farm as needed and will follow the appropriate criteria.

Standards and Specifications, Field Office Technical Guide (FOTG), Pacific Islands

- Surface Cross Drains:
  - Spacing for access roads: Based upon soil type and roadway grade. See Figure 1 of NRCS Conservation Practice Standard Code 560
  - Spacing for animal trails and walkways: As required due to field conditions or as indicated. See NRCS Conservation Practice Standard Code 575
- Waterway Setbacks and Filter Strips (393) / Buffer Plantings (390):
  - Minimum Flow Length per NRCS Conservation Practice Standard Code 393: 10-year life span, with a minimum 20-foot filter strip length. Length shall be increased to 30 feet to provide additional capacity to reduce dissolved contaminants in runoff.
  - Minimum Width of Buffer per NRCS Conservation Practice Standard Code 390: Buffer shall be 2.5 times the stream width from bank-full elevations or 35 feet to provide capacity to maintain or improve water quality and quantity

management. Concentrated flow erosion should be controlled up-gradient of buffer.

- Design Slopes per NRCS Conservation Practice Standard Code 393: Upstream drainage area should have minimum 1% slope. The maximum gradient along the leading edge shall not exceed 5%.

- Grassed Waterway (412) / Field Ditch (607):
  - Minimum Capacity per NRCS Conservation Practice Standard Code 412: Waterway shall convey the peak runoff from the 10-year, 24-hour duration event. Capacity shall be increased to account for potential high volumes of sediment. When the slope is less than 1%, out of bank flow is permitted so long as erosion is minor.
  - Minimum Capacity per NRCS Conservation Practice Standard Code 607: Application of locally tried and proven drainage coefficients, plus consideration for yield of groundwater or irrigation water.
  - Maximum Side Slope per NRCS Conservation Practice Standard Code 412: Flatter than 2 to 1 H:V slopes and should accommodate equipment needed for maintenance and tillage/harvesting.

3 EXISTING CONDITIONS

Since the sugar plantation closed, the project area has been leased to various tenants for ranching and diversified agricultural operations. A small plot of land in the lower center of the valley is currently used for taro lo'i and will continue to be leased and farmed after the dairy and related pastures are in full operation. Neighboring operators consist of beef cattle and banana crops.

Currently, the site is being used for grass trials in preparation of construction and establishment of the dairy facility and pastures. Irrigation systems for growing the grass, watering facilities, limited fencing, and monitoring wells have also been installed, though the site is largely vacant. Clearing and mowing has been taking place as part of ongoing maintenance.

3.1 Topography and Drainage Runoff Patterns

The project site is situated in the Māhā'ulepū Valley on the island of Kaua'i. The valley is on the leeward side of the Ha'upu mountain ridge, which runs in the east-west direction, and the valley is also flanked by ridge lines on both sides. Mt. Ha'upu is the highest point on the ridge line at the back of the valley with an elevation of 2,297 feet. From this point, the ground drops very quickly down to the bottom of the valley to about an elevation of 150 feet. The base of the valley itself is somewhat gradually sloped from an elevation of 150 feet to an elevation of 60 feet along Māhā'ulepū Road on the makai side of the project site near the taro farm.

Runoff from the valley walls is generally conveyed via shallow concentrated flow which collects into cutoff ditches along the exterior of the boundary of the farm. The cutoff ditches are typically located on the uphill side of the proposed fence line for the dairy farm or of the farm roads, including Māhā'ulepū Road, preventing the run on of stormwater onto the farm property. These cutoff ditches then move along the fence lines or roadways and ultimately connect to two main ditches that convey water via channel flow from the upland area, through the farm, and then mauka to the ocean. The ditches were likely configured by historical agriculture uses, based upon their linear shape and as they follow two main roads on the farm site. The two ditches remain separate on the farm: Māhā'ulepū Ditch (East) which runs centrally through the farm, and Māhā'ulepū Ditch (West) which runs near the proposed facility location. Downstream of the farm site, the two separate ditches combine into Māhāʻulepū Ditch, before reaching the ocean.

Runoff from the farm area within the project boundaries itself generally sheet flows or flows in shallow concentration towards and into these ditches.

See Figure 3 – USGS Map

3.2 Existing Water Resources

The Māhāʻulepū Valley has been in agricultural use for a very long time and much of the water resources and infrastructure in the valley are man-made and were constructed to provide irrigation water to the sugar cane lands throughout the valley. Systems of ditches, reservoirs and irrigation pipes and pumps are still in place and are still used to irrigate fields and pasture. Some of these systems cutoff overland flow towards the project site, as they surround the farm. Much of this infrastructure is shown on the USGS maps. **See Figures 4 –Water Resources**

3.3 Soils Condition

According to the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) survey data, the project area consists of a variety of soils. Soil characteristics are summarized in the table below. **See Figure 5 – Soil Map**

Table 1 – Soil Characteristics Summary

Soil Classification	Soil Classification	Slope Range (%)	Hydrologic Soils Group	Drainage Class	Depth to Water Table (inches)	Capacity to transmit water – Ksat (in/hr)	Typical Soil Profile - Layer 1 (depth from surface)	Typical Soil Profile - Layer 2 (depth from surface)	Typical Soil Profile - Layer 3 (depth from surface)
Hanamaulu Silty Clay	HsD	15 to 20%	B	Well Drained	> 80″	0.14 to 1.98	0 to 11″ Silty Clay	11 to 36″ Silty Clay	36 to 72″ Silty Clay Loam
Hanamaulu Stony Silty Clay	HtE	10 to 35%	B	Well Drained	> 80″	0.20 to 2.00	0 to 11″ Stony Silty Clay	11 to 36″ Silty Clay	36 to 72″ Silty Clay Loam
Ka'ena Clay, Brown Variant	KavB	1 to 6%	D	Poorly Drained	24 to 60″	0.00 to 0.20	0 to 10″ Clay	10 to 37″ Stony Clay	37 to 54″ Stony Clay
Ka'ena Clay, Brown Variant	KavC	6 to 12%	D	Poorly Drained	24 to 60″	0.00 to 0.20	0 to 10″ Clay	10 to 37″ Stony Clay	37 to 54″ Stony Clay
Kalapa Silty Clay	KdF	40 to 70%	B	Well Drained	> 80″	0.00 to 0.20	0 to 10″ Silty Clay	10 to 60″ Clay	
Kalihi Clay	Ke	n/a	D	Poorly Drained	24 to 60″	0.06 to 0.60	0 to 16″ Clay	16 to 70″ Clay	
Kalapa Very Rocky Silty Clay (Very Rocky)	KEHF	40 to 70%	B	Well Drained	> 80″	0.00 to 0.20	0 to 10″ Silty Clay	10 to 60″ Clay	
Kalapa Very Rocky Silty Clay (Rock Outcrop)	KEHF	40 to 70%	D			0.00 to 0.06	0 to 60″ Bedrock		
Lualualei Clay	LuB	2 to 6%	D	Well Drained	> 80″	0.00 to 0.20	0 to 10″ Clay	10 to 60″ Clay	
Pakala Clay Loam	PdA	0 to 2%	B	Well Drained	> 80"	0.60 to 1.98	0 to 16″ Clay Loam	16 to 60″ Silty Clay Loam	
Pakala Clay Loam	PdC	2 to 10%	B	Well Drained	> 80"	0.60 to 1.98	0 to 16″ Clay Loam	16 to 60″ Silty Clay Loam	
Rock Land	rRK	n/a	D	Well Drained	> 80"	0.00 to 0.06	0 to 4″ Silty Clay	4 to 8″ Silty Clay	8 to 20″ Bedrock
Rock Land (Rock Outcrop)	rRK	n/a	D			0.00 to 0.06	0 to 60″ Bedrock		
Waikomo Stony Silty Clay	Ws	n/a	D	Well Drained	> 80"	0.00 to 0.06	0 to 14″ Stony Silty Clay	14 to 20″ Stony Silty Clay Loam	20 to 30″ Bedrock

3.4 Rainfall Data

Precipitation depths for various durations and recurrence intervals were obtained from NOAA Atlas 14, Volume 4, Version 3.

Table 2 – NOAA 24-Hour Rainfall Data

Storm Event (Recurrence Interval)	Storm Duration	
	1-hour	24-hour
1-year	1.18"	3.47"
2-year	1.55"	4.78"
10-year	2.54"	8.18"
25-year	3.17″	10.4″
50-year	3.70"	12.2"
100-year	4.25"	14.1"

3.5 Existing Hydrology

As previously noted, the site is currently utilized for diversified agriculture, though some of the site is used for grass trials for the proposed dairy. Therefore, the site is assumed to generally consist of grass, in "fair" condition, on a gentle to moderate sloping surface.

Because the entire farm site drains into two major ditches running mauka to makai, the runoff generated over the farm area is split into two drainage areas and drainage systems. Additionally, run-on onto the site and into the farm area must be considered from the upland areas and from the ridges which form Māhāʻulepū Valley, though the majority of run-on is diverted by cutoff ditches on the uphill side of the farm boundary.

Generally, runoff from the west side of the valley sheet flows or is conveyed via shallow concentrated flow through the various system of ridges and valleys along the west side of Māhāʻulepū Valley. Runoff concentrates into several ditches, cut from agricultural operations, before ultimately collecting into one of the major ditches that runs mauka to makai along the west side of the farm, and along the proposed location of the dairy facility. This ditch conveys both water collected from the various tributary ditches, but also sheet flow from the west side of the farm, to the makai boundary of the farm along Māhāʻulepū Road, before leaving the site and ultimate discharge into the ocean.

Runoff from the east side of the valley, similarly, sheet flows or is conveyed via shallow concentrated flow through the various system of ridges and valleys along the east side of Māhāʻulepū Valley. Runoff concentrates into several ditches, cut from agricultural operations, before ultimately collecting into one of the major ditches that runs mauka to makai along the central or east side of the farm. This ditch conveys both water collected from the various tributary ditches, but also sheet flow from the central and eastern areas of the farm, to the makai boundary of the farm along Māhāʻulepū Road, before leaving the site and ultimate discharge into the ocean.

The flows from these two ditches converge beyond the boundary of Hawai‘i Dairy Farms before discharge to the ocean.

See Figure 8 – Hydrology Exhibit – Existing Conditions

Utilizing TR-55 for analysis of both ditches running through the valley (Māhāʻulepū Ditch East & Māhāʻulepū Ditch West), the following parameters were input into the TR-55 program to estimate the existing peak discharge from both reaches:

Table 3 – Existing Hydrology

Parameter	Māhāʻulepū Ditch West	Māhāʻulepū Ditch East
Total Drainage Area (acs)	**598.3 acs**	**1179.2 acs**
Runoff Curve Number (CN) *By Area and Condition*	**Weighted = 72** **Woodlands (Fair Condition)** Soil Group B = 215.6 acs Soil Group D = 87.7 acs **Pasture (Fair Condition)** Soil Group B = 124.1 acs Soil Group D = 170.9 acs	**Weighted = ~~68~~ 69** **Woodlands (Fair Condition)** Soil Group B = 673.7 acs Soil Group D = 139.9 acs **Pasture (Fair Condition)** Soil Group B = 35.5 acs Soil Group D = 330.1 acs

Time of Concentration (Tc) *By Length of Flow*	**Total = 0.257 hours** **Sheet Flow (Valley - Woods)** 100 feet @ ~35% **Shallow Concentrated** 1,890 feet @ ~35% **Shallow Concentrated** 650 feet @ ~8% **Channel (Farm – Stream)** 250 feet @ 4% **Channel to Outlet** 5,060 feet @ 0.8%	**Total = 0.246 hours** **Sheet Flow (Valley - Woods)** 100 feet @ ~97% **Shallow Concentrated** 4,150 feet @ ~97% **Shallow Concentrated** 575 feet @ ~2.3% **Channel (Farm – Stream)** 1,350 feet @ 2.6% **Channel to Outlet** 5,780 feet @ 0.9%
Average Velocity (fps) *Based on Tc*	**8.59 feet per second**	**13.50 feet per second**
Rainfall Intensity (I) *Refer to NOAA 24-hour Rainfall Data*	**2-year = 4.78 in** **10-year = 8.18 in** **25-year = 10.4 in** **50-year = 12.2 in** **100-year = 14.1 in**	**2-year = 4.78 in** **10-year = 8.18 in** **25-year = 10.4 in** **50-year = 12.2 in** **100-year = 14.1 in**
Rainfall Distribution	**Type I**	**Type I**
Peak Flow (Q) @ Makai Māhā'ulepū Road Boundary *In cubic feet per second*	**2-year = 702.4 cfs** **10-year = 1,813.1 cfs** **25-year = 2,586.6 cfs** **50-year = 3,226.2 cfs** **100-year = 3,907.3 cfs**	**2-year = 1,195.0 cfs** **10-year = 3,319.5 cfs** **25-year = 4,846.1 cfs** **50-year = 6,109.9 cfs** **100-year = 7,461.0 cfs**
Estimated Peak Flow (Q) @ Outlet *When Flows Combine Beyond Farm*	**2-year = 1,896.9 cfs** **10-year = 5,131.1 cfs** **25-year = 7,429.6 cfs** **50-year = 9,336.0 cfs** **100-year = 11,358.2 cfs**	

4 PROPOSED CONDITIONS

As previously noted, Hawai'i Dairy Farms will be the first pasture-based rotational-grazing dairy in the state, and was formed as a positive step toward the island state's food security, economic diversity, and sustainability. At steady-state production with 699 milking cows, the farm will produce roughly 1.2 million gallons annually. The farm will be based on the most successful island dairy models in the world, and will utilize a sustainable, pasture-based rotational-grazing system and 21st century technology. The farm will be very different from conventional feedlot dairy operations.

