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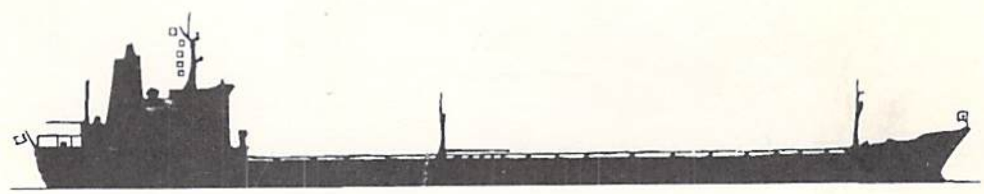
Port Needs Study (Vessel Traffic Services Benefits)

Volume I: Study Report

Research and Special Programs
Administration
John A. Volpe National
Transportation Systems Center
Cambridge MA 02142-1093

August 1991



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U.S. Department
of Transportation

**United States
Coast Guard**

Office of Navigation Safety and Waterway Services
Washington DC 20593

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16. Abstract

This study documents 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. The U.S. Department of Transportation's Research and Special Programs Administration's Volpe National Transportation Systems Center (VNTSC) conducted the study for the U.S. Coast Guard, Office of Navigation Safety and Waterway Service, Special Projects Staff. The entire study is documented in three separately bound volumes plus a separate Study Overview. Volume I is the main document covering all aspects of the input data, analysis methods, and results. The focus of Volume I is presentation of information across all 23 study zones concurrently. Volume II focuses on organization and presentation of information for each individual study zone. It contains the appendix tables of input data, output statistics and the documentation of the candidate Vessel Traffic Services (VTS) Design by NavCom Systems. Volume III is a compendium of technical papers on data sources, analytical methods, and models supplementing material in Volume I.

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PREFACE

This study documents 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. The U.S. Department of Transportation, Research and Special Programs Administration (RSPA), Volpe National Transportation Systems Center (VNTSC) conducted the study for the U.S. Coast Guard, Office of Navigation Safety and Waterway Services, Special Projects Staff.

METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

$[(x - 32)(5/9)]$ °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

$[(9/5)y + 32]$ °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 | 25.40

QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

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FOREWORD

This study is the product of the collective efforts of several teams of analysts within the U.S. Coast Guard, the Volpe National Transportation Systems Center, VNTSC on-site contractors and VNTSC off-site contractors. The entire study is documented in three separately bound volumes. Volume I is the main document covering all aspects of the input data, analysis methods, and results. The focus of Volume I is presentation of information across all 23 study zones concurrently. Volume II focuses on organization and presentation of information for each individual study zone. It contains maps of each zone and appendix tables of input data, output statistics and the documentation of the Candidate Vessel Traffic Services (VTS) Design by NavCom Systems. Volume III is a compendium of technical papers on data sources and analytical methods to supplement material in Volume I. Each section of Volume III is written by VNTSC analysts, or on-site or off-site contractors responsible for that specific element of the analysis.

The individuals who have participated in this study are too numerous to list, but the principal contributors are listed here by organization.

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This study documents the benefits and costs of potential U.S. Coast Guard Vessel Traffic Services (VTS) in selected U.S. deep water ports on the Atlantic, Gulf and Pacific coasts. The U.S. Department of Transportations Research and Special Programs Administrations (RSPA) Volpe National Transportation Systems Center (VNTSC) conducted the study for the U.S. Coast Guard, Office of Navigation Safety and Waterway Services, Special Projects Staff.

APPROACH

The Study uses a benefit-cost approach. The benefits of VTS are defined as the human, environmental, and economic losses associated with vessel casualties that are potentially avoidable by VTS. A Candidate VTS Design in each study zone is projected to reduce the risk of vessel casualties over the 15-year period, 1996-2010. The VTS costs are the initial federal investment and annual O&M costs of the Candidate VTS Design at each of the 23 study zones.

After consulting with each of the Regional Offices, Captains of The Port, and headquarters personnel, the Coast Guard Special Projects Staff selected 23 study zones. The 23 study zone boundaries encompass 82 deep draft ports, which load and unload over 80% of the U.S. total international and domestic cargo vessel tonnage and enclose 64% of the 1979-1989 vessel casualties in U.S. waters that are potentially VTS addressable.

Historical vessel casualties are analyzed to develop an understanding of the causes, circumstances and consequences of vessel casualties and to aid in modeling navigation risk and estimating the reduction in casualties which would result from the operation of a VTS system. From the Coast Guard central file, 36,000 vessel casualty records are within the 23 study zone boundaries for the period 1979 to 1989; a total of 2,210 are selected. These are casualties that are considered to be "VTS addressable" by the Coast Guard Candidate VTS system.

Navigational risk modeling focuses on the number of VTS addressable casualties (collisions, groundings, and rammings) by vessel type and size for each of 99 study subzones. To project the probable number of future vessel casualties of each type in each study subzone an estimated subzone-specific probability of vessel casualties by vessel type and size and casualty type is applied to the forecast vessel transits. In order to estimate the avoided casualties attributable to the Candidate VTS Design, VTS Effectiveness Factors reflecting different navigational situations, vessel sizes and VTS levels of technology are applied to the vessel casualties of a hypothetical No-VTS case in each study subzone.

The benefits of VTS are the avoided consequences associated with the avoided vessel casualties. The study estimates these benefits by applying a series of conditional probabilities. Physical units and dollar values measure these avoided consequences. The study estimates eight consequence types: 1) vessel damage, 2) human deaths and injuries, 3) emergency response 4) cargo damage or loss, 5) navigational aid damage, 6) bridge damage, 7) LNG and LPG explosions, and 8) hazardous commodity spills. Hazardous commodity spills in turn, are responsible for specific subcategories of loss: 1) marine mammal and bird losses, 2) commercial fish species losses, 3) spill assessments costs, 4) spill cleanup costs, 5) recreation and tourism losses, 6) property value loss.

The costs of VTS are the initial federal investment and the annual O&M costs. The basic concept of the "Candidate VTS Design" includes a central data gathering and watch standing location, known as a Vessel Traffic Center, and an array of surveillance sensors and communications units covering each subzone within each study zone. The unique characteristics of each study zone dictate the number and type of surveillance sensors needed to support each Vessel Traffic Center. The study defines the Candidate VTS Design for each study zone by a unique selection of surveillance and communications modules (from a master list of 18) for each subzone.

The final product of this study is the estimated net benefit of the Candidate VTS Design in each of 23 study zones. The net benefit is the difference between the discounted 1993 value of the annual stream of benefits (1996-2010) and the annual stream of costs (1993-2010).

Avoided Vessel Casualties

The Candidate VTS Designs for the 23 study zones are projected to avoid a total of 980 vessel casualties during the period 1996-2010. This number represents a 29% decrease in vessel casualties projected without any VTS. VTS is more effective in avoiding collisions than it is in avoiding rammings and groundings. Therefore, 53% of the avoided vessel casualties are collisions. Rammings and groundings represent a combined total of 47% of the avoided vessel casualties.

New Orleans overwhelmingly leads with 4.5 times as many as Port Arthur. In New Orleans, 56% of the avoided vessel casualties involve barge tows (i.e., 33% barge collisions and 23% barge rammings and groundings).

Avoided Human Injuries and Deaths

If all 23 Candidate VTS Designs are implemented, a total of 138 injuries and 31 human fatalities can be avoided during the 15-year period.

New Orleans leads with 50 avoided deaths and injuries, followed by Puget Sound with 33 and New York with 14 avoided deaths and injuries.

Avoided Hazardous Commodity Spills

If all 23 study zones implement the Candidate VTS Designs, a total of 100 hazardous commodities spills of all sizes can be avoided during the 15-year period. This includes bulk cargo spills from tankers and tank barges and vessel fuel (bunker) spills from all vessel types involved in vessel casualties resulting in damage. In each of the top four-zones, over 80% of the spills are 10,000-750,000 gallons each.

New Orleans overwhelmingly leads with 40 avoided hazardous commodity spills. New York, Houston/Galveston and Puget Sound each have eight avoided spills.

Hazardous commodity spills result in a number of environmental and commercial losses. The major losses are estimated as follows:

Avoided Marine Mammal and Bird Loss to Hazardous Commodity Spills

If all 23 study zones implement the Candidate VTS Designs, a loss of 3.9 million marine birds and mammals from hazardous commodity spills can be avoided during the 15-year period.

New Orleans leads with 1.6 million. Los Angeles/Long Beach has 550 thousand, Port Arthur has 522 thousand, and New York has 209 thousand marine mammal and bird losses from hazardous commodity spills.

Avoided Commercial Fish Spec: es Losses From Hazardous Commodity Spills

If all 23 study zones implement the Candidate VTS Design, a total of 396 million pounds of commercial fish species can be avoided during the 15-year period.

Houston/Galveston leads with 176 million pounds; Port Arthur and New Orleans follow with 67 million pounds each of commercial fish species losses.

Avoided Dollar Losses of All Consequences - (Undiscounted 15-Year Total)

When all avoided vessel casualty consequences attributed to the 23 Candidate VTS Designs are converted to dollar values, the 15-year avoided losses total $1.9 billion (undiscounted).

New Orleans, Port Arthur, and Houston/Galveston are responsible for 60% of this total; Mobile, Los Angeles/Long Beach, New York, and Corpus Christi for an additional 23%. The first seven study zones are responsible for 83% of the total potential avoided dollar losses (undiscounted) attributed to the 23 Candidate VTS Designs.

Losses associated with hazardous commodity spills are responsible for 74%-92% of the total avoidable dollar losses. In each of these zones, cleanup costs are a large portion of the spill costs. However, in Los Angeles/Long Beach, property value losses associated with spills reaching shore dominate. In Houston/Galveston and Mobile, the commercial fish species losses dominate.

Projected VTS Net Benefit

The 1993 discounted value of the life cycle Net Benefit (i.e., total avoided losses minus the VTS investment and O&M costs) transforms all future benefits and costs to a single objective measure suitable for ranking the 23 study zones in terms of the aggregate national interest. The net benefit is discounted at an annual rate of 10% to the beginning of FY 93, the time of the initial commitment of the VTS investment. The annual streams of VTS benefits and O&M costs begin in FY 96 and continue through FY 2010.

FINDINGS

The study indicates that the 23 study zones can be divided into three groups in terms of their relative life cycle net benefits. Analysis of the sensitivity of the relative value of net benefit among the 23 study zones to underestimates or overestimates of VTS costs or benefits suggests the following groupings. The first seven zones have a positive net benefit over the range of uncertainty tested.

Positive Net Benefit:

- New Orleans
- Port Arthur
- Houston/Galveston
- Mobile
- Los Angeles/Long Beach
- Corpus Christi
- Boston

The relative net benefits of the following eight study zones may be considered sensitive because their respective values are comparatively small and may be either positive or negative over the range of uncertainty tested.

Sensitive Net Benefit:

- New York
- Tampa
- Portland, OR.
- Philadelphia/Delaware Bay
- Chesapeake North/Baltimore
- Providence
- Long Island Sound
- Puget Sound

The last eight study zones retain their negative net benefit status over the range of uncertainty tested.

Negative Net Benefit:

- Jacksonville
- Wilmington
- Santa Barbara
- Portsmouth
- Portland, ME.
- San Francisco
- Chesapeake South/Hampton Roads
- Anchorage/Cook Inlet

1. INTRODUCTION

1.1 OVERVIEW

The concept of VTS has gained international acceptance by governments and maritime industries as a means of advancing safety in rapidly expanding ports and waterways. This study documents the costs and benefits of potential U.S. Coast Guard Vessel Traffic Services (VTS) in selected U.S. deep water ports on the Atlantic, Gulf and Pacific Coasts.

The U.S. Department Of Transportation's Research and Special Programs Administration's Volpe National Transportation Systems Center (VNTSC) conducted the study for the U.S. Coast Guard, Office of Navigation Safety and Waterway Services, Special Projects Staff.

The U.S. Coast Guard initiated the study at VNTSC in February 1990. On August 18, 1990 Congress passed "The Oil Pollution Act of 1990" (Public Law 101-380). Section 4107 of this act, Vessel Traffic Service Systems, amends the Ports and Waterways Safety Act (33 U.S.C. 1223[a]) and mandates that the Secretary shall conduct a study:

"To determine and prioritize the United States ports and channels that are in need of new, expanded, or improved vessel traffic service systems, by evaluating:

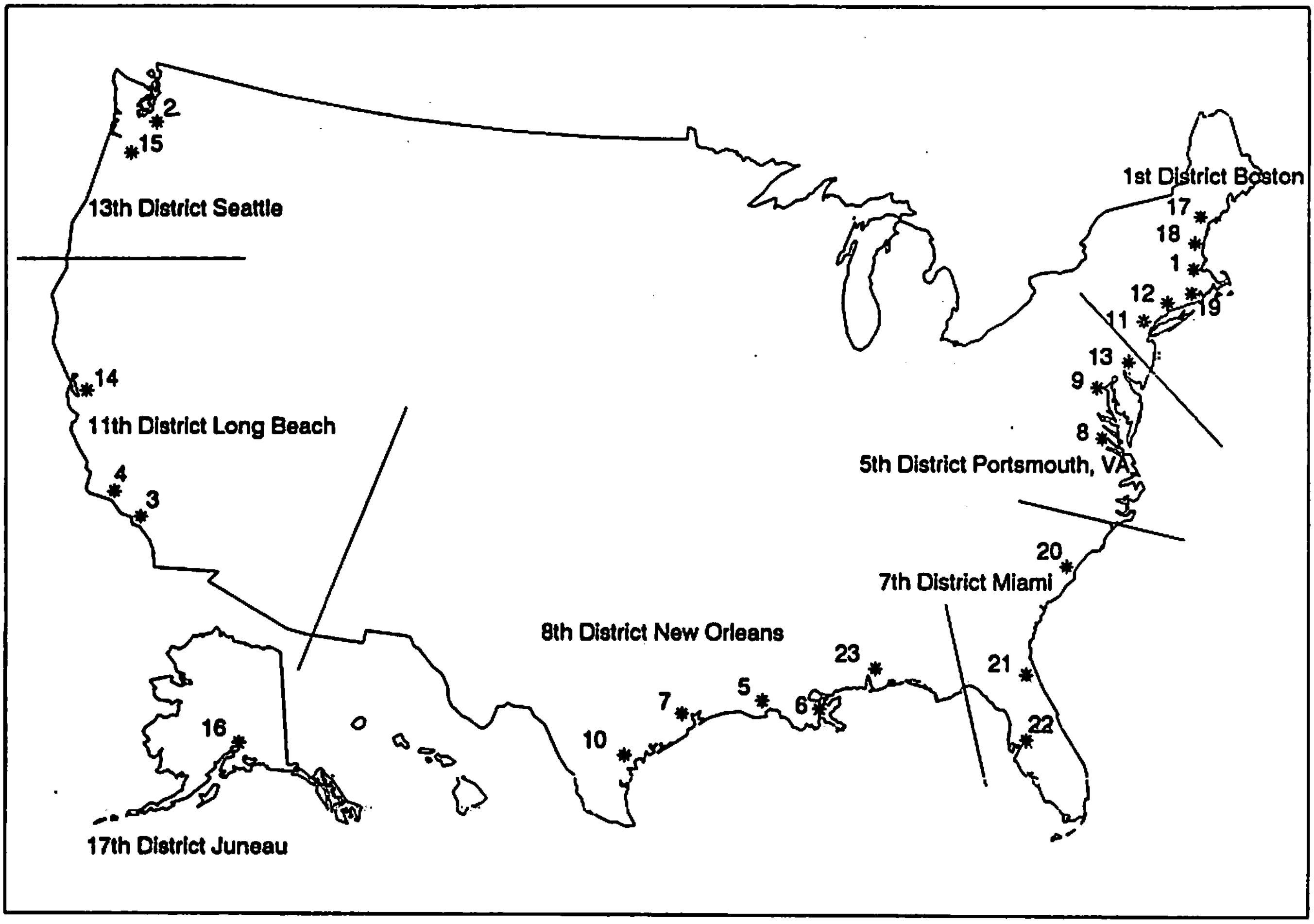
- The nature, volume, and frequency of vessel traffic.
- The risks of collisions, spills, and damages associated with that traffic.
- The impact of installation, expansion, or improvement of a vessel traffic service system.
- All other relevant costs and data."

Also, "report to the Congress the results of the study and recommendations for implementing the results of that study by August 18, 1991."

1.1 OVERVIEW (Cont.)

This study analyzes historical vessel casualties and potential future navigational risk in 23 study zones. It uses a benefit-cost approach and considers factors such as navigational risk, the probability of a collision, ramming, or grounding, and the costs that result from such casualties. Historical vessel casualties and their consequences are analyzed and future vessel casualties and consequences are projected for 23 study zones. This study uses a benefit-cost approach and focuses on navigational risk, measured in terms of probabilities of vessel collisions, rammings, or groundings and the human, environmental consequences and economic losses that attend vessel casualties. VTS benefits are defined as the avoided vessel casualties and the associated consequences, which are measured in physical units and assigned monetary values. VTS costs are defined as the initial federal investment for a state of the art VTS system in each study zone and its annual operating and maintenance costs.

Figure 1-1 is a map of the U.S. identifying the 23 study zones. The study quantifies in physical and monetary terms the human, environmental and commercial losses associated with potentially avoidable vessel casualties in each of the 23 study zones. The 23 study zones encompass 82 deep draft ports and their respective approaches. These ports load and unload over 80% of the U.S. total international and domestic cargo vessel tonnage. Approximately 64% of the 1979-1989 vessel casualties in U.S. waters that were potentially VTS addressable occurred within these 23 study zones.



Study Zone Code	Study Zone Name	Study Zone Code	Study Zone Name
1	Boston, MA	11	New York City, NY
2	Puget Sound, WA	12	Long Island Sound, NY
3	Los Angeles /Long Beach, CA	13	Philadelphia/Delaware Bay, PA
4	Santa Barbara, CA	14	San Francisco, CA
5	Port Arthur, TX	15	Portland, OR
6	New Orleans, LA	16	Anchorage/Cook Inlet, AK
7	Houston/Galveston, TX	17	Portland, ME
8	Chesapeake South /Hampton Roads, VA	18	Portsmouth, NH
9	Chesapeake North /Baltimore, MD	19	Providence, RI
10	Corpus Christi, TX	20	Wilmington, NC
		21	Jacksonville, FL
		22	Tampa, FL
		23	Mobile, AL

FIGURE 1-1. MAP OF VTS STUDY ZONES

1.1 OVERVIEW (Cont.)

The study examines each zone for waterway navigational characteristics and traffic patterns. It analyzes the historical VTS addressable vessel casualties and quantifies significant navigational risk factors to enhance the estimation of future vessel casualties. A navigational risk model is developed and applied to estimate the potential future avoidable vessel casualties in each of 23 study zones.

The study develops a state of the art Candidate VTS Design for each study zone for the purpose of estimating investment costs and operations and maintenance costs over a 15-year life cycle. Annual VTS costs and benefits (i.e., avoidable consequences of vessel casualties) are estimated for each study zone. To assure comparability among the 23 study zones, it is assumed that the VTS investment costs are committed in FY 1993 and the VTS is fully operational in each study zone by the end of FY 1995. Therefore, the annual operations and maintenance costs and the annual benefits accrue from FY 1996 through the assumed 15-year life cycle to FY 2010.

1.2 BACKGROUND

The authority for the Coast Guard to operate vessel traffic services is determined by the Ports and Waterways Safety Act of 1972. This Act authorizes the Coast Guard to "... establish, operate, and maintain vessel traffic services in ports and waterways subject to congestion." The Valdez spill in March of 1989, the three spills just months later in the coastal waters of Rhode Island, the Delaware River, and the Houston Ship Channel occurring within a 24 hour period and a seemingly continuous stream of vessel casualties involving crude oil prompted Congress to task the U.S. Coast Guard (via the Secretary of Transportation) to evaluate the need for Vessel Traffic Services (VTS) in several major U.S. ports and waterways.

The purpose of VTS is to enhance safety by reducing the number and severity of vessel casualties. Vessel casualties often result in adverse consequences, the impacts of which affect numerous vessels, maritime personnel and the general public. The benefits of reducing vessel casualties are clearly extensive, and can be translated into lives and property saved. The environment also suffers significantly through loss of marine life, sea birds, long-term damage to marine habitats, and estuaries due to the spills of crude oil and petroleum products and other hazardous commodities.

VTS is a safety tool with increasing potential as it is continually being refined. Vessel traffic services are lacking in many ports and not sufficiently understood where they do exist. In fact, few U.S. ports have incorporated VTS systems to enhance safety. The VTS works through position and situation advisory communications with all vessels navigating harbor waterways and approaches. Vessel traffic services are advisory in nature, providing enhanced information to the mariner and thus stronger potential for safe operation. VTS do not implement direct control by ordering specific course directions or speeds to maneuver around other traffic or fixed obstructions. "While the Vessel Control Center (VTC) will have the authority to direct the movement of a vessel in a dangerous situation, a master remains responsible for the safe and prudent maneuvering of the vessel at all times."[1] Government and industry together are seeking proper assessment of VTS capabilities and determination of ports which will most greatly benefit.

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[1] Federal resister, Vol. 55, No. 166, August 27, 1990 Rules and Regulations pg 34909.

1.2 BACKGROUND (Cont.)

The climate of heightened awareness for safety in the marine system puts strong emphasis on rational expansion of the VTS to ports of highest need. This study lays justification and direction for such expansion. Proper VTS resource allocation requires the Coast Guard to determine which port areas might realize the greatest benefits from VTS. This study compares the 23 study zones in terms of their respective VTS benefits and costs.

1.2.1 Prior U.S., European and Canadian VTS Studies

Only four studies of this type have been performed previously; (1) the USCG Study Report - Vessel Traffic Systems Analysis of Port Needs (August 1973), (2) Canadian Ministry of Supply and Services, Bureau of Management Consulting (BMC) Study - Vessel Traffic Services (October 1984) and the Update Study (February 1988), (3) BMC Hong Kong Study, Operational Solutions and Alternatives, Volume II, Site Configuration and Equipment Analysis (June 1984), and (4) the European Economic Community's COST Project 301 (June 1987). This current study is the most comprehensive quantitative analysis to date that has been performed in this subject area.

- USCG Study Report - Vessel Traffic Systems Analysis of Port Needs (August 1973)

Twenty-two major ports and waterways were examined in this study using an accident analysis methodology in order to establish a relative ranking of the need for VTS in each port area. Candidates were selected on the basis of cargo tonnage handled, number of vessel transits and the number of collisions, rammings and groundings over a five-year period (1967-1972). The study analyzed each port's casualty data, examining every vessel casualty to determine whether a traffic system might have prevented it. It also examined traffic patterns, congestion, anticipated growth, and potential for catastrophic accidents. The result was a list ranking the 22 ports and waterways in order of priority for a VTS.

Based on this study, VTS systems were established in San Francisco, Puget Sound, New Orleans and New York.

1.2.1 Prior U.S., European and Canadian VTS Studies (Cont.)

- Canadian Ministry of Supply and Services, Bureau of Management Consulting (BMC) Study - Vessel Traffic Services (October 1984 and February 1988)

  In 1984 the Canadian Coast Guard, supported by the Canadian Ministry of Supply and Services, Bureau of Management Consulting (BMC), completed a highly quantitative risk analysis of 17 ports/waterways divided into approximately 106 subzones. In the VTS Benefit/Cost Update Study of February 1988 the same computer programs were used with additional data for the intervening years.

- BMC Hong Kong VTS Study, Operational Solutions and Alternatives, Volume II, Site Configuration and Equipment Analysis (June 1984)

  In 1984 the BMC completed the Hong Kong Study in which the benefits and costs of vessel traffic management alternatives were analyzed and compared.

- European Economic Community's COST Project 301

  "COST 301 Final Report, Shore Based Marine Navigation Aid System" - Main Report and Annexes 1 to 10 - June 1987

  In 1982 the Council of Ministers of the European Economic Community (EEC) entered into a cooperative effort to reduce collisions and grounding in European waters. In 1983 Finland, Sweden, Norway and Spain joined the Committee on Science and Technology (COST) Project 301. The primary objective of the project was to determine the requirements for VTS in Western Europe and to identify and assess shore-based marine traffic services' ability to improve the safety and efficiency of vessel traffic in European waters and to make recommendations on a coordinated European approach to shore-based marine traffic services on the basis of the assessment. The study took over four years to complete.

1.2.2 U.S. Coast Guard Port Needs Study Of 1991

This study builds on the foundations of these prior studies and is the most comprehensive analysis to date that has been performed in this subject area. It is guided by "A Study Approach and Activity Plan" which was prepared for the U.S.C.G. by the Canadian Bureau of Management Consulting. For example, this is the first comprehensive study that estimates vessel casualties on the basis of a navigational risk model developed from regression analysis of aggregate historical casualties and related navigational risk factors. This study includes the most exhaustive analysis to date of the commercial and environmental impacts of hazardous commodity spills. It is also the first to perform a case-by-case analysis of 12,500 vessel casualties to assess the VTS addressability of these casualties.

1.2.3 U.S. VTS Development History

The use of VTS to promote safety has been proven by their successful implementation in major ports of the world. Table 1-1 provides a chronology of VTS development.

TABLE 1-1. CHRONOLOGY OF VTS TRAFFIC CONTROL AND VTS DEVELOPMENT

Date	VTS Established	Legislation	Misc (Casualty, etc.)
1948	Liverpool, England First VTS with active surveillance		
1949	Long Beach, CA Port Authority organizes VTS		
1951	New York harbor radar demonstration		
1956	VTS Rotterdam, the Netherlands		
1962	Experimental CG VTS in New York Harbor (program abandoned due to technical and frequency congestion problems		
1964	Hamburg, Germany Milfordhaven, Wales Keele, Germany La Harve, France		
1967	Canada - St. Lawrence River VTS		
1968	San Francisco Bay Harbor Advisory (HAR) project began		
1971	Puget Sound VTS opened USCG	Bridge-to-Bridge Radiotelephone Act	Collision of Oregon Standard and Arizona Standard in San Francisco Bay
Prior TO 1972	New Orleans, LA COE Cape Cod Canal, MA COE Chesapeake and Delaware Canal COE Honolulu, HW Harbor Master Los Angeles/Long Beach, CA LA/LB Pilots Baltimore, MD Private Portland, Oregon Private Boston, MA Private		
1972	HAR San Francisco upgraded to VTS (first with active surveillance) (August 22, 1972) (voluntary) Puget Sound VTS commissioned (September 25, 1972) (mandatory). Developed under congressional budget pressure due to alaska pipeline	Ports and Waterways Safety Act (PWSA) of 1972	
1973	VTS Louisville, KY opened (mandatory)	Trans-Alaska Pipeline Act of 1973	CG VTS Analysis of Port Needs Study determines priority for VTS location and level of coverage
1974	VTS Houston/Galveston, TX opened (voluntary) VTS Berwick Bay, LA opened (mandatory)		Puget Sound VTS regulations became effective in 1975?
1977	Houston/Galveston VTS Commissioned (on line in 1985?) Prince William Sound VTS Commissioned (mandatory) New Orleans VTS Commissioned	Clean Water Act of 1977	
1978	New York VTS Commissioned (officially fully operational in 1985)	Port and Tanker Safety Act of 1978	
1986	New York VTS closed due to budget constraints 1988		
1988	New Orleans VTS closed due to budget constraints		
1989			Exxon Valdez Casualty (March 1989)
1990	New York VTS reopened (December 1990) (mandatory).	Oil Pollution Act of 1990 (Public Law 101-380) August 18, 1990	

1.2.4 VTS FOCUS - United States Versus European

Since the inception of VTS traffic management services there has been a decidedly different focus between the VTS systems developed in the United States and those developed in other countries. The official Coast Guard mission of VTS is "to prevent damage to, or the destruction or loss of any vessel, bridge, or other structure on or in the navigable waters of the United States."[2] This is quite different from VTS designs in Europe, the primary purpose of which is to increase the throughput of harbor facilities. In Europe, economic profit is the driving force; maritime safety and environmental protection are secondary benefits. European VTS systems are also usually funded with both user fees and governmental support.

1.2.5 Past Coast Guard VTS Development

At least 200 ports throughout the world have some form of vessel traffic management service, either publicly or privately funded. Prior to 1970, few U.S. government or private entities were providing traffic services; since then the government, through the U.S. Coast Guard, has emerged as the primary significant provider of traffic services. Safety has been the Coast Guard's principal focus for VTS development, however development of many private systems has been economically driven to facilitate traffic flow.

The Coast Guard's mission is consistent with their role as a provider of VTS services. Within the Coast Guard, VTS falls under the mission areas of Port Safety and Security and Waterways Management. These missions charge the Coast Guard with the following tasks:

1. Safeguarding the nation's ports, waterways, waterfront facilities and vessels, personnel and property therein, from either accidental or intentional damage, disruption, destruction or injury.

2. Developing and implementing passive and active traffic management techniques and navigation safety procedures to assure acceptable levels of safety in U.S. ports and waterways.

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[2] Marine Safety Manual, Commandant Instruction M16000.6, US Coast Guard, Washington, DC, 1987.

1.2.5 Past Coast Guard VTS Development (Cont.)

The routine functions of VTS are also beneficial in several other Coast Guard mission areas such as Search and Rescue, Maritime Defense, Aids to Navigation, and Maritime Law Enforcement.

Since 1970 the Coast Guard has had the lead in VTS operations. Historically, however, many private and local sources have provided and continue to provide similar vessel movement services. As U.S. federally maintained VTS have grown in visibility, smaller ports have seen the benefits and sought private activities to promote safety as well as economic advantage over their competition. Implementation or improvement of privatized or local specific traffic services has evolved through a variety of circumstances.

1.3 STUDY APPROACH

Following the guidance provided by "A Study Approach and Activity Plan" performed for the U.S.C.G. by the Canadian Bureau of Management Consulting, the study develops a comparative analysis of the relative benefits and costs of implementing state of the art Coast Guard VTS systems in each of 23 study zones. The study employs methods to assure consistent treatment of the benefits and the costs of VTS for each study zone. The study approach consists of the following seven steps:

1. Defining study zones and subzones.

2. Analyzing historical vessel casualties.

3. Forecasting future vessel casualties.

4. Estimating the avoidable vessel casualties and their associated losses (benefits in physical and monetary units) attributable to VTS.

5. Estimating cost of candidate state of the art VTS systems.

6. Comparing the benefits and costs among the 23 study zones.

7. Analysis of sensitivity of relative net benefits among the study zones to the range of uncertainty in key variables.

1.3 STUDY APPROACH (Cont.)

The VTS Benefits =

Forecast Vessel Transits x
Probability of Vessel Casualties x
VTS Effectiveness x
Probability of Consequences x
Probability of Consequence Severity x
Unit Dollar Value of Consequences.

1.3.1 Study Zones and Subzones

The Coast Guard Special Projects Staff consulted with each of the Regional Offices, Captains of the Port, and headquarters personnel to select the 23 study zones to be analyzed. The selection was made on the significance of:

- Tonnage of cargo handled;
- Number of vessel transits;
- Number of vessels involved in collisions, rammings, and groundings;
- Likelihood of future casualties;
- Presence of environmentally sensitive area(s);
- Vessel sizes and types; and
- Volume of petroleum and other hazardous materials moved.

These criteria are consistent with the IMO's guidelines which state that VTS is "particularly appropriate in the approaches to a port, in its access channels and in areas having one or more of the following characteristics: high traffic density; traffic carrying noxious or dangerous cargoes; navigational difficulties; narrow channels; environmental sensitivity."[3]

[3] IMO Guidelines for Vessel Traffic Services Resolution A.578(14) Adopted on November 20, 1985 Page 5.

1.3.1 Study Zones and Subzones (Cont.)

Each study zone incorporates at least one major port, at least one major navigational challenge and at least one environmentally sensitive area. The study zone numbering used is an arbitrary coding implemented at the initiation of this study to assist in the analysis; it does not imply any priority.

This study subdivides each study zone into two or more subzones based on the generic characteristics defined for six types of subzones. Each subzone type characterizes the common navigational attributes of the waterways in the study zones. The six subzone types are:

A. Open Approach;
B. Convergence;
C. Open Harbor or Bay;
D. Enclosed Harbor;
E. Constricted Waterway; and
F. River.

1.3.2 Vessel Casualties

The study examines historical casualties in order to develop an understanding of the causes, circumstances and consequences of vessel casualties and to aid in estimating the reduction in casualties which may result from a Candidate VTS Design. The Coast Guard central file of vessel casualties contains 56,382 records. The boundaries of the 23 study zones enclose approximately 36,000 records. A subset of 2,337 vessel casualties within the 23 study zones is selected as "VTS addressable." These are casualties that may have been prevented by a Coast Guard VTS system.

The study analyzes casualty cases including Coast Guard and National Transportation Safety Board (NTSB) investigated incidents between 1979 and 1989. The circumstances of 12,500 casualties are examined on a case-by-case basis to determine which accidents could have been prevented either directly or indirectly by VTS.

Incidents that are VTS addressable include:

- Open water collisions between two vessels caused by surprise, poor visibility, severe weather, or simple miscalculation on the bridge;

- Certain overtaking situations;

1.3.2 Vessel Casualties (Cont.)

- Collisions during situations when vessels are not anchored in confined waters where the vessel enters a congested channel or waterway directly from the pier, dock, or anchorage;
- Casualties at dredging operations or at similar work activities in a channel; and
- Some casualties involving vessels at anchorage.

Incidents which are not addressable by VTS include:

- Mechanical failure, fire or explosion;
- Non participating vessels (i.e., fishing vessels or other vessels less than 20 meters in length);
- Casualties outside of the VTS range of surveillance;
- Groundings or collisions in close quarter situations such as docking, undocking, maneuvering in a crowded anchorage; and
- Incidents which occur with insufficient warning or lead time (e.g., micro bursts).

1.3.3 Forecasting Future Vessel Casualties

1.3.3.1 Vessel Traffic

The study measures navigational risk as a probability of the number of vessel casualties per a selected traffic unit of exposure. The selected unit of exposure is the volume of vessel transits through each subzone. The historical vessel casualty risk is presented as a rate (i.e., vessel casualties per hundred thousand vessel transits) and the future vessel casualty risk as a probability measured in the same units. Historical vessel transits and future vessel transits by vessel type and vessel size transiting each vessel route within each study subzone are presented. Vessel transits for the historical base period 1979-1989 are used to estimate the navigational risk model. The risk model generates subzone specific vessel casualty probabilities, which are subsequently applied to forecast traffic for the period 1996-2010 to project the probable future vessel casualties. To forecast traffic the study applies growth rates to the base period vessel traffic patterns.

1.3.3.1 Vessel Traffic (Cont.)

Vessel transits are forecast to grow, in each study zone, in proportion to the growth in tonnage of the commodities shipped and received by the deep water ports. The study incorporates the historical distribution of the commodities among the several vessel types and sizes within each subzone and the changes in vessel sizes through the historical period and the forecast period into the forecasts.

1.3.3.2 Risk Assessment

Navigational risk assessment estimates the probable number of future vessel casualties of each type in each study subzone, taking into consideration the unique navigational character of each study zone. This includes historical casualties, navigational characteristics as well as vessel traffic volumes and patterns. The study bases the risk assessment process for estimating the number of future vessel casualties by type of casualty and by category of vessel (type and size) and their respective consequences in each study zone on application of risk probabilities to forecast traffic. The study estimates risk probabilities from historical casualties and traffic as well as subzone specific navigational attributes. Multiple regression analysis identified those statistically significant factors/parameters that the study uses to estimate future casualties in each subzone. Factors such as meteorologic, hydrographic, waterway configuration channel width and depth, and vessel traffic density in each of the subzones are explored to test the relative contribution of each factor to the overall navigational risk in that specific subzone.

Of the 99 study subzones, 27 of them had Coast Guard VTS operating during the historical casualty period, and 18 other subzones had non-Coast Guard vessel traffic management services in operation. The historical vessel casualties for these subzones were reduced by operation of these services. Therefore, the study adjusts the casualty history for these zones upward so that all subzone risk probabilities represent the hypothetical NO-VTS base case.

1.3.3.3 Projecting Future Vessel Casualties

The study projects future vessel casualties for each subzone for each of three different cases: (a) a No-VTS Case representing the absence of any vessel traffic service (the basic vessel casualty risk probability represents the absence of any VTS); (b) an Existing VTS

1.3.3.3 Projecting Future Vessel Casualties (Cont.)

Case representing the continuation of the current status quo (i.e., in subzones where an existing Coast Guard or non-Coast Guard vessel traffic service is operating); and (c) a Candidate VTS Design Case representing full operation of the Candidate VTS Design in all study zones. The difference between (a) and (c) represents the avoided vessel casualties attributable to the Candidate VTS Design in each study zone. The difference between (b) and (c) represents the marginal increase in avoided vessel casualties over-and-above those that would accompany continuation of the existing vessel traffic service.

1.3.4 VTS Benefits (Avoided Losses)

To estimate the avoided vessel casualties for each study zone, the study applies VTS Effectiveness Factors to the projected vessel casualties under the NO-VTS Case. To estimate the avoided consequences the study subsequently applies conditional probabilities to the avoided vessel casualties. The avoided consequences (VTS benefits) considered include:

- Loss of human life and personal injuries;
- Vessel hull damage;
- Cargo loss and damage;
- Economic cost of the vessel out of service;
- Spill clean up costs;
- Losses to tourism/recreation;
- Losses to commercial fish species;
- Impacts on marine birds and mammals;
- Losses due to LPG/LNG fires and explosions; and
- Bridge and navigational aids damage.

These avoided consequences may be considered the direct benefits of VTS. The indirect benefits of VTS operations in a port area may extend beyond this list to such advantages as the availability of additional port specific and timely weather information and current traffic information for non-participating vessel traffic, as well as enhancement of the reputation as a safe port of entry. This study does not quantify these indirect benefits of VTS.

The risk assessment process yields the total expected number of avoided casualties by casualty type, vessel type and size, and the associated avoided losses by loss type, and their respective monetary values in each study subzone.

1.3.5 VTS Candidate Design and Costs

The study develops one VTS Candidate Design for each study zone to provide comparable VTS service given all the characteristics of the port. The basic concept of the "Candidate VTS Design" includes a central data gathering and watch standing location known as a Vessel Traffic Center and an array of surveillance sensors covering each subzone within each study zone. The unique characteristics of each study zone dictate the number and type of surveillance sensors (radar, television, communications, ADS, etc.) that support the Vessel Traffic Center.

A survey of state of the art VTS technology resulted in a list of 18 modules of VTS technology. The study defines a Candidate VTS Design for each study zone by a unique selection of these modules for each study subzone. The appropriate technology module(s) are selected on the basis of engineering judgement of the requirements of each individual subzone. Seven representative in-depth port surveys are the basis of the Candidate VTS Design developed for each of the seven study zones. The study bases the candidate VTS designs for the remaining 16 study zones on knowledge gained from the surveys and analyses of the initial seven representative study zones.

The Candidate VTS Design is a best engineering judgement made for the sole purpose of developing cost estimates that are consistent and comparable among the 23 study zones. VTS costs include non-recurring initial capital investments as well as recurring operations and maintenance costs. For four study zones, the study incorporates existing Coast Guard VTS facilities (i.e., radar towers) into the Candidate VTS Design. Thus the initial investment cost for each of these study zones is reduced by the estimated value of the existing VTS facilities. The study also provides cost estimates for the Candidate VTS Design without incorporation of the existing VTS facilities.

1.3.6 Evaluation Of VTS Benefits and Cost

The product of this step is the comparison of the benefits and the costs among the 23 zones. The study estimates the net benefits of state of the art Candidate VTS Design in each of 23 study zones. The net benefit is the difference between the present value of the life cycle benefits and costs.

1.3.6 Evaluation Of VTS Benefits and Cost (Cont.)

This study assumes that any existing non-Coast Guard vessel traffic management service in a study zone will be terminated when the Candidate VTS Design becomes operational except for the functions of transportation brokering, specific berthing instructions, etc. The beneficial effect of any existing vessel traffic management service during the casualty analysis base period is "backed out" to establish comparable No-VTS cases among all 23 study zones.

The net benefit in each study zone assumes that the decision to implement is made by FY '93 and the funds are appropriated in FY '93, and further assumes that the Coast Guard Candidate VTS Design is fully operational (accruing operating and maintenance costs as well as benefits) by the beginning of FY '96. The study assumes the life cycle will run through FY 2010.

1.3.7 Sensitivity

This study involves a large number of individual input estimates, derived from data of varying scope and quality and a number of imperfect assumptions. A reasonable level of confidence in the results can only be obtained by testing the sensitivity of the final results to the range of uncertainty of the major inputs. The final step in this study process is analyses of the sensitivity of the relative net benefits among the study zones to a range of uncertainty in key input variables.

2. PORT STUDY ZONES AND SUBZONES

2.1 OVERVIEW

The study defines all zones in a consistent manner, giving equal consideration to four factors:

1. Existing deep draft vessel and major barge traffic patterns.
2. Navigational hazards as evidenced by NOAA charts.
3. Recent vessel casualty history.
4. Guidance of the Coast Guard sponsor and local marine authorities.

The study defines subzones in each study zone based upon a generic definition of six waterway/subzone types. This limited set of subzone types results in a total number of 99 subzones.

The 23 zones in this study represent the significant ports in the United States. They also represent waterfront areas that are particularly sensitive to environmental disturbance and pollution. While most of the zones contain a single port, several contain more than one port.

Each study zone is bounded by an imaginary line around the area defined by latitude and longitude coordinates. Each study zone includes the waterways surrounding the major port facilities and enough of the offshore area to assure that any reported casualties related to the approach or departure from the port area will be included in the analysis of the study zone.

2.2 SUBZONE CATEGORIES

This study uses a six subzone classification scheme that is based more on the physical and hydrographic characteristics of the waterways in question with some attention given to traffic patterns volume and type. Each zone is divided into subzones based upon generic waterway types. The six subzone types are as follows:

- Subzone Type A - Open Approach;
- Subzone Type B - Convergence;
- Subzone Type C - Open Harbor or Bay;
- Subzone Type D - Enclosed Harbor;
- Subzone Type E - Constricted Waterway; and
- Subzone Type F - River.

Hydrographic characteristics and waterway configuration determine the subzone categories more so than traffic patterns. This results in some zones having more than one subzone of a particular category. (Zone 2: Puget Sound has three "Enclosed Harbor" subzones).

Port facilities can lie in an open harbor, an enclosed harbor, a narrow waterway, or river. In fact, some zones have port facilities in more than one of these subzone types.

Application of this predefined set of subzone/waterway types supports the detailed traffic, casualty, and consequences analyses at the subzone level. This approach allows a comparison among study zones based upon a commonality of navigational characteristics of subzones contained within each zone.

A subzone need only meet one criteria to be categorized. In some cases a section of a waterway may contain characteristics of more than one subzone definition. In such cases the subzone which best describes the waterway section is selected. To identify each subzone the study uses a unique five character alphanumeric code. Figure 2-1 illustrates the subzone numbering scheme.

2.2 SUBZONE CATEGORIES (Cont.)

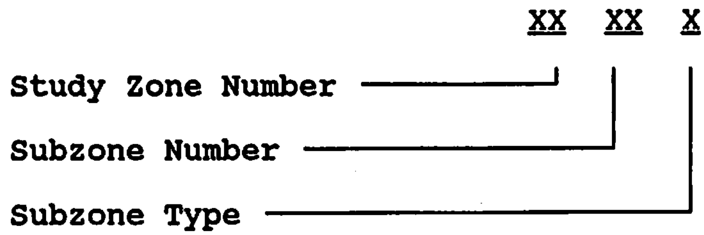

FIGURE 2-1. SUBZONE NUMBERING SCHEME

This section presents descriptions of each zone and associated subzones. See Table 2-1 for a list of the 99 subzones resulting from this exercise.

- **Subzone Type A - Open Approach**
  - Entrance from sea to the study zone.
  - Usually extends to Pilot boarding location.
  - Includes marked channel wide enough to allow deep draft vessels to pass or overtake safely with maneuvering room outside the marked channel.

The study restricts the subzones designated as open approach areas, in most cases, to those areas of each zone from the sea inward to a line drawn across the main traffic routes near the pilot pickup point.

The subzone may extend beyond the three-mile territorial limit to accommodate the unique hydrographic, traffic, and geographic conditions. It may include areas too shallow for deep draft vessels to transit safely. There are two main reasons for this:

1. In some cases, the subzone extends to assure that historical accidents/incidents that occur to vessels leaving or entering a study zone are not excluded simply because they occur outside reasonable potential VTS boundaries.

2. An incident may occur in shallow water outside the usual traffic lanes due to navigational or other problems that an active VTS may be aware of while the vessel is in the major traffic area.

2.2 SUBZONE CATEGORIES (Cont.)

There are 22 "Open Approach" subzones in the 23 study zones. Each of the 23 zones has an "Open Approach" subzone with the exception of Zone 9, Chesapeake North/Baltimore, MD. The approach to Zone 9 is via either the Zone 8 part of the Chesapeake Bay or via the Delaware Bay which is part of Zone 13.

- **Subzone Type B - Convergence**

  - Area of water dominated by converging of major traffic lanes or channels.

  - Immediately inbound of "Open Approach."

In most of the study zones there are sections of the waterway where traffic converges or funnels via existing lanes or channels, i.e., traffic lanes or channels intersect, creating precautionary zones for either merging or crossing traffic. The only intersections of this type that the study classifies as "Convergence" subzones are those that occur outside the major port areas. In fact the waterway sections so classified are all adjacent to an "Open Approach" subzone. This category of waterway was created because the waterway contained in these subzones usually reflects a major merging of inbound traffic immediately after a deep draft vessel picks up a pilot and then proceeds through a constriction of the channel or traffic lane.

There are ten zones that each have a single "Convergence" subzone.

- **Subzone Type C - Open Harbor or Bay**

  - Harbor/Port area which includes relatively open water containing some port facilities.

  - Identifiable harbor or bay which may contain significant port facilities.

  - Segment of waterway having Traffic Separation Scheme (TSS) or Traffic Lanes (TL) with available area outside the lanes for shallow draft vessels.

  - Sometimes locally referred to as "Outer Harbor."

2.2 SUBZONE CATEGORIES (Cont.)

Subzones identified as "Open Harbor or Bay" are less uniform in their configuration than the other subzone categories. In some cases, such as San Francisco Bay, this classification for a part of the waterway is straightforward. In other zones, Portland, Oregon, for example, it is perhaps not quite so obvious. The most heavily weighted factor in the determination of this subzone type is the availability of water outside the marked channels for shallow draft vessels to maneuver.

The study classifies 18 subzones as "Open Harbor or Port" distributed over 15 zones.

- **Subzone Type D - Enclosed Harbor**
  - Harbor/Port area mostly enclosed by land or shallow water or bordered by significant fixed obstructions, containing major port facilities.
  - Includes areas with significant meeting, intersecting, and overtaking traffic of many types and sizes.
  - Sometimes locally referred to as "Inner Harbor."

Some study zones do not contain an enclosed harbor subzone. In zones where the port facilities lie along a narrow waterway or a river there is no section which would be called a harbor. The study distinguishes port areas by the major waterway type within which these facilities lie.

Each study zone does not have an "Enclosed Harbor" subzone. There are 17 "Enclosed Harbor" subzones distributed across 14 zones.

2.2 SUBZONE CATEGORIES (Cont.)

- **Subzone Type E - Constricted Waterway**
  - Area of water with or without TSS/TL bounded by land fixed obstructions or shallow water limiting the maneuverability of deep draft vessels and requiring most barge traffic to travel in lanes/channel.
  - Excludes most identifiable rivers.
  - Subject to restrictions on overtaking and passing.

Constricted waterways represent those areas of the zones where maneuverability is limited. In most cases, narrow passages with blind turns indicate this. In other cases, the study classifies subzones as constricted waterways even though the channel may be situated in a relatively open section of water because the main shipping channel is narrow and is surrounded by shallow water or other obstructions.

This study classifies 20 subzones in 14 zones as "Constricted Waterways."

- **Subzone Type F - River**
  - An identifiable river or waterway whose currents are determined more by river flow rather than tidal action.

For a waterway section to be classified as "River" the above criteria must be met. There is one such subzone in each of 9 of the study zones. One zone, Zone #6 New Orleans, is a special case in that the Mississippi River is divided into three adjacent Type F subzones.

TABLE 2-1. SUBZONES

ZONE NO.	NAME	SUBZONE TYPES A	B	C	D	E	F	TOTALS
1	BOSTON, MA	1	1	1	1	1		5
2	PUGET SOUND, WA	1	1	2	3	3		10
3	L.A./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

2.3 STUDY SUBZONE NAVIGATIONAL CHARACTERISTICS

The study describes each of the 99 study subzones in terms of their vessel route configurations, ship channel physical characteristics as well as the hydrographic and meteorologic characteristics of the navigable waterway. The 99 subzones are the basic geographical units for: (1) the collection and analysis of historical data on deep draft vessel traffic, local vessel activity, vessel casualties and consequences of vessel casualties; (2) forecasting future vessel traffic; (3) the application of risk probabilities to forecast future vessel casualties and their consequences in each of the 99 subzones. Section 5 describes the development and application of vessel casualty probabilities reflecting the unique navigational characteristics of each of the 99 subzones.

The sources of the physical characteristics of the study subzones (i.e., shoreline, ship channel alignment, width and depth, waterway configuration and size, location of obstructions, anchorages, current and wind velocities, visibility) are National Oceanographic and Atmospheric Administration (NOAA) charts, publications, and data. A Geographic Information System (GIS) plots the graphic representations of the boundaries of each study zone and subzone. These study zone and subzone plots are the foundation for subsequent analyses of casualties, traffic patterns, navigational risk, forecasts of future vessel traffic and casualties with and without VTS, and the associated marine losses and their respective costs.

Figures 2-2 through 2-24 are reduced copies of the GIS plots depicting the zone and subzone boundaries in each of the 23 study zones. To provide a broad perspective of the zones and their subzones, the chapter includes the entire series.

