The United States Coast Guard | **The American Waterways Operators**

May 21, 2003

MEMORANDUM

TO: AWO Board of Directors
Designated Representatives, AWO Carrier Members

FROM: Tom Allegretti, The American Waterways Operators
RADM Paul Pluta, U.S. Coast Guard

RE: Coast Guard-AWO Bridge Allision Work Group Report

We are pleased to enclose the Report of the Coast Guard-AWO Bridge Allision Work Group, formed by the Coast Guard-AWO Safety Partnership in the wake of fatal barge-bridge accidents at South Padre Island, Texas, in September 2001 and Webbers Falls, Oklahoma, in May 2002. The Work Group was established by the Safety Partnership's National Quality Steering Committee and functioned as a Quality Action Team as provided for in the Coast Guard-AWO Partnership Agreement of 1995. The Work Group examined Coast Guard casualty data on bridge allisions involving barges and towing vessels and attempted to answer the questions, "How often do bridge accidents involving barges and towing vessels occur? What causes them? What do we need to do to prevent them and ensure that public safety is not placed at risk?" This report attempts to provide some answers to those questions, based on a study of towing vessel bridge allisions over the ten-year period 1992-2001, led by a group of Coast Guard and towing industry experts, including active and former towing vessel captains.

Because formal government investigations into the Texas and Oklahoma casualties are continuing, the Work Group did not attempt to draw conclusions about the causes of those particular incidents. This report is meant not to preempt the forthcoming accident investigation results, but to serve as context for them. Together, we expect that all of these inputs – the Work Group report **and** the Coast Guard and National Transportation Safety Board investigation results, combined with feedback from Congress and other federal agencies – will serve as the basis for well targeted and effective actions by industry and government to address the challenge of towing vessel/bridge accidents and ensure the safety of the traveling public. Copies of the report are also being shared with the Towing Safety Advisory Committee and the Navigation Safety Advisory Council for consideration.

Your feedback is an important part of this process. We hope that you will take the time to read the report carefully and offer your comments, questions, and suggestions for improvement. If you have any questions about the report, please feel free to contact Jennifer Carpenter, AWO Senior Vice President-Government Affairs and Policy Analysis, at jcarpenter@vesselalliance.com, or Captain Mike Karr, Chief, Office of Investigations and Analysis, U.S. Coast Guard, at mkarr@comdt.uscg.mil.

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Report of the

U.S. Coast Guard - American Waterways Operators
Bridge Allision Work Group

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EXECUTIVE SUMMARY

Introduction

On May 26, 2002, a tow struck the I-40 highway bridge over the Arkansas River. The bridge collapsed, resulting in the tragic loss of the lives of 14 motorists. Under the auspices of the U.S. Coast Guard-American Waterways Operators (AWO) Safety Partnership, the Coast Guard and AWO convened a work group to investigate the prevalence and causes of bridge allisions involving barges and towing vessels and develop recommendations to prevent allisions and mitigate their consequences.[1] The group's work was **not** intended to address the I-40 accident itself, since that casualty is the subject of an ongoing investigation by the National Transportation Safety Board, which may result in additional recommendations for Coast Guard-industry action.

The Bridge Allision Work Group ("the Work Group," or "the Group") included members from both the Coast Guard and AWO member companies with expertise in towing operations and safety, including four active or former towing vessel captains. The Work Group also drew on subject-matter experts from the Coast Guard and the AWO staff. The Group used the principles of Risk-Based Decision Making (RBDM) to provide structure and discipline to its analysis.

Data Extract and Analysis

Data on all bridge allisions in which the primary event was either an allision or breakaway were extracted from the Coast Guard's databases. This resulted in a study database of 2,692 bridge allision cases involving towing vessels and barges in U.S. waters for the years 1992-2001. This number must be viewed in the context of the number of trips conducted by tugboats and towboats each year. Using data from the U.S. Army Corps of Engineers for the year 2000 (the most recent year for which published data is available) as a reference point, the Work Group calculated that bridge allisions occur at the rate of approximately 0.06%, or six allisions for every 10,000 towing vessel trips.

The Work Group divided the bridge allision cases into five severity classes. The table below gives the definitions of the classes and the number of cases in each:

Table 1: Severity Classes

Class	Definition	Count
0	Damage recorded as "None or Not Specified."	1,702
1	Damage between $1 and $25,000.	610
2	Damage between $25,001 and $100,000.	220
3	Damage between $100,001 and $500,000.	99
4	One or more of: damage > $500,000; loss of life > 0; injured > 0; missing > 0; oil spilled.	61

[1] An allision is a collision with a stationary object, such as a bridge or dock.

A statistical analysis of the entire study database was conducted. This provided the Work Group with information about the most frequently hit bridges, the bridges that sustained the most damage, and the bridges currently scheduled for alteration or removal under the Truman-Hobbs Act. Analyses of the allisions by vessel characteristics (e.g., length, horsepower, etc.), time of day of the accident, and occurrence of a pollution incident showed no correlations or patterns suggesting fruitful areas for further study.

To investigate the causal factors behind the bridge allisions, a subset of the cases was produced consisting of all the cases in severity classes 3 and 4, plus a random sample of cases from the other classes. The subset was sent to teams of industry experts, each chaired by a Work Group member. A computer-based tool was used by the experts to categorize and assign causal factors to each case. This exercise returned detailed data on 459 cases.

The information contained in the Coast Guard casualty reports posed a significant challenge to the Work Group. Current Coast Guard standards for gathering casualty facts and information, especially human factors information, were incompatible with the intent of the Work Group to conduct a detailed analysis. In many cases, the detail necessary to determine precisely the causal factors of an allision was not available. Work Group members were therefore forced to rely on their own operational experience, judgment, and knowledge of a particular waterway in interpreting the limited information in the Coast Guard casualty reports and classifying allisions by mishap type and causal factor. With this admittedly significant caveat, the Group concluded that 90% of the cases were related to human performance (78% to pilot error and 12% to other operational errors). Only 5% were related to mechanical problems, and for the remaining 5% there was insufficient information to assign a cause. The Group's analysis of the performance-based cases showed that the predominant causal factor in bridge allisions was decision making error on the part of the towing vessel operator, which surfaced as a causal factor in 68% of the 435 sampled cases in which a mishap category could be identified. Significantly, this pattern was the same for cases across the range of severity classes, meaning that both high- and low-consequence cases exhibited the same causal factors.

Development of Recommendations

Based on this information, the Work Group focused on improving decision making in the wheelhouse. Cognitive models of the decision making process were developed and used to construct a systems model of the factors involved. Development of the systems model showed clearly that reducing the number of bridge allisions is a complex issue; there are no "silver bullets" or quick fixes. The Work Group identified leverage points in the model where changes could be made to reduce the frequency of bridge allisions or mitigate the consequences of allisions and generated a list of potential recommendations. A cost-benefit analysis was applied to the list. Based on the results of the cost-benefit exercise, the Group developed this five-point action plan:

1) The Coast Guard and AWO should initiate a joint program to implement the six prevention recommendations with the highest efficiency scores resulting from the cost-benefit analysis. These are:

a) Identify vulnerable bridges where measures to prevent and/or mitigate allisions should be applied.

b) Develop navigation best practices for transiting bridges vulnerable to allision.
c) Train operators in the application of navigation best practices.
d) Require route familiarization, posting, or a check-ride before an operator is permitted to navigate under a vulnerable bridge alone.
e) Improve Coast Guard-industry information sharing on near misses.
f) Require the implementation of Crew Endurance Management Systems (CEMS) throughout the towing industry as a means of improving decision making fitness.

2) The Coast Guard and AWO should use this report to accelerate the removal and alteration of bridges under the authority and procedures of the Truman-Hobbs Act. More than 900 bridge allisions – 34% of all allisions between 1992-2001 – occurred at bridges under order to be altered or on the Truman-Hobbs backlog priority list.

3) The costs and benefits of requiring additional protection for bridge piers should be given further consideration in the process of identifying vulnerable bridges as proposed in Recommendation #1 above. Targeting improved bridge protection measures on those bridges identified as most vulnerable to allision or to severe consequences should an allision occur may be a meaningful and cost-effective addition to the prevention recommendations offered here and should be given further study.

4) The Coast Guard Research and Development Center should use this report as a basis to consider future studies to explore combinations of the potential recommendations that can generate greater benefits acting together than indicated by their individual cost-benefit scores (i.e., a study of the non-linear dynamics of the causes of bridge allisions).

5) The Coast Guard should implement a special investigative effort for certain bridge allision incidents, over a specified period of time (three to five years). As part of this effort, the Coast Guard would conduct a thorough investigation of each bridge allision for which the preliminary investigation showed human factors issues as possible causal factors. Coast Guard and AWO analysts would regularly evaluate the data from these completed investigations and report their findings to the National Quality Steering Committee (QSC) of the Coast Guard-AWO Safety Partnership. This effort would provide future analysts with more detailed information than was available in most of the cases reviewed by the Work Group.

Conclusion

The core findings of the Work Group are as follows:

1) The human element, in particular decision making errors, is the predominant factor in bridge allisions. This does not mean that towing vessel operators are poor decision makers. Indeed, the fact that the overwhelming majority of bridge transits take place without incident – and that most bridge allisions that do occur result in no damage to people, property, or the environment – testifies to the skill and professionalism of towing vessel operators who do a difficult job under challenging conditions, with very little margin for error.

2) A myriad of factors contribute to the human factor-based errors, thus there is no “silver bullet” or “quick fix” for reducing bridge allisions.

3) The recommendations advocated by the Work Group involve a mix of industry and government action to reduce the occurrence of bridge allisions. However, the risk of bridge allisions cannot be reduced to zero. Thus, additional actions by transportation authorities are needed to remove hazardous bridges and improve protection standards for bridges so that consequences from a bridge allision are minimized.

4) These findings should be distributed to industry, government, and related parties by as many channels as possible.

5) Additional research may develop other recommendations.

The Work Group is confident that it thoroughly explored the information it had available and that its findings and recommendations will provide a solid foundation for future work to reduce the frequency of bridge allisions and minimize the consequences of those that do occur.

BACKGROUND

In 2001 and 2002, two towboat/bridge allisions occurred that claimed a total of 22 lives. The first accident occurred on September 15, 2001, when the M/V BROWN WATER V, pushing four barges, struck the Queen Isabella Causeway Bridge that connects Port Isabel to South Padre Island, Texas. The accident severely damaged the bridge and resulted in the loss of eight lives. On May 26, 2002, the M/V ROBERT LOVE, pushing two empty asphalt barges, allided with the I-40 Bridge crossing the Arkansas River near Webbers Falls, Oklahoma. The allision collapsed two sections of the bridge and resulted in 14 deaths. Both accidents are the subject of ongoing governmental investigations, the conclusions of which may result in additional recommendations for Coast Guard-industry action.[2]

Shortly after the I-40 accident, the U.S. Coast Guard and The American Waterways Operators (AWO) convened a work group under the auspices of the Coast Guard-AWO Safety Partnership to investigate all bridge allisions involving towing vessels and barges over the past decade. The Work Group included Coast Guard personnel and AWO member company representatives and was supported by Coast Guard and AWO staff. Work Group members included the following:

Table 2: Work Group Members

Organization	Name	Office or Title
Coast Guard	CAPT Michael B. Karr	Chief, Office of Investigations and Analysis
Coast Guard	CAPT Dan Ryan	Chief, Marine Safety, 8th Coast Guard District
Coast Guard	CDR Lyle Rice	Chief, Compliance Analysis Division
Coast Guard	Ed LaRue LCDR Alan Blume	Waterways Management Directorate
Coast Guard	LCDR Luke Harden	Maritime Personnel Qualifications Division
Coast Guard	LCDR Martin Walker	Domestic Compliance Division
Coast Guard	LT Scott Calhoun LT Sam Stevens	Office of Design and Engineering Standards
American Commercial Barge Lines	Captain Mark Dougherty	Process Analyst
Kirby Corporation	Les Sutton	Manager, Governmental Affairs
Marathon Ashland Petroleum LLC	Bruce D. Tilton Captain David Smith	Manager, Marine Transportation Captain, M/V ASHLAND
MEMCO Barge Line	Mark Knoy Keith Darling	President Senior Vice President, Boat Operations
Moran Towing Corporation	Peter Nistad	Senior Vice President
Sause Bros.	Dale Sause	President
Western Kentucky Navigation	Captain Luke Moore	Captain, M/V ROY MECHLING
Western Towboat	Captain Jeff Slesinger	Director, Safety & Training

[2] The Queen Isabella Causeway accident is under investigation by the Coast Guard, and the I-40 accident is under investigation by the National Transportation Safety Board. Because the ongoing investigations are not complete, the causes of these two casualties are not addressed in this report.

The Coast Guard members provided expertise from a variety of disciplines aimed at tackling the problem of bridge allisions from both theoretical and operational perspectives. The AWO members were selected both for their expertise in towing operations (the group included four active or former towing vessel captains) and representation of the geographic and operational diversity of the industry. Staff support to the Work Group was provided by David Dickey, U.S. Coast Guard; Joseph Myers, U.S. Coast Guard; Jennifer Carpenter, AWO Senior Vice President-Government Affairs and Policy Analysis; Doug Scheffler, AWO Manager-Research and Data Analysis; and Amy Brandt, AWO Manager-Government Affairs.

The group met for the first time on July 14, 2002. At this meeting the Work Group agreed on a statement of the problem, established the goals of the group, and agreed on a process for analyzing the data.

Problem

The Work Group agreed on this problem statement:

> Allisions with bridges involving barges and towing vessels have occurred. These allisions have caused deaths, injuries, and property damage that are unacceptable.

Goals

The Work Group defined the following goals:

1) Develop a profile of bridge allisions involving barges and towing vessels (e.g., number, location, consequences, and trends).

2) Catalog measures already taken to reduce risks.

3) Minimize risk of bridge allisions by developing recommendations to:
   a) Prevent bridge allisions;
   b) Eliminate loss of life resulting from bridge allisions; and,
   c) Reduce the consequences of bridge allisions.

4) Effectively communicate findings and recommendations.

Goals #1 and #3 formed the heart of the Work Group's tasking and are the focus of this report. Goal #2 is addressed in Appendix 1, which catalogs measures taken by the Coast Guard and industry to reduce the risk of bridge allisions after the 1993 MAUVILLA casualty.[3] Goal #4 will be accomplished through an ongoing process beginning with the publication of this report.

Risk-Based Decision Making Methodology

To accomplish Goals #1 and #3, the Work Group decided to use Risk-Based Decision Making (RBDM). The RBDM process organizes information about the possibility of one or more

[3] On September 22, 1993, barges pushed by the towboat MAUVILLA struck and displaced the Big Bayou Canot railroad bridge near Mobile, Alabama, causing the derailment of the Amtrak Sunset Limited passenger train.

unwanted outcomes into a broad, orderly structure that helps decision makers make more informed management choices. RBDM provided the Work Group with a well-defined process for developing recommendations that would be reasonable, defendable, and reproducible.[4]

The Work Group pursued five general task areas, all of which are consistent with the RBDM process:

1) Collect and consolidate all available data and information about past bridge allisions.
2) Create a profile of allision casualties.
3) Use a national team of towing experts to review cases from the Coast Guard databases.
4) Analyze case reviews to determine most probable events and associated causal factors.
5) Develop recommendations and publish findings.

The Work Group executed the first four phases of its investigation from July-December 2002. This report completes the fifth task. Discussions, development of analysis tools, and review of results were conducted via e-mail, conference calls, and an additional in-person meeting on November 14, 2002.

The remainder of the report details the activities taken pursuant to each task. Since there were many review steps, and some activities were conducted simultaneously, a precise chronology of activities will not be referenced in the report. The subsequent sections of this report are organized as follows: data collection and allision profile, case review, causal factors analysis, and conclusion and recommendations.

DATA COLLECTION AND ALLISION PROFILE

Data Collection and Context

The data for this review were extracted from the U.S. Coast Guard Headquarters Marine Safety Management System (MSMS), which uses the Marine Safety Information System (MSIS) as its source. MSIS was the Coast Guard's repository of marine casualty data from March 19, 1990, through December 13, 2001.

The initial extract from the MSMS was vessel casualties with a primary event recorded as either ALLISION or BREAKAWAY**.** This generated a file of 3,121 allisions over the 10-year period from January 1, 1992, through December 31, 2001. These cases were screened to eliminate those that did not involve U.S.-flag towing vessels or bridges. **The Work Group's population data set thus contained 2,692 cases where a U.S.-flag towing vessel (with or without a tow) allided with a bridge.** The data set included 912 cases that were classified as CLOSED TO FILE.[5]

[4] For more information on RBDM, go to www.uscg.mil/hq/g-m/risk/jobaids.html.

[5] Most of the cases CLOSED TO FILE occurred before a change in the marine casualty reporting requirements. These earlier cases were reported to the Coast Guard, but the damages were trivial and the cases were closed without further collection of information because the incident did not meet the definition of a marine casualty in effect at that time. Following the MAUVILLA casualty, 46 CFR Part 4 was revised to define any unintentional bridge allision as a marine casualty, even if the damage was less than $25,000. In the course of reviewing cases for this report, the Work Group did find that after 1994, some unintentional bridge allisions were incorrectly CLOSED TO FILE because the report noted no damage to the bridge or a vessel.

The number of allisions must be viewed in the context of the number of trips by tugboats and towboats. The Work Group used navigation data from the U.S. Army Corps of Engineers (Corps) to provide a snapshot comparison, focusing on the Mississippi River System to ensure an apples-to-apples comparison. According to the Corps, in 2000 (the most recent year for which published statistics are available) there were 274,978 trips by towing vessels on the Mississippi River System.[6] According to the Coast Guard's bridge allision data set, there were 153 towing vessel bridge allisions on the Mississippi River System in 2000. **These figures yield an allision rate of approximately 0.06%, or six allisions for every 10,000 towing vessel trips.**

<u>Severity Classes</u>

The Work Group sought to classify and distinguish the incidents of significance from the majority of bridge allisions involving little or no damage. After examining the data, the Group defined a significant case (Class 4) as one meeting one or more of the following criteria:

- Loss of life, injury, or missing person.
- Pollution incident.
- Bridge collapse or damage requiring removal from service for more than safety inspection.
- More than $500,000 in damages resulting from the allision.

The remaining cases involved only monetary damage and were divided into four classes (Classes 0-3). The table below shows the definitions of all the severity classes and the number of cases in each.

Table 3: Severity Classes

Class	Definition	Count
0	Damage recorded as "None or Not Specified."	1,702
1	Damage between $1 and $25,000.	610
2	Damage between $25,001 and $100,000.	220
3	Damage between $100,001 and $500,000.	99
4	One or more of: damage > $500,000; loss of life > 0; injured > 0; missing > 0; oil spilled.	61

Ninety-four (94) percent of all bridge allisions between 1992-2001 resulted in no injury, fatality, or environmental damage and less than $100,000 in damages reported to the Coast Guard. Three allisions during the study period resulted in fatalities: the 1993 CHRIS allision with the Judge Seeber Bridge, which caused one fatality; the 1993 MAUVILLA allision, which killed 47; and the 2001 BROWN WATER V at South Padre Island, which took eight lives.

[6] The Corps of Engineers defines a trip as follows: "A trip is a vessel movement. For self-propelled vessels, a trip is logged between every point of departure and every point of arrival." Thus, the number of bridges transited by a towing vessel in a single trip can range from none to many.

Trend Analysis

The table below presents the 2,692 bridge allisions by calendar year.

Table 4: Bridge Allisions by Year

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Bridge Allisions	122	193	586	357	348	277	232	194	170	203

It is difficult to draw meaningful conclusions from this trend line because Coast Guard casualty reporting regulations were amended in 1994 as a result of a recommendation made following the 1993 MAUVILLA casualty. The revisions to 46 CFR Part 4 required reporting of any unintentional striking of a bridge, whether or not any damage occurred. As a result of this regulatory change, the trend line is discontinuous; that is, the data for 1992 and 1993 are not comparable to the data for 1994 and subsequent years. While the data appear to show a substantial decline in bridge allisions from the peak year of 1994, the Work Group believes that this result may have been significantly affected by the change in reporting requirements and evolving Coast Guard guidance on the reporting and investigation of bridge allisions that took place after 1994.

Other Analyses

AWO and Coast Guard staff conducted an exploratory data analysis to develop a profile of the cases and identify any issues or patterns that might warrant further study. Topics examined included bridges involved, geographical distribution of damages, circadian cycle, Truman-Hobbs bridges, type of vessel, and pollution incidents.

Details on these analyses are found in Appendix 2. Below is the summary of each topic and the Work Group's adjudication.

Bridges Involved

The table below lists the six bridges most frequently struck by barges or towing vessels and the number of allisions recorded at each.

Table 5: Most Frequently Struck Bridges

Bridge	Location	Allisions
EJE Railway Bridge	Morris, IL	170
CNW Railroad Bridge	Pekin, IL	95
Burlington Railroad Bridge	Burlington, IA	92
Galveston Causeway	Galveston, TX	76
Franklin Street Bridge	Peoria, IL	67
Naheola Bridge	Pennington, AL	67

The frequency with which these bridges have been hit is not a function of traffic volume; in other words, the bridges most frequently struck by towing vessels and barges are not the bridges that experience the heaviest volume of barge and towing vessel traffic. This suggests that characteristics of the bridges themselves, or their location on the waterways, may be a factor in the occurrence of allisions.

The complete list of bridges struck is included in Appendix 2. The Work Group reviewed the distribution and found it to be complete and consistent with the professional experience of operators familiar with the local geography and bridges in question. Appendix 2 also includes a map that aggregates the number of allisions by Coast Guard reporting unit.

Geographical Distribution of Damages

The Work Group thought that examining the distribution of bridge allisions by the amount of damage recorded might provide additional insight into the most important areas for future attention. The total damages were aggregated by Coast Guard reporting area. The area with the most damages was Charleston, SC. The Work Group concurred with the analysis of the Coast Guard/AWO data analysis team that this conclusion was a spurious result – most likely caused by a single allision with high dollar damages reported -- and does not warrant further examination. A map of the aggregated damages is included in Appendix 2.

