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Oil Spill Risk Assessment Model and the Ranking of Ports for Oil Spill Vulnerability

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16. Abstract

The U.S. Coast Guard's Marine Safety Office (MSO) of each port is required to develop contingency plans to respond to oil spills. The contingency plans at present do not use rigorous risk assessment procedures to identify the spectrum of spills that are possible in each port and estimate the frequency of occurrence of different size spills. In order to provide these procedures, there was a need to develop, for use in contingency planning, a uniform guidance methodology based on risk assessment principles. The development of port specific oil spill risk assessment methodology is described in this report.

The port model takes into consideration the specifics of the water body in the port, vessel traffic, current or projected oil transport volume into the port per year, size distribution of vessels, as well as the size distribution of the oil carrying vessels (tankers and barges), weather and channel characteristics, etc. The model uses the accident risk factors for a number of U.S. ports developed in the Ports Need (Vessel Traffic Services Benefit) Study and takes into account the reduction in the vessel accident rate due to the provision of vessel traffic management systems. The output from the risk model is a histogram of the frequency of accidents vs the size of potential spill volume. A PC based computer program ("OILRISK") has also been developed to calculate the risk for any port.

Using the results, the spill risks in different ports can be compared and the ports ranked based on the susceptibiity to small, medium and large spills. The oil spill risk for a number of major U.S. ports has been calculated and presented.

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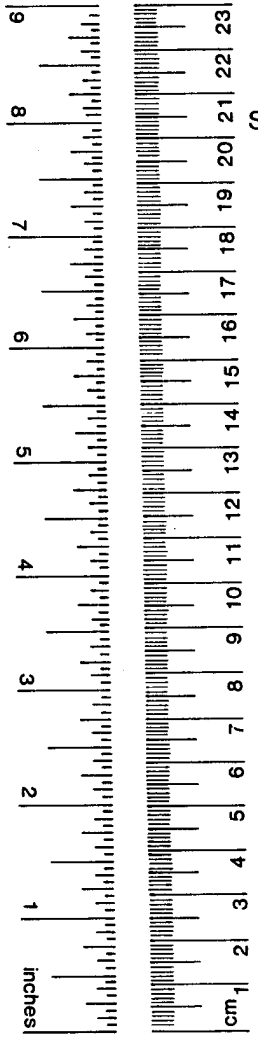
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

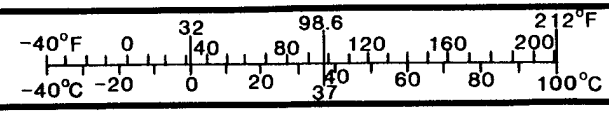
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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CHAPTER 1

Introduction

1.1 BACKGROUND

The Federal Water Pollution Control Act (FWPCA) was passed in 1972. Based on the authority provided in the Act (33 USC 1151, et sequ.), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) has been developed and published (40 CFR 300). This Plan provides for a pattern of coordinated and integrated response by Departments and Agencies of the Federal Government to protect the environment from damaging effects of pollution spills. It also promotes the coordination and direction of Federal, State and local response systems and encourages the development of local government and private capabilities to handle pollution spills. The plan also provides for coordinated Federal action to prevent discharges of oil and designated substances into the navigable waters of the United States and to protect the environment from damage caused by discharges. Pre-designated federal On Scene Coordinators (OSC) have responsibilities to coordinate the federal response to remove discharges as they occur.

The objectives of the NCP are to provide for efficient, coordinated and effective action to minimize damage from oil and hazardous substance discharges, including containment, dispersal and removal. The plan, among other things, calls for the (i) assignment of duties and responsibilities among various Federal, State and Local jurisdictions, (ii) development of contingency plans to combat potential oil or other hazardous material spills, and (iii) establishment and identification of strike forces and emergency task forces, etc.

The development of the U.S. Coast Guard's (USCG) Marine Environmental Protection program was the direct result of the requirements under the NCP. The USCG provides OSC's for coastal waters, specified ports and harbors on the inland waterways and the Great Lakes. The Environmental Protection Agency (EPA) has jurisdiction over all other inland water and land areas. The authority granted in the FWPCA and Executive Orders 11735 and 12316 assign certain functions and responsibilities to several different Federal agencies to carry out the provisions of the Acts. These Federal agencies meet at the national level, forming the National Response Team (NRT) and at the Regional level forming the Regional Response Teams (RRTs). These organizations serve as coordinating bodies and provide technical, planning and other non intervention assistance to the OSC.

In order to be prepared for responding to a potential spill of oil or other hazardous substance, the USCG has required all Marine Safety Offices (MSOs) to develop

contingency plans. These contingency plans are written documents which indicate the procedures to be followed (both management and technical) and the resources that need to be applied to combat spills of specific substances within the jurisdiction of the particular COTP or the Region. These plans cover a spectrum of issues including, (i) notification procedures, (ii) responsibility of both USCG and other members of the RRT, (iii) organization structure for response, (iv) planning, (v) incident assessment and technical response procedures, (vi) nature and quantity of resource requirements, etc.

The effectiveness of a Contingency Plan depends on the depth of evaluations and considerations of different types of events that could occur and the nature, type and level of response that have been taken into consideration during the development process. The contingency plans developed by different ports vary both in quality and considerations of various quantitative aspects of a potential release of oil or a hazardous material. It is, in general, difficult to assess, *a priori*, the effectiveness of a plan prior to its actual use in a real emergency.

The U.S. Coast Guard has recognized that it is essential to provide a uniform guidance methodology for use in the development or assessment of contingency plans. This methodology can then be utilized by all ports to either generate new contingency plans or to review their current plans so that all potential hazardous situations are considered in a structured approach. This is particularly true of potential oil spill events. It is necessary to conduct a standardized analysis (in all ports) to effectively determine the largest spill that can potentially occur, causes of spills and an assessment of how such spills can be responded to effectively. In other words, a formalized risk analysis based methodology development is needed which can then be applied to all ports in the U.S. without regard to the location of the port, port size, traffic volume, or other peculiarities. That is, the USCG has been interested in developing a generic system for risk assessment methodology which will form the foundation in the formulation of contingency plans which are similar in layout irrespective of the size of the port. Only the length and content of such plans will differ dependent on the areas covered and the degree of risk.

The Oil Pollution Act (OPA, 1990) requires "the establishment of an Interagency Coordinating Committee on Oil Pollution Research consisting of representatives from several Federal Agencies. The committee was established to coordinate a comprehensive program of oil pollution research, technology development, and demonstration among the Federal agencies in cooperation with industry, universities, state and local governments to foster cost-effective research" and to minimize occurrence of oil spills and their effects on the environment (*OPA, 1990, Title VIII(2)*). This Interagency Coordinating Committee is to be chaired by a U.S. DOT agency. The USCG has been nominated to be the chairman of this committee. OPA further requires that the Committee conduct Marine Simulation Research including "contingency plan evaluation" (OPA, 1990, Title VII, Section 5(A)).

Under the purview of the directives of the above sections of the Act, the USCG has initiated a Spill Response System Configuration Model Development Study. The purpose of the study is to provide answers to such questions as:

1. What new equipment is required to insure better response to oil spills?

2. How should new and existing equipment be distributed?

3. What deficiencies would exist in the equipment inventories at each of the locations throughout the United States if there were to be a major oil spill?

4. Should the "blend" of equipment at all spill equipment sites be the same or are there special circumstances in some areas which require a different blend of equipment?

To answer these and other questions that the National Strike Force (NSF), Coast Guard Marine Safety (G-MS), and Coast Guard Marine Environmental Protection (G-MEP) may have concerning equipment resources, a configuration model development has begun. This model is expected to be a desktop, computer-based, interactive analysis model that could be used to answer the questions posed above, as well as other questions concerning the purchase and siting of equipment resources for oil spills. The model is anticipated to be capable of analyzing equipment needs for large spills, small spills, or even for analyzing the needs and requirements of distributing one type of equipment. The overall constituents of this configuration model are schematically illustrated in Figure 1.1.

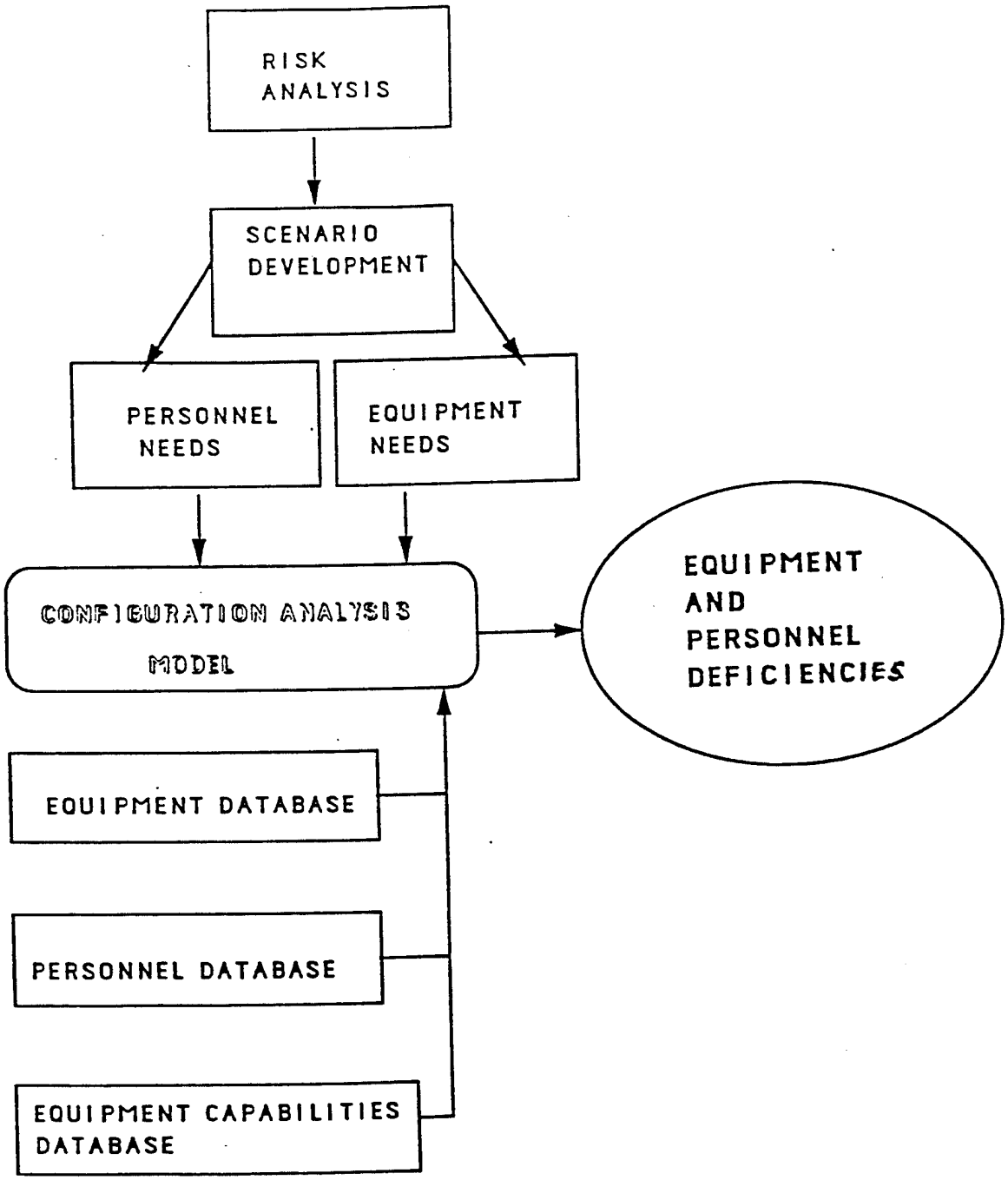
To determine the equipment and personnel that are needed for response to an oil spill, worst case scenarios need to be generated. These scenarios must be generated from risk assessments. Therefore, risk analysis forms the very first part of the overall configuration model development program. The subject of this report is the development of the oil spill risk analysis methodology. Indicated in the next section is a brief review of the current approaches used in risk analysis.

1.2 BRIEF REVIEW OF OIL SPILL RISK ANALYSIS MODELS

Over the past two decades a number of risk analysis models have been developed specifically to evaluate the potential risks associated with the transport and transfer of oil in and near ports. These models range in complexity from the very cursory back of the envelope type of analysis to very complex models that consider the influences of a large number of parameters including the environmental variables (such as the weather, ocean currents, tidal phases, etc.) and response variables. Reviewed below, in brief, are the different models that are currently available in the literature.

FIGURE 1.1

Constituents of the USCG's Configuration Model for the Spill Response System



1.2.1 NRT-1 Guideline

The National Response Team (NRT) has developed a quick hazard assessment approach, mostly applicable for fixed sites, which illustrates the methodology for conducting a simple hazard analysis for chemical and other hazardous substance storage facilities (NRT-1). This document is more useful for developing a contingency/emergency response plan than for performing a detailed risk analysis. The steps to perform risk analysis provide only the basic elements of a risk assessment procedure. For example, it is stated that the analyst should determine:

- the probability that a release will occur and any unusual environmental conditions, such as areas in flood plains, or the possibility of simultaneous emergency incidents.
- the type of harm to people (acute, delayed or chronic) and the associated high risk group.
- the type of damage to property (temporary, repairable, permanent); and
- the type of damage to the environment (recoverable, permanent).

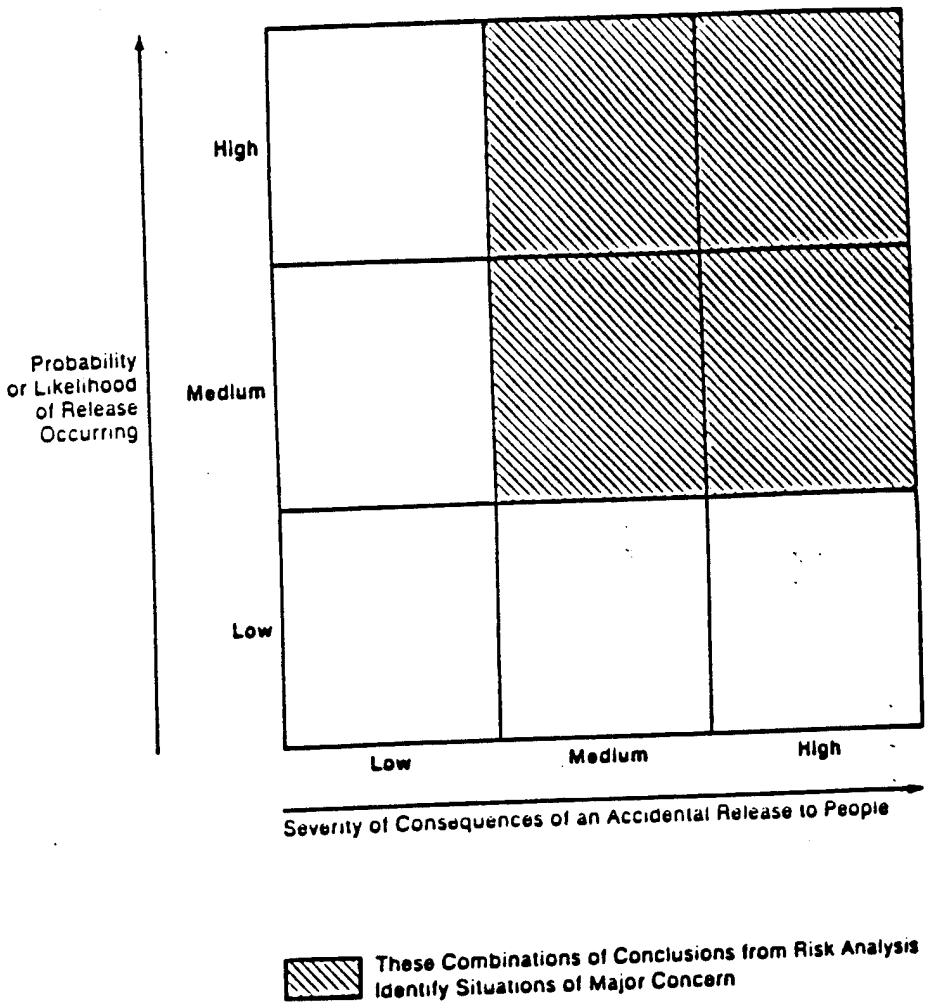
No other detailed step by step approach is provided. A companion document published by EPA, FEMA and the U.S. DOT provides somewhat more details of how to go about performing a risk assessment. Basically, the steps involve the following:

- collecting information on potential hazards from the operation (transport or storage of hazardous materials) and evaluation of the vulnerability of the local population and property to hazards.
- obtaining additional information on community and facility safeguards, response capabilities, and accident records.
- making judgment on probability of release and severity of consequences.
- organizing the information in a matrix format by grouping the probability of occurrence into "low, medium and high" categories and similarly categorizing the consequences into the same type of groupings. Figure 1.2 shows the risk matrix proposed indicating the high risk areas.

The procedure indicated in the above documents are very subjective and provides only broad guidelines.

FIGURE 1.2

Risk Matrix Indicated in NRT-1



1.2.2 MIL Standard 882-B Approach

MIL Standard 882-B stipulates a methodology by which screening risk analysis can be conducted on proposed systems. This standard stipulates that calculations be made of the hazard probability and the consequence. The hazard probability is categorized into 5 classes (A through E) and the consequences are categorized into 4 groups (I through IV). Figure 1.3a shows the hazard severity categories and Figure 1.3b shows the hazard probability categories. MIL Standard 882 B indicates the risk acceptability by defining various regions in the probability-consequence plane which are acceptable, undesirable, and unacceptable. Figure 1.3c shows the hazard risk indices and the acceptability criteria.

As can be seen in Figure 1.3a the hazard categories primarily refer to personnel injuries or deaths. These categories may, however, be applicable to oil spill risk analysis as well, if instead of personnel injuries and deaths, environmental damage and effect on marine mammals are considered.

The MIL Standard does not provide any guidance as to how to determine the probability category. Significant subjective judgment is involved. For example, the definition of the category of "probable" indicates that the event will occur frequently. What constitutes "frequently" is ill defined. In the case of oil tanker movements would one spill per year be considered as frequent or is one spill over the life of a tanker (say 20 years) "frequent?" There is less subjective categorization in the description of hazards, even though the application to the oil spill case may lead to a very subjective assessment.

1.2.3 The MMS Model

The Oil Spill Risk Analysis model *(Anderson, et al, 1987)* developed by the Minerals Management Service (MMS) of the U.S. Department of Interior has been primarily used in determining the effect of off shore oil leases on the environment, particularly on the beaches and marine mammal breeding grounds on the California coast. The model is stochastic in nature and contains principally two parts. The first part is the determination of the probability of spills at various geographic locations (on the leased area of the ocean) due to (i) production wells, (ii) lightering operations and (iii) normal tanker traffic on the leased area. The second part of the calculation involves the determination of the probability of impact on a particular shore line area due to a spill at a specified location off shore. The calculation involves the tracking of the oil slick, taking into consideration the variabilities in the environmental parameters (wind, currents, tidal currents, etc).

FIGURE 1.3a

Undesired Event Severity Categories

CATEGORY	SEVERITY	CHARACTERISTICS
I	Catastrophic	Death to person or employee, loss of system
II	Critical	Severe injury to public or employee, or major system damage.
III	Marginal	Minor injury not requiring hospitalization or the hazard present does not by itself threaten the safety of the public. Also minor system damage.
IV	Negligible	Less than minor injury. Does not impair any of the critical systems.

FIGURE 1.3b

Undesired Event Probability Categories

CATEGORY	LEVEL	SPECIFIC EVENT
A	Frequent	Not an unusual event, could occur several times in annual operations.
B	Probable	Event could occur several times in the lifetime of the system.
C	Occasional	Expected to occur at least once in the lifetime of the system.
D	Remote	Event is unlikely to occur during the lifetime of the system.
E	Improbable	Event is so unlikely that it is not expected to occur in the lifetime of the system.

FIGURE 1.3c

Risk Assessment Matrix

FREQUENCY OF OCCURRENCE	UNDESIRED EVENT CATEGORIES			
	I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A) FREQUENT	IA	IIA	IIIA	IVA
(B) PROBABLE	IB	IIB	IIIB	IVB
(C) OCCASIONAL	IC	IIC	IIIC	IVC
(D) REMOTE	ID	IID	IIID	IVD
(E) IMPROBABLE	IE	IIE	IIIE	IVE

RISK INDEX

IA, IB, IC, IIA, IIB, IIIA	UNACCEPTABLE
ID, IIC, IID, IIIB, IIIC	UNACCEPTABLE (MANAGEMENT DECISION REQUIRED)
IE, IIE, IIID, IIIE, IVA, IVB	ACCEPTABLE WITH REVIEW BY MANAGEMENT
IVC, IVD, IVE	ACCEPTABLE WITHOUT REVIEW

The MMS model does not identify the causes of release or even calculate different sizes of release due to different influencing parameters. The spill or release probabilities are calculated for 1000 bbls and greater spills and 10,000 bbl and greater spills using historical records. These volumes are used for the spill tracking calculations also. The spill statistic is assumed to follow the Poisson distribution.

The major effort in this model is the determination of the spill probability and the voluminous calculation of the slick path. Also, the environmental parameter data determination forms another significant effort in this model. The principle on which the model is based is relatively simple. Because of the large volume of calculations (especially the Monte Carlo technique of tracking the slick), the use of a high powered computer is necessary.

1.2.4 MIT Model

This model developed at MIT *(Psaraftis, et al, 1980)* utilizes a systems approach for formulating the overall problem of oil spill pollution response in the United States. The objective of the model is to provide a tool for analysis of the options available to policy makers on the most effective response actions.

This model is not strictly a "Risk Analysis" model but is a "Decision Model" with Functional Minimization of Selected Parameters or Actions. Oil spill response actions involve many actions each of which may conflict with another. For example, in responding to an oil spill the following "goals" may be of interest:

- Respond to the spill as fast as possible.
- Maximize the volume of oil recovered in containment and clean up operations.
- Minimize clean-up costs
- Minimize oil spill damage costs;
- Maximize protection of environmentally and economically sensitive areas;
- Maximize the use of non-dedicated clean-up equipment (e.g., barges or vessels of opportunity)

This model provides the policy makers with quantitative estimates of damage costs averted by any hypothetical system for oil spill response. It considers the spill response system in three hierarchical levels: strategic, tactical and operational. In the first level "Strategic," such variables as the <u>location types and quantity</u> of response equipment are considered. Tactical decisions are made in response to a <u>specific</u> spill. The model considers the tactical costs by evaluating, at an aggregate level, (i) the recovery capability to respond to the spill (ii) the specific sets of clean-up equipment deployed and (iii) the number of pieces of clean-up equipment deployed.

The focus of the MIT model is the cost of response. It does take into account the cost of damage to the environment and to the ocean creatures. It does also take into account the operational costs. It does not, however, provide any specific guidance as to what needs to be done or not done in terms of planning or locating the equipment and manpower resources. It also does not take into account the probabilities of various sizes of spills or which parameters need to be modified or minimized to reduce the spill probability. None of the models discussed above take into consideration details of vessel traffic, hydrographic parameters of the port, or other port specific factors.

1.2.5 Port Needs Study

The risk from spill of oil and other hazardous substances in different ports has been one of the issues addressed in a recently completed study *(Maio, et al, 1991)*. Several of the factors that have impact on the overall oil spill risk in a port have been studied and their values for 23 of the U.S. ports are indicated in the Port Needs Study.

The risk model described in this report is based, significantly, on the results from the Ports Needs Study. These port factors and their values are fully described in this report (Chapter 3).

The Port Needs Study did not address the issue of the oil risk profile for each port, nor did it compare relative port risks from the perspective of ranking the ports by susceptibility to oil spills. These issues form the basis of the work reported in this report.

