Section II. SETTING AND HISTORY[3]

INTRODUCTION

Kawai Nui Marsh is located in the Kailua *ahupua`a* in the Ko`olaupoko District of Windward O`ahu, Hawai`i. The present freshwater marsh is part of the largest remaining intact wetland in Hawai`i, covering an area of about 3.4 km² (830 acres). The marsh lies in a depositional basin, the site of successive phases of sedimentation in marine, brackish, and freshwater environments over the past 5000 years. Figure II-1 is a map of the marsh and environs showing place names mentioned in the text.

Previous studies of basin sediments document this evolution, and associated faunal and floral fossil and microfossil assemblages. Determinations of K-Ar and ^{14}C ages provide a time framework for successive sedimentary environments and allow estimates of sedimentation rates. These studies were largely coring programs conducted in the central area of the marsh, often in association with civil engineering, palaeobotanical, or archaeological investigations. There has been no systematic investigation of the spatial distribution of sedimentary facies and associated fossil flora and fauna within the Kawai Nui Basin.

Kawai Nui Marsh is a wetland seemingly well along in the process of terrestrialization: a sequence of physical changes that convert an open body of water such as a pond or lake into a marsh and ultimately into terrestrial forest (Russell, 1942; Dansereau and Segadas-Vianna, 1952). Mineral soils may accumulate in a basin shoaling it, or floating vegetation mats may create a substratum for terrestrial or facultative wetland plants, providing a matrix which traps water-borne sediment (Smith, 1978).

LOCATION AND CLIMATE

Kawai Nui Marsh is centered at about 21°23′51″N latitude and 157°44′56″W longitude on the windward (*ko'olau*) coast of the island of O`ahu, Hawai`i (Figure II-2). The marsh fully encompasses the lower floodplain of Maunawili Stream on the Kailua Plain. It is bounded to the north and west by Ulamawao and Mahinui (hills), to the southeast by the Kukanono Subdivision of Kailua, and to the northeast by the Kailua accreted sand barrier, site of the Coconut Grove

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[3] Substantial parts of this section are modified from Moye (2002a) *Preliminary sedimentological investigations of the Kawai`nui Basin, Kailua Ahupua`a, Ko`olaupoko, O`ahu, Hawai`i* a separate document prepared in part as fulfillment of work done under the KBAC grant.

Subdivision. The Oneawa Channel connects the northern portion of the marsh to the sea at the northwest end of Kailua Bay (Figure II-1).

Figure II-1. Map of Kawai Nui Marsh and environs with place names.

The climate of Kailua is mild, with a mean annual temperature of 24°C (75°F) and 70 to 80% relative humidity. Estimates of solar insolation are 300 calories/cm² in the upper Maunawili Valley watershed and 375 calories/cm² in Kawai Nui Marsh (WOA, 1994). Air circulation in the area is dominated by the Northeast Tradewinds about 313 days of the year (86% of the time), by southerly Kona winds around 36 days (10%), and by calm conditions on 16 days (4%) (WOA, 1994).

Interaction of the moisture laden Tradewinds with the Ko`olau *pali* produces orographic precipitation with maximum rainfall along the ridge crest. Median annual rainfall may exceed 3800 mm (150 inches) along the crest of the Ko`olau, and averages about 2100 mm (84 inches) in upper Maunawili Valley, exceeding the loss to evapotranspiration (WOA, 1994). Median annual rainfall of about 1270 mm (50 inches) over Kawai Nui Marsh is exceeded by estimated annual evapotranspiration of 1780 mm (70 inches), with a net loss of 510 mm (20 inches). Median annual rainfall continues to decrease towards the coastline, with around 1015 mm (40 inches) in Kailua and 760 mm (30 inches) at the northeast tip of Mōkapu Peninsula.