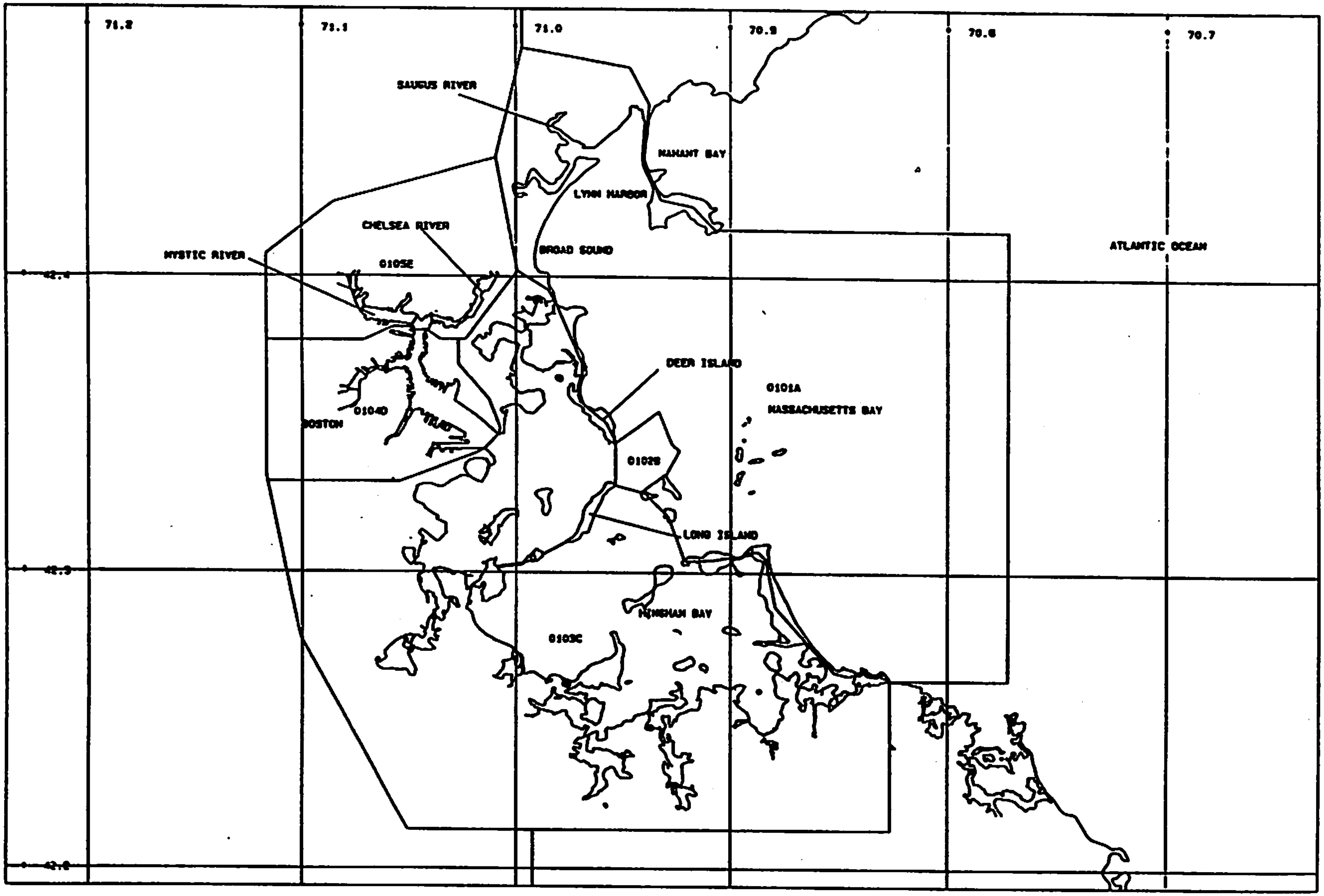

FIGURE 2-2. ZONE 1 - BOSTON, MA - ZONE & SUBZONE BOUNDARIES

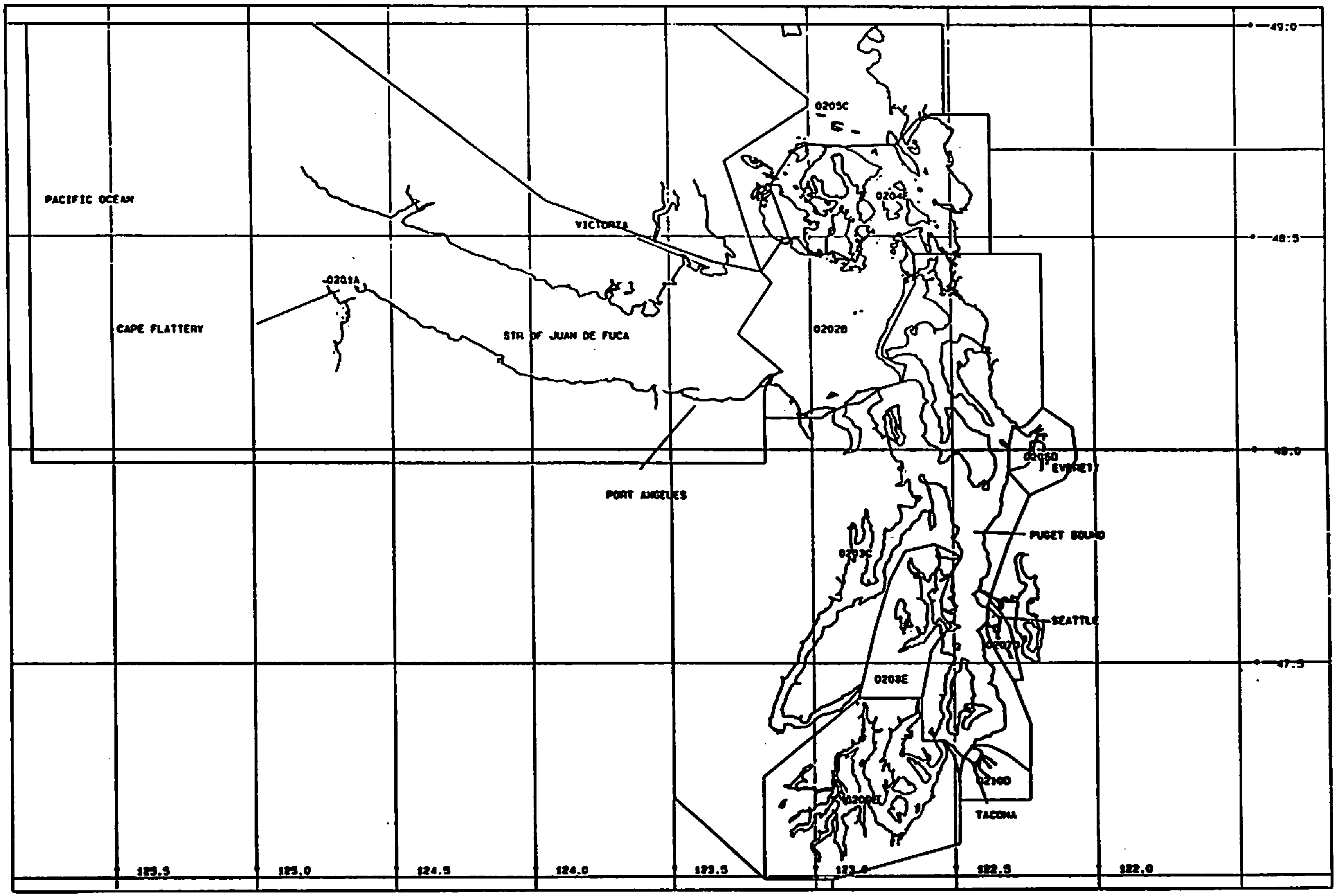

FIGURE 2-3. ZONE 2 - PUGET SOUND, WA - ZONE & SUBZONE BOUNDARIES

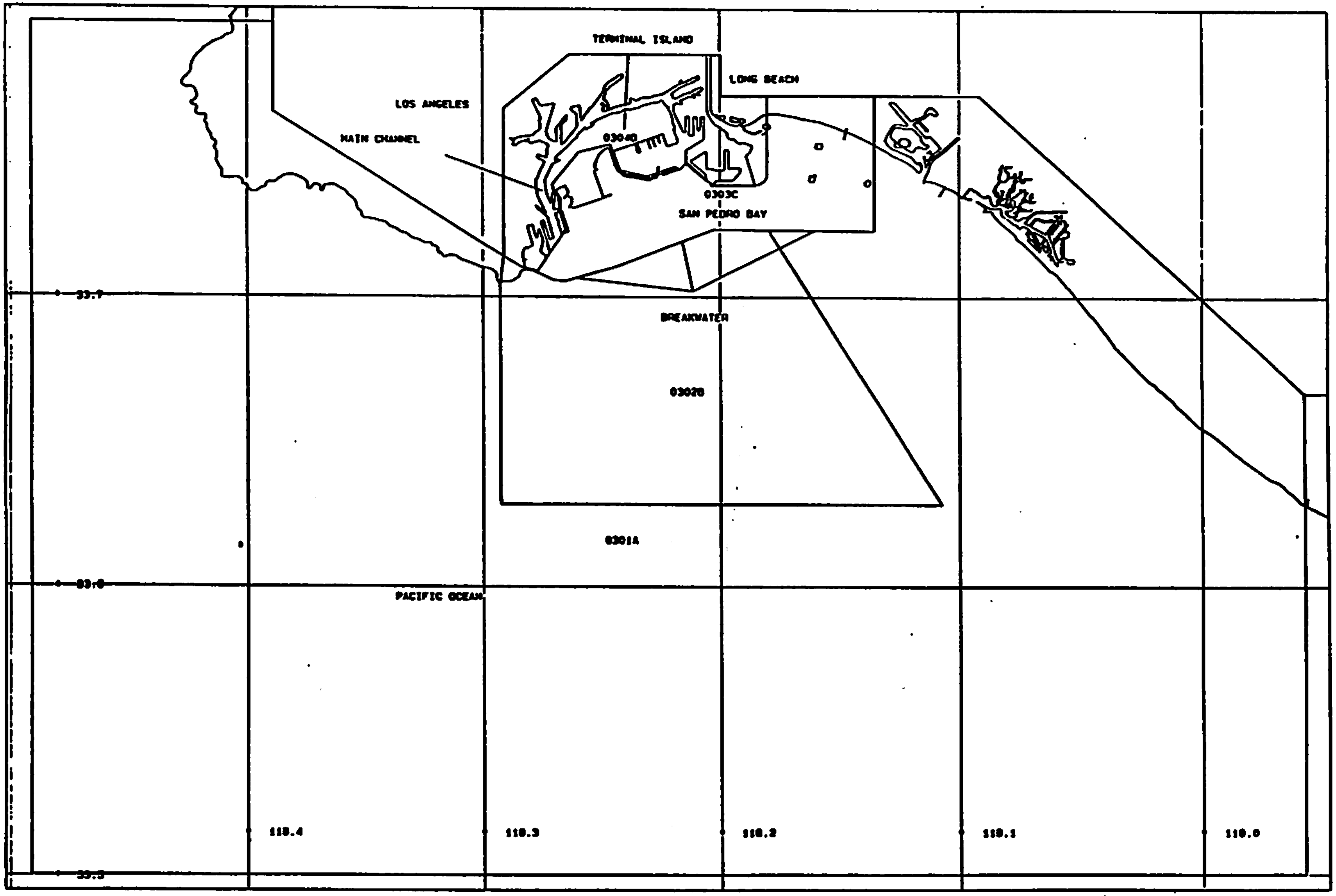

FIGURE 2-4. ZONE 3 - LOS ANGELES/LONG BEACH, CA - ZONE & SUBZONE BOUNDARIES

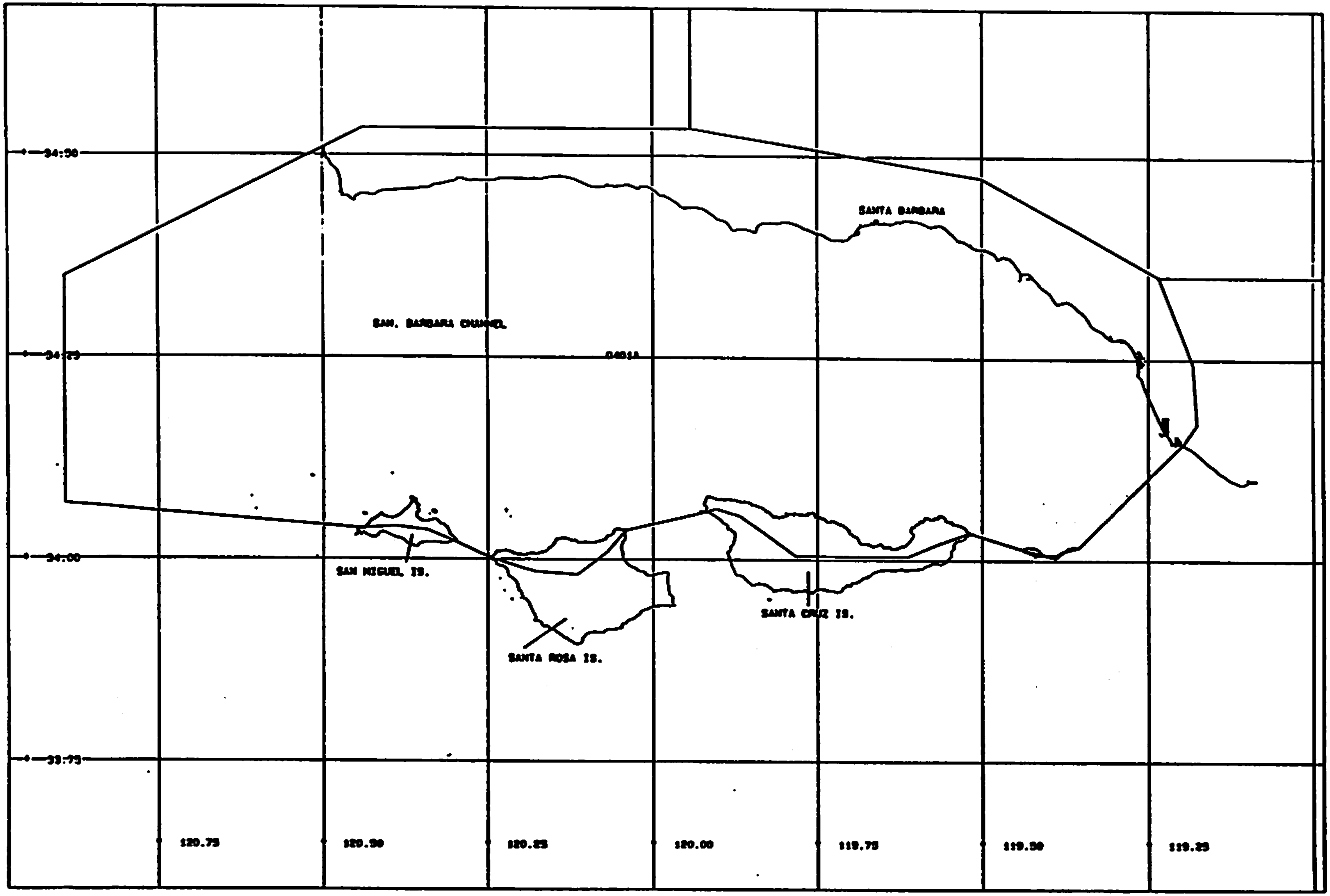

FIGURE 2-5. ZONE 4 - SANTA BARBARA, CA - ZONE & SUBZONE BOUNDARIES

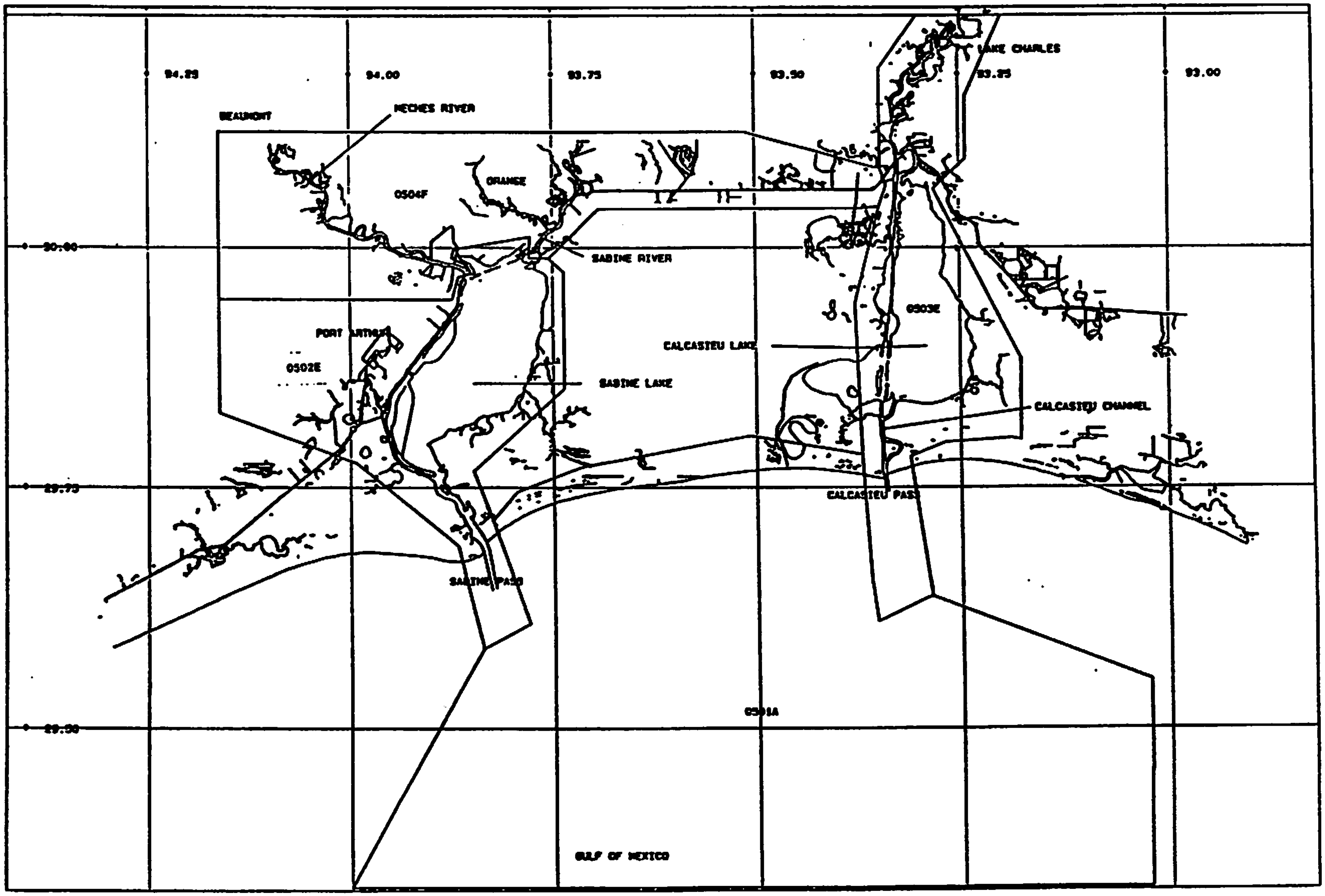

FIGURE 2-6. ZONE 5 - PORT ARTHUR, TX - ZONE & SUBZONE BOUNDARIES

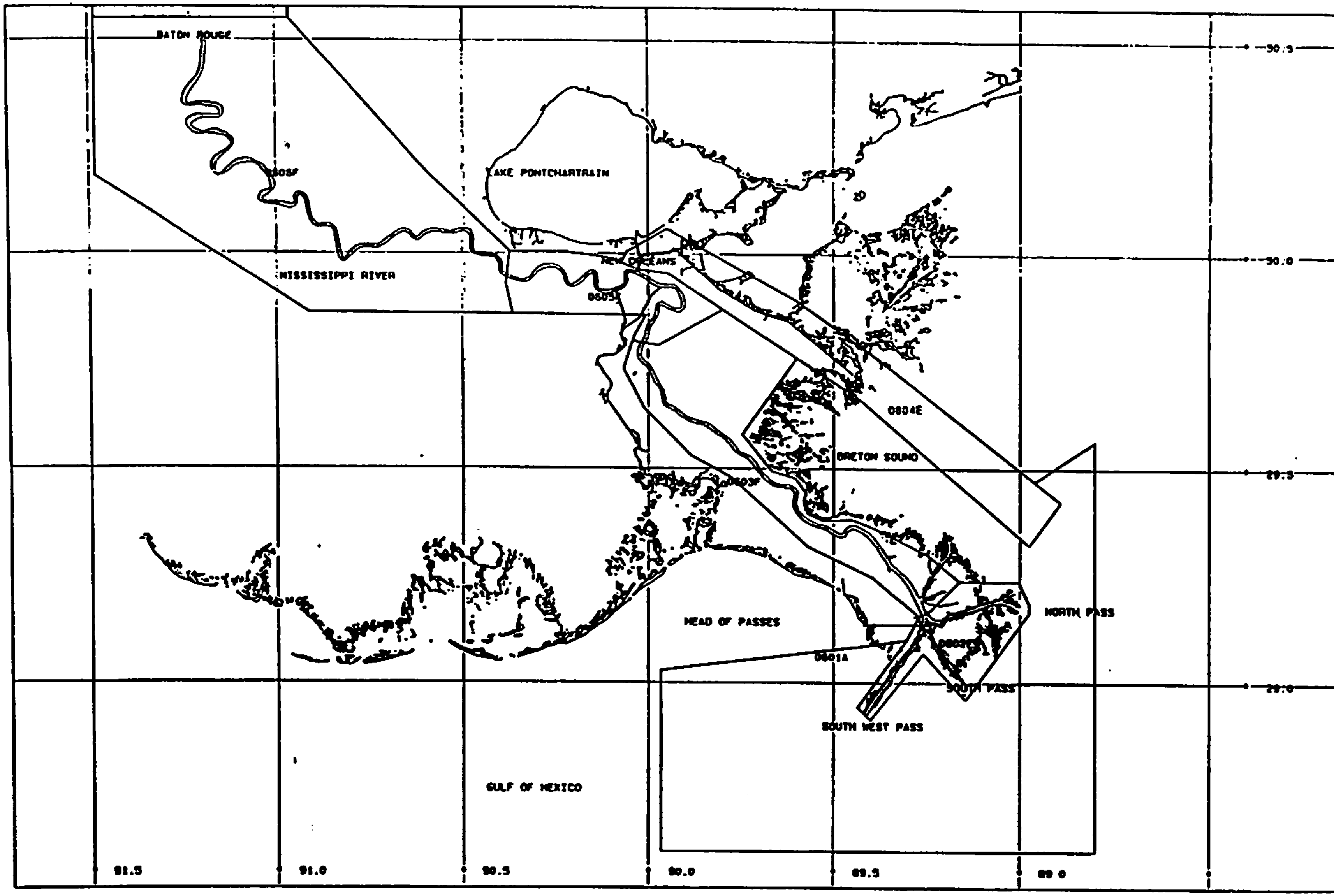

FIGURE 2-7. ZONE 6 - NEW ORLEANS, LA - ZONE & SUBZONE BOUNDARIES

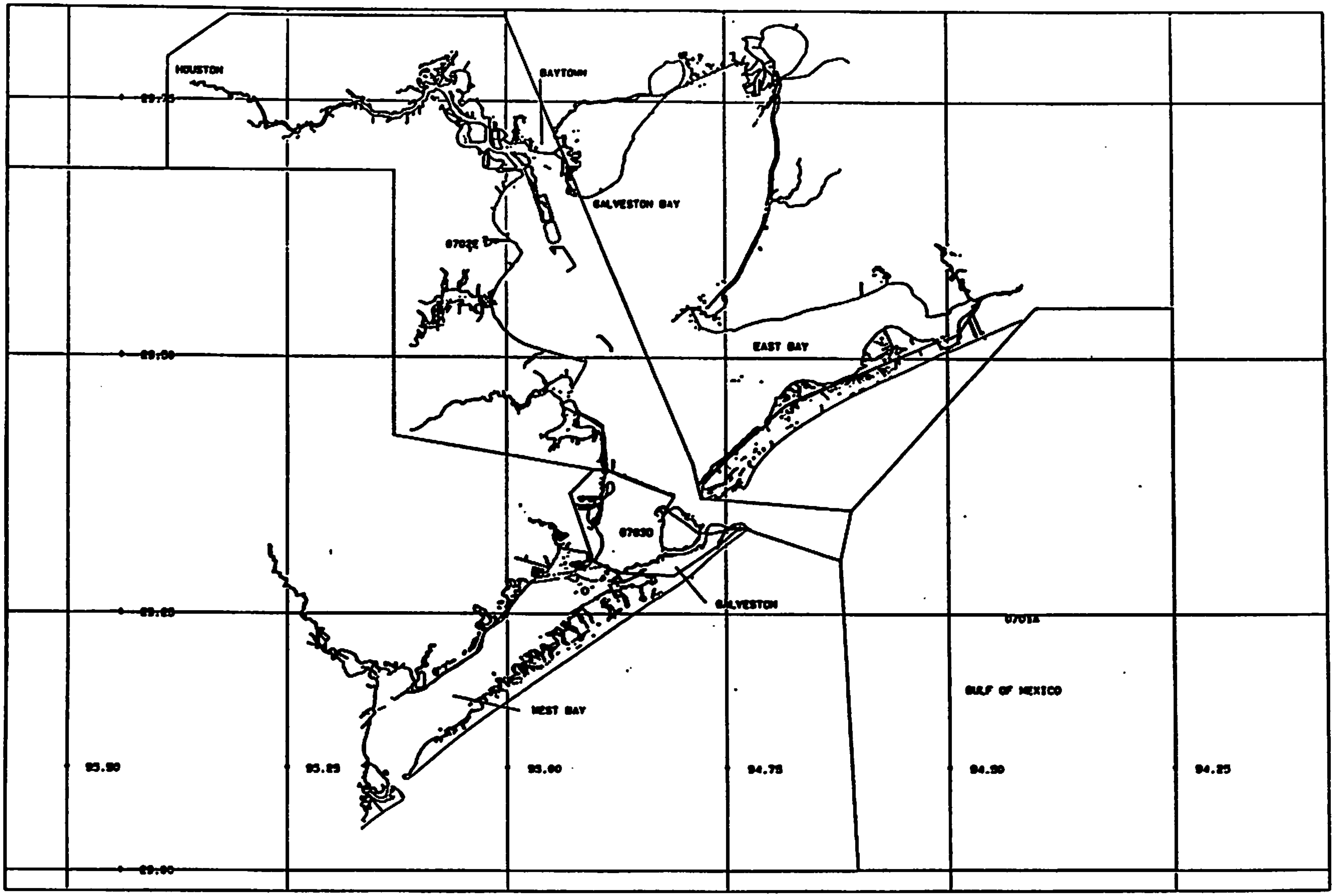

FIGURE 2-8. ZONE 7 - HOUSTON/GALVESTON, TX - ZONE & SUBZONE BOUNDARIES

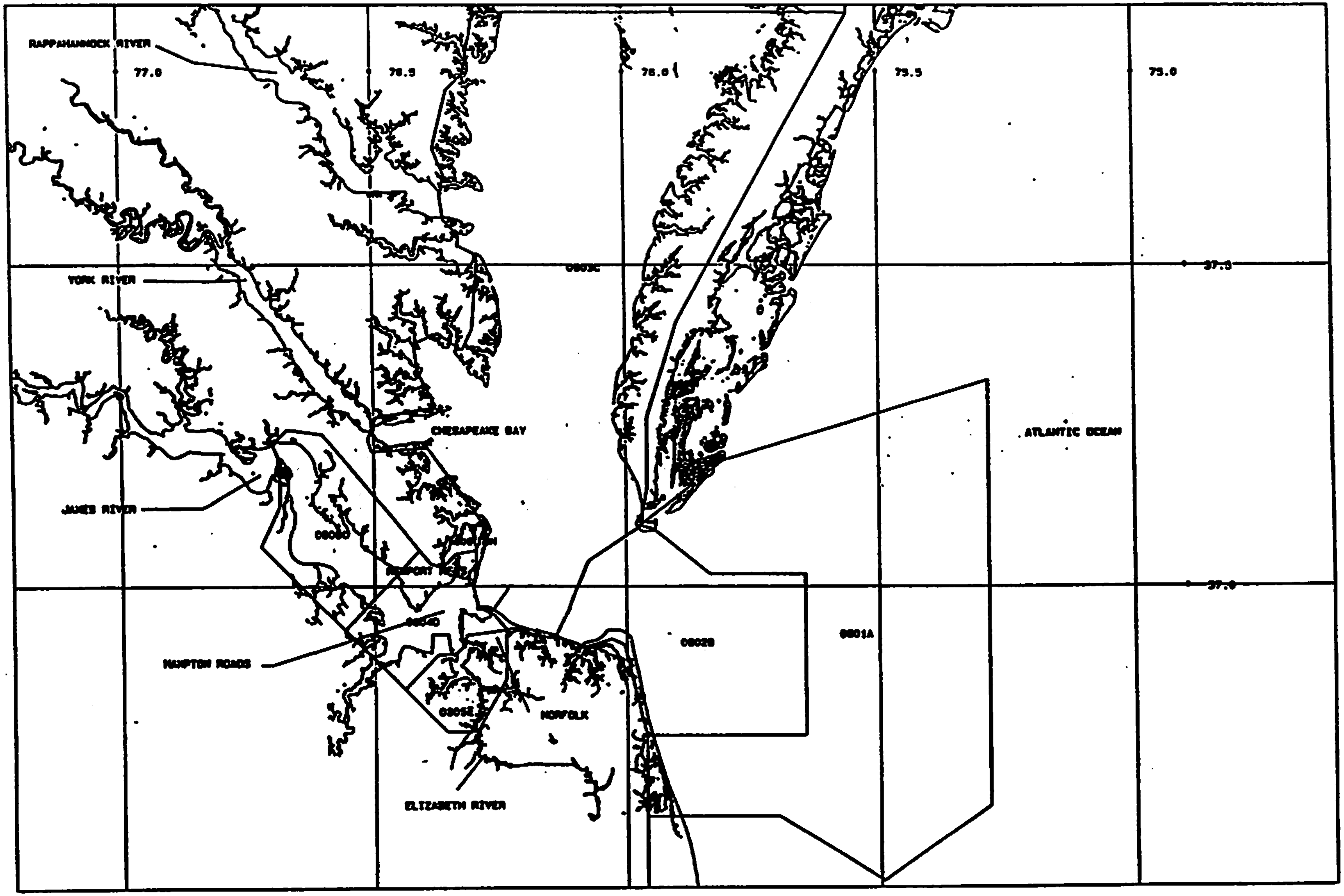

FIGURE 2-9. ZONE 8 - CHESAPEAKE SOUTH/HAMPTON ROADS, VA - ZONE & SUBZONE BOUNDARIES

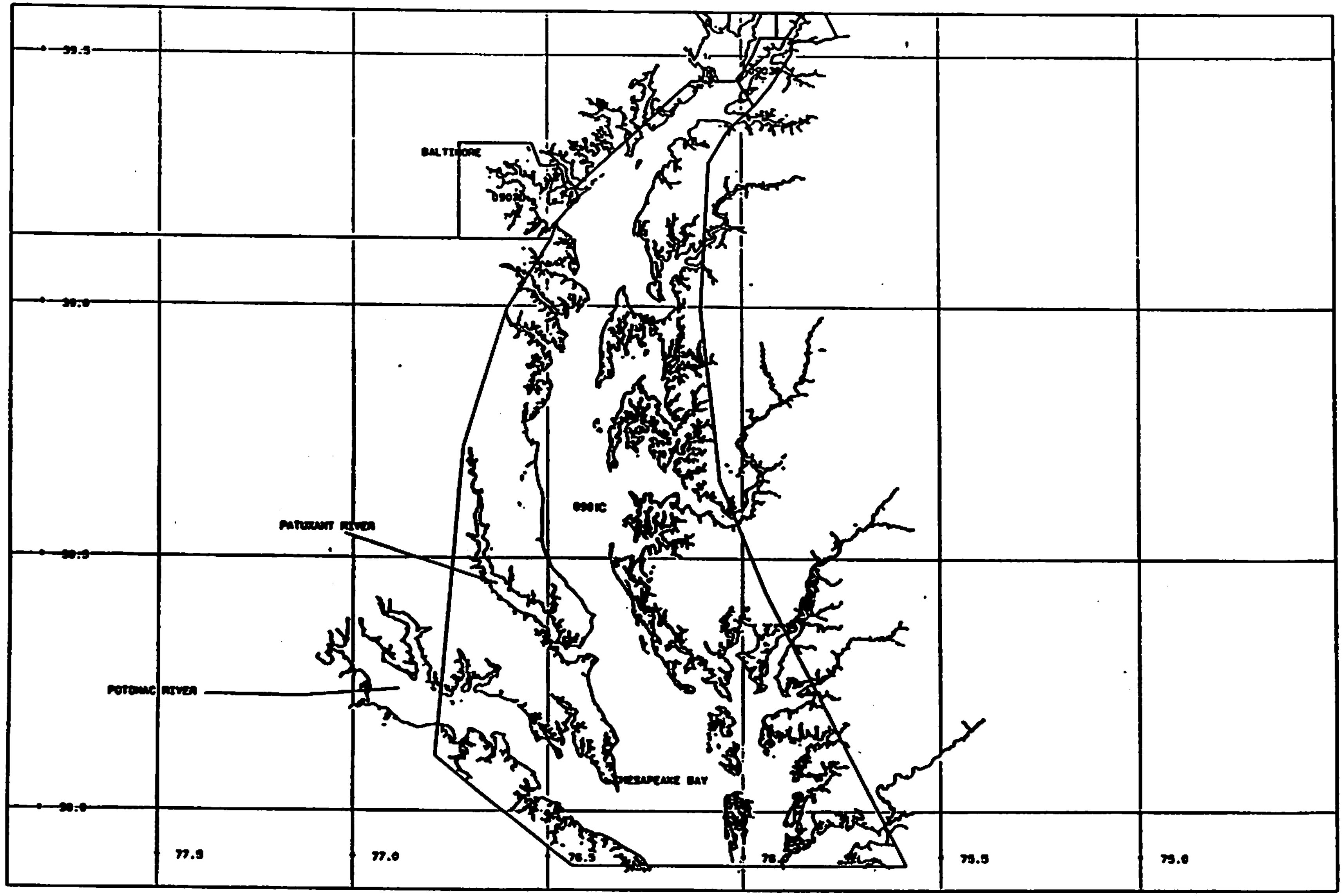

FIGURE 2-10. ZONE 9 - CHESAPEAKE NORTH/BALTIMORE, MD - ZONE & SUBZONE BOUNDARIES

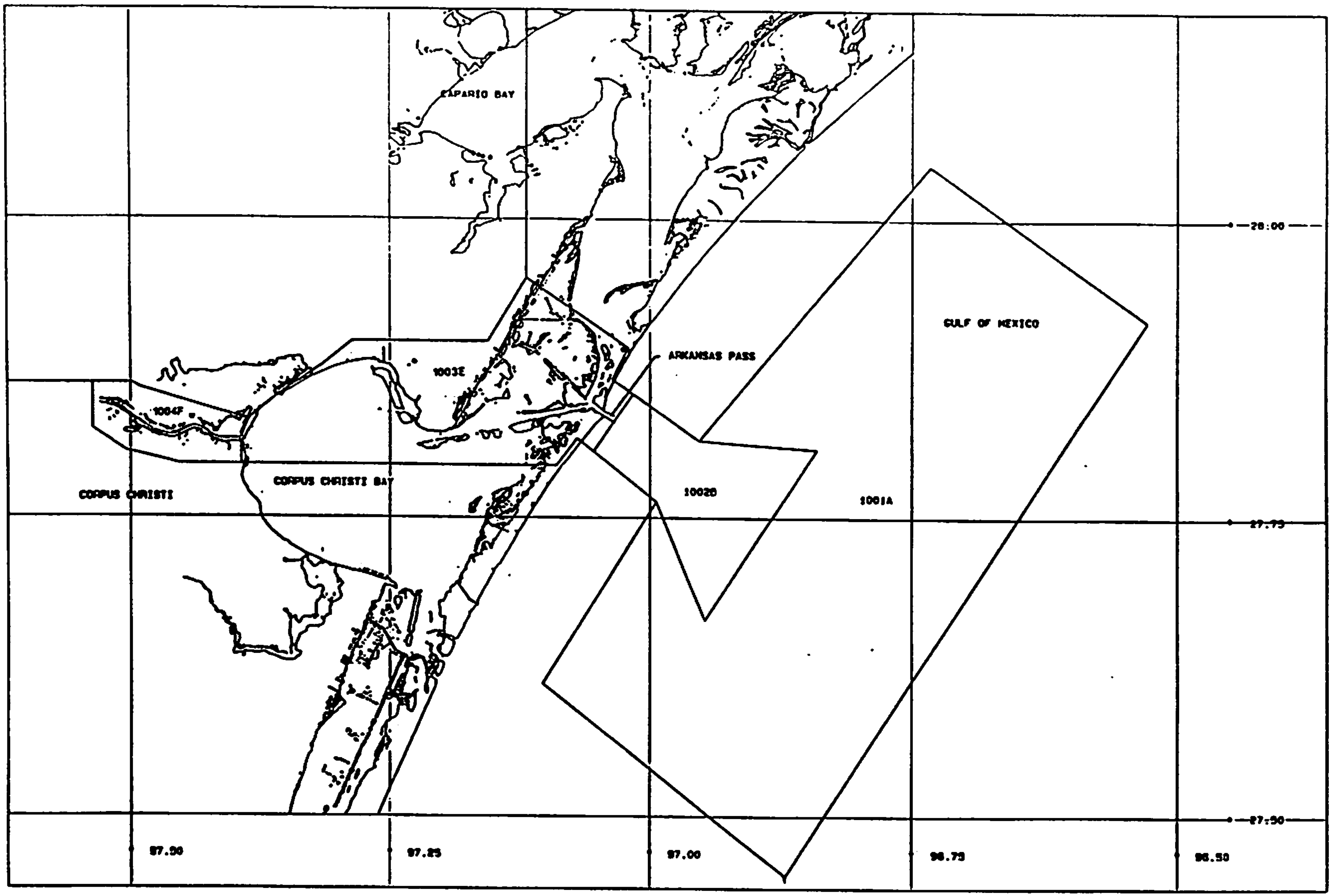

FIGURE 2-11. ZONE 10 - CORPUS CHRISTI, TX - ZONE & SUBZONE BOUNDARIES

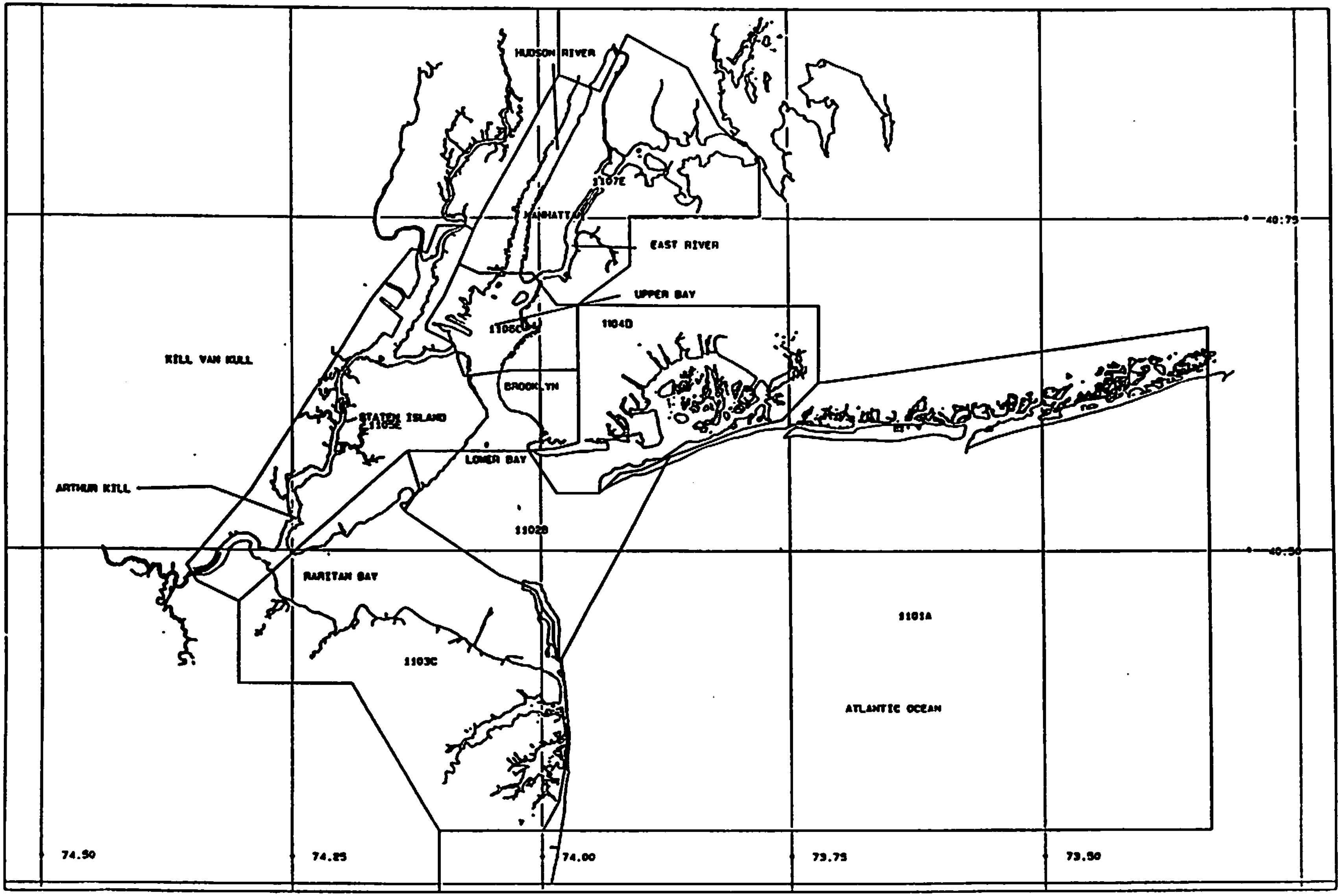

FIGURE 2-12. ZONE 11 - NEW YORK CITY, NY - ZONE & SUBZONE BOUNDARIES

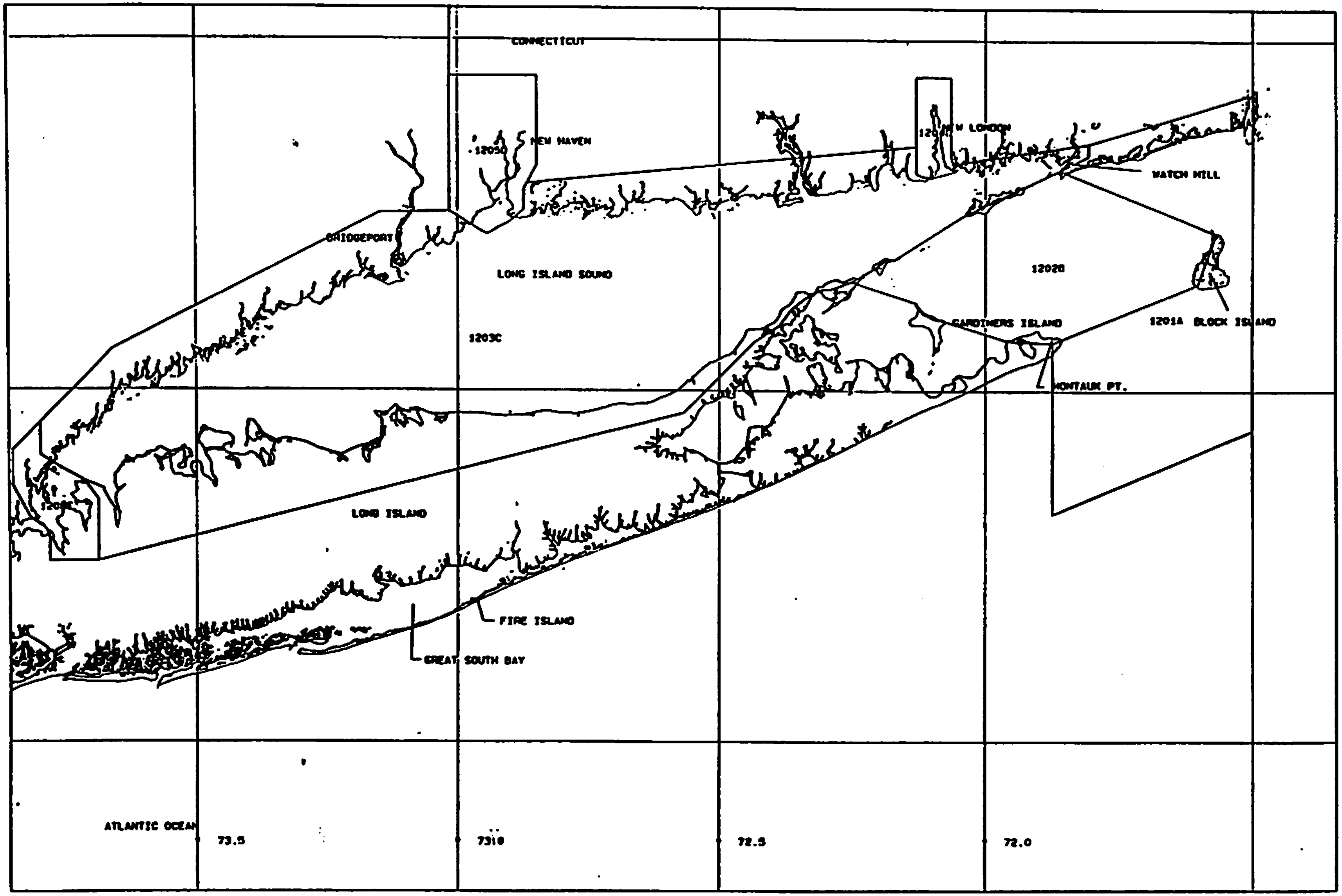

FIGURE 2-13. ZONE 12 - LONG ISLAND SOUND, NY - ZONE & SUBZONE BOUNDARIES

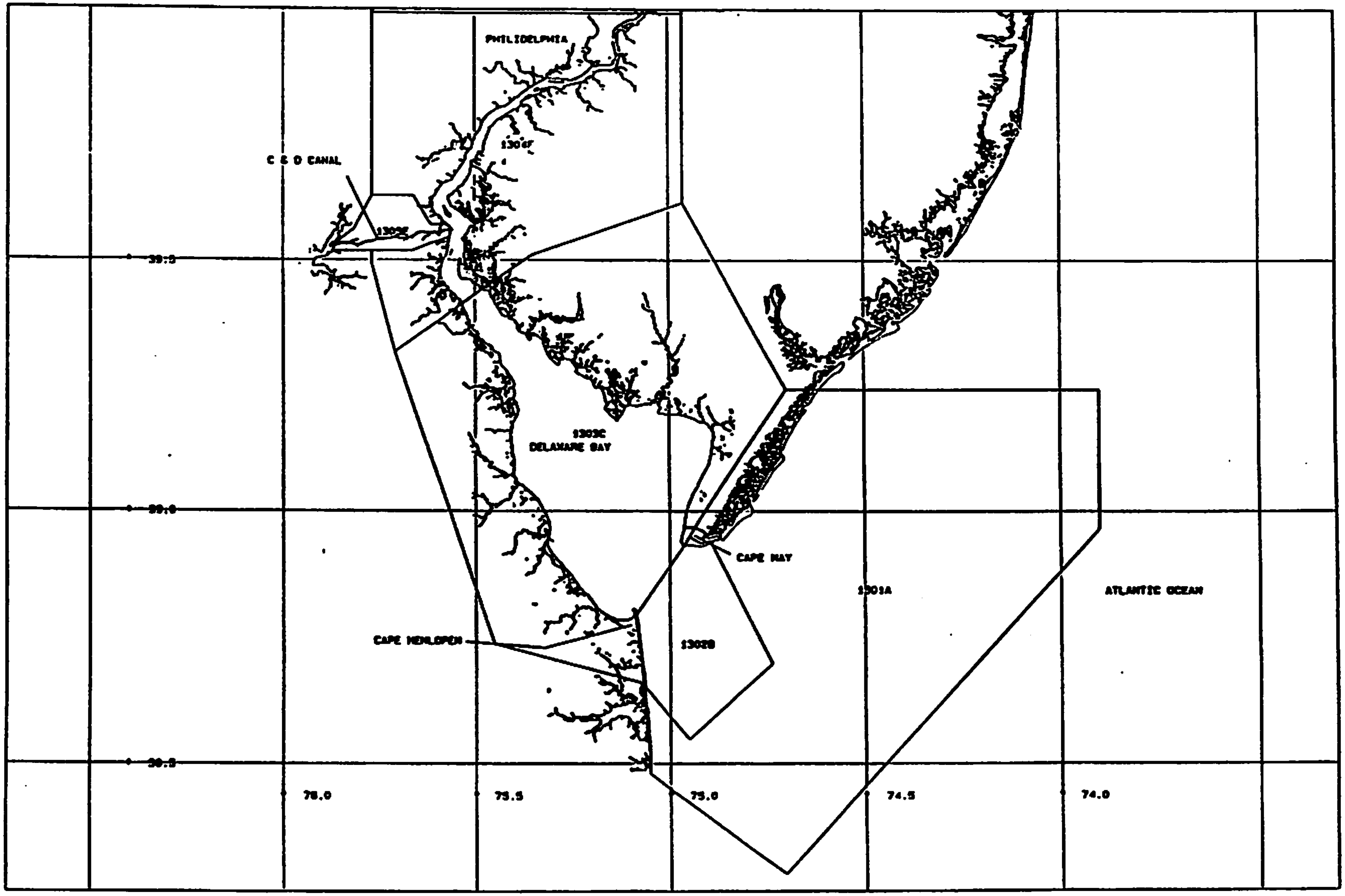

FIGURE 2-14. ZONE 13 - PHILADELPHIA/DELAWARE BAY, PA - ZONE & SUBZONE BOUNDARIES

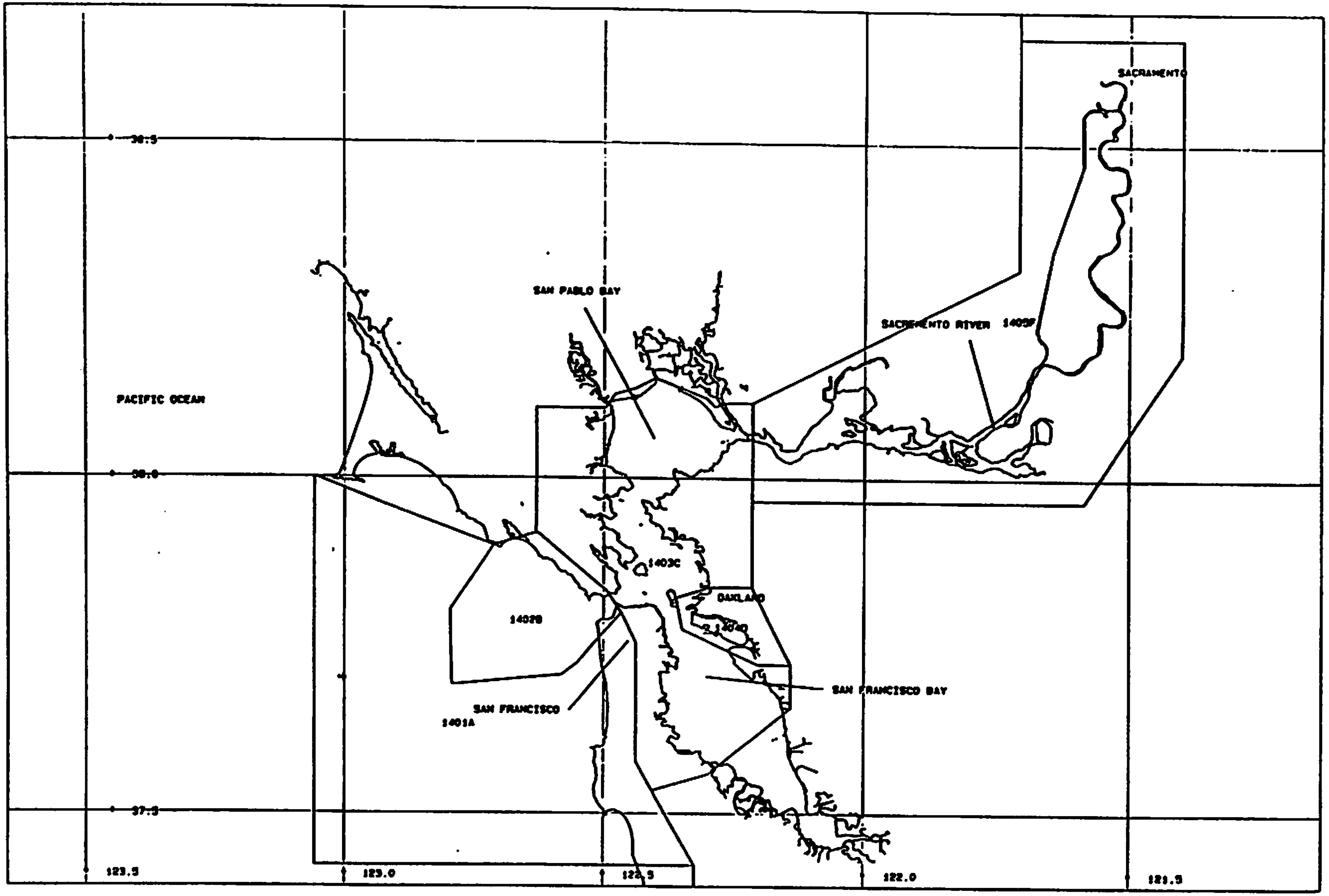

FIGURE 2-15. ZONE 14 - SAN FRANCISCO, CA - ZONE & SUBZONE BOUNDARIES

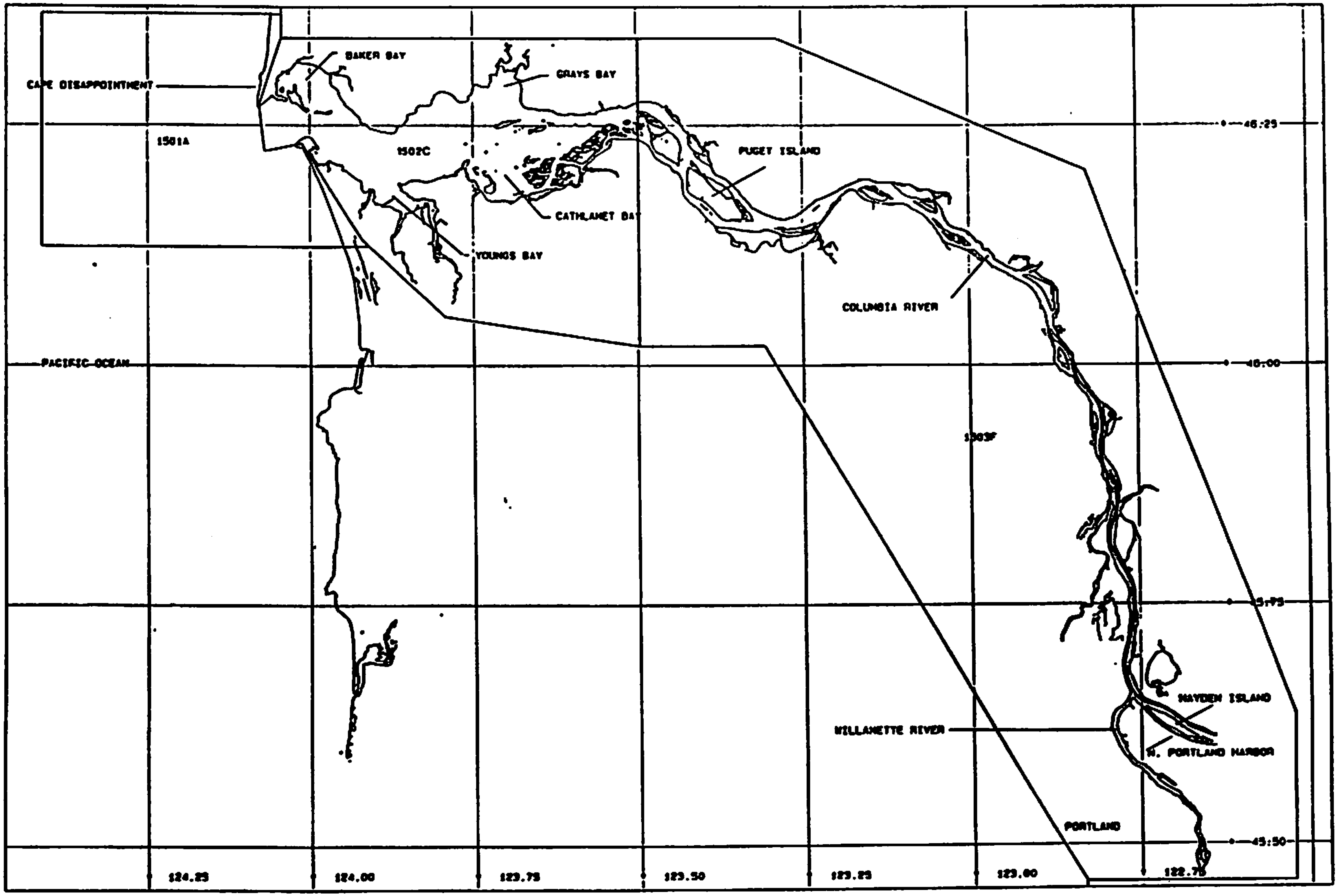

FIGURE 2-16. ZONE 15 - PORTLAND, OR - ZONE & SUBZONE BOUNDARIES

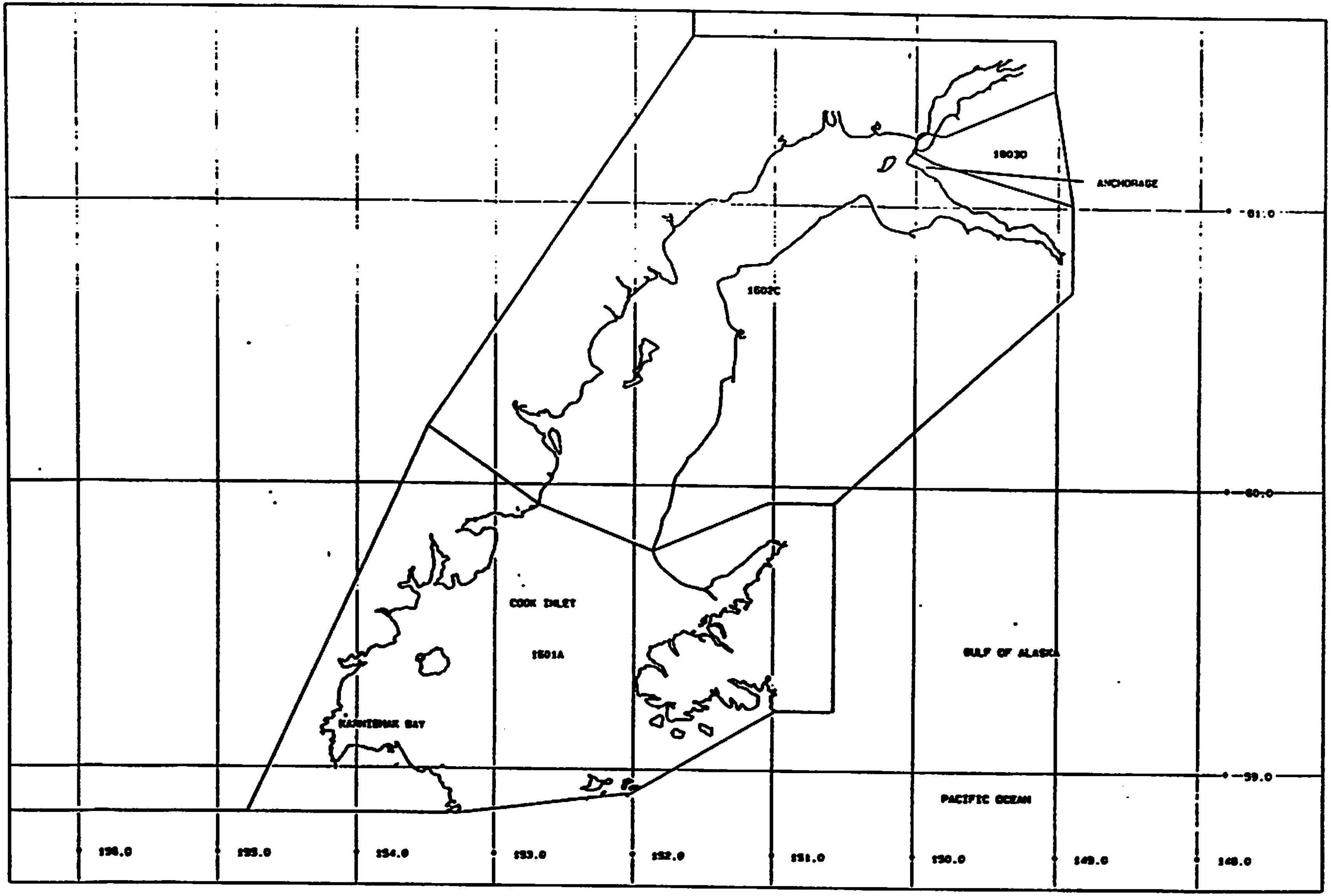

FIGURE 2-17. ZONE 16 - ANCHORAGE/COOK INLET, AK - ZONE & SUBZONE BOUNDARIES

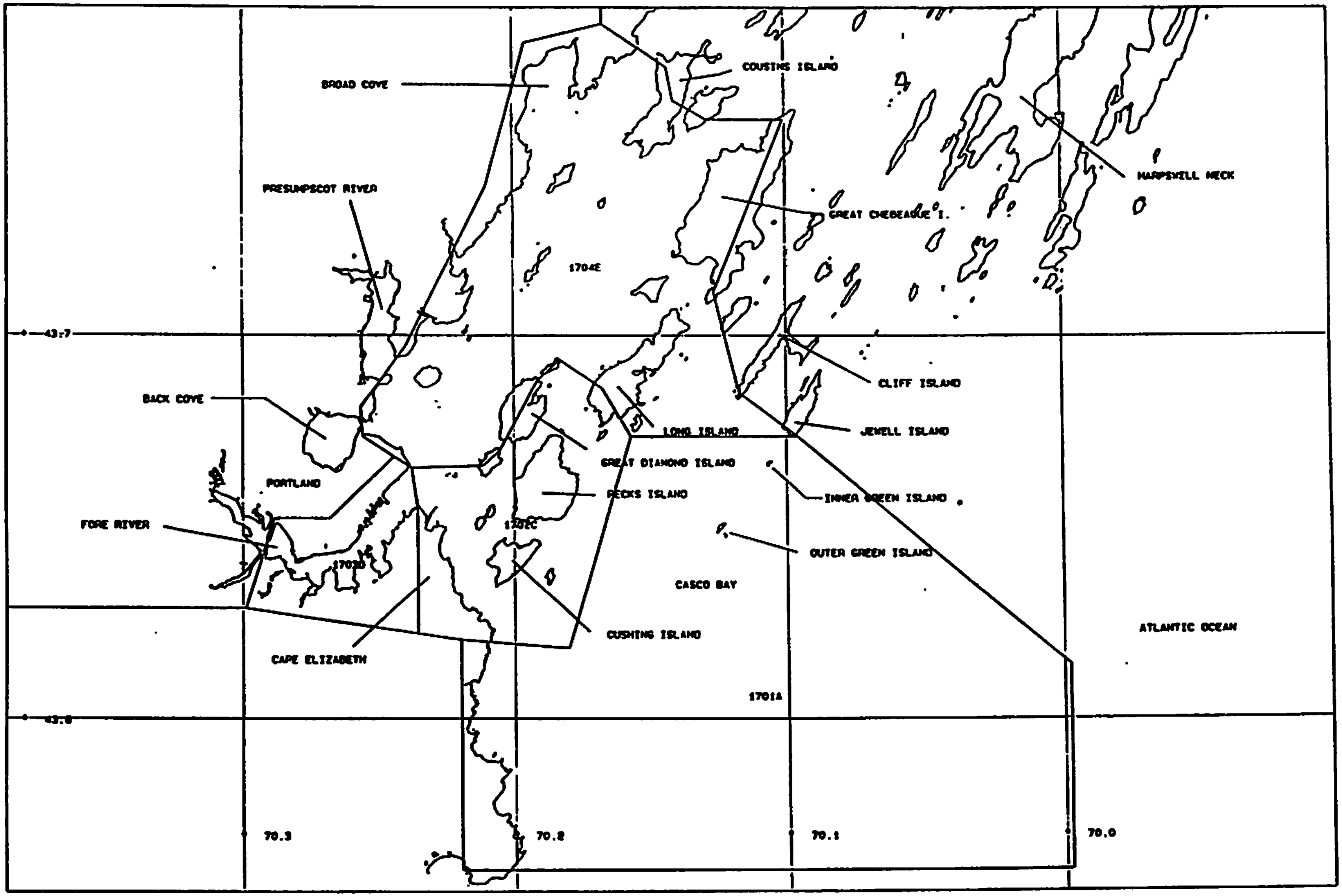

FIGURE 2-18. ZONE 17 - PORTLAND, ME - ZONE & SUBZONE BOUNDARIES

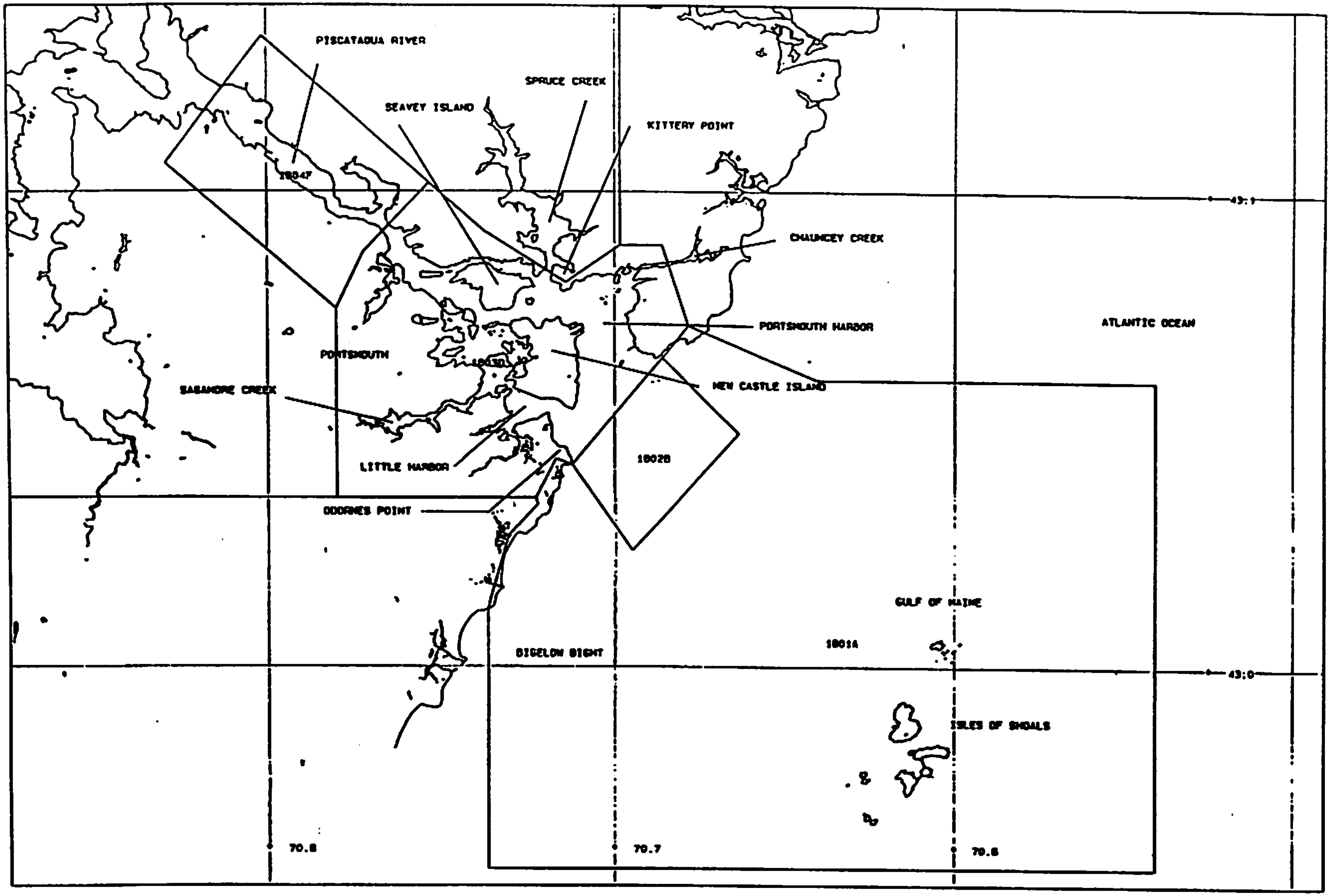

FIGURE 2-19. ZONE 18 - PORTSMOUTH, NH - ZONE & SUBZONE BOUNDARIES

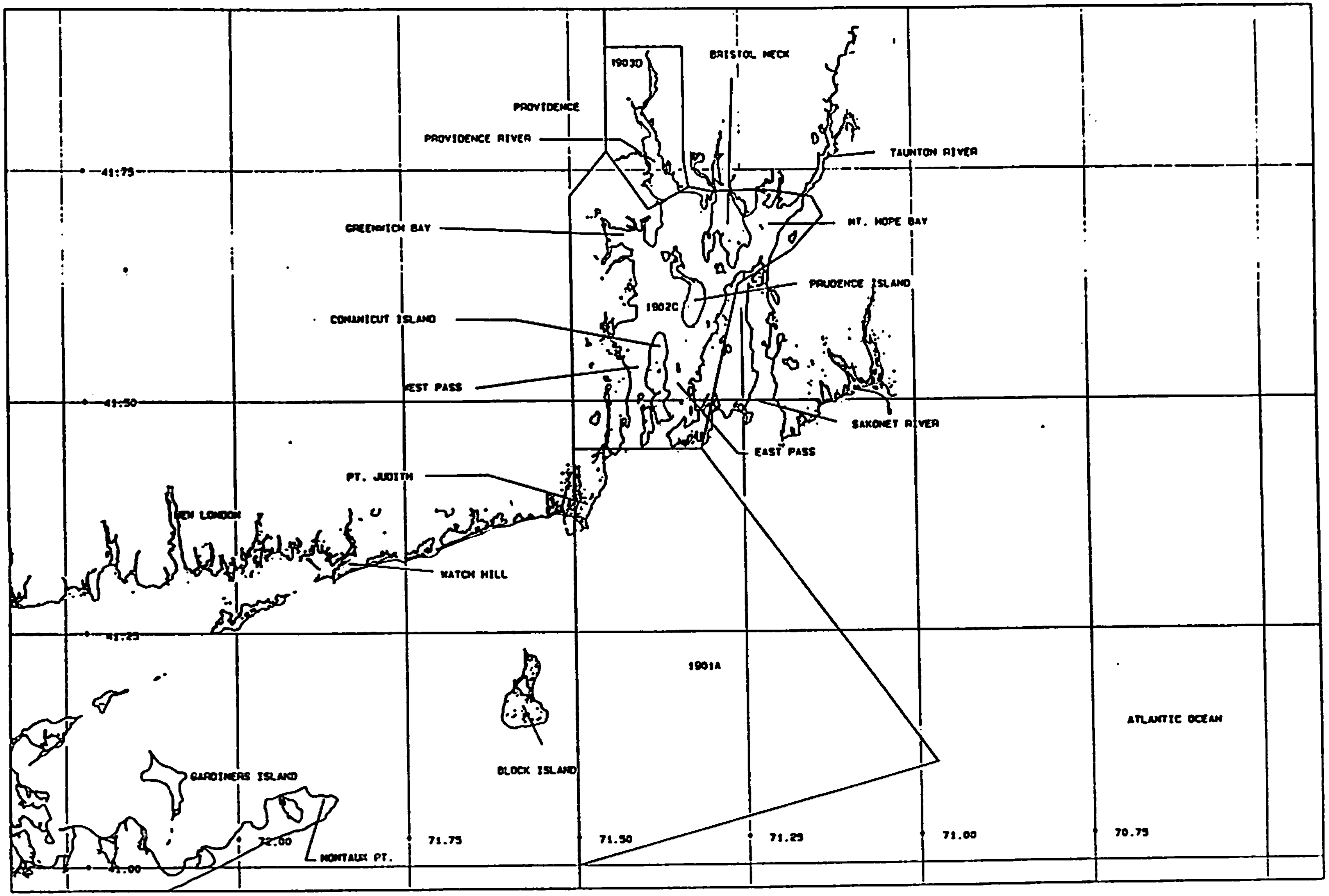

FIGURE 2-20. ZONE 19 - PROVIDENCE, RI - ZONE & SUBZONE BOUNDARIES

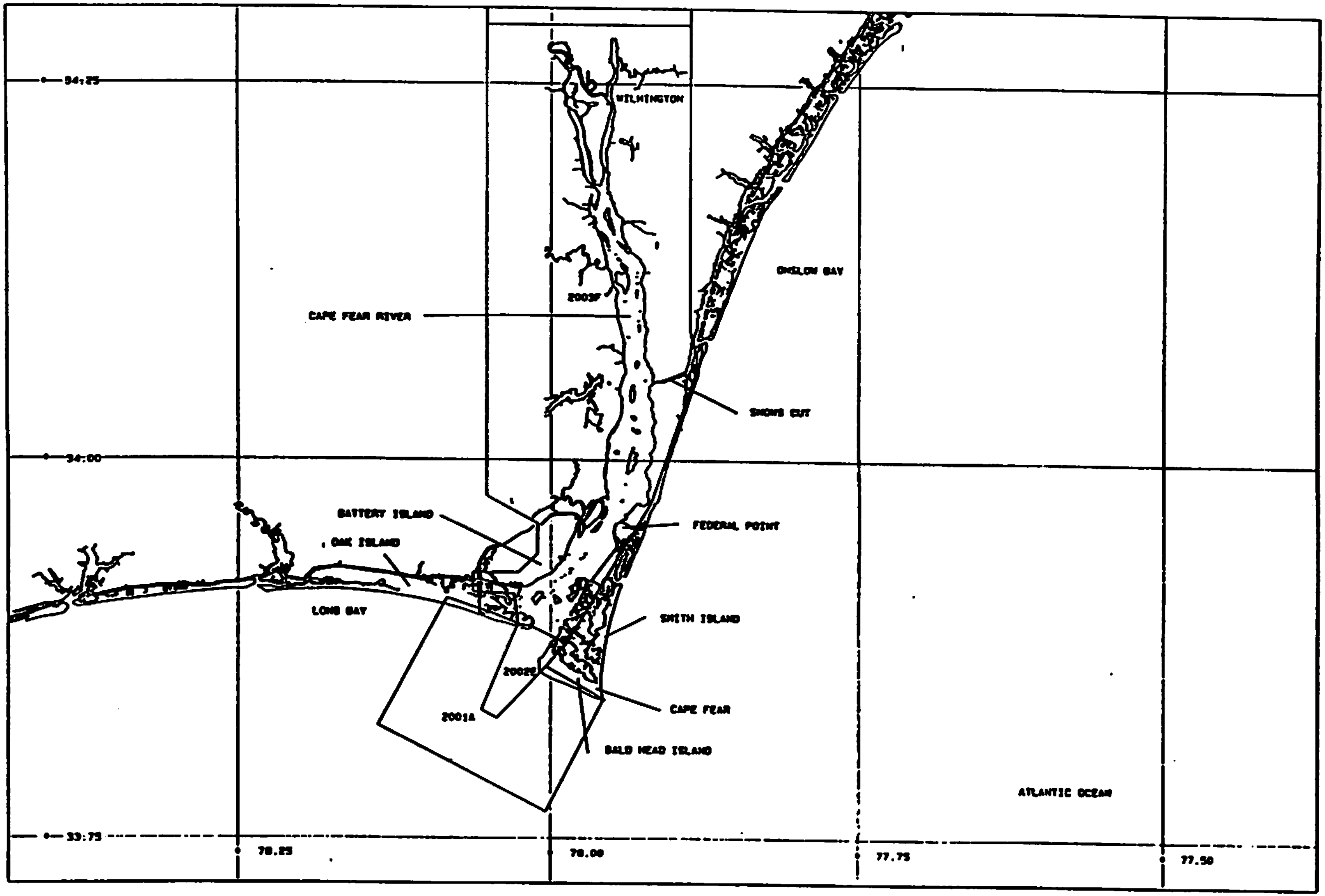

FIGURE 2-21. ZONE 20 - WILMINGTON, NC - ZONE & SUBZONE BOUNDARIES

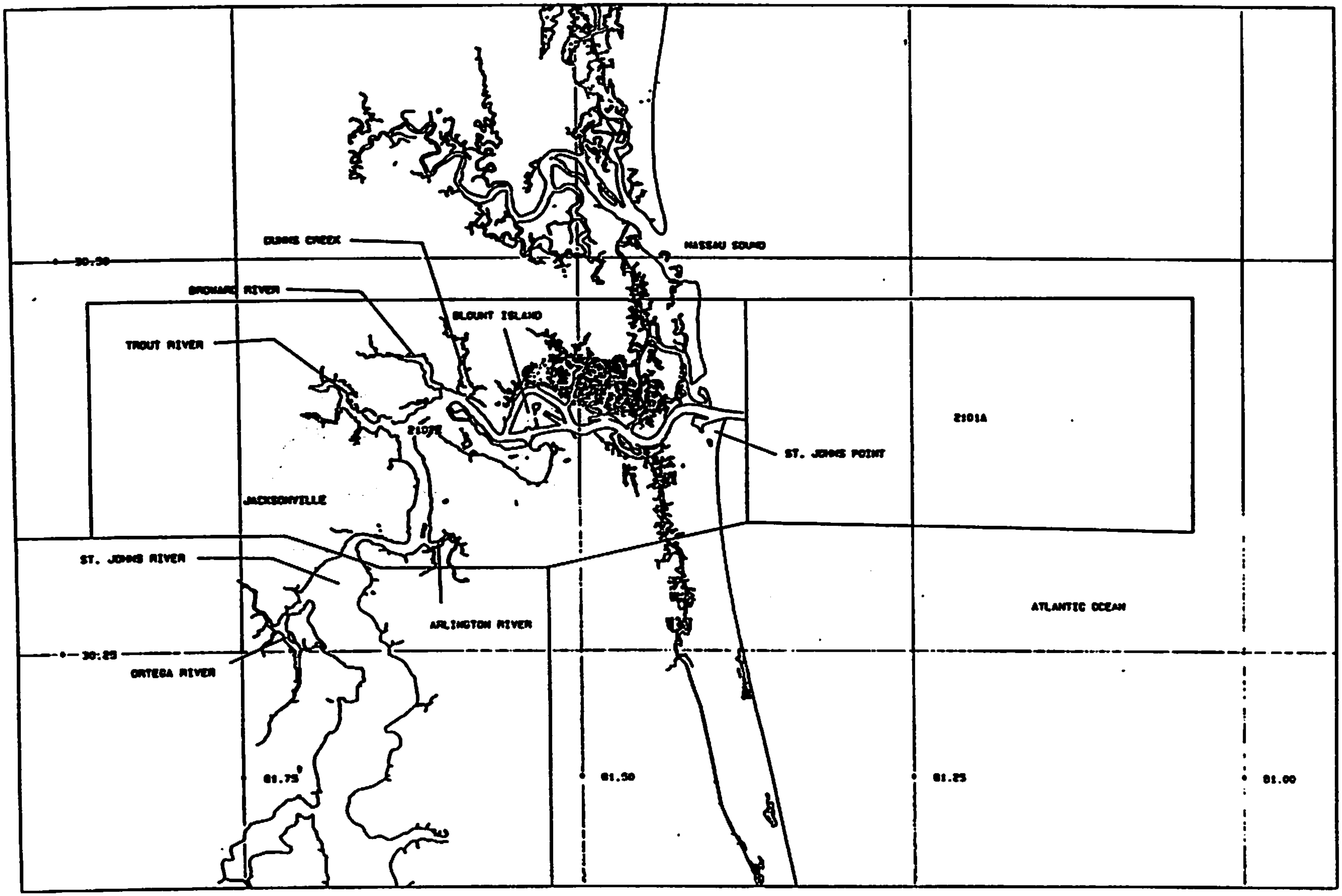

FIGURE 2-22. ZONE 21 - JACKSONVILLE, FL - ZONE & SUBZONE BOUNDARIES

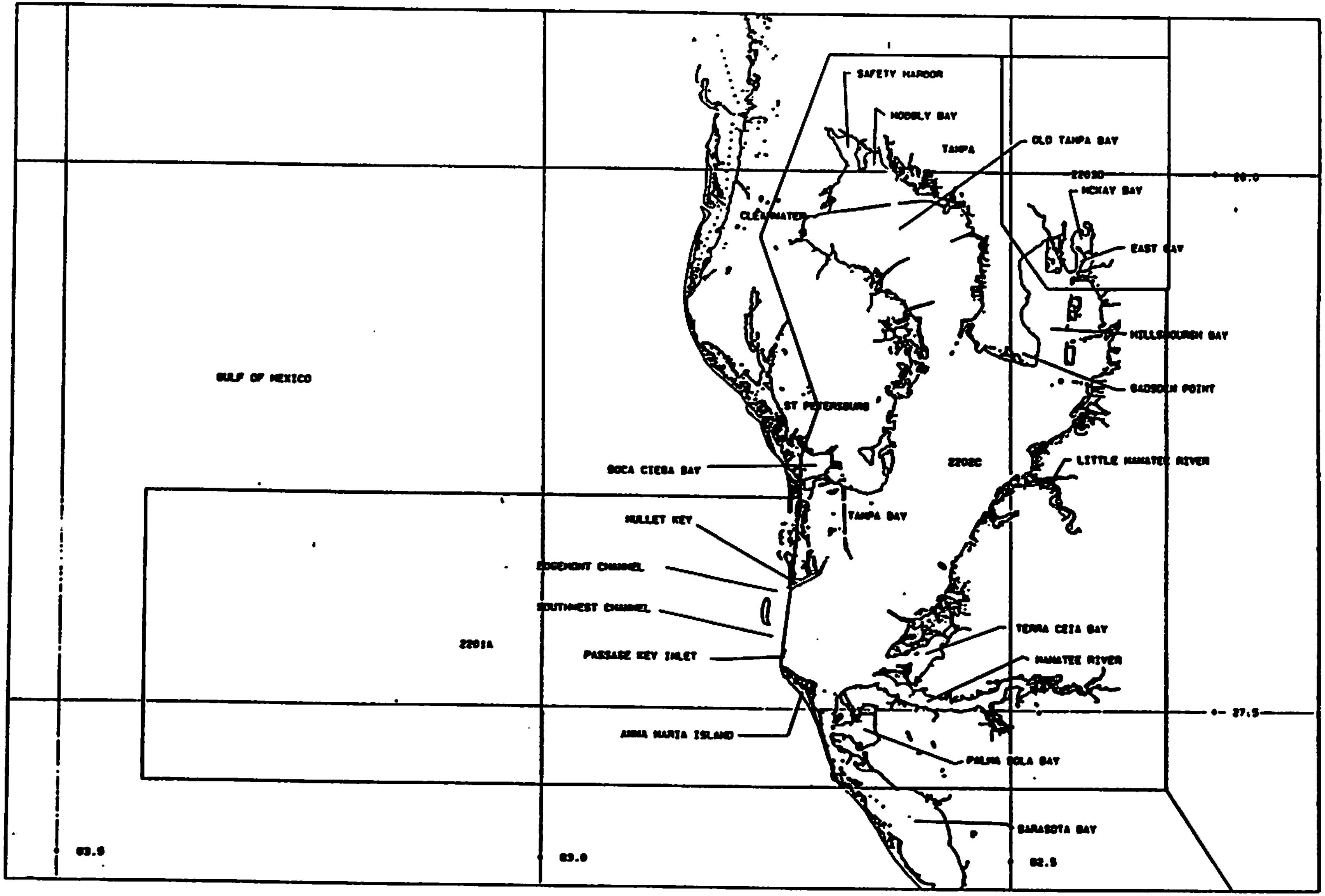

FIGURE 2-23. ZONE 22 - TAMPA, FL - ZONE & SUBZONE BOUNDARIES

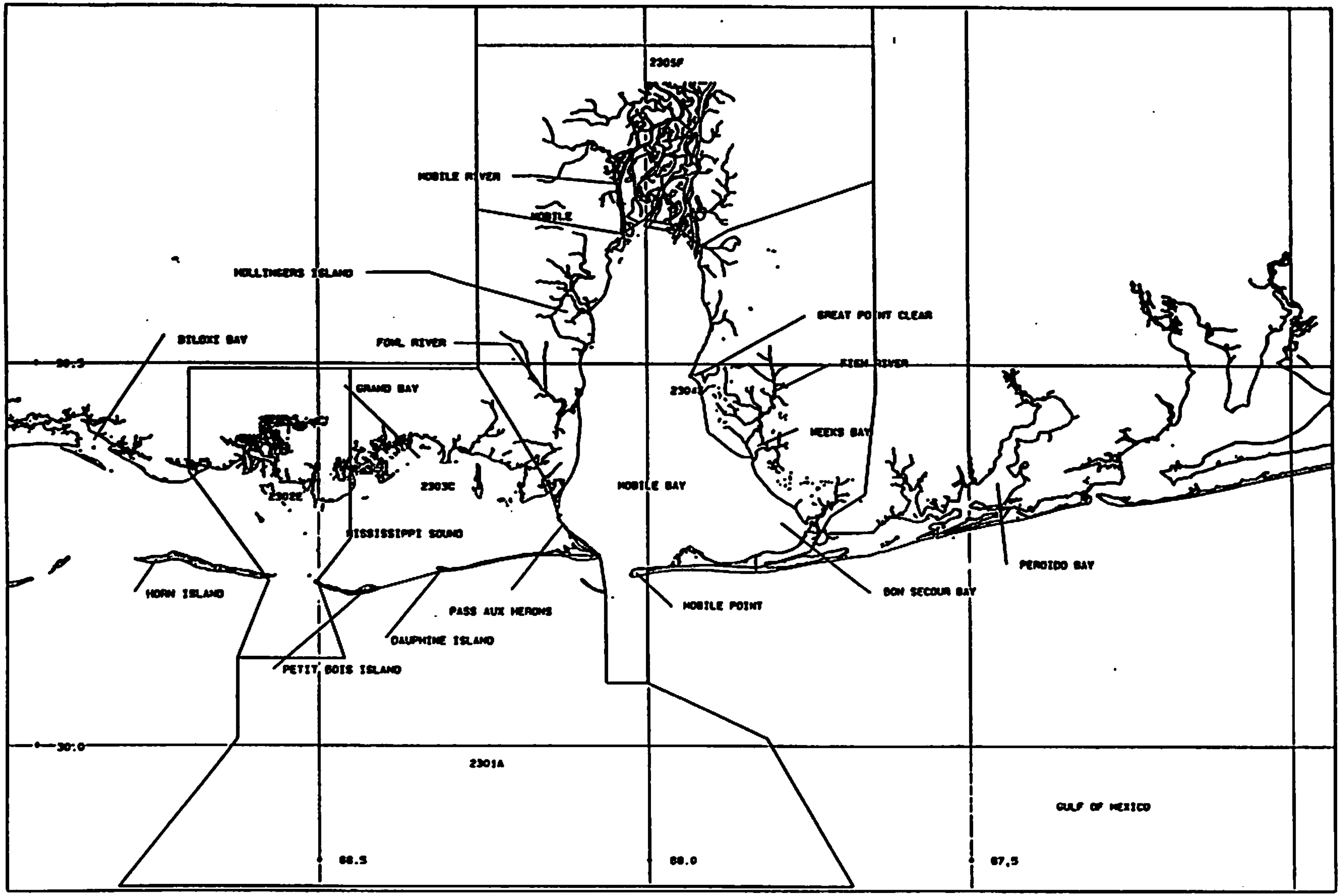

FIGURE 2-24. ZONE 23 - MOBILE, AL - ZONE & SUBZONE BOUNDARIES

3. VESSEL TRAFFIC

3.1 OVERVIEW

The study uses estimates of vessel traffic in each study zone to measure the exposure to navigational risk. The probability of a vessel casualty in a specific waterway during a particular year is a function of the vessel traffic in that waterway, as well as the physical characteristics of the waterway, the meteorological characteristics of the subzone and the fixed and moving hazards to navigation. To calculate historical vessel casualty rates and to estimate the navigational risk values for the large vessels that will be participating in VTS, historical vessel traffic flows are used. Applying navigational risks (or future casualty rates) to forecasts of these vessel traffic flows, yields estimates of future vessel casualties of specific vessel categories in each subzone.

When estimating navigational risk, the study limits the scope of vessel traffic to large (20 meters and greater) vessels moving into, out of, or through the study subzones. The study includes large cargo vessels and passenger (ferry and cruise) vessels in the categories for which vessel transits and navigational risk are estimated. Small commercial fishing vessels, recreation boating and all other vessel activity on the waterways are treated as moving navigational hazards by the large inbound and outbound vessels within the study zones. Small commercial fishing, recreational boating and all other vessel activity are estimated as a single category "OTHER LOCAL VESSELS." They are represented as traffic density factors within each study subzone. The study does not represent military vessel transits nor does it include naval vessels or Military Sea Lift Command vessel traffic.

3.1 OVERVIEW (Cont.)

The Corps Of Engineers (COE) vessel traffic statistics represent the only centralized database providing extensive coverage of the large cargo vessels moving in and out of all the study zones. However, the COE vessel transit data and commodity flow data lack specificity relative to the origins, destinations and routing of traffic within the study zones. The COE data requires considerable interpretation, verification and adjustment using supplemental sources. Data obtained by the study team directly from individual port sources supplement COE vessel transit data. Local sources provided supplemental data on passenger ferries, cruise vessels, recreation, small fishing and other local small boat activity as well as cargo vessel transits. The vessel and geographical coverage, the level of aggregation and the reporting consistency of locally obtained data varies considerably among the study zones requiring considerable judgement on the part of the analytical team. The study team, with a Coast Guard representative, visited each of the 23 study zones early in the study period. The purpose of these visits was to:

1. Brief Coast Guard District and port personnel on the status of the study and to gain local Coast Guard participation in the study effort.

2. Discuss technical issues with local maritime interests concerning local developments.

3. Gather available data on a local level.

Discussions were held with pilot associations, maritime exchanges, and port authorities in addition to fishing, ferry, environmental and recreation boating interests.

The study uses passenger ferry data obtained directly from local sources in each study zone. Cruise ship activity data were obtained through a combination of local sources and major cruise line publications. These data sources are the basis for the cargo and passenger vessel transit estimates in each study subzone for the 1979-1989 historical casualty base period, and with application of forecast growth rates, the basis for 1995-2010 VTS life cycle period estimates.

3.1 OVERVIEW (Cont.)

The study treats commercial fishing, recreation boating and all other vessel activity within the study subzone as background traffic measured as a unique density factor (i.e., vessels per square mile of waterway area) for each subzone. The basic source for estimates of the number of vessels whose home port/mooring falls within each subzone, is the state registrations of these vessels. The study does not include Coast Guard documented vessels in this category.

Tabulations of these traffic data were submitted for verification and/or comment to the Coast Guard Marine Safety Offices responsible for each of the study zones via the Coast Guard District Commanders. The study makes selected adjustments to the basic input data in response to comments and changes submitted by these officials.

3.2 COMMERCIAL CARGO VESSEL TRAFFIC

3.2.1 Defining Base Year Traffic Patterns

The study assigns the base year (1987) cargo vessel transits recorded by the COE for each port (inbound and outbound) to the vessel routes through each study subzone from the sea to the port terminal facility. Vessel traffic is segregated by vessel type and size category. Six basic vessel types are defined for the study: passenger, dry cargo, tanker, dry cargo barge, tank barge and tugs/tow boats. The aggregation of the several traffic flows along each route through the subzone constitutes the total vessel traffic within each subzone for the base year. Two types of self-propelled cargo vessels and two types of barges are defined:

- Self-Propelled Cargo Vessels

  Type

  - Dry Cargo (many fishing and other vessels are included)
  - Tanker

  Size

  - Small = less than 19-foot draft
  - Medium = 19 to 30-foot draft
  - Large = those greater than 30-foot draft

3.2.1 Defining Base Year Traffic Patterns (Cont.)

- Barge Tows (Tugs plus Barge[s])

  Type

  - Dry Cargo Barge
  - Tank Barge

  Size

  - Small = less than 19-foot draft
  - Large = 19-foot and greater draft

- Tugs and Tow Boats (Moving without Barges)

  - Small = less than 19-foot draft

Table 3-1 displays the 1987 base year vessel transits (inbound plus outbound) for each cargo vessel type in each of the study zones. The values represent the sum of all vessel transits within the study zone. This study calculates barge tows by applying the average tow factors displayed in each appendix (Volume II). The 11 study zones marked by an asterisk (*) have required adjustment to the dry cargo vessel transits as reported by the COE data to extract passenger ferry boat transits. Subsection 3.2.2. presents the COE vessel traffic data.

The notably large values for Dry Cargo Vessels remaining in some zones after extracting ferries are dominated by small-sized vessels (e.g., commercial fishing boats in Puget Sound and recreation boats in Long Island Sound). These small vessels include activity of commercial fishing boats, recreation boating, charters and other local traffic. It is not clear how much overlap exists between commercial fishing transits included in the Dry Cargo Vessels and the small commercial fishing boat registrations included in the "Other Local Vessels."

TABLE 3-1. BASE YEAR CARGO VESSEL TRANSITS

ZONE		NAME	VESSEL TYPES: DRY CARGO	TANKER	DRY CARGO BARGE TOWS	TANKER BARGE TOWS	TUG/TOW BOATS	TOTAL
1		Boston, MA	11,383	921	183	1,473	1,872	15,832
2	*	Puget Sound, WA	330,111	1,056	13,300	7,083	56,302	407,852
3		Los Angeles/Long Beach, CA	67,165	3,511	1,078	16,248	37,895	125,897
4		Santa Barbara, CA	6,902	1,313	11	172	0	8,398
5		Port Arthur, TX	8,578	4,876	3,886	17,576	12,130	47,046
6		New Orleans, LA	68,182	12,296	29,353	49,613	65,529	224,974
7	*	Houston/Galveston, TX	17,837	10,206	7,560	32,843	22,987	91,433
8	*	Chesapeake South/Hampton Roads, VA	119,021	8,881	35,353	9,790	43,571	216,615
9	*	Chesapeake North/Baltimore, MD	30,059	2,057	7,797	7,996	14,590	62,499
10		Corpus Christi, TX	3,782	2,507	1,745	8,768	5,571	22,373
11	*	New York, NY	116,469	15,358	8,306	14,159	63,503	217,795
12	*	Long Island Sound, NY/CT	293,411	2,053	24,507	4,948	7,355	332,274
13	*	Philadelphia/Delaware Bay, PA	62,406	913	1,110	8,838	9,700	82,967
14	*	San Francisco, CA	15,384	5,436	7,189	4,113	12,901	45,023
15	*	Portland, OR	16,276	433	13,990	4,574	26,594	61,867
16		Anchorage/Cook Inlet, AK	450	100	80	56	135	820
17		Portland, ME	19,690	389	19	511	519	21,128
18		Portsmouth, NH	2,756	207	12	161	111	3,247
19	*	Providence, RI	1,571	690	184	1,359	2,220	6,024
20	*	Wilmington, NC	7,146	593	3,393	2,001	2,960	16,092
21		Jacksonville, FL	8,782	440	945	2,953	757	13,877
22		Tampa, FL	6,079	966	986	1,348	911	10,290
23		Mobile, AL	7,977	1,986	6,701	5,000	7,511	29,175
		Totals	1,221,417	77,188	167,686	201,583	395,624	1,667,874

* C.O.E "Passenger/Dry Cargo" data adjusted to extract ferry traffic. (see section 3.2.2)

Notes:

(1) Sum of arrivals and departures to/from all terminals within the study zone.

(2) Barge tows derived by application of a factor representing the average number of barges per tow in each C.O.E. Waterway per appendices table 4.

(3) Dry Cargo vessel transits are predominantly small vessels such as commercial fishing, recreation, charters, and other local traffic.

07/11/91

3.2.2 Adjustment of COE Commercial Cargo Vessel Traffic Data

The COE vessel traffic data is the basic source for vessel transit estimates in each study zone in the base year. The study adjusts the COE data to obtain a more accurate estimate of the Dry Cargo vessel transits. The adjustment involved the extraction of the ferry transits included by the COE in 11 of the study zones. Table 3-1 is the result of extracting ferry transits from the COE vessel category "Passenger/Dry Cargo" to produce a more accurate estimate of "Dry Cargo" vessel transits. The COE indicated that 11 of the study zones reported ferry trips as well as dry cargo in this category. The study extracts estimated ferry trips from study zones marked with an asterisk (*) in Table 3-1. Other zones are not adjusted.

3.2.3 Assignment to Study Subzones

The routes of the cargo vessels are plotted through the study zone waterways between the COE waterway terminal facility and the sea on National Oceanographic and Atmospheric Administration (NOAA) charts using the ship channel, traffic lane and navigational aids. These routes are loaded into the PC based GIS to support subsequent analyses. Vessel course changes are defined on each segment of the transit through the study zone, inbound and outbound. Figure 3-1 is a map of one of the study zones illustrating the approximation of the vessel route through the subzones. Each route segment is identified by unique node numbers at each end of the segment. Each segment node is located through latitude and longitude coordinates and is associated with the appropriate subzone. All cargo vessel traffic is assigned to the vessel routes within the study zone and to specific subzones through which they transit. Vessel transits and vessel-miles along the routes are, therefore, available as navigational risk exposure measures. Each appendix in Volume II displays the 1987 base year transits of each vessel category in each numbered subzone.

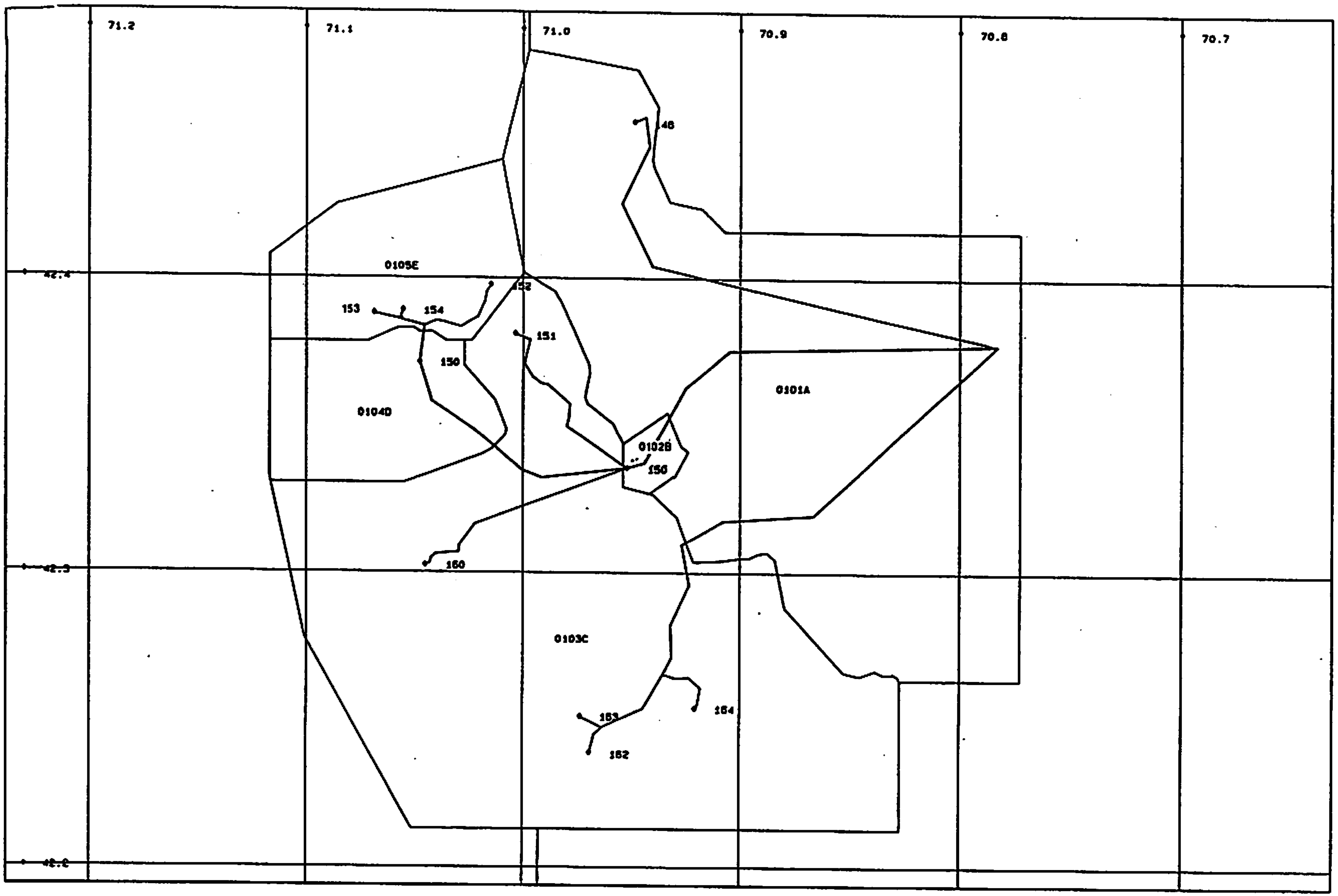

FIGURE 3-1. STUDY ZONE, SUBZONE AND VESSEL ROUTES

3.3 COMMERCIAL PASSENGER VESSEL TRAFFIC

3.3.1 Estimating Ferry and Cruise Ship Traffic Volume

To estimate the annual ferry and cruise ship transits within each subzone, the study uses published ferry schedules and then assigns each to a subzone through which the ferry routes and cruise ships pass. Individual ferry routes are not plotted but the route-miles that the ferries generate are estimated. Cruise ships (medium draft vessel) are assigned to the vessel route defined for deep draft vessels, from the nearest COE Waterway terminal to the sea. Therefore, ferry boat and cruise ship vessel-transits and vessel-miles are available as navigational risk exposure measures. Table 3-2 displays the base year vessel transits for each passenger vessel category in each of the study zones. The values are the sum of all vessel transits within the study zone.

TABLE 3-2. BASE YEAR PASSENGER VESSEL TRANSITS

ZONE	NAME	FERRY TRIPS	CRUISE SHIP TRIPS
1	Boston, MA	41,416	26
2	Puget Sound, WA	264,344	110
3	Los Angeles/Long Beach, CA	12,900	770
4	Santa Barbara, CA	0	0
5	Port Arthur, TX	75,416	0
6	New Orleans, LA	212,745	52
7	Houston/Galveston, TX	68,811	0
8	Chesapeake South/Hampton Roads, VA	26,834	18
9	Chesapeake North/Baltimore, MD	0	20
10	Corpus Christi, TX	138,866	0
11	New York, NY	349,388	132
12	Long Island Sound, NY/CT	10,829	0
13	Philadelphia/Delaware Bay, PA	11,760	38
14	San Francisco, CA	38,157	60
15	Portland, OR	13,140	6
16	Anchorage/Cook Inlet, AK	220	16
17	Portland, ME	31,996	32
18	Portsmouth, NH	650	0
19	Providence, RI	3,168	52
20	Wilmington, NC	14,120	4
21	Jacksonville, FL	23,360	0
22	Tampa, FL	0	148
23	Mobile, AL	5,400	0

NOTE: Sum of all one way transits within the study zone. 06/18/91

3.3.2 Assignment to Study Subzones

Local area maps identify the location of ferry and cruise ship terminals. The study manually assigns passenger vessel traffic to study subzones by referencing the GIS plot of the study subzone boundaries. Each appendix in Volume II displays the base year transits of each passenger vessel category in each numbered subzone.

3.4 OTHER LOCAL VESSEL TRAFFIC

Local small vessel activity within the major traffic lanes may contribute to the overall risk facing VTS vessels navigating each study subzone. Comprehensive local surveys in each study zone would be required to fully and accurately represent the current vessel transit activity within each study subzone along the following lines:

1. Commercial fishing fleets, by type, home port, and their areas of operations.

2. Recreation boating fleets home ported/moored/docked in the study subzone and their operating ranges and frequencies.

3. Other local vessels (i.e., charters of all types, local cruises, and local barges) operating in each study subzone.

The study estimates the volume of Other Local Vessel activity within each study subzone indirectly via a surrogate measure. The average vessel density (i.e., number of vessels per square mile of water) of commercial fishing boats, pleasure boats and other vessels registered by the state in each study zone serves as a surrogate measure. If consistent across all 23 study zones, this density factor is adequate for the purposes of developing comparative values for these moving navigational hazards confronting VTS vessels.

Telephone requests to each of the 16 states covering the 23 study zones yield statistics on the numbers of vessels registered by the state and recorded as home ported or moored/docked in each county, parish or city. Many states are unable to disaggregate the registered fleets into commercial fishing, recreation boating and other vessel types as requested. Therefore, to be consistent throughout, a single category of "Other Local Vessels" represents this type of activity in each study subzone zone.

3.4.1 Assignment to Study Subzones

The county, parish, or town associated with each registered vessel provides the identity of the home port/mooring/docking location. The registered vessels in each county, parish and town are assigned to that subzone having shoreline within the subzone. The study divides registered vessels among the subzones when two or more of the subzones abut. The current number of Other Local Vessels operating in each study zone is displayed in Table 3-3. Each appendix in Volume II displays the current number of Other Local Vessels by subzone.

TABLE 3-3. OTHER LOCAL VESSELS

ZONE	NAME	NUMBER VESSELS	AVERAGE DENSITY VES./SQ. MI.
1	Boston, MA	6,421	47.14
2	Puget Sound, WA	142,910	20.03
3	Los Angeles/Long Beach, CA	184,791	358.33
4	Santa Barbara, CA	30,120	12.30
5	Port Arthur, TX	45,551	28.74
6	New Orleans, LA	79,502	29.24
7	Houston/Galveston, TX	91,787	95.31
8	Chesapeake South/Hampton Roads, VA	37,908	11.81
9	Chesapeake North/Baltimore, MD	96,394	54.86
10	Corpus Christi, TX	13,964	19.84
11	New York, NY	63,679	69.89
12	Long Island Sound, NY/CT	180,925	89.06
13	Philadelphia/Delaware Bay, PA	109,044	31.91
14	San Francisco, CA	172,882	117.25
15	Portland, OR	37,401	71.51
16	Anchorage/Cook Inlet, AK	3,752	0.47
17	Portland, ME	36,054	326.28
18	Portsmouth, NH	16,399	220.42
19	Providence, RI	22,480	34.91
20	Wilmington, NC	14,837	167.84
21	Jacksonville, FL	30,382	123.50
22	Tampa, FL	119,750	106.59
23	Mobile, AL	32,705	16.08

Note: State registered vessels estimated to be operated within the study zone. (1989/90) 07/21/91

3.5 BASE YEAR TRAFFIC AND FORECASTS

The 1987, base year, vessel traffic defines the vessel traffic patterns within each study zone and subzone. Comparable vessel transits for the ten-year base period of 1979 through 1988 (required for calculations of historical casualty rates) are constructed from aggregate historical data. Estimates of cargo vessel traffic in the other years of the base period are developed by multiplying the 1987 vessel transits by annual cargo tonnage growth factors for each study zone, adjusting for changes in average capacity of cargo vessels over the period.[1] The study develops passenger vessel transits for the ten-year base period by applying annual growth rates to the 1987 vessel transits in each study zone.

The study constructs forecast cargo vessel transits for the period 1995 through 2010 by applying commodity tonnage growth rates to each vessel type, adjusting for projected changes in average capacity of vessels.[2] Coastal population growth trends (prepared by the Coast Guard Strategic Planning Staff, Memorandum G-CCS-3, November 1, 1990, Coastal Population Change 1990-2010) are the basis for passenger vessel traffic forecasts. The study assumes that the vessel route patterns within the study zones remain essentially unchanged during the entire period of 1979 through 2010.

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[1] JFA Report, "Commodity and Vessel Traffic Forecasts," by Jack Faucett Associates, March 1991.

[2] See note 1 above.

3.5.1 Assigning Commodities to Vessel Categories

The distribution of commodities among the several vessel types and sizes is a key element in the forecast of vessel traffic.[3] Forecasts of commodity production, consumption and transport by vessel are the basis of forecasts of cargo vessel traffic in the study zones. The link between the macro-economic commodity tonnage forecasts and the study zone specific vessel transits is the distribution of commodities among vessel types and sizes in each study subzone. The study treats the base year distribution as constant throughout the 1979-2010 period. Each appendix in Volume II displays the complete matrix of base year distribution of commodities, by vessel type, and study subzone. The base year commodity distribution among vessel types are developed by combining the COE commodity flows (the study zone terminus of the flows identified by COE waterway code) with the COE vessel trips (the study zone terminus also identified by the same codes). Table 3-4 displays the base year commodities moved into and out of one typical subzone by each vessel type.

[3] JFA Report, "Commodity and Vessel Traffic Forecasts," by Jack Faucett Associates, March 1991.

TABLE 3-4. MAJOR COMMODITY MOVEMENTS BY VESSEL TYPE

(TONS)

STUDY ZONE: 02 PUGET SOUND, WA

SUBZONE: 0204D Anacortes Area and Islands

COMMODITY CODE	COMMODITY NAME	DRY CARGO	TANKER	DRY CARGO BARGE TOW	TANKER BARGE TOW	TOTAL
1	FARM PRODUCTS	55,327	0	0	0	55,327
3	FISHERIES PRODUCTS	14,031	0	0	0	14,031
4	MINING PRODUCTS, NEC	516,377	0	2,910	0	519,287
5	PROC. FOODS & MFTRS, NEC	1,555,947	0	475,920	0	2,031,867
6	WASTE OF MANUFACTURING	5,404	0	223,722	0	229,126
1311	CRUDE PETROLEUM	0	9,042,429	0	0	9,042,429
2810	SODIUM HYDROXIDE (CAUSTI	110,487	0	0	0	110,487
2813	ALCOHOLS	0	2,020	0	0	2,020
2817	BENZENE AND TOLUENE	0	4,323	0	0	4,323
2818	SULPHURIC ACID	0	8,843	0	0	8,843
2911	GASOLINE, INCL NATURAL	0	864,000	0	45,308	909,308
2912	JET FUEL	0	242,622	0	26,219	268,841
2914	DISTILLATE FUEL OIL	0	524,858	0	79,131	603,989
2915	RESIDUAL FUEL OIL	0	1,028,082	0	212,625	1,240,707
2916	LUBRIC OILS-GREASES	0	3,150	0	144	3,294
2917	NAPHTHA, PETRLM SOLVENTS	0	70,191	0	0	70,191
2921	LIQUI PETR-COAL-NATR GAS	13,752	0	0	186	13,938
	TOTALS	2,271,325	11,790,518	702,552	363,613	15,128,008

07/16/91

3.5.2 Macro Economic Forecasts to 2010

Cargo vessel traffic growth is a function of commodity tonnage growth, which in turn is a function of the national industrial activity. The study develops forecasts of commodity tonnage for 1995, 2000, 2005 and 2010 from base year tonnages and industrial activity forecasts for the 1986-2000 time period published by the Bureau of Labor Statistics (BLS) in 1988. The BLS industrial activity forecast ended with the year 2000, therefore the study calculates average annual growth rates for the period 1986-2000 from the BLS forecasts and projects these rates to the year 2010. The BLS "Moderate-Growth" forecasts of real domestic output, exports and imports by industrial sector are used.

The study uses the export and import growth rates for export and import commodity transport by vessel respectively, and uses the production growth rates for all other commodity transport by vessel. The BLS industrial sectors are mapped to the COE commodity codes and derives the national average annual growth rates for each COE commodity. The national average growth rates for each COE commodity are applied to the base year commodity movement in each study zone. Exceptions are made for three types of cargo movements - Liquified Natural Gas, Coastwise Petroleum Shipments and Crude Oil Imports. Separate forecasts for each of these are developed for specific study subzones where appropriate.

The study estimates national total import tons of LNG for the forecast years and allocates them to the three LNG terminals projected to be operating in the forecast time period (i.e., Everett, MA in Subzone 105E, Lake Charles, TX in Subzone 503E and Cove Point, MD in Subzone 901C).

Two categories of coastwise petroleum shipments are amenable to development of specific forecasts by industrial sector and region of the country (i.e., shipments of Alaskan crude to West Coast refineries, and shipments of petroleum products from refineries in Texas and Louisiana to other Gulf ports and East Coast ports).

3.5.2 Macro Economic Forecasts to 2010 (Cont.)