1.3 PROJECT OBJECTIVES

The objectives of the project are to:

- identify important parameters that influence the effectiveness of an oil spill contingency plan;
- develop a generic risk analysis methodology applicable to all ports and which can be used for evaluating (and updating) the individual port contingency plans; and
- demonstrate the methodology developed to rank order the ports for oil spill susceptibility.

1.4 STATEMENT OF WORK

In order to achieve the above project objectives, a study consisting of the following tasks was undertaken.

Task 1: Analyze the Contingency Plan Reviews prepared by MSO/COTPs

Task 2: Prepare a list of variables that influence the risk factors for all ports

Task 3: Develop a standardized methodology for oil spill risk assessment

Task 4: Incorporate risk assessment methodology into a computer program

Our analysis of the contingency plan reviews submitted by the MSOs at various ports in response to the USCG Commandant's Directive of July 1989 are presented in Chapter 2. It is found that the contingency plan reviews are neither uniform in content nor are they based on a comprehensive assessment of the different magnitude of potential spills, at different times of year, and in different locations. Also, no formal evaluation procedures are indicated for judging the effectiveness of equipment and personnel currently available at each port to respond to any magnitude spill.

In Chapter 3 we discuss the various port parameters that may influence the "riskiness" of a port to oil spills. Vessel traffic, port hydrography, and weather parameters are discussed. Several of the factors have been investigated in the Ports Needs Study; we have borrowed heavily from this study the values for the various factors.

The risk analysis methodology is discussed in Chapter 4. The model execution is illustrated using a step by step procedure. The risk model developed is applied to a set of 10 U.S. ports. These ports include:

- Boston
- New York
- Philadelphia
- New Orleans
- Houston
- Corpus Christi
- Port Arthur
- Long Beach
- San Francisco
- Puget Sound/Seattle

The oil risk profiles (i.e., the plot of annual frequency of experiencing a given volume or greater oil spill vs. the spill volume) are shown for a sample of the ports. The risks from oil tankers, oil barges, and the total port risk are compared for New York, as an example.

Other interport comparisons (New York vs. San Francisco) and effectiveness of the Vessel Traffic System (VTS) in reducing the oil spill risk are discussed.

Conclusions from the study described in each Chapter are provided at the end of the chapter. An Appendix A is provided which contains the details of the structure and values of parameters in several databases.

CHAPTER 2

Review of Currently Used Oil Spill Contingency Planning Methodologies

2.1 BACKGROUND

Following the *Exxon Valdez* oil spill in Alaska in March 1989, the Commandant of the U.S. Coast Guard issued a directive[1] to all U.S. ports to review their oil spill contingency plans and identify shortfalls. Specific guidelines on the items to review were included in the directive. One of the items to be considered included the ability to respond to "catastrophic spills."

In this chapter we have evaluated the responses submitted by the Marine Safety Offices (MSO) of forty-one U.S. ports to the Commandant, U.S. Coast Guard. These ports are located on the east coast, gulf coast, and west coast of the U.S. and on the Great Lakes. The evaluation is limited to the methodologies used in the development of oil spill contingency response and their adequacies. Contingency plans, per se, have not been reviewed. Table 2.1 lists, by geographic region, the ports for which oil spill contingency plan reviews[2] were evaluated.

In general, each port review consisted of a description of the port's assumed worst case spill scenario, the predicted environmental impacts associated with the worst case spill, and the equipment and personnel resources needed and available in order to respond to the spill emergency (the resources needed less those available comprise each port's submitted shortfall list). Also, for many of the 41 ports, the review contained listings of local agencies and contractors scheduled to respond to the spill, as well as predicted response time for each.

Each review also contained the port MSO Commander's response to a series of questions compiled by the port's On Scene Coordinator. Questions addressed the adequacy of available personnel and equipment resources, obstacles in the way of creating an effective, workable contingency plan, liaison with local agencies, legislative actions which could improve MSO authority and capabilities, and other factors involved in contingency planning.

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[1]Commandant directive issued on 26 July 1989.

[2]The responses from the MSOs to USCG headquarters in response to the Commandant's directive is termed the "Contingency Plan Review."

TABLE 2.1

Listing of Ports by Region

East Coast	Gulf Coast	West Coast	Great Lakes
Portland, ME	Mobile, AL	Guam	Duluth, MN
Boston, MA	New Orleans, LA	San Diego, CA	Milwaukee, WI
Providence, RI	Morgan City, LA	Los Angeles/ Long Beach, CA	Chicago, IL
Philadelphia, PA	Port Arthur, TX	San Francisco, CA	Sault Ste. Marie, MI
Baltimore, MD	Houston, TX	Honolulu, HI	Grand Haven, MI
Huntington, WV	Galveston, TX	Portland, OR	Detroit, MI
Hampton Roads, VA	Corpus Christi, TX	Puget Sound, WA	Toledo, OH
Paducah, KY		Valdez, AK	Cleveland, OH
St. Louis, MO		Anchorage, AK	Buffalo, NY
Wilmington, NC			
Memphis, TN			
Savannah, GA			
Jacksonville, FL			
Tampa, FL			
Miami, FL			
San Juan, PR			

2.2 BROAD CATEGORIZATION OF THE METHODOLOGIES

The goal of the MSO oil spill contingency plan review was to identify shortfalls in the equipment and personnel needed to respond to a catastrophic oil spill emergency. This was achieved by identifying a worst case scenario and predicting the trajectory of the resulting oil slick, given that such a spill occurs. The impacted on-shore and off-shore areas were then identified as well as the equipment and personnel which would be needed to respond to the spill and impacted areas. Available resources were identified and shortfall lists generated.

In general, the methodology used by each MSO in performing the contingency plan review consisted of:

1. Developing the worst case oil spill scenario.

2. Predicting the oil slick trajectory.

3. Identifying coastal and off-shore areas impacted by the predicted slick trajectory.

4. Compiling a list of MSO spill contractors, local agency personnel and equipment <u>needed</u> to respond to the spill and to protect predicted impacted areas.

5. Compiling a list of MSO spill contractors, local agency personnel and equipment <u>available</u> to respond to the spill and to protect predicted impacted areas.

6. Compiling a list of personnel and equipment shortfalls based on items 4 and 5 above.

It is noted that some ports simply presented 3 and 4 above as a resource shortfalls list. For selected ports, Table 2.2 highlights a number of the methods used in addressing the items above.

Common approaches and differences used in achieving the above objectives are discussed in the following section.

TABLE 2.2

Example of Methodologies Used in Contingency Plan Assessment for Selected Ports

MSO/ Port Name	Worst Case Scenario				Spill Trajectory Position				Resource Shortfalls Identified		
	MAX TANKER OR BARGE SIZE	MOST FREQUENT TANKER OR BARGE SIZE	LAND BASED STORAGE OR PIPELINE	HISTORIC ACCIDENT	ASSUMPTION	ESTIMATE FROM WIND & CURRENTS	COMPLEX MODEL	IMPACTED AREAS IDENTIFIED	EQUIPMENT	PERSONNEL	USCG/ CONTRACTOR ITEMIZED
Baltimore	✓						✓	✓	✓		
Boston	✓				✓				✓	✓	
Chicago		✓			✓				✓	✓	
Detroit			✓	✓	✓						
Galveston	✓				✓				✓	✓	✓
Hampton Roads	✓	✓					✓	✓	✓	✓	✓
LA/Long Beach	✓					✓			✓	✓	✓
Miami		✓			✓				✓	✓	
Philadelphia/ Delaware River				✓	✓				✓	✓	
San Francisco		✓			✓				✓	✓	✓

2.3 COMMON APPROACHES AND DIFFERENCES

(a) Selecting a Worst Case Scenario

In identifying the worst case scenario to be used in the plan review, many ports researched historical traffic data in order to determine the maximum vessel size regularly coming into or passing through the port zone. In many cases, the draft limitations imposed by the depth of a port channel restrict the size of the vessel that can visit the port (ex: Hampton Roads). In those cases, where lightering operations are usually invoked until the ship can safely navigate the channel, the maximum volume spilled was assumed to be the maximum volume of the largest vessel less the volume which is normally unloaded during lightering. One particular office (MSO Chicago) chose the scenario based on a statistical analysis of historic spill data.

Ports exhibiting deep draft channels and large volumes of traffic generally based the spill on vessel damage due to a collision. On the other hand, ports with unusually shallow channels often based the scenario on a grounding while ports exhibiting extensive petroleum storage facilities, (Cleveland, Detroit) based the worst case scenario on a catastrophic failure of one or more large capacity tanks. One port, San Juan, based the scenario on actual spills resulting from hurricane Hugo.

Some spill scenarios, such as that used by the MSO Portland, OR, were determined by employing the expertise of representatives from federal, state, and local agencies, as well as clean-up contractors and industry. The MSO Portland eventually concluded that the most realistic worst case scenario would occur due to a pipeline failure and subsequent spillage into the Willamette River.

The spill scenarios used by many of the MSO's involved # 6 oil because of its thick, sticky, persistent, and difficult to clean up characteristics. The meteorological conditions at the time of the spill, as well as the spill location, were chosen such that either the greatest environmental impact was realized, or such that response action would be hampered.

(b) Predicted Spill Trajectory and Environmentally Sensitive Areas Impacted

A number of ports based the trajectory of the spilled oil on predictions generated by available oil or pollution spill trajectory models. For example, the MSO Puget Sound's worst case scenario spill trajectory was predicted by employing the National Oceanographic and Atmospheric Administration oil spill model. Similarly, the MSO Hampton Roads utilized the National Response Center's Pollution Spill Trajectory Forecasting System (PSTFS). Other offices, such as MSO Baltimore, based trajectory predictions on known water current

directions and velocities and meteorological conditions over the duration of the spill. Impacted environmental areas were then identified based on predicted oil spill trajectories.

Resources Shortfall List. Based on the predicted oil spill trajectory and the areas impacted by the slick, each MSO compiled a response resource shortfalls list. This list itemized the equipment needed and available in order to respond to the worst case spill.

The presentation of resource shortfalls was very diverse from port to port. In some cases, available equipment (or equipment and personnel) was itemized on an MSO and contractor basis. MSO Hampton Roads, MSO Savannah, and MSO Jacksonville, to name a few, itemized the listing as a function of supplier. Furthermore, MSO Savannah as well as MSO Jacksonville configured the list as a function of equipment application, i.e. sand beach clean-up, wildlife recovery, communications gear, etc. A number of ports submitted equipment needs and availability lists simply as a summarized shortfalls list.

The most comprehensive resource needs and availability list (as well as the entire contingency plan review) was submitted by MSO Portland, OR. This port's review included a very detailed listing of needed and available equipment based on the impacted area and the number of personnel involved in the response and clean-up efforts. Other ports were very general in presenting worst case scenario shortfalls and did not provide itemized resource lists at all.

2.4 SHORTCOMINGS IN THE APPROACHES

A number of shortcomings were apparent in the approaches used in the contingency plan evaluation process. Where some ports were more thorough in certain aspects of the assessment, others were lacking. A number of the more apparent problems are listed below. Shortcomings listed in this section may not be applicable to all ports performing the review.

Scenario Development & Hazard Analysis

In assessing a contingency plan's adequacy, an emphasis should be placed on testing resource responsiveness and availability when developing the spill scenario. This may include choosing a remote spill location or a location such that the spill trajectory impacts areas not easily accessible. Although a number of ports specified that the worst case scenario was developed to test the deployment of personal and equipment, the majority of ports did not specify how the adequacy of the resources measured against the task. Certainly, the variabilities in the spill location or movement of the slick to areas that could be either inaccessible to equipment or make deployment difficult do not seem to have been considered carefully.

Evaluating a contingency plan on the basis of a catastrophic or worst case oil spill has its merits. A different approach would be to assess the plan's adequacy in light of the most probable, or most realistic spill. This scenario would not be based on the largest tanker entering the port, but instead would be based on a review of historic vessel traffic data and historic port spill experience. This type of approach will provide a foundation for developing the configuration system.

Spill Trajectory Determination

In order to identify the equipment and personnel needed to respond to a given spill, it is necessary to predict the movement of the oil and the impacted areas on and off shore. For ports located on rivers where the confines of the shoreline would act as a barrier and restrict the movement of oil to an up stream and down stream direction, the trajectory of the oil may be approximated based on known currents and wind speeds over the duration of the spill. However, for spills in waterways and ports exhibiting complex shorelines and varying currents and winds, spill trajectories are best predicted by models which take into account the physical forces influencing the slick motion. Because of the importance of predicting the spill trajectory, a thorough assessment should include the assumptions and methods used to determine the trajectory as well as detailed maps of the trajectory over the time frame considered. Also, since it is impossible to predict the exact conditions under which an accident leading to an oil spill may occur, it would be necessary to perform simulation exercises on a computer to determine the most probable impact areas for high risk accident locations in the port.

Response Strategy

Most of the evaluations did not include a detailed listing of the step by step actions needed to be taken in order to deploy response equipment and personnel, and perform the necessary response and clean-up tasks. While a number of ports did provide an overview of the steps necessary, and the time frame in which the steps were expected to be taken, the majority of ports provided only a minimal outline and explanation. Ports which provided detailed strategies also included expected response times for arrival of equipment, contractors, and personnel. An expected response times list for a variety of equipment could be a part of a complete contingency plan.

The information contained in risk assessment is a first step in developing a system which can formulate a response strategy based on expected response times for equipment.

Equipment and Personnel Shortfall List

While most ports provided a reasonably itemized listings of needed and available equipment and personnel, the majority of the ports did not segregate the list into MSO, local agency, and/or contractor responsibility. In addition, some of the lists did not even address equipment and personnel shortfalls at all but instead listed general shortfalls such as equipment and personnel as a whole, lack of communications between the MSO and local agencies, lack of training for MSO personnel, etc.

2.5 CONCLUSIONS

Our very brief review of the "Contingency Plan Reviews" submitted by the different port MSOs indicates the following deficiencies:

1. No port uses a risk assessment methodology to evaluate its worst case scenario or the most frequently expected size of spill.

2. There is a lack of uniformity in both the approach to contingency plan evaluations as well as the depth of evaluations.

3. A systematic assessment of the personnel and equipment needs for combating the perceived worst case accident or for responding to more frequent size spills is lacking.

4. Differences in resources required to respond to same size spills occurring at different locations and in different weather and seasonal conditions have not been adequately addressed in any of the reviews.

5. The diversity in the level of detail given in the Contingency Plan Reviews is too large. It may be necessary for the USCG to develop a uniform methodology for conducting a Contingency Plan Review.

CHAPTER 3

Parameters Influencing Oil Spill Risks in a Port

3.1 LIST OF PARAMETERS POTENTIALLY INFLUENCING OIL SPILL RISKS

Large oil spills that can cause long term damage of significant proportions results from accidents involving bulk oil transport vessels such as tankers and barges. Accidents involving the breach of the containment vessel wall due to such events as collisions, groundings and rammings, result in spills, the sizes of which will depend on the extent of damage to the vessel (and the tanks within it) and the quantity of oil transported by the particular vessel.

The degree of ecological damage to the environment depends not only on the nature of the oil (crude, refined petroleum, etc.) but also on the rate of release, total quantity of release, location of spill, condition of the waterbody (rough sea, windy atmosphere, high river current velocity, etc.), and the ecological sensitivity of the area that may be affected. In general, a number of parameters affect the degree of "riskiness" of a port that has oil vessel traffic. The riskiness of a port will depend on both the chance of occurrence of accidents leading to oil spills of different magnitudes and the subsequent movement of oil and its effects on the local environment.

Table 3.1 lists the parameters of importance related to the occurrence of accidents leading to spills of oil. The parameters are segregated by traffic related causes, hydrography, and weather related variables. We discuss below the effect of individual parameters on the potential risk of oil spills in a port.

a. Traffic Parameters

The larger the number of vessel trips into or out of a port, the greater the potential for accidents and, hence, the spilling of oil. The vessels include both oil carriers and general cargo vessels. In addition, in the case of vessel collisions and grounding, the size of vessel and the speed before the accident will influence whether the oil cargo vessel tanks are breached or not.

Tanker Transits. The larger the oil throughput in a port, the larger will be the tanker traffic as measured by the number of tanker transits per year through the port. The higher the tanker traffic volume, the greater is the chance for one of the tankers to be involved in an accident.

TABLE 3.1

Parameters of Importance
(For Occurrence of Marine Accidents)

TYPE OF VARIABLE			DESCRIPTION
I.	Traffic	1.	Tanker transits – oil and oil product throughput.
		2.	General cargo vessel transits.
		3.	Vessel size and type mix.
		4.	Miscellaneous (presence of VTS, etc.).
		5.	Vessel speed (average and maximum values).
II.	Hydrographic	6.	Waterway configuration (open approach, convergence, open harbor or bay, enclosed harbor, constricted waterway, river).
		7.	Channel length, width, and depth. Also statistics indicating the variability in these parameters.
		8.	Number of bearing changes in the approach channel. Also the total change in bearing angle.
		9.	Nature of channel and of channel bottom (silt, shoals and rocky).
		10.	Current magnitude (adverse currents)
III.	Weather	11.	Frequency of reduced visibility.
		12.	Frequency of high wind speed and/or high sea states.

General Cargo Vessel Traffic. In general, the higher the density of traffic in the channel, the greater the risk of accidents. Hence, the tanker vessel accident rate will depend not only on the number of oil vessels, but also on the number of cargo and other vessels transiting the port channels.

Vessel Size and Type Mix. Large vessels are generally less able to avoid an imminent accident (compared to smaller vessels) because of the high momentum and inertia associated with size. For example, in collisions, a large vessel will be unable to change course if the colliding vessel is very close (even several hundred feet may be insufficient distance). In the case of a grounding, the energy of hull tearing will be directly proportional to the size (and hence, mass) and the square of the speed of the vessel. Also, large vessels have large drafts and therefore have a higher probability of encountering submerged objects or grounding. It is clear, therefore, that vessel size is an important parameter in determining the probability of vessel accidents leading to an oil spill.

The vessel mix is important because in collision, the masses of both vessels (and their relative vectorial speed) determine whether the oil tanker/barge will be punctured or not. Therefore, the release probability will depend on the vessel size and mix, among other parameters.

Vessel Speed. The vessel speed has two important effects on the accident and release probabilities. Higher speeds result in less time available for collision avoidance as well as higher momentum which makes maneuverability much more difficult. Also, impacts at higher momentum will result in greater damage to the vessel, therefore leading to a higher probability of oil release. In addition to vessel speed, the direction of motion of the two colliding vessels determines the depth of penetration of one vessel into the other.

b. Hydrographic Parameters

Waterway Configuration. The shape of the waterway and the traffic lane locations within the general port area can have an influence on the occurrence of vessel accidents. In the recently completed Port Needs Study performed by the Volpe National Transportation Systems Center (VNTSC) for the U.S. Coast Guard, six different categories of waterway configurations have been used. These include:

- open approach from the sea;
- convergence zone;
- open harbor or bay;
- enclosed harbor;
- constricted waterway; and
- river.

Open approach areas include the entrance from the sea up to the location of pilot boarding. It also includes a marked channel deep enough to allow deep draft vessels to pass safely with maneuvering room outside the marked channel. Convergence zones include those areas of the waterbody in which traffic lanes (channels) intersect or converge. This zone is also immediately inbound of the "open approach." Open harbor or bay includes the relatively open water containing some port facilities.

Channel Characteristics. The channel width and depth are also important parameters. The wider the channel, the less is the probability of collisions with other large vessels. In general, the channel depth will be sufficient to accommodate the largest draft ships that call on the port. However, from the point of view of grounding risks, the off channel depth and the type of water bottom are equally important. This is because the shallower the off channel depth is, the greater will be the probability of vessels grounding that veer off course (due to mechanical problems, instrument errors, or operator failures). Depending on the nature of the channel bottom, the speed of the vessel, and the off channel depth variation, groundings could lead to significant vessel damage and potential oil leaks from tankers.

Number of Bearing Changes. The potential for veering off course becomes higher in a channel if the channel has several turns (especially near right angle turns); i.e., the number of bearing changes from the open water to the inner harbor is an important hydrographic parameter that may influence both collision and grounding risks.

Channel Bottom Characteristics. The nature of the ground at the water bottom, especially in off channel locations, has influence on the groundings and the potential vessel tank breaches. If the bottom is silty, one can expect a low probability of a leak for a given speed of grounding compared to when the bottom is rocky or has reefs.

Cross Channel Currents. These are expected to have a lesser influence on the potential for accidents, because, in general, the details of currents are known to pilots. However, the presence of unknown currents or currents generated by sudden floods into the channel (following, say, a heavy rain) can pose problems.

c. Weather Parameters

Visibility. Reduced visibility due to fog is an important parameter that may contribute to collision accidents or groundings due to the vessel going off course. However, with the availability of radar and other electronic navigational instruments on modern tankers, it can be expected that the influence of this parameter or potential oil release accidents is not significant.

High Sea States and Wind. These (interrelated) parameters can have significant effect on the mechanical integrity of steering and stability of a vessel. A loss of steering of a vessel can render it impotent and subject to drifting and grounding, shoaling, or colliding with rocky outcrops. Therefore, the frequency of occurrence of high wind and corresponding high sea states can be expected to influence oil spill probabilities *provided, however,* the ship traffic is continued in these types of weather conditions.

The influence of one or more of the above parameters on the occurrence of marine vessel accidents leading to potential oil spills are discussed in the next section. Most of the results are taken from the recently completed Port Needs Study *(Maio, et al, 1991)*. In section 3.5, we present results of our analysis of historical oil vessel accidents in and out of transit channels in ports.

3.2 SUMMARY DESCRIPTION OF THE VTS STUDY & RESULTS

The Volpe National Transportation Systems Center (VNTSC) recently completed a study analyzing the benefits and costs of potential U.S. Coast Guard Vessel Traffic Services (VTS) in selected U.S. deep draft ports on the Atlantic, Gulf, and Pacific coasts. This study, known as the Port Needs Study (PNS), analyzed historical vessel casualties and their consequences, and projected future accident rates and consequences for 23 U.S. ports studied. The study included the evaluation of rates of vessel collisions, rammings, and groundings for different levels of projected traffic density. The study, in addition, evaluated the potential for reduced accident rates due to the provision of (or improvements in the currently operating) vessel traffic services at different levels of sophistication. Also included in the study was the calculation of benefits of VTS expressed in economic parameters such as, avoided vessel casualties, monetary values of prevented damages to vessels, and the avoided environmental pollution, human injuries and deaths.

The waterbody in each of the 23 study ports was divided into several subzones, depending on the marine characteristics of the waterbody. The PNS study has defined six different types of waterbodies, namely

- open approach (Subzone Type A);
- convergence (Subzone Type B);
- open harbor or bay (Subzone Type C);
- enclosed harbor (Subzone Type D);
- constricted waterway (Subzone Type E); and
- river (Subzone Type F).

Table 3.2 provides a summary description of the water characteristics of the different subzones defined. These definitions have been retained in the present oil spill risk assessment study also. Table 3.3 shows the different U.S. ports analyzed in the PNS study and the types of waterbodies considered in each of the ports.