Circadian Cycle

Medical literature documents the changes in human performance levels that occur throughout the day as a result of circadian cycles. (The relationship between circadian rhythms and human performance is thoroughly discussed in the Coast Guard's *Crew Endurance Management Guide*.) The AWO staff analyzed the data to see if there were large numbers of allisions that occurred during circadian "lows." No direct correlation could be established between the time of day and allisions; however, the group did not discount the possible effect of working at night and during expected circadian lows on a mariner's cognitive reasoning and decision making ability. These issues were further discussed in the development of prevention recommendations.

Truman-Hobbs Bridges

To maintain navigation safety and freedom of mobility, the Truman-Hobbs Act is administered by the Commandant to ensure that bridges provide sufficient clearance for the types of vessels that transit the bridge site. Bridges that are deemed to be unreasonable obstructions to navigation are placed on a list for removal or alteration.[7]

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[7] Information regarding the Coast Guard's Bridge Administration Program, including the bridge permitting process for approving the location and clearances of bridges, can be found at <http://www.uscg.mil/hq/g-o/g-opt/g-opt.htm>. The Coast Guard has no statutory authority or responsibility for the structural integrity of bridges across the navigable waters of the United States. This responsibility rests with the bridge owner, the Federal Highway Administration (FHWA), and the Federal Railroad Administration (FRA). Structural standards for the design of bridge piers and their appurtenant fendering systems to protect against collapse due to vessel hits can be found in the publications of The American Association of State Highway Officials (AASHTO) for highway bridges, and The American Railway Engineering and Maintenance Association (AREMA) for railroad bridges.

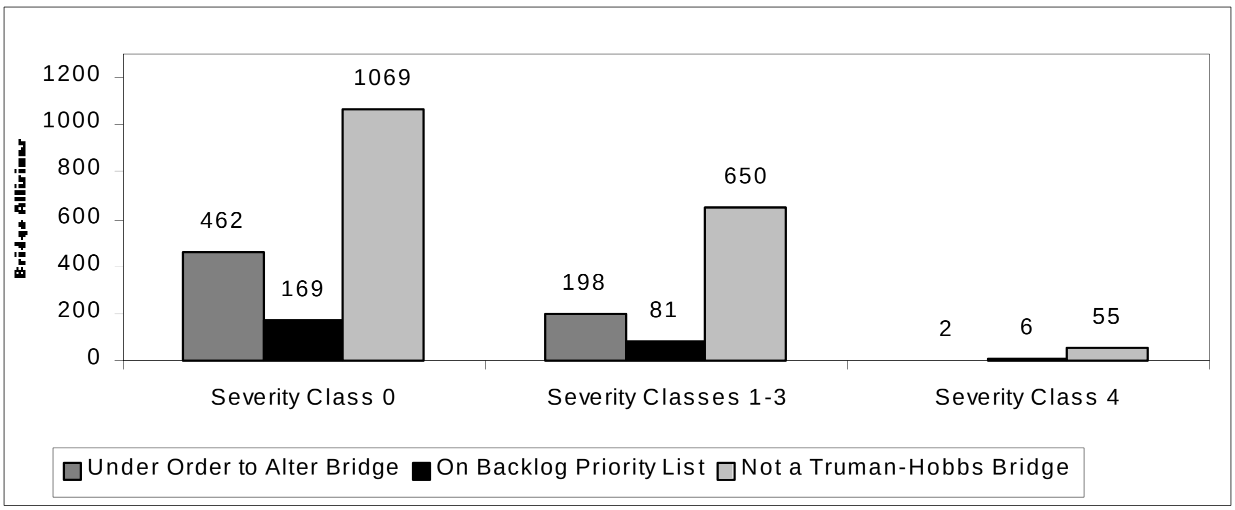
Table 6 shows the number of allisions by Truman-Hobbs classification.

Table 6: Allisions by Truman-Hobbs Classification

Classification of Bridge	Allisions	Percent
Not in program	1,774	66
Under order to alter bridge	662	25
On backlog priority list	256	9
Total	**2,692**	**100**

Figure 1 shows the number of allisions by Truman-Hobbs classification for each severity class.

Figure 1: Allisions by Severity Class and Truman-Hobbs Classification



Additional information on the Truman-Hobbs program can be found in Appendix 3.

Type of Vessel

The case database was linked to the Corps of Engineers' fleet data file (*Waterborne Transportation Lines of the U.S.*) by the common vessel identification code. Various tabulations and cross-tabulations of vessel characteristics, such as length, horsepower, and age, were generated. Unfortunately, the vessel characteristics are so diverse that there was no easy way to generate a classification scheme. Moreover, many cases did not have complete information on vessel characteristics, making it impossible to track patterns across the universe of all allision cases. The Work Group therefore concluded that there was little value in pursuing this area of inquiry further at this time.

Pollution Incidents

The data set contained 19 allisions that resulted in oil pollution over the 10-year study period. AWO and Coast Guard staff examined these cases from a number of perspectives and found no patterns.

Summary

In summary, the most important characteristics of the case universe were location and severity. These played an important role in defining the sample of cases to be individually reviewed.

CASE REVIEW

Sample

The Work Group determined that it did not have sufficient resources to read and analyze all 2,692 cases individually. Instead, the Group decided to generate a manageable subset by random sample based on the severity class. The Group directed that the sample include all of the cases from severity classes 3 and 4 and a random sample from the other severity classes. AWO staff generated a subset of 473 cases. Details of the sampling methodology are found in Appendix 4.

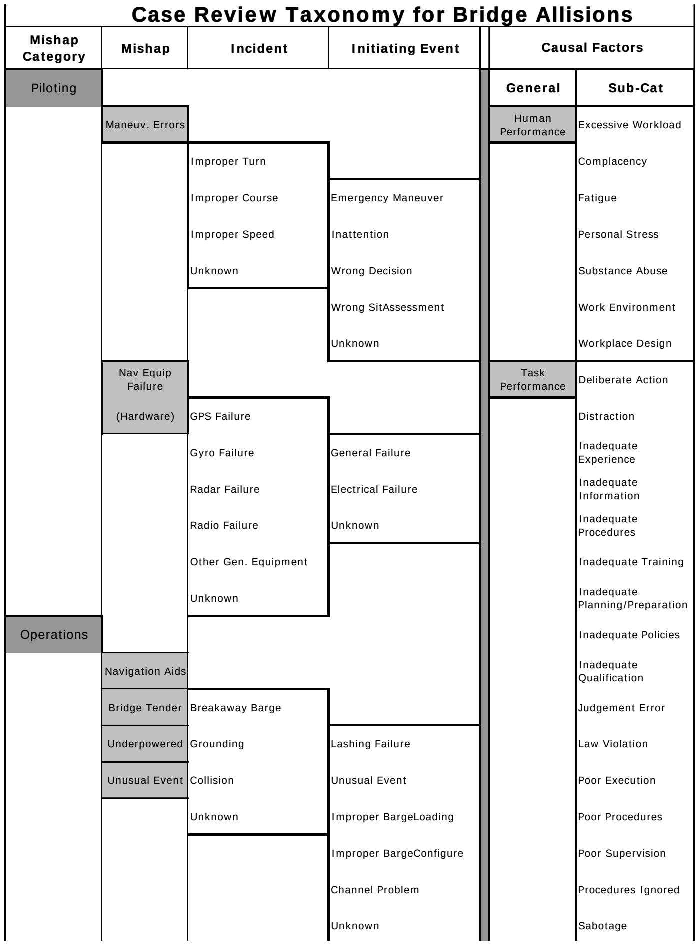
The casualty investigation reports for these 473 cases were distributed to teams of towing operations experts. The teams were organized by geography, and each was led by an AWO member of the Work Group. Each team consisted of active towing vessel captains and other experts with knowledge of conditions and operations in that area. The teams reviewed the cases from the specific region of the country with which they were most familiar (e.g., Upper Mississippi River, Lower Mississippi River/Gulf of Mexico, Ohio River, East Coast, West Coast). The cases were analyzed using an agreed upon-taxonomy and data collection tool described below.

Taxonomy

A fault tree was created and used to develop a taxonomy for reviewing the MSIS cases. The taxonomy was needed to ensure data consistency and prevent ambiguity in the case reviews. The taxonomy was particularly important because there were a large number of cases to review, there were many different reviewers with different backgrounds and experience, and the quality and detail of MSIS case information varied greatly from one case to another.

The taxonomy used was a hierarchical structure consisting of two tracks: mishaps and causal factors. The mishaps track includes four levels: mishap category, mishap, incident, and initiating event. The causal factors track is divided into general and sub-category. The structure for the first two mishap categories is shown below. The entire taxonomy is available in Appendix 5.

Figure 2: Case Review Taxonomy for Bridge Allisions



The teams were instructed to review each case using this taxonomy. After reviewing the case, each team used a data collection tool to populate a database with selections from the taxonomy.

CAUSAL FACTORS ANALYSIS

Of the 473 cases sent out for review, usable analyses on 459 were returned.[8] Data from the case reviews were compiled and a statistical analysis was performed to identify the most probable events and causes that led to bridge allisions during the study period.

The information contained in the Coast Guard casualty reports posed a significant challenge to the Work Group. Current Coast Guard standards for gathering casualty facts and information, especially human factors information, were incompatible with the intent of the Work Group to conduct a detailed analysis. In many cases, the detail necessary to determine the causal factors of an allision was not available; in 24 cases, it was impossible even to classify the mishap by type (piloting error, steering system failure, etc.) based on the information available. Work Group members were thus forced to rely on their own experience and judgment in interpreting the often limited information in the Coast Guard casualty reports and classifying allisions by

[8]Missing files or data entry problems were the reasons for the 14 unusable cases.

mishap type and causal factor, though the use of a standard taxonomy provided some consistency in the process. The results that follow must be read with the limitations of the Coast Guard casualty data in mind.

Using the taxonomy, the geographic expert teams categorized the incidents by the four mishap categories.

Mishap Categories

Table 7: Allisions by Mishap Category

Mishap Category	Cases	Percent
Piloting error	361	78
Operations error	54	12
Steering system	12	3
Propulsion system	8	2
Unknown/missing	24	5
Total	**459**	**100**

The 24 incidents in the unknown/missing category are cases that did not contain enough information for the group to make a reasonable decision as to the mishap category. The group was able to place 435 cases, or 95% of the total, into a mishap category.

Piloting error (an error in the wheelhouse affecting the movement of the vessel) and operations error (error by an individual other than the pilot, such as miscommunication by the deckhand on the head of the tow, tow configuration problem, etc.) combined for 90% of the cases, while mechanical failures accounted for only 5%. This first look at the data provided strong indications that a large majority of bridge allision cases result from human factors.

A drill-down analysis of the cases in the mishap category piloting error illustrates how the taxonomy and data collection tool were used by the expert teams to arrive at their conclusions about the leading causes of bridge allision casualties.

Piloting Error Drill-Down Analysis

The expert teams identified the following mishaps for the 361 cases in the mishap category piloting error.

Table 8: Mishap Category Piloting Error: Mishaps

Mishap	Cases	Percents
Maneuvering error	359	99.4
Navigation equipment failure	1	0.3
Missing information	1	0.3
Total	**361**	**100.0**

As the next step using the taxonomy, the teams then identified the following incidents for each of the maneuvering errors.

Table 9: Mishap Maneuvering Error: Incidents

Incident	Cases	Percent
Improper approach	263	73
Improper course	69	19
Improper speed	12	3
Improper turn	9	3
Unattended helm	3	1
Missing information	3	1
Total	**359**	**100**

Improper approach and improper course accounted for 92% of the maneuvering error incidents.

Next, the teams identified the initiating events for these two incident types. The results are shown below.

Table 10: Incident Improper Approach or Course: Initiating Events

Initiating Event	Cases	Percent
Wrong situational assessment	241	72.6
Wrong decision	64	19.3
Inattention	5	1.5
Emergency maneuver	4	1.2
Navigation aids	2	0.6
Chart problem	1	0.3
Incapacitation	1	0.3
Missing information	14	4.2
Total	**332**	**100.0**

Wrong situational assessment and wrong decision were combined into a decision making error group. This group accounted for 91.9% of improper approach/improper course incidents. Only 2.1% of the incidents were deemed the result of external factors (e.g., emergency maneuver, navigation aids, and chart problems).

In addition to the mishap category track, the taxonomy used by the expert teams also included a two-level analysis of causal factors. The first level is general causes. Table 11 shows the breakout by cause for the 305 cases in which the initiating event was a decision making error. Note that the data analysis tool provided the capability to assign up to three causes to each case. For this reason, the number of causes is greater than the number of cases examined.

Table 11: Decision Making Error Casualties: General Cause

General Cause	Count	Percent
Task performance	451	83
External event	56	12
Communications	18	3
Human performance	8	1
Equipment operations	2	0
Unknown	7	1
Total	**542**	**100**

The drill-down to the sub-categories for the task performance cause produced these results.

Table 12: Task Performance Errors: Sub-Category Cause

Sub-Category Cause	Count	Percent
Judgment error	248	55
Poor execution	90	20
Inadequate planning, preparation, or information	69	15
Others	39	9
Missing information	5	1
Total	**451**	**100**

Of the 305 decision-making error cases, 94% (287 cases) included judgment error or poor execution among their causes. Thus, the Work Group concluded that decision making errors were the predominant cause of bridge allisions classified as piloting error casualties.

Operations Error Drill-Down Analysis

Operations error was the second largest mishap category, with 54 cases or 12% of the total. A drill-down of the taxonomy, similar to the one described above for piloting error, was also conducted on these cases. The most common mishap in the operations error category was unusual event, with 36 cases or 66.7%. The incident breakout for the unusual event mishap included 14 cases of breakaway barge, 16 collisions, and one improper approach. With this nearly even split in incident type, the following distribution of initiating events was generated for all 36 unusual event cases.

Table 13: Mishap Category Operations Error: Initiating Events

Initiating Event	Count	Percent
Unusual event	21	58
Lashing failure	7	19
Improper barge loading	2	6
Inattention	1	3
Missing information	5	14
Total	**36**	**100**

For the initiating event of unusual event, the breakout by general causes showed that task performance and external event were each tallied nine times, or 32%. On a case basis, eight of the 21, or 38%, had task performance among their causes. External event was a general cause in eight cases. The number of cases was too small to facilitate a meaningful breakout by sub-category causes.

In summary, the operations error data show that external events and task performance are the two major causes. This is a different profile than piloting error, with its single predominant cause of decision making error.

Significant Consequence Cases

Appendix 6 contains an analysis of the 61 bridge allision incidents in Severity Class 4. This analysis generated results similar to the results for the entire universe of 459 incidents sampled by the Work Group. These data indicate that the significant consequence cases share the same causal pattern as bridge allisions across the range of severity classes. (See Appendix 7 for narrative summaries of selected allisions in Severity Class 4.)

Analysis of Findings

The piloting error and operations error mishap categories together account for 415 allisions, or 90% of the cases sampled. Drilling down to the general cause of allisions in both categories, judgment error and poor execution (the leading causes of piloting error casualties) can be combined with task performance (the leading cause of operations error casualties) to form a decision making cause. Applying the results of the preceding drill-down analyses shows that decision making errors were causal factors in 295 cases – that is, 68% of the 435 sampled cases with an identified mishap category.

The mishap categories relating to mechanical failure -- steering system and propulsion system -- account for 5% of the 435 cases with an identified mishap category. The drill-downs into the mishap and causal factor hierarchies show that the remaining causes are a mix of external events; other technical failures, such as navigation aids; and other human factors, such as improper planning, poor communication, and inattention. Thus, the data clearly demonstrate that human factors – in particular, decision making errors -- are the predominant cause of towing vessel bridge allisions.

DEVELOPMENT OF RECOMMENDATIONS

The finding that the significant consequence cases had the same causal pattern as bridge allisions in general led the Work Group to adopt the strategy of a broad-based attack on all bridge allisions. Reducing the frequency of bridge allisions overall, and mitigating the results of those allisions that do occur, should lead to a similar reduction in significant consequence allisions.

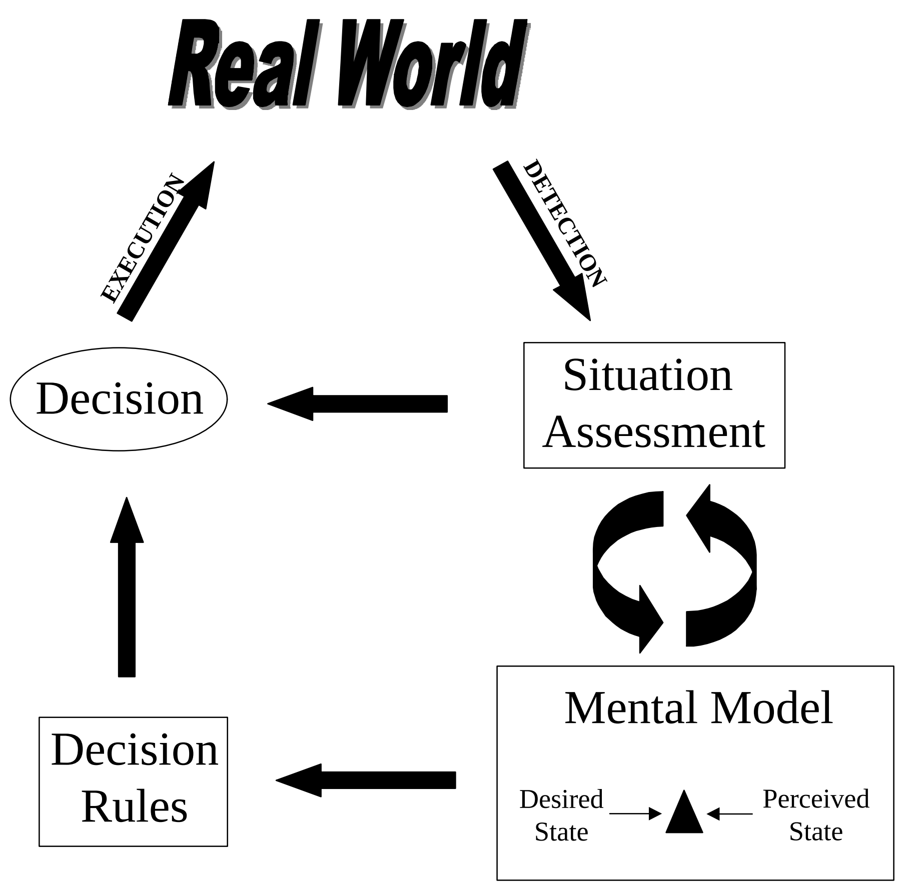
Based on its analysis of the data, the Work Group decided to target its recommendations on the human factors issue – decision making – that underlies the majority of towing vessel bridge allisions. The Group used a three-step process to develop its recommendations: developing an analytical framework, generating potential recommendations, and evaluating each recommendation for effectiveness and cost.

Analytical Framework

Cognitive Model

In order to develop its recommendations, the group first agreed upon a cognitive model that provided a reasonable representation of the decision making process. The model for this process is provided below:

Figure 3: Cognitive Model



Detailed descriptions of the components of this model are provided in Appendix 8.

The Work Group used this model to identify areas where the decision making process could be severely compromised or completely break down. Recommendations would then be developed to safeguard the decision making process.

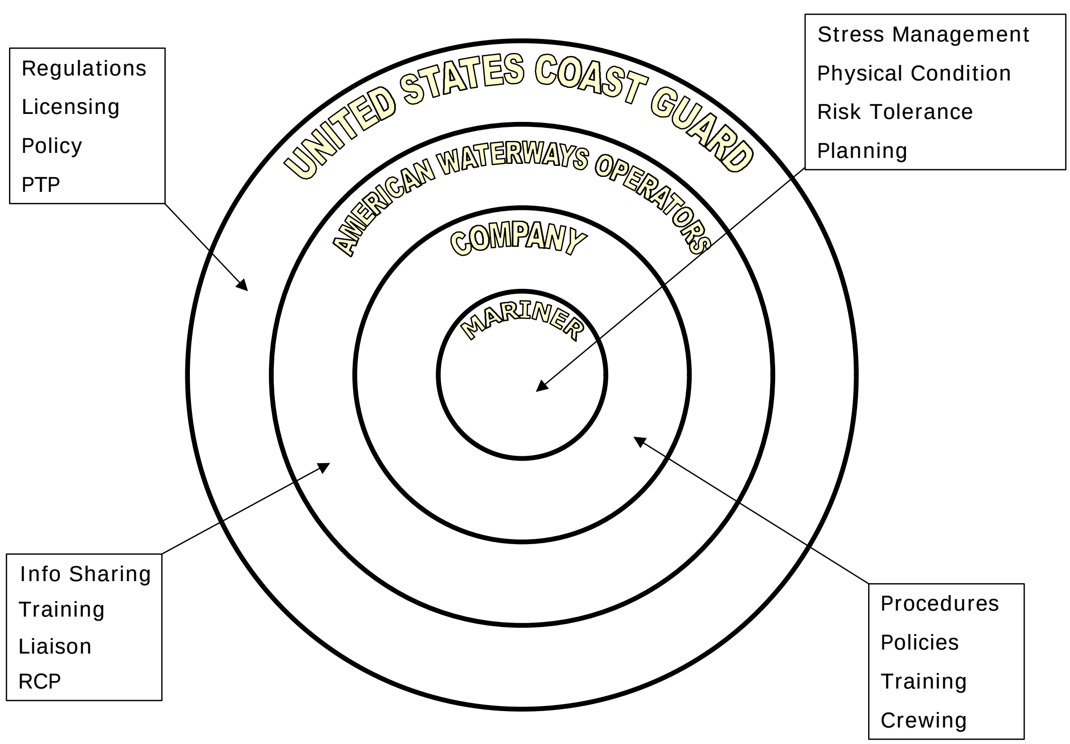
Systems Thinking

Although the Group focused on human factors, the cognitive model demonstrated that this is a complex issue. Applying the case review taxonomy to the cognitive model, the Group realized that there are many inputs to decision making by vessel operators, and their interactions are complex. Thus, there are no quick fixes or “silver bullets” that will prevent bridge allisions altogether.

To identify and address the interactions, the Group determined that it was necessary to think of safe navigation through bridges as a **system**. Appendix 9 provides more detail on the application of systems theory to vessel navigation.

The Work Group modeled safe navigation under bridges as a system, with mariner decision making at the center of the system. Other parties that affect the navigation process include the company, AWO, and the Coast Guard, each depicted by a separate layer of the model. Within each layer are shown examples of factors that bear on the decision making process that are within the control or subject to the influence of that party.

