HILO AREA
COMPREHENSIVE STUDY

Hilo Bayfront

SURVEY REPORT AND
ENVIRONMENTAL
IMPACT STATEMENT

US Army Corps
of Engineers
Honolulu District

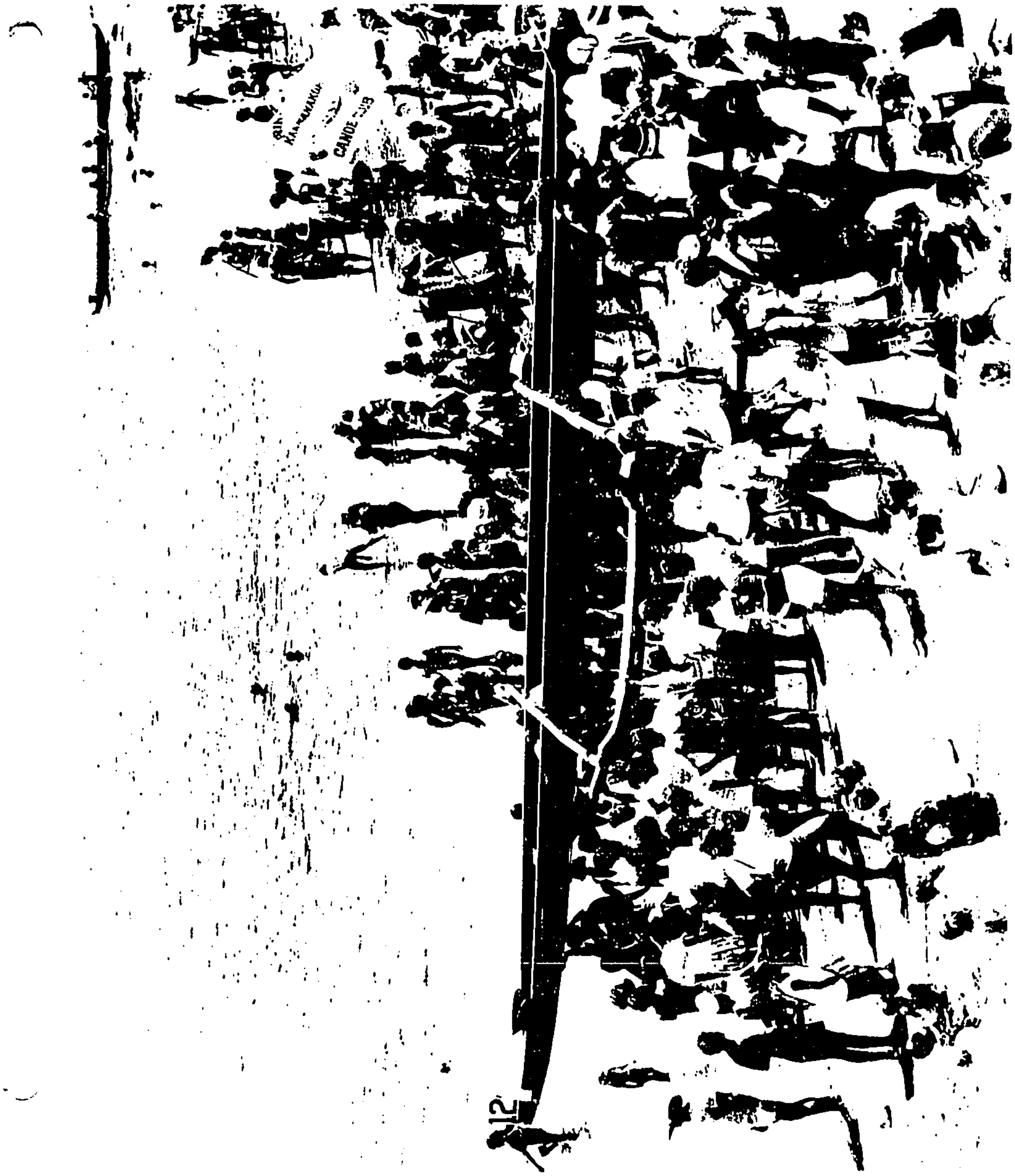
FINAL FEBRUARY 1985

DEPARTMENT OF THE ARMY
US ARMY ENGINEER DISTRICT, HONOLULU
FORT SHAFTER, HAWAII 96858-5440

HILO BAYFRONT
A SURVEY REPORT AND ENVIRONMENTAL IMPACT STATEMENT FOR SHORE PROTECTION AND BEACH RESTORATION

FEBRUARY 1985
HONOLULU ENGINEER DISTRICT

HAWAIIAN CANOE CLUB RACING COMPETITION, BAYFRONT, HILO, HAWAII



SYLLABUS

This survey report presents the findings and conclusions of studies conducted in the interest of beach erosion control and related purposes for the Bayfront Beach of Hilo, Hawaii. The primary purpose of this study was to determine the nature and extent of problems being experienced and the need for corrective or protective action. Also under consideration were the desires of local interests, the range of measures available for reducing or ameliorating these problems, the feasibility of these measures, and the Federal interest in both the problems being experienced and possible solutions to these problems.

The bayfront shoreline and beach at Hilo Bay are subject to erosion and inundation during storm wave attack. Storm waves have eroded the natural beach; overtopped an existing revetment; and deposited rocks and debris onto the Bayfront Highway. The bayfront black sand beach has eroded nearly 50 feet in width to its current size of 0.84 acres.

A practical plan would include a combination of rock revetment, longard tubes, and protective beach with stabilizing structures to protect the shoreline and restore part of the beach. The first cost of such a plan (including future sand nourishment) would be $9,072,000 with a benefit-cost ratio of 1.7. There would be no significant adverse environmental or social effects. The plan would protect the shoreline from future erosion and prevent damages to the highway and delays in traffic. Beach restoration would create recreational benefits due to the increase in visits by tourists and residents.

The above-mentioned plan of improvement, however, lacks Federal interest because projects designed primarily to provide recreational opportunities are not in agreement with the Administration's policies. Local interests may consider implementing the project because it is technically and economically feasible and there are no significant adverse environmental impacts. This report is being published and distributed for information purposes and not as an action or decisionmaking document.

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HILO BAYFRONT

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MAIN REPORT

AUTHORITY

This study was conducted in response to Resolutions 144 (1973) and 480 (1975) by the Hawaii County Council. In 1976, the Hilo Area Comprehensive Study was authorized by the U.S. Congress and initiated by the Honolulu Engineer District. The authority for this report is Section 144 of the Water Resources Development Act of 1976 (Public Law 94-587) which states:

> The Secretary of the Army, acting through the Chief of Engineers, in cooperation with the State of Hawaii and appropriate units of local government, shall make a study of methods to develop, utilize, and conserve water and land resources in the Hilo Bay Area, Hawaii, and Kailua-Kona, Hawaii. Such study shall include, but not be limited to, consideration of the need for flood protection, appropriate use of flood plain lands, navigation facilities, hydroelectric power generation, regional water supply and wastewater management facilities systems, recreational facilities, enhancement and conservation of water quality, enhancement and conservation of fish and wildlife, other measures for environmental enhancement, and economic and human resources development. Based upon the findings of such study, the Secretary of the Army, acting through the Chief of Engineers, shall prepare a plan for the implementation of such findings which shall be compatible with other comprehensive development plans prepared by local planning agencies and other interested Federal agencies.

PURPOSE AND SCOPE

This report describes study findings to improve the shore protection and restore the beach along the Bayfront at Hilo, Hawaii (Figure 1). This survey report addresses shore protection, recreation and environmental enhancement issues of the authority and was prepared as part of the Hilo Area Comprehensive Study.

The investigations described in this report cover Hilo Bay and the Bayfront Beach (Figure 2). Investigations were made of the immediate and future needs for shore protection; measures or combinations thereof capable of satisfying such needs; and the accompanying economic, environmental, and social considerations. These studies provide the depth and detail required to determine plan feasibility. This report contains an environmental impact statement in addition to supporting documents for engineering, design, costs, geology, and economics.

The recommendation of this report is that there is no Federal interest in the implementation of plans to resolve problems at this location and that no further action should be taken by the U.S. Army Corps of Engineers. The project lacks Federal interest because the benefits would be primarily for recreation and water projects which provide primarily recreational opportunities that are not in agreement with the Administration's policy to rely on the private sector to provide public services whenever possible. Local interests may consider implementing the project because it is technically and economically feasible and there are no significant adverse environmental impacts.

Average annual benefits of the selected plan are greater than the average annual cost. Accordingly, the project would produce net economic benefits to the nation. We have published the report so that the public may benefit from the extensive planning, engineering, environmental, and economic evaluations which have been completed.

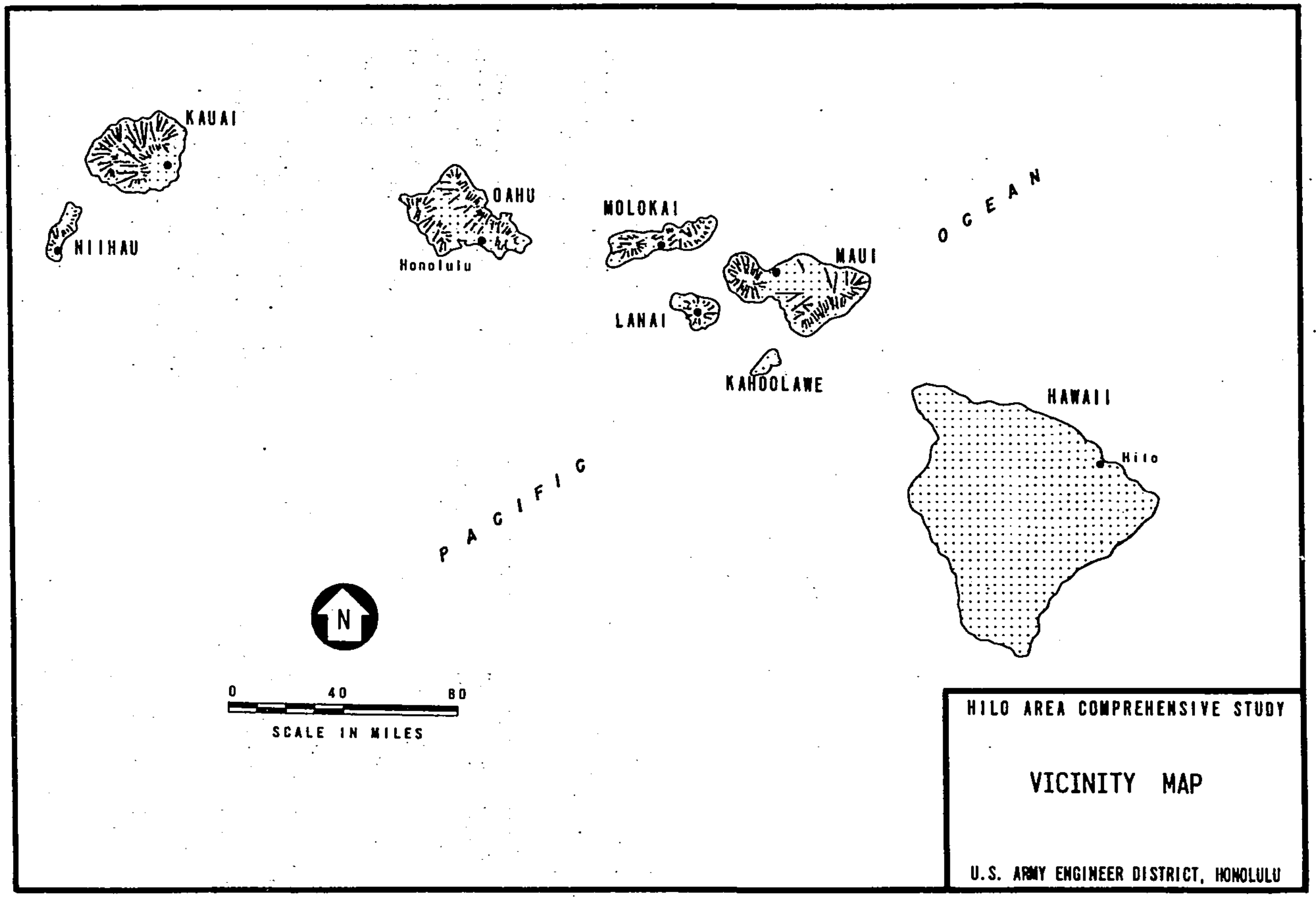
KAUAI
NIIHAU
OAHU
Honolulu
MOLOKAI
LANAI
MAUI
KAHOOLAWE
HAWAII
Hilo
OCEAN
PACIFIC
N
0
40
80
SCALE IN MILES
HILO AREA COMPREHENSIVE STUDY
VICINITY MAP
U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE 1

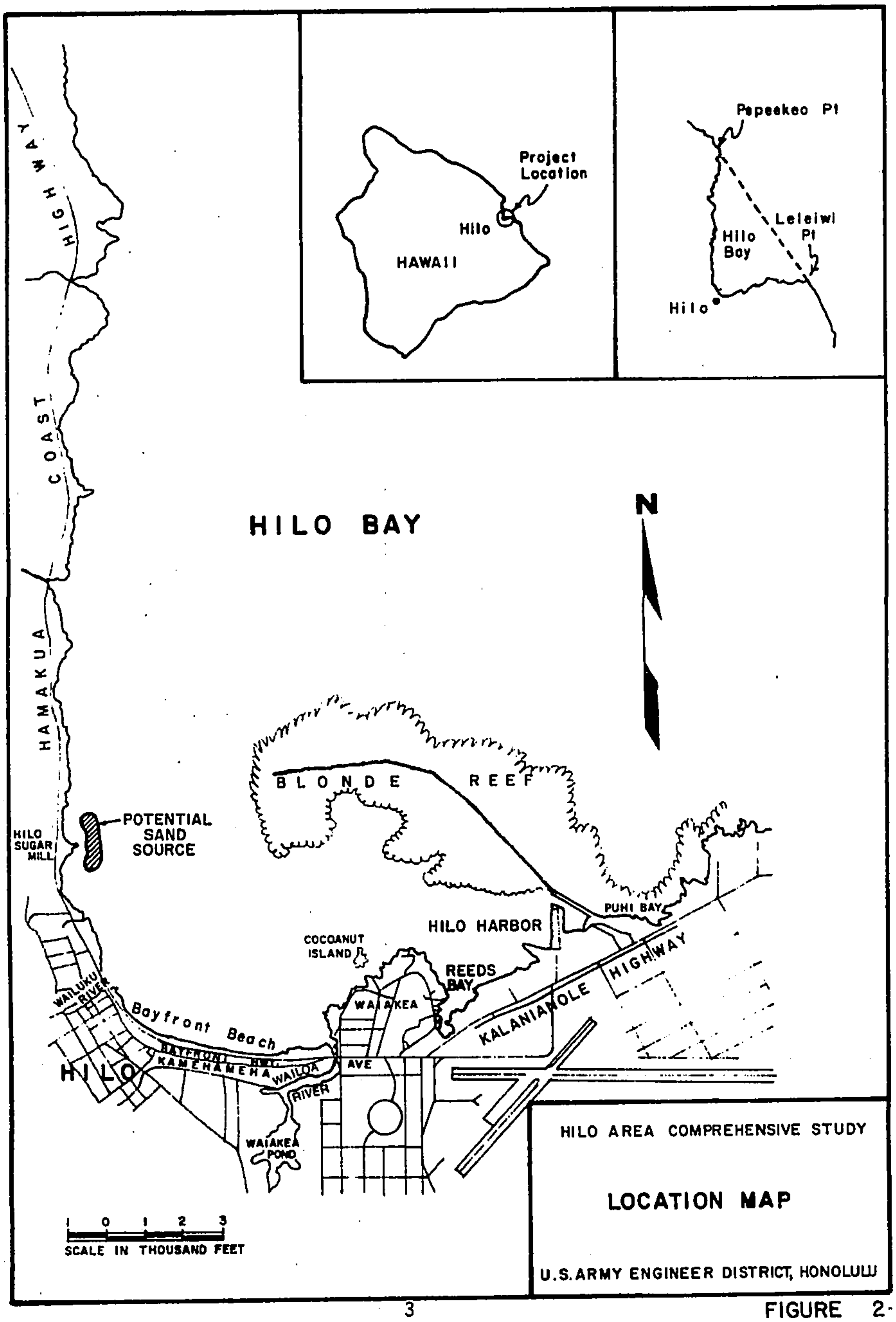
Project Location
Hilo
HAWAII
Papeekeo Pt
Leleiwi Pt
Hilo Bay
Hilo
HILO BAY
N
HAMAKUA COAST HIGHWAY
BLONDE REEF
POTENTIAL SAND SOURCE
HILO SUGAR MILL
PUHI BAY
HILO HARBOR
COCOANUT ISLAND
REEDS BAY
WAIAKEA
KALANIANAOLE HIGHWAY
WAILUKU RIVER
Bayfront Beach
BAYFRONT HWY.
KAMEHAMEHA AVE
WAILOA RIVER
HILO
WAIAKEA POND
1 0 1 2 3
SCALE IN THOUSAND FEET
HILO AREA COMPREHENSIVE STUDY
LOCATION MAP
U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE 2-

PRIOR STUDIES, REPORTS, AND EXISTING WATER PROJECTS

Hilo Harbor is an authorized project for deep-draft navigation which includes a rubblemound breakwater 10,080 feet long; an entrance channel 35 feet deep; and a turning basin 1,400 feet wide, 2,300 feet long, and 35 feet deep. The project was authorized under the River and Harbor Acts of 2 March 1907, 25 July 1912, and 3 March 1925 and was completed in July 1930. Sixty percent of the breakwater was seriously damaged during the 1946 tsunami and repairs were completed in 1948. Later breakwater repairs were completed in 1968, 1975 and 1981. A report recommending that Hilo Harbor be deepened to 39 feet in the entrance channel and 38 feet in the turning basin was approved by BERH in April 1983.

A tsunami protection project was authorized by the 1960 River and Harbor Act and a post-authorization study was completed in 1967. The study found that protective works at a cost of $60 million would be feasible. However, the local government rejected the plan and its $10 million local cost-sharing requirement. Therefore, the project was deauthorized in 1977.

A study to determine the feasibility of modifying Hilo Harbor to prevent surge was authorized by House Resolution 739 in 1967. The results were not fully conclusive but suggested that surge was correlated with short-period waves generated by North Pacific storms.

A reconnaissance report for major rehabilitation of the breakwater portion of the Hilo Harbor project was submitted to OCE in May of 1984. The report recommends constructing an inner breakwater 2,000 feet long to replace the outer 7,500 feet of the existing breakwater.

PLAN FORMULATION

Existing Conditions

Hilo is the urban, commercial and government center for Hawaii County, and is located on the Island of Hawaii which has more than 4,000 square miles and some 92,000 people. Forty-six percent of the population resides in Hilo. It contains one of the County's two major airports and the primary deep-draft harbor, the third largest in the State, after Honolulu and Barbers Point Harbors.

The basic elements of the economy of Hawaii County are tourism, agriculture, fishing, manufacturing and scientific research, with tourism being the number one industry. Hilo serves as a gateway to and from Hawaii due to its airport facilities (for more detail, refer to SUPPORTING DOCUMENTATION: Economics).

The Bayfront Study area (Figure 2a) is within Hilo Bay and consists of a shoreline 6,300 feet long bounded on the west by the Wailuku River and on the east by the Wailoa River. Cocoanut Point lies between the Wailuku River and Station 0+00 and is composed of basalt rock. There are narrow strips of sand, exposed at low water from Station 0+00 to Station 20+00, but the land-sea interface is mostly rubble and rock placed as a revetment to protect the shoreline. There is a narrow sand beach from Station 20+00 to Station 58+00,

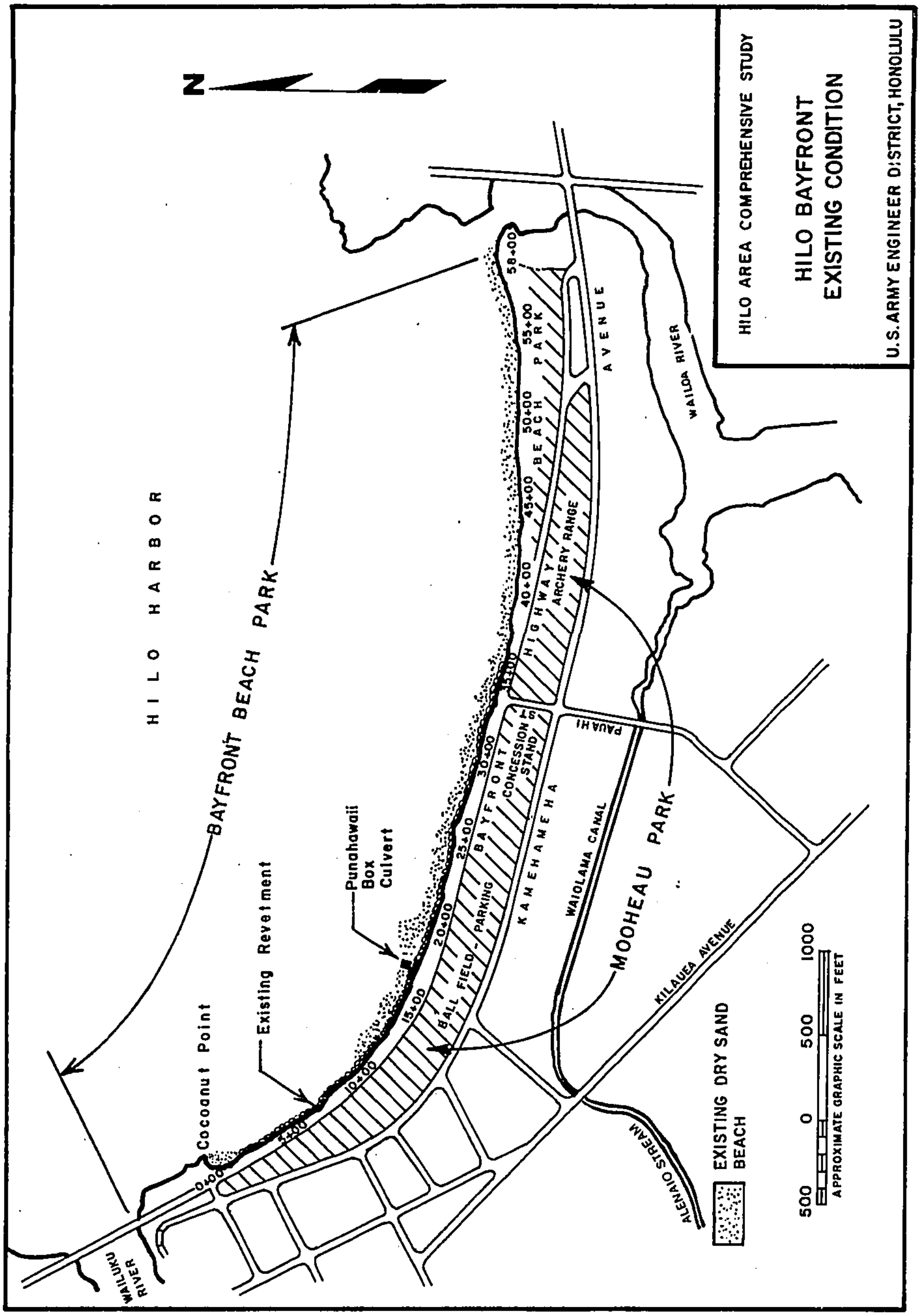
HILO AREA COMPREHENSIVE STUDY
HILO BAYFRONT
EXISTING CONDITION
U.S. ARMY ENGINEER DISTRICT, HONOLULU
N
HILO HARBOR
BAYFRONT BEACH PARK
MOOHEAU PARK
Cocoanut Point
Existing Revetment
Punahawaii Box Culvert
BALL FIELD - PARKING
BAYFRONT
CONCESSION STAND
ARCHERY RANGE
BEACH PARK
HIGHWAY
KAMEHAMEHA
AVENUE
PAUAHI
WAIOLAMA CANAL
KILAUEA AVENUE
ALENAIO STREAM
WAILUKU RIVER
WAILOA RIVER
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
40+00
45+00
50+00
55+00
58+00
EXISTING DRY SAND BEACH
500
0
500
1000
APPROXIMATE GRAPHIC SCALE IN FEET

FIGURE 2a

which is backed up by a continuation of the rubble and rock revetment which terminates at Station 35+00. The beach backshore becomes extensive between Stations 35+00 and 58+00. The dry sand beach gradually widens from Station 20+00 to 58+00 and is about 0.8 acres.

In profile, the beach slopes horizontally to the sea at 11 feet for each vertical foot. The seabed has less slope which varies between 45 to 60 feet horizontally for each vertical foot. The seabed is hard substrate with solid basalt exposed in some spots.

The area between the Wailuku and the Wailoa Rivers, and from the Bay inland for approximately 1,000 feet, comprise two County of Hawaii parks: the Bayfront Beach Park and Mooheau Park. The two parks are bisected by the Bayfront highway. Both parks have public access for pedestrians and vehicles; parking areas; restrooms; and general recreation facilities. The Bayfront Beach Park has showers.

History of Erosion and Shore Protection

In the mid-1800's the Bayfront was composed of a single beach for its entire length (except Cocoanut Point) between the two rivers. According to cores drilled in 1950, the depth of sand at some locations along the shore exceeds 40 feet. This depth of sand permitted natural reconfiguration of the beach in conformance to wave forces or current changes. Such a condition no longer prevails today due to extensive *human-induced* changes to the shoreline. These changes have altered the natural beach system to such an extent that it has lost up to 50 feet in width. It cannot restabilize itself under present circumstances.

Early settlers at Hilo constructed a landfill (1861), a pier (1865) and a sewage outfall (1906) at Cocoanut Point adjacent to the mouth of the Wailuku River. These structures functioned as a partial barrier to the natural process of sand movement down and out the mouth of the Wailuku River on to the east. The Wailuku River is the major sand source for the beach. By 1880, the urban settlement of Hilo pushed very close into the backshore of the Bayfront Beach. This settlement interfered with the natural fluctuation of the beach's profile. Storms acted to reclaim the shoreline and in 1892 and 1894 houses and the pier at Cocoanut Point were badly damaged by storm waves. Consequently, local interests moved the pier to the Waiakea peninsula east of the Wailoa River in the hopes of reducing damage caused by storm wave and having calmer water for cargo unloading.

During the late 1800's while Hawaii's sugar industry was developing, rail lines were constructed to carry raw sugar and supplies to and from Hilo's pier and the sugar mills which were located both south and north of town. In 1901, the Hilo Railroad Company was requested by a number of leading citizens of Hilo town to extend a new rail line from Waiakea along the Bayfront Beach to Hilo, a distance of 1.5 miles. The tracks were laid along the shoreline berm between the urban settlement and the water. The railroad's right-of-way extended into the sea at the western-most end and evidently the beach in this area was covered over the construction process. This line was completed in 1903. At first there was no revetment on the seaward side. In 1906, the 80-foot-long sewer outfall at Cocoanut Point was completed which worsened beach erosion on the east side of the Point. The railroad company began dumping stone to form a crude revetment at some locations along the line where the beach was receding.

PHOTO NO. 1. Tracks 'makai' of Mo'oheau Park.

PHOTO NO. 2. Tracks with riprap stone revetment wall, Hilo Bay.

RAILROAD TRACKS ON HILO BEACH BERM
PRE-1946

PHOTO CREDIT NO. 1. Copy of photograph in Hawaii State Archives by B. Nakamura.

PHOTO CREDIT NO. 2. Bishop Museum Photo Collection (CN47148).

In 1907, the US Congress authorized the construction of a 7,000-foot breakwater at Hilo Bay. The construction of the breakwater, under the management of the US Army Corps of Engineers, was justified on the basis of estimated savings in transportation costs. It was finally completed in 1929. An extension of the breakwater to its present length of 10,080 feet was later authorized in 1960. A breakwater structure, such as the one in Hilo, can change and impede the natural littoral processes within the original harbor. The Hilo breakwater may have altered the westward component of littoral drift that may have existed. Currently, the longshore movement of sand occurs in an easterly direction.

Between 1915 and 1922, two sanitation and reclamation projects were in progress which conceivably had a tremendous impact on the Bayfront Beach. The first project, called the Waiolama Sanitation Project, required the filling of approximately 33.4 acres of predominantly low-lying swampland in the area between what is now Kilauea and Kamehameha Avenues. Over 215,000 cubic yards (CY) of fill material were needed. Of this, 207,000 CY of black sand were obtained from the nearby Bayfront Beach. The remaining 8,000 CY or so of fill material were obtained from the dredging spoils of the Waiolama Canal which was also a part of the project. The second project, called the Ponahawi Reclamation Project, required another 32,000 cubic yards of fill material, all of which was obtained from the Bayfront Beach. In all, about 247,000 CY of fill material were required for the two projects. Approximately 239,000 CY of this total came from the Bayfront Beach.

Apparently, sand mining along the ocean side was also occurring at about this period. This was accomplished by the railroad company by using a rail-mounted crane with a clamshell to load gondola cars. The sand was used for bedding and a variety of construction purposes in East Hawaii. Detailed records are not available for the volume of sand removed but letters refer to the sand mining going on near the Wailoa River where the beach was widest.

On 16 December 1921, high waves undermined the railway and deposited sand at various areas. All of Mooheau Park was inundated except for the inlandmost 100 feet. Opposition was raised by the Hilo Railroad Company over the dredging of sand from the beach for the Ponahawai Reclamation Project. They claimed that the dredging of sand from the earlier Waiolama project had compounded the heavy surf and had contributed to the undermining of the tracks through the removal of beach frontage. It was at about this time that the railroad company began dumping stone to form a crude revetment at the western portion of the bayfront shoreline. After some delay, the railroad relented their objections to further dredging of beach sand. Then on 3 February 1923, a tsunami (seismic sea wave) again damaged the railroad tracks along Hilo's bayfront shoreline. The net result of the dredging of sand and the high waves and tsunamis of 1921 and 1923, respectively, led to the erosion in the approximate area between STA 07+00 and STA 20+00. Two US Army Corps of Engineers maps from 1918 (Figure 3) and 1933 (Figure 4) indicate how the sea encroached up to the rail lines in this area. When a major tsunami hit the Hilo bayfront area on 1 April 1946, structures along the waterfront were totally destroyed, lives were lost, and damage to the rail lines were so extensive that the railroad company was forced into receivership.

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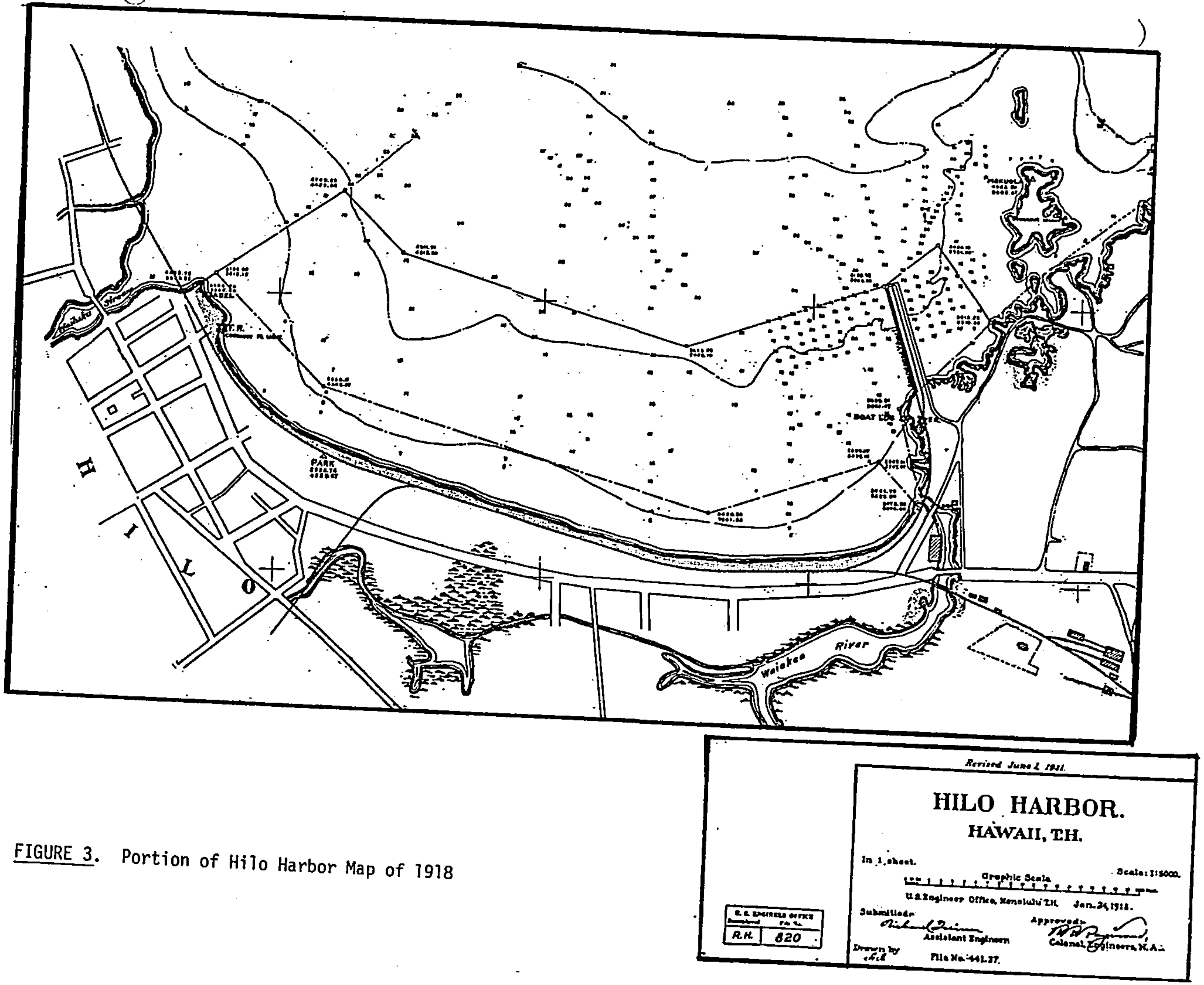

FIGURE 3. Portion of Hilo Harbor Map of 1918

FIGURE 3 - MAP CREDIT. Hilo Harbor - Hawaii, T.H., U.S. Engineer Office, Honolulu T.H., 24 January 1918. File No. 441.27. Originally compiled from various maps of latest data.

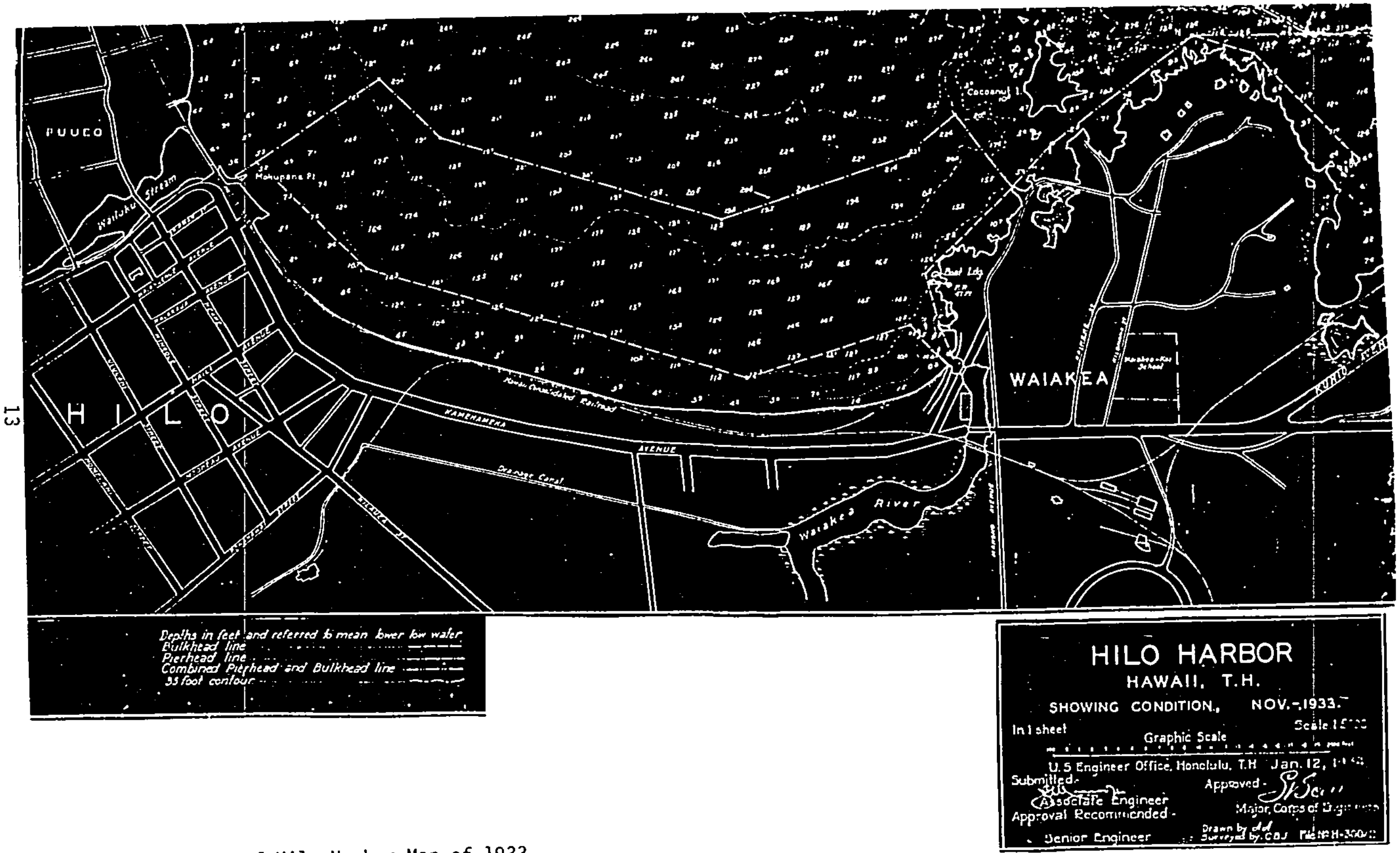

FIGURE 4. Portion of Hilo Harbor Map of 1933

FIGURE 4 - MAP CREDIT. Hilo Harbor - Hawaii, T.H., November 1933. File No. H-300/2. U.S. Engineer Office, Honolulu, T.H.

PHOTO NO. 3. SAND DREDGE AND FILLING IN OF WAIOLAMA MARSH AREA. Dredged sand being piped into marsh area near Waiolama Canal.

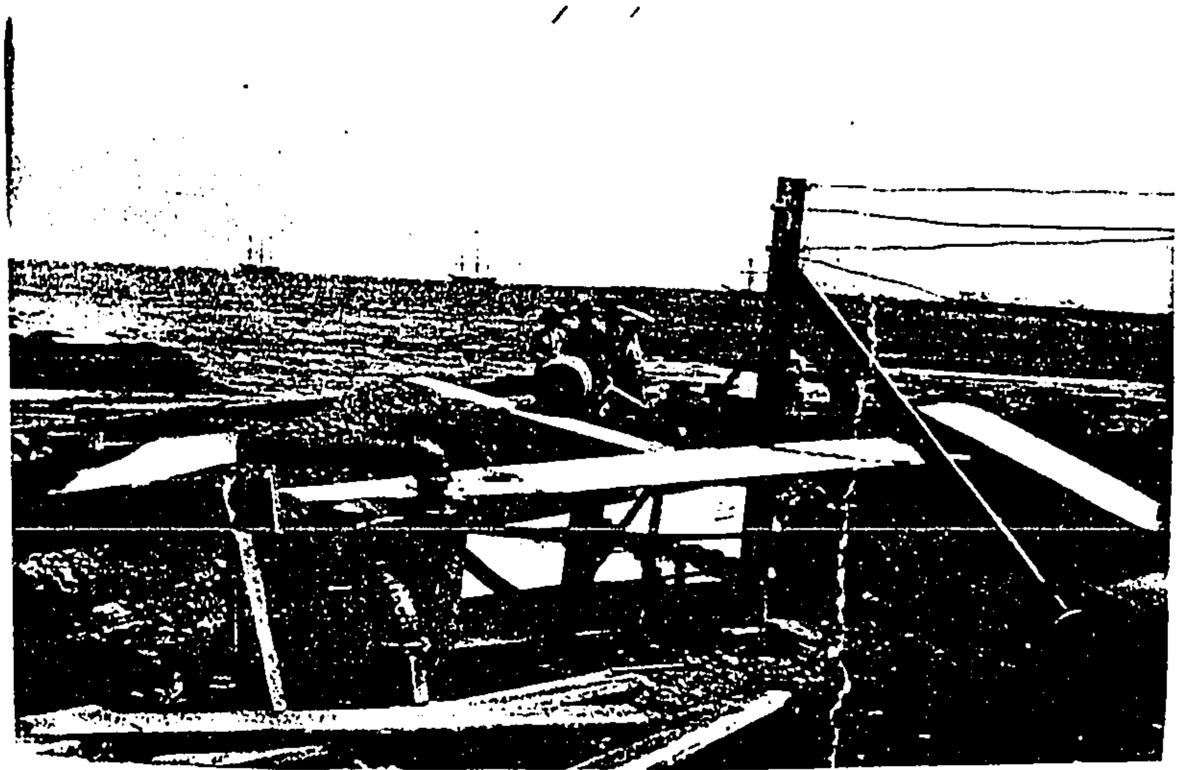

PHOTO NO. 4. HILO SEWER SYSTEM EXTENSION AT MOKUPANE POINT (December 19, 1904). Six-inch pump at work.

PHOTO CREDIT NO. 3. Hawaii Department of Public Works, Report for the Year Ending June 30, 1916 by B. Nakamura.

PHOTO CREDIT NO. 4. Public Works photo, Hawaii State Archives. Copied by B. Nakamura.

In 1957, the existing highway was constructed along the bayfront over much of the former Hilo Railroad Company rights-of-way. This included additional revetment work.

Of all the man-induced changes, the two aforementioned dredge and fill projects contributed most to the destruction of the bayfront beach. 239,000 CY of sand is roughly equivalent to a volume consisting of the entire 6,100 feet length of the historic beach shoreline, 100 feet wide, and 10.5 feet deep. A study performed by the US Geological Survey in 1984 estimated the amount of sand-sized sediment discharged by the Wailuku River to be approximately 4,500 CY annually. On this basis, it would have taken roughly 50 years to replenish the sand removed by the two projects given the present eastward littoral drift. Today, sections of beach can be seen in the area, although the tendency is for the sand to collect on the eastern reach beyond the existing rock revetment. A comparison of maps from 1891 (Figure 5) and 1977 (Figure 6) indicates a sizable area in this region has been reclaimed by the accumulation of sand. The change in shoreline between STA 00+00 and STA 07+00 indicates an accretion of sand. Since the highway now skirts the bay in this area, it seems clear that this is an area filled in by the railroad in 1902 and again in 1957 by the highway.

The next 1,300 feet of shoreline between Station 07+00 and Station 20+00 shows evidence of erosion. It is likely that the dredging of sand was undertaken in this section of shoreline. Highway construction maps suggest the present rock revetment was generally lain atop the location of railroad revetment washed out by the 1946 tsunami. The revetment once hugged the railroad tracks in this vicinity due to the loss of beach frontage.

Perhaps the most distinguishing feature seen from the comparison of the two maps is the amount of accretion evident in the remaining eastern portion of the bayfront shoreline. In some areas, the shoreline extends as much as 100 to 150 feet further out to sea than that recorded in 1891. One possible cause for the accretion in this area is the existence of the revetment to the west. The revetment may be preventing the reaccumulation of sand, to any degree, in front of the structure. Instead, sediment emanating from the Wailuku River bypasses the area of revetment and collects at the eastern end of the shoreline. US Army Corps of Engineers maps of Hilo Bay from 1918 to 1977 (Figures 3 and 6) indicate that the accretion of sand in this area has been a gradual, continuous process starting at around the 1920's (about the time the revetment was first constructed). This all but rules out single event occurrences, such as tsunamis, as being the sole cause of the accretion. The amount of the accretion evident in this region and the shoaling of the Wailoa River mouth, just downdrift and to the east, thus supports the claim that the revetment along the bayfront may be accountable for the relative abundance of sand and beach area at the east end of the bayfront and not the west.

The Natural Sand Source

The Wailuku River drains an area of 250 square miles and is the main source of sediment to Hilo Bay. Most sediment is in the form of suspended load. Of the total suspended load, between 25 to 48 percent is sand sized (0.062 to 2.0 mm). Suspended sediment and streamflow are measured at the Hilo gage (Station 16713000) by the U.S. Geological Survey (USGS). The annual average daily flow of the Wailuku River is 450 cubic feet per second. During a storm in November 1979, the peak flow exceeded 70,000 CFS and destroyed the Hilo gaging station. Sediment volume varies with rainfall intensity and streamflow. Intense storms with high flows produce the most sand.

During a 31-month period, from 1977 to 1979, the Wailuku River discharged 58,000 tons (annual average of 23,000 tons) of suspended sediment into Hilo Bay. Just one storm (February 1979) during that period produced 14,000 tons of suspended sediment which was 24 percent of the total (60 percent of the annual average) discharge during the 31 months.

The sand is black or dark grey because of its basalt origin. The sand weighs about 125 pounds per cubic foot. Average annual yield is estimated to range between 5,500 tons (22,000 tons x 0.25) and 10,600 tons (22,000 tons x 0.48). By volume, the range is between 3,300 and 6,300 cubic yards. These values may understate the volume of sand delivered because less frequent storms may produce disproportionately higher sediment yields.

Figure 7 shows the instantaneous suspended sediment discharge in tons per day. Rare runoff events such as the November 1979 peak of 70,000 CFS brought unusually large quantities of sand to the sea. In the following few months, much of this sand had moved east along the Bayfront where the Wailoa River mouth, as the eastern terminus of this littoral system, was almost blocked. This was caused by a large sand spit which built up along the easternmost edge of the Bayfront Beach and spilled around to the left bank of the Wailoa River at its mouth.

None of this sand build up can be attributed to the Wailoa River because it is not a sediment producer. Its drainage area is about one hundred times smaller than the Wailuku. It is a dry stream with a poorly defined streambed. During storms, it flows into Waiakea Pond (which is fed by springs) before reaching Hilo Bay. In the pond, its velocity slows to the point where sand and silt settle out long before reaching the river mouth. There is virtually no sediment movement from the Wailoa River to Hilo Bay.

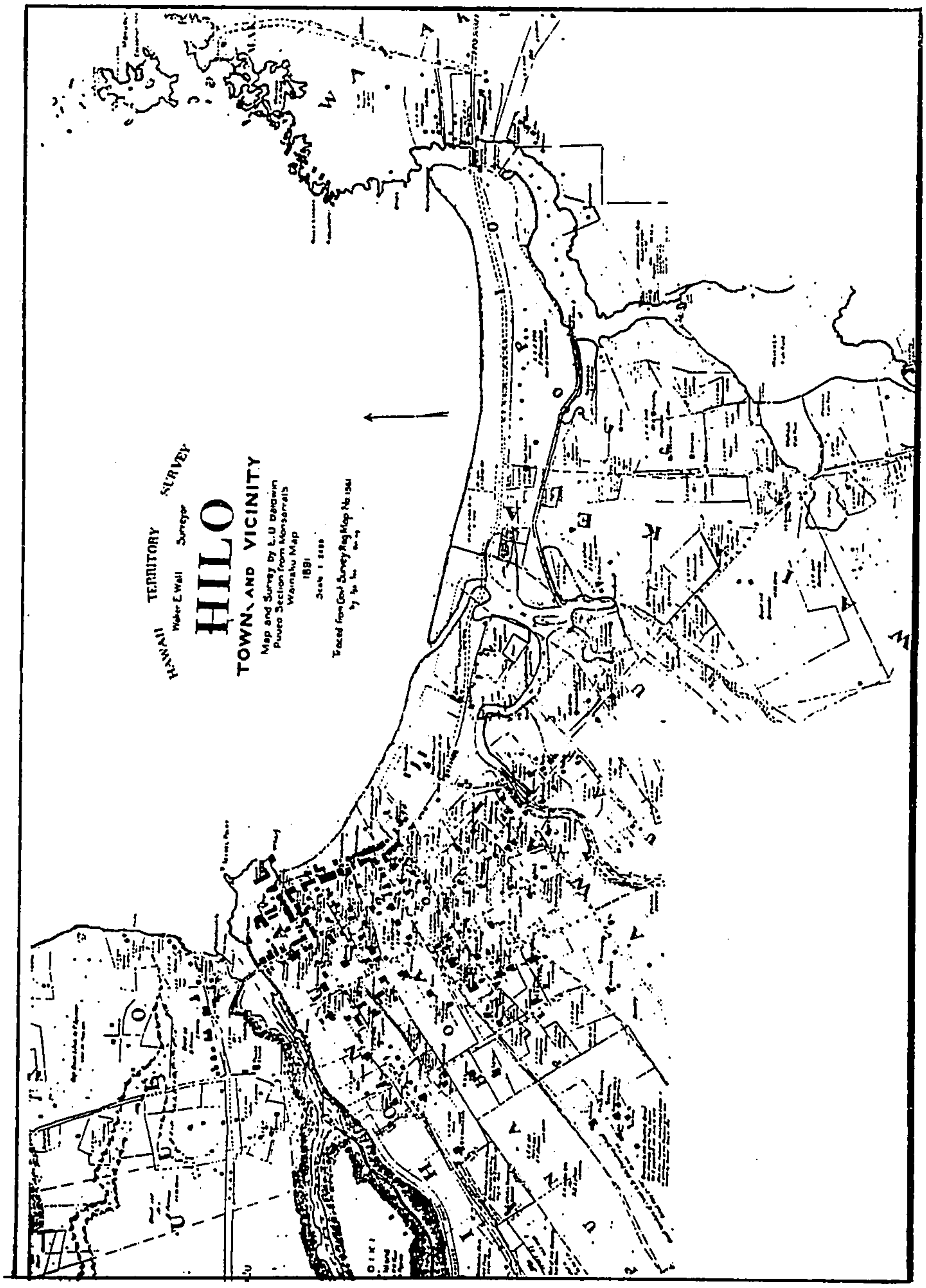

FIGURE 5. Portion of Hilo Harbor Map of 1891

FIGURE 5 - MAP CREDIT. Map and Survey by E.D. Baldwin of Hilo Town and Vicinity - 1891. Traced from Govt Survey Reg Map No. 1561. Hawaii Territory Survey.

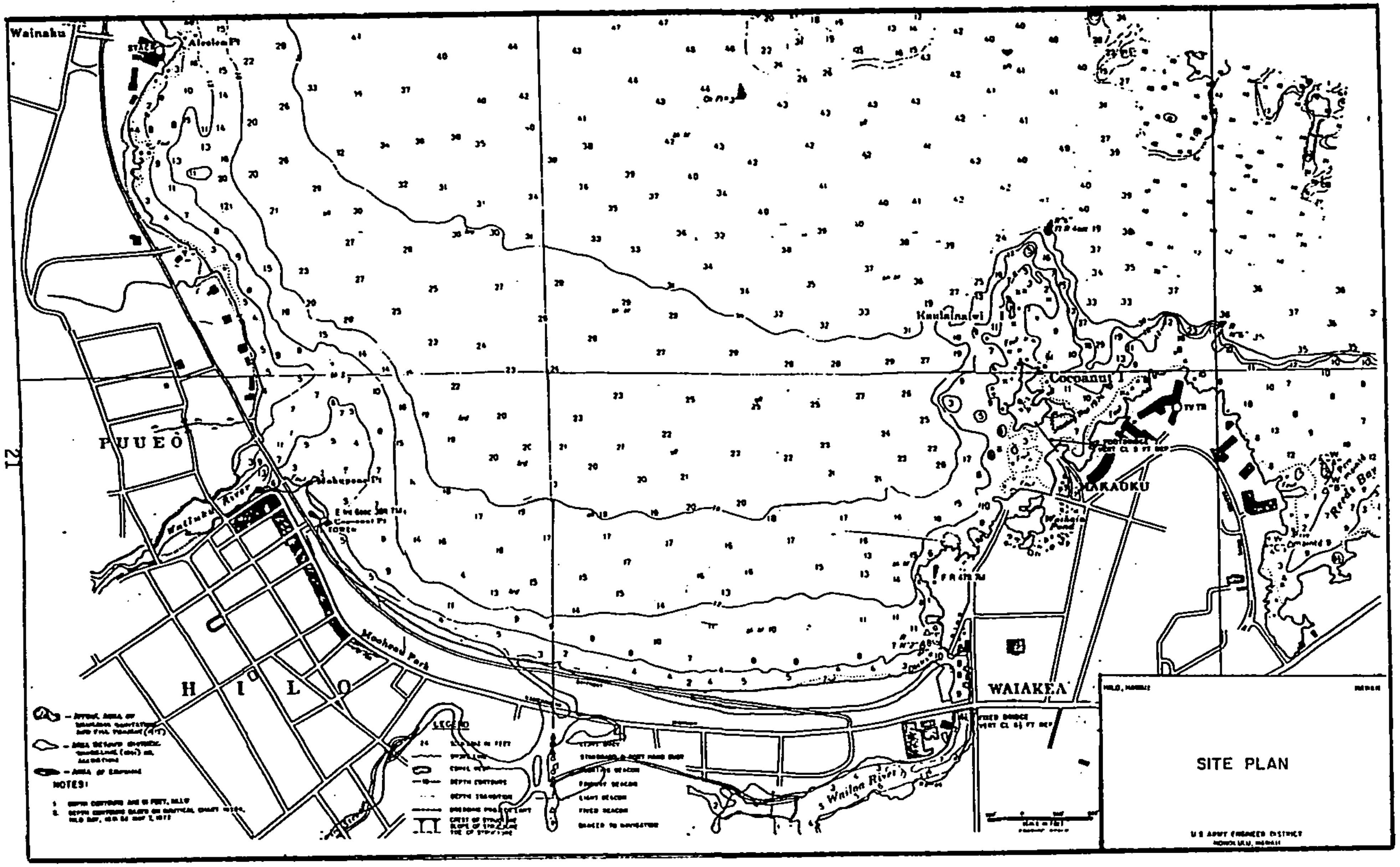

FIGURE 6. Portion of Hilo Harbor Map of 1977

FIGURE 6 - MAP CREDIT. Hilo Harbor, Site Plan - US Army Engineer District, Honolulu, 1977.

EFFECT OF TSUNAMI APRIL 1, 1946
ON RAILROAD BRIDGE AND TRACKS

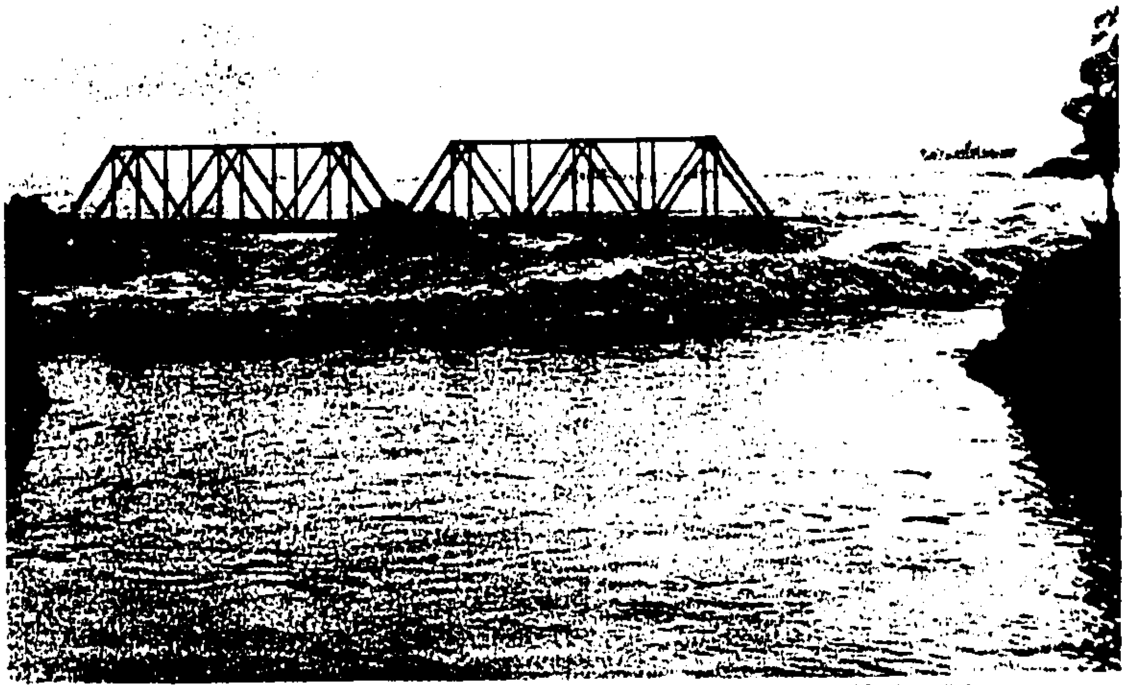

PHOTO NO. 5. Portion of railroad bridge across Wailuku River washed away by tsunami action.

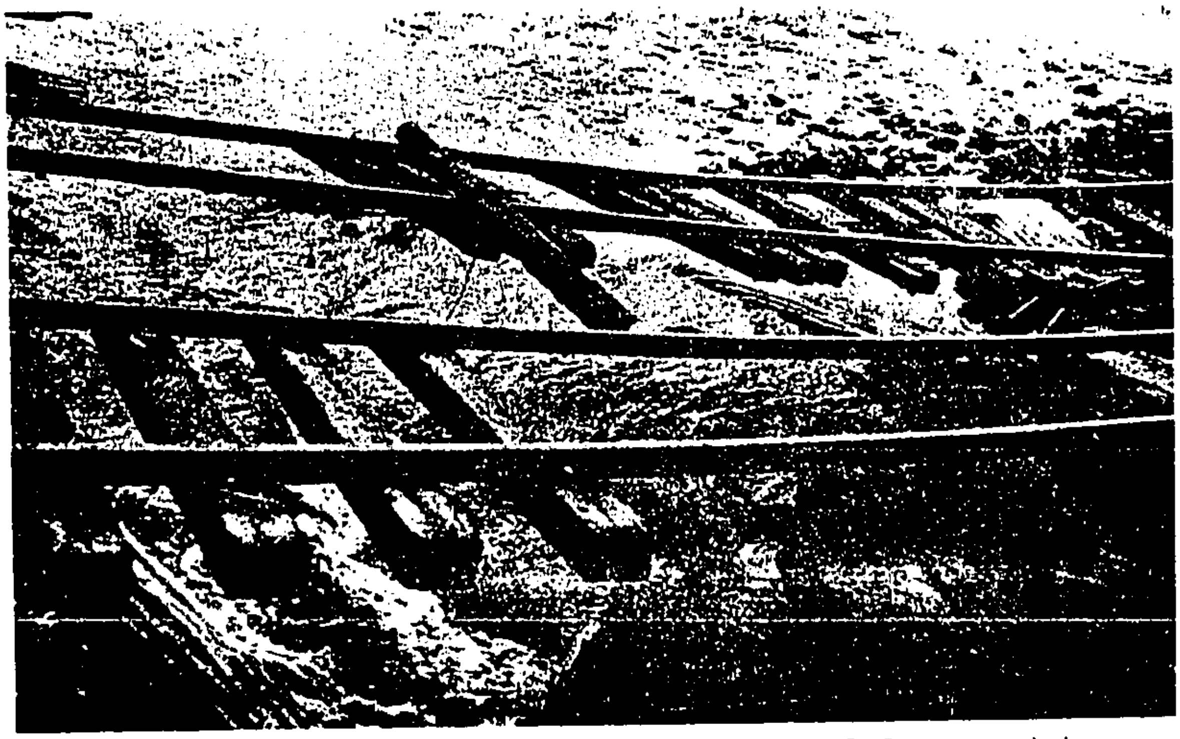

PHOTO NO. 6. Railroad tracks at Hilo Bay beach left suspended after sand washed out from underneath them.

PHOTO CREDIT NO. 5. Bishop Museum Photo Collection (CN76715)

PHOTO CREDIT NO. 6. By Kogasaki, April 1946. Lyman House Memorial Museum Photo (TB1-1).

Future Conditions (Without Project)

Erosion of the Bayfront shoreline would continue. The Bayfront Highway would be periodically closed due to overtopping storm waves, damage, and debris. Local residents would be denied full use of the historic beach. Hilo will continue to lose revenues because of the low visitor count in part due to the poor beach in Hilo Bay.

Problems and Opportunities

The two main problems along the Hilo Bayfront are storm wave damages to the highway and loss of the natural sand beach.

Shoreline erosion has been a continuing problem along the Bayfront. The net transport of sand is west to east and occurs during storm wave attack. These storms are relatively brief and infrequent, however, they have the potential to move a very large amount of sand in a short time. The small sandy beach on the eastern end of this reach represents a small portion of what once was a wider beach.

The State Department of Transportation is concerned about the impact of storm waves on the Bayfront Highway. Storm waves have overtopped the existing revetment, thrown rock and debris onto the highway, and forced the closure of the highway due to danger to motorists. Highway storm damage reports show that the Bayfront Highway was closed 13 times between 1970 and 1980, with an average closure time of 1.5 days (varied from a low of 6 hours to a high of 4 days).

The shoaling of the Wailoa River mouth is a problem for the commercial and recreational boats going to and from the two small boat harbors located in the Wailoa River. Erosion from the west end of the reach settles at the mouth of the Wailoa River.

The opportunity exists to restore the Bayfront beach, protect the Bayfront Highway from wave attack, prevent shoaling of the Wailoa River mouth, and enhance the human environment where the City of Hilo was to the shore of Hilo Bay.

Objectives

The following objectives were established for this study:

a. Protect the Bayfront Highway from overtopping.

b. Prevent shoaling of the Wailoa River mouth.

c. Enhance the human environment by providing recreational opportunities along the Bayfront which add to the economic benefit of the nation and of the island of Hawaii.

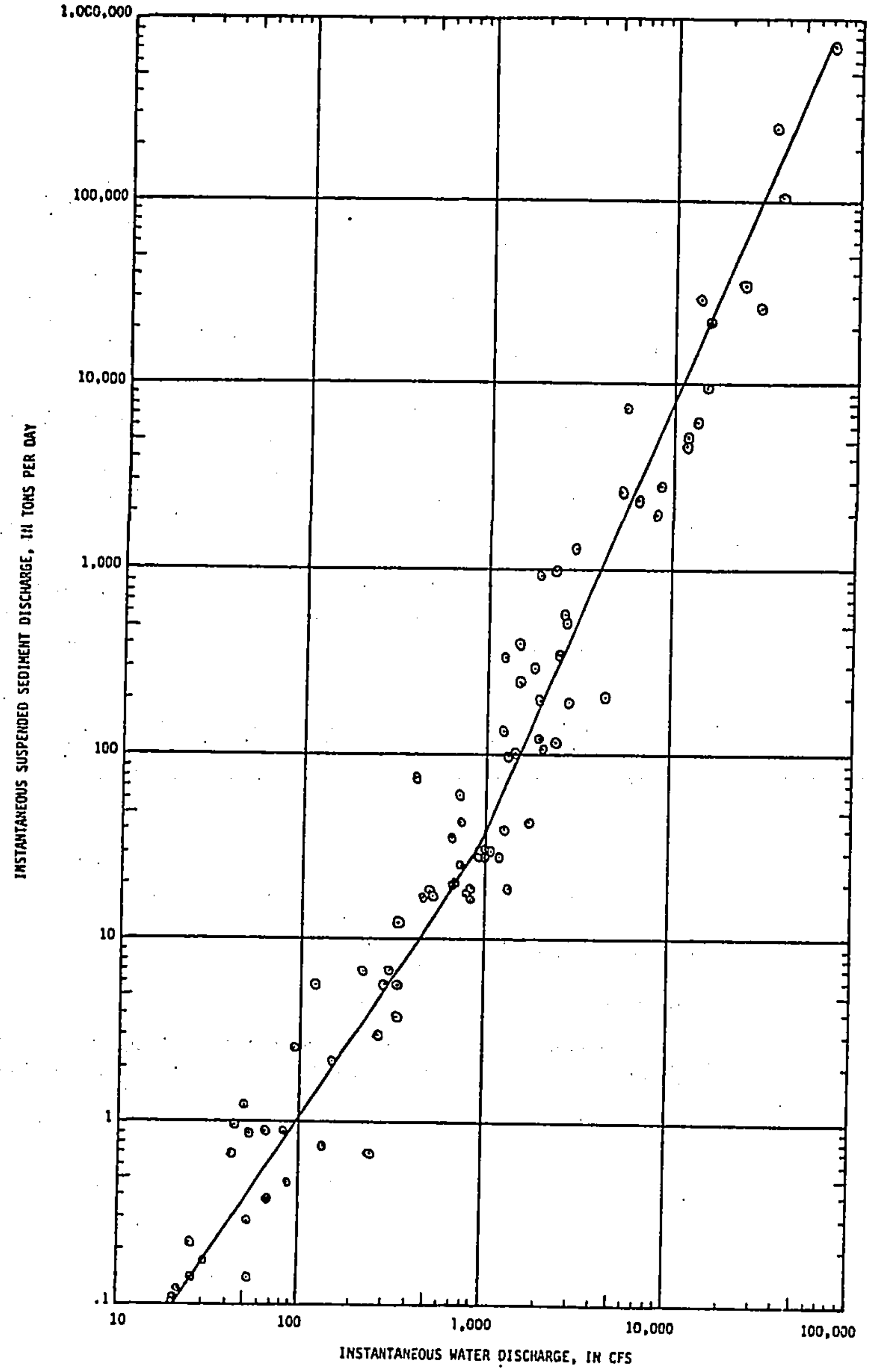

FIGURE 7. INSTANTANEOUS WATER AND SEDIMENT DISCHARGE CURVE, STATION 16713000, WAILUKU RIVER AT HILO

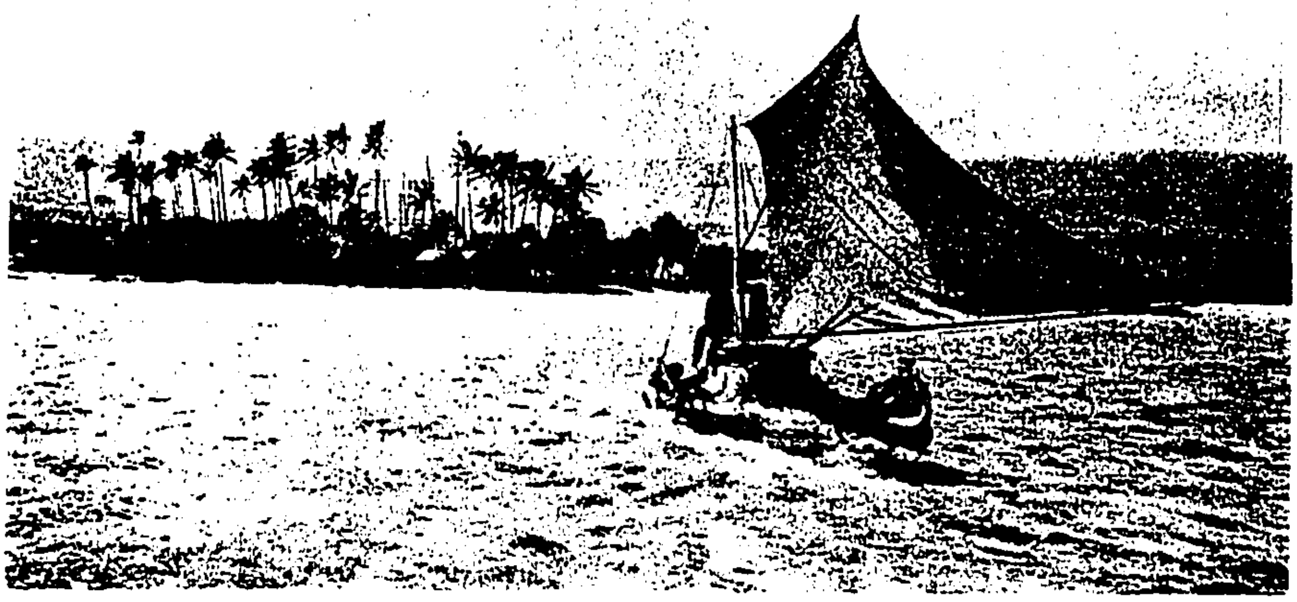

PHOTO NO. 7. HAWAIIAN DOUBLE-HULLED CANOE. Under sail at Hilo Bay.

PHOTO NO. 8. Hilo Bay Beach.

PHOTO CREDIT NO. 7. Lyman House Memorial Museum. Photo St615-6.

PHOTO CREDIT NO. 8. Bishop Museum Photo Collection (CP76731).

ALTERNATIVES

Available Measures

A broad range of diverse measures are available for application to solve the problems along the Bayfront shoreline. These are summarized below and are discussed in detail in the Supporting Documentation (Engineering, Design, and Cost).

Non-structural Measures

There are no true non-structural measures which fulfill the planning objectives. For example, "doing nothing" would not contribute to solving the present problems and is unresponsive to the needs of the study area.

Suggestions have been made that the Bayfront Highway be relocated inland. This would be a costly structural measure which would require a much longer highway alignment through developed urban areas. It would require new bridges, road crossings, entrances and exits. Moreover, realignment of the highway generates few benefits because no recreational uses of the beach are gained unless the project is coupled with structural measures to restore and maintain the Bayfront Beach.

Structural Measures

Structural measures to reduce shoreline erosion, to stabilize sand movement, and to prevent more overtopping may be used singly or in combination depending upon the purposes to be met.

Revetments along shore are a classic approach to reducing wave energy and stabilizing the shoreline. A revetment may be constructed from several different materials depending upon the required lifespan and conditions of use at the project site. Rock revetments are practical in Hawaii because often, large size stone can be placed at a lower cost than can precast concrete devices such as doloses. Structure made of wood or sheet pile are less commonly used because of their relatively higher cost and frequent maintenance requirements. Revetments may also be constructed from sand filled bags or tubes. The "Longard" tube is an example of a device which can be placed at very low cost. However, maintenance may be a problem depending on the conditions of use at the site of application.

Detached breakwaters serve to absorb wave energy. Areas of calm water and sand spits called "Tombolos" may form between the shoreline and the detached breakwater. These structures are more costly to maintain than are onshore revetments. They function well in situations where the littoral action is predominantly onshore and offshore. They do not always work well when the littoral currents move along shore as they do at the Bayfront shoreline.

Groins, jutting perpendicular to the shoreline are effective in stabilizing beaches in longshore transport situations. Groins can be made of a variety of materials but in Hawaii, stone is often cost effective.

A beach can be an effective wave energy absorber which will serve as a measure to control erosion. It will function effectively providing there is sufficient periodic nourishment to replace inevitable sand losses. The beach configuration must be ample in dimensions to permit fluctuations due to intensive wave attacks and the concomitant rebuilding which must follow. Natural beaches are ideal since they have stabilized over time and presuming there are no alterations in the backshore or offshore conditions. Restoration of natural beaches where manmade alterations have occured is a complex endeavor which is often desirable from the standpoint of retrieving recreation, aesthetic, and environmental enhancement benefits.

Initial Plan Formulation

Initially, available measures were formulated into alternative plans with the intent of meeting the planning objectives where possible. Costs were estimated for these initial alternative plans. The details of this effort are discussed in the Supporting Documentation (Engineering Investigations, Design and Costs) which is bound as part of this report. The following discussion summarizes the initial plan formulation effort and compares the costs and effects in preparation for screening the initial set of plans in order to choose several for more detailed evaluation.

Beach Replenishment with Groins

Description. Where there is a predominant longshore transport of sand in one direction, groins can be an effective method for retarding erosion of a restored beach. The groins may be constructed perpendicular to the shoreline and sand accumulates on the updrift side. This assists the beach configuration to orient itself to conform to the predominant wave crests and thus reduce longshore transport. The trapping of sand on the updrift side can result in downdrift erosion. To cope with this, a series of groins must be built and artificially filled initially. The groins can be designed to permit some sand transport to continue either around the end or over the groin, or to act as a complete littoral barrier. Because of the unknown volume of sand transported to the beach for nourishment naturally by the Wailuku River, it is proposed that the beach be restored using offshore sand and the groins constructed to permit very little transport over and around them in order to reduce the periodic nourishment requirements. An adequate supply of suitable sand is available about 800 feet offshore of the old Wailuku Sugar Mill site (see Figure 2). See the Supplemental Documentation (Geology) for a description of the sand source.

Groin Design. A general plan for beach replenishment stabilized by a series of groins is shown on Figure 8 The first groin is spaced at a 700-foot distance from Station 0+00, and the rest at 600-foot intervals from Station 7+00 to Station 36+00. The potential longshore energy flux, and thus the sediment transport, is generally low and reverse direction at about Station 40+00, so there should be little adverse impact to the downdrift beach past this point.

The landward ends of the groins would be tied to the existing rock revetment, and the groin length is determined by the shape of the fillet oriented parallel to the prevailing wave fronts and assuming a minimum beach crest width of 50 feet on the updrift side of the fillet. Consideration was also given to limiting the seaward extent of the groin to an approximate 10-foot depth. The

ALTERNATIVES

Available Measures

A broad range of diverse measures are available for application to solve the problems along the Bayfront shoreline. These are summarized below and are discussed in detail in the Supporting Documentation (Engineering, Design, and Cost).

Non-structural Measures

There are no true non-structural measures which fulfill the planning objectives. For example, "doing nothing" would not contribute to solving the present problems and is unresponsive to the needs of the study area.

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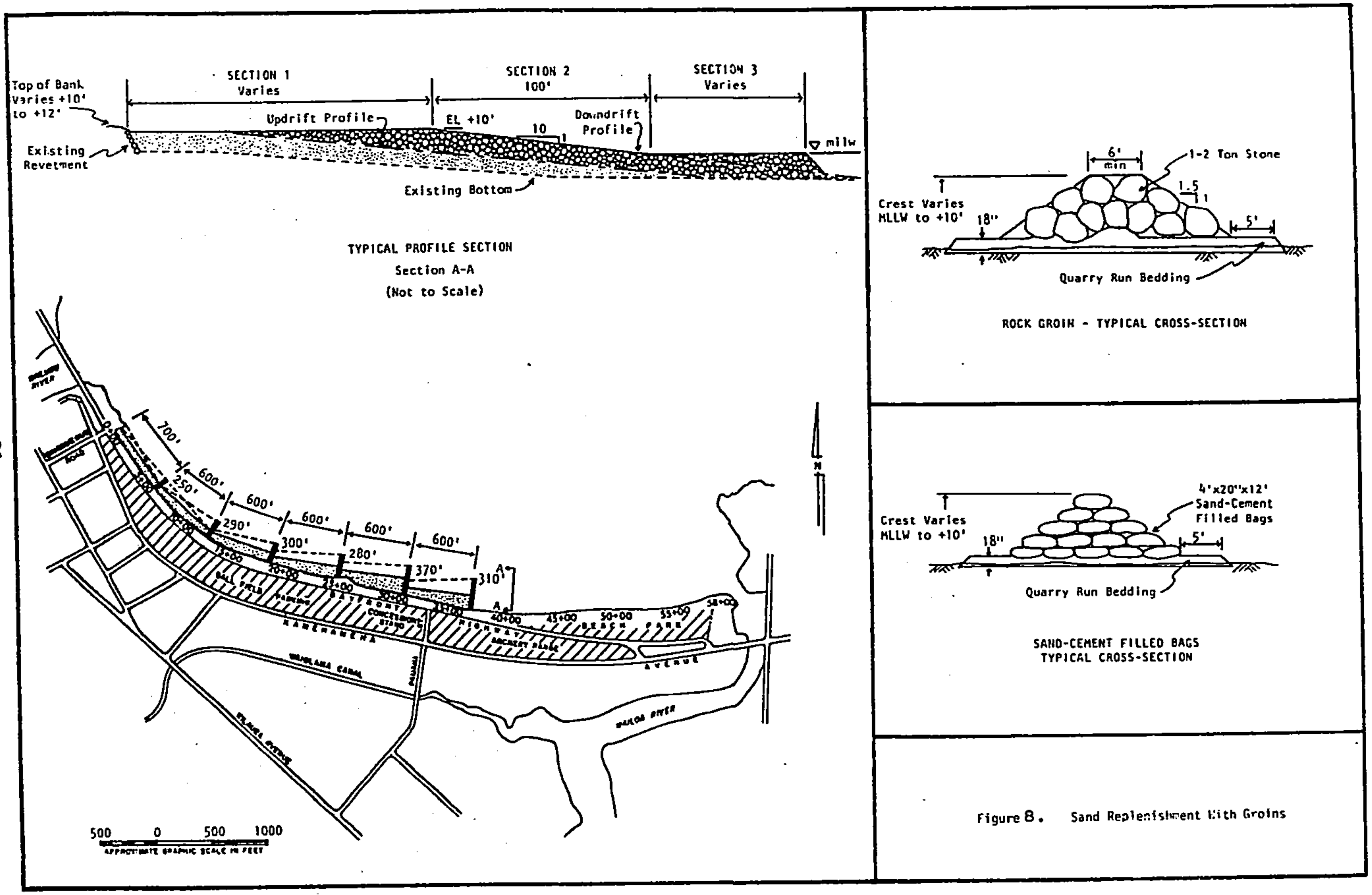

Figure 8. Sand Replenishment With Groins

groins are designed to allow very little sand bypassing around the ends or over the top. The groin lengths are divided into three sections: Section 1 extends horizontally at the beach crest elevation (+10 feet) for the maximum crest width; Section 2 slopes 1 on 10 along the beach slope to the mllw line; and Section 3 extends seaward with a crest elevation at about mllw a sufficient distance to prevent sand bypassing around the end, assuming a 1 on 10 beach slope below mllw to intersect the existing bottom.

Groins could be constructed by using either standard rock rubblemound techniques or, as an alternative, the less expensive and probably less durable sand-cement filled bags.

Beach Replenishment with Detached Breakwaters

Description. A detached breakwater is a structure constructed offshore, parallel to the shoreline, which reduces wave energy and the direction of wave propagation in its lee. They can be very effective for controlling the longshore transport of sand by reducing or eliminating the wave energy reaching the shore. Their effectiveness for erosion control is directly proportional to their waive attenuation. Littoral drift deposits in the lee of the breakwater, and if the wave energy is sufficiently reduced, the sand deposits can form natural groins, called tombolos, which stretch from the shoreline to the structure and completely block longshore transport. The breakwater need not act as a complete littoral barrier, however; a low elevation overtopping detached breakwater may be economical and still reduce longshore transport. Adequate protection can usually be achieved if the structure causes the waves to break, but still transmits some of the wave energy. A series of short breakwaters can have the same general effect as a larger structure or a series of groins, although their efficiency as a sand trap may be reduced.

Design. A restored beach stabilized by a series of detached breakwaters is shown on Figure 9. Sand would be initially placed to form a minimum 50-foot-wide crest at the +10-foot elevation. A series of six detached breakwaters, each 400 feet long and separated by a gap of 200 feet, would be constructed 150 feet offshore at the six to eight-foot depth. The breakwaters would extend from Station 2+00 to Station 36+00.

Rock rubblemound is considered the only feasible construction technique for the breakwaters. Sand-cement filled bag construction would require 800 to 1,000 bags for each breakwater, most of which would have to be filled underwater. Longard tubes would not have the necessary crest elevation or width.

Perched Beach and Artificial Surf Shoal

Description. The perched concept involves retaining a protective beach or shallow offshore area by means of terracing using submerged breakwaters or beach retaining sills. Wave energy is dissipated while propagating over the shallow region by breaking and through bottom friction and, thus, sediment transport along the shoreline is reduced. As with other protective beach systems, an abundant supply of sand in the active wave zone is necessary to artificially fill the terraces initially, and probably to nourish the beach periodically. Several terraces can be used to maintain a wide dry beach at the desired elevation.