TABLE 3.2

Water Body Classifications

WATER BODY		DESCRIPTION
LETTER	TYPE	
A	Open Approach	• Entrance from sea • Extends to pilot boarding location • Deep marked channels
B	Convergence	• Convergence of major traffic lanes/channels • Immediately in bound of "open approach"
C	Open Harbor or Bay	• Harbor area including relatively open water • Identifiable harbor area with considerable port facilities • Segment of waterway with Traffic Separation Scheme or Traffic Lanes for shallow draft vessels • "Outer Harbor"
D	Enclosed Harbor	• Harbor area mostly enclosed by land or shallow water • Significant meeting, intersecting traffic • "Inner Harbor"
E	Constricted Waterway	• Area of water with fixed obstructions and limited maneuverability space for deep draft vessels • Excludes rivers • Restrictions on vessel parking
F	Rivers	• Navigable rivers

Source of Data: Maio, et al (1991)

TABLE 3.3

Different Ports and Subzones in the PNS Study

ZONE	NAME	SUBZONE TYPES						TOTALS
		A	B	C	D	E	F	
1	Boston, MA	1	1	1	1	1		5
2	Puget Sound, WA	1	1	2	3	3		10
3	LA/Long Beach, CA	1	1	1	1			4
4	Santa Barbara, CA	1						1
5	Port Arthur, TX	1				2	1	4
6	New Orleans, LA	1				2	3	6
7	Houston/Galveston, TX	1			1	1		3
8	Ches. So./Hamp. Roads, VA	1	1	2	1	1		6
9	Ches. No./Baltimore, MD			1	1		1	3
10	Corpus Christi, TX	1	1			1	1	4
11	New York City, NY	1	1	2	1	2		7
12	Long Island Sound, NY	1	1	1	2	1		6
13	Phil./Delaware Bay, PA	1	1	1		1	1	5
14	San Francisco, CA	1	1	1	1		1	5
15	Portland, OR	1		1			1	3
16	Anchorage/Cook Inlet, AK	1		1	1			3
17	Portland, ME	1		1	1	1		4
18	Portsmouth, NH	1	1		1		1	4
19	Providence, RI	1		1	1			3
20	Wilmington, NC	1				1	1	3
21	Jacksonville, FL	1				1		2
22	Tampa, FL	1		1	1			3
23	Mobile, AL	1		1		2	1	5
	Totals	22	10	18	17	20	12	99

Source of Data: Maio, et al (1991)

The PNS study has evaluated the vessel casualties by analyzing 36,000 vessel casualty records in the USCG's CASMAIN database pertaining to marine accidents in the 23 ports during the period 1980-1989. Out of these, 2,210 are indicated to have been selected as VTS addressable.[1] These accidents have been categorized into three main types, namely, collision, rammings, and groundings. The number of vessel transits of different types of vessels (passenger, dry cargo, tanker, barge, etc.) and vessel sizes (small, medium, and large) have also been collected for the 1979-1989 period. Using these data, the national average casualty rates for different vessel sizes and types have been compiled. These results obtained in the PNS study are indicated in Table 3.4.

The casualty rate for a water subzone of interest is predicted in the PNS Study by using the national average casualty rate corrected by a subzone specific "Risk Factor." The total number of casualties for the particular vessel category is then obtained by using the corrected national casualty rate and the vessel traffic (in number of transits/year). The PNS study has provided details of how the Risk Factors are evaluated for each water subzone of each of the 23 ports studied. Table 3.5 shows the values for these Risk Factors.[2] The determination of the values for risk factors involves regressing the actual casualty rates for all U.S. waterbodies with potential casualty influencing parameters, obtaining mean values for regression coefficients, predicting the casualty rate for a particular waterbody using the regression equation, and calculating the mean casualty rate using the calculated and actual rate and dividing this mean casualty rate for the particular waterbody by the national casualty rate. The result of such a calculation procedure yields the values indicated in Table 3.5.

Not all vessel casualties result in the release of cargo. The probability of release given a vessel casualty depends on the type and size of vessel and the nature of the accident. In fact, the severity of the accident will determine the magnitude of cargo release. Table 3.6 indicates the different values for the conditional probabilities of cargo (in this case, oil) release from tankers and barges *given* that an accident has occurred. Similarly, Table 3.7 indicates the conditional probabilities of sustaining different levels (or seriousness) of damage. Both these tables were developed in the PNS study based on the review of available vessel damage data specifically for oil carrying tankers and barges. It is seen from the results presented in these tables that a larger fraction of collision and ramming accidents result in releases compared to groundings. Also, the larger the vessel size, the larger the probability of release given an accident (Table 3.6). This, as indicated earlier, has to do with the higher momentum of larger vessels.

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[1]VTS addressable accidents are those in which the presence of a VTS would have made a difference in the occurrence of the casualty. These include accidents in open water (collisions), poor visibility, severe weather, overtaking, congested channels, etc.

[2]In Chapter 4 we have provided the details of how these water subzone specific casualty correction factors (Risk Factors) are used in the risk analysis for oil spills.

TABLE 3.4

Marine Vessel Casualty Rates
U.S. National Averages for No VTS
(Based on 1979-1989 Accident Data)

VESSEL TYPE	SIZE	(NUMBER OF CASUALTIES PER 100,000 TRANSITS)			
		COLLISION	RAMMING	GROUNDING	TOTAL
Passenger	Small	0.218	0.056	0.343	0.617
	Medium	8.425	0.000	16.764	25.189
	Large	---	---	---	---
Dry Cargo	Small	0.582	0.114	0.162	0.858
	Medium	1.552	0.507	1.123	3.182
	Large	3.872	1.336	8.717	13.925
Tanker	Small	0.462	0.000	0.578	1.040
	Medium	0.960	0.183	1.069	2.212
	Large	7.718	3.634	19.373	30.725
Dry Cargo Barge	Small	2.986	1.551	1.907	6.444
	Medium	---	---	---	---
	Large	18.901	0.000	29.270	48.171
Tanker Barge	Small	3.221	0.966	3.455	7.642
	Medium	---	---	---	---
	Large	2.277	2.167	2.708	7.152
Tug/Tow Boat	Small	0.388	0.226	0.454	1.068
	Medium	---	---	---	---
	Large	---	---	---	---

Source: Maio, et al (1991)

TABLE 3.5

Port and Water Subzone Risk Factors

PORT #	PORTNAME, STATE		
SUBZONE #	WATER Type	RISKFACTOR	
1	BOSTON, MA		
0		4.43453	
1	A	0.37508	
2	B	0.03127	
3	C	0.75154	
4	D	0.46461	
5	E	2.81203	
2	PUGET SOUND, WA		
0		7.97133	
1	A	0.91939	
2	B	0.30525	
3	C	0.64297	
4	E	1.04813	
5	C	0.01971	
6	D	0.95930	
7	D	0.78129	
9	E	2.90479	
10	D	0.39050	
3	LONG BEACH, CA		
0		1.30800	
1	A	0.02371	
2	B	0.44709	
3	C	0.23691	
4	D	0.60029	
4	SANTA BARBARA, CA		
0		0.26169	
1	A	0.26169	
5	PORT ARTHUR, TX		
0		8.38194	
1	A	0.53874	
2	E	2.38349	
3	E	4.38490	
4	F	1.07481	
6	NEW ORLEANS, LA		
0		17.90824	
1	A	0.85570	
2	E	1.94588	
3	F	3.02567	
4	E	4.51479	
5	F	1.63881	
6	F	5.92739	
7	HOUSTON, TX		
0		3.13818	
1	A	0.03408	
2	E	2.91751	
3	D	0.18659	
8	CHESAPEAKE SOUT, VA		
0		2.77404	
1	A	0.04265	
2	B	0.44280	
3	C	0.30003	
4	D	0.37894	
5	E	1.25083	
6	C	0.35879	
9	BALTIMORE, MD		
0		3.96903	
1	C	1.91003	
2	D	0.32546	
3	F	1.73354	
10	CORPUS CHRISTI, TX		
0		3.13385	
1	A	0.06922	
2	B	0.50529	
3	E	1.72868	
4	F	0.83066	
11	NEW YORK CITY, NY		
0		3.99649	
1	A	0.10112	
2	B	0.21879	
3	C	0.14023	
4	D	0.15273	
5	E	1.68713	
6	C	0.42998	
7	E	1.26651	
12	LONG ISLAND SOU, NY		
0		2.26377	
1	A	0.02232	
2	B	0.07547	
3	C	1.01728	
4	D	0.04759	
5	D	0.05255	
6	E	1.04856	
13	PHILADELPHIA, PA		
0		3.84089	
1	A	0.50696	
2	B	0.33529	
3	C	1.08857	
4	F	1.91007	
14	SAN FRANCISCO, CA		
0		4.43990	
1	A	0.14195	
2	B	0.45094	
3	C	0.84060	
4	D	0.46885	
5	F	2.53756	
15	PORTLAND, OR		
0		5.50423	
1	A	0.17350	
2	C	1.96100	
3	F	3.36973	
16	ANCHORAGE, AK		
0		7.65366	
1	A	0.43966	
2	C	5.84886	
3	D	1.36514	
17	PORTLAND, ME		
0		0.32666	
1	A	0.00920	
2	C	0.13546	
3	D	0.18200	
18	PORTSMOUTH, NH		
0		0.18486	
1	A	0.02258	
2	B	0.04338	
3	D	0.11890	
19	PROVIDENCE, RI		
0		4.53813	
1	A	1.43090	
2	C	1.76036	
3	D	1.34687	
20	WILMINGTON, NC		
0		2.53804	
1	A	0.00840	
2	E	0.85509	
3	F	1.67455	
21	JACKSONVILLE, FL		
0		3.27027	
1	A	0.22962	
2	E	3.04065	
22	TAMPA, FL		
0		6.42569	
1	A	0.79077	
2	C	5.12433	
3	D	0.51059	
23	MOBILE, AL		
0		7.23417	
1	A	0.04222	
2	E	2.10450	
3	C	0.44332	
4	E	4.19989	
5	F	0.44424	

Source: Maio, et al (1991)

TABLE 3.6

Probability of Bulk Commodity Spill Given a Vessel Casualty

CASUALTY TYPE	VESSEL TYPE*	VESSEL SIZE	COUNT OF INDICATOR** INCIDENTS	ADJUSTMENT FACTOR***	COUNT OF VESSEL**** CASUALTIES	PROBABILITY OF BULK COMMODITY SPILL
Collision/ Ramming	Cargo	L, M	6	x 3	82	0.21951
		S	13	x 3	217	0.17972
Grounding	Cargo	L, M	6	x 3	127	0.14173
		S	1	x 3	155	0.01935
Average Probability			26	x 3	581	0.13425

* Tankers and tank barges only; other vessel types excluded

** Number of vessels reporting both vessel damage and cargo damage/loss is taken as an indicator of a breached hull and spill.

*** Adjustment factor to compensate for CASMAIN undercount of indicator incidents.

**** Only tankers and tank barges included; other vessels excluded.

Once the vessel is damaged enough to leak its oil contents, the rate of oil release and volume of oil released depends on the severity of the accident. This severity, expressed in terms of the fraction of the cargo released, is indicated in Table 3.7. Also shown are the conditional probability values for the occurrence of given levels of severity of damage leading to the indicated volume of fraction of cargo release. It is seen that most vessel accidents result in a smaller fraction of the vessel inventory being released. However, the larger release probability in the case of a tanker vessel is about four times higher than for a barge (note the differences in the inventory fraction released in the most severe barge accident and most severe tanker accident).

3.3 OTHER RESULTS FROM THE PORT NEEDS STUDY

The PNS Study also evaluated in detail the effect of some of the factors indicated in Table 3.1. Historical vessel casualty rates (expressed in number of casualties per 100,000 vessel transits) were regressed against a number of subzone specific (independent) variables indicated in Table 3.1. Both linear and non-linear regression analysis techniques are reported to have been used. The results indicate that the following are *statistically significant* factors influencing the vessel casualties:

1. **Waterbody Type.** Represented by a variable. (Open = 1 for open approach, otherwise 0. Narrow = 1 for constricted waterway, otherwise 0.)

2. **Route Length.** From the open ocean entrance to the harbor dock.

3. **Average Width.** Mean width of the traffic channel.

4. **Sum of Delta Headways.** Cumulative (sign independent) changes in the bearing angle (in degrees) from the open ocean to the dock.

5. **Density of Other Vessel Population.** Expressed in number of other vessels per mile length of channel.

It is indicated in the PNS Study that the weather variables correlated poorly with the historical casualty data for the 23 ports studied. Also found were the poor correlations between casualties vs. average channel depth, casualties vs. currents, wind speed, number of obstructions, etc.

The number of casualties (of medium and large dry cargo and tanker transits in a subzone) are correlated *(Maio, et al, 1991)* with the statistically important factors as follows:

$$C = -0.372321 - 3.529773 \times \text{open} + 16.327722 \times \text{narrow} + 0.228527 \times \text{route length} - 0.000407 \times \text{average channel width} + 0.012121 \times \text{sum of delta headings (in degrees)} + 0.000392 \times \text{other vessels per mile} \quad (3.1)$$

TABLE 3.7

Probability of Spill Severity Given a Bulk Commodity Spill

VESSEL TYPE	SEVERITY % OF VES. CAP. LOST	NUMBER OF OBSERVATIONS	ADJUSTMENT*	PROBABILITY OF SEVERITY
Tanker Barge	1-Total Loss (>90%)	1	0	0.02222
Tanker Barge	2-Large Loss (50-90%)	4	0	0.08889
Tanker Barge	3-Medium Loss (10-50%)	4	0	0.08889
Tanker Barge	4-Small Loss (<10%)	6	+30	0.80000
		15	+30	1.00000
Tanker	2-Large Loss (5-10%)	3	0	0.09091
Tanker	3-Medium Loss (1-5%)	5	0	0.15152
Tanker	4-Small Loss (<1%)	3	+22	0.75757
		11	+22	1.00000

* Total tripled to agree with adjustment in Table 3-6. All increase assigned to small capacity losses only.

where,

C = number of casualties (i.e., accidents) per 100,000 vessel transits

The Ports Needs Study report provides additional details of the statistical confidence limits on the coefficients of the various parameters in the correlation equation 3.1.

The results presented in this section are used in the Risk Analysis Methodology discussed in Chapter 4. In the next section, we describe our assessment of the vessel accident data to determine the in channel and off channel accidents.

3.4 ASSESSMENT OF VESSEL ACCIDENTS IN AND OFF NORMAL TRANSIT CHANNELS IN PORTS

A useful parameter in the study of oil carrying vessel accidents and associated oil spill risk is the number of tanker and barge groundings and collisions occurring inside and outside of the traffic channel of a given port. This information would indicate specific, channel related, problems associated with tanker traffic.

This section describes the analysis performed to determine the number of oil releasing tanker and barge groundings and collisions, and their locations relative to the traffic channel, for a selected number of ports.

3.4.1 Marine Vessel Accident Information Sources

In order to obtain the number of tanker and barge collisions and groundings releasing oil, as well as the latitude and longitude of the incident, the Coast Guard Marine Safety Office (MSO) of selected ports[3], as well as the U.S. Army Corps of Engineers[4], were contacted in

[3]The MSO's Valdez, San Francisco/Long Beach, Peugeot Sound, New York City, Houston, Galveston, Philadelphia, Corpus Christi, and New Orleans, were contacted in an effort to obtain data relative to tanker and barge spills. The only information available from these ports was a listing of the names, ID numbers, call signs and destinations of tankers. A listing of barge arrivals was not available since these vessels are used primarily for inner port transportation of oil and lightering operations. Tankers are required to provide a 24 hour notice of arrival to the port.

[4]The U.S. Army Corps of Engineers, New Orleans, LA, maintains and publishes two reports relative to marine vessel traffic. The first, "Waterborne Commerce of the United States," consists of four regional publications; Pacific, Great Lakes, Atlantic, and Mississippi Valley. Each publication documents origin and destination information, as well as tons moved by commodity, for domestic and foreign marine vessels through the year 1989. The second report, "Transportation Lines of the United States," lists the names and characteristics (draft, length, width, etc.) of vessels used in domestic marine commerce. Neither of these reports contains marine vessel accident data.

an effort to obtain vessel traffic data relative to oil vessel accidents. Also, a number of currently available marine pollution and vessel casualty databases were studied. If the information was available, the location of the incident relative to the channel could be determined by plotting the latitude and longitude coordinates on navigation charts for the port published by the National Oceanographic and Atmospheric Administration (NOAA). For the most part, usable information was obtained from marine pollution and vessel casualty databases only. The MSO's, as well as the Army Corps of Engineers, were not able to provide the required data due to time constraints and, in some cases, non availability of the requested data. The following summarizes the findings from the review of data collected from computerized databases maintained by the USCG.

Marine Pollution Incident Report (MPIR). The Marine Pollution Incident Report, a module of the USCG's Marine Safety Information System (MSIS), contains data on marine pollution and oil spills. Any release of a hazardous material in U.S. waters, above a regulatory reporting threshold limit, is required to be reported and is entered into this database. The database does not identify the source of release.

The MPIR database lists such information as a unique MSIS case number for each incident, a port code identifying the investigating MSO, the spill time and date, latitude and longitude of the incident, and water body in which the spill occurred. A field also exists for linking the database to the Marine Casualty Database (CASMAIN). However, it is cautioned in the USCG's MPIR file description that records in the MPIR database are not guaranteed to correspond to those in the CASMAIN database.

While the data contained in the MPIR database is useful, it does not by itself support determination of the desired information. It also does not indicate the source of the release, i.e. ship, loading terminal, recreation boat, etc.

Marine Pollution Vessel Source (MPVS). The Marine Pollution Vessel Source database is also a module of the USCG'S MSIS system. This particular database, unlike the MPIR database, contains pollution information specific to releases from marine vessels. Included are fields listing the MSIS case number, vessel name, vessel identification number (VIN) and call sign, as well as the vessel size in gross weight tons.

The MPVS database does not contain latitude or longitude information by which the location of the spill can be determined. The database can, however, be linked to the MPIR database using the MSIS case number field which is common to the two databases. If a case number in the MPVS database appears in the MPIR database, then the latitude and longitude can be determined through the link.

Although the MPVS database contains information relative to the release of pollutants, it is not specific as to the type of vessel from which the release occurred and the type of material released. In light of this, the data in this database could not be used for determining the desired information.

Marine Casualty Database (CASMAIN). The CASMAIN database is maintained by the USCG's Office of Marine Safety, Security and Environmental Protection. It contains a compilation of data on marine vessel incidents. The database spans the years 1979 to 1990 and contains, among others, fields designating the CASMAIN case number (not the same as the MSIS case numbers listed in the MPIR and MSIS databases), Lloyds vessel identification number, date of incident and body of water in which the incident occurred, latitude and longitude of incident site, weather conditions at the time of the incident, nature of the incident (grounding, collision, explosion, fire), vessel hull design (barge, conventional, etc.) vessel use (bulk oil, bulk solids, passenger, etc.), and gross vessel tonnage.

Although the database does not identify incidents resulting in the release of oil, it does contain the information necessary to determine, as a function of port, the number of barge and tanker collisions and groundings, location, and gross vessel tonnage.

3.4.2 Analysis of Data

In determining oil spill risks, any incident which threatens the integrity of oil containment in the vessel and which increases the probability of an oil release occurring should be considered. This includes both intentional and non-intentional groundings as well as collisions between oil vessels and other ships (i.e. fishing boats, freighters, tugs, etc.), oil vessels and stationary objects (bridges, docks, etc), oil vessels and navigational aids, and collisions with submerged and floating objects. Therefore, in identifying the number of tanker and barge collisions and groundings for a particular port, it was decided that all types of collisions and both intentional and non intentional groundings would be considered.

In this study it was initially intended to determine the number of barge and tanker collisions and groundings incidents in which oil was released. Although the CASMAIN database contains most of the needed information, it does not identify whether or not an incident released oil. Since the MPIR database contains information exclusive to the release of pollutants, an attempt was made to link the CASMAIN database to the MPIR database. If the same case number appeared in both databases, it could be considered as an oil releasing incident. However, because the CASMAIN database and the MPIR database do not contain a common field, it was necessary to link the two through the MPSV database (the CASMAIN database and the MPVS database contain a common field listing the vessel ID number while the MPVS and MPIR database share a common field listing the MSIS case number).

Once the CASMAIN and MPIR databases were linked, it was found that the dates and latitudes and longitudes of accidents did not correspond. These results suggest that linking the CASMAIN and MPIR databases solely on the CASMAIN vessel ID number is not sufficient due to the difference in the reporting methods and time span over which the information was compiled (a ship listed in CASMAIN in 1980 could have released oil 10 years later and been listed in MPIR).

As a result of this work, the CASMAIN database was identified as the only available source from which the number of tanker and barge collisions and groundings, as well as the incident location, could be determined for a specific port. It was not possible, given available sources of data, to determine whether or not a particular grounding or collision released oil.

Utilizing a database application software called dBase IV, selected fields of the CASMAIN database were copied to another database file for all records pertaining to incidents involving oil tanker and oil barge collisions and groundings. This newly created database is called "CAS_OIL.dbf." This contains information identifying the CASMAIN case number, date of the incident, vessel identification number, reporting USCG MSO (assumed to be the port in which the incident occurred), latitude and longitude of the incident, the nature of the incident (grounding or collision), the gross vessel tonnage, and the design of the hull (conventional tanker or barge). The field descriptions for CAS_OIL.dbf are listed in Table 3.8. An example of the records contained in the CAS_OIL.DBF file is listed in Table 3.9.

Using the CAS_OIL.DBF file, databases for five selected ports, Valdez (VAL), San Francisco (SFC), Houston (HOU), New York City (NYC), and Philadelphia (PHI), were developed. The field descriptions for each database are identical to those listed in Table 3.8. The database for each port identifies oil tanker and oil barge collisions and groundings, the location of occurrence, and the gross vessel tonnage for each incident for the years 1979 through 1990. Table 3.10 lists, as an example, the contents of the database for the port of Houston. By grouping the data in each file based on the nature of the incident and counting the number of records in each group, the number of oil tanker and barge collisions and groundings was determined.

3.4.3 Results

Table 3.11 lists the total number of tanker and barge collisions and groundings, as well as the vessel tonnage involved, as determined from the database generated for each of the five ports studied (geographic location has not been considered, i.e., all tanker and barge collisions and groundings listed in the CASMAIN database for each port have been included). It is clear from the results that the port of New York City experiences, comparatively, many more accidents than do the remainder of the ports studied, especially for transportation of oil in barges. This is probably due to the fact that in New York a large number of barges are used for lightering operations and transporting oil from the outer port to oil terminals upstream. Valdez is a deep water port which allows tankers to transport oil directly to the terminal. There is no barge operation in the port of Valdez. Therefore, barge accidents number is recorded as zero in Table 3.11. Only one tanker incident, a collision, was identified for the port of Valdez.

