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TANK BARGE OIL POLLUTION STUDY.

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16. Abstract

This study was conducted to determine and categorize the causes of tank barge oil spill incidents and the extent of the resulting pollution. Coast Guard pollution incident data files were reviewed for the 3-year period from 1974-1976, and discussions were held with pollution control and marine safety personnel in four Coast Guard district offices. Operational and causal patterns were identified, present pollution prevention efforts were examined, and means of reducing the spill volumes and number of incidents were investigated. The analysis revealed a preponderance of small oil spills (<100 gal) which occur during cargo transfer operations; however, these incidents contributed less than 10% of the total volume spilled. The major spills (>100 gal), which occur primarily during underway operations, represented a small portion of the total incidents but contributed the bulk of the oil volume spilled. A number of preventive measures were examined. Improved tankerman training and use of coamings should substantially reduce the number of small spills. Double-hull barge construction should prove effective in preventing many large spills resulting from collisions or groundings. Several other preventive measures were also considered which involve the regulatory area and barge/shore facility interfaces.

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FINAL REPORT

NOTICE

PREPARED FOR

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

OFFICE OF MARINE ENVIRONMENT AND SYSTEMS
WASHINGTON, D. C. 20590

EXECUTIVE SUMMARY

The purpose of this study is to analyze in detail available Coast Guard data sources for tank barge oil pollution incidents, and to determine and categorize the causes of these incidents and the extent of the resulting pollution. Operational and causal patterns are identified, present Coast Guard pollution prevention efforts are examined, and means of reducing the spill volumes and number of incidents are investigated. The scope is limited to tank barges carrying oil products during the 3-year period from 1974-1976 in four sample Coast Guard districts; the second, fifth, eighth, and ninth. Together, these four districts provide data over a broad spectrum of marine transporation routes (rivers, lakes, and ocean) and encompass 90% of the oil volume spilled and 75% of the total number of tank barge oil pollution incidents during these three years.

DATA DEVELOPMENT AND ANALYSIS

The data base examined in this study was extracted and developed from the following information sources: Pollution Incident Reporting System (PIRS), Commercial Vessel Casualty Reporting System (CVCRS), Inspected Barge File, and District Penalty Files. Valuable supplementary information was obtained by discussions with pollution control and marine safety personnel in the four districts visited.

A total of 1,647 cases were extracted from the PIRS File for oil spill incidents occurring during 1974-1976 which fell under PIRS causal codings of Structural Failure or Loss, Equipment Failure, or Personnel Error. Approximately 1,300 of these cases were identified as having had penalty action. Listings of the penalty cases were then generated for each of the four Coast Guard districts and were subsequently used during the visits to locate and examine each incident. Because of time limitations, and in order to minimize any interference with district office operations, only 416 individual cases could be reviewed in the District Penalty Files during the above visits. Priority was assigned to the most recent incidents and those involving major oil spills. In addition, the Inspected Barge File, obtained from the Office of Merchant Marine Safety, was used to provide information concerning the types of hulls for the barges involved in the pollution incident cases analyzed.

The data extracted directly from the sources cited above did not lend itself readily to causal categorization and analysis. Therefore, the data was restructured to provide a breakdown into three major causal areas: Personnel Error, Equipment Failure, and Hull Damage. Subsequent analysis of the total PIRS sample population of 1,647 incidents indicated that approximately 56% of the incidents were due to personnel error, 12% to equipment failure, and 32% to hull damage. However, the hull damage incidents were responsible for the bulk of the oil spilled (about 3,800,000 gallons) which was more than 93% of the total spill volume associated with all 1,647 incidents.

The detailed data obtained for the 416 cases reviewed in the District Penalty Files was also restructured in essentially the same manner as the PIRS File data. Analysis of this restructured data yielded a breakdown similar to that previously cited for the larger PIRS sample. Approximately 50% of the incidents were due to personnel error, 7% to equipment failure, and 43% to hull damage. The hull damage incidents were again responsible for the bulk of the oil spilled (about 3,100,000 gallons) which was 82% of the total spill volume associated with all 416 incidents.

In order to develop further insight into the underlying causes for incidents categorized under hull damage, a matching process was applied to the PIRS and CVCRS File data using the official number of the barge and the date of the incident as common parameters. Only 47 incidents were matched by this process. The casualty reports for these 47 cases were then reviewed in detail to develop more comprehensive causal information. It was found that 32 of the incidents (68%) could be directly attributed to personnel error during underway operations, resulting in hull damage and pollution. These 32 incidents were responsible for 98.5% of the oil spill volume associated with the entire 47 incident sample.

PREVENTIVE MEASURES

The more definitive causal data obtained through examination and analysis of the District Penalty Files and the narrative reports of the CVCRS File were used as the basis for assessment of pollution prevention measures. The above data represents those cases for which additional information was obtained and verification and/or classification of PIRS File data was essentially effected. Assessment of pollution prevention measures and their effectiveness is based on the subjective judgement of the authors, with the data described above and supportive information obtained in discussions with Coast Guard district office personnel providing the definitive characteristics and quantitative basis for this assessment.

Four basic areas of preventive measures were considered for reducing or preventing tank barge oil spills: hull design, coamings, tankerman training, and pollution prevention regulations. Subjective application of these four basic measures was made to each of the 416 District Penalty File incidents reviewed in the study. The analysis indicated that about 33% of the incidents could have been prevented by double containment of the cargo, 10% by installation of deck coamings, 24% by improved tankerman performance, 21% by either installation of coamings or improved tankerman performance, and 2% by intensified regulation or regulatory presence. For approximately 10% of the incidents, there was insufficient data upon which to base a reasonable judgement; these were indicated as Indeterminate.

The 47 CVCRS cases previously categorized as caused by hull damage (obtained by cross referencing and matching to PIRS incidents) were examined to assess the effect of double-wall or double-bottom construction as preventive measures. Double wall refers to tank barges with longitudinal inner bulkheads, port and starboard, between the rake bulkheads. Double bottom refers to tank barges with a continuous inner bottom between the rake compartments. It was considered that 26 incidents (55%) could have been prevented by double-wall and double-bottom construction. In four cases (9%), double-wall or double-bottom construction would have had no effect. For the remaining 17 incidents (36%), there was insufficient data upon which to base a reasonable assessment; these were considered as Indeterminate.

CONCLUSIONS

1. Transfer and transport activities are the operational phases which foster the largest number of tank barge oil spill incidents and associated volume of oil spilled.

2. Most of the minor spills ($\leq$100 gal) occur during cargo transfer operations when oil is being loaded or discharged; however, these incidents contribute only a small portion of the total oil spill volume.

3. Most of the major spills (>100 gal) occur during underway operations (including mooring and docking); these represent only a small fraction of the total number of tank barge oil pollution incidents but contribute the bulk of the total oil spill volume.

4. The primary causes for both minor and major spills are related to personnel error. In the case of minor spills, these errors usually involve mishandling of equipment and insufficient attention to regulations and operating procedures during cargo transfer operations. For major spills, misjudgements by barge pilots lead to collision or grounding incidents with subsequent hull damage and large oil spill volumes. Improved personnel performance could have been effective in preventing a large number of both minor and major oil spill incidents reviewed in this study.

5. Coaming installations could have been effective in preventing over half of the minor oil spill incidents reviewed in this study.

6. Double containment (double-wall and/or double-bottom construction) could have been effective in reducing or preventing major spills for a majority of the tank barge oil pollution incidents categorized as caused by hull damage.

7. Tank barge oil pollution prevention efforts must involve consideration of the overall "system" and procedures utilized by the Coast Guard and should include consideration of the interfaces between barge structural design, operational procedures, personnel capabilities, equipment characteristics, and regulatory requirements.

RECOMMENDATIONS

1. Continue ongoing efforts to upgrade performance of personnel involved in tank barge cargo transfer operations. Intensified training and qualification programs must be integrated into the existing Coast Guard regulatory and operational system to ensure attainment of the desired improvement in performance.

2. Consider implementation of a mandatory requirement for installation of deck coamings as positive overflow containment for all tank barge cargo tank openings.

3. Foster and encourage the long-range implementation of a requirement for double-containment construction for all tank barges carrying oil products on U.S. waters.

4. Conduct a study to assess the state-of-the-art and regulatory feasibility of automatic gauging and loading controls as a tank barge oil pollution reduction/ prevention measure.

5. Conduct a follow-on effort similar to this current study to evaluate the effectiveness of present and proposed pollution prevention measures; e.g., in the 1980 time frame when data for the 3-year period from 1977-1979 will be available.

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Section 1
INTRODUCTION

BACKGROUND

Recent oil spills from marine vessels have created increasing concern for the adequacy of U.S. maritime safety and pollution control laws, their enforcement, and the adequacy of efforts to protect U.S. inland and coastal waterways. During the 3-year period from 1974-1976, a total of approximately 2,700 tank barge oil pollution incidents were reported, with an associated oil spillage of about 7 million gallons. As shown on figure 1-1, oil spills from marine vessels represent about one-half of the total volume spilled when all sources are considered.[1] In turn, tank barge incidents comprise about one-quarter of the oil pollution from all marine vessels, as shown on figure 1-2.

Problems relating to tank barge oil pollution are presently addressed by a number of Coast Guard mission areas including Commercial Vessel Safety, Marine Environmental Protection, Port Safety, Aids to Navigation, and Bridge Administration. This has led to a fragmented overall program. Several studies of limited scope have been performed which address reduction or elimination of marine pollution. A joint Coast Guard/Maritime Administration study focused on barge construction standards and the potential use of double hulls to eliminate pollution incidents resulting from hull damage.[2] Another study addressed those incidents which could have been prevented by the availability of vessel traffic services.[3] A third study of the effectiveness of the Coast Guard's Marine Environmental Protection Program provided a broad overview of the pollution problems and an evaluation of mission objectives.[4]

OBJECTIVES OF THIS STUDY

The purpose of this study is to analyze in detail available Coast Guard data on tank barge oil pollution incidents and to determine and categorize, as quantitatively as possible, the causes of these incidents and the extent of the resulting pollution over at least a 3-year period. To the extent data was available, and within the time constraints of this study, operational and causal patterns are

