

 DESIGN PRACTICES	MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS	Section	Page
		XXXI-C	1 of 43
		December, 2000	

CONTENTS

Section	Page
SCOPE	4
REFERENCES	4
INTRODUCTION	4
FACILITY TYPES	5
DATA NEEDS	9
NAVIGATIONAL APPROACH	9
ORIENTATION OF PORT ENTRANCE & CHANNELS	10
WIDTH OF PORT ENTRANCE & CHANNELS	12
Channel Bends	13
Channel Side Slopes	14
Maneuvering Area & Turning Basin	14
Area Alongside the Berth	14
Water Depth	15
LOCATION AND ORIENTATION OF FIXED BERTH(S)	15
ENVIRONMENTAL CONDITIONS	15
SPACING GUIDELINES	15
SPECIAL CONSIDERATIONS FOR LNG BERTHS	16
LAYOUT OF BREASTING AND MOORING DOLPHINS	17
LOADING PLATFORMS	17
Elevation	17
Alignment & Setback	18
Dimensions	18
EQUIPMENT SPACING	19
Loading Arms	19
Hose / Hose Tower	21
BUNKERING	22
GANGWAYS (POWERED / MANUAL)	23
PIPELINE MANIFOLDS	24
METER RUNS / PROVERS	27
OPERATOR'S SHELTER	27
CRANES (HOSE / GANGWAY HANDLING OR MAINTENANCE)	28
CONTAINMENT AREA	28
FIRE FIGHTING (PUMPS, DRUM, MONITORS, ETC.)	29
Fire Pumps	29
Foam Tanks	30
Water / Foam Monitors	30
Fire Hydrants / Hose Reels	30
Fire Equipment Cabinet	30
EMERGENCY ISOLATION EQUIPMENT	30



Section XXXI-C	Page 2 of 43	MARINE TERMINAL	ExxonMobil
December, 2000		FACILITY LAYOUT CONSIDERATIONS	DESIGN PRACTICES

CONTENTS (Cont)

Section	Page
UTILITY RACKS, BACKFLOW PREVENTER & METER	31
ELECTRICAL PANELS / JUNCTION BOXES	32
OIL SPILL RESPONSE EQUIPMENT	32
MVR VAPOR HEADER & ARRESTORS	32
WALKWAY / OPEN AREAS	32
SMALL CRAFT / LAUNCH ACCESS.....	32
ACCESS TRESTLE	33
OTHER FACILITIES AND EQUIPMENT	36
ANCHORAGE.....	36
Breakwaters	37
Navigational Aids	38
Small Boat Harbor.....	38
Tier 1 Oil Spill Response Equipment	38
BUOY TERMINALS (MBM & SPM).....	38
LOCATION	38
ORIENTATION	40
Water Depth.....	40
CBB SHIP ANCHOR LAYOUT CONSIDERATIONS	40
CBB BUOY LAYOUT CONSIDERATIONS	41
CBB PLEM LOCATION CONSIDERATIONS	43
TABLES	
Table 1 Port Entrance Channel Segment Length.....	10
Table 2 Loading Arm Spacing Guidelines	19
Table 3 Loading Arm Setback Guidelines	20
Table 4 Space Guidelines for Meter Runs	27
Table 5 Space Guidelines for Meter Provers	27
Table 6 Space Guidelines for Isolation Valves	30
Table 7 Pipeline Loop Dimensions.....	36
Table 8 Tanker Anchor Chain Length	40



 DESIGN PRACTICES	MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS	Section	Page
		XXXI-C	3 of 43
		December, 2000	

CONTENTS (Cont)

Section		Page
FIGURES		
Figure 1	Types of Conventional Piers	6
Figure 2	Types of Sea Islands	6
Figure 3	Types of Multiple Buoy Berths	7
Figure 4	Types of Single Point Mooring Berths	8
Figure 5	Channel Sections	9
Figure 6	Types of Harbors / Ports	11
Figure 7	Navigational Channel Lane Types	12
Figure 8	Channel Segment Arrangement	13
Figure 9	Layout of Widened Parallel Bends	14
Figure 10	Finger Pier Spacing	16
Figure 11	Loading Platform Alignment & Setback	18
Figure 12	Loading Arm Layout and Spacing	21
Figure 13	Space Allocation for Hose Towers	22
Figure 14	Space Allocation for Tower Gangway	24
Figure 15	Pipeline Manifold Layout -- Single Corridor Arrangement	25
Figure 16	Pipeline Manifold Layout -- Dual Corridor Arrangement	26
Figure 17	Meter Run -- Typical Arrangement	27
Figure 18	Meter Prover -- Typical Arrangement	28
Figure 19	Typical Layout for Firewater Pump Station	29
Figure 20	Isolation Valve -- Vertical Installation	31
Figure 21	Isolation Valve -- Horizontal Installation	31
Figure 22A	Access Trestle Arrangement #1	33
Figure 22B	Access Trestle Arrangement #1	34
Figure 23A	Access Trestle Arrangement #2	34
Figure 23B	Access Trestle Arrangement #2	35
Figure 24A	Diameter of Free-Swinging Anchorage Areas	37
Figure 24B	Maneuvering at Conventional MBM's	39
Figure 25	Layout of SPM's	39
Figure 26	Layout of MBMs	41
Figure 27	MBM with Forward Breast Buoy	42