HDF is committed to establishing a herd of up to 699 mature dairy cows, and demonstrating the pasture-based system as an economically and environmentally sustainable model for Hawai'i. With proven success at a herd size of 699, HDF will contemplate the possibility of expanding the herd in the future, to up to 2,000 mature dairy cows. Precision agricultural technology that monitors cows' health, grass productivity, and effluent management will be used to ensure environmental health and safety, as well as best management practices, and help determine the ultimate carrying capacity of the land.

The majority of infrastructure must be constructed prior to commencement of dairy operations, regardless of the amount of animals on the farm. Improvements to be constructed include a milking facility, storage shed, calf sheds, concrete walkways and pads, vehicular turnaround, an animal holding area, a wastewater settling pond and storage pond, and a berm to provide secondary containment for the ponds. Additional farm improvements include the installation of gravel and dirt animal walkways and trails, gravel and dirt access roadways, fencing, paddocks and pasture, irrigation systems, refurbishment of an existing potable water well, animal watering facilities, and an animal cemetery. Utilities, including water, sewer, storm drainage, electrical, and communications, will be installed to support the farm.

Due to the agricultural nature of the project, improvements are not expected to significantly alter existing runoff amounts and drainage patterns. NRCS Conservation Practice Standards will be used to design Best Management Practices (BMPs) to manage stormwater run-on from the adjacent valley, as well as runoff from the farm. These BMPs will be designed, implemented, and utilized specifically for the existing and proposed site conditions of HDF and will mitigate impact from proposed uses to the extent practicable. Stormwater management on the farm will be critical to ensure minimal impact from runoff, and to prevent nutrients from cow manure, liquid effluent, slurry applications, and commercial fertilizer (used as nutrient for grass forage growth essential to the cows' diet) from entering into the drainage system and ultimately, the ocean.

See Figure 6 – Paddock Map & Figure 7 – Farm Map

4.1 Grading and Topography

No grading activities have occurred on site thus far. After the proposed improvements to the site, topography of the farm is not expected to be significantly altered. Low lying areas, berms, and other features that have been installed by previous agricultural operations may be removed or smoothed out, per the appropriate NRCS Conservation Practice Code (466), to allow for more level land for grass growth and the cows to graze on. Smoothing will also improve stormwater flow by allowing runoff to properly drain from lower-lying areas and behind berms. Old irrigation field ditches, not including the main ditches running mauka to makai used for conveyance purposes, which were previously installed and have not been maintained, will either be restored or removed. Grading will not impact overall drainage patterns throughout the farm and will not affect the two major ditches serving the site.

4.2 Soils Conditions

According to available soils testing data from the site, the soils are severely nutrient deficient. Part of the project involves the land application of liquid effluent, as-excreted manure, slurry, and commercial fertilizers which will assist with the nutrient content of the soil needed for adequate grass growth to sustain the dietary needs of the cows. As such, it is expected that soils conditions will improve and will assist with the management of stormwater runoff quantity and quality as the grass becomes established.

4.3 Stormwater Management

Stormwater management, including provisions for both water quantity as well as water quality, for **during-construction** stormwater discharges from new construction projects are governed by NPDES General Permit coverage under the State of Hawai‘i Department of Health, Clean Water

Branch. As the disturbed area of the dairy facility, including the milking parlor, effluent ponds, holding yards, calf sheds, and implement shed, is greater than 1 acre, the facility construction site will be subject to NPDES General Permit coverage and requirements. For farm improvements done for the sole purpose of growing crops (HAR 11-55 Appendix C and DOH E-Permitting Portal for NPDES Permits) beyond the dairy facility, NPDES General Permit coverage is typically not required. However, after consultation with the Clean Water Branch and the County of Kauai, the proposed project will submit for NPDES General Permit coverage for Construction Activities for select farm improvements, including the construction of the farm roads, and will prepare a Storm Water Pollution Prevention Plan (SWPPP) to manage stormwater runoff during construction.

Stormwater management best management practices, including provisions for both water quantity as well as water quality, for **post-construction** stormwater discharges from the proposed farm infrastructure will be installed around the farm under NRCS guidance, and in conjunction with the West Kauai Soils and Water Conservation District (SWCD) – approved and NRCS-reviewed Conservation Plan for the Hawai‘i Dairy Farm project.

Infrastructure improvements which will impact runoff patterns, conveyance, and water quantity and quality around the farm will be installed per NRCS Conservation Practice Codes and Standards in accordance with the Conservation Plan for the project, and include:

Table 4 – NRCS Practice Codes and Infrastructure Improvements

NRCS Practice Code:	**Discipline**	**Summary**
Access Roads (560)	Water Quantity	Governs design of access roadways and installation of surface cutoff ditches or cross drains.
Animal Trails and Walkways (575)	Water Quantity	Governs design of animal walkways and installation of surface cutoff ditches or cross drains.
Filter Strip (393)	Water Quality	Governs the installation of filter strips and buffers along waterways. Recommends minimum of 30 feet setback to provide removal of dissolved pollutants. HDF intends to install 35 foot setbacks.

Grassed Waterway (412)	Water Quantity and Water Quality	Governs the installation of grassed swales intended to provide conveyance of collected surface runoff and promote biofiltration and infiltration of collected pollutants.
Riparian Herbaceous Cover (390)	Water Quality	Governs the planting required to provide water quality benefits from setback areas. Recommends minimum of 2.5 times the width of a waterbody as a total setback to provide removal of pollutants. HDF intends to install 35 foot setbacks on each side for a total of 70 feet of riparian herbaceous cover area.
Sediment Basin (350)	Water Quality	Governs the design and installation of a sediment basin intended to capture and remove sediment prior to discharge.
Stream Crossings (578)	Water Quantity	Governs the design and installation of culverts or bridges required for stream crossings for animal walkways or access roads. Sizing of the culvert shall be per the practice code.
Stormwater Runoff Control (570)	Water Quantity	Provides general guidance for the design of runoff controls on site.
Surface Drainage – Field or Ditch (607)	Water Quantity	Governs the design and installation of surface drainage such as ditches or field drains to drain specific sections of farm lands.
Surface Drainage – Main or Lateral (608)	Water Quantity	Governs the design and installation of main line surface drainage and conveyance from Practice Code 607 (field drainage).
Water and Sediment Control Basin (638)	Water Quality	Governs the design and installation of a sediment basin intended to capture and remove sediment prior to discharge.

Conservation Practice Number in (Parenthesis)

4.4 Proposed Hydrology (Farm)

Hydrology for the post-construction conditions on the farm will be analyzed using the TR-55 program. Because the drainage patterns, pathways, and conveyance systems primarily remain the same, the only appreciable difference in the analysis of runoff generation will be the condition of the pasture and fields. This change will be input into the TR-55 program.

Due to the tillage, cultivation, maintenance, and maturation of the pastures needed to ensure that adequate grass growth and management of stormwater occurs on fields used for grazing dairy cattle, the condition of the pastures will be assumed to improve to "good" for the purposes of the TR-55 program. Kikuyu grass, which will be planted on each of the paddocks on the farm, will be carefully managed, monitored, and maintained. Grassed waterways will be used to drain paddocks, and vegetated filter strips with riparian herbaceous cover will be provided along water courses and ditches to provide water quality protection and improved bio-filtration and infiltration.

See Figure 10 – Hydrology Exhibit – Proposed Conditions

Utilizing TR-55 for analysis of both ditches running through the valley (Māhāʻulepū Ditch East & Māhāʻulepū Ditch West), the following parameters were input into the TR-55 program to estimate the proposed peak discharge from both reaches:

Table 5 – Proposed Hydrology

Parameter	**Māhāʻulepū Ditch West**	**Māhāʻulepū Ditch East**
Total Drainage Area (acs)	**598.3 acs**	**1179.2 acs**
Runoff Curve Number (CN) *By Area and Condition*	**Weighted = 69** **Woodlands (Fair Condition)** Soil Group B = 215.6 acs Soil Group D = 87.7 acs **Pasture (Good Condition)** Soil Group B = 124.1 acs Soil Group D = 170.9 acs	**Weighted = 68** **Woodlands (Fair Condition)** Soil Group B = 673.7 acs Soil Group D = 139.9 acs **Pasture (Good Condition)** Soil Group B = 35.5 acs Soil Group D = 330.1 acs
Time of Concentration (Tc) *By Length of Flow*	**Total = 0.257 hours** **Sheet Flow (Valley - Woods)** 100 feet @ ~35% **Shallow Concentrated** 1,890 feet @ ~35% **Shallow Concentrated** 650 feet @ ~8% **Channel (Farm – Stream)** 250 feet @ 4% **Channel to Outlet** 5,060 feet @ 0.8%	**Total = 0.246 hours** **Sheet Flow (Valley - Woods)** 100 feet @ ~97% **Shallow Concentrated** 4,150 feet @ ~97% **Shallow Concentrated** 575 feet @ ~2.3% **Channel (Farm – Stream)** 1,350 feet @ 2.6% **Channel to Outlet** 5,780 feet @ 0.9%
Average Velocity (fps) *Based on Tc*	**8.59 feet per second**	**13.50 feet per second**
Rainfall Intensity (I) *Refer to NOAA 24-hour Rainfall Data*	**2-year = 4.78 in** **10-year = 8.18 in** **25-year = 10.4 in** **50-year = 12.2 in** **100-year = 14.1 in**	**2-year = 4.78 in** **10-year = 8.18 in** **25-year = 10.4 in** **50-year = 12.2 in** **100-year = 14.1 in**

Rainfall Distribution	Type I		Type I	
Peak Flow (Q) @ Makai Māhā'ulepū Road Boundary *In cubic feet per second*	2-year = 10-year = 25-year = 50-year = 100-year =	597.5 cfs 1,661.2 cfs 2,422.5 cfs 3,053.9 cfs 3,730.2 cfs	2-year = 10-year = 25-year = 50-year = 100-year =	1,126.5 cfs 3,218.5 cfs 4,732.3 cfs 5,991.3 cfs 7,331.2 cfs
Estimated Peak Flow (Q) @ Outlet *When Flows Combine Beyond Farm*		2-year = 10-year = 25-year = 50-year = 100-year =	1,723.3 cfs 4,874.0 cfs 7,146.3 cfs 9,036.3 cfs 11,054.1 cfs	

Table 6 – Comparison in Peak Flows (Existing to Proposed)

Parameter	Mahaulepu Ditch West		Mahaulepu Ditch East	
Difference in Peak Flow (Q) Existing to Proposed *In cubic feet per second*	2-year = 10-year = 25-year = 50-year = 100-year =	(104.9) cfs (151.9) cfs (164.1) cfs (172.3) cfs (177.1) cfs	2-year = 10-year = 25-year = 50-year = 100-year =	(68.5) cfs (101.0) cfs (113.8) cfs (118.6) cfs (129.8) cfs
Difference in Estimated Peak Flow (Q) Existing to Proposed @ Outlet *When Flows Combine Beyond Farm*		2-year = 10-year = 25-year = 50-year = 100-year =	(173.6) cfs (257.1) cfs (283.3) cfs (299.7) cfs (304.1) cfs	

As indicated in Table 6, it is anticipated that due to the tillage, cultivation, maintenance, and maturation of the pastures, needed to ensure that adequate grass growth and management of stormwater occurs on fields used for grazing dairy cattle, the condition of the pastures will be improved. As a result, stormwater runoff flows from existing conditions are not expected to be significantly impacted, and will slightly reduce. The proposed dairy is not expected to significantly impact drainage conditions and peak flow patterns on the farm.

Kikuyu grass, which will be planted on each of the paddocks on the farm, will be carefully managed, monitored, and maintained. Grassed waterways will be used to drain paddocks, and vegetated filter strips with riparian herbaceous cover will be provided along water courses and ditches to provide water quality protection and improved bio-filtration and infiltration.

4.5 Proposed Drainage Infrastructure

Due to the agricultural nature of the project, drainage infrastructure will be limited to surface improvements including but not limited to:

- Filter Strip (393)
- Grassed Waterway (412)
- Sediment Basin (350)
- Stream Crossings (578)
- Surface Drainage – Field or Ditch (607)
- Surface Drainage – Main or Lateral (608)
- Water and Sediment Control Basin (638)

Conservation Practice Number in (Parenthesis)

Design and installation of these drainage improvements will be governed by the NRCS-reviewed and SWCD-approved Conservation Plan for the Hawai'i Dairy Farms project. An agricultural exemption from U.S. Army Corps of Engineers – Section 404 Permitting (For regular maintenance work in waters of the U.S.) applies to NRCS Standard Practice Codes.

