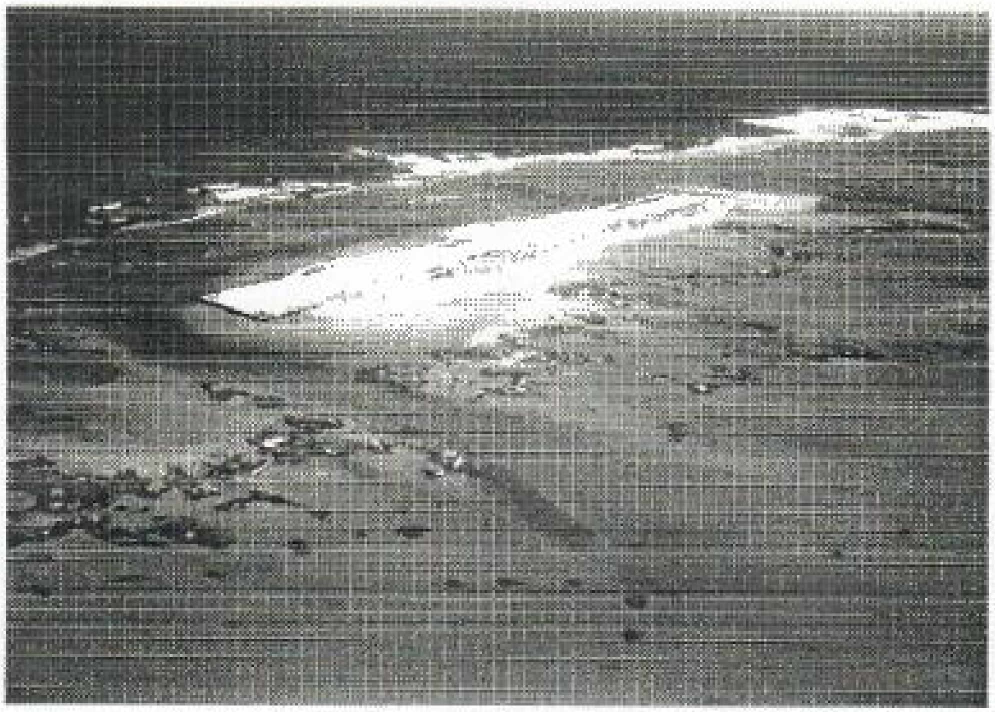
TERN ISLAND SHORE PROTECTION STUDY

Hawaiian Islands National Wildlife Refuge

French Frigate Shoals, Northwestern Hawaiian Islands



Tern Island 1988

Prepared for

U.S. Fish and Wildlife Service

By

U.S. Army Corps of Engineers
Honolulu Engineer District

January 1992

TERN ISLAND SHORE PROTECTION STUDY

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

FIGURES

TABLES

INTEGRATED TECHNICAL REPORT

TERN ISLAND SHORE PROTECTION
HAWAIIAN ISLANDS NATIONAL WILDLIFE REFUGE
FRENCH FRIGATE SHOALS, NORTHWESTERN HAWAIIAN ISLANDS

I. INTRODUCTION

A. PURPOSE

The purpose of this study is to identify suitable protective measures to functionally replace the existing deteriorated steel sheet pile bulkhead along the shoreline of Tern Island within the French Frigate Shoals, Northwestern Hawaiian Islands, Hawaii.

B. STUDY AUTHORITY

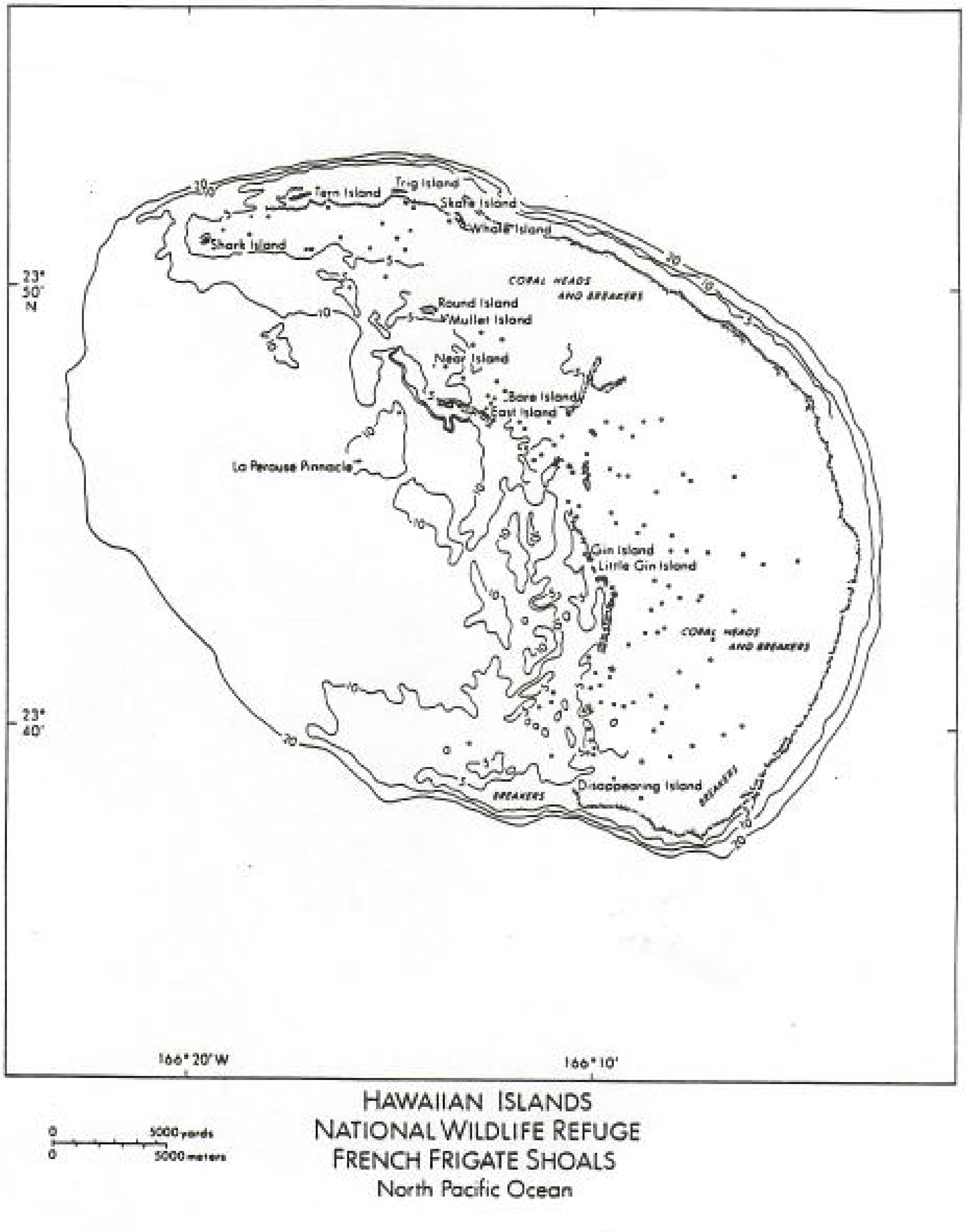
The Tern Island Shore Protection Study was initiated upon the receipt of a letter dated September 22, 1990 from the United States Fish and Wildlife Service (USFWS), requesting a detailed study of the shoreline erosion problem at Tern Island, French Frigate Shoals.

This study and report were accomplished under the authority of Interagency Agreement No. 14-16-0001-91511 executed between the USFWS and the Honolulu Engineer District on January __, 1991.

C. STUDY AREA

1. <u>French Frigate Shoals</u>. French Frigate Shoals is a low coral atoll in the Northwestern Hawaiian Islands (NWHI) situated 490 nautical miles northwest of Honolulu, Hawaii, between latitude 23°37′18" and 23°52′50" North and longitudes 166°03′14" and 166°20′04" West (Figure 1).

2. <u>Tern Island</u>. Tern Island is a 37 acre islet located at the northern extremity of French Frigate Shoals atoll. The island's existing size is an artifice of U.S. Navy construction during World War II to place unanchored steel sheet pile around the original 11 acre islet and fill the interior with coralline spoil from adjacent dredging of a ship channel. The sheet pile was reportedly driven to a depth of -15 feet and has an average top elevation of +6.5 feet referenced to mean lower low water (MLLW). The maximum elevation on Tern Island is approximately +9 feet MLLW (Figure 2).



HAWAIIAN ISLANDS
NATIONAL WILDLIFE REFUGE
FRENCH FRIGATE SHOALS
North Pacific Ocean

FIGURE 1

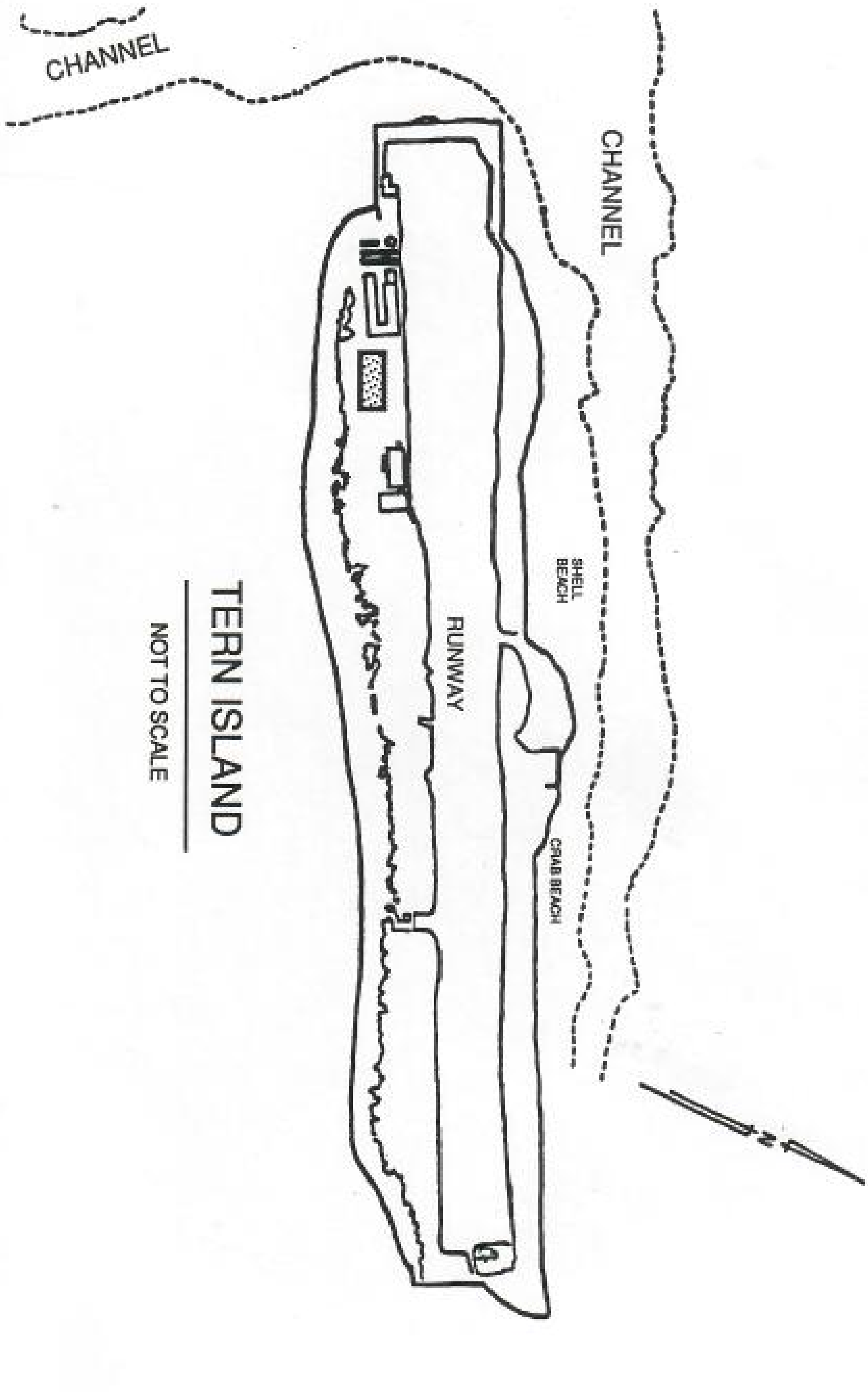

CHANNEL
CHANNEL
SHELL BEACH
RUNWAY
CRAB BEACH
TERN ISLAND
NOT TO SCALE
N

FIGURE 2

D. SCOPE OF STUDY

This study examines the problem of erosion of coralline fill material from the interior of Tern Island due to chronic and severe deterioration of the original steel sheet pile bulkhead along the northern, eastern, and western shorelines of Tern Island. Should this erosion of fill material continue unchecked, the runway surface at Tern Island will eventually be endangered, and the USFWS will be unable to support their research station by air and will have to discontinue its operation. Based upon an analysis of the economic, environmental, social, and transportation consequences, if the erosion were left unchecked, the result would be losses of the shoreline, roadway, and affected infrastructure. Therefore, alternative plans for shoreline protection were developed.

Other appurtenant activities conducted for this study include: hydrographic and topographic surveys, analysis of existing fish and wildlife studies, and a preliminary biological assessment.

E. STUDY PARTICIPANTS AND COORDINATION

The U.S. Army Corps of Engineers, Honolulu District (HED), was responsible for conducting and coordinating the overall study and preparing the study report. Studies and investigations were performed with the assistance of the U.S. Fish and Wildlife Service (USFWS), Department of the Interior (DOI).

Other agencies and organizations contacted during the study to help identify study concerns and obtain study information were the National Marine Fisheries Service (NMFS), U.S. Department of Commerce, the Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii, the Marine Mammal Commission (MMC), and the Interagency Monk Seal Recovery Team.

G. PRIOR STUDIES

A prior assessment of the erosion condition at Tern Island was conducted by the Honolulu Engineer District in April 1984 for the USFWS under the authority of Section 22 of the Water Resources Development Act of 1984, Planning Assistance. A total of 2,100 feet of the existing sheet pile bulkhead were identified as requiring replacement. Engineering and biological observations made during a site reconnaissance were compiled into a concept level recommendation for replacing the bulkhead with new sheet pile or with a rock revetment, as well as a preliminary identification of associated environmental impacts.

II. PROBLEM IDENTIFICATION

A. PURPOSE

The purpose of this section is to define in detail the study site and the problems to be addressed by this report, i.e., describing base conditions, identifying customer concerns, establishing planning criteria, and analyzing the shore erosion problem.

B. PROFILE OF EXISTING BASE CONDITIONS (AFFECTED ENVIRONMENT)

The historical, physical, and environmental characteristics of Tern Island are briefly discussed in the following paragraphs. Information was obtained from various documents including the Hawaiian Islands National Wildlife Refuge Final Master Plan/Environmental Impact Statement, May 1986; The Natural History of French Frigate Shoals, Northwestern Hawaiian Islands by A. B. Amerson, Jr. 1971; Historic Ownership Patterns, Wildlife, and Related Resources of East and Tern Islands, French Frigate Shoals by D.K. McDermond, 1990; Symposia results on Resource Investigations in the Northwestern Hawaiian Islands; Atoll Research Bulletin No. 150; other research papers, articles and reports; personal communication with individuals; and a site visit. The planning and design of shoreline protection improvements are detailed in subsequent sections of this report.

