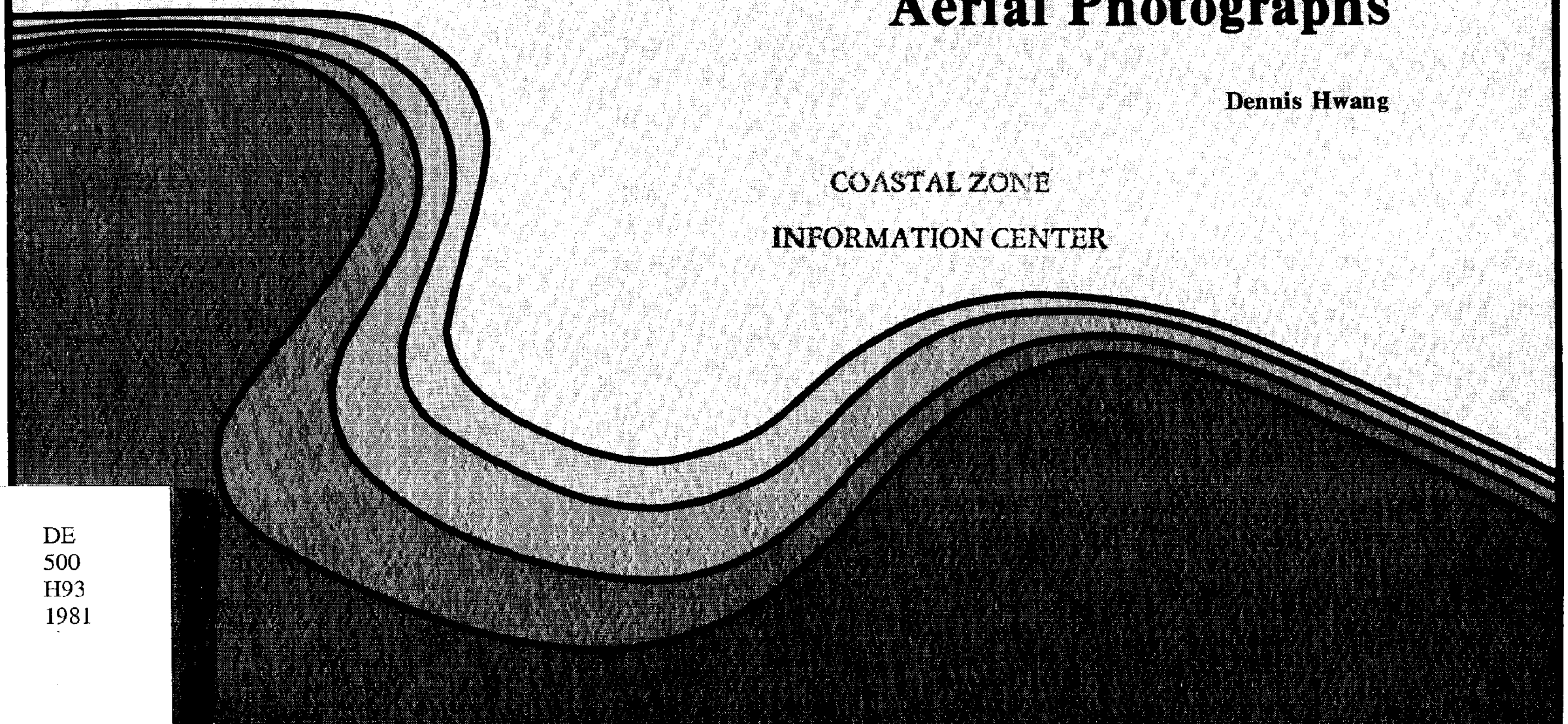
Beach Changes on Oahu as Revealed by Aerial Photographs

Dennis Hwang



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ABSTRACT

An aerial photographic analysis of the beaches of Oahu was conducted for a period of up to 50 years. The results indicate that the most unstable beaches are on sand bodies projecting from the coastline, such as Kualoa Point, Iroquois Point, and Paiko Peninsula.

Beach changes on Oahu can be characterized by the coastline. On the north shore, intermittent erosion occurs when the beach is overwashed by waves of unusual height and force. Aerial photographs record the effects of the December 1-4, 1969 storm, 1946 tsunami and possibly the 1957 tsunami.

Beaches facing the northeast trade wind direction are especially dynamic systems. The large long-term changes at Kualoa Beach, Kailua Beach and Lanikai Beach are partly caused by variations in sand transport along the shoreline. Erosion problems on the windward coast exist at north Kahuku Golf Course Beach, Kalanai Point, Laniloa Beach, Hauula Beach Park, Swanzy Beach Park, Kaaawa Beach Park and Waimanalo Beach.

Along much of the south shore, waves break at the seaward edge of a shallow fringing reef. As wave energy is reduced, many of the beaches are relatively stable. Erosion during the 1967 to 1971 interval, however, occurred at Hanauma Bay, east Kahala Beach and Paiko Peninsula. Sandy Beach, which is not protected by a fringing reef, also eroded during that period. Ewa Beach experienced erosion between 1958 and 1967. West Iroquois Point has been chronically eroding.

On the leeward coast, the south end of Kahe Beach and the ends of Maili Beach have a history of persistent erosion. Most other beaches had no apparent long-term change. Nevertheless, periodic damage to the backshore area may occur from large Kona Storm waves or refracted North Pacific swell.

The sandy shoreline on Oahu has been placed into the following management categories:

(1) **Hazard Areas** are subject to inundation by large winter waves.

(2) **Chronic Erosion Areas** have a long-term history which indicates erosion will continue in the future.

(3) **Unstable Beaches** have an alternating history of erosion and accretion. These changes are unpredictable.

(4) **Stable Beaches** have had a small net change and range in the position of the vegetation line.

(5) **Accreting Beaches** have grown continuously seaward.

The first three categories are of the greatest concern to coastal managers.

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Aerial photographs were obtained from the R. M. Towill Company, Air Survey Hawaii, U. S. Geological Survey and the U. S. Army Corps of Engineers.

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Field assistance was provided by Annabelle Lee (East-West Center) and Carol Leong. The photomaps were designed and developed by Nancy Brown with the help of Karen Fukushima and Donald Houston.

Numerous drafts of this document were typed by the URPP staff of Paulette Dahlen, Pam Hunt and Barbara Awa. Rita Pujalet (HIG) edited the final report. Wendy Nakano of Sea Grant spent much time with the graphics and layout of the photomaps and text. Wendy Yokota, URPP, set the type for this report.

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INTRODUCTION

Beach erosion and accretion are continuous natural processes to be expected on any sandy shoreline. So often in the past, however, development has progressed with the misconception that the beach is stable. This lack of appreciation for the dynamic nature of the beach has led to the following problems.

(1) In an attempt to protect endangered buildings from erosion, seawalls, stone revetments and boulder piles have been placed along much of Oahu's coast. Some of these structures may have adverse impacts on the beach. For example, seawalls may reflect wave energy resulting in the transport of sand offshore. This may cause the beach to narrow so much that access along the shore is blocked and the utility of the beach eliminated. In this manner, the total length of recreational beaches on Oahu has steadily declined over the last 30 years.

(2) During development near the beach, many buildings have been placed in areas that are extremely vulnerable to inundation by the large waves associated with hurricanes, tsunamis and winter storms. Erosion compounds this problem by reducing the natural buffer zone that protects beachfront structures from the sea.

Although beach erosion in Hawaii will continue, the problems associated with this process can be alleviated and in some cases prevented. The most effective strategy against erosion is to plan for the seasonal and long-term changes of the beach prior to shoreline development. Implementing such a strategy would require a thorough understanding of the idiosyncrasies for each beach. It must be known, for example, whether a particular beach is likely to prograde or recede. If erosion is in process, what is the rate of retreat? Does the beach experience cycles of erosion and accretion and if so what is the range in the cycle? What is the magnitude of the seasonal change on the beach, or how susceptible is the backshore area to high wave inundation? This information must be obtained before the natural changes of the beach can be planned for.

The seasonal changes on Hawaii's beaches were first determined by comprehensive field surveys during the 1962 to 1963 period (Moberly and Chamberlain, 1964). In 1971, resurveys on selected beaches were conducted to determine the long-term trend over a period of approximately ten years (Campbell, 1972). While most study sites showed insignificant changes in the volume of beach sand, a few areas did display net accretion or erosion.

The objective of this study was to determine the patterns of long-term beach change on Oahu by the use of sequential aerial photography. Since aerial photography extends further back in time than comprehensive beach surveys, a systematic analysis of old air photos would provide for many beaches, the first indication of the long-term trend over a period of up to 50 years. This is a time scale that coastal planners may find particularly useful.

The use of aerial photographs to monitor past shoreline movements on Oahu was applied for a study of Kailua Beach Park (Noda, 1977), Kualoa Beach Park (U.S. Army Engineers, 1977) and Kailua Beach (Hwang, 1980). The methodology used in this report was described in detail and tested for the study of Kailua Beach. Briefly, the method involves the following steps. Sequential aerial photography of a given beach is obtained. The photos are scaled using field measurements, orthophoto maps or extended control from tilt-free photographs. Points on the photo which have a stable position over the beach monitoring period are then selected. Measurements from these stable reference points to the vegetation line and water line on photographs of different years will reveal how the beach has changed through time.

Beaches on Oahu have been divided into four sections. Beginning with the North Shore, Section I; and moving clockwise around the island, the next 3 sections are on the Windward Coast, Section II; South Shore, Section III; and Leeward Coast, Section IV (Figure 1).

On the windward coast, a gap in the coverage exists for the stretch between Kualoa Beach Park and Kailua Beach. Generally, the few beaches in Kaneohe Bay are composed of silt and mud. The beaches of Waikiki were also excluded from this study because of the artificial alterations along the shoreline.

For each studied beach there is a textual description of the patterns of long-term shoreline change. For most of the beaches, except the small pocket cells, there is a table with the historic data and an air photo map showing the location of established transects. After presentation of the results for Oahu, a section on management problems which became apparent during the course of research follows. The final section of this paper is on beach management strategy based on the data from this report.

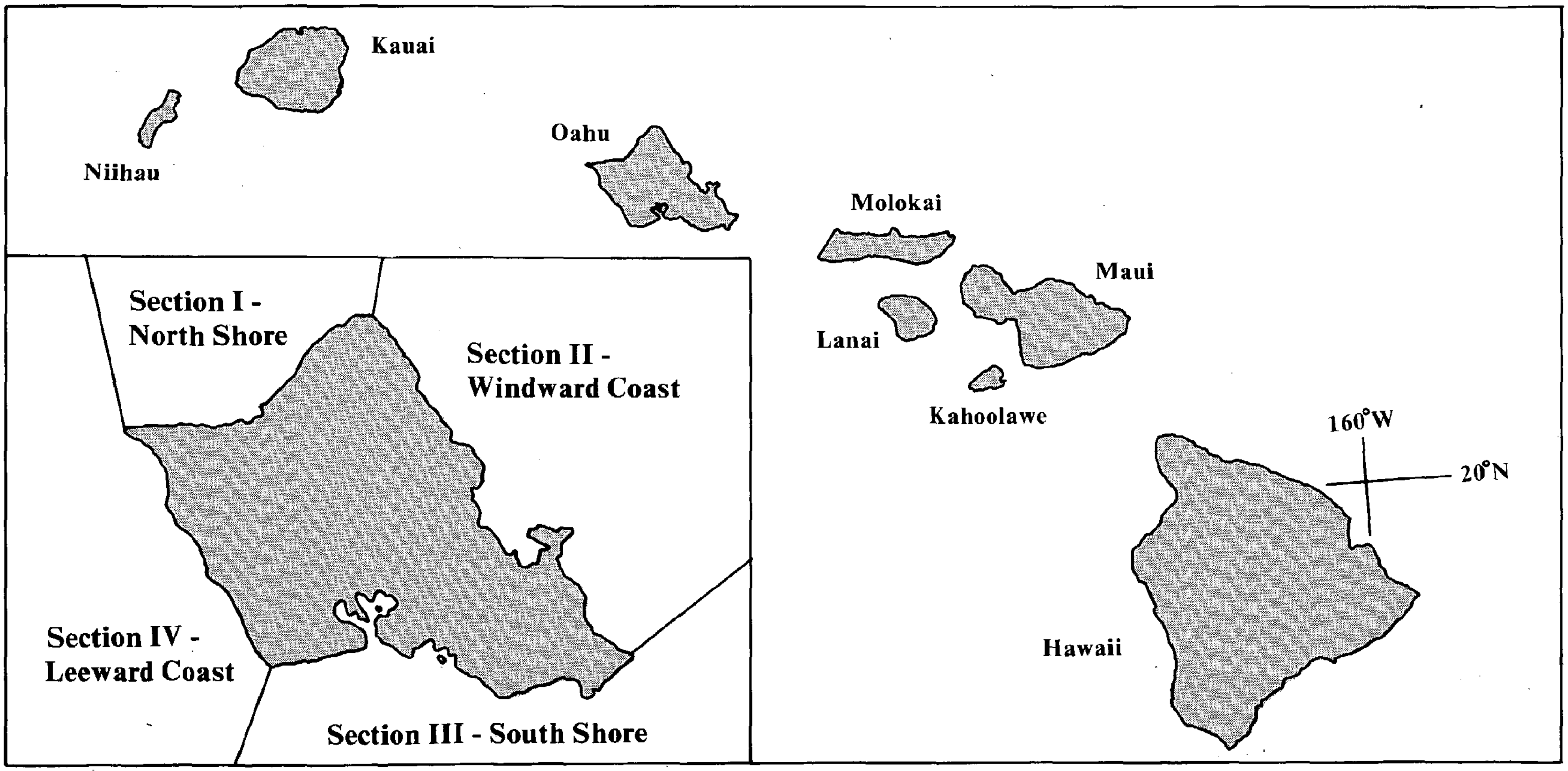


Figure 1. Map of Oahu.

STUDY LIMITATIONS

Before using this report, the reader should be aware of the limitations summarized below.

Accuracy - The accuracy of the measurements for each beach varies according to the height of the stable reference points, their distance from the beach, and the quality of the aerial photographs. A theoretical estimate of the likely error computed at a 95% confidence interval was determined as 12 feet for Kailua Beach (Hwang, 1980). Subsequent field surveys and ground checks indicate that this figure may be conservative.

Calculating the likely error for each beach is time consuming, requires that many assumptions are made and often leads to an estimate that is misinterpreted. For this reason, the uncertainty in the error for the individual beaches was not determined.

Generally, changes in the vegetation line greater than 10 feet can be seen on the aerial photographs. This figure gives a rough approximation of the accuracy in the data. On some beaches, the accuracy of the measurements may be greater because of the low reference points and their proximity to the beach. This is the case at Hauula Beach Park and Sandy Beach, to name two examples.

Any problems that were encountered in collecting data are mentioned in the sections for the individual beaches. For some areas, the stable reference points were in unfavorable locations. In such cases, a connecting line was drawn between the reference points. Measurements to the beach were then made from a point on the stable line. While this procedure introduces errors, it was the only way to obtain data for the Yokohama and Makapuu beach systems. Therefore, the data for these beaches should be regarded as first approximations subject to later revision.

All effort was made to determine the long-term beach change no matter how unfavorable the study conditions. Not to do so would leave many problem areas on the coast unidentified. As some of the reference points are far from the beach, it is conceivable that an error greater than 10 feet could occur. If the reader is aware of such a case, disclosure of this information would be welcome.

Transect Spacing - Transects along the beach were established at intervals of approximately 1,000 feet. For beaches that erode intermittently during large storm events this sample spacing could lead to the following problem.

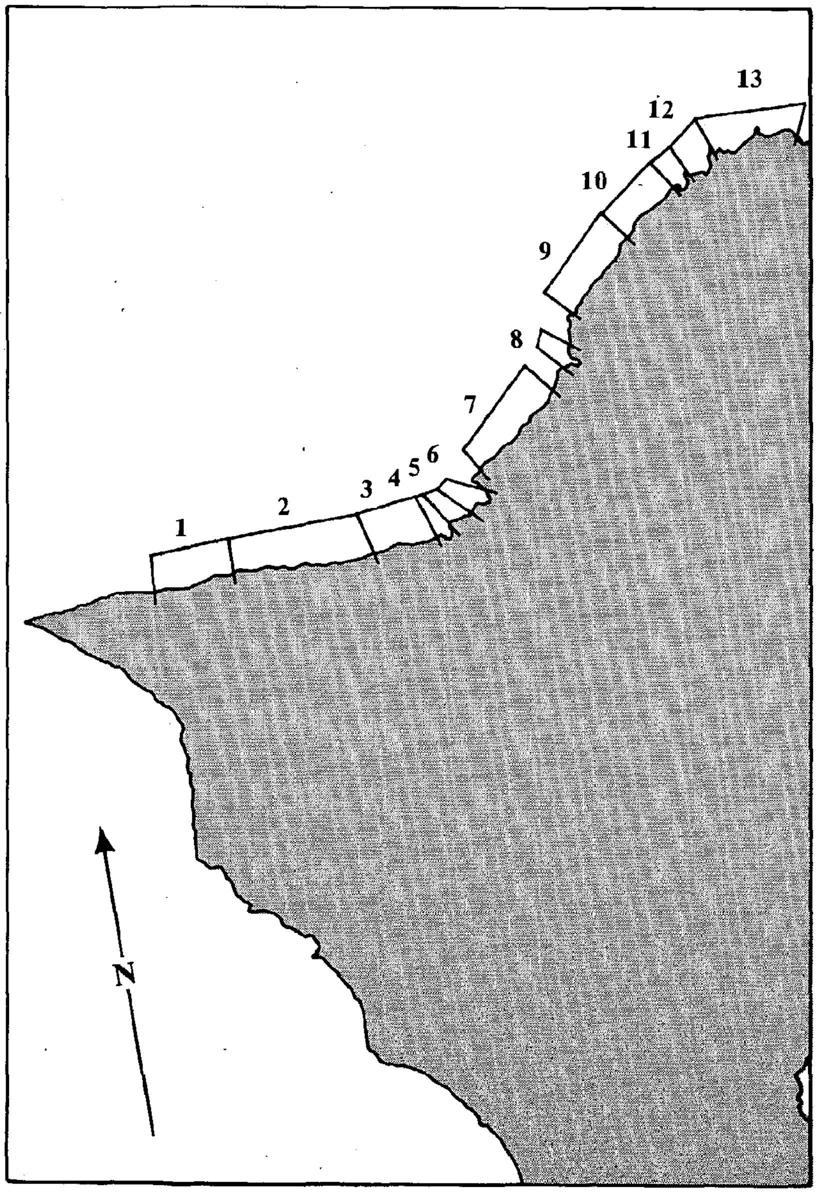
The degree of erosion caused by storm waves can vary significantly from place to place. For example, one beach section may erode severely, whereas one hundred feet to the side no storm damage may be evident. These variations may be caused by the location of offshore reefs and channels, the exposure of beachrock, the orientation of the beach, and numerous other factors.

When using the data in the report, it should be remembered that uncertainties are introduced when a beach change is extrapolated between the transects. This is especially so for beaches on the north shore where the major long-term changes are caused by high wave inundation.

If the exact long-term change is required for a particular location far from the transects reported in this study, the information can be obtained on the aerial photographs filed with the Urban and Regional Planning Department, University of Hawaii.

Aerial Photographic Coverage - On some beaches, the most recent aerial photographs were taken in 1975 for the Army Corps of Engineers. Although more current photography is desirable, it is not essential in order to determine the characteristic change for each beach. For some of the shoreline in this study, the data exist over the 26-year period from 1949 to 1975. In most cases the data are more current.

It was originally hoped to monitor the beaches with aerial photographs taken every five years. For beaches where the coverage is sparse, large gaps in the data may exist. On such beaches it is difficult or impossible to determine the timing of erosion events. In such a case, all that can be mentioned is that the beach had a specific net change over a certain time interval.



SECTION I - NORTH SHORE

The north shore extends from Kaena Point on the west to Kahuku on the east (Figure 2). The major long-term changes on this coast are caused by winter North Pacific swell. During the summer, the beaches are wide and have a gentle slope. When the winter surf arrives, the beaches narrow and the foreshore slope steepens. Generally, no permanent damage to the backshore area occurs unless large waves overwash the beach-buffer zone. This may occur during a strong winter storm or tsunami.

During the December 1-4, 1969 storm, almost all sections of the north shore suffered erosion. For many beaches, this storm caused the major retreat in the vegetation line over a period of several decades. At Waimea Beach, approximately half of the loss in the vegetation line between 1928 and 1975 occurred during this brief event.

For beaches that are relatively narrow and have an irregular reef offshore, winter surf damage may occur more frequently. This may be the case for certain sections of Mokuleia Beach.

Historical data indicate that the north shore of Oahu is particularly susceptible to tsunami runup. The 1949 aerial photograph of Kahuku Point shows that inundation from the 1946 tsunami was about 1,200 feet inland. On the 1958 photograph for Kealia Beach, the possible effects of the 1957 tsunami are seen opposite the middle of Dillingham Air Field. Because runup data for this beach section are unavailable, it cannnot be determined whether the killing of the vegetation was caused by tsunami inundation or artificial sand removal.

Figure 2. Photomap Arrangements - North Shore.

Mokuleia Beach

Mokuleia Beach is located at the west end of the north shore. In order to facilitate data presentation, this 6-mile-long stretch has been divided into a western, a middle and an eastern section.

Mokuleia Beach (West End)

The west end of Mokuleia Beach is relatively undeveloped. Except for the cabins at Camp Erdman, the bathhouse at the Army Beach and the houses near transect 7, the land is otherwise bare (Photomap 1).

West Mokuleia Beach experienced severe erosion during the December 1-4, 1969 storm. At Camp Erdman, the vegetation line during the 1967 to 1971 interval was cut back 38 feet (Table 1). One cabin, situated near the vegetation line in 1967, was removed because of high waves. Other than the heavy damage from the 1969 storm, the beach at Camp Erdman appeared stable over the 26 years of observation.

At the west end of Dillingham Air Field, near Mokuleia Army Beach, two transects were established. The large fluctuations in the position of the vegetation line for transect 3 are partly due to the effects of drainage from a nearby sand mining operation. At transect 4, the vegetation line receded 66 feet during the 1967 to 1971 interval. This loss is attributed to the recession of sparse vegetation from inundation by the December 1969 storm.

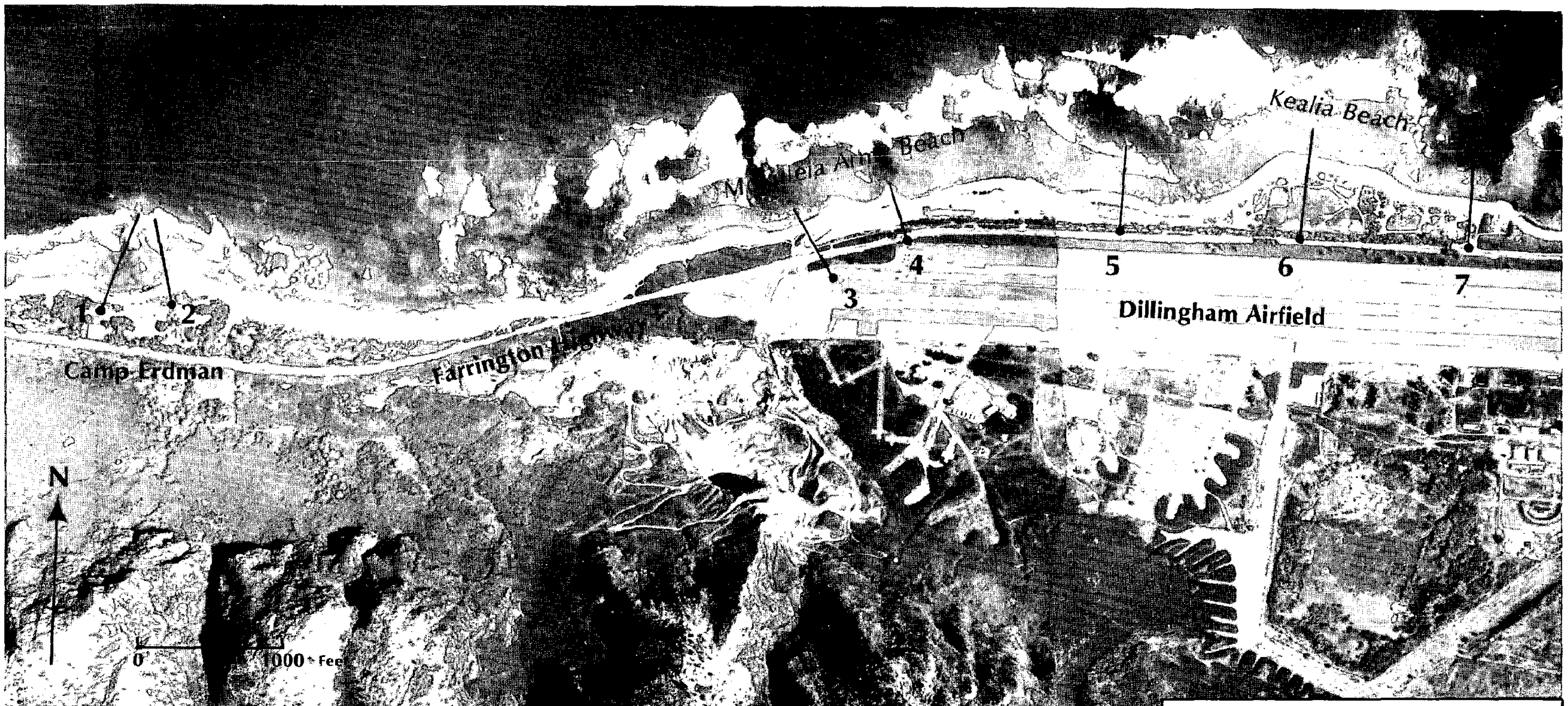
Along Kealia Beach, transects 5 and 6 showed a net increase in the vegetation line over a 30-year period. Although this section of Mokuleia appears safe, the aerial photographs show the possible effects from tsunami inundation.

On the 1958 photograph for Kealia Beach, the vegetation has a light tone and is less extensive than in 1949 (Plate 1). On certain sections of this beach the stripping of the vegetation due to a sand mining operation is clearly evident. On other beach sections, however, it appears that the vegetation may have been killed by the inundation of seawater, sand and debris from the 1957 tsunami. Although runup data for this beach are unavailable, about 1 mile to the west, estimated wave heights of 24 feet were recorded (Loomis, 1976). This estimate is the height of the maximum intrusion of the water onto the land. If the 1958 photograph records tsunami inundation, then wave runup was about 500 feet inland.

Table 1 - Mokuleia Beach (West End). Changes in the Vegetation Line in Feet.

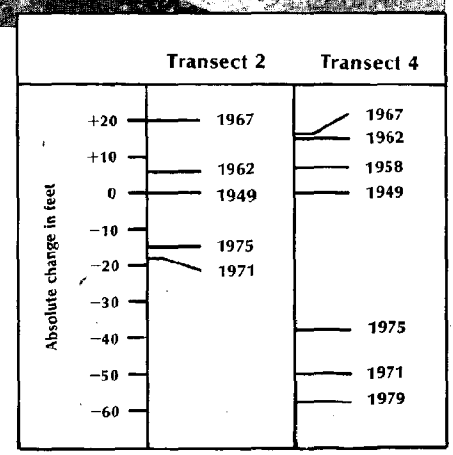
Observation Period	Transect Number 1	2	3	4	5	6	7
Sep 28, 1949 - Nov 01, 1958	*	*	-79	+7	+1	-9	-85
Nov 01, 1958 - Aug 22, 1962	-2[1]	+6[1]	+95	+8	+16	+26	+62
Aug 22, 1962 - Apr 22, 1967	+11[2]	+14[2]	+6	+1	+9	-8	+80
Apr 22, 1967 - Mar 17, 1971	-18[2]	-38[2]	-22	-66	+2	-3	-19
Mar 17, 1971 - Apr 11, 1975	-6	+3	-67	+12	+1	-2	+4
Apr 11, 1975 - Aug 06, 1979	*	*	0	-19	+6	+3	-79
Net Change - Vegetation Line	-15	-15	-67	-57	+17	+7	-37
Range - Vegetation Line	24	38	101	73	17	26	142
Net Change - Water Line	-6	-32	-2	+21	-2	+26	-8
Range - Water Line	26	42	45	56	23	33	31

** No data*
[1] Change from Sept. 1949 - Aug. 1962
[2] The 1967 photographs were taken on May 29
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

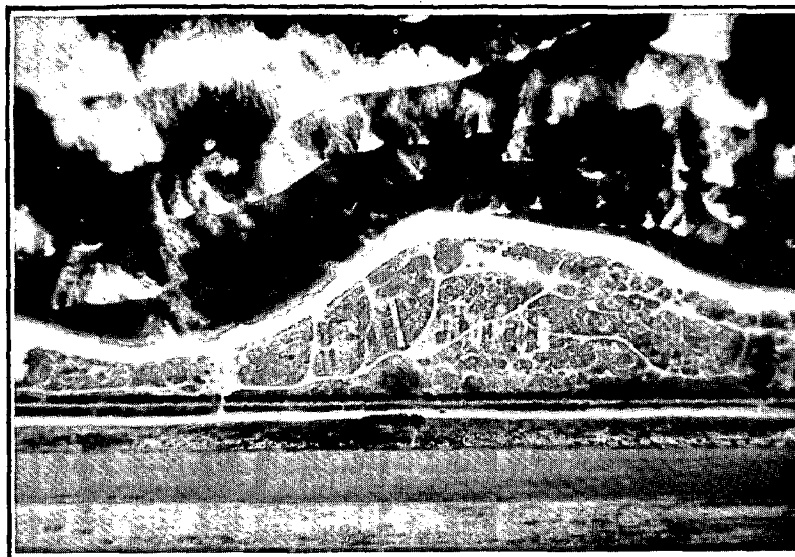


Photomap 1. Mokuleia Beach (West End)

Photographs by Air Survey Hawaii: March 1971



Absolute change is the change in the position of the vegetation line compared to the earliest or base year.



1949

1958

Plate 1. Mokuleia Beach (West End). Possible inundation from the 1957 tsunami at Mokuleia Beach (opposite the middle of Dillingham Airfield). The light streaks on the right side of the 1958 photograph are attributed to sand mining.

At transect 7, the vegetation line has undergone large changes. The retreat of the vegetation line by 85 feet during the 1949 to 1958 period is attributed to human alterations. From 1958 to 1967, the vegetation line advanced seaward 142 feet. Over the 1967 to 1971 interval, the vegetation line receded 19 feet. This change is partly due to the December 1-4, 1969 storm. Since 1971, the changes in the vegetation line have been partially influenced by man. Over a 30-year period, there appears to be no significant net change in the position of the water line.

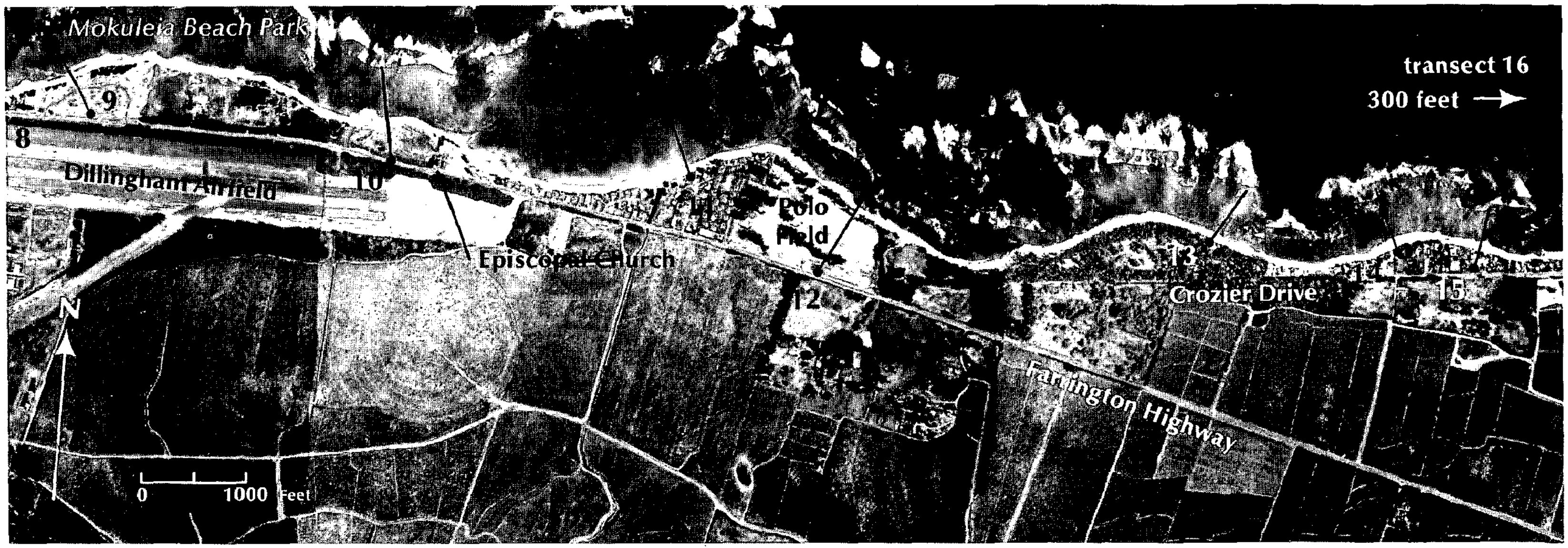
Transect 7 faces a large offshore channel. This bottom configuration would allow storm waves to break closer to shore.

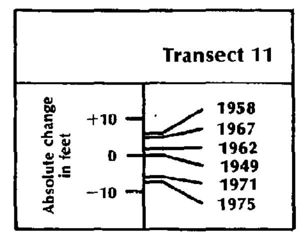
Mokuleia Beach (Middle Section)

The middle section of Mokuleia Beach has experienced small long-term changes. Transects 10 to 13 had a net loss in the vegetation line of 8 to 12 feet (Photomap 2, Table 2). Generally, the major erosion occurred during the 1967 to 1971 period. At transect 15 the vegetation line receded 15 feet during the 1949 to 1958 period.

Many of the homes from the Episcopal Church to the Polo Field and along Crozier Drive are less than 20 feet from the edge of the vegetation line or a seawall. Because of this development close to the shore, any loss to the beach or vegetation is of great concern to the residents. For many of these homes, erosion of only 10 feet would reduce the natural buffer zone significantly.

Since the 1946 and 1957 tsunamis, much of the land behind this beach has been developed. When a large storm or tsunami reoccurs, the property damage for these residential areas could be extensive.





Photomap 2. Mokuleia Beach (Middle Section)

Photographs by Air Survey Hawaii: March 1971

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Table 2 - Mokuleia Beach (Middle Section). Changes in the Vegetation Line in Feet.

Observation Period	Transect Number								
	8	9	10	11	12	13	14	15	16
Sep 28, 1949 - Nov 01, 1958	*	-6	+4	+6	-4	*	+1[2]	-15[2]	-4[2]
Nov 01, 1958 - Aug 22, 1962	*	-1	-5	-4	+3	-6[3]	+7	+28	+20
Aug 22, 1962 - Apr 22, 1967	*	+8	+7	+3	-3	-7	-2	-8	-9
Apr 22, 1967 - Mar 17, 1971	-2	-3	-8	-12	-5	-2	+7	-1	*
Mar 17, 1971 - Apr 11, 1975	-1	-2	-8	-1[1]	-7	+2	-3	+5	+2[4]
Apr 11, 1975 - Aug 06, 1979	+12	+9	-1	*	+8	+1	-4	-8	+1
Net Change - Vegetation Line	+9	+5	-11	-8	-8	-12	+6	+1	+10
Range - Vegetation Line	12	12	17	14	16	15	13	28	20
Net Change - Water Line	-18	-8	+22	+6	-7	0	-5	+17	0
Range - Water Line	18	49	50	25	31	25	43	89	43

**No data*
1 To seawall
2 The 1949 photographs were taken on May 7
3 Change from 1949 to 1962
4 Change from 1967 to 1975
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

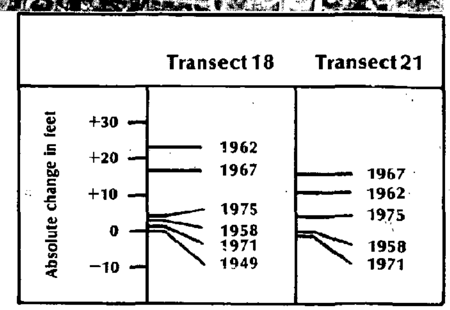
Mokuleia Beach (East End)

Between 1949 and 1979, the vegetation line along most of East Mokuleia grew seaward. Although this stretch appears to have a long-term history of accretion, there are periods when erosion occurs. During the 1949 to 1958 period, the vegetation line at transect 20 receded 21 feet (Photomap 3, Table 3). Over the 1967 to 1971 interval, the vegetation line for transects 18 and 21 receded over 15 feet. This change is attributed to the severe damage from the December 1969 storm.

The most recent aerial photograph for East Mokuleia was taken on August 1979. Since then, several sections of the beach were damaged

Photomap 3. Mokuleia Beach (East End)

Photographs by Air Survey Hawaii: March 1971



Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

by the large waves during the winter of 1980. Near transect 21, a six-foot-high escarpment was cut within a few feet of one house.

East Mokuleia Beach has the same problems as many sections of the north shore. The development close to the beach makes homes extremely susceptible to inundation from winter waves and tsunamis.

Table 3 - Mokuleia Beach (East End). Changes in the Vegetation Line in Feet.

Observation Period	Transect Number 17	18	19	20	21	22	23
May 07, 1949 - Nov 01, 1958	-1	+3	*	-21	*	*	*
Nov 01, 1958 - Aug 22, 1962	0[1]	+20	*	+11	+11	+20	+19
Aug 22, 1962 - May 29, 1967	+21	-6	*	+7	+5	+8	-2
May 29, 1967 - Mar 17, 1971	+3	-16	+7	-2	-17	-1	-1
Mar 17, 1971 - Apr 11, 1975	-1	+3	-3	-3	+5	-5	+8
Apr 11, 1975 - Aug 06, 1979	+11	*	+3	*	*	*	*
Net Change - Vegetation Line	+33	+4	+7	-8	+4	+22	+24
Range - Vegetation Line	34	23	7	21	17	28	24
Net Change - Water Line	+10	-16[2]	+1	-17	+14	+37	+13
Range - Water Line	25	18[2]	26	33	14	37	24

** No data*
[1] Built wall
[2] From 1949-1979
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

Kaiaka Bay Beach

The aerial photographic data for Kaiaka Bay Beach exist from 1958 to 1975. Over this 17-year interval, the vegetation line and water line at mid-beach advanced seaward 45 to 50 feet (Photomap 4, Table 4). The major accretion of the vegetation occurred during the 1958 to 1962 and 1971 to 1975 intervals.

The dark sand at Kaiaka Beach consists primarily of sediments derived from erosion of the hinterland. There appears to be little source of carbonate sand, for the beach is a closed littoral cell with no offshore reef. The small amount of calcareous sand present may be derived from coastal erosion of a fossil reef.

Table 4 - Kaiaka Bay Beach. Changes in the Vegetation Line and Water Line in Feet.

Observation Period	Vegetation	Water
Nov 01, 1958 - Aug 22, 1962	+21	-16
Aug 22, 1962 - May 29, 1967	+1	+22
May 29, 1967 - Mar 17, 1971	+4	+44
Mar 17, 1971 - Apr 11, 1975	+23	-4
Net Change	+49	+46
Range	49	66

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

Photomap 4. Kaiaka Bay Beach

Photographs by Air Survey Hawaii: March 1971

Haleiwa Residential Area to Alii Beach Park

The beach from the Haleiwa residential area to Alii Beach Park is about 4,000 feet long. Over this stretch six transects were established (Photomap 5).

Along the residential section, seawalls are present along much of the beach. Therefore, the set of data on the vegetation line is limited. In front of one undeveloped lot at transect 1, the vegetation line grew seaward 35 feet over the 1962 to 1971 period (Table 5).

The water line data for transects 1 and 2 also show an accretion of 28 to 50 feet. This accretion was recorded during all four observation intervals. From May 1949 to April 1975 several outcrops of rock have become surrounded or covered by sand.

The Haleiwa residential area appears to have a long-term history of accretion. Unfortunately, when the beach was developed, no allowance was made for the large seasonal changes or short-term erosion events that are inevitable on the north shore. As a result, protective structures were required at this beach.

Several of the houses at Haleiwa are less than 20 feet inland of the seawalls. Although the offshore reef may absorb some wave energy, the potential for damage from winter waves and tsunamis is always present.

At Alii Beach Park, the littoral cell is divided by an outcrop of rock. To the west of the rock, the beach has grown over a 26-year period. From 1949 to 1975 the vegetation line for transects 3 and 4 grew seaward 14 feet and 9 feet, respectively. Over the same interval, accretion of the water line was up to 52 feet.

East of the rock, the water line and vegetation line changes indicate a different beach history. From 1949 to 1975, the water line near the park bathhouse extended seaward 42 feet. On the aerial photograph this change is shown by the coverage of beachrock by sand.

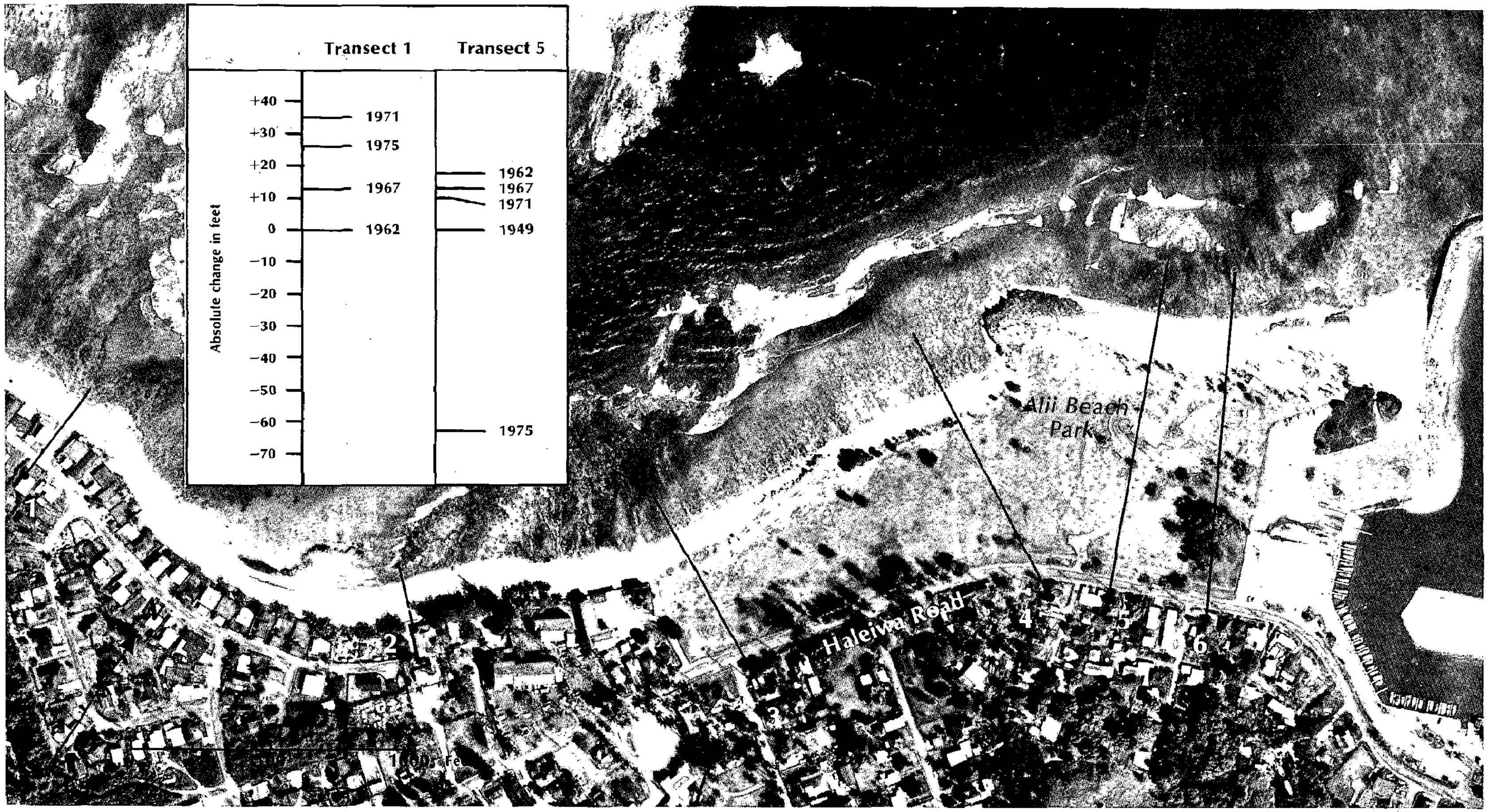
Measurements on the vegetation line, however, suggest a large erosion event during the 1971 to 1975 period. This change could be attributed to the deposition of sand inland by strong winds or waves. There appears to be no long-term erosion, as many palm trees are located seaward of the line of lower vegetation.