Forecasts of crude oil imports entering the three Texas study zones (i.e., Port Arthur, Houston/Galveston and Corpus Christi) for the effect of the planned TEXPORT offshore petroleum terminal. This terminal will be located in international waters 27 miles from shore in the vicinity of Galveston outside the study zone boundaries. Operation of TEXPORT will result in substantial reduction in crude oil received at existing Texas ports. This study assumes full operation of such an offshore terminal in the 2000-2010 time period, effectively reducing by 50% the projected tonnage to be received at the Houston/Galveston study zone and by 10% each the projected tonnage received at the Port Arthur study zone and the Corpus Christi study zone.

3.5.3 Vessel Traffic Forecasts by Study Subzone

The study develops forecasts of cargo vessel traffic by vessel type and size and by COE Waterway (within each subzone) for 1995, 2000, 2005 and 2010 from the commodity tonnage forecasts, the base year average tonnage load factors and adjustments for trends in the average size of vessel. Forecasts of passenger vessel traffic are developed by vessel size and subzone by applying annual growth rates to the base year values. Coastal population growth trends (prepared by the Coast Guard Strategic Planning Staff, Memorandum G-CCS-3, November 1, 1990, Coastal Population Change 1990-2010) are the basis for annual growth rates applied to the base year passenger vessel transits.

Table 3-5 displays forecast vessel traffic in each study zone for the final year of the forecast period 2010. The values are the sum of all vessel transits within the study zone. Each appendix in Volume II displays the forecast vessel transits by vessel type in each subzone for 1995, 2000, 2005 and 2010.

The "Other Local Vessels" densities are, for the purposes of this study, assumed constant from the base year though the forecast period.

TABLE 3-5. STUDY ZONE VESSEL TRANSITS - 2010

ZONE	NAME	VESSEL TYPES						TOTAL FOR ZONE
		PASSENGER	DRY CARGO	TANKER	DRY CARGO BARGE TOW	TANKER BARGE TOW	TUG/TOW BOATS	
1	Boston, MA	51,770	21,880	1,076	5,150	1,884	3,165	84,925
2	Puget Sound, WA	317,640	538,503	1,568	20,859	9,745	89,261	977,576
3	Los Angeles/Long Beach, CA	21,707	120,331	4,618	1,434	22,265	79,535	249,890
4	Santa Barbara, CA	2,210	13,215	1,696	15	237	2	17,375
5	Port Arthur, TX	90,273	16,523	6,943	5,891	19,522	20,734	159,885
6	New Orleans, LA	257,296	126,595	16,441	42,772	55,035	99,665	597,804
7	Houston/Galveston, TX	83,038	25,242	13,081	11,113	39,080	19,832	191,387
8	Chesapeake South/Hampton Roads, VA	31,772	178,099	14,139	54,578	13,411	81,390	373,388
9	Chesapeake North/Baltimore, MD	2,666	46,681	2,838	11,565	10,968	31,106	105,824
10	Corpus Christi, TX	175,316	5,165	3,807	2,694	10,488	3,806	201,275
11	New York, NY	386,664	270,862	19,454	12,413	18,637	115,630	823,660
12	Long Island Sound, NY/CT	21,406	337,820	2,657	27,634	6,212	6,527	402,256
13	Philadelphia/Delaware Bay, PA	14,613	82,195	1,760	1,707	12,357	20,366	132,998
14	San Francisco, CA	50,092	27,819	6,776	10,866	4,940	27,938	128,431
15	Portland, OR	16,860	30,074	598	21,066	6,277	42,670	117,545
16	Anchorage/Cook Inlet, AK	280	557	126	60	64	95	1,182
17	Portland, ME	36,683	37,115	580	18	827	1,041	76,264
18	Portsmouth, NH	2,108	4,917	259	10	205	179	7,678
19	Providence, RI	13,835	2,673	865	217	1,723	3,336	22,649
20	Wilmington, NC	18,812	12,145	817	5,326	2,833	1,093	41,024
21	Jacksonville, FL	30,303	15,103	587	1,418	4,087	793	52,291
22	Tampa, FL	3,848	8,918	1,348	1,550	1,876	1,182	18,722
23	Mobile, AL	6,456	11,977	3,518	10,366	6,801	10,794	49,913

NOTE: (1) Sum of arrivals and departures to/from all terminals within the study zone.
(2) Barges per tow may vary by subzone.

07/10/91

4. ANALYSIS OF VESSEL CASUALTIES

4.1 OVERVIEW

Understanding the causes, circumstances, and consequences of vessel casualties is essential in order to assess the benefits that may result from a Candidate VTS Design in each study zone. For the 23 study zones, the historical record of vessel casualties and their consequences are examined for the period 1980-1989[1]. This encompasses a review of casualty studies, analysis of official Coast Guard and National Transportation Safety Board written reports and investigations, and discussions with knowledgeable individuals in the U.S. Coast Guard Marine Safety Offices (MSOs) and local areas.

The final database includes 2,337 vessel casualties, representing only those considered to be addressable by a state of the art VTS. The study assigns conditional probabilities of occurrence to distributions of consequences associated with each casualty type and vessel type and size from a 2,210 casualty subset (i.e., excluding 127 barge breakaway and weather caused vessel casualties). Refer to Section 5 for a discussion of consequence probabilities.

To put the final numbers in perspective: the original database contained 56,382 records (vessels) representing all U.S. casualties investigated by Coast Guard MSOs. Restricting the data to the 23 study zones left 36,000 records (or approximately 64%). Next, the study applies latitude/longitude boundaries along with a set of selection criteria to include only potential VTS addressable casualties. This step narrowed the data down to 12,500

[1] The study also includes partial data for 1979 and 1990. A casualty case may consist of one or more vessels. For purposes of analysis, the term "casualty" signifies a single vessel and not the entire incident. For example, the final data base contains 2,337 vessels, but only 1,084 cases. Unless otherwise specified, this report will use the same method of reporting.

4.1 OVERVIEW (Cont.)

casualties, constituting about 6500 total cases. Each such case was manually reviewed in detail and then grouped as to its VTS addressability (see Section 4.2). The final database was thus reduced to 2,337 vessel casualties, or about 6.5% of the original total for the 23 study zones.

4.1.1 Sources of Data

- Vessel Casualties (Time Frame: 1980-1989)

The Casualty Maintenance (CASMAIN) Data Base is a central source of vessel casualty data maintained by the Coast Guard.[2] It contains over 70 fields of information such as administrative detail, vessel characteristics, location, causes, weather conditions, dollar damages, and a broad range of other factors involved in the casualty. Although it is the best single source of information available, the CASMAIN Data Base requires many adjustments before proceeding with analysis.

It is important to recognize the distinction between a casualty record (i.e., individual vessel) and a casualty case in CASMAIN terminology. Several vessels may be involved or damaged in a single case. Particularly in cases involving barges, analysis based on vessel data can overstate the casualty activity in a given study zone; many tows and their barges may be involved in the same casualty event.

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[2] For CASMAIN reporting purposes, a vessel casualty must meet one of the following criteria: accidental grounding; intentional grounding that meets any other reporting criteria or that creates a hazard to navigation, the environment or safety of the vessel; loss of main propulsion or primary steering, or associated component or control system, the loss of which causes reduction of maneuvering capabilities of the vessel; an occurrence materially and adversely affecting the vessel's seaworthiness or fitness for service or route; injury causing a person to remain incapacitated for a period in excess of 72 hours, or; an occurrence not meeting any of the above criteria, but resulting in damage to property in excess of $25,000. (In 1981, the threshold for property damage was raised from $1,500 to $25,000.)

4.1.1 Sources of Data (Cont.)

Where there is a 'major' marine casualty, the Coast Guard also publishes supplemental reports which detail the findings from the Marine Board of Investigation. Thresholds for damage to property are higher than CASMAIN ($75,000); other criteria are also higher.[3]

- Personnel Casualties (Time Frame: 1980-1989)

The Personnel Casualties (PCAS) data base is linked to CASMAIN, and provides more detailed information regarding deaths and injuries associated with a vessel casualty. It includes, among other items, the nature and cause of the accident and injury, the part of body affected, and whether a fatality resulted.

- Marine Pollution Retrieval System (Time Frame: 1986 - 1988)

The Coast Guard maintains the Marine Pollution Retrieval System (MPRS) and a database of pollution incidents, known as the pollution segment of the Marine Safety Information System (MSIS). It contains spill activity from both vessel and non-vessel sources. Pollution Incident Reports are required for all incidents reported to the Coast Guard, as well as for incidents which are reported to the EPA and occur in waters under Coast Guard jurisdiction. There are several record types in the pollution database, containing such information as location, spill size, spill potential, vessel type, contributing cause, response to the incident, violations, and type of substance. The type of substances conform to the CHRIS codes (Chemical Hazards Response Information System).

The study examines a sample of data for the period 1986-1988 for pollution incidents resulting from vessel casualties. In keeping with procedures for VTS addressability used in CASMAIN, the study chooses a set of selection criteria that correspond closely with those used for vessel casualties.

Many differences exist in the manner in which the Coast Guard collects data on casualty and pollution incidents and the terminologies used. Casualties and pollution are investigated by different parts of the Coast Guard, thus only the largest spills in congested waters are typically reported in CASMAIN. Conversely, spills involving smaller vessels in less congested waters appear understated.

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[3] The Coast Guard Marine Board coordinates its investigation with the National Transportation Safety Board, although each releases its own report on the casualty.

4.1.1 Sources of Data (Cont.)

Although it is possible to derive surrogate estimates of pollution incidents from CASMAIN alone, the surrogate appears to understate the spills. To correct for this, the study uses a sample of MPRS data to adjust the surrogate estimates to a more realistic level. See Subsection 5.5.

- National Transportation Safety Board

  The National Transportation Safety Board (NTSB) issues marine accident reports on significant marine casualties. Such reports were especially useful in situations when a casualty was not found in the CASMAIN database but otherwise conformed to the selection criteria. The reports also provide substantial narrative information on the circumstances surrounding the casualty, such as hydrographic conditions and radio communications. Recommendations are often made concerning what effect a VTS may have had on the casualty.

- Confirmation With Coast Guard Offices in Study Zones

  Following the review and coding of casualty files, a concurrence check was made with each Marine Safety Office represented in the study zones. All casualties selected for that zone were sent to the MSO with the request that any omissions or inclusions that were not listed be identified. The feedback yielded valuable additional information on such casualties as well as on port characteristics and their potential relationship to a VTS.

4.1.2 Method of Analysis

The study employs a sequential screening process to determine the number of VTS addressable casualties that fall within the individual study zones. The primary factors governing the inclusion of each casualty are: location, nature, vessel types, causes, and file narrative information.

4.1.2 Method of Analysis (Cont.)

- Location

  The screening for geographic inclusion involves correlating the latitude and longitude coordinates with those contained in a software program designed to visually plot such data on a computer generated coastal map. Some cases are found to have only river milepost information available. Thus, the study converts river mileposts to latitude and longitude coordinates wherever possible in order to assign records to study zones and subzones. Other casualties have neither coordinates or milepost locators, and these require further research in order to give a reasonable proxy for their geographic position.

- VTS Addressability

  Of all the principles underlying the selection process, foremost is the concept that "only casualties addressable by VTS can be used, or marine risk and ultimately VTS benefits will be over-estimated."[4] Consistent application of this concept results in a lower than desired sample size in an analysis such as this one. The quality of the resultant database is, however, markedly improved and more reflective of actual, addressable casualty conditions. Subsection 4.2 discusses the concept of VTS addressability and how it is used in the analysis.

- Casualty Types

  A VTS cannot address all types of casualties that occur. Fires, explosions, docking errors, and equipment failures are well beyond the capabilities of a VTS. Dynamic casualties, however, such as collisions, groundings, and rammings are potentially addressable incidents. Also, certain types of weather related casualties and barge breakaways are addressable under some conditions.

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[4] Canada, Bureau of Management Consulting, Risk Assessment and VTS Needs, A Study Approach and Activity Plan (October 1989). p. 23.

4.1.2 Method of Analysis (Cont.)

- Vessel Types

  The study includes all vessel types greater than 20-meters[5] except for drilling units and offshore platforms. Because of their growing importance in such congested port areas as New York, San Francisco, and Seattle, the study also includes passenger ferries (regardless of length).

  Not every vessel involved in a given case passed the initial selection criteria. Such vessels are part of the VTS addressable case, however, and the potentially addressable impact of their involvement necessitates their inclusion in the final database in order to perform a complete analyses of a casualty's consequences.

- Causes of Casualties

  Another selection criterion is the primary cause of the casualty. The initial review procedure includes all casualties caused by personnel error, environmental, management or regulatory factors. The functions of a VTS are numerous, and may reasonably be expected in many situations to address deficiencies caused by such factors.

- Review of Casualty Files

  Until this point in the screening process, casualty selection was accomplished mainly on a computer. A sample of cases selected, however, indicated the need for a more detailed review of the circumstances surrounding each case. Under scrutiny, it is apparent that many casualties that seem to be addressable, in fact are not. From the results of the initial criteria, a case-by-case review and coding process was conducted at Coast Guard headquarters. A total of 6,500 actual cases were reviewed in this manner. The file contents of each casualty selected through the initial criteria were grouped for VTS addressability, and comments pertinent to the case were entered on a printout sheet. These comments provided additional information on the case (e.g., oil spills) not found in CASMAIN.

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[5] The 20-meters threshold is used to conform to a Coast Guard regulation governing mandatory participation of vessels in a VTS system which was proposed at the beginning of this study. In the latter stages of the study when the data had already been taken, the Coast Guard made the decision to remain with 300-gross tons as the mandatory participation criteria.

4.2 VTS ADDRESSABILITY

4.2.1 Assumptions Regarding VTS Level and Effectiveness

When the reviewers conducted their case-by-case analysis and grouping of CASMAIN files, certain implicit assumptions were made regarding the type of VTS that would be in existence. For the purpose of inferring VTS addressability during the review, it was assumed the event was potentially avoidable if a state of the art VTS had been operational at the time of casualty (not the VTS that actually existed or did not exist at the time).[6]

A critical review question was: could such a VTS system have addressed the casualty that occurred, either indirectly or directly, and if directly, then what would have been its likely effectiveness in addressing that casualty?

As stated earlier, it was assumed that all vessels 20-meters in length or greater would have been required to participate in the VTS system.

- VTS Addressability Grouping Methodology

Casualties were reviewed and grouped from I through IV with a definition assigned to each group as follows:

I. Case was in study zone, but was not addressable (preventable) by VTS.

II. Indirectly addressable by VTS, but resulting in sufficient risk to navigation such that a VTS advisory may have prevented subsequent risk or casualties to other vessels in the affected waterway.

III. Directly addressable with a presumed lower range of VTS effectiveness. An operating VTS may have provided advisory information to sufficient parties or vessels to have prevented the casualty from occurring.

IV. Directly addressable with a presumed higher degree of VTS effectiveness. An operating VTS may have provided advisory information to sufficient parties or vessels to have prevented the casualty from occurring.

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[6] The postulated VTS was to include a combination of independent surveillance, automatic dependent surveillance, computer tracking, voice radio, and meteorological sensors (refer to Chapter 7 for details).

4.2.2 The Concept of VTS Addressability

Numerous casualties occur within the harbors and ports of the U.S., but only a portion are VTS addressable. As noted earlier, the concept of VTS Addressability is a basic premise of the U.S. Coast Guard Port Needs Study as it was in the study performed for Canadian waters by the Bureau of Management Consulting (BMC).

Common causes of VTS addressable casualties include human error, restrictive hydrographic conditions, adverse environmental or weather conditions, and insufficient regulatory guidance. The addressability of any particular dynamic casualty, however, is dependent on the type of activity in which the vessel is engaged (e.g., open transit, docking, at anchor), and the location in the port zone where the casualty occurs (e.g., open water, or confined area). It must be stressed that there is no standard list of circumstances; almost every case has unique aspects to be considered.

- Examples That Are Generally Addressable

Many dynamic casualties (i.e., collisions, rammings, and groundings) are potentially avoidable with a VTS operating in a port zone, and when one or more of the vessels heading for a casualty is participating. Open water collisions between two vessels caused by surprise, poor weather, or simple miscalculation are classic examples of VTS addressable casualties. Collision avoidance is contingent, however, upon full communications, advance advisories to the vessels, and the ability of the vessels to react in sufficient time to avert a casualty.[7]

[7] The January 1971 collision, in dense fog, under the Golden Gate Bridge between the Arizona Standard and the Oregon Standard is often recognized as the catalyst for modern VTS in the United States. Approximately 800,000 gallons of bunker fuel escaped from the Oregon Standard, causing significant pollution of San Francisco Bay. The experimental, voluntary, Harbor Advisory Service was in operation at the time, but was not being used by the Oregon Standard. Also, radio communication between the two vessels was reported to be faulty.

4.2.2 The Concept of VTS Addressability (Cont.)

In certain overtaking situations, where both vessels are already aware of the developing situation, only the skill of the pilots will prevent the casualty from occurring. Often, hydrodynamic interactions between the vessels or an adjacent river bank cannot be overcome in time to prevent the collision. Situations where VTS supplements required separation of meeting or overtaking traffic may be VTS addressable.

Given the state of the art VTS system envisioned in this study, casualties involving anchored vessels are usually also addressable. Vessels dragging anchor or vessels entering a congested channel or waterway directly from a pier, dock or anchorage are examples of addressable situations.[8] In such cases, a VTS can effectively advise vessels of meetings or potential hazards.

Potential casualties from dredging operations or similar work activity in a channel are often addressable through VTS advisories. Hazards to mariners in these situations may include submerged cables and pipelines, as well as the possible unpredictable movement of vessels engaged in such operations.

Mechanical casualties such as steering or power failure are not VTS preventable, yet may lead to situations where an operating VTS will benefit other traffic in the waterway by advising of the existing navigational risk. VTS related benefits may exist in some situations where an initial casualty is not directly preventable by a VTS, but subsequent casualty situations might be prevented. This includes notification and even redirection advisement of all traffic in the immediate vicinity of the casualty. An example is a multiple casualty where a mechanically disabled vessel collides with a second vessel.

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[8] See NTSB News Digest, "February Collision in New York Bay Highlights Concern About Reductions in Vessel Traffic Service," Vol. 7, no. 10, 11/25/87.

4.2.2 The Concept of VTS Addressability (Cont.)

- **Examples That Are Generally Not Addressable**

  Collisions with a dock, bridge, or moored vessel in confined waters (e.g., turning basins, berths, docks, piers, anchorages and moorings), especially during mooring situations, are often not VTS addressable. This is especially true where the vessel collides with the dock. In such cases it is the responsibility of the vessel (master and pilot) to determine through visual, radar, and communications all vessels and fixed objects that are in the immediate vicinity.

  Berthing and docking maneuvers are not generally addressable. Maneuvering activities in close quarters are rarely addressable. A barge colliding with its own tug or tow is also a typical casualty that is not VTS addressable.

- **Borderline Addressability Situations**

  VTS addressability for bridge rammings depends on the size and characteristics of bridge clearances. In confined bridge situations, the clearance between the bridge and most VTS participating vessels leaves all responsibility to the pilot and assisting tugs.

  Depending on the width of a channel, a VTS may or may not detect a potential grounding in time to recommend corrective action. This includes vessels such as tugs, tows, and barges that stray out of the channel (due to poor visibility, lack of diligence to local conditions, local knowledge, or the effects of winds, tides and currents). A vessel deviating from an intended track in open water can usually be detected by a VTS, whereas a vessel about to stray out of 400-foot dredged channel is more difficult to detect. In narrow channels, a casualty may occur before significant deviation can be determined by a VTS.

4.3 VESSEL CASUALTIES BY TYPE

Table 4-1 presents summary statistics from the addressable casualty database of 2,337 records. It shows the distributions of these casualties by such measures as subzone type, casualty type, vessel type and size, and VTS group. This section discusses these items in detail.

TABLE 4-1. SUMMARY STATISTICS FROM VTS ADDRESSABLE CASUALTIES (2337 Records)

Subzone Type	Number	Percent
Open Approach	176	7.5%
Convergence	43	1.8
Open Harbor	332	14.2
Enclosed Harbor	137	5.9
Constricted	757	32.4
River	892	38.2
	2,337	100 %
Casualty Type		
Collision	986	42.2
Ramming	350	15.0
Grounding	874	37.4
Other	127	5.4
	2,337	100 %
Vessel Type		
Passenger	110	4.7
Dry Cargo	316	13.5
Tanker	206	8.8
Dry Barge	480	20.5
Tank Barge	388	16.6
Fishing	103	4.4
Tow	628	26.9
Other	106	4.5
	2,337	100 %
Vessel Size		
Large	431	18.4
Medium	93	4.0
Small	1813	77.6
	2,337	100 %
VTS Addressable Groups		
II	629	26.9
III	876	37.5
IV	823	35.6
	2,337	100 %

4.3.1 Distribution of Vessel Casualties by Study Zone

Figure 4-1 indicates the gross distribution by study zone of VTS addressable vessel casualties. New Orleans and Houston have experienced the largest number of casualties, while Cook Inlet (Anchorage) and Portland (ME) have the fewest number. These distributions provide only an overview of the types of accidents, vessel types, and locations that have occurred to date. Alone, they provide no indication of future risk of a casualty. Casualties are a function of traffic volume, waterway characteristics, navigational hazards, and other risk factors which are discussed in Section 5.

