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**ARCHAEOLOGY IN THE
KĪLAUEA EAST RIFT ZONE**

**PART I: LAND-USE MODEL AND
RESEARCH DESIGN**

**KAPOHO, KAMĀ'ILI AND
KĪLAUEA GEOTHERMAL
SUBZONES**

**PUNA DISTRICT,
HAWAI'I ISLAND**

by

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**MANAGED BY
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PUNA DISTRICT, HAWAI'I ISLAND

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Kapoho Bay and Crater lie at the eastern margin of the Puna Geothermal Resource Area. Prehistoric fishponds are still visible under the bay's surface.

PREFACE

This report was prepared by International Archaeological Research Institute, Inc., under subcontract to Oak Ridge National Laboratory. The report makes available and archives the background scientific data and related information collected during the development of a predictive model and research design for conducting an archaeological survey in the Kilauea East Rift Geothermal Resource Zone on the island of Hawaii. The task was undertaken during preparation of an environmental impact statement (EIS) for Phases 3 and 4 of the Hawaii Geothermal Project (HGP) as defined by the state of Hawaii in its April 1989 proposal to Congress. The U.S. Department of Energy (DOE) published a notice in the *Federal Register* on May 17, 1994 (*Fed. Regis.* 59, 25638) withdrawing its Notice of Intent (*Fed. Regis.* 57, 5433) of February 14, 1992, to prepare the HGP EIS. Since the state of Hawaii is no longer pursuing or planning to pursue the HGP, DOE considers the project to be terminated.

ABSTRACT

The Puna Geothermal Resource Subzones (GRS) project area encompasses approximately 22,000 acres centered on the Kīlauea East Rift Zone in Puna District, Hawai'i Island. The area is divided into three subzones proposed for geothermal power development --Kīlauea Middle East Rift, Kamā'ili and Kapoho GRS. Throughout the time of human occupation, eruptive episodes along the rift have maintained a dynamic landscape. Periodic volcanic events, for example, have changed the coastline configuration, altered patterns of agriculturally suitable sediments, and created an assortment of periodically active, periodically quiescent, volcanic hazards. Because of the active character of the rift zone, then, the area's occupants have always been obliged to organize their use of the landscape to accommodate a dynamic mosaic of lava flow types and ages.

While the specific configuration of settlements and agricultural areas necessarily changed in response to volcanic events, it is possible to anticipate general patterns in the manner in which populations used the landscape through time. This research design offers a model that predicts the spatial results of long-term land-use patterns and relates them to the character of the archaeological record of that use. In essence, the environmental/land-use model developed here predicts that highest population levels, and hence the greatest abundance and complexity of identifiable prehistoric remains, tended to cluster near the coast at places that maximized access to productive fisheries and agricultural soils. With the possible exception of a few inland settlements, the density of archaeological remains is expected to decrease with distance from the coastline. The pattern is generally supported in the region's existing ethnohistoric and archaeological record.

While the Puna coastline lies outside of the three geothermal resource subzones *per se*, there is reason to expect agricultural, residential and ceremonial features related to coastal settlement to extend inland into the geothermal resource subzones. Prior to modern disturbance, archaeological remains in the vicinity of Kapoho Bay in the easternmost margin of the Kapoho GRS should have been particularly densely distributed due to its agricultural and fishery potential.

On the windward side of the Rift Zone, agricultural zones adjacent to the coast and further inland are expected to be associated with a high to moderate density (i.e., count per unit area) of varied archaeological sites. In the most inland agricultural zone, abundance should decrease overall, and should reflect a shift toward a higher fraction of agricultural and short-term task specific features relative to residential and ceremonial remains. Both coastal margin and inland agricultural zones are present in the Kapoho subzone. It is recommended that undisturbed older lava flows and crater floors be surveyed to attempt to test for the presence and relative density of these prehistoric cultural remains.

On the leeward side of Puna District, the coastal margin and inland agricultural zones are expected to reflect increased upslope-downslope agricultural stratification and somewhat decreased feature density overall. Agricultural features in immediate support of coastal communities are expected to extend further inland than those adjacent to comparable windward communities. Feature density should grade from moderate to low with increasing distance from the coastline. The leeward inland agricultural zone is found along the southeastern margin of both the Kīlauea and Kamā'ili subzones. Due to access problems and environmental constraints, the leeward inland agricultural zone is not expected to extend substantially beyond the rift zone crest in these subzones. It is

recommended that particular attention be paid to isolated pockets of older volcanic material (*kīpuka*) in order to document the possible presence of prehistoric archaeological features related to human occupation on the leeward side.

The upper forest exploitation zone is the final environmental/land-use category modeled in the report. The zone is found in the upper (northern) half of the Kīlauea and Kamā'ili geothermal subzones. This area is expected to be characterized by a low overall density of surface archaeological remains. Those present should reflect predominantly short-term tasks such as hunting encampments and/or low-investment agricultural features used to support inland travel and/or as hedges against shortfalls from primary gardens elsewhere.

While not modeled in terms of land-use zones, the report also considers the presence and potential significance of trails, lava tube caves, and historic period remains. Recommendations are offered for the identification and documentation of such features.

Environmental descriptions, land-use expectations and existing prehistoric and historic background information are developed in detail in the body of the report. The existing archaeological record, while generally consistent with the expectations developed here, is far too limited to constitute an adequate test of model predictions. The final research design section provides tabular summary of these predictions and outlines recommendations for examining them in the field. Specific discussion of field procedures complete the document. It is hoped that the effort serves to improve our understanding of the region's extensive cultural record, assists in protecting cultural remains in the event geothermal development proceeds in the three subzones, and helps to stimulate constructive debate on the relationship between extant spatial archaeological patterns and the long-term processes related to human settlement in Puna District and Hawai'i generally.

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A number of individuals have been most helpful offering suggestions and direct assistance with this phase of the Puna geothermal research design. Lillian Trettin has assisted in coordinating activities with Oak Ridge National Laboratories in Tennessee. Her patience and faith in the ultimate utility of the final document are most appreciated. Archaeologists with the Hawai'i State Historic Preservation Division also have been quite helpful in all phases of the effort. Special thanks goes to Holly McEldowney for help in ferreting out SHPD library materials, for interpreting and copying aerial photographs, for an informative field introduction to the project area, and for her obvious enthusiasm for the archaeology of the region. Hawai'i Island archaeologist, Marc Smith, also participated in the initial field inspection. His logistical help and sense of humor brightened the field inspection effort. U.S. Fish and Wildlife biologists Steve Miller and Jeff Burgett helped stimulate survey ideas and were most generous in making available their extensive subzone land ownership lists.

Several International Archaeological Research Institute archaeologists assisted with various phases of the research design and report production. David Welch has coordinated both Puna and Maui geothermal project areas, and served as our primary contact person with Oak Ridge Laboratories. Both he and Maria Sweeney provided valuable editorial assistance with this report. Michael Kaschko helped to select the initial survey blocks recommended in this document. Gail Murakami of the IARII Wood Identification Laboratory found stacks of East Rift Zone botanical surveys. Pennie Moblo conducted the report's historical background research and wrote the historical section of the research design. Christine Fadden and Joan Clarke helped prepare portions of the final text and took on the task of final paste-up and report production. Finally, much thanks goes to Roger Blankfein for his technical skill and exceptional patience as we waded through multiple productions of the maps included in this report. The fine quality of the final lava flow map and land-use zone overlay is a credit to his skill.

To these and others who have expressed a genuine interest in the archaeology of the Puna area, I extend my thanks.

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INTRODUCTION TO THE GEOTHERMAL PROJECT AREA AND INVENTORY RESEARCH DESIGN

For some time, geothermal development efforts have focused on the Kīlauea East Rift Zone of Puna District on the Island of Hawai'i (see Figure 1). The rift zone has witnessed the most sustained volcanic activity in the archipelago and is potentially the best suited area in the Islands for exploitation of this energy source. Earliest, and largely unsuccessful, exploratory drilling in the region took place in the early 1960s. Spurred by fears of oil shortages and funded by various state, federal and private agencies, exploration increased sharply in the 1970s (True 1982:3-8). These efforts led to construction of a 3-megawatt wellhead generating facility near Pāhoa in 1981. In subsequent years, continuing efforts have been made to locate well and generating sites, and to find economically, environmentally and socially acceptable means to develop geothermal power. Indeed, the present effort is a part of this larger process.

Presently, development and exploration in Kīlauea East Rift Zone is directed toward three geothermal resource subzones (GRS) --the Kīlauea Middle East Rift GRS, the Kamā'ili GRS and the Kapoho GRS shown on map Figure 2¹. Cumulatively, they make up over 22,000 acres of the rift zone landscape; ranging from relatively undeveloped 'ōhi'a forest of the westernmost Kīlauea GRS (situated within the Puna Forest Reserve) through moderately to extensively farmed and developed land in the lower Kamā'ili and Kapoho subzones.

Geothermal development is one of a long line of land-use pursuits directed toward this portion of the Puna District. To varying degrees, these uses have all affected the lives of the local population, the character of the landscape, and the nature of the archaeological record left behind. Currently, residential development --including large subdivision complexes-- and large-scale plantation agriculture --papaya, bananas and sugar, among others-- are major elements of the Kamā'ili and Kapoho subzones and Puna District generally. Much of the District's population is dependent on these enterprises either through direct labor, or indirectly through various commercial services and businesses. Local-level agricultural and fishing pursuits continue, but at a scale much reduced from the earlier historic and prehistoric past. In terms of their impact on the landscape, such local-level practices are overwhelmed by larger-scale endeavors linked to the broader state, national and international economy.

¹Land within the Kīlauea subzone falls wholly within Hawai'i County Tax Map Key (TMK) Zone 1- Section 2- Plats 8 and 10 (or 1-2-8 & 10). Property in Kamā'ili subzone can be found on TMK 1-2-8,9 & 10; TMK 1-3-1; and TMK 1-5-1. Kapoho lands are on TMK 1-3-45 & 46; and TMK 1-4-1,2,5,6,7,8,9,12,13,14,15,16,17,18,19,20,21,22,23,24,78 & 90.

Figure 1. Puna District and the Kilauea East Rift Zone, Hawai'i Island

Figure 2. Kilauea, Kamā'ili and Kapoho Geothermal Resource Subzones

Pressure for geothermal development largely reflects the current energy-intensive character of the modern industrial economy as well as Hawai'i's near total reliance on imported fuels. Broad-based economic interests, however, have not been limited solely to modern times. In the late 1800s and early 1900s, a variety of commercial pursuits were attempted in Puna District (see Moblo's historical summary in this volume). Coffee, pineapple and sugar plantations, ranching, and logging operations were among the larger-scale enterprises attempted within the District's rift zone area. The town of Pāhoa itself grew largely as a result of sugar production and logging/milling of the local 'ōhi'a forest. Towns like Pāhoa and the rift zone plantations developed and existed through links to a broader cash economy. Importantly, they required reorientation of labor away from local-level pursuits, clearing of large land tracts, construction of relatively sophisticated road and rail networks, and residential reorientation consistent with changing work and transportation options.

At the time of contact, and certainly for some time prior, Hilo was a major political and population center on the island. McEldowney (1979:16) emphasized that the combination of abundant freshwater, low gradient terrain well suited for taro and fish production and "advantages of the largest, best protected bay along this portion of the coast for the exploitation of marine resources, helped to make Hilo the single most populated spot in the study area". While clearly the largest population center, Hilo was but one of a number of villages along Puna's coast at places providing access to productive fisheries and agricultural ground. For at least a few hundred years prior to intrusion of the western economy, day to day Hawaiian life was geared toward exploitation and largely *ahupua'a*-based² redistribution of these combined marine and terrestrial resources.

At a general level, we expect areas near the coast (places such as lower Kapoho GRS) to have been the primary focus of long-term residence as well as a wider variety of economic and ceremonial activities. Particularly productive or otherwise important inland areas may have supported settlements as well; but the number and temporal duration of these places is expected to be small relative to the coast. Agricultural and short-term residential uses of the landscape, however, are likely to have extended inland for some distance. In the study area, it is reasonable to expect extensive use of productive sediments on the southeast (seaward) side of the rift slope in both Kamā'ili and Kīlauea subzones. By whatever means we reconstruct past settlement and agricultural patterns, we must recognize that, in Puna, they are sure to have undergone recurrent reorganization as volcanic flows periodically altered the coastline and rearranged the pattern and quantity of productive agricultural land. Nonetheless, it is reasonable to expect the reorganization of settlement patterns to have correlated with the basic *ahupua'a* (coastal-inland) pattern as adjusted to accommodate Pele's³ fickle volcanic nature. Primary residence should have centered near the coast with frequency and duration of land-use decreasing in the upper zones as distance from the coastline becomes greater.

It is also reasonable to expect differences in the manner and use intensity of coastal versus inland terrain to correlate with patterned variation in the character of the archaeological record left behind⁴. Despite repeated volcanic reordering of residentially and agriculturally suitable land,

²The traditional land division called the *ahupua'a* was a land tract that began at the coast and extended inland.

³Several myths and legends about the goddess Pele, the volcano deity who inhabits Kīlauea, are documented in Beckwith (1970:167-200).

⁴Because of its constant importance for population maintenance and the relatively high density of resulting archaeological features, agricultural land-use is emphasized throughout this report. Other practices such as overland travel on upland trails, human burial, refuge and burial in extensive lava tube cave networks, and task specific resource extraction were also important aspects of the prehistoric cultural landscape. The full range archaeological features must be considered in the research design.

primary residence should have concentrated on the coast throughout the prehistoric and early historic past. In comparison to inland terrain, Puna's coastal archaeological record should reflect 1) an overall higher count of structural features per unit area (i.e., highest site and/or feature *density*); 2) greater functional variety in those features (as indicated by greater variability in structural and artifact remains); and 3) higher labor investment (indicated by size and structural elaboration) in a sub-set of preserved archaeological features.

With some exceptions, inland zones provided collection areas and land for agricultural support to coastal settlements. Use intensity of inland terrain varied largely as a function of its agricultural or collecting potential, and physical distance from these settlements. In general, we can expect inland use intensity to have decreased as collecting and agricultural value was increasingly offset by transportation difficulty and by cold/cloud cover related reductions in agricultural productivity. Archaeologically, then, increasing distance from the coast should be associated with 1) decreasing site/feature density overall (interspersed with exceptional places of particularly high productivity and/or where situated along major overland travel routes);⁵ 2) narrowing functional variability to primary emphasis on collecting, agriculture and short-term residence; and 3) lower labor investment in constructed features (particularly in prime growing areas where productive agriculture is possible without use of terraces or other structures).

Please note that the coastal/inland dichotomy used here simplifies reality in order to draw attention to basic patterns in the ways early Puna populations organized their use of the landscape. This is characteristic of all models. There is little doubt that non-coastal inland settlements existed in the prehistoric as well as the historic past. William Ellis, alludes to early historic-period settlements in Kaau (Kea'au) and the vicinity of Kahuwai (presumably Kahuwai Crater in western Kāpoho Subzone) (Ellis 1979:211-212) --both well inland from the Puna coast. McEldowney (pers. comm.) suggests that constraints on agricultural land resulting from the rift's volcanic activity may have increased inland land-use intensity to a level beyond what would be expected in more uniform environments. Further, this volcanic activity will also reduce the number of archaeological remains presently visible to the archaeologist. Whatever the causes, inland settlements are to be expected. This does not invalidate the coastal settlement bias proposed here. The pattern is broadly supported by ethnographic accounts, and consistent with the extant (albeit limited) archaeological record. William Ellis (1979:190) traveling through dry western coastal Puna in the early 1800s observed the bias toward coastal settlement even in relatively arid areas. His comments also show unusual sensitivity to underlying environmental-economic causes of this basic settlement pattern.

The population of this part of Puna, though somewhat numerous, did not appear to possess the means of subsistence in any great variety or abundance; and we have often been surprised to find the desolate coasts more thickly inhabited than some of the fertile tracts in the interior; a circumstance we can only account for, by supposing that the facilities which the former afford for fishing, induce the natives to prefer them as places of abode; for they find that where the coast is low, the adjacent water is generally shallow.

* * * *

⁵It is important to be aware that agricultural land-use may not involve construction of physical features and, consequently, may be under represented in the archaeological record. Care must be taken not to assume a simple direct relationship between feature density and land-use intensity *per se*.

Through prehistoric and historic time, changing human uses of the Puna landscape have left traces of their presence in the archaeological record. Unfortunately, extensive terrain disturbance from repeated volcanic events and modern development tend to obliterate the record. Consistent with state and federal cultural resource protection guidelines, the overriding objective of the present effort is to help develop means to identify and preserve the physical integrity of the archaeological record, and/or to use it to derive meaningful information about Hawaii's past. This document is an initial effort in that process. The intent of this research design is to 1) clarify basic patterns in long-term regional land-use strategies; 2) clarify implications that these patterns hold for the archaeological record of Puna District and the rift zone; and 3) develop a sample inventory strategy suitable for examining archaeological patterns in the three geothermal resource subzones.

The research design is organized into three major sections. The first section outlines the environmental setting of the Kīlauea East Rift Zone and the three geothermal subzones. Included are background accounts of geology, vegetation and the character of the modern landscape emphasizing the relationship of the rift zone environment to the archaeological record. The second section provides cultural background to the project area. It includes a summary of previous archaeology in the region, and background into both prehistoric and historic settlement and land-use practices. The third section outlines research strategy in terms of archaeological expectations, and specific research and management recommendations. A short summary concludes the document. I hope that combined results help to enhance our understanding of the organized human processes that shaped Puna's archaeological record, and proves useful for managing that dwindling cultural resource.

ENVIRONMENTAL SETTING

EAST RIFT ZONE GEOLOGY AND THE ARCHAEOLOGICAL RECORD

Kīlauea is the youngest and most active of Hawaii's volcanos. Active lava flows are not limited to the central caldera itself, but have emanated from a number of lesser craters and eruptive fissures situated along two linear rift zones extending southwest and northeast of the summit --the Southwest and East Rift Zones respectively (see Figure 1). The East Rift Zone is of particular interest to the present project. It extends virtually the full length of Puna District plus at least 70 miles under the sea floor (MacDonald and Abbott 1979:313). The placement of the three geothermal subzones, straddling the rift, is an attempt to capitalize on the area's particular geothermal and hydrological qualities.

Volcanic features and flows are variable along the rift zone. A complex network of pāhoehoe and 'a'ā flows punctuated by spatter cones, craters and cracks intertwine along the rifts and in the geothermal subzones. Holcomb (1987:266) succinctly summarizes the general character of the Kīlauea flows and the events that created them:

...The morphology of a lava flow is influenced by the behavior of the eruption that produces it, with sustained effusion leading to a high degree of channelization and formation of lava tubes (... Peterson and Swanson, 1974). Different kinds of eruption produce different kinds of vent edifices and flow assemblages (Swanson, 1973; Holcomb 1976...). Brief eruptions produce small edifices and simple assemblages of surface-fed pāhoehoe and aa, while long-sustained eruptions produce large lava shields and assemblages dominated by tube-fed pāhoehoe... . Eruptions of intermediate duration, several weeks to a few years, typically produce small shields and complex assemblages of all three flow types. ...

Figure 3 is adapted from Holcomb's article. It shows the basic distribution of flow types across both the East and Southwest Rift Zones. The three geothermal subzones are superimposed to show the general character of the distribution within the project area. In a general sense, the pattern is important to understanding the archaeological record of the region. For reasons discussed further below, agricultural uses of the landscape are most productively (though not exclusively) pursued on 'a'ā flows. Lava tube caves form in tube-fed pāhoehoe and may be expected to be most heavily represented there. Awareness of flow patterns and their potential influence on the character of past human use, and hence on the archaeological record of that use, is an important element in structuring an effective regional research strategy. All else being equal, we should expect to find the greatest density of agricultural features in the 'a'ā flow areas shown in black. Lava tube caves should be restricted to tube-fed flows shown in gray.

Kīlauea's geological variability is not limited to the character of the substrate. The region also exhibits substantial variation in the age of its volcanic events. Kīlauea and both rift zones have undergone repeated eruptive episodes throughout the last millennium. According to Holcomb (1987:279), 90% of the surface is younger than 1,100 years old (or years before the present --B.P.). About 70% of the surface is less than 500 years old, and accordingly, well within the human occupation period. Substantial volcanic activity has continued through the historic period. Flows emanating from the East Rift obliterated Kalapana town and much of the adjacent coastline as recently as 1990. Lava flows and spatter eruption from Pu'u O'o continue at the time of writing. Figure 4 illustrates Kīlauea's eruptive history during the last 1,500 years (through 1986). Individual time frames clearly show the extent of land modification along both rift zones. Note that extensive volcanic activity has occurred within the past 300 years in the geothermal subzones. In general, these have been rift zone in origin rather than eruptions from the main Kīlauea summit.

Because of East Rift Zone volcanic activity, much of Puna and eastern Ka'ū Districts have presented an actively changing landscape throughout the period of human occupation of the region. The geological setting, then, created a dynamic context for human populations. Repeated volcanic activity and related events necessarily influenced land-use practices and affected the archaeological record in a number of ways. Aside from the physical risks imposed by various volcanic hazards, larger scale impacts are implied by such events as 1) destruction of fields and structures and filling coastal bays --while creating new areas elsewhere; 2) earthquakes and tsunamis capable of destroying structures and coastal settlements; 3) generation of a variably productive agricultural landscape even in relatively stable areas; and 4) development of lava tube cave networks in tube-fed pāhoehoe flows (cf., Somers 1991). Clearly, the first issue directly affects both land-use practices and the physical integrity of the archaeological record. In most cases, flows are destructive and simply obliterate portions of the landscape --unlucky humans, structures, fields and all. Very few archaeological remains of human occupation will predate the majority of flows emanating from the Kīlauea eruptions. For present purposes, very young flows (ca. A.D. 1950 on) are excluded from surface cultural inventory. Older flows, however, may preserve earlier historic and/or prehistoric remains post-dating the particular eruptive event in question. Clearly, then, it is important to date flows with sufficient accuracy to establish basal dates for features located in or on top of them. The oldest available flows assume particular importance to the present research design because of the length of the archaeological record that they may preserve. Figure 3 provides a general notion of the pattern that may be anticipated in the project area. Figure 5 is a larger scale flow map showing the relationship of volcanic flows to the geothermal resource subzones.

Figure 3. Kilauea Lava Flows Classified by Morphology (after Holcomb 1987:279)

Damage from earthquakes and tsunamis in areas that were not physically covered by lava flows have occurred on Kīlauea's flanks and coastline (see Somers 1991). These events may not be observable (or at least unambiguously interpreted) in the archaeological record. In general, we can assume that population movement away from temporarily devastated areas will eventually reverse after initial danger subsides; assuming that economic factors (especially productive fishing and or agricultural ground) underlying selection of the location(s) in the first place continue to hold.

Figure 4. Kīlauea's 1,500 Year Eruptive History (after Holcomb 1987:343)

Figure 5. Major Lava Flows in Kilauea, Kamā'ili and Kapoho Subzones

Variable productivity of the landscape reflects differential capability of pāhoehoe versus 'a'ā to support vigorous plant growth. In this area, the most productive agricultural ground is well weathered 'a'ā. Very young flows (pāhoehoe or 'a'ā) generally do not provide an effective planting medium without mechanical crushing (really a form of artificially accelerated mechanical weathering). However, because it is porous and has low bulk density relative to pāhoehoe, 'a'ā is subject to more rapid chemical decomposition in Puna's wet environment. Under conditions of high rainfall, 'a'ā's rough surface and porous texture, appear to facilitate root penetration, promote nutrient exchange, and provide drainage for relatively productive and diverse plant growth (cf., McEldowney 1979:18). Pāhoehoe, on the other hand, weathers more slowly and, on low gradient land, tends to drain slowly, creating swampy conditions less suitable for production of many crop plants.⁶ Accordingly, we would expect agricultural feature density to be biased toward 'a'ā flows generally. Highest feature density should be on oldest flows, increasing with proximity to the coastline; particularly where old 'a'ā converges on bays with productive fisheries.

Tube-fed pāhoehoe flows frequently contain lava tube caves suitable for human use. During prehistoric times, lava tubes were commonly used for residence, refuge, burial and other ceremonial functions. Extensive cave systems have been reported for the general East Rift area. McEldowney and Stone (1991) explored portions of three systems, and tentatively identified others, in the massive summit flow (called *Aila'au* flows by Holcomb [1987]) passing through the northern half of the Kīlauea GRS (see Figure 3). Aerial photographs suggest that at least two and perhaps all of these tubes enter the subzone. Portions of these and other tubes in the same *Aila'au* flow have been reported by Emory (1945), Olson (1984), Major (1992a, 1992b and 1993), Komori (1987) and Yent (1983). These cave systems contain extensive burial and refuge/residential remains. Similar remains should be anticipated for the Kīlauea GRS. Caves have also been reported in the southeasterly tube-fed flows emanating from the East Rift Zone. The location and content of these caves remains imperfectly known. Because of their cultural importance and often dramatic content, local residents and professionals alike are understandably reluctant to divulge cave locations. Nonetheless, it is important that these geological and cultural features be identified; recorded in a manner that protects their integrity and respects their cultural importance; and protected from vandalism and from intrusion by geothermal drilling and related construction.

Clearly, timing and type of volcanic events has had substantial effect on the region's archaeological record. Accordingly, volcanism must be considered in developing an inventory plan. Flow age is perhaps most important by virtue of establishing a basic cultural time frame. Fold-out Figure 5 shows dated volcanic events across the geothermal subzones in five time periods.

Modern	Volcanic events occurring from A.D. 1950 to the present.
Late Historic	Flows dating between A.D. 1840 and 1950. The area is dominated by the flow of 1840. Cultural features necessarily post-date that event, though most of the flow effected land outside project boundaries.
Early Historic	Flows dating between A.D. 1790 and 1839. The primary event is the flow of 1790 impacting parts of Kamā'ili and Kapoho. Features on these flows or in associated lava tubes must post-date that year.

⁶Interestingly, in arid regions the pattern may be reversed. In places like low elevation landforms on the Kona Coast, plant productivity appears to be highest on either very well weathered fine-grained sediments (seldom found along the Kīlauea rift zones) or on pāhoehoe. Here, water seems to be the controlling variable, 'a'ā does not weather rapidly in the absence of abundant rainfall, and is so well drained that it supports only xeric plants. Pāhoehoe's capacity to perch water makes it marginally better suited for plant production. In any case plant production is maximized on well weathered sediments that can provide for water retention, nutrient bonding and exchange, and root penetration.