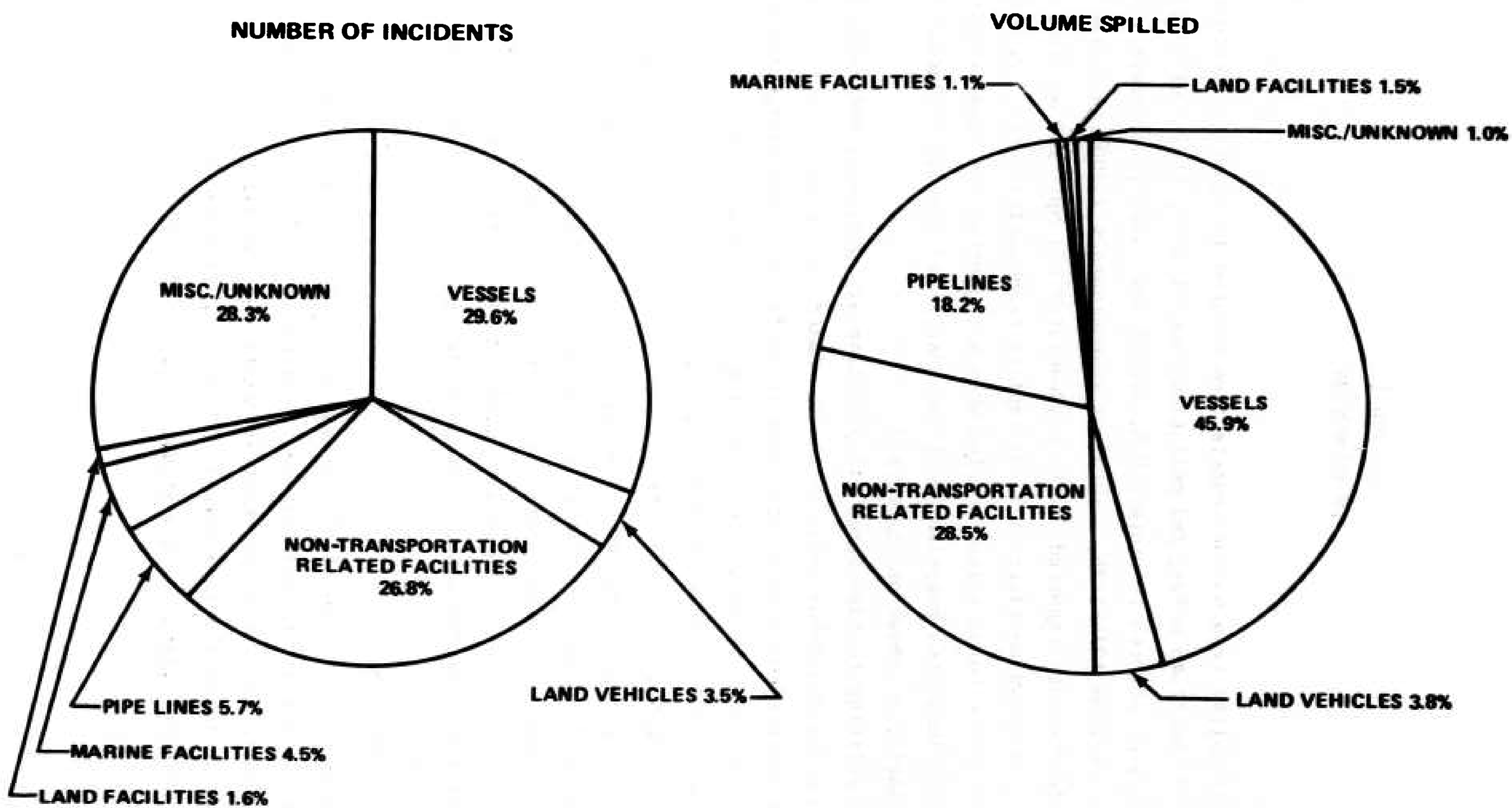

Figure 1-1. Oil Pollution from All Sources: 1975-1976

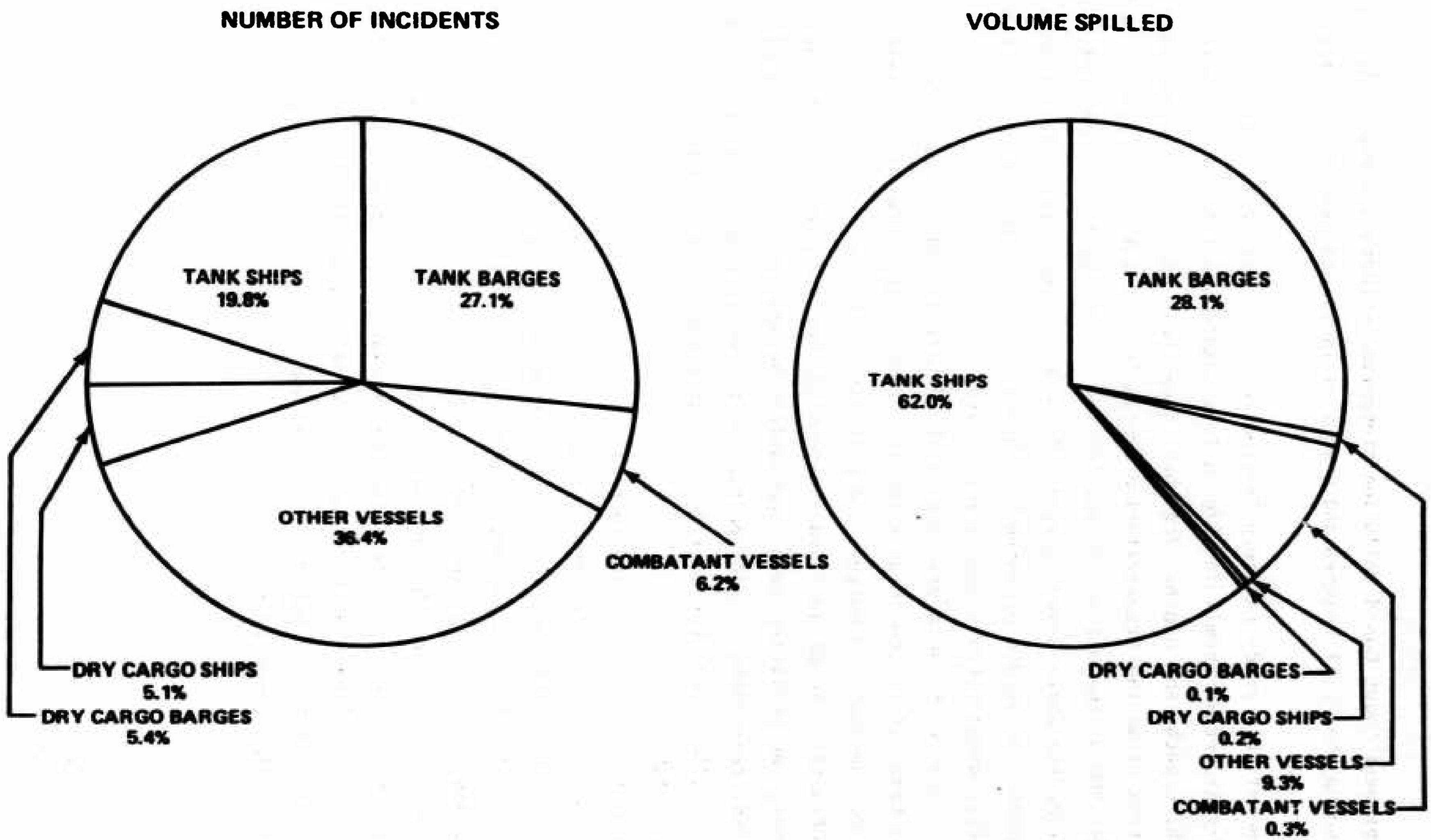

Figure 1-2. Oil Pollution from Marine Vessels: 1975-1976

identified, present Coast Guard pollution prevention efforts are examined, and means of reducing the spill volumes and number of incidents are investigated.

SCOPE

The scope of this study has been limited to tank barges carrying oil products during the 3-year period from 1974-1976 in four sample Coast Guard districts; the second, fifth, eighth, and ninth. Together, these four districts provide data over a broad spectrum of marine transportation routes (river, lakes, and ocean), and they encompass 90% of the oil volume spilled and 75% of the total number of barge incidents during the above 3-year period. These estimates were derived from a series of computer printouts prepared by G-WEP-1 and from computer runs on the entire PIRS File using Vitro's computer facility.

The total number of incidents used in the detailed analysis was actually somewhat less than 75% of the total barge incidents during 1974-1976. Limitation of the study to Subchapter D barges, and elimination of some items due to the absence of definitive causal data, was responsible for this reduction in data inputs. However, the remaining data, upon which the analysis and findings of this study are based, represents a major portion of the total tank barge oil pollution incident data available for the most recent 3-year time frame; 1974-1976.

REPORT ORGANIZATION

The development, restructuring/correlation, and analysis of the data is described in section 2. Results are presented in tabular and graphic format summarizing the number, causes, and extent of tank barge oil spills. Section 3 discusses potential pollution prevention measures within the framework of Coast Guard regulations, responsibilities, and procedures. Preventive measures are summarized; correlative approaches and barge structural aspects are examined. Conclusions and recommendations are presented in section 4. Appendixes A through C contain a more detailed tabular breakdown of the data upon which the results of the study are based. References noted in the body and tables of this report are listed immediately following appendix C.

Section 2

DATA DEVELOPMENT AND ANALYSIS

INFORMATION SOURCES

The data base used in this study was developed from the Pollution Incident Reporting System (PIRS), the Commercial Vessel Casualty Reporting System (CVCRS), the Inspected Barge File, and District Penalty Files. This was supplemented by discussions with pollution control and marine safety personnel in four principal Coast Guard district offices. Each of these sources contributed an essential segment for the overall analysis of tank barge oil spill incidents. Following is a brief description of the individual data sources and their application in this study.

Pollution Incident Reporting System

The primary source of tank barge pollution incident data was obtained from the PIRS File. This data system was developed in 1971 as a Coast Guard management tool for evaluating the effectiveness of its Marine Environmental Protection Program and for providing information to inquiries from Congress, the press, industry, academic institutions, other government agencies, and the general public. The PIRS is the Coast Guard's most comprehensive data base on marine pollution, containing information on all reported pollution incidents in the U.S. inland and coastal waterways. The information content and handling capability of the system makes it amenable to quantitative analysis; this capability was essential for addressing specific problem areas and for extracting the detailed PIRS data used in this study. This detailed data is tabulated in appendix A.

Specific information on tank barge oil pollution was extracted from the PIRS File by G-WEP-1 and provided to Vitro via a set of computer printouts. In order to expedite the large data extraction effort during the initial phase of the study, the PIRS File was also loaded into Vitro's computer facility (via magnetic tape) and additional information was obtained through another set of computer runs.

The information extracted from the PIRS File for use in this study was limited to the following:

1. Tank barges involved in pollution incidents during calendar years 1974-1976.

2. Tank barge incidents in the second, fifth, eighth, and ninth Coast Guard districts.

3. Tank barges involved in the transport of Subchapter D commodities indicated by the PIRS Coding Manual[5] as material series 1000-1099, oil products only.

4. Pollution incidents which fell under one of the following PIRS causal codings:

a. Structural failure or loss

b. Equipment failure

c. Personnel error

Pollution incidents which fell under the non-definitive category of "Unknown" were excluded. The above limitations reduced the total number of PIRS incidents for subsequent analysis to 1,647 cases.

Commercial Vessel Casualty Reporting System

The CVCRS is maintained by the Office of Merchant Marine Safety in support of its enforcement of the vessel inspection laws contained in Title 46, CFR and other Federal Codifications. This is one of the oldest data systems in the Coast Guard and has been in existence both external and internal to the service for many years. The CVCRS File contains data on all marine casualty incidents which fall into one or more of the following areas:[6]

1. Actual physical damage to property in excess of $1,500.

2. Material damage affecting the seaworthiness or efficiency of a vessel.

3. Stranding or grounding (with or without damage).

4. Loss of life.

5. Injury causing any person to remain incapacitated for a period in excess of 72 hours, except injury to harbor workers not resulting in death and not resulting from vessel casualty or vessel equipment casualty.

District Penalty Files

Approximately 1,300 of the pollution incidents extracted from the PIRS (those falling into the areas previously called out in the discussion of the PIRS) were identified as having had penalty action. Listings of these penalty cases were generated for each of the four sample districts. These were used in subsequent visits to district offices to locate and examine the individual files for each incident. A typical district penalty file case contains:

1. A Coast Guard Investigative Report which describes the nature of the pollution incident and the quantity spilled. This report forms the basis for eventual data input into the PIRS.

2. A statement by tankerman or cargo transfer personnel describing how the spill occurred and a Declaration of Inspection (DOI).

3. Correspondence between the Coast Guard and owners of the tank barge.

4. In some instances, pictures showing the spill and damage.

Because of the large total sample population (about 1,300 incidents), time constraints of the study, and in order to minimize any interference with the operational duties of the district offices, only 32% of these penalty cases were selected for review. Priority was assigned to the most recent incidents involving major oil spills.

Inspected Barge File

The Inspected Barge File was obtained from the Office of Merchant Marine Safety. This was used to provide information concerning the types of hulls for the specific barges involved in the pollution incident cases extracted for use in this study from the PIRS and CVCRS Files.

District Office Visits

Discussions with marine pollution personnel in the four Coast Guard districts visited provided supplementary information and a more comprehensive understanding of the scope of the Coast Guard's pollution prevention responsibilities. This information proved useful in consideration of potential pollution prevention measures. However, care was taken to ensure that these expert opinions and judgements were not applied improperly. Conclusions and recommendations of the study are based on analysis of the data, unless specifically identified as judgements resulting from the above interviews and discussions.

DATA ANALYSIS

The data analysis effort was initially focused on isolation of the major causes of tank barge oil spill incidents. A more definitive data base was then developed for subsequent review and further analysis. Although occurrences of pollution incidents are reported and described in a concise tabulated format,[1] this descriptive information does not lend itself readily to the in-depth causal categorization and analysis required to meet the objectives of this study. Therefore, restructuring of data and rearrangement of causal combinations was necessary before continuing with further analytical efforts.

This process is described in the immediately following paragraphs. The data restructuring/correlation process and results of analysis of the restructured data are presented in graphic and tabular format.

PIRS Data Restructuring

After preliminary examination and analysis of the information obtained from the PIRS File, it was apparent that a more definitive and consistent data base for the purposes of this study could be derived by restructuring of some of the PIRS causal codings. Rearrangement of causal combinations shifted the emphasis from what was previously given as the nature of the casualty to why the incident occurred. Figure 2-1 illustrates the potential causal coding combinations. The following major causal areas are indicated:

1. Structural Failure or Loss
2. Equipment Failure
3. Personnel Error
4. Unknown

Causal combinations are entered into the PIRS by selecting the most appropriate Immediate Cause and Contributing Factor under one of the four major headings above.[5]

The type of information obtained from a typical query of the PIRS File is shown in table 2-1; this presents the number of incidents and volume of the oil spill attributed to each of the major causes. Referring back to the PIRS causal code breakdown on figure 2-1, it is seen, for example, that Equipment Failure is associated with a number of events. Therefore, a PIRS causal combination arrangement was developed as defined in table 2-2 which attempts to categorize the underlying cause of the incident in a more definitive and accurate manner. As an example of this restructuring process, valve failure resulting from material fault (coding M-D on figure 2-1) has remained in the causal category Equipment Failure; however, valve failure resulting from improper valve operation (coding M-J on figure 2-1) has now been placed in the causal category Personnel Error.