Revision Memo

12/00 Initial issue of Design Practice XXXI-C.

**Documents**

Document Sharing Hub

ExxonMobil Research and Engineering Company – Fairfax, VA

Section XXXI-C	Page 4 of 43	MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS	ExxonMobil DESIGN PRACTICES
December, 2000			

SCOPE

This design practice covers the layout and spacing considerations for conventional piers, sea islands, multi-buoy moorings, and single point moorings. These considerations are primarily intended to apply to the design of new terminals or new berths at existing terminals. This Design Practice may also be used to determine if an existing berth is suitable to handle a different size / type of vessel.

This Design Practice provides general guidelines and rules of thumb for use in the early planning phases of projects (Gate 1 review). These considerations should be supplemented and reconfirmed by detailed studies e.g. shiphandling simulation, model testing, mooring analysis, numerical modeling of coastal processes, etc prior to project approval and final design.

Because the basic units for this technology are metric, the usual convention of using customary first has been reversed for the units.

REFERENCES

DESIGN PRACTICES

- [Section XXXI-I](#) Safety Considerations for the Design of Marine Terminals
- [Section XXXI-L](#) Evacuation, Egress, and Safe Haven Considerations
- [Section XXXI-M](#) Fender Systems

INTERNATIONAL PRACTICES

- [IP 3-2-3](#) Firewater Systems
- [IP 3-7-1](#) Piping Layout, Supports and Flexibility

OTHER REFERENCES

1. *Approach Channels – A Guide for Design*, Permanent International Association of Navigation Congresses (PIANC), June 1997
2. *Site Selection and Design for LNG Ports and Jetties*, Society of International Gas Tanker and Terminal Operators, Information Paper 14, 1st Edition, January 1997
3. *Design Manual 26.1 – Harbors*, Naval Facilities Engineering Command, December 1984
4. *Port Engineering – Volume 1*, 4th Edition, Per Brun, Gulf Publishing, 1989
5. *Underkeel Clearance in Ports*, Exxon International Tanker Department, EIL.1TTM.82, Nov. 1982
6. *Design Manual 25.1 – Piers & Wharves*, Naval Facilities Engineering Command, October 1987
7. *Marine Safety Criteria for Industry Vessels in ExxonMobil Service*, International Marine Transportation Ltd., 2000 Edition
8. *Planning and Design of Pier Facilities*, Mobil Technology Company, MP 05-P-02, July 1999
9. *Manual of Petroleum Measurements*, API
10. *Shore Protection Manual*, US Army Corps of Engineers, 1984
11. *Planning and Selection Guide for Oil Spill Response Equipment*, ER&E Report No. EE.39E.93
12. *Rules for Classifying and Building Steel Vessels-Part 3*, American Bureau of Shipping (ABS), 1997

INTRODUCTION

The siting and layout of a berth and the navigational approach are critically important to a project with respect to risk prevention, berth operability, and investment costs. The orientation, layout and dimensioning of navigational channels and maneuvering areas should be properly determined in order to reduce the probability of port passage collisions and grounding incidents. Conventional piers, Sea Islands, and multiple buoy moorings (MBM) should be carefully positioned and oriented to minimize exposure to waves so that berth downtime is minimized. The investment cost will be significantly impacted if a pier or sea island is positioned without suitable natural sheltering thus requiring construction of a breakwater. The need for dredging and/or installation of a long access trestle or submarine pipeline length from shore can also significantly affect the investment cost. The layout of the berth structures and loading platform can help to prevent and mitigate berth-related incidents (berthing, mooring, fires, etc.).

 DESIGN PRACTICES	MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS		Section	Page
			XXXI-C	5 of 43
	December, 2000			

FACILITY TYPES

Many different types of marine facilities exist to satisfy different geographical conditions, environmental conditions, and operating requirements. Marine berth facilities are broadly classified into the following four categories:

- Conventional Piers
- Sea Islands
- Multiple Buoy Moorings (MBM)
- Single Point Moorings (SPM)

Downstream terminals typically fall in the first three categories with most being conventional piers. Upstream terminals frequently are of the single point mooring type.