- Late Prehistoric Flows with radiocarbon ages of 400 to 200 years: A.D. 1600 to 1789 (1789). Flows are common in southern Kīlauea, western Kamā'ili and various parts of Kapoho subzones.
- Mid Prehistoric Flows with radiocarbon ages of 750 to 400 years: A.D. 1250 to 1600. The massive Aila'au tube-fed pāhoehoe flow crosses northern Kīlauea and Kamā'ili. It contains extensive lava tubes with cultural features. Other events occurred in southeastern Kamā'ili and parts of Kapoho.
- Early Prehistoric Flows dating between 1500 and 750 years: A.D. 500 to 1250. Flows overlap the full occupation range and may contain earliest cultural materials in the region. Limited old *kīpuka* found in all subzones.

Because they plausibly preserve the most complete archeological record in the study area, survey procedures should be structured to investigate as many of the oldest flows and isolates (*kīpuka*) as possible. Within flow zones, attention should be given to the distinction between flow types ('a'ā, surface-fed pāhoehoe and tube-fed pāhoehoe) in order to determine their effect on variable land-use patterns, if any, and to maximize the probability of identifying lava tube cave features. These issues are discussed further in the Research Strategy section of this document.⁷

CLIMATE AND VEGETATION

The climate of Puna District is determined largely by latitude and position in relation to northeasterly trade winds. Throughout most of the year, trade winds dominate air flow patterns; passing from northeast to southwest over the coastline between Hilo Bay and Kumukahi Point, blowing up over the rift zone and flowing back out to sea over the southeastern Puna coast. The effect is particularly pronounced during the spring and summer months when trade winds may dominate airflow patterns as much as 85% to 95% of the time. During the remainder of the year, trade wind domination falls to circa 45% to 60% (True 1982:3-11). At any time of year, nocturnal cooling may temporarily reverse the pattern, causing air to sink from Mauna Loa/Kīlauea northeast toward Hilo, and down the rift zone bending downslope south to southwest. The interaction of cool offshore airflow with opposing trade winds tends to cause highest rainfall levels during the night and early morning hours (Price 1973:57).

Typical of windward Hawai'i Island, Puna District receives relatively high annual precipitation. Figure 6 shows basic precipitation patterns. For Puna District as for the island generally, precipitation increases as a function of elevation. Within the three geothermal subzones, mean rainfall varies from approximately 80 inches to 140 inches annually, with highest totals in the upper section of the Kīlauea subzone. Severe rainstorms are infrequent and thunderstorms, which average eight per year, are rarely damaging (DBED 1989:IV-23). Heaviest rainfall generally occurs during the winter months, but precipitation is common, and occasionally heavy, throughout the year (see "Kapoho, Mountain View and Hawaii Nat'l Park" graphs on Figure 6 and DBED 1989:IV-25). At Mountain View, for example, average rainfall for the wettest month --March--is circa 20 inches while an average of 10 inches falls in June, the driest month. Precipitation on the leeward coastline decreases gradually from northeast to southwest as winds lose moisture traveling up and over Kīlauea's eastern rift.

⁷Temporal data for the Kamā'ili and Kapoho subzones and the easternmost section of the Kīlauea are taken from Moore and Trusdell's (1991) flow map. Data on the eastern section of the study area are from earlier work by Holcomb (1987). 'A'ā, pāhoehoe and tube fed flows have proven difficult to distinguish unambiguously from map data. Aerial photographs and other sources be consulted to refine basic survey strata.

Seasonal temperature variation also is moderate and varies with elevation. Data from Mountain View (elevation 1530 feet) most closely approximates that of the project area (particularly for the Kīlauea and Kamā'ili subzones). Here, mean highs range between the low 70's to high 80's Fahrenheit regardless of season (late summer is the warmest, mid winter the coolest). Average lows vary between the upper 50's in March to the lower 70's in August and September (Price 1973:58).

This combination of stable, moist, and warm weather strongly influences dominant vegetation patterns across the project area. Except for the southern extreme of the District which lies in Kīlauea's lee, Puna is wet enough to support forest vegetation throughout. Very generalized classification systems (Knapp 1975:114-116, and Sohmer and Gustafson 1987:39-57) indicate a shift from mixed mesic or sub-montane forest to true montane rain forest with increasing elevation (i.e., increasing moisture and decreasing evapotranspiration stress). Vegetation zones shown on Figure 7 and summarized in Table 1 show a similar pattern. Coastal and inland areas up to about 1500 feet fall within the mixed mesic forest/closed guava forest zone. Where relatively undisturbed, forests are characterized by a mix of native and introduced lowland species such as ('ōhi'a lehua) *Metrosideros collina*, pandanus (*hala*) *Pandanus tectorius* candlenut (*kukui*) *Aleurites moluccana*, and strawberry guava *Psidium cattleianum* (McEldowney 1979:3). Figure 7 shows this zone dominating all but the westernmost tip of the project area. However, much of Kīlauea GRS flora more closely approximates the higher closed 'ōhi'a lehua rain forest. Here, forest maturity is locally variable. On younger lava flows near the rift, 'ōhi'a is mixed with dense stands of early successional species such as *Dicranopteris linearis* (*uluhe*), *Pipturus albidus* (*māmaki*) and grasses. *Melastoma* is invasive, and is particularly dense in the eastern and central parts of the Kīlauea subzone. Lower on the lee side, drier conditions favor stands more characteristic of the open guava forest/shrub zone.

THE MODERN LANDSCAPE

Lamoureux and Char's (1985) study of floral associations in the project area suggest that basic qualities of the environment characterized above remain characteristic of lesser disturbed parts of the modern landscape. Young lava flows punctuate, in black relief, the tangle of 'ōhi'a-uluhe and more uniform 'ōhi'a stands that still characterize much of the landscape --particularly in the Kīlauea GRS. However, market demands and technical innovations of the last century, have provided the cause and means to develop extensive tracts of both coastal and inland terrain. Such developments as speculative housing or "homestead" projects and large-scale agriculture have altered a substantial fraction of land in the general project area. Few of these activities have been preceded by archaeological or other environmental studies; resulting in a loss, to an unknown extent, of our ability to reconstruct the region's prehistoric past. Damage to the archaeological record, of course, has not been limited to human intervention alone. Modern lava flows along the eastern rift zone have covered large portions of the landscape, including sizable pieces of the three geothermal subzones. Because the integrity of the archaeological record is affected by both classes of events, the basic character of the modern environment and archaeological implications are summarized briefly for each geothermal subzone.

Table 1. Hawai'i Island Vegetation Zones (cf., Ripperton and Hosaka 1942, Burtchard 1993)

Lumped Zones (Sohmer & Gustafson 1987)	Split Zones (Lamoureux 1973)	Elevation (ft amsl)	Precip. (in/yr)	In Puna Dist.	In Proj. Area	Characteristic Plants (Native Hawaiian Plants in Boldface)
Coast	Kiawe & lowland shrub	<1000	<20	Yes	No	Kiawe, koa haole, finger grass, pili grass
Dryland Forest & Shrub	Lantana-koa haole shrub	<3000	20-40	Yes	No	Lantana, koa haole, klu, paini, ilima, Natal redtop grass
Mixed Mesic Forest	Open guava forest with shrubs	<2500	40-60	Yes	Lee Coast	Guava, koa haole, lantana, Spanish clover, Bermuda grass
	Mixed open forest	2500-4000	40-60	Yes	No	'Ōhi'a lehua, koa, Spanish clover, Bermuda grass
	Closed guava forest with shrubs	<1500	>60	Yes	Yes	Guava, Boston fern, Hilo grass, basket grass, false staghorn fern, kukui, hala, 'ōhi'a lehua, hapu'u tree, olapa
Rain Forest	Closed 'ōhi'a lehua rainforest	1500-7000	60-400	Yes	Yes	'Ōhi'a lehua, uluhe, hapu'u tree fern, olapa
	Open koa forest	4000-7000	>60	No	No	Koa, 'ōhi'a lehua, rattail grass, hue pueo grass
Subalpine & Alpine	Open koa forest with mamane	4000-7000	<50	No	No	Koa, mamani, hue pueo grass, pukiawe, a'ali'i
	Open mamani- naio forest with subalpine shrubs	7000-10000	<50	No	No	Mamani, nalo, pukiawe, a'ali'i, ohelo
	Alpine stone desert	>10000	<20	No	No	Scattered mosses, silversword, Hawaiian bent grass

Kīlauea Subzone

Farthest removed from the Hilo market and redistribution center, the Kīlauea subzone has, until now, been exposed to the lowest level of development of all the geothermal subzones. Most historic period construction impacts have been restricted to limited logging and construction of an associated rail line in the subzone's northeast quadrant; forest clearing and ranching on land grant tracts in the southeast corner; and exploratory drilling of the recent geothermal test well and access road in the center-east section of the subzone. While there is little doubt that these events have altered the natural terrain, the overall impact to the archaeological record from these activities is low.

Post-1950 lava flows represent the single largest intrusion into the subzone (see Figure 5). Young flows cover much of the southwest quadrant. Additional flows include a moderate sized event roughly in the center of the subzone and a number of smaller isolated flows along the rift. Except for surrounded and isolated "islands" (*kīpuka*) of older flows surrounded by younger volcanic material, these areas may be excluded from archaeological inventory.

The above intrusions notwithstanding, approximately 80% to 85% of the Kīlauea subzone remains in natural condition. Most of the zone is dominated by wet 'ōhi'a forest with native species or 'ōhi'a woodland with *uluhe* fern (Lamoureux and Char 1985). Except for the intrusive geological and human features noted above, the canopy appears relatively uniform across the subzone surface. The most obvious source of variation in vegetative cover results from differences in the volcanic substrate. Pāhoehoe flows in the northern part of the subzone include areas in which the relatively impermeable substrate tends to perch water near the surface. In these places, the ground is boggy, 'ōhi'a cover less complete, and *uluhe* and grasses quite dense. Importantly, lava tube sink holes tend to be visible from the air over these zones, providing a preliminary means to locate and chart the course of caves. For the most part, however, tree cover is moderate to dense, precluding areal observation of other than approximate lava flow boundaries. The primary problems the Kīlauea environment poses to archaeological survey center on difficulties of access, dense ground cover (limiting visibility), poorly consolidated substrate, and volcanic hazards (threatening personal safety of survey team members). The archaeological record, while difficult to identify, should be relatively intact. For maximal effectiveness, that survey should focus on oldest flows *kīpuka* and lava tubes.

Kamā'ili Subzone

Development has been more pronounced in the Kamā'ili subzone. An extensive area in the northern part of the subzone (south of Pāhoa town) has been cleared for sugar production. More recently, roads have been extended and lots opened for sale as *Kaohe Homesteads*. Roads and homestead parcels also have been opened on old grant lands east of 'Ī'lewa Crater (shown on map Figure 1). Several mining operations are located in the southeast quadrant. All development areas, of course, are linked by roads.

Post-1950 lava flows have been active on the lower edge of the rift zone. As shown on Figure 5, these flows now cover much of the southwest quadrant, a moderate portion of the southeast corner, and smaller isolated areas along the rift. In older pāhoehoe flows, lava tubes should be expected to contain archaeological remains.

Because of their massive scale, young flows and sugar production represent the most significant sources of impact to Kamā'ili's archaeological record. Combined with other construction areas, these intrusions comprise approximately 25% to 30% of the total area within the subzone. Environmental conditions on intact ground are not unlike those of the Kīlauea subzone. 'Ōhi'a woodlands are mixed with dense *uluhe* pockets and contain localized sub-canopies of exotic introductions and shrubs (Lamoureux and Char 1985). The most effective survey strategy in this subzone, again, would focus on the oldest flows, *kīpuka* and lava tubes. Because of more thoroughly developed road networks, access should be less time-consuming than in the Kīlauea subzone. Other survey constraints are equally applicable to both geothermal development areas.

Kapoho Subzone

Due to massive agricultural development, mining, and recent volcanic activity, the Kapoho subzone has undergone the most extensive terrain alteration of all the proposed geothermal development areas. Agriculture initially focused primarily on sugar, but in recent years, increasing amounts of land have been turned to papaya production as well as other market crops. Recent aerial photographs⁸ clearly show extensive farm operations covering 60% to 70% of the total area. These farm operations have

⁸1992 and 1993 false infrared imagery of the project area is on file at IARII offices in Honolulu (also available through *Air Survey Hawaii*, Honolulu).

involved extensive clearing, mechanical leveling and planting. Associated terrain modification is extensive throughout the subzone. While less spatially expansive, mining impact on the natural terrain is massive. Mines here and in the Kamā'ili subzone extract red and black cinder for road surfacing, horticulture and decorative uses. These operations essentially strip away the sides of hills with the proper color and texture characteristics (mostly spatter cones). In addition to these, the existing HPG-A geothermal well and generating facility, spreads over a substantial parcel in the west-central portion of the project area. It is unlikely that ground put to either agricultural or mining/geothermal uses will preserve a substantial portion of the previous archaeological record (though the possibility exists for remnant disturbed, but exposed, cultural remains). In Kapoho GRS, it is particularly important that remnant, intact land surfaces be surveyed thoroughly. Surviving cultural features are most likely to be found in lava tubes and in small, non-impacted *kīpuka*-like spots such as the volcanic crater floors (e.g., Halekamahina and Pu'ulena craters) and older volcanic cones (e.g., Pu'u Kūkae). Photograph 1 shows recent clearing and papaya fields in the Kapoho subzone. Kapoho Crater is visible in the background.

Recent volcanic activity is also quite extensive in the Kapoho subzone. The single most massive event is a 1960 flow covering Kumukahi point on the eastern end of the subzone. Other recent rift zone flows are located in the center and western portions of the subzone respectively (see Figure 5).

Photo 1. Cleared Ground and Papaya Fields in the Kapoho Subzone

Combined development and recent volcanic activity have substantially altered over 90% of the natural landforms in the Kapoho subzone. This is particularly unfortunate since, as will be discussed below, the Kapoho subzone probably received the most intensive prehistoric human use within the study

area. Thus, the question still remains to what extent have lava flows disrupted the pattern of material culture remains? Remnant stands of unaltered forest are now rare except in areas of little economic utility. These principally are volcanic cones and craters, and small parcels widely scattered throughout the subzone. In the Kapoho subzone, it appears that the most practical strategy would be to survey remnant terrain wherever it occurs (giving precedence to older landforms). Land-use patterns for this subzone would have to be inferred through extension of these and other available archaeological data, as they relate to modelled prehistoric settlement for the general region.

ENVIRONMENT, LAND-USE AND THE ARCHAEOLOGICAL RECORD

The environment of the East Rift Zone and its surrounding area affects the archaeological record in at least two ways: 1) through constraints imposed on human use of the region and hence on generation of the archaeological record during the past; and 2) on site integrity and our ability to accurately identify archaeological localities in the present. The effects of both have been discussed throughout the environmental background section. As approached here, constraints on long-term human use emphasize the continuing need for resident populations to extract and redistribute a stable supply of critical subsistence resources. The need to do so, necessarily affects the location of human settlements and activity patterns across the landscape. Recognizing that humans are complex organisms capable of undertaking a wide range of activities not always linked to critical resources (and indeed are capable of actively maladaptive behavior for limited periods of time), *most* members of human populations act in what they believe to be their best interest *most* of the time. Because of the constant and critical importance to maintenance of cultural systems, extraction and distribution of certain resources will have had particularly strong influence on settlement patterns across the landscape. Most frequently, this is expressed by locating residences and fields at places that maximize access to as many critical resources as possible, while minimizing risk in sustaining their availability (as much as possible). That is to say, remains of past human activity may be expected *anywhere*, but through time, certain landforms tend to be used with greater intensity, duration and/or redundancy than others. We predict that, for Puna District, that these will be places where critical subsistence and other maintenance resources were most effectively exploited. Accordingly, patterns in the *relative density* of archaeological remains (per unit area) left behind will tend to reflect this differential use of the landscape as well.

In prehistoric Hawai'i, this pattern is expressed by a general tendency to locate settlements in coastal settings providing adequate access to both marine resources and inland agricultural ground. Variations from the pattern most plausibly reflect effects of local-level environmental variability, high population density, intergroup conflict, and so on. Even though the pattern is general (and exceptions are to be anticipated) the pan-human tendency to exploit critical resources in a predictable fashion provides empirical foundation for examining basic settlement patterns in the absence of written records. For present purposes, it provides means to predict patterns in the relative density of cultural remains in a manner that allows refinement or rejection of the model through archaeological survey techniques.

McEldowney's Early Historic Period Land-Use Model

Holly McEldowney has developed what is currently the most thoroughly conceived and widely used land-use/settlement model for windward Hawai'i Island (McEldowney 1979). While based largely on early historical accounts, the model is genuinely ecological in character in that it considers the relationship between observable environmental variables and human resource needs in a manner that provides predictive power for the prehistoric past. Principal environmental variables are elevation, distance from the coastline and agricultural potential of the volcanic substrate (particularly for Mauna Loa/Kīlauea slopes in southern South Hilo and northern Puna Districts), cloud cover and soil temperature

(both elevation related). Essentially, McEldowney's model provides an environmental basis to accommodate high settlement density near the coast, routine agricultural use of adjacent inland terrain and shorter-term, specialized use of forest and montane zones. While intended primarily to clarify settlement patterns in South Hilo District, her observations offer insight into use of Puna District as well. McEldowney's model partitions the environment and general land-use patterns as follows:

Zone I - Coastal Settlement

Situated from sea level to ca. 50 ft elevation or one half mile inland, the coastal settlement zone incorporates both compact and elongated village complexes paralleling the coastline. Primary settlement determinants are access to marine resources, fresh or brackish water and agricultural potential of the substrate (principally older 'a'ā flows on the Kīlauea side). Early historic sources report production of the full suite of Hawaiian crops, including high moisture requirement plants such as dryland taro (*Colocasia esculenta*), banana (*Musa* spp.) and sugarcane (*Saccharum officinarum*). Structures reflect a wide range of residential, ceremonial and agricultural functions.

Zone II - Upland Agriculture

In this zone, McEldowney includes inland terrain to ca. 1500 ft elevation or five to six miles from the coastline. Historically, the zone was characterized by scattered huts with garden plots and small groves of economically useful trees. Exploiting increased rainfall, dryland taro and bananas may have been more extensively planted than in the Coastal Zone. Related structural features should have been limited largely to low construction investment residences, agricultural terraces and walls, and ceremonial features and burials. Features should be more widely scattered than at the coast, but still biased toward older, agriculturally productive lava flows. Trails and lava tube caves are also found in this (and other) land-use zones, their locations determined by transportation needs and presence of tube-fed pāhoehoe flows respectively. Residential, refuge, burial features may be quite elaborate in lava tube caves.

Zone III - Lower Forest

McEldowney's Lower Forest Zone lies at ca. 1500 to 2500 ft elevation. This essentially is the upper edge of cleared agricultural lands to the lower koa band on the slopes of Mauna Kea and Mauna Loa (McEldowney pers. comm.). The comparable elevation range in Puna would include the central and westernmost portion of the Kīlauea Subzone. Unlike Mauna Kea, forest maturity is repressed by repeated volcanism along Kīlauea's East Rift Zone. Here, forest cover is expressed generally as more open 'ōhi'a lehua-uluhe stands. In both places, lower soil temperatures and frequent cloud cover represses agricultural productivity and reliability. The zone represents the upper limit of subsistence agriculture. Because of repeated volcanism in Puna, this zone may have been somewhat less economically useful than comparable elevation terrain on more the more stable landforms for which McEldowney's model was developed. Most human use of the zone should have been directed toward travel; task-specific collection of wood, fiber and bird products; and for scattered plantings for travel and crop-failure insurance. Structures should have been limited to temporary huts, agricultural mounds and other low-investment structures at very low overall density.

Zone IV - Rainforest

The upper elevation rainforest (ca. 2500 to 5500 ft) extends well above the limits of all but the most marginally productive agriculture. Nonetheless, the rainforest produced products that should have been exploited at low-intensity by task-specific groups operating out of coastal settlements. While, some economically useful items are found in the rainforest, most are less productive than in lower windward locations (McEldowney notes *māmaki*, *'ei'ei*,

olonā and *Koa* for Mauna Kea and Mauna Loa). Use of the upper rainforest both there and in Puna can be expected to have been limited largely by its negligible agricultural potential, increased access difficulty, and frequent cold and wet conditions. Accordingly, the density of structural features related to prehistoric use should be comparably low. The geothermal resource study area does not extend into this elevation.

Zone V - Subalpine or Montane

Above 5500 ft, land-use should have been largely restricted to travel and exploitation of specific resources such as adz basalt. The zone is restricted to upper elevation reaches of Mauna Loa, Mauna Kea and Hualalai.

As will be seen, the land-use model offered below focuses only on low to mid elevation terrain found within the geothermal resource area --essentially McEldowney's first three zones. It is consistent with her general approach, but partitions the study area in a manner that attempts to better accommodate environmental and settlement density patterns expected for the East Rift Zone. McEldowney's model remains relevant, however, because of its historical grounding and consideration of resource/environmental variables underlying human settlement distribution.

Puna Agricultural and Settlement Patterns

Assuming adequate marine productivity and suitable access to agricultural soils, the most important issue in the general environmental/land-use discussion relates to the potential of inland Puna District to provide agricultural support for its resident population. We have some environmental and historically- based reasons to believe that parts of the District were relatively productive in the past. Handy and Handy (1972:542), underscore the point:

One of the most interesting things about Puna is that Hawaiians believe, and their traditions imply, that this was once Hawaii's richest agricultural region and that it is only in relatively recent time that volcanic eruption has destroyed much of its best land. Unquestionably lava flows in historic times have covered more good gardening land here than in any other district. But the present desolation was largely brought about by the gradual abandonment of their country by Hawaiians after sugar and ranching came in.

Because agriculture in itself is not sufficient to support a resident population over the long term, most prehistoric Hawaiians maintained a combined fishing and farming economy. To do so effectively, people tended to orient their permanent settlements toward the best available agricultural land near the best available coastal fisheries (or at least places affording relatively calm-water access to these waters). The issue of *where* agriculture can be productively pursued, then, becomes important to understanding inland settlement patterns.

There is reason to believe that the full critical range of Hawaiian crops could be produced successfully in near coastal context for the entire Puna coastline northeast of Kamā'ili (see Handy and Handy 1972:539-543 and map Figures 2 and 7). Moving southwest of Kamā'ili beyond Kalapana and into Ka'ū District, however, the coastline becomes progressively drier; requiring agricultural practices to be spread over greater distances inland. At lower Kaimū, just six miles southwest of Kamā'ili, Handy and Handy suggest that sweet potatoes could be grown but taro could not (see quote below). Assuming similar conditions applied in the prehistoric past, the Kamā'ili to Kaimū coastline represented a transition zone to climatic conditions requiring production of wetland staples (particularly taro) upslope where rainfall is higher and more reliable. Near coastal staples would have been dominated by more drought tolerant species such as sweet potato (*Ipomoea batatas*).

Assuming adequate availability of marine resources, agricultural potential can be expected to have had an impact on the distribution of people and their archaeological traces across the landscape. It is reasonable to expect earliest and densest occupation to occur in the most equable environmental zones the District had to offer. In Puna, these were along the windward coast northwest of Kamā'ili, around Cape Kumukahi and on toward Hilo Bay. Particularly productive places (e.g., Kapoho Bay and Crater) should have been particularly intensively used. Unlike more leeward locations on Hawai'i Island, precipitation along this portion of the coastal strand was adequate to sustain most important agricultural commodities that required moist growing conditions --especially dryland taro (*kalo*) *Colocasia esculenta*, breadfruit ('Ulu) (*Artocarpus altilis*), plus bananas and plantain (*mai'a*) *Musa acuminata*, sugarcane (*kō*) *Saccharum officinarum*, ti (*kī*) *Cordyline fruticosa* and others (see Abbott 1992)-- and do so in close association with accessible fisheries.

William Ellis' writings support the notion of increasing population density windward of Kaimū Bay. In describing a return trip from Kona to Hilo, Ellis noted population levels at a number of coastal settlements. He estimated a population of ca. 2000 for the Kaimū area (probably including Kalapana) (Ellis 1979:196). As he traveled northeast from Kaimū to 'Opihikao and Keahia-Laka he noted continued increases. At the latter location, Ellis (1979:201-202) wrote:

We were fatigued with the labours of the day though we had not traveled so far as usual. The country had been *much more populous than any we had passed since leaving Kona*, and we felt thankful for the opportunities that we had this day; enjoyed of speaking to so many about those things which concern their everlasting peace. ... [*emphasis added*]

Along the coastal margin of the Kapoho GRS, then, we would expect relatively dense prehistoric settlement. The number and variety of archaeological features in this area should reflect that relatively high level of prehistoric use. Not surprisingly, extant archaeological surveys along this portion of the coast (Bevacqua and Dye 1972, Crozier and Barrère 1971, Cox 1983a, Ladd 1981, Cordy 1989, Kennedy 1991c and Franklin et al. 1992) report a high density of prehistoric features relative to areas further inland in the Kapoho area (Ewart and Luscomb 1974, Bonk 1984, Rogers-Jourdane and Nakamura 1984, Kennedy 1990, Major 1992b and Davidson et al. 1991).⁹ However, it is plausible that inland Kapoho (as well as other inland areas) saw increasing use through time as higher population density, soil depletion and/or volcanic reduction in planting space forced concomitant increases in production further from the coast. It is likely that by the late prehistoric period agricultural soils --particularly older 'a'ā flows-- were widely used for agricultural purposes throughout the Kapoho GRS. A few inland settlements, logistically linked to the coast, may also have developed. It is no accident that this subzone is in heavy agricultural use today. It is unreasonable not to expect its productive capacity to have been recognized and exploited in the past --given sufficient need to do so.

Moving southwest, it is likely that at least the southern rift slopes of the Kamā'ili and Kīlauea subzones also were used for agricultural purposes, though perhaps with less intensity and later in time than the Kapoho area. Southwest of Kamā'ili settlement, the progressively drier coastline obliged residents to integrate coastal resources with agricultural commodities, at least some of which, required planting higher on inland slopes. The following passage from Handy and Handy (1972:541) illustrates the changing leeward pattern (see place names on Figure 7):

Taro was still, in 1935, grown on homesteads in 'Opihikao and Kamā'ili and beyond them in *upper* Kaimū, Makena, and Kalapana, *as far as the forested slopes* behind the village

⁹These and other archeological inventories in the general study area are summarized on Figure 9 and Table 2 in the *Cultural Background* section of this report.

of Kapa'ahu. One energetic Hawaiian of Kapa'ahu had cleared 'ohi'a forest, at a place called Kaho'onoho about 2.5 miles inland, and had a good stand of taro, bananas, and sugar cane in two adjacent clearings. According to this planter, there used to be some planting in the forest southwest of Kapa'ahu, *but the coast is too dry*. However, the whole forest land northeast of Kapa'ahu, with the exception of sections destroyed by lava flows, is capable of supporting taro and used to be covered with plantations. [*emphases added*]

Assuming agricultural exploitation of inland terrain was carried out primarily for the benefit of coastal communities, it is reasonable to expect a more diversified and spatially segregated pattern in agricultural production in areas southwest of Kamā'ili or perhaps Kaimū. Plants adapted to dryland conditions, such as sweet potato 'uala (*Ipomoea batatas*), should have been emphasized in the lowlands, while taro, banana and other more drought sensitive crops were grown farther inland as indicated above. Because of the greater overall labor investment, and because the most important xeric plant --sweet potato-- probably was not introduced until later in the prehistoric period, it is reasonable to expect sustained use of this area to post-date that of the more equable Kapoho area (a place requiring lower investment to integrate marine and terrestrial resources). It is also reasonable to expect overall use intensity of the leeward slope, as reflected in settlement and feature density, to be lower than better watered eastern Puna.