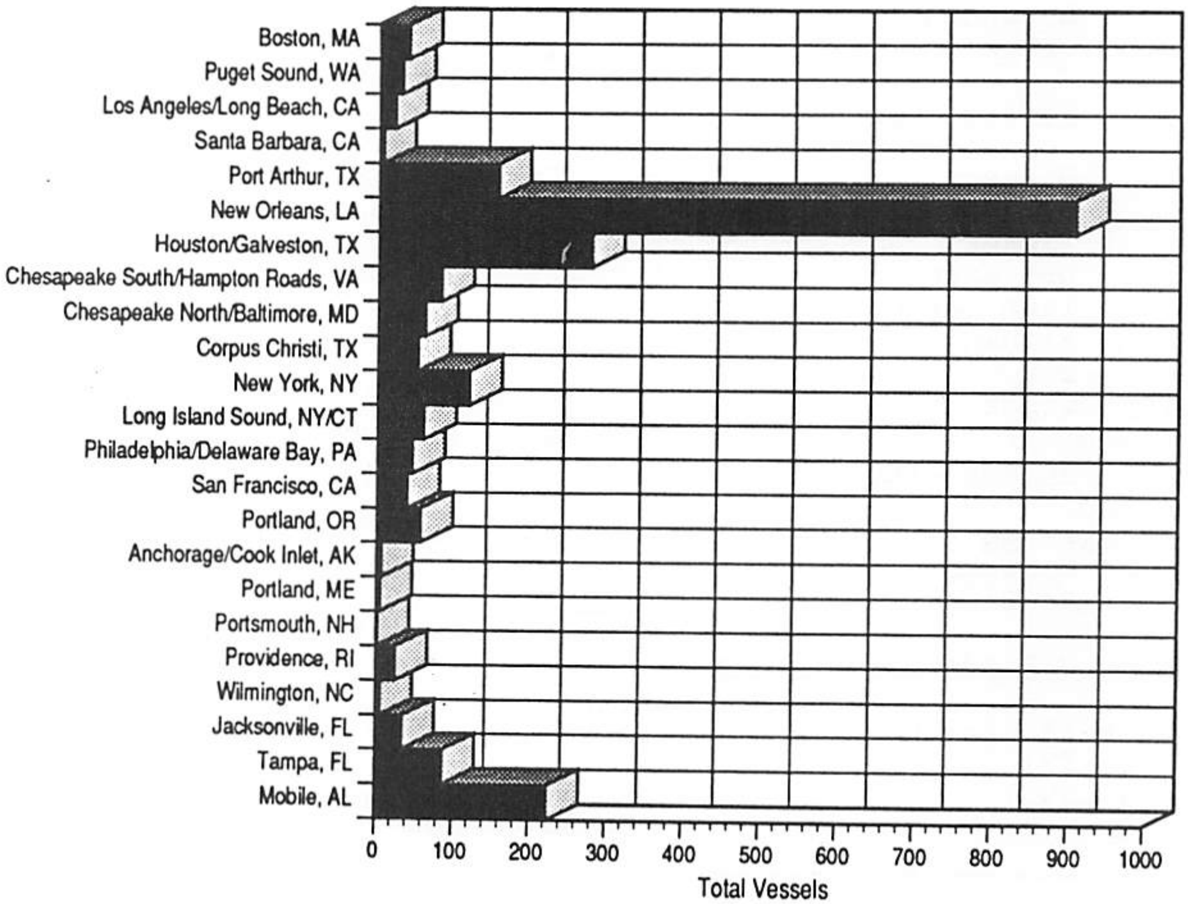

FIGURE 4-1. ADDRESSABLE CASUALTIES DISTRIBUTED BY STUDY ZONE

4.3.1 Distribution of Vessel Casualties by Study Zone (Cont.)

Many study zones have unique characteristics that affect the level of vessel casualties. In New Orleans, which is dominated by the Mississippi River, shoals are a leading cause of groundings. Most such casualties involve deep draft ships that run aground during high water season on the river. This occurs due to a saturated silt load that develops in the fast moving water. According to the New Orleans MSO, "in shallow areas, particularly around the Head of Passes, the silt precipitates in massive quantities to form shoals."[9] To compound the problem, shoals have a tendency to move about, thus creating unpredictable bottom conditions.

The waters of the Houston Ship Channel present another difficult navigational challenge. The channel is a dredged, very narrow and confining waterway, in many cases with industry and marine facilities built-up to the edge of the navigable channel. For many casualties, according to the Houston MSO, "this environment, coupled with a high traffic density and dissimilar traffic mix, creates a virtual extremis situation for the majority of vessel meeting and overtaking situations." As an illustration, in order for two large, deep draft vessels to safely pass one another in certain parts of the channel, a so-called "Texas Chicken" maneuver must be precisely executed, an intentional near-miss situation.[10]

Groundings in the Houston Ship Channel have several characteristics. During a recent analysis,[11] it was found that the majority occurred during the winter months (reduced visibility from rains and fog), and at night. A possible contributing factor at night may be the high level of background lighting throughout the industrialized portions of the VTS area. This may affect night vision as well as obscure aids to navigation.

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[9] Correspondence, 12/13/90, Captain W.J. Loefstedt, Officer in Charge, Marine Inspection, New Orleans, LA.

[10] The actions require the respective pilots in meeting situations to intentionally call for a collision course, and then at a certain interval to suddenly turn their respective bows towards the adjacent banks, utilizing a controlled combination of bank suction and bank cushion to effect a successful passage.

[11] "Vessel Traffic Service Area Houston/Galveston Analysis of Grounding Incidents, January 1986 to December 1989," presented at the HOGANSAC meeting, 4/26/90.

4.3.1 Distribution of Vessel Casualties by Study Zone (Cont.)

Although it is possible to construct casualty trends over time for a given study zone, apparent reductions may be attributable to improvements in aids to navigation or other safety features not directly related to VTS operations. Houston noted this specifically after making improvements to aids to navigation in the Intra Coastal Waterway (ICW) precautionary area and at Carpenter's Bayou.

In every study zone, there have been near-miss situations over the analysis period, not reflected in these casualty figures. Accurate records are difficult to maintain, although operational VTS systems (Puget Sound, Houston, and New York City) over the years have kept data on near-miss situations, and on casualties prevented.[12] These are documented instances when VTS had a direct influence on a situation where an accident appeared imminent, but was prevented by VTS intervention. Such data are speculative and not all instances are documented, but they help assist in gauging the effectiveness of VTS in certain critical situations.

The New York City study zone has a large ferry system; about 80,000 persons are carried daily. Several casualties involving ferries were prevented by the VTS that operated during part of the study period, including a potentially catastrophic collision in 1986 between a freighter and ferry with 3200 passengers aboard.[13]

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[12] For example, records from the Houston VTS show the following potential casualty was prevented in December 1989:

> "The [VTS] sector controller noticed the dimensions of the M/V Kenia were 555 ft by 69 ft. This vessel would be transiting the narrow Texas City Ship Channel. From prior experience, the sector controller felt there was a discrepancy with the vessel's posted dimensions. Further research indicated the Kenia's dimensions were 869 ft by 136 ft. Soon after the Kenia's correct dimensions were found, the Towboat Dixie Trader checked into the system with a beam of 105 ft. In addition to the excessive beams of both vessels, a dredge was conducting operations at a major turn in the channel at Texas City Buoy 11A. A possible collision involving a wide tow, a dredge, and large ship was prevented by the diligent actions of the sector operator."

[13] The two vessels eventually cleared by 200 feet. See National Transportation Safety Board, Letter to the Chairman, House Subcommittee on Coast Guard and Navigation (March 11, 1991), and Safety Recommendation (June 2, 1988).

4.3.2 Distribution of Casualties by Type of Casualty

The analysis deals with four types of casualties: collisions, groundings, rammings, and other (weather related and barge breakaway). Figure 4-2 illustrates the distribution of VTS addressable casualties by type. Collisions and groundings account for nearly 80% of all casualties. Different study zones appear to have different mixes of casualty types. The appendix (Volume II) details these differences. As a percentage of all addressable casualties, collisions are relatively more frequent in Port Arthur, New Orleans, and San Francisco, whereas groundings predominate in Long Island Sound, Tampa Bay, and Philadelphia.

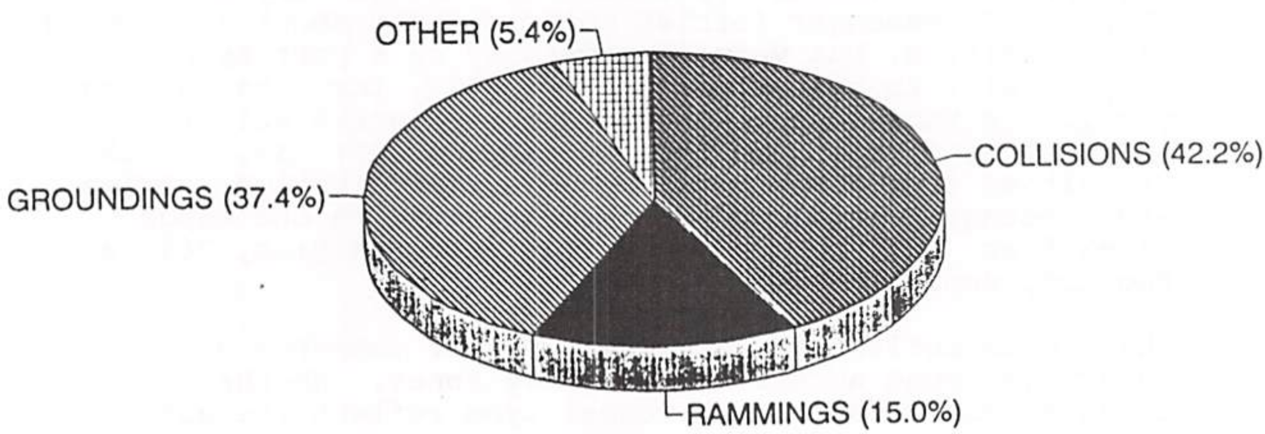

FIGURE 4-2. ADDRESSABLE CASUALTIES DISTRIBUTED BY CASUALTY TYPE

4.3.3 Distribution of Casualties by Vessel Type

Figure 4-3 illustrates that barges (dry and tank) are the most common vessels involved in addressable casualties, accounting for about 37% of all vessel casualties. Towing (or tug) vessels are also relatively frequent, at nearly 27% of the total. Thus, nearly two-thirds of all vessels involved in casualties have been tug, towboats and barges in towing operations. Examination of the detailed casualty data in the appendix (Volume II) indicates the dominance of barge operations in the three Gulf Coast Ports of New Orleans Houston/Galveston, and Mobile.

To reemphasize a point made earlier, these data reflect the number of vessels involved in a casualty event (case), not the number of events per se. Many vessels may be involved in the same casualty and each vessel would be reported as a separate record in CASMAIN. In the barge and tow casualties, which will be shown to occur mostly on rivers, it is common for several vessels to be involved in a single event, although not all will suffer damages or even have been a cause of the reported casualty.

At the other extreme are collisions where a primary cause is a large vessel producing hydrodynamic interaction that forces two other vessels to collide. Since the first vessel makes no contact, it is generally not reported as part of the casualty. A fleet of barges being towed, however, means that each one will be reported separately as a casualty.

Self-propelled vessel types such as tankers, dry cargo ships, and passenger ferries comprise only about a fourth of all casualties, but vary considerably on a port by port basis (refer to the appendix, Volume II, for data on each port). In Puget Sound, this group represents 62% of addressable casualties, and in Portland (OR) 53%. Of the 60 casualties in Long Island Sound, 30 alone involve ferries and passenger vessels. By contrast, tow/tug and barge casualties account for 81% of Mobile casualties, 76% in Houston, and 69% in New Orleans.

These data reflect the different mix of commerce and waterways found across the 23 study zones. Whether the casualty distributions by vessel type reflect the actual traffic distributions in a port area may be pursued as a research question in both the design and operational phases of a VTS.

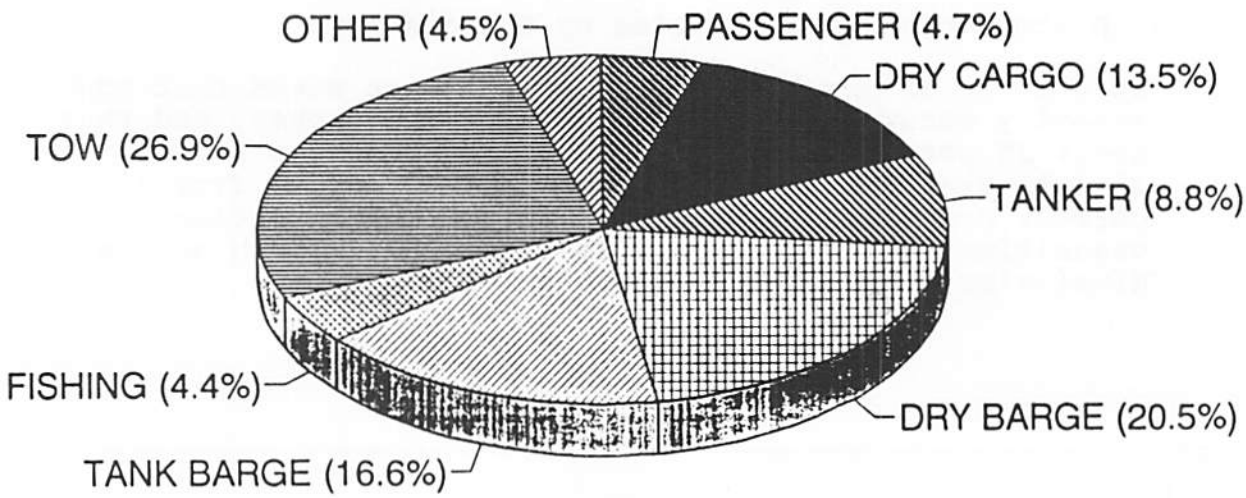

FIGURE 4-3. ADDRESSABLE CASUALTIES DISTRIBUTED BY VESSEL TYPE

4.3.4 Distribution of Casualties by Subzone Type

Of the six subzone types, rivers, constricted waterways, and open harbors experience the largest volume of casualties, representing nearly 85% of the total. The major casualty types are also distributed almost uniformly along the same lines. For example, out of 350 casualties involving rammings, 143 occur in constricted waterways, and 103 in rivers. Together these two subzones account for 70% of all rammings.

Another view of addressable casualties may be seen by taking the number of casualties per 10-square miles of subzone. These ratios give another indication of casualty activity for subzone types, but do not reflect actual traffic flow (see Section 5 for a complete discussion of the modeling approach the study uses to determine risk factors). As Figure 4-4 shows, rivers, enclosed harbors, and constricted waterway have the highest rates per 10-square miles, confirming the vessel counts above. These data support the differentiation among subzone types of VTS Effectiveness estimates shown in Section 5.

4.3.4 Distribution of Casualties by Subzone Type (Cont.)

In a study of European casualties, it was noted that the majority occurred in port and harbor approaches, and that about 25 percent of all the world's casualties occurred in five rivers in northwest Europe.[14] The results from the current casualty analysis confirm the concentration of casualties on highly travelled water bodies such as the Mississippi River and the Houston Ship Channel.

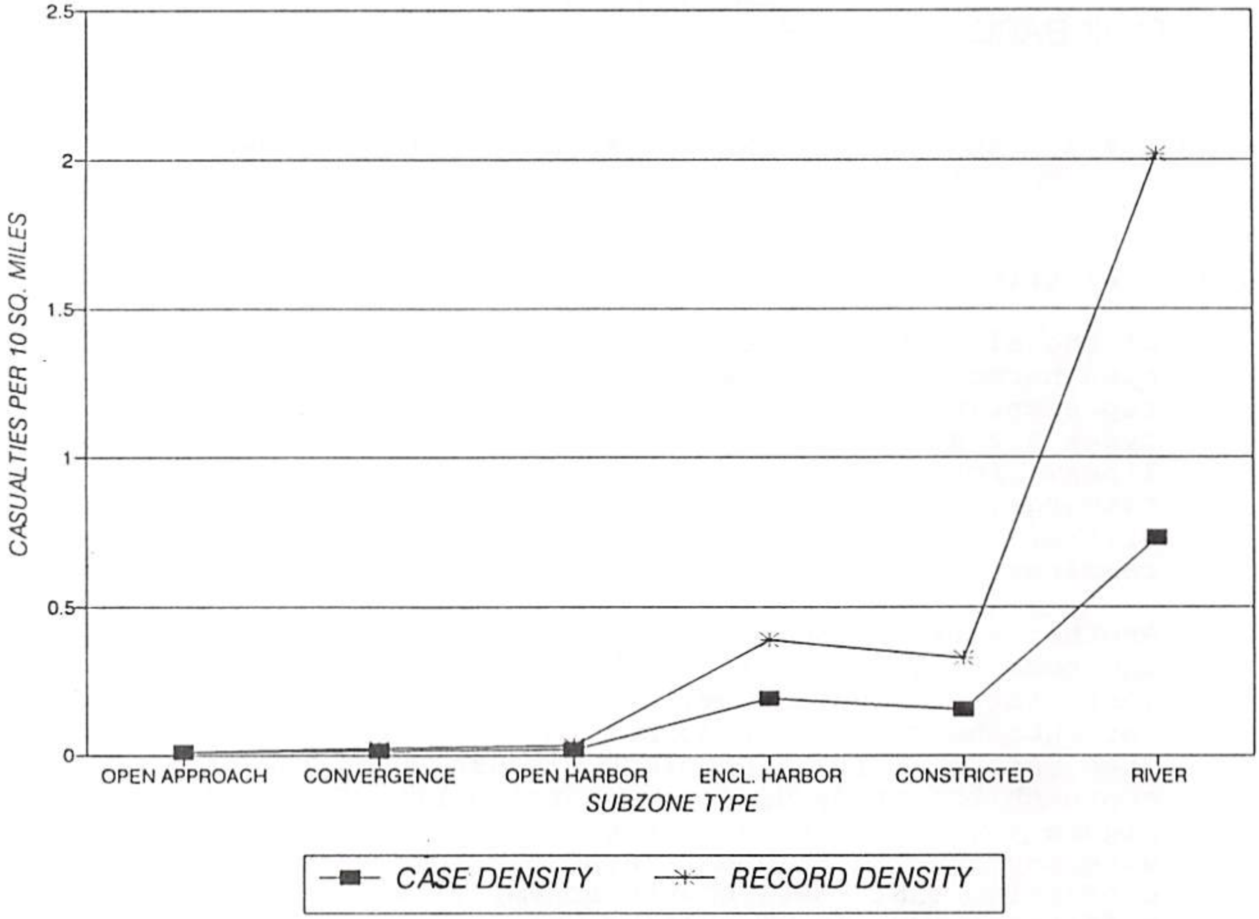

FIGURE 4-4. ADDRESSABLE CASUALTIES DISTRIBUTED BY 10 SQUARE MILES OF SUBZONE

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[14] Coldwell, T.G., "Marine Traffic Flow and Casualties on the Humber," Journal of Navigation, No. 1, Vol. 34, (1981).

4.3.4 Distribution of Casualties by Subzone Type (Cont.)

Figure 4-5 presents the distribution of casualties by subzone type. Many of the individual water bodies comprising the subzones, such as the Houston Ship Channel and Mississippi River, are very difficult channels to navigate. They present a host of risk factors, ranging from 90-degree angle turns, to congested two-way traffic patterns, to unpredictable shoal situations.

These subzone data, however, also reflect a variety of traffic management techniques, ranging from the existence of enforced traffic separation schemes and upgraded aids to navigation, to privately maintained traffic management services, and sophisticated VTS systems in such places as Houston and Puget Sound. Of the 23 study zones, 11 once had or now have a traffic management service during at least a portion of the data analysis period. These operate with varying levels of service, and participation requirements are not uniform. The Coast Guard now operates or has operated VTS systems in five of the 11 zones: Houston, Puget Sound, New York, New Orleans (not operating at the time of this study), and San Francisco. Six other study zones have had privately operated advisory services in place for many years.

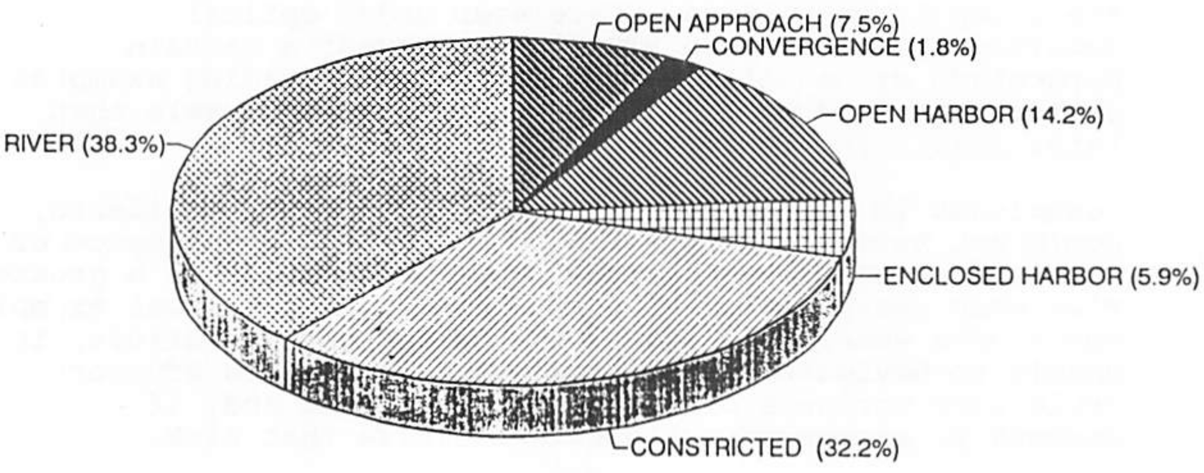

FIGURE 4-5. ADDRESSABLE CASUALTIES DISTRIBUTED BY SUBZONE TYPE

4.3.5 Distribution of Casualties by VTS Group (Addressability)

The grouping method that was used in the review process is another useful way of viewing at casualties. See Table 4-2 for a summary of the coding and subsequent tallies of addressable casualty cases.[15]

TABLE 4-2. VTS ADDRESSABILITY GROUPING

Group	Definition	Number of Casualties
II.	Indirectly addressable	629 (26.9%)
III.	Directly addressable (lower VTS effectiveness)	876 (37.5%)
IV.	Directly addressable (higher VTS effectiveness)	832 (35.6%)
		TOTAL 2,337 (100%)

The differences between a group III and IV casualty are sometimes difficult to determine. A group III designation is a borderline addressability situation. For example, in certain types of groundings near the edge of a channel, the addressability may be very low. On the other extreme are the group IV casualties, where even under optimal conditions, an advanced VTS cannot prevent a certain percentage of casualties from occurring. Leading examples are crossing and meeting encounters between vessels that later result in a collision.

Casualties in group II, indirectly addressable incidents, could not have been prevented by VTS. As a consequence of the initial casualty, however, other vessels incur a greater risk when approaching the first casualty. A typical example would be a vessel that, due to sudden steering failure, is unable to navigate in a narrow waterway. A VTS advisory could warn mariners of the impending hazard and, if necessary, recommend actions to minimize that risk.

[15] Refer back to Section 4.2.1 for a full description of the coding process.

4.3.5 Distribution of Casualties by VTS Group (Addressability) (Cont.)

As stated by the Galveston MSO: "While VTS cannot prevent all casualties along a waterway, they are of incalculable value when reacting to an incident. The ability to quickly notify all vessels of an incident, the ability to manage the waterway during an incident, and the information provided about the status of the waterway are crucial to responding effectively to an incident on a waterway as congested as Galveston Bay."[16]

VTS addressability groups display little variation by subzone type; each group had over 70% located in rivers and constricted waters. Among vessel types, the VTS addressability groups similarly show a uniform distribution. In terms of casualty type, however, some significant differences are found among the three VTS addressability groups, as the percentage distribution in Table 4-3 shows.

TABLE 4-3. TYPE OF CASUALTY

VTS Addressability Group	Collision	Ramming	Grounding	Other	Total
II	16.1%	27.7%	37.4%	18.9%	629
III	33.3	12.1	53.7	0.9	876
IV	71.3	8.4	20.3	0.0	832

These data suggest that VTS may be more effective in addressing collision casualties (71.3%) than either groundings or rammings. The result indicates that VTS controllers, tracking two or more moving targets on radar or computer screens, are generally able to directly address a possible collision more often than a possible grounding or ramming. Groundings were more likely to be coded by the reviewers as being a type III casualty, meaning a VTS could have directly addressed it, but with a lower range of effectiveness.

[16] Correspondence, December 13, 1990.

4.4 MAJOR CAUSES OF ADDRESSABLE VESSEL CASUALTIES

The instructions for filing a Coast Casualty Report (Form 2692) list 105 different causes for the investigating officer to select from. For that reason, some of the more general causes, such as "operator error" or "error in judgment" probably are overstated in the database simply because they overlap many of the more specific causes available as choices. Thus, distributions of causes may conceal many specific details of interest. Recognizing this caveat, data from the VTS addressable casualty database show the primary causes to be grouped as listed in Table 4-4.

TABLE 4-4. MAJOR CASUALTY CAUSES

Primary Cause	Number of Vessels
Personnel Related	1632 (69.8%)
Environment Related	500 (21.4%)
Vessel Related	95 (4.1%)
All Other (unknown, nec, etc)	110 (4.7%)
TOTAL	2337 (100.0%)

4.4.1 Personnel Related Causes

Specific personnel related causes are almost all the result of human error. Several of these factors may be involved in any specific casualty. Table 4-5 lists the most frequent specific causes of the 1632 general, personnel related causes which are mentioned above (percentages <5% are not listed).

4.4.1 Personnel Related Causes (Cont.)

TABLE 4-5. PERSONNEL RELATED CAUSALITY CAUSES

Primary Cause (CASMAIN)	Percent
Operator errors	19.0%
Errors in judgment	10.7%
Failure to account for current	6.1%
Failure to maintain position	5.6%
Failure to establish passing agreement	5.4%
Failure to keep proper lookout	5.0%
All others	48.2%
Total	100.0%

4.4.2 Environment Related Causes

Leading environment specific causes associated with addressable casualties include shoaling (9.0%) and adverse weather (6.4%). Along the Mississippi River and Gulf Intercoastal Waterway, shoaling is a common cause of grounding.

Poor visibility, fog conditions, and inclement weather often are associated with vessel casualties. Under these circumstances, dependence on radar and voice radio becomes essential. This is particularly the case in confined waterways where meeting, crossing, and overtaking agreements between vessels need to be worked out well in advance of actual encounters.

4.4.3 Other Causes

Some addressable casualties are the result of equipment or material failure of some part of the vessel. As indicated earlier, these are typically situations where a VTS can perform an advisory service to other vessels in the vicinity, even though it was unable to directly address the initial casualty[17]. Such causes accounted for 4% of the casualties investigated in the study.

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[17] In fact, 81% of vessel related causes are grouped as indirectly addressable casualties (VTS Addressability Group II).

4.4.3 Other Causes (Cont.)

Other factors that may affect casualty frequencies include the type and volumes of traffic levels, and export and import activities. Shipments of oil and grain, in particular, may be very volatile over the course of time, thereby affecting the number of deep draft vessels and barge operations in many of the 23 ports.

Shipments of liquefied natural gas (LNG) are similarly sensitive to the overall economic climate. Although there have been no major casualties involving LNG tankers in U.S. waters, there is probably more vigilance connected with their passage in and out of ports than any vessel type.[18] However small the chances of occurrence, the potentially catastrophic results of casualties involving LNG tankers are of continuing concern in marine safety programs. (See Section 6 for a discussion of the potential effects of a LNG accident.)

4.4.4 Case Analysis of Collisions, Rammings, and Groundings

In the review of 6500 casualty files conducted at Coast Guard headquarters, and reviews of other casualty studies, some of the leading causes could be broadly categorized as follows:

- Human error and negligence;
- Converging, meeting, overtaking, and crossing caused by surprise or miscalculation;
- Excessive speed;
- Communications Problems (insufficient bridge to bridge communications. Language and communication problems including foreign captains and radio difficulties.);
- Restricted visibility, adverse environmental or weather conditions;

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[18] Waterways are generally cleared of all other traffic during passage of LNG tankers; escort vessels are usually provided. Tankers have double hulls and are otherwise reinforced to prevent the accidental release of LNG vapors, which are extremely flammable. Outside the U.S. there have been two major LNG casualties (Tobata, Japan, and the Strait of Gibraltar), both groundings that resulted in severe outer hull damage but no loss of LNG.

4.4.4 Case Analysis of Collisions, Rammings, and Groundings (Cont.)

- Restrictive hydrographic conditions (constricted waters, strong currents, shoaling);
- Hydrodynamic interaction (squat, suction, cushion);
- Inadequate navigational aids/insufficient regulatory guidance (missing or improperly marked aids to navigation); and
- Equipment or mechanical problems.

4.4.4.1 Collisions

Some of the cases reviewed indicate several of these causes may have played a role in a given incident. A classic example of a VTS addressable group IV collision casualty occurred in Mobile Harbor on June 13, 1989 at 9:48 P.M. The casualty involved the tugs Paul Candies and C-MC, and their respective tows. Weather was not a factor, although visibility may have been impaired due to background lighting and a 30-degree bend in the channel. The barges sustained $400,000 damage as a result of the collision. According to the narrative, the apparent cause was,

"..the attempt of the C-MC to effect a starboard to starboard passage with the Paul Candies and tow within the confines of a narrow channel, without such passage having been agreed upon by the operators of both vessels. A contributing cause was the failure of the operator of the Paul Candies to observe the approach of the C-MC and tow until the vessels had closed to an extremis position."[19]

A nearby dredge operator monitoring channel 13 reported hearing no radio communication until the moment before the collision. Neither tug sounded any whistle signals. Had a VTS been operational at the time of the casualty it is probable that this casualty could have been addressable. Human error, lack of radio communication, and possibly restrictive waterway conditions all played a role in the casualty.

Communication difficulties may occur not only from a failure to monitor radio frequencies, but also by the necessity to monitor too many frequencies with possibly different amplifications. The Lower Mississippi River Safety Advisory Committee (LMRSAC) VTS Subcommittee found that there is a

[19] CASMAIN Case Number MC890034594.

4.4.4.1 Collisions (Cont.)

"significant danger to navigation that is the result of the mariner being required to navigate a vessel while simultaneously monitoring a multitude of VHF radio frequencies."[20]

The May 1981 collision between the Staten Island Ferry, American Legion, and the cargo carrier Hoegh Orchid, illustrates the effects of excessive speed, dense fog, and improper communications. In its report, the NTSB concluded that the collision,

"..may have been prevented if a limited VTS had been in operation pending activation of a fully operational VTS for New York Bay. An operational VTS would have provided the pilot of the Hoegh Orchid and the master of the American Legion with specific information about vessels that were entering the VTS sector on the morning of May 6, 1981."[21]

On June 23, 1986, the bulk carrier Palm Pride collided with a barge fleet on the Mississippi River while trying to overtake two tows. The voluntary New Orleans VTS was operational at the time, but none of the vessels involved was participating. Further, the operating VTS was at an elementary level. It involved only a movement reporting system with no independent surveillance technology.

4.4.4.2 Rammings

Addressable rammings include bridges, navigational aids, and stationary vessels. On January 10, 1988, the 883-foot tanker ARCO Juneau rammed the Carquinez Strait bridge in San Francisco Bay, causing $3 million damage to the vessel, but only $250,000 to the bridge.[22] No pollution was reported. Dense fog was present at the time of impact, although the proximate cause was the failure of the master and pilot to adequately plot the vessel's course and position in the strait. The reviewers felt that had an advanced VTS been operating at the time of casualty, that the bridge ramming probably could have been averted.

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[20] Meeting minutes, 3/8/90 meeting of the LMRSAC.

[21] NTSB, "Collision of the Norwegian Cargo Vessel M/V Hoegh Orchid and New York Ferry American Legion, Upper New York Bay, May 6, 1981).

[22] CASMAIN case number MC8800168.

4.4.4.2 Rammings (Cont.)

One of the most significant casualties in recent times was the May 1980 ramming by the bulk carrier Summit Venture of the Sunshine Skyway Bridge in Tampa.[23] Damage was catastrophic: $30 million to the bridge, $1 million for the vessel, and 35 deaths as a bus and 7 seven motor vehicles fell into the water. Severe squalls in the vicinity of the bridge were found to be a probable cause of the casualty. An advanced VTS, equipped with appropriate meteorological sensors and linked with NOAA Doppler radar, could have foreseen the potential for casualties and provided guidance on the impending weather.

4.4.4.3 Groundings

The grounding in February 1987 of the car carrier Fernpassat on the South Jetty of the entrance to the St. Johns River in Jacksonville, could likely have been addressed by a VTS. As a result of the grounding, about 110,000 gallons of heavy marine oil and diesel oil were released into the surrounding waters. The vessel also rammed and dragged a buoy as it left the marked channel. Among the causes cited for the casualty are: the master failed to maintain a proper lookout, (allowing the radar observer to leave the pilot house while in the channel); failure to use published tidal information, failure to have a pilot aboard inside the breakwater, and a weak light on the St. John Bar Cut Range.[24] In such a potentially hazardous passage, it is possible a VTS operator could have provided valuable information to the master regarding his faulty course and impending contact with the jetty.

See Section 5 for the conditional probabilities of consequences of vessel casualties developed and used for this study.

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[23] NTSB, Marine Accident Report, NTSB-MAR-81-3.

[24] CASMAIN case number MC87004914.

5. FORECASTING VESSEL CASUALTIES AND THEIR CONSEQUENCES

5.1 OVERVIEW

The purpose of risk assessment in this study is to estimate the relative net benefit (i.e., reduced consequences, or losses, associated with avoided vessel casualties) of the Candidate VTS Design in each study zone. The forecasts of future casualties in each study zone, over the 15-year life cycle period, are sufficiently accurate for a benefit cost analysis such as this. However, forecasting an actual vessel casualty and/or a major spill of a hazardous commodity within a specific waterway, in any particular year, is beyond the scope of this study.

Applying vessel casualty probability values to the forecasted future vessel transits in each study zone enables estimation of the number of future vessel casualties by type of casualty (i.e., collision, grounding or ramming) and by vessel type and size. A vessel casualty risk model represents the unique navigational risk in each study subzone. Vessel casualty probabilities apply to each type of vessel traffic in each of the 99 subzones. Applying another set of probability factors based upon historical distributions of the immediate consequences, produces estimates of these consequences (i.e., vessel damage, cargo loss, hazardous commodity spilled, cleanup costs, loss of human and/or marine animal life, human injuries other environmental and economic losses).

The risk estimation process involves the development of national average probabilities by casualty type, vessel type and size followed by subzone specific adjustments to represent the navigational characteristics of the subzone. This process compensates for the absence of casualty observations in several of the cells of the multidimensional analysis matrix. The subzone specific adjustment estimates are derived by incorporating into the model, via regression analyses, a number of the risk variables which characterize the unique navigational risk and explain the historical casualties in each of the 99 subzones.

5.1 OVERVIEW (Cont.)

The risk variables characterizing the unique navigational risk in each subzone include configuration, meteorologic and hydrologic attributes of the waterway as well as the length and alignment of the vessel routes through the waterway and the vessel traffic densities. The risk variable coefficients, derived from the regression analysis, express the relative contribution of each factor to the overall navigational risk in that specific subzone.

The risk assessment process must be sensitive enough to the major variables that differentiate the navigational risk among the study zones, for the purpose of supporting subsequent comparisons of estimates of the net benefits of Candidate VTS Designs among the 23 study zones. The study develops the probabilities and applies them within the constraints of the quality and quantity of the available data on casualties, traffic, and the other variables incorporated into the navigational risk model.

Given historical vessel casualty data and related exposure data (i.e., vessel transits), as well as data characterizing navigational hazards of waterways through which vessels traverse, and forecasts of future vessel transits, the risk model provides an estimate of future vessel casualty rates (i.e., vessel casualty probabilities). Upon applying these probabilities (or future casualty rates) to appropriate future vessel transits within a specific subzone, they yield estimates of the future (NO-VTS case) vessel casualties. Application of a second set of factors (i.e., VTS Effectiveness Factors presented in Subsection 5.4) yields the forecast of avoided casualties attributed to the Candidate VTS Design. Application of still another set of probabilities (i.e., occurrence and severity of vessel casualty consequences) yields an estimate of associated consequences, avoided by the Candidate VTS Design in each study zone.

5.1 OVERVIEW (Cont.)

The study estimates the avoided vessel casualties and their associated consequences with and without VTS, all other navigational risk factors assumed constant. The avoided vessel casualties (by casualty type and vessel category) in each study subzone have associated with them a number of material losses, human losses, marine animal losses, other marine environment losses as well as losses to the regional economy. It is assumed that historical distributions of the occurrence and severity of these types of losses associated with each vessel casualty (by casualty type and vessel category) will remain unchanged in the future.[1]

Therefore the estimates of Candidate VTS Design benefits (i.e., avoided losses) are a function of the estimates of avoided vessel casualties by casualty type, by type of vessel and cargo, the projected distribution of loss severity associated with each consequence type, and the location within the study zone (i.e., spill site). Figure 5-1 is a top-level schematic of this process.

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[1] The gradual integration of new hull technologies into the tanker fleet and improved spill response capabilities during the next decade may reduce the probability of hull failures and spills and/or the size of spills and their environmental impacts when groundings, rammings and collisions do occur. These changes could affect the estimation of the NO-VTS case consequences. The study does not estimate these effects because it is not clear to what extent substantive changes will occur during the study forecast period.

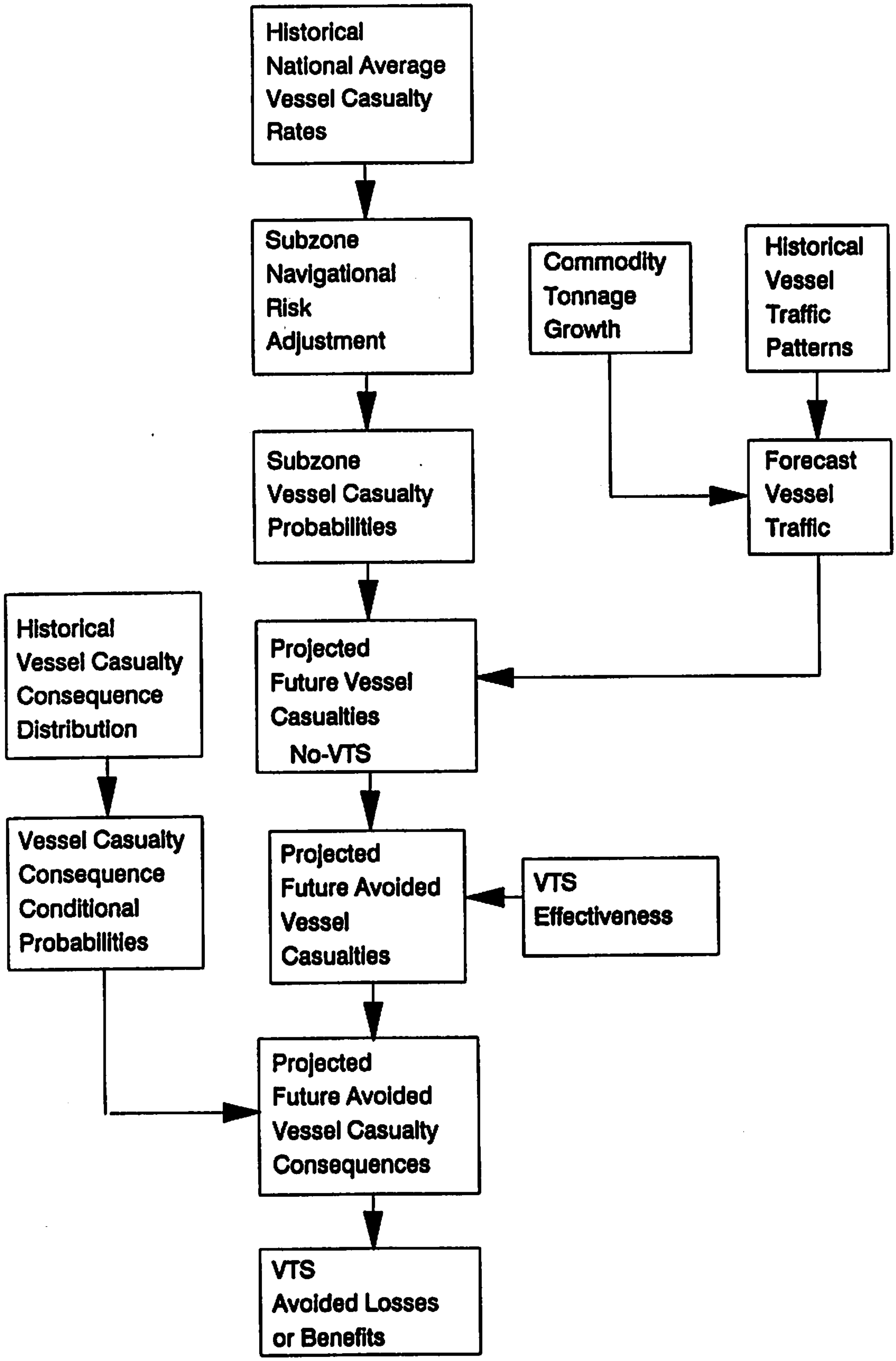

FIGURE 5-1. RISK ASSESSMENT PROCESS

5.1 OVERVIEW (Cont.)

The analytical approach to vessel casualty and consequence forecasts in this study involves:

- Navigational Risk

  1. Definition of a risk assessment framework.

  2. Analysis of available risk exposure data, vessel casualty data, and data on the associated material, human, and marine animal losses as well as other environmental and regional economic losses.

  3. Analysis of the contributing factors to the vessel casualty events and the future navigational hazards of the waterways in the study zones.

  4. Specification and calibration of a vessel casualty risk model for estimating vessel casualties.

- Vessel Casualties

  5. Application of the risk model in order to forecast casualties during the study period within each subzone by vessel casualty type, and by vessel category.

- VTS Effectiveness

  6. Development of VTS Effectiveness Factors for each subzone, by casualty type and vessel category.

  7. Application of the VTS Effectiveness Factors to estimate vessel casualties avoided by the Candidate VTS Design in each subzone.

- Consequences

  8. Application of consequence probabilities to the avoided vessel casualties to estimate avoided consequences of all types and their respective dollar values attributable to the Candidate VTS Design in each subzone.

Subsequently, the study compares the life cycle avoided losses with the life cycle VTS costs to estimate the potential net benefit attributed to a new Coast Guard Candidate VTS Design in each study zone.

5.1 OVERVIEW (Cont.)

The specification and calibration of the subzone specific vessel casualty probabilities (i.e., risk specific to each study subzone's navigational characteristics) involves analyses of a large number of risk variables, vessel categories, casualty types and subzone types. Table 5-1 lists the major navigational risk variables for which data are available for the assessment process.

TABLE 5-1. MAJOR RISK ASSESSMENT VARIABLES

- NAVIGATIONAL VARIABLES
  - Frequency of Reduced Visibility
  - Prevailing Wind Conditions
  - Adverse Currents
  - Waterway/Subzone Configuration
  - Vessel Route Alignment
  - Route Channel Width and Depth
  - Vessel Traffic Volume in Channel
  - Density of Other Local Traffic
- VESSEL CATEGORIES
  - Passenger
  - Dry Cargo
  - Tanker
  - Dry Cargo Barge Tows
  - Tanker Barge Tows
  - Tug/Tow Boats
- CASUALTY TYPES
  - Collision
  - Ramming
  - Grounding
- SUBZONE (Waterway) TYPE
  - Open Approach
  - Convergence
  - Open Harbor or Bay
  - Enclosed Harbor
  - Constricted Waterway
  - River

5.2 NAVIGATIONAL RISK MODEL

Navigational risk addresses the estimation of the number of VTS addressable vessel casualties (collisions, groundings, and rammings) by vessel type and size for each subzone. The approach is to:

- Develop national average casualty rates based on historical casualty data.
- Develop a subzone specific adjustment factor for each subzone based on regression model.
- Apply subzone specific adjustment factor to national average casualty rates by casualty type, vessel type and size to generate subzone specific vessel casualty probabilities.

The study approach is to first develop national average "VTS addressable" vessel casualty rates. The study estimates these national average casualty rates by vessel type, (passenger, dry cargo, tanker, dry cargo barge, tank barge, and tug/tow boat), by vessel size, (small, medium, and large), and by type of casualty (collision, grounding, and ramming).

To obtain the No-VTS case (i.e., "back-out" VTS beneficial effects) for those subzones that have had VTS services during the time period 1979 to 1989, the study increases VTS addressable casualties by the VTS effectiveness. The observed casualties are not increased in locations where services have not been operating. The study then sums all subzone casualties and divides them by the appropriate vessel transits to develop national average vessel casualty rates by casualty type, vessel size and casualty type. Table 5-2 lists these rates.

The study then adjusts the national average casualty rates using adjustment factors that reflect local navigational risk characteristics in order to produce vessel casualty probabilities representing each specific subzone. The study generates these subzone specific adjustment factors through a multiple regression analysis. The analysis focuses on those statistically significant variables that represent the unique navigational risk in each subzone.

5.2 NAVIGATIONAL RISK MODEL (Cont.)

For the multiple regression the best fit is obtained when regressing historical casualty rates against the following variables: open waterway, narrow waterway, route length, (length in statute miles of the primary traffic route in the subzone), average width, (average channel/waterway width in yards), sum of headings, (sum of the total degrees of course changes along the primary route in subzone), and other local vessel density (other local vessel density divided by route length). Other vessels consist of commercial fishing fleets, recreational boating, local charters and local cruises of all types.

The study then estimates a subzone specific probability of a vessel casualty by multiplying the national average vessel casualty rates by the subzone risk adjustment factor. The study estimates these subzone specific vessel casualty probabilities by vessel type (passenger, dry cargo, tanker, dry cargo barge, tank barge, and tug/tow boat), by vessel size (small, medium, and large), and by type of casualty (collision, grounding, and ramming).

TABLE 5-2. NATIONAL AVERAGE CASUALTY RATES BY VESSEL TYPE, VESSEL SIZE AND CASUALTY TYPE (1979 TO 1989) 23 STUDY ZONES (Adjusted for Effects of Existing Vessel Traffic Systems)

		(Number of Casualties per 100,000 Transits)			
Vessel Type	Size	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	---	---	---	---

5.2.1 Data Analyses

The study calculates the historical casualty rates referred to in this section from the VTS-addressable casualty file (as presented in Section 4). There is, however, a distinction between the vessel transits as defined here in the risk modeling process and the vessel casualty "records" in the casualty analyses discussed in Section 4. For the risk model, the study combines individual barge and tug/towboats into barge-tows. This is done to both casualties and vessel transits (i.e., tugs with one or more barges). For example, the study treats barge-tow with 10 barge vessels and one tugboat as one transit here, and thus one casualty, whereas in the CASMAIN file, the 11 vessel units are counted as 11 individual vessel casualties. For self-propelled vessel casualties (i.e., passenger, dry cargo, tanker, tugboats without barges), the study counts as one casualty event each vessel involved in a VTS addressable incident. In the case of a collision, there are usually two vessel casualties involved.

As a result of the barge to barge tow conversion, the total number of vessel casualties are reduced from 2,337 individual vessels to 1,492 self-propelled vessel and barge/tows involved in 1,084 casualty incidents.

Of the 1,492 vessels and barge/tows the study counts as VTS addressable casualties, 600 are collisions (two or more vessels), 208 rammings, 645 groundings and 39 other incidents. See Table 5-3 for a breakdown of the three types of VTS addressable casualties (i.e., collisions, rammings and groundings) by vessel type.

TABLE 5-3. NUMBER OF VESSEL CASUALTIES BY CASUALTY TYPE AND VESSEL TYPE (1979-1989) 23 STUDY ZONE TOTAL

Vessel Type	Collision	Ramming	Grounding	Total
Passenger	38	9	61	108
Dry Cargo	109	33	171	313
Tanker	53	22	127	202
Dry Barge	109	54	75	238
Tank Barge	123	40	130	293
Tugboat	37	22	44	103
Fishing	64	7	24	95
Other Vessels	67	21	13	101
Total	600	208	645	1453

5.2.1.1 Sample Selection For Calibration Of Risk Models

The national average casualty rates (previously mentioned in Table 5-2) show large vessels have the highest casualty rates among vessel types. This may be attributed to the 20-meter threshold for inclusion in the "VTS Addressable" casualty database. The only vessels less than 20 meters included are those involved in incidents with VTS addressable vessels. A close examination of the historical casualty data (which Table 5-4 presents) among the self-propelled dry cargo and tanker vessels shows that only 7% of the 515 combined dry cargo and tanker vessel casualties are categorized as small vessels as compared to 16% medium and 77% large vessel casualties.

The study transforms the national average vessel casualty rates into subzone specific vessel casualty probabilities by applying adjustment factors. To develop these adjustment factors, the study selects self-propelled deep draft vessels from the casualty file.

The study combines the medium and large dry cargo and tanker vessels into a sample group to represent the subzone unique navigational situation along the dominant vessel route. The study conducts model calibrations using only these selected vessels, because they are adequately represented by the vessel transit data and the casualty data.

TABLE 5-4. NUMBER OF DRY CARGO AND TANKER VESSEL CASUALTIES BY SIZE AND CASUALTY TYPE

Self-Propelled Vessel	Vessel Size	Casualty Type: Collision	Ramming	Grounding	Total
Dry Cargo	Small	20	2	7	29
	Medium	33	11	26	70
	Large	56	20	138	214
Tanker	Small	4	0	5	9
	Medium	5	1	6	12
	Large	44	21	116	181
Total		162	55	298	515

5.2.1.2 Exclusion Of Subzones With No Deep Draft Vessel Traffic and Outliers

The medium and large dry cargo and tanker vessels dominate the ocean-going deep draft vessels along the traffic route selected to represent the navigational attributes of each subzone.

To derive the subzone historical vessel casualty rates, the study divides the 10-year vessel casualties by the 10-year vessel transits of the selected vessel group along the dominant route. Of the 99 subzones, four subzones (subzones No. 2-8, 13-5, 17-4 and 18-4) have no dominant vessel routes through their subzones. Also, five additional subzones (subzones No. 2-5, 8-5, 11-4, 12-6 and 23-3) have no medium or large dry cargo or no tanker vessel transits. Hence the study does not include these nine subzones in the model calibration process. The study later estimates the probabilities of vessel casualties for these subzones (except the four with no traffic route going through) with their respective subzone variables and the calibrated parameters in the model.

- Outliers

Of the remaining 90 subzones, the study classifies three subzones as outliers and thus excludes them from the regression analyses. Two of them have one historical casualty each for the 10-year period which, when divided by the very small volume of traffic, results in two extremely high subzone casualty rates. The other one has moderate traffic compared to the average but with a proportionally higher number of casualties. The observed historical casualties of these three subzones can not be explained by the subzone variables or the other subzone observations, so the sample excludes these too. This results in 87 observations for calibrating the final models.

5.2.2 Pool Of Subzone Risk Variables

The study defines, collects, and synthesizes a number of variables which are considered to characterize the navigational attributes of a waterway. To characterize each of the subzones, this subsection describes the potential risk model variables. There are five types of risk model variables:

5.2.2 Pool Of Subzone Risk Variables (Cont.)

- Subzone Type Constant Variables;
- Meteorological and Hydrographic Conditions;
- Route Characteristics;
- Traffic Volumes/Densities; and
- Traffic or Route Characteristics Per Route Mile.

- Subzone Type Constant Variables

  The study defines the six subzone types (defined in Section 2 based on generic waterway characteristics and subzone configurations) as six dummy variables with 0 or 1 values for the regression analyses:

  - Open Approach = is assigned value 1 if subzone type is open approach otherwise 0.

  - Convergence = is assigned value 1 if subzone type is convergence otherwise 0.

  - Open Harbor or Bay = is assigned value 1 if subzone type is open harbor or bay otherwise 0.

  - Enclosed Harbor - is assigned value 1 if subzone type is enclosed harbor otherwise 0.

  - Constricted Waterway = is assigned value 1 if subzone type is constricted waterway otherwise 0.

  - River = is assigned value 1 if subzone type is river otherwise 0.

- Meteorological and Hydrographic Conditions

  - Average Maximum Current = the average maximum current velocity in knots for the subzone.

  - Visibility = percent of time over a 4-year period that visibility is less than one nautical mile. (Because of data limitations the visibility value is the same for all subzones of a study zone).

  - Wind Speed = percent of time wind velocity is greater than 20 knots over the same time period as visibility is recorded. (Similarly, there are no separate recordings for subzones).

- Route Characteristics

  - Route Length = statute miles of the primary deep draft traffic route in subzone.

5.2.2 Pool Of Subzone Risk Variables (Cont.)

- Minimum Width = minimum channel/waterway width along the primary traffic route in yards.
- Average Width = average channel/waterway width along the primary traffic route in yards.
- Minimum Depth = minimum channel/waterway depth along the primary traffic route in feet.
- Number of Turns = number of course changes along the primary traffic route in subzone.
- Sum of Delta Headings = total degrees of delta values of course changes with no regard of direction along the primary traffic route in subzone.
- Average Delta Heading = average degrees of a course change along the primary traffic route in subzone.
- Number of Obstructions = total number of bridges, anchorages, crossing lanes and other obstructions along the primary traffic route in the subzone.

• Traffic Volumes/Densities

  - M&L Dry Cargo and Tanker = Sum of 10-year medium and large dry cargo and tanker vessel transits for the subzone.
  - All Transits = sum of 10-year transits of all vessel types for the subzone.
  - Ferry Miles = total estimated 1-year ferry miles for the subzone.
  - Other Vessels = total number of registered other vessels for the subzone.

• Traffic or Route Characteristics Per Route Mile

  - M&L Dry Cargo and Tanker Per Route Mile.
  - All Transits Divided Per Route Mile.
  - Ferry Miles Per Square-Mile.
  - Other Vessels Per Route Mile.
  - Number of Turns Per Route Mile.

5.2.2 Pool Of Subzone Risk Variables (Cont.)

- Sum of Delta Headings Per Route Mile.

- Number of Obstructions Per Route Mile.

5.2.3 Calibration of Risk Models

The calibration of the risk model is the process of fitting a model with various combinations of the data elements for the specification of variables, functional form and coefficients which best describe the relationships of the designated dependent variable (i.e., casualties per 100,000 transits) with the independent or explanatory variables (i.e., subzone variables).

The historical subzone casualty rate, defined as the dependent variable, is regressed against a large pool of subzone-specific (independent) variables. The historical casualty rate, projected as the vessel casualty probability per unit of traffic, can be measured as either the number of historical casualties per 100,000 vessel transits or the number of casualties per 100,000 vessel transit-miles. The study specifies and analyzes both measures in the calibration process. Although the alternative casualty rate per transit-mile would imply an additional dimension of traffic exposure measure (i.e., distance travelled) the subzone variables do not predict it well. Traffic density or route characteristics do not explain the variations in the vessel mile casualty rates (even after proportional adjustment of subzone route lengths). The study represents the distance factor however, (defined as route length of the primary traffic route within subzone), as an explanatory variable which predicts well along with other variables in the model. Based on the overall statistical fit and the most significant parameters, subzone casualties per transit movement are a relatively better predictor for subzone casualty rates and projected casualties.

In the calibration process, the study uses both linear and non-linear (i.e., logit) regression procedures to fit the model. The generalized logit model presents an alternative functional form for the casualty rate distribution. In fact, the generalized logit model not only yields similar results to the linear regression model but also shows significant coefficients for visibility and all five subzone type variables (except Open Approach which is captured in the default constant variable) in the model. It does not, however, improve

5.2.3 Calibration of Risk Models (Cont.)

the predictability over the linear model. The root mean square errors of predicted casualties from both the linear and logit models. The logit model generally requires refined data at more disaggregate levels than are currently available. The coarseness of some subzone data (e.g., visibility and wind speed data are available only at zone levels) limit the power of the logistic form.

The study selects the multiple linear regression model of vessel casualty probability (i.e., number of casualties per 100,000 vessel "transits") for its overall statistical fit and its specification of explanatory variables. The study estimates the best estimators of the parameters by the weighted least squares procedure in which each subzone observation is weighted by the traffic for the selected vessel group. The study then multiples the subzone specific vessel casualty probability by the forecasted vessel transits to predict the number of casualties. Therefore, the weighted least squares procedure yields the most efficient estimators for prediction of future vessel casualties.

5.2.4 Results

Table 5-5 presents the results of the selected model. The model can be described as:

<u>Probability of Vessel Casualties</u> =

- 0.372321 - 3.529773 * Open

+ 16.327722 * Narrow

+ 0.228527 * Route Length - 0.000407 * Average Width

+ 0.012121 * Sum of Delta Headings

+ 0.000392 * Other Vessels Per Mile

where: Probability of Vessel Casualties is the predicted number of casualties per 100,000 Medium and Large Dry Cargo and Tanker transits in a subzone.

The explanatory variables in combination explain 75% of the total variation of the historical casualty rates among the sample subzones with a highly significant F value. The t-statistics for each of the parameters are all significant at or greater than the 92.5% level.

5.2.4 Results (Cont.)

Among the explanatory variables in the model, Open (i.e., Open Approach) and Narrow (i.e., Constricted Waterway) are the two subzone type variables that indicate a constant effect on the risk level in addition to the effects of the subzone specific variables. The four subzone-specific variables, route length, average width and sum of delta headings jointly describe the physical characteristics of route alignment and waterway/channel width. The fourth variable, "Other Vessels" per route mile, represents a proxy of the density of other local vessel activities and contributes a marginal effect to the predicted vessel casualty probability. The four continuous variables plus two subzone type variables and the constant factor explain the subzone vessel casualty probability sufficiently well. The signs of those independent variables are all as expected. The estimators for the other four subzone type constants (i.e., Convergent, Open Harbor or Bay, Enclosed Harbor and River) are not as significant as the other variables in the model.

TABLE 5-5. SUBZONE RISK PROBABILITY MODEL

Explanatory Variable	Parameter Estimate	t-statistic	Prob > |t|
Constant	-0.372321	-0.235	0.8145
Open	-3.529773	-1.862	0.0662
Narrow (Constricted Waterway)	16.327722	7.187	0.0001
Route Length	0.228527	4.802	0.0001
Average Width	-0.000407	-1.879	0.0638
Sum of Delta Headings	0.012121	4.251	0.0001
Other Vessels Per Mile	0.000392	1.809	0.0741
R-square	0.7476		
F Value	39.488		
Prob > F	0.0001		

5.2.5 Weighted Historical and Predicted Casualty Rates

The study compares the predicted subzone casualty rates and casualties with subzone historical casualty rates and casualties. In general, the model predicts the subzone casualty rates and number of casualties well. More than two-thirds of the subzones have predicted casualties that match well the number of historical casualties. Less than one-third of the subzones show greater differences. The most extreme cases include the over-predicted zones: New York City (+44%), San Francisco (+48%), and Philadelphia (+56%), and those under-predicted: Tampa (-81%, primarily due to an outlier), Portland, OR (-32%) and Houston (-30%). Table 5-6 compares, at a summary level, the historical casualties with the predicted casualties of each study zone.

It is apparent that the systematic measures specified by the model can not predict some of the variations of the casualty rates. There is, however, no systematic error discovered within those zones except for the one or two subzone outliers which cause discrepancies. In order to smooth the difference between the predicted and observed casualties, the study averages the subzone historical casualty rate and the predicted casualty rate to represent the probability for projecting future vessel casualties. This procedure is supported by prior research performed by others.[2]

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[2] Haver, Ezra, "On the Estimation of the Expected Number of Accidents," Accident Analysis and Prevention Vol. 18, No. 1, pp. 1-12, 1986.

TABLE 5-6. COMPARISON OF PREDICTED AND HISTORICAL CASUALTIES AT STUDY ZONE

Zone	Name	Historical Casualties	Predicted Casualties	Weighted Casualties
6	New Orleans, LA	213.95	220.72	219.87
7	Houston/Galveston, TX	62.61	43.56	53.59
22	Tampa, FL	33.00	6.24	19.69
5	Port Arthur, TX	28.00	23.68	26.11
15	Portland, OR	26.00	17.67	22.04
11	New York City, NY	23.80	34.28	29.43
9	Chesapeake North/Baltimore, MD	17.46	17.92	17.90
8	Chesapeake South/Hampton Roads, VA	16.96	20.95	19.20
14	San Francisco, CA	14.97	22.11	18.79
23	Mobile, AL	13.00	11.20	12.23
13	Philadelphia/Delaware, PA	12.91	20.15	16.76
2	Puget Sound, WA	12.77	12.76	12.92
3	Los Angeles/Long Beach, CA	9.97	13.64	11.96
21	Jacksonville, FL	8.00	8.48	8.34
10	Corpus Christi, TX	7.47	8.30	7.98
1	Boston, MA	6.00	1.47	3.75
19	Providence, RI	5.00	0.82	2.92
16	Anchorage/Cook Inlet, AK	4.00	1.73	2.89
20	Wilmington, NC	3.00	4.09	3.59
4	Santa Barbara, CA	1.00	2.76	1.91
12	Long Island Sound, NY	1.00	1.31	1.17
17	Portland, ME	0.00	0.20	0.10
18	Portsmouth, NH	0.00	0.08	0.04
	TOTAL	520.88	494.11	513.17

5.2.6 Subzone Risk Adjustment Factors

The study then normalizes the weighted subzone casualty rates derived from both the regression model and the historical casualty rates by the mean casualty rate of all the subzones. More specifically, the study divides each subzone casualty rate by the mean casualty rate of all the medium and large dry cargo and tanker vessels of all subzones over the 10-year period. The results are the subzone risk adjustment factors. Table 5-7 presents these results. The study applies these subzone specific adjustment factors to the national average vessel casualty rates (which have been previously displayed in Table 5-2) and then applies the product to the appropriate forecasted vessel transits in each subzone over the forecast period.

TABLE 5-7. SUBZONE RISK ADJUSTMENT FACTORS

Subzone	Type	Risk Value
1 BOSTON, MA		
1	A	0.37508
2	B	0.03127
3	C	0.75154
4	D	0.46461
5	E	2.81203
2 PUGET SOUND, WA		
1	A	0.91939
2	B	0.30525
3	C	0.64297
4	E	1.04813
5	C	0.01971
6	D	0.09593
7	D	0.78129
9	E	2.90479
10	D	0.03905
3 LA/LONG BEACH, CA		
1	A	0.02371
2	B	0.44709
3	C	0.23691
4	D	0.60029
4 SANTA BARBARA, CA		
1	A	0.26169
5 PORT ARTHUR, TX		
1	A	0.53874
2	E	2.38349
3	E	4.38490
4	F	1.07481
6 NEW ORLEANS, LA		
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		
1	A	0.03408
2	E	2.91751
3	D	0.18659
8 CHESAPEAKE SOUTH, VA		
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		
1	C	1.91003
2	D	0.32546
3	F	1.73354
10 CORPUS CHRISTI, TX		
1	A	0.06922
2	B	0.50529
3	E	1.72868
4	F	0.83066
11 NEW YORK CITY, NY		
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 SOUND, NY		
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		
1	A	0.50696
2	B	0.33529
3	C	1.08857
4	F	1.91007
14 SAN FRANCISCO, CA		
1	A	0.14195
2	B	0.45094
3	C	0.84060
4	D	0.46885
5	F	2.53756
15 PORTLAND, OR		
1	A	0.17350
2	C	1.96100
3	F	3.36973
16 ANCHORAGE, AK		
1	A	0.43966
2	C	5.84886
3	D	1.36514
17 PORTLAND, ME		
1	A	0.00920
2	C	0.13546
3	D	0.18200
18 PORTSMOUTH, NH		
1	A	0.02258
2	B	0.04338
3	D	0.11890
19 PROVIDENCE, RI		
1	A	1.43090
2	C	1.76036
3	D	1.34687
20 WILMINGTON, NC		
1	A	0.00840
2	E	0.85509
3	F	1.67455
21 JACKSONVILLE, FL		
1	A	0.22962
2	E	3.04065
22 TAMPA, FL		
1	A	0.79077
2	C	5.12433
3	D	0.51059
23 MOBILE, AL		
1	A	0.04222
2	E	2.10450
3	C	0.44332
4	E	4.19989
5	F	0.44424

Note: Subzones No. 2-8, 13-5, 17-4 & 18-4 are not included because they have no dominant vessel route.