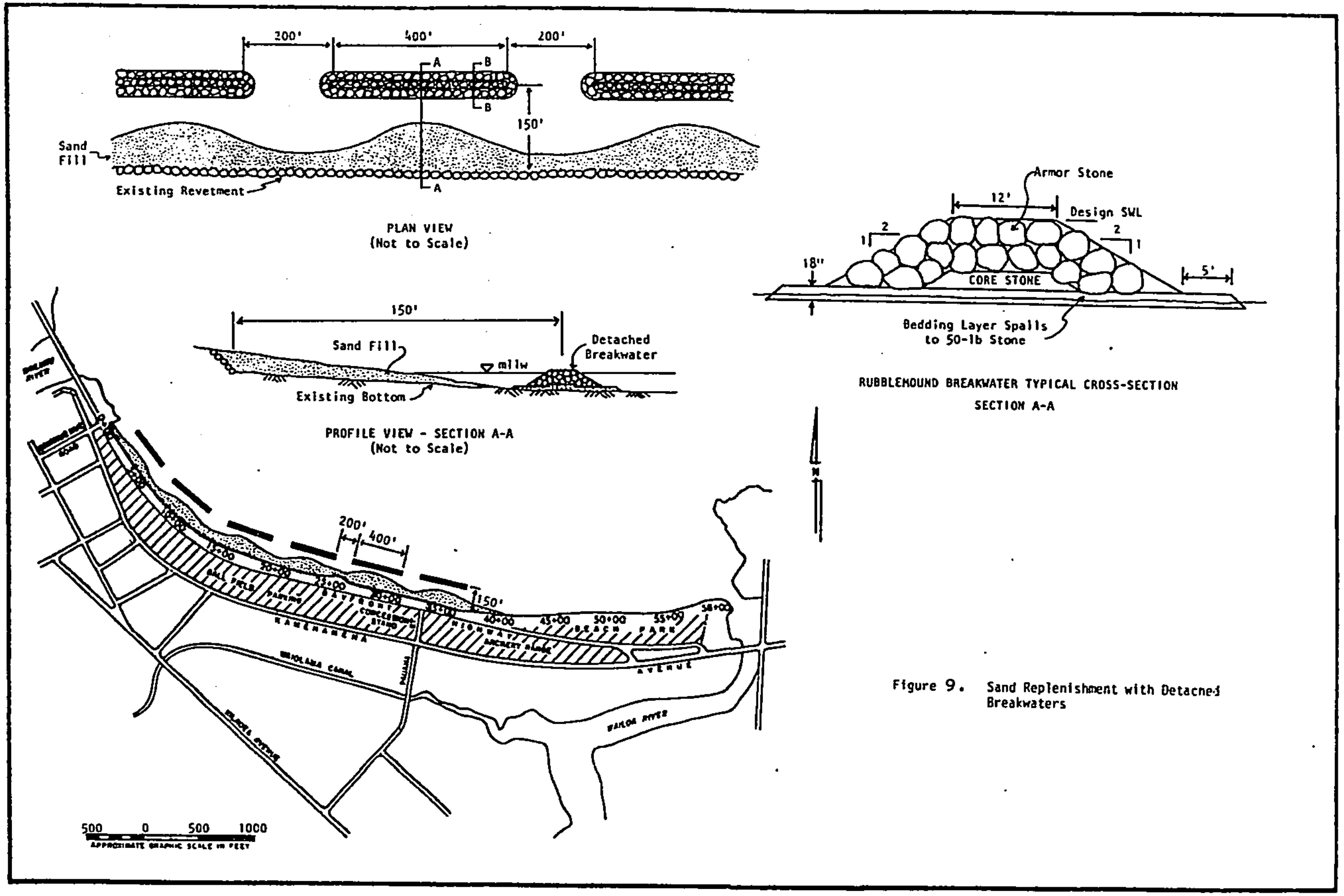

Figure 9. Sand Replenishment with Detacned Breakwaters

The concept of constructing a man-made shoal area, such as a perched beach, to provide shore protection and to provide recreational opportunity by creating or enhancing surfing waves is also possible. A report prepared by Moffatt & Nichol, Engineers (1981) for the Los Angeles District of the Corps of Engineers discusses the general feasibility of constructing an artificial surf shoal or modifying coastal structures to create or enhance recreational surfing.

A perched beach and surf shoal using Longard tubes to construct the sills is shown on Figure 10 and described in detail in the following paragraph.

Design. The perched beach would be constructed using double 40" Longard tubes parallel to shore to form a terraced beach slope. One double tube sill would be placed 100 feet offshore at the approximate 6-foot depth and then backfilled with sand, and the second double tube sill would be on top of the fill 50 feet from shore at the approximate mllw line and backfilled. A double 40" tube would also be run perpendicular to shore at 600-foot intervals to compartmentalize the perched beach and act as a groin to retard any longshore sand transport. Protection against scour and undermining of the tubes would be provided by placing them on woven plastic filter cloth secured by 10" sand-filled "sacrificial" tubes. The perched beach would extend from Station 5+00 to 35+00.

The surf shoal would be constructed between Stations 0+00 and 5+00. Longard tubes would be used to create a terraced, parabolic-shaped shoal extending approximately 220 feet seaward of the existing shoreline, as shown on Figure 6. This location has the greatest exposure to approaching waves without being immediately adjacent to the Wailuku River mouth and the potential for river debris damage to the Longard tubes. A small change in water depth produces a large change in wave height near the breaker zone, and the shoal, with contours at an angle to the incident wave approach, would produce a rapid variation in wave height along the wave crest line. The shoal would refract the incident waves and cause them to peak up and thus help to initiate breaking.

Rock Revetment

Description. Should a protective beach not be desired, a rock revetment could be used to provide protection against damage and overtopping of the bayfront highway. Properly designed rock revetments are durable, flexible, and highly resistant to wave damage.

Design. The most common method of revetment construction, and generally the most satisfactory, is to place armor stone sized according to the design breaking wave height over an underlayer and bedding layer designed to distribute the weight of the armor stone and to prevent the loss of shoreline material through voids in the armor stone. Generally, the slope of the revetment should not be steeper than 1V on 1.5H. Toe scour protection can be provided by constructing the foundation as much as practicable below the maximum depth of anticipated scour (a general rule is one design wave height below the sea bottom fronting the structure) and extending the toe seaward to provide excess stone to fill the possible scour through and to provide wave protection to the toe to prevent scour.

Evaluation of Initial Alternatives

Summaries of the initial alternatives (including their respective construction cost estimates) are displayed in Table 1. All of the initial alternatives meet

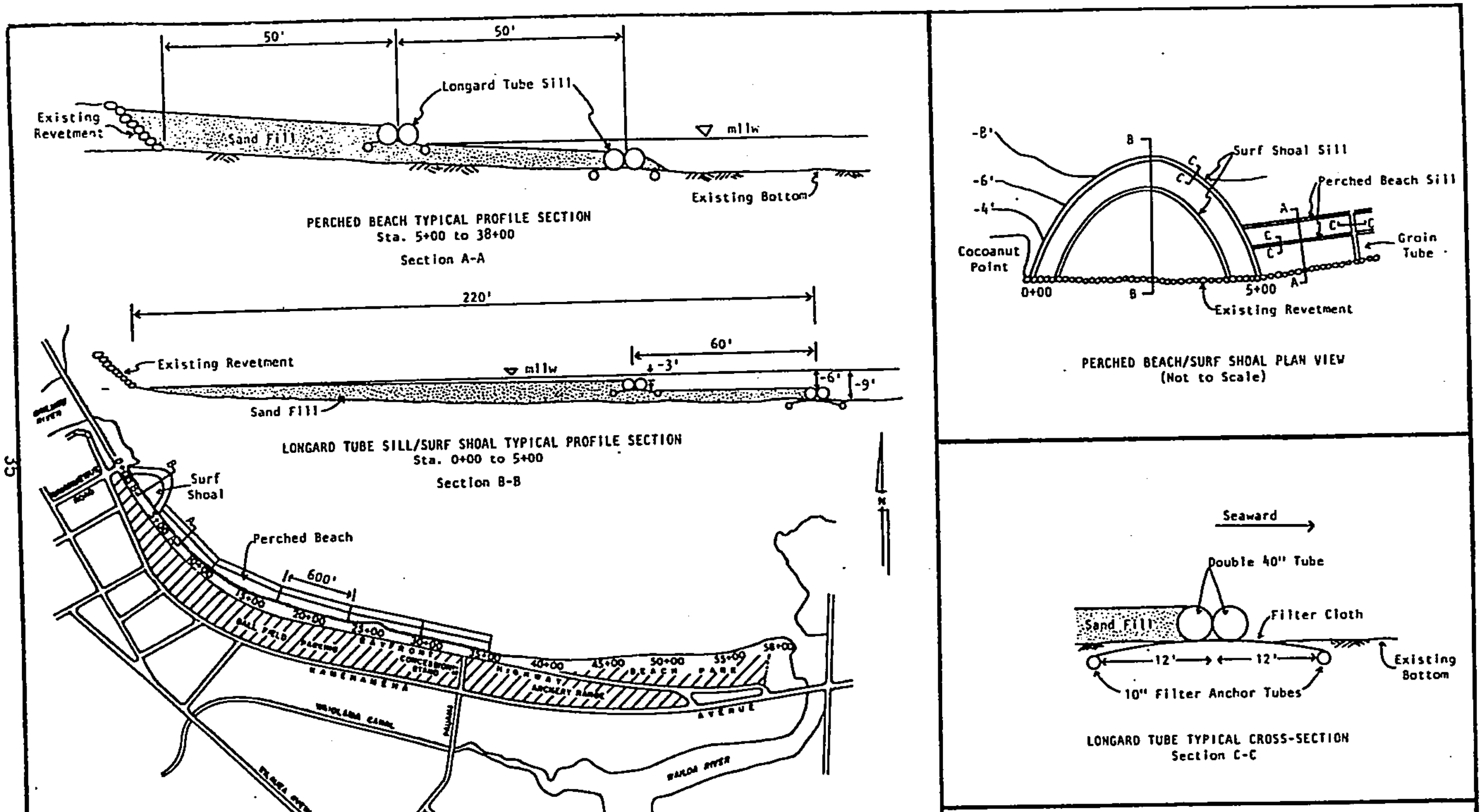

Figure 10. Perched Beach and Surf Shoal

the project objectives fully with the exception of a Rock Revetment which has no environmental or recreational enhancement. All of the initial alternatives are effective and constructable. The initial alternatives differ when considering maintenance, reliability and cost.

Screening of Initial Alternatives

The initial alternatives were screened based on the evaluation criteria and costs shown in Table 1. These alternatives were developed to allow trade-off for major features of shore protection plans which might be considered for the site. Detailed description of this process and of the computer model used to evaluate the effects of storm waves on the initial alternatives can be found in the Supporting Documentation (Engineering, Design and Cost). The initial alternatives were then compared (see the summary of this process in Table 1) in order to choose the most appropriate approach and to generate suitable components into a comprehensive plan for estimating and evaluation.

The costs of the initial alternatives were originally estimated at October 1982 price levels. Table 1 shows an update of prices to October 1984 price levels. Although five initial alternative measures are shown in Table 1, only two distinct plans are being compared. One of these is shore protection using beaches which is represented by the first four initial alternatives. The second is shore protection using a revetment without beaches (and without recreational benefits) and is represented by the fifth initial alternative measure.

The first three variations of shore protection with beaches are nearly identical in cost. Only the fourth variation is significantly less costly. Unfortunately, the technology of this alternative (based on manmade fibers woven into the form of large diameter tubes into which sand would be pumped) is not presently considered to be a totally reliable method of shore protection because of the potential for rupture of the tubes due to vandalism or damage from storm wave tossed objects such as rocks or logs. Therefore, this low-cost plan which would have provided extensive recreational benefits was not considered further. However, it is not to be discarded lightly and may have merit, particularly if a project were to be implemented by local interests where in this situation no catastrophic damage would result from failure of the tubes.

Sand Replenishment With Groins meets all evaluation criteria. Rock groins were chosen over sand-cement bag groins because the life span and durability of rock is well known. Testing has shown significant failure rates of bags and the difficulty of good and placement caused this measure to be rejected on the basis of practical considerations.

Sand Replenishment With Detached Breakwaters was rejected because of the anticipated requirements for more frequent and costly nourishment of sand which would be lost during storm wave attacks. Also this, the highest cost measure, would be less effective in a Bayfront application than would be groins.

The Perched Beach With Surf Shoal, was the lowest cost measure which met all planning objectives. The high risk of frequent damage and potentially high maintenance, repair and nourishment costs caused this measure to be viewed in its totality as technically unacceptable. However, there is an opportunity to integrate a portion of this plan into the final alternatives in order to reduce costs and add surfing benefits.

A Rock Revetment at the lowest cost did not meet all the planning objectives. However, it was carried on to final planning with the objective of including a full complement of alternatives for review.

DESCRIPTION OF PLANS

Two final plans were formulated based on the screening of initial alternative measures. Their costs include not only the first costs of construction which are compared in Table 1 for the initial plans, but also the added costs of engineering and design, supervision and administration, operation and maintenance and, in the case of Plan A, periodic nourishment.

The first final alternative plan, called Plan A, is a shore protection plan using a manmade beach suitable for recreation as the protective structure. Plan B, is a shore protection plan using a rock revetment which does not provide for recreation.

Plan A is a composite plan formulated from components discussed and separately costed as initial alternatives. It includes the use of groins, sand replenishment and nourishment, rock revetment, and longard tubes. Plan A was formulated to take advantage of the best features of several of the initial alternative measures. It has a lower cost than each of the first initial alternative measures, yet provides virtually the same protection while offering considerable more benefits in terms of recreational opportunities. It uses longard tubes and rock revetments for shore sections to take advantage of low costs. It exemplifies value engineering.

Plan B is the basic revetment plan described in the initial alternatives. The cost is higher than shown in the initial alternative measures (Table 1) because of the added cost items discussed in a previous paragraph.

Plan A (Figure 11), or the Recreational Enhancement Plan, combines elements of several initial alternatives considered in order to meet the project objectives. Beginning at the west end of the beach, Plan A includes the construction of a surfing shoal, a protective beach (providing 250,000 square feet of dry recreational beach area) stabilized by 4 rock groins, a rock revetment (crest elevation 15 feet and 1,200 feet long), and a 200-foot long jetty groin near the Wailoa River.

Plan B (Figure 12) or the Shore Protection Plan, consists of the construction of a 3,500-foot long rock revetment (crest elevation 15 feet).

Costs and benefits for both plans use 1984 price levels at 8-1/8 percent interest.

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Costs and benefits for both plans use 1984 price levels at 8-1/8 percent interest.

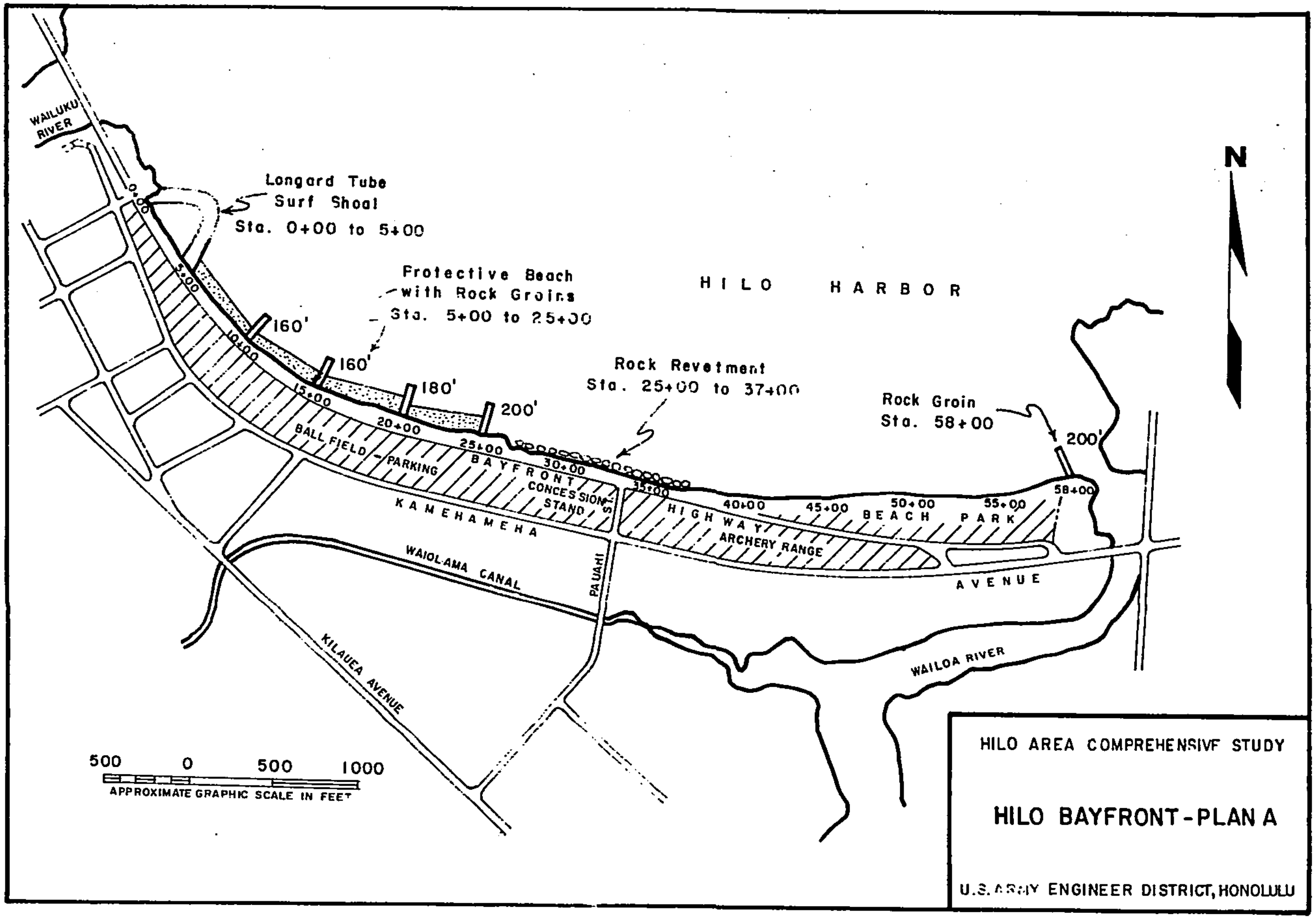
Table 1 Evaluation of Initial Alternatives

Evaluation Criteria	Sand Replenishment With Groins: Rock Groins	Sand Replenishment With Groins: Sand-Cement Filled Bags	Sand Replenishment With Detached Breakwaters	Perched Beach With Surf Shoal	Rock Revetment
I. Meets project objectives					
a. Shore protection for the bayfront highway	A stable protective beach would dissipate wave energy and provide storm wave pro-tection for the bayfront highway.	Would provide protection similar to that of the beach stabilized by rock groins.	Would provide excellent storm wave protection for the shore-line by retaining a protective beach as well as dissipating wave energy by initiating breaking well offshore.	A stable protective beach and shallow nearshore depths would dissipate wave energy and provide storm wave pro-tection.	The non-overtopping rock revet-ment would provide complete pro-tection for the bayfront highway.
b. Recreational beach enhance-ment	A dry sand recreational beach area of approximately 400,000 square feet would be provided. Beach shape and orientation would vary seasonably.	Same as with rock groins.	Longshore sand transport would be significantly reduced by the reduction of wave energy at the shoreline.	The "compartmentalizing" of the shoreline would greatly reduce longshore transport, however, some transport over the groin tubes may occur due to their relatively low elevation.	No reduction in the predominant longshore transport toward the Wailoa River.
c. Reduction of longshore trans-port toward the Wailoa River	The groins would significant-ly reduce the longshore trans-port of sand by aiding the beach face to achieve a stable configuration parallel to the predominant wave crests. Only a small amount of sand would by-pass the groins during severe storm wave conditions and/or high sediment discharge from the Wailoa River.	Same as with rock groins.	A dry sand recreational beach of approximately 300,000 square feet would be provided.	A dry sand recreational beach of approximately 150,000 square feet would be provided. Access to the water may be hindered by the Longard tube sill. The artificial surf shoal would enhance recrea-tional surfing, however, the quality of the waves for surfing would vary consider-ably with tide level and incident wave direction and height.	No significant change in the shoreline from existing condi-tions, and increased wave energy reflection may further reduce the seasonal sand accretion along the shore.
II. Engineering effectiveness and constructability	The natural beach slope would be a very effective energy absorber, and the use of groins would stabilize the protective beach and essen-tially eliminate longshore sand transport. Standard rock rubblemound construction techniques would be utilized for the groins. This plan would provide an effective and relatively maintenance-free protective and recrea-tional beach.	If properly constructed, this plan would be as effective as the beach with rock groins. However, there is some question whether the bags can be properly filled with the sand-cement grout, particularly as they would have to be filled in-place and underwater along much of the groin length.	Properly designed detached breakwaters can be a very effective method for stabi-lizing and protecting a sand shoreline. More detailed engineering design studies are required prior to actual implementation of a beach nourishment project stabi-lized by detached breakwaters to fully assess the required breakwater spacing, crest elevation and width, and dis-tance from shore to insure that the desired energy reduc-tion is achieved. The break-waters would be built using standard rock rubblemound construction techniques.	The perched beach concept is an effective way to dissipate wave energy seaward of the shoreline. The primary advan-tage of Longard tubes is the speed and ease with which the sills can be constructed once the sand is in place for fill-ing. They are functionally effective as long as they remain structurally sound (intach and not torn) and are not displaced. The surf shoal concept must be studied using a hydraulic model in order to determine the most effective shape, size, and configuration for producing surfing waves. The percentage of time that it would provide surfable waves is probably low due to the generally low prevailing wave heights along the bayfront shoreline.	A properly designed and con-structed rock revetment would provide proven protection for the highway. Construction is relatively easy.

Table 1 . (continued)

Evaluation Criteria	Sand Replenishment With Groins: Rock Groins	Sand Replenishment With Groins: Sand-Cement Filled Bags	Sand Replenishment With Detached Breakwaters	Perched Beach With Surf Shoal	Rock Revetment
III. Maintenance requirements	The groins are designed to minimize sand by-passing, and thus reduce the need to periodically nourish the beach. Some loss of sand can be expected, however, and a periodic nourishment rate of about 10 percent of the original beach fill every 15 years is considered reasonable for planning purposes. The rock groins are durable and long-lasting, and should require only nominal maintenance.	The durability of the sand-cement filled bag groins is directly related to the degree to which the bags can be evenly filled with the correct grout mixture. Properly filled, and if not displaced prior to hardening of the grout, the groins will be reasonably durable. If improperly filled (uneven mix or loss of cement during filling), the bags will readily crack and be subject to possible displacement by storm waves. Provided the groins remain functional, the beach nourshment requirements would be the same as for the rock groin plan.	Properly designed detached rock rubblemound breakwaters are durable and long-lasting. Beach nourishment requirements may be higher than for the groin plans due to sand being moved seaward between the breakwaters due to strong rip currents formed during severe storm wave attack.	Longard tubes are very vulnerable to damage by vandalism and floating debris. Surf-board fins could be a source for tearing or puncturing the tubes used to contain the surf shoal. Once torn, wave action can rapidly winnow sand out of the tube rendering them ineffective. Beach nourishment requirements are estimated to be similar to that for the detached breakwater plan.	A properly designed and constructed rock revetment is a time proven, durable and relatively maintenance free method for protecting a shoreline from erosion and the backshore area from storm wave damage.
IV. Cost (see Appendix A)					
Mob and Demob	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 30,000
Sand Fill*	5,600,000	5,600,000	4,400,000	1,289,000	0
Structures	1,571,000	1,196,000	3,284,000	1,155,000	2,372,000
Contingency (±15%)	1,109,000	1,044,000	1,186,000	396,000	358,000
TOTAL COST	$8,480,000	$8,040,000	$9,070,000	$3,040,000	$2,760,000
(Updated to Oct 84)	9,543,000	9,124,000	9,991,000	3,356,000	2,799,000

*Dredging quantity is twice the desired in-place fill quantity.


HILO AREA COMPREHENSIVF STUDY
HILO BAYFRONT - PLAN A
ENGINEER DISTRICT, HONOLULU
HILO HARBOR
Longard Tube
Surf Shoal
Sta. 0+00 to 5+00
Protective Beach
with Rock Groins
Sta. 5+00 to 25+00
Rock Revetment
Sta. 25+00 to 37+00
Rock Groin
Sta. 58+00
160'
160'
180'
200'
200'
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55+00
58+00
WAILUKU RIVER
BALL FIELD
PARKING
BAYFRONT
CONCESSION STAND
HIGHWAY
ARCHERY RANGE
BEACH PARK
KAMEHAMEHA
AVENUE
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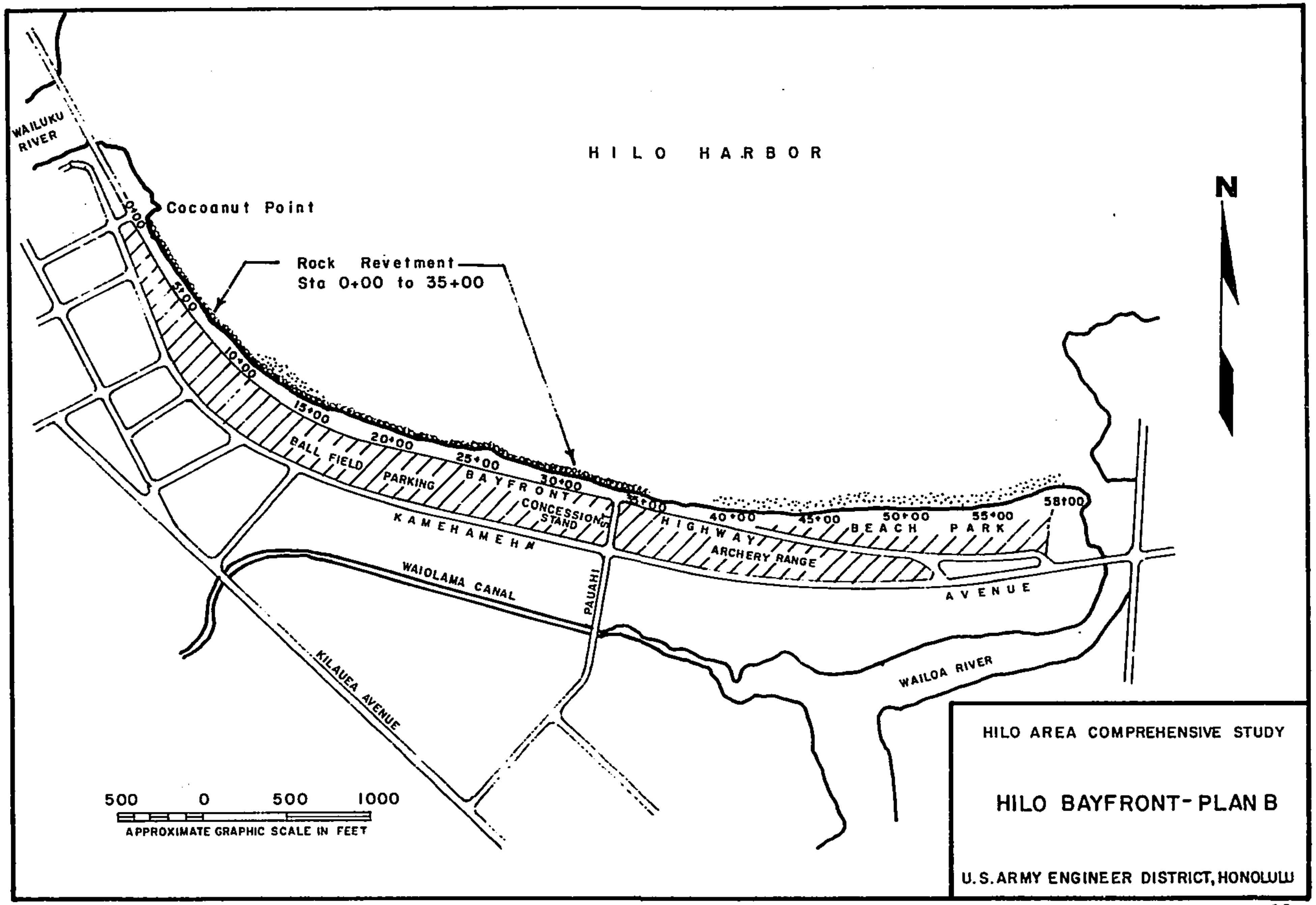
APPROXIMATE GRAPHIC SCALE IN FEET

FIGURE 11


HILO HARBOR
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WAILUKU RIVER
Cocoanut Point
Rock Revetment
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58+00
BALL FIELD
PARKING
BAYFRONT
CONCESSION STAND
HIGHWAY
ARCHERY RANGE
BEACH PARK
KAMEHAMEHA
AVENUE
WAIOLAMA CANAL
PAUAHI
KILAUEA AVENUE
WAILOA RIVER
500 0 500 1000
APPROXIMATE GRAPHIC SCALE IN FEET
HILO AREA COMPREHENSIVE STUDY
HILO BAYFRONT - PLAN B
U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE 12

PLAN A

Description. This plan (Figure 11) uses a combination of techniques to protect the shoreline and enhance recreation and the environment along the bay front. It includes a surfing shoal stabilized by Longard tubes, a protective beach stabilized by groins and a rock revetment. Table 2 shows the summary of project costs of this plan. Table 3 shows the investment cost summary and Table 4 shows a Summary of Costs, Charges and Benefits. Cost sharing is based on a formula of 70 percent Federal and 20 percent local because of the protection of a public park and restoration of a public beach.

TABLE 2. PLAN A
SUMMARY OF PROJECT COSTS

	Project Total	Federal Share	Non-Federal Share
Project First Cost			
Initial Construction Cost	$6,978,000 1/	$4,885,000	$2,093,000
Engineering, Design, Supervision & Administration (E&D, S&A)	968,000 2/	678,000	290,000
Total Project First Cost	7,946,000	5,563,000	2,383,000
Periodic Nourishment Cost, including E&D, S&A	1,126,000 3/	788,000	338,000
Total Project First Cost Including Periodic Nourishment	$9,072,000	$6,351,000	$2,721,000
Annual Maintenance			
Maintenance	19,000 4/	0	19,000
Reconstruct Surf Shoal @ 25 yrs	5,000 5/	0	5,000
Total Annual Maintenance	$24,000	0	$24,000

1/ Includes 25% contingency
2/ Includes $200,000 for hydraulic model study
3/ Based on 10% nourishment of beach every 15 years
4/ Based on 1% of armor stone cost
5/ Annualized cost to reconstruct surf shoal

TABLE 3. PLAN A - INVESTMENT COST SUMMARY

First Cost (initial)	$7,946,000
Future Nourishment (present worth)	163,000 1/
Interest During Construction	498,000 2/
Total Investment Cost	$8,607,000

1/ Based on 8-1/8% interest rate and beach nourishment at 15, 30, and 45 years from construction.
2/ Based on 8-1/8% interest rate and an 18 month construction period.

TABLE 4. SUMMARY OF COSTS, CHARGES and BENEFITS - PLAN A

Project Investment Cost	$8,607,000
Annual Charges	
Interest and Amortization on investment	714,000 1/
Operations and Maintenance	19,000
Reconstruct Surf Shoal @ 25 yrs.	5,000
Total Annual Charges	$ 738,000
Annual Benefits (From Supplemental Documentation, Economics)	$1,266,000
Benefit-Cost Ratio	1.7
Net Annual NED Benefits	$ 528,000

1/ Interest and Amortization at the rate of 8-1/8% and based on an economic life of 50 years.

Impact Assessment. The dredging of the offshore sand site and the construction portions of this project would cause temporary impacts on water quality in the bay. Design of the stabilizing structures for the surf shoal and beach would require a model study to effectively reduce or eliminate sand loss.

Mitigation Requirements. None.

Implementation Responsibilities. The Corps would provide overall management for implementation and the County would be responsible for all local requirements.

Cost Allocation. None.

Public Views.

Federal Agencies: No objections from USF & WS.

Non-Federal Agencies: The Parks Department, County of Hawaii, supports this project.

PLAN B

Description. This plan (Figure 12) requires the construction of 3,500 feet of rock revetment on top of the existing rock revetment. Table 5 displays the summary of project costs for Plan B, table 6 shows the investment cost summary and table 7 shows the summary of costs changes and benefits.

Table 5. PLAN B
SUMMARY OF PROJECT COSTS

	Project Total	Federal Share	Non-Federal Share
Project First Cost			
Project Construction Cost	$2,799,000 1/	$1,400,000	$1,400,000
Engineering, Design, Supervision & Administration (E&D, S&A)	336,000	168,000	168,000
Total Project First Cost	$3,135,000	$1,568,000	$1,568,000
Annual Maintenance Cost	$23,000 2/	0	$23,000

1/ Includes 25% contingency.
2/ Based on 1% of armor stone cost.

TABLE 6. PLAN B - INVESTMENT COST SUMMARY

Total First Cost	$3,135,000
Interest During Construction	196,000 1/
Total Investment Cost	$3,331,000

1/ Based on 8-1/8% interest rate and an 18 month construction period.

TABLE 7. PLAN B - SUMMARY OF COSTS, CHARGES AND BENEFIT

Project Investment	$3,135,000
Annual Charges	
Interest and Amortization on Investment	$ 260,000 1/
Operation and Maintenance	23,000
Total Annual Charges	$ 283,000
Annual Benefits	$ 22,000
Benefit-Cost Ratio	0.1
Net Annual NED Benefits	NONE

1/ Interest and Amortization at the rate of 8-1/8% and based on an economic life of 50 years.

Impact Assessment. No significant impacts due to construction of new rock revetment anticipated.

Mitigation Measures. None.

Implementation Responsibilities. The Corps would provide overall management for implementation and the State and/or County would be responsible for all local requirements.

Cost Allocation. None.

Public Views.

Federal Agencies: No objections.

Non-Federal Agencies: This plan is not supported by the County of Hawaii.

EVALUATION OF FINAL PLANS

PLAN A (FIGURE 11). This plan has a benefit-to-cost ratio greater than unity (BCR = 1.7). It would provide adequate shoreline protection and would significantly improve the recreational opportunities in the Hilo area.

PLAN B (FIGURE 12). This plan has a benefit-to-cost ratio less than unity (BCR = 0.1) and should provide adequate shoreline protection.

Table 8 shows the breakdown of the benefits attributed to these plans. The computations are based on a 8-1/8 percent interest rate on a 50-year project life. The project base year 1985 is when benefits are expected to begin accruing. Figure 13 shows the economic benefits compared with project costs.

TABLE 8. COMPARISONS OF AVERAGE ANNUAL BENEFITS ($)

Benefit	Plan A	Plan B
Savings in Highway Maintenance and Repair	$ 22,000	$22,000
Recreational Benefits	1,244,000	0
	$1,266,000	$22,000

Costs for construction were estimated at October 1984 price levels. Table 9 shows the summary of costs and benefits for the alternative plans.

TABLE 9. SUMMARY OF COSTS AND BENEFITS ($)

	Plan A	Plan B
Total Project First Cost	$9,072,000 1/	$3,135,000
Federal First Cost	6,351,000	1,568,000
Non-Federal First Cost	2,721,000	1,568,000
Average Annual Project Costs + Average Annual O&M	738,000	283,000
Average Annual Benefits	1,266,000	22,000
Net Annual NED Benefits	528,000	NONE
Benefit-Cost Ratio	1.7	0.1

1/ Includes Periodic Nourishment

Rationale for Designation of National Economic Development (NED) Plan.

Plan A would be the NED plan because it has net annual NED benefits of $528,000 and a benefit-to-cost ratio of 1.7. Plan B has no net benefits.

TRADE-OFF ANALYSIS

Plan A makes net contributions to the national economic development (NED), environmental quality (EQ), regional economic development (RED) and other social effects (OSE) accounts. Plan B makes a net deduction from NED and has no positive effect on EQ, RED, or OSE. Figure 13 shows the relationship between the area of the dry sand beach, the project first cost and the annual recreational benefits. The following data were used to develop the figure which indicates the optimum beach area to be 250,000 square feet.

Size of Beach vs Initial First Cost

Size of Beach (sq. ft.)	Initial First Cost 1/
125,000	$7,123,000 2/
250,000 (Plan A)	9,072,000
350,000	10,142,000 2/

1/ Includes 25% contingencies and E&D, S&A, and periodic nourishment.
2/ Developed based on Plan A.

Size of Beach vs Average Annual Recreational Benefits

Size of Beach (sq. ft.)	Avg. Annual Benefits
165,000	$ 934,000
185,000	1,035,000
207,000	1,103,000
225,000	1,143,000
250,000	1,176,000
350,000	1,207,000

FIGURE 13.
SENSITIVITY ANALYSIS OF BENEFITS VERSUS COSTS

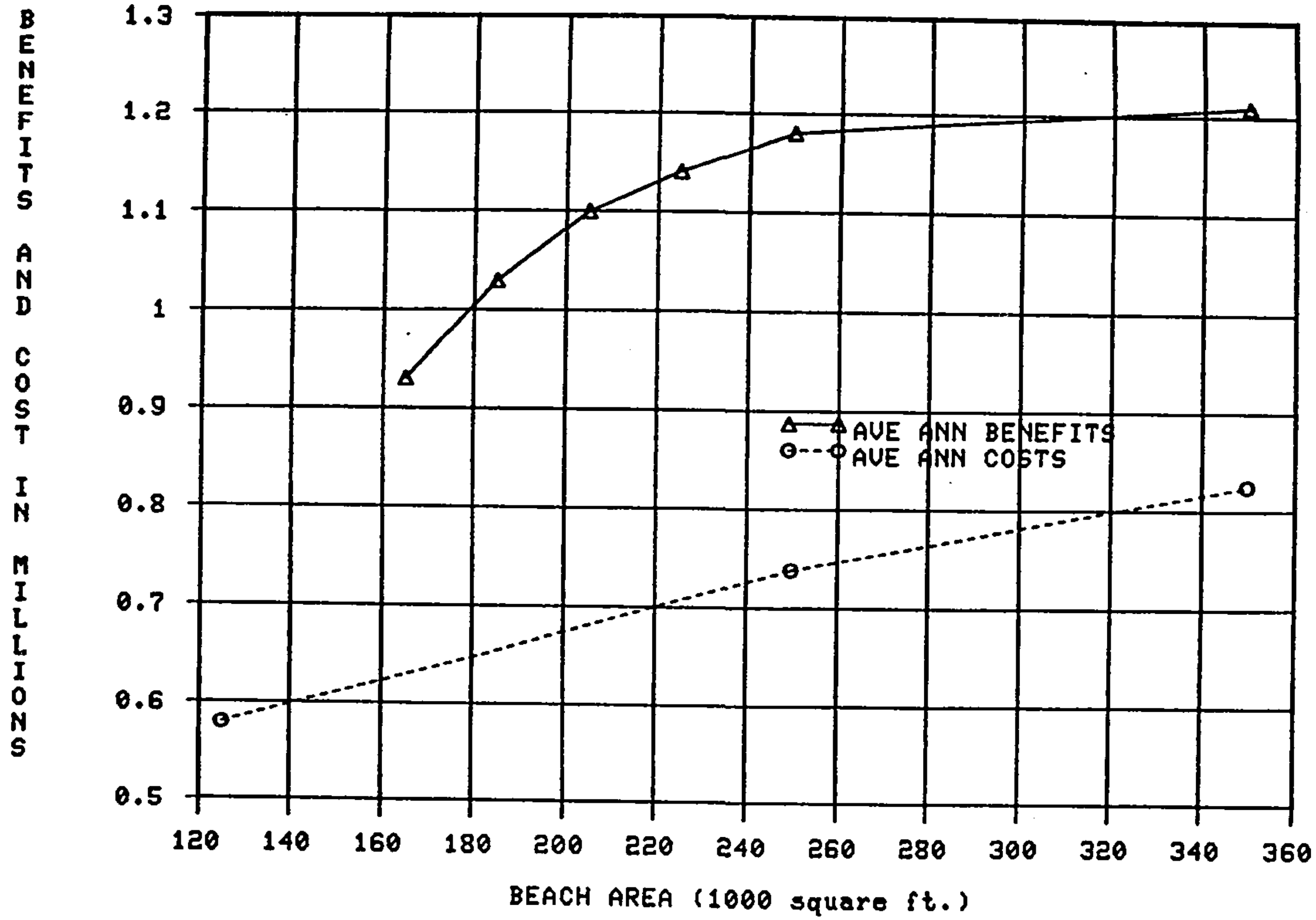


Table 10 displays the existing and future resource conditions in the Bayfront study area without the implementation of the alternative plans. The table also shows the problems and opportunities at the Bayfront.

Table 11 displays the alternative measures which were not developed into plans.

Table 12 displays reasonable alternatives including those required by the National Environmental Policy Act.

Table 13 shows existing or planned Federal and non-Federal projects or facilities having significant economic, environmental, or physical interactions with the recommended plan together with a discussion of these interactions.

BAYFRONT BEACH

TABLE 10

EXISTING AND FUTURE CONDITIONS WITHOUT THE ALTERNATIVE PLANS

	Existing	Future
DESCRIPTION	The Bayfront Beach extends between the Wailuku and Wailoa Rivers on the west side of Hilo Harbor, a distance of about 5,800 feet. The shoreline is generally protected by a rock revetment, of which only the western most 700 feet appear to be functioning satisfactorily.	The limited beach area would remain basically what it is today.
PROBLEMS	Shoreline erosion has significantly reduced the recreational beach area; wave damage to the highway; and, shoaling of the Wailoa River mouth.	Sand from the shoreline erosion will cause continued shoaling of Wailoa River mouth.
OPPORTUNITIES	There is an opportunity to restore the recreational beach which would protect the shoreline from wave attack.	Without the project, storm waves will continue to erode the shoreline. There are no future opportunities without the project.

BAYFRONT BEACH

TABLE 11

ALTERNATIVES WHICH WERE CONSIDERED BUT NOT DEVELOPED INTO PLANS

Measures	Effects	Reason for Not Proceeding Further
Doing Nothing.	No change in the conditions at the Bayfront.	Unresponsive to problems and needs of the study area.
Relocation of the Bayfront Highway.	There would no longer be a need for protecting the highway from storm wave attack.	Significantly higher costs are predicted over and above any plan devised for the Bayfront.

BAYFRONT BEACH

TABLE 12

ALTERNATIVES AND EFFECTS
(Initial Plans)

Measure	EFFECTS: NED	EFFECTS: Other
Sand Replenishment With Groins Construct 6 groins, 250 to 310 feet in length, spaced 600 feet. Provide sand fill to restore the beach and stabilize it. Project length 3,500 feet.	All tangible NED benefits are obtained with this plan. This is the next highest cost plan.	Economic Total Project First Cost: $9.1 to 9.5 million. BCR: Calculated only for final plans. Environmental No significant adverse effects. Visual and recreational opportunities are enhanced. No enhancement to surfing. Social Long-term benefits to the community by providing beach recreational area for residents and visitors. Regional Benefits would accrue from increased visitations.

BAYFRONT BEACH

TABLE 12 (Cont)

ALTERNATIVES AND EFFECTS
(Initial Plans)

Measure	EFFECTS	
	NED	Other
Perched Beach with Surf Shoal		Economic
Construct longard tube revetment and back fill with sand to restore the beach. Project length 3,500 feet.	All tangible NED benefits are obtained with this plan.	Total Project First Cost: $3.4 million. BCR: Calculated only for final plans.
High maintenance needs. Great potential for catastrophic failure of tube system.		Environmental
		No significant adverse effects. Visual and recreational opportunities are enhanced. Surfing opportunities are enhanced.
		Social
		Long-term benefits to the community.
		Regional
		Benefits would accrue from increased visitations.

BAYFRONT BEACH

TABLE 12 (Cont)

ALTERNATIVES AND EFFECTS
(Initial Plans)

Measure	EFFECTS: NED	EFFECTS: Other
Sand Replenishment With Detached Breakwaters Construct 6 detached breakwater, 400 feet long, spaced 200 feet for a distance of 3,500 feet. Provide sand fill to restore the beach and stabilize it.	All tangible NED benefits are obtained with this plan. This is the highest cost plan.	Economics Total Project First Cost: $10.0 million. BCR: Calculated only for final plans. Environmental No significant adverse effects. Visual and recreational opportunities are enhanced. No enhancement to surfing. Social Long-term benefits to the community by restoring the beach for resident and visitor use. Regional Benefits would accrue from increased visitations.

BAYFRONT BEACH

TABLE 12 (Cont)

ALTERNATIVES AND EFFECTS
(Final Plans)

Measure	EFFECTS: NED	EFFECTS: Other
Plan A		Economic
Construct a surfing shoal, a protective beach (250,000 square feet of dry beach) stabilized by 4 rock groins, a 1,200-foot long rock revetment with a 15-foot crest elevation and a 200-foot long jetty-groin near the Wailoa River.	This plan is designated the NED plan because of its greatest net benefits.	Total Project First Cost: $7.0 million. BCR: 1.7 Environmental No significant adverse effects. Improve visual and recreational opportunities. Social Long-term benefits to the community by providing beach recreational area for the residents and the tourists. Regional This plan would have significant regional benefits to beach users, including visitors and residents.

BAYFRONT BEACH

TABLE 12 (Cont)

ALTERNATIVES AND EFFECTS
(Final Plans)

Measure	EFFECTS: NED	EFFECTS: Other
Plan B Construction of a 3,500-foot rock revetment on top of the existing one.	There are no net NED benefits and the benefit-to-cost ratio is less than unity (BCR = 0.1).	Economic Total Project First Cost: $3.1 million. BCR: 0.1 Environmental No improvements to environmental values. Social No improvements. Regional No benefits.

BAYFRONT BEACH

TABLE 13

EXISTING OR EXPECTED
FEDERAL AND NON-FEDERAL PROJECTS
WHICH MAY AFFECT THE
RECOMMENDED PLAN

Project	Interactions		
	Economic	Environmental	Physical
FEDERAL			
Breakwater Change Proposal to perform a major rehabilitation of the breakwater portion of the Federal Project at Hilo Harbor. The outer 7,500 feet of the 10,280-foot breakwater would be deauthorized and changes in profile and elevation would occur to permit improved circulation in the Bay.	None	Would expedite recolonization of Blonde Reef and improve the water quality in the bay and water contact recreation.	No significant effect on Bayfront Beach.
NON-FEDERAL			
None			

PLAN SELECTION

Plan A was selected as the final plan because it fulfills all of the project objectives by contributing to economic development, recreation and environmental quality. It provides the greatest net NED benefits.

SELECTED PLAN DESCRIPTION

Components

The selected plan includes the following components (Figure 14):

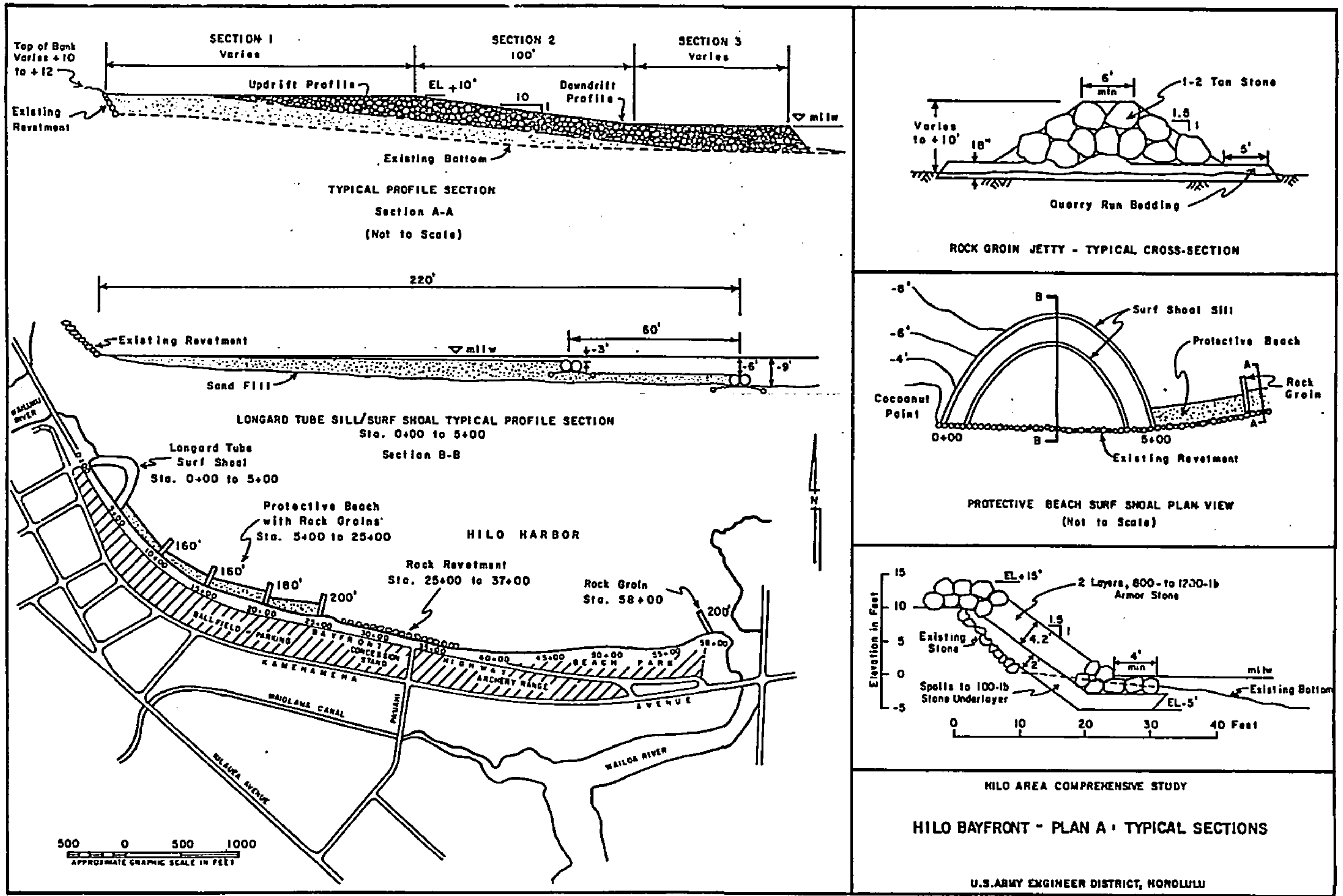
a. Construction of a stabilized surfing shoal.
b. Construction of a stabilized protective beach.
c. Construction of a rock revetment.

The plan has three distinct features.

a. Artificial Shoal. This structure restores the former beach area and stabilizes it with the use of longard tubes. It will prevent overtopping of the Bayfront Highway. A shoal was chosen for this 500 foot section (stations 0+00 to 5+00) of the project in order to take advantage of higher wave conditions at this location. The shoal would create a wet beach which would significantly restore the opportunity for the traditional native Hawaiian sport of surfing. This also would be a relatively safe place to surf for beginners. Dry beach users would take advantage of this area since part of their attraction to the beach will be the multiple water sport opportunities available. These include swimming, sunbathing, surfing, canoeing and fishing. The artificial shoal is an integral part of the overall project because it restores and enhances surfing use at the bayfront. The first cost of the shoal is less than the dry beach restorations (the shoal must be replaced midway through the project life). This is due to the lesser cost of longard tubes as stabilizing structures and also because a lesser volume of sand is required.

The use of longard tubes was felt to be justified here because their use below mean lower low water and the short reach involved. The actual cost of the longard tube system is slightly less per lineal foot over the project's 50 year life than is a rock revetment. The use of sand-cement mixture to stabilize the tube if the fabric fails is intended to prolong the useful life of the shoal to equal or exceed the 25-year replacement point. Benefits are obtained by enhancing the recreational opportunities for surfing at this location. Specific monetary benefits have not been taken however.

b. Dry Beach Restoration. Restoration of the beach was chosen in order to provide recreation benefits as well as benefits from the prevention of highway overtopping. A combination of groins and sand replenishment from a convenient offshore source was designed in order to provide stable structures for sand retention over the 2,000' reach (stations 0+5 to 0+25). Rock was chosen over the slightly less costly sand-cement filled bags to construct the groins. This decision was made because of the construction problems associated with sand-cement filled bags. Similarly, construction of a perched beach more extensive than surf shoal using longard tubes was rejected because of the high risks of damage to the the long length of the tubes from pounding waves,



SECTION 1
Varies
SECTION 2
100'
SECTION 3
Varies
Top of Bank Varies +10 to +12
Existing Revetment
Updrift Profile
EL +10'
10
1
Downdrift Profile
mllw
Existing Bottom
TYPICAL PROFILE SECTION
Section A-A
(Not to Scale)
220'
60'
Existing Revetment
mllw
-3'
-6'
-9'
Sand Fill
LONGARD TUBE SILL/SURF SHOAL TYPICAL PROFILE SECTION
Sta. 0+00 to 5+00
Section B-B
Longard Tube Surf Shoal
Sta. 0+00 to 5+00
Protective Beach with Rock Groins
Sta. 5+00 to 25+00
HILO HARBOR
Rock Revetment
Sta. 25+00 to 37+00
Rock Groin
Sta. 58+00
160'
160'
180'
200'
200'
WAILUKU RIVER
KAMEHAMEHA
AVENUE
WAIOLAMA CANAL
PAUAHI
WAILOA RIVER
KILAUEA AVENUE
BALL FIELD
PARKING
BAYFRONT
CONCESSION STAND
HIGHWAY
ARCHERY RANGE
BEACH PARK
500 0 500 1000
APPROXIMATE GRAPHIC SCALE IN FEET
N
6' min
1-2 Ton Stone
1.8
1
Varies to +10'
18"
5'
Quarry Run Bedding
ROCK GROIN JETTY - TYPICAL CROSS-SECTION
-8'
-6'
-4'
Surf Shoal Sill
Protective Beach
Rock Groin
Coconut Point
0+00
5+00
Existing Revetment
PROTECTIVE BEACH SURF SHOAL PLAN VIEW
(Not to Scale)
EL +15'
2 Layers, 800- to 1200-lb Armor Stone
1.5
1
4.2'
4' min
2'
Existing Stone
Spalls to 100-lb Stone Underlayer
mllw
Existing Bottom
EL -5'
Elevation in Feet
15
10
5
0
-5
0 10 20 30 40 Feet
HILO AREA COMPREHENSIVE STUDY
HILO BAYFRONT - PLAN A : TYPICAL SECTIONS
U.S.ARMY ENGINEER DISTRICT, HONOLULU

FIGURE 14

debris or vandalism. A groin is included at the eastern end of the beach to capture and prevent the new sand used to construct the beach from forming a sand bar in the Wailoa River. This groin is an integral part of the project because it functions to provide sand to be used for periodic nourishment. It also will prevent shoaling of the Wailoa River.

Groins have been designed to minimize, not completely stop, sand bypassing. The nature of this beach system is such that sand movement occurs both longshore (typically to the east) and onshore-offshore (during the severe storms). The best professsional judgment using the results of field investigations of currents, waves and sand movement is that groins would be better than detached breakwaters for stabilizing the shore.

c. Revetment. A revetment constructed of rock was chosen as the means of protection for the 1200 feet between stations 25+00 and 37+00. The revetment would protect the fishing and hiking path along this reach of the project as well as the highway. This is an integral part of the entire plan in order to maintain maximum public access between all recreational facilities, parking, restrooms and showers.

d. Periodic Nourishment. Up to 25,000 cubic yards of sand would be required every 15 years to nourish the beach. The groin at the east end of the bayfront beach functions as a sand trap to provide a partial source of sand for periodic nourishment. Nourishment is a more economical erosion protection measure than retaining structures such as revetments or detached breakwaters. Nourishment is an integral part of beach stabilization and shore protection.

Operation and Maintenance

Operation and maintenance of the stabilizing structures and revetment is estimated to cost $24,000 annually. The shoal would be replaced after 25 years.

Accomplishments

Plan A provides adequate shoreline protection and the best use of the Hilo Bayfront.

The surfing shoal and the protective beach would enhance the recreational opportunities in the Hilo area. The protective beach would add over 5 acres (250,000 sq ft) of much needed dry recreational beach area to the existing 0.84 acres.

The rock revetment would protect the shoreline in the area not protected by the surfing shoal or the protective beach. Sand trapped by the eastern most groin would be used to nourish the beach.

Summary of Economic Effects
SELECTED PLAN - (PLAN A)

Economics

Total Project First Cost 1/	$9,072,000
Annual Maintenance	24,000
Benefit-Cost Ratio	1.7

1/ Including periodic nourishment

IMPLEMENTATION

The following is provided for informational purposes only since Federal implementation is not warranted for the Bayfront project at this time.

Institutional Requirements

Traditionally, following authorization by Congress, the Honolulu Engineer District would perform final preconstruction engineering and design work. The District would administer construction. The Department of Parks and Recreation, County of Hawaii is the local sponsor and responsible administrator for the Bayfront Park and its facilities.

Federal and Non-Federal Responsibilities

Local government would be responsible for maintenance and repair of the project. The Federal government would be responsible for construction of the project and periodic nourishment of the beach subject to the cost sharing provisions stated above.

Views of the Sponsor

The sponsor approves of the plan and has submitted a letter of intent (Figure 15).

Summary of Coordination, Public Views and Comments

A draft Survey Report and EIS was circulated for public review and comment in April 1983. A public meeting was held in Hilo on 25 August 1983. Comments were favorable towards Plan A and no adverse comments were received. See the comments section of the EIS for a detailed discussion of comments received during the report's public review.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The existing shoreline at the Hilo Bayfront is relatively stable except at the Wailoa River end (the eastern end) of the beach where substantial accretion has been occurring. The stability has been established because of the existing revetment which was constructed and is being maintained by the State Department of Transportation for the purpose of protecting the Bayfront Highway. This revetment and highway were built over the natural beach backshore in the alignment of the railroad track which was first built in 1903, but destroyed during the 1946 tsunami.

The maintenance and repair costs to the highway because of storm wave damages are estimated to be $22,000 per year based on the information provided by the County of Hawaii and the State Department of Transportation. The benefit of constructing a shore protection project at this location would be the reduction of these costs. An ancillary benefit would be an added value of newly created recreation at the site. In this case, recreation benefits have been estimated to be $1,244,000 per year for Plan A. Recreation opportunities are projected to be largely for local residents and assume that the beach would be used less than 30 percent of the time because of weather conditions in Hilo. The projection also holds hotel rooms constant at 1980 levels with a 40 percent occupancy rate. It is a conservative projection based on several recreation studies by State and County agencies.

Plan A, which provides for recreation, would cost $9.1 million with a benefit to cost ratio of 1.7. The recreation benefits are 98 percent of the total benefits. This plan is feasible from the standpoint of economics, engineering and environmental effects.

Plan B, which does not provide for recreation, would cost $3.1 million with a benefit to cost ratio of 0.1. Therefore, Plan B is not economically feasible because it's average annual cost exceeds the estimated annual benefit.

Plan A is feasible by virtue of it's large recreation benefits to be obtained through the creation of a beach which serves to protect the highway from overtopping waves and subsequent damages. Because of the creation of beach extension beyond the approximate historic shoreline, Plan A does not meet the intent of the Congress which was expressed in Committee reports in 1956 (Public Law 826, 84th Congress; 70 Stat. 702) which stated in part: "...the Committee believes that the intent is to restore lost lands rather than to create new lands...." (House Report No. 2544 and Senate Report No. 2691). Moreover, it is the policy of the Administration insofar as recreational opportunities are concerned, to rely on the private sector to provide public services whenever possible.

Based on the evaluation and findings, the District Engineer believes that sufficient investigations have been made, and information on the environmental, social, economic and engineering aspects of the alternatives considered have been reviewed. The District Engineer has also reviewed the intent of Congress regarding shore protection and preservation, and program policies of the Administration. In light of the study findings, the District Engineer concludes that a project at the Bayfront Beach lacks Federal interest and that further Federal involvement is not warranted.

Recommendations

Due to the lack of Federal interest, I recommend that no Federal action be taken at the Hilo Bayfront Beach. However, because a plan exists which is technically and economically feasible, and environmentally acceptable, I further recommend that this report be made available to local interests and interested parties for their information and possibly project implementation.

Michael M. Jenks
Colonel, Corps of Engineers
District Engineer

DEPARTMENT OF PARKS & RECREATION
COUNTY OF HAWAII

Herbert Matayoshi, Mayor
Milton Hakoda, Director

December 28, 1983

Colonel Michael M. Jenks
District Engineer
U. S. Army Engineer District, Honolulu
Building 230
Fort Shafter, HI 96858

Dear Colonel Jenks:

With reference to the Bayfront Shore Protection Project as described in the draft report of April, 1983, the County of Hawaii intends to participate in the following manner:

(1) Contribute the local share of the project construction cost.

(2) Provide without cost to the United States all necessary lands, easements, rights-of-way and relocations required for construction of the project.

(3) Hold and save the United States free from claims for damages which may result from construction and subsequent maintenance of the project, except damages due to the fault or negligence or the United States or its contractors.

(4) Assure continued conditions of public ownership and use of the shore upon which the amount of federal participation is based during the economic life of the project.

(5) Assure maintenance and repair and local share of periodic beach nourishment where applicable, during the useful life of the works as required to serve the project's intended purpose.

(6) Provide and maintain necessary access roads, parking areas and other public use facilities open and available to all on equal terms.

•25 AUPUNI STREET • HILO, HAWAII 96720 • TELEPHONE 961-8311

The County of Hawaii further assures that the subject project will provide and be maintained as a public park and that:

(1) The land is publicly owned.

(2) The park includes a zone extending landward from the mean low water line which excludes all permanent human habitation. This excludes summer residences, but does not preclude residences of park personnel or management and administrative buildings.

(3) The park includes a beach suitable for recreational use.

(4) The park provides for preservation, conservation and development of natural resources of the environment.

(5) The park or conservation area extends landward a sufficient distance to include protective dunes, bluffs or other natural features which will absorb and dissipate wave energy and flooding effects of storm tides. The purpose of this requirement is to provide a protective buffer zone which would prevent damage of upland property and development.

(6) Full park facilities are provided for appropriate public use.

We understand that this letter expresses the intent of the County of Hawaii and that a legally binding agreement would be executed following authorization of the project by the Congress.

Sincerely,

MILTON HAKODA
Director

cc: Mayor
Corporation Counsel
Park Planner

FIGURE 15

FIGURE 15

FINAL
ENVIRONMENTAL IMPACT STATEMENT
BAYFRONT BEACH

FINAL
ENVIRONMENTAL IMPACT STATEMENT
BAYFRONT BEACH SHORELINE IMPROVEMENTS
HILO AREA COMPREHENSIVE STUDY

The responsible local cooperating agency is the State of Hawaii Department of Land and Natural Resources, Division of State Parks, Outdoor Recreation and Historic Sites.

The responsible lead agency is the US Army Engineer District, Honolulu, Hawaii.

The US Fish and Wildlife Service is a cooperating federal agency.

Information, figures and displays referred to in the main report and appendices are incorporated as a part of this Environmental Impact Statement.

Abstract: As part of the continuing Hilo Area Comprehensive Study, the need to protect the Bayfront Beach from eroding, and the improvement of recreational opportunities were investigated. Several alternatives were considered, but only two were studied in detail. Plan A was selected as the National Economic Development Plan because of its more favorable benefits. It is also designated the Environmental Quality Plan because of the creation of new recreational features which are part of the Plan. There is no nonstructural plan which will fulfill the objectives of the study. No significant adverse environmental impacts are anticipated.

The Notice of Availability of the FEIS is expected to be published in the Federal Register by the Environmental Protection Agency on ________________, 1984. If you have comments, send them to the District Engineer so they are received not later than 30 days after the date of publication.

If you would like further information on this environmental impact statement, please contact:

Dr. James E. Maragos, Chief
Environmental Resources Section
US Army Engineer District, Honolulu
Building T-1
Fort Shafter, HI 96858
Phone: (808) 438-2263

TABLE OF CONTENTS

1. SUMMARY

1.1 MAJOR CONCLUSIONS AND FINDINGS. Two plans were evaluated in the Hilo Comprehensive Study, Bayfront Beach Shoreline Improvements Study. These Plans were Plan A - Recreational Enhancement Plan and Plan B - Shore Protection Plan.

TABLE 1. PLAN FEATURES

Plan A	Construct a surfing shoal, a protective beach (250,000 square feet of dry beach) stabilized by 4 rock groins, a rock revetment 1,200 feet long with a crest elevation of 15 feet and a 200-foot long groin near the Wailoa River (Figure 11 - Main Report).
Plan B	Construct a 3,500-foot long rock revetment with a crest elevation of 15 feet (Figure 12 - Main Report).

Plan A is designated the National Economic Development Plan because of its greater overall benefits.

There is no Nonstructural Plan.

Plan A is designated the Environmental Quality Plan since it enhances recreational opportunities in the project area.

No wetlands or prime agricultural lands are involved.

The Bayfront Beach is in a floodplain and a high tsunami hazard area.

The Hilo Breakwater, Hilo Iron Works and the Wailoa River Bridge are eligible for inclusion to the National Register of Historic Places. Neither of the plans will have an adverse impact on these structures.

1.2 AREAS OF CONTROVERSY. None.

1.3 UNRESOLVED ISSUES. None.

1.4 RELATIONSHIP TO ENVIRONMENTAL REQUIREMENTS. (See Table 2).

TABLE 2. RELATIONSHIP OF THE PLANS TO ENVIRONMENT PROTECTION STATUTES AND OTHER ENVIRONMENTAL REQUIREMENTS (CONTD)

State and Local Policies	Plan A	Plan B
State Conservation District Use Application Permit (See Section 6.2)	NA	NA
County General Plan	Full	Full
State Land Use Law	Full	Full
Required Federal Entitlements (Permits)		
None required		

NOTES:

a. Full (Full Compliance). Having met all requirements of the statute, Executive Order or other environmental requirements for the current stage of planning (either pre- or post-authorization).

b. Partial (Partial Compliance). Not having met some of the requirements that normally are met in the current stage of planning. Partial compliance entries should be explained in appropriate places in the report and/or EIS and referenced in the table.

c. Non-Compliance. Violation of a requirement of the Statute, Executive Order, or other environmental requirement. Non-compliance entries should be explained in appropriate places in the report and/or EIS and referenced in the table.

d. N/A (Not applicable). No requirements for the statute, Executive Order or other environmental requirement for the current stage of planning.

2. NEED FOR AND OBJECTIVES OF THE ACTION.

2.1 STUDY AUTHORITY. The study of Bayfront Beach Shoreline Improvements is conducted under Section 144 of the Water Resources Development Act of 1976. The Act authorizes a study of methods to develop, utilize and conserve water and land resources in the Hilo Bay area, including the consideration of the need for navigation facilities, for enhancement and conservation of water quality and fish and wildlife, for environmental enhancement and for economic and human resources development. The recommendations shall be compatible with other local comprehensive development plans and plans of other interested Federal agencies.

2.2 PUBLIC CONCERNS. Local residents as well as the State of Hawaii Department of Transportation have long been concerned about the overtopping and damage to the bayfront highway caused by storm waves and the ineffectiveness of the existing revetment in some areas. Additionally, the need to improve water related recreational opportunities in Hilo Bay has been expressed during all the public workshops and meetings for the Hilo Comprehensive Study. Since it began in 1976, improvements to Bayfront Beach and the improvement of water quality in the bay have been major aspects of the study. This report deals with the Bayfront Beach; bay water quality is covered in a separate report.

2.3 PLANNING OBJECTIVES.

a. Protect the bayfront highway.

b. Enhance recreation.

c. Prevent shoaling of the Wailoa River mouth.

3. ALTERNATIVES, INCLUDING THE PROPOSED ACTION.

3.1 PLANS ELIMINATED FROM FURTHER STUDY.

a. Sand replenishment with detached breakwaters. This alternative was eliminated because of excessive cost.

b. Sand replenishment with sand-cement filled bag groins. This alternative was eliminated because the structure would not be resistant to Hilo Bay storm waves.

c. Beach replenishment alone. This alternative was rejected because of excessive annual maintenance required to replenish lost sand.

d. Nonstructural Plan. A feasible nonstructural plan could not be identified that would fulfill the objectives of the planning study.

3.2 PLANS CONSIDERED IN DETAIL.

a. Plan A - The Recreational Enhancement Plan. This plan contains a mix of structural means as well as beach replenishment to meet all the objectives of the study. The beach would be replenished to a minimum width of 50 feet, stabilized by four rock groins providing 250,000 square feet of dry beach. A 200-foot long rock groin would be constructed near the Wailoa River and a surfing shoal would be constructed near the Wailuku River (Figure 11 - Main Report).

b. Plan B - The Shore Protection Plan. This plan consists of the construction of a 3,500-foot long rock revetment with a crest elevation of 15 feet (Figure 12 - Main Report).

3.3 COMPARISON OF ALTERNATIVE IMPACTS. (See Table 3).

TABLE 3. COMPARISON OF ALTERNATIVE IMPACTS

Resource	Base Condition	Plan A	Plan B
Recreation Beach Parks	Mooheau Park erosion	No effect	No effect
	Bayfront Park		
	erosion	Eliminates erosion	Eliminates erosion
	canoeing	No effect	No effect
	sun bathing, wading	Provides 250,000 sq ft more beach area	No effect
	parking	May require more parking in the future	No effect
	Wailoa River Park	No effect	"
	Liliuokalani Gardens and adjacent areas	"	"
	Coconut Island	"	"
	Banyan Drive shoreline	"	"
	Reed's Bay swimming	"	"
	Baker's Beach	"	"

TABLE 3. COMPARISON OF ALTERNATIVE IMPACTS (CONTD)

Resource	Base Condition	Plan A	Plan B
Recreation Beach Parks (Contd)	Radio Bay	"	"
	Radio Bay Park	"	"
	Hilo Breakwater	No effect	No effect
Surfing	Coconut Island area (1)	No effect on existing surf sites. Adds new site near Wailuku River	No effect on existing sites
	Wailuku River Mouth (3)		"
	Tip of Hilo Breakwater	No effect	No effect
Fishing	Hilo Breakwater	No effect	No effect
	Shoreline areas	Groins will add shoreline fishing site and rocky habitat	"
Boating	Wailoa River shoaling	Reduce shoaling	No effect
	Radio Bay	No effect	"
	Reed's Bay	"	"
Natural Hazards Volcanic	High risk	No effect	No effect
Tsunami	Very high risk	No significant effect	No significant effect
Endangered Species Humpback Whale (endangered)	No critical habitat in harbor, seasonal migration offshore	No effect	No effect
Hawksbill Turtle (endangered)	No critical habitat in harbor	"	"
Green Sea Turtle (threatened)	No critical habitat in harbor possibly foraging.	"	"
Hawaiian Coot (endangered)	Two nests in Waiakea Pond	"	"

TABLE 3. COMPARISON OF ALTERNATIVE IMPACTS (CONTD)

Resource	Base Condition	Plan A	Plan B
Migratory Waterbirds			
Ducks	Winter population in Waiakea Pond.	"	"
Estuaries			
Waiakea Pond		"	"
Wailoa River		"	"
Wailuku River		"	"
Terrestrial Area	0.8± acres of beach	5± acres additional beach created	"
Marine Resources			
Blonde Reef	16% coral cover, 220 acres	No effect	"
Bayfront Beach	Sand/silt bottom, No habitat diversity	2 acres rocky intertidal and subtidal habitat created.	
Coconut Island Reef	10% coral cover	No effect	"
Fishery Resources	Recreational value low. Number of fish species low	"	"
Water Quality	Turbidity	No long-term effect	No long-term effect
	High nutrients	"	"
	High salinity gradient	No effect	No effect
	High turbidity, high nutrient concentration	Temporary turbidity increase during construction.	No effect
	High sedimentation	No effect on sediment quality, may reduce sedimentation rate in inner harbor.	No effect on sediment quality, may reduce sedimentation rate in inner harbor.
	Pollution discharges terminated.	No pollution discharges.	No pollution discharges.

TABLE 3. COMPARISON OF ALTERNATIVE IMPACTS (Contd)

Resource	Base Condition	Plan A	Plan B
Sediment Quality	Sediments contaminated with Arsenic, PCB and Pesticides.	No change	No change
Historic Properties Hilo Breakwater	Hilo Breakwater eligible for inclusion to National Register of Historic Places.	No effect, adds groins to harbor vista	No effect
Discharge of Fill or Dredged Material	Not applicable	16,500 cy of stone for the groins and revetment	29,000 cy of rock for the revetment
		255,000 cy of sand for beach replenishment and surf shoal	

4. AFFECTED ENVIRONMENT.

4.1 PHYSICAL SETTING

a. The Hawaiian Islands are centrally located in the North Pacific Ocean. The eight islands form a 400-mile-long arc at the southeastern end of the archipelago and constitute 6,500 square miles of land area. The Island of Hawaii, the largest of the Hawaiian Archipelago covers an area of over 4,000 square miles. The island has been forming for the past 800,000 years through volcanic activity, which is still taking place.

b. The planning area is located on the shore of Hilo Bay, on the windward, northeast coast, and fronts the town of Hilo, the island's largest city, major port and county seat. The wave climate at the project site is explained in detail in Supporting Documentation - Engineering, Investigations and Design.

c. Natural Hazards.

(1) Volcanic Hazards. Hilo is located in a high risk volcanic area exposed to lava flow threats, earthquakes and subsidence. The risk generally decreases with distance from the northeast rift zone of Mauna Loa volcano. During the past 15 years the island of Hawaii has experienced 11 earthquakes with Richter magnitude ratings of 6 or more. The 1975 earthquake resulted in an estimated $4 million dollars of damage island wide. Most lava flows from Mauna Loa have stopped short of the Hilo suburbs including one in 1984. Public fears of volcanic damages and losses are still significant.

(2) Riverine and Tsunami Flood Hazards. Hilo is subject to riverine flooding principally due to high intensity rainfall and surface runoff in undefined drainage ways. The flood prone areas are located within the Alenaio Stream floodplain, which is a tributary to the Wailoa River. Hilo is also subject to tsunami flood hazards. The tsunamis of 1946 and 1960 were particularly destructive resulting in the loss of 234 lives and about $52 million in property damage. After the 1960 tsunami, vulnerable waterfront areas were rezoned to open space, such as the Bayfront and Wailoa River Parks, and structural design regulations were imposed in order to reduce tsunami damages. The Bayfront Beach area is located within the tsunami flood hazard area.

d. Estuaries. Reed's Bay, Waiakea Pond, Wailoa River and Wailuku River are estuaries within the Hilo Bay and Harbor area. Approximately 1000 mgd of freshwater is discharged into the harbor from the tributaries and springs. The estuaries are important recreational fishing areas within the bay and are planned for open space. Reed's Bay, Wailoa River and Waiakea Pond are planned by the local government for park use, and the Wailuku River is planned as a natural wilderness area.

e. Water Quality.

(1) Hilo Bay inside the breakwater is classified as an embayment with Class A waters according to the State of Hawaii water quality standards of 1979. It is the objective of this class of waters that their use for recreational purposes and aesthetic enjoyment be protected. There are nine

parameters whose standards are applicable to Hilo Bay. The geometric means of three parameters did not meet State standards, and three others exceeded the maximum values specified in the standards during the 1980 study done for the Corps by M&E Pacific, Inc. (Table 4).

(2) In general, water inside and outside the breakwater is vertically stratified due to the discharge of ground and riverine water into the ocean. The salinity gradient inside the harbor is greater than that outside due to the reduced mixing behind the breakwater. The depth of the freshwater layer in the bay sometimes reaches 20 feet indicating that although mixing is occurring between surface and bottom layers, it is not sufficient to reduce the salinity gradient. The depth of freshwater on Blonde Reef sometimes reaches 10 feet inside the breakwater. The primary water column mixing forces are wind and occassional ship traffic. Nutrient concentrations and suspended solids and turbidity vary with the volume of surface runoff and groundwater discharge entering the bay. Fecal strep bacteria tend to survive longer in the bay due to the freshwater layer in the bay than other areas in the State. Chlorophyll-a concentrations vary with water turbidity, increasing during periods of low riverine flow and decreasing during periods of high flow. Water temperature in the surface layer is warmer than the bottom layer due to solar heating, but is colder near the source of groundwater discharge. During periods of low freshwater discharge, solar heating can warm the bottom layer because the depth of the freshwater layer is reduced.

f. Sedimentation and Sediment Quality. Most of the sediment in Hilo Bay consists of silty-clays. The low wave energy environment behind the breakwater allows much of the water-borne sediment to settle out in the harbor and on Blonde Reef where the sediment is smothering and destroying the reef ecosystem. The rate of sedimentation may be slow based upon the frequency of maintenance dredging in Hilo Harbor--once every ten years. In 1977, about 54,000 cubic yards of material was removed from the harbor during the maintenance cycle and the material was disposed of by ocean dumping at the EPA approved Hilo ocean disposal site. Historically, about 35,000 tons of silt per year were deposited in the bay from the Wailuku River; that quantity may be less now than in the past, because a 1881 lava flow covered up erodible soils within the Wailuku River drainage basin and the discharge of 20,000 tons of sediment a year from the Wainaku Sugar Mill was terminated in 1976. Based upon sediment analysis by the State Department of Health, Hilo Bay sediments are contaminated with arsenic, PCB and chlordane. Arsenic trioxide was discharged into Waiakea Pond by the Canec Plant during the 1930's to the 1960's and served as a wood preservative and termicide. The PCB's probably orginated from the Shipman Power Plant near the Wailoa River. Chlordane probably occurs due to agricultural activities and use as a termicide in home construction in Hilo.

TABLE 4. COMPARISON OF AMBIENT WATER QUALITY OF HILO HARBOR WITH WATER QUALITY STANDARDS (Adapted from M&E Pacific, Inc. 1980)

Parameter	Geometric Mean Ambient Water Quality (Mar-Jun 1980)	Water Quality Storm Period Mar 18, 1980	State Water Geometric Mean	Quality Maximum Value
pH	8.12	7.86	*	*
Temperature (°C)	23.4	21.6	**	**
Dissolved Oxygen (mg/l)	7.07	7.61	***	***
Suspended Solids (mg/l)	7.9	18.7	25	50
Turbidity (NTU)	1.55	7.42	1.5	5.0
Total Kjeldahl Nitrogen (Ug N/l)	166.3	232.1	200	500
Nitrate + Nitrite Nitrogen (ug N/l)	19.7	34.9	8.0	35
Chlorophyll-a (ug/l)	0.79	-	1.5	8.5
Total Phosphorus (ug/l)	30.0	17.8	25.0	75.0

* ±5 from 8.1
** Not more than 1°C from ambient conditions
*** Not less than 75% saturation

TABLE 5. CONTAMINANT CONCENTRATION IN HILO HARBOR SEDIMENTS

Total Arsenic concentration: Range from 33-104 ppm

PCB concentration: a mean value of 200 ppb

Chlordane concentration: a range of values of 2-84 ppb

Source: State of Hawaii 1978

Tests of crab and fish tissue indicate that arsenic and PCB are not bioconcentrating in the tissue. Fish viscera contained chlordane residue in concentrations 3-4 times higher than the flesh, where concentrations ranged from 80-160 ppb.

g. Air Quality. Air quality in Hilo is good, lacking major industrial emissions. The sulfur dioxide concentration in 1980 was less than 5 micrograms per cubic meter. Volcanic gases, agricultural fires, sugar mills, aircraft and automotive engines and the power plant are the only major sources of air pollution in the Hilo area.

h. Noise. Hilo is a quiet urban area with the exception of aircraft landing and taking off from Hilo Airport. The aircraft landing pattern takes aircraft over the bayfront area. The Hilo Bayfront in the study area is bordered by a two 4-lane wide State Highway (Kalanianaole Avenue), but traffic is usually light except in the mornings and evenings on weekdays. Noise levels are believed to be usually less than the sound of surf breaking on the beach and rocks.

4.2 SIGNIFICANT RESOURCES. The significant resources identified by Section 122 of Public Law 91-611 (River and harbor Act of 1970) were considered in the following discussion:

a. Human Resources and Activities.

(1) Hilo Community. Hilo is the capital and business center of the County of Hawaii. The 1980 population of Hilo was 35,269 (State of Hawaii, 1982), and continues to grow at a slow rate in comparison to the Kona (western) side of the island. Hilo is considered a mildly depressed area with disproportionately higher unemployment than the State and one of the lowest visitor counts in a State in which tourism is a major industry. Hilo's principal industry is sugar production, which has been stable but not growing. The principal employers in Hilo are government, services and trades. The city of Hilo is situated along the shoreline of Hilo Bay and is a

fully developed urban area. A University of Hawaii campus is located in the city together with the main county hospital, modern shopping centers and a variety of other commercial establishments. Hilo Harbor is the principal port-of-call and handles most of the cargo, agricultural and petroleum shipments in the county.