1. History. Tern Island was discovered by the French explorer La Perouse on 6 Nov 1786. The French Frigate Shoals were acquired by the United States under the U.S. Guano Act of August 1856. The Shoals were later annexed by the Republic of Hawaii on 13 July 1895, and then transferred to the Territory of Hawaii under the Organic Act of 1900. The French Frigate Shoals were established as a U.S. Department of Agriculture Bird reservation under Executive Order 1019 in 1909 and then transferred to the Department of the Interior in 1939. Tern Island was then occupied by the U.S. Navy beginning in 1942 , although it was never transferred from DOI. In 1948, the Navy transferred the airstrip and Navy structures to Territory of Hawaii. In 1952, the U.S. Coast Guard was issued a permit from the Territory of Hawaii to occupy Tern Island. A Coast Guard long range aid to navigation (LORAN) station was established in 1967. The USCG LORAN station was decommissioned in July 1979.

2. Physical Setting

a. Topography and Physical Features.

French Frigate Shoals was created by volcanic upheaval which formed a mountain ridge, rising 2,500 fathoms above the ocean floor. The atoll, once an exposed top of a volcanic mountain, now forms a series of sand islands with two small exposed volcanic remnants (La Perouse Pinnacle is the most prominent feature) and a double coral reef. The eighteen mile long exposed coral reef, which is crescent shaped, sits atop the submerged mountain which drops off to depths of 12,000 feet and deeper.

b. Climate.

(1) Temperature and Precipitation. French Frigate Shoals has a tropical climate. It is influenced by the Pacific High, with easterly tradwinds prevailing. During winter this High is slightly affected by the Aleutian Low which moves south bringing increased and variable winds and increased precipitation. The mean annual temperature is 75.5° F. From December through April the means are between 71° and 74° F and during the rest of the year between 75° and 80° F. The warmest months are August and September and the coolest months are February and March. During the 11 year period from 1951 to 1962, a 37° degree difference existed between the extreme high of 91° and the extreme low of 54°. The mean annual precipitation is 45 inches with rainfall heaviest from December through March.

(2) Winds. Surface tradewinds prevail from the east. The annual mean windspeed is 13 knots. Windspeeds are higher from November through April and lower from March through October.

During winter the mean windspeed is 14 knots; winds are high from all directions; the highest are from northwest to east-southeast, with a mean maximum from the east-northeast. The spring mean windspeed is 13 knots; winds are highest from west to south, with a mean maximum from the northeast. During summer the mean windspeed is 11.5 knots; winds are highest from northeast to east-southeast with the mean maximum from the east. The mean autumn windspeed is 11.6 knots; the highest winds are from the west-northwest and northwest, and north through south-southeast, with the mean maximum being from the northeast.

(3) Hurricanes. Direct passage of severe tropical storms or hurricanes near French Frigate Shoals is are rare. Winter storms are common with noticeable increases in precipitation, winds and waves. The maximum recorded sustained wind for the period 1951 through 1962 was 52 knots from the east-northeast in December. Storm waves severely damaged the airstrip and Coast Guard facilities on 1 December 1969 without information known of its effect on the wildlife. It took a month and one half to restore the runway to operational status. No one was hurt, but the island's seawall was crushed in various places, soil was badly eroded along the north shore and around the base of the LORAN tower. The vegetation, especially on the northwest side, was washed away. A Coast Guard rescue plane was unable to land. Damage caused by overtopping waves during a major winter storm in the mid-1970's led to the complete reconstruction of the barracks building.

c. Geology and Soils.

Tern Island soils are sparse and have formed above the coral sand, shells and crushed coral rock previously dredged from the reef flat to build the island. Bird guano comprises a major portion of the soil which has assisted in the formation of some humus in vegetated areas.

d. Tidal Data.

Long term tidal data is not available for Tern Island. The tidal data for nearby East Island, French Frigate Shoals, shown below, were obtained from the National Ocean Survey, and are referenced to MLLW. The tides are diurnal.

Table 1. Tidal Data

Data	Elevation (ft.)
Highest Tide Observed	3.00
Mean High Water	1.25
Mean Sea Level	0.00
Mean Low Water	-1.25
Lowest Tide Expected	-2.50

e. <u>Tsunamis and Earthquakes</u>. The French Frigate Shoals are in Seismic Probability Zone 3, where major damages can be anticipated from seismic activity. A tidal wave was reported on 1 April 1946 which completely inundated the islands in the atoll. Damage to the military stations was said to be light; but effects on nesting birds and other wildlife is unknown. Another wave 15 feet in height was observed one-fourth mile offshore on 4 November 1952 which broke up on the reefs. Still another wave caused a 3 foot rise in the water level on 27 March 1954.

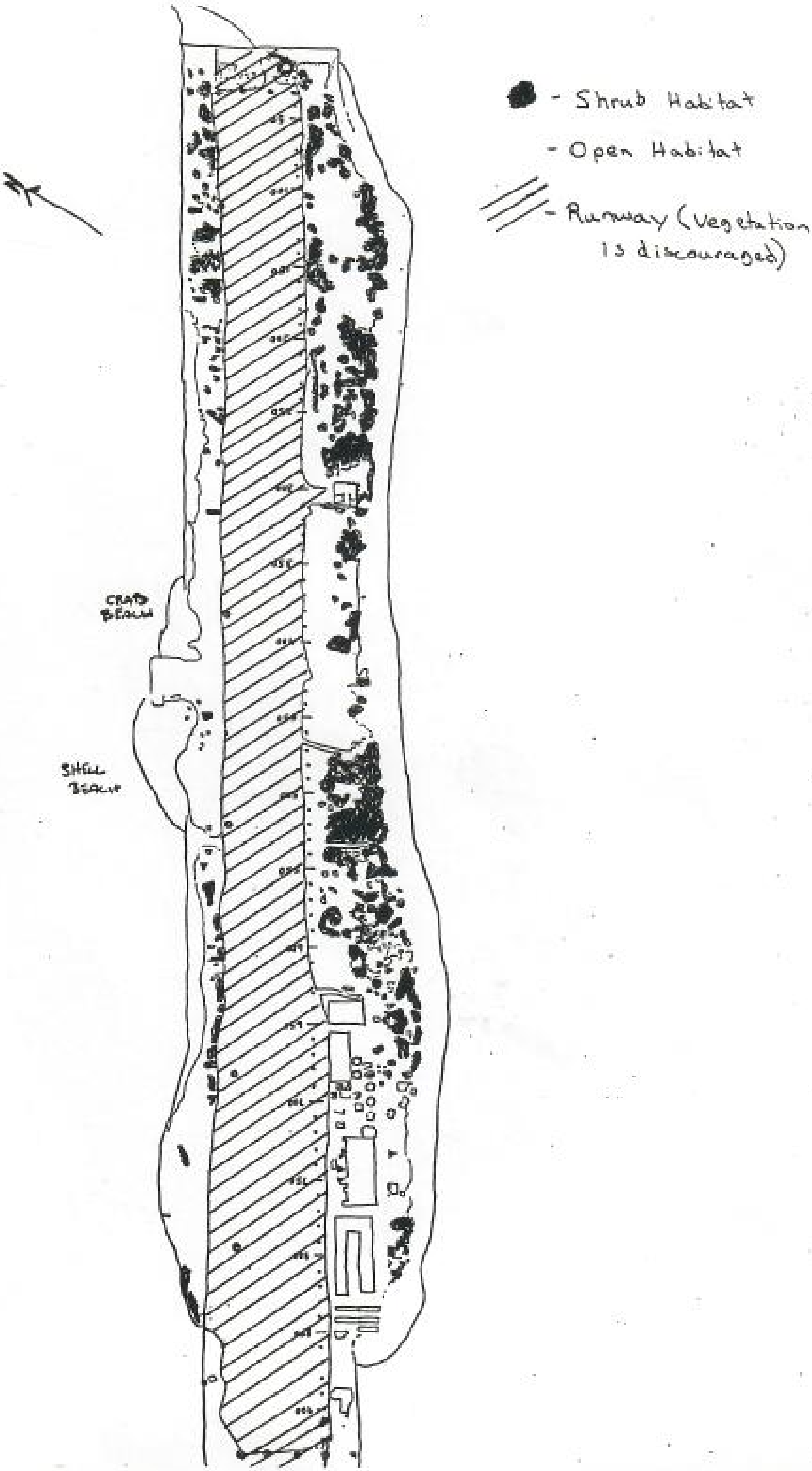
f. <u>Terrestrial Biota</u>.

After the depredation by bird poachers in the late 1800's, the importance of the preservation of wildlife in the NWHI was recognized. President Theodore Roosevelt signed an Executive Order on 3 February 1909 setting aside French Frigate Shoals and most other Northwestern Hawaiian Islands as a preserve and breeding ground for birds. Periodic studies accomplished by various scientists which began a chronology of natural history of the islands focusing primarily on the bird population of the islands.

Little reference is made to vegetation on the islands until the Tanager Expedition visited the atoll in 1923. Six species of plants on nine of the islands were recorded. Another nine species were planted by expedition personnel. None apparently survived long but may have been reintroduced since. World War II activities completely scraped the island of vegetation, covering the island with dredged coral from the lagoon, and began the introduction of exotic species. In 1961, Lamoureux visited Tern Island and collected 21 species of vascular plants; 14 of which were new records for the atoll.

By 1971 thirty-seven vascular plants were recorded from Tern Island (Amerson, 1971). Of these 37 species, 30 are exotic. The vegetation is dominated by 18 species. No candidate endangered plants are located on Tern Island. Only 16 acres of the 37 acre island are vegetated. The runway, which takes up most of the island, is kept free from vegetation. The vegetated areas have been divided into "north of the runway" and "south of the runway". Figure 3 identifies the vegetation by habitat type.- shrub and open. The shrub habitat is dominated by tree heliotrope *(Tournefortia argentea)*, naupaka *(Scaevola sericea)*, and sour bush *(Pulchea symphytifolia)*. The open habitat is covered with numerous low growing forbs and grasses. Species present in abundance include: *Heliotropium curassavicum, Spergularia marina, Chenopodium oahuense, Ipomea pescaprae, Boerhavia repens, Portulaca lutea, Portuaca oleracea, Tribulus cistoides,* and *Cenchrus echinatus*. Several ironwood and palm trees are scattered over the island but form no distinct groups.

Figure 3   Tern Island Vegetation Types.



Birds are definitely the most conspicuous land animals in the atoll. Over 100,000 pairs of nesting birds roost on the limited land area of French Frigate Shoals. The sooty-Tern (*Sterna fuscata*), for which Tern Island was named is the most abundant breeding seabird in the central Pacific and is the most numerous nesting seabird in the NWHI, accounting for almost half of the total breeding population. The populations of Christmas shearwater, gray-backed tern, and the blue-gray noddy are sizable and may be the most important populations worldwide. No seabird species are endemic to the NWHI although the islands provide breeding habitat for a substantial portion of the worldwide population of the black-footed albatross, Laysan albatross, Bonin petrel and the sooty storm-petrel. Other seabirds that nest regularly are the wedge-tailed shearwater, red-tailed tropic bird, and masked booby. Also found in significant numbers are the red-footed booby and the great frigatebird. No endemic land birds are known from Tern Island, but attempts have been made to transplant endemic species from other islands unsuccessfully. Regular migrant shorebird species include the Pacific golden plover, ruddy turnstone, sanderling, wandering tattler, and the bristle-thighed curlew. Although birds breed yearlong on the island, the least disturbing time for nesting seabirds is September and the first half of October. There is an influx of shore birds in the fall starting about August. Counts start to decrease in May as many migrating birds move north for the nesting season (Figure 4).

g. Marine Biota.

The nearshore marine community reflects the characteristics of a tropical atoll with fringing reefs, sandy expanses and shallow lagoons which support the land based creatures including monk seals and turtles that also spend time on land. Since 1948 various research ships of the National Marine Fisheries Service, U.S. Fish and Wildlife Service have visited French Frigate Shoals. Tripartite research in the Northwestern Hawaiian Islands during the 1970's and early 1980's provides considerable information about present day nearshore and offshore resources.

The nearshore marine community consists of various species of coral, over 700 species of fish, over 400 species of algae, over 1,000 species of molluscs, and over 1,350 species of other marine invertebrates. Most of the species are representative of species found throught the Pacific with approximately 20% being endemic to Hawaii. The number of fish species tends to diminish in a northwest direction along the NWHI with a difference in dominant fish species between the main islands of Hawaii and the rest of the NWHI.

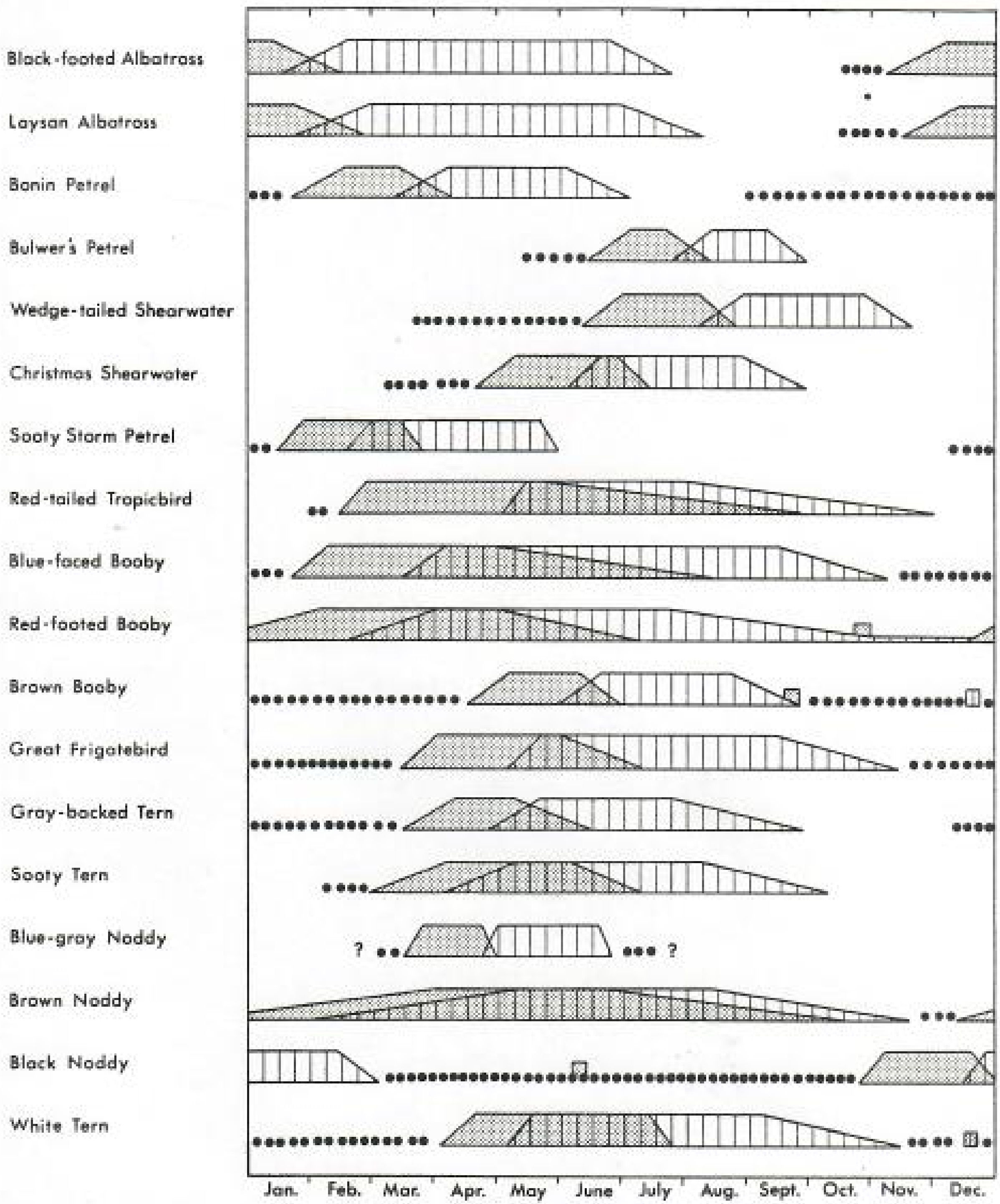


Figure 4 Breeding cycles of seabirds at French Frigate Shoals; stippled areas represent eggs, barred areas young, and black dots nonbreeding birds. (From Amerson, Jr., 1971)

Schooling species, many of which have commercial value, include aholehole (*Kuhlia sandvicensis*, mullet, *Mugil cephalus* and *Neomyxus leuciscus*, and various baitfish including silverside, *Pranesus insularum*, sprat, *Spratelloides delicatulus*, and big-eye scad, *Selar crumenophthalmus*. A commercial lobster fishery was booming in the early 1980s in the waters around French Frigate Shoals. Very large carangid species are nearshore marine predators as are sharks which are ubiquitous around the island with a small population of white tip that frequents the northwest corner of the island. Common species of sharks found in the waters include Galapagos (*Carcharhinus galapagensis*), gray reef (*Carcharhinus amblyrhynchos*), and tiger (*Galeocerdo cuvieri*).

h. <u>Threatened and Endangered Species</u>

There are no candidate, proposed, listed, threatened, or endangered terrestrial species on Tern Island.