5.2.7 Casualty Rate Table

The study then applies the subzone risk adjustment factors to the national average casualty rates by vessel type, vessel size and casualty type as previously displayed in Table 5-2. As the subzone risk adjustment is the estimated subzone risk probability relative to the national average, multiplying the national average of any vessel casualty category by the subzone adjustment factor results in a vessel casualty probability of that vessel category and casualty type for that subzone. This process results in a matrix of 5,130 values for vessel casualty probabilities (i.e., 95 subzones, by six vessel types, by three vessel sizes and by three casualty types with some blank cells).

5.3 PROJECTION OF FUTURE VESSEL CASUALTIES

Applying this subzone specific probability of a casualty by vessel type and size and casualty type, to the forecasted traffic yields an estimate of the probable number of future vessel casualties of each type in each study subzone for the NO-VTS Case. This process takes into consideration the unique navigational character of each study zone, including historical casualties, navigational characteristics as well as vessel traffic volumes and patterns. In order to estimate the avoided casualties attributable to the Candidate VTS Design, the study then applies a VTS Effectiveness Factor to the NO-VTS case vessel casualties in each study subzone. A table of VTS Effectiveness Factors was derived for each subzone and casualty type, and vessel size.

The study applies the appropriate casualty risk probability to the forecasted future (i.e., 1996-2010) traffic flow for each vessel category in each study subzone to estimate the future vessel casualties in each subzone. The study calculates two cases for each time period (beginning with 1996 and ending with 2010) in each subzone, the NO-VTS case (i.e., without VTS) and the Candidate VTS Design case. The difference in the number of casualties between the two cases represents the avoided casualties which the study attributes to the VTS services.

5.4 VTS EFFECTIVENESS

The study represents the effect of VTS on the number of vessel casualties on a matrix of VTS Effectiveness Factors (or casualty reduction factors) which the study applies to the NO-VTS case casualties. A review of the VTS effectiveness literature covering U.S. and foreign research suggests three potential approaches to estimation of VTS effectiveness:

- o Statistical analysis of casualties in situations "with and without" VTS;
- o Simulation of a VTS system; and
- o Synthesis of expert opinion.

The current state of experience suggests that statistical "with and without" analyses are impractical because of the sparsity of observations within a short enough time frame to permit exclusion of the many confounding variables which obscure the effect of the VTS. Simulation methods are effective training tools but are not capable of addressing VTS effectiveness in the overall content of this study.

Therefore this study uses a synthesis of expert opinion as the primary method to develop VTS effectiveness factors for application in the vessel casualty forecasting.[3]

Three levels of VTS service have been defined, for which the effectiveness of VTS is estimated in combination with other factors (e.g., type of casualty, type of waterbody, and vessel size). Two of the levels represent the technologies applied as part of the Candidate VTS Design (i.e., Level I and Level III) which this subsection discusses. The other level (i.e., Level II) represents the technology currently in existence in several of the study zones. Subsection 5.4.2. discusses Level II.

- VTS Level I

A Vessel Movement Reporting System consisting of VHF radio communications and various vessel reporting way points. This level does not include radar surveillance.

[3] A.T. Kearney, "Effectiveness of Vessel Traffic Service Systems in Reducing Vessel Accidents," March 1991, Vol III.

- VTS Level II

The Vessel Movement Reporting System of Level I is coupled with basic radar surveillance. The study assumes the radar technology to be equivalent to a good quality, recent vintage, standard shipboard type radar without any advanced features.

- VTS Level III

This level represents the new Coast Guard state of the art Candidate VTS Design defined for each study zone in Section 7.

5.4.1 Candidate VTS Design

Table 5-8 presents a matrix of VTS Effectiveness Factors (i.e., vessel casualty reduction factors) for the Candidate VTS Design. The study applies Levels I and III effectiveness factors to the forecasted NO-VTS case vessel casualties in each study subzone to estimate the avoided casualties attributable to the Candidate VTS Design. Table 5-8 represents the maximum level of differentiation feasible without comprehensive data gathered from a controlled experiment. The study applies the factors by casualty type, vessel size, and subzone type to each of the 99 subzones.

The VTS effectiveness factor for each of these VTS levels, casualty types and vessel sizes represents a judgement call. The VTS effectiveness factor matrix is the product of combining the results of recent published international research on VTS effectiveness with the results of a series of three "focus group" panel sessions conducted as part of this project, and application to the "VTS Addressable Casualties" from the Coast Guard historical file of vessel casualties. The focus groups each contained five or six individuals (retired and active), each with some combination of deep draft vessel navigation experience, vessel traffic service experience and knowledge of the circumstance that have attended recent vessel casualties and/or "near misses."

TABLE 5-8. VTS EFFECTIVENESS FACTORS

	SUBZONE TYPES A, B OR C — VTS LEVEL I	SUBZONE TYPES A, B OR C — VTS LEVEL III VESSEL MOVEMENT AUTO. REPORTING SURV.	SUBZONE TYPES D, E OR F — VTS LEVEL I	SUBZONE TYPES D, E OR F — VTS LEVEL III VESSEL MOVEMENT AUTO. REPORTING SURV.
LARGE AND MEDIUM VESSELS				
COLLISIONS				
TWO VTS PARTICIPANTS	.11	.68	.19	.52
ONE VTS PARTICIPANT	.00	.27	.00	.27
RAMMING				
NAV AIDS	.00	.00	.00	.00
OTHER	.22	.43	.22	.36
GROUNDING				
SHOAL	.10	.20	.10	.20
OTHER	.05	.46	.05	.25
SMALL VESSELS				
COLLISIONS				
TWO VTS PARTICIPANTS	.13	.65	.18	.55
ONE VTS PARTICIPANT	.00	.27	.00	.27
RAMMING				
NAV AIDS	.00	.00	.00	.00
OTHER	.25	.50	.20	.38
GROUNDING				
SHOAL	.10	.20	.10	.20
OTHER	.06	.51	.02	.25

Table 5-9 presents a list of the VTS Effectiveness Factor Levels (i.e., Level I or Level III) that the study judges most applicable to each of the 99 subzones. Section 7 defines the Candidate VTS Design for each study zone as a compilation of VTS modules assigned to each subzone.

TABLE 5-9. VTS EFFECTIVENESS FACTOR APPLICATION TO SUBZONES (Page 1 of 3)

ZONE NO.	NAME	SUBZONE NO.	SUBZONE TYPE	VTS EFF. LEVEL
1	BOSTON, MA	101	A	III
		102	B	III
		103	C	III
		104	D	III
		105	E	III
2	PUGET SOUND, WA	201	A	III
		202	B	III
		203	C	III
		204	E	III
		205	C	III
		206	D	III
		207	D	III
		208	E	I
		209	E	I
		210	D	III
3	LOS ANGELES/LONG BEACH, CA	301	A	III
		302	B	III
		303	C	III
		304	D	III
4	SANTA BARBARA, CA	401	A	III
5	PORT ARTHUR, TX	501	A	III
		502	E	III
		503	E	III
		504	F	I
6	NEW ORLEANS, LA	601	A	III
		602	E	III
		603	F	III
		604	E	III
		605	F	III
		606	F	I
7	HOUSTON/GALVESTON, TX	701	A	III
		702	E	III
		703	D	III
8	CHESAPEAKE SO./HAMPTON ROADS, VA	801	A	III
		802	B	III
		803	C	III
		804	D	III
		805	E	III
		806	C	III

TABLE 5-9. VTS EFFECTIVENESS FACTOR APPLICATION TO SUBZONES (Page 2 of 3)

ZONE	NAME NO.	SUBZONE NO.	SUBZONE TYPE	VTS EFF.
9	CHESAPEAKE NO./BALTIMORE, MD	901	C	I
		902	D	III
		903	F	III
10	CORPUS CHRISTI, TX	1001	A	III
		1002	B	III
		1003	E	III
		1004	F	I
11	NEW YORK CITY, NY	1101	A	III
		1102	B	III
		1103	C	III
		1104	D	I
		1105	E	III
		1106	C	III
		1107	E	III
12	LONG ISLAND SOUND, NY	1201	A	III
		1202	B	III
		1203	C	III
		1204	D	III
		1205	D	III
		1206	E	III
13	PHILADELPHIA/DELAWARE BAY, PA	1301	A	III
		1302	B	III
		1303	C	III
		1304	F	I
		1305	E	III
14	SAN FRANCISCO, CA	1401	A	III
		1402	B	III
		1403	C	III
		1404	D	III
		1405	F	I
15	PORTLAND, OR	1501	A	III
		1502	C	III
		1503	F	I
16	ANCHORAGE/COOK INLET, AK	1601	A	I
		1602	C	III
		1603	D	III
17	PORTLAND, ME	1701	A	III
		1702	C	III
		1703	D	III
		1704	E	III
18	PORTSMOUTH, NH	1801	A	III
		1802	B	III
		1803	D	III
		1804	F	I
19	PROVIDENCE, RI	1901	A	III
		1902	C	III
		1903	D	III

TABLE 5-9. VTS EFFECTIVENESS FACTOR APPLICATION TO SUBZONES (Page 3 of 3)

ZONE NO.	NAME	SUBZONE	SUBZONE VTS NO.	TYPE	EFF. LEVEL
20	WILMINGTON, NC	2001	A	III	
		2002	E	III	
		2003	F	III	
21	JACKSONVILLE, FL	2101	A	III	
		2102	E	I	
22	TAMPA, FL	2201	A	III	
			2202	C	III
			2203	D	III
23	MOBILE, AL	2301	A	III	
			2302	E	III
			2303	C	III
			2304	E	III
			2305	F	I

The VTS Effectiveness Factors previously mentioned in Table 5-8 differ significantly for each casualty type subcategory. The historical casualty data indicates that the historical collisions, rammings, and groundings are of two subtypes. Therefore, the projected casualties of each type are in turn subdivided into two categories. Table 5-10 presents the percentage of each type of vessel casualty to be assigned to each subtype prior to application of the appropriate VTS Effectiveness Factor.

TABLE 5-10. VTS EFFECTIVENESS FACTOR APPLICATION TO VESSEL CASUALTY SUB-TYPES

	PERCENT OF CASUALTIES			
	LARGE & MEDIUM VESSELS		SMALL VESSELS	
	SUBZONE TYPES		SUBZONE TYPES	
	A,B,C	D,E,F	A,B,C	D,E,F
COLLISIONS				
BOTH VTS PARTICIPANTS	51	89	40	67
ONE NON-PARTICIPANT	49	11	60	33
	---	---	---	---
	100	100	100	100
RAMMINGS				
RAMMING NAVAID	35	39	43	33
OTHERS	65	61	57	67
	---	---	---	---
	100	100	100	100
GROUNDINGS				
SHOALING	27	46	35	31
OTHERS	73	54	65	69
	---	---	---	---
	100	100	100	100

5.4.2 Existing Vessel Traffic Services

During the base period (1979-1989) used by this study to calculate historical vessel casualty rates, five of the study zones had some form of Coast Guard VTS in operation in one or more of their respective subzones. The vessel casualty history (during all or part of the base period) of Puget Sound, New Orleans, Houston/Galveston, New York, and San Francisco have been affected, to some extent, by the vessel traffic management services in operation. Several other study zones (Los Angeles/Long Beach, Hampton Roads, Baltimore, Corpus Christi, Delaware Bay and Mobile) had some form of vessel traffic management service operated by local organizations.

The vessel casualties in these study zones are assumed to have been lower than they would have been had the existing vessel traffic management services not been operating. To account for the beneficial effect of existing traffic services in these study zones, and to "back out" any avoided casualties attributable to the operating vessel traffic management services in these study zones and make them comparable to all other study zones, the study increases the base period historical casualties.

5.4.2 Existing Vessel Traffic Services (Cont.)

The adjustment equation is:

Adjusted Historical Vessel Casualties =
Historical Casualties ÷
(1 - Effectiveness Factor)

The existing systems are judged to be either Level I or Level II technologies. Table 5-11 presents a set of effectiveness factors for Level II. (The study derives estimated effectiveness factors for Level II from the results obtained from development of Levels I and III.) The study bases the application of the appropriate VTS adjustment factors to the subcategories of vessel casualty types on the percentage distributions listed previously in Table 5-10.

TABLE 5-11. EXISTING VESSEL TRAFFIC SERVICE EFFECTIVENESS FACTORS (HISTORICAL CASUALTY ADJUSTMENT FACTORS)

	SUBZONE TYPES A, B OR C		SUBZONE TYPES D, E OR F	
	VTS LEVEL I	VTS LEVEL II	VTS LEVEL I	VTS LEVEL II
	VESSEL MOVEMENT RADAR REPORTING SURVEILLANCE		VESSEL MOVEMENT RADAR REPORTING SURVEILLANCE	
LARGE AND MEDIUM VESSELS				
COLLISIONS				
TWO VTS PARTICIPANTS	.11	.53	.19	.41
ONE VTS PARTICIPANT	.00	.20	.00	.20
RAMMING				
NAV AIDS	.00	.00	.00	.00
OTHER	.22	.39	.22	.35
GROUNDING				
SHOAL	.10	.20	.10	.20
OTHER	.05	.38	.05	.22
SMALL VESSELS				
COLLISIONS				
TWO VTS PARTICIPANTS	.13	.51	.18	.44
ONE VTS PARTICIPANT	.00	.20	.00	.20
RAMMING				
NAV AIDS	.00	.00	.00	.00
OTHER	.25	.48	.20	.35
GROUNDING				
SHOAL	.10	.20	.10	.20
OTHER	.06	.43	.02	.21

NOTES:
1) ADJUSTED HIS. CAS. = HIS. CAS. / (1 - FACTOR)
2) TABLES 5-12 AND 5-13 INDICATE APPLICATION OF THESE FACTORS TO HISTORICAL CASUALTIES IN SPECIFIC SUBZONES DURING SPECIFIC YEARS.

5.4.2 Existing Vessel Traffic Services (Cont.)

Table 5-12 presents a list of subzones in each zone where Coast Guard existing VTS systems have been operational, the time period of operation, and the VTS level believed to apply to each subzone.

NOTE: Tables 5-12 and 5-13 present results of study team investigations as reviewed by Coast Guard MSO's and VTS offices.

TABLE 5-12. EXISTING VTS LEVELS - CASUALTY DATA PERIOD 1979-1990 (COAST GUARD VTS SYSTEMS CASUALTY ADJUSTMENTS)

STUDY SUBZONES	OPERATING PERIOD			
2 PUGET SOUND	'79	'80	'81-'91	'92>
201A	I	I	II	II
202B	I	I	II	II
203C	II	II	II	II
204E	I	I	II	II
205C	I	II	II	II
206D	I	I	I	I
207D	II	II	II	II
208E	I	I	I	I
209E	I	I	I	I
210D	I	I	I	II
6 NEW ORLEANS(1)	'79-'80		'82-'88	
601A	-		-	
602E	I		I	
603F	I		I	
604E	I		I	
605F	I		I	
606F	I		I	
7 HOUSTON/GALVESTON	'79>			
701A	I			
702E	II			
703D	II			
11 NEW YORK CITY(1)	'79-'80		'85-'88	'90>
1101A	-		-	-
1102B	II		II	II
1103C	II		II	II
1104D	-		-	-
1105E	II		II	II
1106C	II		II	II
1107E	I		I	I
14 SAN FRANCISCO	'79>			
1401A	-			
1402B	II			
1403C	II			
1404D	II			
1405F	-			

Table 5-13 presents a list of subzones in each study zone where non-Coast Guard vessel traffic services have been operational, the VTS level, and coverage believed applicable.

TABLE 5-13. EXISTING VTS LEVELS - CASUALTY DATA PERIOD 1979-1990 (NON-COAST GUARD VTS SYSTEMS CASUALTY ADJUSTMENTS)

STUDY SUBZONES	VESSEL PARTICIPATION	
3 LA/LONG BEACH		(1)
301A	-	
302B	II	
303C	II	
304D	II	
8 CHESAPEAKE SOUTH/HAMPTON ROADS		(2)
801A	II	
802B	II	
803C	II	
804D	-	
805E	-	
806C		-
9 CHESAPEAKE NORTH/BALTIMORE		(2)
901C	-	
902D	-	
903F	I	
10 CORPUS CHRISTI		(3)
1001A	-	
1002B	-	
1003E	I	
1004F	I	
13 PHILADELPHIA/DELAWARE BAY		(3)
1301A	-	
1302B	II	
1303C	I	
1304F	I	
1305E	I	
23 MOBILE, AL		(1)
2301A	-	
2302E	-	
2303C	-	
2304E	-	
2305F	-	

NOTES:
(1) PARTICIPATION = 100% OF MEDIUM SIZED PASSENGER VESSELS, LARGE AND MEDIUM DRY CARGO VESSELS, AND LARGE AND MEDIUM TANKERS
(2) PARTICIPATION = ALL OF (1) PLUS 60% OF BARGES
(3) PARTICIPATION = 100% OF ALL COMMERCIAL VESSELS
(4) ALL NON-COAST GUARD SYSTEMS OPERATING FROM 1979 TO PRESENT

5.4.2 Existing Vessel Traffic Services (Cont.)

The study applies these adjustment factors to the historical vessel casualties to delete the VTS beneficial effects by increasing the historical casualties, in each subzone, in the years the respective traffic services were operational. The study applies the factors using the following criteria:

- VTS Level
- Casualty Type
- Vessel Size
- Subzone Type

Only after applying the appropriate adjustment factors to increase the historical casualties in these study zones (i.e., reflect a non-VTS environment) the study aggregates these casualties with casualties in other study zones for the purpose of estimating base NO-VTS risk probabilities.

5.5 CONSEQUENCES OF CASUALTIES

The purpose of this section is to utilize the Section 4 analysis of consequences of addressable casualties that occurred during the 1979-1990 study period as a basis for developing probability distributions of each of seven consequence types, given a vessel casualty. The study explored several procedures in order to extract the necessary information from the limited data available. Section 6 provides the unit cost values of each consequence type associated with these casualties and Section 8 presents the projected avoided losses or benefits attributable to the Candidate VTS Design. The VTS benefits of Section 8 are the product of the vessel casualty probabilities, the consequence probabilities and VTS effectiveness factors and the unit value of each avoided consequence projected for the time period 1996-2010.

To determine the probability of occurrence of a particular consequence and its severity, the study examines several factors. These factors include vessel type and size, casualty type, and measures of severity. Addressable casualties will result in consequences ranging from near zero impact to potentially catastrophic impacts.

5.5 CONSEQUENCES OF CASUALTIES (Cont.)

The consequences of VTS addressable casualties that this section addresses include the following:

- Human Deaths;
- Human Injuries;
- Vessel Damage;
- Cargo Damage or Loss;
- Bridge Damage;
- Navigational Aid Damage; and
- Spills of hazardous commodities.

  The environmental and commercial impact of hazardous commodity spills of various sizes are addressed in Section 6.

It would be desirable to develop unique probability values for each type of casualty, for each type and size of vessel in each type of subzone. The discussion in Section 4 indicates that the historical data in the CASMAIN file are too sparse, necessitating aggregations across one or more of these dimensions. The aggregation the study selects for each consequence type is dictated by the number of actual observations available.

5.5.1 Human Deaths

Table 5-14 displays the historical data for human fatalities associated with VTS addressable vessel casualties and probabilities of future human fatalities given a projected vessel casualty. From 2,210 vessel casualties of all types, a total of 61 human fatalities occurred during the historical period. The probability for projection of future fatalities, given projected vessel casualties, is unique for each of the four categories shown. The overall average indicates that 2.8% of the vessel casualties result in a fatality.

TABLE 5-14. PROBABILITY OF LOSS OF HUMAN LIFE - GIVEN A VESSEL CASUALTY

Casualty Type	Vessel Type (Aggregated)	Vessel Size	Count of Human Deaths	Count of Vessel * Casualties	Probability of Human Life Lost
All Casualty Types	Pass., Dry Cargo	L, M	37	295	0.12542
All Casualty Types	Pass., Dry Cargo	S	21	328	0.06402
All Casualty Types	Tanker/Barge/Tug	L, M	0	226	0.00000
All Casualty Types	Tanker/Barge/Tug	S	3	1,361	0.00220
Average Probability			61	2,210	0.02760

* All Vessel types and sizes L = Large, M = Medium, S = Small

5.5.2 Human Injuries

Table 5-15 displays the historical data for human injuries associated with VTS addressable vessel casualties and probabilities of future injuries, given a projected vessel casualty. Out of 2,210 vessel, casualties, 227 human injuries occurred during the historical period. The overall average indicates that 10.3% of the vessel casualties result in human injuries.

TABLE 5-15. PROBABILITY OF HUMAN INJURY - GIVEN A VESSEL CASUALTY

Casualty Type	Vessel Type (Aggregated)	Vessel Size	Count of Human Injuries	Count of Vessel * Casualties	Probability of Human Injury
All Casualty Types	Pass., Dry Cargo	L, M	3	295	0.01017
All Casualty Types	Pass., Dry Cargo	S	193	328	0.58841
All Casualty Types	Tanker/Barge/Tug	L, M	0	226	0.00000
All Casualty Types	Tanker/Barge/Tug	S	31	1,361	0.02278
Average Probability			227	2,210	0.10271

* All Vessel types and sizes

5.5.2 Human Injuries (Cont.)

Table 5-16 displays the historical distribution of injuries by type of injury and the probability of each of the eight types of injuries, given projected future injuries.

TABLE 5-16. PROBABILITY OF INJURY TYPE - GIVEN A HUMAN INJURY

Injury Type	Number of Observations	Probability of Injury Type
1. Spinal Cord	7	0.03084
2. Brain	2	0.00881
3. Lower Extremity	8	0.03524
4. Upper Extremity	4	0.01762
5. Trunk & Abdomen	10	0.04405
6. Face, Head, Neck	0	0.00000
7. Minor External	19	0.08370
8. Multiple Injuries	177	0.77973
	227	1.00000

5.5.3 Vessel Damage

Table 5-17 displays the historical data for vessels damaged in VTS addressable vessel casualties and the probabilities of future vessel damage given projected vessel casualties. Out of 2,210 vessel casualties, 889 vessels were damaged during the historical period. The probability of vessel damage resulting from a projected vessel casualty is unique for each of the 24 categories shown; the overall average indicates that 40.2% of the vessel casualties result in vessel damage.

TABLE 5-17. PROBABILITY OF VESSEL DAMAGE - GIVEN A VESSEL CASUALTY

Casualty Type	Vessel Type (Aggregated)	Vessel Size	Count of Vessels Damaged	Count of Vessel * Casualties	Probability of Vessel Damage
Collision	Barge	L, M	10	11	0.90909
Collision	Barge	S	277	363	0.76309
Collision	Dry Cargo	L, M	66	89	0.74157
Collision	Dry Cargo	S	132	154	0.85714
Collision	Passenger	S	29	34	0.85294
Collision	Tanker	L, M	37	49	0.75510
Collision	Tugboat	S	49	278	0.17626
Ramming	Barge	L, M	2	4	0.50000
Ramming	Barge	S	60	142	0.42254
Ramming	Dry Cargo	L, M	22	31	0.70968
Ramming	Dry Cargo	S	23	33	0.69697
Ramming	Passenger	S	6	9	0.66667
Ramming	Tanker	L, M	20	25	0.80000
Ramming	Tugboat	S	12	106	0.11321
Grounding	Barge	L, M	3	15	0.20000
Grounding	Barge	S	32	230	0.13913
Grounding	Dry Cargo	L, M	16	164	0.09756
Grounding	Dry Cargo	S	23	44	0.52273
Grounding	Passenger	M	3	7	0.42857
Grounding	Passenger	S	17	54	0.31481
Grounding	Tanker	L, M	16	122	0.13115
Grounding	Tugboat	S	29	233	0.12446
All Casualty Types	Tanker	S	2	9	0.22222
Coll/Ram.	Passenger	M	3	4	0.75000
Average Probability			889	2,210	0.40226

* All Vessel types and sizes

Barge = Tank Barge + Dry Cargo Barge

Table 5-18 displays the distribution of vessel damages among three levels of severity (i.e., dollar value) - severe, moderate and light damage. The study defines each of these levels by dollar ranges which vary by vessel type and size, with 42 ranges in all. The specific definitions are too cumbersome to present here.

TABLE 5-18. PROBABILITY OF VESSEL DAMAGE SEVERITY - GIVEN VESSEL DAMAGE

Casualty Type	Vess. Size	Severity	Number of Vessels Damaged	Probability of Severity
Coll/Ram.	L, M	Severe	15	.09375
Coll/Ram.	L, M	Moderate	26	.16250
Coll/Ram.	L, M	Light	119	.74375
			160	1.00000
Coll/Ram.	S	Severe	23	.03898
Coll/Ram.	S	Moderate	99	.16780
Coll/Ram.	S	Light	468	.79322
			590	1.00000
Grounding	L, M	Severe	5	.13158
Grounding	L, M	Moderate	2	.05263
Grounding	L, M	Light	31	.81579
			38	1.00000
Grounding	S	Severe	6	.05941
Grounding	S	Moderate	22	.21782
Grounding	S	Light	73	.72277
			101	1.00000

5.5.4 Cargo Damage/Loss

Table 5-19 displays the historical data for vessels experiencing cargo damage and/or losses as the result of vessel casualties, and the probabilities of future cargo loss given a vessel casualty. Out of 2,210 vessel casualties, 83 vessels experienced damage or loss of cargo during the historical period. The probability of cargo damage or loss associated with projected vessel casualties is unique to each of eight categories shown; the overall average indicates that 11.2% of the vessel casualties suffer damage (or loss of) cargo.

TABLE 5-19. PROBABILITY OF CARGO DAMAGE/LOSS - GIVEN A VESSEL CASUALTY

Casualty Type	Vessel Type (Aggregated)	Vessel Size	Count of Vessels W/Cargo Damage	Count of Vessel * Casualties	Probability of Cargo Damage	Adjusted ** Probabilities Cargo Damage/Loss
Coll/Ram.	Cargo	L, M	8	209	0.03828	x 3 = 0.11484
Coll/Ram.	Cargo	S	49	696	0.07040	x 3 = 0.21120
Coll/Ram.	Non-Cargo	M	0	4	0.00000	x 3 = 0.00000
Coll/Ram.	Non-Cargo	S	7	427	0.01639	x 3 = 0.04917
Grounding	Cargo	L, M	11	301	0.03654	x 3 = 0.10962
Grounding	Cargo	S	8	279	0.02867	x 3 = 0.08601
Grounding	Non-Cargo	M	0	7	0.00000	x 3 = 0.00000
Grounding	Non-Cargo	S	0	287	0.00000	x 3 = 0.00000
Average Probability			83	2,210	0.03756	x 3 = 0.11268

* All Vessel Types and Sizes
** Adjustment to Compensate for Under-Reporting by CASMAIN.

Table 5-20 displays the distribution of cargo damage/loss occurrences by severity level (i.e., dollar value). The table shows three levels of cargo damage/loss as severe, moderate and light. The study defines these severity levels for each vessel type and size in terms of dollar ranges; 36 ranges in all. The specific definitions are too cumbersome to present here.

NOTE: For consistency with the spill probability (discussed in Subsection 5.5.8), the study applies an adjustment factor of 3.0 to the cargo damage/loss to compensate for CASMAIN under reporting.

TABLE 5-20. PROBABILITY OF CARGO DAMAGE/LOSS SEVERITY - GIVEN CARGO DAMAGE/LOSS

Cargo Damage/Loss Severity	Number of Observations	Adjustment **	Adjusted ** Probability
Severe	37	0	0.14859
Moderate	18	0	0.07229
Light	28	+ 166	0.77912
	83	+ 166	1.00000

** Adjustment to Agree With Table 5-19, Applied to Light Damage/Loss Only.

5.5.5 Bridge Damage From Vessel Casualties

Table 5-21 displays the data for bridge damage from vessel rammings during the historical period, and the probabilities of bridge damage resulting from projected future vessel casualties. These probabilities apply only to those subzones having one or more bridges across the vessel routes. The probability of bridge damage is heavily concentrated in vessel rammings in subzones with bridges, but the overall probability of bridge damage is 1.3% of the total vessel casualties.

TABLE 5-21. PROBABILITY OF BRIDGE DAMAGE - GIVEN A VESSEL CASUALTY

Casualty Type	Vessel Type (Aggregated)	Vessel Size	Count of Vessels Damaging Bridges	Count of Vessel * Casualties	Probability of Bridge Damage
Collision	All Vess. Types	L, M	0.0	120	0.00000
Collision	All Vess. Types	S	1.0	717	0.00139
Ramming	All Vess. Types	L, M	5.5 **	47	0.11702
Ramming	All Vess. Types	S	16.5 **	264	0.06250
Grounding	All Vess. Types	L, M	0.0	233	0.00000
Grounding	All Vess. Types	S	0.0	450	0.00000
Average Probability			23.0	1,831	0.01256

* Only those casualties in subzones having bridges.
** Fractional counts reflect incidents where two or more vessels share responsibility for bridge damage.

The study divides bridge damage from vessel casualties into three levels of severity with a dollar value assigned to each level and the probability of bridge damage severity as Table 5-22 illustrates.

TABLE 5-22. PROBABILITY OF BRIDGE DAMAGE SEVERITY - GIVEN BRIDGE DAMAGE

Severity	Dollar Range	Number of Observations	Probability of Severity
Severe	>$500,000	4	0.17391
Moderate	$100,000 - $500,000	8	0.34783
Light	<$100,000	11	0.47826
		23	1.00000

5.5.6 Navigational Aids Damage

Several types of Navigational Aids (NAVAID) are used to manage marine traffic, including lighthouses, bell buoys, radio beacons, and similar fixed or floating objects. When these aids are rammed by vessels, causing movement, damage, or loss, the NAVAID must be repositioned, repaired, or replaced, resulting in a cost to the Coast Guard.

Table 5-23 displays the data for NAVAIDs damage during the historical period, and the probability of NAVAID damage associated with projected future vessel casualties. The probability of damage to NAVAIDS is concentrated in the vessel rammings, but the overall probability is 2.0% of the total vessel casualties.

TABLE 5-23. PROBABILITY OF NAVAID DAMAGE - GIVEN A VESSEL CASUALTY

Casualty Type	Vessel Type (Aggregated)	Vessel Size	Count of Vessels Damaging NAVAIDS	Count of Vessel * Casualties	Probability of NAVAID Damage
Collision	All Types	All Sizes	0	986	0.00000
Ramming	All Types	All Sizes	40	350	0.11428
Grounding	All Types	All Sizes	5	874	0.00572
Average Probability			45	2,210	0.02036

* All Vessel types and sizes

The study divides NAVAID damage into three levels of severity with a dollar value assigned to each level and the probability of severity level as Table 5-24 shows.

TABLE 5-24. PROBABILITY OF NAVAID DAMAGE SEVERITY - GIVEN NAVAID DAMAGE

Severity Level	Dollar Range	Number of Observations	Probability of Severity
Severe	>$5,000	9	0.20000
Moderate	$1,500 - $5,000	19	0.42222
Light	<$1,500	17	0.37778
		45	1.00000

5.5.7. Probabilities for Projections of Future Spills

5.5.7.1 Analysis Of Historical Data

A small percentage of VTS addressable casualties result in pollution incidents. The CASMAIN data does not directly indicate spills of hazardous commodities associated with vessel casualties. The study uses a surrogate measure, or indicator, of spills to identify 26 "spills" during the historical period. The surrogate measure, or indicator, is the count of vessel casualties reporting both vessel damage and cargo damage or loss. Analysis of the MPRS data, suggests that the spills actually associated with CASMAIN casualties are significantly greater in number than the raw value of the surrogate indicator. The study uses an adjustment factor of 3.0 to produce overall spill probabilities that are considered realistic. CASMAIN appears to report only the largest spills in heavily travelled waterways, thus understating VTS addressable "spill" incidents. Casualties involving smaller vessels in less congested waters, appear to be under reported in CASMAIN. By contrast, the Coast Guard's Marine Pollution Retrieval System (MPRS) appears to overstate the VTS addressable casualties pollution incidents, because VTS addressable casualties can not be isolated from spills at docks, piers, marinas, loading/unloading and other non-VTS pollution incidents.

Using the MPRS data helps to develop a better understanding of the number of potentially addressable pollution incidents, their relative distributions according to vessel and casualty type, and to provide an adjustment factor for the understated "spill" values derived from CASMAIN.

Considering CASMAIN and MPRS as a composite data source, and setting a minimum threshold of 100 gallons to eliminate the many small (and difficult to trace) non-VTS addressable spills, Table 5-25 shows a percentage distribution of the spills among three of the four spill sizes this study uses.

TABLE 5-25. VTS ADDRESSABLE SPILL SIZES

Spill Size	MPRS	CASMAIN
Large = >100K gallons	11.9%	63.6%
Medium = 10K-100K gallons	13.6%	21.2%
Small = 100-10K gallons	74.6%	15.2%

5.5.7.1 Analysis Of Historical Data (Cont.)

Comparison of the distributions from the two sources indicates that the CASMAIN data overstate the large spills as a percentage of the total. Conversely the MPRS data overstate the small spills as a percentage of the total, even after screening out spills less than 100 gallons.

5.5.7.2 Method Of Estimating Probabilities

A method for estimating the probability of spills of hazardous commodities (chemicals as well as petroleum products and crude oil), of various sizes, resulting from projected vessel casualties, has been implemented. This method involves application of a series of probabilities (given a specific vessel casualty type, specific vessel type and size), the probability of a spill of bulk cargo from a breached hull, followed by the probability of the spill being a specific percentage of the total vessel capacity, followed by the probability that the breached vessel hold contains a specific hazardous commodity. Table 5-26 presents the definitions of spill sizes.

TABLE 5-26. SPILL SIZES

Severity Level	Gallons of Commodity
1 = Catastrophic	>750,000 gallons
2 = Large	100,000 - 750,000 gallons
3 = Medium	10,000 - 100,000 gallons
4 = Small	<10,000 gallons

NOTE: Section 6 presents the unit costs to the environment and to local economies of spills of specific commodities and severity levels.

Table 5-27 displays the historical data for vessels experiencing both vessel damage and cargo damage/loss during the historical period. The study derives this indirect indicator from tank vessels and barges on the assumption that if bulk cargo were reported damaged, the hull was breached. As noted in the previous subsection, the study factors up the raw counts of the spill indicator before calculating the probabilities of spills to compensate for the CASMAIN undercount. The study then applies these probabilities to future casualties of tanker vessels and tank barges only, on the assumption that these are the vessels carrying the spillable bulk hazardous commodities. The overall

5.5.7.2 Method Of Estimating Probabilities (Cont.)

adjusted average probability suggests that 13.4% of the vessel casualties result in a "spill." A larger than average probability applies to collisions and rammings and a much smaller probability applies to groundings.

TABLE 5-27. 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
Coll./Ramm.	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. This is used as a surrogate measure of the probability of a breached hull and spill.
*** Only Tankers and Tank Barges Included; Other Vessels Excluded.
**** Adjustment Factor to compensate for CASMAIN undercount of indicator incidents.

Table 5-28 displays the distribution of "spills" by spill severity level. At this point, the four severity levels - total loss, large loss, medium loss, and small loss refer to the percent of the vessel's total capacity that is lost. The study then converts these severity levels to spill sizes defined by gallons of commodity. To arrive at these severities, the study converts the cargo damage/loss events, in dollar value, to tons of commodity lost and then combines them with vessel tonnage capacities, which the study estimates by vessel type, vessel size and commodity carried, yielding the percentage of capacity values shown.

TABLE 5-28. 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 5-27, Applied to Small Capacity Losses Only.

The derivation of the size of the hazardous commodity spill associated with a projected vessel casualty may be represented by the following equation:

<u>Probability of a given spill size (gallons) of a given commodity</u> =

Probability of a Vessel Casualty x
Probability of a Spill x
Probability of Spill Severity (% capacity) x
Probability of a Specific Commodity x
Vessel Capacity (tons) x
Commodity Conversion Factor (gallons/ton)

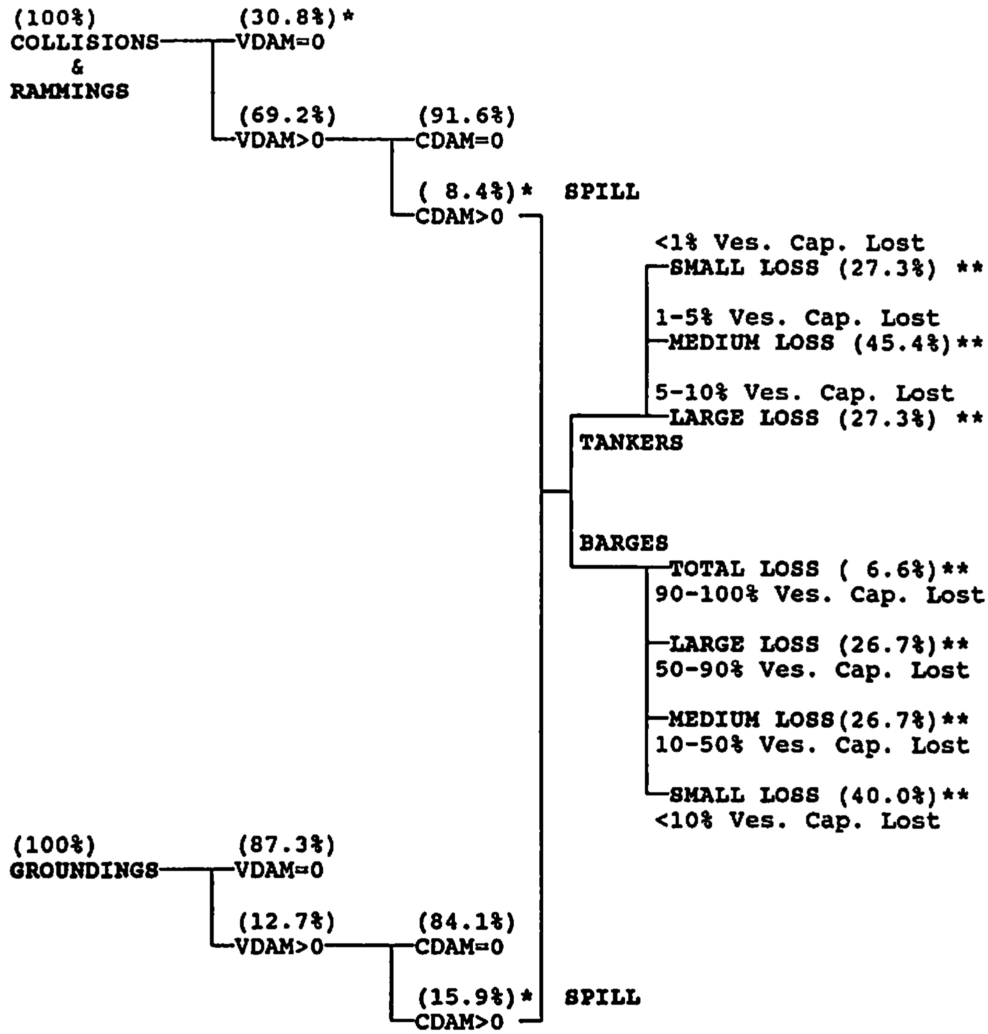
The first two elements of this equation have already been explained. The third element of this equation (i.e., probability of the spill severity as a percentage of vessel capacity is explained in the following paragraphs.

Casualties of vessels carrying crude oil or petroleum products reporting cargo loss or damage in dollars comprise the subset of CASMAIN data the study uses to develop Table 5-28. The study converts the reported dollar value of each cargo loss to gallons of commodity assumed to have spilled by applying an average cost per gallon ($0.65). The study then converts the spill, in gallons, converted to tons of commodity spilled by an average density factor. The study divides the tons of spilled commodity by the average vessel capacity (from a table of vessel tonnage capacities by vessel type, vessel size, and by commodity) to obtain the percent of vessel capacity spilled. The study then distributes all of the observations into the severity levels (1) >90% capacity, (2) 50-90% capacity, (3) 10-50% capacity and (4) <10% capacity to produce the probabilities of spill severity levels.

5.5.7.2 Method Of Estimating Probabilities (Cont.)

The study applies the spill severity probabilities to all projected bulk commodity spills irrespective of bulk commodity carried. The fourth element of this equation (i.e., probability of a specific hazardous commodity) projects the commodity expected in the projected spill. The study derives this element from the vessel traffic and commodity distributions by vessel type and size, and by COE Waterway within each subzone in which the vessel casualty occurs.

Figure 5-2 illustrates the development of the hazardous cargo spill and severity probabilities. Subsequent application of distributions of commodities among vessel types and sizes results in projections of spills of specific hazardous commodities of specific sizes. The previous subsections discussed the process of projecting future spills by spill size. Spills of vessel fuel (bunker) were not included. Subsection 5.5.7.3 discusses vessel fuel spills as incremental additions to cargo spills.



* Derived from CASMAIN - Dry Cargo, Tankers & Barges all Sizes, As a Surrogate for Spill Estimate, as Such Believed to Underestimate Spills by a Factor of 3.

** Derived From CASMAIN - Tankers, & Tank Barges Only all Sizes; Cargo $ Losses Converted to Gallons @ $.65/Gal., and Gallons Spilled Divided by Vessel Hold Capacities.

FIGURE 5-2. HAZARDOUS COMMODITY SPILL AND SEVERITY PROBABILITIES BY CASUALTY TYPE AND VESSEL TYPE

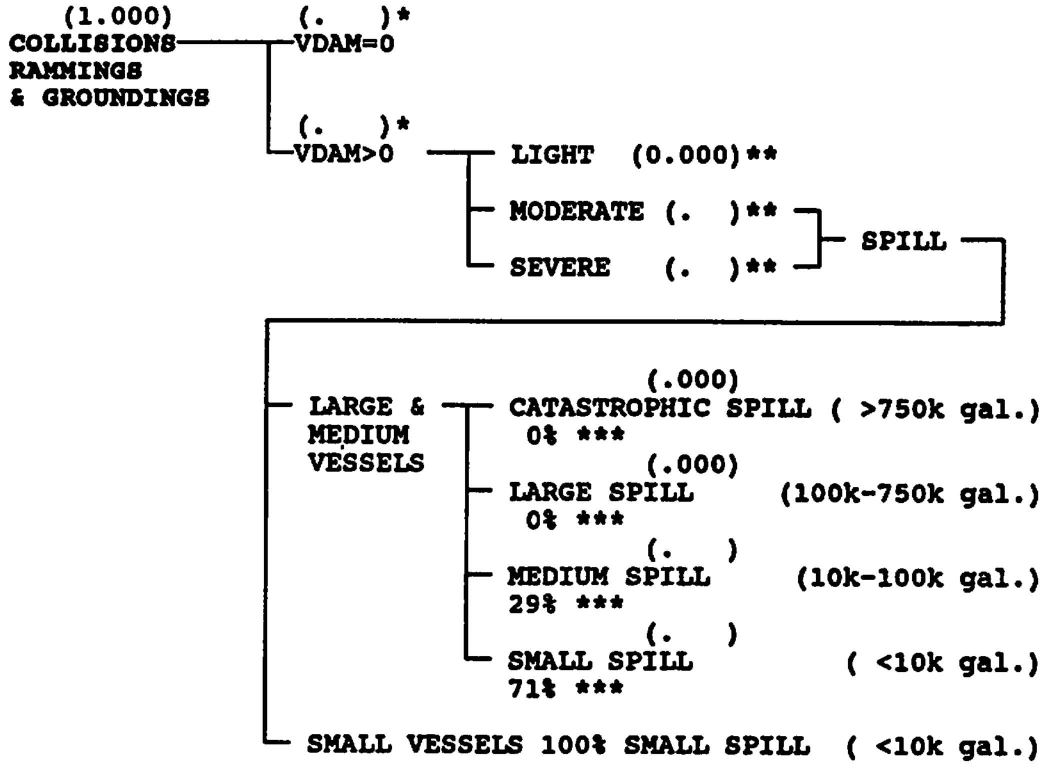
5.5.7.3 Probability Of Vessel Fuel (Bunker) Spills

In addition to spills of hazardous commodities from the bulk cargo holds of vessels, VTS addressable vessel casualties also result in spills of vessel fuels (i.e., bunker). Again, the historical data precludes accurate isolation of vessel fuel spills specifically related to VTS addressable vessel casualties. However, the study develops a method of estimating vessel fuel spills, in addition to the bulk cargo spills, and applies this to all projected vessel casualties. Given a vessel casualty with vessel damage, the study assumes a fuel spill and estimates a specified size from the distribution of spill sizes in Table 5-29. The study makes the assumption that fuel types spilled are #2 fuel oil for small vessels and #6 fuel oil for medium and large vessels. Figure 5-3 illustrates the development of the vessel fuel spill and spill size probabilities. The tables in the appendix (Volume II) display the aggregate result of the complete process of projecting spills (both cargo and vessel fuel) by spill size and commodity type for each study zone.

TABLE 5-29. FUEL (BUNKER) SPILL SIZE DISTRIBUTION

Vessel Type	Spill Size	Observations	Distribution
All	Medium	6	29%
	Small	15	71%
Totals		21	100%

Source: MPRS data set from spill cleanup analysis of Section 6. Selected spills that appear to be vessel fuel (bunker) associated with VTS addressable vessel casualties.



* Vessel Damage Probability Varies By Casualty Type, Vessel Type and Vessel Size (Table 5-17).

** Vessel Damage Severity Probability Varies By Casualty Type & Vessel Size (Table 5-18). Light Vessel Damage Assumed to Result in No Vessel Fuel Spills

*** Derived From ERG Spill Cleanup Cost Study Data (Section 6).

NOTES:

1. Section 6 presents the unit costs to the environment and to the local economies of spills of specific commodities and severity levels.

2. Fuel types spilled are #2 fuel oil (C.O.E. Commodity Code 2914) for small vessels and #6 fuel oil (C.O.E. Commodity Code 2915) for medium and large vessels.

3. Vessel Fuel Spill Probabilities applied to all vessel casualties in addition to hazardous commodity spills from cargo vessels.

FIGURE 5-3. VESSEL FUEL (BUNKER) SPILL AND SPILL SIZE PROBABILITIES

5.5.7.4 Hazardous Commodity Spill Size Distribution

The result of this complex process for projecting future commodity spills may be assessed by examination of Table 5-30. This table presents the 23 study zone aggregate hazardous commodity spills for the forecast period 1996-2010, assuming that the existing VTS situation in all zones is continued unchanged into the future. The table includes all crude oil, petroleum products and chemicals from casualties of tankers and tank barges as well as the vessel fuel (bunker) spills from all vessel types sustaining vessel damage.

TABLE 5-30. HAZARDOUS COMMODITY SPILLS (23 ZONES) 1996-2010

SPILL SIZE		CRUDE OIL	PETROLEUM PRODUCTS	CHEMICAL PRODUCTS	TOTAL
Catastrophic	>750K gallons	5	3	0	8
Large	100-750K gallons	15	10	4	29
Medium	10K-100K gallons	13	81	20	114
Small	<10K gallons	2	133	10	145
TOTAL		35	227	34	296

5.5.7.5 LPG and LNG Spill Probabilities

Section 6 describes the method of estimating probabilities of these liquified petroleum gas (LPG) and liquified natural gas (LNG) spills, and the probabilities of fire and/or explosion given a vessel collision. This study assumes that LPG tanker vessels have the same probability of vessel casualty as any other large tanker in each subzone. The study also assumes that LNG tankers have a probability of vessel casualty one-tenth of that of large tankers in the subzones through which they transit.

6. UNIT COSTS OF VESSEL CASUALTY CONSEQUENCES

6.1 OVERVIEW

The life cycle benefits attributable to an operating Candidate VTS Design in each study zone are the avoided human, environmental and economic losses during the 15-year period from 1996 through 2010. The avoided vessel casualty consequences in terms of their physical units (e.g., number of human fatalities and injuries, number of marine animals lost, etc.) are of concern, but these units must be converted to monetary terms before they can be compared with the costs of installing and operating the Candidate VTS Design. This section presents the average unit dollar values of 11 types of consequences associated with vessel casualties. The study applies the unit dollar values, or loss factors, to the projected consequences (measuring them in physical units) avoided in each subzone over the forecast period, thus producing the aggregate losses avoided. Section 5 discusses the projection of the total quantity of each consequence type and Section 8 presents the results of applying the loss factors.

6.1.1 Consequences Included In The Port Needs Study

The Port Needs Study includes the consequences listed below because they frequently result from the types of vessel casualties likely to occur in the 23 study zones:

- Vessel damage and repair;
- Emergency response;
- Injury to and loss of human life;
- Cargo damage and loss;
- Loss of marine animal species;
- Decrease in tourism and recreational use and in property value of shoreline and harbor;
- Cleanup activities;

6.1.1 Consequences Included In The Port Needs Study (Cont.)

- Losses to subsistence households;
- Damage assessment;
- Damage to bridges and NAVAIDS; and
- Damage from LNG and LPG explosions.

6.1.2 Consequences Not Addressed by the Port Needs Study

The Port Needs Study excludes the consequences listed below for various reasons. In some cases, data are unavailable. In other cases, the consequences are outside the scope of the study. Some of the consequences would occur with a low frequency in a very limited number of casualties. In addition, due to data or estimation limitations the study does not address some minor costs related to the consequences in Section 6.2.1.

- Legal fees for litigation over vessel casualties;
- Damages to overhead power cables, pipelines, docks, piers and platforms;
- Damages to facilities and water supplies;
- Cumulative effects of consecutive spills of hazardous materials on natural resources;
- Effects of chemical releases into the air;
- Damages to vessels too small for participation in VTS; and
- Blockage of channels and waterways.

6.1.3 Social Costs

The costs due to vessel casualties are "social" costs, defined to be the value of the reduced availability of goods and services desired by society as the result of vessel casualties.[1] Social costs include costs that are measured directly by market prices, costs that are borne by others not subject to market fluctuations, such as government agencies and volunteers, and damages that cannot be measured by market prices, such as loss of wildlife and natural resources. The latter is measured in dollar terms by applying the "willingness-to-pay" methodology, since individuals are "willing to pay" to preserve, for instance, endangered species or pristine coastline, using resources that might otherwise be used to purchase goods or services in the marketplace.

The following examples illustrate social costs. The costs of government response to a vessel casualty are social costs, because limited resources must be diverted from other important activities. The reduced enjoyment of persons visiting a beach soiled with oil spilled from a vessel is a net loss to society that cannot be replaced. Similarly, people who are totally prevented from visiting an oil-damaged beach experience reduced enjoyment of an alternative beach. The social costs resulting from vessel damage represent the value of the lost vessel resource to industries needing it to transport their goods.

The Port Needs Study presents the net present value of future losses from a vessel casualty as losses occurring in the year of the casualty.

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[1] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, "Assessing the Social Costs of Oil Spills: The AMOCO CADIZ Case Study," July 1983.

6.2 LOSS FACTOR ANALYSIS AND DEVELOPMENT

6.2.1 Vessel Damage and Repair Costs

6.2.1.1 Background

A vessel casualty sets in motion a series of possible events that depend on the precise nature and severity of the casualty and its location. The costs that result can vary widely. At one extreme, a vessel involved in a grounding may float free in a few hours when the tide rises and have only some scraped paint and minor damage above the water line. At the other extreme, two vessels involved in a collision may suffer millions of dollars of damage apiece, block the waterway until they can be towed away, undergo repairs that take three months to complete, and cause a major release of a hazardous commodity, triggering a cleanup response and causing severe environmental damage.

This section deals with costs stemming directly from damages to the VTS-addressable vessels involved in casualties. These costs cover the repair of the vessels and related charges as well as the social costs of the idle vessels during their repair.

- Repair costs

Repair costs include not only the costs of repairing the vessel, but also the costs associated with other activities that take place prior to the actual repair. A vessel may require refloating before it can be towed to the shipyard. Dry-docking may be necessary if the vessel's hull has been damaged below the water line. Damaged fuel and cargo tanks must be cleaned and freed of gases before welding can begin to prevent explosions and fires that the repair process might set.

- Other social costs

During times of full utilization of the world vessel fleet, a vessel's unavailability while being repaired represents an idle resource that imposes a cost on society. The various costs that accrue to the shipowner over and above the repair costs and lost profit during the idle time are assumed to represent the lost worth of that vessel for the period, and are used as a proxy for the cost to society.

Typically, these costs are attributable to crew dismissal, vessel operation, capital charges, and exceptional port services. Operating costs include crew salaries, stores, supplies, maintenance, management and insurance.

6.2.1.1 Background (Cont.)

The study develops costs for individual vessels, rather than casualty events. For example, the total cost of a collision between a passenger vessel and a barge-towboat combination is the sum of the costs incurred by each of the three vessels involved in the casualty.

6.2.1.2 Results

Table 6-1 shows total damages by vessel type and damage severity category, including total loss of the vessel. The total column represents the sum of vessel damage repair and appropriate ancillary costs. The basis for repair costs is an analysis of historical CASMAIN data, and the basis for replacement costs for vessels suffering total losses is five-year-old vessel prices published in Lloyd's Shipping Economist. For some vessel types, especially passenger and dry cargo, estimated costs for a total vessel loss are significantly greater than those for a severe casualty. Historical distributions of damages to those vessel types reveal they have enjoyed a record of low damages relative to overall vessel value.

TABLE 6-1. VESSEL DAMAGE AND ANCILLARY COSTS (Page 1 of 2)

Vessel Type	Size	Casualty Type	Severity	Damage ($1,000)	Ancillary Costs ($1,000)	Total ($1,000)
Passenger	S	C	L	16.0	0.0	16.0
			M	99.2	25.7	124.9
			S	625.0	45.0	670.0
		G	L	11.2	7.0	18.2
			M	261.6	31.2	292.8
			S	1,870.0	41.1	1,911.1
		T	T	10,000.0	10.5	10,010.5
	L	C	L	62.5	0.0	62.5
			M	187.5	30.0	217.5
			S	1,240.0	80.0	1,320.0
		G	L	67.3	7.0	74.3
			M	140.9	43.0	183.9
			S	1,250.0	87.0	1,337.0
		T	T	60,000.0	21.0	60,021.0
Dry Cargo	S	C	L	18.1	0.0	18.1
			M	58.9	25.7	84.6
			S	600.0	42.1	642.1
		G	L	12.3	7.0	19.3
			M	125.0	37.1	162.1
			S	1,000.0	45.1	1,045.1
		T	T	3,200.0	14.0	3,214.0
	M	C	L	48.1	0.0	48.1
			M	231.4	30.0	261.4
			S	6,250.0	191.8	6,441.8
		G	L	25.4	7.0	32.4
			M	231.4	64.8	296.2
			S	1,300.0	85.8	1,385.8
		T	T	8,548.3	21.0	8,569.3
	L	C	L	62.5	0.0	62.5
			M	248.2	39.5	287.7
			S	6,000.0	582.5	6,582.5
		G	L	23.1	7.0	30.1
			M	344.7	132.5	477.2
			S	1,800.0	279.5	2,079.5
		T	T	18,000.0	21.0	18,021.0
Tanker	S	C	L	25.0	0.0	25.0
			M	112.7	29.0	141.7
			S	220.7	38.9	259.6
		G	L	55.2	7.0	62.2
			M	169.1	37.9	207.0
			S	441.2	42.9	484.1
		T	T	5,000.0	10.5	5,010.5
	M	C	L	78.7	0.0	78.7
			M	330.9	40.0	370.9
			S	1,360.0	237.0	1,597.0
		G	L	40.5	7.0	47.5
			M	163.4	94.5	257.9
			S	1,051.0	184.0	1,235.0
		T	T	15,000.0	28.0	15,028.0
	L	C	L	58.9	0.0	58.9
			M	136.0	58.0	194.0
			S	1,870.0	397.0	2,267.0
		G	L	63.6	14.0	77.6
			M	462.8	170.0	632.8
			S	12,500.0	767.0	13,267.0
		T	T	20,000.0	42.0	20,042.0

TABLE 6-1. VESSEL DAMAGE AND ANCILLARY COSTS (Page 2 of 2)

Vessel Type	Size	Casualty Type	Severity	Damage ($1,000)	Ancillary Costs ($1,000)	Total ($1,000)
Dry Barge	S	C	L	17.7	0.0	17.7
			M	99.8	2.0	101.8
			S	270.5	7.2	277.6
		G	L	7.3	2.0	9.3
			M	42.0	6.2	48.2
			S	281.8	7.2	288.9
		T	T	300.0	3.5	303.5
	L	C	L	52.9	0.0	52.9
			M	120.0	3.5	123.5
			S	405.0	13.8	418.7
		G	L	26.3	3.5	29.8
			M	120.0	11.1	131.1
			S	318.1	13.8	331.8
		T	T	650.0	7.0	657.0
Tank Barge	S	C	L	30.0	0.0	30.0
			M	112.7	22.5	135.2
			S	294.5	33.0	327.5
		G	L	13.6	7.0	20.6
			M	108.9	28.2	137.1
			S	1,051.0	43.0	1,094.0
		T	T	1,300.0	10.5	1,310.5
	L	C	L	52.5	3.5	56.0
			M	240.0	40.0	280.0
			S	563.5	52.9	616.4
		G	L	33.1	7.0	40.1
			M	259.0	43.5	302.5
			S	1,200.0	65.5	1,265.5
		T	T	3,000.0	21.0	3,021.0
Tow, Tug		C	L	25.2	0.0	25.2
			M	87.5	6.0	93.5
			S	516.7	14.8	531.5
		G	L	28.2	3.5	31.7
			M	98.0	8.5	106.5
			S	625.0	14.8	639.8
		T	T	800.0	7.0	807.0

Size: S = small; M = medium; L = large
Casualty type: C = collision or ramming; G = grounding; T = total loss
Severity: L = low; M = moderate; S = severe; T = total loss

6.2.1.2 Results (Cont.)

Table 6-2 shows the social costs of idle vessels.[2] Because no comprehensive written sources exist, this information was obtained through personal interviews with industry experts, shipyard operators, ship's agents, and consultants, and through published information on specific cases, anecdotes and examples.

TABLE 6-2. SOCIAL COSTS OF IDLE VESSELS PER VESSEL CASUALTY ($1,000)

Vessel Type	Size	Vessel Damage Severity		
		Low	Moderate	Severe
Passenger/ferry				
	small	151	751	1,051
	medium	407	2,007	2,807
Dry cargo vessel				
	small	94	242	692
	medium	125	321	921
	large	167	426	1,226
Tanker				
	small	164	417	1,217
	medium	205	521	1,521
	large	247	626	1,826
Barges - dry/tanker (including tow boat)				
	small	9	38	83
	large	13	60	135

[2]The study bases this table on information found in "Develop Estimates of Costs Associated with Oil and Hazardous Chemical Spills and Costs of Idle Resources during Vessel Repairs," Eastern Research Group, Inc., November, 1990, Vol. III.

6.2.2 Emergency Response

6.2.2.1 Background

- Range of response activities

  The Coast Guard responds to every casualty that is reported. At a minimum, a Coast Guard cutter or other vessel is sent to the scene for casualties occurring near the shore, or an overflight is conducted in a helicopter or search plane for casualties occurring offshore. For severe casualties, the Coast Guard may respond by sending numerous vessels and personnel to the scene, monitoring the situation until the vessel is moved or the spill is cleaned up, conducting search and rescue missions, federalizing the spill cleanup, and more.

  Search and rescue situations often bring local agencies into action. Harbor patrols, harbor police, the Coast Guard Auxiliary, the harbormaster, and volunteers may all contribute to the effort.

  Spills of hazardous commodities bring other federal and state and local agencies into action, as well as many volunteers. For example, the federal Departments of the Interior, Commerce, Agriculture, Defense, Health and Human Services, Justice, Labor, and Transportation, and the Environmental Protection Agency all participated in the response to the Exxon Valdez spill. In addition, many agencies from the state of Alaska were heavily involved.

6.2.2.1 Background (Cont.)

- Cost of response activities

  The cost of response includes salaries of personnel involved in the response, equipment and vessel usage charges, and costs of supplies. The costs are broken down into the cost source activity categories listed below.

  - Basic response assumes a single Coast Guard vessel visits the scene of the casualty, performs a brief NAVAID check, and remains on scene to assure that no complications develop before the vessel departs.

  - Pollution threat is assumed to be present for all self-propelled vessels and for barges. Some threat to navigation is also assumed, and a safety zone is created until such time as the salvage master has determined there is no danger.

  - Light pollution cases are assumed to need no cleanup action and to remain unfederalized. The Coast Guard would maintain a safety zone while the vessel was patched. This category incorporates costs from the pollution threat category, as well as costs of investigation and report writing.

  - Medium pollution cases are assumed to be federalized thirty percent of the time. Aircraft may be called in as well as a three-person strike team.

  - Heavy pollution figures are based on the costs of response in the World Prodigy grounding. In addition, the cost of maintaining a strict safety zone or waterway closure are added in.

  - Catastrophic pollution costs are based on federal agency costs reported by the General Accounting Office in connection with the Exxon Valdez. This case included costs of other federal and state government agencies involved in the response.

  - Evacuation of crew and/or passengers is divided into two classes based on the size of the vessel and the complexity of the evacuation. It includes the usage cost of the vessel to which the persons on board are transferred and the costs of housing them and providing them with passage home.

6.2.2.1 Background (Cont.)

- Bridge collision assumes two days of channel closing, enforced by two boats, 80 hours of work by Coast Guard and other bridge engineering personnel, a NAVAID check, and 40 hours of investigative time.

6.2.2.2 Results

Table 6-3 shows the dollar costs for each of the response activity categories described in Section 6.2.2.1.

