Guinther brush clearing trail at the marsh restoration site

Student volunteers working on mitigation islet

Sampling well A-5 with drop-line and writing slate

Montgomery setting fish trap in marsh

Moye and student retrieving core sample

Marsh restoration area, south end on I-25-03

Section VI. DISCUSSION

RELATIONSHIPS BETWEEN HISTORIC AND MODERN FEATURES

Although our report cannot purport to draw all of the connections between the Kawai Nui Marsh present on the landscape today and the geological processes and human activities that have influenced the modern form, much of this story is believed known and can be summarized. As well, is it important to understand, on a smaller scale, what features described in the geological and historical discussions above express themselves in the vicinity of Na Pohaku o Hauwahine, in order to put our work in perspective for the marsh overall.

For the bigger picture, the work of Kraft (1980) drawing as well upon geological explorations of others, tells us that the marsh started on its physiomorphic path when a deep valley was carved into the Ko'olau shield over 10,000 years ago. The depth of this valley relative to the present-day landscape was enhanced by the lowered base level of a low stand of the sea. This enabled the streams to cut a valley deep enough, that upon the rise of sea level following glaciation, an embayment formed. That embayment was populated by tropical marine reef organisms, and the reef and reef debris deposits gradually filled the basin, perhaps more from the front back than vice versa. The bay became enclosed, much like present-day Kāne'ohe Bay behind a barrier reef. The usual reason given (originally by Darwin, 1842) for this uneven growth leading to a lagoon is that the organisms responsible for the most rapid reef growth are the corals and coralline algae that do better on the seaward face than on the lagoon face of any reef. Perhaps the fact that this process involved rising sea level also helped. The reef would have started upward growth on a platform at the mouth of the incipient bay.

We also strongly suspect from the stratigraphy, that after a long period of reef growth, changes occurred inside the bay or lagoon that enhanced its isolation from the ocean, changing the nature of the aquatic environment from one that was clearly homoiohaline marine, to one that was increasingly brackish, and perhaps poikilohaline. The significance here is that organisms that produce essentially external calcareous skeletal material (like the corals, calcareous algae, mollusks, tube worms, etc.) become increasingly excluded as the average pH declines. In marine waters, it is not energetically taxing to precipitate calcium carbonate for skeletal support and protection. It is in brackish water, with lower pH and lower calcium concentration. Closer examination of the marine fossils in the stratigraphy might reveal more about the subtle changes occurring over time, but the composition revealed so far is that of an enclosed bay (like Kaneohe Bay). Deeper cores made further out towards the mouth might reveal a community make-up that is more open coast, but this information is presently lacking.

The exact sequence of changes that occurred during this closing off of the lagoon is not known. The stratigraphy reveals a change to deposition of predominantly silt and clay, as might typify an enclosed body of water such as a lake or lagoon.

The stratigraphic sequence is potentially interrupted at the point where Kawai Nui is clearly no longer a coastal lagoon. Above the clay layer occurs a layer of peat, indicative of continuous inundation with fresh (or weakly brackish) and anoxic water. At times, or all of the time in some places, this layer separates from the underlying sediment, leaving a slurry of organic rich mud and intervening water. This process of separation is possibly destructive of the lowest layers of peat. However, the work by Moye and his students (Section III) appears to indicate a sequence in the floating peat from bottom to top showing a changing pattern of vegetation that crosses the 1779 boundary[26] used by botanists to separate native (indigenous, endemic, and early Polynesian introductions) from non-native or naturalized species brought in increasingly during the 19th and 20th centuries.

It is somewhere in this sequence, that the Hawaiians arrived in the area. It is presently only speculation whether they could have sailed into the lagoons (for there was also Kaelepula to the east). Hawaiian legends cited in Kelley and Nakamura (1981) deal with subjects that mostly suggest a brackish or poikilohaline environment:

- *…ka manu o ka loko o Kawainui ma Ko'olaupoko, O'ahu.*
- The *akua mo`o Hauwahine* as the guardian spirit of Kawai Nui.
- And her companion who belonged at the "hala grove down there ….near Kaelepulu Stream."
- The *lepo'ai'ia*, or edible mud of Kawai Nui, supposedly originally brought there from *Kahiki*.

