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This handbook for the port of Cartagena, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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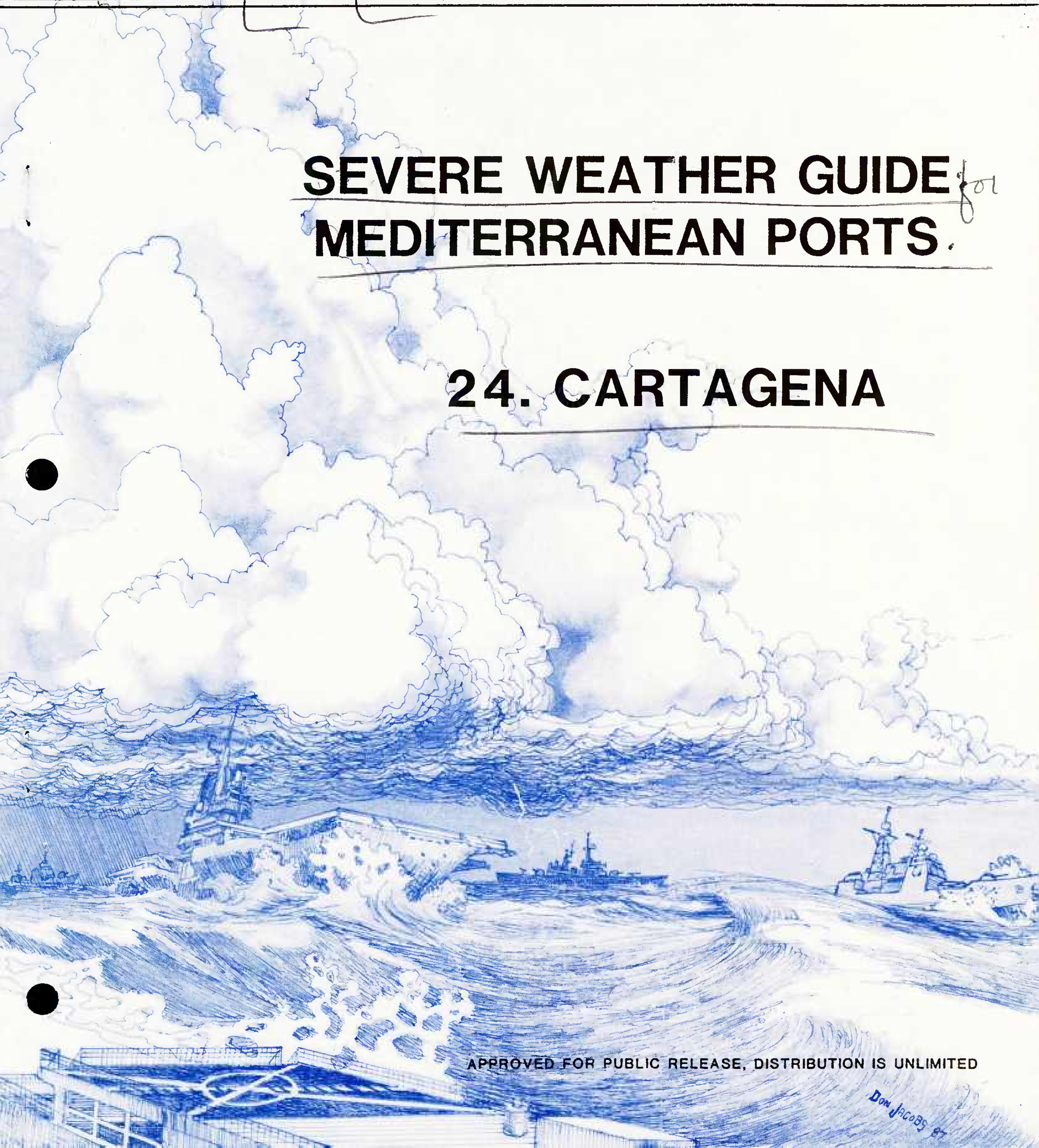
SEVERE WEATHER GUIDE for MEDITERRANEAN PORTS.

24. CARTAGENA



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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (COMNAVOCEANCOM) requirements validated by the Chief of Naval Operations (OP-096).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to Naval Oceanography Command Center (NAVOCEANCOMCEN), Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

W. L. SHUTT
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
16	BARCELONA, SPAIN
17	PALMA, SPAIN
18	IBIZA, SPAIN
19	POLLENSA BAY, SPAIN
20	LIVORNO, ITALY
21	LA SPEZIA, ITALY
22	VENICE, ITALY
23	TRIESTE, ITALY
24	CARTAGENA, SPAIN
25	VALENCIA, SPAIN

1989	PORT
	SAN REMO, ITALY
	GENOA, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY
	BENIDORM, SPAIN
	TANGIER, MOROCCO

1990	PORT
	TARANTO, ITALY
	ROTA, SPAIN
	SOUDA BAY, CRETE
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	GOLCUK, TURKEY
	ISTANBUL, TURKEY
	GULF OF SOLLUM
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.
B. Cruise reports were reviewed.
C. Navy personnel with current or previous area experience were interviewed.
D. A preliminary report was developed which included questions on various local conditions in specific harbors.
E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.
F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,
B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,
C. local wind wave conditions, and
D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2 CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

The city of Cartagena is located on the southeast coast of Spain near the eastern side of the Alboran Sea and western limit of the Mediterranean (Figure 2-1). It is situated on a section of south-facing coastline and is, therefore, protected from most of the wind regimes of the western Mediterranean Sea.

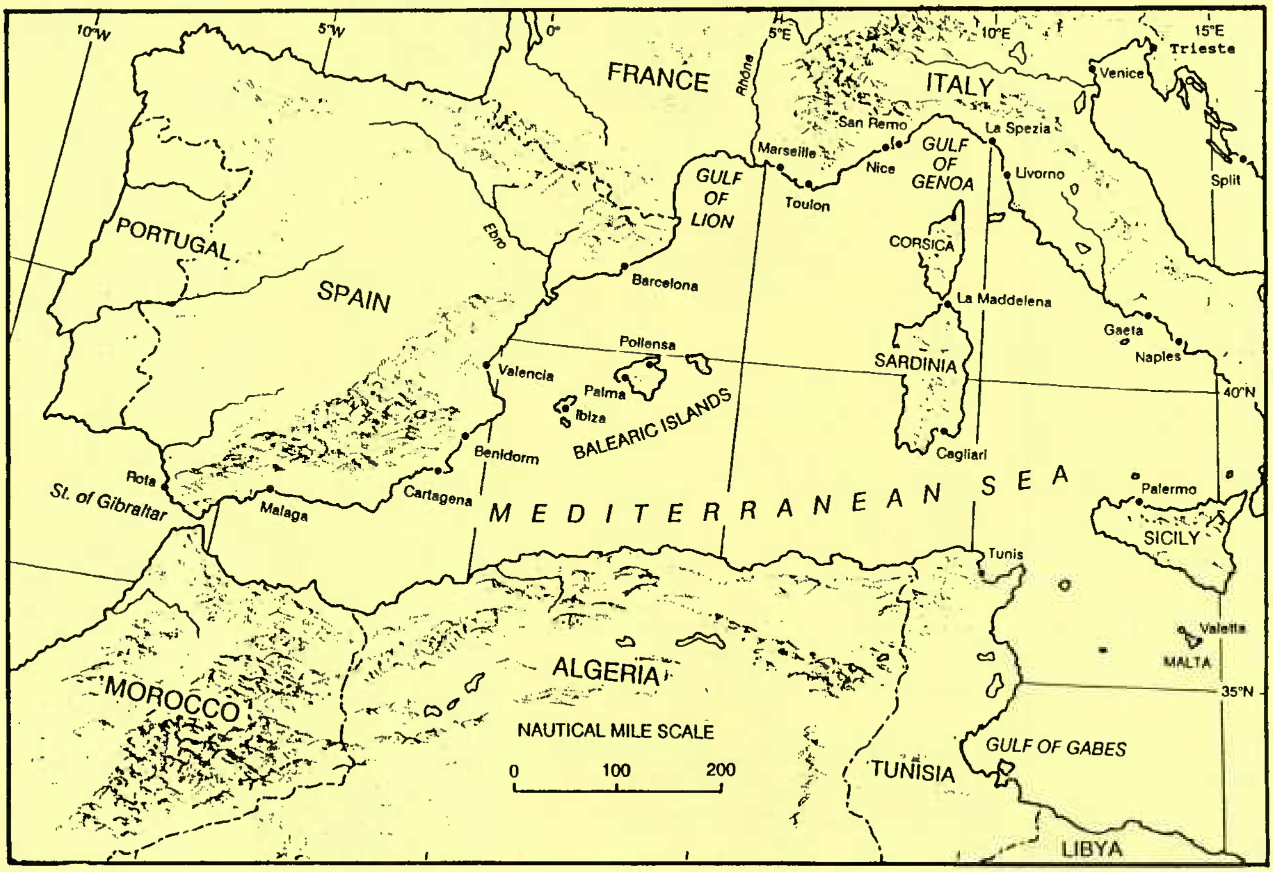

Figure 2-1. Western Mediterranean Sea.