In addition, incidents which had previously been described as Structural Failure or Loss have been placed under the new category of Hull Damage. Implication

TABLE 2-1. TANK BARGE OIL POLLUTION INCIDENTS: 1974-1976
PIRS CAUSAL CATEGORIES

Cause	Minor Spills[1]				Major Spills[2]				Total			
	Number	%	Volume (gal)	%	Number	%	Volume (gal)	%	Number	%	Volume (gal)	%
Structural Failure	467	35.4	9,083	28.7	133	40.8	3,787,868	94.0	600	36.4	3,796,951	93.4
Equipment Failure	370	28.0	7,659	24.2	66	20.2	34,823	0.9	436	26.5	42,482	1.1
Personnel Error	484	36.6	14,958	47.1	127	39.0	208,722	5.1	611	37.1	223,680	5.5
Total[3]	1,321	100	31,700	100	326	100	4,031,413	100	1,647	100	4,063,113	100

Source: PIRS File - 1974-1976; 2nd, 5th, 8th, and 9th Coast Guard districts.

NOTES:
1. Minor Spills ≤100 gal
2. Major Spills >100 gal
3. Incidents coded as unknown, or those incidents for which a casual coding was not available, are not included in totals.

Immediate Cause	Contributing Factor
(1) **Structural Failure or Loss** A Hull rupture or leak B Tank rupture or leak H Other structural failure	A Collision B Grounding C Fire & explosion D Capsizing and Overturning E Sinking F Other casualty G Adverse weather or sea conditions H Earthquake or other natural disaster I Minor damage J Material fault K Design fault L Personnel error (PE) improper maintenance M PE - overpressurization N Other personnel error O Corrosion Q Other or unknown factor R Ramming
(2) **Equipment Failure** I Pipe rupture or leak J Hose rupture or leak K Manifold rupture or leak M Valve failure N Pump failure O Flange failure P Gasket failure R Other equipment failure	A Minor damage B Excessive wear C Corrosion D Material fault E Design fault F PE - improper installation G PE - improper maintenance H PE - hose, pipe, or loading arm cut or severed I PE - hose, pipe, or loading arm twisted or kinked J PE - improper valve operation K PE - flanges improperly secured L PE - overpressurization M Other personnel error P Other or unknown factor
(3) Personnel Error (Unintentional Discharge) S Tank overflow T Improper equipment handling or operation W Other personnel error	A Inadequate sounding B Failure to shut down C Topping off at excessive rate D Loading too many tanks simultaneously E Overfilling (and subsequent overflow) F Improper hose handling G Improper valve operation H Flanges improperly secured I Failure to communicate J Inattention to duty K Other or unknown factor L Improper training
(4) **Unknown Cause** Z Unknown	Z Unknown

Figure 2-1. PIRS Composite Causal Combination Codes
(Source: PIRS Coding Manual, pp. 41-43)

TABLE 2-2. TANK BARGE OIL POLLUTION STUDY
PIRS CAUSAL COMBINATION DEFINITIONS

Causal Coding	Original PIRS Causal Combination*	PIRS Causal Combination Recategorization
Structural Failure	(A,B,H) with A-R	-
Personnel Error	(S,T,W) with A-L	(A,B,H) with L,M,N, (I-R) with F-M (S,T,W,) with A-L
Equipment Failure	(I-R) with A-P	(I-R) with A-E, P
Hull Damage	-	(A, B, H) with A-K, O, Q,R.

* Source: PIRS, CG-450, 1976, pp. 41-43.
(Refer to figure 2-1)

of structural failure (failure of the barge structure to perform an anticipated action), in that the hull or tank was breached due to non-barge design loadings such as caused by groundings and collisions, is an inaccurate assessment of the performance of the barge structure as designed. The Hull Damage category provides a more definitive descriptive account of the nature of the casualty, but is vague as far as definition of the underlying cause is concerned; collisions and groundings are more descriptive of how the incident occurred, but the causes of the collision or grounding are indeterminate.

Based on the new definitions and the type of causal combination rearrangement described above, more definitive data was culled from the PIRS File and is presented in table 2-3. This restructuring has resulted in a shift of the causal pattern between equipment related incidents and personnel related incidents. An increase in the number of personnel related incidents resulted from placing equipment misuse incidents under the Personnel Error category.

PIRS/CVCRS Data Correlation

An attempt was made to develop further insight concerning the underlying causes for incidents categorized under Hull Damage by cross referencing those incidents which appeared in both the PIRS and the CVCRS. This was accomplished by using the official number of the barge and the date of the incident as the common factors. Only 47 incidents were matched up by this process. Based on the type of incidents which are entered into both systems, it was originally anticipated that a greater number of incident matches would be obtained, especially for the cases in which grounding occurred and pollution resulted. Discussions with district personnel indicated that the probable reason for the smaller number than expected is the discretionary measures they must use in investigating these incidents. Although many oil pollution incidents occur annually, only those which happen as a result of a marine casualty, as defined by law, are examined under the marine casualty procedures. All others are investigated as pollution incidents and are subsequently entered into the PIRS.

Each of the casualty incidents are backed by a comprehensive casualty investigation, copies of which are available at the Office of Merchant Marine Safety. For the 47 incident matches identified, the casualty reports were reviewed and more comprehensive causal information was developed for those incidents involving hull damage. The results of matching the two files are shown in table 2-4. Approximately 70% of these incidents were directly attributed to personnel error resulting from

TABLE 2-3. TANK BARGE OIL POLLUTION INCIDENTS: 1974-1976
PIRS CAUSAL PROFILE RESTRUCTURED

Cause	Minor Spills[1]				Major Spills[2]				Total			
	Number	%	Volume (gal)	%	Number	%	Volume (gal)	%	Number	%	Volume (gal)	%
Hull Damage	380	28.8	7,590	23.9	147	45.1	3,781,651	93.8	527	32.0	3,789,241	93.2
Equipment Failure	176	13.3	2,807	8.9	28	8.6	29,136	0.7	204	12.4	31,943	0.8
Personnel Error	765	57.9	21,303	67.2	151	46.3	220,626	5.5	916	55.6	241,929	6.0
Total	1,321	100.0	31,700	100.0	326	100.0	4,031,413	100.0	1,647	100.0	4,063,113	100.0

Source: PIRS File - 1974-1976; 2nd, 5th, 8th, and 9th Coast Guard districts.

NOTES: 1. Minor Spills ≤100 gal
2. Major Spills >100 gal

TABLE 2-4. CAUSAL ANALYSIS OF CVCRS FILE FOR INCIDENTS INVOLVING TANK BARGE HULL DAMAGE

Cause	Number of Incidents	Total Spill Volume (gal)
Equipment Failure	1	8,400
Personnel Error	32	1,531,000
Weather Conditions	4	607
Unknown	10	13,581
Total	47	1,553,588

pilot errors during underway operations. Detailed descriptions of these incidents are provided in the tabulation in appendix B.

Penalty Incident Data

Causal analysis of 416 cases in the District Penalty Files is presented in table 2-5. This data, which basically supports the PIRS causal codings, has also been restructured in essentially the same manner as previously described for the PIRS data restructuring. Any coding errors evident during the analysis of each of the files were corrected. The results indicate the same trend previously found in the PIRS data analysis. Incidents resulting in hull damage encompass the bulk of the pollution spill volume, while personnel error is the source of the greatest number of spills. In the 416-case sample considered here, Hull Damage and Personnel Error were more evenly distributed than in the larger PIRS sample previously described and summarized in table 2-3. This is due to priority given to the more recent and major incident cases during the review process at the district offices.

Nature and Extent of Tank Barge Oil Pollution

Minor pollution incidents are generally passive in nature in that they occur during other than the actual transport phase of tank barge operations. As indicated on figure 2-2, minor incidents are numerous but are responsible for only a small portion of the overall spill volume.

Transfer operations are the primary activities which generate the minor pollution incidents, as shown in table 2-6. These activities are intimately interrelated with shore facility operations. The associated oil pollution incidents are continuing day-to-day occurrences which individually attract little public awareness, and their cumulative impact is difficult to quantify. The small volumes of these spills generally facilitates industry booming and cleanup. This was evident from review of the District Penalty Files.

The primary reasons for these minor incidents, as shown on figure 2-3, involve personnel error. Problems range from seemingly unavoidable misjudgements to actions which reflect carelessness or lack of experience. For example, a mandatory procedure prior to any transfer operation is the signing of the DOI by the tankerman and the shore facility operator. The DOI is a listing of preventive measures which involve checking all connections, flanges, valves, etc. Numerous incidents were attributed to improper installation of flanges or valves. Such incidents

TABLE 2-5. TANK BARGE OIL POLLUTION INCIDENTS: 1974-1976 DISTRICT PENALTY FILES SAMPLE[1]
CAUSAL PROFILE RESTRUCTURED

Cause	Minor Spills[2]		Major Spills[3]		Total			
	Number	Volume (gal)	Number	Volume (gal)	Number	%	Volume (gal)	%
Hull Damage	88	1,782	91	3,078,113	179	43.0	3,079,895	81.6
Equipment Failure	20	225	9	3,506	29	7.0	3,731	0.1
Personnel Error	108	2,450	100	689,537	208	50.0	691,987	18.3
Total	216	4,457	200	3,771,156	416	100.0	3,775,613	100.0

NOTES: 1. This sample represents 32% of the total penalty files from 1974-1976 at the four sample districts.
2. Minor Spills ≤100 gal
3. Major Spills >100 gal

Original PIRS codings have been verified or recorded on the basis of District Penalty File review for the 2nd, 5th, 8th, and 9th Coast Guard districts.

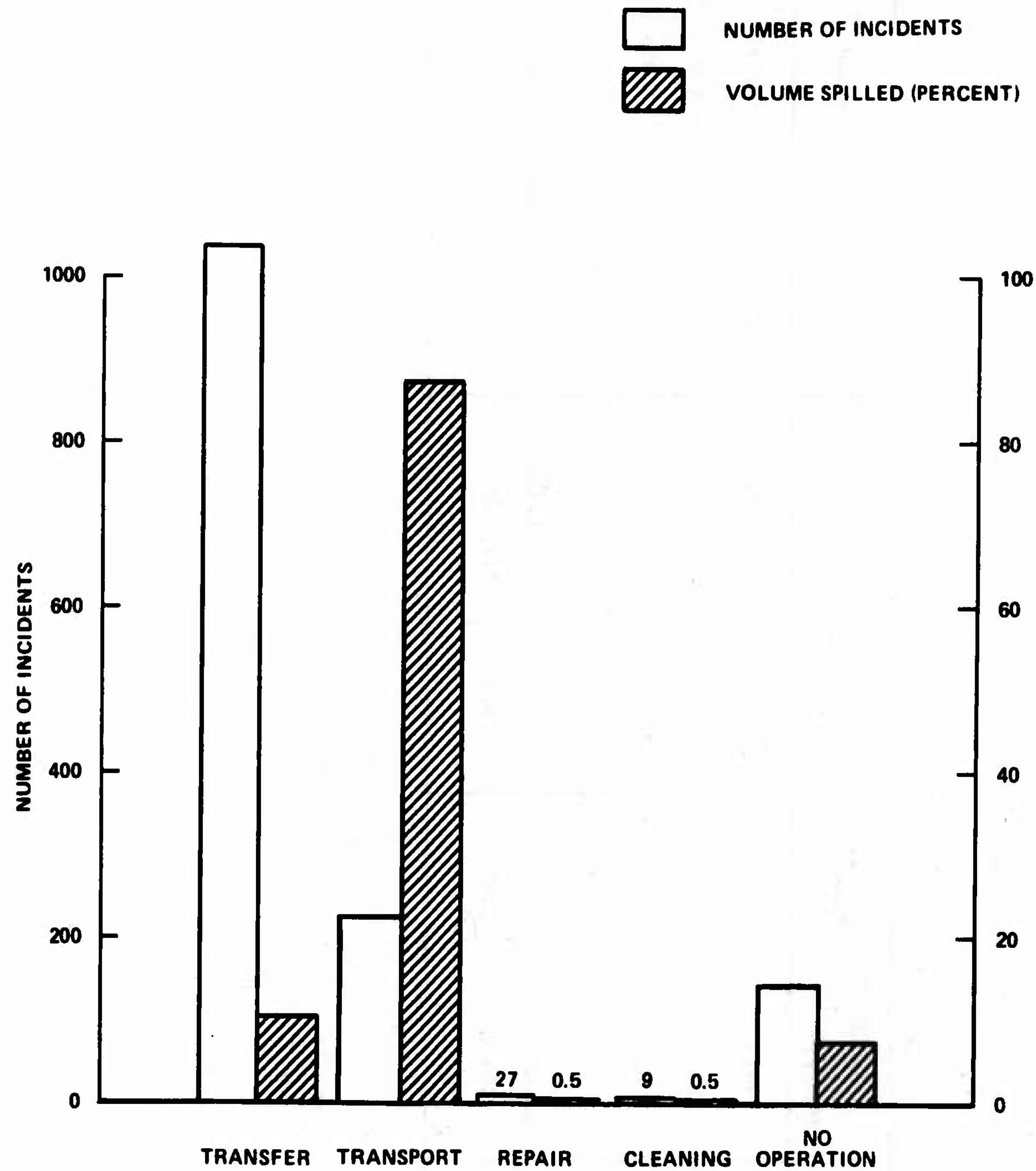

Figure 2-2. Number of Tank Barge Oil Spill Incidents During Major Transport and Nontransport Activities: 1974-1976

TABLE 2-6. OCCURRENCE OF OIL POLLUTION INCIDENTS DURING TANK BARGE OPERATIONS

Activity	Minor Spills[1]		Major Spills[2]		Total			
	Number	Volume (gal)	Number	Volume (gal)	Number	%	Volume (gal)	%
Transfer	903	23,521	208	214,202	1,111	74	237,723	8
Transport	163	3,528	75	2,416,327	237	16	2,419,855	86
Repair	25	721	2	294	27	2	1,015	0.5
Cleaning	9	99	-	-	9	1	99	0.5
No Operation	94	1,973	19	141,690	113	7	143,663	5
Total	1,194	29,842	304	2,772,513	1,497	100	2,802,355	100

Source: PIRS File - 1974-1976; 2nd, 5th, 8th, and 9th Coast Guard districts.