Whenever initiated, permanent residential use of the drier leeward coast should have involved farming of inland terrain from the outset. Early maps of the area (Cook 1902) show land grants and trails in old volcanic *kīpuka* at the southern margin of the Kīlauea subzone and in the south central portion of the Kamā'ili subzone. Given relatively high population density during the late prehistoric period, it is reasonable to expect regular inland agricultural activity to have extended at least to the southeastern slopes of the rift zone (i.e., to the southern margin of the upper two geothermal subzones). Accordingly, it is plausible that older flows southeast (downslope) of the East Rift Zone were farmed and linked to coastal settlements via a network of upslope/downslope trails during mid to late prehistoric times. Because of increasing distance, cloud cover and presence of substantial volcanic obstacles (e.g., volcanic cracks), terrain north of the rift in Kīlauea and Kamā'ili subzones is less likely to have been the primary focus of agricultural or settlement activity. Deeper inland use, rather, was more likely to have been associated with short-term exploitation of forest floral and faunal resources, cross-country travel between Hilo Bay and points west, travel way-stations, emergency crop areas, and refuge and ceremonial places. On strictly environmental grounds then, we would expect the density of prehistoric residential and agricultural features to decrease with increasing distance (and elevation) from the coastline; particularly in these subzones. As elevation increases, leeward agricultural features should first become more prevalent, then decrease sharply as the benefits of more predictable rainfall are overcome by the liabilities of decreasing temperature and lengthening transportation lines. These issues are addressed further below.

Historic period land-use practices were less tightly constrained to the coast. Horse, rail and eventually truck transport made exploitation of the inland terrain easier and more economically viable. Sugar and coffee, for example, could be produced on the wet mid-elevation lands around Pāhoa, processed and shipped to Hilo Bay for distribution to markets elsewhere. 'Ōhi'a forests could be cut for lumber and fuel while simultaneously clearing additional plantation land. For modeling purposes, however, our prime focus must be on the prehistoric archaeological record. Not only does it represent the longest fraction of the record, it is the least accessible by other information sources (i.e., we cannot use documents to pinpoint more distant prehistoric land-use areas). Accordingly, the emphasis above, and throughout this research design, is geared primarily (though not exclusively) toward the prehistoric archaeological record. This is not meant to imply that the historic record is uninteresting or unimportant, it simply reflects the greater need for modeling methods to clarify the prehistoric past.

A Land-Use Model for the East Rift Zone

Elements of a Puna land-use model have been developed above. Basic variables influencing the character and distribution of prehistoric archaeological features over the landscape can be summarized and illustrated in a four-part preliminary land-use model for the general study area. The structure developed here is intended to expand and build on basic environmental elements of McEldowney's (1979) earlier model, in a manner accommodates particular characteristics of Kilauea's East Rift zone, including the region's windward to leeward declining rainfall pattern, slope characteristics and volcanic activity. It divides southeastern Puna District into land-use zones in which we may anticipate patterned variation in the character, relative density and (perhaps) temporal range of archaeological remains.

The reader is reminded that models necessarily simplify reality to clarify underlying patterns that we believe have genuine, testable validity. There is little doubt that settlement patterns described above and formalized below are more complex than can be fully accommodated by reference to fishery and agricultural productivity, transportation distance, volcanism and population density. For example, it is possible that Puna fishery production was more variable than anticipated here, thereby distorting settlement toward fewer coastal locations. It is possible, too, that repeated volcanic disruption of planting areas intensified inland agriculture within remnant *kīpuka* and/or generated more features on young flows than would be expected if arable land were not so constrained (McEldowney pers. comm.). This same volcanic activity may have caused boundaries between land-use zones --always imprecisely defined and subject to change through time-- to be more irregular than anticipated for more stable areas. There also may have been variation in the rate at which soil depletion caused temporary field abandonment under different sediment and rainfall regimes. Additional complicating variables should be expected.

Such complicating factors notwithstanding, I suggest that basic environmental requirements of sustained human settlement in Puna caused differential use of inland and coastal terrain in a pattern approximating that offered here. Constant importance of coastal resources and efficacy of sea-borne transportation placed a premium on near-water settlement. Elevation related losses in agricultural production and the inefficiency of lengthy overland travel favored maintenance of critical field systems as near these coastal areas as possible. Throughout the prehistoric period, inland areas should have provided *primarily* agricultural and foraging support to coastal communities. The probability that the formal arrangement of communities and field areas below the rift periodically changed, does not alter these basic constraints (i.e., people *required* marine resources and *could not* effectively farm places that were too cloudy and cool). Accordingly, I maintain that an upslope/downslope partitioning of land-use areas that recognizes the variable windward/leeward agricultural potential described above provides a reasonable model of long-term Puna land-use patterns; it does so despite the unpredictable character of volcanic activity, variation in precise settlement location along the coast, and the possible effects of field movement due to soil depletion.

The basic land-use pattern proposed here is illustrated on Figure 8. Within the general zone structure it should be assumed that oldest, most completely weathered sediments would have been the most intensively used and (assuming site visibility) would preserve the highest density of archaeological remains resulting from that use. Coastal settlements were not evenly distributed along the coast, but rather tended to be clustered around embayments where fishery access and agricultural potential better supported aggregated populations. In addition, certain features such as lava tube caves, trails and burials respond to geological, transportation and social variables not included in the model. Nonetheless, the land-use zones offered here provide a framework through which we can examine the relationship between environmental, land-use, and archaeological relative density expectations. The model should be taken as a starting point to be refined further during verification survey and beyond.

1) Coastal Settlement Zone

The Coastal Zone is essentially the same as that offered by McEldowney (1979:15-18). As with her model, it includes coastal terrain to about one half mile inland. This is the zone expected to have the greatest density and variety of prehistoric surface features in the general study area. Primary settlements are expected in places where agriculturally productive sediments (principally well-weathered 'a'ā flows) co-occur with sheltered embayments and productive fisheries. Settlements within this zone are expected to be logistically linked to inland agricultural and forest exploitation zones accessed through a network of upslope-downslope (*Mauka-makai*) trails. Larger settlements and resource acquisition areas may have been connected by cross-terrain trail networks.

For the present, the model does not distinguish windward from leeward settlement locations. By virtue of enhanced agricultural potential in near coastal context (see Windward Agricultural Zones below) it is possible that windward locations may have been occupied somewhat earlier than their leeward counterparts southwest of Kaimū. Alternatively, it is possible that leeward fisheries were sufficiently productive to offset the additional labor investment involved with farming on the dryer side. The possibility of temporal and logistic distinctions between windward and leeward coastal settlements should be investigated further as research continues.

2) Windward Agricultural Zone

The Windward Zone includes coastal and adjacent inland terrain beginning at ca. Kaimū northeast to Cape Kumukahi then northwest to Hilo Bay and beyond. Throughout the prehistoric period, rainfall is assumed to have been sufficient to support the full range of Hawaiian subsistence crops. In general, this area should have been the earliest and most heavily used of the inland resource zones modeled here. It should also retain the highest density of agricultural and agriculturally associated features in the general study area. Feature density should be particularly high on older flows where sediment characteristics maximize agricultural productivity. At present, the zone is divided into two subzones, based on proximity to coastal settlements. General land-use intensity is expected to decrease from subzone *a* to *b*, largely as a function of distance and related increase in logistical cost for effective integration with coastal settlements.

a. **Windward Coastal Margin:** The seaward portion of the zone includes land adjacent to the coastline and inland terrain to 200 ft elevation or circa 1 to 1.5 mile inland. Along the coast, initial settlement and inland agricultural use *may* have been directed to this area. Because of enhanced agricultural potential, maximum population and feature density is expected on the coast, with correspondingly high agriculturally related feature density for the coastal margin. As always, particularly high feature density should be expected on older, well weathered flows.

b. **Windward Inland Terrain:** The inland portion of the zone includes low to moderate elevation landforms (circa 200 to 700 ft) extending to approximately five miles inland from the coast. Because of relatively easy access and reliable rainfall, this zone is expected to have been linked to the coast, providing agricultural support throughout the prehistoric period. Land-use intensity should have increased as volcanic destruction of arable ground and/or late prehistoric population demands increased pressure to exploit available agricultural land. Agricultural feature density should be moderate and decrease with distance to the coast.

3) Leeward Agricultural Zone

South and west of Kamā'ili/Kaimū, the coastline becomes increasingly arid. Less reliable rainfall in near coastal contexts favors development of a stratified agricultural system with moisture sensitive crops grown on better watered upland slopes. Through time, agricultural land-use practices are expected to have been extended farther inland to natural limits imposed by volcanic hazards and decreasing

Figure 8. Modeled Land-Use Zones in the Puna Geothermal Project Area

redistribution efficiency. For the present, the lower margin of the Kīlauea East Rift Zone is a plausible bounding feature.

a. **Leeward Coastal Margin:** The seaward portion of the zone includes the terrain adjacent to the coastline to approximately three miles inland (ca. 1100 ft). Inland landforms at this elevation have sufficient rainfall to support wet adapted crops such as taro, and their use is consistent with historical land-use accounts. Initial use is expected to have been associated with coastal settlement. Use may post-date settlement and use of Windward Coastal Settlement and Agricultural Zones. Agricultural practices should have been associated with greater spatial separation between dry and wet adapted crops from the outset. The density of agricultural and agriculturally related features is expected to be moderate in places with agriculturally suitable sediments.

b. **Leeward Inland Terrain:** Leeward inland agricultural terrain is estimated to extend from circa 1100 ft to the lower margin of the East Rift Zone. Expansion into this zone is expected to be relatively late and of moderate to low intensity. Feature density is expected to be moderate to low. Agricultural use is expected to be biased toward oldest, most thoroughly weathered flows. Given adequate rainfall, structural features may not be a necessary part of agricultural production in these *kīpuka*. On younger, less decomposed flows, it may have been necessary to clear planting areas, or build planting mounds and terraces to develop satisfactory planting media.

4) Upland Forest Exploitation Zone

The farthest inland zone includes terrain lying inland from the East Rift on its southwestern margin and circa five miles from the coastline on the northeast. The zone is expected to have been exploited on a short-term, task-specific basis; primarily for upland game, low investment agriculture, overland travel, and ceremonial and refuge uses. Because of distance to the coast and access difficulties, agriculture is expected to be limited to inland travel and emergency support. Exploitable Upland Forest resources include *māmaki* (*Pipturus* sp.) for barkcloth, *olonā* (*Touchardia latifolia*) for cordage, 'ie'ie (*Freycinetia arborea*) for baskets, 'ohi'a lehua (*Metrosideros polymorpha*), edible ferns such as *pala* (*Marattia douglasii*) and *hāpu'u* (*cibotium* spp.), and upland birds such as 'amakihi (*Hemignathus virens*), 'elepaio (*Chasiempis sandwichensis*), *mamo* (*Drepanis pacifica*), 'o'o (*Moho braccatus*) and 'i'iwi (*Vestiaria coccinea*) for feathers (see McEldowney 1979:26-29).

Limited use of the Upland Forest Exploitation Zone may be anticipated early in the archaeological record, and should have increased somewhat through time as a function of increasing population density dependant demands on available resources, high status commodities, back-up food supplies and refuge. In general, however, use should have remained low relative to the coastal and inland agricultural zones outlined above. Archaeological surface features should reflect short-term low intensity use --i.e., simple, in very low numbers, and difficult to recognize given heavy vegetation and rough terrain that characterize the inland East Rift Zone today. Trails to and between coastal settlements will be equally difficult to discern. Lava tube cave openings probably served as temporary shelters and refuges, and may represent the most readily recognizable prehistoric features in the Upland Forest Zone.

* * * *

In sum, throughout Puna District we can expect the most intense occupation to have been directed toward the coast, particularly during the prehistoric and early historic past. Because precipitation is more reliable, earliest and most intensive occupation should have been directed toward the District's eastern margin from about Kaimū, around Kumukahi Point toward Hilo Bay. Agricultural use of the Kapoho

subzone is expected to have increased through time, largely as a result of demands imposed by increasing population density. Southwest of Kaimū, drier conditions are likely to have caused a more stratified agricultural system with precipitation-sensitive crops grown farther inland. Here we anticipate coastal settlements possibly initiated somewhat later in time and linked to inland farmed fields from the start. Through time, land-use intensity should have increased here as well, eventually extending into at least the downslope flank of the East Rift Zone in the Kamā'ili and Kīlauea geothermal subzones. Use of the upper margins of these zones is likely to have been restricted largely to low investment fields serving to guard against unexpected short-falls in primary fields, hunting and collecting areas, overland trail routes and way stations, burial and other ceremonial grounds (surface and lava tubes, and hiding places particularly in lava tube caves). Within the subzones (and elsewhere), the highest density of agricultural features should be located on older, more weathered flows --particularly 'a'ā. Lava tube caves will be in tube-fed pāhoehoe flows. Trails should extend inland from established coastal settlements and overland between Hilo Bay and Kīlauea.¹⁰

Survey strategy designed to examine these patterns should be structured to investigate the oldest flows available in all subzones. Efforts should be made to stratify sample survey units within all three modeled zones in a manner, and with a sufficiently large sample size, that will facilitate meaningful refinement or rejection of the model's land-use implications. Efforts should be made, too, to record feature density on 'a'ā versus pāhoehoe substrate. While not emphasized in the model, lava tube caves are particularly important cultural properties. Caves should be sought with particular attention directed toward tube-fed flows in all zones. Photograph and helicopter survey are useful in tentatively establishing the route of subterranean tubes by noting vegetational anomalies along cave roofs and at sink holes. Cooperation of local residents should be sought to help locate features of any sort.

In closing the environmental/land-use discussion, it should be noted that certain qualities of the rift zone environment affect both site integrity and our ability to find archaeological localities even if intact. Obviously the primary natural mechanism responsible for the loss of archeological sites is simply inundation by volcanic flows. Flow data shown on Figure 5 were developed, in part, to help establish a maximum age that can be expected for archaeological features. Dense near-ground vegetation -- particularly *uluhe* (*Dicranopteris linearis*) and grasses common to the survey area not only physically impede survey, but make cultural features extremely difficult to locate as well. It is important that final survey procedures be designed to accommodate flow ages, and be provided sufficient time to expose and identify the features that remain.

¹⁰As a practical matter, prehistoric trails will be extremely difficult to locate under current conditions. Early historical records perhaps provide our best source of information on trail networks, many of which probably have continuity with the more distant past (see Cook 1902).

CULTURAL BACKGROUND

PREVIOUS ARCHAEOLOGY

Archaeological surveys and excavations have been conducted sporadically in Puna District since the early 1900s. Most early studies were funded by the B.P. Bishop Museum and oriented toward documenting larger, more structurally complex features, usually in near-shore context. At about mid-century, archaeological work turned to more serious consideration of archaeology as a means to develop a better understanding of past Hawaiian culture. Studies, however, remained infrequent and continued to be oriented toward larger, more vicariously rewarding site types (e.g., caves, *heiau*, residential complexes, fish ponds).

Following passage of the National Environmental Policy Act (NEPA) and associated executive orders in the 1970s, government and most private concerns were legally required to consider the impact of development on the populace and on certain aspects of the local environment --including damage to significant prehistoric and historic properties. The quantity of archaeological research increased dramatically as development firms endeavored first to meet NEPA requirements, then increasingly stringent state and county cultural resource regulations. Currently, the vast bulk of archaeological research in the United States and its territories is conducted on a contracted basis.

The requirements and funding base driving modern contract archaeology not only has increased the quantity of work undertaken, but has changed the character and popular view of archaeological research as well. Cultural resource regulations typically require inventory of *all* prehistoric and historic remains within specified project boundaries, and protection of properties judged to be of significant research or heritage value to the United States and/or Hawai'i. Largely because of this spatial focus, increased attention has been paid to documentation (if not protection) of a wide range of archaeological remains within development boundaries, rather than to more limited classes of structurally impressive features. While variable in content, contracted reports have tended to include more complete descriptive documentation of archaeological remains, but do so within more narrowly defined project boundaries. Time and budget constraints induced by project schedules and a cost-competitive consulting environment has contributed to a tendency for simple description of survey and data recovery results rather than more time-consuming (and costly) analyses and research syntheses. While archaeology has remained popular with the general public, some Hawaiians have come to associate archaeological research with the destruction of cultural remains that often follows. In Hawai'i, recent efforts to involve local communities (such as those involved with the geothermal environmental study) will hopefully improve awareness of archaeology's potential to enhance understanding of Hawaiian heritage issues and general human cultural processes in a manner more in line with what the regulations were intended to promote in the first place. Finally, growing concern by reviewing agencies (principally the Hawai'i SHPD) with heritage and more encompassing research issues has helped to stimulate a shift toward more broadly based interpretive approaches to archaeological data.

Archaeological projects and reports of direct concern to Puna District and the three geothermal subzones have reflected the basic pattern outlined above. Hammatt, writing in the 1989 geothermal environmental statement (DBED 1989:VI14), provides a general introduction.

Archaeological research, concerning Puna in general, was first initiated in the early 1900s. These early investigations (Stokes, 1919, Thrum, 1907a) were almost exclusively concerned with major stone structures (i.e. *heiau*). In the 1930s A.E. Hudson conducted a more comprehensive archaeological survey which involved mostly coastal areas from Waipi'o

Valley (Hamakua) to Punalu'u (Ka'u). In the 40s and 50s K.P. Emory and other Bishop Museum staff members conducted surveys in two different Puna locations. Emory, in 1945 conducted an exploration of "Shipman's Cave" in Keaau, Puna. In 1959 the Bishop Museum did research on the "Kala-pana Extension of Hawai'i Volcanoes National Park" which included a section of the "Political History of Puna" by Dorothy Barrere. The 1960s through 1980s saw the advent of contract archaeology which has produced numerous reports concerning the Puna area.

Specific projects reflect the changing character of research interest and contract requirements. Figure 9 shows the location of projects in the general geothermal development area. Table 2 summarizes extant archaeological work relevant to Puna District. It classifies projects by date, director/report author, research type, and several aspects of project results. Note that in the category "Project Type," *Reconnaissance* refers to a simple pedestrian inspection of an area designed simply to discover and superficially record archeological remains present within a specified project area (cf. Haun et al. 1985:1). The term *Inventory w/out Test* denotes more systematic coverage with more detailed site documentation, but lacking sufficient detail to evaluate site significance. *Inventory with Test* includes the above plus testing efforts sufficient to make functional and/or significance recommendations (i.e., conforms to Hawai'i SHPD standards for "Inventory Survey"). An *Overview* is a general synopsis of local archaeology, generally based on literature review. *Data Recovery* refers to archaeological site excavation. Summary discussion of the manner in which results of these efforts relate to our understanding of the archaeological record of the area follows below. Interested readers are encouraged to consult the original reports for more thorough descriptive detail.

In a very general sense, information from combined archaeological studies in Puna District are consistent with land-use patterns as modeled here. The most detailed of these studies relate to coastal settlement and to the Kapoho GRS (see citations on page 22, this document). Surface surveys further inland in Kamā'li and Kīlauea GRS are quite limited in scale but, with the exception of mound features on the flanks of Heiheiāhulu (Kīlauea Subzone --see Haun et al. 1985), are consistent in their failure to identify prehistoric archaeological remains. Aside from clear settlement clustering in near-coastal context, then, extant data are too limited to relate to site density expectations in other than a cursory fashion. For the geothermal project area, perhaps the most instructive observation is the general paucity of recorded prehistoric remains other than caves and trails in the upper Kīlauea and Kamā'ili subzones. Here (essentially the Upland Forest Exploitation Zone), we anticipate a low density of low-investment cultural features. As expected, too, density of recorded materials increases in the lower subzones --particularly Kapoho (in the two Windward Agricultural Zones). While this general pattern is consistent with modeled expectations, it is important to emphasize that extant data do not constitute an adequate test. The model should be refined further as results of the continuing verification survey and other projects become available.

Figure 9. Previous Archaeological Research in the Project Area

Table 2. Puna District Archaeological Projects

Date	Director/Author	Project Type & Coverage	Project Location	Model Zone	Results
1906	Stokes, J.F.G. (in Stokes 1991)	Reconnaissance of religious structures of Hawai'i Island	N/A	N/A	Summary descriptions of known <i>heiau</i> . Includes coastal and Kūki'i Heiau in Puna District.
1909	Thrum, T.G.	Special: description of Kūki'i Heiau	Kapoho Subzone (SE) Kula Ahupua'a	1: Coastal Settlement (windward)	Surface Features; <i>heiau</i> on hillside bench
1932	Hudson, A.E.	Reconnaissance: general archaeology of East Hawai'i	Coastal and adjacent inland terrain	N/A	Summary descriptions of known large features on eastern, coastal Hawai'i
1945	Emory, K.P.	Reconnaissance: Shipman Lava Tube Cave	North of Project Area Kea'au near coastline	2a: Windward Margin 2b: Windward Inland	Lava Tube Cave (refuge); multiple features; charcoal & faunal remains; burials; also see Yent (1983), McEldowney & Stone (1991)
1959	Emory et al.	Reconnaissance Overview of Kalapana extension Hawaii Volcanoes National Park	Southwest of Kīlauea Subzone near the coastline and inland	1: Coastal Settlement 3a: Leeward Margin 3b: Leeward Inland	Overview and historical documentation; see esp. Barrère's Political History of Puna and the Botanical Survey
1963	Soehren, L.J.	Reconnaissance: Kahuwai Village	Northeast of Kapoho Subzone Coastal Kahuwai Ahupua'a	1: Coastal Settlement (windward)	Field notebook; not reviewed
1965	Ladd, E.J.	Data Recovery: Chain-of-Craters Rd. Volcanos N.P.	West of Kīlauea Subzone	1: Coastal Settlement (leeward)	Surface Features; misc. residential & burial; Lapakahia area
1965	Smart, C.	Overview, Hawai'i Volcanos Nat Park, Kalapana Extension	West of Kīlauea Subzone	N/A	Not reviewed
1967	Hansen, V.	Reconnaissance-Overview: Coastal Puna District	Puna District near the coastline	1: Coastal Settlement	List of documented Puna Dist. archaeological sites (see Hansen 1968)
1967	Orr, J.	Reconnaissance & Data Recovery: Kahuwai Village	Northeast of Kapoho Subzone Coastal Kahuwai Ahupua'a	1: Coastal Settlement (windward)	Unpub. feature descriptions; sketch map
1968	Hansen, V.	Reconnaissance: Field Notes Coastal Puna District	Puna District near the coastline	1: Coastal Settlement	Unpub. field notes; basic background on coastal features (see Hansen 1967)

Date	Director/Author	Project Type & Coverage	Project Location	Model Zone	Results
1970	Loo & Bonk	Overview: N Hawai'i with background to Puna Dist	N/A	N/A	Overview of with background to Puna; emphasizes <i>heiau</i> & ponds
1971	Barrera and Barrère	Reconnaissance: Kupahua, Puna	Coastal Margin South of Kīlauea Subzone	1: Coastal Settlement (leeward)	Surface Features; multi. residential & misc. south of Hakuma Point
1971	Crozier and Barrère	Reconnaissance: Pu'ala'a, Puna	Southeast of Kapoho Subzone Pu'ala'a Subzone	1: Coastal Settlement & 2a: Windward Margin	Surface Features; multi. residential and agr. features near Kalaea Bay
1972	Bevacqua & Dye	Reconnaissance: Kapoho to Kalapana Highway	Coastal Margin Southeast of the Project Area	1: Coastal Settlement (windward & leeward) 2a: Windward Margin	Surface Features; multiple residential, ceremonial, agricultural in coastal context
1973	Barrera, W.M.	Reconnaissance: Portion of Puala'a	South of Kapoho Subzone Puala'a Ahupua'a	1a: Coastal Settlement	Surface Features; ca. 1000 mounds, platforms, terraces & ceremonial features
1973	Kikuchi, W.K.	Overview: Aquaculture	N/A	1: Coastal Settlement	Partial list of Puna Fishponds
1974	Ching et al.	Reconnaissance: Kai-mū area County Beach Park - 18 acres	Southwest of Kīlauea Subzone Kaimū-Makena Homesteads	1: Coastal Settlement (leeward)	Surface Features; multiple residential, agricultural and ceremonial near the coast
1974	Ewart & Luscomb	Reconnaissance: 16 mi road corridor near NE Puna Coast	Kapoho Subzone and North Multiple Ahupua'a	1: Coastal Settlement (windward)	Surface Features; multiple agricultural, residential, ceremonial features; 118 site designations; most north of Kapoho Subzone
1977	Bordner, R.M.	Reconnaissance: Radar Station, ca. 200 x 200 sq ft	North of Kamā'ili Subzone Maku'u Ahupua'a near Pāhoa	2b: Windward Inland	Surface Feature; one stone cairn
1977	Cordy, R.	Reconnaissance: Pohoiki Bay	Southeast of Kapoho Subzone Coastal Pohoiki Ahupua'a	1: Coastal Settlement (windward)	No cultural Materials at boat ramp (see Bevacqua & Dye 1972) for larger area
1977	Palama & Bordner	Reconnaissance: Kaimū-Kalapana Beach extension	Southwest of Kīlauea Subzone Kaimū & Kalapana Ahupua'a	1: Coastal Settlement (leeward)	Surface Features; multiple residential, agricultural and ceremonial near the coast
1979	Fed. Highway Admin.	Inventory w/out Test: Pāhoa bypass corridor	North of Kamā'ili Subzone Waiakahiula 2 Ahupua'a	2b: Windward Inland, transition to 4: Upland Forest	Summary description of Pāhoa town buildings; map
1979	McEldowney	Overview & Research Design	South Hilo & Puna Districts	N/A	General prehistoric and historic overview and land-use model for the Hilo area, Hawai'i Is.