Conventional Piers - Encompass all variations of wharf, bulkhead, breasting platform and dolphin-type piers. Conventional piers are generally sub-categorized into the following two types of piers based on their orientation to the shoreline:

- **Marginal Pier** – Oriented parallel to the shoreline because of current patterns or pier line or channel restrictions.
- **Finger Pier** – Oriented perpendicular to the shoreline usually due to limited waterfront area and the need for multiple berths

Breasting Dolphins – A water based structure, independent of the loading platform, that absorbs the impact of a berthing ship and against which a moored ship breasts.

Breasting Platform – A water based structure that serves the dual purpose of breasting dolphins and a loading platform.

Bulkhead / Quay Wall – A continuous faced, land based type of pier typically oriented parallel to the shoreline and backed by fill.

Loading Platform – A water based structure used to support cargo transfer equipment, firefighting and safety equipment, sumps, etc. when breasting dolphins are used.

Mooring Dolphin – A water based structure, independent of the loading platform, to which the vessel's mooring lines are attached.

Mooring Point – A land based structure, to which the vessel's mooring lines are attached.

Trestle – A water based structure used to connect a breasting or loading platform to shore. Trestles usually consist of pipe supports and a roadway.

Turning Dolphin – A water based structure, located at the offshore end of a finger pier that may be contacted by the vessel during the turning maneuver into the berth and to which the vessel's mooring lines are attached.

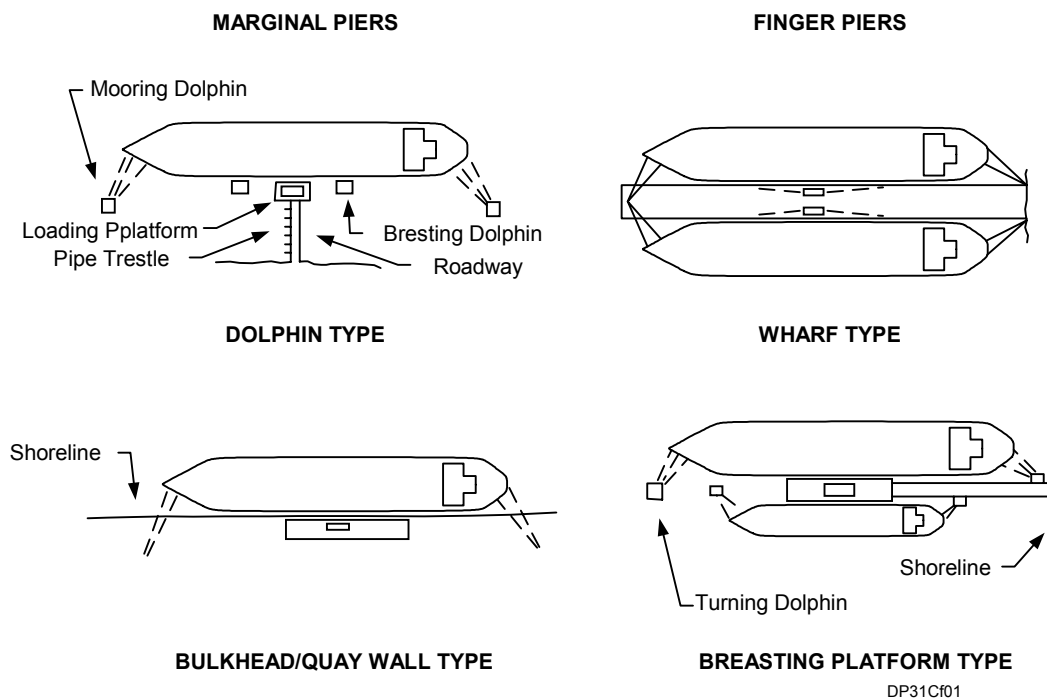
Wharf – A continuous faced, water based type of construction used for finger piers and supported on piles.

Generally, dolphin type piers usually require less investment than wharf or bulkhead type terminals. Bulkhead type terminals are normally suitable for water depths of 7 meters or less. Breasting platforms are generally not recommended due to concerns of possible damage to cargo transfer equipment (and spill) should a berthing incident occur.