KAWAI NUI BASIN HYDROLOGY AND WATER QUALITY

The floor of the Kawai Nui Basin slopes 1° to 3° seaward (Allen-Wheeler, 1981), ranging in elevation from 6 m (20 ft) above to just below present-day sea level (Dames and Moore, 1961). The surface of the marsh vegetation mat lies at an average elevation of about 1.5 m (5 ft) above sea level (Athens et al., 1992, WOA, 1994). The marsh is extensively overgrown and obscured by a thick mat of largely non-indigenous vegetation that ranges from 30 cm (1 ft) to over a meter (3 ft) in thickness, and floats on less than 1 m (3 ft) to over 5 m (16 ft) of water and water-sediment slurry. This mat has a profound impact on basin hydrology and water quality.

BASIN HYDROLOGY — The basin receives drainage from an area of about 25 km² within the Kailua watershed (WOA, 1994). Most of the input is from the sub-basins of Maunawili Stream (14.5 km²), Kahanaiki Stream (4.9 km²), and Kapa`a Stream (3.1 km²). The total freshwater input to Kawai Nui Marsh is estimated at 6.8 mgd (25,700 m³/day) (Drigot et al., 1982) to 9.5 million gallons per day (35,900 m³/day) (WOA, 1994), with 23,800 m³/day (6.3 mgd) discharged to Kailua Bay through the Oneawa Channel and 12,100 m³/day (3.2 mgd) lost to evapotranspiration.

Smith (1978) considered the water budget of the marsh in similar detail, presenting several lines of evidence (mostly after Takasaki et al., 1969) that

indicated stream inputs amounted to 36,000 m³/day, and evapotranspiration estimated at 12,000 m³/day, or 33% of the total water budget. Losses due to uses (domestic or otherwise) and groundwater flux were considered to be trivial, leaving only outflow via Oneawa Channel for the balance (some 24,000 m³/day).

The Kawai Nui Basin acts as a flood control reservoir, ponding runoff from major rainfall events that is gradually discharged to Kailua Bay. A levee 3 m (10 ft) high and 2073 m (6800 ft) long was constructed (completed in 1966) on the *makai* side of the basin to protect the Coconut Grove Subdivision from flooding (Kailua levee, Figure II-1). The levee increased the basin storage capacity to about 3,780,000 m³ (almost a billion gallons). Kawainui Stream connecting Kawai Nui Marsh to Kaelepulu Pond was isolated from the marsh by the levee, and the ponded water of the marsh forced to drain through the Oneawa Channel.

The basin is also a sediment trap and sink for nutrients and pollutants, reducing negative impacts to Kailua Bay and the coral reef ecosystem. Rapid urbanization of the Kailua watershed beginning in the 1950s increased soil erosion and produced higher rates of basin sedimentation, steadily decreasing the volume of the basin and water storage capacity. WOA (1994) calculated an average annual sediment yield from the Kailua watershed of 1049 short tons/mi², or 10,081 short tons (9145 metric tons).

When increased urbanization and higher population exceeded waste water infrastructure capacity in the 1960's, partly treated effluent was discharged directly into the marsh and its tributary streams. Nutrient loading stimulated rapid growth of exotic vegetation, negatively impacting water quality and possibly expanding the floating vegetation mat through nutrient loading. The vegetation mat retards flow through friction and damming, ponding water in the basin. Reduced storage capacity and ponding may have contributed to 100-year floodwaters topping the levee and flooding hundreds of homes in the Coconut Grove area on January 1, 1988. In response, a channel was cleared through the vegetation mat with explosives (transverse channel, Figure II-1), the levee wall was raised by up to 1.4 m (4.6 ft), and 1920 m (6300 ft) of the levee was topped by a 1.2 m (4 ft) concrete floodwall.