Is it reasonable to imagine an embayment open enough to receive sea-going canoes that changed, within the early generations of Hawaiians, into a fish pond as asserted by Kraft (1980)? Athens and Ward (1991) have suggested that the embayment was sealed off during the first millennium BC as a result of a drop in sea level (see also Hammatt, et al., 1990; Mann and Hammatt, 2003). Most likely Kawai Nui was by the arrival of the earliest Polynesian settlers, a more-or-less but not completely isolated (from the sea) body of water and probably brackish.

[26] This is not intended as an absolute dating point, but as a functional temporal marker. Obviously alien wetland plants will not appear in the stratigraphic sequence before they were introduced to the Hawaiian Islands or even before they arrived (sometime later) at Kawai Nui. We can use the first date (introduction to Hawaii) on a species by species basis as a conservative temporal marker to indicate a layer formed sometime after that date.

We note that even in historical times, effort by way of weirs, was expended to isolate the wetlands of Kaelepula and Kawai Nui from the influence of the tide, lest these become salty and unsuitable for agriculture. In the time before written history, the Hawaiians would have made advantage of the estuarine nature: a fish pond or *loko pu'uone* as the receiving water of the discharges from *lo'i kalo* located closer to the mountain source of their fresh water. This arrangement would be traditional (McAllister, 1933).

Summers (1964) relates that this fish pond existed and was perhaps 180 ha in extent. But where was this pond? Since infilling of the isolated basin or lagoon would have been most rapid off the mouths of the tributary streams (Kapa'a, Kahanaiki, and Maunawili), it seems likely the pond would have been at the *makai* end of the basin, its northern shore the sand barrier separating the pond from Kailua Bay (now Coconut Grove). Assuming that the width of the basin has changed little (indeed, Kraft and others speculate that there were natural outlets at either end of the barrier in approximately the locations of these "outlets" now), a feature of 180 ha extent would be satisfied by the dimensions 1920 m (width of the barrier) by 940 m (180 ha is 1,800,000 m^2). The distance from the shore at Na Pohaku to the levee, on a line generally perpendicular to the levee, is approximately 1130 m. It is very possible then, that the size of the pond related by Summers (1964) is just about that area shown in the Hawai'i Territorial Survey Map of 1908-1913 and labeled "Kawainui Swamp" (Figure II-2). To answer the question, where exactly was the ancient *loko pu'uone*, the answer is all of the present-day marsh between the levee and a line roughly drawn from Na Pohaku o Hauwahine (a conspicuous point on the western shore) to Ulupo heiau on the eastern side.

Smith (1978) concluded that this fishpond was brackish and surrounded by bulrush (*Schoenoplectus* or something similar; we would suggest *Bulboschoenus maritimus*, a native bulrush fairly tolerant of saline water), and the pond was kept clear of vegetation through massive annual efforts of the residents (citing McAllister, 1933 and Summers, 1964). It is known that areas along Kawainui Stream down to Kaelepula were in *lo`i kalo*, so it seems unlikely that the pond was much if at all brackish, or an *auwai* existed that diverted fresh water from above Kawai Nui to these fields (recall that rice growers in the area maintained weirs on Kawainui and Kaelepulu Streams to prevent incursion of salt water). The channel that has replaced Kawainui Stream is saline today (Smith, 1978; *AECOS*, 1992a, b) and no longer receives flow from the Maunawili streams.

The Territorial Map shows the lands interior to the "swamp"/former loko as divided into fields of rice. These pondfields were formerly all *lo'i kalo*. The complex land dealings in the ahupua'a of Kailua from before recorded time involved mostly lands

beside the marsh and on the uplands. The largest parcel within the marsh area was the *ili* of Kawainui. It was awarded to Queen Kalama and included the fishpond and immediate surrounding wetlands (TMK 4-2-16). From Kelley and Nakamura (1981, p 25):

> The Land Commission Awards [during the Mahele] to commoners in the area surrounding the marsh seemed to concentrate in the two extremities of the marsh area, with a few scattered between. One concentration in the area under consideration was the *'ili* of Oneawa and Ka'eleuli, located in the northwestern edge of Kawainui Marsh (TMK 4-2-15). The other large concentration was at the southern border of the marsh, *makai* of Kalanianaole Highway (TMK 4-2-13).