The Port of Cartagena is located at 34° 36'N 00° 59'W (Figure 2-2). It stands on a small plain between a large, semicircular bay to the south and an extensive expanse of low, flat ground to the north. The Mediterranean squadron of the Spanish Navy maintains headquarters at the Cartagena Naval Base. A submarine school with a small submarine flotilla is also located in Cartagena. Facilities exist for servicing naval vessels up to cruiser size and for building naval vessels up to the size of destroyers. The port is a medium-sized natural harbor protected by breakwaters and has anchoring and berthing facilities for large vessels up to 35 ft (10.6 m) draft in the harbor. The entrance faces south and is approximately 984 ft (300 m) wide (FICEURLANT, 1987).

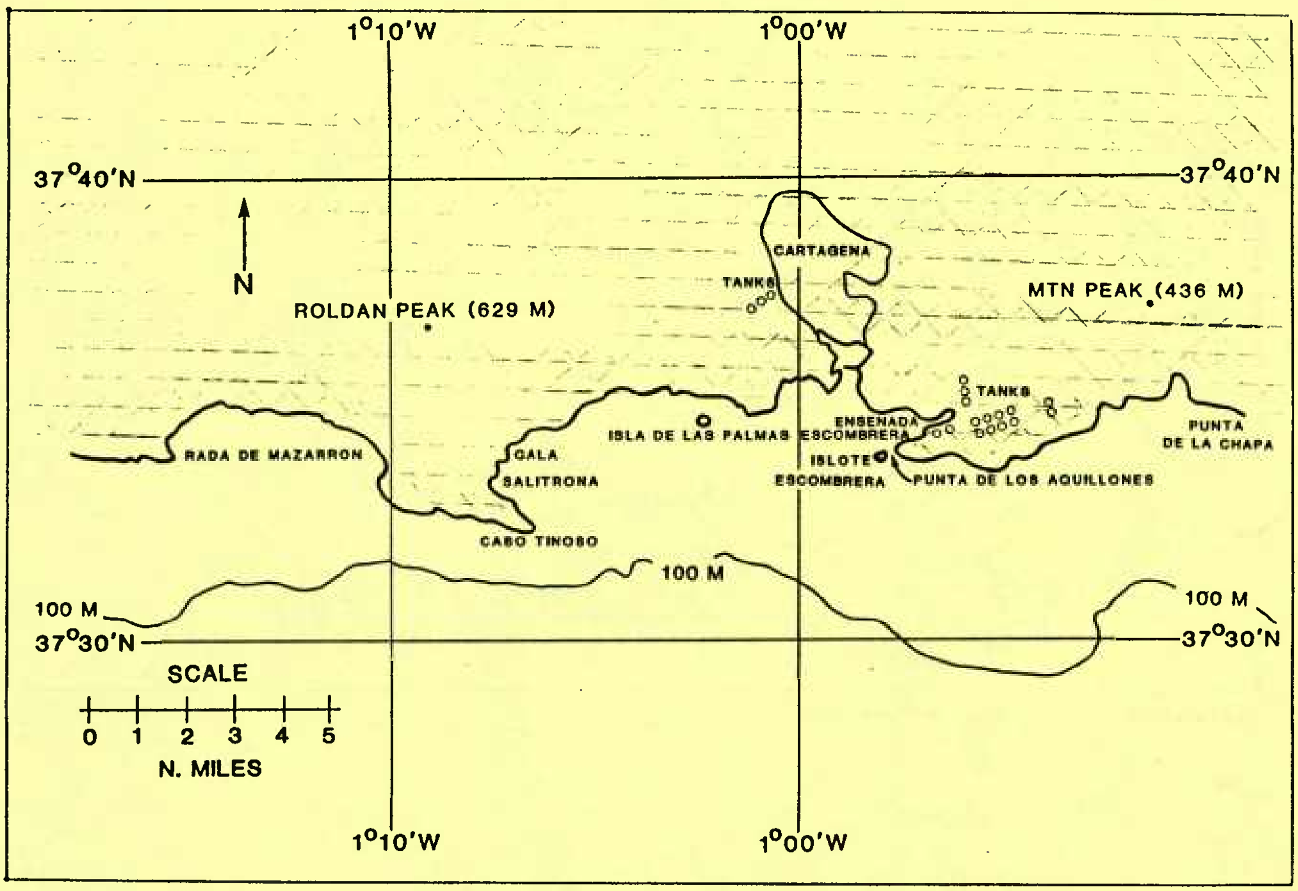

Figure 2-2. Cartagena Region.

A good landmark to use on approach to the harbor is Castillo de Galeras, a castle atop a 656 ft (200 m) hill just west of the harbor (Figure 2-3). The main anchorage is located approximately one mile south of the harbor entrance. This anchorage has a depth of 131 ft (40 M) with good holding ground consisting mainly of mud. Another anchorage area is inside the entrance, just south of Dique de la Curra (Figure 2-3). Depths here range from 42 ft to 54 ft (13 m to 16.5 m). Additionally, a deep water anchorage 213 ft (65 m) is located approximately 7 n mi west of the harbor entrance in Cala Salitrona. This anchorage provides protection from strong southwesterly winds but is exposed to easterlies and southeasterlies. Holding ground in Cala Salitrona is very good in mud and sand.

The barging of ammunition to and from anchored ships is subject to postponement when waves are greater than one to two ft (1/2 m). During an 18-month period, between early 1986 and mid-1987, one of six ammunition transfers was cancelled due to rough seas.

U.S. Navy berthing is on the eastern half of Dique de la Curra which is designated as the Naval Fuel Pier. The western half of this pier is used by the Spanish Navy. The total length of the pier is 1,968 ft (600 m). Berthing is on the northern side of the pier where the depth is 35 ft (10.7 m). Cement loading at the south end of the adjacent pier, Muelle de San Pedro, can cause dust problems on windy days. Additional mooring is possible at commercial docks such as the Muelle de San Pedro and at the west end of Muelle de

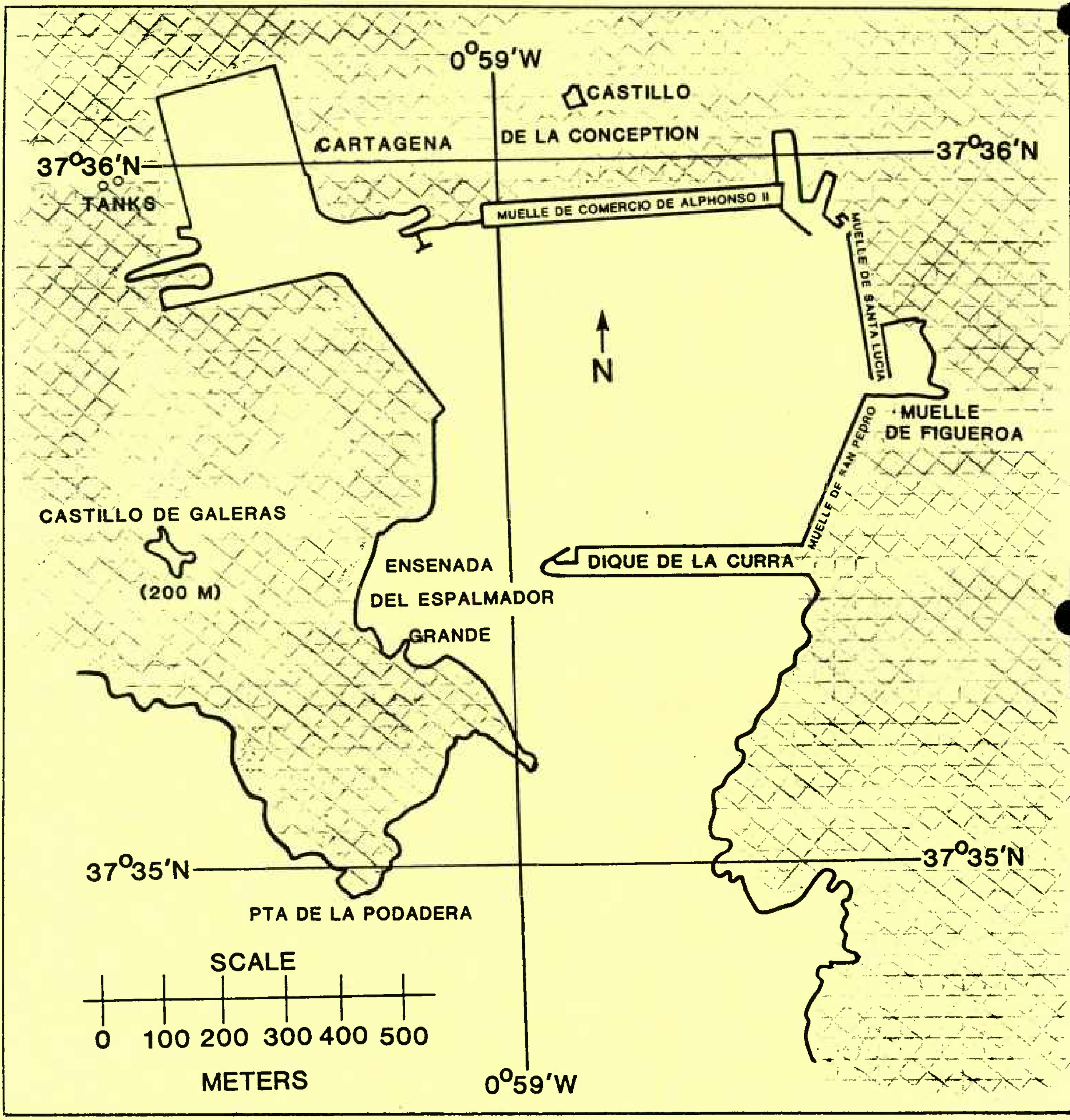

Figure 2-3. Port of Cartagena.

