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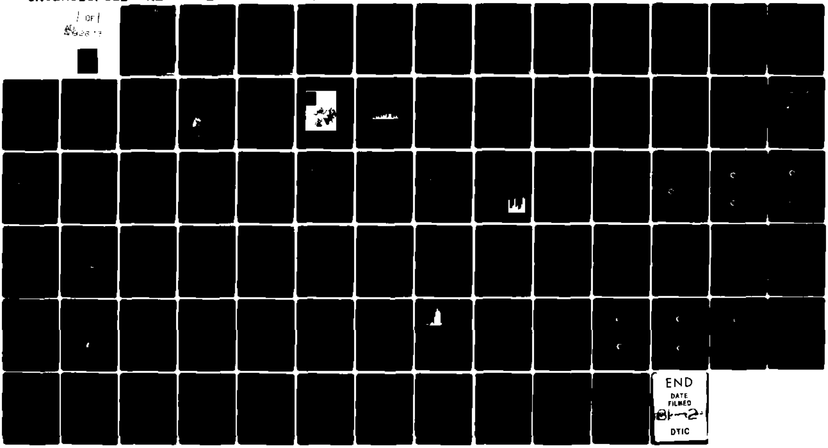

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Instructions for entering Change TWO to NAVENVPREDRSCHFAC Technical Paper 5-76, Typhoon Havens Handbook for the Western Pacific and Indian Oceans.

Page Numbers	Action
DD Form 1473 of Change TWO	Replaces DD Form 1473 of Change ONE.
pp 5-9 of Change TWO	Replaces pp 5-9 of Change ONE.
pp I-A-5 — I-A-11 of Change TWO	Replace pp I-A-5 — I-A-11 of the original publication.
pp V-1 — V-6 pp V-11/12 pp V-15 — V-18 pp V-95/96 of Change TWO	Replace same-numbered pages of the original publication.
Text sections & divider tabs for XIII -- Palau XIV -- Saipan-Tinian XV -- Indonesia attached as part of Change TWO	Add text sections and divider tabs to loose leaf binder of Technical Paper 5-76 in numerical order following last page of Section XII, Diego Garcia (p. XII-5).

Chg 2

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Typhoon haven
Tropical meteorology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This publication is a compilation of many typhoon-haven studies of ports and harbors in the western Pacific and Indian Oceans. Some of the studies, originally published in long form by the Naval Environmental Prediction Research Facility, have been restructured and condensed for this compilation; others have been prepared directly for this condensation format. This publication is designed to serve as a decision-making aid for commanders, ship captains, and ship routing personnel regarding typhoons that threaten the ports discussed.

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CONTENTS

INTRODUCTION

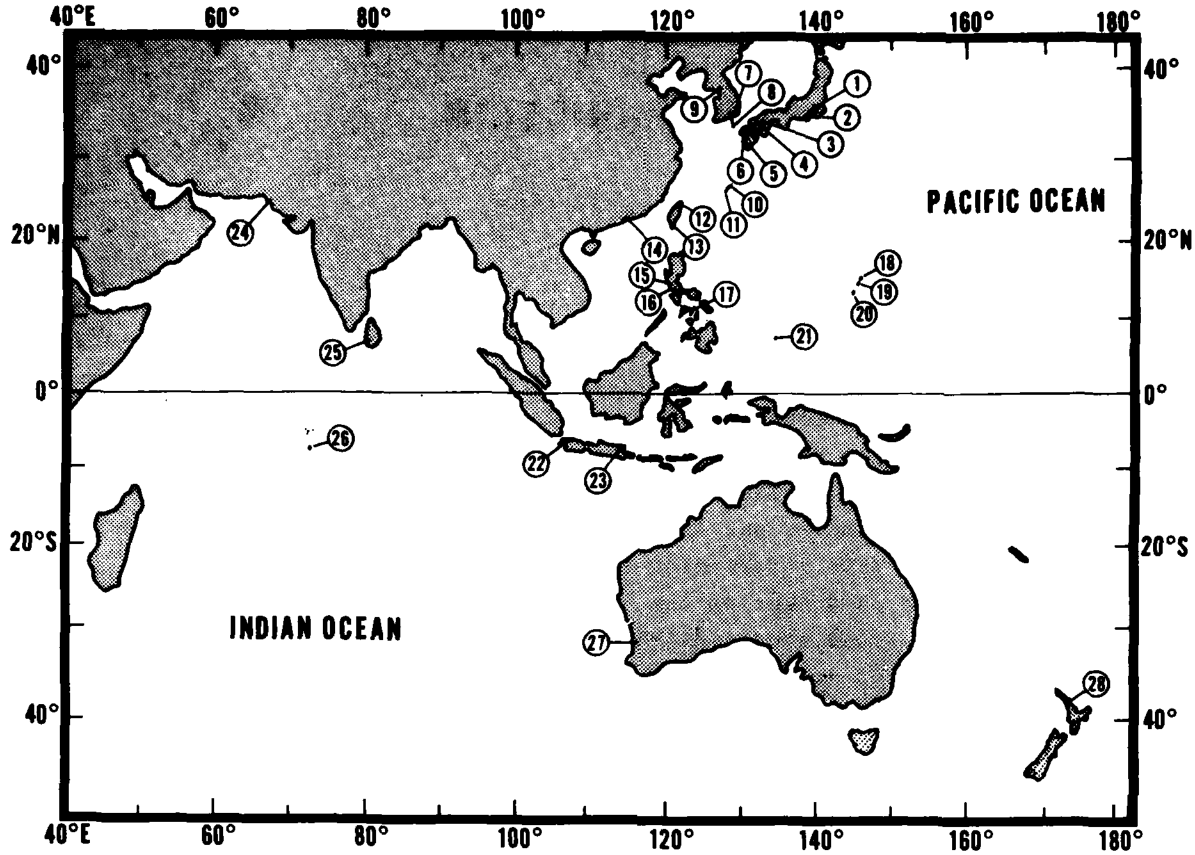
Severe tropical cyclones, also known as typhoons or hurricanes, are among the most destructive weather phenomena a ship may encounter whether the ship be in port or at sea. When faced with an approaching tropical cyclone, a timely decision regarding the necessity and method of evasion must be reached. Basically, the question is: Should the ship remain in port, evade at sea, or if at sea, should it seek the shelter offered by the harbor? This study examines a number of western Pacific and Indian Ocean ports and evaluates their potential as typhoon havens. This information should provide useful guidance to commanding officers in answering the above questions.

In general it is an oversimplification to label a harbor as merely good or bad. Consequently, an attempt is made to present enough information about the harbors to aid a commanding officer in reaching a sound decision with respect to his ship. The decision should not be based on the expected weather conditions alone, but also on the ship itself, as well as characteristics of the harbor. These characteristics include: natural shelter provided, port congestion, and support facilities (normal and emergency) available.

Chapter I presents a general description of tropical cyclones and the environmental phenomena associated with them. Discussions of ship performance under tropical cyclone conditions, and details of tropical cyclone warnings are also given.

Each remaining chapter presents information about a particular geographical area including details of individual ports and harbors, local topographical influences on tropical cyclones, and helpful guidelines for the decision-making process of whether to sortie or remain in port.

On the basis of the studies conducted in the development of this handbook, each port considered has been given an adjective rating of its suitability as a typhoon haven. These ratings are presented as Table 1.



1 - Yokosuka
2 - Numazu
3 - Kure
4 - Iwakuni
5 - Kagoshima
6 - Sasebo
7 - Pusan
8 - Chinhae
9 - Inchon
10 - Buckner Bay
11 - Naha
12 - Chilung
13 - Kaohsiung
14 - Hong Kong
15 - Subic Bay
16 - Manila
17 - Cebu
18 - Saipan
19 - Tinian
20 - Guam
21 - Palau
22 - Jakarta
23 - Surabaya
24 - Karachi
25 - Colombo
26 - Diego Garcia
27 - Fremantle
28 - Auckland

Figure 1. Locator map of western Pacific and Indian Ocean ports evaluated as typhoon havens.

Table 1. Ratings of western Pacific and Indian Ocean ports evaluated as typhoon havens.

GUAM	
APRA HARBOR	POOR
TAIWAN	
KAOHSIUNG	POOR
CHILUNG (KEELUNG)	POOR
HONG KONG	
HONG KONG HARBOR	POOR
JAPAN	
YOKOSUKA	GOOD
NUMAZU OPERATING AREA	POOR
IWAKUNI	MARGINAL (but has easily accessible anchorages close by which are considered good)
KURE	GOOD
SASEBO	GOOD (except for carriers)
KAGOSHIMA	POOR
BUCKNER BAY, OKINAWA	POOR
NAHA, OKINAWA	POOR
PHILIPPINE ISLANDS	
SUBIC BAY	MARGINAL TO POOR
MANILA	POOR
CEBU	POOR
KOREA	
INCHON	POOR (unless shelter is available in the tidal basin; then it would be considered a good haven)
PUSAN	POOR
CHINHAE	MARGINAL (but has easily accessible anchorages close by which are considered good)
SRI LANKA	
COLOMBO	GOOD
PAKISTAN	
KARACHI	MARGINAL
NEW ZEALAND	
AUCKLAND	GOOD TO MARGINAL
AUSTRALIA	
FREMANTLE	MARGINAL (unless shelter is available in Cockburn Sound or the inner harbor; then it would be considered good)
DIEGO GARCIA	
DIEGO GARCIA HARBOR	POOR
PALAU	POOR
SAIPAN	POOR
TINIAN	POOR (but marginal for small ships)
INDONESIA	
JAKARTA	UNAFFECTED
SURABAYA	UNAFFECTED

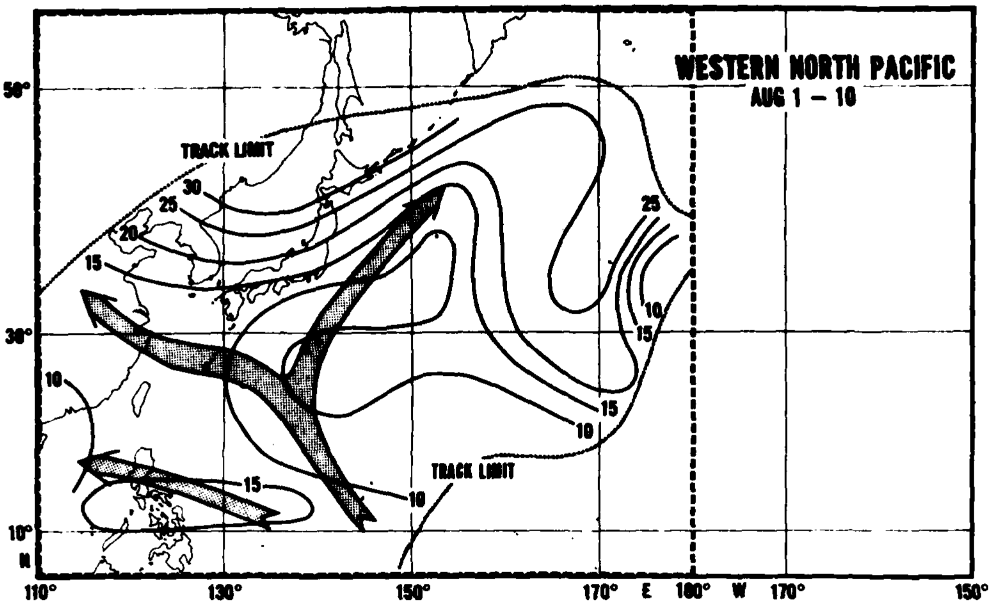


Figure I-A-7. Preferred western North Pacific tropical storm and typhoon tracks (AUG 1-10). Isolines show the average storm speed of movement in knots.

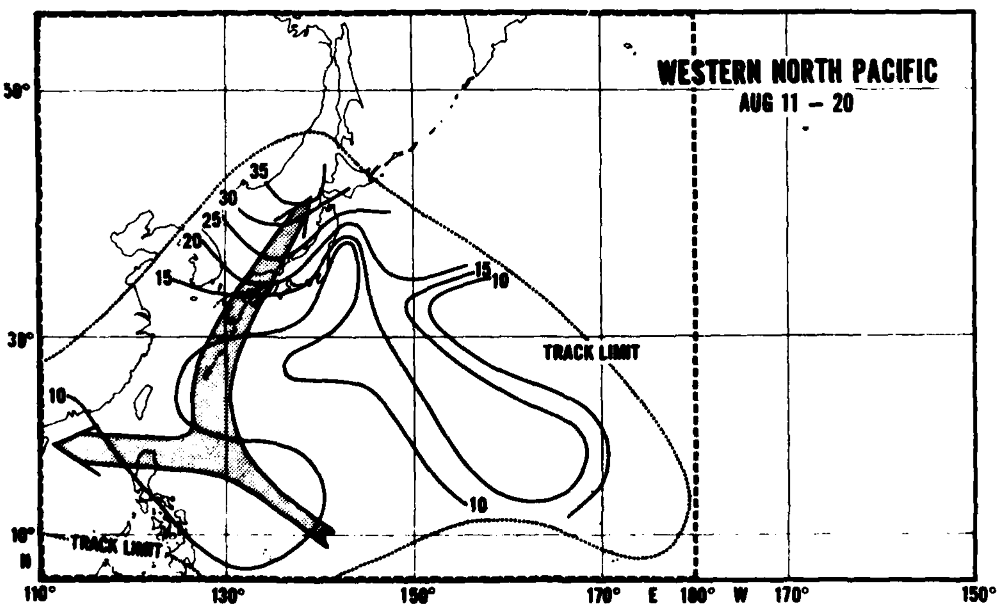


Figure I-A-8. Preferred western North Pacific tropical storm and typhoon tracks (AUG 11-20). Isolines show the average storm speed of movement in knots.

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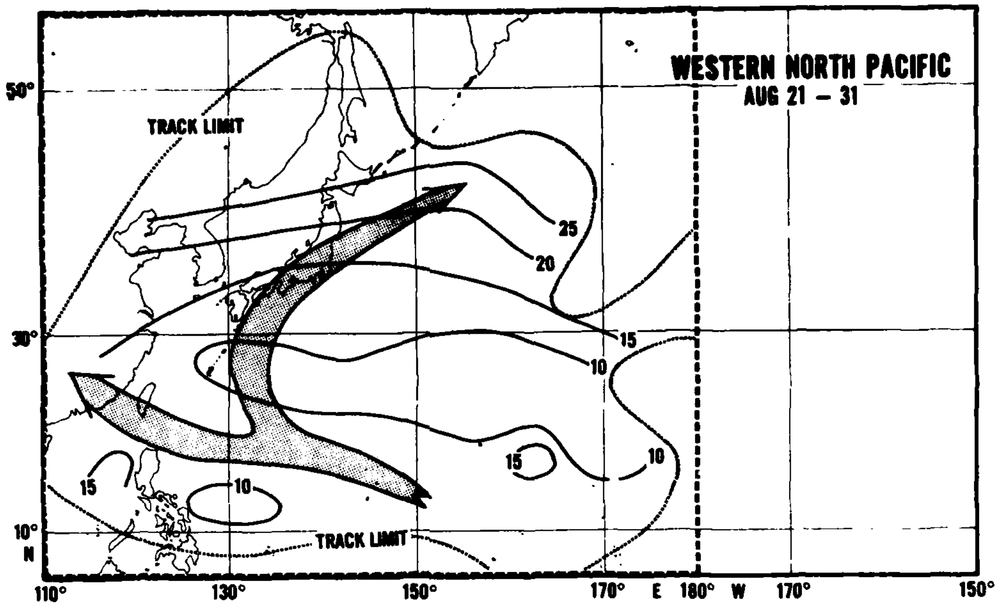

Figure I-A-9. Preferred western North Pacific tropical storm and typhoon tracks (AUG 21-31). Isolines show the average storm speed of movement in knots.

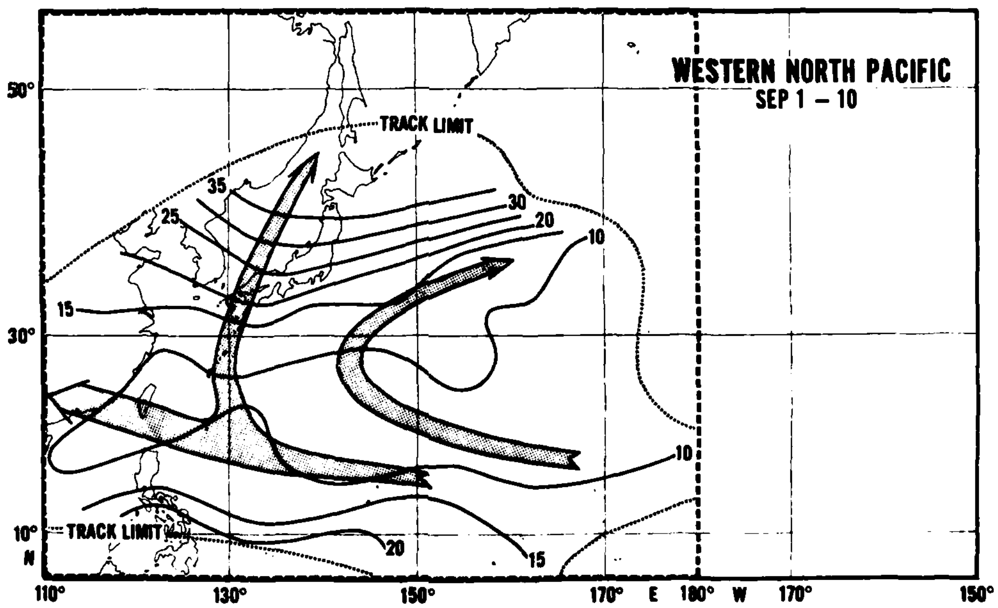

Figure I-A-10. Preferred western North Pacific tropical storm and typhoon tracks (SEP 1-10). Isolines show the average storm speed of movement in knots.

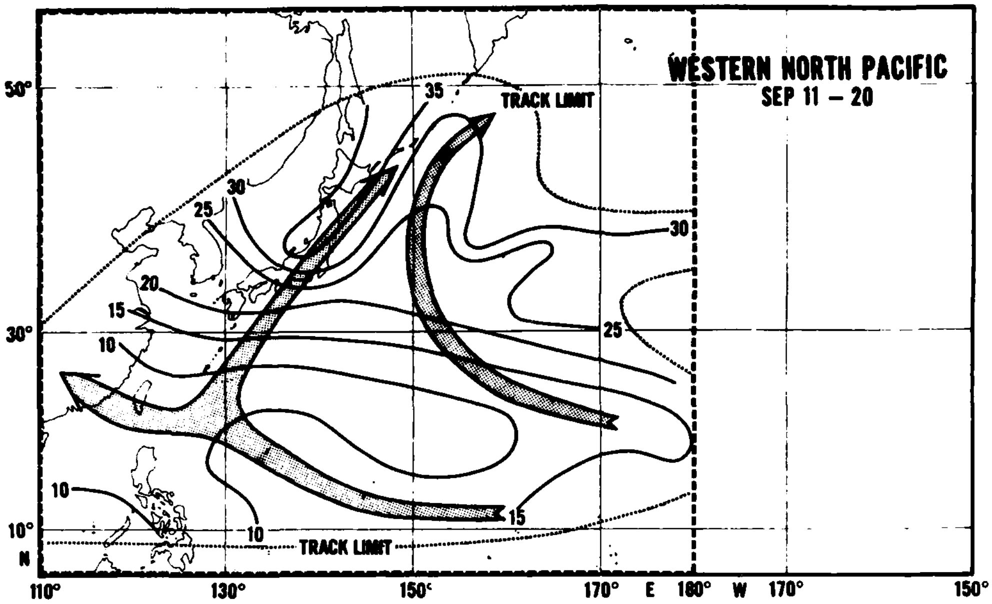

Figure I-A-11. Preferred western North Pacific tropical storm and typhoon tracks (SEP 11-20). Isolines show the average storm speed of movement in knots.

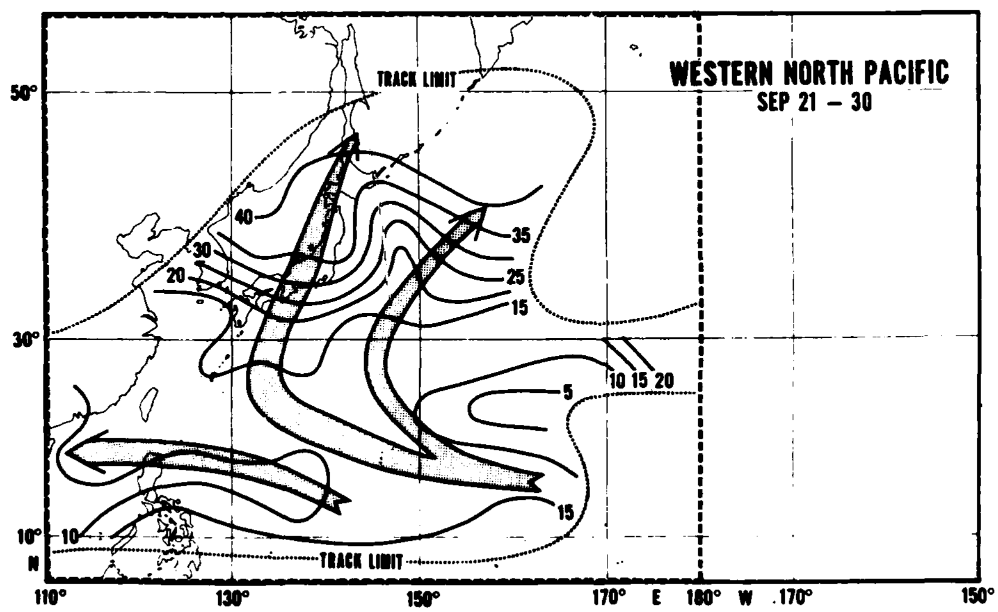

Figure I-A-12. Preferred western North Pacific tropical storm and typhoon tracks (SEP 21-30). Isolines show the average storm speed of movement in knots.

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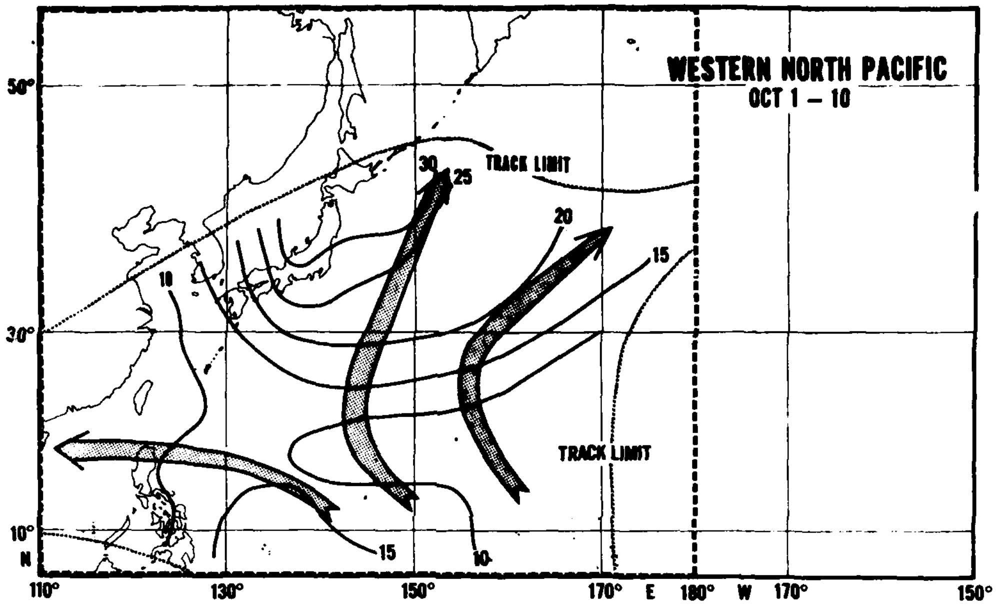

Figure I-A-13. Preferred western North Pacific tropical storm and typhoon tracks (OCT 1-10). Isolines show the average storm speed of movement in knots.

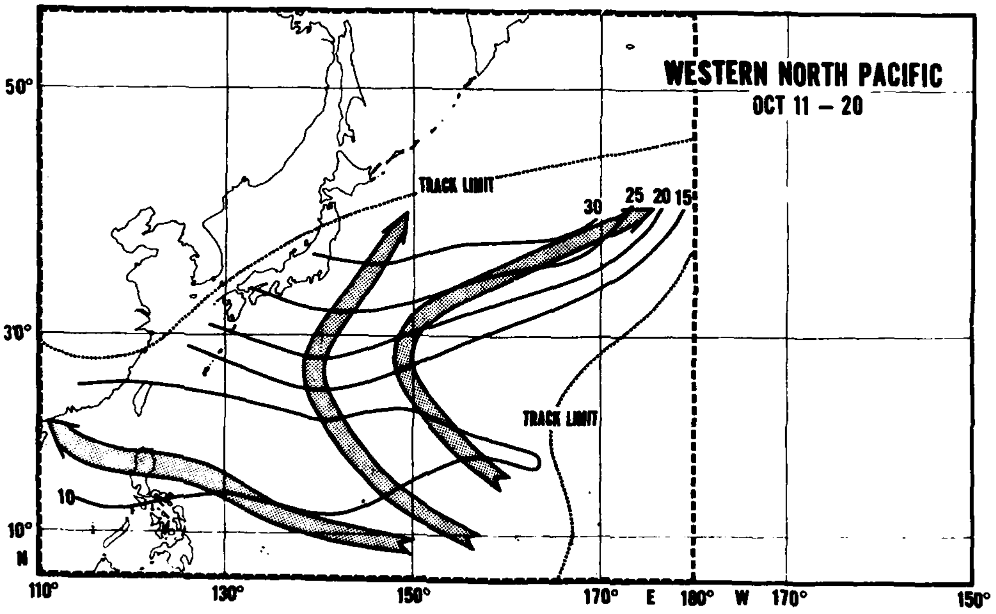

Figure I-A-14. Preferred western North Pacific tropical storm and typhoon tracks (OCT 11-20). Isolines show the average storm speed of movement in knots.