When Alii Beach Park was built, the change from salt-tolerant coastal plants to the grass at the park may have caused the vegetation line to recede.

Table 5 - Haleiwa Residential Area to Alii Beach Park. Changes in the Vegetation Line in Feet.

	Transect Number					
Observation Period	1	2	3	4	5	6
May 08, 1949 - Aug 24, 1962	*	+4[1]	+7	+7	+18	+9
Aug 24, 1962 - Apr 22, 1967	+13	*	+2	-2	-5	-14
Apr 22, 1967 - Jan 23, 1971	+22	*	+4	+20	-3	0
Jan 23, 1971 - Apr 11, 1975	-9	*	+1	-16	-73	-56
Net Change - Vegetation Line	+26	+4	+14	+9	-63	-61
Range - Vegetation Line	35	4	14	25	81	70
Net Change - Water Line	+28	+50[2]	+52	+29	+36	+42
Range - Water Line	28	50[2]	52	46	38	46

** No data*
[1] To seawall
[2] From 1949-1975
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 5. Haleiwa Residential Area to Alii Beach Park

Photographs by Air Survey Hawaii: April 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Haleiwa Beach Park

The history of erosion at Haleiwa Beach Park prior to 1965 is described in the National Shoreline Study (U.S. Army Engineers, 1971). Since 1965, the configuration of the beach has been altered by a groin, an offshore breakwater and several beach repair projects.

In this study, the data for Haleiwa Beach Park were obtained from measurements to the water line over the eight-year period from 1967 to 1975. During this interval the beach changes were partly artificial. In 1970, the Army Corps of Engineers spread 7,000 cubic yards of sand along the shoreline to repair the beach from the December 1969 storm (U.S. Army Engineers, 1971). The high waves during this storm washed beach sand onto the parking lot, baseball field and highway. Sand was also carried over the boulder groin into the boat channel. In 1974, an estimated 4,000 cubic yards of sand from the Haleiwa boat channel were placed on the beach.

The photographic data between 1971 and 1975 show that the water line at the south end of Haleiwa Beach grew seaward 64 feet while at the north end it eroded 30 feet (Photomap 6, Table 6). Erosion was also recorded for the sections immediately to the north and south of the offshore breakwater. Although Haleiwa Beach was modified artificially during this period, the data indicate the possibility of a slight long-term littoral drift to the south.

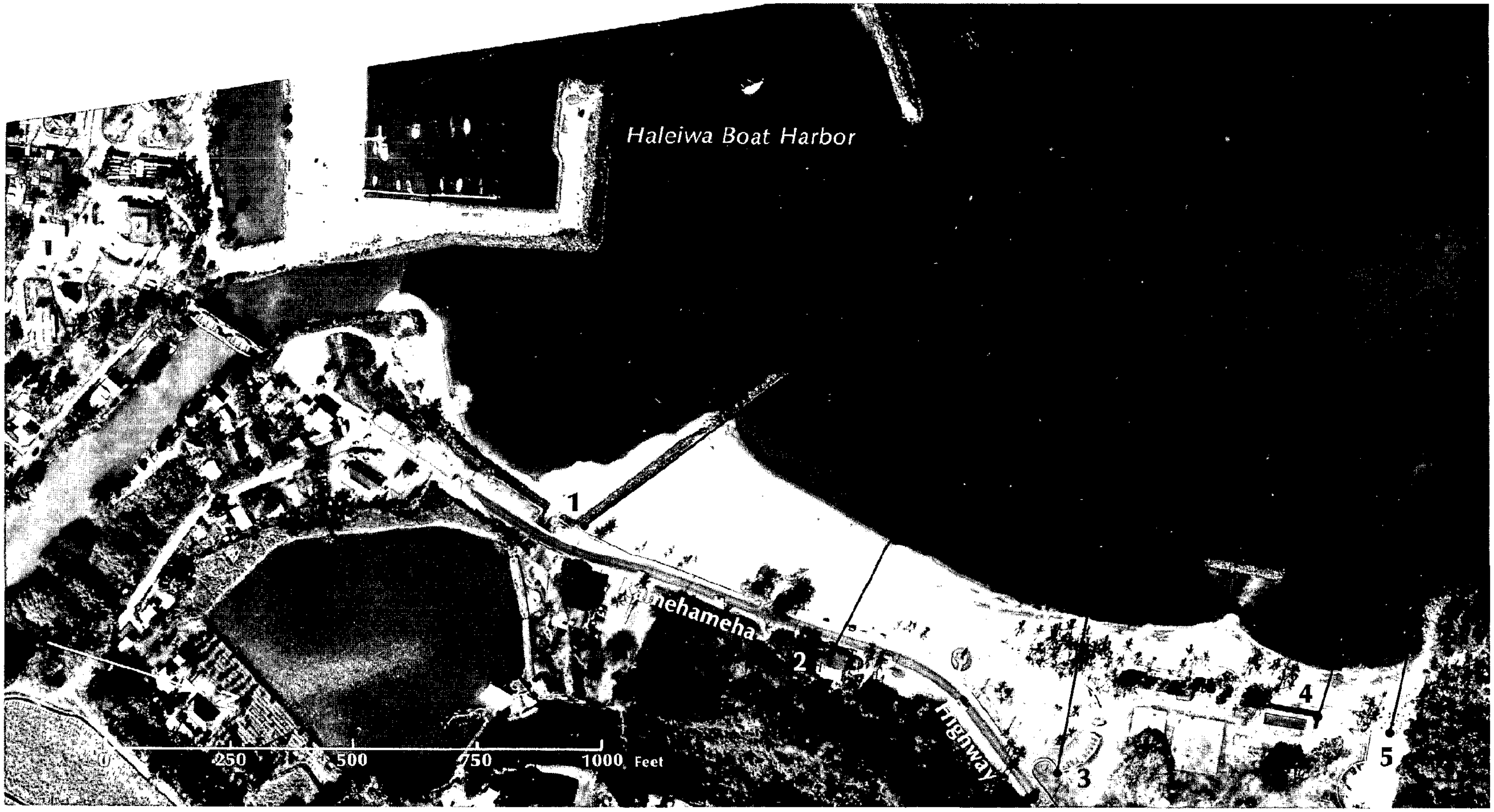
Observations during October and December of 1972 indicate a predominant north-south current with strong rip currents to either side of the breakwater (Gerritsen, 1978a). This circulation pattern coincides strongly with the beach changes observed during the 1971 to 1975 period. Generally, longshore currents carry sand along the beach in a southerly direction. The sand is carried seaward by strong rip currents to either side of the breakwater. These currents have formed a tombolo near the breakwater. Weaker rip currents in the vicinity of the groin have the potential to carry sand offshore.

To reduce the possibility of sand loss from the beach, "T" groins can be constructed to divide the system into three subcells (Gerritsen, 1978a). A cheaper and more esthetically pleasing alternative might be a combination of structural measures and periodic sand relocation from the south end of the beach to the north.

Table 6 - Haleiwa Beach Park. Changes in the Water Line in Feet.

	Transect Number				
Observation Period	1	2	3	4	5
Apr 22, 1967 - Jan 23, 1971	+49	+11	+15	+12	-1
Jan 23, 1971 - Apr 11, 1975	+64	+22	-30	-22	-30
Net Change - Water Line	+113	+33	-15	-10	-31
Range - Water Line	113	33	30	22	31

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 6. Haleiwa Beach Park

Photographs by Air Survey Hawaii: April 1975

Kawailoa Beach

The western section of Kawailoa Beach covered by transects 1 through 5 is characterized by small long-term changes (Photomap 7). All five transects show the range and net change in the position of the vegetation line to be under 10 feet (Table 7). At transect 4, however, the water line receded 57 feet over the 1962 to 1975 period. This change has gradually exposed rock along the shoreline. If the protective beach continues to diminish in size, several homes may become more susceptible to winter wave inundation.

From transects 6 to 11, the vegetation line has had a tendency to grow seaward. This accretionary trend was offset by the large losses of up to 42 feet during the 1967 to 1971 interval (Photomap 7 cont.). The high waves during the December 1-4, 1969 storm caused erosion of the vegetation and much structural damage on Kawailoa Beach.

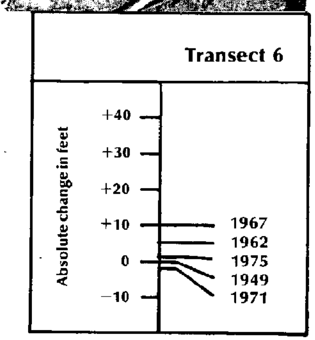
Table 7 - Kawailoa Beach. Changes in the Vegetation Line in Feet.

	Transect Number										
Observation Period	1	2	3	4	5	6	7	8	9	10	11
May 08, 1949 - Aug 24, 1962	*	+4	+6	*	+7	+5	*	+11	*	-3	+23
Aug 24, 1962 - Apr 22, 1967	0	+1	+1	-2	0	+5	+3	+3	+5	+7	+13
Apr 22, 1967 - Jan 23, 1971	-2	-1	-4	-3	-7	-12	-13	-7	-12	-2	-42
Jan 23, 1971 - Apr 11, 1975	-4	-4	-1	-4	+2	+3	+10	+2	0	+3	+10
Net Change - Vegetation Line	-6	0	+2	-9	+2	+1	0	+9	-7	+5	+4
Range - Vegetation Line	6	5	7	9	7	12	13	14	12	8	42
Net Change - Water Line	*	+2	+4	-57	+46	+41	-30	-1	+6	+4	+4
Range - Water Line	*	68	39	57	46	104	30	29	17	45	20

** No data*

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.

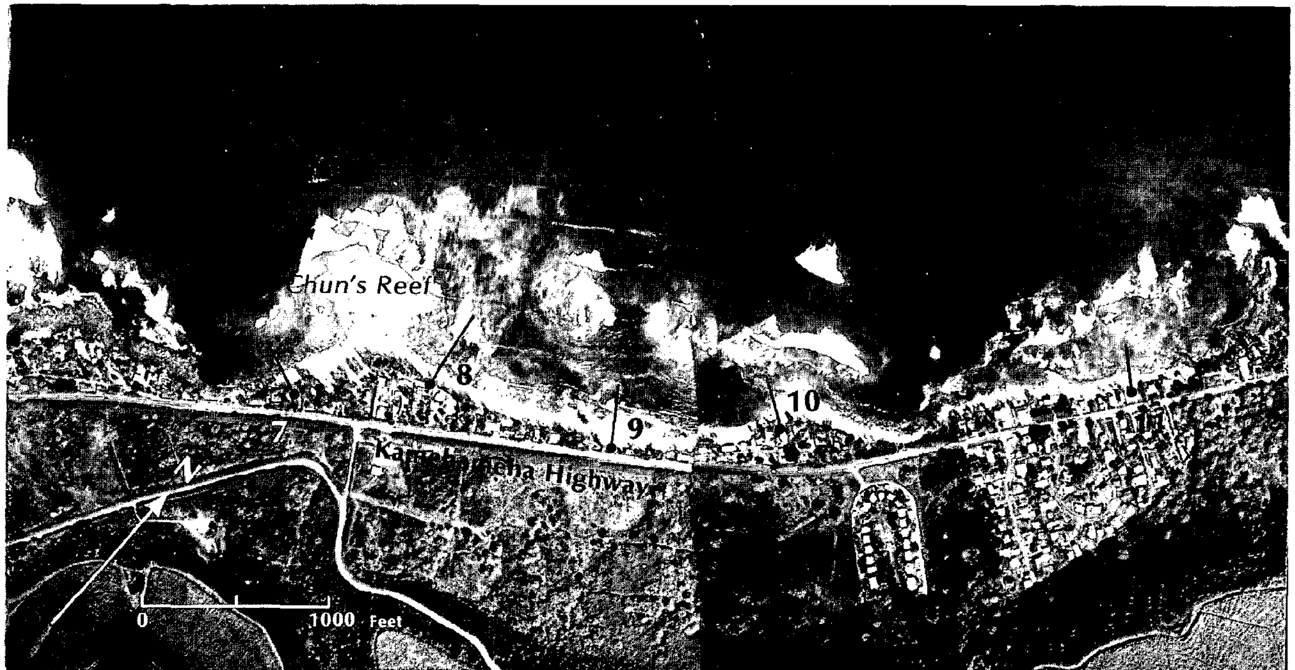
Range is the difference between the observed extremes in the position of a beach index line.

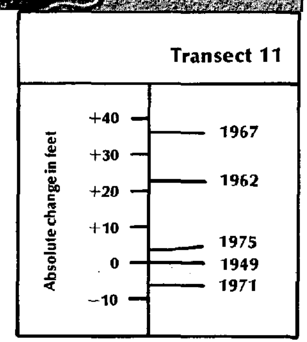


Photomap 7. Kawailoa Beach

Photographs by Air Survey Hawaii: April 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.





Photomap 7. Kawailoa Beach (continued)

Photographs by Air Survey Hawaii: April 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Waimea Bay Beach Park

Waimea Beach is a closed littoral cell bounded by two rocky promontories and deep offshore waters. Therefore, there is little supply of sand from adjacent sections of the coast. There also appears to be little contribution from Waimea Stream as most of the sand is of marine origin (Moberly and Chamberlain, 1964). Finally, the offshore reef at Waimea is limited in extent and confined to the narrow shelf at the northeast side of the bay. For this reason, biological contributions of sand to the beach may be exceedingly slow.

With no active sand supply to balance the losses from sand mining and winter storms, Waimea Beach must be eroding. Evidence from an 1884 survey map and old air photos support this conclusion.

The 1884 survey map of Waimea Bay reveals that the water line was once seaward of Table Rock (Photomap 8). The 1928 aerial photograph also shows this rock surrounded by sand. Today, Table Rock is used as a diving platform and a race marker for swimmers. It is apparent that Waimea Beach has receded considerably.

Table 8 shows the historic changes in the position of the vegetation line for the three transects established at Waimea. Because of the extensive alterations inland, no single transect records the beach change over the entire 47-year period. In order to maintain continuity, the average of the measured changes for each observation interval has been computed. This figure appears in the right-hand column of Table 8. A similar calculation was performed for the data on the water line.

On Figure 3, the historic position of the vegetation line and water line is drawn against time. Over a 47-year period, the net loss in the water line was 194 feet. The major erosion occurred during the 1928 to 1962 period when the beach receded 215 feet. It is not known how much of this change is seasonal as opposed to long-term. The 1962 photograph, however, was taken at the end of the summer when the beach should have been in a high accretion state. Therefore, the 215 feet of erosion may be an underestimate of the real long-term change. The water line retreat during this interval was partly caused by the sand mining operation at Waimea, although the full impact of the industry on the beach is unknown.

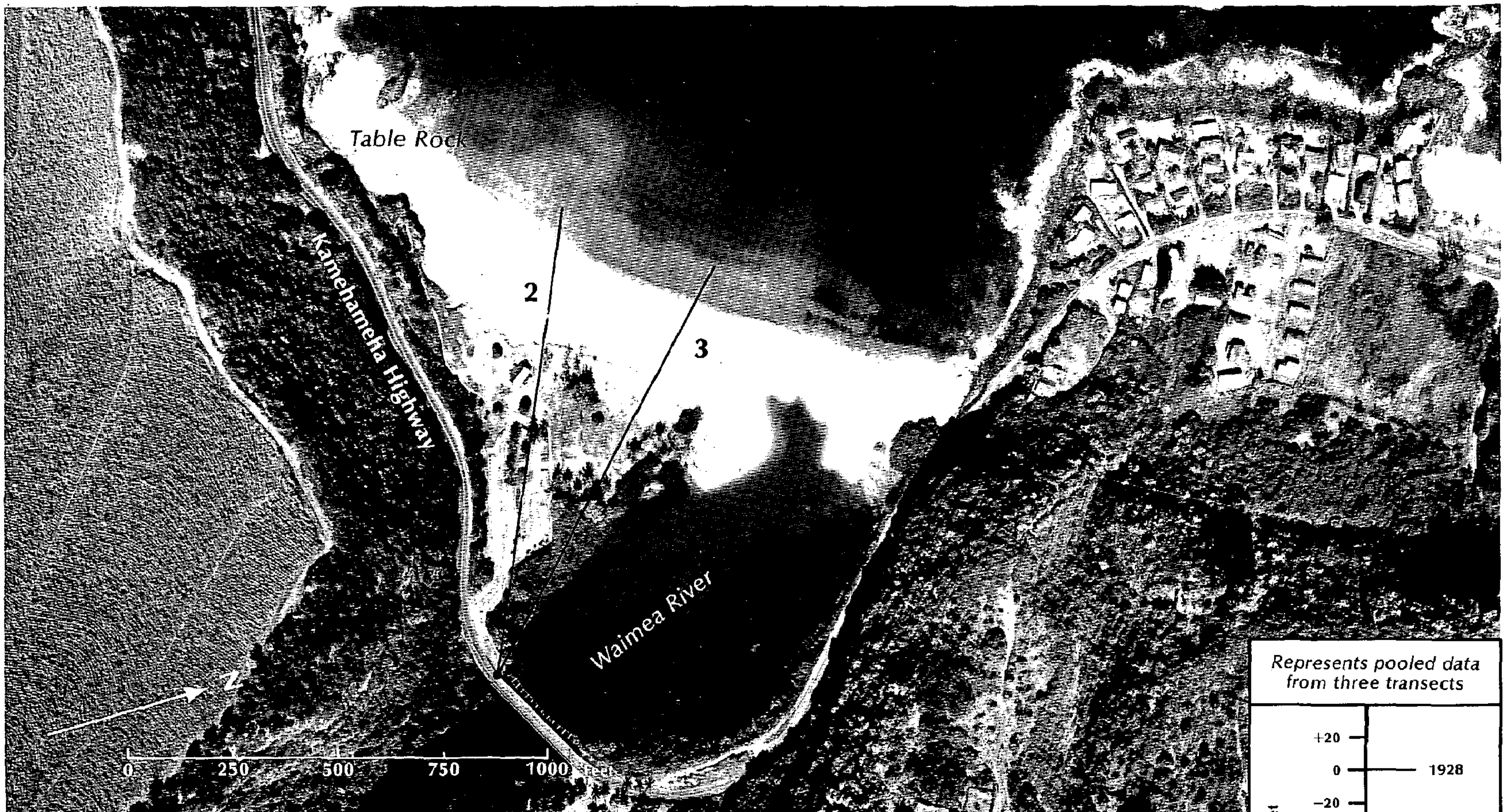
From August 24, 1962 to April 22, 1967, the water line grew seaward 75 feet. During the next observation period, to January 1971, the beach receded about 60 feet. A possible cause for this change is discussed below.

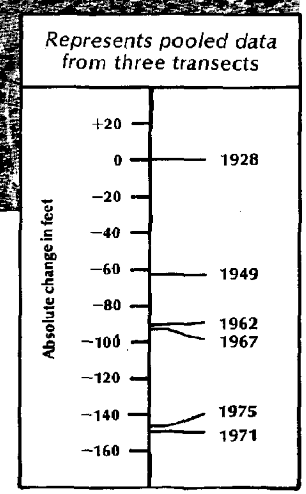
The changes of the vegetation line at Waimea Beach show a considerably different trend than the water line. From 1928 to 1949, the vegetation line at mid-beach receded about 63 feet. Due to a lack of aerial photographic coverage, it is not known whether the loss occurred at a steady 3 feet per year or suddenly during a large storm event. Perhaps some of the erosion was caused by the 1946 tsunami, which did tremendous damage to the Hawaiian Islands.

Table 8 - Waimea Bay Beach Park. Changes in the Vegetation Line in Feet.

	Transect Number			
Observation Period	1	2	3	Average
1928 - May 08, 1949	-63	*	*	-63
May 08, 1949 - Aug 24, 1962	*	*	-28	-28
Aug 24, 1962 - Apr 22, 1967	*	0	-6	-3
Apr 22, 1967 - Jan 23, 1971	*	-65	-46	-56
Jan 23, 1971 - Apr 11, 1975	*	+11	-5	+3
Net Change - Vegetation Line				-147
Range - Vegetation Line				150
Net Change - Water Line				-194
Range - Water Line				215

** No data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.





Photomap 8. Waimea Bay Beach Park

Photographs by Air Survey Hawaii: April 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

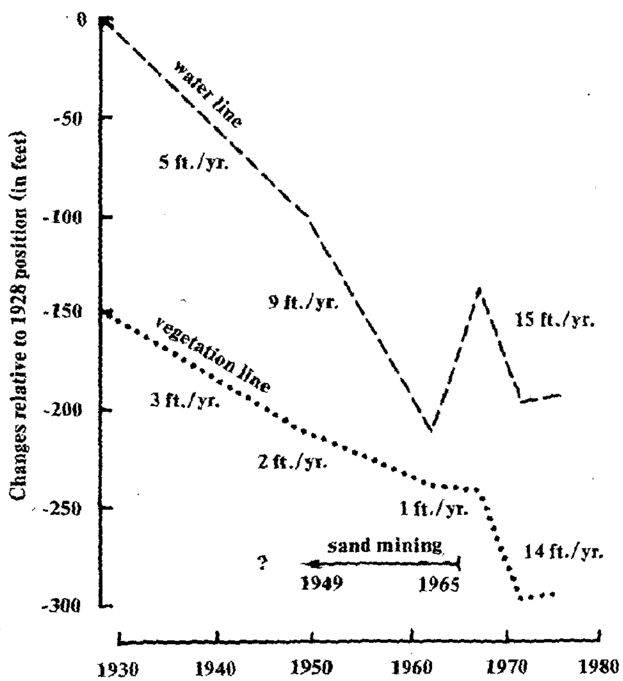


Figure 3. Waimea Beach Erosion. The changes in the water line and vegetation line represent the average of three transects established at the beach.

From 1949 to 1967, the vegetation line receded at a rate of about 1-2 feet per year. This loss is concurrent with the sand mining operation at Waimea.

The highest rates of erosion for both the water line and vegetation line occurred during the 1967 to 1971 period (Figure 3). The rates of retreat were about 14 to 15 feet per year when averaged over a four-year period. This loss was not steady, however, but occurred during the large storm of December 1-4, 1969. During this storm, tremendous waves filled Waimea Bay with turbulent water. Ground photographs show storm waves running up onto the beach and cutting a scarp in the vegetation. Inundation was more than 750 feet inland and several sections of the highway and parking lot were covered with rocks and sand (State of Hawaii, DLNR, 1970).

It appears that sand put into suspension by storm waves was carried outside the breaker zone by rip currents and deposited at depths where summer waves cannot move sediment shoreward. Thus, the sand was permanently removed from the beach system.

If the vegetation line records the real long-term trend, then the data show that Waimea has eroded continuously. Although the sand mining operation was undoubtedly part of the cause, the measurements indicate that Waimea Beach can be permanently damaged by periodic storm events.

Since the water line has a large seasonal change superimposed on the long-term trend, it is difficult to determine the full impact of the sand mining operation on Waimea Beach. In this case, the seasonal change is noise in the data and complicates the interpretation on changes in the water line.

Over nearly half a century, Waimea Beach, which acts as a buffer zone to protect the vegetation and inland structures from wave attack, has been reduced in size. Another storm, such as the one that occurred in December 1969, could damage the facilities at the beach park. If this occurs, the state may be inclined to save the park by structural means or sand replenishment. Either of these measures would be a costly and perhaps temporary solution.

Pupukea Beach

The small 300-foot-long pocket beach east of Waimea had a net change of +12 feet between 1949 and 1975. Over the same period, the vegetation line receded 25 feet. The major loss occurred during the 1967 to 1971 interval when the vegetation line receded 42 feet. This change is attributed to the December 1969 storm.

Sunset Beach

Sunset Beach is characterized by large seasonal changes in the water line and relatively small long-term changes in the vegetation line. Over a 30-year period, there has been a slight tendency for the vegetation to grow seaward. This trend was offset during the 1967 to 1971 period by losses of up to 21 feet caused by the storm of December 1-4, 1969 (Photomap 9, Table 9).

The severe damage at Sunset caused by the 1969 storm is explained in a post-flood report (State of Hawaii, DLNR, 1970). One of the worst-stricken areas was at the west end of Sunset Beach, in front of Ke Iki Road. An examination of the 1967 and 1971 photographs shows that at least two houses were swept off their foundations by the large waves (Plate 2). In all, 14 houses were demolished along this stretch.

Retreat of the vegetation line was recorded for transect 8 during the 1971 to 1975 observation period. This change appears localized. All transects, except for 8, show little net change or small gains in the vegetation line over a 30-year period.

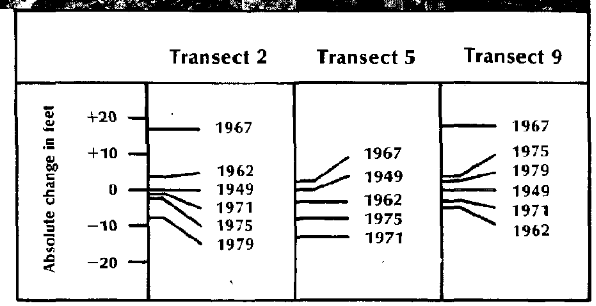
Table 9 - Sunset Beach. Changes in the Vegetation Line in Feet.

	Transect Number										
Observation Period	1	2	3	4	5	6	7	8	9	10	11
May 08, 1949 - Aug 24, 1962	-4	+4	+12	+15	-3	+5	+2	*	-5	+6	-2
Aug 24, 1962 - Apr 22, 1967	0	+13	+12	-1	+5	-2	+7	0	+23	+4	+9
Apr 22, 1967 - Jan 23, 1971	-2	-18	-11	+1	-15	-2	-14	-10	-21	+7	-11
Jan 23, 1971 - Apr 11, 1975	+4	-1	-4	-4	+5	+9	-3	-10	+7	+4	+12
Apr 11, 1975 - Apr 03, 1979	-6	-5	-2	+5	*	+3	+1	+1	-1	-7	+2
Net Change - Vegetation Line	-8	-7	+7	+16	-8	+13	-7	-19	+3	+14	+10
Range - Vegetation Line	8	24	24	16	15	13	17	20	23	21	14
Net Change - Water Line	-22	-15	+42	-48	-99	+2	-17	-16	+59	-26	-6
Range - Water Line	140	64	92	158	199	133	118	53	77	33	33

** No data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

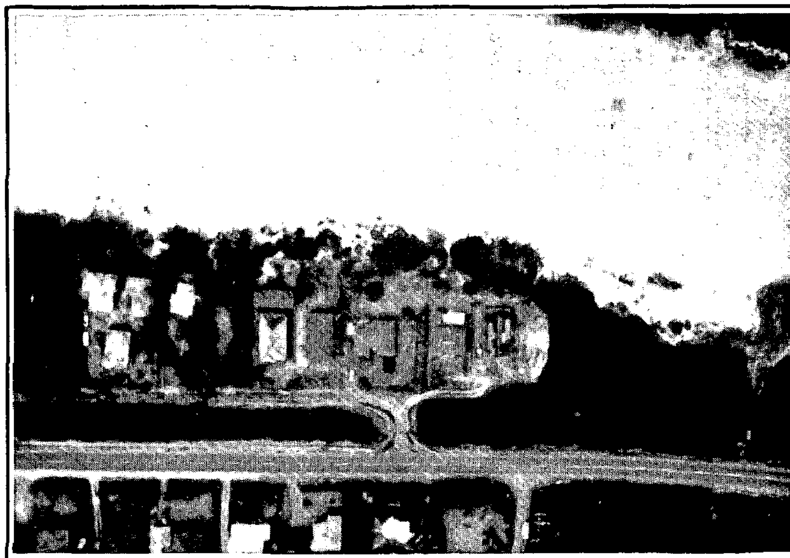
Photomap 9. Sunset Beach

Photographs by Air Survey Hawaii: April 1975



Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Plate 2. Sunset Beach (West End). Damage from the December 1-4, 1969 storm at west Sunset Beach. Note the recession of the vegetation and the houses missing on the 1971 photograph.



1967

1971

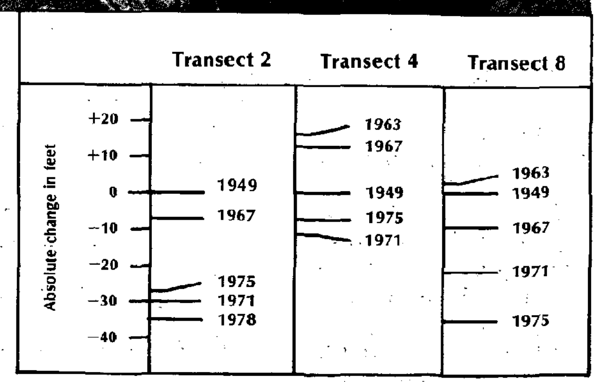
Sunset Point to West Kawela

The beach from Sunset Point to West Kawela is about 2 miles long. Along this stretch of coast are found the following beach sections: Kaunala Beach, Waialee Beach Park, and Pahipahialua Beach (Photomap 10).

At west Kaunala Beach, the vegetation line for transects 1 and 2 has receded over a 29-year period (Table 10). The stable reference point for transect 1 is located far from the vegetation line so the accuracy may be poor. Although the stable reference point for transect 2 is in the water, it is closer to the beach and probably has an accuracy of under ten feet. Over the 1949 to 1978 interval, the vegetation line at transect 2 receded 35 feet. This erosion was recorded in three of the four observation periods. The loss was especially high during the 1967 to 1971 interval and may be attributed to erosion by the December 1-4, 1969 storm.

Photomap 10. Sunset Point to West Kawela

Photographs by Air Survey Hawaii: June 1975



Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Table 10 - Sunset Point to West Kawela. Changes in the Vegetation Line in Feet.

Observation Period	Transect Number 1	2	3	4	5	6	7	8	9
May 08, 1949 - Nov 01, 1963	-7	*	+62	+16	+3	0	+25	+3	-2
Nov 01, 1963 - Apr 22, 1967	-10	-7[1]	-18	-3	+14	+7	0	-12	+13
Apr 22, 1967 - Jan 23, 1971	-3	-23	-16	-24	-13	+7	+3	-12	-15
Jan 23, 1971 - Jun 03, 1975	-3	+3	+9	+4	-4	-4	+9	-14	+2
Jun 03, 1975 - Jun 02, 1978	+3	-8	-10	*	+5	-8	*	*	-2
Net Change - Vegetation Line	-20	-35	+27	-7	+5	+2	+37	-35	-4
Range - Vegetation Line	23	35	62	27	17	14	37	38	15
Net Change - Water Line	+11	*	+7	-1	-39	+11	+8	-27	-2
Range - Water Line	59	*	42	24	54	25	14	27	23

**No data*
[1] Change from 1949-1967
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

At transect 3, the large changes in the vegetation line reflect the strong influence of a stream flowing 35 feet to the east. These changes are not representative of adjacent beach sections. Over a 29-year period, there has been little net change in the position of the water line.

Transects 4 and 5 are located at east Kaunala Beach. Generally, the vegetation line for this stretch had an increasing trend except for the large losses during the 1967 to 1971 interval. Erosion of up to 24 feet was probably caused by the December 1-4, 1969 storm.

The stretch of beach covered by transects 6 and 7 has been stable or shows a slight increasing trend.

At Waialee Beach Park, the vegetation line at transect 8 receded 38 feet over the 1963 to 1975 period. The erosion at this section has undermined an old bridge.

Transect 9 was established at Pahipahialua Beach. Over a 29-year period there has been a small net change in the vegetation line and water line. Thirteen feet of sparse vegetation grew seaward from 1963 to 1967 but was cut back during the next observation period.

Kawela Bay

All five transects at Kawela Beach show that the vegetation line was either stable or grew seaward between 1949 and 1978. Over this period, the vegetation at the west end of the beach had no net change while at the east end there was accretion of 37 feet (Photomap 11, Table 11). The changes in the vegetation at mid-beach fell between these extremes.

The water line data for Kawela Bay show beach accretion of 18 to 27 feet over a 29-year period. Although these changes may be seasonal, the gradual growth of the beach during four of the five observation periods suggests a long-term accretionary trend.

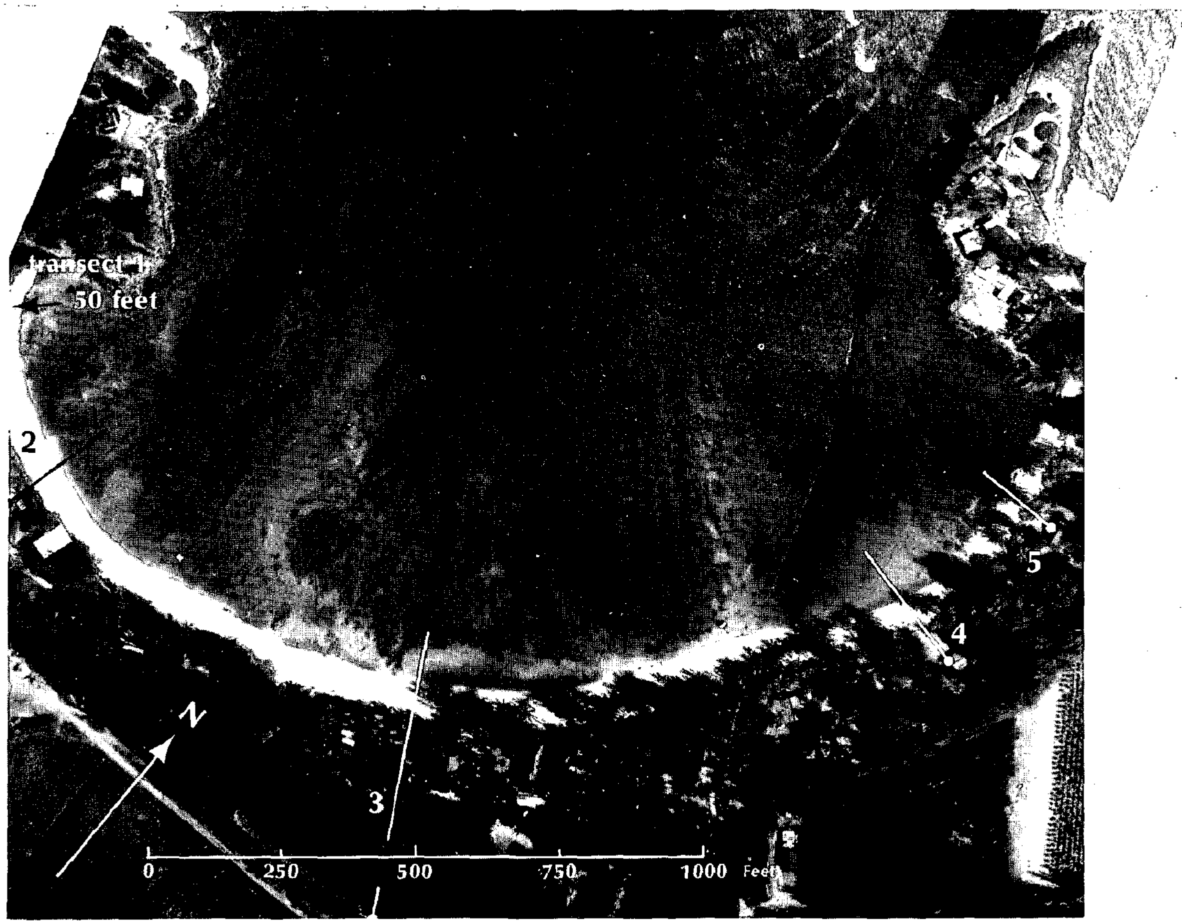
Kawela Bay is a natural sediment sink. Sand produced on the extensive reef is washed ashore by wave action. Once on the beach, the sand is confined by the rocky promontories to either side of the bay. Some loss may occur through the small reef channels but not enough to cause beach retreat.

Even though the beach at Kawela Bay has a history of accretion, storm and tsunami events have inflicted severe damage to the residential areas. During the 1946 tsunami, one house at Kawela was lifted off its foundation and carried across the road into the sugar field (Shepard et al., 1950). On December 1-4, 1969 large storm waves demolished two homes and damaged at least ten others (State of Hawaii, DLNR, 1970). The property damage inflicted at Kawela by these separate events demonstrates the potential danger in developing the north shore.

Table 11 - Kawela Bay. Changes in the Vegetation Line in Feet.

	Transect Number				
Observation Period	**1**	**2**	**3**	**4**	**5**
May 08, 1949 - Nov 01, 1963	+6	+18	-2	+7	+31
Nov 01, 1963 - Apr 22, 1967	+9	+2	+4	-1	+3
Apr 22, 1967 - Jan 23, 1971	*	-2	+7	+11	*
Jan 23, 1971 - Jun 03, 1975	-11[1]	-7	-8	+5	+2[1]
Jun 03, 1975 - Jun 02, 1978	-4	+2	+17	-9	+1
Net Change - Vegetation Line	0	+13	+18	+13	+37
Range - Vegetation Line	15	20	20	22	37
Net Change - Water Line	+18	+26	+19	+27	+19
Range - Water Line	25	26	26	29	25

** No data*
[1] Change from 1967-1975
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 11. Kawela Bay

Photographs by Air Survey Hawaii: June 1975

Turtle Bay

The shoreline at Turtle Bay has two beaches that are separated by a 400-foot stretch of rock and raised reef. To the west of the rock lies a 1,000-foot-long beach and residential area (Photomap 12). Over a 29-year period the vegetation for this beach grew seaward. At transects 1 and 2, the net gains were 19 and 6 feet, respectively (Table 12). During the same period, the water line for both transects receded 15 feet. This change may be seasonal.

Although the vegetation line for this beach section grew from 1949 to 1978, there is an indication that erosion had occurred previously. On the 1949 photograph, several houses are almost at the vegetation's edge. It is unlikely that these structures were built so close to the beach.

To the east of the beachrock, lies a concave beach fronting the Hyatt Kuilima Golf Course. Because of the extensive modifications inland, the data for this beach are not continuous.

Between 1949 and 1967, the vegetation line for the beach was stable or grew slightly. In 1971, the construction of the golf course was in progress. From 1975 to 1978, erosion of the vegetation line of 11 to 12 feet occurred. At the east end of this beach the water line receded 18 feet. Some of the condominiums at east Turtle Bay are about 35 feet from the vegetation line. Any erosion along this stretch would make these structures more susceptible to wave inundation.

As the data from the aerial photographs for this portion of the beach are scattered, it is not possible to predict future trends. It appears, however, that the position of the vegetation line was stable for most of the 29 years covered by the aerial photographs.

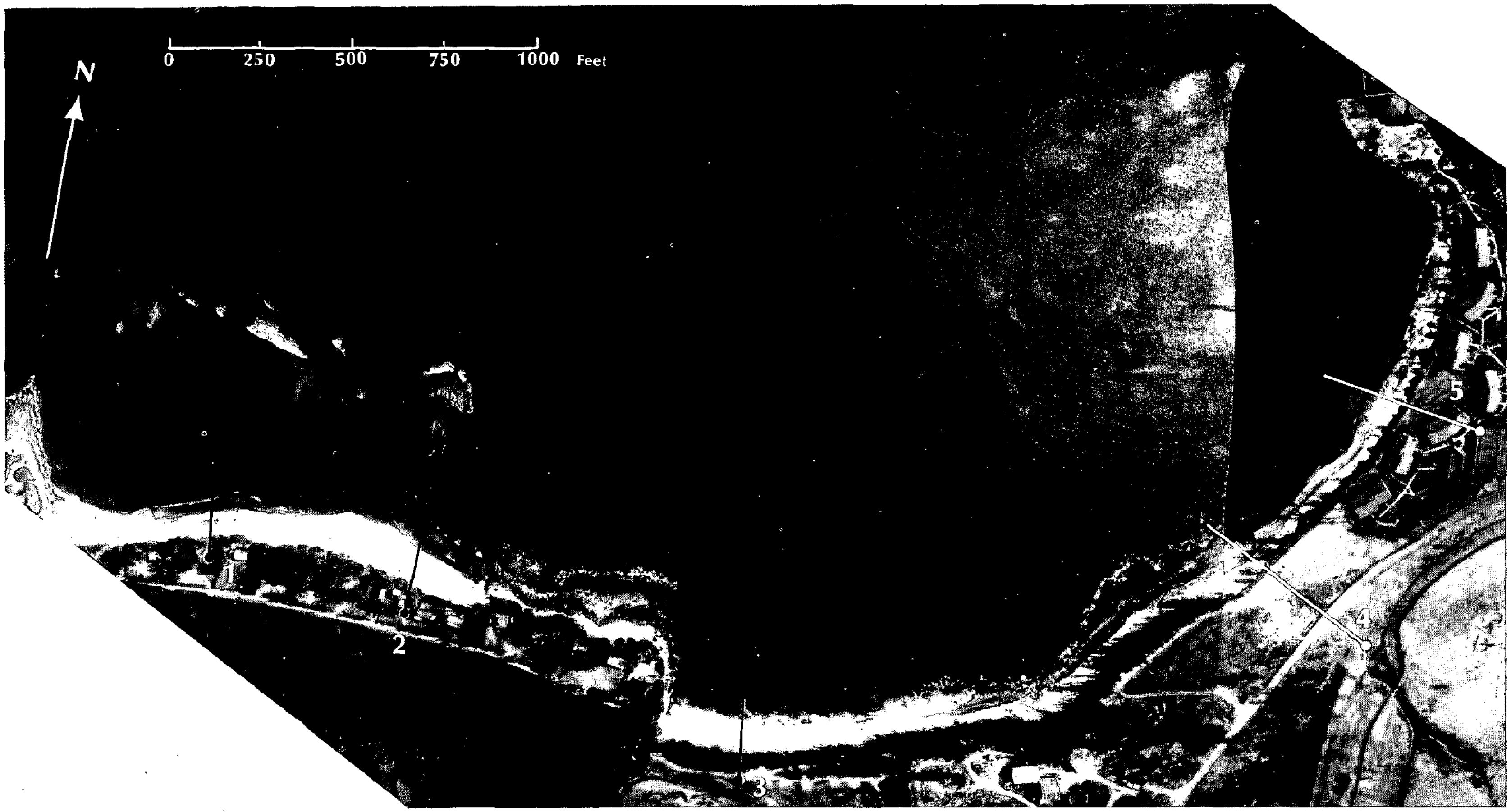
Table 12 - Turtle Bay. Changes in the Vegetation Line in Feet.

	Transect Number				
Observation Period	**1**	**2**	**3**	**4**	**5**
May 08, 1949 - Nov 01, 1963	+7	-3	*	*	*
Nov 01, 1963 - Apr 22, 1967	+7	+11	*	*	*
Apr 22, 1967 - Jan 23, 1971	+8	+1	*	*	*
Jan 23, 1971 - Jun 03, 1975	-3	+2	*	*	*
Jun 03, 1975 - Jun 02, 1978	0	-5	-11	-5	-12
Net Change - Vegetation Line	+19	+6	-11	-5	-12
Range - Vegetation Line	22	14	11	5	12
Net Change - Water Line	-15	-15	+4	-4	-18
Range - Water Line	22	16	4	4	18

**No data*

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.

Range is the difference between the observed extremes in the position of a beach index line.



Photomap 12. Turtle Bay

Photographs by Air Survey Hawaii: June 1975

Kaihalulu Beach

Kaihululu Beach is situated between Kalaeokamanu Point and Kahuku Point (Photomap 13). Over a 29-year period, the vegetation line for this beach had a small net change. Nevertheless, the vegetation line at transect 1 receded 18 feet during the 1967 to 1975 period (Table 13). This loss was probably caused by the December 1-4, 1969 storm.

The data from the water line indicate that this beach has diminished in size. In 1949, beachrock extended from Kahuku Point to the west end of Kahuku Airfield. The 2,700-foot stretch to the west was primarily sandy beach. By 1963, the beach at transects 1 and 2 receded 57 and 69 feet. This loss exposed 2,400 feet of beachrock along the shore. As of June 1978, only a 300-foot-wide beach was in direct contact with the sea.