(2) Land Use. The Hilo Bay shoreline is developed park open space as a result of local land use zoning in the tsunami hazard area. The developed nature of the shoreline and the high urbanized nature of the area precludes significant vegetation and wildlife habitats, except in Waiakea Pond and Wailuku River. The Hilo Community Development Plan recommends the elimination of Bayfront Highway, widening and realigning Kamehameha Avenue, and the restoration of the Black Sand Beach along Hilo Bay. This would provide park/open space throughout most of the Hilo shoreline.

(3) Recreation. Recreation occurs all along the bay shoreline of the study area. Mooheau and Bayfront beach parks extend along the bay shoreline from the Wailuku River to the Wailoa River. There is both boat berthing and open space recreation in Wailoa River Park. Liliuokalani Gardens and Coconut Islands provide open space along the Waiakea Peninsula. Radio Bay is used for berthing of recreational craft and the Radio Bay Park provides additional open space within the harbor area. Hilo Breakwater is a popular fishing site, despite signs warning fishermen of the hazardous conditions on the breakwater. The breakwater is frequently overtopped during high surf conditions, and waves can sweep fishermen from the breakwater. Recreational fishing is the most significant recreational activity in the bay. Fishermen use every location in the bay as a fishing site, including the harbor facilities, the abutments of the Wailuku River Bridge and the adjacent shoreline revetment. Boating and canoeing are also important recreational activities together with wading. Swimming is not a major recreational activity, possibly due to the highly turbid waters, and the trash in the water and on the shoreline. Five surf sites in the bay were identified by Kelly, 1981. Few surf sites exist in the Hilo and Puna regions of the Big Island outside of Hilo Harbor. The Kalapana-Pohoiki area is the only other popular surfing area. Surfing is a popular recreational pastime but surfing opportunities are limited on the Big Island.

(4) Historic Resources. The Hilo Iron Works and the Wailoa River bridge are the closest structures to the study area which have been declared eligible for the National Register of Historic Places. Neither are in the project area. Research by the Corps' archaeological technician determined that there are no historic resources at Bayfront Beach.

b. Natural Resources

(1) Marine Resources. The two important marine areas within the bay are the areas with the greatest coral cover, Blonde Reef (16% coral cover) and Coconut Island (10% coral cover). Both the live and dead coral mass on Blonde Reef and at Coconut Island provide habitat for a variety of reef fish important to recreational fishing in the bay. Commercial fishing in the bay has declined, but the sale of the catch occurs at Suisan Harbor and fish market at the mouth of the Wailoa River. Fishermen suggest that fish stocks are declining due to over-exploitation, sedimentation and chemical pollution. However, exact factors affecting fish abundance have not been determined, although, high water turbidity reduces spear fishing success and sedimentation can bury fish shelter and food resources reducing the amount of nearshore fish habitat. Nehu (tuna fishing bait fish) resources have declined and are insufficient to support a fishing fleet. Presently, principal nehu catch areas are located within the commercial port.

(2) Migratory Waterbirds. During the winter season, migratory ducks are frequently seen in Waiakea Pond, but not along the Bayfront Beach.

(3) Endangered Species. The endangered humpback whale seasonally migrates through waters outside of Hilo Harbor. The whales begin to appear in November and leave the islands by the end of June. The greatest number of whales in the islands appear during February and March. The National Marine Fisheries Service indicates that no whales have been sighted inside Hilo Harbor, although there have been consistant sightings in Hilo Bay. Data indicate that the whales concentrate at Upolu Point in northern Hawaii, and suggest that the Hilo Harbor area is not a major calving, nursing and breeding area in the Hawaiian Islands. The endangered hawksbill turtle and the threatened green sea turtles have been observed in Hilo Harbor, but no nesting grounds exist in the harbor and no seasonal aggregations in the harbor have

been reported. The turtles are also reported by the US National Marine Fisheries to forage along the entire coastline from Hilo to Kalapana.

5. ENVIRONMENTAL EFFECTS.

5.1 PHYSICAL EFFECTS

a. The proposed project will not affect the wave climate or current patterns near the project site or elsewhere in Hilo Bay. It will reduce the shoaling at the mouth of the Wailoa River.

b. If the Hilo Breakwater is modified, the current patterns along the Bayfront may change slightly, slowing the long-shore transport of material entering the Bay from the Wailuku River. This situation would further reduce the shoaling at the mouth of the Wailoa River. Both of the alternatives considered in this study would provide the desired protection to the Bayfront area regardless of a modification to the Hilo Breakwater.

c. Natural Hazards.

(1) Volcanic Hazards. Neither of the plans increase volcanic hazard risks.

(2) Tsunami and Riverine Flood Hazards. Neither of the plans significantly effect riverine flooding or tsunami hazards.

d. Estuaries. Neither of the plans involve work in the Wailuku River, Wailoa River or Reed's Bay estuaries, nor will they have any effect on those estuaries.

e. Water Quality.

(1) All plans involve dredging and a temporary increase in water turbidity as a result of dredging. The impact is a cumulative impact which adds to the stress already created by the influx of sediment from the tributaries entering Hilo Bay. Usually the color of the water returns to normal within a day after each dredging operation, but transmissiometer and

visual underwater observations indicate that fine sediments remain in suspension longer obscuring underwater visibility. The duration of dredging is used as a gross indicator of the extent of turbidity change anticipated. Neither of the plans affect the amount of sediment carried into the harbors.

(2) Sedimentation and turbidity stress related to dredging is dependent upon the characteristics of the material being dredged, the type of dredge used, and the strength of water currents in the area. The material to be dredged from Hilo Bay is expected to consist of sand, with few fines, therefore, sedimentation and turbidity stress are expected to be much less than from silty material. Use of a suction dredge, clamshell or dragline in combination with a barge have the potential of increasing suspended sediment load, turbidity, and siltation stress because water draining from the dredge or barge can wash material back into the water. A suction dredge, piping material directly onto land to a settling basin results in less turbidity and siltation. Although turbidity can induce stress to photosynthetic organisms, the effect is temporary as water clarity will return to ambient levels after termination of dredging. The period of stress may be long, depending upon the length of time required to complete the dredging, and can be aggrevated by rainfall induced turbidity. Periodic rainstorms impart similar sediment stress to Hilo Bay because large amounts of sediments can be discharged from the rivers and streams entering the bay.

(3) Replenishment of the beach using the offshore sand source and piping the sand directly onto the beach will result in significant increased turbidity. Since the offshore sand source contains finer grained and more poorly sorted sand than the native beach sand, it is estimated that up to 50% or 125,000 cy of the replenishment sand could be washed back into the bay. Although the water may be highly turbid during construction, no long-term adverse biological impacts are expected due to the depauperate nature of the biota in that portion of Hilo Bay. The sediments being washed into the bay will be the same as those presently there, and the volume will be less than occurs naturally from heavy storm runoff.

f. Sedimentation and Sediment Quality. Neither of the plans will effect the rate of sedimentation nor the quality of the sediment in Hilo Bay.

g. Air Quality. Neither of the plans will have a long-term effect on air quality, however, if dry sand is used the dumping and spreading of sand for beach replenishment may create temporary dust clouds. In addition, there will be an increase in vehicle exhaust emissions from the construction equipment.

h. Noise Quality. Neither of the plans will have a long-term effect on noise. There will be a temporary increase during the construction phase of both plans due to the operation of heavy equipment.

5.2 SIGNIFICANT RESOURCES

a. Human Resources and Activities

(1) Hilo Community. Modification of the Bayfront Beach area will have no immediate direct effect on Hilo; however, when the expected water quality improvements are realized, there will likely be a positive effect on tourism.

(2) Land Use. No significant impacts on land use are expected as a result of this project. No residences, farms or businesses will be affected, and the project will not cause a significant change in property values or taxes. As use of the new beach proposed in Plan A increases, increased parking spaces will be required.

(3) Recreation. Plan A will significantly improve the recreational opportunities for Hilo residents and visitors. Approximately 5 acres of new beach will be created and the rock groins will provide more fishing sites for recreational fishermen. In addition, surfing opportunities will be created. Plan B will not add to recreational opportunities, and will have no effect on existing facilities or activities.

(4) Historic Resources. There are no historic resources in the project area. The rock groins and jetty which are part of Plan A may have a minimal impact on the view plain of the Hilo Bay from some locations.

b. Natural Resources

(1) Marine Resources.

(a) Dredging sand in Hilo Bay will eliminate resident benthic infauna within the dredged areas and will temporarily increase siltation and turbidity stress in adjacent areas. Rapid recolonization of dredged and stressed areas is anticipated because of the homogeniety of the habitat and the relatively high mobility and tolerance of the fauna to sediment compared to reef organisms.

(b) During dredging, an artificial feeding situation will develop as predatory fish will exploit food resources displaced, exposed, or stirred up by the dredging activities. This fish concentrating effect may attract fishermen to the area.

(2) Migratory Waterbirds. Neither of the plans will effect Waiakea Pond where migratory ducks have been observed.

(3) Endangered Species.

(a) Endangered Humpback Whale. None of the plans will affect the migratory route of the humpback whale, or any critical whale calving, nursing or breeding areas in Hawaii.

(b) Endangered hawksbill turtle and threatened green sea turtle. Neither of the plans would affect turtle nesting areas or areas of turtle aggregations in Hawaii. The plans would not eliminate foraging areas along the coast outside of Hilo Harbor, nor within Hilo Bay.

(c) Endangered Hawaiian Coot. Neither of the plans involves modification of Waiakea Pond where the endangered Hawaiian Coot was reported nesting.

5.3 ADVERSE EFFECTS THAT CANNOT BE AVOIDED

a. There are no significant long-term adverse effects from the project.

b. Construction activities, including dredging or sand pumping will cause a significant increase in turbidity and sedimentation, increased noise and increased air pollution from dust and equipment exhaust.

c. The sand dredging will kill the resident infauna from the sand site; however, recolonization is expected to be rapid.

5.4 MEANS TO MITIGATE ADVERSE ENVIRONMENTAL EFFECTS

a. Hawaii State Regulations pertaining to construction activities will be followed to mitigate noise, air and water pollution, erosion and other environmental effects.

b. Silt retention devises will be used where practical.

6. PUBLIC INVOLVEMENT

6.1 PUBLIC INVOLVEMENT PROGRAM. The public involvement program has consisted of meetings and workshops with the public at large, meetings and workshops with members of the Federal, State, and County agencies, and the distribution of various reports and documents resulting from studies conducted under the Hilo Area Comprehensive Study to the public and agencies concerned with the progress of the study. In total, 10 public meetings were held including the initial public meeting in 1976, and eight technical studies have been released to the public. Tsunami hazards were the most frequent concern expressed by the public and the agencies, and beach restoration of the Bayfront beach was the most frequently mentioned recreational need.

6.2 REQUIRED COORDINATION. The following coordination has been completed with the following agencies:

a. Coastal Zone Management Act. A Federal Consistency determination has been prepared by the Corps and concurrence received from the State of Hawaii, Department of Planning and Economic Development, Coastal Zone Management Office (Appendix C).

b. State and County Approvals. The State of Hawaii, Department of Land and Natural Resources, is responsible for obtaining all necessary local permits and approvals and satisfying the requirements of Chapter 343, Hawaii Revised Statues and EIS Regulations.

c. Clean Water Act. A copy of the EIS and the Section 404(b)(1) and Water Quality Evaluation (Appendix A) was sent to the Hawaii State, Department of Health for review and comment on 1 March 1984. No comments have been received as of 24 May 1984.

d. Fish and Wildlife Coordination Act. The final US Fish and Wildlife Service Coordination Act report for this project dated December 1983 is included as a part of Appendix D. The comments of the National Marine Fisheries Service are also included in Appendix D.

e. Endangered Species Act. The comments of both the US Fish and Wildlife Service and the National Marine Fisheries Service on endangered species are included in Appendix D.

f. National Historic Preservation Act. A reconnaissance of the project site by the Corps archaeological technician did not reveal the presence of historic resources. The nearest known sites eligible to or listed on the National Register of Historic Places are located well outside the project area. The State Historic Preservation Officer and the US Advisory Coucil on Historic Preservation were solicited for review and they provided no comments.

6.3 STATEMENT RECIPIENTS. The following agencies and public-at-large were sent copies of the draft and final environmental statement and survey report.

Federal Government

US Advisory Council on Historic Preservation
Washington DC Office
Western Project Review Office

Federal Government (Cont)

US Environmental Protection Agency
- Office of Environmental Review
- Region IX
- Pacific Islands Office

US Army Corps of Engineers
- Coastal Engineering Research Center

US Department of Agriculture
- Institute of Pacific Islands Forestry
- Soil Conservation Service
- Hawaii District Office

US Department of Energy

US Department of Commerce
- Secretary of Environmental Affairs
- National Marine Fisheries Service
  - Southwest Region Office
    - Pacific Program Office
- Office of Coastal Zone Management
- National Weather Service, Pacific Region

US Department of the Interior
- Office of Environmental Review
- US Geological Survey, Hawaii Volcano Observatory
- Secretary Field Representative, Pacific Southwest Region
- US Fish and Wildlife Service
  - Regional Office
  - Pacific Islands Office
  - Endangered Species Coordinator
- National Park Service
  - Office of Archaeological and Historic Preservation
  - Interagency Archaeological Service
  - Arizona Archaeological Center
  - Pacific Southwest Region Office
  - Hawaii State Office

US Department of Housing and Urban Development - no comment

US Department of Health, Education and Welfare

US Department of Transportation
- Federal Highway Administration - no comment
- 14th Coast Guard District
  - Cape Small, Hilo
- Federal Maritime Commission

State Government

Governor George R. Ariyoshi

Hawaii Congressional Delegation

Department of Planning and Economic Development - Clearinghouse

Department of Health
- Office of Environmental Quality Control

International Tsunami Information Center

Department of Land and Natural Resources
- State Historic Preservation Officer
- Division of State Parks
- Division of Fish and Game
- Forestry and Wildlife Division
- Land Management Division

State Government (Cont)

- Water and Land Development Division
- Conservation and Resources Enforcement Division
- Hawaii District and Agent
- Board of Land and Natural Resources

Marine Affairs Coordinator
Department of Transportation
- Highways Division
- Harbors Division

Department of Accounting and General Services
Attorney General
State Department of Agriculture
Board of Agriculture
Public Utilities Commission
Hawaii State Library
- Hawaii Island Branches

Department of Hawaiian Home Lands
Keaukaha School
University of Hawaii
- Water Resources Research Center
- Library
- Environmental Center
- Hawaii Institute of Marine Biology
- Seagrant/Marine Advisory Program, Kona and Hilo Offices

County Government

Mayor Herbert T. Matayoshi
Hawaii County Council
Hawaii Legislative Delegation
Department of Parks and Recreation
Department of Planning
Planning Commission
Department of Public Works
Department of Research and Development
Department of Water Supply
County Fire Department
Department of Civil Defense

Organizations

Big Island Resource Conservation and Development Council
Big Island Casting Club
Association of Hawaiian Civic Clubs
Big Island Fish and Game Association
Conservation Council for Hawaii
- Hawaii Island Chapter

Hale Consultants, Inc.
Hawaii Audobon Society
Hawaii Community College Library
Hawaii Electric Light Co.
Hawaii Island Board of Realtors
Hawaii Island Chamber of Commerce
Hawaii Tribune Herald
Hawaiian Civic Club

Organizations (Cont)

Hawaii Leeward Planning Conference
Hilo Transportation and Terminal Co., Inc.
Hilo Trolling Club
Hawaiian Paradise Park Corp.
Hilo Sailing Club
Life of the Land
Kalapana Community Association
Hilo Downtown Improvement Association
Kailua Trolling Club
Kawaihae Trolling Club
Japanese Chamber of Commerce and Industry of Hawaii
Kona Mauka Troller, Inc.
Kona Yacht Club
Mark's Boat Works
North Hilo Community Council
Moku Loa Sierra Club Group
Matson Navigation Co.
Puna Community Council
Suisan Co.
Save Our Surf
Young Brothers Inc.
Wester Division Project Review, Lake Plaza South

Individuals

Mr. Alika Cooper
Mr. Dan Pakele
Mr. Dave Soderland
Mr. Edward Bumatay
Mr. Herbert Mann
Ms. Lei Keliipio
Mr. Paul Friesema

6.4 PUBLIC VIEWS AND COMMENTS. Letters of comment were received from Federal, State and local government agencies and private organizations and individuals. The letters frequently commented on all phases of the Hilo Comprehensive Study; however, only comments specifically addressing or otherwise applicable to the Bayfront Beach project are responded to in this section. Letters containing "No Comments" or statements of support are not included, and some of the comments, along with the Corps responses, are reproduced in Appendix E.

a. Federal Agencies

(1) US Environmental Protection Agency

Comment: Appropriate procedures must be followed if dredged material is proposed for ocean disposal at the EPA approved disposal site.

Response: Ocean disposal is not planned at this time. If ocean disposal is proposed, appropriate regulations will be followed.

Comment: The FEIS should discuss whether the sand trap would be likely to collect sediments contaminated with arsenic, PCB's and chlordane such as those of Hilo Bay.

Response: The sand trap (groin) would trap the sand used for beach replenishment and that transported easterly along shore from the Wailuku River. These sand sized particles will contain significantly lower quantities of contaminants than do the silty sediments in Hilo Harbor.

(2) Federal Highway Administration.

Comment: We suggest the final EIS include the fact that the Hilo Ironworks and Wailoa River Bridge have been determined eligible for the National Register of Historic Places.

Response: Neither of these sites is within the study area, but their eligibility for the National Register has been indicated in Section 4.2a.

b. Hawaii State Agencies

(1) Department of Land and Natural Resources.

Comment: The Bayfront Beach project should take into account the altered current patterns caused by modification of the Hilo Breakwater.

Response: The computer model study described in the Survey Report showed no effects on the Bayfront Beach from alteration of the breakwater. The design of the project is adequate for a condition without the breakwater.

(2) Department of Planning and Economic Development.

Comment: The EIS should assess the beach protection project in terms of changes which may occur as a result of the breakwater modification.

Response: The computer model study described in the Survey Report showed no effects on the Bayfront Beach from alteration of the Breakwater. The design of the project is adequate for a condition without the project.

(3) Department of Transportation.

Comment: A major concern is the recurring shoaling at the mouth of the Wailoa River, and the possibility that modification of the breakwater will increase erosion along Bayfront Highway.

Response: The preferred alternative for the Hilo Bayfront Beach project includes a jetty groin at the mouth of the Wailoa River to control shoaling, and the computer model study discussed in the Bayfront Beach report does not show a significant change in wave energy before and after breakwater modification.

Comment: The DEIS refers to the State Land Use Plan. it should be titled State Land Use Law.

Response:s The title has been corrected in the final EIS.

c. Hawaii County Agencies

(1) Departmenbt of Parks and Recreation.

Comment: We are concerned about the groins. As natural a setting as possible should be maintained.

Response: The groins proposed are necessary to slow beach erosion. They will be low in profile, so that when filled with sand they will be barely visible.

d. Private Organizations.

(1) Hawaii Island Contractors Association.

Comment: The Wailoa River shoaling problem needs your immediate attention and action.

Response: The Bayfront Beach plan includes construction of a jetty groin to prevent shoaling of the Wailoa River.

e. Individuals.

(1) Mr. Lance Foreman:

Comment: Groins should not be constructed until after the breakwater has been modified, so that the new conditions can be studied.

Response: The detailed design of the beach will be accomplished after the model studies have been completed and will consider the effects caused by the modifications.

Comment: The EIS should discuss vegetative stabilization for the Bayfront Beach.

Response:s This alternative was considered and rejected during the course of planning because vegetative barriers are not capable of protectinq the shore from the over-topping waves that occur along the bayfront.

(2) Mr. Jim Patterson:

Comment: An artificial surfing shoal would be a waste of time and money as there always exists in that area a natural shoal caused by the Wailuku River, which breaks on a northerly swell and creates some of the best waves on the Big Island.

Response: The shoal will not affect the existing surfing, but will cause smaller waves to peel and break.

Comment: Bayfront Beach is not eroding; it is increasing in size.

Response: According to State surveys predating the 1900's the shoreline has eroded more than 50 feet. Sand is accreting at the present time, and this is a positive sign; however, during winter storms, much of the sand is lost or moves down to block the Wailoa River.

7. List of Preparers

The following people were primarily responsible for preparing this Environmental Impact Statement:

Name	Expertise	Experience	Professional Discipline
Dr. James E. Maragos	Marine Ecology	BS, Zoology; PhD, Oceanography; 2 yrs postdoctoral research; 8 yrs environmental consultant; 9 yrs EIS studies, Corps of Engineers.	Review, overall impact assessment. (NEPA-Coordinator)
Mr. William B. Lennan	Biology	BA, Zoology; 2 yrs postgraduate studies, University of Hawaii; 3 yrs fishery biologist, USFWS 2 yrs environmental biologist Corps of Engineers.	Overall impact assessment.
Mr. David G. Sox	History and Culture	BA, MA Geography; 6 yrs research; 9 yrs EIS studies; Corps of Engineers.	Cultural and historical impact assessment.
Mr. David W. Cox	Archaeology	BA, Anthropology; 2 yrs postgraduate studies; w/diploma in cultural resources management, EWC; 1 yr EIS studies, Corps of Engineers.	Archaeological/ historic sites reconnaissance and impact assessment.
Mr. John I. Ford	Limnology	BS MS Zoology; 4 yrs EIS studies, Corps of Engineers; 2 yrs, fishery biologist, USFWS	Fish and Wildlife assessment.

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APPENDIX A

404(b)(1) EVALUATION
AND
WATER QUALITY

APPENDIX A
404(b)(1) EVALUATION
AND
WATER QUALITY

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APPENDIX A

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List of Tables

A. DISCHARGE OF DREDGED OR FILL MATERIAL, BAYFRONT IMPROVEMENTS, SECTION 404(b)(1), FACTUAL DETERMINATION.

1. Special Aquatic Areas.

Sanctuaries and Refuges: None.

Wetlands: None.

Vegetated Shallows: None.

Mudflat: None.

Coral Reefs: None.

Riffle and Pool Complex: None.

2. Human Use Characterization.

Municipal Water Supply: Not applicable.

Recreational and Commercial Fisheries: Hilo Bay supports a large recreational shoreline fishery, and fishing sites are located all along the bay shoreline. Fishing within the discharge area occurs from the existing revetment and from the beach shoreline. Recreational boaters possibly troll in the discharge areas. Common reef and nearshore coastal (neritic) fish are caught in the bay (see Attachment 1 for fish species list). The productivity of the bay fishery has not been measured, however, it supports an estimated 2,100 local recreational shoreline fishermen, based on a 1972 survey (Hoffman and Yamauchi in Cheney, 1977). The State Division of Fish and Game indicated that 456 two-year permits for night fishing in the bay were issued between May 1975 and May 1976. Commercial fishing in Hilo Bay is no longer a significant industry. Effect: While the discharges will eliminate some water area in the bay, the groins will provide new recreational fishing sites in the bay. The discharge of the rock used in construction will provide intertidal and subtidal habitat for fish and invertebrates, and should improve fishing in the area.

Water Related Recreation: Surfing, wading, swimming, canoeing and boating are significant recreational activities in Hilo Bay. Bayfront Beach Park is the focal point for Hilo area canoeing activities, and the beach also provides some sunbathing, picnicking and wading. Effect:

Base Condition	Plan A	Plan B
Boating	Groins will remove a small amount of open water from boating use, and create new navigational features in the bay. It will require canoes to paddle further offshore.	No effect
Wading, Swimming and Open Space	The groins will have a visual impact on former open view planes and the new beach will add a significant area for wading and swimming.	No effect
Surfing	Construction of a surfing shoal will add a surf site to the bay.	

Aesthetics: Hilo Bay's vista is dominated by the breakwater. Effect: The discharge will create new visual elements in Hilo Bay.

Plan A - Adds new groins to the Bayfront Beach.

Plan B - No effect.

National Monuments: None.
National Seashores: None.
National Wilderness Areas: None.
Research Sites: None.

National Historic Sties: Hilo Breakwater is eligible for inclusion on the National Register of Historic Places, based on its role in the development of Hilo port. The breakwater is also associated with events that facilitated the expansion of the railroad and port facilities in the Hilo area, the reestablishment of Hilo as the hub of transportation on the island of Hawaii, and the growth of Hilo.

Base Condition	Plan A	Plan B
Historical significance	No effect	No effect
Visual and physical appearance	No significant effect	No effect

3. Physical Substrate Determination.

Size Gradation and Coarseness: In general, the beach and offshore area are composed of fine to coarse black sand and silts, the deposits of sediment from the flow of the Wailuku River and from currents along the northwestern portion of Hilo Bay. The sand is largely of basalt origin. Sand thickness varies from 2 to 40 feet. Larger percentages of silt, lava basalt, and debris cover the sand offshore. Seaward of the 6-foot contour, the bottom is essentially mud with some fine sand.

Compaction: Not applicable. The discharge involves replenishment of a beach and the construction of groins with the rockfill protected by armor stone, or a rock revetment to protect the shore.

Bottom Elevation/Contour: See table below

Base Condition	Plan A	Plan B
Water depths at the discharge site	0 to -10' MLLW Surf shoal -4 to -8 MLLW	0 to -1' MLW
Condition after the Discharge	0 to +10' MLLW Surf shoal -0.5 to -3.5 MLLW	

Material Movement: The Bayfront Beach area is presently eroding. The sand has receded on the west end and accreted on the east end. Due to the Hilo Breakwater, only northly waves and diffracted trade wind waves can now reach the shore, resulting in a one-way longshore transport of littoral material toward the east. The amount of material available for transport is primarily governed by the sediment discharged from the Wailuku River. The net longshore transport rate was recently measured as approximately 5-6 cubic yards per day, moving toward the Wailoa River.

Deposition: Sand is accreting at the mouth of the Wailua River and westward for approximately 1,800 feet.

4. Water Quality, Circulation, Fluctuation and Salinity Determination:

Current Velocity, Direction and Pattern: Presently a predominant surface outflow occurs in Hilo Harbor along the breakwater due to the discharge of groundwater and riverine water into the bay. Studies indicate that current velocity varies between 0.03 and 0.19 knots. Ocean water lies beneath the surface freshwater layer, and its movement is tidal, with no set current direction. Effect: Neither plan is expected to change the general current pattern in Hilo Harbor, or the bay.

Downstream Flow: Not applicable.

Normal Water Fluctuations: No estuarine tidal lags are evident in Hilo Bay and the discharges are not expected to interfere with normal tidal fluctuations.

Salinity Gradient/Stratification: A salinity gradient is measurable in Hilo Harbor to a depth of 20 feet at the mouth of the harbor and 10 feet over Blonde Reef. The gradient is related to the amount of groundwater and riverine water discharged into the bay and the percent of freshwater in the surface layer can vary between 25 percent in the dry season to 75 percent following a storm event. Salinity measurements in the bay vary from 32-34 parts per thousand in the bottom layer and 11-30 parts per thousand in the surface layer. The formation of the salinity gradient is partially attributable to the breakwater which reduces wave energy as a water-column mixing force in the bay. Mixing is dependent upon wind and tidal forces, and ship traffic in the bay. Effect: Neither plan is expected to have an effect on bay salinity.

Potability: Not applicable.

Water Physical Characteristics: Water Chemical and physical characteristics in Hilo Bay are dependent upon riverine and groundwater discharges into the bay. Wastewater discharges into the bay were terminated. Effect: See Table A-1.

TABLE A-1. DISCHARGE EFFECTS ON WATER CHARACTERISTICS

Base Conditions (Mean Values)	Surface	Bottom	Plan A	Plan B
pH	7.60-8.32	8.04-8.36	No effect	No effect
Tem (°C)	19.7-24.9	23.4-25.2	No effect	No effect
Dissolved oxygen (mg/l)	7.59-9.71	4.64-8.00	No effect	No effect
Total nitrogen (ug/l)	172-403	28.4-90.4	No effect	No effect
Total phosphorus (ug/l)	13.9-53.5	17.8-60.2	No effect	No effect

Source: M&E Pacific, 1980.

Pathogens/Biological Content: Fecal coliform mean concentrations (number per 100 ml) ranged from 10 to 239 and fecal strep mean concentrations ranged from 62 to 1480. The source of the fecal bacteria was the riverine and storm drainage discharges into Hilo Bay. Effect: Neither plan will affect the amount of storm drainage water entering the bay.

Eutrophication: Not applicable.

5. Suspended Particulate and Turbidity Determination.

Turbidity: The waters in Hilo Bay are highly turbid due to the discharge of suspended material from Wailoa River and other drainage ways into the bay. Turbidity usually increases with the volume of water discharged into the bay. Ship traffic and periodic maintenance dredging (once every 10 years) also contribute to normal turbidity levels in the bay. During the dry season, turbidity is considerably lower than the wet season. High chlorophyll-a and zooplankton concentrations are principal turbidity causing material during the dry season compared with inorganic sediment during the wet season (Table A-2).

TABLE A-2

	Storm	Wet Season	Dry Season
Turbidity (NTU, mean values)			
Surface	7.82-22.3	2.92-7.52	0.56-1.67
Bottom	4.9-7.65	3.65-9.15	0.69-2.20
Total Suspended Molds (mg/l, mean values)			
Surface	9.30-75.4	6.43-17.3	No data Available
Bottom	16.1-44.5	7.40-28.6	

Source: M&E Pacific, 1980.

Effect: The discharge of rock to construct the groins in Plan A is not expected to result in a significant increase in turbidity. The discharge of sand for beach replenishment will result in a temporary increase in turbidity. Construction of the surf shoal will not effect turbidity if the sand or cement is contained in Longard Tubes.

6. Contaminant Determination.

Initial Evaluation:	Plan A	Plan B
a. The material proposed for discharge:	Basalt rock and sand	Basalt rock
b. Source site:	Quarry and offshore sand deposit	Quarry
c. Contaminants can flow into extraction site:	No	No
d. The material proposed for discharge was previously tested	No	No
e. Can pesticides enter the extraction site	No	No
f. Spills or disposal of contaminants have been documented in the past	Yes. Sediments in Hilo Bay are known to be contaminated with arsenic, PCBs and chlordane	Yes. Sediments in Hilo Bay are known to be contaminated with arsenic, PCBs and chlordane
g. Natural deposits of minerals or other substances harmful to man are present at the extraction site	No	No

The sediments in Hilo Harbor are contaminated with chlordane, PCB and arsenic based on analysis by the State Department of Health.

Findings:

a. The material proposed for discharge in Plans A and B consist of uncontaminated basalt stone and dredged material (sand). The dredged material is contaminated at a low level with arsenic.

b. The material classification for the basalt stone is Category 5 - Discharge without potential for environmental contamination. The material classification for the dredged material is Category 2, Open water discharge with level of contamination similar to the discharge site.

List of Contaminants to be Further Evaluated: None.

Zone of Mixing: Not applicable. The dredged material will be used for construction purposes.

7. Aquatic Ecosystem and Organisms Determination.

Fishery resources which support a recreational shoreline fishery are identified in Attachment 1. Corals are not present.

Rare/Threatened and Endangered Species: The threatened green sea turtle and the endangered hawksbill turtle have been seen near the breakwater and may enter the harbor. No nesting areas are found within the harbor or along the bayfront. Effect: No effect.

Aquatic Ecosystem Dependency: Fishery resource dependency on Blonde Reef is unknown, however, fish surveys indicate that the most fish species and the greatest number of fish were found on Blonde Reef in comparison to other areas in Hilo Bay. Effect: Both plans would add rocky habitat to the present bayfront depauperate sandy/silty substrate; fish populations in the area should increase. Neither plan would effect Blonde Reef.

Determination: The discharge of armor units into the harbor under Plans A and B do not significantly degrade water quality or human uses of the water. The basalt rock is not expected to contain contaminants, cause prolonged water turbidity problems and will not significantly degrade the aquatic ecosystem. The dredged material, although containing some with arsenic, is not expected to be a hazard to humans or other organisms.

Material Proposed for Discharge:

	Plan A	Plan B
Basalt rock	16,500 cy	29,000 cy
Sand (beach replenishment)	250,000 cy	None
Sand (surf shoal)	5,000 cy	None
Sand (in Longard tubes)	1,200 cy	None

ATTACHMENT 1

CHECK LIST OF FISH AND SHELLFISH TAKEN
BY FISHERMEN WITHIN THE HILO BAY SURVEY AREA
(From Sunn, Low, Tom & Hara, Inc. 1977)

LOCAL/COMMON NAME	SCIENTIFIC NAME	LOCATION BY REGION
Aholehole	Kuhlia sandvicensis	5,6,7,9,11,12,14,16,17
Aku	Katsuwonus pelamis	3
Akule (Aji)/Hahalalu	Trachurops crumenophthalmus	1,6,9,11,14
Amaama (mullet)	Mugil cephalus	5,6,7,8,9,13,15
Awa (milkfish)	Chanos chanos	1,7
Aweoweo	Priacanthidae	16
Ehu (red snapper)	Etelis marshi	4
Hihimanu (ray)	Dasyatidae	11,14
Hinalea (wrasse)	Labridae	9,16
Humuhumu	Balistidae	16,17
Kaku (barracuda)	Sphyraena barracuda	1
Kawakawa	Euthynnus yaito	14
Kumu	Parupeneus porphyreus	1,4,11,14,15,16
Kupipi	Abudefduf sordidus	9,11,16,17
Lae	Scomberoides sancti-petri	9
Maiko	Acanthurus nigroris	16,17
Manini	Acanthurus sandvicensis	11,14,16,17
Mano (tiger shark)	Galeocerdo cuvieri	1
Mano kihikihi (hammerhead shark)	Sphyrna lewini	1,2,11,14,16,17
Maomao	Abudefduf abdominalis	15,17
Menpachi	Myripristis spp.	16
Moano	Parupeneus multifasciatus	1,14,16,17
Moi/moi-lii	Polydactylus sexfilis	3,4,5,6,7,14
Nehu	Stolephorus purpureus	1,2,11,13,14

ATTACHMENT 1 (Cont)

LOCAL/COMMON NAME	SCIENTIFIC NAME	LOCATION BY REGION
Nenue	Kyphosus cinerascens	14
Oio	Albula vulpes	1,5,6,9
Omaka	Caranx mate	1
Oopuhue (balloon fish)	Arothron hispidus	4
Opakapaka	Pristipomoides microlepis	4
Opelu	Decapterus pinnulatus	9
Pakii (flatfish)	Bothus spp.	15
Palani	Acanthurus dussumieri	9,12,13,16,17
Piha	Spratelloides delicatulus	16
Pualu	Acanthurus xanthopterus	1
Puhi (moray eel)	*Muraenidae*	14
Puhi (tohe--conger eel)	Conger marginatus	14
Taape	Lutjanus kasmira	1,2
Toau	Lutjanus vaigiensis	11
Ulua/Papio	Carangidae	1,3,4,5,6,7,9,11,14,15, 16,17
Upapalu (cardinal fish)	Apogon snyderi	15
Weke/Oama	Mulloidichthys samoensis	1,11,12,13,15
Tilapia	Tilapia spp.	10
Oopu (goby)	Gobidae	5
Crab - Kuanono	Portunus sanguinolentus	3,4,6,7,15
Crab - Samoan	Scylla serrata	3,4
Opae (glass shrimp)	Palaemon debilis	7,8,10,15
Ula	Panulirus spp.	3,4,16,17
Tako (octopus)	Octopoda	4,16,17
Opihi	Cellana spp.	4,16,17

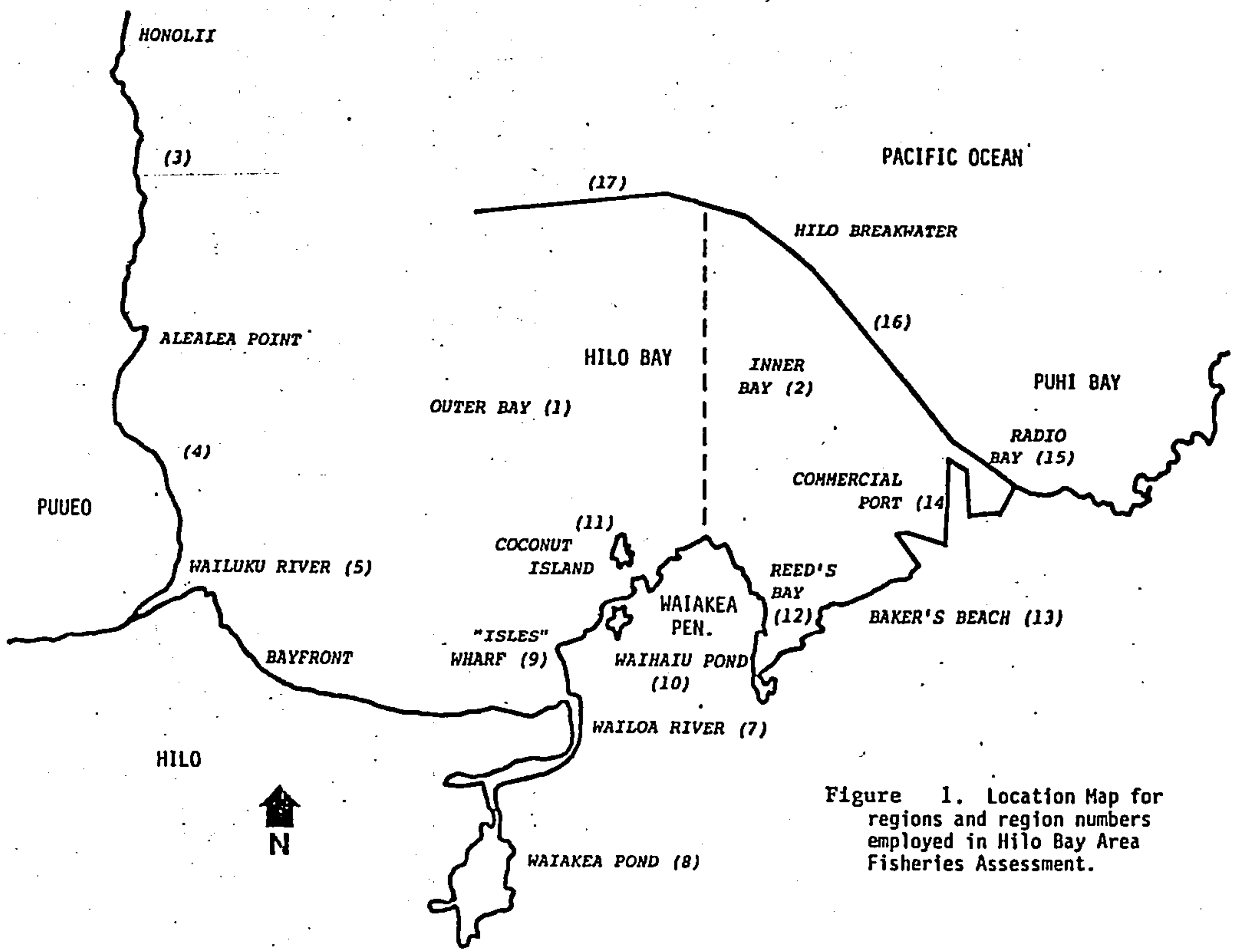

Figure 1. Location Map for regions and region numbers employed in Hilo Bay Area Fisheries Assessment.

From Sunn, Low, Tom & Hara, Inc. 1977

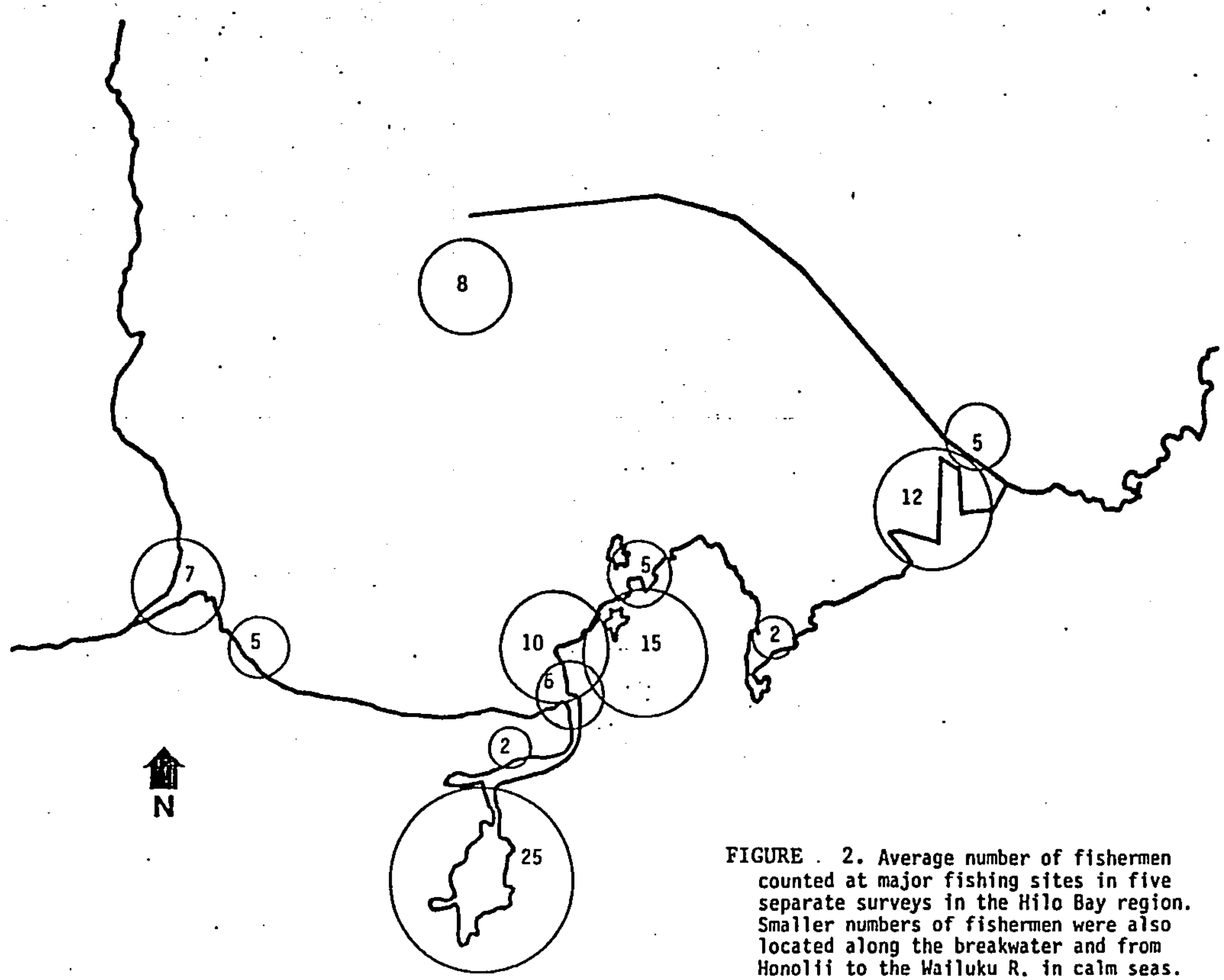

FIGURE . 2. Average number of fishermen counted at major fishing sites in five separate surveys in the Hilo Bay region. Smaller numbers of fishermen were also located along the breakwater and from Honolii to the Wailuku R. in calm seas.

From Sunn, Low, Tom & Hara, Inc. 1977

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DATE:

SUBJECT: Dredging in Hilo Bay for Black Sand Beach Replenishment

FROM: Gregory Baker
Technical Support Branch, EPA, Region 9

TO: Art Cropper
Honolulu District, Corps of Engineers

This memo is a follow-up of our phone conversations on 15 March 1982.

The primary questions is whether further testing is required for the above referenced dredging and disposal operation, based on testing results obtained from a previous dredging project in Hilo Bay. Testing has indicated a presense of arsenic in the material at concentrations greater than background levels.

Tests that have been performed:

Bulk Sediment Analysis (BSA) at extraction site

Results:

96 micrograms / gram total arsenic

Recommended further testing:

Particle size analyses of extraction site and disposal site.

Discussion:

We do not recommend further testing for arsenic on the basis of results from a previous dredging project in Hilo Bay. You have stated that those results showed:

BSA:	133 micrograms / gram
E.E. Toxicity Test:	10 micrograms / liter

According to the 1976 EPA publication entitled, Quality Criteria for Water, the domestic water supply criterion for arsenic is 50 micrograms / liter. Under EPA's Notice of Water Quality Criteria Documents (Federal Register/ Vol. 45, No. 231/Friday, November 28, 1980), arsenic is listed as having acute toxicity on saltwater aquatic life at concentrations as low as 508 micrograms/liter.

Although the EP Toxicity test is designed for land disposal of hazardous wastes rather than aquatic disposal of dredged material, it is clear that the EP Toxicity result (10 micrograms/liter) is not only below RCRA standards, but also the water quality criteria for arsenic. Normally, we would request an elutriate test using the water of the disposal site as an extractant rathern than the mildly acidic solu-

EPA FORM 1320-6 (REV. 3-76)

tion required by the EP Toxicity test. However, since a) the BSA for the proposed project showed lower concentrations of arsenic than the BSA for the previous project, b) an elutriate test with sea water would probably not extract as much arsenic as the EP Toxicity Test, and c) the previous toxicity testing showed a level of arsenic below the EPA criteria; an elutriate test of the material should not be necessary.

This conclusion is based on the presumption that the particle size of the material at the proposed extraction site and the previous extraction site are similar. Furthermore, particle size of the dredged material should also be compatible with the particle size at the disposal site prior to authorization. For this reason I have enclosed a copy of a testing procedure developed in conjunction with the Los Angeles District of the Corps of Engineers, dealing primarily with beach nourishment. In addition, I have enclosed a copy of testing procedures developed by the San Francisco District. Note that material determined to be 80% sand is typically exempt from chemical testing under this procedure.

Enclosures

DEPARTMENT OF THE ARMY
PACIFIC OCEAN DIVISION, CORPS OF ENGINEERS
FT. SHAFTER, HAWAII 96858

March 1, 1984

Mr. Charles Clark, Director
Department of Health
State of Hawaii
1250 Punchbowl Street
Honolulu, Hawaii 96813

Dear Mr. Clark:

As part of the procedure for implementing the Shore Protection of the Hilo Bayfront Beach, Hilo, Hawaii, the Corps has completed an environmental impact statement (EIS) which includes a discussion of the effect of the proposed project improvements on water quality in accordance with the Clean Water Act. Enclosed for your review is a copy of the EIS for the project with an evaluation of the effects of the discharge of dredged or fill material into waters of the U.S. under the Section 404(b)(1) Guidelines promulgated by the U.S. Environmental Protection Agency.

At this time, we request your comments on the EIS. We would appreciate a response on this matter by March 30, 1984.

Sincerely,

Clarence S. Fujii
Acting Chief, Engineering Division

Enclosure

APPENDIX B

CULTURAL AND SOCIAL RESOURCES

APPENDIX B
CULTURAL AND SOCIAL RESOURCES

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Figure

1. RECREATIONAL RESOURCES.

a. National Scenic and Wild Rivers. None present. Local land use planning documents propose the development of Wailuku River as a natural wilderness area and the development of Wailoa River and Waiakea Pond as park, open space.

b. National Trails. None present.

c. Natural Landmarks. None present.

d. National Shoreline Parks or Beaches. None present. Several State and County parks are present along the shoreline. While public access and use of the Hilo Breakwater is discouraged due to hazardous conditions, fishermen use the breakwater as a fishing site.

TABLE B-1. RECREATIONAL RESOURCES

Recreation Site	Acres	Ownership	Park Use
Wailuku River Mouth	-		Surfing
Mooheau Park	18.9		Beach (eroding)
Bayfront Park	6.8		Beach (eroding), canoeing, fishing
Wailoa River Park	146.0	State	General, boating, shoaling, river mouth
Liliuokalani Gardens and adjacent areas	20.5		General
Coconut Island	3.1		General, surfing
Banyan Drive Shoreline	-		Scenic
Reeds Bay	15.5		Beach (man-made) swimming
Baker's Beach		State	Beach (man-made)
Radio Bay		State	Boating
Radio Bay Park		State	General
Hilo Breakwater		Federal	Fishing

e. Water Contact Recreation. Principal water contact recreation activities in Hilo Bay include shoreline fishing, boating, wading and canoeing. Swimming is seldom observed possibly due to the highly turbid nearshore waters and concentrated mats of vegetative debris carried into the bay from the tributary systems. Six surfing sites were identified in Hilo Bay in the "Hilo Bay - a Chronological Study" in 1981. According to the Hawaii Chamber of Commerce, 1973, surfing demands have grown sufficiently to warrant investigations for increasing the number of surfing sites on the island. Fishing and boating are judged the most significant recreational activities. Canoeing is centered on use of the Bayfront beach and Wailoa River. Swimming is most prevalent in Reeds Bay.

(1) Fishing. Recreation fishing areas and resources in Hilo Bay are limited, popular, and need to be protected. Leisure time, recreational fishing is more important in Hilo Bay than commercial fishing as a source of seafood for local residents. Commercial fishing interests are principally interested in the offshore fishing grounds. The number of recreational fishermen in the Hilo Bay area is about 2,100 persons; 60% are shore fishermen, 5% are net fishermen, and the remainder utilize other fishing methods (Cheney, 1977). Favorite fishing sites, list of recreational fish species and general locations where the fish are caught are provided in Cheney, 1977. Fishermen believe that too many fishermen and poor enforcement of fishing regulations are partially responsible for over-exploitation. Fishermen are also competing for water use with canoe paddlers, surfers and boaters. Increasing the number of fishing sites and enforcing existing fishing regulations were believed to be beneficial to recreational fishing in Hilo Bay.

(2) Surfing. Five surfing sites are located in Hilo Bay (Kelly, 1981). One is located at Coconut Island, 2 at the Wailuku River mouth, one at Wainaku, and one at the tip of the breakwater. Kelly indicated that more surfing sites existed in the bay in the 1800's prior to construction of the breakwater.

(3) Beach Parks. The principal beach parks in Hilo Bay are Baker's Beach, Reeds Bay, Hilo Black Sand Beach, and Liliuokalani Gardens. Both Reeds Bay and Baker's Beach are man-made. Portions of Reeds Bay were created from material dredged from Hilo Harbor turning basin during the period from 1925-1930. Hilo Black Sand Beach was formed by the natural accretion of eroded basalt material from the 1881 lava flow in the Wailuku River drainage basin. Black sand was mined from the beach in the 1900's. Both beaches are eroding. The creation of Baker's Beach appeared to have altered the dynamic equilibrium of the shoreline area and erosion is believed to be a natural process which reestablishes equilibrium. Erosion at Hilo Black Sand Beach appears to be related to the Hilo Breakwater (Reference M & E Pacific, 1980). The breakwater protects a portion of the beach which has remained stable. However, the exposed portion has eroded and beach sand is transported in an easterly direction. The breakwater appears to have eliminated the westerly component of the littoral transport.

(4) Boating. Wailoa River provides berthing for recreational and fishing craft. A State launch ramp is located in the river. Radio Bay and Reeds Bay are also used for berthing principally for sail craft and vessels with high superstructures which prevent use of the Wailoa River area. Boats using the Wailoa river must have an over-the-water height of less than 8 feet to pass under the Kamehameha Highway bridge. The existing facilities provide berthing for only 106 vessels. Only 4 transient berths are available.

2. NATURAL RESOURCES.

a. Land Resources. The Hilo Bay shoreline is classified as Keaukaha Extremely Rocky Muck with 6-20% slope. The bay shoreline specifically consists of rocky headlands at Wailuku River, rock revetment and black sand along the Mooheau Beach Park, black sand at the Bayfront Beach park, rock headlands around Waiakea Penninsula, dredged coral fill at Baker's Beach and Reeds Bay and the developed port area. The harbor bottom consists of silty clays carried into the bay from upland areas by the Wailuku and Wailoa Rivers. Blonde Reef is principally a coralline reef area.

b. Prime and Unique Agricultural Lands. None present.

c. Natural Hazards.

(1) Volcanic Hazards.

TABLE B-2. RECORDED OR ESTIMATED NUMBER OF VOLCANIC ERUPTIONS ON THE ISLAND OF HAWAII DURING HISTORIC TIMES (1800-Present)

The summit and major rift zones of Mauna Loa and Kilauea volcanoes on the island of Hawaii have been very active during historic times, and volcanic activity is expected to continue through the foreseeable future.

Volcano	Total Eruptions	Eruptions Outside the Caldera
Mauna Loa	30-40	About 15
Kilauea	40-50	About 25
Mauna Kea	0	-
Hualalai	2	-
Kohala	0	-

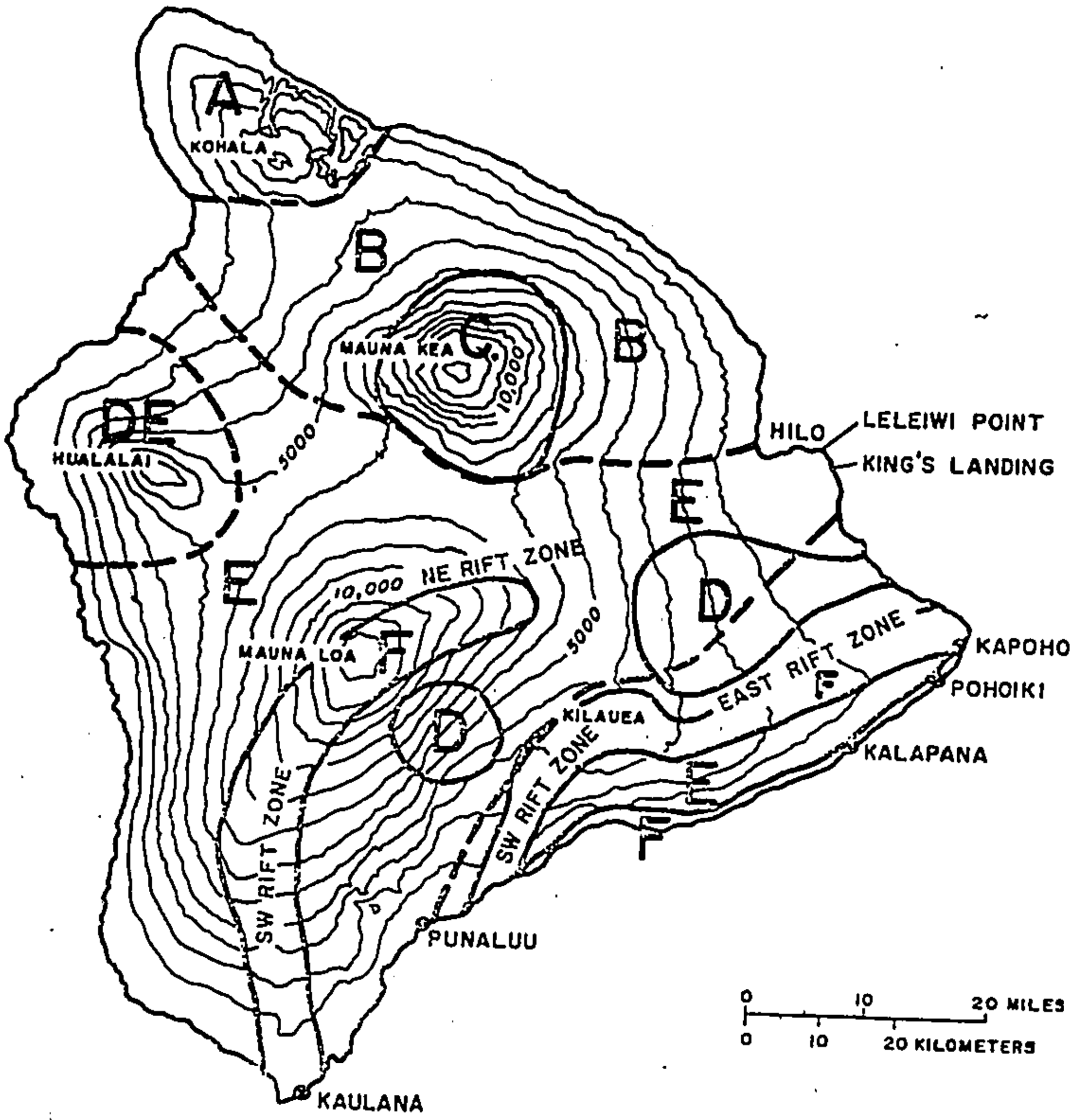
Adapted from US Geological Survey, 1974.

TABLE B-3. NUMBER OF ERUPTIONS ORIGINATING WITHIN HAZARD AREAS AND NUMBER OF TIMES LAVA FLOW COVERED LAND WITHIN HAZARD AREAS DURING HISTORIC TIMES (SINCE 1800) ON THE ISLAND OF HAWAII

Hazard Area	# of Eruptions	# of Lava Flows	% Land Covered by Lava
A	0	0	0
B	0	0	0
C	0	0	0
D	0	0	0
DE	1	2	6
E	1	35	15
F	80	More than 80	50

Source: US Geological Survey, 1974.

Hilo is located in a high risk volcanic area (designated risk area E in U.S. Geological Survey, 1974; see Figure B-1). While the greatest danger to Hilo from volcanic activity is associated with eruptions within the



THE FIVE VOLCANOES THAT FORM THE ISLAND OF HAWAII: KOHALA, MAUNA KEA, HUALALAI, MAUNA LOA AND KILAUEA. CONTOUR INTERVAL 1,000 FEET. DASH LINES SEPARATE NAMED VOLCANOES. (USGS, 1974)

HAZARD DESIGNATION	EXPLANATION
F	AREA OF HIGHEST RISK WITH HISTORIC AND RECENT PREHISTORIC RECORD OF ACTIVE VOLCANISM, FAULTING AND SUBSIDENCE.
E	AREA SUSCEPTIBLE TO BURIAL BY LAVA FLOWS ORIGINATING FROM AREA F. DEGREE OF RISK GENERALLY DECREASES WITH DISTANCE FROM SUMMITS AND MAJOR RIFT ZONES.
DE	HUALALAI VOLCANO ONLY. LAVA BURIAL MORE FREQUENT THAN AREA D, BUT LESS THAN AREA F.
D	MODERATE RISK. NO HISTORIC OR RECENT PREHISTORIC LAVA FLOWS.
C	MAUNA KEA VOLCANO SUMMIT. SMALL RISK. ERUPTION FREQUENCY LOW, LAST ERUPTION 3000 - 5000 YEARS AGO.
B	NO ERUPTIONS DURING LAST 10,000 YEARS.
A	NO VOLCANIC ACTIVITY IN LAST 60,000 YEARS.

SOURCE: USGS, 1975

FIGURE B-1

northeast rift zone of Mauna Loa, the risk of potential damages and losses from lava flow and other hazards (ejecta, gases, subsidence and surface rupture) generally decreases down the volcanic slopes toward Hilo. Most lava flows from Mauna Loa have stopped short of the Hilo suburbs. Subsidence and surface rupture risks are considered low in Hilo, although earthquake property damage has occurred. An earthquake in 1975 caused about $4 million in property damage throughout the island. Since major structural damage risks are high, earthquake resistant structural design regulations are enforced.

(2) Tsunami and Riverine Flood Hazards

Hilo Bay is susceptible to tsunami and riverine flooding. Forty destructive tsunamis have reached Hilo since 1819, seven of which inflicted loss of life and property. The tsunamis of 1946 and 1960, resulted in the combined loss of 234 lives and damages in excess $52 million. Actions taken to lessen the impact of tsunamis included rezoning of vulnerable waterfront areas to open space and the adoptions of structural design codes to reduce future losses and damages. The highest tsunami runup elevation recorded was 35 feet in 1960. Riverine flood hazards are related to high intensity rainfall, overland sheetflow and undefined drainageways, the last of which is the consequence of the geological youthfulness of the region. The Alenaio Stream flood plain is the principal flood hazard area in Hilo.

APPENDIX C

NATURAL RESOURCES

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APPENDIX C

NATURAL RESOURCES

A. FLORA

No significant vegetation communities or species are found around the Hilo Bay shoreline, although the Wailuku River is planned as a natural wilderness area by local planners.

B. FAUNA

1. Endangered Species.

a. The endangered Hawaiian coot was observed nesting in Mohouli Pond in Waiakea Pond by Shallenberger, 1977. The endangered hawksbill turtle and the threatened green sea turtle forage along the coastal areas and have been observed in Hilo Bay.

b. The humpback whale seasonally migrates through Hawaiian waters and can be found around all the major islands from Hawaii to Kaula Rock during the seasonal migration. The whales begin to appear during November and leave the islands by June with the greatest number occurring during February and March.

The National Marine Fisheries Service indicated that 500-700 whales annually migrate through Hawaiian waters to mate, calve and nurse their young. The whales prefer relatively shallow water, usually waters less than 100 fathoms deep, and are particularly numerous on Penquin Banks, in the area between Maui, Lanai, Molokai and Kahoolawe, around the northwest tip of Hawaii and between Niihau and Kauai. However, they are consistently seen in small numbers in other areas of the Hawaiian Islands during the season. Herman (1981) suggests that the whales first arrive in Hawaii around the island of Hawaii and travel northward toward the islands in Maui County and continuing

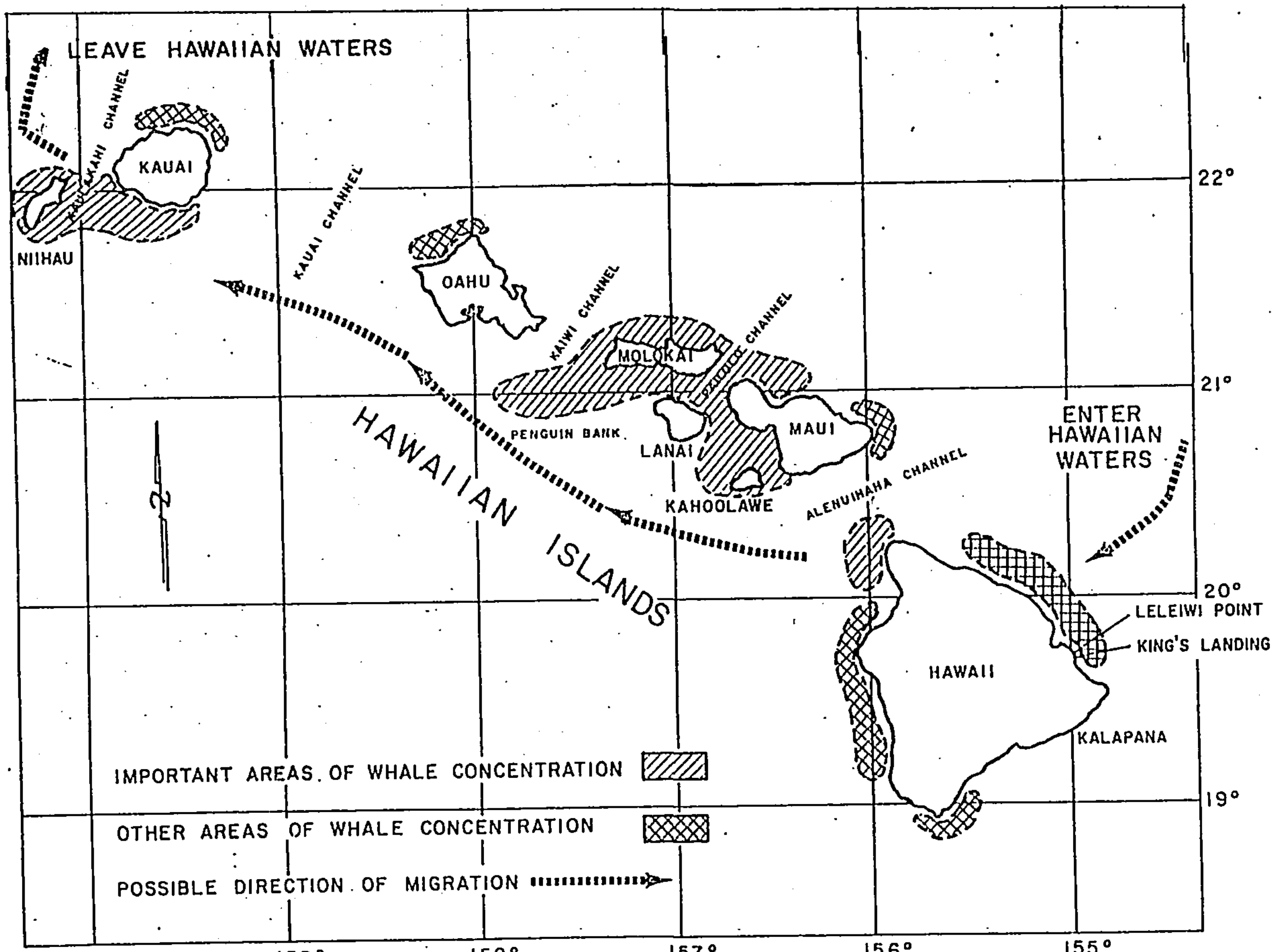


FIGURE C-1. DISTRIBUTION OF HUMPBACK WHALES IN HAWAII (Adapted from: Wolman and Jurasz, 1976 and Rice and Wolman, 1977. Herman in Whitten, 1981).

FIGURE C-1

toward Niihau and Kauai, where they leave on their return to the northern summer feeding grounds. The relative concentrations of whales in the Hawaiian Islands is illustrated in Figure C-1 based upon information provided in 1976 and 1977 census (Wolman and Jurasz 1976, and Rice and Wolman, 1977). The National Marine Fisheries Service provided the following whale census in the Leleiwi Point area of Hawaii. The whales have not been seen in Hilo Harbor.

TABLE C-1. WHALE SIGHTINGS OFF LELEIWI POINT

Year	# Whales Sighted
1976	12
1977	7
1978	5
1979	9

2. Wildlife Refuges. No wildlife refuges are established in the area.

3. Marine Sanctuaries. No marine sanctuaries are established in the area.

4. Migratory Waterbirds. The Hilo Bay area is not a major area of concentration for migratory shorebirds or waterbirds. However, migratory and domestic ducks have been observed in Waiakea Pond during the winter seasons. The most common waterbird in the Waiakea Pond is the domestic mallard.

5. Marine Resources.

a. Hilo Bay is biologically depauperate, possibly the consequence of freshwater, siltation and turbidity stresses. The breakwater reduces the wave energy and water transport into the harbor, possibly allowing increases siltation in coral areas and reduce the mixing of marine and freshwaters masses. Freshwater stress prevents the establishment and growth of benthic marine communities on the reefs, and poor light penetration in water limits photosynthetic activity. The silt areas lack a developed infauna (Reference M & E Pacific, 1981). No live organisms were found in benthic samples taken from the silt areas probably as a result of recent maintenance dredging in the harbor. Six samples containing live organisms were obtained from rocky coralline areas in the bay. Scour and freshwater stress may be factors limiting benthic development in the Wailuku River mouth area.

b. Live coral cover based on a survey of 5 sites in Hilo Bay ranged from 1-16% attaining the highest cover on Blond Reef (16%). The areas around Coconut Island had a live coral cover ranging from about 1-10% (M&E Pacific, 1980a). The survey detected a decline in coral cover between 1977 and 1980 possibly attributed to large floods in March 1980. Coralline algae, Porolithon, was more abundant than coral increasing its substrate coverage between 1977 and 1980. Porolithon is responsible for the consolidation of loose reef material and encrusting coral skeletons. Large dead coral heads on the reefs inside the breakwater suggest that the reef was once a viable ecosystem. Wave energy on the reef would have created a high energy environment that flushed silt from the reef and reduced salinity stress by rapidly dissipating freshwater concentrations before the freshwater could affect the reef area. The wave action would have also created a high dissolved oxygen environment, and surge and wave currents would have promoted excellent water circulation over the reef, creating favorable conditions for coral growth. Areas within the breakwater exposed to waves refracted around the end of the breakwater have flourishing coral communities. The dead coral mass does provide habitat for fish and invertebrates and are areas of richness within the generally depauperate bay. The number of fish observed on the hard substrate habitat ranged from 4-365 fishes representing 3-29 species. For comparative purposes, areas seaward and to the east of the breakwater had coral cover ranging from 40-70% and fish numbers ranging from 172-543 fish representing 36-39 species (M&E Pacific, 1980b). Plankton densities in Hilo Bay, based upon 300 measurements, were not considered significantly different from other areas in the State, but were similar to ocean areas.

c. Fishermen believe fish stocks in Hilo Bay are declining (Reference Cheney, 1977) and attribute this reduction to a variety of factors including over-exploitation, removal of juveniles by bait fishermen, mechanical sugarcane harvesting and chemical pollutants. Whether or not a decline has actually occurred is unknown and the exact factors affecting fish abundance have not been determined. The inshore fish catch presently accounts for less than 10% of the total fish landings in Hilo Bay, and are represented by fewer species than offshore fish. This contrasts to earlier trends at the turn of the century, when inshore reef fish accounted for 50% of the total pounds of fish landed in Hilo Bay and represented more species caught than offshore fish. Nehu catches have declined and are presently insufficient to support a fishing fleet. The decline in nehu resources is attributed by fishermen to overfishing, nutrient and sediment loading and an overall decline of the tuna fishery. The Hawaii Island Chamber of Commerce, 1973, would like to see nehu of other bait resources improved in hopes of revitalizing the commercial fishing industry in Hilo. The principal nehu catch areas are located within the commercial port. Former baiting areas were along the Bayfront shoreline to Hoolii.

d. The development of the bay as a commercial port, dredging and filling shoreline areas, and disposal of industrial and domestic wastes have affected the aquatic habitat and may have affected fishery resources. However, the long-term trend in fishing stocks and composition is unclear. Fishermen opinions concerning cause and effect relationships on local fishery stocks suggest that certain natural or man-related factors influence fish abundance and species, and the fishing methods used. For example, siltation probably fills habitat required by moi, aweoweo amd menpachi. Low stream flow and dry winters appear correlated to increased catch rates, but high stream flows usually correlate with increased papio catches. Murky water tended to increase ulua and moi catch rates, but reduced reef fish and nehu catches. High waves are thought to clear out the mud and improve fishing. The canec plant discharge into Waiakea Pond were thought to improve fishing. Good crabbing along the bayfront was associated with abundant Enteromorpha and Ulva growth. Chlorine from the sewage plant discharge was believed to be the cause of decline in piha (Spratelloides delicatulus) abundance. Shutting down and cleaning the sugar mills have resulted in a decrease in papio, ulua and moi catch and in an increase in menpachi, aweoweo, aku and other reef fish catch. Trawlers no longer foul their lines on rafts of bagasse. Turbid waters reduced spearfishing success and probably accounted for reduced reef fish catches.

e. There are no harvestable shellfish beds present.

f. Water Quality

(1) Water quality in Hilo Bay has improved over the long-term with the removal and treatment of agricultural, industrial and domestic wastewater discharges. The pollutant sources have included wastewater from sugarcane and canec processing operations, raw sewage discharges, periodic shipboard waste disposal, cesspool overflow and leachates, surface runoff from agricultural lands, a thermal discharge, fish wastes, and petroleum wastes. At present, the major, point source discharges in Hilo Bay are the municipal sewage treatment plant discharge outside of the breakwater in Puhi Bay, and the Hilo Electric Company's Shipman power plant thermal discharge (28 mgd) into Wailoa River. The only sugar mill discharge in the area is located 8 miles north of Hilo Harbor entrance at Pepeekeo. The principal nonpoint pollution sources in Hilo Bay are the surface runoff from agricultural lands and leachates from cesspools. Groundwater seepage and riverine discharge into Hilo Bay has a significant influence on bay water quality.

(2) Hilo Bay is a two-layered water body (M & E Pacific, 1980a) due to the discharge of 300 mgd of freshwater from Wailuku River and 700 mgd of groundwater into the harbor. The freshwater forms a distinct surface layer over the more saline bottom water. The surface layer persists throughout the year and is thicker in the wet season than in the dry season reflecting hydrologic conditions in the watershed. Salinity gradients are higher near the shore where groundwater discharges into the harbor and persist next to the breakwater, suggesting that the breakwater forms a barrier that inhibits mixing of marine and freshwaters.

(3) The predominant surface current direction is seaward out of the harbor. A continuous outflow occurs along the breakwater possibly as a result of groundwater outflow from Radio Bay. The surface current is dependent upon the influx of freshwater and the predominant wind direction. The influence of freshwater is measurable to a depth of 10 feet on Blonde Reef inside the breakwater and outside of the harbor mouth. In some areas the freshwater influence extends down to 20 feet. The depth of the freshwater influence generally reflects the low degree of mixing between the surface and bottom waters in the bay. The primary mixing force is provided by the wind with some mixing at the interface due to the shear force between the freshwater layer

and the saline bottom water. Turbulence from ship traffic periodically mixes the two water layers. During certain periods (20% of the time) the prevailing wind direction is onshore retarding the outward flow of water on the surface. A two-cell circulation pattern was measured in 1973 (Reference Neighbor Island Consultants, 1973), but this condition may be the exception rather than the norm. Subsurface currents are influenced by the predominant westerly offshore coastal current off Blonde Reef (M & E Pacific, 1980a). Subsurface waters flow into Hilo Bay at a depth of 20-40 feet along the western side of the harbor mouth. Water continuously flows out of the harbor along the eastern side of the harbor mouth.

(4) Water quality baseline data are incomplete to compare annual variations with the State Water Quality Standards. The problem is due to water quality monitoring patterned after standards which were later revised in September 1979. The existing data are not reported in the same units of measurements contained in the new standards, and were not collected at a frequency sufficient to determine compliance with the new standards. In some instances the constituents analyzed are not the same as those required by the standards. The new standards classify Hilo Bay (inside the breakwater) as an embayment with marine water standards for a wet and dry season. Other types of water qaulity standards are further provided for artificial basins, reef communities and soft bottom areas within Hilo Bay. Data collected between March and June 1980 in comparison with the State Water Qaulity Standards indicate that turbidity, nitrate plus nitrite and total phosphorus exceed the geometric mean standard, and values for suspended solids, total kjeldahl nitrogen and chlorophyll-a exceeded standard maximum values (M & E Pacific, 1980). In general, Hilo Bay is vertically stratified due to freshwater discharges from surface and groundwater sources. Nutrients concentrations do not limit phytoplankton growth and do reflect seasonal fluctuations related to surface runoff and groundwater influx. Water temperatures are warmer in the surface waters than in subsurface waters, but solar heating can warm subsurface waters when the surface outflow is retarded. Suspended solids and turbidity fluctuate with seasonal water runoff and do not appear related to phytoplankton density. Subsurface seawater pH values are normal for seawater conditions and are higher than the freshwater surface layer. Generally, pH values are high when photosynthetic activity increases. Chlorophyll-a concentrations also fluctuate seasonally, being lower in the wet season when

light water-penetration is reduced and when water turbidity is higher due to increased suspended solids. Dissolved oxygen levels are near saturation on the surface and attain super-saturated conditions in areas of high photosynthetic activity. Dissolved oxygen levels were lowest near the silty bottoms of the inner harbor and in Wailoa River probably due to reduced mixing with surface waters, to organic loading from terrestrial sources, and to organic material in the harbor that settles out of the water column. Fecal strep and fecal coliform bacteria concentrations have decreased over the past years with the removal of the sewage discharges, and are presently influenced by riverine and groundwater discharges. Fecal strep bacterial tend to survive longer in Hilo Bay than other areas in the State due to the freshwater layer in the harbor.

(5) Sedimentation. Water quality data indicate that sedimentation is a significant factor influencing water quality in Hilo Bay. The low wave energy environment created by the breakwater allows silt to settle out onto the coral reef environments smothering and destroying the reef ecosystem. The rate of sedimentation may be slow based on maintenance dredging records for Hilo Bay Harbor; approximately 54,000 cubic yards of material was removed from the harbor in 1977 reflecting the amount of material accumulated in the harbor since 1962. The estimated maintenance dredging cycle for Hilo Harbor is once every ten years based on past records. Silt is derived primarily from upland erosion within the Wailuku River drainage basin. Based on Table G-14, the principal sources of silt are the agricultural areas and the areas around the summit of Mauna Loa. However, about 35,000 tons of silt per year are deposited into Hilo Bay from Wailuku River (Corps of Engineers, 1976). Based on average annual rainfall in the region, significant soil losses are related to severe storm or intense rainfall events which affect severe erosion areas rather than smaller daily rainfall events. The rates of sedimentation in the harbor may be lower than in the past due to volcanism depositing new lava over erodible soils and to the termination of the sugar mill processing wastewater discharge into the harbor. The lava flow of 1881 covered some of the erodible soil in the Wailuku River drainage basin, and Wainaku Mill discharged 20,000 tons of suspended solids a year into the bay until it closed in 1976.

TABLE C-2. LAND-USES AND EROSION HAZARD OF THE WAILUKU RIVER DRAINAGE BASIN

Land-Use	Acres	% Total Area	Estimated Erosion Damage (Tons/Acres/Year)
Urban	1,800	1.0	4
Sugarcane and Diversified Crops	3,900	2.5	7-11
Forest	77,500	46.5	0.2
Pasture	33,800	20.2	2-3
High Mountains Conservation	50,000	29.8	1-15

Source of Data: Hilo Comprehensive Study, Plan of Study, December 1976, Honolulu District, U.S. Army Corps of Engineers

(6) Sediment Quality. Pollutant discharge into Hilo Bay have left arsenic, PCB (Polychlorinated biphenyls), and pesticide contaminants in the bay sediments. A State Department of Health survey in 1978 indicated that arsenic, PCB and chlordance concentrations were found in significantly high amounts in Hilo Bay (State of Hawaii, 1978) in comparison with other sites surveyed in thd state. The contaminants in dredged material may make the material unsuitable either for land or ocean disposal, and may require special handling or treatment of the material prior to disposal. Sand sediments from a shoal in the mouth of Wailoa River were found suitable for upland disposal following Environmental Protection Agency EP testing which indicated that pollutants did not leach from the sediment.

(a) Arsenic.

Based on the State survey, sediment samples from the Hilo Bay area contained total arsenic residues in concentrations ranging from about 22 ppm to 6370 ppm. A Canec plant, which manufactured canec boards from bagasse, discharged wastewater containing arsenic trioxide, a termicide, into Waiakea Pond. Sediments form the pond contain total arsenic residues in concentrations of about 6370 ppm. Sediments from the mouth of Wailoa River contained 131 ppm total arsenic, and sediments from Hilo Harbor contained total arsenic concentrations ranging from about 33 to 104 ppm. Total arsenic concentrations from sediments obtained from the outer part of the harbor ranged from about 22 to 33 ppm. The analysis indicated that arsenic migrated from Waiakea Pond into the bay environment. Arsenic concentrations in other Hawaiian estuarine sediments ranged from less than 4 ppm at Manele/Hulopoe, Lanai to about 20 ppm in Kaneohe Bay, and may reflect natural levels in Hawaiian soils. Analysis of fish and crab tissue indicate that arsenic is not bioconcentrating in the species tested.

(b) PCB.

Out of ten sites sampled in the State of Hawaii only two, Hilo Bay, Hawaii and Ala Wai Canal, Oahu, had measurable concentrations of PCB. Concentrations of PCB in Ala Wai Canal sediment ranged from 200 to 740 ppb with a mean of 372.6 ppb. The mean PCB concentration in Hilo Bay sediments was 200 ppm. The mean PCB concentration for other sample sites was less than 200 ppb. Under the test procedure the detectable limit was 200 ppb. No concentration of PCB was found in 27 biota samples analyzed.

(c) Chlordane.

Hilo Bay sediments also contained measurable quantities of chlordane. The sum of the mean values of three deriatives of chlordane was 84.2 ppb and was one of four sites in Hawaii found to have chlordane present in the sediments. Sediment from six other sites contained no chlordane residues above the detectable limit of 10 ppb. The levels df chlordane residue in mullet flesh from Waiakea Pond ranged from 80-160 ppb. No mullet from Hilo Bay was analyzed. The mullet viscera contained a chlordane residue 3 to 4 times higher than the flesh. The mean concentration of chlordane residue in Hilo sediment were considerable lower than the range of mean concentrations of chlordane residue (about 296 to 567 ppb) found in the Ala Wai and Kapalama canals.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
Western Pacific Program Office
P. O. Box 3830
Honolulu, Hawaii 96812

December 13, 1983 F/SWR1:ETN

Mr. Kisuk Cheung
Chief, Engineering Division
U.S. Army Engineer Division
Pacific Ocean
Building 230
Fort Shafter, HI 96858

Dear Mr. Cheung:

Your request to the Director, Southwest Region regarding the Biological Assessment for the Hilo Area Comprehensive Study has been referred to this office for reply. Of the four proposed projects evaluated only the Cape Kumukahi Small Craft Navigation Improvements will require formal consultation at this time.