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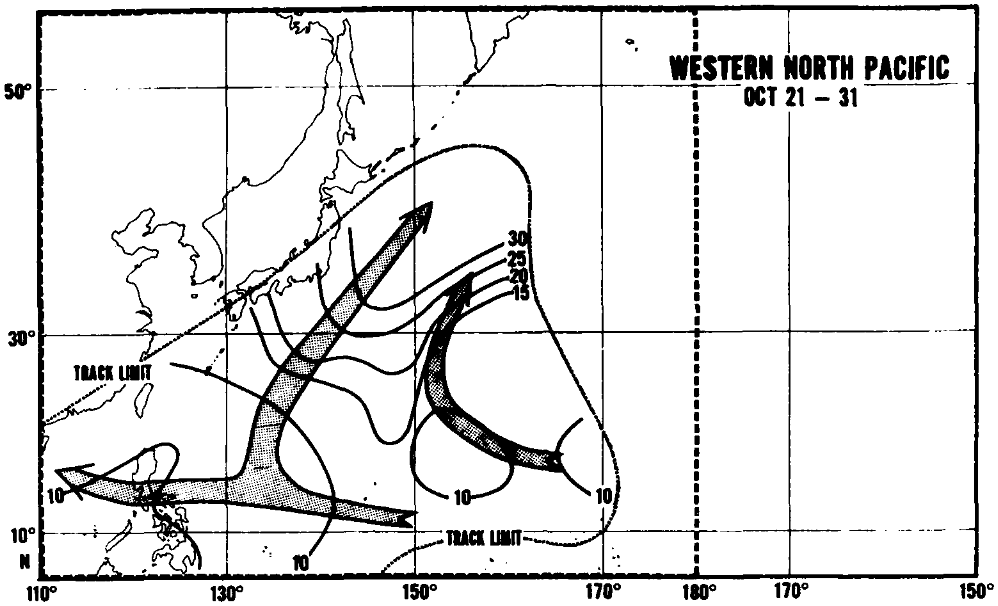

Figure I-A-15. Preferred western North Pacific tropical storm and typhoon tracks (OCT 21-31). Isolines show the average storm speed of movement in knots.

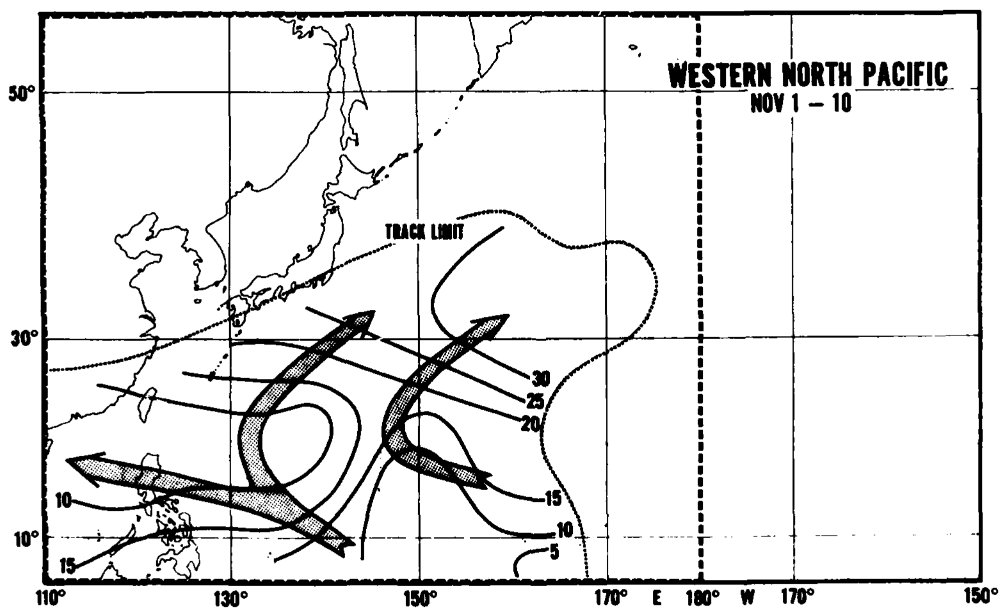

Figure I-A-16. Preferred western North Pacific tropical storm and typhoon tracks (NOV 1-10). Isolines show the average storm speed of movement in knots.

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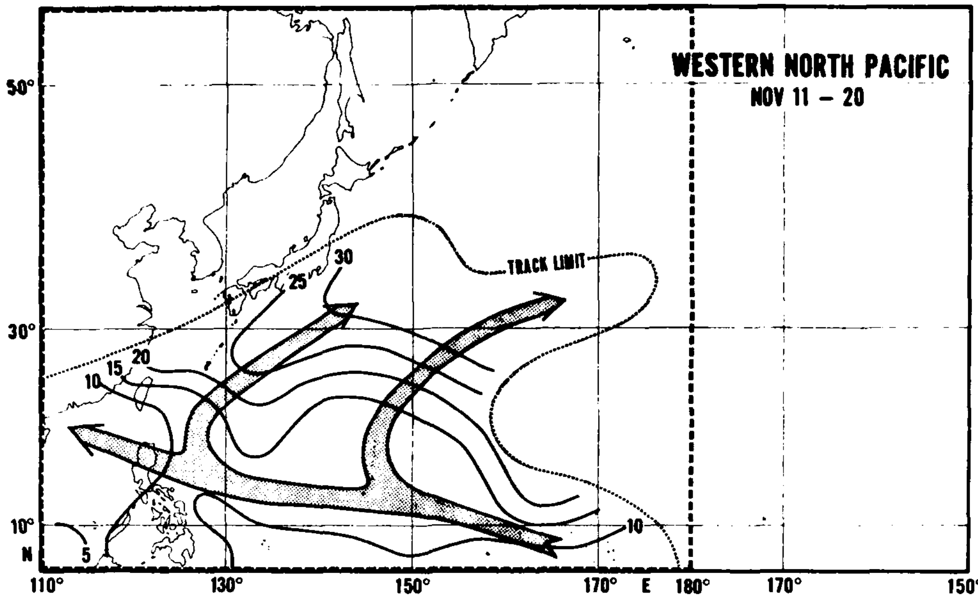

Figure I-A-17. Preferred western North Pacific tropical storm and typhoon tracks (NOV 11-20). Isolines show the average storm speed of movement in knots.

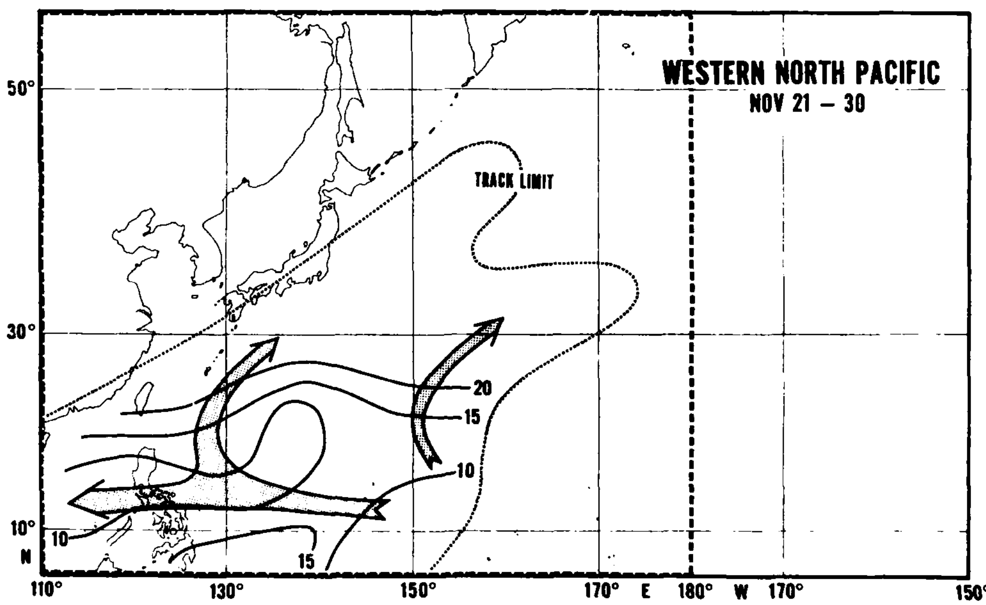

Figure I-A-18. Preferred western North Pacific tropical storm and typhoon tracks (NOV 21-30). Isolines show the average storm speed of movement in knots.

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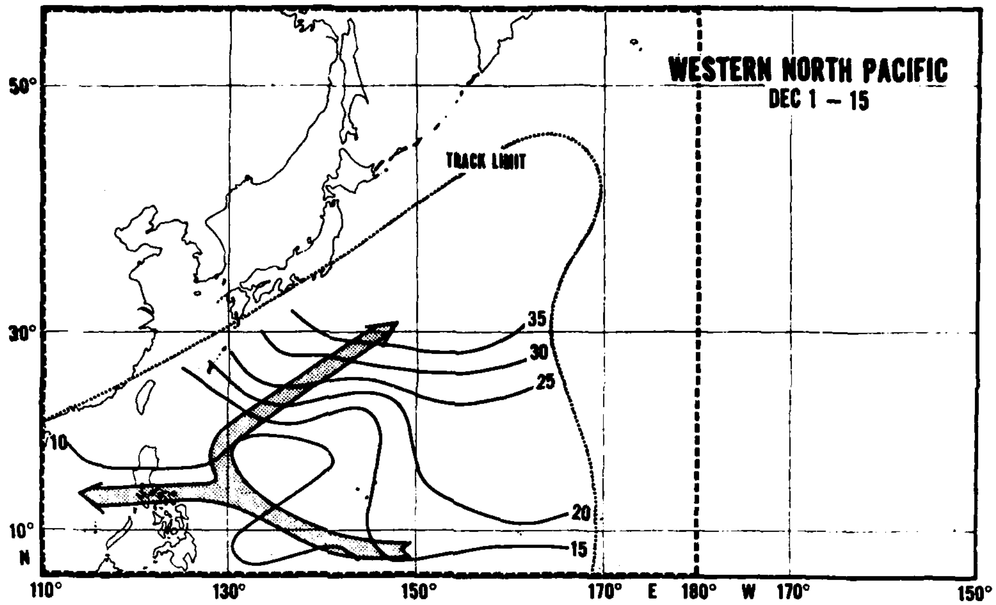

Figure I-A-19. Preferred western North Pacific tropical storm and typhoon tracks (DEC 1-15). Isolines show the average storm speed of movement in knots.

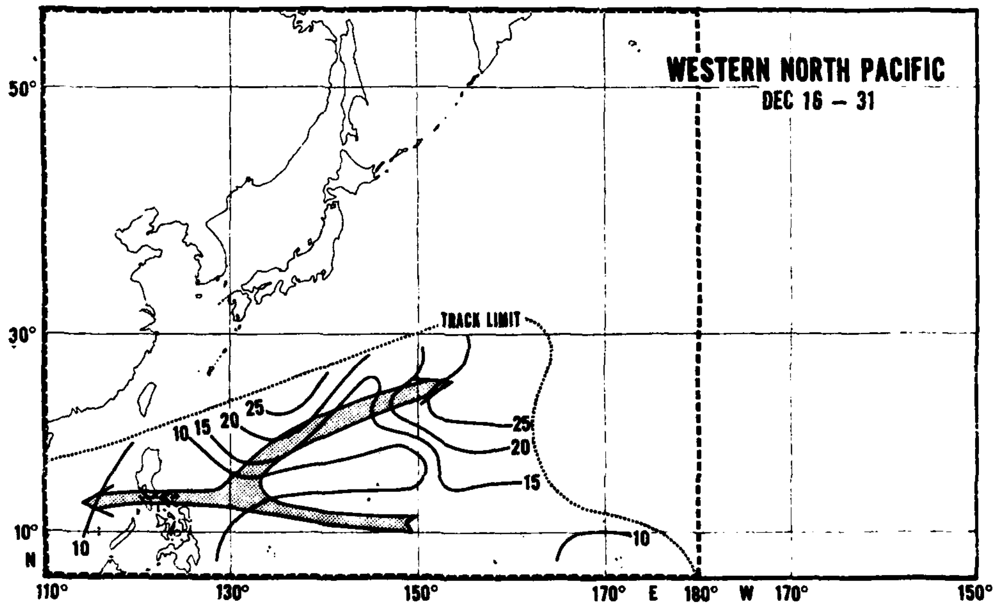

Figure I-A-20. Preferred western North Pacific tropical storm and typhoon tracks (DEC 16-31). Isolines show the average storm speed of movement in knots.

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V JAPAN

1. GENERAL

Japan is an island nation in the western part of the North Pacific Ocean off the eastern coast of the Asiatic mainland consisting of a chain of islands extending in an arc from northeast to southwest. The four main islands of Japan from north to south are Hokkaido, Honshu, Shikoku and Kyushu. Hundreds of smaller islands lie off the coasts of the main ones.

Honshu is the largest of the main Japanese Islands. Yokosuka, a major port city in southeast Honshu, is used continuously by the U Navy. It is currently homeport for a number of SEVENTH Fleet units. The Numazu Operating Area in south central Honshu is used routinely by the U.S. Navy. Additionally commercial shipping firms utilize three small harbors in the Numazu area. Iwakuni and Kure are located in the southwestern region of Honshu.

Kyushu is the third largest and the southernmost major island land mass of Japan. The two major ports of interest for the U.S. Navy on this island are Sasebo and Kagoshima.

Okinawa is located approximately 350 n mi south of Kyushu and has two major ports of interest to Department of Defense vessels, Buckner Bay and Naha.

A detailed description of the coasts and harbors of Honshu and Kyushu and Okinawa can be found in the Sailing Directions (Enroute) for Japan, Pub. No. 156.

2. YOKOSUKA

SUMMARY

The conclusion reached in this study is that the port of Yokosuka is a "safe" typhoon haven; a port in which to remain if already there or in which to seek shelter if at sea when threatened by a typhoon. The primary factors in reaching this conclusion are:

(1) The port provides shelter from wind and sea due to the surrounding land masses.

(2) Wave action induced by typhoons has been negligible in the port.

(3) Storm surge has negligible effect.

(4) The orientation of the berths and drydocks with respect to the local topography is good.

(5) The experience level and the high degree of competence of the Port Services personnel.

(6) The history of the port. Conversations with Japanese employees at Fleet Activities, Yokosuka indicated that since 1945 there is no recollection of U.S. Navy, Japanese Maritime Self Defense Force or merchant ships sortieing from the port of Yokosuka due to a typhoon.

(7) Except for carriers the only situation in which the port would not be a safe haven is when a very intense typhoon (>120 kt) passed directly over or just to northwest (within 100 n mi) of Yokosuka. For carriers, if a berth shift to drydock six is not feasible, a sortie from Yokosuka is recommended when Tropical Cyclone Condition of Readiness Three (48 hours) is set for sustained winds of 75 kt or greater at the Naval Oceanography Command Facility Yokosuka.

2.1 LOCATION AND TOPOGRAPHY

The port of Yokosuka is located at 35°17'N, 139°40'E in the central part of the Miura Peninsula on the southwest side of landlocked Tokyo Bay. The harbors of Yokohama and Tokyo are also in Tokyo Bay and Figure V-1 locates some pertinent features. Tokyo Bay penetrates the southeast coast of Honshu in a northerly direction for a distance of almost 35 n mi. Approximately 200 ships transit Uraga Suido, the entrance to Tokyo Bay, daily.[1]

The terrain immediately adjacent to Tokyo Bay is low, but to the west and northwest are high mountains. The island of Honshu is one of the most rugged of land areas (see Figure V-2). The mountains in the north central area average 5,000 to 10,000 ft in height and are often called the Japanese Alps. The highest mountain, Fujiyama (12,395 ft), is located 60 miles due west of Yokosuka. Northern Honshu is less mountainous.

[1]Uraga Suido is a controlled traffic route, one of several controlled routes established by the Japanese Maritime Safety Agency to regulate shipping traffic in highly congested areas in an effort to avert marine accidents.

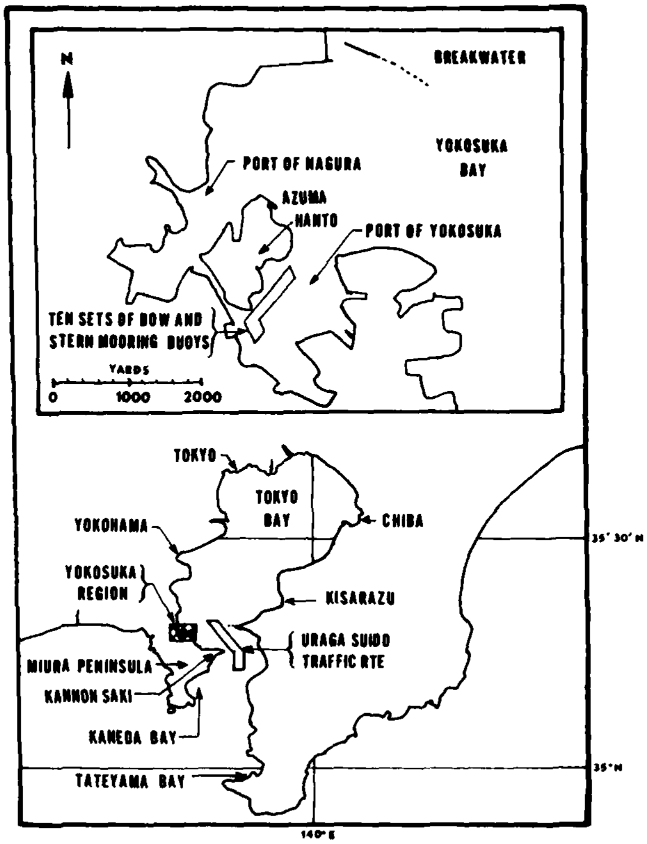

Figure V-1. Tokyo Bay and the surrounding land area. The Yokosuka region is enlarged at the top of the figure.

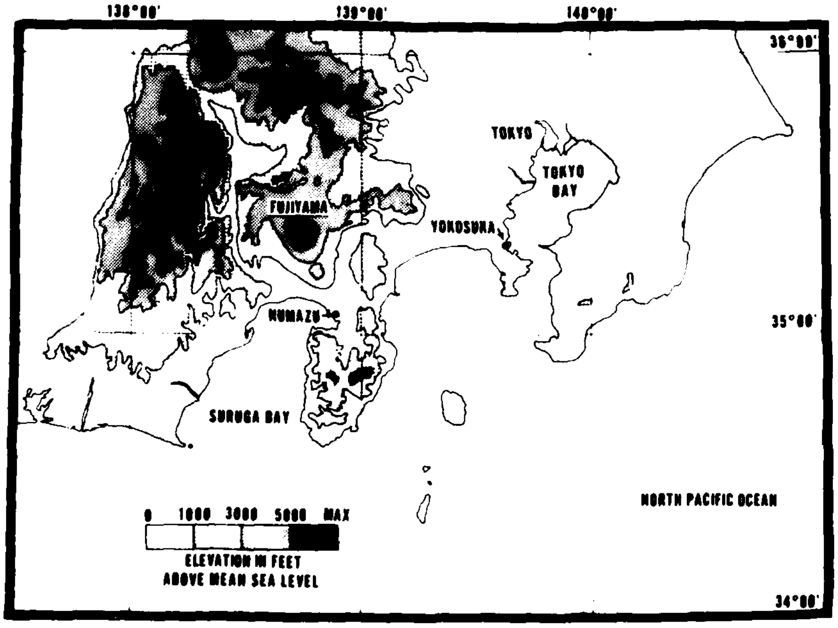

Figure V-2. Topography of central Honshu.

Note the relative flatness of the terrain north and east of Yokosuka as compared with the terrain to the west and northwest. Southern Honshu is even less jagged with no peaks rising over 5,000 ft. The rugged terrain of Honshu influences the weather at Yokosuka.

Yokosuka Bay is at the southwestern end of the inner part of Tokyo Bay. The harbor of Yokohama, a large commercial port, is about 10 n mi northward of Yokosuka Bay. Tokyo Harbor is about 20 n mi north-northeastward of Yokosuka. The harbor of Yokosuka can be classified as a medium-sized harbor of the coast breakwater type.

2.2 YOKOSUKA HARBOR

Yokosuka Harbor is entered from the southern part of Tokyo Bay. The harbor is bounded on the east by part of the Miura Peninsula which is the site of U.S. Fleet Activities (FLEACTS) Yokosuka, and on the west by Azuma Hanto which is actually an island. Azuma Hanto separates Yokosuka Harbor from Nagura Harbor which is used by the Japanese Maritime Self Defense Force (JMSDF) and is a commercial port. Nagura Harbor is entered from the southwestern part of Yokosuka Bay. A small, narrow channel separates Azuma Hanto at its southwestern end from the mainland.

The entrance to the harbor of Yokosuka is about 500 yards wide between the 5-fathom curves. Depths in the harbor decrease from 11 fathoms at the entrance to less than 5 fathoms near the head. A pilot is required when proceeding into or out of drydocks and their services are recommended when a vessel exceeds 5000 tons and/or has a single screw. The harbor can accommodate about 20 ships of various types at any one time.[2]

Figure V-3 is a photograph of Yokosuka Harbor which shows the local topographical features in the immediate vicinity of the port of Yokosuka. Note the protection afforded berths 8, 9, 10, 11, and 12 and drydock 6 from northerly winds clockwise to southerly direction winds.

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[2] The trend toward larger ship types has reduced the pierside berthing capacity inside the port. The optimum load out for the port has been suggested as 1 CV, 1 CG, and 14-18 other various ship types.

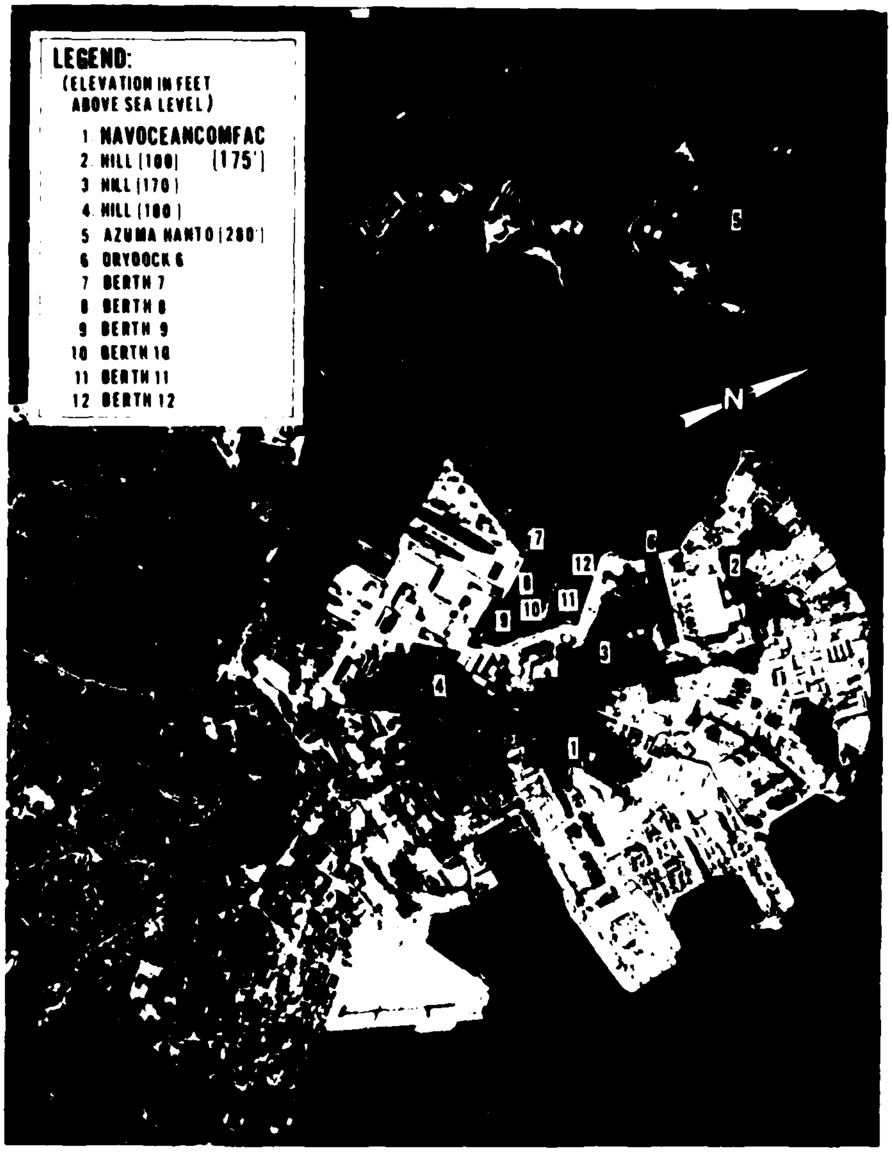

Figure V-3. Aerial photograph of the Port of Yokosuka.

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2.3 TROPICAL CYCLONES AFFECTING YOKOSUKA

2.3.1 Tropical Cyclone Climatology for Yokosuka

Tropical cyclones which affect Yokosuka generally form in an area bounded by the latitudes 5N and 30N and the longitudes 120E and 165E. The latitudinal boundaries shift poleward during the summer months and then equatorward in winter in response to the seasonal changes of the synoptic environment.

In the genesis area mentioned above typhoons have occurred in all months but, with rare exceptions, those affecting the main Japanese Islands are confined to the period of May to November. Late summer and early autumn are the likeliest seasons. Size and intensity of the storms vary widely.

The majority of those that pose a threat to Yokosuka (any tropical cyclone approaching within 180 n mi of Yokosuka is defined as a "threat" for the purpose of this study) occur during the months June-October. Figure V-4 gives the frequency distribution of threat occurrences by 5-day periods. This summary is based on data for the 27 years 1947-1973. Note that the maximum number occur during August and September.[3]

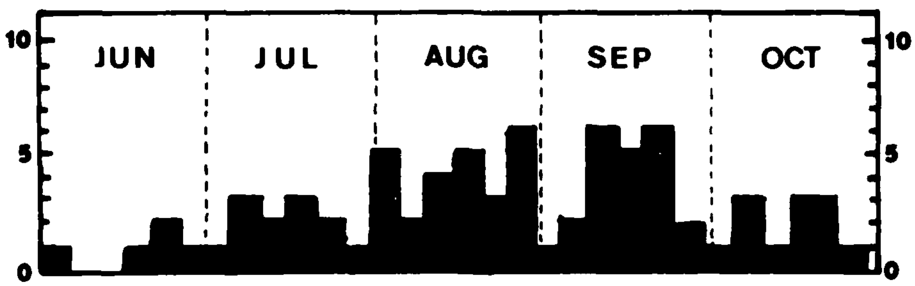

Figure V-4. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Yokosuka. Subtotals are based on 5-day periods for tropical cyclones that occurred during 1947-1973.