NOTES: 1. Minor Spills $\leq$100 gal
2. Major Spills $>$100 gal

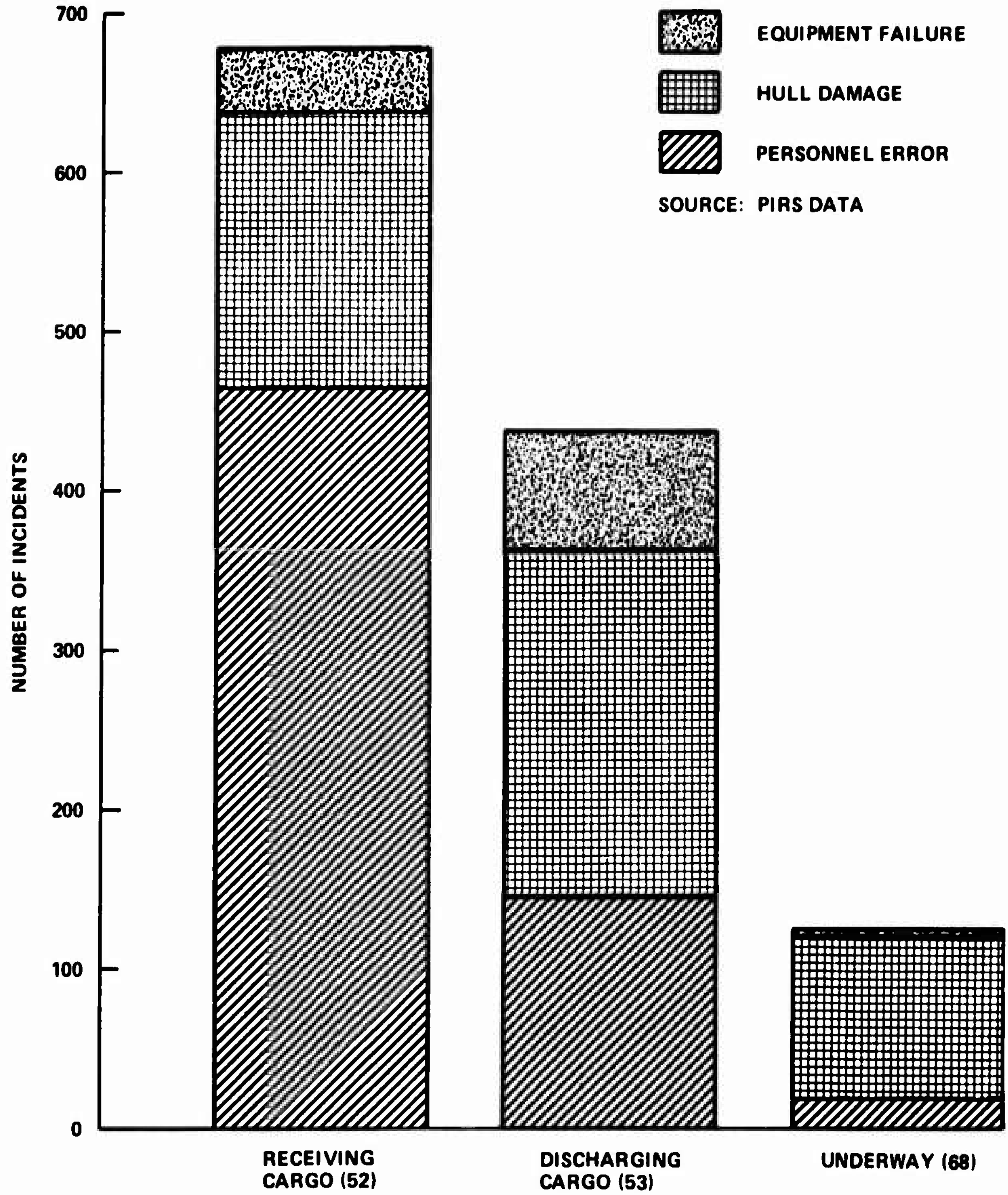

Figure 2-3. Major Causes of Tank Barge Oil Spills During Transfer and Transport Activities: 1974-1976

could have been prevented if greater scrutiny was given to the contents of the DOI, rather than treating it as a formality prior to transfer operations.

It should be noted that some of the minor incidents discovered during transfer operation were associated with prior underway activities such as minor groundings or collisions (from discussions with district personnel). However, the data was used as reported in the PIRS.

Tank Barge Operations

The five major tank barge activities are:

1. Cargo Transfer
2. Transport
3. Repair
4. Cleaning
5. No Operation

The bulk of pollution incident occurrences are associated with: (1) cargo transfer, which involves the receipt and discharge of cargo, fuel, and ballast; and (2) transport activity, which covers underway operations, mooring, lightering, and anchoring. Of the remaining three activities, only "No Operation" is significant in terms of the spill volumes and number of incidents. Interestingly, this categorization represents an example of potential system coding improvement since all tank barge operations should be grouped under vessel-related operations. Changing PIRS operation coding (99) from "Unknown" to "Unknown or No Operation" would tend to reduce the use of the (00) "No Operation" coding in relation to tank barge incidents. These definitions of the tank barge operation cycle were programmed through the PIRS data for the four representative districts and the three calendar years of this study, producing the results shown in table 2-6.

Illustrative of the care with which the PIRS data must be exercised is the fact that the tabulated total of 1,497 incidents represents only 91% of the total incidents reflected in tables 2-1 and 2-3. Review of the PIRS incident data sheets, printed out for use in this study, indicated a large number of operation codings (05), (06), (07), etc.; these are more properly related to facility and land transportation, vice barge operations. In programming to profile the barge operation, these codings were not called out and accordingly were not included in the totals of table 2-6. Their inclusion would not alter the profile presented since they would, if included, fall in the same line activity as if they had been properly coded using vessel-related codes. Figure 2-2 pictorially presents the same information and clearly indicates that transfer-related spills contribute the greatest number of tank barge oil pollution incidents, while transport-related spills produce the largest spill volumes.

Appendix C contains a detailed tabulation of the spill volume category (minor spills ≤100 gal, major spills >100 gal) and number of oil pollution incidents associated with the five major tank barge activities. This breakdown was derived from the PIRS File in accordance with the coding assigned to each of the individual functions shown under the major activity items.

Having examined the overall barge operation by line item activities, it became apparent that transfer and transport are the operational phases which foster the largest number of spill incidents and volume spilled (see figure 2-2). Within these activities, receiving cargo (PIRS code 52), discharging cargo (53), and underway (68) are the three predominant operations causing pollution (see appendix C). Employing the same concept previously utilized in generating the restructured PIRS causal data, the causal combination definitions set forth in table 2-2 were utilized to analyze each of these operations and to develop the causal breakdown shown in figure 2-3. Discounting the large percentage of incidents for which no fundamental cause could be determined using only the PIRS data, it is evident that personnel error, and not equipment failure, is the predominant causal factor. This is most pronounced in the Receiving Cargo phase when the barge tankerman may be lading at rates in excess of 2,500 barrels an hour, with little control over the lading rate other than via communication with the dockman. The number of incidents and the percentage of spills attributed to personnel error are materially reduced when the barge is engaged in cargo discharge. In the latter operational phase, the tankerman has positive control over the transfer pump, an important consideration from the viewpoint of improved pollution control. Since he nominally is considered the individual with the prime responsibility for pollution-free transfer, control of the pumping medium provides him with authority commensurate with his designated responsibility. The intimate interrelationship of barge and facility during the lading activity is important and regulatory effects to reduce barge pollution incidents should be keyed to the concept of a pollution control boundary which includes both. Regulation cannot look solely on one side or the other of the hookup flange.

Since most PIRS causal codings for underway incidents involve collision, grounding, or unknown contributing factors, the basic causes of those incidents cannot be determined without more detailed factual data. Some of the causes will be amplified by examining the small casualty file sample in appendix B; however, figure 2-3 indicates that personnel error is an important causal factor in all three of the major operational phases examined.

Multiple Offenders

Tank barges involved in more than one incident over the 3-year period from 1974-1976 were identified through a computer search of the PIRS File. A total of 304 barges were identified which were involved in more than one pollution incident; these barges accounted for a total of 565 incidents. For the purposes of further analysis, repeat offenders were defined as those barges which were involved in four or more incidents over the 3-year period. This singled out 50 barges which were responsible for a total of 259 oil pollution incidents, with a total oil spill volume of 1,939,092 gallons.

Operational and causal data for these 50 repeat offenders is provided in table 2-7. The bulk of the incidents appear to occur during facility transfer operations and the cause of the incident is attributed mainly to hull damage. Eighty-five percent of the incidents occurred during transfer activities at a facility, and 131 (52%) of the incidents involved some type of hull damage. It should be noted that, in the analysis of operations and causes, several coding omissions in each of the groups resulted in the omission of four incidents for the operational analysis and seven incidents for the causal analysis.

Since hull damage incidents contribute the bulk of oil spilled, an in-depth analysis was made of the 131 hull damage incidents identified in table 2-7. The results of this breakdown are presented in table 2-8. Forty-seven of the 50 repeat barges in table 2-8 were single-hulled (94%); these contributed to 119 pollution incidents with a total of almost 2 million gallons of oil spilled. Only three double-hulled barges were repeat offenders, but in only one incident was the cause related to hull damage. In this incident, 50 gallons of oil were spilled; an insignificant portion of the total volume. The eight double-hull related incidents in the second and eighth districts were attributed to personnel errors and equipment failures, and did not involve damage to the hull.

The repeat barge incidents represent about 25% of the total number of hull damage incidents and 50% of the total oil volume spilled for incidents related to hull damage. Even though a relatively small sample was considered, the results

TABLE 2-7. REPEAT TANK BARGE OIL POLLUTION OFFENDERS - CAUSAL DATA

Coast Guard District	Number of Repeat Barges	Number of Incidents	Spill Volume (gal)	Number of Incidents by Operation/Cause				
				Operation		Cause		
				Underway	Facility	Hull Damage	Personnel Error	Equipment Failure
2	5	20	22,690	6	14	12	2	6
5	4	19	700,227	3	14	14	2	0
8	35	194	1,212,426	27	165	92	76	25
9	6	26	3,749	2	24	13	6	4
Total	50	259	1,939,092	38	217	131	86	35

Source: PIRS File - 1974-1976; 2nd, 5th, 8th, and 9th Coast Guard districts.

TABLE 2-8. REPEAT TANK BARGE OIL POLLUTION OFFENDERS - DATA BREAKDOWN FOR HULL DAMAGE INCIDENTS

Coast Guard District	Number of Repeat Barges	Single Hull Barges			Double Hull Barges		
		Number of Barges	Number of Incidents	Spill Volume (gal)	Number of Barges	Number of Incidents	Spill Volume (gal)
2	5	4	8	22,083	1	4	0
5	4	4	14	700,061	0	0	0
8	35	34	88	1,196,606	1	4	0
9	6	5	9	936	1	4	50
Total	50	47	119	1,919,686	3	12	50

Source: PIRS File - 1974-1976; 2nd, 5th, 8th, and 9th Coast Guard districts.

amplify the sensitivity of the single-hulled barge for sustaining hull damage and for contributing to the bulk of the volume of oil spillage.