Figure 4: Safe Navigation Model



The first layer consists of factors influenced by the mariner. These include, but are not limited to, such things as voyage planning and the individual mariner's risk tolerance, physical condition, and ability to manage stress.

The second layer includes factors that companies control, such as policies and procedures, training, and crewing decisions.

The third layer includes factors influenced by the American Waterways Operators as the industry trade association, such as sharing of information, providing and encouraging certain training, acting as a liaison with the Coast Guard, and administering the AWO Responsible Carrier Program (RCP).[9]

The fourth layer is the Coast Guard, which controls regulations, licensing, agency policies, the Prevention through People (PTP) program, and other government-initiated activities relating to maritime safety.

There are other layers affecting the navigation process, such as the Cabinet department in which the Coast Guard is operating,[10] other federal agencies, Congress, and the expectations of the American public. However, the Work Group chose to focus the model on the people and organizations represented by the Work Group members. This approach was intended to facilitate the development and timely implementation of recommendations to prevent and mitigate bridge allisions.

Safe Bridge Navigation Decision Making Systems Model

All of the layers shown in the model combine to form the system of elements that impact decision making in the process of safe bridge navigation. The Work Group created a systems model by identifying factors that influence decision making and safe navigation under a bridge. The structure of the systems model created by the Group is shown in Figure 5.

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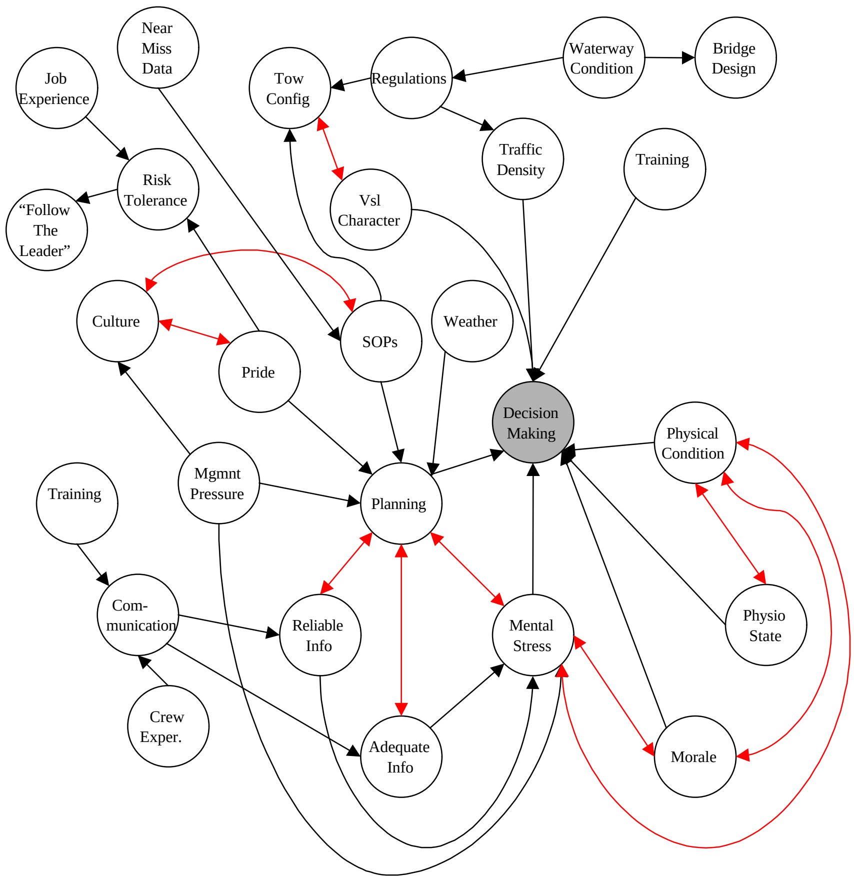
[9] The RCP, a third-party-audited safety management system, is a condition of membership in AWO. For more information on the RCP, see Appendix 1.

[10] When this study was begun, the Coast Guard was an operating agency of the Department of Transportation. On March 1, 2003, the Coast Guard was transferred to the newly created Department of Homeland Security.

Figure 5: Systems Model



This model was used to understand where leverage points exist in the decision making process where small investments may result in large returns. Clusters of mutually reinforcing feedback loops (double arrows) gave the Work Group insight into the leverage points within the system and helped the Group focus on the most promising issues to address in its recommendations.

The Work Group categorized the clusters into four areas: Human Performance, Planning and Information, Culture and Organization, and Training, Qualifications and Experience. Factors associated with each cluster that may influence the decision-making process and affect safe navigation include:

1) Human Performance
   a) Physiological and physical state
   b) Mental stress
   c) Health and well-being
   d) Morale

2) Planning and Information
   a) Adequate, reliable, and timely information
   b) Tow configuration
   c) Weather
   d) Waterway configuration
   e) Coast Guard investigations

3) Culture and Organization
   a) Management pressures
   b) Pride

4) Training, Qualifications, and Experience

Development of Potential Recommendations

Having identified these four clusters as potential high leverage points within the system, the Work Group used the systems model to develop a list of potential recommendations. In a brainstorming exercise, the Group considered the safeguards or processes that currently exist to address each influence factor. The Group identified areas in which current safeguards may not be adequate and brainstormed potential measures to supplement existing safeguards and improve the decision making process.

In the category of human performance, for example, the Group noted the importance of physical/physiological/mental condition to good decision making. The Group acknowledged that while many companies have programs to address crew health, wellness, and fitness for duty, such programs are not in place industry-wide. Hence, the Group identified implementation of the Crew Endurance Management System (CEMS), which provides a holistic approach to enhancing crewmember fitness for duty, as a potential recommendation targeted at the human performance leverage point.

In a similar fashion, the Work Group considered the other clusters and associated influence factors and brainstormed potential recommendations aimed at prevention (reducing the number of bridge allisions) and consequence management (preventing loss of life and reducing the consequences of bridge allisions), the dual focus of the group's Goal #3. Table 14 lists the potential recommendations developed by the Group to prevent bridge allisions; Table 15 lists the potential recommendations to mitigate the consequences of bridge allisions.

While the Group sought to identify measures it believed had a reasonable chance of reducing the number of bridge allisions or mitigating their consequences, the Group did not actively critique or evaluate the potential recommendations at this stage in the process.

Table 14: Potential Recommendations to Prevent Bridge Allisions

Number	Recommendation
1.	Continue or initiate navigation training.
2.	Continue real-life management training.
3.	Develop navigation best practices for particular transits.
4.	Develop wheelhouse/pilotage management training.
5.	Identify vulnerable bridges where measures to prevent and/or mitigate allisions should be applied.
6.	Improve accessibility of information in wheelhouse.
7.	Improve and revise agreements like the River Crisis Action Plans and cooperative agreements on vessel restrictions in certain areas.
8.	Improve communications training
9.	Improve dispatch policies by making dispatchers aware of factors like crew stressors and crew experience levels
10.	Improve tow configuration planning/develop standard operating procedures for tow configuration planning.
11.	Improve near miss reporting requirements so the Coast Guard collects better data.
12.	Improve Coast Guard/industry information sharing on near misses.
13.	Improve vessel information sharing (data links).
14.	Improve weather detection equipment.
15.	Improve the quality and distribution time of weather and other information (e.g., Notices to Mariners) to vessels.
16.	Initiate training for all levels in organization (e.g., support staff).
17.	Initiate wellness programs, if not already in place.
18.	Require annual physical exams.
19.	Require Crew Endurance Management System (CEMS) implementation throughout the towing industry.
20.	Require electronic chart systems on all vessels
21.	Require implementation of safety management systems like the International Safety Management (ISM) Code for the towing industry.
22.	Require implementation of the Responsible Carrier Program throughout the towing industry.
23.	Require route familiarization/posting/checkrides before an operator can conduct a particular transit alone.

Table 15: Potential Recommendations to Mitigate Consequences of Bridge Allisions

Number	Recommendation
1.	Identify vulnerable out-of-channel spans.
2.	Improve pollution prevention/product outflow prevention measures.
3.	Improve vessel protection measures (double-hulls, reinforced wheelhouses).
4.	Install proximity alarms to alert motorists, railroads of potential allision.
5.	Ensure adequate Truman-Hobbs Act funding.
6.	Reform bridge construction/protection guidelines to better withstand allisions.
7.	Review existing bridge design and construction standards.
8.	Review contingency planning for all relevant modal authorities.

Cost-Benefit Analysis

Having brainstormed these lists of potential recommendations to prevent and mitigate the consequences of bridge allisions, the Work Group next conducted a cost-benefit analysis to calculate the "efficiency" of each recommendation. **Benefit** was defined as the fraction of allisions that could be affected by a particular measure multiplied by its effectiveness in reducing risk. For example, a recommendation might address 25% of allision cases, and be 100% effective in those cases. This would result in a benefit score of .25 * 100, or .25. Another recommendation might address 50% of the allisions but be only 50% effective in those cases. This would result in the same benefit score (.50 * .50 = .25). **Cost** was defined as the industry-wide cost of implementing a recommendation over a 10-year period. **Efficiency** was calculated by dividing benefit by cost.

The complete list of potential recommendations was sent to each AWO member of the Work Group for cost-benefit scoring. Each member evaluated all of the recommendations. To provide some consistency in the process, the Work Group developed a four-level scale for calculating the three components of the efficiency equation.

Table 16: Cost-Benefit Scoring

Fraction of Allisions Addressed by Recommendation	
1	0% to 25%
2	25% to 50%
3	50% to 75%
4	75% to 100%
Effectiveness of Recommendation	
1	Reduce frequency of allisions by less than 10%
2	Reduce frequency of allisions 10% to 30%
3	Reduce frequency of allisions 30% to 60%
4	Reduce frequency of allisions by more than 60%
Cost of Recommendation	
1	Minimal
2	Low
3	Medium
4	High

Efficiency scores for each recommendation were then compiled by the Coast Guard. To produce a single score for each recommendation, the average of the scores from the six review teams was calculated and normalized to a 100-point scale. Tables 17 and 18 below show the average efficiency of each recommendation, along with its standard deviation (SD), median, minimum, and maximum, listed from highest efficiency to lowest:

Table 17: Potential Recommendations to Prevent Bridge Allisions: Efficiency Scores

Number	Recommendation	Average	SD[11]	Median[12]	Min.	Max.
1.	Develop navigation best practices for particular transits.	21.79	38.97	3.93	1.43	100.00
2.	Identify vulnerable bridges.	11.55	14.45	6.79	2.14	40.00
3.	Continue or initiate navigation training.	8.53	9.30	5.71	0.71	25.00
4.	Require route familiarization/posting/checkrides before the operator can conduct a particular transit alone.	7.70	8.88	4.05	0.71	23.81
5.	Improve Coast Guard/industry information sharing on near misses.	7.10	12.92	1.79	0.71	33.33

[11] SD: Standard Deviation, a measure of dispersion or spread of the data.
[12] Median: Midpoint of the sorted data. Fifty percent are above and 50% are below the median.

6.	Require Crew Endurance Management System (CEMS) implementation throughout the towing industry.	6.13	3.88	5.71	0.71	12.86
7.	Continue real-life management training.	5.52	9.17	1.07	0.71	23.81
8.	Develop wheelhouse/pilotage management training.	5.08	5.14	3.57	0.71	13.33
9.	Improve near miss reporting requirements so the Coast Guard collects better data.	4.76	6.88	1.79	0.71	18.57
10.	Require implementation of safety management systems like ISM for the towing industry.	4.32	4.73	3.45	0.36	10.00
11.	Improve dispatch policies by making dispatchers aware of factors like crew stressors and levels of crew experience.	4.10	4.57	1.43	0.48	11.43
12.	Require electronic chart systems on all vessels.	3.85	4.71	2.38	1.07	13.33
13.	Improve/revise agreements like the River Crisis Action Plans and cooperative agreements on vessel restrictions in certain areas.	3.33	3.43	1.43	0.71	9.29
14.	Require implementation of the RCP throughout the towing industry.	3.21	2.29	2.14	1.43	6.43
15.	Improve accessibility of information in wheelhouse.	3.13	2.26	2.62	0.71	5.71
16.	Improve communications training.	2.90	2.49	2.26	0.71	5.71
17.	Initiate training for all levels in organization (e.g., support staff).	2.88	4.23	1.25	0.48	11.43
18.	Improve vessel information sharing (data links).	2.88	4.63	0.71	0.36	12.14
19.	Improve tow configuration planning/develop standard operating procedures for tow configuration planning.	2.14	2.02	1.43	0.71	5.71
20.	Improve the quality and distribution time of weather and other information (e.g., Notices to Mariners) to vessels.	2.14	1.92	1.43	0.71	5.71
21.	Improve weather detection equipment.	1.63	1.19	1.43	0.48	3.81

22.	Initiate wellness programs, if not already in place.	1.03	0.51	0.71	0.71	1.90
23.	Require annual physical exams.	0.99	0.92	0.71	0.48	2.86

Table 18: Potential Recommendations to Mitigate Consequences of Bridge Allisions: Efficiency Scores

Number	Recommendation	Average	SD	Median	Min.	Max.
1.	Reform bridge construction/protection guidelines to better withstand allisions.	17.57	15.22	13.33	1.43	40.00
2.	Ensure adequate Truman-Hobbs Act funding.	15.29	16.38	6.07	3.57	42.86
3.	Review existing bridge design and construction standards.	5.71	7.30	3.57	0.71	18.57
4.	Review contingency planning for all relevant modal authorities.	2.74	4.86	0.71	0.36	11.43
5.	Identify vulnerable out-of-channel spans.	1.62	1.28	1.43	0.71	3.81
6.	Install proximity alarms to alert motorists, railroads of potential allision.	1.02	0.56	1.43	0.36	1.43
7.	Improve pollution prevention/product outflow prevention measures.	0.74	0.67	0.36	0.36	1.90
8.	Improve vessel protection measures (double-hulls, reinforced wheelhouses).	0.54	0.47	0.36	0.36	1.43

RECOMMENDATIONS

Based on the results of the cost-benefit analysis, the Work Group devised this five-point action plan:

1) The Coast Guard and AWO should undertake a joint program to implement the six prevention recommendations with the highest efficiency scores. These are:

a) Identify vulnerable bridges where measures to prevent and/or mitigate allisions should be applied.
b) Develop navigation best practices for transiting bridges vulnerable to allision.
c) Train operators in the application of navigation best practices.
d) Require route familiarization, posting, or a check-ride before an operator is permitted to navigate under a vulnerable bridge alone.
e) Improve Coast Guard-industry information sharing on near misses.
f) Require the implementation of Crew Endurance Management Systems (CEMS) throughout the towing industry as a means of improving decision making fitness.

2) The Coast Guard and AWO should use this report to accelerate the removal and alteration of bridges under the authority and procedures of the Truman-Hobbs Act. More than 900 bridge allisions – 34% of all allisions between 1992-2001 – occurred at bridges under order to be altered or on the Truman-Hobbs backlog priority list.

3) The costs and benefits of requiring additional protection for bridge piers should be given further consideration in the process of identifying vulnerable bridges as proposed in Recommendation #1 above. Targeting improved bridge protection measures on those bridges identified as most vulnerable to allision or to severe consequences should an allision occur may be a meaningful and cost-effective addition to the prevention recommendations offered here and should be given further study.

4) The Coast Guard Research and Development Center should use this report as a basis to consider future studies to explore combinations of the potential recommendations that can generate greater benefits acting together than indicated by their individual cost-benefit scores (i.e., a study of the non-linear dynamics of the causes of bridge allisions).

5) The Coast Guard should implement a special investigative effort for certain bridge allision incidents, over a specified period of time (three to five years). As part of this effort, the Coast Guard would conduct a thorough investigation of each bridge allision for which the preliminary investigation showed human factors issues as possible causal factors. Coast Guard and AWO analysts would regularly evaluate the data from these completed investigations and report their findings to the National Quality Steering Committee (QSC) of the Coast Guard-AWO Safety Partnership. This effort would provide future analysts with more detailed information than was available in most of the cases reviewed by the Work Group.

The marine environment for the towing vessel industry is a complex, highly interdependent system. It encompasses waterways, vessels, human operators, navigational aids and a supporting infrastructure for pilotage, vessel and port management, policy and regulation, and professional development. There is much interaction within the system. Because of this complex system of interaction and the infrequent number of accidents relative to the number of safe bridge transits, the Group could not identify any quick fixes or “silver bullets” that will prevent bridge allisions. The Group’s conclusion that decision making error appears to be the predominant cause of bridge allisions underscores this result: the decision making process is complex and subject to multiple influences. There is no “one way” to ensure that an operator makes good decisions. However, the Work Group believes that the decision making process can be improved by a combination of process improvements based on the highest-rated safety strategies. These process improvements should be supplemented by additional measures to reduce the occurrence of bridge allisions and minimize their consequences.

CONCLUSION

The Work Group was guided by analysis of the data and expert judgment and employed structured methodologies in its deliberations. The methodologies facilitated the incorporation of both quantitative and qualitative inputs. The core findings of the Work Group are as follows:

1) The human element, in particular decision making errors, is the predominant factor in bridge allisions. This does not mean that towing vessel operators are poor decision makers. Indeed, the fact that the overwhelming majority of bridge transits take place without incident – and that most bridge allisions that do occur result in no damage to people, property, or the environment – testifies to the skill and professionalism of towing vessel operators who do a difficult job under challenging conditions, with very little margin for error.

2) A myriad of factors contribute to the human factor-based errors, thus there is no “silver bullet” or “quick fix” for reducing bridge allisions.

3) The recommendations advocated by the Work Group involve a mix of industry and government action to reduce the occurrence of bridge allisions. However, the risk of bridge allisions cannot be reduced to zero. Thus, additional actions by transportation authorities are needed to remove hazardous bridges and improve protection standards for bridges so that consequences from a bridge allision are minimized.

4) These findings should be distributed to industry, government, and related parties by as many channels as possible.

5) Additional research may develop other recommendations.

The Work Group is confident that it thoroughly explored the information it had available and that its findings and recommendations will provide a solid foundation for future work to reduce the frequency of bridge allisions and minimize the consequences of those that do occur.

APPENDIX 1
MEASURES TAKEN TO REDUCE BRIDGE ALLISIONS

Since the 1993 MAUVILLA accident on Bayou Canot, the Coast Guard and AWO have undertaken a wide variety of measures aimed at preventing the occurrence of bridge allisions and improving the safety of the tugboat, towboat, and barge industry overall. This appendix provides an overview of significant actions taken since that time.

Review of Marine Safety Issues Related to Uninspected Towing Vessels

In December 1993, the Coast Guard completed a comprehensive *Review of Marine Safety Issues Related to Uninspected Towing Vessels*. The review made 19 recommendations for changes to laws, regulations, or administrative practices governing towing vessel operations. These recommendations are summarized below, along with a description of the Coast Guard actions proposed and the results achieved.

Recommendation 1: The Operator of Uninspected Towing Vessel (OUTV) license should have levels of qualification. Restrictions for such levels of qualifications may include route, gross tonnage or horsepower of the towing vessel, type of towing configuration, etc. The basic three-year apprenticeship should qualify an applicant for a basic OUTV license only.

> **Commandant Action:** Commandant (G-MVP) will initiate rulemaking to propose the recommended regulatory changes.
>
> **Results:** In November 1999, the Coast Guard published regulations that replace the OUTV and Second Class OUTV licenses with a three-step licensing system. A mariner is eligible for an Apprentice Mate or Steersman license after 18 months of service and passage of a written exam. This license permits a mariner to stand watch in the wheelhouse of a towing vessel under the direct supervision of a Master, Mate, or Pilot of Towing Vessels. A mariner is eligible for a Mate or Pilot license after accruing an additional 12 months of service and either completing an approved training course or submitting a Towing Officer Assessment Record (TOAR) documenting a practical demonstration of skill before a Designated Examiner. A mariner is eligible for a Master of Towing Vessels license after an additional 18 months of service as Mate or Pilot of Towing Vessels. Minor modifications to the licensing rules were made in a revised interim rule issued in April 2001.

Recommendation 2: OUTVs holding a basic license should be able to increase the scope of the license after acquiring additional service. In addition to service, they should be required to attend a Coast Guard approved simulator course, pass a written or simulator examination, or some combination thereof.

> **Commandant Action:** Commandant (G-MVP) will initiate rulemaking to propose the recommended regulatory changes.

Results: The new Coast Guard regulations for licensing of towing vessel officers provide that in order to obtain an endorsement for a route superior to the route currently held, the mariner must spend 30 days of observation and training and pass a limited examination, as well as complete the Towing Officer Assessment Record (TOAR) for the route. The TOAR is a document to record demonstrations of proficiency. The mariner is given the option to conduct the demonstration of proficiency on a simulator; however, the use of simulators is not required.

Recommendation 3: OUTVs seeking to increase the scope of their license to the highest level should be required to attend a Coast Guard approved simulator course.

Commandant Action: Commandant (G-MVP) will initiate rulemaking to propose the recommended regulatory changes.

Results: During the rulemaking process, the Coast Guard determined not to require the use of simulators because of the relatively high cost and limited availability of simulator courses. The new regulations offer mariners the option of attending simulator courses; mariners are also allowed to complete their demonstrations of proficiency on actual towing vessels.

Recommendation 4: All OUTVs should be required to demonstrate their skills on a simulator when renewing their license.

Commandant Action: Commandant (G-MVP) will initiate rulemaking to propose the recommended regulatory changes.

Results: See response to Recommendation 3.

Recommendation 5: Regulations should be developed that limit a Second Class OUTV to service on smaller towing vessels. The operator for larger vessels should always be an OUTV.

Commandant Action: Commandant (G-MVP) will initiate rulemaking to propose the recommended regulatory changes.

Results: The new regulations have increased the service requirement for Mate or Pilot of Towing Vessels (the successor license to 2nd class OUTV), now requiring 30 months of service in order to obtain the license. Mariners are also required to demonstrate proficiency before obtaining a Mate or Pilot of Towing Vessels license.

Recommendation 6: Applicants desiring a Western Rivers route on their license must acquire operating experience on that route and pass an appropriate examination.