Date	Director/Author	Project Type & Coverage	Project Location	Model Zone	Results
1980a	Bonk, W.J.	Reconnaissance: 6 geothermal well pads	Kapoho Subzone (SW) Keahialaka Ahupua'a	2b: Windward Inland	Lava Tube Cave sinkhole (not investigated)
1980b	Bonk, W.J.	Reconnaissance: (as above)		2b: Windward Inland	(see Bonk 1980a)
1981	Ladd, E.J.	Reconnaissance: Lighthouse area of Cape Kumukahi	Kapoho Subzone Cape Kumukahi point	1: Coastal Settlement (windward)	Surface Features; 1 platform & 2 cairns; extensive volcanic & mechanical disturbance
1982	Holmes, T. (in TRUE 1982: Appendix A)	Overview: Kahauale'a geothermal project	West of Kīlauea Subzone Kahauale'a Ahupua'a	N/A	Brief overview emphasizing trails and upland planting areas; notes a <i>heiau</i> 2 mi below Kalaua Crater (see map in Hommon 1982)
1982	Hommon, R.	Inventory w/out Test: 5 acre well pad and 8.75 mi access corridor	West of Kīlauea Subzone Kahauale'a Ahupua'a	4: Upland Forest 3b: Leeward Inland	No Cultural Remains; planting areas, trails & surface features reported by historic sources only (also see Holmes 1982)
1982	Kennedy, J.	Overview: Kahaualea, Puna	West of Kīlauea Subzone Kahaualea Ahupua'a	4: Upland Forest	Not reviewed
1982	Yent & Ota	Reconnaissance: Nanawale Forest Reserve	North of Kapoho Subzone Halepua'a Ahupua'a	2a: Windward Margin 2b: Windward Inland	Surface Features; enclosures, mounds & walls; low density; in Coastal Margin Zone
1983	Yent, M.	Inventory w/out Test: Pāhoa Lava Tube Cave	North of Project Area near Pāhoa, 4.5 mi inland Maku'u Halona Ahupua'a	4: Upland Forest	Lava Tube Cave; three recorded sections; multiple entrances & features; charcoal & faunal remains; burials; see McEldowney & Stone (1991)
1983a	Cox, D.	Reconnaissance: Small Craft Navigation Improvmt Project	Southeast of Kapoho Subzone Halekamahina 2 Ahupua'a	1: Coastal Settlement (windward)	Surface Features; 36 platforms & misc. features in 8 clusters; burials
1983b	Cox, D.	Reconnaissance: Small Craft Navigation Improvmnt Project	Southeast of Kapoho Subzone Halekamahina 2 Ahupua'a	1: Coastal Settlement (windward)	(see Cox 1983a)
1984	Bonk, W.J.	Reconnaissance: 75 acres	Kapoho Crater area (NE) Kapoho & Kula Ahupua'a	2a: Windward Margin	No cultural remains observed (1.5 person/day total survey time ..results suspect)

Date	Director/Author	Project Type & Coverage	Project Location	Model Zone	Results
1984	Olson, L.G.	Reconnaissance: Kapo Kohe Lele-Flying Vagina-Kasumura Lava Tube Cave	North of project area Waikahekahe Nui Ahupua'a (14 mi investigated)	2a: Windward Margin 2b: Windward Inland	Lava Tube Cave; Flying Vagina feature, 14 mi length; multi features; burials; <i>heiau</i> ; charcoal & fauna; see Franklin et al. (1991:7-9)
1984	Rogers-Jourdane & Nakamura	Reconnaissance: 12 acres, potential geothermal well sites	Kapoho Subzone (SW) Kapoho Ahupua'a	2b: Windward Inland	No Cultural Remains; 5 recorded sites for Kapoho; archaeological and historical overview (see Kennedy 1990)
1985	Haun et al.	Reconnaissance: 5 transects ca. 6.9 mi total length	Kīlauea Subzone (NE corner, SE near Heiheiāhulu, and S of the Project area)	3b: Leeward Inland 4: Upland Forest	Five to six cairns and mounds on the SE side of Heiheiāhulu Crater (Zone 2b); possible burial; observed banana in S Kīlauea subzone
1985	Holmes, T.	Overview: Puna Forest Reserve	Kīlauea Subzone Wao Kele 'o Puna	3b: Leeward Inland 4: Upland Forest	Thorough historic overview emphasizing widely scattered agricultural sites & related habitations, trails, birding stations; see maps
1985	Rosendahl	Reconnaissance	South of Kīlauea Subzone	3b: Leeward Inland	Not reviewed (see Haun et al. 1985)
1987	Komori, E.K.	Inventory w/out Test: series of linear transects	North of Kapoho Subzone (crosses 12 Ahupua'a)	2b: Windward Inland & transition to 4: Upland Agriculture	Surface and Lava Tube Features; 11 single feature prehistoric & 3 historic sites; terraces, platforms, lava tube sinks & caves, burials, petroglyphs; rail berm, foundation, estate land
1988	Bonk, W.J.	Reconnaissance: well pad & road	Kīlauea Subzone (ECent) Wao Kele 'o Puna	4: Upland Forest	No cultural remains
1989	Cordy, R.	Inventory w/out Test: Kahuwai Village	Northeast of Kapoho Subzone Coastal Kahuwai Ahupua'a	1: Coastal Settlement (windward)	Surface Features; heavily distributed in mixed forest around Kapela Bay
1989	Hammatt, H. (in DBED 1989)	Overview: Puna geothermal development project area	Puna Geothermal Project Area	N/A	General archaeological overview of the geothermal development area; no fieldwork
1989a	Bonk, W.J.	Reconnaissance: well pad	Kamā'ili Subzone (NW) Kaohe Homesteads	4: Upland Forest	No cultural remains
1989b	Bonk, W.J.	Reconnaissance: road (same as Bonk 1988)	Kīlauea Subzone (ECent) Wao Kele o Puna	4: Upland Forest	No cultural remains
1989c	Bonk, W.J.	Reconnaissance: same as above Bonk 1988)	Kīlauea Subzone (ECent) Wao Kele o Puna	4: Upland Forest	No cultural remains

Date	Director/Author	Project Type & Coverage	Project Location	Model Zone	Results
1990	Bonk, W.J.	Reconnaissance: 2 well pads and access roads	Kīlauea Subzone (ECent) Wao Kele o Puna	4: Upland Forest	No cultural remains
1990	Kennedy, J.	Inventory w/out Test: two geothermal well pads	Kapoho Subzone (SW) Kapoho Ahupua'a	2b: Windward Inland	No Cultural Remains (Rogers-Jourdane and Nakamura 1984)
1991	Davidson et al.	Inventory with Test: Pohoiki #1 Transmission Corridor	Kapoho Subzone and North Kahuwai Ahupua'a	2b: Windward Inland	Not reviewed
1991	Kennedy et al.	Inventory Survey: Coastal Development Parcel	South of Kapoho Subzone Ahalanui Laepao'o Oneloa Ahupua'a	1: Coastal Settlement (windward)	Surface & Cave Features; Multiple caves, platforms, mounds, enclosures and agricultural features; test returned limited residential debris
1991	McEldowney & Stone	Inventory w/out Test: Multiple Lava Tube Caves	Kīlauea Subzone (N) Mapped tubes north of project area; Puna Forest Reserve	4: Upland Forest	Lava Tube Caves; North, Middle & South Tubes; at least Middle Tube extends into Kīlauea Subzone; multiple features & entrances; refuge features; charcoal, flora & fauna; see Yent (1983)
1991a	Kennedy, J.	Inventory w/out Test: geothermal well pad & buffer	Kīlauea Subzone (ECent) Wao Kele 'o Puna	4: Upland Forest	No Cultural Remains; emphasized dense vegetation and geological hazards
1991b	Kennedy, J.	Inventory w/out Test: geothermal well pad	Kīlauea Subzone (NCent) Wao Kele 'o Puna	4: Upland Forest	Historic Features; logging railroad berm ca. 1910
1992	Franklin et al.	Inventory with Test: 200 acres	North of Project Area Waikahekahe Nui & Waikahekahe Ahupua'a	4: Upland Forest	Surface Features; 2 sites with 3 features: rock alignment & lava tube blister, agricultural terrace; poor ground visibility; very low feature density
1992a	Major, M.	Inventory with Test: Pohoiki #2 Transmission Corridor	Kapoho Subzone and North Kahuwai Ahupua'a	2b: Windward Inland	Lava Tube Cave and historic wall (see Major 1992b & 1993)
1992b	Major, M.	Inventory with Test: lava tube cave	North of Kapoho Subzone Kahuwai Ahupua'a	2b: Windward Inland	Lava Tube Cave; multiple chambers; multiple features; burials; historic period remains (see Major 1992a & 1992b)
1993	Major, M.	Inventory with Test: lava tube cave	North of Kapoho Subzone Kahuwai Ahupua'a	2b: Windward Inland	Lava Tube Cave; refinement of Major 1992b (also see Major 1992a)

Table 3 summarizes extant site information directly relevant to the three geothermal subzones. Figure 10 shows approximate site locations. Citations to Loebenstein (1895), Cook (1902), Ellis (1979), Holmes 1985 and DBED (1989) lack field confirmation.

Table 3. Cited Archaeological Site Localities in the Geothermal Resource Subzones

Site No.	Site Type	Geothermal Subzone	Land-Use Zone	Source
1	Lava Tube Cave	Kapoho	2a. Windward Coastal Margin	Loebenstein 1895
2-7492	Lyman Ranch & Grave	Kapoho	2a. Windward Coastal Margin	Hudson 1932
3-2501	Petroglyphs	Kapoho	2a. Windward Coastal Margin	Loo & Bonk 1970
4	Koae Hawaiian Village	Kapoho	2a. Windward Coastal Margin	DBED 1989
5-2500	Kūki'i Heiau	Kapoho	2a. Windward Inland	Stokes 1991
6	Spring -- <i>Kawai o Kekua</i>	Kapoho	2a. Windward Coastal Margin	Cook 1902
7-295	Unknown State site	Kapoho	2b. Windward Inland	DBED 1989
8	Small coffee plantation	Kapoho	2b. Windward Inland	Loebenstein 1895
9-5245	Hōlua Slide -- <i>Kahōlua o Kahawali</i>	Kapoho	2b. Windward Inland	Ellis 1972
10	Hōlua Slide	Kapoho	2b. Windward Inland	Hudson 1932
11	Lava tube sinkhole	Kapoho	2b. Windward Inland	Bonk 1980
12	Rycroft Coffee Plantation	Kapoho	2b. Windward Inland	Loebenstein 1895
13	Leioumi Hōlua Slide	Kapoho	2b. Windward Inland	Loebenstein 1895
14-110	Agricultural Complex	Kapoho	2b. Windward Inland	Hudson 1932
15	Wilkes Trail of 1840 (location not established)	Kīlauea & Kamā'ili	3b. Leeward Inland	Holmes 1985
16	Rock Cairns	Kīlauea	3b. Leeward Inland	Haun et al. 1985
17	Kaimū Trail	Kīlauea	3b. Leeward Inland	Loebenstein 1895
18	Forest planting areas	Kīlauea	3b. Leeward Inland	Loebenstein 1895
19	Lava Tube Cave	Kīlauea	3b. Leeward Inland	Burgett: pers com
20	Railroad grade	Kīlauea	4. Upland Forest	Kennedy 1991b
21- 14900	Middle Lava Tube Cave	Kīlauea	4. Upland Forest	McEldowney & Stone 1991
22- 14901 14902	Southern Lava Tube Cave (Lower Segment) (Upper Segment)	Kīlauea	4. Upland Forest	McEldowney & Stone 1991
23	Northern unnamed trail	Kīlauea	4. Upland Forest	Loebenstein 1895

Figure 10. Known Site Locations Puna Geothermal Project Area

PUNA --A BRIEF PREHISTORY OF TIME¹¹

Traditional Political and Cultural History

To this point, little systematic research has been done on long-term population dynamics or prehistoric land-use patterns for Puna District. Indeed, at least part of the intent of the present effort is to begin to look at the broader region in an integrated fashion. Extant culture histories are based largely on projections of early historical observation into the prehistoric past and on traditional legendary accounts. McEldowney's (1979) historical projections, while limited in scope, are useful for present purposes because they are linked directly to environmental land-use zones. Traditional histories most frequently rely heavily on the works of Fornander (1969 [1880]) and Kamakau (1961). Dorothy Barrère's *Political History of Puna* (1959) is perhaps the most complete compilation of traditional culture history related directly to Puna District. An excerpt of her work is presented below to provide an introduction to general events that may have characterized the District's position among its neighbors during the late prehistoric period.

We find that Puna, as a political unit, played an insignificant part in shaping the course of the history of Hawaii island. Unlike the other districts of Hawaii, no great family arose upon whose support one or another of the chiefs seeking power had to depend for his success. Puna lands were desirable, and were eagerly sought, but their control did not rest upon the conquering of Puna itself, but rather upon control of the adjacent districts, Ka-'u and Hilo. An attempt to follow in detail the course of Puna's history is meaningless, since her history is bound up with the fortunes of the ruling families on either side of her. Only such mileposts as were significant to the district itself are therefore given here.

Puna in the time of Liloa - circa 1475 A.D. [the *Intensification Period* below] - was one of the six district kingdoms of Hawaii whose chiefs were autonomous within their own districts, but who all acknowledged Liloa as their supreme chief. After Liloa's death, his son 'Umi killed Hakau, his half brother [and took control of Hamakua and, ultimately, the entire kingdom].

...Both writers [Fornander and Kamakau] note that Hua-'a was the chief of Puna during 'Umi's time and the account of his conquest as given by Kamakau is quoted here:

Hua-'a was the chief of Puna, but Puna was seized by 'Umi and his warrior adopted sons, Pi'i-mai-wa'a, 'Oma'o-kamau, and Ko'i. These were noted war leaders and counsellors during 'Umi's reign over the kingdom of Hawaii. Hua-'a was killed by Pi'i-mai-wa'a on the battlefield of Kuolo in Kea'au, and Puna became 'Umi-a-Liloa's (Dec. 1, 1870).

...Imaikalani is the first chief of Ka-'u mentioned as having had sway over "parts of Puna." Fornander credits him with a restoration of Waha'ula heiau (1880, p. 35), an indication of his supreme authority in at least that part of Puna. Our modern authority, Mary Kawena Pukui, herself a descendant of Ka-'u chiefs, notes that from time immemorial Ka-'u and Puna people have been closely connected by blood ties. ...

Imaikalani's son Kahalemilo and Hua-'a's son Lililehua are recorded as having been killed by 'Umi's son, Keawe-nui-a-'Umi, who gained control of the island in the

¹¹Apologies to Stephen W. Hawking (1988).

next generation (Fornander, 1916, p. 318). This seems to have extinguished both their lines as autonomous chiefs of Ka-'u and Puna. Hereafter we find Ka-'u being ruled by some member of the Kona chiefs' family, which stemmed from Keawe-nui-a-'Umi. All of Puna is linked with Ka-'u until the time of Keawe-i-kekahi-ali'i-o-ka-moku {of Hale o Keawe fame}, when we find that the I family of Hilo control "part of Puna" The other "part" ...was [probably] still linked with Ka-'u.

Puna seems then to have enjoyed a brief resurgence of at least semi-autonomous rule. Two generations after Keawe, in the time of Kalani'opu'u, I-maka-ko-loa, the only other Puna chief of note besides Imaikalani, becomes powerful. [This is in the *Competition Period* discussed below.] ...Abstracting from Fornander:

Imakakoloa, a great chief in the Puna district, and Nuuanu-paahu, a chief of Naalehu in the Kau district became the head and rallying-point of the discontented. The former resided on his lands in Puna, and openly resisted the orders of Kalaniopuu and his extravagant demands for contributions of all kinds of property....

...[Later] Kalaniopuu started with his chiefs and warriors for Hilo, in order to subdue the rebel chief of Puna... The rebel chieftain ...was finally overpowered and beaten. For upwards of a year he eluded capture, being secreted by the country-people of Puna. ...In the meanwhile Kalaniopuu moved from Hilo to the Kau district. ...Finally, exasperated at the delay, and the refuge given to the rebel chief by the Puna people, Kalaniopuu sent Puhili, one of his Kahus, to ravage the Puna district with fire... Commencing with the land of Apua, it was literally laid in ashes...

Soon after the death of Kalani'opu'u in 1782, Kiwala-'o, his eldest son and heir to the government, was killed at the battle of Moku'ohai. Then began ten years of civil war on Hawaii. The antagonists were Kamehameha cousin of Kiwala'o [Kona, Kohala and part of Hamakua], Kiwala'o's half-brother Keoua Kuahu'ula [lower Puna and Ka'u], and Kiwala-'o's uncle, Keawe-a-ma'u-hili [part of Hamakua, Hilo and upper Puna].

...The battles among these three chiefs culminated in the triumph of Kamehameha... The subsequent history of Puna is inseparable from the history of all Hawaii. (Barrère 1959:15-19)

Although conceived as tangential to environmentally based models, traditional and legendary accounts offer alternative means to understand the past. Since the model used in this research design directs attention to the *archaeological* record as a means of reconstructing Puna's past, traditional political and cultural history is complementary to the material record. The source of material-culture information interpreted in environmentally based models is less bound by informant memory biases and is amenable to refinement or rejection on empirical grounds¹². However, since it lacks in rich cultural detail, the potential loss of a portion of the archaeological record by geothermal development can affect a richer understanding of Puna's past.

¹²Archaeological and ethnographic approaches are not mutually exclusive. These comments should not be construed as denigrating the value of ethnohistoric data or informant interviews.

A Model of Changing Settlement Patterns

Land-use models offered earlier in this report have stressed environmental and economic variables underlying patterned distribution and density of cultural features across the landscape (i.e., cultural patterns expressed by variations in the archaeological record *across space*). Below, I offer the outline of a general temporal model for settlement of the Hawaiian archipelago with implications for Puna District (i.e., cultural patterns expressed by variations in the archeological record *through time*). The model is an abbreviated version of one presented in greater detail in the *Mauka Land* study of the Keauhou Bay area on Hawai'i Island's Kona Coast (Burtchard 1993). It builds on earlier approaches by Kirch (1985), Hommon (1986 and 1992), and Chun and Spriggs (1987). Because the primary focus of the present report is on spatial site distribution, and because temporal data presently are so limited, the temporal model is presented in summary fashion only. It is included to stimulate thought and argument relevant to Puna District archaeology. Efforts should be made to examine its predictions and refine it further as regional research progresses.

Colonization: ca. A.D. 300-600

Despite some uncertainty, it is likely that during the middle of the first millennium A.D., Polynesian voyagers reached the Hawaiian archipelago from points farther east and south --possibly the Marquesas Islands. The Hawaiian Islands were among the last places to be occupied in a punctuated stream of population movements spreading across the Pacific Basin during the last several thousand years. It is assumed here that these migrations were largely the result of increasing population density and/or environmental instability repeatedly causing acute competition for limited critical resources in bounded island environments. Such demographic/resource stress created social contexts selecting for some segments of the population to accept the risk and social dislocation inherent in long over-water moves and in colonizing new environments such as Hawai'i.

This model also assumes that, when forced to relocate, colonizing populations tend to minimize adaptive stress by locating in the most equable environments available in the new location. Given that colonists depended on combined exploitation of agricultural and marine resources, it is reasonable to expect *most* early island occupants to settle in windward coastal locations at places maximizing access to arable land, fresh water, and productive fisheries. During the Colonization Period, then, we should see the development of settled communities to be directed toward productive windward coastal zones over much of the Hawaiian archipelago. Except for areas of particularly productive fisheries, we should not expect to see substantial early occupation of drier leeward locations. In addition we should not anticipate use of elaborate irrigation or other food extraction technology, hostile competition, or indicators of elaborate social ranking or control mechanisms until competitive pressures were sufficiently acute to stimulate such behaviors on a general level.

Given these expectations, it is reasonable to expect to find limited evidence of very early use of Hilo and windward Puna and Kohala Districts (assuming reef and exploitable pelagic fisheries were sufficiently abundant to sustain a resident population). Because of its size, extensive inland plain and access to productive fisheries (eventually aquaculture as well), Hilo Bay may have been a particularly desirable place for early populations. Similar considerations may apply to coastal areas farther southeast near the study area as well, though smaller embayments, poorly developed offshore reefs and more limited agricultural ground may have made these areas somewhat less desirable in the face of ample unoccupied space elsewhere. Even so, given suitable access to marine resources, agriculturally productive areas between Kamā'ili and Kīpū Point may also have been settled early.

Very limited exposures of old sediments in near-coastal context remain in the study area. A small volcanic *kīpuka*, for example, preserves a sample of these sediments in the extreme northeast

corner of the Kapoho subzone. This area should be examined carefully during the verification survey for possible presence of early Hawaiian material culture. While lying just outside project boundaries, Kapoho Crater and the coastal bay north of Kapoho Point may also preserve old cultural remains. Arguably, the land becomes less desirable for colonizing populations farther southwest into the drier lee of Kilauea and Mauna Loa.

Unfortunately, there are no radiocarbon dates indicating very early use of the study area. Indeed, there are only two dates recorded for Puna District on file at Hawai'i State Historic Preservation Division offices (Komori 1993:pers. comm.). The dearth of information reflects a corresponding dearth of data recovery research in the District. The possibility of finding very early Hawaiian cultural remains continues, however. If such archaeological remains exist, they are probably limited in extent and overlain by centuries of reuse. Efforts should be made to search for such evidence as possible, and to be aware of its importance once found.

Early Expansion: ca. A.D. 600-1100

The model offered here assumes a constant tendency for increasing population density given sufficient ecological and/or technological elasticity to support increasing numbers. Accordingly, we must expect the area of occupied land to expand through time as populations search for unoccupied ground to support their increasing numbers. Whenever it occurred, however, we can expect early expansion to continue to be directed toward the most equable of the remaining unoccupied space. In general, this expansion should have emphasized other, perhaps somewhat less productive, areas in coastal locations throughout the island chain. Owing to generally higher overall terrestrial productivity, however, such early expansion should have continued to focus primarily on windward localities. Leeward areas, particularly on the younger high islands of Hawai'i and Maui, should have received more scattered, limited term or task-specific uses.

During the early expansion period, it is reasonable to expect agricultural settlement to have pushed into Puna's windward coastal settlement and coastal margin agricultural areas. Indeed, it is possible that Puna's volcanic activity restricted arable land causing resource and population density imbalances that pushed populations into more marginal areas at an earlier date than elsewhere. Even if early expansion avoided the rigors of East Rift Zone environment, it is likely that by the end of the period population levels were sufficient for remains to be detected in the archaeological record. Windward inland agricultural areas should have been used as well, but overall, use intensity should have remained relatively low.

As populations began filling the most desirable windward locations, settlements should also have pushed into less equable parts of the leeward coast. Coastal settlement should have been associated from the outset with a somewhat extensive agricultural system stretching upslope as necessary to reliably produce dry-land taro (ostensibly, more drought adapted sweet potatoes had yet to be introduced [Abbott 1992:29] and pond-field agriculture is impractical on porous East Rift Zone sediments).

By the end of the Early Expansion period, it is reasonable to expect most of the coastline in the general project area to have been inhabited within the general environmental constraints discussed here. Use of the inland areas should have been limited to that necessary to support the coastal settlements. That is, agricultural features related to this period should be relatively few in number and found in as close an association with coastal settlements as practical given the need to maintain a stable food supply in a somewhat changeable environment.

Late Expansion: ca. A.D. 1100-1400

Based on the gross number of radiocarbon dates associated with residential locations in other areas (Dye and Komori n.d.), population density throughout the islands appears to have increased dramatically between A.D. 1100 and A.D. 1400. Dated archaeological remains also attest to a substantial number of new settlements established in a still wider variety of environmental contexts. Most notably, settlement activity was increasingly directed toward drier leeward coastal areas and toward increased use of interior valleys on the wetter windward sides (see Chun and Spriggs 1987). These areas simply represented the best choices available as people continued to seek new land and ways to earn a living in a context of increasing competition for space and critical subsistence resources.

Assuming expansion was occurring essentially as indicated above, it is reasonable to expect both windward and leeward sections of Puna District (as well as Ka'ū farther into the lee of Mauna Loa), to have become fully settled. Communities should have expanded into places of greater difficulty and/or risk to extract essential marine and terrestrial resources. Use of inland agricultural zones should have increased. Accordingly, the density of agricultural and short-term residential features and access trails in inland contexts should increase markedly. Throughout the project area, we should see evidence of increased human activity. We may also begin to see the beginning of increasing social status differentiation (e.g., increasing ceremonial elaboration, evidence of more elaborate high-status residences, status markers in burial remains) as a reflection of increasing hierarchical control in the production, distribution and allocation of available resources.

Intensification: ca. A.D. 1400-1600

This period appears to have been one of dramatic changes in sociopolitical structure and in the distribution and character of archaeological remains throughout the archipelago. By the start of the period, Polynesians occupied most of the available windward and leeward coastal locations that combined moderate agricultural productivity with access to marine resources. In better watered places, agricultural features extended inland into the most productive of the windward valleys. With the most equable zones occupied, continuing resource pressure was met by increased use of heretofore marginal leeward slopes and other relatively less productive and/or unstable zones, and through more labor intensive use of previously occupied space. Accordingly, the period saw dramatic increase in the number and dispersal of agricultural and related residential features in a wide variety of environmental circumstances throughout the islands. Clearing of inland forests should have accelerated as a direct consequence of agricultural expansion. Resulting increases in erosional sediment loss, if any, should be linked to this and subsequent periods. On the coasts and in windward valleys, expansion of aquaculture and more elaborate irrigation practices would have served to increase overall subsistence yield at the expense of correspondingly higher labor and organizational demands. Indeed, the period name itself was given to account for the increasingly intensive use of the landscape required to support increasing numbers on now limited or marginal agricultural land.

During this period, Hawai'i Island witnessed rapid expansion in the number and complexity of agricultural and residential features on its leeward slopes, and plausibly into upper elevation landforms previously only marginally economically useful. In some places, sophisticated agricultural systems were developed to maximize yield by adjusting cropping patterns to elevation sensitive variation in effective moisture. In drier leeward areas, planting patterns emphasized drought tolerant staples at lower elevation and crops adapted to moister conditions upslope (Abbott [1992:29] suggests that available data cannot place sweet potato in Hawai'i earlier than A.D. 1465, and perhaps substantially later). Extensive terracing within the most suitable agricultural zone of this elevational gradient served to increase planting space and to enhance the moisture retention capacity of ground so modified.