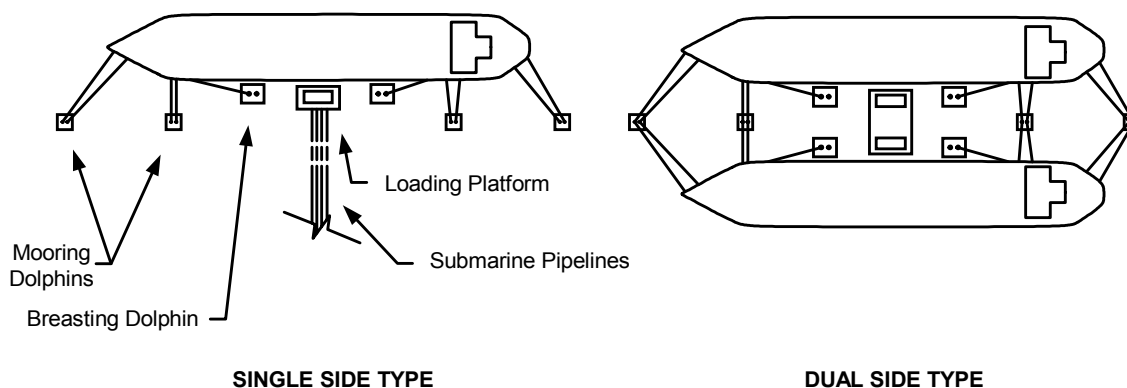


MARINE TERMINAL
FACILITY LAYOUT CONSIDERATIONS

FACILITY TYPES (Cont)

FIGURE 1
TYPES OF CONVENTIONAL PIERS

Sea Islands – Offshore berths that are similar in construction to dolphin or breasting platform types of conventional piers except that their only connection to shore is by submarine pipelines. Sea Islands can be designed to service ships on one or both sides.

FIGURE 2
TYPES OF SEA ISLANDS

ExxonMobil DESIGN PRACTICES	MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS	Section	Page
		XXXI-C	7 of 43
		December, 2000	

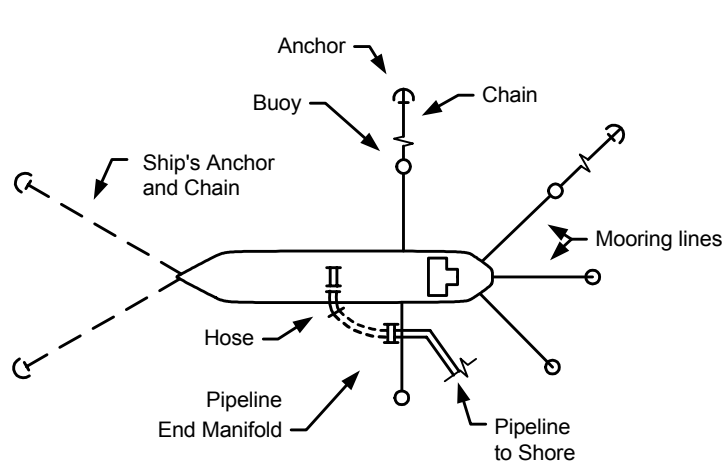
FACILITY TYPES (Cont)

Multiple Buoy Moorings (MBM) – There are two main categories of Multiple Buoy Moorings (MBM):

- Conventional Buoy Berth (CBB)** Offshore berths in which the ship's bow is held in position by the ship's own anchors while 3 to 7 mooring buoys are used to secure the stern. CBB are the most common type of MBM.
- All Buoy Berth (ABB)** Offshore berths in which both the ship's bow and stern are held in position by a total of four to eight mooring buoys. ABB's are generally located where bottom conditions prevent the use of ship's anchors or where additional mooring restraint is needed for the expected environmental conditions.

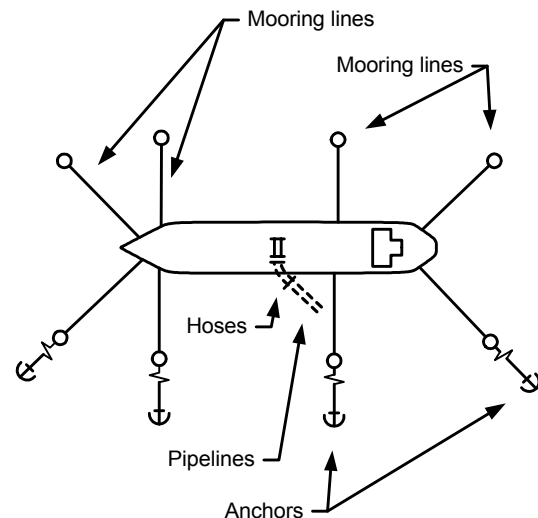
At buoy berths, submarine pipelines run from shore tankage to the area of the buoys. Loading or unloading operations are accomplished through a system of flexible hoses that are connected between the submarine pipeline end manifold and the ship's manifold.