Figure V-5 depicts, on an 8-point compass, the "threat" tropical cyclones according to the octant from which they approached Yokosuka. The circled numbers indicate the total that approached from an individual octant. The count for an octant of approach includes both recurvers (northeasterly direction of movement at CPA) and non-recurvers. Note that a majority of these approach from the south-southwest and west-southwest. A more detailed inspection of the sample of 76 tracks revealed that only 9 (12%) did not recurve before passing within 180 n mi of Yokosuka.

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[3]A total of 82 tropical cyclones passed within 180 n mi of Yokosuka during the May-November period for the years 1947-1973. Seventy-six (93%) of these tropical cyclones passed within 180 n mi during the 5 months, June-October, and the remaining 6 passed in the months of May and November, 3 in each month.

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It can be discerned from Table V-2 that only 20 (31%) of the total 64 tropical cyclones for the period June-October (1952-1973) resulted in winds of 34 kt or greater at Yokosuka. However, note that of the 19 tropical cyclones in September, 11 (58%) of these resulted in winds of 34 kt or greater.

Figures V-11 and V-12 show the tracks of the 20 tropical cyclones that resulted in gale force winds or greater at Yokosuka for the period June-October, 1952-1973. Figure V-12 isolates the 11 tracks of September in order to show that most of these passed west of Yokosuka and initially struck Japan on the south coast of Honshu. Note in Figures V-11 and V-12 that recurvature generally occurs further south for the September and October tropical cyclones than do the July and August systems. Also, in Figure V-11 note the track of the tropical cyclone which is headed in an easterly direction and then looped back toward Honshu again!

When the tracks in Figures V-11 and V-12 are compared with all the tracks for the same monthly period in Appendix 1-A it can be seen that, while tropical cyclones have approached Yokosuka from virtually all southerly directions, the vast majority approach along a threat axis that is oriented generally southeast to west-southwest from Yokosuka. This threat axis is evident in Figures V-6 to V-10 by the "percent threat" lines.

The observation station for the Naval Oceanography Command Facility (NAVOCEANCOMFAC) is located on top of a 175 ft hill at FLEACTS Yokosuka, and the wind instrument is another 55 feet above the station; the observed wind velocity is about 10 kt greater than that observed in the harbor, but otherwise is representative. In the period 1953-1973, the highest recorded wind (gust) in Yokosuka was 96 kt. The southerly gust of 96 kt was attributed to Typhoon Ida which passed about 20 n mi to the northwest of Yokosuka on 26 September 1958.

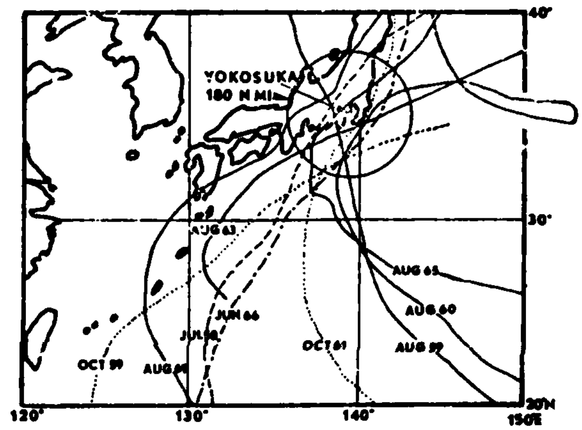

Figure V-11. Tracks of 9 tropical cyclones resulting in winds ≥34 kt at Yokosuka for the months June-August and October. (Based on data from 1952-1973.)

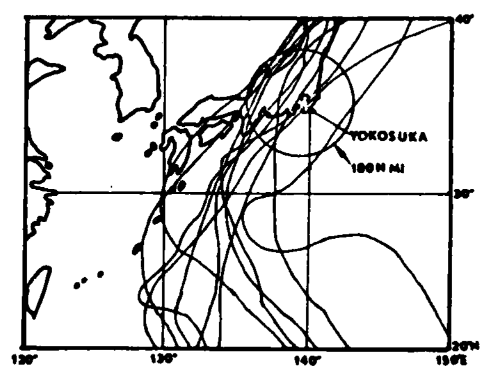

Figure V-12. Tracks of 11 tropical cyclones resulting in winds ≥34 kt at Yokosuka for the month of September. (Based on data from 1952-1973.)

Winds in the harbor during the passage of a severe tropical cyclone are greatly influenced by the surrounding topography and the extent of this influence is dictated by the direction of approach of the storm and the passage relative to Yokosuka. From an analysis of the tropical cyclone tracks in Figures V-11 and V-12, it is apparent that tropical cyclones can pass to the east or to the west of Yokosuka and result in gale force winds or greater at Yokosuka. The basic difference between the two passages is the direction of the resultant wind on the harbor. If the tropical cyclone passes to the west of Yokosuka, the winds will generally be from the south. For a passage to the west, the storm must necessarily cross the mountain ranges of Honshu (see Figure V-2). An example of this was Typhoon Nancy (September, 1961) which had a closest point of approach (CPA) of 140 n mi west-northwest of Yokosuka. Nancy pounded the harbor with gusts of 71 kt from the south-southwest and a sustained wind of about 50 kt for a 4-hour period.

If the tropical cyclone passes to the east of Yokosuka, the path will be over water and the winds will be generally northerly. An example of this was Typhoon Violet (Oct, 1961) which had a CPA of 30 n mi to the southeast of Yokosuka. As a result of Violet, the harbor experienced gusts of 74 kt from the north-northeast.

Units of the SEVENTH Fleet in port Yokosuka during the threatening times of Nancy and Violet reported negligible damage.

The beginning and end point of the arrows in Figure V-13(A) give the positions of tropical cyclone centers when winds ≥22 kt occurred at Yokosuka for 47 of the 64 tropical cyclones (June-December, 1952-1973) that passed within 180 n mi of Yokosuka. Seventeen of these 64 tropical cyclones did not result in winds ≥22 kt. Similarly, Figure V-13(B) shows the positions of tropical cyclone centers when winds ≥34 kt occurred at Yokosuka.

In Figure V-13(A), it appears that 22-kt winds or greater do not generally occur until the tropical cyclone center has reached 32°N. The tracks of the 64 tropical cyclones indicate that 47% passed to the west of Yokosuka and the remainder passed to the east. A high concentration of line segments is found in the northeast and southeast quadrants, relative to Yokosuka, implying that centers located in this region tend to cause ≥22 kt winds in more instances than centers located in other quadrants. The relative flat regions to the north and northeast of Yokosuka account for this. Several of the centers over 600 n mi from Yokosuka continued to generate 22-kt or greater winds at Yokosuka.

Note in Figure V-13(B) that 12 (60%) of the 20 tracks associated with the positions of tropical cyclone centers passed to the west of Yokosuka. The observed gale force wind velocities in Yokosuka resulting from these tropical cyclones generally first exceeded 33 kt when the center was to the north and east of Yokosuka. A number of times tropical cyclone centers were nearly 300 n mi to the north and east, yet gale force winds were observed at Yokosuka.

2.4 THE DECISION TO EVADE OR REMAIN IN PORT

2.4.1 General

The responsibility for overall coordination of action to be taken by Naval activities in the Yokosuka area has been assigned to Commander, Fleet Activities, Yokosuka. The Naval Oceanography Command Facility, Yokosuka issues the local wind warnings. The established procedures in the event hazardous weather is expected are given in SOPA (ADMIN) YOKOSUKA INSTRUCTION 5000.1 series.

Wind from any direction with expected sustained speeds of 48 kt or gusts in excess of 55 kt is sufficient to set tropical cyclone conditions as directed by SOPA. Typhoon conditions will be set as above for an approaching typhoon, i.e., expected sustained winds of 64 kt or greater. The same precautions taken for a typhoon will also be taken for any tropical cyclone.

For general information on tropical cyclone warnings, refer to paragraphs 6 and 7 of Chapter I.

2.4.2 Evasion Rationale

Of utmost importance is that the commander recognize the inherent dangers that exist when exposed to the possibility of hazardous weather. By proper utilization of the meteorological products, especially the FWC/JTWC, Guam Tropical Cyclone Warnings, and a basic understanding of weather, the commander will be able to act in the best interest of his unit and to complete his mission when the unfavorable weather subsides. The following time table (in conjunction with Figures V-14 to V-18 corresponding to the five months June-October) has been set up to aid in these actions. The orientation of the threat axis in Figures V-14 to V-18 was derived by considering the general direction from which the tropical cyclones approached to within 180 n mi of Yokosuka. The time in days to reach Yokosuka was based on typical speeds of tropical cyclones affecting Yokosuka.

I. An existing tropical cyclone moves into or development takes place in Area A with long range forecast movement toward Yokosuka (recall that about 40% of all tropical storms and typhoons recurve):

   a. Review material condition of ship.

   b. Reconsider any maintenance that would render the ship incapable of riding out a storm or typhoon with the electrical load on ship's power, or would render the ship incapable of getting underway, if need be, within 48 hours.

   c. Plot FWC/JTWC, Guam warnings if issued and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters Area B with forecast movement toward Yokosuka (recall that prior to recurvature tropical cyclones tend to slow in their forward motion and after recurvature accelerate rapidly):

a. Reconsider any maintenance that would render the ship incapable of shifting to a new berth assignment, anchorage or buoy or otherwise getting underway, prior to the commencement of strong winds within the harbor.

b. Anticipate Tropical Cyclone Condition III.

III. Tropical cyclone has entered Area C and is moving toward the Yokosuka area:

a. Anticipate Tropical Cyclone Conditions II and I.

A high velocity wind is the single most important factor to be considered. The effects of wave action and storm surge are negligible in the port of Yokosuka.

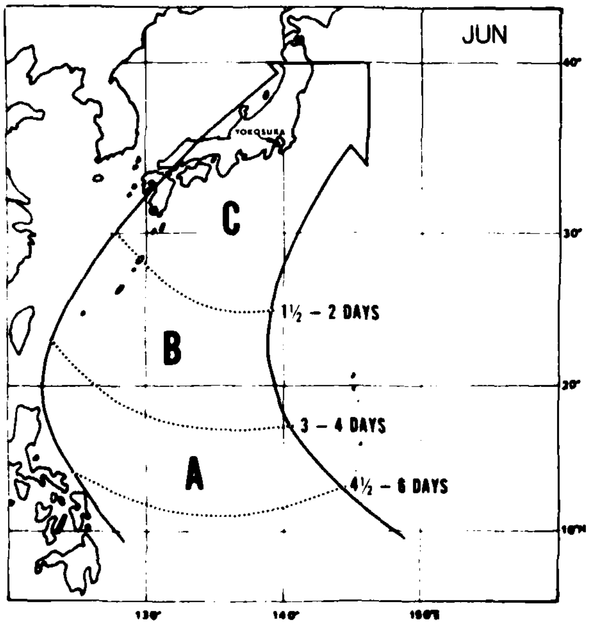

Figure V-14. Tropical cyclone threat axis for Yokosuka for the month of June.

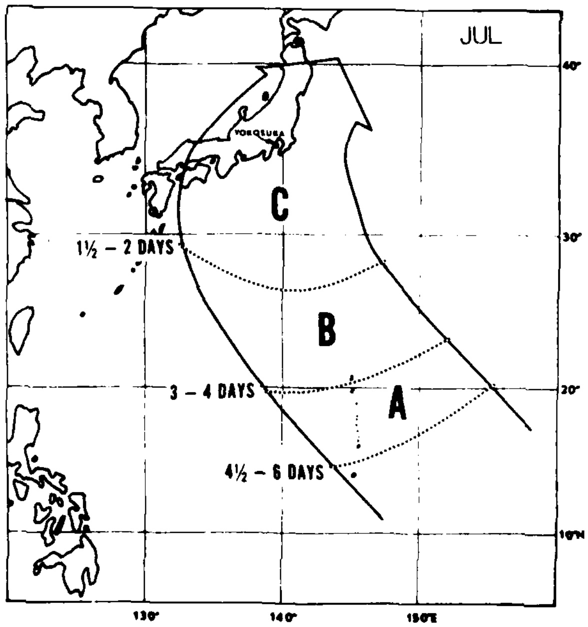

Figure V-15. Tropical cyclone threat axis for Yokosuka for the month of July.

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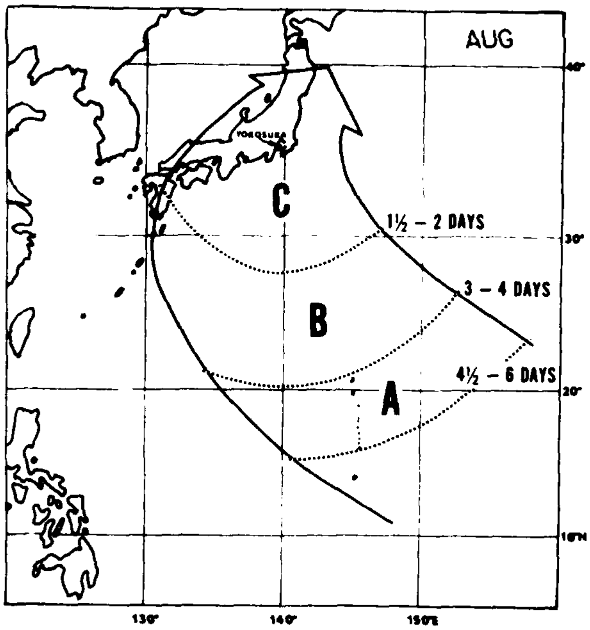

Figure V-16. Tropical cyclone threat axis for Yokosuka for the month of August.

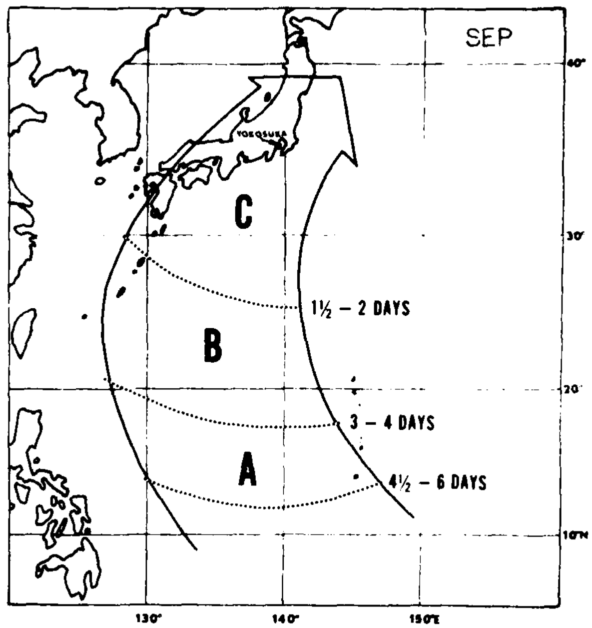

Figure V-17. Tropical cyclone threat axis for Yokosuka for the month of September.

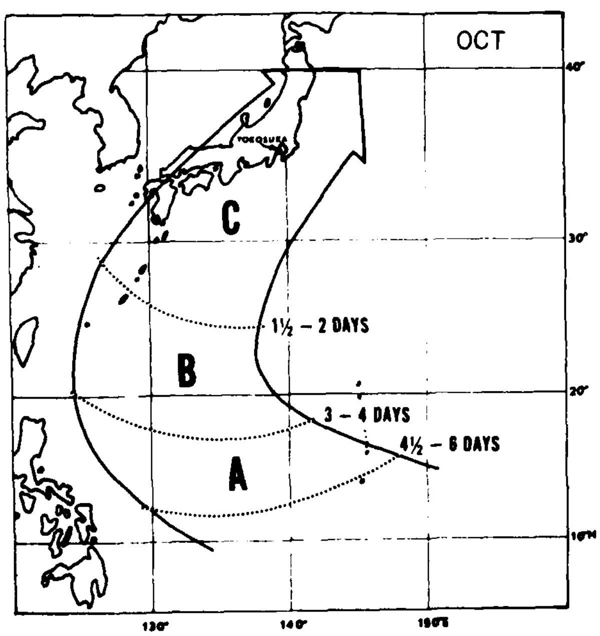

Figure V-18. Tropical cyclone threat axis for Yokosuka for the month of October.

2.4.3 Remaining In Port

Remaining in port is, in almost all instances, the recommended course of action when a tropical storm or typhoon threatens Yokosuka. The following items must be considered:

(1) Berth reassignments, if necessary, should be accomplished before 20-kt winds begin.

(2) Ships with large sail areas should be assigned preferred berthing depending on the direction of the closest point of approach (CPA); i.e., if a typhoon is forecast to pass to the east, use berth 8, and use berth 12 if the forecast passage is to the west.[5]

(3) For CV's, a shift to drydock six is recommended when Tropical Cyclone Condition of Readiness Three (48 hours) is set for sustained winds of 75 kt at Naval Oceanography Command Facility Yokosuka. If shift is not feasible, a sortie is recommended.

(4) Some flooding, caused by heavy precipitation, of the U.S. Fleet Activities land complex may occur; therefore, all ships should provide their own electrical power.

(5) A ship with a large sail area, for example an LPD that is berthed at the floating pier (berth 10 or 11) may want to have a tug standing by during the period of highest winds.

(6) Ships should put out extra line and wire as deemed necessary and should be ready to tend mooring lines.

(7) Although the rated holding strengths of the mooring buoys inside the confines of the port are good, they are not the preferred location to be when high velocity winds are expected. Their orientation with respect to the surrounding land masses does not give them the same protection as do the pierside berths.

(8) The anchorages within Yokosuka Bay have mud and sand bottoms, hence their holding quality would be poor in the event of typhoon intensity winds. In addition, anchorages and mooring buoys in Yokosuka Bay are unprotected from northerly winds and relatively unprotected from southerly winds.

Where there are crowded conditions within the port of Yokosuka and thus limited pierside facilities, this may be an instance when a ship would elect to evade the typhoon at sea or anchor in Tokyo Bay.

Ships of the JMSDF consider their port of Nagura (see Figure V-1) a good typhoon haven if a ship is pierside and, generally, do not sortie to avoid a typhoon. However, ships anchored in the vicinity of Nagura or moored to a buoy usually get underway and proceed to anchorages in various parts of Tokyo Bay.

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[5] See SOPA (ADMIN) YOKOSUKA INSTRUCTION 5000.1, Harbor Movements - Entering and Leaving Harbor.

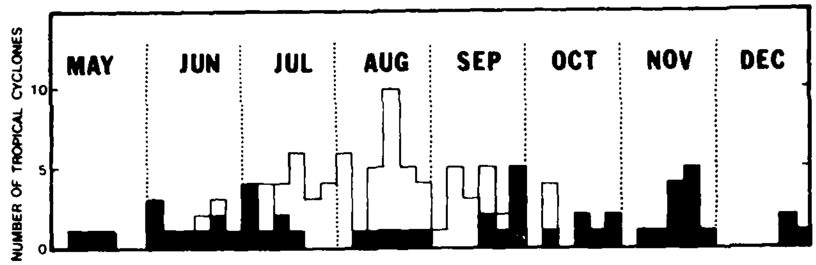

Figure V-94. Frequency distribution of the number of tropical cyclones that passed within 180 n mi of Buckner Bay/Naha. Subtotals are based on 5-day periods, for tropical cyclones that occurred during 1947-1973. The shaded area indicates the number of recurving tropical cyclones per 5-day period (northeasterly direction of motion at their closest point of approach to Buckner Bay/Naha after an initial north-westerly direction of motion).

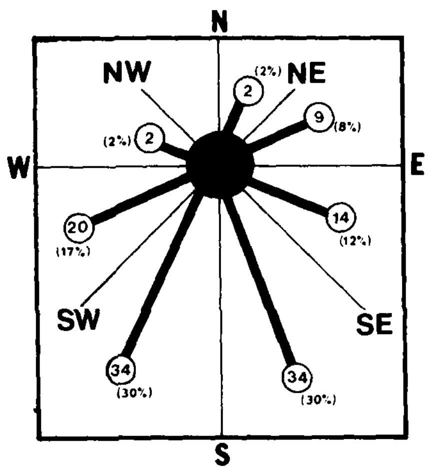

Figure V-95. Directions from which tropical cyclones entered threat area (a 180 n mi radius circle centered at the middle of a line between Buckner Bay and Naha during the period May-December, 1947-1973. Numbers circled indicate the number of tropical cyclones that entered from each octant. This is expressed as a percentage adjacent to the circled number.

Table V-23 indicates that, out of the 115 "threat" tropical cyclones during May-December, 1947-1973, 57 passed the midpoint of a line connecting Buckner Bay/Naha to the east and 58 passed to the west. Therefore, the chance of having a "threat" tropical cyclone pass to the west or east of Buckner Bay/Naha during the typhoon season is equal. However, it is interesting to note that during June, July, and September, the majority of "threat" tropical cyclones pass to the west of Buckner Bay/Naha, while during May, August, October, November, and December the likelihood of having a tropical cyclone pass to the east of Buckner Bay/Naha is greater.

Table V-23. "Threat tropical cyclone passage relative to the midpoint of a line between Buckner Bay and Naha.

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Passed east of midpoint	3	2	7	18	9	6	9	3	57
Passed west of midpoint	0	9	18	13	12	3	3	0	58

Figures V-96 to V-103 represent analyses of the probability of any tropical cyclone approaching within 180 n mi of Buckner Bay/Naha for May through December, respectively. The solid lines represent the "percent threat" for any storm location. The dashed lines represent approximate approach times to Buckner Bay/Naha, computed from average tropical cyclone speeds of movement for tropical cyclones affecting Buckner Bay/Naha during May-December (speeds of movement were derived from climatological data (U.S. NWSED, Asheville, 1973). For example, a tropical cyclone located at 20N/119E in May has a 40% probability of coming within 180 n mi of Buckner Bay/Naha and it can hit Buckner Bay/Naha in about 1½-2 days (see Figure V-96).

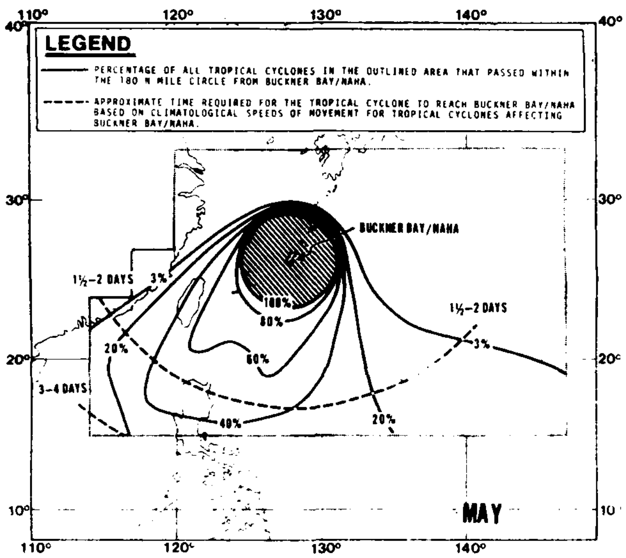

Figure V-96

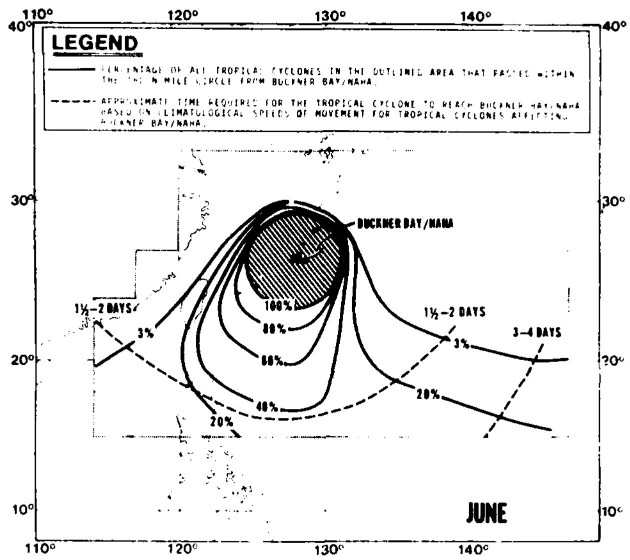

Figure V-97

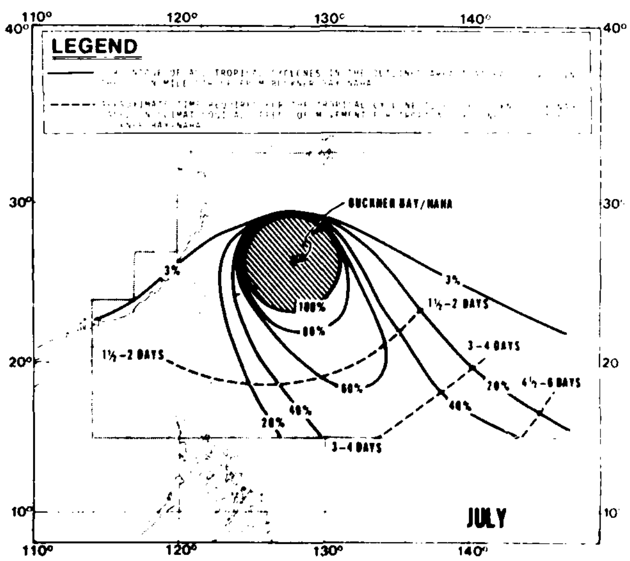

Figure V-98

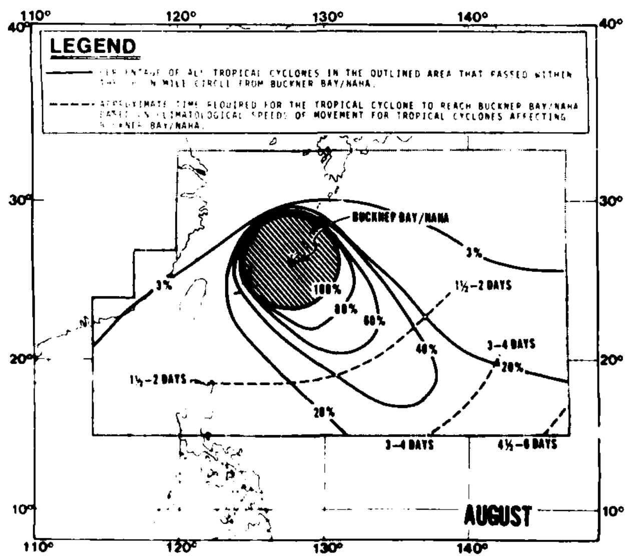

Figure V-99

PALAU

XIII PALAU

1. GENERAL

Figure 1 of the Introduction to this Handbook shows the western North Pacific area with Palau located approximately 900 n mi southeast of Manila in the Philippines and approximately 720 n mi southwest of Guam.