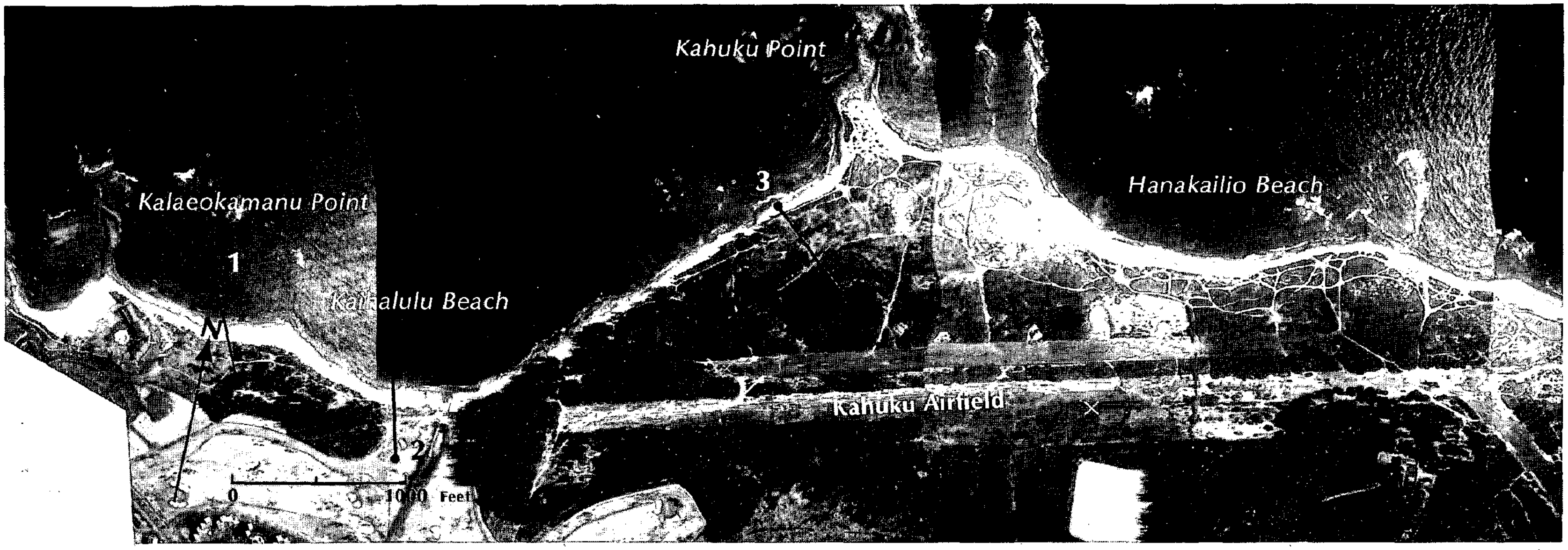
Since 1963 west Kaihalulu Beach has had small fluctuations in its width. From a qualitative analysis of the aerial photographs, this beach has grown slightly from 1963 to 1978.

The middle portion of Kaihalulu Beach near west Kahuku Air Field was inundated by the 1946 tsunami. On the 1949 aerial photograph, it is seen that sand and debris were scattered up to 900 feet inland along several sections of the Kahuku runway. These deposits do not appear to be windblown for the same reasons as discussed in the next section for Hanakäilio Beach.

Table 13 - Kaihalulu Beach. Changes in the Vegetation Line in Feet.

	Transect Number		
Observation Period	1	2	3
May 08, 1949 - Nov 01, 1963	+4	0	+6
Nov 01, 1963 - Apr 22, 1967	+7	-4	+7
Apr 22, 1967 - Feb 06, 1971	*	*	-5
Feb 06, 1971 - Jun 03, 1975	-18[1]	*	0
Jun 03, 1975 - Jun 02, 1978	+5	*	0
Net Change - Vegetation Line	-2	-4	+8
Range - Vegetation Line	18	4	13
Net Change - Water Line	-54	-77	*
Range - Water Line	57	77	*

**No data*
[1] Change from 1967 to 1975
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 13. Kaihalulu Beach and Hanakailio Beach

Photographs by Air Survey Hawaii: June 1975

Hanakailio Beach

Hanakailio Beach is bounded by Kahuku Point on the west and Kalaeuila Rock on the east (Photomap 13). This beach is fronted by a nearly continuous stretch of beachrock that protects the vegetation from normal winter waves. Occasionally, the protective barrier is overcome by waves of unusual height and force. This occurred during the 1946 tsunami, when large waves drove inland across the beachrock and dunes. Inundation onto the Kahuku airstrip was more than 1,200 feet inland (Plate 3).

1949

Plate 3. Kahuku Airfield. Sand washed ashore by the 1946 tsunami is shown on the 1949 photograph of Kahuku Airfield.

It may be argued that the sand deposits located on the airfield in 1949 are windblown. This appears unlikely for the following reasons:

(1) The sand deposits do not have a shape characteristic of dunes.

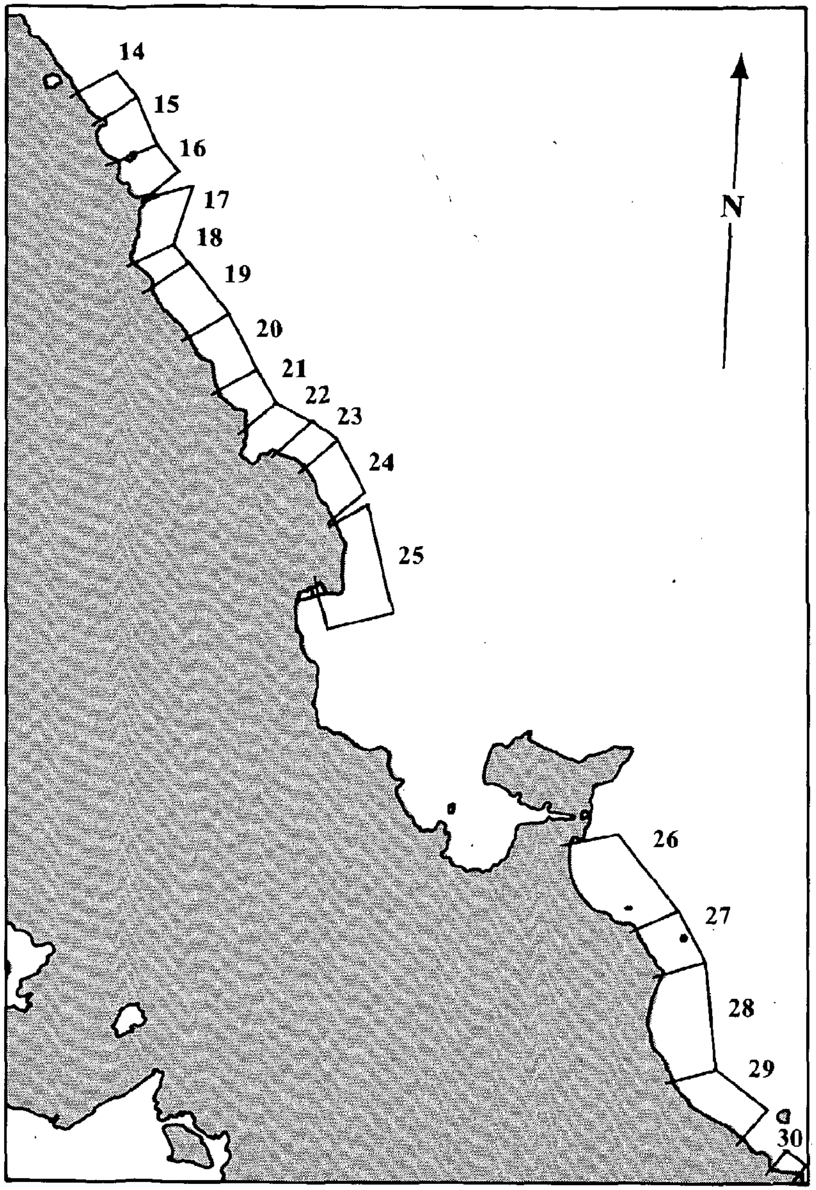
(2) The long axis of the sand body does not have a preferred orientation. This would be expected of dunes formed by strong prevailing northeast trade winds. Instead, the axis is approximately perpendicular to the shoreline. This would occur as the tsunami wave refracts to hit the shoreline head on.

(3) The sand deposits are seen only on the 1949 aerial photograph but not on photographs before or after. If the sand bodies are wind derived, they should be forming continuously. On the 1928 photograph, some wind deposits with the characteristic shape and orientation are evident. These deposits are located south of Kalaeuila Rock.

(4) Stereoscopic examination of the 1949 photographs show that debris and rubble are concentrated where the wave crossed the vegetation.

(5) On a field check during the end of summer 1980, several blocks of beachrock were located on and near the airfield. These rocks could not be moved by the wind.

The tsunami inundation at Kahuku Airfield was aided by the smooth surface of the runway. Waves lost little energy in crossing this feature. As a result, structures more than 1,200 feet inland were threatened by runup. For more information on the damage caused by the 1946 tsunami, the reader is referred to Shepard et al., 1950.



SECTION II - WINDWARD COAST

The windward coast extends from Kahuku on the north to Makapuu Point on the south (Figure 4). Generally, beaches on this shore are dynamic features that change under trade wind conditions and refracted North Pacific swell. The major findings for this section are summarized below.

The most unstable beach on the windward coast is at Kualoa Point where chronic erosion of 350 to 400 feet occurred during the 1928 to 1980 period.

The accretion-erosion cycle at Kailua Beach Park coincides in timing and magnitude with the one for south Lanikai Beach. This suggests that similar nearshore processes are in operation at both beach systems. Some important differences exist that are discussed for the individual beaches.

At Waimanalo Beach, the north end (Bellows Air Field Beach) and the south end have a history of erosion. Some sections at middle Waimanalo grew while others receded. No clear pattern is seen.

Chronic erosion areas on the windward coast include north Kahuku Golf Course Beach, middle and south Laniloa Beach, Hauula Beach Park, Kualoa Beach Park and Bellows Air Field Beach. Erosion problems exist at Kalanai Point, Swanzy Beach Park, Kaaawa Beach Park, Kailua Beach, Lanikai Beach, south Waimanalo Beach and many sections of the coast along the Kamehameha Highway.

Accretion was found at Kahana Bay, Punaluu Beach Park and Kaluanui Beach.

Figure 4. Photomap Arrangements - Windward Coast.

Kahuku Golf Course Beach

The adverse effects of a sand mining operation on Kahuku Golf Course Beach are shown on the aerial photographs. During the 1949 to 1967 period, water line retreat of 114 feet exposed beachrock along the shoreline. Over the same interval, the vegetation line at transect 4 grew seaward 283 feet (Photomap 14, Table 14). This change reflects the recovery of the vegetation line from its stripped position in 1949. On some sections of Kahuku, where the beachrock is wide and offers adequate protection, the vegetation has grown within a few feet of the exposed rock.

Since termination of the sand mining operation, most sections of Kahuku Golf Course Beach have been stable or grew. One exception is the northwest end of the beach where erosion of 53 feet was recorded during the 1949 to 1975 period. On the aerial photographs, this change is shown by undermining of the cemetery fence. This section of the beach has a 15-foot-high erosional scarp cut into the vegetated dune field.

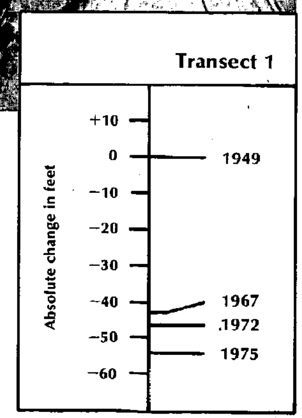
Table 14 - Kahuku Golf Course Beach. Changes in the Vegetation Line in Feet.

	Transect Number			
Observation Period	1	2	3	4
Sep 28, 1949 - Apr 23, 1967	-43	+49	+75	+283
Apr 23, 1967 - May 26, 1972	-3	-5	+18	+7
May 26, 1972 - Jun 03, 1975	-7	+9	+15	-9
Net Change - Vegetation Line	-53	+53	+108	+281
Range - Vegetation Line	53	53	108	290
Net Change - Water line	-34	-88	-65	-58
Range - Water line	68	104	114	58

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

Photomap 14. Kahuku Golf Course Beach

Photographs by Air Survey Hawaii: May 1972



Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Malaekahana Beach

Malaekahana Beach is situated between Makahoa Point and Kalanai Point. The most unstable section of this beach is at the south end, near Kalanai Point (Photomap 15). Over a 26-year period, the vegetation line and water line receded 26 feet and 64 feet, respectively (Table 15). The major loss occurred during the 1967 to 1975 period when the vegetation line retreated at a rate of about 5 feet per year.

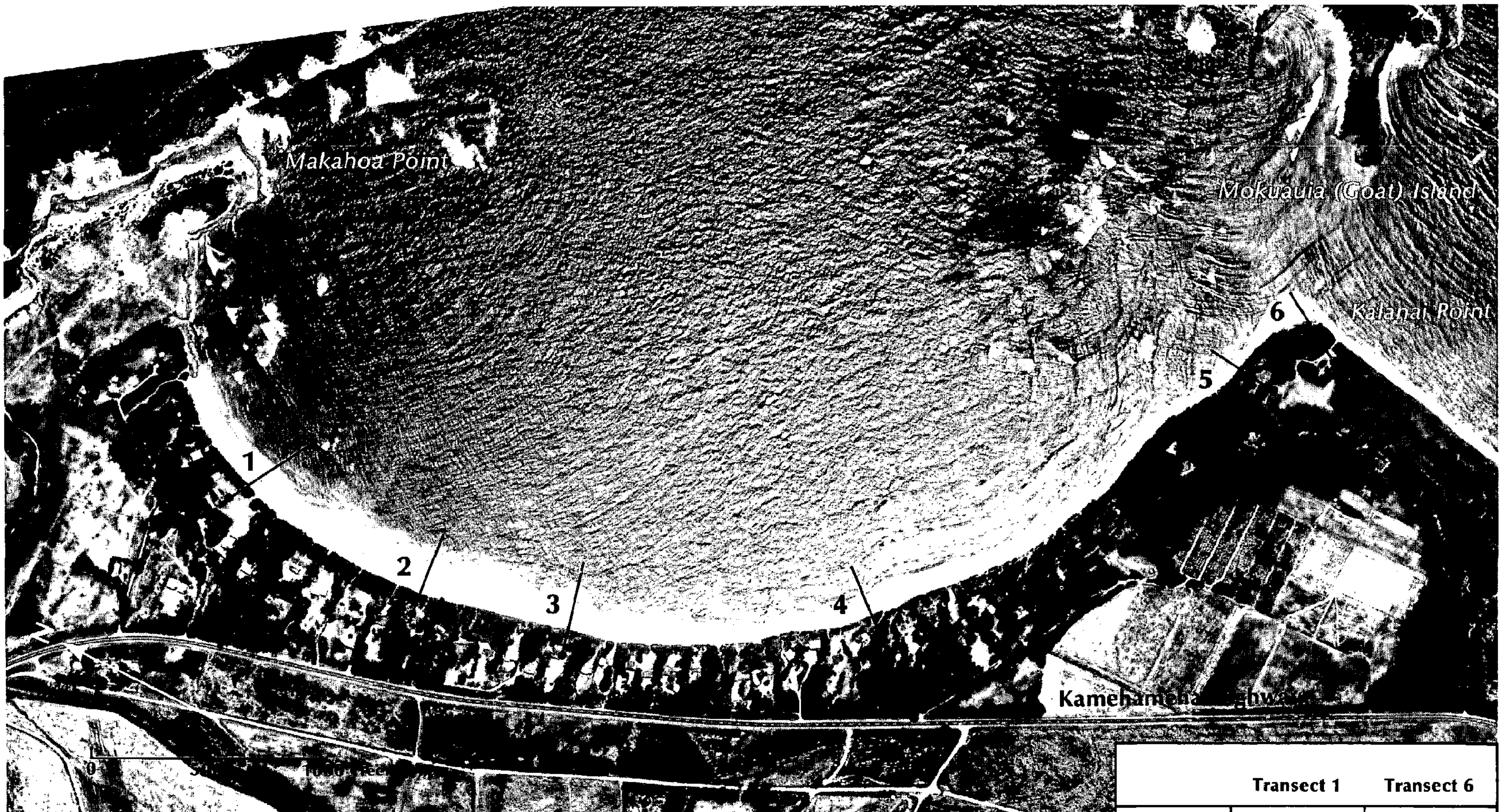
The wave pattern at Kalanai Point is complicated by refraction around Mokuauia (Goat) Island. Wave sets hit the point from the north, south and east. The erosion at Kalanai is caused by the concentrated wave energy at the point. The lost sand may be transported north, toward Makahoa Point, or to the south near Laie Point. These two beach sections have a 26-year history of accretion (see Laie Beach).

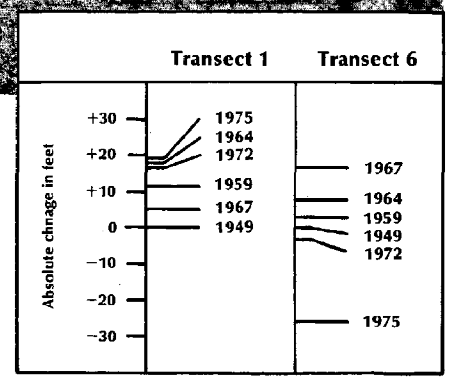
Most of Malaekahana Beach has been stable or grew when averaged over a 26-year period. Nevertheless, short erosion events can occur. During the 1964 to 1967 period, the vegetation line receded for much of the beach. It has been estimated, though, that about half of the recorded loss for transects 1 to 3 is due to relief displacement on the 1967 aerial photographs.

Table 15 - Malaekahana Beach. Changes in the Vegetation Line in Feet.

	Transect Number					
Observation Period	1	2	3	4	5	6
Sep 28, 1949 - Dec 29, 1959	+11	+10	+11	+11	+29	+3
Dec 29, 1959 - May 12, 1964	+7	+15	+4	-7	0	+5
May 12, 1964 - Apr 23, 1967	-13	-18	-17	+1	-11	+9
Apr 23, 1967 - May 26, 1972	+12	-2	+8	*	+11	-20
May 26, 1972 - Apr 13, 1975	+2[1]	+11	+1	*	-12	-23
Net Change - Vegetation Line	+19	+16	+7	+5	+17	-26
Range - Vegetation Line	19	25	17	11	29	43
Net Change - Water Line	+40	+36	-11	-3	-6	-64
Range - Water Line	94	99	72	24	77	96

** No Data*
[1] The 1975 photographs were taken on June 3
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.





Photomap 15. Malaekahana Beach

Photographs by Air Survey Hawaii: May 1972

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Laie Beach

Laie Beach is bounded by Kalanai Point to the north and Laie Point to the south. The erosion at Kalanai Point was discussed previously in the section for Malaekahana Beach. The data for this portion of the beach appear as transect 1 on Photomap 16 and Table 16.

Except for the erosion at Kalanai Point, most sections of Laie Beach have been stable or grew when data were averaged over a 30-year period. The maximum accretion occurred at the south end of the beach, where the vegetation line advanced seaward 28 feet over the 1949 to 1979 period. Although the net changes of the vegetation line indicate beach stability or growth, minor erosion events were recorded for transects 2 and 6.

The changes in the vegetation line for Laie show a strong relationship with adjacent beach sections. Over a period of observation between 26 and 30 years, the vegetation line at the northwest end of the beach eroded 26 feet while at the opposite end, it grew seaward 28 feet. The net changes in the vegetation line for the middle of Laie fell between these extremes. The range in the position of the vegetation line is greatest for the two ends and smallest in the middle. The overall pattern suggests that the long-term changes at Laie are caused by sand transport along the shoreline from northwest to southeast. This hypothesis can be tested by conducting sand tracer experiments at Laie.

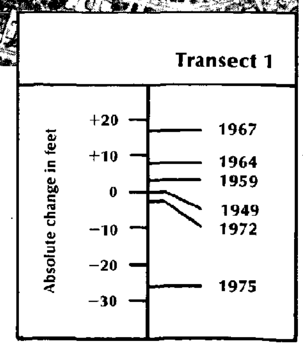
That sand accumulates north of Laie Point is to be expected. This protrusion, which consists of eolianite, protects sections of the beach from southerly waves but allows waves from the north to transport sand.

Laie Beach goes through an annual variation in width of about 30 feet (Moberly and Chamberlain, 1964). These annual changes are primarily due to onshore-offshore exchange between the beach and reef reservoirs. It appears that both onshore-offshore and alongshore transport of sand are processes occurring at the beach.

Table 16 - Laie Beach. Changes in the Vegetation Line in Feet.

	Transect Number						
Observation Period	1	2	3	4	5	6	7
Sep 28, 1949 - Dec 29, 1959	+3	-13	+10	-7	-2	-12	+8
Dec 29, 1959 - May 12, 1964	+5	0	+2	-1	+8	+7	+10
May 12, 1964 - Apr 23, 1967	+9	+20	0	-3	-2	-12	+4
Apr 23, 1967 - May 26, 1972	-20	-1	+9	+9	+10	+12	-2
May 26, 1972 - Apr 13, 1975	-23	-8	-9	-2	-3	+8	+9
Apr 13, 1975 - Apr 12, 1979	*	*	*	-1	+5	+3	-1
Net Change - Vegetation Line	-26	-2	+12	-5	+16	+6	+28
Range - Vegetation Line	43	20	21	11	18	23	29
Net Change - Water Line	-64	+46	+20	+76	+34	+50	+64
Range - Water Line	96	46	32	76	45	50	64

** No Data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 16. Laie Beach

Photographs by Air Survey Hawaii: May 1972

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Laie Point to Pali Kilo Ia

The 1.25-mile stretch of beach between Laie Point and Pali Kilo Ia curves around Kehukuuna Point (Photomap 17). To the north of the point is the 1-mile-long Laniloa Beach. South of the point is Pounders Beach.

The vegetation line at the north end of Laniloa Beach (transects 1-3), has had small changes of erosion and accretion (Table 17). No clear pattern is seen from the data. Over a 26-year period, this section of beach has been stable or grew.

The middle and south sections of Laniloa Beach (transects 4-7) have a history of severe erosion. The worst problem is located on a 500-foot section of the beach near transect 5. An examination of the 1949 aerial photograph shows fallen trees on the beach, an indication that erosion had occurred previously. Since 1949, the beach at transect 5 has receded for all five observation periods. Between 1949 and 1975, the vegetation line eroded 70 feet (Plate 4).

During a field check in August 1980, the northeast trade waves broke against the base of a 15-foot-high escarpment in the vegetated dune field. Forty-foot trees were being undermined and several were on the beach. Stone walls and piles of boulders, which were built to protect houses, completely blocked access along the shoreline.

Between 1972 and 1975, one house was removed because of erosion. On the 1975 photographs, several houses are within 30 feet of the vegetation line. Along this 500-foot stretch of Laniloa Beach, erosion of about 3 feet per year has occurred. If the trend continues as it has in the past, these houses would be undermined in a decade.

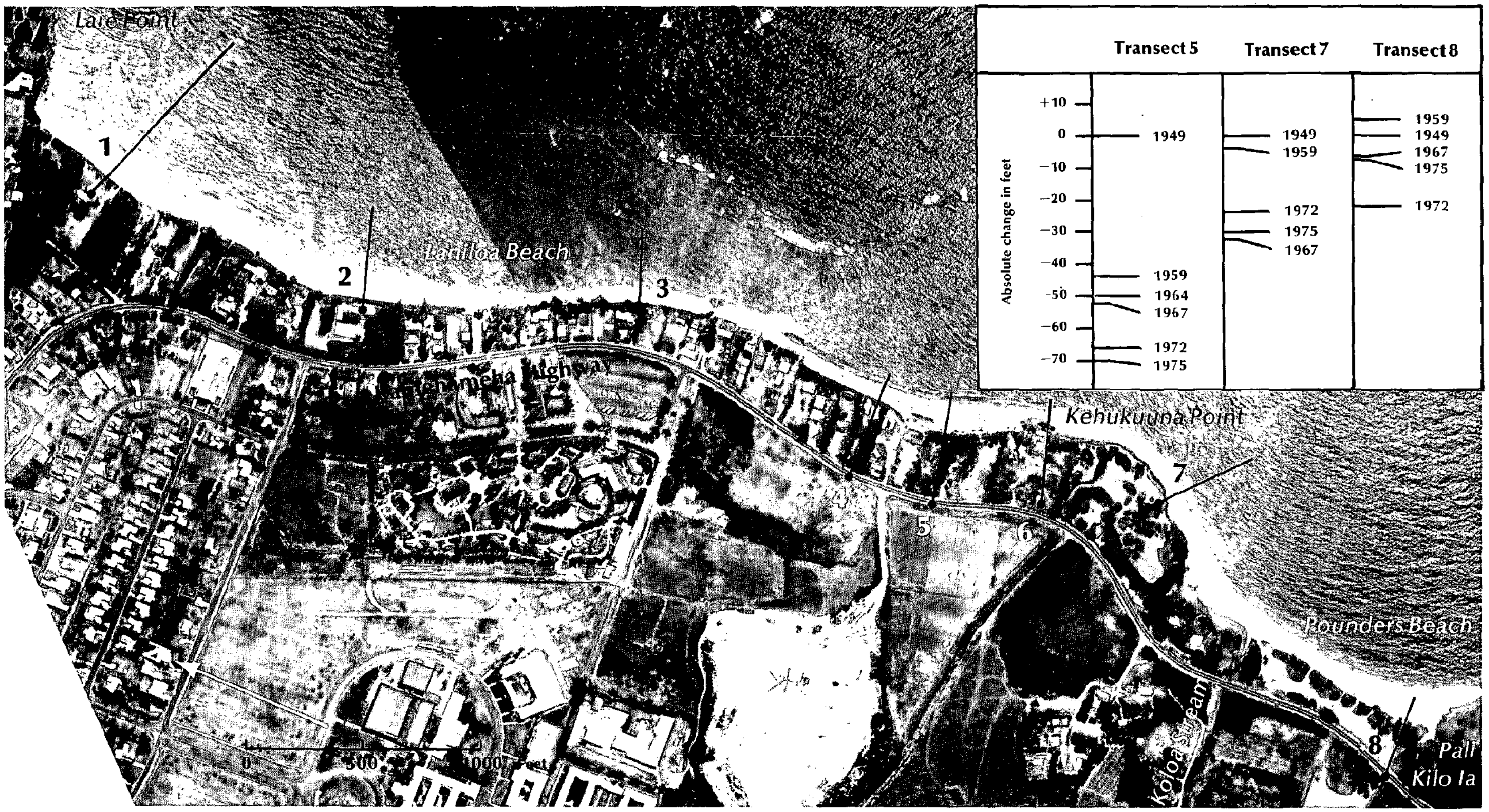
It is apparent that the 40-foot-setback line for this beach is of little value. Under the Coastal Zone Management Act of 1977, the county has the power to regulate new development within the 100-yard zone of the Special Management Area.

To the south of Kehukuuna Point is the 1,500-foot-long Pounders Beach. Over a 26-year period, this beach has had a net change in the position of the vegetation line of -7 feet. This beach was not necessarily stable, as the range in the position of the vegetation line was 27 feet.

Table 17 - Laie Point to Pali Kilo Ia. Changes in the Vegetation Line in Feet.

	Transect Number							
Observation Period	1	2	3	4	5	6	7	8
Sep 28, 1949 - Jul 23, 1959	-8	+8	+2	-35	-44	-22	-4	+5
Jul 23, 1959 - May 12, 1964	+11	+1	-9	+4	-6	-5[1]	*	*
May 12, 1964 - Apr 23, 1967	-8	+1	-1	+2	-2	*	-28[2]	-11[2]
Apr 23, 1967 - May 26, 1972	+3	-3	+11	-2	-14	*	+8	-16
May 26, 1972 - Apr 13, 1975	+1	+8	-6	-3	-4	*	-6	+15
Net Change - Vegetation Line	-1	+15	-3	-34	-70	-27	-30	-7
Range - Vegetation Line	11	15	11	35	70	27	32	27
Net Change - Water Line	+12	+22	-8	-23	-54	-17[3]	+20	-20
Range - Water Line	20	36	23	38	60	27[3]	44	68

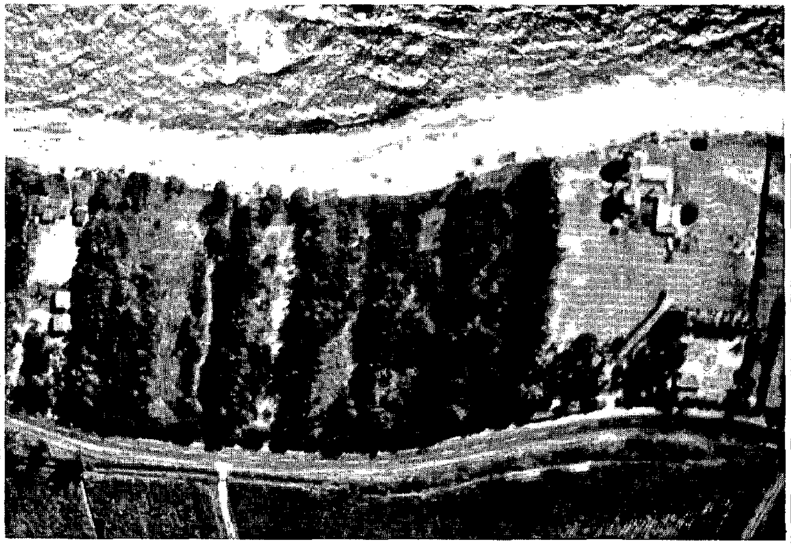
** No Data*
[1] To boulder wall
[2] Change from 1959-1967
[3] From 1949-1975
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 17. Laie Point to Pali Kilo Ia

Photographs by Air Survey Hawaii: May 1972

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.



1949

1975

Plate 4. Laniloa Beach. Between 1949 and 1975, chronic erosion at Laniloa Beach resulted in a 70-foot retreat of the vegetation line. Note the trees on the beach on the 1949 photograph. Compare the position of the vegetation line with the highway on the 1949 and 1975 photographs.

Kokololio Beach

The stretch of shoreline between Pali Kilo Ia and Kaipapau Point is about 4,000 feet long (Photomap 18). Over a 26-year period, the north end of this beach grew slightly while the south end, at transect 3, was relatively stable (Table 18).

Table 18 - Kokololio Beach. Changes in the Vegetation Line in Feet.

	Transect Number		
Observation Period	1	2	3
Sep 28, 1949 - Jul 23, 1959	+10	-6	-5
Jul 23, 1959 - Apr 23, 1967	+6	+7	+4
Apr 23, 1967 - May 26, 1972	-1	+12	0
May 26, 1972 - Apr 13, 1975	+1	-2	-7
Net Change - Vegetation Line	+16	+11	-8
Range - Vegetation Line	16	19	8
Net Change - Water Line	+10	+21	+2
Range - Water Line	47	35	62

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

Photomap 18. Kokololio Beach

Photographs by Air Survey Hawaii: May 1972

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Hauula Beach to Makao Beach

Over a 30-year period, the residential beach at north Hauula (transect 1) has been stable (Photomap 19). The range in the position of the vegetation line was about 10 feet and the net change was insignificant (Table 19).

The northern section of Hauula Beach Park has had a history of minor erosion. From 1949 to 1979, the vegetation line receded inland 10 feet. This trend appears to be continuous. For the middle section of Hauula Beach Park, erosion has been more severe. Retreat of the vegetation line was recorded for all six observation periods. The major losses occurred during the 1949 to 1959 and 1975 to 1979 intervals. Over a 30-year period, the vegetation line has receded about 39 feet. A continuation of the trend would undermine more of the ironwood trees and threaten the pavilion that was constructed in 1947. For further details on the erosion at this park, the reader is referred to the National Shoreline Study (U.S. Army Engineers, 1971). The vegetation line at the south section of the park (transect 4) has grown slightly over a 30-year period.

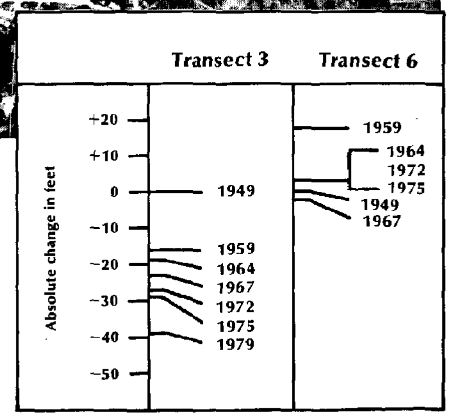
Although the vegetation line at transects 5 and 6 has had a small change in position, erosion problems exist because houses have been built close to the shore. Along much of the beach near transect 5, seawalls have been built to protect the property. At transect 6 the range in the position of the vegetation line over a 26-year period was 20 feet.

Along the highway at Makao Beach, the vegetation line for transect 7 receded 10 feet during the 1959 to 1975 period. If this trend continues, the construction of a stone wall would be required to protect the road. A boulder wall protects the highway in front of transect 8.

Table 19 - Hauula Beach to Makao Beach. Changes in the Vegetation Line in Feet.

	Transect Number							
Observation Period	1	2	3	4	5	6	7	8
Sep 28, 1949 - Dec 29, 1959	-8	-4	-16	+10	*	+18	+5	-6
Dec 29, 1959 - Nov 14, 1964	+6	+1	-3	-2	-6	-15	-2	+3
Nov 14, 1964 - Apr 23, 1967	-6	-1	-4	-3	+8[1]	-5	0	-2[1]
Apr 23, 1967 - May 26, 1972	0	-2	-4	+11	*	+5	-1	*
May 26, 1972 - Apr 13, 1975	-2	-3	-2	0	*	0	-7	*
Apr 13, 1975 - Apr 19, 1979	+9	-1	-10	-1	*	*	*	*
Net Change - Vegetation Line	-1	-10	-39	+15	+2	+3	-5	-5
Range - Vegetation Line	10	10	39	16	8	20	10	6
Net Change - Water Line	+17	+9	+3	+25	-8[2]	-4	-4[3]	-11[2]
Range - Water Line	20	28	33	32	32[2]	19	53[3]	30[2]

** No Data*
[1] To seawall
[2] From 1949-1975
[3] From 1949-1972
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 19. Hauula Beach to Makao Beach

Photographs by Air Survey Hawaii: May 1972

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Kalaipaloa Point to Waiono Stream

The stretch of beach between Kalaipaloa Point and Waiono Stream is approximately 2 miles long. Both the residential sections and the highway along this coast have been stabilized by seawalls and boulder piles.

The residential section marked by transect 1 has had a history of erosion as indicated by the structures built along the shoreline. In 1967, seawalls and revetments spanned the entire 900-foot stretch of beach. Between 1967 and 1972, several of these structures had disappeared, perhaps because of damage from the winter storms of 1968 and 1969.

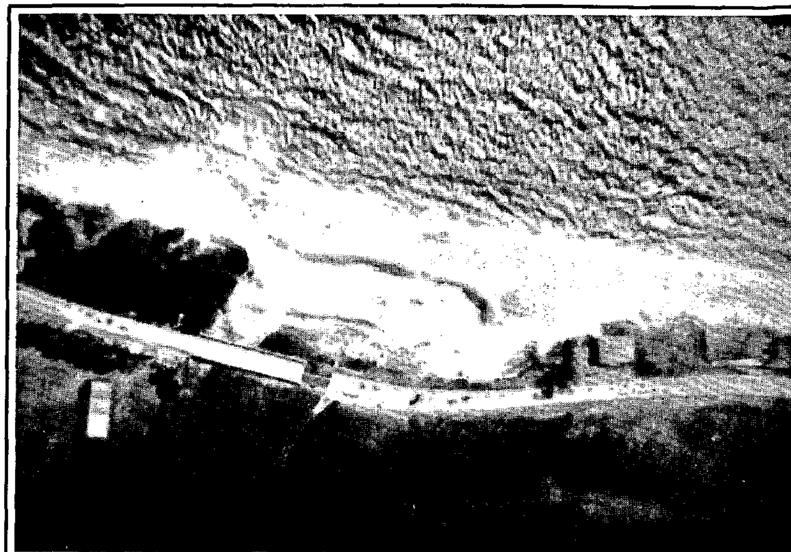
The residential area at transect 2 is completely spanned by seawalls. At the south end of this stretch, a wall was constructed perpendicular to the shoreline to provide flood protection from Kaliuwaa Stream (Photomap 20). This structure and the stream tend to trap sand transported from offshore or along the coast. Immediately to the south, at Kaluanui Beach, accretion in the vegetation line of approximately 75 feet has occurred over a 26-year period. A major residential area has been built on this accretion plain (Plate 5).

The section of the shoreline covered by transects 3 to 5 has been relatively stable over a 26-year observation period. The net changes in the vegetation line for the three transects were under 10 feet (Table 20).

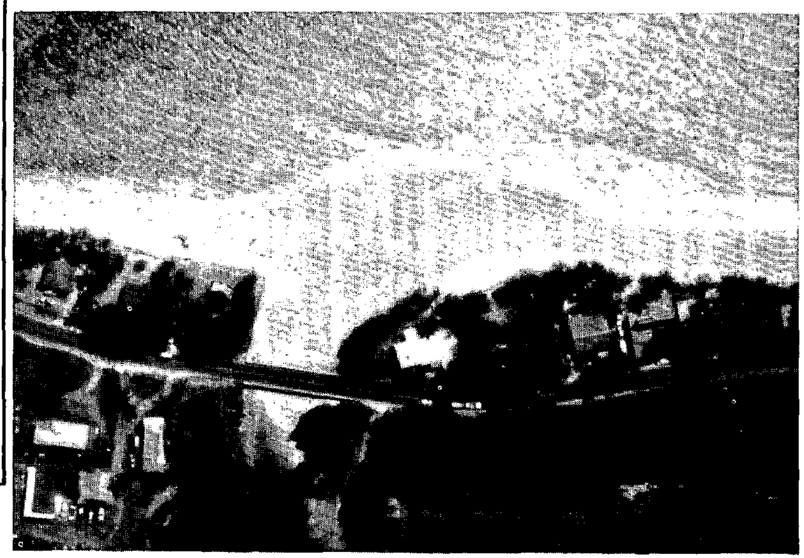
At transect 6, the vegetation line receded 26 feet over the 1949 to 1967 period. This erosion has threatened three houses.

Transect 7 was established behind the Kamehameha Highway. By 1959 a stone wall was constructed to protect this roadway.

Over a 26-year period, the net change in the position of the vegetation line for transect 8 was under 10 feet. The range in the position of the vegetation line was 19 feet.

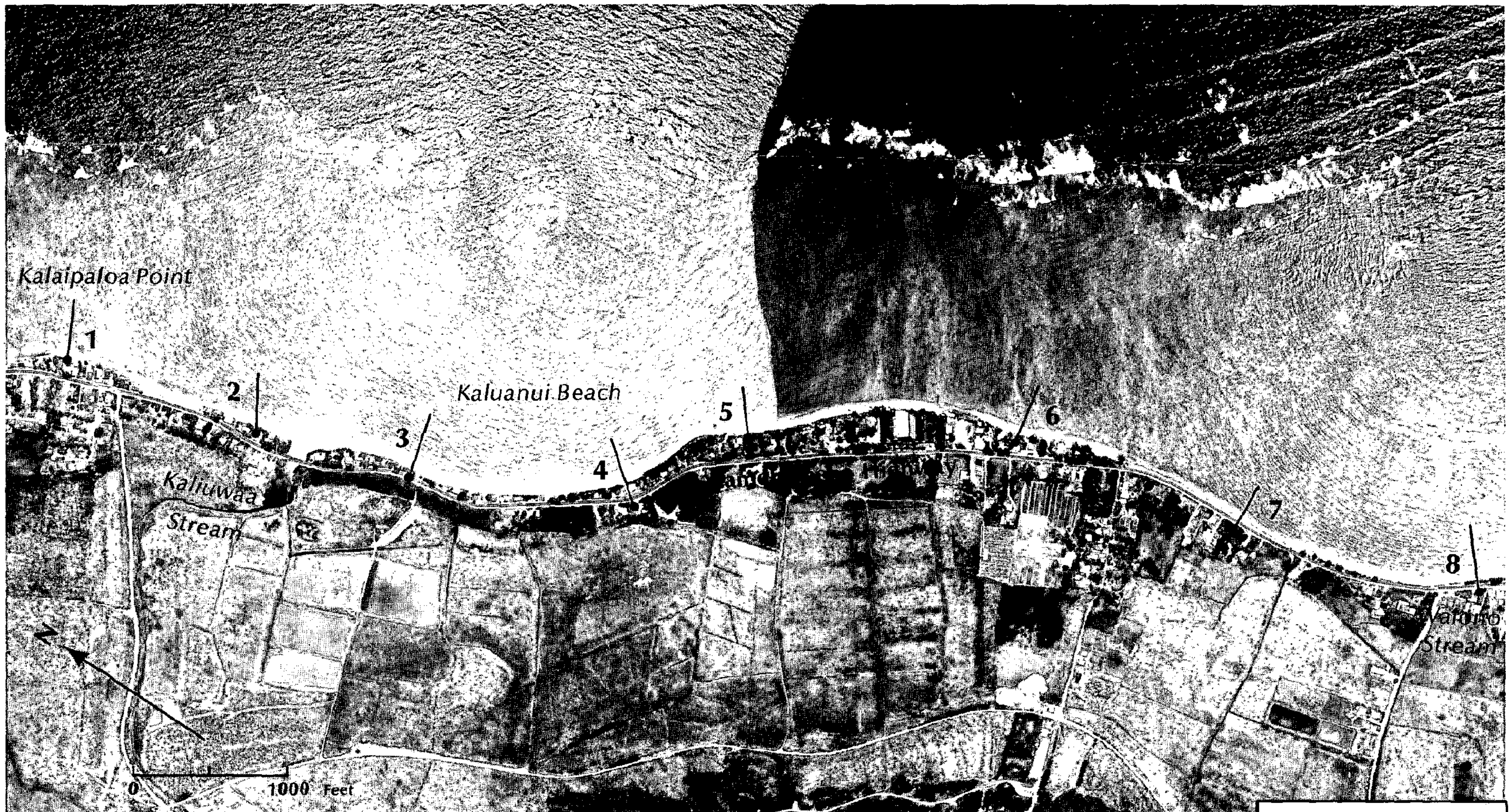


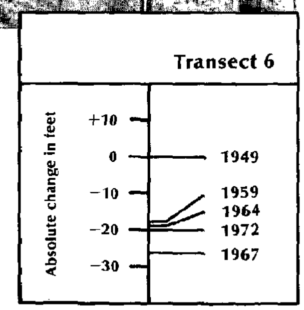
1949



1975

Plate 5. Kaluanui Beach. Accretion to the south of Kaliuwaa Stream. Note the houses built on the newly formed land.





Photomap 20. Kalaipaloa Point to Waiono Stream

Photographs by Air Survey Hawaii: May 1972

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Table 20 - Kalaipaloa Point to Waiono Stream. Changes in the Vegetation Line in Feet.