FIGURE 3
TYPES OF MULTIPLE BUOY BERTHS



CONVENTIONAL BUOY BERTH (CBB)

(May have 3,5,or 7 Buoys, Shown Above)



ALL BUOY BERTH (ABB)

DP31Cf03

Single Point Moorings (SPM) – At SPMs, ships are moored with only a bowline to a single buoy or tower. Consequently, the ship is free to weathervane around the point to which the bowline is attached. The cargo is transferred by rubber hoses between the ship's manifold and a cargo swivel located on the SPM. The two most common types of SPM's are:

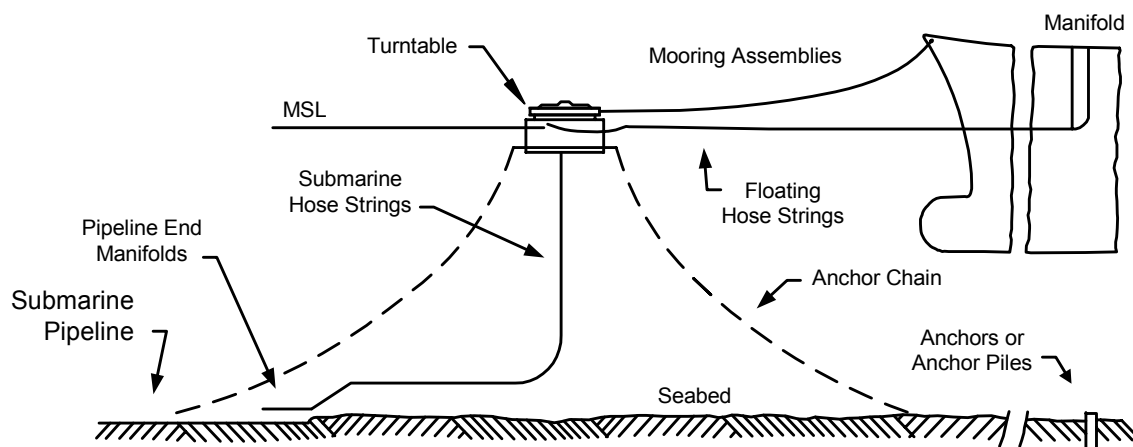
- CALMs** Catenary Anchor Leg Moorings are comprised of a single buoy restrained by a five to eight conventional chain-anchor legs. The cargo is conveyed between the submarine pipeline and the buoy by submarine hoses. The mooring line is connected to the cargo swivel on the buoy by a lever arm. This device is used to rotate the swivel with the mooring line. Floating hoses connect the cargo swivel on the buoy to the vessel manifolds. CALMs are the most common type of single point mooring.
- SALMs** Single Anchor Leg Moorings are comprised of a buoy moored by means of one vertical chain or pipe attached to a single base anchored to the seabed. The cargo is transferred from a submerged cargo swivel to the ship's manifold by rubber hoses. The swivel is turned by the cargo hoses. The ship's bow mooring line is attached to the buoy.



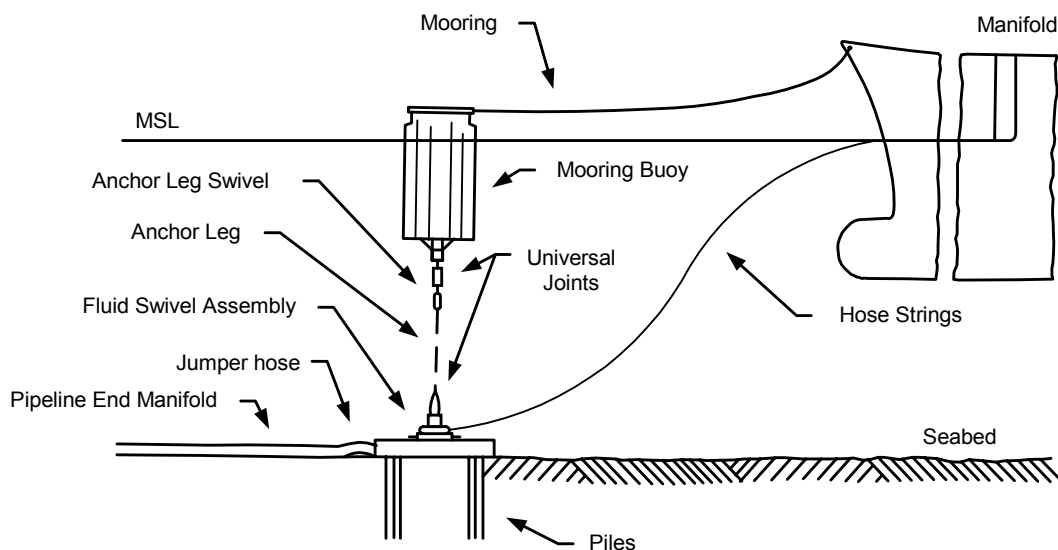
MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS

FACILITY TYPES (Cont)

**FIGURE 4
TYPES OF SINGLE POINT MOORING BERTHS**



TYPICAL CALM SYSTEM



TYPICAL SALM SYSTEM

DP31Cf04

ExxonMobil DESIGN PRACTICES	MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS	Section	Page
		XXXI-C	9 of 43
		December, 2000	

DATA NEEDS

The principal information needed for the siting and layout of the berth and navigational channel include:

- Hydrographic Charts & Bathymetry
- Tidal Range & Water Level Variations
- Environmental Conditions:
(For different return periods)
 - + Wave Intensity & Direction
 - + Current patterns, velocity & direction
 - + Wind Rose
 - + Other (seismicity, ice, fog, etc.)
- Geotechnical Information of Seabed Conditions & Materials
- Location of Environmentally Sensitive Areas and Navigational Restrictions
- Fleet of Vessels (parameters for expected range of products and sizes)

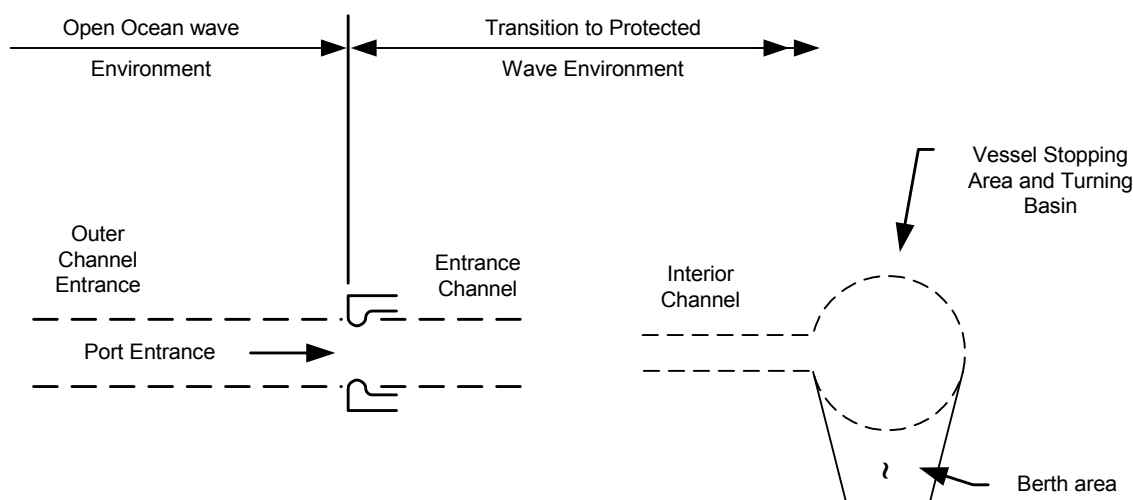
NAVIGATIONAL APPROACH

The general location of the terminal site and the navigational approach often will be dictated by the proximity to the onshore process or producing facilities. Guidelines for port siting are not covered in the Design Practice. Siting guidelines are covered in References 1-4. Layout, orientation and dimensioning of navigational approaches should be jointly developed in consultation with a nautical specialist from one of ExxonMobil's marine transportation companies (SeaRiver Maritime or International Marine Transportation).

For a particular site location, the first step in developing a preliminary layout of the navigational approach is to subdivide it into sections based on the severity of the environmental conditions. Typically, these sections include (**Figure 5**):

- Outer Approach Channel & Port Entrance
- Inner Approach Channel
- Vessel Stopping Area and Turning Basin
- Berth Maneuvering Area

FIGURE 5
CHANNEL SECTIONS



DP31Cf05

BERTHS MANEUVERING AREA



Section XXXI-C Page 10 of 43		MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS	ExxonMobil DESIGN PRACTICES
December, 2000			

NAVIGATIONAL APPROACH (Cont)

The terminal may be sited within different types of natural or artificially protected harbors (**Figure 6**) that include land extensions (man-made or natural) that border and protect the inner port area. The port entrance provides vessel passage from the outer channel in the open sea to a wave-sheltered inner channel and berth area. Where there is no defined barrier, the entrance to the dredged approach channel may be considered as the port entrance. In the latter case, the design of the approach channel from the sea entrance to the maneuvering area at the berth should be adjusted along its length to account for the differences in natural sheltering and environmental conditions.