Palau consists of a group of approximately 200 islands, with most of the land area concentrated in a central cluster of islands stretching 50 n mi from Peleliu in the south to the big island of Babelthuap in the north (Figure XIII-1). Near the center of this cluster lies the main town of Koror, where most of the population resides. To the southwest of Koror lies the main commercial port, Malakal Harbor. To the northwest of Koror lies Komebail Lagoon, unused by any commercial shipping.

This whole group of islands is almost completely surrounded by coral reefs, penetrated by only a few relatively narrow channels. The islands themselves, although quite steep sided are relatively low with only a few points reaching above 656 ft (200 m).

For a detailed description of the Palau Islands, the reader is referred to Hydrographic Center Publication No. 82, Sailing Directions for the Pacific Islands, Volume 1, Section 6-C (1976).

Note: This typhoon haven evaluation was prepared by LT CDR Geoffrey A. Stevenson, RN, Royal Navy Exchange Officer at NAVENVPREDRSCHFAC.

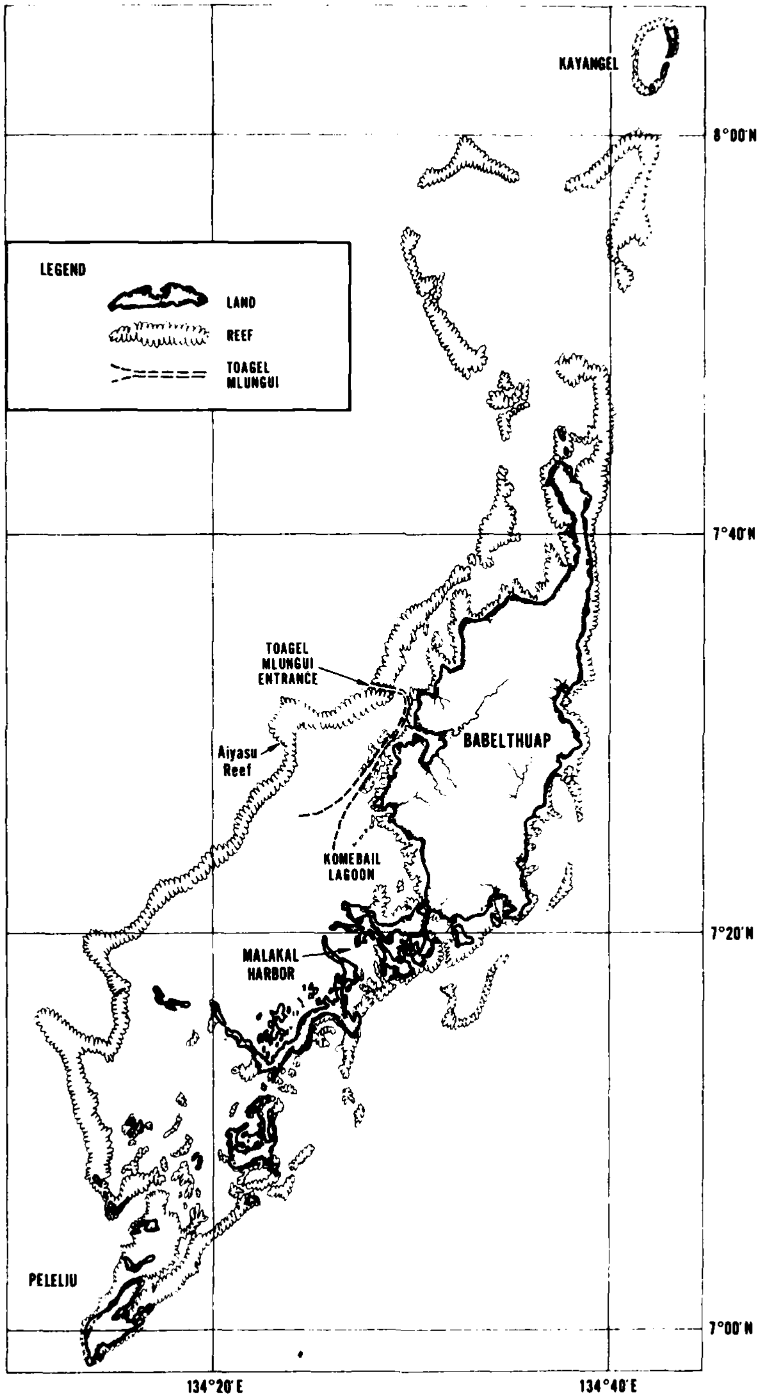

Figure XIII-1. Location map of Palau from Peleliu to Kayangel showing places mentioned in text and main reef areas.

SUMMARY

Neither Malakal Harbor nor Komebail Lagoon is recommended as a typhoon haven. The surrounding topography is low and therefore does not provide much of a wind break. For certain directions there is no protection from the wind at all. The cost of evasion in terms of time and money would be small since the evasion routes (mainly to the southwest) are relatively direct and likely to be short. Access to the anchorages is via a long narrow channel, Toagel Mlungui, which would present a considerable navigational hazard if it became necessary to exit during heavy weather. Finally, there are no repair facilities, the nearest being in Guam.

Positive haven aspects for Palau are as follows. The anchorages are completely protected from externally generated sea and swell by the various reefs. Climatologically, no really severe typhoon has ever been recorded as affecting Palau (the strongest gust recorded at Koror in 32 years of measurements was only 78 kt in 1967). Of course, this in no way implies that Palau is immune to severe typhoons. If sufficient warning time is not given, or the means to evade does not exist, then the anchorages would be sufficiently large to allow some maneuvering and a minimal typhoon could be ridden out with some use of the engines.

2. MALAKAL HARBOR AND KOMEBAIL LAGOON

2.1 MALAKAL HARBOR

Malakal Harbor, shown in Figure XIII-2, is a natural harbor formed by a chain of rock islands which almost surrounds it except for a narrow gap to the northwest and a wide gap to the southeast. The opening to the southeast is protected from wave action by an extensive coral reef, Ngadarak Reef, which is penetrated by two narrow channels. One of the channels, Malakal Pass, is marked by buoys and is generally used by local shipping. The other, Ngell Channel, is unmarked and is only used by small boats with local knowledge.

The only deep water entrance is at the northwest end of the harbor. The entrance is approached via Toagel Mlungui (western passage), a channel which penetrates the Aiyasu barrier reef 12 n mi to the north (see Figure XIII-1). The channel has a general width of 2000 ft and a minimum width of 800 ft and has been swept over its entire length to a minimum depth of 36 ft (11 m).

The harbor is approximately 3 n mi long and 1 1/2 n mi wide, so there is plenty of room for maneuvering. However, it should be noted that there are several reef areas within the harbor, not all of which are marked. These must be considered a major hazard should maneuvering be required during a period of heavy weather.

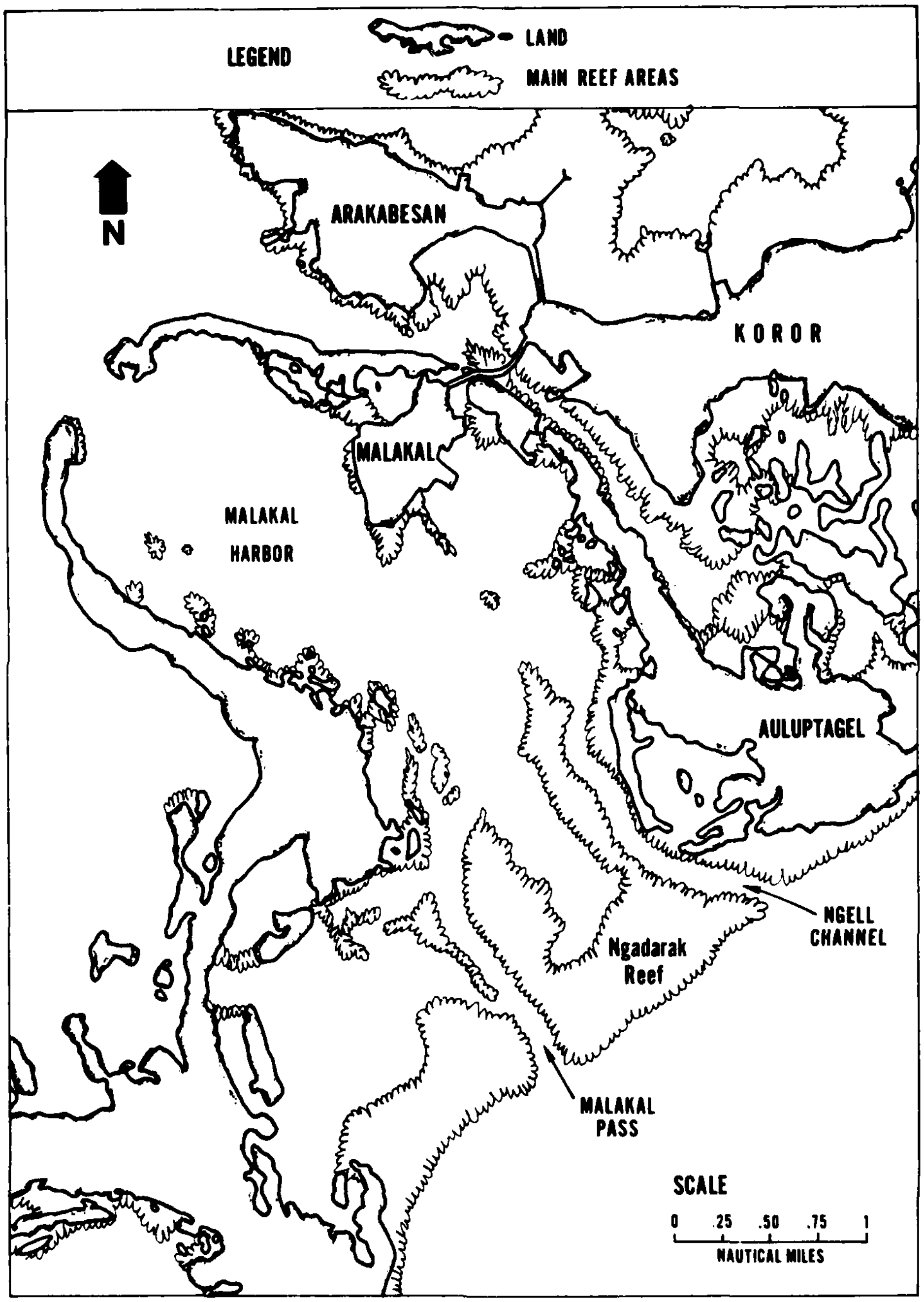

Figure XIII-2. Malakal Harbor showing surrounding rock islands and reef areas.

The commercial port lies at Malakal Island in the middle of the northern side of the harbor. The wharves which are in use are located at a concrete pier on the eastern side of Malakal Island. The front of the pier has a length of 510 ft and the sides have a usable length of 400 ft where the depth is 42 ft (13 m).

United States Navy ships (normally LSTs) using the harbor normally enter via Toagel Mlungui and occupy the front portion of the pier. There are no mooring buoys or designated anchorages, but vessels can anchor in a position about half a mile southeast of the pier. There are many other anchorages both inside and outside the harbor, all of which have goodd holding in a bottom consisting mainly of sand and coral.

2.2 KOMEBAIL LAGOON

Komebail Lagoon (see Figure XIII-3) is a roughly circular area of water fringed to the north, east and south by coral reefs and open to the west where the main deep water channel, Toagel Mlungui, leads to Malakal Harbor. Protection to the north and east is provided by the island of Babelthuap. Protection to the south is provided by the islands of Koror and Arakabesan. The only protection to the west is Aiyasu reef (see Figure XIII-1).

Much of the lagoon has a depth between 66 and 132 ft (20-40 m). The area which has been swept to at least 20 ft (6 m) is shown in Figure XIII-3. Detailed information on swept depths is provided on Chart No. 81148 (Defense Mapping Agency Hydrographic Center, 1972).

The lagoon provides a very large area of usable anchorages, approximately 3 n mi by 2 n mi, where the bottom provides good holding in the form of sand and coral. Plenty of maneuvering room would be available in the event of rough weather.

2.3 TOPOGRAPHY

Contours have not been shown in Figures XIII-1 to 3 because of the rather complicated structure of the islands. In general, the islands surrounding Malakal Harbor rise steeply to heights of approximately 164 ft (50 m), but in isolated places exceed 492 ft (150 m). The islands surrounding Komebail Lagoon tend to be less steep and to have a relatively low profile. Despite the relatively large size of the island of Babelthuap, the highest point is still only 794 ft (242 m).

It can be seen therefore, that the topography does not offer particularly good protection from the wind, Malakal Harbor being open to the southeast and Komebail Lagoon being open to all points west.

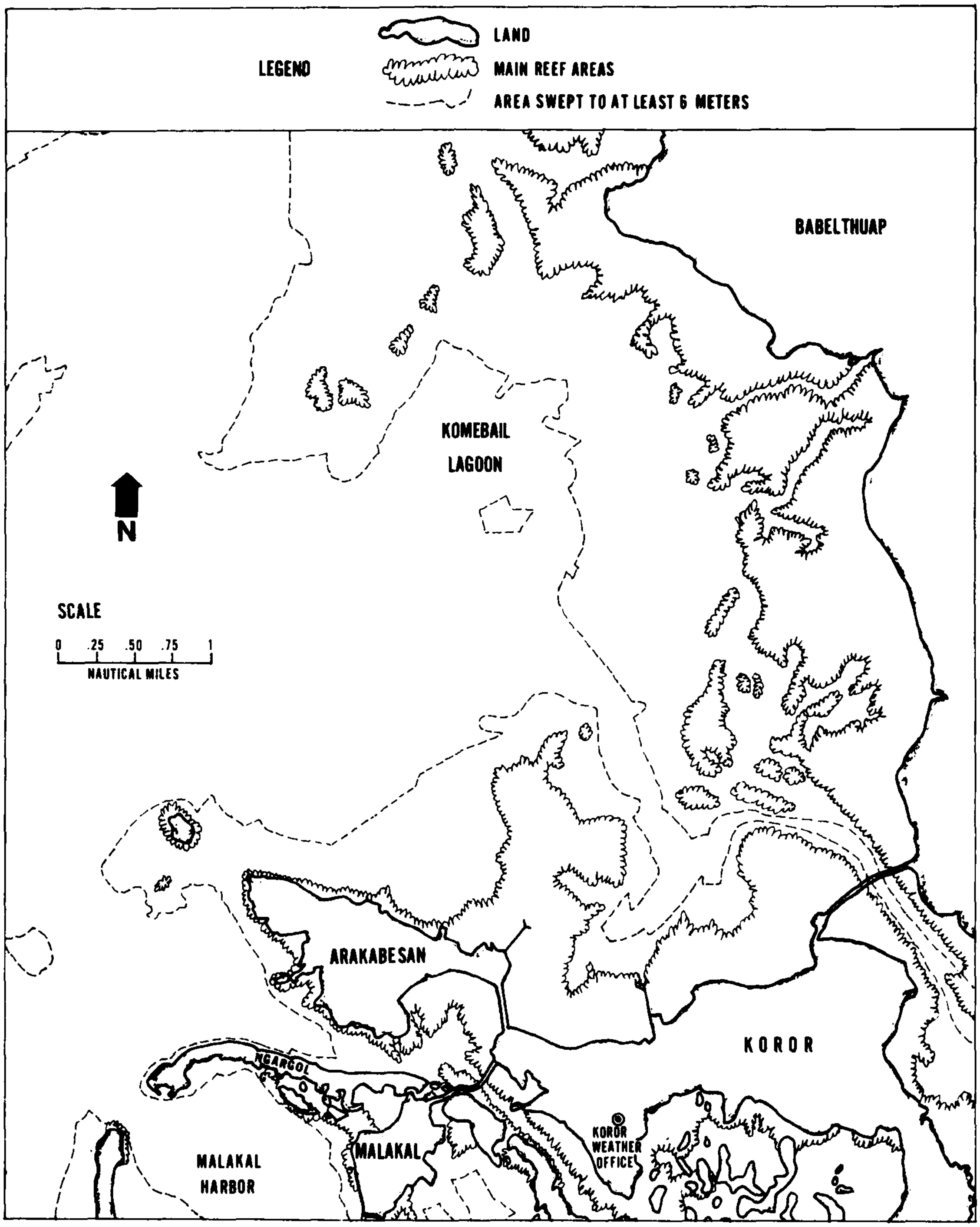

Figure XIII-3. Komebail Lagoon showing surrounding land and reef areas.

2.4 HARBOR FACILITIES

Harbor facilities in Malakal Harbor are sparse. For details, the reader is referred to Hydrographic Center Publication No. 82, Sailing Directions for the Pacific Islands, Volume 1, Section 6-C.

3. TROPICAL CYCLONES AFFECTING PALAU

3.1 CLIMATOLOGY

For the purposes of this series of studies, any tropical cyclone approaching within 180 n mi of Koror is considered a threat to Palau. It is recognized that a few tropical cyclones which did not approach within 180 n mi may have affected Palau. However, cyclones in this region tend to have a small diameter, and 180 n mi is the criterion normally chosen in order to limit the size of the data sample.

Although tropical cyclones occur throughout the year, the majority of those which threaten Palau occur in May and from October through January. Figure XIII-4 depicts the monthly summary of tropical cyclone occurrences based on data for the 31 years, 1947-1977. Of the 71 tropical cyclones that threatened Palau in this period (more than two threats per year), it can be seen that the threat period has a double peak, one in late spring/early summer and the other in late fall/early winter. This phenomenon is due to the very low latitude of Palau (7°20'N), which puts it south of the climatological position of the near-equatorial trough in August and September, and therefore south of the main typhoon tracks, when the remainder of the western North Pacific is at the height of its typhoon season. The near-equatorial trough is at lower latitudes in the late spring/early summer as well as the late fall/early winter and therefore produces the higher threat periods during those times of the year.

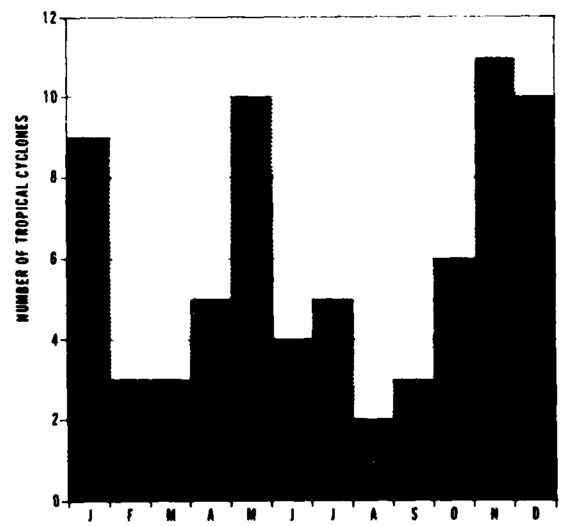

Figure XIII-4. Monthly frequency distribution of the number of tropical cyclones that passed within 180 n mi of Palau (1947-1977).

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Figure XIII-5 displays the above storms as a function of the compass octant from which they approached Palau. The open numbers indicate the number of storms which approached from that octant or which were first detected in that octant. The numbers in parentheses represent the same information, but as percentages. It is evident from this figure that the majority of storms approach Palau from the east.

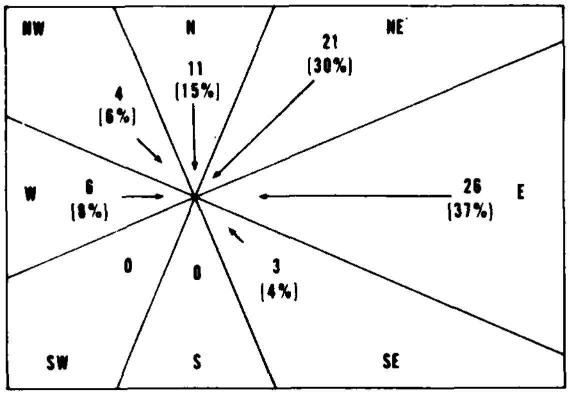

Figure XIII-5. Direction of approach to Palau of the tropical cyclones (1947-1977) which passed within 180 n mi of Palau. Tropical cyclones which first formed within 180 n mi of Palau have been included in the direction in which they were first detected. Open numbers indicate the number that approached from each octant. The numbers in parentheses are the percentage of the total sample (71) which approached from that octant. Arrow length is proportional to frequency.

Approximately two tropical cyclones each year pose a threat to Palau. Since Palau is in the development area for WESTPAC tropical cyclones many of these storms are in the formative stages of their life cycle and have not, as yet, achieved typhoon intensity. Of the 71 tropical cyclones that approached or developed within 180 n mi of Palau in the period 1947-1977, the point where these storms attained tropical storm intensity ($\geq$34 kt) is in many cases to the west of Palau (see Figure XIII-6). In fact, approximately 45% of threat tropical cyclones which reached tropical storm intensity did so after their closest point of approach (CPA) to Palau (given that most were heading on a generally westerly track).

Figure XIII-7 shows the points at which threat tropical cyclones reached typhoon intensity ($\geq$64 kt). Notice that about 65% of threat cyclones which attained typhoon intensity did so to the west of Palau. Of all the threat tropical cyclones, only one in four reaches typhoon intensity before threatening Palau, a fact that must not allow the reader to develop a false sense of security. Not only does a tropical storm, which has not yet reached typhoon status, have significant potential for damage, but also the possibility exists that a cyclone lying to the east of Palau can intensify rapidly (see for example, the case of Typhoon Sally in Section 3.5).

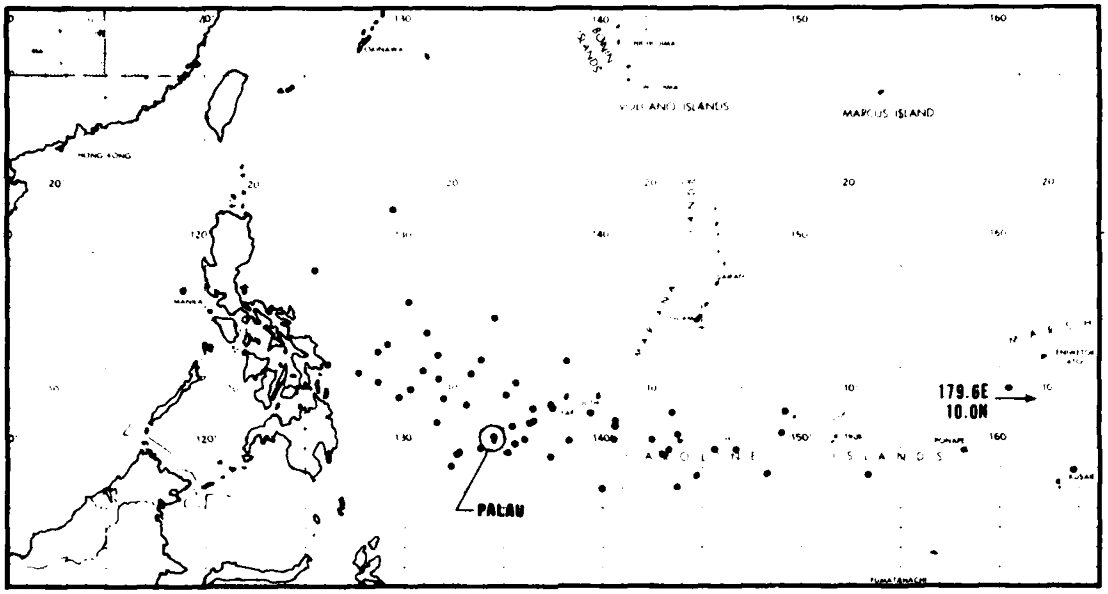

Figure XIII-6. Point of attainment of tropical storm intensity (≥34 kt) for 71 tropical cyclones passing within 180 n mi of Palau (1947-1977) since 9 tropical depressions did not achieve the above criteria, only 62 positions are plotted.

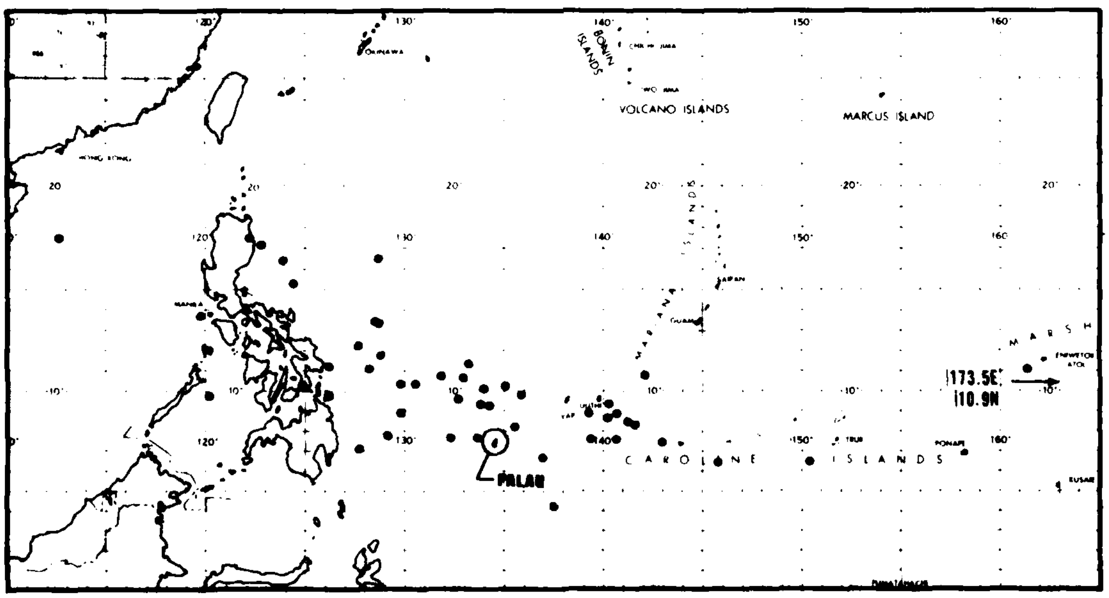

Figure XIII-7. Initial point of attainment of typhoon intensity (≥64 kt) for 71 tropical cyclones passing within 180 n mi of Palau (1947-1977) since 23 tropical cyclones did not achieve the above criteria, only 48 positions are plotted.