> **Commandant Action:** Commandant (G-MVP) will initiate rulemaking to propose the recommended regulatory changes.
>
> **Results:** The revised regulations require at least 90 days of training and observation on the Western Rivers and the completion of a TOAR for that route. No additional examination is required for mariners holding a towing officer license.

Recommendation 7: Regulations should be developed requiring a radar equipped towing vessel more than 26 feet in length to be operated by an OUTV qualified as a radar observer.

> **Commandant Action:** Commandant (G-MVP) will initiate rulemaking to propose the recommended regulatory changes.
>
> **Results:** This regulatory requirement became effective September 30, 1997.

Recommendation 8: The Coast Guard and the Maritime Administration (MARAD) should review the existing standard of the approved inland radar observer courses. The review should determine if the existing curriculum meets the operational and safety needs of the inland mariner. In addition, the review should develop the standards necessary to reflect current technology.

> **Commandant Action:** Commandant (G-MVP) will initiate the recommended review in cooperation with MARAD.
>
> **Results:** Completed.

Recommendation 9: The Coast Guard, with assistance from the Towing Safety Advisory Committee, should review the oceans (domestic trade) route authorized for an OUTV license and propose alternatives that conform to international standards.

> **Commandant Action:** Commandant (G-MVP) will initiate the recommended review and request assistance from the Towing Safety Advisory Committee.
>
> **Results:** The revised regulations restrict the Master of Towing Vessels license to vessels less than 200 GRT on domestic coastwise routes only. Mariners on towing vessels on international routes must obtain a license that meets international standards.

Recommendation 10: Regulations should be developed to specify the equivalency of licensed masters and mates of 500/1,600 GRT vessels to service as an OUTV. Licensed masters of vessels of 200 GRT or less should be limited to service as a second-class OUTV.

> **Commandant Action:** Commandant (G-MVP) will initiate rulemaking proposing the recommended license limitations.
>
> **Results:** The revised regulations require mariners who operate towing vessels to obtain a towing endorsement, which requires completion of 30 days of training and observation on towing vessels and completion of a TOAR, for the routes being sought. If an individual is seeking an endorsement for the Western Rivers, 90 days of training and observation is required. Masters and mates with authority on vessels less than 200 GRT must comply with the towing officer licensing regulations in effect since May 21, 2001, to obtain the Master of Towing Vessels license.

Recommendation 11: The Coast Guard should initiate a regulatory project to amend Title 46 CFR 4.05-01 to require that casualties be reported immediately after the resulting safety concerns have been addressed. In addition, all unintentional allisions (collisions of a vessel with a stationary object) with bridges or other structures should be reported.

> **Commandant Action:** Commandant (G-MMI) will initiate rulemaking proposing the recommended amendments to 46 CFR Part 4
>
> **Results:** Regulations now require the immediate reporting of marine casualties. Regulations have expanded the definition of a reportable marine casualty to include any unintentional striking of a bridge.

Recommendation 12: The Coast Guard should initiate a legislative proposal to amend 46 USC 6103 to increase the maximum civil penalty from $1,000 to $25,000 for failing to report a marine casualty as defined under 46 CFR 4.05-1.

> **Commandant Action:** Commandant (G-MMI) will initiate the recommended action through discussion regarding amendment of H.R. 3282 (see Recommendation 19) or as a separate legislative proposal, as appropriate.
>
> **Results:** 46 USC 6103 was amended, increasing the maximum civil penalty to $25,000 for failing to report a marine casualty.

Recommendation 13: The Coast Guard should initiate a regulatory project to amend 33 CFR 160.215 to clearly indicate that the required notice of a hazardous condition includes a condition caused by a vessel or its operation even when the hazard is not on board the vessel.

> **Commandant Action:** Commandant (G-MPS) will initiate the recommended regulatory action.
>
> **Results:** 33 CFR 160.215 has been amended to require the immediate notification of hazardous conditions caused by the vessel or its operations.

Recommendation 14: It is recommended that each Coast Guard district conduct a survey of all bridges under Coast Guard jurisdiction and make a case-by-case determination regarding the adequacy of existing systems, and the requirement for additional fendering systems, and the requirements, if any, for additional bridge lighting.

> **Commandant Action:** Commandant (G-NBR) will initiate the appropriate action.
>
> **Results:** Completed.

Recommendation 15: The Coast Guard should initiate rulemaking under authority of the Ports and Waterways Safety Act (33 USC 1231) to require that all uninspected towing vessels carry: 1) a marine radar system for surface navigation; 2) marine charts for the area to be transited; and 3) current or corrected publications. In addition, the rulemaking should seek to identify areas of operation where a compass and depth finder are necessary tools for safe navigation. This will result in carriage requirements wile navigating in specified areas.

> **Commandant Action:** Commandant (G-NSR) will initiate rulemaking under the authority of H.R. 3282, if enacted (see Recommendation 19), or 33 USC 1231, proposing the recommended action.
>
> **Results:** Regulations now require uninspected towing vessels to carry and properly use equipment including radars, compasses, and nautical charts and publications. During the rulemaking process, the Coast Guard determined that depth sounders were needed on ocean and coastal towing vessels. Towing vessels operating on the Western Rivers, because of the nature of their operations and the environment in which they operate, did not stand to gain any safety benefit from use of a depth sounder, so no such requirement was imposed on those vessels.

Recommendation 16: The Coast Guard should amend the Aids to Navigation Manual - Administration (COMDTINST M16500.7) to specifically address the need to consider approaches to bridges in the design for aids to navigation systems.

Commandant Action: Commandant (G-NSR) will make the recommended amendments to the Aids to Navigation Manual

Results: The Aids to Navigation Manual - Administration (COMDTINST M16500.7) now specifically addresses the need to consider approaches to bridges in the design for aids to navigation systems.

Recommendation 17: The Commander, Eighth Coast Guard District should initiate the improvements in the vicinity of Big Bayou Canot recommended in the WAMS Study Update for the Mobile River.

Commandant Action: Commander, Eighth Coast Guard District will initiate the recommended improvements in the vicinity of the Big Bayou Canot.

Results: Completed.

Recommendation 18: The Coast Guard should emphasize the responsibility of towing vessel owners to employ qualified, experienced personnel as operators in charge (or masters) of their vessels.

Commandant Action: Commandant (G-MVP) will initiate the recommended action.

Results: The Coast Guard was added at 46 CFR10.464 (f). The regulation reads: "Each company must maintain evidence that every vessel it operates is under the direction and control of a licensed mariner with appropriate experience, including 30 days of observation and training on the intended route other than Western Rivers." (Western Rivers routes require 90 days of observation and training.)

Recommendation 19: The Coast Guard should support H.R. 3282 and discuss with Congressional staff the inclusion of provisions for an increased maximum civil penalty for failure to report marine casualties and provisions to link the requirement for compasses and fathometers to the area of operation of a towing vessel.

Commandant Action: Commandant (G-CC) will coordinate support for H.R. 3282 and discussions with Congressional staff to include provisions for an increased maximum civil penalty and flexibility in the requirements compasses and fathometers on towing vessels.

Results: H.R. 3282 was not enacted. However, 46 USC 6104 was amended increasing the civil penalty to $25,000 for failing to report a marine casualty. In addition, the Coast Guard implemented towing vessel equipment carriage requirements through a rulemaking.

AWO Responsible Carrier Program (RCP)

In April 1994, the AWO Board of Directors commissioned a working group to "develop a series of recommended positions, practices, and standards aimed at enhancing the safety of the barge and towing industry." That effort produced the AWO Responsible Carrier Program (RCP), a comprehensive code of safety practices for tugboat, towboat, and barge operators that encompasses virtually every aspect of fleet operations, including company management and administration, vessel equipment and inspection, and human factors. The AWO Board of Directors adopted the Responsible Carrier Program as a code of practice for AWO member companies in December 1994.

Since that time, the RCP has continued to evolve. In 1998, the AWO membership voted to make compliance with the Responsible Carrier Program a condition of membership in the association. As of January 1, 2000, all AWO members were required to undergo a third-party audit as evidence of compliance with the Responsible Carrier Program. New members have two years from the date of joining the association to achieve audited compliance. Re-audits are required every three years.

The RCP is a living program that is regularly reviewed by the AWO Responsible Carrier Program Accreditation Board to identify recommended changes and additions based on lessons learned about safety improvements. Changes to the RCP are recommended by the Accreditation Board and approved by the AWO Board of Directors.

Coast Guard-AWO Safety Partnership

The Coast Guard-AWO Safety Partnership, established in November 1995, was the first of its kind to bring together Coast Guard and industry leaders in a cooperative effort to improve marine safety and environmental protection. The Partnership was founded on the belief that the Coast Guard and the tugboat, towboat, and barge industry share a common interest in improving marine safety and environmental protection, and that these goals are best served by a cooperative approach that emphasizes dialogue and non-regulatory action. Since its inception, the Partnership has launched more than 25 Quality Action Teams that have worked to improve safety in a number of areas critical to industry safety and environmental protection, including crew fatalities, oil spills, crew endurance, and bridge allisions.

Mississippi River Crisis Action Plan

The Mississippi River Crisis Action Plan provides the marine industry, U.S. Coast Guard, U.S. Army Corps of Engineers, states, and local governments with a plan for facilitating the safe and orderly movement of traffic during low and high water navigation crises on the Mississippi River. The River Crisis Action Plan is particularly helpful in reducing bridge allisions when high water causes faster river currents.

The River Industry Executive Task Force (RIETF), in conjunction with the Corps of Engineers and the Coast Guard, chartered the River Crisis Response Working Group in

September 1995. The group's goal was to draft a standard Crisis Action Plan for dealing with navigation crises on the Mississippi River system. Subsequently, floods in the Ohio valley in the spring of 1997 resulted in high water and excessive river flows in the lower Mississippi River from Vicksburg, Mississippi, to the mouth of the river. The Eighth Coast Guard District Commander then directed the Captain of the Port-New Orleans to convene a working group of stakeholders operating between Baton Rouge and Southwest Pass to modify the plan to include the entire Lower Mississippi River. These stakeholders included the Corps of Engineers, the four pilot associations, the Steamship Association of Louisiana, the American Waterways Operators, the Greater New Orleans Barge Fleeting Association, and Marine Navigation Safety Association. These and other stakeholders are to be consulted during high and/or low water situations.

A standing organization of senior Coast Guard, Corps of Engineers, and industry personnel has been established to administer the plan. This Waterway Management Committee (WMC) is a Unified Command (UC) that adheres to the nationally accepted Incident Command System (ICS) model. The UC promotes synergistic activity among all river stakeholders and ensures that joint evaluations and decisions are made that take all perspectives into account.

Chapters 1-5 of the plan detail the essential issues, authorities, and traffic management tools that enable government and industry to manage a river crisis. Particularly critical is the guidance for executing waterway management intervention actions. Responses are broken down into four phases: the Watch Phase, Implementation Phase, Emergency Phase, and Recovery Phase. Each phase triggers recommended actions for each phase of response. Actions to avert casualties are automatically triggered when certain river gauge levels are attained. The plan initiates Traffic Information Centers (TIC) to disseminate safety information and Traffic Control Centers (TCC) to temporarily perform active vessel traffic management.

The River Crisis Action Plan can be found at:
http://www.uscg.mil/d8/mso/nola/library/rcap/missrcap.pdf .

APPENDIX 2
PROFILE OF BRIDGE ALLISIONS

Coast Guard and AWO staff conducted a series of statistical analyses to provide a quantitative description of the bridge allisions and identify variables that could serve as indicators of incidents. The sections below recap the analyses of allision counts by bridge, geographic distribution of damages, circadian cycle, type of vessel, and pollution incidents. For more information, please contact Doug Scheffler, AWO Manager - Research and Data Analysis, by phone at (703) 841-9300 or by e-mail at dscheffler@vesselalliance.com.

Table 1: Bridge Allisions by Name of Bridge

Name of Bridge	Number of Allisions
E, J, & E Railway Bridge, MM-270.6, Illinois River, Morris, IL	170
Chicago & Northwestern Railroad Bridge, MM-151.2, Illinois River, Pekin, IL	95
Burlington Railroad Bridge, MM-403, Upper Mississippi River, Burlington, IA	92
Galveston Causeway (I-45) Bridge, MM-357, GICW, Galveston, TX	76
Franklin Street Bridge, MM-162, Illinois River, Peoria, IL	67
Naheola Bridge (Highway 114 Bridge), MM-173, Tombigbee River, Pennington, AL	67
East Main Street Bridge, MM-57, GICW, Houma, LA	50
Sabula Railroad Bridge, MM-535, Upper Mississippi River, Sabula, IA	48
South Quay (Highway 198) Bridge, Blackwater River, South Quay, VA	47
Camden Railroad Bridge, Pasquotank River, Camden, NC	46
Southern Pacific Railroad Bridge, MM-118, Atchafalaya River, Morgan City, LA	46
Clinton Railroad Bridge, MM-518, Upper Mississippi River, Clinton, IA	44
Bayou Dularge Bridge, MM-60, GICW, Houma, LA	42
CSX Railroad Bridge, MM-14, Mobile River, Mobile, AL	42
Crescent Railroad Bridge, MM-481.4, Upper Mississippi River, Davenport, IA	42
Illinois Central Railroad Bridge, MM-579.9, Upper Mississippi River, Dubuque, IA	33
McDonough Street Bridge, MM-287.3, Des Plaines River, Joliet, IL	29
Cairo Highway Bridge, MM-980.4, Ohio River, Cairo, IL	28
Cass Street Bridge, MM-288.1, Des Plaines River, Joliet, IL	26
Illinois Central Railroad Bridge, MM-977.8, Ohio River, Cairo, IL	26
Norfolk Southern Railroad Bridge, MM-90, Tombigbee River, Jackson, AL	26
Florence Highway Bridge, MM-56, Illinois River, Florence, IL	24
Burlington & Ohio Railroad Bridge, MM-254.1, Illinois River, Seneca, IL	23
Lacrosse Railroad Bridge, MM-700, Upper Mississippi River, Lacrosse, WI	23
Chickasaw Creek Railroad Bridge, MM-4, Mobile River, Prichard, AL	22
Louisiana Railroad Bridge, MM-282.1, Upper Mississippi River, Louisiana, MO	22
Fort Madison Railroad Bridge, MM-383.9, Upper Mississippi River, Fort Madison, IA	19
Victory Swing Bridge, Mouth Of Raritan River, Perth Amboy, NJ	17
Burlington Northern Railroad Bridge, Duwamish River, Seattle, WA	16
Jefferson Street Bridge, MM-287.9, Des Plaines River, Joliet, IL	16
Simmesport Railroad Bridge, MM-4.9, Atchafalaya River, Simmesport, LA	16
Bayou Blue Bridge, MM-49, GICW, Bourg, LA	15
Rigolets Pass Railroad Bridge, MM-34, GICW, Chalmette, LA	15

Name of Bridge	Number of Allisions
Chelsea Street Bridge, Chelsea River, Boston, MA	14
Highway 182 Bridge, MM-118, Atchafalaya River, Morgan City, LA	14
Black Bayou Bridge, MM-238, GICW, Lake Charles, LA	13
CSX Railroad Bridge, Back Bay Biloxi, Biloxi, MS	13
Chowan River (Highway 17) Bridge, Chowan River, Edenton, NC	13
DuPont Bridge, MM-295, GICW, Panama City, FL	13
Florida Avenue Bridge, Industrial Canal, New Orleans, LA	13
Highway 190 Bridge, MM-233.9, Lower Mississippi River, West Baton Rouge, LA	13
Highway 82 (Greenville Bridge) Bridge, MM-531, Lower Mississippi River, Greenville,	13
Norfolk & Western Railroad Bridge #5, East Branch, Elizabeth River, Chesapeake, VA	13
Walking Horse & Eastern RR Bridge, MM-185.2, Cumberland River, Nashville, TN	13
Melville Railroad Bridge, MM-30, Atchafalaya River, Melville, LA	12
Merchants Railroad Bridge, MM-183, Upper Mississippi River, St. Louis, MO	10
Pensacola Beach (Bob Sykes) Bridge, MM-189, GICW, Pensacola, FL	10
Spottsville Railroad Bridge, MM-8, Green River, Spottsville, KY	10
Thebes Railroad Bridge, MM-43.7, Upper Mississippi River, Thebes, IL	10
West Port Arthur Bridge, MM-289, GICW, Port Arthur, TX	10
B & O Railroad Bridge, MM-184.5, Ohio River, Parkersburg, WV	9
Berkeley (I-264) Bridge, Elizabeth River, Norfolk, VA	9
Caney Creek Bridge, MM-418, GICW, Freeport, TX	9
FEC Railroad Bridge, St. Lucie River, Stuart, FL	9
Grand Lake Pontoon Bridge, MM-232, GICW, Grand Lake, LA	9
Houma Navigation Canal Bridge, Houma Channel, Houma, LA	9
Ottawa Railroad Bridge, MM-239.4, Illinois River, Ottawa, IL	9
Bayou Sorrel Bridge, MM-38, Port Allen Route, Bayou Sorrel, LA	8
Bryan Beach Swing Bridge, MM-397, GICW, Freeport, TX	8
Eads Highway & Railroad Bridge, MM-180, Upper Mississippi River, St. Louis, MO	8
Humble Canal (Highway 55) Bridge, Humble Canal, Houma, LA	8
I-74 Bridge, MM-158, Illinois River, Peoria, IL	8
Illinois Central Railroad Bridge, MM-225.5, Illinois River, Lasalle, IL	8
Irvin Cobb (Highway 45) Highway Bridge, MM-937, Ohio River, Paducah, KY	8
Louisa Bridge, MM-134, GICW, Cypremort, LA	8
Popps Ferry Bridge, Back Bay Biloxi, Biloxi, MS	8
Venetian Causeway Bridge, AICW, Miami, FL	8
Bridge Of Lions, St. Johns River, St. Augustine, FL	7
Eltham Swing Bridge, Pamunkey River, West Point, VA	7
Henry R. Lawrence Memorial Bridge, MM-63.1, Cumberland River, Canton, KY	7
Highway 14 Bridge, MM-267.8, Black Warrior River, Eutaw, AL	7
Highway 49 Bridge, MM-662, Lower Mississippi River, Helena, AR	7
L & N Railroad Bridge, Industrial Canal, New Orleans, LA	7
New York Central Railroad Bridge, MM-265, Ohio River, Point Pleasant, WV	7
Pigs Eye Railroad Bridge, MM-836, Upper Mississippi River, St. Paul, MN	7
Railroad Bridge, Susquehanna River, Havre De Grace, MD	7
Rock Island Railroad Bridge, MM-288, Des Plaines River, Joliet, IL	7
2nd Avenue Bridge, Miami River, Miami, FL	6
Bayou Boeuf Southern Pacific Railroad Bridge, Amelia, LA	6
Blair Waterway Drawbridge, Tacoma, WA	6

Name of Bridge	Number of Allisions
Charenton Canal Railroad Bridge, Baldwin, LA	6
Dulac Swing Bridge, Houma Navigation Channel, Houma, LA	6
Gilmerton Highway Bridge, Elizabeth River, Chesapeake, VA	6
Hannibal Railroad Bridge, MM-309.9, Upper Mississippi River, Hannibal, MO	6
Highway 41 Dual Bridge, MM-786.8, Ohio River, Henderson, KY	6
Highway 80 Bridge, MM-435.8, Lower Mississippi River, Vicksburg, MS	6
Hylebos Waterway Bridge, Tacoma, WA	6
I-155 Highway Bridge, MM-838.9, Lower Mississippi River, Caruthersville, MO	6
Longboat Key Pass Bridge, GICW, Cortez, FL	6
P & I Railroad Bridge, MM-944.1, Ohio River, Metropolis, IL	6
West Larose Lift Bridge, MM-35, GICW, Larose, LA	6
B. B. Comer Highway Bridge, MM-385.9, Tennessee River, Scottsboro, AL	5
Belle Chasse Highway Bridge, MM-3.8, GICW, Belle Chasse, LA	5
Burlington Northern Railroad Bridge, Snohomish River, Everett, WA	5
Conrail Bridge #620, Rouge River, Dearborn MI	5
Decatur Highway Bridge, MM-305, Tennessee River, Decatur, TN	5
Eggners Ferry (Highway 68-80) Bridge, MM-41, Tennessee River, Aurora, KY	5
I-10 Highway Bridge, MM-60, Atchafalaya River	5
I-110 Highway Bridge, Back Bay Biloxi, Biloxi, MS	5
I-24 Highway Bridge, MM-940.8, Ohio River, Paducah, KY	5
I-5 Bridge, Columbia River, Vancouver, WA	5
Jackson Street Bridge, MM-288.4, Des Plaines River, Joliet, Il	5
L & N Railroad Bridge, MM-126.5, Cumberland River, Clarksville, TN	5
Navassa Railroad Bridge, Cape Fear River, Navassa, NC	5
Ocean City-Longport Bridge, AICW, Ocean City, NJ	5
Pelham Bay Parkway Bridge, Eastchester, NY	5
Pensacola Bay Bridge, GICW, Pensacola, FL	5
Sisters Creek Bridge (Highway 105), Sisters Creek, Jacksonville, FL	5
Southern Pacific Railroad Bridge, GICW, Amelia, LA	5
Southern Railroad Bridge, MM-647.3, Tennessee River, Knoxville, TN	5
Sunshine Bridge, MM-167.4, Lower Mississippi River, Union, LA	5
UPRR-SPRR Railroad Bridge, Martinez, CA	5
Union Pacific Railroad Bridge, MM-44, Atchafalaya River, Krotz Springs, LA	5
Wappoo Creek Bascule Bridge, Charleston, SC	5
Westlake Railroad Bridge, Calcasieu River, Westlake, LA	5
5th Street Bridge, Miami River, Miami, FL	4
B & M Railroad Bridge, Newport River, Morehead City, NC	4
Beardstown Highway Bridge, MM-88.1, Illinois River, Beardstown, IL	4
Burlington Northern Railroad Bridge, MM-105, Columbia River, Vancouver, WA	4
Chester Highway Bridge, MM-110, Ilinois River, Chester, IL	4
Dauphin Island (Highway 193) Bridge, MM-129, GICW, Dauphin Island, AL	4
East Park Avenue Bridge, MM-57, GICW, Houma, LA	4
Eureka Highway Bridge, MM-30, Cumberland River	4
Harahan Railroad Bridge, MM-734.8, Lower Mississippi River, Memphis, TN	4
Hood River Bridge (I-35), MM-169.8, Hood River, Hood River, OR	4
Huey P. Long Bridge, MM-106, Lower Mississippi River, New Orleans, LA	4
James River Bridge, James River, Newport News, VA	4