Agricultural expansion to its productive limits implies considerably more than simply the elaboration of agricultural features and innovative use of marginal ground. Such changes are intricately bound with a shift to more complex forms of political and economic control as well. A geo-political correlate of the general shift in subsistence organization is the development of *ahupua'a* land units incorporating wedge-shaped political units running from island interiors to the coast. Plausibly, such units serve to maintain unified political control and co-operative alliances over the entire range of resources necessary to sustain the population so organized. Increased labor requirements, elevated population density, and competition may also have brought an end to the kin-based archaic *maka'ainana* system in favor of a more highly stratified division between commoners and politically powerful and wealthy elite (cf., Hommon 1986). Architecturally, the changes were associated with a proliferation of built features. While the majority of these were agricultural in nature --terraces, irrigation features, fish empondments and so on --Kirch (1985:306) argues that marked elaboration of *heiau* features reflects the increasing religious and political stratification that was becoming dominant in the islands.

Irrespective of the causes underlying social and architectural elaboration throughout the islands, the Intensification Period should have represented a time of substantial increase in human use of Puna and Hilo Districts. It is plausible that fishpond aquaculture was moved toward greater structural elaboration during this period as a result of increasing demand on food resources. The elaborate pond system in Kapoho Bay and once at Kalapana, for example, may have been part of a substantially more elaborate aquacultural system since inundated by subsequent lava flows (see Kikuchi 1973:35). It is reasonable to expect that a relatively dense population aggregation centered on Kapoho Bay would also be associated with agricultural, ceremonial and at least short-term residential elaboration for some distance inland. Accordingly, a substantial portion of the Kapoho subzone very likely received intensive use during the late prehistoric period (Kapoho Bay fishponds, Kapoho crater and the general project area can be seen in the frontispiece photograph on page ii). Intensive use of the subzone continues into the present as well in the form the mechanized agriculture. Unfortunately, associated terrain modification and repeated volcanism has destroyed much of Kapoho's archaeological record. It is important, then, that particular attention be paid to remaining intact landforms --particularly older *kīpuka* and crater floors. Efforts should be made, too, to investigate arable ground wherever it occurs in the project area, particularly in windward and leeward agricultural areas as shown on Figure 8.

Competition: ca. A.D. 1600-1778

Though there is room for argument, there is reason to believe that by the start of the 17th century population density throughout the islands was approaching elastic limits of the environment's ability to sustain it reliably (cf. Stannard 1989). It is plausible that further expansion into still more marginal agricultural terrain and continuing attempts to intensify production in established areas were meeting with sharply decreasing success. Dye and Komori's (n.d.) radiocarbon data suggest that population growth had ceased or even entered a period of decline by this time. The pattern is generally consistent with carrying capacity responses in non-human populations (see Boughey 1973:5-8) and indirectly lends support to the notion that resource limits had been reached that could not be significantly extended either through continuing social reorganization, more intensive cropping or in situ technological innovation. It is under these conditions, exacerbated by the inability for populations to emigrate to new unpopulated regions, that we would expect the development of vigorous intra and intergroup competition among island residents.

Oral traditions suggest that the last two centuries prior to European intrusion were indeed a highly competitive period in the Hawaiian Islands (see Fornander 1969 and Kamakau 1961). Referring to traditional sources, Hommon (1986:66-67) argues that by the late 1500s to early 1600s

military resolution of jurisdictional disputes was replacing prerogatives of senior kinsmen. Consistent with the position taken here, he goes on to suggest "that these early instances of conquest, usurpation, and rebellion may have been precipitated by shortages resulting ultimately from the inland expansion..." While more equivocal in relating late historic events to population/resource variables, Kirch (1985:307-308) also emphasizes repeated attempts by ruling chiefs to extend their influence through hostile confrontation and territorial annexation. He indicates that "expansion of a chiefdom was generally short lived, followed within a generation or two by collapse and retrenchment, frequently precipitated by usurpation of the paramountship by a junior collateral able to enlist the aid of other malcontent chiefs and warriors."

Elevated levels of hostile competition can be monitored in the archaeological record by documenting increased presence of features such as fortifications and refuges, more effective weaponry, and increased frequency of traumatic injury in burial remains. Puna District, including the geothermal resource area, was not free of competitive interactions building through the islands generally. Indeed, Kamakau and Fornander's remarks as interpreted by Barrère above, suggest that hostile competition in the District, at least for short periods of time, may have been quite acute. Accordingly, we should see indications of such events preserved in the region's archaeological record.

Refuge caves are among the strongest indirect indicators of hostile competition. Assuming that construction of refuge features is induced primarily by conflict, refuges should predominantly date to the final prehistoric period when conflict should have been the most acute. Extant radiocarbon data from refuge caves in the Keauhou and Kahalu'u Bay area of the Kona Coast suggest that this is so. There, dated hearths and middens clearly associated with refuge use date exclusively to the very late prehistoric to early historic period (Burtchard 1993:86). Though the sample is small (five dated features), the results are consistent with general competitive expectations. The observation is particularly germane to the geothermal resource area given the presence of extensive lava tube cave complexes with refuge and fortification features (personal observation 1993, also see McEldowney and Stone 1991). Because of exceptional preservation that caves often afford cultural remains, they retain a wealth of archaeological information that can be dated with relatively high accuracy. Their presence in the project area provides an unusual opportunity to investigate a variety of cultural issues. Presence of refuge and fortification features, suggests hostile interaction for at least part of the prehistoric past. The model suggests that such patterns appeared relatively late in the sequence. Datable remains in the caves will allow us to examine that issue further.

In addition to archaeological indications of competition, general land-use intensity should have remained high. We can expect a relatively high density of residential, agricultural, ceremonial and other features to date to the late pre-contact and early contact periods. Both windward and leeward agricultural and settlement zones should have been extensively used. Upland forests should have continued primarily as short-term hunting and collecting, back-up cropping, refuge and travel areas.

* * * *

Events of the late 1700s brought significant changes to traditional Hawaiian lifeways. Captain Cook's arrival in 1778 represented far more than implied by the brief stays and eventual unpleasantness at Kealahou Bay. It was an exploratory probe of European and American economic systems in the early stages of rapid expansion into the Pacific Basin. Within a few years of the Cook expedition, exploration and trading ships were landing in Hawai'i in increasing numbers to exploit local products and manpower, and trade in goods, weapons, and other industrial technology, the combination of which soon altered the character of inter-island competition and power. Old world

diseases first introduced by the crews of the *Discovery* and *Resolution* sent the local population into rapid decline that did not taper off until the late 1800s (see Stannard 1989 and Nordyke 1989).

While removed from the seat of these events, Puna District nonetheless was involved in historic processes beyond local control. Moblo's summary below focuses on Puna's place in this larger process. It is intended to provide general background for historic period events and related cultural resources relevant to the project area.

PUNA --A BRIEF ACCOUNT OF HISTORIC TIMES by Pennie Moblo

The basic organizational structure of this section is adapted from Burtchard (1993), who has delineated five politically and economically discrete divisions for the Hawaiian historic period. Reference should be made to that report for consideration of broader historical processes affecting the Hawaiian archipelago. This section focuses on events germane to the geothermal study area. The five-part division is maintained to link Puna history to the islands generally. The first division marks consolidation of power over the Hawaiian islands under King Kamehameha I. An interval of increased trade between the Hawaiian elite and foreign merchants follows. The third term begins with the shift in rights over land associated with the increased demands of foreign entrepreneurs. This period ends with Hawaiian loss of control over government, the imposition of the "Bayonet Constitution" in 1887, and ultimately, the overthrow of the Monarchy in 1893. Economic growth in commercial agriculture was the dominant feature of the Republic and Territorial phases of Hawaiian history. The final period discussed is that since Hawai'i achieved Statehood. Some of the remains still evident in the general project area are shown on map Figure 11.

Political Consolidation: 1778-1819

At the time of Captain Cook's visit to Hawai'i in 1778-1779, the island chain was divided into four kingdoms. The Island of Hawai'i was under the control of King Kalani'ōpu'u, a very old man at the time. After his death in 1782, ascendancy was disputed among rival chiefs and, following the battle at Moku'ōhai, the island was split into three kingdoms. Puna was divided between Keōua Kū'ahulu'ula, a son of Kalani'ōpu'u who also controlled Ka'ū, and Keawema'uhili of Hilo. Kamehameha had control of Kona and Kohala, from which he launched a campaign against Maui, Lāna'i and Moloka'i. In about 1785, a feud between Keōua and Keawema'uhili ultimately resulted in the death of the latter. In 1791, Keōua was lured to Kawaihae on the pretense of making peace with Kamehameha. He was killed disembarking from his canoe, and Kamehameha took possession of his lands, including Puna. Kuykendall (1938:38) notes that there are several interpretations of Keōua's death and of what appears to be treachery on the part of Kamehameha. With power then consolidated on the island of Hawai'i, Kamehameha could set his sights to the north.

Keōua probably stayed at one of the villages frequented by his father, Wai 'Ahukini (or Wai o 'Ahukini) near Ka Lae (South Point) Ka'ū. Puna's role in the tempestuous period of consolidation, seems to have been as an obstacle between the embattled political centers of Kona/Kohala, Ka'ū and Hilo. It appears in a legend interpreted as Pele lending her supernatural force to the support of Kamehameha. Once, after a battle between Kamehameha and Keōua had ended in stalemate, Keōua's retreated toward Puna. As the troops passed Kīlauea Crater, they were accosted by a violent eruption and an entire division of warriors, women and children was lost in the dense clouds of smoke and rock. Barrère (1984) contends that Puna was insignificant in shaping the course of the political history of the islands. It was sought primarily for control of the adjacent districts of Ka'ū and Hilo.

Whether or not the chiefs spent much time in Puna, area resources were undoubtedly important as shown by numerous ancient trails passing through the region. These trails are partially documented on early maps, but their full importance may never be known unless they are carefully recorded with reference to points of origin, destination and resources found or cultivated along their routes. Trails probably provided for movement of armies during warfare as well as for trade goods. Remnants of these routes could be found in the undeveloped sections of the project area.

Royal Trade: 1819-1850

Although the first half of the nineteenth century is characterized by trade between Hawaiian chiefs and Europeans, there was little to attract direct foreign involvement in Puna. Historians have depicted early contact in the region as a scene of missionary fervor generated among the Hawaiians. When William Ellis passed through in 1823, he found the people receptive to Christianity and they conversed with him on religious matters late into the night (Ellis 1979:214). Titus Coan, who arrived in 1835, is said to have been an evangelist of exceptional talent who brought nearly 7,000 Hawaiians to the fold in a district encompassing Hilo and Puna (Kuykendall 1938:338). Under his guidance, native ministers were assigned to perform the duties of local pastors in remote areas, including Puna.

William Ellis kept a journal of his travels through Puna describing a mixed landscape of austere volcanic flows, active coastal villages and verdant gardens. He found Green Lake at Kapoho a spot of singular beauty. The crater rim and interior hills were covered in vegetation. The slopes were almost entirely laid out in plantations, "enlivened with the cottages of their proprietors" (Ellis 1979:206). Around the lake, land was cultivated in taro, bananas and sugar cane. The steep slopes were lined with grass, native huts, and bread-fruit, *kukui*, and 'ōhi'a trees. He visited the *hōlua* slide at Kula, where he heard legends about the slide and Kahawali's encounter with Pele.¹³

The economic activity of the area centered around farming and fishing. The people of 'Ōla'a and inland Puna were known for the quality of their mats and *Kapa*, which were sold at markets in Hilo. *Māmaki* shrubs from which some of the cloth was made, grew readily in the region.¹⁴ Other valuable crops include pigs, gray *kapa* (probably from *Broussonetia papyrifera*), fine mats and feathers. It appears from the nature of the exchange, that trade was conducted primarily among native Hawaiians. It is possible that the forests were also exploited for sandalwood. While travelling from the village of 'Ōla'a to Hilo, the Ellis party overtook the chief of Waiākea with three or four hundred people returning from the mountains laden with fragrant sticks.

Early maps of Puna show the shoreline dotted with villages and a densely wooded interior honeycombed with trails (Loebenstein 1895). Ellis (1979:190) found the coast west of the project area somewhat desolate and speculated that the reason it was thickly inhabited compared to the more fertile tracts inland was because of the choice fishing. Fish were cured and exchanged for vegetable products from Hilo and Hamakua. Both coastal and forest zones in Puna undoubtedly provided critical subsistence and maintenance resources such as birds, pigs, thatching material, weaving and *kapa* making materials (see Appendix A), firewood and 'awa (*kava*, *Piper methysticum*). Numerous upslope-downslope inland trails provided routes for the transportation and exchange of forest and

¹³It should be mentioned that Pele remains an important figure in Puna District. Offerings to Pele continue to be made at Kīlauea, in the general project area and at other volcanically active places.

¹⁴Ellis (1979:230) indicates the species as *Morus papyrifera*, but more likely it is *māmaki* or *Pitrus* spp. (Pukui and Elbert 1971). *Māmaki* is still found in the Puna Natural Reserve Area and the project area where it grows vigorously. A more durable *kapa* was made from the *wauke* (*Broussonetia papyrifera*).

coastal resources. Isolated plantations and cottages, like the one described by Ellis (1979:182-3), were scattered along these trade routes where springs provided access to fresh water.

The paths were probably used for the movement of people maintaining social obligations as well. In the Western Pacific, the web of kinship maintained through visits and exchange provides residence alternatives in a hurricane prone environment. For those living in Pele's domain, maintaining habitation options would be prudent. The introduction of the horse enhanced movement options, and some of the trails on the 19th century maps may have been of relatively recent origin.

Chester Lyman (1924) travelled with Rev. Coan through Puna in 1846 and found it so poor that people could barely eke out subsistence, and consequently had no time for sinful activity.¹⁵ Their morals, he believed, surpassed those of natives in more fertile districts. He thought that the Kealakomo area described by Ellis might have suffered depopulation. Lyman's observation needs to be considered with caution, however. He passed through the village at mid-day when most of the people would have been working. The people who thronged around Ellis' hut, came in the evening. Note, too, that Lyman's visit was before, not after, the epidemics of 1848 and 1849 as purported in an earlier study (Holmes 1985). Population estimates made by both missionaries were crude and misleading. Langlas (1990) uses actual church enrollment to estimate the mid-19th century population of Kalapana as a starting point for charting depopulation.

Both Ellis and Lyman found parts of the coastal environment harsh (probably leeward Puna), but whether the difference in accounts of the circumstances, just two decades apart, was actual or a matter of individual interpretation is not readily evident. Ellis was a more careful student of Hawaiian culture and economic practices than was Lyman. Although, missionary accounts can provide valuable information on the early contact period, they often suffer from religious biases and must be used critically.

Portions of the project area which have not been heavily impacted by commercial agriculture may hold clues that will help us better understand how the pre- and early contact Hawaiians utilized the resources available to them. Attention should be given to the named openings or *kīpuka* in the lava where cultivation was possible (see Appendix D). The people of Puna supplemented their abundant sea resources with inland products. The location and identification of trails in the project area may help us understand their trade and economy.

Imperial Government & Western Land Rights 1850-1893

There appears to have been little foreign influence in Puna, except for the itinerant missionaries, until the 1870s. The churches were thatched houses and the local ministers Hawaiian. The Land Commission Awards given in Puna during the Great Māhele of 1848 were primarily for large *ahupua'a* given to high ranking chiefs (see Appendix B). Because these parcels were parts of claims to lands throughout the kingdom, and because they went to such high-ranking persons, no detailed description of the lands is given in their testimonies. Testimonies of the *ali'i* were focused on the genealogical and socio-political claims to land rather than the habitation-cultivation rights of commoners. Many of these large claims would eventually fall into the hands of the sugar barons. This appears to have been the case at Puna.

¹⁵Note that Lyman was probably referring to the drier leeward Puna coast.

Figure 11. Historical Trails, Land Grants and Selected Features

Large quantities of Puna lands remained in the hands of the government. Some of these lands were sold as grants. Land grants fall neatly into two categories: traditional farms and commercial investment properties. The grants along the coastline were taken by Hawaiians who continued to practice subsistence and small scale farming (see Appendix C). These were claimed in the 1850s. Starting in the mid 1880s, land held by the government was sold as fee-simple homesteads. The property of the wooded interior was taken for the most part by non-Hawaiians, many of them resident on O'ahu. Nearly all of the homestead grants were purchased during the 1890s coffee boom.

Robert Rycroft, who moved to Pohoiki in 1877, was a pioneer in Puna industry. He purchased 652 acres in Pohoiki *ahupua'a* in 1879 and built a home, sawmill, courthouse, jail and wharf. Later he planted coffee, built a coffee mill and bought more land. Others followed his lead and, by 1894, William Gowdie (or Goudie) had planted coffee at Waikahiola, Reed (or Reid) and Co. from Honolulu had opened a plantation in the area, and R.A. Lyman was cultivating land east of Rycroft. In addition, four or five foreigners living on government land were growing coffee as were most of the Hawaiians. Rycroft was confident that coffee had a bright future once government lands were opened up with roads (Rycroft 1894). Others shared this vision and between 1896 and 1906, 300 grants were taken, almost all of them by coffee speculators. 'Ōla'a was the primary investment region, but coffee was also expanded in the Pāhoa area. Coffee acreage in Lower Puna expanded from 168 acres in 1895 to 272.5 in 1899 (Thrum 1895c, 1899). It was hoped that coffee would help to diversify the Hawaiian economy (Thrum 1895a). One serious difficulty of coffee growing was that it required a large work force only when the coffee was to be picked. Keeping men employed when not picking coffee was a serious economic drain on the fledgling industry (Thrum 1895b).

It was sugar, rather than coffee, that finally became the dominant crop in the region. Puna sugar was established at Kapoho in 1900. Railroads were built as the land was cleared for cane fields. The trains transported the felled 'ōhi'a logs out. The third major commercial activity in Puna was cattle ranching, established by W.H. Shipman on the interior highland grazing lands and lowland sections of Kea'au.

The changed land laws of 1884 and especially of 1895 allowed for the economic development of Puna. Some local farmers chose to respond to economic change by experimenting with cash-cropping on a limited basis. The impact of the changes on the physical environment and the traditional culture should be more carefully addressed. The reaction of the local population to this sudden influx of capital investment in developing the land could be researched further in letters to the Legislature and other archived sources.

Republic and Territory: 1893-1959

After the overthrow of the monarchy, with the government solidly in the hands of the commercial empire builders, there seemed few obstacles to solid economic growth. An optimistic spirit prevailed. One of the areas to which the new government gave attention was the surveying, opening and expanding of lands under the 1884 Homestead Act, neglected by the Gibson regime (Kuykendall 1967:423). Roads and harbors were upgraded to allow freer transport of products. This included work on the Hilo Breakwater started in 1908 with rock from the Puna quarry (Thrum 1909). While land was rapidly being cleared for sugar, there was an attempt to diversify the economy.

Pineapple was started in the region for export to California. By 1908, excess fruit was being canned at Hilo and the product had attained importance as an industry. The Canning Company bought fruit from Japanese, American, Portuguese, Hawaiian and Chinese growers (Marques 1909:64). The Japanese farmers dominated, providing roughly half the pineapple to be processed.

The Hawaiian Mahogany Lumber Co. (also known as the Pāhoa Lumber Co.) was started in 1907 by James B. Castle of Honolulu, to meet a demand in the continental United States for ties to expedite the expansion of the railroads. 'Ōhi'a was harder than Pacific Northwest fir and pine, which seemed to make it more suitable for ties. The company was started with a contract from the Santa Fe Railroad and several thousand acres of fee simple land acquired from the Territorial Government.

The mill was erected in the cane fields of Pāhoa where logs were hauled on temporary railroad spurs from homestead lots around 'Ōla'a, which were being cleared for sugar. Logs not suitable for making ties, were sawed into construction lumber. It was hoped that most of the land denuded by logging could be converted to agricultural use. The Government contemplated reforestation with useful trees of land which was good for nothing else (Irwin 1909:11). Some of the land was to be used for rubber (Condé and Best 1973).

According to Irving Jenkins (1983:304) mill euphoria was dampened in 1909, when underestimated costs and a poorly negotiated contract with the Santa Fe brought foreclosure. It was reorganized as the Pāhoa Mill. In 1910, Castle obtained, at public auction, the right to log 12,000 acres of unleased government land next to the Ka'ōhe Homesteads. The mill employed about 600 men and had ten miles of track, four locomotives, and nine logging donkeys (Thrum 1910:136).

The mill was leveled by fire in 1913, damaging much of the equipment. It was rebuilt and running within a few months under the same management as before, but with yet another name: the Hawaii Hardwood Company. By this time, however, the test track laid by the Santa Fe had found that 'Ōhi'a did not last as long as expected in the dry climate of the Southwest and the contract for ties was not renewed. In 1917, the mill was leased to the Puna Sugar Company for plantation use.

The Pāhoa lumber company exemplifies turn of the century industrial optimism. Irwin wrote that the "development of the railroad tie industry and the establishment of this large lumber and tie plant go to illustrate the truth of the statement that Hawai'i still has many undeveloped resources which promise profit to him who has the courage, foresight and means to exploit them" (1909:11). Although there was little concern with replanting, there may have been some thought to the future of timber resources, because land was set aside as forest reserve starting in 1911 (Hammett 1989).; though watershed protection may have been the most compelling factor in their formation (McEldowney pers. com.)

The Puna Forest Reserve map (Hawai'i Territory 1927) shows the large expanses set aside for the Puna Forest Reserve, The Nānāwale Forest Reserve at Puua, and the Malama-Kī Forest Reserve¹⁶. Most of the surrounding area was still held by the government.

Tourism became popular around the turn of century. Green Lake and several warm springs --including some now lost under the 1960 lava flow near Kūki'i Heiau, and others near Pohoiki-- were popular picnic spots as evidenced by numerous photos in the Lyman and Bishop Museum collections. In the 1930s, Puna was advertised as "a Primitive Spot Little Changed From 100 Years Ago" where vestiges of ancient Hawaiian life and unspoiled scenery could be observed (Star-Bulletin 1934).

¹⁶Malama Kī: Lit. bright ti plant. The game *ho'olele kī* is said to have been played only there. A ti leaf was held while the player chanted 'O kēlā kī, 'o kēlā kī, na Ka-moho-ali'i ka'u i, lele! that ti, this ti, my ti is for Ka-moho-ali'i, fly! The leaf was then hurled and if the chant had been said correctly and the wind was right, it returned to the sender. Ka-moho-ali'i, a celebrated shark deity, was Pele's older brother (Pukui et al. 1974).

Because portions of Puna remained in the hands of small farmers, it offers the opportunity to study the small-scale involvement of independent growers in a localized economy. Both coffee and pineapples were produced at this level. There was also, most likely, a change in the ethnicity of the population as non-Hawaiians, starting as laborers in the cane and pineapple fields, sought land of their own. Langlas (1990) has provided a model of how oral histories can enrich the understanding of an area. Such a study in Puna could illuminate a segment of Hawaiian heritage that has been obscured in the shadow of the sugar giant. The archaeologist may find evidence of cultivation in feral crops. The extent of logging in the area could become evident with the discovery of abandoned railroad spurs into areas not under sugar production.

Statehood & Tourism: 1959-Present

Puna Sugar continued to be important in the area until the 1970s, when the sugar and pineapple industries started to go into decline in Hawaii. The Puna plant started to shut down in 1982, and by 1984 it was closed (Cooper and Daws 1985:206). Sugar is still grown in the area and is presumably processed in another plant.

Big Island real estate became a boom industry starting in 1958. Sizeable acreages, of little real economic utility, were subdivided to sell as house lots. Despite the lack of well developed soils and serious risk of volcanic eruption, many plots were sold. Most of the buyers were not from the area and bought the property as a retirement or vacation investment. One of these, The "Royal Gardens Subdivision", once advertised for its favored locations adjacent to the scenic lava flows of Volcanoes National Park, is now under a scenic flow of its own. Homes in Kalapana Gardens were also swallowed by molten lava. Even recent volcanic activity may not curtail real estate speculation. There seems to be boundless faith in the *Kīpuka*--pockets of land that Pele has, for now, overlooked.

The subdivision boom allowed for the persistence of another Puna tradition: the small-scale, independent farmer. Marijuana has proven to be an economically significant, albeit illegal, commodity in the recent past. One realtor went so far as to advertise parcels in the drug culture magazine, *High Times* (Cooper and Daws 1985:277). More visible to the casual passer-by is the cultivation of papayas for commercial enterprise. Expanses of Kula, Halekamahina and Kapoho have been bulldozed for large plantations, and smaller farms are seen at 'Opihikao.

Volcanic activity continues to draw tourists. In addition to the geological phenomena and scenic beauty, Puna has historic features that attract attention. Historic landmarks, those structures and areas which might attract visitors due to their historic interest, listed in the Puna Community Development Plan (Community Management Associates Inc. 1992) include:

1. Lyman marker at Kapoho
2. Damien Church in Kapa'ahu--destroyed by lava 1987-1988 (Weisel and Stapleton 1992:69)
3. Kurtistown
 - a) Kamauloa Oka malama-malama Hoomana Naauao O Hawaii'i
 - b) First Hawaiian Church
 - c) Iwasaki Camp
 - d) Yamashita residence (Sugar manager's house)
 - e) Kurtistown Jodo Mission
4. Pū'ula Congregational Church at Nānāwale
5. Kahaloa house and 'Opihikao Congregational Church in 'Opihikao
6. Kea'au
 - a) Puna Hongwanji Temple
 - b) Holy Rosary Catholic Church
 - c) Puna Sugar Manager's house

7. Pāhoa
 - a) YBA Hall
 - b) Sacred Heart Catholic Church
 - c) Tao House
8. Kamahale house in Maku'u
9. Coffee Mill in Pohoiki
10. Old Kudo camp in Kaueleau
11. The towns of Mt. View, Keaau and Glenwood.

* * * *

Clearly, the three geothermal subzones offer opportunities for learning about the region's historic as well as prehistoric past. Although much of the arable land has been severely impacted by commercial agriculture, other areas remain essentially untouched. Historic features of particular interest include prehistoric and historic trails utilized in trade between coastal and inland communities, pockets of arable land which appear to have been used continuously since before European contact, small historic farms, and turn of the century industrial structures such as railroad spurs and mills.

The area also offers some opportunity to investigate the economic expansion, expectations, successes and failures of late 19th and early 20th century Hawai'i. Much of the emphasis in Hawaiian history has been on the large, powerful industries such as sugar. In Puna, small-scale farming, like that practiced by the local Hawaiians, was encouraged as part of the hoped for a coffee future. In 1842, for example, the government accepted coffee for land taxes and, as a further incentive for native farmers, they accepted coffee for taxes at above market value (Fundamental Law of Hawaii 1842 [May 11]:122 and Report of the Minister of Finance 1876:6).

In sum, Puna has experienced a varied historical past consistent, on a local level, with events common to Hawai'i generally. Archaeological remains of this period, as well as those associated with the more distant prehistoric past are now part of the cultural landscape of Puna District. Potential impact to both prehistoric and historic remains should be evaluated on a project specific basis as geothermal development proceeds.