Figures XIII-8 through XIII-11 constitute a statistical summary of threat probability based on tropical cyclone tracks for the years 1947-1977.[1] The data are grouped by seasons which depend on the relative position of Palau to the climatological position of the near equatorial trough. Figure XIII-12 summarizes the threat probability for all months. The solid lines represent the "percent threat" for any storm location. The dashed lines represent approximate approach times to Palau based on an approach speed of 8-12 kt. For example, in Figure XIII-8, a storm located at 148°E and 5°N has approximately a 40% probability of passing within 180 n mi of Palau and will reach Palau in 3-4 days if its speed remains between 8 and 12 kt.

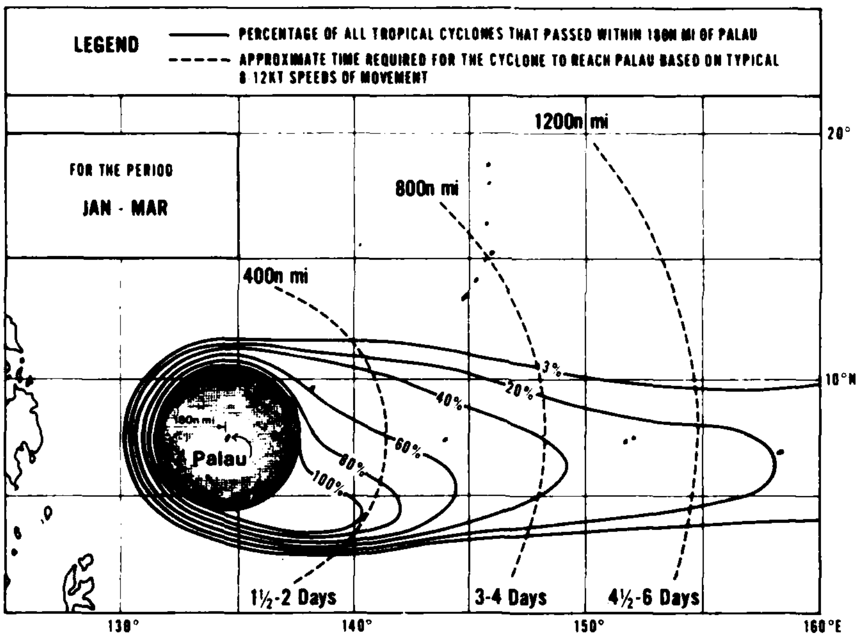

Figure XIII-8. Percentage of tropical cyclones that passed within 180 n mi of Palau for the months January-March. (Based on data from 1947-1977.)

[1] From Chin (1972) for years 1947-70 and from JTWC Guam Annual Typhoon Reports (1971-77).

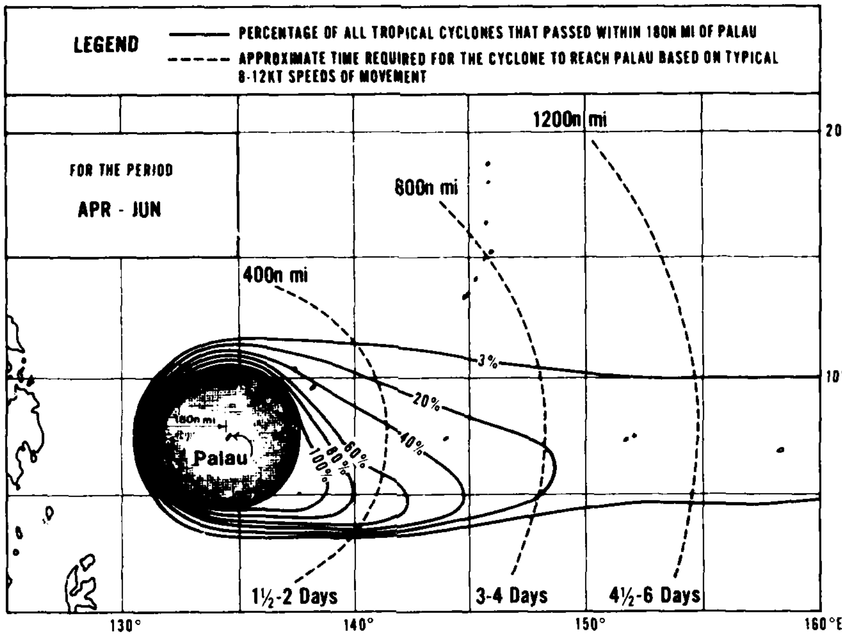

Figure XIII-9. Percentage of tropical cyclones that passed within 180 n mi of Palau for the months April-June. (Based on data from 1947-1977.)

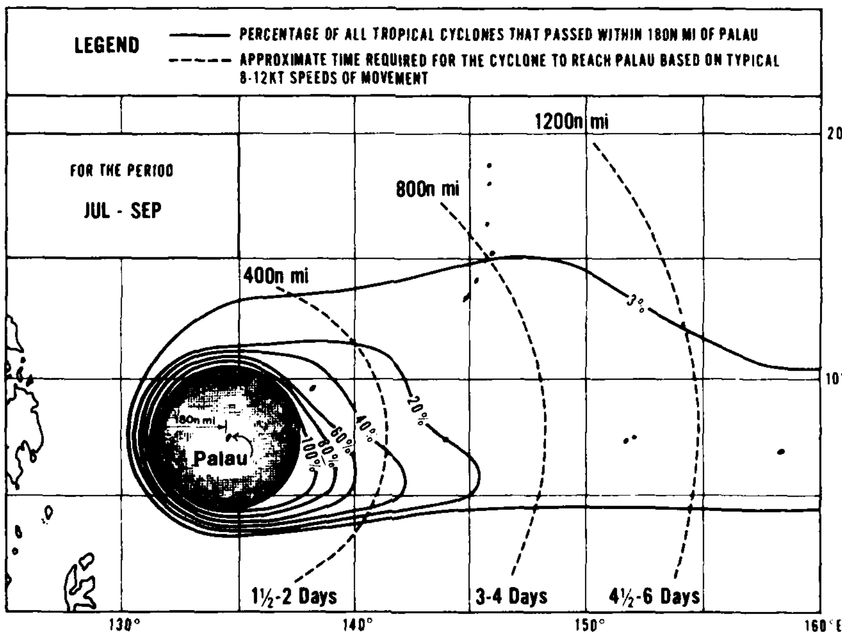

Figure XIII-10. Percentage of tropical cyclones that passed within 180 n mi of Koror for the months July-September. (Based on data from 1947-1977.)

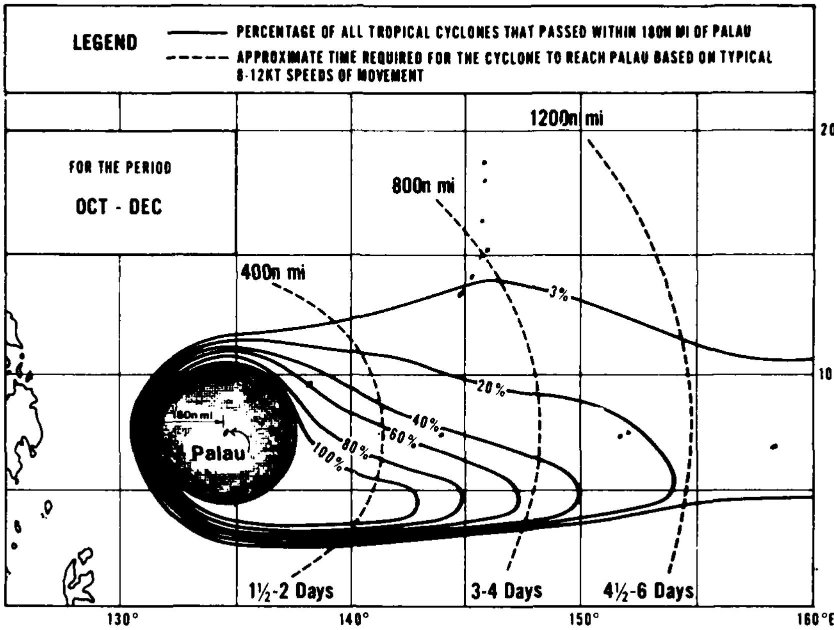

Figure XIII-11. Percentage of tropical cyclones that passed within 180 n mi of Koror for the months October-December. (Based on data from 1947-1977.)

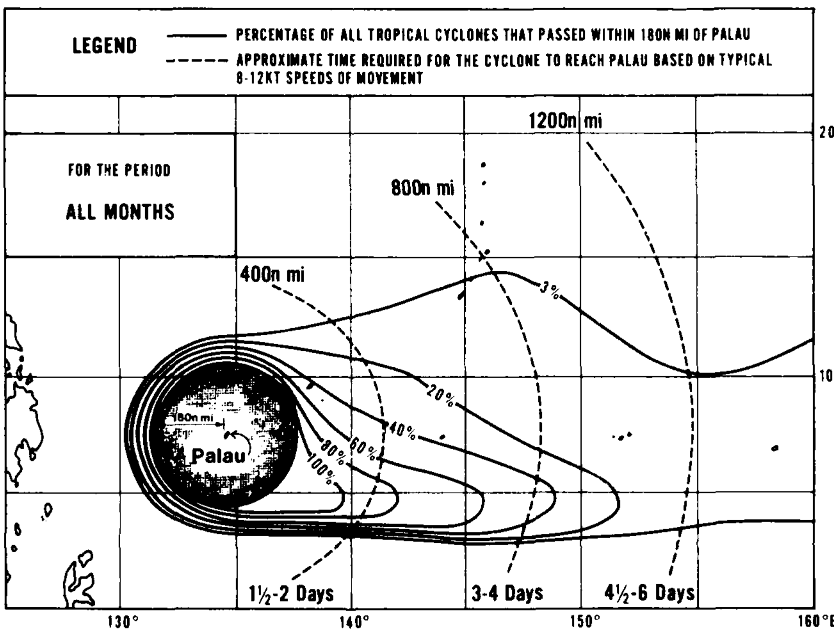

Figure XIII-12. Percentage of tropical cyclones that passed within 180 n mi of Koror for all months. (Based on data from 1947-1977.)

3.2 WIND AND TOPOGRAPHICAL EFFECTS

In the 31 year period from 1947-1977 a total of 71 tropical cyclones approached within 180 n mi of Palau, an average of 2.3 per year. By far the largest number that threatened in any single year was 8 in 1971. Approximately 88% of the sample passed to the north of Koror and 12% passed to the south of Koror. Table XIII-1 groups the above 71 tropical cyclones according to the wind intensity that they produced at Koror.

Table XIII-1. Extent to which tropical cyclones affected Koror, Palau during the period 1947-77.

Number of tropical cyclones that passed within 180 n mi of Palau	71
Number of tropical cyclones that resulted in winds ≥22 kt at Koror	14
Number of tropical cyclones that resulted in winds ≥34 kt at Koror	6

Of the 71 tropical cyclones concerned, 20% resulted in strong winds (>22 kt) and 8% resulted in gale force winds (≥34 kt). These results are based on available wind data which vary from hourly to only five observations per day. Such sparse data will have the effect of considerably obscuring the true frequency of strong winds. Although gale force or greater winds were noted on only six occasions, significantly higher winds are known to have occurred between reporting times on several other occasions. Similarly, strong winds have occurred between reporting times more often than Table XIII-1 would imply. An example of such an event was the passage of Typhoon Sally in 1967 (see Section 3.5 for description of Typhoon Sally). Only one synoptic report contained a wind observation over 20 kt -- the local midnight report was 340°/42 kt. However, it was observed from the meteorological log that the maximum mean wind was 50 kt, and the wind measured during squalls exceeded 70 kt both before and after passage of the eye.

The location of Koror Weather Office is shown in Figure XIII-3. Its elevation of 98 ft (30 m) puts it at one of the highest points on the western half of Koror Island, and therefore in a well exposed position. The wind data are considered to be highly representative of the winds at both Komebail Lagoon and Malakal Harbor.

Figure XIII-13 depicts the tracks of tropical cyclones that occurred between 1947 and 1977, and which resulted in strong winds ($\geq$22 kt) at Koror. When the tracks in Figure XIII-13 are compared with the mean tracks in Appendix I-A, it becomes apparent that the majority of tropical cyclones that caused strong winds approached along a major threat axis that is oriented due east from Pala' . This threat axis is also represented by the "percent threat" lines of Figures XIII-8 through XIII-12 and in Figure XIII-5 by the octant approach arrows.

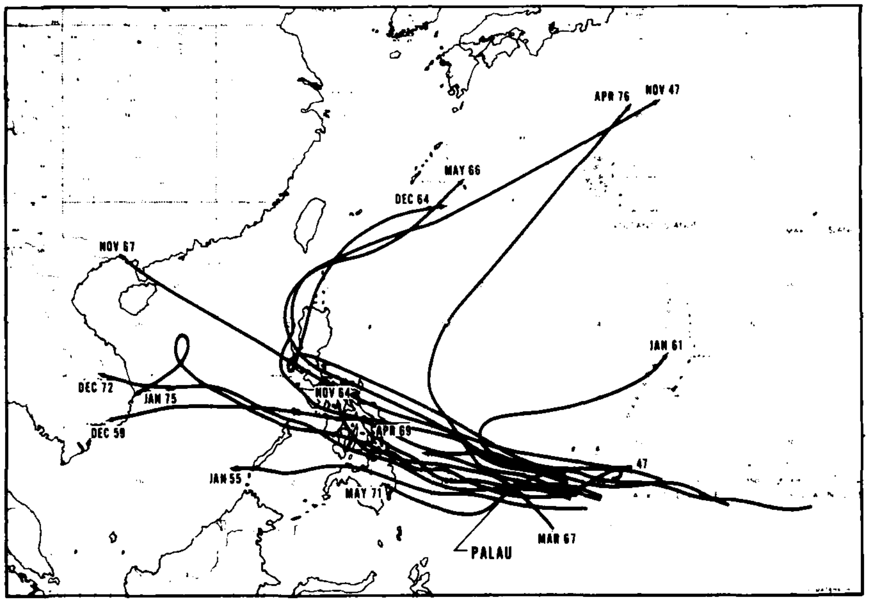

Figure XIII-13. Tracks of tropical cyclones associated with strong winds ($\geq$22 kt) at Koror for all months 1947-1977. Of these tropical cyclones of Nov 64, Dec 64, Mar 67, Apr 69, Jan 75, and Apr 76 resulted in gale force or greater winds at Koror.

Another significant feature indicated in Figure XIII-13 is that the 14 tropical cyclones that resulted in strong winds at Koror all occurred between November and May. This is coincident with the northeasterly monsoon season when the near equatorial trough is to the south of Palau. This observation does not imply that strong winds cannot occur during the other months (it has already been shown in Figure XIII-4 that typhoons can occur during any month), but climatology indicates that typhoon tracks lie further to the south during winter

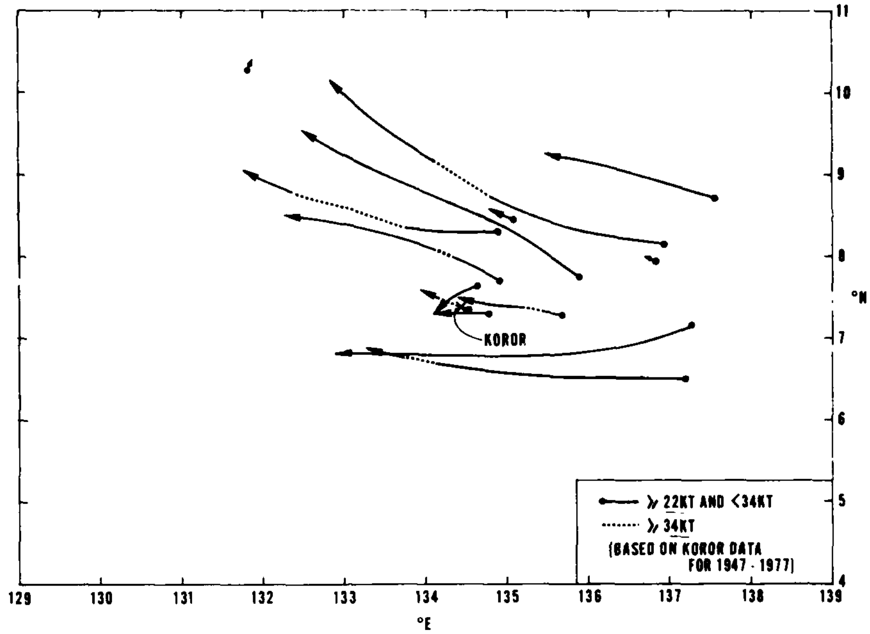

Figure XIII-14. Tracks of tropical cyclone centers for periods when they were causing strong winds at Koror. (Based on Koror data for 1947-1977.)

In Figure XIII-14 the lines showing tropical cyclone movement give the positions of tropical cyclone centers when strong winds (≥22 kt) and when gale force winds (≥34 kt) were first and last recorded at Koror Weather Office. It is apparent from this diagram that strong winds have occurred with the cyclone center up to 250 n mi away, and gale force winds have occurred with the center up to 150 n mi away. In general, strong winds can arise from tropical cyclones passing to the north or south and there is no sector that is a particular threat. However, there are proportionally more strong wind situations for tropical cyclones passing to the south than to the north (i.e., the 12% of storms which had a CPA to the south produced 29% of the strong wind cases). This is logical, since storms passing south would place Koror in the high wind or dangerous semicircle.

3.3 WAVE ACTION

Maximum wave action is normally associated with the right semicircle of a typhoon, which in the case of Palau means a passage to the south since tropical cyclones almost invariably approach from the east. However, even though Malakal Harbor and Komebail Lagoon both have a certain amount of exposure to the wind, they are both completely protected from externally generated waves by the surrounding land and coral reefs. The maximum wave action possible, therefore, would be at the western end of Malakal Harbor in an easterly wind and the eastern side of Komebail Lagoon in a westerly wind. The maximum wave height ever observed in Malakal Harbor by the Port Director was 4 ft. A rough calculation[2] indicates that the maximum wave height possible in Malakal Harbor is just over 3 ft in a 60 kt wind, and 5 ft in a 90 kt wind. In Komebail Lagoon where the fetch is considerably longer, if the wind is westerly, 4 1/2 ft waves are indicated for 60 kt winds and 7 ft waves for 90 kt winds.

3.4 STORM SURGE AND TIDES

Conversations with harbor authorities in Palau revealed no observations of significant storm surge within Malakal Harbor. However, conversations with local fishermen revealed a 6 ft surge just after the passage of the eye of Typhoon Sally in 1967.

A detailed description of tides is given in Publication 82, Sailing Directions for the Pacific Islands, Volume I. The normally reported tidal flow in both Malakal Pass and Toagel Mlungui is about 2-3 kt, but apparently it can attain a rate of 4-5 kt at times, although this was outside the experience of personnel now employed at the harbor. If such is the case, then it is the opinion of local personnel that during a close typhoon passage tidal currents in Malakal Pass and Toagel Mlungui could attain values as high as 7 kt which would be a considerable restriction for any ship trying to sortie or even for a ship trying to maneuver within the harbor.

Where Toagel Mlungui opens to the anchorage areas of Komebail Lagoon, tidal currents are reported to be less than 1 kt. This is unlikely to be much exceeded even during close typhoon passage due to the hydrography.

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[2] Based on forecasting curves for shallow water waves from U.S. Army Coastal Engineering Research Center, 1973: "Shore Protection Manual (Vol. 1)."

3.5 CASE STUDIES OF INDIVIDUAL TYPHOONS

3.5.1 Typhoon Sally, March 1-6, 1967

Typhoon Sally is an example of how a typhoon can hit Palau with virtually no warning. The disturbance was first detected 800 n mi away to the east southeast 60 hours before it struck Koror. However, the disturbance was very weak and ill defined. It was not until 0245Z on the 1st of March that hourly observations were requested from Koror by Guam, and the first fix was not until 0412Z when the center was determined by satellite imagery to be 150 n mi southeast of Koror.

At 1100Z Koror weather conditions were observed near normal with an 8 kt northerly wind and pressure 29.665 inches and rising. By 1400Z the wind was gusting to 65 kt and the pressure falling rapidly. At 1437Z the eye passed just north of the weather station and by 1500Z the wind was gusting 75 kt from the south. At this time, the mean wind was at its maximum, only 50 kt, but during squalls the wind was recorded as 72 kt from the north and then 73 kt from the south.

It was not until 1800Z that the first warning was issued, probably based on these Koror observations, since there were no observation stations in the area that the storm was developing. With the more sophisticated and more frequent satellite imagery that is available today, and with the experience that has been gained over the years, it is unlikely that such a lack of warning will happen again.

Figure XIII-15 shows the best track for Typhoon Sally from the 1967 Annual Typhoon Report. Here it can be seen that the typhoon was described as being in the formative stage until the time it reached a position 50 n mi west of Koror when it already possessed winds of 70 kt. It can also be seen that as the typhoon passed over Palau it had a forward velocity exceeding 18 kt.

Certain items appearing in local newspapers and correspondence at the time indicate the possibility that tornadoes may have been embedded in Sally's circulation. Aircraft reconnaissance over southern Babelthuap just after the typhoon had passed showed that damage was selective "as if a giant claw had raked the earth." The vegetation was described as alternating strips of destroyed and flourishing vegetation. There were also reports of a noise like a train, and an eye witness report from a local fisherman whose boat was wrecked in the typhoon described "swirling and foaming water" in an area that was reasonably well sheltered from the southerly wind.

All the above evidence points to the fact that Sally was a small, intense rapidly developing, fast moving typhoon which was therefore extremely difficult to locate especially in the data void area in which it was generated. Such storms are therefore very difficult to evade.

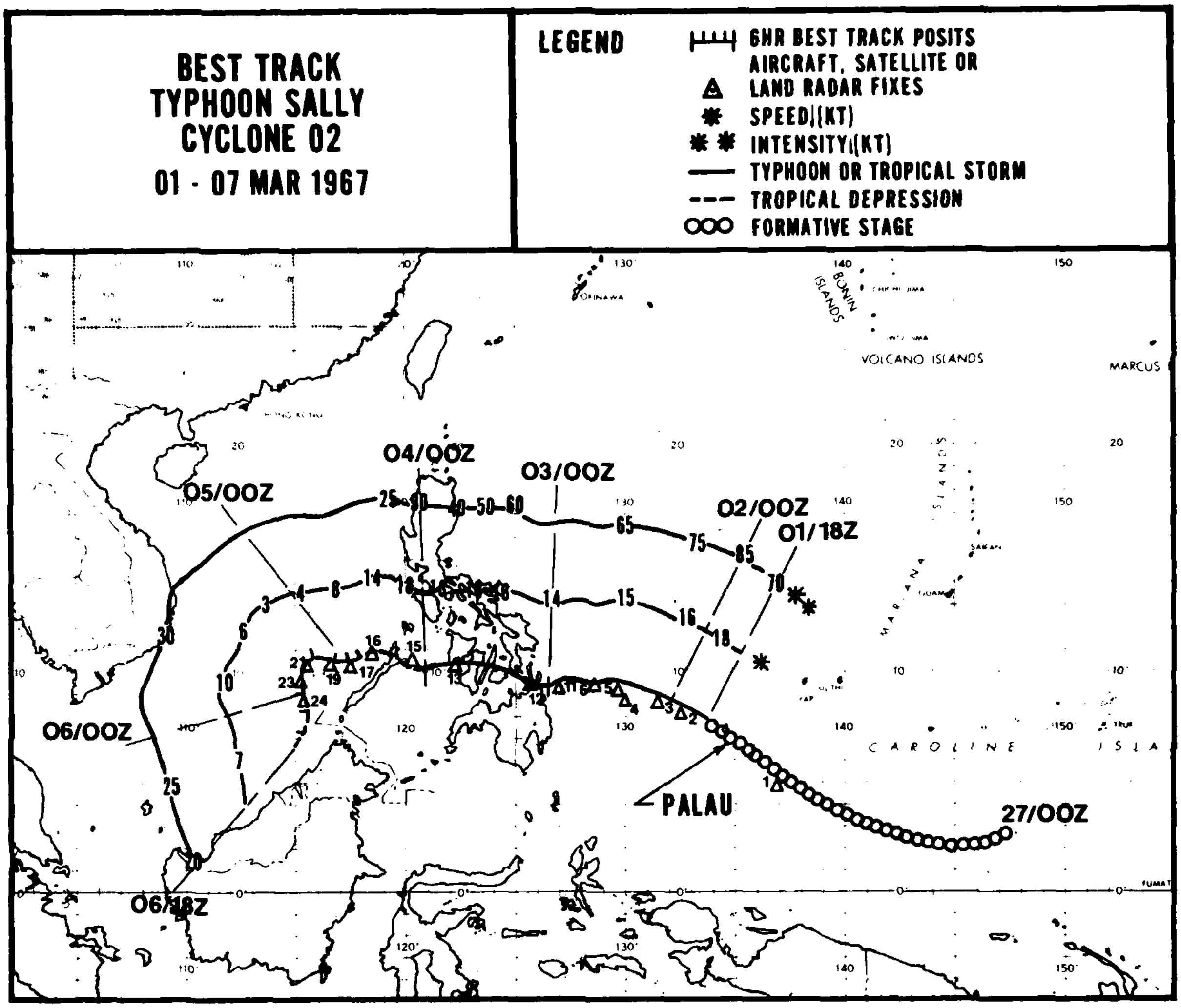

Figure XIII-15. Best track of Typhoon Sally 1-7 March 1967. (From JTWC Guam Annual Typhoon Report, 1967.)

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3.5.2 Typhoon Marie, April 3-14, 1976

Unlike Sally, Marie was a much larger, slower moving system, typical of most typhoons. The following is extracted verbatim from the 1976 annual typhoon report. The best track is shown in Figure XIII-16.