	Transect Number							
Observation Period	1	2	3	4	5	6	7	8
Sep 28, 1949 - Dec 29, 1959	+3[1]	+1[1]	-8	+6	+2	-18	+5[1]	0
Dec 29, 1959 - Oct 14, 1964	*	*	+5	-4	-5	-1	*	-5
Oct 14, 1964 - Apr 23, 1967	*	*	+3	-8	-1	-7	*	+19
Apr 23, 1967 - May 26, 1972	*	*	-10	+12	+4	+6	*	-10
May 26, 1972 - Apr 13, 1975	*	*	+3	-4	-3	*	*	-2
Net Change - Vegetation Line	+3	+1	-7	+2	-3	-20	*	+2
Range - Vegetation Line	3	1	10	12	6	26	*	19
Net Change - Water Line	-20[2]	+17[2]	+42	-10	+8	-11	+17[2]	+3
Range - Water Line	22[2]	30[2]	53	43	34	29	30[2]	47

** No Data*
[1] To stone or boulder wall
[2] From 1949-1975
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

Punaluu Beach Park and Residential Area

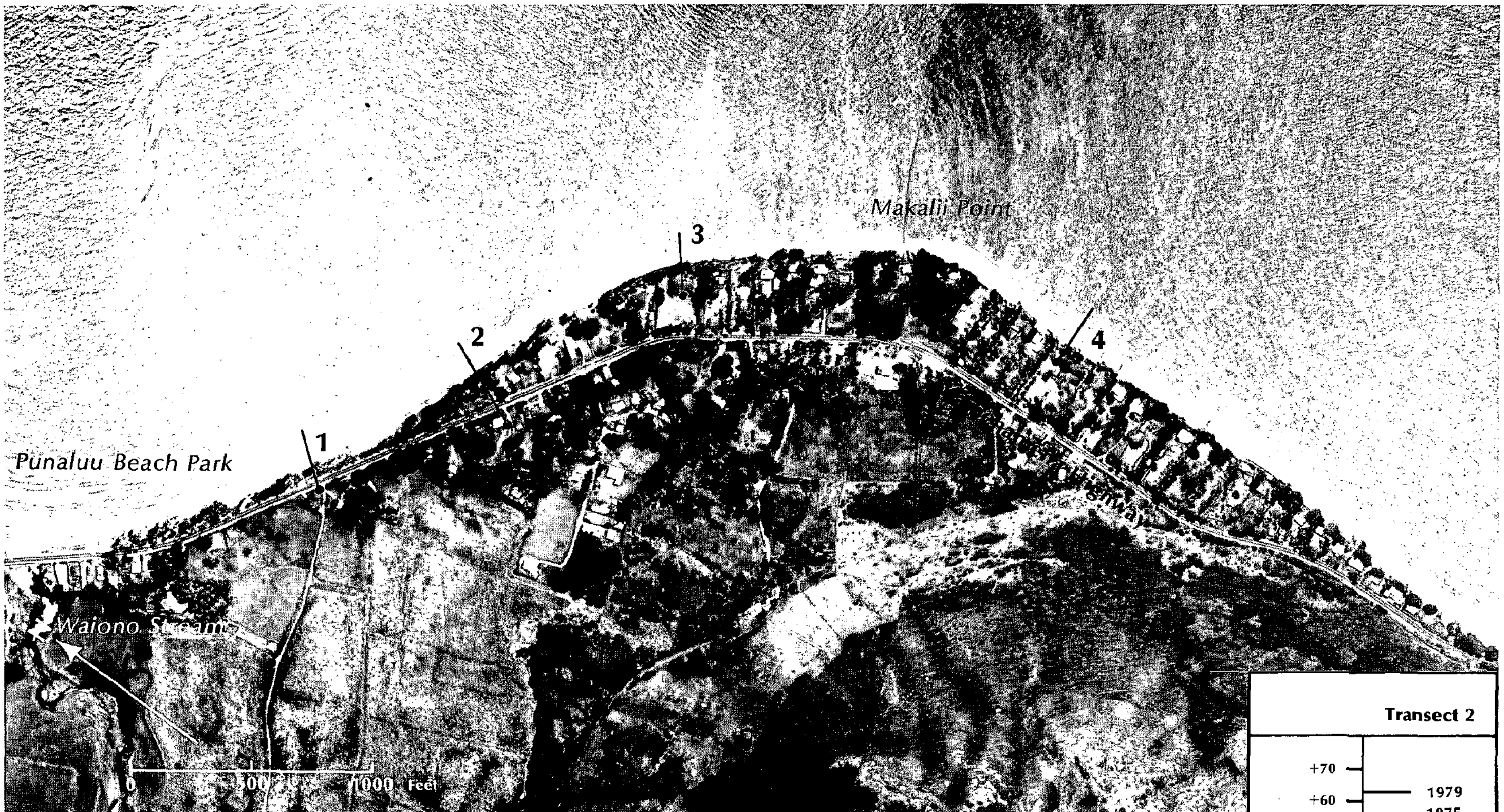
Prior to 1949, the north section of Punaluu Beach Park experienced erosion. Boulders were placed along the shoreline to protect the undermined trees. Since then, the beach fronting the park and residential area has grown considerably (Photomap 21).

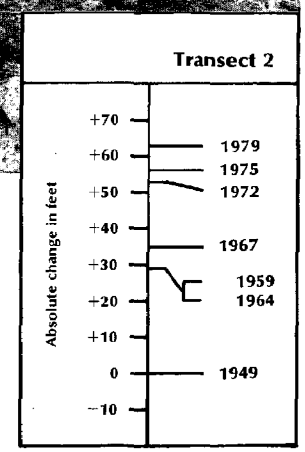
Over a 30-year period, the vegetation line at the beach park grew seaward about 59 feet (Table 21). A bathhouse was constructed on this newly formed land. Accretion at the park appeared continuous except for the 1964 to 1972 period when the vegetation line receded 16 feet. This change is partly attributed to the large winter storms of 1968 and 1969 (U.S. Army Engineers, 1971).

At the residential section of Punaluu, field surveys indicate that the vegetation line advanced seaward 18 feet during the 1962-1972 period (J. F. Campbell, unpub. data). From aerial photographic measurements, the vegetation line accreted 63 feet over a 30-year period (Plate 6). It appears that sand from the nearby reef is an important contributor to this beach.

The portion of the shoreline marked by transect 3 appears relatively stable. Over a 26-year period the net change in the vegetation line was -8 feet and the range was 12 feet.

Transect 4 was established along the north-trending section of the Punaluu residential area. Nine groins and several seawalls were constructed along this stretch. These structures may have temporarily stabilized the shoreline. Over a 26-year period, the beach within the groin field has grown slightly.





Photomap 21. Punaluu Beach Park and Residential Area

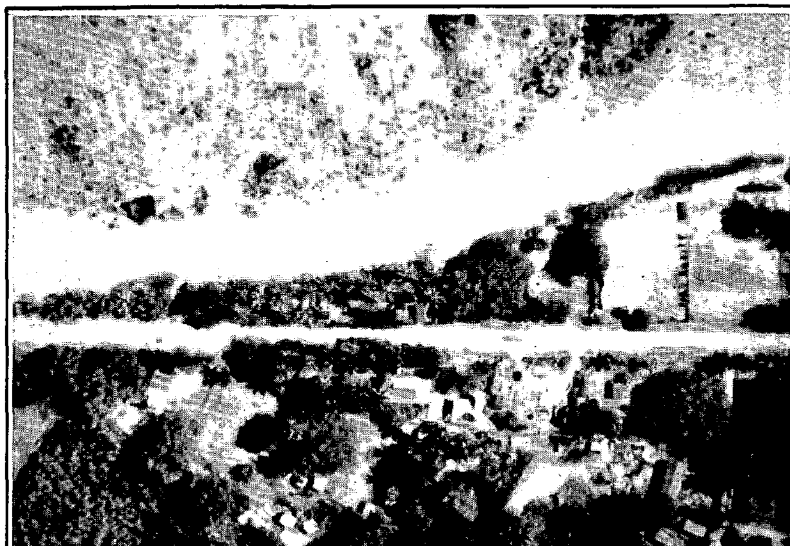
Photographs by Air Survey Hawaii: May 1972

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

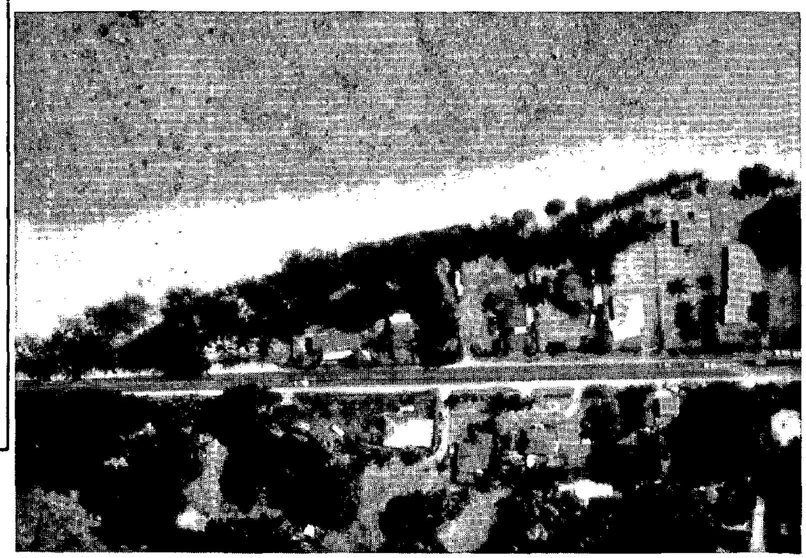
Table 21 - Punaluu Beach Park and Residential Area. Changes in the Vegetation Line in Feet.

	Transect Number			
Observation Period	**1**	**2**	**3**	**4**
Oct 29, 1949 -Dec 29, 1959	+35	+29	-3	*
Dec 29, 1959 - Oct 14, 1964	+3	0	+7	+15[1]
Oct 14, 1964 - Apr 23, 1967	-6	+6	-9	+6
Apr 23, 1967 - May 26, 1972	-10	+18	+1	-7
May 26, 1972 - Apr 13, 1975	+28	+3	-4	-6
Apr 13, 1975 - Apr 17, 1979	+9	+7	*	*
Net Change - Vegetation Line	+59	+63	-8	+8
Range - Vegetation Line	59	63	12	21
Net Change - Water Line	+18	+20	-47	+19
Range - Water Line	112	48	39	69

** No Data*
[1] Change from 1949-1964
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



1949



1975

Plate 6. Punaluu. Over a 26-year period, the vegetation line for the beach at Punaluu grew seaward 56 feet. Compare the position of the vegetation line with the highway on the 1949 and 1975 photographs.

Kahana Bay Beach Park

The sedimentology of Kahana Bay has been described in a report by Coulbourn (1971). According to this study, the barrier beach at Kahana receives sand from two main sources. Some terrigenous sediment is supplied to the beach from Kahana Stream. Most of the sediment from the stream is finer than sand size and is eventually lost offshore. The major supply of beach sand is derived from the eastern reef flat near Huilua fishpond. On the aerial photographs, a sand bar is seen extending from the reef flat to the east central portion of the beach. This sand plume may delineate the avenue of sand transport to the beach.

The field evidence for accretion at Kahana Beach is abundant. Two crescentic beach ridges marking former shoreline positions are located inland of the present-day beach (Coulbourn, 1971). Young ironwood trees and sparse vegetation extend seaward, indicating recent accretion (J. F. Campbell, personal communication). Kahana Beach has a gentle slope and a profile that is continuous in the absence of an erosional scarp.

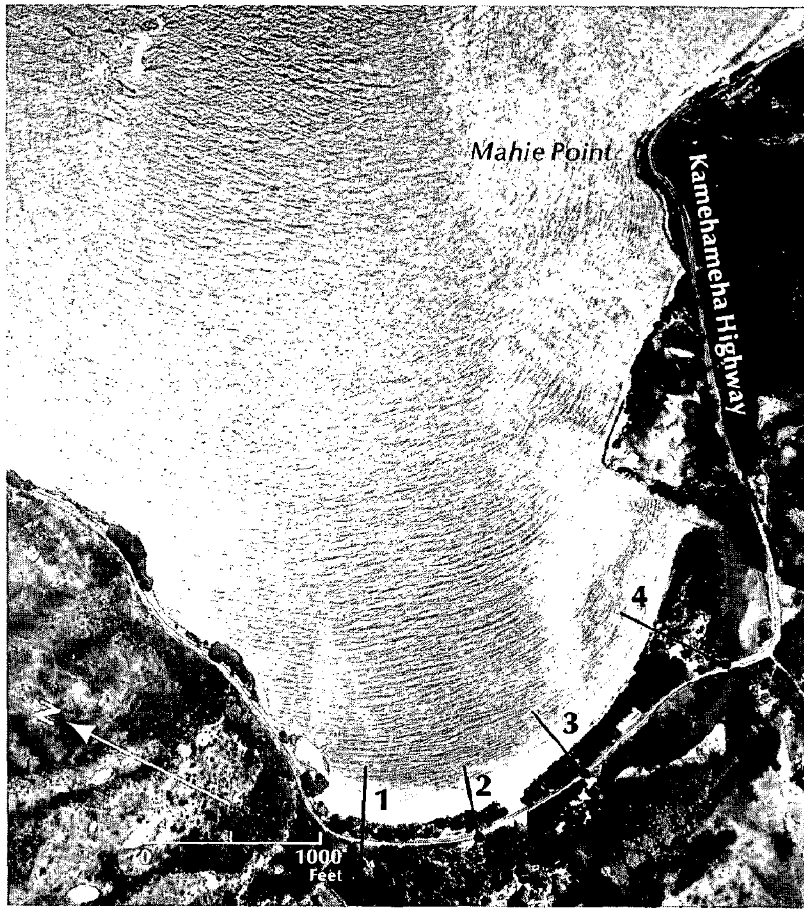
From aerial photographic measurements, the vegetation line at the east section of the beach grew seaward 113 feet over a 47-year period (Photomap 22, Table 22). Over a similar period, accretion of the vegetation line at the west end was 39 feet.

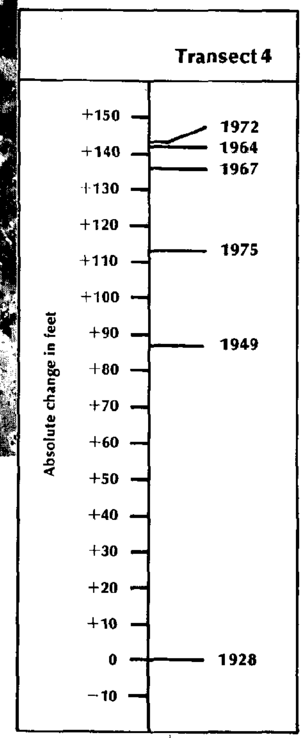
Although Kahana Beach has a long-term history of accretion, there are periods when erosion occurs. In April 1963, a storm cut the beach back 100 feet, but by mid-August of the same year, the beach grew back 50 feet (Moberly and Chamberlain, 1964). During the 1972 to 1975 period, the vegetation line receded 30 feet at the east end of Kahana Beach.

Table 22 - Kahana Bay Beach Park. Changes in the Vegetation Line in Feet.

	Transect Number			
Observation Period	1	2	3	4
1928 - Oct 29, 1949	*	+16	*	+87
Oct 29, 1949 - Oct 14, 1964	+7	+16	+13	+55
Oct 14, 1964 - Apr 23, 1967	+7	0	+2	-6
Apr 23, 1967 - May 26, 1972	+7	+6	+7	+7
May 26, 1972 - Jun 02, 1975	*	+1	+29	-30
Net Change - Vegetation Line	+21	+39	+51	+113
Range - Vegetation Line	21	39	51	143
Net Change - Water Line	-4	+76	+54	+116
Range - Water Line	38	76	69	134

** No Data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.





Photomap 22. Kahana Bay Beach Park

Photographs by Air Survey Hawaii: May 1972

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Mahie Point to Swanzy Beach Park

The stretch between Mahie Point and Swanzy Beach Park is about 4,000 feet long. Seawalls protecting the highway and beach park from erosion are found along much of this coast.

Four transects were established for those sections of the beach that had vegetation fronting the seawalls (Photomap 23). It was hoped that the changes in the vegetation would provide clues on the timing and extent of wave attack on this shore.

For the stretch of beach along the highway there has been little net change in the vegetation line and water line over a 26-year period (Table 23). From the historic data, there appears to be no immediate danger to the highway or to the seawall near the Crouching Lion Restaurant. Nevertheless, a large storm or hurricane could cause structural damage as many sections of the road are within a few feet of the water.

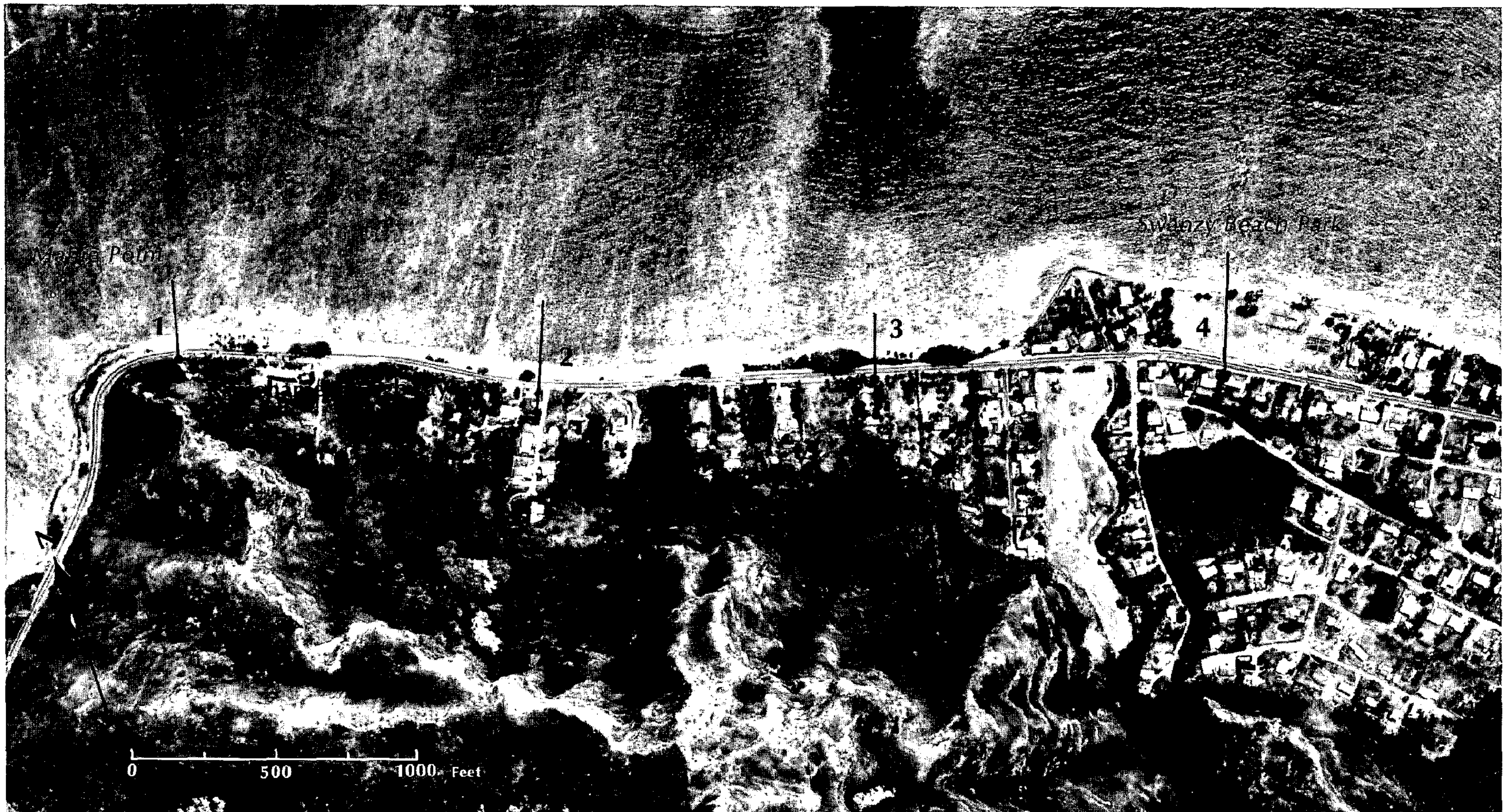
At Swanzy Beach Park, historic data indicate that the seawall is becoming increasingly vulnerable to wave attack and deterioration. The 1949 photograph shows this structure fronted by a continuous beach that varied in width from 23 to 70 feet. Over the next 26 years, water-line retreat of up to 41 feet has exposed sections of the wall to wave attack.

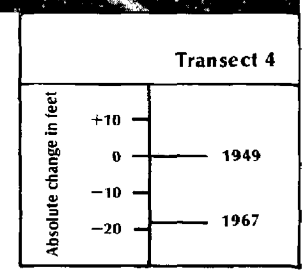
From 1949 to 1967, 18 feet of vegetation fronting the seawall was lost. During the 1968 to 1969 period, winter storms damaged the beach and undermined the wall (U.S. Army Engineers, 1971). Problems such as these will become more common if the small amount of sand that remains continues to disappear. At the present, boulders front the wall to provide additional protection from waves.

Table 23 - Mahie Point to Swanzy Beach Park. Changes in the Vegetation Line in Feet.

	Transect Number			
Observation Period	1	2	3	4
Oct 29, 1949 - Apr 23, 1967	*	-9	-16	-18[1]
Apr 23, 1967 - May 26, 1972	-2[2]	-3	+6	*
May 26, 1972 - Apr 13, 1975	+5	+12	+7	*
Net Change - Vegetation Line	+3	0	-3	-18
Range - Vegetation Line	5	12	16	18
Net Change - Water Line	+3	-2	+15	-41[3]
Range - Water Line	16	13	25	54[3]

** No Data*
1 To seawall
2 Change from 1949 to 1972
3 From 1949-1975
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.





Photomap 23. Mahie Point to Swanzy Beach Park

Photographs by Air Survey Hawaii: May 1972

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

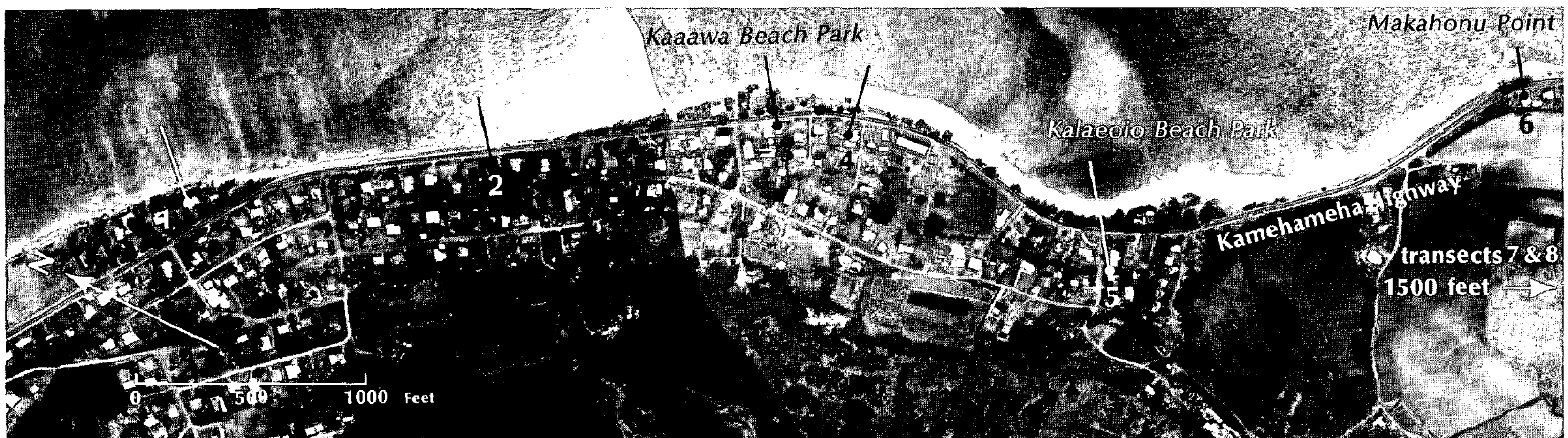
Kaaawa Residential Area to Kalaeokaoio Point

The portion of the windward coast covered in this section is about 1.7 miles long and includes the Kaaawa residential area, Kaaawa Beach Park, Kalaeoio Beach Park, Kanenelu Beach and several stretches of beach fronting the highway. The reader is referred to Photomap 24 for the location of the transects.

The section of Kaaawa Beach at transect 1 has a history of change similar to that of Swanzy Beach Park. On the 1949 photograph, a narrow beach once fronted the residential area. By 1975, the beach was replaced by boulders, and 14 feet of vegetation was lost (Table 24).

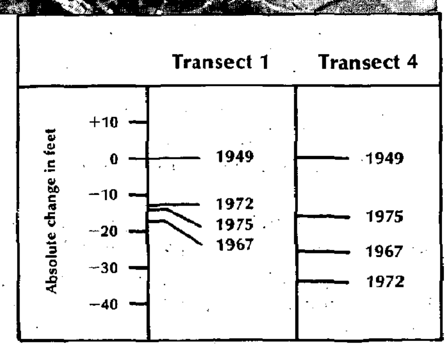
To the south of the residential area, boulders and a stone wall protect the highway from wave attack. Measurements at transect 2 show a net loss in the vegetation line of 14 feet during the 1949 to 1967 period. Over a 26-year period, the water line advanced seaward 24 feet. Under normal wave conditions, there appears to be little danger from erosion. Nevertheless, a large storm or hurricane could undermine the seawall and damage the highway.

At Kaaawa Beach Park (transects 3 and 4), severe erosion has occurred. Between 1949 and 1972, the vegetation line at transect 4 receded 34 feet. Over the same period, the vegetation to the side of the park bathhouse was cut back 55 feet. Most of the erosion occurred prior to 1967. Part of the loss is attributed to the high winter waves of December



Photomap 24. Kaaawa Residential Area to Makahonu Point

Photographs by Air Survey Hawaii: April 1975



Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Table 24 - Kaaawa Residential Area to Kalaeokaoio Point. Changes in the Vegetation Line in Feet.

	Transect Number							
Observation Period	1	2	3	4	5	6	7	8
Oct 29, 1949 - Apr 23, 1967	-17	-14[1]	-12	-26	+8	*	*	*
Apr 23, 1967 - May 26, 1972	+4	*	+3	-8	-5	+15[2]	-13[2]	-15[2]
May 26, 1972 - Apr 13, 1975	-1	*	-3	+18	-4	-7	*	*
Net Change - Vegetation Line	-14	-14	-12	-16	-1	+8	-13	-15
Range - Vegetation Line	17	14	12	34	9	15	13	15
Net Change - Water Line	-18	+24[3]	-74	-75	-46	-4	-36	-32
Range - Water Line	35	27[3]	74	81	46	21	36	32

** No Data*
1 To Seawall
2 Change from 1949-1972
3 Change from 1949-1975
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

1968 and January 1969, which undercut coconut trees and the park bathhouse (U.S. Army Engineers, 1971). From 1972 to 1975, the vegetation line grew seaward about 18 feet. Part of this change may be attributed to a sand replenishment project (U.S. Army Engineers, 1974).

Over a 26-year period, the water line at Kaaawa Beach Park receded 75 feet. This figure may be an overestimate as problems were encountered in locating the water line on the 1949 photograph.

Measurements on the vegetation line for Kalaeoio Beach Park (transect 5), indicate that the beach has been stable over a long-term. Although there was a net loss of 46 feet to the beach, the significance of this change is unknown, since difficulty was encountered in locating the water line.

Transects 6 to 8 were established for the stretch of beach fronting the highway. The changes at Makahonu Point (transect 6) were relatively small, but immediately northwest of the point, a section of beach has disappeared and the highway is fronted by boulders. South of Makahonu Point (transects 7-8), erosion was recorded over the 1949 to 1972 period. The maximum losses were 15 feet from the vegetation line and 36 feet from the water line. This stretch of highway is susceptible to erosion.

Kualoa Beach

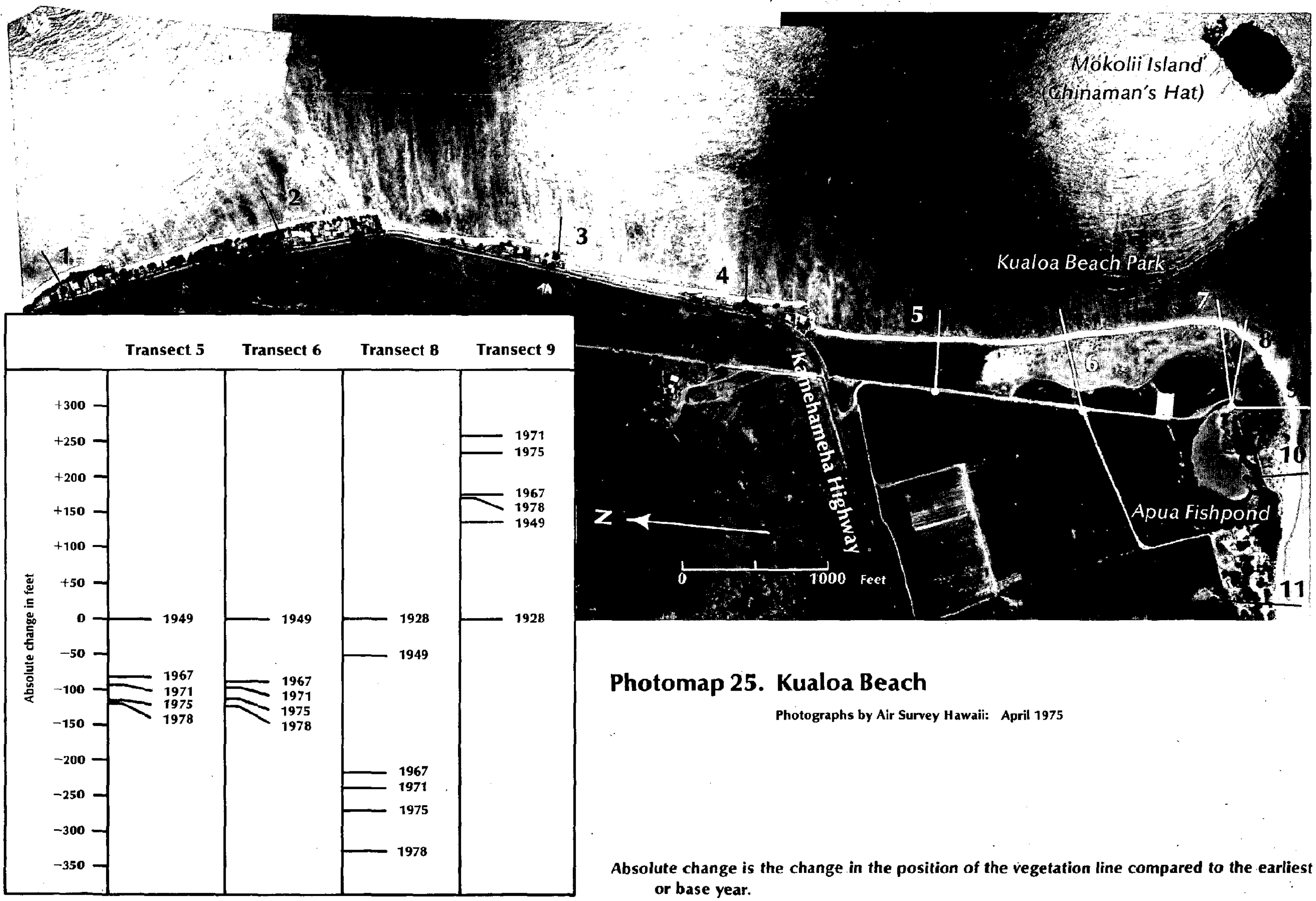
Kualoa Beach is a cuspate foreland, or simply, a cusp-shaped sand body projecting from the coastline. In order for this feature to have formed, accretion must have predominated in the past. Now, however, analysis of the most recent erosion indicates that this entire plain may disappear (J. C. Kraft, Sea Grant Report, in prep.).

A detailed report on erosion has been conducted for Kualoa Beach Park (U.S. Army Engineers, 1977). The major findings of that study show erosion between 1949 and 1975 of 215 feet at the point, and 120 to 150 feet along the eastern section of the beach. At the south shore, there has been a long history of accretion.

The U.S. Army Engineers study contains an 1882 survey map of Kualoa Beach, showing Apua Fishpond at the water's edge, and Kualoa Point with a blunt shape. Sometime between 1882 and 1928 accretion had built the point so that it protruded seaward. Since then, erosion has returned the point to a blunted shape.

Although the history of erosion at Kualoa Beach has been documented, a further investigation was made using a slightly different approach. By this study, it was hoped some additional conclusions could be drawn that would help in the management of the beach. Some of the findings in the study are summarized below:

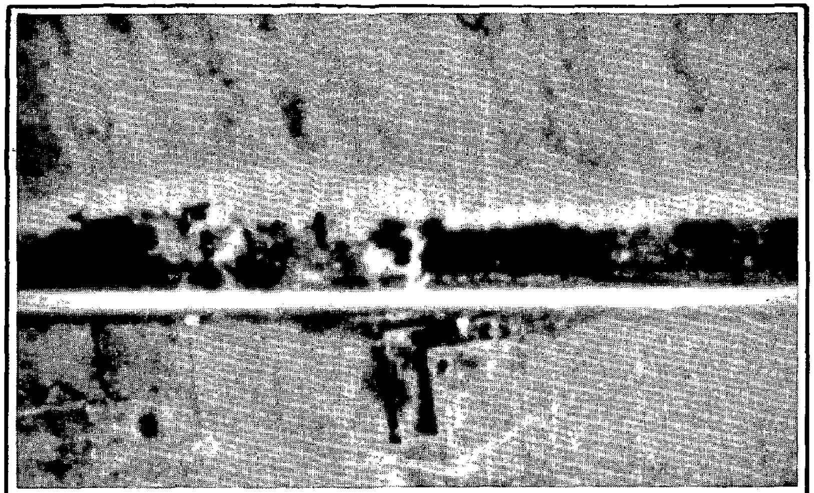
(1) To the north of the beach park, the stretch of shoreline along the highway has been severely altered by a series of groins (Photomap 25). Immediately upcurrent of each groin, the beach has been stable or grew. The net changes in the vegetation line for transects 1 to 4 are less than 10 feet (Table 25). Downcurrent of each groin, the beach has been starved (Plate 7). Along several sections of the coast, only a seawall protects



Photomap 25. Kualoa Beach

Photographs by Air Survey Hawaii: April 1975

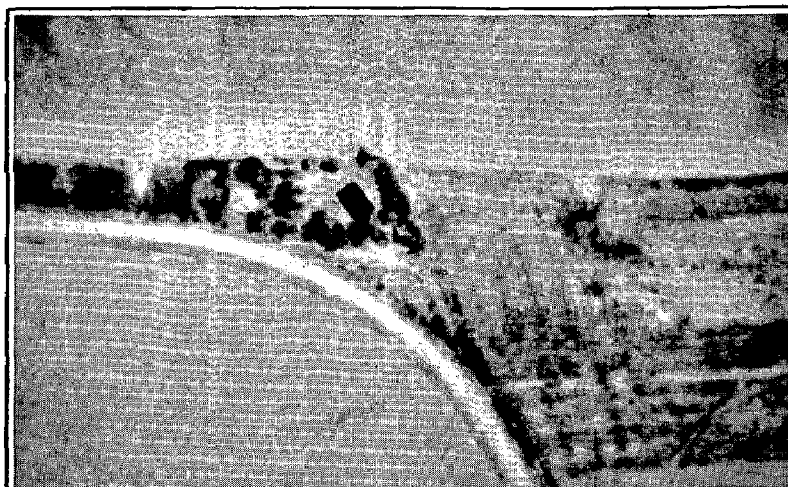
Absolute change is the change in the position of the vegetation line compared to the earliest or base year.



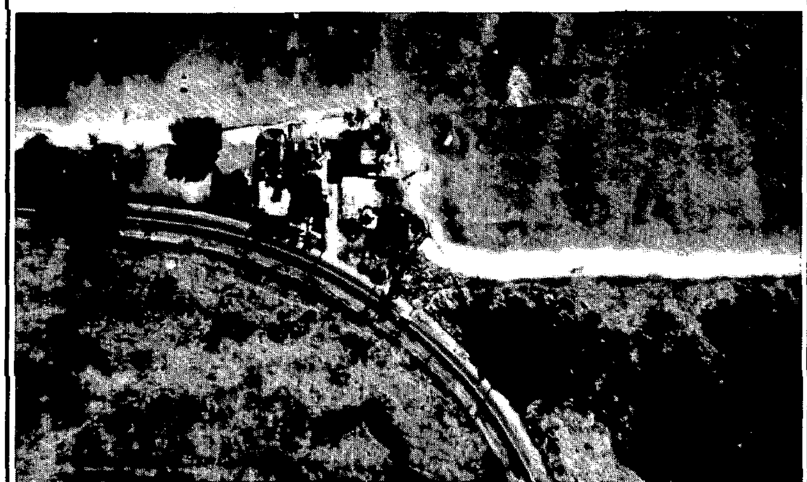
1928

1978

Plate 7. Kualoa. Between 1928 and 1978, erosion to the south (right) of the groin has stripped the protective beach and vegetation fronting the highway.



1928



1978

Plate 8. Kualoa Beach Park. A continuation of the erosion trend at the north end of Kualoa Beach Park would undermine the Kamehameha Highway. Compare the position of the vegetation line with the highway on the 1928 and 1978 photographs.

Table 25 - Kualoa Beach. Changes in the Vegetation Line in Feet.

Observation Period	Transect Number 1	2	3	4	5	6	7	8	9	10	11
1928 - Nov 29, 1949	*	*	*	*	*	*	-56	-53	+138	-159	+72
Nov 29, 1949 - Apr 22, 1967	*	0	*	-1	-81	-91	-134	-165	+38	+64	+85
Apr 22, 1967 - Dec 16, 1971	*	*	*	-6	-14	-7	-19	-21	+82	-4	+31
Dec 16, 1971 - Apr 13, 1975	+8[1]	0[1]	+1[1]	+4	-22	-15	-12	-30	-22	+153	-3
Apr 13, 1975 - Oct 09, 1978	-1	+9	-1	0	-1	-9	-51	-58	-66	-7	-8
Net Change - Vegetation Line	+7	+9	0	-3	-118	-122	-272	-327	+170	+47	+177
Range - Vegetation Line	8	9	1	7	118	122	272	327	258	213	188
Net Change - Water Line	+6	-10	-20	-14	-134	-147	-312	-367	+122	+14	+159
Range - Water Line	17	12	20	25	134	147	312	367	230	222	175

** No Data*
[1] Change from 1967-1975
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

the highway from wave attack. During a large storm or hurricane, extensive damage to the residential areas and highway could occur.

Unless remedial measures are taken, the erosion downcurrent of the southernmost groin will undermine the highway in the near future (Plate 8). From 1928 to 1978, the vegetation line receded about 135 feet. As of 1978, there was 60 feet of vegetation fronting the highway.

It may be more than a coincidence that the emplacement of the groins and the onset of erosion at Kualoa Point occurred sometime after 1882 (U.S. Army Engineers, 1977). Before these structures were installed, the shoreline was continuous. Sand flowed easily from north to south building the point. With the installation of the groins came three major changes. First, accretion updrift and erosion downdrift of the structures occurred. Second, the groins may have reduced the strength of the north-south longshore current. Finally, the groins have deflected some sand offshore. These three changes have combined to reduce or cut off the sand formerly feeding Kualoa Point.

(2) The eastern section of Kualoa Beach Park has receded about 120 feet over the 1949 to 1978 observation period (transects 5-6). When averaged over a 29-year

period, the rate of erosion is about 4 feet per year. This rate has not been constant but varies from 2 to 5 feet per year. Over the study interval there appears to be no significant increase in the rate of retreat. This suggests that the reduction in sand from upcurrent has been uniform through time.

(3) Several unique problems were encountered in the study of erosion at Kualoa Point. First, there were no obvious stable reference points for beach changes to be measured against. This problem was resolved by selecting points in Apua Fishpond which appeared stable over the 50-year observation period. Measurements taken between these points on all the photographs had a range of 7 feet.

The transects for this study were established perpendicular to the 1949 beach. As Kualoa Point changed shape, the orientation of transects 7 to 9 became more oblique to the shoreline. Trigonometric relations indicate that the largest error is about 18% for the most recent measurement on transect 8. On Table 25, the shoreline changes for this transect were corrected by determining the percent error for each observation period. The most recent measurements for transects 7 and 9 were off by 7% and 6%, respectively. No corrections were made for these measurements as the total error is under 10 feet.

From 1928 to 1978, the vegetation line at Kualoa Point eroded about 327 feet. Over the same interval, water line retreat of 367 feet was recorded. Between October 1978 and August 1980, field and photographic measurements indicate that the beach receded an additional 27 feet. From the available data, an estimate of the total loss at Kualoa Point since 1928 is about 350 to 400 feet.

The cumulative movement curve for transect 8 (corrected for errors) shows a progressive increase in the rate of erosion at Kualoa Point (Figure 5). From 1928 to 1949, the vegetation line receded about 3 feet per year. During the 1949 to 1975 period, erosion occurred

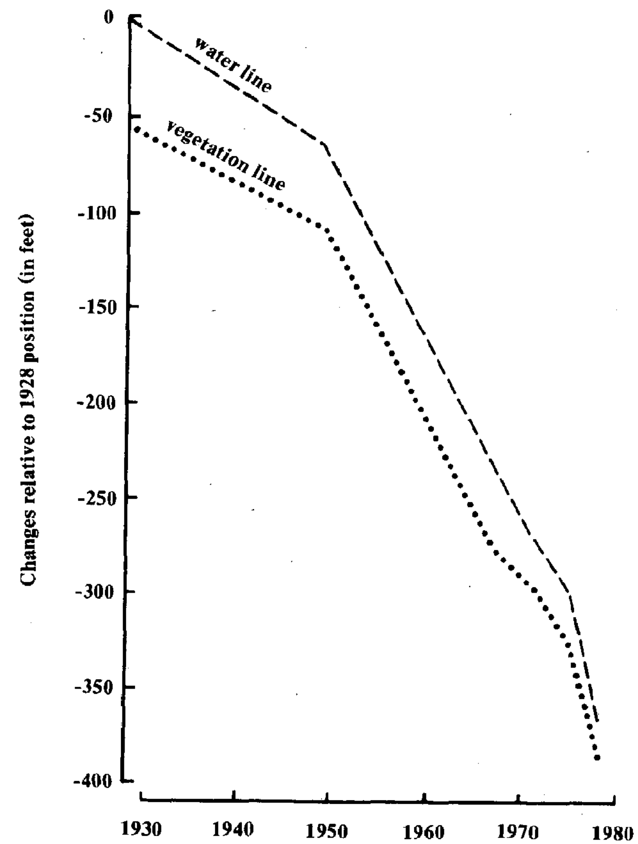


Figure 5. Kualoa Beach Erosion. Graph shows the historic shoreline changes at Kualoa Point (transect 8).

at 8 feet per year. For the last observation period, to 1978, the rate of retreat was 17 feet per year.

Several factors have caused an accelerated erosion rate at Kualoa Point. One important variable appears to be the changing shape of the point itself. In 1928, the tip of Kualoa protruded seaward. Sand transport from the eastern shore around the protrusion to the southern shore was difficult. In addition, waves hit parallel to the beach causing minor longshore currents. By 1978, the point had become blunted. Sand from the north was easily transported around the point. Furthermore, trade wind waves hit the beach at a larger angle and therefore increased the alongshore drift.

As sand was carried past the point, the beach narrowed significantly. The reduction in beach width through time can be seen on the 1928 and 1978 aerial photographs for Kualoa Point. Without the protection of a wide sloping beach, waves of less than two feet high can cut back the beach scarp during periods of high tide combined with strong onshore winds (D. Griffin, personal communication).

Another possible factor causing the increased erosion within recent years is the sandgrabber, which was installed in December 1977. As the most recent aerial photographic observation period covered the interval between 1975 and 1978, it cannot be determined whether the high rates of erosion during this time were all natural or partly influenced by this structure. Nevertheless, the sandgrabber appears to be hoarding sand to the north (upcurrent). This would increase erosion south of the structure in a manner similar to the erosion downcurrent of the groins along the highway.

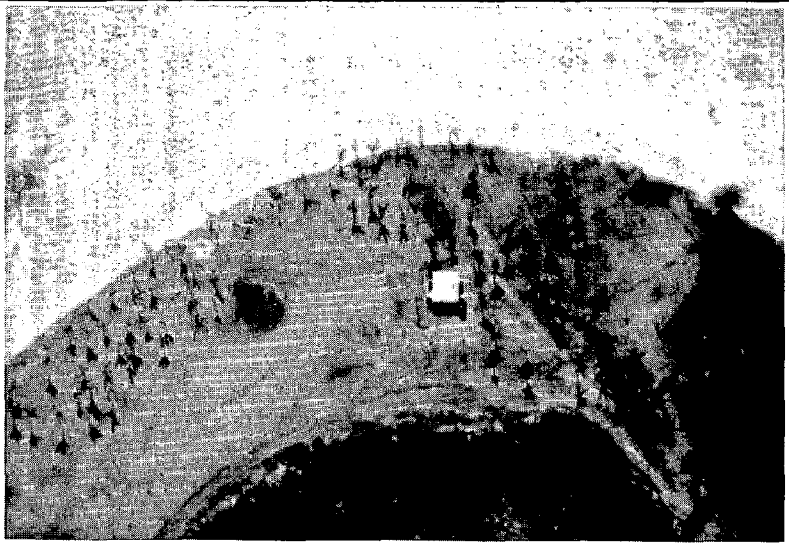
It is also possible that the increased erosion is caused by a steady reduction in the sand supply from the north. There appears, however, to be no significant increase in the rate of erosion along the eastern shore of the beach park. Thus, this factor may be minor in importance.

The bathhouse at Kualoa Point was 35 feet from the vegetation line on August 9, 1980. Given the present rate of retreat, this structure has about two years before it is undermined (Plate 9).