WATER QUALITY — The quality of the water flowing into Kawai Nui Marsh was studied in considerable detail during the period of 1988 through 1994 in a monitoring program conducted at selected stations in the Maunawili watershed. Monitoring was undertaken for the Royal Hawaiian Country Club (now Luana Hills Golf Course) to satisfy requirements originally established by the Department of Land Utilization, City and County of Honolulu. The frequency of sampling and the location of sample stations were determined by *AECOS*, Inc. in consultation

with the State of Hawaii, Department of Health, and the results reported in several documents (see *AECOS*, 1990, 1991, 1993, 1995).

Baseline studies of water quality in Kawai Nui Marsh were conducted by M&E Pacific for the 1990 Flood Damage Mitigation Project EIS, and by the University of Hawaii Water Resources Research Center (WRRC). These data were reviewed and analyzed by WOA (1994). They report that ending discharge of partially treated sewage into the marsh in 1988 significantly reduced nutrient loading. Over 90% of the remaining nitrogenous and phosphoric nutrient loading of the marsh is removed through uptake by marsh vegetation, incorporation into bottom sediments, and loss to the atmosphere. It seems likely that increased nutrient loading may also have occurred between 1850 and 1950, accompanying intensive cultivation of rice and later sugar cane in the Kailua watershed. Nutrient input is also associated with livestock pasturage, present in the southern (upper) portion of the basin since 1890.

Anomalous concentrations of heavy metals found in the marsh sediments include Cu, Cr, Fe, Ni, and Zn (M&E Pacific, 1990). Although WOA (1994) considered these to derive primarily from the weathering and erosion of basalt in the catchment area, they acknowledge possible input from urban pollution. Urban and agricultural runoff, treated sewage discharge, and seepage from reclaimed landfills are all possible sources of toxic metals and other pollutants in the Kawai Nui basin. However, the concentrations quoted by WOA (1994) from the City and County FEIS seem largely compatible with values sourced from weathering and erosion of a basalt substrate: 35.9 ppm Cu, 56.7 ppm Cr, 53 ppm Ni, and 35 ppm Zn, with trace As, Cd, Hg, Pb, and Ag (values are for dry weight of sediment samples).

The sediments of Kawai Nui Marsh are dominantly organic-rich, chemically reduced clays that readily adsorb most toxic metals. These metals are generally sequestered in nonsoluble forms with low bioavailability. Bioavailability and toxicity may become a concern if the pH of the sediments becomes acidic, as might accompany excavation and oxidation due to exposure to the atmosphere (WOA, 1994).

A WRRC study indicated that concentrations of three fecal indicator bacteria (fecal coliform, *Escherichia coli*, and enterococci) exceeded recreational water quality standards in Maunawili Stream below urbanized areas and in Kawai Nui Marsh. Elevated concentrations were also observed at the head of the Oneawa Canal, attributed to duck feces (WOA, 1994). Detailed surveys of pollutant and bacterial concentrations in the Kawai Nui Basin, and partitioning among biotic and abiotic reservoirs, are not available.

GEOLOGIC AND GEOMORPHIC SETTING AND EVOLUTION

The Kawai Nui Basin occupies an area of almost 3.5 mi^2 within the Kailua Plain, a portion of the ancient caldera of the Ko`olau Volcano eroded almost to present day sea level. The basin encompasses the lower floodplains of Maunawili, Kahanaiki, and Kapa`a Streams, and hosts the Kawai Nui wetland. The basin formed through deep down-cutting of Maunawili and Kapa`a Streams into the Kailua Plain during ocean lowstands associated with Pleistocene glaciations, drowning of the river valleys by rising Holocene sea level, and blockage of the outflow to the sea by accumulation of the Kailua sand barrier.