RESEARCH STRATEGY

RESEARCH QUESTIONS

The preceding sections presented detailed discussions of environmental and human land-use patterns that allow us to generate a model regarding the distribution and relative density of archaeological remains across the three geothermal subzones and beyond. Predictions derived from this general model relate to the probable distribution of prehistoric remains to patterned human use of area over time. The cultural background section summarized extant archaeological and early historical data. Those data, while limited, are consistent with general provisions of the relative density model. That section also considered changing human use of the region through time, and summarized Puna District historical events. Here, archaeological expectations for the geothermal project area are pulled together in summary fashion and developed into a survey research strategy by which they may be evaluated and improved.

Based on the predictive associations between Puna's environment and the potential for long-term settlement, a land use model for the district has been developed. Testing the fit between this model and the extant archaeological record of the Puna District, while considering the factors of a

changing and dynamic environment will be the focus of the Puna geothermal project survey. Related to this model and to Hawaiian land-use patterns are a number of research questions that could be examined productively with archaeological investigations in Puna District, including the three geothermal subzones. Although the limited survey that will be a part of the geothermal project evaluation will probably only be able to address at an initial level three of these questions, the research problems enumerated below suggest a context which can potentially guide archaeological research in the District. The list is only intended as a starting point for archaeological research in the region. It should be refined and expanded as our understanding of these issues improves.

1. Did settlement of the windward coastal regions of Puna occur early in the sequence of Polynesian settlement of the Hawaiian islands? Other windward coasts such as Halawa on Moloka'i and Waimanalo on O'ahu have yielded evidence of early settlement. Windward Puna, especially areas nearest Hilo Bay, should have provided the type of favorable environmental setting in which such early settlement could be expected.
2. How did Hawaiians adapt to life in an unstable environment, one in which recurrent volcanic activity from Kilauea was continually altering the natural environment in which they lived? Much of the evidence relevant to answering this question has, of course, been covered over by the flows that altered the landscape. However, especially for the late prehistoric and early historic period, evidence might remain with which researchers could begin to address this question.
3. How did Hawaiians adapt to conditions in the various environmental zones that comprise Puna? How did those exploiting different zones interact with one another? Can these interactions, especially between upland and coastal sections, be seen in terms of relationships within the *ahupua'a* system?
4. How did Hawaiian adaptation vary between windward and more leeward sections of Puna, especially as perceived through the archaeological record? What effects did these environmental differences have upon the density and distribution of Hawaiian settlements?
5. What is the character of the historical record in the project area? What can we learn about Hawaiian lifeways after the arrival of Europeans? What special preservation needs are warranted?

The Puna geothermal survey, by providing evidence of variation in types of sites among the several environmental zones within the project area, can potentially yield information that will relate directly to the final three research problems. Much of this research design has accordingly focused on defining factors of particular importance in understanding Hawaiian settlement patterns within the East Rift Zone environment and consequent differential use of the landscape.

ARCHAEOLOGICAL EXPECTATIONS

The general character and distribution of prehistoric archaeological remains may be summarized in terms of the six environmental/land-use zones described earlier in this document -- Coastal Settlement, Windward Coastal Margin and Inland Agriculture, Leeward Coastal Margin and Inland Agriculture, and Upland Forest Exploitation. While the number and complexity of trail systems probably conforms to the general model, it should be noted that, because they traverse substantial distances, trails will occur in multiple zones as laid out here. Lava tube caves also are

somewhat less sensitive to land-use zones as structured, though intensity of use probably increases toward the coast as expected here.¹⁷

Table 4 summarizes basic archaeological patterns anticipated for the geothermal study area by land-use zone and offers basic research recommendations for each. Trails and lava tube caves are presented as separate entries. Figure 12 displays current lava flow data and the six modeled land-use zones. Figure 12 also indicates sample survey blocks considered to be particularly (but not exclusively) useful for examining expectations generated here (i.e., for verification survey). Combined, the table and figure encapsulate many of the land-use and archaeological implications generated earlier in the report. Readers are urged to refer to environmental and cultural background text for more thorough discussion of these linked environmental, economic and settlement issues.

Table 4. Land-Use Zones, Settlement Patterns and the Archaeological Record (Refer to Fig. 12)

Land-Use Zone	Expectations	Project Area Archaeological Data
1. Coastal Settlement	Highest density, variety and complexity of prehistoric surface features. Primary aggregations of residential, ceremonial, garden and associated features at sheltered embayments with adjacent inland agricultural soils. Earliest, densest aggregations may have been weighted toward the windward margin.	Extant Data: Coastal surveys and early historic accounts consistent with expected pattern. No recent systematic compilation of archaeological data for the Puna coastline. Project Area: Represented only at the easternmost tip of the Kapoho subzone. In other areas, inland remains linked to coastal settlement via trail networks. Recommended: Survey <i>kīpuka</i> as indicated at NE corner of Kapoho subzone. Extant coastal settlement data should be compiled to establish firmer interpretive framework for inland remains.
2a. Windward Agriculture: Coastal Margin	High density and variety of surface remains linked to support of windward coastal settlements. Particularly high density anticipated inland of Kapoho Bay and Cape Kumukahi and other areas where weathered, agriculturally productive soils permit.	Extant Data: Research limited to linear transects and small block areas, largely over disturbed ground and scattered sample areas. Regularly report moderate density of varied cultural features (see Table 2). Project Area: Limited to Kapoho Subzone. Most terrain disturbed by modern flows. Known sites include Kūki'i Heiau and Pu'u Kūkae historic cemetery. Recommended: Survey of Pu'u Kūkae as indicated, also survey intact ground on 1250-1650 flow and 1600-1789 flow west of Kapoho Crater.
2b. Windward Agriculture: Inland	Moderate density of primarily agricultural and temporary residential features supporting coastal settlements. Trails link agricultural areas with settlements.	Extant Data: Limited to extended linear transect surveys, well pad surveys and sample transects, most north of the project area. Results indicate lower than expected frequency of agricultural features some of which may be due to recent volcanic destruction.. Project Area: Western half of Kapoho subzone. Most terrain disturbed by recent farming, mining and lava flows. Undisturbed pockets, and crater floors remain. Known sites include <i>hōlua</i> slides, lava tubes and historic features. Recommended: Survey older intact sediment zones and crater floors. Units indicated on Figure 11 are intended to sample such areas widely dispersed across the zone. Additional areas should be sought as appropriate.

¹⁷Some ceremonial features such as *heiau* and burial platforms may also be less tightly constrained to these essentially economically driven land-use zones. I suggest, however, that most of these features tend to be placed in or near regularly used terrain, and that their distribution is roughly consistent with expectations generated by the model.

Land-Use Zone	Expectations	Project Area Archaeological Data
3a. Leeward Agriculture: Coastal Margin	Moderate to high density and variety of surface features spatially linked to coastal settlements and agriculturally productive sediments.	<p>Extant Data: Transect surveys as far west as Kaimū and Kalapana (prior to the 1990 flow) indicate aggregated settlement remains <i>in coastal context</i>. No known surveys of the inland margin. Early historical accounts indicate farming activity. Known lava tube caves.</p> <p>Project Area: Zone not represented in project area.</p> <p>Recommended: Consolidate extant archaeological and historical data as possible to reconstruct land use patterns.</p>
3b. Leeward Agriculture: Inland	Moderate to low density of surface features linked to agricultural land use, possibly in isolated pockets of suitable agricultural sediments. Trails link agricultural areas with coastal settlements.	<p>Extant Data: Very limited survey transects. Stone cairns/possible burial platforms in vicinity of Heiheiāhulu Crater and remains noted below. Historical sources generally suggest spatially distinct planting areas.</p> <p>Project Area: Zone extends in to lower (southern) Kīlauea and Kamā'ili subzones. Known features include Wilkes and Kaimū trails, lava tube caves, rock cairns, and historically documented planting areas. Land grants in SE Kīlauea and central Kamā'ili subzones.</p> <p>Recommended: Survey of isolated older lava flows. Areas shown on Figure 11 sample <i>kipuka</i> and craters widely scattered across the zone within the project area. Efforts should be made to document agricultural features in Land Grant areas to establish comparative base for survey in the Upland Forest Zone.</p>
4. Upland Forest Exploitation	Very low feature density consisting of isolated agricultural and short-term surface and lava tube residences, low-investment agricultural features, trails and historic sugar and logging related features.	<p>Extant Data: Surveys limited to well pad and road corridors, and lava tube cave exploration. Prehistoric features identified only in lava tube caves. Historical records indicate presence of widely scattered hunting shelters, and agricultural/residential way-sides adjacent to the Hilo to Kīlauea Trail.</p> <p>Project Area: Upper Kīlauea and Kamā'ili subzones. Railroad berm identified in NE Kīlauea subzone.</p> <p>Recommended: Survey to sample oldest sediment zones represented in the subzones. Figure 11 shows recommended sample blocks.</p>
Trails	Most trails run upslope-downslope linking inland agricultural areas to coastal settlements. Major cross country routes linking Hilo, Puna and Ka'ū Districts may date from mid to late prehistoric period. Cross country routes become more complex during historic times.	<p>Extant Data: Early historic maps document upslope-downslope trails, cross-slope trails and roads. Age of these routes cannot be assured, but many may be trails associated with prehistoric agriculture.</p> <p>Project Area: Wilkes and Kaimū Trails documented in lower Kīlauea and Kamā'ili subzones. Rail lines in upper Kīlauea.</p> <p>Recommended: Trails will be difficult to document in dense vegetation. However, effort should be made to relocate and trace Wilkes and Kaimū Routes to attempt to document presence and possible association with agricultural and short-term residential features.</p>

Land-Use Zone	Expectations	Project Area Archaeological Data
Lava Tube Caves	Located in tube-fed lava flows both on the south and northeast rift slopes. Subterranean feature density should be high in near coastal context and through inland agricultural zones, decreasing density in upland forest. Caves typically preserve a wide range of prehistoric and early historic remains including refuge, residential and ceremonial features, hearths, lamps, midden remains, burials and more.	<p>Extant Data: A number of caves have been located and partially mapped, most in massive pāhoehoe flow north and east of the project area. Others documented on the south slope of the Rift Zone. Dense, varied mix of cultural features.</p> <p>Project Area: Known tubes extend into southern and northern Kīlauea subzone (Figure 12). Actual routes and content yet to be determined.</p> <p>Recommended: Extensive mapping of known lava tube cave segments relevant to the project area. Consultation with residents and local experts on cave locations and appropriate documentation procedures. Limited testing to establish function, temporal range, and floral and faunal assemblages. Develop means to record caves and general contents in a manner that insures protection from public exposure and vandalism.*</p>

*Please note that appropriate protective measures should be extended to all cultural remains regardless of location in any of the land-use zones.

Most of the expectations and recommendations included in Table 4 refer to prehistoric archaeological remains. This is not meant to denigrate the importance of more recent cultural resources. It simply reflects the fact that less information is available for the prehistoric past than for the most recent 200 years of recorded history. Historical resources should be carefully documented, evaluated and protected as appropriate during the continuing inventory process. It is likely that some, heretofore unknown, historical remains will be documented through inventory survey procedures. These, of course, should be documented as any other archaeological indication of past human use of the region. In the implementation recommendations that follow, however, most emphasis is given to documentary research for prehistoric period remains. Combined pedestrian survey and synthesis of extant data are recommended for both prehistoric and historic archaeological records.

IMPLEMENTATION PROCEDURES

To this point, substantial attention has been given to clarifying environmental parameters and long-term human land-use assumptions underlying patterned use of the Puna landscape. I have suggested that certain landforms and environmental zones are used with greater regularity and/or intensity than others, and that over time such differential use creates corresponding patterns in the relative density of archaeological remains across the landscape. Building on these arguments, a land-use model was developed to predict basic patterns in the relative density of archaeological remains in the project area. Table 4 and Figure 12 summarized much of that information and directed attention to procedures aimed at examining those expectations and, in the process, refining our understanding of Puna District settlement patterns.

Figure 12. Lava Flows, Land-Use Zones and Survey Blocks

This section offers specific recommendations for conducting field verification survey and continuing documentary research for the geothermal resources area. Pedestrian survey procedures are the primary concern of the section. While general survey recommendations have been implied above, issues of sample stratification and selection, recommended survey techniques and risk factors are addressed further here. This section also briefly addresses project coordination with local experts and organizations, and Hawaiian concerns. It also recommends specific documentary research procedures intended to expand an understanding of historic and prehistoric land-use practices. Recommendations for documenting trails and lava tube caves complete the section.

Local-level Coordination and Native Hawaiian Concerns

It is important that any organization hoping to successfully complete survey work in the geothermal resource area coordinate activities with other organizations and individuals maintaining a serious interest in the resources of the area. At a fundamental level, entry permission must be gained in order to complete a large survey effort successfully. Most of the land in the three subzones is owned or leased by private individuals or companies. Indeed, four property owners, or lease holders, control circa 70% of the land area: Campbell Estate/True Geothermal (Kīlauea and Kamā'ili subzones), AMFAC/Puna Sugar Co., Ltd. and B.P. Bishop Estate/Kamehameha Schools (Kamā'ili subzone), and Kapoho Land and Development Corporation (Kapoho subzone). The remaining 30% is controlled by the state, and a number of smaller organizations and individuals. Though smaller in size, in many cases, these areas coincide with historic land grants and homesteads. These often contain the best agricultural sediments and may have been the site of particularly intense use in both the prehistoric and historic past. Consequently, the value of the smaller holdings exceeds that implied by the relatively small land fraction. In any case, it is most important to receive entry permission for the bulk of the geothermal development area if a survey widely representative of the project area's environmental zones is to be conducted successfully.

Contact also should be made with individuals or organizations with particular knowledge of, or interest in, cultural resources in the area. At present, little direct effort has been given to developing such contacts beyond acquiring the names of several individuals with particular interest in the region's lava tube caves. Several of these persons have been contacted informally. Additional effort should be made to work formally with these and other individuals to develop as thorough an understanding as possible as to the location and content of this particularly important class of archaeological/cultural heritage remains. Similar efforts should be applied to surface remains and trails as well. Dense ground cover in the project area will make any pedestrian search for archaeological remains difficult at best. If willing, local residents can provide important information on the character and location of remains, remains that could easily be overlooked by sample survey techniques alone.

Not all individuals with interest in local archaeology will be anxious to share that information with archaeologists. Often, people are reluctant to provide information to professionals who generally can offer little in return for the information they receive. At worst, archaeologists are seen as precursors to development that poses a direct risk to their life-style and cultural remains, as academics insensitive to Hawaiian cultural heritage issues, and/or as information conduits to others who may vandalize local archaeological remains. While we cannot hope to reverse all of these views, it is important to attempt to convey the seriousness of our concern for Hawaiian archaeology and cultural heritage to the local population, and to reach others more inclined to assist with the archaeological investigation and learning process. A combination of public and/or private meetings may help to alleviate concerns. The author has also had success with employing interested residents on survey and data recovery projects. Such efforts not only provide some small economic gain to the

community, they provide a means to acquaint people with archaeological procedures, to learn about Hawaiian concerns and interests on a face to face basis, and provide information to interested residents from persons they know and (hopefully) trust.

To this point, all presentation and coordination of archaeological issues with Hawaiian residents for both Puna and Maui geothermal study areas has been undertaken by an independent ethnographic research group --Community Action Network Developing Options (CAN-DO).¹⁸ It is important that archaeologists continue this relationship with local residents. The legitimate concerns of the Hawaiian community should be addressed, and in order to make well-informed decisions it is also important that archaeology's methods, goals and value be represented. Accordingly, it is suggested that members of the archaeological team work closely with the ethnographers to assure that information is exchanged effectively and accurately. In so doing, the project can benefit from the ethnographers' sensitivity and skill in working with the local community, and archaeological research can be presented in a manner that better reflects modern approaches and concern for Hawaiian interests.

Documentary and Informant Research

Assuming land entry permission can be gained, informed individuals located and involved, and local concerns addressed satisfactorily; archaeological research should proceed through documentary and physical site survey procedures. Documentary efforts are particularly useful for historical properties. Pennie Moblo's historical summary in this document is intended to provide introductory background to Puna history and to provide a useful tool for continuing historical work if warranted. Her work involved rapid review of materials contained in a number of documentary sources (see Appendices B through E). In subsequent research stages, those materials can be used to develop a more complete picture of local history. For the second stage of historical research, Moblo offers the following recommendations:

The history of the area could best be recorded in a three-part investigation. Further documentation of the area should make use of the Lyman House Library at Hilo, which houses the diaries of local residents dating back to the early part of the 19th century; the Hawaiian Children's Mission Society of Honolulu which holds letters from Rev. Coan and Chester Lyman, William Kamau, and Mission records; and the Bishop Museum Archives and Library. Archaeological reconnaissance should be employed to identify physical remains of habitation and land utilization. These could be greatly expanded by the use of oral history after the model set by Langlas. Such a study could include talking with long-time residents and farmers in the area who can explain individual subsistence strategies in the region and the participation of small-scale agriculturalists in the commercial economy. They could also give some idea as to how it is to live with the threat posed by volcanic activity. The dominant commercial concerns in the area should also be explored. Informants with knowledge of the Shipman ranch, railroads, forest reserves and historic sites should be consulted. A list of prospective informants is given in Appendix E.

Literature review and informant interviews are not limited to historical research. The value of contacting local residents and experts to help us locate and understand the prehistoric archaeological record has been noted above. Existing site data should also be reviewed and systematically compiled in a fashion that maximizes our archaeological database for the region as a whole. With the possible exception of McEldowney's (1979) research design, little effort has been made to integrate the

¹⁸At the time of writing, primary ethnographic team members are Dr. Luciano Minerbi, Dr. Jon Matsuoka and Dr. Davianna McGregor of the University of Hawai'i at Mānoa.

growing body of contracted archaeological work into a systematic study of long-term settlement and land-use of the region as a whole. The present research design has attempted to begin that process. Extant archaeological literature has been reviewed and summarized briefly above (Table 2). Continuing efforts should be made to review this literature in greater detail in order to more precisely chart site and feature distribution, link inland and coastal use areas, and, to the extent possible, investigate environmental correlates of site and feature locations. Because past projects were carried out with variable aims and sophistication, documentary syntheses alone will not permit refined land-use statements. Nonetheless, they preserve information that should not be overlooked in a broader attempt to clarify the archeological record of the geothermal resource area. Furthermore, because recent lava flows have inundated much of the area, these data sources now represent all that remains of a good portion of Puna's archaeological record.

Pedestrian Survey

The importance of documentary research notwithstanding, a major aspect of the present design involves field survey. Recall that the research design stratifies the Puna geothermal project area by lava flow age and land-use/environmental zones (Figure 12). It also considers effects of recent volcanic, agricultural and development disturbance in each of the three geothermal subzones. For these zones, certain human land-use assumptions were combined with geological, biological and historical information to develop a model for predicting basic patterns in the distribution and density of prehistoric archaeological remains. At a basic level, this model segregates areas with negligible potential for significant archaeological remains (post-1950 lava flows); areas where Historic Period features are possible (flows post-dating 1790); and areas which may contain intact prehistoric features (pre-1790 flows --all on Figure 12). Based on such factors as distance from coastal embayments, flow age and type, and environmental/land use zone, the model predicts the relative density and types of archaeological surface features most likely to be encountered. Applying the relative density model, a field strategy can be developed oriented toward archaeological survey of different sample strata. The strategy, also focuses on areas with the greatest potential for presence of significant remains the overall distribution of which may be less sensitive to the land-use model --especially trails and lava tube caves.

Verification survey is based on a ca. 5% sample of the total land area partitioned between the three geothermal subzones. Procedures outlined below are presented at two levels --the basic survey; and partial survey to begin the verification process in the event funding or access problems prevent completion of the larger effort in a single phase. It is important to note, however, that the partial survey option is not a substitute for verification survey. It is only intended as a means of providing a meaningful beginning to the archaeological effort in the event the larger stratified survey cannot be implemented as a single project.

1) Stratified Verification Survey

In order to examine implications of the relative density model, we recommend survey of 5% of the three geothermal subzones stratified by lava flow and environmental/land-use zone --approximately 1000 acres in total. Field strategy employs pedestrian coverage of sample blocks dispersed to sample oldest lava flows over as wide an area as practical in each subzone. On large flows, sample blocks would consist of rectangular land areas varying between about 25 and 50 acres in size. Smaller flows, *kīpuka* and crater floors would be surveyed in their entirety. We believe that, given the mosaic of variably aged flows across the study area, block surveys of oldest available sediments maximize the potential for intercepting prehistoric use localities. In this area, it would be difficult to conduct linear transect surveys that would not cross-cut substantial areas of young volcanic terrain (effectively precluding identification of older prehistoric remains in that portion of the survey).

Table 4 outlines basic expectations and Figure 12 shows initial survey blocks recommended for the project area.

Within each sample block or special survey area, survey procedures would consist of systematic transects with field archaeologists spaced at approximately 8 m to 10 m intervals. Given the dense vegetation and often hazardous terrain of the project area, it is felt that wider intervals would unacceptably reduce site discovery potential, and would increase personal risk and difficulty controlling transect lines. Along these transects, the ground would be visually inspected, probed and cleared as necessary to locate structural remains. The field crews should also be alert to the presence plants commonly associated with Hawaiian agricultural and residential areas (e.g. *kukui* (*Aleurites moluccana*), *ki* (*Cordyline fruticosa*), *'awa* (*Piper methysticum*) and others (see Appendix A). The locations of traditional Hawaiian cultigens, particularly when co-occurring in mixed stands, provide an indirect indication of past human use.

As archaeological features and marker plant associations are encountered, the area will be cleared sufficiently to expose the range of cultural materials present. Prior to clearing, permission will be obtained from appropriate land owners/managers. Native plants will be protected during the clearing process. Visible features will be described and photographed, and locations recorded with a Global Positioning System (GPS) receiver. In all subzones, size and precise location of survey units should remain flexible to allow incorporation of new information as the survey proceeds. Note that Stage 2 survey procedures proposed here do not involve subsurface testing or collection of cultural materials. Procedures are intended to document the presence and basic character of cultural remains in a manner that addresses expectations of the relative density model. Procedures are not intended to meet full inventory survey standards as specified by the Hawai'i State Historic Preservation Division (SHPD 1990). Regular inventory survey and evaluation procedures should be completed for proposed roads, wells and power generation facilities prior to acting on specific permit requests.

In addition, fieldwork should involve directed survey designed to identify certain locations where specific classes of features are likely to be present --historically documented trails, lava tube caves, or informant guided features. Such procedures would be based on examination of aerial photographs (for lava tube cave sink holes, special vegetation boundaries, etc.); study of historical documents (trails); informant interviews; and helicopter survey. Helicopter inspection of the upper zones should help identify highly visible features, such as lava tube openings and trails, and provide access into remote, heavily vegetated areas that hinder access or effective pedestrian survey. Other directed survey to document specific sites, such as historically or traditionally known cultural properties (e.g., the *heiau* and historic cemetery at Pu'u Kūkae), should also be included as part of the field research strategy.

As shown on Figure 12, sample blocks include at least seven areas in the Kapoho subzone. These areas are selected primarily on the basis of the absence of modern disturbance, relative antiquity of the substrate and variable distance from the coastline. In the most disturbed parts of this subzone, survey should include remnant crater floors and areas not presently disturbed by modern agriculture, recent lava flows, cinder mining or geothermal power generating and transmission facilities. Photo 2, for example, shows Halekamahina Crater surrounded by agricultural ground. Vegetation on the crater floor appears little disturbed and includes *kukui* (candlenut), a Hawaiian cultigen. Other cultigens --*Hala* (*Pandanus tectorius*), coconut (*Cocos nucifera*) and *kī*-- also were observed during a brief field reconnaissance of the upper crater margin.

In the Kamā'ili subzone, at least seven areas should be surveyed. Most of the blocks indicated on Figure 12 are isolated areas of older lava (*kīpuka*) surrounded, but not covered, by more recent

flows. Younger flows immediately surrounding *kīpuka* should also be surveyed to provide a sample of these flows adjacent to locations most likely to contain features. Sample blocks on both sides of the rift zone crest are also marked for survey on Figure 12.

Photo 2. Halekamahina Crater in Kapoho Subzone. Lighter trees are *kukui*.

In the Kīlauea Middle East Rift subzone, at least eight sample blocks are recommended. These include several *kīpuka*, some of which are part of large flows. As in the Kamā'ili subzone, survey blocks are proposed for each side of the rift zone escarpment. While the sample block survey is designed to focus on older flows, more recent flow areas should also be investigated while walking to the sample blocks. Access frequently will require walking substantial distances in an area with few roads. Part of that time and effort can be turned to survey advantage.

For both the Kamā'ili and Kīlauea subzones, spot inspections should be conducted at locations identified from aerial photographs and helicopter survey, or as indicated by informants as important cultural properties. In the lower portion of these zones, we recommend that efforts be made to delineate the Wilkes Trail. The trail was of some importance during the late prehistoric and early historic periods. During its use, it was associated with planting and overnight accommodation places along the route. If such places could be identified, they may provide reasonable models for other short-term use areas in the Inland Agricultural to Upland Forest Exploitation land-use zones.

Trails generally are important land-use markers as well as interesting features in their own right. Loebenstein's 1895 and Cook's 1902 maps show a network of trails into the interior of the East Rift Zone area. The 1895 map also shows a number of *kīpuka*, where soil and a reliable water source permitted plant cultivation. These now may be indicated by feral food plants and springs. The project historian (Moblo) noted that these locations often were named, had trails leading to them, and had structures on them. Although most of these appear to lie outside the geothermal subzones,

at least one (Kama'a) extends into the Kamā'ili subzone. Kipapaia may be in the Kīlauea Middle East Rift subzone. As late as the twenties, *kīpuka* near Kalapana were used by individual families for growing taro (Langlas 1990:26). It is reasonable to expect that these areas were used in prehistoric times as well. Accordingly, trails and associated agricultural areas may provide information of both prehistoric and historical importance, and should be investigated through examination of early historic maps and normal pedestrian survey procedures.

Lava tube caves represent particularly important cultural and natural resources that must be anticipated to lie within geothermal resources area boundaries. For all subzones, efforts should be made to identify and map the subsurface routes of these caves. Known tubes in the vicinity of the project area should be explored in their entirety. Within these caves, cultural features should be documented in a similar manner to surface features described above. It is important to emphasize, too, that means must be developed to protect caves (and indeed all cultural properties) from vandalism once documented. Procedures should be developed with the Hawai'i State Historic Preservation Division to insure that information gained during the verification survey not be used in a fashion that accelerate destruction of significant cultural resources. At a minimum, results of the verification survey should be published in two volumes; one including site specific details that can be held for *bona fide* professional or appropriate uses as determined by the SHPD, and a second limited to narrative text detailing results and implications of the survey without drawing attention to precise site locations.