Name of Bridge	Number of Allisions
Keokuk Highway Bridge, MM-363.9, Upper Mississippi River, Keokuk, IA	4
L & N Railroad Bridge, MM-190.4, Cumberland River	4
Lansing Highway Bridge, MM-663.4, Upper Mississippi River, Lansing, IA	4
Leeville Lift Bridge, MM-13, Bayou Lafourche, Leeville, LA	4
Liberty Street Bridge, Saginaw River, Bay City, MI	4
Louisiana Highway 54 Bridge, MM-283, Upper Mississippi, Louisiana, MO	4
Mermentau River Railroad Bridge, Lake Arthur, LA	4
Middle Thoroughfare Bridge, Cape May Canal, Cape May, NJ	4
Natchez-Vidalia Highway Bridge, MM-363.3, Lower Mississippi River, Natchez, MS	4
Penn Central Railroad Bridge, MM-332, Calumet River, Chicago, IL	4
Sanibel Causeway Bridge, GICW, Fort Myers, FL	4
Tomlinson Bridge, Quinippiac River, New Haven, CT	4
Tule Lake Lift Bridge, Corpus Christi, TX	4
Bourdeaux Railroad Bridge, MM-190.5, Cumberland River	3
Burlington Northern Railroad Bridge, MM-328, Upper Mississippi River, Quincy, IL	3
Burlington Northern Railroad Bridge, Swinomish Channel, Anacortes, WA	3
CSX Railroad Bridge, MM-1, Big Sandy River, Kenova, WV	3
Campostella Bridge, Elizabeth River, Norfolk, VA	3
Casco Bay Bridge, Casco Bay, Portland, ME	3
Choctawhatchee Mid Bay Bridge, Destin, FL	3
Claiborne Avenue (Judge Seeber) Bridge, New Orleans	3
Dubuque Highway Bridge, MM-579.3, Upper Mississippi River, Dubuque, IA	3
FEC Railroad Bridge, St. Johns River, Jacksonville, FL	3
Gateway Western Railroad Bridge, MM-43.2, Illinois River	3
George P. Coleman Bridge, York River, Yorktown, VA	3
Great Bridge Highway Bridge, MM-12.6, AICW, Chesapeake, VA	3
Highway 84 Bridge, MM-41, Tensas River, Jonesville, LA	3
Highway 90 Bridge, Atchafalaya River, Morgan City, LA	3
Highway 90 Bridge, Back Bay Biloxi, Biloxi, MS	3
Hilton Railroad Bridge, Cape Fear River, Wilmington, NC	3
I-30 Highway Bridge, MM-118.5, Arkansas River, Little Rock, AR	3
I-55 Highway Bridge, MM-734.8, Lower Mississippi River, Memphis, TN	3
I-64 Highrise Bridge, Elizabeth River, Chesapeake, VA	3
Isabelle Stallings Holmes Bridge, Cape Fear River, Wilmington, NC	3
Jefferson Barracks (I-255) Bridge, MM-169.1, Upper Mississippi River, St. Louis, MO	3
K & I Railroad Bridge, MM-607, Ohio River, Louisville, KY	3
Kenova Railroad Bridge, MM-315, Ohio River, Kenova, WV	3
L & I Railroad Bridge, MM-605, Ohio River, Louisville, KY	3
Lake Pontchartrain Causeway Bridge, New Orleans, LA	3
Lexington Highway Bridge, MM-318, Missouri River, Lexington, MO	3
Louisiana Midland Railroad Bridge, MM-40.6, Ouachita River, Jonesville, LA	3
Mackay River Bridge, MM-674, AICW, St. Simons Island, GA	3
McArdle Street Bridge, Boston, MA	3
Omaha Railroad Bridge, MM-841, Upper Mississippi River, St. Paul, MN	3
P & LE Railroad Bridge, MM-8.6, Monongahela River, Pittsburgh, PA	3
Parkersburg Highway Bridge, MM-184.3, Ohio River, Parkersburg, WV	3
Peter P. Cobb Bridge, AICW, Fort Pierce, FL	3

Name of Bridge	Number of Allisions
Raritan River Railroad Bridge, South Amboy, NJ	3
Rock Island Railroad Bridge, MM-487, Upper Mississippi River, Rock Island, IL	3
Seabrook Railroad Bridge, Industrial Canal, New Orleans, LA	3
Shawneetown Highway Bridge, MM-858.2, Ohio River, Shawneetown, IL	3
Smithfield Street Bridge, MM-1, Monongahela River, Pittsburgh, PA	3
Southern Pacific Railroad Bridge, MM-227, Red River, Shreveport, LA	3
Southern Railroad Bridge, MM-472.5, Ohio River, Cincinnati, OH	3
Southern Railroad Bridge, MM-591.3, Tennessee River	3
Spuyten Duyvil Bridge, East River, Bronx, NY	3
Stono River Bridge, AICW, Charleston, SC	3
Wilkes Bridge, Back Bay Biloxi, Biloxi, MS	3
1st Avenue South Bridge, Duwamish River, Seattle, WA	2
3 Mile Slough Bridge, Sacramento River, Rio Vista, CA	2
92nd Street Bridge, Calumet River, Chicago, IL	2
AGS Railroad Bridge, MM-267.8, Black Warrior River	2
B. B. McCormick Bridge, MM-747, AICW, Jacksonville, FL	2
Baker Haulover Inlet Bridge, AICW, Miami, FL	2
Bayou Sallie Bridge, MM-113, GICW	2
Biggs-Maryhill Bridge, MM-208.1, Columbia River, Biggs, OR	2
Brightman Street Drawbridge, MM-1.8, Taunton River, Somerset, MA	2
Broadway Bridge, MM-12, Willamette River, Portland, OR	2
Buffalo Bluff Railroad Bridge, St. Johns River, Palatka, FL	2
Burlington Northern Railroad Bridge, MM-105.3, Alabama River, Pine Hill, AL	2
CSX Railroad Bridge, Pascagoula River, Pascagoula, MS	2
Cape Girardeau Highway Bridge, MM-53, Upper Mississippi, Cape Girardeau, MO	2
Chef Menteur (Highway 90) Bridge, New Orleans, LA	2
Cochran-Africatown Bridge, Mobile River, Mobile, AL	2
Congress Street Bridge, Fort Point Channel, Boston, MA	2
Conrail Bridge, Maumee River, Toledo, OH	2
Coronado Bridge, AICW, New Smyrna Beach, FL	2
Coronado Bridge, San Diego Bay, San Diego, CA	2
Crown Point Bridge (Highway 3134), GICW, Crown Point, LA	2
Douglas MacArthur Bridge, MM-179, Upper Mississippi River, St. Louis, MO	2
E, J, & E Railway Bridge, Indiana Harbor Ship Canal, East Chicago, IN	2
Grassy Sound Bridge (Route 147), Cape May, NJ	2
Grosse Ile Toll Bridge, Detroit River, Grosse Ile, MI	2
Grosse Tete Swing Bridge, MM-48, GICW, Port Allen Route	2
Gulf Beach (Highway 292) Bridge, MM-172, GICW, Gulf Beach, FL	2
Hackensack River Drawbridge, MM-5.4, Hackensack River, Hackensack, NJ	2
Hardin Drawbridge, MM-21.5, Illinois River, Hardin, IL	2
Henry Ford Lift Bridge, Cerritos Channel, Los Angeles, CA	2
Hickman-Lockhart Bridge, MM-100, Tennessee River	2
Highway 231 Bridge, MM-333, Tennessee River	2
Highway 302 Bridge, Barataria Waterway, Lafitte, LA	2
Highway 56 Bridge, Boudreaux Canal	2
Highway 80 Bridge, MM-166.5, Ouachita River, Monroe, LA	2
Highway 90 Bridge, Escambia River, Pensacola, FL	2

Name of Bridge	Number of Allisions
Hobucken Swing Bridge, Hobucken, NC	2
I-10 Highway Bridge, MM-229, Lower Mississippi River, Baton Rouge, LA	2
I-24 Highway Bridge, MM-429, Tennessee River, Chattanooga, TN	2
I-35 Bridge, Victoria Barge Canal, San Antonio Bay, Port Lavaca, TX	2
I-57 Bridge, MM-7.5, Upper Mississippi River, Cairo, IL	2
Indian Rocks Bridge, MM-128.2, GICW, Indian Rocks Beach, FL	2
Lewis & Clark Bridge, MM-13.5, Columbia River, Astoria, OR	2
Limehouse Swing Bridge, Stono River, Johns Island, Charleston, SC	2
Little River Swing Bridge, AICW, Little River, SC	2
Lockport Bridge, MM-291, DesPlaines River, Lockport, IL	2
McKinley Bridge, MM-182.2, Upper Mississippi River, St. Louis, MO	2
McWhorter Bridge, MM-66, Tennessee River	2
Mermentau River Railroad Bridge, Jennings, LA	2
Metro North Railroad Bridge, Norwalk River, Norwalk, CT	2
Monitor-Merrimac Causeway Bridge, James River, Newport News, VA	2
Navarre Beach (Highway 87) Highway Bridge, MM-207, GICW, Navarre Beach, FL	2
New Bridge Under Construction, MM-158, Cumberland River	2
Norfolk & Southern Railroad Bridge, Maumee River, Toledo, OH	2
Old Lyme Railroad Bridge, Old Saybrook, CT	2
Old River Bridge, Orwood, CA	2
Pekin Highway Bridge, MM-152.9, Illinois River, Pekin, IL	2
Pelham Bay Railroad Bridge, Eastchester, NY	2
Pelican Island Bridge, Galveston Channel, Galveston, TX	2
Poplar Street Bridge, MM-179.2, Upper Mississippi River, St. Louis, MO	2
Port Isabel Swing Bridge, GICW, Port Isabel, TX	2
Queen Isabella Causeway Bridge, GICW, Port Isabel, TX	2
Quincy Memorial Bridge, MM-327, Upper Mississippi River, Quincy, IL	2
Railroad Bridge, Ballard Locks, Seattle, WA	2
Railroad Bridge, MM-320, Chicago Sanitary & Ship Canal	2
Rankin Highway Bridge, MM-10.4, Monongahela River, Braddock, PA	2
Ravenswood Bridge, MM-221.3, Ohio River, Ravenswood, OH	2
Rockaway Railroad Bridge, AICW, Rockaway, NY	2
Roosevelt Railroad Bridge, AICW, Stuart, FL	2
Route 104 Steel Bridge, Elizabeth River, Chesapeake, VA	2
Route 313 Bridge, Nanticoke River, Sharptown, MD	2
Route 3A Bridge, Weymouth Fore River, Quincy, MA	2
Route 50 Bridge, Nanticoke River, Vienna, MD	2
Sidney Lanier Bridge, AICW, Brunswick, GA	2
Smallhouse Railroad Bridge, MM-79.7, Green River, South Carrollton, KY	2
Southern Railroad Bridge, MM-470.7, Tennessee River, Chattanooga, TN	2
Spokane Street Bridge, Duwamish River, Seattle, WA	2
Spokane Street Railroad Bridge, Duwamish River, Seattle, WA	2
State Highway Bridge, MM-725.8, Upper Mississippi River, Winona, MN	2
Steubenville Highway Bridge, MM-68, Ohio River, Steubenville, OH	2
Summer Street Bridge, Boston, MA	2
Sunset Beach Swing Bridge, AICW, Sunset Beach, NC	2
T, C & W Railroad Bridge, MM-14.3, Minnesota River, Savage, MN	2

Name of Bridge	Number of Allisions
Tucannon Railroad Bridge, MM-61.8, Snake River, Tucannon, WA	2
Union Pacific Railroad Bridge, Aberdeen, WA	2
Valentine Bridge, Bayou Lafourche, Valentine, LA	2
Victoria Island Bridge, Sacramento River, Antioch, CA	2
Vilano Beach Bridge, AICW, Vilano Beach, FL	2
Winfield Highway Bridge, MM-32, Kanawha River, Winfield, WV	2
100th Street Bridge, Calumet River, Chicago, IL	1
10th Street Bridge, Manitowoc River, Manitowoc, WI	1
16th Avenue Bridge, Duwamish River, Seattle, WA	1
17th Avenue Bridge, Miami River, Miami, FL	1
40th Street Bridge, MM-3, Allegheny River, Pittsburgh, PA	1
4th Street Bridge, MM-1, Licking River, Cincinnati, OH	1
4th Street Bridge, MM-135, Lower Mississippi River, New Orleans, LA	1
6th Street Bridge, Menomonee River, Milwaukee, WI	1
8th Street Bridge, Manitowoc River, Manitowoc, WI	1
A, T & SF Railroad Bridge, MM-181.9, Illinois River	1
ASB Railroad Bridge, MM-365.9, Missouri River, Kansas City, MO	1
Albany Railroad Swing Bridge, Hudson River, Troy, NY	1
Albany-Renssalaer Railroad Bridge, Hudson River, Albany, NY	1
Alford Street Bridge, MM-1.4, Mystic River, Boston, MA	1
Ambridge-Aliquippa Bridge, MM-15, Ohio River, Glenwillard, PA	1
Amelia Island-Kingsley Creek Bridge, AICW, Fernandina Beach, FL	1
Amtrak Bridge, Charles River, Boston, MA	1
Amtrak Railroad Bridge, MM-325, Chicago Sanitary & Ship Canal, Chicago, IL	1
Apalachicola Northern Railroad Bridge, MM-347, GICW, Apalachicola, FL	1
Apalachicola Railroad Bridge, Apalachicola, FL	1
Appomatox Railroad Bridge, Appomatox River, Petersburg, VA	1
Ashland Highway Bridge, MM-323, Ohio River, Ashland, KY	1
Astoria-Megler Bridge, MM-14.5, Columbia River, Astoria, OR	1
Atlantic Avenue Highrise Bridge, MM-744.7, AICW, Jacksonville, FL	1
Atlantic Beach Bridge, Long Island Sound, Long Island, NY	1
Atlantic Beach Causeway Bridge, AICW, Atlantic Beach, NC	1
B & O Railroad Bridge, Cuyahoga River, Cleveland, OH	1
B & O Railroad Bridge, MM-311, Chicago Sanitary & Ship Canal	1
Ballard Bridge, Lake Washington, Seattle, WA	1
Ballard Railroad Bridge, Ballard, WA	1
Bayou Blue (Highway 316) Bridge, GICW, Houma, LA	1
Bayou Pigeon Bridge, MM-41, GICW, Pigeon, LA	1
Bayou Portage Bridge, Pass Christian, MS	1
Beaufort High Rise Bridge, Newport River, Beaufort, NC	1
Betsy Ross Bridge, Delaware River, Port Richmond, PA	1
Beverly-Salem Bridge, Beverly Harbor, Salem, MA	1
Blackpoint Railroad Bridge, Petaluma River	1
Blynman Bridge, Annisquam River, Gloucester, MA	1
Bourg Lift Bridge, Bourg, LA	1
Brandon Road Bridge, MM-285.8, Des Plaines River, Joliet, IL	1
Brickell Avenue Bridge, Miami River, Miami, FL	1

Name of Bridge	Number of Allisions
Brielle Railroad Bridge, Manasquan Channel, Brielle, NJ	1
Broad Causeway Bridge, AICW, North Miami, FL	1
Broad River Bridge, Beaufort, SC	1
Broadway Bridge, AICW, Daytona, FL	1
Burham Railroad Bridge, Menomonee River, Milwaukee, WI	1
Burlington & Ohio Railroad Bridge, MM-312, Illinois River, Chicago, IL	1
Burlington Northern Railroad Bridge, Ballard Locks, Seattle, WA	1
Burlington Northern Railroad Bridge, MM-328, Columbia River, Pasco, WA	1
Burlington Northern Railroad Bridge, MM-89, Illinois River, Beardstown, IL	1
C & A Railroad Bridge, MM-14, AICW, Chesapeake, VA	1
CSX Railroad Bridge, AICW, Fernandina Beach, FL	1
CSX Railroad Bridge, Big Bayou Canot, Saraland, AL	1
CSX Railroad Bridge, MM-104.8, Apalachicola River	1
CSX Railroad Bridge, Maumee River, Toledo, OH	1
Calhoun-Rumsey Highway Bridge, MM-63.2, Green River, Calhoun, KY	1
Cathlamet Channel Bridge, MM-40, Columbia River, Cathlamet, WA	1
Cedar Street Bridge, MM-161, Illinois River, Peoria, IL	1
Celilo Railroad Bridge, MM-201.3, Columbia River, Wishram, WA	1
Center Street Bridge, Cuyahoga River, Cleveland, OH	1
Centerville Turnpike Bridge, AICW, Chesapeake, VA	1
Central Avenue Bridge, MM-1.3, Kansas River, Kansas City, KS	1
Central Ferry Bridge, MM-83.2, Snake River, Central Ferry, WA	1
Central Gulf Railroad Bridge, MM-167.1, Ouachita River, Monroe, LA	1
Chehalis River Highway Bridge, Aberdeen, WA	1
Chicago & Northwestern Railroad Bridge, MM-3.3, Fox River, Green Bay, WI	1
Chicago Avenue Bridge, North Branch, Chicago River, Chicago, IL	1
Cicero Avenue Bridge, MM-317, Chicago Sanitary & Ship Canal	1
Clark Bridge, MM-202.7, Upper Mississippi River, Alton, IL	1
Columbia Highway 62 Bridge, Chattahoochee River, Columbia, LA	1
Commodore Heim Bridge, Cerritos Channel, Los Angeles, CA	1
Conrail Bridge, Hackensack River, Hackensack, NJ	1
Conrail Bridge, MM-11.8, Monongahela River, Duquesne, PA	1
Conrail Bridge, Mantua Creek, Paulsboro, NJ	1
Conrail Railroad Bridge #308, Rouge River, River Rouge, MI	1
Conrail Railroad Bridge, Indiana Harbor Ship Canal, East Chicago, IN	1
Conrail Railroad Bridge, Indiana Harbor, Gary, IN	1
Conrail Railroad Bridge, MM-604.4, Ohio River, Louisville, KY	1
Cow Bayou Swing Bridge, Cow Bayou, Bridge City, TX	1
Dahoo River Bridge, AICW, Charleston, SC	1
Del Air Railroad Bridge, MM-90.5, Delaware River, Philadelphia, PA	1
Del Miller Bridge, GICW, Corpus Christi, TX	1
Demopolis Highway Bridge, MM-219, Black Warrior River, Demopolis, AL	1
Devalls Bluff Highway Bridge, MM-121.7, White River, Devalls Bluff, AR	1
Dodge Island Bridge, Miami, FL	1
Dow Canal Railroad Bridge, GICW, Freeport, TX	1
Dumbarton SPRR Railroad Bridge, San Francisco Bay, San Francisco, CA	1
E, J, & E Railroad Bridge, Calumet River, Chicago, IL	1

Name of Bridge	Number of Allisions
Ellender Bridge, GICW, Ellender, LA	1
Erie-Jacknife Railroad Bridge, MM-7.7, Hackensack River, Secaucus, NJ	1
Fairfax Dual Bridge, MM-372.6, Missouri River, Kansas City, MO	1
Fairfield Bridge #17, AICW, Belhaven, NC	1
Falgout Canal Bridge, Bayou Lafourche, LA	1
Figure 8 Island Bridge, Wilmington, NC	1
Flagler Beach Bridge, AICW, Flagler Beach, FL	1
Flagler Street Bridge, Miami River, Miami, FL	1
Fore River Bridge, Fore River, Portland, ME	1
Forked Island Bridge, MM-165.8, GICW, Forked Island, LA	1
Fort Madison Highway Bridge, MM-383, Upper Mississippi River, Fort Madison, IA	1
Fort Pierce Bridge, MM-965.8, AICW, Fort Pierce, FL	1
Fort Street Bridge, Rouge River, River Rouge, MI	1
Francis Scott Key Bridge, Patapsco River, Baltimore, MD	1
Fuller Warren (I-95) Bridge, St. Johns River, Jacksonville, FL	1
George Rogers Clark Memorial Bridge, MM-5.3, Tennessee River	1
Gibbstown Bridge, MM-220, GICW, Gibbstown, LA	1
Glasglow Bridge, MM-226.4, Missouri River	1
Golden Gate Bridge, San Francisco Bay, San Francisco, CA	1
Golden Meadow Lift Bridge, Bayou Lafourche, LA	1
Great Egg Inlet Bridge, AICW, Ocean City, NJ	1
Grosse Ile Toll Bridge, Trenton Channel, Riverview, MI	1
Harbor Island Reach Bridge, Duwamish River, Seattle, WA	1
Harris Saxon Bridge, AICW, New Smyrna, FL	1
Hastings Railroad Bridge, MM-813.7, Upper Mississippi River, Hastings, MN	1
Henley Street Bridge, MM-647, Tennessee River, Knoxville, TN	1
High Rise Bridge, AICW, Morehead City, NC	1
High Street Bridge, Alameda, CA	1
Highway 101 Bridge, Grays Harbor, Aberdeen, WA	1
Highway 159, MM-320, Black Warrior River	1
Highway 165 Bridge, MM-110, Ouachita River, Columbia, LA	1
Highway 165 Bridge, MM-88.6, Red River, Alexandria, LA	1
Highway 17 Bridge, Pasquotank River, Elizabeth City, NC	1
Highway 172 Bridge, AICW, Onslow Beach, NC	1
Highway 182 Bridge, GICW, Perdido Pass, Orange Beach, AL	1
Highway 23 Bridge, MM-354, Ohio River, Portsmouth, OH	1
Highway 27 Bridge, MM-469.9, Ohio River, Cincinnati, OH	1
Highway 278 Bridge, AICW, Hilton Head, SC	1
Highway 288 Bridge, MM-401, GICW, Freeport, TX	1
Highway 32 Bridge, Albemarle Sound, Edenton, NC	1
Highway 331 Bridge, Choctawhatchee Bay, Point Washington, FL	1
Highway 4 Bridge, Old River, Discovery Bay, CA	1
Highway 402 Bridge, AICW, Titusville, FL	1
Highway 453 Bridge, MM-25.2, Tennessee River	1
Highway 521 Bridge, San Bernard River, Freeport, TX	1
Highway 63 Bridge, MM-791, Upper Mississippi River, Red Wing, MN	1
Highway 70 Bridge, MM-90.4, Ohio River, Wheeling, WV	1