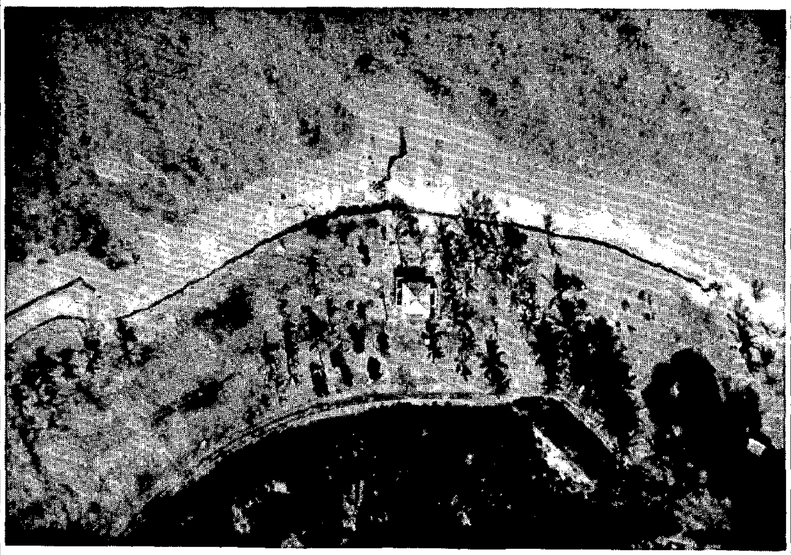
(4) Along the south shore of Kualoa Beach, erosion began in 1971 after a long history of accretion dating back to 1928. The vegetation line at transect 9 grew seaward 258 feet during the 1928 to 1971 interval but receded 88 feet in the next seven years. The erosion at transect 10 began around 1975 and is less severe. Shoreline retreat for this section of the beach will increase progressively as Kualoa Point is washed away. To the west of transect 10, accretion has been the general trend, as illustrated by the widening of the camping beach since the late 1970's (D. Griffin, personal communication). The force delivering sand to this section of the beach is the refracted waves from Mokolii Island.

The projections for Kualoa Beach are based on the assumption that no remedial measures are taken to save the park. Of the several measures that have been proposed, sand replenishment would not require the installation of artificial structures on the beach or offshore. This option is not available to the public as the present regulations prevent mining an offshore deposit that was identified as a possible donor of sand.

Kualoa Point eroded at least 250 feet prior to the construction of the beach park. Few people were aware of this change, for the land had little value then. After the park was constructed and trees were undermined, it was realized that the beach was unstable. Now costly remedial measures will be required if the park is to be saved.



1975



1979

Plate 9. Kualoa Point. Erosion at Kualoa Point threatens to undermine the park comfort station. Compare the position of the vegetation line with the bathhouse on the 1975 and 1979 photographs.

Kailua Beach

Table 26 summarizes the historic changes in the position of the vegetation line for the fifteen transects established at Kailua Beach. From the data, several interesting trends are apparent. Within the total littoral cell known as Kailua Beach are three distinct units or subcells. Although the sand transport processes in any of the subcells is dependent on the others, each unit seems to behave as a separate entity.

For the period from 1949 to 1957, Kailua Beach grew throughout its entire length, except for the middle portion between transects 7 and 9 (Photomap 26). During the monitoring interval from 1957 to 1963, accretion was also prevalent with especially high growth in the middle section of the beach.

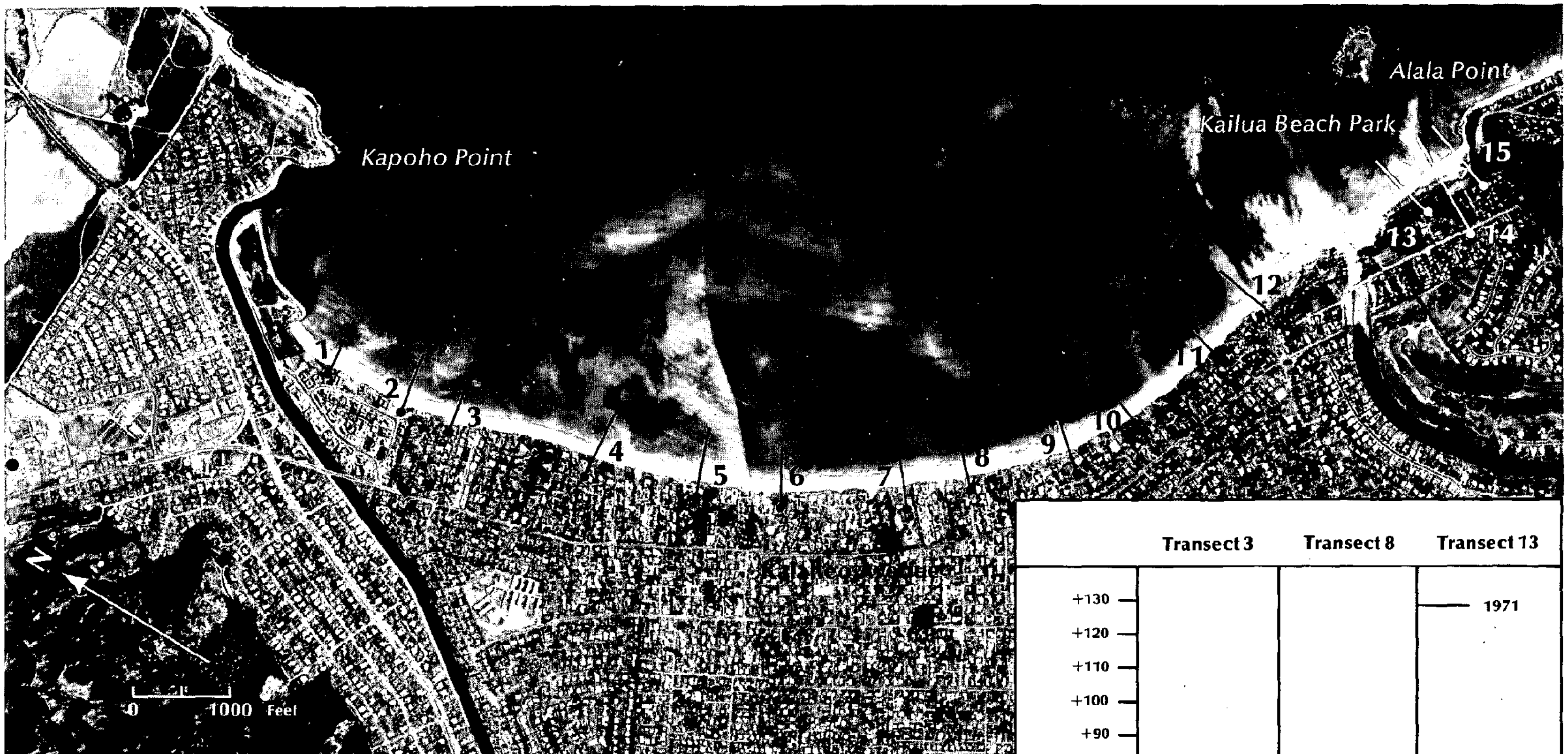
It is not obvious why the middle portion of Kailua Beach changed the way it did for these two observation periods. When the two monitoring intervals are combined, however, and net changes computed from 1949 to 1963, all transects show the beach growth to be more regular. This fact may be an important clue to the beach processes operating at that time. Since an aerial photograph represents only a spot observation, it may be possible that the 1957 photographs recorded unstable conditions for the central part of the beach. An examination of the 1957 photograph shows the shoreline changing its orientation abruptly in this area. During the monitoring interval, from 1957 to 1963, the middle portion of the beach grew about twice as much as adjacent parts to realign itself with other sections of the shoreline.

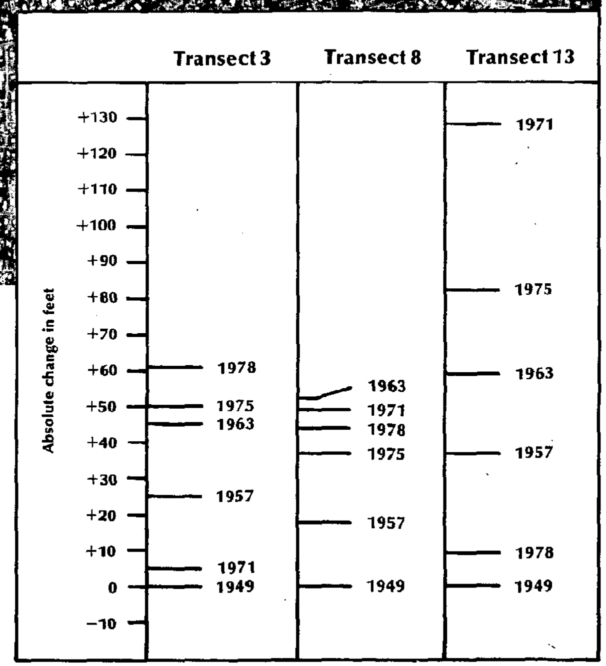
For the next three observation periods, from 1963 to 1978, an interesting pattern of beach change is clearly seen in the data. While one end

Table 26 - Kailua Beach. Changes in the Vegetation Line in Feet.

	Transect Number														
Observation Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Nov 22, 1949 - Sep 07, 1957	*	*	+25	+42	+41	+32	-1	+18	-13	+23	+30	+34	+37	+30	-1
Sep 07, 1957 - Nov 20, 1963	*	*	+20	+17	+7	+19	+34	+34	+45	+18	+3	+14	+22	+51	+77
Nov 20, 1963 - Feb 06, 1971	*	*	-40	-13	-20	-15	+6	-3	+9	+6	+18	+40	+69	+65	+51
Feb 06, 1971 - Apr 13, 1975	+34	*	+45	+17	+29	+18	-3	-12	-13	-6	+1	-23	-46	-72	-26
Apr 13, 1975 - Oct 16, 1978	+10	+17	+11	-6	-3	+2	+3	+7	-7	+9	+7	-2	-73	-48	-14
Net Change - Vegetation Line	*	*	+61	+57	+54	+56	+39	+44	+21	+50	+59	+63	+9	+26	+87
Range - Vegetation Line	*	*	61	63	57	56	40	52	54	50	59	88	128	146	128
Net Change - Water Line	*	*	+67	+37	+79	+60	+18	+44	+30	+65	+40	+87	+101	+104	+119
Range - Water Line	*	*	68	63	79	69	73	57	56	65	59	115	129	170	175

** No data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.





Photomap 26. Kailua Beach

Photographs by Air Survey Hawaii: February 1971

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

of Kailua Beach is accreting, the other end is retreating. The middle sections tend to remain relatively stable. This conclusion is also supported by the historic ranges in the position of the vegetation and water lines.

During the monitoring interval from 1963 to 1971, the southeast end of Kailua Beach was in an accreting cycle while the north end of the beach eroded by as much as 40 feet. For the two observation periods from 1971 to 1978, the direction of net littoral drift shifted and resulted in significant erosion at Kailua Beach Park while the Kaneohe end of the littoral cell grew considerably.

The cyclic trend of erosion and accretion at opposite ends of Kailua Beach is similar to the seasonal changes on some other Hawaiian beaches, such as Lumahi Beach on Kauai (Moberly and Chamberlain, 1964). This pattern indicates that sand eroded at one end of the beach is transported to the opposite end. Therefore, it should be realized that any structures designed to hoard sand at one end of the littoral cell may starve all down-current sections of the beach.

Any shifts in the trend of beach change reflect reversals in the direction of littoral transport. Two possibilities are presented to account for these reversals.

(1) It has been suggested that the direction of littoral transport varies seasonally for Kailua Beach (Noda, 1977). During the summer months, strong persistent trade wind waves tend to transport sand to the northwest. In the winter, sand transport may be to the northwest or southeast, depending on the interaction of northeast trade waves with North Pacific swell. According to this concept, the direction of littoral transport would be to the southeast if unusually strong or persistent North Pacific swell occurred during a winter storm.

    An examination of a 1967 photograph for north Kailua Beach shows considerable erosion of the vegetation line during the 1967 to 1971 interval. This erosion is concurrent with similar events at Punaluu Beach Park, Swanzy Beach Park and Kaaawa Beach Park. The erosion at these beaches was caused by the winter storms of 1968 and 1969.

(2) It is also possible that a shift in the direction of the trade winds causes the direction of trade wind waves to change. Since the orientation of Kailua Beach is almost perpendicular to the northeast trade wind direction, any fluctuations in this wind system would have a pronounced effect on the direction of littoral drift. If over a 10-year period, the trade winds blew from a more easterly direction than usual, erosion might result at Kailua Beach Park and accretion at the opposite end of the littoral cell. This trend might be reversed if the trade winds blew from a more northerly direction, when averaged over a multi-yearly period.

    According to Wentworth (1949), the trade winds shifted in direction from northeast to east and back to the northeast over a period of 40 years. If trade wind cycles of this periodicity are the rule, then beach changes at Kailua Beach may also have a natural cycle of 40 years.

Although the two hypotheses presented have been mentioned separately, they are not mutually exclusive. For example, the long-term direction of littoral drift may be to the southeast for active winter wave activity accompanied with a northerly shift in the trade winds.

Since the littoral processes on Kailua Beach are dependent on meteorological factors, an accurate prediction on beach changes would require a knowledge of future weather conditions. Although our ability to forecast trade wind directions or North Pacific swell activity is limited, it should be realized that the historic record for Kailua Beach shows a tendency towards cyclic erosion and accretion. Therefore, these cycles may occur in the future. This means that trees, houses or any other structures must not be placed on that portion of an accreting beach that may retreat many years later as part of the natural cycle. Unfortunately, this practice has not been followed for several sections of Kailua Beach. For example:

(1) During the period from 1949 to 1971 the vegetation line in front of transect 13 grew seaward about 128 feet. Within this time interval, two rows of trees were planted approximately 95 feet and 40 feet inland of the 1971 vegetation line. Between 1971 and 1978, the vegetation line retreated about 119 feet to the position where the 1978 vegetation line was within 10 feet of its 1949 location. As a result many trees fell in the water (Plate 10).

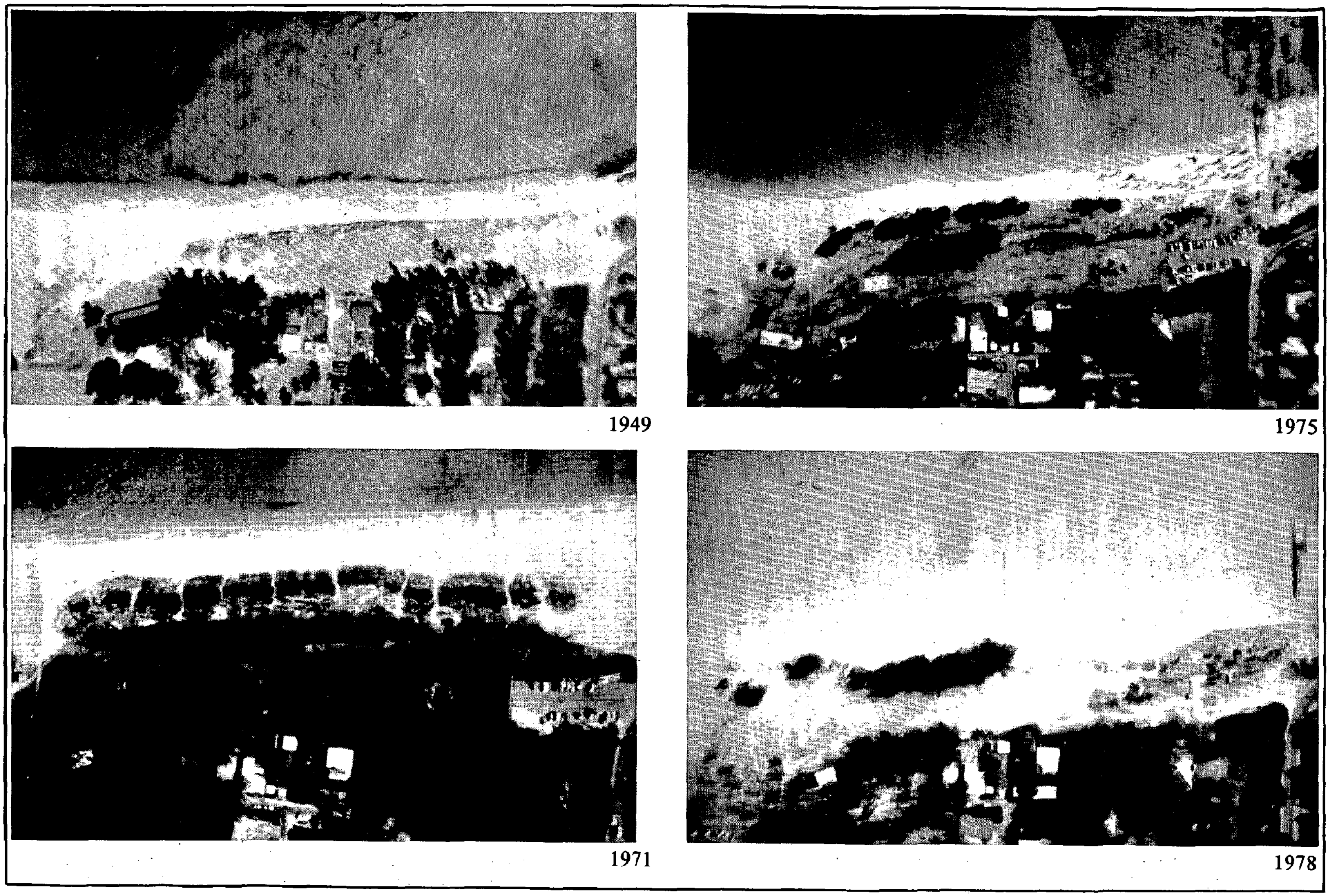


Plate 10. Kailua Beach Park. This sequence of aerial photographs show the accretion-erosion cycle at Kailua Beach Park. Between 1949 and 1971, the vegetation line grew seaward 128 feet. Over the next seven years, a net erosion of 119 feet was recorded.

(2) From 1949 to 1978, the net change in the position of the vegetation line for transect 8 was +.44 feet. During this period a house was built 35 feet inland of the 1978 vegetation line. If the beach retreats to its 1949 position, this house will be undermined.

(3) Between transects 5 and 6, the vegetation line advanced seaward about 54 feet over the 29-year observation period. Five houses have been built along this stretch and are located from 47 to 40 feet inland of the 1978 vegetation line.

(4) Approximately 300 feet south of transect 3, the vegetation line advanced seaward about 61 feet over the 29-year monitoring period. A house was constructed at this location about 32 feet inland of the 1978 vegetation line. In fact, this house is situated within 10 feet of the 1949 land-water boundary. If the vegetation recedes 40 feet as it did during the 1963 to 1971 interval, this house will be undermined. A field check in August 1980 shows the accretion trend at North Kailua has reversed. Erosion during the winter of 1980 has threatened to undermine this house.

It cannot be predicted whether any section of the beach will retreat to its 1949 position. The data for most of the transects at the beach indicate a general increasing trend. The Kailua Beach Park area, however, showed a general increasing trend for 22 years until rapid erosion began without any forewarning. Since our knowledge of the littoral cycles at Kailua Beach is imperfect, it would be wise to keep all future development well inland of the most withdrawn historic position of the vegetation line, as determined by aerial photographs. If this practice is followed, extensive property damage may be avoided in the near future, for the historic record indicates that Kailua Beach is a dynamic zone that will continue to change through natural cycles of erosion and accretion.

Lanikai Beach

The patterns of shoreline change at Lanikai are similar to those of Kailua Beach. Lanikai can be separated into three major subcells, consisting of a stable middle and two end sections that change differently. The approximate boundary of the subcells, as interpreted from the data, appears on Table 27.

During the 1961 to 1971 period, the vegetation line at the south end of Lanikai grew seaward by 139 feet. From 1971 to 1980, the trend reversed, and the vegetation line eroded 111 feet at a rate of about 12 feet per year (Photomap 27, Plate 11). This accretion-erosion cycle coincides in timing and magnitude with the one for Kailua Beach Park.

Over the 30-year observation period, the middle section of Lanikai remained relatively stable (transects 6 and 7). This inflection point separates opposite ends of the beach that change differently.

For north Lanikai, four of the five observation periods show changes that differ from those at the south end. During the 1950 to 1961 period, north Lanikai eroded while the opposite end grew slightly. Between 1961 and 1967, sections of north Lanikai experienced severe erosion (transects 4 and 5) while the south end grew by up to 105 feet. From 1967 to 1971, the north end was stable while the opposite end was still accreting. The photographic data prior to 1971 indicate that the long-term direction of littoral transport may have been from north to south. This trend reversed during the 1971 to 1975 interval when north Lanikai showed its maximum accretion while the south end began to erode. Only during the 1975 to 1980 period was a net erosion at both ends of the beach experienced.

The pattern of erosion and accretion at opposite ends of Lanikai suggests that major beach changes are determined by the direction of sand transport along the shoreline. As explained for Kailua Beach, this is determined by the direction of the northeast trade waves, and the interaction of these waves with North Pacific swell.

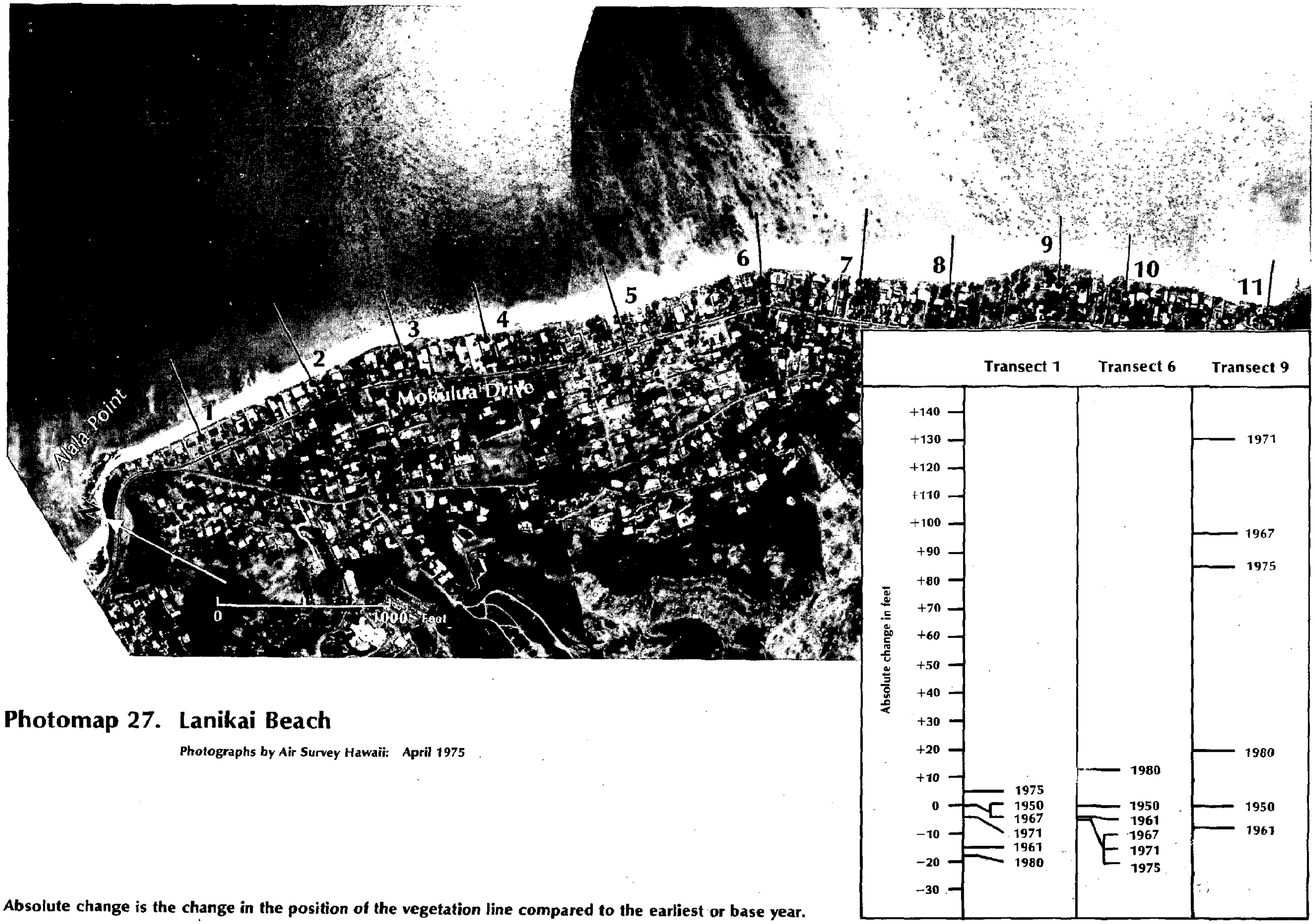
Although shoreline changes at Kailua and Lanikai are similar, three important differences exist:

(1) The beach changes within and between subcells at Lanikai are not always transitional but sometimes fluctuate unpredictably.

Table 27 - Lanikai Beach. Changes in the Vegetation Line in Feet.

Observation Period	Transect Number 1	2	3	4	5	6	7	8	9	10	11
Apr 19, 1950 - Jan 20, 1961	-15[1]	0[1]	-13	+3	-26	-4	+14	+8	-8	+10	-4
Jan 20, 1961 - May 08, 1967	+15[2]	+8[2]	-4	-29	-35[3]	-1	-5	+18	+105	+56	-6
May 08, 1967 - Feb 06, 1971	-4	-1	+10	+4	*	0	-7	+19	+34	+5	-6
Feb 06, 1971 - Apr 13, 1975	+9	+7[3]	+20	+8[3]	*	0	+6	+9	-46	-30	+10
Apr 13, 1975 - Jan 19, 1980	-23	*	-8	*	*	+18	+2	-32[3]	-65	-16	-11
Net Change - Vegetation Line	-18	+14	+5	-14	-61	+13	+10	+22	+20	+25	-17
Range - Vegetation Line	23	14	30	29	61	18	14	54	139	71	17
Net Change - Water Line	-54	-30[4]	-8	-53[4]	-39[4]	+15	*	*	+40[5]	-8[6]	*
Range - Water Line	54	31[4]	37	71[4]	39[4]	57	*	*	151[5]	147[6]	*

**No Data*
[1] April 19, 1950 - July 23, 1959
[2] July 23, 1959 - May 8, 1967
[3] To seawall
[4] From 1950-1980
[5] From 1967-1980
[6] From 1961-1980
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 27. Lanikai Beach

Photographs by Air Survey Hawaii: April 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

1950

1980

1971

Plate 11. Lanikai Beach. The accretion-erosion cycle at south Lanikai Beach is depicted in these aerial photographs. Between 1950 and 1971, the vegetation line had a net change of +131 feet. This accretion was concentrated during the 1961 to 1971 interval. Over the next nine years, erosion of 111 feet occurred.

(2) The maximum variation in the position of the vegetation line at Lanikai is not found at the ends of the littoral cell. For Lanikai, the maximum range is recorded at transects 5 and 9.

(3) Even though the middle and south sections of Lanikai record changes in phase with Kailua, the north end differs slightly. In particular, during the period from 1950 to 1961, the north end of Kailua grew appreciably while north Lanikai eroded.

Several factors could account for the differences between the two beach systems. Wave diffraction between Mokulua Islands and refraction around them would give Lanikai a wave regime different from Kailua's. Another factor is the shape of the two beaches. Kailua Beach is concave seaward, whereas Lanikai has three seaward protruding points separating linear beach segments (Photomap 27). Finally, Lanikai may not be a closed littoral cell. It has been suggested that sand transport to the north may occur around Alala Point (Noda, 1977). This could explain the difference in the patterns of beach change between the north ends of Kailua and Lanikai.

Significant erosion at north Lanikai occurred during the 1975 to 1980 period. It is unlikely that the sewage pipe constructed on the beach was the cause of the recent erosion, as field checks show no sand hoarded to either side of the structure.

Erosion for the entire beach during the 1975 to 1980 period is unusual compared to that of previous observation periods. The sand from Lanikai Beach may have been transported around Alala Point but it appears that a major portion was temporarily lost offshore. Field checks in April and August of 1980 showed a large seasonal change that exposed and then covered a section of beachrock.

Since Lanikai is developed, little can be done to alleviate the problems that exist or may occur. Nevertheless, no structures or trees should be established seaward of the present houses for any part of the beach. Even if accretion occurred, the aerial photographs show that the trend may reverse quickly, given the cyclic nature of the beach.

With few exceptions, practically all of Lanikai has had a history of alternating erosion and accretion. It is not possible to predict the long-term trend for it is partly or wholly dependent on meteorological factors. In such a case, planners should use the historic range in the position of the vegetation line to estimate the inland extent of prohibitive development.

Severe erosion problems exist at north Lanikai and many houses are at the water's edge. As a result, several sections of seawall were constructed during the summer of 1980. If the beach retreats in the winter, both access and recreation of this shoreline will be limited or nonexistent. This has been the trend for much of Oahu's shoreline in the last 30 years.

Waimanalo Beach

The Waimanalo Beach system is bounded by Wailea Point on the north and the Pahonu Fish Pond to the south. Along this crescent-shaped beach are found the following sections: Bellows Air Field Beach, Waimanalo Beach Park, and Kaiona Beach Park.

Nineteen transects were established perpendicular to Waimanalo Beach. One transect was established to the south of this beach. The data for these transects appear on Table 28 (transects 1-11) and Table 29 (transects 12-20). A summary of the major findings appears below.

Over a 30-year period, the north section of Waimanalo Beach near Bellows Air Field has experienced chronic erosion (Photomap 28). Between 1950 and 1962, the retreat of up to 53 feet in the vegetation line threatened to undermine several cabins. As a result, a 350-foot boulder wall was installed for protection. Over the next 13 years, erosion to either side of the wall resulted in the construction of 1,650 feet of stone revetment. In 1978, a sandgrabber was placed south of these structures.

Table 28 - Waimanalo Beach. Changes in the Vegetation Line in Feet.

	Transect Number										
Observation Period	1	2	3	4	5	6	7	8	9	10	11
Apr 19, 1950 - Apr 06, 1962	-33	-53	*	-35	*	+26	-19	+3	+34	*	+34
Apr 06, 1962 - May 29, 1967	+6	-6	-8	-12	*	+32	+15	+17	+4	+11[2]	+18[2]
May 29, 1967 - Feb 06, 1971	-16[1]	-17[1]	-24	-32	+2	-28	+2	-36	-12	-95[2]	-34[2]
Feb 06, 1971 - Apr 13, 1975	*	*	-7	+1	+26	+2	-9	-6	-5	+36	+8
Apr 13, 1975 - Jan 09, 1980	*	*	+27	*	+3	-2	-16	*	+2	-28	-40
Net Change - Vegetation Line	-43	-76	-12	-78	+31	+30	-27	-22	+23	-76	-14
Range - Vegetation Line	43	76	39	79	31	58	27	42	38	95	66
Net Change - Water Line	-72[3]	-82[3]	-93[4]	-57	-12	+44	+111	+72	+63	-44	+74
Range - Water Line	72[3]	82[3]	93[4]	60	23	61	124	100	63	80	78

** No Data*
[1] To rock barrier
[2] 1967 photographs taken on April 23
[3] From 1950-1975
[4] From 1962-1980
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

Table 29 - Waimanalo Beach (cont.). Changes in the Vegetation Line in Feet.

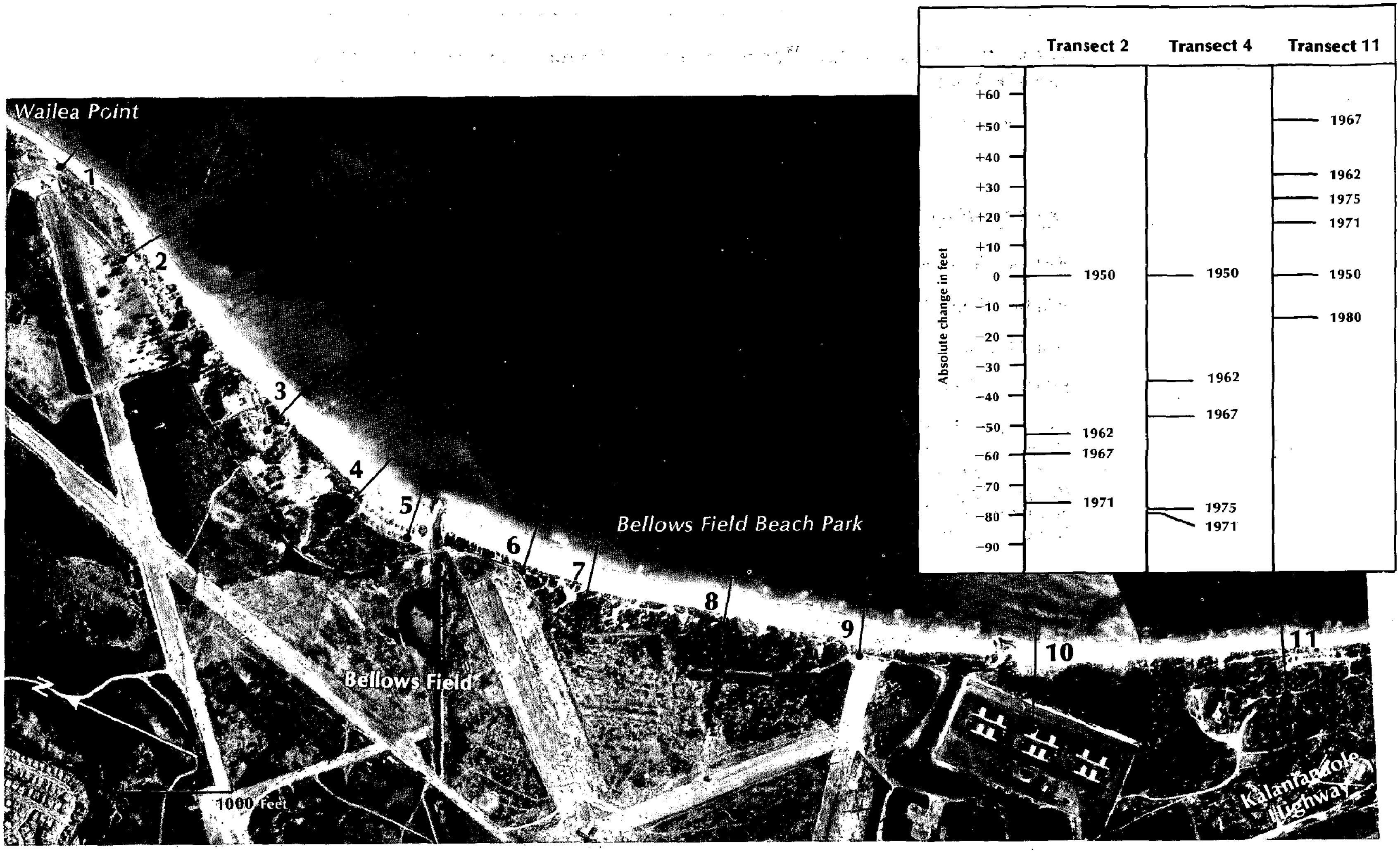
	Transect Number								
Observation Period	12	13	14	15	16	17	18	19	20
Apr 19, 1950 - Apr 06, 1962	+5	+66	-25	-25	*	-48	-62	-20	+7
Apr 06, 1962 - Apr 23, 1967	+60	-10	0	-7	-2	+1	+26	+1	+1
Apr 23, 1967 - Feb 06, 1971	-47	-13	+16	+45	-2	+8	-13	-7	+1
Feb 06, 1971 - Apr 13, 1975	+7	+1	+8	+2	-6	+16	+15	+15	-1
Apr 13, 1975 - Jan 19, 1980	-9	-9	-20	-34	+6	-11	-9	*	*
Net Change - Vegetation Line	+16	+35	-21	-19	-4	-34	-43	-11	+8
Range - Vegetation Line	65	66	21	47	10	48	62	26	9
Net Change - Water Line	-19	+50	+1	+14	+9	+18	+4[1]	+15	+10
Range - Water Line	102	90	38	53	85	73	60[1]	18	39

**No Data*
[1] From 1962-1980
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

The stone revetment at north Waimanalo may have reduced the recreational value of the beach. In 1950, the beach was continuous and about 60 feet wide. Now only a narrow strip of sand fronts the revetment. Access along the shore is limited and the beach cannot be used for sunbathing or picnics.

At north Waimanalo Beach, sections to the south of the artificial structures have had a history of erosion (transects 3-4). This suggests that more remedial measures will be required in the future. From 1975 to 1980, erosion south of the sandgrabber began to undermine a public bathhouse. Over the same interval, the stretch of shoreline between transects 3 and 4 grew slightly. The long-term trend for these transects, however, has been shoreline retreat.

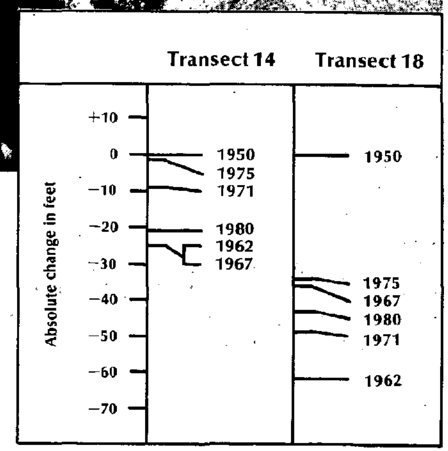
The middle section of Waimanalo Beach (transects 6-13) experienced alternate periods of erosion and accretion. Generally, the major erosion events occurred during the 1967 to 1971 and 1975 to 1980 periods. During the 1967 to 1971 interval, the vegetation line at transect 10 receded 95 feet. Erosion for much of Waimanalo occurred during this period, possibly because of the high waves of December 1968 and January 1969, which damaged other sections on the windward coast. From 1975 to 1980, the vegetation line for transect 11 receded 40 feet, and again, erosion occurred along most of the beach (Photomap 29). Other than these two periods of erosion, accretion at middle Waimanalo Beach was recorded for most of the time.



Photomap 28. Waimanalo Beach

Photographs by Air Survey Hawaii: February 1971

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.



Photomap 29. Waimanalo Beach (cont.)

Photographs by Air Survey Hawaii: February 1971

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

When averaged over a 30-year period, some sections of middle Waimanalo grew while others receded. No clear pattern is seen from the data. For planning purposes, the transect closest to the point of interest should be chosen to indicate the past shoreline change.

It is possible that the net change of the vegetation line for middle Waimanalo records the combined effects of storm wave damage and the migration of large beach cusps in the direction of littoral drift. Studies indicate that small beach cusps are stable over a period of a few months, but no measurements were made over a multi-yearly period (Gerritsen, 1978a). Data on the water line from 1950 to 1980 give no clear indication of a migrating sand wave.

Along the middle section of Waimanalo, stone jetties have been built perpendicular to the beach to constrain the flow of two streams. Both the jetties near transect 5, and the one near transect 10 have a slight buildup of sand at the south end. This indicates that the direction of littoral drift for these beach sections is from south to north.

The southern section of Waimanalo Beach (transects 14 to 19), has experienced periods of alternate erosion and accretion. Unlike middle Waimanalo Beach, this section eroded significantly during the 1950 to 1962 period. The maximum loss was at transect 18 where the vegetation line receded 62 feet. Between 1950 and 1980, the data indicate that erosion for this stretch predominates in terms of time and net change.

Transect 19 was established at Kaiona Beach Park. The pattern of change for this beach is similar to that of other sections of southern Waimanalo.

The shoreline changes at transect 20 indicate that the northwest end of Kaupo Beach is stable. This beach system is separated from the Waimanalo littoral cell by Pahonu Fishpond.

When averaged over a 30-year period, data show that the north and south sections of Waimanalo have eroded. Some sections in the middle grew, while others receded. If this pattern is representative of the the long-term trend, then the crescent shape of Waimanalo Beach should become less distinct with time.

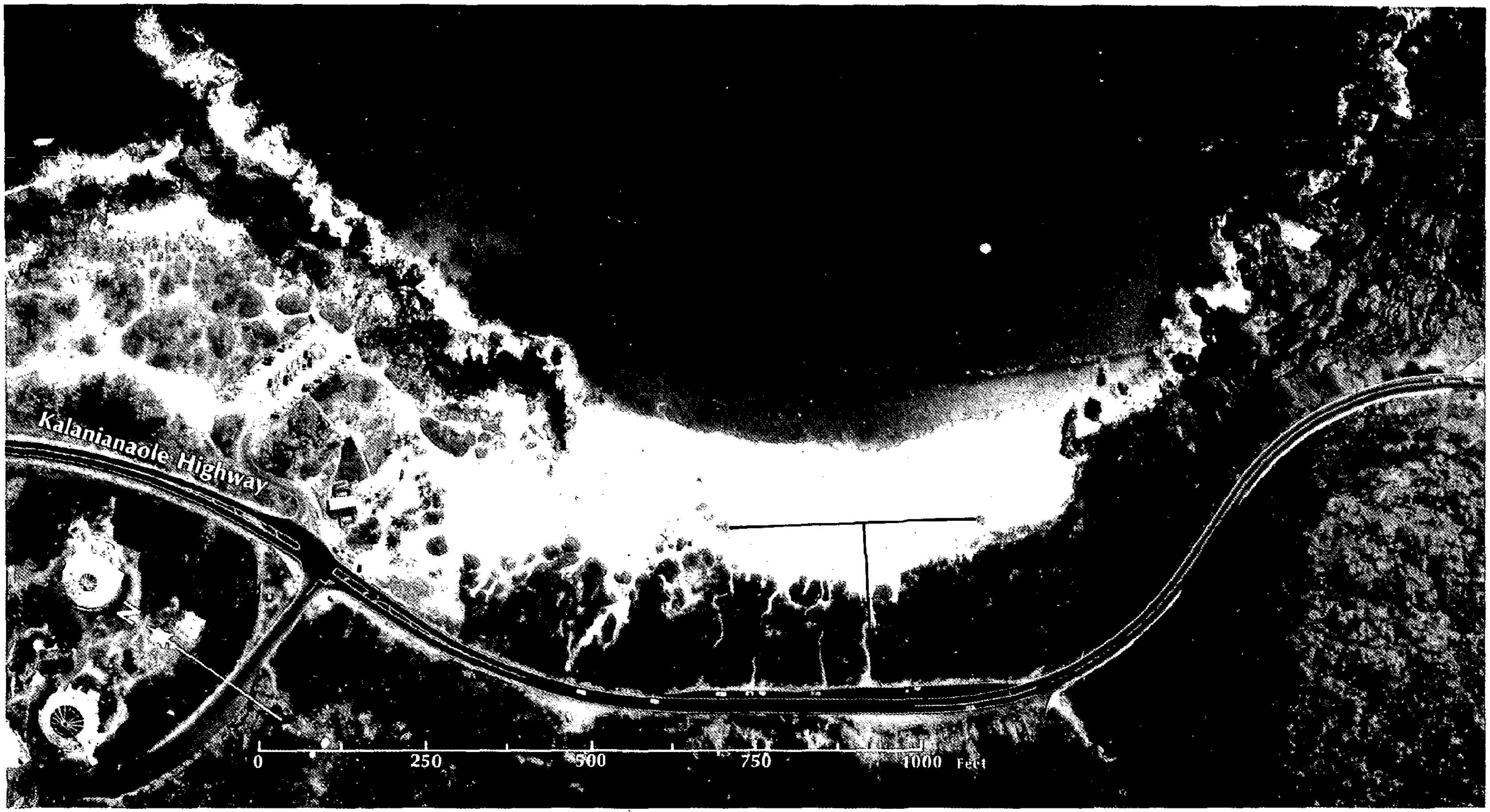
Makapuu Beach Park

The stable reference points at Makapuu Beach were located in unfavorable positions. In order to obtain data for this beach, a connecting line was drawn between the stable reference points. Measurements to the beach were then made from a point on the stable line. Although this procedure introduces inaccuracies, it does provide a first approximation of the historic changes at Makapuu over a 25-year period.

Analyses of the aerial photographs for Makapuu Beach show that the vegetation line at mid-beach advanced seaward 14 feet during the 1950 to 1967 period (Photomap 30, Table 30). During the next eight years, the vegetation line at mid-beach receded 48 feet. The major loss occurred during the 1967 to 1971 interval. This erosion is concurrent with similar events experienced for many of the beaches on the windward coast. The vegetation line at Makapuu Beach may have been cut back during the winter storms of December 1968 and January 1969.