Our determination of "no effect" to listed endangered or threatened species from the Hilo Breakwater Modification project was forwarded to the Corps in August 1981 and reaffirmed in a subsequent communication dated November 2, 1983.

The proposed Hilo Bayfront Beach Shore Protection and Reeds Bay Small Craft Harbor projects as described in the Assessment and the April 1983 DEIS are not likely to affect any listed species under National Marine Fisheries Service (NMFS) jurisdiction. The NMFS concurs with the Corps' determination of "no effect"and finds that formal consultation pursuant to Section 7 of the Endangered Species Act of 1973, as amended, will not be required for these two specific projects at this time. However, should project conditions, locations or other parameters change significantly from those currently described, consultation may be required when such changes are identified.

Much of the information presented in the Assessment and particularly the April 1983 DEIS for the Cape Kumukahi Small Craft Navigation Improvements concerning the endangered humpback whale (Megaptera novaeangliae) and hawksbill turtle (Eretmochelys imbricata) and the threatened green turtle (Chelonia mydas) is taken out of context and/or interpreted without sufficient regard to the type and amount of data collected for these species in the area. Because of the variability in distribution and abundance of whales and turtles over time, the small number of sightings based on such little effort should not be the basis for discounting the impact of the project on endangered and threatened species. Furthermore, secondary impacts such as vessel traffic, lighting, and shoreline development on listed species from a small boat harbor in the area were not sufficiently considered and should be evaluated more rigorously during consultation. Thus, NMFS believes that the proposed

FIGURE C-2

Cape Kumukahi Small Craft Navigation Improvements project and the resultant activities associated with its operations may affect humpback whales, green turtles and hawksbill turtles and recommends that the Corps initiate formal Section 7 consultation for this project at the appropriate time.

Should there be any questions regarding this action please contact Mr. Eugene Nitta at 955-8831.

Sincerely yours,

Doyle E. Gates
Administrator

cc: F/SWR

FIGURE C-2 (contd)

United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 ALA MOANA BOULEVARD
P.O. BOX 50167
HONOLULU, HAWAII 96850

IN REPLY REFER TO:
ES
Room 6307

APR 5 1984

Colonel Michael M. Jenks
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Re: Final Coordination Act Report
for Hilo Bayfront Beach

Dear Colonel Jenks:

This is the U.S. Fish and Wildlife Service's Final Coordination Act Report regarding plans of the Honolulu District to construct beach restoration features within the Hilo Comprehensive Study planning area. This study has been conducted as a component of the Hilo Comprehensive Water Resources Study.

The Service's report has been prepared under the authority of and in accordance with the provisions of Section 2(b) of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and other authorities mandating Department of Interior concern for environmental values. It is also consistent with the intent of the National Environmental Policy Act.

This report has been prepared by John Ford and Yvonne Ching using the results of previous planning studies conducted in the Hilo area, current scientific literature, results of joint-agency field surveys conducted by John Ford and William Lennan in June 1982, and numerous planning reports and conceptual drawings provided by the Honolulu District. The opinion of the Hawaii Department of Land and Natural Resources concerning this action is appended to this report.

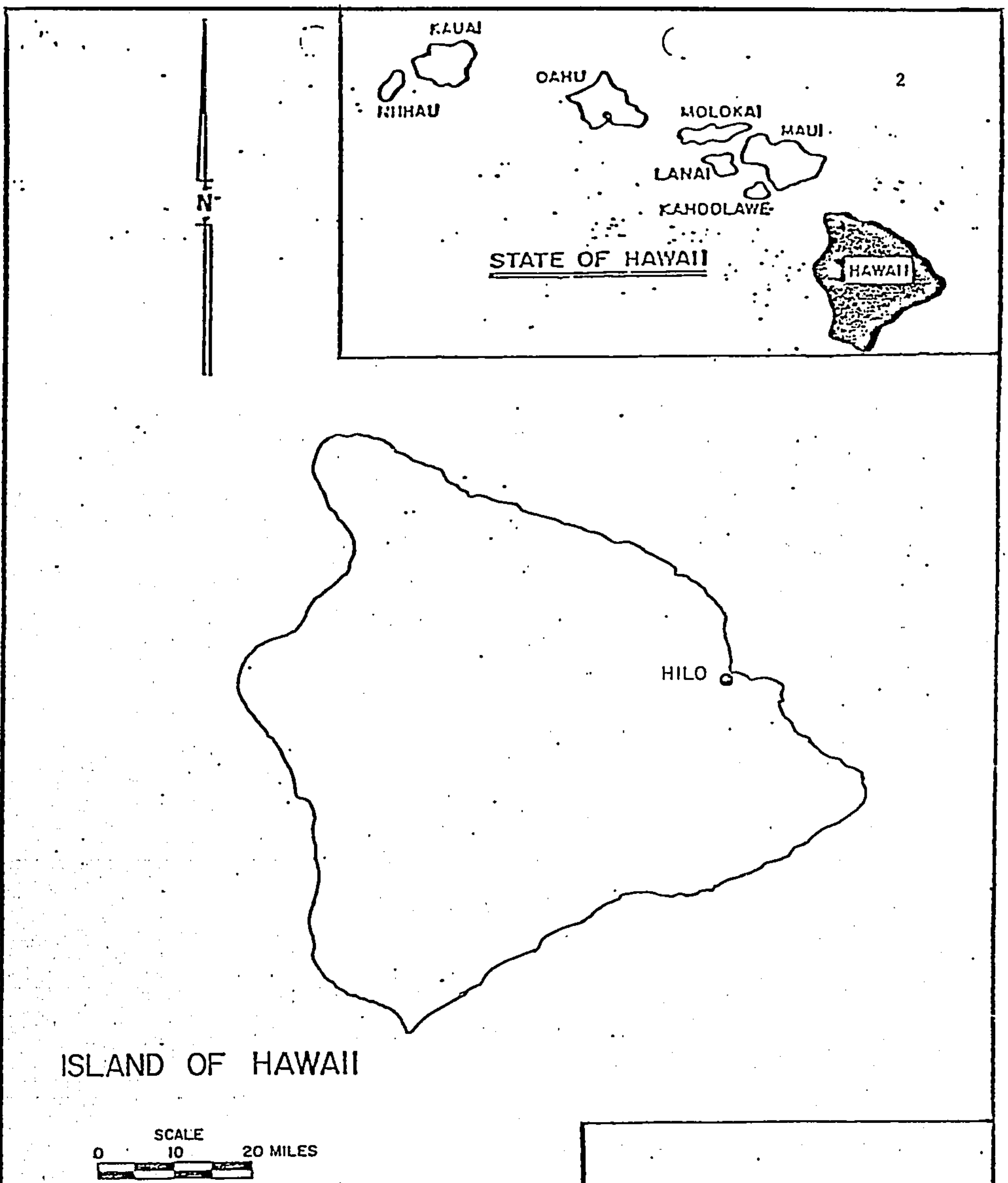
DESCRIPTION OF THE PLANNING AREA

The study area is located on the eastern side of the island of Hawaii (Figure 1). Features discussed in this letter are centered in Hilo Bay (Figure 2). Previous Corps studies and reports which present detailed descriptions of the geology, hydrology, oceanography, water quality, and fish and wildlife resources in the study area include References 2, 4, 8, 10-12, and 15-20. In the interest of avoiding redundancy, the information presented here is intended to supplement existing data developed by the Corps for these studies.

Hilo Bayfront Beach

Existing descriptions of the intertidal and nearshore fish and wildlife habitat along Hilo Bayfront appear in the references mentioned above. Extremely poor water clarity (0-2 ft. horizontal visibility) during the June

FIGURE C-3

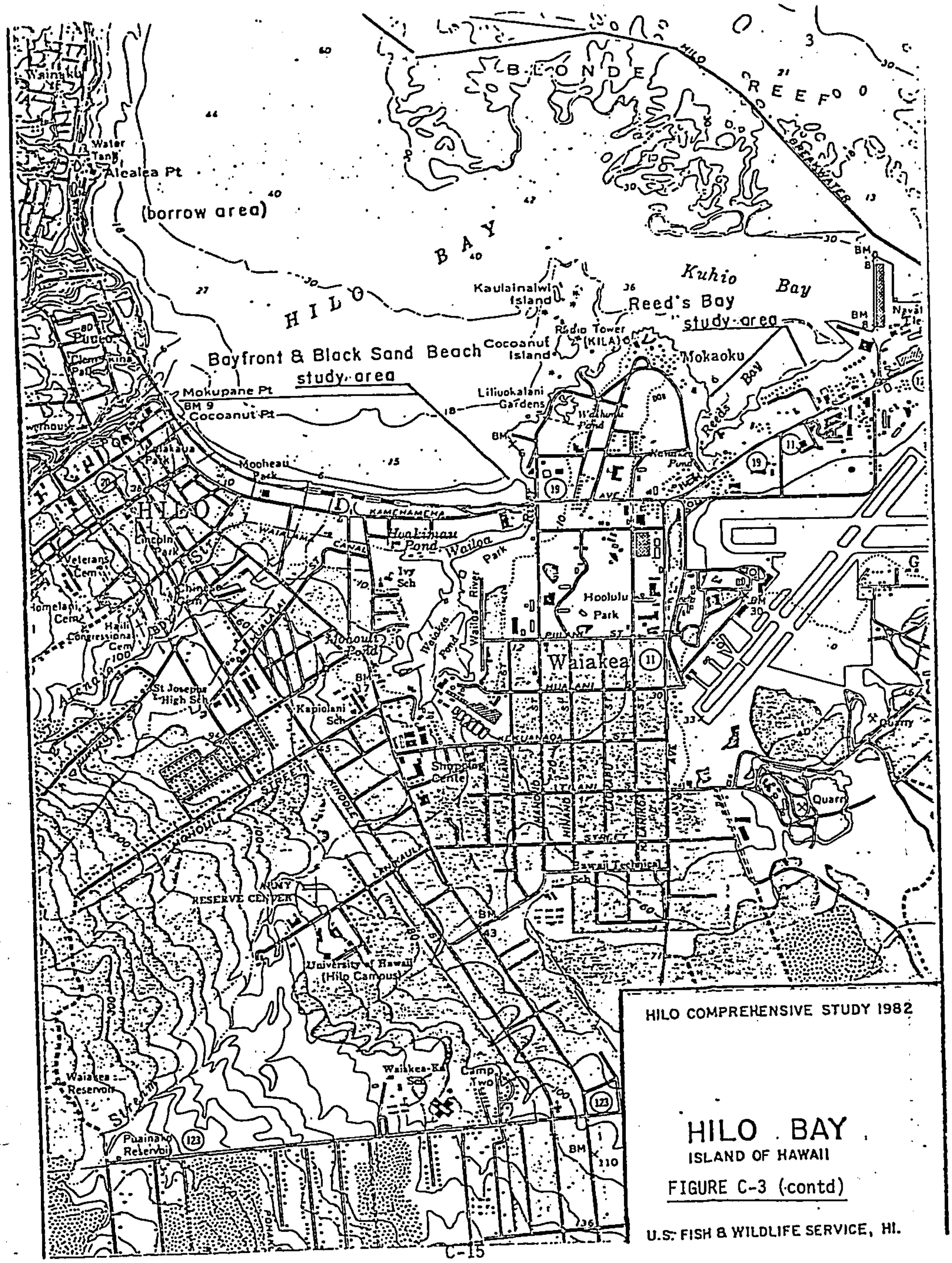


PROJECT LOCATION MAP

ADAPTED FROM
U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE 1

FIGURE C-3 (contd)



HILO COMPREHENSIVE STUDY 1982

HILO BAY
ISLAND OF HAWAII

FIGURE C-3 (contd)

U.S. FISH & WILDLIFE SERVICE, HI.

1982 field survey precluded meaningful visual surveys. Water quality here is generally poor due to the discharge of terrigenous silt, debris and nutrients from the Wailuku and Wailoa Rivers. This is complicated by reduced circulation and prolonged residence time of water within the Bay. Predominant nearshore currents along the bayfront set westerly during both flood and ebb tides. There is some evidence that a local gyre exists near shore, which rotates in a counter-clockwise direction (Reference 10). There was no appreciable erosion of the beach evident in June 1982.

Reference 2 reports finding no benthic resources within this area. Reference 11 does not list any fishery resources in this area. However, in the vicinity of the Wailuku River mouth, popular sport fishery species include aholehole, amaama (Mugil cephalus), moi and moi li'i (Polydactylus sexfilis), oio (Alubla vulpes), papio and ulua, and o'opu (various Gobiidae and Eleotridae).

Shore casting from the abutments of the Wailuku River bridge and adjacent shoreline revetments is a popular pastime. We observed several persons fishing along the bayfront during our June 1982 field survey. Recreational fishermen questioned during the June 1982 survey indicated that oio, papio and moi were the preferred catch at this location.

The black sand beach does provide habitat for several species of migratory shorebirds such as the wandering tattler (Heteroscelus incanus), golden plover (Pluvialis dominica fulva), ruddy turnstone (Arenaria interpres), and sanderling (Calidris alba).

There are no known endangered species of plants or animals that frequent the study area.

DESCRIPTION OF THE PROPOSED ACTION

Two alternative plans have been developed to enhance recreational values within the project area and to provide shore protection. Plan A (Figure 3) includes several components:

a. construction of a parabolic surfing shoal 220' offshore;
b. construction of a 220,000 sq. ft. dry sand beach;
c. construction of four rock groins to stabilize the beach;
d. construction of a 1,200' long rock revetment along shore;
e. construction of a 200' long jetty adjoining the mouth of the Wailoa River.

The proposed artificial surfing shoal will be constructed at the west end of the bayfront beach. Patented "Longard Tubes" will be used to create a terraced, parabolic shoal. The shoal will refract incident waves causing them to peak and break. The beach will consist of black sand material having essentially similar physical characteristics to the existing beach sands. The new sand will be dredged from bottom sediments near the mouth of the Wailuku River and Alealea Point in Hilo Bay. Washing and screening of the dredged sand may be required before it is suitable for use. Chemical testing for toxic substances as specified by the Environmental Protection Agency will be required prior to dredging.

FIGURE C-3 (contd)

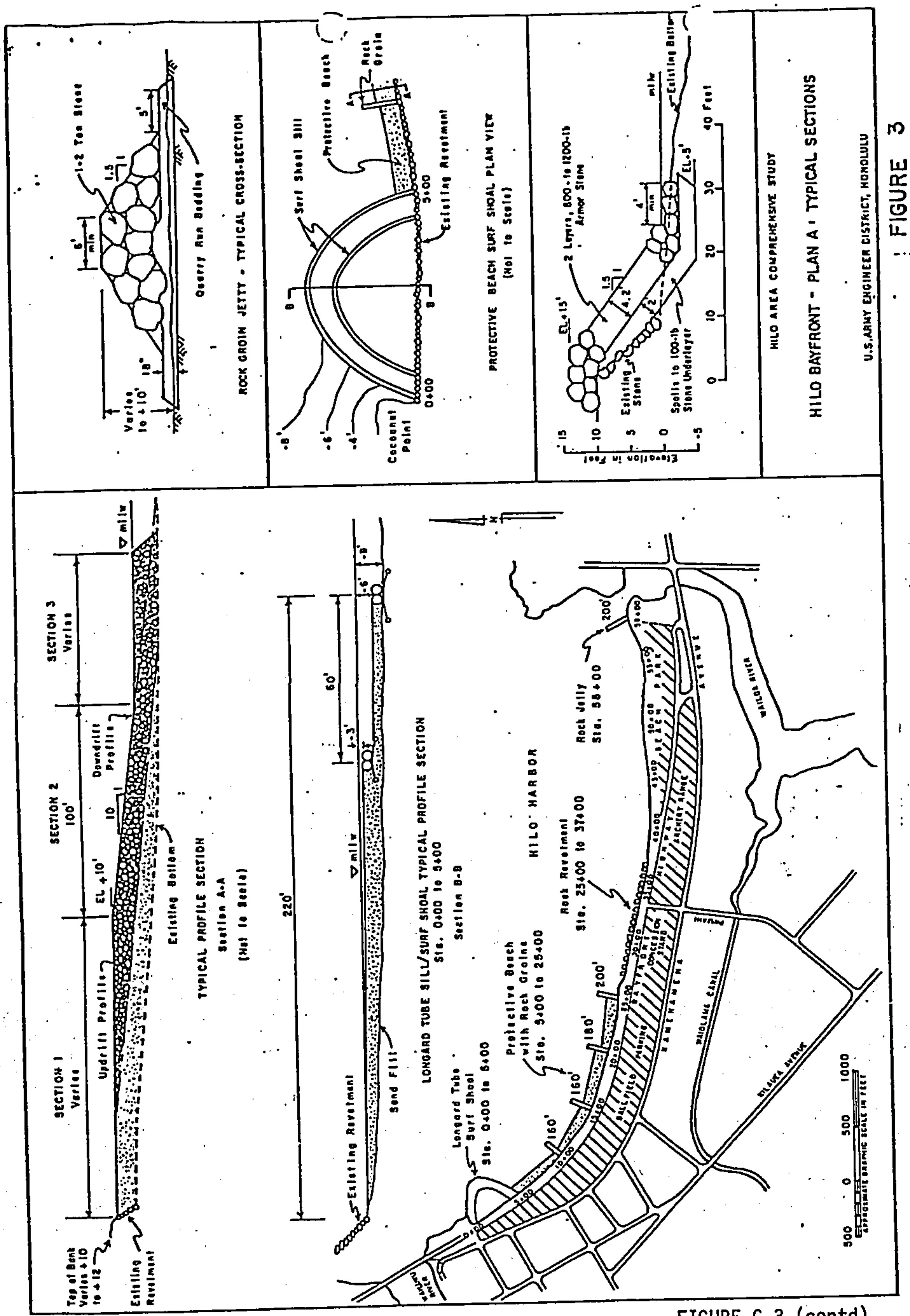


FIGURE C-3 (contd)

The proposed rock groins will be spaced approximately 600' apart along shore. Construction alternatives include rock rubble mound or sand-cement filled bags. The groins will be constructed of ungrouted armor stone overlying a bedding layer of quarry run stone. The proposed revetment, however, will consist of a double layer of armor stone over an under- and bedding layer, designed to distribute the weight of armor stone and to prevent the loss of shoreline material through voids in the armor stone. No construction details for the proposed jetty are available. Source of fill and armor stones will be from either of two existing rock quarries in the study area.

Plan A has been tentatively selected as the preferred alternative as it satisfies all project objectives and carries a net contribution to National Economic Development (NED). It is also considered to be the Environmental Quality (EQ) Plan since the surfing shoal, beach and jetty will enhance recreational opportunities in the study area.

Plan B simply involves the construction of a 3,500' long rock revetment for shore protection along Hilo bayfront (Figure 4).

ANTICIPATED ENVIRONMENTAL CONSEQUENCES

Potential impacts include temporary degradation of water quality parameters (specifically, increased turbidity, dissolved and suspended nutrient concentrations, and biological oxygen demand; and decreased dissolved oxygen concentrations and pH). These impacts may be minimized by implementation of careful construction methods (refer to Recommendations). Construction may lead to temporary restrictions upon access for shore fishermen, and reduced fishing success.

Construction of groins perpendicular to the shore along Hilo bayfront would be expected to change existing current patterns.

However, it is doubtful that these changes would result in adverse impacts to fish and wildlife resources. No important benthic habitat would be destroyed by placement of armor stone groins into the surf. The completed structures will provide suitable habitat for benthic algae and invertebrates as well as cover for some fishes.

No long-term adverse impacts are anticipated at the site of the proposed offshore sand dredging north of the Wailuku River mouth. However, if the existing shallow sand banks are significantly lowered in depth, the resulting habitat may be of reduced value to fishes due to low dissolved oxygen concentrations. Subsequent accretion of sediments carried by bay current systems may gradually restore the area to its previous depth.

RECOMMENDATIONS

The Service does not anticipate significant impacts to fish and wildlife resources as a result of the proposed action. All construction activities should be conducted in a manner which will minimize unnecessary disturbance to benthic habitat. In addition, we support the following recommendations of the Department of Land and Natural Resources:

FIGURE C-3 (contd)

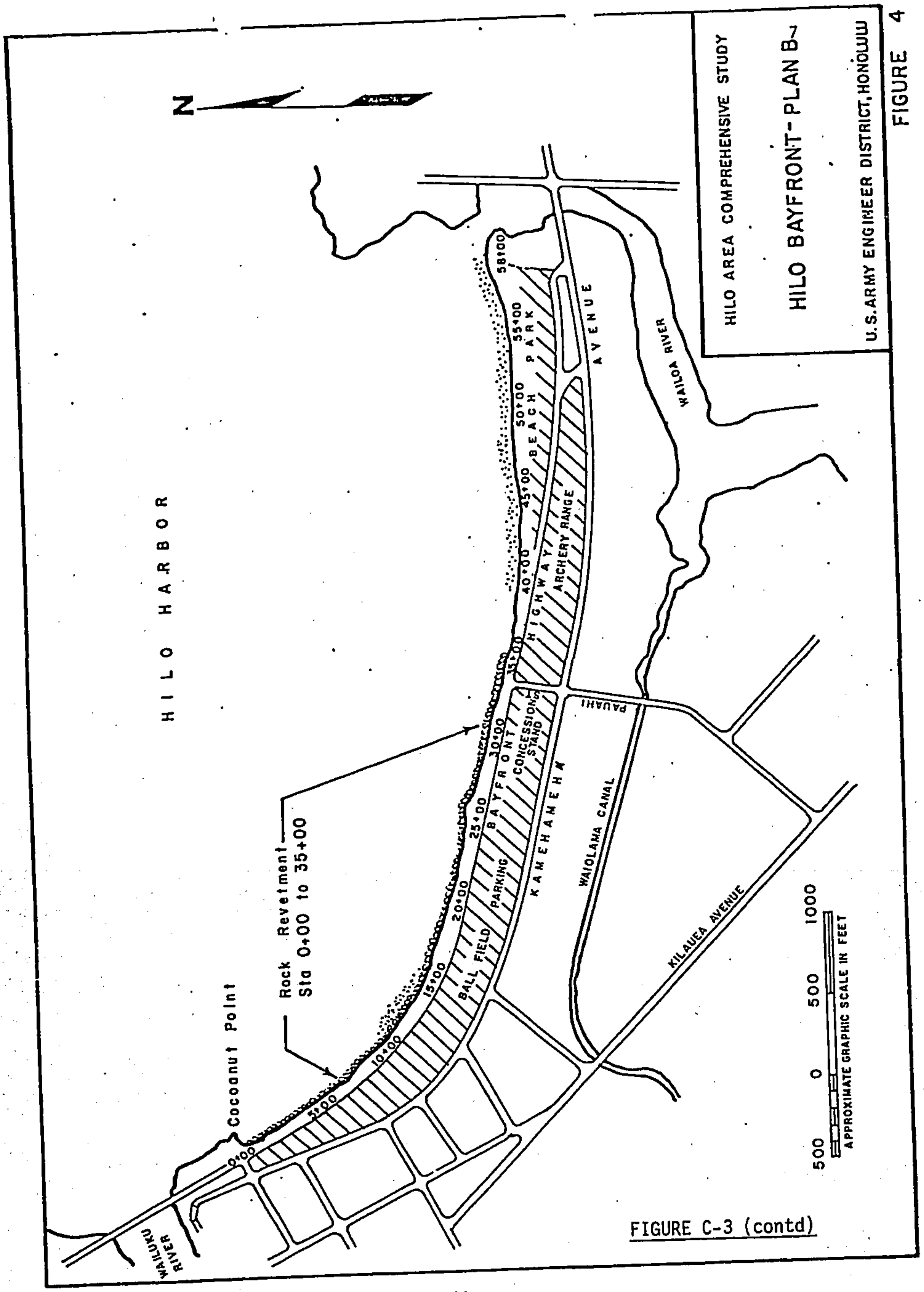


FIGURE C-3 (contd)

1. A responsible agency should undertake a public information and consultation effort sufficient to allay public concern if any blasting is to be initiated.

2. Spoils excavated from the bottom of Hilo (and Reeds) Bay should not be used as core material for the proposed breakwater unless toxicologically safe and unless such use would not increase turbidity outside the Bay.

Sincerely,

Allan Marmelstein
Pacific Islands Administrator

Attachment

cc: Director FWS, Washington, DC (AHR-ES/FP)
Regional Director, FWS, Portland, OR (AHR)
NMFS-WPPO
EPA San Francisco
HDF&W
HDAR

FIGURE C-3 (contd)

BIBLIOGRAPHY

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FIGURE C-3 (contd)

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FIGURE C-3 (contd)

APPENDIX D

COASTAL ZONE MANAGEMENT FEDERAL CONSISTENCY DETERMINATION

DEPARTMENT OF THE ARMY
PACIFIC OCEAN DIVISION, CORPS OF ENGINEERS
FT. SHAFTER, HAWAII 96858

March 8, 1984

REPLY TO
ATTENTION OF

Mr. Kent Keith, Director
Department of Planning and Economic
Development
250 South King Street
Honolulu, Hawaii 96813

Dear Mr. Keith:

In accordance with the National Coastal Zone Management Act of 1972 and 15 CFR Part 930, Federal Consistency with Approved Coastal Management Program, we have prepared an environmental impact statement (previously provided) and a Supplemental Information form (attached) for the Bayfront Beach protection project, County of Hawaii. The proposed project was reported in Volume 3 of the Hilo Area Comprehensive Study, and is intended to provide protection for the existing beach and the Bayfront Highway, and to enhance recreation facilities.

We have determined that the proposed project is consistent with Hawaii's Coastal Zone Management Program, and would appreciate your concurrence by April 8, 1984 so that we may meet our final report preparation schedule.

Sincerely,

Kisuk Cheung
Chief, Engineering Division

Enclosure

FEDERAL CONSISTENCY
SUPPLEMENTAL INFORMATION FORM

Date: 8 March 84

Project/Activity Title or Description: Bayfront Beach Shore Protection

Location: Island Hawaii District Hilo

Tax Map Key No. ____

Other applicable area(s), if appropriate ____

Est. Start Date: Unknown Est. Duration: 18 months

APPLICANT

Name & Title Colonel Michael M. Jenks

Agency/Organization Honolulu District Engineer

Address Building 230

Fort Shafter, Hawaii Zip 96858

Telephone No. during business hours:

A/C (808) 438-1091

A/C (808) 438-1069

AGENT

Name & Title Kisuk Cheung, Chief, Engineering Division

Agency/Organization Honolulu District Engineer

Address Building 230

Fort Shafter, Hawaii Zip 96858

Telephone No. during business hours:

A/C (808) 438-9523

A/C (808) 438-1634

CATEGORY OF APPLICATION (check one only)

[x] I. Federal Activity
[ ] II. Permit or License
[ ] III. OCS Plan/Permit
[ ] IV. Grants & Assistance

TYPE OF STATEMENT (check one only)

[x] Consistency
[ ] General Consistency (Category I only)
[ ] Negative Determination (Category I only)
[ ] Non-Consistency (Category I only)

APPROVING FEDERAL AGENCY (Categories II, III, & IV only)

Agency ______________________

Contact Person ______________________

Telephone No. during business hours:

A/C ( ) ______________

A/C ( ) ______________

FEDERAL AUTHORITY FOR ACTIVITY

Title of Law Water Resources Development Act of 1956

Section Section 144

OTHER STATE AND COUNTY APPROVALS REQUIRED

Agency	Type of Approval	Date of Applic.	Status
DLNR	CDUA	N/A	Application n[illegible] yet made
Hawaii County Planning Department	SMA	N/A	Application n[illegible] yet made

CZM 9/7[illegible]

CORRECTION

THE PRECEDING DOCUMENT(S) HAS BEEN REPHOTOGRAPHED TO ASSURE LEGIBILITY
SEE FRAME(S)
IMMEDIATELY FOLLOWING

DEPARTMENT OF THE ARMY
PACIFIC OCEAN DIVISION, CORPS OF ENGINEERS
FT. SHAFTER, HAWAII 96858

REPLY TO ATTENTION OF

March 8, 1984

Mr. Kent Keith, Director
Department of Planning and Economic Development
250 South King Street
Honolulu, Hawaii 96813

Dear Mr. Keith:

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Sincerely,

Kisuk Cheung
Chief, Engineering Division

Enclosure

FEDERAL CONSISTENCY
SUPPLEMENTAL INFORMATION FORM

Date: 8 March 84

Project/Activity Title or Description: Bayfront Beach Shore Protection

Location: Island Hawaii District Hilo

Tax Map Key No. ______

Other applicable area(s), if appropriate ______

Est. Start Date: Unknown Est. Duration: 18 months

APPLICANT

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[x] I. Federal Activity

[ ] II. Permit or License

[ ] III. OCS Plan/Permit

[ ] IV. Grants & Assistance

TYPE OF STATEMENT (check one only)

[x] Consistency

[ ] General Consistency (Category I only)

[ ] Negative Determination (Category I only)

[ ] Non-Consistency (Category I only)

APPROVING FEDERAL AGENCY (Categories II, III, & IV only)

Agency ______________________________

Contact Person ______________________________

Telephone No. during business hours:

A/C ( ) ______________

A/C ( ) ______________

FEDERAL AUTHORITY FOR ACTIVITY

Title of Law Water Resources Development Act of 1956

Section Section 144

OTHER STATE AND COUNTY APPROVALS REQUIRED

Agency	Type of Approval	Date of Applic.	Status
DLNR	CDUA	N/A	Application not yet made
Hawaii County Planning Department	SMA	N/A	Application not yet made

CZM 9/7

Discussion: The proposed project will add 5 acres of beach to the Bayfront area of Hilo. The beach will be easily accessible from the Bayfront Highway. Additionally, a surfing shoal would be constructed on the west end of the beach which would provide more surfing opportunity for Hilo residents.

RECREATIONAL RESOURCES

Objective: Provide coastal recreational opportunities accessible to the public.

Policies

1) Improve coordination and funding of coastal recreation planning and management.

2) Provide adequate, accessible, and diverse recreational opportunities in the coastal zone management area by:

   a) Protecting coastal resources uniquely suited for recreational activities that cannot be provided in other areas;

   b) Requiring replacement of coastal resources having significant recreational value, including but not limited to surfing sites and sandy beaches, when such resources will be unavoidably damaged by development; or requiring reasonable monetary compensation to the State for recreation when replacement is not feasible or desirable;

   c) Providing an adequate supply of shoreline parks and other recreational facilities suitable for public recreation;

   e) Encouraging expanded public recreational use of County, State, and Federally owned or controlled shoreline lands and waters having recreational value;

   f) Adopting water quality standards and regulating point and non-point sources of pollution to protect and where feasible, restore the recreational value of coastal waters;

   g) Developing new shoreline recreational opportunities, where appropriate, such as artificial reefs for surfing and fishing; and

   h) Encouraging reasonable dedication of shoreline areas with recreational value for public use as part of discretionary approvals or permits by the land use commission, board of land and natural resources, county planning commissions; and crediting such dedication against the requirements of section 46-6.

COASTAL ECOSYSTEMS

Objective: Protect valuable coastal ecosystems from disruption and minimize adverse impacts on all coastal ecosystems.

Policies

1) Improve the technical basis for natural resource management;

2) Preserve valuable coastal ecosystems of significant biological or economic importance;

3) Minimize disruption or degradation of coastal water ecosystems by effective regulation of stream diversions, channelization, and similar land and water uses, recognizing competing water needs; and

4) Promote water quantity and quality planning and management practices which reflect the tolerance of fresh water and marine ecosystems and prohibit land and water uses which violate State water quality standards.

Discussion: The area off-shore from Bayfron Beach is depauperate, and therefore no significant dedradation of the ecosystem is expected. Some benthic infaura will be killed when they are covered with sand, and similar organisms will be killed at the sand site during the dredging or pumping. None of the organisms are unique, and recruitment is expected to be rapid.

ECONOMIC USES

Objective: Provide public or private facilities and improvements important to the State's economy in suitable locations.

Policies

1) Concentrate in appropriate areas the location of coastal dependent development necessary to the State's economy.

2) Insure that coastal dependent development such as harbors and ports, visitor industry facilities, and energy generating facilities are located, designed, and constructed to minimize adverse social, visual, and environmental impacts in the coastal zone management area; and

3) Direct the location and expansion of coastal dependent developments to areas presently designated and used for such development and permit reasonable long-term growth at such areas, and permit coastal dependent development outside of presently designated areas when:

   a) Utilization of presently designated locations is not feasible;

   b) Adverse environmental effects are minimized; and

   c) Important to the State's economy.

Discussion: The increased beach area and surfing shoal will attract tourists to the area, especially if the water quality of Hilo Bay improves. This may result in higher visitor counts for the Hilo area.

COASTAL HAZARDS

Objective: Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion, and subsidence.

Policies

1) Develop and communicate adequate information on storm wave, tsunami, flood, erosion, and subsidence hazard;

2) Control development in areas subject to storm wave, tsunami, flood, erosion, and subsidence hazard;

3) Ensure that developments comply with requirements of the Federal Flood Insurance Program; and

4) Prevent coastal flooding from inland projects.

Discussion: The project will not have an effect on subsidence or volcanic activity, but it will protect the beach and highway from storm waves. It will also reduce erosion along this section of the Bayfront.

MANAGING DEVELOPMENT

Objective: Improve the development review process, communication, and public participation in the management of coastal resources and hazards.

Policies

1) Effectively utilize and implement existing law to the maximum extent possible in managing present and future coastal zone development;

2) Facilitate timely processing of application for development permits and resolve conflicting permit requirements; and

3) Communicate the potential short and long-term impacts of proposed significant coastal developments early in their life cycle and in terms understandable to the general public to facilitate public participation in the planning and review process.

Discussion: Not applicable. The project is not expected to influence coastal development.

HISTORIC RESOURCES

Objective: Protect, preserve, and where desirable, restore those natural and man-made historic and pre-historic resources in the coastal zone management area that are significant in Hawaiian and American history and culture.

Policies

1) Identify and analyze significant archaeological resources;

2) Maximize information retention through preservation of remains and artifacts or salvage operations; and

3) Support State goals for protection, restoration, interpretation, and display of historic resources.

Discussion: Not applicable. There are no historic resources in the area of the proposed project.

SCENIC AND OPEN SPACE RESOURCES

Objective: Protect, preserve and, where desirable, restore or improve the quality of coastal scenic and open space resources.

Policies

1) Identify valued scenic resources in the coastal zone management area;

2) Insure that new developments are compatible with their visual environment by designing and locating such developments to minimize the alteration of natural landforms and existing public views to and along the shoreline;

3) Preserve, maintain and, where desirable, improve and restore shoreline open space and scenic resources; and

4) Encourage those developments which are not coastal dependent to locate in inland areas.

Discussion: The proposed project will not significantly disrupt the view plane along the Bayfront. The new beaches will be attractive, and the groins will be designed to be visually unobtrusive.

DEPARTMENT OF PLANNING
AND ECONOMIC DEVELOPMENT
KAMAMALU BUILDING, 250 SOUTH KING ST, HONOLULU, HAWAII
MAILING ADDRESS: P.O. BOX 2359, HONOLULU, HAWAII 96804

GEORGE R. ARIYOSHI
GOVERNOR
KENT M. KEITH
DIRECTOR
JOHN R. PINGREE
DEPUTY DIRECTOR
MURRAY E. TOWILL
DEPUTY DIRECTOR

DIVISIONS
ECONOMIC DEVELOPMENT DIVISION
ENERGY DIVISION
FOREIGN-TRADE ZONE DIVISION
HAWAII INTERNATIONAL SERVICES AGENCY
LAND USE DIVISION
PLANNING DIVISION
RESEARCH AND ECONOMIC ANALYSIS DIVISION

OFFICES
ADMINISTRATIVE SERVICES OFFICE
HAWAII FILM OFFICE
INFORMATION OFFICE
OCEAN RESOURCES OFFICE
TOURISM OFFICE

Ref. No. 9079

March 28, 1984

Mr. Kisuk Cheung
Chief
Engineering Division
Corps of Engineers
Department of the Army
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

Subject: Coastal Zone Management Consistency Determination, Hilo Bayfront Beach, Hilo, Hawaii

We have reviewed the subject proposal and agree with your determination that it is consistent with Hawaii's Coastal Zone Management Program. Your assistance and cooperation in complying with the CZM Porgram requirements are appreciated.

Very truly yours,

Kent M. Keith
Kent M. Keith

APPENDIX E

LETTERS OF COMMENT AND RESPONSE

United States Department of Agriculture — Soil Conservation Service

P.O. Box 50004
Honolulu, Hawaii
96850

August 18, 1983

District Engineer
U.S. Army Corps of Engineers
Honolulu District
Building 230
Fort Shafter, Hawaii 96858

Dear Sir:

Subject: Draft Environmental Impact Statements for the Hilo Area Comprehensive Study

We have reviewed the subject environmental impact statements and have no comments to make.

Thank you for the opportunity to review these documents.

Sincerely,

FRANCIS C.H. LUM
State Conservationist

The Soil Conservation Service is an agency of the Department of Agriculture

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K. INOUYE
HAWAII

United States Senate
ROOM 722, HART SENATE BUILDING
WASHINGTON, D.C. 20510

July 26, 1983

Colonel Alfred J. Thiede
District Engineer
Corps of Engineers
U.S. Army Engineer District, Honolulu
Fort Shafter, Hawaii 96759

Dear Colonel Thiede:

I wish to thank you for sharing with me copies of draft reports and draft environmental impact statements for the Hilo Area Comprehensive Study.

You can be assured that I will be reviewing these reports very closely. Your thoughtfulness in keeping me apprised of your activities with this project is most appreciated. I look forward to hearing from you further on the time and place of the public meeting to be held in Hilo.

Aloha,

DANIEL K. INOUYE
United States Senator

DKI:bhm

United States Department of Agriculture — Forest Service — Pacific Southwest Region, 1151 Punchbowl Street, Room 323, Honolulu, Hawaii 96813

Reply to: 2100 (PIF)

Date: July 19, 1983

Alfred J. Thiede, Colonel
District Engineer
Honolulu District
U.S. Army Corps of Engineers
Building 230
Ft. Shafter, HI 96858

Dear Colonel Thiede:

We have reviewed the following Reports and Draft Environmental Impact Statements:

1. Summary Report.
2. Hilo Breakwater Modification: Draft Survey Report and Draft Environmental Impact Statement.
3. Hilo Bayfront Beach: Draft Survey Report and Draft Environmental Impact Statement.
4. Reeds Bay Small Craft Harbor: Draft Reevaluation Report and Draft Environmental Impact Statement.
5. Kumukahi Small Craft Harbor: Draft Survey Report and Draft Environmental Impact Statement.

We do not have any comments to make on these reports and EIS's. Thank you for providing the above referenced documents.

Sincerely,

Robert V. Clayton

ROBERT V. CLAYTON
Pacific Islands Forester

E-2

631

United States Department of Agriculture — Soil Conservation Service

Subject: Hilo Area Comprehensive Study - Draft Summary Report

Date: July 19, 1983

To: Gene Dashiell
U.S. Army Corps of Engineers
Honolulu District
Building 230
Fort Shafter, HI 96858

Dear Gene:

Thank you for sending us a copy of the Hilo Area Comprehensive Study Volume 1 of 4 Summary Report.

We would like to assist with the coordination and attainment of the public's view by circulating sufficient copies to our various resource committees. Can you send us twenty(20) copies of the above Summary Report? These will be distributed to the following committees:
- Fish & Wildlife (5)
- Public Facilities (3)
- Forestry (2)
- Historic Sites (2)
- Flood Control (2)
- RC&D Council (6)

Please do not hesitate to call on us should you need any assistance.

Sincerely yours,

Mike Tulang
RC&D Coordinator

The Soil Conservation Service is an agency of the Department of Agriculture

SCS-AS-2
10-79

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS PACIFIC AIR FORCES
HICKAM AIR FORCE BASE, HAWAII 96853

REPLY TO ATTN OF: DEEV

12 AUG 1983

SUBJECT: Hilo Area Comprehensive Study

TO: Division Engineer/PODED
US Army Engr Div, Pacific Ocean
Bldg 230
Ft Shafter, HI 96858

1. Reference your July 12, 1983 letter which forwarded environmental studies for the Hilo area.

2. We have no comment to render on subject study.

3. We appreciate your including this office in the environmental review process. However, please address future requests for comment to HQ PACAF/DEEV, Hickam AFB, HI 96853, in lieu of addressing them to HQ PACAF/CC.

FOR THE COMMANDER IN CHIEF

Thomas E. Lollis

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
PACIFIC SOUTHWEST REGION
BOX 36098 • 450 GOLDEN GATE AVENUE
SAN FRANCISCO, CALIFORNIA 94102
(415) 556-8200

ER 83/892

SEP 6 1983

Colonel Alfred J. Thiede
District Engineer, Honolulu District
U.S. Army Corps of Engineers
Building 230
Fort Shafter, Hawaii 96858

Dear Colonel Thiede:

The Department of the Interior has reviewed the draft environmental statement and draft reports for the Hilo Area Comprehensive Study, Hilo Bay and Kailua-Kona, Hawaii and has no comments to offer at this time.

Thank you for the opportunity to review and comment on the draft reports and draft environmental statement.

Sincerely,

Patricia Sanderson Port
Regional Environmental Officer

cc: Director, OEPR (w/copy incoming)
Reg. Dir., FWS

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF WATER AND LAND DEVELOPMENT
P. O. BOX 373
HONOLULU, HAWAII 96809

SUSUMU ONO, CHAIRMAN
BOARD OF LAND & NATURAL RESOURCES
EDGAR A. HAMASU
DEPUTY TO THE CHAIRMAN

DIVISIONS:
AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

July 27, 1983

Colonel Alfred J. Thiede
District Engineer
U.S. Army Corps of Engineers
Honolulu District
Building 230
Fort Shafter, Hawaii 96858

Dear Col. Thiede:

Comments on Hilo Area
<u>Comprehensive Study Draft Reports</u>

Thank you for your letter of July 12, 1983, inviting our comments on the draft reports for the Hilo Area Comprehensive Study.

Of interest to this office is the study recommendation relating to hydropower development. Based on your reconnaissance study findings, you have indicated that further detailed study is warranted for hydroelectric power generation at two perennial streams in the study area, Wailuku River and Honolii Stream. Because of our agency's responsibilities in water resources management statewide and also because of the possible involvement of State-owned land at the stream sites, we would appreciate your keeping us informed of further investigations pursued.

At this time, we have no specific comments to offer on the study's Hilo Breakwater Modification, Hilo Bayfront Beach, Reeds Bay Small Craft Harbor, and Kumukahi Small Craft Harbor projects.

Very truly yours,

ROBERT T. CHUCK
Manager-Chief Engineer

GM:ko

HEADQUARTERS
NAVAL BASE PEARL HARBOR
BOX 110
PEARL HARBOR, HAWAII 96860

IN REPLY REFER TO:
002:09P2:ci
Ser 1629

From: Commander Naval Base, Pearl Harbor
To: District Engineer, U. S. Army Corps of Engineers, Honolulu District

Subj: Summary Report, Draft Survey Report and Draft Environmental Impact Statement, April 1983; Hilo Area Comprehensive Study

Ref: (a) DISTENGR USAED HONO ltr of 12 July 1983, same subj

1. The subject Summary Report forwarded by reference (a) has been reviewed.

2. Since this project has no effect on existing Navy programs, we have no comments to offer at this time.

B. W. CLOUD
Chief of Staff

GEORGE R. ARIYOSHI
GOVERNOR

STATE OF HAWAII
DEPARTMENT OF SOCIAL SERVICES AND HOUSING
HAWAII HOUSING AUTHORITY
P. O. BOX 17907
HONOLULU, HAWAII 96817

PAUL A. TOM
EXECUTIVE DIRECTOR

IN REPLY REFER
TO: 83:DEV/3318

July 19, 1983

District Engineer
U. S. Army Corps of Engineers
Honolulu District
Building 230
Fort Shafter, Hawaii 96858

Gentlemen:

Subject: Hilo Area Comprehensive Study - Draft Survey Report and Environmental Impact Statement

We have reviewed the subject draft survey report and EIS and have no comments to offer relative to the proposed action at this time.

Thank you for the opportunity to comment on this matter.

Sincerely,

PAUL A. TOM
Executive Director

GEORGE R. ARIYOSHI
GOVERNOR

State of Hawaii
DEPARTMENT OF AGRICULTURE
1428 So. King Street
Honolulu, Hawaii 96814

JACK K. SUWA
CHAIRMAN, BOARD OF AGRICULTURE

SUZANNE D. PETERSON
DEPUTY TO THE CHAIRMAN

Mailing Address:
P. O. Box 22159
Honolulu, Hawaii 96822

September 12, 1983

MEMORANDUM

To: District Engineer
U.S. Army Corps of Engineers

Through: Office of Environmental Quality Control

Subject: Draft Reports and Draft Environmental Impact Statements for the Hilo Bay Area Comprehensive Study

The Department of Agriculture has reviewed the subject documents and offers the following comments.

1) Summary Report. No comment.
2) Hilo Breakwater Modification: Draft Survey Report and Draft Environmental Impact Statement. No comment.
3) Hilo Bayfront Beach: Draft Survey Report and Draft Environmental Impact Statement. No comment.
4) Reeds Bay Small Craft Harbor: Draft Reevaluation Report and Draft Environmental Impact Statement. No comment.
5) Kumukahi Small Craft Harbor: Draft Survey Report and Draft Environmental Impact Statement.

The proposed Leleiwi Point, King's Landing, and Kumukahi small-craft harbor facilities sites are situated on State Urban or Conservation District lands. None of the sites are classified according to the Agricultural Lands of Importance to the State of Hawaii (ALISH) system. To our knowledge, no agricultural activities will be affected by the construction of any of the facilities, nor do we foresee any impact upon the agricultural resources of the areas involved.

Thank you for the opportunity to comment.

JACK K. SUWA
Chairman, Board of Agriculture

"Support Hawaiian Agricultural Products"

University of Hawaii at Manoa

Water Resources Research Center
Holmes Hall 283 • 2540 Dole Street
Honolulu, Hawaii 96822

7 September 1983

District Engineer
U.S. Army Corps of Engineers
Honolulu District
Building 230
Ft. Shafter, Hawaii 96858

Attn: Mr. Gene Dashiell

Dear Sir:

SUBJECT: Draft Survey Report and Environmental Impact Statement, Hilo Area Comprehensive Study, June 1983

We have reviewed the subject Draft Survey and EIS, and have no comment to offer at this time.

Thank you for the opportunity to comment. This material was reviewed by WRRC personnel.

Sincerely,

Edwin T. Murabayashi

Edwin T. Murabayashi
EIS Coordinator

ETH:jm

AN EQUAL OPPORTUNITY EMPLOYER

DEPARTMENT OF WATER SUPPLY • COUNTY OF HAWAII

25 AUPUNI STREET • HILO, HAWAII 96720

July 25, 1983

District Engineer
US Army Corps of Engineers
Honolulu District
Building 230
Fort Shafter, HI 96858

ENVIRONMENTAL IMPACT STATEMENTS - HILO AREA COMPREHENSIVE STUDY

Thank you for giving us the opportunity to comment on the Environmental Impact Statements. We have no comments at this time.

We are returning to you the five drafts.

William Sewake

H. William Sewake
Manager

CS

Encs.

...Water brings progress...

Hawaii Society of Professional Engineers

P. O. BOX 942 • HILO, HAWAII 96720

16 SEP 1983

September 15, 1983

Colonel Alfred Thiede, District Engineer
Corps of Engineers
Department of the Army
U.S. Army Engineer District, Honolulu
Ft. Shafter, Hawaii 96858

RE: HILO AREA COMPREHENSIVE STUDY

Colonel Thiede:

On behalf of the Hawaii Society of Professional Engineers - Big Island Chapter, thank you for giving us the opportunity to respond to your draft proposals.

The Board of Directors have reviewed and discussed your proposals and we have no comments to offer at this time.

The Chapter, at this point, would like to go on record supporting the concepts of the proposals. We feel the projects are necessary and desirable for the Hilo Area.

Kenneth Ikemori, P.E.

President,
Hawaii Society of Professional Engineers
Big Island Chapter

Marine Recreation & Education Committee
for the Big Island of Hawaii
c/o The Richardson Ocean Center
2349 Kalanianaole Street
Hilo, Hawaii 96720

September 2, 1983

Colonel Alfred J. Thiede
U.S. Army Corps of Engineers
Planning Branch
Building T-1
Fort Shafter, Hawaii 96858

Dear Colonel:

The Marine Recreation and Education Committee for the Big Island of Hawaii endorses the recommendation of the U.S. Army Corps of Engineers Pacific Ocean Division made in the Hilo Area Comprehensive Study (April 1983).

The Committee is looking at ways to promote and develop marine activities to benefit residents and visitors. The Committee was organized as an advisory body to the University of Hawaii Sea Grant Extension Service and Waikiki Aquarium in response to a resolution initiated by the 1983 State Legislature.

We feel that the improvements proposed by the Corps will benefit the community in the following ways:

1. Enhance the water quality in Hilo Bay for marine recreation
2. Assist the struggling visitor industry by providing opportunities for new recreational activities
3. Meet the pressing needs of the commercial fishing industry for berthing

We look forward to participating at future meetings in further refining these projects. Please include us on your mailing list and keep us informed of your progress.

Sincerely,

George Applegate
Chairman, East Hawaii

Enclosure: List of Committee Members
East Hawaii

Big Island Marine Recreation & Education Project
Steering Committee Members
East Hawaii
(as of September 2, 1983)

Mr. George Applegate
Public Relations
Naniloa Surf Hotel
93 Banyan Drive
Hilo, Hawaii 96720

Mr. David Arnold
375 Waianuenue Avenue
Hilo, Hawaii 96720

Mr. Charles Auld
President
Leleiwi Community Association
2336 Kalanianaole Street
Hilo, Hawaii 96720

Mr. Ben Bland
200 Kanoelehua Ave.
Hilo, Hawaii 96720

Dr. Walter Dudley
University of Hawaii
Hilo Campus
1400 Kapiolani Street
Hilo, Hawaii 96720

Mr. Milton Hakoda
County of Hawaii
Department of Parks and Recreation
25 Aupuni Street
Hilo, Hawaii 96720

Dr. Harlene Hapai
University of Hawaii
Hilo Campus
1400 Kapiolani Street
Hilo, Hawaii 96720

Mr. Marvin Iida
Dept. of Research and Development
34 Rainbow Drive
Hilo, Hawaii 96720

Mr. Seiso Kamimura
Superintendent
Division of State Parks
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Hilo, Hawaii 96720

Ms. Kikuye Kohashi
Acting County Administrator
Cooperative Extension Service
875 Komohana Street
Hilo, Hawaii 96720

Dr. Robert Nishimoto
Aquatic Biologist, DLNR
Aquatic Resource Division
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Hilo, Hawaii 96720

Dr. Craig Severance
Anthropology Department
University of Hawaii at Hilo
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Hilo, Hawaii 96720

Ms. Frances Sherrard
Chairperson
East Hawaii Cultural Center
141 Kalakaua Street
Hilo, Hawaii 96720

Mr. Shuichi Tanaka
District Education Specialist
Department of Education
75 Aupuni Street
Hilo, Hawaii 96720

Ms. Jane Testa
Community Service Specialist
Office of Aging, Hawaii County
34 Rainbow Drive
Hilo, Hawaii 96720

Mr. Michael Tulang, coordinator
Office of Resource Conservation
and Development, Hawaii County
P.O. Box 915
Hilo, Hawaii 96720

Ms. Deborah Ward
County Extension Agent
Cooperative Extension Service
875 Komohana Street
Hilo, Hawaii 96720

Mr. Dick West
President
Hawaii Chamber of Commerce
180 Kinoole Street
Hilo, Hawaii 96720

Ms. Jeanne Yagi
Deputy Director
Dept. of Research and Devmt.
34 Rainbow Drive
Hilo, Hawaii 96720

August 6, 1983

Mr. Gene Dashiell
Honolulu District Engineer
Bldg. 230
Fort Shafter
Hawai'i, 96858

Dear Mr. Dashiell,

As you stated in the July 29 issue of the Tribune Herald the last opportunity for public input before the Honolulu Engineer District is tentatively scheduled for August 25. Your timely advertisement in this regard is greatly appreciated; however, i would like to urge you to schedule this meeting at a later date due to the spate of other important meetings scheduled for the public of Hilo, and the Big Island. Specifically these meetings are concerning the Hawai'ian Homes Commission, and the Department of Transportation's meeting concerning the launch site at Kaulana Bay, Ka'u. If you can effect the schedule change, this person, as well as many other Island residents will greatly appreciate your accomodation. Thank You very much.

Sincerely,

Lance Foreman

Lance Foreman
POB 4141
Hilo, 96720
935 7254

SUPPORTING DOCUMENTATION

COASTAL ENGINEERING DESIGN AND EVALUATION
FOR SHORELINE IMPROVEMENTS
HILO BAYFRONT BEACH
HILO, HAWAII

COASTAL ENGINEERING DESIGN AND EVALUATION
FOR SHORELINE IMPROVEMENTS
HILO BAYFRONT BEACH
HILO, HAWAII

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FOR SHORELINE IMPROVEMENTS
HILO BAYFRONT BEACH
HILO, HAWAII

INTRODUCTION

Study Purpose and Objectives

This study of the Hilo Bayfront Beach was accomplished as part of the Hilo Area Comprehensive Study (HACS) being conducted by the U.S. Army Corps of Engineers, Honolulu District, under the authority of Section 144 of the Water Resources Development Act of 1976 (Public Law 94-587). The primary purpose of the HACS is to investigate methods to develop, utilize and conserve water and related land resources in the Hilo Bay area.

The purpose of this study is to investigate the engineering feasibility of alternative improvements to provide shore protection and beach restoration along the Hilo bayfront. Project objectives include shore protection for the bayfront highway, beach restoration and recreational enhancement, and reduction of shoaling of the Wailoa River mouth.

Study Area Location and General Description

Hilo Bay is located on the east coast of the island of Hawaii. For this report Hilo Bay is considered as the area encompassed by a line drawn from Pepeekeo Point to the north and Leleiwi Point to the east. Hilo Harbor is that portion of Hilo Bay bounded by the breakwater and a line extended from the tip of the breakwater westward to the shore. The Hilo bayfront beach extends between the Wailuku and Wailoa Rivers on the west side of Hilo Harbor. The east half of the harbor shoreline consists of the irregular and rocky shoreline of Waiakea Peninsula, small boat mooring in Reeds Bay, and the commercial port area in Kuhio Bay. The focus of this study is on the bayfront beach, with some discussion of wave energy in Reeds Bay and Kuhio Bay. The study area location and a general vicinity map are shown on Figure 1-1.

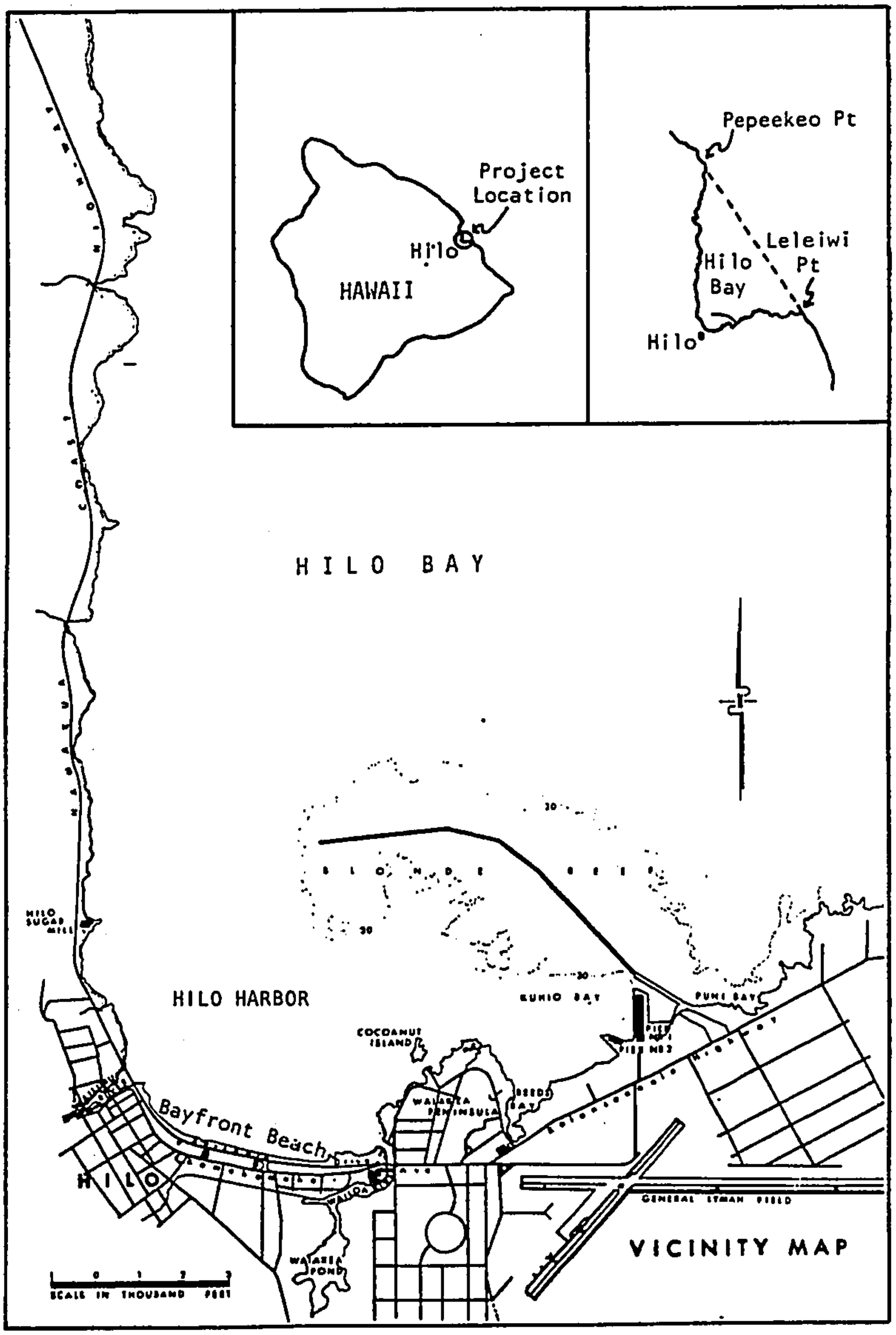


Figure 1-1. Location and Vicinity Map

Work Tasks and Methodology

Available Information Review. Historical records and previous oceanographic, environmental and engineering studies were reviewed for applicable coastal engineering design data and to assess the past and present coastal engineering characteristics of the study area. Information sources included the U.S. Army Corps of Engineers, Pacific Ocean Division, the University of Hawaii Hamilton Library and the Hawaii Institute of Geophysics library, and prior engineering studies accomplished for the State of Hawaii and Hawaii County. The existing available information, particularly available wave data and studies of the physical characteristics of Hilo Bay, provides the starting point for the analyses in this report.

Determination of Coastal Engineering Design Parameters. The available information was used to determine the general wave, water level and sediment transport characteristics in Hilo Harbor. The estimated deepwater wave climate (height, period, direction and frequency of occurrence) outside of Hilo Bay was determined, as well as the theoretical transformation of the deepwater waves due to refraction, diffraction, bottom friction, shoaling and breaking as they enter the bay and propagate shoreward. The estimated sediment transport characteristics of the bayfront shoreline was assessed based on the physical characteristics of the shore and the theoretical wave analysis. The design parameter analysis was based on existing state-of-the-art coastal engineering techniques and methodology contained in publications by the U.S. Army Corps of Engineers Coastal Engineering Research Center, engineering publications such as the Journal of the Waterways, Harbors and Coastal Engineering Division of the American Society of Civil Engineers, and other published coastal engineering research studies. A numerical computer model was utilized for the analysis of wave transformation and sediment transport. The existing condition of the shoreline was verified by field investigation.

Design of Shoreline Improvements. Preliminary planning and design of alternative shoreline improvements to meet the general project objectives of shore protection and beach restoration have been accomplished. The design includes type, location, typical sections, construction materials and costs for the alternative plans of improvement. Discussed are protective beaches, structures including revetments, groins, offshore breakwaters and shoals, and combinations thereof. Modification of the existing Hilo Harbor breakwater is also considered. The designs generally follow the methodology contained in the Shore Protection Manual (SPM) (U.S. Army Corps of Engineers, 1977). All depths and elevations referred to in this report are referenced to Mean Lower Low Water datum.

Assessment and Evaluation. An engineering assessment and evaluation have been made of the feasibility and effectiveness of the alternative plans of improvement in achieving the project objectives. Estimated costs are presented based on recent prior U.S. Army Corps of Engineers estimates for similar projects in Hilo Harbor and costs obtained from product manufacturers and distributors. The adequacy of the existing available baseline data and the limitations of the analytical techniques used as they affect the accuracy and completeness of the study results are addressed.

Summary and Recommendations

1. The majority of the existing Hilo bayfront shoreline is protected by a random dumped rock revetment which varies considerably in construction, general condition and adequacy for wave protection. Much of the revetment is in very bad repair, with armor stones displaced and undermining extending 3 to 5 feet under the adjacent highway shoulder in several locations. The revetment overtops during winter season north swell wave attack, at times forcing closure of the highway for a day or two. Little stable sand beach remains along the shoreline, except for the eastern most 1,800 feet of the bayfront beach, primarily as a result of man's interference with the natural coastal processes. The present beach represents only a small portion of what was, in the last century, a much wider beach.

2. Tradewind generated seas and North Pacific swell during the winter provide the energy for sediment transport along the shoreline. The Hilo breakwater blocks the direct approach of the deepwater tradewind waves, however, these waves do refract and diffract around the breakwater and into the harbor. North Pacific swell waves approach Hilo Harbor directly, and this, coupled with their larger size, makes their impact on the shoreline much greater. Previous studies have shown the net transport of sand to be west to east, in the surf and swash zone. The primary sediment source for the bayfront beach is the Wailuku River. The amount of sand along the shoreline presumably varies directly with the amount of sediment discharged by the river and the prevailing wave energy.

3. The numerical model shows that considerable divergence of wave energy due to refraction occurs for all the deepwater wave periods and directions affecting Hilo Harbor. Refraction coefficients are generally between 0.1 and 0.3 for all the conditions tested. For tradewind waves this is primarily a result of the breakwater blocking the direct approach of the waves. Only a very small portion of the incident deepwater wave energy can refract and diffract around Blonde Reef and the breakwater tip to actually reach the bayfront beach. North swell, on

the other hand, approaches the shoreline directly. However, considerable refraction occurs as the wave direction parallels the coastline for almost 8 miles before reaching the harbor entrance and results in a very narrow corridor from which north swell wave energy can enter the harbor.

4. During the tradewind conditions the longshore energy flux is generally less than about 10 ft-lbs/sec/ft of beach front, and the greatest concentration of the energy is between shoreline stations 20+00 to 40+00 (Figure 2-3, page 18). During the winter season there is two to four times as much potential energy flux along the shoreline, with much more energy present along the western portion of the beach between stations 5+00 and 20+00.

The energy flux is very sensitive to the angle of wave approach to the shoreline. Where there is existing sand along the shore, or if the beach should be restored, the beach will attempt to orient itself perpendicular to the predominant wave direction and reduce the energy flux and longshore transport.

The calculated energy flux indicates that the greatest potential for transport both seasonally and annually is between stations 5+00 and 40+00, which agrees with what has been observed. Energy flux is concentrated at stations 10+00 to 15+00 and 20+00 to 40+00. The net transport direction is west to east; however, there is an interesting nodal point between stations 15+00 and 20+00, where the energy flux is greatly reduced or reverses direction. Energy flux at both ends of the beach also reverses direction and moves east to west. During severe storm wave attack (e.g., the 10-year return period storm event), the potential energy flux can increase by two or three times above that normally experienced during periods of north swell. These storms are relatively brief and infrequent; however, they have the potential to move a very large amount of sand in a short time.

5. The Bayfront Beach is well sheltered from approaching deepwater waves, and wave heights at the shoreline are greatly attenuated. Tradewind wave heights in the harbor are generally about 9% to 12% of the deepwater height, with a low of 2% to 4% for waves from due east. North swell relative wave heights are greater, being about 10% to 30% of the

deepwater height for 10- to 16-second waves from due north. Northwest swell is greatly attenuated as it refracts around Pepeekeo Point and is only 1% to 3% of its deepwater height inside the harbor.

Wave heights in Reeds Bay and the commercial port area are further attenuated by diffraction around the breakwater and refraction as they propagate across the harbor. Tradewind wave heights are generally less than 2% to 3% of the incident deepwater heights in Reeds Bay and the commercial port, respectively. North swell wave energy reaching Reeds Bay and the port area is greater; however, wave heights are still generally less than 5% of the deepwater height.

6. The potential for longshore transport as shown by the energy flux indicates the probable need for structures to help stabilize a restored beach and reduce sand losses due to longshore transport by either reducing the wave heights at the shoreline (offshore structures) or assisting the beach to obtain a stable configuration perpendicular to the incident wave approach (groins). There are feasible alternatives from an engineering standpoint to meet the project objectives of protecting the highway, enhancing beach recreation, and reducing longshore transport and the resultant shoaling of the Wailoa River mouth. These alternatives include beach replenishment stabilized by groins or offshore breakwaters, at a cost of about $9 million, or a lower cost perched beach concept stabilized by Longard tubes. The Longard tubes cost less than more conventional rock structures, a little over $3 million for comparable improvements, however, their vulnerability to vandalism makes their durability highly questionable. The Longard tubes could also be used to construct an artificial surf shoal. A rock revetment is probably the best and least costly method for protecting the backshore area ($3 million for the entire shoreline), however, it would not meet the other project objectives. A reasonable plan of improvement would be to combine portions of several of the alternatives. A plan including a surf shoal, 2,000 linear feet of protective beach stabilized by rock groins to reduce longshore transport, and 1,200 feet of rock revetment would enhance recreational surfing, provide approximately 250,000 square feet of dry beach area and protect the highway. The cost of this combination plan would be about $6.1 million.

7. Decreasing the crest elevation of the seaward 7,000 feet of the Hilo breakwater and constructing a 2,000-foot long stub breakwater to protect the commercial port area will not significantly alter the coastal processes along the bayfront beach shoreline.

8. The results of an analytical study such as this are only as good as the data input. The results of this study could be made significantly more accurate by quantifying in more detail and accuracy the following:

- the wave climate at the entrance to Hilo Harbor (typical height, period and direction for a full year); and
- the relationship between longshore energy flux and the sand transport rate applicable to the study area.

In addition, a hydraulic model study should be conducted to aid in the design of an artificial surf shoal and to assess the impacts of modifying the Hilo breakwater.

EXISTING CONDITIONS

General Physiography

Hilo Harbor encompasses an area approximately 12,000 feet by 7,000 feet in the bight of Hilo Bay. The 10,070-foot-long Hilo breakwater extends across the northeastern half of the harbor, constructed on the relatively shallow Blonde Reef. The shoreline on the west side of the harbor, north of the Wailuku River, is comprised of steep, rocky basalt sea cliffs. The western two-thirds of the 5,800-foot-long shoreline between the Wailuku and Wailoa Rivers is primarily a rock revetment fronted by short stretches of narrow black sand (lava basalt) beach, which is highly variable both in size and location seasonally and from year to year. The eastern one-third of this portion of the shoreline is fronted by a 100 to 150-foot-wide, relatively stable, black sand beach. The harbor shoreline is bisected by the rocky and irregular shoreline of Waiakea Peninsula. This area is extensively developed for tourists, including hotels, restaurants and public parks and gardens. East of Waiakea Peninsula are the small boat anchorage in Reeds Bay and the commercial port facilities in Kuhio Bay at the far east end of the harbor. A detailed site plan is shown on Figure 2-1.

Bathymetry and Bottom Conditions

Bathymetry. The water depth in the central portion of Hilo Harbor generally varies between 35 and 45 feet. The controlling depth for navigation in Kuhio Bay is 35 feet. Blonde Reef, which extends almost two miles northwesterly from the southeast side of Hilo Bay, has a width between the 30-foot contours of 2,500 to 4,500 feet and depths generally ranging between 10 to 20 feet. Several deep holes in the reef are 30 to 40 feet deep. The average nearshore bottom slope along the bayfront beach, seaward of the 6-foot contour, is about 1V on 50H. Closer to shore, landward of the 6-foot contour,

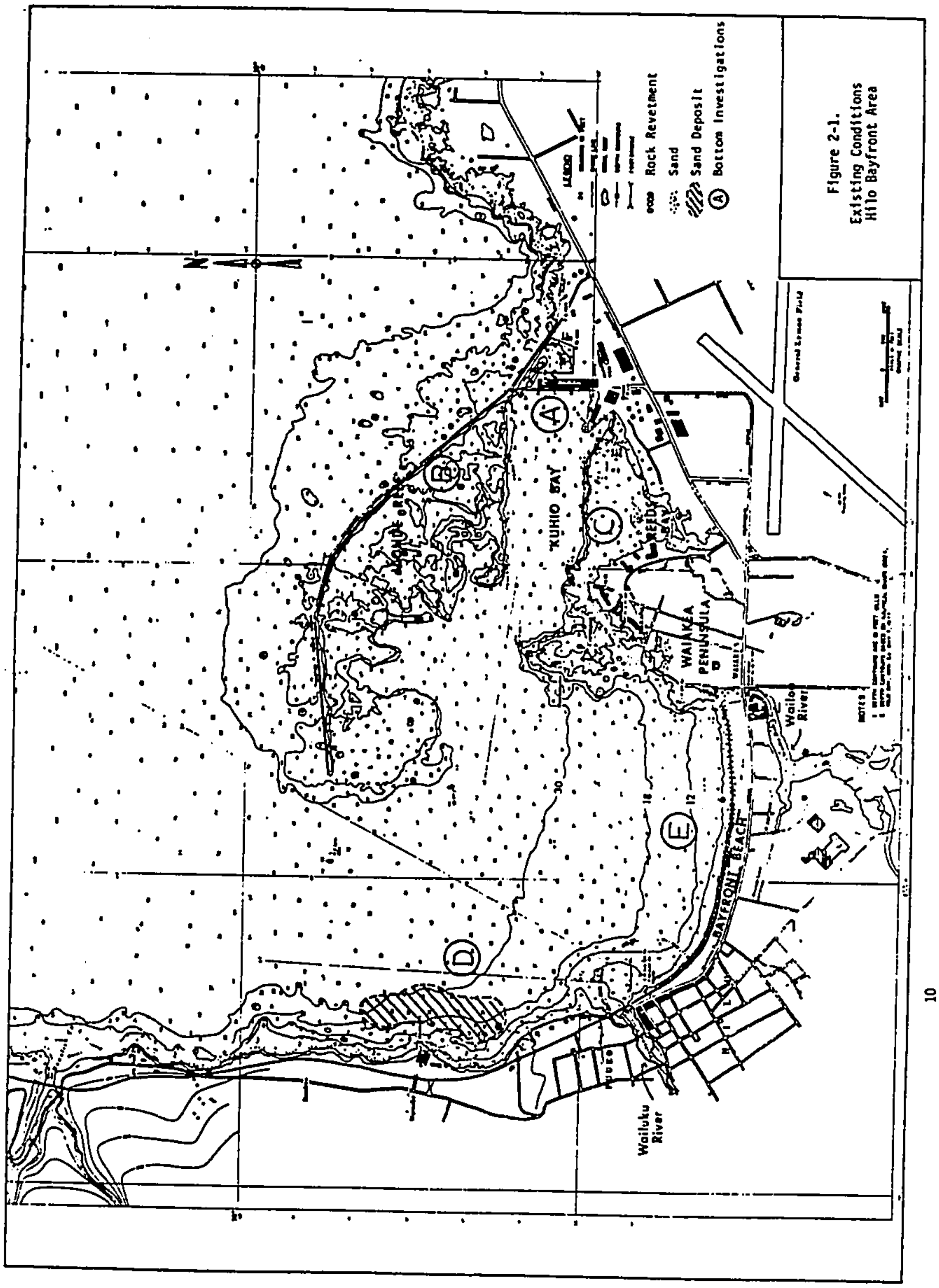


Figure 2-1.
Existing Conditions
Hilo Bayfront Area

the bottom slope is steeper, varying between 1V on 25H at the west end to 1V on 10H atthe east end. A shallow, submarine delta extends seaward at the mouth of the Wailuku River.

Bottom Sediments. Bottom and sub-bottom investigations have been conducted in Hilo Harbor by Ocean Innovators (1979) and M & E Pacific, Inc. (1980). These studies were accomplished to determine the nature of the bottom sediments and to define the extent and quality of possible nearshore sand sources. Both of these studies were undertaken for the U.S. Army Corps of Engineers in connection with the HACS. The general areas investigated are labeled A, B, C, D and E and shown on Figure 2-1. Visual observation, jet probes, and surface and wash samples were used to describe the nature of the bottom sediments. The general bottom characteristics in the areas investigated are as follows:

Area A. The bottom sediments in Kuhio Bay consist mainly of mud (silt to clay range) at least 13 feet thick.

Area B. This area is the southeast portion of Blonde Reef. The bottom is generally hard coralline reef partially covered by a 2 to 4-foot-thick veneer of fine sediment. Pockets and surge channels in the reef flat not covered by sediments are overlain with scattered basalt boulders, live coral heads, and coral rubble.

Area C. The bottom at the entrance to Reeds Bay generally consists of sand, gravel and coral rubble about 7 feet thick over hard coral reef material.

Area D. Area D consists of a deposit of fine to coarse black volcanic sand suitable for beach restoration and nourishment. The deposit is 95 to 99 percent sand, with a medium grain size about 0.5 mm, specific gravity about 2.9 and organic content generally about 10 percent. The sand is inside the 30-foot contour and varies from about 15 to 25 feet thick. Estimates of the total volume range from 550,000 to 775,000 cubic yards. Seaward of the 30-foot contour the sand becomes mixed with silt and mud, and at the 40-foot-depth is primarily mud.

Area E. Along the bayfront beach, seaward of the 6-foot contour, the bottom is essentially mud with some fine sand.

Currents and Circulation

Previous studies which included current measurements in Hilo Harbor provide a good general picture of the circulation patterns. These studies were summarized by Sea Engineering Inc. (1981) and the summaries are presented in the following paragraphs.

The Public Health Service (1963) conducted a dye tracer study to determine flushing and mixing patterns in Hilo Bay. Rhodamine-B dye mixed with sea water was released on six separate occasions from May 6 to May 27, 1963. The PHS found that the surface layer movement was generally seaward, out of the harbor, and could have been due to the easterly tradewinds present on the release days. Tidal changes did not exert a significant effect on the released dye.

Neighbor Island Consultants (1973) measured selected physical, chemical and biological conditions in Hilo Harbor during the period of July 17 through August 21, 1972. Six one-day cruises were made to track current drogues and surface drift bottles. Most of the work was concentrated in the main ship channel and in Kuhio Bay. The data indicated a two cell circulation pattern in the upper layers of the harbor. The eastern cell, in Kuhio Bay, circulated clockwise with the tide, while the western cell, centered northwest of Waiakea Peninsula, circulated counterclockwise. The two cell circulation system was fringed by small eddies and a constant seaward flow along the breakwater. Net transport of the entire system was seaward, due at least in part to fresh water runoff from the Wailoa and Wailuku Rivers and ground water inflow. Salinity of the deeper harbor waters indicated replenishment from the ocean; the depth and extent of the inward flow was not defined.

M & E Pacific, Inc. (1977 and 1980) conducted the most detailed studies to date of Hilo Bay. The studies included evaluation of circulation characteristics, water quality, geological definition of bottom types, and biological and fishery resources. Circulation measurements were made with drogues and recording current meters. Drogues were tracked on three days in April 1977, four days in March 1980, and four days in June 1980. Two current meters recorded data for three weeks in June 1980. The circulation measurements were concentrated in the main reaches of the harbor and the harbor entrance channel. Drogues were placed in the nearshore area off the bayfront beach on only one day, April 7, 1977. A summary of the M & E findings is as follows:

1. There is a two-layer salinity stratified pattern in Hilo Harbor. Vertical stratification of the water column is caused by the large amounts of fresh water entering the harbor from both ground water and surface flow. The salinity gradient is more pronounced during the wet season (winter).

2. The net transport of the surface layer is out of the harbor at a rate dependent upon the quantity of freshwater input and wind speed and direction.

3. The subsurface flows at the harbor mouth are influenced by the tide. During flood tide, subsurface flow was generally into the harbor and during ebb tide the flow generally reversed. During ebb tide, however, occasions were noted when an inward flow persisted along the western half of the harbor mouth. Similarly, there were times when the subsurface water along the eastern side of the channel moved continually seaward, even during flood tide. Flood and ebb tide current speeds in the harbor entrance area averaged approximately 4 cm/second during the 1980 phase of the study. Current meter data at the harbor entrance showed a net transport into the harbor. The relatively small volume of tidal exchange (the tidal prism) relative to the large cross-section areas of the harbor entrance results in the very low tide-related currents.

4. The two cell circulation in the upper layer described by Neighbor Island Consultants (1973) was not confirmed by the M & E Pacific findings. Variations between studies and even between drogues placed on the same day were thought to be due to eddies with higher speeds than those associated with the tidal flow.

5. Drogues placed off the mouth of the Wailoa River on April 7, 1977 during an ebbing tide moved north and west, or in a seaward direction. Drogue depths were surface and 5 feet.

Current studies nearshore in the vicinity of the bayfront beach by Sea Engineering (1981) generally indicated weak and variable currents, with the presence of eddies and tidal reversals. Wind conditions were typical of the diurnal pattern prevalent in the area. Early morning winds were from the south or west, shifting to moderate trades by mid-morning. Current drogues near the surface and at mid-depth between the 6 and 18-foot-contours seaward of the bayfront beach were tracked during strong flood and ebb tides and typical tradewind conditions. Current speeds were slow, ranging from 1 to 10 cm/second.

The Bayfront Beach Shoreline

History. The history of the Hilo Bay area has been extensively documented by Kelly, et al (1981) in a report prepared for the U.S. Army Corps of Engineers. Three maps and charts from the late 1800's and early 1900's reproduced in that report show the bayfront beach with a significantly different configuration than the existing beach. An 1825 detail chart of Hilo Bay shows a crescent-shaped beach with a pronounced point (Cocoanut Point) protruding seaward at the west end of the beach. The chart shows Waiolama Stream discharging across the center of the beach. Although not to scale, the beach characteristics are indicative of a stable configuration and are similar to those of natural beaches fronting stream mouths at other locations in Hawaii. An 1882 map of Hilo Bay, drawn to 1" = 1,000' scale and registered with the State Surveyor's Office, shows the same beach characteristics as the 1825 chart (Figure 2-2a). A third map in the report was based upon an 1891 government survey and drawn to 1:2400 scale. This map shows the discharge of Waiolama Stream skewed to the west by the buildup of a beach berm on the east side (Figure 2-2b). This stream discharge configuration is indicative of a predominant longshore transport to the west.