Name of Bridge	Number of Allisions
Highway 73 Causeway Bridge, Sabine River, Port Arthur, TX	1
Highway 80 Bridge, MM-3, Yahzoo River, Vicksburg, MS	1
Highway 82 Bridge, MM-94.8, Chattahoochee River, Eufala, AL	1
Highway 82 Bypass Bridge, MM-314.5, Black Warrior River, Tuscaloosa, AL	1
Highway 90 Bridge, Bayou Savage, New Orleans, LA	1
Highway 90 Draw Bridge, Gautier, MS	1
Highway Bridge, MM-228, Illinois River, LaSalle, IL	1
Hood Canal Bridge, Hood Canal, WA	1
Houma Twin Span Bridge, MM-58, GICW, Houma, LA	1
Hutchinson Parkway Bridge, Hutchinson River, Bronx, NY	1
I-10 Bridge, Neches River, Beaumont, TX	1
I-10 Bridge, San Jacinto River, Houston, TX	1
I-20 Highway Bridge, MM-435.8, Lower Mississippi River, Vicksburg, MS	1
I-24 Dual Bridges, MM-28, Cumberland River, Nashville, TN	1
I-24 Bridge, MM-21.1, Tennessee River	1
I-24 Highway Bridge, MM-940-8, Ohio River, Paducah, KY	1
I-275 Bridge, Hillsborough River, Tampa, FL	1
I-275 Highway Bridge, MM-491.5, Ohio River, Lawrenceburgh, IN	1
I-471 Bridge, MM-470, Ohio River, Cincinnati, OH	1
I-520 Floating Bridge, Lake Washington, Seattle, WA	1
I-58 Bypass Bridge, Blackwater River, Franklin, VA	1
I-64 (Sherman Minton) Bridge, MM-608.6, Ohio River, Louisville, KY	1
I-695 Bridge, Patapsco River, Baltimore, MD	1
I-77 Bridge, MM-63.5, Kanawha River, Charleston, WV	1
I-80 Highway Bridge, MM-495.4, Upper Mississippi River, Davenport, IA	1
I-90 Highway Bridge, MM-701, Upper Mississippi River, Lacrosse, WI	1
Illinois Central Railroad Bridge, MM-952, Lower Mississippi River	1
Isle Of Palms Connector Bridge, MM-458.9, AICW, Mount Pleasant, SC	1
JJ Railroad Bridge, AICW, Titusville, FL	1
James Island Bridge, Charleston Harbor, Charleston, SC	1
Joliet Railroad Bridge, MM-287.6, Des Plaines River, Joliet, IL	1
Judge Perez Bridge, Belle Chasse, LA	1
Kelley Memorial Drawbridge (Route 50), Chincoteague, VA	1
L & L Railroad Bridge, Lower Mississippi River, New Orleans, LA	1
Lacon Highway Bridge, MM-189, Illinois River, Lacon, IL	1
Lafayette Bridge, MM-838.7, Upper Mississippi River, St. Paul, MN	1
Lake State Railroad Bridge, Saginaw River, Detroit, MI	1
Lapalco Drawbridge, MM-98, GICW, Harvey, LA	1
Lockwood Street Bridge, Buffalo Bayou, Houston, TX	1
Loop Parkway Draw Bridge, Long Island Sound, Long Island, NY	1
Low Level Bridge, Chesapeake Bay Bridge Tunnel, Fishermans Island, VA	1
Lower Hackensack Bridge, Hackensack River, Hackensack, NJ	1
Lucy J. Lewis Memorial Bridge, MM-3, Cumberland River	1
Lyons Ferry Bridge, MM-58, Snake River, Snake River, WA	1
Madison Highway Bridge, MM-557.3, Ohio River, Madison, IN	1
Main Street Bridge, St. Johns River, Jacksonville, FL	1
Mansfield Highway Bridge, MM-16.6, Monongahela River, Dravosburg, PA	1

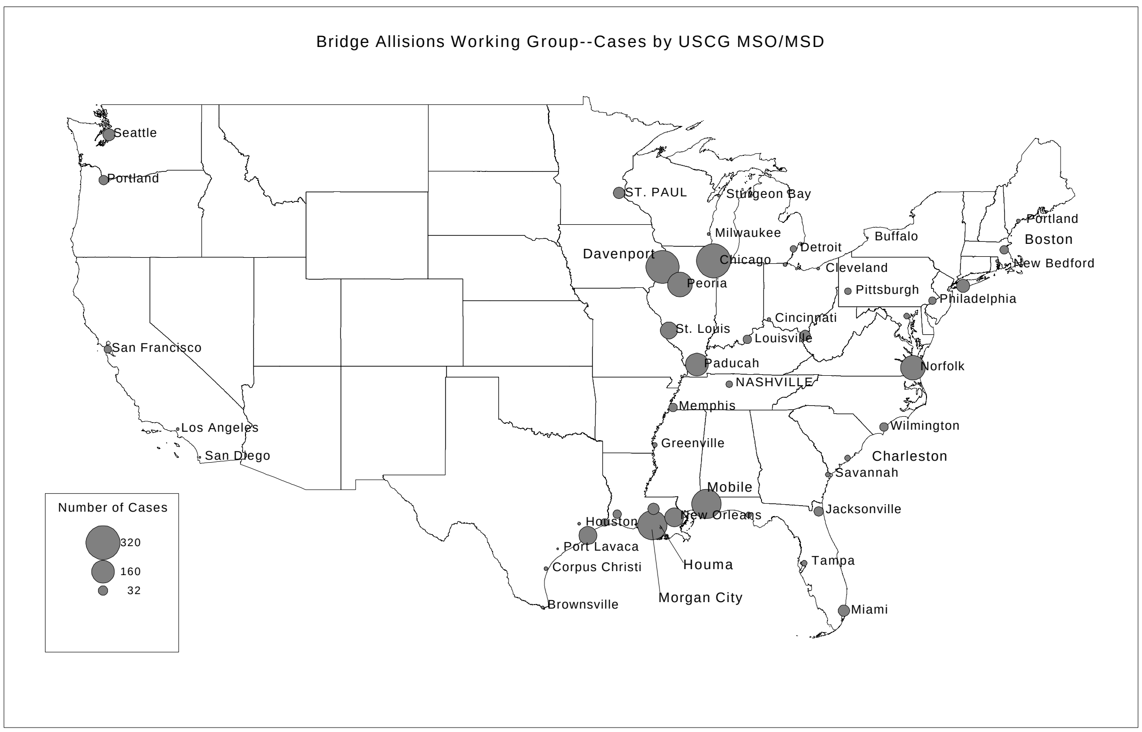
Name of Bridge	Number of Allisions
Margate Bridge, AICW, Margate City, NJ	1
Marietta-Williamston Highway Bridge, MM-171.8, Ohio River, Marietta, OH	1
Market Street Bridge, Christina River, Wilmington, DE	1
Marley Railroad Bridge, MM-57, Port Allen Route, Baton Rouge, LA	1
Martin Luther King Bridge, MM-180, Upper Mississippi River, St. Louis, MO	1
Martin Luther King Bridge, Sabine River, Port Arthur, TX	1
Matagorda Swing Pontoon Bridge, MM-440, GICW, Matagorda, TX	1
Maxine Mine Bridge, MM-397, Black Warrior River	1
McArthur Railroad Bridge, MM-179.3, Upper Mississippi River, St. Louis, MO	1
Meadowbrook Parkway Bridge, Jones Inlet, Long Island, NY	1
Memorial Bridge, MM-155, Ohio River, St. Marys, WV	1
Mermentau River Railroad Bridge, Mermentau, LA	1
Metro Rail Bridge, Miami River, Miami, FL	1
Million Dollar Bridge, Portland, ME	1
Milton Bridge, MM-32, Vermillion River, Milton, LA	1
Milwaukee Hoan Bridge, Milwaukee Inner Harbor, Milwaukee, WI	1
Missouri Railroad Bridge, MM-114.5, Ouachita River	1
Mokelumne Bridge, Sacramento River, Isleton, CA	1
Montauk Point Bridge, Hutchinson River, Bronx, NY	1
Montgomery Highway Bridge, MM-85.8, Kanawha River, Montgomery, WV	1
N & W Railroad Bridge, Maumee River, Toledo, OH	1
Nassau Sound Bridge, AICW, Nassau Sound, FL	1
Neponset River Railroad Bridge, Neponset River, Boston, MA	1
New Bedford-Fairhaven Bridge, New Bedford, MA	1
New Jamestown Bridge, Narragansett Bay, Jamestown, RI	1
Nitro-St. Albans Bridge, MM-43, Kanawha River, St. Albans, WV	1
Norfolk & Southern Railroad Bridge, MM-315, Ohio River, South Point, OH	1
Norfolk & Western Lift Bridge, Elizabeth River, Chesapeake, VA	1
Norfolk & Western Railroad Bridge #7, Elizabeth River, Chesapeake, VA	1
North Avenue Bridge, North Branch, Chicago River, Chicago, IL	1
North Landing Highway Bridge, AICW, Virginia Beach, VA	1
Northwestern Pacific Railroad Bridge, Petaluma River, Petaluma, CA	1
O'Neil Highway Bridge, MM-256.4, Tennessee River	1
Oakland Bay Bridge, B-C Span, Oakland, CA	1
Oakmont Highway Bridge, MM-12, Allegheny River, Oakmont, PA	1
Old River Railroad Bridge, Benicia, CA	1
Onslow Beach Swing Bridge, Onslow Beach, NC	1
Oregon Street Bridge, Oshkosh, WI	1
Orwood Santa Fe Railroad Bridge, Sacramento River, Rio Vista, CA	1
Outerbridge Crossing Bridge, Arthur Kill, Staten Island, NY	1
Passyunk Avenue Bridge, Schuykill River, Philadelphia, PA	1
Peace Bridge, Black Rock Canal, Buffalo, NY	1
Pierre Part Bridge, Bayou Maringouin, Pierre Part, LA	1
Prospect Avenue Bridge, MM-53.5, GICW, Houma, LA	1
Pungo Ferry Bridge, AICW, Virginia Beach, VA	1
Quarrier Street Bridge, MM-1, Elk River, Charleston, WV	1
R. V. Woods Bridge, Beaufort, SC	1

Name of Bridge	Number of Allisions
Railroad Bridge, Duwamish River, Seattle, WA	1
Railroad Bridge, MM-119, Arkansas River, Little Rock, AR	1
Railroad Bridge, MM-170, Ouachita River	1
Raritan River Bridge, Raritan River, Perth Amboy, NJ	1
Rice Creek Bridge, St. Johns River, Palatka, FL	1
Robert Michael Bridge, MM-162.1, Illinois River	1
Rock Island Railroad Bridge, MM-118.2, Arkansas River, Little Rock, AR	1
Route 136 Bridge, Norwalk River, Norwalk, CT	1
Route 836 Overpass Bridge, Miami River, Miami, FL	1
Ruby Street Bridge, MM-288.7, Des Plaines River, Joliet, IL	1
SL & SF Railroad Bridge, MM-220, Black Warrior River	1
San Jacinto River Railroad Bridge, San Jacinto River, Houston, TX	1
San Mateo-Hayward Bridge, San Francisco Bay, San Francisco, CA	1
Santa Fe Railroad Bridge, MM-315, Chicago Sanitary & Ship Canal	1
Sarah Long Bridge, Piscataqua River, Portsmouth, NH	1
Sawpit Creek Bridge, AICW, Nassau Sound, FL	1
Sea Island Bridge, St. Simons Island, GA	1
Shortcut Railroad Bridge, Rouge River, River Rouge, MI	1
Sidney C. Lewis Highway Bridge, MM-88.8, Tennessee River, Dover, TN	1
Simmesport Highway Bridge, MM-5, Atchafalaya River, Simmesport, LA	1
Skull Creek Bridge, Hilton Head, SC	1
Sloop Channel Bridge, Freeport, NY	1
South Park Bridge, MM-5.2, Buffalo River, Buffalo, NY	1
South Quay (Highway 189) Bridge, Blackwater River, South Quay, VA	1
Southern Pacific Railroad Bridge, Calcasieu River, Lake Charles, LA	1
Southern Pacific Railroad Bridge, Coos Bay, OR	1
Southern Pacific Railroad Bridge, Entrance To Buffalo Bayou, Houston, TX	1
Southern Railroad Bridge, MM-248.5, Tombigbee River	1
Southport Bridge, Boothbay Harbor, Southport, ME	1
St. Claude Avenue Bridge, Industrial Canal, New Orleans, LA	1
St. Georges Bridges, C & D Canal, St. Georges, DE	1
St. Lucie Railroad Bridge, AICW, St. Lucie, FL	1
Stephenville Pontoon Bridge, Bayou Milhomme, Stephenville, LA	1
Sterlington Bridge, MM-192, Ouachita River, Sterlington, LA	1
Summit Bridge, MM-313, Illinois River, Summit, IL	1
Sunrise Boulevard Bridge, AICW, Fort Lauderdale, FL	1
Surfside Bridge, GICW, Freeport, TX	1
TX-LA Causeway Bridge, Sabine River, Port Arthur, TX	1
Tacony-Palmyra Bridge, Delaware River, Philadelphia, PA	1
Tappan Zee Bridge, Hudson River, Tarrytown, NY	1
Tensas River Railroad Bridge, MM-20, Tensas River, Stockton, AL	1
Thomas Rhodes Highway Bridge, MM-27, Cape Fear River, Wilmington, NC	1
Townsend Inlet Bridge, AICW, Townsend Inlet, NJ	1
Union Pacific Railroad Bridge, MM-196.3, White River, New Augusta, AR	1
Union Pacific Railroad Bridge, MM-227, Red River, Shreveport, LA	1
Union Terminal Bridge, Cuyahoga River, Cleveland, OH	1
Veterans Memorial Bridge, MM-464.5, Tennessee River, Chattanooga, TN	1

Name of Bridge	Number of Allisions
Vincent Thomas Bridge, Los Angeles Harbor, Los Angeles, CA	1
Wallops Island Bridge, AICW, Wallops Island, VA	1
Walter Groves Bridge, AICW, Hilton Head, SC	1
Washington Street Bridge, Norwalk River, Norwalk, CT	1
Water Street Bridge, Milwaukee River, Milwaukee, WI	1
West Bay Bridge, Quantuck Canal, West Hampton Beach, NY	1
West End Bridge, MM-310.9, Ohio River, Huntington, WV	1
West Seattle High Rise Bridge, Seattle, WA	1
Western Electric Bridge, Passaic River, Passaic, NJ	1

The map below shows the bridge allisions aggregated by Coast Guard Marine Safety Office/Marine Safety Detachment. The size of the circle marking the unit's headquarters is proportional to the number of allisions.

Figure 1: Bridge Allisions by Coast Guard Marine Safety Office/Detachment



Bridge Allisions by Total Damage

AWO and Coast Guard staff hypothesized that the geographic distribution of damage amounts could provide an indicator of areas of interest. The map on the next page shows the monetary damages for each allision aggregated by Coast Guard Marine Safety Office/Marine Safety Detachment:

Figure 2: Bridge Allisions by Total Damage

Bridge Allision Working Group -- U.S.C.G. Data File

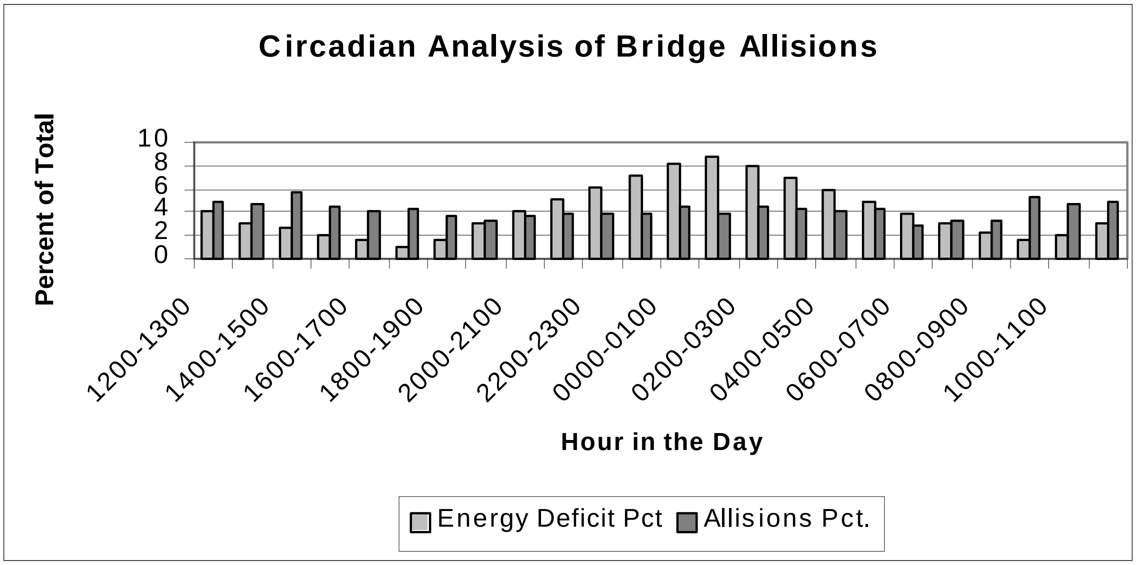
The map shows that the unit with the largest damage is Charleston, followed by New Orleans, Paducah, and Chicago. Examination of the data showed that one very costly incident, or a few incidents with significant damages, skewed the results. Coast Guard and AWO staff agreed that this analysis did not suggest useful areas for further research.

<u>Circadian Cycle</u>

Medical literature documents the changes in human performance levels that occur throughout the day as a result of circadian cycles. The Coast Guard and AWO staff hypothesized that if there was a circadian component in the causes of bridge allisions, then it could be tested as a correlation between circadian lows -- the times of the day with low energy levels -- and the times when the allisions occurred.

An "energy deficit" was derived for each hourly interval in the day and then that interval's percent of the total deficit was calculated. The percentage of bridge allisions occurring in the same intervals was also calculated. This provided two similar rates that were input into a statistical correlation analysis. The results strongly indicated no correlation. The chart on the next page shows each percentage as separate bars. If there was a circadian effect, then the lengths of the bars would be approximately the same at each interval.

Figure 3: Circadian Analysis of Bridge Allisions



As the chart shows, for some intervals the allisions percentage is greater than the energy deficit, for others the energy deficit is greater, and rarely are the two close.

Similar analyses were run independently for each year. The results were inclusive for all years, except for one which showed a weak negative correlation -- the opposite of the hypothesis. Thus, this high-level analysis yielded no indication, in the aggregate, of a relationship between circadian rhythm and bridge allisions. This does not rule out the possibility of environmental factors or fatigue in particular circumstances or in a subset of the cases.

Type of Vessel

The case database was linked to the Corps of Engineers' fleet data file (*Waterborne Transportation Lines of the U.S.*) by the common vessel identification code. Various tabulations and cross-tabulations were generated for the characteristics of the towboats/tugboats involved. The tables below are the high-level distributions for registered gross tons, length, draft, horsepower, and age.

Table 1: Registered Gross Tons

Gross Tons	Number of Tow/Tugboats	Percent
Missing	59	2.0
1-250	1,649	57.2
251-500	428	14.9
501-750	559	19.4
751-1,000	152	5.3
1,001 +	36	1.2
Total	**2,883**	**100.0**

Table 2: Registered Length

Length in Feet	Number of Tow/Tugboats	Percent
Missing	58	2.0
1-100	1,703	59.1
101-150	856	29.7
151 +	266	9.2
Total	**2,883**	**100.0**

Table 3: Registered Draft

Draft in Feet	Number of Tow/Tugboats	Percent
Missing	60	2.1
1-9	1,361	47.2
9.1-10	848	29.4
10.1-11	296	10.3
11.1 +	318	11.0
Total	**2,883**	**100.0**

Table 4: Horsepower

Horsepower	Number of Tow/Tugboats	Percent
Missing	330	11.4
1-1,000	566	19.6
1,001-2,500	887	30.8
2,501-5,000	816	28.3
5,001 +	284	9.9
Total	**2,883**	**100.0**

Table 5: Age

Age	Number of Tow/Tugboats	Percent
Missing	327	11.3
40+	368	12.8
30-39	721	25.0
20-29	1,289	44.7
Under 20	178	6.2
Total	**2,883**	**100.0**

(1) Age is calculated from year built or year rebuilt.

As the above data indicate, the characteristics of the towing vessels involved in bridge allisions are as varied as those of the entire fleet. AWO and Coast Guard staff examined these and other tabulations and cross-tabulations and found nothing that indicated that a particular type of vessel was more likely to be involved in a bridge allision. More sophisticated statistical analyses could possibly discover some correlations, but the Work Group concluded that there were more important lines of analysis to pursue at this time.

APPENDIX 3
TRUMAN-HOBBS BRIDGES

Authority

Authority to order the alteration of unreasonably obstructive bridges to meet the reasonable needs of navigation pursuant to the Truman-Hobbs Act was transferred to the Secretary of Homeland Security by Section 1512(d) of the Homeland Security Act of 2002. This authority was subsequently delegated by the Secretary to the Commandant of the U.S. Coast Guard on February 28, 2003. The Commandant, represented by the Chief, Office of Bridge Administration (G-OPT), is responsible for overall management of the alteration program for unreasonably obstructive bridges, including planning, programming and budgeting; legal interpretations whenever such questions arise; and technical engineering assistance necessary in any portion of the program. The laws relating to unreasonably obstructive bridges across the navigable waters of the United States are contained in the following statutes:

1) The Rivers and Harbors Appropriations Act of 1899, Section 18 (30 Stat. 1153; 33 USC 502).

2) The Bridge Act of 1906, Sections 4 and 5 (34 Stat. 85; 33 USC 494-495).

3) The Act of June 21, 1940, as amended (Truman-Hobbs Act) (54 Stat. 497; 33 USC 511-523).

Policy

Coast Guard regulations pertaining to the administration of these statutes are found in Part 116 of Title 33, Code of Federal Regulations.