"On the 1st of April a tropical disturbance was detected by satellite near 10N-140E. Synoptic data revealed a weak surface cyclonic circulation with an associated upper level anticyclone. The system drifted slowly southward for the next two days. At 0030Z on the 3rd a formation alert was issued when synoptic data indicated the system had intensified to 25 kt, and increasing upper level outflow to the north promised good potential for further intensification. At 0600Z on the 3rd the first warning was issued. Six hours later the system was upgraded to Tropical Storm Marie when synoptic data confirmed aircraft reports of 35 kt winds.

Influenced by weak steering flow, the storm turned eastward in a counterclockwise loop, and during the evening of the 4th began taking a slow, southerly heading. Tropical Storm Marie intensified, and by 0600Z on the 5th had attained typhoon strength. Twelve hours later the typhoon had acquired a 6 kt movement toward the west-northwest, and for the next 48 hours maintained 65 kt winds.

"On the evening of the 7th, the typhoon once again began to intensify, as upper tropospheric winds over the Philippine Islands backed, indicating deeper troughing to the west and a more efficient link of the storms outflow channel with the mid-latitude westerlies. This intensification continued slowly during the subsequent 84 hours at a rate of about 1/2 mb per hour.

"At 1500Z on the 7th Typhoon Marie passed 40 nm north of Palau with peak gusts of 75 kt and a minimum sea level pressure of 993 mb recorded at Koror. While no deaths or injuries were reported, damage of more than $4 million was incurred on the Palau Islands. Crop destruction was extensive as was damage to buildings and public utilities. As a result, Palau was declared a major disaster area.

"By 0000Z on the 8th a weakness in the subtropical ridge appeared near the eastern coast of the Philippines. In response, Marie turned northward and recurved. During the typhoon's westernmost position at 2100Z on the 10th, the system reached its maximum intensity of 115 kt. The lowest sea level pressure was 929 mb recorded by aircraft at 2031Z on the 10th. Typhoon Marie maintained 115 kt winds for 24 hours as its northeast movement increased to 11 kt. By 1800Z on the 11th Marie began to weaken while accelerating on a northeast track, closely following the 700 mb flow. Two days later the final warning was issued as Marie became extratropical."

Koror Observations

Peak wind and direction	78 kt 250 deg at 071352Z
Lowest pressure recorded	987.5 mb
Total rainfall amount	18.54 in

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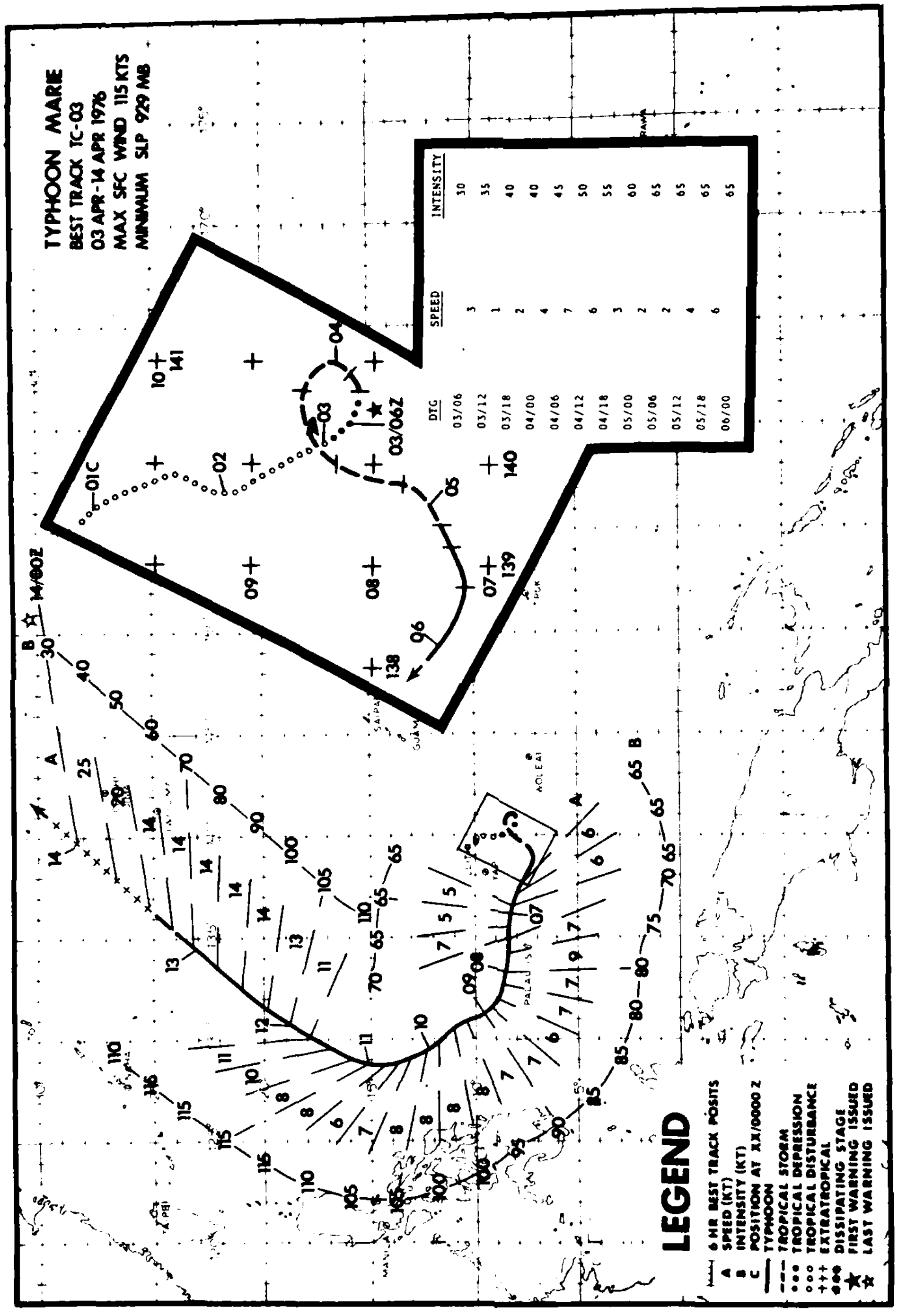

Figure XIII-16. Best track of Typhoon Marie 3-14 April 1976.
(From JTWC Guam Annual Typhoon Report, 1976.)

4. PREPARATION FOR HEAVY WEATHER

4.1 TROPICAL CYCLONE WARNINGS

Even with sophisticated modern techniques for locating tropical cyclones and for monitoring their progress, such as aircraft reconnaissance, satellite observations and radar, the present state of meteorological knowledge does not permit perfect predictions of storm movements. Many variables exist which can alter the path of a typhoon; hence, every typhoon or potential typhoon should be treated with the utmost respect.

There are no specific instructions to U.S. Navy ships for setting local weather readiness conditions while operating near Palau. However, Annex H to CINCPACREP GUAM/TTP1/COMNAVMARIANAS/COMNAVBASE GUAM JOINT PLAN 101, Heavy Weather Doctrine, is applicable in concept. Advice and specific action found therein should be followed when possible.

4.2 EVASION RATIONALE

The most important aspect of any decision concerning heavy weather is an early appraisal of the threat posed by an individual tropical cyclone. Historically, the vast majority of tropical cyclones have approached Palau from the east, and since they are invariably in the developing stages, their intensity and wind distribution as well as movement are difficult to forecast. This makes long range evasion planning very difficult, but some rough guidelines are presented here in conjunction with Figure XIII-17 (following page).

I. An existing tropical cyclone moves into area C, or significant development takes place in area C, with forecast movement towards Palau:
   a) Review material condition of ship. A sortie may be desirable 2-4 days hence.
   b) Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

II. A tropical cyclone moves into area B, or significant development takes place in area B, with forecast movement towards Palau:
   a) Operational plans should be made in the event that a sortie is required.
   b) Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

III. A tropical cyclone enters area A moving towards Palau:
   a) Execute sortie

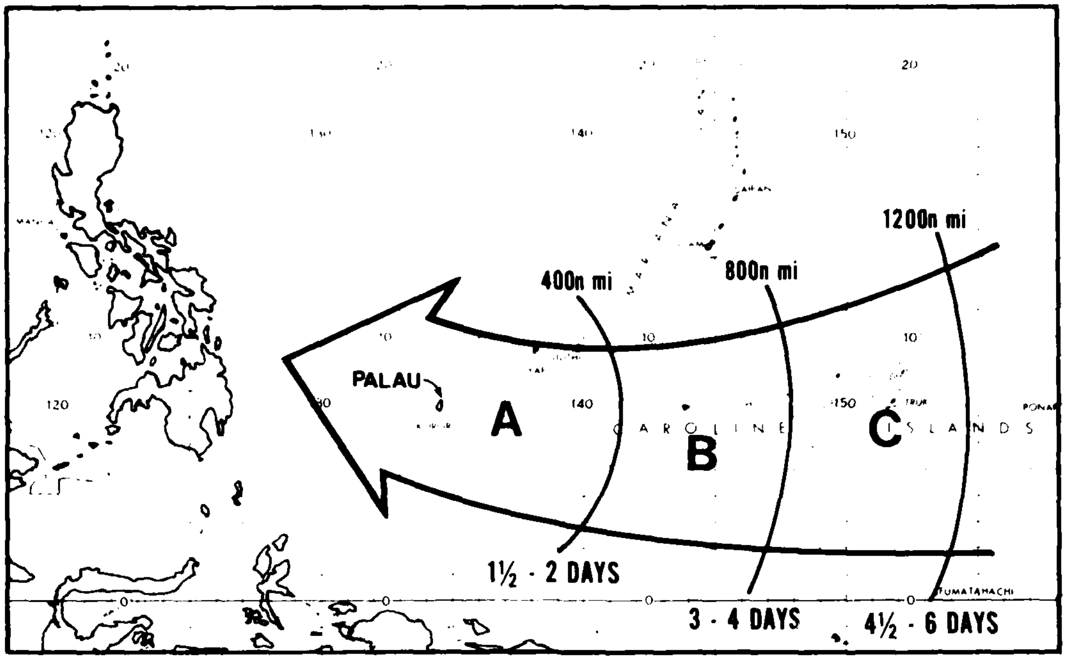

Figure XIII-17. Tropical cyclone threat axis for Palau. Distances and approach times are measured from Koror based on an 8-12 kt speed of movement.

4.3 REMAINING IN PORT

Remaining in port when the means to evade a storm is available is a decision contrary to most of the traditional rules of seamanship. However, if the decision to remain in port is made, every available fact concerning the impending storm and the port in which the vessel lies should be considered. In the case of Palau, the following points should be noted:

(1) Very few alongside berths are available, since the total usable wharf length is only 910 ft.

(2) Anchoring in Malakal Harbor should be completed before the onset of 20 kt winds since maneuvering could become hazardous due to the proximity of several sunken, and in some cases unmarked, reefs. There is very little protection from the wind, especially wind from the west or southeast. The preferred anchorage (half mile southeast of pier) provides some protection against winds from the northwest through east.

(3) Anchoring in Komebail Lagoon provides less of a maneuvering problem, but its large size means that it is exposed to the wind in all directions, especially the west. Similarly, the large fetch to the west would allow sea heights up to 7 ft to develop.

(4) If anchoring is contemplated, it is suggested that Komebail Lagoon would be preferable for typhoons forecast to pass to the south and Malakal Harbor for typhoons forecast to pass to the north.

(5) Once the decision to remain in port has been made, any later reversal in plans could become extremely dangerous. The only exit for ships of over 5000 tons is Toagel Mlungui, a passage 12 n mi in length. Even for small ships, Malakal passage is extremely narrow and would be difficult to navigate with an imminent typhoon.

(6) The holding action of the coral and sand bottom of both Malakal Harbor and Komebail Lagoon is considered good.

4.4 EVASION AT SEA

Evasion at sea is the recommended course of action for any seaworthy vessel when a tropical cyclone threatens. When evasion is contemplated, the importance of correctly assessing the threat posed by the storm and acting quickly so as to retain flexibility cannot be overemphasized. Obviously, the Commanding Officer, with his experience and knowledge of his unit, will always make the final evasion decision. One of the more successful evasion tactics involves running downwind and downsea relative to the typhoon in order to reach a latitude south of the storm and to be in the navigable semicircle. The success of this method depends on almost continuous reconnaissance/satellite coverage and a relatively slow movement and gradual expansion of the initially small area affected by severe winds which is characteristic of typhoons in these latitudes.

For a ship in or near Palau, evasion to the southwest is a particularly sound tactic due to the close proximity to the equator. Typhoons rarely pass much to the south of Palau and have not passed Palau south of 5°N since 1946.

The following evasion techniques are suggested for the more common threat (any tropical cyclone expected to have a CPA within 180 n mi) situations:

1. Tropical cyclone approaching from the east or southeast and forecast to pass north of Palau -- evasion should be southwest. The unit is already in the safe or navigable semicircle with a following wind and sea, and will remain there.

2. Tropical cyclone forming within 180 n mi to the west or northwest -- remain in port or evade to the southeast after exiting via Malakal Pass or Toagel Mlungui as appropriate. No strong winds have occurred since 1947 with the threat approaching from the west.

3. Tropical cyclone approaching from the east or southeast and forecast to pass south of Palau -- evasion should be to the southwest. This decision should be made as early as possible to avoid meeting the storm.

Crossing ahead of an approaching typhoon, as recommended in the latter case above, is not without hazard, and must be accomplished well ahead of the typhoon. If, in attempting this track crossing, the ship is caught in the wave and swell pattern ahead of the storm, the speed of advance may be reduced to the point that the ship will be unable to maneuver clear of the storm (see Section I-5).

It is very possible, especially in this area of the Pacific and at any time of year, for rapid storm development to occur. This should be kept in mind as evasion plans are formulated and executed. In all cases, careful monitoring of the storm should be conducted to permit the utilization of the proper evasion technique in the event of a sudden change of storm track.

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SAIPAN-TINIAN

SECTION XIV - CONTENTS

XIV SAIPAN - TINIAN

1. GENERAL

Figure 1 of the Introduction to this Handbook shows the western North Pacific area with Tinian located approximately 100 n mi north-northeast of Guam and Saipan a further 10 n mi north-northeast of Tinian. The islands are part of the Mariana Chain which stretches north to south close to the 145°E meridian.

SUMMARY

The conclusion reached by this study is that Saipan Harbor, Bahia Laulau and Tinian Harbor should not be considered as typhoon havens. The key factors in reaching this conclusion were:

1. Sea state in Saipan Harbor and Bahia Laulau can exceed 20 ft during typhoon conditions.

2. There is a threat from other vessels adrift within the confined harbors of Saipan and Tinian.

3. Saipan Harbor lacks sheltered berths and is susceptible to large storm surge.

4. The topography surrounding all three harbors is relatively low and does not provide significant shelter from typhoon force winds.

5. Typhoon Olive, which passed 5 n mi to the west of Saipan Harbor in 1963, produced sustained winds of 110 kt and a storm surge of 15-20 ft. All three ships seeking shelter in the harbor were destroyed.

6. There are no ship repair facilities on Saipan or Tinian; the nearest is on Guam.

It is the recommendation of this study that all capable U.S. Navy ships take action to evade at sea when typhoon conditions threaten. Any small unit (LST and below) not capable of evading at sea should seek shelter in Tinian Harbor which, of the three harbors evaluated, would provide the best shelter in most situations.

Note: This typhoon haven evaluation was prepared by LT CDR Geoffrey A. Stevenson, RN, Royal Navy Exchange Officer at NAVENVPREDRSCHFAC.

1.1 SAIPAN

Figure XIV-1 is a topographical map of Saipan. The island of Saipan is approximately 13 n mi in length and has an average width of about 3 n mi, making it the second largest of the Mariana Islands. The island has a rugged structure. A ridge extends from the northern tip of the island southwestwards and attains a greatest height of 1555 ft (474 m) at Ogso Tagpochau (Mount Tagpochau), an extinct conical volcano located near the middle of the island. The east side of the ridge is steep and the west side slopes gradually to flat, cultivated land which extends to the coast. The south part of the island is a low, flat plateau. The whole eastern shore of the island is formed by rugged, rocky cliffs.

The northeast and southeast shores of the island are, for the most part, steep-to and clear of off-lying dangers. The west and northwest shores are fronted by barrier reefs, within which are shallow lagoons.

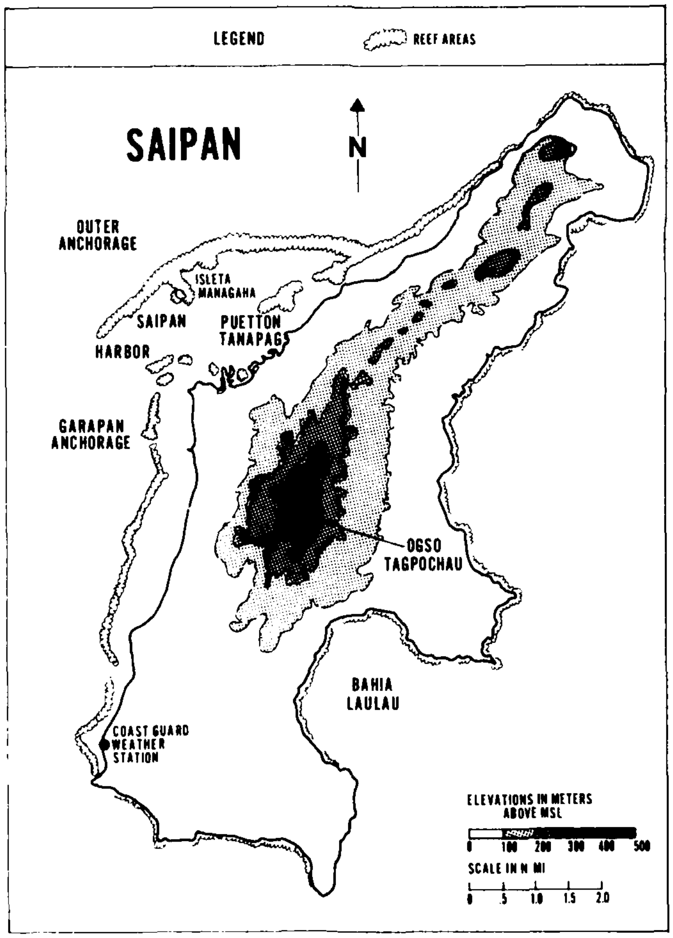

Figure XIV-1. Topographical map of Saipan Island.

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1.2 TINIAN

Figure XIV-2 is a topographical map of Tinian. Tinian Island is approximately 10 n mi from north to south and about 5 n mi wide at its widest point. In comparison with Saipan, Tinian is relatively low and flat. Lasso Hill, which rises to a height of 564 feet (172 m) is the summit of the northern part of the island. An extensive ridge, which rises to a height of 584 ft (178 m), is located at the southeast extremity of the island.

The only reef area is on the southwest coast of the island, fronting the town of Tinian, where the harbor has been constructed.

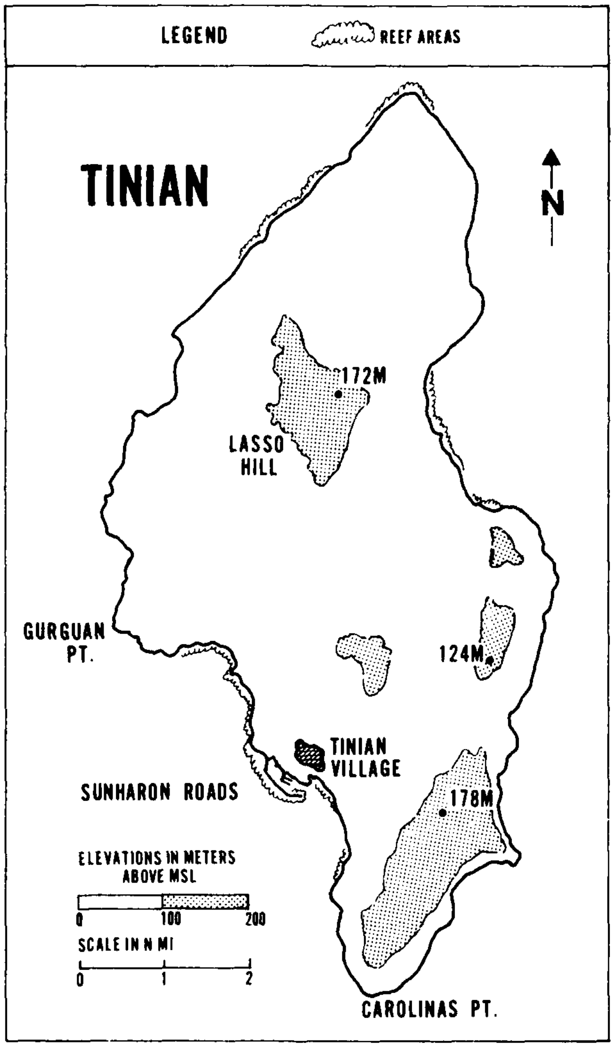

Figure XIV-2. Topographical map of Tinian Island.

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2. HARBORS AND ANCHORAGES

2.1 SAIPAN HARBOR

Saipan Harbor includes Garapan Anchorage, the outer anchorage, and Puetton Tanapag as indicated in Figure XIV-1. Puetton Tanapag (Tanapag Harbor) is also referred to as the inner harbor. Figure XIV-3 is a larger scale version of Puetton Tanapag showing it to be sheltered by a barrier reef to the north.

Most of the outer anchorage has been swept to 52 ft (15.9 m), with some shallower areas swept to lesser depths. The lagoon formed by the barrier reef is mostly shallow except for the harbor basin. The entrance channel to Puetton Tanapag lies due west of the harbor basin. As of 1979 the channel had been dredged to a depth of 29 ft (9 m) and a width of 350 ft; it was proposed to be dredged to a least depth of 30 ft (9.1 m) and a width of 540 ft, as indicated in Figure XIV-3, in the near future.

The usable portion of Puetton Tanapag, the harbor basin, is aproximately 1 n mi from east to west and 1/2 n mi from north to south. This leaves little room for maneuvering if conditions become rough.

The commercial port lies on the southeast shore of the harbor at pier C; the other piers were rendered unusable by a typhoon in 1968. The front of the pier, which faces north, has a length of 530 ft and a minimum depth of only 23 ft (7 m). The south side of the pier is the most sheltered but is only 200 ft in length and only 20 ft (6 m) deep. The wharf on the east side of the pier is used by small local boats. U.S. Navy ships (normally LSTs) occupy wharves 2 and 3 on the front of the pier.

There are several anchorages within the harbor basin; the recommended maximum draft for anchoring is 26 ft (8 m). The holding ground consisting of coral and sand is considered good. The two buoys which exist are not intended for use in typhoon conditions.

2.2 BAHIA LAULAU

Bahia Laulau, also called Magicienne Bay, lies on the southeast coast of Saipan Island, as indicated in Figure XIV-1. The bay is used solely as an anchorage, there being no berthing facilities whatsoever. The bay is entirely open to the southeast and thus is exposed to the prevailing winds and swells. The bay, however, does offer protection from northerly and westerly winds. Much of the shoreline is fringed by reef and fronted for a short distance by shoals. The 10-fathom line lies generally less than 400 yards off shore and outside this the bottom drops away steeply. Large vessels can anchor in convenient depths off the village of Laulau at the northern side of the bay.

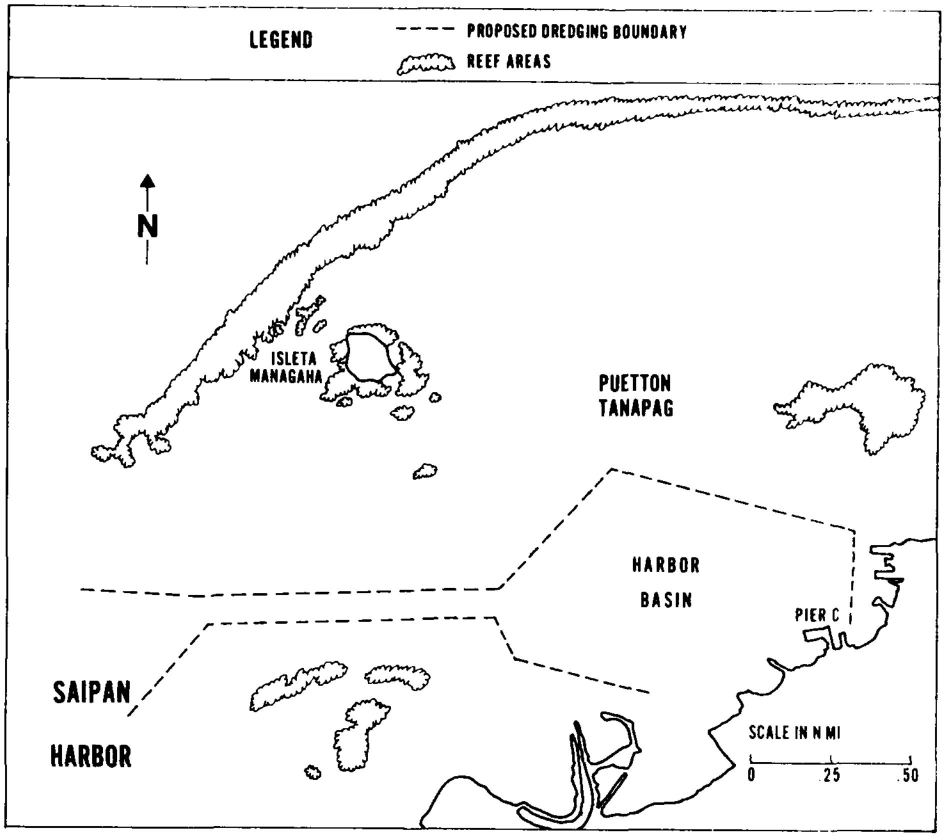

Figure XIV-3. Puetton Tanapag, the inner part of Saipan Harbor, showing proposed dredging boundary.

2.3 TINIAN HARBOR

Tinian Harbor or Sunharon Roads (Figure XIV-4) includes both the inner harbor near the town of Tinian, and the large swept area lying up to 1 1/2 n mi off shore between Garguan Point and Carolinas Point (see Figure XIV-2). This area has been swept to various depths between 15 and 55 ft (4.6-17 m), the lesser depths being nearer the shore. Many anchorages are available in this outer area.

The inner harbor is entered via a channel which has a navigable width of 500 ft and although it is claimed that the channel has been dredged to 30 ft (9 m), the Port Director reports a minimum depth of 25 ft (7.6 m) for the channel and quays.