"In 1901, the Hilo Railroad Company was requested ... to extend the line a mile and a half from Waiakea, along the beach at Hilo Bay, to Hilo town ... The railroad line from Waiakea was completed in 1903,

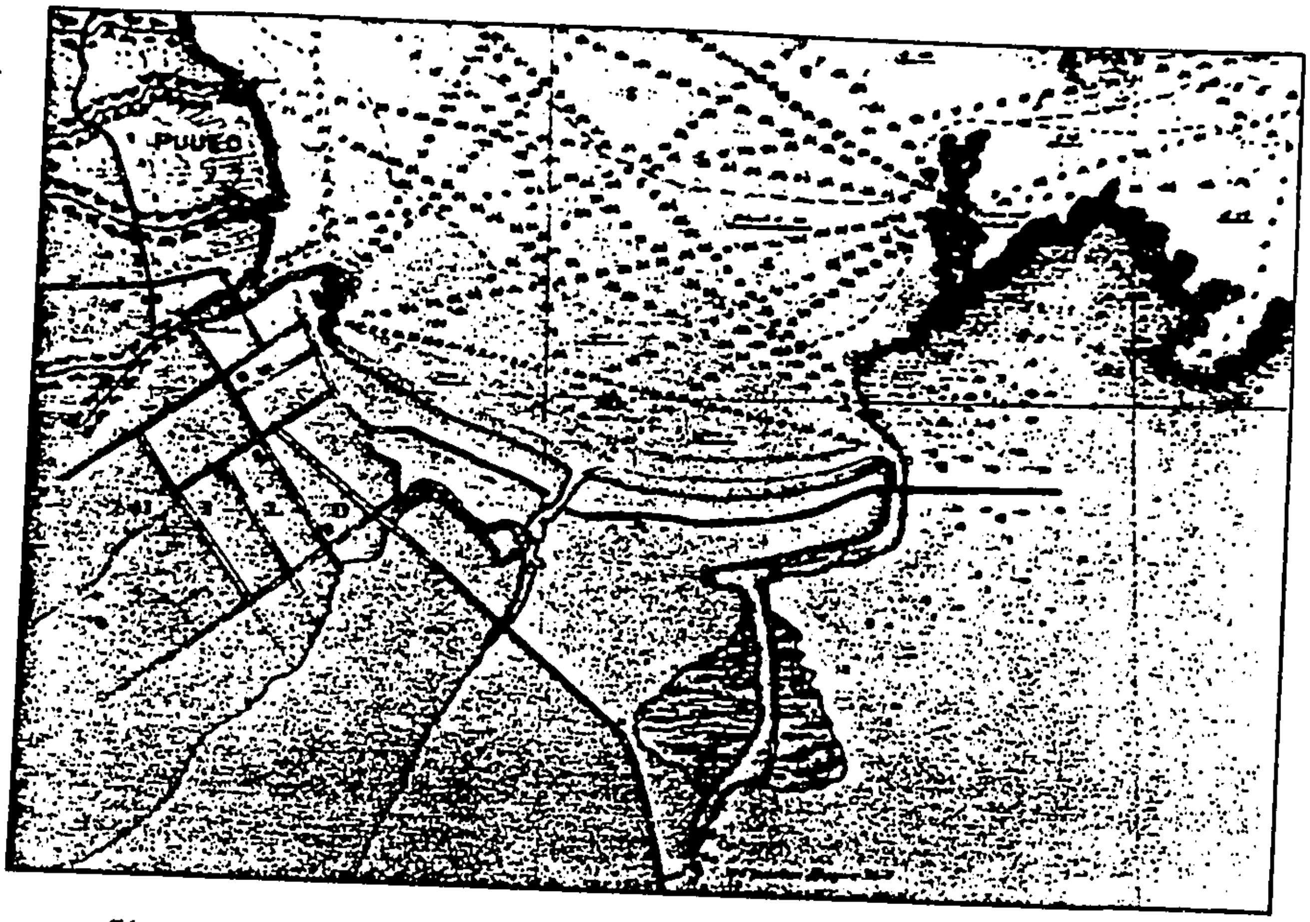


Figure 2-2a. Chart of Hilo Bay, 1882 (from Kelly et al., 1981)

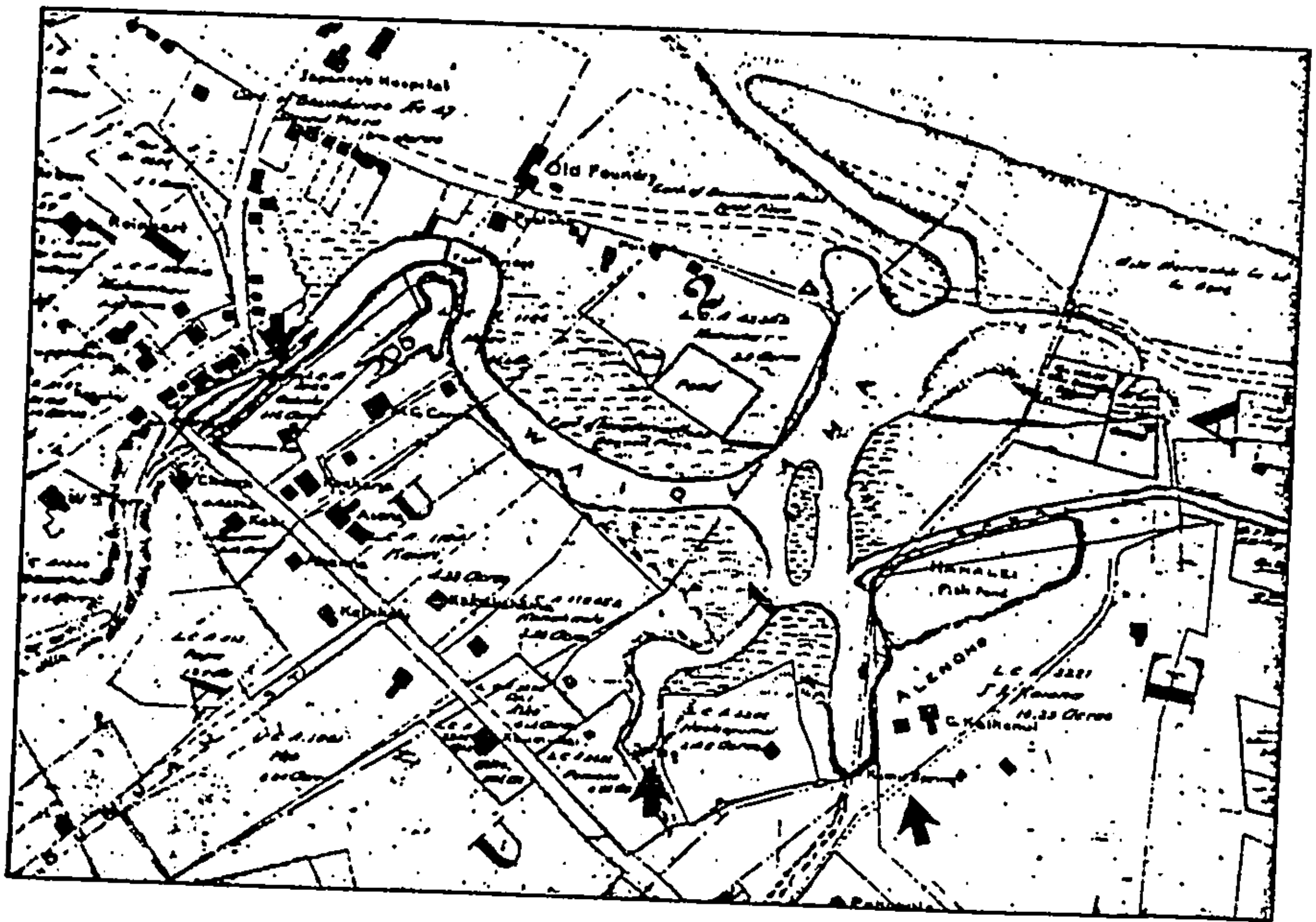


Figure 2-2b. Hilo Survey, 1891 (from Kelly et al., 1981)

running across the Wailoa River and along the black sand beach of Hilo Bay, to Hilo town" (Kelly et al., 1981). The railroad line was protected by a rock revetment. A circa 1916 photo looking west from the vicinity of the Wailoa River shows a crude erosion barrier near the river mouth, and a narrow black sand beach extending all along the shoreline. A map made in 1921 by the U.S. Army Engineer Office shows the railroad track on the beach berm, and also shows what is presumably a sand shoreline seaward of the railroad line.

Waiolama Stream, before 1915, was situated nearly in the center of the crescent beach surrounding Hilo Bay, between the Wailuku and Wailoa Rivers. Between 1915 and 1923 the river and adjacent wetlands were filled and the river flow diverted by canal to the Wailoa River. An estimated 250,000 cubic yards of black sand from the beach was used as fill material (Kelly et al., 1981). An aerial photo (circa 1923) showing the western end of the bayfront beach and the Wailuku River shows no evidence of a sand beach remaining.

Several storm drains have been constructed along the bayfront shoreline. The largest of these is the Punahawaii relief box culvert, built about 1925 just west of the center of the bayfront beach. The culvert was approximately 10 feet wide by 5 feet high, built upon pilings and extended about 50 feet into the bay. At low tide children would play on the beach under the culvert (Kelly et al., 1981).

Following the 1946 tsunami (between 1949 and 1951), the existing bayfront highway was built along the railroad right of way, with a rock revetment along the shoreline constructed as part of the highway embankment. The shoreline, at least at the west end of the bayfront beach, has now been moved so that Cocoanut Point protrudes only slightly beyond the revetted shoreline.

Moberly and Chamberlain (1964) sum up the present condition of the shoreline by stating, "The present beach represents only a small portion of what was, in the last century, a much wider beach."

Existing Condition. A visual inspection of the bayfront shoreline between the Wailoa River and the Wailuku River was conducted in August 1982. A black sand beach extends approximately 1,800 feet west of the Wailoa River, at which point the bayfront highway intersects the shoreline and runs parallel to it for approximately 4,000 feet. The shoreline fronting the highway is generally protected by a rock revetment which varies considerably in construction, general condition, and adequacy for wave protection. According to an "as built" drawing of the shoreline revetment, it is constructed of a single layer of 2- to 3-ton armor stone placed on a 1V on 1.5H slope over existing rock fill. This armor stone size is adequate for wave protection; however, the single layer construction over small size fill material has resulted in the fill material being eroded through voids in the armor layer, with resultant undermining of the armor stone foundation and collapse and displacement of the armor stone itself. Undermining extends 3 to 5 feet underneath the road shoulder in several locations. Portions of the revetment have been grouted with concrete in an apparent effort to prevent its failure. The rock revetment also varies in side slope, ranging from near vertical to the "as built" design slope of 1V on 1.5H. Portions of the shoreline are fronted by a black sand beach which does not show on a September 1979 shoreline survey by the U.S. Army Corps of Engineers, indicating the transient nature of sand along this shoreline. The rock revetment crest elevation varies between 9 and 12 feet above mean lower low water. The highway is generally lower than the revetment, being as low as 7.5 feet in places. Many of the storm drains which extend through the revetment are broken and/or plugged. The Punahawaii culvert is twisted and the culvert sections are disjointed. The general configuration of the shoreline is shown on Figure 2-3, with position along the shoreline indicated by station numbers representing feet west to east from Cocoanut Point (e.g., Sta. 10+00 = 1,000 feet). Typical shoreline profiles are shown on Figure 2-4, and the general nature of the shoreline is summarized in Table 2-1. Photographs illustrating the existing shoreline are shown in Figure(s) 2-5a-c.

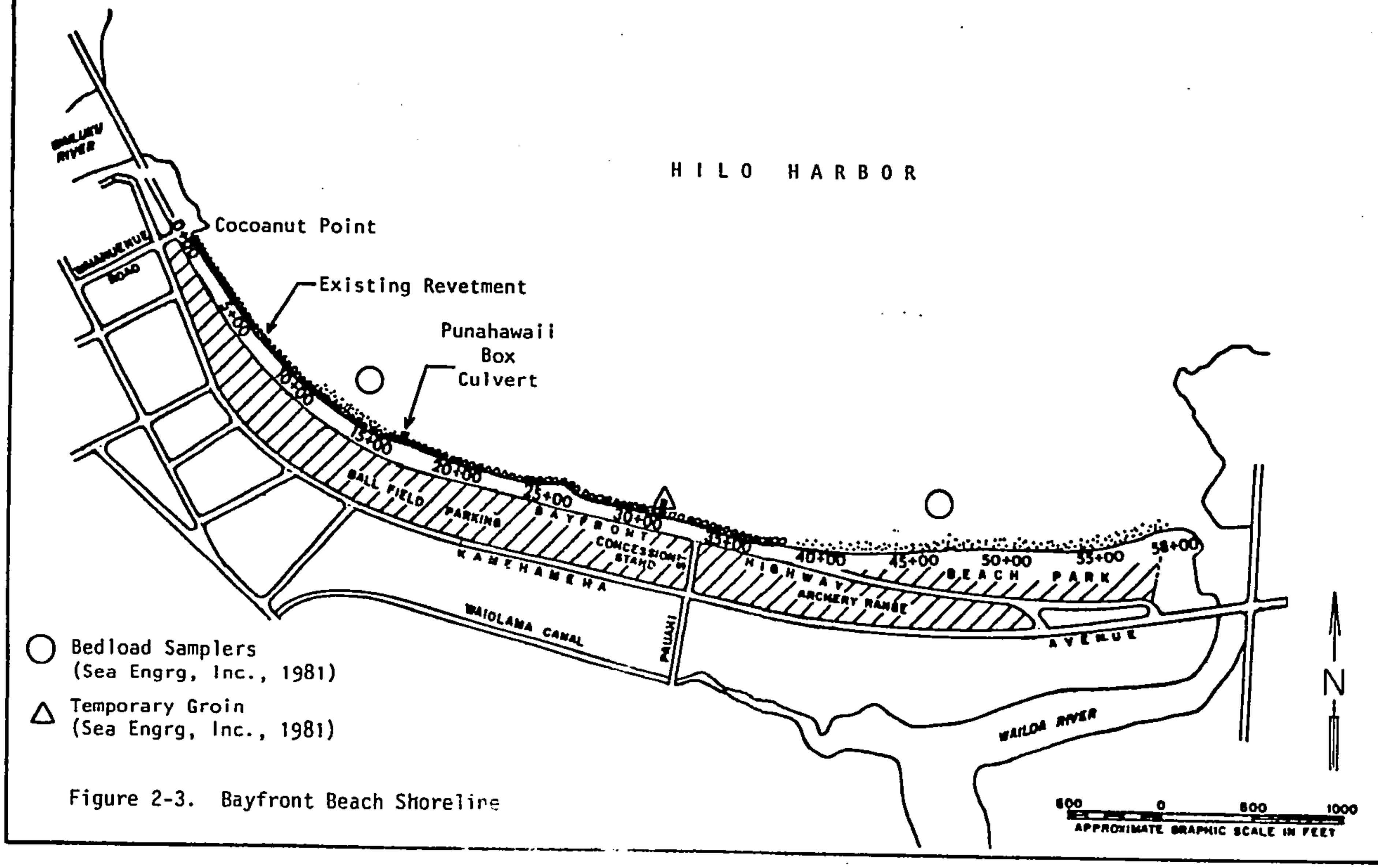


Figure 2-3. Bayfront Beach Shoreline

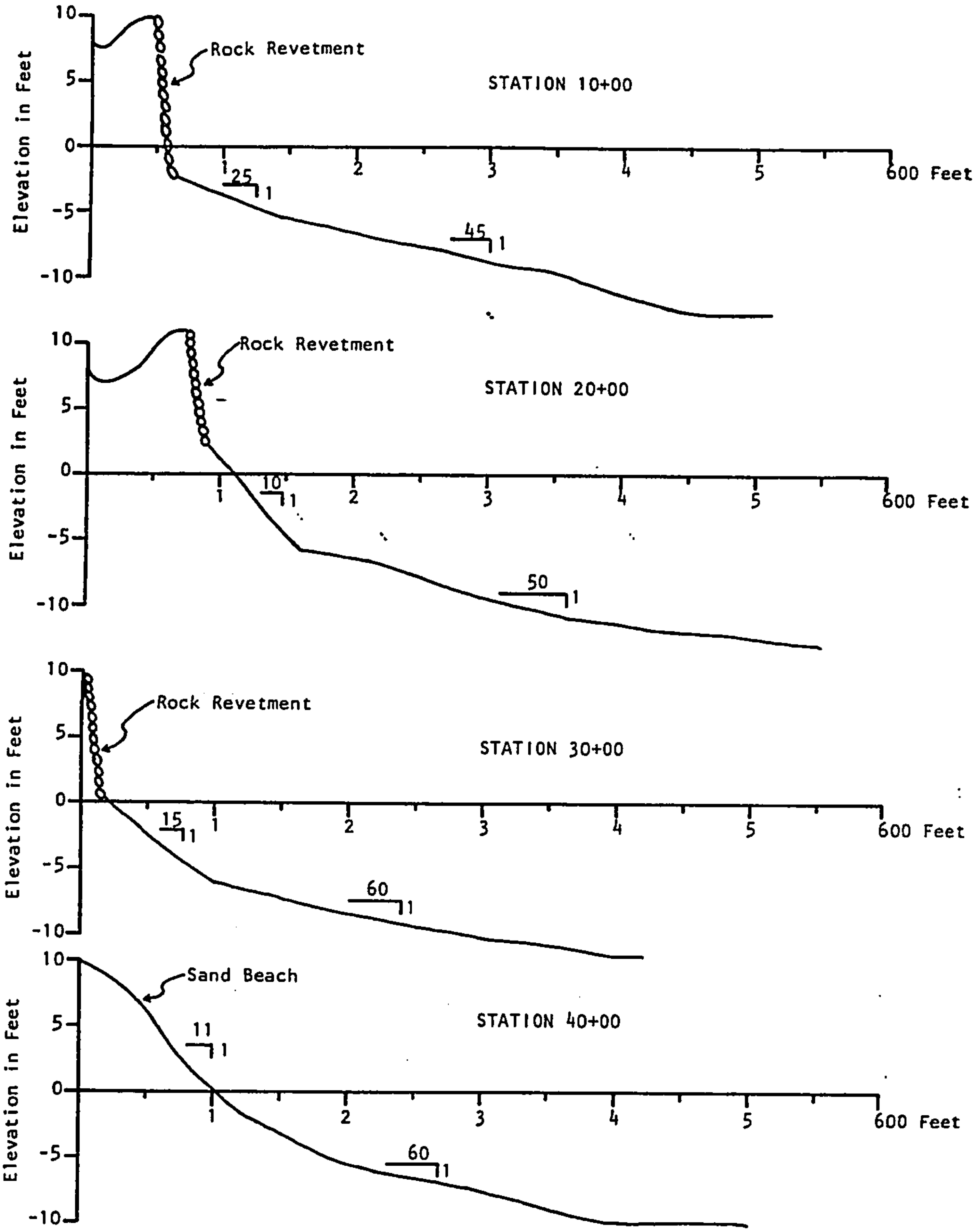
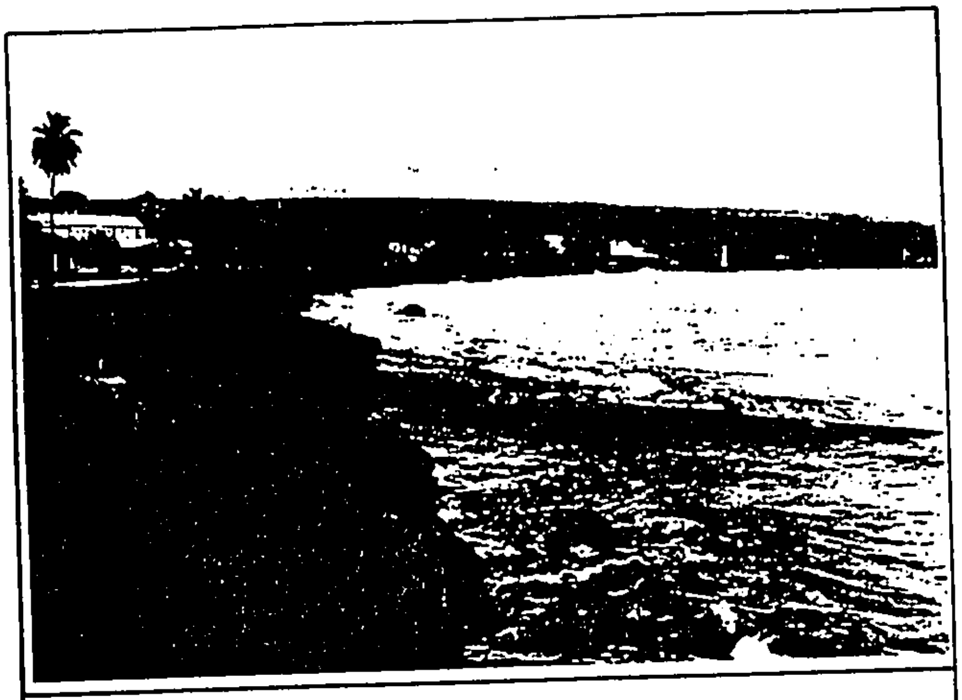


Figure 2-4. Typical Shoreline Profiles

Table 2-1. EXISTING SHORELINE CONDITION

Station	Shoreline Condition
0+00 to 7+00	The shoreline in this reach is protected by a rock revetment which is in good condition. The side slope is steeper than desirable, however, the revetment appears to be functioning satisfactorily. See photograph 2-5a.
7+00 to 25+00	The shoreline is composed of random dumped rock, grouted in places with concrete. Portions of the shoreline are fronted by a black sand beach with 1V on 10H slope. Much of the rock is undersized and poorly placed for adequate wave protection. Small rocks and cobbles along the shore likely become wave tossed debris during storms. This reach is very poorly protected and could be expected to sustain considerable damage during wave attack, particularly the northern end of the reach. See photograph 2-5b.
25+00 to 40+00	The shoreline in this reach is protected by a single layer of armor stone with a side-slope of approximately 1V on 1.5H, apparently placed over unconsolidated fill material. Erosion of fill material between voids in the armor stone has resulted in collapse and displacement of the armor stone and undermining of the road shoulder in several areas. The revetment is presently fronted by a 50 to 100-foot-side sand and debris beach. This beach does not appear on a 1979 survey of the shoreline. Considerable organic debris (grass, twigs, etc.) is present along the shore. See photograph 2-5c.
40+00 to 58+00	Black sand beach fronting a wide, grassed park area. Beach slope is 1V on 11H. The sand is medium grain size, well-sorted, volcanic rock fragments.



a. Looking west from Station 18+00. Note broken Punahawaii box culvert in foreground.

b. Looking west from Station 25+00.

c. Looking east from Station 25+00.

Figure 2-5.

Existing Shoreline Condition August 10, 1982.

Sediment Source

M & E Pacific, Inc. (1980) states that the sediment load to Hilo Harbor is primarily attributable to the Wailuku River. From data collected by the U.S. Geological Survey for one year, the estimated sediment load from the Wailuku River is approximately 12,000 tons per year. The data also shows that normally less than 10 tons per day of sediment is discharged, and thus most of the sediment is transported by a few large storm discharges each year. During a two-day rain storm in March 1980, judged to be in the order of a 10-year return period storm, an estimated 4,000 tons of sediment was transported to Hilo Harbor by the Wailuku River. No estimate of the percent of sand-sized material carried by the river is available.

General Coastal Processes

The bayfront beach has undergone considerable change in the past 100 years as physical changes to the shoreline and the nearshore area altered the coastal processes of the area. Maps and charts from the late 1800's and early 1900's show that prior to about 1900 the bayfront shoreline was fronted by a crescent-shaped beach, bounded to the west by Cocoanut Point and to the east by Waiakea Peninsula. The beach was black volcanic sand of terriginous origin, presumably carried to the shore by the Wailuku, Waiolama and Wailoa Rivers.

Construction of a railroad line and later a highway along the top of the beach, both protected by a rock revetment, and the use of 250,000 cubic yards of the beach sand to fill the Waiolama River not only altered the shape and configuration of the shoreline but also used its own sand to eliminate one of the beach's sources of nourishment. Probably the most significant factor in altering the bayfront coastal processes was the construction of the Hilo breakwater.

The breakwater has reduced wave energy from the east and northeast, and has thereby considerably reduced the mechanism for sand transport to the west. Only northerly waves and diffracted tradewind waves can now reach the shore, resulting in a primarily one-way longshore transport of littoral material toward the east. In addition to the one-way sand transport, energy reflection from the existing rock revetment inhibits the accretion of sand. Except for approximately 1,800 feet at the east end of the bayfront shoreline, there is presently no stable dry sand beach fronting the revetted shore.

The tradewind generated waves and north swell during the winter provide the energy for sediment transport along the shoreline. The Hilo breakwater blocks the direct approach of the deepwater tradewind waves. These waves do, however, refract and diffract around the breakwater and into the harbor. The net transport is apparently to the east along the bayfront beach, as evidenced by previous studies (Sea Engineering, Inc., 1981) and the configuration of the shoreline. Transport measurements during the summer showed net transport to the east at a rate of 5 to 6 cubic yards per day. Existing barriers to longshore transport (e.g., the Punahawaii box culvert) have accretted sand on their west sides, indicative of the predominant transport to the east.

During the winter months north Pacific swell is present. These waves from the northwest and north approach the harbor directly and also move sediment to the east. The north swell waves are considerably larger than the tradewind waves, and thus their impact on the shoreline is much greater.

The coastal processes and sand transport are not only governed by the available wave energy, but also by the amount of nearshore sand available for transport. The Wailuku River is an active sediment producer, however, most of the material is discharged during storm (high rainfall) occurrences. Once the sediment discharged by the storm flow of the river is moved eastward, material available for transport is limited until the next large sediment discharge by the river.

Field Investigations of Sediment Transport

General. There are three possible zones of nearshore sediment transport along the bayfront beach:

(1) Transport in the swash zone due to the skewed uprush and backrush of the waves;

(2) Transport in the surf zone, where the sand grains are suspended by the breaking wave turbulence and then transported by longshore currents; and

(3) Bedload transport seaward of the surf zone due to the passage of unbroken waves or by strong currents.

Field investigations of sediment transport conducted by Sea Engineering, Inc. (1981) indicated that the transport was primarily in zones 1 and 2. These investigations were conducted in August, during the summer season, when the wave climate is very mild. Because the wave heights are low and periods short, there is little movement of sediment beyond the surf zone. In addition, due to the relatively steep nearshore bottom slopes, the waves break at or very near the shore and the surf zone is narrow. During the summer season the swash zone and surf zone are essentially the same.

Bedload Transport. Nearshore bedload sediment transport along the bayfront beach was measured by Sea Engineering, Inc. (1981) using VUV pressure difference samplers. The estimated efficiency of these samplers is 70 percent (Hubbell, 1964). The samplers were located at Sta. 13+00 and Sta. 47+00 (see Figure 2-3) approximately 30 feet seaward of the mllw line in approximately 4 feet of water. Transport was measured for slightly over 10 days during late August. Longshore bedload transport averaged about 0.08 to 0.15 cubic feet per foot of beach width per day. Onshore/offshore transport averaged less than half the longshore transport rate. Median grain size of the sediment collected at Sta. 15+00 was about 1.4 mm (coarse sand and gravel), and at Sta. 40+30 was about 0.2 mm (fine to medium sand). This distinct variation in grain sizes is indicative of a more severe wave climate at the western end of the beach.

Swash Zone Transport. Most of the sediment transport along the bayfront beach takes place on the relatively narrow beach swash zone. To measure transport in the swash zone a temporary groin, consisting of 150-pound sand filled bags, was constructed from above the high water mark to the -2.5 foot depth in the vicinity of Sta. 30+00 (Figure 2-3). Beach elevation changes were measured on both sides of the groin, and volume changes were then computed for each transect line using Simpson's Rule for irregular areas. The net longshore transport rate based on the groin measurements was about 5-6 cubic yards/day moving east toward the Wailoa River. This rate may be low because the efficiency of the groin was somewhat less than 100% due to a loss of material around the seaward end of the groin and the movement of some material over the top. Littoral environment observations during the measurement period showed wave heights at the shore to be less than 1 foot and the wave period to be about 6 seconds. The deepwater significant wave height and period as measured by the Makapu'u wave buoy (see the report section on wave climate data) was about 2 feet and 7 seconds during this period. Dye along the shore moved east at speeds of 2 to 6 feet per minute. The sand trapped by the groin had a median grain size of 0.65 mm and was well sorted. Because of the large seasonal differences in wave energy entering the harbor during the summer and winter, this transport rate measured during summer conditions is probably a lower bound. The rate may be much higher during winter north swell periods when there is considerably more energy reaching the shoreline.

Hilo Breakwater

The Hilo breakwater was constructed in increments, beginning in 1908 and completed in 1929. A detailed documentation of the construction is presented by Kelly et al.(1981). The existing length of the breakwater is 10,070 feet, and it is constructed on Blonde Reef in water depths of about 10 to 20 feet. The breakwater is of rubblemound construction, originally with a single layer of 8-ton minimum armor stone on the crest and seaward slope to a depth of -3 feet. The armor stone was placed over a quarry run core, with minimum stone weight of 25 pounds and three-quarters of the core stone by weight greater than 1 ton. The crest elevation is +11 feet and the seaward slope is 1.5H to 1V. A typical breakwater section is shown on Figure 2-6. The breakwater has been repaired and rehabilitated over the years, and recently the landward end has been improved with tribar concrete armor units.

The breakwater has considerably reduced wave energy along the Hilo Harbor shoreline, particularly the prevailing tradewind wave energy from the northeast and east. Dye studies of wave induced water transport through the breakwater by M & E Pacific, Inc. (1980) indicated a transport of only 32 mgd during the dry season and less than 5 mgd during the wet season. The difference was attributed to changes in the hydraulic head inside the harbor as a function of freshwater inflow. Seas during the breakwater permeability tests were less than 5 feet. M & E Pacific (1980) also states that construction of the breakwater has had a detrimental effect on water quality in the harbor and has had an especially detrimental impact on Blonde Reef. They state that the elimination of breaking wave energy and transport across the reef has reduced the exchange rate within the harbor and increased sedimentation on Blonde Reef.

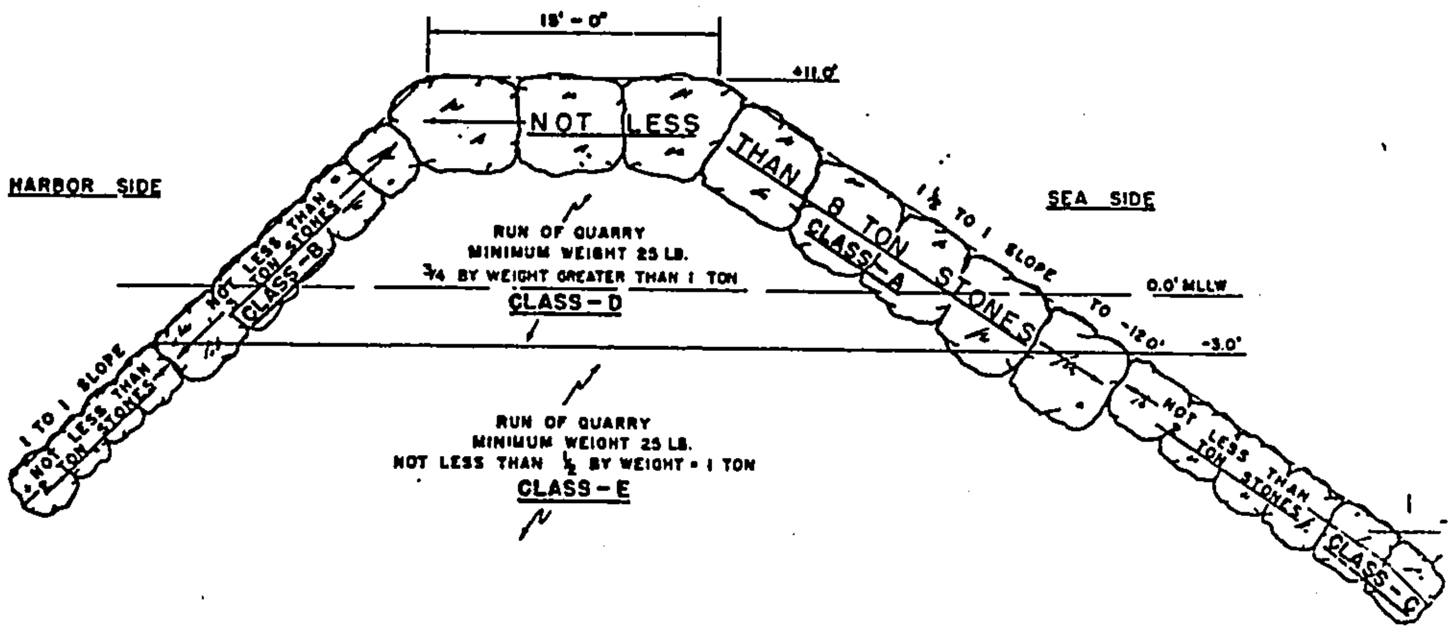


Figure 2-6. Hilo Breakwater - Typical Section

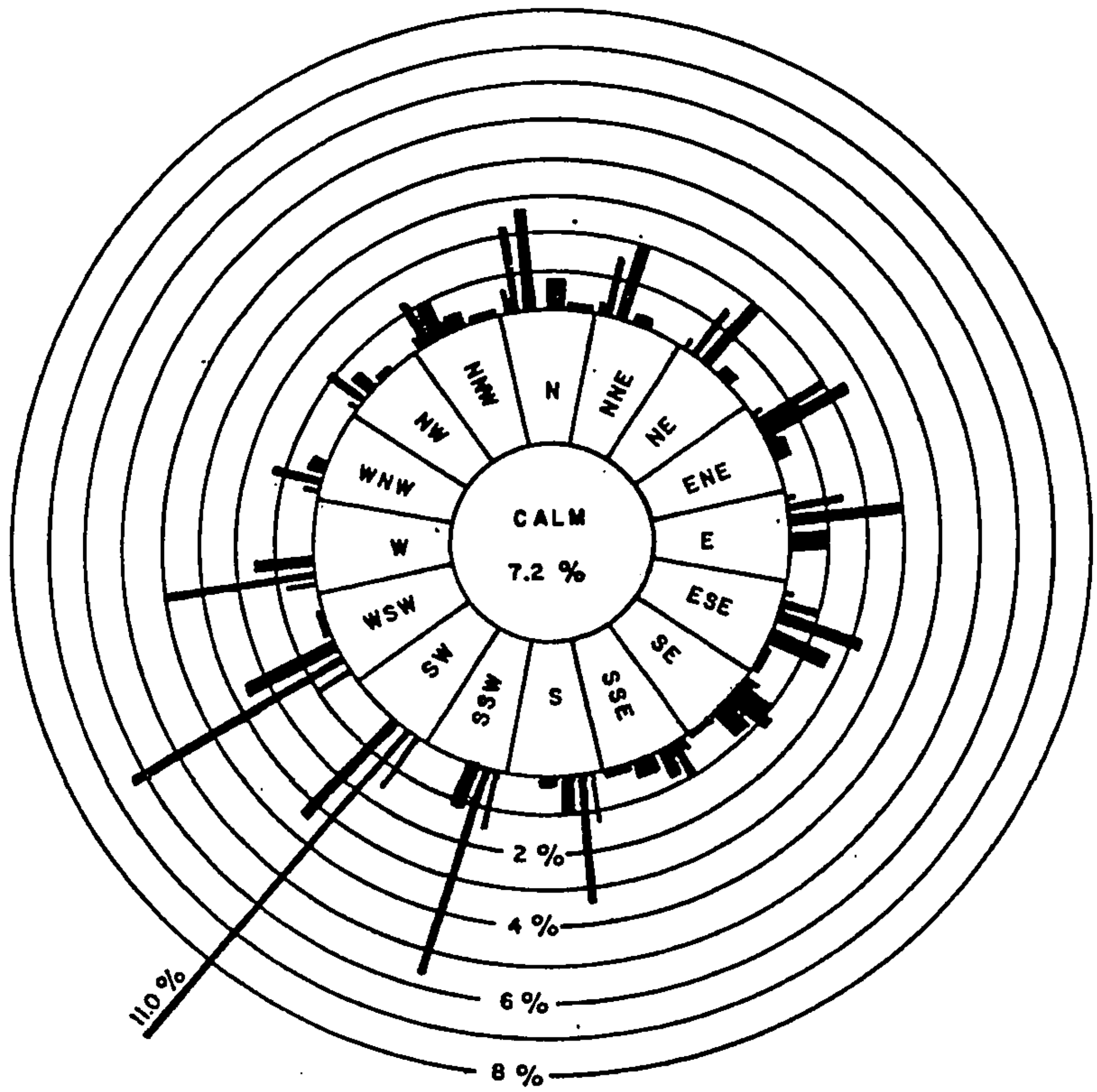
COASTAL ENGINEERING DESIGN PARAMETERS

General Wind and Wave Considerations

Wind. The climate in Hawaii is characterized by two distinct seasons, primarily defined by the annual variation in persistence of the northeast tradewinds. During the summer months of about May through September, the tradewinds predominate, blowing out of the northeast 80 to 90 percent of the time with speeds generally from 10 to 25 mph. The winter season, from about November through March, is characterized by a weakening of the tradewind persistence and the occurrence of southerly or westerly winds as a result of localized low pressure and frontal systems. The months of October and April are generally considered transitional periods between seasons.

The northeast coast of the island of Hawaii is exposed to the direct approach of the northeast tradewinds. However, in the Hilo area the tradewinds are modified by the presence of the large mountains, Mauna Loa and Mauna Kea. During typical east-northeast tradewind conditions, the wind speeds nearshore off East Hawaii are lighter than over the open ocean. This area of lower wind speed is centered around Hilo. The lower wind speeds are caused by the stagnation effect of the tradewinds hitting the high mountains directly behind Hilo. In addition, the temperature differential between land and sea results in the formation of a land/sea breeze system in the Hilo vicinity, which alternately reinforces and opposes the weakened tradewind flow. A wind rose for the years 1965-1974 based on data obtained at the Hilo Airport is shown on Figure 3-1. The average wind speed is about 8 mph (Atlas of Hawaii, 1973).

Waves. Hilo Bay is exposed to deepwater waves generated from the north-northwest clockwise to the east. Two primary wave types from these directions affect the study area, as illustrated on Figure 3-2: (1) the prevailing tradewind generated waves from the northeast; and (2) North Pacific swell. The Hilo area is protected by the island



NOTE: THE PERCENTAGES AND THE DIRECTIONS ARE AVERAGES DURING THE 10 YEAR PERIOD, 1965 TO 1974 INCLUSIVE.

LEGEND:
- 0-3 KNOTS
- 4-6 KNOTS
- 7-10 KNOTS
- 11-16 KNOTS
- OVER 16 KNOTS
- —8%— TOTAL % OF YEAR

SOURCE – HONOLULU DLNR, DOWALD

Figure 3-1.
WIND ROSE FOR
GENERAL LYMAN FIELD
HILO, HAWAII

itself from South Pacific swell and storm waves from the west.

Tradewind waves may be present throughout most of the year, but are most frequent between April and September, the summer season, when they usually dominate the local wave climate. They result from the strong and steady tradewinds blowing from the northeast quadrant over long fetches of open ocean. Typically, the deepwater tradewind waves have periods of 6 to 8 seconds and heights of 4 to 10 feet.

North Pacific swell is produced by severe winter storms in the Aleutian area of the north Pacific Ocean and by mid-latitude low pressure areas. North swell may arrive in the Hawaiian Islands throughout the year but is largest and most frequent during the winter months of October through March. North Pacific swell typically has periods of 10 to 16 seconds and heights of 5 to 15 feet. Some of the largest waves reaching the Hawaiian Islands are of this type.

In addition to the primary wave types, infrequent tropical storms and hurricanes may generate large waves which affect the study area.

For this study, the Hilo area was assumed to be affected by deepwater waves refracting and diffracting around the island from about the northwest (315^{o} TN) clockwise to about due east (90^{o} TN). All wave directions in this report are referenced to true north (^{o} TN). Wave climate seasons are divided into winter (October through March) and summer (April through September).

Prevailing Deepwater Wave Climate Data

Qualitative and quantitative information on the height, period, direction and frequency of occurrence of the prevailing wind waves in Hawaii has been developed by local and Federal government agencies and the University of Hawaii beginning in the early 1960's. The following paragraphs summarize the methodology and results of these studies. Data base locations are shown on Figure 3-2.

Marine Advisors (1964). This study characterized the "deepwater waves in the Oahu area for a typical year", based primarily on hindcasts of meteorological data. Monthly, seasonal (winter -

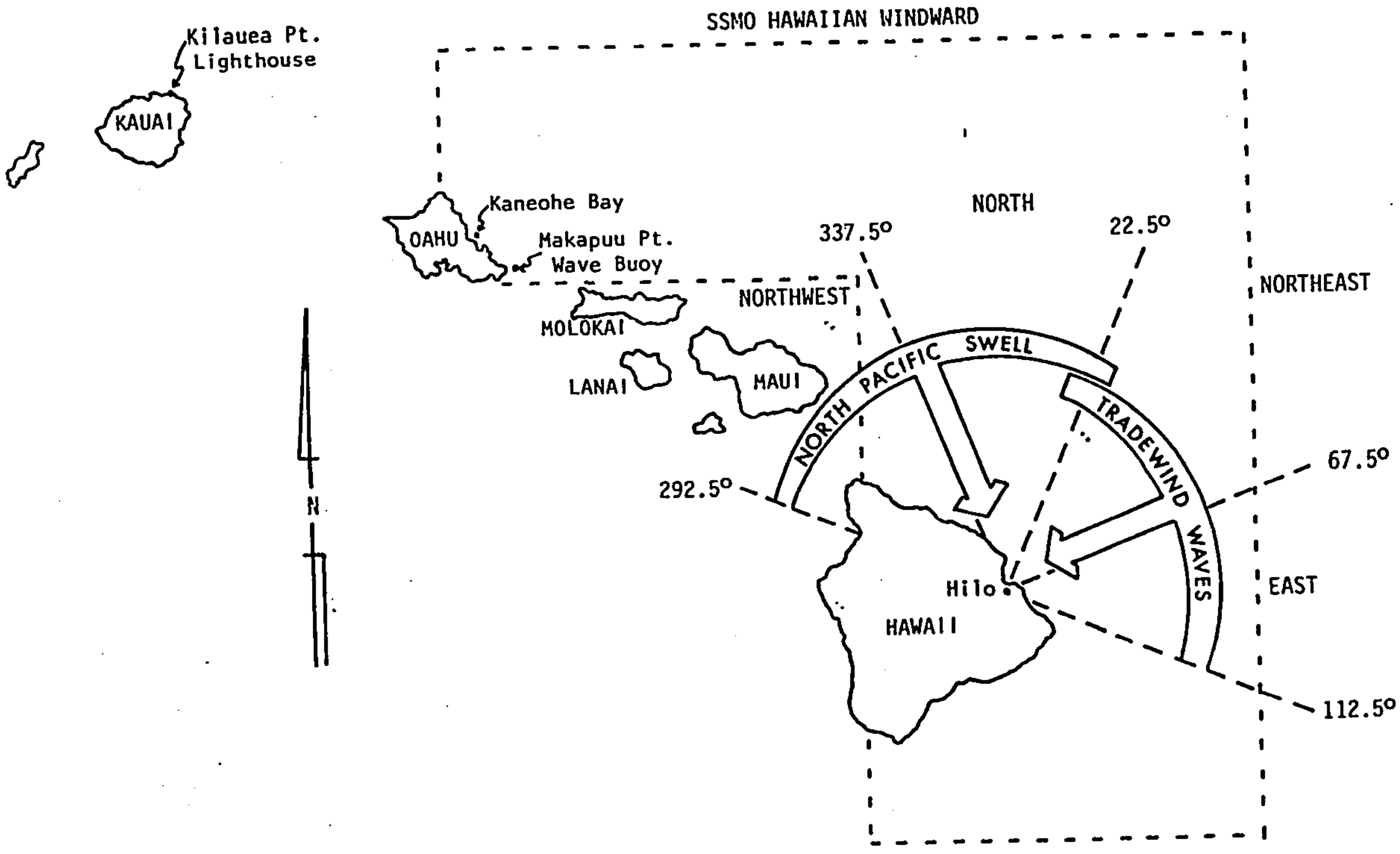


Figure 3-2. Hilo Wave Climate and Data Base Locations

December through March, and summer -April through November) and annual summaries of significant wave height and period and frequency of occurrence by direction (16 sectors of 22.5^{o}) are presented.

The "typical" year used for analysis was actually a composite consisting of data for January-March 1951, April-June 1963, July-November 1962, and December 1952 in order to be able to satisfy the "typical in all aspects" criterion with the information that was available. Wave statistics for the summer season northern hemisphere swell were obtained by correlating wave data information from the U.S. Navy, U.S. Weather Bureau synoptic weather charts, and from both wave gauge and visual observations at Kahuku Point on Oahu. Wave statistics for the winter months of December through March were derived by wave hindcasting from the Synoptic Series of Historical Weather Maps, Northern Hemisphere, published by the U.S. Weather Bureau.

Table 3-1 presents seasonal wave climate statistics derived by averaging the Marine Advisors monthly distribution of wave frequency of occurrence. Direction classes are based on the Marine Advisors direction classifications.

Ho and Sherretz (1969). Wave height and direction observations made twice daily by U.S. Coast Guard personnel at the Makapuu Lighthouse on the eastern tip of Oahu and Kilauea Lighthouse on the north coast of Kauai have been tabulated for the seven-year period 1961 through 1967. The observations are obtained by visual estimate of prevailing conditions at a distance of 300 to 400 yards offshore and are considered representative of the open ocean. Wave heights (crest to trough) are estimated in feet, and the direction (^{o} TN) from which the waves are moving is estimated to the nearest eight-point compass point. Ho and Sherretz tabulated the data by month (e.g., January data is the average of seven Januarys) in order to study possible seasonal variations.

The mean wave height at Makapuu varied little throughout the year, and Ho and Sherretz hypothesized that the large north swell from the northwest generated by Aleutian storms is blocked by the

Table 3-1.

Seasonal Distribution of Deepwater Waves Affecting Hilo Based on Marine Advisors (1964) Data: Percent Frequency of Occurrence of Significant Height (H_s, feet) and Period (T_s, sec) and Direction (°TN)

Summer (April-Sept.)

NW (304°-348°)

H_s \ T_s	7-8.9	9-10.9	11-12.9	13-14.9	15	Total
1-1.9						
2-3.9						
4-5.9						
6-9.9						
10-13.9						
14						
Total						0

N (349°-033°)

H_s \ T_s	7-8.9	9-10.9	11-12.9	13-14.9	15	Total
1-1.9						
2-3.9	0.5					0.5
4-5.9		0.6				0.6
6-9.9		0.6				0.6
10-13.9						
14						
Total	0.5	1.2				1.7

NE (034°-078°)

H_s \ T_s	7-8.9	9-10.9	11-12.9	13-14.9	15	Total
1-1.9						
2-3.9	4.9	3.1				8.0
4-5.9	5.5	5.4				10.9
6-9.9		8.6	1.1			9.7
10-13.9						
14						
Total	10.4	17.1	1.1			28.6

E (079°-101°)

H_s \ T_s	7-8.9	9-10.9	11-12.9	13-14.9	15	Total
1-1.9						
2-3.9	6.0	7.7	0.6			14.3
4-5.9	11.0	24.1	4.3			39.4
6-9.9	0.6	2.7	0.6			3.9
10-13.9						
14						
Total	17.6	34.5	5.5			57.6

Table 3-1.
(Continued)

Winter (Oct.-March)

	H_s \ T_s	7-8.9	9-10.9	11-12.9	13-14.9	15	Total
NW (304^o-348^o)	1-1.9	0.8	3.8	3.8	0.3		8.7
	2-3.9		1.4	7.2	7.1	1.1	16.8
	4-5.9			1.4	5.5	4.1	11.0
	6-9.9		0.5	1.4	3.0	13.3	18.2
	10-13.9					3.0	3.0
	14					1.6	1.6
	Total	0.8	5.7	13.8	15.9	23.1	59.3
N (349^o-033^o)	1-1.9	0.6	2.5	2.0			5.1
	2-3.9	0.3	1.1	4.1	0.8	1.6	7.9
	4-5.9			0.3	1.1	1.7	3.1
	6-9.9	0.3	0.3	0.5	1.3	2.2	4.6
	10-13.9					0.3	0.3
	14						0
	Total	1.2	3.9	6.9	3.2	5.8	21.0
NE (034^o-078^o)	1-1.9	1.3	0.3				1.6
	2-3.9		1.9	2.4			4.3
	4-5.9	1.3	3.8	2.8	0.8		8.7
	6-9.9	2.1	3.3	0.3	1.6		7.3
	10-13.9		0.8	2.4			3.2
	14			0.8			0.8
	Total	4.7	10.1	8.7	2.4		25.9
E (079^o-101^o)	1-1.9	1.6	0.3				1.9
	2-3.9	4.9	6.0	3.5			14.4
	4-5.9	5.7	11.0	4.3	0.3		21.3
	6-9.9	1.1	3.0	2.5	2.7		9.3
	10-13.9		1.3	6.4	1.1		8.8
	14		0.3	2.8	2.9		6.0
	Total	13.3	21.9	19.5	7.0		61.7

island of Oahu and is not represented in the Makapuu data. The Kilauea data, on the other hand, exhibits a marked seasonal variation in wave height values, with mean values being higher in winter than in summer. The Kilauea data is likely very representative of the open ocean, relatively deepwater, wave climate from the northwest to the east.

Figure 3-3 presents the mean height and maximum height during the seven-year period and the average maximum height (arithmetic mean of each month's maximum) in feet versus the months of the year as observed at Kīlauea. The standard deviations of the mean height are also shown. The marked summer-winter seasonal wave climate differences are apparent, particularly the difference in maximum wave heights. Standard deviations are smaller in the summer, probably due to the "steady" tradewind influence. The mean monthly wave direction at Kilauea is also shown on Figure 3-3. The seasonal change in mean wave direction is apparent, the winter combination of tradewind waves and north swell producing a north-northwast mean direction and the summer tradewinds being more easterly.

SSMO (1971). Open ocean wave statistics have been compiled by the U.S. Naval Weather Service Command in the Summary of Synoptic Meteorological Observations (SSMO) - Hawaiian and Selected North Pacific Island Coastal Marine Areas. The SSMO data was obtained through direct synoptic observations by ships in passage and represents average conditions recorded during the 8-year period from 1963 to 1970. The wave data is summarized both monthly and annually and is presented two ways. Sea waves generated by local winds in the vicinity of the observer are presented as percent frequency of sea height versus surface wind speed and direction (8 compass points), and percent frequency of wave height versus wave period. For the latter presentation when both sea and swell waves are present, the higher of the two is used. If both are the same height, the longer period is recorded. Sea is defined as waves generated by winds in the vicinity of the observer, and swell as waves generated by winds distant from the local area of observation. It must be noted that ships tend to avoid bad

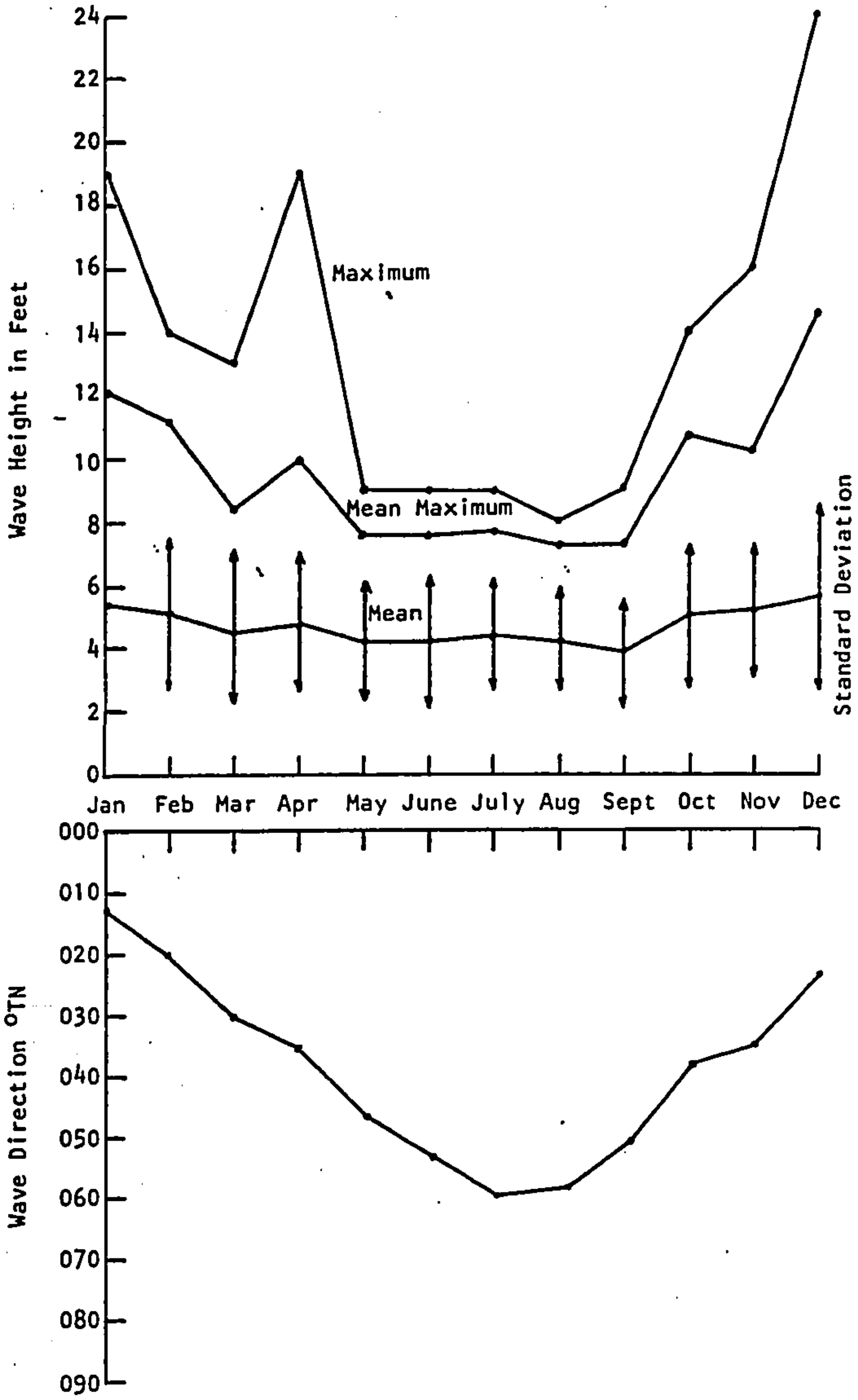


Figure 3-3. Maximum, Mean Maximum, and Mean Wave Heights and Mean Monthly Wave Direction for Kilauea Point, Kauai

weather when possible, thus biasing the SSMO data toward good weather samples (and thus lower wave heights).

The seasonal distribution of wave heights by direction based on SSMO data is shown on Table 3-2, and the annual percent frequency of wave height versus wave period is shown on Table 3-3. Inspection of this data shows that the longer period, higher wave height north swell is not well represented in the SSMO data because of the ships' avoidance of large waves and bad weather and, perhaps even more so, because the longer period swell (12 to 20 seconds) may be masked from visual observation by shorter period local wind waves superimposed on top of the swell.

Shimada (1973). This report compares the energies of north Pacific storm waves and tradewind waves seaward of Kaneohe Bay on the northeast (windward) coast of Oahu. This area is exposed to waves from the north and east and is sheltered by the island itself from waves from the south or west. Wave heights and periods were measured over a 6.5-month period (January-August 1971) using a pressure sensor wave gauge located at about the 25-foot depth. Surface weather maps, surface wind summaries, and marine forecast records from the National Weather Service and the Navy Fleet Weather Central were examined to determine the time and location of north Pacific storm and tradewind occurrences during this period. Corresponding wave height records were then selected, and wave energy spectra as a function of wave frequency were calculated. Among the weather conditions investigated were a gale 750 miles to the northwest, a low 3,100 miles to the northwest, a storm 1,250 miles to the north, and strong and weak tradewinds. Strong tradewinds are defined as periods during which the winds in the channels between islands were approximately 25 knots or greater. The results of the study showed that the average total energy of all the spectra for the strong local tradewinds was found to be greater than the average total energy of all the spectra for identifiable storms. In addition, the average total energy of all the spectra for the strong local tradewinds was twice as great as that for the weaker tradewinds. The period of peak energy for northerly storm waves was generally centered on a steep peak between 12-15 seconds or greater,

Table 3-2.

Average Seasonal Distribution of Percent Frequency of Wave Heights by Direction Based on SSMO Data.

Summer (April to September)

H, ft.	NW 292°-337°	N 338°-22°	NE 23°-67°	E 68°-112°	Total
2	0.7	2.0	4.9	11.9	19.5
2-4	0.3	2.7	7.6	24.9	35.5
4-6	0	1.5	4.8	15.7	22.0
6-9	0.1	0.6	2.3	9.1	12.1
9-12	0	0.1	0.2	5.2	5.5
12	0	0.02	0.03	0.03	0.08
Total	1.1	6.9	19.8	66.8	94.7

Winter (October-March)

H,ft.	NW 292°-337°	N 338°-22°	NE 23°-67°	E 68°-112°	Total
2	0.6	3.0	2.3	11.0	16.9
2-4	0.7	2.5	6.5	13.2	22.9
4-6	0.4	1.4	4.1	11.9	17.8
6-9	0.4	1.3	3.8	9.3	14.8
9-12	0.05	0.3	0.4	1.9	2.7
12	0.05	0.1	0.2	0.5	0.9
Total	2.2	8.6	17.3	47.8	76.0

Table 3-3.

Annual Percent Frequency of Wave Height (H, ft.) Versus Wave Period (T, sec) Based on SSMO Data.

T \ H	≤2	2-4	4-6	6-9	9-12	>12	Total
<6	9.7	17.9	9.4	4.6	0.4	0.1	42.1
6-7	1.3	6.9	10.8	8.6	1.7	0.2	29.5
8-9	0.3	1.6	3.8	6.8	1.6	0.5	14.6
10-11	0.1	0.4	0.9	2.6	1.1	0.5	5.6
12-13	0	0.1	0.3	0.8	0.5	0.1	1.8
>13	0	0	0.1	0.2	0.2	0.1	0.6
INDET	3.2	0.8	0.7	0.5	0.1	0	5.3

while tradewind wave energy was primarily contained in a relatively flat, broad peak from 5 to 10 seconds.

Coastal Data Information Program. The Coastal Data Information Program (CDIP) is a 6-year-old coastal wave data collection and analysis program conducted by Scripps Institution of Oceanography under the sponsorship of the South Pacific Division, U.S. Army Corps of Engineers,and the California Department of Boating and Waterways. This system consists of 31 wave monitoring stations, primarily located on the west coast, connected to a central data acquisition and analysis station at Scripps Institution. The system provides near real time data processing. In August 1981 Hawaii was added to this program with the installation of a Datawell Waverider wave buoy five miles east of Makapuu Point, Oahu, in 600 feet of water. The buoy transmits wave data to shore, where it is directly linked by telephone line to the computer at Scripps Institution. The buoy is "called" by the computer at 6-hour intervals for approximately 30 minutes of data collection. Monthly data summary reports are published which present daily summaries of significant wave height, total energy, and percent energy by frequency in 2-second bandwidths from 4 to 22 seconds. Monthly summary reports for the Makapuu buoy were available for August 17, 1981 through May 31, 1982. Annual reports are also prepared which present cumulative wave height and period probabilities, height and period frequency of occurrence and seasonal probability of exceedence, and the joint distribution of height versus period. Unfortunately, the 1981 annual report only includes the Makapuu Point data for 4.5 months (August-December 1981).

The significant wave height probability distribution for both the summer and winter season based on the CDIP data is shown on Figure 3-4. The considerable difference in the seasonal wave climates is well evidenced by this data. During the summer the wave heights are about 5 feet or less 50 percent of the time and exceed 8 to 10 feet only about 10 percent of the time. A significant increase in wave energy is evident during the winter, when wave heights are 7 to 8

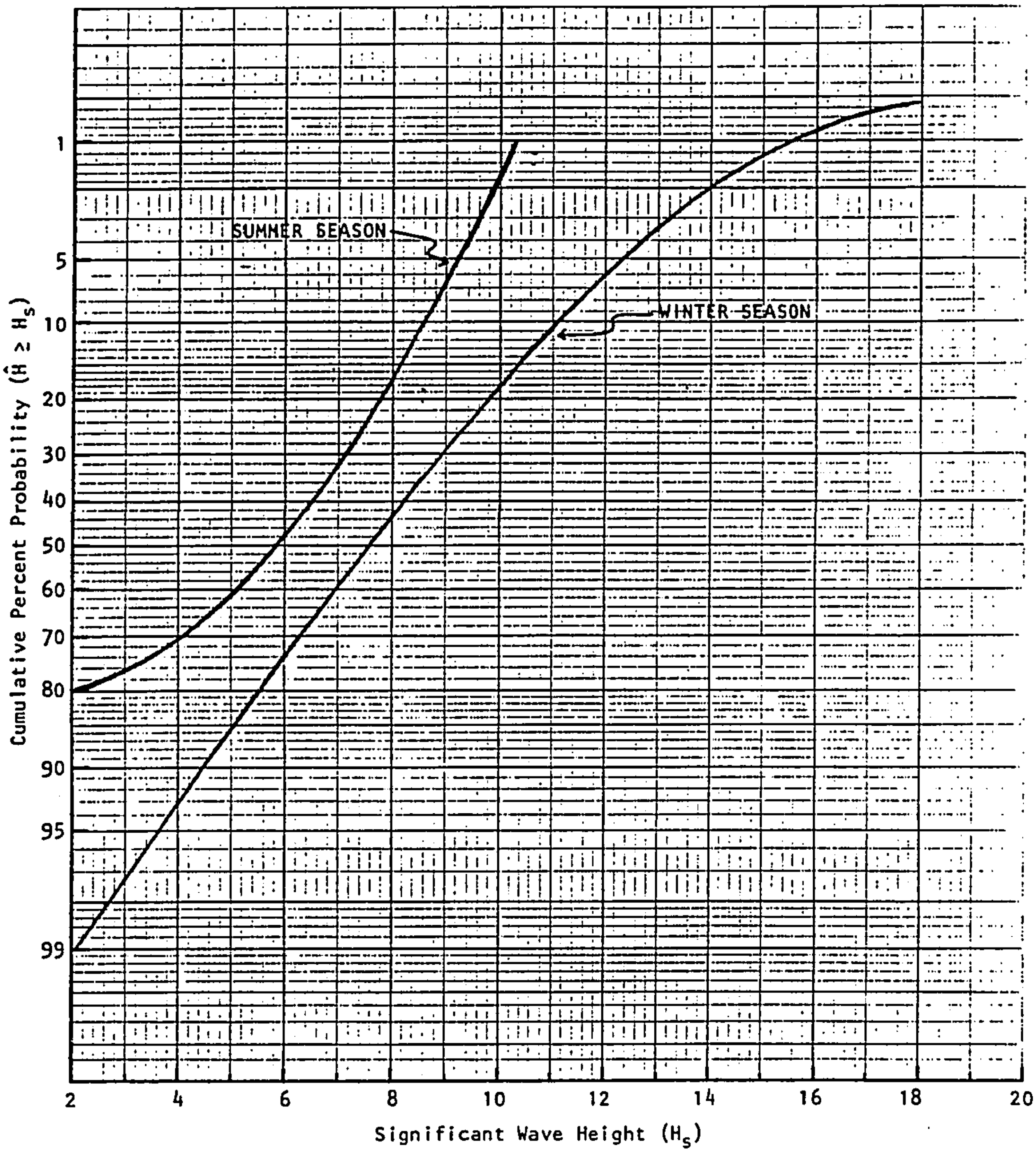


Figure 3-4. Wave Height Distributions Based on the Coastal Data Information Program

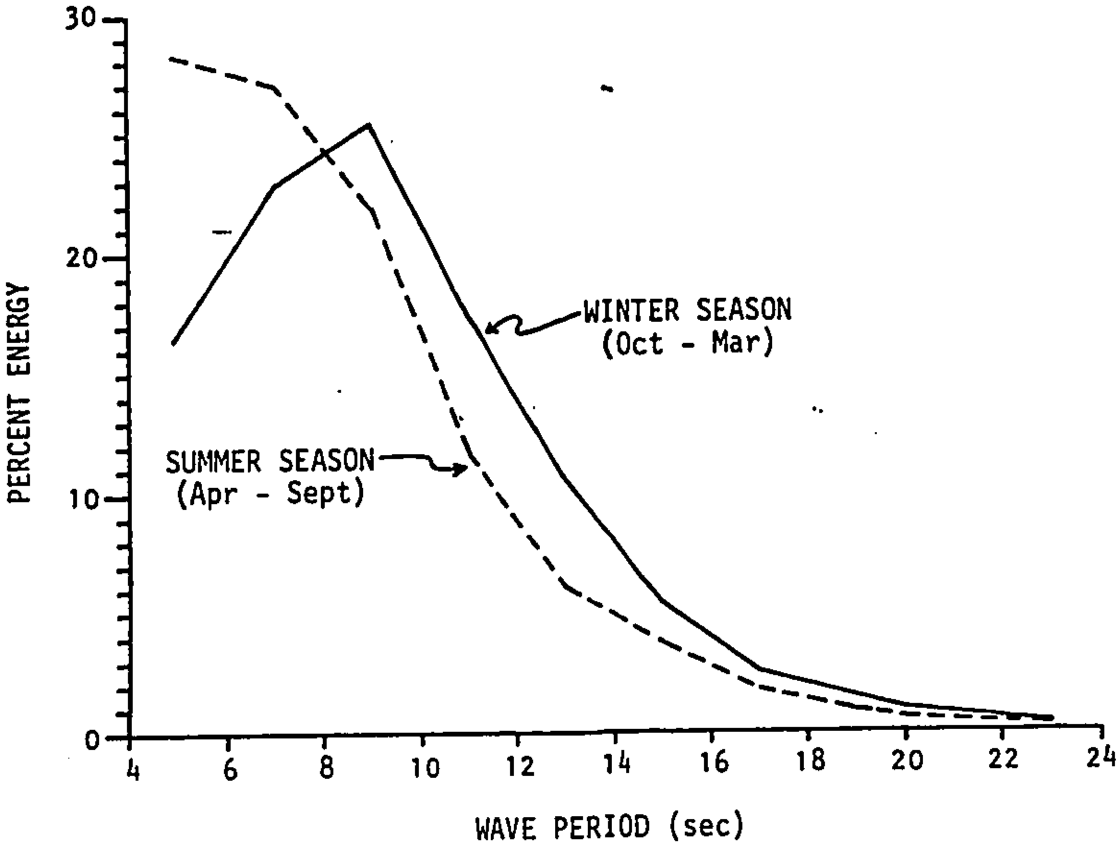


Figure 3-5. Percent Energy Distribution by Wave Period (from CDIP, 1981-82)

feet 50 percent of the time and exceed 10 feet about 20 percent of the time. Maximum deepwater heights recorded during the winter were 18 to 20 feet. The dominant wave period also changes seasonally, as shown on Figure 3-5. During the summer over 50 percent of the wave energy is contained in the 4 to 8-second wave period band, which is typical of tradewind conditions. During the winter about 40 percent of the energy is still contained in the higher frequency 4 to 8-second period band; however, 50 percent of the energy is contained in the period band from 8 to 14 seconds, indicating a mix of both local wind waves and longer period swell.

The Makapuu wave buoy is exposed to south swell and local wind waves from the southeast to the southwest, and thus the data is not entirely representative of the wave climate at Hilo, particularly during the summer season. However, the island of Oahu does block the direct approach of waves from the west and northwest, which is more common during the winter and from which Hilo is also shielded, thus the data is probably very typical of the winter deepwater wave climate in the Hilo area.

Deepwater Storm Waves

Available data for deepwater storm waves approaching Hawaii from the north Pacific was statistically analyzed to determine the frequency of storm wave height as a function of return period. The return period is the average interval between occurrences of a given event. The technique used for wave prediction is to calculate an equation of best fit for the available data, and then assume that extrapolation beyond the range of that data is valid. Gumbel's (1958) first asymptotic distribution has been shown to provide the best fit for extreme wind and wave prediction and was used for this analysis. Data sources for historical information on severe north Pacific storms included:

1. Hindcasts by Marine Advisors, Inc. (1963) for deepwater water conditions produced by the ten worst storms of the 15-year period from 1947 to 1961;

2. Hindcasts of deepwater wave heights and periods at different locations in the Hawaiian Islands by the U.S. Army Engineer District, Honolulu (1967), for 17 major storms occurring near the islands between 1947 and 1965;

3. Hindcasts of storm waves occurring in November-December 1969, November 1970, and January 1974.

When these sources provided slightly differing information for the same storms, the wave height and period most applicable to the study area were used. The predicted deepwater significant wave height versus the estimated return period for storm waves affecting the study area is shown in Table 3-4. The storm waves are estimated to have a duration of one to three days.

Table 3-4
Deepwater Significant Storm Wave Height Versus Return Period

Return Period (Years)	Wave Height (Feet)
1	5.0
2	11.5
5	18.0
10	22.5
15	25.0
20	26.5
30	29.0
50	32.0

Typical storm wave periods are 10 to 14 seconds.

Selected Deepwater Wave Parameters

Based on an inspection and analysis of the wave data contained in the sources discussed in the previous paragraphs, the seasonal deepwater wave climate as shown on Table 3-5 was selected as being representative for the Hilo area. The summer season is comprised entirely of tradewind generated seas. Light tradewind (winds less than about 20 mph) waves predominate 70 percent of the time, primarily from the east-northeast. During the winter the wave climate is a mix of north Pacific swell, with heights of 5 to 15 feet and periods from 10 to 16 seconds from the north-northwest and north, and tradewind waves, with heights of 5 to 8 feet and periods of 6 to 8 seconds.

For analysis of the impact of infrequent but severe local storm waves, a 10-year return period storm from the due north was selected. Deepwater wave height and period parameters for this storm are 22.5 feet and 12 seconds.

Table 3-5

Selected Deepwater Wave Climate

	% Frequency of Occurrence	Significant Deepwater Wave Height (ft.)	Significant Period (sec.)	Deepwater Direction (^{o}TN)
SUMMER (April-Sept.)	45%	5	6	90^{o}
	25%	5	6	45^{o}
	18%	8	8	90^{o}
	12%	8	8	45^{o}
WINTER (Oct.-March)	17%	10	12	315^{o}
	3%	15	16	315^{o}
	12%	10	12	0^{o}
	3%	15	16	0^{o}
	10%	5	10	0^{o}
	30%	5	6	90^{o}
	10	5	6	45^{o}
	5%	8	8	90^{o}
	5%	8	8	45^{o}
	5%	Calm		

Tide

Tide levels in Hilo Bay reported by the U.S. Department of Commerce, Coast and Geodetic Survey are as follows:

Highest Tide Observed (8/25/61)	3.8 feet
Mean Higher High Water	2.4 feet
Mean High Water	1.9 feet
Mean Tide Level	1.1 feet
Mean Low Water	0.3 feet
Mean Lower Low Water	0.0
Lowest Tide Observed	-1.6 feet

All elevations in this report are referenced to the mean lower low water (mllw) datum.

Wave Transformation from Deep to Shallow Water

General. The analysis of coastal processes and the determination of design criteria rely on being able to predict the nearshore wave conditions given the deepwater wave climate. A quantitative description of longshore sediment transport or design wave conditions for shoreline structures is based on the wave characteristics in the surf zone of a wave that has traveled over a variable bottom and around physical obstacles from deep to shallow water.

Deepwater waves approaching land are altered by refraction as they pass over changing bottom contours, shoaling as they move from deep to shallow water, diffraction as they pass physical obstacles such as natural points of land or manmade breakwaters, energy loss due to bottom friction, and ultimately by breaking. The following paragraphs discuss these phenomena as they apply to the study of waves in Hilo Harbor.

Refraction. Linear wave theory shows that wave celerity is proportional to the water depth in which it is propagating. As the water depth decreases, the wave celerity decreases, and the wavelength must decrease proportionally. As waves move at an angle over underwater contours, the part of the wave in deep water moves faster than the part in shallow water and the wave crest bends or refracts toward alignment with the bottom contours. This change in wave direction of different parts of the wave results in convergence or divergence of wave energy and has a major influence on the wave height and distribution of wave energy along a coastline.

Wave refraction is a function of wave direction and period and bathymetry. Linear wave theory relates the celerity, C, of a wave to these parameters by the formula

$$C = \sqrt{\frac{gL}{2\pi} \tanh \frac{2\pi d}{L}} \qquad (1)$$

where

- L = wave length
- g = acceleration of gravity
- T = wave period
- d = water depth

Refraction is significant when the water depth is less than one-half the wavelength, and in shallow water ($d/L < 1/25$) the velocity equation reduces to $C = \sqrt{g/d}$.

The total energy, E, in a wave crest per unit width can be approximated by

$$E = \frac{\rho g H^2 L}{8} \qquad (2)$$

where H = wave height. If orthogonals are constructed perpendicular to the advancing wave crests, they will converge or diverge due to refraction. The energy between two orthogonals a distance b apart is given by

$$E = \frac{\rho g H^2 L b}{8} \qquad (3)$$

Assuming no energy flows laterally along a wave crest (energy transmitted shoreward remains constant between orthogonals), then

$$\frac{\rho g H^2 L b_o}{8} = \frac{\rho g H^2 L b}{8} \qquad (4)$$

and thus

$$\frac{H}{H_o} = \sqrt{\frac{b_o}{b}} \qquad \text{(The subscript o denotes deepwater conditions)} \qquad (5)$$

which is the refraction coefficient, K_R. If the energy transmitted forward remains constant, then as the distance between orthogonals changes, either converging or diverging, the wave height must increase or decrease, respectively. Snell's Law of geometrical optics (Munk and Arthur, 1951, Weigel, 1964 and Ippen, 1966) can be used to solve the problem of wave refraction.

At Hilo considerable divergence of wave energy by refraction occurs for all of the incident deepwater waves, and thus only a portion of the deepwater energy actually reaches the bayfront beach shoreline.

Shoaling. As waves move from deep to shallow water, they are subject to a second transformation in addition to refraction. The wave power transmitted forward (average energy flux) is proportional to the energy of the wave and the wave speed. If the rate of shoreward energy transfer remains constant, as the wave slows down in shallower water, the wave height must increase. The ratio of the wave height in shallow water to the deepwater height is given by (Worthington and Herbich, 1970).

$$\frac{H}{H'_o} = \left[\frac{1}{1+\left(\frac{2Kd}{\sinh 2Kd}\right)\tanh Kd}\right]^{1/2} \qquad (6)$$

where H'_o is the unrefracted (equivalent) deepwater wave height and $K = 2\pi/L$. This ratio is known as the shoaling coefficient, K_s.

Diffraction. As waves propagate shoreward into Hilo Harbor, they are interrupted by the breakwater. The portion of the wave striking the breakwater will have some energy reflected and the rest dissipated by breaking and viscous turbulence. The portion of the wave passing the breakwater tip will be the source of a flow of energy laterally along the wave crest and into the lee of the breakwater. The end of the wave crest passing the breakwater tip will act as a potential source and the wave in the lee of the breakwater will spread out in approximately a circular arc with the amplitude decreasing exponentially along this arc. This phenomenon, called diffraction, is discussed in detail by Wiegel (1964), and he presents a mathematical solution taken from the theory of accoustic and light waves. Wave height reduction due to diffraction is given in terms of a diffraction coefficient, K_D, which is defined as the ratio of the wave height in the lee of the breakwater to the incident wave height.

Bottom Friction. Waves propagating toward shore are attenuated by turbulent bottom friction in shallow water. Laboratory and theoretical studies have been conducted to evaluate the effects of bottom friction on wave energy; however, little field data is available for verification. Bretschneider and Reid (1954) recommended using a constant value of 0.01 for the bottom friction coefficient. Recent studies have shown that the friction coefficient appears to be dependent on the Reynolds number and relative bottom roughness (Skovgaard et al, 1975 and Grosskopf, 1980) and is related to the orbital velocities of the waves and thus to the wave heights (Trindade, 1982). Field investigations by Grosskopf (1980) found that Bretschneider and Reid's (1954) theory for calculating the effect of bottom friction and shoaling on incoming waves, as presented in the Shore Protection Manual, provided a close correlation with observed data. Grosskopf also stated, however, that caution must be used in applying the Bretschneider and Reid theory near manmade structures or in areas of irregular bathymetry. Gerritsen (1981) found that the friction coefficient is somewhat larger, usually having a value from 0.02 to 0.04, and becoming significantly larger on coral reefs.

The effect of bottom friction on wave height (modified friction coefficient, K_f) along an orthogonal can be calculated using methodology by Skovgaard et al (1975) as follows:

$$\frac{d}{dt} K_f = - \frac{8}{3L} \frac{dC}{dd} a_{bm} f_e K_f \qquad (7)$$

in which $a_{bm} = (\tfrac{1}{2})H/(\sinh \frac{2\pi d}{L})$ and f_e is a wave energy loss factor based on a ratio between a_{bm} (maximum wave particle amplitude at the bottom) and the Nikuradse bottom roughness.

Wave Breaking. Deepwater waves with given characteristics will propagate toward shore until the water depth becomes shallow enough to initiate breaking. This depth is called the breaking depth, d_b. Munk (1949) derived a breaker height (H_b) and breaking depth relationship based on solitary wave theory, expressed as $d_b/H_b = 1.28$. Galvin (1969), among others, established that the relationship d_b/H_b is dependent on the beach slope and incident wave steepness. The SPM presents an empirical relationship between d_b/H_b, beach slope (m) and wave steepness, H_b/gT^2, as

$$\frac{d_b}{H_b} = \frac{1}{b - (aH_b/gT^2)}$$

where a and b are functions of the beach slope, m, approximated by

$$a = 43.75\ (1 - e^{-19m})$$

$$b = \frac{1.56}{(1 + e^{-19.5m})}$$

LeMehaute and Wang (1980) also developed an empirical breaking criterion to determine the point of breaking accounting for beach slope, and this equation is expressed as

$$\frac{H_b}{H_o} = 0.76m^{1/7}\left(\frac{H_o}{L_o}\right)^{-1/4} \qquad (8)$$

modifying this equation to include wave refraction and diffraction and attenuation due to bottom friction yields

$$H_b = (H_o K_R K_D K_f)^{3/4}\ (0.76m^{1/7})\ (L_o)^{1/4} \qquad (9)$$

The LeMehaute and Wang equation is based on observed data and takes into account non-linear effects such as wave height peak-up just before breaking.

Breaking waves have been classified as spilling, plunging or surging depending on the way they break (Weigel, 1964). The SPM describes spilling breakers as gradually breaking and characterized by white water at the crest; plunging breakers as curling over at the crest with a plunging forward of the mass of water at the crest; and surging breakers as building up as if to form a plunging breaker but the base of the wave surges up the beach before the crest can plunge forward. Galvin (1969) classified breaker type by an inshore parameter H_b/gmT^2, and stated that plunging usually occurs when the parameter is in the range 0.003 to 0.068. Spilling occurs when the parameter is greater than 0.068. The breaker type is important to sediment transport because breaking waves suspend the sediment, and the amount suspended is partly determined by breaker type. Data collected by Fairchild (1972) showed that plunging breakers usually produce higher suspended sediment concentrations than do spilling breakers.

Design Water Level and Wave Heights

General. The choice of a design wave height for coastal structures depends on whether the structure is subject to non-breaking, breaking, or broken waves, as well as the structure type and construction.

Factors that determine the maximum breaker height include: (1) the water depth, including water level rise due to astronomical tide, storm surge, and wave setup; (2) the bottom slope; and (3) the transformation of waves as they propagate toward shore. Galvin (1968) described the design wave height as the height of the wave that is potentially most damaging to an economically feasible structure. For a breaking wave, this is generally assumed to be the largest wave to break directly on the structure, and for non-breaking waves, to be the largest wave to reach the structure.

Water Level Rise. The stillwater level rise during extreme conditions consists of (1) the astronomical tide; (2) the rise due to a drop in atmospheric pressure; and (3) storm surge due to onshore winds.

For design purposes an astronomical tide of 2.4 feet (mean higher high water) is considered appropriate because of the frequency of occurrence of this tide level.

Based on the parameters of hurricane Fico, which passed near the island of Hawaii in 1978, the U.S. Army Corps of Engineers (1982) calculated the water level rise in Hilo Harbor due to atmospheric pressure drop and wind stress to be approximately 0.4 feet and 0.5 feet, respectively.

The design stillwater level, dswl, is thus equal to +3.3 feet mllw.