Over a 25-year observation period, the water line grew seaward 72 feet. On the aerial photographs, several rocks that were in the water on April 19, 1950 were covered by sand on April 13, 1975. It is possible that the apparent accretion is due to a variation in the seasonal change. Surveys taken during the 1962 to 1963 period indicate a seasonal variation of 50 feet (Moberly and Chamberlain, 1964). Field surveys taken over a 10-year period indicate that Makapuu may have actually been reduced in volume (Campbell, 1972).

Since it is difficult to separate the seasonal and long-term changes from the water line, the vegetation line should be used as an indicator of the long-term trend. In this case, Makapuu has had a long history of slight accretion offset by shorter erosion events.



Photomap 30. Makapuu Beach Park

Photographs by Air Survey Hawaii: April 1975

Table 30 - Makapuu Beach Park. Changes in the Vegetation Line and Water Line in Feet.

Observation Period	Vegetation	Water
Apr 19, 1950 - Apr 23, 1967	+14	+8
Apr 23, 1967 - Mar 17, 1971	-35	+13
Mar 17, 1971 - Apr 13, 1975	-13	+51
Net Change	-34	+72
Range	48	72

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

SECTION III - SOUTH SHORE

The south shore extends from Makapuu Point on the east to Barbers Point on the west (Figure 6). Along much of this stretch a shallow fringing reef absorbs incoming wave energy. As a result, the beaches on this shore have been stable or have grown slightly. Some exceptions are listed below.

Paiko Peninsula is a barrier spit projecting into Maunalua Bay. Between 1928 and 1961, this spit grew over 800 feet to the east while the arm thinned considerably.

During the 1967 to 1971 period, erosion was experienced at Sandy Beach Park, Hanauma Bay, Paiko Peninsula and east Kahala Beach. It appears that high waves during this interval inundated the backshore area.

Keahi Point is located at the west end of Iroquois Point. From 1928 to 1976, the vegetation line and water line receded about 180 feet.

Erosion at Ewa Beach was concentrated during the 1958 to 1967 period. Many of the seawalls at Ewa were installed during that time.

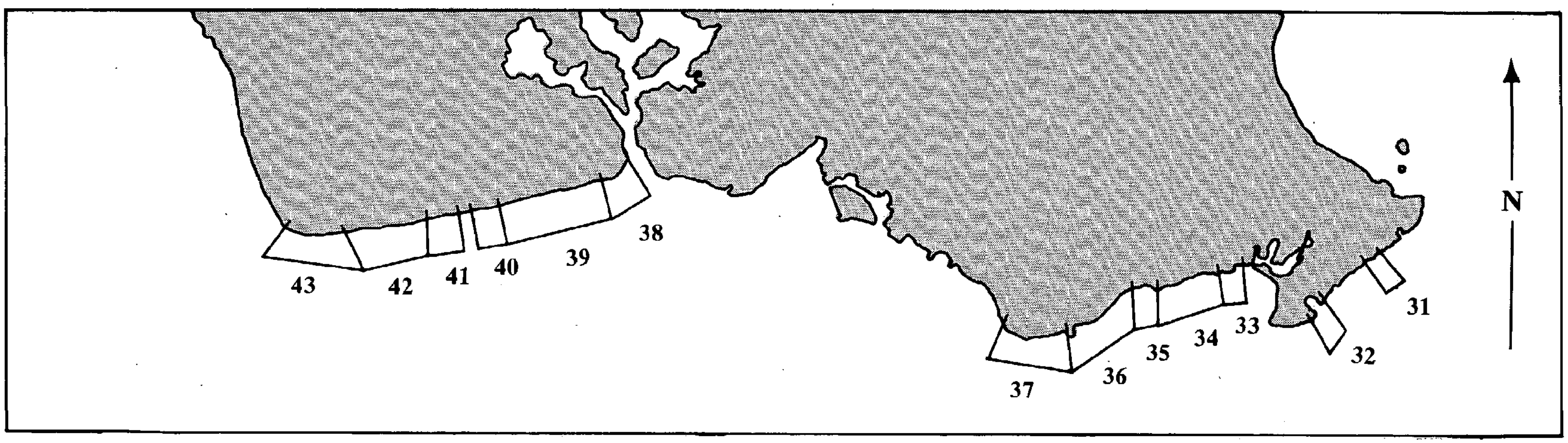


Figure 6. Photomap Arrangements - South Shore.

Sandy Beach Park

Over a 30-year period, the water line at Sandy Beach receded about 13 to 16 feet (Table 31). As Sandy Beach may have an annual variation in width of at least 25 feet (Moberly and Chamberlain, 1964), it cannot be determined if this represents a significant long-term loss in the beach system.

The changes in the vegetation line for transect 1 are small, partly because rocks protect the vegetation in front of this transect (Photomap 31).

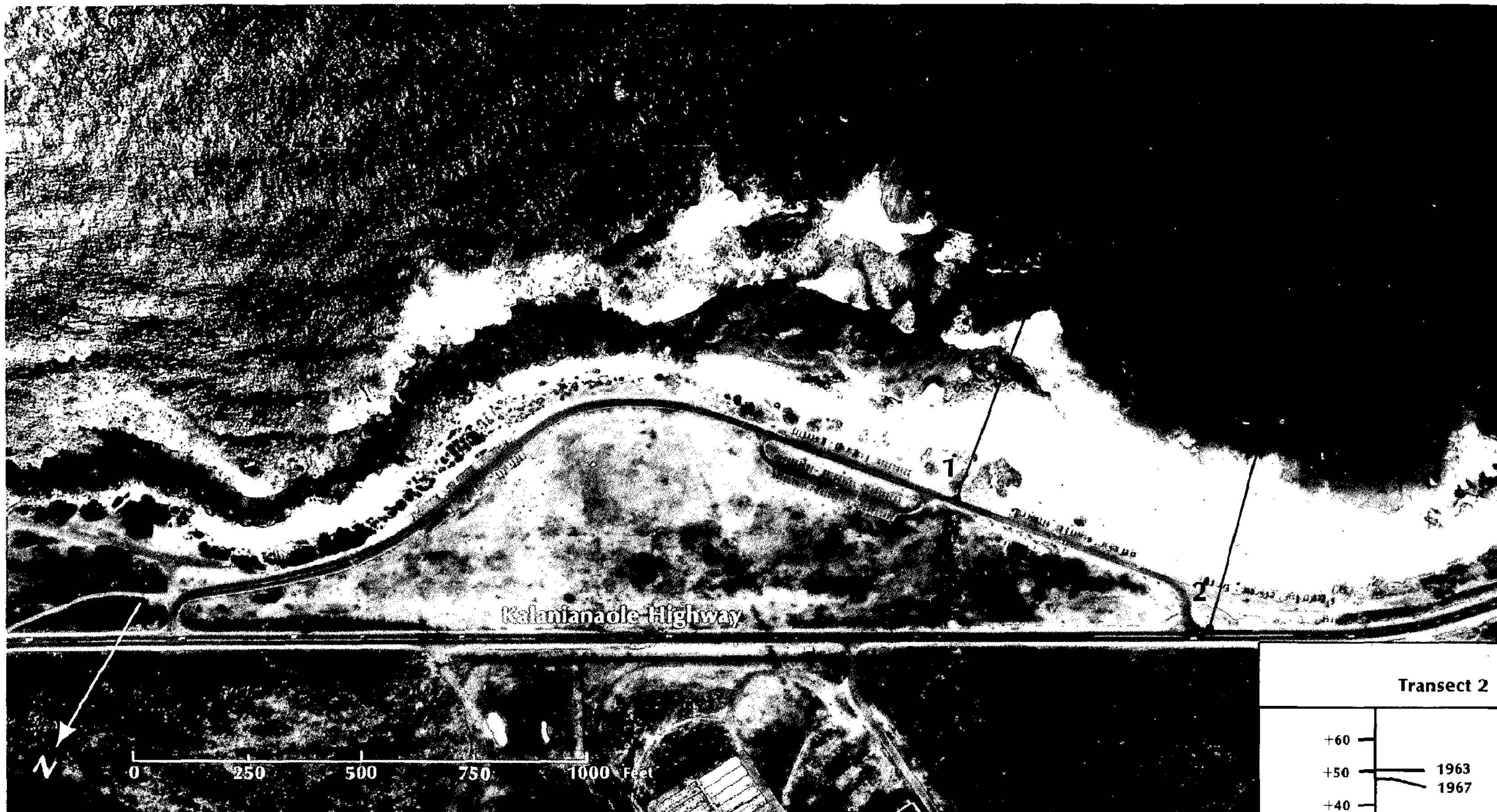
Transect 2 is located at the west end of the parking lot. Between 1949 and 1963, the vegetation line grew seaward 51 feet. During the 1967 to 1971 interval, the vegetation was cut back 71 feet, perhaps by high wave runup onto the backshore.

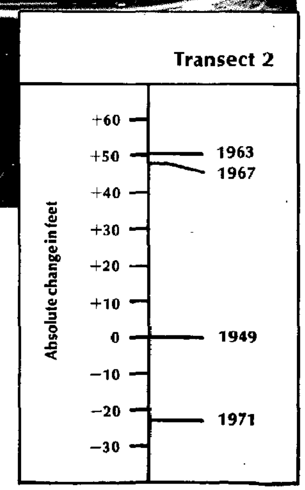
Since 1971, the vegetation at Sandy Beach has not recovered. This makes the parking lots more susceptible to wave inundation. Part of Sandy Beach has no offshore reef structure and therefore receives the full energy of the ocean waves.

Table 31 - Sandy Beach Park. Changes in the Vegetation Line in Feet.

	Transect Number	
Observation Period	1	2
Oct 29, 1949 - Nov 20, 1963	-1	+51
Nov 20, 1963 - Apr 23, 1967	+8	-3
Apr 23, 1967 - Dec 18, 1971	-9	-71
Dec 18, 1971 - Apr 13, 1975	+6	*
Apr 13, 1975 - Apr 03, 1979	+3	*
Net Change - Vegetation Line	+7	-23
Range - Vegetation Line	9	74
Net Change - Water Line	-16	-13
Range - Water Line	41	17

** No data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.





Photomap 31. Sandy Beach Park

Photographs by Air Survey Hawaii: April 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Hanauma Bay Beach Park

Hanauma Bay may be a natural sediment sink. Over a 47-year period, the water line grew seaward by as much as 41 feet. While part of this change is attributed to artificial sand replenishment, much of the accretion occurred prior to 1967.

At transect 1, the vegetation line receded 26 feet during the 1928 to 1949 period (Photomap 32, Table 32). This change was localized. Generally, the vegetation for the east end of the beach had a net gain over this interval. The vegetation line for much of the beach also grew from 1949 to 1967.

The severe erosion at Hanauma Beach in the late 1960's was partly influenced by man. In 1949, the shallow fringing reef at Hanauma Bay was continuous. Much of the wave energy was dissipated on the reef flat instead of on the beach. As a result, the trees and vegetation grew within a few feet of the water.

In 1957, a 250-foot-wide channel was cut through the reef. The artificial channel allowed waves to cross the reef flat more readily. On the 1967 aerial photograph, wave sets over the reef are found only where the channel had been dredged.

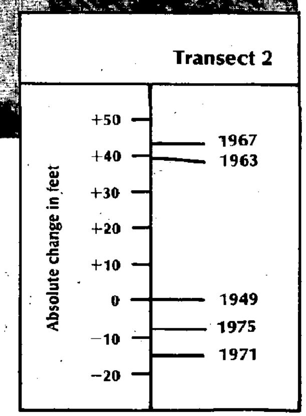
Sometime between 1967 and 1971, many beaches on the south shore experienced erosion. This suggests a high amount of wave energy during that period. At Hanauma Bay, large waves coupled with a high tide may have crossed the reef channel and run up the beach. This wave action undermined the vegetation and coconut trees which had previously grown within 10 feet of the water.

In April of 1970, the City and County of Honolulu, Department of Parks and Recreation, constructed a wave barrier and placed 4,100 cubic yards of sand on the beach.

Table 32 - Hanauma Bay Beach Park. Changes in the Vegetation Line in Feet.

	Transect Number		
Observation Period	1	2	3
1928 - Oct 29, 1949	-26	*	*
Oct 29, 1949 - Nov 20, 1963	-2	+39	+9
Nov 20, 1963 - Apr 23, 1967	-2	+4	+8
Apr 23, 1967 - Dec 18, 1971	-5	-58	+9
Dec 18, 1971 - Apr 13, 1975	0	+7	+2
Net Change - Vegetation Line	-35	-8	+28
Range - Vegetation Line	35	58	28
Net Change - Water Line	+41	+8	+27
Range - Water Line	59	37	63

**No data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 32. Hanauma Bay Beach Park

Photographs by Air Survey Hawaii: April 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Paiko Peninsula

Paiko Peninsula is the most unstable coastal feature on Oahu. A Hawaiian government survey map taken of the Maunaula Bay area in 1884 indicate that this feature did not exist. Over the past century the peninsula has grown approximately 2,000 feet to the east.

Geomorphologists would classify Paiko Peninsula as a barrier spit, an elongate sand body that extends from the coastline in a roughly parallel trend and is separated from the land by a lagoon. The peninsula changes in the following manner. Wave action transports sand from the fringing reef to the beach along two distinct sand plumes. One is located to the east of Niu Peninsula and the other is near transect 1 (Photomap 33).

Once on the beach, the sand is carried from west to east by longshore currents. As the sand passes the tip of Paiko, two results may occur that are dependent on the relative amounts of wave energy. If the wave action is strong, sand is deposited in a fork-shaped washover fan extending into Paiko Lagoon. When the wave energy is low, the spit grows to the east.

Between 1928 and 1949, the tip of Paiko Peninsula grew eastward about 550 feet (Table 33, Plate 12). This extension to the east occurred at an average rate of over 25 feet per year. Meanwhile, the arm of the spit thinned considerably. If not for a rock wall built along the shoreline, the eastern end of the peninsula might have separated and become a barrier island.

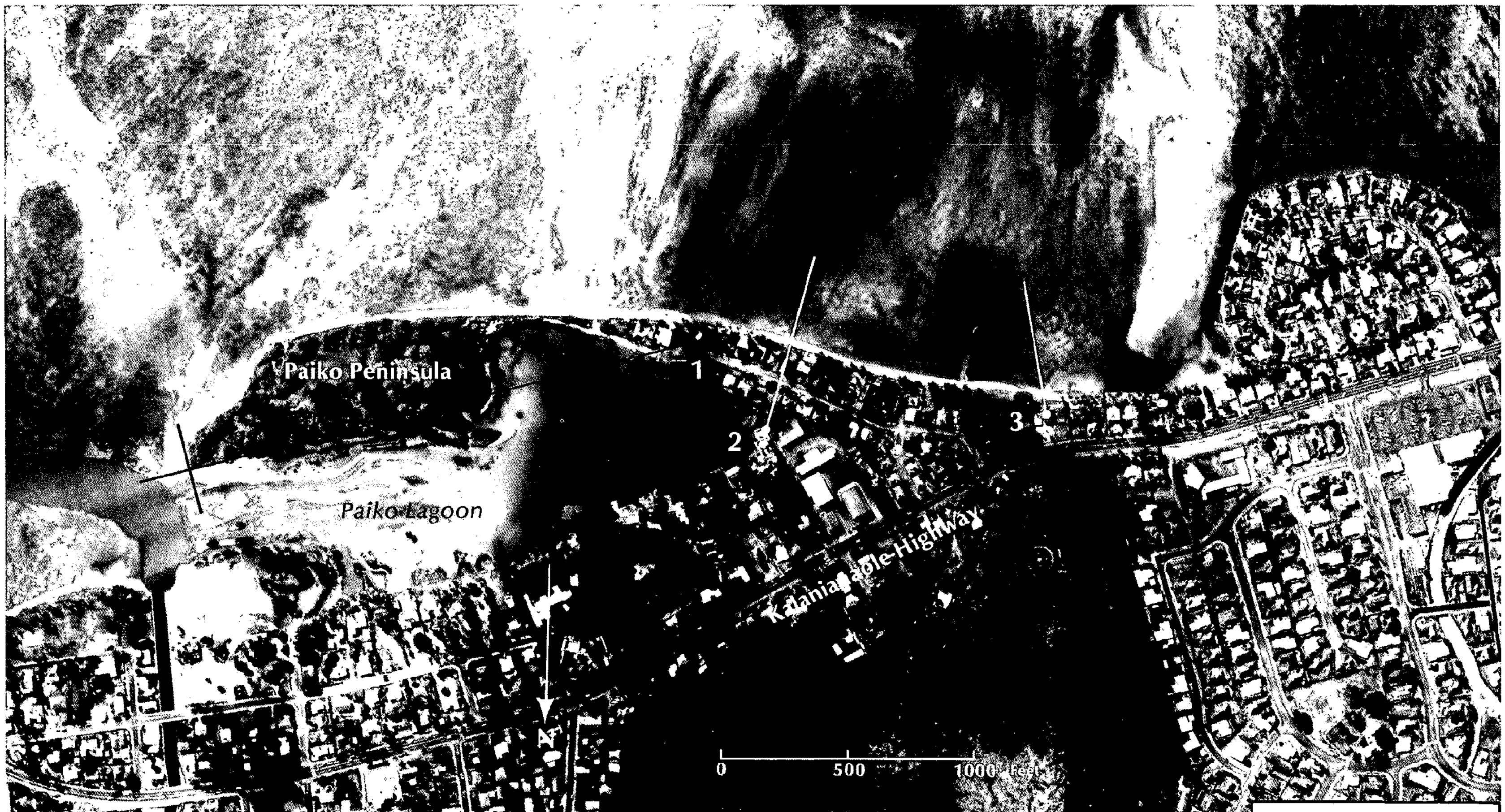
From 1949 to 1961, Paiko Peninsula grew an additional 350 feet to the east. Since then, the shape of Paiko has been influenced by a nearby artificial channel and extensive dredging operations. In the early 1970's, several channels were dredged within Paiko Lagoon to increase water circulation. Dredged material was deposited in the lagoon to create islands for wildlife habitation.

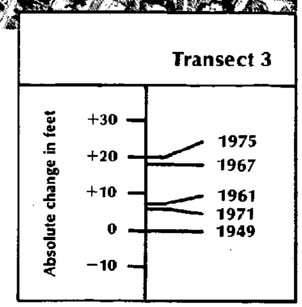
Paiko Peninsula is an extremely unstable geomorphic feature. Therefore, it may be wise to keep the eastern portion of Paiko a wildlife preserve before additional interference with natural processes occcurs.

Table 33 - Paiko Peninsula. Changes in the Vegetation Line in Feet.

	Transect Number		
Observation Period	1	2	3
1928 - Oct 29, 1949	+554	*	*
Oct 29, 1949 - Jan 20, 1961	+359	+18	+7
Jan 20, 1961 - Aug 29, 1967	*	-2	+11
Aug 29, 1967 - Jan 04, 1971	*	-2	-12
Jan 04, 1971 - Apr 13, 1975	*	+4	+14
Net Change - Vegetation Line	+913	+18	+20
Range - Vegetation Line	913	18	20
Net Change - Water Line	+865	+2	+34
Range - Water Line	865	19	34

**No data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



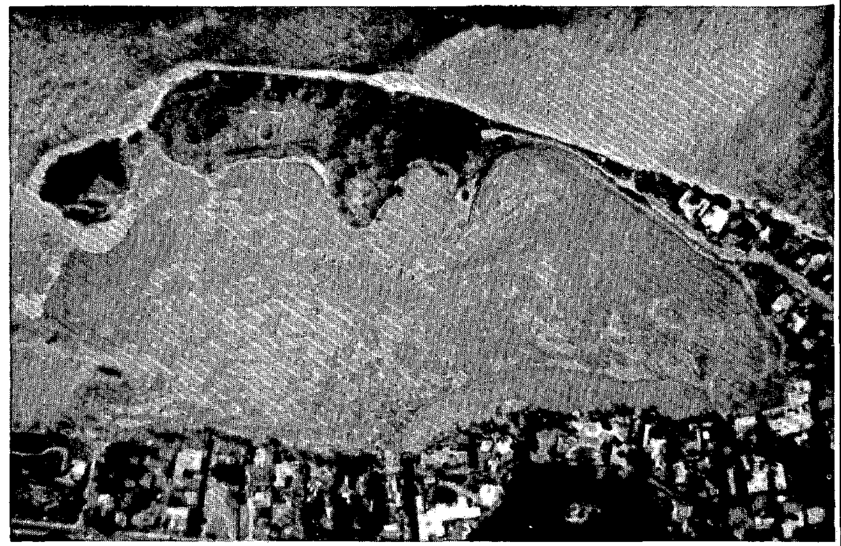


Photomap 33. Paiko Peninsula

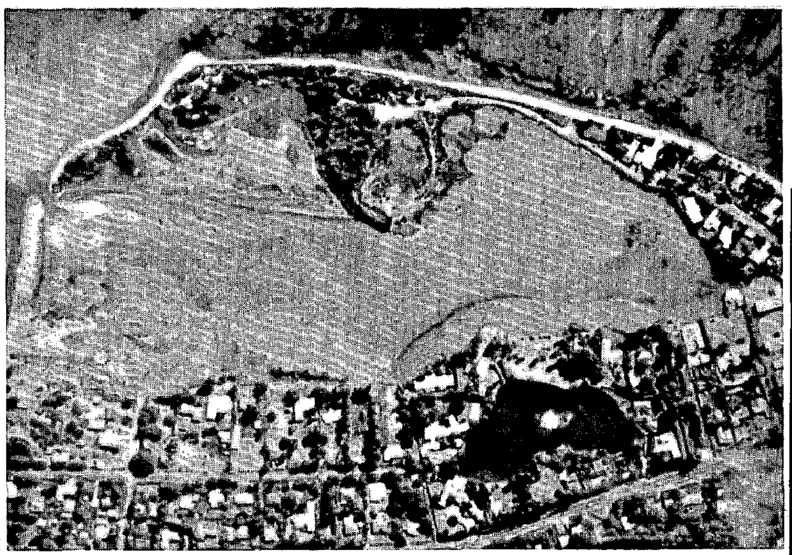
Photographs by Air Survey Hawaii: January 1971

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

1928



1975



1961

Plate 12. Paiko Peninsula. During the 1928 to 1961 interval, Paiko Peninsula grew over 900 feet to the east (left). Since 1961, the shape of the peninsula has been modified artificially.

Along the residential section of Paiko, the vegetation line grew seaward about 20 feet during the 1949 to 1975 period. Accretion predominated over the 26-year interval, although the vegetation line at transect 3 receded 12 feet between 1967 and 1971. This erosion is concurrent with the losses recorded at Sandy Beach Park and Hanauma Bay.

Niu Beach to Wailupe Peninsula

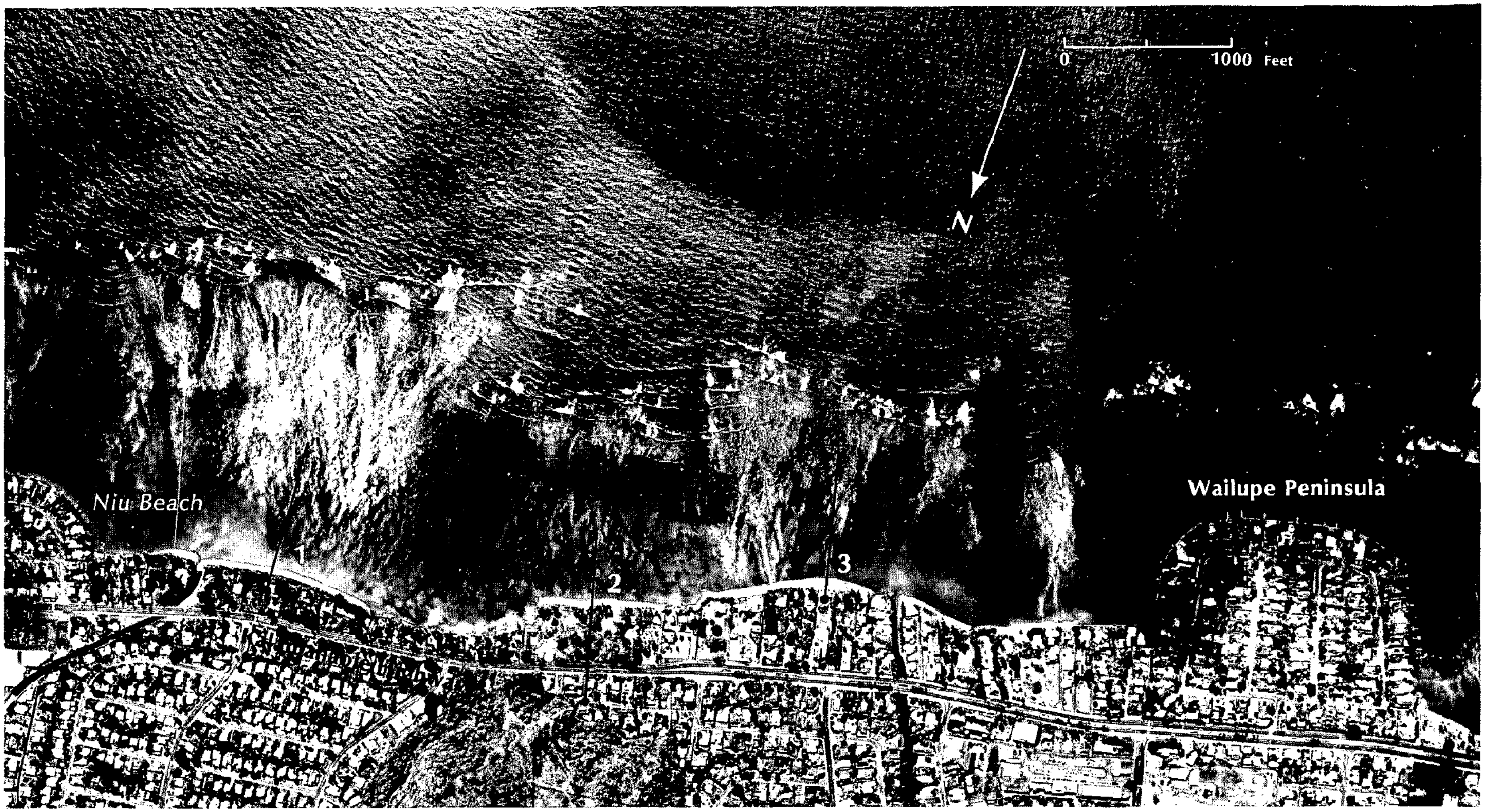
The shoreline between Niu Beach and Wailupe Peninsula underwent small changes during the 1949 to 1975 period. The net changes in the vegetation line indicate slight growth or stability for the beach section covered by transects 1 and 2 (Photomap 34). Transect 3 showed a tendency toward long-term accretion. Over a 26-year observation period the vegetation line grew seaward 23 feet (Table 34). The water line had a net change of +21 feet.

This stretch of shoreline has a shallow fringing reef between 1,000 and 1,800 feet offshore; the reef absorbs wave energy and supplies sand to the beach.

Table 34 - Niu Beach to Wailupe Peninsula. Changes in the Vegetation Line in Feet.

	Transect Number		
Observation Period	**1**	**2**	**3**
Oct 29, 1949 - Jan 20, 1961	+4	+11	+8
Jan 20, 1961 - Aug 29, 1967	+14	-3	+7
Aug 29, 1967 - Jan 04, 1971	-5	+2	+13
Jan 04, 1971 - Apr 13, 1975	-6	0	-5
Net Change - Vegetation Line	+7	+10	+23
Range - Vegetation Line	18	11	28
Net Change - Water Line	+10	+21	+21
Range - Water Line	23	30	37

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 34. Niu Beach to Wailupe Peninsula

Photographs by Air Survey Hawaii: January 1971

Wailupe Beach Park and Residential Area

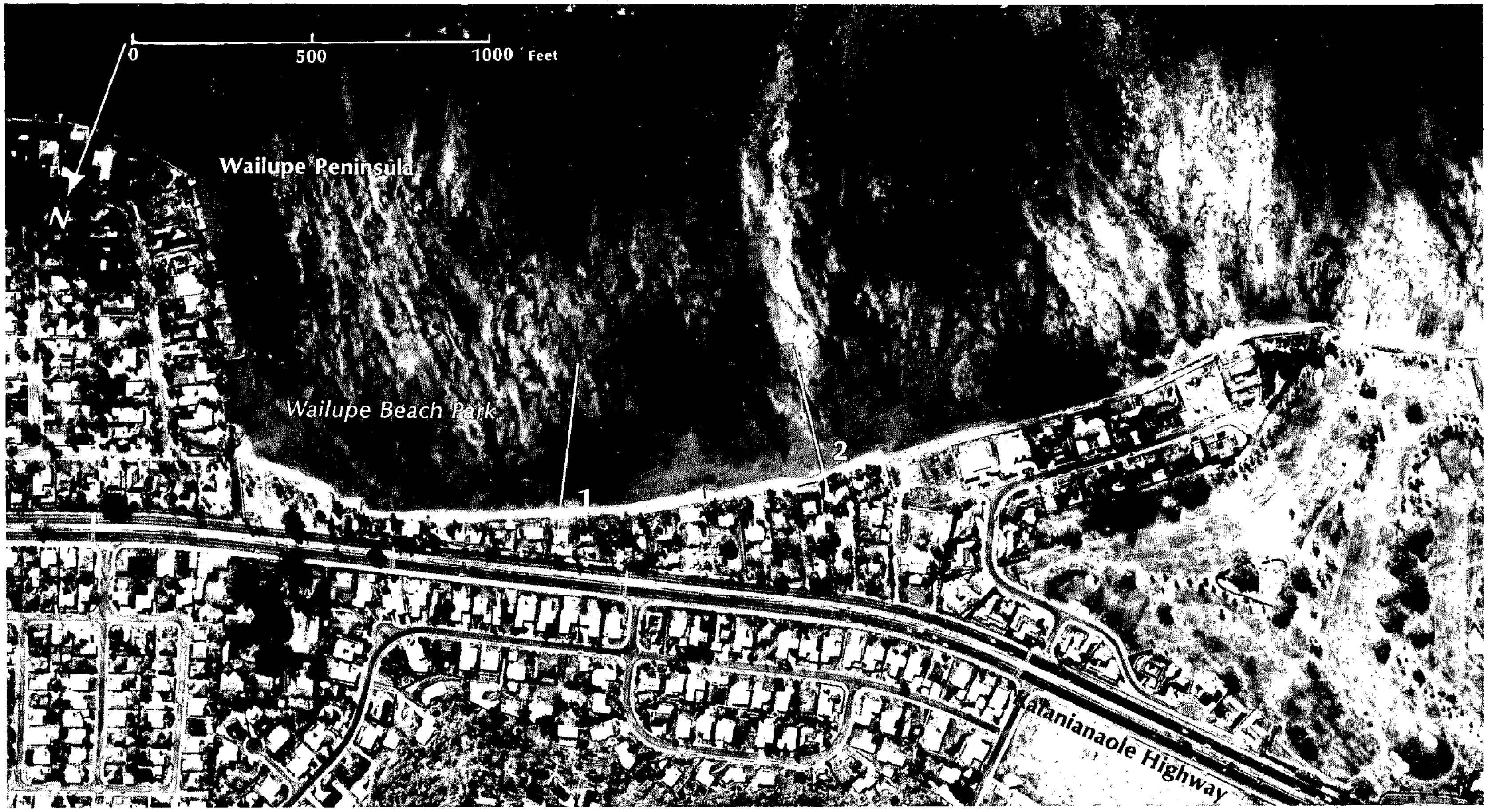
The 2,000-foot stretch of beach west of Wailupe Peninsula has grown or remained stable over a 26-year period. From 1949 to 1975, the net change in the position of the vegetation line at transects 1 and 2 were +14 feet and -1 feet, respectively (Photomap 35, Table 35).

The fringing reef along this beach is about 1,500 feet offshore. Numerous channels and sand plumes extend from the reef to the beach.

Table 35 - Wailupe Beach Park and Residential Area. Changes in the Vegetation Line in Feet.

	Transect Number	
Observation Period	**1**	**2**
Oct 29, 1949 - Jan 20, 1961	+2	+4
Jan 20, 1961 - Aug 29, 1967	+5	+3
Aug 29, 1967 - Jan 04, 1971	-2	-2
Jan 04, 1971 - Apr 13, 1975	+9	-6
Net Change - Vegetation Line	+14	-1
Range - Vegetation Line	14	8
Net Change - Water Line	+16	-8
Range - Water Line	30	11

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 35. Wailupe Beach Park and Residential Area

Photographs by Air Survey Hawaii: January 1971

Kahala Beach

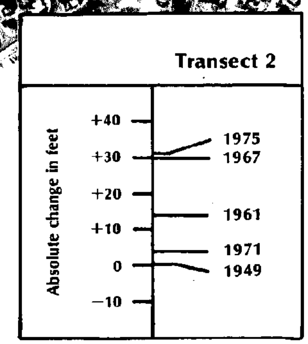
The net change in the vegetation line for the five transects established at Kahala Beach indicate beach stability or growth. During the 1967 to 1971 period, however, the vegetation line at transect 2 receded 26 feet (Photomap 36, Table 36). This loss is concurrent with other erosion events on the south shore. Despite the brief period of erosion, the vegetation line for this transect had a net change of +31 feet over a 26-year interval.

The net loss in the water line for all the transects is difficult to interpret because of problems with tidal fluctuations, seasonal changes, and light reflection on the aerial photograph. Field surveys conducted in 1962 and 1972 show an increase in the vegetation line and water line for Kahala (Campbell, 1972).

Table 36 - Kahala Beach. Changes in the Vegetation Line in Feet.

	Transect Number				
Observation Period	1	2	3	4	5
Feb 16, 1949 - Jan 20, 1961	+12	+14	0	*	*
Jan 20, 1961 - Aug 29, 1967	+3	+16	+2	0[1]	-2[1]
Aug 29, 1967 - Jan 04, 1971	-4	-26	0	+2	-3
Jan 04, 1971 - Apr 13, 1975	-11	+27	+9	+1	+1
Net Change - Vegetation Line	0	+31	+11	+3	-4
Range - Vegetation Line	15	31	11	3	5
Net Change - Water Line	-21	-5	-7	-19	-21
Range - Water Line	43	51	28	*	21

**No data*
[1] Change from 1949-1967
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 36. Kahala Beach

Photographs by Air Survey Hawaii: January 1971

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Kaalawai Beach and Kuilei Cliffs Beach Park

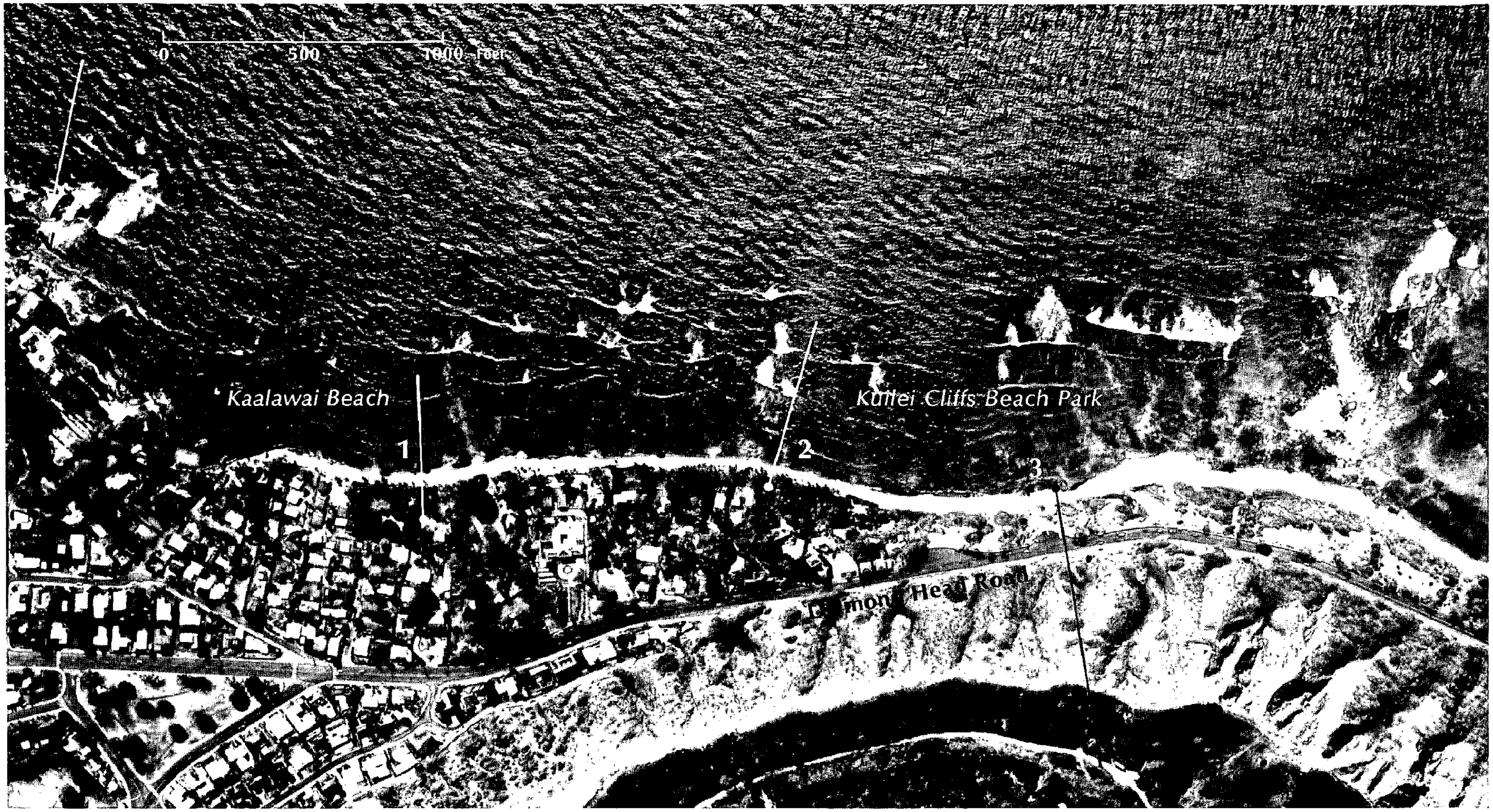
Measurements of the vegetation line over a 26-year period indicate that Kaalawai Beach is stable. Transects 1 and 2 record net changes of 0 and +3 feet, respectively (Photomap 37, Table 37). At transect 3, the vegetation line receded 7 feet over a 26-year period. Erosion of 15 feet during the 1949 to 1967 period may be an overestimate as the stable reference point used for the measurement was the inner edge of beachrock. This rock may have been covered by sand, altering the exact position of the supposedly stable point.

The interpretation for the change of the water line at transects 1 and 2 is complicated by seasonal changes, tidal fluctuations, and problems in locating the water line on the aerial photograph.

Table 37 - Kaalawai Beach and Kuilei Cliffs Beach Park. Changes in the Vegetation Line in Feet.

	Transect Number		
Observation Period	1	2	3
Feb 06, 1949 - Aug 29, 1967	-5	*	-15
Aug 29, 1967 - Jan 04, 1971	-3	+2[1]	+7
Jan 04, 1971 - Apr 13, 1975	+8	+1	+1
Net Change - Vegetation Line	0	+3	-7
Range - Vegetation Line	8	3	15
Net Change - Water Line	-27	-20	*
Range - Water Line	32	20	*

**No data*
[1] Change from 1949-1971
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 37. Kaalawai Beach and Kuilei Cliffs Beach Park

Photographs by Air Survey Hawaii: January 1971

Iroquois Point

Iroquois Point is located to the west of the Pearl Harbor entrance. Over a 48-year period, the shape of the point has changed significantly. Along the eastern sections of the beach, between transects 2 and 4, accretion has been the general trend. At Keahi Point, however, transects 5 and 6 record a history of severe erosion (Photomap 38).

Due to the development of the residential section in the 1950's, transect 6 had to be relocated to give a continuous record of the shoreline change. On the photographs preceding 1961, transect 6 is 40 feet to the west of its present position. Still, the combined changes for this transect are believed to give a reasonable estimate of the net loss at Keahi Point.

From 1928 to 1976, the vegetation line and water line receded about 180 feet (Table 38, Plate 13). The rates of erosion for the vegetation line were not constant but varied from 1.2 feet per year during the 1961 to 1967 period, to 4.7 feet per year between 1967 and 1976.

On the 1976 photograph for Keahi Point, several exposures of rock are found along the shore. This rock has not stabilized the beach. During a field check in September 1980, the algae-covered rock was under several feet of water. This suggests that the erosive trend, which dates back to at least 1928, is still in process.

One of the homes at Keahi Point is within 60 feet of the 1976 vegetation line. If the beach continues to recede, some type of remedial measure will be required if the property is to be saved.

It appears that sand is transported along the shore from Keahi Point to the eastern sections of Iroquois Point where accretion was experienced. Therefore, any erosion-control structures that may hoard sand updrift may cause erosion downcurrent on other portions of the beach.

Several of the homes at Keahi Point have sand bags and plastic barriers placed along the vegetation line. As the beach diminishes in size, these remedial measures will provide meager protection to the backshore area. According to one resident, 20 sand bags were washed away during the wave activity from May to June 1980.

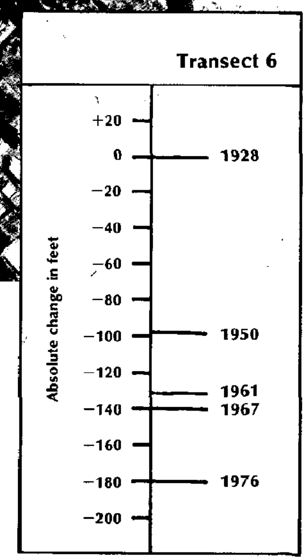
Table 38 - Iroquois Point. Changes in the Vegetation Line in Feet.

	Transect Number						
Observation Period	1	2	3	4	5	6	7
1928 - Sep 23, 1950	*	*	*	*	-86	-98	*
Sep 23, 1950 - Jan 20, 1961	*	*	*	*	*	-34	*
Jan 20, 1961 - Jun 20, 1967	+4	+21	-3	+76	*	-8	+11
Jun 20, 1967 - Feb 12, 1976	-4	+23	-6	+5	*	-41	-34
Net Change - Vegetation Line	0	+44	-9	+81	-86	-181	-23
Range - Vegetation Line	4	44	9	81	86	181	34
Net Change - Water Line	-10	+47	+32	+36	-48	-183	-14
Range - Water Line	*	54	32	65	48	183	13

**No Data*

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.

Range is the difference between the observed extremes in the position of a beach index line.

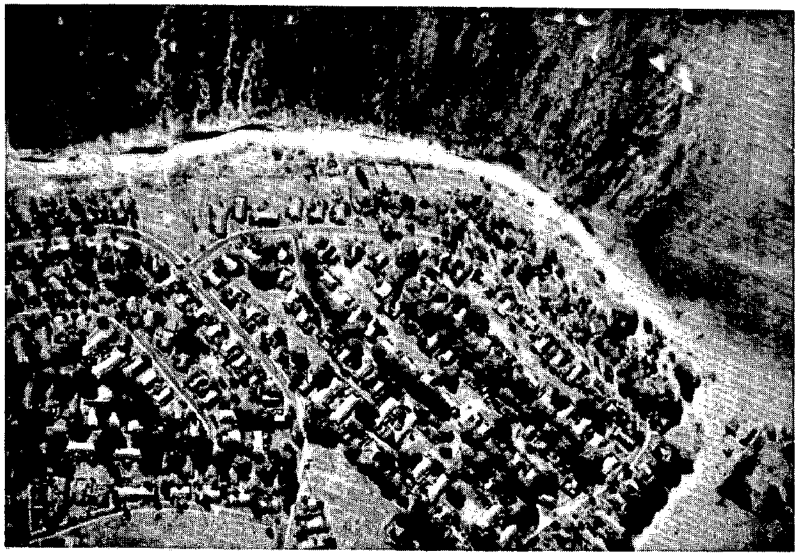


Photomap 38. Iroquois Point

Photographs by Air Survey Hawaii: February 1976

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

1928



1976

Plate 13. Iroquois Point. Over a 48-year period, erosion at west Iroquois Point (Keahi Point) has been over 180 feet. Compare the shape of the point on the 1928 and 1976 photographs.

Ewa Beach

Ewa Beach is two miles long and has an average width of about 50 feet (U.S. Army Engineers, 1971). Along this stretch are found the Puuloa Rifle Range, Ewa Beach Park and the Ewa residential area.

At east Ewa Beach, transects 1 to 3 were established near the rifle range (Photomap 39). Over a 26-year period, the vegetation line has been stable or has grown seaward. One exception is the erosion recorded at transect 1 during the 1958 to 1967 period (Table 39).