Because much of the original agricultural infrastructure from the sugar plantation is largely still in place, improvements to the existing drainage infrastructure, such as the cutoff and main ditches, pipe crossings, and outlets are not anticipated. Existing ditches will be maintained or restored, where required, to improve stormwater runoff conveyance capacities, while vegetation will be restored to improve stormwater quality from runoff entering the ditches.

5 REFERENCES

5.1 County of Kauai

- *Storm Water Runoff System Manual*, Department of Public Works, County of Kauai, dated July 2001.

5.2 State of Hawaiʻi

- *Water Pollution Control, NPDES Permitting Requirements*, HAR Chapter 11-55, Appendix C, State of Hawaiʻi, Department of Health, amended November 2014.

5.3 U.S. Department of Agriculture

- *Drainage Water Management Plan Criteria, Practice/Activity Code (130) (No.)*, United State Department of Agriculture, National Resource Conservation Service, dated May 2013.
- *Standards and Specifications, Field Office Technical Guide (FOTG), Pacific Islands*, United States Department of Agriculture, National Resource Conservation Service, dated Various.
- *Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55)*, USDA, NRCS, Conservation Engineering Division, June 1986

FIGURES

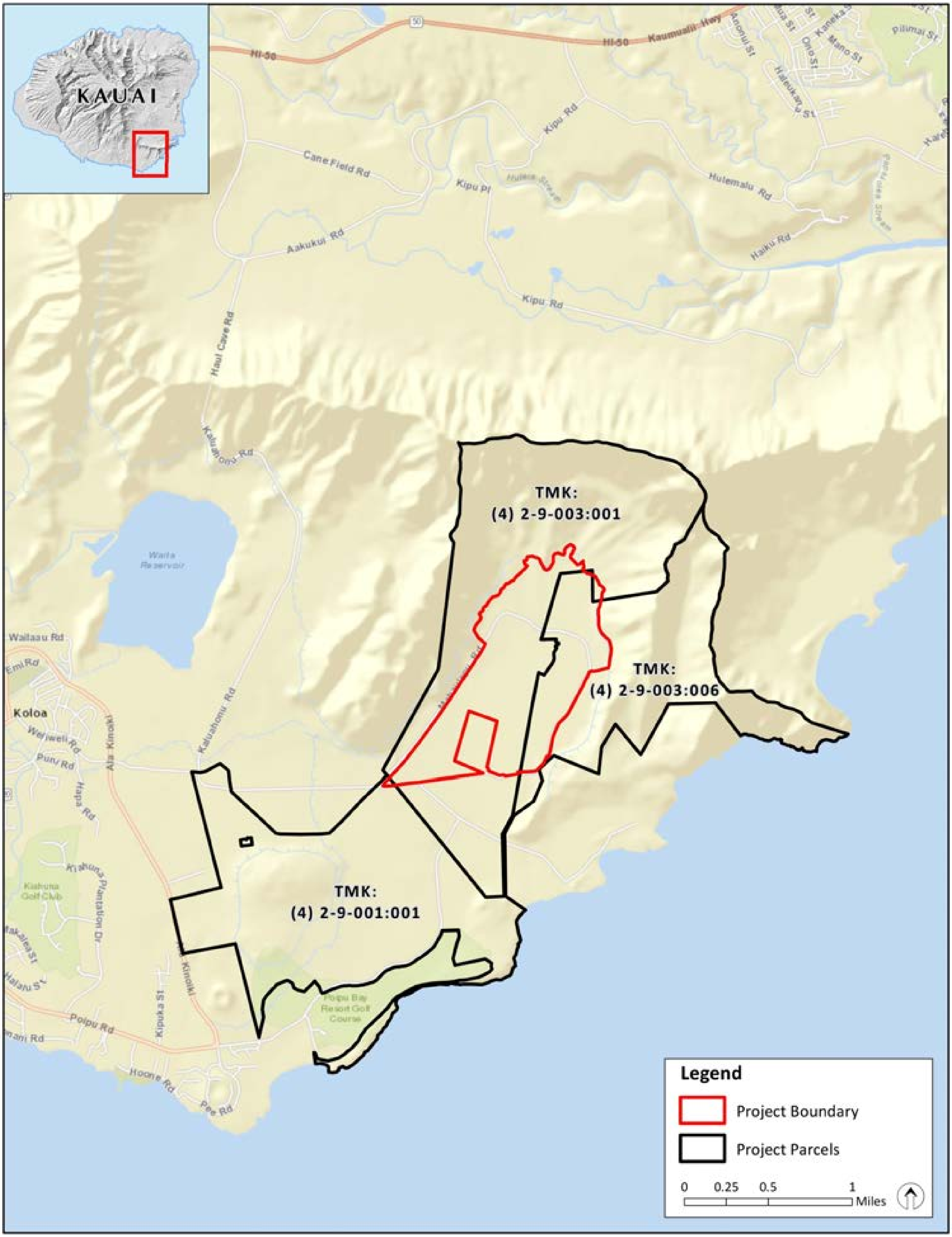

Figure 1 – Vicinity Map

Hawai'i Dairy Farms

GROUP 70 INTERNATIONAL

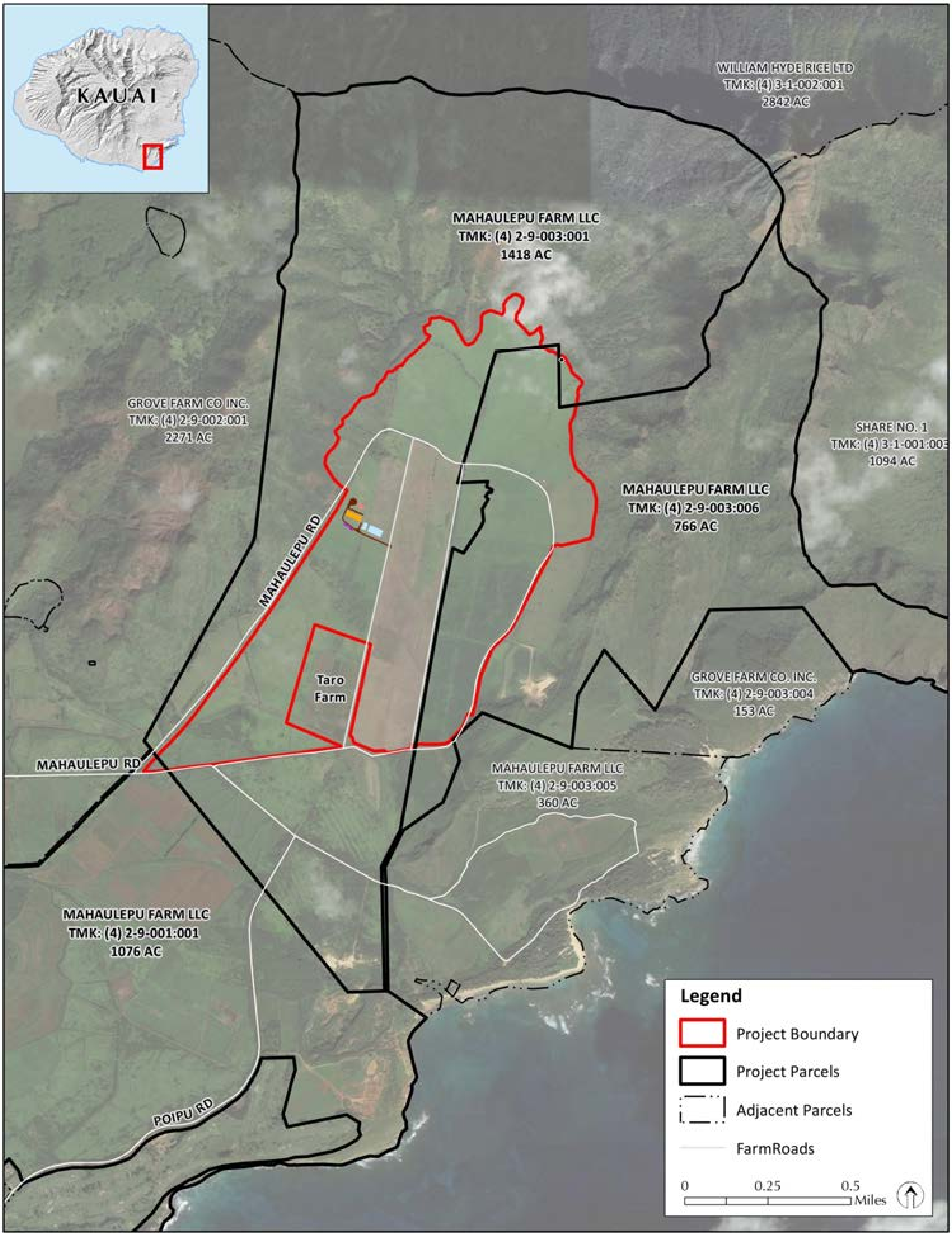

Figure 2 – Project Location Map

Hawai'i Dairy Farms
MAHA'ULEPU, KAUA'I

GROUP 70 INTERNATIONAL

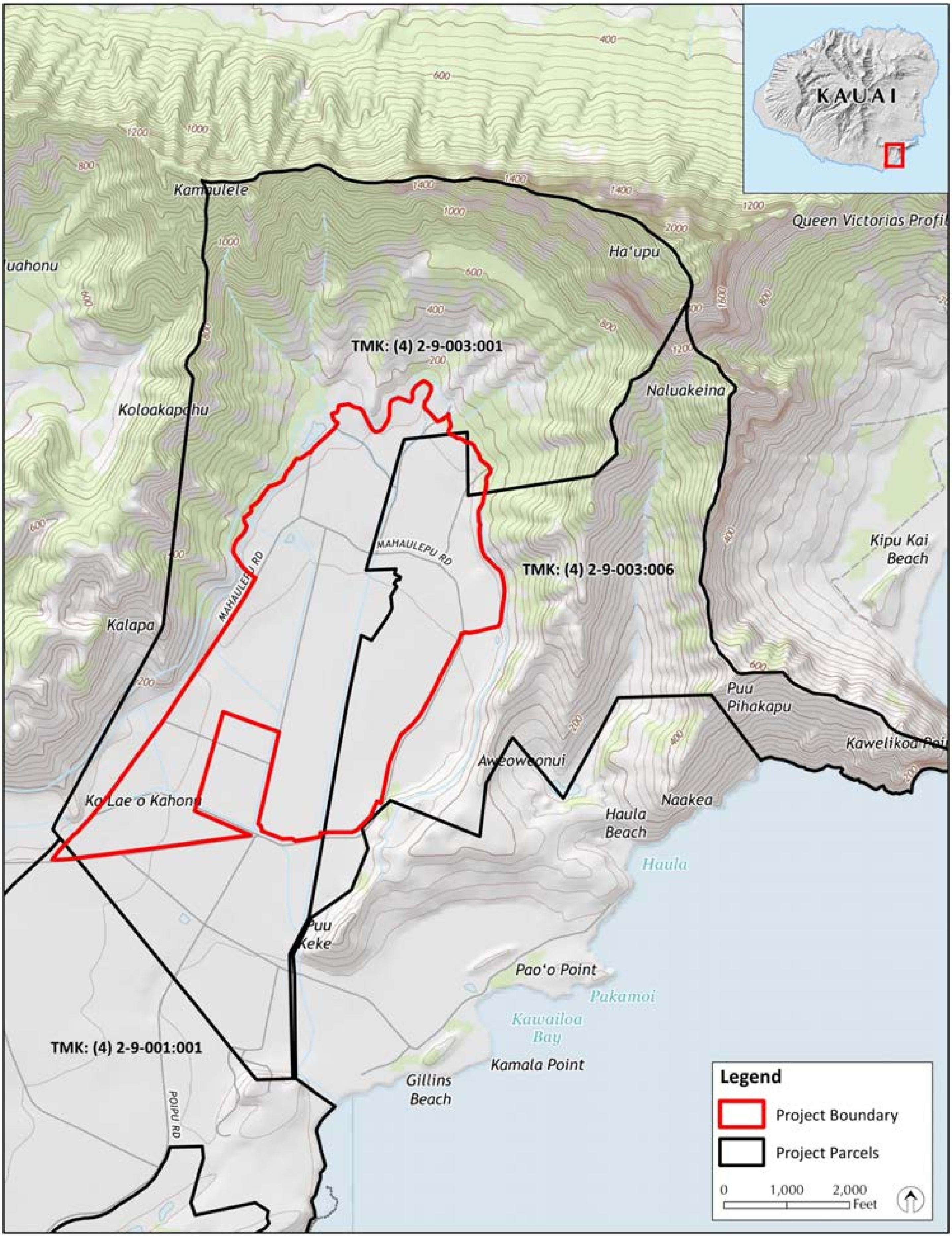

Figure 3 – USGS Map

Hawai'i Dairy Farms

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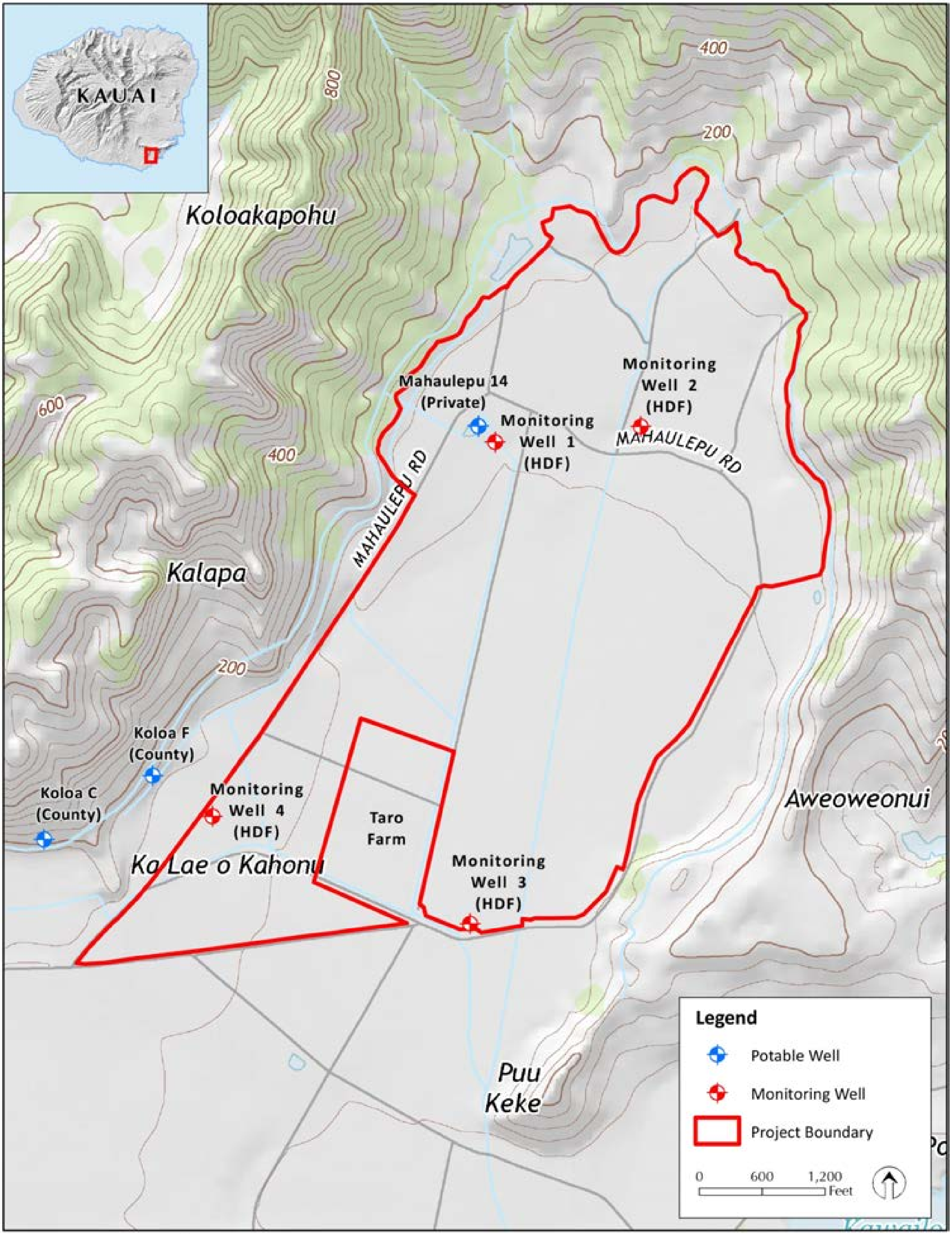

Figure 4 – Water Resources

Hawai'i Dairy Farms

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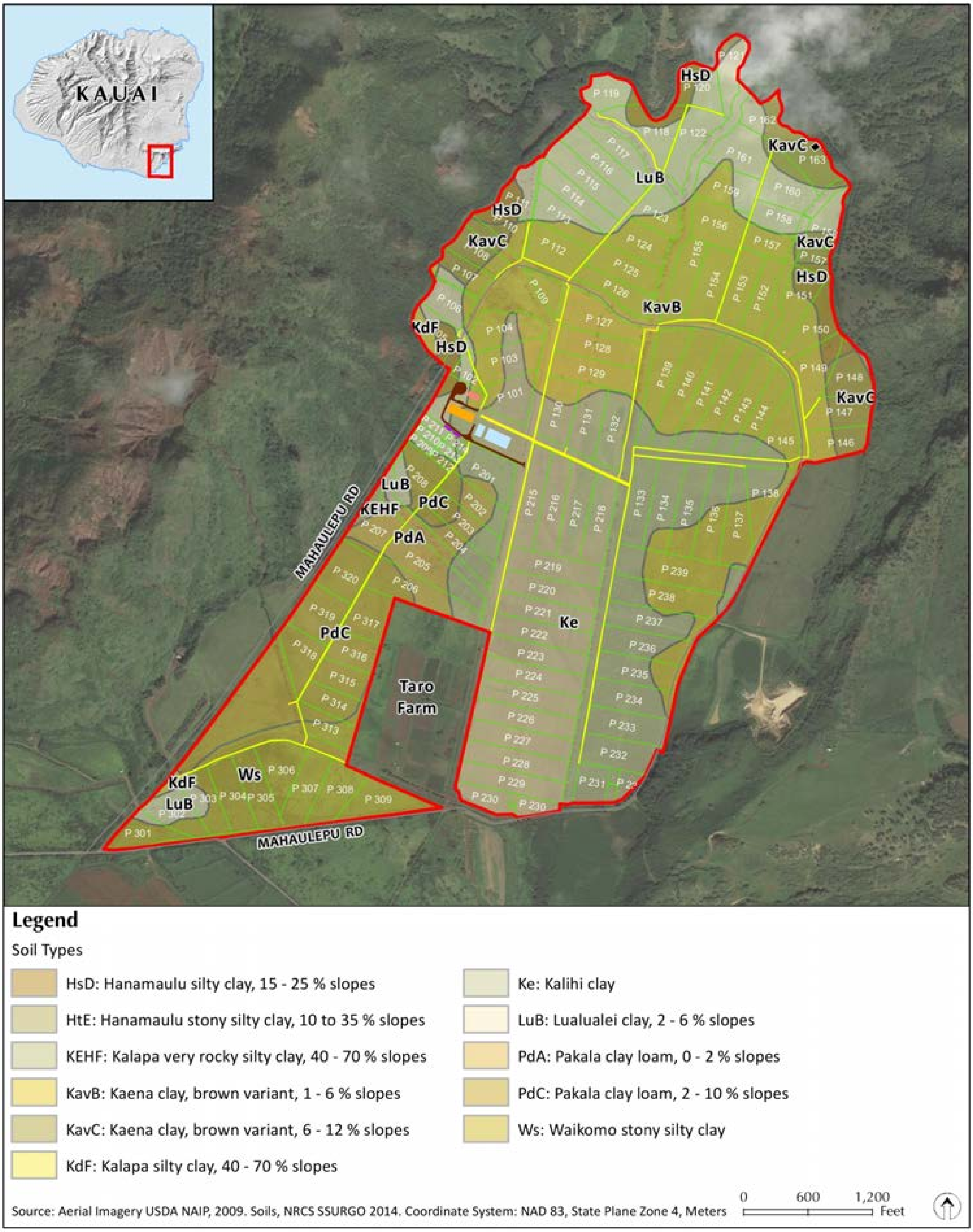

Figure 5 – Soils Map

Hawai'i Dairy Farms

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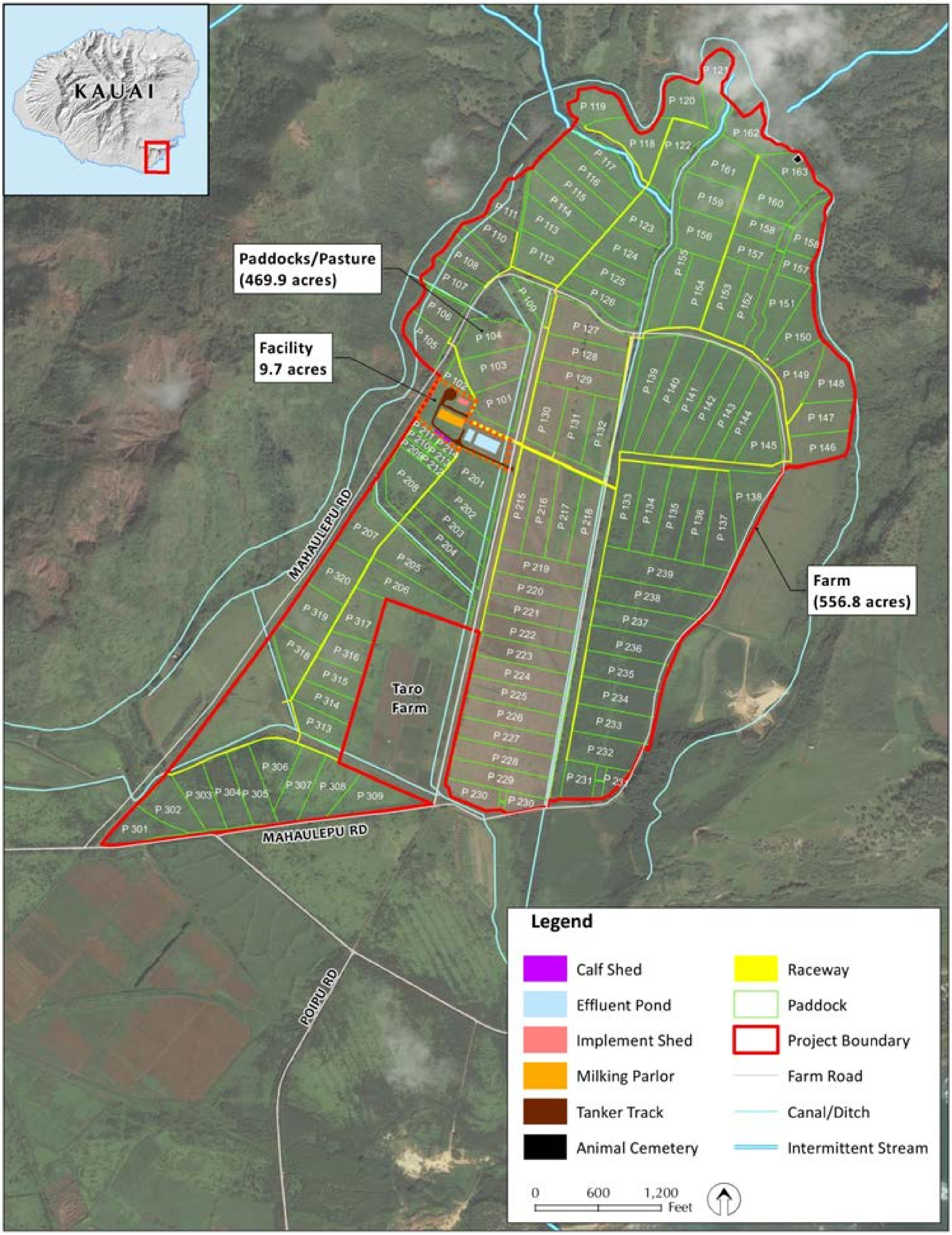