2) Partial Survey

In an adequate stratified sample survey cannot be completed in a single phase, it may be possible to begin the process with initial survey procedures, the remainder to be completed in a multi-phased approach. It is suggested that initial survey be directed at either of two strategies: a) normal stratified verification survey of one or two of the subzones, or b) a survey of particular areas, survey blocks and site types more widely distributed across the project area.

Survey of a single subzone would implement the stratified verification survey strategy as outlined above, but at a limited scale. In this system, sample blocks should be surveyed within one or two of the subzones. Conclusions and management recommendations would be restricted to those subzones.

The second, directed survey, option should be oriented toward surveying the oldest lava flows, lava tube caves, large volcanic craters, and a limited number of historically documented features and trails more widely distributed across the project area. Such locations are likely to contain a relatively high fraction of some of the most significant archaeological remains in the project area. As above, survey would involve pinpointing such locations through examination of aerial photographs and helicopter survey, as well as block survey of selected *kīpuka*. For either alternative, archaeological documentation procedures would be identical to those proposed for the normal verification survey.

It should be noted again, that while the limited survey approach would appear likely to produce useful information in the event larger-scale inventory is not possible, such procedures should not be taken as an adequate test of the relative density model developed here. A partial survey focused on limited areas can be regarded as an informative first step in meeting research design requirements, but more thorough survey procedures should follow to complete requirements of the sample design in an effective manner.

SUMMARY

The primary intent of this research design has been to develop a better understanding of the patterned distribution of archeological remains across the Puna landscape by reference to the long-standing interaction between Puna environmental patterns and human settlement and land-use practices. It is widely recognized that archaeological features are not uniformly or randomly distributed across the landscape, but tend to vary in type and density in respect to such variables as distance from the coastline, presence of agriculturally productive soils, access to lava tube caves, and so on. It also is generally known that, over time, both land-use practices and the archeological record of that use near the Kīlauea East Rift Zone have been impacted by repeated eruptive volcanic events. Aside from McEldowney's (1979) *Lava Flow Control Study*, however, no effort has been given to isolating causes underlying patterned distribution of archeological features, to build site distribution models based on those causal relationships, or to develop means to test the accuracy of archeological expectations so derived. This project has provided an opportunity to begin that process for portions of Puna District in which the Kīlauea, Kamā'ili and Kapoho geothermal resource subzones are found.

This document has approached the problem of developing and presenting a relative density site distribution model and research design in three parts. The first, and perhaps the most important, part was to establish the basic relationship between environmental characteristics of the Kīlauea East Rift Zone and patterned human use of the region. Reflecting its importance, the first section of this report described regional geological, climatic and vegetative patterns and related them to their anticipated impact on human use and, consequently, on the prehistoric archaeological record. The section closed with a review of McEldowney's model, early historical accounts of Puna District land-use, and presentation of a revised land-use model. At its most basic level, the model predicts that the density, spatial distribution and range of archaeological features will vary as a function of distance from coastal embayments, rainfall, and agricultural potential of the substrate.

The second section provided cultural background to the project area. It reviewed existing archaeological research and offered a tabular summary of known cultural resource projects and results in the geothermal project area and Puna District generally. The section also included prehistoric and historic period summaries set in a temporal sequence designed to reflect changing economic and settlement patterns dominating the island and district over time. Because of the paucity of existing information, the prehistoric account is framed in terms of a five-part temporal model with general implications for settlement in the project area. The historic period account, reviews documentary sources to outline events directly pertinent to Puna and the project area.

The final section used environmental and cultural background information developed earlier in the document to derive a series of expectations regarding the distribution of archaeological materials across the project area. The final table and map in that section (Table 4 and Figure 12), encapsulate implications of much of that information. The section closes with recommended procedures to implement verification survey and documentary research in the project area.

Throughout this report, the intent has been to draw attention to the critical relationship between basic ways human groups have used the landscape over time and the character of the physical environment to which those groups have been obliged to adapt over the long term. The research design and land-use models upon which it is built should be taken as part of a continuing process aimed at improving our understanding of long-term organized human behavior in Hawai'i and beyond. I hope that the effort proves useful in this regard and that predictions offered here will be refined or replaced by more comprehensive settlement models as archeological research continues.

REFERENCES CITED

- Abbott, Isabella Aiona
1992 *La'au Hawai'i, Traditional Hawaiian Uses of Plants*. Bishop Museum Press. Honolulu.
- Andrews, Lorrin
1974 *A Dictionary of the Hawaiian Language*. A reprint of the 1865 edition. Rutland Vermont: Charles E. Tuttle.
- Barrera, W. and Dorothy B. Barrère
1971 *Archaeological and Historical Survey: Ahupua'a of Kapahua, District of Puna, Island of Hawaii*. Prepared for Hawaii Land Corporation, Hilo. Report 71-6, B.P. Bishop Museum. Honolulu.
- Barrera, W.
1973 *Archaeological Reconnaissance of a Portion of Pualaa, Puna, Hawaii*. Department of Anthropology, B.P. Bishop Museum. Honolulu.
- Barrère, Dorothy B.
1959 Political History of Puna. In K. Emory et al., *Natural and Cultural History Report on the Kalapana Extension of the Hawaii National Park*. Department of Anthropology, B.P. Bishop Museum. Honolulu.

1984 Appendix A. In *Archaeological Reconnaissance for Thermal Power Site*. Report by Elaine Haunani Jourdan. Bishop Museum Anthropology Department report MS 72484.
- Beckwith, Martha
1970 *Hawaiian Mythology*. University of Hawaii Press. Honolulu.
- Bevacqua, Robert and Tom Dye
1972 *Archaeological Reconnaissance of Proposed Kapoho-Kalapana Highway, District of Puna, Island of Hawaii*. Departmental Report Series 72-3. Department of Anthropology, B.P. Bishop Museum. Honolulu.
- Bonk, William J.
1980a *An Archaeological Survey in Keahiakala, Puna, Hawai'i*. Prepared for Geothermal Exploration and Development Corp. Hilo, Hawai'i.

1980b *An Archaeological Survey in Keahiakala and Pohoiki, Puna, Hawai'i*. Prepared for Geothermal Exploration and Development Corp. Hilo, Hawai'i.

1984 *An Archaeological Survey in Portions of Kapoho and Kula, Puna, Hawai'i*. Prepared for Richfield of Hawai'i.

1988 *An Archaeological Reconnaissance Survey in the Geothermal Resource Subzone of Upper Kaimu and Makena, Puna, Hawaii*. Prepared for Mid-Pacific Geothermal, Inc. Hilo.

Bonk, William J. (continued)

- 1989a *An Archaeological Reconnaissance Survey in the Geothermal Resource Subzone of Upper Kamaile, Kehena and Kikala, Puna, Hawaii.* Prepared for Hawai'i Natural Energy Institute. University of Hawaii, Manoa, Honolulu.
- 1989b *An Archaeological Monitoring and Additional Reconnaissance Survey in the Geothermal Resource Subzone of Upper Kaimu, Makuu, Kaohe, Kehena, Kaapahu and Kamaile, Puna, Hawaii.* Prepared for Mid-Pacific Geothermal, Inc. Hilo.
- 1989c *Additional Notes on an Archaeological Survey in the Geothermal Resource Subzone of Upper Kamaile, Kehena and Kikala, Puna, Hawaii.* Letter report prepared for Hawai'i Natural Energy Institute, University of Hawaii, Manoa, Honolulu.
- 1990 *An Archaeological Reconnaissance Survey in the Geothermal Resource Subzone of Upper Kaimu, Makuu, Kaohe, Kehena, Kaapahu and Kamaile, Puna, Hawaii.* Prepared for True/Mid-Pacific Geothermal, Inc.. Hilo.

Bordner, Richard M.

- 1977 *Archaeological Reconnaissance of the Proposed FAA Air Traffic Control Radar Beacon System (ATCRBS) Facility at Pahoa, Puna, Hawai'i Island.* Prepared for the Federal Aviation Administration, Pacific-Asian region. Archaeological Research Center Hawai'i, Inc. Lawai.

Boughey, Arthur S.

- 1973 *Ecology of Populations.* The Macmillan Company. New York.

Bowser, George

- 1880 *Hawaiian Kingdom Statistical and Commercial Directory and Tourists' Guide, 1880-1881.* Honolulu: George Bowser & Co. Publishers.

Burtchard, Greg C.

- 1993 *Population and Land Use on the Keauhou Coast, The Mauka Land Inventory Survey, Keauhou, North Kona, Island of Hawai'i. Part I: Narrative.* Draft copy prepared for Belt, Collins and Associates, Honolulu and Kamehameha Investment Corporation, Kailua-Kona. International Archaeological Research Institute, Inc. Honolulu.

Ching, F., Catherine Stauder, and Stephen L. Palama

- 1974 *The Archaeology of Puna, Hawaii: na ahupua'a Kaimu, Kalapana. Surface Survey Kalapana-Kaimu Beach Park.* Prepared for the County of Hawaii, Department of Public Works, Department of Parks and Recreation. Archaeological Research Center Hawai'i. Lawai.

Chun, Malcolm Naea and Matthew Spriggs

- 1987 *New Terms Suggested for Early Hawaiian History.* In *Ka Wai Ola O Oha*, monthly newspaper of the Office of Hawaiian Affairs, February 1987:4. Honolulu.

Commissioner of Public Lands, Hawaii

- 1916 *Grants and Patents, Land Sales.* Honolulu: Territory of Hawaii.

Community Management Associates, Inc.

- 1992 *Puna Community Development Plan*. Technical Reference Report prepared for the County of Hawaii Planning Department, Jan. 15, 1992.

Condé, Jesse C. and Gerald M. Best

- 1973 *Sugar Trains: Narrow Gauge Rails of Hawaii*. Felton, California: Glenwood Publishers.

Cook, T.E.

- 1902 Hawaii Territory Survey. Map showing a portion of Puna District, Hawaii. Registration No. 2191.

Cooper, George and Gavan Daws

- 1985 *Land and Power in Hawaii*. Honolulu: Benchmark Books.

Cordy, Ross

- 1978 *Cultural Reconnaissance Report for Pohoiki Bay Navigation Improvements, Pohoiki Bay, Hawaii*. Prepared for Army Engineer Division, Pacific Ocean. Manuscript available at State Historic Preservation Division, Department of Land and Natural Resources, State of Hawai'i.

- 1989 *1989 Survey Work at Kahuwai Village. Kahuwai, Puna, Hawai'i*. State Historic Preservation Division. Department of Land and Natural Resources, State of Hawai'i.

Cox, David W.

- 1983a Preliminary Archaeological Reconnaissance of Cultural Resources at the Proposed Site of the Kumukahi Small Craft Navigational Improvements, Appendix B. In *A Draft Survey Report and Environmental Impact Statement for the Kumukahi Small Craft Harbor*. Prepared for U.S. Army Engineer District, Honolulu. B.P. Bishop Museum. Honolulu.

- 1983b *Archaeological Reconnaissance of Additional Cultural Resources at the Proposed Location of the Cape Kumukahi Small Craft Navigation Improvement Project, Puna, Island of Hawaii*. Prepared for U.S. Army Engineer District, Honolulu. Manuscript available at State Historic Preservation Division, Department of Land and Natural Resources, State of Hawai'i.

Crozier, S.N. and D.B. Barrere

- 1971 *Archaeological and Historical Survey of the Ahupua'a of Pualaa, Puna District, Island of Hawaii*. Report 71-1. Department of Anthropology, B.P. Bishop Museum. Honolulu.

Davidson, E. Dow, Jeffery Pantaleo, and Aki Sinoto

- 1991 *An Archaeological Inventory Survey of the Right-of-Way Corridor, Pohoiki Geothermal Transmission Line No. 1, Puna, Hawai'i Island*. B.P. Bishop Museum. Honolulu.

DBED

- 1989 *Environmental Review: 500 MW Geothermal Development, Puna District, Island of Hawaii*. Prepared for the Energy Division Department of Business and Economic Development by MCM Planning, Honolulu.

Dye, Thomas and Eric Komori

- n.d. A Precensal Population History of Hawai'i. Unpublished manuscript on file at Hawai'i State Division of Land and Natural Resources and at the International Archaeological Research Institute, Inc. Honolulu.

Ellis, William

- 1979 *Journal of William Ellis: Narrative of a Tour of Hawaii, or Owhyhee; with Remarks on the History, Traditions, Manner, Customs, and Language of the Inhabitants of the Sandwich Islands*. Rutland, Vermont: Charles E. Tuttle Company. First British and American Edition, 1825.

Emory, Kenneth P.

- 1945 Exploration of Herbert C. Shipman Cave, Keaau Division of Puna, Hawaii, Sept. 13 and 14, 1945. Letter report on file at Hawai'i State Historic Preservation Division. Honolulu.

Emory, Kenneth P., J.H. Cox, W. Bonk, Y. Sinoto, and D. Barrere

- 1959 *Natural and Cultural History Report on the Kalapana Extension of the Hawaii National Park*, Vol. 1. Prepared for the National Park Service. Department of Anthropology, B.P. Bishop Museum. Honolulu.

Ewart, N. and M. Luscomb

- 1974 *Archaeological Reconnaissance of Proposed Kapoho-Keaukaha Highway, Puna, Highway*. Department of Anthropology, B.P. Bishop Museum. Honolulu.

Franklin, Leta Jane, Paul H. Rosendahl, and Lehua Kalima

- 1992 *Archaeological Inventory Survey Ainaloa Project: Lands of Waikahekahe Nui and Waikahekahe Puna District, Island of Hawaii (TMK: 3-1-6-04: 21,57)*. Prepared for Ainaloa Development Corporation. Hilo.

Federal Highway Administration (and Land Transportation Facilities Division, State of Hawaii Department of Transportation)

- 1979 *Final Impact Statement, Keaau-Pahoa Road, Pahoa By-Pass*. Archaeological Research Center Hawaii. Lāwa'i, Kaua'i.

Fornander, Abraham

- 1969 *An Account of the Polynesian Race, its Origins and Migrations*. Vol. II. Reprint of 1878-1880 editions. Tokyo: Charles Tuttle & Co.

Hammatt, Hallett H.

- 1989 Cultural Resources. In *Environmental Review: 500 MW Geothermal Development within the Puna District, Island of Hawaii*. Report prepared by Cultural Surveys Hawaii for MCM Planning.

Handy, E.S. Craighill and Elizabeth Green Handy

- 1972 *Native Planters in Old Hawaii: Their Life, Lore, and Environment*. Bishop Museum Press, Honolulu.

Hansen, Violet

- 1967 List of Historical Sites, Island of Hawai'i. Ms. on file, Department of Anthropology, B.P. Bishop Museum and at Hawai'i State Historic Preservation Division Offices. Honolulu.
- 1968 Unpublished notes in Department of Anthropology, B.P. Bishop Museum. Honolulu. Ms. also on File at Hawai'i State Historic Preservation Division Offices. Honolulu.

Haun, Alan E., Paul H. Rosendahl, and James Landrum III

- 1985 *Limited Archaeological Reconnaissance Survey Proposed Geothermal Development Area, Wao Kele O Puna Natural Area Reserve, Puna District, Island of Hawaii*. Prepared for True/Mid-Pacific Geothermal Venture, Honolulu.

Hawaii, Kingdom of

- 1884 *Laws of His Majesty Kalakaua I, King of the Hawaiian Islands passed by the Legislative Assembly at its Session 1884*. Honolulu: P.C. Advertiser Steam Print.

Hawaii, Republic of

- 1895 *Laws of the Republic of Hawaii*. Honolulu: R. Grieve.

Hawaii Territory Survey

- 1927 *Puna Forest Reserve, Keauohana For. Reserve and Malama-Ki For. Reserve*. HTS Plat. 814.
- 1952 *Map Showing a Portion of Puna District, Hawaii*. Traced from Reg. Map 2191 by C.K. Tanonakaka

Hawking, Stephen W.

- 1988 *A Brief History of Time, From the Big Bang to Black Holes*. Bantam Books. Toronto.

Holcomb, Robin T.

- 1976 Complexity and Hazards of Hawaiian Shield Volcanoes [abs.]. *Geological Society of America, Abstracts with Programs* 8(6):920-921.
- 1980 Preliminary Geologic Map of Kilauea Volcano, Hawaii. Department of the Interior. United States Geological Survey.
- 1987 Eruptive History and Long-Term Behavior of Kilauea Volcano. In *Volcanism in Hawaii*, edited by R.W. Decker, T.L. Wright and P.H. Stauffer, pp. 261-350. U.S. Geological Survey Professional Paper 1350, Volume 1. United States Government Printing Office. Washington, D.C.

Holmes, Tommy

- 1985 *A Preliminary Report on the Early History and Archaeology of the Puna Forest Reserve/Wao Kele'o Puna Natural Area Reserve*. Manuscript H-480, Library of Historic Preservation Division, State of Hawai'i. Honolulu.

Hommon, Robert J.

- 1982 *An Archaeological Reconnaissance Survey in Upland Kahauale'a, Puna, Hawaii*. Prepared for The Estate of James Campbell, Honolulu. Science Management Inc., Honolulu.

Hommon, Robert J. (continued)

- 1986 *Social Evolution in Ancient Hawai'i*. In *Island Societies: Archaeological Approaches to Evolution and Transformation*, edited by Patrick V. Kirch. Cambridge University Press. Cambridge.
- 1992 *The Butterfly Effect in Ancient Hawaii*. Paper delivered at the Society for Hawaiian Archaeology, Fifth Annual Hawaiian Archaeology Conference. Puhi, Kaua'i.

Honolulu Star-Bulletin

- 1934 *Hawaii of Old Still Exists on Big Island*. Honolulu Star-Bulletin, Roosevelt Edition, supplement to July 26.

Hudson, Alfred E.

- 1932 *Archaeology of East Hawaii*. Department of Anthropology, B.P. Bishop Museum. Honolulu.

Irwin, Edwin P.

- 1909 *Lumbering In Hawaii. Paradise of the Pacific*. July Pp. 9-11.

Jenkins, Irving

- 1983 *Hawaiian Furniture and Hawaii's Cabinet Makers, 1820-1940*. Honolulu: Editions Limited for Daughters of Hawaii.

Kamakau, Samuel M.

- 1961 *Ruling Chiefs of Hawaii*. The Kamehameha Schools Press. Honolulu.

Kelly, Marion, Barry Nakamura, and Dorothy Barrère

- 1981 *Hilo Bay: A Chronological History*. Report prepared for U.S. Army Engineer District, Honolulu. Honolulu: Bishop Museum.

Kennedy, Joseph

- 1982 *An Archaeological Literature Search for the Ahupua'a of Kahaualea (Mauka Section), District of Puna, Island of Hawaii*. Archaeological Consultants of Hawaii. Haleiwa.
- 1990 Archaeological walk-through reconnaissance survey for the proposed Puna geothermal venture, project site TMK: 1-4-01: POR 2 & POR 19, Puna District, Island of Hawaii. Letter report prepared for Puna Geothermal Venture, Hilo.
- 1991a *An Inventory Survey at the Site of the Proposed Kilauea Middle East Rift Zone (KMERZ), Well Site #2, TMK: 1-2-10:3, Island of Hawaii*. Prepared for True/Mid-Pacific Geothermal, Hilo.
- 1991b *Archaeological Inventory Report for Buffer Zone Surrounding Proposed Well Site SOH-3, Puna, Island of Hawaii, TMK: 1-2-10: POR 1*. Prepared for Hawai'i Natural Energy Institute, University of Hawaii, Manoa, Honolulu.
- 1991c *An Inventory Survey and Subsurface Testing at TMK: 1-4-02: 13, 14, 24, 69, and 70, Puna, Island of Hawai'i*. State Historic Preservation Department. Honolulu.

Kikuchi, W.K.

- 1973 *Hawaiian Aquacultural System*. Ph.D. dissertation, Department of Anthropology, University of Arizona. Tucson.

Kirch, Patrick V.

- 1985 *Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory*. University of Hawaii Press. Honolulu.

Knapp, Rudiger

- 1975 *Vegetation of the Hawaiian Islands*. *Newsletter of the Hawaiian Botanical Society*. Translated by Alvin Y. Yoshinaga and Hugh H. Iltis. University of Hawai'i. Honolulu.

Komori, Eric K.

- 1987 *Cultural and Biological Resources Survey of the Pohoiki to Puna-Substation 69KV Transmission Corridor, Kapoho to Kea'au, Puna, Hawai'i Island*. Prepared for DMH Inc., Honolulu. Department of Anthropology, B.P. Bishop Museum. Honolulu.

Kuykendall, Ralph S.

- 1938 *The Hawaiian Kingdom, Volume I: 1778-1859, Foundation and Transformation*. Honolulu: University Press of Hawaii.

- 1967 *The Hawaiian Kingdom, Volume III: 1874-1893, The Kalakaua Dynasty*. Honolulu: University of Hawaii Press.

Ladd, Edmund J.

- 1965 *Chain of Craters Road, Hawaii Volcanoes National Park, Puna: Salvage Report*, edited by Richard Pearson. Social Science Research Institute. Honolulu.

- 1981 *Archaeological Survey Report, Cape Kumukahi and Kawaihae Light, Hawaii*. Prepared for the U.S. Coast Guard, Honolulu. State Historic Preservation Division, Department of Land and Natural Resources, State of Hawai'i.

Lamoureux, Charles H.

- 1973 *Plants*. In *Atlas of Hawaii*, edited by R. Warwick Armstrong. The University of Hawaii Press. Honolulu.

Lamoureux, Charles H. and W.P. Char

- 1985 *Puna Geothermal Area Biotic Assessment, Puna District, County of Hawaii*. Prepared for Hawaii State Department of Planning and Economic Development. Department of Botany, University of Hawai'i, Manoa. Honolulu.

Langlas, Charles

- 1990 *The People of Kalapana, 1832 - 1950*. Hilo: Charles Langlas.

Loebenstein, A.B.

- 1895 *Hawaiian Government Survey. Survey Map of a Portion of Puna, Hawai'i Showing Sea Coast Section from Pohoiki to Kahena*. Hawai'i State Survey Office.

Loo, Virginia H., and William J. Bonk

- 1970 *A Historical Site Study and Evaluation of North Hawai'i*. Prepared for the Department of Planning, County Hawaii. Archaeological Research International. Hilo.

Lyman, Chester S.

- 1924 *Around the Horn to the Sandwich Islands and California, 1845-1850*. New Haven: Yale University Press.

MacDonald, Gordon A and Agatin T. Abbott

- 1979 *Volcanoes in the Sea, The Geology of Hawaii*. The University of Hawaii Press. Honolulu.

Major, Maurice

- 1992a *An Archaeological Inventory Survey of the Pohoiki #2 Transmission Line Corridor, Puna District, Island of Hawai'i*. Prepared for Hawai'i Electric Company, Inc., Honolulu. Public Archaeology Section, Applied Research Group, B.P. Bishop Museum. Honolulu.

- 1992b *A Burial Report Concerning the Pohoiki N. 2 Transmission Line Corridor, Puna District, Island of Hawai'i*. Prepared for State Historic Preservation Division and Hawai'i Island Burial Council. Public Archaeology Section, Applied Research Group, B.P. Bishop Museum. Honolulu.

- 1993 *Monitoring Report Concerning the Pohoiki No. 2 Transmission Line Corridor, Puna District, Island of Hawaii*. Prepared for Helco, Honolulu. Public Archaeology Section, Applied Research Group, B.P. Bishop Museum. Honolulu.

Marques, A.

- 1909 The Pineapple Industry in Hawaii. In *Hawaiian Almanac and Annual*. Pp. 58-82. Honolulu: Press Publishing Co.

McEldowney, Holly

- 1979 *Archaeological and Historical Literature Search and Research Design, Lava Flow Control Study, Hilo, Hawai'i*. Report prepared for U.S. Army Engineer Division, Pacific Ocean, Honolulu. Department of Anthropology, B.P. Bishop Museum. Honolulu.

McEldowney, Holly and F.D. Stone

- 1991 *Survey of Lava Tubes in the Former Puna Forest Reserve and on Adjacent State of Hawaii Lands*. Prepared for the State Historic Preservation Division, Division of Water Resource Management, Department of Land and Natural Resource, State of Hawai'i. Honolulu.

Moore, Richard B. and Frank A. Trusdell

- 1991 Geologic Map of the Lower East Rift Zone of Kilauea Volcano, Hawaii. U.S. Department of the Interior. U.S. Geological Survey.

Nordyke, Eleanor C.

- 1989 *The Peopling of Hawai'i. Second Edition*. University of Hawaii Press. Honolulu.

Olson, Larry G.

- 1984 *Kapo Kohe Lele and the Puna Cave*. Report on file at Hawai'i State Historic Preservation Division. Honolulu.

Orr, John

- 1967 Unpublished Field Notebook on Excavations at Kahuwai. Ms. on file at Hawai'i State Historic Preservation Division Offices. Honolulu.

Peterson, D.W. and D.A. Swanson

- 1974 Observed Formation of Lava Tubes during 1970-1971 at Kilauea Volcano, Hawaii. *Studies in Speleology* 2:209-222.

Palama, Stephen L. and Richard M. Bordner

- 1976 *Emergency Escape Road Surface Survey: The Archaeology of Puna, Hawai'i, na Ahupua'a Kaimu a me Kalapana*. Prepared for Park Engineering, Inc. Archaeological Research Center Hawaii, Inc. Lawa'i.

Price, Saul

- 1977 Climatic maps. In *Atlas of Hawaii*, edited by R. Warwick Armstrong. Reprinted. Originally published 1973. The University Press of Hawaii. Honolulu.

Pukui, Mary Kawaena and Samuel H. Elbert

- 1971 *Hawaiian Dictionary*. Honolulu: University Press of Hawaii.

Pukui, M.K., S.H. Elbert and E.T. Mookini

- 1974 *Place Names of Hawaii*. Honolulu: University Press of Hawaii.

Ripperton, J.C. and E.Y. Hosaka

- 1942 Vegetation Zones of Hawai'i. *Hawai'i Agricultural Experiment Station Bulletin* 89:1-60.

Rogers-Jourdane, Elaine H. and Barry Nakamura

- 1984 *Archaeological Reconnaissance and Historical Surveys of Lands at Kapoho, Puna, Hawai'i Island*. Ms. in Department of Anthropology, B. P. Bishop Museum. Honolulu.

Rosendahl, Paul H.

- 1985 Archaeological Field Inspection, BioPower Project Area, Kapaahu, Kaunaloa, Hulunani, Kupahua, and Kalapana, Puna District, Island of Hawai'i. Letter report prepared for the Estate of James Campbell.