Transects 4 and 5 record the shoreline changes at Ewa Beach Park. Between 1958 and 1967, the vegetation fronting the park receded about 20 feet. This erosion threatened to undermine several coconut trees. From 1967 to 1979, the vegetation line had a net change of +5 to +22 feet.

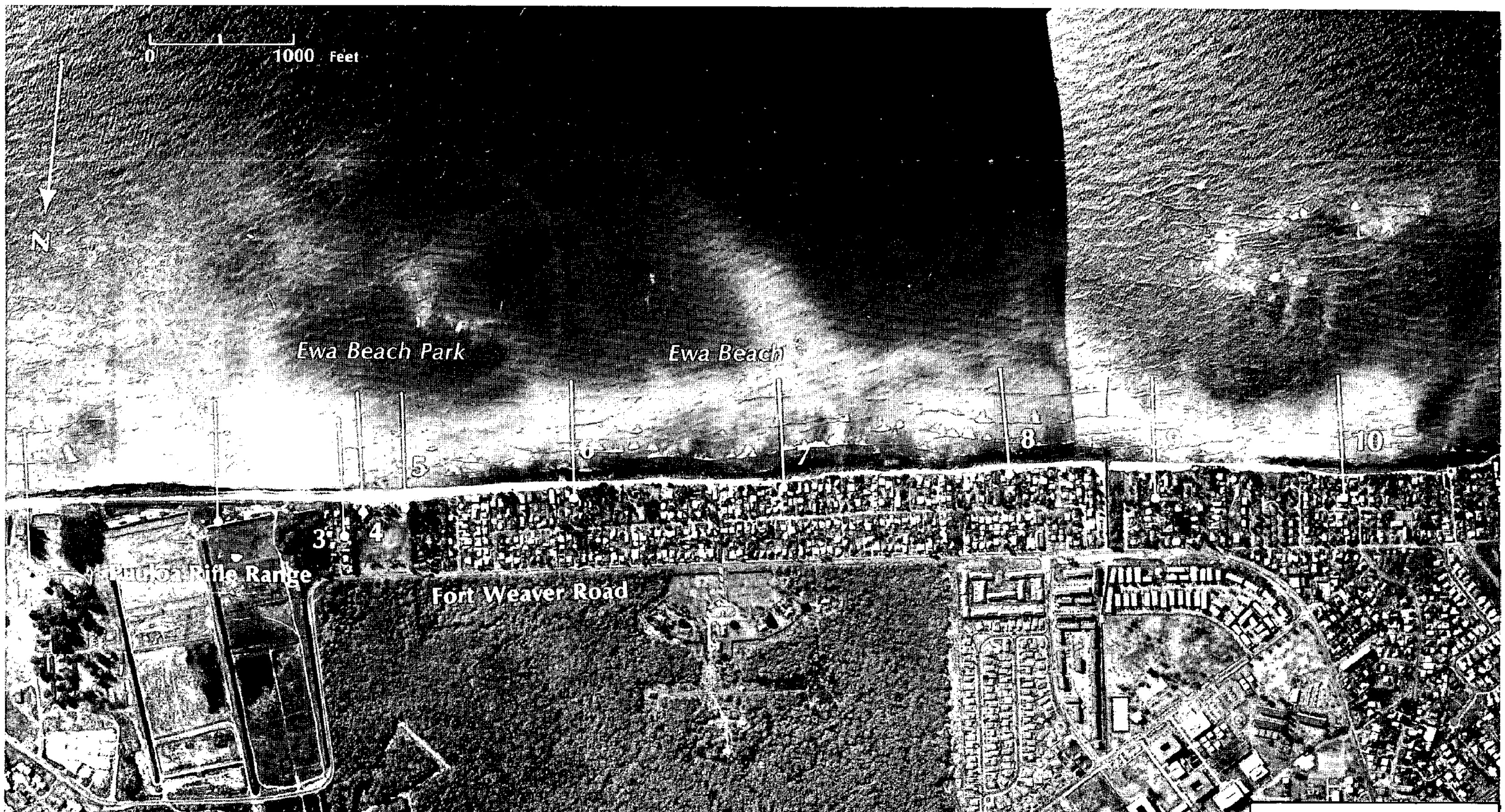
The beach along the residential section of Ewa is about 1.3 miles long. In 1950, there were few if any seawalls along this stretch. Between 1950 and 1958, the vegetation line was stable or grew seaward. At transect 9, however, erosion along a 400-foot-section was experienced.

Sometime during the 1958 to 1967 period, erosion along much of the beach occurred. The losses were especially noticeable along a 3,000-foot-stretch to the west of the beach park. Many of the seawalls at Ewa were installed during that time.

Table 39 - Ewa Beach. Changes in the Vegetation Line in Feet.

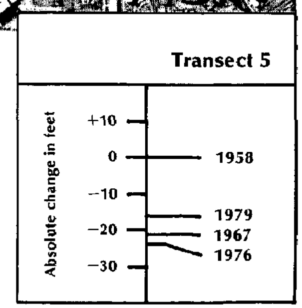
	Transect Number									
Observation Period	1	2	3	4	5	6	7	8	9	10
Sep 23, 1950 - Jun 19, 1958	+11	+15	+15	*	*	+8	+20	+2	-26	+1
Jun 19, 1958 - Jun 13, 1967	-12	0	+33	-19	-21	0[1]	0[1]	0	+12	-5
Jun 13, 1967 - Feb 12, 1976	-1	+16	-2	+5	-3	*	*	-8	+11	-3[1]
Feb 12, 1976 - Jul 19, 1979	*	*	-1	+17	+8	*	*	*	*	*
Net Change - Vegetation Line	-2	+31	+45	+3	-16	+8	+20	-6	-3	-7
Range - Vegetation Line	13	31	48	22	24	8	20	8	26	8
Net Change - Water Line	-21	+4	-18	+6	+2	+4[2]	-16[3]	-8	+5	-21
Range - Water Line	25	20	19	54	47	17[2]	16[3]	11	5	31

**No Data*
[1] Built Seawall
[2] From 1950-1979
[3] From 1950-1976
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 39. Ewa Beach

Photographs by Air Survey Hawaii: February 1976



Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Between 1967 and 1979, the vegetation line along much of Ewa Beach was stable or grew slightly. The historic data indicate that this may be the long-term trend. Over a 29-year observation period, accretion predominated for 20 of the years. Field surveys taken during 1962 and 1972 indicate accretion of both the water line and vegetation line (Campbell, 1972).

The brief period of erosion during the 1958 to 1967 interval resulted in the construction of many of the seawalls. If some allowance had been made for small fluctuations in the shoreline prior to beach development, such remedial measures should have been unnecessary.

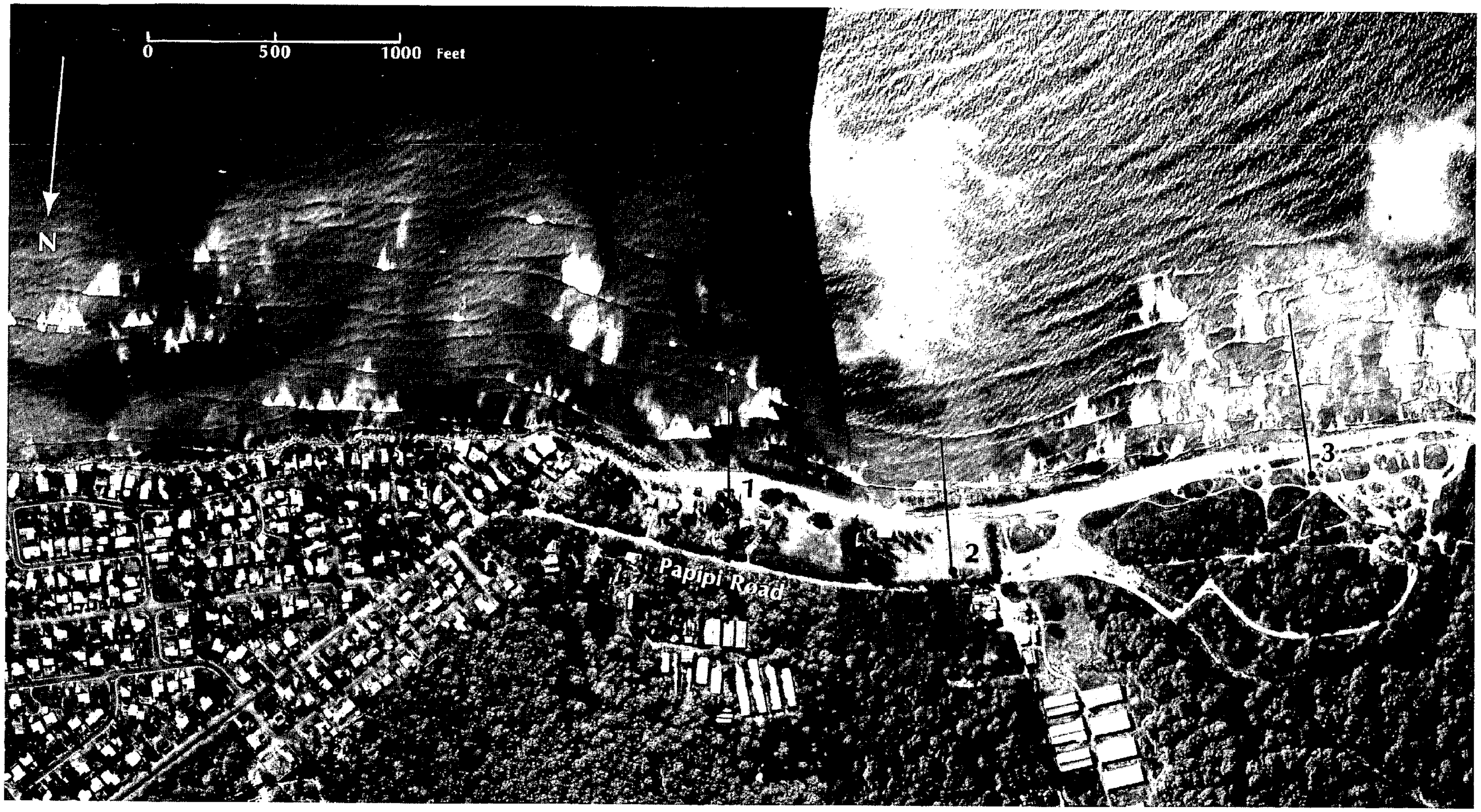
Oneula Beach

Oneula Beach has changed little over the 26 years covered by the aerial photographs; net changes for the vegetation line are under 10 feet for all three transects (Photomap 40, Table 40). Data for transect 3 exist for only an eight-year period.

Table 40 - Oneula Beach. Changes in the VegetationLine in Feet.

	Transect Number		
Observation Period	**1**	**2**	**3**
Sep 23, 1950 - Jun 19, 1958	+11	+5	-4
Jun 19, 1958 - Jun 13, 1967	+2	+4	*
Jun 13, 1967 - Feb 12, 1976	-5	-9	*
Net Change - Vegetation Line	+8	0	-4
Range - Vegetation Line	13	9	*
Net Change - Water Line	+24	-7	-23
Range - Water Line	24	7	*

**No data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 40. Oneula Beach

Photographs by Air Survey Hawaii: February 1976

Nimitz Officers Beach

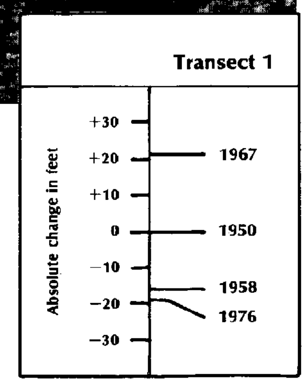
Nimitz Officers Beach has had large fluctuations in the position of the vegetation line. Between 1950 and 1958, the vegetation at the east end of the park was cut back 16 feet (Photomap 41, Table 41). During the 1958 to 1967 interval, sparse vegetation grew seaward. This accretion was lost during the next nine years when the vegetation line receded 40 feet. It is likely that the vegetation recedes when high waves inundate the backshore.

Over a 26-year period, the water line has had a net change of +60 feet. Although the water line data are complicated by numerous factors, accretion of the beach seems to be the long-term trend. Beach growth was recorded during all three of the observation intervals.

Table 41 - Nimitz Officers Beach. Changes in the Vegetation Line in Feet.

	Transect Number	
Observation Period	**1**	**2**
Sep 23, 1950 - Jun 19, 1958	-16	*
Jun 19, 1958 - Jun 13, 1967	+37	*
Jun 13, 1967 - Feb 12, 1976	-40	-9
Net Change - Vegetation Line	-19	-9
Range - Vegetation Line	40	9
Net Change - Water Line	+60	+9
Range - Water Line	60	9

** No data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 41. Nimitz Officers Beach

Photographs by Air Survey Hawaii: February 1976

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Nimitz Beach

The artificially constructed Nimitz Beach consists of alternating stretches of sand and rock. Over a 26-year period, this beach has had a history of accretion. The data from the vegetation line show a seaward growth of up to 27 feet. Over the same period, the water line grew seaward by as much as 57 feet. Accretion of the vegetation was concentrated during the 1950 to 1958 period whereas the water line grew seaward between 1967 and 1976.

Although accretion is the predominant trend, brief erosion events have occurred. During the 1967 to 1976 period, the vegetation line at transect 2 receded 17 feet (Photomap 42, Table 42). This loss may have been caused by high-wave runup onto the backshore.

Table 42 - Nimitz Beach. Changes in the Vegetation Line in Feet.

	Transect Number					
Observation Period	1	2	3	4	5	6
Sep 23, 1950 - Jun 19, 1958	+27	+32	+19	+19	*	+17
Jun 19, 1958 - Jun 13, 1967	-4	-7	+11	-7	-3	+12
Jun 13, 1967 - Feb 12, 1976	+4	-17	-7	+5	+7	-6
Net Change - Vegetation Line	+27	+8	+23	+17	+4	+23
Range - Vegetation Line	27	32	30	19	7	29
Net Change - Water Line	+9	+24	+28	+27	+1	+57
Range - Water Line	10	41	28	31	12	57

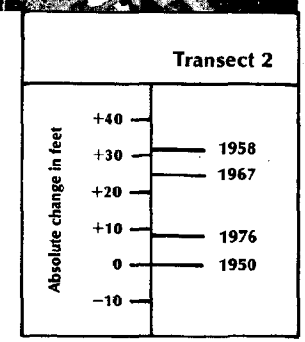
** No data*

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.

Range is the difference between the observed extremes in the position of a beach index line.

Photomap 42. Nimitz Beach

Photographs by Air Survey Hawaii: February 1976



Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Barbers Point

Although the aerial-photographic record for Barbers Point is scant, the measurements indicate that the beach is suprisingly stable. Over a period of observation between 8 and 18 years the net change in the position of the vegetation line at the point has been under 10 feet (Photomap 43, Table 43).

Barbers Point Beach consists of alternating stretches of sand and rock. The rock may prevent major shoreline changes by absorbing wave energy.

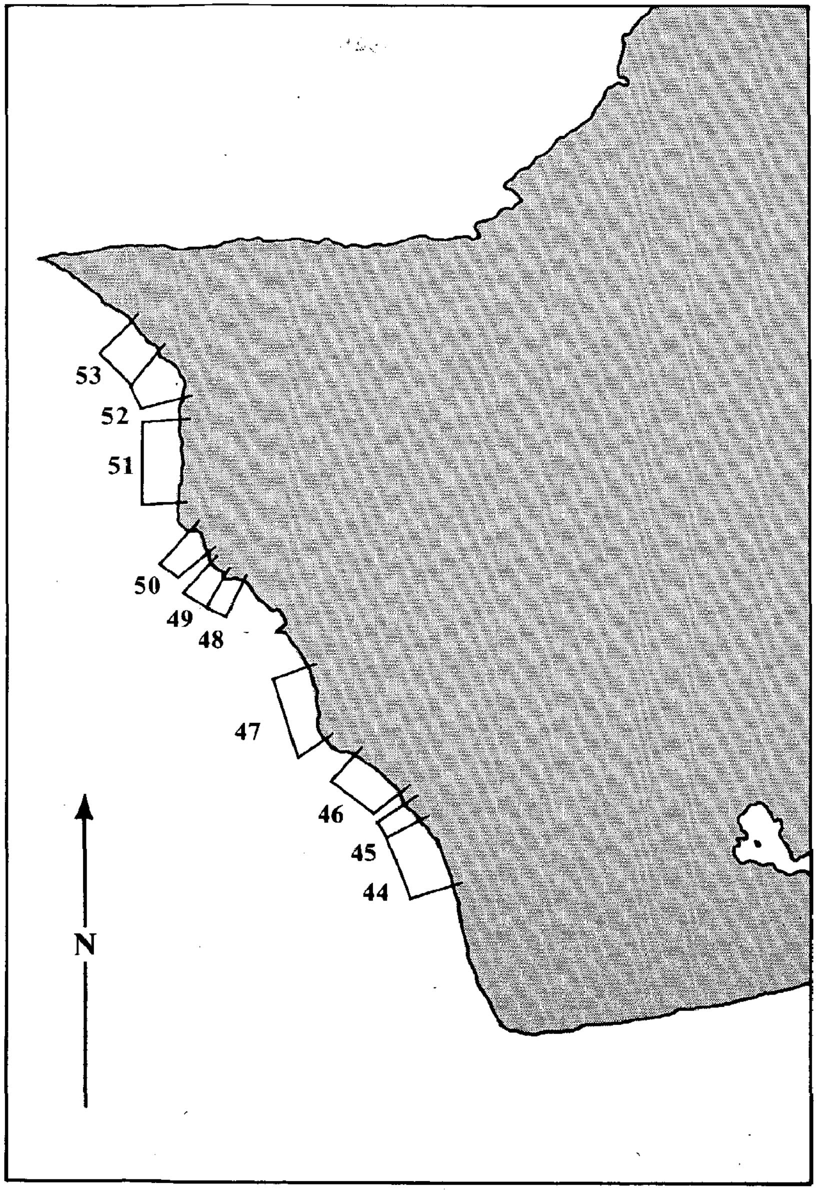
Table 43 - Barbers Point. Changes in the Vegetation Line in Feet.

	Transect Number		
Observation Period	1	2	3
Sep 23, 1950 - Jun 19, 1958	+6	+4	*
Jun 19, 1958 - Feb 12, 1976	*	*	0
Net Change - Vegetation Line	+6	+4	0
Net Change - Water Line	-18	-12	+12

** No data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

Photomap 43. Barbers Point

Photographs by Air Survey Hawaii: February 1976



SECTION IV - LEEWARD COAST

On the leeward coast (Figure 7), the south end of Kahe Beach and the two ends of Maili Beach experienced chronic erosion between 1949 and 1979. Most other beaches showed no obvious long-term change when data were averaged over a multi-yearly period. Nevertheless, winter surf inundation from large Kona Storm waves or refracted North Pacific swell may cause periodic damage to the backshore area. Beaches that appeared susceptible to inundation between 1949 and 1975 include mid-Pokai Bay, Papaoneone Beach (Turtle Beach), Makaha Beach and Keaau Beach.

Figure 7. Photomap Arrangements - Leeward Coast.

Lanikuhonua Beach

The pocket beach at north Lanikuhonua is about 100 feet long. Between 1949 and 1971, the vegetation line for the beach had a net loss of 42 feet. Over the same period, there was no significant change in the water line.

On the 1971 photograph, several trees are located seaward of the line of scrub vegetation. This suggests that the lower vegetation was covered by thin sand or temporarily killed by high-wave inundation. There appears to be no long-term erosion.

During the 1971 to 1975 period, the vegetation line advanced seaward 16 feet. Over a 26-year period, the net change in the position of the vegetation line was -26 feet.

Kahe Beach

Kahe Beach is located to the west of the Hawaiian Electric power plant. The south end of this beach has a 30-year history of chronic erosion. Between 1949 and 1979, the vegetation line and water line for transect 2 receded 40 and 42 feet (Photomap 44, Table 44). Erosion of the vegetation line was recorded during all five observation intervals.

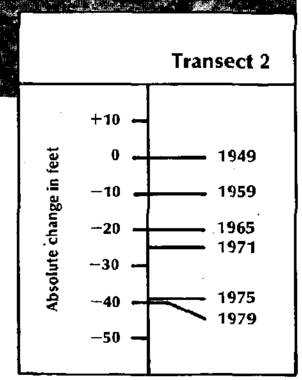
Although it does not show in the data, the north section of Kahe Beach has receded also. An examination of the 1949 and 1979 aerial photographs reveal that exposed rock and basalt cobbles have replaced a former sandy shoreline. Much of this change occurred prior to 1971. The data from the water line and vegetation line indicate that the north end (Manners Beach) has been stable since 1971.

The sand at Kahe Beach is lost offshore. It appears that no sand is lost to adjacent coastal sections, for Kahe Beach is bounded by a jetty to the south and several rock points to the north. Some beach sand is sucked into the intake basin of the Hawaiian Electric Company where it is deposited offshore. Occasionally, HECO removes sand from the intake basin and deposits it at the north end (U.S. Army Engineer District, 1980). This may account for the stability at the north end of the beach within recent years.

Table 44 - Kahe Beach. Changes in the Vegetation Line in Feet.

	Transect Number			
Observation Period	**1**	**2**	**3**	**4**
May 08, 1949 - May 19, 1959	+16	-10	*	*
May 19, 1959 - Dec 22, 1965	*	-10	*	*
Dec 22, 1965 - Feb 06, 1971	-1[1]	-5	*	*
Feb 06, 1971 - Mar 30, 1975	-4	-14	-4	+94[2]
Mar 30, 1975 - Mar 13, 1979	-4	-1	+8	0
Net Change - Vegetation Line	+7	-40	+4	*
Range - Vegetation Line	16	40	8	*
Net Change - Water Line	-28	-42	+16	+25
Range - Water Line	43	73	18	32

** No data*
1 Change from 1959-1971
2 Artificial change - vegetation stripped by man
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 44. Kahe Beach

Photographs by Air Survey Hawaii: March 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

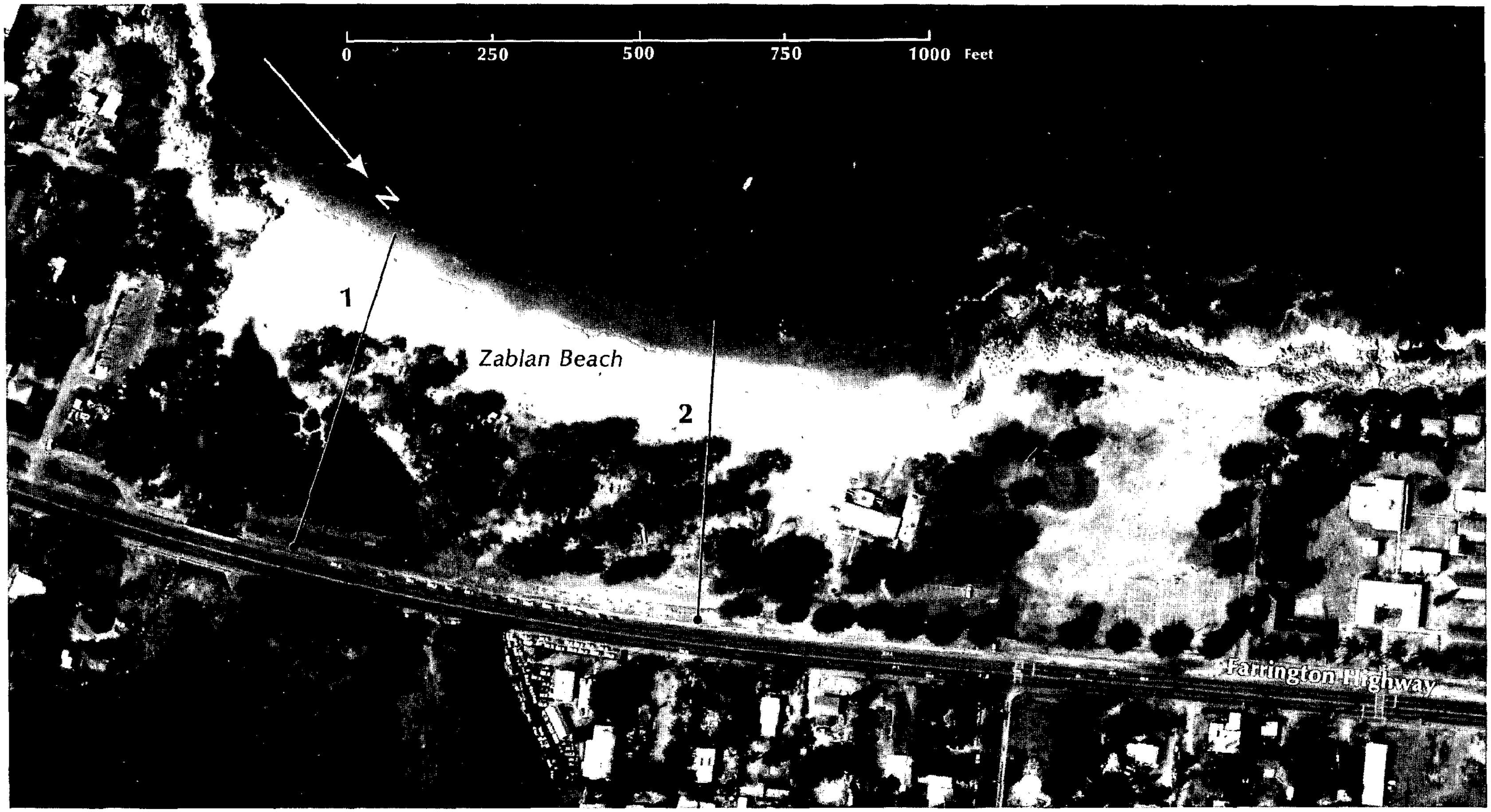
Nanakuli Beach Park

The 1,300-foot-long pocket beach at south Nanakuli appears to have a 26-year history of accretion. Data on the vegetation line for transect 2 show a seaward growth of up to 37 feet (Photomap 45, Table 45). From the small changes in the water line, no conclusions can be drawn.

Table 45 - Nanakuli Beach Park. Changes in the Vegetation Line in Feet.

	Transect Number	
Observation Period	1	2
May 08, 1949 - May 19, 1959	+27	+16
May 19, 1959 - Dec 22, 1965	+3	+9
Dec 22, 1965 - Mar 30, 1975	+3	+12
Net Change - Vegetation Line	+33	+37
Range - Vegetation Line	33	37
Net Change - Water Line	+14	-5
Range - Water Line	37	41

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 45. Nanakuli Beach Park

Photographs by Air Survey Hawaii: March 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Ulehawa Beach Park

Over a 30-year period, the 1.5-mile-long beach at Nanakuli has been stable. Between 1949 and 1979, the net change in the position of the vegetation line at four of the five transects was under 3 feet. The vegetation line at transect 3, however, advanced seaward 55 feet during the 1959 to 1975 period (Photomap 46, Table 46). This accretion was localized.

Uelehawa Beach has alternating stretches of sand and beachrock; this rock may serve to stabilize the beach.

Photomap 46. Ulehawa Beach Park

Photographs by Air Survey Hawaii: March 1975

Table 46 - Ulehawa Beach Park. Changes in the Vegetation Line in Feet.

Observation Period	Transect Number 1	2	3	4	5
May 08, 1949 - May 19, 1959	-7	-6	*	+8	-5
May 19, 1959 - Mar 30, 1975	+3	+5	+55	-6	-1
Mar 30, 1975 - Mar 13, 1979	+5	+3	-4	0	+5
Net Change - Vegetation Line	+1	+2	+51	+2	-1
Range - Vegetation Line	8	8	55	8	6
Net Change - Water Line	+19[1]	+31	-10	-1	+13
Range - Water Line	61[1]	51	29	68	73

**No data*

[1] Change from 1959-1979

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.

Range is the difference between the observed extremes in the position of a beach index line.

Maili Beach

Offshore of Maili Beach is a dead reef flat that is sufficiently deep to allow high waves to break on the shore. As a result, sand on the beach is constantly shifting over the seasons and years in response to the changing wave regime.

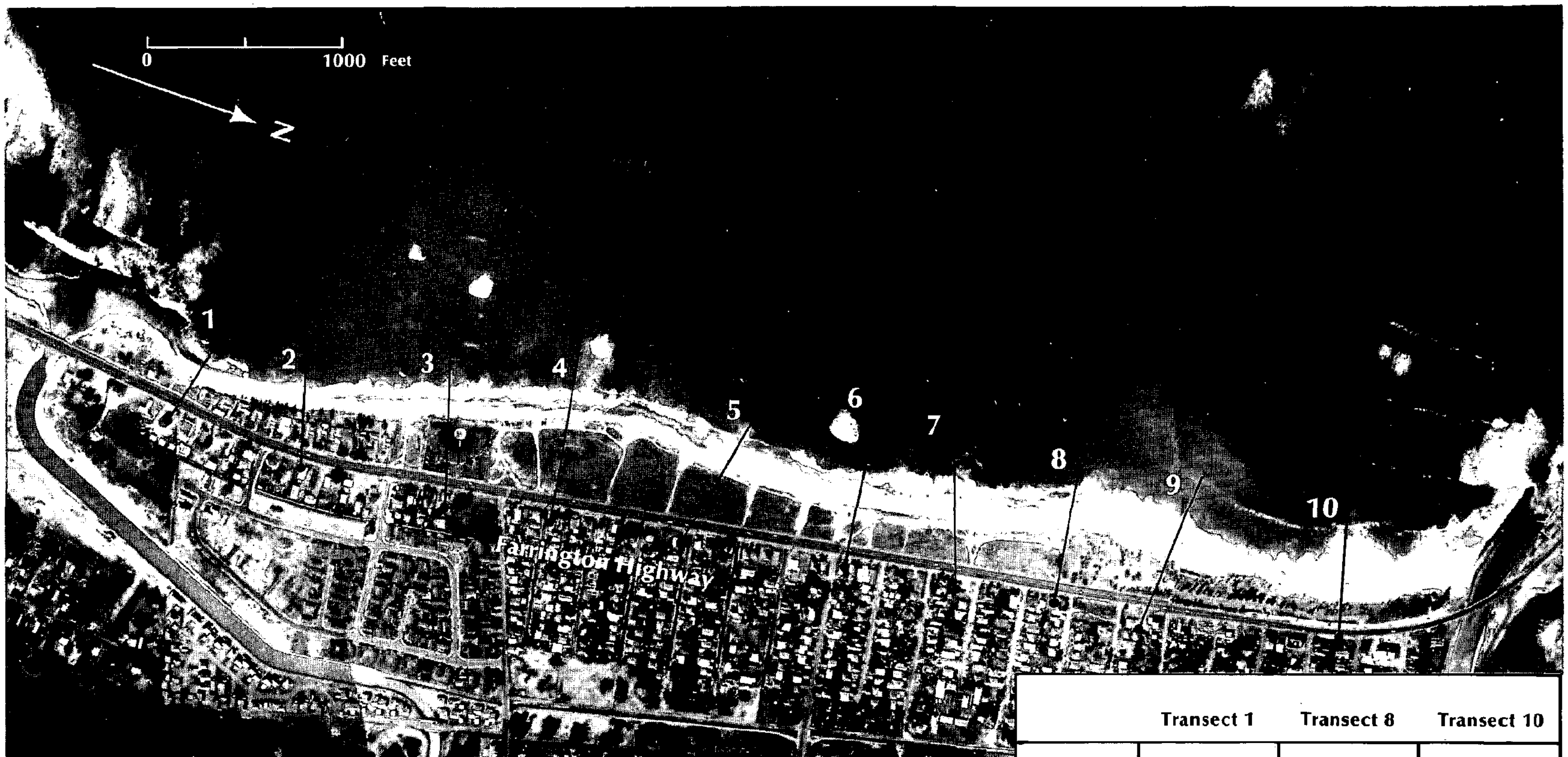
Field surveys taken between 1962 and 1963 indicate that north Maili Beach has a seasonal variation of about 75 feet. During the winter, the foreshore slope is fairly steep, whereas in the summer it is flat (Moberly and Chamberlan, 1964). These seasonal changes indicate an onshore-offshore sand exchange between the beach and the nearshore area.

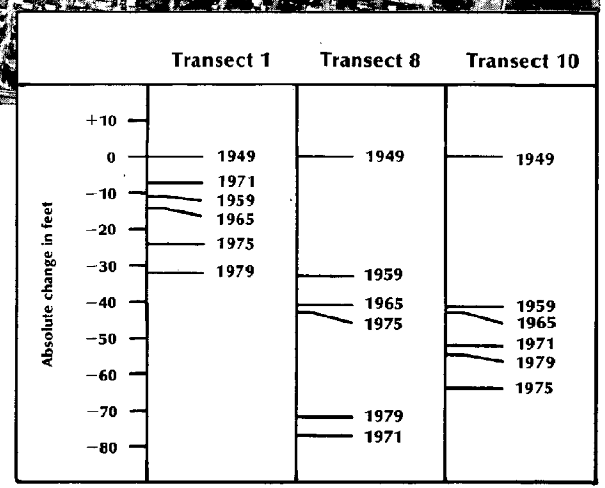
Over a long-term period, the middle section of Maili has grown while the two ends have experienced chronic erosion. At north Maili Beach erosion along a 2,500 stretch appears continuous. During the 1949 to 1979 interval the vegetation line at transect 8 receded by as much as 72 feet (Photomap 47, Table 47). The major erosion was concentrated during the 1949 to 1959, 1965 to 1971 and 1975 to 1979 intervals. The retreat during the 1965 to 1971 period was partly caused by the winter waves of 1968 and 1969. During this time, erosion undermined a shower facility and threatened the park comfort station (U.S. Army Engineers, 1971). The erosion during 1975 to 1979 may have been caused in part by the Kona Storm of January 1979.

A continuation of the erosion trend at North Maili would undermine more coconut trees and jeopardize the park bathhouse. The data from the vegetation line suggest that this is likely. It is always possible that the sand mining operation at Maili caused a delayed retreat in the vegetation line. Unfortunately, it is not possible to determine the full impact of the mining operation on the beach because of the large seasonal changes.

At south Maili Beach, the vegetation line receded 32 feet over a 30-year period. The erosion at transect 1 was recorded during four of the five observation intervals. This indicates that shoreline retreat for that beach section predominates through time. In the future the residential areas at south Maili may become susceptible to winter wave inundation.

At transect 2, the vegetation line has had a small net change in its position but a range of about 20 feet. This beach section has an alternating history of erosion and accretion.





Photomap 47. Maili Beach

Photographs by Air Survey Hawaii: March 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Table 47 - Maili Beach. Changes in the Vegetation Line in Feet.

Observation Period	Transect Number 1	2	3	4	5	6	7	8	9	10
May 08, 1949 - May 19, 1959	-11	*	+14	*	-11	+17	-13	-33	-25	-42
May 19, 1959 - Dec 22, 1965	-3	-11	+3	+37	+19	+18	+9	-8	-6	-1
Dec 22, 1965 - Feb 06, 1971	+7	0	+41	+16	+44	+67	-35	-36	-1	-9
Feb 06, 1971 - Mar 30, 1975	-17	-6	+27	+16	+9	+1	+2	+34	-20	-12
Mar 30, 1975 - Mar 31, 1979	-8	+20	-10	-19	-4	-4	*	-29	-5	+9
Net Change - Vegetation Line	-32	+3	+75	+50	+57	+99	-37	-72	-57	-55
Range - Vegetation Line	32	20	85	69	72	103	39	77	57	64
Net Change - Water Line	-1	-15	+12	-52	+25	+150	+52	-61	-100	-39
Range - Water Line	33	37	49	65	57	150	53	81	138	98

** No Data*

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.

Range is the difference between the observed extremes in the position of a beach index line.

Over a period of up to 30 years, the section of Maili covered by transects 3 to 6 experienced accretion. Between 1949 and 1979, the vegetation line for the middle of the beach grew seaward by as much as 99 feet. The sand for this stretch is possibly delivered from the eroding ends.

From an inspection of the incoming wave orientations on the aerial photographs, it appears that two currents may be set up. At the north end, refracted North Pacific swell would induce a southerly littoral drift. Near the south end of Maili, waves refract around an offshore shoal and strike the beach at an opposite angle. Although the described wave directions are seen on only a few of the photographs, they may explain the pattern of long-term changes shown in the data. More studies are required to test this hypothesis.

Pokai Bay

Several artificial structures are found along Pokai Bay. A breakwater and launching ramp to the south, a retaining wall in the center, and stone jetties in the middle and north have modified the natural processes of this beach system. Because of the retaining wall along much of the beach, a photographic analysis of the vegetation line was conducted only for the south end of the bay.

Data from 1965 to 1977 show the vegetation line near the beach park advanced seaward 58 feet. This is to be expected as the south end of Pokai Beach has been accreting ever since the breakwater was constructed in the 1950's. Before this structure was built, the north end of Pokai Beach was much wider than the south end.

Studies on the present configuration of Pokai Bay indicate accretion in the south, erosion along the center section where the retaining wall has been undermined and stability in the north (U.S. Army Engineers, 1971). Occasionally, sand from the accreting southern section has been transferred to the center. The artificial transfer of sand complicates interpretation of the water line data. From a qualitative analysis of the aerial photographs between 1965 and 1977, it appears that north Pokai Beach has been stable while the center section has varied in width.

As the beach at mid-Pokai Bay is narrow, large waves can easily run up the foreshore and break against the retaining wall. Therefore, more problems with deterioration of this structure may occur.

Mauna Lahilahi Beach Park

Data from the vegetation line for Mauna Lahilahi Beach Park indicate beach stability or accretion over a 28-year period. Between 1949 and 1977, the vegetation line for transect 1 grew seaward 22 feet (Photomap 48, Table 48).

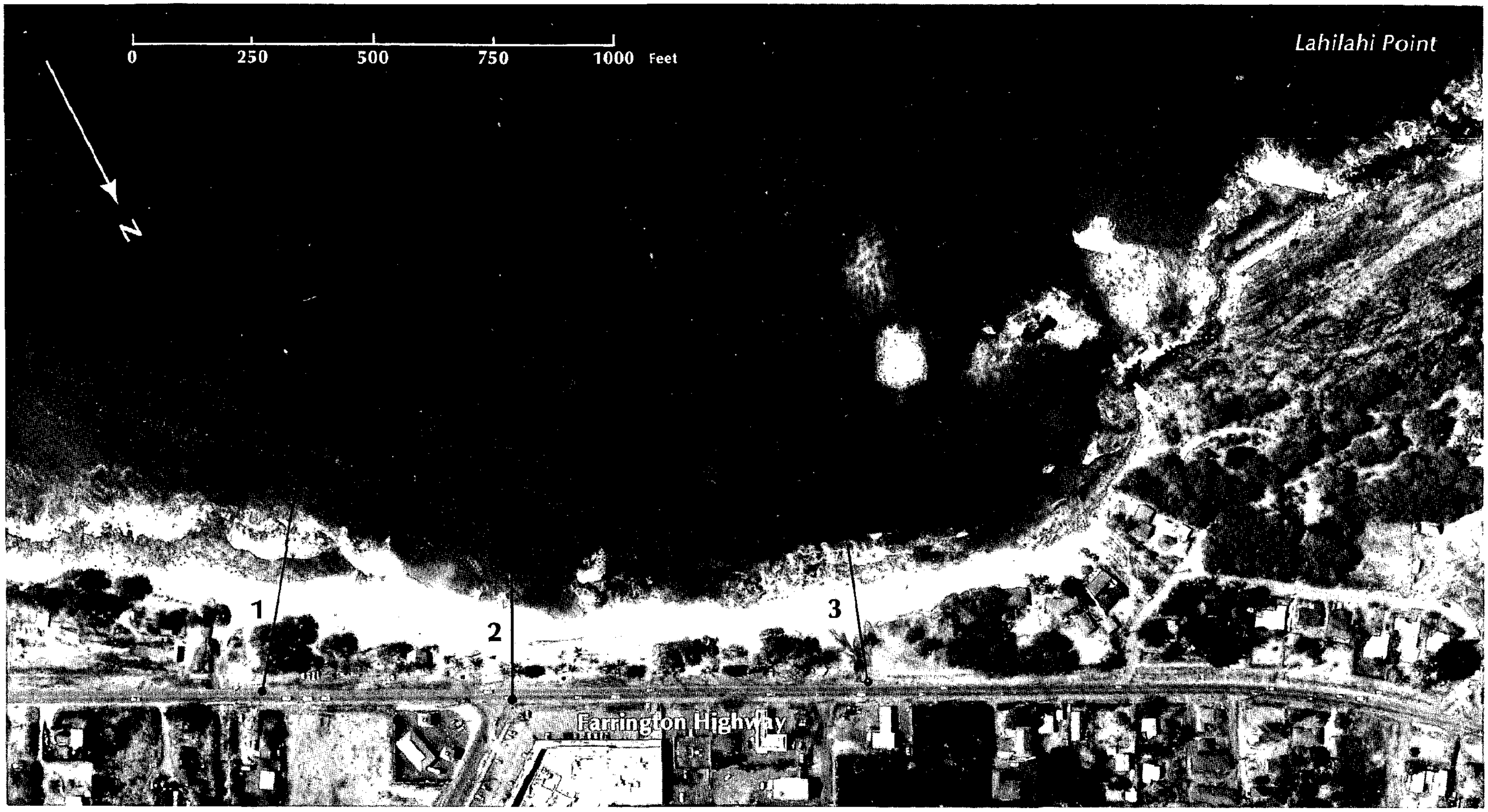
It is unusual that the changes in the vegetation line and water line show opposite trends. Over the study period the water line receded by as much as 63 feet. This loss, which was concentrated during the 1949 to 1959 period, has exposed rock at the ends of the beach. It is not known how much of this change is seasonal. In addition, wave runup and light reflection complicate the measurements of the water line.

Although the vegetation line has grown seaward over a long-term period, the narrow beach and steep offshore bottom may make the park property susceptible to erosion by high waves. Fortunately, Lahilahi Point may block some of the wave energy refracting from the north.

Table 48 - Mauna Lahilahi Beach Park. Changes in the Vegetation Line in Feet.

	Transect Number		
Observation Period	1	2	3
Nov 22, 1949 - May 19, 1959	+5	-3	-2
May 19, 1959 - Dec 22, 1965	-13	+2	+3
Dec 22, 1965 - Feb 06, 1971	+13	+5	+4
Feb 06, 1971 - Mar 30, 1975	+11	0	+5
Mar 30, 1975 - Dec 20, 1977	+6	0	+1
Net Change - Vegetation Line	+22	+4	+11
Range - Vegetation Line	30	7	13
Net Change - Water Line	-1	-63	-46
Range - Water Line	19	63	50

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 48. Mauna Lahilahi Beach Park

Photographs by Air Survey Hawaii: March 1975

Papaoneone Beach (Turtle Beach)

Papaoneone Beach is a closed littoral cell bounded on the south by Lahilahi Point and on the north by exposed rock (Photomap 49). The offshore reef is not sufficiently shallow to absorb much of the incoming wave energy. As a result, this beach may receive high winter surf that could form strong rip currents and beach cusps.

Between 1949 and 1977, the vegetation line for the south and north ends of the beach grew seaward (Table 49). Over the same period the water line had a small net change in its position but a large range. This indicates that the major changes at Papaoneone Beach are seasonal.

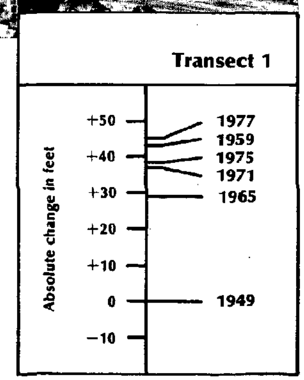
Limited data were obtained for the center of the beach where two tall buildings are located. These structures obscure the position of the vegetation line on the aerial photographs. Before these structures were built, the vegetation line at mid-beach receded 20 feet during the 1949 to 1959 period. Meanwhile the water line had a small change. This sugests that Papaoneone Beach may be stable over a long-term period but may erode temporarily during a large winter storm.

As the buildings at Papaoneone Beach are located close to the shoreline, the potential exists that high winter waves may run up onto the beach and inundate the lower patios.

Table 49 - Papaoneone Beach (Turtle Beach). Changes in the Vegetation Line in Feet.