Comercio de Alphonso II. The fleet landing is located at the extreme west end of Muelle de Comercio de Alphonso II.

There are no astronomical tides in the harbor of Cartagena; however, the water level can decrease as much as one ft (30 cm) with high pressure and a northerly wind. Conversely, a southerly wind and low pressure can raise the water level a like amount.

There is no current inside the harbor. Outside the harbor, an easterly current of 0.5 to 1.0 kt will be present when easterly winds have lasted for 15 days or so. Otherwise, current outside the harbor is negligible.

Specific hazardous environmental conditions, vessel situations, and suggested precautionary/evasion action scenarios for the Port of Cartagena are summarized in Table 2-1.

Table 2-1. Summary of hazardous environmental conditions for the Port of Cartagena, Spain

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
1. E'ly winds/waves - Levante * Occurs year-round; most frequent in summer, most intense in winter. * Causes SE'ly waves at outer anchorage. * Accompanied by clouds and rain in cool season. * Will often precede cold front in cool season.	Advance warning * An intense low south of the Balearics will bring gale (30+ kt) easterlies to the east coast of Spain. * The Azores high building into Spain and France will usually precede a Levante event. * An approaching cold front will normally be preceded by easterlies.	(1) Moored - inner harbor.	(a) Wind sensitive operations and ships with large sail areas will, on occasion, be affected in the harbor. * Vessels moored at the Naval Fuel Pier may be exposed to dust if cement loading is being conducted at the adjacent pier.
		(2) Anchorages.	(a) The harbor anchorages are minimally affected by the Levante. * Outer anchorage exposed to waves from southeast but protected from easterly winds. * The secondary anchorage at Cala Salitrona is exposed to Levante winds and should not be used.
		(3) Arriving/departing.	(a) Maneuvering room is limited in the harbor entrance. * Movements in/out of harbor should be completed prior to onset of bad weather or postponed until weather improves. * Levante winds have little affect in the harbor. * Use caution on departure as southeasterly waves may be present a mile or so offshore.
		(4) Small boats.	(a) Inner harbor operations will be minimally affected. * Runs to/from the outer anchorage may be curtailed due to southeasterly waves at the anchorage. * Winds can change direction quickly, especially when Levante is associated with an approaching front.
2. SW'ly winds - Vendaval * Occurs year-round; strongest and most frequent in winter. * Often precedes cold fronts. * Gale force winds (34 to 47 kt) can be associated with well-defined cold fronts in winter. * Precipitation usually accompanies the front but can be delayed as much as 12 hours after Vendaval wind onset.	Advance warning * Any approaching cold front has potential for a strong Vendaval episode. * Watch for clouds atop Roldan peak on an otherwise cloudless day--southwesterlies can be expected next day. * A low, long period southwest swell will sometimes precede the onset of southwest winds by a day or so. * A clear night with bright stars often will indicate southwest winds the next day.	(1) Moored - inner harbor.	(a) Ships berthed at the Naval Fuel Pier will be pushed away from pier in strong Vendaval. * Extra lines may be needed. * Ships at other piers will feel a small to moderate degree of motion.
		(2) Anchorages.	(a) The harbor anchorage south of Dique de la Curra is exposed to southwest winds/southerly waves. * Outer anchorage is even more exposed to southwest winds and waves. * Moving to secondary anchorage in Cala Salitrona will offer protection from both winds and waves.
		(3) Arriving/departing.	(a) Maneuvering room is limited in the harbor entrance. * Movements to/from the harbor should be completed prior to the onset of bad weather or postponed until weather improves. * On departure, southwest winds and waves can be felt while still in the harbor. Once clear of harbor wind and waves intensify dramatically. * Wave heights can be 6 m (20 ft).
		(4) Small boats.	(a) Inner harbor operations will be minimally affected. * Runs to/from the inner anchorage may be interrupted due to the southerly waves at the inner anchorage. * Runs to/from the outer anchorage will be affected even more as southwest waves will be much higher outside the harbor than inside. * Boating can be curtailed for extended periods during Vendavals.

Table 2-1. (Continued)

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
3. NW'ly winds - Poniente * Strongest and most frequent in winter; can occur in spring and autumn. * Often follows cold fronts. * Strongest winds usually last for only 1 to 2 hours. * Moderate (15 kt) Poniente can last for days with occasional peaks to 30 kt.	Advance warning * Any cold front can be followed by Poniente winds. * Winds are most intense just following frontal passage.	(1) Moored - inner harbor.	(a) Wind sensitive operations may be interrupted for a short time. * Strong northwest winds are normally short-lived, lasting only an hour or two.
		(2) Anchorages.	(a) The harbor anchorages and the outer anchorage are minimally affected by Poniente winds. * For short periods, wind sensitive operations may be disrupted. * Fetch limitations will minimize waves heights.
		(3) Arriving/departing.	(a) Maneuvering room is limited in the harbor entrance. * Movements should be completed prior to onset of bad weather or postponed until weather clears. * Poniente winds will raise minimal waves due to fetch limitations. * Gales (30+ kt) possible for short durations.
		(4) Small boats.	(a) Inner harbor operations will be minimally affected. * Runs to/from the outer anchorage will not be affected to a great extent due to fetch limited waves. * Northwesterlies associated with cold fronts usually short-lived with strong winds lasting an hour or two.
4. Sea breeze * Occurs March through November. * Southerly 10 to 20 kt.	Advance warning * Daily occurrence. Begins 1000 LST, ends 1 hour after sunset.	(1) Moored - inner harbor.	(a) Sea breeze has little effect.
		(2) Anchorages.	(a) Small boat operations outside of breakwater typically secured by 1500 LST during March through November.
		(3) Arriving/departing.	(a) Maneuvering room is limited in the harbor entrance. * Vessels with large sail area should complete movements prior to mid-afternoon and strongest sea breeze.
		(4) Small boats.	(a) Small boat operations outside of breakwater typically secured by 1500 LST during March through November. * Runs to/from outer anchorages typically secured from about 1500 LST until after sunset.

Table 2-1. (Continued)

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
5. Southwest swell * After southwest winds cease, swell can last an additional 36 hours. * Occurs year-round; strongest and most frequent in winter. * Wave heights of 20 ft (6 m) possible at onset, diminishing in time.	Advance warning * Southwest waves will accompany the southwest winds as seas then, gradually, as winds die down, waves become swell waves and their period lengthens. * When southwest winds occur over a large area, southwest swell will normally last longer than if winds are more localized.	(1) Moored - inner harbor.	(a) Swell can enter the harbor area and affect ships berthed at piers other than the Naval Fuel Pier. * Swell can last for a day or more and a berthing change to the Naval Fuel Pier may be necessary.
		(2) Anchorages.	(a) The inner anchorage south of Dique de la Curra is exposed to southerly swell. * Moving to an anchorage north of the Dique will lessen the affects. * Outer anchorage is exposed to this swell; moving to Cala Salitrona will offer protection.
		(3) Arriving/departing.	(a) Maneuvering room is limited in the harbor entrance. * Movements should be completed prior to the onset of bad weather or postponed until weather improves. * Use caution on departure as waves inside harbor may be 7 ft (2 m) while outside waves are 20 ft (6 m).
		(4) Small boats.	(a) Inner operations will be minimally affected. * Runs to/from the inner anchorage can be curtailed as some waves will enter the harbor. * Outer anchorage much more affected with delays of 24 to 36 hours possible.

SEASONAL SUMMARY OF CARTAGENA HAZARDOUS WEATHER CONDITIONS

(Much of this information is adapted from Brody and Nestor, 1980).

WINTER (November thru February):

* Easterly winds (Levante) can precede cold front or occur when low is south of Balearics.
* Southwesterly wind (Vendaval) may follow Levante and precede cold front or be caused by low near Gibraltar. Wind speeds can reach 40 to 50 kt. Most common wind direction in winter.
* Strong Vendavals can cause 16 ft (5 m) waves at the outer anchorage. Even after wind shifts northerly, swell will last another 24 to 36 hours, decreasing in height with time.
* Hazardous wind chill factors are possible although extremely rare.

SPRING (March through May):

* Early spring similar to winter. Sea breezes occur on warm days.
* Thunderstorms, though infrequent, begin to occur.

SUMMER (June through September):

* Sea breeze daily occurrence.
* Thunderstorms more frequent - gusts to 45 kt possible.

AUTUMN (October):

* Short transition season as winter weather returns by end of month.
* Peak season for thunderstorms (2 to 3 during the month).