Section 3
PREVENTIVE MEASURES

GENERAL CONSIDERATIONS

An overview of the tank barge oil pollution problem is illustrated on figure 3-1. This shows not only the broad technical considerations (causes and major parameters associated with tank barge oil spills), but also points out the interfaces and involvement with the industrial and public sectors.

In section 2 of this report, detailed examination of available data was performed to derive quantitative characteristics of the nature, extent, and causes of tank barge oil pollution incidents. The analysis of preventive measures discussed in this section is based on the results derived in section 2, supplemented by information and clarification obtained in discussions with Coast Guard personnel during visits to the four Coast Guard districts; the second, fifth, eighth, and ninth. Assessment of pollution prevention measures and their effectiveness is based on the subjective judgement of the authors, with the supportive information described above providing the definitive characteristics and the quantitative basis for this assessment.

The entire pollution prevention process must be examined within the framework of the Coast Guard's overall "system" for monitoring, investigation, administration, evaluation, and regulation associated with tank barge pollution incidents. An overview of the Coast Guard's pollution prevention procedures is shown on figure 3-2. It is within this framework or context that tank barge pollution prevention measures are considered.

ANALYSIS OF PREVENTIVE MEASURES

Although the greater number of incidents for a purely statistical analysis is contained in the PIRS data (see appendix A), the more definitive causal data obtained through supplemental examination and analysis of the District Penalty Files and the narrative reports of the CVCRS File provided a more accurate basis for assessment of pollution prevention measures. The above data represents those cases for which additional information was obtained and verification and/or clarification of PIRS File data was essentially effected.

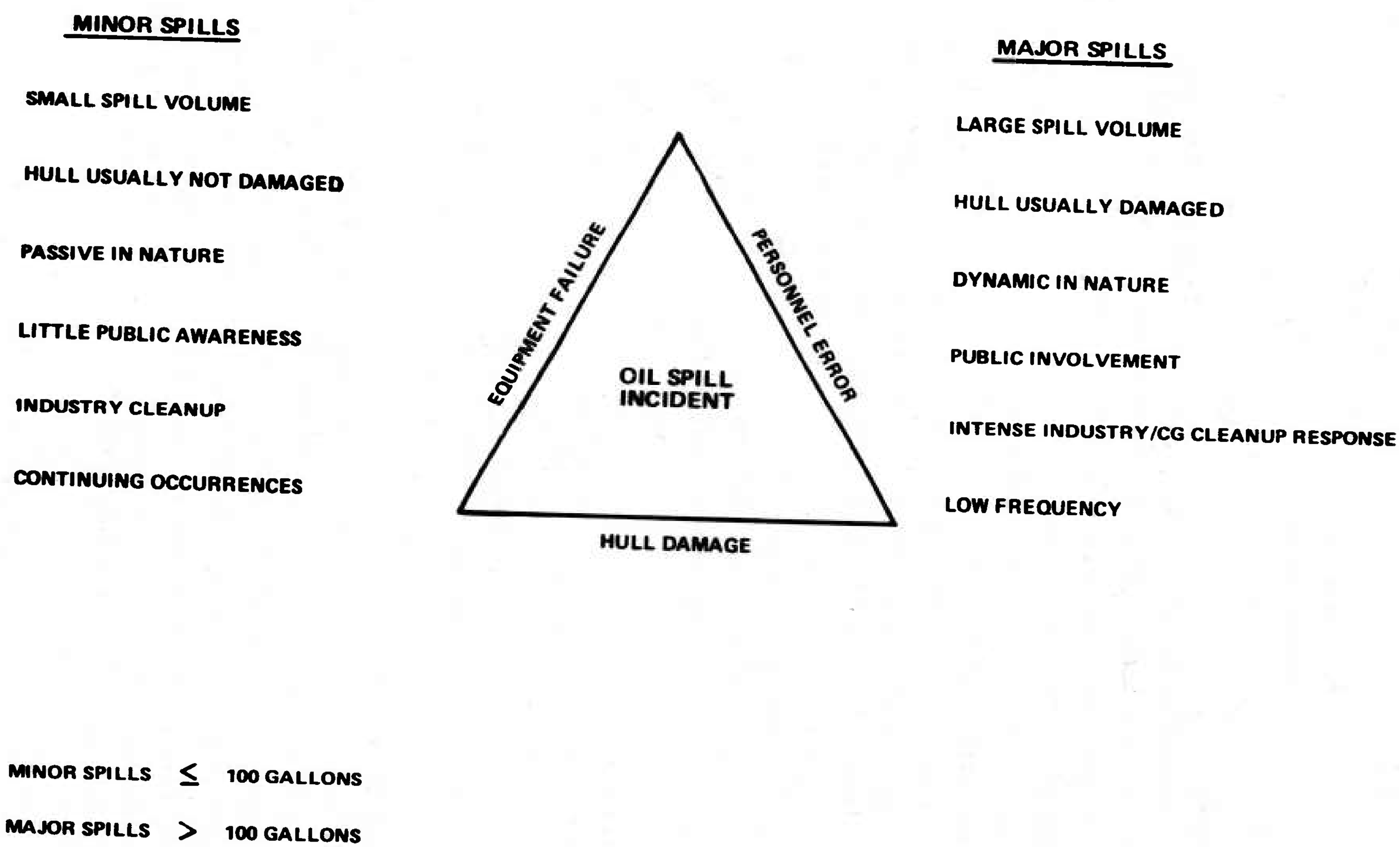

Figure 3-1. Nature and Extent of Tank Barge Oil Pollution

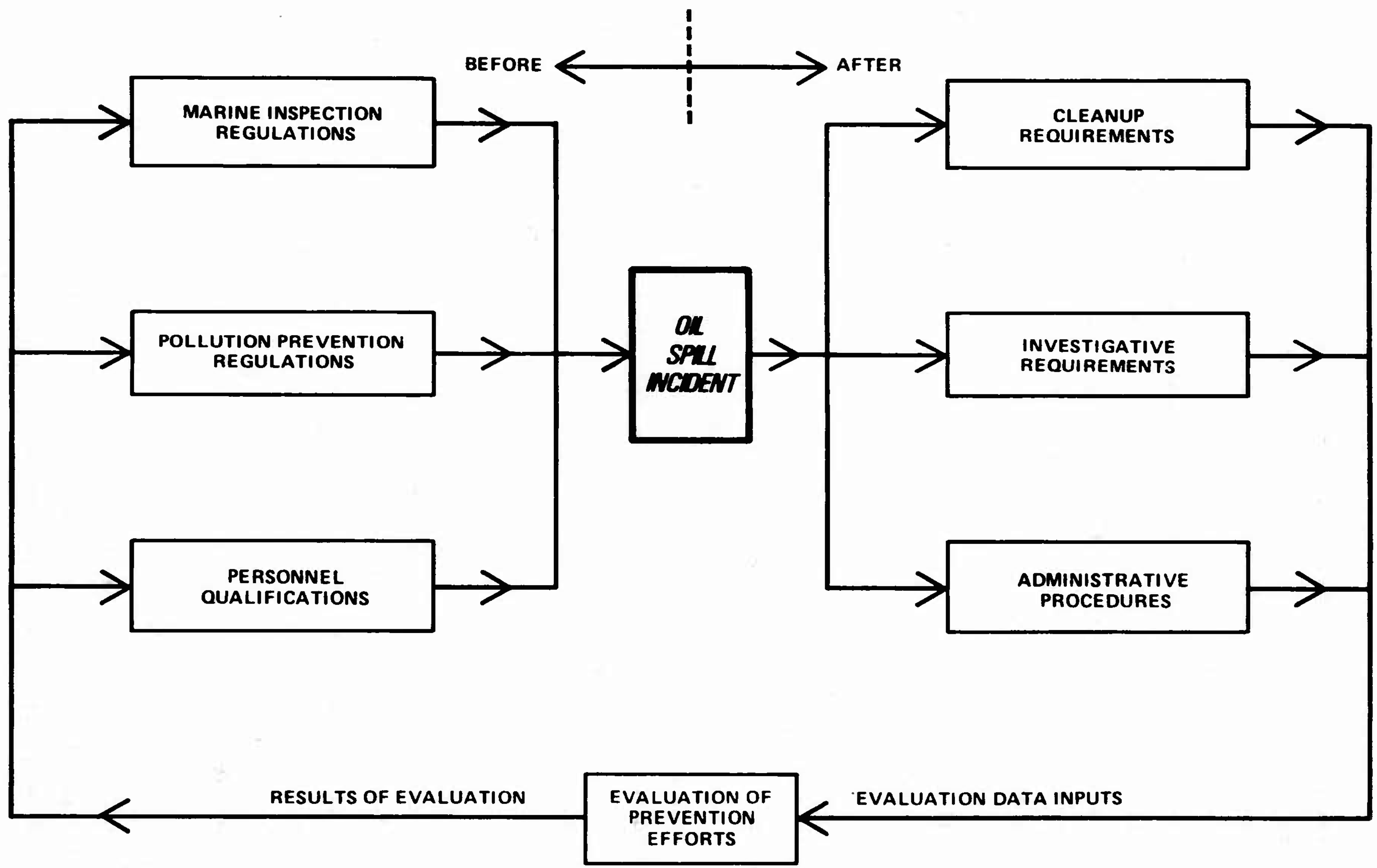

Figure 3-2. Overview of Coast Guard Pollution Prevention Procedures

Hull damage was a primary cause of pollution, especially from the viewpoint of oil volume spilled. However, as indicated on figure 3-1, interfaces between personnel, equipment, and hull design are an important aspect of the overall pollution prevention problem. Improvement in barge structure and design will not, by itself, prevent oil pollution; therefore, essential to any future pollution prevention efforts is consideration of all the underlying causes and their interfaces. This was the general approach taken in this study, which is reflected in the discussion of preventive measures which follows.

Types of Preventive Measures Considered

The following four basic measures were considered for reducing or preventing tank barge oil spills:

- o Hull Design
- o Coamings
- o Tankerman Training
- o Pollution Prevention Regulations

Two of the above preventive measures (tankerman qualification requirements upgrade[7] and an intensification of pollution prevention regulations[8]) are currently being processed through Federal administrative procedures for eventual incorporation into existing regulations. Barge coamings and full or partial double-hull requirements have been considered in the past as pollution prevention measures for Subchapter D barges.

Assessment of District Penalty File Data

Subjective application of the four basic preventive measures was made to each of the 416 District Penalty File incidents reviewed in this study; the detailed results are shown in table 3-1. Approximately 33% of the incidents may have been prevented by double containment of the cargo; 10% by installation of deck coamings; 24% by improved tankerman performance; 21% by either installation of coamings or improved tankerman performance; and 2% by intensified regulatory presence. For 40 incidents (approximately 10% of the total) there was insufficient data upon which to base a reasonable judgement; these cases are indicated as Indeterminate in table 3-1.

Assessment of CVCRS Data

The 47 CVCRS pollution incidents previously categorized as caused by Hull Damage, obtained by cross-referencing and matching to PIRS incidents (see section 2, PIRS/CVCRS Data Correlation) were examined to assess the effect of double-wall

TABLE 3-1. ANALYSIS OF OIL SPILL PREVENTIVE MEASURES

Corrective Measure	Minor Spills[1]		Major Spills[2]		Total	
	Number	%	Number	%	Number	%
Double Hull	62	29	76	38	138	33
Coaming	41	19	-	-	41	10
Tankerman Qualification Upgrade	5	2	97	48.5	102	24
Coaming/Tankerman Qualification Upgrade	86	40	-	-	86	21
Pollution Prevention Regulations	7	3	2	0.5	9	2
Indeterminate	15	7	25	13	40	10
Total	216	100	200	100	416	100

NOTES:
1. Minor Spills $\leq$100 gal
2. Major Spills >100 gal

or double-bottom construction as preventive measures. Double wall refers to tank barges with longitudinal inner bulkheads, port and starboard, between the rake bulkheads. Double bottom refers to tank barges with a continuous inner bottom between rake compartments. Double-wall and double-bottom construction will be referred to as double hull. The results are shown in table 3-2. Twenty-six of the 47 incidents (approximately 55%) may have been prevented by double-wall or double-bottom construction. In four cases (approximately 9%) double-wall or double-bottom construction would have had no effect. For the remaining 17 incidents (approximately 36%) there was insufficient data upon which to base a reasonable assessment; these are indicated as Indeterminate in table 3-2.