The two species that have received the greatest scrutiny in the marine community and are the subject of intensive study are the threatened green sea turtle (*Chelonia mydas*) and the endangered Hawaiian monk seal, (*Monachus schauinslandi*). Although other species of turtles are found in the waters the green turtle is the most widely distributed througout the archipelago. Over 90% of the Hawaiian green sea turtles nest at French Frigate Shoals, principally on East Island although nesting at Tern has increased over the past few years (Figure 5). The aproximate number of nesting females at French Frigate Shoals ranges from only 94-248. Most nesting occurs in June with hatching occurring approximately 60 days later in August. Nesting season at Tern Island has been documented from mid-April to later October. Hatching occurs from July through December (Figure 6). The majority of turtle nesting on Tern Island occurs along the south beach (Figure 7). In 1988, 88 nests were located on Tern Island. All but four of these nests were located on the south shoreline. . The last 3 weeks of March are the least disruptive to the turtle nesting season.

The endemic Hawaiian monk seal is an endangered species which was almost eliminated by sealing expeditions in the mid-19th century. Its endangered relatives in the Mediterranean and the apparently extinct population in the Caribbean bode ill for the survival of this relic population. Since 1975 an intensive program to recover the species has taken place at French Frigate Shoals. Beach counts of seals have been conducted at least weekly on Tern Island by FWS and NMFS personnel since 1979. Although counts increased at Tern following the abandonment by the Coast Guard, dramatic decline has been observed over the last two years bringing concern for recovery efforts. In

FIGURE 5 Green turtle nesting-activity trend at Tern Island, 1986 - 1990.

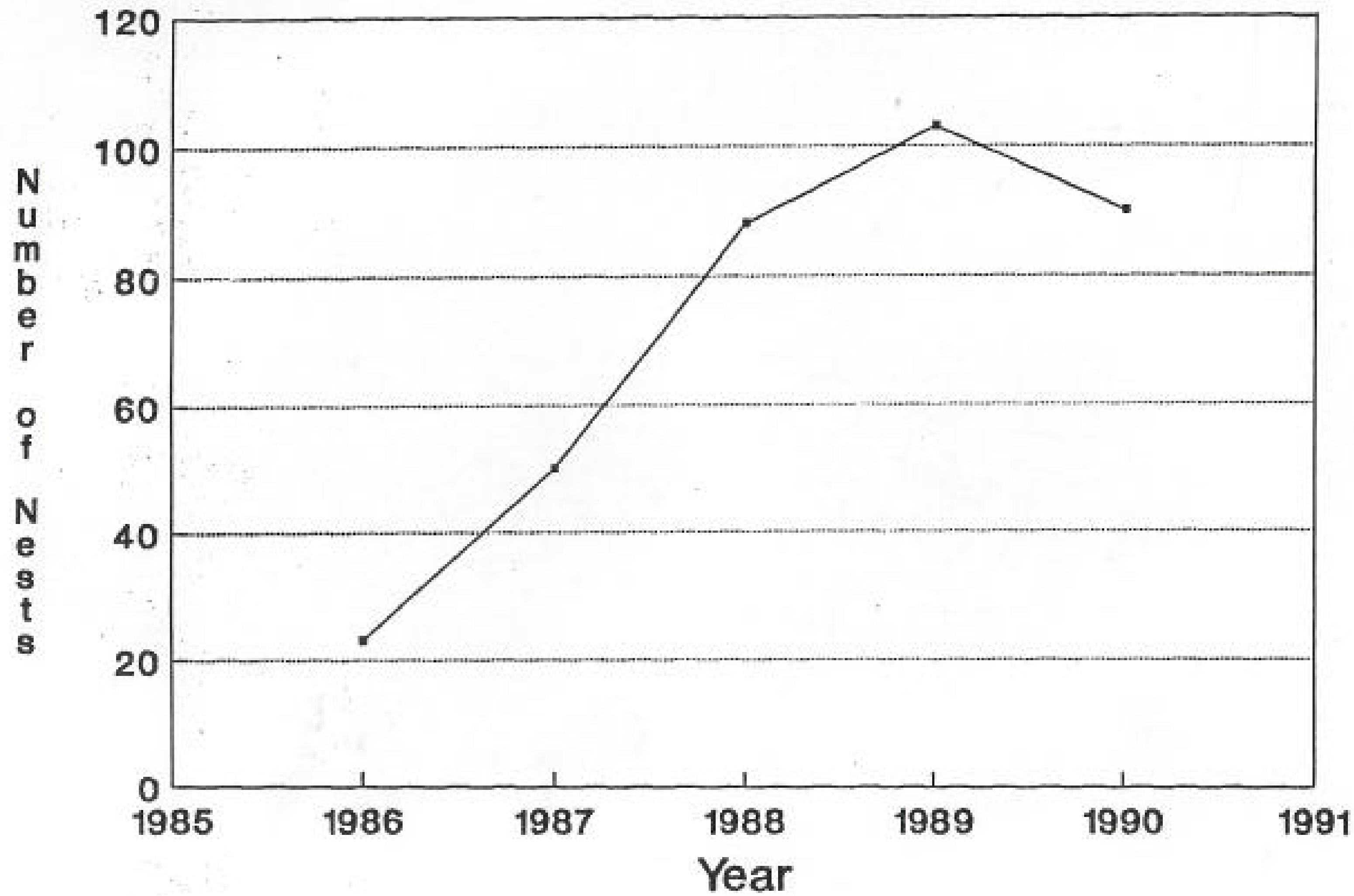
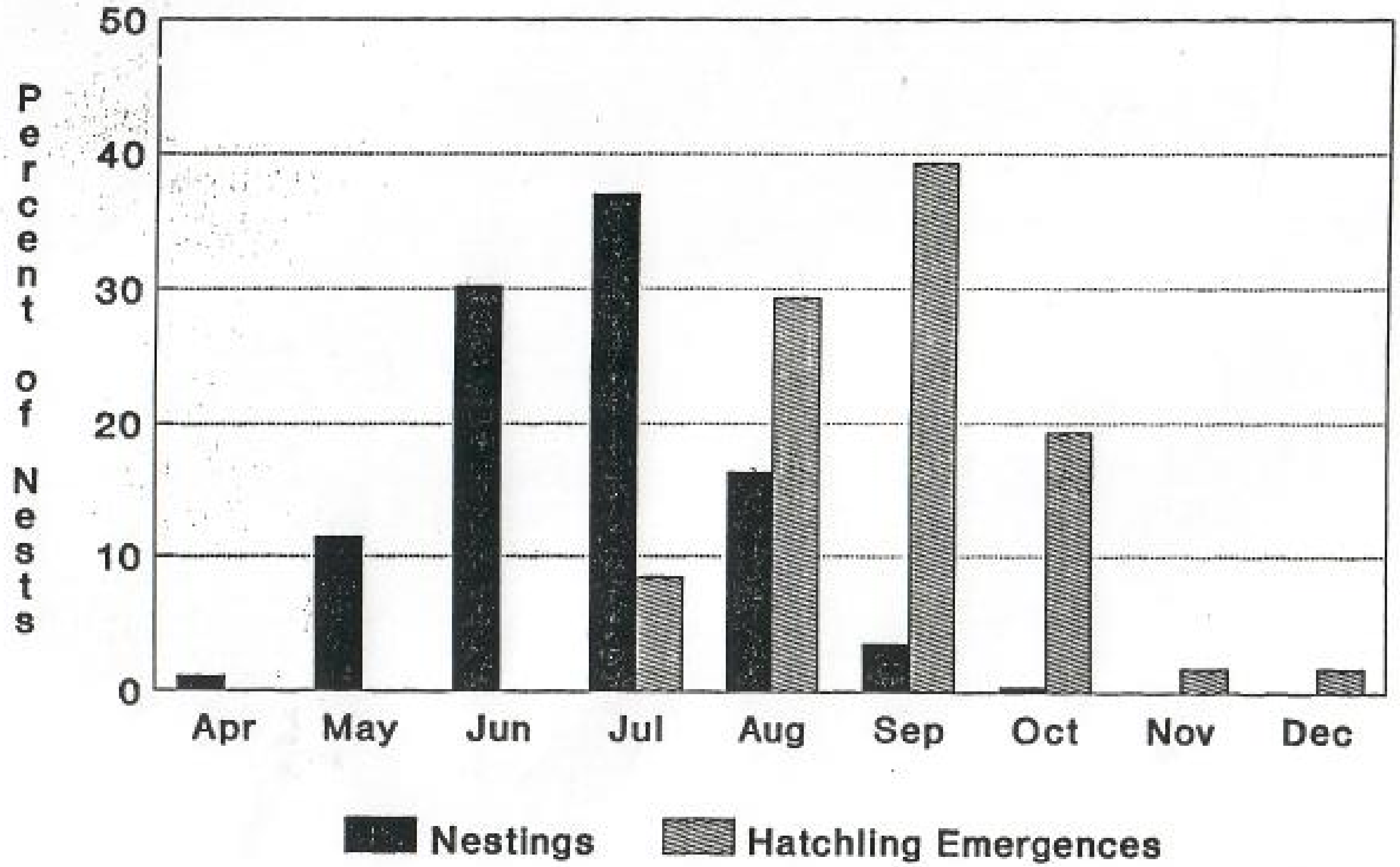
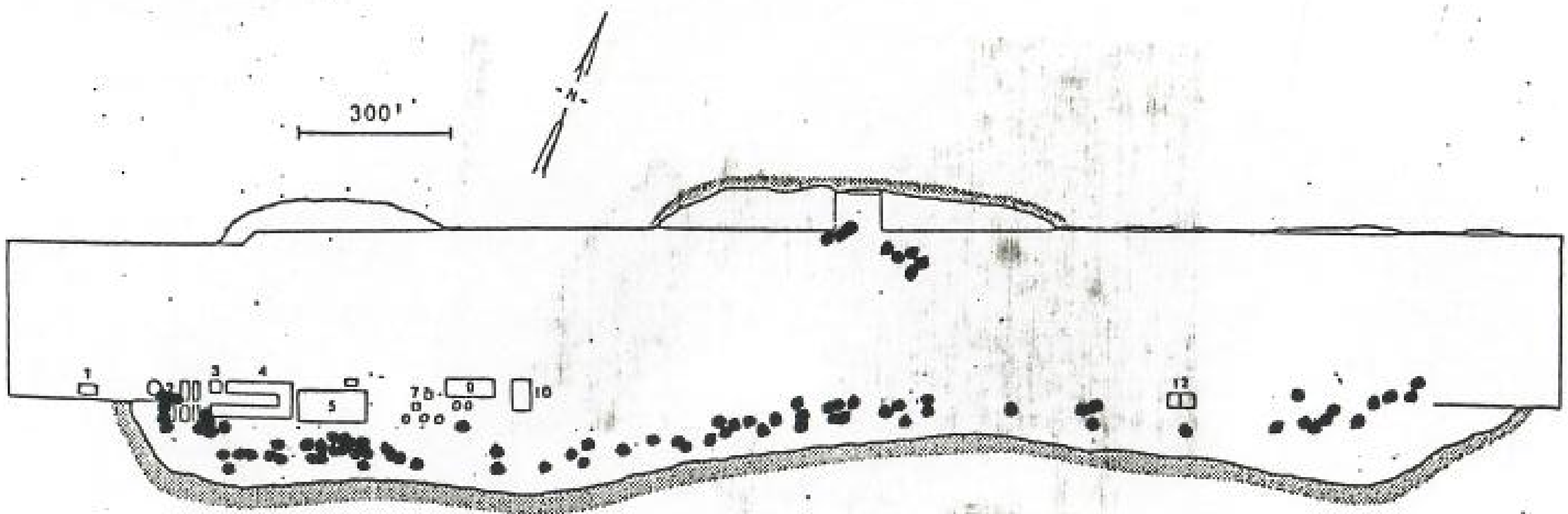


FIGURE 6 **Combined nesting and hatchling emergence phenologies at Tern Island, 1988/89/90.**



Data based upon 281 nests and 270 hatchling emergences.

Figure 7 Locations of 90 green turtle nests found on Tern Island, French Frigate Shoals, 1990.



1. Boat House
2. Fuel Oil Storage Tanks
3. Garage
4. Barracks-Subsistence Bldg.
5. Recreation Court
7. Pump House
8. Fresh Water Tanks
9. Signal Power Bldg.
10. Old Signal Power Bldg.
12. Storage Buildings

1990 there was a substantial decline in the number of monk seal pups born at the major breeding locations. The cause of the decline has not been determined, however the cause is being related to a large-scale environmental phenomenon. In 1991 there was also a substantial decrease in atoll-wide beach counts at FFS with an overall decline of between 25-30 percent. This suggests a loss of 150-200 seals.

Pupping season is the most sensitive time for seals. The first pupping on Tern Island was recorded in 1989 on the south shore. There is little haul out habitat along the north shoreline. Monk seals primarily use Tern Island as a haul-out habitat (Figure 8). They move toward the beach crest in the later afternoon and evening hours, spending the night within vegetation or under buildings. From early to mid-morning they begin to move back down toward the waters edge. Many animals haul out during the heat of the day to bask primarily along the south shore (Figure 9).