TABLE 3.8

Description of CAS_OIL Database File

FIELD NAME	DESCRIPTION
CASE	CASMAIN Case Number (unique from MSIS system)
CASDATE	Date Vessel Casualty Occurred
VIN	Vessel Identification Number
OFFICE	Investigating MSO Office
LATITUDE	North Latitude
LONGITUDE	West Longitude
NATURE1	Nature of Incident (entries beginning with "COL" are collisions, entries beginning with "GRNDG" are groundings)
GTON	Gross Vessel Tonnage
DESIGN	Hull Design ("CONV" = conventional/tanker, "BRGE" = barge)

TABLE 3.9

Example of CAS_OIL.dbf Tanker and Barge Collision and Grounding Database[1]

CASE	CASDATE	VIN	OFFICE	LATITUDE	LONGITUDE	NATURE1[2]	GTON	DESIGN[3]
0029POM81	800625	D252768	POM	N 44 47.8	W 068 46.2	COLSUO	001488	CONV
0002SIM81	801105	D230184	SIM	N 00 00.0		COLSPC	004432	CONV
0083MEM81	801221	D569065	MEM	N 35 00.9	W 090 17.4	COLMTG	000994	BRGE
0083MEM81	801221	D274797	MEM	N 35 00.9	W 090 17.4	COLMTG	001768	BRGE
0083MEM81	801221	D273940	MEM	N 35 00.9	W 090 17.4	COLMTG	001734	BRGE
0083MEM81	801221	D277115	MEM	N 35 00.9	W 090 17.4	COLMTG	000928	BRGE
0083MEM81	801221	D277478	MEM	N 35 00.9	W 090 17.4	COLMTG	000928	BRGE
0083MEM81	801221	D276965	MEM	N 35 00.9	W 090 17.4	COLMTG	001734	BRGE
0097MEM81	810112	D529354	MEM	N 35 08.6	W 090 3.9	GRNDGA	000626	BRGE
0097MEM81	810112	D529360	MEM	N 35 08.6	W 090 3.9	GRNDGA	001510	BRGE
0125MEM81	810122	D529035	MEM	N 34 13.3	W 090 50.3	GRNDGA	001314	BRGE
0125MEM81	810122	D529034	MEM	N 34 13.3	W 090 50.3	GRNDGA	001705	BRGE
0125MEM81	810122	D529003	MEM	N 34 13.3	W 090 50.3	GRNDGA	001644	BRGE
0125MEM81	810122	D529209	MEM	N 34 13.3	W 090 50.3	GRNDGA	001227	BRGE
0126MEM81	810128	D286804	MEM	N 33 19.9	W 091 9.6	GRNDGA	000956	BRGE
0081MEM81	810128	D602254	MEM	N 35 50.7	W 089 43.1	GRNDGA	001856	BRGE
0100MEM81	810130	D567136	MEM	N 33 52.0	W 091 3.6	GRNDGA	001716	BRGE
0100MEM81	810130	D558337	MEM	N 33 52.0	W 091 3.6	GRNDGA	000812	BRGE
0107MEM81	810208	D562271	MEM	N 34 51.8	W 090 19.6	GRNDGA	001472	BRGE
0084MEM81	810214	D547008	MEM	N 35 51.0	W 089 44.1	GRNDGA	000270	BRGE
0084MEM81	810214	D512795	MEM	N 35 51.0	W 089 44.1	GRNDGA	000273	BRGE
0069SFC82	820101	D241851	SFC	N 38 02.0	W 121 52.0	GRNDGA	008538	CONV
0003MOB82	820103	D535923	MOB	N 30 38.4	W 088 1.9	COLMTG	002074	BRGE
0019NEW82	820107	D630040	NEW	N 28 54.3	W 089 25.5	GRNDGA	005449	BRGE

1. Refer to Table 1 for Field Descriptions and Definitions.
2. Entries starting with "COL" are collisions, those starting with "GRNDG" are groundings.
3. Entries of "BRGE" are barges, those of "CONV" are conventional hull (tankers).

TABLE 3.10

Example of the Port of Houston Tanker and Barge Collision and Grounding Database[1]

CASE	CASDATE	VIN	OFFICE	LATITUDE	LONGITUDE	NATURE1[2]	GTON	DESIGN[3]
0518HOU81	8110128	L6422224	HOU	N 29 39.0	W 094 58.2	COLOTK	038598	CONV
2025HOU81	810202	KSH9JO	HOU	N 29 41.4	W 094 59.3	COLSPC	040632	CONV
2452HOU81	810606	D275193	HOU	N 29 43.7	W 095 1.4	COLDOC	020138	CONV
3359HOU81	810718	PN4565A	HOU	N 29 43.8	W 095 1.3	COLSPC	034542	CONV
2717HOU81	810727	D634540	HOU	N 29 44.7	W 095 10.6	COLDOC	021937	CONV
2472HOU81	810607	D278624	HOU	N 29 49.0	W 095 0.0	GRNDGA	018272	CONV
MC87004526	870804	D684688	HOU	N 32 25.2	W 064 37.8	GRNDGA	019037	CONV
MC90000575	900103	D553623	HOU	N 29 43.0	W 095 1.2	GRNDGA	022357	CONV
0531HOU81	801120	D567122	HOU	N 29 43.4	W 095 14.0	COLSPC	001902	BRGE
0532HOU81	801130	D535777	HOU	N 29 45.0	W 095 17.1	COLDOC	001209	BRGE
3367HOU81	810313	CG019943	HOU	N 29 45.0	W 095 3.8	COLMTG	001699	BRGE
3367HOU81	810313	CG019836	HOU	N 29 45.0	W 095 3.8	COLMTG	001699	BRGE
2526HOU81	810417	D285104	HOU	N 29 45.0	W 095 17.3	COLDOC	001703	BRGE
3350HOU81	811204	D622646	HOU	N 29 43.3	W 095 14.0	COLSPC	002192	BRGE
3349HOU81	811217	D618903	HOU	N 29 45.0	W 095 17.4	COLDOC	001992	BRGE
MC86000462	851126	D628721	HOU	N 29 48.0	W 095 4.0	COLBDG	001000	BRGE
MC90000577	890827	CG005033	HOU	N 29 44.7	W 095 10.5	COLMTG	000850	BRGE
0533HOU81	801201	CG001644	HOU	N 29 45.5	W 095 5.3	GRNDGA	000704	BRGE
0535HOU81	801229	D621333	HOU	N 29 43.7	W 095 1.2	GRNDGA	001269	BRGE
0520HOU81	810120	D567392	HOU	N 29 45.4	W 095 4.1	GRNDGA	001661	BRGE
2420HOU81	810607	D630051	HOU	N 29 41.0	W 094 59.0	GRNDGA	001897	BRGE
3355HOU81	811127	D290256	HOU	N 29 41.9	W 095 0.0	GRNDGA	001512	BRGE
0020HOU82	820108	D567123	HOU	N 29 35.5	W 094 56.3	GRNDGA	001901	BRGE
0020HOU82	820108	D567125	HOU	N 29 35.5	W 094 56.3	GRNDGA	001038	BRGE
0020HOU82	820108	D567122	HOU	N 29 35.5	W 094 56.3	GRNDGA	001901	BRGE
0093HOU84	840906	D580101	HOU	N 29 37.3	W 094 57.5	GRNDGA	018671	BRGE

1. Refer to Table 1 for Field Descriptions and Definitions.
2. Entries starting with "COL" are collisions, those starting with "GRNDG" are groundings.
3. Entries of "BRGE" are barges, those of "CONV" are conventional hull (tankers).

TABLE 3.11

Oil Tanker & Barge Collision & Groundings Determined from CASMAIN Data 1979-1990*

PORT	ALL COLLISIONS**				ALL GROUNDINGS***			
	TANKERS		BARGES		TANKERS		BARGES	
	NO. TANKERS	GROSS TON	NO. BARGES	GROSS TON	NO. TANKERS	GROSS TON	NO. BARGES	GROSS TON
HOU	9	220,147	9	14,246	5	97,012	9	30,554
NYC	51	1,112,011	93	358,680	42	498,123	73	288,634
PHI	7	257,158	20	167,323	33	1,295,833	15	87,782
SFC	12	258,207	3	3,312	18	372,268	6	16,258
VAL	1	114,285	0	0	0	0	0	0

* The CASMAIN database does not indicate if an accident resulted in a release of oil.

** Collisions include rammings, overtakings, stationary objects, navigation aids, submerged and floating objects, etc., inside and outside channels.

*** Groundings include those both accidental and intentional, inside and outside channels.

Note: "gross ton" is the total gross tonnage of the number of vessels listed. The number of individual vessels is indicated, not the number of cases.

It is seen from Table 3.11 that although the total number of tankers running aground for the port of Philadelphia is somewhat less than that for New York City (33 vs 42, respectively), the total gross tanker tonnage of these vessels is substantially greater for Philadelphia (1,295,833 for Philadelphia vs 498,123 for New York City). These results suggest that perhaps the port of Philadelphia experiences tankers of a much greater size than does the port of New York City.

The results presented in Table 3.11 are also illustrated in Figures 3-1 through 3-4. Note once again that for each port, the results presented in these Figures represent all tanker and barge collisions and groundings regardless of the geographic location of the incident.

For each port, the latitude and longitude coordinates of each incident were plotted on NOAA navigational charts for the port to determine whether an incident occurred inside or outside the channel. Figure 3-5 illustrates the result of plotting latitude and longitude coordinates for a number of incidents occurring within the port of Houston. In some cases, the resolution needed to accurately identify the incident location relative to the channel was not available. For example, note the location of the incident identified by the arrow. Since the latitude and longitude coordinates in the database are represented down to a 10th of a minute, the best resolution which can be obtained on the chart is also equal to a tenth of a minute. Note from the Figure, however, that within a tenth of a minute in the latitudinal of longitudinal directions, it possible for the point to fall on or outside the water boundaries of the channel.

For a few incidents, the location of the incident, plotted on the charts using the longitude and latitude values from the CASMAIN database, fell on land in the vicinity of the water. In these cases, the coordinates were considered to be an error and the incident was assumed to have occurred outside the channel. The total number of tanker and barge collisions and groundings relative to the location of the channel is presented in Table 3.12 and Table 3.13 for the five ports selected. These tables also include, for each port, the percentage of the total number of barge and tanker collisions and groundings falling within the boundaries of the channel. The results presented do not include incidents having latitude and longitude coordinates falling outside the range of the NOAA charts available for each port. Therefore, the number of incidents in Table 3.12 differs from those presented in Table 3.11 and Figures 3-1 through 3-4.

Although this analysis was performed for selected ports, the methodology can be extended to additional ports if those ports appear in the CASMAIN database.

FIGURE 3.1

Tanker Collisions and Groundings
(1979-1990 CASMAIN Data)

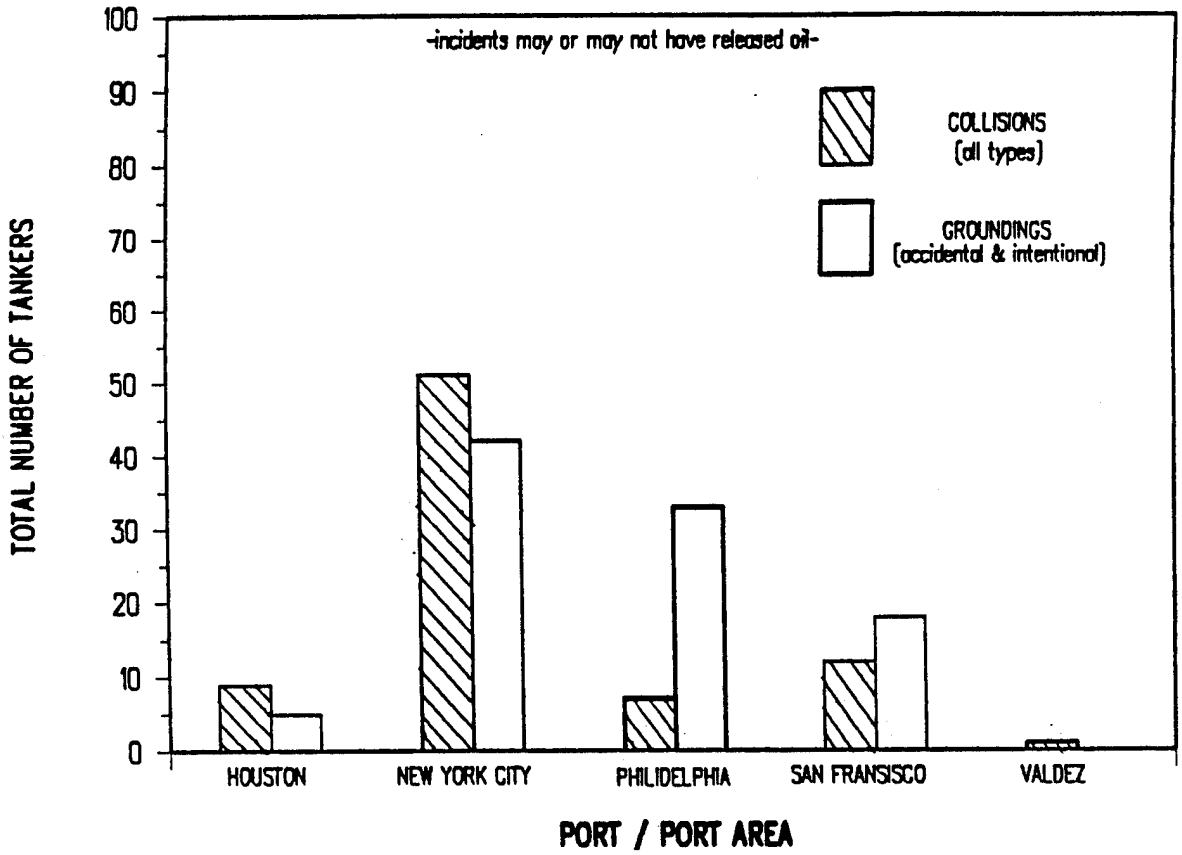

FIGURE 3.2

Barge Collisions and Groundings
(1979-1990 CASMAIN Data)

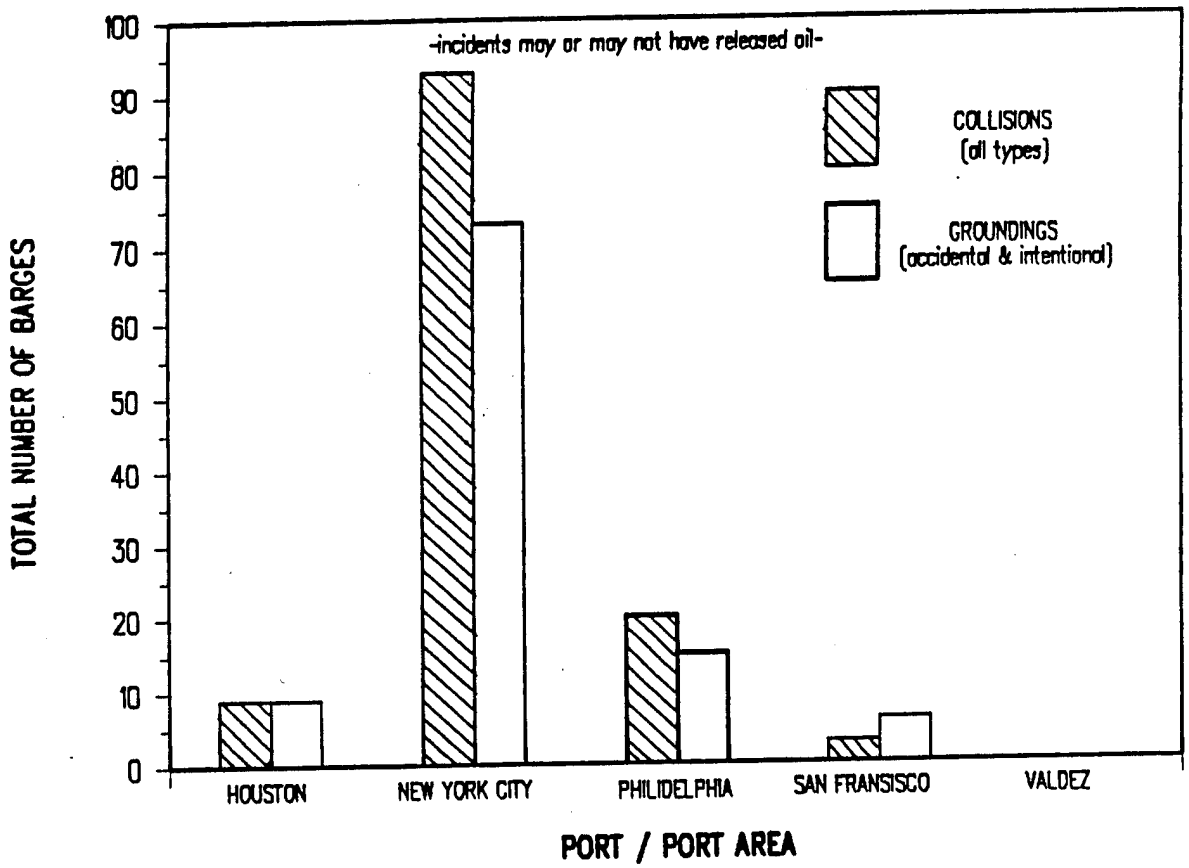

FIGURE 3.3

Gross Tons of Tankers Involved in Collisions and Groundings
(1979-1990 CASMAIN Data)

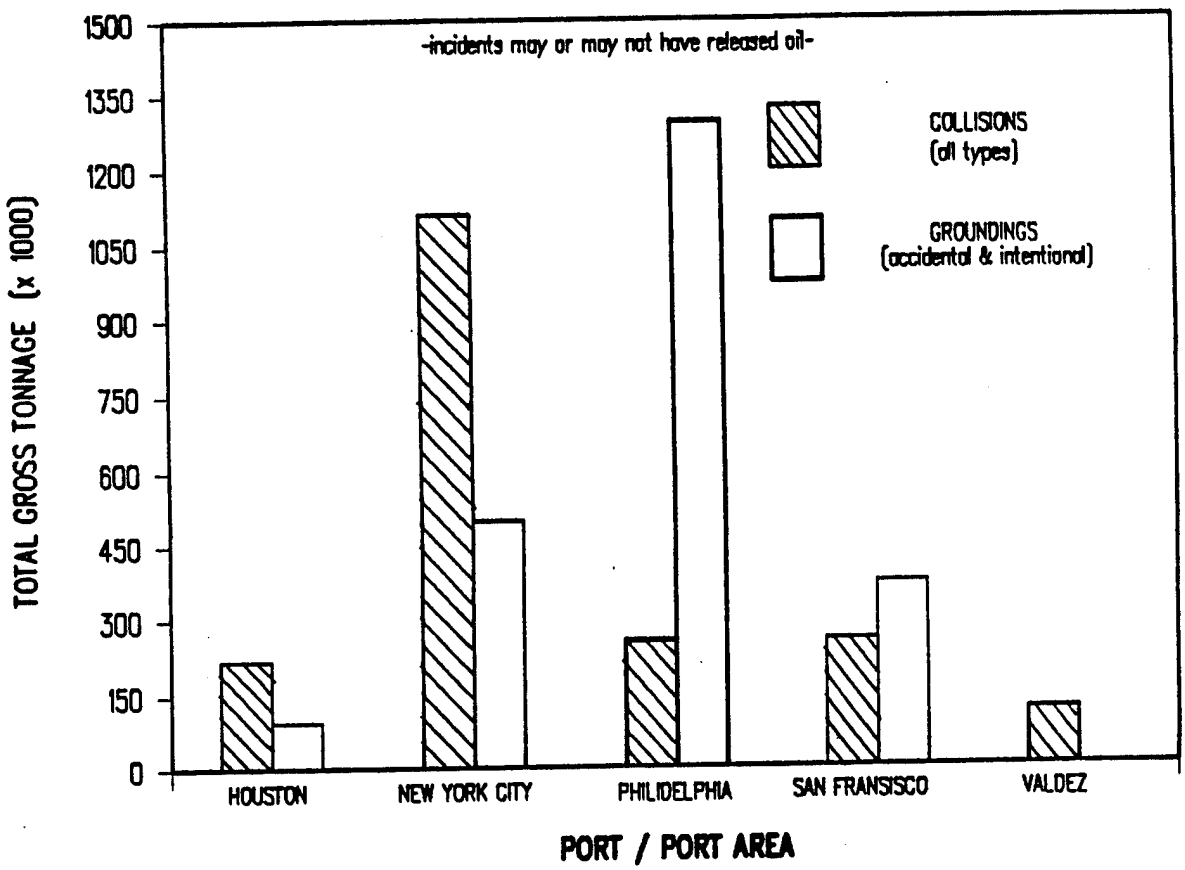

FIGURE 3.4

Gross Tons of Barges Involved in Collisions and Groundings
(1979-1990 CASMAIN Data)

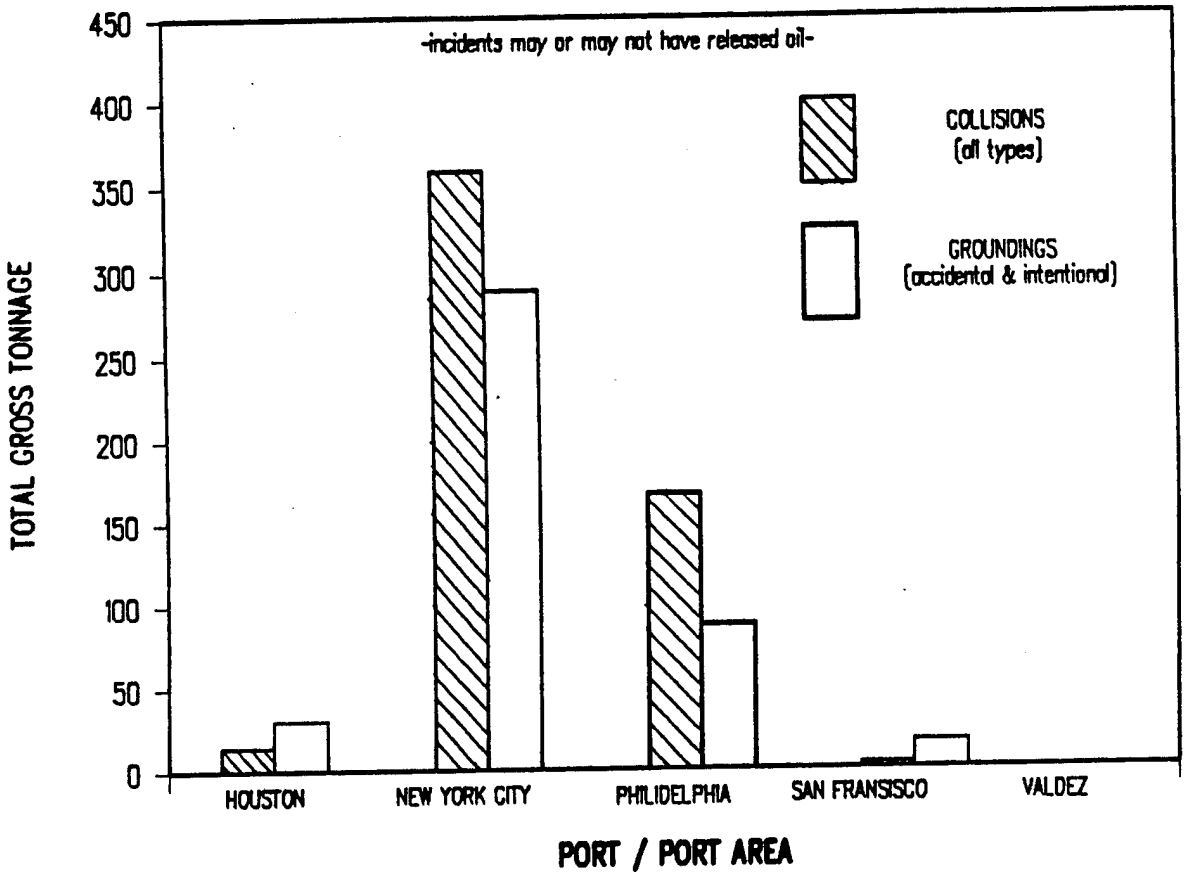

FIGURE 3.5

Location of Tanker In Channel and Off Channel Collisions and Groundings in a Section of the Port of Houston