The fishpond at Kawai Nui remained so at least well into the 19th century (Kelly and Nakamura, 1981), and we may presume, the early 20th Century. Bowser visiting Kawai Nui in 1880 (reproduced in Kelly and Nakamura, 1981, p. 46) described the area as follows:

> To my left as I looked …[seaward] was the valley of Kawainui, about one-fourth of which is already laid out in rice plantations. ….In the bosom of the valley there is a large pond or lake celebrated for its mullet and ava. The latter fish grows here to four feet in length. Wild duck and the famous Hawaiian goose [nene] are also to be found here in abundance.

It is evident in maps from the period (reproduced in Smith, 1978, figs 3 and 4)[27] that by this time marsh vegetation predominated over open water area. Both maps show an outline of the "marsh" (generally the same as described above) within which is shown one large and two smaller bodies of open water. Indeed, the 1890 map indicates two *auwai* cutting across the marsh towards the open water. It is difficult to envision what these might be without there being either exposed soil or thick marsh vegetation in the area. They are located to suggest drainage from the upper, pond fields (then in rice) in Kawai Nui. However, we point out that the suggested hydrology is inconsistent with Smith's (1978) contention that water level in the marsh was forced to rise to + 1 m msl by impoundment around 1878 to serve as a source of irrigation water for Waimanalo.

Sugar cane development in relatively dry Waimanalo followed closely on the heels of the 1876 Reciprocity Treaty with the United States that allowed importation of Hawaiian grown sugar duty free into the U.S. The Waimanalo Sugar Company initially utilized water diverted from upper Maunawili Valley through a series of flumes, ditches, and tunnels constructed in the 1870s. By the 1920s, tunnels were excavated into the base of the Ko`olau to increase flow. It was at this time (1923)

[27] Fig. 3 is an 1890 map at the Bishop Museum, and Fig. 4 is drawn from an 1899 map by W.A. Wall.

when a system of pumps, pipes, and ditches were completed to move water directly from the marsh to the Waimanalo Irrigation System (Mann and Hammatt, 2003). It is therefore not likely that Kawai Nui Marsh would, as suggested by Smith, be forced to a higher level by impoundment until 1923. And therefore the period after 1878 was more likely one of low (or at least "normal") water level in the marsh. Upstream diversion would have promoted incursion of saline water unless measures had been taken to prevent this; and certainly upstream diversion could have enhanced coverage by wetland vegetation at the expense of open water features.

The situation of elevated water levels prevailed from 1923 until the 1950s, when it was to the advantage of the land owner, Kane`ohe Ranch, to lower water level in the marsh to expand cattle pasturage at the upper end (H. Wong, pers. comm., cited in Smith, 1978; also Hall, 1997, and Kelly and Nakamura, 1981). Water level in the marsh was supposedly maintained at –1.5 m msl through a pump located at the head of the then new Oneawa Canal (Smith, 1978). This water level would seem to require a rather massive dike structure at the head of the canal to hold back the tide while all of the base flow of water entering the marsh was removed.

We also have the detailed study made by Linda Smith (1978) which specifically considered the question of emergent marsh vegetation development in Kawai Nui. This study is not only valuable because it concerned itself with questions of continuing interest today, but also for the fact that 25 years—one-quarter of a century—has passed since her observations and speculations were made. In geological time, this is a span not worth considering. But Kawai Nui Marsh appears to be on an accelerated schedule of terrestrialization, and 25 years has significance in that regard. As always, in returning to compare observations made early with present-day, where obviously differences exist, one must question the veracity of the earlier observations. As a matter of faith, we generally accept that things were in the marsh exactly as earlier observers tell us they were. But this is not necessarily the case, and our conclusions of significant or insignificant changes may be invalidated as much by our errors of observation as by those of earlier efforts. Kawai Nui is a marsh of considerable size and complexity, and errors in observation are not likely to be errors of fact but errors of place. Thus, care must be taken in determining if our observations today disagree with those made earlier only because they were made in a different place in the marsh, both observations being essentially correct, but not directly comparable. We have certainly seen that our impression of what the marsh is depends very much on where our experiences occur. In this regard, we point out that Smith appears to have widely explored the marsh, but concentrated her quantitative efforts in the wetland directly off the levee. Our work has been concentrated around Na Pohaku. We accept that these

are somewhat different aspects of the marsh, and bear this in mind in drawing our conclusions.