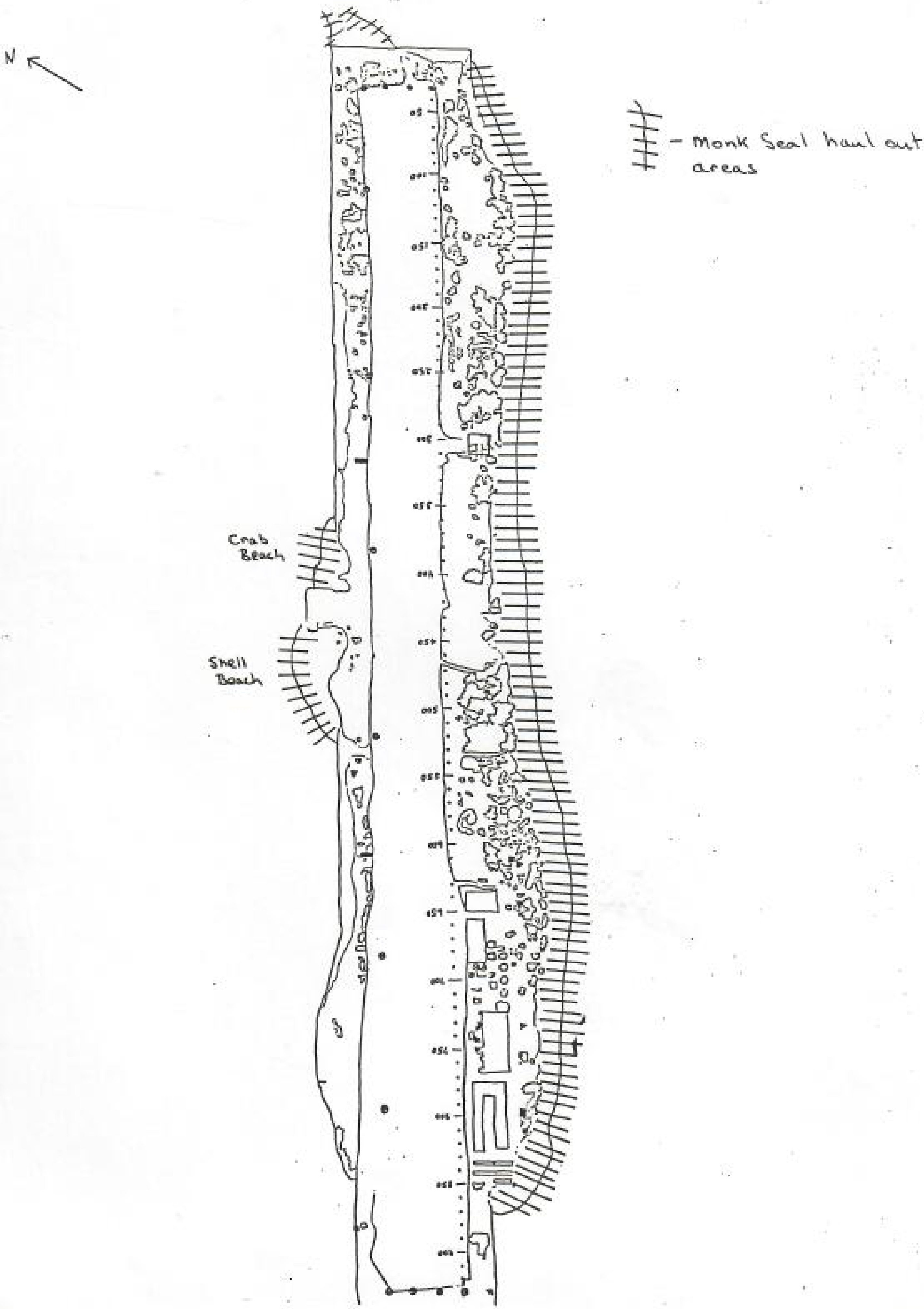
i. Access and Utilities. Logistical support for Tern Island is provided by a private air charter firm under contract to the Fish and Wildlife Service. Unscheduled surface transport assistance is provided by port calls by a U.S. Coast Guard cutter from Honolulu. The support facilities for the USFWS staff are contained within the abandoned Coast Guard buildings.

j. Land Use. The present and expected use of Tern Island is that of a National Wildlife Refuge.

C. FUTURE OF PROJECT SITE WITHOUT PROPOSED PROJECT

If no action is taken to provide adequate shore protection improvements, then continued deterioration of the sheet pile bulkhead will result in accelerated shoreline erosion along the northern and western shorelines of Tern Island. Due to the high degree of exposure to storm waves along the west and northwest portions of the Tern Island shoreline, it is highly possible that erosion in this area may jeopardize the runway within two to five years. Continued corrosion and weathering will probably render most of the steel sheet pile incapable of retaining the fill materials that comprise most of Tern Island within ten years. Due to man's interference with the natural atoll processes by dredging the World War II ship channel, it is difficult to assess either the ultimate configuration of Tern Island in the absence of the sheet pile bulkhead or the rate at which natural forces would reshape the island.

Figure 9 Monk Seal Haul out areas on Tern Island.



D. PROBLEMS AND NEEDS

1. Existing Shore Protection at Tern Island.

The existing shore protection structure at Tern Island consists of an unanchored steel sheet pile bulkhead initially constructed during 1943. The sheet pile is driven directly into the coral reef which has an average depth of between -6 and -8 feet MLLW. The sheet pile top elevation is a generally uniform +6.5 feet MLLW around the entire island. Maintenance and repair records for the existing structure do not exist.

2. Problem Description.

a. General.

The main problem area is along the northern and western faces of the existing steel sheet pile bulkhead. A ship channel dredged during World War II extends along the entire western shoreline and approximately 3,200 feet of the northern shoreline. The channel width varies from 300-400 feet along the west shoreline to 150-300 feet at its terminus near the east end of Tern Island. The channel depth averages 20 feet with some deeper portions of up to 24 feet. The approximate channel centerline varies from 280 to 180 feet offshore from the existing sheet pile bulkhead.

The northern shoreline of Tern Island is exposed to storm waves from the northeast through northwest directions. Storm waves break on the the fringing reef, and reform across the reef flat. Tern Island receives direct attack from the reformed storm waves along the northern, eastern and western faces. The smooth vertical face of the existing sheet pile bulkhead serves to reflect incident wave energy with the return energy tending to wash scourable materials such as sands and gravels to the deeper water of the ship channel where they are lost from the littoral system. The face of the bulkhead also redirects wave runup along a near vertical path where the predominant onshore winds exacerbate overtopping and the resultant onshore flooding. Actual erosion effects along Tern Island are evident in the areas where the steel sheet pile has corroded and deteriorated to an extent where the overtopping waves wash the backshore fill materials into the ocean. It is likely that these materials are also washed into the deep water of the ship channel due to the scour effects exacerbated by the bulkhead face.

The southern or leeward shoreline of Tern Island is sheltered by the interior expanse of the French Frigate Shoals, with the consistently calm conditions evidenced by the stable accreted beach burying the remnants of the steel sheet pile bulkhead.

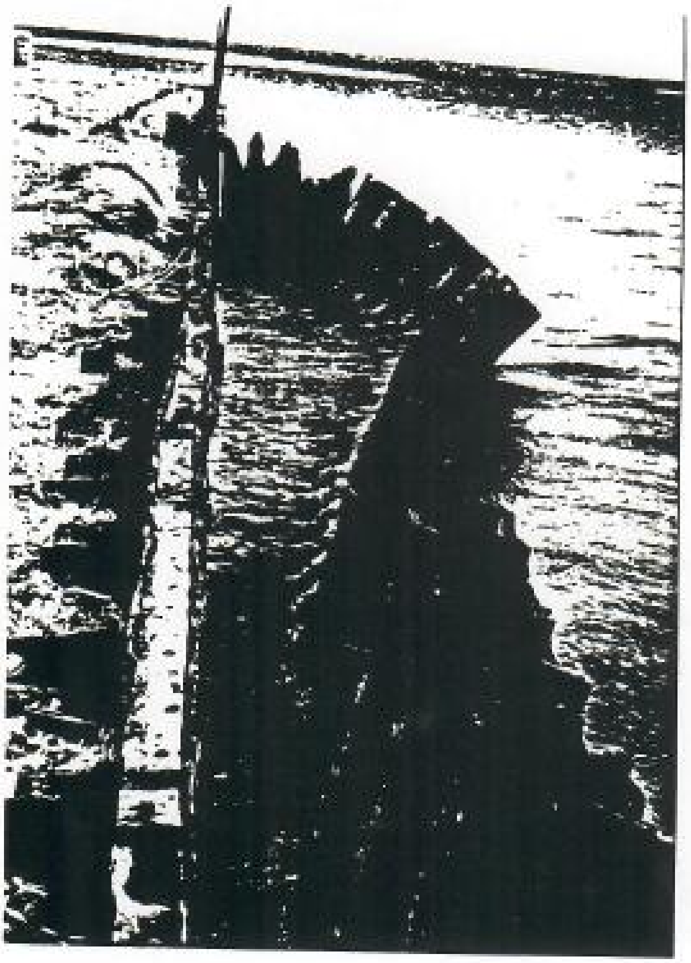
b. Condition of Existing Shore Protection at Tern Island.

The portions of the existing steel sheet pile bulkhead which are subject to failure are adjacent to the deep water of the old Navy ship channel and are vulnerable to overturning due to a lack of any deadman anchoring system (Figure 10). In addition, portions of the sheet pile are sufficiently corroded that they are transparent to wave attack, and the overtopping action has washed coralline fines into the ocean. The sheet pile poses an entrapment hazard to turtles and seals (Figure 11). Entrapment sightings are unpredictable and irregular (Table 2).

c. Shore Protection Reaches.

(1) Reach 1. Reach 1 is approximately 330 feet long and extends along the west end of Tern Island. Reach 1 is adjacent to the deepest portion of the ship channel, but is not directly exposed to breaking waves due to its generally north-south orientation. The average height of the sheet pile bulkhead in this reach as viewed from land is between 0 and 0.5 feet.

(2) Reach 2. Reach 2 is approximately 370 feet long and extends from the extreme northwest corner of Tern Island through the area in which the existing tide gage station is located. Reach 2 is the portion of the northern shoreline of Tern adjacent to deep water. Reach 2 has the greatest wave exposure along the northern shoreline as the presence of the dredged ship channel has reduced the width of the offshore reef platform to the maximum extent found off Tern Island. The average height of the sheet pile bulkhead in this reach as viewed from land is between 0.5 and 3.5 feet.



Buckled seawall on west end of Tern Island.

FIGURE 10

Example of potential seal entrapment behind Tern Is. seawall.

FIGURE 11

Table 2

Table of Seawall Entrapment Sitings at Tern Island

	Turtles	Monk Seals
1986	1 stranded on runway 1 trapped along seawall behind shell and crab beaches 1 trapped along seawall under diesel fuel tanks 1 stranded near Ironwood tree above north seawall	NIA
1987	no entrapments or strandings reported	NIA
1988	1 trapped between the 2 seawalls just east of boat shed	NIA
1989	NIA	NIA
1990	NIA	NIA
1991	NIA	1 subadult male behind seawall

NIA= No Information available

(3) Reach 3. Reach 3 is comprised of approximately 1,070 feet of shoreline from the end of Reach 2 to the Crab and Shell Beach area near the midpoint of Tern Island. Portions of the sheet pile have deteriorated to the point of structural failure, with the bulkhead visibly bowed into the water. The width of the dredged ship channel begins to diminish from the start of Reach 3 towards the east end of Tern Island. As more of the remaining reef flat is intact from Reach 3 east, the amount of natural protection from storm waves increases from this point east. The average height of the sheet pile bulkhead in this reach as viewed from land is between 0 and 5 feet.

(4) Reach 4. Reach 4 is comprised of the Crab and Shell Beach portions of the northern shoreline of Tern Island and extend approximately 735 feet in length. This area is characterized by a 100′ wide peninsular extension of the sheet pile approximately 80′ feet seaward which acts as a groin in allowing the accretion of the coarse coral sand and gravel beach slopes to the east and west of this feature. The average height of the sheet pile bulkhead in this reach as viewed from land is between 0 and 3 feet.

(5) Reach 5. Reach 5 is comprised of the northeast shoreline of Tern Island from the Crab and Shell Beach area to the extreme east end of the island and is approximately 1,155 feet long. Distinct evidence of the ship channel dredging is found up to approximately 300 feet from the extreme east end of the island. The average height of the sheet pile bulkhead in this reach as viewed from land is between 3.5 and 5.5 feet.

(6) Reach 6. Reach 6 is 350 feet long and is comprised of the extreme eastern end of Tern Island. The sheet pile bulkhead is generally in its best condition along this reach. In addition, the backshore land displays mimimal evidence of shoreline erosion. The average height of the sheet pile bulkhead in this reach as viewed from land is between 0.5 and 1.0 feet.

d. Problem Summary.

A total of 4,130 feet of west, north and east shoreline of Tern Island was reviewed in order to identify appropriate levels of shore protection measures. Remedial stabilization of the northwest corner of Tern Island was provided as a portion of a U.S. Army Corps of Engineers cleanup action undertaken to remediate the abandoned Navy fuel tanks. The USFWS resident staff lacks the resources and capability to maintain or repair the deteriorated steel sheet pile bulkhead. In addition, the extreme age and advanced corrosion of the sheet pile serve to provide minimal retention of the coral fill material during storm wave attack.

Under the worst case scenario, portions of the fill material in Reaches 1, 2 and 3 would wash-out completely, damaging the runway surface and precluding emergency as well as routine air support to Tern Island. Such an occurance would thereby deny USFWS the ability to safely maintain a human presence on Tern Island for research and enforcement purposes, as the travel distance from the main Hawaiian islands precludes other expedient transportation means.

(1) Critical Requirements. The sheet bulkhead along the northern shoreline of Tern Island from Station 0+00 to Station 14+40 requires replacement within the immediate 5 years. In addition, the sheet pile bulkhead from Station 20+00 to Station 28+40 has deteriorated to the point where the upper 3-4 feet of the wall are ineffective against wave attack, and merit replacement to the original elevation of +6.5′ MLLW.

(2) Intermediate Requirements

(3) Long Term Requirements. The remaining lifespan of the exposed portions of steel sheet pile bulkhead is not known and may be less than 10 years. The exposed bulkhead along the east end of Tern Island may require stabilization in order to protect the runway safety zone.

E. PLANNING OBJECTIVES

The planning objectives of this study were established to guide the development and evaluation of alternative plans for the mitigation of shore erosion along Tern Island. These planning objectives are based on the analyses of technical and environmental aspects of this problem, and the concerns and needs of the Pacific Islands Refuge Complex, USFWS. The planning objectives are as follows:

1. *Structures must minimize wildlife entrapment hazard in perpetuity.* The selected shore protection measures should not pose entrapment hazards during their functional lifespan. In addition, the shore protection structure should deteriorate in a fashion that its remnants shall not pose a wildlife entrapment hazard at the end of its functional life.

2. *Structures must maintain stable shoreline for a minimum of 25 years.* The selected shore protection measure shall protect or maintain the alignment of the existing shoreline for not less than 25 years following the

completion of construction. As Tern Island will remain an isolated research station within an operating wildlife refuge, the structure will be of a type which will require no maintenance for the duration of the 25 year lifespan

3. Structure must contain debris on and in the island. Construction of shore protection measures along the shoreline shall include the appropriate degree of removal of the deteriorated steel sheet pile along the structures' alignments. The selected shore protection measure should not allow buried debris near the shoreline to become exposed at any time during the project's 25-year lifespan.

III. FORMULATION OF ALTERNATIVE PLANS

A. FORMULATION AND EVALUATION CRITERIA

This section of the study is directed toward the development and evaluation of alternative measures to stabilize the shoreline of Tern Island. First, the broad range of technical measures available to resolve shoreline erosion problems must be identified. Second, these measures are evaluated to formulate a recommendation for short term and long term actions, which best resolves the shoreline erosion problem and meets the needs of both the USFWS refuge management staff and the wildlife dwelling in the refuge itself.

The formulation and analysis of alternative solutions to achieve the planning objectives is based on U.S. Army Corps of Engineers regulations and engineering guidance regarding the planning and design of shore protection measures. The evaluation and assessment of environmental effects follows the guidelines of the National Environmental Policy Act of 1969 (NEPA), and pertinent Corps of Engineers regulations and guidelines. The formulation and evaluation of alternative improvement plans are guided by the following technical and environmental criteria.

1. <u>Technical Criteria</u>. The following technical criteria were established for plan formulation. Alternative measures should:

a. <u>Short Term</u>. Provide protection for the shoreline of Tern Island from further land loss due to erosion of its coral fill material over a 2 to 5 year timeframe. Protect the runway and refuge operations buildings from storm wave damage.

b. <u>Long Term</u>. Provide shore protection that serves as a replacement for the existing steel sheet pile bulkhead that will allow maintenance of the existing runway, terrestrial habitat and appropriate refuge operations over a 25 year planning analysis period.