THE KO`OLAU VOLCANO AND CALDERA COMPLEX — Kawai Nui Marsh lies in the approximate center of the deeply eroded caldera of the ancient Ko`olau volcano, one of two shield volcanoes that form the island of O`ahu (Figure 2). Interpretation of a gravity high anomaly (Strange et al., 1965) and seismic studies (Adams and Furumoto, 1965) suggest that a large body (4.8 to 5.6 km in diameter) of dense (3.2 g/cm^3) rock is present at a depth of about 1.6 km beneath Kawai Nui Marsh. This body may represent a gabbroic plug formed by crystallization of basaltic magmas in the primary magma chambers below the Ko`olau Caldera. Hydrothermal fluids formed by mixing of acidic volatiles escaping from this magma chamber with groundwater were probably responsible in large part for the intensive hydrothermal alteration of rocks within and adjacent to the caldera.

Ko`olau volcanism ended about 1.8 million years BP, and was followed by a long period of subsidence and erosion. Removal of the northeast flank of the volcano by gravitational collapse and erosion breached the caldera walls. Rapid erosion of the hydrothermally altered rocks within and adjacent to the caldera denuded the area to the present low relief topography prior to about 1 million years BP. Erosional remnants of intracaldera deposits include Olomana Peak and Mahinui. Area drainage basins originate in steep-walled amphitheater valleys along the Pali, fronted by steeply dipping alluvial and colluvial fans and aprons, and coalesce to flow across the lowland plains into the ocean. Renewed volcanism of the Honolulu Series began about 850,000 years BP and continued intermittently until perhaps as recently as 5000 year BP, erupting a series of localized cinder cones, tuff cones, and lava flows onto this erosional landscape.

The northern flank of the Kawai Nui Basin is formed by alluvial and colluvial sediments derived from lava flows and intracaldera breccias intruded by numerous dikes of the Ko`olau rift zone, exposed along the Mokapu Saddle Road and Interstate H-3. Thick basalt flows ponded in the Ko`olau caldera outcrop along the center west side of the marsh, adjacent to Kapa`a Quarry Road, and along Kailua Road on the flank of Pu`u o Ehu. These flows are hydrothermally

altered, with abundant veinlets and amygdules of epidote, calcite, zeolites, and quartz. Alteration of plagioclase feldspars and ferromagnesian minerals to chlorite, epidote, and clays greatly facilitates weathering and erosion of these intracaldera flows.

The northwest and southeastern flanks of the basin are composed of younger Honolulu Series alkalic basalt flows erupted less than 500,000 years ago on the deeply eroded windward landscape. To the northwest a basalt flow issued from a cinder cone perched near the summit of Ulumawao. This flow was largely quarried away by Ameron, and the site later converted to a municipal landfill, now reclaimed. The marsh is bordered to the southeast by an extensive Honolulu series lava flow that underlies the Pohakupu and Kukanono subdivisions of Kailua. This flow issued from the Training School cinder cone on the northern flank of Olomana Peak.

SEA LEVEL VARIATION AND FORMATION OF THE KAWAI NUI BASIN — Sea level in Hawai`i has fluctuated dramatically over the past 1.6 million years, through a combination of isostatic subsidence and global sea level fluctuations accompanying the glacial and interglacial events of the Pleistocene. Possible paleoshorelines have been documented in the islands at elevations ranging from – 1100 to +365 meters relative to present sea level. Evidence of +3.6 and +7.6 m shorelines (above present mean sea level) were documented in the vicinity of Kawai Nui Marsh by Stearns (1935, 1978). The valleys of Maunawili Stream and Kapa`a Stream across the Kailua Plain were deeply incised during low sea level stands associated with glacial intervals, and extended well seaward of the present shoreline. The lower portion of this incised stream valley network was progressively drowned during Holocene sea level rise, forming an open marine embayment similar to present day Kane`ohe Bay. The marine transgression was at a maximum of about +1.5 m MSL (mean sea level) between about 2000 and 5000 years BP (Fletcher and Jones, 1996).