Rycroft, Robert

- 1894 Coffee Culture in Puna, Hawaii. In *Paradise of the Pacific*. August P.99.

Scott, Susan

- 1991 *Plants and Animals of Hawai'i*. Bess Press. Honolulu.

SHPD (Hawai'i State Historic Preservation Division)

- 1989 Title 13 Department of Land and Natural Resources, Subtitle 6 Division of State Parks, outdoor Recreation & Historic Sites, Chapter 146 Rules Governing Procedures for Historic Preservation Review. Outside Draft #2. Ms. on file at Hawai'i State Historic Preservation Division Offices, Department of Land and Natural Resources. Honolulu.

Smart, C.

- 1965 *The Archaeological Resources of Hawaii Volcanoes National Park*. B.P. Bishop Museum. Honolulu.

- Sohmer, S.H. and R. Gustafson
1987 *Plants and Flowers of Hawai'i*. University of Hawaii Press. Honolulu.
- Soehren, L.J.
1963 Field Book No. 1, Kahuwai Village, in author's possession.
- Somers, Gary F.
1991 The Effects of Rapid Geological Change on Archaeology in Hawai'i. *Asian Perspectives* 30(1):133-145.
- Stannard, David E.
1989 *Before the Horror, The Population of Hawai'i on the Eve of Western Contact*. Social Science Research Institute, University of Hawaii. Honolulu.
- Stokes, John F.G.
1991 *Heiau of the Island of Hawai'i: A Historic Survey of Native Hawaiian Temple Sites*. T. Dye (ed), Bishop Museum Press. Honolulu.
- Swanson, D.A.
1973 Pahoe flows from the 1969-1971 Mauna Ulu Eruption, Kilauea Volcano, Hawai'i. *Geological Society of America Bulletin* 84:615-626.
- Sweeney, Maria T.K. and Greg C. Burchard
1994 *Archaeology in the Kilauea East Rift Zone Part II: A Preliminary Sample Survey, Kapoho, Kamā'ili and Kilauea Geothermal Subzones, Puna District, Hawai'i Island*. Draft report prepared for Oak Ridge National Laboratory, Oak Ridge, Tennessee, International Archaeological Research Institute Inc. Honolulu.
- Thrum, Thomas G.
1895a History of Coffee in Hawaii: Its Introduction, Success and Decline. In *Hawaiian Almanac and Annual*. Pp. 63-64. Honolulu: Press Publishing Co.
1895b Coffee Outlook in Hawaii. In *Hawaiian Almanac and Annual*. Pp. 65-68. Honolulu: Press Publishing Co.
1895c Coffee Growers Throughout the Islands. In *Hawaiian Almanac and Annual*. Pp. 146-149. Honolulu: Press Publishing Co.
1896 Table of Coffee Growers Throughout the Islands. In *Hawaiian Almanac and Annual*. Pp. 160-162. Honolulu: Press Publishing Co.
1897 Table of Coffee Growers Throughout the Islands. In *Hawaiian Almanac and Annual*. Pp. 161-163. Honolulu: Press Publishing Co.
1898 Table of Coffee Growers Throughout the Islands. In *Hawaiian Almanac and Annual*. Pp. 179-183. Honolulu: Press Publishing Co.
1899 Table of Coffee Growers Throughout the Islands. In *Hawaiian Almanac and Annual*. Pp. 177-182. Honolulu: Press Publishing Co.

Thrum, Thomas G. (continued)

1909a Retrospective for 1908. *Hawaiian Almanac and Annual*. Honolulu: Press Publishing Co.

1909b Heiaus and Heiau Sites Throughout the Hawaiian Islands. Island of Hawaii. *Hawaiian Almanac and Annual* for 1909:38-43. Honolulu.

1910 Hilo and the Island of Hawaii. In *Hawaiian Almanac and Annual*. Pp. 129-135. Honolulu: Press Publishing Co.

True (True/Mid-Pacific Geothermal Venture)

1982 *Environmental Impact Statement for the Kahauale'a Geothermal Project*. By True/Mid-Pacific Geothermal Venture in coordination with The Trustees of the Estate of James Campbell. Honolulu. Prepared for The Board of Land and Natural Resources, State of Hawai'i. Honolulu.

Weisel, Dorian and Frankie Stapleton

1992 *Aloha o Kalapana*. Honolulu: Bishop Museum Press.

Yent, Martha

1983 *Survey of a Lava Tube, Pahoa, Puna, Hawaii Island*. Report for Department of Land and Natural Resources, Divisions of State Parks (Historic Sites) and Forestry. On file at Hawai'i State Historic Preservation Division. Honolulu.

Yent, Martha and Jason Ota

1982 *Archaeological Reconnaissance Survey of Nanawale Forest Reserve, Halepua'a Section, Puna, Hawai'i*. On file in Division of State Parks and Historic Sites, Department of Land and Natural Resources, State of Hawai'i.

APPENDIX A: PUNA FOREST RESOURCES¹⁹

<u>Name</u>	<u>Genus</u>	<u>Uses</u>
'ōhi'a lehua	<i>Metrosideros</i>	traditional: carved images, spears, mallets. commercial: flooring, furniture.
'ākia	<i>Wikstroemia</i>	traditional: bark used as fiber; bark, roots and leaves used as fish poison.
'ie'ie	<i>Freycinetia</i>	traditional: one of five plants used on the hula altar. Also used for basketry.
lama	<i>Diospyros</i>	traditional: wood used in medicine, on hula altars, and for hut construction.
māmaki	<i>Pipturus</i>	traditional: bark used for making coarse <i>kapa</i> .
olomea	<i>Perottetia</i>	traditional: hard wood used with the soft <i>hau</i> wood to produce fire; plant form of god Kamapua'a.
pilo	<i>Coprosma</i>	appears to have had little value as it's name was used as a generic term; eg. <i>I lei paha no kākou</i> , 'a'ohe <i>pilo lei</i> --let's wear leis, any kind of leis.
'ahakea	<i>Bobea</i>	traditional: poi boards and canoe rims.
alani	<i>Pelea</i>	traditional: fragrant leaves used in scenting <i>kapa</i> ; bark used in medicine.
maile	<i>Alyxia</i>	traditional: decoration and leis; one of five plants used on the hula altar; bird catching.
ōpuhe	<i>Urera</i>	traditional: bark used for fishing nets.
kōpiko	<i>Psychotria</i>	none given.
hāpu'u	<i>Cibotium</i>	traditional: young shoots were used to make hats; the <i>pulu</i> fibers were used as a dressing and to embalm the dead. commercial: <i>pulu</i> fibers were used for stuffing pillows and mattresses, and making plant baskets; the starch core has been used in cooking and for doing laundry.
uluhe	<i>Dicranopteris</i>	none given.
pala	<i>Marattia</i>	traditional: frond stems baked for famine food; soaked stems were used in medicine; stems were mixed with <i>maile</i> to enhance its smell and the fern was used in <i>heiau</i> ceremonies.
hō'i'o	<i>Athyrium</i>	commercial: young fronds can be eaten raw and are good with fresh water shrimp or salted salmon; used cooked in Oriental cuisine; was formerly sold at markets.
hāhā	<i>Cyaneapilosa</i>	traditional: 1) <i>hā</i> , with edible fruit and bark used in coloring <i>kapa</i> ; or 2) <i>hāhā'aiakamanu</i> , which was used for catching birds.

¹⁹From Holmes (1985) and Pukui and Elbert (1971).

Plants found most *Mauka*, inland

'ōlapa	<i>Cheirodendron</i>	none given.
kāwa'u	<i>Ilex</i>	none given in Pukui; Andrews says it was used "somewhat" for canoes and other things.
manono	<i>Gouldia</i>	none given in Pukui; Andrews it was used for parts of the canoe.
kanawao ke'oke'o	<i>Cyrtandra</i>	none given.
kanawao	<i>Broussaisia</i>	traditional: was believed that eating fruit helped in fecundity.
'ōhā	<i>Clermontia</i>	traditional: see <i>hāhā</i> above, note 5.
ānini	<i>Eurya</i>	none given.

Marker Plants for Possible Prehistoric Human Use Localities

Plants listed below are Polynesian introductions commonly associated with prehistoric Hawaiian residential and/or agricultural areas. Included species are fairly competitive and generally able to survive in a feral state. All have been observed in the project area (though their specific locations seldom recorded). The locations of these plants, particularly when co-occurring in mixed stands, provide an indirect indication of past human use.

<u>Common Name</u>	<u>Hawaiian Name</u>	<u>Taxon</u>
candlenut	<i>kukui</i>	<i>Aleurites moluccana</i>
ti	<i>ki</i>	<i>Cordyline fruticosa</i>
yam	<i>pi'a</i>	<i>Dioscorea pentaphylla</i>
bitter yam	<i>hoi</i>	<i>Dioscorea bulbifera</i>
kava	<i>'awa</i>	<i>Piper methysticum</i>
shampoo ginger	<i>'awapuhi</i>	<i>Zingiber zerumbet</i>
Hawaiian bamboo	<i>'ohe</i>	<i>Schizostachyum glaucifolium</i>
pandanus (not introduced)	<i>hala</i>	<i>Pandanus tectorius</i>

Other plants of interest are:

coconut	<i>niu</i>	<i>Cocos nucifera</i>
mango (historic introduction)	<i>manako</i>	<i>Mangifera indica</i>
avocado (historic)	<i>pea</i>	<i>Persea americana</i>
jackfruit (historic)	<i>?</i>	<i>Artocarpus heterophyllus</i>
coffee (historic)	<i>kope</i>	<i>Coffea arabica</i>

APPENDIX B: LAND COMMISSION AWARDS IN THE PROJECT AREA

<u>LCA No.</u>	<u>Land Name</u>	<u>Grantee</u>	<u>Notes</u>
4452 ²⁰	Kula	Kalama	Kula appears to be one of 18 properties awarded by the Privy Council on Aug. 29, 1850; R.P. 7483; LCA book 10:467 'apana 1
8452	Puua	Keohokālōle	Part of a massive claim including land at 23 locations on Maui, Kona, Hilo and Oahu; listed LCA bk. 10:431; R.P. no. 7788 bk. 29:125; N.R. 5:567; F.T. 3:573; N.T. 10:326.
8559-B	Keahialaka	W.C. Lunalilo	One of 44 properties claimed throughout the islands. LCA book 10:479; R.P. 8088 & 8094, 32:55, 35:1; no testimony or register
9971	Pū'āla'a	Leleiohoku	Claim included land in 43 locations; recorded LCA bk. 10:609; N.T. 4:502; R.P. no. 7714 bk. 29:53; F.T. 10:439-50; N.T. 10:210,433,445.
11216	Waiakahiula	Kekauonohi	Part of a large grant at 58 locations, including Maui, Hawaii, Oahu, Kaua'i and Moloka'i.

All of these people held high chiefly rank and the claims above are for entire *ahupua'a*. Because their claims were so massive, there is scant description of lands except for the property where they resided at Honolulu.

Kalama, Hakaleleponi Kapakuhaili: dowager queen; b. Kailua 1817; d. Hon. Sept. 20, 1870; married King Kamehameha III.

Kekauonohi, M.: (Keahikuni); d. Hon. Jn. 2, 1851; granddaughter of Kamehameha I.; one of Kamehameha II's wives, also married Keliiahonui after the death of Kamehameha II.

Keohokālōle, Ane: d. 1896; Ali'i Nui, daughter of 'Aikanaka and Kamae, mother of David Kalākaua, who succeeded Lunalilo on the throne.

Leleiohoku, Wm. Pitt: d. Hon. Oct. 21, 1848; son of Kalanimoku (Karaimoku or Billy Pitt); married sister of Kamehameha II and III (Harieta Nahienaena).

Lunalilo, Wm. C.: sixth monarch of Hawaii; grandson of a half-brother of King Kamehameha I. Succeeded Kamehameha V to the throne in 1873.

²⁰ The LCA number, 4459, which appears on the 1904 copy of Registered Map 2192 appears to be an error. Claim 4459 was not Granted.

APPENDIX C:
PUNA DIRECTORY, 1880²¹

<u>Name</u>	<u>Occupation</u>	<u>Address</u>	<u>P.O.</u>	<u>Acres</u>	<u>Planted</u>
Mrs. Haula'a	Taro planter	Okī	Kalehua	20	2
Hoomana	Potato planter, etc.	Kapaahu	Kapaahu	200	2½
Ili, John	potato planter, etc.	Kalapana	Kalapana	434	1½
Kaaihili, D.H.	potato planter, etc.	Kalapana	Kalapana	280	3
Kaimuloa	taro planter	Makuu	Makuu	70	1½
Kalahoolewa	land owner	Kalapana	Kalapana	31	--
Kalaokahaku	rice planter	Opihikao	Kalehua	220	2½
Kaloi	potato planter	Kapa'ahu	Kapa'ahu	12	1
Kanakaole, Samuel & Co.	potato planters	Kalapana	Kalapana	80	1½
Kanoa	landowner	Kehena	Kalehua	7	--
Kapahee	coffee planter	Halepuaa	Halepuaa	136	3
Kapai	landowner	Kaukulau	Honolulu	31	--
Mrs. Kapela	widow	Kaohe	Honolulu	277	--
Kapuaikahikina & Napuaika	potato planters	Kalapana	Kalapana	70	1
Kea	taro planter	Makuu	Makuu	50	3
Keahi	potato planter, etc.	Kanekiki	Kanekiki	5	2
Keaweopela	landowner	Honolulu	Honolulu	350	--
Kekino	landowner	Halepuaa	Halepuaa	5	--
Kelemenekē	landowner	Opihikao	Kalehua	11	--
Kiakahi	taro planter	Makuu	Waipio	5	1½
Kilua	landowner	Okī	Kalehua	15	--
Kuana	potato planter, etc.	Kapaahu	Kapaahu	124	2
Kuhaupio	taro planter	Opihikao	Kalehua	16	2
Kumahoa	coffee planter	Okī	Kalehua	370	3
Makua	taro planter	Malaana	Malaana	25	3
Makuakane	potato planter, etc.	Opihikao	Kalehua	52	1
Maluo	taro planter	Opihikao	Kalehua	110	3
Manoa	wood cutter	Opihikao	Kalehua	127	trees
Paakaula	potato planter	Kaimu	Kaimu	130	5
Paku	potato planter	Kapaahu	Kapaahu	62	1
Pea	landowner	Panau	Kaluapele	78	--
Perry Frank	land owner	Koae	Koae	33½	--
Piihonua	potato planter	Kalapana	Kalapana	31	2½
Robert Rycroft	coffee planter	Pohoiki	Pohoiki	660	40
Shipman & Elderts	grazier & dairy	Kapoho	Kapoho	93,979	pasture & trees

²¹ Source: Bowser 1880.

**APPENDIX D:
TRAIL AND PLACE NAMES, LOEBENSTEIN'S 1895 MAP OF PUNA**

Trails Shown:

1. "Government Road"; follows coastline, connecting villages
2. "Ancient Kipapaia Trail" By Kamaili & to Gr. 1023 (from Kamā'ili Village).
3. "Approx. Location of Ancient Trail from Kamaili to Kamaa" (Gr. 3195--portion with in Kamā'ili sub-zone).
4. "Kauaeleau Trail to 'Opihikao"
5. Fragment of "Ancient Kauaea trail from Kiiikii"
6. "Short-cut to Malama Trail"
7. "Trail from Malama opening to seacoast"
8. "Kehena Trail"
9. "Ancient Trail to Kaukulau"
10. "Coney's Trail to Keahialaka beach"
11. Rycroft's Road
12. "Trail to Kapoho"
13. "Short-cut to 1840 flow" or Kalo
14. unnamed trail through Halekamahina
15. Trail to Malama
16. Puna Rd.
17. To Pakeepakee and Pahulu, Kehena and Malama
18. Kahena Trail

Place Names:

Pakeepakee
Kukuihala
Kama'a
Kauaeleau
Kiiikii (Kipuka)
Malama opening
Koma
Kaukulau
Papuaa opening

These appear to be the names of openings or *kīpuka* in the lava flows. Some of them show houses and others are designated as "cultivation land." Most of the trails terminate at or cross these areas.

Trails and Roads

19. Upper Puna Road
20. Road to Kupahua Homesteads
21. Unnamed Trail in Kalapana

APPENDIX E: PUNA HISTORY RESOURCES

Resource Persons

Charlene Dahlquist, archivist
Lyman Museum Library
276 Haili, Hilo, HI
phone: 935-5021

Museum hours are M-Sa. 9-5; Sun. 1-4. Charlene is normally at the library Mon., Wed., Fri., and should be called for an appointment since the library isn't open if she's not there.

Ian Birnie, Harbor-master, Hilo
Volcano
phone: 969-9990, 967-8181
for information on trains (referred by Ms. Dahlquist)

Dolores Marvin
13-3622 Luana St., Pāhoa, Hawaii
phone: 965-9307
Resident of Pāhoa, volunteer at Lyman museum; knows location of Rycroft's coffee mill and other historic sites in and around Pāhoa (referred by Ms. Dahlquist)

Roy Blackshire
Keaau
phone: 966-9711
Mr. Blackshire is a Shipman descendant. For information on ranching; access to Shipman holdings (referred by Holly McEldowney)

Emmett Cahill
Volcano
phone: 967-7413
in regards to Shipman Ranch (referred by Holly McEldowney)

Virginia Goldstien
Hawaii County Planning Department
County Building
25 Aupuni St., Hilo, HI 96720
phone: 961-8288

Charles Langlas
EKH 264
University of Hawaii at Hilo
Hilo, HI
phone: 933-3465
compiled report on Kalapana Oral History Project

Lyman Museum, Hilo

Photographs of Puna

Hawaiian Islands Collection Strips

Album I

Strip #6

- 1 Lower Puna Transportation, horse drawn cart in forest

Strip #8

- 5 Black Sand Beach
- 6 Kalapana lagoon

Strip #16

- 4-6 Warm Springs < 1960

Strip #20

- 1-6 Warm Springs

Strip #21

- 1-5 Puna coastline
- 6 Old Hawaiian Trail, Puna-Kalapana (people on horseback, on slope with sparse vegetation)

Strip #22, Coastal scenes, '24 earthquake

Strip #24 Nellie Thrum Album, ca. 1900?

- 5 Green Lake, Puna

Strip #36

- 2 Old Coffee Mill, Puna (taken in 1959) identified by Ms. Dahlquist as that she'd seen near McKenzie Park, Rycroft's. The mill in Pohoiki is listed as a registered State Historic site in the Puna Community Development Plan, 1992. Registration, however has not been made with the Hawai'i State Historic Preservation Division.)

Strip #46 Lyman Collection

- 6 Pāhoa sawmill, (shows mill and tracks)
- 5 Old Kapoho Station, Puna

Strip #47

- 1 cinder hill, Puna
- 2 Quarry, train hauling rocks from Quarry, Puna
- 3 Quarry, Puna
- 4 Puna Home (Lyman's?)
- 5-6 Green Lake

Strip #48, Lyman Collection

- 1 Pāhoa
- 2 Cinder Hill (distant)
- 3 Lava tree mound
- 4 Lava Arch, Puna
- 5 Kapoho Plantation (sugar) Puna
- 6 Lava trees, Puna

Strip #49, Lyman Collection

- 1 lava arch
- 2 Coconut grove near Warm Springs

Strip #57

- 3 Hawaiian Association Meeting, Kalapana (at church, 19th century)
- 4 View of Kalapana

Strip #64, Nellie Thrum (daughter of Thomas)

- 1 Green Lake, Kapoho (panorama)
- 5 Coffee Planters Association Meeting at Mountain View
- 6 Old Sugar Mill? (location not given)

Strip #66, Nellie Thrum

- 3 Pohoiki landing (not very clear)

Strip #67, Nellie Thrum

- 2 Green Lake
- 3 Pohoiki?

Strip #69

- 3 Green Lake, Puna
- 4 Kaimū, Kalapana, Puna (coast)

Strip #70

- 5 Green Lake
- 6 Warm Springs

Strip #71

- 1 Warm Springs
- 2-3 Pohoiki (coast, coconut grove)

Strip #72

- 6 Green Lake (fairly good, 1898?)

Strip #73

- 2 Warm Springs
- 4 Lauhole

Album I-B Strips 1347-1420

1388-

- 2 Pohoiki Village, 1916 (Rycroft Home?, could be coffee mill in background)

1391-

- 3 Kalapana Rd, 1916

1400-

- 5 Horse-drawn coach on Rd., Puna (forest)
- 6 Puna Road

1404-

- 3 Kalapana Puna (clear print)

1406-

- 1-4 Hakalau Sugar (in South Hilo District)
- 5 Green Lake
- 6 Warm Spring

Wessel Collection LHMM Prints

L.86.4.-

- 116 logging
- 214 lumber mill
- 215 lumber mill
- 216 stock lumber
- 217 mill interior
- 218 lumber yard
- 219 coffee plant
- 220 Coffee plantation
- 245 train hauling rocks

B.P. Bishop Museum

Photo Collection

Agriculture, Coffee

- general, picking raising, etc. some same as State archives
- + Coffee mill near Pahoa, Hawaii, ca. 1934 [probably Rycroft's] neg. #CP97033
- Coffee grove at Ōla'a (post card) coffee trees
- + Robert Rycroft (out standing in his field); photo printed in Paradise of the Pacific. no negative; thus add \$8 to cost of print
- Forest scene, coffee planted among trees ('ōhi'a) ABM 3826 (next is better)
- Coffee in cleared forest, ABM 3825

Ranching

- numerous general ranching photos,
- Ranching and coffee photos from Charles Furneaux, ca. 1890 look like may be Puna

Lumber Mills

- Lumber Mill in Pahoa, (from 1911, Paradise of Pacific, P.19) Neg. # 49011

Ethnic Culture, Hawaii

Recreation, Sledding

- Restored *Hōlua* sled; neg. # G23577, a-f
- Old Sled, detail of (lashing, etc.) neg. # CP38090-B and A; also #CP96587 and 96586
- Man laying on sled, titled "Holua sliding" neg. no. CP96349 [no date, but photo is yellowed, looks like staged in museum (rather Boasian), would guess early part of century, shows how sled was used]
- Man holding reconstructed sled upright, 1957 no. BM50131, similar 28855
- Man posed with sled (on a lawn) ca. 1930s? titled "Ready for Speed-thrill on Hawaiian Holua" from Pan-Pacific Press BM33007

Geography, Hawaii

Kalapana

- village ca. 1890
- coconut grove ca. 1900
- many shots of Puna Road
- Kaimu (also in Black Sand Beach file)
- misc. shots of scenery, beach

Puna

- Pahoa, 1965, and 1973
- Keaau, 1973
- Kamoamoa canoe landing, 1931 neg. #CN; also canoe landing detail
- Puna earthquake damage (ca. 1920s)
- Lyman Estate, 1949
- Road to Puna, CP96551
- 'Ōhi'a forest. 1955.187
- Coconut Groove, Keaau, no negative
- People with Canoe, ca. 1900?, no negative, photo no. 2047
- Man standing in rift in roadway after earthquake (up to his shoulders)
- "Destroying 'ōhi'a forest" with bulldozer (Castle & Cook) Neg. #CP112,174

- Downed 'ōhi'a
- Many spectacular eruption photos
- Series of photos from an album
 - Earthquake damage to railroad & lava damage
 - ca. 1920, "people waiting for the lava flow" at Hoopuloa #31992.220.32 (in South Kona District, destroyed by lava flow in 1926)
 - "Village wiped out" (by lava) 1992.220.31
 - more earthquake damage
 - + Evacuation of Kapoho area because of eruption (shows people with suitcases #1992.220.24)
- Opihikao, 1924, coastline
- Puna Road through sugar fields, 1917; no neg. from album 1986.03 page 7
- Puna settlement, 1880s, from stereo slide #121
- Puna, Kapoho (farm scene) 1892 from 1967.289.1 #579; similar image 1967.289.2 #128
- From Album no. 1978.04 p.36
 - Beach at Pohoiki with canoe
 - Mr. George Watt
 - Watt family
 - Old Rycroft house
- Puna Sugar Co. fields, c.1905 album 1985-648.02 #31
- "The Illustrious town of Ōla'a, entire and complete, from Volcano Rd." c. 1890, album 1986-153.04 #32; also:
 - .04 #29 (detail of grass house)
 - .04 #6 (detail of wood house)
 - .04 #37 (grass house)
- Puna fishing scene, 1905, neg. #103.652 [people on beach with canoes, etc.]

Puna-Green Lake

- scenic lake starting 1890, many views
- Pump plant for Lyman Ranch c. 1912; #1988.348

Puna, Hot Springs

- at Kapoho, 1916; #1978.484e
- many others, not identified
- with bath house, c. 1891; album 1986.153.03 #45, & 153.06 #34 (P.L. Lord, photographer)

Puna, Lava Formations

- fern tree lava mold
- Lava tree molds and various formations from 1890

Manuscripts

Hawaiian Ethnological Notes (HEN)

File headings pertinent to Puna include:

1. Birds and Bird catching
2. Kapa
3. Historical Objects (eg. Henriques: Sled; "sled of chiefess" from Pac. Advertiser)
4. History
5. Places, Hawaii (various legends from and about locations)
6. Plants, Planting (cultivation and use of various plants)

Manuscript card file

Puna: Anthropology Department MS. #072484 by Elaine Haunanai Jourdane, Archaeology Reconnaissance with short history note by Barry Nakamura and political history by Dorothy Barrère.

Dictionary Catalogue of the LibraryPuna

McDonald, Gordon A.

1941 Lava Flows in Eastern Puna, Volcano letter 474:1

Polynesian

1845 Ruins on the Shore of a Lake in Puna. Extracts from the *Polynesian* Mar. 8.

Coffee

Hawaii, Republic of

1896 Coffee the Coming Staple Product. Dept. of For. Affairs report, p. 95. Honolulu

Miller, Charles D.

1895 Coffee Planting in Hawaii. *Overland Monthly* 25(150)669-675.

Museum Library Holdings

Landgraf, Anne Kapulani

1987 E nea hulu Kupuna nea puna ola naoli neo. (oral histories)

Beamer, Winoa Desha

1984 *Talking Story with Nona Beamer*. (folk tales)

Bostwick Jr., Burdette E. and Brian Murton, Ed.s

1971 *Puna Studies*: Preliminary research in human ecology. UH

Nakuina, Moses K.

1972 *Moolelo Hawaii o Kalapana, Ke keiki hoopapa o Puna: ka mea hana ko olelo o Lono-a-ipu ika kamaeu nuna i hoopahu a o Kalanialiiloa, ke alii hoopapa o Kauai*. BPBM MS.

Hawaiian Mission Children's Society LibraryManuscripts:

Mission Reports

Chester Lyman journal, photocopy of original

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