2. Environmental Criteria. The following environmental criteria were established for plan formulation. Alternative measures should:

a. Minimize or eliminate wildlife entrapment along the shoreline of Tern Island.

b. Possess minimal adverse impacts on the indigenous wildlife during the construction phase of the action.

c. Protect terrestrial and aquatic flora and fauna.

B. PRELIMINARY SCREENING OF ALTERNATIVE SHORE PROTECTION MEASURES

Numerous nonstructural and structural measures are available to manage or prevent shoreline erosion. The applicability of these measures in resolving the specific problems of the study area is discussed in this section.

1. Nonstructural Measures.

a. No Action. The no-action alternative would leave the existing erosion condition unchanged. The shoreline would remain vulnerable to storm wave damage, resulting in continued loss of coral fill material. The erosion process will accelerate with continued corrosion and deterioration of the steel sheet pile bulkhead, resulting in uncovering of additional buried debris which will pose further entrapment hazards to wildlife. If the erosion remains unchecked, additional terrestrial habitat will be lost as well.

b. Vegetative Barriers. Vegetative barriers are not sufficient to protect the shore from erosion under conditions of direct wave action under storm conditions. Vegetation does not protect against storm waves, and is more fragile than other available erosion control measures. Consequently, maintenance of a vegetative barrier requires reconstruction and replanting after major storms. This measure is not considered to be an acceptable alternative as the northern shoreline of Tern Island receives direct wave action.

c. Shoreline Management. Shoreline management is defined as the planning and implementation of shoreline uses compatible with the recognized erosion risk. As Tern Island is operated as a wildlife refuge with a minimal human presence, there is no land available for a setback area to mitigate the effects of the natural erosion processes.

2. Structural Measures.

a. Revetment. A revetment is a sloped facing of stone, concrete blocks, sandbags, or other materials, built to protect a scarp, embankment, or shore structure against erosion caused by wave action. Revetments are characterized by multiple layers of porous graded materials which serve to filter or prevent the migration of the fine underlying soils against wave and tidal action. A permeable, sloping revetment has an excellent capacity for dissipating wave energy. The placing or fitting of the materials used to construct a revetment result in a flexible structure which is tolerant of variations in foundation conditions. There are many types of revetments, and many kinds of materials are used in their construction. Rock revetments have been widely used for shore protection throughout Hawaii and the Pacific Islands, using either quarried basalt, coral or limestone, depending upon local availabilty. Revetments using precast concrete armor units have been considered for use in Pacific Islands areas where quarry stone is unavailable, however structure costs can be prohibitive. The irregular surface of a revetment also minimizes wave scour and will provide a surface more conducive to sand accretion than the smooth steep surfaces of a bulkhead or a seawall.

The cost of revetment construction is generally lower than those of other types of shoreline armoring structures. Where quarry stone is readily accessible or available, a rock revetment is generally the lowest cost shoreline armoring measure, based on the cost and availability of materials, constructibility, durability, and maintenance requirements.

b. Seawall. A seawall is a generally massive self-supporting structure intended to protect a backshore area against wave action by its own resistance to wave action. The disadvantages of a seawall include a wider benthic footprint than a bulkhead, but equal to or narrower than a revetment, high wave reflection and overtopping potential, zero wildlife access from the ocean side, less than ideal egress from the land side. Seawalls are similar to gravity retaining walls constructed on dry land. The stability of a seawall against wave and earth forces is dependent on its massive weight. The facing is generally vertical or steeply sloped, which allows for the maximum use of land areas. In general, seawalls are the costliest measures per foot of shoreline protected due to the the large quantities of concrete required, in combination with the need for dewatering. Disadvantages of a seawall are the near total wave reflection characteristics due to its impermeable near-vertical face, and the lack of access for wildlife.

c. Offshore Breakwater. An offshore breakwater is an offshore structure designed to protect a stretch of shoreline from wave action. An offshore breakwater can provide shoreline protection by dissipating wave energy that would normally strike the shore and cause erosion. An offshore breakwater may be built as low profile structures, or to a height sufficient to prevent overtopping under design wave conditions. Depending on the level of protection desired, offshore breakwaters can be either continuous or segmented to allow for water passage and increased water circulation, and are generally of rubble-mound construction. Disadvantages of an offshore breakwater include covering previously undisturbed portions of reef, disturbance to the reef due to causeway filling or excavation in order for construction equipment access to place the breakwaters. In addition, offshore breakwaters do not serve to retain backshore land, and in high wave energy environments only reduce the erosion rate. During extremely severe storms, erosion of the unprotected shoreline will still occur, which will expose the buried debris.

d. Groins. Groins are long, narrow shore perpendicular structures intended to (1) build or widen a beach by trapping littoral drift; (2) stabilize a beach by reducing longshore transport out of the groin-compartmented area; (3) reduce the rate of longshore transport out of an area by reorienting a section of the shoreline to an alignment more nearly perpendicular to the the predominant wave direction; (4) prevent loss from an area by acting as a littoral barrier. Groins which are too short in length may act to "jet" littoral materials to deep water and remove them from the littoral system. Groins will not shield the shoreline during periods of extreme storm waves nor will they serve to retain backshore land. Buried debris may be exposed as a result of erosion during the extreme storm events.

e. Bulkheads. A bulkhead is a vertical earth-retaining structure. In comparison with a seawall, a bulkhead may be considered a membrane structure which requires an anchoring system in order to sustain its structural integrity. A properly designed steel sheet pile bulkhead requires installation of an anchoring system to stabilize the structure against passive movement of the retained soil. The primary advantage of a bulkhead is the narrow benthic footprint of the structure. The disadvantages of a bulkhead include high wave reflection and overtopping potential, zero wildlife access from the ocean side, less than ideal egress from the land side, high noise and vibration generated during the pile driving operations, and severe disturbance of terrestrial habitat due to excavation required to install the anchoring system.

FUNCTIONAL ANALYSIS

Structure must minimize wildlife entrapment hazard in perpetuity. At no time during or past the service life of the shore protection structure should the remaining materials serve to entrap wildlife. Flexible, placed structures such as rubble or concrete unit revetments, offshore breakwaters or groins will tend to fail in such a way that they collapse upon themselves. The remnants of such structures would thus functionally resemble natural rock formations and should, therefore, not pose any entrapment hazard. Rigid structures such as seawalls and bulkheads may deteriorate or fail with portions of wall intact which would pose possible entrapment hazards.

Structure must maintain stable shoreline for a minimum of 25 years. The wave attenuation characteristics of the shallow fringing coral reefs surrounding most Pacific Islands largely determines the maximum height of the waves which will strike land. The ability of waves to reach the shoreline of Tern Island is largely dependent solely upon the amount of elevation of the water level (storm surge) in combination with high tides. As a result, there are neglible cost differences between shore protection structures with design wave heights for a 25 year return interval and those for higher return interval storms. The computed depth-limited breaking wave for shorelines in the Hawaiian Islands, American Samoa and other Pacific Islands may be only fractions of a foot higher for a 50 year storm than for a 25 year storm. The design wave computed for this study is based upon a storm of the intensity of Hurricane Iwa (1982) passing close to French Frigate Shoals.

Structure must contain debris on and in the island. A shore protection structure placed along the alignment of the existing sheet pile bulkhead may contain the sheet pile by providing that the steel be removed to a depth that will encapsulate material during the functional life of the structure. If the shore protection structure posseses an adequate lifespan, it may be considered a near permanent encapsulation of the debris buried within Tern Island. If the shore protection measure does not possess an adequate lifespan, at some point after its useful life, the structure will allow erosion to continue and ultimately expose additional buried debris.

Final Screening of Alternative Shore Protection Measures.

All three study objectives may be met by replacing the deteriorated steel sheet pile bulkhead with a sloping revetment of quarry stone or precast armor units.

IV. DEVELOPMENT OF DETAILED PLANS

A. GENERAL

The maximum retention of backshore land is provided by providing a shoreline structure (shoreline armoring). Offshore breakwaters alone will not meet the study objective of containing buried debris. In addition, shore protection structures which provide a sloping, rough and porous facing will serve to reduce wave overtopping as compared to the existing impermeable vertical sheet pile bulkhead or a functional equivalent.

B. DESIGN/CONSTRUCTION CONSIDERATIONS

Several factors were identified as having potential impacts upon the design or construction of the proposed project. In addition, the long Corps of Engineers involvement in shore protection throughout Hawaii and the Pacific Islands has resulted in the adoption of certain standard practices regarding the design and construction of coastal projects. These were as follows:

(1) No subsurface geotechnical investigations have been conducted along the Tern Island shoreline. Onshore structures will require an appropriate design for the seaward toe in areas where site investigations indicate the presence of a sandy bottom. The reef elevation will be considered to be of a uniform depth except in areas where hydrographic surveys indicate the effects of the World War II channel dredging.

(2) Cover (armor) layer materials will be either graded basaltic quarry stone or precast (portland cement) concrete (Figure 12). Underlayer and bedding materials will be entirely basaltic quarry stone. Filtering material will consist of synthetic geotextile fabric. No reinforcing steel or coating materials will be used in the shore protection structures.

(3) Based upon standard Corps of Engineers criteria for design of coastal structures, all seaward facing structure slopes will be 1.0 vertical on 1.5 horizontal (33.69° from horizontal) or 1.0 vertical on 2.0 horizontal (26.57° from horizontal).

(4) There are currently no Corps approved sources for stone within French Frigate Shoals. Thus all stone used in the construction of shore protection structures at Tern

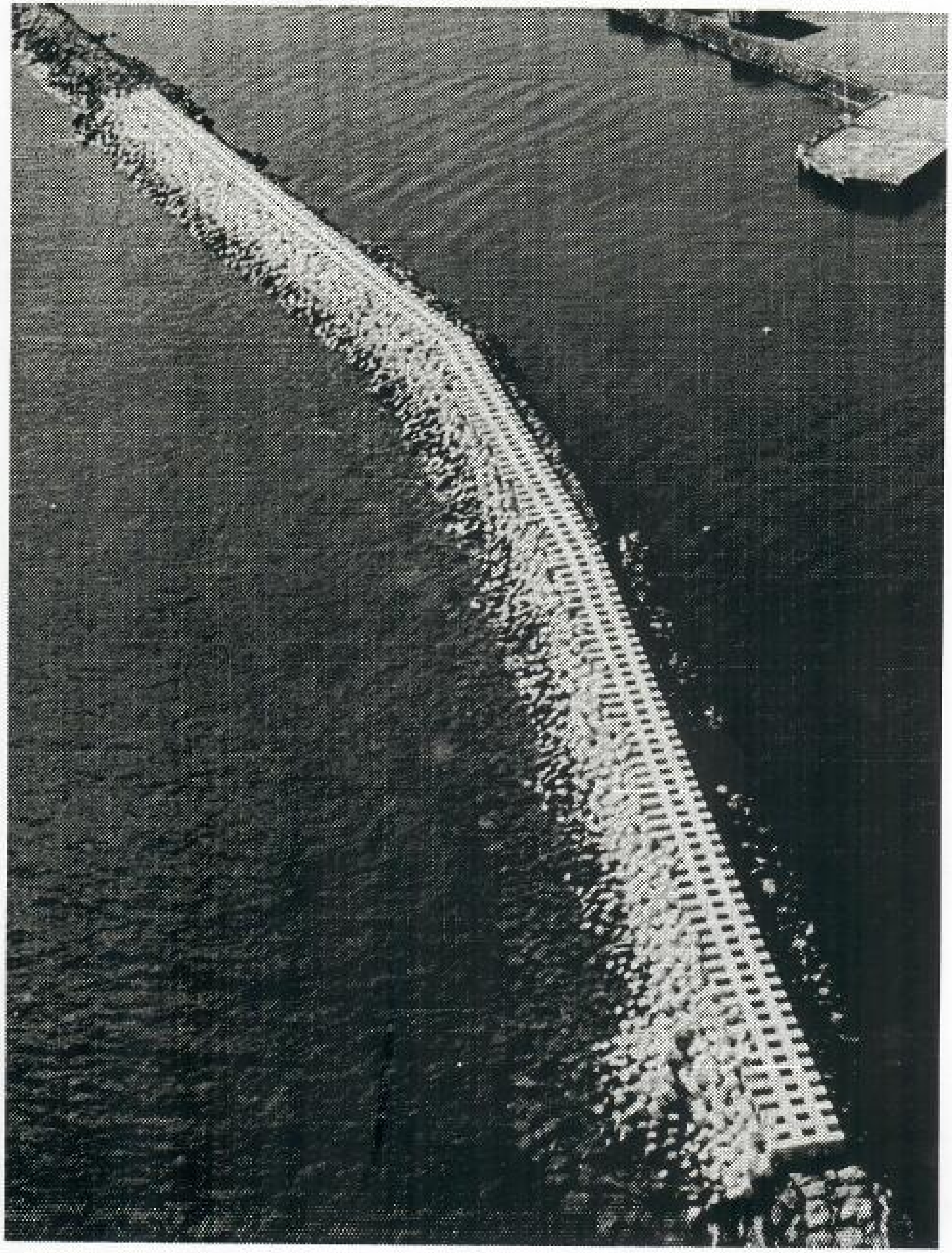


Figure 12
Example of Tribar Breakwater

Island is assumed to be basaltic material imported from existing Corps approved commercial quarry operations on the islands of Kauai or Oahu.

(5) The alignment of onshore structures shall correspond to that of the existing sheet pile bulkhead in order to minimize disturbance of the reef, and to eliminate alteration of the existing current regime around Tern Island in order to eliminate far-field effects that may alter the existing beach on the south shoreline. Sharp corners or abrupt changes in structure alignment such as are present in the existing bulkhead will be avoided in order to reduce eddy currents which may have negative effects on the littoral regime.

(6) Where structures are proposed for construction in loose unconsolidated material such as sands, gravels and cobbles, Corps of Engineers construction contract specification requires that material excavated in order to place a shoreline structure will be replaced along the seaward toe of the structure.

(7) All debris and scrap metal uncovered or removed from the project site will be disposed of at an approved site on the main Hawaiian islands.

C. ALTERNATIVE PLANS

1. <u>General Formulation</u>.: The initial formulation of alternative plans is based upon consideration of a project life of 25 years or greater in order to identify the maximum project scope and cost necessary to stabilize Tern Island at its present acreage. Under this extremely conservative assumption, all of the bulkhead face which is either permanently or seasonally not covered by sandy beach will be replaced by revetment (shoreline armoring) or indirectly shielded. The following further assumptions are made:

a. Crab and Shell Beaches will remain permanent features providing that a shore-perpendicular structure such as the existing sheet pile extension or its functional equivalent, remains in place.