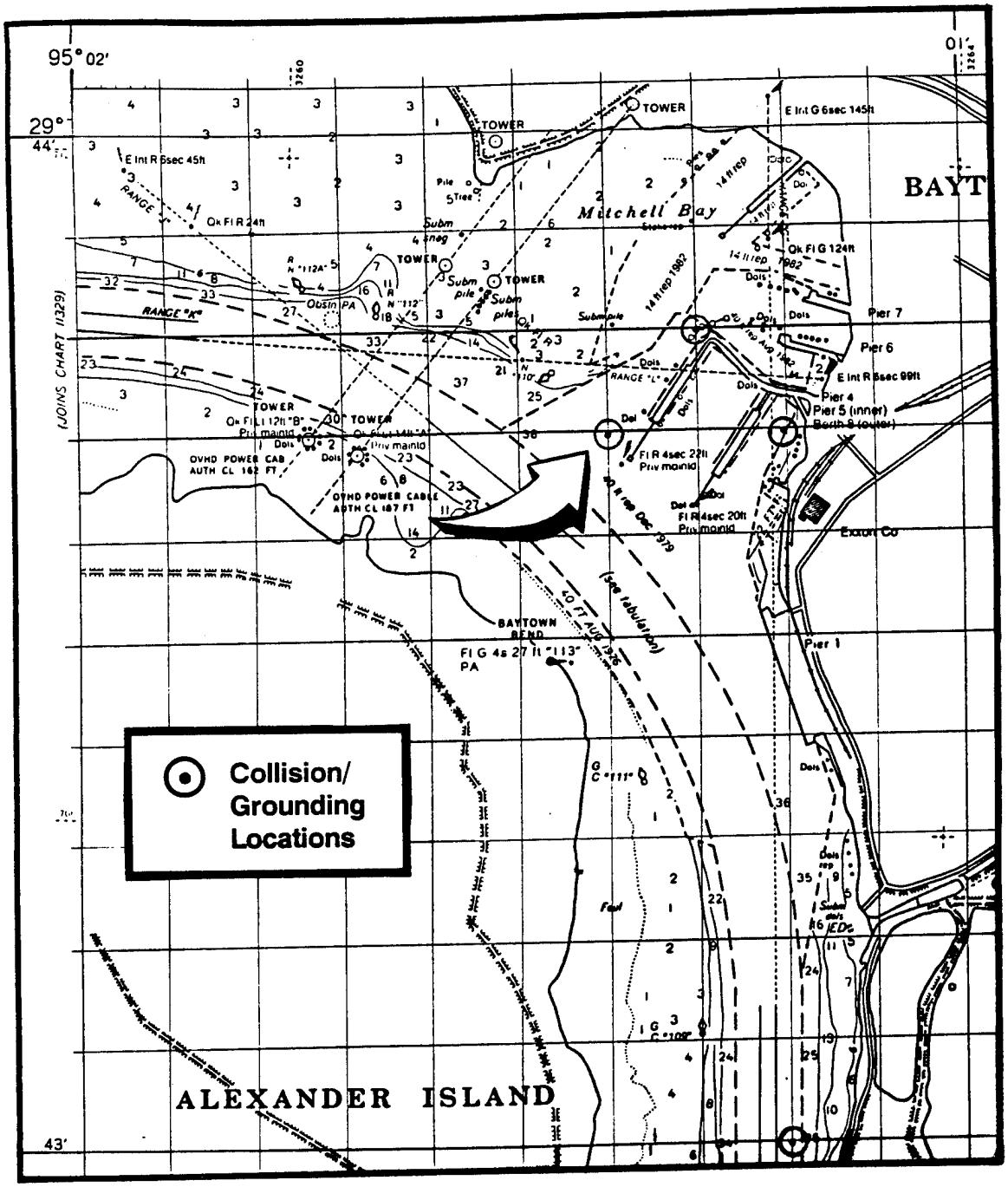

TABLE 3.12*

Number of Tanker Collisions and Groundings Relative to Channel

PORT	COLLISIONS			GROUNDINGS		
	IN	OUT	% IN	IN	OUT	% IN
San Francisco	0	2	0.0	1	9	10.0
Houston	3	2	60.0	1	0	100.0
Philadelphia	3	4	42.9	6	19	24.0
New York	7	9	43.8	4	6	40.0
Valdez	1	0	100.0	0	0	0

TABLE 3.13*

Number of Barge Collisions and Groundings Relative to Channel

PORT	COLLISIONS			GROUNDINGS		
	IN	OUT	% IN	IN	OUT	% IN
San Francisco	0	2	0.0	0	0	0.0
Houston	3	5	37.5	4	5	44.4
Philadelphia	5	10	33.3	2	11	15.4
New York	18	11	62.1	11	8	57.9
Valdez	0	0	0.0	0	0	0.0

IN = Number of incidents inside channel
OUT = Number of incidents outside channel
% IN = Percent of total incidents occurring inside channel

*Incidents having latitude and longitude coordinates not falling on available NOAA charts not included

3.4.4 Conclusions from Channel Accident Data Analysis

From the data presented in Table 3.12 and Table 3.13, we conclude that on the average,

1. 45% of tanker collisions occur within the channel markers.

   However, if the uncertainties in the data (especially the values of latitude and longitude) are considered, it may suffice to say that about 50% of tanker collision accidents occur inside the channel. That is, given a tanker collision, it is equally likely to be inside or outside the channel.

2. 26% of the tanker groundings are within the channel. That is, given that a tanker grounding has occurred, the probability that the grounding occurred inside the channel is 26%.

3. Barge collision inside the channel boundaries occurs about 44% of the time. Again, if uncertainties in data are considered, one can state that the in channel collision probability is 50% for barges.

4. In channel barge groundings occur about 41% of the time. That is, about 60% of barge groundings are off channel.

In short, significantly more tanker grounding accidents occur off channel (by a 3:1 ratio) compared to those occurring within the channel.

In the next chapter we discuss an oil spill Risk Assessment Model and utilize the data and findings presented in this chapter. A selected number of ports is studied and the ports are ranked on the basis of the risk/susceptibility of each port to experiencing oil spills.

CHAPTER 4

Risk Analysis Methodology

In this chapter a generic oil spill risk assessment model applicable to all ports is developed. This model is then exercised with data from several U.S. ports to illustrate the nature of the results and their dependence on important traffic and hydrographic parameters. Using this model, several U.S. ports are rank ordered in the descending order or riskiness (i.e., susceptibility to experiencing oil spills of equal to or greater than a certain volume).

4.1 DESCRIPTION OF THE MODEL

4.1.1 Definition of Risk

The word "risk" has different meaning to different people depending upon the context in which it is used and what quantitative measure it represents. In general, "risk" represents a measure of the frequency or probability with which an unwanted or detrimental event occurs *and* the magnitude of the resulting consequence. Many risk indices are based on the product of probability of occurrence and a measure of the consequence. That is,

$$R = p * c \tag{4.1}$$

where,

R	=	the risk
p	=	probability of occurrence of an event over a specified time (generally one year)
c	=	consequence expressed in a number of different measures (injuries, deaths, $ cost, quantity released, area affected, etc.)

In the case of systems which exhibit different modes of failure resulting in a number of different levels of consequences, the risk from such a system is defined in terms of an "average" consequence. That is, the risk is defined in terms of an average as follows:

$$R = \overline{p * c} \tag{4.2}$$

where the line over p*c represents an average.

The principal drawback with the above definition of the risk is that a high consequence, low probability event (such as a very large oil spill occurring extremely rarely) will be considered to have the same risk as a high probability, low consequence event (many occurrences of nuisance quantity oil spills in a port). Clearly, from the perspective of response to mitigate the detrimental effects or to plan the resource requirements to prevent/minimize serious consequences, the definition of risk indicated in equation 4.2 is inadequate. What is needed is a histogram of the probabilities for the occurrence of different magnitude events, so that the relative occurrence of high consequence events can be determined.

In this project, dealing with oil spill risks, we are interested in determining the probabilities of oil spills of different volumes occurring in a port due to vessel accidents. These results are then presented in the form of a graph of probabilities vs. quantity (i.e., volume) of oil potentially released in a port jurisdiction. Such a graph is called a "risk profile" (see Figure 4.1).

4.1.2 The Risk Model

Consider the movement of a loaded oil tanker into a port. Under most circumstances the sailing in and out of the harbor will be uneventful, i.e., the probability of the ship *not* being involved in any accident in that trip is very high, close to unity. However, there is a finite, albeit low, chance that there could be an accident. Involvement in an accident does not necessarily lead to the release of the cargo (oil). Only when the severity level of the accident exceeds a threshold is there the condition for oil release. Again this threshold severity level for release itself is dependent on the size and structural details of the ship, the type of accident (collision, grounding, ramming) etc. Even when the release occurs, the quantity of oil released depends on the extent of damage to the individual tanks in the ship and the size of the ship. That is, the volume of oil released is dependent on the seriousness of the accident above the leak threshold damage and the ship size. Finally, the circumstances under which the ship may be involved in an accident will themselves be dependent on many of the port parameters discussed in Chapter 3 (see, specifically Table 3.1). The model discussed below takes into consideration all of the above issues.

In developing the risk model indicated below, the following **assumptions** are made:

1. The vessel accidents are independent events.

2. Accidents caused by or attributable to human errors or other human factors are not included.

3. Specific locations of accidents, other than by water subzones (discussed in Chapter 3) are not considered.

4. The total volume of oil released (only) is considered. That is, the rate of oil spill which will depend on the size and location of the hole on the vessel is not explicitly taken into account.

5. The tracking of the movement of oil or the determination of the ultimate fate of the released oil is not within the purview of this model.

Consider a specific type of vessel, for example, an oil tanker. The annual probability that *in a given port* and in a specified water subzone, tanker accidents occur leading to the release of oil of volume Q is expressed by the following equations.

$$P(Q|VT, PN, SN) = \sum_{VS=VS_{min}}^{VS=VS_{max}} (1-VTS_{eff}) \, [R_f \, (PN, SN) * TRV \, (PN, SN, VT, VS) * \sum_{AT = collision}^{AT = grounding} CS(VT, VS) * P_R \, (VS, AT|A) * P_S \, (VS, VT|R)] \tag{4.3}$$

$$Q = Q \, (VS, S) \tag{4.4}$$

In the above equations, the parameters have the following definitions:

AT	=	Accident type (collision, ramming, grounding)
PN	=	Port (Name)
SN	=	Subzone (Name) in the port
VS	=	Vessel Size (small, medium, large)
VT	=	Vessel Type (tankers, barges, or both)
Q	=	Quantity of oil released (tons or m^3)

$P(Q \mid VT, PN, SN)$	=	Annual probability of realizing an oil release event in which Q quantity of oil is released due to an accident to vessel of type VT in a port PN and water subzone SN.
VTS_{eff}	=	Accident rate reduction fraction in the presence of a VTS
R_f (PN, SN)	=	Risk factor which is a function of the port and water subzone
TRV (PN, SN, VT, VS)	=	Traffic volume in number of transits per year in the specified water subzone of the port for vessels of type VT and size VS.
CS (VT, VS)	=	National average casualty rate for the vessel type VT and size VS (number of accidents per transit)
P_R (VS, AT | A)	=	Conditional probability of release (of any quantity of oil) given that an accident has occurred. This is a function of vessel size and accident type. (The subscript R represents release.)
P_S (VS, VT | R)	=	Conditional probability that given a spill has occurred, the spill is of size (severity) designated by S. This probability is a function of the vessel type and vessel size. (Note this is *not* a function of the type of accident.)
Q (VS, S)	=	Quantity of oil released (tons or m^3) in an accident of severity S. This is a function of the vessel size.

Equation 4.3 and equation 4.4 can be evaluated for all sizes of vessels that call on the port (keeping in mind their traffic volumes) and all types of accidents. From these one obtains a table of results of probabilities of oil spill of different magnitudes. These values can then be arranged in increasing order of spill quantities. The cumulative probabilities of exceeding a specified spill volume can then be calculated and plotted against the spill quantity. Such a plot presents an oil spill risk profile.

4.2 DATA FOR EXECUTING THE RISK MODEL

In order to calculate the various probabilities indicated in equation 4.3, several sets of data are needed. Some of the port specific data on the risk factors for different subzones of selected U.S. ports and also several conditional probabilities were discussed in Chapter 3. In Table 3.4 the national average casualty rates (CS) are provided. The individual risk factors (R_f) for several water subzones in 23 ports studied in the Ports Needs Study *(Maio, et al, 1991)* are shown in Table 3.5. The values for the conditional probability (P_R (VS, AT|A)) of a vessel experiencing a puncture given that an accident has occurred are shown in Table 3.6. The fraction of the vessel inventory released given a puncture and the conditional probability (P_S (VS, VT|R)) of the severity are indicated in Table 3.7.

The Ports Needs Study does not provide values for the port wide risk factor. We have calculated the port specific overall risk factor by using the historical casualty data (for the years 1980-1989) and actual number of vessel transit data for the year 1987 provided in the VTS study report. These overall risk factors are indicated in Table 3.5 with the water subzone type designator 0. For the ports in which the number of vessel transits is essentially the same in all water subzones, the port wide risk factor can be calculated using the formula

$$(R_f)_{port} = \sum_{i=1}^{N} (R_f)_i \qquad \textbf{(4.5)}$$

where,

N = number of subzones in the port

The other parameter of importance in the risk model is the traffic volume by vessel type and size. The Ports Needs Study has developed traffic forecasts for the various ports for the years 1995, 2000, 2005, and 2010. The database TRAFFIC.dbf provided in Appendix A shows the forecast data for 1995 for the 23 ports in the Ports Needs Study by different subzones. We have also estimated the overall traffic into the ports for the same year (1995) and these are indicated in the database as values for subzone 0.

The designation of the sizes of tankers and barges into small, medium, and large is dependent on the draft of the vessel. Table 4.1 shows the categorization used by the Port Needs Study. It is seen that there are three size categories for tankers whereas tanker barges are categorized by only two sizes.

TABLE 4.1

Correlation of Vessel Drafts with Common Deadweight Tonnage Levels by Type of Vessel

VESSEL TYPE/ DRAFT CATEGORY	GROSS TONNAGE	DEADWEIGHT TONNAGE	LENGTH		VESSELS INCLUDED IN CATEGORY
			METERS	FEET	
Tanker					
< 19 ft.	< 2,500	< 4,000	< 90	< 300	Smallest LPG, chemical tankers
19-30 ft.	2,500-11,000	4,000-20,000	90-170	300-550	Parcel tankers, (carriers of oil, chemicals, molasses), smaller oil tankers
> 30 ft.	11,000 +	20,000 +	170 +	550 +	Largest oil tankers, Exxon Valdez
Barge-Tanker					
Small	NE	NE	20-75	65-300	30,000-50,000 bbl tankers
Large	NE	NE	75 +	300-600	Over 50,000 bbl tankers

Source: *ERG (1991)*

The size mix of tankers and tank barges that visit a port is an important parameter as is the maximum size of the vessel. A database called MAXTNKR.dbf was developed to indicate the maximum size of tankers that can call on a port. This information was available only for a few ports *(from the NRC report - Marcus, et al, 1991)*. When no specific data were available, it was assumed that the maximum size of a tanker that can call on a port was 100 k. tons. Table 4.2 shows the data used in our analysis. Additional details of this database are indicated in Appendix A.

The size mix in the fleet of tankers or barges that calls on a port is another factor in the risk analysis. Again, this type of data was available only for a few ports. Table 4.3 shows the distribution of vessels in different dead weight ton categories for the oil tankers in the world fleet. Similar data that were available for U.S. ports are included in Appendix A in the databases TNKRFLET.dbf for tankers and BRGEFLET.dbf for barges.

In the case of U.S. ports for which the fleet mix data were not available, we have used the world fleet statistics. The ports for which the fleet mix data are available are indicated with "T" in the last column of Table 4.2.

The values in the databases indicated in Appendix A can be modified or added when new information becomes available for the various ports. In fact, the correct data, if available, can be incorporated by the MSO's of particular ports by simply editing the databases which are in the standard database format.

The next section illustrates how these data are used in calculating the risk.

4.3 RISK CALCULATION PROCEDURE

A computer program was developed to perform the various calculations involved in equation 4.3. (The computer program for these calculations was written in a database language supported by the database application software called dBase IV.) In this subsection, the calculation procedure is described step by step. In Section 4.4, results obtained using the program are discussed. Volume II of this report ("Users Guide to Oil Spill Risk Assessment Computer Program") provides details of how the program can be executed on a computer.

Because the various functions that appear in equation 4.3 are discrete, we follow the following stepwise calculation procedure. (All databases referred to here are described in Appendix A.)

1. First, a determination is made whether tanker risks, barge transportation risks, or risks due to both modes of transportation are needed. (Depending on this, appropriate flags are set and databases are selected.)

   For illustration purposes, we assume that tanker transport risks are to be calculated.

TABLE 4.2

Size of Maximum Dead Weight Tanker that can Call on a Port

PORT NUMBER	PORT NAME	MAXIMUM TANKER SIZE (k. TONS)	FLEET MIX
1	Boston, MA	100	F
2	Puget Sound, WA	100	F
3	Long Beach, CA	320	T
4	Santa Barbara, CA	100	F
5	Port Arthur, TX	100	F
6	New Orleans, LA	100	F
7	Houston, TX	320	T
8	Chesapeake So., VA	100	F
9	Baltimore, MD	100	F
10	Corpus Christi, TX	600	T
11	New York City, NY	160	T
12	Long Island Sound, NY	100	F
13	Philadelphia, PA	320	T
14	San Francisco, CA	320	T
15	Portland, OR	100	F
16	Anchorage, AK	600	F
17	Portland, ME	100	F
18	Portsmouth, NH	100	F
19	Providence, RI	100	F
20	Wilmington, NC	100	F
21	Jacksonville, FL	100	F
22	Tampa, FL	100	F
23	Mobile, AL	100	F

TABLE 4.3

Size Distribution of Tankers - World Fleet (1979)

TANKER DEAD WEIGHT (IN K TONS)		NO. OF VESSELS IN THE FLEET	VESSEL SIZE DESIGNATION		PROBABILITIES (%) OF FINDING THE TANKER SIZE RANGE	
					THE FLEET	SIZE CATEGORY
0	10	863	Small	1	17.98	100.00
10	15	212	Medium	2	4.42	39.26
15	20	328	Medium	2	6.83	60.74
20	30	566	Large	3	11.79	17.00
30	40	471	Large	3	9.81	14.00
40	50	166	Large	3	3.46	5.00
50	60	202	Large	3	4.21	6.00
60	70	168	Large	3	3.50	5.00
70	80	196	Large	3	4.08	6.00
80	90	182	Large	3	3.79	5.00
90	100	125	Large	3	2.60	4.00
100	110	90	Large	3	1.88	3.00
110	120	69	Large	3	1.44	2.00
120	130	94	Large	3	1.96	3.00
130	140	107	Large	3	2.23	3.00
140	150	42	Large	3	0.88	1.00
150	160	76	Large	3	1.58	2.00
160	170	44	Large	3	0.92	1.00
170	180	25	Large	3	0.52	1.00
180	190	14	Large	3	0.29	0.00
190	200	9	Large	3	0.19	0.00
200	210	26	Large	3	0.54	1.00
210	220	87	Large	3	1.81	3.00
220	230	82	Large	3	1.71	2.00
230	240	111	Large	3	2.31	3.00
240	250	24	Large	3	0.50	1.00
250	260	96	Large	3	2.00	3.00
260	270	93	Large	3	1.94	3.00
270	280	74	Large	3	1.54	2.00
280	290	41	Large	3	0.85	1.00
290	300	6	Large	3	0.12	0.00
300	325	34	Large	3	0.71	1.00
325	350	18	Large	3	0.38	1.00
350	375	17	Large	3	0.35	0.00
375	400	14	Large	3	0.29	0.00
400	600	28	Large	3	0.58	1.00

Source: *Sun Transport (1981)*

2. A range of tanker size (in deadweight k. tons) is selected for consideration (from TNKRFLET database). Generally, this selection is made from the lowest range record first.

3. The mean tanker size in the selected deadweight range is calculated. Also the size designation of the mean size tanker is noted from TNKRFLET.

4. The probability of finding this mean size tanker in the size category of the fleet is then obtained from TNKRFLET database.

5. A severity of accident (from the low to high) category is chosen. The probability of occurrence of the chosen level severity of accident is then obtained from the SEVERITY database.

   Also noted in this step will be the fraction of the tanker inventory that is likely to be released. The number is also read from the SEVERITY database.

6. An accident type (collision, ramming, grounding) is chosen. For the type of accident chosen and for the size of the tanker, the conditional probability of cargo release given the accident is determined from the database BLKREL_P.

7. The volume of oil likely to be released under the above assumptions is calculated (an oil density of 900 kg/m^3 is assumed in our calculations).

$$Q = \begin{matrix}[\textit{deadweight of the average tanker} \\ \textit{in the size range chosen}]\end{matrix} * \frac{[\textit{fraction of inventory released}]}{[\textit{oil density}]} \quad \textbf{(4.6)}$$

8. The conditional probability of releasing the Q volume of oil, given that an accident has occurred to the chosen vessel, is then calculated by multiplying the probability values obtained in Steps 4, 5, and 6.

9. The overall traffic volume (in number of vessel transits per year) of the size and type of vessel is obtained from the TRAFFIC database.

10. The probability of an accident of the type chosen in Step 6 and to the size of vessel assumed in step 3 is calculated using the data in the databases NATLRATE and PORTS.

    This combined probability will be the product of the National Casualty rate, the subzone risk factor, the traffic volume (obtained in step 9) and the fraction of the fleet representing the size of vessel chosen (this is determined

in step 4). If a VTS exists then the VTS effectiveness is taken into account here to reduce the accident probability.

11. The total annual probability "P" of realizing a Q volume oil spill with the vessel chosen in step 3, the accident severity in step 5, and the type of accident in step 6, is equal to the product of the probabilities calculated in steps 8 and 10. This pair P and Q are then stored in temporary database, say TEMP.

12. Steps 6 through 11 are repeated for all possible types of accidents.

13. Steps 5 through 12 are repeated for all possible types of accident severities.

14. Steps 2 through 13 are repeated for all sizes of tankers (up to the maximum size given by MAXTNKR database for the port in question) calling on the port.

15. The records in TEMP database created in step 11 are sorted in increasing order of spill volumes into, say, another database called OUT.

16. The cumulative probability that any given spill will have a volume <u>less than or equal</u> to Q is then given by

$$P_c(Q) = \sum_{q=Q_{min}}^{q=Q} P(q) \tag{4.7}$$

where,

$P_c(Q)$ = Cumulative annual probability that any spill will be of a volume less than or equal to Q.

q = Running summation volume variable

P(q) = Probability of realizing exactly q volumes of spill (this is stored in each record of the sorted database OUT).

17. The maximum spill volume that can occur, Q_{max}, is equal to the maximum size of the tanker multiplied by the largest fraction of the inventory that can be released consistent with the most severe accident that can occur (in the case of large tankers, this fraction is about 10%)

18. The cumulative probability, $P_{c,max}$, is that value consistent with $Q=Q_{max}$ and is obtained from equation 4.7.

19. The risk profile is then obtained by plotting on the ordinate $[P_{c,max} - P_c(Q)]$, the annual probability of exceeding Q volumes of spill, vs. Q the volume of oil spilled.

The results from the above calculation procedure are discussed in the next section.

4.4 RISK RESULTS

The oil spill risk results can be presented in the form of a risk profile for each port (or a particular water subzone of the port). Typical results are shown in Figure 4.1. The ordinate in this figure is the annual probability of experiencing one or more spills of volume larger than a specified volume. The oil spill volume is on the abscissa. As can be seen from the results in Figure 4.1, the annual probability of exceeding a given spill volume decreases with increase in the volume of interest. Also as the maximum spill volume is approached, the rate of decrease of probability is very significant, indicating that very large spills are highly unlikely to occur.

We have divided the spill volume axis into three regions, namely, "medium spill" ($Q < 10^3$ m^3), "large spill" ($10^3 \leq Q \leq 10^4$ m^3), and "catastrophic"[1] ($Q > 10^4$ m^3). This division is somewhat arbitrary.

The results indicated in Figure 4.1 are for the port of New York. Three different curves are plotted. The risks due to oil transportation in/out of New York by barge are indicated by line 1. Line 2 shows the similar risk due to transport of oil in tankers. The line 3 represents the combined risk to the port of New York from the transport of oil in barges and tank ships.