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and the Hazardous Weather Summary in Section 3.

REFERENCES

Brody, L.R. and M.J.R. Nestor, 1980: Regional Forecasting Aids for the Mediterranean Basin, NAVENVPREDRSCHFAC Technical Report TR 80-10. Naval Environmental Prediction Research Facility, Monterey, California 93943-5006.

FICEURLANT, 1987: Port Directory for Cartagena, (1985), Spain. Fleet Intelligence Center Europe and Atlantic, Norfolk, Virginia.

3. GENERAL INFORMATION

The information in this section is intended for fleet meteorologists/oceanographers and staff planners. Paragraph 3.5 provides a general discussion of winds and weather and Table 3-1 presents a summary of hazards and actions by season.

3.1 Geographic Location

Cartagena is located on the southeast coast of Spain near the eastern side of the Alboran Sea and western limit of the Mediterranean Sea (Figure 3-1). It is situated on a section of south-facing coastline and is, therefore, protected from most of the wind regimes of the western Mediterranean Sea.

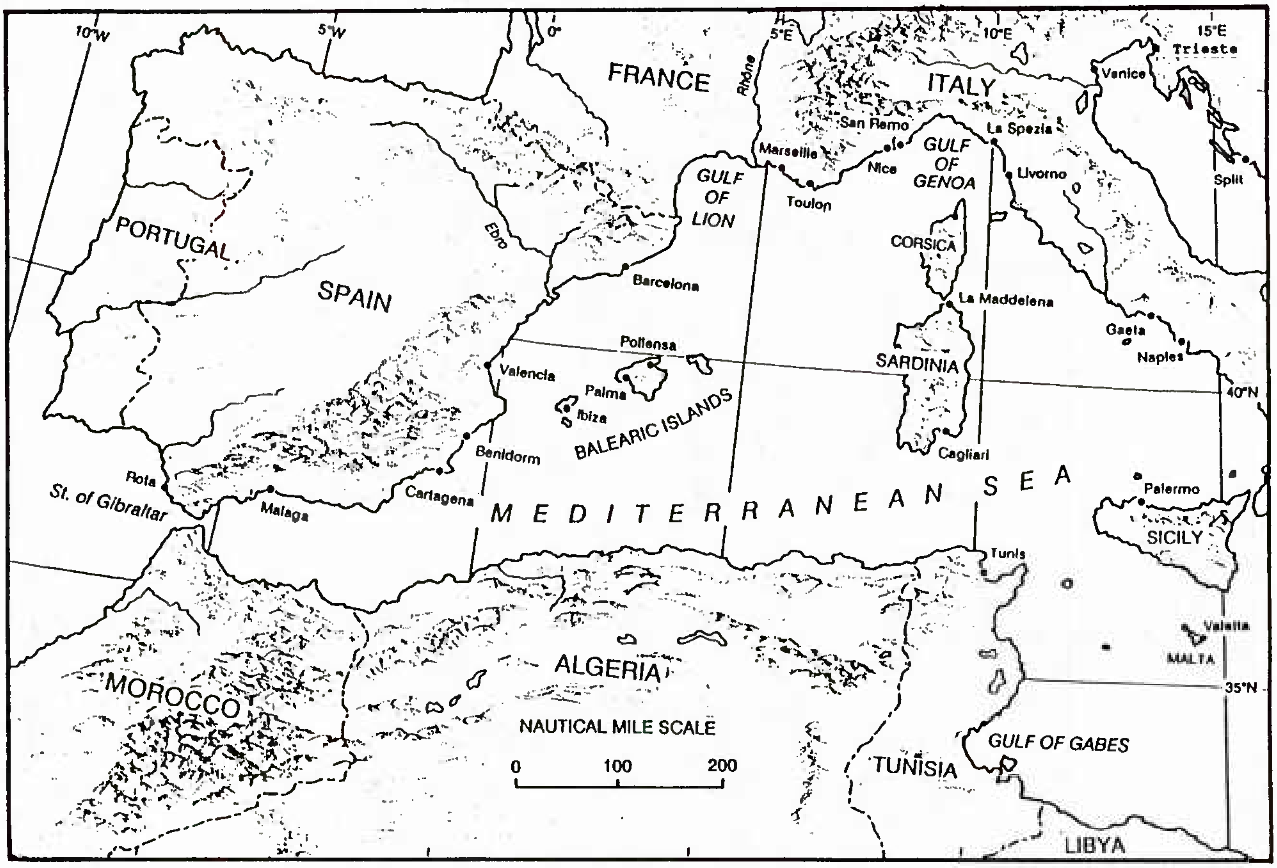

Figure 3-1. Western Mediterranean Sea.

The Port of Cartagena is located at 34° 36'N 00° 59'W (Figure 3-2). It stands on a small plain between a large, semicircular bay to the south and an extensive expanse of low, flat ground to the north. The Mediterranean squadron of the Spanish Navy maintains headquarters at the Cartagena Naval Base. A submarine school with a small submarine flotilla is also located in Cartagena. Facilities exist for servicing naval vessels up to cruiser size and for building naval vessels up to the size of destroyers. The port is a medium-sized natural harbor protected by breakwaters and has anchoring and berthing facilities for large vessels up to 35 ft (10.6 m) draft in the harbor. The entrance faces south and is approximately 984 ft (300 m) wide (FICEURLANT, 1987).

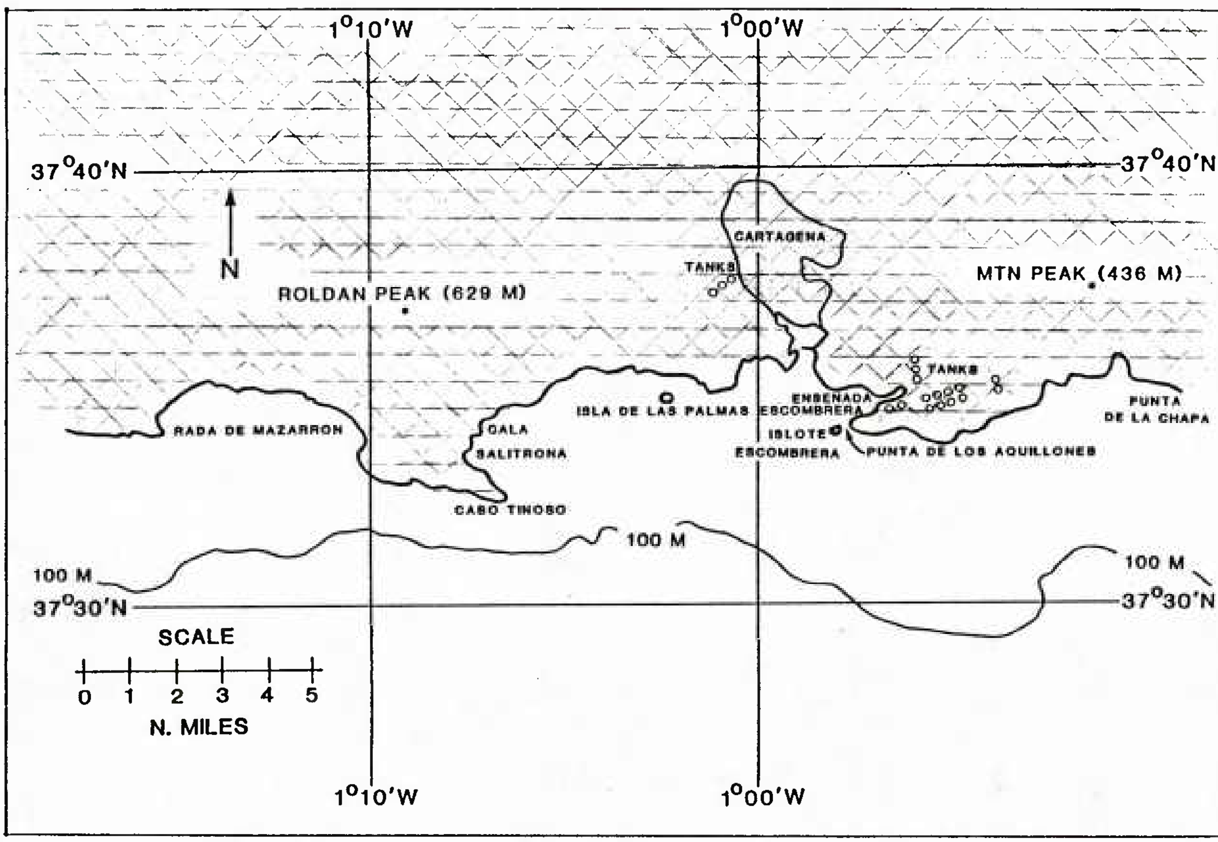

Figure 3-2. Cartagena Region.

A good landmark to use on approach to the harbor is Castillo de Galeras, a castle atop a 656 ft (200 m) hill just west of the harbor (Figure 3-3). The main anchorage is located approximately one mile south of the harbor entrance. This anchorage has a depth of 131 ft (40 m) with good holding ground consisting mainly of mud. Another anchorage area is inside the entrance, just south of Digue de la Curra. Depths here range from 42 ft to 54 ft (13 m to 16.5 m). Additionally, a deep 213 ft (65 m) anchorage is located approximately 7 n mi west of the harbor entrance in Cala Salitrona. This anchorage provides protection from strong southwesterly winds but is exposed to easterlies and southeasterlies. Holding ground in Cala Salitrona is very good in mud and sand.