TANKERMAN TRAINING

Better trained tankerman and transfer personnel are necessary for reduction of tank barge oil pollution incidents. Tankerman performance deficiencies were the cause of a large number of small oil spills. These deficiencies were confirmed during discussions with Coast Guard district office personnel.

Sixty-five percent of the spills attributed to personnel error resulted from tank or ullage opening overflow, rather than from manifold leaks, ruptures, or cachment overflow. The potential sources for these minor spills are listed on the DOI. Greater adherence to the DOI, and conscientious scrutiny of its contents by both tankerman and shore personnel, could prevent many minor incidents.

The currently proposed Tankerman Regulations may help correct some of the present deficiencies. Characteristic of the proposals are training curriculum outlines, prerequisite elegibility requirements, and tankerman endorsement grades tailored to the particular transfer service for which the applicant will be certified. For both major and minor spills, improved personnel performance could have been effective in preventing pollution for about one-half of the incidents reviewed (see table 3-1).

COAMINGS

Coaming installations could have been effective in preventing oil spills in over one-half of the minor pollution incidents (see table 3-1). However, this preventive measure would probably be ineffective for major spills. All spills of more than 100 gallons were considered to be uncontrolled by coaming installation.

The numerous minor overflows from ullage, expansion trunks, and butterworth accesses could be precluded from being pollution incidents by preventing their entrance into the surrounding water. Some mandatory coaming requirements, other

TABLE 3-2. EFFECT OF HULL DESIGN ON TANK BARGE POLLUTION PREVENTION

Corrective Measure	Minor Spills[1]		Major Spills[2]		Total	
	Number	Volume (gal)	Number	Volume (gal)	Number	Volume (gal)
Double Wall	8	327	10	227,608	18	227,935
Double Bottom	1	8	7	589,284	8	589,292
No Effect	1	50	3	704,300	4	704,350
Indeterminate	5	220	12	31,795	17	32,011
Total	15	605	32	1,552,987	47	1,553,588

NOTES:

1. Minor Spills $\leq$100 gal
2. Major Spills >100 gal

than the present optional manifold and cargo connection cachment requirements of 33 CFR 155.310(a), are indicated. In some instances, it was apparent that cargo connection cachments were filled with oil due to a previous minor spill. These were not emptied, thereby rendering the cachment useless should another spill occur.

Resistance to coamings in the past has been centered on the potential undesirable deck accumulation of low flash point commodities such as gasoline. On several occasions during the review of District Penalty Files, tankerman statements indicated deliberate washdown as a safety measure in the case of gasoline spills. Figure 3-3 indicates that gasoline spills represent a relatively small portion of the total incidents in the four districts sampled. Some spills may not be reported, due, partially, to the highly volatile nature of products which dissipate quickly. The fact that transfer operations are conducted under inherently fire-safe conditions, and the careful means with which the light products are handled, may offset the avowed unsafe aspects of coaming containment.

DOUBLE HULLS

The effectiveness of doubled-hulled vessels as a pollution prevention measure was indicated in a recent joint MARAD/USCG study project[2]. Although this present study does not involve a similar structural/economic analysis, the results indicated in tables 3-1 and 3-2 tend to support the effectiveness of double hulls in preventing pollution in those incidents involving hull damage. In addition, similar indication of the effectiveness of double-hulled barges is shown by the results of the analysis of multiple offenders in section 2 (see table 2-8).

A detailed description of the type of damage incurred by tank barges is provided in appendix B for the cases identified in the CVCRS File. Double walls were judged effective in the case of side damage, and double bottoms in the case of grounding and bottom damage. In those cases where the damage description was not specific, the corrective measure was judged indeterminate; where double hulls would not have effectively deterred a pollution incident, the classification "No Effect" was assigned. Although a very small sample, 87% of the incidents for which a determination of double-hull effectiveness could be made would probably have been preventable. Four of the barges in the sample were double hulled, two were empty and were incorrectly cited as pollution sources in the PIRS listing, and one involved a system failure for which the hull configuration could not have

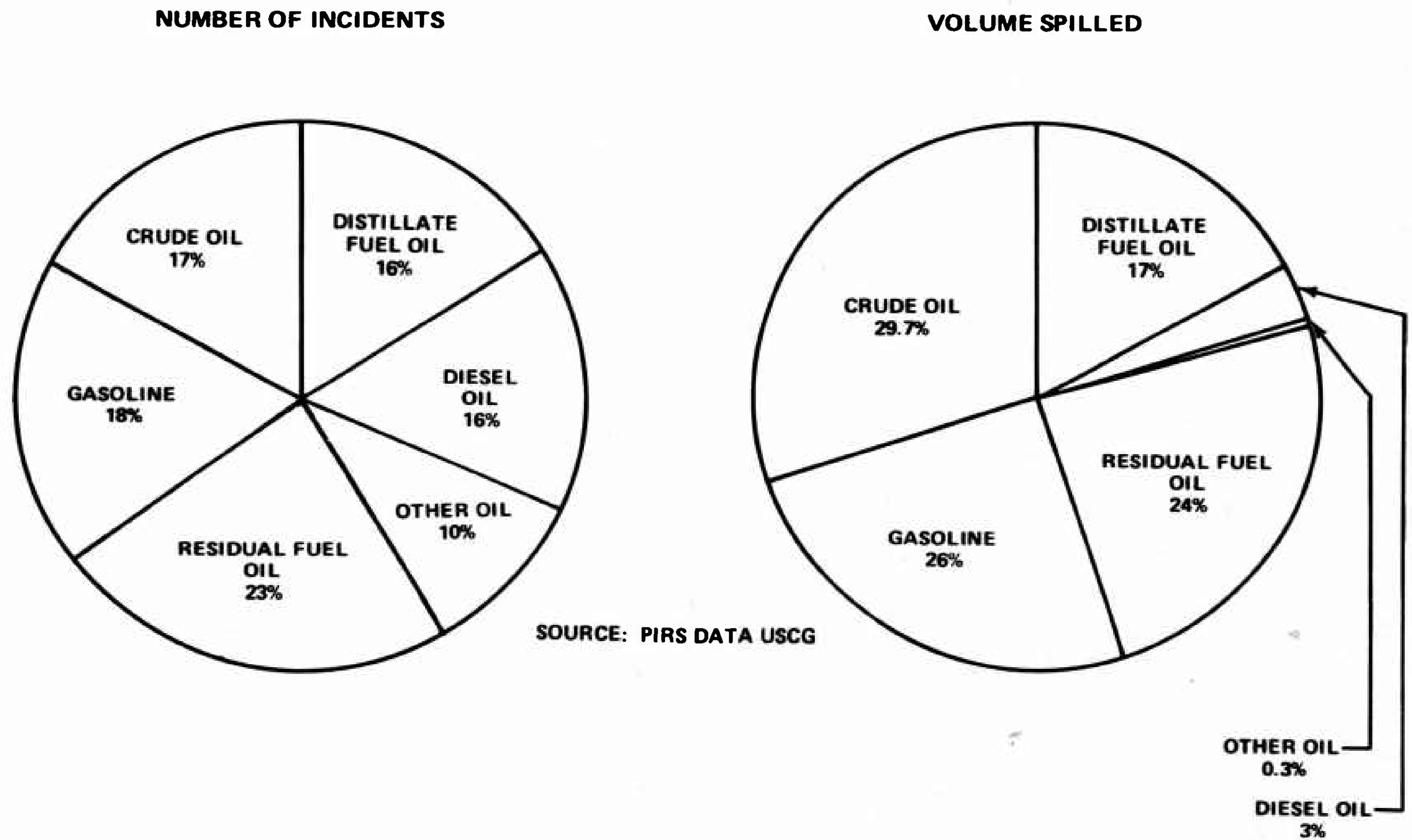

Figure 3-3. Major Tank Barge Oil Cargo Spills for Sample Districts: 1974-1976

been considered a preventive measure. In only one incident, which apparently involved a heavy grounding as indicated by the reported excessive deck buckling, did the double-hull configuration fail to prevent pollution.

The majority of the incidents from the CVCRS (described in appendix B) occurred at night when reduced visibility may have impaired the operator's perception of distance, drift, wind, current, and similar parameters affecting the underway phase of tank barge operations. The bulk of the incidents were major spills occurring underway, involving collisions or groundings, and resulting in hull damage and large volumes of oil spilled.

Fortunately, there has been a slow, but steady increase in the relative number of double-hulled Subchapter D barges in the commercial fleet, as indicated on figure 3-4. The results of this study support continued effort in this direction as a deterrent to tank barge oil spills, especially with regard to reduction in the total spill volume; large oil spill volumes are frequently associated with tank barge incidents involving hull damage and rupture. However, the present higher insurance rates for double hulls and the low liability for oil spills essentially constitute a disincentive toward implementation of double-hull construction.

OTHER PREVENTION CONSIDERATIONS

Many of the minor pollution incidents which occurred as a result of tank overflows could have been prevented by improved gauging techniques and a higher level of performance by attendant personnel. Closely allied to the need for improved gauging capability is more positive control of shore-based pumping sources. Any efforts directed toward barge control of remote pumping sources must consider shoreside throttling, recirculation, or automatic flow diversion capabilities in the event of barge shutdown action. Both improved gauging and loading control techniques are worthy of state-of-the-art investigations as potential alternate pollution control strategies.

Although this study did not focus on the dockman as a significant pollution incident causal factor, he is closely related to the loading operation and to the tank barge as a pollution source. Pollution control efforts associated with licensing of dockside personnel, under regulations similar to those currently proposed for tankerman, might prove effective. This is particularly important if the technical shortcomings of barge control of shoreside pumping facilities cannot be overcome.

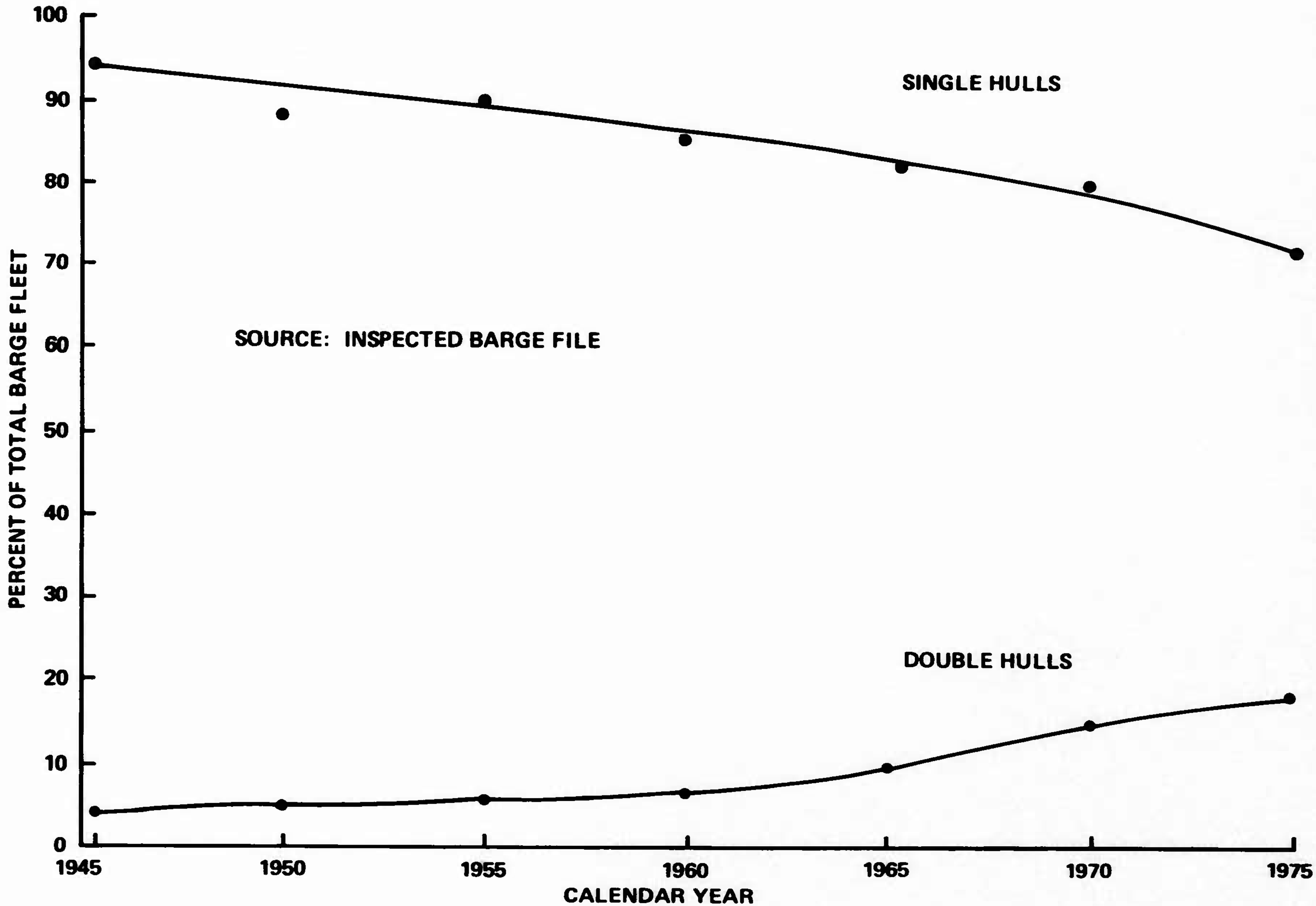

Figure 3-4. Subchapter D Barge Type Construction Trends

Section 4

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations resulting from this study are presented below. They are based on analysis of the oil pollution incident information obtained from Coast Guard data files and consideration of preventive measures which are described in detail in sections 2 and 3, respectively.