Figure 6 – Paddock Map

Hawai'i Dairy Farms

GROUP 70 INTERNATIONAL

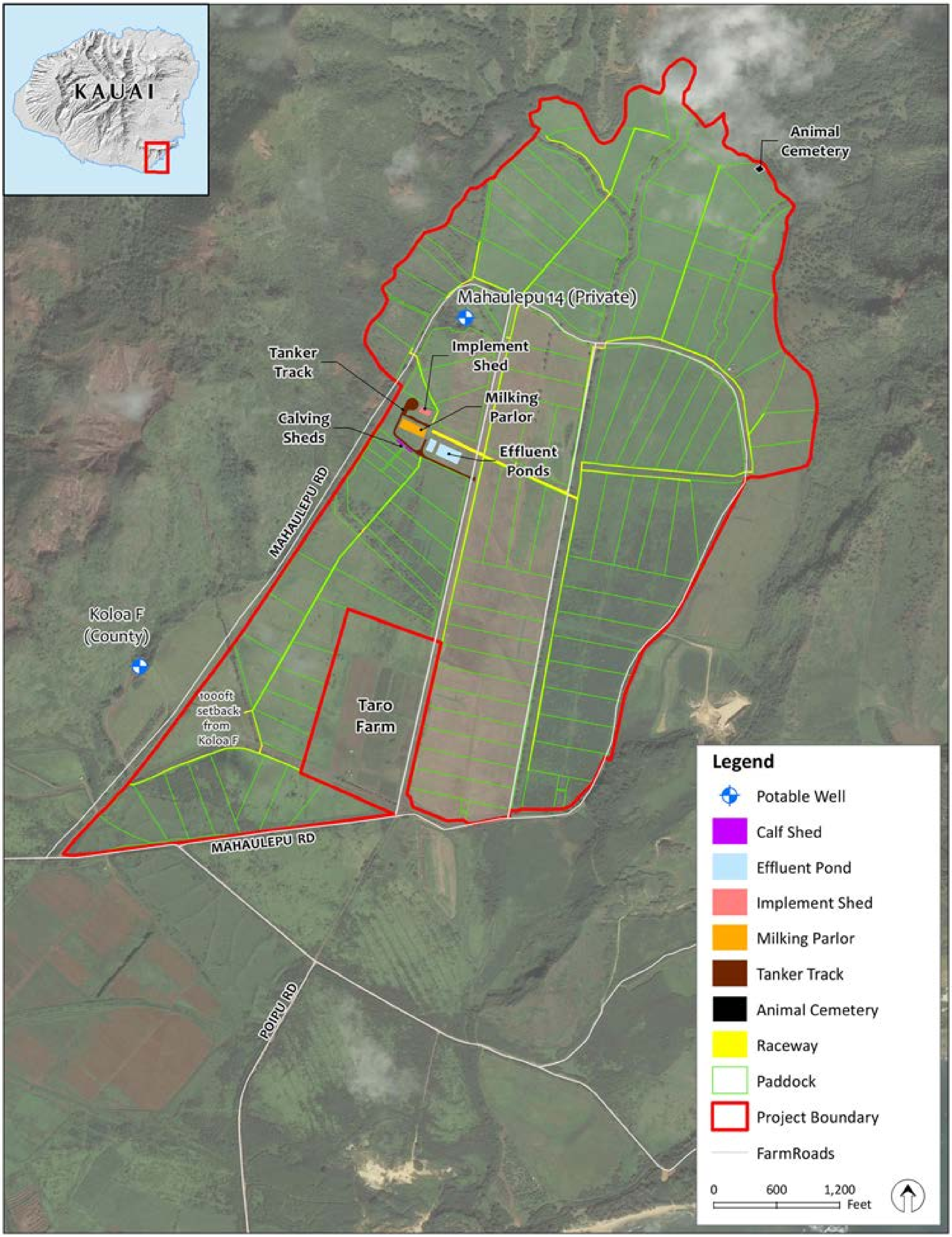

Figure 7 – Farm Map

Hawai'i Dairy Farms

GROUP 70 INTERNATIONAL

APPENDICES

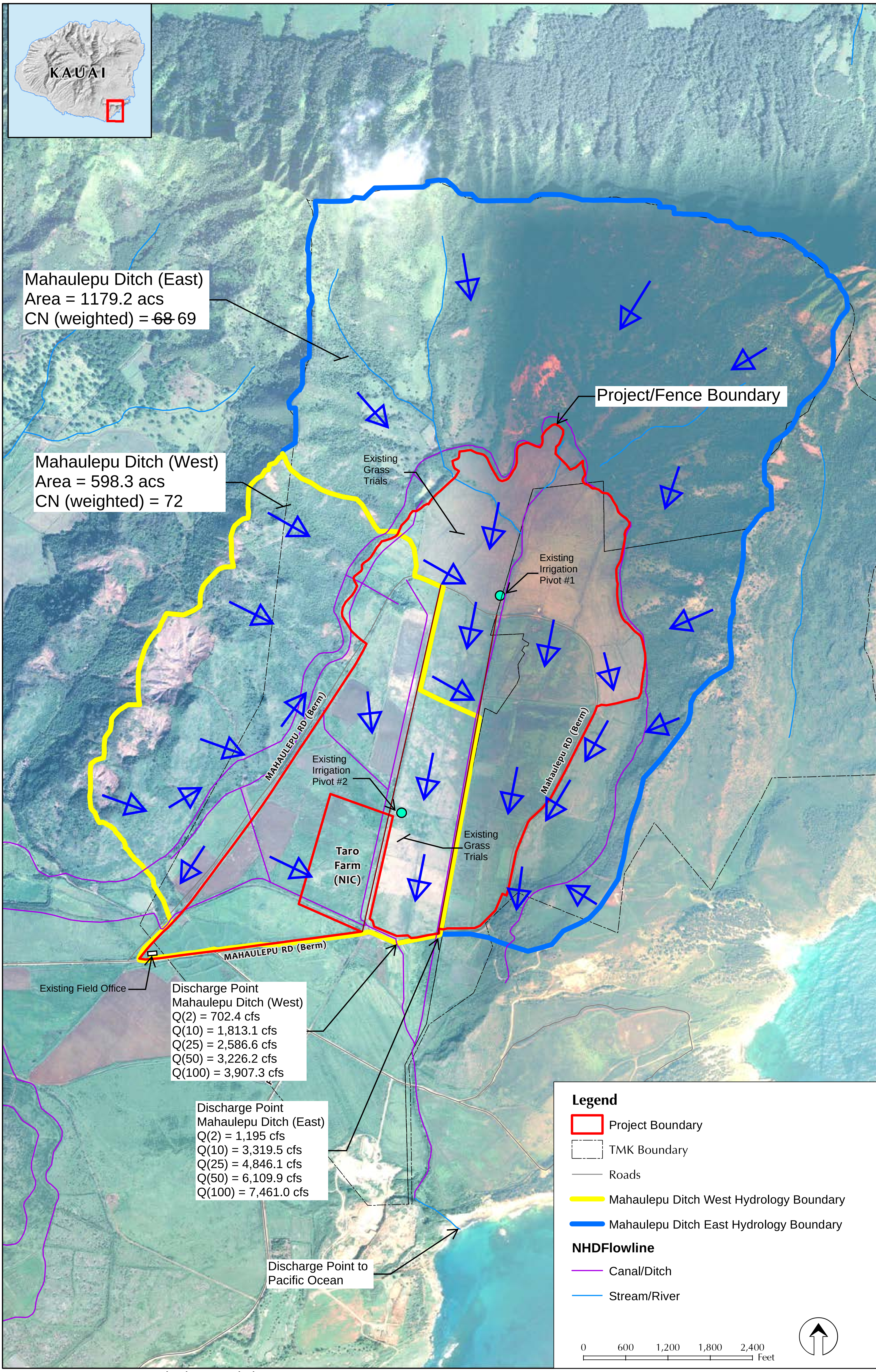

Figure 8 - Existing Hydrology Exhibit

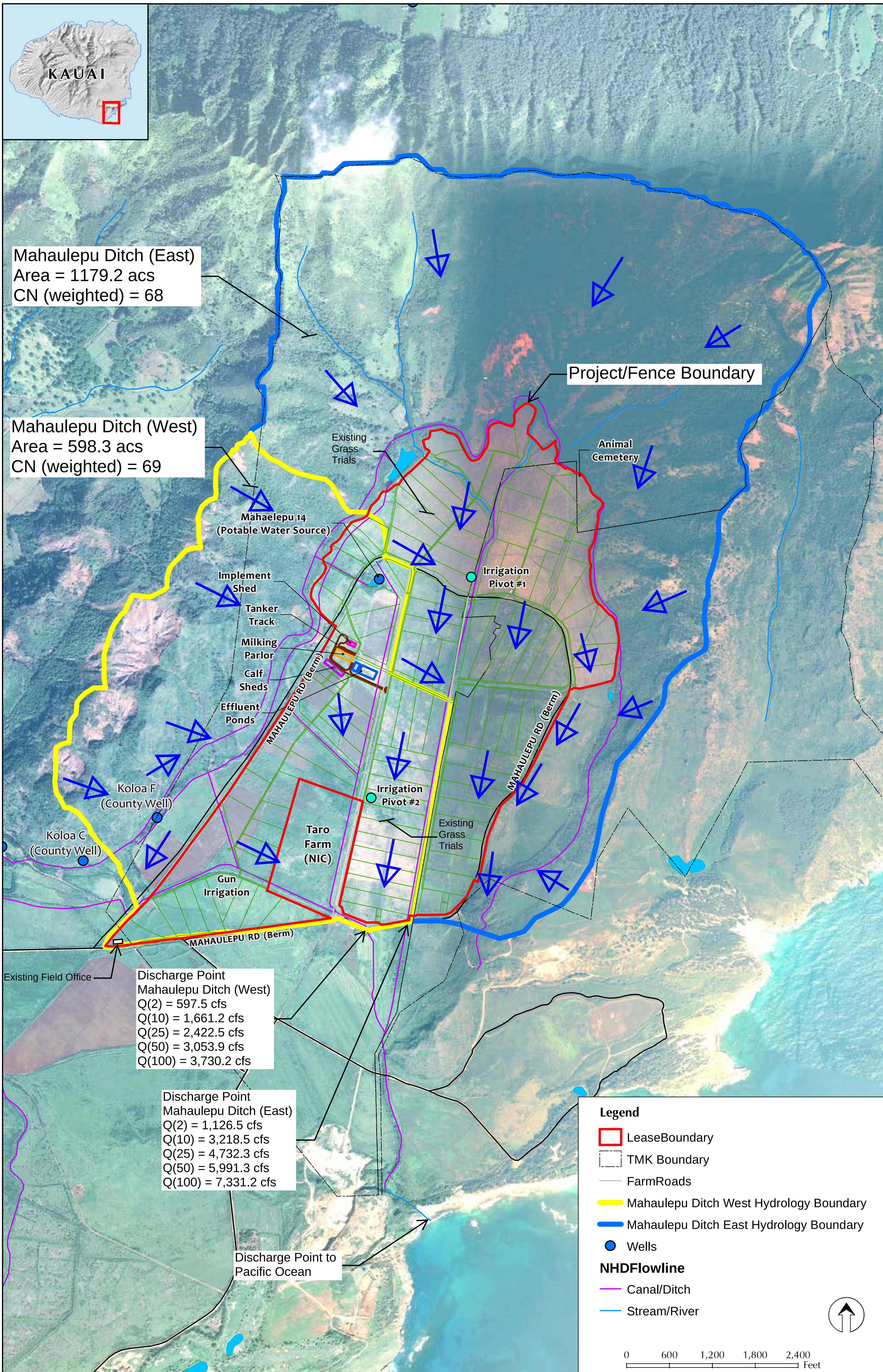

Figure 9 - Proposed Hydrology Exhibit

APPENDICES

HDF

HDF - Entire Farm
Existing Conditions
Kauai County, Hawaii

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period 2-Yr (cfs) (hr)	10-Yr (cfs) (hr)	25-Yr (cfs) (hr)	50-Yr (cfs) (hr)	100-Yr (cfs) (hr)
SUBAREAS					
MahaulepuE	702.40	1813.13	2586.61	3226.19	3907.28
	10.06	10.04	10.03	10.03	10.03
MahaulepuW	1195.04	3319.53	4846.14	6109.88	7460.96
	10.05	10.05	10.03	10.04	10.03
REACHES					
OUTLET	1896.92	5131.11	7429.63	9336.03	11358.19

HDF - Entire Farm

Kauai County, Hawaii

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period 2-Yr (cfs) (hr)	10-Yr (cfs) (hr)	25-Yr (cfs) (hr)	50-Yr (cfs) (hr)	100-Yr (cfs) (hr)
SUBAREAS					
MahaulepuE	597.50	1661.18	2422.48	3053.87	3730.19
	10.05	10.04	10.04	10.03	10.05
MahaulepuW	1126.46	3218.52	4732.33	5991.28	7331.17
	10.06	10.04	10.03	10.03	10.03
REACHES					
OUTLET	1723.30	4873.95	7146.33	9036.32	11054.11

APPENDIX L

HAWAI'I DAIRY FARMS ENDANGERED SPECIES AWARENESS AND PROTECTION PLAN, MĀHĀ'ULEPŪ, KAUA'I, HAWAI'I

RANA BIOLOGICAL CONSULTING

Hawaiʻi Dairy Farms Endangered Species Awareness & Protection Plan Māhāʻulepū, Island of Kauaʻi, Hawaiʻi

Prepared by:

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P.O. Box 1371
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Honolulu, Hawaiʻi 96813-4307

WORKING DRAFT
December 12, 2016

Table of Contents

Introduction and Background

During the course of the environmental disclosure process for the proposed Hawaiʻi Dairy Farms project, it became clear that with the presence of several endangered species within the general project area and the known presence of endangered seabirds overflying the property that to be good stewards of the these rare and protected species that it was incumbent on the project proponents to develop and implement an Endangered Species Awareness and Protection Plan to ensure that proposed activities do not result in deleterious impacts to any of the eight endangered species potentially present within the project area.