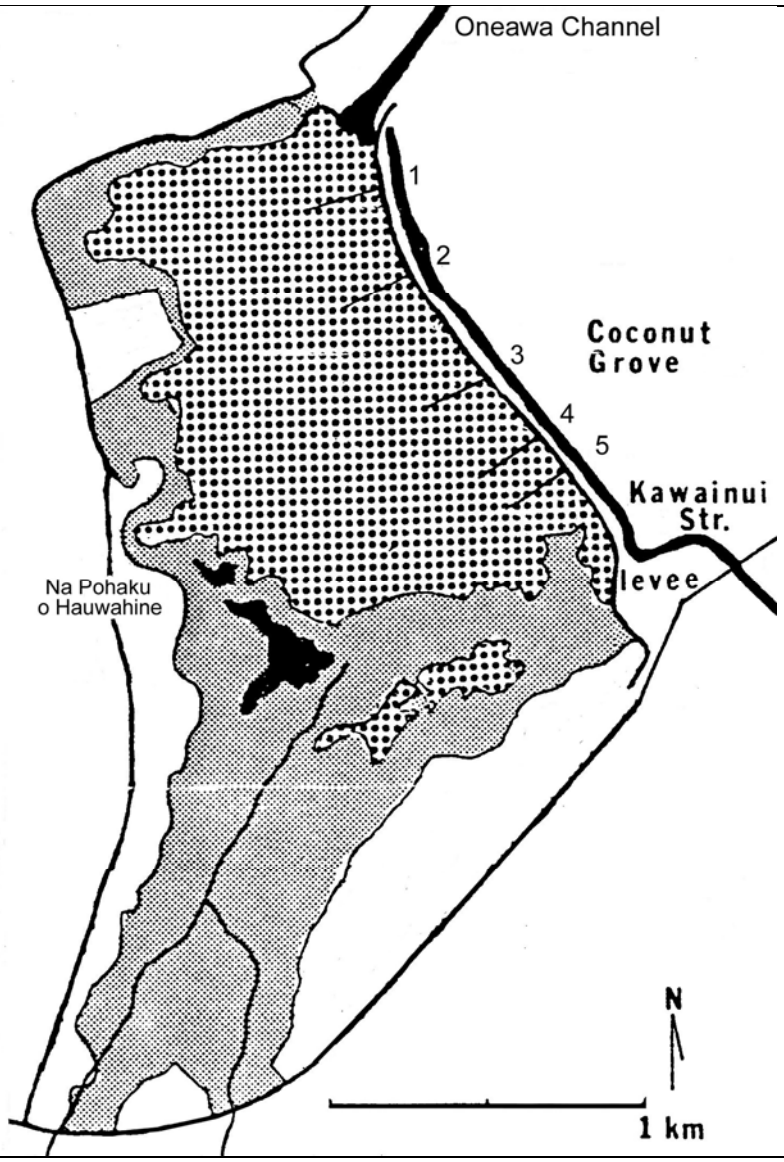

Figure VI-1. Map of Kawai Nui as presented in Smith (1978, Fig. 2) slightly modified to match current place names and some non-relevant detail removed. Black = open water; fine stippled area = grass community; coarse stippled areas = bulrush community.

CONCLUSIONS

BASIN STRATIGRAPHY — Soil auger borings along the margins of Kawai Nui Marsh are an effective technique for determining the geographic distribution of discrete sedimentary facies within the Kawai Nui basin, and the character and composition of associated biological communities. The presence of numerous well preserved seeds throughout much of the observed basin sedimentary fill sequence offers the potential for tightly constrained paleoenvironmental reconstructions and provides suitable organic sample materials for possible ^{14}C age determinations. A program of systematic auger sampling of sediments around the periphery of the marsh could significantly improve understanding of the evolution of the basin environment, the timing of sedimentological and environmental changes associated with Holocene sea level variations, and the impact of human-induced alteration of the Kailua watershed.

WATER LEVEL CHANGES — The majority of the work described in this report occurred during a period of distinct wet and dry seasons on O`ahu. The sharpness of the seasonality was the result of very dry summer conditions having the status of droughts on Maui and Hawai`i. This condition did not prevail in 2004. The wet season in 2003-2004 was at or above normal, and by mid-2004 rainfall received on O`ahu was well above average. Although data gathering had mostly ceased, various observations continued to be made, and these may be added to a subsequent report. Of relevance here was the fact that the water level in the marsh failed to decline below the normal wet-season level.