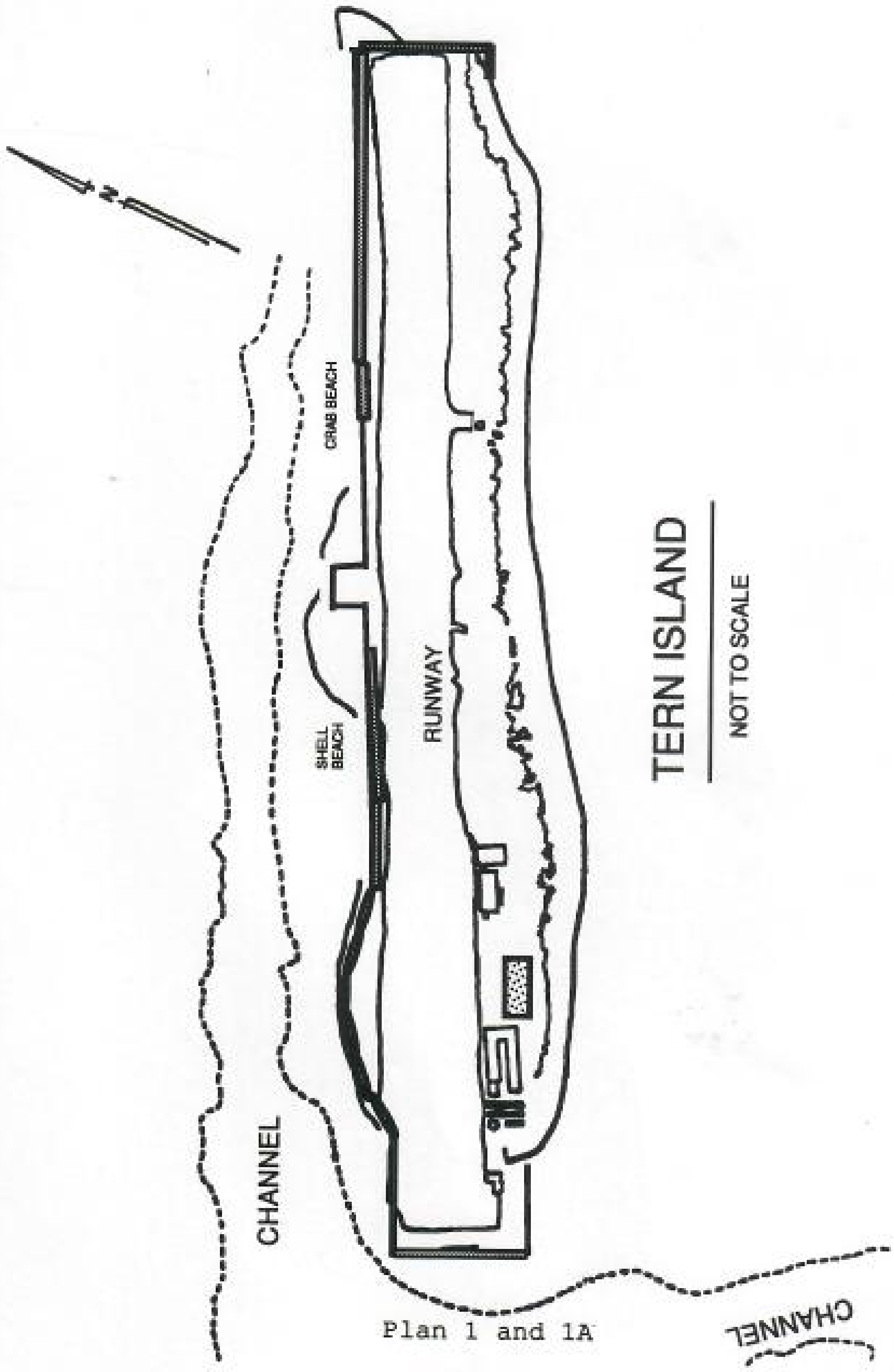
b. All of the north facing sheet pile bulkhead will require replacement within 5 years.

c. The sheet pile bulkhead at the east and west ends of the runway will require replacement within 10 years.

2. Plan Descriptions. Nine possible courses of action for shore protection at Tern Island are briefly described in the following discussion:

a. Plan 1: Rock Revetment. Plan 1 consists of a total of 3,430 linear feet of rock revetment along the west, north and east shorelines of Tern Island. No structures will be constructed within Shell and Crab Beaches. The revetment will be constructed to a design crest elevation of +6.5 feet MLLW to correspond to the height of the existing sheet pile bulkhead. Reach 1 will be protected by two layers of armor stones varying from 1,100 to 1,800 pounds on a slope of 1.5 horizontal to 1 vertical in order to minimize the structure width adjacent to the ship channel. Reaches 2, 4 and 6 will be protected by two layers of 900 to 1,500 pound armor stones on a slope of 2.0 horizontal to 1 vertical in order to minimize runup and overtopping effects. The revetment crest width will be three stones or approximately 6 feet wide in order to mitigate the effects of overtopping waves. The revetment underlayer will consist of a 2 foot thick layer of 50 pound to 150 pound stones. A layer of synthetic geotextile will be placed under the underlayer stones to prevent migration of the underlying soils through the structure. The existing sheet pile will be removed to an elevation of -2.0 feet MLLW so that the remaining bulkhead face is encapsulated within the revetment cross section. The nominal diameter of the surface voids between the contacting faces of the armor stones will be approximately 6 to 8 inches in diameter. Careful fitting can result in smaller diameter voids between the armor stones. The amount of reef covered is estimated at 2.1 acres by this plan (Figure 13).

b. Plan 1A: Concrete Tribar Revetment. Plan 1A consists of a total of 3,430 linear feet of precast concrete tribar revetment along the west, north and east shorelines of Tern Island. The revetment will be constructed to a design crest elevation of +6.5 feet MLLW to correspond to the height of the existing sheet pile bulkhead. Reaches 1 through 6 will be protected by single layer of 1,000 pound precast tribars on a slope of 2.0 horizontal to 1 vertical in order to minimize runup and overtopping effects. The revetment crest will consist of 900 to 1,500 stones placed three units or approximately 6 feet wide. The revetment underlayer will consist of a 2 foot thick layer of 50 pound to 150 pound stones. A layer of synthetic geotextile will be placed under the underlayer stones to filter the underlying soils. The tribar armor layer will have surface voids approximately 18 inches in diameter and 6 inches deep.



Plan 1 and 1A

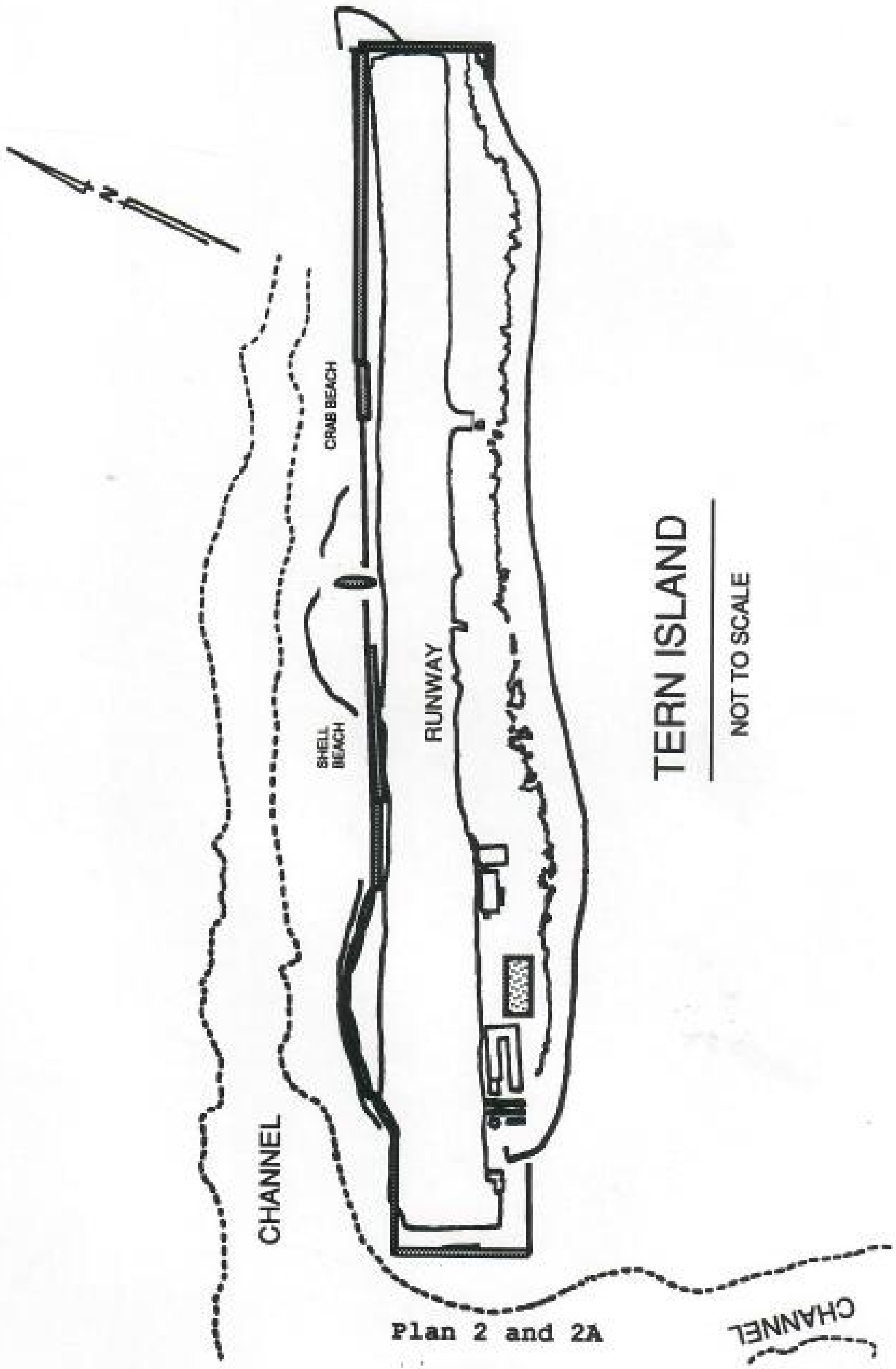
Figure 13

c. Plan 2: Rock Revetment Combined with 80′ Stub Groin. Plan 2 consists of a the identical 3,430 feet of revetment coverage used in Plan 1, with the addition of an 80-foot long stub rock groin located between Crab and Shell Beaches. The groin will replace the existing sheet pile bulkhead extension and will be constructed the same crest elevation of +6.5 feet MLLW as the existing structure. The groin length is identical to that of the existing sheet pile extension. The side slopes of the groin will be 2.0 horizontal on 1 vertical. The groin crest width will be three stones or approximately 6 feet wide. The core material for the groin will consist of 50 to 150 pound basaltic stones. Approximately 2.2 acres of reef flat will be covered by this plan (Figure 14).

d. Plan 2A: Tribar Revetment Combined with 80′ Stub Groin. Plan 2A is identical to Plan 2, however a single layer of 1,000 pound concrete tribar armor units is utilized for the cover layer of the revetment groin to allow for faster construction placement as well as a higher factor of safety under wave attack. As only a single 80′ groin is proposed for this plan, the slightly longer time required to construct a rock groin over a tribar groin would likely be offset by the savings in construction cost.

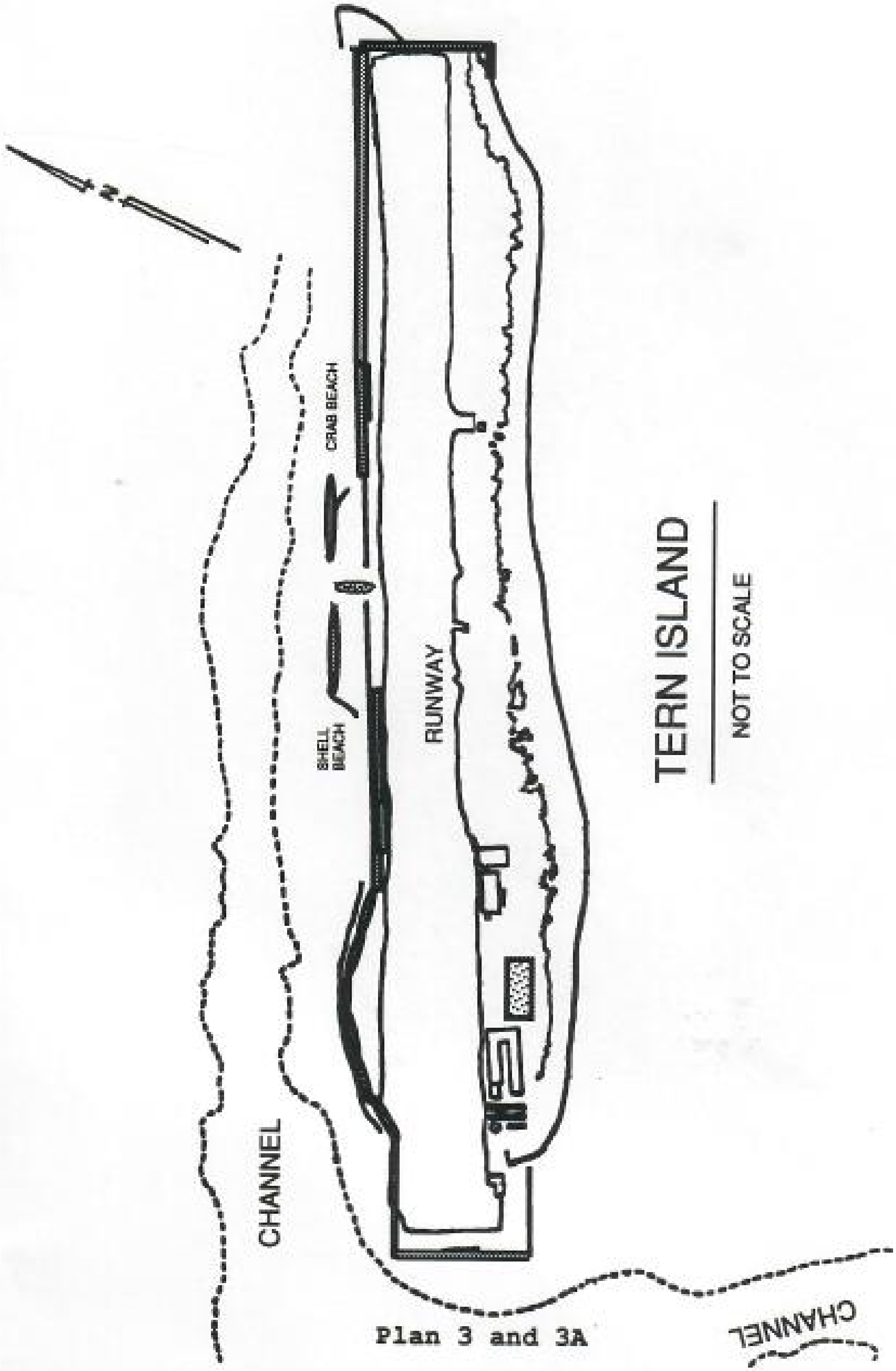
e. Plan 3: Rock Revetment Combined with 80′ Stub Groin and Two 200′ Offshore Breakwaters. Plan 3 is similar to Plan 2, however revetment protection is reduced to 3,080 linear feet of shoreline. An 80′ rock groin is located between the existing Crab and Shell Beaches and flanked on each side by a 200-foot long offshore breakwater. The centerline of the offshore breakwaters is located 100 feet offshore of the existing bulkhead alignment, and a 100 foot wide gap is provided between the breakwaters. The offshore breakwater construction is identical to that of the revetments and groin. The breakwater crest elevation is set at +6.5′MLLW to minimize obstructing observation of offshore activities. The breakwater crest width is set at four stones or approximately 8 feet to accommodate overtopping conditions. The side slopes of the breakwaters will be 2.0 horizontal on 1 vertical. The breakwater core material will consist of 50 to 150 pound stone. Approximately 24,000 square feet of reef or 0.55 acres will be covered by the offshore breakwaters. An additional 1.8 acres of reef will be covered by the revetment (Figure 15).

f. Plan 3A: Tribar Revetment Combined with 80′ Stub Groin and Two 200′ Offshore Breakwaters. Plan 3A is identical to Plan 3, however the cover layer material consists of 1,000 pound precast concrete tribars for the revetment, groin and seaward face of the offshore breakwaters to allow for faster construction placement as