ORIENTATION OF PORT ENTRANCE & CHANNELS

The principle considerations governing the layout of channels are:

- Shortest channel length
- Conditions / basins at either end of the channel
- The need to avoid obstacles that are difficult / costly to remove / dredge and areas subject to high siltation rates that would require excessive maintenance dredging
- Prevailing winds, currents and waves
- Avoiding bends near port entrances
- The edge of channels should be positioned such that passing ships do not damage neighboring berths, facilities and do not cause excessive movements / forces on moored vessels.
- Channels should be oriented parallel to the berth lines and directed to a safe position off the berth (to avoid possibility of direct collision with the berth if vessel engine fails).

The outer channel and port entrance should be designed so that the action of waves, currents and winds are directed as close as possible toward the bow or stern of the ship. Both outer and inner channels should follow as straight a line as possible. Bends in close proximity to the entrance should be avoided with straight channel segments extending to and from the entrance. Length of straight segments on either side of the port entrance should be set based on length of the largest vessel and speed per **Table 1**.

TABLE 1
PORT ENTRANCE CHANNEL SEGMENT LENGTH

PORT ENTRANCE CHANNELS	
VESSEL SPEED, (KNOTS)	STRAIGHT SEGMENT LENGTH*
5 - 8	2.5-3 L
8 - 12	3-4 L
> 12	4-5 L

* - Multiplier of largest vessel LOA

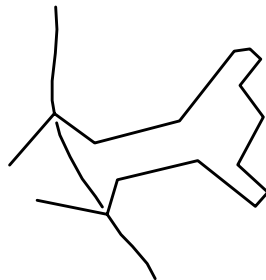
The effect of cross currents, winds or waves together with limited maneuverability or speed results in vessels proceeding forward at a small angle (drift) to their correct course. The orientation of the channel / entrance should consider the environmental conditions and vessel maneuverability and should be adjusted as needed to ensure that the drift angle does not exceed 10 - 15 degrees.

ExxonMobil DESIGN PRACTICES	MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS	Section XXXI-C	Page 11 of 43
		December, 2000	

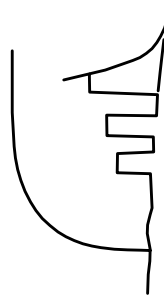
NAVIGATIONAL APPROACH (Cont)

FIGURE 6
TYPES OF HARBORS / PORTS

ARTIFICIAL HARBORS

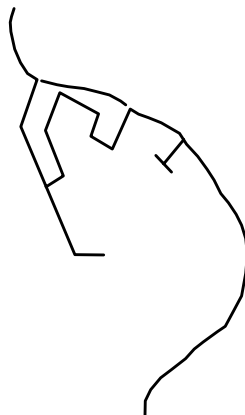


Inland Basin

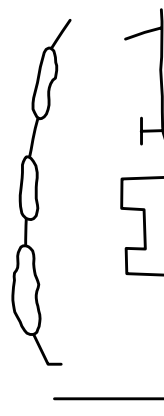


Offshore Basin

PROTECTED HARBORS



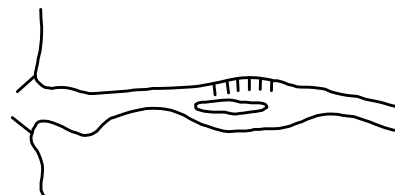
Bay Indentation



Offshore Island



Natural Harbor



River Harbor

DP31Cf06

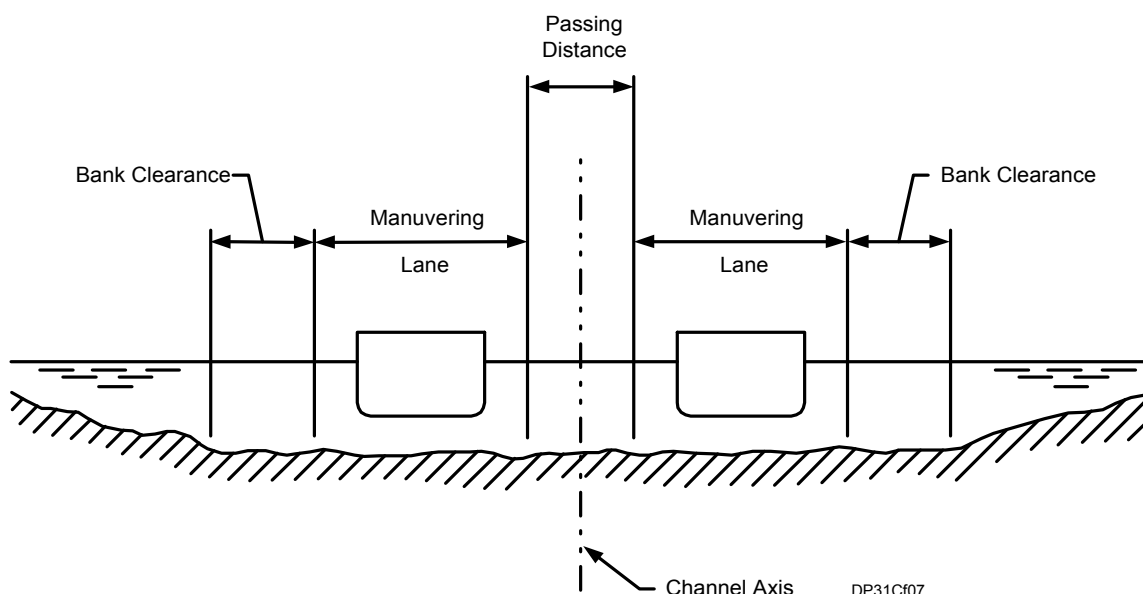
Section XXXI-C	Page 12 of 43	<i>MARINE TERMINAL</i> FACILITY LAYOUT CONSIDERATIONS	 DESIGN PRACTICES
December, 2000			