It is evident from the results in Figure 4.1 that the barge risk (i.e., probability for spill of a specified quantity or larger) is generally lower than that from tankers for the oil spill volume greater than 100 m^3 (26,400 gallons). Initially, this would appear to be a somewhat surprising result because there are about 7300 barge transits per year compared to 6300 for tanker transits (See TRAFFIC.dbf in Appendix A) in the port of New York. However, this finding can be explained on the basis of two sets of data. First, the casualty rate (# per 100,000 transits) for large tankers is about 3 times higher than that for barges (see database NATLRATE in Appendix A). Second the probability of very severe accidents in barges is only 2.2% of all accidents whereas in ships it amounts to about 7.7% – a factor of 3½ higher! Hence, even though the barge traffic is higher than the tanker traffic the accident occurrence and severity probabilities counteract so that the risk is of the same order of magnitude for both barge and tanker traffic in New York.

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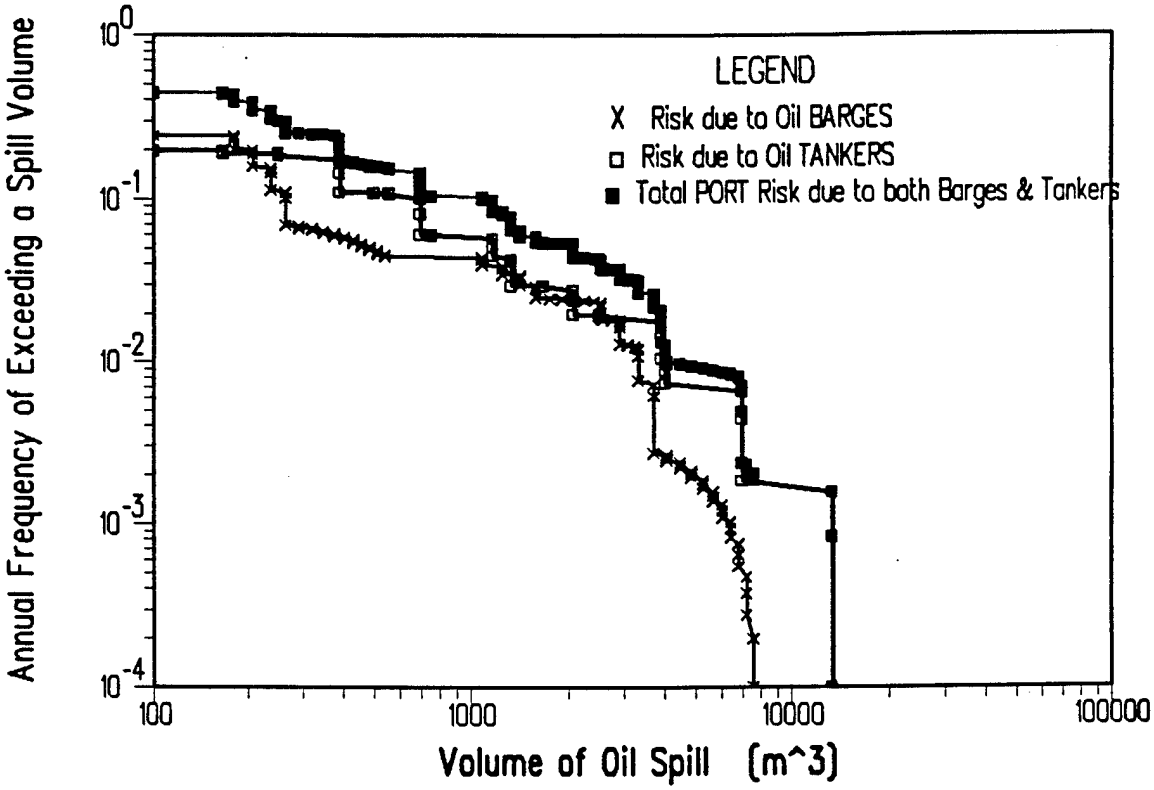
[1]The Exxon Valdez spill has been estimated to be about 4 x 10^4 m^3 and has been termed "catastrophic."

FIGURE 4.1

Oil Spill Risk Profile for the Port of New York



The other interesting finding from Figure 4.1 is that the maximum size of potential spills is about the same for both barge and tanker in New York port, even though the maximum size of tanker that may visit the port is 16 times the size (160 k. tons) of the largest size barge (10 k. tons). (See TNKRFLET and BRGEFLET databases in Appendix A.) This is because, while in the most severe barge accident the entire inventory of the barge may be released, in the most sever tanker accident, we have *assumed* that at best 10% of the inventory is released (see SEVERITY database in Appendix A).

The combined tanker and barge risk,, shown in Figure 4.1 as the total port risk is the sum of the tanker and barge risks for some spill volumes.

The effect on a port oil risk by providing VTS is illustrated in Figure 4.2. The port of New York is again used as an example. It is seen that the provision of VTS reduces the risk, but only by about a factor of 3. Also the risk reduction is more observable for low end spill volumes. The probability for a large spill is small to begin with; the provision of VTS will further reduce the already small risk. However, the risk reduction may be of the same order as the uncertainty in calculating the risk for higher spill volumes.

The comparative risks among different ports is illustrated in Figure 4.3. The ports of New York and San Francisco are chose as examples. In New York total barge and tanker traffic volumes are comparable whereas San Francisco has high levels of traffic of large tankers and virtually no large barges. The second difference between the two ports lies in the maximum size of tankers that can call on a port. In the case of New York, the largest tanker is 160 k. tons dead weight whereas a 320 k. ton dead weight tanker can visit San Francisco (see TNKRFLET database in Appendix A). Finally, the fleet mix of tankers calling on the two ports are different also.

It is seen from the results shown in Figure 4.3 that the risks from smaller spills (i.e., less than 10^3 m^3) are larger in New York than in San Francisco. This is clearly due to higher volumes of barge traffic in New York. At the higher end of the spill volume scale the risks in San Francisco are higher, clearly due to the larger ships that can visit this port. The results in this figure clearly show that the ranking of port by risk is *not independent* of the spill volumes.

We have attempted to rank order a selection of ten U.S. ports in terms of their riskiness to oil spills using only currently available information on traffic, fleet, mix of vessels, etc. These rankings are compared at spill volumes of 10^2m^3, 10^3m^3, and 10^4m^3 (forming, respectively, the low end boundaries of spill types categorized by "medium size," "large size," and "catastrophic"). These comparisons are shown as bar charts in Figures 4.4a, 4.4b, and 4.4c. The results are also presented in Table 4.4.

Discussion on the results presented in the various figures is provided in Section 4.6.

FIGURE 4.2

Oil Spill Risk Profile Effectiveness of VTS in the Port of New York

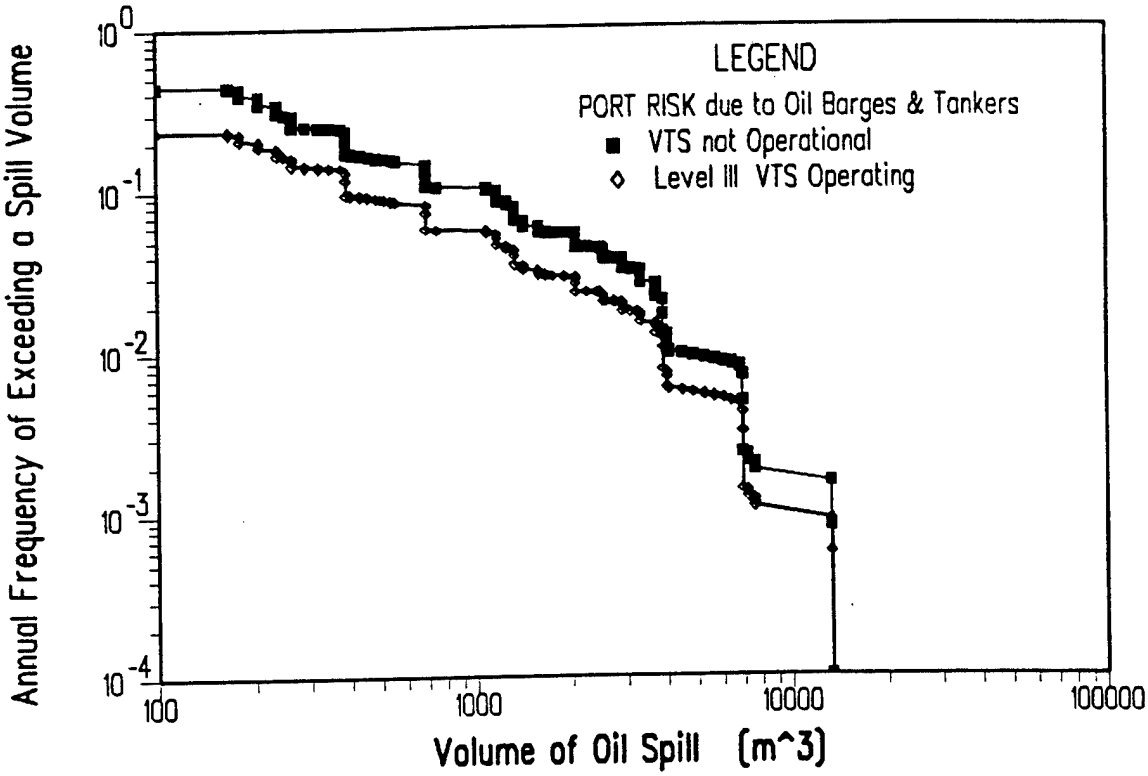


FIGURE 4.3

Oil Spill Risk Profile New York & San Francisco Port Risks Comparison

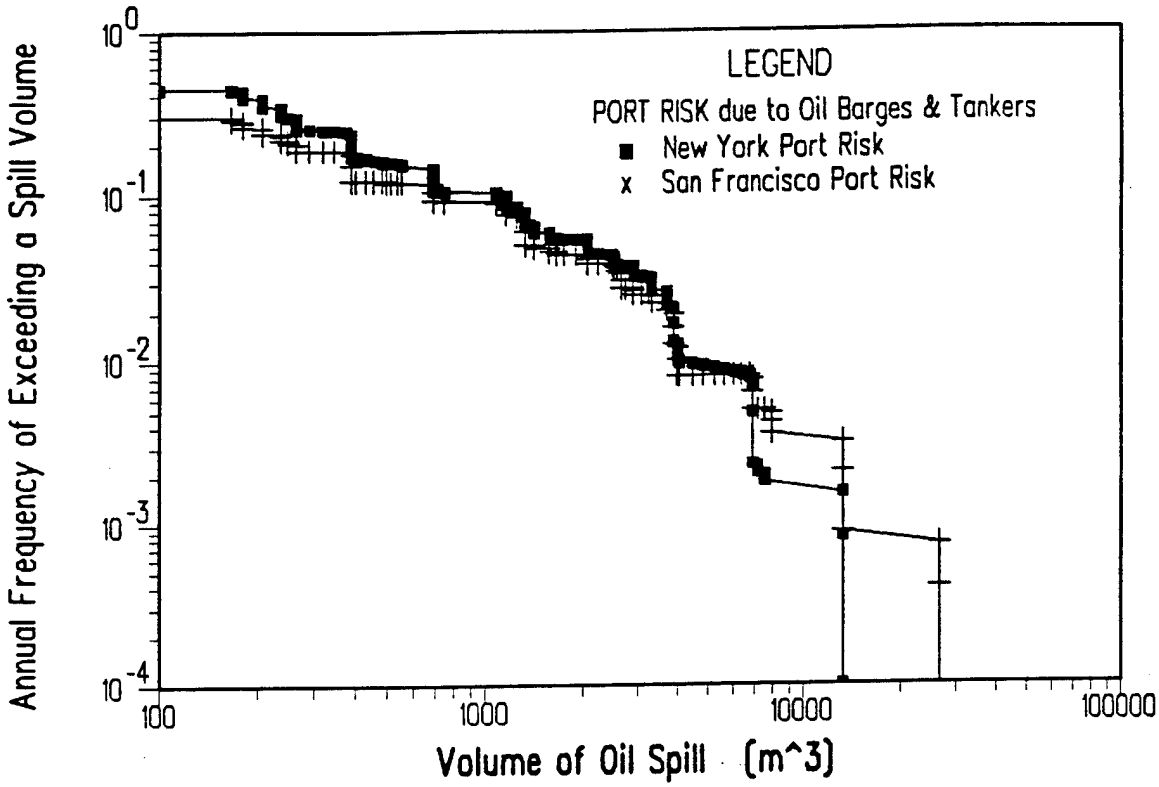
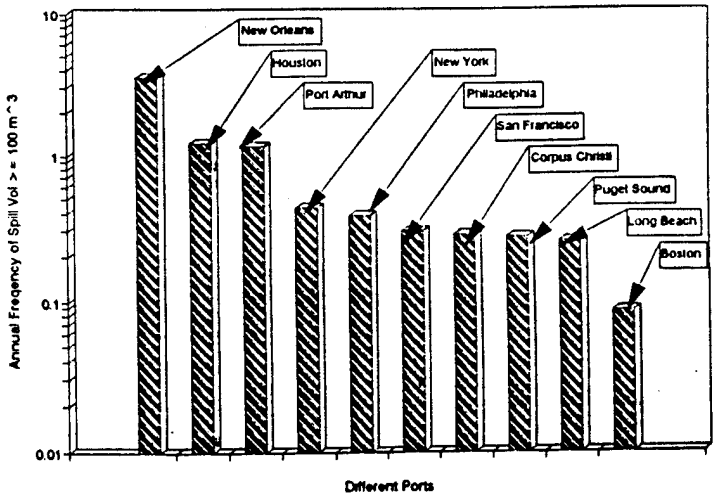


Figure 4.4a: Ranking of Ports by Small Size Oil Spills



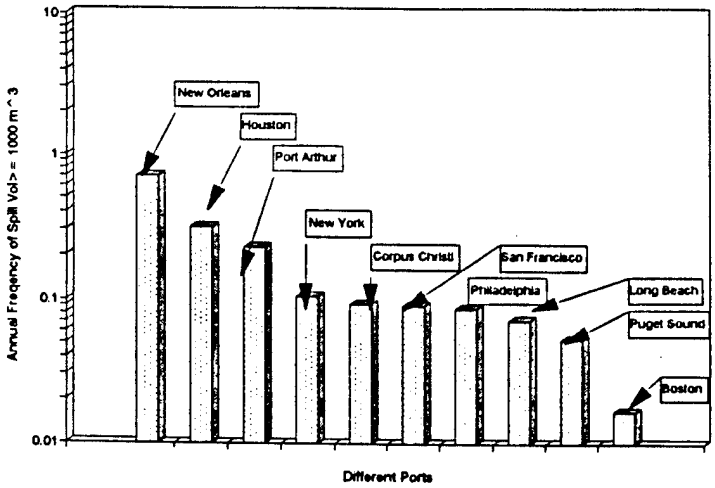


Figure 4.4b: Ranking of Ports by Medium Size Oil Spills

Figure 4.4c: Ranking of Ports by Large Size Oil Spills

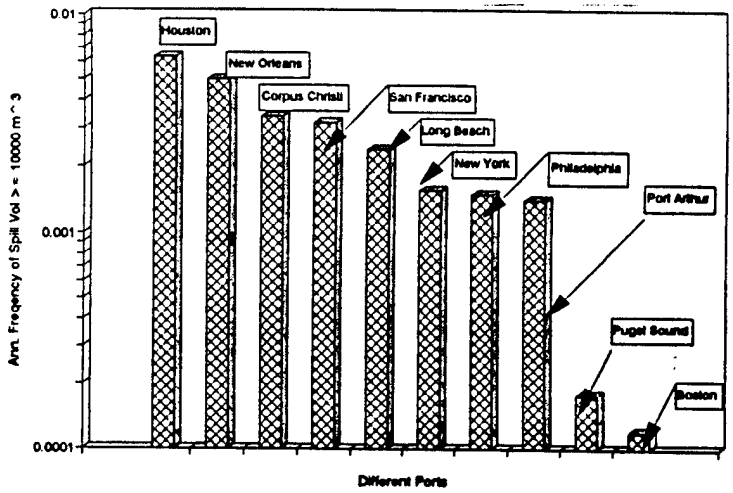


TABLE 4.4

Ranking of Ports by Annual Frequency* by Spill Size

SMALL SPILL**			MEDIUM SPILL***			LARGE SPILL****		
RANK	NAME OF PORT	ANNUAL FREQUENCY	RANK	NAME OF PORT	ANNUAL FREQUENCY	RANK	NAME OF PORT	ANNUAL FREQUENCY
1	New Orleans	3.5900	1	New Orleans	0.70000	1	Houston	0.006400
2	Houston	1.2500	2	Houston	0.31300	2	New Orleans	0.005000
3	Port Arthur	1.1800	3	Port Arthur	0.22900	3	Corpus Christi	0.003400
4	New York	0.4440	4	New York	0.10450	4	San Francisco	0.003200
5	Philadelphia	0.3900	5	Corpus Christi	0.09300	5	Long Beach	0.002400
6	San Francisco	0.3000	6	San Francisco	0.09100	6	New York	0.001560
7	Corpus Christi	0.2860	7	Philadelphia	0.08700	7	Philadelphia	0.001500
8	Puget Sound/ Seattle	0.2800	8	Long Beach	0.07200	8	Port Arthur	0.001400
9	Long Beach	0.2600	9	Puget Sound/ Seattle	0.5350	9	Puget Sound/ Seattle	0.000179
10	Boston	0.0868	10	Boston	0.01670	10	Boston	0.000120

* Annual frequency here refers to the frequency/year of experiencing a volume of spill equal to or greater than the specified volume.

** Small spill is defined as oil spill volume of $10^2 m^3$

*** Medium spill is of volume $10^3 m^3$

**** Large spill is of volume $10^4 m^3$

4.5 GUIDE TO DATA MODIFICATION BY INDIVIDUAL PORTS

The results presented in the previous section are based on the best available data (and traffic forecast for the year 1995) at this time. Needless to say, there are a number of parameters, associated with each port, whose values may not be correct. In order to assist the individual port MSOs to perform their own assessment of the risks using the oil spill risk model presented earlier (by executing, perhaps, the computer program described in Volume II of this report) we provide here a list of items/databases that may need to be modified and updated with the port specific data. The databases identified below are described in detail in Appendix A.

1. The value in the field MAXTNKRSIZE in the database MAXTNKR.dbf corresponding to the specific port should be modified appropriately. This field contains the size of the largest tanker that can visit the port (size in k tons dead weight).

2. The fleet size mix of both tankers and barges that call on the port need to be input properly.

   The tanker fleet size data are provided in the TNKRFLET database.

   - First, the port number corresponding to the named port is obtained from PORTS.dbf database;

   - This port number is input into field PORTNUM in the TNKRFLET database;

   - The tanker fleet mix in terms of number of vessels in a given dead weight range is now input into the fields DWT_FROM, DWT_TO, and NVESSELS;

- The size of the vessel per the definition indicated in Table 4.1 is now input into VESL_SIZE and S_INDEX fields;

  - As many records as there are data on the size range available are input into this database;

  - The value of the ratio of the total number of vessels in a given size range and the total number of vessels calling on a port is entered into the FLET_PROB field (for each size range); and

  - The value of the ratio (in %) of the vessels in a given range to all vessels belonging to the same vessel size category is entered in the SZFLETPROB field.

Procedure similar to the above is followed for modifying the barge fleet mix also (BRGEFLET database).

3. The vessel traffic data, in terms of the number of transits in the port area, discriminated by the vessel sizes and vessel type (tankers, barges) have to be input into the TRAFFIC.dbf database. If only total port wide data are available, then the SUBZONENUM field should contain the value 0. If data are available for other water zones, these could be input. (However, please note that the geographical areas for the water zones *must* correspond to that defined in the USCG's Ports Needs Study *(Maio, et al, 1991)*.)

4. If a Vessel Traffic System is currently operating in the specific port and its characteristics in terms of effectiveness in preventing accidents is known then the values in the database VTSFACTR.dbf can be changed appropriately. It is our opinion, however, that the MSOs of the ports are unlikely to have the data required in the format of the VTSFACTR database. (Note that these data should cover all types and sizes of vessels.)

4.6 DISCUSSIONS ON THE RESULTS

The principal results obtained by exercising the risk model are indicated in Figures 4.1 through 4.4c and in Table 4.4. It is evident that the provision of a VTS in a port reduces the accident frequency and thus the overall risk. The reduction in risk (measured by the annual frequency of exceeding a specified volume of spill) is by about a factor of 3 – this reduction factor being dependent on the type of vessels and the traffic.

The ranking of a sample of 10 ports is provided in Table 4.4 as well as in the form or bargraphs in Figures 4.4a through 4.4c. The ordinate in these figures represents the annual frequency of exceeding a small size spill, a medium size spill, and a large size spill, respectively. For the purposes of discussion, we have defined the various ranges of spill volumes to constitute different degrees of spill size:

Small Size Spill	spill volume $< = 10^2$ m^3
Medium Size Spill	$10^2 <$ spill volume $\leq 10^3$ m^3
Large Size Spill	$10^3 <$ spill volume $\leq 10^4$ m^3
Catastrophic Spill	spill volume $> 10^4$ m^3

Based on the above definitions, we find that for small and medium size spill risks, the port of New Orleans seems to get the dubious distinction of being number 1 and Boston the last. That is, New Orleans has the probability of experiencing 3.6 accidents/year in which volume of oil spilled is greater than $10^2 m^3$ and 0.7 accidents/year where the volume of oil spilled is $> 10^3 m^3$. The ranking at lower oil spill volumes seems to be very much dependent on the oil vessel traffic and to some extent on the risk factor associated with the port. For example,

New Orleans has an overall risk factor of 17.9 (see Table 3.5) compared to about 4 for New York and 3.1 for Houston. New Orleans also has significantly more vessel traffic (2,436 large tanker transits/year compared to 1,252 for New York; 15,900 small, and 581 large barge transits compared to, respectively, 6,738 and 566 barge transits in New York). Therefore, it is not surprising that New Orleans has higher probabilities for spills of a specified volume of oil than New York.

The small size and medium size spill risks for Houston, TX and Port Arthur, TX are both comparable. This is somewhat surprising, considering that Houston has a lot more vessel traffic than Port Arthur and that Houston can host larger DWT size ships. (We have arbitrarily assumed that Port Arthur can receive 100 k. ton DWT maximum size — see MAXTNKR.dbf database in Appendix A.) The principal difference lies in the port risk factor; Houston has a value of 3.13 whereas Port Arthur has a value of 8.38. This is a clear illustration of how the risk of an oil spill in a port is dependent on *both* the port conditions *and* the traffic volume (and maybe to a lesser degree on the size mix in the vessel fleet).

Figure 4.4a indicates that several ports (New York, Philadelphia, San Francisco, Corpus Christi, Puget Sound, and Long Beach) have very similar risks for small spills. Boston has the lowest risk. A similar pattern is seen in Figure 4.4b for medium size spills. Clearly noticed is the higher risk of Gulf ports. The large spill risks shown in Figure 4.4c indicate again the high riskiness of Gulf ports. Puget Sound and Boston are on par (at the low end). This is because both of these ports have very low large tanker traffic. Also the maximum size of the vessel that can call on these ports is 100 k tons DWT.

Finally, the risk difference between the most risky port and the least risky port is (on the average) a factor of about 35!

4.7 CONCLUSIONS

In this chapter we have discussed the development of the port risk assessment model to determine oil spill risks. This model was then exercised for a selected number of U.S. ports and these ports are ranked in decreasing order of oil spill risk. It is found from these analyses that:

1. The port risk is dependent both on the vessel traffic volume and the specific geographic and other vessel traffic parameters included in the generalized port risk value.