CONCLUSIONS

1. Transfer and transport activities are the operational phases which foster the largest number of tank barge oil spill incidents and associated volume of oil spilled.

2. Most of the minor spills ($\leq$100 gal) occur during cargo transfer operations when oil is being loaded or discharged; however, these incidents contribute only a small portion of the total oil spill volume.

3. Most of the major spills (>100 gal) occur during underway operations (including mooring and docking); these represent only a small fraction of the total number of tank barge oil pollution incidents but contribute the bulk of the total oil spill volume.

4. The primary causes for both minor and major spills are related to personnel error. In the case of minor spills, personnel error usually involves mishandling of equipment and insufficient attention to regulations and operating procedures during cargo transfer operations. For major spills, misjudgements by barge pilots lead to collision or grounding incidents with subsequent hull damage and large oil spill volumes. Improved personnel performance could have been effective in preventing a large number of both minor and major oil spill incidents reviewed in this study.

5. Coaming installations could have been effective in preventing over half of the minor oil spill incidents reviewed in this study.

6. Double containment (double-wall and/or double-bottom construction) could have been effective in reducing or preventing major spills for a majority of the tank barge oil pollution incidents categorized as caused by hull damage.

7. Tank barge oil pollution prevention efforts must involve consideration of the overall "system" and procedures utilized by the Coast Guard, and should include consideration of the interfaces between barge structural design, operational procedures, personnel capabilities, equipment characteristics, and regulatory requirements.

RECOMMENDATIONS

1. Continue the ongoing efforts to upgrade the performance capability of personnel involved in tank barge cargo transfer operations. Intensified training and qualification programs must be integrated into the existing Coast Guard regulatory and operational system to ensure attainment of the desired improvement in performance.

2. Consider implementation of a mandatory requirement for installation of deck coamings as positive overflow containment for all tank barge cargo tank openings.

3. Foster and encourage the long-range implementation of a requirement for double-containment construction for all tank barges carrying oil products on U.S. waters.

4. Conduct a study to assess the state-of-the-art and regulatory feasibility of automatic gauging and loading controls as a tank barge oil pollution reduction/prevention measure.

5. Conduct a follow-on effort similar to this current study to evaluate the effectiveness of present and proposed pollution prevention measures; e.g., in the 1980 time frame when data for the 3-year period from 1977-1979 will be available.

APPENDIX A

POLLUTION INCIDENT REPORTING SYSTEM
CAUSAL DATA FOR TANK BARGE
OIL POLLUTION:
1974-1976

TABLE A-1. STRUCTURAL FAILURE - ALL SPILL CATEGORIES*

CONTRIBUTING FACTORS / SPILL SIZE	A. Collision	B. Grounding	C. Fire and Explosion	D. Capsizing/ Overturning	E. Sinking	F. Other Casualty	G. Adverse Weather	I. Minor Damage	J. Material Fault	K. Design Fault	L. PE Improper Maintenance	M. PE Over-pressurization	N. Other PE	O. Corrosion	P. Sand Cutouts	Q. Other/Unknown	R. Ramming	TOTAL
MINOR SPILLS	17/442	22/572	2/125	1/70	3/112	6/351	2/21	51/858	78/1,193	3/26	2/11	3/139	3/165	4/65	5/108	262/4,796	3/29	467/9,083
MAJOR SPILLS	34/2,501,917	22/405,276	1/58,674		3/701,000	1/1,200	1/2,100	7/22,534	11/22,487		2/300	1/2,100	1/200			49/70,080		133/3,787,868
TOTAL	51/2,502,359	44/405,848	3/58,799	1/70	6/701,112	7/1,551	3/2,121	58/23,392	89/23,680	3/26	4/311	4/2,239	4/365	4/65	5/108	311/74,876	3/29	600/3,796,951

*The numbers $(\frac{x}{y})$ in the table represent the following: x - number of incidents,
y - total spill in gallons

TABLE A-2. EQUIPMENT FAILURE - MAJOR SPILLS*

CONTRIBUTING FACTOR / IMMEDIATE CAUSE	A. Minor Damage	B. Excessive Wear	C. Corrosion	D. Material Fault	E. Design Fault	F. Improper Installation	G. Improper Maintenance	H. PE-Hose/Pipe or Load. Arm Twisted or Kinked	I. PE-Hose/Pipe or Load. Arm Twisted or Kinked	J. PE-Improper Valve Operation	K. PE-Flanges Improperly Secured	L. PE-Over-pressurization	M. Other PE	P. Other/Unknown	TOTAL
I. Pipe Rupture or Leak				1/840										2/780	3/1,620
J. Hose Rupture or Leak		3/2,552		4/1,107			1/840					1/168		8/10,998	17/15,665
K. Manifold Rupture or Leak								1/2,640							1/2,640
L. Loading Arm Failure, Rupture or Leak	1/110														1/110
M. Valve Failure		1/120		1/252		1/840	1/630			1/840			2/356	7/2,247	14/5,285
N. Pump Failure														1/150	1/150
O. Flange Failure												1/2,100		5/1,680	6/3,780
P. Gasket Failure		2/360		3/1,092			1/210					2/410		6/1,680	14/3,752
R. Other Equipment Failure				1/200	1/126							1/270		6/1,225	9/1,821
TOTAL	1/110	6/3,032		10/3,491	1/126	1/840	3/1,680	1/2,640		1/840		5/2,948	2/356	35/18,760	66/34,823

*The numbers ($\frac{x}{y}$) in the table represent the following: x - number of incidents,
y - total spill in gallons

TABLE A-3. EQUIPMENT FAILURE - MINOR SPILLS*

CONTRIBUTING FACTOR / IMMEDIATE CAUSE	A. Minor Damage	B. Excessive Wear	C. Corrosion	D. Material Fault	E. Design Fault	F. Improper Installation	G. Improper Maintenance	H. PE-Hose/Pipe or Load. Arm Twisted or Kinked	I. PE-Hose/Pipe or Load. Arm Twisted or Kinked	J. PE-Improper Valve Operation	K. PE-Flanges Improperly Secured	L. PE-Over-pressurization	M. Other PE	P. Other/Unknown	TOTAL
I. Pipe Rupture or Leak	2/29		2/52	6/49			4/13	1/20		1/3		4/34	2/150	13/264	35/614
J. Hose Rupture or Leak	1/20	4/106	1/20	7/71			2/114	1/90			2/6	3/85	1/84	16/424	38/1,020
K. Manifold Rupture or Leak				2/51							2/13		1/3	3/39	8/106
L. Loading Arm Failure, Rupture or Leak							2/4	2/31							4/35
M. Valve Failure	1/50	4/170		10/243	3/28		4/77			11/303			9/345	32/1,092	74/2,308
N. Pump Failure		2/2	1/2	9/85			5/149						1/10	14/376	32/624
O. Flange Failure		1/100	1/84	3/28	1/1	1/5		1/2		2/142	6/77	2/15		10/175	28/629
P. Gasket Failure	1/2	13/223	1/5	13/188		2/22	5/106			3/114	3/13	7/189	2/126	29/472	79/1,460
R. Other Equipment Failure	1/5	1/3		5/7	1/5	4/66	4/37					2/6	5/20	49/714	72/863
TOTAL	6/106	25/604	6/163	55/722	5/34	7/93	26/500	5/143		17/562	13/109	18/329	21/738	166/3,556	370/7,659

*The numbers ($\frac{x}{y}$) in the table represent the following: x - number of incidents, y - total spill in gallons

TABLE A-4. EQUIPMENT FAILURE - TOTAL SPILLS*

IMMEDIATE CAUSE \ CONTRIBUTING FACTOR	A. Minor Damage	B. Excessive Wear	C. Corrosion	D. Material Fault	E. Design Fault	F. Improper Installation	G. Improper Maintenance	H. PE-Hose/Pipe, or Load. Arm cut or Severed	I. PE-Hose/Pipe or Load. Arm Twisted or Kinked	J. PE-Improper Valve Operation	K. PE-Flanges Improperly Secured	L. PE-Over-pressurization	M. Other PE	P. Other/Unknown	TOTAL
I. Pipe Rupture or Leak	2/29		2/52	7/889			4/13	1/20		1/3		4/34	2/150	15/1,044	38/2,234
J. Hose Rupture or Leak	1/20	7/2,658	1/20	11/1,178			3/954	1/90			2/6	4/253	1/84	24/11,422	55/16,685
K. Manifold Rupture or Leak				2/51				1/2,640			2/13		1/3	3/39	9/2,746
L. Loading Arm Failure, Rupture or Leak	1/110						2/4	2/31							5/145
M. Valve Failure	1/50	5/290		11/495	3/28	1/840	5/917			12/1,143			11/761	39/3,339	88/7,363
N. Pump Failure		2/2	1/2	9/85.			5/149						1/10	15/526	33/774
O. Flange Failure		1/100	1/84	3/28	1/1	1/5		1/2		2/142	6/77	3/2,113		15/1,855	34/4,409
P. Gasket Failure	1/2	15/583	1/5	16/1,280		2/22	6/316			3/114	3/13	9/599	2/126	35/2,152	93/5,212
R. Other Equipment Failure	1/5	1/3		6/207	2/131	4/66	4/37					3/276	5/20	55/1,939	81/2,684
TOTAL	7/216	31/3,636	6/163	65/4,213	6/160	8/933	29/2,390	6/2,783		18/1,402	13/109	23/3,277	23/1,154	201/22,316	436/42,732

*The numbers $(\frac{x}{y})$ in the table represent the following: x - number of incidents,
y - total spill in gallons

TABLE A-5. PERSONNEL ERROR - ALL SPILL CATEGORIES*

	CONTRIBUTING FACTOR / IMMEDIATE CAUSE	A. Inadequate Sounding	B. Failure to Shut Down	C. Topping Off at Excessive Rate	D. Loading too Many Tanks Simultaneously	E. Overfilling (and Subsequent Overflow)	F. Improper Hose Handling	G. Improper Valve Operation	H. Flanges Improperly Secured	I. Failure to Communicate	J. Inattention to Duty	K. Other/Unknown	L. Improper Training	TOTAL
MINOR SPILLS	S. Tank Overflow	12/380	15/521	19/794	7/204	85/2,843	1/50	57/2,367	1/84		12/532	96/2,912	3/77	308/10,764
	T. Improper Equipment Handling or Operation	1/75				4/49	23/205	31/1,353	14/572		5/156	35/504		113/2,914
	W. Other Personnel Error		1/84			2/101	6/10	4/207	8/147		6/49	36/682		63/1,280
MAJOR SPILLS	S. Tank Overflow		13/5,753	3/3,126	3/1,260	24/11,029		11/65,810		1/840	3/756	30/9370		88/97,944
	T. Improper Equipment Handling or Operation					2/588	1/150	7/4,422	8/4,794		3/1,300	3/950		24/12,204
	W. Other Personnel Error					1/8000		5/1334	1/120			8/89,120		15/98,574
TOTAL	S. Tank Overflow	12/380	28/6,274	22/3,920	10/1,464	109/13,872	1/50	68/68,177	1/84	1/840	15/1,288	126/12,282	3/77	396/108,708
	T. Improper Equipment Handling or Operation	1/75				6/637	24/355	38/5,775	22/5,775		8/1,456	38/1,454		137/15,118
	W. Other Personnel Error		1/84			3/8,101	6/10	9/1,541	9/267		6/49	44/89,802		78/99,854

*The numbers $(\frac{x}{y})$ in the table represent the following: x - number of incidents,
y - total spill in gallons