Plan 2 and 2A

Figure 14



Plan 3 and 3A

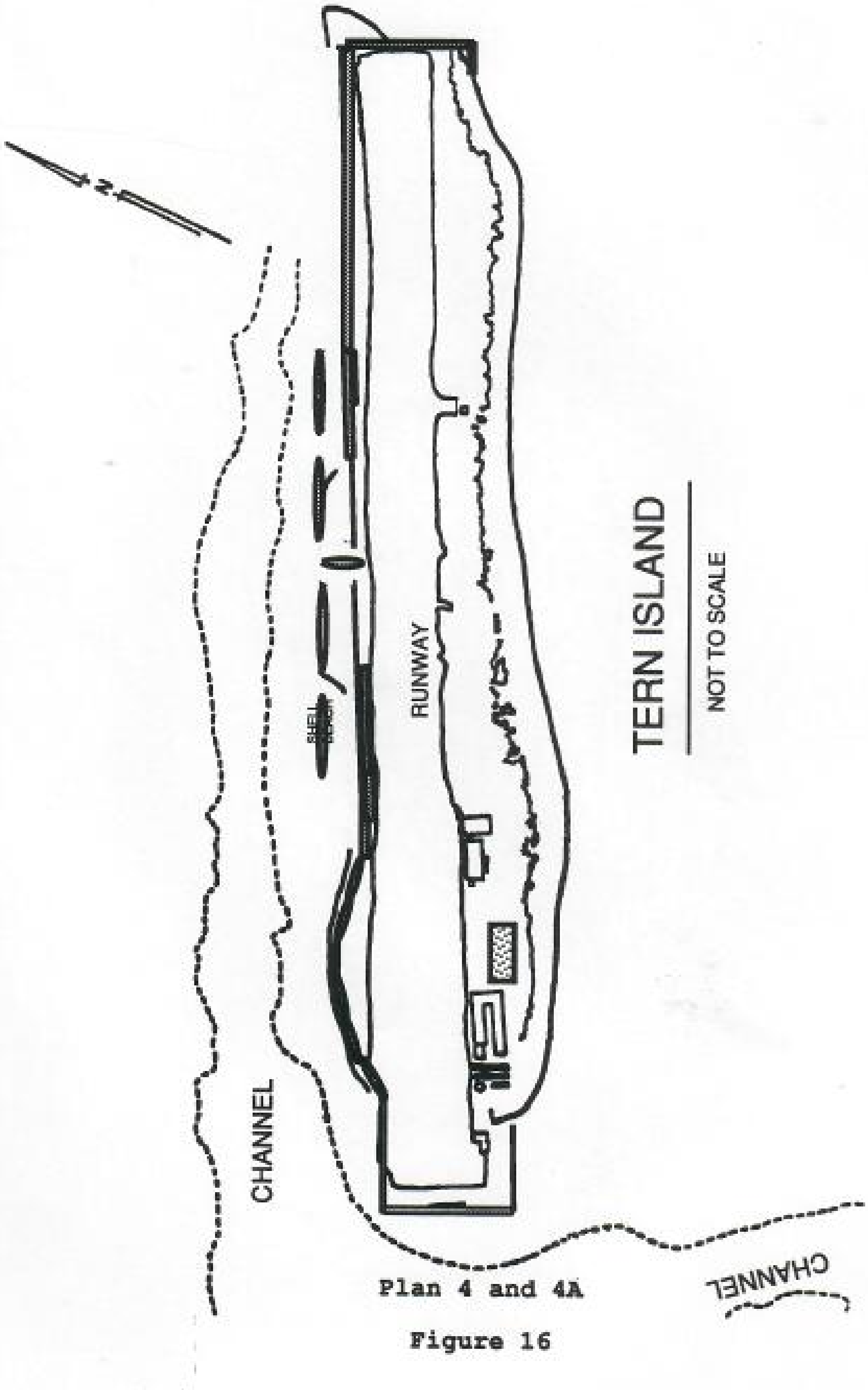
Figure 15

well as a higher factor of safety under wave attack. The cover layer crest and inboard faces of the offshore breakwaters will be composed of 900 to 1,500 pound armor stone.

g. Plan 4: Rock Revetment Combined with 80′ Stub Rock Groin and Four 200′ Offshore Breakwaters. Plan 4 is similar to Plan 3, however revetment protection is reduced to 2,680 linear feet of shoreline. An 80′ rock groin is located between the existing Crab and Shell Beaches and flanked on each side by two 200-foot long offshore breakwaters. The centerline of the offshore breakwaters is located 100 feet offshore of the existing bulkhead alignment. A 100 foot wide gap is provided between the two center breakwaters, and a 75-foot wide gap is provided between the center and outside breakwaters. The offshore breakwater construction is identical to that of the revetments and groin. The breakwater crest elevations and crest widths are identical to those used in Plans 3 and 3A. Approximately 48,000 square feet or 1.1 acres of reef will be covered by the offshore breakwaters. An additional 1.6 acres of reef flat will be covered by the revetment (Figure 16).

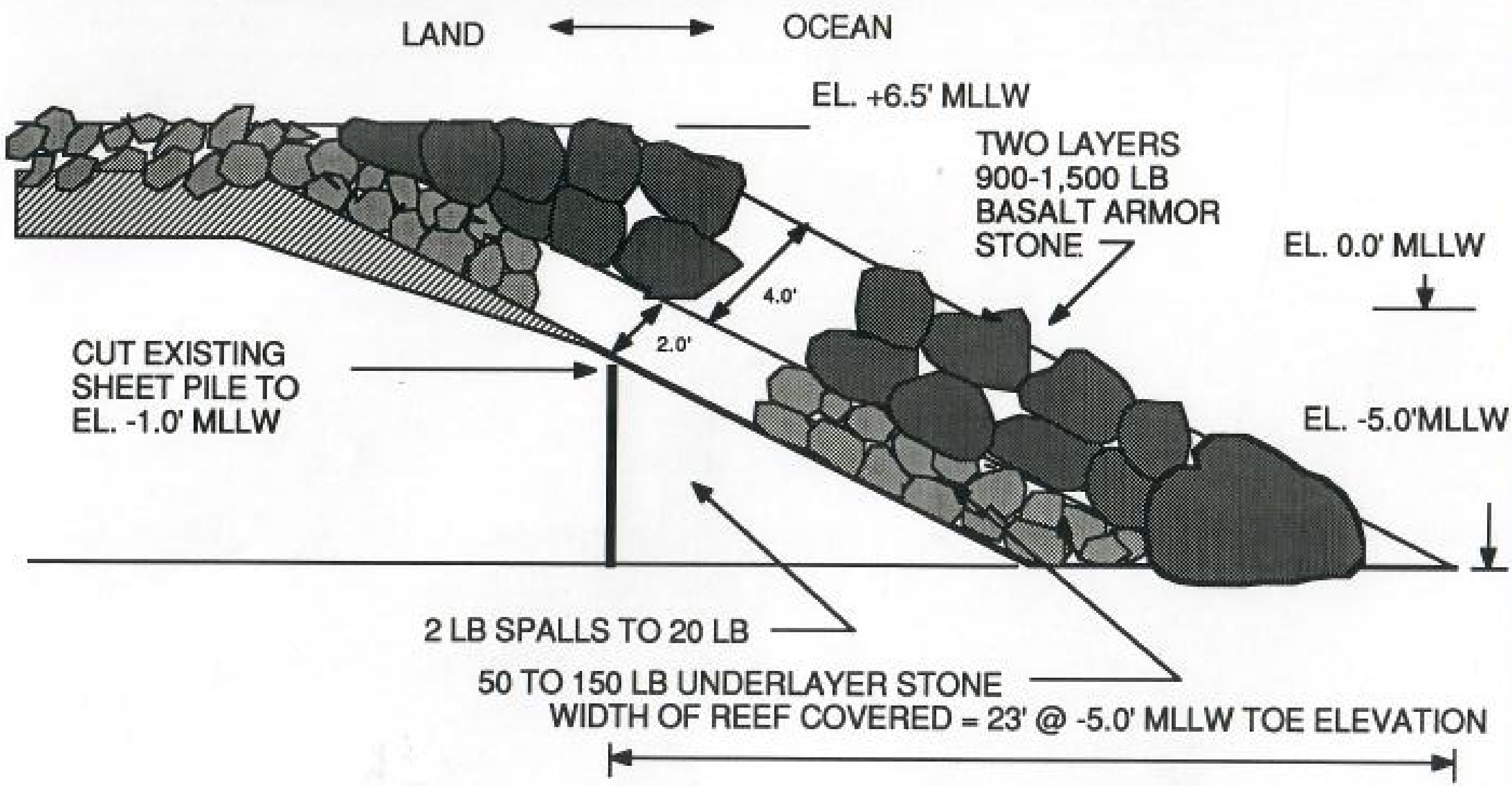
h. Plan 4A: Tribar Revetment Combined with 80′ Stub Groin and Four 200′ Offshore Breakwaters. Plan 4A is identical to Plan 4, however the cover layer material consists of precast 1,000 pound concrete tribars for the revetment, groin and seaward face of the offshore breakwaters to allow for faster construction placement as well as a higher factor of safety under wave attack. The cover layer crest and inboard faces of the offshore breakwaters will be composed of 900 to 1,500 pound armor stone

i. Plan 5 (Without Project Plan). No Action.



Plan 4 and 4A

Figure 16



TERN ISLAND | FRENCH FRIGATE SHOALS

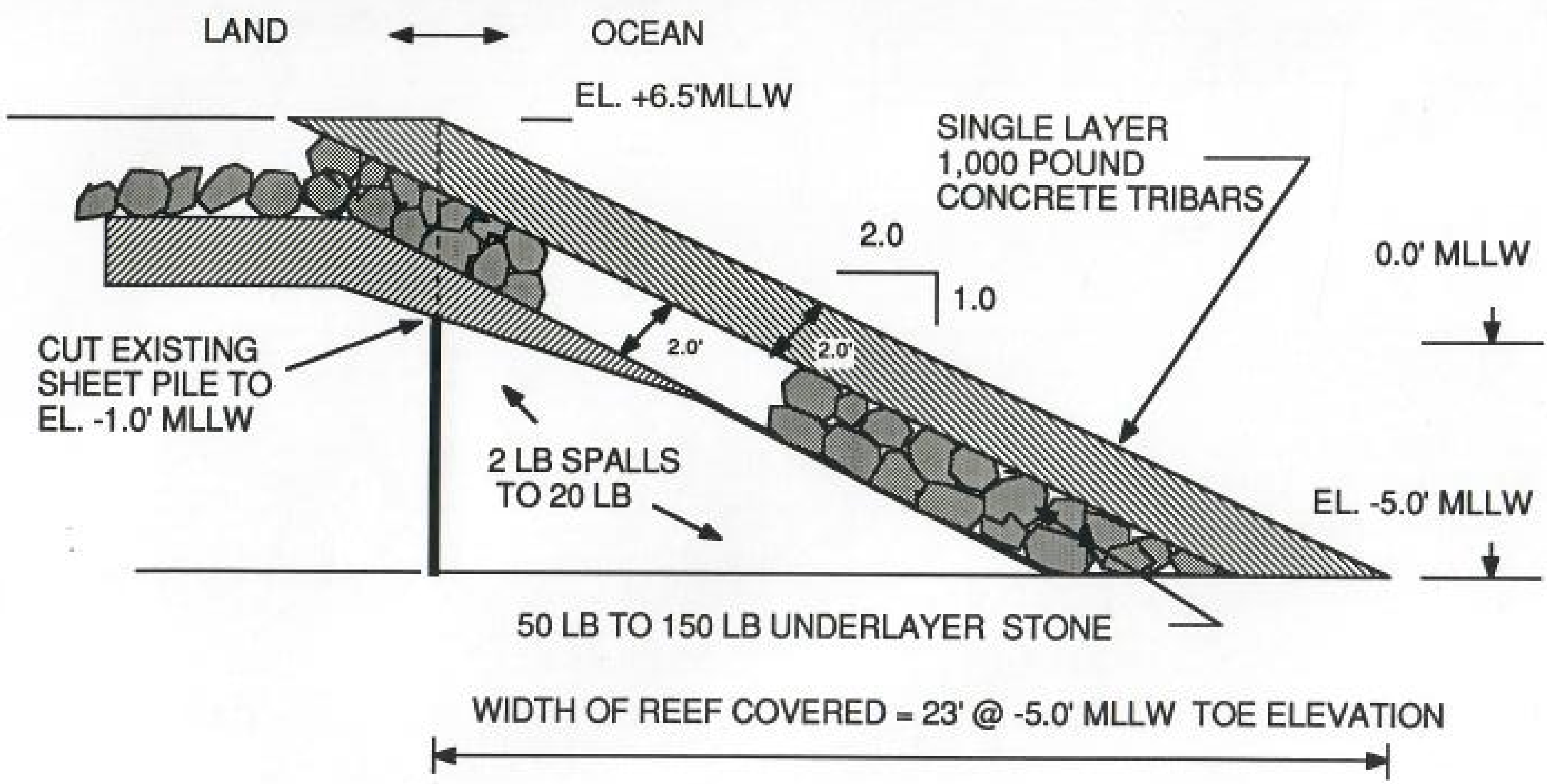
SHORE PROTECTION STUDY

TYPICAL REVETMENT SECTION

BASALT ROCK ARMOR

US ARMY ENGINEER DISTRICT | HONOLULU

FIGURE 17



TERN ISLAND FRENCH FRIGATE SHOALS

SHORE PROTECTION STUDY

TYPICAL REVETMENT SECTION

TRIBAR ARMOR UNITS

US ARMY ENGINEER DISTRICT HONOLULU

FIGURE 18

V. EVALUATION OF ALTERNATIVE PLANS

A. GENERAL

The purpose of this section is to evaluate the shore protection alternatives developed in the previous section, to determine which alternative plan best satisfies planning objectives and economic criteria.

B. PROJECT LIFE CYCLE COST

1. Criteria

The economic assessment of the alternative plans were guided by the following economic criteria:

a. The project life cycle cost, which consists of the annualized initial investment into construction costs, plus the estimated annual maintenance requirement, should be minimized.

b. The costs are to be based on the latest unit prices and assumptions based on the prevailing conditions. Annual costs should be based on a 25-year period of analysis and an 8-1/2 percent interest rate, and should include the annual maintenance cost. Base year of the project is assumed to be 1993.

3. Costs

General cost comparison

Double Layer Revetment = 1.00

Offshore Breakwater = 1.67

CRM Seawall = 1.67

Steel Sheet Pile with Deadman = 1.48

Steel Sheet Pile with Concrete Cap = 1.81

1984 Price Level Contract Cost Imported Rock = $1,000/foot

CCWIS Cost Escalation to FY 94 = 1.32

1994 Price Level Contract Cost Imported Rock = $1,320/foot

C. ENVIRONMENTAL IMPACTS

General Issues:

The Tern Island station is an integral part of the purpose of the Hawaiian Islands National Wildlife Refuge. Without the FWS presence on the island, attainment of objectives would be jeopardized. The presence of the station serves as an important deterrent to illegal entry into the Refuge. Abandonment of the station, however, is a possible scenario should escalating operations and maintenance costs and other budgetary constraints require removal of staff. The island should be placed into a condition that would allow it to revert back to its more natural state (i.e. without runway maintenance). Shoreline protection should be designed to accommodate such a possibility without posing a future risk to animals using the island.

Loss of island vegetation during construction is not expected to be significant. Vegetation on atoll islands is fairly resilient and subject to frequent disturbance by turtles and occasional inundation by sea water. The vegetation eventually reestablishes itself. Shrub habitat takes several years to return to existing conditions whereas open habitat plants grow back more quickly. Loss of shrubs would be a significant impact on some seabird populations which depend upon it for nesting and roosting habitat. A tradeoff exists between using some land for the shoreline revetment vs encroaching further into nearshore waters.

The disadvantage of any structural alternative which replaces the entire length of sheetpile wall is that it is too time consuming to be accomplished between August and October as required to avoid disturbing the breeding and nesting seabirds. This will mean that if disturbance is to be avoided, a contractor will either have to work multiple crews thus taxing the space, water and waste resources of the island or remobilize every year until the project is completed.