2. The Gulf Coast ports seem to have significantly higher risk levels compared to East and West Coast ports.

3. The maximum deviation between the highest risk and lowest risk port (among the sample ports chosen) is about a factor of 35.

4. The ranking of ports by their susceptibility to oil spills depends on the size of the spill considered.

5. The port ranking results can be usefully included into a decision support system in evaluating the optimal locations of personnel and equipment to combat different levels of oil spills.

Acronyms

CFR	Code of Federal Regulations
COTP	Captain of the Port
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FWPCA	Federal Water Pollution Control Act (1972)
LOOP	Louisiana Offshore Oil Platform
MIT	Massachusetts Institute of Technology
MMS	U.S. Mines and Minerals Service
MPIR	Marine Pollution Incident Report
MPVS	Marine Pollution Vessel Source
MS	Military Standard
MSIS	Marine Safety Information System
MSO	Marine Safety Office
NCP	National Contingency Plan
NOAA	National Oceanic & Atmospheric Administration
NRT	National Response Team
OPA	Oil Pollution Act (1990)
OSC	On Scene Coordinator
R&D	Research & Development
RRT	Regional Response Team
TMS	Technology & Management Systems, Inc.
USCG	United States Coast Guard
VIN	Vessel Identification Number
VNTSC	Volpe National Transportation Systems Center
VTS	Vessel Traffic System
VTS Study	This is the same as the Port Needs Study performed by the VNTSC

References

Anderson, C.M., Notario, J.J., LaBelle, R.P., and Lucas, A.D. "Oil Spill Risk Analysis–Northern California (Proposed Sale 91) Outer Continental Shelf," NTIS Report No. PB88-122486. Minerals Management Service Branch of Environmental Modeling, U.S. Department of the Interior, August 1987.

Commandant/G-MER-2. "Criteria for Reviewing a Local Contingency Plan," Letter No. 16465. July 26, 1989.

ERG. "Estimates of Costs Associated with Oil and Hazardous Chemical Spills and Costs of Idle Resources During Vessel Repairs," Section 7, Volume III of Ports Needs Study Report (Maio, et al, 1991). Arlington, MA: Contributed by Eastern Research Group, Inc., 1991.

Frasher, S., Vice President, Midland Enterprises, Inc. Private Communication, September 1992.

Hantzes, H.N., Ponce, P.V., Fell, M., and Robey, M.T. "High Risk Areas for Pollution Incidents," report to USCG. Cambridge, MA: Volpe National Transportation Systems Center, December 1989.

Maio, D., Ricci, R., Rossetti, M., Schwenk, J., and Liu, T. "Port Needs Study (Vessel Traffic Services Benefits)," Volume I, Study Report, Report No. DOT-CG-N-01-91-1.2. Cambridge, MA: Prepared for the U.S. Coast Guard by the John A. Volpe National Transportation Systems Center, USDOT/RSPA, August 1991.

Marcus, H.S. (Chairman). "Tanker Spills–Prevention by Design." Washington, DC: Committee on Tank Vessel Design, Marine Board Commission on Engineering and Technical Systems, National Research Council, National Academy Press, 1991.

NRT-1. "Hazardous Materials Emergency Planning Guide." Washington, DC: National Repsonse Team, EPA/USCG, 1987.

Psaraftis, H.N., Baird, A.V., and Nyhart, J.D. "National Response Capability to Oil Spills: A Systems Approach" *Oceans*. Seattle, WA: Murray Publishing Co., 1980.

Sun Transport, Inc. "Analysis of World Tank Ship Fleet, December 31, 1979." Aston, PA: March 1981.

"Technical Guidance for Hazards Analysis." U.S. EPA, FEMA, U.S. DOT, December 1987.

APPENDIX A

This appendix contains information on the structure, field definitions and contents of the various databases used in the the evaluation of the Oil Spill Risks. The databases described in the following pages include:

BLKREL_P	.dbf		
BRGEFLET	.dbf		
INPUT	.dbf	&	OUT .dbf / RESULTS .dbf
MAXTNKR	.dbf		
NATLRATE	.dbf		
PORTS	.dbf		
SEVERITY	.dbf		
SPILSIZE	.dbf		
TNKRFLET	.dbf		
TRAFFIC	.dbf		
VTSFACTR	.dbf		

Structure for database: BLKREL_P.dbf

Information on the Database:

The name of this database represents BULK RELEASE PROBABILITY. The database contains information on the conditional probabilities of release of oil by size of vessel and type of accident. There is no distinction between barge and oil tanker.

	Field Name	Type	Width.Dec		
1	VESL_SIZE	C	8	=	Size category of the vessel (Small, Medium, Large)
2	S_INDEX	N	1	=	Size Index (1=Small, 2=Medium, 3=Large)
3	ACC_TYPE	C	10	=	Type of Accident(Collision, Ramming, Grounding)
4	A_INDEX	N	1	=	Accident Type Index (1=Collision, 2=Ramming, 3=Grounding)
5	REL_P	N	7.5	=	Conditional Probability (in fractions) of oil release given that the vessel is involved in an accident.
6	REFERENCE	C	20	=	Reference from which the data were taken

Record#	VESL_SIZE	S_INDEX	ACC_TYPE	A_INDEX	REL_P	REFERENCE
1	Small	1	Collisions	1	0.17972	Table 5-27, pg 5-42
2	Small	1	Rammings	2	0.17972	
3	Small	1	Groundings	3	0.01935	
4	Medium	2	Collisions	1	0.21951	
5	Medium	2	Rammings	2	0.21951	
6	Medium	2	Groundings	3	0.14173	
7	Large	3	Collisions	1	0.21951	
8	Large	3	Rammings	2	0.21951	
9	Large	3	Groundings	3	0.14173	

Structure for database: BRGEFLET.dbf

Information on the Database:

The name of this database represents the BARGE FLEET. The database contains information on the size distribution of barges that call on a port. The distribution should be given for each port. If the data for any specified port are not available then a default port = 0 data are used. These data are indicated below.

	Field Name	Type	Width.Dec		
1	PORTNUM	N	2	=	Port Number (1 to 23)
2	DWT_FROM	N	3	=	Barge Dead Weight range in k.tons (this field is the beginning of the range)
3	DWT_TO	N	3	=	End of the Dead Weight Range
4	NVESSELS	N	5	=	Number of Barges calling on the port per year in this range of Dead Weight class
5	VESL_SIZE	C	8	=	Vessel size (Small, or Large)
6	S_INDEX	N	1	=	Vessel Size Index (1=Small, 3= Large)
7	FLET_PROB	N	6.2	=	% Probability of a Barge with size in the middle of the range being in the entire fleet that calls on the port.
8	SZFLETPROB	N	6.2	=	% Probability of a Barge with size in the middle of the range being in the fleet of the specified size class that calls on the port.
9	PORTNAME	C	15	=	Name of the Port.

Record#	PORTNUM	DWT_FROM	DWT_TO	NVESSELS	VESL_SIZE	S_INDEX	FLET_PROB	SZFLETPROB	PORTNAME
1	0	3.0	3.5	0	Small	1	12.50	25.00	All U.S. Ports
2	0	3.5	4.0	0	Small	1	12.50	25.00	All U.S. Ports
3	0	4.0	4.5	0	Small	1	12.50	25.00	All U.S. Ports
4	0	4.5	5.0	0	Small	1	12.50	25.00	All U.S. Ports
5	0	5.0	5.5	0	Large	3	5.00	10.00	All U.S. Ports
6	0	5.5	6.0	0	Large	3	5.00	10.00	All U.S. Ports
7	0	6.0	6.5	0	Large	3	5.00	10.00	
8	0	6.5	7.0	0	Large	3	5.00	10.00	
9	0	7.0	7.5	0	Large	3	5.00	10.00	
10	0	7.5	8.0	0	Large	3	5.00	10.00	
11	0	8.0	8.5	0	Large	3	5.00	10.00	
12	0	8.5	9.0	0	Large	3	5.00	10.00	
13	0	9.0	9.5	0	Large	3	5.00	10.00	
14	0	9.5	10.0	0	Large	3	5.00	10.00	

Structure for database: INPUT.dbf

Information on the Database:

The name of this database represents INPUT DATA. The input data contains the port and water sub-zone information, the type of vessel of interest for which the risk values are to be calculated (note: combined risks due to more than one type of vessel can also be calculated) and an indication of whether the port has an operating VTS system or not. If the system is present it is automatically assumed that the VTS is of the best level (level III).

	Field Name	Type	Width.Dec		
1	BLANK	C	1	=	A blank space to accommodate the data structure
2	PORTNAME	C	25	=	Name of the Port
3	STATE	C	3	=	State in which the Port is located
4	SUBZONENUM	N	3	=	Subzone number (0= Overall Port)
5	VTI	N	2	=	Vessel Type Index (1 = Tanker, 2 = Barge, 3 = Tanker & Barge)
6	VTS_INDEX	N	2	=	Flag which indicates whether the Port has a Vessel Traffic System (VTS) or not (0 = No, 1 = Yes)
7	VTS	L	1	=	A Logical field (.T. if VTS is present)

Record#	BLANK	PORTNAME	STATE	SUBZONENUM	VTI	VTS_INDEX	VTS
1		New York	NY	9	3	0	.F.

Structure for database: OUT.dbf
Structure for database: RESULTS.dbf

Information on the Database:

The results of the calculations are output into the above name databases. Bothe RESULTS.dbf and OUTP.dbf have the same structure. The only difference is that the OUTP is the database into which the final results from calculation, sorted by volume of spill are written. RESULTS serves as the structure template for OUT.

	Field Name	Type	Width.Dec		
1	VOLUME	N	8.1	=	Volume of oil spill in cubic meters (m^3)
2	PROB	N	12.10	=	Annual probability of realizing exactly the spill volume in the VOLUME field
3	CUMPROB	N	12.10	=	Cumulative probability that in a year the spill volume exceeds the volume in the VOLUME field

Structure for database: **MAXTNKR.dbf**

Information on the Database:

The name of this database represents the MAXIMUM SIZE of TANKER that can come into a port. For each port it is necessary to indicate the maximum tanker size in DWt k.tons that **can** call on the port. These data have to be given when available. In the case the data are not available, this value is set to 100 ktons.

	Field Name	Type	Width.Dec		
1	PORTNUM	N	2	=	Port number (1 to 23)
2	PORTNAME	C	15	=	Name of Port
3	STATE	C	2	=	State in which the port is located
4	MXTNKRSIZE	N	3	=	Maximum size of tanker that can visit the port. Size is expressed in Dead Weight kilo tons (metric).
5	FLEETMIX	L	1	=	A flag which indicates whether data on the mix of fleet of tankers that call on the port is available or not. If not available (.F.) then the world tanker fleet mix is used in the calculations.

Record#	PORTNUM	PORTNAME	STATE	MXTNKRSIZE	FLEETMIX
1	1	BOSTON	MA	100	.F.
2	2	PUGET SOUND	WA	100	.F.
3	3	LONG BEACH	CA	320	.T.
4	4	SANTA BARBARA	CA	100	.F.
5	5	PORT ARTHUR	TX	100	.F.
6	6	NEW ORLEANS	LA	100	.F.
7	7	HOUSTON	TX	320	.T.
8	8	CHESAPEAKE SOUT	VA	100	.F.
9	9	BALTIMORE	MD	100	.F.
10	10	CORPUS CHRISTI	TX	600	.T.
11	11	NEW YORK CITY	NY	160	.T.
12	12	LONG ISLAND SOU	NY	100	.F.
13	13	PHILADELPHIA	PA	320	.T.
14	14	SAN FRANCISCO	CA	320	.T.
15	15	PORTLAND	OR	100	.F.
16	16	ANCHORAGE	AK	600	.F.
17	17	PORTLAND	ME	100	.F.
18	18	PORTSMOUTH	NH	100	.F.
19	19	PROVIDENCE	RI	100	.F.
20	20	WILMINGTON	NC	100	.F.
21	21	JACKSONVILLE	FL	100	.F.
22	22	TAMPA	FL	100	.F.
23	23	MOBILE	AL	100	.F.

Structure for database: **NATLRATE.dbf**

Information on the Database:

The name of this database represents the NATIONAL ACCIDENT RATE data. The database contains the average accident rate values by size & type of vessel and type of accident. The rate is expresssed in number of accidents per 100,000 transits.

	Field Name	Type	Width.Dec		
1	VESL_TYPE	C	10	=	Vessel Type (Tanker, Barge, or both)
2	V_INDEX	N	1	=	Vessel Type Number (1 = Tanker, 2= Barge)
3	VESL_SIZE	C	6	=	Size category of the vessel (Small, Medium, Large)
4	S_INDEX	N	1	=	Size Index (1=Small, 2=Medium, 3=Large)
5	ACC_TYPE	C	10	=	Type of Accident(Collision, Ramming, Grounding)
6	A_INDEX	N	1	=	Accident Type Index (1=Collision, 2=Ramming, 3=Grounding)
7	CSULTYRATE	N	7.3	=	Number of casualties for 100,000 transits for the specified vessel type and for specified accident type

Record#	VESL_TYPE	V_INDEX	VESL_SIZE	S_INDEX	ACC_TYPE	A_INDEX	CSULTYRATE
1	Tanker	1	Small	1	Collisions	1	0.462
2	Tanker	1	Small	1	Rammings	2	0.000
3	Tanker	1	Small	1	Groundings	3	0.578
4	Tanker	1	Medium	2	Collisions	1	0.960
5	Tanker	1	Medium	2	Rammings	2	0.183
6	Tanker	1	Medium	2	Groundings	3	1.069
7	Tanker	1	Large	3	Collisions	1	7.718
8	Tanker	1	Large	3	Rammings	2	2.634
9	Tanker	1	Large	3	Groundings	3	10.373
10	Tnk_Barge	2	Small	1	Collisions	1	3.221
11	Tnk_Barge	2	Small	1	Rammings	2	0.966
12	Tnk_Barge	2	Small	1	Groundings	3	3.455
13	Tnk_Barge	2	Large	3	Collisions	1	2.277
14	Tnk_Barge	2	Large	3	Rammings	2	2.167
15	Tnk_Barge	2	Large	3	Groundings	3	2.708

Structure for database: PORTS.dbf

Information on the Database:

The name of this database represents PORTS DATA. This database contains the data on each port including the number of sub-water zones and the sub-zone dependent "Risk Factor" (as defined by the Ports Needs Study). Also included is a water sub-zone type 0 which implies the entire port. The risk factor for the entire port is, generally, the sum of all sub-zone risk factors.

	Field Name	Type	Width.Dec		
1	PORTNUM	N	2	=	Port Number (Currently between 1 and 23)
2	PORTNAME	C	15	=	Name of the Port
3	STATE	C	2	=	State in which the Port is located
4	SUBZONENUM	N	2	=	Subzone number of the water zone in the Port (0 = Entire Port Area, 1=A, 2=B, etc)
5	WATERTYPE	C	1	=	Type of water body (A,B,C, etc)
6	RISKFACTR	N	8.5	=	Risk Factor for the specified port and water body. This factor multiplies the average national casualty rate to give the specific port and water body casulaty rate for the specified vessel type and accident type.
7	REFERENCE	C	20	=	Reference from which the data are obtained

PORTNUM	PORTNAME	STATE	SUBZONENUM	WATERTYPE	RISKFACTR
1	BOSTON	MA	0		4.43453
1	BOSTON	MA	1	A	0.37508
1	BOSTON	MA	2	B	0.03127
1	BOSTON	MA	3	C	0.75154
1	BOSTON	MA	4	D	0.46461
1	BOSTON	MA	5	E	2.81203
2	PUGET SOUND	WA	0		7.97133
2	PUGET SOUND	WA	1	A	0.91939
2	PUGET SOUND	WA	2	B	0.30525
2	PUGET SOUND	WA	3	C	0.64297
2	PUGET SOUND	WA	4	E	1.04813
2	PUGET SOUND	WA	5	C	0.01971
2	PUGET SOUND	WA	6	D	0.95930
2	PUGET SOUND	WA	7	D	0.78129
2	PUGET SOUND	WA	9	E	2.90479
2	PUGET SOUND	WA	10	D	0.39050
3	LONG BEACH	CA	0		1.30800
3	LONG BEACH	CA	1	A	0.02371
3	LONG BEACH	CA	2	B	0.44709
3	LONG BEACH	CA	3	C	0.23691
3	LONG BEACH	CA	4	D	0.60029
4	SANTA BARBARA	CA	0		0.26169
4	SANTA BARBARA	CA	1	A	0.26169
5	PORT ARTHUR	TX	0		8.38194
5	PORT ARTHUR	TX	1	A	0.53874

5	PORT ARTHUR	TX	2	E	2.38349
5	PORT ARTHUR	TX	3	E	4.38490
5	PORT ARTHUR	TX	4	F	1.07481
6	NEW ORLEANS	LA	0		17.90824
6	NEW ORLEANS	LA	1	A	0.85570
6	NEW ORLEANS	LA	2	E	1.94588
6	NEW ORLEANS	LA	3	F	3.02567
6	NEW ORLEANS	LA	4	E	4.51479
6	NEW ORLEANS	LA	5	F	1.63881
6	NEW ORLEANS	LA	6	F	5.92739
7	HOUSTON	TX	0		3.13818
7	HOUSTON	TX	1	A	0.03408
7	HOUSTON	TX	2	E	2.91751
7	HOUSTON	TX	3	D	0.18659
8	CHESAPEAKE SOUT	VA	0		2.77404
8	CHESAPEAKE SOUT	VA	1	A	0.04265
8	CHESAPEAKE SOUT	VA	2	B	0.44280
8	CHESAPEAKE SOUT	VA	3	C	0.30003
8	CHESAPEAKE SOUT	VA	4	D	0.37894
8	CHESAPEAKE SOUT	VA	5	E	1.25083
8	CHESAPEAKE SOUT	VA	6	C	0.35879
9	BALTIMORE	MD	0		3.96903
9	BALTIMORE	MD	1	C	1.91003
9	BALTIMORE	MD	2	D	0.32546
9	BALTIMORE	MD	3	F	1.73354
10	CORPUS CHRISTI	TX	0		3.13385
10	CORPUS CHRISTI	TX	1	A	0.06922
10	CORPUS CHRISTI	TX	2	B	0.50529
10	CORPUS CHRISTI	TX	3	E	1.72868
10	CORPUS CHRISTI	TX	4	F	0.83066
11	NEW YORK CITY	NY	0		3.99649
11	NEW YORK CITY	NY	1	A	0.10112
11	NEW YORK CITY	NY	2	B	0.21879
11	NEW YORK CITY	NY	3	C	0.14023
11	NEW YORK CITY	NY	4	D	0.15273
11	NEW YORK CITY	NY	5	E	1.68713
11	NEW YORK CITY	NY	6	C	0.42998
11	NEW YORK CITY	NY	7	E	1.26651
12	LONG ISLAND SOU	NY	0		2.26377
12	LONG ISLAND SOU	NY	1	A	0.02232
12	LONG ISLAND SOU	NY	2	B	0.07547
12	LONG ISLAND SOU	NY	3	C	1.01728
12	LONG ISLAND SOU	NY	4	D	0.04759
12	LONG ISLAND SOU	NY	5	D	0.05255
12	LONG ISLAND SOU	NY	6	E	1.04856
13	PHILADELPHIA	PA	0		3.84089
13	PHILADELPHIA	PA	1	A	0.50696
13	PHILADELPHIA	PA	2	B	0.33529
13	PHILADELPHIA	PA	3	C	1.08857
13	PHILADELPHIA	PA	4	F	1.91007
14	SAN FRANCISCO	CA	0		4.43990
14	SAN FRANCISCO	CA	1	A	0.14195
14	SAN FRANCISCO	CA	2	B	0.45094

14	SAN FRANCISCO	CA	3	C	0.84060
14	SAN FRANCISCO	CA	4	D	0.46885
14	SAN FRANCISCO	CA	5	F	2.53756
15	PORTLAND	OR	0		5.50423
15	PORTLAND	OR	1	A	0.17350
15	PORTLAND	OR	2	C	1.96100
15	PORTLAND	OR	3	F	3.36973
16	ANCHORAGE	AK	0		7.65366
16	ANCHORAGE	AK	1	A	0.43966
16	ANCHORAGE	AK	2	C	5.84886
16	ANCHORAGE	AK	3	D	1.36514
17	PORTLAND	ME	0		0.32666
17	PORTLAND	ME	1	A	0.00920
17	PORTLAND	ME	2	C	0.13546
17	PORTLAND	ME	3	D	0.18200
18	PORTSMOUTH	NH	0		0.18486
18	PORTSMOUTH	NH	1	A	0.02258
18	PORTSMOUTH	NH	2	B	0.04338
18	PORTSMOUTH	NH	3	D	0.11890
19	PROVIDENCE	RI	0		4.53813
19	PROVIDENCE	RI	1	A	1.43090
19	PROVIDENCE	RI	2	C	1.76036
19	PROVIDENCE	RI	3	D	1.34687
20	WILMINGTON	NC	0		2.53804
20	WILMINGTON	NC	1	A	0.00840
20	WILMINGTON	NC	2	E	0.85509
20	WILMINGTON	NC	3	F	1.67455
21	JACKSONVILLE	FL	0		3.27027
21	JACKSONVILLE	FL	1	A	0.22962
21	JACKSONVILLE	FL	2	E	3.04065
22	TAMPA	FL	0		6.42569
22	TAMPA	FL	1	A	0.79077
22	TAMPA	FL	2	C	5.12433
22	TAMPA	FL	3	D	0.51059
23	MOBILE	AL	0		7.23417
23	MOBILE	AL	1	A	0.04222
23	MOBILE	AL	2	E	2.10450
23	MOBILE	AL	3	C	0.44332
23	MOBILE	AL	4	E	4.19989
23	MOBILE	AL	5	F	0.44424

Structure for database: **SEVERITY.dbf**

Information on the Database:

The name of this database provides information on the fraction of vessel inventory released depending on the vessel type and the severity level of the accident.

	Field Name	Type	Width.Dec		
1	VESL_TYPE	C	10	=	Vessel Type (Tanker, Barge, or both)
2	V_INDEX	N	1	=	Vessel Type Number (1 = Tanker, 2= Barge)
3	SPILL_SIZE	C	10	=	Spill Size Class (Small, Medium, Large, Catastrophic)
4	INVFR_REL	N	5.3	=	% volume of vessel inventory which is released due to the accident of given severity.
5	SEV_INDEX	N	1	=	Accident Severity Index (Total,Large, Medium, Small)
6	SEV_PR	N	7.5	=	Conditional Probability that given an accident leading to a release the severity of accident is that specified by the SEV_INDEX.
7	NOTES	C	25	=	Notes on the information in the database
8	REFERENCE	C	18	=	Reference from where the data are taken from

Record #	VESL_TYPE	V_INDEX	SPILL_SIZE	INVFR_REL	SEV_INDEX	SEV_PR	NOTES	REFERENCE
1	Tanker	1	Small	0.010	1	0.75757	Small loss (< 5 % Cargo)	Table 5-28, p 5-43
2	Tanker	1	Medium	0.030	2	0.15152	Medium loss(1 - 5 % loss)	
3	Tanker	1	Large	0.100	3	0.09091	Large loss(5 -10 % loss)	
4	Tnk_Barge	2	Small	0.050	1	0.80000	Small loss(<10 % loss)	
5	Tnk_Barge	2	Medium	0.300	2	0.08889	Medium loss(10 - 50% loss	
6	Tnk_Barge	2	Large	0.700	3	0.08889	Large loss(50 - 90% loss)	
7	Tnk_Barge	2	Very Large	0.950	4	0.02220	V.Large loss(50 - 90% los	

Structure for database: SPILSIZE.dbf

Information on the Database:

The name of this database indicates that it provides information on the different sizes (volumes of spill of oil) for different size indexes. The ranges of volumes released for different size definitions are indicated.