To briefly recap the proposed project, Hawaiʻi Dairy Farms LLC (HDF) is proposing to establish a herd of up to 699 mature dairy cows, and to demonstrate the pasture-based system as an economically and environmentally sustainable model for Hawaiʻi. With proven success at a herd size of 699, HDF will contemplate the possibility of expanding the herd in the future up to 2,000 mature dairy cows. Precision agricultural technology that monitors cows' health, grass productivity, and effluent management will be used to ensure environmental health and safety, as well as best management practices, and help determine the ultimate carrying capacity of the land. The project site in located on approximately 557 acres of land identified as TMK: (4) 2-9-003: 001 por. and 006 por. and (4) 2-9-001: 001 por. Located in Māhāʻulepū Valley (Figure 1).

General Site Description

The project area was historically used for sugar cane production as part of the Kōloa Plantation until the late 1990s when the Kōloa Mill closed. Since the mill closure, the project area has been leased to various tenants for ranching and diversified agricultural operations. A small plot of land in the lower center of the valley is currently used for mixed agriculture, including taro *loʻi*, and will continue to be leased and farmed separate from the dairy and related pastures.

The original sugar cane agricultural infrastructure is largely still in place and continues to be used for on-going agricultural activities. Much of this existing infrastructure will also support the dairy, but with significant upgrades and improvements. The existing infrastructure in the project area includes: gravel access roads, field roads, water wells, reservoirs, pipelines, pumps, irrigation ditches, drainage ways and culverts.

The project site is situated in the Māhāʻulepū Valley on the island of Kauaʻi. The valley is on the leeward side of the Hāʻupu mountain ridge, which runs in the east-west direction, and the valley is flanked by ridgelines. Mt. Hāʻupu (Fig. 3) is the highest point on the ridgeline at the back of the valley reaching an elevation of 700 meters above mean sea level (AMSL). From this point, the ground drops away very quickly down to the bottom of the valley to an elevation of approximately 45 meters AMSL. The base of the valley itself gradually slopes from an elevation of approximately 45 meters AMSL down to an elevation of approximately 18 meters AMSL along Māhāʻulepū Road on the *makai* side of the project site near the taro farm. Current vegetation on the site is best categorized as pasture land (Figures 2 and 3).

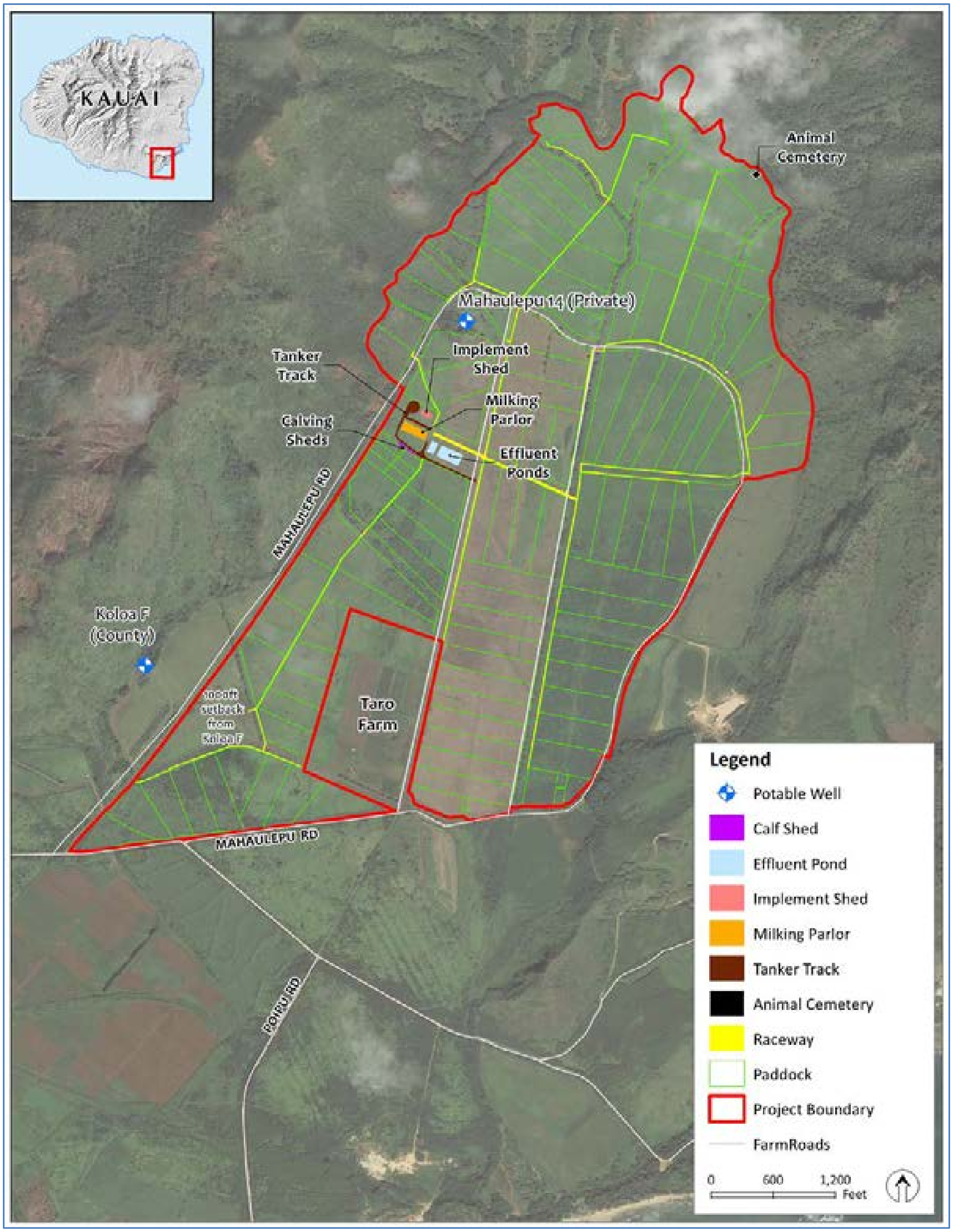

Figure 1 – Project Site Boundaries

Figure 2 - Māhāʻulepū Valley looking south from the northern crossroad showing typical pastureland.

Figure 3 - Māhāʻulepū Valley looking north to Hāʻupu peak from the central road showing typical pasture land and valley walls

Plan Outline

This plan is separated into three major chapters detailed below.

The first section includes:

- A description of the eight endangered species, which could potentially be harmed by the proposed action, and for each species, the potential issues during both the construction phase of the project as well as following build-out and during operation of the farm.
- Specific minimization measures that will be implemented to minimize impacts to listed species to the maximum extent practicable during both construction and project as well as following build-out and during operation of the farm.
- Specifics commitments on how fences will be built – and the non-usage of barbed wire.
- Details on the raceways and the fencing and buffers that are designed to prevent cows from getting into the ditches and channels, which may be used by threatened and endangered (T&E) birds.
- Cow pasturage rotation system and the expected grass regime that will be maintained in the paddocks, especially as this potentially impacts nesting Nēnē.
- Details on the effluent pond fencing and predator control response.
- Botulism issues – testing, monitoring and response to potential episodes.
- Predator attractive nuisance of a dairy farm and steps to address increased mammalian predator load.
- Lighting plan with specifics of the number and description of the lights that will be installed, their purpose and usage – all dark sky compliant.

The second section details the standard operating (BMPs) that will be implemented to protect the T&E species. In this section the following topics are covered:

- T&E waterbird and Nēnē species monitoring protocols.
- Downed seabird monitoring protocols.
- Downed seabird response protocols.
- Emergency response procedures and protocols to be followed in the event harm befalls any of the T&E species.
- Avian botulism monitoring and emergency response and procedures.
- Predator Control and Monitoring Protocols.
- Adaptive Management.

The third section of the plan contains the Endangered Species Awareness Training Program with a PowerPoint Training module – which includes.

- Photographs of all of the T&E species with a brief description of each.
- Details on behavior, especially those that may cause them to get into trouble.
- Specific BMP protocols and restrictions to be followed by all employees, construction personnel and following build-out entities that will be accessing the farm on a regular basis, for example milk truck drivers.
- Emergency response protocols, contact information.
- Reporting information.

Hawaiian and scientific names are italicized in the text. A glossary of technical terms and acronyms used in the document, which may be unfamiliar to the reader, are included at the end of the narrative text.

Section 1 – Endangered Species, Potentials Threats and Specific Minimization Measures

Eight avian and mammalian species listed as endangered or threatened under federal and State of Hawai'i endangered species statutes were recorded during the survey or are known to be present in the general project area on a seasonal basis. During the course of the biological surveys conducted for this project four avian waterbird species, Hawaiian Duck (*Anas wyvilliana*), the Hawaiian sub-species of both the Common Gallinule (*Gallinula galeata sandvicensis*) and Black-necked Stilt (*Himantopus mexicanus knudseni*) as well as the Hawaiian Coot (*Fulica alai*) were recorded either on the property or in the case of the coot flying over it. Additionally, Nēnē (*Branta sandvicensis*) was also recorded during the survey. The endangered Hawaiian Petrel (*Pterodroma sandwichensis*), and the threatened Newell's Shearwater (*Puffinus newelli*) are both known to overfly the greater Kōloa /Po'ipū area on a seasonal basis. The endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*) is widespread in the lowland areas of the island of Kaua'i.

The principal potential impacts that the development and operation of the proposed dairy farms on the site pose to these species can be broken down into those potentially associated with construction activities and those associated with dairy farm operations following build-out.

Construction Phase Potential Impacts

During construction especially during clearing and grubbing phases of the project, clearing vegetation, opening up and clearing of agricultural irrigation features and the construction and/or upgrading of roadways within the farm has the potential to disturb nesting waterbird and Nēnē nests, eggs and young. Waterbirds and Nēnē disturbed when nesting may abandon their nest, eggs and to a lesser degree chicks. Increased vehicular traffic associated with construction activities also increases the risk of birds being run over or hit by vehicles, within the project site. All of the waterbirds nest in or close to water features, Nēnē on the other hand nest on land and potentially could nest anywhere on the site which has shade.

Specific potential threats to waterbirds and Nēnē posed during the construction phase of the project:

- Direct injury or fatality from interactions with vehicles or construction equipment.
- Direct disturbance of nests, eggs or chicks by construction equipment or activity.
- Temporary increase in avian mammalian predators as a result of human presence, food, and pets associated with construction personnel.

Specific potential threats to overflying seabirds posed during the construction phase of the project:

- Increase in lighting on the site as a result of potential nighttime construction activity or construction equipment maintenance. Nighttime outdoor lighting has the potential to attract and down fledgling seabirds on their first flight out to see during the fledgling season that runs from September 15 through December 1 each year.

Specific potential threats to Hawaiian hoary bats posed during the construction phase of the project:

- The removal of vegetation within the project site may temporarily displace individual bats, which may use the vegetation as a roosting location. As bats use multiple roosts within their home territories, the potential disturbance resulting from the removal of the vegetation is likely to be minimal. During the pupping season, females carrying their pups may be less able to rapidly vacate a roost site as the vegetation is cleared. Additionally, adult female bats sometimes leave their pups in the roost tree while they forage. Very small pups may be unable to flee a tree that is being felled.

Construction Phase Specific Minimization Measures

Specific minimization measures that will be developed and implemented during the construction phase of the project to minimize potential impacts to trust resources:

- An Endangered Species Awareness and Protection training program will be developed and all construction and farm employees and managers will be required to complete the training before commencing work on the property. Please see Section 3 of this document.
- Speed limit signs will be posted on all roads on which construction personnel have access limiting the speed limit to 15 miles an hour.
- No nighttime construction will be permitted.
- Any lights that may need to be used to service construction equipment after dark during the construction phase will have 100% cutoff, fully shielded luminaires and be mounted high enough of the ground that they can be directed directly perpendicular to the ground.
- Prior to the initiation of clearing and grubbing activities a nesting waterbird survey will be conducted by a qualified biologist if any nesting activity locations are found – a 100 foot buffer will be places around the site and construction activity in any such area will not be allowed to proceed until the nesting activity has finished.
- Immediately prior to construction activities, surveys for nesting waterbirds and Nēnē should be conducted by a qualified biologist, or consultation with the state and federal wildlife regulators should be initiated to determine the best course of action.

- Woody vegetation taller than 4.6 meters (15-feet) will not be removed between June 1 and September 15, the period in which bats are potentially at risk from vegetation clearing.
- A complete ban on construction personnel bringing pets such as dogs to work will be enforced.
- Any locations where construction personnel will be eating while on site shall be designated and covered trash receptacles provided for the proper disposal of food and beverage containers and waste.
- Personnel will be prohibited from feeding, petting or approaching endangered species.
- Construction managers will be provided with a response protocol to follow in the event that an incident occurs involving an endangered species, or they encountered an injured or sick endangered species.

Dairy Operation Phase Potential Impacts

Specific potential threats to waterbirds and Nēnē posed during operation of the farm.

- Direct injury or fatality from interactions with vehicles or farm equipment.
- Direct disturbance of nests, eggs or chicks by dairy farm activities.
- Interactions of endangered birds and mammals with barbed wire on fencing.
- Trampling of nests by cows in pastures and as they are moved between paddocks.
- Protect watercourses from cow entry or damage, as there is small chance that Common Gallinules could nest in one if the water ever stayed deep enough.
- Increase in avian mammalian predators as a result of dairy operations.
- Increased potential for the outbreak of avian botulism in the effluent ponds.