At Tinian the main quay has recently been repaired. The usable length is 2200 ft with depths varying between 25 and 29 ft (7.6-8.8 m). There are two piers, pier 1 and pier 2 lying to the southwest of the main quay. Each has a usable length of 500 ft at both sides and a depth of 25 ft (7.6 m). Two shorter quays between the main quay and pier 1 and between piers 1 and 2 have 225 ft of berthage space each and a depth of 25 ft (7.6 m), bringing the total berthing space to 4650 ft. There are also some short quays in a shallow lagoon at the northwest end of the inner harbor, but these are used by local craft. United States Navy ships normally occupy the new part of the main quay. There is also an area available for anchorage within the inner harbor, but it is very small with a diameter of only 1000 ft. The bottom here consists of coral and sand providing reasonable holding.

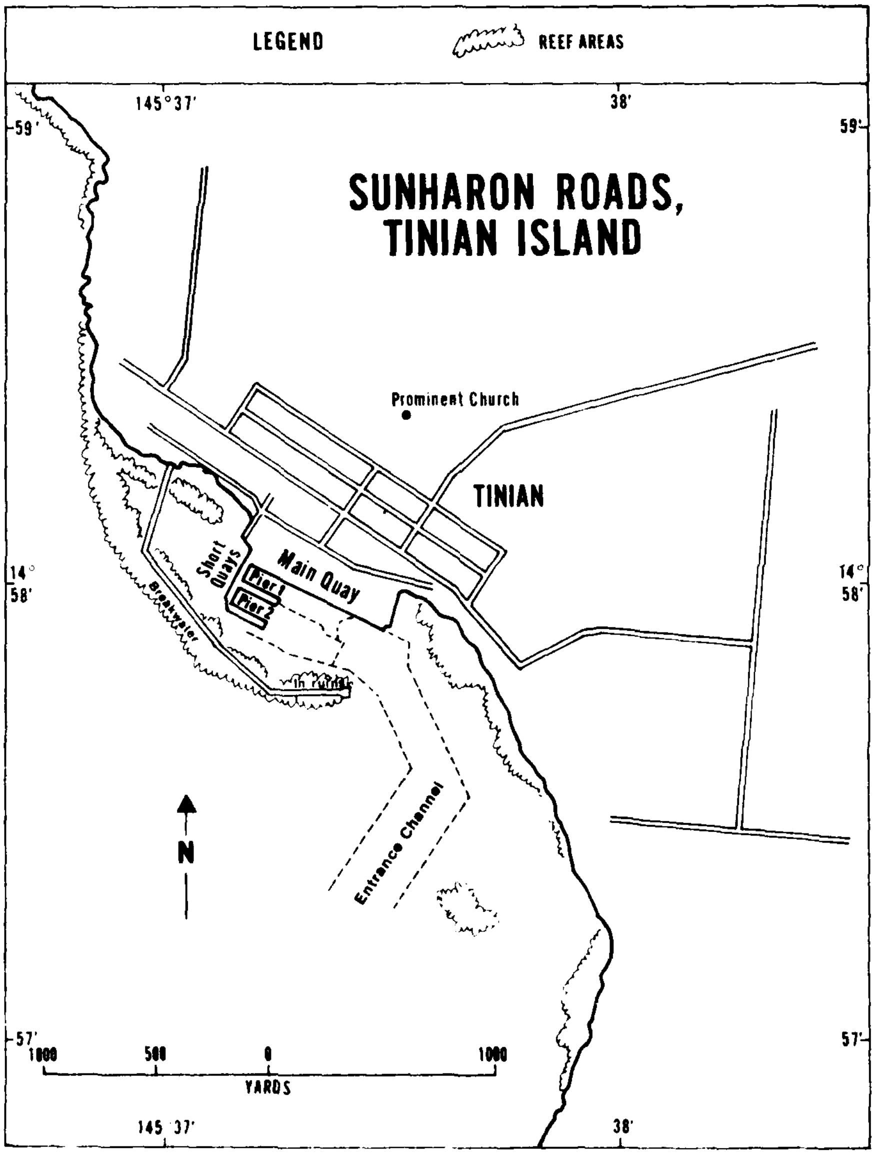

Figure XIV-4. Sunharan Roads (Tinian Harbor).

The outer anchorage provides no shelter from westerly winds and there is very little protection from easterly winds except close to the shore. The inner harbor, however, provides some protection from all winds, especially those between north and southeast. For winds between south and west, protection is provided by a breakwater built on the barrier reef that fronts the town, and is therefore minimal. For best protection from all winds, a berth at the northwestern end of the main quay is recommended. Although the breakwater has sustained some damage, it still provides an effective barrier against wave and swell action. It is therefore considered that the inner harbor at Tinian would provide protection against both wind and wave action in all conditions except the close passage of a typhoon.

2.4 HARBOR FACILITIES

Harbor facilities are, to say the least, sparse. Saipan offers the most facilities. Tinian offers very few, and none are available at Bahia Laulau. Details can be found in Defense Mapping Agency Hydrographic Center Publication No. 82, "Sailing Directions for the Pacific Islands," Vol. 1, Section 6D. The nearest ship repair facilities are at Guam.

3. TROPICAL CYCLONES AFFECTING SAIPAN AND TINIAN

3.1 CLIMATOLOGY

For the purposes of this study, any tropical cyclone approaching within 180 n mi of the south end of Saipan Island is considered a threat to Saipan and Tinian. It is recognized that a few tropical cyclones that did not approach within 180 n mi may have affected Saipan or Tinian. However, cyclones in this region tend to be in the developing stage and to have a small diameter, thus 180 n mi is chosen in order to limit the size of the data sample.

Although tropical cyclones occur throughout the year, the majority of those which threaten Saipan and Tinian occur from July to November and the minimum number occurs in March. Figure XIV-5 depicts the monthly summary of tropical cyclone occurrences based on data for the 31 years 1947-1977. Of the 126 tropical cyclones that threatened Saipan/Tinian in this 31-year period (more than four threats per year), 105 occurred in the period July to November with the peak threat in September. The July-November period is considered the normal typhoon season for the western North Pacific Ocean.

Figure XIV-6 depicts the above storms as a function of the compass octant from which they approached Saipan/Tinian. The open numbers indicate the number of storms which approached from that octant or which were first detected in that octant. The numbers in parentheses represent the same information but as percentages. It is evident from this figure that the majority of storms approach Saipan/Tinian from directions between east and south.

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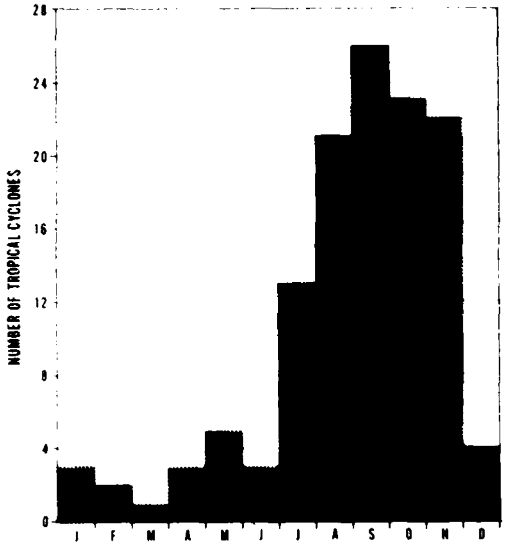

Figure XIV-5. Frequency distribution by month of the number of tropical cyclones that passed within 180 n mi of Saipan/Tinian (1947/1977).

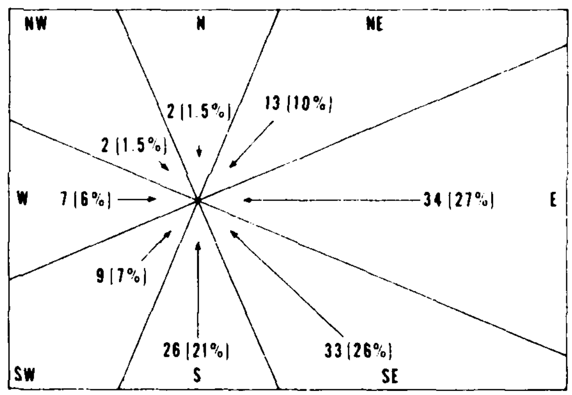

Figure XIV-6. Direction of approach to Saipan/Tinian of the tropical cyclones (1947-1977) which passed within 180 n mi have been included in the direction in which they were first detected. Open numbers indicate the number that approached from each octant. The numbers in parentheses are the percentage of the total sample (126) which approached from that octant. Arrow length is proportional to frequency.

Approximately four tropical cyclones each year pose a threat to Saipan/Tinian. Since Saipan and Tinian are in the development area for WESTPAC tropical cyclones, many of these storms are in the development stages of their life cycle and have not, as yet, achieved typhoon intensity. Of the 126 tropical cyclones that approached or developed within 180 n mi of Saipan/Tinian in the period 1947-1977, 115 reached tropical storm intensity ($\geq$34 kt). The point where tropical storm intensity is first attained is generally in the vicinity of Saipan/Tinian and in many cases is to the west (see Figure XIV-7). In fact, approximately 33% of the threat tropical cyclones which reached tropical storm intensity did so after their closest point of approach (CPA) to Saipan/Tinian (given that most were heading on a generally west-northwesterly track).

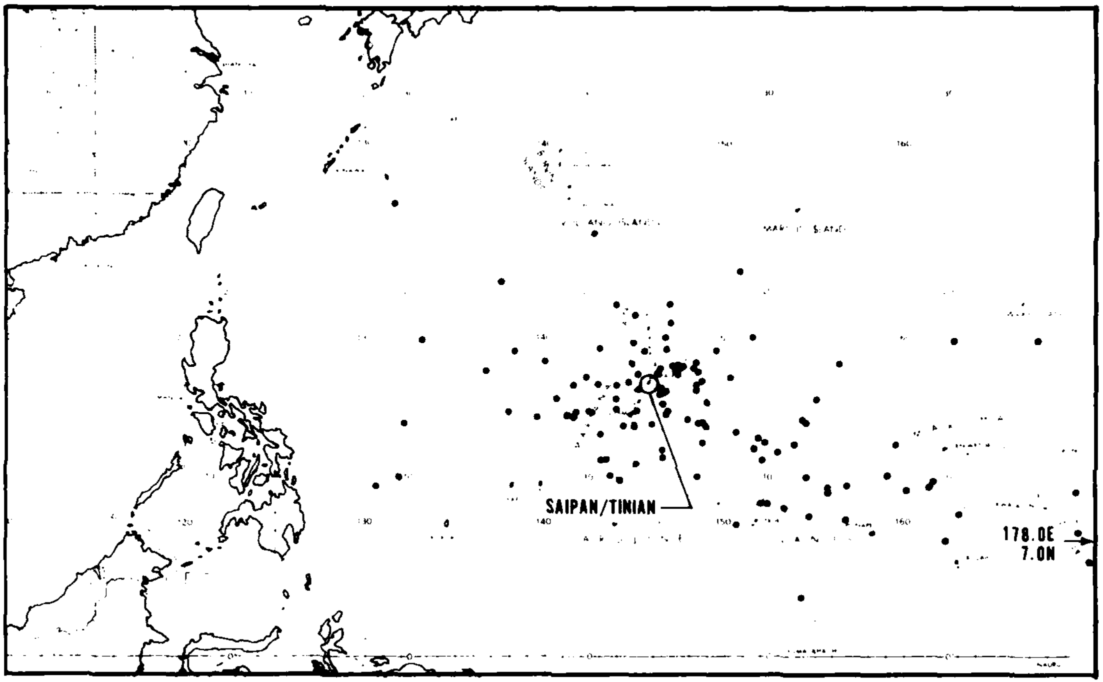

Figure XIV-7. Initial point of attainment of tropical storm intensity (≥34 kt) for 126 tropical cyclones passing within 180 n mi of Saipan/Tinian (1947-1977). Since 11 tropical depressions did not achieve the above criteria, only 115 positions are plotted.

Similarly, Figure XIV-8 shows the points at which threat tropical cyclones reached typhoon intensity (≥64 kt). Notice that about 66% of threat cyclones which attained typhoon intensity (101 in all) did so after passing Saipan/Tinian (again assuming a generally west-northwesterly track). Of all the threat tropical cyclones, 28% attained typhoon intensity and 33% attained storm intensity before the closest point of approach to Saipan/Tinian, a fact that must not allow the reader to develop a false sense of security. Not only does a tropical storm have significant potential for damage, but the possibility also exists that a tropical cyclone close by can intensify rapidly.

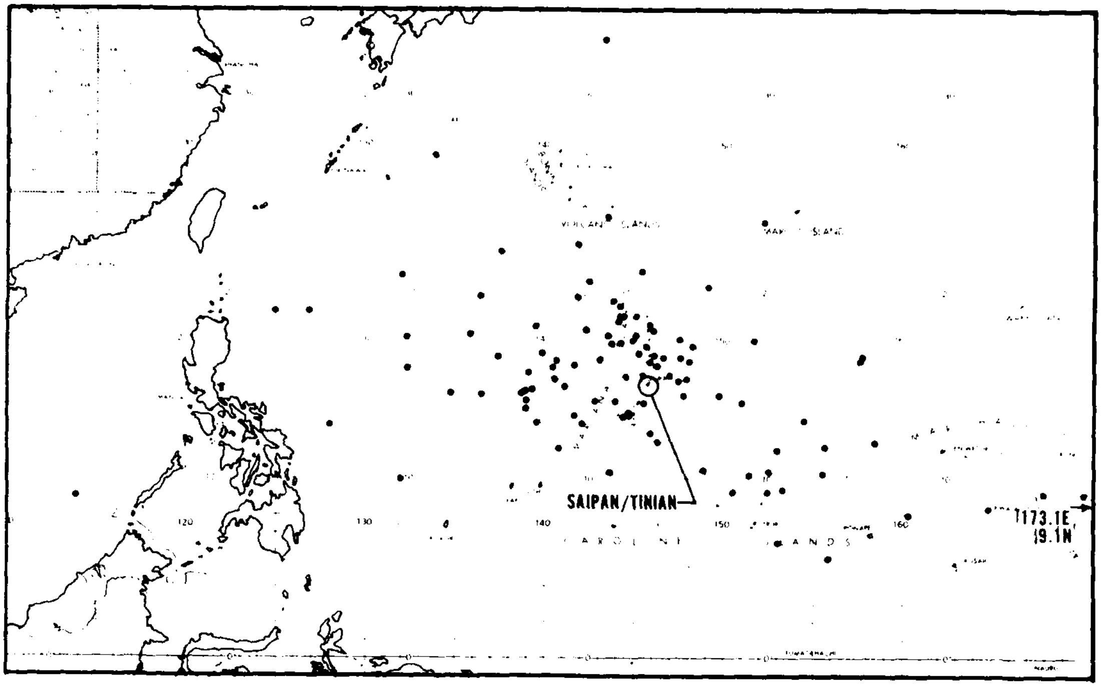

Figure XIV-8. Initial point of attainment of typhoon intensity ($\geq$64 kt) for 126 tropical cyclones passing within 180 n mi of Saipan/Tinian (1947-1977) since 25 tropical cyclones did not achieve the above criteria, only 101 positions are plotted.

Figures XIV-9 through XIV-14 constitute a statistical summary of threat probability based on tropical cyclone tracks for the years 1947-1977. (From Chin (1972) for years 1947-70; and from U.S. FWC/JTWC Guam, Annual Typhoon Reports, 1971-77.) The data are presented monthly during the typhoon season, July to November, and the remainder of the year is combined into one figure (Figure XIV-14). The solid lines represent the "percent threat" for any storm location. The dashed lines represent approximate approach times to Saipan/Tinian based on an approach speed of 8-12 kt. For example in Figure XIV-9, a cyclone located at 159°E and 10°N has approximately a 60% probability of passing within 180 n mi of Saipan/Tinian and will reach Saipan/Tinian in 3-4 days if the speed remains between 8 and 12 kt. It will be noted from Figures XIV-9 through XIV-13 that during the typhoon season, the major threat axis is consistently from the east-southeast. During the rest of the year when the statistics are distorted by the smaller number of cyclones, the major threat is still from the east-southeast, but there is a significant threat from other directions, notably the west (see Figure XIV-14). This results from a small number of cyclones which developed well to the south and recurved on an easterly track before threatening Saipan/Tinian.

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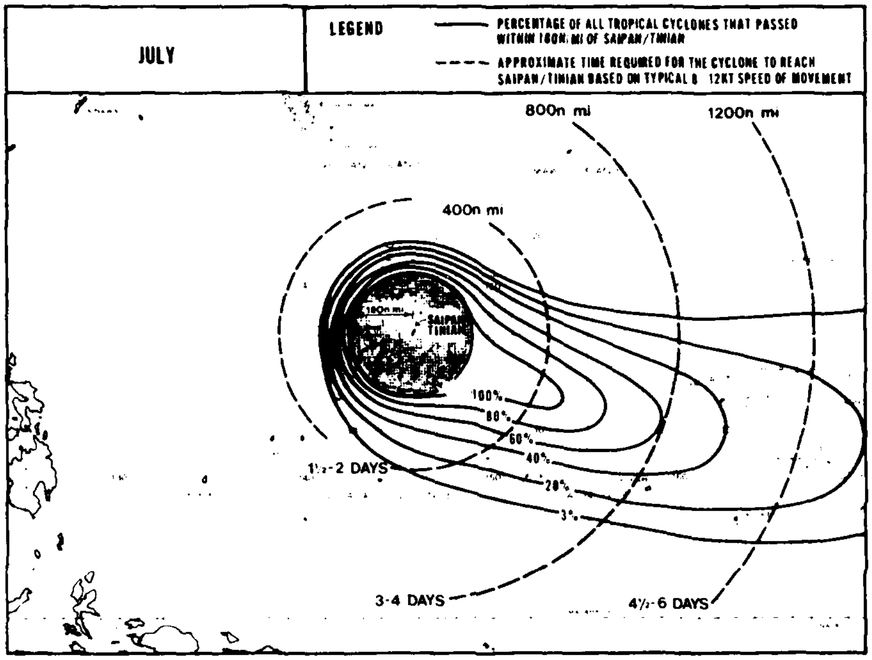

Figure XIV-9. Percentage of tropical cyclones that passed within 180 n mi of Saipan/Tinian for the month of July. (Based on data for 1947-1977.)

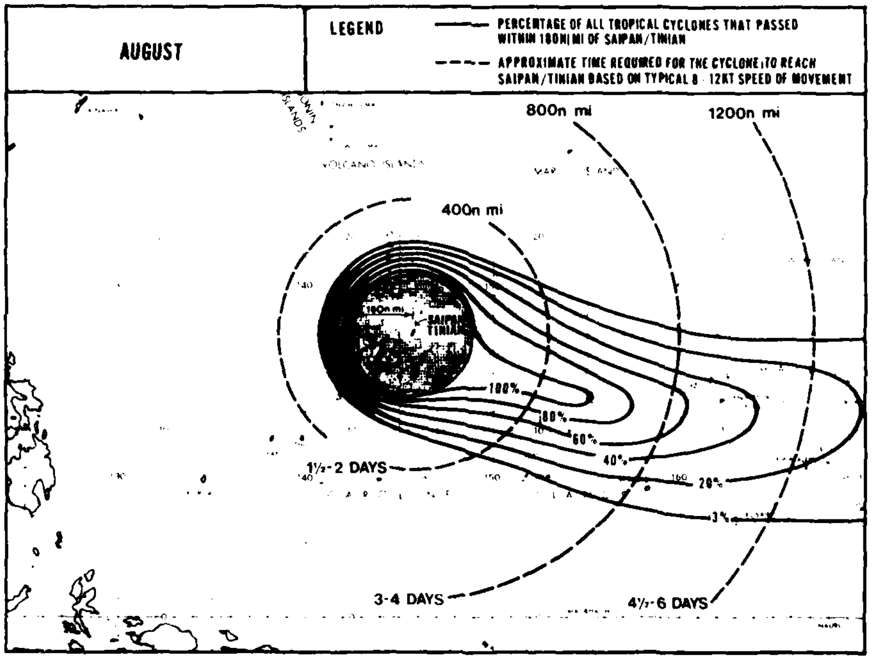

Figure XIV-10. Percentage of tropical cyclones that passed within 180 n mi of Saipan/Tinian for the month of August. (Based on data for 1947-1977.)

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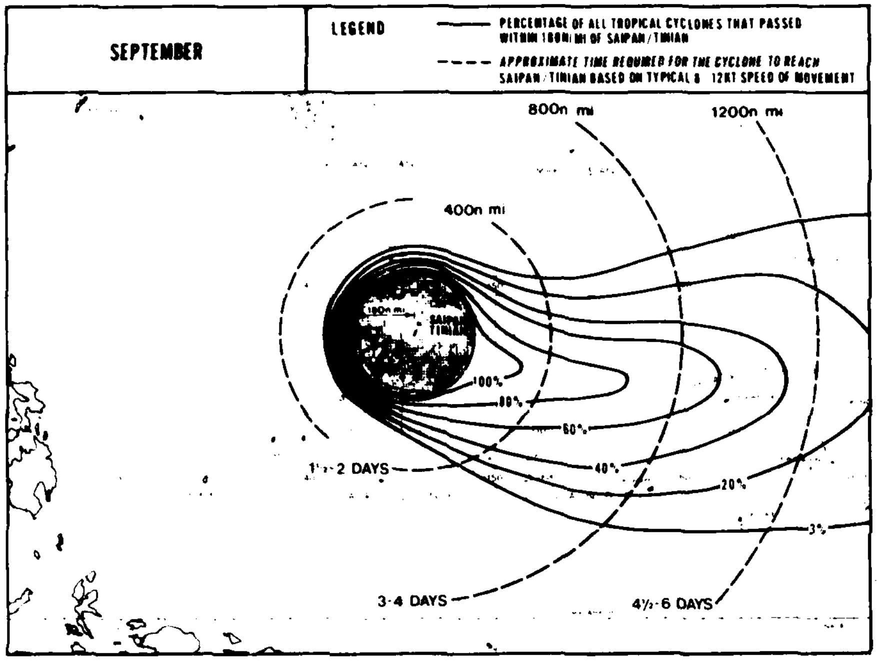

Figure XIV-11. Percentage of tropical cyclones that passed within 180 n mi of Saipan/Tinian for the month of September. (Based on data for 1947-1977.)

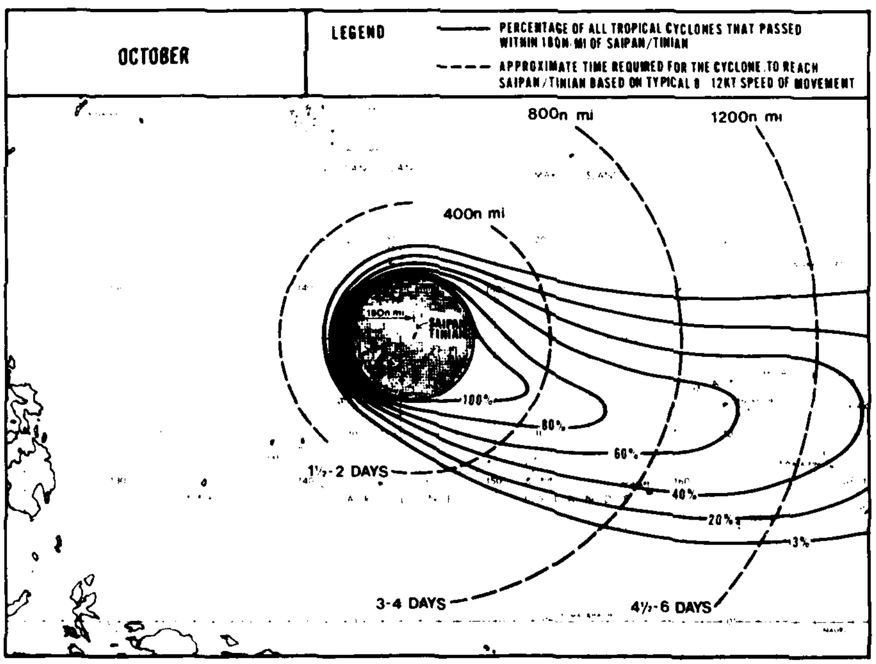

Figure XIV-12. Percentage of tropical cyclones that passed within 180 n mi of Saipan/Tinian for the month of October. (Based on data for 1947-1977.)

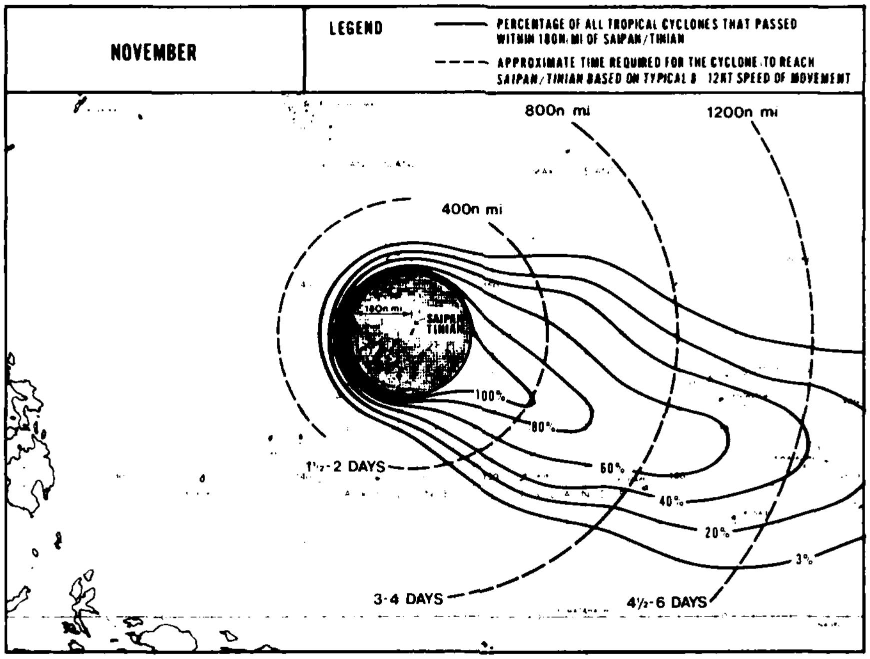

Figure XIV-13. Percentage of tropical cyclones that passed within 180 n mi of Saipan/Tinian for the month of November. (Based on data for 1947-1977.)