The barging of ammunition to and from anchored ships is subject to postponement when waves are greater than one to two ft (1/2 m). During an 18-month period between early 1986 and mid-1987, one of six ammunition transfers was cancelled due to rough seas.

U.S. Navy berthing is on the eastern half of Dique de la Curra which is designated as the Naval Fuel Pier. The western half of this pier is used by the Spanish Navy. The total length of this pier is 1,968 ft (600 m). Berthing is on the northern side of the pier where the depth is 35 ft (10.7 m). Cement loading at the south end of the adjacent pier, Muelle de San Pedro, can cause dust problems on windy days. Additional mooring is possible at commercial docks such as the Muelle de San Pedro and at the west end of Muelle de Comercio de Alphonso II. The fleet landing is located at the extreme west end of Muelle de Comercio de Alphonso II.

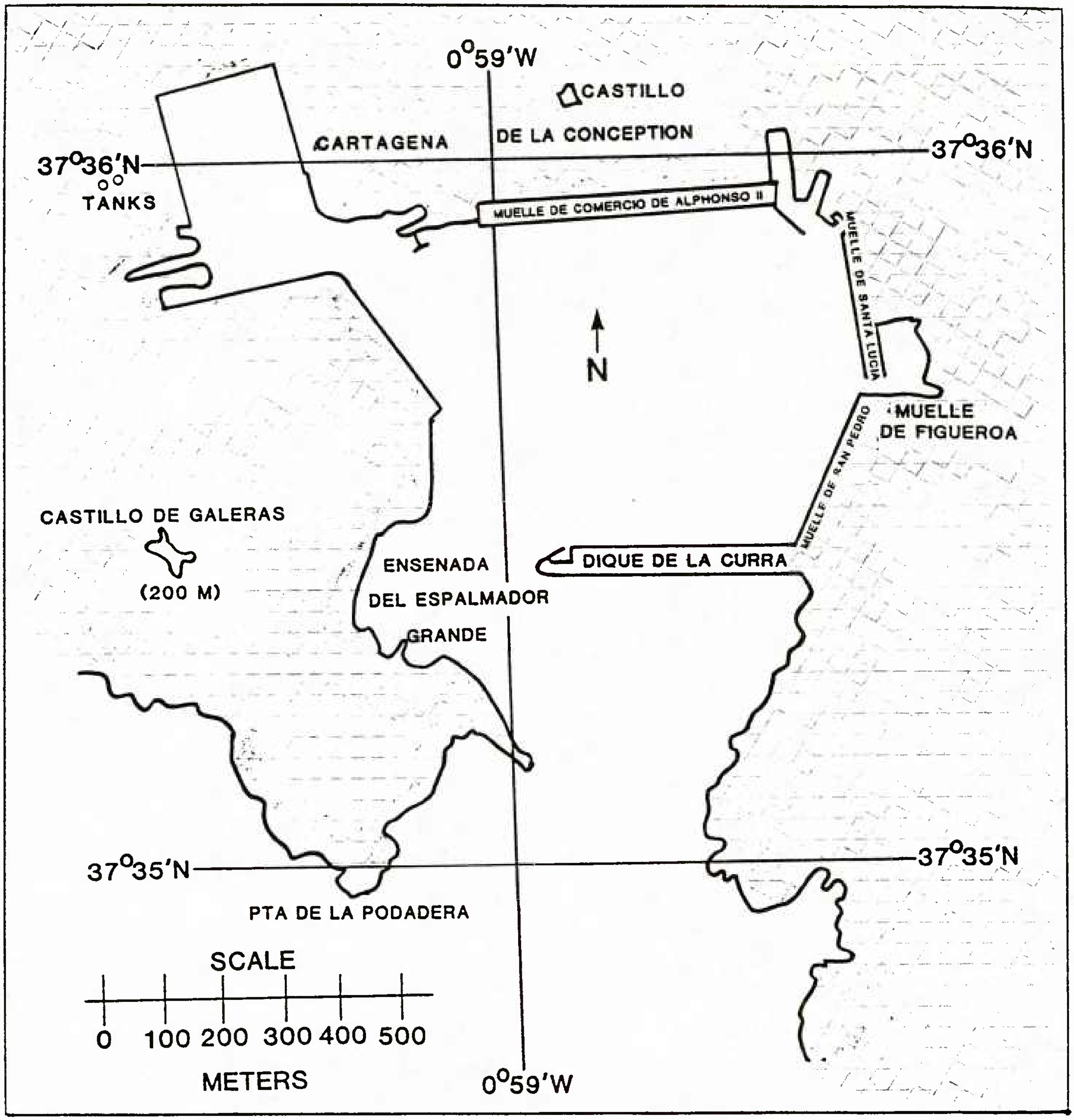

Figure 3-3. Port of Cartagena.

There are no astronomical tides in the harbor of Cartagena; however, the water level can decrease as much as one ft (30 cm) with high pressure and a northerly wind. Conversely, a southerly wind an low pressure can raise the water level a like amount.

There is no current inside the harbor. Outside the harbor, and easterly current of 0.5 to 1.0 kt will be present when easterly winds have lasted for 15 days or so. Otherwise, current outside the harbor is negligible.

3.2 Qualitative Evaluation of the Port of Cartagena

The harbor of Cartagena is well protected from most sea and swell waves. The harbor entrance faces south (Figure 3-3). Just inside the harbor entrance a point of land extends eastward from the west bank while just beyond, a long pier (Dique de la Curra) extends more than halfway across the entrance channel from the east side. This pier must be circumnavigated to reach the inner harbor area. Waves entering the harbor are similarly blocked and, therefore, have little effect on the inner harbor. Vessels anchored in the harbor or berthed on the north side of Dique de la Curra will usually feel little or no wave motion; however, vessels anchored south of Dique de la Curra will feel the effects of open sea waves, especially if from a southerly direction.

U.S. Navy berthing is on the eastern half of Dique de la Curra which is designated as the Naval Fuel Pier. The western half of this pier is used by the Spanish Navy. The total length of the pier is 1,968 ft (600 M). Berthing is on the northern side of the pier where the depth is 35 ft (10.7). Cement loading at the south end of the adjacent pier, Muelle de San Pedro, can cause dust problems on windy days. Additional mooring is possible at commercial docks such as the Muelle de San Pedro and at the west end of Muelle de Comercio de Alphonso II. The fleet landing is located at the extreme west end of this pier.

3.3 Currents and Tides

As is true for most of the ports in the Mediterranean, there are no significant astronomical tides at Cartagena. Minor changes in water levels can occur, however, from a combination of atmospheric pressure and wind conditions. With high pressure and a northerly wind, the water level will lower. With a southerly wind and low pressure, the water level will rise. Neither of these combinations occur frequently. Maximum water movement is about one ft (30 cm) in either case.

There are no currents inside the harbor nor are there currents outside the harbor except in instances of long lasting wind patterns which, after time, can cause surface water movement. The most common of these occurrences in the Cartagena area is in conjunction with the Levante wind in the summer. These easterly winds can last for days or weeks. After about 15 days of constant easterly winds, a current of 0.5 kt to 1.0 kt will set up. The direction will, of course, be with the wind and the current will be close along the coast but not in the harbor.

3.4 Visibility

Visibility is generally good in the Cartagena area. Best visibilities are normally in late summer through early winter (September through December) and worst visibilities are during the late spring to early summer (April through July). Zero visibility occurs two to four times per year, usually in April. This will be due to early morning fog and haze and will improve to at least two miles by 1000L-1100L. Several late spring/early summer mornings will have visibilities in the two to three mile range until noon.

3.5 Winds and Weather

Cartagena is geographically situated in an area of mild climate and the weather is generally good year-round. The port and harbor area normally will not feel the full effects of most of the western Mediterranean wind regimes such as the Levante, Vendaval and Poniente. The Vendaval and the Levante will, on occasion, cause problems at the outer anchorage and the Levante will affect the alternate anchorage area in Cala Salitrona. The following paragraphs discuss these winds and their effects on the Port of Cartagena. Except where noted, this information is adapted from Brody and Nestor, 1980.

3.5.1 Levante

The Levante is an easterly or northeasterly wind that occurs in an area form the coast of southern France to west of the Strait of Gibraltar. It can occur as a result of several different weather patterns. The most typical situation is when the Azores High extends northeastward over Spain and southern France. The Levante will be widespread under this situation with the large anticyclone over western Europe and relatively low pressure over the western Mediterranean. The Levante will also precede the arrival of a cold front from the Atlantic during the cool season (November through April) when a lee depression or trough forms in the region off the Balearic Islands. A third situation when gale force Levante winds can be expected along the east coast of Spain is due to an intense cyclone south of the Balearics. Yet another pattern which results in a

Levante is when a migratory low moves eastward in southern Spain to a position near the Greenwich Meridian. In this case, gale northeasterlies can be expected off the east coast of Spain as far east as Ibiza.