TABLE 6-3. RESPONSE COST FACTORS BY SOURCE ($1,000)

VESSEL TYPE	BASIC RESP	POLL THRT	POLL LITE	POLL MED	POLL HVY	POLL CATA	EVAC SIMP	EVAC DIFF	BRDG RAM
TANKER	1.4	4.5	11.7	28.0	701.6	29,500.0	0.0	0.0	20.7
DRY CARGO	1.4	4.5	11.7	28.0	701.6	0.0	0.0	0.0	20.7
TANK BARGE	1.4	4.5	11.7	28.0	701.6	19,667.0	0.0	0.0	20.7
DRY BARGE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.7
SMALL PASS	3.3	3.4	10.6	20.6	0.0	0.0	58.0	116.0	20.7
LARGE PASS	4.5	4.5	11.7	28.0	701.6	0.0	220.0	440.0	20.7
TOW	1.4	2.2	5.8	22.2	0.0	0.0	0.0	0.0	0.0

6.2.3 Injury to and Loss of Human Life

6.2.3.1 Background

When a crew member or a passenger is injured in a vessel casualty, costs are incurred by the individual injured and by society in general from a number of sources:

- Hospital care, medical treatment, and rehabilitation training;
- Legal fees;
- Insurance payments;
- Pain and suffering compensation; and
- Lost productivity and wages.

When a human fatality results from a vessel casualty, the cost types above are also incurred except for medical costs, assuming the fatality occurs during the casualty. However, the pain and suffering compensation to bereaved relatives and the lost productivity and wages may be much greater. Many studies, too numerous to list here, have attempted to place a value on human life with as many different estimates of value resulting. Even within the U.S. Department of Transportation (DOT) values for human life used in benefit-cost analyses have ranged from one to one and a half million dollars. A recent study performed at VNTSC for the Office of the Secretary of Transportation recommends that DOT use a value of one and one half million dollars. The VTS study complies with this recommendation.

6.2.3.2 Results

Table 6-4 shows the cost factors for human injuries and human fatalities by body region. The table separates pain and suffering costs from all other costs to illustrate their magnitude. The source of these results is an unpublished database of costs of nonfatal highway accident injuries developed by the Urban Institute.

TABLE 6-4. COSTS OF HUMAN INJURIES AND FATALITIES

BODY REGION	PAIN and SUFFERING	ALL OTHER*	TOTAL
Spinal Cord	$813,000	$713,000	$1,526,000
Brain	76,000	17,000	93,000
Lower Extremity	118,000	39,000	157,000
Upper Extremity	40,000	21,000	61,000
Trunk & Abdomen	37,000	10,000	47,000
Face, Other Head and Other Neck	11,000	7,000	18,000
Minor External	2,300	2,100	4,400
Multiple Injuries	220,000	60,000	280,000
Death			1,500,000

* ALL OTHER includes medical care, hospitalization, vocational rehabilitation, lost productivity, lost wages, insurance administration, employer costs, emergency services, court costs, and legal expenses.

6.2.4 Cargo Loss

6.2.4.1 Background

This section confines the area of cargo loss primarily to cargo that is lost overboard in a vessel casualty by falling from the deck or leaking into the water from a ruptured cargo tank. This cargo is generally not retrievable and the Port Needs Study considers it totally lost. The study does not make allowances for the small proportion of oil and petroleum products that may be recovered from the surface of the water. Packaging and containerization generally prevent damage to most non-bulk cargo, barring the vessel's sinking. Such cargo is often lightered from the damaged vessel for delivery to port, and damages are not an issue.

The list of commodities for which values are derived consists of the individual hazardous commodities customarily carried in bulk form and used in the environmental damages model described in Section 6.2.5 and commodity groups at the two-digit Army Corps of Engineers (ACOE) code level for the remaining non-toxic commodities. In addition to specific commodities, the study calculated the value of a typical import and the value of a typical export container for container vessel casualties, which often result in one or more containers falling overboard.

6.2.4.2 Results

Table 6-5 shows the unit prices of commodity groups. Commodity prices are derived from numerous sources, including MARAD's Oceanborne Trade Routes, Journal of Commerce, Wall St. Journal, American Metals Market, and Petroleum Supply Annual. The study calculated the prices per short ton to be in line with the ACOE commodity flow data, and then adjusted them to 1990 dollars using producer price indexes of the Bureau of Labor Statistics for appropriate categories.

An analysis of the value of containers and their contents was conducted. Since a significant difference in value was found between containerized imports and exports, the study derived two comprehensive values. The cost of the container itself was the same for both imports and exports and the study estimated it at $3,000 regardless of the container size. (There are two standard sizes: 20-foot TEU and 40-foot TEU containers.) Combined

6.2.4.2 Results (Cont.)

with the value of its contents, the study determined the total average values to be $43,450 for containers of imported goods, and $15,930 for containers of exported goods.

TABLE 6-5. UNIT COST OF DAMAGED COMMODITIES

CODE	COMMODITY GROUP	COST PER SHORT TON* ($)
1	Farm products	213
2	Timber, timber products	158
3	Fresh fish	2300
4	Mining products	113
5	Processed foods, other manufactured goods	1742
6	Manufactured waste	200
1311	Crude petroleum	92
1492	Sulfur, dry	140
1493	Sulfur, molten	84
2810	Sodium hydroxide	342
2811	Crude products, coal tar, petroleum	890
2813	Alcohols	418
2817	Benzene, toluene	375
2818	Sulfuric acid	76
2871	Nitrogenous fertilizers	231
2872	Potassic fertilizers	74
2873	Phosphatic fertilizers	144
2911	Gasoline	203
2912	Jet fuel	183
2913	Kerosene	189
2914	Distillate fuel oil	147
2915	Residual fuel oil	113
2916	Lubricating oils, greases	883
2917	Naphtha, petroleum solvents	188
2921	LPG, LNG, liquid coal gas	2,780**

* Short ton = 2000 pounds
** Cost per million cubic feet

6.2.5 Loss Of Animal Species and Environmental Damage Resulting From Spill

6.2.5.1 Background

When a vessel casualty produces a spill of the vessel's cargo or fuel, environmental damages may occur if the spilled material is toxic to organisms living in waters exposed to the substance or when it destroys the aesthetic quality of the water or shoreline. These damages directly affect not only people who rely on those resources for their livelihoods, but also people who use them for recreation and enjoyment. Further, the simple existence of natural resources in a pristine state is indirectly important to many people.

Placing a value on a natural resource that has been lost or damaged is an extremely controversial and somewhat subjective process, and the value may vary widely according to the valuation method used and the valuator. The use or the importance of the natural resource has a great deal to do with its value. Valuation of a natural resource with a tangible use, such as a food source, is less controversial than valuation of one whose main importance is merely its existence. The use value as determined by the willingness-to-pay method, generally accepted in the literature as most appropriate for natural resources, is the value determined in this analysis.

6.2.5.2 Natural Resource Damage Assessment Model for Coastal and Marine Environments

The search for spill damage assessment models revealed numerous small-scale models developed for specific spills and specific ports, but only one developed for application throughout the United States. This model is the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME).[3] It was developed by the Department of the Interior (DOI) as part of CERCLA regulations for assessing damages due to Type A spills of hazardous materials. It estimates the lost use values of damaged natural resources, specifically, commercially and recreationally valuable animal species that are lost and thus cannot be caught or viewed due to the spill. The value of damaged vegetation and habitat is reflected in the model as they affect the food chain of the animal species, causing decreased primary and secondary productivity up the food web.

The NRDAM/CME estimates the effects on marine animal life of 469 petroleum and chemical substances spilled into the sea in terms of both quantities of organisms killed and their economic value. Originally applicable to marine and estuarine environments in ten U.S. "provinces" or regions, the model was modified to represent the species found in the 23 study zones of the Port Needs Study.[4] Given the details of a spill, such as substance spilled, quantity, date, wind and current speed and direction at time of spill, location of spill relative to land, and other information, the model demonstrates the dispersion of the substance in the water and air and its effects on marine organisms. The model also estimates the economic value of losses not only in the year of the spill, but also for 20 years following the spill. Marine organisms are grouped by their ecological roles into 14 categories,[5] which Table 6-6 defines.

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[3]This section is based on information from "Measuring Damages to Coastal and Marine Natural Resources," Volume I, U.S. Department of the Interior, January, 1987.

[4]Applied Science Associates, Inc. of Narragansett, RI, the original developers of the model, performed the modifications to the computer model and species databases for the Port Needs Study.

[5]"Measuring Damages to Coastal and Marine Natural Resources", Volume I, p. III-2.

TABLE 6-6. SPECIES CATEGORY DEFINITIONS

	Category	Habitat	Examples
1.	Anadromous fish	upper water column	salmon, alewives, shad
2.	Planktivorous fish	upper water column	menhaden, herring, butterfish, mackerel
3.	Piscivorous fish	upper water column	bluefish, striped bass, angler fishes, weakfish
4.	Top carnivores	entire water column	tuna, bonito, sharks
5.	Demersal fish	lower water column	flat fishes
6.	Semi-demersal fish	entire water column	cod, hake, scup, sea bass, groupers, snappers
7.	Mollusks	sediments	clams, mussels, oysters
8.	Decapods	sediments	shrimp, lobsters, crabs
9.	Squid	entire water column	squid, cuttlefish
10.	Mammals	surface	fur seals, sea otters
11.	Waterfowl	surface near shore	ducks, geese, swans
12.	Shorebirds	intertidal	sandpiper, plovers, turnstones
13.	Seabirds	surface	cormorants, loons, pelicans, puffins, shearwaters
14.	Raptors*	surface, intertidal	hawks, eagles

* This category was added in a modification of NRDAM/CME for the Port Needs Study.

6.2.5.3 Development of Spill Scenarios

A hypothetical spill site was determined and scenarios developed for each subzone based on a number of criteria.

- The site is placed in the navigation channel toward the center of the subzone.

- The site is located near a known obstacle, such as a shoal or anchorage area, or a convergence point of traffic lanes.

- Multiple spill sites are chosen for subzones with wide-ranging environments and those covering a large area.

The scenarios for spills of hazardous commodities reflect typical conditions under which the spills might occur. The study makes limiting assumptions to minimize the number of model runs required.

- Predominant weather conditions for the zone occur rather than worst case conditions.

- Only those hazardous commodities passing through each subzone in the greatest quantities based on annual Army Corps of Engineers data spill.

- Four spill sizes occur for each commodity and spill site. The categorization of spill sizes on categories is defined by the Coast Guard in 40 CFR Part 300, as well as by environmental groups, and agencies that are involved with monitoring and classifying spill data. Table 6-7 shows these categories. NRDAM was run only for small, medium and large spills. Since the damages resulting from a catastrophic spill would be more severe than those of a CERCLA Type A spill, it would not be appropriate to use the model to estimate them. Catastrophic spills would not only cause decreases in the size and productivity of the fisheries, but also might affect fish market prices, seafood processors and other supporting business. Shellfish beds and fishing areas are likely to be closed for lengthy periods of time.

6.2.5.3 Development of Spill Scenarios (Cont.)

Catastrophic damages are a function of damages from a large spill. In most cases, the study multiplied the damages due to a large spill of 500,000 gallons by a factor of eight to obtain an estimate of damages due to a catastrophic spill of 4,000,000 gallons. Exceptions occur when the result approaches or exceeds the overall value of the fishery for the zone, and a lower factor is used.

TABLE 6-7. SPILL SIZE CATEGORIES

SPILL SIZE	RANGE	SIZE USED AS POINT ESTIMATE
Small	<10,000 gallons	8,000 gallons
Medium	10,000 - 100,000 gallons	90,000 gallons
Large	100,000 - 750,000 gallons	500,000 gallons
Catastrophic	>750,000 gallons	4,000,000 gallons

- Bottom characteristics and water depth are uniform throughout the subtidal areas within each subzone.

- Damages for each season of the year are calculated.

- The effects of closing shellfish beds and fisheries are estimated. The costs of closures, however, would be quite significant if they lasted for a long period of time or if alternate fishing grounds did not exist. They would inflict a loss not only on the fishing industry, but also to secondary industries relying on fish as their raw materials. Long-term loss of a fishery might also result in higher fish market prices.

6.2.5.4 Results

See Table 6-8 for the total dollar value of all species lost per spill of the most damaging hazardous commodity in one subzone (i.e., the subzone with the largest total loss) for each study zone, by spill size and the commodity responsible. The loss value reflects the total dollar loss per spill of the 14 species groups, including future year effects of each spill measured in constant 1990 dollars.

TABLE 6-8. NATURAL RESOURCE LOSSES IN ONE SUBZONE DUE TO A SPILL OF THE MOST DAMAGING HAZARDOUS COMMODITY ($1,000)

ZONE	COMMODITY	SPILL SIZE			
		SMALL	MEDIUM	LARGE	CATASTROPHIC
1 Boston, MA	Gasoline	32	432	2,567	20,536
2 Puget Sound, WA	Gasoline	26	556	9,498	75,984
3 Los Angeles /Long Beach, CA	#6 Fuel Oil	65	736	4,100	32,800
4 Santa Barbara, CA	#6 Fuel Oil	61	672	3,725	29,800
5 Port Arthur, TX	Alcohol	3,500	31,618	142,418	569,671
6 New Orleans, LA	Alcohol	374	18,120	86,521	692,168
7 Houston/Galveston, TX	Alcohol	10,339	76,458	263,926	1,055,704
8 Chesapeake South /Hampton Roads, VA	#6 Fuel Oil	31	359	2,014	16,112
9 Chesapeake North /Baltimore, MD	Gasoline	16	11,093	191,159	764,636
10 Corpus Christi, TX	Gasoline	33	1,110	88,673	709,384
11 New York City, NY	Gasoline	94	1,415	8,015	64,120
12 Long Island Sound, NY	Gasoline	51	639	3,239	25,912
13 Philadelphia /Delaware Bay, PA	#6 Fuel Oil	127	1,429	7,964	63,712
14 San Francisco, CA	Gasoline	134	3,430	29,004	232,032
15 Portland, OR	Gasoline	53	901	5,110	40,880
16 Anchorage /Cook Inlet, AK	Crude	432	980	2,615	20,920
17 Portland, ME	Gasoline	10	218	1,987	15,896
18 Portsmouth, NH	#2 Fuel Oil	14	164	939	7,512
19 Providence, RI	Gasoline	84	3,560	57,470	459,760
20 Wilmington, NC	Alcohol	841	10,750	32,324	258,592
21 Jacksonville, FL	Gasoline	75	1,047	7,652	61,216
22 Tampa, FL	#2 Fuel Oil	153	1,148	5,937	47,486
23 Mobile, AL	Gasoline	435	31,959	227,254	1,818,032

6.2.5.4 Results (Cont.)

The severity of losses resulting from a given spill scenario depends on many variables, as the extent of spill information required by the model indicates. The effects of the variables are interrelated, and thus difficult to identify individually. However, analysis of the results reveals some general trends and patterns.

- Holding other conditions constant, damages increase with the amount spilled.

- Among petroleum and petroleum products, the damages to fish and shellfish increase and the damages to birds and mammals decrease as the product becomes more refined. The toxicity of unrefined crude and of residual fuel oil to organisms living in the water, for example, is not as great as that of highly refined gasoline. Toxins in gasoline affect organisms in two significant ways: 1) toxins will kill larvae in the water column affecting population numbers in years to come; and 2) toxins will sink to the sediments, where they will remain for years and cause long-term damage to bottom-feeding and bottom-dwelling species.

- Commodities such as residual fuel oil that tend to float on the water's surface or to foul the beaches, cause significant losses to birds and mammals which feed there, while commodities such as gasoline tend to evaporate from the water's surface before harming significant numbers of birds.

- When a hazardous commodity reaches an intertidal area such as a marsh, damages increase dramatically because the intertidal ecosystem, where many deepwater organisms spawn, hosts higher concentrations of larvae. Larvae are more vulnerable to these commodities than adult fish. Significant damages to larvae are manifested years after the spill in decreased productivity of the species.

As Table 6-8 shows, the greatest damages to natural resources occur in the ports on the Gulf of Mexico and in Chesapeake North/Baltimore, MD due to spills of gasoline and alcohol. Although spills of gasoline and alcohol appear to vanish because a significant portion evaporates quickly, their toxins remain in the environment indefinitely by sinking into the sediments, as previously explained. These ports are characterized by extremely high concentrations of shellfish, oysters and rangia in the Gulf ports and mussels and oysters in Chesapeake North/Baltimore, MD, which are extremely susceptible to the effects of the toxins in the

6.2.5.4 Results (Cont.)

sediments. The toxins also cause harm in the water column to shrimp and blue crab larvae, found in high concentrations in the Gulf and the Chesapeake, respectively.

In contrast, Puget Sound, known for its productive fisheries, shows relatively low damages due to spills of hazardous commodities. Its deep waters cause the materials spilled to disperse more quickly to concentrations that are tolerable to adult fish. The depth also makes it less likely that toxins will settle in the sediments in high concentrations. Salmon spawning upriver will not be exposed to pollutants resulting from a spill downriver in the Sound.

6.2.6 Decrease In Tourism and Recreational Use and In Property Value Of Shoreline and Harbor Due To Spills Of Hazardous Commodities

6.2.6.1 Background

This section addresses losses from spills of hazardous commodities to tourism and recreational uses of shoreline and coastal waters and to values of shoreline properties.[6] Marine-related recreational activities, such as beach use, swimming and surfing, water sports, boating, fishing, and wildlife observation, rely on clean water and unspoiled coastal areas, and are negatively affected when spills occur. Both local residents and visitors to the spill area are forced to participate in alternate activities or to forgo their planned activities. In addition, spills cause a temporary decrease in property values until the spill is cleaned up and the spill fades from the public's memory.

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[6]The study bases this section, in part, on two chapters from a report by A.T. Kearney entitled "Methodology for Estimating the Environmental Costs of OCS Oil and Gas Exploration, Development, Production, and Transportation," Preliminary Draft Report. The report, dated November, 1990, describes a study performed under contract to the U.S. Department of the Interior - Minerals Management Service. The original sources of information in the discussion can be found at the end of Chapter 8.0 "Property Losses" and Chapter 10.0 "Spill-Related Recreation and Tourism Losses" in the Kearney report.

6.2.6.1 Background (Cont.)

This section estimates the net cost to the U.S. as a whole, rather than individual localized costs. Losses to commercial entities in the vicinity of a closed beach, for example, may be gains to commerce in the vicinity of beaches experiencing increased usage by people displaced from the closed beach, yielding no net loss to society.

6.2.6.2 Methodology

- Recreation and tourism losses

  The study developed a model to predict spill-related tourism and recreation losses due to spills of crude petroleum. The highlights below describe some of its features.

  - Losses in a region are a function of the estimated number of recreational users and the length of shoreline in the region.[7]

  - The model uses the willingness-to-pay method to determine the cost of a recreational user day for the U.S. as a whole. It determines two costs: one, for shore-based recreation, such as beach activities and swimming; the other, for at-sea recreation, such as waterskiing and sailing.

  - The model separates user counts and values into two groups: residents and tourists. The model further separates tourists into U.S. and foreign.

  - The model assumes the duration of a spill's effects to be 35 days, based on an analysis of historical spills. Seasonality of usage is averaged.

  - The model assumes that the user will substitute an alternate for the desired activity about 75% of the time, in which case half the value of the desired experience will be lost, and the user will not be able to find a substitute about 25% of the time, in which case the total value of the experience will be lost.

  - There is some overlap between the values of some recreational activities this model estimates and the value of recreationally caught fish estimated by the NRDAM/CME.

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[7]The regions are Outer Continental Shelf (OCS) Planning Areas.

6.2.6.2 Methodology (Cont.)

- Property value losses

  The study developed a second model to predict property value losses due to spills of crude petroleum and petroleum products. The highlights below describe some of the features of this model.

  - The model estimates property value losses for land held by individual property owners. Property losses occur whether or not the property changes hands; they are equivalent to the decrease in rent the owner would experience while the property was damaged or perceived to be at risk. The model includes, in the valuation, only the portion of coastal property in each zone which has a non-industrial use.

  - The model bases property values on a survey of current waterfront property values in the 23 study zones of the Port Needs Study.

  - The model assumes that land values decrease an average of 2.74 percent of the total property value during the year of the spill, and return to their full market value at the end of the year.

6.2.6.3 Results

Table 6-9 presents the results of the recreation and tourism loss model and Table 6-10 presents the results of the property value loss model. Losses due to spills of petroleum products are taken to be a percentage of the losses due to crude petroleum, since effects of more refined products, at least visibly, have a shorter duration. The study could not estimate the effects of other chemicals because it was not possible to identify any studies in the literature that quantified them.

The two tables show dollar losses per barrel of spilled substance reaching shore. The study obtains total losses for a particular spill by multiplying the appropriate table entry by the number of barrels that reached the shore. That amount as a percent of the entire amount spilled varies according to a number of factors, especially wind direction and speed and location of spill.

TABLE 6-9. LOSSES TO RECREATION AND TOURISM DUE TO RELEASES OF PETROLEUM AND PETROLEUM PRODUCTS ($ PER BARREL REACHING SHORE)

	PORT	COMMODITY SPILLED	
		PETROLEUM	PETROLEUM PRODUCT
1.	Boston, MA	213	160
2.	Puget Sound, WA	341	255
3.	Los Angeles/Long Beach, CA	2,524	1,892
4.	Santa Barbara, CA	2,788	2,091
5.	Port Arthur, TX	678	509
6.	New Orleans, LA	678	509
7.	Houston/Galveston, TX	678	509
8.	Chesapeake South/Hampton Roads, VA	1,008	755
9.	Chesapeake North/Baltimore, MD	1,008	755
10.	Corpus Christi, TX	678	509
11.	New York City, NY	213	160
12.	Long Island Sound, NY	213	160
13.	Philadelphia/Delaware Bay, PA	1,008	755
14.	San Francisco, CA	461	346
15.	Portland, OR	341	255
16.	Anchorage/Cook Inlet, AK	3	2
17.	Portland, ME	213	160
18.	Portsmouth, NH	213	160
19.	Providence, RI	213	160
20.	Wilmington, NC	593	444
21.	Jacksonville, FL	593	444
22.	Tampa, FL	421	316
23.	Mobile, AL	253	190

TABLE 6-10. PROPERTY LOSS DUE TO RELEASES OF PETROLEUM AND PETROLEUM PRODUCTS ($ PER BARREL REACHING SHORE)

	PORT	COMMODITY SPILLED	
		PETROLEUM	PETROLEUM PRODUCT
1.	Boston, Ma	614	460
2.	Puget Sound, WA	2,104	1,578
3.	Los Angeles/Long Beach, CA	10,522	7,891
4.	Santa Barbara, CA	10,522	7,891
5.	Port Arthur, TX	140	105
6.	New Orleans, LA	70	53
7.	Houston/Galveston, TX	526	395
8.	Chesapeake South/Hampton Roads, VA	701	526
9.	Chesapeake North/Baltimore, MD	701	526
10.	Corpus Christi, TX	701	526
11.	New York City, NY	614	460
12.	Long Island Sound, NY	1,228	921
13.	Philadelphia/Delaware Bay, PA	701	526
14.	San Francisco, CA	1,403	1,052
15.	Portland, OR	2,104	1,578
16.	Anchorage/Cook Inlet, AK	104	105
17.	Portland, ME	701	526
18.	Portsmouth, NH	701	526
19.	Providence, RI	1,228	921
20.	Wilmington, NC	526	395
21.	Jacksonville, FL	526	395
22.	Tampa, FL	2,104	1,578
23.	Mobile, AL	526	395

6.2.7 Cleanup Costs For Spills Of Petroleum, Petroleum Products and Other Hazardous Commodities

6.2.7.1 Background

Spills of petroleum, petroleum products and other hazardous commodities require extensive cleanup efforts to minimize their effects on the environment.[8] The general cleanup techniques for petroleum products and other chemicals that float on the water surface consist of the following:

- Containing the commodity at sea using containment or absorbent booms.
- Siphoning the commodity from the water surface using skimmers onboard vessels.
- Controlled burning of the commodity.
- Application of chemical or biological dispersant or neutralizers.
- Siphoning the commodity near the shore from the water surface with vacuum trucks.

Removing hazardous commodities from rocky shorelines is more difficult, requiring:

- Spraying water onto the covered rocks and the use of waterborne skimmers to scoop the resulting slick of removed commodity from the surface as it reenters the water.
- Shovelling solidified commodity into containers or depositing them into plastic garbage bags.
- Wiping off rocks with absorbent rags.
- Removing contaminated sand using bulldozers and other large equipment.
- Using chemical fertilizers to stimulate oil-eating bacteria in the sand to break down petroleum products into harmless substances.

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[8]This section is based on "Develop Estimates of Costs Associated with Oil and Hazardous Chemical Spills and Costs of Idle Resources During Vessel Repairs," Eastern Research Group, Inc., November, 1990.

6.2.7.1 Background (Cont.)

Spills that enter marsh and grassland areas are most difficult to clean up, because in many situations the cleanup efforts cause more harm than the commodity itself. Allowing these areas to cleanse themselves over time is often the method chosen.

This section covers the costs associated with cleaning up hazardous commodities from the environment, and does not address other costs associated with spills, such as the cost of environmental damages and the costs of the Coast Guard and other agencies and groups involved in responding to the incidents and monitoring the cleanup efforts. Sections 6.2.2 and 6.2.5 cover damage and response costs.

6.2.7.2 Methodology

A database of about 650 spill incidents occurring both in U.S. waters and worldwide was compiled from a variety of sources. It contains information affecting the cost of spill cleanup, such as material and amount spilled, weather conditions, sea state, cleanup methods and equipment used, movement of spill slick, and amount recovered. Since only five of the incidents deal with spills of hazardous chemicals, the analysis concentrates only on cleanup costs of petroleum and petroleum products.

Regression analysis produced a statistical relationship for the cost of spill cleanup efforts as a function of explanatory variables. The analysis revealed that spill size is the most significant factor, explaining over 75 percent of the cleanup cost. The equation is applicable to spill sizes ranging from 1,000 gallons to more than 11,000,000 gallons, the size of the Exxon Valdez spill.

6.2.7.3 Results

Table 6-11 lists cost factors based on results of the regression equation for the same four spill sizes used in the analysis of damages to natural resources previously discussed in Section 6.2.5. The table contains values which represent the upper bounds of 95 percent confidence intervals for average spill cleanup costs for given spill sizes. The higher values are preferable to the mean values because the regression equation appears to underestimate spill cleanup costs in the current U.S. environment. Much of the data that contributed to the equation's development describes spills in foreign countries, where standards are not as strict as those in the U.S. The equation is based on 10 years of data; during

6.2.7.3 Results (Cont.)

that time, standards within the U.S. have become stricter.

TABLE 6-11. CLEANUP COST FACTORS BY SPILL SIZE

Spill Size	Cleanup Cost ($1,000)
8,000 gallons	1,239
90,000 gallons	7,132
500,000 gallons	24,650
4,000,000 gallons	110,901

6.2.8 Losses To Subsistence Households

6.2.8.1 Background

Native Americans in Alaska and the Pacific Northwest are the primary groups that participate in the subsistence harvesting of foods.[9] To Alaskan Native American communities, this activity is not only important economically, but also essential to their diet and culture. However, subsistence activities are not as extensive in the Pacific Northwest, nor are they as well-documented. The special fishing rights of Native Americans in Puget Sound are generally used for commercial purposes rather than subsistence harvesting. Consequently, this section does not address subsistence losses due to oil spills in the Pacific Northwest over-and-above commercial and recreational losses covered in previous sections of Section 6.

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[9]A chapter from a study by A.T. Kearney entitled "Methodology for Estimating the Environmental Costs of OCS Oil and Gas Exploration, Development, Production, and Transportation," Preliminary Draft Report is the basis for this section. The report, dated November, 1990, describes a study performed under contract to the U.S. Department of the Interior - Minerals Management Service. The original sources of information in the discussion below can be found at the end of Chapter 13.0 "Spill and Non-spill Subsistence Losses" of the A.T. Kearney report.

6.2.8.1 Background (Cont.)

To Alaskan Native Americans, the wildlife has subsistence value as well as value as a natural resource and as a commercial or recreational harvest. Subsistence losses are the costs of resources that cannot be harvested and the reduction in opportunities to participate in the harvesting experiences due to a spill of oil.

Valuation of subsistence losses has two components: the cost of the lost resources as represented by the alternate cost of substitute retail purchases of foodstuffs, and the cost of the lost experiential value in purchasing foodstuffs rather than hunting or fishing for them. This study did not attempt to include cultural losses in this valuation.

This section assesses the effects of petroleum and petroleum products on subsistence harvesting. The section does not specifically address the effects of spills of chemicals but, assumes them to be similar to the effects of oil.

6.2.8.2 Results

The study derived subsistence losses for Cook Inlet from estimates of damages to subsistence harvests for the Kodiak/Shumagin region of Alaska as developed in a study by A.T. Kearney for the Minerals Management Service. Table 6-12 shows the estimated subsistence losses by spill size. Subsistence losses, like other environmental losses in general, do not become significant until a large quantity of oil is spilled, and then the losses rise at a faster rate than the increasing spill size.

TABLE 6-12. ALASKAN SUBSISTENCE LOSSES RESULTING FROM A SPILL OF PETROLEUM OR PETROLEUM PRODUCT ($1,000)

SPILL SIZE	LOSS
small	0.0
medium	5.1
large	12.3
catastrophic	6,109.2

6.2.9 Damage Assessment

6.2.9.1 Background

When a spill occurs, the spiller must compensate the government and injured parties for damages to environmental resources, as well as pay for cleaning up the spill. In addition, the spiller must reimburse the federal government (DOI or NOAA) and/or state environmental agencies for their expenses in assessing the damages. For small spills, the assessment may be a relatively simple process requiring some on-the-scene inspection and the use of the NRDAM/CME to obtain an estimate of damages. Assessing damages from large spills may be quite complicated and costly, necessitating inspections, water and sediment testing, and special studies to determine both short- and long-term damages.

6.2.9.2 Results

Based on published references to damage assessment expenses for specific spills and on conversations with NOAA and DOI representatives, Table 6-13 lists the costs of assessing damages resulting from spills of hazardous substances. The costs would be even higher for persistent substances that remained in the environment for long periods of time.

TABLE 6-13. COSTS OF ENVIRONMENTAL DAMAGE ASSESSMENT AFTER A SPILL OF PETROLEUM OR PETROLEUM PRODUCT ($1,000)

SPILL SIZE	COST
small spill	no cost
medium spill	$15.0
large spill	$3,000.0
catastrophic spill	$15,000.0

6.2.10 Damage To NAVAIDS and Bridges

6.2.10.1 Background

In a ramming, a vessel impacts a stationary object, such as a navigational buoy, drilling platform, pier or bridge, causing damage not only to the vessel but also to the object. This section addresses the costs of damages to navigational aids and bridges, the objects most likely to be involved in a VTS-addressable casualty.

When a vessel hits a NAVAID, the NAVAID may simply be pulled off position, or it may be damaged or totally destroyed. Equipment and labor charges would be incurred. In a vessel collision with a bridge, bridge damage may range from light to severe. In general, critical bridge supports are equipped with cushioned fenders to minimize damage to the supports, to vessels, and to the fenders themselves. However, occasionally a vessel strikes a bridge support with enough force to cause not only major damage to the vessel, but also to the bridge, possibly even collapsing a bridge span. When this happens, vehicles on the bridge may fall into the water below, and traffic must be rerouted until the bridge is repaired. Traffic congestion may ensue, wasting automobile fuel and causing driver aggravation and delays. Resulting costs would be extremely high.

6.2.10.2 Results

The cost of replacing a typical NAVAID is $20,400. The study bases this value on Coast Guard Standard rates and the distribution of NAVAID types in a sample of study zones. This value includes the cost of the replacement buoy, vessel and personnel charges, and the cost of a temporary buoy for two months. The analysis did not include fixed NAVAIDS (daymarkers and lights) because they generally are located in shallow water or on top of the obstacle they are marking, thus out of range of most of the vessels that would be participating in VTS.

6.2.10.2 Results (Cont.)

Table 6-14 shows the typical bridge damage resulting from varying severities of bridge rammings. The study bases the values on an analysis of historical CASMAIN data, described in Section 4. No attempt has been made to estimate the costs of bridge closure to bridge users for two reasons. First, the probability of a bridge sustaining enough damage to rupture its span or to close it for a lengthy period of time is extremely small. In practice, the fendering systems and the slow speeds at which vessels approach bridges keep bridge damage from rammings at a minimum. Although a bridge closing would be quite costly (it was estimated that a ramming of the Tobin Bridge in Boston that closed it for 180 days would cost over $85 million in deaths and injuries, loss of automobiles, travel delays and wasted gasoline), its low probability of occurrence would minimize its effect on the outcome of the benefit-cost analysis. Second, costs of bridge closure would vary according to a large number of variables, including the type of bridge (rail or auto), level of bridge traffic, availability of alternate routes, congestion of alternate routes, and gasoline prices. Impact studies for the closure of the approximately 170 bridges over navigable waters of the 23 study zones are beyond the scope of the VTS Port Needs Study.

TABLE 6-14. COST OF BRIDGE DAMAGE BY SEVERITY OF CASUALTY

Severity Of Casualty	Cost Of Bridge Damage
Low	$35,196
Moderate	$254,741
Severe	$10,784,868

6.2.11 LNG and LPG Explosions

6.2.11.1 Background

The transport by sea of liquified natural gas (LNG) and liquified petroleum gas (LPG) in tankers and in tank barges (LPG only) makes it possible, however unlikely, for a vessel casualty to cause a release of one of these fuels and a subsequent fire. The potential for catastrophic damage to both the vessels and nearby populations and structures requires an analysis of the consequences of such an occurrence.[10]

LNG and LPG tankers must be double-hulled for entry into U.S. waters. Their customized tanks contain the gases in a liquidized state by maintaining extremely low temperatures.

One of two scenarios would likely occur if an LNG or LPG tank were ruptured in a high energy casualty. The severity of damages would differ according to the physical characteristics of the two gases. The first, the pool fire scenario, would occur in a collision or ramming in which a tank was ruptured above the water line of the vessel and its contents spilled onto the water. The second scenario, the vapor cloud, would occur if the initial release due to a collision or ramming were not ignited at the release site or if a release resulted from a grounding. The vapor cloud would be blown through the air until it was ignited, either by a nearby vessel or by a spark from a land-based source. Although the probable scenarios can be described with some degree of accuracy because of the known physical properties of the gases, resulting damages are speculative because no tanker releases have occurred to date.

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[10]This section uses information mainly from the following study: "The Consequences of Casualties Affecting LNG and LPG Tankers," Jack Faucett Associates, prepared for the U.S. Department of Transportation, Volpe National Transportation Systems Center, December, 1990, Vol. III.

6.2.11.4 Results

The study developed models to predict the type and amount of damage resulting from a release of LNG and LPG, given the type of casualty, the location of the casualty, and the substance spilled. For LNG, the study developed a model for each of 11 subzones through which LNG moves or is expected to in the future. For LPG, the study developed a model by subzone type, instead of specific subzone, because of the large number of subzones through which LPG passes. The models predict the damages to the tankers and their crew, other vessels and crew, people and structures on shore, and nearby bridges.

Tables 6-15 and 6-16 show the losses due to LNG tanker collisions and rammings, and groundings. Table 6-15 treats the area around the Chesapeake Bay Bridge-Tunnel as a separate subzone because of the unique consequences that might occur in that area. Table 6-15 represents losses occurring on the LNG tanker itself and on land in the proximity of the tanker. Table 6-16 shows the damages that would occur to the second vessel involved in a collision by type of vessel. The human losses are so great on passenger vessels because of the large number of persons assumed to be on board: 400 crew and 940 passengers on a cruise ship, and 15 crew and 44 passengers on a ferry. In an LNG tanker grounding that produces a vapor cloud, there is potential for a second vessel to be the ignition source for the vapor cloud and to incur damages.

TABLE 6-15. PROPERTY AND HUMAN LOSSES ON AN LNG TANKER AND ON LAND IN PROXIMITY OF THE TANKER DUE TO A COLLISION, RAMMING OR GROUNDING

SUBZONE	COLLISION OR RAMMING			GROUNDING		
	TOTAL LOSS ($1,000)	FATALITIES DUE TO COLL OR RAM	INJURIES AND BURNS DUE TO COLL OR RAM	TOTAL LOSS ($1,000)	FATALITIES DUE TO GROUNDING	INJURIES AND BURNS DUE TO GROUNDING
0101	141,326	27	3	10,864	0.1	30.0
0102	141,326	27	3	11,147	0.1	29.8
0103	223,771	76	9	14,862	1.2	30.0
0104	6,025,385	3700	431	588,354	275.0	294.0
0105	5,690,330	3500	421	675,803	320.0	332.0
0501	141,326	27	3	10,853	0.1	29.9
0503	175,826	32	4	10,853	0.1	29.9
0801	141,326	27	3	10,853	0.1	29.9
0802	175,826	50	3	10,853	0.1	29.9
TUNNEL	157,798	27	26	15,562	1.6	30.4
0803	141,326	27	3	11,520	0.2	29.9
0901	141,326	27	3	11,158	0.1	29.9

TABLE 6-16. LOSSES TO SECOND VESSEL INVOLVED IN AN LNG TANKER COLLISION

VESSEL TYPE	EXPECTED LOSS ($1,000)
LARGE TANKER	27,813.96
MEDIUM TANKER	22,511.13
SMALL TANKER	16,292.86
LARGE BULK CARRIER	31,399.46
MEDIUM BULK CARRIER	25,904.30
SMALL BULK CARRIER	16,270.36
LARGE TANK BARGE	1,291.40
SMALL TANK BARGE	620.00
LARGE DRY BARGE	564.95
SMALL DRY BARGE	345.10
LARGE PASSENGER	1,162,279.09
SMALL PASSENGER	53,442.45
TOW BOAT	5,096.28

6.2.11.4 Results (Cont.)

Tables 6-16 and 6-18 show losses due to LPG tanker collisions, rammings, and groundings. Technical Supplement, Volume III, Section 6 shows the construction of the losses in the two tables as well as losses to the second vessel ignition source in an LPG tanker grounding.

TABLE 6-17. PROPERTY AND HUMAN LOSSES ON AN LPG TANKER AND ON LAND IN PROXIMITY TO THE TANKER DUE TO A COLLISION, RAMMING OR GROUNDING

SUBZONE TYPE	COLLISION OR RAMMING			GROUNDING		
	TOTAL LOSS ($1,000)	FATALITIES DUE TO COLL OR RAM	INJURIES AND BURNS DUE TO COLL OR RAM	TOTAL LOSS ($1,000)	FATALITIES DUE TO GROUNDING	INSURIES AND BURNS DUE TO GROUNDING
A. OPEN APPROACH	75,438	22.5	2.5	7,498	0.1	22.9
B. CONVERGENCE	75,438	22.5	2.5	7,738	0.2	22.8
C. OPEN HRBR/BAY	80,688	25.0	3.5	8,221	0.5	22.7
D. ENCLOSED HRBR	664,496	390.0	43.8	60,817	21.0	34.5
E. CONSTR WATER	361,078	200.0	23.1	32,505	10.0	28.0
F. RIVER	361,078	200.0	23.1	32,505	10.0	28.0

TABLE 6-18. LOSSES TO SECOND VESSEL INVOLVED IN AN LPG TANKER COLLISION

VESSEL TYPE	EXPECTED LOSSES ($1,000)
LARGE TANKER	25,340.31
MEDIUM TANKER	20,374.76
SMALL TANKER	14,128.20
LARGE BULK CARRIER	28,835.81
MEDIUM BULK CARRIER	23,477.60
SMALL BULK CARRIER	14,024.70
LARGE TANK BARGE	1,426.40
SMALL TANK BARGE	678.50
LARGE DRY BARGE	594.20
SMALL DRY BARGE	358.60
LARGE PASSENGER	1,004,280.00
SMALL PASSENGER	46,815.70
TOW BOAT	4,429.44

7. VTS CANDIDATE SYSTEM DESIGNS AND COSTS

7.1 OVERVIEW

In order to consistently estimate the life cycle costs of a VTS system in each of the study zones, the study defines a "Candidate VTS Design" for each study zone using a uniform set of design criteria. Each study zone Candidate VTS Design is a composite of generic modules selected from a master list of 18 state of the art surveillance modules, communications and display technology. Among the surveillance modules in the master list are several levels of technical performance from which the selection is made to address the local navigational surveillance needs of each subzone. The Candidate VTS Design in each study zone represents a consistent application of the surveillance modules at the subzone level. Subsequently, the introduction of state of the art communications and display consoles at the Vessel Traffic Center (VTC) in each zone enables the integration of the subzone surveillance technology into a total system for the study zone.

The application of the surveillance modules in each subzone responds to the technical requirements of that subzone as perceived by the study team. The Candidate VTS Design represents a preliminary engineering judgement call on the appropriate level of technology in each subzone. The Candidate VTS Design may be considered as an informed judgement made by the study team for the sole purpose of developing cost estimates that are consistent across the 23 study zones and suitable for benefit-cost comparisons among the study zones and initial planning for implementation.

7.1 **OVERVIEW** (Cont.)

The methodology involves six key elements which may be described as follows:

1. A survey of the current international state of the art VTS related technology for performance and cost attributes.

2. Definition of a set of basic VTS system building blocks (i.e., surveillance modules and communications and display consoles) and unit costs based on the technology survey.

3. An on-site survey of VTS system design requirements of seven study zones that appear to typify most U.S. ports to identify surveillance and traffic management requirements.

4. A definition of typical surveillance subzones to facilitate design of a candidate VTS system specific to each of the 23 study zones.

5. Application of the on-site survey results and the VTS technology survey results to define a Candidate VTS Design and to estimate the associated investment costs and operations and maintenance costs for each of the seven selected study zones.

6. Development of Candidate VTS Designs and cost estimates for the remaining 16 study zones based on the knowledge gained from the selected seven study zones, NOAA charts, published information and other data obtained from initial visits to each study zone.

The appendices (Volume II) document the Candidate VTS Designs for all 23 study zones.

7.2 VTS TECHNOLOGY SURVEY

The VTS technology survey concentrates on contact with:

- Government and industry personnel familiar with existing U.S. VTS systems and advanced overseas VTS systems.

- Private sector producers and developers of VTS equipments and systems.

- Segments of the radar, navigation and display industry marketing or producing radar and Dependent Surveillance type systems.

- Segments of the Radio Determination Satellite Service (RDSS), mobile satellite, and cellular telephone industry.

7.3 VTS CANDIDATE DESIGN SYSTEM MODULES

Many types of surveillance sensors are employed or proposed for use in VTS systems. To simplify development of the Candidate VTS Design, the various types of sensors have been divided into several levels of performance and cost called Surveillance Modules. This section describes these modules and provides data on the cost and performance of each one. The major categories of modules are Radar, Automatic Dependent Surveillance (ADS) and Ancillary Surveillance Technologies. They are listed as follows:

- RADAR

  Radar Module 1 - Average Performance, X Band

  Radar Module 2 - Average Performance, S Band

  Radar Module 3 - High Performance, X Band

  Radar Module 4 - High Performance, S Band

  Radar Module 5 - Special Purpose, X Band

  Radar Module 6 - Special Purpose, S Band

7.3 VTS CANDIDATE DESIGN SYSTEM MODULES (Cont.)

- AUTOMATIC DEPENDENT SURVEILLANCE

ADS Module 7	- Active Radar Transponder (Type 1)
ADS Module 8	- Positional Transponder, Small Area, Very High Accuracy (Type 5)
ADS Module 9	- Positional Transponder, Small Area, High Accuracy (Type 6)

- ANCILLARY SURVEILLANCE TECHNOLOGIES

VHF Module 10	- Low Power VHF Transmitting/Receiving Facility
VHF Module 11	- High Power VHF Transmitting/Receiving Facility
Meteorological Module 12	- Air Temperature, Wind Direction and Speed
Meteorological Module 13	- Air Temperature, Wind Direction and Speed, and Visibility
Hydrological Module 14	- Water Temperature and Depth
Hydrological Module 15	- Water Temperature, Depth and Current
VHF/DF MODULE 16	- Line of Position Measurement to 2 Degree RMS
CCTV MODULE 17	- Fixed Focus CCTV via Telephone Lines
CCTV MODULE 18	- Remotely Controllable CCTV via Microwave

7.3.1 Radar Technology In VTS

The study makes certain capability assumptions regarding radar systems. For the purposes of the study, radar systems:

- Detect vessels that are typical to the area monitored at the ranges expected.
- Remove most sea clutter and extraneous target data.
- Eliminate interference by shipboard radars.
- Have a very high degree of reliability.
- Detect the design size target on three out of five scans.
- Display a target continuously, i.e., scan-to-scan integration.
- Display capability which enhances the radar resolution.

Selection of appropriate generic levels of radar performance depends on identifying the major variables in radar equipment that affect radar performance, such as: power output, noise figures, operating frequency, radar video processing, and radar antenna.

- <u>Radar Module 1</u> - Average Performance
    - Can detect a 20-meter vessel at the radar horizon in a relatively open area with average sea clutter (sea state = 1, radar cross section = 10 square meters).
    - Horizontal Beam width is assumed to be 0.7 degrees.
    - AZ Resolution @ 6nm =
(2pi/360)(6nm)(0.7)(1852)
= 135.8 meters.
    - X Band Radar.
    - 12-foot antenna.

7.3.1 Radar Technology In VTS (Cont.)

- Radar Module 2 - Average Performance
  - Can detect a 20-meter vessel at the radar horizon in a relatively open area with average sea clutter (sea state = 1, radar cross section = 10 square meters.
  - Horizontal Beam width is assumed to be 2 degrees.
  - AZ Resolution @ 6 nm = (2PI/360)(2)(6nm)(1852) = 388 meters.
  - Enhanced performance in heavy rain over Module 1.
  - S Band Radar.
  - 12-foot antenna.
- Radar Module 3 - High Performance
  - Can detect 5 to 20-meter vessel at 6 miles in relatively open areas (sea state = 1, radar cross section = 5 square meters) or where ships and smaller targets must be tracked in relatively narrow channels (approximately 300+ feet).
  - Horizontal Beam width is assumed to be 0.5 degrees.
  - AZ Resolution @ 6 nm = 97 meters.
  - X Band Radar.
  - 18-foot antenna.

7.3.1 Radar Technology In VTS (Cont.)

- <u>Radar Module 4</u> - High Performance

  - Can detect a 5 to 20-meter vessel at 6 miles in relatively open areas (sea state = 1, radar cross section = 5 square meters) or where ships and smaller targets must be tracked in relatively narrow channels (approximately 300+ feet).

  - Horizontal Beam width is assumed to be 1.4 degrees.

  - AZ Resolution @ 6 nm = 271.5 meters.

  - Enhanced performance over Module 3 in heavy rain.

  - S Band Radar.

  - 18-foot antenna.

- <u>Radar Module 5</u> - Special Purpose

  - Detects the same targets as Module 3 but is also able to track these targets in narrowly confined waterways with obstructions on either or both sides due to the outstanding side/backlobe rejection characteristics.

  - Horizontal Beam width is assumed to be 0.5 degrees.

  - AZ Resolution @ 6 nm = 97 meters.

  - X Band Radar.

  - Large size, exceptional performance antenna, low noise installation (special wave guides, etc.).

7.3.1 Radar Technology In VTS (Cont.)

- Radar Module 6 - Special Purpose
  - Detects the same targets as Module 4 but is also able to track these targets in narrowly confined waterways with obstructions on either or both sides due to the outstanding side/backlobe rejection characteristics.
  - Horizontal Beam width is assumed to be 1.4 degrees.
  - AZ Resolution @ 6 nm = 271.5 meters.
  - Enhanced performance over Module 5 in heavy rain.
  - S Band Radar.
  - Large size, exceptional performance antenna, low noise installation (special wave guides, etc.).

7.3.2 Automatic Dependent Surveillance (ADS) Technology In VTS

The two levels of accuracy and three levels of range lead to six possible choices for positional type devices. Of these six, the large area, very high accuracy choice is not considered realistic. The remaining five positional type devices plus one radar transponder device leads to six ADS types as follows:

Type 1 = Radar Transponder

Type 2 = Positional Transponder, large area, high accuracy

Type 3 = Positional Transponder, intermediate area, very high accuracy

Type 4 = Positional Transponder, intermediate area, high accuracy

Type 5 = Positional Transponder, small area, very high accuracy

Type 6 = Positional Transponder, small area, high accuracy

7.3.2 Automatic Dependent Surveillance Technology In VTS (Cont.)

Since surveillance requirements and performance are being considered only within one VTS zone, it is not logical to consider large or intermediate area systems. These have much lower data rates and wider area communications requirements than surveillance systems designed to service only one zone (refer to Section 3.0, VTS Technology Survey, Technical Supplement TS-4). Accordingly, only ADS Types 1, 5, and 6 are used as ADS modules. The ADS modules then, become:

- <u>ADS Module 7</u> - Active Radar Transponder (Type 1)

  This device is similar to the radar transponders carried aboard aircraft but must respond to all land based VTS radar frequencies. The device enhances the radar return and provides positive vessel identification. The accuracy provided by this device would be the same as that of the surveillance radar in use.

- <u>ADS Module 8</u> - Positional Transponder, Small Area, Very High Accuracy (Type 5)

  This device is assumed to be a differential GPS (DGPS) receiver, coupled with a VHF communications system. The performance of this device is assumed to be:

  - Range = Line of Sight (LOS) from the VHF facilities.
  - Accuracy = 5 to 10 meters (2 drms).
  - Relative Accuracy = 5 to 10 meters (2 drms).
  - Relative accuracy is defined as the accuracy of measurement between vessels.
  - Positive Vessel Identification = Yes, if required in the vessel ADS device.

7.3.2 Automatic Dependent Surveillance Technology In VTS (Cont.)

- <u>ADS Module 9</u> - Positional Transponder, Small Area, High Accuracy (Type 6)

  This device is assumed to be a Loran-C receiver coupled with a VHF communications system. The performance of this device is assumed to be:

  - Range = Line of Sight (LOS) from the VHF facilities.

  - Accuracy = 0.25 nm (2 drms). This accuracy can be increased to at least 0.03 nm by very careful local calibration of the VTS zone coupled with active monitoring of the Loran-C grid with a monitor station located in the VTS zone.

  - Relative Accuracy = Better than 0.05 nm. Relative accuracy is equal to the repeatable accuracy of the Loran-C system.

  - Positive Vessel Identification = Yes, if required in the vessel ADS device.

7.3.3 Ancillary Surveillance Technologies

7.3.3.1 <u>VHF</u>

VHF communications are employed in all VTS subzones. The major variations are the number of frequencies used and the radiated power output of the installation. Since the existing regulations and the VTS design itself determine the number of frequencies, this is not variable. Radiated power output, however, is a significant choice for the VTS designer. Low power (1-10 watts) facilities are used within subzones when it is desirable to limit the coverage area and reduce interference in other subzones. High power (10 to 50 watts) is used when wider coverage is desired and the resultant interference can be tolerated. This leads to two VHF modules.

7.3.3.1 VHF (Cont.)

- VHF Module 10 - Low power VHF Transmitting/ Receiving Facility
    - Output power = 1-10 watts.
    - Effective range = up to 10 miles, capable of operating on four frequencies simultaneously.
- VHF Module 11 - High power VHF Transmitting/ Receiving Facility
    - Output power = 10-50 watts.
    - Effective range = as required up to LOS, capable of operating on four frequencies simultaneously.

7.3.3.2 Meteorological Sensors

Meteorological sensors in current VTS systems are capable of measuring air temperature, wind speed/direction, and visibility. The measurement of visibility is not always required at remote sensor sites and is employed only when fog presents a significant navigation problem. This leads naturally to two levels of meteorological sensor implementation. All meteorological sensors are assumed to be connected to a general purpose computer that can be interrogated over a telephone line.

- Meteorological Module 12 - Air Temperature, Wind Direction and Speed
    - Air temperature (to ±1 degree F.).
    - Wind direction (to ±1 degree).
    - Wind speed (to ±1 kt.).
- Meteorological Module 13 - Air Temperature, Wind Direction and Speed, Visibility
    - Air temperature (to ±1 degree F.).
    - Wind direction (to ±1 degree).
    - Wind speed (to ±1 kt.).
    - Visibility (to less than ¼ nm).

7.3.3.3 Hydrological Sensors

The hydrological sensors employed in modern VTS systems measure one or more of the following: water temperature, current, and water depth. The major division in capabilities for a VTS designer is the choice between measuring either current or depth or both. This leads to a logical choice of two levels of performance. It is assumed that all sensors are interfaced to a general purpose computer that can be interrogated by telephone modem.

- Hydrological Module 14 - Water Temperature and Depth
  - Water temperature (to ±1 degree F.).
  - Water depth (to ±0.5').
- Hydrological Module 15 - Water Temperature, Depth and Current
  - Water temperature (to ±1 degree F.).
  - Water depth (to ±0.5').
  - Current (to ±0.2 kt.).

7.3.3.4 VHF/DF Sensors

Many VTS systems make use of these radio direction finders. The major technical variable is the accuracy of the measured line of position in degrees. This accuracy varies according to on-site conditions and the aperture of the antenna used. A VHF/DF site furnishes one LOP. If used in conjunction with a radar it can provide positive vessel identification. If it is used alone, two sites are required to locate a vessel. The technical variation is not great enough to justify more than one VHF/DF hardware level. This level assumes complete remote control capability, a wide aperture array of at least 16 dipoles, and a site accuracy of 2 degrees.

- VHF/DF MODULE 16 - Line of position measurement to 2 degree RMS

7.3.3.5 Closed Circuit Television (CCTV) Modules

Many VTS systems use low light level closed circuit television. These devices provide visual surveillance of small areas where specific problems exist that are not solved by other surveillance sensors. Some CCTV installations are also used to identify vessels. Current CCTV installations range from fixed focus, fixed azimuth cameras to cameras with complete remote control of pan, tilt and zoom functions. Video data can be sent to the VTC via telephone lines (delayed in time) or microwave links. Two levels of performance have been selected for CCTV implementation. Both levels are assumed to require a climate controlled, weatherproof housing with window wipers, washers and defogger.

- CCTV MODULE 17 - Fixed Focus CCTV via Telephone Lines

  This module consists of two fixed focus cameras. These are not remotely controllable except for camera selection. The data is compressed and transmitted over a 9600 baud modem. The following are performance data for each camera:

  - Magnification = 1 camera less than 50 mm.
    1 camera greater than 50 mm.
  - Minimum scene illumination = 0.01 lux
  - Image update rate @ 9600 baud = 10-20 seconds

- CCTV MODULE 18 - Remotely Controllable CCTV via Microwave

  This module consists of two independently controllable cameras. Each camera is capable of remotely producing over 50 pre-set scenes under microprocessor control. The computerized control is also capable of producing any programmed sequence of preset scenes, each visible for a selected time period. Video from these cameras is multiplexed and sent to the VTC over a microwave link. The following are performance data for each camera:

  - Magnification = 10 to 160 mm.
  - Zoom = 10X.
  - Minimum scene illumination = 0.01 lux.

7.4 DESIGN APPROACH

Seven on-site study zone surveys produced a set of preliminary requirements for typical subzones used to guide the definition of the Candidate VTS Designs. The study selects the surveillance modules for each subzone from the master list of modules and examines each subzone to determine the minimum number of surveillance modules of each type needed to respond to the requirements identified in the on-site surveys for that subzone. The study then "surveys" the 16 study zones not subjected to on-site visits, using NOAA charts supplemented by information obtained from other published sources, and the knowledge gained from the previous on-site surveys. The published information on the individual port areas provides the needed overview of each study zone and assists in defining subzones in each of these zones analogous to those defined via the on-site visits for the first seven zones.

7.4.1 Study Zone Surveys

The study selects seven study zones, representative of generic classes of waterways, for the on-site surveys. They are: Boston, Puget Sound, Los Angeles/Long Beach, Santa Barbara, Port Arthur, New Orleans, and Chesapeake Bay. A survey report for each of the seven study zones detailing local traffic management considerations is part of the Candidate VTS Design included in the appendices.

The survey team developed and used a standard list of survey questions for each on-site visit to assure the collection of consistent core data from each port. The questions solicited the following:

- A complete set of harbor charts;
- Applicable Light List and Current Tables;
- The Coast Pilot;
- The U.S. Navy Fleet Guide;
- Corps of Engineers publications on Commodity flow;
- Code of Federal Regulations; and
- U.S. Coast Guard Captain of the Port Orders.

7.4.1 Study Zone Surveys (Cont.)

Study of this documentation supplies fundamental knowledge, helps to identify potential traffic problem areas, and provides an initial list of traffic management concerns to be addressed. The appropriate U.S. Coast Guard personnel were interviewed. These interviews supplement landside and waterside surveys of pertinent port waterways. The on-site survey reports contain the initial selection of subzones and a list of specific traffic management problem areas within each subzone. The conclusion drawn is that some subzones require only procedural monitoring, while others require active surveillance of some specific level.

The study "surveys" the 16 study zones not receiving on-site visits, primarily from charts and other published sources. The traffic management problem area templates, developed by the seven on-site surveys guide the development of design considerations for Candidate VTS Designs in the remaining 16.

7.4.2 Developing Candidate Designs for Surveyed Study Zones

The study selects surveillance sensors to achieve the VTS mission which is defined as insuring the safety of navigation and the protection of the environment. In order to accomplish this mission, participation of all vessels greater than 20 meters in length is assumed. Other assumptions made are that the VTC will provide navigational safety advice to all vessels and that the VTS is not employed to facilitate commerce or to offer piloting assistance.

The primary criteria for determining adequate surveillance sensors are:

- Percentage of vessels above 20 meters in the surveillance area;
- Percentage of lost tracks;
- Accuracy of position and track obtained;
- Reliability of the surveillance system;
- Timeliness of the data obtained; and
- Ability to interpret and use the data obtained.

7.4.2 Developing Candidate Designs for Surveyed Study Zones (Cont.)

The secondary criteria are:

- Cost of the VTS System: minimum labor requirement for operations; and
- Expendability: VTS level, responsibility level, geographical area to support other missions.

Active surveillance sensors, including radar, communications, and closed circuit television (CCTV) installations are used where detection and tracking of vessels is paramount to providing safety advice. The selection of modules is such as to assure that the necessary operational criteria identified for each subzone are accommodated.

The study looks at many dependent surveillance techniques ranging from voice radio reporting of required VTS data to automatic position and identification recording devices that can be interrogated from shore (ADS). Some form of position and/or movement dependent surveillance is used in existing VTS systems in regions which do not require active surveillance. To apply ADS technology to a specific subzone, the following criteria are considered:

- The number and class of vessels interacting in the subzone and the identification of interactions that are important to the VTS mission. All vessel classes participating must be appropriately equipped with an ADS device.

- It must be established that additional information obtained from ADS, beyond that obtained from active surveillance, is necessary.

- If the class or group of vessels to be monitored is a "controlled" group, ADS can be more easily implemented and satisfactory operation more readily achieved. A controllable group would be defined as a subset of vessels such as a particular barge company, or vessels carrying specific cargo.

- The number of different vessels in each class of interest that passes through the subzone in question must be determined in order to estimate the cost of selecting this option.

7.4.2 Developing Candidate Designs for Surveyed Study Zones (Cont.)

- A specific ADS solution for one subzone in one zone could affect VTS designs for subzones in other zones.

The study bases the Candidate VTS Design in each study zone on the following set of assumptions:

- As recommended by the IMO, all vessels of 20-meters or more in length would be required to participate. Participation is defined (at a minimum) as monitoring the VTS frequency and reporting as required.

- The software architecture would allow upgrades to process ADS data.

7.5 CANDIDATE VTS DESIGNS

Table 7-1 summarizes the number of surveillance modules selected to represent the integrated Candidate VTS Design for each of the 23 study zones. Maps displaying radar installation locations for each study zone are in the appendices (Volume II). Section 5 defines subzone coverage by VTS level.

TABLE 7-1. SUMMARY OF STUDY CANDIDATE VTS DESIGNS

Z	NAME	VTS SURVEILLANCE MODULES: RADAR 1	RADAR 2	RADAR 3	RADAR 4	RADAR 5	RADAR 6	ADS 7	ADS 8	ADS 9	VHF 10	VHF 11	MET 12	MET 13	HYD 14	HYD 15	DF 16	CCTV 17	CCTV 18
1	BOSTON	2									2	2		2					
2	PUGET SOUND	8		2							10	3	2	4		1			
3	LA/LONG BEACH	2		2							5	1	2	2		1	1		
4	SANTA BARBARA			3							3	2	1	1					
5	PORT ARTHUR	2		1							9	3	2	3	1	1			1
6	NEW ORLEANS	7		5							14	6	1	8		3	1	2	
7	HOUSTON/GALVESTON	11		1							7	2		4		1			
8	CHES SO/HAMPTON RDS	4		2							11	3	2	3		2			
9	CHES NO/BALTIMORE	1		1							3	2		2					
10	CORPUS CHRISTI			2							4	2		2		2			
11	NEW YORK CITY	3	1					25			10	3	1	3		2		3	
12	LONG ISLAND SOUND	1		2							5	2		2		1			
13	PHILADELPHIA	1		3				10			8	3	1	2		1			
14	SAN FRANCISCO	5	1	1	1			25			10	4	1	4	1		1		1
15	PORTLAND, OR			1							11	5		4					
16	ANCHORAGE			2							2	3	1	1					
17	PORTLAND, ME	2									2	1		1					
18	PORTSMOUTH	1									2	1		1					
19	PROVIDENCE	2									3	1	1	1					
20	WILMINGTON	1		1							3	2	1	1					
21	JACKSONVILLE	1									2	1		1					
22	TAMPA	2	1								3	1		1	1				
23	MOBILE	1		1	1						4	2				1			

7.6 LIFE CYCLE COSTS OF CANDIDATE SYSTEMS

7.6.1 Cost Estimating Approach

The cost to implement the Candidate VTS Design and to operate and maintain it over the 15-year life cycle period defined for this study must be consistently derived for each study zone. By applying a consistent cost estimating process, the study estimates three major elements of cost:

1. Equipment acquisition
2. Engineering
3. Operations and Maintenance

The study develops a national average set of unit costs and applies it in each element, except for Anchorage/Cook Inlet, AK where construction costs are doubled. The appendix (Volume II) documents the cost estimating process. The following subsections provide a brief description of what is included.