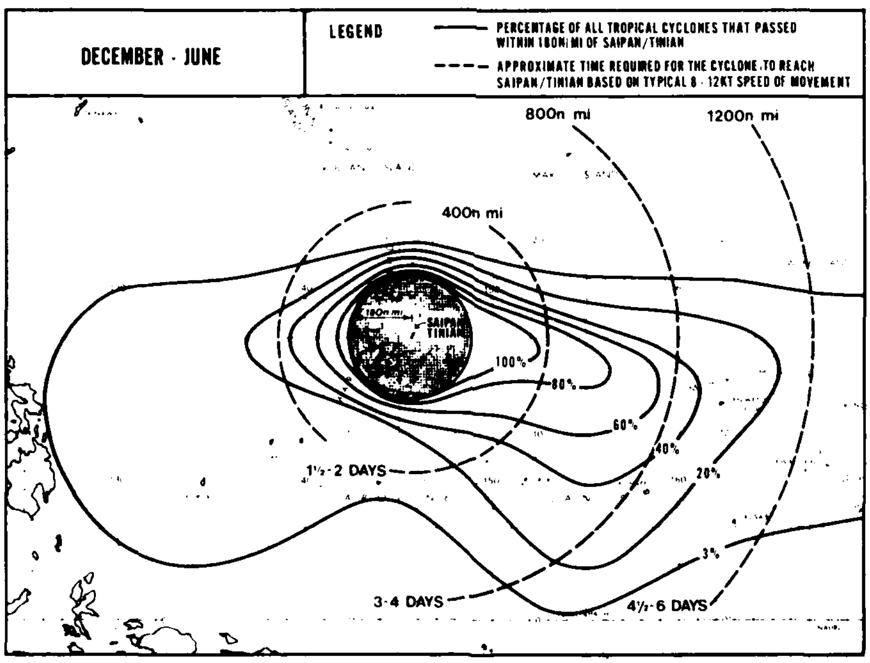

Figure XIV-14. Percentage of tropical cyclones that passed within 180 n mi of Saipan/Tinian for the months of December through June. (Based on data for 1947-1977.)

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3.2 WIND AND TOPOGRAPHICAL EFFECTS

In the 31-year period 1947-1977, a total of 126 tropical cyclones approached within 180 n mi of Saipan/Tinian, an average of four per year. By far the largest number that threatened in any single year was 10 in 1968. Most tropical cyclones approach from directions between east and south, and of these, about half pass with Saipan/Tinian to the right of the storm center, i.e., in the dangerous semicircle.

The wind data available from Saipan is very sparse. In the earlier years of the period, there was a tendency for observations to stop whenever a tropical cyclone approached, and therefore some of the more important observations appear to be missing. The data set since 1972, however, is reasonably complete, and since this data is supplemented with further information in the U.S. FWC/JTWC Annual Typhoon Reports, it is probably more meaningful to confine this analysis to the six years 1972-1977, despite the much smaller sample size.

It appears that out of the 17 threat tropical cyclones, 13 produced winds of 22 kt or stronger (including Typhoon Pamela) and out of these 13, an estimated five produced winds of 34 kt or stronger and one (Theresa, 1976) produced estimated sustained winds of 75-100 kt. (Pamela, 1976, produced gusts of 55 kt despite passing 120 n mi to the west.) This assessment lends weight to the report of the Saipan Port Director who estimated that Saipan experiences an average of two to three strong wind cases ($\geq$22 kt) a year from tropical cyclones, and that typhoon force winds ($\geq$64 kt) affect the island every 7-10 years.

The location of the coast guard station where weather observations are taken is indicated in Figure XIV-1. Although the station elevation is only 12 ft (4 m), the anemometer is well exposed to all southwesterly through northerly winds. However, the station receives some sheltering from other directions, especially the east, even though the southern end of Saipan Island is relatively low and flat.

Figure XIV-15 depicts the tracks of tropical cyclones that occurred between 1972 and 1977, and which resulted in strong winds ($\geq$22 kt) at Saipan. It is apparent from this figure that the majority of tropical cyclones that caused strong winds approached from directions generally between east and south. This major threat direction is also represented by the "percent threat" lines of Figures XIV-9 through XIV-14 and in Figure XIV-6 by the octant approach arrows.

It is also apparent from Figure XIV-15 that the threat of strong winds is spread throughout the year, but that the highest frequency occurs, as expected, during the main typhoon season, July to November.

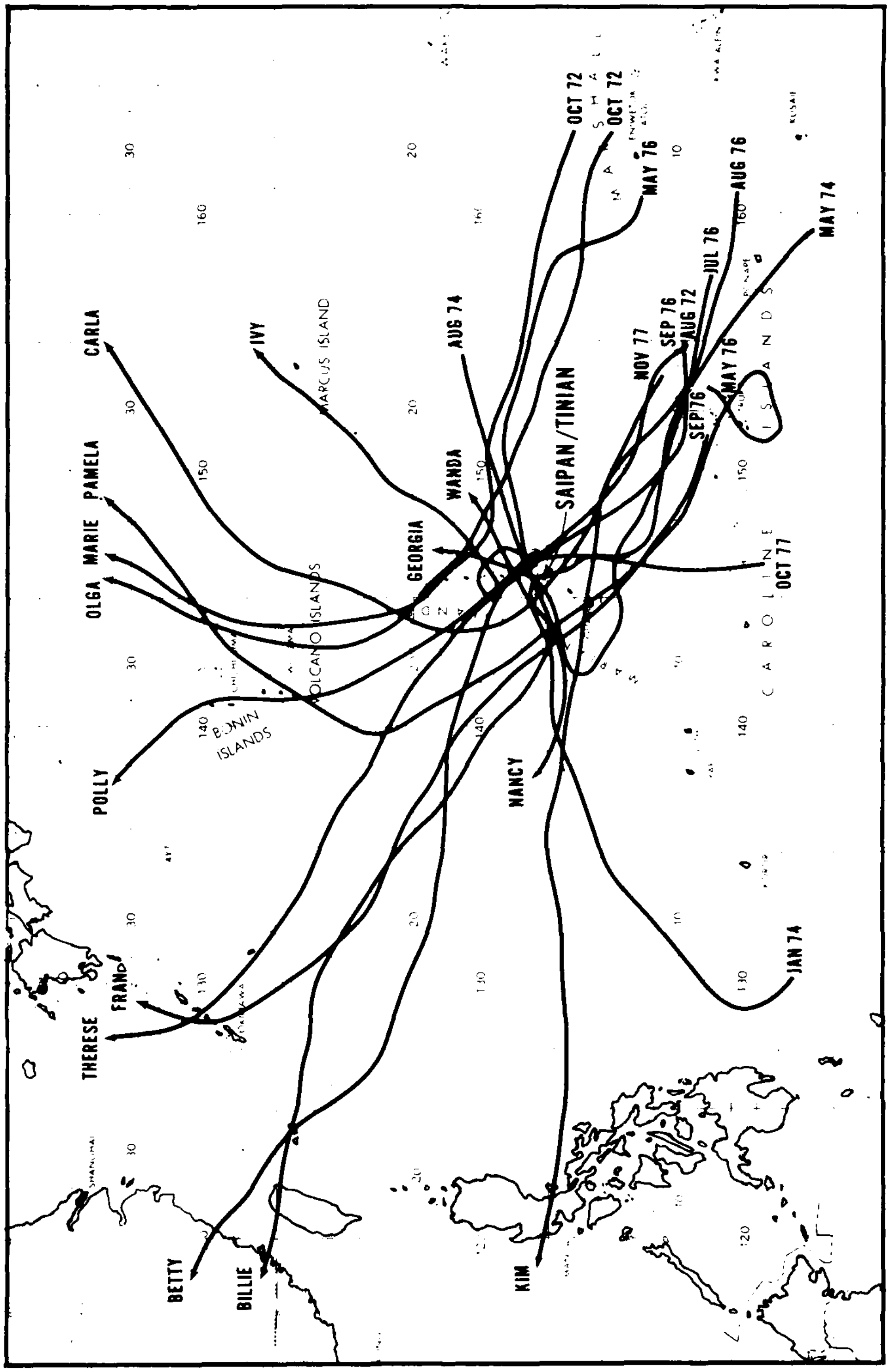

Figure XIV-15. Tracks of the tropical cyclones that resulted in strong winds ($\geq$22 kt) on Saipan from 1972-1977.

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Figure XIV-16 gives the positions of tropical cyclone centers when strong winds (≥22 kt) and gale force winds (≥34 kt) were recorded at Saipan Coast Guard Weather Station for the years 1972-1977. It is apparent from this diagram that strong winds have occurred with the cyclone center up to 330 n mi away, and gale force winds have occurred with the center up to 230 n mi away. It is also noteworthy that the majority of strong wind cases have occurred (during 1972-77) with the tropical cyclone center to the northeast, i.e., with Saipan/Tinian in the less dangerous semicircle.

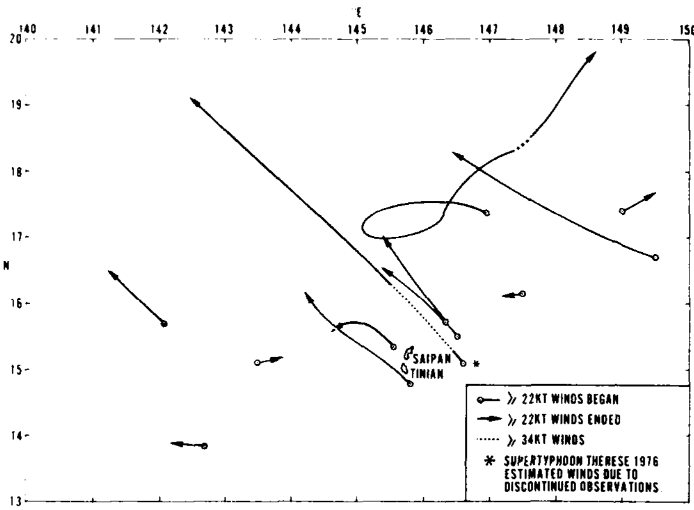

Figure XIV-16. Positions of tropical cyclone centers when ≥22 kt winds and >34 kt winds were occurring on Saipan. (Based on available wind data for Saipan Coast Guard Station from 1972-1977.)

Since Saipan Harbor lies on the northwest coast of the island, it is more susceptible to wind from typhoons which pass to the northeast. The topography of the island provides some shelter from easterly, southeasterly and southerly winds. However, typhoons which pass to the west can still produce devastating winds. For example, Typhoon Pamela (1976) produced 55 kt gusts even though it passed 120 n mi to the west, and Typhoon Olive (1963) whose center passed only 5 n mi west of Saipan Harbor, produced estimated peak gusts of 180 kt and destroyed 95% of the crops and buildings on the island.

Tinian Harbor on the southwest coast of the island is most susceptible to typhoons which pass to the northwest and produce southwesterly winds. There is some protection provided by the topography for winds between north through east to south. For winds between south and northwest, there is only the minimal protection of the harbor wall built on the coral reef. The best protection is provided in a position at the northwest end of the main quay. In the past, most damage has been caused by typhoons passing up the west coast and giving southwesterly winds.

Bahia Laulau, being on the southeast coast of Saipan Island, provides best protection from north to northwesterly winds which are considerably reduced by the elevation of the extinct volcano Ogso Tagpochau. Winds between south and northwest and between north and east are moderated to some extent by the topography, but southeasterly winds affect the bay with their full force.

3.3 WAVE ACTION

Maximum wave action is normally found in the right semicircle of a typhoon, which in the case of Saipan and Tinian means a passage to the south or west since the majority of tropical cyclones approach from directions between east and south.

3.3.1 Saipan Harbor

Saipan Harbor, being small and shallow, is not susceptible to extreme seas being generated within the barrier reef. A rough calculation using forecasting curves from the U.S. Army Coastal Engineering Center Shore Protection Manual (1973) shows that the maximum possible sea heights in the harbor basin would be 3 ft (.9 m) for 45 kt winds and 6 ft (1.8 m) for 90 kt winds. The main problem is with externally-generated seas and swells entering through the harbor entrance, which is almost 1 n mi wide. Since the harbor entrance faces southwest, Saipan is most susceptible to tropical cyclones which pass to the west and especially those on a northward track. Such an event happened with the passage of Typhoon Olive on 30 April 1963.

Typhoon Olive was the worst typhoon to hit Saipan in living memory. It can be seen from the best track shown in Figure XIV-17 that this tropical cyclone developed rapidly from a depression to a typhoon in the area south of Guam. The typhoon then moved northwards on a recurving track and passed 20 n mi to the west of Guam. By the time the typhoon reached Saipan, she was beginning to weaken a little, but was still packing sustained winds of 110 kt. The eye passed directly over Saipan with the center of the eye passing 5 n mi to the west of Saipan Harbor during the afternoon of 30 April. The Port Director estimated that the peak gusts reached 180 kt and the storm surge was between 15 and 20 ft (4.6-6.0 m). Ninety-five percent of the island was destroyed, both crops and buildings.

There were two ships in the harbor with a length of 230 ft and one of 400 ft length. One of the 230-ft vessels was sunk at the wharf; the other was carried away by the surge and westerly winds to end up on a highway 400 yards from the wharf. The 400-ft vessel, which was moored to a buoy, dragged its buoy and ran aground.

It is readily apparent, therefore, that there is no berth or anchorage available in Saipan Harbor that would be safe during the close passage of a typhoon.

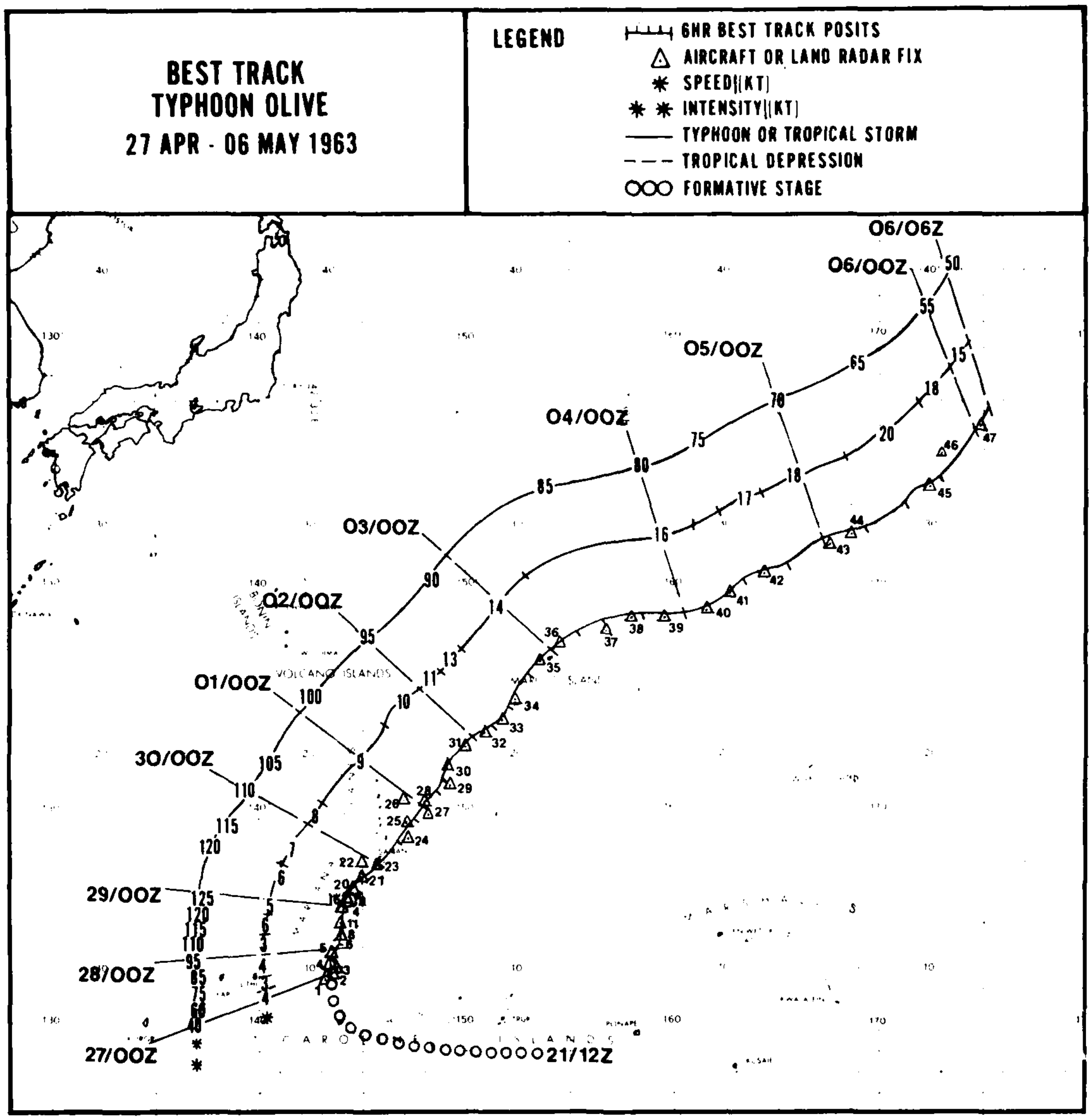

Figure XIV-17. Best track of Typhoon Olive (27 April-6 May 1963).

3.3.2 Bahia Laulau

Bahia Laulau, having no protection to seaward whatsoever and being very deep except close to shore, is susceptible to all southeasterly seas and swells without attenuation. However, protection is afforded for all seas and swells approaching from directions between southwest through northwest to northeast. The best protection is afforded for northwesterly seas and swells. Since most tropical storms approach from directions between south and east, Bahia Laulau is likely to be severely affected in the majority of cases.

3.3.3 Tinian Harbor

Tinian Harbor is well protected from seas and swells approaching from every direction except south through southwest. The harbor wall built on a barrier reef is very close to the wharf area and allows no room for the buildup of seas inside the harbor. The harbor wall and entrance channel have been constructed in such a way as to greatly attenuate even southwesterly seas and swells. However, seas and swells approaching from the south can severely affect the southeastern end of the main quay, although still with considerable attenuation. This situation makes the inner harbor of Tinian the safest of the three harbors in most conditions; the most preferable berth is at the extreme northwest end of the main quay.

In the past, most of the damage at Tinian has been caused by the wind action, but on occasions, swells have built up sufficiently to overtop the breakwater. This was the case in 1976 with Typhoon Pamela, even though she passed 120 n mi to the west.

3.4 STORM SURGE AND TIDES

Storm surge can be defined as the difference in observed water level at a given location during storm and non-storm conditions. Storm surge is a major problem in Saipan Harbor. The Port Director reports storm surges of 15 to 20 ft (4.6-6 m) during the close passage of a severe typhoon to the west.

Although storm surges have not been reported at Tinian, a comparison of its bathymetry with that of Saipan would indicate that storm surge is probable but with less amplitude than that experienced at Saipan. Obviously, these large changes in water level must be taken into account when preparing for heavy weather situations.

Tides in the vicinity of Saipan and Tinian are normally weak. Maximum ranges are of the order of 4 ft (1.2 m) at Tinian and 2 ft (.6 m) at Saipan. Tidal currents also tend to be weak, rarely exceeding 1 kt at Tinian and 2 kt at Saipan. However, during the northeast trades, the flood stream at Saipan sometimes reaches a rate of 4 kt. At Saipan, the tidal stream is reported to increase to 6-7 kt under typhoon conditions, causing additional maneuvering problems within the harbor. At Tinian, no increase of tidal stream is reported, even under typhoon conditions.

4. THE DECISION TO EVADE OR REMAIN IN PORT

There are no specific instructions to U.S. Navy ships for setting local weather readiness conditions while operating near Saipan and Tinian. However, Annex H to CINCPACREPGUAM/TTP1/COMNAVMARIANAS/COMNAVBASE GUAM JOINT PLAN 101, Heavy Weather Doctrine, is applicable in concept. Advice and specific action found therein should be followed when possible.

4.1 EVASION RATIONALE

The most important aspect of any decision concerning heavy weather is an early appraisal of the threat posed by an individual tropical cyclone. Historically, tropical cyclones have approached Saipan/Tinian from all directions and since most are in the developing stages, their movement as well as intensity and wind distribution, are difficult to forecast. This makes long range evasion planning very difficult, but some rough guidelines are presented here in conjunction with Figure XIV-18.

I. An existing tropical cyclone moves into, or significant development takes place in, area C with forecast movement toward Saipan/Tinian.
   a. Review material condition of ship. A sortie may be desirable 2-4 days hence.
   b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

II. Tropical cyclone moves into, or significant development takes place in, area B with forecast movement toward Saipan/Tinian.
   a. Operational plans should be made in case a sortie is required.
   b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

III. A tropical cyclone enters area A moving towards Saipan/Tinian.
   a. Execute sortie.

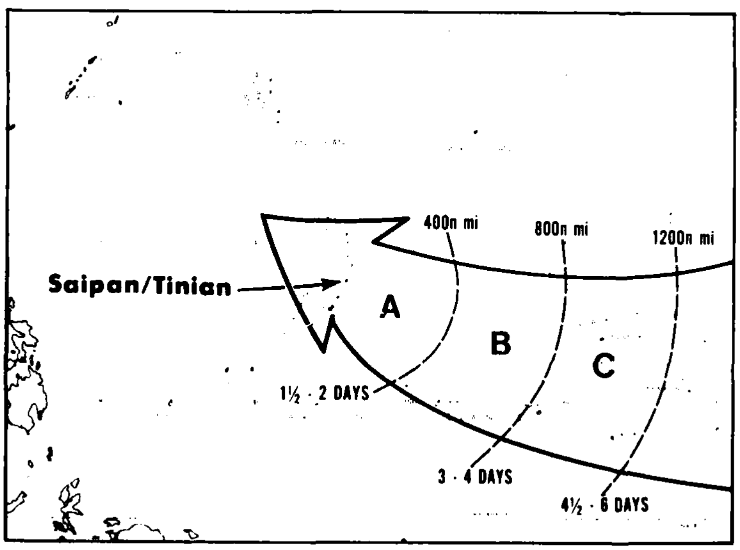

Figure XIV-18. Tropical cyclone threat axis for Saipan/Tinian. Distances and approach times are measured from Saipan/Tinian based on an 8-12 kt speed of movement.

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4.2 REMAINING IN PORT

Remaining in port when the means to evade a storm is available is a decision contrary to most of the traditional rules of seamanship. Because of their lack of natural protection, Saipan Harbor, Bahia Laulau and Tinian Harbor provide few haven qualities. As a result, remaining in harbor is not the recommended course of action when typhoon conditions threaten.

If the decision to remain in port is made, every available fact concerning the impending storm and the port in which the vessel lies should be considered. In the case of Saipan and Tinian, the following points should be noted:

(1) Very few alongside berths will be available in Saipan Harbor, since the total usable wharf length is less than 1000 ft, much of which will be taken up by small boats. In Tinian Harbor, there will be plenty of wharf space available.

(2) Anchoring in Saipan Harbor is hazardous due to the extremely restricted maneuvering room of adequate depth. There will also be a threat of damage from other ships that may become loose. In Saipan Harbor, reasonable protection is only provided for winds and seas between east and south.

(3) Anchoring in the outer anchorage at Saipan or at Sunharan Roads off Tinian provides no shelter from westerly winds and seas, and minimal protection from easterly winds.

(4) The best shelter from most winds and seas is provided by Tinian Harbor. Even this harbor, however, is susceptible to winds and seas from between south and southwest, and to storm surge.

(5) Bahia Laulau will provide good protection only against northwesterly winds and seas.

(6) The holding action of the bottom -- which is sand and coral at Tinian; coral, sand and mud at Saipan; and fine sand in Bahia Laulau -- is considered good.

4.3 EVASION AT SEA

Evasion at sea is the recommended course of action for any seaworthy vessel when a tropical cyclone threatens. When evasion is contemplated, the importance of correctly assessing the threat posed by the storm and acting quickly so as to retain flexibility cannot be overemphasized. Obviously, the commanding officer, with his experience and knowledge of his unit, will always make the final evasion decision.

The following evasion techniques are suggested for the more common threat (any tropical cyclone expected to have a CPA within 180 n mi of Saipan/Tinian) situations.

I. Tropical cyclone approaching from the east or southeast and forecast to pass north of Saipan or within 60 n mi south of Tinian -- evasion should be southwest. The unit will be in the "safe" or "navigable" semicircle with following wind or sea.

II. Tropical cyclone approaching from the east or southeast and forecast to pass more than 60 n mi south of Tinian -- evasion should be northeast.

III. Tropical cyclone approaching from the south and forecast to pass east of Saipan and Tinian -- evasion should be west-southwest.

IV. Tropical cyclone approaching from the south and forecast to pass west of Saipan and Tinian -- evasion should be east-southeast.

Whichever of the above cases presents itself, the following general comments should be noted:

(1) Crossing ahead of an approaching typhoon, as recommended in I above, is not without hazard, and must be accomplished well ahead of the typhoon. If, in attempting this track crossing, the ship is caught in the sea and swell pattern ahead of the storm, the speed of advance may be reduced to the point that the ship will be unable to maneuver clear of the storm (see page I-5).

(2) It is very possible, especially during the peak typhoon season, for rapid storm development to occur, resulting in multiple tropical cyclones coexisting in the western Pacific area. (This occurs approximately 50 days of each year.) This possibility would greatly complicate the evasion problem, and should be kept in mind as evasion plans are formulated and executed.

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SECTION XV - CONTENTS

XV INDONESIA

1. JAKARTA AND SURABAYA

The locations of Jakarta and Surabaya are shown in Figure 1 of the Introduction. Jakarta lies near the western end of Java and Surabaya lies near the eastern end. Although Indonesia has occasionally been affected by tropical cyclones either from the western Pacific Ocean or from the southern Indian Ocean, these tropical cyclones have never produced strong winds at either Jakarta or Surabaya. The reason for this is mainly the close proximity to the equator, and the effects of adjacent land areas.

The probability is therefore almost nil that either Surabaya or Jakarta will be affected by tropical storms in the future, and both therefore can be considered as havens. Since climatology is no guarantee that these areas will never be affected, it would be prudent when using these ports to remain alert to tropical cyclone warnings.

LME