Landward of the breaker zone an additional water level rise occurs due to the mass transport of water by breaking waves, termed wave setup. Based on methodology in the SPM, the wave setup along a shoreline with a 1 on 10 slope for wave steepness (H_b/gT^2) less than about 0.01, is approximately 8 to 10 percent of the breaking wave height.

Design Wave Height. The maximum breaker height in shallow water is a function of water depth at breaking, the beach slope and wave steepness. Galvin (1969) has shown that because a wave travels rapidly shoreward as it breaks, the water depth that initiates breaking directly against a structure is actually some distance seaward of the structure and not necessarily the depth at the structure toe. Based on methodology contained in the SPM and Galvin (1969), the maximum design breaker height plunging on a structure may be obtained from

$$H_b = \frac{d_s}{\beta - m\tau_p}$$

where d_s is the depth at the structure toe; β is the ratio of breaking depth to breaker height (d_b/H_b); m is the bottom slope; and τ_p is the dimensionless plunge distance 4.0-9.25m. The magnitude of β cannot be directly evaluated until H_b is known and, therefore, graphical solutions are presented in SPM Figure 7-4 in order to solve for maximum design breaker height.

The depth limited maximum breaker height must be compared with the theoretical wave heights in the harbor and nearshore area based on the transformation of deepwater waves to shallow water. Wave heights in any given location within the harbor may be limited by refraction and diffraction, and the maximum possible breaker height for a given water depth may not be obtainable even during extreme wind and wave conditions. In this case a non-breaking wave condition exists, and the design height is selected from a statistical height distribution.

Littoral Transport

General. Littoral transport is the movement of sediment in the near-shore zone by waves and currents. The zone of active transport generally extends from the shoreline to just seaward of the surf zone. In order to plan and evaluate improvements to the bayfront beach, it is necessary to know what the sediment transport conditions are, what the zone of active transport is, what the net direction and volume rates of transport are, and what the expected beach shapes might be. Once these factors are known the feasibility and effects of beach improvements and shoreline structures for erosion control and shore protection can be evaluated.

Littoral transport includes both onshore-offshore transport perpendicular to the shoreline and longshore transport parallel to the shoreline. Both longshore and onshore-offshore transport are significant in the surf zone. The transport also occurs either as bedload movement induced by the shear of water motion over the sediment or suspended-load transport by currents after the sediment has been stirred up by turbulence as in wave breaking. Previous field investigation along the Hilo bayfront (Sea Engineering, 1981) has shown little transport seaward of the surf zone, and the predominant form of transport appears to be longshore transport shoreward of the breaker zone. The field investigations to date, however, have been conducted during moderate, primarily tradewind sea conditions resulting in low wave heights along the bayfront shoreline. During periods of large north swell and increased wave heights along the shore, there will likely be greater bedload transport and onshore-offshore movement.

Longshore Transport Prediction. Numerous field investigations and laboratory studies have been conducted in order to establish methods for computing the longshore transport rate. For this report the methodology presented in the SPM, along with additional explanatory discussion by Vitale (1980) and Galvin and Schweppe (1980), are used. The SPM states that the best way to predict longshore transport is to adopt the known rate from a nearby site or compute it from historical changes in the shoreline. Unfortunately, however, because the existing shoreline and the shoreline history is a direct result of man's, and not nature's, actions, the use of engineering judgement in the application of local data or historical data is not possible.

Under most conditions longshore transport takes place in the surf zone and is caused by waves striking the shoreline at an angle. Wave motion and breaking suspends the sediment, which is then carried alongshore by the skewed uprush and downrush of the waves and the longshore current generated by the waves' oblique approach to the shore. The accepted theoretical approach to longshore transport prediction is to use measured or calculated wave conditions to compute a longshore component of wave energy flux which is then related through empirical data to a longshore transport rate. The following paragraphs summarize the derivation of the energy flux method, as developed from small-amplitude linear wave theory.

Energy density at breaking per unit length of wave crest is given by linear theory as

$$\bar{E} = (\rho g H_b^2)/8 \doteq 8\ H_b^2$$

Energy flux per unit length of wave crest is then

$$\bar{P} = \bar{E}\ C_g$$

C_g = C at breaking, and breaking speed given by solitary wave theory is approximately

$$C = \sqrt{2gH_b} = 8.02\sqrt{H_b}$$

Therefore,

$$\bar{P} = 64.2\ H_b^{5/2}$$

If waves approach the shoreline at an angle α, $\bar{P}$ in the direction of wave advance per unit length of beach is given by

$$\bar{P}\cos\alpha_b = 64.2\ H_b^{5/2}\cos\alpha_b$$

The longshore component of energy flux in the surf zone is then

$$P_{\ell s} = \bar{P}\cos\alpha_b\sin\alpha_b = 64.2\ H_b^{5/2}\cos\alpha_b\sin\alpha_b$$

and since $\cos\alpha_b\sin\alpha_b = 1/2\sin 2\alpha_b$

$$P_{\ell s} = 32.1\ H_b^{5/2}\sin 2\alpha_b \text{ ft-lbs/sec/ft. of beach} \qquad (11)$$

The longshore transport rate, Q, is the volumetric rate of movement of sand parallel to the shoreline, expressed in terms of sand volume per unit time. Longshore transport to the right of an observer onshore looking seaward is Q_{rt}, and transport to the left is $Q_{\ell t}$. The gross longshore transport rate is

$$Q_g = Q_{rt} + Q_{\ell t}$$

and the net rate is

$$Q_{net} = Q_{rt} - Q_{\ell t}$$

Note that a negative Q_n means net transport to the left.

The SPM presents an empirical relationship between Q and $P_{\ell s}$ which is largely based on field observations by Komar and Inman (1970) at two west coast beaches, in which they measured transport rates using dyed sand tracers and related them to the direction and flux of wave energy in the surf zone. The SPM states that the relation between Q and $P_{\ell s}$ can be approximated by

$$Q = (7.5 \times 10^3)\ P_{\ell s} \tag{13}$$

The SPM design curve is shown on Figure 3-6. Studies on a South Carolina beach by Knoth and Nummedal (1977) appear to support this factor. The SPM cautions, however, that judgement is required in applying this equation. There is considerable scatter in the data relating energy flux to transport rate and, in addition, some incomplete measurements suggest transport rates an order of magnitude above and below the SPM design curve.

There is also some question as to the applicability of a coefficient derived for west and east coast beaches to beach conditions in Hawaii. The studies from which the SPM coefficient was derived were conducted on relatively long, wide, and flat sloped beaches with wide surf zones. On the other hand, beaches in Hawaii are generally short and often in embayments such as at Hilo, and they are relatively narrow with steep foreshores and narrow surf zones.

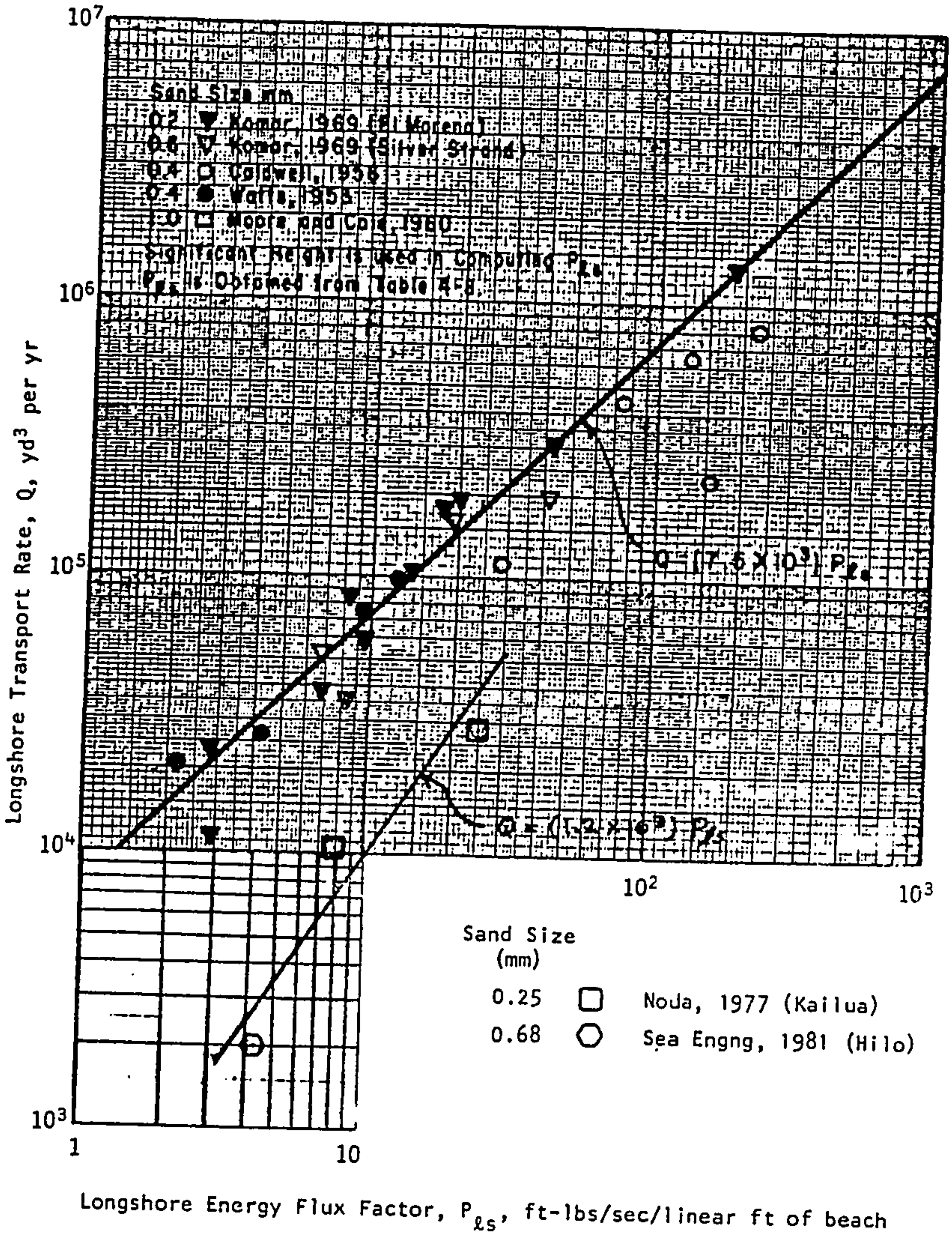


Figure 3-6. Longshore Transport Rate Versus Energy Flux

Using data from Noda (1977) and Sea Engineering (1981), a relationship between Q and $P_{\ell s}$ can be developed which may be more applicable to Hawaii beach conditions. Noda (1977) used dyed sand tracers to measure sediment transport in the surf zone at three locations along Kailua Beach, Oahu. Wave height and direction were recorded by visual observation. One of the measurement sites was located at the extreme downdrift end of a littoral cell, and the data is not considered representative of unimpeded transport and, hence, was not used in this analysis. Sea Engineering (1981) measured the longshore transport rate along the Hilo bayfront beach by measuring the volume of sand trapped by a temporary groin. Wave height and direction was again recorded by visual observation. This data is also plotted on Figure 3-6, and the relation between Q and $P_{\ell s}$ is approximated by

$$Q = 1.2 \times 10^3 P_{\ell s}$$

which is considerably lower than that presented in the SPM. The data is reasonable, however, and does exhibit a high positive linear correlation.

The calculation of the energy flux factor is very sensitive to the wave height. Most ocean wave conditions are characterized by a variety of heights with a distribution which can be described by a Rayleigh distribution. The average energy density of a group of waves is not determined by the average height but rather from the root-mean-square (rms) height. Thus, the rms wave height is the correct height to use in evaluating $\bar{E}$ and P_ℓ. However, the general practice in coastal engineering is to use the significant wave height, which is the average of the highest one-third of the waves. The ratio of the significant wave height, H_s, to the rms height, H_{rms}, is $H_s/H_{rms} = 1.416 \approx \sqrt{2}$. Thus, if H_s is used to compute P_ℓ, the result will be much higher than what it should be using the rms wave height. In order to use H_s in the calculations, the empirical coefficient relating Q and $P_{\ell s}$ derived from the field data has been "calibrated" for use with H_s in the SPM design curve (Galvin and Schweppe, 1980) and the design curve derived in this study.

Tsunami Characteristics

General. Hilo Bay is directly exposed to two major tsunami wave generating areas, the Kuril-Kamchatka-Aleutian region of the north Pacific and the west coast of South America. Tsunamis, or seismic sea waves, are principally generated by undersea earthquakes of magnitudes greater than 6.5 on the Richter scale. They have very long periods (five minutes to an hour or more) and low wave heights in the open ocean (generally less than a foot).

When tsunami waves approach the Hawaii coastline they are affected by wave refraction and diffraction, shoaling, and resonance phenomena which can greatly increase their wave height. The bathymetry in the vicinity of Hilo Bay and the irregular coastline has a funneling effect that tends to focus and trap tsunami waves, thus increasing their destructive potential. Tsunami waves do not approach perpendicular to the shoreline, and different parts of the wave crest arrive at the shoreline at different times. Where a coastline is irregular, parts of a wave crest reflected from one section of coastline may be refracted and trapped so that they coincide with an incident wave on another section of coastline. Palmer et al (1965) illustrated wave trapping at Hilo for the 1960 tsunami, as shown in Figure 3-7. The reflected waves were turned by refraction so that they arrived simultaneously at a point inside Hilo Harbor.

Hilo has been struck by several very severe tsunamis in recent years. On April 1, 1946 an earthquake in the East Aleutian Islands generated a tsunami which killed 173 people in Hawaii and caused $26 million in property damage in Hilo alone. "The tsunami which struck the shores of the Hawaiian Islands on the morning of April 1, 1946, was the most destructive, and one of the most violent in all the history of the islands ... At most places ... the waves of the tsunami swept toward shore with steep fronts and great turbulence ... Locally, the wave closely resembled a tidal bore, the steep front rolling in over comparatively quiet water in front of it. Behind the steep front, the wave crest was broad and nearly flat, with smaller storm waves superimposed upon it. ... Between crests, the water withdrew from shore, exposing reefs, coastal mud flats, and

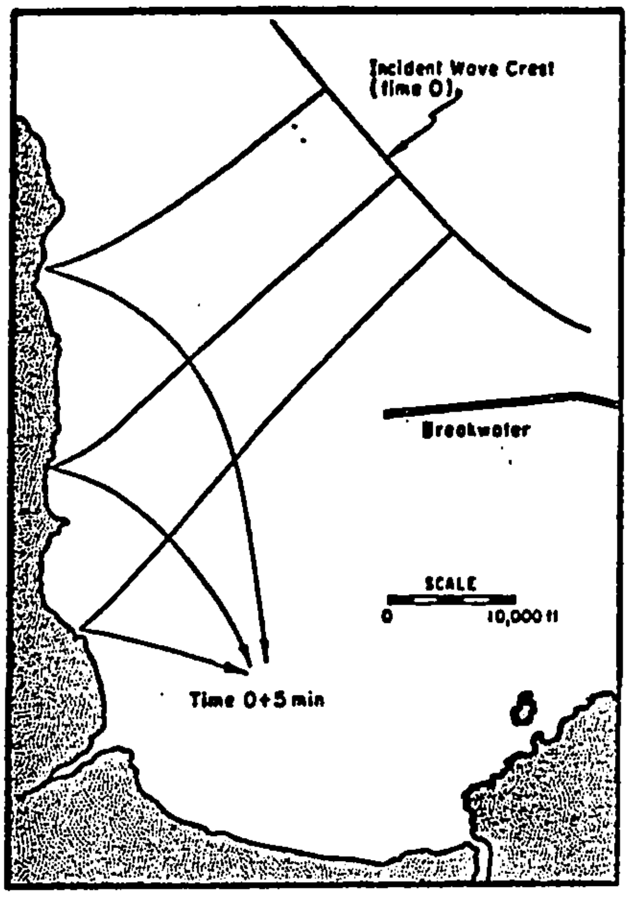


Figure 3-7. Tsunami Reflection and Refraction.

harbor bottoms for distances up to 500 feet or more from the normal strand line (Macdonald et al, 1947."

On May 23, 1960, a tsunami generated by an earthquake along the coast of Chile struck the Hawaiian Islands. Wave heights on the island of Hawaii were generally low, ranging between 3 and 17 feet, and averaging 9 feet. At Hilo, however, the third wave, which developed into a bore as it entered the bay, rose 35 feet above sea level. This wave went on to level the Hilo water front, killing 61 people and destroying 537 buildings.

Historical Tsunami Runup Heights, Frequency of Occurrence, and Wave Characteristics. Loomis (1976) has collected the available runup data for major tsunamis occurring in Hawaii beginning with the 1946 tsunami and recorded it on shoreline maps. Runup heights in the vicinity of the bayfront beach from the tsunamis of 1946, 1952, 1957, and 1960 were 17, 9, 14 and 35 feet, respectively.

Loomis (1976) states that some confusion exists as to what the reported heights represent. "What is desired is the height of the highest wave at the shoreline measured above sea level at the time of the tsunami; more often what is measured is the height of the maximum intrusion of the water onto the land. This height could be lower than the wave height at the shoreline if the water floods far inland, or higher if the slope of the beach is steep." There is also some confusion as to the reference datum for the height measurements. The 1946, 1952, 1957, and 1960 data are presumably referenced to mean lower low water.

Loomis (1976) also discusses the difficulty in predicting the future occurrence of tsunamis based on the sparse and often questionable available data. Based on an historical-statistical evaluation, he discussed the probability of occurrence of a 20-foot tsunami in Hilo. "It is not known absolutely how many times this has occurred in the past, but in the time span 1819 to 1976, 20-foot runup heights somewhere in the Hilo area resulted from the following earthquakes: Chile, 1837, 1877, 1960; Kamchatka, 1923; and Aleutians, 1946. This makes five events in 157 years for an estimated average return time of 31 years. This means that the chances are 0.05 of having another such tsunami in 1.6 years, 0.5 of having one in 21.5 years, or 0.95 of having one in 93 years. If these data are extrapolated to predict a 30-foot tsunami, an average return time of 164 years is obtained. Actually, just one such tsunami has occurred in 157 years, namely in 1960." Loomis also states that this illustrative example for Hilo should be used with caution, and when there are safety and/or economic reasons for making the best possible predictions of tsunami wave heights it is necessary to go beyond the historical-statistical evaluation and "employ techniques which utilize oun physical knowledge of the hydrodynamics of tsunamis."

The U.S. Army Corps of Engineers has established tsunami wave elevation near the shoreline versus frequency of occurrence curves as part of their tsunami flood hazard evaluations for floodplain management and flood insurance rate calculations. Houston et al (1977) discusses the variability of tsunamis, both in frequency of occurrence and place of origin. "... the two largest and four of the ten largest tsunamis striking Hilo from 1837 through 1976 occurred during the 15-year period from 1946 through 1960. Two of the tsunamis from 1946 through 1960 originated in the Aleutian Islands, one in Kamchatka, and one in Chile, However, six of the ten largest tsunamis occurred during the 109-year period from 1837 through 1945 with three originating in Chile, two in Kamchatka, and one in Hawaii." They state that frequency of occurrence calculations should consider the long term historical data, and not just the unrepresentative years from 1946 through 1960, in spite of the fact that early tsunami data likely includes observational inaccuracies.

Housten et al (1977) calculated the 1-in-100 year tsunami elevation for Hilo as 27.3 feet, based on a least-squares fit of the available tsunami runup data using a logarithmic frequency distribution and data for the ten largest tsunamis in Hilo from 1837 through 1976. The 1-in-10 year tsunami elevation was calculated to be 4 to 6 feet, depending on location in the bay.

NUMERICAL COASTAL PROCESSES MODEL

Derivation

General. The scale and scope of this study, the number of conditions to be tested, and the desire to measure the effects of changes in the physical characteristics of the study area make the use of digital computing techniques and numerical modeling well suited to assist in the analysis. Coupled with sound coastal engineering judgement and experience and thorough understanding of the actual physical characteristics of the study area, the use of a computer permits the investigation of a large number of complex phenomena in a relatively short time. The model developed for this study starts with computer techniques for the analysis of wave refraction and diffraction developed by the Coastal and Ocean Engineering Division of Texas A & M University, and expands the program to include wave attenuation, wave breaking, and longshore transport. The following paragraphs summarize the derivation of the computer program, for detailed derivations and explanations refer to the references cited. A computer program flow chart is shown on Figure 4-1. A Hewlett-Packard Model 9845B mini-computer was used for all the analysis.

Area Modeled. The first step in the numerical model is to represent the bathymetry in the study area by depth values in a rectilinear grid system. The transformation of the selected waves from Table 3-5 from deepwater to the shoreline in Hilo Harbor required the modeling of three coastal areas. In order to include the deepwater north swell from the northwest, a bathymetry grid was developed for the northeast coast of the island from the shoreline to the 100 fathom line. The swell from the northwest was then refracted around Pepeekeo Point so that portion of the energy reaching Hilo Bay could be included. The available bathymetric chart for this area (USC & GS Chart 19320) is relatively large scale (1:250,000), with very little detailed depth information, and it was necessary to estimate bottom contours at

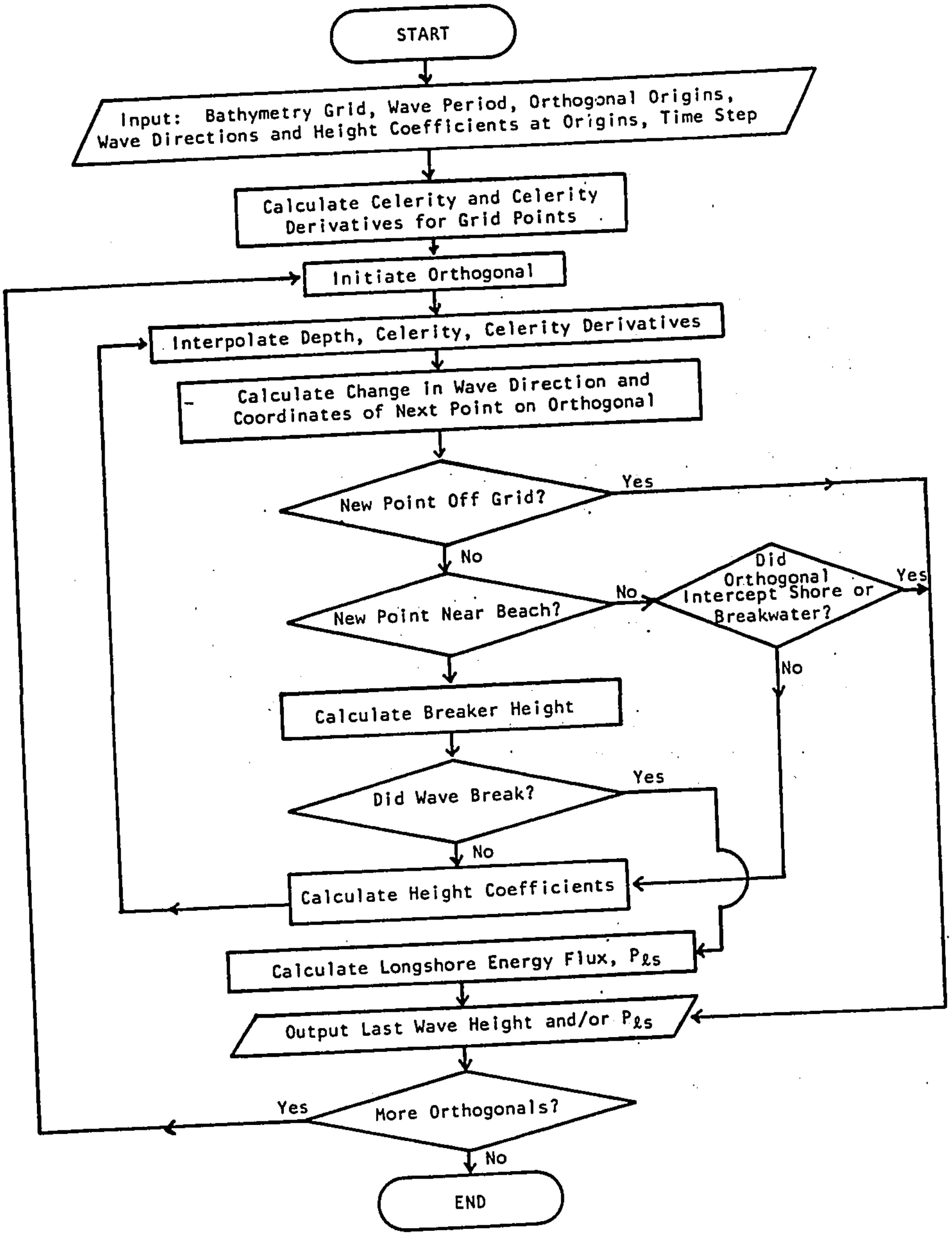


Figure 4-1. Numerical Model Program Flow Chart

10 fathom intervals from the limited data presented. Grid spacing (prototype) was 1,560 feet.

The bathymetry in Hilo Bay seaward of the breakwater was modeled based on a detailed bathymetric chart of the bay developed by the USACOE, POD. The chart scale was 1:12,000 and contour intervals were 15 feet. Grid spacing (prototype) was 800 feet.

The third area modeled was Hilo Harbor, including Blonde Reef and the breakwater. Detailed bathymetric information was obtained from NOAA/NOS chart number 19324 (scale 1:10,000). The grid spacing for the model area was 333 feet in the prototype.

Deep to Shallow Water Wave Transformation. The computer program used for this study is an adaptation of of the REDSEA program developed by Orr and Herbich (1969), Worthington and Herbich (1970), and Herbich (1977) at Texas A&M University. Errors in these programs noted by Whalin (1971) and Skovgaard et al. (1975) have been corrected. The required input data to the program are the bathymetry represented as depth values in a rectilinear grid system and the period and direction of the incident deepwater wave. A brief description of the workings of the program follows; see the references cited for detailed derivations of the equations used.

Given the wave period, celerity values are calculated for each grid point using the formula derived from linear wave theory:

$$C^2 = \frac{gT}{2\pi} \tanh\left(\frac{2\pi d}{L} \right)$$

where C = wave celerity
g = acceleration due to gravity
T = wave period
d = water depth
L = wave length

This is done by iterating the equivalent equation

$$C_{i+i} = \frac{gT}{2\pi} \tanh\left(\frac{2\pi d}{C_i T} \right)$$

using deepwater celerity, C = 5.12T, as a first approximation, and

$$|C_{i+i} - C_i| < .001\ C_i$$

as a convergence criterion. Partial derivatives of C with respect to the x and y directions are calculated for each grid point using finite difference expressions. The depth, celerity, and celerity derivatives at an orthogonal point not lying on a grid intersection are determined by linear interpolation between the four nearest grid points.

Wave orthogonals are traced one at a time, being initiated at positions specified in the input, with similarly specified values for the original direction, original height coefficients, and time interval between orthogonal points. The governing equations for tracing the orthogonals are:

$$dx/dt = C \cos A$$
$$dy/dt = C \sin A$$
$$dA/dt = (\partial C/\partial x) \sin A - (\partial C/\partial y) \cos A$$

where x and y are the cartesian coordinates of points on the orthogonal, C is the wave celerity and A is the angle the orthogonal makes with the x axis.

The dependence of the change in wave direction on the velocity gradient and the wave direction is derived through applying Fermat's principle of wave propogation. This derivation can be found in Munk and Arthur (1951) or Orr and Herbich (1969).

The program solves the above system using a two-step Runge Kutta method and calculates the x and y coordinates of successive points along the orthogonal separated by the specified time interval.

Orthogonals are terminated in any one of the following cases:

(a) when they reach the end of the bathymetry grid;
(b) when they intercept the shore or breakwater;
(c) if, in the deepwater run, they intersect a predetermined stopping line outside the Hilo breakwater;
(d) if, in the Hilo Harbor grid, they satisfy breaking criteria on Hilo Bayfront Beach.

Each newly calculated point is tested for termination criteria, and if the orthogonal is not terminated, wave height coefficients are then calculated for the new point.

The height coefficients calculated by the program are the coefficients of refraction, K_R; friction, K_F; shoaling, K_S; and diffraction, K_D. Linear wave theory predicts a wave height, H, such that

$$H = K_R K_F K_S K_D H_o$$

where H_o is the deepwater wave height. Presented here are the equations used to calculate these coefficients and the publications that may be referred to for their respective derivations.

a) $K_R = 1/\sqrt{\beta}$

where β is the orthogonal separation factor and is calculated by solving the differential equation:

$$\frac{d^2\beta}{dt^2} + p\frac{d\beta}{dt} + q\beta = 0$$

where $p = -2(\partial C/\partial x \cos A + \partial C/\partial y \sin A)$

and $q = C(\partial^2 C/\partial x^2 \sin^2 A - \partial^2 C/\partial x \partial y\, 2\sin A \cos A + \partial^2 C/\partial x^2 \cos^2 A)$

To start the calculations, $\beta = 1$ for the first two points in deepwater where the wave is unaffected by refraction (see Orr and Herbich, 1969; Skovgaard, Jonsson and Bertelson, 1975).

b) K_F is calculated by solving the equation

$$\frac{dK_F}{dt} = -\frac{1}{T}\left(\frac{4\pi}{3}\right)\frac{H_{ST}}{L_o}\sqrt{n_{ST}}\,C_{ST}\,\frac{f_e}{n\sqrt{nc}\,\sinh\,(2\,d/L)}\,\frac{K_F}{\sqrt{\beta}}$$

where T = wave period

L_o = deepwater wavelength = $5.12\ T^2$

$$n = \frac{8\ d/L}{1 + \sinh(4\pi d/L)}$$

d = depth

L = wavelength

C = celerity

β = orthogonal separation factor

f_e = wave energy loss factor (bottom friction coefficient)

Subscript ST refers to corresponding values at wave starting position.

The initial value used to start the calculations is $K_F = 1$ in deepwater (see Herbich, ; Skovgaard, Jonsson and Bertelsen, 1975).

c) $$K_S = \frac{\cosh(2\pi d/L)}{\sqrt{\frac{\sinh(4\pi d/L)}{1} + \frac{2\pi d}{L}}}$$

(See Orr and Herbich, 1969, SPM.)

d) $$K_D = |f(\sigma)\ e^{-i\, kr \cos(\theta-\theta_0)} + f(\sigma')\ e^{-i\, kr \cos(\theta+\theta_0)}|$$

where $$f(\sigma) = \frac{1+i}{2} \int_{-\infty}^{\sigma} e^{-\ iu^2/2}\ du$$

$$\sigma = 2 \sqrt{\frac{kr}{\pi}}\ \sin 1/2\ (\theta - \theta_0)$$

$$\sigma' = -2 \sqrt{\frac{kr}{\pi}}\ \sin 1/2\ (\theta + \theta_0)$$

k = wave number = $2\pi/L$

r = radial distance from breakwater tip

θ = angle between breakwater and radius from breakwater tip to orthogonal point location

θ_0 = angle that approaching wave orthogonal makes with breakwater

(See Worthington and Herbich, 1970; Wiegel, 1964.)

When orthogonals come within range of intersecting the bayfront beach, the following equation is used to calculate a tentative breaker height, H_B, for each successive point:

$$H_b = .76\,(H_o K_R K_F K_D)^{3/4}\, m^{1/7}\, L_o^{1/4}$$

where m = bottom slope and
L_o = deepwater wavelength
(See LeMehaute and Wang, 1980.)

The depth at each new point is then compared to the breaking depth, $d_B = 1.28\ H_B$, predicted by solitary wave theory. When $d \leq 1.28\ H_B$, the orthogonal is terminated and the longshore energy flux, $P_{\ell s}$, is calculated for the point of intersection with the beach using:

$$P_{\ell s} = 32.1\ H_B^{5/2} \sin 2\alpha_b$$

where α_b is the angle the wavefront makes with the beach at breaking. A positive sign indicates an energy flux toward the east along the beach in the direction of the Wailoa River. A negative sign indicates a flux in the opposite direction.

When an orthogonal is terminated, all relevant information is stored: if in the harbor area, wave height predicted by linear wave theory; if on the beach, the position of intersection with the beach and the value of longshore energy flux. A new orthogonal is then begun and the process is repeated.

Primary orthogonals originate in deepwater where the waves are unaffected by refraction, shoaling and friction, and are projected toward the Hilo area. Orthogonal origins are chosen by trial and error to result in endpoints on the bayfront beach providing a representative distribution of wave heights and wave angles along the beach. After all primary orthogonals have been traced, radial orthogonals are generated at the breakwater tip, representing the wave diffraction occurring in the lee of the breakwater and with original directions chosen to give endpoints in areas where wave height information is desired. The computations for the radial orthogonals are identical to those for the primary orthogonals with the exception that the original wave height for the radial orthogonals is taken to be the height of the closest primary wave orthogonal to clear the breakwater as it passes the breakwater tip. The wave angle used for diffraction calculations is the angle at which the nearest orthogonal passes the breakwater tip.

Assumptions and Limitations

The numerical model developed for this study is an extremely useful engineering tool, permitting relatively rapid evaluation of many variables and complex mathematical formulas. An understanding of the assumptions and limitations of the methodology is necessary; however, along with experience and sound coastal engineering judgement, to guide its use and application.

Major assumptions of the wave transformation methodology include:

(1) No wave energy is transferred laterally along the wave crest (i.e., energy remains constant between orthogonals). This is reasonable except where extreme refraction and energy convergence occurs, resulting in the crossing of orthogonals (caustics). What happens at a caustic is not well understood. Energy is transferred along the crest, and the waves peak up and break to release energy, but the mechanics of this are not defined and there is little quantitative information dealing with the area beyond caustics. Caustics occur in the Hilo Harbor model along the edge of the reef.

(2) Changes in bottom topography are gradual, with a bottom slope less than 1V on 10H. The refraction calculations are derived for straight, parallel contours - it is difficult to carry an orthogonal accurately over complex bottom features. These are probably not serious limitations in the Hilo model except in the vicinity of Blonde Reef.

(3) Constant period, small-amplitude, long-crested monochromatic waves, perhaps the most significant source of error for two reasons. One, the wave climate in the vicinity of Hilo is complex and definitely not monochromatic. A more accurate wave energy model could be developed by refracting the wave spectrum according to its frequency distribution, as discussed in Ippen (1966) and by Seelig and Ahrens (1980). This is beyond the scope of the present study, however. The second source of error is assuming that the incident waves are all long-crested. This is reasonably true for longer period north swell; however, the local tradewind seas are less well defined and have irregular amplitudes and crest lengths.

(4) The methodology also assumes that reflection, small non-uniform bottom variations and abrupt depth changes, current effects, and wave generation within the zone of study are negligible. These are all reasonable, with perhaps the exception of local wave generation (or attenuation) shoreward of the breakwater as a result of the diurnal onshore-offshore winds. Because there is so little wave energy which can refract and diffract into the harbor, particularly during the summer tradewind season, reinforcement or attenuation of the incoming energy by onshore or offshore breezes, respectively, may significantly affect the actual wave energy available at the shoreline for sand transport.

The calculation of the breaker height, and thus the longshore energy flux and transport rate, also assumes a monochromatic wave. This over-estimates the actual average breaker height due to irregular seas as discussed by Seelig (1979 and 1980) and thus probably over-estimates the transport rate. This source of error may be compounded by the diurnal wind changes as discussed in the previous paragraph. Considering the irregularity of the seas could reduce the breaker heights by an estimated 10 to 15 percent.

The empirical relationship between longshore transport and energy flux of 1.2×10^3 appears reasonable for application to the study area; however, it is based on very limited field data and must be treated with caution. Thus, while the predicted relative transport rates between wave types, the winter/summer seasons, and with and without breakwater modifications are valid, the absolute volumes of sand transport cannot be relied on as being quantitative values without additional field verification. The model predicts beach shapes and transport directions and relative transport volumes.

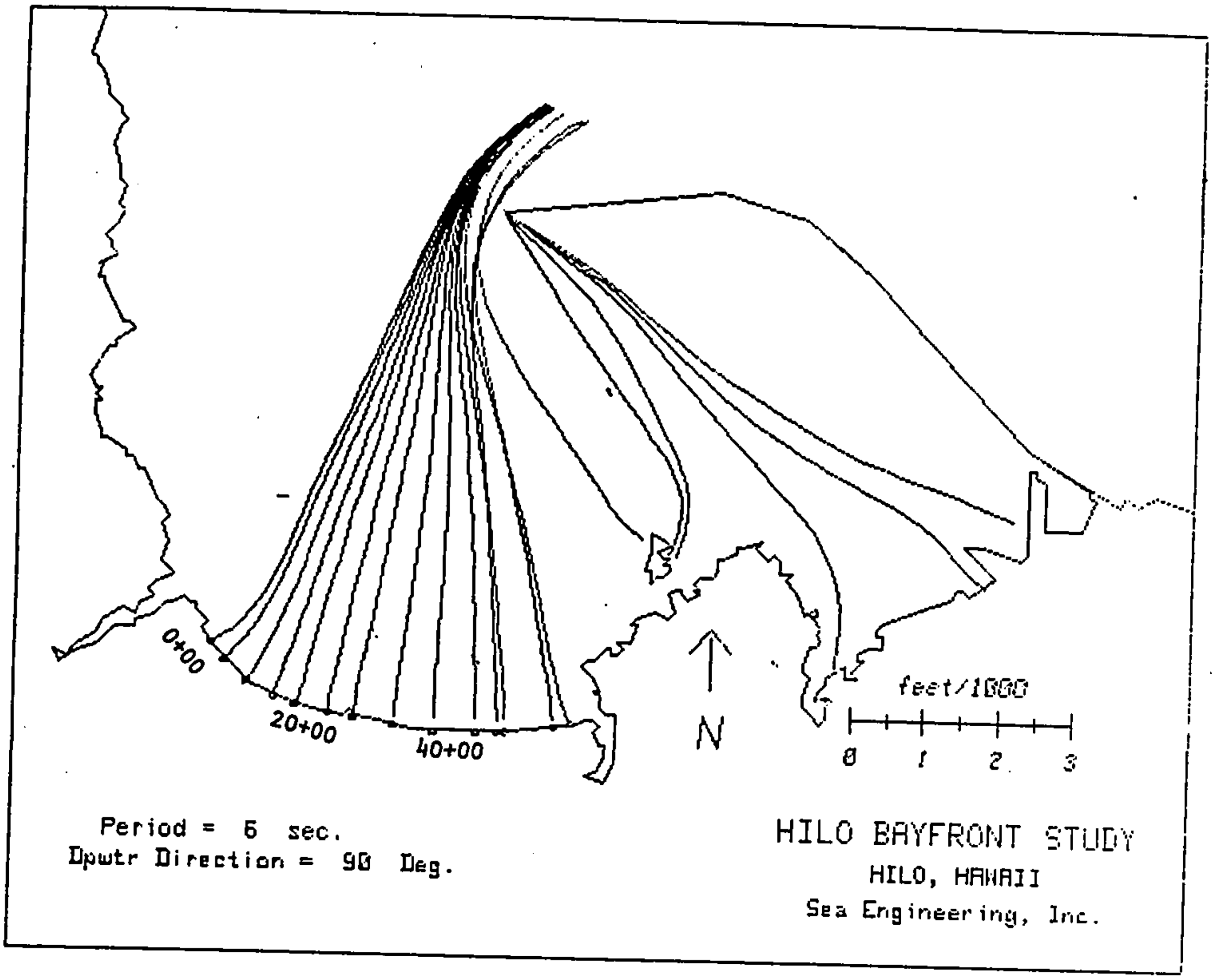
In order to properly evaluate and apply the numerical model results,they must be checked against available field data, aerial photographs and visual observations of the study area as discussed in a following section.

Computer Simulation of Existing Conditions

Refraction and Diffraction. Refraction and diffraction patterns for the deepwater wave types listed in Table 3-5 are shown on Figures 4-2 through 4-9. As evidenced by the figures, considerable divergence of wave energy due to refraction occurs for all the deepwater wave periods and directions affecting Hilo Harbor. Refraction coefficients are generally between 0.1 and 0.3 for all the conditions tested. For tradewind waves this is primarily a result of the breakwater blocking the direct approach of the waves. Only a very small portion of the incident deepwater wave energy can refract and diffract around Blonde Reef and the breakwater tip to actually reach the bayfront beach. North swell, on the other hand, approaches the harbor directly. However, considerable refraction occurs as the wave direction parallels the coastline for almost 8 miles before reaching the harbor entrance and results in a very narrow corridor from which north swell wave energy can enter the harbor.

Wave Heights in Hilo Harbor. Hilo Harbor is well sheltered from approaching deepwater waves, and wave heights within the harbor are greatly attenuated. The average nearshore wave height along the bayfront beach as a percent of the deepwater height is shown in Table 4-1 for various deepwater periods and directions. Tradewind wave heights in the harbor are generally about 9% to 12% of the deepwater height, with a low of 2% to 4% for waves from due east. North swell relative wave heights are greater, being about 10% to 30% of the deepwater height for 10 to 16-second waves from due north. Northwest swell is greatly attenuated as it refracts around Pepeekeo Point and is only 1% to 3% of its deepwater height inside the harbor. The numerical model does not consider wave energy reflected into the harbor from the steep rocky shoreline west of the bay. Thus, the relative wave heights in the harbor may be slightly higher than the model predicts, particularly during the tradewind conditions.

Wave heights in Reeds Bay and the commerical port area are further attenuated by diffraction around the breakwater and refraction as they propagate across the harbor. Tradewind wave heights are generally less than about 2% to 3% of the incident deepwater heights in Reeds Bay and the commercial port, respectively. North swell wave energy reaching Reeds Bay and the port area is greater; however, wave heights are still generally less than about 5% of the deepwater height.



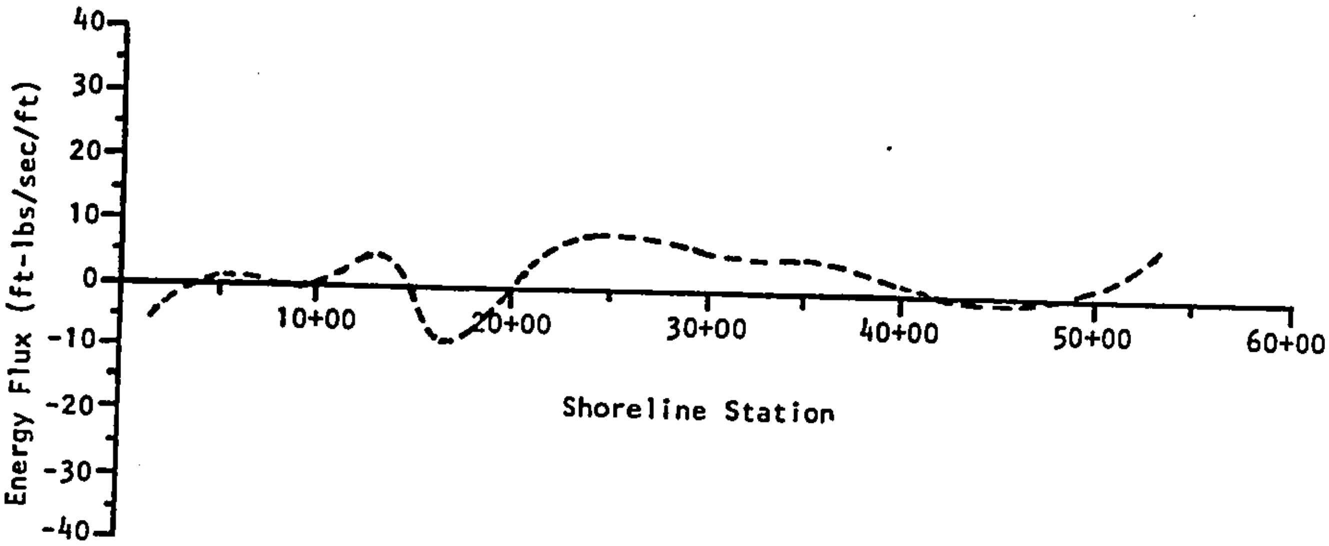


Figure 4-2. Refraction, Diffraction and Longshore Energy Flux for $T = 6$ sec, $H_0 = 5$ feet, Dir = 090°

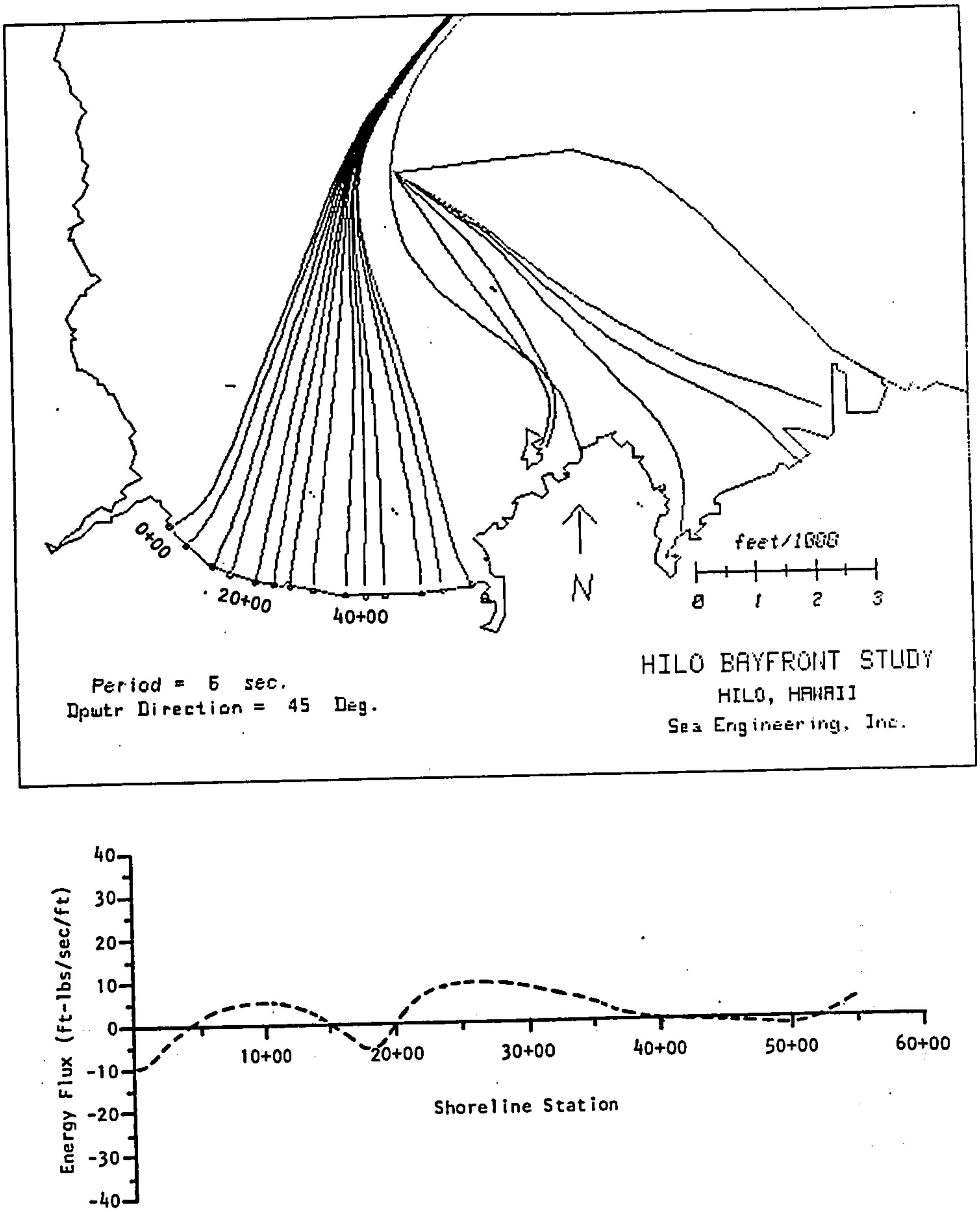
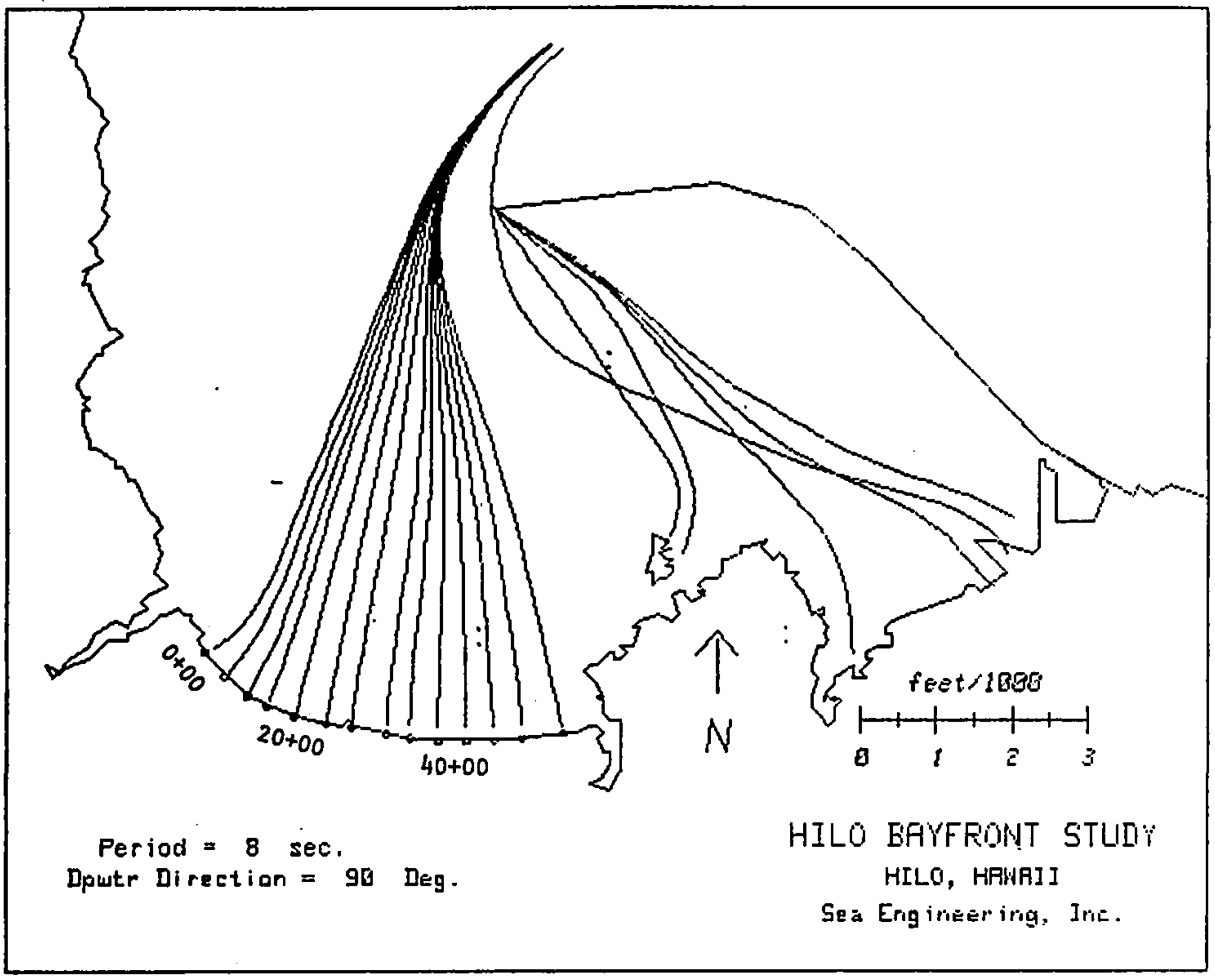


Figure 4-3. Refraction, Diffraction and Longshore Energy Flux for $T = 6$ sec, $H_0 = 5$ feet, Dir = 045°



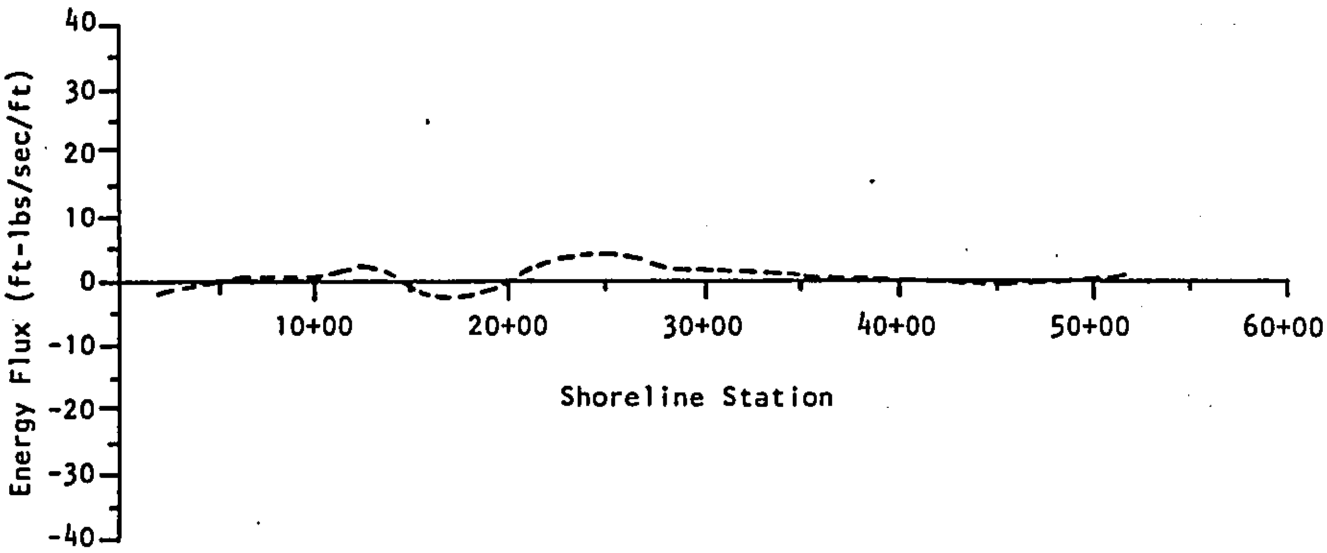
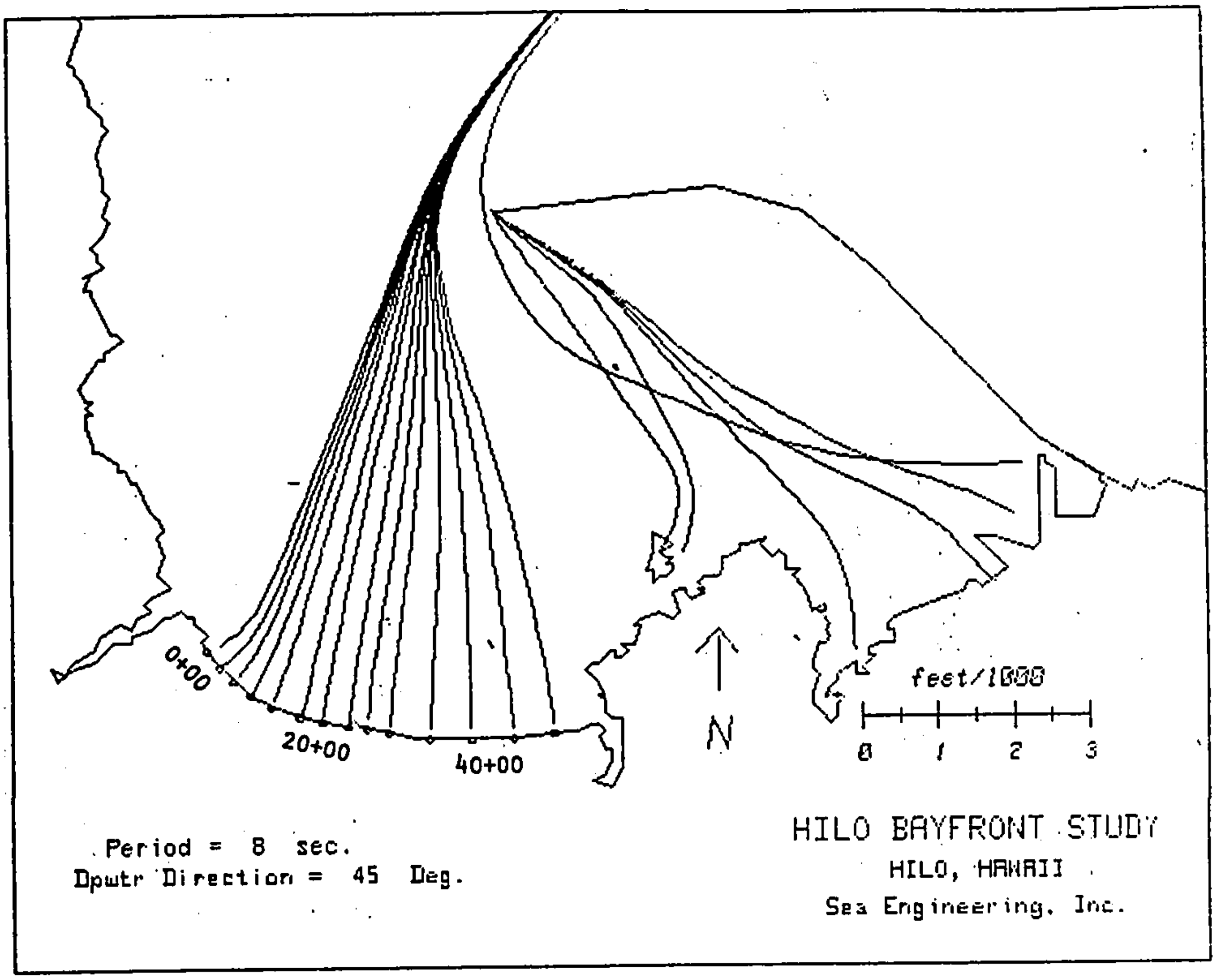


Figure 4-4. Refraction, Diffraction and Longshore Energy Flux for $T = 8$ sec, $H_0 = 8$ feet, Dir = 090°



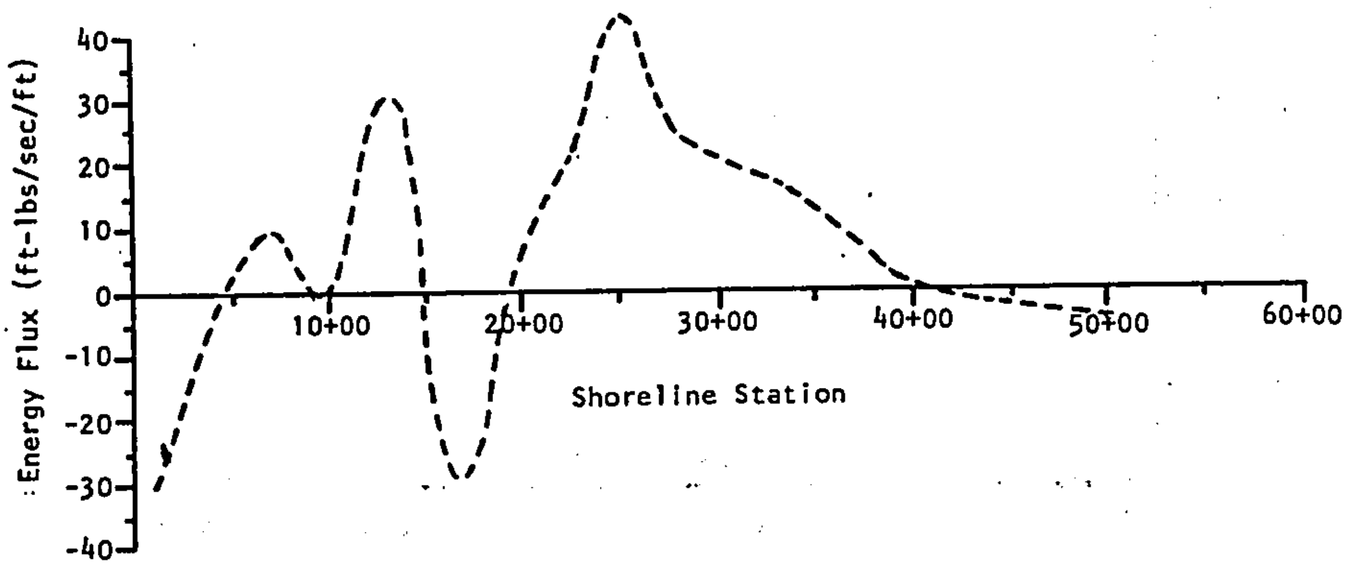


Figure 4-5. Refraction, Diffraction and Longshore Energy Flux for T = 8 sec, H_o = 8 feet, Dir = 045°

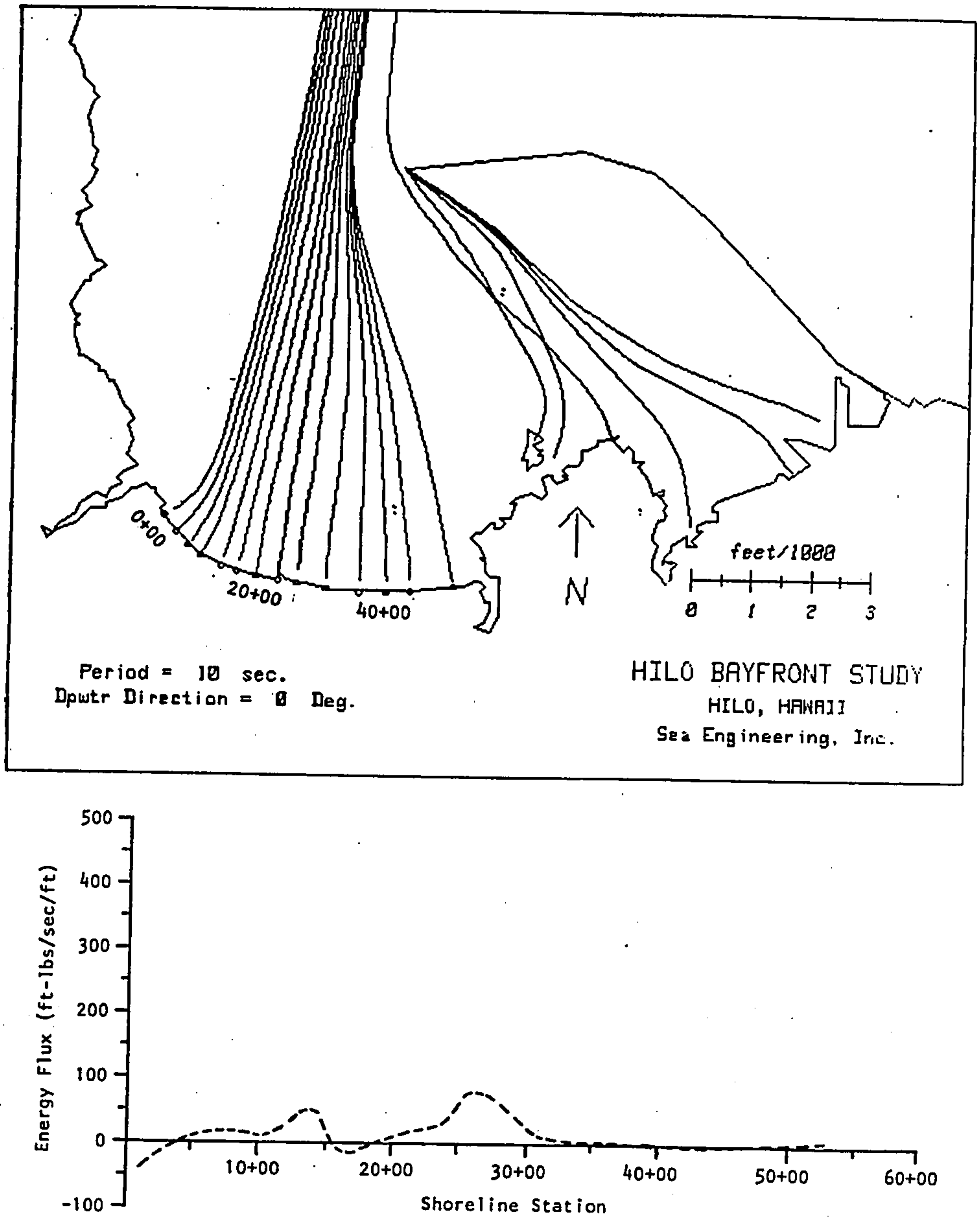


Figure 4-6. Refraction, Diffraction and Longshore Energy Flux for $T = 10$ sec, $H_0 = 5$ feet, Dir = 000°

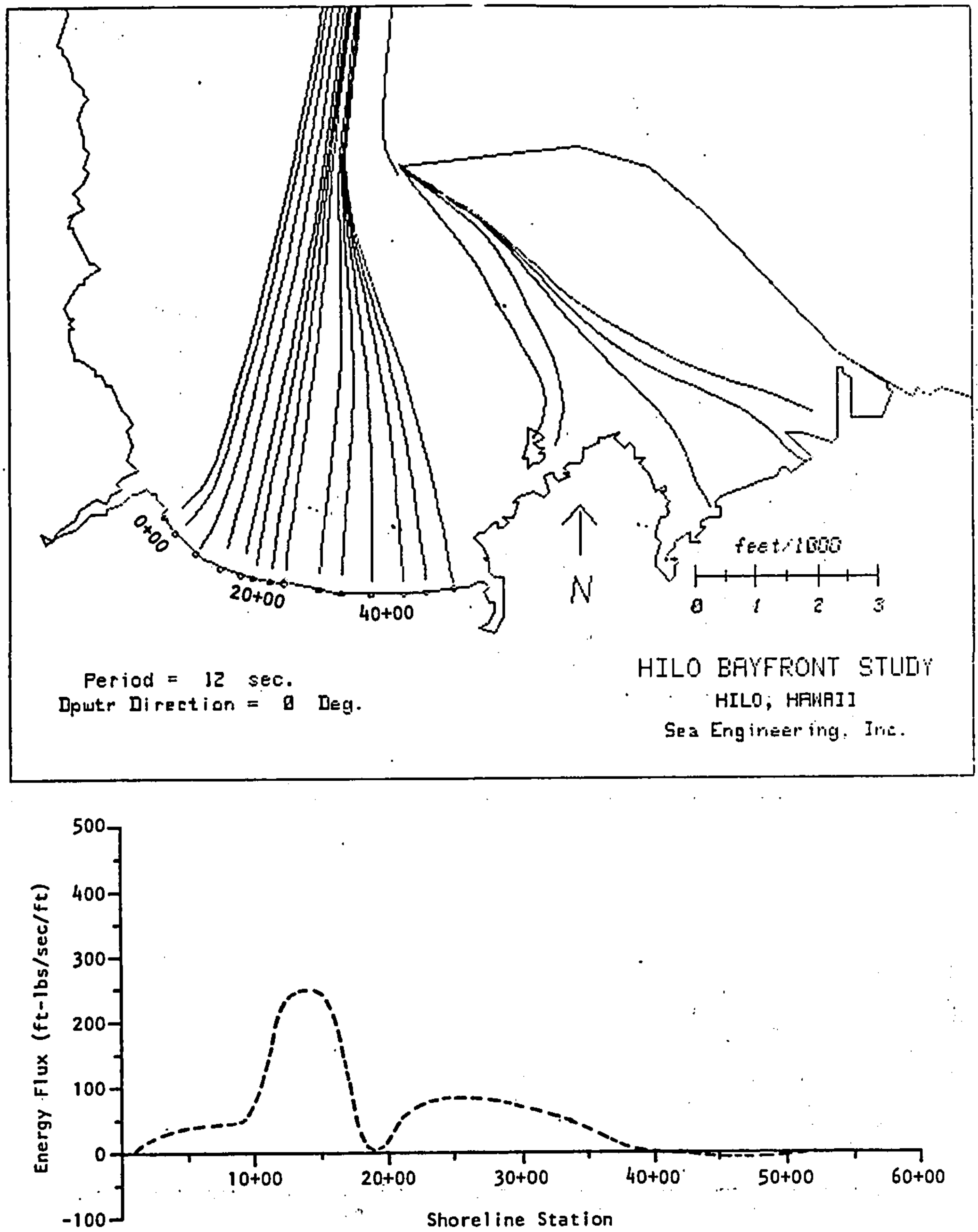
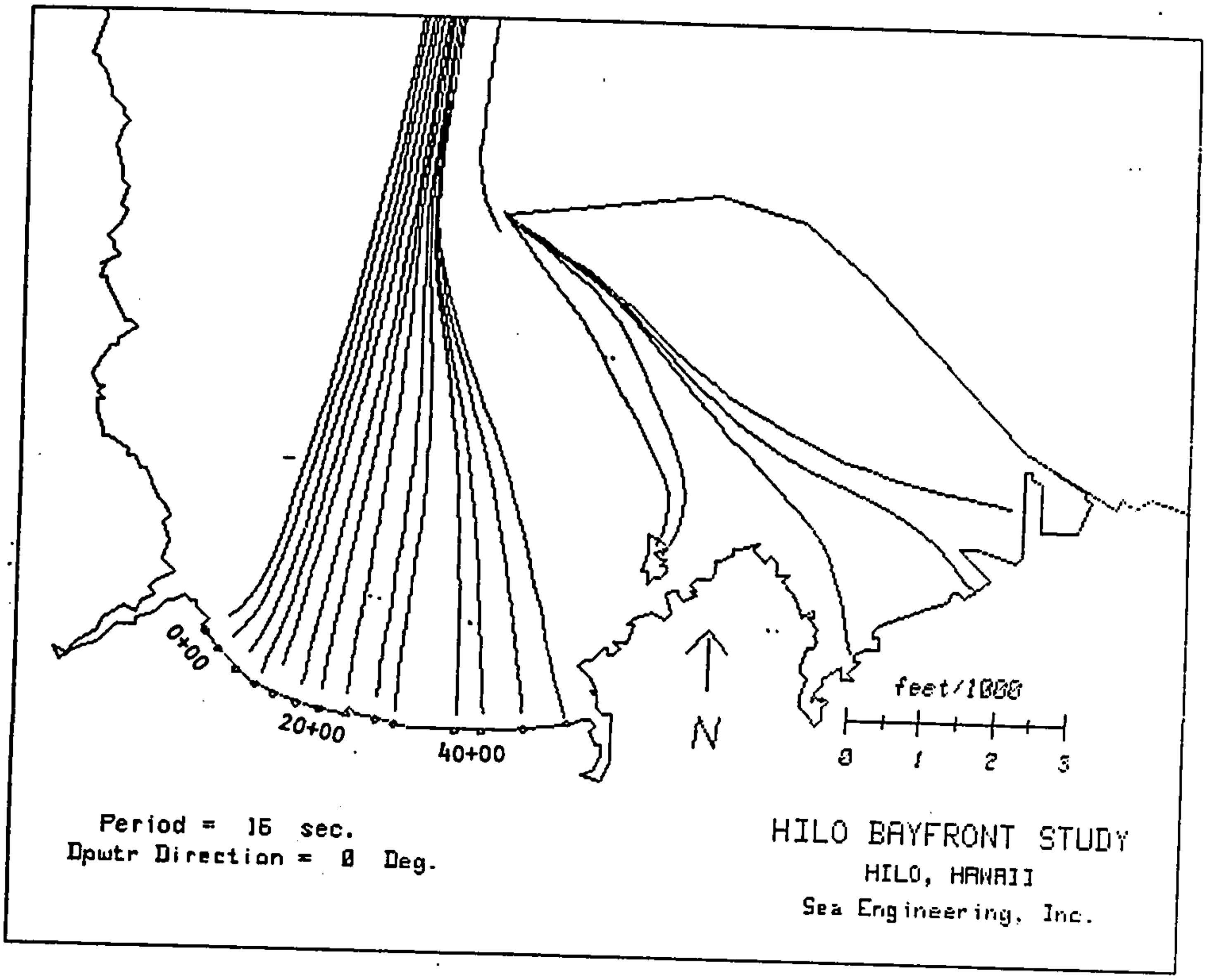


Figure 4-7. Refraction, Diffraction and Longshore Energy Flux for $T = 12$ sec, $H_0 = 10$ feet, Dir = 000°



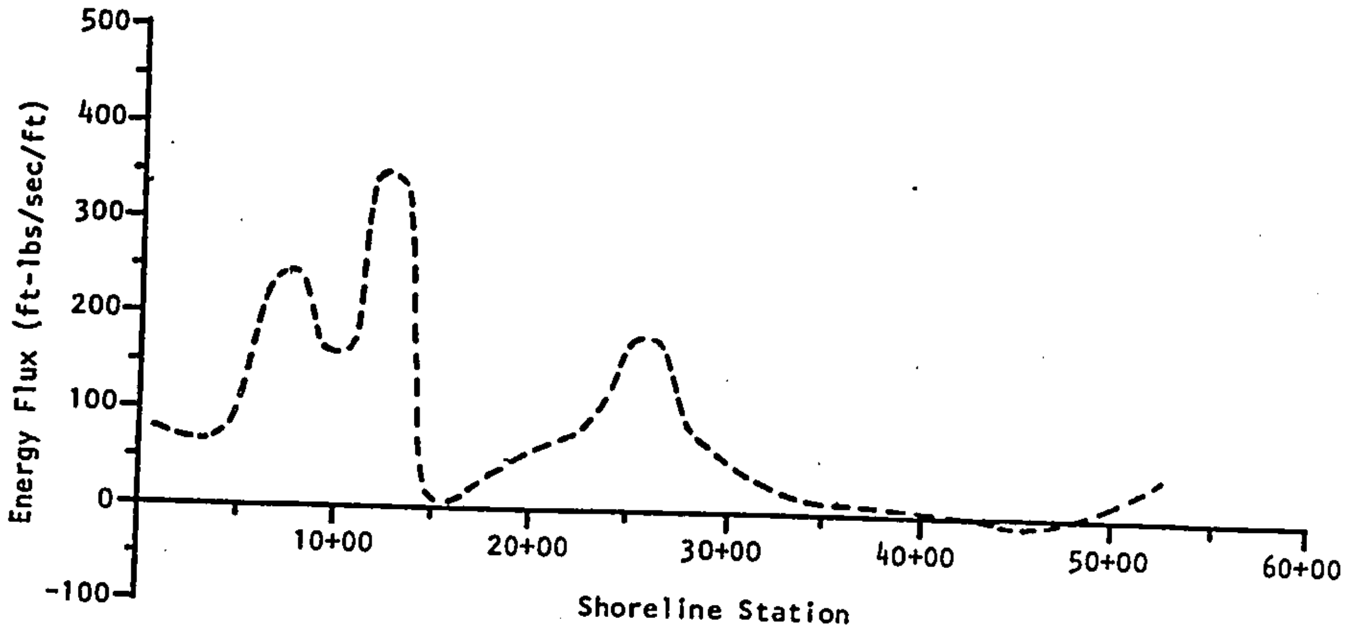
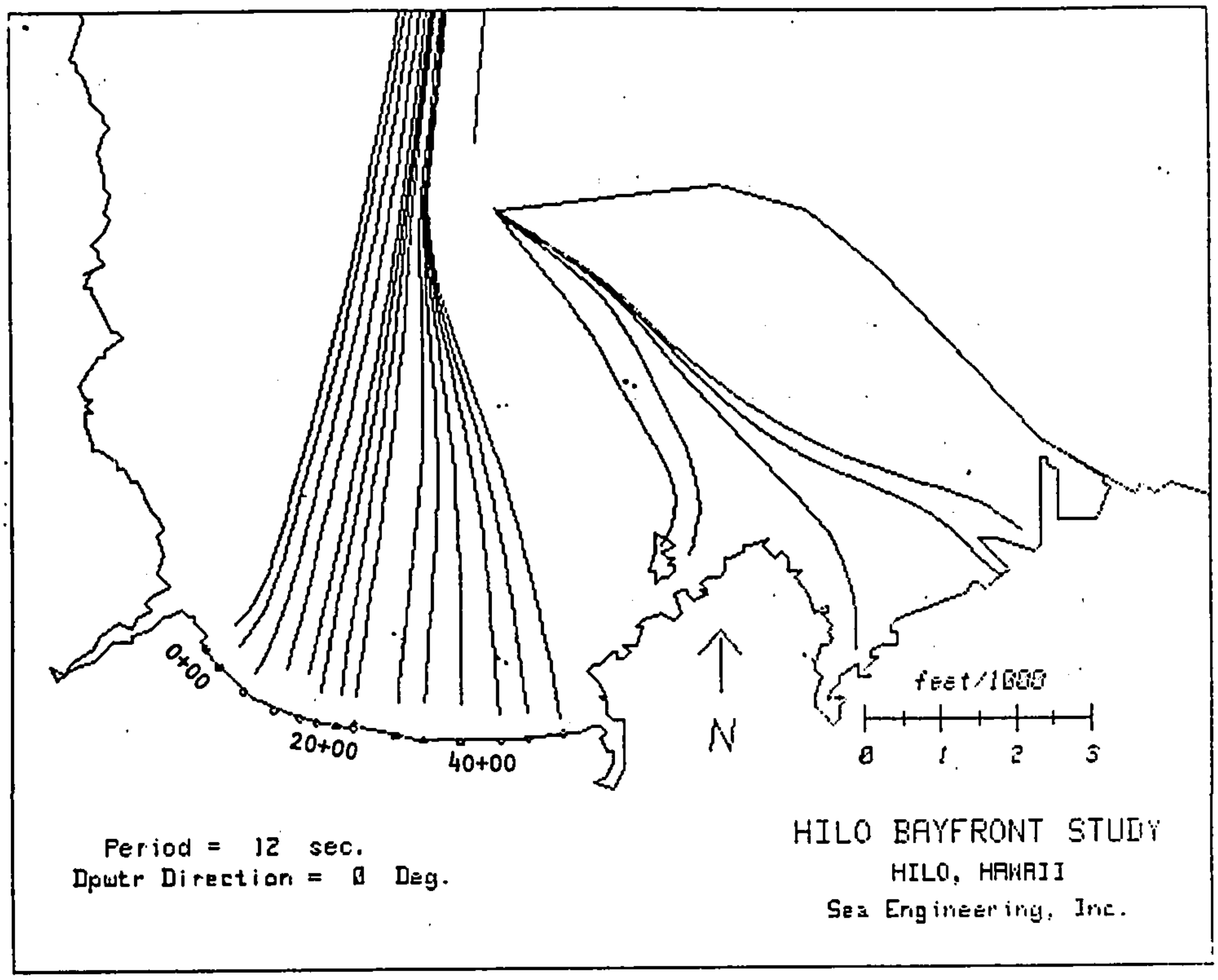


Figure 4-8. Refraction, Diffraction and Longshore Energy Flux for $T = 16$ sec, $H_0 = 15$ feet, Dir = 000°



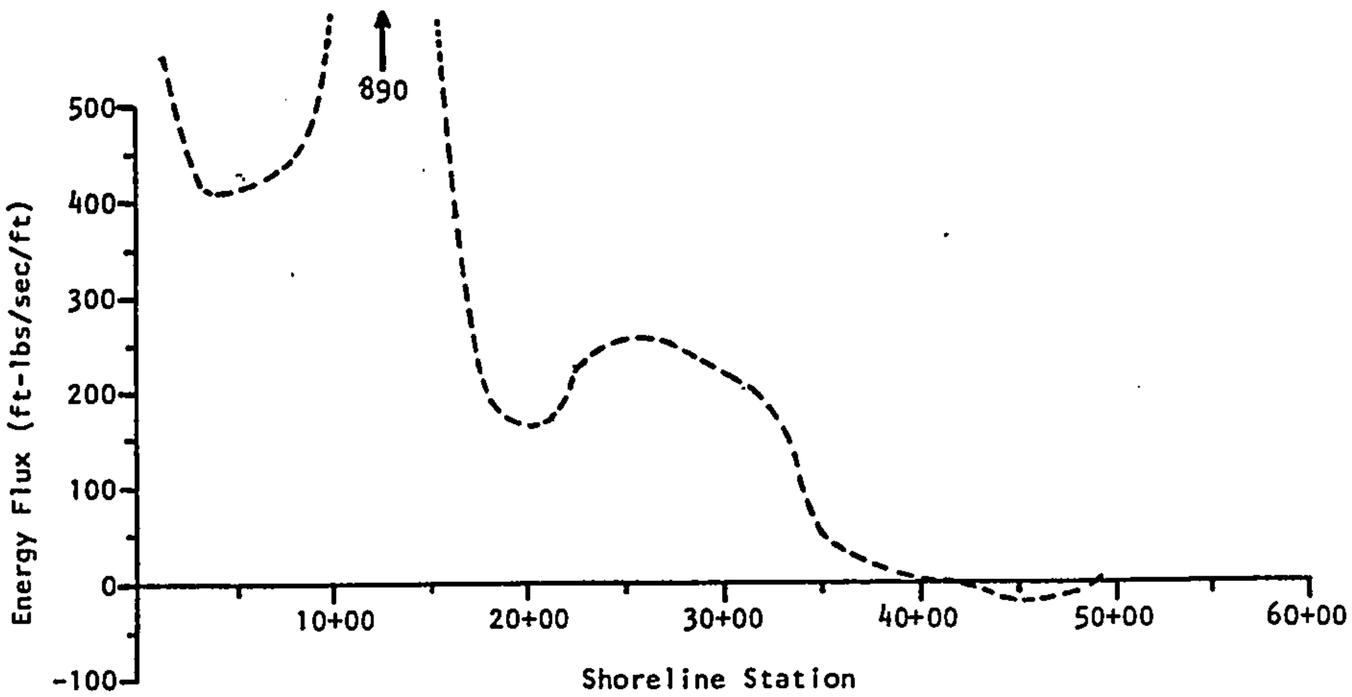


Figure 4-9. Refraction, Diffraction and Longshore Energy Flux for 10-year Storm Waves, T = 12 sec, H_0 = 22.5 feet, Dir = 000°

Table 4-1. Average Nearshore Wave Height as a Percent of Deepwater Height in the Vicinity of the Bayfront Beach.