7.6.1.1 Equipment Acquisition

This element includes the acquisition of all the physical infrastructure as well as the initial operating staff. The sub-elements are:

- All electronic equipment for the Vessel Traffic Center and the remote sensor sites.

- All support hardware for the electronic equipment, including consoles, racks, emergency power supplies, conventional power handling devices, special interfaces, cables, ancillary wiring, etc.

- All site acquisition costs.

- All physical structures, including towers, buildings, fences, etc.

- Civil engineering services for site preparation, road construction, building construction, etc.

- Interviewing and hiring operating personnel to staff 24 hours per day, 365 days per year operations.

7.6.1.2 Engineering

The engineering element includes system design, integration, installation, testing, documentation and operator training.

System design includes concept definition in response to predefined performance requirements, detailed field surveys of each zone, final definition of surveillance subzones, selection of technology, verification of sensor performance in each subzone, design of VTC.

Integration includes interfacing all hardware and software selected so that they function smoothly as a system.

Testing of all system sensors and software capabilities is necessary to verify system performance prior to commissioning.

Documentation includes review and verification of manufacturers technical and operating manuals and the preparation of a system manual for each study zone.

Training includes the development and initiation of a regular program of training and proficiency testing of all watchstanding personnel and maintenance technicians.

7.6.1.3 Operations and Maintenance

Operations and Maintenance (O&M) costs are those recurring expenses associated with operational and technical personnel, utilities, maintenance contracts, leased equipment and replacement parts. These costs are a direct function of the VTS equipment and system design selected.

7.6.1.4 Study Zone VTS Cost Elements

Table 7-2 presents a summary of the unit costs (non-recurring initial investment costs and the recurring annual equipment maintenance costs) for each VTS surveillance module.

TABLE 7-2. VTS SURVEILLANCE MODULE UNIT COSTS

MODULE		NON-RECUR. UNIT COST ($1,000)	RECURRING UNIT COST ($1,000/YR)
RADAR			
1	X BAND, 12' ANT., AV. PERFORMANCE	310	31
2	S BAND, 12' ANT., AV. PERFORMANCE	310	31
3	X BAND, 18' ANT., HIGH PERFORMANCE	400	40
4	S BAND, 18' ANT., HIGH PERFORMANCE	400	40
5	X BAND, LARGE, SPECIAL PURPOSE	650	65
6	S BAND, LARGE, SPECIAL PURPOSE	650	65
ADS			
7	ACTIVE RADAR TRANSPONDER (VTS)	0	0
	(Each Vessel)	1.5	0.1
8	POSITIONAL TRANSPONDER, DGPS (VTS)	97	0.1
	(Each Vessel)	9	0.5
9	POSITIONAL TRANSPONDER, LORAN-C (VTS)	58	1.0
	(Each Vessel)	3.77	0.25
VHF			
10	LOW POWER VHF	19	1.3
11	HIGH POWER VHF	48	2
MET			
12	AIR TEMP., WIND DIR. & VEL.	20	0.5
13	AIR TEMP., WIND DIR. & VEL., plus VIS.	40	0.5
HYD			
14	WATER TEMP. & DEPTH	10	0.25
15	WATER TEMP. & DEPTH plus CURRENT	50	0.5
DF			
16	RADIO DIRECTION FINDER (VHF/DF)	90	0.5
CCTV			
17	CLOS. CIR. TV, F. FOCUS, TEL.	13.4	1
18	CLOS. CIR. TV, RE. CON., MICROWAVE	116.85	5

7.6.1.4 Study Zone VTS Cost Elements (Cont.)

Table 7-3 displays the total Initial Investment (non-recurring costs) and the Operation and Maintenance (recurring costs) for each study zone. This table also displays the estimated full-time equivalent personnel required assuming the VTC is staffed at a constant level 24 hours per day 365 days per year. These costs are for completely new facilities and equipment, and do not include allowance for usable Coast Guard existing VTS facilities. It is assumed that participating vessels will not incur additional investment or O&M cost attributable to the Candidate VTS Design. Therefore, the costs shown in Table 7-3 represents the total costs this study considers.

TABLE 7-3. STUDY ZONE CANDIDATE VTS DESIGN COSTS

ZONE NAME	INITIAL INVESTMENT COST ($1,000)	FULL TIME EQUIVALENT PERSONNEL	ANNUAL O & M COST ($1,000)
1 BOSTON, MA	4,988	7	457.2
2 PUGET SOUND, WA	16,175	18	1,450.0
3 LOS ANGELES/LONG BEACH, CA	7,664	12	813.5
4 SANTA BARBARA, CA	5,316	7	508.9
5 PORT ARTHUR, TX	10,313	12	841.7
6 NEW ORLEANS, LA	25,474	19	1,755.7
7 HOUSTON/GALVESTON, TX	16,030	20	1,915.8
8 CHESAPEAKE SO./HAMPTON ROADS	13,186	19	1,477.8
9 CHESAPEAKE NO./BALTIMORE, MD	5,103	8	529.9
10 CORPUS CHRISTI, TX	4,924	8	666.2
11 NEW YORK CITY, NY	16,234	19	1 ,550.5
12 LONG ISLAND SOUND, NY	5,706	7	513.0
13 PHILADELPHIA/DELAWARE BAY, PA	8,570	12	829.4
14 SAN FRANCISCO, CA	13,917	14	1,322.2
15 PORTLAND, OR	5,687	8	601.3
16 ANCHORAGE/COOK INLET, AK	11,113	7	510.2
17 PORTLAND, ME	4,677	7	457.1
18 PORTSMOUTH, NH	3,301	7	426.1
19 PROVIDENCE, RI	4,243	7	458.9
20 WILMINGTON, NC	4,492	7	469.9
21 JACKSONVILLE, FL	3,615	7	426.1
22 TAMPA, FL	4,784	7	489.6
23 MOBILE, AL	6,177	7	520.7

7.6.1.4 Study Zone VTS Cost Elements (Cont.)

Table 7-4 is a listing of the costs of implementing the Candidate VTS Design while taking credit for the value of existing VTS facilities in four of the study zones: Puget Sound, Houston/Galveston, New York, and San Francisco. Displayed in this table is the difference between the estimated 1990 value of these existing facilities and the full investment cost of the Candidate VTS Design.

TABLE 7-4. COST OF VTS CANDIDATE DESIGNS FOR ZONES WHERE EXISTING COAST GUARD VTS FACILITIES ARE INCORPORATED

ZONE	NAME	INITIAL INVESTMENT COST ($1,000)
2	PUGET SOUND, WA	11,765
7	HOUSTON/GALVESTON, TX	15,439
11	NEW YORK CITY, NY	13,443
14	SAN FRANCISCO, CA	12,795

7.6.1.4 <u>Study Zone VTS Cost Elements</u> (Cont.)

Table 7-5 displays the current annual O&M costs of operating the Existing Coast Guard VTS Systems. In addition to projecting the cost of operating the Candidate VTS Design, a complete benefit-cost analysis requires estimating the marginal cost of the Candidate VTS Design over-and-above the cost of continued operation of the existing systems through 2010. Section 8 uses the Total O&M Costs shown in Table 7-5 to determine the marginal benefits and cost comparisons.

TABLE 7-5. EXISTING COAST GUARD VTS O&M COSTS

ZONE	NAME	FACILITIES & EQUIPMENT MAINTENANCE COST ($1,000)	STAFFING COST ($1,000)	TOTAL ANNUAL O&M COST ($1,000)
2	Puget Sound, WA	2,900	1,650	4,550
7	Houston/Galveston, TX	650	2,150	2,800
11	New York, NY	1,600	1,650	3,250
14	San Francisco, CA	1,100	1,150	2,250

8. EVALUATION OF VTS BENEFIT AND COST RELATIONSHIPS

8.1 OVERVIEW

The objective of this study is to estimate the net benefit of the Coast Guard Candidate VTS Design postulated for each of the 23 study zones. The net benefit is the difference between the present value of the annual stream of benefits and the present value of the annual stream of costs for each study zone. The magnitude of the net benefit in each study zone will assist the Coast Guard in determining the assignment of priorities for planning implementation of VTS services at each study zone.

Section 8 provides two perspectives for viewing the benefits and costs of the Candidate VTS Design (i.e., Full Benefits and Costs and Marginal Benefits and Costs) to assist Coast Guard evaluation and priority assignments. This section presents summary tables, but a more detailed set of tables of the annual stream (1993 - 2010) of investment costs, and operations and maintenance costs and the annual stream of benefits is in the appendices (Volume II) for each of the 23 study zones.

8.1.1 Method

Consistency, among the 23 study zones, in estimating both benefits and costs is of paramount importance, because of the planned use of the study results to assist in establishing priorities for implementation. **Consistency** among study tasks at each task level has been a primary rule of this project. **Consistency** guides data collection and analysis, definition of subzones, approximation of vessel routes within each study zone, estimation of vessel traffic (past and future), assignment of all types of vessel traffic to subzones, screening of historical casualties for VTS addressability, and estimation of future vessel casualties and their associated losses, with and without the new Coast Guard Candidate VTS Design.

8.1.1 Method (Cont.)

Applying the consistent methodology described in Section 7 allows estimation of initial investment costs and annual operations and maintenance costs for each study zone. A similar methodology described in Section 5 and 6, enables estimation of avoided vessel casualties and their associated losses (i.e., vessel, cargo, cleanup, human life and injuries, marine life, other environmental losses and regional economic losses).

8.1.2 Defining the No-VTS Case for Future Years

A hypothetical No-VTS case for the future years against which the Candidate VTS Design may be compared must be explicitly defined for each study zone. In those study zones where no central vessel movement reporting system or surveillance system has been operating during the 1980-1990 decade, projecting forward the historical vessel casualty risk permits representation of the future No-VTS case. However, in those zones where some form of vessel movement reporting and/or surveillance system has been in operation during some portion of the past decade, defining the future No-VTS case requires some adjustment of the historically based vessel casualty rates. Estimating the marginal benefits and marginal costs attributable solely to the Candidate VTS Design over-and-above what would have attained if the existing systems continued to operate unchanged through 2010 requires some additional steps.

In order to establish a comparable future No-VTS Case in each of the study zones having existing vessel traffic management services, safety benefits of those existing services are extracted or "backed-out" of the historical casualty data of these study zones, using VTS Effectiveness Factors previously displayed in Table 5-11. Having "backed-out" the effects of the existing systems prior to estimation of the vessel casualty risk model, the subzone specific vessel casualty probabilities may be estimated. Using these vessel casualty probabilities and applying the VTS Effectiveness Factors (displayed in Table 5-8) to forecasted vessel transits, produces estimates of the avoidable vessel casualties attributed to the Candidate VTS Design.

8.1.3 Defining the Benefits of the Candidate VTS Design

There are two perspectives from which to view the benefits and costs of the Candidate VTS Design: 1) the full benefits and full costs of the Candidate VTS Design (i.e., ignoring any existing VTS services), or 2) the marginal benefits and marginal costs of the Candidate VTS Design (acknowledging the benefits and costs of existing VTS services).

- **FULL BENEFITS AND COSTS**

  The full benefits are the difference between the No-VTS Case future vessel casualties and the Candidate VTS Design future vessel casualties (i.e., the Avoided Vessel Casualties). Applying the VTS Effectiveness Factors of Table 5-8 (displayed earlier) to the No-VTS case vessel casualties and their associated consequences or losses, estimates the full benefits. The full costs of the Candidate VTS Design are the "Clean Sheet" costs (i.e., no existing facilities incorporated into the Candidate VTS Design). These costs include both initial investment and annual O&M costs. This method estimates the benefits and costs of all 23 study zones and the study compares them on this basis.

- **MARGINAL BENEFITS AND COSTS**

  The process for assessing the benefits and costs of the Candidate VTS Design over-and-above the <u>status quo</u> in those study zones where existing vessel traffic services are currently in operation includes developing marginal benefits and marginal costs. Estimating marginal benefits for those study zones involves estimating avoided casualties from the <u>differences</u> in the Candidate VTS Design Effectiveness Factors and the Existing VTS System Effectiveness Factors, previously displayed in Section 5, Tables 5-8 and 5-11 respectively. The difference in avoided vessel casualties and their associated consequences/losses represents the marginal benefit. The marginal VTS Costs incorporate investment reductions associated with utilization of certain existing Coast Guard facilities (e.g., radar facilities in Puget Sound) into the Candidate VTS Design. The marginal VTS costs also incorporate any differences between current O&M costs and projected O&M costs for the Candidate VTS Design. The marginal costs are defined as the difference between the full costs of the Candidate VTS Design and the incremental costs of expanding the Existing VTS System to the Candidate VTS Design as Table 7-4 in Section 7 presented earlier.

The output tables located in Section 8.4 (Study Zone Benefit and Cost Comparisons) present the results of both perspectives.

8.1.4 Integrated Model

Assuring the required consistency and continuity of the results, and also facilitating analyses of the sensitivity of the reported results to the uncertainty associated with several of the key inputs and assumptions, requires development of an integrated P.C. based accounting model. See Figure 8-1 for a data flow diagram representation of the integrated model. A relational DBMS supports the integrated model, providing a residence for the numerous files containing data for each study zone such as:

- Subzones;
- Vessel Routes;
- Vessel Transits;
- Commodity Tonnage Loaded/Unloaded;
- Historical Casualties;
- Probabilities of Vessel Casualties;
- Probabilities of Consequences/Losses;
- Consequence Unit Cost Factors;
- Candidate VTS Costs;
- VTS Effectiveness Factors; and
- Annual Benefits and Costs.

The integrated model provides four capabilities:

1. Automatic processing of the final tabulations of VTS avoided vessel casualties, avoided consequences in physical and monetary units, and the discounted annual streams of benefits and costs.

2. A single location for final data files, a single access point for any changes to algorithms and parameters.

3. Quick response reruns of outputs anytime any input is revised.

4. Storage of the highly desegregate data by subzone, by vessel type and size, by casualty type, by consequence type, by year, etc.

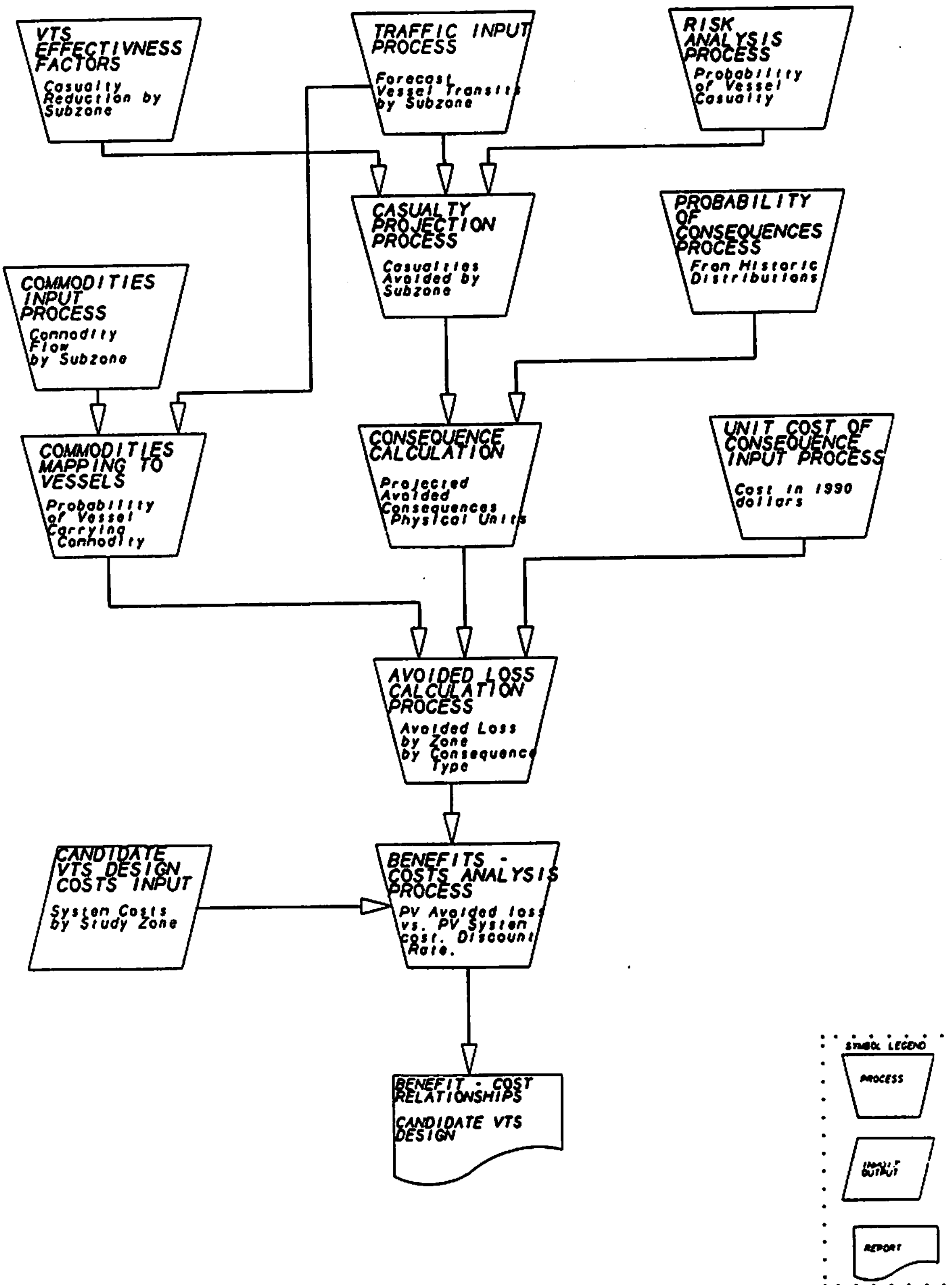

FIGURE 8-1. INTEGRATED MODEL DATA FLOW DIAGRAM

8.1.4 Integrated Model (Cont.)

The integrated model outputs are in the form of tabulations as follows:

1. Avoided future vessel casualties by casualty type, vessel type and size, by study zone, by year attributed to the Candidate VTS Design and to the Existing VTS Systems.

2. The annual stream of avoided consequences by type, in physical units and their dollar values, attributed to the Candidate VTS Design in each study zone, and where applicable also those attributable to the Existing VTS Systems.

3. The annual stream of Candidate VTS Design investment costs and O&M costs, full and marginal.

4. The discounted (i.e., 1993) value of these streams of benefits and costs for each study zone, full and marginal.

5. The net benefit and the benefit-cost ratios for each study zone from the perspective of full benefits and costs and marginal benefits and costs.

In addition to these five types of outputs, the integrated model provides the capability to determine the sensitivity of the reported benefit-cost relationships in each study zone to the range of uncertainty associated with the key input variables. Section 8.5 discusses sensitivity analysis (Sensitivity Of Discounted Life Cycle Total Benefits and Total Costs To Range Of Uncertainty In Key Variables).

8.2 STUDY ZONE LIFE CYCLE COSTS

8.2.1 Initial Capital Investments

Several basic capital investment assumptions are relevant:

1. A single federal entity will be the owner and operator of the Candidate VTS Design system in each of the 23 study zones.

2. Funding will be appropriated, and implementation will proceed in each study zone by the beginning of FY '93.

3. Initial Capital Investment in each study zone includes all non-recurring costs associated with:

   a. Acquisition, installation and testing of all equipment/hardware and computer software.

   b. Acquisition of all sites, and design and construction of all facilities.

   c. Acquisition of initial staff for full 24 hours/day 365 days/year operation.

4. Existing Coast Guard VTS facilities that are integrated into the Candidate VTS Design reduces the actual initial investment required by an amount equivalent to the 1990 replacement value. The full initial investment of the Candidate VTS Design without any existing facilities and the investment incorporating the existing facilities are both of interest in the Coast Guard evaluation.

5. Existing Non-Coast Guard vessel traffic service facilities are assumed not usable, or if usable must be purchased at current market values by the federal government from the current owners. The costs of such purchases, and any reconstruction required, are assumed to be included in the initial investment for the Candidate VTS Design.

6. State of the art, surveillance equipment, console displays, computer hardware and software are estimated at 1990 off-the-shelf prices.

8.2.1 Initial Capital Investments (Cont.)

A listing of the initial investment for the Candidate VTS Design in each study zone and for the initial investment in those study zones where the Candidate VTS Design incorporates existing Coast Guard facilities were previously displayed in Section 7, Tables 7-3 and 7-4 respectively.

8.2.2 Annual Costs for Operations and Maintenance

Several basic Operations and Maintenance (O&M) assumptions are relevant:

1. Each implemented Candidate VTS Design will be fully operational (i.e., begin incurring both operations and maintenance costs as well as benefits) by the beginning of FY '96.

2. The O&M costs include all recurring annual expenses associated with hiring, training and supervising operating and maintenance personnel (in-house or contract personnel), utilities, leased equipment and replacement parts, and management and other administrative costs.

3. A varying number of full-time equivalent personnel who stand watch have been estimated to staff each Vessel Traffic Center (VTC) 24 hours per day 365 days per year. Table 7-3 tabulates the number of full-time equivalent labor years/year (displayed earlier in Section 7).

4. Where existing Coast Guard VTS systems are in operation, their 1990 O&M costs will represent the O&M costs (in constant dollars) for the hypothetical case of continuing these operations, unchanged, through 2010. The marginal O&M cost is the difference between these costs and the O&M costs of the Candidate VTS Design.

The annual O&M costs of the Candidate VTS Design in each study zone and the annual O&M costs for existing Coast Guard VTS operations at four study zones which will serve for the projection of the Existing VTS System through 2010 were displayed in Section 7, Tables 7-3 and 7-5 respectively.

8.3 STUDY ZONE LIFE CYCLE BENEFITS

8.3.1 Non-Monetary Value of Vessel Casualty Reductions

The following tables present the results of all the analyses, estimated probabilities, and projections through the year 2010. These tables present summary values suitable for comparisons among the 23 study zones. Disaggregation of these values are in a series of detailed tables in the appendix (Volume II) for each study zone. The values presented in each table represents the aggregate of the avoided vessel casualties and associated losses for the entire period 1996 through 2010.

Table 8-1 displays the avoided physical losses calculated by taking the difference between the No-VTS Case and the Candidate VTS Design Case. The values shown are rounded off to the nearest whole number; zeros are actually values greater than zero but less than 0.5. The first five columns show the projected number of vessel casualty events and the associated major consequences - human deaths and injuries, vessels damaged, and spills of hazardous commodities. The last two columns show the marine life impact of these hazardous commodity spills - the number of pounds of commercial fish species lost and the number of individual marine mammals and birds killed respectively.

Table 8-2 displays the same avoided physical loss categories but for the difference between the No-VTS Case and the Existing VTS Systems Case runs of the model. These values represent the avoided vessel casualties and consequences if the existing systems continue unchanged into the future. Only the nine study zones having operating Coast Guard or Non-Coast Guard Systems; all others are blank; the values from Table 8-1 apply.

Tables 8-1 and 8-2 present hazardous commodity spills rounded to the nearest whole number. The hazardous commodity spills shown are the sum of spills of crude oil, petroleum products and chemicals from bulk tank vessels and spills of vessel fuels (bunker) from all vessels involved in casualties. The values on Tables 8-1 and 8-2 also include very small expected values of LPG and LNG events.

TABLE 8-1. STUDY ZONE AVOIDED LOSSES IN PHYSICAL UNITS - CANDIDATE VTS DESIGN LIFE CYCLE TOTALS 1996-2010

ZONE	NAME	VESSEL CASUALTIES	HUMAN DEATHS	HUMAN INJURIES	VESSELS DAMAGED	HAZMAT SPILLS	MARINE SPECIES LOST	
							POUNDS (1,000'S)	INDIVIDUALS
1	Boston, MA	13	0	3	7	1	972	11,645
2	Puget Sound, WA	61	3	30	37	8	423	129,673
3	Los Angeles/Long Beach, CA	33	2	5	16	4	187	550,596
4	Santa Barbara, CA	2	0	0	1	0	30	49,447
5	Port Arthur, TX	85	1	11	45	11	67,026	522,645
6	New Orleans, LA	386	11	39	201	40	66,665	1,608,336
7	Houston/Galveston, TX	55	2	6	28	8	175,898	90,478
8	Chesapeake South/Hampton Roads, VA	19	1	3	10	1	78	5,379
9	Chesapeake North/Baltimore, MD	10	0	1	5	1	3,735	34,830
10	Corpus Christi, TX	30	1	7	16	4	18,740	37,704
11	New York, NY	79	4	10	35	8	15,188	209,149
12	Long Island Sound, NY/CT	28	0	4	16	1	754	5,685
13	Philadelphia/Delaware Bay, PA	24	1	5	13	3	1,216	104,453
14	San Francisco, CA	22	1	2	10	2	1,038	137,623
15	Portland, OR	42	1	3	20	2	1,924	19,577
16	Anchorage/Cook Inlet, AK	2	0	0	1	0	18	7,408
17	Portland, ME	1	0	1	1	0	18	1,870
18	Portsmouth, NH	0	0	0	0	0	0	53
19	Providence, RI	6	0	1	3	1	4,121	30,095
20	Wilmington, NC	7	0	1	4	1	1,287	19,498
21	Jacksonville, FL	3	0	1	2	0	331	31,148
22	Tampa, FL	28	1	2	13	2	1,214	50,292
23	Mobile, AL	45	1	3	24	4	34,855	210,295
	TOTAL	980	31	138	506	100	395,719	3,867,881

NOTE: (1) Each marine species loss is measured either in pounds or in individuals but never both. Therefore, the values posted here represent the totals of each of these categories without double counting.
(2) Vessels in the first column are single vessels and tug/barge tows.
(3) 0's (zero's) represent a value equal to or less than 0.5.

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TABLE 8-2. STUDY ZONE AVOIDED LOSSES IN PHYSICAL UNITS - EXISTING VTS SYSTEM LIFE CYCLE TOTALS 1996-2010

ZONE	NAME	VESSEL CASUALTIES	HUMAN DEATHS	HUMAN INJURIES	VESSELS DAMAGED	HAZMAT SPILLS	MARINE SPECIES LOST	
							POUNDS (1,000'S)	INDIVIDUALS
1	Boston, MA							
2	Puget Sound, WA	50	3	25	30	6	344	105,857
3	Los Angeles/Long Beach, CA	28	1	4	13	3	157	454,062
4	Santa Barbara, CA							
5	Port Arthur, TX					-		
6	New Orleans, LA							
7	Houston/Galveston, TX	46	1	5	23	6	148,635	76,621
8	Chesapeake South/Hampton Roads, VA	6	0	0	3	0	50	2,246
9	Chesapeake North/Baltimore, MD	2	0	0	1	0	1,249	904
10	Corpus Christi, TX	8	0	2	5	1	6,217	11,974
11	New York, NY	56	3	6	23	5	11,848	168,698
12	Long Island Sound, NY/CT							
13	Philadelphia/Delaware Bay, PA	8	0	1	4	1	426	82,396
14	San Francisco, CA	14	1	1	6	1	511	99,598
15	Portland, OR							
16	Anchorage/Cook Inlet, AK							
17	Portland, ME							
18	Portsmouth, NH							
19	Providence, RI							
20	Wilmington, NC							
21	Jacksonville, FL							
22	Tampa, FL							
23	Mobile, AL							
	TOTAL	218	9	45	108	24	169,439	1,002,357

NOTE: (1) Each marine species loss is measured either in pounds or in individuals but never both.
Therefore, the values posted here represent the totals of each of these categories without double counting.
(2) Vessels in the first column are single vessels and tug/barge tows.
(3) 0's (zero's) represent a value equal to or less than 0.5.

07/31/91

8.3.1 Non-Monetary Value of Vessel Casualty Reductions (Cont.)

LPG and LNG events are extremely rare events and their associated losses are from fire and explosion rather than from fouling the waterway and the adjacent shores. Estimating the LPG and LNG vessel transits involves considering them as a subset of the total tanker vessel transits in each subzone. The expected value of vessel casualties for the LPG and LNG tankers is a function of the expected values for tanker vessel casualties in each study subzone. LPG tankers operate in most of the study zones. The study assigns the same vessel casualty probability to LPG tankers as to other tanker vessels in the subzone (as Section 5 defines). Section 6 defines the probability of an LPG or LNG fire/explosion, given a vessel casualty. The estimates allow for the fact that only three of the 23 study zones will be operating LNG terminals during the forecast period. LNG tankers have a substantially lower probability of vessel casualties in the three study zones, where they are projected to operate, because of the high level of traffic control exercised for these vessels. The vessel casualty probability value used for LNG is the result of application of a factor (i.e., 0.10) to the probabilities for large tanker casualties in each subzone in which these vessels transit.

Tables 8-3 and 8-4 show the relative magnitude of the expected values of hazardous commodity spills into the waterway and the expected values of explosion events of LPG and LNG tank vessels. The only reason for segregating the total expected values and presenting them to six places after the decimal point is to capture the extremely small expected values of LPG events in several of the study zones. The reader is cautioned not to infer a level of accuracy from these statistics.

TABLE 8-3. STUDY ZONE AVOIDED HAZMAT SPILLS AND LPG & LNG INCIDENTS - CANDIDATE VTS DESIGN - LIFE CYCLE TOTALS 1996-2010

ZONE	NAME	HAZARDOUS COMMODITY SPILLS	LPG EXPLOSIONS	LNG EXPLOSIONS	TOTAL EVENTS
1	Boston, MA	1.475173	0.000000	0.016051	1.491224
2	Puget Sound, WA	7.562363	0.000178	0.000000	7.562541
3	Los Angeles/Long Beach, CA	3.661017	0.001011	0.000000	3.662028
4	Santa Barbara, CA	0.227081	0.000108	0.000000	0.227189
5	Port Arthur, TX	10.708138	0.071050	0.011079	10.790267
6	New Orleans, LA	39.274188	0.360059	0.000000	39.634247
7	Houston/Galveston, TX	7.667597	0.046412	0.000000	7.714009
8	Chesapeake South/Hampton Roads, VA	1.179945	0.000254	0.000626	1.180825
9	Chesapeake North/Baltimore, MD	0.744113	0.000011	0.001168	0.745292
10	Corpus Christi, TX	3.528402	0.005487	0.000000	3.533889
11	New York, NY	7.623835	0.001089	0.000000	7.624924
12	Long Island Sound, NY/CT	1.345485	0.000000	0.000000	1.345485
13	Philadelphia/Delaware Bay, PA	2.620861	0.002167	0.000000	2.623028
14	San Francisco, CA	1.970190	0.000004	0.000000	1.970194
15	Portland, OR	2.229870	0.000001	0.000000	2.229871
16	Anchorage/Cook Inlet, AK	0.186290	0.002070	0.000000	0.188360
17	Portland, ME	0.128141	0.000000	0.000000	0.128141
18	Portsmouth, NH	0.009156	0.000000	0.000000	0.009156
19	Providence, RI	0.651574	0.002318	0.000000	0.653892
20	Wilmington, NC	0.646232	0.000376	0.000000	0.646608
21	Jacksonville, FL	0.363022	0.001800	0.000000	0.364822
22	Tampa, FL	2.262994	0.009844	0.000000	2.272838
23	Mobile, AL	3.701380	0.049319	0.000000	3.750699
	TOTAL	99.767047	0.553558	0.028924	100.349529

NOTE : TOTAL EVENTS of this table equals HAZMAT SPILLS OF Table 8-1

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TABLE 8-4. STUDY ZONE AVOIDED HAZMAT SPILLS AND LPG & LNG INCIDENTS - EXISTING VTS DESIGN - LIFE CYCLE TOTALS 1996-2010

ZONE	NAME	HAZARDOUS COMMODITY SPILLS	LPG EXPLOSIONS	LNG EXPLOSIONS	TOTAL EVENTS
1	Boston, MA				
2	Puget Sound, WA	6.141769	0.000147	0.000000	6.141916
3	Los Angeles/Long Beach, CA	2.973888	0.000854	0.000000	2.974742
4	Santa Barbara, CA				
5	Port Arthur, TX				
6	New Orleans, LA				
7	Houston/Galveston, TX	6.330738	0.039514	0.000000	6.370252
8	Chesapeake South/Hampton Roads, VA	0.478234	0.000155	0.000832	0.479221
9	Chesapeake North/Baltimore, MD	0.126648	0.000000	0.000000	0.126648
10	Corpus Christi, TX	1.048474	0.001572	0.000000	1.050046
11	New York, NY	5.199808	0.000396	0.000000	5.200204
12	Long Island Sound, NY/CT				
13	Philadelphia/Delaware Bay, PA	0.859180	0.000902	0.000000	0.860082
14	San Francisco, CA	1.227644	0.000003	0.000000	1.227647
15	Portland, OR				
16	Anchorage/Cook Inlet, AK				
17	Portland, ME				
18	Portsmouth, NH				
19	Providence, RI				
20	Wilmington, NC				
21	Jacksonville, FL				
22	Tampa, FL				
23	Mobile, AL				
	TOTAL	24.386383	0.043543	0.000832	24.430758

NOTE : TOTAL EVENTS of this table equals HAZMAT SPILLS OF Table 8-2

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8.3.2 Monetary Value of Vessel Casualty Reductions

The total dollar benefit in each study zone is an aggregation of the avoided dollar losses associated with each of the eight major consequence types:

1. Human Deaths
2. Human Injuries
3. Vessel Damage
4. Cargo Loss/Damage
5. Bridge Damage
6. Navigational Aid Damage
7. Emergency Response
8. Hazardous Commodity Spills

Tables 8-5 and 8-6 display the undiscounted dollar values for the period 1996-2010 of each of these loss types and the total for each study zone. Table 8-5 shows the avoided losses, for Candidate VTS Design, and Table 8-6 shows the avoided losses if the Existing Systems are continued unchanged into the future. The dollar value of losses from hazardous commodity spills dominate the total VTS avoided losses in each zone. These losses are, in turn, aggregations of eight major loss categories:

1. Damage Assessment Costs
2. Cleanup Costs
3. Loss of Commercial Fish Species
4. Marine Bird and Mammal Losses
5. Property Value Loss
6. Tourism/Recreation/Subsistence Household Losses
7. LPG Deaths/Injuries/Damage
8. LNG Deaths/Injuries/Damage

Tables 8-7 and 8-8 display the 15 year total dollar value (undiscounted) of each of these loss categories in each study zone as well as the total of all loss categories. Table 8-7 shows the avoided losses for Candidate VTS Design, and Table 8-8 shows the avoided losses if the Existing Systems are continued unchanged into the future.

TABLE 8-5. STUDY ZONE AVOIDED LOSSES - CANDIDATE VTS DESIGN: LIFE CYCLE TOTALS 1996-2010 UNDISCOUNTED ($1,000's)

ZONE	NAME	HUMAN DEATHS	HUMAN INJURIES	VESSEL DAMAGE	CARGO LOSSES	BRIDGE DAMAGE	NAVAID DAMAGE	EMERGENCY RESPONSE	HAZMAT SPILL LOSSES	TOTAL LOSSES ($1000's)
1	Boston, MA	595	757	2,091	66	139	1	231	50,174	54,055
2	Puget Sound, WA	4,643	7,264	9,416	100	41	5	859	28,678	51,006
3	Los Angeles/Long Beach, CA	2,292	1,261	5,958	163	0	2	583	120,074	130,333
4	Santa Barbara, CA	274	8	633	13	0	0	16	8,077	9,020
5	Port Arthur, TX	2,166	2,681	13,250	683	1,313	7	1,055	231,968	253,122
6	New Orleans, LA	16,805	9,315	61,617	2,010	6,335	34	3,545	576,669	676,330
7	Houston/Galveston, TX	2,489	1,390	17,781	460	990	4	699	184,306	208,119
8	Chesapeake South/Hampton Roads, VA	937	621	2,351	28	103	2	141	6,509	10,692
9	Chesapeake North/Baltimore, MD	448	169	1,203	36	187	1	48	14,133	16,226
10	Corpus Christi, TX	1,180	1,651	6,146	260	397	2	659	72,816	83,110
11	New York, NY	5,909	2,415	13,032	311	831	6	812	64,773	88,089
12	Long Island Sound, NY/CT	643	1,067	1,892	61	347	3	106	11,749	15,867
13	Philadelphia/Delaware Bay, PA	1,220	1,161	3,546	132	437	2	171	31,807	38,477
14	San Francisco, CA	1,481	408	4,869	85	322	2	219	22,177	29,562
15	Portland, OR	1,698	771	4,194	96	1,005	5	151	20,006	27,926
16	Anchorage/Cook Inlet, AK	172	7	527	8	0	0	8	1,443	2,166
17	Portland, ME	68	121	161	3	0	0	16	606	973
18	Portsmouth, NH	5	6	22	1	0	0	1	20	55
19	Providence, RI	379	222	1,225	53	73	0	179	10,189	12,319
20	Wilmington, NC	372	307	1,261	49	103	1	84	4,721	6,897
21	Jacksonville, FL	260	192	846	21	94	0	55	4,251	5,720
22	Tampa, FL	1,744	361	6,036	250	317	2	594	21,549	30,854
23	Mobile, AL	804	607	4,973	294	900	4	189	130,223	137,992
	TOTAL	46,584	32,761	163,032	5,182	13,932	84	10,421	1,616,917	1,888,912

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Note: CARGO LOSSES includes the dollar value of vessel fuels spilled.

TABLE 8-6. STUDY ZONE AVOIDED LOSSES - EXISTING VTS SYSTEMS LIFE CYCLE TOTALS 1996-2010 UNDISCOUNTED ($1,000's)

ZONE	NAME	HUMAN DEATHS	HUMAN INJURIES	VESSELS DAMAGED	CARGO LOSSES	BRIDGE DAMAGE	NAVAID DAMAGE	EMERGENCY RESPONSE	HAZMAT SPILL LOSSES	TOTAL LOSSES ($1000's)
1	Boston, MA									
2	Puget Sound, WA	3,808	5,959	7,662	88	41	4	722	23,449	41,732
3	Los Angeles/Long Beach, CA	1,901	1,024	4,852	147	0	2	484	98,528	106,939
4	Santa Barbara, CA									
5	Port Arthur, TX									
6	New Orleans, LA									
7	Houston/Galveston, TX	2,085	1,160	14,786	425	944	4	591	155,112	175,107
8	Chesapeake South/Hampton Roads, VA	434	81	1,007	18	99	0	48	4,000	5,687
9	Chesapeake North/Baltimore, MD	87	16	260	11	0	0	7	3,360	3,741
10	Corpus Christi, TX	313	418	1,790	84	210	1	170	22,884	25,870
11	New York, NY	3,934	1,464	8,821	245	722	5	529	47,224	62,945
12	Long Island Sound, NY/CT									
13	Philadelphia/Delaware Bay, PA	357	208	1,267	70	239	1	66	13,567	15,776
14	San Francisco, CA	1,010	325	2,971	55	209	1	168	12,999	17,738
15	Portland, OR									
16	Anchorage/Cook Inlet, AK									
17	Portland, ME									
18	Portsmouth, NH									
19	Providence, RI									
20	Wilmington, NC									
21	Jacksonville, FL									
22	Tampa, FL									
23	Mobile, AL									
	TOTAL	13,930	10,655	43,416	1,142	2,465	20	2,785	381,124	455,536

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Note: CARGO LOSSES includes the dollar value of vessel fuels spilled.

TABLE 8-7. STUDY ZONE AVOIDED SPILL CONSEQUENCES: CANDIDATE VTS DESIGN LIFE CYCLE TOTALS 1996-2010 UNDISCOUNTED ($1,000's)

ZONE	NAME	DAMAGE ASMT.	CLEAN UP	COMM. FISH SPECIES	BIRDS & MAMMALS	PROPERTY DAMAGE	TOURISM	LPG	LNG	TOTAL HAZMAT LOSSES ($1000's)
1	Boston, MA	1,115	12,874	385	52	1,319	4[illegible]7	0	33,982	50,174
2	Puget Sound, WA	919	18,954	236	575	6,894	1,088	12	0	28,678
3	Los Angeles/Long Beach, CA	2,059	26,666	51	2,259	72,029	16,834	176	0	120,074
4	Santa Barbara, CA	128	1,624	9	194	4,862	1,255	5	0	8,077
5	Port Arthur, TX	10,885	121,610	53,270	1,894	4,394	20,707	18,457	750	231,967
6	New Orleans, LA	25,718	336,950	62,289	5,920	4,964	46,792	94,036	0	576,669
7	Houston/Galveston, TX	5,301	61,857	86,863	182	8,501	10,682	10,920	0	184,306
8	Chesapeake South/Hampton Roads, VA	232	4,770	18	25	564	790	64	47	6,510
9	Chesapeake North/Baltimore, MD	421	5,840	6,038	162	661	925	3	82	14,132
10	Corpus Christi, TX	3,070	33,630	23,935	99	5,639	5,315	1,128	0	72,816
11	New York, NY	3,349	48,460	5,679	868	4,723	1,601	94	0	64,774
12	Long Island Sound, NY/CT	611	7,936	370	38	1,552	1,241	0	0	11,748
13	Philadelphia/Delaware Bay, PA	2,076	23,111	449	480	4,243	1,258	191	0	31,808
14	San Francisco, CA	991	13,393	1,097	559	4,648	1,488	0	0	22,176
15	Portland, OR	834	13,115	1,017	84	4,280	675	0	0	20,005
16	Anchorage/Cook Inlet, AK	69	1,091	3	40	29	1	210	0	1,443
17	Portland, ME	35	467	7	8	68	20	0	0	605
18	Portsmouth, NH	0	18	0	0	1	0	0	0	19
19	Providence, RI	528	5,943	1,948	136	1,086	184	364	0	10,189
20	Wilmington, NC	175	3,107	887	74	185	203	90	0	4,721
21	Jacksonville, FL	214	2,705	233	113	272	300	414	0	4,251
22	Tampa, FL	1,192	15,998	997	248	1,241	969	905	0	21,550
23	Mobile, AL	5,182	53,096	47,225	758	7,654	3,593	12,715	0	130,223
	TOTAL	65,104	813,215	293,006	14,768	139,809	116,368	139,784	34,861	1,616,915

Note: TOURISM includes recreation: Anchorage/Cook Inlet tourism also includes losses to subsistence households.

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TABLE 8-8. STUDY ZONE AVOIDED SPILL CONSEQUENCES: EXISTING VTS SYSTEMS LIFE CYCLE TOTALS 1996-2010 UNDISCOUNTED ($1,000,s)

ZONE	NAME	DAMAGE ASMT.	CLEAN UP	COMM. FISH SPECIES	BIRDS & MAMMALS	PROPERTY DAMAGE	TOURISM	LPG	LNG	TOTAL HAZMAT LOSSES ($1000's)
1	Boston, MA									
2	Puget Sound, WA	757	15,463	192	470	5,664	894	9	0	23,449
3	Los Angeles/Long Beach, CA	1,693	21,820	42	1,861	59,144	13,823	145	0	98,528
4	Santa Barbara, CA									
5	Port Arthur, TX									
6	New Orleans, LA									
7	Houston/Galveston, TX	4,483	51,836	73,512	154	7,185	9,028	8,913	0	155,112
8	Chesapeake South/Hampton Roads, VA	170	2,824	12	10	382	534	7	60	4,000
9	Chesapeake North/Baltimore, MD	69	1,004	2,040	5	101	141	0	0	3,360
10	Corpus Christi, TX	929	10,228	7,993	35	1,696	1,598	405	0	22,884
11	New York, NY	2,479	35,035	4,375	697	3,422	1,160	56	0	47,224
12	Long Island Sound, NY/CT									
13	Philadelphia/Delaware Bay, PA	897	9,661	152	365	1,815	538	138	0	13,567
14	San Francisco, CA	573	7,899	563	402	2,699	864	0	0	12,999
15	Portland, OR									
16	Anchorage/Cook Inlet, AK									
17	Portland, ME									
18	Portsmouth, NH									
19	Providence, RI									
20	Wilmington, NC									
21	Jacksonville, FL									
22	Tampa, FL									
23	Mobile, AL									
	TOTAL	12,049	155,771	88,882	4,000	82,107	28,580	9,674	60	381,123

Note: TOURISM includes recreation: Anchorage/Cook Inlet tourism also includes losses to subsistence households.

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8.4 STUDY ZONE BENEFIT AND COST COMPARISONS

8.4.1 Net Benefits, and Ratio of Benefits to Costs

- Study Zone Net Benefit
  - The net benefit is the difference between the discounted value of the annual stream of benefits and the discounted value of the annual stream of costs. The basic annual discount rate applied is 10%.
  - The net benefit provides a measure of the absolute difference in the discounted values of the benefits and the costs in each zone.
  - The absolute magnitude of the net benefit is a suitable measure for comparisons among study zones for the purpose of prioritizing zones for implementation.
- Study Zone Benefit/Cost (B/C) Ratio
  - The B/C Ratio is the result of dividing the discounted annual stream of benefits by the discounted annual stream of costs.
  - The B/C Ratio provides a measure of the relative magnitudes of the discounted value of the annual stream of benefits and the discounted value of the annual stream of costs.
  - The magnitude of the B/C Ratio is more suited to a "Go - No Go" decision of a specific study zone than for prioritizing implementation among several study zones. It fails to reveal the absolute values of the savings that are required for assignment of priorities for implementation.

Those making decisions and priority assignments may desire additional methods for comparing the Candidate VTS Design benefits and costs for each study zone. Therefore, for each study zone, there is a set of tables in the appendices of Vol. II. Full Benefits and Costs of the Candidate VTS Design and the Benefits and Costs of continuing the Existing VTS Systems appear for each of the nine study zones that currently have operating vessel traffic services projected as operating during the forecast period of 1996-2010.

8.4.1 Net Benefits, and Ratio of Benefits to Costs (Cont.)

Five study zones have existing Non-Coast Guard traffic services whose safety benefits have been incorporated into the marginal benefits, but no marginal costs are incorporated. The premise for this is that the safety benefits derived from the Non-Coast Guard services will continue to accrue and cannot be attributed to the Candidate VTS Design. The benefits of these existing systems are a free byproduct of commercial enterprises, which will continue even in the presence of a Coast Guard Candidate VTS Design. It follows that the costs of operating these Non-Coast Guard services should not be charged to the Candidate VTS Design, because the private sector will continue to incur these costs as an integral part of its commercial operations. Table 8-9 defines the life cycle costs and benefits for (a) the Candidate VTS Design Case, (b) the case where Existing VTS Systems are continued unchanged through 2010 (i.e., maintaining the status quo), and (c) the marginal costs and marginal benefits (i.e. difference between these two cases).

TABLE 8-9. DEFINING COSTS AND BENEFITS OF CANDIDATE VTS DESIGNS AND CONTINUING EXISTING VTS SYSTEMS UNCHANGED

	VTS COSTS					VTS BENEFITS		
	CAND. VTS DESIGN		CONTINUE EXIST. VTS SYSTEM		MARGIN COSTS	CAND. VTS DESIGN	CONTINUE EXIST. VTS SYSTEM	MARGIN BENEFITS
STUDY ZONE WITH:	I	O&M	I	O&M				
NO-VTS	(1)	(2)	(5)	(6)	(8)	(11)	(13)	(15)
EXIST. VTS COAST GUARD	(3)	(4)	(5)	(7)	(9)	(12)	(14)	(16)
EXIST. VTS NON-C.G.	(1)	(2)	(5)	(6)	(10)	(12)	(14)	(16)

(1) I = Initial Investment for Candidate VTS Design (Table 7-3)
(2) O&M = Annual O & M Cost for Candidate VTS Design (Table 7-3)
(3) I = Initial Investment to Upgrade Existing VTS System to Candidate VTS Design (Table 7-4)
(4) O&M = Annual O & M Cost for Candidate VTS Design (Table 7-3)
(5) Zero Initial Investment
(6) Zero O & M Cost
(7) O&M = Annual O & M Cost to Continue Existing VTS System Unchanged (Table 7-5)

(8) MARGINAL COSTS = [(1)+(2)] - [(5)+(6)]
(9) MARGINAL COSTS = [(3)+(4)] - [(5)+(7)]
(10) MARGINAL COSTS = [(1)+(2)] - [(5)+(6)]

(11) BENEFITS = CANDIDATE VTS DESIGN AVOIDED LOSSES
(12) BENEFITS = CANDIDATE VTS DESIGN AVOIDED LOSSES - EXISTING VTS AVOIDED LOSSES
(13) ZERO BENEFITS
(14) BENEFITS = EXISTING VTS AVOIDED LOSSES
(15) MARGINAL BENEFITS = [(11)] - [(13)]
(16) MARGINAL BENEFITS = [(12)] - [(14)]

8.4.1 Net Benefits, and Ratio of Benefits to Costs (Cont.)

Tables in the Vol II appendix for each study zone detail the annual streams for the life cycle period (1993-2010) of investment costs, operations and maintenance costs and benefits. Table 8-10 summarizes the present value analysis of the benefits and costs for each of the 23 study zones using Full Benefits and Full Costs. Table 8-11 does the same using Marginal Benefits and Marginal Costs.

Comparison of full benefits and full costs of the Candidate VTS Design vis-a-vis the No-VTS case is clear for all 23 study zones. However, comparison of marginal benefits and costs of the Candidate VTS Design vis-a-vis continuation of Existing VTS Systems in nine of the study zones is not quite so clear. In the four study zones with existing Coast Guard VTS, the marginal values must be limited to the incremental additional benefits and costs that accrue over and above what would have accrued if the Candidate VTS Design did not materialize and the Existing VTS System continued to operate unchanged through 2010. In the five zones with Non-Coast Guard services, the marginal values must also be limited to the incremental additional benefits that accrue over and above what would have accrued if the existing system were extended through 2010. In the latter zones, there are no incremental additional costs; the marginal costs equal the full costs of the Candidate VTS Design.

Table 8-10 presents the 1993 discounted value of the annual streams of VTS total benefits and total costs for each study zone for the entire life cycle period (1993-2010) from the perspective of the full benefits and costs for the Candidate VTS Design. The first column is the 1993 discounted value of the life cycle total benefits. The second is the discounted value of the total costs. The third column is the difference between the first two columns; the forth column is the ratio of the first column over the second.

Table 8-11 presents the marginal benefit-cost perspective for those study zones that have existing systems. The results shown on Table 8-11 raise a new issue that requires some discussion here. Puget Sound displays a negative marginal cost. This marginal life cycle cost is negative because the annual O&M costs estimated for the Candidate VTS Design in Puget Sound are considerably lower than the O&M costs estimated for continuing the existing VTS system unchanged into the future, as indicated in Section 7.6.1.4. Of the four

TABLE 8-10. STUDY ZONE 1993 VALUE OF LIFE CYCLE BENEFITS AND COSTS - CANDIDATE VTS DESIGN - FULL BENEFITS AND COSTS

ZONE	NAME	TOTAL BENEFIT ($1,000's)	TOTAL COST ($1,000's)	NET BENEFIT ($1,000's)	B/C RATIO
1	Boston, MA	23,149	7,999	15,150	2.89
2	Puget Sound, WA	21,717	25,724	(4,007)	0.84
3	Los Angeles/Long Beach, CA	55,848	13,021	42,827	4.29
4	Santa Barbara, CA	3,888	8,667	(4,779)	0.45
5	Port Arthur, TX	108,270	15,856	92,414	6.83
6	New Orleans, LA	290,771	37,036	253,735	7.85
7	Houston/Galveston, TX	89,661	28,646	61,014	3.13
8	Chesapeake South/Hampton Roads, VA	4,531	22,918	(18,387)	0.20
9	Chesapeake North/Baltimore, MD	6,924	8,593	(1,669)	0.81
10	Corpus Christi, TX	35,424	9,311	26,113	3.80
11	New York, NY	35,480	26,445	9,036	1.34
12	Long Island Sound, NY/CT	6,837	9,084	(2,248)	0.75
13	Philadelphia/Delaware Bay, PA	16,221	14,032	2,189	1.16
14	San Francisco, CA	12,694	22,624	(9,930)	0.56
15	Portland, OR	11,850	9,647	2,203	1.23
16	Anchorage/Cook Inlet, AK	935	14,473	(13,538)	0.06
17	Portland, ME	410	7,687	(7,277)	0.05
18	Portsmouth, NH	23	6,107	(6,084)	0.00
19	Providence, RI	5,281	7,265	(1,984)	0.73
20	Wilmington, NC	2,939	7,586	(4,647)	0.39
21	Jacksonville, FL	2,473	6,421	(3,948)	0.39
22	Tampa, FL	13,185	8,008	5,176	1.65
23	Mobile, AL	57,747	9,606	48,141	6.01
	TOTALS	806,255	326,756	479,499	

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TABLE 8-11. STUDY ZONE PRESENT VALUE OF LIFE CYCLE BENEFITS AND COSTS - CANDIDATE VTS DESIGN - MARGINAL BENEFITS AND COSTS

ZONE	NAME	BENEFIT ($1,000's)	COST ($1,000's)	NET BENEFIT ($1,000's)	B/C RATIO
1	Boston, MA				
2	Puget Sound, WA	3,945	(4,240)	8,184	* 2.07
3	Los Angeles/Long Beach, CA	10,020	13,021	(3,001)	0.77
4	Santa Barbara, CA				
5	Port Arthur, TX				
6	New Orleans, LA				
7	Houston/Galveston, TX	14,216	10,207	4,008	1.39
8	Chesapeake South/Hampton Roads, VA	2,153	22,918	(20,765)	0.09
9	Chesapeake North/Baltimore, MD	5,467	8,593	(3,125)	0.64
10	Corpus Christi, TX	24,397	9,311	15,086	2.62
11	New York, NY	10,358	5,042	5,316	2.05
12	Long Island Sound, NY/CT				
13	Philadelphia/Delaware Bay, PA	9,578	14,032	(4,454)	0.68
14	San Francisco, CA	5,087	7,807	(2,720)	0.65
15	Portland, OR				
16	Anchorage/Cook Inlet, AK				
17	Portland, ME				
18	Portsmouth, NH				
19	Providence, RI				
20	Wilmington, NC				
21	Jacksonville, FL				
22	Tampa, FL				
23	Mobile, AL				
	TOTALS	85,222	86,692	(1,470)	

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* Puget Sound B/C Ratio Calculated after Transfer of O&M Cost Reduction from Cost Column to Benefit Column.

8.4.1 Net Benefits, and Ratio of Benefits to Costs (Cont.)

study zones with operating Coast Guard VTS (i.e., Puget Sound, Houston/Galveston, New York, and San Francisco) only Puget Sound has an O&M cost for the Candidate VTS Design that is sufficiently lower than the Existing System that the incremental initial investment is overwhelmed. The discounted value of the difference in O&M costs in Puget Sound exceeds the incremental initial investment required to implement the Candidate VTS Design by 26%.

In many benefit/cost analyses, a reduction in future annual O&M costs would be added to the benefits of the proposed system rather than subtracted from the other costs of the proposed system. This study accounts for all VTS system costs (including O&M cost reductions) under COSTS. The BENEFITS in this study are purely the dollar value of all consequences associated with avoided vessel casualties. The NET BENEFITS (full and marginal), which are the focus of this study, accurately reflect all VTS benefits and costs (positive and negative) The MARGINAL B/C RATIO, however cannot accurately reflect the O&M cost reduction unless the reduction is transferred from the cost column to the benefit column.

The discounted O&M cost reduction in question is $20.4 million, which, when added to the discounted $3.9 million marginal benefit, yields a new discounted marginal benefit of $24.4. The marginal cost is the $11.8 million initial investment required for the Candidate VTS Design (i.e., utilizing existing facilities). Under this method, the MARGINAL B/C RATIO for Puget Sound becomes 2.07, while all other MARGINAL B/C RATIOS remain as shown on Table 8-11.

8.5 SENSITIVITY OF DISCOUNTED LIFE CYCLE TOTAL BENEFITS AND TOTAL COSTS TO RANGE OF UNCERTAINTY IN KEY VARIABLES

> "In circumstances where firm probabilities cannot be attached to the future value of parameters which are likely to affect the outcome of a benefit/cost study, sensitivity analysis may represent the only method of describing, quantitatively, uncertain outcomes to decision-makers. In this simple technique, different values for uncertain variables are used to construct alternative scenarios of outcomes for presentation to the decision-maker."[1]

Different reviewers of this study may view any one or more of the key variable inputs as being somewhat uncertain and therefore subject to sensitivity analyses. The key variables of the benefits and the cost of the Candidate VTS Designs are discussed separately.

8.5.1 Cost Variables

The 1993 value of VTS life cycle total costs may be underestimated or overestimated in either of the two major elements:

1. Initial investment/non-recurring cost required to reach full operational status.

2. Annual operating and maintenance costs during the 15 year life cycle period.

Moreover, the assumed date of full operational status of the Candidate VTS Design, at which point the annual operations and maintenance costs begin to accrue, may be optimistic. This study assumes that the decision for implementation will be made, and funds authorized and committed by October 1, 1992, and that the Coast Guard Candidate VTS Design in each study zone will be fully operational by October 1, 1995. For purpose of objective comparisons among the study zones, the same dates are applied to each study zone.

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[1] Benefit-Cost Analysis Guide, Planning Branch, Treasury Board Secretariat of Canada, March 1976, p. 36.

8.5.1 Cost Variables (Cont.)

It would be possible to vary any of these cost parameters over some reasonable range to determine the relative importance to the end results reported here, but this study documents only one sensitivity test. The cost estimates may be assumed to be low; therefore all costs are increased by a factor. The combined result of an underestimate of both the investment and the annual operating cost is tested (i.e., the investment and annual operations and maintenance costs are each inflated by 50%) to determine the effect. An overestimate of either the investment or annual operations and maintenance costs is considered to be highly unlikely, thus obviating the need to test a 50% reduction in the Candidate VTS Design costs. The resultant effect on the net benefit and the benefit-cost ratio in each study zone is displayed in Table 8-12. The first column shows the effect of increasing all VTS costs (investment and O&M cost) by 50%. The second column of values are the full benefits unchanged from those presented in Table 8-10. The third and forth columns i.e., the Net Benefit and Benefit-Cost Ratio suggest the level of sensitivity of these measures to the VTS cost estimates when compared with Table 8-10.

TABLE 8-12. SENSITIVITY OF BENEFIT-COST RELATIONSHIPS TO CANDIDATE VTS DESIGN COSTS - FULL BENEFITS AND COSTS (+50%)

ZONE	NAME	TOTAL VTS BENEFIT X 1.0 ($1,000's)	TOTAL VTS COST X 1.5 ($1,000's)	NET BENEFIT ($1,000's)	B/C RATIO
1	Boston, MA	23,149	11,998	11,151	1.93
2	Puget Sound, WA	21,717	38,586	(16,869)	0.56
3	Los Angeles/Long Beach, CA	55,848	19,532	36,316	2.86
4	Santa Barbara, CA	3,888	13,001	(9,113)	0.30
5	Port Arthur, TX	108,270	23,784	84,486	4.55
6	New Orleans, LA	290,771	55,554	235,217	5.23
7	Houston/Galveston, TX	89,661	42,969	46,691	2.09
8	Chesapeake South/Hampton Roads, VA	4,531	34,377	(29,846)	0.13
9	Chesapeake North/Baltimore, MD	6,924	12,889	(5,965)	0.54
10	Corpus Christi, TX	35,424	13,967	21,457	2.54
11	New York, NY	35,480	39,667	(4,186)	0.89
12	Long Island Sound, NY/CT	6,837	13,626	(6,790)	0.50
13	Philadelphia/Delaware Bay, PA	16,221	21,048	(4,827)	0.77
14	San Francisco, CA	12,694	33,936	(21,242)	0.37
15	Portland, OR	11,850	14,470	(2,621)	0.82
16	Anchorage/Cook Inlet, AK	935	21,709	(20,774)	0.04
17	Portland, ME	410	11,531	(11,121)	0.04
18	Portsmouth, NH	23	9,161	(9,138)	0.00
19	Providence, RI	5,281	10,898	(5,617)	0.48
20	Wilmington, NC	2,939	11,380	(8,440)	0.26
21	Jacksonville, FL	2,473	9,632	(7,159)	0.26
22	Tampa, FL	13,185	12,012	1,172	1.10
23	Mobile, AL	57,747	14,409	43,338	4.01
	TOTALS	806,255	490,134	316,121	

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8.5.2 Benefit Variables

The 1993 value of life cycle benefits may be low or high because of underestimated or overestimated input variables. Estimating the effect of any uncertainty related to the basic input values on the reported results, may be done by varying each of the input variables. The dollar value of the total benefits for a study zone is the product of the following factors: (a) forecasted vessel traffic over the 15 year life cycle period, (b) a series of casualty and consequence probabilities, (c) a set of consequence unit dollar values, and (d) an annual discount rate. The benefit values on Table 8-10 - Full Benefits and Full Costs Case, and Table 8-11 - Marginal Benefits and Marginal Costs, are derived from the following generic equation:

BENEFIT = AVOIDED LOSSES = VESSEL TRANSITS x
VESSEL CASUALTY PROBABILITIES x
VTS EFFECTIVENESS FACTORS x
CONSEQUENCE PROBABILITIES x
CONSEQUENCE UNIT COST

A fifty percent decrease or increase in the matrix of input values for any one of these variables results in a comparable change in the value of the total benefits. Any percentage variation in any two or more of the variables would result in a percentage change in the total benefit equal to the product of the individual percentage variations specified for each variable. For example, a twenty percent reduction (x 0.80) in the total vessel transits over the 15 year period, a fifty percent increase (x 1.50) in the vessel casualty probabilities, and a thirty percent decrease (x 0.70) in the consequence probabilities would, in combination, result in a reduction of sixteen percent (x 0.84) in the total dollar benefit before discounting to 1993. Additional sensitivity analyses may be conducted by specifying variations like this example for any or all of the study zones.