NAVIGATIONAL APPROACH (Cont)

WIDTH OF PORT ENTRANCE & CHANNELS

Channels can be classified for either one way or two way ship traffic. The width of a channel for one way traffic is determined by subdividing into “lanes”, a basic maneuvering lane with additions for environmental and operational conditions and a bank clearance on each side of the channel. For channels with two-way traffic, an additional lane or width for the passing clearance between ship lanes is provided. The lanes are illustrated on **Figure 7**.

FIGURE 7
NAVIGATIONAL CHANNEL LANE TYPES



The basic maneuvering lane is the vessel's beam plus the distance required for the pilot to identify and execute a required change in course. This lane is expanded to account for the additional channel width necessary to contain the ship's track due to wind, wave, and current effects and account for other operational factors. A bank clearance is included on each side of the channel if there is a natural bank or bank created by dredging.

The width of the channels and port entrance should be determined in accordance with Reference 1 with the following input data:

- Maximum Vessel Size (Length & Beam)
- Channel Use (one-way or two-way)
- Vessel Maneuverability
- Vessel speed
- Prevailing cross wind & current, longitudinal current, & wave conditions
- Navigation aids
- Depth to draft ratio
- Seabed conditions
- Cargo Hazard Level
- Bank Condition
- Port Traffic Density

Reference 1 (Section 5.3) defines the channel width as a multiple of the ship beam based on the above factors. Different values are provided for outer channels exposed to open sea and for inner channels in protected waters. Values for outer channels should be selected if the section of channel is exposed to waves of significant wave height of 1 meter or more. Channel use i.e. one-way or two-way, should consider the number of vessels calling at the terminal and any other traffic calling at other terminals within the port. The operational delay cost of incoming vessels awaiting departure and clearance of outgoing vessels needs to be weighed against the additional investment cost of dredging a wider channel.

ExxonMobil DESIGN PRACTICES	MARINE TERMINAL FACILITY LAYOUT CONSIDERATIONS	Section XXXI-C	Page 13 of 43
		December, 2000	

NAVIGATIONAL APPROACH (Cont)

Moderate vessel maneuverability may be assumed for most tankers and gas carriers in selecting the width of the basic maneuvering lane width (1.5 times beam) from Reference 1. Assumptions regarding vessel speed should be checked with a nautical specialist from one of ExxonMobil's marine companies (SeaRiver Maritime or International Marine Transportation). The selection of environmental parameters should reflect site-specific meteocean conditions and be set high enough to avoid excessive port downtime. The value of the navigational aid factor should be assumed as moderate for most port locations unless site-specific visibility conditions warrant an adjustment. Cargo hazard should be assumed as moderate for tankers and high for gas carriers. Reference 2 states that the total channel width should be about five times the beam for LNG ships.

The width of the port entrance should be determined from Reference 1 using the above approach or set equal to the vessel length, whichever is greater.

Channel Bends

A channel bend should be included in a design only where absolutely necessary. Channel bends increase the risk of vessel grounding due to failure of the steering gear or human error. The change in water flow in a bend will also affect the handling of the vessel and requires more width than a straight section. Other factors that increase the difficulty of maneuvering in a bend include the reduction of clear sight distance and navigational aid effectiveness.

Where possible, channels should also be oriented to meet the following idealized objectives:

- A single curve is preferred over a sequence of smaller turns at close intervals, provided the channel is clearly marked.
- Straight segments with lengths not less than five times the vessel LOA should separate successive bends (**Figure 8**).

FIGURE 8
CHANNEL SEGMENT ARRANGEMENT