VEGETATION MAT — Studies of the vegetation mat described herein demonstrate that the interactions between bottom sediment, “open” water, and the peat layer are complex. While the mechanisms operating have been elucidated, the spatial distribution of mat types or models is not as straight-forward as hoped. Further effort needs to be expended before a relationship between the plant community developing in various parts of the marsh can be related to behavior of the substratum.

WATER QUALITY — The results of water quality monitoring at established stations distributed from the upper end of the marsh to the outlet demonstrate a reasonably coherent picture of chemical and physical changes occurring to water as it moves through Kawai Nui Marsh. The results were very useful in suggesting patterns of flow, although additional work needs to be done to confirm the suggested flow pattern and explain anomalies. Water quality measurements were obtained from the penetrating wells using a probe (no water samples were obtained for laboratory analyses). However, these data have yet to be summarized. It is anticipated that

these results will fill in at least one of the missing pieces of information: describing the water quality beneath the floating vegetation mat.

VEGETATION AND VEGETATION CHANGES — The vegetation of Kawai Nui Marsh is now very well described, although several aspects remain open to further exploration. The relationship between vegetation communities and the underlying physical soil/water interface and its nature remains to be established. Significant to that consideration is the role played by increasing numbers (species and biomass) of terrestrial plants establishing in the marsh. Of more than passing interest regarding the future of Kawai Nui as a wetland is deriving a better understanding of the spread of papyrus.

Although some problems in interpretation of results were uncovered in our critical review of the Smith (1978) Thesis, the author states that her estimates of plant species abundances were made "both from traversing the areas and viewing them from elevated vantage points." Neither method would confuse bulrush and saw-grass. Smith also noted that attempted transects through the saw-grass had to be abandoned (on Transects 1 & 2; see Figure VI-1 above) because of the difficulty of penetrating pure stands of this plant, and therefore such stands did exist in 1977. We therefore conclude that differences in our assessment of the make-up of the lower marsh and those of Smith do not necessarily constitute a real change in the marsh vegetation since 1977.

MARSH HABITAT RESTORATIONS — Restoration of a small islet at the upper end of Oneawa Channel has been successful to the extent that the vegetation change is a visual improvement and lowering of parts of the islet has allowed establishment of a more diverse flora, including some natives wetland plants. Utilization of the newly created habitats by water birds was almost immediately evident, although limited to various ducks (mainly mallard) that inhabit the area. To date, no endangered native water birds have been observed on the islet. Nonetheless, establishment of native vegetation, removal of alien plants such as *Pluchea* that invade, and further refinement of the topography are tasks that are continuing. As a demonstration project, the effort has been clearly successful in accomplishing some goals, although others (namely, creating endangered water bird habitat) remain elusive.

Efforts at creating open water surrounded by native wetland plants at Na Pohaku are also far from complete. However, success here has been demonstrated in two significant areas. With the wet season flooding of the area in late 2003, two `alae `ula arrived and attempted to nest. Although unsuccessful in hatching eggs (it is thought these were taken by predatory rat or mongoose), these birds have become residents of the wetlands we restored. Thus, the project goal of creating habitat

attractive to an endangered species has been realized. With respect to the vegetation, it is evident by observation following a period of no activity in terms of planting or weeding within the new habitat between November 2003 and September 2004 due to the constant high water level that no significant change in the vegetation, vis-à-vis loss of native species or invasion by non-natives, occurred. There were localized vegetation changes caused by the higher water level, of course, but these did not favor invasions by alien plants. To the contrary, the conditions prevailing during this period appear to have been favorable to those natives that either appeared naturally or were earlier planted around the ponds. It may turn out, that it is the gradual dewatering of the marsh that is the single greatest threat to the native vegetation there. While this conclusion may seem obvious considering the interplay between wetland and terrestrial vegetation, it is not so obvious concerning relationships between wetland species.

2006 ADDENDUM: The report by Oceanit (2006) explores such questions as what are the relationships between substratum and vegetation, what roll are invasive plant species playing in the marsh, and what can and should be done about these invasives. The ʻalae ʻula population at Na Pohaku o Hauwahine took off within a couple of months of implementing a predator control program in March 2005. It is estimated that 11 chicks were successfully hatched in 2005.