	Field Name	Type	Width.Dec		
1	SIZE_TYPE	C	12	=	Spill size type (Small,Medium,Large,Catastrophic)
2	SPL_INDEX	N	1	=	Spill Size Index (1 = Small, 2 = Medium, (3 = Large, 4 = Catastrophic)
3	RANGE	C	20	=	Spill Volume range in thousnds gallons
4	SIZE_VOL	N	4	=	Estimated average spill volume in the range (k.gal)
5	UNITS	C	10	=	Units of the volume of spill (gallons)

Record#	SIZE_TYPE	SPL_INDEX	RANGE	SIZE_VOL	UNITS
1	Small	1	Less than 10 kgal	8	Kilo gal
2	Medium	2	10 to 100	90	kilo gal
3	Large	3	100 to 750	500	kilo gal
4	Catastrophic	4	> 750	4000	kilo gal

Structure for database: TNKRFLET.dbf

Information on the Database:

The name of this database indicates that it includes data on the size distribution of the tankers that call on each port. The size range in DWt k.tons is indicated in each record as well as the number of vessels calling on the port in each range. Note that the fleet probability is the overall probability that given that a tanker is visiting a port it is in the range specified by the record. Also note that port number = 0 represents a default size distribution based on the world oil tanker fleet mix data for the year 1988.

	Field Name	Type	Width.Dec		
1	PORTNUM	N	2	=	Port Number (1 to 23)
2	DWT_FROM	N	3	=	Tanker Dead Weight range in k.tons (this field is the beginning of the range)
3	DWT_TO	N	3	=	End of the Dead Weight Range
4	NVESSELS	N	5	=	Number of vessels calling on the port per year in this range of Dead Weight class
5	VESL_SIZE	C	8	=	Vessel size (Small, Medium or Large)
6	S_INDEX	N	1	=	Vessel Size Index (1=Small, 2= Medium, 3= Large)
7	FLET_PROB	N	6.2	=	% Probability of a tanker with size in the middle of the range being in the entire fleet that calls on the port.
8	SZFLETPROB	N	6.2	=	% Probability of a tanker with size in the middle of the range being in the fleet of the specified size class that calls on the port.
9	PORTNAME	C	15	=	Name of the Port.

Record#	PORTNUM	DWT_FROM	DWT_TO	NVESSELS	VESL_SIZE	S_INDEX	FLET_PROB	SZFLETPROB	PORTNAME
1	0	0	10	863	Small	1	17.98	100.00	World Fleet #s
2	0	10	15	212	Medium	2	4.42	39.26	
3	0	15	20	328	Medium	2	6.83	60.74	
4	0	20	30	566	Large	3	11.79	17.00	
5	0	30	40	471	Large	3	9.81	14.00	
6	0	40	50	166	Large	3	3.46	5.00	
7	0	50	60	202	Large	3	4.21	6.00	
8	0	60	70	168	Large	3	3.50	5.00	
9	0	70	80	196	Large	3	4.08	6.00	
10	0	80	90	182	Large	3	3.79	5.00	
11	0	90	100	125	Large	3	2.60	4.00	
12	0	100	110	90	Large	3	1.88	3.00	
13	0	110	120	69	Large	3	1.44	2.00	
14	0	120	130	94	Large	3	1.96	3.00	
15	0	130	140	107	Large	3	2.23	3.00	
16	0	140	150	42	Large	3	0.88	1.00	
17	0	150	160	76	Large	3	1.58	2.00	
18	0	160	170	44	Large	3	0.92	1.00	
19	0	170	180	25	Large	3	0.52	1.00	
20	0	180	190	14	Large	3	0.29	0.00	
21	0	190	200	9	Large	3	0.19	0.00	
22	0	200	210	26	Large	3	0.54	1.00	

23	0	210	220	87	Large	3	1.81	3.00	
24	0	220	230	82	Large	3	1.71	2.00	
25	0	230	240	111	Large	3	2.31	3.00	
26	0	240	250	24	Large	3	0.50	1.00	
27	0	250	260	96	Large	3	2.00	3.00	
28	0	260	270	93	Large	3	1.94	3.00	
29	0	270	280	74	Large	3	1.54	2.00	
30	0	280	290	41	Large	3	0.85	1.00	
31	0	290	300	6	Large	3	0.12	0.00	
32	0	300	325	34	Large	3	0.71	1.00	
33	0	325	350	18	Large	3	0.38	1.00	
34	0	350	375	17	Large	3	0.35	0.00	
35	0	375	400	14	Large	3	0.29	0.00	
36	0	400	600	28	Large	3	0.58	1.00	
37	3	0	10	33	Small	1	2.75	100.00	Long Beach
38	3	10	20	145	Medium	2	12.08	100.00	
39	3	20	25	72	Large	3	6.00	7.05	
40	3	25	45	409	Large	3	34.08	40.02	
41	3	45	80	122	Large	3	10.17	11.94	
42	3	80	160	213	Large	3	17.75	20.84	
43	3	160	320	206	Large	3	17.17	20.16	
44	7	0	10	92	Small	1	5.54	100.00	Houston
45	7	10	20	145	Medium	2	8.73	100.00	
46	7	20	25	72	Large	3	4.34	5.06	
47	7	25	45	763	Large	3	45.96	53.62	
48	7	45	80	373	Large	3	22.47	26.21	
49	7	80	160	213	Large	3	12.83	14.97	
50	7	160	320	2	Large	3	0.12	0.14	
51	10	0	10	52	Small	1	5.98	100.00	Corpus Christi
52	10	10	20	19	Medium	2	2.18	100.00	
53	10	20	25	10	Large	3	1.15	1.25	
54	10	25	45	380	Large	3	43.68	47.56	
55	10	45	80	190	Large	3	21.84	23.78	
56	10	80	160	209	Large	3	24.02	26.16	
57	10	160	320	8	Large	3	0.92	1.00	
58	10	320	600	2	Large	3	0.23	0.25	
59	11	0	10	61	Small	1	4.36	100.00	New York
60	11	10	20	103	Medium	2	7.36	100.00	
61	11	20	25	51	Large	3	3.64	4.13	
62	11	25	45	640	Large	3	45.71	51.78	
63	11	45	80	411	Large	3	29.36	33.25	
64	11	80	160	134	Large	3	9.57	10.84	
65	13	0	10	1	Small	1	0.10	100.00	Philadelphia
66	13	10	20	57	Medium	2	5.88	100.00	
67	13	20	25	29	Large	3	2.99	3.18	
68	13	25	45	217	Large	3	22.37	23.79	
69	13	45	80	243	Large	3	25.05	26.64	
70	13	80	160	419	Large	3	43.20	45.94	
71	13	160	320	4	Large	3	0.41	0.44	
72	14	0	10	8	Small	1	0.72	100.00	San Francisco
73	14	10	20	145	Medium	2	13.06	100.00	
74	14	20	25	72	Large	3	6.49	7.52	
75	14	25	45	463	Large	3	41.71	48.38	
76	14	45	80	198	Large	3	17.84	20.69	
77	14	80	160	170	Large	3	15.32	17.76	
78	14	160	320	54	Large	3	4.86	5.64	

Structure for database: TRAFFIC.dbf

Information on the Database:

The name of this database indicates that it provides data on the annual traffic of vessels in the port area for any specified port. These numbers are th number of vessel transits by size and vessel type.

	Field Name	Type	Width.Dec		
1	PORTNUM	N	2	=	Sequential number of the Port
2	PORTNAME	C	15	=	Name of the Port
3	SUBZONENUM	N	2	=	Subzone number of the water body (0= Overall Port)
4	VESL_TYPE	C	10	=	Vessel Type (Tanker, Barge, or both)
5	V_INDEX	N	1	=	Vessel Type Number (1 = Tanker, 2= Barge)
6	SMALL	N	6	=	# of Small vessel transits per year in the port
7	MEDIUM	N	6	=	# of Medium size vessel transits per year
8	LARGE	N	6	=	# of Large vessel transits per year
9	REFERENCE	C	20	=	Reference to the data source

PORTNUM PORTNAME	SUBZONENUM VESL_TYPE	V_INDEX	# of Vessel Transits/Year SMALL	MEDIUM	LARGE
1 Boston					
	0 Tanker	1	259	319	236
	1 Tanker	1	305	375	271
	2 Tanker	1	234	312	239
	3 Tanker	1	304	375	271
	4 Tanker	1	234	312	239
	5 Tanker	1	218	222	160
	0 Tnk_Barge	2	1086	0	307
	1 Tnk_Barge	2	1247	0	321
	2 Tnk_Barge	2	979	0	321
	3 Tnk_Barge	2	1247	0	321
	4 Tnk_Barge	2	978	0	321
	5 Tnk_Barge	2	978	0	251
2 Puget Sound					
	0 Tanker	1	68	191	145
	1 Tanker	1	196	566	415
	2 Tanker	1	189	519	415
	3 Tanker	1	104	277	120
	4 Tanker	1	85	242	295
	5 Tanker	1	0	0	0
	6 Tanker	1	0	4	0
	7 Tanker	1	36	107	56
	8 Tanker	1	0	0	0

	9 Tanker	1	0	0	0
	0 Tnk_Barge	2	2982	0	0
	1 Tnk_Barge	2	7910	0	0
	2 Tnk_Barge	2	7306	0	0
	3 Tnk_Barge	2	6658	0	0
	4 Tnk_Barge	2	648	0	0
	5 Tnk_Barge	2	0	0	0
	6 Tnk_Barge	2	300	0	0
	7 Tnk_Barge	2	3994	0	0
	8 Tnk_Barge	2	0	0	0
	9 Tnk_Barge	2	26	0	0
3 Los Angeles					
	0 Tanker	1	1515	833	1425
	1 Tanker	1	1515	833	1425
	2 Tanker	1	1515	833	1425
	3 Tanker	1	1515	833	1425
	4 Tanker	1	1515	833	1425
	0 Tnk_Barge	2	18025	0	15
	1 Tnk_Barge	2	18025	0	15
	2 Tnk_Barge	2	18025	0	15
	3 Tnk_Barge	2	18025	0	15
	4 Tnk_Barge	2	18025	0	15
4 Santa Barbara					
	0 Tanker	1	0	468	940
	1 Tanker	1	0	468	940
	0 Tnk_Barge	2	192	0	0
	1 Tnk_Barge	2	192	0	0
5 Port Arthur					
	0 Tanker	1	252	1292	1460
	1 Tanker	1	433	2207	2467
	2 Tanker	1	373	1829	1959
	3 Tanker	1	64	378	508
	4 Tanker	1	137	752	906
	0 Tnk_Barge	2	12640	0	74
	1 Tnk_Barge	2	9481	0	131
	2 Tnk_Barge	2	14982	0	119
	3 Tnk_Barge	2	11005	0	12
	4 Tnk_Barge	2	15091	0	33
6 New Orleans					
	0 Tanker	1	421	2236	2436
	1 Tanker	1	552	3309	3276
	2 Tanker	1	550	3309	3276
	3 Tanker	1	455	2458	2459
	4 Tanker	1	7	0	0
	5 Tanker	1	667	3591	3745

	6 Tanker	1	294	749	1859
	0 Tnk_Barge	2	15905	0	581
	1 Tnk_Barge	2	9620	0	1101
	2 Tnk_Barge	2	9302	0	1101
	3 Tnk_Barge	2	14643	0	421
	4 Tnk_Barge	2	3550	0	0
	5 Tnk_Barge	2	42687	0	640
	6 Tnk_Barge	2	15626	0	225
7 Houston					
	0 Tanker	1	810	3655	4675
	1 Tanker	1	974	4256	5287
	2 Tanker	1	974	4256	5287
	3 Tanker	1	482	2453	3452
	0 Tnk_Barge	2	25602	0	136
	1 Tnk_Barge	2	33992	0	148
	2 Tnk_Barge	2	33992	0	148
	3 Tnk_Barge	2	8823	0	112
8 Chesapeake S.					
	0 Tanker	1	5531	617	259
	1 Tanker	1	8509	1016	427
	2 Tanker	1	8782	1016	427
	3 Tanker	1	8782	1016	427
	4 Tanker	1	7056	640	275
	5 Tanker	1	0	0	0
	6 Tanker	1	56	14	0
	0 Tnk_Barge	2	5986	0	148
	1 Tnk_Barge	2	10363	0	257
	2 Tnk_Barge	2	10451	0	257
	3 Tnk_Barge	2	10444	0	257
	4 Tnk_Barge	2	4222	0	116
	5 Tnk_Barge	2	111	0	0
	6 Tnk_Barge	2	325	0	0
9 Chesapeake N.					
	0 Tanker	1	1142	288	56
	1 Tanker	1	1723	435	95
	2 Tanker	1	1632	306	70
	3 Tanker	1	70	122	3
	0 Tnk_Barge	2	5488	0	94
	1 Tnk_Barge	2	8727	0	141
	2 Tnk_Barge	2	5432	0	141
	3 Tnk_Barge	2	2306	0	0
10 Corpus Christi					
	0 Tanker	1	129	829	1341
	1 Tanker	1	145	952	1538
	2 Tanker	1	145	952	1538

	3 Tanker	1	155	952	1538
	4 Tanker	1	71	460	750
	0 Tnk_Barge	2	4663	0	24
	1 Tnk_Barge	2	3271	0	24
	2 Tnk_Barge	2	3271	0	24
	3 Tnk_Barge	2	9106	0	24
	4 Tnk_Barge	2	3003	0	24
11 New York					
	0 Tanker	1	5077	400	1252
	1 Tanker	1	9932	1319	3572
	2 Tanker	1	7633	279	1368
	3 Tanker	1	68	0	66
	4 Tanker	1	2676	0	0
	0 Tnk_Barge	2	6738	0	566
	1 Tnk_Barge	2	12506	0	1512
	2 Tnk_Barge	2	11720	0	746
	3 Tnk_Barge	2	10	0	5
	4 Tnk_Barge	2	2716	0	0
12 Long Island Sound					
	0 Tanker	1	962	162	114
	1 Tanker	1	1803	254	180
	2 Tanker	1	1803	254	180
	3 Tanker	1	1803	254	180
	4 Tanker	1	32	46	11
	5 Tanker	1	318	162	135
	6 Tanker	1	11	0	0
	0 Tnk_Barge	2	2781	0	256
	1 Tnk_Barge	2	4911	0	426
	2 Tnk_Barge	2	4911	0	426
	3 Tnk_Barge	2	4911	0	426
	4 Tnk_Barge	2	274	0	0
	5 Tnk_Barge	2	1596	0	258
	6 Tnk_Barge	2	81	0	0
13 Philadelphia					
	0 Tanker	1	408	484	293
	1 Tanker	1	390	453	292
	2 Tanker	1	390	453	292
	3 Tanker	1	390	453	292
	4 Tanker	1	460	575	295
	0 Tnk_Barge	2	9410	0	1003
	1 Tnk_Barge	2	8837	0	1003
	2 Tnk_Barge	2	8834	0	1003
	3 Tnk_Barge	2	8840	0	1003
	4 Tnk_Barge	2	11127	0	1003
14 San Francisco					
	0 Tanker	1	632	1271	1038

	1 Tanker	1	1064	2564	2170
	2 Tanker	1	848	1503	1208
	3 Tanker	1	848	1503	1208
	4 Tanker	1	0	0	1
	5 Tanker	1	398	786	603
	0 Tnk_Barge	2	2973	0	0
	1 Tnk_Barge	2	4266	0	0
	2 Tnk_Barge	2	4057	0	0
	3 Tnk_Barge	2	4057	0	0
	4 Tnk_Barge	2	700	0	0
	5 Tnk_Barge	2	1785	0	0
15 Portland OR					
	0 Tanker	1	53	383	181
	1 Tanker	1	79	567	264
	2 Tanker	1	40	293	140
	3 Tanker	1	40	289	140
	0 Tnk_Barge	2	5097	0	0
	1 Tnk_Barge	2	5337	0	0
	2 Tnk_Barge	2	5099	0	0
	3 Tnk_Barge	2	4855	0	0
16 Anchorage					
	0 Tanker	1	9	55	27
	1 Tanker	1	25	55	27
	2 Tanker	1	1	55	27
	3 Tanker	1	1	55	27
	0 Tnk_Barge	2	26	0	0
	1 Tnk_Barge	2	57	0	0
	2 Tnk_Barge	2	11	0	0
	3 Tnk_Barge	2	11	0	0
17 Portland ME					
	0 Tanker	1	153	98	81
	1 Tanker	1	204	130	108
	2 Tanker	1	204	130	108
	3 Tanker	1	204	130	108
	4 Tanker	1	0	0	0
	0 Tnk_Barge	2	284	0	158
	1 Tnk_Barge	2	379	0	210
	2 Tnk_Barge	2	379	0	210
	3 Tnk_Barge	2	379	0	210
	4 Tnk_Barge	2	0	0	0
18 Portsmouth NH					
	0 Tanker	1	33	111	76
	1 Tanker	1	33	111	76
	2 Tanker	1	33	111	76
	3 Tanker	1	33	111	76

	0 Tnk_Barge	2	121	0	52
	1 Tnk_Barge	2	121	0	52
	2 Tnk_Barge	2	121	0	52
	3 Tnk_Barge	2	121	0	52
19 Providence RI					
	0 Tanker	1	358	233	82
	1 Tanker	1	381	268	86
	2 Tanker	1	381	268	86
	3 Tanker	1	311	163	75
	0 Tnk_Barge	2	1002	0	266
	1 Tnk_Barge	2	1121	0	303
	2 Tnk_Barge	2	1121	0	303
	3 Tnk_Barge	2	764	0	193
20 Wilmington NC					
	0 Tanker	1	44	435	176
	1 Tanker	1	44	435	176
	2 Tanker	1	44	435	176
	3 Tanker	1	44	435	176
	0 Tnk_Barge	2	3217	0	41
	1 Tnk_Barge	2	3217	0	41
	2 Tnk_Barge	2	3217	0	41
	3 Tnk_Barge	2	3217	0	41
21 Jacksonville FL					
	0 Tanker	1	62	238	175
	1 Tanker	1	62	238	175
	2 Tanker	1	62	238	175
	0 Tnk_Barge	2	3111	0	191
	1 Tnk_Barge	2	3111	0	191
	2 Tnk_Barge	2	3111	0	191
22 Tampa FL					
	0 Tanker	1	143	593	322
	1 Tanker	1	148	593	322
	2 Tanker	1	148	593	322
	3 Tanker	1	132	593	322
	0 Tnk_Barge	2	1229	0	288
	1 Tnk_Barge	2	1231	0	288
	2 Tnk_Barge	2	1231	0	288
	3 Tnk_Barge	2	1225	0	288
23 Mobile AL					
	0 Tanker	1	35	429	474
	1 Tanker	1	62	982	1165
	2 Tanker	1	10	819	1124
	3 Tanker	1	0	0	0
	4 Tanker	1	52	173	41

5	Tanker	1	49	173	41
0	Tnk_Barge	2	2376	0	36
1	Tnk_Barge	2	5065	0	88
2	Tnk_Barge	2	3007	0	84
3	Tnk_Barge	2	1	0	0
4	Tnk_Barge	2	2450	0	4
5	Tnk_Barge	2	1357	0	4

Structure for database: **VTSFACTR.dbf**

Information on the Database:

The name of this database indicates that it has data on the factor by which the accident frequency in a port is reduced by the provision of a Vessel Traffic System (VTS). The effectiveness factor depends on the vessel size and type of accident. If VTS is present it is assumed in this database that the VTS FACTOR represents the level I type of VTS or level III type (considered to be the best system available at the present time).

	Field Name	Type	Width.Dec		
1	VESL_SIZE	C	6	=	Size category of the vessel (Small, Medium, Large)
2	S_INDEX	N	1	=	Size Index (1=Small, 2=Medium, 3=Large)
3	ACC_TYPE	C	10	=	Type of Accident(Collision, Ramming, Grounding)
4	A_INDEX	N	1	=	Accident Type Index (1=Collision, 2=Ramming, 3=Grounding)
5	VTS_LEVEL	N	1	=	VTS System level (1 or 3)
6	SUBZONEMX	N	1	=	A subzone range over which the VTS factor applies (for SUBZONENUM = 0 SUBZONEMX = 0) (for SUBZONENUM = 1, 2 or 3 SUBZONEMX = 3) (for SUBZONENUM = 4, 5 or 6 SUBZONEMX = 6)
7	VTS_FACTR	N	4.2	=	VTS Effectiveness Factor (a fraction). That is the factor by which the casulaty rate is reduced

Record#	VESL_SIZE	S_INDEX	ACC_TYPE	A_INDEX	VTS_LEVEL	SUBZONEMX	VTS_FACTR
1	Small	1	Collisions	1	1	3	0.13
2	Small	1	Rammings	2	1	3	0.25
3	Small	1	Groundings	3	1	3	0.10
4	Medium	2	Collisions	1	1	3	0.11
5	Medium	2	Rammings	2	1	3	0.22
6	Medium	2	Groundings	3	1	3	0.10
7	Large	3	Collisions	1	1	3	0.11
8	Large	3	Rammings	2	1	3	0.22
9	Large	3	Groundings	3	1	3	0.10
10	Small	1	Collisions	1	3	3	0.65
11	Small	1	Rammings	2	3	3	0.50
12	Small	1	Groundings	3	3	3	0.20
13	Large	3	Collisions	1	3	3	0.68
14	Large	3	Rammings	2	3	3	0.43
15	Large	3	Groundings	3	3	3	0.20
16	Medium	3	Collisions	1	3	3	0.68
17	Medium	3	Rammings	2	3	3	0.43

18	Medium	3	Groundings	3	3	3	0.20
19	Small	1	Collisions	1	1	6	0.18
20	Small	1	Rammings	2	1	6	0.20
21	Small	1	Groundings	3	1	6	0.10
22	Medium	2	Collisions	1	1	6	0.19
23	Medium	2	Rammings	2	1	6	0.22
24	Medium	2	Groundings	3	1	6	0.10
25	Large	3	Collisions	1	1	6	0.19
26	Large	3	Rammings	2	1	6	0.22
27	Large	3	Groundings	3	1	6	0.10
28	Small	1	Collisions	1	3	6	0.55
29	Small	1	Rammings	2	3	6	0.38
30	Small	1	Groundings	3	3	6	0.20
31	Large	3	Collisions	1	3	6	0.52
32	Large	3	Rammings	2	3	6	0.36
33	Large	3	Groundings	3	3	6	0.20
34	Medium	3	Collisions	1	3	6	0.52
35	Medium	3	Rammings	2	3	6	0.36
36	Medium	3	Groundings	3	3	6	0.20
37	Small	1	Collisions	1	1	0	0.16
38	Small	1	Rammings	2	1	0	0.23
39	Small	1	Groundings	3	1	0	0.10
40	Medium	2	Collisions	1	1	0	0.15
41	Medium	2	Rammings	2	1	0	0.22
42	Medium	2	Groundings	3	1	0	0.10
43	Large	3	Collisions	1	1	0	0.15
44	Large	3	Rammings	2	1	0	0.22
45	Large	3	Groundings	3	1	0	0.10
46	Small	1	Collisions	1	3	0	0.60
47	Small	1	Rammings	2	3	0	0.44
48	Small	1	Groundings	3	3	0	0.20
49	Large	3	Collisions	1	3	0	0.60
50	Large	3	Rammings	2	3	0	0.40
51	Large	3	Groundings	3	3	0	0.20
52	Medium	3	Collisions	1	3	0	0.60
53	Medium	3	Rammings	2	3	0	0.40
54	Medium	3	Groundings	3	3	0	0.20