Wave Period (sec.)	Deepwater Direction (°TN)	Percent of Deepwater Height at Shoreline Stations			
		0+00-10+00	10+00-25+00	25+00-40+00	40+00-58+00
6	090	9	12	10	9
6	045	11	12	9	6
8	090	3	4	2	2
8	045	12	14	9	7
10	000	24	30	11	8
12	000	23	26	12	9
12	315	2	3	1	1
16	000	19	19	8	5
16	315	3	3	1	1

Longshore Energy Flux and Sediment Transport. The predicted longshore energy flux along the bayfront beach for the various deepwater wave periods and directions tested is also shown on Figures 4-2 through 4-9. The net energy flux along the beach seasonally and annually is shown on Figure 4-10. A positive energy flux indicates transport from west to east, and a negative flux indicates transport from east to west. During tradewind conditions the energy flux is generally less than about 10 ft -lbs/sec/ft of beach front, and the greatest concentration of energy is between shoreline stations 20+00 to 40+00. During the winter season there is two to four times as much potential energy flux along the shoreline, with much more energy present along the western portion of the beach between stations 5+00 and 20+00.

The energy flux is very sensitive to the angle of wave approach to the shoreline. The model uses a generalized shoreline taken from NOAA/NOS chart 19324 and represents the general orientation of the coastline. Thus, the calculated energy flux represents the potential for longshore transport and not necessarily the actual transport at any given point or time. Where there is existing sand along the shore, or if the beach should be restored, the beach will attempt to orient itself perpendicular to the predominate wave direction and reduce the energy flux and longshore transport.

The calculated energy flux indicates that the greatest potential for transport both seasonally and annually is between stations 5+00 and 40+00, which agrees with what has been observed. Energy flux is concentrated at stations 10+00 to 15+00 and 20+00 to 40+00. The net transport direction is west to east; however, there is an interesting nodal point between stations 50+00 and 20+00, where the energy flux is greatly reduced or reverses direction. Energy flux at both ends of the beach also reverses direction and moves east to west. During severe storm wave attack (e.g., the 10-year return period storm event), the potential energy flux can increase by two or three times above that normally experienced during periods of north swell. These storms are relatively brief and infrequent; however, they have the potential to move a very large amount of sand in a short time.

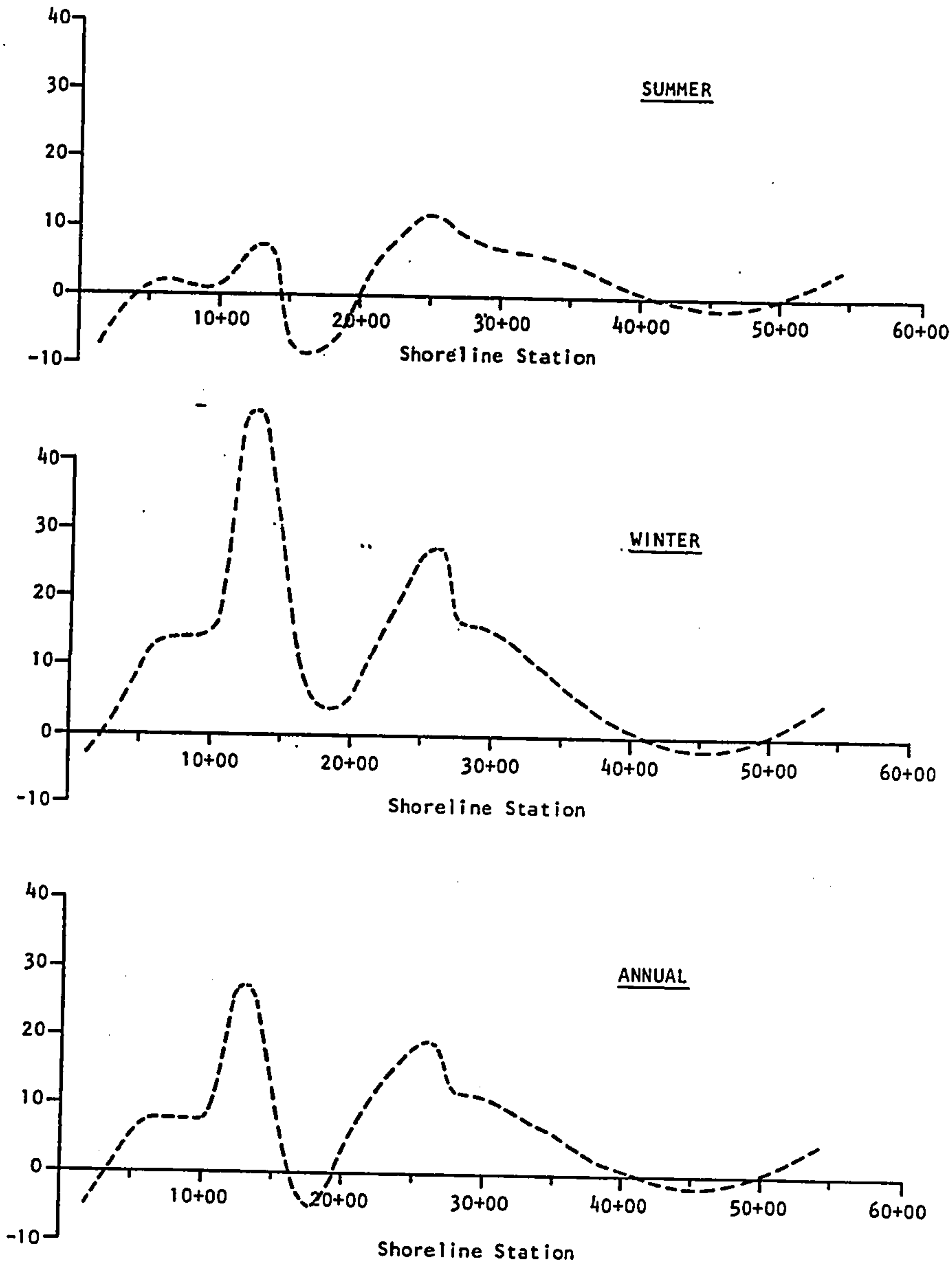


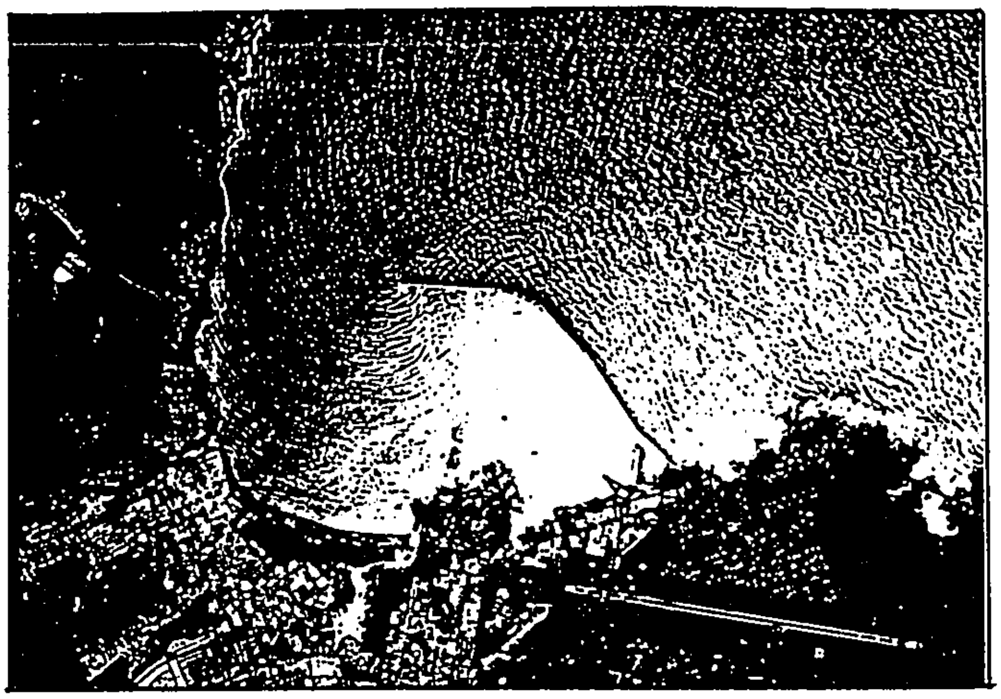
Figure 4-10. Seasonal and Annual Net Longshore Energy Flux

The potential for longshore transport as shown by the energy flux indicates the probable need for structures to help stabilize a restored beach and reduce sand losses due to longshore transport by either reducing the wave heights at the shoreline (offshore structures) or assisting the beach to obtain a stable configuration perpendicular to the incident wave approach (groins).

Comparison of Model to Prototype

Very little quantitative data exists regarding actual conditions inside Hilo Harbor and along the shoreline for specific deepwater wave conditions with which to verify the accuracy of the numerical model. Simultaneous measurements of deepwater wave height, period and direction, nearshore wave height and angle incident to the shoreline, and longshore sand transport are necessary to completely validate the model. However, a qualitative assessment of the model results can be made based on existing information, and it generally appears to reproduce the typical shoreline processes. Caution must be used in applying computer derived absolute values of parameters at specific locations (e.g., breaking wave height at a specific location or magnitude of sand transport past a specific point). Until the model can be verified by actual controlled field measurements, it should be used only to assess relative changes and average conditions. For example, the energy flux should be used to assess the direction and relative magnitude of potential longshore transport along the beach, rather than using the model to quantitatively assess the cubic yards of sand moved at any given point.

A comparison of existing aerial photographs of Hilo Harbor with the results of the numberical model shows similar refraction and diffraction patterns within the harbor. This is illustrated by Figure 4-11, which shows a photograph taken during what appears to be easterly tradewind conditions and the computer picture of 6-second tradewind waves from the east. Both show rapidly decreasing wave heights eastward of the Wailuku River and a band of wave energy convergence extending from the tip of the breakwater along the edge of Blonde



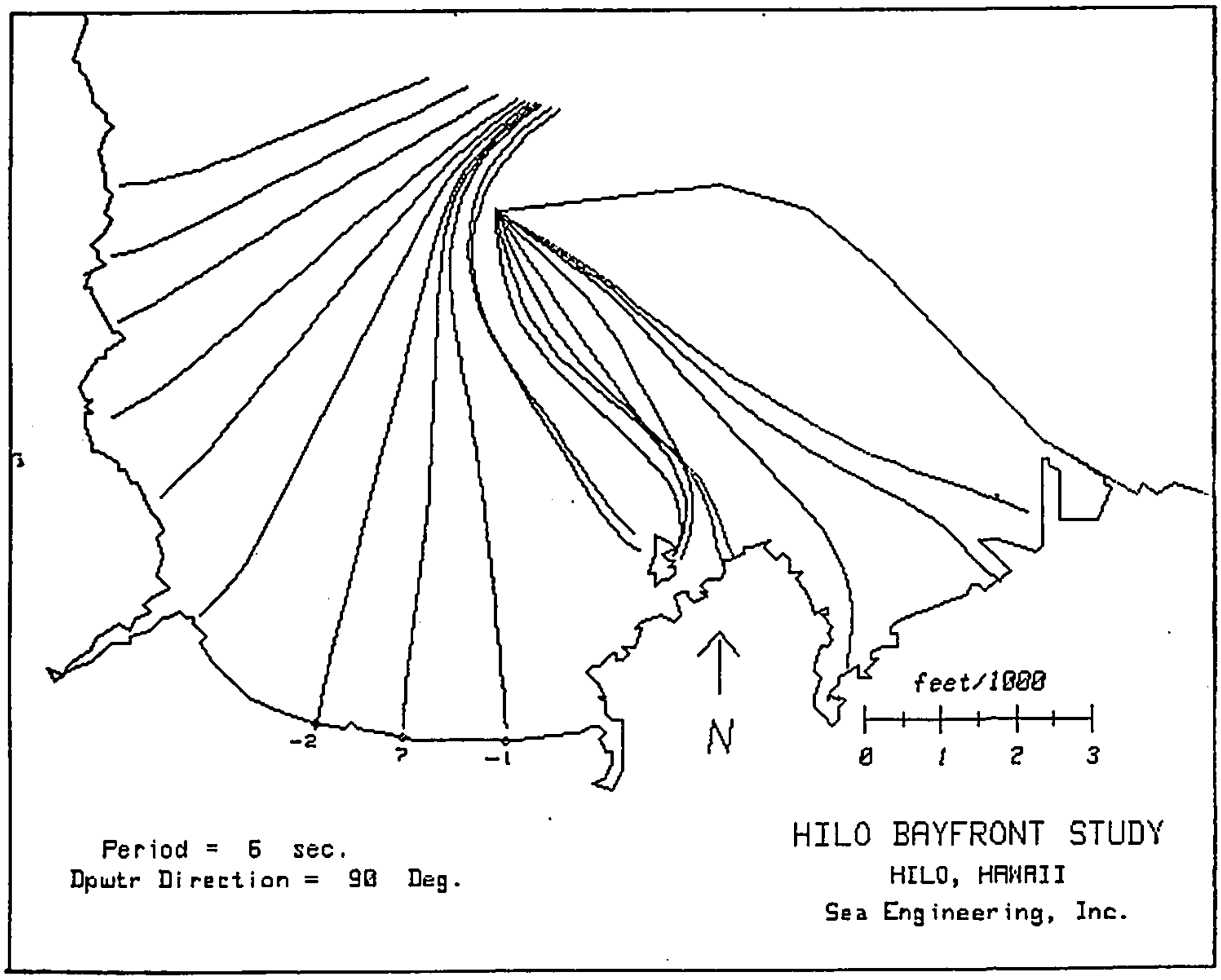


Figure 4-11. Prototype and Model Comparison

Reef to Waiakea Peninsula. This band of energy convergence is present for all the wave periods and directions tested.

Previous field investigations and inspection of the existing shoreline conditions support the numerical model results. The predominant longshore transport from west to east has been documented, and this is borne out by the model. There is an apparently stable sand shoreline at the eastern end of the bayfront beach, and the model shows relatively little energy flux along this existing beach location.

The breaking wave heights and angle of approach to the shoreline predicted by the model are reasonable and correlate well with observed waves along the shoreline during similar deepwater wave conditions. The bayfront highway revetment along the western portion of the bayfront beach is overtopped on occasion during periods of large north swell during the winter. The model predicts breaking wave heights of 4 to 5 feet along the western half of the beach from large 12 and 16-second north swell, and the estimated runup on the existing rock revetment is estimated to be +12 to +14 feet. The revetment elevation is about +12 feet and, thus, overtopping would likely occur.

Field measurements of the volume rate of longshore transport by Sea Engineering (1981) showed a transport of approximately 5 to 6 cubic yards per day to the east at station 32+00 during typical tradewind conditions. Using the empirical transport coefficient of 1.2×10^3 and average summer season energy flux from Figure 4-10, the model predicts transport of about 20 cubic yards per day at this location. This is a reasonable correlation, considering the questionability of the transport coefficient and the fact that the measured transport rate may have underestimated the actual rate as previously discussed.

An interesting correlation between actual shoreline conditions and the model predictions was observed during a field trip to the project site in early August 1982. The longshore energy flux calculated by the model shows a nodal point of energy direction reversal in the vicinity of station 16+00 to 20+00 during the summer season. The summer of 1982 has been particularly rainy, which means an unseasonably heavy discharge from the Wailuku River, including debris, grass, tree limbs, etc. During the site visit, a large pile of debris was located on the beach at station 18+00 to 19+00. The pile of debris was extensive and was the only pile along the entire beach. Most of the debris was above the high tide line, and the portion of the debris that was in the water at high tide moved a little bit back and forth and in and out but did not appear to move along the shore.

SHORELINE IMPROVEMENT ALTERNATIVES

Objectives and Alternative Selection

As previously discussed, the shoreline improvement objectives are three-fold: (1) to provide storm wave protection for the bayfront highway; (2) to restore the bayfront beach for recreational uses; and, (3) to reduce shoaling of the Wailoa River mouth. This report presents a discussion of feasible shoreline improvement alternatives to meet these objectives, including:

1. Beach replenishment for shore protection and recreation;
2. Beach replenishment stabilized with groins. Groin construction alternatives include rock rubblemound or sand-cement filled bags;
3. Beach replenishment stabilized by detached rock rubblemound breakwaters;
4. A perched beach and artificial surf shoal stabilized by Longard tubes; and
5. Rock revetment shore protection.

Improvements are considered only for the shoreline between stations 0+00 to about 40+00. The existing sand beach east of station 40+00 is stable and adequately meets the project objectives. The alternatives are evaluated in terms of their general feasibility and effectiveness in meeting the project objectives and their efficiency in terms of relative costs. The cost estimates are adopted from cost estimates for previous projects and study reports conducted by or for the Corps of Engineers.

Construction Materials

General. Coastal shore protection and erosion control structures have been constructed of almost every material imaginable, from rock, concrete, timber and steel to rubber tires, rock-filled baskets, and textile bags and tubes. In general, where quarrystone or field stone of the proper size and quality is available at a reasonable price in sufficient quantity, it is the best all around construction material for use in the ocean environment. It is durable and longlasting, both as a material and in a structural configuration, and there is a large amount of quantitative design data and experience to guide its use. However, stone and concrete can be relatively costly to use, as is the case in Hilo. As construction costs have increased, new materials have been developed for the construction of groins and breakwaters, particularly for applications where design wave heights are low and cost and ease of construction are major factors. These "low-cost" shore protection methods have been studied in detail by the Federal Shoreline Erosion Control Demonstration Program, and the results are presented in a report by the U.S. Army Corps of Engineers, Chief of Engineers (1981). Of the methods tested, large sand-cement filled bags and sandfilled Longard tubes appear to have some application for use in Hilo, primarily because of the availability of offshore sand as a construction material. Sand-cement filled bags and Longard tubes are discussed in the following paragraph as alternatives to the more conventional rock construction techniques.

Sandfilled and Grout-Filled Bags. Large textile sandfilled and sand-cement filled bags have been used effectively in groins, sills and detached breakwaters. The bags are approximately 4 feet wide, 20 inches thick, and 12 feet long, and can be woven of Acrylan and nylon synthetic fibers. Acrylan has the best UV deterioration resistance when exposed to sunlight; however, nylon has greater tensile strength. The bags must be filled by a pump.

Although the sandfilled bags effectively resist movement by wave action, they are very vulnerable to damage by vandals and tears by debris impact. Once torn they quickly lose their sandfill under wave action.

Filling the bags with a sand-cement grout eliminates the inherent weakness of the fabric in sandbag construction. As soon as the grout hardens, the modules are essentially irregularly shaped concrete blocks nested together and are very vandal and damage resistant. One problem with the grout filled bags, however, is that the cement tends to separate from the sand in the pumping process and the modules may crack. Grout-filled bags have been found effective for wave heights up to about 8 feet (Porraz, 1976).

Longard Tubes. Longard tubes are patented sand filled fabric tubes used as seawalls, groins, sills and breakwaters for shore protection and erosion control. The Longard tube actually consists of two tubes: an inner tube of impermeable polyethylene sheet and an outer tube of woven polyethylene fabric. The inner tube aids in the filling process, and structural strength is provided by the high density, UV stabilized outer tube. The tubes are available in diameters of 10", 40" and 70", in lengths up to about 330 feet. Double 40" tubes, stitched together, are available where extra lateral stability is required, such as conditions of active longshore transport.

The primary advantage of Longard tubes is the speed and ease with which they can be filled. The filling process does require specialized, patented filling equipment, however. Their chief drawback is a high vulnerability to damage by vandals and floating debris. This problem was well documented during the low-cost demonstration program (U.S. Army Corps of Engineers, 1981). An epoxy coating is available which reduces the damage potential. However, this coating can only be applied to dry surfaces which greatly reduces its usefulness. The tubes have been found reasonably effective in low to moderate wave height areas, as long as they remain structurally sound and are not displaced. A good foundation is necessary as protection against displacement due to wave scour.

General Design of Improvements

Protective Beach

General. Constructing or nourishing a protective beach by placing sand of suitable grain size in a particular shape along a shoreline is an effective and attractive means of protecting the backshore area as well as providing recreational opportunities. A wide, natural beach slope is very effective for dissipating wave energy. Restoring and/or nourishing the beach remedies the basic problem - lack of a sufficient natural sand supply. However, the capacity of the waves to remove sand may be so great that it is not economically feasible to nourish the beach, and a beach without structural backup may not provide the required protection during severe wave attack.

Design. The design of a protective beach requires the following information and analysis:

1. The incident wave climate (height and direction nearshore) and the direction and rate of longshore transport;

2. The necessary beach width and crest elevation to provide the desired shore protection, as well as the orientation and slope of the beach face; and

3. The characteristics of the native beach sand and the borrow material to be used for restoration and/or nourishment.

The shape of the restored beach and the volume of sand placed within the fill is intended to provide a relatively stable configuration and enough sand to exceed the long-term erosion losses characteristic to the area as well as erosion during infrequent but severe storms. The shape of Hilo Bay and the prevailing wave directions at the shoreline as a result of refraction, as well as the magnitude of potential sediment transport from west to east, make it virtually impossible to restore the beach under existing conditions without the use of structures to help stabilize the beach fill and reduce the loss of fill material. Structures are necessary to either reduce the energy reaching the beach or to assist in reorienting the beach face perpendicular to the wave approach.

It is estimated that a minimum beach width above the design stillwater level of about 50 feet is necessary to provide adequate severe storm wave protection as well as a reasonable recreational dry beach area. Based on the numerical model, the average 10-year storm wave height along the shoreline is about 6 feet, and the wave runup height on a 1 on 10 beach slope is estimated to be about +9 feet mllw. A beach crest elevation of +10 feet is, therefore, recommended.

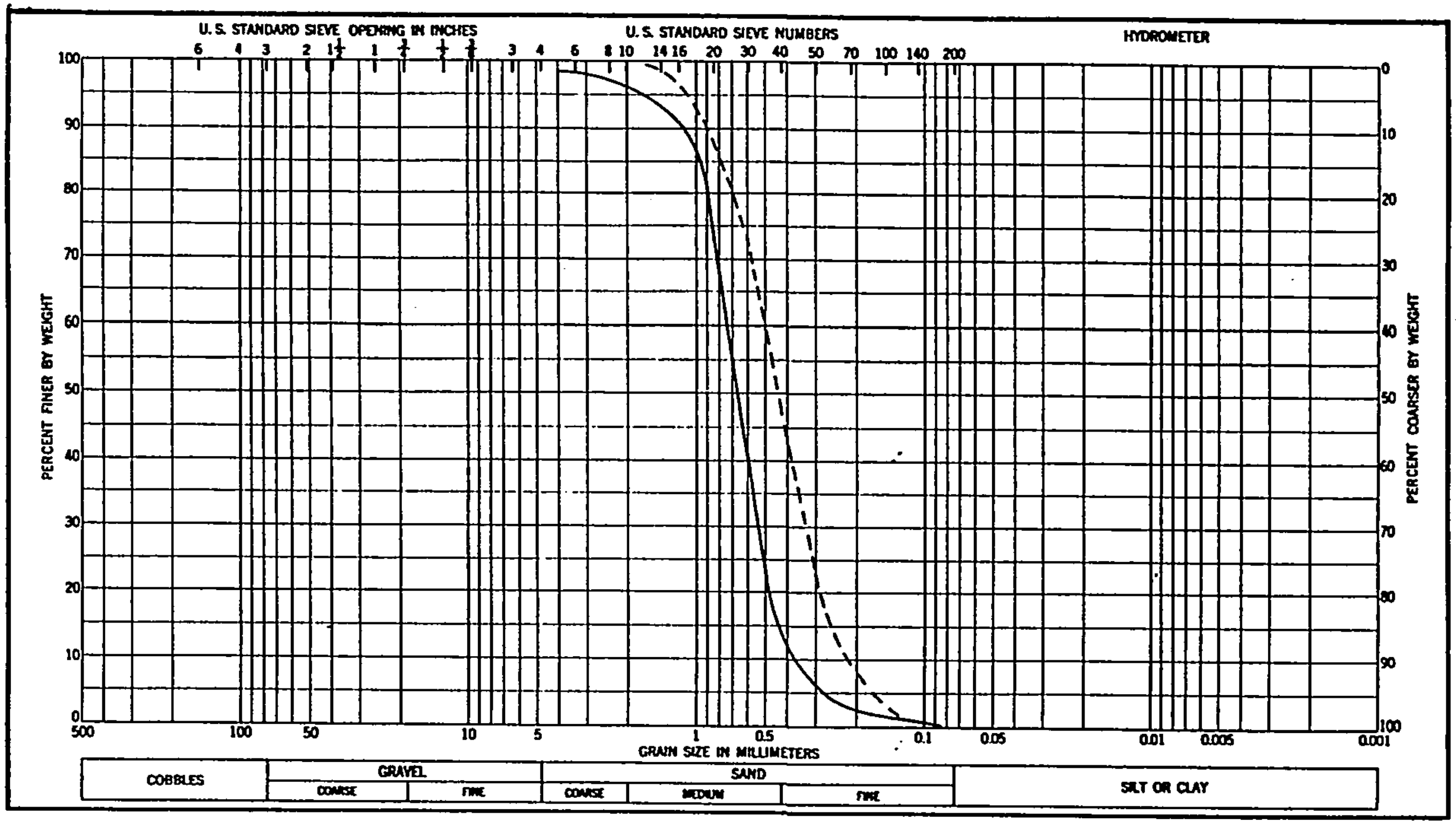
Beach Replenishment Material. When fill material is deposited on the shoreline, wave action immediately starts a sorting and winnowing action. Finer material is removed until only the material compatible with the wave climate remains. When the replenishment material is finer than the native material, large losses often occur immediately after its placement. Borrow material with the same grain-size distribution as sand already on the beach is the most suitable for replenishment, and slightly coarser material is usually suitable. If material finer than that naturally occurring on the beach is used for restoration, an additional volume may be required to provide the desired finished beach dimensions. The amount of overfill required and the effect of the borrow material on estimated renourishment rates can be estimated using techniques in the SPM and Hobson (1977) to compare the grain-size characteristics of the native beach sands and the borrow sands. Grain-size distributions are compared to determine:

(a) Fill factors (R_A) which are used to estimate the excess volume of fill required to satisfy project dimensions, and;

(b) Renourishment factors (R_J) which predict the stability of potential fill materials against erosion as compared to native beach

The basic assumption is that natural winnowing and sorting processes will modify the fill sands until their textural and areal distribution resembles that of native beach sands as nearly as possible. Comparative grain-size distributions for the native beach sand and the offshore borrow area samples are shown on Figure 5-1. Table 5-1 summarizes the comparison between sand samples taken from the shoreline and the potential offshore sand borrow source.

The offshore borrow sand is finer grained and more poorly sorted than the native beach sand. This is reflected by a fill factor (R_A) of 2.3, indicating that a loss of approximately 50% of the replenishment sand can be expected during the initial textural adjustments of the beach fill. The renourishment factor of 1.75 predicts that the borrow sand will erode at a faster rate than the native beach sand.



——— Sea Engineering, 1981
Temporary Groin Location

- - - - Ocean Innovators, 1979
Offshore Sand Deposit

Figure 5-1. Grain-Size Distributions, Native Beach Sand and Potential Offshore Borrow Source

Table 5-1. Existing Beach and Offshore Sand Grain-Size Distribution Parameters and Comparisons

	Native Bayfront Beach Sand	Offshore Sand Borrow Source
Diameter 16th Percentile, mm	1.0	0.8
Diameter 84th Percentile, mm	0.47	0.28
Mean Size, mm	0.7	0.46
Phi 16th Percentile (ϕ_{16})	0.0	0.32
Phi 84th Percentile (ϕ_{84})	1.09	1.84
Phi Mean Diameter (M_{ϕ})	0.55	1.08
Phi Sorting ($_{\phi}$)	0.55	0.76
	-	1.382
$(M_{\phi} - M\phi n)/ _{\phi n}$	-	0.964
Percent Sand	99	99
Fill Factor, R_A	-	2.3
Renourishment Factor, R_J	-	1.75

Note

R_A taken from SPM Figure 5-3.

R_J taken from SPM Figure 5-4.

Beach Replenishment with Groins

Description. Where there is a predominant longshore transport of sand in one direction, groins can be an effective method for retarding erosion of a restored beach. The groins are constructed perpendicular to the shoreline and sand accumulates on the updrift side. This assists the beach configuration to orient itself to conform to the predominant wave crests and thus reduce longshore transport. The trapping of sand on the updrift side can result in downdrift erosion. To cope with this, a series of groins must be built and artificially filled initially. The groins can be designed to permit some sand transport to continue either around the end or over the groin, or to act as a complete littoral barrier. Because of the unknown volume of sand transported to the beach for nourishment naturally by the Wailuku River, it is proposed that the beach be restored using offshore sand and the groins constructed to permit very little transport over and around them in order to reduce the periodic nourishment requirements.

Groin Design. A general plan for beach replenishment stabilized by a series of groins is shown on Figure 5-2. The first groin is spaced at a 700-foot distance from station 0+00, and the rest at 600-foot intervals from station 7+00 to station 36+00. The potential longshore energy flux, and thus the sediment transport, is generally low and reverses direction at about station 40+00, so there should be little adverse impact to the downdrift beach past this point.

The landward ends of the groins are tied to the existing rock revetment, and the groin length is determined by the shape of the fillet oriented parallel to the prevailing wave fronts as determined by the numerical model and assuming a minimum beach crest width of 50 feet on the updrift side of the fillet. Consideration was also given to limiting the seaward extent of the groin to an approximate 10-foot depth. The groins are designed to allow very little sand bypassing around the ends or over the top. The groin lengths are divided into three sections: Section 1 extends horizontally at the beach crest elevation (+10 feet) for the maximum crest width; Section 2 slopes 1 on 10 along the beach slope to the mllw line; and Section 3 extends seaward with a crest elevation at about mllw a sufficient distance to prevent sand bypassing around the end, assuming a 1 on 10 beach slope below mllw to intersect the existing bottom.

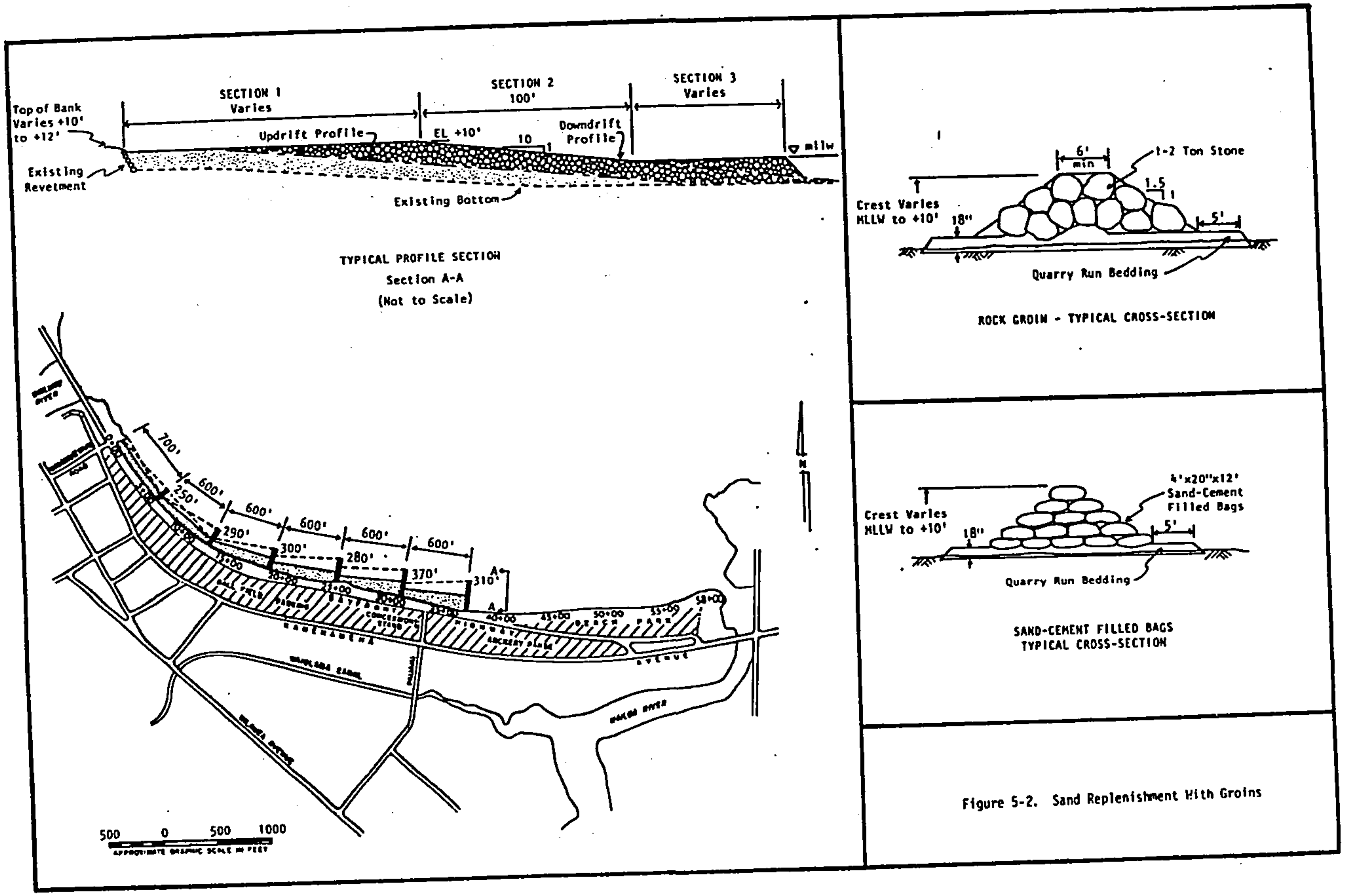


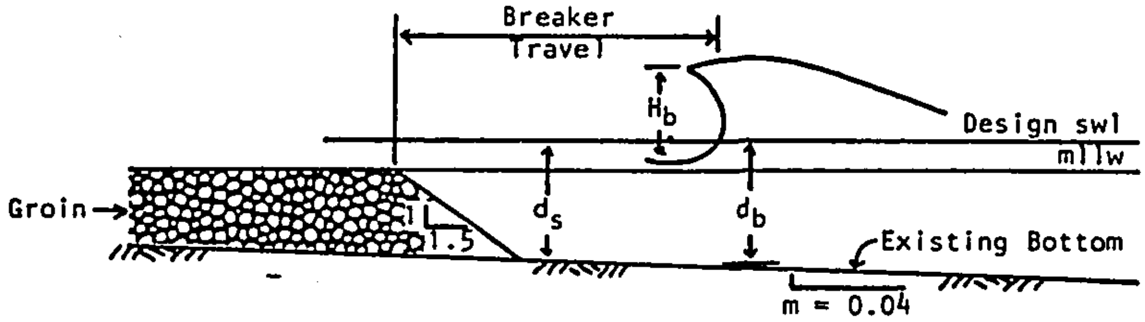
Figure 5-2. Sand Replenishment With Groins

Groins could be constructed by using either standard rock rubblemound techniques or, as an alternative, the less expensive and probably less durable sand-cement filled bags. Typical cross-section profiles for both the rock groin and the sand-cement bag groin are shown on Figure 5-2. The required rock groin stone weight calculations are shown on Table 5-2. Care must be exercised to insure that the foundation of any structure placed on the shoreline is adequate to protect against failure due to scour and undermining of the toe by wave action. This is of particular concern in an area such as Bayfront Beach, where the shoreline is composed of readily erodible, unconsolidated marine and alluvial deposits. Both the rock groin and the sand-cement bag groin should be placed on a bedding layer of quarry run stone, a minimum of 18 inches thick and extending 5 feet out from the groin toe.

Beach Replenishment with Detached Breakwaters

Description. A detached breakwater is a structure constructed offshore, parallel to the shoreline, which reduces wave energy and the direction of wave propagation in its lee. They can be very effective for controlling the longshore transport of sand by reducing or eliminating the wave energy reaching the shore. Their effectiveness for erosion control is directly proportional to their wave attenuation. Littoral drift deposits in the lee of the breakwater, and if the wave energy is sufficiently reduced, the sand deposits can form natural groins, called tombolos, which stretch from the shoreline to the structure and completely block longshore transport. The breakwater need not act as a complete littoral barrier, however; a low elevation overtopping detached breakwater may be economical and still reduce longshore transport. Adequate protection can usually be achieved if the structure causes the waves to break, but still transmits some of the wave energy. A series of short breakwaters can have the same general effect as a larger structure or a series of groins, although their efficiency as a sand trap may be reduced.

Table 5-2. Rock Groin Design Calculations



Design Breaker Height (H_b)

	T	H_o	d_s	Max H_b Sta 0+00-25+00	Sta 25+00 -40+00	Min Depth	Distance Offshore	Travel
SPM Fig. 7-4:	12 s	-	11'	12.7'	12.7'	12.7'	400'	46'
	16 s	-	11'	13.2'	13.2'	13'	400'	48'
Numerical Model:	12 s	22.5'	11'	7.1'	-	8'	250'	26'
(10-yr storm)				-	4.1'	6'	120'	15'

H_b predicted by SPM Fig. 7-4 would break seaward of the structure. Use H_b = 8' from Sta 0+00 to 25+00, and H_b = 6' from Sta 25+00 to 40+00.

Armor Stone Weight (W)

$$W = \frac{w_r H_b^3}{K_D(s_r - 1)^3 \cot\theta}$$

where w_r, unit weight of stone = 165 lbs/ft^3
s_r, specific gravity of stone = 2.58
K_D, stability coefficient = 3.5 for angular stone
θ, side slope = 1:1.5

Use:	Groin Section 1&2 (Trunk)	Groin Section 3 (Head)
H_b = 8'	1-2 ton stone	min 2 ton stone
H_b = 6'	0.5-1 tone stone	min 1 ton stone

Design. A restored beach stabilized by a series of detached breakwaters is shown on Figure 5-3. Sand would be initially placed to form a minimum 50-foot-wide crest at the +10-foot elevation. A series of six detached breakwaters, each 400 feet long and separated by a gap of 200 feet, would be constructed 150 feet offshore at the six to eight-foot depth. The breakwaters would extend from station 2+00 to station 36+00. The crest elevation would be at the design stillwater level (+3.3 feet), the crest width would be 12 feet, and side slopes would be 1 on 2. The breakwaters would be rock rubblemound construction, using minimum 2-ton armor stones over a core of 300 to 500-pound stone and a bedding layer of quarry run to 50 pound stone. Design calculations are shown on Table 5-3.

Rock rubblemound is considered the only feasible construction technique for the breakwaters. Sand-cement filled bag construction would require 800 to 1,000 bags for each breakwater, most of which would have to be filled underwater. Longard tubes would not have the necessary crest elevation or width.

Perched Beach and Artificial Surf Shoal

Description. The perched beach concept involves retaining a protective beach or shallow offshore area by means of terracing using submerged breakwaters or beach retaining sills. Wave energy is dissipated while propagating over the shallow region by breaking and through bottom friction and, thus, sediment transport along the shoreline is reduced. As with other protective beach systems, an abundant supply of sand in the active wave zone is necessary for beach sills to function properly. For Hilo, it will be necessary to artificially fill the terraces initially, and probably to nourish the beach periodically. Several terraces can be used to maintain a wide dry beach at the desired elevation.

The concept of constructing a man-made shoal area, such as a perched beach, to provide shore protection and to provide recreational opportunity by creating or enhancing surfing waves is also possible.

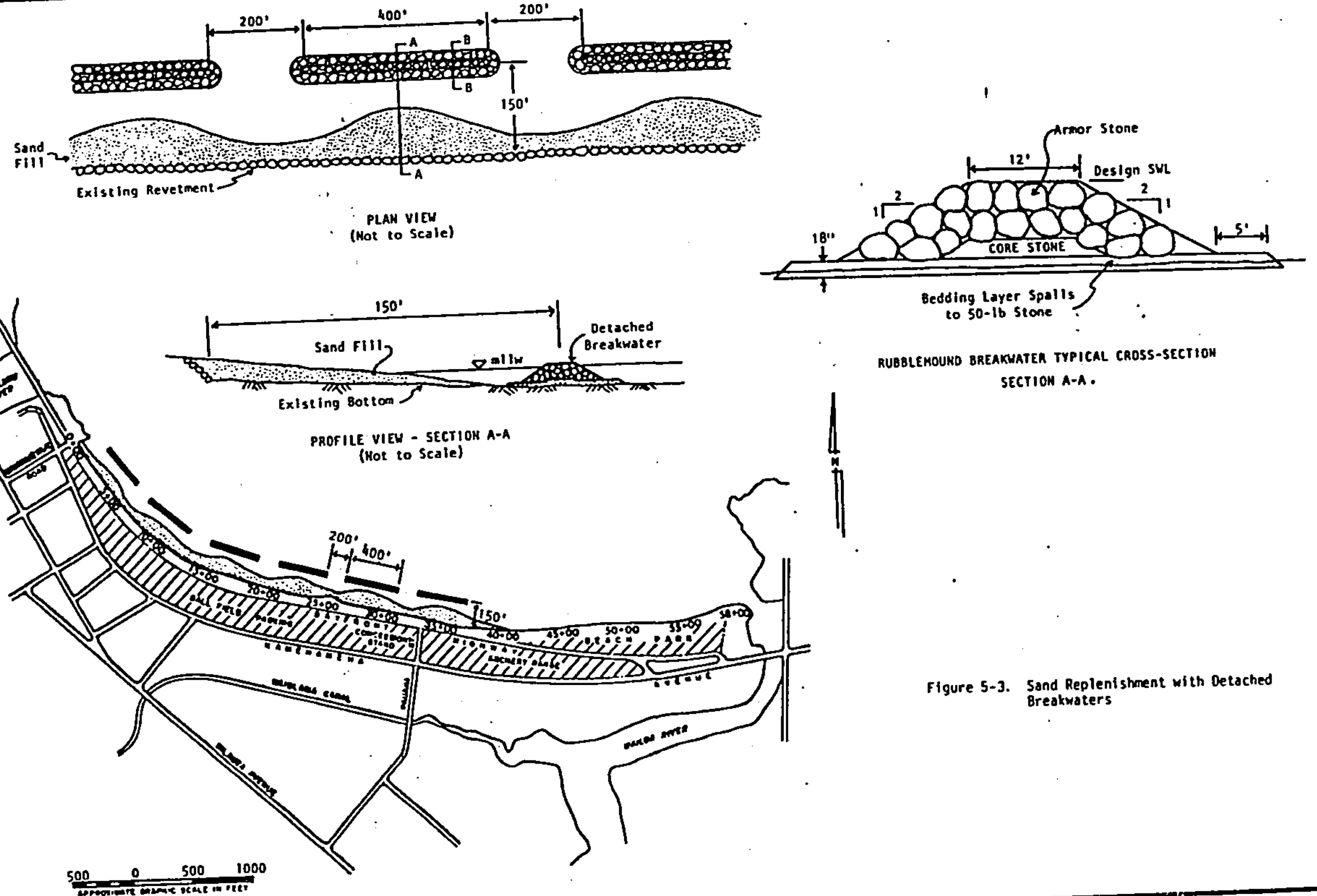


Figure 5-3. Sand Replenishment with Detached Breakwaters

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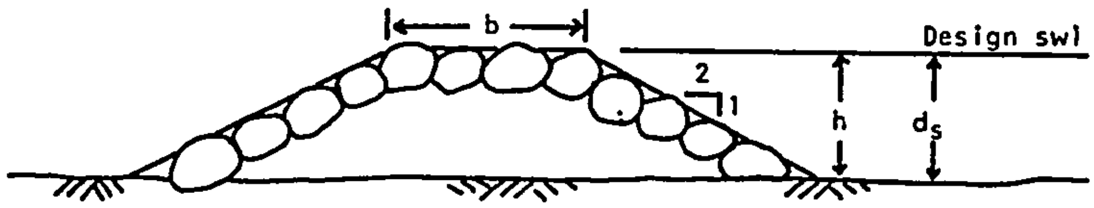
Table 5-3. Detached Breakwater Design Calculations



Design Breaker Height (H_b)

Same as shown on Table 5-1: Sta. 0+00 to 25+00 - 8'
Sta. 25+00 to 40+00 - 6'

Armor Stone Weight (W)

Same as shown on Table 5-1 plus 25% for overtopping safety factor.

Sta. 0+00 to 25+00 - 2-3 ton stone
Sta. 25+00 to 40+00 - 1-1.5 ton stone

Wave Transmission (permeable rubblemound breakwater)

H_i = 8', T = 12 sec, b = 12', h = 11.3', d_s = 11.3'

b/h = 12'/11.3' = 1.06; h/d_s = 11.3/11.3' = 1.0

$H_i/gT^2 = 8/(32.2)(12)^2 = 0.0017$; $d_s/gT^2 = 0.0024$

From SPM Figure 7-40: $H_t/H_i \approx 0.4$

Thus, the breakwater reduces the wave height at the shoreline by 60%, from 8' to about 3.2'. The resultant energy reduction is about 85%.

A report prepared by Moffatt & Nichol, Engineers (1981) for the Los Angeles District of the Corps of Engineers discusses the general feasibility of constructing an artificial surf shoal or modifying coastal structures to create or enhance recreational surfing.

A perched beach and surf shoal using Longard tubes to construct the sills is shown on Figure 5-4 and described in detail in the following paragraph.

Design. The perched beach would be constructed using double 40" Longard tubes parallel to shore to form a terraced beach slope. One double tube sill would be placed 100 feet offshore at the approximate 6-foot depth and then backfilled with sand, and the second double tube sill would be on top of the fill 50 feet from shore at the approximate mllw line and backfilled. A double 40" tube would also be run perpendicular to shore at 600-foot intervals to compartmentalize the perched beach and act as a groin to retard any longshore sand transport. Protection against scour and undermining of the tubes would be provided by placing them on woven plastic filter cloth secured by 10" sandfilled "sacrificial" tubes. The perched beach would extend from station 5+00 to 35+00.

The surf shoal would be constructed between stations 0+00 and 5+00. Longard tubes would be used to create a terraced, parabolic-shaped shoal extending approximately 220 feet seaward of the existing shoreline, as shown on Figure 5-4. This location has the greatest exposure to approaching waves without being immediately adjacent to the Wailuku River mouth and the potential for river debris damage to the Longard tubes. A small change in water depth produces a large change in wave height near the breaker zone, and the shoal, with contours at an angle to the incident wave approach, would produce a rapid variation in wave height along the wave crest line. The shoal would refract the incident waves and cause them to peak up and thus help to initiate breaking. A wave does not break instantaneously, but rather over some distance related primarily to the bottom slope. Galvin (1968) estimates that the breaker travel distance upon encountering an abrupt depth transition is about five times

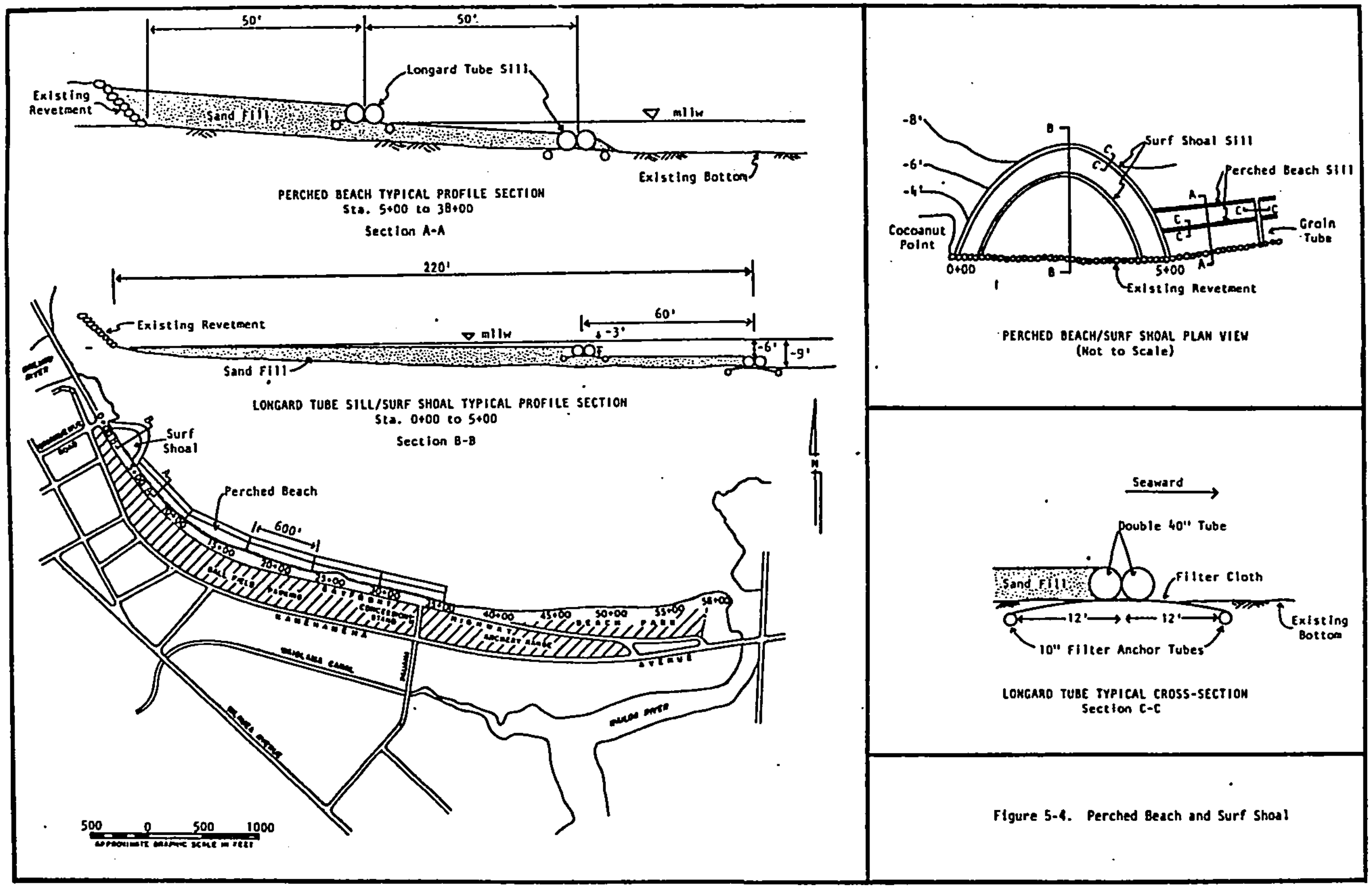


Figure 5-4. Perched Beach and Surf Shoal

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the breaker height. Wave theories, however, are not very precise near the breaker zone. Refraction analysis by linear wave theory gives only an indication of the general wave convergence or divergence and is not valid in the breaker zone and over complex bathymetry such as the surf shoal. A hydraulic model study is necessary to refine the surf shoal design to provide reasonable breaking wave patterns for surfing.

Rock Revetment

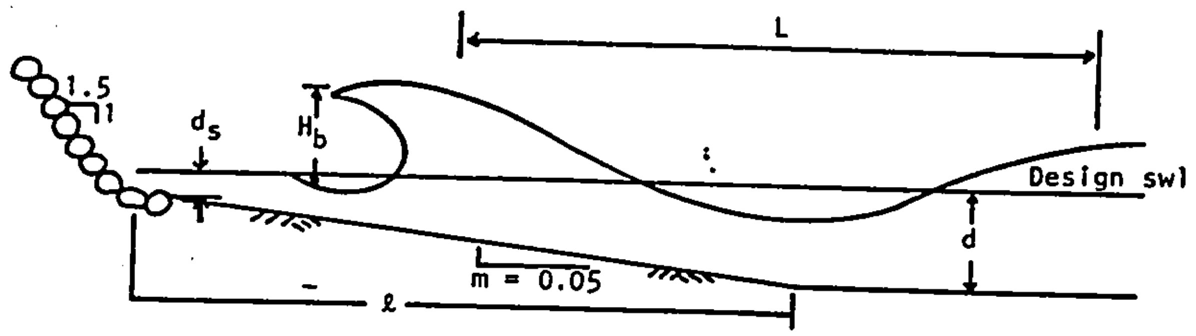
Description. Should a protective beach not be desired along the entire length of the bayfront beach, a rock revetment could be used to provide protection against damage and overtopping of the bayfront highway. Properly designed rock revetments are durable, flexible, and highly resistant to wave damage.

Design. The most common method of revetment construction, and generally the most satisfactory, is to place armor stone sized according to the design breaking wave height over an underlayer and bedding layer designed to distribute the weight of the armor stone and to prevent the loss of shoreline material through voids in the armor stone. Generally, the slope of the revetment should not be steeper than 1V on 1.5H. Toe scour protection can be provided by constructing the foundation as much as practicable below the maximum depth of anticipated scour (a general rule is one design wave height below the sea bottom fronting the structure) and extending the toe seaward to provide excess stone to fill the possible scour trough and to provide wave protection to the toe to prevent scour. Rock revetment design calculations are shown on Table 5-4, and a typical rock revetment section is shown on Figure 5-5.

Evaluation of Improvement Alternatives

A summary comparison and evaluation of the shoreline improvement alternatives is presented on Table 5-5. Detailed cost estimate breakdowns are provided in Appendix A.

Table 5-4. Rock Revetment Design Calculations



Design Breaker Height (H_b)

Use methodology contained in the SPM (Fig. 7-4). Maximum breaker heights calculated by the numerical model break well seaward of the shoreline position of the revetment.

H_b from SPM Fig. 7-4:

T	d_s	H_b
12 sec	3.3'	4.5'
16 sec	3.3'	4.6'

Armor Stone Weight (W)

$$W = \frac{w_r H_b^3}{K_D (s_r - 1)^3 \cot\theta} = \frac{(165)(4.6)^3}{3.5(2.58 - 1)^3(1.5)} = 775 \text{ lbs}$$

Use 2 layers, 800- to 1,200-lb stone.

Armor Layer Thickness (t)

$$t = nK\left(\frac{W}{w_r}\right)^{1/3}, \text{ where } n = 2 \text{ layers and } K = 1.15$$

$$= 2(1.15)\left(\frac{1000}{165}\right)^{1/3} = 4.2 \text{ feet}$$

Underlayer Stone Size

W/10 = spalls to 100 lb

Table 5-4. (continued)

<u>Crest Elevation</u>

Runup calculation based on methodology in Stoa (1978 & 1979).
Assume $H_b \approx H'_o = d_s/H'_o = 3.3'/4.6' = 0.7$.
Wave length, $L = T\sqrt{gd}$; for 16-sec wave in 10 depth $L = 287'$.

For $\ell = 150'$; $\ell/L = 0.52$.
Interpolating between Fig. 8 & 9 (Stoa, 1978) for $\cot\theta = 1.5$ and $H'_o/gT^2 = 0.0006$; $R/H'_o = 4.9$ on smooth slope. From Stoa (1979), Appendix A, $r = 0.6$.
Runup, R (rough slope) $= (K)(r)(H'_o)(R/H'_o)_{ss} = (1)(0.6)(4.6)(4.8) = 13.2'$.
Non-overtopping crest elevation = R + SWL = 13.5' + 3.3' = 16.5'.
Use minimum elevation +15 feet with 3 stone crest width.

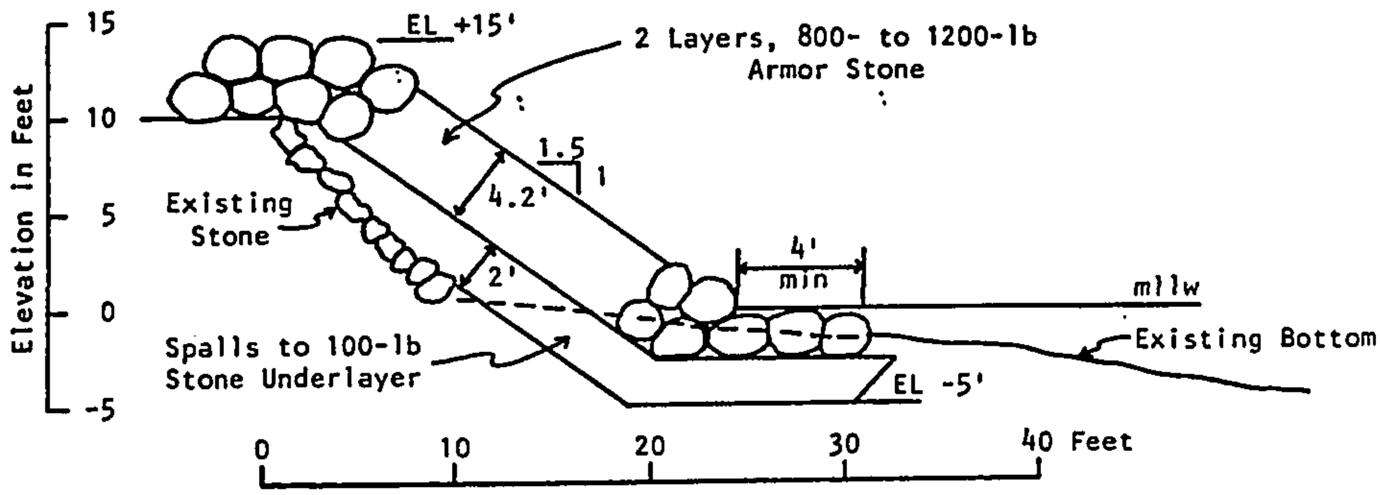


Figure 5-5. Typical Rock Revetment Section

Table 5-5. Evaluation and Comparison of Alternative Shoreline Improvements

Evaluation Criteria	Sand Replenishment With Groins: Rock Groins	Sand Replenishment With Groins: Sand-Cement Filled Bags	Sand Replenishment With Detached Breakwaters	Perched Beach With Surf Shoal	Rock Revetment
I. Meets project objectives					
a. Shore protection for the bayfront highway	A stable protective beach would dissipate wave energy and provide storm wave protection for the bayfront highway.	Would provide protection similar to that of the beach stabilized by rock groins.	Would provide excellent storm wave protection for the shoreline by retaining a protective beach as well as dissipating wave energy by initiating breaking well offshore.	A stable protective beach and shallow nearshore depths would dissipate wave energy and provide storm wave protection.	The non-overtopping rock revetment would provide complete protection for the bayfront highway.
b. Recreational beach enhancement	A dry sand recreational beach area of approximately 540,000* square feet would be provided. Beach shape and orientation would vary seasonably.	Same as with rock groins.	Longshore sand transport would be significantly reduced by the reduction of wave energy at the shoreline.	The "compartmentalizing" of the shoreline would greatly reduce longshore transport, however, some transport over the groin tubes may occur due to their relatively low elevation.	No reduction in the predominant longshore transport toward the Wailoa River.
c. Reduction of longshore transport toward the Wailoa River	The groins would significantly reduce the longshore transport of sand by aiding the beach face to achieve a stable configuration parallel to the predominant wave crests. Only a small amount of sand would by-pass the groins during severe storm wave conditions and/or high sediment discharge from the Wailoa River.	Same as with rock groins.	A dry sand recreational beach of approximately 300,000 square feet would be provided.	A dry sand recreational beach of approximately 150,000 square feet would be provided. Access to the water may be hindered by the Longard tube sill. The artificial surf shoal would enhance recreational surfing, however, the quality of the waves for surfing would vary considerably with tide level and incident wave direction and height.	No significant change in the shoreline from existing conditions, and increased wave energy reflection may further reduce the seasonal sand accretion along the shore.
II. Engineering effectiveness and constructability	The natural beach slope would be a very effective energy absorber, and the use of groins would stabilize the protective beach and essentially eliminate longshore sand transport. Standard rock rubblemound construction techniques would be utilized for the groins. This plan would provide an effective and relatively maintenance-free protective and recreational beach.	If properly constructed, this plan would be as effective as the beach with rock groins. However, there is some question whether the bags can be properly filled with the sand-cement grout, particularly as they would have to be filled in-place and underwater along much of the groin length.	Properly designed detached breakwaters can be a very effective method for stabilizing and protecting a sand shoreline. More detailed engineering design studies are required prior to actual implementation of a beach nourishment project stabilized by detached breakwaters to fully assess the required breakwater spacing, crest elevation and width, and distance from shore to insure that the desired energy reduction is achieved. The breakwaters would be built using standard rock rubblemound construction techniques.	The perched beach concept is an effective way to dissipate wave energy seaward of the shoreline. The primary advantage of Longard tubes is the speed and ease with which the sills can be constructed once the sand is in place for filling. They are functionally effective as long as they remain structurally sound (intach and not torn) and are not displaced. The surf shoal concept must be studied using a hydraulic model in order to determine the most effective shape, size, and configuration for producing surfing waves. The percentage of time that it would provide surfable waves is probably low due to the generally low prevailing wave heights along the bayfront shoreline.	A properly designed and constructed rock revetment would provide proven protection for the highway. Construction is relatively easy.

*Beach area above the +2-foot elevation.

Table 5-5. (continued)

Evaluation Criteria	Sand Replenishment With Groins: Rock Groins	Sand Replenishment With Groins: Sand-Cement Filled Bags	Sand Replenishment With Detached Breakwaters	Perched Beach With Surf Shoal	Rock Revetment
III. Maintenance requirements	The groins are designed to minimize sand by-passing, and thus reduce the need to periodically nourish the beach. Some loss of sand can be expected, however, and a periodic nourishment rate of about 10 percent of the original beach fill every 10 years is considered reasonable for planning purposes. The rock groins are durable and long-lasting, and should require only nominal maintenance.	The durability of the sand-cement filled bag groins is directly related to the degree to which the bags can be evenly filled with the correct grout mixture. Properly filled, and if not displaced prior to hardening of the grout, the groins will be reasonably durable. If improperly filled (uneven mix or loss of cement during filling), the bags will readily crack and be subject to possible displacement by storm waves. Provided the groins remain functional, the beach nourishment requirements would be the same as for the rock groin plan.	Properly designed detached rock rubblemound breakwaters are durable and long-lasting. Beach nourishment requirements may be higher than for the groin plans due to sand being moved seaward between the breakwaters due to strong rip currents formed during severe storm wave attack.	Longard tubes are very vulnerable to damage by vandalism and floating debris. Surfboard fins could be a source for tearing or puncturing the tubes used to contain the surf shoal. Once torn, wave action can rapidly winnow sand out of the tube rendering them ineffective. Beach nourishment requirements are estimated to be similar to that for the detached breakwater plan.	A properly designed and constructed rock revetment is a time proven, durable and relatively maintenance free method for protecting a shoreline from erosion and the backshore area from storm wave damage.
IV. Cost (see Appendix A)					
Mob and Demob	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 30,000
Sand Fill*	5,600,000	5,600,000	4,400,000	1,289,000	0
Structures	1,571,000	1,196,000	3,284,000	1,155,000	2,372,000
Contingency (±25%)	1,839,000	1,744,000	1,966,000	656,000	598,000
TOTAL COST	$9,210,000	$8,740,000	$9,850,000	$3,300,000	$3,000,000

*Dredging quantity is twice the desired in-place fill quantity.

A reasonable plan of improvement would be to combine elements of several of the alternatives previously discussed in order to meet the project objectives while keeping the overall costs down. The Longard tube surf shoal at the west end of the beach would enhance recreational surfing and at the same time dissipate wave energy to reduce overtopping of the existing revetment. A protective beach constructed between stations 5+00 and 25+00 would protect the highway against storm wave damage and provide approximately 250,000 square feet of dry recreational beach area (beach area above the +2-foot elevation). The groins would be spaced at 500-foot intervals to optimize the number of groins required to stabilize the desired 20,000-foot reach, which would permit them to be slightly shorter while still maintaining their ability to stabilize the beach fill. The balance of the shoreline between stations 25+00 and 37+00, where the existing beach begins, could be protected by improving the existing sloping rock revetment.

Although there is very little longshore transport east of about station 40+00 during prevailing wind and wave conditions, there are occasional severe storms with high waves from the north coupled with high rainfall and a resultant high discharge from the Wailuku River, and during these periods sediment can be transported eastward to the Wailoa River. It is also recommended that a 200-foot long groin be constructed adjacent to the Wailoa River to block any littoral drift from reaching the navigation channel. This would reduce possible shoaling of the Wailoa River mouth and its adverse impact on the fishing boats which moor upriver and must daily navigate the river entrance. This groin would also act as a trap to collect any beach sand which does move eastward, and this sand can periodically be removed and used for maintenance of the beach at the updrift end of the shoreline.

The combination plan is shown on Figure 5-6, and the costs are given in Table 5-6.

Table 5-6.

Surf Shoal-Beach-Revetment Plan Costs

Feature	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	LS			$ 150,000
Surf Shoal				
Sand Fill –	CY	5,400	$ 10.70	58,000
Longard Tubes	Ft	1,200	150.00	180,000
Protective Beach with Rock Groins				
Sand Fill	CY	250,000	10.70	2,675,000
Groins	Ft	1,100	1,340.00	1,474,000
Rock Revetment	Ft	1,200	725.00	870,000
Jetty Groin	Ft	200	875.00	175,000
Contingency ±25%				1,396,000
			TOTAL COST	$6,978,000

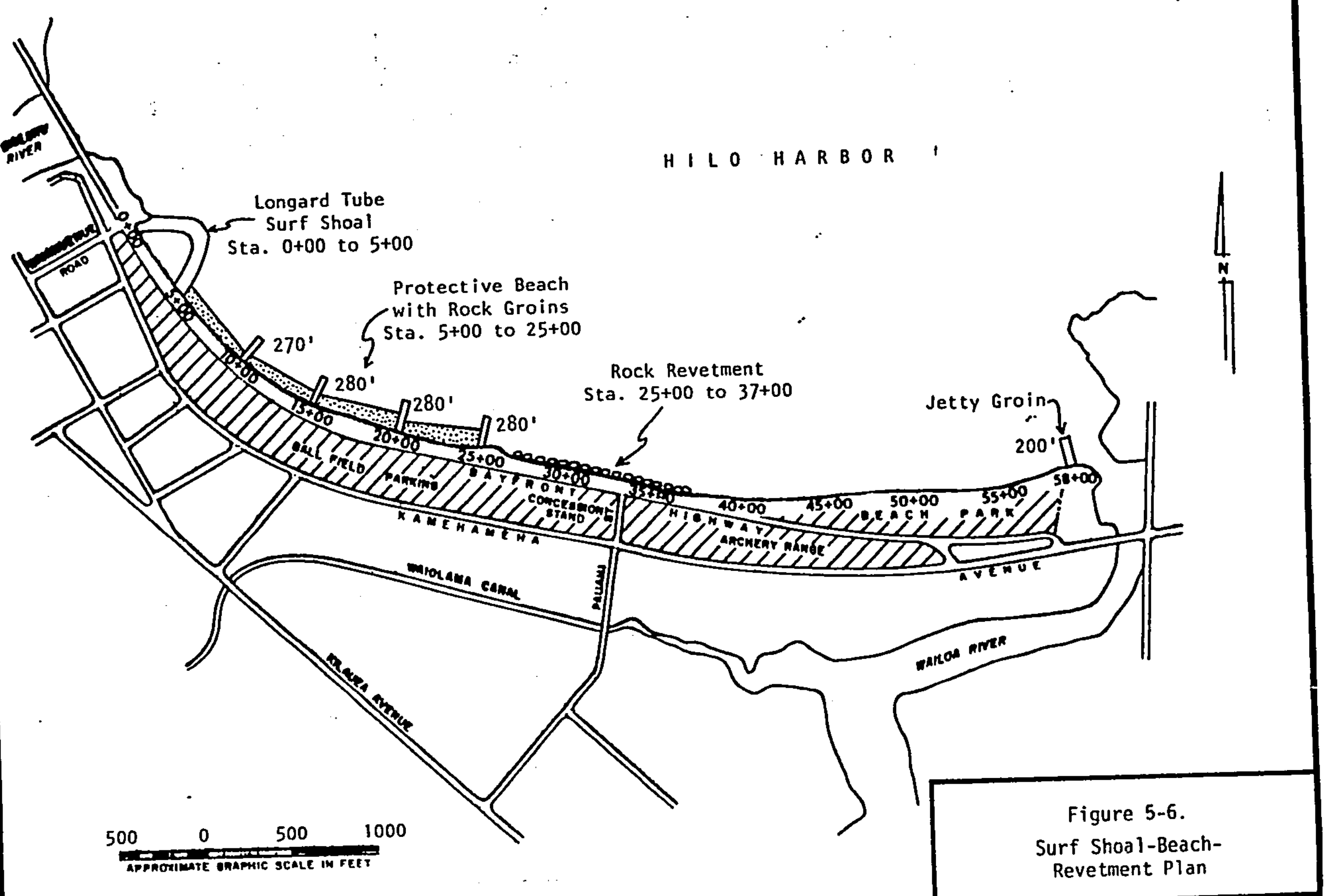


Figure 5-6.
Surf Shoal-Beach-Revetment Plan

MODIFICATIONS TO HILO BREAKWATER

Proposed Modifications

Modifications to the height of the existing Hilo breakwater have been proposed to aid in improving circulation and flushing on Blonde Reef and in the harbor area. Proposed modifications include removing armor and crest stone on the seaward 7,000 feet of the breakwater to reduce the crest elevation to approximately +3 feet, and to use this stone to construct a 2,000-foot long stub breakwater running east-west from the tip of the remaining unmodified existing breakwater. It is assumed for the numerical model analysis that wave action on the modified breakwater will further reduce the crest elevation to about mean sea level, resulting in a structure approximating a still water level elevation impermeable overtopping breakwater, as discussed in the SPM.

Numerical Model Analysis

Description. The effect of the proposed breakwater modifications on the wave energy input to Hilo Harbor was analyzed using the numerical model. The effect of the modified breakwater was simulated by assuming that a percentage of the incident wave energy was transmitted over the breakwater and continued to propagate toward shore. A transmitted wave height (H_t) versus incident wave height (H_i) ratio of $H_t/H_i = 0.28$ was used, estimated from information on SPM Figure 7-38. No refraction effects of the breakwater itself as the wave passed over were considered, nor was the wave period altered. The wave orthogonals were simply propagated shoreward over the breakwater with a 72 percent reduction in height occurring at the breakwater location. This is an over simplification, as the modified breakwater will certainly have some refraction effect on the wave, and more importantly, wave breaking initiated by the breakwater and subsequent reforming will likely change the wave period. The model does, however, reflect the energy increase along the shoreline as a result of modifying the breakwater. The energy coming over the modified breakwater must be added to the energy which already enters the harbor under the existing conditions to determine the total net energy flux along the shoreline.

The impact of breakwater modifications on the energy entering Reeds Bay and the commericial port area was assessed by analyzing diffraction and refraction around the proposed 2,000-foot long non-overtopping stub breakwater.

Results. Refraction and diffraction patterns for waves propagating over the reduced elevation existing breakwater and around the new stub breakwater are shown on Figures 6-1 through 6-7. Total net longshore energy flux along the bayfront beach with and without the breakwater modifications is also shown on Figures 6-1 through 6-7. The total energy flux with the breakwater modifications includes the energy entering the harbor under existing conditions, as well as the additional energy coming over the lower elevation breakwater. As is evident in the figures, wave refraction over Blonde Reef is very complex, and the caustics which appear to develop make accurate calculation of wave refraction and thus net energy flux along the shoreline using numerical techniques somewhat questionable. However, as Griswald (1963) disucsses, ". . . a refraction diagram for a single wave period and direction represents an infinitesimal amount of energy in the wave spectrum. When this infinitesimal amount is infinitely increased, as represented by the crossing of adjacent rays, it is possible that only a finite amount of energy results. Thus, it would not be inconsistent for waves to pass through this region without breaking, as is often observed in nature. The refraction coefficient should be representative of the wave energy beyond a caustic if diffraction is insignificant."