	Transect Number		
Observation Period	1	2	3
Nov 22, 1949 - May 19, 1959	+43	-20	+21
May 19, 1959 - Dec 22, 1965	-14	*	+11
Dec 22, 1965 - Feb 06, 1971	+8	*	-3
Feb 06, 1971 - Mar 30, 1975	+1	*	-9
Mar 30, 1975 - Dec 20, 1977	+7	*	+3
Net Change - Vegetation Line	+45	-20	+23
Range - Vegetation Line	45	*	32
Net Change - Water Line	+4	-7	+21
Range - Water Line	80	*	75

**No Data*
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 49. Papaoneone Beach (Turtle Beach)

Photographs by Air Survey Hawaii: March 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Makaha Beach

During the 30-year period from 1949 to 1979, the vegetation line at the south section of Makaha Beach grew seaward. Nevertheless, erosion was recorded for transects 1 and 2 during the 1975 to 1979 time interval. This change can be attributed in part to the Kona Storm of January 1979.

The north section of Makaha Beach Park (the bathhouse to transect 3) may be retreating slowly. On the 1949 photograph, an old railroad track running parallel to the Farrington Highway is seaward of the vegetation line. Between 1949 and 1979 the vegetation line at transect 3 receded 22 feet (Photomap 50, Table 50).

The bathhouse at Makaha Beach Park was damaged by high winter surf in the early 1960's and late 1970's. Apparently no allowance was made for the large seasonal changes on the beach. During the June 1962 to January 1963 period, Makaha Beach varied in width by 145 feet. These variations are believed to be caused by North Pacific swell refracted around the island (Moberly and Chamberlain, 1964).

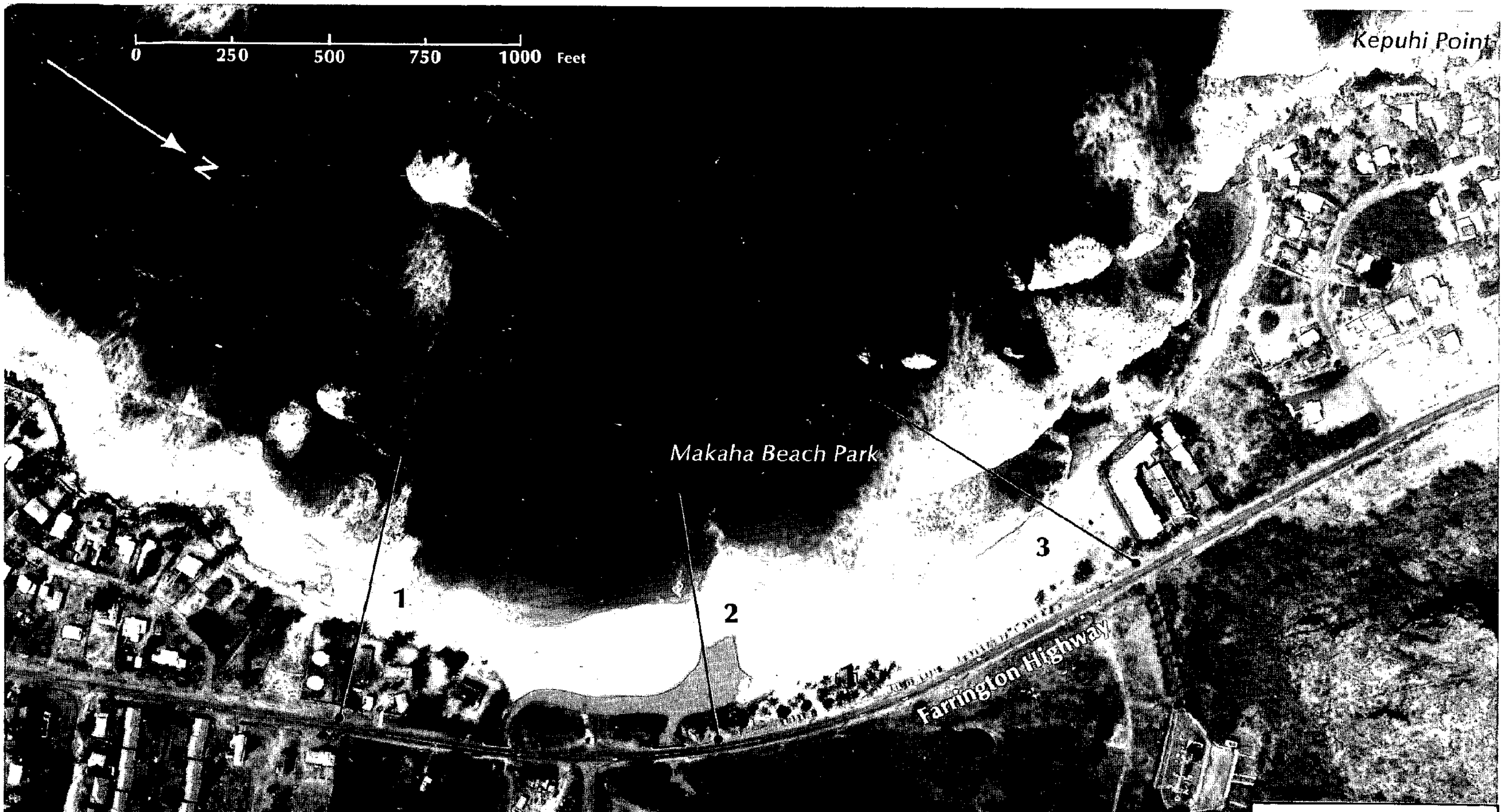
Although the bathhouse at Makaha was under repair during September 1980, it is still in the same location and therefore subject to the same forces that damaged it previously.

Table 50 - Makaha Beach. Changes in the Vegetation Line in Feet.

Observation Period	Transect Number 1	2	3
Nov 22, 1949 - May 19, 1959	+24	+10	-20
May 19, 1959 - Dec 22, 1965	0	+18	+16
Dec 22, 1965 - Feb 06, 1971	+9	+1	-5
Feb 06, 1971 - Mar 30, 1975	+12	+5	+1
Mar 30, 1975 - Mar 13, 1979	-13	-9	-14
Net Change - Vegetation Line	+32	+25	-22
Range - Vegetation Line	45	34	22
Net Change - Water Line	-1	+10	+5
Range - Water Line	63	32	46

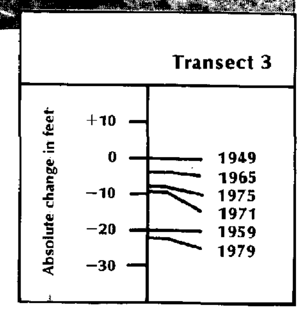
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.

Range is the difference between the observed extremes in the position of a beach index line.



Photomap 50. Makaha Beach

Photographs by Air Survey Hawaii: March 1975



Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Keaau Beach

The vegetation line at Keaau Beach has had a history of alternating erosion and accretion. No clear pattern is seen from the changes.

Most likely there is a tendency for the vegetation to grow seaward. Occasionally, the vegetation is cut back when high winter surf runs up onto the beach. The degree of erosion may vary from place to place depending on incoming wave parameters, the location of reefs or exposed beachrock and the offshore bathymetry.

The major erosion at Keaau Beach occurred during the 1965 to 1971 period. This loss was probably caused by North Pacific swell which was refracted around the island. In particular, the large waves during the winter of 1968 to 1969 and December 1969 may have been an important factor.

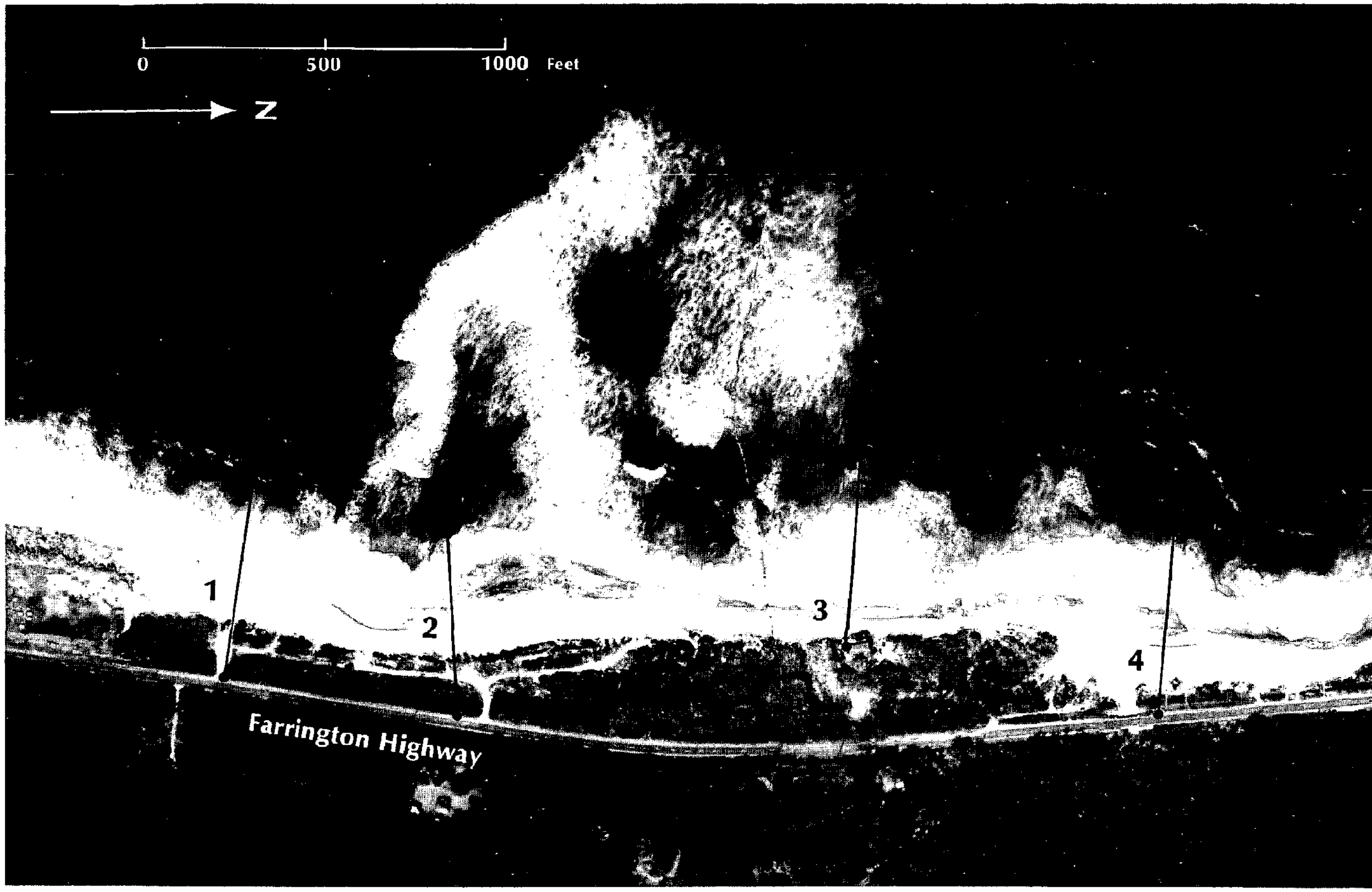
Transect 2 marks an especially unstable portion of the beach (Photomap 51). The large changes are partly due to the growth of sparse vegetation that is occasionally cut back by high surf inundation. It appears that this beach section may experience greater than average winter wave runup.

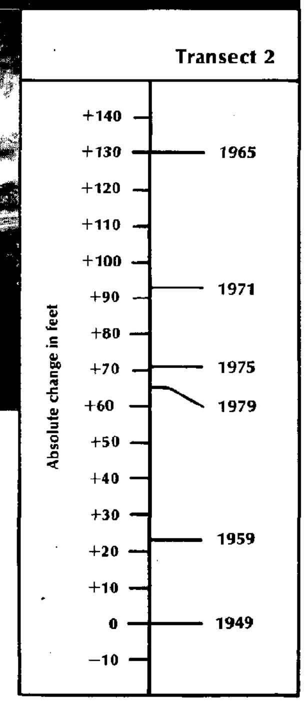
The data from the water line at Keaau Beach show a net loss of 34 to 51 feet over a 30-year period (Table 51). Much of this change may be seasonal.

Table 51 - Keaau Beach. Changes in the Vegetation Line in Feet.

	Transect Number			
Observation Period	**1**	**2**	**3**	**4**
Nov 22, 1949 - May 19, 1959	+3	+23	-9	+14
May 19, 1959 - Dec 22, 1965	-8	+107	-7	-8
Dec 22, 1965 - Feb 06, 1971	-10	-37	0	-26
Feb 06, 1971 - Mar 30, 1975	-2	-22	-2	-16
Mar 30, 1975 - Mar 13, 1979	+11	-6	+8	+11
Net Change - Vegetation Line	-6	+65	-10	-25
Range - Vegetation Line	20	130	18	50
Net Change - Water Line	-40	-41	-34	-51
Range - Water Line	77	67	74	57

Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.





Photomap 51. Keaau Beach

Photographs by Air Survey Hawaii: March 1975

Absolute change is the change in the position of the vegetation line compared to the earliest or base year.

Makua Beach

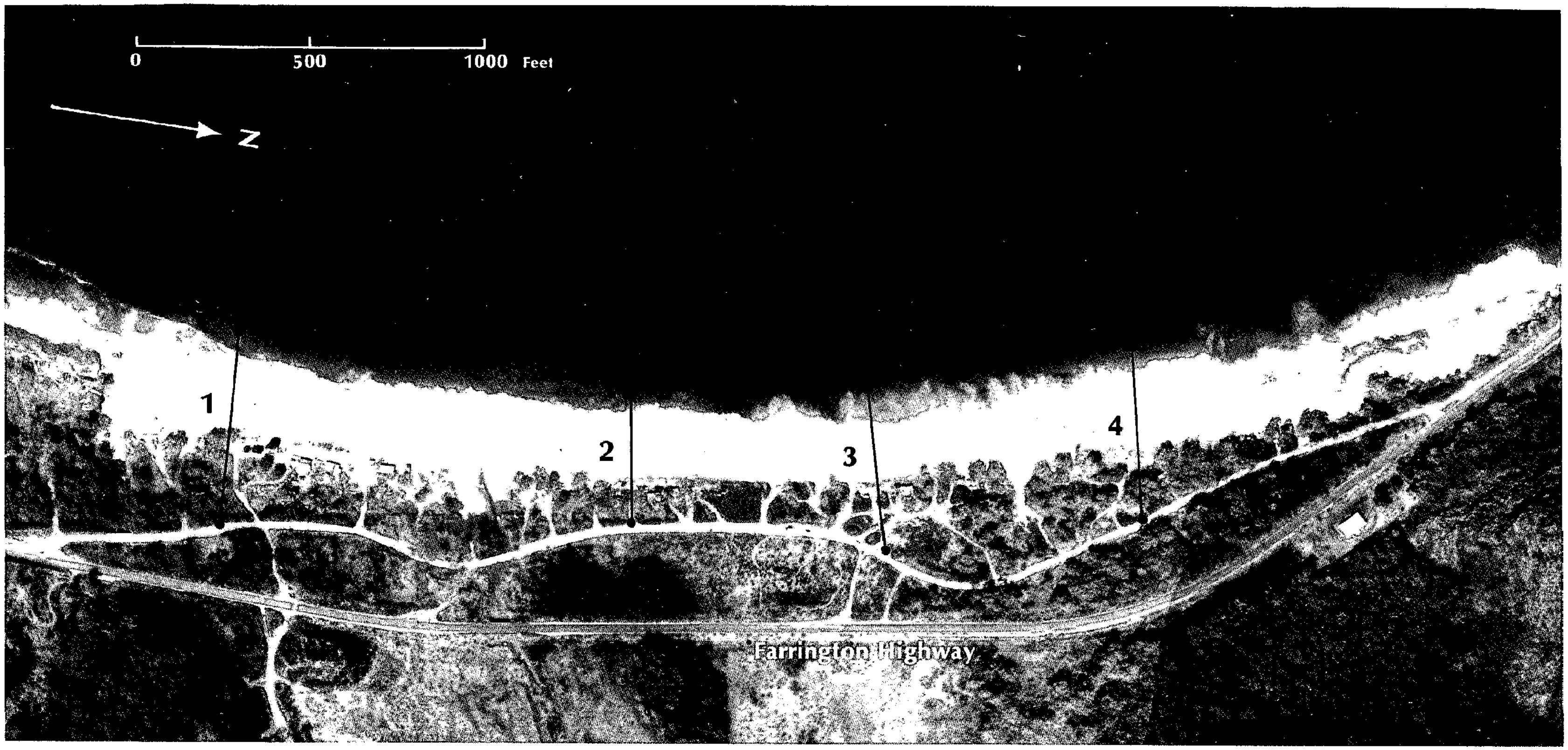
Generally, the vegetation line at Makua Beach has had small changes over a 26-year period. The net change is under 20 feet for all the transects established at this beach (Photomap 52, Table 52).

The large loss at transect 1 during the 1949 to 1965 period is possibly attributed to a clandestine sand mining operation. On the 1965 aerial photograph, the vegetation appears stripped and numerous tire tracks are on the beach.

Table 52 - Makua Beach. Changes in the Vegetation Line in Feet.

	Transect Number			
Observation Period	1	2	3	4
May 08, 1949 - Dec 22, 1965	-60	-4	-17	*
Dec 22, 1965 - Feb 06, 1971	+34	+3	+6	+8[1]
Feb 06, 1971 - Mar 30, 1975	+10	-1	+9	+3
Net Change - Vegetation Line	-16	-2	-2	+11
Range - Vegetation Line	60	4	17	11
Net Change - Water Line	-33	+21	+50	-14
Range - Water Line	104	46	50	14

** No data*
[1] Change from 1949-1971
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.



Photomap 52. Makua Beach

Photographs by Air Survey Hawaii: March 1975

Yokohama Beach (Keawaula)

The measurements to the water line and vegetation line at Yokohama were made from a point on a stable reference line. Although this procedure introduces inaccuracies, it was the only way to obtain data for the beach. Therefore the data should be regarded as a first approximation, subject to later revision.

Yokohama Beach is a confined littoral cell bounded by rocky coast to either side (Photomap 53). Between 1949 and 1979, this beach lost up to 64 feet from the vegetation line and 124 feet from the water line (Table 53). The major change, during the 1949 to 1972 period, is attributed to an extensive sand mining operation.

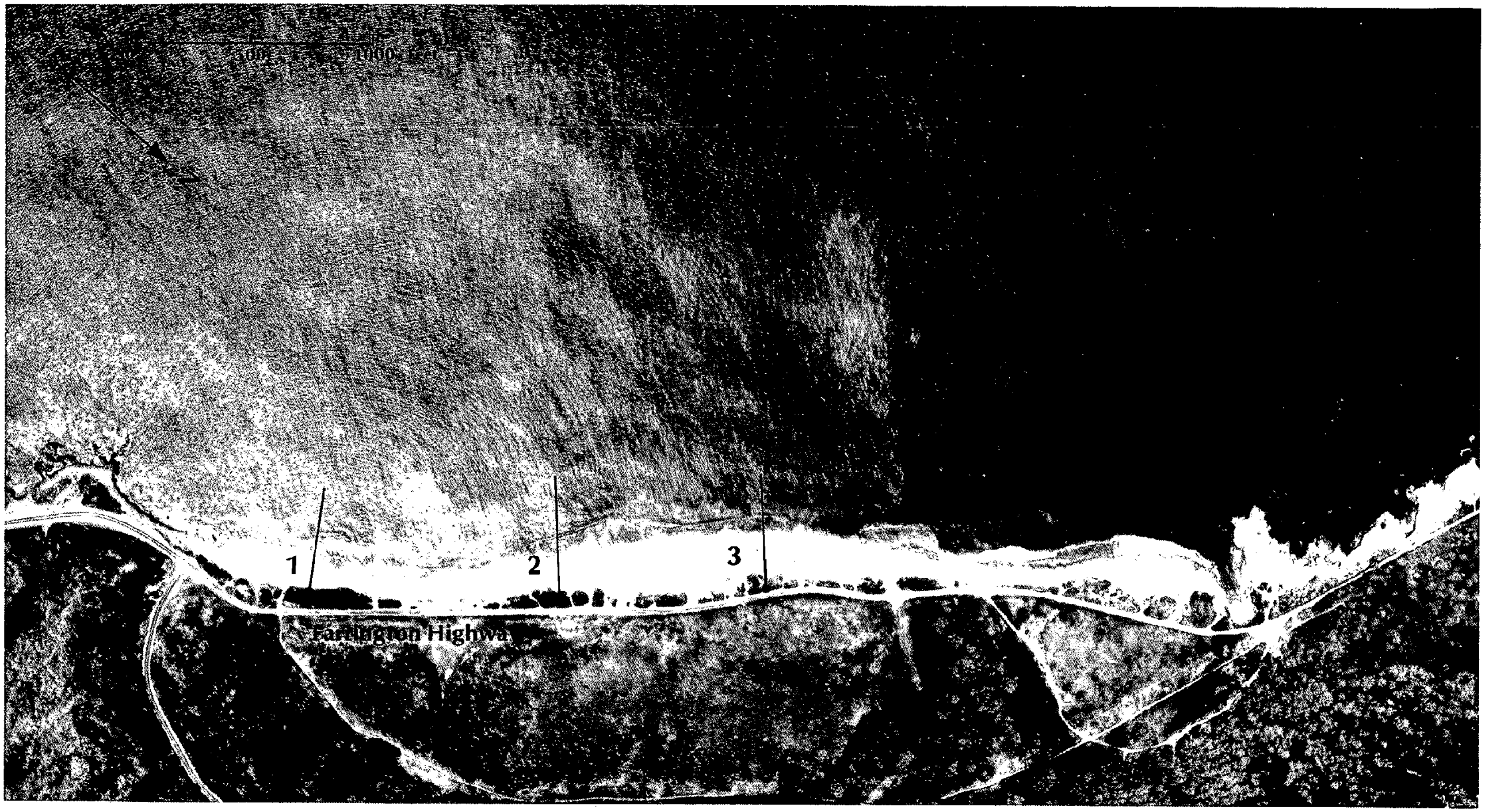
In 1957, 54,455 cubic yards (almost 1.5 million cubic feet) of sand was removed to build Ala Moana Beach (Campbell and Moberly, 1978). The effect of sand mining is especially noticeable at the southeast end of Yokohama. At this section, retreat of the beach since 1949 has exposed rock along the shoreline (Plate 14). Although this change may be seasonal it appears unlikely. All the aerial photographs used in the study of Yokohama were taken during the spring months. Furthermore, the rocks were exposed during the end of summer 1980, when the beach should have been in a high accretion state.

It may take some time before Yokohama returns to its former width. This beach receives no sand from adjacent coastal sections or by river runoff. An offshore reef exist, but it is uneven and slopes moderately seaward.

Table 53 - Yokohama Beach (Keawaula). Changes in the Vegetation Line in Feet.

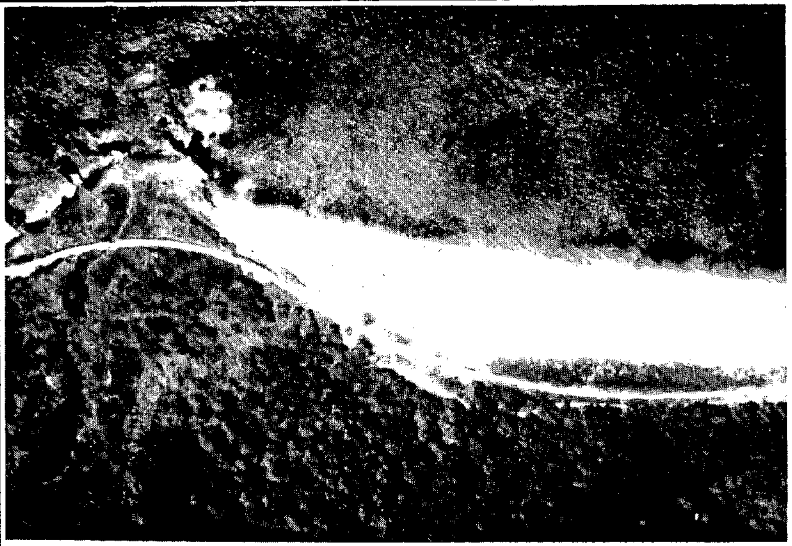
	Transect Number		
Observation Period	1	2	3
May 08, 1949 - May 26, 1972	-9	-84	-13
May 26, 1972 - Mar 30, 1975	*	*	+3
Mar 30, 1975 - Mar 21, 1979	-9[1]	+20[1]	*
Net Change - Vegetation Line	-18	-64	-10
Range - Vegetation Line	18	84	13
Net Change - Water Line	-124	-71	-49
Range - Water Line	124	84	49

** No Data*
[1] Change from 1972-1979
Net change is the total change in the position of a beach index line between the earliest and most recent observation year.
Range is the difference between the observed extremes in the position of a beach index line.

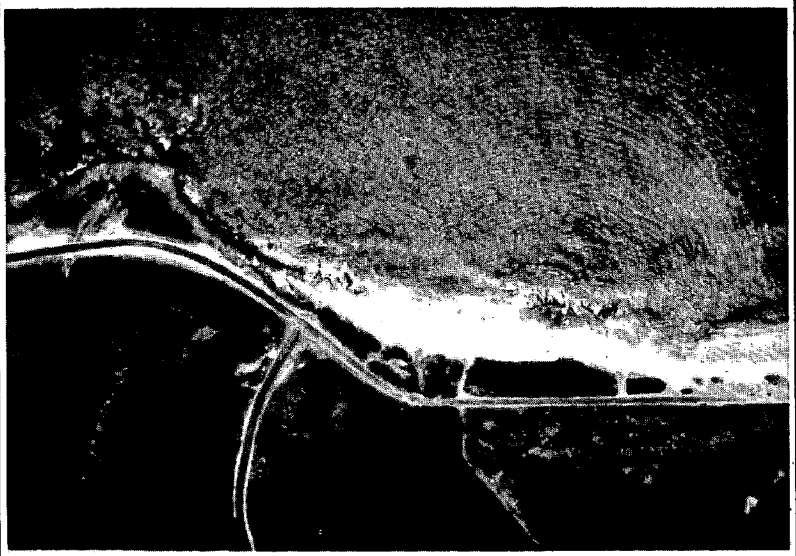


Photomap 53. Yokohama Beach (Keawaula)

Photographs by Air Survey Hawaii: May 1972



1949



1972

Plate 14. Yokohama Beach (Keawaula). The loss to the beach from sand mining is shown on the 1949 and 1972 photographs for Yokohama.

MANAGEMENT PROBLEMS ON OAHU

Once a house or park facility is constructed along an eroding shoreline, the difficult question must be faced of whether to save the buildings or preserve the beach. For most cases in the past, artificial structures have been placed on the beach to protect endangered buildings.

Each year an increasing percent of Oahu's shoreline is spanned by seawalls, stone revetments, and boulder piles. This trend can be seen on the aerial photographs for Mokuleia Beach, Kawailoa Beach, Laniloa Beach, Lanikai Beach, Bellows Air Field Beach, and Ewa Beach. In addition, future problems at Kailua Beach, Iroquois Point, Kahe Beach and Maili Beach may lead to the proposal of more erosion-control structures.

Several problems are associated with some artificial structures. Besides being detrimental to scenic views, structures may also reduce the recreational utility of the beach. For example, a seawall may reflect wave energy, causing sand to be carried offshore. Therefore, a beach that recedes during the winter might never regain its former width in the summer if a seawall were built in the interim. As a consequence, access along the shore would be blocked and the beach could not be used for picnics or sunbathing. In this manner, seawalls have reduced the total length of recreational beaches on Oahu. With the ever-increasing demand for limited beach resources, it is apparent that this trend will lead to greater conflicts in the future.

Another concern with some remedial measures is the possible disruption of the littoral cell. At Mokuleia Beach, seawalls and stone revetments cause erosion at the flanks. Therefore, more protective structures may be proposed. At Kualoa Beach, groins accelerate erosion to the south and appear to be the ultimate cause of erosion at the beach park. If certain erosion-control structures were installed at north Kailua Beach, sand might accumulate at one end of the littoral cell and result in subdivision of the beach system.

For beaches on the north shore, seawalls may provide adequate protection from normal winter waves. During a large storm or tsunami, however, these structures will eventually fail or be overtopped. When this occurs the loss to the resident may be greater than if the structure had never been built. For this situation, seawalls have two evils. Not only do they encourage development in hazard areas, but they give the homeowner a false sense of security.

The management problems presented here have one common root. Development was too close to the shore. No allowance was made for the dynamic nature of the beach.

To prevent problems before they begin it will be necessary to place buildings sufficiently inland so that the natural changes of the beach can take place. The 20-to 40-foot setback established by the Land Use Commission of the State of Hawaii will not protect homeowners or preserve the beach. For example, Kualoa Point eroded 350 to 400 feet over a 50-year period. At Iroquois Point, the vegetation line and water line receded about 180 feet between 1928 and 1976. When erosion began at Kailua Beach Park or South Lanikai, the vegetation line receded at a rate of more than 10 feet per year.

The Coastal Zone Management Act of 1977 gives the counties jurisdiction over an area extending 100 yards inland of the kahakai. The kahakai is the line of greatest annual wave reach as marked by debris left by the highest reaching waves with mean annual frequency, or by the seaward edge of the vegetation excluding especially salt-tolerant species (Cox, 1978).

From the aerial photographic study of Oahu, the minimum 100-yard zone of the special management area should be sufficient to prevent erosion problems on all the beaches except for Kualoa Beach Park. As the counties have control on construction within this zone, new amendments to the setback rules and regulations should not be required.

MANAGEMENT STRATEGY

The characteristic long-term change for a beach may vary significantly from one system to the next. Therefore, to generalize all beaches by having one arbitrary setback for the entire island can only lead to problems in the future.

In the study for Oahu, it was found that the beaches could be placed into five management categories based on their history of erosion and accretion and their susceptibility to inundation by large winter waves. These categories are presented below.

(1) **Hazard Areas** are subject to inundation by large storm waves. The beaches on the north shore of Oahu have been placed in this category. Every winter, residents on this coast are threatened by high surf. In addition, the north shore is particularly susceptible to tsunami damage, although this threat is common to all sections of the island.

From past history, it is apparent that a 40-foot setback line is not sufficient to prevent problems on the north shore. Houses built this close to the vegetation line often require the construction of a seawall or revetment for protection from large waves. These protective structures may give the homeowner a false sense of security. The seawall or revetment may provide adequate protection during normal winter waves, but the large storm or tsunami that occurs every decade or two can cause considerable damage.

During the December 1-4, 1969 storm, structural damage from large surf was experienced on every developed beach on the north shore. At west Sunset Beach alone, 14 homes were damaged or destroyed (State of Hawaii, DLNR, 1970). Yet, when property along this beach was redeveloped, several homes were placed closer to the shore than before the storm. Construction at this beach and the rest of the north shore has continued with no regard to the dangers involved. At Mokuleia Beach, several houses are less than 20 feet from the edge of the vegetation line or a seawall. One house under construction was less than 10 feet from the vegetation line as of January 1981. Because of this development close to the shore, the potential for disaster involving loss of life and property damage from events similar to the December 1969 storm and the tsunamis of 1946 and 1957 has increased enormously.

Recommendations: (A) In hazard areas, an 80-foot setback should be established to minimize the damage from large waves. New subdivisions that require the construction of houses within this 80-foot zone should not be approved. This recommendation would not require amendments to the Shoreline Setback Rules and Regulations of the City and County of Honolulu. Under the Coastal Zone Management Act of 1977, the counties have been given jurisdiction over an area extending 100 yards inland.

The rationale for selecting 80 feet as an appropriate setback is the following. During 1967 to 1971, the photographic data indicate that the vegetation line for many of the beaches on the north shore receded more than 40 feet. This erosion is attributed to the winter storm of December 1969. It would be dangerous to place buildings within 40 feet of the vegetation line when erosion of this magnitude can occur during one brief event.

The data from the vegetation line indicate none of the beaches on the north shore eroded more than 80 feet during the 1967 to 1971 interval. This does not preclude the possibility, however, that erosion of 80 feet did occur during the December 1969 storm. Significant seaward growth of the vegetation line may have transpired during the time after the storm and 1971, when the next aerial photographs of the north shore were taken.

The photographic data for hazard areas does not allow a precise determination of a suitable setback for each beach. When more data become available, this 80-foot zone can be adjusted. As the major long-term changes in hazard areas occur intermittently during large storm events, a beach mobility-energy classification scheme should be considered (Nordstrom, 1979). This plan would require the daily monitoring of beaches in the hazard area category over a two-month period.

(B) When houses or other structures are destroyed by large waves, reconstruction on the plot of land should be carefully analyzed and in some cases advised against. If redevelopment of the land is to occur, the use of pile supports to elevate buildings should be considered. It should be realized that areas inundated by large waves have a beach profile and offshore reef structure that make them susceptible to damage from future storms.

(C) The practice of cutting down storm berms and dunes to provide vistas for homeowners should be discouraged. These beach features provide a natural protection against large waves and in some areas their removal can accelerate erosion (K. Keller, personal communication).

(2) **Chronic Erosion Areas.** Beaches with a long-term history that indicates erosion will continue in the future are here defined as chronically eroding. The beaches in this category include Iroquois Point on the south shore, Maili Beach and Kahe Beach on the leeward coast, and north Kahuku Golf Course Beach, Laniloa Beach, Hauula Beach Park, Kualoa Beach Park, and Bellows Air Field Beach on the windward coast.

The management of chronically eroding beaches should be based on historic studies on the rate of erosion as determined by aerial photographs, maps, charts and field surveys. An example of how these studies may be utilized is given for Laniloa Beach on the windward coast.

The vegetation line at Laniloa Beach has had a history of continuous retreat. On the 1949 aerial photograph, fallen trees on the beach indicate prior erosion. Between 1949 and 1975, the vegetation line receded 70 feet. On a field check in 1980, the northeast tradewind waves broke against the base of an erosional scarp in the vegetated dune field, indicating that the erosive trend is still in process.

Although the littoral processes at Laniloa are not fully known, the historic data allow the prediction that erosion will continue in the future. From the aerial photographic measurements, an average rate of retreat of up to three feet per year can be expected.

In determining the inland extent of prohibitive beach development at Laniloa, planners should multiply the rate of erosion by the life expectancy of a structure and then add 40 feet as a buffer. For example, if a house has a 40-year-life expectancy, it should be placed at least 160 feet inland to preserve the beach. Placing the house any closer insures that some type of remedial measure will be required to protect the building in the future.

Recommendations: (A) Periodic field surveys or aerial photographic studies should be made to determine significant changes in the rate of retreat for chronically eroding beaches. Kualoa Point has had a steady increase in the rate of erosion from 4 feet per year to 8 feet per year to more than 17 feet per year. Laniloa Beach has a rate that varies from 1-4 feet per year. Erosion at Iroquois Point has ranged from 1-5 feet per year.

(B) New subdivisions requiring the construction of buildings in the chronic erosion area should not be allowed. The extent of an appropriate setback should be based on the local rate of erosion and the life expectancy of the proposed structure.

(3) **Unstable Beaches** have an alternating history of erosion and accretion. The long-term changes on these beaches are unpredictable and dependent partly on meteorological conditions. Areas on Oahu in this category include Malaekahana Beach, Kailua Beach, Lanikai Beach, sections of Waimanalo Beach, and Makapuu Beach on the windward coast and Sandy Beach Park, Ewa Beach and Nimitz Officers Beach on the south shore.

Development on unstable areas should be far enough inland to allow for the natural changes of the beach. This has not occured at Lanikai Beach and Ewa Beach. On these beaches, seawalls span large portions of the shore even though Lanikai may have a constant sand budget and Ewa appears to be accreting.

An appropriate setback to prohibit development on unstable beaches may be obtained by using the historic range in the position of the vegetation line. For example, the vegetation line at Kailua Beach Park has a range of about 150 feet between its maximum accretion and erosion state. When a 40-foot buffer is added, inland development at this section should be no closer than 190 feet.

At the north end of Kailua Beach, the range in the position of the vegetation line over a 29-year period was about 60 feet. Therefore, development any closer than 100 feet to the edge of the vegetation line should be prohibited in order to preserve the littoral cell. Unfortunately, several houses were placed too close to the vegetation line on a portion of the beach that grew between 1971 and 1978. Since 1978, erosion has set in and the houses now require the protection of sand bags and tires. If the trend continues, remedial measures will be proposed that could disrupt the entire beach system.

Recommendations: (A) On unstable beaches, development on portions of the beach in an accreting cycle should be avoided because erosion can set in as part of the normal sequence.

(B) An appropriate setback may be obtained by adding the historic range in the position of the vegetation line and 40 feet as a buffer. Subdivisions in which houses must be placed within the setback zone should not be approved.

(4) **Accreting Beaches** have a long-term history that indicates accretion will continue in the future. The beaches in this category are relatively few. They include Kaiaka Bay and Kawela Bay on the north shore; Kahana Bay, Kaluanui Beach and Punaluu Beach on the windward coast and Nanakuli Beach Park on the leeward coast.

Generally, no major problems exist on accreting beaches except at Kawela Bay, where houses were damaged by the 1946 tsunami and the December 1969 storm. This beach also falls in the hazard area category and management should therefore follow the guidelines previously described.

The major issue on accreting beaches is one of land ownership. At Kawela Bay, Kaluanui Beach and Punaluu Beach, residential dwellings are located in the backshore zone.

(5) **Stable Beaches** have had a small net change and range in the position of the vegetation line. No major problems exist on these areas, except for the potential of damage from tsunamis and storms.

Areas that have been stable over a long-term period include sections of Laie Beach, Kokololio Beach, sections of Kaluanui Beach, the stretch from Mahie Point to Swanzy Beach Park, the stretch from Niu Beach to Kuilei Cliffs Beach Park, Oneula Beach, Barbers Point, Ulehawa Beach Park and Mauna Lahilahi Beach Park.

On table 54, the beaches of Oahu have been placed into the five management categories. Some of these beaches may fall into more than one category. In other cases, one section of the beach may have a different classification from another. Finally, there are some beaches that await classification until more data become available.

The beach classification scheme presented here is based on a determination of historic beach trends. Although the past record gives the best insight into possible future trends, there is no guarantee that these changes will occur. It may be found that the past shoreline movements for a particular beach were not representative of the long-term trend. For this reason it is necessary to continuously update the data file on the beaches. This could be done with periodic field surveys or aerial photographs taken every five years.

Table 54 - Oahu Beach Classification. The Numbers in Parenthesis Refer to the Established Transects at the Beach.

NORTH SHORE		WINDWARD COAST	
Mokuleia Beach	Hazard	Kahuku Golf Course Beach	Erosion (1)-Stable
Kaiaka Bay Beach	Hazard-Accretion	Malaekahana Beach	Unstable Stable (4)
Haleiwa Residential Area to Alii Beach Park	Hazard	Laie Beach	Unstable (1,2,6) Stable (3 to 5) Accretion (7)
Haleiwa Beach Park	Hazard		
Kawailoa Beach	Hazard	Laie Point to Pali Kilo Ia (Laniloa Beach)	Erosion (5 to 7) Unstable (4) Stable (1 to 3)
Waimea Bay Beach Park	Hazard-Erosion		
Pupukea Beach	Hazard	(Pounders Beach)	Unstable
Sunset Beach	Hazard	Kokololio Beach	Stable
Sunset Point to West Kawela	Hazard-Erosion (1,2,8)	Hauula Beach to Makao Beach	Erosion (2,3) Unstable (5 to 8) Stable (1,4)
Kawela Bay	Hazard-Accretion		
Turtle Bay	Hazard	Kalaipaloa Point to Waiono Stream	Unstable (1,2,6,7,8) Stable (3 to 5) Accretion (between 2+3)
Kaihalulu Beach	Hazard		
Hanakailio Beach	Hazard	Punaluu Beach Park and Residential Area	Stable (3,4) Accretion (1,2)
		Kahana Bay Beach Park	Accretion

Mahie Point to Swanzy Beach Park	Erosion (4) Stable (1 to 3)
Kaaawa Residential Area to Kalaeokaoio Pt.	Unstable (1 to 4, 7,8) Stable (5,6)
Kualoa Beach	Erosion
Kailua Beach	Unstable Accretion (7 to 11)
Lanikai Beach	Unstable Stable (6,7)
Waimanalo Beach	Erosion (1 to 4) Unstable
Kaupo Beach	Stable(north) Unclassified
Makapuu Beach Park	Unstable

SOUTH SHORE

Sandy Beach Park	Unstable
Hanauma Bay Beach Park	Unclassified
Paiko Peninsula	Unstable
Niu Beach to Wailupe Peninsula	Stable-Accretion (3)
Wailupe Beach Park and Residential Area	Stable
Kahala Beach	Unstable (1,2)-Stable
Kaalawai Beach and Kuilei Cliffs Beach Park	Stable
Iroquois Point	Erosion (6,7) Accretion (2 to 4) Stable (1)
Ewa Beach	Unstable (1,4 to 7,9,10) Stable (8) Accretion (2,3)
Oneula Beach	Stable
Nimitz Officers Beach	Unstable
Nimitz Beach	Unstable (2)-Accretion
Barbers Point	Stable

LEEWARD COAST

Lanikuhonua Beach	Unstable
Kahe Beach	Erosion (2) Unclassified
Nanakuli Beach Park	Accretion
Ulehawa Beach Park	Stable
Maili Beach	Erosion (1,7 to 10) Unstable (2) Accretion (3 to 6)
Pokai Bay	Unstable-stable (north) Accretion (south)
Mauna Lahilahi Beach Park	Unstable (1)-Stable
Papaoneone Beach (Turtle Beach)	Unstable
Makaha Beach	Hazard-Unstable
Keaau Beach	Hazard-Unstable
Makua Beach	Unclassified (1) Unstable (3)-Stable
Yokohama Beach (Keawaula)	Unclassified

SUMMARY

From the aerial photographic survey of Oahu's shoreline, the following conclusions may be drawn.

(1) The most unstable beaches on Oahu are located on sand bodies projecting from the coastline. Examples of these features include Paiko Peninsula, Kualoa Point and Iroquois Point.

(2) On the north shore beaches are wide and have a large seasonal change. Generally, no permanent damage to the backshore area occurs unless large waves overwash the beach zone. This situation may occur during a strong winter storm or tsunami. Aerial photographs record the effects of the December 1969 storm, 1946 tsunami and possibly the 1957 tsunami. For many beaches on the north shore, the largest retreat in the vegetation line over a period of 26 to 30 years occurred during the December 1969 storm. At Waimea Beach, almost half the loss in the vegetation line over a 47-year period occurred during this brief event.

(3) Beach changes on the windward coast are caused by trade wind waves and refracted North Pacific swell. The large long-term changes at Kailua Beach, Lanikai Beach and Kualoa Beach are partly caused by variations in sand transport along the shoreline. Chronic erosion areas on the windward coast include North Kahuku Golf Course Beach, middle and south Laniloa Beach, Hauula Beach Park, Kualoa Beach Park and Bellows Air Field Beach. Erosion problems exist at Kalanai Point, Swanzy Beach Park, Kaaawa Beach Park, the ends of Kailua Beach, Lanikai Beach, and Waimanalo Beach. Accretion was found at Kaluanui Beach, Punaluu Beach and Kahana Bay.

(4) Beaches on the south shore have been relatively stable over the study interval. The exceptions are Paiko Peninsula and Iroquois Point. A brief period of erosion between 1967 and 1971 was experienced at Sandy Beach Park, Hanauma Bay, sections of Paiko Peninsula, and east Kahala Beach. Ewa Beach eroded between 1958 and 1967. Many of the seawalls at Ewa were constructed during this time.

(5) On the leeward coast, Kahe Beach and the ends of Maili Beach experienced chronic erosion. Most other beaches had no apparent long-term change. Nevertheless, periodic damage to the backshore area may occur from refracted North Pacific swell or Kona Storm waves. Beaches that appeared susceptible to inundation over a 26-year period include mid-Pokai Bay, Papaoneone Beach, Makaha Beach and Keaau Beach.

The beaches of Oahu have been placed into five management categories based on their history of erosion and accretion, and their susceptibility to inundation from large waves. Beaches on the north shore have been placed in the ***Hazard Area*** category. It is recommended that the setback line on this coast be increased by the distance of 80 feet to minimize the damage from large winter storms and tsunamis. ***Chronic Erosion Areas*** have a long-term history that indicates that erosion will continue in the future. On these beaches, an appropriate setback line may be obtained by multiplying the rate of erosion by the life expectancy of the structure and then adding 40 feet as a buffer. ***Unstable Beaches*** have had an alternating history of erosion and accretion. The long-term changes on these beaches are unpredictable and are dependent partly on meteorological factors. In order to preserve the beach, planners should use the historic range in the position of the vegetation line to determine a suitable inland setback. Development on ***Stable Beaches*** is generally not a problem except for the threat from tsunamis. On ***Accreting Beaches*** the major issue is one of land ownership.

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