The Kailua Barrier accumulated as an arcuate series of littoral calcareous sand spits and bars capped by windblown dune deposits (Stearns 1935), probably on a substrate of discontinuous baymouth reef deposits. The barrier deposits are up to 1.6 km in width, extend for almost 5 km from the Mokapu Peninsula southeast to Alala Point, and average only about 2.5 meters in elevation above mean sea level. Sand spits began to extend across the mouth of the Kawai Nui and Kaelepulu embayments from the Mokapu Peninsula, the Pu`u o Ehu headland, and Alala Point about 1600 to 1300 years BP (Kraft, 1980). Continued barrier growth progressively isolated both embayments as restricted lagoons, although Kraft (1980) suggests that substantial open channels to the sea existed at Kawai Nui Marsh as late as 200 years BP.

Continued accumulation of the Kailua Barrier isolated the Kawai Nui Basin from the ocean sometime after the arrival of the first Polynesian colonists to the area (about 500 AD). Fluvial inflow to the basin was discharged through Kaelepulu Stream into Kaelepulu Pond, and from the pond to Kailua Bay. This hydrologic isolation produced an essentially closed depositional basin. Without direct discharge to the ocean and tidal flushing, the Kawai Nui basin became an effective sediment trap.

Numerous factors may have affected the rate of sediment accumulation. Reorganization of terrestrial and aquatic ecosystems accompanied variations in Holocene sea level and associated local and global climatic variations. Variations in average annual rainfall and degree of ocean connection and tidal influence determined sediment input and basin flushing. The incidence of major storms, tsunamis, and other natural disasters may have periodically affected basin sedimentation. Within the last 1500 years, surface disturbance accompanying increasingly invasive anthropogenic land use practices may have facilitated accumulation of terrestrial sediments in the Kawai Nui basin. Sediment accumulation may have increased significantly during rapid urbanization of the Kailua watershed during the 1970's through 1990's.

Soils in the vicinity of the marsh vary with time of formation, parent material, topography, microclimate, and position of the water table. Rocky prominences and steep denuded slopes are classified as Stony Steep Land, with Papaa Clay and Alaeloa Silty Clay on steep to moderate slopes. Kawaihapai Clay Loam, Kokokahi Clay, and Waikane Silty Clay occur on low angle slopes, including talus slopes, alluvial fans, and terraces. Hanalei Silty Clay dominates the lower portions of the Maunawili and Kahanaiki Stream valleys to their confluence in the southwest portion of the marsh. Pearl Harbor Clay characterizes the lower portion of the Maunawili Valley floodplain, with Marsh Soils occupying areas of permanent saturation.

Erosion of soil from slopes bordering the basin has contributed to the infilling of the basin (WOA, 1994). Erosion and basin infill may have accelerated significantly during the previous 600 years, the result of deforestation and surface disturbance associated with anthropogenic land use practices. Observations around the shoreline at Na Pohaku suggest a major influx of eroded topsoil from the adjacent slopes within the last 50 to 100 years.

SUMMARY OF LAND USE PRACTICES

The marsh basin has been extensively utilized and impacted by human society since the arrival of the first colonists from the Marquesas around 1500 to perhaps

2000 years ago. The site of a large precontact Hawaiian *loko pu`uone* (fishpond) with extensive peripheral areas of *kalo* cultivation, the Kawai Nui basin has been subsequently used for rice and sugar cane cultivation and horse and cattle pasturage, with extensive deforestation of the surrounding hills. These activities have affected the character and rate of sedimentation in the basin, and drastically changed the indigenous ecosystem through disturbance and the introduction of numerous exotic species of plants and animals. This history is presented in great and loving detail in the report "Historical study of Kawainui Marsh area, Island of O'ahu" by Marion Kelley and Barry Nakamura (1981).

The Kawai Nui basin may have been one of the first areas colonized by Polynesian settlers on O`ahu, and was one of the most important areas of food production prior to and following European contact. Expansion of Hawaiian population and resource utilization between about 1200 and 1400 AD is cited as a possible factor in the degradation of lowland ecosystems, including the Kawai Nui basin. Kirch (1982) estimates that perhaps 80% of all lands in Hawai`i below and elevation of 1500 feet were extensively altered by Hawaiian land use practices by 1600 AD.