The Levante can occur in any month; however, wind speeds tend to be higher in the cool season. Levante wind speeds in the Cartagena area are usually moderate (15 to 25 kt) and speeds greater than 33 kt are rare. Wind statistics show that the occurrence of east and northeast winds are at a minimum in December (25 percent) and a maximum (44 percent) in August (Naval Weather Service, 1975). In summer, haze and reduced visibility will often accompany the Levante while, during the other three seasons, cold fronts or depressions will bring low clouds and rain. Also, during the summer months, the Levante can last for weeks. These long-lasting occurrences are associated with the thermal low over North Africa.

3.5.2 Vendaval

Vendaval winds are southwesterlies which precede cold fronts or are associated with lows in the Gibraltar area and are most likely to occur in the cool season with gale force intensity (34 to 47 kt). Precipitation usually accompanies the Vendaval/cold front system but can be delayed by as many as 12 hours after the onset of the Vendaval.

Strong southwesterly to westerly winds are common at Cartagena. Occurrence of Vendaval winds are at a minimum (25 percent) during August and a maximum (40 percent) November through April (Naval Weather

Service, 1975). In addition to the cold fronts, another synoptic situation causing these winds is one characterized by an intensifying high that lies south of the Azores with a deep low in the Atlantic approaching the British Isles and the coast of Europe thereby resulting in a steepening pressure gradient between the high and low.

3.5.3 Poniente

The Poniente is a northwesterly wind behind the cold front and usually occurs in the cool season; however, northwesterlies often occur in other seasons, except for summer, when high pressure builds in from the Atlantic. Consequently, the Poniente can be expected nearly year round with peak frequency and peak intensity during the cool season. In winter the Azores high is displaced southward, resulting in northwesterlies which will last for days in the Cartagena area. During these episodes, winds will average 15 kt with peaks to 30 kt; however, due to the harbor configuration, wave heights will be minimal.

3.5.4 Sea breeze

The sea breeze occurs between March and November and is from a southerly direction. In the warmest months it will begin at 1000L and continue until one hour after sunset. Wind speed is generally 10 to 15 kt with occasional peaks to 20 kt. Generally, the sea breeze is more southerly than the Vendaval. When speeds are greater than 20 kt, it is usually due more to the Vendaval than the sea breeze. The late afternoon sea breeze causes a heavy chop outside Dique de la Curra.

Small boat operations are typically secured outside of the breakwater by 1500 LST.

3.5.5 Southwest swell

Swell will often be observed a the outer anchorage after south or southwest winds have ceased. It may still be present as long as 36 hours after a particularly strong outbreak of southerly/southwesterly winds. When the wind ceases, wave heights can be 20 ft (6 m) and will steadily decrease in height. Some southerly swell will enter the harbor and affect ships anchored south of Dique de la Curra and ships moored at Muelle de Comercio de Alphonso II and Muelle de Santa Lucia. Ships berthed at the Naval Fuel Pier will feel very little, if any, wave motion. Also southwesterly swell at the outer anchorage will reflect off the land east of the anchorage and turn into southerly swell and enter the harbor. There have been cases, although extremely rare, when waves have broken over the Dique de la Curra, which is 16 ft (5 m) high. This occurs when wind waves produced by strong southerly winds combine with southerly swell to cause the extreme condition.

3.6 Seasonal Summary of Cartagena Hazardous Weather Conditions

The seasonal weather patterns in the western Mediterranean area will vary in response to the movement of the Azores High. This high moves southward during winter, allowing low pressure systems to move in over Europe. The high builds northward as summer approaches and the storms become less frequent. In the middle of summer, they are nearly non-existent. Much of the information in this section is adapted from Brody and Nestor, 1980.

A. Winter (November through February)

The easterly (Levante) wind is strongest in winter and spring. It will precede the arrival of cold fronts from the Atlantic. When there is an intense low south of the Balearic Islands, gale Levante winds can be expected along Spain's entire eastern coast. The pre-frontal Levante may turn into a southwesterly wind (Vendaval) and reach gale force in wintertime. Once the front has passed, the winds will turn northwesterly (Poniente). Because the inner harbor areas of Cartagena are protected from most wave conditions, only wind sensitive operations are affected during these events. The outer anchorage will, however, be exposed to 16 ft (5 m) waves during a strong Vendaval episode. A wintertime Levante is usually from the east-northeast and the anchorage area is shielded from that direction.

The most common wind direction in winter is from the southwest. Four or five times during the winter these winds will increase to speeds of 40 to 50 kt and last three to four days. The strongest winds will normally last one day. Winds will generally shift to the north after a strong Vendaval episode; however, the swell associated with the southwesterlies will continue, decreasing in time, for another 24 to 36 hours after the winds shift.

Below freezing temperatures are extremely rare at Cartagena; however, if low temperatures are combined with high wind speeds, hazardous wind chill factors could occur.

B. <u>Spring (March through May)</u>

Springtime in the western Mediterranean is noted for periods of stormy winter-like weather alternating with false starts of summer. Temperatures are warming, and storm events are decreasing in both strength and frequency. Sea breezes are starting to occur on warm days. Thunderstorms begi;n to sxhow up in April.

C. <u>Summer (June thru September)</u>

Summers are characterized by the almost constant, light to moderate wind. The Levante occurs nearly 45 percent of the itme during the summer and blows for days--even weeks--at a time. This usually causes a 3 ft (1 m) southeasterly swell at the outer anchorage. Precipitation amounts are minimal until September when the rainy season begins. The sea breeze regime is a daily occurrence except when interrupted by either the Levante or the Vendaval.

Thunderstorms continue to occur throughout summer. One or two occurrences can be expected each month. These storms are usually preceded by hot temperatures and southerly winds. Hail and gusts up to 45 kt can accompany these storms in rare instances.

D. <u>Autumn (October)</u>

The autumn season is a short, transitional period lasting only for the month of October. By month's end an abrupt change to winter-like weather has taken place. Thunderstorms occur two to three times in October.

3.7 Local Indicators of Hazardous Weather Conditions

Because the port is most susceptible to south and southwest winds, local mariners have noted some indicators which are helpful in predicting these winds. One of the most accurate of these indicators is the presence of clouds, on an otherwise cloudless day, atop Roldan Peak west of the harbor. Winds will be southwesterly the next day. Another fairly accurate indicator is a low long period swell (less than one meter, period 12-15 seconds) which will arrive at the anchorage area the day before the onset of southwesterly winds. A third indicator is a clear night with bright stars, which will denote southwest winds the next day. None of these indicators are 100 percent accurate; however, when two or more occur in combination, reliability is improved.

The following "forecaster hints" are adapted from Brody and Nestor, 1980:

o Correct placement of fronts is very difficult in the western Mediterranean basin due both to the lack of ship reports and to terrain effects. These problems are accentuated during the summer when fronts are weakest. The worst locations in this respect are Spain and the Balearic Islands. Forecasters should be aware of the lee trough which develops along the east coast of Spain during periods of northwesterly flow. There is a tendency to designate this trough as frontal, instead of correctly moving the front eastward, out of the region.

- Surface cyclones generally weaken while traversing the Iberian Peninsula, then deepen rapidly when they reach the east coast of Spain.

3.8 Protective and Mitigating Measures

Moving from outside to inside the harbor during bad weather may be hazardous due to the restricted maneuvering area at the entrance. If possible, these movements should be made before the onset of a storm or strong wind episode.

Prior to the onset of strong southwesterlies, the best choice would be to move from the main outer anchorage to an anchorage inside the harbor, preferably north of Dique de la Curra. The best choice after the onset would be to move to the secondary anchorage in Cala Salitrona, which provides protection from the winds and waves due to the high terrain of Cape Tinoso.

Easterly winds usually bring easterly to southeasterly waves to the outer anchorage area in the form of swell. The wave heights are normally not excessive but can last for long periods of time. Entering the harbor or leaving the area are the two choices available if there is a need to minimize the affects of the southeasterly swell.

The barging of ammunition to and from anchored ships is subject to postponement when waves are greater than one to two ft (1/2 m). During an 18-month period between early 1986 and mid-1987, one of six scheduled ammunition transfers was cancelled due to rough seas.

If berthed at the Naval Fuel Pier, extra lines may be needed during strong outbreaks of southwest winds. The pier protects vessels from waves, but strong winds tend to push the vessels away from the pier, especially those ships with large sail areas.

3.9 Summary of Problems and Actions

Table 3-1 is intended to provide easy to use seasonal references for meteorologists on ships using the Port of Cartagena. Table 2-1 (Section 2) summarizes Table 3-1 and is intended primarily for use by ship captains.