Coast Guard policy is to ensure that bridges that cross the navigable waters of the United States do not unreasonably obstruct the reasonable needs of waterway traffic. To maintain navigation safety and freedom of mobility, the Truman-Hobbs Act is administered by the Commandant to ensure that bridges provide sufficient clearances for the types of vessels that transit through the bridge site. In the implementation of this policy and in determining what action may be appropriate, the following general guidelines are used:

1) All bridges constructed across the navigable waters of the United States are considered obstructions to navigation tolerated only so long as they serve the needs of land transportation while still providing for the **reasonable** needs of navigation.

2) Only the location and vertical and horizontal navigation clearances of a bridge's navigational opening(s) affect its eligibility for alteration under the Truman-Hobbs Act. The structural integrity of a bridge or its adequacy for land transportation, while valid concerns of a bridge owner, have no bearing on the determination that a bridge unreasonably obstructs navigation.

3) The Truman-Hobbs Act applies only to actively used bridges. Bridges that have been abandoned or that are no longer being used for transportation purposes should be removed at the expense of the owner (33 CFR 116).

4) The Coast Guard may determine a bridge to be unreasonably obstructive to navigation if the navigational benefits that would accrue as a result of altering the bridge equal or exceed the cost of the bridge alteration.

5) Complaints by land transportation interests concerning delays or impediments to highway or rail traffic are not valid complaints under the provisions of the Truman-Hobbs Act, and may not be used as reasons to declare a bridge an unreasonable obstruction to navigation.

The Truman-Hobbs Team

On October 1, 1999, the Coast Guard program for conducting Truman-Hobbs investigations was centralized in the St. Louis, Missouri, Bridge Office (CGD8(obr)) to maximize the use of limited program resources. The CGD8(obr) Truman-Hobbs (T-H) Team is responsible for administering Truman-Hobbs investigations nationwide in conjunction with local district support and policy guidance from and oversight by the Commandant (G-OPT).

Investigation

The Commandant (G-OPT) solicits district bridge office input for a Truman-Hobbs Backlog Priority List that ranks bridges as potential candidates for investigation and alteration under the Truman-Hobbs Act by using an average point scoring system with the following criteria:

1) Complaints, i.e., type and number.

2) Allisions, i.e., number of hits, amount of monetary damages. In the absence of complaints, the district may use its discretion in determining whether a bridge's allision history warrants initiating a preliminary investigation.

3) Economic Value, i.e., vessel transit times and the cost, type, and tonnage of products or services that transit the bridge.

4) Clearance, i.e., adequacy of vertical and horizontal navigation clearances, angle of navigation span, bridge channel width, and pier locations.

5) Critical Waterway, i.e., significance of waterway's role in the national transportation infrastructure in terms of the economy, intermodal safety, and/or national security.

6) Water Flow, i.e., currents, tides, snowmelts.

7) Geographic Location, i.e., in relation to bends and/or nearby bridges and difficulty in transit lineups.

8) Vessels, i.e., specific types, numbers, and/or their size.

9) Cargo Type, i.e., types of cargo and their tonnage.

Overview of the Investigation Process

1) Upon receipt of complaints that a bridge is unreasonably obstructive or based on the bridge's allision history, the district will determine which bridges to recommend to Commandant (G-OPT) for further study under the Truman-Hobbs Act. The district's opinion as to whether or not the complaint warrants additional study will be formed through informal discussions with the complainant, users of the affected waterway, and other interested parties.

2) All decisions to conduct, or not conduct, a preliminary investigation shall be based on the criteria outlined above by the Commandant (G-OPT), which will add the bridge in question to a Truman-Hobbs Priority Backlog List. This priority list is used by the T-H Team for further investigation as available resources permit.

3) Before conducting a preliminary investigation, the T-H Team will notify the local District Commander and coordinate with the local district bridge office for assistance as needed. Upon completion of the preliminary investigation, the report will be signed by the preparer (Chief, T-H Team) and submitted by the district to the Commandant (G-OPT). If there is insufficient reason for pursuing a more detailed investigation, the Commandant (G-OPT) will inform the T-H Team and the concerned district, which will inform the complainant. The district will also make the complainant aware of the appeals process available.

4) The Commandant (G-OPT) will review the preliminary investigation report, with due consideration given to the district's recommendation, to determine whether there is sufficient reason for the T-H Team to pursue a more detailed investigation, including a public hearing. The local district bridge office will continue to assist the T-H Team as needed.

5) Upon completion of the detailed investigation, the report will be signed by the preparer (Chief, T-H Team) and submitted by the district to the Commandant (G-OPT). The Commandant (G-OPT) will analyze the detailed investigation report, with due consideration given to the district's recommendation, to determine whether the navigation benefit to be obtained from altering the bridge in question will support a benefit/cost ratio equal to or greater than 1.00:1.00. If so, the Commandant (G-OPT) will provide the bridge owner with written notification of a pending Order to Alter. The bridge owner will have 60 calendar days to provide the Commandant (G-OPT) with written reasons in opposition to an Order to Alter. If the bridge owner objects, Commandant (G-OPT) has 90 calendar days to reevaluate and make a decision based on additional information submitted by the bridge owner.

6) The Commandant signs the Order to Alter. The original document will be hand-delivered to the bridge owner by the T-H Team leader.

7) After the Order to Alter is served on the bridge owner, the Commandant (G-OPT) will provide the bridge owner with a letter of technical engineering instructions.

8) The Commandant (G-OPT) supervises the bridge alteration project through completion.

Funding

Apportionment of Cost

From 33 USC 516:

> At the time the Secretary of Homeland Security shall authorize the bridge owner to proceed with the project and after an opportunity to the bridge owner to be heard thereon, the Secretary shall determine and issue an order specifying the proportionate shares of the total cost of the project to be borne by the United States and by the bridge owner. Such apportionment shall be made on the following basis:
>
> The bridge owner shall bear such part of the cost as is attributable to the direct and special benefits which will accrue to the bridge owner as a result of the alteration, including the expectable savings in repair or maintenance costs; and that part of the cost attributable to the requirements of traffic by railroad or highway, or both, including any expenditure for increased carrying capacity of the bridge, and including such proportion of the actual capital cost of the old bridge or of such part of the old bridge as may be altered or changed or rebuilt, as the used service life of the whole or a part, as the case may be…The United States shall bear the balance of the cost, including that part attributable to the necessities of navigation…

Payment of Share of United States

From 33 USC 517:

> Following service of the order requiring alteration of the bridge, the Secretary of Homeland Security may make partial payments as the work progresses to the extent that funds have been appropriated. The total payments out of Federal funds shall not exceed the proportionate share of the United States of the total cost of the project paid or incurred by the bridge owner, and, if such total cost exceeds the cost guaranteed by the bridge owner, shall not exceed the proportionate share of the United States of such guaranteed cost, except that if the cost of the work exceeds the guaranteed cost by reason of emergencies, conditions beyond the control of the owner, or unforeseen or undetermined conditions. All payments to any bridge owner herein provided for shall be made by the Secretary of the Treasury through the Fiscal Service upon certifications of the Secretary of Homeland Security.

Current Status

Currently there are 14 bridge projects undergoing alteration, with a total funding liability of $516 million. Of this amount, the U.S. government share is estimate at $432 million. Thus far, $148 million has been appropriated. The entire $148 million has been obligated to specific projects. Future funding needs are placed at $284 million. The average annual amount that the Coast Guard received from 1991 to 2002 was $11.58 million. In 1995, the program received no funding; in 1997, the Coast Guard received $42.8 million, the largest amount received during this period.

APPENDIX 4
SAMPLING METHODOLOGY

The Work Group determined that it did not have sufficient resources to read and analyze all 2,692 bridge allisions cases individually. Instead, the Group decided to generate a manageable subset for review by teams of industry experts. The sampling process involved three steps: 1) defining the sampling criteria, 2) selecting the sample size, and 3) reviewing and refining the results.

In a September 20, 2002 teleconference, the Group decided to organize the cases by a cross-classification of severity class by region. The severity class is a measure of the impact of the accident. Table 1 lists the five severity classes, their definitions, and the number of allisions in each class.

Table 1: Severity Classes

Class	Definition	Count
0	Damage recorded as "None or Not Specified."	1,702
1	Damage between $1 and $25,000.	610
2	Damage between $25,001 and $100,000.	220
3	Damage between $100,001 and $500,000.	99
4	One or more of: damage > $500,000; loss of life > 0; injured > 0; missing > 0; oil spilled.	61

A review of a few cases in Severity Class 0 showed that in some cases "None or Not Specified" was recorded as the damage because estimates from the state or local transportation agency were not available at the time the Coast Guard casualty report was filed. Addenda then provided damage amounts ranging up to $87,000. Thus, Severity Class 0 is not homogenous and should not be interpreted as including only cases with trivial damages. As will be explained later, this finding had an impact on the sampling rate.

The Group designated six regions: Atlantic, Ohio Valley, Upper Mississippi, Lower Mississippi, Gulf, and Pacific. Table 2 lists the regions, their definitions, and the number of allisions in each region. The definitions are based on a review of the water body names in the source data file from the Coast Guard.

Table 2: Regions

Region	Definition	Count
Atlantic	All waters in ME, NH, MA, RI, CT, NY, NJ, MD, DE, VA, NC, SC, & GA; in PA, the Delaware & Schuylkill Rivers; and in FL ports and rivers from Jacksonville to Key West.	444
Gulf	All waters in TX; in LA all waters identified on the Gulf; in MS, all waters other than Mississippi and Yahzoo (sic) Rivers; in AL, other than Tennessee River; and in FL, all waters emptying into the Gulf.	596
Lower Miss.	All waters in AR & OK; in LA all non-Gulf; in TN, the Mississippi River.	299
Ohio Valley[1]	All waters in WV, IL, IN, KY; in TN other than Mississippi River.	814
Pacific	All waters in WA, OR, & CA.	113
Upper Miss.	All waters in WI, MN, MI, IA, KS, MO.	426
Total		**2,692**

The Group decided to review all of the 160 cases in Severity Classes 3 and 4. The next issue was to decide the sample size for each cross-classification of Severity Classes 0, 1, and 2 by region.

For populations with known characteristics, such as the U.S. population, the selection of a sample size is fairly straightforward. It is guided by factors such as cost, degree of precision required, time available, and variables of interest such as race, age, and gender. This case was more complicated because the Group was dealing with a population (the universe of bridge allisions) about which little was known. Three factors guided the selection of the sample size. The first was to get a sample of at least five cases in each cross-classification or cell. This would enable application of some statistical tests after the results were returned.

The second factor involved the aforementioned unreported damage amounts in Severity Class 0. To compensate for these problems, a sample rate was chosen that would enhance the probabilities of accurately representing the full range of damage in each cell.

Available time for the reviewers was the third factor. The Group decided that the reviews should be completed and returned in approximately six weeks to enable compilation and presentation of results at the November 14, 2002 meeting. Given the job responsibilities of the reviewers, the number of cases needed to be small enough that they could devote sufficient time to each one and yet large enough to yield meaningful results. As the cell sizes ranged from 11 to 668, a sample rate for each cell was chosen that would generate a representative sample for the cell **and**

[1] The Illinois River, Calumet River, Des Plaines River, and Indiana Harbor Ship Canal should have been assigned to the Upper Mississippi River (UMR) region. After the sample cases were selected, 52 cases from these waterways were transferred to the UMR region subgroup for review.

keep the total for the region at a manageable level. Table 3 presents the cross-classification table, each cell population, and the initial sample rate.

Table 3: Severity/Region Counts and Sample Rates

Class & Definition	Atlantic	Gulf	Lower Miss	Ohio Valley	Pacific	Upper Miss	**Total**
0: Non or Not Spec.	268 10%	386 10%	173 15%	563 5%	68 20%	244 10%	**1,702**
1: $1-$25,000	107 15%	132 15%	65 15%	151 15%	30 30%	125 15%	**610**
2: $25,001-$100,000	37 20%	47 20%	26 30%	62 20%	11 75%	37 20%	**220**
3: $100,001-$500,000	21 100%	21 100%	13 100%	28 100%	2 100%	14 100%	**99**
4: $500,001+, death, missing, injury, or poll.	11 100%	10 100%	17 100%	15 100%	2 100%	6 100%	**61**
Total	**444**	**596**	**294**	**819**	**113**	**426**	**2,692**

The sample cases were selected by a computer program that utilized a random number generator function. Each case in the universe was a record in the input file. A record/case was read and if the severity class was 3 or 4, then the record was output to the review file. For records/cases with severity classes 0, 1, or 2, the random number generator function was run, yielding a number from 0 to 1, with all numbers having equal chance of appearing. The number was compared to the selection percentage for the particular record's cell and if the random number was less than or equal to the selection percentage, then the record was output to the review file.

For example, consider a record in the Atlantic Region with Severity Class 0. This cell has a selection rate of 10%. Assume the random number generator produced 0.042. This is less than 0.10, so the record is output to the review file. Assume a second record with the same characteristics, but a random number of 0.683. The random number is greater than 0.10, so it would be discarded.

The use of the random number generator eliminates any human bias in the selection process, but the randomness introduces some imprecision in the control on the sample size. That is, a sampling rate of 10% probably will not yield a sample that is exactly 10% of the cell population.

After the initial round of selections, the sample was calibrated using the distribution of bridges within each region. If the sample was a representative sample, then the percentage of each bridge in the sample from a given region should be roughly the same as its corresponding percentage in the population for the region. The large number of bridges with only a few allisions introduces a range of imprecision in this comparison. For example, a bridge with only one allision may represent a small percentage of the region's population, possibly less than 1%. If by chance it is selected, it may represent 3% of the sample, a three-fold overweighting. This phenomenon is known to statisticians as "the tyranny of small numbers" and cannot be avoided in the case of bridge allisions, because a partial case does not exist.

The calibration review detected three bridges that were significantly under-represented. A second sample was executed on these three bridges, resulting in an additional nine cases. These were added to the original sample. The final sample file contained 473 cases. Table 4 is a copy of Table 3, with the inclusion of the number of selected cases in each cell.

Table 4: Severity-Class/Region Counts, Sampling Rate, and Sampled Cases

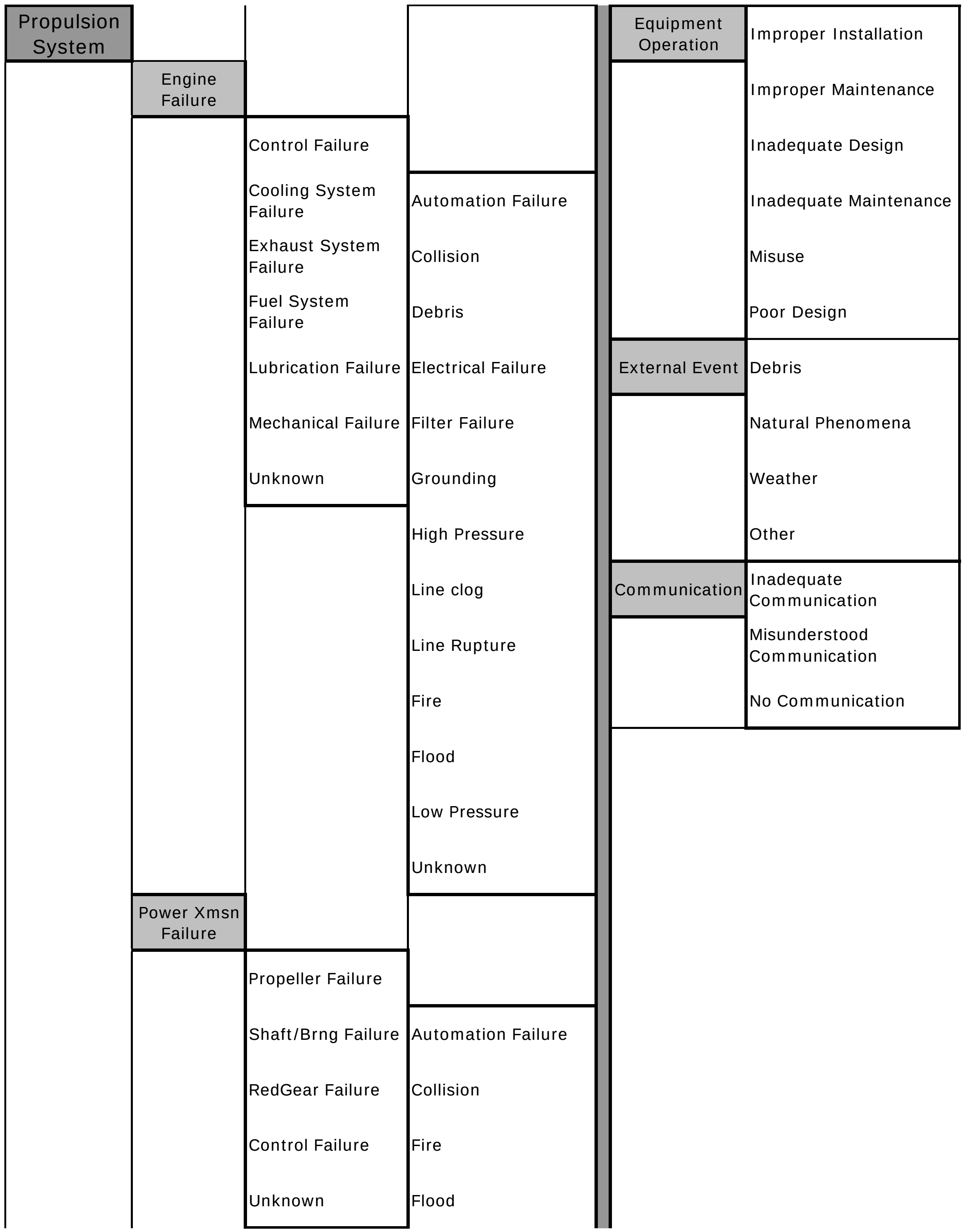
Class & Definition	Atlantic	Gulf	Lower Miss	Ohio Valley	Pacific	Upper Miss	**Total**
0: Non or Not Spec.	268 10% 23	386 10% 48	173 15% 27	563 5% 24	68 20% 11	244 10% 24	**1,702** **157**
1: $1-$25,000	107 15% 12	132 15% 28	65 15% 11	151 15% 21	30 30% 8	125 15% 24	**610** **104**
2: $25,001-$100,000	37 20% 10	47 20% 7	26 30% 9	62 20% 712	11 75% 7	37 20% 6	**220** **51**
3: $100,001-$500,000	21 100% 21	21 100% 21	13 100% 13	28 100% 28	2 100% 2	14 100% 14	**99** **99**
4: $500,001+, death, missing, injury, or poll.	11 100% 11	10 100% 10	17 100% 17	15 100% 15	2 100% 2	6 100% 12	**61** **61**
Total	**444** **77**	**596** **114**	**294** **77**	**819** **100**	**113** **30**	**426** **74**	**2,692** **472**

The resulting file of sampled cases was divided into separate files for each region and then distributed to the industry members of the Working Group.

APPENDIX 5
CASE REVIEW TAXONOMY FOR BRIDGE ALLISIONS

Case Review Taxonomy for Bridge Allisions

Mishap Category	Mishap	Incident	Initiating Event	Causal Factors	
				General	Sub-Cat
Piloting					
	Maneuv. Errors			Human Performance	Excessive Workload
		Improper Turn			Complacency
		Improper Course	Emergency Maneuver		Fatigue
		Improper Speed	Inattention		Personal Stress
		Unknown	Wrong Decision		Substance Abuse
			Wrong SitAssessment		Work Environment
			Unknown		Workplace Design
	Nav Equip Failure			Task Performance	Deliberate Action
	(Hardware)	GPS Failure			Distraction
		Gyro Failure	General Failure		Inadequate Experience
		Radar Failure	Electrical Failure		Inadequate Information
		Radio Failure	Unknown		Inadequate Procedures
		Other Gen. Equipment			Inadequate Training
		Unknown			Inadequate Planning/Preparation
Operations					Inadequate Policies
	Navigation Aids				Inadequate Qualification
	Bridge Tender	Breakaway Barge			Judgement Error
	Underpowered	Grounding	Lashing Failure		Law Violation
	Unusual Event	Collision	Unusual Event		Poor Execution
		Unknown	Improper BargeLoading		Poor Procedures
			Improper BargeConfigure		Poor Supervision
			Channel Problem		Procedures Ignored
			Unknown		Sabotage


Propulsion System
Engine Failure
Control Failure
Cooling System Failure
Exhaust System Failure
Fuel System Failure
Lubrication Failure
Mechanical Failure
Unknown
Automation Failure
Collision
Debris
Electrical Failure
Filter Failure
Grounding
High Pressure
Line clog
Line Rupture
Fire
Flood
Low Pressure
Unknown
Power Xmsn Failure
Propeller Failure
Shaft/Brng Failure
RedGear Failure
Control Failure
Unknown
Automation Failure
Collision
Fire
Flood
Equipment Operation
Improper Installation
Improper Maintenance
Inadequate Design
Inadequate Maintenance
Misuse
Poor Design
External Event
Debris
Natural Phenomena
Weather
Other
Communication
Inadequate Communication
Misunderstood Communication
No Communication

APPENDIX 6
CAUSAL ANALYSIS OF SIGNIFICANT CONSEQUENCE CASES

Introduction: Definitions and Methodology

This Appendix examines the significant consequence cases.

Significant consequence cases are those that have one or more of these characteristics: one or more fatalities, one or more injuries, damage worth $500,001 or more, or pollution incident. There are 61 cases that fall into this category; usable analyses of 51 of these cases were returned by the industry review teams.[1]

The same "drill-down" analysis that was conducted on the dataset of all cases (hereafter referred to as the "master") was replicated for the subset of 51 significant cases. The results of the significant cases subset are remarkably similar to those from the master. The only difference of note is that "weather" appears as a causal factor in 6% of the significant cases subset, whereas it was trivial in the master.

Below are the results from the analyses of the significant cases subset and all cases. Note that the percentage total may not equal 100 due to independent rounding of the components.

Top-Level Analysis

The starting point for the analysis is the first level of accident type, Mishap Category.