8.5.2 Benefit Variables (Cont.)

The effect of variations in any of the numerous sub-elements **within** each of the variable matrices of inputs is far more complex and too cumbersome to illustrate here. It would be necessary to change the integrated model input matrices associated with each variable and add extensive sets of output tables. Figure 8-2 (Sensitivity Analysis) illustrates the points of application of sensitivity factors in the process. The analysis applies the first five factors:

A. Vessel Transits
B. Vessel Casualty Probabilities
C. Consequence Probabilities
D. Consequence Unit Costs
E. VTS Effectiveness

at the end of the Avoided Loss Calculation, and the last two factors:

F. VTS Costs
G. Discount Rate

at the end of the Benefit-Cost Analysis, prior to discounting to present values.

Tables 8-13 and 8-14 show the effects of a 50% decrease and increase respectively in total benefits on the benefit-cost relationships in each study zone.

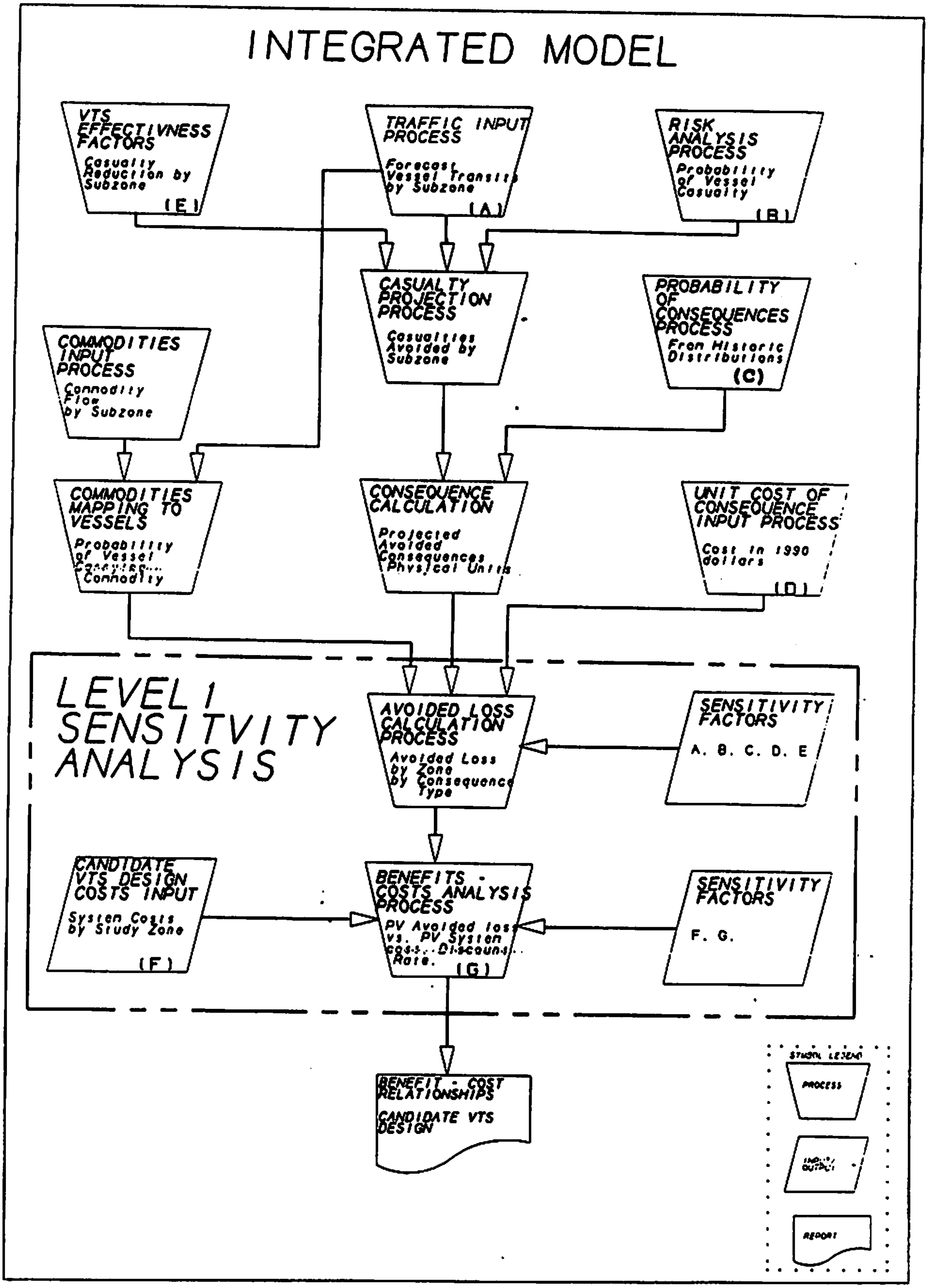

FIGURE 8-2. SENSITIVITY ANALYSIS

TABLE 8-13. SENSITIVITY OF BENEFIT-COST RELATIONSHIPS TO CANDIDATE VTS DESIGN BENEFITS-BENEFITS (-50%) AND FULL COSTS

ZONE	NAME	TOTAL BENEFIT X 0.5 ($1,000's)	TOTAL COST X 1.0 ($1,000's)	NET BENEFIT ($1,000's)	B/C RATIO
1	Boston, MA	11,574	7,999	3,576	1.45
2	Puget Sound, WA	10,858	25,724	(14,865)	0.42
3	Los Angeles/Long Beach, CA	27,924	13,021	14,903	2.14
4	Santa Barbara, CA	1,944	8,667	(6,723)	0.22
5	Port Arthur, TX	54,135	15,856	38,279	3.41
6	New Orleans, LA	145,385	37,036	108,349	3.93
7	Houston/Galveston, TX	44,830	28,646	16,184	1.56
8	Chesapeake South/Hampton Roads, VA	2,265	22,918	(20,652)	0.10
9	Chesapeake North/Baltimore, MD	3,462	8,593	(5,131)	0.40
10	Corpus Christi, TX	17,712	9,311	8,401	1.90
11	New York, NY	17,740	26,445	(8,704)	0.67
12	Long Island Sound, NY/CT	3,418	9,084	(5,666)	0.38
13	Philadelphia/Delaware Bay, PA	8,110	14,032	(5,921)	0.58
14	San Francisco, CA	6,347	22,624	(16,277)	0.28
15	Portland, OR	5,925	9,647	(3,722)	0.61
16	Anchorage/Cook Inlet, AK	468	14,473	(14,005)	0.03
17	Portland, ME	205	7,687	(7,482)	0.03
18	Portsmouth, NH	12	6,107	(6,096)	0.00
19	Providence, RI	2,640	7,265	(4,625)	0.36
20	Wilmington, NC	1,470	7,586	(6,117)	0.19
21	Jacksonville, FL	1,236	6,421	(5,185)	0.19
22	Tampa, FL	6,592	8,008	(1,416)	0.82
23	Mobile, AL	28,873	9,606	19,267	3.01
	TOTALS	403,128	326,756	76,372	

TABLE 8-14. SENSITIVITY OF BENEFIT-COST RELATIONSHIPS TO CANDIDATE VTS DESIGN BENEFITS- BENEFITS (+50%) AND FULL COSTS

ZONE	NAME	TOTAL BENEFIT X 1.5 ($1,000's)	TOTAL COST X 1.0 ($1,000's)	NET BENEFIT ($1,000's)	B/C RATIO
1	Boston, MA	34,723	7,999	26,724	4.34
2	Puget Sound, WA	32,575	25,724	6,852	1.27
3	Los Angeles/Long Beach, CA	83,772	13,021	70,751	6.43
4	Santa Barbara, CA	5,832	8,667	(2,835)	0.67
5	Port Arthur, TX	162,405	15,856	146,549	10.24
6	New Orleans, LA	436,156	37,036	399,120	11.78
7	Houston/Galveston, TX	134,491	28,646	105,845	4.69
8	Chesapeake South/Hampton Roads, VA	6,796	22,918	(16,122)	0.30
9	Chesapeake North/Baltimore, MD	10,386	8,593	1,793	1.21
10	Corpus Christi, TX	53,136	9,311	43,825	5.71
11	New York, NY	53,221	26,445	26,776	2.01
12	Long Island Sound, NY/CT	10,255	9,084	1,171	1.13
13	Philadelphia/Delaware Bay, PA	24,331	14,032	10,299	1.73
14	San Francisco, CA	19,041	22,624	(3,583)	0.84
15	Portland, OR	17,774	9,647	8,128	1.84
16	Anchorage/Cook Inlet, AK	1,403	14,473	(13,070)	0.10
17	Portland, ME	615	7,687	(7,073)	0.08
18	Portsmouth, NH	35	6,107	(6,072)	0.01
19	Providence, RI	7,921	7,265	656	1.09
20	Wilmington, NC	4,409	7,586	(3,177)	0.58
21	Jacksonville, FL	3,709	6,421	(2,712)	0.58
22	Tampa, FL	19,777	8,008	11,769	2.47
23	Mobile, AL	86,620	9,606	77,014	9.02
	TOTALS	1,209,383	326,756	882,627	

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8.5.3 Discount Rate for Present Value

A high discount rate for calculating the 1993 value of life cycle benefits, where a large initial investment is made at the beginning of the period to gain annual benefits over the life cycle, has a significant negative effect on the net benefits and the benefit-cost ratios. The OMB recommended 10% discount rate is used here, and the effect of different rates is tested by varying the discount rate for both costs and benefits concurrently - upward and downward 50% (i.e., Rate = 5% and 15%). The resultant effect on the net benefit and benefit/cost ratio in each study zone is displayed in Tables 8-15 and 8-16 respectively.

TABLE 8-15. SENSITIVITY OF BENEFIT-COST RELATIONSHIPS TO DISCOUNT RATE (5%): CANDIDATE VTS DESIGN FULL BENEFITS AND COSTS

ZONE	NAME	DISCOUNT RATE = 5% TOTAL BENEFIT ($1,000's)	TOTAL COST ($1,000's)	NET BENEFIT ($1,000's)	B/C RATIO
1	Boston, MA	34,306	9,397	24,909	3.65
2	Puget Sound, WA	32,271	30,159	2,112	1.07
3	Los Angeles/Long Beach, CA	82,740	15,510	67,230	5.33
4	Santa Barbara, CA	5,744	10,224	(4,480)	0.56
5	Port Arthur, TX	160,447	18,431	142,017	8.71
6	New Orleans, LA	430,098	42,406	387,691	10.14
7	Houston/Galveston, TX	132,488	34,507	97,982	3.84
8	Chesapeake South/Hampton Roads, VA	6,748	27,438	(20,690)	0.25
9	Chesapeake North/Baltimore, MD	10,279	10,214	65	1.01
10	Corpus Christi, TX	52,615	11,349	41,266	4.64
11	New York, NY	54,278	31,187	23,090	1.74
12	Long Island Sound, NY/CT	10,102	10,654	(551)	0.95
13	Philadelphia/Delaware Bay, PA	24,220	16,569	7,651	1.46
14	San Francisco, CA	18,787	26,669	(7,881)	0.70
15	Portland, OR	17,638	11,486	6,151	1.54
16	Anchorage/Cook Inlet, AK	1,381	16,034	(14,653)	0.09
17	Portland, ME	612	9,085	(8,473)	0.07
18	Portsmouth, NH	34	7,410	(7,376)	0.00
19	Providence, RI	7,822	8,669	(847)	0.90
20	Wilmington, NC	4,366	9,024	(4,657)	0.48
21	Jacksonville, FL	3,649	7,724	(4,075)	0.47
22	Tampa, FL	19,560	9,506	10,054	2.06
23	Mobile, AL	86,531	11,199	75,332	7.73
	TOTAL	1,196,717	384,850	811,866	

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TABLE 8-16. SENSITIVITY OF BENEFIT-COST RELATIONSHIPS TO DISCOUNT RATE (15%): CANDIDATE VTS DESIGN FULL BENEFITS AND COSTS

ZONE	NAME	DISCOUNT RATE = 15% TOTAL BENEFIT ($1,000's)	TOTAL COST ($1,000's)	NET BENEFIT ($1,000's)	B/C RATIO
1	Boston, MA	16,454	7,151	9,304	2.30
2	Puget Sound, WA	15,402	23,033	(7,632)	0.67
3	Los Angeles/Long Beach, CA	39,710	11,512	28,198	3.45
4	Santa Barbara, CA	2,772	7,723	(4,951)	0.36
5	Port Arthur, TX	77,038	14,294	62,744	5.39
6	New Orleans, LA	207,040	33,778	173,262	6.13
7	Houston/Galveston, TX	63,901	25,092	38,810	2.55
8	Chesapeake South/Hampton Roads, VA	3,207	20,176	(16,969)	0.16
9	Chesapeake North/Baltimore, MD	4,914	7,609	(2,696)	0.65
10	Corpus Christi, TX	25,132	8,075	17,057	3.11
11	New York, NY	24,408	23,568	840	1.04
12	Long Island Sound, NY/CT	4,872	8,132	(3,260)	0.60
13	Philadelphia/Delaware Bay, PA	11,455	12,493	(1,038)	0.92
14	San Francisco, CA	9,034	20,171	(11,136)	0.45
15	Portland, OR	8,391	8,531	(140)	0.98
16	Anchorage/Cook Inlet, AK	667	13,526	(12,859)	0.05
17	Portland, ME	289	6,839	(6,550)	0.04
18	Portsmouth, NH	16	5,316	(5,300)	0.00
19	Providence, RI	3,756	6,414	(2,658)	0.59
20	Wilmington, NC	2,085	6,715	(4,630)	0.31
21	Jacksonville, FL	1,763	5,630	(3,868)	0.31
22	Tampa, FL	9,363	7,100	2,263	1.32
23	Mobile, AL	40,648	8,640	32,008	4.70
	TOTAL	572,316	291,518	280,798	

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9. STUDY FINDINGS

9.1 OVERVIEW

Section 8 presents the results for the 23 study zones listed according to the arbitrary code number assigned at the beginning of the study. The two perspectives of "Full" and "Marginal" Benefits, Costs and Net Benefits are carried forward in this section, but the 23 study zones are now ranked by the values of each of several measures of benefit presented in Section 8.

Assessment of the overall value, to the nation as a whole, of the Coast Guard Candidate VTS Designs in all 23 study zones, entails an examination of the national total physical losses, as well as the undiscounted dollar values and the 1993 discounted values of the net benefits. It is informative to examine several of the major loss categories at the national aggregate level prior to considering the ranking of the individual study zones by the 1993 value of the net benefits.

9.2 AVOIDED VESSEL CASUALTIES

The Candidate VTS Designs for the 23 study zones are credited with avoiding a total of 980 vessel casualties during the period 1996-2010 (as presented earlier in Table 8-1). This represents a 29% decrease in vessel casualties that would occur without any VTS.

More than half of the avoided vessel casualties are collisions. Rammings and groundings, combined, represent only 47% of the avoided vessel casualties because VTS is less effective in reducing rammings and groundings than it is in avoiding collisions.

Figure 9-1 displays the 23 study zones in descending order of avoided vessel casualties (i.e., benefit) attributed to the Candidate VTS Design. In the nine study zones having operating Existing VTS Systems during 1990, the upper bar indicates the Full Benefit of the Candidate VTS Design, and the lower bar the Marginal benefit (i.e., over-and-above the Existing VTS Case). New Orleans is an overwhelming leader in avoided vessel casualties with 4.5 times as many as Port Arthur in second place. Fifty six percent of the avoided vessel casualties in New Orleans involve barge tows (i.e., 33% barge collisions, and 23% barge rammings and groundings).

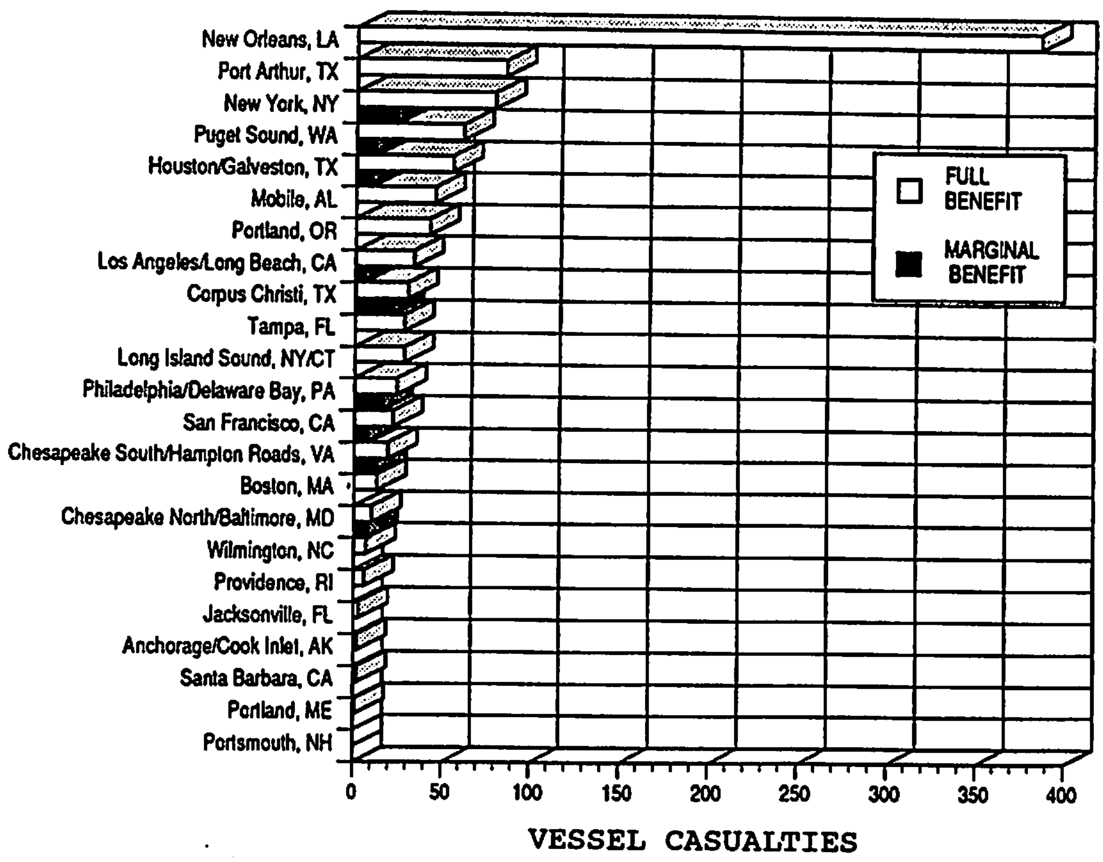

FIGURE 9-1. CANDIDATE VTS DESIGN AVOIDED VESSEL CASUALTIES 1996-2010

9.3 AVOIDED HUMAN INJURIES AND DEATHS

The 23 Candidate VTS Designs are credited with avoiding a total of 138 injuries and 31 human fatalities during the 15 year forecast period (displayed earlier in Table 8-1).

Figure 9-2 displays the 23 study zones in descending order of avoided Injuries and Deaths (i.e., benefit) attributed to the Candidate VTS Design. In the nine study zones with operating Existing VTS Systems, the upper bar indicates the full benefit of the Candidate VTS Design, and the lower bar the marginal benefit (i.e., over-and-above the Existing VTS Case). New Orleans leads with 50 avoided deaths and injuries, followed by Puget Sound with 33. New York is a distant third place with 14.

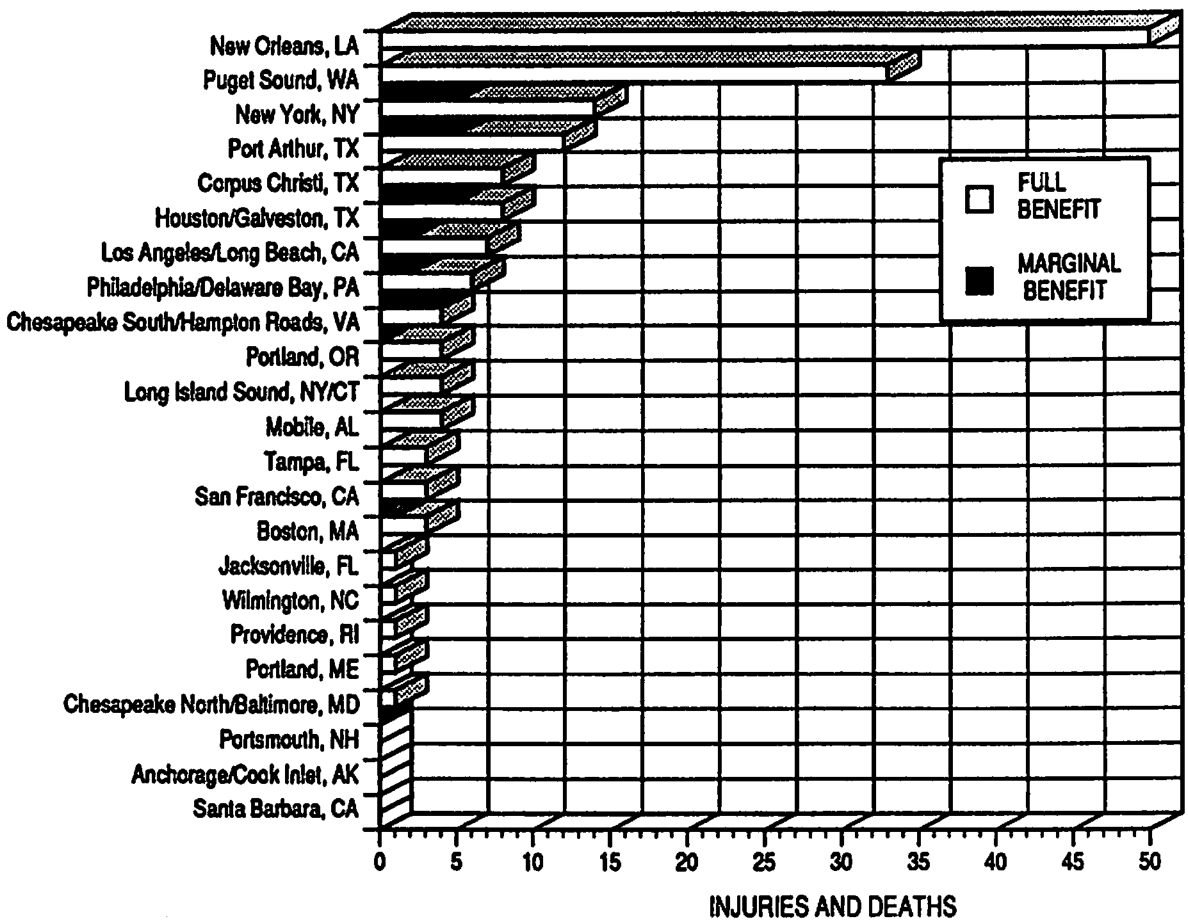

FIGURE 9-2. CANDIDATE VTS DESIGN AVOIDED HUMAN INJURIES AND DEATHS 1996-2010

9.4 AVOIDED HAZARDOUS COMMODITY SPILLS

The 23 Candidate VTS Designs are credited with preventing a total of 100 spills of hazardous commodities. These are spills of all sizes (small, medium, large, and catastrophic); they include bulk cargo spills from tankers and tank barges and vessel fuel (bunker) spills from all vessel types involved in vessel casualties with vessel damage.

Figure 9-3 displays the 23 study zones in descending order of avoided Hazardous Commodity Spills attributed to the Candidate VTS Designs.

Here also, New Orleans is the overwhelming leader with 40 avoided spills of hazardous commodities, followed by Port Arthur with 11 avoided spills. New York, Houston/Galveston, and Puget Sound are tied in third place with 8 avoided spills each. In each of these zones over 80% of the spills are moderate or severe (i.e., 10,000-750,000 gallons).

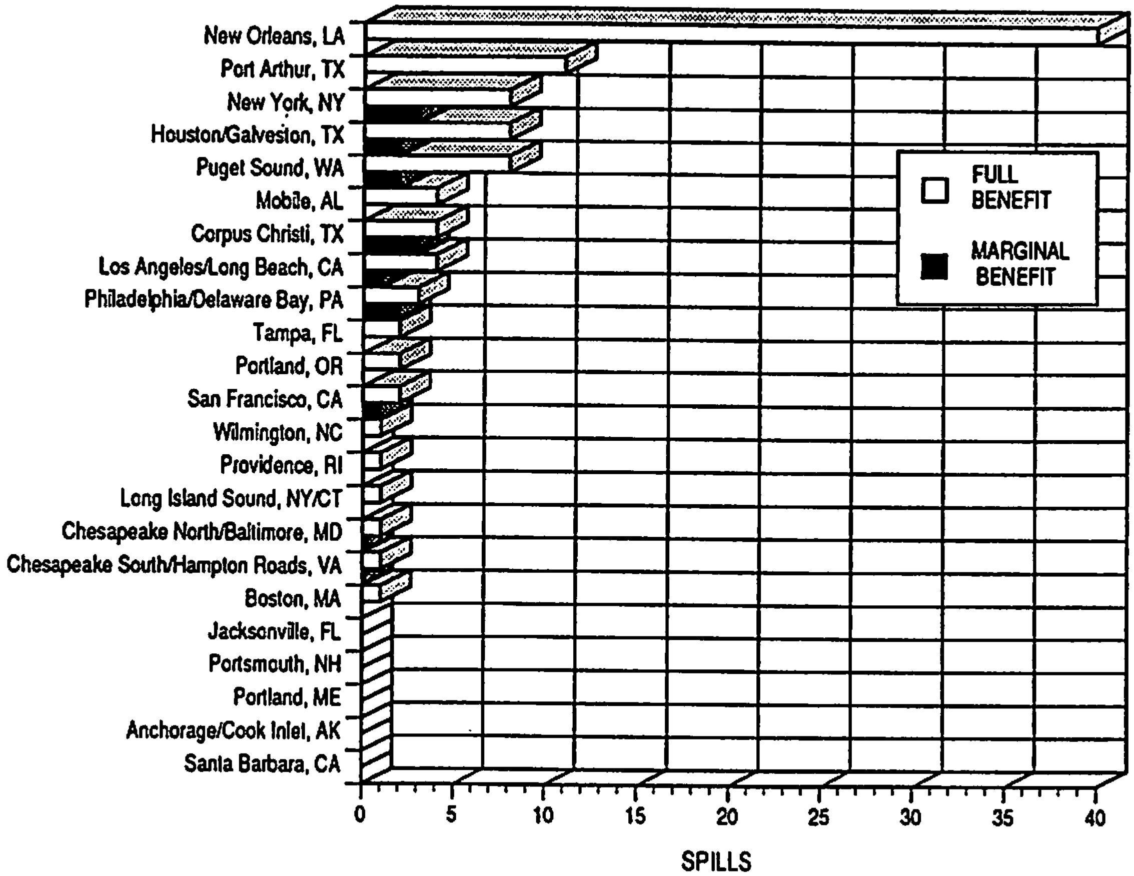

FIGURE 9-3. CANDIDATE VTS DESIGN AVOIDED HAZARDOUS COMMODITY SPILLS 1996-2010

9.5 AVOIDED MARINE MAMMAL AND BIRD LOSS TO HAZARDOUS COMMODITY SPILLS

Hazardous commodity spills result in a series of environmental and commercial losses. The 23 Candidate VTS Designs take credit for preventing the loss of 4 million individual marine birds and mammals from hazardous commodity spills (displayed earlier in Table 8-1).

Figure 9-4 displays the 23 study zones in descending order of avoided Marine Mammal and Bird Losses attributed to the Candidate VTS Design. In the nine study zones having operating Existing VTS Systems, the upper bar indicates the full benefit of the Candidate VTS Design, and the lower bar the marginal benefit (i.e., over-and-above the Existing VTS Case).

New Orleans leads with the loss of 1.6 million individual birds and mammals avoided. Los Angeles/Long Beach and Port Arthur follow in second and third place with 550 thousand and 522 thousand respectively. New York is fourth with 209 thousand.

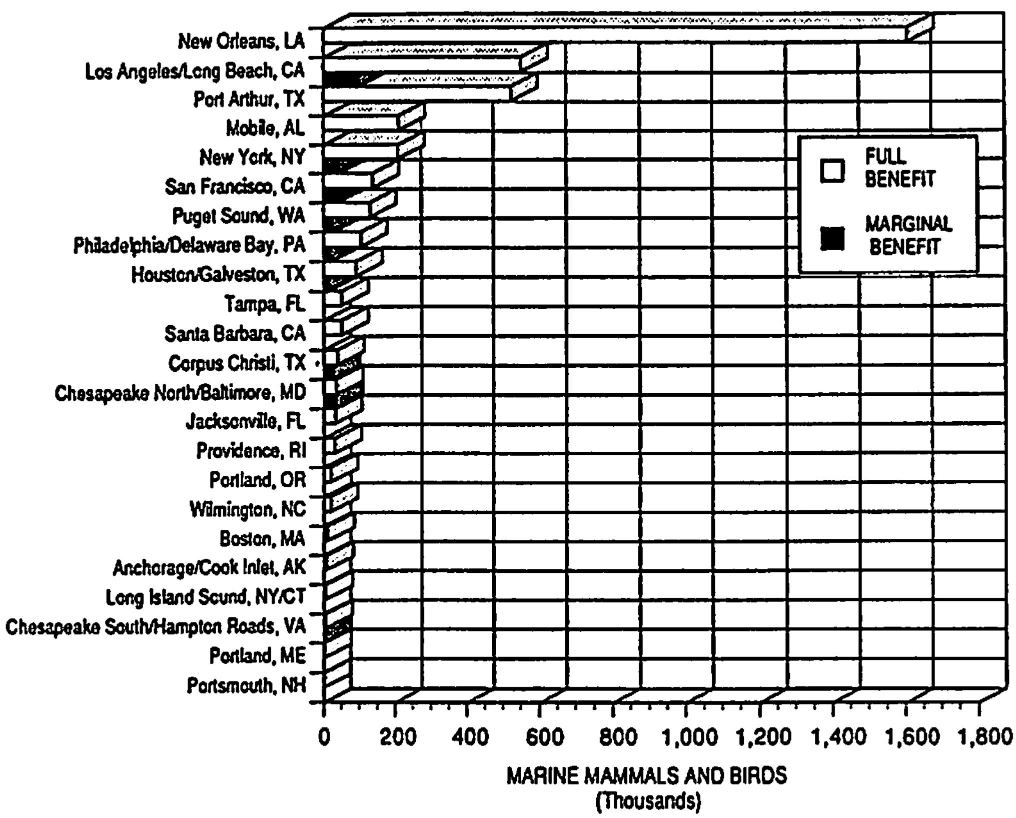

FIGURE 9-4. CANDIDATE VTS DESIGN AVOIDED MAMMAL AND BIRD LOSSES TO SPILLS 1996-2010

9.6 AVOIDED LOSSES OF COMMERCIAL FISH SPECIES DUE TO HAZARDOUS COMMODITY SPILLS

The 23 Candidate VTS Designs take credit for preventing the aggregate loss of 396 million pounds of commercial species of fish (displayed earlier in Table 8-1).

Figure 9-5 displays the 23 study zones in descending order of avoided Commercial Fish Species Losses attributed to the Candidate VTS Design. In the nine study zones with operating Existing VTS Systems, the upper bar indicates the full benefit of the Candidate VTS Design, and the lower bar the marginal benefit (i.e., over-and-above the Existing VTS Case).

Houston/Galveston leads in avoided losses of commercial species of fish with 176 million pounds. Port Arthur and New Orleans follow in second and third place respectively with 67 million pounds each.

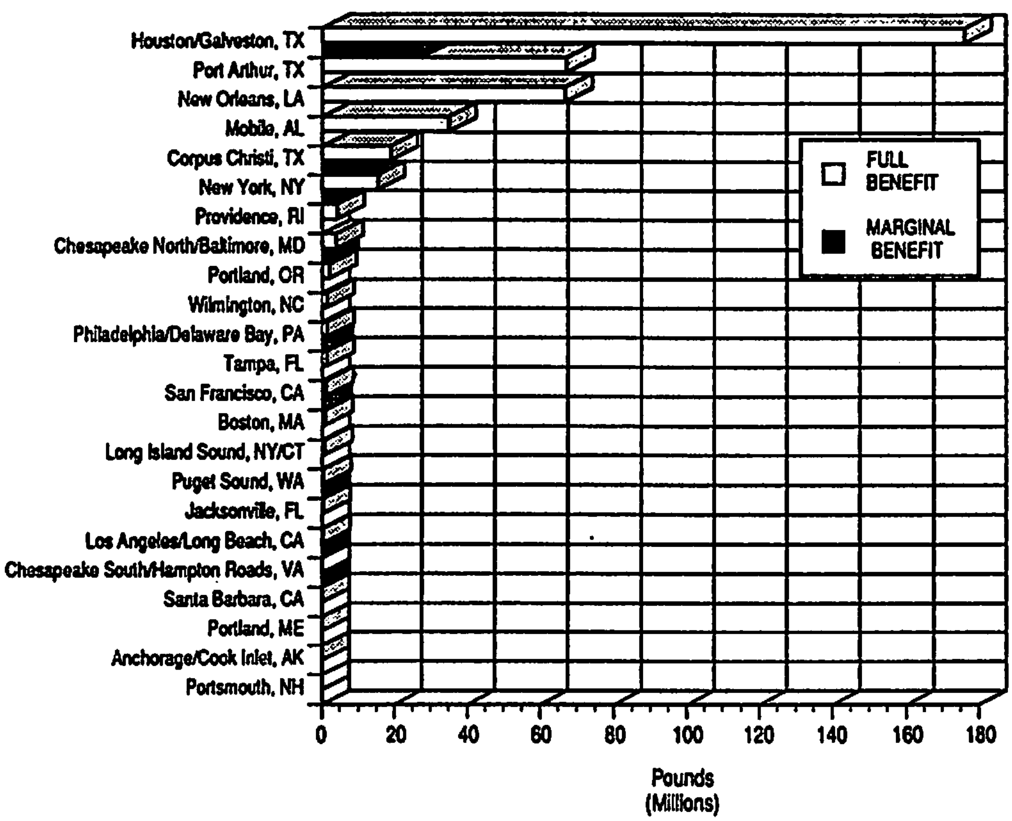

FIGURE 9-5. CANDIDATE VTS DESIGN AVOIDED COMMERCIAL FISH SPECIES LOSSES TO SPILLS (Millions Pounds) 1996-2010

9.7 AVOIDED DOLLAR LOSSES OF ALL CONSEQUENCES - (UNDISCOUNTED 15-YEAR TOTAL)

When the consequences from the avoidance of vessel casualties attributable to the 23 candidate designs, are expressed in dollars, the 15-year avoided losses total $1.9 billion (undiscounted).

Figure 9-6 displays the 23 study zones in descending order of total avoided dollar losses (undiscounted) attributed to the Candidate VTS Design.

New Orleans, Port Arthur, Houston/Galveston, are responsible for 60% of this total. Mobile, Los Angeles/Long Beach, New York, and Corpus Christi contribute an additional 23%. Thus, these first seven study zones are responsible for 83% of the total potential avoided dollar losses (undiscounted) of the 23 Candidate VTS Design. Losses associated with hazardous commodity spills are responsible for 74%-92% of the total avoidable dollar losses in each of these zones. In each of these zones cleanup costs are a large portion of the spill costs. However, in Los Angeles/Long Beach, property losses associated with spills reaching the shore preponderate. In Houston/Galveston, losses in connection with commercial species of fish outnumber the rest.

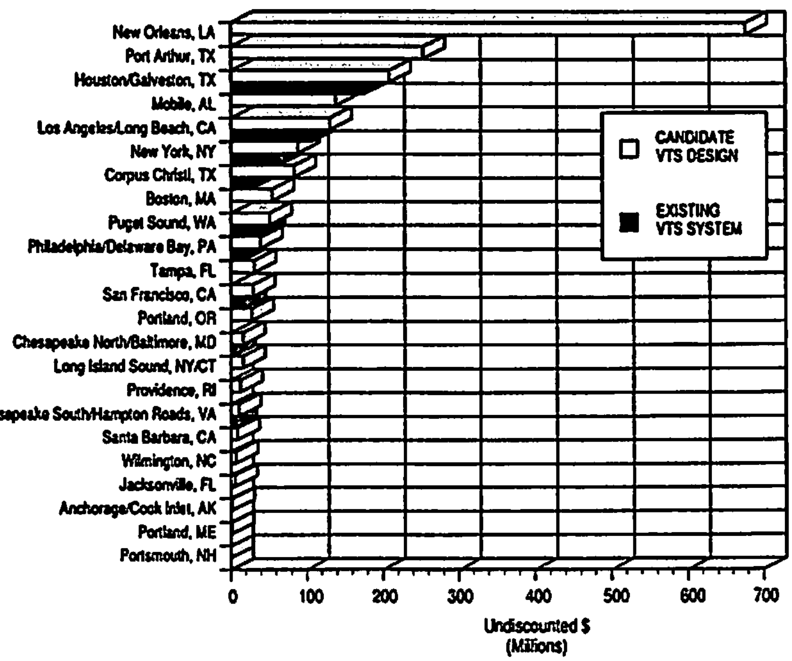

FIGURE 9-6. CANDIDATE VTS DESIGN AVOIDED DOLLAR LOSSES (UNDISCOUNTED) OF ALL CONSEQUENCES OF VESSEL CASUALTIES 1996-2010

9.8 NET BENEFIT

The 1993 discounted value of the life cycle Net Benefit (i.e., total avoided losses minus the VTS investment and O&M costs) transforms all future benefits and costs to a single objective measure suitable for ranking the 23 study zones in terms of the aggregate national interest.

Figure 9-7 displays the 23 study zones in descending order of the Net Benefit (i.e., discounted annual stream of benefits minus the discounted annual stream of VTS investment and O&M costs) attributed to the Candidate VTS Design (already displayed in Table 8-5). In the nine study zones with Existing VTS Systems in operation, the upper bar indicates the full Net Benefit of the Candidate VTS Design, and the lower bar the Marginal Net Benefit (i.e., over-and-above the Existing VTS Case), displayed earlier in Table 8-6. The net benefit is discounted to the beginning of FY '93, the time of the initial commitment of the VTS investment. The annual streams of VTS Benefits and O&M costs begin in FY '96 and continue through FY 2010.

With regard to the Full Net Benefit, the 23 study zones are distributed half with positive net benefit and half with negative net benefit. From the perspective of the Marginal Net Benefit, the rank order changes somewhat. The most significant changes are Los Angeles/Long Beach, which changes from a positive to a negative net benefit and Puget Sound which changes from a negative net benefit to positive net benefit. The positive Marginal Net Benefit in Puget Sound reflects the fact that the reductions in annual O&M cost greatly exceeds the incremental investment for the Candidate VTS Design. Except for Los Angeles/Long Beach, the top ten zones remain positive under the Marginal Net Benefit. Philadelphia/Delaware Bay, with the lowest positive full net benefit changes to negative when Marginal Net Benefit is considered.

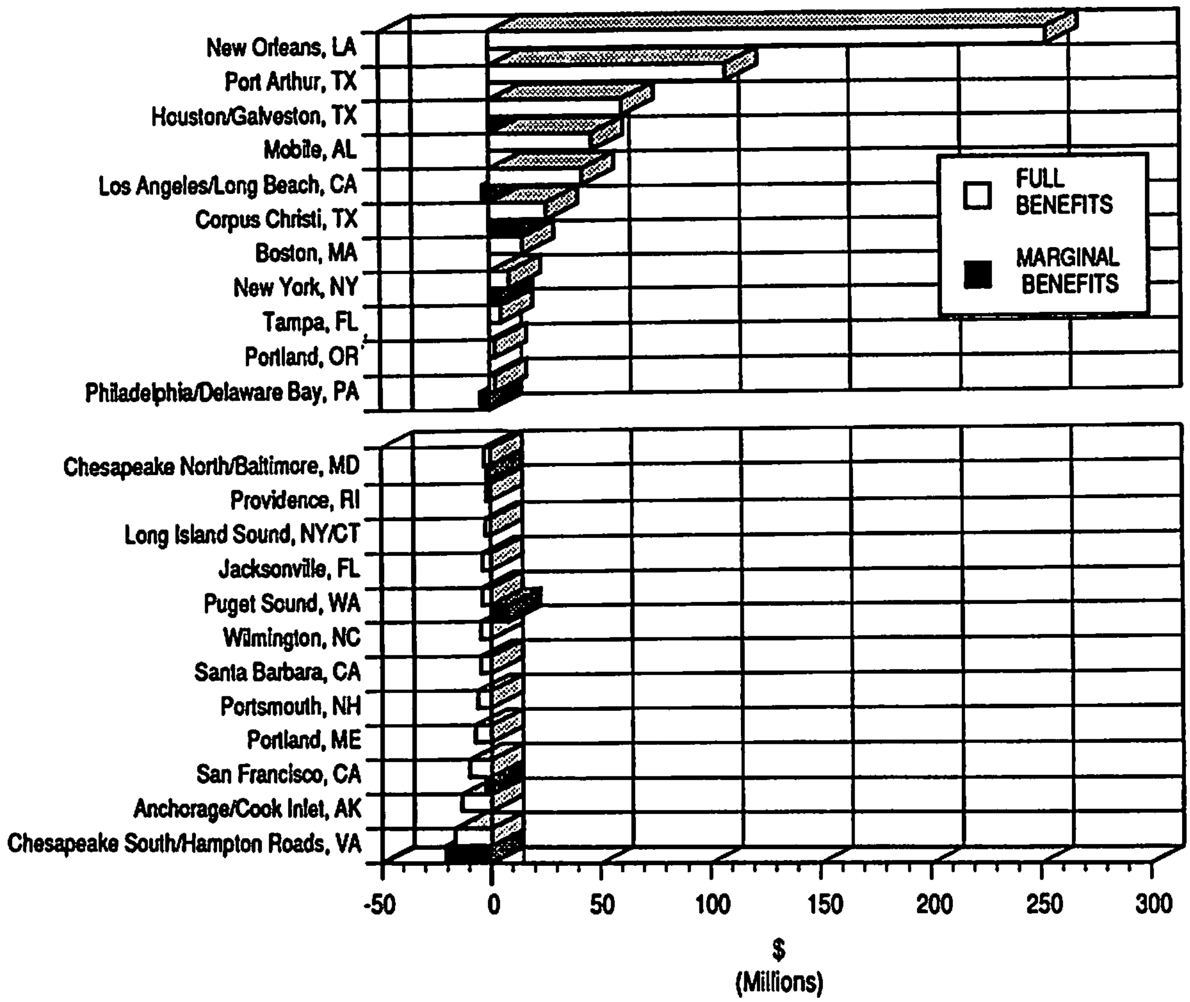

FIGURE 9-7. CANDIDATE VTS DESIGN 1993 VALUE OF NET BENEFITS (1993-2010)

9.9 SENSITIVITY - UNCERTAINTY OF STUDY VARIABLE ESTIMATES

Section 8.5 presents the sensitivity of the relative net benefits of the 23 study zones to any uncertainty over selected major variables. The analysis results presented in Tables 8-12 through 8-16 take a global perspective of the analytical process and change the selected inputs for all 23 study zones concurrently. Figures 9-8 through 9-10 display the changed net benefit order reflecting these global changes.

Figure 9-8 presents the effect of a 50% increase in the estimated VTS costs in each zone above the values presented earlier in Section 7. Minor changes in the order appear, but the most significant change is that three of the zones (i.e., New York, Portland,OR and Philadelphia/Delaware Bay) shift from positive to negative net benefit.

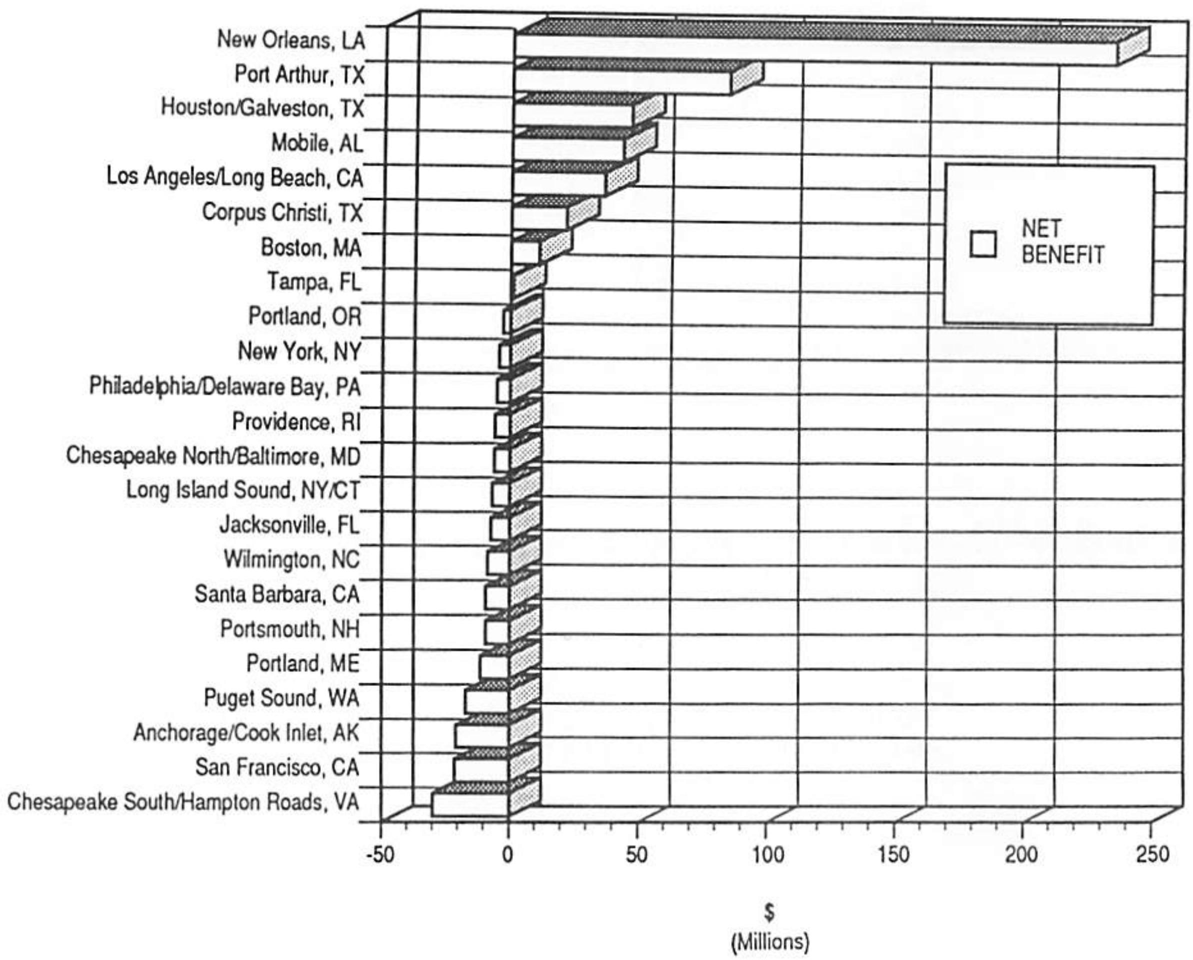

FIGURE 9-8. PRESENT VALUE OF NET BENEFIT SENSITIVITY TO COST ESTIMATES - VTS COST INCREASED 50%

9.9 SENSITIVITY - UNCERTAINTY OF STUDY VARIABLE ESTIMATES (Cont.)

Figure 9-9 presents the effect of a 50% reduction in the estimated total benefit in each zone. Some changes in the order appear, but the most significant change is that four zones (i.e., New York, Tampa, Portland, OR and Philadelphia/Delaware Bay) shift from positive to negative net benefit.

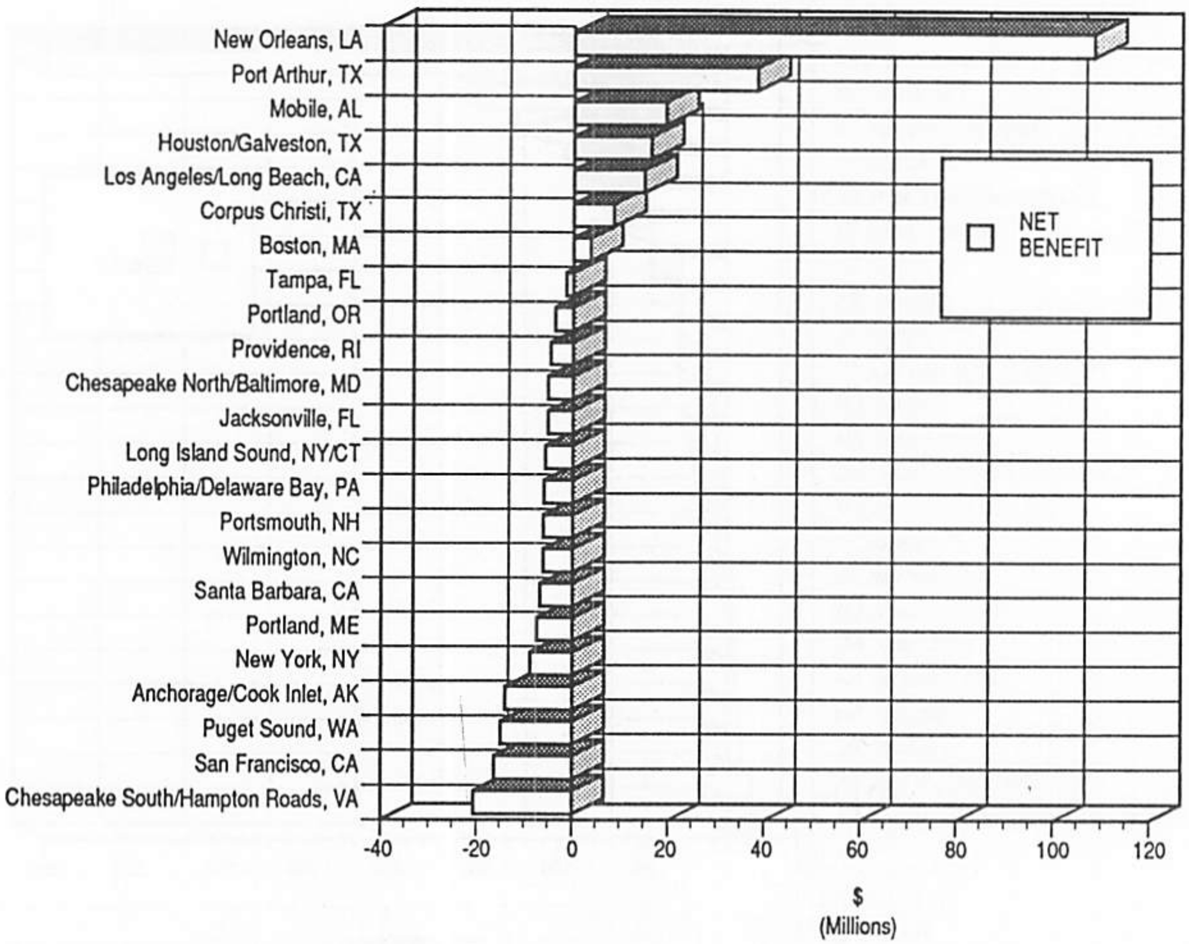

FIGURE 9-9. PRESENT VALUE OF NET BENEFIT SENSITIVITY TO BENEFIT ESTIMATES - BENEFITS DECREASED 50%

9.9 SENSITIVITY - UNCERTAINTY OF STUDY VARIABLE ESTIMATES (Cont.)

Figure 9-10 presents the effect of a 50% increase in the estimated total benefit in each zone. Here also some changes in the order appear, but the most significant change is that four zones (i.e., Puget Sound, Chesapeake North/Baltimore, Long island Sound and Providence) have shifted from negative to positive net benefit.

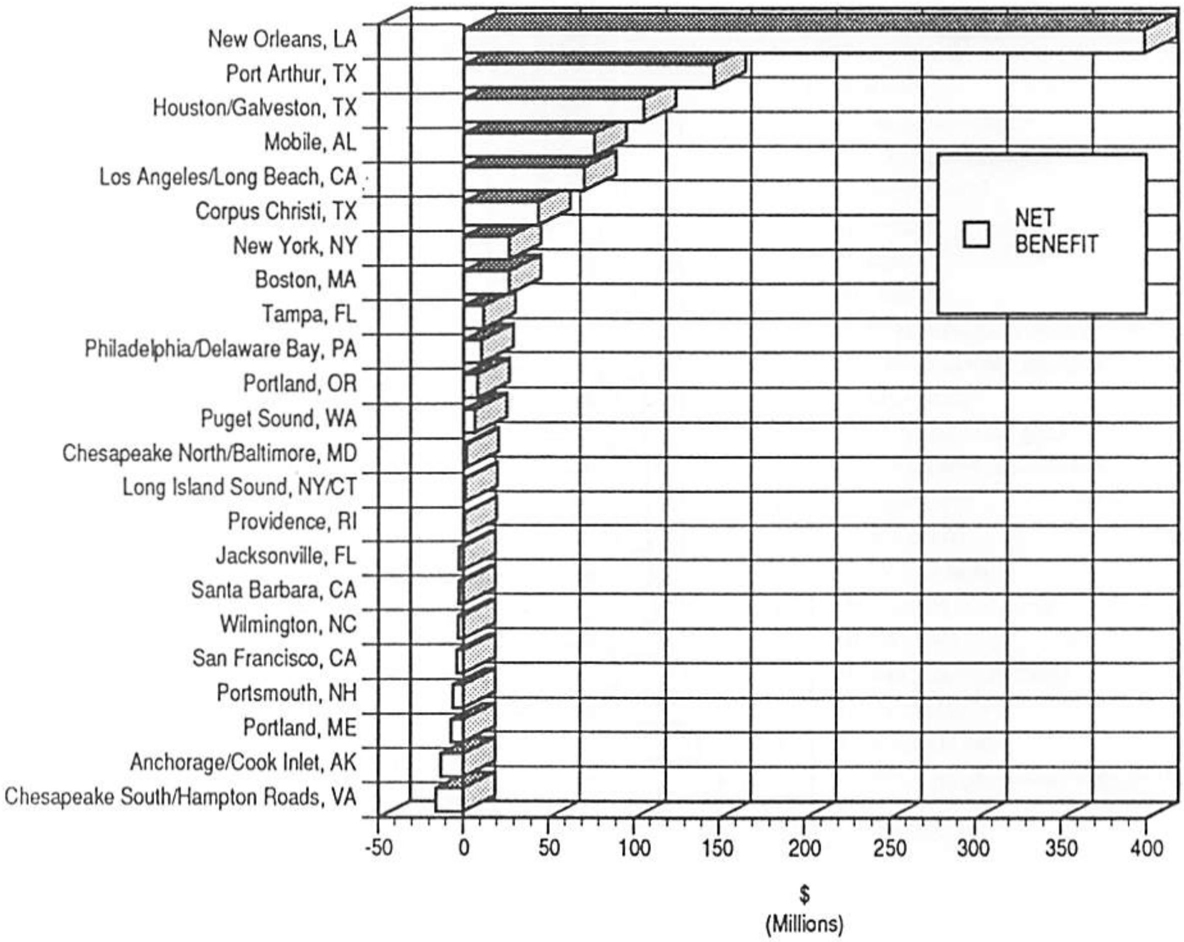

FIGURE 9-10. PRESENT VALUE OF NET BENEFITS SENSITIVITY TO BENEFITS ESTIMATES - BENEFITS INCREASED 50%

9.10 SENSITIVITY - ZONE SPECIFIC DOMINANT AVOIDED LOSS

Up to this point the analysis of sensitivity has involved testing the effects of uncertainty in the study inputs to the relative rankings when changes are concurrently applied across all 23 zones. There may be some concern about estimates of selected types of VTS avoided losses in each of the zones. To address this concern, the focus now shifts to the individual study zone life cycle net benefits, and the specific loss type(s) that dominate the VTS benefits in each zone.

Considering the Full (rather than the Marginal) Net Benefit, the sensitivity of the relative net benefits of the study zones may be assessed in terms of each zone's respective dominant loss type and the effect that any uncertainty about that loss might have on the net benefit. Table 9-1 lists the 23 study zones in order of their relative net benefits and highlights the dominant categories of avoided losses in each zone.

TABLE 9-1. RANK ORDER BY NET BENEFIT

Rank	Zone	Net Benefit (millions)	Largest Avoided Loss
1.	New Orleans	$254	Hazardous commodity spills cleanup (50% of total)
2.	Port Arthur	$92	Hazardous commodity spills cleanup (48% of total)
3.	Houston/Galveston	$61	Commercial fish species (42% of total) and cleanup (30% of total)
4.	Mobile	$48	Hazardous commodity spills cleanup (38% of total) and commercial fish species (34% of total)
5.	Los Angeles/Long Beach	$43	Property damage from hazardous commodity spills (55% of total)
6.	Corpus Christi	$26	Hazardous commodity spills cleanup (40% of total) and commercial fish species (29% of total)
7.	Boston	$15	LNG explosion damage (63% of total). LNG loss is the dollar value of all deaths, injuries, and material losses associated with LNG explosions during the 15-year period (i.e. a total expected value of 0.016 or an average annual expected value of 0.0011 which translates to approximately one probable LNG explosion in 1,000 years). The probability of an LNG vessel casualty (which is assumed to precede an explosion) is estimated at 10% of other large tankers in the zone.
8.	New York	$9	Hazardous commodity spills cleanup (55% of total)
9.	Tampa	$5	Hazardous commodity spills cleanup (52% of total)
10.	Portland, OR	$2	Hazardous commodity spills cleanup (47% of total), property damage (15% of total) and vessel damage (15% of total)
11.	Philadelphia/Delaware Bay	$2	Hazardous commodity spills cleanup (60% of total)

TABLE 9-1. RANK ORDER BY NET BENEFIT (Cont.)

Rank	Zone	Net Benefit (millions)	Largest Avoided Loss
12.	Chesapeake/North Baltimore	($2)	Hazardous commodity spills cleanup (36% of total) and commercial fish species (37% of total)
13.	Providence,RI	($2)	Hazardous commodity spills cleanup (48% of total)
14.	Long Island Sound	($2)	Hazardous commodity spills cleanup (50% of total)
15.	Jacksonville	($4)	Hazardous commodity spills cleanup (47% of total)
16.	Puget Sound	($4)	Hazardous commodity spills cleanup (37% of total) and vessel damage losses (18% of total)
17.	Wilmington, NC	($5)	Hazardous commodity spills cleanup (45% of total) and vessel damage (18% of total)
18.	Santa Barbara	($5)	Property damage (54% of total)
19.	Portsmouth, NH	($6)	Vessel damage (40% of total) and cleanup (33% of total)
20.	Portland, ME	($7)	Hazardous commodity spills cleanup (48% of total)
21.	San Francisco	($10)	Hazardous commodity spills cleanup (45% of total)
22.	Anchorage/Cook Inlet	($14)	Hazardous commodity spills cleanup (50% of total)
23.	Chesapeake South/ Hampton Roads	($18)	Hazardous commodity spills cleanup (45% of total)

In each of these study zones, the effect of the level of uncertainty with respect to the dominant loss type(s) on the net benefit can be estimated by application of a factor to each dominant loss type considered suspect. The reader may conduct this level of analysis of sensitivity of the relative net benefits in conjunction with a review of the detailed statistics presented in the appendix tables, Volume II.

9.11. FINDINGS

The study indicates that the 23 study zones can be divided into three groups in terms of their relative life cycle net benefits. Analysis of the sensitivity of the relative values of net benefits to underestimates or overestimates of the VTS benefits or the VTS costs suggests the following groupings. The first seven zones have a positive net benefit over the range of uncertainty tested.

Positive Net Benefit:

- New Orleans
- Port Arthur
- Houston/Galveston
- Mobile
- Los Angeles/Long Beach
- Corpus Christi
- Boston

The net benefits of the following eight zones may be considered sensitive because their relative values are comparatively small, and may be positive or negative over the range of uncertainty tested.

Sensitive:

- New York
- Tampa
- Portland, OR.
- Philadelphia/Delaware Bay
- Chesapeake North/Baltimore
- Providence
- Long Island Sound
- Puget Sound

The following eight study zones retain their negative net benefit status over the range of uncertainty tested.

Negative Net Benefit:

- Jacksonville
- Wilmington
- Santa Barbara
- Portsmouth
- Portland, ME
- San Francisco
- Anchorage/Cook Inlet
- Chesapeake South/Hampton Roads

A

ACOE = Army Corps Of Engineers
ADS = Automatic Dependent Surveillance

B

BC = Benefit Cost
BLS = Bureau Of Labor Statistics
BMC = Bureau Of Management Consulting

C

CASMAIN = Casualty Maintenance File (Coast Guard)
CCTV = Closed Circuit Television
CHRIS = Chemical Hazards Response Information System
COE = Corp Of Engineers (Army)
COST = Committee On Science and Technology
CRG = Collisions, Ramming, and Grounding

D

DF = Direction Finder
DGPS = Differential Global Position System
DOI = Department of Interior

E

EEC = European Economic Community

G

GIS = Geographic Information System
GPS = Global Position System

GLOSSARY (Cont.)

H

HAZMAT = Hazardous Materials

I

ICW = Intra Coastal Waterway
IMO = International Maritime Organization

L

LMRSAC = Lower Mississippi River Safety Advisory Committee
LNG = Liquified Natural Gas
LOP = Line Of Position
LOS = Line Of Sight
LPG = Liquified Petroleum Gas

M

MER = Marine Environmental Response
MRIR = Marine Pollution Incident Report
MPRS = Marine Pollution Retrieval System
MSIS = Marine Safety Information System
MSO = Marine Safety Office

N

NAVAID = Navigational Aids
NOAA = National Oceanographic and Atmospheric Administration
NRDAM/CME = National Resource Damage Assessment Model for Coastal and Marine Environments
NTSB = National Transportation Safety Board

O

OCS = Outer Continental Shelf
O&M = Operations and Maintenance
OMB = Office of Management and Budget

GLOSSARY (Cont.)

P

PCAS = Personnel Casualty File (Coast Guard)

R

RDSS = Radio Determination Satellite Service
RSPA = Research and Special Programs Administration

T

TL = Traffic Lanes
TSS = Traffic Separation Scheme

U

UI = Urban Institute
USCG = United States Coast Guard
USDOT = U.S. Department of Transportation

V

VCC = Vessel Control Center
VHF = Very High Frequencies
VNTSC = Volpe National Transportation Systems Center
VTC = Vessel Traffic Control
VTS = Vessel Traffic Services

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