Table 3-1. Potential problem situations at Port of Cartagena, Spain - ALL SEASONS

VESSEL LOCATION/SITUATION	POTENTIAL HAZARDS	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
1. Moored-inner harbor Occurs year-round with highest frequency in summer but most intense in winter.	a. E'ly winds/waves - Levante Has minimal influence in the harbor but can cause SE'ly swell at the outer anchorage. In the cool season, usually accompanied by clouds and rain.	a. Wind sensitive operations and ships with large sail areas will, on occasion, be affected in the harbor. Vessels moored at the Naval Fuel Pier may be exposed to dust if cement loading is being conducted at the adjacent pier.	a. The Levante occurs with several different weather patterns. The most typical is when the Azores high extends northeastward over Spain and southern France. Also, the Levante will precede the arrival of a cold front during the cool season. In this case, a lee trough forms in the region of the Balearic Islands. At times, an intense low will form south of the Balearics and gale force (30+ kt) can be expected along the east coast of Spain.
Occurs year-round. Strongest and most frequent in winter.	b. SW'ly winds - Vendaval Precedes cold fronts; strongest winds (34 to 47 kt) likely to occur in cool season. Precipitation usually accompanies the front but can be delayed as much as 12 hours after Vendaval wind onset.	b. Ships berthed at the Naval Fuel Pier will be pushed away from the pier with southwest or south winds and extra lines may be needed. Ships at other piers will feel a small to moderate degree of motion as some southerly swell will enter the harbor.	b. The most intense and frequent Vendavals are associated with cold fronts and any cold front has the potential for causing strong southwest winds; however, strong southwesterly winds can also occur at Cartagena when a high lying south of the Azores intensifies and a steep gradient develops between the high and migratory lows approaching the British Isles. Some indicators of southwest winds are: (1) Clouds atop Roldan Peak to the west of the harbor, on an otherwise cloudless day, indicate southwest winds the next day; (2) A low, long period swell will arrive at the anchorage a day before the onset of winds; and (3) A clear night with bright stars will indicate southwest winds the next day.
Strongest and most frequent in winter. Also occurs in spring and autumn.	c. NW'ly winds - Poniente Follows cold fronts in the cool season. Winds can last for days at 15 kt with peaks to 30 kt.	c. Wind sensitive operations may be interrupted for a short time. Strong northwest winds are normally short-lived and will usually last for only an hour or two.	c. Inner harbor operations will be minimally affected. Also, runs to/from the outer anchorage will not be affected to a great extent because of fetch limitations on wave heights. The Poniente winds associated with frontal passages are normally strong for only one or two hours so delays in boating are minimal.
Occurs year-round. Strongest and most frequent in winter.	d. Southwest swell - After southwest winds cease, swell can last an additional 36 hours. At onset, wave heights can be as high as 20 ft (6 m), diminishing with time.	d. Swell can enter the harbor area and will affect ships berthed at piers other than the Naval Fuel Pier. Swell can last for a day or more and, if operations are impacted, a berthing change to the Naval Fuel Pier may be necessary.	d. Inner harbor operations will be minimally affected. Runs to/from the inner anchorage can be curtailed as some waves will enter the harbor. The outer anchorage is much more affected and boating can be curtailed for as long as 24 to 36 hours due to swell.

Table 3-1. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARDS	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
2. Anchorages Occurs year-round with highest frequency in summer but most intense in winter.	a. E'ly winds/waves - Levante Has minimal influence in the harbor but can cause SE'ly swell at the outer anchorage. In the cool season, usually accompanied by clouds and rain.	a. Wind sensitive operations and ships with large sail areas will, on occasion, be affected in the harbor. Vessels moored at the Naval Fuel Pier may be exposed to dust if cement loading is being conducted at the adjacent pier.	a. The Levante occurs with several different weather patterns. The most typical is when the Azores high extends northeastward over Spain and southern France. Also, the Levante will precede the arrival of a cold front during the cool season. In this case, a lee trough forms in the region of the Balearic Islands. At times, an intense low will form south of the Balearics and gale force (30+ kt) can be expected along the east coast of Spain.
Occurs year-round. Strongest and most frequent in winter.	b. SW'ly winds - Vendaval Precedes cold fronts; strongest winds (34 to 47 kt) likely to occur in cool season. Precipitation usually accompanies the front but can be delayed as much as 12 hours after Vendaval wind onset.	b. Ships berthed at the Naval Fuel Pier will be pushed away from the pier with southwest or south winds and extra lines may be needed. Ships at other piers will feel a small to moderate degree of motion as some southerly swell will enter the harbor.	b. The most intense and frequent Vendavals are associated with cold fronts and any cold front has the potential for causing strong southwest winds; however, strong southwesterly winds can also occur at Cartagena when a high lying south of the Azores intensifies and a steep gradient develops between the high and migratory lows approaching the British Isles. Some indicators of southwest winds are: (1) Clouds atop Roldan Peak to the west of the harbor, on an otherwise cloudless day, indicate southwest winds the next day; (2) A low, long period swell will arrive at the anchorage a day before the onset of winds; and (3) A clear night with bright stars will indicate southwest winds the next day.
Strongest and most frequent in winter. Also occurs in spring and autumn.	c. NW'ly winds - Poniente Follows cold fronts in the cool season. Winds can last for days at 15 kt with peaks to 30 kt.	c. Wind sensitive operations may be interrupted for a short time. Strong northwest winds are normally short-lived and will usually last for only an hour or two.	c. Any cold front can be followed by a Poniente wind. In the Cartagena area, strong winds are not usually long-lived but can be gale force (30+ kt) for an hour or two. Forecasters should be aware of the lee trough that forms along the coast during an outbreak of northwesterlies; there is a tendency to designate this trough as frontal instead of correctly moving the front eastward, out of the region.
Occurs daily March through November.	d. Sea breeze - S'ly 10 to 20 kt. Strongest 1500 LST to sunset.	d. Small boating typically secured 1500 LST to sunset.	d. Sea breeze is a daily occurrence March through November and raises heavy chop outside the breakwater.
Occurs year-round. Strongest and most frequent in winter.	e. Southwest swell - After southwest winds cease, swell can last an additional 36 hours. At onset, wave heights can be as high as 20 ft (6 m), diminishing with time.	e. Swell can enter the harbor area and will affect ships berthed at piers other than the Naval Fuel Pier. Swell can last for a day or more and, if operations are impacted, a berthing change to the Naval Fuel Pier may be necessary.	e. Southwest waves will normally accompany the strong southwinds common in the Cartagena area. These waves will start as wind waves (seas) and gradually change to a mixture of sea and swell. After the wind ceases, only the swell will be observed. Southwest swell will reflect off the land to the east of the outer anchorage and enter the harbor as southerly swell.

Table 3-1. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARDS	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
3. Arriving/Departing Occurs year-round with highest frequency in summer but most intense in winter.	a. E'ly winds/waves - Levante Has minimal influence in the harbor but can cause SE'ly swell at the outer anchorage. In the cool season, usually accompanied by clouds and rain.	a. Maneuvering room is limited in the harbor entrance so movements should be completed before the onset of bad weather or postponed until weather improves. Levante winds have little effect in the harbor. Use caution on departure, however, as southeasterly waves may be present a mile or so offshore.	a. The Levante occurs with several different weather patterns. The most typical is when the Azores high extends northeastward over Spain and southern France. Also, the Levante will precede the arrival of a cold front during the cool season. In this case, a lee trough forms in the region of the Balearic Islands. At times, an intense low will form south of the Balearics and gale force (30+ kt) can be expected along the east coast of Spain.
Occurs year-round. Strongest and most frequent in winter.	b. SW'ly winds - Vendaval Precedes cold fronts; strongest winds (34 to 47 kt) likely to occur in cool season. Precipitation usually accompanies the front but can be delayed as much as 12 hours after Vendaval wind onset.	b. Maneuvering room is limited in the harbor entrance so movements should be completed before the onset of bad weather or postponed until weather improves. On departure, the southwest winds and southerly waves can be felt while still in the harbor. Once clear of the harbor, however, both wind and waves will intensify. Wave heights can reach up to 20 ft (6 m).	b. The most intense and frequent Vendavals are associated with cold fronts and any cold front has the potential for causing strong southwest winds; however, strong southwesterly winds can also occur at Cartagena when a high lying south of the Azores intensifies and a steep gradient develops between the high and migratory lows approaching the British Isles. Some indicators of southwest winds are: (1) Clouds atop Roldan Peak to the west of the harbor, on an otherwise cloudless day, indicate southwest winds the next day; (2) A low, long period swell will arrive at the anchorage a day before the onset of winds; and (3) A clear night with bright stars will indicate southwest winds the next day.
Strongest and most frequent in winter. Also occurs in spring and autumn.	c. NW'ly winds - Poniente Follows cold fronts in the cool season. Winds can last for days at 15 kt with peaks to 30 kt.	c. Maneuvering room is limited in the harbor entrance so movements should be completed before the onset of bad weather or postponed until weather improves. Poniente winds will raise minimal waves due to the fetch limitations of the area. Winds may be gale force (30+ kt) but are usually short-lived.	c. Any cold front can be followed by a Poniente wind. In the Cartagena area, strong winds are not usually long-lived but can be gale force (30+ kt) for and hour or two. Forecasters should be aware of the lee trough that forms along the coast during an outbreak of northwesterlies; there is a tendency to designate this trough as frontal, instead of correctly moving the front eastward, out of the region.
Occurs daily March through November.	d. Sea breeze - SW'ly 10 to 20 kt. Strongest 1500 LST to sunset.	d. Maneuvering room is limited in the harbor entrance. Movement of vessels with large sail area should be conducted before mid-afternoon.	d. Sea breeze is a daily occurrence March through November and raises a heavy chop outside the breakwater.
Occurs year-round. Strongest and most frequent in winter.	e. Southwest Swell - After southwest winds cease, swell can last an additional 36 hours. At onset, wave heights can be as high as 20 ft (6 m), diminishing with time.	e. Maneuvering room is limited in the harbor entrance so movements should be completed before the onset of bad weather or postponed until weather improves. Use caution on departure. Swell heights inside the harbor may be 7 ft (2 m) or less, while outside the harbor heights can be 20 ft (6 m).	e. Southwest waves will normally accompany the strong southwinds common in the Cartagena area. These waves will start as wind waves (seas) and gradually change to a mixture of sea and swell. After the wind stops, only swell will be observed. Southwest swell will reflect off of the land to the east of the outer anchorage and enter the harbor as southerly swell.