Table 1: Mishap Category

	Significant Cases		All Cases	
Mishap Category	Number	Percent	Number	Percent
Piloting Error	35	69	361	78
Operations Error	8	16	54	12
Steering	0	0	12	3
Propulsion System	1	2	8	2
Unknown/Missing Data	7	14	24	5
Total	**51**	**101**	**459**	**100**

The two largest categories, piloting error and operations error, account for 85% of the significant cases and 90% of the master. The absence of steering in the subset is not noteworthy because it is a relatively small amount, 3%, in the master.

[1] Missing files or data entry problems were the reasons for the unusable cases.

Piloting Error Analysis

As piloting error is the largest mishap category in both datasets, the next step was to generate a breakout of the specific mishaps. As the table below shows, maneuvering error accounts for nearly all the mishaps in both the significant cases subset and the master.

Table 2: Piloting Error Mishaps

	Significant Cases		All Cases	
Mishap	Number	Percent	Number	Percent
Maneuvering Error	33	94	359	99
Navigation Equipment Failure	1	3	1	0
Missing	1	3	1	0
Total	**35**	**100**	**361**	**99**

The next level is the composition of the incidents for the piloting error/maneuvering error combination. The top two incidents, improper approach and improper course, account for about 90% of the incidents in both datasets.

Table 3: Piloting Error/Maneuvering Error Incidents

	Significant Cases		All Cases	
Mishap	Number	Percent	Number	Percent
Improper Approach	26	79	263	73
Improper Course	4	12	69	19
Improper Speed	2	6	12	3
Improper Turn	0	0	9	3
Unattended Helm	0	0	3	1
Missing Data	1	3	3	1
Total	**33**	**100**	**359**	**100**

The final level in the accident typology is initiating event. Improper approach and improper course account for 92% of the subset’s incidents, so these served as the bases for the breakout for initiating events.

Table 4: Initiating Events for Mishap Category: Piloting Error, Mishap: Maneuvering Error, and Incident: Improper Approach or Improper Course

	Significant Cases		All Cases	
Mishap	Number	Percent	Number	Percent
Wrong Situation Assessment	22	73	241	73
Wrong Decision	7	23	64	19
Inattention	1	3	5	2
Others	0	0	7	2
Missing Data	0	0	14	4
Total	**30**	**99**	**331**	**100**

The review of the cases also included the identification of up to three causal factors for each case. The table below shows the general causal factors for 29 cases with initiating events "wrong situation assessment" or "wrong decision" from the previous table and corresponding cases from the master dataset.

Table 5: Piloting Error/Maneuvering Error/Improper Approach or Course

	Significant Cases		All Cases	
General Causal Factor	Number	Percent	Number	Percent
Task Performance	37	79	451	83
External Event	3	6	56	12
Communications	3	6	18	3
Human Performance	4	9	0	0
Equipment Operations	0	0	2	1
Unknown	0	0	7	1
Total	**47**	**100**	**534**	**100**

For the significant cases subset, the total of the task and human performance causes is 88%, which is reasonably close to the 83% for task performance from the master.

The final drill-down is a breakout of the sub-category causes of the task performance causes. As the table shows, on a percentage basis, the significant cases have an almost identical profile of sub-category causes to the master.

Table 6: Piloting Error/Maneuvering Error/Improper Approach or Course/
Task Performance General Cause

	Significant Cases		All Cases	
General Causal Factor	Number	Percent	Number	Percent
Judgment Error	20	54	248	55
Poor Execution	6	16	90	20
Inadequate Planning/ Prep/Info	5	14	69	15
Others	4	11	39	9
Missing	2	5	5	1
Total	**47**	**100**	**451**	**100**

Through every level of analysis, the piloting errors in the significant cases subset track the corresponding results from the master dataset.

Operations Error Analysis

The analysis of the operations error mishap category follows the same pattern as the one for piloting error. The first breakout is the specific mishaps. Despite the small total for the significant cases subset, the breakouts follow the same general pattern, with unusual event the predominant mishap in both.

Table 7: Operations Error Mishaps

	Significant Cases		All Cases	
Mishap	Number	Percent	Number	Percent
Unusual Event	5	62	36	67
Navigation Aids	2	25	5	9
Bridge Tender	1	13	9	17
Underpowered	0	0	4	7
Total	**10**	**100**	**361**	**100**

With only five cases for unusual event mishaps, this is too small make a meaningful comparison to its counterpart from the master dataset. For the record, the incidents were three breakaway barges and two collisions.

Reaching a dead-end at the accident typology, the next line of analysis is the causal factors. The table below shows the comparison of the general causes breakout.

Table 8: Operations Error/Unusual Event

	Significant Cases		All Cases	
General Causal Factor	Number	Percent	Number	Percent
Task Performance	3	38	9	32
External Event	2	25	9	32
Communications	1	12	2	7
Human Performance	1	12	2	7
Equipment Operations	1	12	2	7
Unknown	0	0	4	14
Total	**8**	**100**	**28**	**99**

Combining the top two causes, task performance and external events, they sum to 63% and 64% for the significant cases subset and master, respectively. The small number of cases in the significant cases subset renders meaningless any comparison of the sub-category breakout for the task performance and external event general causes.

As far as the data allow, the breakouts of the operations errors in the significant cases look very much like the ones from the master dataset.

Conclusion

In both the significant cases subset and the master dataset, the top two mishap categories are piloting error and operations error, with almost identical percentages. The analyses of both the accident typologies and the causal factors show very similar patterns at every level. The statistical evidence indicates that the significant cases have the same causal factors as the non-significant cases. Thus, an optimal strategy will be to reduce all bridge allisions and thereby reduce the number of allisions causing the most damage.

Concurrently, a deeper analysis of the causal factors could be executed to obtain information on the human, mechanical, and environmental factors not captured. Potential techniques include review of the Coast Guard reports; interviews with crew; interviews with shore side personnel; and capturing environmental data from other agencies such as the Corps of Engineers, the National Oceanic and Atmospheric Administration (NOAA), and state agencies.

APPENDIX 7
SEVERITY CLASS 4 BRIDGE ALLISION NARRATIVES

This appendix contains seven narrative summaries of the severity class four bridge allision incidents that occurred or had investigations completed in 2001.[1] These narratives are provided so a reader unfamiliar with operating a towing vessel will get an understanding for how a bridge transit may result in an allision with a bridge. The other 54 narratives for severity class four incidents may be found with this report on line at http://www.uscg.mil/hq/g-m/moa/marin.htm. Please note that the names of the vessels involved were changed to generic names.

Name of Towing Vessel: TOWBOAT1
Date of Casualty: 03 November 1999
Case Number: MC00014230
Number of Barges Involved: 1
Description of the Allision: The westbound loaded 236 ft diesel powered tug and tow allided with the CSX Railroad Bridge at MM 6.2 of ICW East Rigolets Pass. One minor injury, 5 gallons of ethylene glycol released, and minor damage to the barge resulted. The bridge sustained significant damage as a result of the allision. The crewmember was out on the barge when the barge made contact with the starboard side fendering system and struck his shoulder on one of the discharge pipelines as a result of the impact with the bridge. The resulting injury was a minor contusion. The impact also caused approximately 5 gallons of the cargo (ethylene glycol) to expel from a cargo vent. The product was contained on the deck of the barge and did not result in any pollution.
Cause of the Allision: Operator misjudged currents upon approach to the bridge.
Deaths: 0
Injuries: 1
Pollution Incident: None
Damage Amount: $110,000

Name of Towing Vessel: TUGBOAT 1
Date of Casualty: 03 February 2001
Case Number: MC01001713
Number of Barges Involved: No barges involved. Ship being towed.
Description of fhe Allision: Approximately 0040, 03 FEB 01, the TUGBOAT1 while being towed outbound the Miami River stern-first and deadship by the tugs TUGBOAT2 and TUGBOAT3 allided with the northeast corner of the NW 5th St. bridge abutment and the bridge's opened north span. The bridge sustained major damage to the pedestrian sidewalk, the north span's eastern-most girder, and its trunnion. The TUGBOAT1sustained damage to the upper starboard corner of the transom including a 5-inch hole in the side shell plating just below the weather deck, buckled bulwarks, and bent handrails. The TUGBOAT1 also sustained damage to a 2 feet wide by 1-foot deep section of deck, the deck-edge combing, and handrails on the starboard, after side of the boat deck. There were no injuries as a result of the incident.
Cause of the Allision: Unexpected currents and shoaling in vicinity of the bridge.
Deaths: 0
Injuries: 0
Pollution Incident: 0
Damage Amount: $2,000,000

[1] A severity class 4 bridge allision involves one or more of the following: lives lost > 0, injured > 0; missing > 0; damage > $500,000; oil spilled.

Name of Towing Vessel: TOWBOAT1
Date of Casualty: 12 February 2001
Case Number: MC01002574
Number of Barges Involved: 2
Description of the Allision: On 02/12/01 about 1700 CST the TOWBOAT1 was southbound on the Illinois River running 8 knots, when she became sideways in the channel above the Florence Highway Bridge at mile 56.0, resulting in an allision with one personnel injury. The pilot of the TOWBOAT1 stated that he had made his approach to the center span, but was turned by the high water from snow and ice melt off. The river current had increased substantially over the prior couple of days and had contributed to the vessel coming moving off line. The pilot had realized that the vessel was being set back and had made attempts to correct his position by backing down full with his engines, but the momentum of the tow had already reached a point of no return. The forward two barges, BARGE1 and BARGE2, both empty red flag gasoline barges, impacted the starboard descending bridge pier causing the TOWBOAT1's tow to break apart. There was no damage sustained to the bridge pier, but both barges sustained damage. BARGE1 had damage to the bow rake in the amount of $36,000. BARGE2 broke the timberhead on the port head and some of the deck plating was pulled up, at around $5000 in total damage costs. A tankerman aboard the TOWBOAT1 was injured in the allision.
Cause of the Allision: Operator lost situational awareness of the changing conditions in the river. The increased current and depth of water was not taken into consideration prior to making his approach to the bridge.
Deaths: 0
Injuries: 1
Pollution Incident: 0
Damage Amount: $41,000

Name of Towing Vessel: TOWBOAT1
Date of Casualty: 01 April 2001
Case Number: MC01004198
Number of Barges Involved: 2
Description of the Allision: On 01 April 2001, at approximately 0025, the southbound, twin screw, 1974 build, 65' towboat, 1360 hp, diesel powered, U.S. -flag tug TOWBOAT1 pushing ahead 02 loaded lube oil barges (12,000 tons in each) had an allision with the Jonesville Bridge at mile 40.9 of the Ouachita River. The vessel was transiting southbound under the Jonesville Bridge when the starboard beam of the vessel's pilothouse allided with the northern side of the opened Jonesville swing bridge. The allision with the bridge rolled the vessel on her port side, which caused uncontrolled flooding, followed by the vessel capsizing and sinking.
Cause of the Allision: The root cause of this casualty was human error in that the pilot misjudged the effect the river under the Jonesville Bridge would have on the vessel as he transited through the bridge opening.
Deaths: 0
Injuries: 0
Pollution Incident: Yes
Damage Amount: $500,000

Name of Towing Vessel: TOWBOAT 1
Date of Casualty: 17 May 2001
Case Number: MC01007108
Number of Barges Involved: 1
Description of the Allision: It was determined that the Operator of the TOWBOAT1 was illicitly using a prescription drug that severely impaired his ability to navigate and maneuver the vessel, causing him to negligently strike the Louisa Bridge. The Bridge Tender witnessed the TOWBOAT1 glance off the south bank three times as the TOWBOAT1 approached the Louisa Bridge just prior to the allision. The bridge tender stated that each time the TOWBOAT1 struck the bank she called the master of the TOWBOAT1 to inquire as to the problem. Each time the master replied that he was having steering problems. It was the opinion of the bridge tender that the master of the TOWBOAT1 was falling asleep because he sounded groggy on the radio. The TOWBOAT2 was approximately 500 yards astern of the TOWBOAT1 at the time of the allision. The master of TOWBOAT2 stated he heard the bridge tender's calls to the TOWBOAT1, confirming the bridge tender's statement. The Marine Surveyor inspected the TOWBOAT1's steering system, verified that the entire system was operating correctly and stated that the allision was not due to mechanical error. During the onboard investigation immediately after the allision, the operator appeared to fall asleep multiple times in the presence of the CG Investigator. On one of these instances, the Marine Surveyor also witnessed the operator appearing to fall asleep. The operator confessed to using Xanax without a prescription.
Cause of the Allision: Operator illegally used Xanax, causing him to fall asleep.
Deaths: 0
Injuries: 0
Pollution Incident: None
Damage Amount: $1,014,000

Name of Towing Vessel: TOWBOAT1
Date of Casualty: 19 July 2001
Case Number: MC01009280
Number of Barges Involved: 1
Description of the Allision: 1. Prior to 0221 the TOWBOAT1 was u/w west bound, pushing a T/B fully loaded with a cargo of PPM (propane-propylene mix), and pushed up on the North bank of the Gulf Intracoastal Waterway (GIWW) mile marker 132.5, 1.5 miles east of the Louisa Bridge awaiting the arrival of their relief pilot. 2. 0221 The TOWBOAT2 and the TOWBOAT3 pushing westbound and the TOWBOAT4 pushing eastbound asked for an opening, received permission and transited through the Louisa Bridge. 3. 0253 The Louisa Bridge closed. 4. 0320 The TOWBOAT5 pushing westbound, passed the TOWBOAT1, asked the Louisa Bridge Tender for an opening, received permission, the bridge opened and they transited the Louisa Bridge. 5. 0333 The Louisa Bridge closed. 6. 0330 The TOWBOAT6 was u/w pushing westbound and the TOWBOAT7 was light boat u/w west bound toward the Louisa Bridge. 7. 0350 (approximate) The TOWBOAT7 overtook the TOWBOAT6 and they both passed the TOWBOAT1 who was still pushed up on the bank. 8. 0410 (approximate) The TOWBOAT1's relief pilot arrived at and drove his vehicle across the Louisa Bridge to speak to the Bridge Tender. 9. 0413 The TOWBOAT7 and the TOWBOAT6 u/w westbound asked the Louisa Bridge Tender for an opening, received permission, the bridge opened and they transited through the Louisa Bridge. 10. 0415 (approximate) The Bridge Tender spoke to the pilot of the TOWBOAT1 on VHF, giving him info that the TOWBOAT 1's relief pilot was at the bridge and that the bridge was going to close to allow the relief to drive back across the bridge. 11. 0420 (approximate) The TOWBOAT1 got u/w without telling the Bridge Tender. 12. 0425 The Louisa Bridge closed and allowed the relief pilot to drive his vehicle to the north side of the channel to facilitate their relief process. The TOWBOAT7 continued westbound GIWW. The TOWBOAT6 pushed up against the bank mile to the west. 13. 0435 (approximate) The Bridge Tender began opening of the bridge for the TOWBOAT1. 14. The TOWBOAT1 struck the bridge with its barge while the bridge was only 50 percent open, breaking relief valves and cracking piping on the STBD Tank, allowing product to be released into the atmosphere.
Cause of the Allision: The pilot started his approach to the bridge despite having been told by the bridge tender that the bridge was closed. The pilot did not check in with the bridge tender after getting underway. The pilot was fatigued based upon the fatigue model worksheet, scoring a fatigue index of 53.67.
Deaths: 0
Injuries: 0
Pollution Incident: Air release
Damage Amount: $697,000

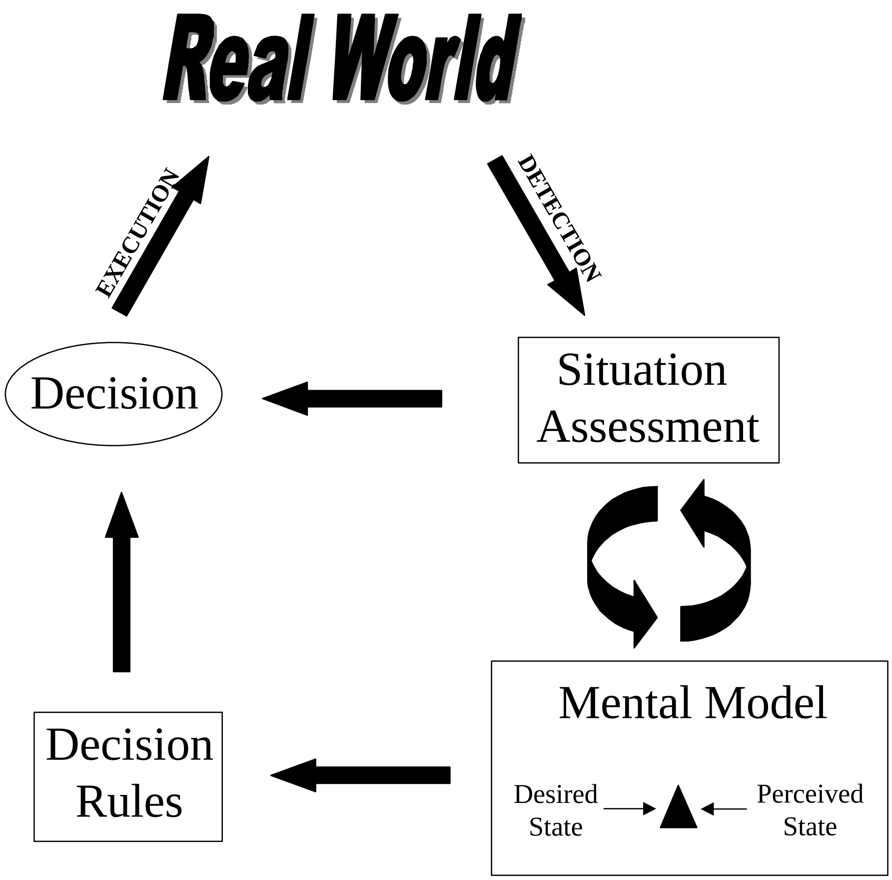
Name of Towing Vessel: TOWBOAT1
Date of Casualty: 15 September 2001
Case Number: MC01011939
Number of Barges Involved: 1
Description of the Allision: TOWBOAT1 allided with the Queen Isabella Causeway, South Padre Island TX, causing the bridge to collapse.
Cause of the allision: Cause of the allision is unknown as this case is still under investigation.
Deaths: 8
Injuries: Unknown
Pollution Incident: Yes
Damage Amount: Not specified.

APPENDIX 8

COGNITIVE MODEL FOR NAVIGATION DECISION MAKING

In order to develop its recommendations, the Work Group first agreed upon a cognitive model that provided a reasonable representation of the decision making process. The model for this process is provided below:

Figure 1: Cognitive Model



The Work Group used this model to identify areas where the process could be severely compromised or completely break down. Recommendations were intended to safeguard the process.

Each component of the model is described below:

<u>The Real World</u>

This is best described as what the operator sees "out the window." It is the primary source of stimulus and information for decision-making (for example, weather, vessel traffic, waterway conditions, etc.). The real world includes events and patterns of events. It is constantly changing and provides a continuous flow of input to the operator.

Situational Assessment

The operator collects this information through detection. Detection comes through the senses and through bridge equipment, such as radar and radio. This is the first place for the process to break down: the detection of information could be too slow or inadequate for the situation.

Situational assessment is based on the operator's evaluation, interpretation, and perception of the real world. It is the integration and computation of all the detected information. Situational assessment is affected by a host of things, such as experience, training, stress, workload, etc.

Mental Model

The mental model is essentially the operator's idea of "how the world works." A mental model is also understood to be a person's representation of reality. It can be used to understand and evaluate patterns. A person's mental model is the basis for all reasoning and has a number of important characteristics:

(1) Mental models are always incomplete and constantly changing and evolving.
(2) Mental models are not always accurate and usually contain errors and contradictions.
(3) Mental models are usually simplified representations of complex situations.
(4) Mental models are developed with uncertainty and are used even when they are incorrect.

Part of the use of the mental model in making decisions is evaluating the difference between the desired state and the perceived state. The desired state is the operator's decided-upon goal, such as turning to port five degrees or maintaining speed at five knots. The perceived state comes from the operator's situational assessment. The operator continuously makes comparisons of the desired state and perceived state. The amount of difference between the two determines the level of action that the operator will take to eliminate the difference.

Decision Rules

These are "If… then…" statements. These rules are personal to the individual and are formed by training, experience, education, etc. They also influence the final decision that gets made.

Decision

This is the part were the operator says, "I am going to take action." The final decision and determined course of action are influenced by the operator's application of his or her decision rules and situational assessment.

Execution

The execution is the actual carrying out of the determined course of action. This is one place where errors can occur. Also, the execution directly changes the "Real World" aspect of the process.

There are numerous opportunities for this process to be severely compromised or completely break down. When this happens, errors are highly likely to occur. For example, poor alertness affects the process in many ways: the entire process slows as a function of impaired cognitive ability, critical information can be missed, situational assessment may be skewed, and there can be errors in execution.

Another example is the influence of training and experience on the process. Inadequate training or lack of experience may prevent the operator for adequately interpreting the "Real World." He or she may not know what information to look for or may display poor pattern recognition, slower execution, or inappropriate application of the decision rules.

APPENDIX 9
SYSTEMS THINKING

Need for Systems Approach

Although the Work Group focused on human factors, the cognitive model demonstrated that this is a complex issue. Applying the case review taxonomy to the cognitive model, the Group realized that:

- There are a number of factors that impact decision-making, and their interactions are complex.
- There are no "quick fixes" or "silver bullets" that will prevent bridge allisions.
- The most effective approach to developing meaningful recommendations is to understand the whole, or rather, to understand safe bridge navigation as a **system.**

Certainly, the issue of bridge allisions could be broken into smaller, more manageable parts. This would make it easier to develop a thorough understanding of each piece. In theory, after each piece is solved, it should be possible to combine them to gain an understanding of the whole. However, this is a reductionist view and only works for simple linear problems.

The factors influencing safe bridge navigation are complex and exhibit non-linear behavior. Therefore, the only way to address the issue is with systems thinking concepts.

Explanation of Systems Thinking

Systems thinking is fundamentally different from "traditional" analysis:

- Traditional analysis typically focuses on separating the individual pieces from the whole and than solving each issue independently.
- **Systems thinking focuses on how the components interact with each other.**

Systems thinking is extremely important to the analysis of bridge allisions because the issues associated with preventing bridge allisions have components with interactions that are complex and have feedback. It is extremely important to understand that breaking apart a system of interdependent parts dissolves the system of its essential properties and of each of its parts.