APPENDIX B

TANK BARGE POLLUTION INCIDENT
CAUSAL DETERMINATION MATRIX

APPENDIX B

TANK BARGE POLLUTION INCIDENT CAUSAL DETERMINATION MATRIX

CVCRS Case Number	PIRS Coding		Spill Volume (Gallons)	Time[1]	CVCRS Narrative Cause	Damage[2]	Potential Preventive Measure[3]
	Cause	Operation					
02/42612/74	AB	68	21,000	N	Pilot misjudgment led to grounding.	Not given.	DB
02/52664/75	AB	80	630	N	Pilot misjudgment of channel caused grounding. Damage occurred while re-floating, causing tug to damage barge.	6"x1/8" tear in stbd. side, 20' forward of stern, 2' below line.	DW
02/60680/75	BA	68	50	N	Pilot failed to align tow when entering lock.	Side damage, 6" hairline crack.	DW
02/60774/75	BB	80	100	D	Pilot failed to keep clear of grounded barge; passed on wrong side.	Not given.	Indet.
02/61414/75	BA	68	28,000	N	Pilot failed to allow for headdrift in canal; evidence of excessive speed.	Bottom damage #1P.	DB
02/61615/76	BA	68	50	N	Pilot misjudgment of current while bringing tow alongside.	"L" shaped fracture from deck down stbd. side approx. 2 1/2".	DW

Notes:
1. D-Day, N-Night
2. P-Port, S-Starboard
3. All existing barges are single hulled except as noted. DB-Double Bottom, DW-Double Wall

TANK BARGE POLLUTION INCIDENT CAUSAL DETERMINATION MATRIX

CVCRS Case Number	PIRS Coding		Spill Volume (Gallons)	Time[1]	CVCRS Narrative Cause	Damage[2]	Potential Preventive Measure[3]
	Cause	Operation					
02/62276/76	AB	68	2,016	N	Pilot failed to recognize unchartered buoy and grounded lead barge in secondary channel.	Ruptured bottom #1S.	DB
02/62586/76	BA	68	2,500	N	Pilot failed to allow for effect of current while transiting bridge.	Crack #3S lower side aft.	DW
05/52557/74	RP	64	50	N	Pilot moored loaded barge alongside pier while tide was falling. Barge grounded and holed.	1/2" dia. hole in bottom plate, #1P, 4' aft of forward bulkhead. 11" inboard.	DW
05/52473/75	AQ	68	5	Unknown	Cause indeterminate; believe barge struck submerged or floating object.	#1P compartment leaking on arrival, fractured plate 7' waterline.	DW
05/52866/75	HQ	68	1,000	D	Pilot misjudgment of current forces affecting tug and barge while negotiating sharp bend in narrow river channel.	#2P set in approx. 2' for 20' in length.	DW

05/61728/76	AE	68	700,000	N	Water entered port pump room vent, flooding pump room and closing coaming drains, permitting boarding seas to partially fill containment area. Stern sank and grounded.	Bottom plate portside in way of stern port void, and #4P set up 2'-3'. Small crack in port void bilge knuckle.	No effect.
08/41711/74	AB	68	Unknown	D	Dense fog; radar did not pick up buoy line. Tow grounded on shell reef.	#2P bilge knuckle fractured 8" long x 3" wide.	DW
08/41800/74	AB	68	300	N	Pilot failed to position tow to compensate for current, prior to rounding bend in river and grounded.	Damaged bottom plate #1S.	DB
08/41945/74	AB	68	8,000	N	Pilot failed to maintain proper course in bend and ran out of channel.	Hole in #1S tank.	Indet.
08/42011/74	AQ	52	180	N	While docked, adverse weather pushed barge against jagged top edge of submerged steel bulk-head.	Split 5" long x 1/4" wide in forward cargo tank.	Indet.
08/42472/74	AB	52	420	N	Barge became windbound while doubling up and grounded. "No damage". 6 Hours later PIRS #08/00905/74 occurred when barge commenced loading.	None.	Indet.

APPENDIX B (Continued)

TANK BARGE POLLUTION INCIDENT CAUSAL DETERMINATION MATRIX

CVCRS Case Number	PIRS Coding		Spill Volume (Gallons)	Time[1]	CVCRS Narrative Cause	Damage[2]	Potential Preventive Measure[3]
	Cause	Operation					
08/43254/74	OP	53	210	N	Pilot struck unknown submerged object while docking.	#3P, 3" dia. hole.	Indet.
08/50547/74	AA	68	378,000	N	Collision with submerged object. Pilot tried to navigate unlighted channel at night knowing that no lighted aids existed and that dredging was in progress.	Holed entire bottom just to stbd. of centerline, including forward rake and all stbd. cargo tanks.	DB
08/50561/74	AA	68	8,400	D	Pilot lost control of tow due to vessel taking suction on south bank. ICW-coupling broke and two lead barges collided with oncoming tow.	Port side bow rake 4' x 3' deep, 3' below deck; collision bulkhead fractured.	Indet. Damage described pertains to empty double-hull barge which was not source of pollution.
08/50667/74	AQ	68	210	N	Necessity for towboat pilot to make emergency maneuver to avoid collision in congested channel. Struck submerged stump.	Holed #1S cargo tank.	Indet.

08/50761/74	HA	00	168	N	Vessel navigator failed to keep to stbd. side of channel after agreeing to port meeting situation.	Damage to rake from head log to #1 cargo tanks. No cargo loss.	Indet. Damage described pertains to empty double-wall, single-bottom barge which was not source of pollution.
08/50950/74	AA	68	252	D	Presence of unchartered submerged object near bank of channel. Operator forced to left of channel to pass moored barges.	Hole in port knuckle below waterline.	Indet.
08/51135/74	AA	68	84	D	Pilot misjudged current effect on movement of tow and struck piling.	Holed #5P under waterline.	DW
08/51210/74	AA	68	3	D	Pilot struck stbd. side of barge while maneuvering.	Not given.	DW
08/51217/75	AM	68	84	N	Pilot misjudgment in permitting towed barge to override tow.	Holed barge in #2P cargo tank. 10'-15' dent in #2P, 12"-16" crack; internals bent out of shape.	DW

APPENDIX B (Continued)

TANK BARGE POLLUTION INCIDENT CAUSAL DETERMINATION MATRIX

CVCRS Case Number	PIRS Coding		Spill Volume (Gallons)	Time[1]	CVCRS Narrative Cause	Damage[2]	Potential Preventive Measure[3]
	Cause	Operation					
08/51510/75	AA	68	2,520	N	Pilot misjudged position of tow while proceeding through bridge and collided with fenders.	#1S gunnale and side plate set in. Holed over 4'x15' area. #2S gunnale and side plate set in and holed over a 4'x24' area.	DW
08/51980/75	HB	68	630	D	Pilot misjudged effects of strong wind and low tide causing barge to ground.	No damage.	Indet.
08/52015/75	AE	64	200	D	Pilot failed to see submerged bulkhead.	Bow rake holed and bow sank. 10"-12" rip in bow rake.	No effect.
08/52579/75	AA	68	209,118	D	Pilot misjudged effect of current on tow, resulting in collision with another barge.	Large gash in steel plate in #1P and #2P.	DW

08/53134/75	BM	52	50	D	Thermal fluid heater expansion tank ruptured due to water in fluid. Failure to follow proper operating procedure prior to lite off.	None given.	No effect. Double wall, single bottom barge; configuration did not bear on pollution incident.
08/53295/75	AB	68	Unknown	D	Pilot misjudgment resulted in barge grounding and cracking side seam.	None given.	DW
08/60547/75	AJ	68	4	N	Pilot misjudged effects of current on vessel; barge grounded.	Split weld in #1P tank.	Indet.
08/61342/75	AQ	68	8,400	N	Grounding occurred because of low tide and shoaling in channel.	Underwater damage to stbd. hull and bottom appears to be in area of No. 1 and 2 tanks.	Indet.
08/63136/75	AB	68	10	N	Low visibility and malfunction of radar on towed vessel caused pilot to overrun sea buoy inbound; grounding occurred.	Holed #1P, 3"x24".	Indet.
08/61849/76	AQ	52	Unknown	D	Collision occurred from surging of barge against fixed offshore platform while moored.	Holed #2P. Six holes punctured in port side of barge.	DW

APPENDIX B (Continued)

TANK BARGE POLLUTION INCIDENT CAUSAL DETERMINATION MATRIX

CVCRS Case Number	PIRS Coding		Spill Volume (Gallons)	Time[1]	CVCRS Narrative Cause	Damage[2]	Potential Preventive Measure[3]
	Cause	Operation					
08/62540/76	BA	68	3,440	D	Pilot misjudged effect of wind and current and struck fixed platform.	Holed #3P at knuckle, 1'x 1' hole.	DW
08/62881/76	AB	53	159,768	D	Pilot unable to detect presence of an uncharted shoal or submerged object, causing lead barge to drag bottom.	Leak in tanks #1, 2, and 5 from bottom damage.	DB
08/63232/76	AA	53	4,914	N	Tank vessel collided with moored barge.	Bow rake and stern rake, #4S, #3P, #4P.	Indet.
08/63298/76	AQ	64	Unknown	D	Pilot unable to detect presence of submerged dolphin which holed lead barge.	Holed bow rake and #1S tank.	Indet.
08/63304/76	AB	68	8	D	Pilot failed to properly assess state of tidal current and its effect on vessel; grounded the tow.	Indentation, bottom #1P and #2P.	DB
08/63304/76	AA	80	1	N	Pilot misjudged state of tidal current and effect on vessel, resulting in grounding.	Indentation, #3S at deck line.	DW

08/63406/76	BB	68	4,100	N	Pilot misjudgment in allowing tow to contact edge of dredged channel. Barge buckled as result of grounding.	Buckled 105' aft to bow on port side, and 125' aft on stbd. side. 4' crack in #2P. Seam weld connecting tank top to deck, crack in same weld in #3S of unknown length.	No eifect. Existing double hulled barge.
08/63880/76	AA	68	8,400	N	Mechanical failure of hydraulic steering system. Tug veered across channel and struck barge.	20' gash along #2P tank.	DW
09/51034/74	AB	53	200	N	Pilot failed to recover from previous turn before lining up for next turn in opposite direction, grounding the tow.	Hole in bottom #1P.	DB
09/53063/74	BQ	53	100	N	Pilot misjudgment permitted tow to be set out of channel and strike rock shelf.	Holed #2S below waterline.	Indet.
09/60600/75	AA	64	10	D	Pilot misjudged speed while making dock.	Fractured weld turn of barge, #2P.	Indet.

APPENDIX C

TANK BARGE OIL POLLUTION BY MAJOR TRANSPORT AND NON-TRANSPORT ACTIVITIES: 1974-1976

TANK BARGE OIL POLLUTION INCIDENTS BY MAJOR TRANSPORT AND NON-TRANSPORT ACTIVITIES: 1974-1976
(Sheet 1 of 2)

Activity	Number of Spills			Percent of Spills	
	Minor[1]	Major[2]	Total	Within Activity	All Activities
Transfer					
Receiving liquid cargo (52)[3]	524	125	649	58.4	43.3
Discharging liquid cargo (53)	341	75	416	37.4	27.8
Receiving fuel (54)	33	6	39	3.5	2.6
Taking on ballast (55)	1		1	0.1	0.1
Discharging ballast (56)	4	2	6	0.6	0.4
Transport					
Mooring at dock (64)	13	3	16	6.7	1.1
Departing from dock (65)	3		3	1.3	0.2
Moored (not engaged in any operating listed above) (66)	51	7	58	24.4	3.9
Underway (68)	62	60	122	51.7	8.1
Lightering (69)	1		1	0.4	0.1
Other vessel-related operation (80)	32	5	37	15.5	2.4

Source: PIRS File - 1974-1976; 2nd, 5th, 8th, and 9th Coast Guard districts.

NOTES:
1. Minor Spills $\leq$100 gal
2. Major Spills $\leq$100 gal
3. ( ) Denotes a PIRS Code

TANK BARGE OIL POLLUTION INCIDENTS BY MAJOR TRANSPORT AND NON-TRANSPORT ACTIVITIES: 1974-1976
(Sheet 2 of 2)

Activity	Number of Spills			Percent of Spills	
	Minor[1]	Major[2]	Total	Within Activity	All Activities
No Operation					
No operation in progress (00)[3]	94	19	113	100.0	7.5
Repair					
Transfer or shifting of liquid within vessel (61)	17	1	18	66.7	1.2
Repair, modification, or maintenance of vessel (62)	6	1	7	25.9	0.5
Rapair, modification, or maintenance of equipment (63)	2		2	7.4	0.5
Cleaning					
Stripping tanks (58)	7		7	77.8	0.5
Cleaning tanks (59)	1		1	11.1	0.1
Other cleaning process (60)	1		1	11.1	0.1
Total	1,193	304	1,497		100.0

Source: PIRS File - 1974-1976; 2nd, 5th, 8th, and 9th Coast Guard districts.

NOTES: 1. Minor Spills $\leq$100 gal
2. Major Spills $\leq$100 gal
3. ( ) Denotes a PIRS Code

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