Foraging green sea turtles will likely be the most impacted by work in the waters along the north side of the seawall.

Tribar material is less desireable than basalt rock for a revetment because it will likely trap animals and debris to a greater extent and is aesthetically less pleasing. Basalt is the most desirable, natural, and durable and is easily colonizable by marine organisms. Steel sheetpile is the least desirable and least colonizable surface.

Structures can influence water quality by altering circulation patterns. Modification in circulation can result in differences in the flushing rates and from changes in scour patterns and deposition of sediments.

Short-term impacts:

Short-term biological impacts are usually associated with the actual construction phase of the project. Transportation of materials to the site, and preparation of the construction site using heavy equipment cause temporary air and noise pollution close to the site. Stockpiling of materials may encroach upon valuable nesting habitat or destroy nearshore reef habitat. Nesting, resting or feeding of animals may be disrupted. Construction will also temporarily reduce water quality, generally by suspending sediment and generating turbidity. The environmental impacts on the benthic communities resulting from suspended solids in the water around the shore protection are for the most part minor.

Long-term impacts:

Long-term effects result from placement of offshore breakwaters which displace existing reef flat habitat and substitute it with other materials which eventually colonize with marine invertebrate species. The spaces created by the structures create an artificial reef which may attract large numbers of fish which find the vertical relief a change from the uniformity of the reef flat. Reef corals tend to be among the slowest of recolonizers. Species comprising marine bottom communities in high-energy areas are adapted to periodic changes in natural erosion and accretion cycles and tolerate perturbations better than those in more stable offshore environments. The biological productivity of the area to be displaced is important.

Aesthetically, Tern Island resembles an aircraft carrier. Nevertheless, shoreline armoring should consider the visual impacts as much as possible.

Other long-term impacts are associated with providing improved access to and from the island for monk seals and turtles by creating a sloping vs a vertical shoreline profile. This is a positive impact unless animals enter the runway surface to the extent that removal of them prior to aircraft takeoffs and landings poses a problem.

Alternative 1 Impacts:

1. stockpiling of materials
2. mobilization time
3. equipment noise and increased human activity
4. coverage of nearshore reef flat with permanent structures
5. spacing size between rocks creating entrapment or debris collection hazard
6. slope angle for access and egress of monk seals and turtles
7. potential loss of Crab and Shell beaches
8. maintenance needs
9. abandonment impacts

Alternative 1A Impacts:

Same as alternative 1 plus:

1. life expectancy of concrete is less than basalt rock, steel rebar?

2. increased space sizes between tribars compared with rock revetment

3. greater aesthetic impacts

Alternative 2 Impacts:

Same as alternative 1 plus:

1. Stub rock groin will likely help accrete sand

Alternative 2A Impacts:

Same as alternatives 1 and 1A plus:

1. Concrete tribar units are likely to entrap animals and debris to a greater extent than basalt rock due to increased spaces between units.

2. Visual impact should be greater with tribar vs rock

Alternative 3 Impacts:

Same as alternative 1, 1A and 2 plus:

1. Significant loss in nearshore reef habitat resulting from placement of offshore breakwaters. Possible dredging required.

2. Improvements to Crab and Shell beaches likely with incresed haul out areas and greater access to north part of island by monk seals and turtles.

3. Monk seals may utilize offshore breakwaters for haul out although less desireable than sandy beach. Birds are likely to perch on breakwaters discoloring them with guano.

Alternative 3A Impacts:

Same as alternative 3 plus:

1. Tribar groin, revetment and offshore breakwaters are less visually attractive and a greater entrapment hazard although likely to serve as an excellent artificial reef.

2. Tribar is less likely to result in accretion of sand than rock revetment.

Alternative 4 Impacts:

Same as alternatives 3 and 3A plus:

1. Four 200 foot offshore breakwaters with gaps of 100 and 75 feet between them may reduce water circulation sufficiently to alter reef flat characteristics (e.g., increase in algae production) on the island side of the breakwaters.

2. Loss of reef flat productivity by placement of these structures may not be offset by substrate colonization of rock.

3. Beach accretion may result from decreased shoreline armoring and sheltering characterisitcs of offshore structures resulting in improvements made to access of the island for monk seals and turtles.

Alternative 4A Impacts:

Same as alternatives 3 and 4 plus:

1. Significant number of tribars serve as an increased entrapment hazard and increased visual impact.

Alternative 5 Impacts (No Action)

If the existing steel bulkhead is not replaced, continued entrapment hazards will exist and eventual erosion of the island will take place.

Proposed Mitigation:

Ciguatera poisoning has been a concern at French Frigate Shoals ever since a suspected outbreak was linked to the deaths of monk seals at Laysan Island in 1975. Although no conclusive evidence exists to link marine construction activities to increased ciguatera incidences, anectodal information suggests that the level of *Gambierdiscus toxicus* should be monitored before, during and after construction of the shore protection structures. A final sample should be taken approximately six months after completion of the project.

The construction process is often responsible for increases in local turbidity levels, releases of toxicants or petroleum products and/or the reduction of dissolved oxygen levels. These impacts can be minimized by modifying or selecting specific construction practices, carefully selecting materials and by proper construction scheduling. The design of the off-shore breakwater will greatly influence its impact on circulation and flushing and thus its impact on water quality.

The water quality impacts of the two armoring materials (rock and tribar) are similar in that both will reduce erosion and decrease suspended solids. In fact, they will likely accrete sand by changing the shoreline protection from the present vertical, highly reflective surface.

Curious animals may approach and enter the construction site. A temporary barrier fence may be erected to keep monk seals from entering the site.

D. SUMMARY COMPARISON OF ALTERNATIVE PLANS

E. DESIGNATION OF THE RECOMMENDED PLAN

VI. THE RECOMMENDED PLAN

A. RATIONALE FOR SELECTION

B. PLAN IMPLEMENTATION

1. Plans and Specifications

Detailed construction drawings and specifications will be required in order to identify the final quantities of construction materials, precise structure alignments and dimensions, and other construction related instructions and restrictions. This project phase is required irrespective of whether the construction is executed by a private construction contractor or by inhouse forces of a government agency.

2. Project Execution and Construction Funding

<Insert project execution discussion>

3. Construction Schedule

<Insert construction schedule discussion>

4. Maintenance

The United States Fish and Wildlife Service, Department of Interior will be responsible for all maintenance requirements of the completed project.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

B. RECOMMENDATION

ENDANGERED SPECIES
COORDINATION

DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, HONOLULU
BUILDING 230
FT. SHAFTER, HAWAII 96858-5440

REPLY TO ATTENTION OF:

April 25, 1991

Planning Division

Mr. Robert P. Smith
Supervisor
U.S. Fish and Wildlife Service
Pacific Islands Field Office
300 Ala Moana Boulevard
P. O. Box 50167
Honolulu, Hawaii 96850

Dear Mr. Smith:

The U.S. Army Corps of Engineers, Honolulu Engineer District, has been requested by the U.S. Fish and Wildlife Service to undertake a study to provide shore protection for Tern Island. The areas designated for repair are identified in the attached map of the island.

This letter serves to formally initiate Section 7 Consultation with your office as required by the Endangered Species Act for species under your jurisdiction. Similar consultation is being initiated with the National Marine Fisheries Service for species under their jurisdiction.

Please contact Ms. Margo Stahl or Mr. Bill Lennan of my staff with any questions you may have (438-7006).

Sincerely,

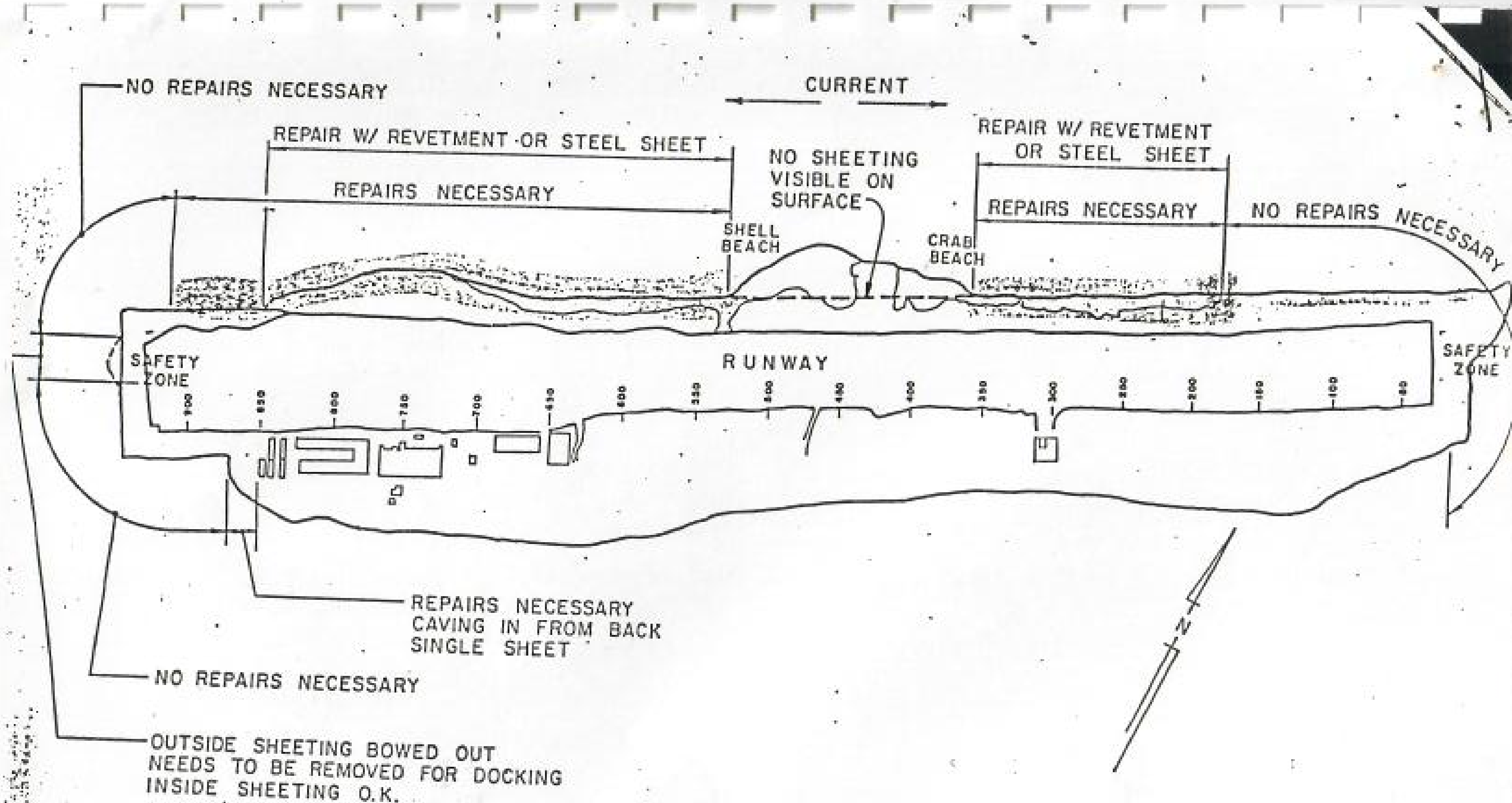
Kisuk Cheung
Director of Engineering

Attachment

Copies furnished:

Mr. Marvin Plenert
Regional Director
U.S. Fish and Wildlife Service, Region 1
(ATTN: Section 7 Coordinator)
911 N.E. 11th Avenue
Portland, Oregon 97232

Mr. Gene Nitta
Protected Species Coordinator
National Marine Fisheries Service
P.O. Box 3830
Honolulu, Hi. 96812



TERN ISLAND

NOT TO SCALE

United States Department of the Interior

FISH AND WILDLIFE SERVICE
PACIFIC ISLANDS OFFICE
P.O. BOX 50167
HONOLULU, HAWAII 96850

April 29, 1991

Mr. Kisuk Cheung
Director of Engineering
U. S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858-5440

Attention: Planning Division

Dear Mr. Cheung:

This acknowledges our April 26, 1991 receipt of your April 25th letter requesting initiation of formal Section 7, Endangered Species Act, consultation on proposed shore protection activities at Tern Island, French Frigate Shoals, Hawaii. The endangered Hawaiian monk seal and the threatened green sea turtle may be affected by your proposed actions.

We have assigned log number 1-2-91-F-12 to this consultation. We will contact Mr. Lennan or Ms. Stahl of your staff should we require additional information.

Sincerely yours,

William R. Kramer

William R. Kramer
Acting Field Supervisor
Pacific Islands Office

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Office
P.O. Box 50167
Honolulu, Hawaii 96850

TAKE PRIDE IN AMERICA

November 1, 1991

Mr. Kisuk Cheung
Director of Engineering
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858-5440

Attention: Planning Division

Dear Mr. Cheung:

This follows up on a telephone conversation I had earlier today with Ms. Margo Stahl of your staff regarding proposed shore protection activities to be undertaken at Tern Island, French Frigate Shoals, Hawaii. You initiated formal section 7 (Endangered Species Act) consultation on the project on April 25, 1991.

Subsequent to initiation of formal consultation, it was determined that additional detail on project alternatives was required for our analysis. This letter documents that we are in agreement that formal consultation is on "hold" until such a time as those details are available.

Should you have any questions concerning this matter, please call me at 541-2749.

Sincerely,

William R. Kramer
Acting Field Supervisor
Pacific Islands Office

DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, HONOLULU
BUILDING 230
FT. SHAFTER, HAWAII 96858-5440

REPLY TO
ATTENTION OF:

April 25, 1991

Planning Division

Mr. Gene Nitta
Protected Species Coordinator
National Marine Fisheries Service
P.O. Box 3830
Honolulu, Hawaii 96812

Dear Mr. Nitta:

The U.S. Army Corps of Engineers, Honolulu Engineer District, has been requested by the U.S. Fish and Wildlife Service to undertake a study to provide shore protection for Tern Island. The areas designated for repair are located on the attached map of the island.

We are formally initiating Section 7 Consultation with the U.S. Fish and Wildlife Service for species under their jurisdiction and wish to initiate the same for species under NMFS jurisdiction at this time.

Please contact Ms. Margo Stahl or Mr. Bill Lennan of my staff (438-7006) for additional information.

Sincerely,

Kisuk Cheung
Director of Engineering

Attachment

Copies furnished (w/attachment):

Mr. Robert P. Smith
Supervisor
U.S. Fish and Wildlife Service
Pacific Islands Field Office
300 Ala Moana Boulevard
P. O. Box 50167
Honolulu, Hawaii 96850

Mr. Marvin Plenert
Regional Director
U.S. Fish and Wildlife Service, Region 1
(Attn: Section 7 Coordinator)
911 N.E. 11th Avenue
Portland, Oregon 97232

Mr. E. C. Fullerton
Regional Director
Southwest Region
National Marine Fisheries Service
300 S. Ferry Street
Terminal Island, CA 90731

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Pacific Area Office - Southwest Region
2570 Dole St. Honolulu, HI 96822-2396
PH: (808)955-8831 FAX: (808)949-7400

May 6, 1991 F/SWR33:ETN

Kisuk Cheung
Director of Engineering
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, HI 96858-5440

Dear Mr. Cheung:

This responds to your request to initiate Section 7 consultation on a proposed study for shore protection at Tern Island, French Frigate Shoals. Because the site inspection has not yet been completed and alternatives are still being explored we will consider this the initiation of early consultation. During this stage of informal consultations we will be available to discuss any proposed alternatives and listed species or critical habitat that might be affected. I would appreciate being kept apprised of the progress of the study as it proceeds.

Sincerely,

Eugene T. Nitta

Eugene T. Nitta
Protected Species Coordinator

cc: F/SWR3 - Lecky
COE - Lennan
COE - Stahl
FWS - McDermond