Specific potential threats to overflying seabirds posed during operation of the farm:

- Increase in lighting on the site that will be required for dairy operations, maintenance and personnel safety. Nighttime outdoor lighting has the potential to attract and down fledgling seabirds on their first flight out to sea during the fledgling season that runs from September 15 through December 1 each year.

Specific potential threats to Hawaiian hoary bats posed during operation of the farm:

- The removal of vegetation within the project site (if any during operations) may temporarily displace individual bats, which may use the vegetation as a roosting location. As bats use multiple roosts within their home territories, the potential disturbance resulting from the removal of the vegetation is likely to be minimal. During the pupping season, females carrying their pups may be less able to rapidly vacate a roost site as the vegetation is cleared. Additionally, adult female bats sometimes leave their pups in the roost tree while they forage. Very small pups may be unable to flee a tree that is being felled.

Dairy Operation Phase Minimization Measures

Specific minimization measures that will be developed and implemented during the construction phase of the project to minimize potential impacts to trust resources:

- An Endangered Species Awareness and Protection training program will be developed and all employees and managers will be required to complete the training before commencing work on the property. All employees will be retrained on an annual basis. Please see Section 3 of this document.
- Speed limit signs will be posted on all roads limiting the speed limit to 15 miles an hour.
- All perimeter and interior fencing will not utilize barbed wire to reduce the risk that birds or bats may be harmed by interaction with the barbs on that type of wire. In place of barbed wire on the top and bottom of the fences – tensioned fence wire will be used and electric fence strands used in certain locations. Please see Figures 4 & 5, which depict typical fence sections.
- All watercourses will be protected by fencing using two electrified wires strung between wooden posts, fences along watercourses will be sited 35 feet from the edge of the ditches. Please see Figure 5.
- All cow races will be fenced to prevent cows from getting into fallow paddocks or the waterway buffers while being moved to and from the milking barn. Fencing for the races will consist of three electrified wires strung between wooden posts (Figure 5).
- The only endangered species that potentially could nest within the individual paddocks are Nēnē. Fallow paddocks will be surveyed for nesting Nēnē prior to each rotation of cows into the specific paddocks. If nesting activity is detected that paddock will not be used for grazing until the nest has successfully fledged or has failed.
- Grass heights in paddocks will be grazed when they get to be eight inches or taller – a height that is not suitable for Nēnē nesting. On Kaua'i, Nēnē tend to nest in locations where there is cover above them, and a relatively easy route to exit the nesting site – grass pastures that are eight inches or lower with no shrubs or bushes are not conducive to Nēnē nesting.
- The dairy effluent will be processed in a two-pond system the primary settling pond and an effluent storage pond – the ponds will be fenced to exclude cattle, and waterbirds that might choose to walk in to the area. As with all other fences on the Dairy Farm, barbed wire will not be used. Fencing around the facility will consist of woven wire fence that has five-inch mesh at the top that diminishes in size towards the ground

A

TYPICAL PERIMETER FENCE

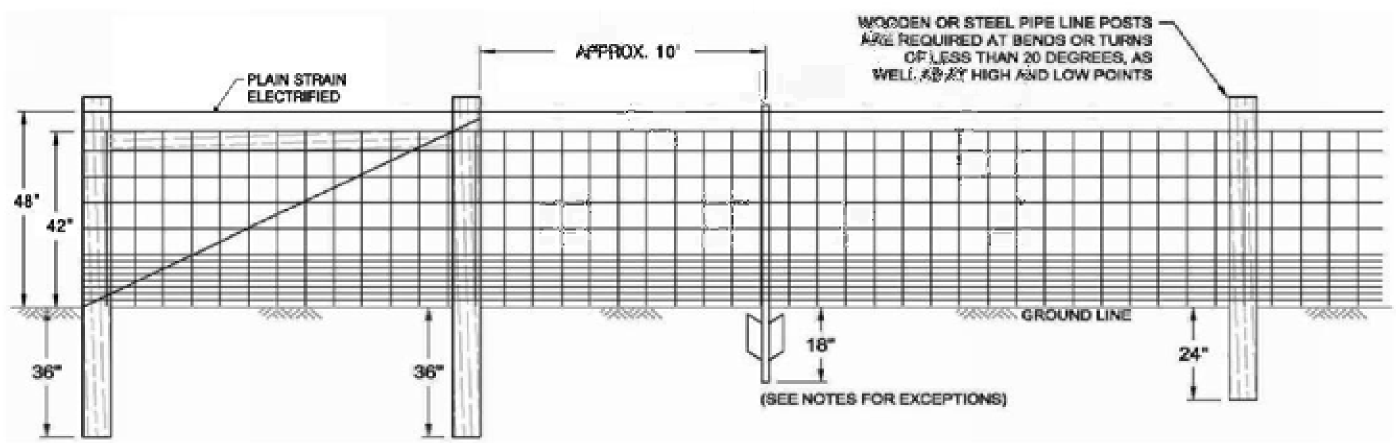

Figure 4 - Typical Perimeter Fence Schematic

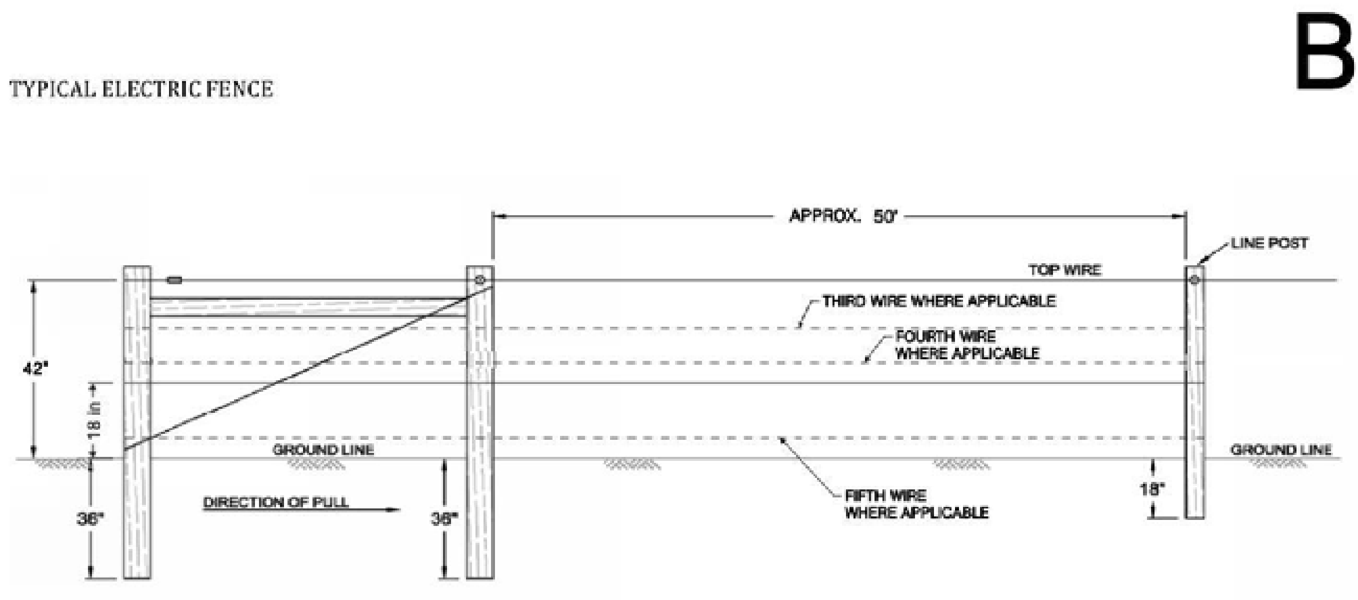

Figure 5 - Typical Electric Fence Schematic

ultimately having a mesh size of two inches. Please see Figure 4, which depict typical fence sections.

- When one creates a new feature containing water in Hawaiʻi there is always the possibility of having an episode of avian botulism occur – many of the wetlands on Kauaʻi have periodic episodic events. Twice daily walkthroughs of the effluent ponds will be conducted by dairy personnel looking for any evidence of an outbreak – in the event that one does appear to be happening, that occurrence will trigger the avian botulism response detailed in Section 2.
- Running any operation that involves cows, and possible supplementary feeding with grain products, will increase the number of rodents on the property, and that in turn will trigger an increase in feral cats visiting the site. It is expected that the primary ingress point for cats will be associated with the milking shed and effluent ponds. Rodent and cat trapping will occur under an integrated pest management protocol, detailed in Section 2 of this document.
- All lighting installed as part of the dairy operation will be full cutoff dark sky compliant fixtures. All luminaires will be mounted sufficiently high enough off of the ground that they can be positioned to shine perpendicular to the ground.
- The project will install 67 lighting fixtures detailed in Table 1. All of these lights will either been inside structures or if visible from outside the structures will be fully shielded down pointed fixtures which will be compliant with Dark Sky Initiative guidelines.

Table 1

• Location	Fixture Type	# of Fixtures
Exterior (building mounted)	(FL1) Lithonia MRT1-LED Omero Area Lighting fixture Wall Mounted 100% Cut Off Dark Sky Compliant Fixture	6
Interior (rotary and covered shed area, calf barns and machine shed)	(PL1) Lithonia FHE LED	41
Interior (restrooms, electrical, storage)	(PL2) Lithonia Low Profile Enclosed Industrial FEM fixture	4
Interior (mechanical room & truck bay)	(PL3) Lithonia VAP LED Rough Service Fixture	4
Interior (truck loading area)	(PL4) Lithonia FHE LED High Pressure Hose-down fixture	2
Interior (office, staff, vet room areas)	(WL1) Lithonia MVS Wraparound fixture	10

Section 2 – Endangered Species Standard Operating Procedures and Best Management Practices

An integral part of operating the dairy will be the stewardship of any threatened and endangered species on the property. The entire endangered species awareness and protection plan outlined in this document reflect core corporate policy on how the daily operations of the facility will be conducted to ensure that operations result in added benefits to the species which may choose to use resources on the property. Starting with employee and construction personnel endangered species awareness and protection training, the design of fencing and cow operations and the management of habitat in which waterbirds and/or Nēnē decide to nest on.

The entire staff will be trained to monitor and record endangered species presence and activity on the active portions of the property – the entire operational area will be monitored for endangered species activity on a daily basis, and activity will be recorded so as to better understand the expected changing activity of endangered species on the property as dairy operations ramp up. These data will allow managers to best respond to specific areas of the property in which T&E species eventually habitually use. Once those activities have stabilized, it will be easier to predict what locations on the active dairy will need to be carefully monitored and specific management activities targeted to ensure that any nesting birds are provided as much protection from disturbance, and predators as practicable.

Waterbirds and Nēnē

All data gathered on nesting T&E species, will be input on a daily basis into the master pasture and cow management database. This is a custom database in which data on individual cows, each pasture, grass management and endangered species activity will be recorded – this is essentially the master decision making tool that will be used to effectively managed the operation of the dairy.

It is currently expected that any nesting activity of endangered waterbirds will occur in drainageways, all of which are fenced to prevent cows from getting into them and all have buffers on either side of them to further protect them (Figure 1). It is possible that Nēnē will attempt to nest in some of the paddocks that are fallow – i.e. do not have cows grazing in them. Though the grazing regime is designed to move cows every 18 days into paddocks where grass has reached 8 to 10 inches tall. A height that is low for Nēnē to nest in since there will be no cover, bushes, trees or other protection in the paddocks. Prior to cows being moved from one pasture to another the herdsman/women will conduct a survey of the new paddock to ensure that there is no endangered species nesting activity occurring in the new target pasture, if none is found the cows will be moved down a raceway and into the new pasture – data confirming that the pasture was searched and had no nesting activity will be recorded in the database. If however, nesting activity is detected on the initial survey the paddock will be taken out of rotation until the nest has hatched or failed, any such paddock will be checked once a week until nesting activity is over – these data will be recorded in the database as well.

Seabirds

During the seabird fallout season – September 15 to December 15 the seabird awareness and protection components of the training module will be repeated for all dairy personnel.

On-ground searches of all of the structures that have lighting will be conducted first thing in the morning for downed seabirds each day during the seabird fallout period. A Seabird Waterbird Recovery Kit will be maintained on site, at a location to be determined following construction – the kit will contain the following components:

Contents of Seabird/Waterbird Recovery Kit

- Latex or nitrile gloves
- Three towels
- Hand sanitizer
- Flashlight or headlamp
- Clipboard, pen and blank Downed Seabird Form (Appendix XX)
- Pet carrier – medium-sized

The following protocols will be followed in recovering and recording a downed seabird incident:

Recovering Downed Seabirds—Standard Operating Procedures (SOP)

- Take the seabird recovery kit and pet carrier to the downed seabird
- Put on gloves
- Using towel to gently cover the bird, pick up the seabird
- Place the seabird in the pet carrier, and close the pet carrier
- Put the gloves and towel back in the seabird rescue kit
- Take the bird and pet carrier to an SOS Aid Station – located at the Kōloa fire station
- Transfer the bird to the Aid Station
- Call SOS at 632-0610 or 635-5117
- Return the seabird rescue kit and pet carrier to the dairy, replace towel and clean cage with bleach, if dirty
- Complete the Downed Seabird Form
- Turn in the completed form to the dairy manager – data will be input into the master database

Following any downed seabird incident the farm manager and, if necessary, a qualified seabird biologist will inspect the area in which the seabird was recovered to determine if any changes in lighting or light shielding is warranted. If so, those changes will be detailed in writing. Modifications will be completed as rapidly as is practicable.