The marsh was an important focus of integrated agriculture and aquaculture management by Hawaiians. The Maunawili Valley and floodplain and low slopes along the marsh periphery were sites of *kalo* cultivation, with about 250 acres of *lo`i* by 500 years BP. The earliest recorded use of the area now marsh is that of a fishpond (*loko pu`uone*) in use by the late 1700's (McAllister, 1933). Summers (1964) states that the pond was about 180 ha (445 ac), about the same as the area of peat soils estimated by Dames & Moore (1961, cited in Smith, 1978). The pond was abandoned during the early 19th century accompanying post-contact collapse of the native population. The significance of the Kailua *ahupua`a* and Kawai Nui basin is illustrated by the history of ownership by Hawaiian high chiefs, and the presence of three *heiau* along its borders.

Traditional land use in the area was replaced by rice farming in the 1850's and 1860's, but declined throughout the late 1800's to end in 1934. It is worth noting that rice growers constructed weirs on Kawainui Stream (natural outlet of the marsh) to prevent saline water from entering the rice fields (McAllister, 1933). Sugarcane was grown in the area from 1878 to 1950, with extensive diversion of water from the Kailua watershed to the adjacent watershed of Waimanalo and this decreased inflow to Kawai Nui Marsh. Shaw (1927) stated that water for Waimanalo came from both Maunawili Stream and directly from Kaiwai Nui, with the Kawai Nui portion (some 15,000 m³/day) coming from a 200 ha (494 ac) "lagoon" (Gilmore, 1931). Smith (1978) relates that H. Wong (Kaneohe Ranch,

pers. comm.) said the marsh was dammed near Kailua Road to maximize storage of wet season input, a practice that ended in 1950 (see also Harloe, 1948).

Kaneohe Ranch began grazing cattle in Kawai Nui in 1890, and California grass (or para grass, *Brachiaria mutica*) was introduced in 1902. Areas of rice cultivation were largely converted to pasturage after the 1920's. Cattle and horse pasturage by Knott Ranch and VO ranch remain the dominant land use practices in and directly adjacent to the wetland.

Raw municipal sewage and later partially treated effluent were discharged directly into the marsh and into tributaries of the marsh until the completion of the Olomana-Maunawili Sewer Line in 1988. The lower portions of the Kapa`a Stream and adjacent marsh are reclaimed municipal landfill sites. The current Model Airplane Park is constructed on a former landfill placed in the wetland. A former Ameron basalt quarry on Kapaa Quarry Road was utilized as a municipal landfill, with closure and reclamation only recently completed. The quarry operation was moved further into the valley and is now approaching its useful life at that site. A new quarry has been started on the opposite side of the valley.

PREVIOUS STUDIES OF KAWAI NUI BASIN

KAWAI NUI BASIN STRATIGRAPHY — Stearns (1935) interpreted Kawai Nui Marsh as a former marine embayment. Several drilling projects in the Kawai Nui basin have documented the presence of coarse, unconsolidated, mid-Holocene marine sediments containing abundant coral rubble in the subsurface (Kraft, 1980; Allen-Wheeler, 1981; Yonekura, 1988; Hammatt et al., 1990; Athens and Ward, 1991). These sediments are dated to about 3200-2400 years BP (Allen-Wheeler, 1981; Athens and Ward, 1991).

Above the open marine sediments are transitional sediments interpreted as an increasingly restricted lagoonal environment (Kraft, 1980; Allen-Wheeler, 1981; Hammatt et al., 1990). These sediments are fine grained, thinly laminated, and organic-rich with variable marine and terrestrial components. Kraft (1980), Allen-Wheeler (1981), and Athens et al. (1992) recognized the presence of a layer of peat above the lagoonal facies. This appears to represent the earliest colonization of the basin interior by terrestrial wetland vegetation, and the transition from restricted lagoon to brackish then freshwater marsh.