Impacts of Breakwater Modifications

Bayfront Beach. Seasonal and annual total net longshore energy flux with the proposed breakwater modifications are shown on Figure 6-8. More east to west energy flux is evident, particularly during the summer season, however, the general energy flux patterns along the shoreline are not greatly changed by the proposed breakwater modifications. This

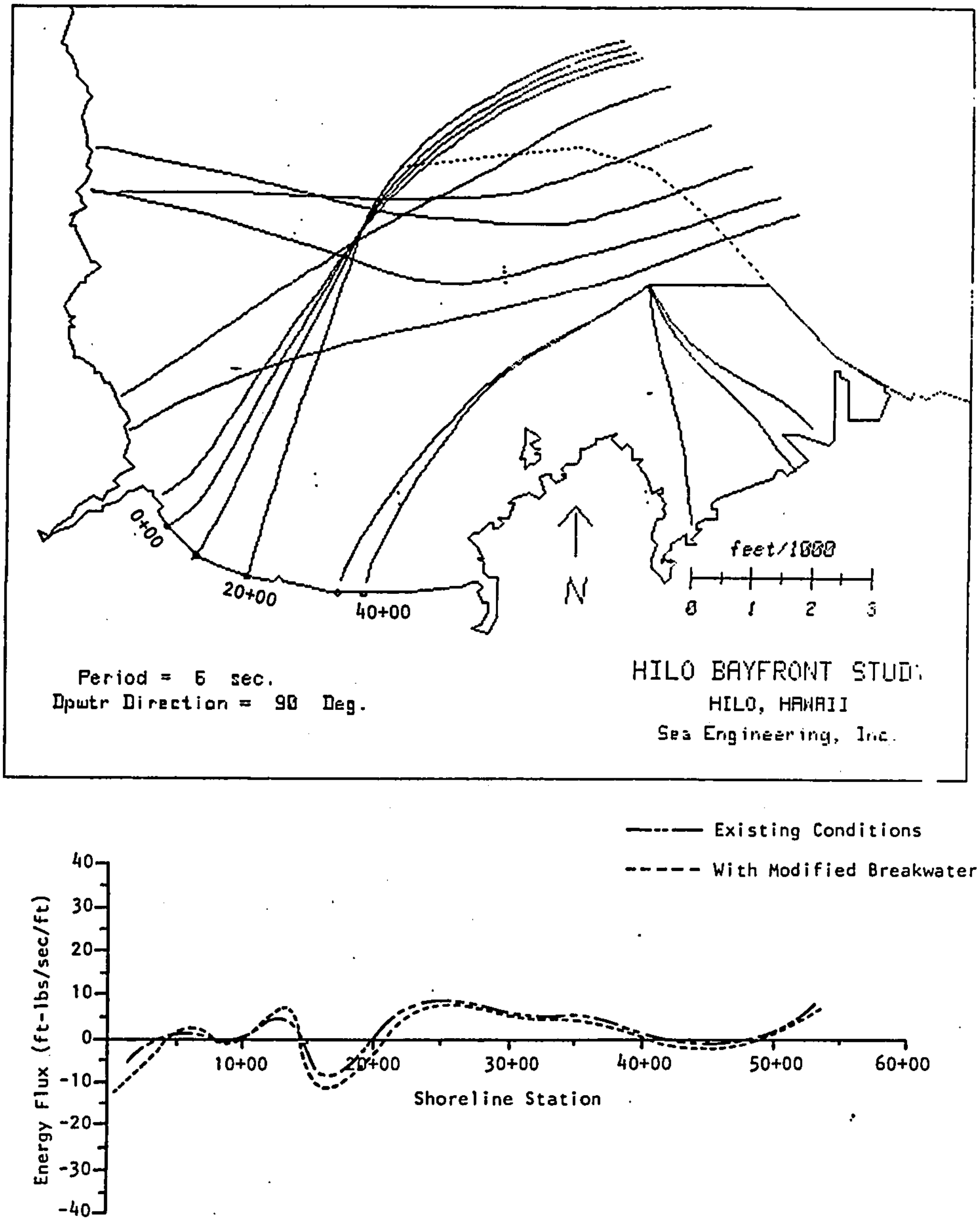
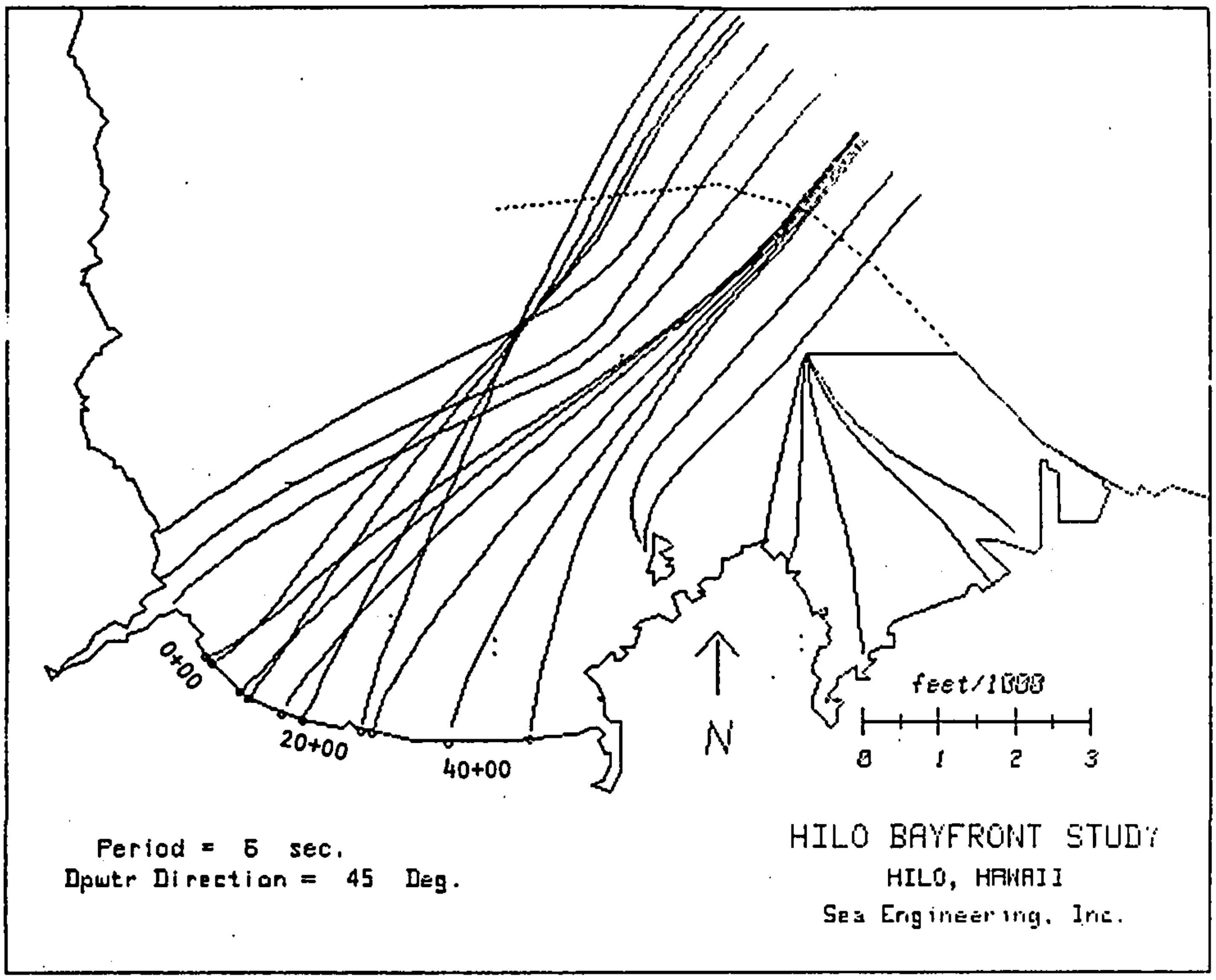


Figure 6-1. Modified Breakwater Refraction and Diffraction Patterns and Longshore Energy Flux for T = 6 sec, H_o= 5 feet, Dir = 090°



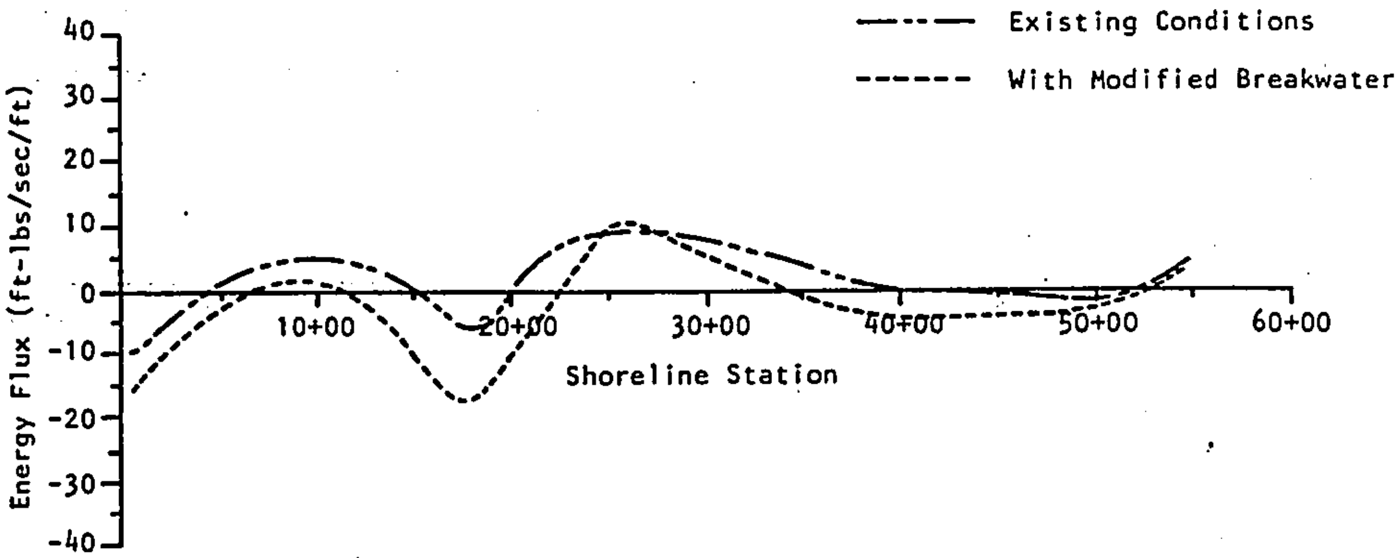
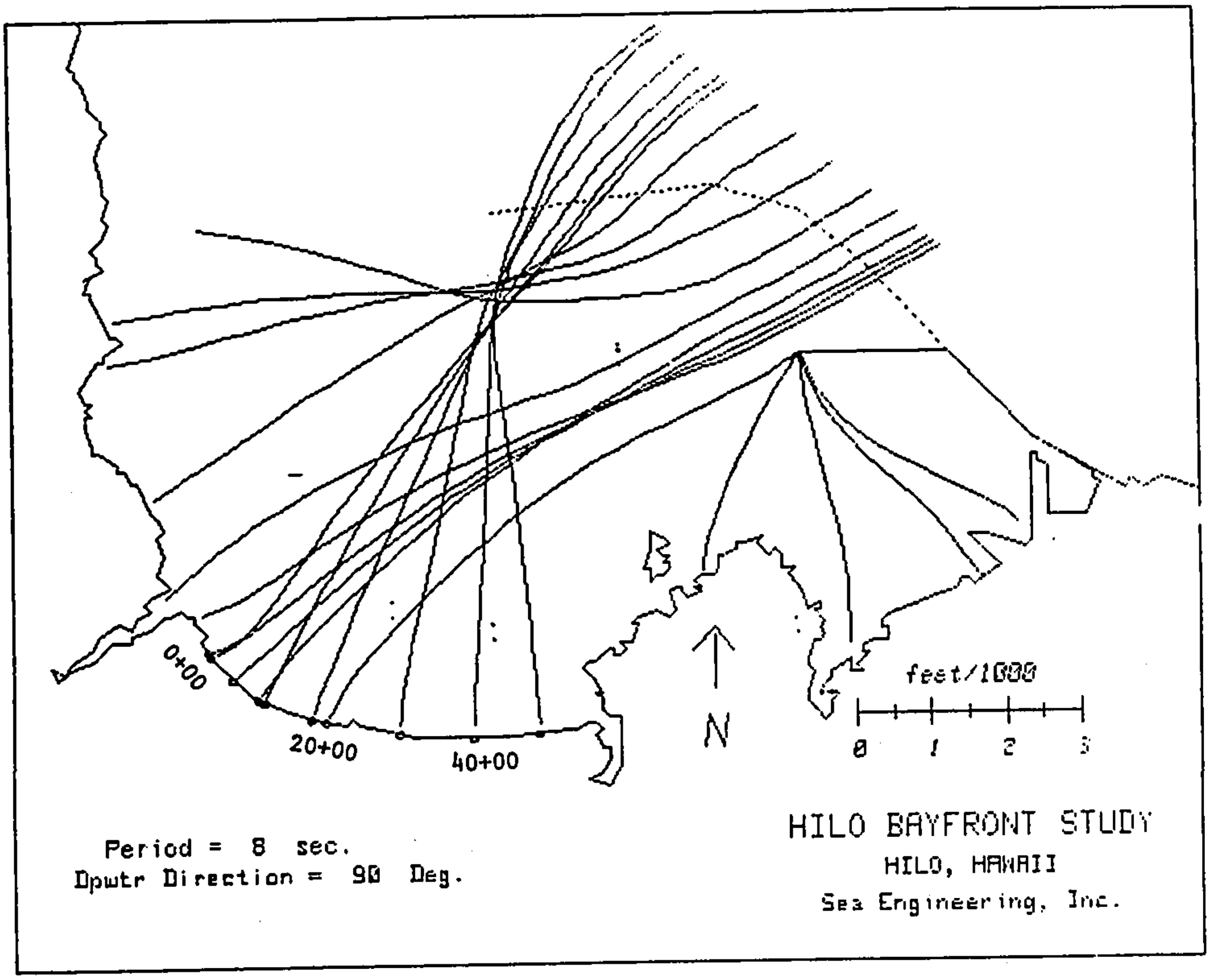


Figure 6-2. Modified Breakwater Refraction and Diffraction Patterns and Longshore Energy Flux for T = 6 sec, H_o = 5 feet, Dir = 045°



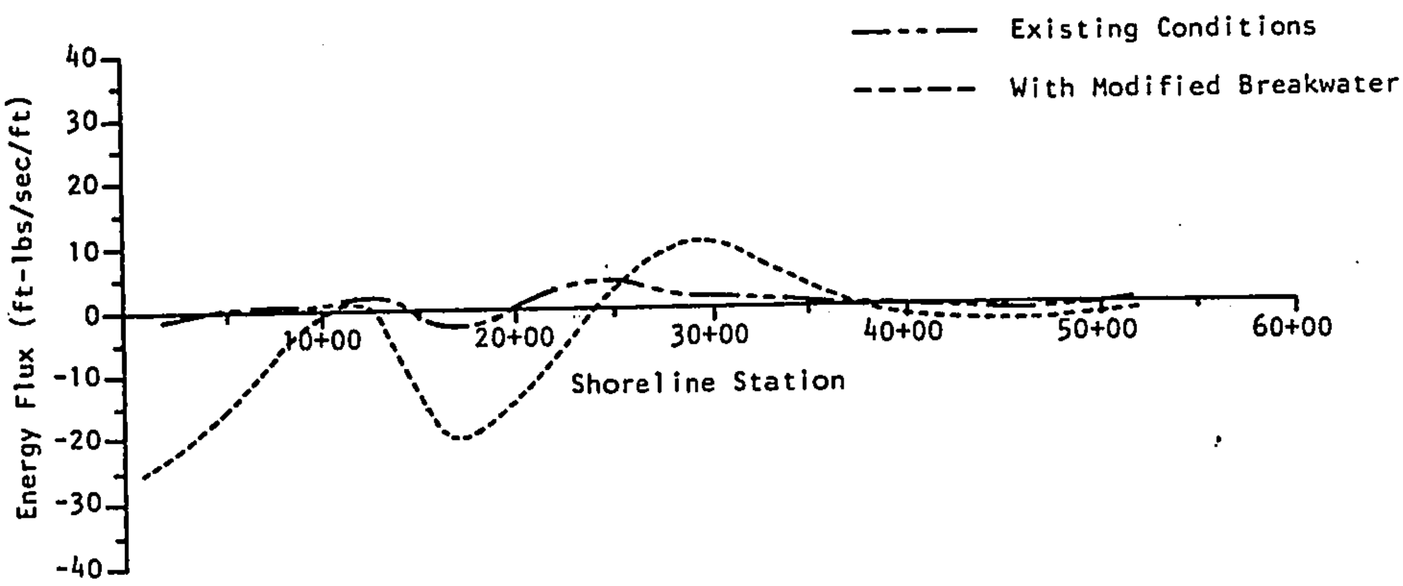


Figure 6-3. Modified Breakwater Refraction and Diffraction Patterns and Longshore Energy Flux for T = 8 sec, H_0 = 8 feet, Dir = 090°

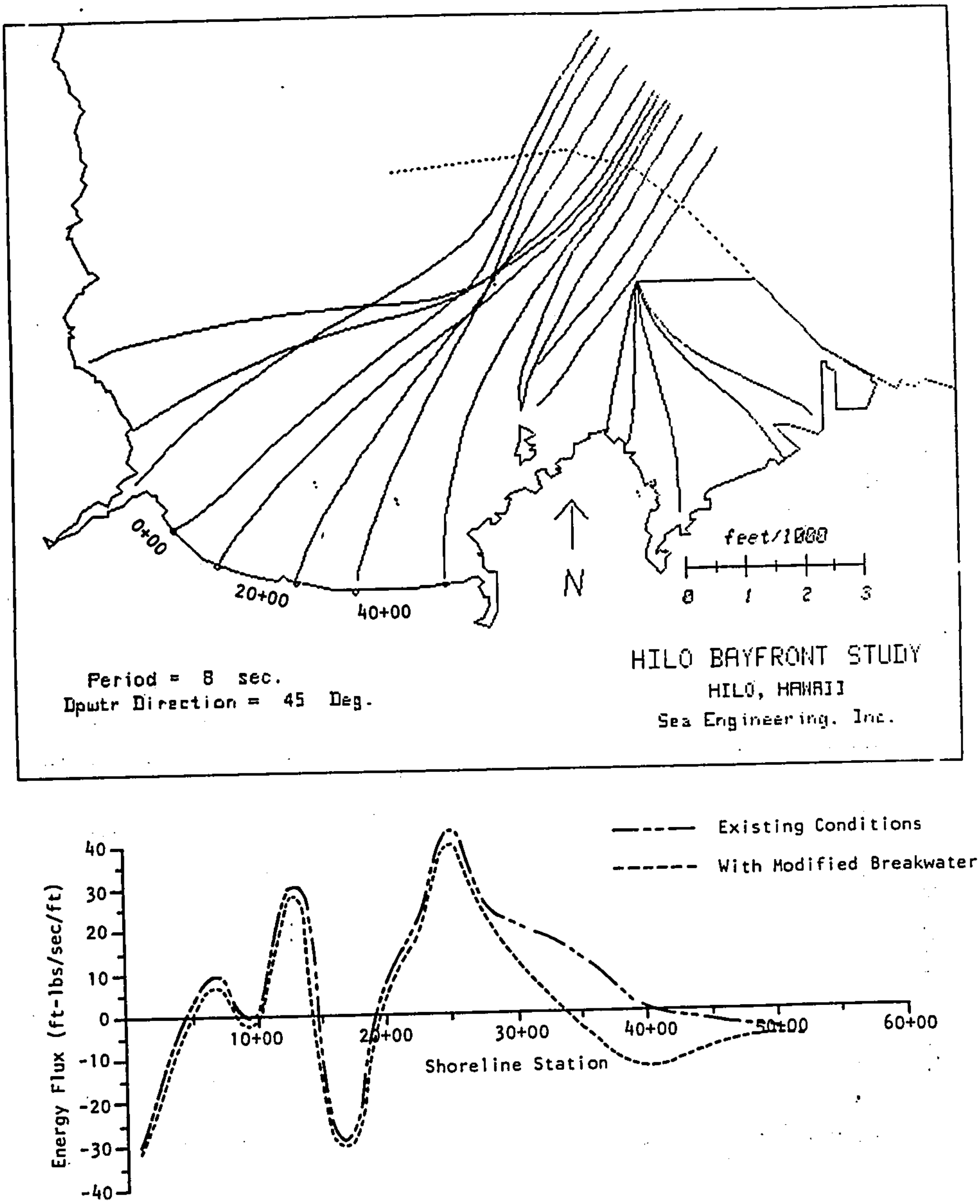
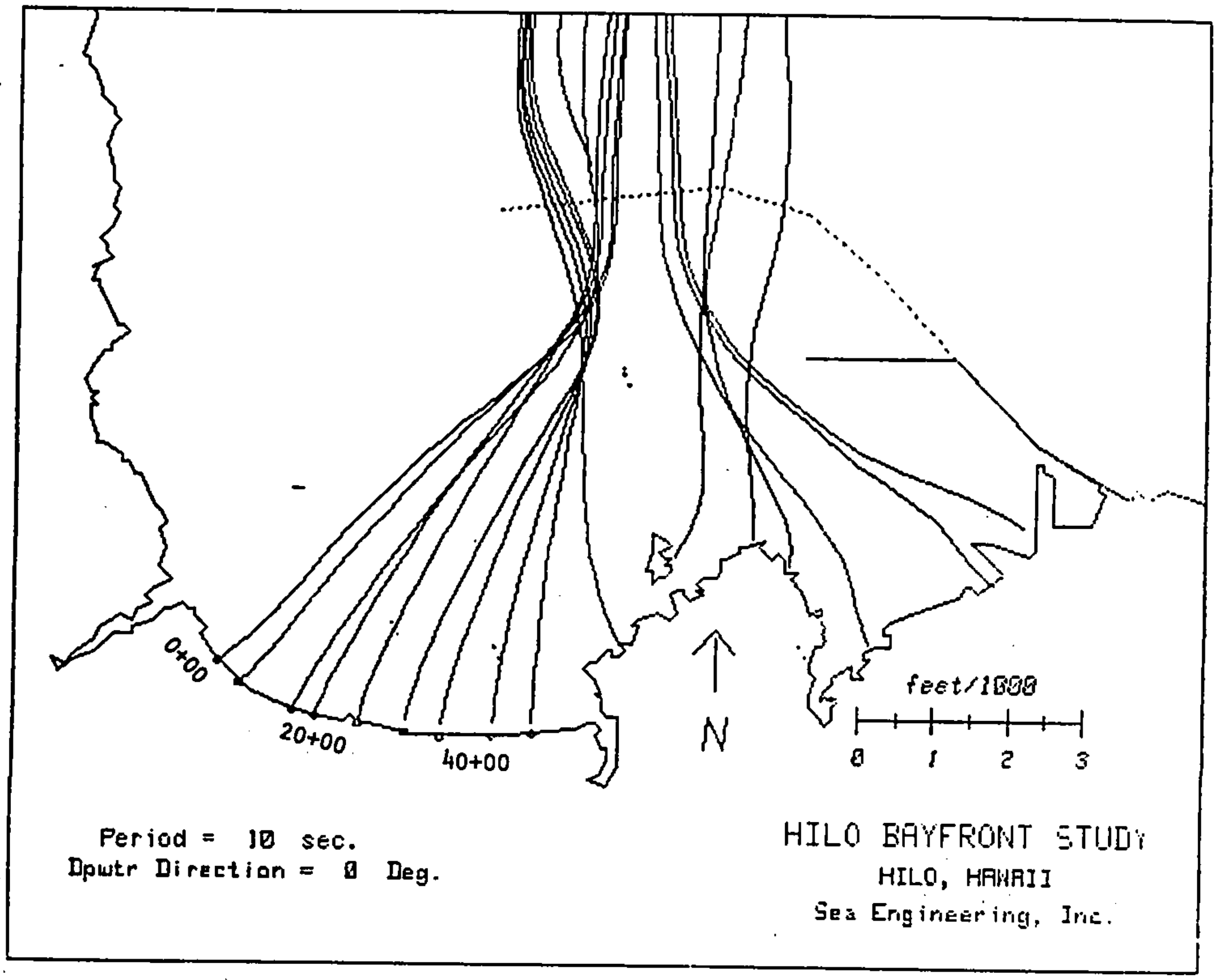


Figure 6-4. Modified Breakwater Refraction and Diffraction Patterns and Longshore Energy Flux for T = 8 sec, H_0 = 8 feet, Dir = 045°



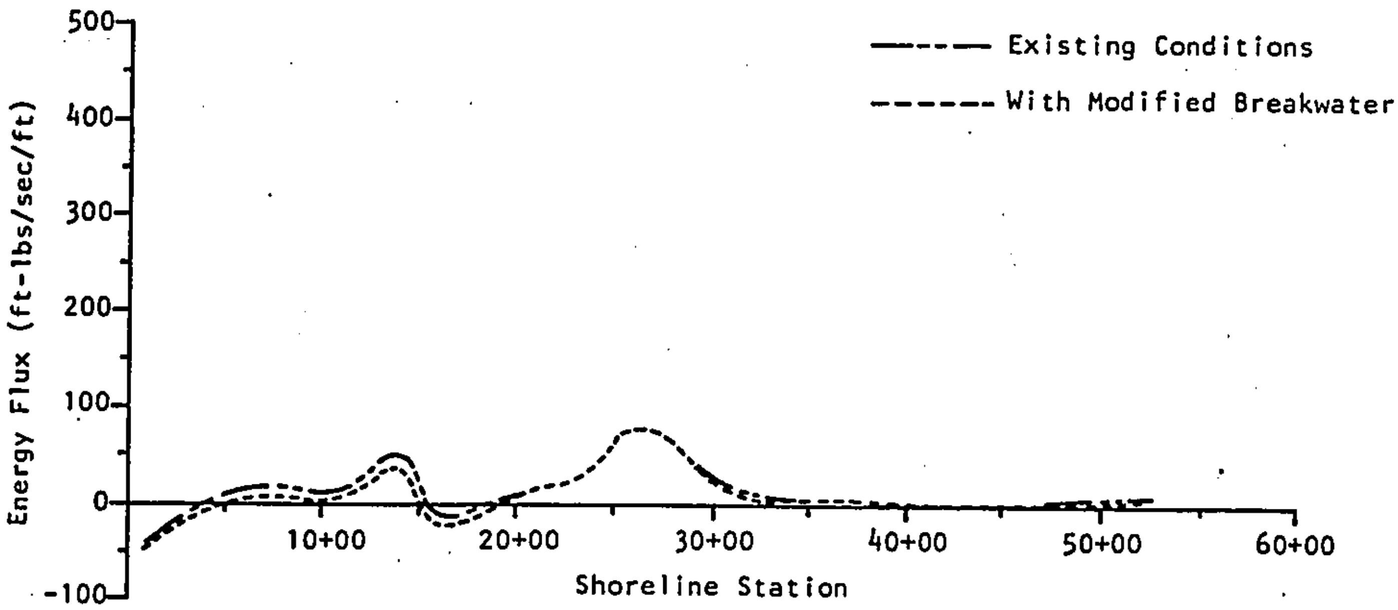
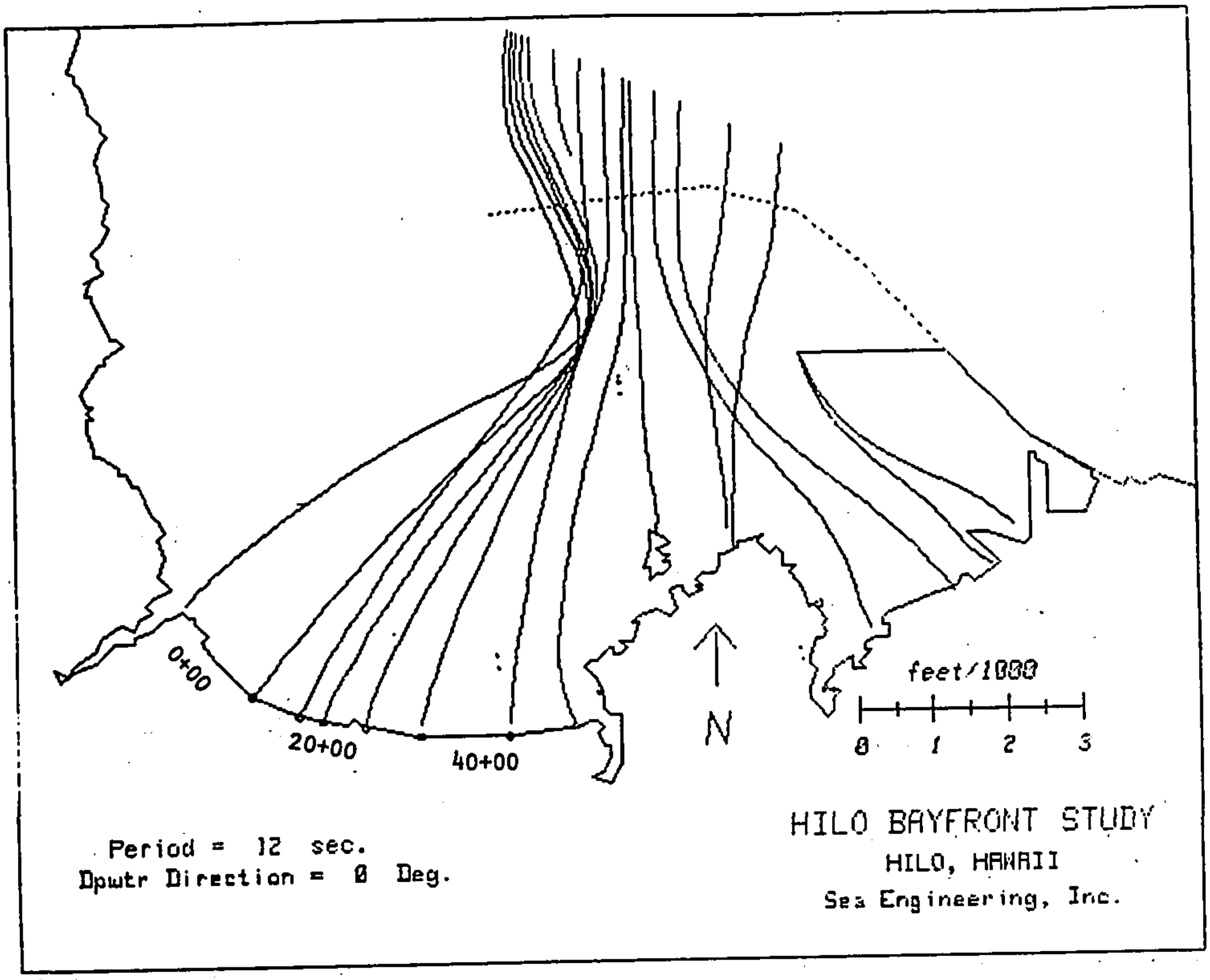


Figure 6-5. Modified Breakwater Refraction and Diffraction Patterns and Longshore Energy Flux for T = 10 sec, H_0 = 5 feet, Dir = 000°



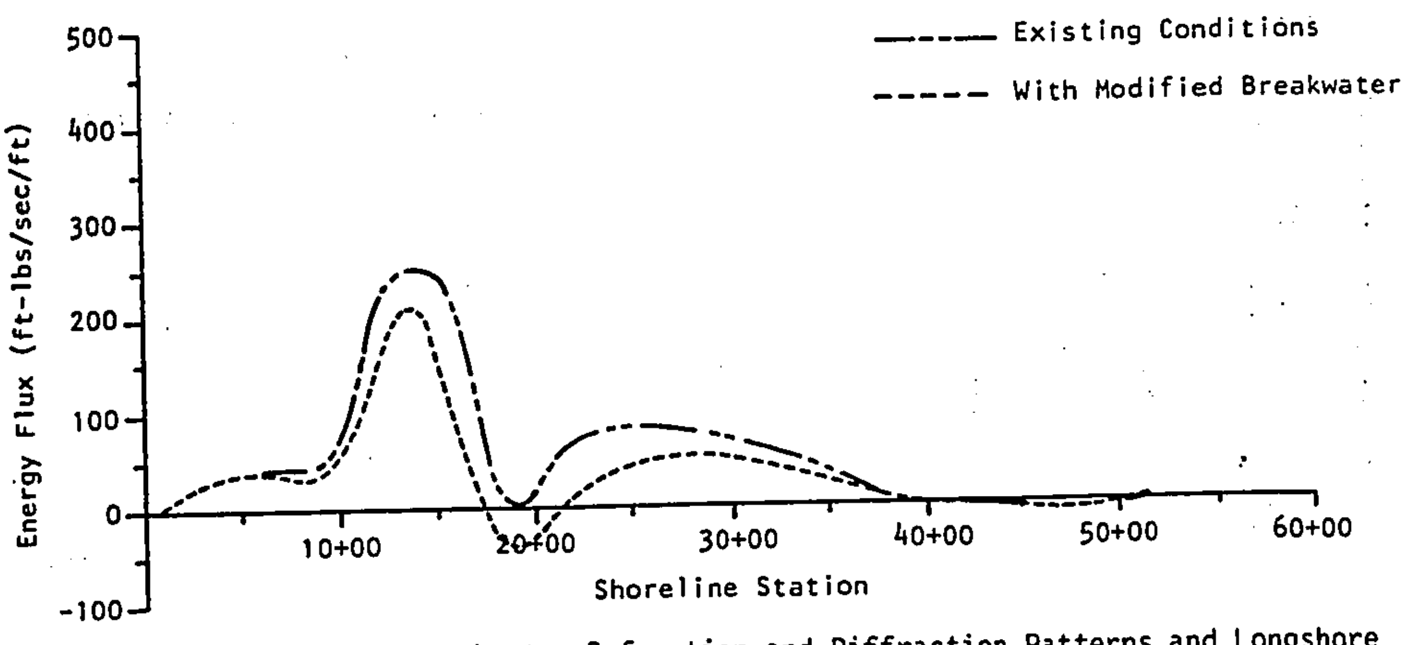


Figure 6-6. Modified Breakwater Refraction and Diffraction Patterns and Longshore Energy Flux for T = 12 sec, H_0 = 10 feet, Dir = 000°

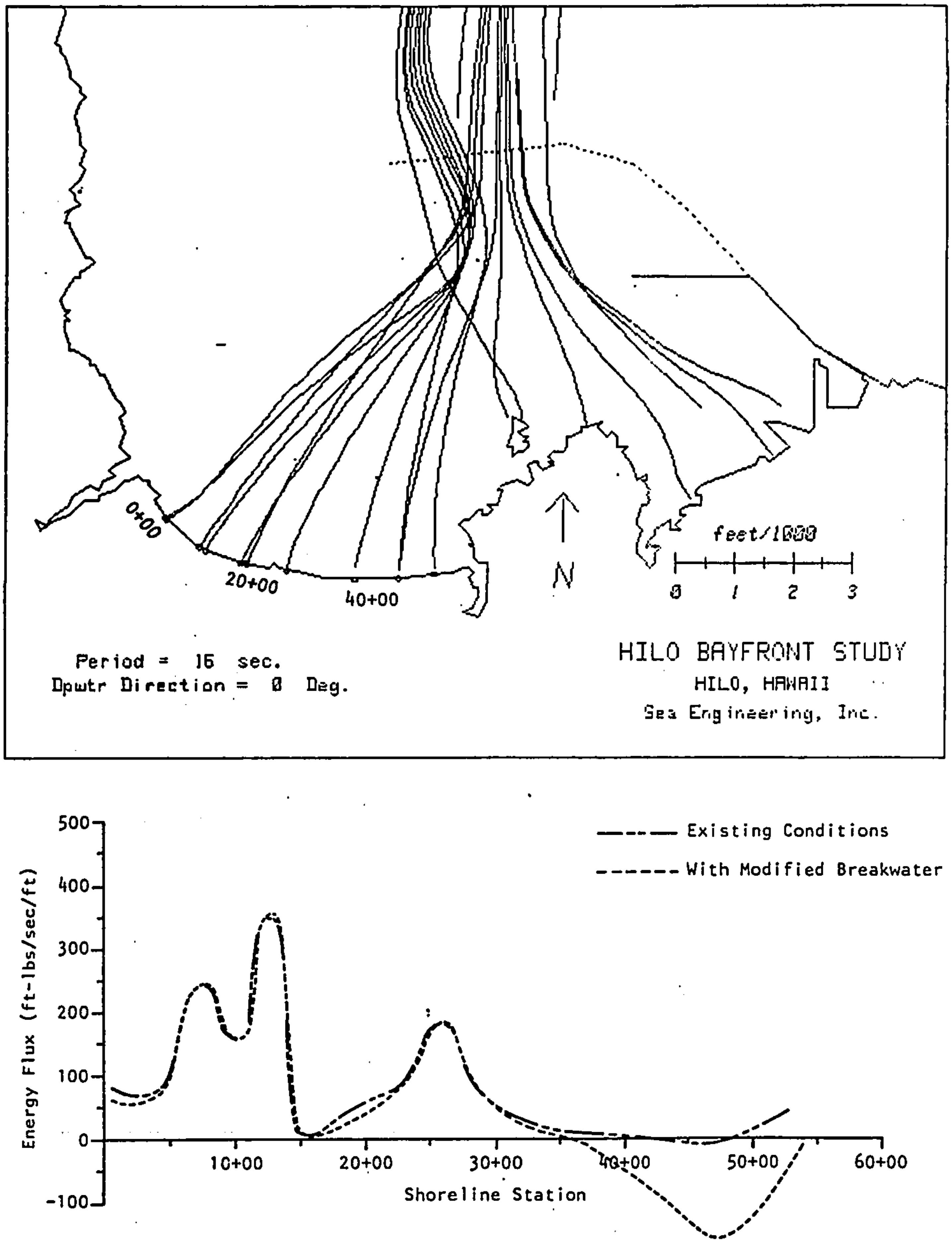


Figure 6-7. Modified Breakwater Refraction and Diffraction Patterns and Longshore Energy Flux for T = 16 sec, H_0 = 15 feet, Dir = 000°

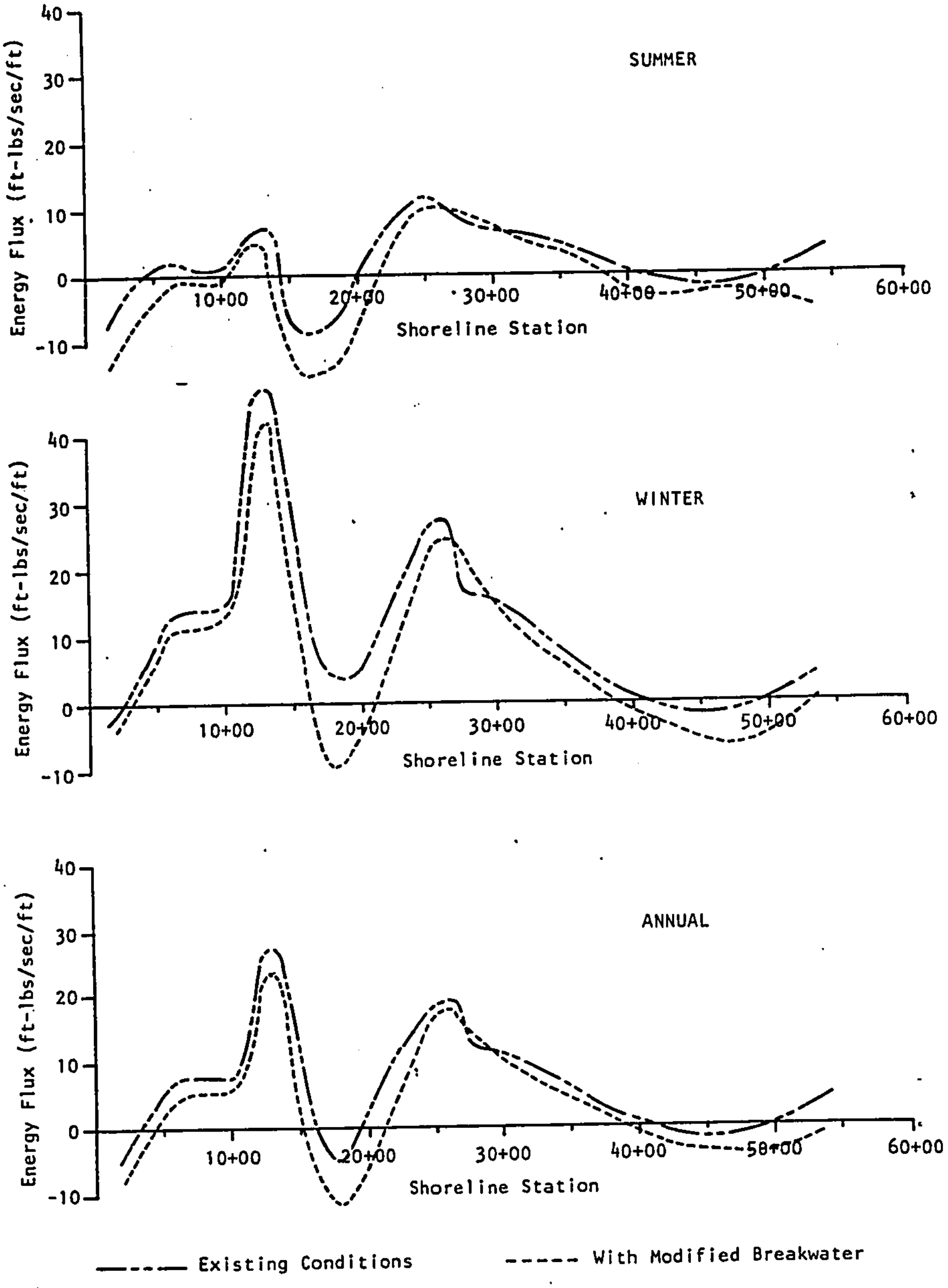


Figure 6-8. Seasonal and Annual Net Longshore Energy Flux With Modified Breakwater

is presumably because the mean sea level breakwater still acts as a considerable barrier to wave energy approaching from easterly directions. The major impact on the shoreline as a result of the proposed modifications appears to be to cause a net energy flux, and hence, longshore transport, from east to west along the western half of the bayfront shoreline (Sta. 0 to 20+00) during the summer months. This reverses during the winter season and net transport is again west to east along most of the shoreline, with a more pronounced direction reversal, or nodal point, centered between about Sta. 15+00 to 20+00.

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APPENDIX A
CONSTRUCTION COST ESTIMATES

Appendix A

CONSTRUCTION COST ESTIMATES

I. Sand Replenishment with Rock Groins

Item	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	LS			$ 150,000
Dredging and Beach Fill[1/]	CY	560,000	$ 10.70	5,992,000
Groins (6 each)				
Core and Bedding Material	CY	4,700	64.35	302,000
Armor Stone	CY	15,100	78.80	1,190,000
Contingency (±25%)				1,909,000
			Total Cost	$9,543,000

II. Sand Replenishment with Sand-Cement Filled Bag Groins

Item	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	LS			$ 150,000
Dredging and Beach Fill[1/]	CY	560,000	$ 10.70	5,992,000
Groins (6 each)				
Bedding Material	CY	4,000	64.35	257,000
4' x 20" x 12' Bags	Ea	3,900	50.00	195,000
Sand Fill	CY	8,600	10.00	86,000
Cement	CY	2,900	200.00	580,000
Bag Filling	Ea	3,900	10.00	39,000
Contingency (±25%)				1,825,000
			Total Cost	$9,124,000

[1/] Dredging quantity is twice the desired in-place fill quantity.

Appendix A (continued)

III. Sand Replenishment with Detached Breakwaters

Item	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	LS			$ 150,000
Dredging and Beach Fill[1]	CY	440,000	$ 10.70	4,708,000
Breakwater (6 each)				
Core and Bedding Stone	CY	9,000	64.35	579,000
Armor Stone	CY	28,000	78.80	2,206,000
Temporary Construction Access	CY	5,000	70.00	350,000
Contingency (±25%)				1,998,000
			Total Cost	$9,991,000

IV. Perched Beach and Surf Shoal

Item	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	LS			$ 150,000
Dredging and Beach Fill				
Perched Beach Fill[1]	CY	115,000	$ 10.70	1,231,000
Surf Shoal Fill[1]	CY	4,600	10.70	49,000
Longard Tube Fill (Beach)	CY	8,500	10.70	91,000
Longard Tube Fill (Shoal)	CY	800	10.70	9,000
Longard Tube Cost (Filled in-place double 40" tube with filter)				
Beach Sill and Groins	FT	6,500	150.00[2]	975,000
Surf Shoal	FT	1,200	150.00[2]	180,000
Contingency (±25%)				671,000
			Total Cost	$3,356,000

---

[1] Dredging quantity is twice the desired in-place fill quantity.

[2] Cost estimate obtained from Robert Small & Associates, Newport Beach, CA, distributor for Longard coastal protection systems.

Appendix A (continued)

V. Rock Revetment (cost for 3,500 feet of revetment)

Item	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	LS			$ 35,000
Underlayer Stone	CY	6,700	$64.35	431,000
Armor Stone	CY	22,500	78.80	1,773,000
Contingency (±25%)				560,000
			Total Cost	$2,799,000

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GEOLOGY

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HILO BAYFRONT BEACH EROSION

Geology

(1) General. - The majority of geological data is based on general findings gathered during the investigations for the construction of the breakwater expansion on Blonde Reef, the Hilo Tsunami studies, and periodic dredging of the navigation channel of Hilo Harbor.

(2) Regional Geology. - The island of Hawaii, the largest of the Hawaiian Archipelago, covers an area of over 4,000 square miles. The island was formed during the last 800,000 years by the gradual emergence and subsequent coalescence of five volcanoes; Mauna Loa and Kilauea, which are still active, Hualalai, which last erupted in 1801, Mauna Kea, which has been inactive in recent geologic time, and Kohala, which has been extinct for eons.

The volcanic mountains are generally oval and dome-shaped. Mauna Loa rises from a base 15,000 feet below sea level to 13,680 feet above sea level. It is the largest active volcano and is considered the biggest single mountain on earth. These five mountains have been formed almost entirely by the accumulation of thousands of thin flows of lava, each separate flow averaging less than ten feet in thickness. The broad, smooth, dome shapes have given rise to the name of "shield" volcanoes. Nowhere are the lower slopes of the mountains steeper than twelve degrees with the average slope around six degrees. Gentle, flat slopes extend outward beneath the water to the sea floor.

The city of Hilo and the breakwater are located where the lower slopes of Mauna Loa and Mauna Kea merge. The surface of the ground in South Hilo, Waiakea District, has a gentle, flat slope northward toward the ocean of one foot in 400 feet, or less than one degree.

Hilo Bay is a broad indentation in the northeastern coastline of the island, created by the Hamakua volcanic series of Mauna Kea and the Ka'u volcanic series of Mauna Loa. Recent scoriaceous, black, lava flows from Mauna Loa have formed the entire central and southern half of the Bay. Older flows from Mauna Kea have made vertical, high, wave-cut cliffs along the north side of the Bay. The existing breakwater structure is built on a coral-limestone reef over lava. Marine sediments consisting of fine- and medium-grained sand and silt from volcanic sources interspersed with fragments of coral limestone, cover the narrow beach and form the ocean floor in shallow water.

The area north of Wailuku River consists of Mauna Kea's Hamakua volcanic series. This series is a permeable basalt, enveloped by an overlying Pahala ash layer (up to 25 feet thick) and its derivative soil, resulting in a surface far less permeable than normal for exposed basalts. As a result, surface runoff from this area is substantial and flow in the Wailuku River, which originates on the ash-covered surface, averages several hundred million gallons per day. Slopes on the Mauna Kea surface are moderately steep and are incised by numerous small streams.

East of Wailuku River, the surface rocks consist of the Ka'u volcanic series of Mauna Loa, an extremely permeable basalt, that is too recent in origin to have had formed a deep soil, and saprolite top layer. Patches of Pahala ash lie on some older Mauna Loa lavas near the Wailuku River but are insignificant in contrast to the wide extent of bare Ka'u lava over the remainder of the study area.

(3) Site Geology. - The small beach in Hilo Bay averages 35 feet in width is about 2,000 feet long, and is bordered by highway fill at its eastern and western ends. The beach surface is composed almost entirely of volcanic rock fragments of volcanic rock fragments of sand size, with very few calcarious constituents. The sand exhibits moderately good sorting at about a medium-grain size. Because of the protection from the breakwater, the beach undergoes mild changes throughout the year.

A highway fill occupies the backshore. The present beach represents only a small portion of what was, in the last century, a much wider beach. A railroad embankment constructed about 1901 covered most of the beach. After the 1946 Tsunami, wider highway fills along the railroad right-of-way further decreased the width of the beach. The offshore area is lava basalt with a thin veneer of mud and silt.

Seismicity

Hawaii has the highest density of earthquakes (occurrence rate of magnitude two and greater earthquakes per unit area) in the United States. During the past 18 years, about 48,000 earthquakes in Hawaii have been located and their magnitude determined. Of these, more than 3,000 events were of magnitude 3.0 to 7.2; magnitude 3.0 is generally the threshold of felt earthquakes.

The strongest earthquakes in historic time in the islands occurred on April 2, 1868 and was centered along the south coast of the island of Hawaii. The earthquake had a Richter magnitude of about 7.5 causing a Tsunami and earth movement which did serious damage across the entire island, even stopping clocks as far away as Honolulu. Practically all earthquakes on the island of Hawaii and Maui are associated with intermittent volcanic activity. However, potential earthquakes in the islands can also be caused by deep-seated tectonic forces and not from the indirect action of volcanic activity. A Richter magnitude 7 earthquake on January 23, 1938 had an epicenter 25 miles north of Pauwela Point on the north shore of Haleakala, Maui. Recent explorations of geophysical methods show that faults and rift zones cut through the major islands and that these faults are branches of a gigantic fracture system known as the Molokai Fracture Zone.

The only major earthquake since 1938 occurred in April 26, 1973. The tremor registered 6.2 on the Richter scale and was centered offshore about twelve miles northeast of Hilo, Hawaii and about 35 miles deep.

The Army Technical Manual 5-809-10 (Feb 1982) assigns a zone four (4) seismic risk rating for the southern half of the island of Hawaii for design considerations.

The magnitude of Hawaiian earthquakes was not routinely determined locally until 1958. Prior to that, magnitudes of large earthquakes were measured by seismograph stations on continental United States, usually by those at the California Institute of Technology, Univeristy of California at Berkeley, and Columbia University.

Subsurface Investigations

No recent subsurface exploration of the Hilo Bayfront beach area has been performed by the Corps of Engineers. Two past explorations supply the basis of present subsurface information: (1) Nine wash borings performed by the Corps of Engineers in 1950 for a sea wall along the bayfront; and (2) Hilo Sand Survey by Ocean Innovators in 1979, probing the floor of Hilo Bay for black sand deposits. Figures 1 and 2 show the extent and findings of the two investigations. In general, the beach and offshore area are composed of fine to coarse black sands and silts, the deposits of sediment from the flow of Wailuku River and from currents along the northwestern portion of Hilo Bay. The sand is largely of basalt origin. Wash borings performed in 1950 show the sand thickness varies from 2 to 40 feet. Larger percentages of silt, lava basalt, and debris cover the sand offshore. See Figure 3 for comparison of existing beach sand gradation with sampled offshore sand deposits.

Design and Construction Considerations

(1) Sand Replenishment. - The existing beach materials will adequately support the design plan of a 50-foot level berm, shaped 1 vertical to 10 horizontal to the existing grade.

(2) Groin Structure. - Undermining of the groin structure will be a design consideration. As all the foundation area is covered with sand which is subject

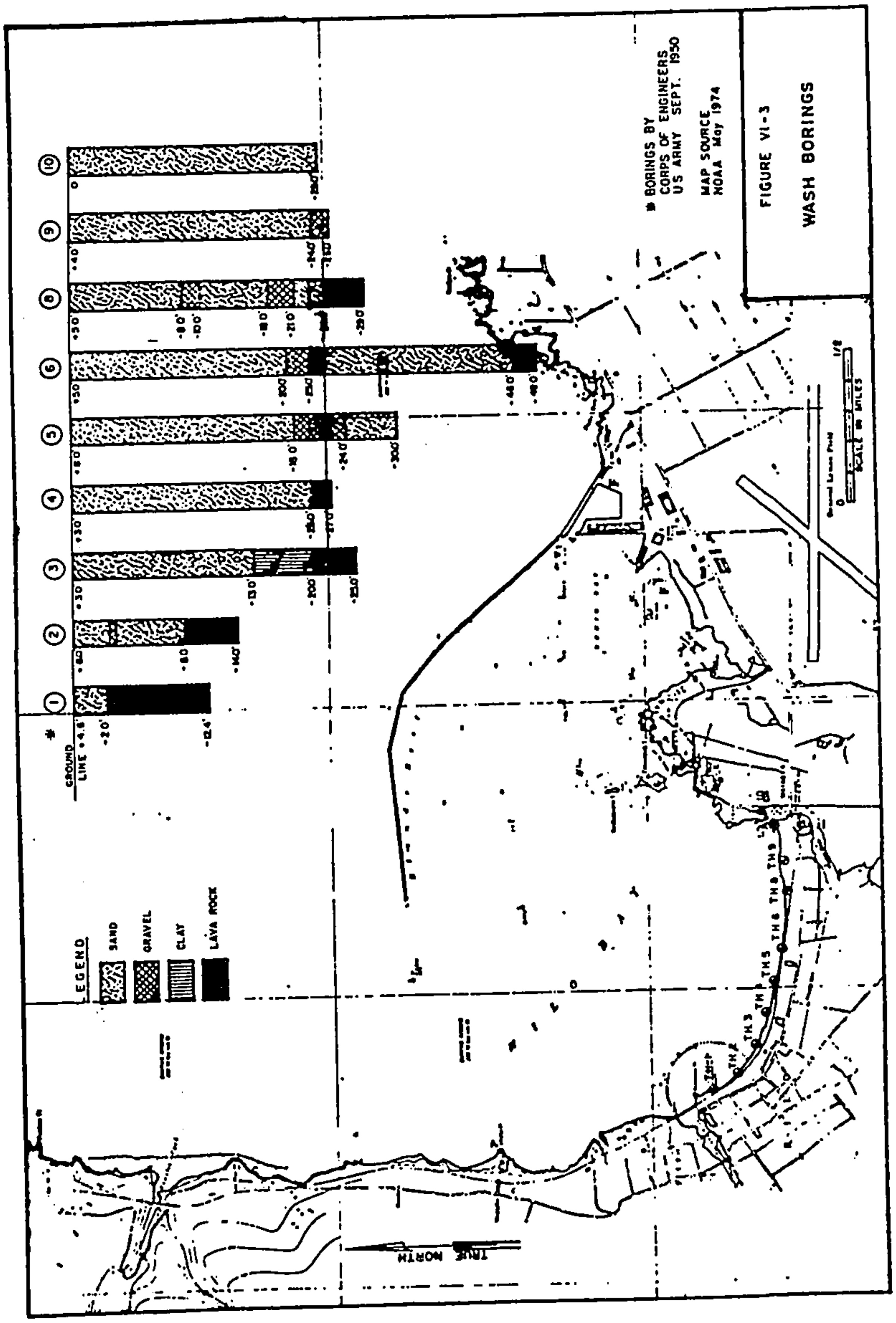
FIGURE VI-3
WASH BORINGS
* BORINGS BY
CORPS OF ENGINEERS
US ARMY SEPT. 1950
MAP SOURCE
NOAA May 1974
LEGEND
SAND
GRAVEL
CLAY
LAVA ROCK
GROUND LINE
TRUE NORTH
SCALE IN MILES

FIGURE 1

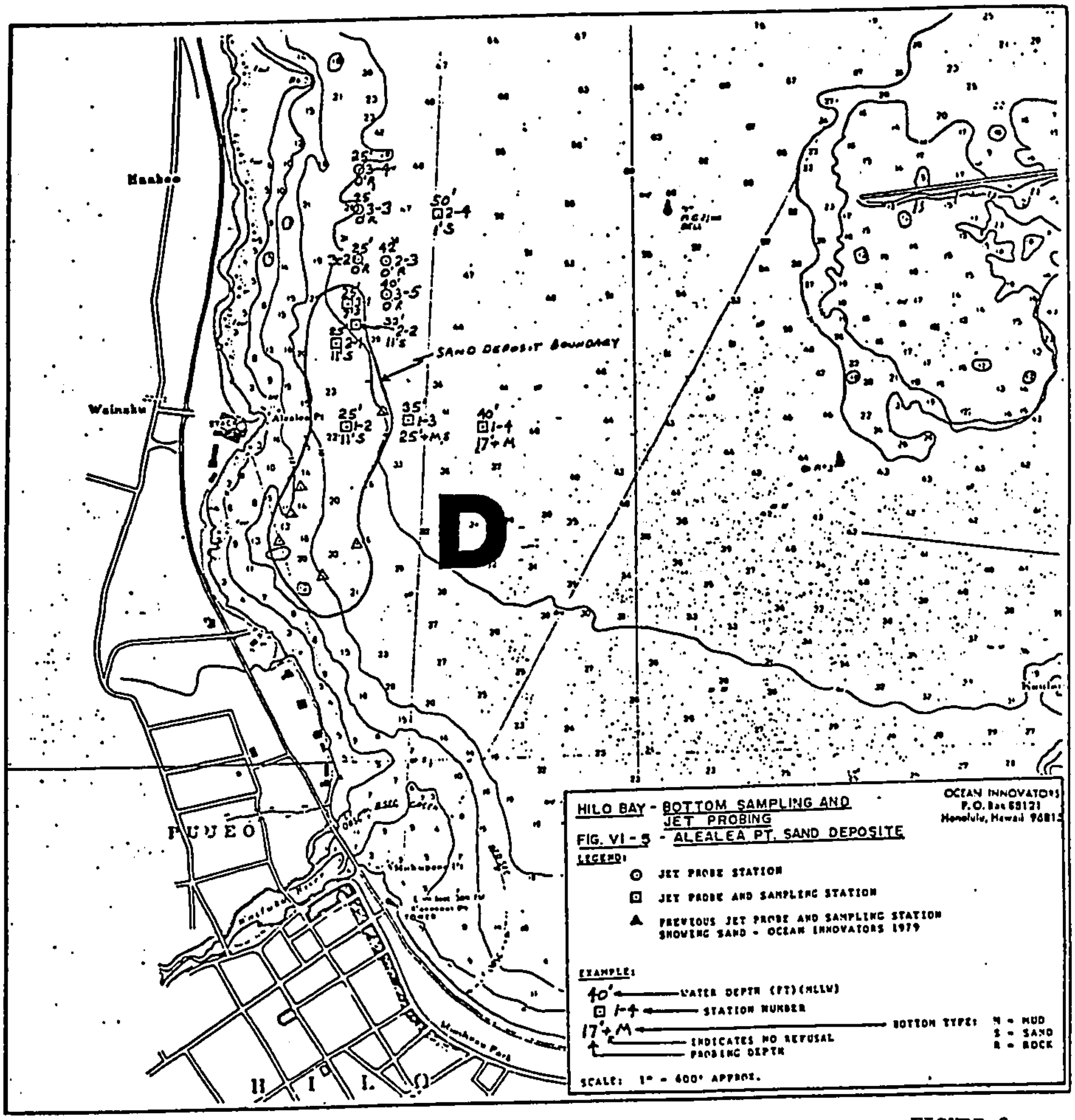
D
Waiakea
Wainaku
PUUEO
HILO
SAND DEPOSIT BOUNDARY
HILO BAY - BOTTOM SAMPLING AND JET PROBING
FIG. VI - 5 - ALEALEA PT. SAND DEPOSITE
OCEAN INNOVATORS
P.O. Box 68121
Honolulu, Hawaii 96815
LEGEND:
JET PROBE STATION
JET PROBE AND SAMPLING STATION
PREVIOUS JET PROBE AND SAMPLING STATION SHOWING SAND - OCEAN INNOVATORS 1979
EXAMPLE:
40' WATER DEPTH (FT)(MLLW)
1-4 STATION NUMBER
17'+M BOTTOM TYPE: M = MUD S = SAND R = ROCK
INDICATES NO REFUSAL
PROBING DEPTH
SCALE: 1" = 400' APPROX.

FIGURE 2

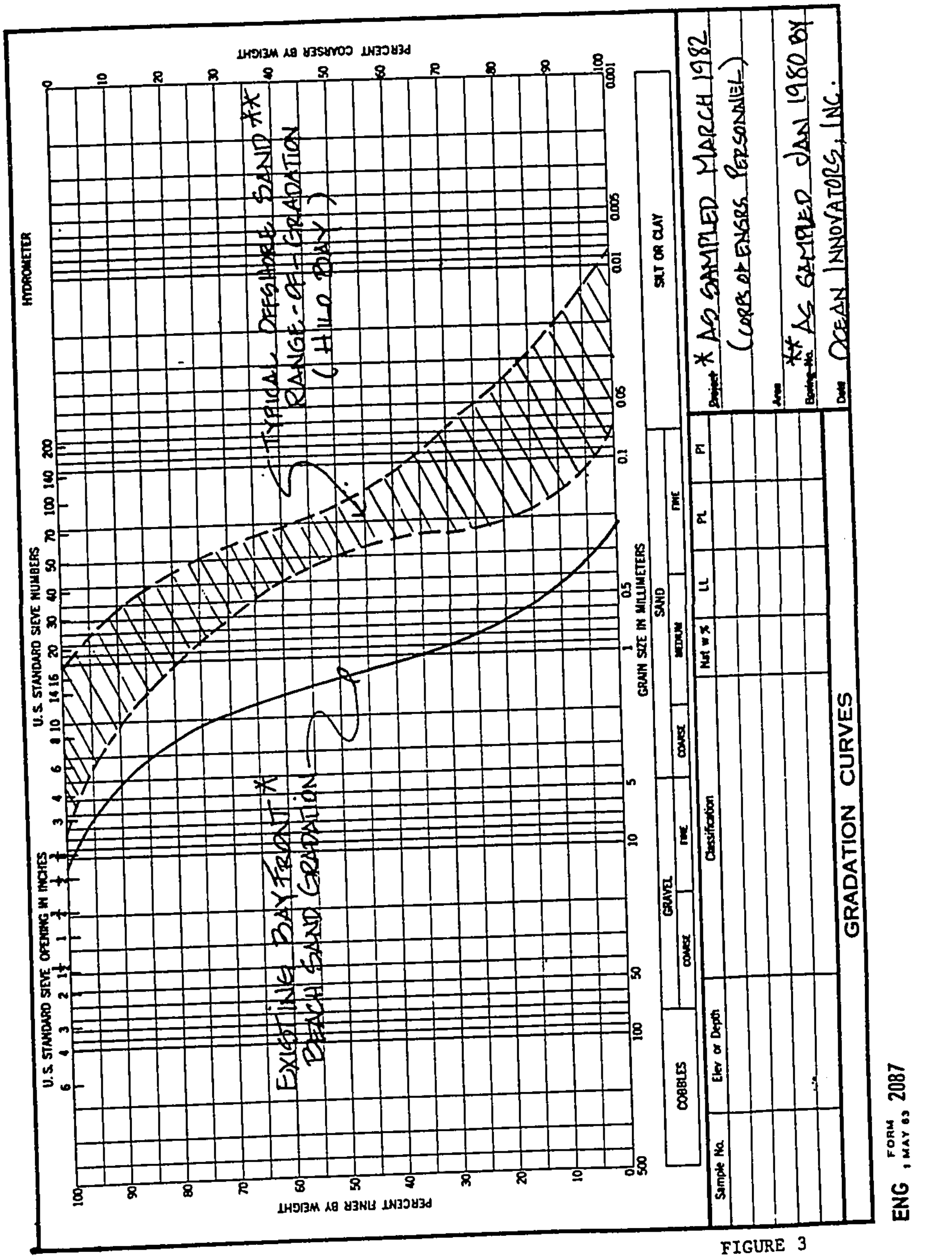
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
EXISTING BAYFRONT BEACH SAND GRADATION *
TYPICAL OFFSHORE SAND ** RANGE-OF-GRADATION (HILO BAY)
Project * AS SAMPLED MARCH 1982 (CORPS OF ENGRS PERSONNEL)
** AS SAMPLED JAN 1980 BY OCEAN INNOVATORS, INC.
GRADATION CURVES
ENG FORM 1 MAY 63 2087

FIGURE 3

to erosion and scour beneath the structure with the currents and tides, adequate toe protection will be required to anchor the structure into position.

(3) Other - If sand mining/dredging in Hilo Harbor is utilized to supply black sand for beach replenishment, measures to control turbidity may be necessary. Gradation curves of the proposed replenishment sand show silt contents of up to 30% (see Figure 3).

Sources of Materials

(1) Armor Stone. - Two commercial quarries operate in the Hilo area; Glovers quarry and the Y and S quarry. Both are located in the industrial Waiakea District about one mile south of the Terminal Building at the General Lyman Airfield, or 1 mile from the project site. The two quarries work the same deposit which was described in detail in Design Memorandum No. 2; Construction of Tsunami Protection and Navigation Improvement Project, Hilo, Hawaii. The rock is a prehistoric member of the Ka'u volcanic series in the Mauna Loa groups of igneous rocks. Neither quarry operates to produce armor stone sizes, and special arrangements have to be made in advance. Small amounts of large stones are stockpiled in both quarries from time to time.

(2) Beach Sand

(a) Ocean Innovators report deposits of black sand within Hilo Harbor at the mouth of the Wailuku River and offshore Alealea Point. The quantity of sand has been estimated as sufficient. Color and gradation of offshore sand is similar to existing beach sand, but washing and screening of sands recovered from offshore areas to remove silt and cobbles may be required before use as beach replenishment. Special permits must be acquired through the State of Hawaii before offshore mining may be accomplished.

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RESOURCES AND ECONOMY

Hawaii is a prosperous state with a growing economy. The gross State product in 1980 amounted to $11.5 billion, or 6.5 times the 1960 total. The three largest contributors to the State economy are tourism ($2.9 billion), defense expenditures ($1.3 billion), sugar production ($594 million), and pineapple production ($226 million). The most rapid growth in the past decade has been in the tourist industry. Visitor expenditures have increased over 400 percent in the ten years from 1970 to 1980. Visitor spending in 1980 resulted in tax revenues of $323 million and generated 117,000 jobs.

The Island of Hawaii (Hawaii County) is located at the southeastern end of the Hawaiian archipelago. It is the largest of the State's major islands containing nearly two thirds of the State's total land area. Nine percent of the State population resided in the County in 1980. Hawaii County experienced a population increase of 50 percent from 1960 to 1980, nearly equaling the State's overall increase of 52 percent for the same period.

Population on the island is concentrated in two areas--Hilo on the east side and Kailua-Kona on the west. Hilo serves as the center of the County government and the hub of major commercial, industrial, and distribution activities. The resident population of Hilo increased 34 percent in the 20-year period of 1960-1980. Forty-six percent of the population in Hawaii County reside in Hilo.

The basic elements of the economy of Hawaii County are tourism, agriculture and fishing, manufacturing, and scientific research, with tourism being the number one industry. Visitor expenditures for Hawaii County grew from $53.4 million in 1970 to $164.5 million in 1980. Hilo is not a major destination area for tourists. The town, however, has one of the County's two major airports and, thus, is a gateway to and from Hawaii for the visitor industry. Hilo has a stronger orientation toward transportation, communications and utilities, trades, services, and government as the urban, commercial, and governmental center for the County. The following tables summarize the demographic, general, social, and economic characteristics of the County.

TABLE 1
RESIDENT POPULATION OF HAWAII COUNTY AND DISTRICTS:
1960 TO 1980

	1960	1970	1980
The State	632,772	769,913	964,691
Hawaii	61,332	63,468	92,053
Puna	5,030	5,154	11,751
South Hilo	31,553	33,915	42,278
North Hilo	2,493	1,881	1,679
Hamakua	5,221	4,648	5,128
North Kohala	3,386	3,326	3,249
South Kohala	1,538	2,310	4,607
North Kona	4,451	4,832	13,748
South Kona	4,292	4,004	5,914
Ka'u	3,368	3,398	3,699
Median Years of School Completed1/	8.6	11.4	12.5

1/ 25 years old and over.

Source: U.S. Bureau of the Census, U.S. Census of Population: 1970, PC(1)-A13, Table 10, and advance counts from the 1980 Census of Population.

TABLE 2
INCOME, LABOR FORCE, AND EMPLOYMENT
HAWAII COUNTY

	1960	1970	1980
Personal Income ($ Millions)	100	241	775
Per Capita Income ($)	1,630	3,785	8,400
Civilian Labor Force	22,2701/	28,300	35,450
Civilian Employment	21,5201/	27,050	33,050
Unemployment (%)	3.4	4.4	6.7
Subcount by Industry			
Total Job (Non-agriculture)	16,040	28,870	28,400
Construction	8201/	1,500	1,650
Manufacturing	3,3001/	2,960	2,750
Transportation, Communication, and Utilities	9701/	1,380	1,900
Trade	3,1001/	5,010	7,000
Finance, Insurance and Real Estate	2501/	900	1,100
Services	1,6401/	3,730	7,450
Government	3,0501/	4,370	6,550
Agriculture	2,9101/	3,610	3,250

1/ Hawaii State Dept of Labor and Industrial Relations

Source: State of Hawaii Data Book 1982 and 1981; County of Hawaii Data Book 1980 and 1979, Department of Research and Development.

TABLE 3
TOURISM HAWAII COUNTY

	1960	1970	1980
Visitor Arrivals	72,300	445,401	761,103
Visitor Expenditures ($ Millions)	5.6	53.4	164.5
Hotel Room Inventory	558	3,092	7,469
Occupancy Rate (%)	NA	68.3	51.0

Source: County of Hawaii Data Book 1981, Department of Research and Development. The State of Hawaii Data Book, 1982, Department of Planning and Economic Development. County Trends in Hawaii, 1970-1982, July 1983, Department of Planning and Economic Development.

BENEFITS

The proposed Plan A for Bayfront Beach Park is to restore and protect the existing beach and shoreline from erosion caused by waves and currents. The restoration of the beach will have three major beneficial effects: (1) it will minimize the existing storm-wave impacts on the Bayfront Highway by eliminating the closing of the highway due to flooding and the collection of debris on the pavement following wave action; (2) the project will significantly enhance the much-demanded coastal recreational opportunities in the local area; and (3) the proposed jetty, by trapping littoral and offshore sand movements, will provide a source for future periodic replenishment of sand for the proposed beach.

Plan B recommends the construction of a 3,500-foot rock revetment on top of the existing rock revetment. The plan will eliminate future shoreline erosion and storm-wave impacts on the Bayfront Highway.

The following analysis evaluates the benefits of the proposed rock revetment and beach restoration plans. Calculations are based on a discount rate of 8-1/8 percent and a 50-year project life. The base year was assumed to be 1985 when the project would be completed and benefits begin accruing to users. Benefits are based on October 1983 price levels.

BAYFRONT HIGHWAY

The State Highway Division has expressed concern about the impact of storm waves upon the Bayfront Highway. During periods of stormy weather, waves breaking against the highway embankment throw rocks and debris across the highway. This has, in the past, severely endangered motorists and has resulted in the closing of the highway. In addition to damages to the highway, drainage culverts get blocked and, on occasion, lower-lying lands inshore of the highway are flooded. The Highway Division reports that cleanup and repair costs to this section of the highway has averaged $22,000 a year at current prices. They point out that these costs are direct costs only and do not include the indirect costs of public inconvenience, delays, traffic hazards, and congestion which result when traffic is detoured through the city streets.

RECREATION

As population, income, and leisure time increase, a greater demand is being put on the existing recreational facilities in Hawaii County. The County has 59 percent of the State's total recreational acreage. It enjoys the largest total recreational acreage per thousand population in the State, but because of the island's rugged coastline it has the least number of beach acres. The County has a total supply of just over 16 acres of park-related beach. Of this, only 0.84 acres are in Hilo, which had 46 percent of the island's population in 1980. Obviously, this is a combination which has generated a high demand for coastal recreation. An inventory of recreational resources in Hawaii County is shown in Table 4.

TABLE 4
HAWAII COUNTY RECREATIONAL RESOURCES - 1980

	Park-Related Beach		Hunting Areas	
Area	Beach Acres	Acres/ 1000 1/	Acres	Acres/ 1000 1/
Ka'u	1.6	0.43	103,221	35,204
Kona	1.0	0.05	13,030	663
Kohala	9.1	1.16	31,712	4,037
Hamakua - N. Hilo	-	-	281,260	41,319
Hilo	0.8	0.02	130,227	3,080
Puna	3.8	0.32	48,650	4,140
TOTAL	16.2	0.2	608,100	7,179

1/ Acres per 1000 Hawaii County population.

Source: STATE RECREATION PLAN, Sep 80, Hawaii Department of Land and Natural Resources.

The State and County recognize the need for coastal recreational facilities. The Hawaii State Recreation Plan, dated September 1980, projects the participation in swimming and sunbathing activities on peak days in Hawaii County will increase 50 percent in the next 15 years from just under 18,000 a day in 1980 to over 26,000 in 1995. The 1980 State Recreation Plan indicated that only through careful planning, conservation and resource management can recreational development meet the growing demand. The Plan indicates that in the Hilo Planning Area emphasis should be placed on improvement and expansion of existing parks to meet projected demand since shoreline recreational areas are limited.

The demand for swimming and sunbathing activities in the Hilo area is already substantially higher than the existing developed park and beach related facilities can handle. As a result, available shoreline areas suitable for multiple recreational uses are in great demand. Recreational facilities are often crowded in the Puna District, which is about one hour traveling distance from Hilo.

The Hawaii 1975 State Comprehensive Outdoor Recreation Plan (SCORP) and the more recent 1980 State Recreation Plan, often referred to as the 1980 SCORP, states that with over 46% of the island's population residing in the Hilo District, recreational participation in the Hilo area largely influences County patterns. According to the demand survey, 37% of the island's activity occur within the Hilo area, while one-half of the total County activity occasions is generated from it. (Activity occasions is defined as the number of separate times people engage in recreational activity.) The recreational participation rates, measured as activity occasions per 1,000 resident people for Hawaii County for all activities, total 765 per peak weekend day and 532 for weekdays. Table 5 shows the distribution of activity participation in the County.

TABLE 5
ACTIVITY PARTICIPATION RATES OF HAWAII COUNTY
IN ACTIVITY OCCASIONS/1,000 RESIDENTS 1/

ACTIVITY	WEEKEND	WEEKDAY
Walking/Jogging	117.00	123.00
Hiking	17.50	20.30
Camping	39.00	22.00
Group Camping	2.60	3.30
Picnicking	107.00	23.70
Hunting/Shooting	12.00	4.00
Archery	2.70	1.00
Golf	10.00	9.00
Swimming/Sunbathing	136.00	112.00
Diving	27.00	8.30
Surfing	13.00	7.10
Boating	25.50	8.30
Canoe Paddling	1.80	.78
Fishing	57.00	26.60
Game Playing	29.80	22.40
Tennis	9.70	19.00
Attending Outdoor Events	47.00	36.20
Bicycling	66.40	69.70
Motorcycling	10.30	1.40
Other Activities	33.30	13.90
TOTAL	764.60	531.98
TOTAL (Rounded)	765	532

1/ The SCORP sample is a multi-stage area probability sample selected proportionate to the population. Sample consists of clusters of dwelling units located in 20 planning areas throughout the State. The survey produced 819 interviews on Oahu yielding an 82% response rate and 254 interviews on the neighbor islands for an 85% response rate. The response rate for the State as a whole was 83%, resulting in a total of 1,073 completed interviews.

Source: Hawaii State Comprehensive Outdoor Recreation Plan, 1975, Hawaii Department of Planning and Economic Development.

On the determination that 26% of total recreation activity in the Hilo area is swimming/sunbathing (Table 6) and with a 1980 population of 92,053, the computed peak resident activity occasions for swimming/sunbathing equals 6,774 (or, 92,053 x 765 ÷ 1,000 x .37 x .26).

With an inventory of 1,648 hotel rooms in Hilo and an occupancy rate of 40% (Hawaii Visitors Bureau Research Report, May 1983), visitor demand equals 296 occasions/peak day, assuming a 25% participation rate for swimming/sunbathing and an estimated 1.8 occupants/room (1,648 x .40 x 1.8 x .25). For this analysis, 296 visitor occasions is held constant.

Thus, in 1980, over 7,000 activity occasions for swimming/sunbathing were generated on a peak day in the Hilo area (Table 7). Translating this demand into beach area, the SCORP standards of 100 square feet per person and 2.5 people per day turnover rate are used.

The significant need for additional dry beach area in Hilo is shown in Table 7. In 1980, for example, peak day demand for beach use totalled 7,070 occasions. In beach area, this equals 282,000 square feet (7,070 ÷ 2.5 x 100) or approximately 6.5 acres.

TABLE 6
RANKING OF ACTIVITIES WITHIN THE
HILO DISTRICT

ACTIVITY	% OF TOTAL ACTIVITY
Swimming/Sunbathing	26%
Walking/Jogging	20%
Outdoor Events	10%
Bicycling	10%
Picnicking	8%
Fishing	6%
Game Playing	3%
Tennis	3%
Golf	3%
Surfing	3%
Boating	2%
Hiking	1%
Diving	1%
Hunting/Shooting	1%
Camping	1%
Other	3%

Source: Hawaii State Comprehensive Outdoor Recreation Plan, 1975, Hawaii Department of Planning and Economic Development

TABLE 7
DEMAND COMPUTATIONS

Year	Population	Peak Day Demand			Peak Hour Demand 3/	Demand for Dry Beach Area 4/ (Sq. Ft.)	Annual User Demand	
		Resident 1/	Visitor 2/	Total			Unconstrained 5/	Adjusted for Weather 6/
1980	92,053	6,774	296	7,070	2,828	282,800	1,350,370	378,104
1985	95,200	7,006	296	7,302	2,921	292,100	1,394,682	390,511
1990	105,100	7,734	296	8,030	3,212	321,200	1,533,730	429,444
1995	115,000	8,463	296	8,759	3,504	350,400	1,672,969	468,431
2000	123,300	9,074	296	9,370	3,748	374,800	1,789,670	501,108
2010	138,000	10,156	296	10,452	4,181	418,100	1,996,332	558,973
2020	155,000	11,407	296	11,703	4,681	468,100	2,235,273	625,876
2030	174,000	12,805	296	13,101	5,240	524,000	2,502,291	700,641
2035	184,000	13,541	296	13,837	5,535	553,500	2,642,867	740,003

1/ Population ÷ 1,000 x 765 x .37 x .26.
2/ 1,648 rooms-Hilo x .40 occupancy rate x 1.8 occupants/room x .25 swimming/sunbathing participation.
3/ Peak day demand is 2.5 times peak hour demand.
4/ Allowance of 100 sq ft per person at peak use.
5/ Annual user demand is the sum of weekend demand (total peak day demand x 365 x 2/7) plus weekday demand (total peak day demand ÷ 3 x 365 x 5/7).
6/ Weather factor of 72% derived from local climatological data for Hilo used to adjust for inclement weather.

Bayfront Black Sand Beach. Along the shoreline between the Wailuku and Wailoa rivers, Bayfront Park encompasses 11.4 acres of improved recreational area and about 0.84 acres of sandy beach. The park facilities include a sportsfield, playground, picnic areas, pavilion, archery range, restrooms, concession stand, and parking. The usable portion of the black sand beach extends along the west end of the Bayfront shore from the Wailoa River to Pauahi Street. The beach is used heavily by canoe clubs. At present, the beach is very narrow and not well suited for sunbathing and swimming activities.

As part of the Bayfront Beach project, a jetty will be constructed at the west end of the beach. Sand trapped by the jetty will be placed on the beach, providing periodic renourishment for the proposed beach. The Wailoa River currently has a shoaling problem in the entrance channel and requires periodic maintenance dredging. At present, the shoal is creating a hazardous condition for the local commercial fishing fleet. The proposed jetty will prevent increased shoaling rates at the entrance to the river caused by the beach restoration project.

The proposed erosion control and beach restoration project will create a stable shorefront by placing along the coastline an additional 252,000 square feet or 5.8 acres of dry beach area. This is estimated to meet the demand for dry sandy beach for swimming/sunbathing in the Hilo area in 1985.

The annual user estimates were adjusted for weather by a "bad weather" factor of 72% derived from local climatological data. For example, in 1985, annual user demand adjusted for inclement weather is 390,511 (or 1,394,682 x .28) as shown in Table 7.

The annual recreational benefits to users of the beach erosion and restoration project were determined using the Unit Day Value (UDV) method of analysis. The method approximates the average willingness to pay of users of Federally-assisted recreational resources. A UDV of $3.49 was calculated as the average amount users would be willing to pay for swimming/sunbathing and related activities at Bayfront Black Sand Beach over the project life. The $3.49 amount was derived using a point rating system which contains five specific criteria and associated measurement standards designed to reflect quality, relative scarcity, ease of access, and esthetic features of the recreational resource. Table 8 shows the guidelines for assigning points. Table 9 summarizes the point values assigned to the Bayfront Beach project, and Table 10 is a conversion table for establishing unit day values based on total points. A total of 53 points for general recreational activities falls between unit day values of $3.40 and $3.70.

Table 11 shows the annual recreational benefits with and without condition to projected users of the Bayfront Black Sand Beach erosion control and beach restoration project based on $3.49 UDV. The base year was assumed to be 1985 when the project would be completed and benefits begin accruing to users. Maximum annual users are limited by the 288,590 square feet or 6.6 acres of total beach area. Net annual benefits is the difference between conditions with and without project. All benefits would be received in 1985, being the base year of the project. The total average annual benefits from increase in recreation is $1,176,000.

TABLE 8
GUIDELINES FOR ASSIGNING POINTS FOR GENERAL RECREATION

CRITERIA	JUDGMENT FACTORS				
a. Recreation Experience	Two general activities 3/	Several general activities	Several general activities; one high quality value activity 4/	Several general activities; more than one high quality activity	Numerous high quality value activities; some general activities
Total Points: 30 Point Value:	0-4	5-10	11-16	17-23	24-30
b. Availability of Opportunity 7/	Several within 1 hr travel time; a few within 30 min travel time	Several within 1 hr travel time; none within 30 min travel time	One or two within 1 hr travel time; none within 45 min travel time	None within 1 hr travel time	None within 2 hr travel time
Total Points: 18 Point Value:	0-3	4-6	7-10	11-14	15-18
c. Carrying Capacity 1/	Minimum facility development for public health and safety	Basic facilities to conduct activity(ies)	Adequate facilities to conduct without deterioration of the resource or activity experience	Optimum facilities to conduct activity at site potential	Ultimate facilities to achieve intent of selected alternative
Total Points: 14 Point Value:	0-2	3-5	6-8	9-11	12-14
d. Accessibility	Limited access by any means to site or within site	Fair access, poor quality roads to site; limited access within site	Fair access, fair road to site; fair access, good roads within site	Good access, good roads to site; fair access, good roads within site	Good access, high standard road to site, good access within site
Total Points: 18 Point Value:	0-3	4-6	7-10	11-14	15-18

TABLE 8 (Cont'd)
GUIDELINES FOR ASSIGNING POINTS FOR GENERAL RECREATION

CRITERIA	JUDGMENT FACTORS				
e. Environmental Quality	Low esthetic factors5/ exist that significantly lower quality6/	Average esthetic quality; factors exist that lower quality to minor degree	Above average esthetic quality; any limiting factors can be reasonably rectified	High esthetic quality; no factor sexist that lower quality	Outstanding esthetic quality; no factors exist that lower quality
Total Points: 20					
Point Value:	0-2	3-6	7-10	11-15	16-20

1/ Value should be adjusted for overuse.
2/ Value for water-oriented activities should be adjusted if significant seasonal water level changes occur.
3/ General activities include those that are common to the region and that are usually of normal quality. This includes picnicking, camping, hiking, riding, cycling, and fishing and hunting of normal quality.
4/ High quality value activities include those that are not common to the region and/or Nation and that are usually of high quality.
5/ Major esthetic qualities to be considered include geology and topography, water, and vegetation.
6/ Factors to be considered in lowering quality include air and water pollution, pests, poor climate, and unsightly adjacent areas.
7/ Likelihood of success at fishing and hunting.
8/ Intensity of use for activity.

TABLE 9
POINT RATINGS GENERAL RECREATION
BAYFRONT BLACK SAND BEACH PROJECT

Criteria	Appropriate Judgment Factor	Comment	Points Assigned
a. Recreation Experience	Several general activities. 5-10 Points	Swimming, sunbathing, surf fishing, picnicking, canoeing, surfing.	10
b. Availability of Opportunity	One or two within 1 hr travel time; none within 45 min travel time. 7-10 Points	Only one beach (.84 acres) within 1 hr travel time.	10
C. Carrying Capacity	Optimum facilities to conduct activity at site potential. 9-11 Points	Sandy beach, bathroom, and drinking facilities, also nearby is merchant district of Hilo	10
d. Accessibility	Good access, high standard road good access to site, within site. 15-18 Points	Project next to main highway artery, and Hilo merchant district.	16
e. Environmental Quality	Above average esthetic quality; any limiting factors can be reasonably rectifed. 7-10 Points	Landscaped sandy beach, picnic areas; replacement of eroded shoreline and rock revetment.	7
TOTAL POINTS			53

TABLE 11
ANNUAL RECREATION BENEFITS
BAYFRONT BLACK SAND BEACH

		With Condition			Without Condition			
Year	Total Demand	Dry Beach Area (Sq Ft) 1/	Maximum Annual Users	Benefits 2/	Dry Beach Area (Sq Ft)	Maximum Annual Users	Benefits 2/	Annual Net Benefits
1980	378,104	---	---	---	36,590	48,921	$170,734	$ -0-
1985	390,511	288,590	385,845	$1,346,599	36,590	48,921	170,734	1,175,865
1990	429,444	288,590	385,845	1,346,599	36,590	48,921	170,734	1,175,865
1995	468,431	288,590	385,845	1,346,599	36,590	48,921	170,734	1,175,865
2000	501,108	288,590	385,845	1,346,599	36,590	48,921	170,734	1,175,865
2010	558,973	288,590	385,845	1,346,599	36,590	48,921	170,734	1,175,865
2020	625,876	288,590	385,845	1,346,599	36,590	48,921	170,734	1,175,865
2030	700,641	288,590	385,845	1,346,599	36,590	48,921	170,734	1,175,865
2035	740,003	288,590	385,845	1,346,599	36,590	48,921	170,734	1,175,865

1/ Limited to 288,590 sq ft of beach; includes existing beach area in addition to 252,000 sq ft of proposed beach project.
2/ Based on unit day value of $3.49.

BENEFITS SUMMARY

The proposed plans to restore and protect the existing beach and shoreline from erosion along Bayfront Beach will result in the following monetary benefits (TABLE 12).

TABLE 12
SUMMARY OF ANNUAL BENEFITS
BAYFRONT BLACK SAND BEACH

Item	Average Annual Benefits	
	Plan A	Plan B
Highway Maint & Repair	$ 22,000	$ 22,000
Recreational Benefits	1,175,900	-0-
TOTAL October 1983 Prices	$1,197,900	$ 22,000
TOTAL October 1984 Prices*	$1,265,900	$ 23,200

* October 1984 price levels estimated by extrapolating CPI trend graphically (Oct 1983 x 1.0568 = Oct 1984).