Recovery and Reporting Procedures for Injured or Dead T&E species

It is hoped that the minimization and standard operating procedures detailed in this document will ensure that no harm befalls any listed avian or mammalian species as a result of dairy operations. In the event that such an event occurs, the dairy will follow the following animal handling and reporting protocols:

The dairy will maintain a Seabird/Waterbird Recovery Kit on property, which is detailed in the seabird section above.

In the event that an injured listed waterbird or Nēnē is found on the property the following protocols will be followed in recovering the injured bird:

Recovering an Injured Waterbird or Nēnē—Standard Operating Procedures (SOP)

- Take the recovery kit and pet carrier to the injured bird
- Put on gloves
- Using towel to gently cover the bird, pick up the bird
- Place the bird in the pet carrier, and close the pet carrier
- Take the bird and pet carrier to the SOS program at the Kauaʻi Humane Society immediately
- Call SOS at 632-0610 or 635-5117 to let them know the bird is inbound
- Return the rescue kit and pet carrier to the dairy, replace towel and clean cage with bleach, if dirty
- Complete the Endangered Waterbird Form (Appendix XX)
- Turn in the completed form to the dairy manager – data will be input into the master database
- Dairy Manager to call DOFAW Kauaʻi Thomas Kaiakapu (274-3440) and Jean Olbert DOFAW Kauaʻi (274-3076)

In the event that an injured listed waterbird or Nēnē is found on the dairy property, the USFWS and DOFAW regulatory branches will be contacted immediately and coordination under the relevant federal and State of Hawaiʻi statutes will be initiated.

Response to a Dead T&E Waterbird or Nēnē—Standard Operating Procedures (SOP)

In the event that a dead listed waterbird or Nēnē is found on the property the following protocols will be followed in response to such and incident.

- Respond to the site immediately
- Confirm that the animal is dead and not injured – if injured follow the recovery protocols detailed in the previous section. If the animal is dead, first secure the site
- Take photographs of the site (multiple), surrounding area and the carcass
- Take a GPS reading of the location

- Collect the carcass, double bag in Ziploc freezer bags
- Write on the outside of the bag with a Sharpie pen the date, time and location of the incident
- Transport the bagged carcass to a refrigerator (not freezer) and place inside
- Complete a Dead Endangered Species Report Form (Appendix XX)
- Give the completed form to the farm manager
- Farm Manager immediately contact DOFAW Kauaʻi, Thomas Kaiakapu (274-3440) and Jean Olbert DOFAW Kauaʻi (274-3076) – follow their instructions on disposition of the carcass, they will likely pick it up, or they may request that it be delivered to the DOFAW base yard.

In the event that listed waterbird or Nēnē is found dead on the dairy property, the USFWS and DOFAW regulatory branches will be contacted immediately and consultation under the relevant federal and State of Hawaiʻi statutes will be initiated.

Avian Botulism Monitoring and Response protocols

Avian botulism outbreaks occur on the island of Kauaʻi on a regular basis, as the effluent ponds will be aerated to promote beneficial bacterial breakdown of the effluent it is not expected that the dairy will pose a heightened risk of having an avian botulism outbreak on the island. To ensure that if such an episodic event does occur it is responded to immediately and in the most expeditious fashion possible, the following monitoring and response protocols are part of the dairy's Standard Operating Procedures:

The effluent ponds will be inspected twice a day, every day, to ensure that there are no dead waterbirds in the fenced effluent pond areas. As the berms surrounding the ponds will be not vegetated and the ponds are relatively small it is anticipated that 100% coverage of the ponds twice a day is a reality. If a dead waterbird is found the following protocols will be followed:

- The ponds will be checked every two hours a day until no further dead birds are found
- All recovered birds will be tagged and bagged following the protocols outlined in the previous section and refrigerated
- If more than three dead birds are found in one 24-hour period the Farm Manager will immediately contact DOFAW Kauaʻi, Thomas Kaiakapu (274-3440) and Jean Olbert DOFAW Kauaʻi (274-3076) – follow their instructions on disposition of the carcasses, they will likely pick them up, or they may request that they be delivered to the DOFAW base yard or the Kauaʻi Humane Society
- If sick waterbirds are encountered in the effluent pond enclosures follow the protocols outlined in the injured waterbird and Nēnē section above
- Searches of the ponds will continue until the event has ceased

Predator Control and Monitoring

This property is agricultural land, which has been under cultivation with one crop or another for over 100 years, and as such, does host the full complement of alien predators currently established on the island of Kauaʻi. The following procedures will be implemented to control predators on the site – as predator usage of lowland areas on Kauaʻi changes depending on what activity is currently ongoing on the property, much of the predator control plan will by definition need to be adaptive, in response to changing patterns of predator attraction to the site and what portions of the property they concentrate their activities on and where trust resources congregate.

- A commercial pest management company will be retained to bait and trap for rodents in and around all structures on the property
- Cat traps will be deployed within the fenced effluent ponds and in and around the milking shed
- Additional cat trapping will be conducted based on presence of and developing ingress points onto the property as needed
- The dairy farm will maintain an inventory of 20 life cat traps such as Havahart traps to be used as required
- Pigs, cats, and any other mammalian predators will be controlled under State of Hawaiʻi depredation permits using all tools currently permissible on the island of Kauaʻi, if needed.
- Records of all mammalian predators removed from the property with the exception of rodents will be maintained within the master management database

Adaptive Management

The term "Adaptive Management" as used in the context of this plan refers to the reality that as the habitat and usage of the site is modified moving forward, the usage of the site by listed species will change and predator response will also change. From years of experience managing properties on Kauaʻi for these same species, our biologist informs us that the monitoring of all pertinent parameters is the key to being able to respond proactively to the change in animal behavior on the site.

Specific changes to habitat management will be dictated by what the birds do. Likewise predator trapping will be modified in response to predator response and the localities on the property that predators are attracted to, or the specific attractive nuisance that draw them in.

Specific minimization measures may be triggered by bird behavior that can't be predicted until the dairy is in full operation as has been shown to be the case on other properties on Kauaʻi. Dairy managers and their consulting biologists will be able to respond rapidly and appropriately to protect trust resources by modifying protocols and/or implementing additional minimization measures as a result of having a small, well-trained staff, and an integrated data gathering and analysis methodology that the dairy will have and is putting into place.

Section 3 - Endangered Species Awareness Training Program

TO BE COMPLETED

- Photographs of all of the T&E species with a brief description of each.
- Details on behavior, especially those that may cause them to get into trouble.
- Specific BMPs protocols and restrictions to be followed by all employees, construction personnel and following build-out entities that will be accessing the farm on a regular basis, for example milk truck drivers.
- Emergency response protocols, contact information.
- Reporting information.

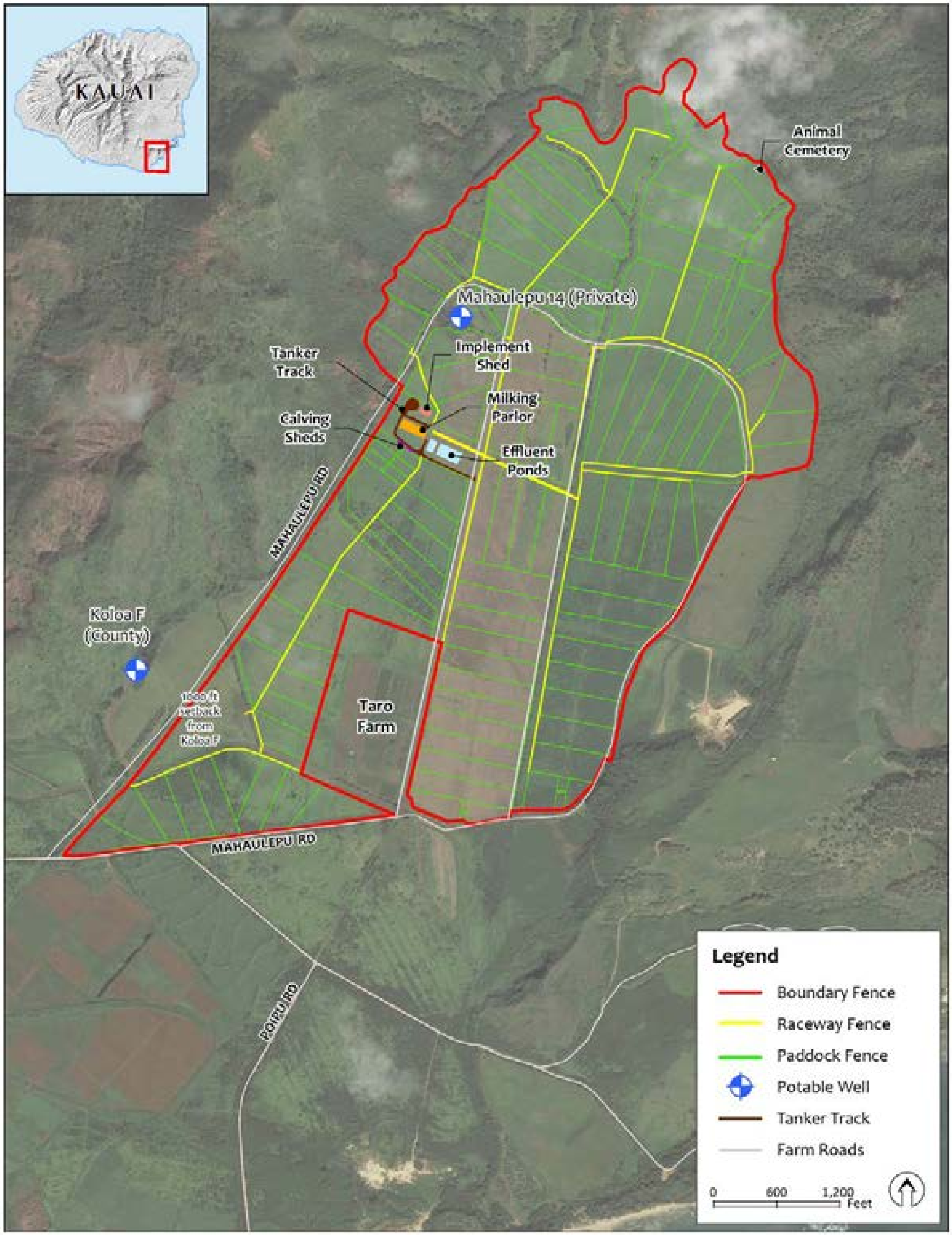

Figure 5 – Farm map showing existing Taro Farm and proposed Dairy Farm Structure

Glossary

Alien – Introduced to Hawaiʻi by humans
Commensal – Animals that share human food and lodgings, such as rats, mice, cats, and dogs
Crepuscular – Twilight hours
Endangered – Listed and protected under the Endangered Species Act of 1973, as amended (ESA) as an endangered species
Endemic – Native to the Hawaiian Islands and unique to Hawaiʻi
Indigenous – Native to the Hawaiian Islands, but also found elsewhere naturally
Mauka – Upslope, towards the mountains
Muridae – Rodents, including rats, mice, and voles -- one of the most diverse families of mammals
Naturalized – A plant or animal that has become established in an area that it is not indigenous to
Nocturnal – Night-time, after dark
ʻŌpeʻapeʻa – Endemic endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*)
Pelagic – An animal that spends its life at sea – in this case seabirds that only return to land to nest and rear their young
Phylogenetic – The evolutionary order that organisms are arranged by
Ruderal – Disturbed, rocky, rubbishy areas, such as old agricultural fields and rock piles
Sign – Biological term referring to tracks, scat, rubbing, odor, marks, nests, and other signs created by animals by which their presence may be detected
Threatened – Listed and protected under the ESA as a threatened species.

AMSL – Above mean sea level
DLNR – Hawaiʻi State Department of Land & Natural Resources
DOFAW – Division of Forestry and Wildlife
ESA – Endangered Species Act of 1973, as amended
GNSS – Global Navigation Satellite System (formerly as Global Positioning System), an accurate worldwide navigational and surveying facility based on the reception of signals from an array of orbiting satellites.
MSL – Mean sea level
TMK – Tax Map Key
USFWS – United State Fish & Wildlife Service
UTM – Universal Transverse Mercator System, a standardized mapping coordinate system that uses grids to identify the specific location of any feature on the surface of the planet

Literature Cited