A thick sequence of dark gray to black, clay-rich, highly reduced sediments with high organic content extends from the basal peat to the present sediment-water interface in the marsh. These are interpreted as terrestrial sediments deposited in

the present freshwater marsh environment (Kraft, 1980; Allen-Wheeler, 1981; Yonekura, 1988; Hammatt et al., 1990; Athens and Ward, 1991).

AGE DETERMINATION OF BASIN SEDIMENTARY FACIES — There is broad general agreement on the character and origin of the sedimentary facies present in the subsurface of the Kawai Nui basin, and the basic framework of the processes and environmental changes represented by this sequence. There is, however, significant disagreement on the precise timing of these changes, possibly reflecting differences in sampling procedures, interpretation of sedimentary facies, the accuracy of age dating and estimation techniques, and location of sample sites within the basin.

Allen-Wheeler (1982) suggests that marine conditions dominated much of the Kawai Nui basin until about 2400 BC, and possibly as late as 668±80 AD when the basal peat layer began to accumulate, possibly under freshwater conditions. Hammatt et al. (1990) suggest that marine conditions prevailed from at least 3890 BC to about 170 BC. Lagoonal conditions dominated from 170 BC to as late as 570 AD, and were transitional into a terrestrial marsh environment. Dramatic changes in the composition of terrestrial plant communities around 1400 AD, with a change from *Pritchardia*-dominated mesic forest to grasses and sedges, may relate to Hawaiian land use practices. Hammett et al. (1990) suggest formation of the Kailua sand barrier around the end of the first millennium BC, with the basin largely isolated from the sea by 1400 AD.

Athens et al. (1992) date the rapid decline of *loulu* palm (*Pritchardia*) mesic forest to around 1000 AD, and cite Hawaiian habitat modification or possibly climatic factors. They estimate the transition from open marine to brackish/freshwater at about 200 B.C, and formation of the Kailua sand berm between 1000 and 600 BC.

ESTIMATED BASIN SEDIMENTATION RATES — Sedimentation rates in the basin are estimated by Hammatt et al. (1990) as 0.04 mm/yr during the early marine period (4158 BC to 295 BC), increasing to 66.0 mm/yr during the lagoonal phase (295 BC to 12 AD), and decreasing to about 1.0 mm/yr from about 400 AD to 1535 AD. The higher rate of sediment accumulation during the lagoonal phase is attributed to the absence of tidal flushing, and lower rates after 400 AD to the expansion of grass and sedge cover in the marsh.

Athens et al. (1992) estimated sedimentation accumulation rates for the marine section of about 5 mm/yr, and rates of 2.7 mm/yr during the brackish and freshwater phases. They suggest sediment accumulation rates actually slowed during the lagoonal and brackish/freshwater marsh phases in the basin

attributable to climatic factors. These estimates differ significantly from those of Hammatt et al. (1990), however both sets of estimates are based on a very limited database.

COMMENTS ON PREVIOUS STUDIES — Some possible limitations of previous studies include the description and classification of Kawai Nui basin sedimentary facies in soil terminology. "Sandy clay loam" is used in describing a coarse biogenic marine sediment composed of 40-60% very coarse coral fragments, 20-30% coarse calcareous sand, and 10-20% bivalve and mollusk shell fragments. This classification obscures the sedimentological character and interpretation of facies, and makes correlation among different studies more difficult.

In addition, most previous studies sought to characterize the evolution of the Kawai Nui basin on the basis of a limited set of data, often collected in highly localized areas of the overall basin environment. Sedimentary facies within the basin are probably time-transgressive, varying in age with their geographic location within the basin. The composition and biotic associations of basin sediments are expected to vary with the proportion of marine versus terrestrial inputs, salinity, water depth, and other environmental variables.