Table 3-1. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARDS	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
4. Small Boats Occurs year-round with highest frequency in summer but most intense in winter.	a. E'ly winds/waves - Levante Has minimal influence in the harbor but can cause SE'ly swell at the outer anchorage. In the cool season, usually accompanied by clouds and rain.	a. Inner harbor operations will be minimally affected. Runs to/from the outer anchorage may be curtailed due to southeasterly waves at the anchorage. Winds can change direction quickly, especially when the Levante is assocated with an approaching front.	a. The Levante occurs with several different weather patterns. The most typical is when the Azores high extends northeastward over Spain and southern France. Also, the Levante will precede the arrival of a cold front during the cool season. In this case, a lee trough forms in the region of the Balearic Islands. At times, an intense low will form south of the Balearics and gale force (30+ kt) can be expected along the east coast of Spain.
Occurs year-round. Strongest and most frequent in winter.	b. SW'ly winds - Vendaval Precedes cold fronts; strongest winds (34 to 47 kt) likely to occur in cool season. Precipitation usually accompanies the front but can be delayed as much as 12 hours after Vendaval wind onset.	b. Inner harbor operations will be minimally affected. Runs to/from the inner anchorage may be interrupted due to southerly waves at the inner anchorages. Runs to/from the outer anchorage will be affected even more as southwest waves can be much higher outside the harbor than inside. Boating can be curtailed for extended periods during Vendavals.	b. The most intense and frequent Vendavals are associated with cold fronts and any cold front has the potential for causing strong southwest winds; however, strong southwesterly winds can also occur at Cartagena when a high lying south of the Azores intensifies and a steep gradient develops between the high and migratory lows approaching the British Isles. Some indicators of southwest winds are: (1) Clouds atop Roldan Peak to the west of the harbor, on an otherwise cloudless day, indicate southwest winds the next day; (2) A low, long period swell will arrive at the anchorage a day before the onset of winds; and (3) A clear night with bright stars will indicate southwest winds the next day.
Strongest and most frequent in winter. Also occurs in spring and autumn.	c. NW'ly winds - Poniente Follows cold fronts in the cool season. Winds can last for days at 15 kt with peaks to 30 kt.	c. Inner harbor operations will be minimally affected. Also, runs to/from the outer anchorage will not be affected to a great extent because of fetch limitations on wave heights. The Poniente winds associated with frontal passages are normally strong for only one or two hours so delays in boating are minimal.	c. Any cold front can be followed by a Poniente wind. In the Cartagena area, strong winds are not usually long-lived but can be gale forece (30+ kt) for an hour or two. Forecasters should be aware of the lee trough that forms along the coast during an outbreak of northwesterlies; there is a tendency to designate this trough as frontal instead of correctly moving the front eastward, out of the region.
Occurs daily March through November.	d. Sea breeze - SW'ly 10 to 20 kt. Strongest 1500 LST to sunset.	d. Small boating typically secured outside breakwater 1500 LST to sunset.	d. Sea breeze is a daily occurrence March through November and raises a heavy chop outside the breakwater.
Occurs year-round. Strongest and most frequent in winter.	e. Southwest Swell - After southwest winds cease, swell can last an additional 36 hours. At onset, wave heights can be as high as 20 ft (6 m), diminishing with time.	e. Inner harbor operations will be minimally affected. Runs to/from the inner anchorage can be curtailed as some waves will enter the harbor. The outer anchorage is much more affected and boating can be curtailed for as long as 24 to 36 hours due to swell.	e. Southwest waves will normally accompany the strong southwinds common in the Cartagena area. These waves will start as wind waves (seas) and gradually change to a mixture of sea and swell. After the wind ceases, only swell will be observed. Southwest swell will reflect off the land to the east of the outer anchorage and enter the harbor as southerly swell.

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PORT VISIT INFORMATION

MAY 1987. NEPRF meteorologists D. Perryman and R. Miller met with LCDR, USN Patrica Rios NAVSTA Rota DET Cartagena, the Port Captain and the Chief Pilot to obtain much of the information included in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN-BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period ($f = 1/T$) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \tag{1.2}$$

Where v is wind speed in knots and $\bar{T}$ is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \tag{1.3}$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \tag{1.4}$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) (hrs)	Sig Wave (H1/3 Period/Height (sec) (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

1 Depth throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

2 For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell there wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

<u>Format:</u> height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

<u>WIND FORECAST OR CONDITION</u>

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

<u>SEA FORECAST OR CONDITION</u>

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

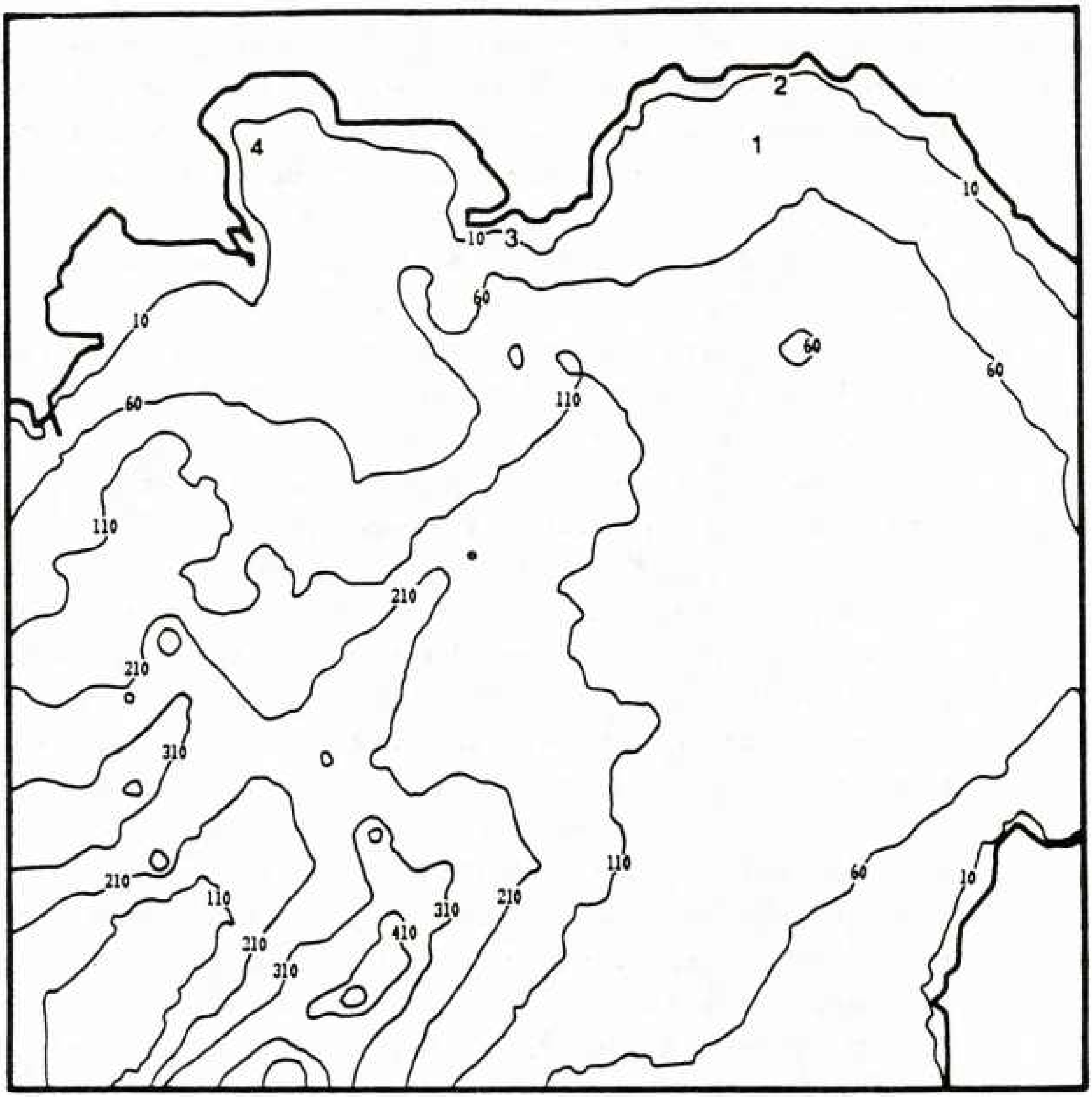

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathom contour. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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